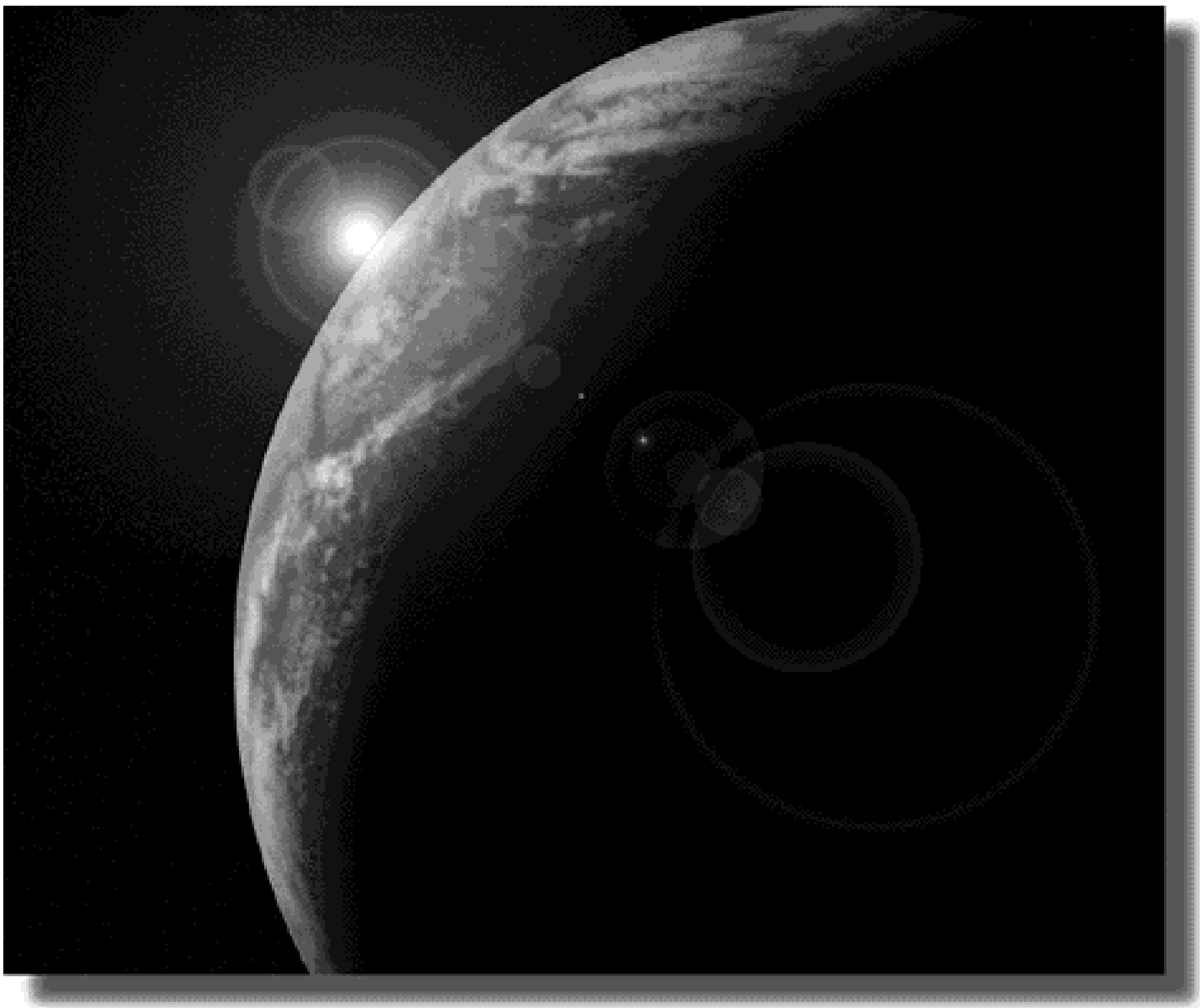
First Light



User Guide

Virtual Reality Laboratories, Inc.
Program License Agreement

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Virtual Reality Laboratories, Inc.
2341 Ganador Court
San Luis Obispo, CA 93401 U.S.A.

Technical support for *First Light* is available from the following sources:

Voice	805-545-8515	
FAX	805-781-2259	
VRLI BBS	805-781-2257 (N-8-1)	
Internet E-Mail	vrli@aol.com	
America Online	Keyword: VRLI	E-Mail screen name: VRLI
Compuserve	GO VRLI	E-Mail address: 75300,3706

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Introduction

The night sky has fascinated mankind for millennia. How many times have you caught yourself gazing upward, wondering which bright “star” that was, setting just after sunset, or what constellation was rising over the neighbor’s trees? Let *First Light* show you.

Using a core database of over 9,000 stars (expandable to over sixteen million with the data included on the *First Light* CD ROM), *First Light* is a powerful tool for acquainting you with the heavens. Indeed, its power rivals that of a small planetarium where, unhindered by your location on the planet, time of day, or the weather, you can freely explore different parts of the sky.

First Light was written to take full advantage of your computer’s configuration and the Windows environment. Simply by pointing and clicking with the mouse, *First Light* lets you discover a fascinating variety of celestial phenomena and, in the process, learn the fundamentals of astronomy.

For information about installing *First Light* and a brief introduction to using the program, see the next chapter *Getting Started*.

The Universe in Brief

In the book *Hitchhiker’s Guide to the Galaxy*, author Douglas Adams sums up the universe this way:

> *Space is big. Really big. You just won’t believe how vastly hugely mind-bogglingly big it is. I mean, you may think it’s a long way down the road to the [pharmacy], but that’s just peanuts to space.*

And so it is. Consider a light beam traveling at 186,000 miles per second leaving the surface of the Sun when your morning alarm clock rings. It is 6:00 am, Monday, February 5, 1996. By the time you’ve finally just started to consider rolling out of the sack at 6:08, the beam is sweeping through the orbit of the Earth as it heads outward bound toward the edge of the solar system. After you’re done showering and are ready to sit down to a bowl of Rice Krispies, it’s 6:41 and Jupiter is catching sight of the ray. It’s mid-morning, 11:12, when the beam sweeps past the orbit of Pluto (and you thought that *you* had a busy morning!). It won’t be until the following Saturday afternoon, five and a half days later, when the beam finally reaches the hypothesized cloud of comets, the *Oort Cloud*, said to surround the solar system. At this point, the beam leaves the solar system, but it is only just beginning its long journey beyond infinity.

Now you won’t have to bother thinking about the ray until the next Presidential election in the fall of 2000. However, after all this waiting, the beam has only reached the nearest star next to the Sun, *Proxima Centuri*. In 2002, it reaches *Barnard’s Star*, followed by tiny *Wolf 359* just in time for the 2004 Olympics. By 2008, the beam will be racing by *Tau*

Cetii with a full twenty stars behind it. In the following year it overtakes *BD5-1668, L725-32, Kapteyn's Star* and *Kruger 60A*. Looking back, our Sun would appear as a rather bland yellowish star slowly receding into the galactic darkness.

Jump to the end of the next century. Your great-great-grandchildren will be alive as the beam passes beyond the likes of *Sharatan, Hamal, Algol* and *Aldebaran*. Likewise it will have overtaken *Regulus, Talitha, Miaplacidus* and *Arcturus*.

In 2227, the sun's light would just be reaching the open cluster of the *Pleiades*, in the constellation of *Taurus*. The starship *Enterprise* is just beginning its five year journey into television history. Even after all of this, our journey is still beginning.

Many mysteries await in the vastness of space

Now, in your imagination, leave this age behind. Leave everything you've ever done or known behind. Leave your CD collection behind. Were the beam directed toward the constellation of *Sagittarius*, it would be headed to the center of our galaxy, the *Milky Way*. However, it won't reach this point until after the year 32,000 A.D. Yet there is still another 50,000 years before the ray can exit the other side of the galaxy. When it does, it will be leaving over 100 billion stars behind. Yet this galaxy is an unremarkable one of unremarkable size with many, many others beyond. And the journey is *still* beginning.

By 200,000 A.D., the beam will be passing by the *Magellanic Clouds* in the constellation *Tucana*, satellite galaxies to our own. After this is nothing. Nothing for the next 1.8 million years. Back on Earth, we would see the Sun as somewhat larger, turning a reddish hue as it begins the process of burning out. But now, looming ahead is the *Andromeda* galaxy, our "sister" galaxy and a member of the local group. Looking back toward the *Milky Way*, you would see a view similar to what the Andromeda galaxy looks like on a fall evening – a fuzzy elliptical patch. Another couple of million years will finally see this beam escaping our corner of the universe, traveling out to the open regions of space. Douglas Adams *said* it was big.

Now advance again, not another few million years, but a full twenty billion years from the present. The light beam from the Sun has at last reached the edge of the known universe. If the solar system still exists it will likely be a rather cold and uninviting place, the Sun having burned itself out fifteen billion years previously. Out here, what the beam would encounter is a giant unknown. Long ago however, scientists were able to see some objects that they said were out here, *quasars*. But these too remain a mystery as are so many other things.

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One of the amazing things in the universe is the range of both times and distances. For instance, in the above example we dealt with distances measured in *trillions times trillions* of miles. Yet, at the same time, some of the most interesting objects, such as black holes and neutron stars, may measure only five to ten miles in diameter. We commonly measure stellar processes in terms of millions of years. Yet there are stars, *pulsars*, which flash thirty times each second!

As you can see, the universe has no shortage of variety. It is my hope that *First Light* will serve to introduce you to this variety, and perhaps encourage you to explore further on your own.

R. Michael Smithwick
San Jose, California

The Development of First Light

First Light is the latest step in a series of planetarium software that has taken nine years to develop. The process began with a program called *Galileo* for the Commodore-Amiga in 1985. In 1989, *Galileo* evolved into *Distant Suns* for the Amiga. *Distant Suns* for Windows followed in 1991 and *Distant Suns* for Macintosh in 1992. The evolution continues with *First Light*. *First Light* takes the power and functionality of *Distant Suns* and gives it a fresh face, making the complex world of astronomy understandable to those who are just beginning their exploration of the subject.

Distant Suns gave the universe to the user and expected him to find something interesting. For an amateur astronomer, this is not a difficult task. For a newcomer to the subject of astronomy it could be quite daunting. *First Light* is designed to lead beginners to what is interesting while, at the same time, being a full-fledged planetarium program for sophisticated amateur astronomers.

First Light begins with the familiar and leads the user to the unfamiliar. The name reflects this new approach. “First light” is the term used by astronomers when a new telescope is christened and turned toward the sky for the first time.

First Light vs. Distant Suns

First Light is a fundamental redesign of *Galileo* and *Distant Suns*. It is the third generation, reflecting the increased power of personal computers and the increased expectations of users. It also takes advantage of the multi-media capabilities of current computer hardware and software.

Two key elements of *First Light* are its navigational tools and methods for roaming around the sky, and a new menu approach.

The new tools include a three dimensional star display, using the mouse to drag the sky around, and a tool called the ***Navigator*** for a “you are here” display. There is also a *Novice* mode for users who are new to astronomy and an *Expert* mode for those already familiar with the sky.

The new menus take an “object-action” approach to astronomy in which the user decides what *object* (planet, star, etc.) he wishes to explore and then decides how he wishes to explore it. Contrast this with *Distant Suns* and most other astronomy program, which used an “action-object” approach, in which the user must know what he wishes to do, then decide upon an object to which to apply the action. The object-action model more closely resembles the way the mind thinks, so it should feel much more natural.

There are also a host of great new features in *First Light*. They include 24 bit planetary rendering, a flyby mode (duplicating the flyby trajectories of the NASA spacecraft), a three dimensional local star display, support for creating movie files, fast real-time animation, and astronomical lessons for every day of the year.

Getting Started

Using This Manual

This *User Guide* assumes that you are familiar with the Windows environment, including using the mouse, menus, buttons and dialog boxes. If you are not, please refer to the appropriate manuals that came with your Windows software.

The *First Light User Guide* is divided into four main sections. The first, *Using First Light*, contains general information about the *First Light* program and basic astronomy concepts that you should understand to use *First Light* most effectively. Use these chapters to familiarize yourself with *First Light* and get the feel of using it to explore the sky.

The next two sections, *The Solar System* and *Beyond the Solar System*, describe the different types of astronomical objects – Sun, Moon, planets, stars, etc. – that *First Light* can show you. These general information chapters also contain tutorial material that shows you how to use *First Light* to explore the universe.

The last section, *First Light Reference*, contains reference material that gives specific details about each of *First Light's* features.

Typographic Conventions

Throughout the manual, names of menu items, buttons and other interface elements are shown in ***bold italic*** type. Settings and other information that you can change from your keyboard are shown in **bold** type.

Installing First Light

In order for you to use *First Light*, the program and some of its data files must be installed onto your hard disk from the CD ROM.

System Requirements

Before installing *First Light* onto your hard disk, make certain that your computer system meets the following minimum requirements:

- 486-33 processor minimum, 486-66DX2 recommended, Pentium will perform even better.
- Windows version 3.0 or later, except Windows NT – *First Light* does not run under Windows NT.
- 8 MB RAM
- Sound card (optional)

- 256 colors
- CD-ROM drive

First Light is optimized for 256 color graphics modes and looks best in 800x600 or higher resolution. One major feature, fast texture mapping of the planets (***Hover*** and ***Flyby*** modes), works *only* in 256 color mode. If you are running with more colors, the fast texture mapping menu items are disabled and planets are displayed as simple wire frames. The slow texture mapping (24 bit rendering) will work with more colors.

Installing First Light from the CD ROM

Certain files, including the *First Light* program, must be installed from the CD ROM onto your hard disk.

To install *First Light* from the CD ROM:

1. Insert the *First Light* CD into your CD ROM drive.
2. From the *Windows Program Manager*, select ***Run...*** from the ***File*** menu. Type the appropriate drive reference for your CD drive followed by install, then press the Enter key. For example, if your CD ROM is drive D, type

   d: install

   followed by Enter.
3. The installer next prompts you for the name of the directory you wish to install *First Light* into. The default directory path is c:\f_light. Click on ***Continue*** to create the directory and start the installation.
4. After all necessary files have been copied onto your hard disk from the CD ROM, an *Installation Complete* message is displayed and the data files are automatically decompressed. Once the files have been decompressed, you are ready to run *First Light*.

Exploring First Light

Now that *First Light* is properly installed on your computer, let's take a quick tour and explore some its many exciting and interesting capabilities. Informative and entertaining for either an advanced astronomy buff or a newcomer, the concepts and skills used in these easy to follow explorations will help you to gain an understanding of how to navigate through the program and give you an overview of some of the important features.

First, we'll transfer our viewpoint into space to observe our own solar system. We'll take a look at the Earth from the viewpoint of NASA's *Galileo* space probe. Then we will set the planets in motion around the Sun and observe their orbits by allowing time to advance at a faster than normal rate.

Next we'll visit Mars and learn more about our red neighbor as we hover near it. We'll explore its surface with photographs taken by space probes and read informative facts. We'll even experience what it would be like to fly over the surface when we view a computer-generated landscape derived from real topographic data sent back to Earth from satellites and probes.

Lastly, we'll come back to Earth and take a look at what the night sky looks like from your home tonight. We'll examine *First Light's* ***Calendar*** for information, including the moon's current phase, and see descriptions of upcoming astronomical events. Finally, we'll dip into the ***Nightly Grabbag*** for interesting photographs and thoughtful articles about the heavens.

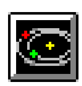
Are you ready? Let's go out and explore space!

Viewing Our Solar System

If *First Light* is not already started, double click on the *First Light* icon in the Windows Program Manager to start the program. After the title screen and music finish, the ***Sky Tonight*** window is displayed. Click on the ***Planetarium*** button to open the ***Planetarium*** window, *First Light's* main sky display window. Your viewing location is displayed in flashing text in the upper left corner of the ***Planetarium*** window. You are looking out into space and seeing stars, and possibly planets, against the sky.

Notice the familiar Windows menu and tool bar across the top of the window. There is also some information about the current view date, direction, and field of view displayed on the status bar at the bottom of the window.

The first thing we need to do in order to look at our solar system is to move our viewpoint off Earth into space. Select ***Lookdown-middle planets*** from the ***Viewpoint*** submenu in the ***View*** menu. Your viewpoint is moved into space (the text in the upper left corner reflects this change).



Off Earth button

The ***Planetarium*** window changes its display to reflect our new position and we can see the Sun, several planets closest to the Sun, and their orbital paths. Also displayed is a series of lines laid out in a grid pattern, defining an imaginary plane. This plane is known as the *ecliptic*. It is the plane of the earth's orbit and approximates the plane of the other planets' orbits.

Let's take a minute and explore some of the objects that we can see. Position the mouse pointer on a planet or a star, and click with the left mouse button. *First Light* verifies the object you have chosen by identifying it with a target sight, then displays its information window. Information such as object attributes and position is displayed in the window, along with other data that vary with the type of object selected. Try clicking on a few planets and stars to learn more about them. When you are finished, close all the information windows by clicking on the ***OK*** button in each one.

Now we'll open a multimedia information window for Earth and view some space-based photographs. Click on ***Earth***, and examine the information window that appears. Click on the ***explore*** button. A multimedia information window containing photos, short films, and explanatory text opens. Clicking on the up and down arrows scrolls you through a catalog of photos and descriptions. Try looking at a few of these now.

Notice the buttons next to the up and down arrows. These represent the ***Photo*** and ***Film*** options (***Film*** option is not available with every image). Clicking on the ***Photo*** button (the one on the far right) displays the current image on your full screen so that you can examine it in more detail. Clicking once anywhere with the left mouse button returns you to the previous screen.

Let's take a look at a film of Earth that was taken by the *Galileo* space probe. Scroll to the photo of Earth with the caption relating to the "Jupiter-bound *Galileo* probe..." (the third image). Click on the ***Photo*** button and view the related short film. When you're finished, you can look through more of the available photos and films. Close the multimedia and information windows when you're through and return to the view of the solar system.

The first step for setting up our planetary orbit animation is to define *First Light's* clock settings. Select ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu open the ***Clock Control*** dialog box. If the ***Tools*** menu is not already displayed on the menu bar, select ***Expert menus*** from the ***File*** menu.

Clock Control dialog box

The five buttons at the left of the ***Clock Control*** dialog box resemble the control buttons on an audio CD or a video cassette player. These buttons are also on *First Light's* tool bar and can be used from there, also. They start and stop *First Light's* clock. The middle button is ***stop***, the two buttons to either side of the ***stop*** button change time forward or backward one step at a time (***step forward*** and ***step back***), and the two outer buttons move time forward or backward by continuous steps until the ***stop*** button is clicked (***Rewind*** and ***Fast forward***).

Use the drop-down list boxes at the right of the ***Clock Control*** dialog box to select ***2 days*** as the ***Step*** interval, then click ***OK***. The ***Clock Control*** dialog box closes. Using the clock buttons on the tool bar, click on the ***step forward*** button (labeled with a right pointing single arrow) to move time forward by one step. Repeat this several times, watching the planets move along their orbits by steps of two days at a time. You can also make time go backward a step at a time by clicking on the corresponding backward button.

To see the planets revolve around the Sun, click on the ***fast forward*** button (labeled with a right pointing double arrow). The planets begin to revolve around the Sun at their respective rates. Notice that each planet revolves at a different speed. Mercury completes its orbit more than four times before the Earth completes its journey once. Stop the animation by either clicking on the tool bar's ***stop*** button or clicking on an object in the ***Planetarium*** window (this will open that object's information window). You can restart the clock by clicking on the clock buttons, or go ahead to the next exploration.

Visiting Mars

In the previous exploration, we looked at the solar system from space and examined Earth in detail. Now we'll see how to hover near a planet, rotate it and look at features on its surface.

From the ***Hover*** submenu located in the ***Planets*** menu, select the planet ***Mars***. A representation of the planet Mars is displayed, along with various data related to it. If your system is set to 256 color mode, the planet's surface is rendered using digital image photograph information. Various features on the surface are labeled, such as geographic landmarks and spacecraft landing sites.

Our viewpoint is set so that we are "hovering" near the planet. We can change the position of the viewpoint relative to Mars by the holding down on the right mouse button and moving the pointer. The distance of our viewpoint from Mars remains the same, but the planet rotates and moves according to the way you move the mouse. Try spinning the planet around a bit until you get the hang of it.

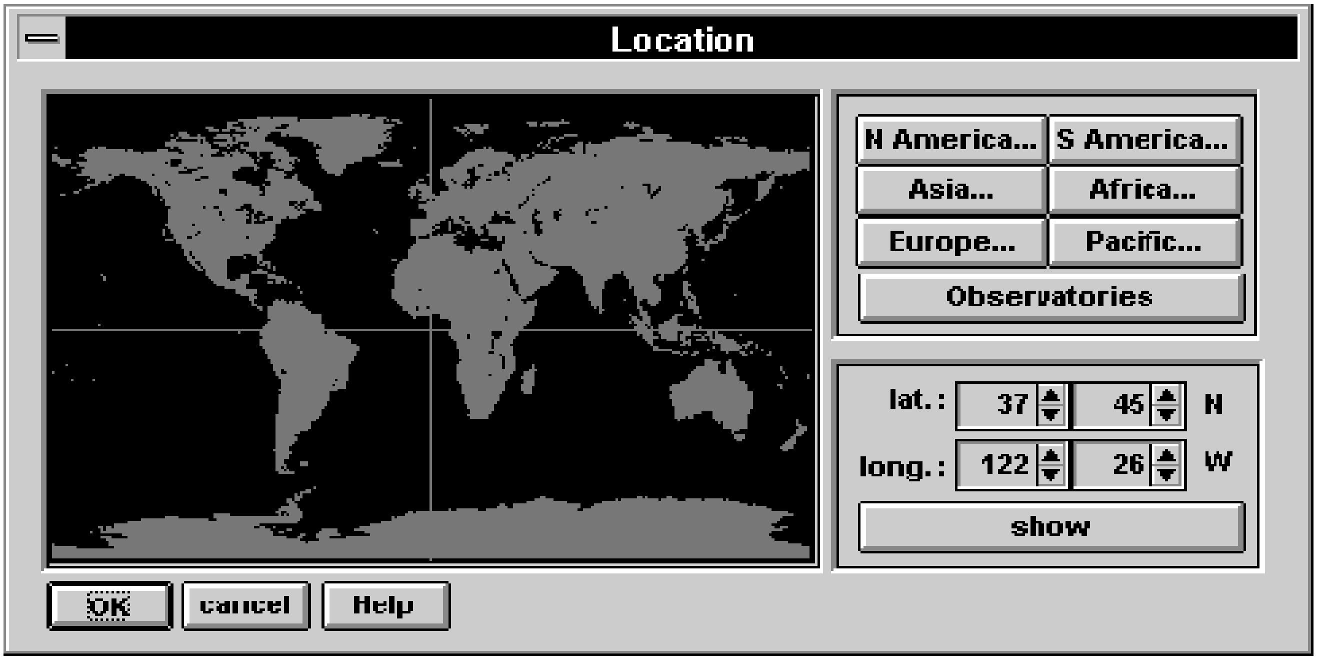
You can open multimedia windows like the one we looked at for the Earth in the previous exploration. Click with the left mouse button on any of the features on the planet's surface that are labeled with a diamond. The target symbol identifies the selected feature and a related multimedia window opens. As with the window we used earlier, you can scroll through photographs, read interesting facts in the captions and view short films. Take some time to explore the surface of Mars in this way.

Now it's time to take a flight over Mars and view a portion of its surface through a computer-generated animation. Rotate the planet using the right mouse button until you find the feature labeled ***Valles Marineris***. Select this feature with the left mouse button, opening the associated multimedia window. Click on the ***Film*** button and you will see an animation that takes you on a flying tour of a portion of the *Valles Marineris*. The surface of the planet has been rendered using topographic data and computer modeling. You can explore other areas of Mars by opening other multimedia windows and looking for more animated fly-overs. When you are finished, close the multimedia and information windows and return to your original hover position near Mars. Select ***Return to earth*** from the ***View*** menu's ***Viewpoint*** submenu to return your viewpoint to the Earth.

The Sky Tonight

We've looked at the solar system from space and we've hovered near Mars. Now let's return to Earth and see what the sky looks right now from your location on Earth.

First we'll have to set our location. Select ***When and where*** from the ***View*** menu. This opens the ***When and where*** dialog box. Click on the ***now*** button to set the time on *First Light's* internal clock to match your computer's date and time. Click on the ***location*** button to open the ***Location*** dialog box.



Location dialog box

The ***Location*** dialog box displays a map of the entire surface of the Earth. You can approximate your position by pointing to a location with the mouse and clicking on it with the left mouse button, or you can select a nearby city from the scrolling list obtained by clicking on the appropriate continent button. Select your position and click ***OK*** to close the ***Location*** dialog box. Then click ***OK*** in the ***When and where*** dialog box.

Now that *First Light* knows where you are and what day it is, let's take a look at tonight's sky. Select ***The Sky tonight*** from the ***View*** menu. This opens a view of the sky from your location as it looks at the date and time displayed in the upper left corner of the screen. You are looking at a 180° view of the sky (as if you stood in one spot and turned completely around) laid out flat on your monitor. The directions of the compass are shown along the simulated horizon. You should see stars and, possibly, the Moon, planets and other objects, just as they appear in the sky from your location on Earth.

Clicking on the ***Now*** button displays the sky as it is right now. The ***Sunset*** and ***Sunrise*** buttons display the sky as it will be at the next sunset and sunrise, respectively.

Click on the ***Calendar*** button to open this month's calendar with today's date highlighted. The calendar shows you the phases of the Moon and upcoming astronomical events. Clicking on today's date displays an information window with the sunrise and sunset times, and more information about any astronomical events that might be taking place. Scroll through the past or upcoming months to look for interesting astronomical phenomena and events, or change the date of the display. Click ***OK*** when you're finished to return to ***The Sky tonight*** display.

Another interesting feature of ***The Sky tonight*** display is the ***Nightly Grabbag***. Clicking on this button opens a window with text and pictures of tidbits and trivia related to the heavens. Each day has a different grabbag item, so there is always something new to discover. Terms in the text that are underlined can be clicked on to view their definitions. Occasionally there are small buttons, labeled with the image of a telescope, that you can click on to center your view on the object in question. Click on the ***Nightly Grabbag*** button now to see today's offering. When you are finished with the ***Nightly Grabbag***, close the window and return to ***The Sky tonight*** display.

Take some time and explore ***The Sky tonight*** display. When you are finished, you can click on the ***Planetarium*** button to return to *First Light's* main display.

Congratulations! You have taken a journey into space, watched the Earth move around its orbit, looked down on the solar system, flown over the surface of Mars and returned to look into the heavens from your hometown – all without leaving home. By doing so, you have acquired skills with *First Light* that will enable you to go as far as your imagination can carry you into the heavens. Now you are ready to take off on your own journey into space. Enjoy!

Using First Light

Basic Concepts

At this point, we will take a brief moment to explore some of the basic concepts of visual astronomy. This will help you in working with *First Light*.

To begin, it is helpful to think of the sky in the same way the early astronomers did – by imagining the stars and planets as being attached to the inside of a hollow sphere with the Earth at the center. This sphere, in turn, revolves around the Earth, creating the stellar motions.

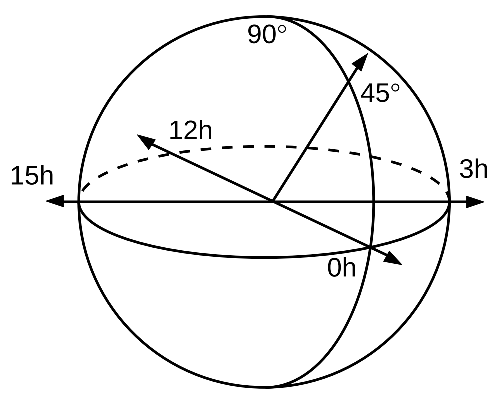
Variations on this theme had each planet on a separate crystalline sphere revolving on its own, which explained their independent movements. But for now, the single sphere model will do.

Coordinate Systems

Another concept that is essential for understanding how astronomers describe the locations of celestial objects is that of *coordinate systems*.

We are all familiar, in one way or another, with coordinate systems. A coordinate system is a method of specifying the location of a particular place, whether it is on a piece of paper, on the Earth or in the sky. Our home addresses, for example, represent one coordinate system, the earth's latitude and longitude lines are another.

In order locate stars, astronomers have developed a system, called the *equatorial coordinate system*, for the sky which is analogous to latitude and longitude on Earth. Latitude in the sky is called *declination* (or *dec*) and longitude is called *right ascension* (or *RA*).

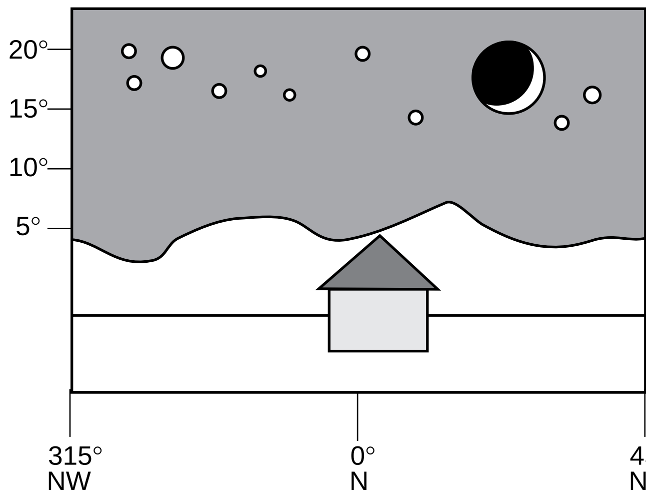


Equatorial coordinate system

Declination is measured in degrees and ranges from –90° to +90°. Zero degrees (0°) declination is called the *celestial equator*.

Right ascension, on the other hand, is measured, not in degrees, but in hours, minutes and seconds. Each hour of right ascension is equivalent to 15°. Right ascension increases to the left (counter-clockwise).

A second coordinate system that is important is the *horizon* or *local coordinate system*, which is used to specify the location of objects in your local sky. In the horizon coordinate system, locations are specified by *azimuth*, or compass heading, with north being 0°, and *altitude*, or the angular elevation above the horizon. Both azimuth and altitude are measured in degrees. Azimuth increases to the right (clockwise), in contrast to right ascension. Because of the earth's rotation, the horizon coordinates of a given object are constantly changing, while its equatorial coordinates remain constant.



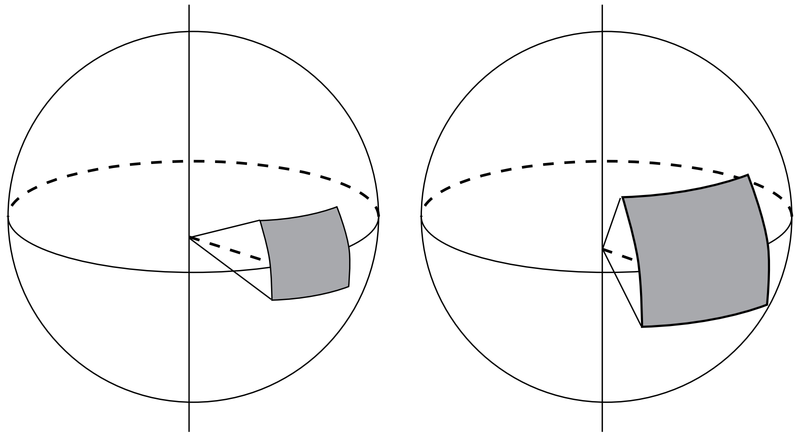
Local coordinate system

First Light can use either equatorial or horizon coordinates. Select the coordinate system for *First Light* to use with the ***Mode*** submenu in the ***View*** menu. The default setting is the equatorial coordinate system, or ***Equatorial*** mode, rather than your local coordinate system, or ***Local*** mode. There are two reasons for this.

1. ***Equatorial*** mode calculates star positions and redraws the sky display somewhat faster than ***Local*** mode, which makes navigating around the sky easier.
2. ***Equatorial*** mode removes the ambiguities introduced by using your local coordinate system. That is, *Altair's* equatorial coordinates are always the same, but its local horizon coordinates change continuously.

Field of View

Another important concept is *field of view*, also referred to as either *field* or *FOV*. Field of view describes how much of the sky is visible at any one time. That is, the magnification of the display. Field of view is measured in degrees width. A 90° field means that 45° of the sky is visible on either side of the screen's center. The smaller the field, the larger the displayed image. In other words, you *zoom in* for a smaller field of view and *zoom out* for a larger field.



Field of view

First Light's field of view controls can be thought of as a zoom lens. You can zoom in for a closer view, or zoom out to see more stars. Remember that as the number of objects on the screen increases due to widening the field, the speed at which the sky is redrawn when the view is changed, slows down. The field of view can be changed in two ways. You can select a particular field of view from the ***Zoom*** submenu in the ***View*** menu or you can use the right mouse button to drag around an area that you wish to zoom to in the ***Planetarium*** window. Dragging diagonally from left to right zooms the view in for a narrower field of view. Dragging diagonally from right to left zooms the view out for a wider field of view. The current field of view is shown in the status bar at the bottom of the ***Planetarium*** window.

The smallest field of view that *First Light* can display is 0.01°. The largest is 180°, which shows half of the entire sky. The most comfortable and natural setting is between 40° and 65°.

Because *First Light* renders a three-dimensional curved surface on a flat, two-dimensional screen, certain distortions occur, similar to what a wide angle camera lens shows. The distortion is most noticeable along the edges of the display when the field of view is greater than about 70°. The least distortion is in the center of the screen.

First Light's Main Windows

The Planetarium Window

The ***Planetarium*** window is *First Light's* main sky display window and it shows the sky and the objects in it, according to the location of *First Light's* viewpoint, the ***Zoom*** setting, and the state of *First Light's* internal clock. The types of objects and the labels displayed with them in the ***Planetarium*** window are selected through various menu items and dialog boxes. See the *Menus* chapter for more information.

Using the Mouse

Aiming the View

The mouse can be used to change the direction of the view shown in the ***Planetarium*** window. Any point in the sky can be centered in the window by clicking on that point with the right mouse button. This is called *point and center*. The sky display can also be dragged within the ***Planetarium*** window by holding down the right mouse button while dragging the mouse. The view in the ***Planetarium*** window can also be aimed with the items in the ***Center*** submenus in the ***Planets*** and ***Stars, etc.*** menus.

The direction of the view in the ***Planetarium*** window can also be set using the ***Navigator*** window. The ***Navigator*** window is opened by selecting ***Navigator*** from the ***View*** menu. When the ***Earth*** button in the ***Navigator*** window is selected, the upper portion of the window displays a wire-frame sphere. The sphere represents the sky, with your viewing position in its center. The Sun, Moon and planets are marked on the surface of the sphere. The red lines represent the field of view. Holding down the left mouse button and dragging with the mouse over the sphere display rotates the field of view around the sphere. Dragging to the left or right rotates the field around the vertical axis. Dragging up or down rotates it around the horizontal axis. As soon as the mouse button is released, the view in the ***Planetarium*** window is updated to show the change. Holding down the right mouse button and dragging with the mouse rotates the sphere display so that you can more clearly see the relationships between the objects.

When the ***Home*** button in the ***Navigator*** window is selected, *First Light* switches to ***Local*** mode, using local coordinates to draw the sky (see the *Basic Concepts* chapter for an explanation of coordinate systems). The display in the upper portion of the window is similar to that with the ***Earth*** button selected. Instead of a sphere, the display is a half sphere representing the portion of the sky that can be seen from your location on Earth. See the *Setting Your Location and Time* chapter for information about how to set *First Light's* viewing location.

See the section on the ***Navigator*** window in the *First Light Menus* chapter for information about the ***Navigator's*** other features.

