Astronomy Lab Help Index

The Index lists the Help topics available for Astronomy Lab.   Use the scroll bar to see entries not currently visible in the Help window.

To learn how to use Help, choose Using Help from the Help menu.

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Commands

Registering this Shareware Program

Astronomy Lab is shareware.   To register your copy, please send $15.00 US plus postage and handling to:

Personal MicroCosms
8547 E. Arapahoe Road
Suite J-147
Greenwood Village, CO   80112   USA

Postage and Handling:

US and Canada: $2.50   Overseas: $10.00 (for airmail delivery)

What you get for registering:

1.   Disk containing the latest version of Astronomy Lab.   Please specify disk type: 5 1/4" high density or 3 1/2" high density.

2.   Personal MicroCosms' customer support telephone number.

3.   Notification by mail when future versions of Astronomy Lab are available.

We Accept:

Checks in US funds drawn on a US bank
Registration on CompuServe ("GO SWREG")
International Postal Mail Orders
American Express International Money Orders
US Cash

Getting Started

1. **On-line Help:**   To get on-line help, press the F1 key.   Pressing the F1 key when a menu item or dialog box is displayed will give help for the menu item or dialog box.   For further details, see the entry for F1 in Astronomy Lab Keys.

2. **User's Guide:**   Astronomy Lab has a comprehensive User's Guide available as on-line help.   See User's Guide for further information.

3. **Setting your Location:**   Astronomy Lab's reports, graphs, and movies are customized for a given latitude, longitude, elevation above sea level, and time zone.   To enter your location, see Set Location.

4. **Assigning Colors:**   To change the color of objects drawn by Astronomy Lab, use the   Assign Colors command.   Run this command to ensure that all objects are displayed attractively on your system.

5. **Times:**   All times entered into Astronomy Lab and output by Astronomy Lab are in standard time, not daylight savings time.

See also: Caveats

Caveats

1. **Times:** All times entered into Astronomy Lab and output by Astronomy Lab are in standard time, not daylight savings time.

2. **Planetarium Movie:** Since the sizes of the <u>disks</u> of the sun and moon are exaggerated at view angles greater than 5°, a view angle of 5° must be specified in order to accurately observe eclipses, <u>transits</u>, and <u>occultations</u>.

What's New in this Version

The following are new in version 1.14:

1.   Astronomy Lab has an automatic Windows installation program.

2.   Minor bugs have been fixed.

3.   Astronomy Lab now requires Windows 3.1 or later.

Astronomy Lab Keys

Use the following keys in Astronomy Lab:

Key(s)	Function
Ctrl+C	Copies current report, movie frame, or graph into the Clipboard
Esc	Stops the current command
F1	Activates the Astronomy Lab Help system.
	To get help on a given **menu item** (for example the Print Setup item), Select the corresponding menu (Alt, F). Then move to the item by typing the up and down arrow keys. Then press F1 for help on the menu item.
	To get help on a given **dialog box**, simply press F1 when the dialog box is displayed.
F2	Increases the rate at which time passes between successive movie frames.
F3	Decreases the rate at which time passes between successive movie frames.
F4	Reverses the rate at which time passes between successive movie frames.
F5	Pauses the current movie.
F6	Decreases the view angle of the movie, causing the center of the screen to be enlarged.
F7	Increases the view angle of the movie, causing the center of the screen to be reduced.
F8	Causes moving objects in movies to leave trails.

File Menu Commands (Alt,F)

Print
Setup Print
Set Font
Exit

File Print (Alt,F,P)

Prints the current report, movie frame, or graph on the currently selected printer.   NOTE: to print a movie frame, the movie must be stopped.

File Print Setup (Alt,F,r)

Allows the user to change printer settings prior to printing.

File Set Font (Alt,F,F)

Allows the user to select the font that will be used to print the next report.

File Exit (Alt,F,x)

Quits the Astronomy Lab program.

If you have changed the color assignments without saving them, you will have a chance to save them.   If you have changed the location database without saving it, you will have a chance to save it.

Edit Menu Commands (Alt,E)

Copy

Edit Copy (Ctrl+C or Ctrl+Insert or Alt,E,C)

Copies the current report, movie frame, or graph into the Clipboard.   After an item has been copied into the Clipboard, it can be pasted into another program (for example, a word processor or paint program).

Once a report, graph, or movie frame has been generated, it can be copied into another program as follows:

1.   If copying a movie frame, stop the movie.

2.   Press Ctrl+C or Ctrl+Insert or choose Copy from the Edit menu.

3.   Go to the program to which you want to copy the item

4.   Select Paste from the Edit menu

The item will now be copied into the program, provided that program can copy items from the Clipboard.

Location Menu Commands (Alt,L)

Set Location

Location Set Location (Alt,L,S)

Allows you to enter a location name, latitude, longitude, elevation above sea level, and a time zone.
Once the location data has been entered, reports, graphs, and movies will be customized for that location.

Dialog Box:

Location

Name of location.   You can choose a location already in Astronomy Lab's location database, or enter a new one.

There are three different ways to choose an existing location:

1.   Type the up and down arrow keys to sequence through the location names.

2.   Press the arrow at the right of the box to open the drop-down list box.   Then select a city from the list.

3.   Type in the city's name exactly as it exists in the database.

To enter the name of a city not already in the location database, simply type the city's name.

Latitude

The location's latitude in degrees, minutes, and seconds.

North

Select if the location is north of the equator.

South

Select if the location is south of the equator.

Longitude

The location's longitude in degrees, minutes, and seconds.

West

Select if the location is west of Greenwich, England.

East

Select if the location is east of Greenwich, England.

Elevation above Sea Level

The location's elevation above sea level in meters.   Enter a negative number if the location is below sea level.   Enter 0 if you don't know the elevation.

Time Zone

Time zone in hours.   For locations in the U.S.A., use the following:

Region	Time Zone
Eastern	-5
Central	-6
Mountain	-7

Pacific   -8

For locations outside the U.S.A., see the Universal Time and Time Zones.

OK

Saves the location information temporarily and quits the dialog box.

Save

Saves the location information in a disk file which will be reloaded every time Astronomy Lab is run.

Cancel

Quits the dialog box without changing the location information.

See also: Caveats

Reports Menu Commands (Alt,R)

General Information About Reports

Introduction
Calendar
Seasons
Dates of Easter
Lunar Eclipses
Solar Eclipses
Planet View Info
Planet Apsides
Planet Conj/Opp
Planet Data
Moon Apsides
Meteor Showers
Twilight
Almanac

Reports, General Information

Customizing a Report For a Location

Most reports are customized for a specific location.   See Set Location for further information.

Scrolling Report Text

After a report has been generated, the report text can be scrolled vertically or horizontally with the scroll bars.   Pressing the Home key will go to the beginning of the report, and pressing the End key will go to the end.   Pressing the Page Up or Page Down will scroll the text up or down one page.   Pressing the up or down arrow keys will move the text up or down one row.   Pressing the left or right arrow keys will move the text one column to the left or right.

Printing a Report

A report can be printed after it has been generated.   See Print and Set Font for further information.

Copying a Report into Another Program

A report can be copied into other Windows programs after it has been generated.   See Copy for further information.

Stopping a Report

Any report can be stopped by pressing the Esc key.   See Stop Command for further information.

See also: Caveats

Reports Introduction (Alt,R,I)

The Introduction report summarizes the most important information needed to interpret all reports generated by Astronomy Lab.   If you generate reports for people who do not own Astronomy Lab, you may want to include an Introduction report.

Reports Calendar (Alt,R,C)

The Calendar report gives the times and dates of the following astronomical events, formatted as a monthly calendar:

* Sun Rise and Set
* Moon Rise and Set
* Solar Eclipses
* Lunar Eclipses
* Moon Phases
* Equinoxes and Solstices

Dialog Box:

Year,
Start Month,
Stop Month
Year and range of months for which the report will be generated.   The Stop Month cannot be less than the Start Month.

OK
Quits the dialog box and generates the report.

Cancel
Quits the dialog box.   The report is not generated.

See also: General Information About Reports

Reports Seasons (Alt,R,n)

The Seasons report gives the times and dates of <u>equinoxes</u> and <u>solstices</u>, and the lengths of the seasons for a range of years.

Dialog Box:

Start Year,
Stop Year
       Range of years for which the report will be generated.   The Stop Year cannot be less than the Start Year.

OK
       Quits the dialog box and generates the report.

Cancel
       Quits the dialog box.   The report is not generated.

See also: <u>General Information About Reports</u>

Reports Dates of Easter (Alt,R,E)

The Dates of Easter report gives the dates of Easter for a range of years.

Dialog Box:

Start Year,
Stop Year

Range of years for which the report will be generated.   The Stop Year cannot be less than the Start Year.

OK

Quits the dialog box and generates the report.

Cancel

Quits the dialog box.   The report is not generated.

See also: General Information About Reports

Reports Lunar Eclipses (Alt,R,u)

The Lunar Eclipses report gives predictions of all umbral lunar eclipses that occur in a given range of years.

Dialog Box:

Start Year,
Stop Year
Range of years for which the report will be generated.   The Stop Year cannot be less than the Start Year.