Zooming the View

The view in the ***Planetarium*** window can be zoomed in to a smaller field of view by holding down the left mouse button and dragging a box diagonally from left to right around the area that you wish to magnify. Likewise, the view can be zoomed out, increasing the field of view, by dragging the mouse diagonally from right to left. The view in the ***Planetarium*** window can also be changed with the items in the ***Zoom*** submenu in the ***View*** menu.

Changing Your Position in Space

When *First Light* is in ***Hover*** or ***Flyby*** mode, dragging the mouse with the right button held down changes the position of your viewpoint rather than changing where the view is aimed. This allows you to keep the view aimed at the same object while easily moving around the object. Moving the mouse left and right rotates the your viewpoint around the planet. Moving the mouse up and down moves your viewpoint north and south in relation to the object, while keeping the object centered. See the *Hover* and *Flying by the Planets* sections in the *Setting Your Location and Time* chapter for more information about these features.

Information About Objects in the Sky

Clicking on any object in the ***Planetarium*** window with the left mouse button opens an information window for the object. The information contained in the window varies, depending on the type of object it describes. See the chapters about each of the various types of objects for an explanation of the meaning of the information in the window.

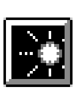
Information windows for stars and deep sky objects (galaxies, nebulae and star clusters) have two buttons labeled ***notes*** and ***center***. Clicking on the ***notes*** button opens another window containing additional information, such as historical notes, common names, etc. The ***notes*** button is disabled if there are no notes for the selected object. Clicking on the ***center*** button centers the object in the ***Planetarium*** window. Information windows for stars also have two buttons labeled with up and down arrows. These buttons cycle the window through the stars in *First Light's* main star database. Information windows for deep sky objects may include a small gray scale image of the object.

Information windows for planets have a button labeled ***explore***. Clicking on this button opens another window containing additional information about the planet. This second window also gives you access to color images and movies of the planet.

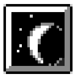
The Tool Bar

First Light's tool bar is located along the top of the ***Planetarium*** window below the menu bar. The buttons on the tool bar duplicate the most commonly used menu items for more convenient access.

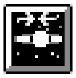
Starting from the left end of the tool bar, the first several buttons control the display of solar system objects and constellations.



Center the Sun in the ***Planetarium*** window.

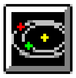


Center the Moon in the ***Planetarium*** window.

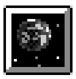


Center a planet – this button opens the ***Planets*** centering dialog box.

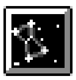
Toggle the names of the planets on or off.



Move your viewpoint off the Earth into the solar system.

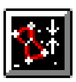


Move your viewpoint back to Earth.



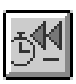
Toggle constellation outlines off or on in the ***Planetarium*** window.

Toggle constellation names off or on in the ***Planetarium*** window.

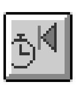


Center a constellation – this button opens the ***Center Constellation*** dialog.

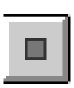
The next buttons in the tool bar control *First Light's* internal clock. They are styled to resemble the buttons on a VCR control pad. With these controls, the clock can be advanced by increments, giving a "time lapse" effect that demonstrates the motions of the planets and other solar system objects against the stars.



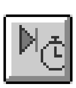
Rewind button. Continuously decrease the time by the increment set in the ***Clock Control*** dialog. Clicking once on this button starts the clock decreasing as fast as possible. Clicking the center button stops the clock.



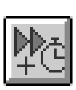
Step back button. Decrease the time by one increment each time the button is clicked. For example, if the increment is set to five hours, this button subtracts five hours from the clock each time it is clicked.



Stop button. Stop *First Light's* internal clock.



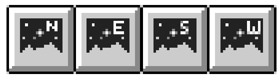
Step forward button. Increase the time by one increment each time the button is clicked. For example, if the increment is set to five hours, this button adds five hours to the clock each time it is clicked.



Fast forward button. Continuously increase the time by the increment set in the ***Clock Control*** dialog. Clicking once on this button starts the clock increasing as fast as possible. Clicking the center button stops the clock.

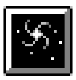
Settings button. Open the ***Clock Control*** dialog, through which the time increment is set. The increment can be as short as one minute, useful for animating eclipses, and as long as one hundred years.

The next set of buttons on the tool bar select *First Light's* ***Quickview*** settings. They turn on a number of features to show the sky from your home position looking toward any of the four cardinal directions (north, east, south or west). Your home position is set through the ***When and Where*** dialog box.



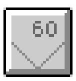
Quickview buttons

The next button controls display of deep sky objects.

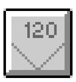


Toggles display of selected objects from the NGC and Messier catalogs on or off.

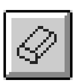
The zoom buttons set the field of view of the display to two commonly used settings.



The first button sets the display to a width of 60°, which is close to what the unaided human eye sees.



The second button sets the display to a width of 120° degrees, giving a wider view – objects appear to be smaller but are shown in a broader context. Remember that the wider the field of view, the slower the display, since *First Light* has more objects to redraw whenever the view changes.



The last button on the tool bar resets the screen to a commonly used set of options. It saves you the time that it would take to turn each feature on or off individually. The ***Save cleanup*** item in the ***File*** menu's ***Settings*** submenu allows you to customize this feature.

The Sky Tonight

One of the more difficult tasks in observing the starry sky is to make sense of just what you are looking at. The ***Sky Tonight*** window, opened by selecting ***The Sky Tonight*** from the ***View*** menu, is designed to help you do that. It displays the sky as it is visible from the location on Earth, and the date and time, for which *First Light* is currently set. See the chapter on *Setting Your Location and Time* for more information about setting *First Light's* viewpoint location and clock. The Sun, Moon and planets are all displayed if they are currently visible, along with a simulated horizon.

The buttons at the bottom of the ***Sky Tonight*** display set the viewing direction and time of day. There are also buttons that give access to other windows.

The ***Planetarium*** button closes the ***Sky Tonight*** window and takes you back to the ***Planetarium*** window, *First Light's* main sky display window.

The ***Calendar*** button opens the ***Calendar*** window, which shows interesting astronomical events occurring in the current month.

The ***Nightly Grabbag*** button opens a window containing information about objects, events and activities pertinent to *First Light's* current date.

The ***Now*** button sets *First Light's* internal clock to your computer's current system time. The ***Sunrise*** and ***Sunset*** buttons set *First Light's* clock to the appropriate times for the current date. The ***N*** and ***S*** buttons center the view in the ***Sky Tonight*** window on either north or south.

Setting Your Location and Time

Location

Exactly what the sky looks like depends on the viewpoint from which you are seeing it. *First Light* can display the sky as seen from any point on Earth or from any point in the solar system up to 400 astronomical units (AU – the average distance between the Earth and the Sun) from the Sun.

Viewing the Sky from Earth

When *First Light* displays the sky in ***Local*** mode, using local coordinates (see the *Basic Concepts* chapter), it uses the location set in the ***When and where*** dialog box to do so. *First Light* also uses this location to calculate things like sunrise and sunset times, regardless of whether it is in ***Local*** or ***Equatorial*** mode. The ***When and where*** dialog box is opened by selecting ***When and where*** from the ***View*** menu.

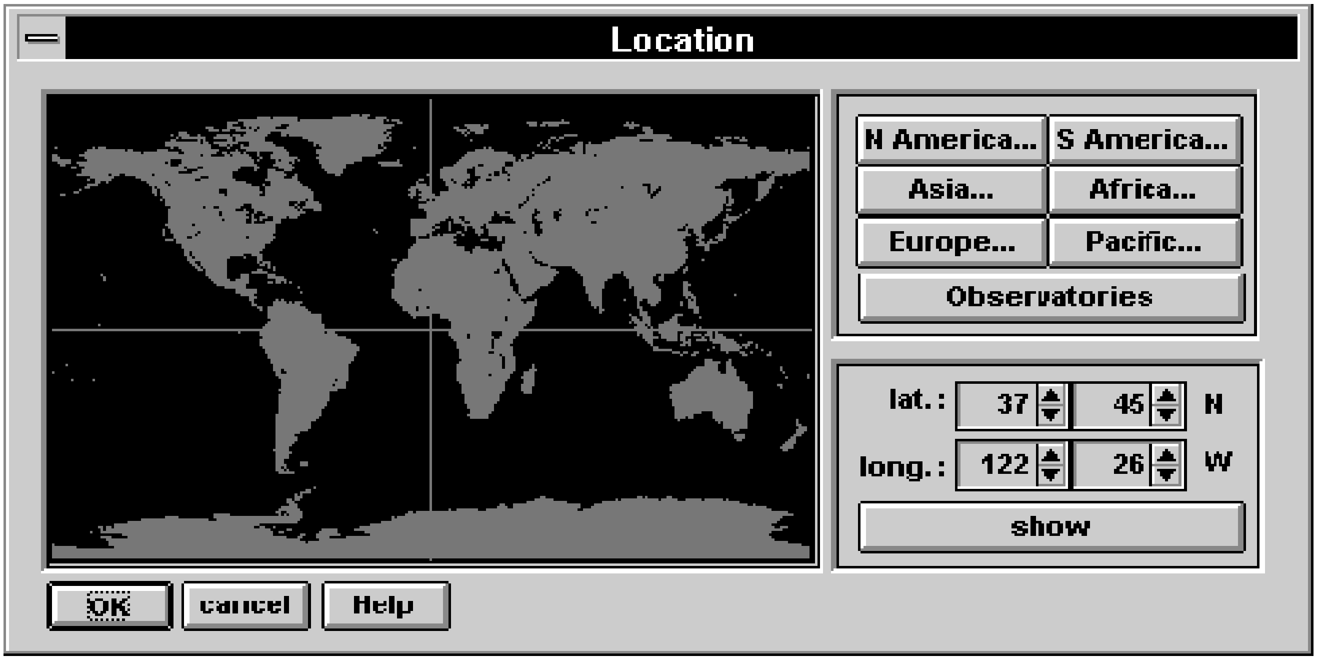
Your viewing location directly effects just what you see and when. For example, in viewing a solar eclipse, the area of totality is so narrow that the viewing position is critical. The situation for lunar occultations is the same. The positions of the stars and planets in the sky change depending on your latitude. The further north you are, the higher in the sky the north star, *Polaris*, is. Also, if your location is very far north of the equator, constellations and objects in the southern hemisphere of the sky become impossible to see, and vice versa.

Setting First Light's Viewing Location

Using the ***When and where*** dialog box, you can specify your location on Earth in a number of ways. You can specify it graphically using a world map, by selecting a city from a list or by direct numerical entry of an exact longitude and latitude. To set your location, open the ***When and where*** dialog box by selecting ***When and where*** from the ***View*** menu. Click on the ***location*** button in the ***When and where*** dialog box to open the ***Location*** dialog box.

The left half of the ***Location*** dialog box contains a map of the world. A flashing circle on the map indicates your current location. Clicking with the left mouse button anywhere on the map changes the viewing location to the point on which you click. The vertical and horizontal red lines mark 0° longitude and latitude, respectively.

The buttons in the upper right of the ***Location*** dialog box open dialogs with drop-down lists of large cities in the corresponding region. That is, the *N America* button opens a list of cities in North America. The *Observatories* button yields a list of major observatories around the world. Selecting an item from any of these lists and clicking on the ***OK*** button sets the viewing location to selected city or observatory.



Location dialog box

If your location is not in any of the lists, you can set it precisely with the ***lat.*** and ***long.*** items. Either use the up and down arrow buttons or type directly into the edit boxes to change the settings. Once you've set the latitude and longitude, click on the ***show*** button to update the map display to the indicate the proper viewing location.

The ***save*** button in the ***When and where*** dialog box saves *First Light's* current viewing location to be used as the default location the next time the program is started from the Program Manager. This saves you from having to reset the viewing location from the default every time you use *First Light*.

First Light offers many pre-set locations from which to choose. Should your location not be among the pre-set locations, you can easily add your custom location data to *First Light's* location data list. Using the Notepad (in the Windows Accessories group) is recommended, but any word processor will do.

1. Open Notepad. Select ***Open*** from Notepad's ***File*** menu.
2. Navigate to the applicable continent file located in the following directory path:

   c:\f_light\data2\user

   This is the default installation directory. If you have installed *First Light* to a directory other than *f_light*, your directory path will be slightly different.
3. Select the appropriate continent file for your location. All location files are named with a *.dat* extension. For example, selecting the *af_loc.dat* file opens the Africa continent file, the *na_loc.dat* file is the continent file for North America.

4. Once the appropriate file has been opened, you will see a list of pre-loaded locations. Each location has the following format:

   `dd:mm    dd:mm     h     aaaaaaaaaaa`

   The first column is the location's latitude (`d` for degrees, `m` for minutes).

   The second column is the location's longitude (`d` for degrees, `m` for minutes). Western longitudes have positive values (North America, South America, Pacific). Eastern longitudes have negative values (most of Europe, Africa, Asia).

   The third column is the location's time zone value. This value can be positive or negative.

   The fourth column is the location's name.

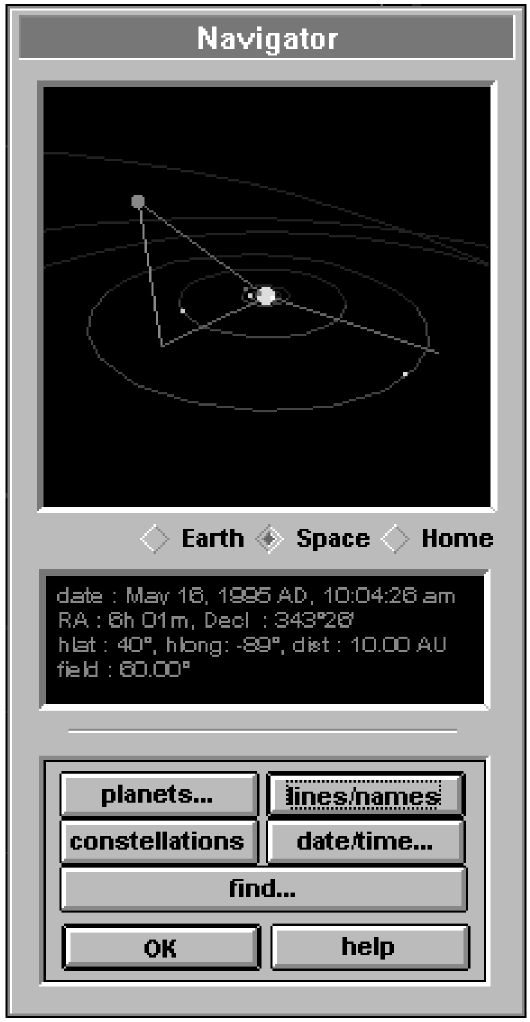
5. When you have finished adding your location to the list, select ***Save*** from the ***File*** menu. Do not save the file in a special format specific to your word processor. The continent location file must be saved as a generic ASCII text file, otherwise *First Light* will not be able to read it.

Moving Your Viewpoint off Earth

Moving *First Light's* viewpoint off the Earth can be accomplished in several ways. If you are primarily interested in viewing our solar system, the easiest is to select one of the ***Lookdown*** items from the ***Viewpoint*** submenu in the ***View*** menu. These items place the viewpoint directly above the Sun, looking down on the solar system so that you can see out to the inner planets (Mercury to Mars), the middle planets (out to Saturn) or the outer planets (out to Pluto, showing all of the planets).

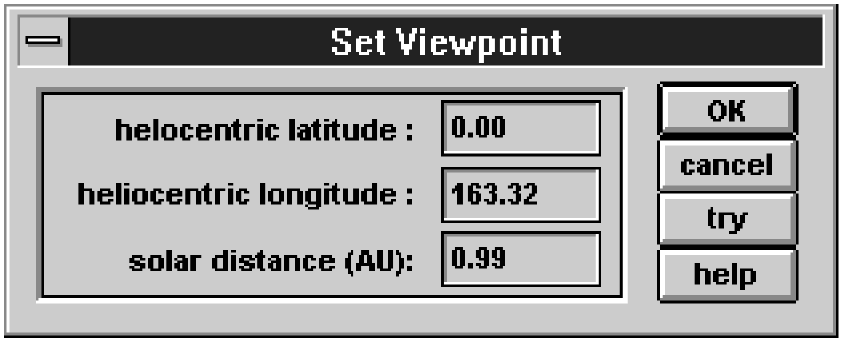
In addition to the ***Lookdown*** menu items, there are two ways to move the viewpoint to any point in the solar system. The ***Navigator*** window provides an easy to use graphical way of doing so. ***Fixed*** in the ***View*** menu's ***Viewpoint*** submenu allows the viewpoint to be set with precise numerical coordinates.

The ***Navigator*** window is opened by selecting ***Navigator*** from the ***View*** menu. To use it to set the viewpoint out into the solar system, click on the ***Space*** button. The display in the upper portion of the window changes to show a view of the solar system. The current viewpoint is shown in this display as a green dot connected to the Sun with green lines. Holding the left mouse button down and dragging the mouse over this display rotates the viewpoint around the Sun. The view in the ***Planetarium*** window is updated to reflect the new viewpoint as soon as the mouse button is released. Dragging with the right mouse button changes the orientation of the display in the ***Navigator*** dialog box to make it easier to see where the viewpoint is in relation to the solar system. When the ***Navigator*** is used to move the viewpoint around the solar system, the distance of the viewpoint from the Sun is changed by dragging the mouse with both buttons held down at the same time. For information about the ***Navigator's*** other features, see the section on the ***Navigator*** in the *First Light Menus* chapter.



Navigator window

Selecting ***Fixed*** from the ***Viewpoint*** submenu in the ***View*** menu opens the ***Set Viewpoint*** dialog box, which is used to set the coordinates of the viewpoint in terms of *heliocentric coordinates*. Heliocentric coordinates describe the position of an object (or a viewpoint) relative to the Sun. Heliocentric latitude and longitude are similar to the earth's latitude and longitude. Latitude ranges from –90° to 90°, with the plane of the earth's orbit being 0°. Longitude ranges from 0° to 360°, with 0° corresponding to 0° right ascension, also called the *First Point of Aries*. The last value in heliocentric coordinates is distance from the Sun, expressed in *astronomical units* (AU). One AU is the mean distance from the Earth to the Sun, approximately 93 million miles.



Set Viewpoint dialog box

The last item in the ***Viewpoint*** submenu, ***From a planet***, opens a dialog box with a drop-down list of planets. Selecting a planet from this list and clicking on the ***OK*** button attaches *First Light's* viewpoint to that planet.

The other two ways of moving the viewpoint off Earth, ***Hover*** and ***Flyby***, each place you in space near a selected planet, with the planet drawn realistically using artwork based on images from NASA spacecraft.

Hover

Hover mode moves *First Light's* viewpoint to a position near a selected planet, with the view locked on the planet. If your system is set to 256 colors, the selected planet is drawn (rendered) using images from NASA spacecraft so that it will look as real as possible. *First Light* slows considerably when rendering images at more than 256 colors, so if your system is set at more than 256 colors, the planets are displayed as wire frame spheres.

To enter ***Hover*** mode, simply select a planet, the Sun or the Moon from the ***Hover*** submenu in the ***Planets*** menu. While in ***Hover*** mode, the mouse is used to change the position of the viewpoint rather than for changing the angle of view as it normally is. By dragging the mouse with the right button held, down you can move the viewpoint around the planet. Moving the mouse left and right rotates the viewpoint around the planet. Moving the mouse up and down moves the viewpoint north and south in relation to the planet. As the viewpoint is moved, the planet is kept centered in the view. The changed view is shown as you drag the mouse.

When ***Hover*** mode is entered, constellation names, outlines and planetary orbit lines are turned off in order to reduce clutter and make the display more comprehensible. These options can be turn back on at any time after entering ***Hover***.

The ***Hover*** dialog box, opened by selecting ***Settings*** from the ***Hover*** submenu in the ***Planets*** menu, gives you additional control over the behavior of the ***Hover*** mode. The ***object*** drop-down list can be used to select an object to hover near. The ***dist. (radii)*** value determines the distance of the viewpoint from the selected object. The distance is in terms of the radius of the planet. For instance if the distance is ***50*** and the object is Earth, the real distance of the viewpoint from Earth is 50 times 4,000 miles (the radius of the Earth), or 200,000 miles. Using a relative distance rather than an absolute distance allows you to see comparable views of different objects with a minimum of confusion.

When the ***landing sites*** check box is checked, the landing sites of NASA's Viking landers are marked on Mars and the sites of the Apollo landings are marked on the Moon. When the ***attach*** check box is checked, the viewpoint is bound to the selected planet, so that as it moves, you move with it. This is the default setting. When the ***features*** check box is checked, major features are labeled, depending on the planet being viewed.

Clicking on the ***show*** button redraws the view in the ***Planetarium*** window using the settings in the ***Hover*** dialog box without closing the ***Hover*** dialog box.

Selecting ***Orbit*** from the ***Hover*** submenu in the ***Planets*** menu sends the viewpoint into orbit around the selected object. The characteristics of the orbit are determined by the ***orbit*** options in the ***Hover*** dialog box. The ***shape*** setting specifies whether the orbit is circular or elliptical. An elliptical orbit is roughly egg shaped, going from close to the planet to far away and back to close. The ***elliptical*** setting has an eccentricity of 0.4 and ***highly elliptical*** launches you far away from the planet with an eccentricity of 0.7. Eccentricity determines how elongated the orbit is. The ***rate*** setting specifies how quickly the view is updated. ***Fast*** updates your orbital position and refreshes the ***Planetarium*** window display every five seconds. ***Medium*** updates every ten seconds and ***slow*** updates every thirty seconds. The ***step*** setting determines how far, in degrees, the viewpoint moves around the orbit between each update. ***Small*** moves 1° at a time, ***medium*** moves 2° and ***large*** moves 5°.

When you have finished exploring the solar system in ***Hover*** mode, select ***Return to earth*** from the ***Planets*** menu's ***Hover*** submenu to return the viewpoint to Earth and exit from ***Hover*** mode.

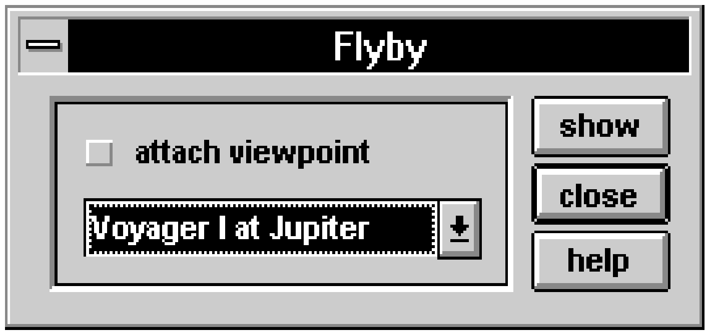
Flying by the Planets

Few NASA programs are more highly regarded than the *Voyager* probes to the outer planets. Because of these probes entire new worlds have been discovered, millions of high quality images returned to us and our concept of the solar system was changed forever. *First Light* gives you the opportunity to duplicate their historical and spectacular flybys of Jupiter, Saturn, Uranus and Neptune.

Using a chance alignment of the planets, the spacecraft were able to use the gravity of each planet to shoot it to the next one. This "gravity assist" method is a highly efficient way of going great distances with very little fuel and, in the late 1970's, the four gas giants were aligned in such a way as to permit the Voyager missions to occur. Such an alignment is possible only every 175 years.

Voyager 1 was launched on September 5, 1977. *Voyager 2* was launched on August 20 of the same year. *Voyager 1* was the first to encounter Jupiter in March of 1979 followed by its sister spacecraft in July of that year. During that time, active volcanoes on Jupiter's moon Io were witnessed for the first time. Jupiter's highly complex atmosphere was filmed and photographed in astonishing clarity. All of the images of these planets that are included with *First Light* are from the *Voyagers*. The probes were then redirected toward Saturn, making their closest approaches to that planet in the early 1980s. During those encounters, the mysterious "spokes" of Saturn's rings were discovered, along with its tangled outer ring, its shepherding moons and the deep atmosphere of the giant moon, Titan.

After Saturn, *Voyager 1* was flung out of the solar system, but *Voyager 2* was sent on to the blue planet Uranus, which it encountered in January of 1986. Here, it photographed the enigmatic moon Miranda along with the faint Uranian rings. Another five years of space travel brought the little spacecraft to Neptune, at that time the furthest planet from the Sun. Neptune surprised scientists with its dynamic atmosphere after a relatively benign Uranus. The Neptunian moon Triton hit the headlines with its tortured pinkish surface and nitrogen geysers.



Flyby dialog box

First Light's ***Flyby*** mode gives you the opportunity to more closely investigate all six of the *Voyager* planetary flybys. Open the ***Flyby*** dialog box by selecting ***Flyby*** from the ***Planets*** menu then select a flyby mission from the dialog box's drop-down list and click on the ***show*** button. Your viepoint is set in the vicinity of the selected planet, looking down on the path of the selected spacecraft. Blue dots form the part of the pathway before the spacecraft's closest approach to the planet. Red dots form the part of the pathway after closest approach. Each dot represents a half hour of motion and the entire trail begins at one day before closest approach and ends a day after.

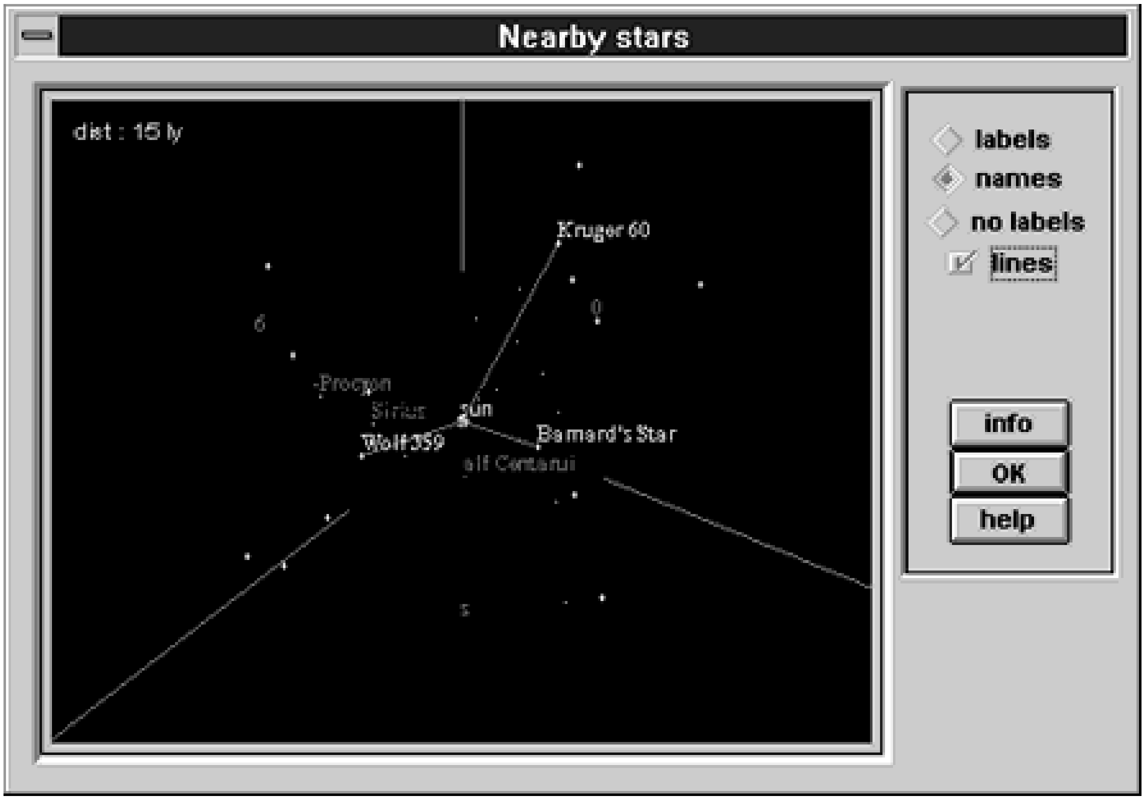
The drop-down list in the ***Flyby*** dialog box allows you to select any of the six possible flybys. The path of fragment Q of the Shoemaker-Levy 9 comet as it approached Jupiter is also available.

Checking the ***attach viewpoint*** check box attaches the viewpoint to the spacecraft (or comet fragment) so that you can see the encounter from its perspective.

In ***Flyby*** mode, the target planet is fixed in the center of the ***Planetarium*** window. By holding down the right mouse button and dragging the mouse, you can reposition the viewpoint to any location around the planet, as in ***Hover*** mode.

Note that ***Flyby*** mode is similar to ***Hover*** mode, but the two cannot be used together.

When you have finished exploring the *Voyager* flybys, select ***Return to earth*** from the ***View*** menu's ***Viewpoint*** submenu to return the viewpoint to Earth and exit from ***Flyby*** mode.



Nearby Stars window

First Light can take your viewpoint up to one hundred light years from our Sun to show you the stars closest to us. Selecting ***Nearby stars*** from the ***Tools*** menu opens the ***Nearby stars*** window. This window has a three dimensional display of the stars up to one hundred light years away from our Sun. Holding down the right mouse button and dragging rotates the display. Holding down the left mouse button and dragging up or down moves the viewpoint closer to or farther from the Sun.

When the ***labels*** button is selected, the scientific names of the major stars are displayed. When the ***names*** button is selected, the proper names of the more prominent stars are displayed. When the ***no labels*** button is selected, the stars are displayed without labeling. When the ***lines*** button is selected, lines are drawn from the Sun to some of the other stars so that you can get a better sense of their distance from the Sun. Lines and labels are displayed in bright colors for stars that are in front of the Sun and in dimmer colors for stars that are behind the Sun.

Time

Since objects in the sky and the Earth itself are moving through space, the locations of objects in the sky change according to date and time. *First Light* uses its own internal clock to keep track of the date and time of day for which the sky is displayed. *First Light's* clock is set through the ***When and where*** window and the rate at which it runs is controlled through the ***Clock Control*** dialog box and the ***Clock*** submenu in the ***Tools*** menu.

Note that the date and time used by *First Light* are not necessarily the same as the date and time on your computer's system clock. However, whenever *First Light* is started from the Program Manager, it automatically sets its internal clock to the current date and time on your computer's system clock.

Setting the Time

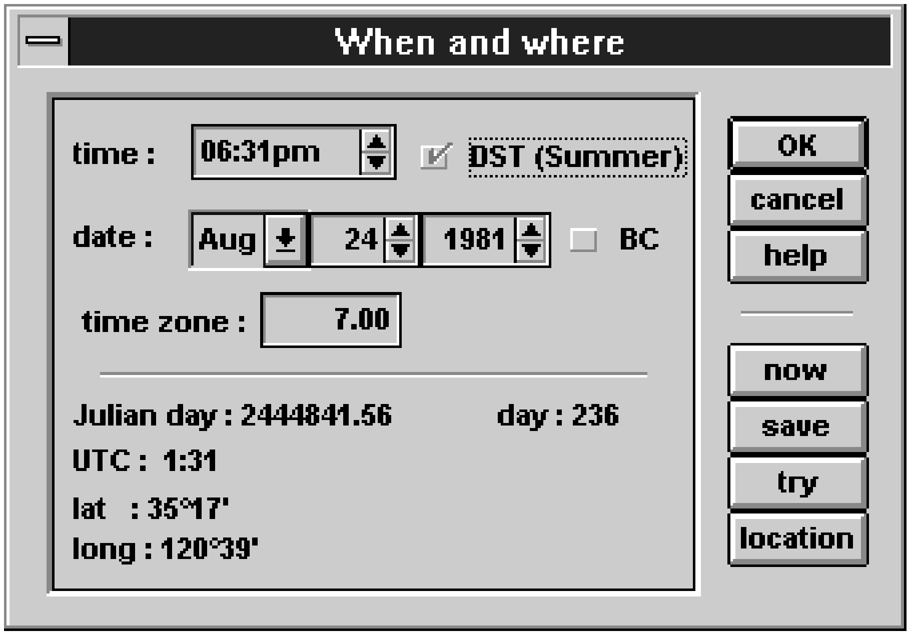
To set *First Light's* clock, open the ***When and where*** dialog box by selecting ***When and where*** from the ***View*** menu. The time and date are displayed in the top half of the dialog box. They can be changed by clicking on the up and down arrow buttons. The month is changed with a drop-down list box. You can type the date, year and time zone directly in the appropriate edit box. The time of day can also be changed by clicking on the hour or minutes portion of the time and using the up and down arrow keys on your keyboard. The date can be set to any year from 4713 B.C. to 9999 A.D.

If the location set through the ***location*** button observes daylight savings time, click on the ***DST*** check box.

The ***time zone*** value is the number of hours that need to be added to the specified time to convert it from local time, or *Standard Time*, to *Universal Time*, or *UTC*. That is, if the ***time zone*** value is 8.0, adding 8 hours to your local time gives you the Universal. Universal time is the time at the Greenwich meridian, formerly referred to as *Greenwich Mean Time* or *GMT*. *First Light* attempts to calculate the proper time zone based on your location. However, the zonal boundaries do not always follow lines of longitude, but are very irregular, often following political boundaries. You may want to check a map for the proper time zone if the position of objects displayed in the ***Planetarium*** window seem to be off by an hour.

The ***now*** button sets the date and time to the current date and time or your computer's system clock. This can be handy if you have been observing historical or future events and wish to return to the present.

The ***Try*** button redraws the display in the ***Planetarium*** window using the date, time and location in the ***When and where*** dialog box without closing the ***When and where*** dialog box.



When and where dialog box

The bottom portion of the ***When and where*** dialog box displays *First Light's* current date and time in terms of the ***Julian date*** and Universal Time (***UT***). The *Julian date* is an absolute date used to pinpoint astronomical events. It is the number of days from January 1, 4713 B.C. The day of the current year is also displayed in the dialog box. January 1 is day 1 and December 31 is day 365. The very bottom of the dialog box shows the latitude and longitude of *First Light's* current viewing location.

Controlling Time

First Light's internal clock can be made to run at different rates in order to animate astronomical events and show the motion of the solar system objects. The clock is controlled through the ***Clock Control*** dialog box, opened by selecting ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu, or by clicking on the ***Settings*** button on the tool bar. The ***Expert menus*** item in the ***File*** menu must be selected so that it has a check mark next to it for the ***Tools*** menu to be available.

The five buttons at the left of the ***Clock Control*** dialog box control the passage of time on *First Light's* clock. These buttons are repeated on the tool bar at the top of the ***Planetarium*** window, so you do not need to open the ***Clock Control*** dialog box to simply start and stop the clock. The button at the left end marked with a double arrow pointing left is like the rewind on a VCR. The button at the right end marked with a double arrow pointing right is like fast forward. Clicking on either of them once starts the clock moving continuously backward or forward. When the clock is moving, each update of the ***Planetarium*** window display changes the clock by the ***Step*** increment set to the right of the control buttons. Clicking on the center button stops the clock. Clicking on the single arrow buttons change the clock backward or forward by one ***Step*** increment each time they are clicked.

The time increment for the clock is set by the two drop-down lists to the right of the ***Step*** label. If ***2*** is selected from the left list and ***hours*** is selected from the right list, the clock will change two hours at a time when any of the arrow buttons are used.

An increment of a single day is useful for studying the motions of the inner planets and the Sun. A one week or greater increment is good for observing the slower moving outer planets. Use an hour or less for lunar motions and a minute or so for animating solar eclipses.

Making Your Own Movies

One of *First Light's* more powerful features is its ability to take an animation sequence and package it in a file that can be played as a movie by any Windows based application. In order to play these movies, you need to have the Windows Media Player utility installed on your computer. If this utility is not already installed (look in the Accessories group in the Program manager), you can install it by running *First Light's* Install program.

You can create and play a movie of, for example, the planets revolving around the Sun. You can then insert the movie into a word processor, spreadsheet, database, or any other Windows based application document, to be played from the application. This gives you the ability to demonstrate astronomical phenomena, teach concepts, show planetary motions and more, independent of *First Light* itself (once the movie file has been created). The only limits are those of your imagination and the space available on your hard disk.