OK
Quits the dialog box and generates the report.

Cancel
Quits the dialog box.   The report is not generated.

See also: General Information About Reports

Reports Solar Eclipses (Alt,R,S)

The Solar Eclipses report gives predictions of all solar eclipses that occur in a given range of years.

Dialog Box:

Start Year,
Stop Year
Range of years for which the report will be generated.   The Stop Year cannot be less than the Start Year.

OK
Quits the dialog box and generates the report.

Cancel
Quits the dialog box.   The report is not generated.

See also: General Information About Reports

Reports Planet View Info (Alt,R,V)

The Planet View Info report gives information useful for observing the planets.

Dialog Box:

Year,
Start Month,
Stop Month
Year and range of months for which the report will be generated.   The Stop Month cannot be less than the Start Month.

Planets
Allows you to select the planets that will appear in the report.   Select at least one planet.

OK
Quits the dialog box and generates the report.

Cancel
Quits the dialog box.   The report is not generated.

See also: General Information About Reports

Reports Planet Apsides (Alt,R,A)

The Planet Apsides report gives the dates of <u>apsides</u> (i.e. <u>perihelion</u> and <u>aphelion</u>) for a set of planets over a given range of years.

Dialog Box:

Start Year,
Stop Year
Range of years for which the report will be generated.   The Stop Year cannot be less than the Start Year.

Planets
Allows you to select the planets that will appear in the report.   Select at least one planet.

OK
Quits the dialog box and generates the report.

Cancel
Quits the dialog box.   The report is not generated.

See also: <u>General Information About Reports</u>

Reports Planet Conj/Opp (Alt,R,P)

The Planet Conj/Opp report gives the dates and times of <u>conjunctions</u> and <u>oppositions</u> for a set of planets over a given range of years.

Dialog Box:

Year,
Start Month,
Stop Month
Year and range of months for which the report will be generated.   The Stop Month cannot be less than the Start Month.

Planets
Allows you to select the planets that will appear in the report.   Select at least one planet.

OK
Quits the dialog box and generates the report.

Cancel
Quits the dialog box.   The report is not generated.

<u>See also</u>:   <u>General Information About Reports</u>

Reports Planet Data (Alt,R,D)

The Planet Data report gives the most important information about the planets.

See also: <u>General Information About Reports</u>

Reports Moon Apsides (Alt,R,M)

The Moon Apsides report gives the dates and times of <u>apsides</u> (i.e. <u>perigee</u> and <u>apogee</u>) of the moon over a range of months.

Dialog Box:

Year,
Start Month,
Stop Month
Year and range of months for which the report will be generated.   The Stop Month cannot be less than the Start Month.

OK
Quits the dialog box and generates the report.

Cancel
Quits the dialog box.   The report is not generated.

See also: <u>General Information About Reports</u>

Reports Meteor Showers (Alt,R,h)

The Meteor Showers report gives information about the meteor showers that occur over a range of months.

Dialog Box:

Year,
Start Month,
Stop Month
Year and range of months for which the report will be generated.   The Stop Month cannot be less than the Start Month.

OK
Quits the dialog box and generates the report.

Cancel
Quits the dialog box.   The report is not generated.

See also: General Information About Reports

Reports Twilight (Alt,R,T)

The Twilight report gives the times of nautical, astronomical, and civil twilight over a range of months.

Dialog Box:

Year,
Start Month,
Stop Month
Year and range of months for which the report will be generated.   The Stop Month cannot be less than the Start Month.

OK
Quits the dialog box and generates the report.

Cancel
Quits the dialog box.   The report is not generated.

See also: <u>General Information About Reports</u>

Reports Almanac (Alt,R,I)

The Almanac report generates all of Astronomy Lab's reports for the specified range of months.

Dialog Box:

Year,
Start Month,
Stop Month
Year and range of months for which the report will be generated.   The Stop Month cannot be less than the Start Month.

OK
Quits the dialog box and generates the report.

Cancel
Quits the dialog box.   The report is not generated.

See also: General Information About Reports

Graphs   Menu Commands (Alt,G)

Graphs, General Information

Customizing a Graph For a Location

Most graphs are customized for a specific location.   See Set Location for further information.

Colors

The colors of items graphed by Astronomy Lab can be customized.   See Assign Colors for further information.

Grid Lines and Tick Marks

Graphs can be drawn with tick marks or grid lines.   See Tick Marks and Grid Lines for further information.

Printing a Graph

A graph can be printed after it has been generated.   See Print for further information.

Copying a Graph into Another Program

A graph can be copied into other Windows programs after it has been generated.   See Copy for further information.

Stopping a Graph

Any graph can be stopped by pressing the Esc key.   See Stop Command for further information.

See also: Caveats

Graphs Jupiter Moons Orbit (Alt,G,J)

The Jupiter Moons Orbit graph shows the configurations of Jupiter's four bright moons.   The horizontal strip in the middle of the graph represents the width of Jupiter's disk.   Following traditional practice, east and west are reversed in the graph - therefore if a moon appears west of Jupiter on the graph, it will appear east of Jupiter when viewed with a non-inverting telescope or binoculars.

Dialog Box:

Year,
Month,
Month for which the graph will be drawn.

Moons
Allows you to select the moons that will appear in the graph.   Select at least one moon.

Label Moons
Place an X in this check box if you want the numbers of moons to appear next to them in the graph.

OK
Quits the dialog box and draws the graph.

Cancel
Quits the dialog box without drawing the graph.

See also: General Information About Graphs

Graphs Planet Orbit (Alt,G,O)

The Planet Orbit graph shows the <u>right ascensions</u> of a set of planets over one year.   Since constellation abbreviations are drawn on the right side of the graph, you can determine the constellation in which a planet will be on a given date.

The thick diagonal line extending from the bottom left to the top right represents the sun's <u>right ascension</u>. When a planet's curve crosses this line, that planet is in <u>conjunction</u> with the sun.   The other two thick diagonal lines represents the sun's right <u>ascension</u> + 12 hours, thus a planet's curve will cross one of these lines when it is in <u>opposition</u>.

Dialog Box:

Year
Year for which the graph will be generated.

Planets
Allows you to select the planets that will appear in the graph.   Select at least one planet.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: <u>General Information About Graphs</u>

Graphs Planet Magnitude (Alt,G,M)

The Planet Magnitude graph shows the <u>visual magnitudes</u> of a set of planets over one year.   The brighter an object is, the smaller its <u>magnitude</u>.   The brightest star has a <u>magnitude</u> of about 1 and a star that is barely visible to the naked eye has a <u>magnitude</u> of about 6.

Dialog Box:

Year
Year for which the graph will be generated.

Planets
Allows you to select the planets that will appear in the graph.   Select at least one planet.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: <u>General Information About Graphs</u>

Graphs Planet Illum. Frac. (Alt,G,F)

The Planet Illum. Frac. graph shows the <u>illuminated fractions</u> of a set of planets over one year.   A celestial body's <u>illuminated fraction</u> is the fraction of the body's disk illuminated by the sun.

Dialog Box:

Year
> Year for which the graph will be generated.

Planets
> Allows you to select the planets that will appear in the graph.   Select at least one planet.

OK
> Quits the dialog box and generates the graph.

Cancel
> Quits the dialog box.   The graph is not generated.

See also: <u>General Information About Graphs</u>

Graphs Planet Diameter (Alt,G,D)

The Planet Diameter graph shows the angular diameters of a set of planets over one year.

Dialog Box:

Year
Year for which the graph will be generated.

Planets
Allows you to select the planets that will appear in the graph.   Select at least one planet.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: General Information About Graphs

Graphs Planet Distance (Alt,G,s)

The Planet Distance graph shows the distances of a set of planets from the earth or sun over one year.

Dialog Box:

Year
Year for which the graph will be generated.

Planets
Allows you to select the planets that will appear in the graph.   Select at least one planet.

From Earth
Select if you want to graph the distance from the planets to the sun.

From Sun
Select if you want to graph the distance from the planets to the earth.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: General Information About Graphs

Graphs Planet Angle (Alt,G,A)

The Planet Angle graph shows the angles between one planet (the Main Planet) and a set of other planets over one month.

Dialog Box:

Year, Month
Year and month for which the graph will be generated.

Main Planet
Allows you to select the main planet.

Other Planets
Allows you to select the other planets that will appear in the graph.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: General Information About Graphs

Graphs Equation of Time (Alt,G,q)

The Equation of Time graph shows the difference between <u>mean time</u> and <u>apparent time</u> over one year. The <u>equation of time</u> is the amount of time that a sundial is in error.

Dialog Box:

Year
Year for which the graph will be generated.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: <u>General Information About Graphs</u>

Graphs Day Length (Alt,G,L)

The Day Length graph shows the length of days over one year.

Dialog Box:

Year
Year for which the graph will be generated.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: General Information About Graphs

Graphs Sun Angle (Alt,G,n)

The Sun Angle graph shows the angle of the sun at local apparent noon over one year.

Dialog Box:

Year
Year for which the graph will be generated.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: General Information About Graphs

Graphs Analemma (Alt,G,e)

The Analemma graph shows an <u>analemma</u> for a given year.   An <u>analemma</u> is the figure-8 path followed by a shadow on the ground observed every day at 12:00 <u>mean time</u> for one year.