A movie file is a collection of consecutive frames. Each frame is an image of an event at a given point in time, placed in proper sequence with the rest of the frames in the movie. The amount of time that elapses between frames is set with the ***Step*** value set in the ***Clock Control*** dialog box. The ***Clock Control*** dialog box is opened by selecting ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu. Creation of movies is accomplished by setting up the beginning of the event or situation that you want to store as a movie file, selecting the time increment between frames, choosing the start and stop points and specifying other movie parameters.

The best way to illustrate the concepts involved is to lead you through an example. Then you can apply these principles to any movie you wish to make. We'll start with a simple animation sequence showing *Voyager 2* as it passed by Saturn.

Keep in mind that you are not limited to the ***Flyby*** animations that we are choosing from in order to illustrate how to use the movie making capability of *First Light*. Any time-incremented sequence can be made into a movie using the ***Create animation*** dialog box. The ***Create animation*** dialog box is opened by selecting ***Create*** from the ***Movies*** submenu in the ***Expert*** menu.

Setting up the First Frame

Select ***Flyby*** from the ***Planets*** menu to open the ***Flyby*** dialog box. Select the ***Voyager 2 at Saturn*** sequence from the drop-down list in the ***Flyby*** dialog box and click on the ***show*** button. You can see Saturn and some of its moons. The flight path of the *Voyager 2* is represented by a series of dots. Each dot represents the position of the *Voyager 2* at a different point in time, with a half hour between each dot. The blue dots represent the flight path before *Voyager 2* reached its closest point to Jupiter on its path and the red dots represent the path after the closest approach. The dots show flight path one full day before and one full day after *Voyager 2's* closest approach to Jupiter. The view shows the planet and the flight path from a viewpoint in space nearby. This view will be the first frame of your movie.

Setting the Clock

Before you start defining the movie, you can preview the animation. To do so, start *First Light's* clock moving forward and watch the resulting animation sequence.

Click once on the ***Fast forward*** button on the tool bar, labeled with a right pointing double arrow. This continuously increases the time by the increment set in the ***Clock Control*** dialog box. To stop the clock, click on the ***Stop*** button (labeled with a square, in the center of the clock buttons on the tool bar).

When you start the clock forward, the Saturn's moons move in their orbits around Saturn, Saturn rotates and, depending on the time increment set in your ***Clock Control*** dialog box, you may see the *Voyager 2* probe as it passes by. To guarantee that you see it go by, you may have to change the clock settings. Stop the animation by clicking on the ***Stop*** button on the tool bar.

Find the ***Clock Control*** button on the tool bar. It is at the far right of the clock buttons group, labeled with the picture of the clock, without any arrows. Click once on it to open the ***Clock Control*** dialog box.

The ***Clock Control*** dialog box contains the same clock control buttons as are on the tool bar and a pair drop-down lists for setting the increment between consecutive time steps. Use the drop-down lists to set the ***Step*** to ***1 hour***. Click ***OK*** to close the dialog box.

Before you test out your new clock settings, reload the ***Flyby*** sequence so that it starts from the beginning. To do this, select *Voyager 2 at Saturn* again from ***Flyby*** dialog box's drop-down list.

Click on the ***Fast forward*** button on the tool bar to start the animation from the beginning. As before, the moons orbit Saturn and Saturn rotates on its axis. As time advances, *Voyager 2* appears at the right side of the window and moves along the path described by the dots. It passes by Saturn and continues to the left side of the window. This animation sequence will comprise your movie.

Stop the clock by clicking on the ***Stop*** button. Reload the ***Flyby*** sequence by again selecting it from the drop-down list in the ***Flyby*** dialog box.

Creating an Animation

Select ***Create*** from the ***Movie*** submenu in the ***Expert*** menu to open the ***Create animation*** dialog box. This dialog box is used to specify various parameters for the movie. Notice that some of the buttons are disabled. They will become enabled later. If you are using a non-Windows-standard screen saver, such as After Dark by Berkely Systems or the Delrina screen saver, you must turn it *off* before creating a movie. If your screen saver is *not* controlled through the Control Panel in the Program Manager, it is non-standard.

The ***show data*** button toggles a textual display of information related to the date and position of the elements in the animation in the movie frame border. The ***no rotation*** button toggles the rotational motion of any planets in the movie. The ***24 bit planets*** button controls the way that planets are drawn (rendered). Turning ***24 bit planets*** on results in more accurate planet surfaces, but it makes creating movies considerably slower. 24 bit movies can only be made when your system is set to more than 256 colors.

The ***frame rate*** drop-down list controls the number of frames per second to be played in the finished movie. Leave the ***frame rate*** set to ***5*** for now. The ***size*** drop-down list is used to set the size of the frames in the movie. Select ***480 x 360*** from the ***size*** list. A red box, or *frame border*, appears in the center of the ***Planetarium*** window, showing the portion of the display that will be included in the movie.

Since the clock controls were set in the previous steps, disregard the ***set clock*** button, and click on the ***Create*** button to begin. This opens a ***Create*** file dialog. Select the drive and directory where you would like your movie to be stored, then type the name of the file that your movie will be saved as. Click on the ***OK*** button to return to the ***Create movie*** dialog box. The dialog box's title bar now reads ***ready***, the ***create*** button is disabled and the ***start*** and ***cancel*** buttons are enabled.

You are now ready to begin "filming" your movie. Click on the ***start*** button. The animation sequence begins as time moves forward according to the step set in the ***Clock Control*** dialog box. Each frame is recorded and saved to disk as a frame in your movie. The movie will consist of the sequence of frames, showing all the activity within the frame border. *First Light's* title bar shows the number of frames that have been recorded. When *Voyager 2* passes by Saturn and moves out of the frame border, hold down the Esc key on your keyboard to stop recording.

A dialog box opens, showing the name and location of the movie file, the number of frames and the size of the file. Click on the ***test movie*** button to open a window in which your movie is played. When the movie finishes playing, this window closes and you will be returned to the ***ready*** dialog box. Click on the ***Done*** button.

That's it! You have made a movie and saved it in a file format that is readable by any Windows based application. Remember, you are not limited to flybys for your movies. You can choose any time-incremented sequence of images. Orbits, eclipses, meteor showers and many other events can be made into interesting and informative movies.

To create movies of events other than flyby's, select ***Create*** from the ***Movies*** submenu in the ***Expert*** menu. This opens the ***Create movie*** dialog box, allowing you to set up a movie, specify a file name for it and begin "filming" it.

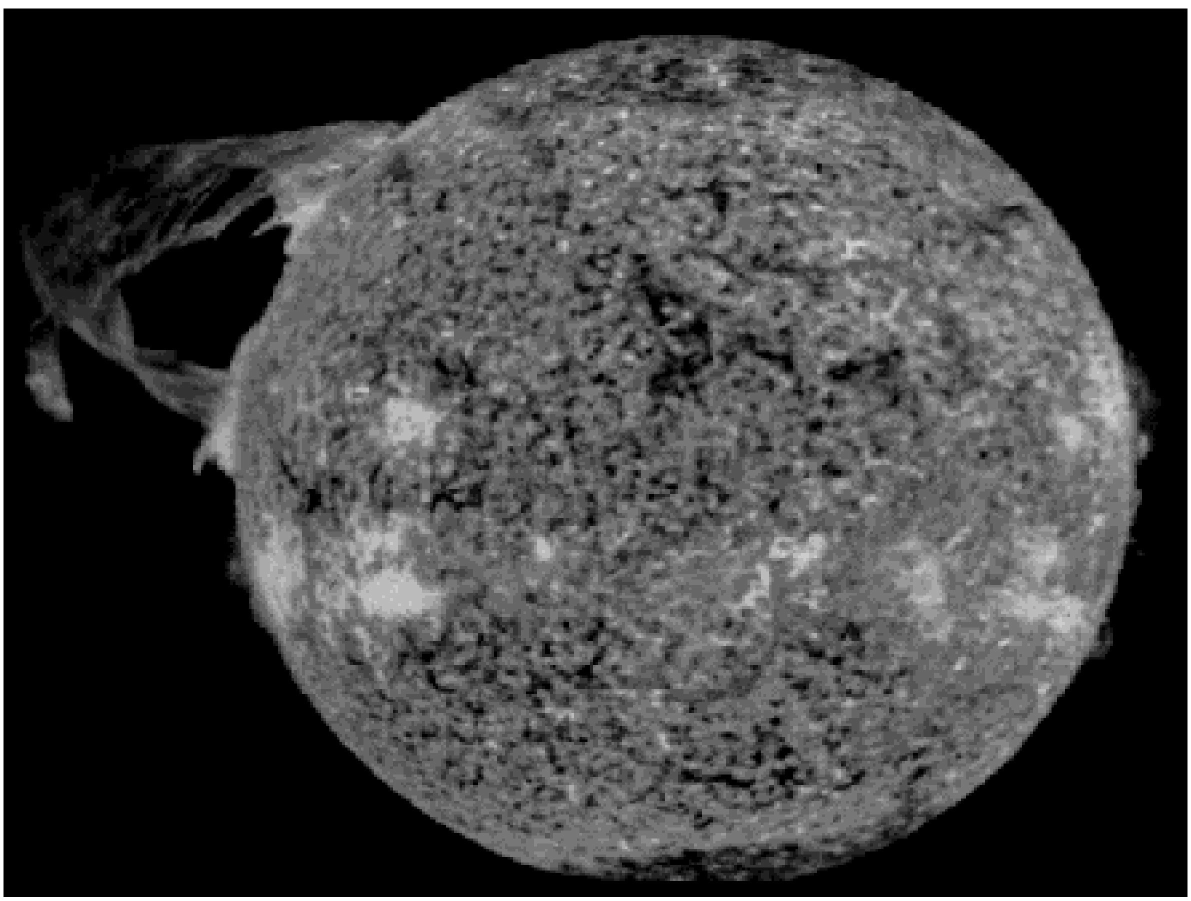
The Solar System

The Sun and the Moon

Without a doubt, the two most prominent objects in the sky are the Sun and the Moon. In the past they have been seen as gods to be appeased or celestial lovers worthy of numerous stories. Their influence on our lives are obvious. From control of the tides, seasons and weather patterns, nearly everything we do can be tied to the Sun and, to a lesser degree, the Moon.

The Sun

WARNING: If you value your eyesight, *never* look directly at the Sun without the aid of a specially equipped telescope!



The Sun

When we talk of the stars, most of us think of the night and the scintillating pinpoints of light scattered across the sky. But the Sun is also one of these pinpoints, only much closer. An unremarkable star of average size (800,000 miles in diameter), the Sun provides us a close up opportunity to study stellar processes.

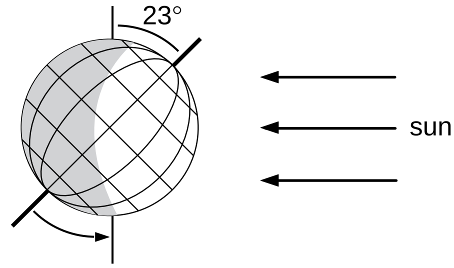
The *surface* temperature of the Sun is approximately 10,000°F (as compared to the interior which can reach millions of degrees! But it's a dry heat.). Without special instruments, there is very little observable detail on the solar surface except, perhaps, sunspots. Sunspots are compact regions which are cooler, dipping down to a brisk 7,000° and which are going through intense magnetic disturbances. Sunspots usually have a lighter fringe, called a *penumbra*, surrounding a darker core, or *umbra*. Since the Sun rotates about once every 27 days, it is possible to observe sunspots as they travel across the disk, disappear, then return days later (if they haven't vanished from the surface in the interim). Altogether, sunspot activity follows an eleven year cycle. The current cycle, number 22 since records have been kept, peaked in 1990. During the cycle minimum, days may go by with no spots visible at all while, at the peak, dozens of patches may be seen.

The activity which causes sunspots directly affects the physical properties of our atmosphere. It is responsible for the aurora (Northern or Southern lights) and for the way radio waves travel around the world. Shortwave listeners are familiar with this phenomenon which, on some days, brings their favorite radio station in loud and clear and, on others, sends it down into static.

You can observe sunspots directly ***only*** through the use of specifically modified telescopes, and only with filters placed over the ***end*** of the scope, ***never over the eyepiece*** (the author almost lost his eyesight when, as a naive youngster an eyepiece filter cracked under the heat of the Sun). For amateur telescopes, use a *reflective* filter, as opposed to the *absorption* ("smoked glass") variety which can still pass dangerous invisible ultraviolet and infrared light.

The Midnight Sun

The maximum altitude that the Sun reaches in the sky depends on two things: 1) the latitude of your location and 2) the tilt of the earth's axis. By changing the latitude in *First Light* while in ***Local*** mode, you can see how the sun's altitude varies – the closer you are to the equator, the higher the Sun is and vice versa. The earth's tilt produces one of the more disorienting phenomena – that of the *midnight Sun*. During the summer, the Sun never sets for any observer within 23° of the north pole. Instead, it travels in a loop just above the horizon. What has happened is that the observer has moved out of the region that can be shaded by the Earth in its rotation.



The Midnight Sun

You can use *First Light* to demonstrate the midnight Sun.

1. Select ***When and where*** from the ***View*** menu to open the ***When and where*** dialog box.
2. Click on the ***location*** button to open the ***Location*** dialog box. Type 67 in the box just to the right of the ***lat.*** label and 0 in the box just to the right of that. This sets the latitude to 67° (23° from the North Pole). Click on the ***OK*** button to close the ***Location*** dialog box.
3. Change the date in the ***When and where*** dialog box to Jun 20, 1994 (the first day of summer) and the time to 12:01 am.
4. Click on the ***OK*** button to close the ***When and where*** dialog box and change *First Light* to the time and location on Earth that you just specified. Don't click on ***save*** unless you want *First Light* to use this location every time it starts up.
5. Select ***Local*** from the ***Mode*** submenu of the ***View*** menu to activate the ***Local*** coordinate mode.
6. Select ***Expert menus*** from the ***File*** menu so that it has a check mark next to it and *First Light's* expert menus are displayed on the menu bar.
7. Select ***Select object*** from the ***Lock view*** submenu in the ***Expert*** menu. Select ***Sun*** from the drop-down list in the resulting ***select*** dialog box and click on the ***OK*** button. This locks the view in the ***Planetarium*** window on the Sun.
8. Select both ***Horizon*** and ***Local altitude*** from the ***Markers*** submenu in the ***Extras*** menu so that it has a check mark next to it. A yellow line appears just below the Sun, representing the local horizon (i.e., relative to the 67° latitude that you set in the ***When and where*** dialog).
9. Select ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu to open the ***Clock Control*** dialog box.
10. Select ***20*** from the first drop-down list to the right of the ***Step*** label and select ***mins*** from the list to the right of that. This sets *First Light's* clock to an increment of twenty minutes for animating the sun's movement.
11. To start the animation, click on the button labeled with a right pointing double arrow in the ***Clock Control*** dialog box. *First Light's* internal clock begins to advance continuously, twenty minutes at a time. As this occurs,

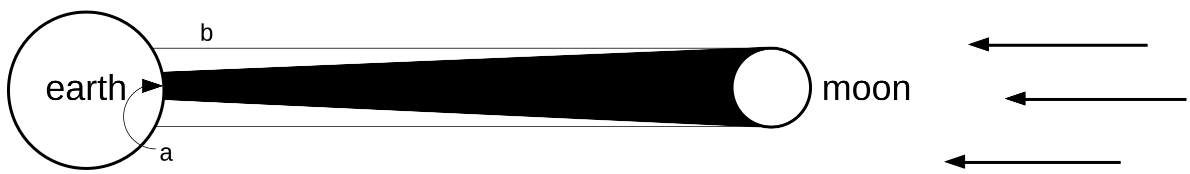
the Sun moves around the horizon, just above it, but never quite dipping below it. Click on the button labeled with a square in the ***Clock Control*** dialog box to stop the animation.

12. Notice that, even though the Sun is moving, it remains in the center of the window because the view is locked on it. To be able to look at other objects, select ***Release*** from the ***Lock view*** submenu in the ***Expert*** menu.

Solar Eclipses

One of the most beautiful and rare of all celestial events is the solar eclipse. A solar eclipse occurs whenever the Moon passes between the Sun and the Earth, casting its shadow onto the surface of the Earth.

The illustration below shows the position of the Earth and Moon during a solar eclipse. Point *a* is the point at which a total eclipse is visible. This is called the *umbra*. Point *b* is the *penumbra*, which marks the range at which an observer can see partial eclipse.



Solar eclipse

First Light can be used to reproduce recent eclipses. Perhaps the finest eclipse of the century occurred on July 11, 1991 when the moon's shadow swept from Hawaii to Central and South America.

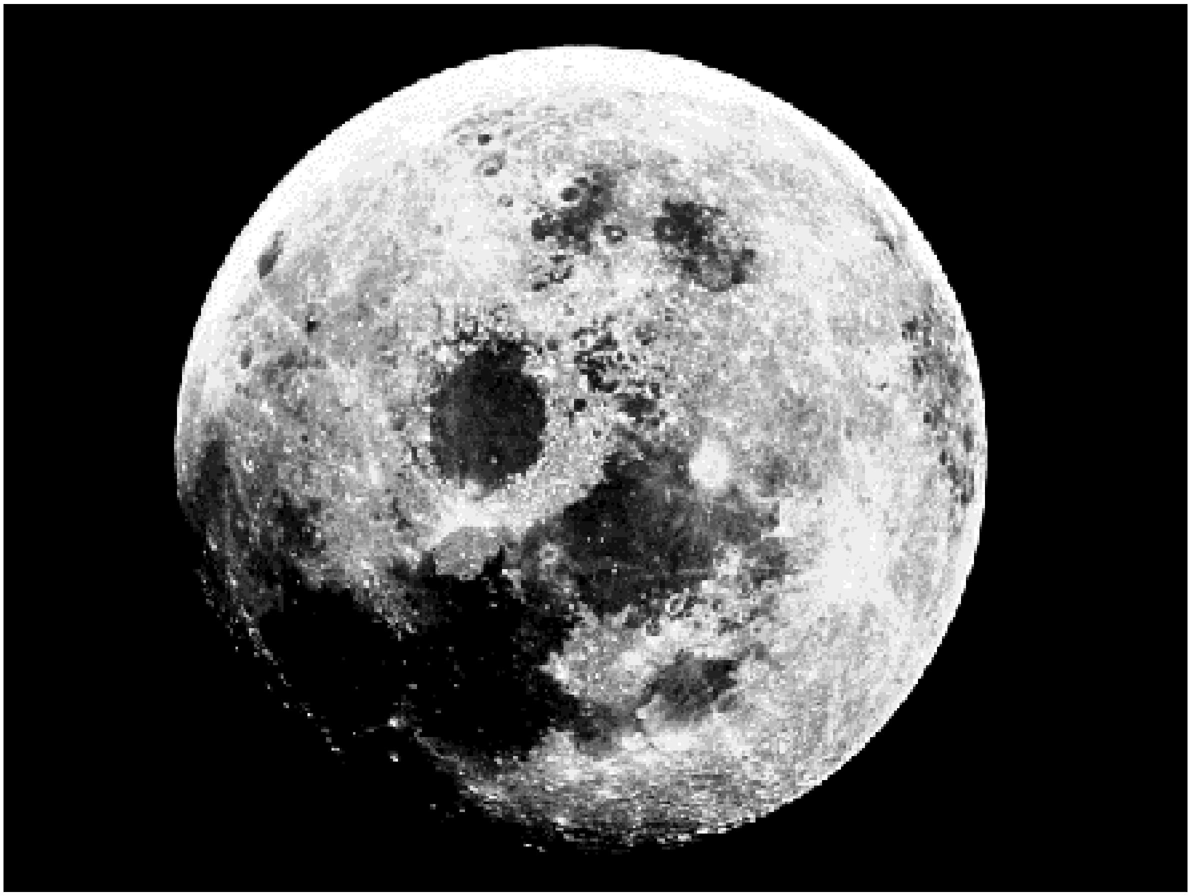
1. Select ***When and where*** from the ***View*** menu to open the ***When and where*** dialog box.
2. In the ***When and where*** dialog box, set the date to ***July 11, 1991***, the time to ***7:30 am***.
3. Click on the ***location*** button to open the ***Location*** dialog box. Set the latitude to ***19:30*** and the longitude to ***156***. Click on the ***OK*** button to accept the settings and close the ***Location*** dialog box.
4. Click on the ***OK*** button in the ***When and where*** dialog box to change the date and location and close the dialog box.
5. Select ***Close up*** from the ***Zoom*** submenu in the ***View*** menu to set the field of view to 10°.
6. Select ***Expert menus*** from the ***File*** menu so that it has a check mark next to it and *First Light's* expert menus are displayed on the menu bar.
7. Select ***Select object*** from the ***Lock view*** submenu in the ***Expert*** menu. Select ***Sun*** from the drop-down list in the resulting ***select*** dialog box and click on the ***OK*** button. This locks the view in the ***Planetarium*** window on the Sun.

8. Select ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu to open the ***Clock Control*** dialog box. Set the ***Step*** to five minute increments and click on the button labeled with a single right pointing arrow. Each time you click on the button, F*irst Light's* internal clock advances by five minutes and the display shows the Moon approaching and then moving across the Sun.
9. Select ***Release*** from the ***Lock view*** submenu in the ***Expert*** menu to release the lock on the Sun.

We recommend going to see an eclipse in person. One of the unfortunate facts about solar eclipses is that the pathway of the lunar shadow is so narrow, being no more that 80 to 100 miles wide. Totality lasts from only a few seconds to a maximum of 7 minutes 40 seconds. The best way for a novice to see an eclipse is with one of the package eclipse tours commonly advertised in the astronomy magazines.

There are between two and five solar eclipses per year and each is preceded or followed by a lunar eclipse. Not all eclipses are total, however. If the Moon is at the furthest point from the Earth in its orbit, it will fail to cover the Sun completely, leaving a thin ring of light around the edge. This is called an *annular* eclipse. At other times, the center of the shadow misses the Earth completely, resulting in a partial eclipse.

The Moon

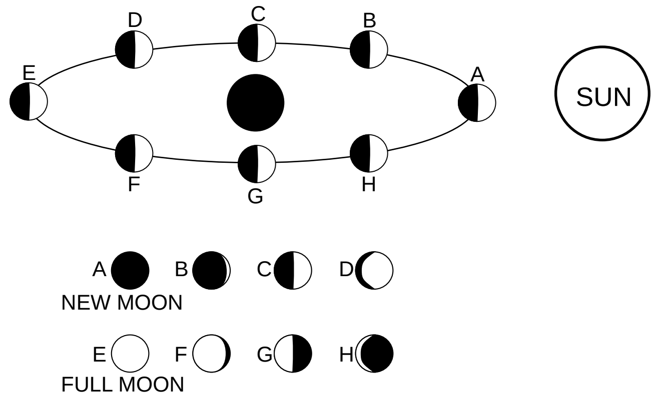


The earth's Moon

The Moon orbits around the Earth at an approximate distance of 235,000 miles. Since the Moon has a diameter of about 2,100 miles, over a quarter that of the Earth, the Earth-Moon system has sometimes been called *twin planets*. The Moon orbits the Earth with a period of 27.3 days, the same length as its day. As a result it always keeps the same face toward the Earth.

The origin of the Moon is shrouded in mystery. Some scientists feel that it might have been formed along with the Earth, others think that is was captured by the Earth when it came too close. No matter where it came from, the Moon easily provides one of the most dramatic views through any telescope, or even binoculars. The rough jagged mountain ranges bordering the smooth *maria* (Latin for *seas*) provide a stunning sight when lit from the side. Craters within craters, lava flows and lunar rilles (lava river beds) can be seen through even the simplest of instruments.

As a result of its orbiting around us, the Moon shows its familiar phases. As it grows in size, it is said to be *waxing* until it is full. After that, as it decreases in size, it is said to be *waning*. The phases are created by the varying angle at which we view the Moon. That is, if the Moon is to the earth's side in its orbit, we see half of its face illuminated. If it is between the Earth and the Sun, we are, in effect, behind it and see no part of it illuminated. At its first quarter phase, the Moon is behind the Earth in its orbit around the Sun and, looking back at the Moon, you see the point in space where the Earth was just three and a half hours earlier.



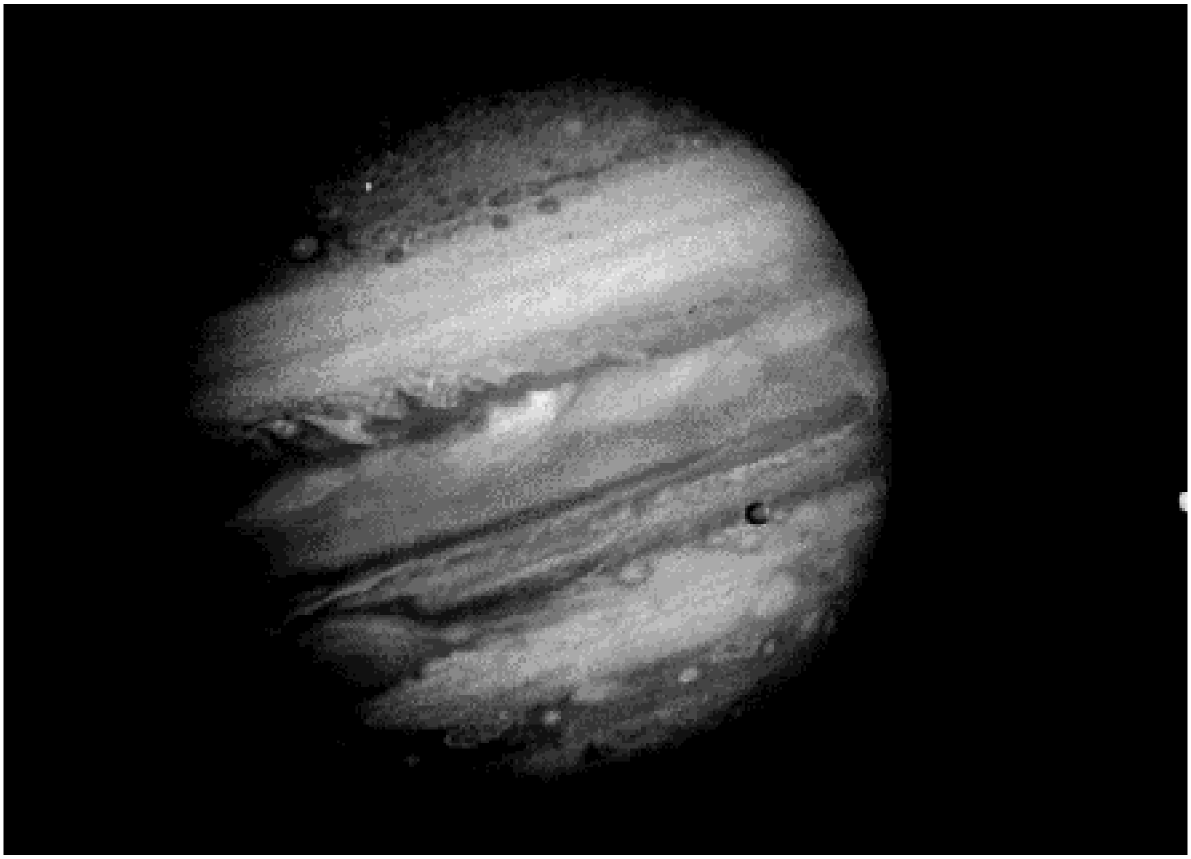
Lunar phases

To see the Moon change its phase:

1. Select ***Select object*** from the ***Lock view*** submenu in the ***Expert*** menu. Use the resulting dialog box to lock *First Light's* view on the Moon.
2. Select ***Close up*** from the ***Zoom*** submenu in the ***View*** menu to set the field of view to 10°.
3. Select ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu to open the ***Clock Control*** dialog box.
4. Set the ***Step*** to one day increments and click on the button labeled with a single right pointing arrow. The display advances by one day each time the button is clicked and shows a different phase of the Moon.
5. To release the lock on the Moon, select ***Release*** from ***Lock view*** submenu in the ***Expert*** menu.

You may be wondering why there is not an eclipse every time there is a new Moon. The plane of the moon's orbit is not exactly in line with the earth's, it is tilted by about 5°. The two intersection points of the moon's orbit with the plane of the earth's orbit are called *nodes*. When the new Moon is near either one of these points, it is in line with the Sun and, therefore, creates an eclipse. When a new Moon occurs at any other point, it is too far above or below the plane of the earth's orbit to block the Sun.

The Planets and Their Motions



Jupiter – the largest planet in our solar system

The planets are believed to be composed of material left over from the formation of the Sun. There are two main types of planets. They are the small rocky variety – *Mercury*, *Venus*, *Earth*, *Mars* and *Pluto* – and the gas giants – *Jupiter*, *Saturn*, *Uranus* and *Neptune*. The gas giants are known for their very dense, deep atmospheres and lack of any substantial surface. Jupiter is an especially interesting case. It has been called a “protostar” because it is actually radiating slightly more energy than it receives. If it were just a little more massive, it might have become an actual star. (See *Appendix E* for general planetary data).

The planets were called “the wanderers” by the ancient astronomers, because they were observed wandering about from evening to evening in relation to the stars. Unless one were to observe the planets on a daily basis, their movements might not be noticed. However, if we plot their motions over a period of several weeks, we can get an idea of just what the ancients saw.

You can use *First Light's* ***Clock Control*** and ***Viewpoint*** features to gain a better grasp of planetary motions.

To plot the motion of the planets against the stars:

1. Select ***Normal*** from the ***Zoom*** submenu in the ***View*** menu to set the field of view to 60°.
2. Select ***Major planets*** from the ***Center*** submenu in the ***Planets*** menu to open the ***Planets*** dialog box. Click on the ***Mars*** button in this dialog box. Mars, represented by a red dot, is centered in the ***Planetarium*** window.
3. If the label ***Mars*** is not displayed next to the planet's dot, click on the ***Planet names*** button on the tool bar (the fourth button from the left end of the tool bar). The label ***Mars*** appears next to the planet.
4. Select ***Line trails*** from the ***Animation prefs*** submenu in the ***Preferences*** menu so that it has a check mark next to it. ***Expert menus*** in the ***File*** menu must be selected for the ***Preferences*** menu to be available.
5. Select ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu to open the ***Clock Control*** dialog box.
6. In the ***Clock Control*** dialog box, set the ***Step*** increment to ***2 days*** for animating the motion of the planets.
7. Click on the ***Fast forward*** button, labeled with a right pointing double arrow. The clock starts moving and Mars moves across the star field, leaving a red trail behind it along its path. Other planets will likely come into view, also leaving trails behind them.
8. Click on the ***Stop*** button, labeled with a square, to stop the animation.

Conjunctions

From time to time, the planets appear to pass very close to each other, causing a co*njunction*. While conjunctions have very little scientific value, they can be quite spectacular.

For an example of a recent conjunction of note:

1. Select ***When and where*** from the ***View*** menu to open the ***When and where*** dialog box.
2. In the ***When and where*** dialog box, set the date to ***June 10, 1991*** and click ***OK***.
3. Select ***20*** from the ***Degrees*** submenu in the ***View*** menu's ***Zoom*** submenu to set the field of view to 20°.
4. Select ***Major planets*** from the ***Center*** submenu in the ***Planets*** menu to open the ***Planets*** dialog box. Click on the ***Mars*** button in this dialog box. Mars, represented by a red dot, is centered in the ***Planetarium*** window. Notice

that three planets, *Mars, Venus* and *Jupiter*, are very close together. This is the famous *Triple Conjunction*, a event which happens only once every couple of hundred years.

5. Select ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu to open the ***Clock Control*** dialog box.
6. Use the drop-down lists to set the clock's ***Step*** increment to ***10 hours***. Click the button labeled with a single right pointing arrow to advance *First Light's* clock in ten hour increments. On June 17 you see the closest approach, when all three planets were visible at the same time in a low power telescope.
7. Select ***Lookdown-middle planets*** from the ***Viewpoint*** submenu in the ***View*** menu. The viewpoint shifts to above the solar system, looking down. Notice that Venus, Mars and Jupiter form nearly a straight line from the Earth.
8. Select ***Return to earth*** from the ***Viewpoint*** submenu in the ***View*** menu to return your viewpoint to Earth.

Alignments: The "Jupiter Effect"

Another event related to the positions of the planets has to do with the so-called *Jupiter Effect* of several years ago. Every great while, all of the planets are aligned in a narrow range of the sky. In the past, such alignments were believed to result in great world catastrophes, causing global panic. A recent throwback to this belief happened in early 1982, when all of the planets were visible in almost the same quadrant of the sky. For years before that time, a popular book, called *The Jupiter Effect*, claimed that this would trigger all sorts of natural disasters culminating in a major California earthquake. This was supposed to be the result of the cumulative effect of the planets' gravity pulling on one side of the Earth.

To observe this alignment with *First Light*:

1. Select ***Return to earth*** from the ***Viewpoint*** submenu in the ***View*** menu to return your viewpoint to Earth.
2. Select ***When and where*** from the ***View*** menu to open the ***When and where*** dialog box. Set the date to ***March 10, 1982*** and click ***OK***.
3. Select ***90*** from the ***Degrees*** submenu in the ***View*** menu's ***Zoom*** submenu to set the field of view to 90°.
4. Select ***Major planets*** from the ***Center*** submenu in the ***Planets*** menu to open the ***Planets*** dialog box. Click on the ***Jupiter*** button in this dialog box. Jupiter, represented by a yellow dot, is centered in the ***Planetarium*** window.
5. If the label ***Jupiter*** is not displayed next to the planet's dot, click on the ***Planet names*** button on the tool bar (the fourth button from the left end of the tool bar). Labels appear next to each planet in the ***Planetarium*** window. Notice that six of the eight planets are within the same 90° quadrant of the sky.

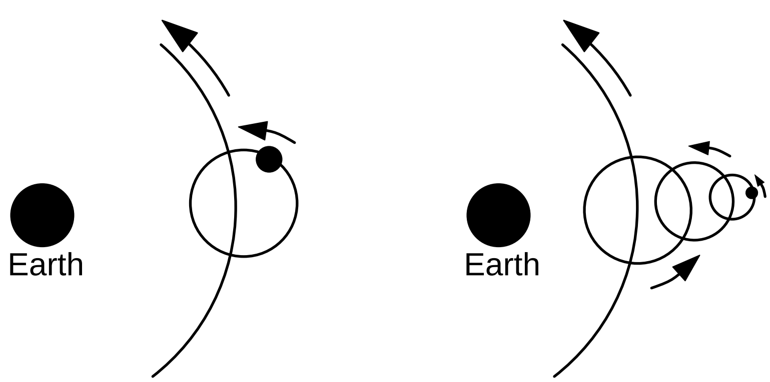
6. Select ***180*** from the ***Degrees*** submenu in the ***View*** menu's ***Zoom*** submenu to set the field of view to 180°. This reveals Venus and Mercury about 45° to the left of Neptune.
7. Now select ***Lookdown-inner Planets***, ***Lookdown-middle planets*** and ***Lookdown-outer planets*** in turn from the ***Viewpoint*** menu in the ***View*** menu. You will see that if this was an alignment, it was marginal at best. Needless to say, California is still here and a couple of authors got rich.
8. Select ***Return to earth*** from the ***Viewpoint*** submenu in the ***View*** menu to return your viewpoint to Earth.

Another, more recent, alignment involved the four outer planets, from Saturn to Neptune. Use the ***When and where*** dialog box to set the date to ***September, 1987*** and you will see that they are, indeed, in the same general area of the sky. This phenomenon played an important part in the so-called *harmonic convergence*, which had hordes of believers heading towards the mountain tops to usher in the New Age.

Retrograde Motion

Another exercise with planetary pathways is to study the motions of Venus and Mercury. Until the time of the astronomer Copernicus, common belief maintained that the Earth was the center of the universe with the Sun, Moon, planets and stars all orbiting around it. Unfortunately, a few inconsistencies crept in to upset this idyllic viewpoint. For example, the planets would occasionally slow down and, of all things, move backwards.