Dialog Box:

Year
Year for which the graph will be generated.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: <u>General Information About Graphs</u>

Graphs Sunrise (Alt,G,r)

The Sunrise graph shows the azimuth of the sun at sunrise over one year.

Dialog Box:

Year
Year for which the graph will be generated.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: General Information About Graphs

Graphs Moon Angular Speed (Alt,G,g)

The Moon Angular Speed graph shows the angular speed at which the moon moves through the ecliptic over one year.

Dialog Box:

Year
Year for which the graph will be generated.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: General Information About Graphs

Graphs Moon Illum. Frac. (Alt,G,u)

The Moon Illum. Frac. graph shows the illuminated fraction of the moon over one month.   A full moon has an illuminated fraction of 1.0.   A new moon has an illuminated fraction of 0.0.

Dialog Box:

Year,
Month
> Year and month for which the graph will be generated.

OK
> Quits the dialog box and generates the graph.

Cancel
> Quits the dialog box.   The graph is not generated.

See also: General Information About Graphs

Graphs Eclipses (Alt,G,c)

The Eclipses graph shows the dates of lunar and solar eclipses over a given range of years.   Lunar and solar eclipses are drawn in the color assigned to the moon and sun, respectively (see Assign Colors for further information).

Dialog Box:

Start Year,
Stop Year
Range of years for which the graph will be generated.   The Stop Year cannot be less than the Start Year.

OK
Quits the dialog box and generates the graph.

Cancel
Quits the dialog box.   The graph is not generated.

See also: General Information About Graphs

Graphs Tick Marks (Alt,D,T)

When the Tick Marks item is selected, graphs will be drawn with tick marks.

Graphs Grid Lines (Alt,G,i)

When the Grid Lines item is selected, graphs will be drawn with grid lines.

Movies Menu Commands (Alt,M)

General Information About Movies

Planetarium
Jupiter Moons Side
Jupiter Moons Top
Ecliptic Side
Ecliptic Top
Day/Night
Binary Star
Speed Up
Slow Down
Reverse Time Speed
Zoom In
Zoom Out
Jet Trails

Movies, General Information

Customizing a Movie For a Location

Most movies are customized for a specific location.   See Set Location for further information.

Time Speed

The time speed of a movie determines how much time passes on the computer's clock between successive movie frames.   The time speed does not change the rate at which movie frames are displayed on the screen.   The time speed can be changed as a movie is running.   For further information, see Speed Up, Slow Down,   Reverse Time Speed, and   Pause.

View Angle

The view angle of a movie determines the field of view.   A large view angle works like a wide angle lens, allowing you to see many objects crowded together.   A small view angle works like a telephoto lens, zooming in on the objects in the center of the screen.   The view angle can be changed as a movie is running.   For further information, see Zoom In and Zoom Out.

Jet Trails

Enabling Jet Trails will cause moving objects to leave trails.   For further information, see Jet Trails.

Colors

The colors of items appearing in movies can be customized.   See Assign Colors for further information.

Printing a Movie Frame

A movie frame can be printed after it has been generated.   See Print for further information.

Copying a Movie Frame into Another Program

A movie frame can be copied into other Windows programs after it has been generated.   See Copy for further information.

Stopping a Movie

Any movie can be stopped by pressing the Esc key.   See Stop Command for further information.

See also: Caveats

Movies Planetarium (Alt,M,P)

The Planetarium movie shows the <u>celestial sphere</u>, complete with the sun, moon, stars, and planets.
Almost every important astronomical event can be observed with the Planetarium movie, including:

* Solar Eclipses
* Lunar Eclipses
* <u>Transits</u> of Mercury and Venus
* Lunar <u>Occultations</u> of Stars and Planets
* Planetary <u>Occultations</u>

Dialog Box:

Year,
Month,
Day
  Date for which the movie will be run.

Time
  Time for which the movie will be run in hours and minutes (24 hour format).

Now
  Automatically inserts the current date and time in the Year, Month, Day, and Time fields.

Time Speed
  Specifies the amount of time that will elapse between successive movie frames.   The Time
  Speed must be between -64 and 64.

Turbo
  Select to increases the amount of time that will elapse between successive movie frames by a
  factor of 1000.   Requires that you track on a star or planet.

View Angle
  Specifies the view angle of the movie.   A large view angle results in a wide view, and a small
  view angle gives a narrow view.   The View Angle must be between 0 and 90.

Body
  Allows you to specify the body that will appear in the center of the screen when the movie begins.

Track Body
  Select to track the movement of the body.

Sun/Moon
  Select to include the sun and moon in the movie.

Planets
  Select to include all planets in the movie.

Stars
  Select to include stars in the movie.

Label Planets
Place an X in this check box if you want the names of planets to appear next to them in the movie.

Star
Allows you to select a star to appear in the center of the screen.   This list box will only appear if you selected the Star radio button in the Body group box, described above.

OK
Quits the dialog box and runs the movie.

Cancel
Quits the dialog box without running the movie.

See also: General Information About Movies

Movies Jupiter Moons Side (Alt,M,J)

The Jupiter Moons Side movie shows the orbits of Jupiter's four bright moons as they would appear to an observer on the earth.   The larger disk in the middle of the screen is Jupiter and the smaller disks are Jupiter's four bright moons.   When a moon moves behind one side of the planet, the moon will disappear and then reappear later on the other side.

The orbits of the moons in the Jupiter Moons Side movie are approximately horizontal.   In reality, the orbits of the moons appear tilted with respect to the horizon to observers on earth.

Movies Jupiter Moons Top (Alt,M,M)

The Jupiter Moons Top movie shows the orbits of Jupiter's four bright moons as they would appear to an observer directly above Jupiter's north pole.

Dialog Box:

Year,
Month,
Day
> Date for which the movie will be run.

Time
> Time for which the movie will be run in hours and minutes (24 hour format).

Now
> Automatically inserts the current date and time in the Year, Month, Day, and Time fields.

Time Speed
> Specifies the amount of time that will elapse between successive movie frames.   The Time Speed must be between -64 and 64.

Moons
> Allows you to select the moons that will appear in the movie.   Select at least one moon.

Label Moons
> Place an X in this check box if you want the numbers of moons to appear next to them in the movie.

OK
> Quits the dialog box and runs the movie.

Cancel
> Quits the dialog box without running the movie.

See also: General Information About Movies

Movies Ecliptic Side (Alt,M,E)

The Ecliptic Side movie shows the orbits of a set of planets in the ecliptic (side-view).

Movies Ecliptic Top (Alt,M,I)

The Ecliptic Top movie shows the orbits of a set of planets in the ecliptic, viewed from above the ecliptic.

Dialog Box:

Year,
Month,
Day
Date for which the movie will be run.

Time
Time for which the movie will be run in hours and minutes (24 hour format).

Now
Automatically inserts the current date and time in the Year, Month, Day, and Time fields.

Time Speed
Specifies the amount of time that will elapse between successive movie frames.   The Time Speed must be between -64 and 64.

View Angle
Specifies the view angle of the movie.   A large view angle results in a wide view, and a small view angle gives a narrow view.   The View Angle must be between 0 and 90.

Note: the View Angle field is not displayed for the Ecliptic Side movie.

Planets
Allows you to select the planets that will appear in the movie.   Select at least one planet.

Label Planets
Place an X in this check box if you want the names of planets to appear next to them in the movie.

OK
Quits the dialog box and runs the movie.

Cancel
Quits the dialog box without running the movie.

See also: General Information About Movies

Movies Day/Night (Alt,M,y)

The Day/Night movie shows where on the earth it is day and where it is night.

Dialog Box:

Year,
Month,
Day
> Date for which the movie will be run.

Time
> Time for which the movie will be run in hours and minutes (24 hour format).

Now
> Automatically inserts the current date and time in the Year, Month, Day, and Time fields.

Real Time
> Causes the time between successive movie frames to change at the same rate as a clock.

1 Hour,
1 Day,
1 Week,
1 Month
> Causes one hour, one day, one week, or one month to elapses between successive movie frames.

OK
> Quits the dialog box and runs the movie.

Cancel
> Quits the dialog box without running the movie.

See also: General Information About Movies

Movies Binary Star (Alt,M,B)

The Binary Star movie shows the orbits of a binary star.

Dialog Box:

Year
Year for which the movie will be run.

Time Speed
Specifies the amount of time that will elapse between successive movie frames.   The Time Speed must be between -64 and 64.

View Angle
Specifies the view angle of the movie.   A large view angle results in a wide view, and a small view angle gives a narrow view.   The View Angle must be between 0 and 90.

Binary Stars
List of all stars for which Binary Star movies can be run.   Select the star that you're interested in.

OK
Quits the dialog box and runs a Binary Star movie for the selected star.

Cancel
Quits the dialog box without running the Binary Star movie.

See also: General Information About Movies

Movies Speed Up (F2 or Alt,M,U)

Increases the rate at which time passes between successive movie frames.

See also: General Information About Movies

Movies Slow Down (F3 or Alt,M,D)

Decreases the rate at which time passes between successive movie frames.