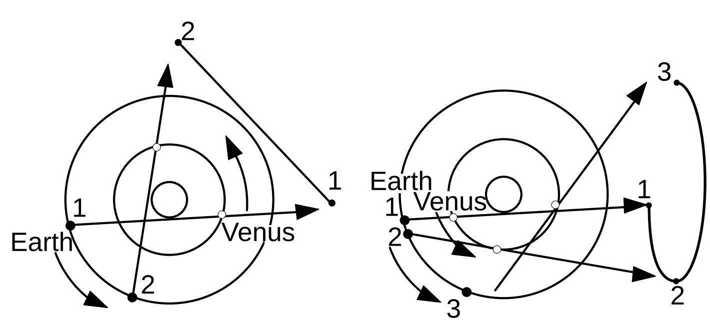
In an effort to explain this phenomenon, astronomers of the day invented *epicycles*, which forced the hapless orbs into making a small orbit on top of their main orbits, causing them to back up every so often. This still did not explain all of the movements, so more epicycles were stacked on top of the earlier ones. Eventually, some planets collected up to fourteen levels of epicycles, but still refused to behave according to the model.



Epicycles

We can see this mysterious behavior (now called *retrograde motion*) by observing Venus and Mercury.

1. Select ***When and where*** from the ***View*** menu to open the ***When and where*** dialog box. Set the date to ***June 30, 1992*** and click ***OK***.
2. Select ***Major planets*** from the ***Center*** submenu in the ***Planets*** menu to open the ***Planets*** dialog box. Click on the ***Mercury*** button in this dialog box. Mercury, represented by a white dot, is centered in the ***Planetarium*** window.
3. Select ***Normal*** from the ***Zoom*** submenu in the ***View*** menu to set the field of view to 60°. Venus should be on the right side of the ***Planetarium*** window.
4. If the label ***Mercury*** is not displayed next to the planet's dot, click on the ***Planet names*** button on the tool bar (the fourth button from the left end of the tool bar). Labels appear next to each planet in the ***Planetarium*** window.
5. Select ***Line trails*** from the ***Animation prefs*** submenu in the ***Preferences*** menu so that it has a check mark next to it. ***Expert menus*** in the ***File*** menu must be selected for the ***Preferences*** menu to be available.
6. Select ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu to open the ***Clock Control*** dialog box. Set the ***Step*** increment to ***1 day*** and click on the ***Fast forward*** button, labeled with a right pointing double arrow. You will see a rather unusual plot for Mercury. Click on the ***Stop*** button, labeled with a square, to stop the animation.
7. Select ***Lookdown-inner planets*** from the ***Viewpoint*** submenu in the ***View*** menu and use the ***When and where*** dialog box to set the date back to ***June 30***.
8. As before, advance the time using the ***Clock Control*** dialog box. Notice that Mercury is actually traveling in the opposite direction of Venus, as seen from Earth, and faster than the Earth to create the loop in the sky.
9. Select ***Return to earth*** from the ***Viewpoint*** submenu in the ***View*** menu to return your viewpoint to Earth.



Retrograde motion

Another fine example of this can be seen by setting the date to September 1, 1990. Center Mercury in the screen and use the same procedure as above.

Orbital Speeds

By now, you may have noticed that some planets move faster than others. There are many reasons for this. One reason is that the farther a planet is from the Sun, the slower it must travel to remain in orbit. You can easily observe this by comparing the relative orbital speeds of the inner planets. Select ***Lookdown-inner planets*** from the ***Viewpoint*** submenu in the ***View*** menu. Use the ***Clock Control*** dialog box to watch Mercury, Venus, Earth and Mars race each other around the Sun.

Planetary Eclipses

One of the rarest forms of eclipses is when one planet actually moves in front of another. One such eclipse occurred on January 19, 1591, when Mars passed in front of Jupiter.

To see this eclipse:

1. Select ***When and where*** from the ***View*** menu to open the ***When and where*** dialog box. Set the date to ***Jan 19, 1591***, the time to ***7:00 am***, and the time zone to ***–1.00***.
2. Click on the ***location*** button to open the ***Location*** dialog box and set the latitude to ***48***° and the longitude to ***7***° (near Stuttgart, Germany, where the astronomer Johannes Kepler recorded this event).
3. Select ***Major planets*** from the ***Center*** submenu in the ***Planets*** menu to open the ***Planets*** dialog box. Click on the ***Jupiter*** button in this dialog box. Jupiter, represented by a yellow dot, is centered in the ***Planetarium*** window. Both Mars and Jupiter are very nearly in the same location. Using the single arrow buttons in the ***Clock Control*** dialog box, you can investigate their motions more precisely.
4. Select ***Now*** from the ***Clock*** submenu in the ***Tools*** menu to return *First Light's* clock to the present.

Which Is the Farthest Planet?

No doubt, you grew up learning that the farthest planet from the Sun is Pluto. Not so, at least for the moment. Pluto's orbit is the most eccentric and the most highly inclined of any of the planets. Because of this, Pluto crossed inside the orbit of Neptune in 1980 and will remain so until 1999. You can verify this by selecting ***Lookdown-outer planets*** from the ***Viewpoint*** submenu of the ***View*** menu.

Ecliptic

Imagine a flat surface extending out from the Sun through the earth's orbit, heading out toward infinity. This forms the plane of the solar system. When projected against the sky, it is known as the *ecliptic*.

To see the ecliptic:

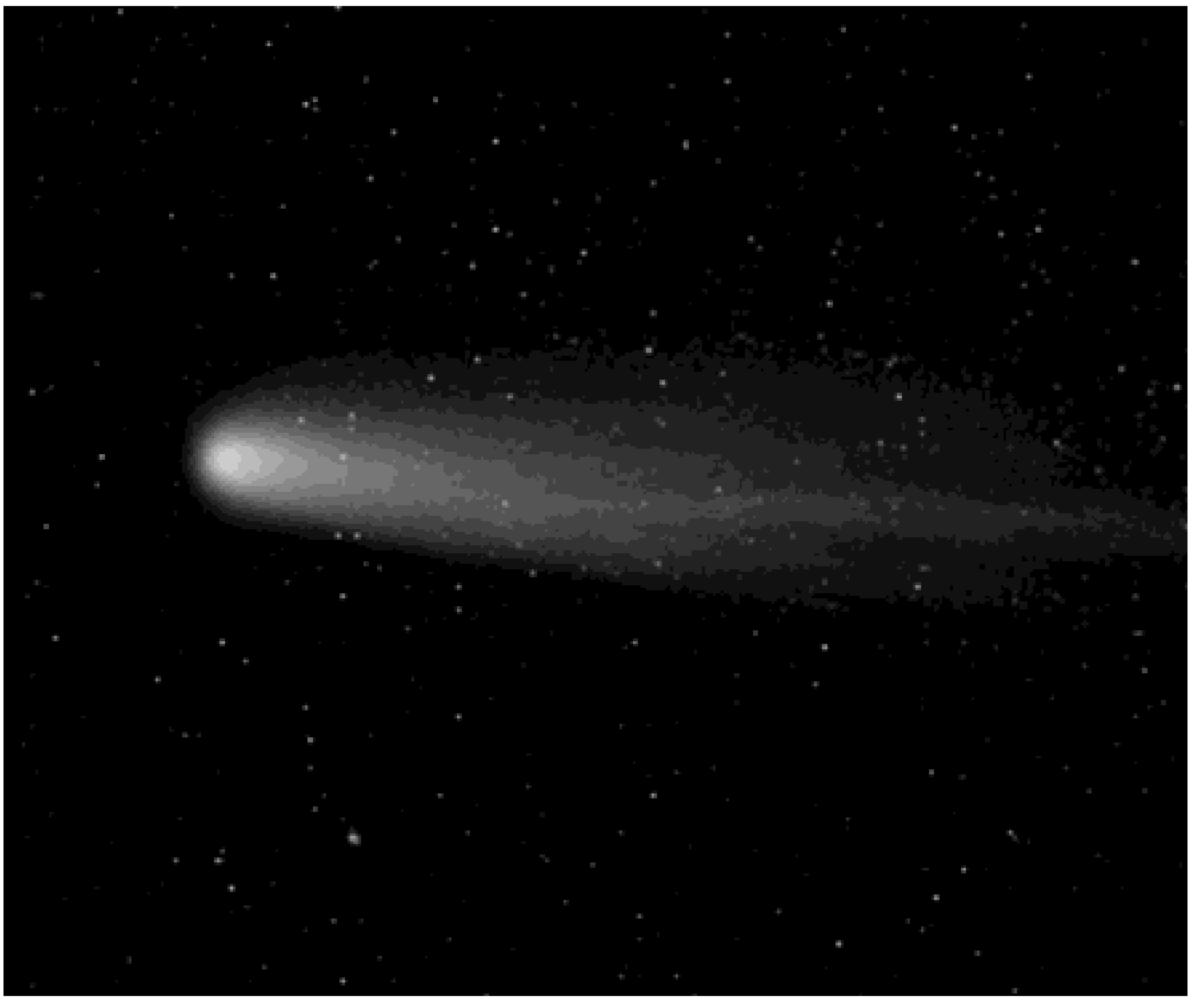
1. Select ***Ecliptic*** from the ***Markers*** submenu in the ***Extras*** menu. The ecliptic is displayed in the ***Planetarium*** window as a yellow line. ***Expert menus*** in the ***File*** menu must be selected for the ***Extras*** menu to be available.
2. Select ***180*** from the ***Degrees*** submenu in the ***View*** menu's ***Zoom*** submenu to set the field of view to 180°.
3. Click on the first button on the left end of the ***Planetarium*** window's tool bar to center the Sun in the ***Planetarium*** window. Notice that each of the planets (and the Sun) roughly follows the ecliptic through the sky.

The planet Uranus is closest to the ecliptic, being inclined only 0° 46', while Pluto's eccentric orbit is tilted a whopping 17°. See *Appendix E* for the inclinations of the other planets' orbits.

Comets and Asteroids

In addition to the nine major planets and untold moons in the solar system, there reside a number of lesser objects, namely comets and asteroids. As with the planets, *First Light* can also display these objects, showing their locations and complex motions.

Comets



Perhaps the most visually interesting of these objects are the comets. Composed mainly of frozen water and particles of other material, comets are often thought of as “dirty snowballs” and are believed to represent the most pristine material in the solar system.

Some comets, such as *Halley's,* are very well known, but most tend to live their lives in relative obscurity far from the Sun in what is called the *Oort Cloud*. The *Oort Cloud* is believed to be located between 30,000 and 100,000 astronomical units from the Sun (an astronomical unit, or AU, is the distance between the Earth and the Sun). Occasionally, a passing star or planetary body might disturb the comets, driving some toward the Sun. Near the Sun, solar heating causes the outer layers of the body to evaporate, creating a fuzzy halo, or *coma*, which can be hundreds of miles across. As it draws closer to the Sun, the comet's distinctive tail begins to form as the electrically charged solar wind sends the gases millions of miles behind the main body. This is why the tail always points away from the Sun. These gases are extremely rarefied, making a comet "the closest thing to nothing which can be called something."

Comets are typically discovered only two or three months before their greatest visibility. Most are found by dedicated amateur astronomers and are named after their discoverers.

Halley's Comet

What makes *Halley's Comet* so unique among the more than 700 plus known comets is that it was the first comet whose return was predicted. Sir Edmund Halley, the second English Astronomer Royal realized that bright comets seen in 1531, 1607 and 1682 were, in fact, the same object. From this information he predicted that a bright comet would be visible in 1759. His prediction proved correct and the comet was named after him in his honor. It is now known that *Halley's Comet* has formed a rich thread through history, being recorded since 240 B.C. in both literature and art. Because of this, its 1986 apparition was eagerly awaited by astronomers and laymen alike. Unfortunately 1986 was a bit of a disappointment due to the fact that, even at its closest approach to Earth, the comet was still 36 million miles away. Compare this to the apparition in 837 A.D. when *Halley's* was a mere 3.7 million miles distant (only fifteen times the distance of the Moon).[1]

To view *Halley's Comet* with *First Light*:

1. Select ***Fixed...*** from the ***Viewpoint*** submenu in the ***View*** menu to open the ***Set Viewpoint*** dialog box. Type 90 for ***heliocentric latitude***, 0 for ***heliocentric longitude*** and 20 for ***solar distance***. Click on ***OK***. *First Light* moves your viewpoint to a point 20 astronomical units (AU) directly above the Sun.
2. If the planets are not labeled with their names, click on the ***Planet names*** button on the tool bar (the fourth button from the left end of the tool bar). Labels appear next to each planet in the ***Planetarium*** window.
3. Select ***75*** from the ***Degrees*** submenu in the ***View*** menu's ***Zoom*** submenu to set the field of view to 75°.
4. Select ***Comets*** from the ***Load*** submenu in the ***Planets*** menu and open the orbit file named *halley.cmt*. *First Light* loads Halley's orbit and centers the comet in the ***Planetarium*** window.

1. Due to the complex gravitational effects of the other planets, a comet's orbit changes over time so that the farther away you are from the present date, the less accurate the current orbital elements become. In fact, Halley's current period is stated to be 75.99 years, but it may actually vary between 74 and 79 years.

5. Click on the first button at the left end of the tool bar to center the Sun in the ***Planetarium*** window.
6. Select ***When and where*** from the ***View*** menu to open the ***When and where*** dialog box. Move the dialog box to a corner of the monitor so that it doesn't obscure the view of Halley's orbit in the ***Planetarium*** window. Set the date to ***Dec 1982*** and click on ***try***. Why 1982? This was when the comet was first seen since 1911, recovered by astronomer G. Edward Danielson of Caltech. Halley's was then just outside the orbit of Saturn. Over the next three years the comet gradually brightened until it was finally visible in medium sized telescopes by the fall of 1985.
7. Set the date to ***Oct 1, 1985*** in the ***When and where*** dialog box and click on ***try***. The comet is sweeping toward the orbit of Mars with a small tail just starting to show. Now things begin to get really busy.
9. Select ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu to open the ***Clock Control*** dialog box. Set the ***Step*** increment to ***1 day***. Click on the ***Fast forward*** button, labeled with a right pointing double arrow, to advance the date to ***Dec. 1*** in one day increments (watch the date at the left end of the status bar at the bottom of the ***Planetarium*** window). Click on the ***Stop*** button, labeled with a square, to stop the clock. The comet has brightened to the point that it is just on the edge of visibility for the naked eye for the first time in nearly 76 years. Notice that the comet moves in the opposite direction of the Earth. As *Halley's* gets closer to the Sun, the Earth moves farther away. Advance the date to ***Jan. 15, 1986***. Now the comet fades from view as it heads into the evening twilight toward its closest approach to the Sun on February 9.
10. Jump ahead to March 15 as *Halley's* emerges from behind the Sun. At this time it is visible in the early morning hours, rising slowly in the sky. *Halley's* closest approach to Earth is on April 10. Notice that the geometry is such that the comet is viewed nearly front on, making the tail appear to be extremely short. This is one reason why this apparition was so poor. By contrast, in 1910 the Earth actually *passed through* the tail.
11. May 25 began the last period to see the comet with the naked eye as it headed outbound.
12. Select ***Return to earth*** from the ***Viewpoint*** submenu in the ***View*** menu to return your viewpoint to Earth.

Asteroids

Asteroid Gaspra as seen from NASA's Galileo spacecraft

In the eighteenth century, an interesting mathematical relationship, popularized by German astronomer Johann Bode, appeared to predict the relative distances of the known planets from the Sun. *Bode's Law*[2], as it was known, pointed out that there was a large gap between Mars and Jupiter where a planet "should" be, at a distance of 2.5 astronomical units (AU) from the Sun. Therefore, astronomers around the world began searching that gap for the missing planet. On the first day of the nineteenth century, January 1, 1801, the Italian astronomer-monk Guiseppe Piazzi discovered a small body later named *Ceres*.

Ceres was the first known asteroid. Since its discovery, over 3,500 have been catalogued. Besides being the first, *Ceres* is also the largest, with a diameter of about 600 miles (a quarter that of the Moon).

2. Bode's Law was later proven invalid by the discovery of the planet Neptune which, according to the law, should not have existed.

To view *Ceres* as Piazzi saw it:

1. Select ***Lookdown-middle planets*** from the ***Viewpoint*** submenu in the ***View*** menu to set your viewpoint looking down on the solar system.
2. Select ***Asteroids*** from the ***Load*** submenu in the ***Planets*** menu and open the orbit file named *ceres.ast*.
3. Select ***When and where*** from the ***View*** menu to open the ***When and where*** dialog box. Set the date to ***Jan 1, 1801***, the night of discovery, and click on ***OK***.
4. Select ***Return to the Earth*** from the ***Viewpoint*** submenu in the ***View*** menu.
5. Select ***Comets and things*** from the ***Center*** submenu in the ***Planets*** menu, select ***ceres*** from the drop-down list in the resulting dialog and click on ***OK***. You will see the asteroid between the constellations *Cetus* and *Pisces*.

Planetary geologists and space visionaries alike see asteroids as an enormously valuable source of raw materials for man's expansion into the solar system. But there is a darker side. Arthur C. Clarke speaks of it so well in his classic book *Rendezvous with Rama* when, in the opening chapters, he describes the potential of a stray asteroid striking the Earth. In *Rama*, the Earth of the future establishes an organization called SPACEGUARD to predict such an event. Even now, scientists are working on programs similar to SPACEGUARD in order to discover and track potentially dangerous asteroids and, if possible, destroy or deflect them to prevent an impact.

While most asteroids stay in their place, snugly between the orbits of Mars and Jupiter, a few venture in closer to the Sun, giving rise to fears that someday we may in fact witness a collision. At this time, only about thirty of these *Apollo* asteroids are known. But the threat became all the more real when, in 1989, a small Apollo asteroid, 1989-FC, made what was determined to have been the closest known approach of any known comet or asteroid in history.

You can witness this event with *First Light*.

1. Use the ***When and Where*** dialog box to set the date to ***Feb 15, 1989***.
2. Select ***Asteroids*** from the ***Load*** submenu in the ***Planets*** menu and open the orbit file named *1989_fc.orb*.
3. Select ***Fixed...*** from the ***Viewpoint*** submenu in the ***View*** menu. Type 90 for ***heliocentric latitude***, 0 for ***heliocentric longitude*** and 5 for ***solar distance***. Click ***OK*** to set *First Light's* viewpoint to those coordinates.
4. Select ***30*** from the ***Degrees*** submenu in the ***View*** menu's ***Zoom*** submenu to set the field of view to 30°. The 1,000 foot diameter 1989-FC is just outside the orbit of Venus heading toward an Earth crossing.
5. Select ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu to open the ***Clock Control*** dialog box. Set the ***Step*** increment to ***1 day***. Click on the right pointing double arrow button and watch what happens. On March 22, asteroid 1989-FC passed within 400,000 miles of the Earth. A little closer and it would have been inside the orbit of the Moon. Notice how it is coming from

the sunward side as seen from Earth. This is why it wasn't discovered until March 31, a full *nine days* after closest approach. Fortunately, such events are exceedingly rare, and the chance of a head on collision even more so. But, had it happened, it could have created a crater over four miles wide. Note also that 1989-FC passed through the point in space that the Earth had been a mere *six hours* earlier!

6. Use the ***When and where*** dialog box to set the date back to mid-March, but watch the asteroid from the Earth by selecting ***Return to earth*** from the ***Viewpoint*** submenu in the ***View*** menu. Set the clock increment to ***5*** or ***10*** hours. Watch how fast 1989 FC moves at its closest approach to Earth, hitting rates of over 70° *in a single day* – crossing nearly a quarter of the sky!

Asteroid and Comet Magnitudes

First Light does not display comets or asteroids at realistic magnitudes. Cometary magnitudes are wildly unpredictable, and both asteroids and comets are typically much too dim to be visible to the naked eye.

Adding a New Orbit

First Light allows you to create new orbits for solar system objects which can then be displayed along with any of the other solar system objects. With this feature, you can add data for any comet, asteroid or satellite. (Note that this applies only to objects in orbit around the Sun, and cannot be applied to Earth orbiting satellites or planetary moons.)

To add a new orbit to *First Light*:

1. Select ***Create a new orbit*** from the ***Expert*** menu to open the ***New object*** dialog box.
2. Fill in the appropriate information (described below) for the orbit that you are adding.
3. Click on ***save*** to add the orbit to *First Light*.

Orbital data can be found in various astronomical books and catalogs or on astronomy computer bulletin boards.

Orbits are typically quite complex and must be defined by several values. An understanding of these values is not really necessary, as the published tables typically have all of the necessary information. Also, not all of the fields are used. Asteroids use a slightly different set of data than comets.

In the following list, the name of the orbital element is given, followed by the Greek or Roman letter most likely to be used in any tables you find.

label: The name of the new object.

color: The color that you wish to have *First Light* display the object with in the ***Planetarium*** window.

epoch date: (sometimes called T) The date that either the data was taken or of the closest approach to the Sun, called the *perihelion epoch*.

eccentricity: (e) Eccentricity serves as a measure of the *flattening* of an orbit. A value of 0 indicates a perfectly circular orbit. Values between 0 and 1.0 indicate an elliptical orbit. Values of 1.0 or larger indicate a parabolic or hyperbolic trajectory. Hyperbolic orbits are not supported in *First Light*. Objects in parabolic orbits are not bound to the Sun and, once having swept by, proceed out of the solar system never to return. Most naked eye comets seem to be of this variety, called *non-periodic* comets, meaning that they come by only once. The recently discovered Comet Mueller appears to be in this category. It made its closest approach in March 1992.

perihelion longitude: (ϖ) The longitude of the perihelion, the closest approach to the Sun. Given in degrees.

longitude of ascending node: (Ω) This is the longitude of the point at which the orbit ascends from below the plane of the solar system (the ecliptic) to above the plane. Given in degrees.

period: (P) The time required to complete one full orbit, not used for non-periodic objects. Given in years.

inclination: (i) The angle at which the orbit is tilted to the plane of the ecliptic. Inclination is between 0° and 180°.

mean anomaly: (M) The angle used to describe the current position of the object. Typically used only for asteroids. Given in degrees.

argument of perihelion: (ω) Sometimes used in lieu of the perihelion longitude, the argument of perihelion is the perihelion longitude minus the longitude of ascending node. Typically used only for asteroids. Given in degrees.

size: (a, c) The size of the orbit is determined by one of three possible values. The *semi-major axis* (a) is a direct measurement of the orbit in astronomical units, generally used for periodic comets. *Mean daily motion* (n) describes an average motion in degrees/day the object moves. *Perihelion* (q) is the distance of the closest approach to the Sun in AU and is used for non-periodic comets with parabolic orbits.

Orbits for several asteroids and comets are provided with *First Light*.

Meteors

Meteors are small solid particles in orbit around the Sun and, in many cases, are believed to be debris left by passing comets. For this reason, meteors tend to be grouped together in comet-like orbits and often have been linked to known comets. When the Earth passes through one of these streams, a meteor shower occurs as the particles burn up in our atmosphere. On any given night, the average observer should be able to see about five stray meteors per hour. The typical shower generally triples that rate, while the best showers (such as the *Perseids* in August and *Geminids* in December) may have fifty or more per hour (see *Appendix F*).

First Light keeps track of the next meteor shower.

1. Select ***Summary*** from the ***View*** menu to open the ***What's Up?*** window. The dates of the next shower are displayed at the bottom of the window.
2. For more information about the shower, click on the ***next meteor shower*** button and a window containing information is opened.

The distribution of meteors along their orbits is not uniform. So what may have been a bland shower one year might be a memorable event the next. The most notable shower of this sort is the *Leonids* in November. The *Leonids* usually produce about fifteen to twenty streakers per hour. But early one morning in November 1966 along the western coast of the United States, rates approaching 150,000 per hour were reported. This was a repeat of the famous 1833 shower which prompted one nineteenth century writer to exclaim, "Never did rain fall much thicker than the meteors fell to the Earth…."

Occasionally, meteors the size of small rocks join the fray, producing what is referred to as a *fireball*. The bigger ones may be seen to break apart forming two or more fiery trails. The biggest of these might survive their entry into the atmosphere and strike the Earth. Meteors which make it to Earth are then called *meteorites*. The 4,000 foot wide Barranger Crater in Arizona is a dramatic example of this.

The names of the showers are derived from the area of the sky from which the meteors appear to radiate (hence the name *radiant*), like spokes in a wheel. For example, the *Leonids* appear to be coming from the constellation of *Leo*.

The best time to observe a meteor shower is from about 2:00 a.m. local time until dawn. Since the meteors can appear in any part of the sky, a telescope or pair of binoculars only hinders viewing.

Traveling with Galileo

In addition to planets, comets and asteroids, *First Light* also lets you track the progress of the *Galileo* Jupiter probe from launch to Jovian intercept.

Few spacecraft have had to endure what *Galileo* has. Starting in the 1970's, *Galileo's* journey to the launch pad was as perilous as its actual mission. Thanks to numerous delays from redesigns, funding threats from politics and technical challenges, it looked like the probe would never get off the ground. Many scientists were betting their entire careers on the success of the probe. Finally, all of the obstacles were overcome and the launch date was set for May, 1986 from the space shuttle *Atlantis*. But, once again, the beleaguered probe would have to sit and wait, due to the explosion of the *Challenger* in January of that year.

The original mission called for a flight time of three years, with arrival at Jupiter in 1989. However, due to extra safety measures, the powerful booster originally intended for use in 1986 was scrapped in favor of a less powerful but "safer" rocket. This had the effect of stretching out the flight time from three years to more than six years. Finally, on October 18, 1989, *Galileo* received its space wings and headed off, not to Jupiter, but to Venus first.

Using a complex technique known as *gravitational assist*, the probe stole a small amount of energy from both Venus and the Earth to increase its speed. This "slingshot effect" is commonly used to extend flights or change trajectories with little or no additional fuel use.

To see the path of *Galileo's* flight:

1. Select ***When and where*** from the ***View*** menu to open the ***When and where*** dialog box. Set the date to ***Oct 1, 1989*** and click on ***OK***.
2. Select ***Spacecraft*** from the ***Load*** submenu in the ***Planets*** menu. Open the orbit file named *galileo.orb*. A dialog box appears telling you that "the current date is before launch, do you want the date changed?" Click the ***No*** button in the dialog box to keep the date unchanged.
3. Select ***Lookdown-inner planets*** from the ***Viewpoint*** submenu in the ***View*** menu. Note the odd spiral flight path of *Galileo*. The probe itself is not visible because, on October 1, 1989, it is still in the shuttle's payload bay on the launch pad.
4. Select ***Settings*** from the ***Clock*** submenu in the ***Tools*** menu to open the ***Clock Control*** dialog box. Set the ***Step*** increment to ***2 days*** and click on the ***Fast forward*** button, labeled with a right pointing double arrow, to start the clock. On October 18, the probe is deployed from the space shuttle and heads toward Venus.

1. Interestingly enough, for a *Jupiter* probe, *Galileo* taught us a lot about the moon when it sent back pictures during a camera test that revealed a massive crater that had never before been photographed.

5. Continue advancing the time to see the Venus fly-by take place three months later, in February of 1990. Gaining new energy from Venus, the probe heads out, not to Jupiter yet, but back home to Earth for a visit. After flying by the Earth in December of 1990[1], *Galileo's* orbit is increased and it is shot out well beyond the orbit of Mars. At this point, click on the button labeled with a square to stop the clock.

   As you may recall, most asteroids are found between the orbits of Mars and Jupiter, so in order to take advantage of the spacecraft's extended voyage, the project scientists changed its pathway to take it by one of those mysterious specks of light.

6. Select ***Asteroids*** from the ***Load*** submenu in the ***Planets*** menu and open the orbit file named for the asteroid *Gaspra*.
7. Select ***Lookdown-middle planets*** from the ***Viewpoint*** submenu in the ***View*** menu to widen the view in the ***Planetarium*** window.
8. Advance the date to October 29, 1991. On this date, *Galileo* flew by Gaspra with a closest approach of a mere 990 miles, taking many highly detailed pictures.

After *Gaspra*, *Galileo* dives back toward Earth for a second encounter exactly two years later. Here, it finally gains enough energy to make it out to Jupiter, where it arrives December 7, 1995. At this point a small probe will be dropped into the atmosphere while the larger orbiter swings around the giant planet sending data back to Earth for two years.

Similar flight procedures were used for the *Voyager* probes and others. Their orbits are also provided with *First Light*.

Beyond the Solar System

Stars

First Light Star Databases

First Light can use two stellar databases, one based on NASA's *SkyMap* star catalog and the other based on the *Hubble Guide Star Catalog*.

Core Star Database

First Light's primary or core database contains the stars that are kept in your computer's memory as long as *First Light* is running. *First Light* uses the *SkyMap* star catalog as its primary database. The core database contains all of the *SkyMap* stars down to magnitude 6.7 for a total of 9,824 stars.

Hubble Guide Star Catalog

In addition to the *SkyMap* catalog, *First Light* can display stars from the *Hubble Guide Star Catalog*. The *Guide Star Catalog* (GSC) was prepared to aid astronomers in research using the *Hubble Space Telescope*. It is used to find stars near an object being observed that the telescope's guidance system can lock on, holding it in place for the duration of the observation. The *Guide Star Catalog* contains sixteen million stars, down to magnitude 16. The GSC contains positional and magnitude data only, so double clicking on a GSC star with the left mouse button does not produce an information window for the star. The GSC stars are displayed by selecting ***More stars*** from the ***Stars*** submenu in the ***Expert*** menu. ***Expert menus*** in the ***File*** menu must be selected for the ***Expert*** menu to be available. The field of view in the ***Planetarium*** window must be 5° or less in order for *First Light* to display the GSC stars. The entire *Guide Star Catalog* is included with *First Light*.

Star Information

The *SkyMap* catalog stars have data associated with them in addition to the position and magnitude data used to draw them in the ***Planetarium*** window. You can access the following data fields in the database either by clicking on a star with the left mouse button or by using the ***Data*** submenu in the ***Expert*** menu's ***Stars*** submenu.

Magnitudes

The brightness of a star or other object in the sky is given by a value called its *magnitude*. The brighter the object, the lower its magnitude. Each magnitude represents an intensity about 2.5 times less than the next lower value. The dimmest stars visible to the unaided eye are about magnitude 6.5.[1] This means that, under the best stargazing conditions, approximately 3000 stars can be seen from horizon to horizon out of a possible 6,000 stars.

It would make sense that the brightest stars would be magnitude 0, but when measurements of stellar brightness were refined, it became necessary to indicate even greater luminosity. Thus, some of the brightest objects are actually given negative magnitudes. For example, the Sun blazes away at a magnitude of –26.3, while the next brightest star, *Sirius*, shines at –1.46.

Absolute Magnitude

In order to rate the stars' luminosities according to some known baseline, astronomers created *absolute magnitude*. This is what the magnitude of a star would be if it were placed at distance of ten parsecs (32.6 light years). With this in mind, our Sun would shine at an unimpressive magnitude 4.79. By comparison, *Sirius* would be 1.5, *Polaris* –4.6 and *Canopus* would blaze away at a searing –8.1.

B–V

B–V (pronounced "B minus V") color is an index of the actual color of the star. Hotter, bluer stars have negative values and cooler, redder stars have positive values. The range of B–V goes from about –0.5 to 2.0, with 0.0 being pure white.

Double Stars

Frequently, what looks like a single star can be resolved into two or more stars through a telescope. These are commonly called *double stars* or *binary star systems*, although many are actually multiple systems containing several stars. *Physical binaries* form an actual system, orbiting around some common gravitational center. *Optical binaries* are two stars which happen to be along the same line of sight.

The orbital periods of binaries range from a few days to several thousands of years or more. Unfortunately, the faster period systems are so close to each other that they cannot be seen with the human eye. Such systems are usually detectable by spectroscopic means and are called *spectroscopic binaries*. In many cases, the stars may actually be so close as to be physically touching each other.

Although most double stars have periods much too long to observe any motion, a few are short enough to show movement within the lifetime of the average astronomer.

Some of the better known double stars include *Polaris* (the north star) and *Sirius* (the brightest star, in *Canis Major*).

Mizar, the bend in the Big Dipper's handle, is perhaps the best known double star and is easily visible with *First Light*. With a period of several thousand years, *Mizar* is said to have been used as an eye test by American Indians.

1. By comparison, an inexpensive set of binoculars will show you stars as faint as magnitude 8; small home telescopes go down to 11 or 12. Large home scopes can show 14th magnitude objects, such as Pluto, while your local observatory can show one or two magnitudes dimmer. The largest observatories can see in excess of magnitude 22 and the Hubble Space Telescope can see stars below 28th magnitude.

Selecting ***Binary stars*** from the ***Data*** submenu in the ***Expert*** menu's ***Stars*** submenu labels any multiple stars in the ***Planetarium*** window with a ***bi***. Clicking on a double star with the left mouse button brings up further information. The first number in the ***binary specs*** section of the star's information window is the angular separation (in arc seconds) between the farthest components of the system. The second value is the difference in magnitudes between the two brightest members of the system.

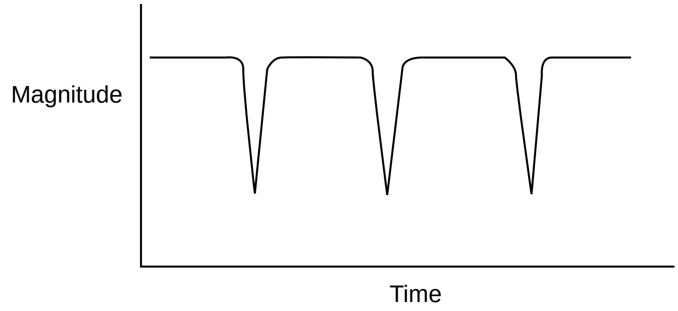
Names

Each star has several different designators. *First Light* supplies up to five of them. The brightest stars have proper names, handed down to us through thousands of years of tradition and myth. To have *First Light* display these, select ***Stars*** from the ***Names*** sub-menu in the ***Stars, etc.*** menu. A somewhat more practical method of naming stars was developed in 1603, in which the main stars in each constellation were assigned a Greek letter. In general the brightest star is termed *Alpha*, the next brightest, *Beta*, and so on. Since then, numerous other cataloging systems have been developed – usually to classify the stars according to some specific characteristic. *First Light* supplies three catalog ID numbers, the *Henry Draper* (HD) catalog number, the *Smithsonian Astrophysical Observatory* (SAO) catalog number and the *SkyMap* (SMAP) catalog number.

Variable stars

Another class of stars is the *variable*, which actually change brightness over time. There are two main varieties: *binary variables* and *physical variables*. Binary variables are nothing more than double star systems, described above, which we view edge on. The variations in brightness are caused when one star eclipses the other. Such variables have long steady light curves with short dips every few days.

Physical variables fluctuate by a physical process which is not clearly understood. There is great variety among physical variables. Some vary with a precise, regular period, while others behave erratically. Many will change several magnitudes in brightness, while others change only a few hundredths of a magnitude. Some have long periods of several years while others have periods of a few hundredths of a second, as in the case of *pulsars*. One variety, the *nova*, varies its brightness by exploding. The supernova of 1987, in a matter of only hours, released 1,000 times the amount of energy that our Sun will release over its entire ten billion year life span.



Light curve for a binary variable

One particular type of variable star that has become very useful is the *cepheid* variety, of which about 500 examples are known. Cepheids are unusual, in that their fluctuations follow a very precise set of rules, the most notable being that there is a close relationship between the period and luminosity of the stars. Knowing the period, you can determine the luminosity, and knowing the luminosity, you can determine the distance when compared to their visual magnitude. Using this method astronomers are able to determine the distances to nearby galaxies.