See also: General Information About Movies

Movies Reverse Time Speed (F4 or Alt,M,R)

Reverses the rate at which time passes between successive movie frames.

See also: General Information About Movies

Movies Pause (F5 or Alt,M,a)

Pauses the current movie.   To pause a movie, select this menu item.   To resume the movie, select it again.

See also: General Information About Movies

Movies Zoom In (F6 or Alt,M,I)

Decreases the view angle of the movie, causing the center of the screen to be enlarged.

See also: General Information About Movies

Movies Zoom Out (F7 or Alt,M,O)

Increases the view angle of the movie, causing the center of the screen to be reduced.

See also: General Information About Movies

Movies Jet Trails (F8 or Alt,M,T)

Causes moving objects in movies to leave trails.

See also: General Information About Movies

Colors Menu Commands (Alt,C)

Assign Colors

Colors Assign Colors (Alt,C,A)

Allows you to change the color of objects drawn by Astronomy Lab (e.g. sun, moon, planets, stars).   To change an object's color, first select the object's button.   Then select a new color with the mouse.   Make sure that you do not assign the window background color to any object, or it will be invisible.

NOTE: since objects are drawn with pure rather than dithered colors, the color used by Astronomy Lab may differ slightly from the color you select.

Dialog Box:

Sun...
...
Callisto...
> Objects which can be assigned colors.

OK
> Quits the dialog box and saves the color assignments until you quit the program.

Save
> Saves the color assignments in a disk file which will be reloaded every time Astronomy Lab is run.

Cancel
> Quits the dialog box without changing the color assignments.

Stop Menu Commands (Alt,S)

Stop Command

Stop Stop Command (Esc or Alt, S, S)

Stops the current command (report, graph, or movie), allowing you to run other commands or quit the program.

Help Menu Commands (Alt,H)

Index
Keyboard
Commands
Using Help
User's Guide
How to Register
About Astronomy Lab

Help Index (F1 or Alt,H,I)

Displays the Astronomy Lab Help index.

Press Tab to move to the topic you want, and then press Enter.

With the mouse, click the name of the topic you want.

Help Keyboard (Alt,H,K)

Gives information about using keyboard keys in Astronomy Lab.

Help Commands (Alt,H,C)

Gives help on all of Astronomy Lab's commands.

Help Using Help (Alt,H,U)

Gives information about getting on-line help with Astronomy Lab.

Help User's Guide (Alt,H,G)

Allows you to read the Astronomy Lab User's Guide.

Help How to Register (Alt,H,R)

Gives information about registering Astronomy Lab.

Help About Astronomy Lab (Alt,H,A)

Displays a dialog box that tells you which version of Astronomy Lab you are using.

Planets

Dialog Box:

Year
 Year for which the report or graph will be generated.

Start Month,
Stop Month
 Range of months for which the report or graph will be generated.   The Stop Month cannot be less than the Start Month.   The Start Month and Start Month may or may not appear in the dialog box.

Planets
 Allows you to select the planets that will appear in the report or graph.   Select at least one planet.

From Earth
 Select if you're interested in the distance from the planets to the sun.   May or may not appear in the dialog box.

From Sun
 Select if you're interested in the distance from the planets to the earth.   May or may not appear in the dialog box.

OK
 Quits the dialog box and generates the report or graph.

Cancel
 Quits the dialog box.   The report or graph is not generated.

Year

Allows you to specify the year for which a report or graph will be generated.

Dialog Box:

Year
Year for which the report or graph will be generated.

OK
Quits the dialog box and generates the report or graph.

Cancel
Quits the dialog box.   The report or graph is not generated.

Year and Month

Allows you to specify the year and month for which a report or graph will be generated.

Dialog Box:

Year,
Month
Year and month for which the report or graph will be generated.

OK
Quits the dialog box and generates the report or graph.

Cancel
Quits the dialog box.   The report or graph is not generated.

Year and Range of Months

Allows you to specify the year and a range of months for which a report or graph will be generated.

Dialog Box:

Year,
Start Month,
Stop Month

> Year and range of months for which the report or graph will be generated.   The Stop Month cannot be less than the Start Month.

OK

> Quits the dialog box and generates the report or graph.

Cancel

> Quits the dialog box.   The report or graph is not generated.

Year Range

Allows you to specify a range of years for which a report or graph will be generated.

Dialog Box:

Start Year,
Stop Year
Range of years for which the report or graph will be generated.   The Stop Year cannot be less than the Start Year.

OK
Quits the dialog box and generates the report or graph.

Cancel
Quits the dialog box.   The report or graph is not generated.