Pulsars are one of the most interesting types of variable stars. The first discovered (in 1968 by the Cambridge University Observatory) had a period of only 1.337 seconds. Its rapid rate is amazing considering that most processes in the universe are measured in terms of thousands to millions of years. Another pulsar, known as *Tau X-1*, has a period of only .033 seconds! Current theories explain pulsars as *neutron stars*, rotating very rapidly. Their energy is focused by a strong magnetic field into a beam which is directed outward along the rotational equator, much like a lighthouse. Each time a beam crosses our line of sight, we receive a flash. The precision of pulsar flashes had astronomers at first thinking that they had discovered an artifact from some alien civilization.

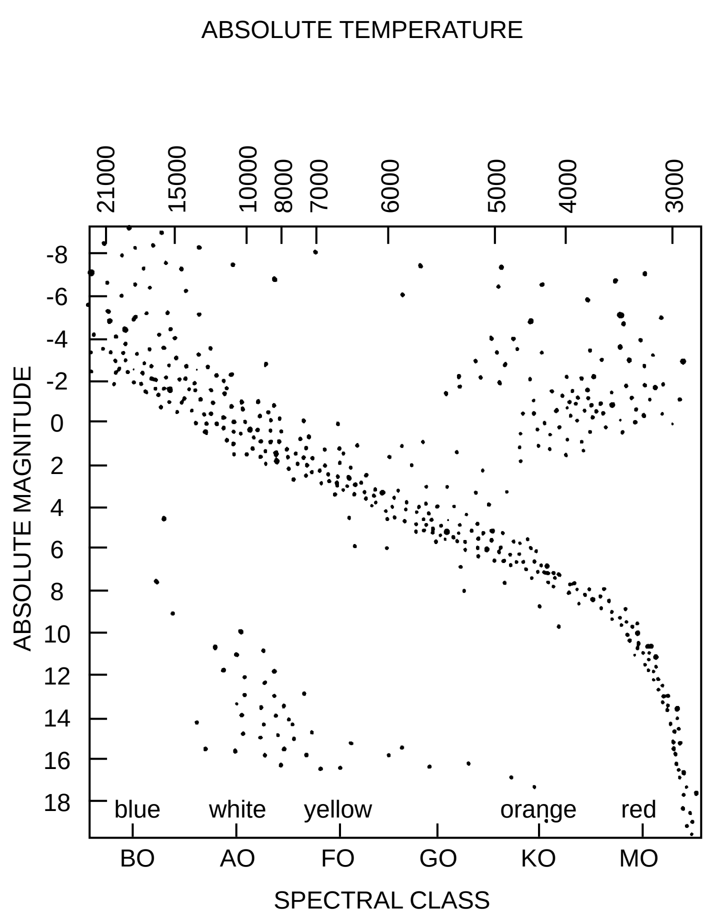
Stellar Classes

Stars are most commonly subdivided into many different classes by chemical makeup as derived by their spectra. The spectra is the finger print of a star, revealed using a spectroscope. A stellar spectra looks like the rainbow band of light that a common prism reveals when placed in the sunlight. By spreading out this band, dark *absorption lines*, caused by different chemical elements in the star absorbing a particular color of light, are revealed. For example, helium shows up as one set of bands and hydrogen as another.

Table 1: The Chief Spectral Classes

O	Very hot (35,000 K) blue-white stars with large mass and high luminosity. Spectral lines include ionized helium, nitrogen, oxygen, and hydrogen. Lambda Orionis, Zeta Puppis and O type stars.
B	Hot (20,000 K) blue-white stars with large mass. Spectral lines include prominent helium bands with highest intensity at B2 and disappearing at AO. Alpha Eridani, Rigel, Spica and Regulus are B type stars.
A	Hot (10,000 K) white stars with luminosities 50 to 100 times that of the Sun. Spectral lines contain strong bands of hydrogen, while helium is missing. Altair, Sirius and Vega are A type stars.
F	Warm (7,000 K) yellow-white stars. Strong calcium lines in spectrum with other metals present, and weaker hydrogen lines. Alpha Persei, Procyon and Canopus are F type stars.
G	Warm (6,000 K) yellow stars. Metals are prominent in spectrum, with weaker hydrogen lines. The Sun, Alpha Centauri, and Capella are G type stars.
K	Warm (4,000 K – 4,700 K) orange stars. The spectrum contains many strong metal lines, weak hydrogen lines and the appearance of hydrocarbon lines. Alpha Ursa Majoris, Pollux and Arcturus are K type stars.
M	Cooler (2,500 K – 3,000 K) red stars. Wide spectral bands from titanium oxide, with many other strong metallic lines. Many show bright hydrogen lines. Betelgeuse, Mira and Antares are type M stars.
N	Deep red cool (2,500 K) giants. Carbon spectral lines appear. Mostly variable stars. Y Canum Venaticorum, R Leporis and S Cephei are type N stars.
R	Orange red stars similar to type N, but warmer. Carbon bands are weaker. May be path through which type G become type N. RU Virginis and S Camelopardi are type R stars.
S	Red stars similar to type M but with zirconium oxide bands replacing titanium oxide. Complex spectra, usually variable, with hydrogen emission lines. R Cygni is a type S star.
W	Hot (50,000 K+) blue giants, known as Wolf-Rayet stars. High luminosities, similar to type O but with expanding gaseous shell and extremely turbulent atmosphere. Gamma Velorum is a type W star.

The illustration below shows the distribution of the stars in terms of luminosity versus spectral class. It is the *H-R* (Hertzsprung-Russell) diagram, developed in 1913. The strong central band is called the *Main Sequence,* describing about 90% of all stars. The Sun is in almost the exact center of the chart. In the upper right are the *red giant* stars, large cool stars several hundred times the size of the Sun. Stretching across the top are the massive *supergiant* stars which may be as much as 50,000 times as luminous as the Sun, such as *Rigel* in *Orion*. In the lower left corner are very hot, small stars such as *white dwarfs*.



The HERTZSPRUNG-RUSSELL DIAGRAM. This color-magnitude graph shows the various types of stars which exist within a few hundred light years of the sun. (For explanation, refer to the text.)

The letters O, B, A, F, G, K and M are used to identify the main spectral classes (*Table 1*). Finer distinctions are marked by the numbers 0 to 9 following the letter. For instance, our Sun is spectral class G2, *Rigel* is B8. Still finer classifications are required due to differences in luminosities within a particular spectral type. These are given by the *MK* identifiers shown in *Table 2*. So, the complete class of the Sun is G2 V, while *Rigel* is B8 Ia.

Table 2: Stellar classes

Ia.	Most Luminous Supergiants
Ib.	Least Luminous Supergiants
II.	Bright Giants
III.	Normal Giants
IV.	Subgiants
V.	Main Sequence
VI.	Subdwarfs

Stellar Motions

While they appear unmoving to us, the stars, along with everything else in the universe, never stand still. The two kinds of stellar motions that *First Light* can show are *radial velocity* (the speed at which a star moves toward or away from us) and *proper motion* (movement against a fixed background).

Radial velocity, measured in kilometers/second, is determined from the star's all important spectra. As a star varies its distance from us, the *Doppler effect* takes hold and shifts the spectral lines described above. If a star is receding, or moving away from us, the lines move toward the red end of the spectrum, hence the term *red shift*. If it is approaching us, the lines move toward the violet end of the spectrum. The red shift has indicated that the entire universe is expanding, much like spots on the surface of an inflating balloon.

Proper motion is measured in arc-seconds per year of angular motion against fixed objects in the sky. Naturally, the closest stars are seen to have the fastest proper motions. *Barnard's Star* (the third closest star at six light years) in *Ophiuchus* is the champ. It can easily be seen zipping through the heavens at the breakneck speed of 1° every 351 years.

Precession

There is yet another stellar motion, called *precession*, which has the unfortunate effect of making all star atlases in the world obsolete every hundred years or so. This phenomenon is due to a subtle motion, or wobble, of the earth's axis, where one complete wobble takes about 25,800 years. All stellar positions gradually shift as a result of this. This is why stellar data is prefaced by an *epoch*, or the year for which it is most valid. For instance, *First Light's* database is epoch 2000, meaning that the positions of the stars are correct for the year 2000 A.D. This doesn't make the data useless for the current year, however. Since the motions are so slow, new epochs are calculated only every fifty years or so. *First Light* can demonstrate precession with the items in the ***Precession*** submenu in the ***Expert*** menu.

One result of precession is that our current north star, *Polaris*, is only temporary. In the year 4145 A.D., the star *Gamma Cephei* will hold the honor.

1. Select ***By name*** from the ***Center*** submenu in the ***Stars, etc.*** menu to open the ***Center*** dialog. Type Polaris and click ***OK***. The north star is centered in the ***Planetarium*** window.
2. Select ***Normal*** from the ***Zoom*** submenu in the ***View*** menu to set the field of view to 60°
3. Select ***Grid*** from the ***Markers*** submenu in the ***Extras*** menu to display a RA/ dec grid in the ***Planetarium*** window. ***Expert menus*** must be selected in the ***File*** menu for the ***Extras*** menu to be available. Note how close *Polaris* is to the 90° declination point.
4. Select ***Names*** and ***Outlines*** from the ***Constellations*** submenu in the ***Stars, etc.*** menu so that they have check marks next to them.
5. Select ***When and where*** from the ***View*** menu and set the year to 4145 A.D. in the ***When and where*** dialog box.
6. Select ***Stars*** from the ***Precession*** submenu in the ***Expert*** menu to calculate the precession for the year 4145 A.D. The constellation outlines remain in their original position so that you can compare the stars' new positions with their original positions. The star *Gamma Cephei* is near the north pole (90° dec). Click on it with the left mouse button to verify this. *Polaris* is now at a declination of about 79°.

Distance

Stellar distances are rarely measured in miles because of the enormous values involved. Astronomers have adopted the unit of the *light year*, which is the distance that light travels in a year. The closest star, *Alpha Centauri*, is a mere 4.34 light years away.

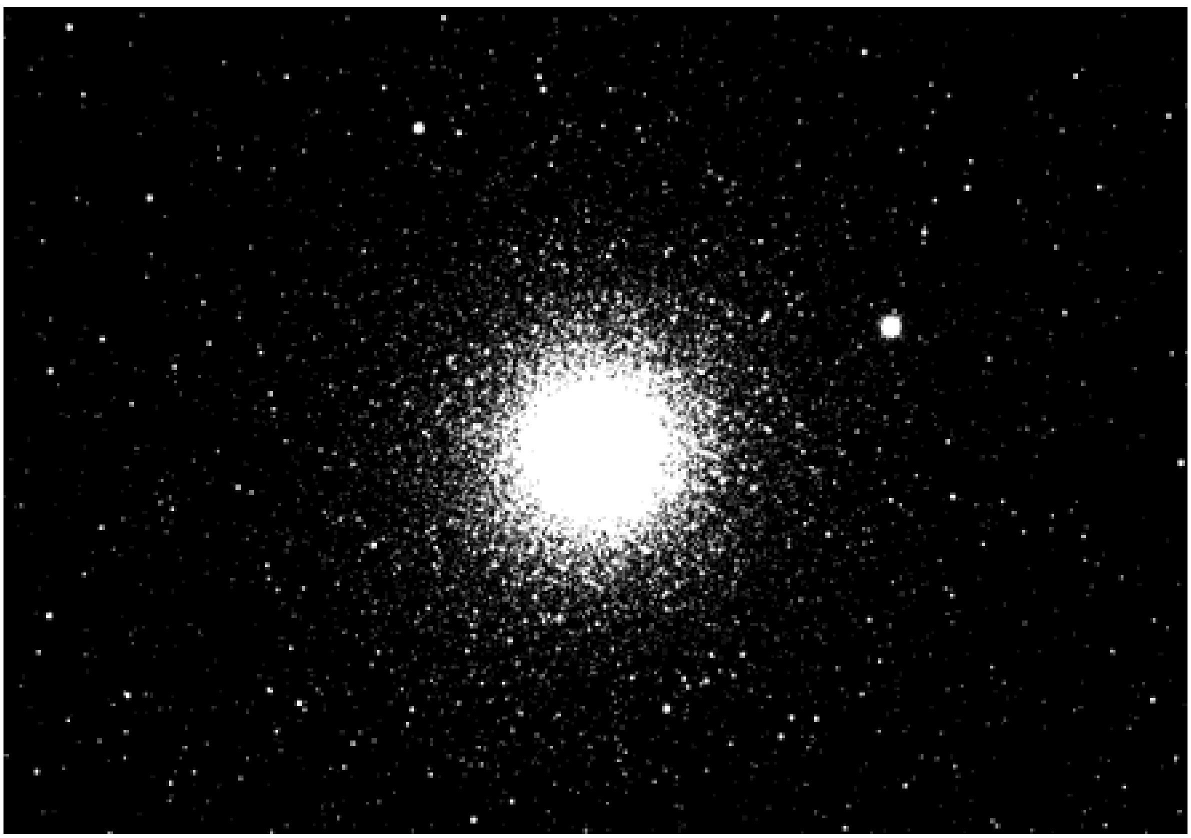
At 4.34 LY distance, the light that you see from *Alpha Centauri* originated from the star four years and four months ago. By comparison, the light you see from the Sun is only eight minutes old and the light from the furthest visible objects is literally billions of years old.

Sometimes a unit called a *parsec* is used instead of light years. A parsec is equal to 3.26 light years.

Deep Sky Objects

Deep sky objects are non-stellar objects outside of our solar system. These include such things as star clusters, galaxies and nebulae. The ***Messier*** and ***NGC*** items in the ***Galaxies, etc.*** submenu of the ***Star, etc.*** menu control whether *First Light* displays deep sky objects.

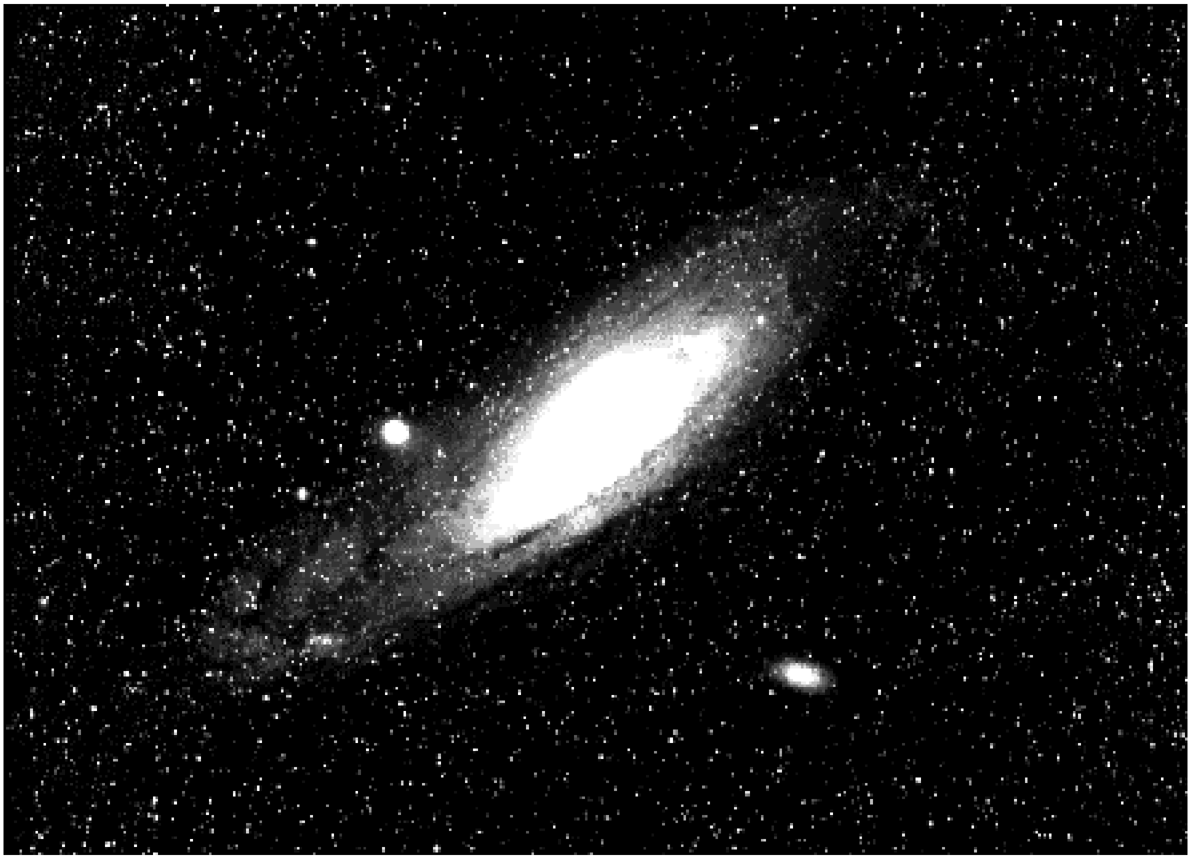
Star Clusters



A globular cluster

Star clusters are groupings of stars which are gravitationally dependent on each other. *Open clusters* are loosely formed groupings. *The Pleiades* (*M45* in *Taurus*) and *The Hyadies* (the head of *Taurus*) are fine examples of open clusters. Some open clusters contain fewer than a dozen stars. Another type of star clusters, *globular clusters*, which are very tight spherical formations containing hundreds of thousands of stars. *M13* in *Hercules* is one of the most notable examples.

Galaxies



The Andromeda Galaxy – our own galaxy's closest neighbor

Galaxies are often referred to as "cities of stars," the most famous being our own *Milky Way*. Galaxies typically contain billions of stars.

Galaxies such as the *Milky Way* and the *Andromeda* galaxy (*M31*) are classified as *spiral galaxies* because of their strong disk shaped appearance. In fact, many spirals show distinct arms curving out from the core, looking much like a giant celestial whirlpool.

Elliptical galaxies have no strong disk shape but still maintain a rounded form.

Irregular galaxies have no recognizable form whatsoever. The *Small Magellanic Cloud* in the southern sky is an example of an irregular galaxy.

Nebulae

Nebulae are interstellar dust and gas clouds which provide raw materials for new stars. It is believed that over a third of our galaxy's mass is in this form. The best known example is the beautiful *M42* in the constellation of *Orion*. It is called a *diffuse* nebula because of its loose, irregular shape.

Planetary nebulae have a rounded planet-like appearance. They usually result from a star which, at one time, became unstable and exploded (a *nova*), shedding its outer layers. The *Ring Nebula* in *Lyra* (*M57*) and the *Rosette Nebula* in *Monoceros* (*NGC2237*) are fine examples of such objects. Visible in even the smallest telescopes, the *Ring Nebula* looks like an intergalactic smoke ring blown there by a relaxing deity.

The Orion Nebula

Nebulae can be either dark or bright. The dark ones, such as the famous *Horsehead Nebula* in *Orion*, look much like “holes in the sky,” obscuring everything behind them. This is because they have no stars near enough to illuminate them. For this reason, some astronomers feel that dark nebulae represent the original matter left over from the creation of the universe.

On the other hand, the bright nebulae have frequently been called “stellar nurseries.” In the center of the 30 light year wide *Orion Nebula*, for instance, objects have been observed which are believed to be stars in the process of forming.

Nebulae are typically composed of hydrogen and helium, with traces of carbon, oxygen and nitrogen.

Deep sky catalogues

Messier Catalog

First Light makes use of two of the main catalogs of deep sky objects. The first is called the *Messier* catalog, named after the French astronomer Charles Messier, which contains 110 entries. Compiled in 1781, the catalog was developed as an aid to comet hunters who might mistake the faint smudge of a galaxy or nebula for a comet. This listing contains the most famous objects in the northern skies. *Appendix C* lists the objects included in the Messier catalog.

To display objects from the Messier catalog in the ***Planetarium*** window, select ***Messier*** from the ***Galaxies, etc.*** submenu in the ***Stars, etc.*** menu.

NGC Catalog

The other catalog used by *First Light* is the *New General Catalogue*, or NGC, which comprises over 7,500 entries. *First Light* displays the best 1,500 or so of these. *Appendix D* lists the NGC objects included with *First Light*.

To display objects from the New General Catalog in the ***Planetarium*** window, select ***NGC*** from the ***Galaxies, etc.*** submenu in the ***Stars, etc.*** menu.

First Light Reference

First Light Menus

File Menu

Printer Setup...

Selecting Printer Setup... from the ***File*** menu opens a ***Print Setup*** dialog box with which you can change your printer options.

Set Page Title...

Set Page Title... opens a dialog box in which you can enter a title to be printed at the top of printout pages.

Print

Selecting ***Print*** from the ***File*** menu prints the ***Planetarium*** window to your printer as a star chart that can be used when you are away from your computer. You might, for example, print a star chart to be used for an observation session in the field. Star charts are printed with black stars on a white sky in order to save printer ink or toner.

Expert menus

When ***Expert menus*** is selected (checked), *First Light* adds four menus to the menu bar. The added menus are ***Extras***, ***Tools***, ***Preferences*** and ***Expert***. They contain items useful to more advanced users.

Startup preferences...

Selecting ***Startup preferences...*** opens a dialog box with which you can select some basic settings to be used each time *First Light* is started from the Windows Program Manager.

Navigator open

When ***Navigator open*** is checked, *First Light's* ***Navigator*** window is open when *First Light* starts up.

Expert menus

When ***Expert menus*** is checked, four new menus (***Extras***, ***Tools***, ***Preferences*** and ***Expert***) are included on the menu bar when *First Light* starts up.

Sky Tonight display

When ***Sky Tonight display*** is checked, *First Light* starts up with the ***Sky Tonight*** display rather than the main ***Planetarium*** display window.

Use km for distances

When ***Use km for distances*** is checked, *First Light* shows distances between solar system objects in kilometers rather than miles. You must exit *First Light* and restart it from the Program Manager for this change to take effect.

Planet selector open

When ***Planet selector open*** is checked, the ***Planets*** selection dialog box is open when *First Light* starts up. The ***Planets*** dialog box can also be opened by selecting ***Major planets*** from the ***Planets*** menu's ***Center*** submenu.

Save settings on exit

When ***Save settings on exit*** is checked, *First Light* saves the current settings into an event file when you exit and uses those settings when you start *First Light* again. See the section on the ***Settings*** submenu for an explanation of event files.

Quickview uses profile

When ***Quickview uses profile*** is checked, the ***Quickview*** feature (***View*** menu) loads the all settings from a selected event file *except* for the date and time (*First Light's* current date and time are used).

Splash Music

When ***Splash Music*** is checked, *First Light* plays music when it starts up.

Settings

The ***Settings*** submenu gives you several options for changing a variety of *First Light's* settings through *event files*. An event file represents the "state" of *First Light* at a given time. For instance, you might set up *First Light* to display an upcoming eclipse and then save it as an event file. When the event file is loaded back into *First Light*, the date, time and all of the program's features are changed to those settings.

Load profile…

Load profile... opens a ***load settings*** dialog box with which you can select an event file to load. Once an event file is selected and the ***OK*** button is clicked, *First Light* loads all of the settings from the selected file except for the date and time (*First Light's* current date and time are used). You might have an event file to highlight the constellations only using their names, outlines and borders, while another one is used to highlight the planets while turning off the stars.

Load event…

Load event is like ***Load Profile***, except that *First Light* loads the entire file, including the date and time saved with the settings. Use this when you wish to load a specific event, such as an eclipse.

Save…

Save opens a ***Save events*** dialog box with which you can name and save *First Light's* current settings, including the program's internal date and time, to an event file.

Save startup…

Save startup is like ***Save***, but it saves an event file that is used automatically whenever *First Light* is started from the Program Manager. Startup settings include the direction of the view in addition to the settings of other features.

Save quickview…

Save quickview… saves an event file that is used when any of the items in the ***View*** menu's ***Quickview*** submenu are selected or any of the ***Quickview*** buttons on the tool bar are used.

Save cleanup…

Save cleanup saves an event file that is used when ***Cleanup*** is selected from the ***View*** menu or the ***Reset*** button on the toolbar is used. For instance, if you want the constellation outlines to always be displayed, set up the star display with only constellation outlines turned on and select ***Save cleanup***.

Exit

Exit quits *First Light* and returns you to the Windows Program Manager.

View Menu

The view menu contains items that control *First Light's* view of the sky.

Tutorials

Selecting ***Tutorials*** opens a series of interactive tutorials designed to teach you about both *First Light* and astronomy in general. It is recommended that the tutorials be completed in order, since they take you from the familiar to the unfamiliar and beyond.

Buttons appear throughout these tutorials. Clicking on them demonstrates events that are being described or shows a short film about the topic being discussed.

Quickview

The items in the ***Quickview*** submenu set up the star display in ***local*** coordinate mode, looking toward any of nine directions. Options saved with the ***File*** menu's ***Save quickview...*** item are also turned on. The ***Quickview*** items save the time that it would otherwise take to turn features on or off individually while waiting through several screen refreshes.

Selecting ***up*** from the ***Quickview*** submenu displays the entire sky as seen from the selected location with a 180° field of view (simulating a "fish-eye" lens). Because of the wide field, constellations near the edge of the display are distorted, or scrunched up. The display is drawn as if you are facing north and looking straight up. So north is below your chin, or down, relative to your face.

The Sky tonight

The Sky tonight displays a screen that shows an overview of your local sky at the current time, according to your computer's system clock. The sky is displayed as seen from the location set in the ***When and where*** dialog box. Three buttons at the bottom of the ***Sky tonight*** screen give you access to different features.

The ***Calendar*** button opens the ***Calendar*** window. When it is first opened, this window displays a calendar for the current month according to the date in the ***When and where*** dialog box. The current day is highlighted with a flashing yellow border. The phase of the Moon and notes of astronomical events are displayed for each day of the month. The left and right arrow buttons at the bottom of the ***Calendar*** window change the month backward and forward, respectively. The ***now*** button takes the calendar back to the current month and day according to the date in the ***When and where*** dialog box.

Clicking on any particular day with the left mouse button opens a window containing more detailed notes for that day. Clicking the ***use date*** button in this window changes *First Light's* ***When and where*** date to the selected day.

The ***Nightly Grabbag*** button opens a window displaying interesting information about a phenomenon, object, or event. You can read through the text, examine the pictures, click on highlighted words or phrases to learn more, or see short films on the subject presented. Items change daily.

The ***Planetarium*** button returns you to the ***Planetarium*** window.

Summary

Selecting ***Summary*** displays the ***What's up?*** window. The ***What's up?*** window contains a text summary of the planets, Sun and Moon. The summary includes the objects' current locations in both equatorial and local coordinates, whether or not they are visible from the location set in the ***When and where*** dialog box, distance in astronomical units from your current viewpoint, rise and set times at the location set in the ***When and where*** dialog box, and the time in minutes that it takes for light to travel from the object to your current viewpoint.

If an object has an asterisk to the left of its name in the summary, it is currently visible from the location set in the ***When and where*** dialog box.

The column labeled *diam*. shows the angular diameter of each object in degrees. For comparison, both the Sun and Moon are about 0.5° in diameter. These values vary throughout the year depending on how far away the object is from the Earth.

The light distance, in the column labeled *time*, plays an important part in how spacecraft such as *Galileo* or *Voyager* are controlled. For instance, when *Voyager* flew by Neptune in August of 1989, it took radio signals over four hours to reach it. So, when a command was sent to the spacecraft by ground control, it took a full *eight hours* to find out whether or not the spacecraft carried out the command.

The ***next meteor shower*** button in the ***What's up?*** window opens another window containing a description of any upcoming meteor showers. Meteor showers are best viewed after midnight when the Moon is not visible.

Mode

The items in the ***Mode*** submenu toggle between *First Light's* two main display modes, ***Local*** and ***Equatorial***. In ***Local*** mode, the sky is displayed from Earth using local coordinates. In ***Equatorial*** mode, the sky is displayed from Earth using equatorial coordinates. When *First Light's* viewpoint is off the Earth, out in the solar system, equatorial coordinates are used, regardless of the mode selected in the ***Mode*** submenu. See the *Basic Concepts* chapter for an explanation of the local and equatorial coordinate systems.

Local

In ***Local*** mode, the sky is displayed, using local coordinates, as seen from the time and location on the Earth given in the ***When and where*** dialog box. Another way of entering ***Local*** mode is to use the ***Quickview*** submenu in the ***View*** menu. Since the ***Quickview*** items change several settings at once, they save time in setting up the ***Planetarium*** display. In ***Local*** mode, the sky changes from night to night and from one location on the Earth to another. This is because the local coordinates of the stars, their altitude and azimuth, change as the Earth rotates. If you view the sky from the northern hemisphere, you will notice that the north star, *Polaris* is at an altitude above the northern horizon equal to your latitude. If you are exactly at the pole, the sky resembles ***Equatorial*** mode.

Equatorial

In ***Equatorial*** mode (the default), the sky is displayed, using equatorial coordinates, as if there were no Earth beneath you to distort your perspective. This removes any ambiguities introduced by your location and is, therefore, the mode used in star charts and by astronomers. ***Equatorial*** mode is slightly faster than ***Local*** mode, since fewer calculations are required to position the stars.

Navigator

The ***Navigator*** is perhaps the single most powerful tool in *First Light*. The ***Navigator*** window gives you a visual overview of where you are or what you're viewing. The ***Navigator*** is also used to graphically move *First Light's* viewpoint and direction of view.

You Are Here

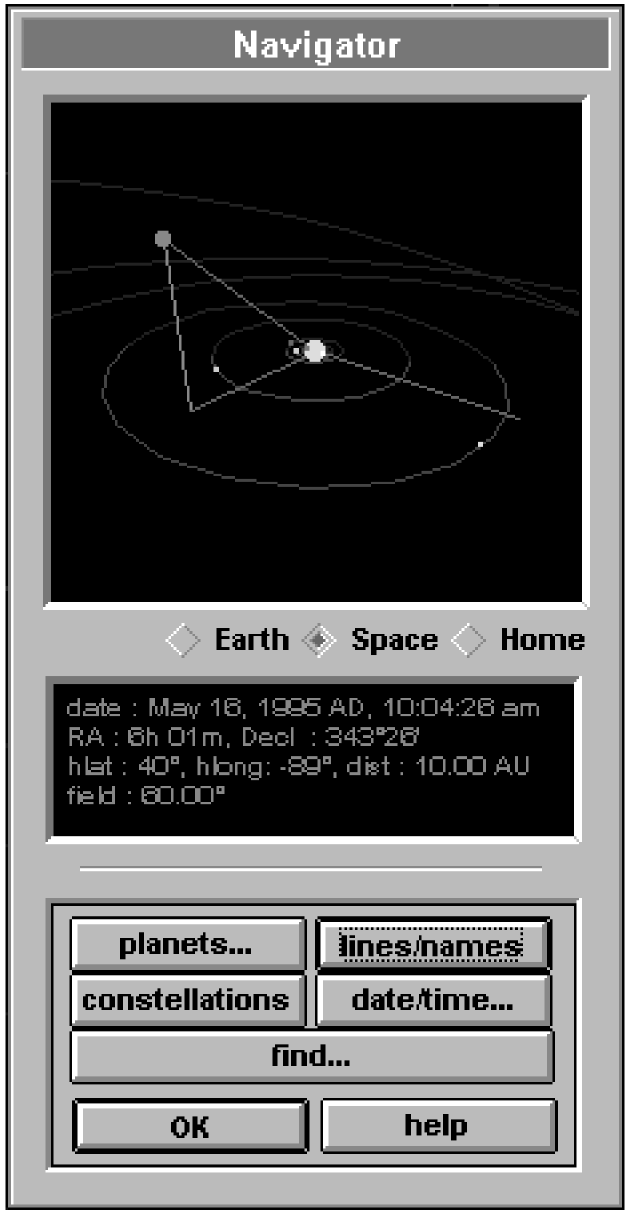
The top portion of the ***Navigator*** window is the ***You are here*** display. It varies, depending on the location of the viewpoint and the viewing mode. Beneath this display are three buttons that are used to select the viewing mode. Selecting the ***Earth*** button puts *First Light* into ***Equatorial*** mode, where the sky is viewed from the Earth, but the viewpoint is not bound to any particular location on the Earth. It is as if you are in the center of the planet looking out. Selecting the ***Home*** button puts *First Light* into ***Local*** mode, where the sky is viewed from the location specified in the ***When and where*** dialog box. Selecting the ***Space*** button moves the viewpoint off the Earth into the solar system.

When the ***Earth*** button is selected, the ***You are here*** display shows a three dimensional diagram of the way man has historically tended to visualize the sky. That is, a globe with the observer at the center and the various celestial objects on the surface of the globe. This sky globe is displayed from the outside the globe so that you can see the entire sky. The red lines radiating from the center of the globe are a *view cone* that represents the portion of the sky that is being displayed in the ***Planetarium*** window. The sky globe display also shows how much of the sky can't be seen in the ***Planetarium*** window – i.e., the portion of the globe that is outside of the view cone. The planets, Moon and Sun are shown on the surface of the sky globe. If you center the Sun in the ***Planetarium*** window, the view cone moves to center on the yellow ball on the surface of the globe. If you move the sky in the ***Planetarium*** window by dragging with the right mouse button, the view cone also moves to keeping track of the view. In equatorial coordinates, the sky is measured in right ascension, so there are right ascension labels on the equator of the sky globe every six hours.

The sky globe can be rotated to any angle by dragging the mouse over the globe with the right mouse button held down. The view cone can be rotated, changing the view in the ***Planetarium*** window, by dragging the mouse over the globe with the left mouse button held down. The size of the view cone, i.e. the field of view, can be changed by holding down both mouse buttons at the same time and dragging the mouse up and down.

When the ***Home*** button is selected, only half the sky globe is displayed. This is because the other half is below the local horizon and is, therefore, not visible. Other than that, the ***Home*** display is identical to the ***Earth*** display.

The ***You are here*** display is quite a bit different when the ***Space*** button is selected. *First Light's* viewpoint is moved off the Earth and out into the solar system. The circles are the orbits of the planets, the bright dots on the circles are the planets themselves and the yellow dot at the center is the Sun.



Navigator window

First Light's viewpoint is marked by the green dot. This is the point in the solar system from which the view in the ***Planetarium*** window is seen. The lines drawn from the green dot show the relative distance of the viewpoint from the plane of the solar system (the *ecliptic*) and from the Sun. If the lines are green, the viewpoint is above the ecliptic. If they are red, the viewpoint is below the ecliptic. The blue line radiating out from the Sun points to 0° right ascension, also referred to as the *first point of Aries*. It is an arbitrary point that is the *origin* of the equatorial coordinate system.

As with the ***Earth*** and ***Home*** displays, dragging with the right mouse button rotates the display to any angle. Dragging with the left mouse button moves the viewpoint. Dragging left or right rotates the viewpoint around the Sun. Dragging up or down moves the viewpoint up or down in relation to the ecliptic. Dragging the mouse up or down with both buttons held down at the same time moves the viewpoint further from or closer to the Sun. This may take some practice, as duplicating three dimensional space on a flat surface like a computer monitor is not always completely intuitive.

Status Display

The area below the ***Earth***, ***Space*** and ***Home*** buttons displays some basic information about the current view in text form. This status display shows the viewpoint's precise location in space and other information about the view, such as zoom value, view angle, date, time, etc.

Button Panel

The ***Planets*** button opens the ***Planets*** dialog box, allowing you to quickly aim the view at any planet you wish. See *Major planets* in the section on the *Planets Menu* for more information.

The ***Constellations*** button opens the ***Center Constellation*** dialog box, so that you can center the view on any of the constellations.

The ***Lines/names*** button toggles on or off several of the common markers in the ***Planetarium*** window, such as constellation outlines and names.

The ***Date/time*** button opens the ***When and where*** dialog box so that you can set *First Light's* date, time and viewing location. See the section on the ***When and where*** for more information about it.

The ***Find*** button opens a dialog box that lets you locate any object in *First Light's* database by name. It is most useful for centering deep sky objects.

Cleanup

The ***Cleanup*** menu item resets the display in the ***Planetarium*** window to a pre-defined set of basic options, removing identifiers and markers that may be cluttering the view. Typically, it can be used to turn off several display options at once and return to a plain display with no identifiers of any kind. If you want some identifiers left on when you use the ***Cleanup*** feature, set up the display the way you wish it to appear and select ***Save cleanup...*** from the ***Settings*** submenu in the ***File*** menu.

Viewpoint

The items in the ***Viewpoint*** submenu set *First Light's* viewpoint off the Earth into the solar system.

Return to earth

Return to earth returns the viewpoint to Earth from a location in the solar system.

Lookdown-inner planets

Lookdown-inner planets places the viewpoint directly above the Sun, looking down on the orbits of the inner planets, from Mercury to Mars.

Lookdown-middle planets

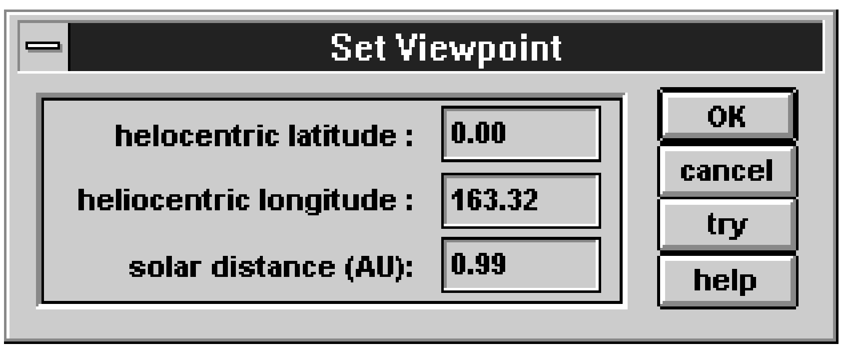
Lookdown-middle planets places the viewpoint directly above the Sun, looking down on the orbits of the planets out to Saturn.

Lookdown-outer planets

Lookdown-middle planets places the viewpoint directly above the Sun, looking down on the entire solar system, out to Pluto.

Fixed...

Fixed opens the ***Set Viewpoint*** dialog box, with which you can specify the location of the viewpoint in *heliocentric coordinates*. Heliocentric coordinates describe the position of an object (or a viewpoint) relative to the Sun. Heliocentric latitude and longitude are similar to the earth's latitude and longitude. Latitude ranges from –90° to 90°, with the plane of the earth's orbit being 0°. Longitude ranges from 0° to 360°, with 0° corresponding to 0° right ascension, also called the *First Point of Aries*. The last value in heliocentric coordinates is distance from the Sun, expressed in astronomical units (AU).



Set Viewpoint dialog box

From a planet...

From a planet opens a dialog box with a drop down list of planets. Selecting a planet from the list and clicking on the ***OK*** button attaches *First Light's* viewpoint to that planet.

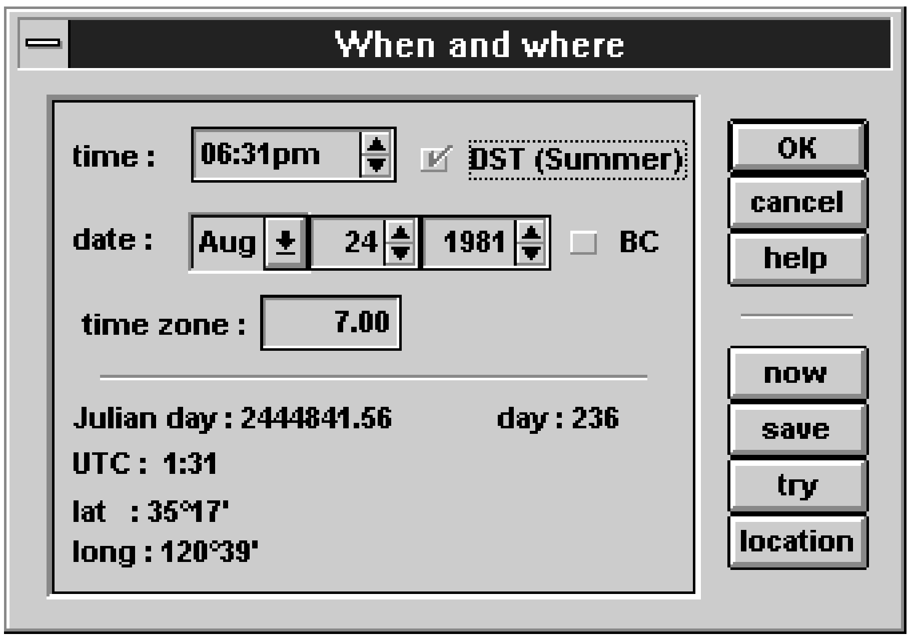
Zoom

The items in the ***Zoom*** submenu set the "magnification" of the display in the ***Planetarium*** window. This is usually called *field of view* and is measured in degrees width. The first four items are general selections which represent the most commonly used fields of view. ***Wide angle*** sets the field of view to 120°. ***Normal*** sets it to 60°, ***Close up*** sets it to 10°, and ***Telescope*** sets it to 2°.

The ***Degrees*** submenu gives a set of specific choices for the field of view. As a comparison to physical viewing instruments, fields of view between 45° and 60° are close to that seen by the unaided eye. A pair of binoculars gives a field of about 5° and a low power telescope gives a field of 1° or less. A field of 0.5° is small enough to cause the Moon to fill the eyepiece.

When and where...

Selecting ***When and where...*** opens the ***When and where*** dialog box, with which you can set the date and location on Earth from which *First Light* displays the sky. The first time you use *First Light*, you should set the location to your own home. See the *Setting Your Location and Time* chapter for more information about using the ***When and where*** dialog box.



When and where dialog box

Planets Menu

Center

The items in the ***Center*** submenu change the view in the ***Planetarium*** window to center on specific objects.

Major planets…

Major planets opens the ***Planets*** dialog box, which contains a button for each of the major planets in the solar system and for the Sun and Moon. Clicking on any of these buttons centers the planet for which it is labeled in the ***Planetarium*** window.

The ***other*** button in the ***Planets*** dialog box opens another dialog box with a drop-down list of any solar system objects other than the planets whose orbits have been loaded with the ***Load*** submenu in the ***Planets*** menu.

The ***hover*** button in the ***Planets*** dialog box opens the ***Hover*** dialog box. See the section on the ***Settings*** item in the ***Planets*** menu's ***Hover*** submenu for a description of the ***Hover*** dialog box.

The ***OK*** button closes the ***Planets*** dialog box.

Comets and things…

Comets and things opens the ***center other*** dialog box. The ***center other*** dialog box contains a drop-down list of comets, asteroids and other non-planetary solar system objects whose orbits have been loaded with the ***Load*** submenu in the ***Planets*** menu. To center the ***Planetarium*** window on an object in the drop-down list, select the object's name from the list and click on the ***OK*** button.

Look behind

Selecting ***Look behind*** centers the view in the ***Planetarium*** window on the point directly opposite to the current view, or its *antipode*. This is equivalent to turning around to look behind you. ***Look behind*** can be used to find the earth's shadow – center the Sun and select ***Look behind***.

Zenith

Zenith centers the point in the sky that is directly overhead from the current location set in the ***When and where*** dialog box.

Load…

The items in the ***Load*** submenu allow you to add solar system objects other than the planets, Sun and Moon to *First Light's* display of the sky. Objects that can be loaded are all objects that orbit the Sun (rather than orbiting a planet). They are divided into three categories: asteroids, comets and spacecraft. For more information about these objects, see the *Comets and Asteroids* chapter.

Asteroids…, Comets…, and Spacecraft…

In *First Light*, solar system objects are defined by their orbits. For each object, there is a file that specifies the object's orbit. The first three items in the ***Load*** submenu – ***Asteroids***, ***Comets*** and ***Spacecraft*** – each open a file dialog box that lists orbit files for the appropriate type of object. Each file is named after the object whose orbit it specifies. Select the orbit file for an object you wish to display and click on ***OK***. *First Light* loads the orbit and displays the object, centering it in the ***Planetarium*** window.

The orbits of several asteroids, comets and spacecraft are included with *First Light*. You can also add solar system objects to *First Light* using ***Create a new orbit*** in the ***Expert*** menu.

Unload…

Unload opens the ***unload object*** dialog box, which contains a drop-down list of solar system objects that are currently loaded. Select an object from the list and click on ***OK*** to unload its orbit from *First Light's* memory and remove it from the sky display. The ***Unload*** feature is useful because the more objects you have loaded into memory, the slower *First Light's* display is. So, you can use ***Unload*** to make sure that you only have those objects that you are currently working with loaded.

Unload all…

Unload all unloads all currently loaded solar system objects from *First Light's* memory and removes them from the star display.

Flyby…

First Light's ***Flyby*** feature allows you to investigate the six *Voyager* planetary flybys and the impact of the Shoemaker-Levy 9 comet with Jupiter. The *Voyager* flybys include *Voyager 1* at Jupiter and Saturn, and *Voyager 2* at Jupiter, Saturn, Uranus and Neptune. Selecting ***Flyby*** from the ***Planets*** menu opens the ***Flyby*** dialog box. Selecting a flyby mission from the ***Flyby*** dialog box's drop-down list and clicking on the ***show*** button sets your viewpoint in the vicinity of the selected planet, looking down on the path of the selected spacecraft. The spacecraft's path is shown as a series of dots, with blue dots forming the part of the path before closest approach to the planet, and red dots forming the part of the path after closest approach. Each dot represents a half hour of motion and the entire trail begins one day before closest approach and ends one day after. You may need to zoom the view out in order to see the entire path.

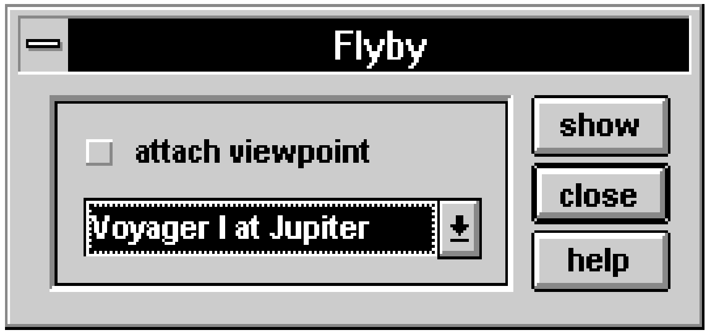
In ***Flyby*** mode, the target planet is fixed in the center of the screen, remaining centered as the time changes. Holding down the right mouse button and dragging the mouse repositions your viewpoint to any location around the planet. Dragging to the left or right rotates the viewpoint around the planet, dragging up or down moves the viewpoint north or south, respectively. Constellation names, outlines and planetary orbit lines are turned off to remove clutter when ***Flyby*** mode is entered. These features can be turned back on after entering ***Flyby*** mode. ***Flyby*** mode is similar to ***Hover*** mode, but the two cannot be used together.

Flyby dialog box

The ***flyby*** dialog box has controls that govern the view of the target planet and spacecraft.

Use the drop-down list at the bottom of the ***flyby*** dialog box to select any of six possible *Voyager* flybys or the path of Shoemaker-Levy 9 fragment Q.

The ***attach viewpoint*** button attaches your viewpoint to the spacecraft (or comet fragment).



Flyby dialog box

Hover

The items at the top of the ***Hover*** submenu are named for the Sun, planets and Moon. Selecting one of these menu items moves your viewpoint to the vicinity of the corresponding object and centers the view on that object. In ***Hover*** mode, the planets, Sun and Moon are drawn (rendered) as three dimensional objects and images of the actual objects are texture mapped onto them to make them appear as real as possible. The rendering process is fastest when your system is set to 256 colors. If a planet that you are hovering next to has moons, the moons are displayed in their current positions and labeled.

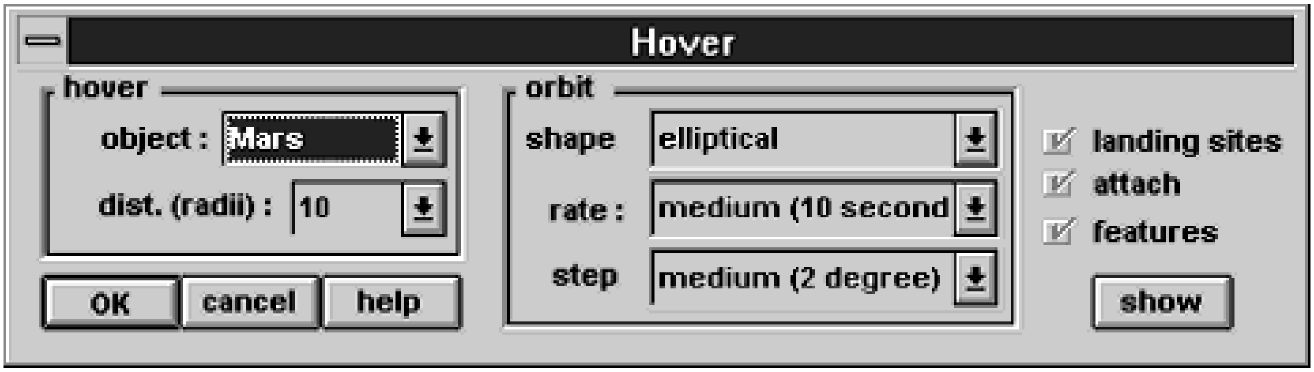
In ***Hover*** mode, as in ***Flyby*** mode, holding down the right mouse button and dragging repositions your viewpoint around the planet, keeping the planet centered in the view. Dragging to the left or right rotates the viewpoint around the planet, dragging up or down moves the viewpoint north or south, respectively.

When you enter ***Hover*** mode, constellation names and outlines, and planetary orbit lines are turned off in order to remove clutter. They can be turned back on at any time after entering ***Hover*** mode.

Settings

Selecting ***Settings*** from the ***Hover*** submenu opens the ***Hover*** dialog box. Whenever you change settings in the ***Hover*** dialog box, click on the ***show*** button for the changes to be displayed in the ***Planetarium*** window.

The drop-down list labeled ***object*** is a list of the same objects at the top of ***Hover*** submenu. Select an object from this list that you wish to view in ***Hover*** mode. The drop-down list labeled ***distance*** specifies the distance of your viewpoint from the planet being viewed. The distance is in units of the radius of the planet. For example, if you are viewing the Earth and you set your hover distance at ***50***, your viewpoint will be 50 times 4,000 miles, or 200,000 miles, away from the Earth.



Hover dialog box

The items under the ***orbit*** label control the ***orbit*** mode. The ***shape*** drop-down list controls the shape of the orbit. An ***elliptical*** orbit has an eccentricity of 0.4 and a ***highly elliptical*** orbit has an eccentricity of 0.7. The ***rate*** drop-down list controls the rate at which the display is updated: every thirty seconds, every ten seconds or every five seconds. The ***step*** drop-down list controls how far the viewpoint moves around the orbit between each update: 1°, 2° or 5°.

If you are viewing the Moon or Mars in ***Hover*** mode and the ***landing sites*** check box is checked, the landing sites of NASA's Apollo missions (on the Moon) and Viking landers (on Mars) are labeled on the planet.

If the ***attach*** check box is checked, your viewpoint is bound to the object being viewed so that it moves with the object as the object moves in its orbit.

If the ***features*** check box is checked, major features on the Moon and Mars are labeled.

Names

When the ***Names*** menu item is selected so that there is a check mark next to it, solar system objects are labeled with their names in the ***Planetarium*** window. Selecting the menu item again toggles this feature off.

Stars, etc. Menu

Center

The ***Center*** submenu in the ***Stars, etc.*** menu is similar to the ***Center*** submenu in the ***Planets*** menu. It allows you to find and center stars and other objects that are not located in the solar system.

Constellations…

Selecting ***Constellations*** opens a dialog box with a drop-down list box containing the names of the constellations. Select a constellation from the list and click the ***OK*** button. The selected constellation is centered in the ***Planetarium*** window.

Galaxies and things…

Selecting ***Galaxies and things*** opens a dialog box with a drop-down list box containing the names of several of the more prominent galaxies, star clusters and nebulae. Select an object from the list and click the ***OK*** button. The selected object's location is centered in the ***Planetarium*** window. For the object to be displayed, you must turn on the display of deep sky objects by either clicking on the ***Galaxy*** button on the tool bar or by selecting ***Messier*** and ***NGC*** from the ***Galaxies, etc.*** submenu in the ***Stars, etc.*** menu.

Custom…

Selecting ***Custom*** opens a dialog box with a drop-down list box containing a user-editable list of objects. Select an object from the list and click the ***OK*** button. The selected object is centered in the ***Planetarium*** window. You can add objects to the list by centering an object that you wish to have listed and then select ***Add to center list*** from the ***Extras*** menu.

By name…

Selecting ***By name*** opens a ***Find*** dialog box into which you can type the name of an object you wish to center. Once you've typed the name of an object, click ***OK*** and the object is centered in the ***Planetarium*** window.

Stars…

Selecting ***Stars*** opens a ***center*** dialog box into which you can type the identifier of a star you wish to center. The identifier can be the star's Greek identifier, its Henry Draper (HD) catalog number, or its Smithsonian Astrophysical Observatory (SAO) catalog number. See the *Stars* chapter for a description of these identifiers. Once you've typed an identifier in the dialog, click the ***OK*** button to center the star.

Zenith

Zenith centers the point in the sky that is directly overhead from the current location set in the ***When and where*** dialog box.

Constellations

The items in the ***Constellations*** submenu control how constellations are displayed.

Borders

When ***Borders*** is selected so that it has a check mark next to it, lines are displayed in the ***Planetarium*** window showing the internationally recognized boundaries of the constellations. In other words, if an object is said to be “in” a particular constellation, then it is within the boundaries of that constellation.

Names

When ***Names*** is selected so that it has a check mark next to it, the constellations are labeled with their names in the ***Planetarium*** window.

Outlines

When ***Outlines*** is selected so that it has a check mark next to it, the traditional outlines of the constellations are displayed in the ***Planetarium*** window.

Galaxies, etc.

The items in the ***Galaxies, etc.*** submenu control the display of *deep sky objects*. A deep sky object is an object that is not a star and is not located within our solar system. They include galaxies, star clusters and nebulae. See the *Deep Sky Objects* chapter for more information about these objects and the two catalogs of deep sky objects used by *First Light*.

Messier

When ***Messier*** is selected so that it has a check mark next to it, objects from the Messier catalog are displayed in the ***Planetarium*** window.

NGC

When ***NGC*** is selected so that it has a check mark next to it, objects from the New General Catalog are displayed in the ***Planetarium*** window.

Legend…

Selecting ***Legend*** opens a window containing a legend of the various symbols used to display deep sky objects.

Names

Galaxies, etc.

When ***Galaxies, etc.*** is selected so that it has a check mark next to it, deep sky objects are labeled with their catalog numbers.

Stars

When ***Stars*** is selected so that it has a check mark next to it, stars that have common names are labeled with those names.

Info Menu

The ***Info*** menu gives you access to a variety of information about objects in the sky and astronomical events.

Calendar…

Calendar opens the ***Calendar*** window. When it is first opened, this window displays a calendar for the current month according to the date in the ***When and where*** dialog box. The current day is highlighted with a flashing yellow border. The phase of the Moon and notes of astronomical events are displayed for each day of the month. The left and right arrow buttons at the bottom of the ***Calendar*** window change the month backward and forward, respectively. The ***now*** button takes the calendar back to the current month and day according to the date in the ***When and where*** dialog box.

Clicking on any particular day with the left mouse button opens a window containing more detailed notes for that day. Clicking the ***use date*** button in this window changes *First Light's* ***When and where*** date to the selected day.

Next event…

Next event opens a window with details about the next major astronomical event that is due to occur.

Nightly Grabbag…

Nightly Grabbag opens a window displaying interesting information about a phenomenon, object, or event. Read through the text, examine the pictures, click on highlighted words or phrases to learn more, or see short films on the subject presented.***Nightly Grabbag*** items change daily.

Constellations…

Constellations opens a window containing the names, three-letter abbreviations and meanings of the names of the constellations.

Planets…

Planets opens a window containing relevant planetary data.

Stars...

Stars opens a window containing information about the fifteen nearest and fifteen brightest stars.

Eclipses...

Eclipses opens a window containing the dates of and other information about upcoming eclipses.

Meteor showers...

Meteor showers opens a window containing the dates of the major recurring meteor showers.

Browse

The ***Browse*** submenu allows you to browse through the images and movies included on the *First Light* CD.

Tables...

Tables opens a ***Help*** window that gives you access to various tables of astronomical data.

Extras Menu

The ***Extras*** menu is only available when ***Expert menus*** is selected in the ***File*** menu.

Add to center list...

Add to center list allows you to add objects to the list of objects that can be centered through ***Custom*** in the ***Stars, etc.*** menu's ***Center*** submenu. To add an object to the list, center the object in the ***Planetarium*** window. Set the ***Zoom*** angle to be used when the object is centered using the ***Custom*** menu item. Select ***Add to center list*** from the ***Extras*** menu and the view angle and zoom are added to the list.

Chart...

Chart opens a window that displays the entire sky at once. The check boxes at the left edge of the window determine what objects are displayed.

Earth's shadow

When ***Earth's shadow*** is selected so that it has a check mark next to it, the location of the earth's shadow is marked in the ***Planetarium*** window by two concentric red circles. To find the shadow, center on the Sun by clicking on the ***Sun*** button on the tool bar and then select ***Look behind*** from the ***Center*** submenu in the ***Planets*** menu. The ***Earth's shadow*** feature is useful for examining lunar eclipses – an eclipse occurs when the Moon passes into the shadow.

Landscape

Landscape displays an artificial horizon that simulates mountains in the distance. It is only available when viewing the sky in ***Local*** mode. When the landscape is being displayed, the center of the view is limited to 20° above or below the horizon.

Magnitude Legend

Magnitude Legend opens a window that shows the symbols used to show star magnitudes in the ***Planetarium*** window.

Markers

The items in the ***Markers*** submenu add various lines and symbols to the sky display that can be useful in finding objects and visualizing the sky. Selecting the items in the ***Markers*** submenu toggles the markers on or off.

Crosshair

When ***Crosshair*** is selected so that it has a check mark next to it, a small red crosshair is added the center of the ***Planetarium*** window, marking the center of the window.

Ecliptic

When ***Ecliptic*** is selected so that it has a check mark next to it, a yellow line is added to the sky display representing the *ecliptic*. The ecliptic is the sun's path through the sky, which defines the plane of the earth's orbit and, thus, the plane of the solar system. This is the region of the sky where the planets are found.

Equator

When ***Equator*** is selected so that it has a check mark next to it, a red line is added to the sky display representing the *celestial equator*. The celestial equator is the line corresponding to 0° declination in the equatorial coordinate system. It is analogous to the earth's equator, which corresponds to 0° latitude.

Horizon

When ***Horizon*** is selected so that it has a check mark next to it, a yellow line is added to the sky display representing the horizon as seen from the location set in the ***When and where*** dialog box. When the display is in ***Equatorial*** mode the horizon line will be tilted according to the latitude set in the ***When and where*** dialog box and it will move according to the time of day, due to the earth's rotation.

Grid

When ***Grid*** is selected so that it has a check mark next to it, a right ascension/declination grid is overlaid on the sky display. The grid is drawn in a medium gray color so that it is not too distracting.

Local altitude

When ***Local altitude*** is selected so that it has a check mark next to it, tick marks showing the altitude, in degrees, above the horizon are displayed on the sky display. The feature is only available when the sky is being displayed in ***Local*** mode.

Redraw

With the many labels and other markers available with *First Light*, it is possible that some display elements may occasionally obscure others. ***Redraw*** simply refreshes the display to clean it up, if possible.

Star trails

Many people's first experience with the art of astrophotography is through taking stellar time exposures with a camera fixed on a tripod. The result is streaks, called *star trails*, caused by the motion of the stars across the camera's field of view. This effect is simulated with *First Light's* ***Star trails*** feature. To do so, change the mode to ***Local*** from the ***Mode*** submenu in the ***View*** menu and turn on ***Star trails*** in the ***Extras*** menu. Advance the time in one or two minute increments. See the section on the ***clock control*** dialog box for information about how to advance the time.

System

Close all windows

Close all windows closes all open windows except for the ***Planetarium*** window.

Twinkle

When ***Twinkle*** is selected so that it has a check mark next to it, the stars are displayed with a twinkling effect that simulates the twinkling of stars in the real sky due to atmospheric effects.

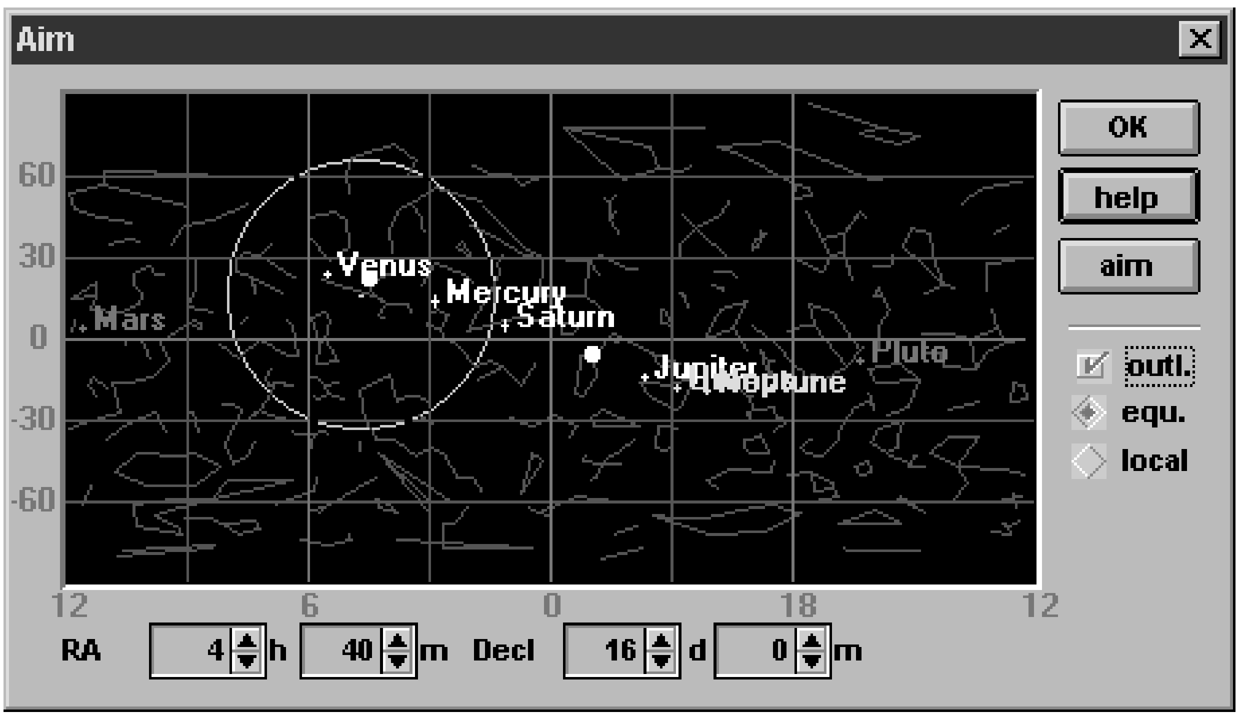
Tools Menu

The ***Tools*** menu is only available when ***Expert menus*** is selected in the ***File*** menu.

Aim…

Aim opens a dialog box containing a chart of the full sky. The green circle in the chart is centered on the same point as the view in the ***Planetarium*** window. To move the view, hold down the right mouse button and drag the green circle in the chart dialog box. The view in the ***Planetarium*** window changes dynamically as the green circle is dragged. The ***outl.*** check box toggles constellation outlines on and off in the chart dialog box. The ***equ.*** and ***local*** buttons switch the display mode between ***Equatorial*** and ***Local***.

The controls at the bottom of the chart dialog box allow you to set the view to a precise angle. Use the up and down arrow buttons to set the right ascension in hours and minutes and the declination in degrees and minutes. Once you've set the correct angle, click on the ***aim*** button to change the view in the ***Planetarium*** window.



Aim dialog box

Clock

The items in the ***Clock*** submenu control *First Light's* internal clock. The clock determines the time for which the sky is displayed.

Settings…

Settings opens the ***Clock Control*** dialog box. The two drop-down lists in the center of the dialog box set the increment for changing *First Light's* clock.

Clock Control dialog box

The five buttons at the left end of the ***Clock Control*** dialog box are exactly the same as the ***clock*** buttons on the tool bar. Clicking on the left-most button continuously decreases the time by the increment selected by the drop-down lists. The next button decreases the time by one increment each time it is clicked. The middle button stops the clock when it is set to ***Auto*** or ***Real-time*** through the ***Clock*** submenu in the ***Tools*** menu. The next button to the right increases the time by one increment each time it is clicked. The last button continuously increases the time by the selected increment.

Freeze

Freeze stops the clock when it is set to ***Auto*** or ***Real-time*** through the ***Clock*** submenu in the ***Tools*** menu.

Auto

When ***Auto*** is selected so that it has a check mark next to it, *First Light's* internal clock is continuously updated as quickly as possible by the increment set in the ***Clock Control*** dialog box (***Settings*** in the ***Clock*** submenu). The speed of this process depends on the speed of your computer.

Real-time

When ***Real-time*** is selected so that it has a check mark next to it, *First Light's* internal clock is continuously updated according to the computer's system clock. That is, for every minute of actual time that passes, the display is updated by a minute.

+1 Day

Selecting ***+1 Day*** adds one day (24 hours) to *First Light's* clock.

Now

Now sets *First Light's* clock to the current time according to your computer's system clock.

–1 Day

Selecting ***–1 Day*** subtracts a day (24 hours) from *First Light's* clock.

Sunrise

Sunrise sets *First Light's* clock to the time of sunrise for the current day at the location specified in the ***When and where*** dialog box.

Sunset

Sunset sets *First Light's* clock to the time of sunset for the current day at the location specified in the ***When and where*** dialog box.

Flashcard…

The ***Flashcard*** feature is provided as an aid to learning to identify the constellations. Selecting ***Flashcard*** turns off all of the identifying markings in the ***Planetarium*** window and centers the display on a random location. The challenge to you is to figure out just what you are viewing. While in ***Flashcard*** mode, a small dialog box with four buttons is displayed. Constellation names and outlines can be turned on and off with the ***hide*** and ***show*** buttons. The ***flash*** button turns the identifiers off and moves the view to a new random location. The ***cancel*** button exits the ***Flashcard*** mode and returns the display to the state that it was in when ***Flashcard*** mode was entered.

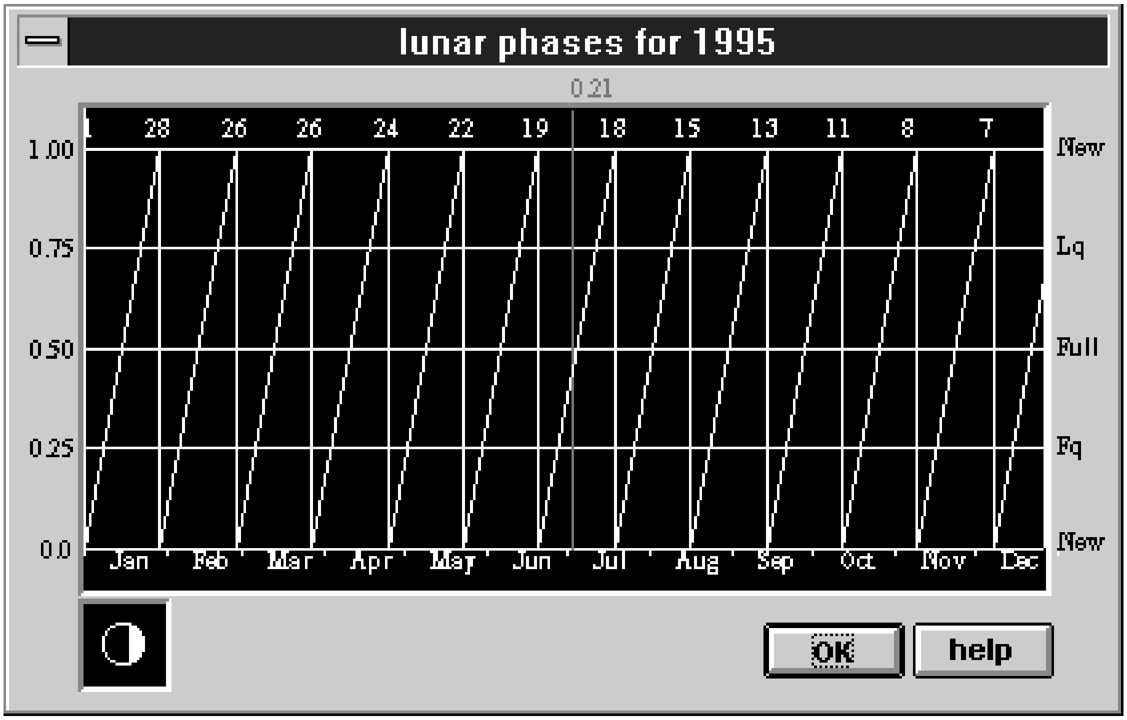
Moon

Map…

Map opens an image of the Moon with major features labeled.

Phases…

Phases opens a chart that shows the moon's phases for the current year. A value of 0.0 or 1.00 corresponds to a new Moon and a value of 0.50 corresponds to a full Moon. For values between 0.0 and 0.50, the Moon is waxing (getting fuller) and for values between 0.50 and 1.00, the Moon is waning (getting smaller). The current day is marked with a red vertical line. The small picture of the Moon in the lower left corner of the chart shows the moon's current phase.



Lunar phases window

Nearby stars...

Nearby stars opens a window that shows a three dimensional display of the stars up to one hundred light years away from our Sun. Holding down the right mouse button and dragging rotates the display. Holding down the left mouse button and dragging up or down moves the viewpoint closer to or farther from the Sun.

When the ***labels*** button is selected, the scientific names of the major stars are displayed. When the ***names*** button is selected, the proper names of the more prominent stars are displayed. When the ***no labels*** button is selected, the stars are displayed without labels. When the ***lines*** button is selected, lines are drawn from the Sun to some of the other stars so that you can get a better sense of their distance from the Sun. Lines and labels are displayed in bright colors for stars that are in front of the Sun and in dimmer colors for stars that are behind the Sun.

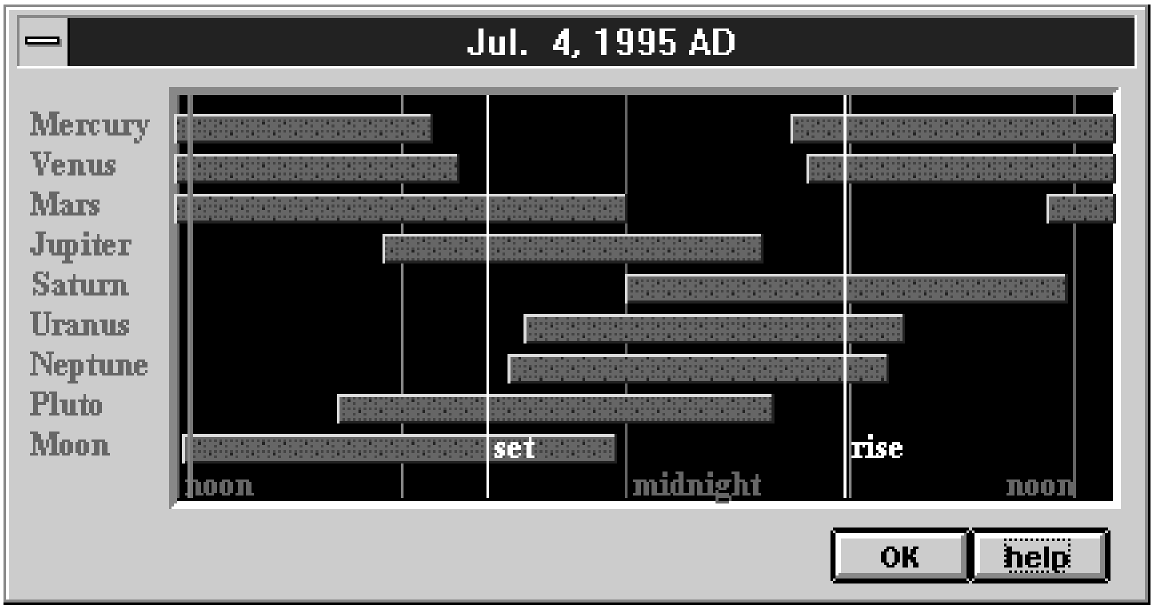
Planets

Planet guide…

Planet guide opens a window with a small chart showing the planets that are currently visible from the location set in the ***When and where*** dialog box. This chart is similar to but much simpler than the ***Sky Tonight*** display.

Rise/set plot…

Rise/set plot opens a chart that shows the visibility of the planets from the location set in the ***When and where*** dialog box during the current 24 hour period from noon to noon. The period when each planet is visible is shown as blue bars on the chart. *First Light's* current time is shown as a vertical red line and sunset and sunrise are shown as vertical yellow lines.



Rise/Set plot

Preferences Menu

The ***Preferences*** menu gives you control over various aspects of *First Light*. The ***Preferences*** menu is only available when ***Expert menus*** is selected in the ***File*** menu.

Animation prefs

The items in the ***Animation prefs*** submenu control how the motion of solar system objects against the star field is depicted when the sky is animated using the buttons in the ***Clock Control*** dialog box or the clock control buttons on the tool bar.

Object droplines

When ***Object droplines*** is selected so that it has a check mark next to it and *First Light's* viewpoint is off the Earth, solar system objects leave trails of *droplines*. The droplines are lines drawn from the planet to the plane of the ecliptic. Lines drawn from planets that are below the ecliptic are red, those from above the ecliptic are green.

Date trails

When ***Date trails*** is selected so that it has a check mark next to it, the position of each object at each clock increment is marked with the date of the clock increment. The effect is that each solar system object leaves a trail of dates along its path.

Line trails

When ***Line trails*** is selected so that it has a check mark next to it, each solar system object leaves a line behind it marking its path through the sky.

Dot trails

When ***Dot trails*** is selected so that it has a check mark next to it, the position of each object at each clock increment is marked with a dot. The effect is that each solar system object leaves a trail of dots along its path. This is slightly less obtrusive than line trails.

Colors

The ***Colors*** submenu gives you a choice of three color sets with which the stars can be drawn. Only one set can be selected at any given time.

Bright

The ***Bright*** color set draws the stars brighter than normal. This is useful for displaying the sky on a low contrast monitor or in a brightly lit room such as a lecture hall.

Colors

The ***Colors*** color set uses various colors to show different magnitudes, rather than shades of gray.

Normal

Normal is the default color set of grays.

Distance units

The item selected in the ***Distance units*** submenu, either ***Miles*** or ***Km***, determines whether distances in information windows are displayed in miles or kilometers.

Sound effects

When ***Sound effects*** is selected so that it has a check mark next to it, *First Light* plays sounds for various events such as zooming and getting info for an object.

Show…

Items in the ***Show*** submenu allow you to select what types of objects are displayed in the ***Planetarium*** window. For example, you might wish to turn off the display of un-needed planets to speed up the display in some circumstances.

Planets…

Planets opens a dialog box with which you can select what planets and other solar system objects are displayed in the ***Planetarium*** window.

Other…

Other opens a dialog box with which display of stars and various types of deep sky objects can be turned on and off.

Magnitudes…

Magnitudes opens a dialog box with which you can set the minimum magnitude of displayed stars. Use the up and down arrow buttons to set the magnitude limit. Stars dimmer than the selected magnitude will not be displayed. The ***eye*** button sets the limit to magnitude 6, which is about the limit of magnitudes that can be seen with the naked eye. The ***all*** button sets the limit to magnitude 16 so that all stars in *First Light's* star databases will be displayed. The ***Try*** button sets the limit to the selected magnitude without closing the ***Show magnitude*** dialog box.

Status bar

Status bar toggles on and off the display of the status bar at the bottom of the ***Planetarium*** window.

Toolbar

Toolbar toggles on and off the display of the tool bar at the top of the ***Planetarium*** window.

Viewpoint…

Viewpoint allows you to set various parameters, according your viewpoint preferences, related the way space and planet orbits are displayed. The ***Viewpoint*** menu item is not available when *First Light's* viewpoint is located on Earth.

Expert Menu

The ***Expert*** menu is only available when ***Expert menus*** is selected in the ***File*** menu.

Create a new orbit…

Create a new orbit opens the ***New object*** dialog box. This dialog is used to add the orbits of solar system objects (asteroids, comets and spacecraft) to *First Light* so that they can be displayed along with the other solar system objects. See the *Adding a New Orbit* section of the *Asteroids and Comets* chapter for information about the various parameters that must be entered into the ***New object*** dialog box to define an orbit.

Lock view

The items in the ***Lock view*** submenu allow you to lock the ***Planetarium*** window's view on the Sun, Moon, or any of the planets. This is useful for keeping a particular object centered while animating an event that involves the object. Such events include eclipses and the changing phases of the Moon.

Select object…

Select object opens a dialog box with a drop-down list box containing the names of the Sun, Moon and planets. Select an object and click ***OK*** to center and lock the view on that object.

Release

When the view is locked on an object, selecting ***Release*** releases the lock and allows you to move the view elsewhere.

Movies

Browse…

Browse opens an open file dialog with which you can select and open a movie file to view.

Create…

Create opens the ***Create animation*** dialog box so that you can create movies of astronomical events. See the *Making Your Own Movies* section for more information about creating movies.

Observing

The ***Observing*** submenu gives you access to various planning aids for actual observation sessions.

Ephemeris…

Selecting ***Ephemeris*** opens the ***Ephemeris*** dialog box that allows you to generate ephemeris tables. An ephemeris is a list of positions of a given object over a given range of time. Click on the ***select*** button in the ***Ephemeris*** dialog box to open a dialog with which to select a solar system object for which to create an ephemeris. Use the controls in the top portion of the dialog box to specify the date range for the ephemeris and the time increment for the entries. Clicking on the ***print*** button send the ephemeris to your printer. Clicking on the ***save*** button saves the ephemeris to your hard disk as a text file.

Planning guide…

Planning guide opens a dialog box that allows you to generate a list of objects that will be visible from the location specified in the ***When and where*** dialog box during a specified time interval. Use the items in the top portion of the dialog box to specify the date, starting and ending times, types of objects and the minimum magnitude of objects to be included in the list. Clicking on the ***save*** button saves the list to your hard disk as a text file. Clicking on the ***print*** button to send the list to your printer.

Reticle

The ***Reticle*** feature displays a series of concentric circles, called a *reticle*, centered at a selected point in the sky. The reticle allows you to measure the angular distances between objects. To display a reticle, select ***Reticle*** from the ***Observing*** submenu. The mouse pointer changes to a circle with a crosshair. Click on the point in the sky at which you want the reticle centered. The reticle will continue to be displayed at that point, even if the view is moved, until it is removed by again selecting ***Reticle*** from the ***Observing*** submenu.

Planet rendering

The items in the ***Planet rendering*** submenu control how the planets are drawn (rendered) in *First Light's* ***Hover*** and ***Flyby*** modes.

Draggable

Normally, when the sky is dragged with the right mouse button to reposition the viewpoint in ***Hover*** or ***Flyby*** mode, the planets are animated as gridded spheres which are drawn much faster than the more realistic texture mapped images. However, if you have a fast enough computer (486-100 or Pentium), the textured mapped planets may be drawn fast enough for you to use the ***Draggable*** option. When ***Draggable*** is selected so that there is a check mark next to it, *First Light* uses the more realistic images even when the sky is being dragged. This feature only works when ***24 bit rendering*** in the ***Planet rendering*** submenu is *not* selected. Otherwise, the ***Draggable*** menu item is disabled.

Sharp shadows

When ***Sharp shadows*** is selected so that it has a check mark next to it, the edge of the terminator is sharpened on rendered planets. The *terminator* of a planet is the twilight line that separates the day side from the night side. Use of the ***Sharp shadows*** feature is left to your own tastes. Leaving it turned off results in more realistic images.

Show clouds

When ***Show clouds*** is selected so that it has a check mark next to it, clouds are drawn on images of Earth and Venus. With ***Show clouds*** turned off, you can see what Venus would look like if stripped of her thick veil.

Show feature names

When ***Show feature names*** is selected so that it has a check mark next to it, major features on several of the planets are labeled. You can click on these labeled features to get further information about them.

24 bit rendering

In *First Light's* ***Hover*** and ***Flyby*** modes, the planets are normally drawn using a relatively quick 256 color (8 bit) process. This default process trades some image quality for speed, typically taking a second or less per image. The resulting images of the planets are relatively coarse at larger sizes. When ***24 bit rendering*** is selected so that it has a check mark next to it, *First Light* uses another method that uses millions of colors (24 bit rendering) and produces more realistic images of the planets. Use this slower method once a view has been set up using the faster 8 bit method. The larger the image, the more time 24 bit rendering will take, but the results should be worth the wait. On slower computers, expect to wait thirty seconds or more for basic images. However, many subtle lighting and shading effects can be included in 24 bit images, such as clouds, atmospheres and surface shadows.

Precession

The items in the ***Precession*** submenu introduce precession into *First Light's* calculation of the star's positions. Precession is a slow wobbling of the earth's axis, much like a child's top, where one "wobble" takes about 25,800 years. Because of this motion, the apparent positions of the stars change over time. This is why star charts are typically assigned a year or *epoch* to show what date was used for the stellar positions. Due to precession, the star *Polaris* will cease being the north star in a few hundred years. See the section on *Precession* in the *Stars* chapter for more information.

Auto

Selecting ***Auto*** from the ***Precession*** submenu causes *First Light* to calculate and display the precession of all stars and markers in the ***Planetarium*** window for the current date of *First Light's* internal clock.

Stars

Selecting ***Stars*** from the ***Precession*** submenu causes *First Light* to calculate and display the precession for stars only in the ***Planetarium*** window for the current date of *First Light's* internal clock. Constellation outlines are not precessed so that you can compare the stars' new positions with their original positions.

Outlines

Selecting ***Outlines*** from the ***Precession*** submenu causes *First Light* to calculate and display the precession for constellation outlines only in the ***Planetarium*** window for the current date of *First Light's* internal clock.

Show custom data

When ***Show custom data*** is selected so that it has a check mark next to it, user-defined custom objects are displayed in the ***Planetarium*** window. See the chapter on *User Data* for information about adding custom objects to *First Light*.

Stars

The items in the ***Stars*** submenu modify how stars are displayed in the ***Planetarium*** window.

Data

When any item in the ***Data*** submenu is selected so that it has a check mark next to it, the corresponding information is displayed next to each star shown in the***Planetarium*** window. Only one item at a time can be selected in the ***Data*** submenu. Select ***None*** to removed any data being displayed. See the *Stars* chapter for explanations of what each item means.

More stars

When the ***Zoom*** value of the view in the ***Planetarium*** window is 5° or less, selecting ***More stars*** displays stars from the Hubble Guide Star Catalog (GSC). Data for the GSC stars consists of position and magnitude only, so clicking on one of them with the left mouse button does not open an information window. For more information about the GSC and the star databases used by *First Light*, see the *Stars* chapter.

Proper motion

Stars move through the sky just as planets do. This effect, *proper motion*, is so slow that it is virtually impossible to see, until now. When ***Proper motion*** is selected so that it has a check mark next to it, a line is drawn through each star in the direction that the star is moving. The lines represent 50,000 years of movement, ±25,000 years from the star's current position. The red dot is the end point. See the *Stars* chapter for more information about proper motion.

Help Menu

The items in the ***Help*** menu give you access to *First Light's* online help system. *First Light* uses the standard Windows Help feature. Select ***Using help*** for more information about using the help system. The rest of the items in the ***Help*** menu give specific information about using *First Light*.

User Data

Adding Your Own Objects

If the millions of objects that ***First Light*** offers aren't enough, you can always add your own!

Using the Notepad (in the Windows Accessories group) is recommended, but any word processor will do.

1. Open Notepad. Then select ***Open*** from the ***File*** menu.
2. Navigate to the following directory path:

   `c:\f_light\data2\user`

   This is the default installation directory. If you have installed *First Light* to a different directory, your directory path will be slightly different.
3. To view the entire list of available files, select ***All Files (*.*)*** from the ***List Files of Type*** field (found below the ***File Name*** list). Select the file *user_obj.dat* from the list.
4. Once the file has been opened, you will see a list of existing objects. Scroll to the end of the list. Information for each object is contained in the following format:

   `id ra dec clr name`

   where:

   `id` = the object's unique identification number

   `ra` = the object's right ascension (`dd.mm` in degrees, minutes)

   `dec` = the object's declination (`dd.mm` in degrees, minutes)

   `clr` = the object's color designation

   `name` = the object's name
5. At the end of the object list, type a unique identification number, right ascension, declination, color number, and the object's name, separating the elements with spaces. A typical entry might be:

   `30014 2030.18 57.38 65 Nova-Cygni`

7. When you have finished adding your custom object to the list, select ***Save*** from the ***File*** menu. Do not save the file in a special format specific to your word processor. The file must be saved as a generic ASCII text file, otherwise *First Light* will not be able to read it.

The following are some of the colors available for customizing your objects:

10 = light yellow

32 through 64 = white to dark gray

65 = blue-green

66 = cyan

67 = red

68 = green

69 = blue

70 = gold

Do not change the first line of the *user_obj.dat* file. It must be:

```
5 1
```

to identify the file for *First Light*. Each subsequent line in the file forms one complete entry. Entries may not span lines. Any line beginning with a semicolon (;) is a comment.

By default, object names are in the form *xxxx* where xxxx is the id number. The id number is used for point and identify operations and it binds the object to a text file whose name is *USR\xxx.CMT*.

A sample database of several objects is provided with *First Light*. Radio sources are gold, pulsars are cyan, quasars are blue and the 1987 supernova is yellow. A maximum of 3,000 objects can be entered.

Glossary

Altitude: The position of an object relative to the horizon in degrees. An object at 0° is exactly on the horizon, and an object at 90° is directly overhead.

Asteroid: A chunk of rock left over from the formation of the solar system which can range in size from only a few dozen feet to over 600 miles. Over 3,500 are now known.

Astronomical unit: A convenient unit used by astronomers instead of miles to state distances within the solar system. One astronomical unit (AU) is equal to the average distance between the Sun and the Earth, or about 93 million miles.

Azimuth: The position of an object relative to north in degrees. An object at an azimuth of 0° is directly north; at 90° it is to the east; at 180°, to the south; and at 270°, to the west.

Comets: Chunks of ice and other matter that move in highly elliptical orbits. When comets are close to the Sun, the ice evaporates and leaves lengthy trails known as streamers or tails. Comets are thought to contain some of the most pristine material left over from the formation of the solar system.

Declination: The sky's "latitude," measured in degrees. Declination, or Dec., is combined with *right ascension* to describe where an object is located in the sky. Declination ranges from –90° to +90° where the north star, *Polaris*, is located.

Deep sky objects: Anything outside our solar system that is not classified as a star, such as galaxies, star clusters and nebulae.

Ecliptic: The plane of the solar system as defined by the earth's orbit. Most planets stay very close to this plane. Only Pluto goes very far above or below it. Comets are notorious for their oddball orbits, straying far away from the plane of the ecliptic.

Gas Giants: The term given to the planets Jupiter, Saturn, Uranus and Neptune due to their size and the fact that they composed primarily of gas with no substantial surface.

Greek ID: A star's Greek identifier is a Greek letter followed by the name of the constellation in which the star is found. The brightest stars are designated by the first letters in the alphabet, so a star designated as "alpha" is usually the brightest in its constellation. Since the letters are limited in number, few stars actually have formal Greek identifiers.

Hubble Guide Star Catalog: A catalog of all stars down to 16th magnitude used by Hubble Space Telescope researchers to guide the telescope during long photographic exposures. A star near the object of interest is chosen as a reference point on which the telescope locks.

Julian Date: An absolute date used to pinpoint astronomical events. The Julian date is the number of days from January 1, 4713 B.C.

Light Year: The distance that light travels in a single year, about 5.86 *trillion* miles. The nearest star, *Alpha Centauri*, is a mere 4.34 light years away. Compare this to our Sun which is only eight light *minutes* away from us.

Magnitude: A measure of the brightness of stars and other objects in the sky, the smaller the number the brighter the object. The brightest star after the Sun is *Sirius*, which shines at a magnitude of –1.46 while the Sun itself shines at –26.3. The unaided eye can see object as dim as a magnitude of about 6.5.

Messier Catalogue: A catalogue of 110 of the most spectacular deep sky objects (galaxies, nebulae, etc.) compiled by Charles Messier in 1781.

Multiple stars: Two or more stars orbiting around each other. Sometimes called *double* or *binary* stars.

Neutron stars: The smallest and densest stars known, typically the final remnant of a supernova which has collapsed so tightly on itself that it, in effect, becomes a single atomic nucleus measuring only a few miles in diameter. Its density is so great that a single teaspoon full of its material would weigh on the order of 1,000 million tons.

NGC: The New General Catalog ("NGC") of deep-sky objects (galaxies, nebulae, etc.) which, contains over 7,500 objects. *First Light* can display the 1,500 most important entries.

Occultation: An occultation occurs when the Moon moves in from of and obscures, or eclipses, a star or other object.

Precession: A slow wobbling of the Earth's axis, much like a child's top, that changes the apparent positions of the stars. Due to precession, the north star will cease being the north star in a few hundred years. One "wobble" takes about 25,800 years. This is why star charts are typically assigned a year, or *epoch*, to show the date that was used for the stellar positions.

Right Ascension: The sky's "longitude", measured in hours, minutes and seconds, each hour being equivalent to 15°. Right ascension, or RA, is combined with declination to describe where and object is located in the sky. Right ascension ranges from 0 to 24 hours.

Supernova: The destructive explosion of a star, one of the most spectacular and dramatic events in the universe. When the balance between a star's gravity and the pressure created by heated material in the star is upset, the star's size can increase to that of our solar system in only a day or two. It will shine brilliantly for a couple of weeks, then collapse back on itself to die a slow and invisible death.

Totality: The time during a solar eclipse when the Moon completely covers the Sun. This usually lasts for only a few minutes at best.

Universal Time: The standard way that time is stated for scientific and technical purposes. It is based on the time at 0° longitude (Western Europe), the *Greenwich meridian*. Universal Time was formerly referred to as *Greenwich Mean Time*, or *GMT*.

Variable star: A star which varies in brightness (magnitude) due to either internal physical processes or eclipses of other nearby stars.

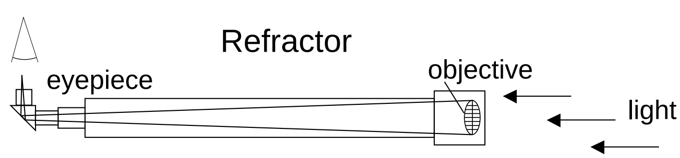
Appendix A
Buying a Telescope

If *First Light* has done its job, you may be saying to yourself, “Self, I wonder if I should get a small telescope?” Well, what’s stopping you?

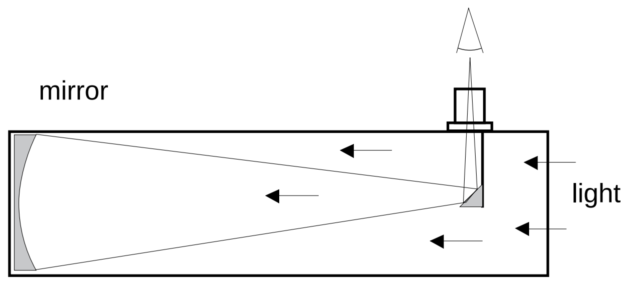
When you first consider buying a telescope, figure out what exactly you want to do. If you are only interested in casual peeks at the planets, there is no need to get a $6,700 Compustar 11. Or, if you want something really portable for backpacking, don’t get a 17 inch Dobsonian when a good pair of binoculars might do the job.

No doubt your first thought is “but I want to see everything!” Unfortunately, there are always going to be drawbacks to accept and choices to be made. Telescopes are measured in the size of their *objective* (either lenses or mirrors). So, a 17 inch Dobsonian contains a mirror 17 inches in diameter (in other words, big). Of course, the larger the diameter, the more you will see, but the drawback is that a 17-inch is large and heavy. Such an instrument may quickly throw water on the enthusiasm of a novice observer if it takes three people to move it out to the backyard. On the other end is a typical beginner telescope, such as a 2.4 inch refractor or 6 inch reflector from your local Sears. While easy to transport, deep sky objects will not be nearly as spectacular, although the planets and the Moon most certainly will be. Other things to consider are the accessories available. The more serious instruments naturally have more goodies to spend your money on, while the simpler models might not.

As mentioned above, the aperture is the chief method of measuring the general performance of a telescope. Scopes are simply *light buckets,* so, the larger the objective, the more light it can capture and the sharper the image that it provides. Don’t be mislead by advertisements for instruments costing only $200 but have 500 power. The *power* or enlarging capability of the telescope is likewise connected to the aperture size. The higher the power, the more spread out, or dimmer, the image is and the less distinct it will be. A general rule of thumb is that the maximum usable power of a telescope is 50 times its objective size in inches. So, a 2.4 inch refractor will be fine up to 120 power. After that you’d be fighting a losing battle. Theoretically, the scope could be pushed to 500 power, but the image would be too dim and fuzzy to be usable. By the way, 50 to 75 power is just right for most solar system observations, so magnification isn’t everything.



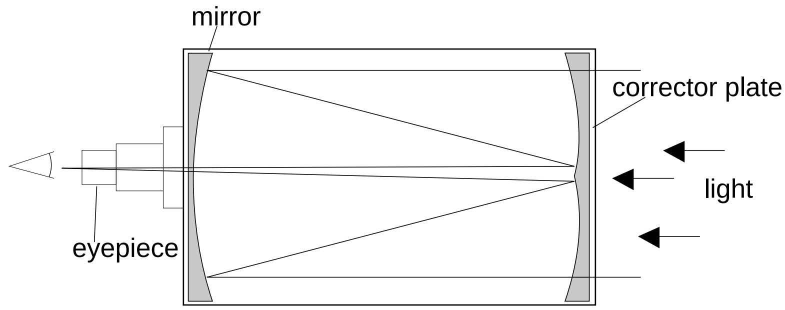
Perhaps the most familiar kind if scope is the good old *refractor,* not much different than Galileo’s original instrument. In its simplest form, a refractor combines a set of lenses at the front of a long tube with an eyepiece at the other end. The standard scope of this type has a lens 60 millimeters in diameter (2.4 inches) and a tube about three feet long. Refractors are the most common small telescopes made, mass produced by several large volume vendors and usually sold in the toy sections of major stores. We recommend staying away from these mass market instruments. While inexpensive, the optical quality is usually so poor as to make them nearly useless for anything but the largest and brightest objects. Quality manufacturers such as Meade, Unitron and Pentax all make similar small refractors, but of much higher quality. These are perfect for casual viewing of the solar system and some of the brighter deep sky objects, but they just don't have the light gathering power to support astrophotography or serious deep sky observations. Larger refractors are available, but once you get above three inch models, the prices become *astronomical* (grin), not to mention the weight.



Newtonian Reflector

Besides the refractors there are *reflectors* which, as the name suggests, use mirrors instead of lenses. The most common of these, the *Newtonian*, was developed by Sir Isaac himself. Light enters through the front, reflects off of the primary mirror, into the secondary mirror back at the front, then out to the eyepiece. A variation of this is the increasingly popular *Dobsonian-Newtonian*, which sacrifices some general convenience for very low cost instruments. Most telescopes are mounted on an *equatorial mount*, which permits it to be tilted parallel to the earth's equator. This allows the scope to track the motion of the stars in only one movement around the central axis of the mount (the diurnal motion is very significant – even at low powers an object can drift out of view in only a minute). The Dobsonian opts for the much simpler fork *alt-azimuth* mount which sits parallel to the ground. This means that tracking objects requires two motions instead of one. Not much effort in and of itself, but it makes the automatic motor drives required for astrophotography next to impossible. If you don't think you'll try photography, a Dobsonian might just be the scope for you. The no frills Odyssey 8 and 10 inch scopes by Coulter Optical have been highly regarded by some, and cost less than $300. Fancier Newtonian scopes by Meade or Celestron in the same sizes are nearly three times as much.

The most popular serious telescopes made today are the *Catadioptrics*, respected for their utter compactness. Known as a *Schmidt-Cassegrain* (SCT), an eight inch instrument might be only 16 inches long, a third the length of a standard Newtonian of the same diameter. The key is the folded optics as shown above. Light enters through a corrector lens, reflects off of the primary to a secondary on the plate and back through a hole in the primary. This places the eyepiece in the back of the scope, making for easy viewing. SCTs come with a wide variety of lenses, camera mounts, tracking devices and computer controls. The *typical* SCT is an eight inch model, going for around $1,000 to $1,300, although sizes range from 3 1/2 inches to 14 inches. The most common manufacturers are the Celestron, Meade and Bushnell.



Schmidt-Cassagrain

While you're looking at all of these high powered instruments, don't overlook the *richest field* telescopes. These are deliberately lower power devices meant to give wider sweeping views of the sky. Normal scopes are much too powerful to view the star clouds of Sagittarius or the larger details of the Hyadies cluster (something like investigating the *Mona Lisa* with an electron microscope). Richest field telescopes are very compact (the Edmund Scientific Astroscan slips over the shoulder) and generally quite inexpensive. Along the same line is a good pair of binoculars. While they don't come close to the light gathering power of an Astroscan, they can provide hours of enjoyment as you sweep across the sky lying on your back munching popcorn and listening to Vivaldi tapes.

You may want to think about getting a used telescope. If it is a name brand, it has already depreciated about as much as it will and, so, could easily be sold at virtually no loss once you outgrow it or lose interest in the hobby. Prices will likely be 15% to 20% less than new instruments.

Before buying, you should visit your local astronomy club. You can probably find out how to get in touch with them through your local college observatory or astronomy department. Astronomy clubs periodically have *star parties* in which the members and any interested visitors spend all night observing at some remote site. From them, you should be able to get hands on experience with every conceivable type and brand of scope, as well as getting names of members who might have one for sale.

In addition to clubs, *Sky and Telescope* or *Astronomy* magazine provide excellent information. *Astronomy* generally runs telescope buyer's guides in the October issues which should be available at your local library, or from *Astro-Media* (address in reference list).

If you are adventurous, you may want to try to make your own telescope. The astronomy department of your local community college may offer telescope making classes during the summer. The typical homemade instrument is either a six or eight inch reflector, and can offer a real sense of accomplishment that buying a scope never can.

Appendix B
Location/Time Zones of Major Cities

Name	Latitude Deg Min	Longitude Deg Min	State/Country	Time Zone
Accra	05 33 N	0 15 W	Ghana, Africa	0
Albuquerque	35 05 N	106 38 W	New Mexico, USA	+7
Anchorage	61 10 N	149 53 W	Alaska, USA	+10
Amsterdam	52 21 N	4 54 E	Netherlands, Europe	–1
Ankara	39 55 N	32 50 E	Turkey, Asia Minor	–2
Asuncion	25 15 S	57 40 W	Paraguay, S. Am.	+4
Athens	38 00 N	23 44 E	Greece, Europe	–2
Atlanta	33 45 N	84 23 W	Georgia, USA	+5
Baghdad	33 20 N	44 26 E	Iraq, Middle East	–3
Baltimore	39 17 N	76 37 W	Maryland, USA	+5
Bangkok	13 44 N	100 30 E	Thailand, Asia	–7
Beirut	33 52 N	35 30 E	Lebanon, Mid East	–2
Benghazi	32 07 N	20 05 E	Libya, Africa	–2
Berlin	52 32 N	13 25 E	W. Germany, Europe	–1
Bern	46 57 N	7 26 E	Switzerland, Europe	–1
Bombay	18 56 N	72 51 E	India, Asia	–5.5
Bonn	50 44 N	7 06 E	W. Germany, Europe	–1
Boston	42 20 N	71 05 W	Massachusetts, USA	+5
Brussels	50 50 N	4 21 E	Belgium, Europe	–1
Bucharest	44 25 N	26 07 E	Romania, Europe	–2
Buenos Aires	34 40 S	58 30 W	Argentina, S. Am.	+3
Cairo	30 03 N	31 15 E	Egypt, Africa	–2
Calgary	51 03 N	114 05 W	Alberta, Canada	+7
Cape Town	33 56 S	18 28 E	South Africa, Africa	–2
Caracas	10 35 N	66 56 W	Venezuela, S. Am	+4.5
Casablanca	33 39 N	7 35 W	Morocco, Africa	0
Chicago	41 59 N	87 38 W	Illinois, USA	+6
Cincinnati	39 06 N	84 31 W	Ohio, USA	+5
Cleveland	41 30 N	81 41 W	Ohio, USA	+5
Dakar	14 38 N	17 27 W	Senegal, Africa	0
Dallas	32 47 N	96 48 W	Texas, USA	+6
Denver	39 45 N	105 00 W	Colorado, USA	+7
Des Moines	45 35 N	93 35 W	Iowa, USA	+6
Detroit	42 20 N	83 03 W	Michigan, USA	+5
Dublin	53 20 N	6 15 W	Ireland, Europe	0
El Paso	31 45 N	106 29 W	Texas, USA	+7
Fairbanks	64 51 N	147 43 W	Alaska, USA	+10
Hanoi	21 01 N	105 52 E	Vietnam, Asia	–8
Havana	23 07 N	82 25 W	Cuba, Caribbean	+5
Helsinki	60 08 N	25 00 E	Finland, Europe	–2
Hiroshima	34 23 N	132 27 E	Japan, Asia	–9
Hong Kong	22 15 N	114 11 E	Asia	–8
Honolulu	21 19 N	157 52 W	Hawaii, USA	+10
Houston	29 46 N	95 22 W	Texas, USA	+6
Indianapolis	39 46 N	86 09 W	Indiana, USA	+5
Istanbul	41 02 N	28 57 E	Turkey, Asia Minor	–3
Jerusalem	31 47 N	35 13 E	Israel, Middle East	–2
Johannesburg	26 10 N	28 02 E	South Africa, Africa	–2
Kabul	34 30 N	69 10 E	Afghanistan, Asia	–5
Kansas City	39 05 N	94 37 W	Kansas/Missouri, USA	+6
Karachi	24 51 N	67 02 E	Pakistan, Asia	–5
Kiev	50 26 N	30 31 E	USSR, Europe	–3
Kyoto	35 02 N	135 45 E	Japan, Asia	–9

Name	Latitude Deg Min	Longitude Deg Min	State/Country	Time Zone
Lagos	6 27 N	3 28 E	Nigeria, Africa	–1
Las Vegas	36 11 N	115 08 W	Nevada, USA	+8
Leningrad	59 55 N	30 25 E	USSR, Europe	–3
Lima	12 06 S	77 03 W	Peru, S. America	+5
Lisbon	38 44 N	9 08 W	Portugal, Europe	0
London	51 30 N	0 10 W	England, Europe	0
Los Angeles	34 00 N	118 15 W	California, USA	+8
Madrid	40 25 N	3 43 W	Spain, Europe	–1
Manila	14 37 N	120 58 E	Philippines	–8
Marrakech	31 49 N	8 00 W	Morocco, Africa	0
Mecca	21 26 N	39 49 E	Saudi Arabia, M.East	–3
Melbourne	37 45 S	144 58 E	Victoria, Australia	–10
Mexico City	19 25 N	99 10 W	Mexico	+6
Miami	25 45 N	80 15 W	Florida, USA	+5
Milwaukee	43 02 N	87 55 W	Wisconsin, USA	+6
Minneapolis	45 00 N	93 15 W	Minnesota, USA	+6
Montreal	45 31 N	73 34 W	Quebec, Canada	+5
Moscow	55 45 N	37 42 E	USSR, Europe	–3
Nairobi	1 17 S	36 50 E	Kenya, Africa	–3
New Delhi	28 37 N	77 13 E	India, Asia	–5.5
New Orleans	30 00 N	90 03 W	Louisiana, USA	+6
New York	40 43 N	74 01 W	New York, USA	+5
Oklahoma City	35 28 N	97 32 W	Oklahoma, USA	+6
Omaha	41 15 N	96 00 W	Nebraska, USA	+6
Oslo	59 56 N	10 45 E	Norway, Europe	–1
Paris	48 52 N	2 20 E	France, Europe	–1
Perth	31 58 S	115 49 E	West Australia	–8
Philadelphia	40 00 N	75 10 W	Pennsylvania, USA	+5
Phoenix	33 30 N	112 03 W	Arizona, USA	+7
Pittsburgh	40 26 N	80 00 W	Pennsylvania, USA	+5
Prague	50 06 N	14 26 E	Czechoslovakia, Eur.	–1
Quebec	46 50 N	71 15 W	Quebec, Canada	+5
Rangoon	16 46 N	96 10 E	Burma, Asia	–6.5
Reykjavik	64 09 N	21 58 W	Iceland	+1
Rio de Janeiro	22 53 S	43 17 W	Brazil, S. America	+3
Rome	41 53 N	12 30 E	Italy, Europe	–1
Saigon	10 46 N	106 43 E	Vietnam, Asia	–7
Salt Lake City	40 45 N	111 55 W	Utah, USA	+7
San Luis Obispo	35 10 N	130 50 W	California, USA	+8
San Francisco	37 45 N	122 27 W	California, USA	+8
San Juan	18 29 N	66 08 W	Puerto Rico, USA	+4
Santiago	33 30 S	70 40 W	Chile, S. America	+4
Seattle	47 36 N	122 20 W	Washington, USA	+8
Seoul	37 30 N	127 00 E	Korea, Asia	–9
Singapore	1 17 N	105 51 E	Malacca, Asia	–7.5
Stockholm	59 20 N	18 05 E	Sweden, Europe	–1
Sydney	33 55 S	151 10 E	New S. Wales, Aus.	–10
Taipei	25 05 N	121 32 E	Taiwan, Asia	–8
Tananarive	18 52 S	47 30 E	Madagascar	–3
Thule	77 30 N	69 29 W	Greenland	+4
Timbuktu	16 49 N	2 59 E	Mali, Africa	0
Tokyo	35 40 N	139 45 E	Japan, Asia	–9
Toronto	43 39 N	79 23 W	Ontario, Canada	+5
Tripoli	32 58 N	13 12 E	Libya, Africa	–2
Tunis	36 50 N	10 13 E	Tunisia, Africa	–1
Vancouver	49 13 N	123 06 W	Br. Columbia, Canada	+8
Vienna	48 13 N	16 20 E	Austria, Europe	–1
Vladivostok	43 09 N	131 53 E	USSR, Asia	–10
Warsaw	52 15 N	21 00 E	Poland, Europe	–1
Washington, DC	38 55 N	77 00 W	USA	+5
Wellington	41 17 S	174 47 E	New Zealand	–12
Winnipeg	49 53 N	97 10 W	Manitoba, Canada	+6
Zanzibar	6 10 S	39 11 E	Tanzania, Africa	–3

Appendix C
Messier Catalogue

MESS	NGC	CON	TYPE	R.A.	DECL	MAG	DIST[1]	COMMENTS
M 1	1952	Tau	PlNeb	0531.5	+2159	8.2	6K	Crab Nebula
M 2	7089	Aqr	GlbCl	2130.9	–0103	6.3	50K	
M 3	5272	CVn	GlbCl	1339.9	+2838	6.3	30K	
M 4	6121	Sco	GlbCl	1620.6	–2624	6.4	10K	
M 5	5904	Ser	GlbCl	1516.0	+0216	6.2	30K	
M 6	6405	Sco	OpCl	1736.8	–3211	5.3	2K	
M 7	6475	Sco	OpCl	1750.7	–3448	4.1	lK	
M 8	6523	Sgr	DfNeb	1801.6	–2420	6.0	6.5K	Lagoon Nebula
M 9	6333	Oph	GlbCl	1716.2	–1828	7.3	25K	
M 10	6254	Oph	GlbCl	1654.S	–0402	6.7	16K	
M 11	6705	Sct	OpCl	1848.4	–0620	6.3	6K	
M 12	6218	Oph	GlbCl	1644.6	–0152	6.6	16K	
M 13	6205	Her	GlbCl	1639.9	+3633	5.7	25K	
M 14	6402	Oph	GlbCl	1735.0	–0313	7.7	23K	
M 15	7078	Peg	GlbCl	2127.6	+1157	6.0	40K	
M 16	6611	Ser	OpCl	1816.0	–1348	6.4	7K	nebula & cluster
M 17	6618	Sgr	DfNeb	1818.0	–1612	7.5	5K	Omega Neb & cluster
M 18	6613	Sgr	OpCl	1817.0	–1709	7.5	6K	
M 19	6273	Oph	GlbCl	1659.5	–2611	6.6	20K	
M 20	6514	Sgr	DfNeb	1758.9	–2302	9.0	2.2K	Trifid Nebula
M 21	6531	Sgr	OpCl	1801.8	–2230	6.5	3K	
M 22	6656	Sgr	GlbCl	1833.3	–2358	5.9	l0K	
M 23	6494	Sgr	OpCl	1754.0	–1901	6.9	4.5K	
M 24	6603	Sgr	OpCl	1815.5	–1827	4.6	10K	star cloud
M 25	IC4725	Sgr	OpCl	1828.8	–1917	6.5	2K	open cloud
M 26	6694	Sct	OpCl	1842.5	–0927	9.3	5K	
M 27	6853	Vul	PlNeb	1957.4	+2235	7.6	1250	Dumbbell Nebula
M 28	6626	Sgr	GlbCl	1821.5	–2454	7.3	15K	
M 29	6913	Cyg	OpCl	2022.2	+3821	7.1	7.2K	
M 30	7099	Cap	GlbCl	2137.5	–2325	8.4	40K	
M 31	224	And	SpGal	0040.0	+4100	4.8	2,200K	Andromeda Galaxy
M 32	221	And	ElGal	0040.0	+4036	8.7	2,200K	satellite of M31
M 33	598	Tri	SpGal	0131.1	+3024	6.7	2,300K	Sc
M 34	1039	Per	OpCl	0238.8	+4234	5.5	1,400	
M 35	2168	Gem	OpCl	0605.7	+2420	5.3	2,800	
M 36	1960	Aur	OpCl	0532.0	+3407	6.3	4,100	
M 37	2099	Aur	OpCl	0549.0	+3233	6.2	4,600	
M 38	1912	Aur	OpCl	0525.3	+3548	7.4	4,200	
M 39	7092	Cyg	OpCl	2130.4	+4813	5.2	900	
M 40	WNC4	UMa	DS	1220.0	+5822	9.1		double star
M 41	2287	CMa	OpCl	0644.9	–2042	4.6	2,400	
M 42	1976	Ori	DfNeb	0532.9	–0525	4.0	1 K	Great Orion Nebula
M 43	1982	Ori	DfNeb	0533.1	–0518	9.1	lK	part of Great Orion Neb
M 44	2632	Cnc	OpCl	0837.5	+1952	3.7	500	Praesepe
M 45		Tau	OpCl	0343.9	+2358	1.6	400	The Pleiades
M 46	2437	Pup	OpCl	0739.6	–1442	6.0	5,400	
M 47	2422	Pup	OpCl	0734.3	–1422	4.5	1,600	
M 48	2548	Hya	OpCl	0811.2	–0538	5.3	1,500	
M 49	4472	Vir	ElGal	1227.3	+0816	8.5	70000K	
M 50	2323	Mon	OpCl	0700.5	–0816	6.3	3K	
M 51	5194	CVn	SpGal	1327.8	+4727	8.1	15000K	Whirlpool Galaxy
M 52	7654	Cas	OpCl	2322.0	+6120	7.3	7K	
M 53	5024	Com	GlbCl	1310.5	+1826	7.6	60K	
M 54	6715	Sgr	GlbCl	1852.0	–3032	8.0	5OK	

MESS	NGC	CON	TYPE	R.A.	DECL	MAG	DIST[1]	COMMENTS
M 55	6809	Sgr	GlbCl	1936.9	–3103	5.0	20K	
M 56	6779	Lyr	GlbCl	1914.6	+3005	8.2	40K	
M 57	6720	Lyr	PlNeb	1851.7	+3258	9.3	4,100	Ring Nebula
M 58	4579	Vir	SpGal	1235.1	+1205	9.2	70000K	Sb–barred spiral galaxy
M 59	4621	Vir	ElGal	1239.5	+1155	9.6	70000K	
M 60	4649	Vir	ElGal	1241.1	+1149	8.9	70000K	
M 61	4303	Vir	SpGal	1219.4	+0445	10.1	70000K	Sc–barred spiral galaxy
M 62	6266	Oph	GlbCl	1658.1	–3003	6.6	26K	
M 63	5055	CVn	SpGal	1313.5	+4217	9.5	14500K	Sb
M 64	4826	Com	SpGal	1254.3	+2157	8.8	12000K	Sb
M 65	3623	Leo	SpGal	1116.3	+1323	9.3	35000K	Sa
M 66	3627	Leo	SpGal	1117.6	+1317	8.2	35000K	Sb
M 67	2682	Cnc	OpCl	0848.3	+1200	6.1	2,250	Alternate decl: 0847.8
M 68	4590	Hya	GlbCl	1236.8	–2629	8.0	40K	
M 69	6637	Sgr	GlbCl	1828.1	–3223	8.9	25K	
M 70	6681	Sgr	GlbCl	1840.0	–3221	9.6	65K	
M 71	6838	Sge	GlbCl	1951.4	+1839	9.0	8,500	
M 72	6981	Aqr	GlbCl	2050.7	–1244	9.8	60K	
M 73	6994	Aqr	OpCl	2056.4	–1250	9.0		cluster of 4 stars
M 74	628	Psc	SpGal	0134.0	+1532	10.2	20000K	Sc
M 75	6864	Sgr	GlbCl	2003.2	–2204	8.0	l00K	
M 76	650	Per	PlNeb	0138.8	+5119	10.2	3,400	
M 77	1068	Cet	SpGal	0240.1	–0014	8.9	30000K	Sb–Seyfert galaxy
M 78	2068	Ori	DfNeb	0544.2	+0002	10.3	1,600	emission nebula
M 79	1904	Lep	GlbCl	0522.2	–2434	8.4	54K	
M 80	6093	Sco	GlbCl	1614.1	–2252	7.7	36K	
M 81	3031	UMa	SpGal	0951.5	+6918	7.9	7000K	Sb
M 82	3034	UMa	IrGal	0951.9	+6956	8.8	7000K	
M 82	6341	Her	GlbCl	1715.6	+4312	6.1	28K	
M 83	5236	Hya	SpGal	1334.3	–2937	10.1	8000K	Sc
M 84	4374	Vir	ElGal	1222.6	+1310	9.3	70000K	
M 85	4382	Com	ElGal	1222.8	+1828	9.3	70000K	SO
M 86	4406	Vir	ElGal	1223.7	+1313	9.7	70000K	giant elliptical galaxy
M87	4486	Vir	ElGal	1228.3	+1240	9.2	70000K	giant elliptical galaxy
M88	4501	Com	SpGal	1229.5	+1442	10.2	40000K	Sb
M89	4552	Vir	ElGal	1233.1	+1250	9.5	70000K	
M90	4569	Vir	SpGal	1234.3	+1326	10.0	70000K	Sb
M91	4548	Com	SpGal	1232.9	+1446	9.5	40000K	barred spiral galaxy
M93	2447	Pup	OpCl	0742.4	–2345	6.0	36K	
M94	4736	CVn	SpGal	1248.6	+4123	7.9	14500K	Sb
M95	3351	Leo	SpGal	1041.3	+1158	10.4	25000K	barred spiral galaxy
M96	3368	Leo	SpGal	1044.2	+1205	9.1	25000K	Sa
M97	3587	UMa	PlNeb	112.0	+5518	12.0	2,600	Owl Nebula
M98	4192	Com	SpGal	1211.3	+1511	11.7	70000K	Sb
M99	4254	Com	SpGal	1216.3	+1442	10.1	70000K	Sc
M100	4321	Com	SpGal	1220.4	+1606	10.6	70000K	Sc
M101	5457	UMa	SpGal	1401.4	+5435	9.6	15000K	Sc–same as M102
M102	5457	UMa	SpGal	1401.4	+5435	9.6	15000K	Sc–same as M101
M103	581	Cas	OpCl	0129.9	+6027	7.4	8K	
M104	4594	Vir	SpGal	1237.3	–1121	8.7	50000K	Sombrero Galaxy
M105	3379	Leo	ElGal	1045.2	+1251	9.2	25000K	
M106	4258	CVn	SpGal	1216.5	+4735	8.6	25000K	Sb
M107	6171	Oph	ClbCl	1629.7	–1257	9.2	l0K	
M108	3556	UMa	SpGal	1108.7	+5557	10.7	25000K	Sb
M109	3992	UMa	SpGal	1155.0	+5339	10.8	25000K	barred spiral galxy
Mll0	205	And	ElGal	0037.6	+4125	9.4	2200K	satellite of M31

OpCl = Open Cluster
GlbCl = Globular Cluster
PlNeb = Planetary Nebula
DfNeb = Diffuse Nebula
SpGal = Spiral Galaxy
ElGal = Elliptical Galaxy
IrGal = Irregular Galaxy

1. Distance is measured in light years

Appendix D
Supplied NGC Catalogue

NGC	CON	CONST	R.A.	DECL	MAG	REMARKS
40	Cas	PlNeb	0010.2	+7215	10.2	central star mag:11.4
55	Scl	SpGal	0012.5	–3930		
104	Tuc	GlbCl	0021.9	–7221	4.5	
129	Cas	OpCl	0027.6	+5957	10.0	number:50
133	Cas	OpCl	0028.4	+6304	9.1	number:50
134	Scl	SpGal	0027.9	–3332		
157	Cet	SpGal	0032.3	–0840	11.2	
185	Cas	ElGal	0036.1	+4804	11.7	
188	Cep	OpCl	0039.4	+8503	9.3	number:70
205	And	ElGal	0037.6	+4125	9.4	
225	Cas	OpCl	0040.5	+6131	9.1	number:20
246	Cet	PlNeb	0044.6	–1209	8.5	central star mag:11.3
247	Cet	SpGal	0044.6	–2101		
253	Scl	SpGal	0045.1	–2534	8.9	
278	Cas	ElGal	0049.2	+4718	11.3	
281	Cas	DfNeb	0050.4	+5919	8.6	spectrum:05e
288	Scl	GlbCl	0050.2	–2652		
300	Scl	SpGal	0052.6	–3758		
404	And	ElGal	0106.6	+3527	10.7	
457	Cas	OpCl	0115.9	+5804	7.5	number:100
488	Psc	SpGal	0119.1	+0500	11.1	
524	Psc	ElGal	0122.1	+0916	11.1	
584	Cet	ElGal	0128.8	–0707	10.8	
596	Cet	ElGal	0130.3	–0717	11.5	
613	Scl	SpGal	0132.0	–2940	10.2	
659	Cas	OpCl	0140.8	+6028	9.8	number:30
663	Cas	OpCl	0142.6	+6101	7.1	number:80
720	Cet	ElGal	0150.6	+1359	10.5	
752	And	OpCl	0154.7	+3725	7.0	number:70
772	Ari	SpGal	0156.6	+1846	10.9	
779	Cet	SpGal	0157.2	–0612	11.3	
821	Ari	ElGal	0205.6	+1046	11.2	
869	Per	OpCl	0215.5	+5655	4.4	number:350–half dbl clus
884	Per	OpCl	0218.9	+5653	4.7	number:300–half dbl clus
925	Tri	SpGal	0224.3	+3322		
936	Cet	SpGat	0225.1	–0122	10.7	
1022	Cet	SpGal	0236.1	–0653	11.2	
1023	Per	ElGal	0237.2	+3852		
1052	Cet	ElGal	0238.6	–0828	11.2	
1084	En	SpGal	0243.5	–0747	11.0	
1097	For	SpGal	0244.3	–3029		
1232	Eri	SpGal	0307.5	–2046		
1245	Per	OpCl	0311.2	+4703	6.9	number:40
1261	Hor	GlbC1	0310.9	–552S		
1316	For	SpGal	0320.7	–372S		
1332	Eri	ElGal	0324.1	–2131	10.4	
1342	Per	OpCl	0328.4	+3709	7.1	number:40
136S	For	SpGal	0331.8	–3618		
1395	Eri	ElGal	0336.3	–2311		
1398	For	SpGal	0336.8	–2630		
1399	For	ElGal	0336.6	–3537		
1407	Eri	ElGal	0337.9	–1844	10.6	
1499	Pcr	DfNeb	0400.1	+3617	4.1	California
1501	Cam	PlNeb	0402.6	+6047	13.3	central star mag:13.4

NGC	CON	CONST	R.A.	DECL	MAG	REMARKS
1502	Cam	OpCl	0403.0	+6211	5.3	number:15
I514	Tau	PlNeb	0406.1	+3038	10.8	central star mag:9.7
I528	Per	OpCl	0411.4	+5107	6.2	number:80
I532	Eri	SpGal	0410.2	–3300		edge–on barred spiral
1535	Eri	PlNcb	0412.1	–1252	9.3	central star mag:11.8
1545	Per	OpCl	0417.1	+5008	8.0	number:25
1554	Tau	DfNeb	0419.9	+1925		spectrum:Gpe/Hind's Var.
1647	Tau	OpCl	0443.2	+1859	6.3	number:30
1664	Aur	OpCl	0447.4	+4337	7.5	number:40
1700	Eri	ElGal	0454.4	–0456	11.9	
1746	Tau	OpCl	0500.6	+2344	6.0	number:60
1792	Col	SpGal	0503.5	–3804		
1817	Tau	OpCl	0509.2	+1638	7.9	number:10
1851	Col	GlbC1	0512.4	–4005	8.1	
1857	Aur	OpCl	0516.6	+3918	8.6	number:45
1893	Aur	OpCl	0522.4	+3321	8.0	number:20
1907	Aur	OpCl	0524.7	+3517	9.9	number:40
1977	Ori	DfNeb	0533.0	–0454	4.6	
1990	Ori	DfNeb	0533.7	–0114	1.8	spcctrum:BOe
2023	Ori	DfNeb	0539.2	–0215	7.9	spectrum:B2
2024	Ori	DfNeb	0539.4	–0152	1.9	spectrum:BOne
2064	Ori	DfNeb	0543.8	–0002	9.9	
2112	Ori	OpCl	0551.3	+0023	8.6	number:90
2141	Ori	OpCl	0600.3	+1026	10.8	number:l00
2158	Gem	OpCl	0604.3	+2406	12.5	number:40
2169	Ori	OpCl	0605.7	+1358	6.4	number:18
2174	Ori	DfNeb	0606.7	+2031	7.4	spectrum:06e
2175	Ori	OpCl	0606.8	+2020	6.7	number:15
2194	Ori	OpCl	0611.0	+1250	9.2	number:l00
2215	Mon	OpCl	0618.4	–0716	8.6	number:20
2237	Mon	DfNeb	0629.6	+0440		Rosetta
2244	Mon	OpCl	0629.7	+0454	6.2	number:16
2261	Mon	DfNeb	0636.4	+0846	8.0	spectrum:Bp/ Hubble's Var
2264	Mon	OpCl	0638.4	+0956	4.7	number:20
2264	Mon	DfNeb	0638.2	+0957	4.7	spectr:07n–Cone Nebula
2266	Gem	OpCl	0640.5	+2702	9.8	number:30
2281	Aur	OpCl	0645.8	+4107	6.7	number:30
2286	Mon	OpCl	0645.1	–0307	8.0	number:50
2298	Pup	GlbC1	0647.2	–3557	10.5	
2301	Mon	OpCl	0649.2	+0031	5.8	number:60
2324	Mon	OpCl	0700.4	+0108	8.8	number:30
2335	Mon	OpCl	0704.2	–1000	9.1	number:35
2353	Mon	OpCl	0712.3	–1012	5.3	number:25
2354	CMa	OpCl	0712.2	–2538	8.9	number:60
2360	CMa	OpCl	0715.4	–1533	9.5	number:50
2371	Gem	PlNeb	0722.4	+2935	13.0	central star mag:13.3
2392	Gem	PlNeb	0726.2	+2101	8.3	central star mag:l0.5 Eskimo
2395	Gem	OpCl	0724.3	+1341	9.4	
2403	Cam	SpGal	0732.0	+6543	8.9	
2419	Lyn	GlbC1	0734.8	+3900	11.5	
2420	Gem	OpCl	0735.4	+2141	10.2	number:20
2421	Pup	OpCl	0734.1	–2030	9.4	number:50
2422	Pup	OpCl	0734.3	–1422	4.5	number:50
2423	Pup	OpCl	0734.8	–1345	6.9	number:60
2438	Pup	PlNeb	0739.6	–1436	11.3	central star mag:16.8
2439	Pup	OpCl	0738.9	–3132	7.1	number:50
2451	Pup	OpCl	0743.6	–3751	3.6	number:50
2477	Pup	OpCl	0750.5	–3825	5.7	number:300
2482	Pup	OpCl	0752.8	–2410	8.7	number:50
2489	Pup	OpCl	0756.2	–29S6	9.4	number:30
2506	Mon	OpCl	0757.7	–1029	1 l.5	number:50
2509	Pup	OpCl	0758.S	–18S6	9.3	number:40
2516	Car	OpCl	0759.7	–6044	3 .0	number:80
2539	Pup	OpCl	0808.4	–1241	8.2	number:150
2547	Vel	OpCl	0808.9	–4907	5.1	number:50

NGC	CON	CONST	R.A.	DECL	MAG	REMARKS
2548	Hya	OpCl	0811.2	–0538	5.3	number:80
2567	Pup	OpCl	0816.6	–3029	8.3	number:50
2571	Pup	OpCl	0816.9	–2935	7.5	number:25
2587	Pup	OpCl	0821.3	–2920	9.1	number:30
2610	Hya	PlNeb	0831.2	–l558	13.6	central star mag:15.7
2627	Pyx	OpCl	0835.2	–2946	8.3	number:40
2655	Cam	SpGal	0849.4	+7825	10.7	
2658	Pyx	OpCl	0841.4	–3229	9.2	number:30
2681	Lyn	SpGal	0850.0	+5131	10.4	
2683	Lyn	SpGal	0849.6	+3338	9.6	
2742	UMa	SpGal	0903.7	+6041	11.2	
2768	UMa	ElGal	0907.8	+6016	10.5	
2775	Cnc	SpGal	0907.7	+0715	10.7	
2787	UMa	SpGal	0914.9	+6925	10.9	
2841	UMa	SpGal	0918.6	+5112	9.3	
2859	LMi	SpGal	0921.3	+3344	10.7	
2903	Leo	SpGal	0929.3	+2144	9.1	
2950	UMa	SpGal	0939.1	+5905	10.9	
2964	Leo	SpGal	0940.0	+3205	11.0	
2976	UMa	SpGal	0943.2	+6808	11.4	
2985	UMa	SpGal	0946.0	+7231	10.6	
2997	Ant	SpGal	0943.5	–3059		
3003	LMi	SpGal	0945.6	+3339	12.7	edge–on
3021	LMi	SpGal	0948.0	+3347	11.7	
3077	UMa	ElGal	0959.4	+6858	10.9	
3079	UMa	SpGal	0958.6	+5557	11.2	
3115	Sex	ElGal	1002.8	–0728	9.3	Spindle Nebula
3132	Vel	PlNeb	1004.9	–4011	8.2	central starmag:10.6
3147	Dra	SpGal	1012.8	+7339	10.9	
3184	UMa	SpGal	1015.2	+4140	12.1	
3201	Vel	GlbC1	1015 .5	–4609		
3242	Hya	PlNeb	1022.4	–1823	9.0	central starmag:11.4–Eye Neb.
3310	UMa	RGal	1035.7	+5346	10.1	
3344	LMi	SpGal	1040.7	+2511	10.4	
3372	Car	DfNeb	1043.1	–5925	5.0	spcctrum:Pec–Keyhole Neb
3377	Leo	ElGal	1045.1	+1415	10.5	
3384	Leo	ElGal	1045.7	+1254	10.2	
3412	Leo	ElGal	1048.3	+1341	10.4	
3486	LMi	SpGal	1057.8	+2915	11.2	
3504	LMi	SpGal	1100.5	+2815	10.9	
3511	Crt	SpGal	1100.8	+2250		
3521	Leo	SpGal	1103.2	+0014	9.5	
3585	Hya	ElGal	1110.9	–2629		
3607	Leo	ElGal	1114.3	+1820	9.6	
3621	Hya	SpGal	1115.9	–3232		
3626	Leo	SpGal	1117.5	+1838	10.5	
3628	Leo	SpGal	1117.7	+1353	10.9	edge–on
3631	UMa	SpGal	1118.3	+5328	11.2	
3646	Leo	SpGal	1119.2	+2027		
3675	UMa	SpGal	1123.5	+4352	10.6	
3810	Leo	SpGal	1138.4	+1145	10.8	
3877	UMa	SpGal	1143.5	+4746	10.9	
3893	UMa	SpGal	1146.1	+4900	11.3	
3923	Hya	ElGal	1148.5	–2833		
3941	UMa	SpGal	1150.3	+3716	9.8	
3945	UMa	SpGal	1150.6	+6057	10.8	
3949	UMa	SpGal	1151.1	+4808	11.0	
3953	UMa	SpGal	1151.2	+5237	10.7	
3962	Crt	ElGal	1152.2	–1342	11.3	
4026	UMa	ElGal	1156.9	+5114	10.7	
4030	Vir	SpGal	1157.8	–0049	11.0	
4036	UMa	ElGal	1158.9	+6210	10.7	
4038	Crv	SpGal	1159.3	–1835		
4041	UMa	SpGal	1159.7	+6225	11.0	
4051	DMa	SpGal	1200.6	+4448	11.0	

NGC	CON	CONST	R.A.	DECL	MAG	REMARKS
4088	UMa	SpGal	1203.0	+5049	10.9	
4105	Hya	ElGal	1204.1	–2930		
4111	UMa	ElGal	1204.5	+4321	9.7	
4125	Dra	ElGal	1205.7	+6527	10.2	
4143	CVn	ElGal	1207.1	+4249	11.0	
4214	CVn	IrGal	1213.0	+3636	10.3	
4216	Vir	SpGal	1213.4	+1325	10.4	
4244	CVn	SpGal	1215.0	+3805	11.9	
4251	Com	SpGal	1215.7	+2827	10.2	
4261	Vir	ElGal	1216.8	+0606	10.3	
4274	Com	SpGal	1217.4	+2953	10.8	
4278	Com	ElGal	1217.7	+2934	10.3	
4314	Com	SpGal	1220.0	+3010	10.8	
4361	Crv	PlNeb	1221.9	–1829	10.8	central star mag:12.8
4365	Vir	ElGal	1222.0	+0736	11.1	
4395	CVn	SpGal	1223.4	+3349		
4414	Com	SpGal	1224.0	+3130	9.7	
4429	Vir	SpGal	1224.9	+1123	11.2	
4438	Vir	SpGal	1225 .3	+1317	10.8	
4449	CVn	IrGal	1225.8	+4422	9.2	
4450	Com	SpGal	1225.9	+1721	10.0	
4459	Com	ElGal	1226.5	+1514	10.9	
4465	Vir	ElGal	1225.2	+1321	10.3	
4473	Com	ElGal	1227.3	+1342	10.1	
4477	Vir	SpGal	1227.6	+1355	10.7	
4490	CVn	SpGal	1228.3	+4155	9.7	
4494	Com	ElGal	1228.9	+2603	9.6	
4526	Vir	ElGal	1231.6	+0758	10.9	
4535	Vir	SpGal	1231.8	+0828		
4536	Vir	SpGal	1231.9	+0228	11.9	
4546	Vir	ElGal	1232.9	–0331	10.0	
4565	Com	SpGal	1233.9	+2616	10.2	edge–on
4631	CVn	SpGal	1239.8	+3249	9.3	edge–on
4636	Vir	ElGal	1240.3	+0257	10.4	
4643	Vir	SpGal	1240.8	+0215	10.6	
4656	CVn	SpGal	1241.6	+3226	11.2	
4660	Vir	ElGal	1242.0	+1126	10.9	
4666	Vir	SpGal	1242.6	–0012	11.4	
4697	Vir	ElGal	1246.0	–0532	9.6	
4699	Vir	SpGal	1246.5	–0824	9.3	
4725	Com	SpGal	1248.1	+2546	8.9	
4753	Vir	SpGal	1249.8	–0055	10.8	
4754	Vir	ElGal	1249.7	+1135	10.5	
4762	Vir	SpGal	1250.4	+1131	11.0	
4775	Vir	SpGal	1251.1	–0621		
4781	Vir	SpGal	1251.8	–1016	11.2	
4800	CVn	SpGal	1252.4	+4648	11.1	
4826	Vir	SpGal	1254.3	+2157	8.8	
4856	Vir	ElGal	1256.7	–1446		
4900	Vir	SpGal	1258.2	+0246	11.3	
4945	Cen	SpGal	1302.4	–4901		
4958	Vir	ElGal	1303.1	–0745	10.9	
4995	Vir	SpGal	1307.0	–0734	11.2	
5005	CVn	SpGal	1308.5	+3719	9.8	
5033	CVn	SpGal	1311.2	+3651	10.3	
5044	Vir	ElGal	1312.8	–1608	11.2	
5053	Com	GlbCl	1313.9	+1757		
5068	Vir	SpGal	1316.2	–2047		
5102	Cen	ElGal	1319.1	–3623		
5128	Cen	IrGal	1322.4	–4245	7.2	Centaurus–A
5139	Cen	GlbCl	1323.8	–4703	3.7	Omega Centauri
5195	CVn	IrGal	1327.9	+4731	8.4	Pec–companion to MSl
5248	Boo	SpGal	1335.1	+0908	11.3	
5322	UMa	ElGal	1347.6	+6026	10.0	
5363	Vir	ElGal	1353.6	+0529	10.7	

NGC	CON	CONST	R.A.	DECL	MAG	REMARKS
5377	CVn	SpGal	1354.3	+4727	11.2	
5427	Vir	SpGal	1400.8	–0547		
5466	Boo	GlbCl	1403.2	+2846	8.5	
5566	Vir	SpGal	1417.8	+0411	10.4	
5746	Vir	SpGal	1442.3	+0210	10.1	
5775	Vir	SpGal	1451.5	+0345		
5824	Lup	GlbCl	1500.9	–3253	10.1	
5846	Vir	ElGal	1504.0	+0148	10.5	EO
5873	Lup	PlNeb	1509.4	–3754	9.7	
5897	Lib	GlbCl	1514.5	–2050	10.9	
5982	Dra	ElGal	1537.6	+5932	10.9	
5986	Lup	GlbCl	1542.8	–3737	8.7	
6058	Her	PlNeb	1602.8	+4049	12.3	central star mag:13.4
6139	Sco	GlbCl	1524.3	–3844		
6144	Sco	GlbCl	1624.2	–2556		
6210	Oph	PlNeb	1642.5	+2353	9.7	central star mag:12.5
6268	Sco	OpCl	1658.6	–3939	9.5	number:30
6281	Sco	OpCl	1701.4	–3749	8.6	number:25
6284	Oph	GlbCl	1701.5	–2441	9.7	
6293	Oph	GlbCl	1707.1	–2630	8.4	
6304	Oph	GlbCl	1711.4	–2924	9.8	
6316	Oph	GlbCl	1713.4	–2805		
6352	Ara	GlbCl	1721.6	–4826		
6356	Oph	GlbCl	1720.7	–1746	8.7	
6369	Oph	PlNeb	1726.3	–2344	9.9	central star mag:16.6
6383	Sco	OpCl	1731.4	–3233	5.5	number r:12
6388	Sco	GlbCl	1732.6	4443		
6397	Ara	GlbCl	1736.8	–5339		
6400	Sco	OpCl	1736.1	–3655	8.9	number:25
6441	Sco	C,lbCl	1746.8	–3702		
6445	Sgr	PlNeb	1746.3	–2000	13.2	central star mag:19.1
6503	Dra	SpGal	1549.9	+7010	9.6	
6528	Sgr	GlbCl	1801.6	–3004		
6541	CrA	GlbCl	1804.4	–4344		
6543	Dra	PlNeb	1758.8	+6638	8.8	central star mag:ll.l
6572	Oph	PlNeb	1809.7	+0650	9.6	central star mag:12.0
6584	Tel	GlbCl	1814.6	–5214		
6620	Sgr	PlNeb	1818.7	–2652	15.0	central star mag:15.8
6624	Sgr	GlbCl	1820.5	–3023		
6629	Sgr	PlNeb	1822.7	–2314	10.6	central star mag:13.6
6638	Sgr	GlbCl	1827.9	–2532	9.8	
6652	Sgr	GlbCl	1832.5	–3302		
6664	Sct	OpCl	1734.0	–0816	8.9	number:25
6709	Aql	OpCl	1749.1	+1017	8.1	number:40
6712	Sct	GlbCl	1850.3	–0847	8.9	
6723	Sgr	GlbCl	1856.2	–3642		
6755	Aql	OpCl	1905.3	+0409	8.3	number:50
6760	Aql	GlbCl	1908.6	+0057	10.7	
6790	Aql	PlNeb	1920.4	+0124	11.4	central star mag:l8.4
6803	Aql	PlNeb	1928.9	+0958	11.4	central star mag:14.1
6811	Cyg	OpCl	1936.7	+4627	9.2	number:50
6818	Sgr	PlNeb	1941.1	–1417	9.9	central starmag:15.0
6819	Cyg	OpCl	1939.6	+4006	10.1	number:150
6822	Sgr	TrGal	1942.1	–1453	10.0	
6826	Cyg	PlNeb	1943.4	+5024	8.8	central starmag:10.8
6830	Vul	OpCl	1948.9	+2258	9.0	number:20
6842	Vul	PlNeb	1953.0	+2909	13.6	central star mag:14.1
6871	Cyg	OpCl	2004.0	+3538	5.6	number:60
6879	Sge	PlNeb	2008.1	+1646	12.1	central star mag:15.2
6885	Vul	OpCl	2009.9	+2620	9.1	number:35
6886	Sge	PlNeb	2010.5	+1950	12.2	central star mag:16.6
6891	Aql	PlNeb	2012.8	+1235	11.4	central star mag:11.6
6894	Cyg	PlNeb	2014.4	+3025	14.4	central star mag:17.0
6905	Del	PlNeb	2020.2	+1957	11.9	central star mag:14.2
6910	Cyg	OpCl	2021.3	+4037	6.7	number:40

NGC	CON	CONST	R.A.	DECL	MAG	REMARKS
6934	Del	GlbCl	2031.7	+0714	9.2	
6939	Cep	OpCl	2030.4	+6028	10.0	number:80
6940	Vul	OpCl	2032.5	+2808	8.2	number:100
6946	Cep	SpGal	2033.9	+5958		
6960	Cyg	DfNeb	2043.6	+3032	8.0	Cirrus, Veil Nebula
7000	Cyg	DfNeb	2057.0	+4408	1.3	spectrum:cA2e/ No. America
7006	Del	GlbCl	2059.1	+1600	10.3	
7009	Aqr	PlNeb	2101.4	–1134	8.4	central star mag:12–Saturn Neb
7023	Cep	DfNeb	2101.4	+6758	7.2	spectrum B5a
7026	Cyg	PlNeb	2104.6	+4739	12.7	central star mag:14.8
7027	Cyg	PlNeb	2105.1	+4202	10.4	central star mag:17.1
7086	Cyg	OpCl	2129.8	+5122	9.4	number:50
7128	Cyg	OpCl	2142.4	+5329	11.2	number:20
7209	Lac	OpCl	2201.8	+4616	7.6	number:50
7217	Peg	SpGal	2205.6	+3107		
7243	Lac	OpCl	2213.2	+4938	7.4	number:40
7293	Aqr	PlNeb	2227.0	–2106	6.5	central star mag:13–Helix Neb.
7331	Peg	SpGal	2234.7	+3410	9.7	
7448	Peg	SpGal	2257.6	+1543	11.2	
7541	Psc	SpGal	2312.2	+0415	12.1	
7635	Cas	PlNeb	2318.5	+6054	8.5	central star mag:8.5
7662	And	PlNeb	2323.5	+4214	8.9	central star mag:12.5
7723	Aqr	SpGal	2336.4	–1314	11.1	
7727	Aqr	SpGal	2337.3	–1234	10.7	
7789	Cas	OpCl	2254.5	+5626	9.6	number:200
7790	Cas	OpCl	2254.5	+6056	7.1	number:25
7793	Scl	SpGal	2355.3	-3251	9.7	

OpCl = Open Cluster
GlbCl = Globular Cluster
PlNeb = Planetary Nebula
DfNeb = Diffuse Nebula
SpGal = Spiral Galaxy
ElGal = Elliptical Galaxy
IrGal = Irregular Galaxy

Appendix E
Planetary Data

	Mean distance from Sun in millions of miles	Period revolution around the Sun	Inclination to ecliptic °	'	Diameter (miles)	Period of rotation on axis
Mercury	36.0	87.9 d	7	0	3,100	58.66d
Venus	67.2	224.7 d	3	24	7,700	243.2d
Earth	93.0	365.2 d	0	0	7,927	23h56m
Mars	141.7	l.8 y	1	51	4,200	24h37m
Jupiter	483.8	11.8 y	1	18	88,700	9h50m
Saturn	887.1	29.4 y	2	29	75,100	16h39m
Uranus	1783.9	84.0 y	0	46	32,000	12.8h
Neptune	2795.4	164.7 y	1	46	27,700	l5.8h
Pluto	3675.2	248.4 y	17	9	1,500(?)	6d8h(?)

	Inclination of equator to orbit plane (°)	Surface gravity (Earth=1.0)	Density (H_2O=1)	Number of satellites	Mean velocity in orbit (mi/sec)	Max. stellar mag.
Mercury	7	0.28	3.8	0	30	–1.2
Venus	—	0.85	5.1	0	22	–4.4
Earth	23.4	1.00	5.5	1	18.5	—
Mars	25.2	0.38	4.0	2	15	–2.8
Jupiter	3.1	2.6	1.3	16	8	–2.5
Saturn	26.8	1.2	0.7	17	6	–0.4
Uranus	98.0	1.1	1.3	15	4	+5.7
Neptune	29.0	1.4	2.2	2	3	+7.8
Pluto	—		>1.0	1	<3	+14

Appendix F
Major Visual Meteor Showers

Shower	Date[1]	Position at Max R.A. (hr)	(min)	Dec (°)	Single Observer Hourly Rate	Normal Duration to 1/4 Strength of Max. (days)
Quadrantids	Jan. 4	15	28	+50	40	1.1
Lyrids	Apr. 22	18	16	+34	15	2.3
π Aquarids	May 5	22	22	–01	20	3
s. ∂ Aquarids	July 29	22	36	–17	20	7
Perseids	Aug. 12	03	04	+58	50	4.5
Orionids	Oct. 21	06	20	+15	25	2
S. Taurids	Nov. 3	03	32	+14	15	—
Leonids	Nov. 18	10	08	+22	15	—
Geminids	Dec. 14	07	32	+32	50	2.5
Ursids	Dec. 23	14	28	+78	15	2.2

1. Peak dates may vary ±1 day from year to year. Call your local planetarium or university astronomy department for more timely information.

Appendix G

Supplementary Reading

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