User's Guide

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Appendix E - Also by the Author

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Acknowledgments

Summary of Contents

This User's Guide gives the information necessary to use and understand Astronomy Lab.   Although this document discusses basic astronomical concepts, it is intended to augment, not replace, a good introductory astronomy text.   See Appendix D for a list of several excellent introductory astronomy books.

Chapter 1 contains a description of Astronomy Lab and information on installing the program.

Chapter 2 is a tutorial designed to rapidly acquaint you with many of the most important features of Astronomy Lab.

Chapter 3 discusses how to simulate many interesting astronomical events with Astronomy Lab.

Chapter 4 contains activities that will help you learn important astronomical concepts in greater depth.

Chapter 5 describes all of Astronomy Lab's features, arranged in the order that they appear in the menu bar.

Appendix A is an explanation of the basic astronomical concepts that you will need to know to make the best use of Astronomy Lab.   If you encounter an unfamiliar concept, it is likely to be explained in this appendix.

Appendix B is a list of the abbreviations used in Astronomy Lab and this User's Guide.

Appendix C gives information on solving various problems that may occur.

Appendix D is a list of recommended books and magazines covering a variety of astronomical topics.

Appendix E is a list of other publications by the author.

The Glossary contains definitions of astronomical terms.

1.1. Purpose

The purpose of this chapter is to describe Astronomy Lab, list the hardware and software required to run the program, give the program's limited warranty, and give instructions on installing the program.

1.2.   Description of Astronomy Lab

Astronomy Lab is one of the most innovative, interesting, and useful astronomy programs available for Microsoft Windows 3.1.   Astronomy Lab allows users to generate animated movies simulating a host of astronomical events (including solar and lunar eclipses, lunar <u>occultations</u>, planetary <u>occultations</u>, <u>transits</u> of Mercury and Venus, the orbits of Jupiter's bright moons, and the motions of the planets in the plane of the <u>ecliptic</u>).   In addition, Astronomy Lab can produce several reports that contain predictions of the most important and exciting astronomical events of the present, future and past.   Also, Astronomy Lab can generate several graphs that illustrate many fundamental astronomical concepts.

This program will provide hour after hour of fascination and education to anyone interested in astronomy. The novice can use Astronomy Lab as an excellent learning tool.   Seasoned astronomers can make the best use of their observing time by using the program to calculate when astronomical events will occur, and where in the sky they will be found.

1.3. Required Hardware and Software

Astronomy Lab requires Microsoft Windows 3.1 or later, 1 megabyte of available memory, and a mouse. Astronomy Lab will use an 8X87 compatible math coprocessor if one is installed.   A Windows compatible printer is optional.

1.4. Disclaimer

This program and User's Guide are distributed "as is," without warranty as to their performance, merchantability, or fitness for any particular purpose.   You assume the entire risk as to the results and performance of this program.

Personal MicroCosms shall not be liable for indirect, special, or consequential damages resulting from the use of this product.   Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitations might not apply to you.   This warranty gives you specific legal rights, and you may also have other rights that vary from state to state.

1.5. Installation

In the following discussion, the disk included with this user's guide is called the distribution disk.   The examples below assume that you will be inserting the distribution disk into drive A to install Astronomy Lab.   If you will be inserting the distribution disk into a different drive, substitute that drive letter for A in the examples below.

The disk on which Astronomy Lab will be installed is called the destination disk.   The examples below assume that the destination disk is drive C.   If your destination disk has a different drive letter, substitute that letter for C in the examples below.

1.   Insert the distribution disk in your floppy disk drive.

2.   Uncompress the files on the distribution disk if necessary.

3.   Create a subdirectory for Astronomy Lab on the destination disk (e.g. C:\ALW).

4.   Copy all files from the distribution disk to the new subdirectory except for COMMDLG.DLL.

5.   Windows 3.0 users only: If you do not already have a file named COMMDLG.DLL in your Windows system subdirectory, copy COMMDLG.DLL from the distribution disk into the Windows system subdirectory (e.g. C:\WINDOWS\SYSTEM).

6.   Go to the Program Manager and select the File menu and the New item (Alt,F,N).   Press the Program Group button and the OK button.   Enter Astronomy Lab in the Description text box, and ALW in the Group File text box.   Press the OK button.

7.   Select the File menu and the New item.   Press the Program Item button and the OK button.   Enter Astronomy Lab in the Description text box, and enter the location of the program in the Command Line text box (e.g. C:\ALW\ALW.EXE).   Press the OK button.

Astronomy Lab is now installed.   Store the distribution disk in a safe place in case you need to repeat the installation process.   The distribution disk contains the following files:

Table 1: Contents of Distribution Disk:

```
Filename        Notes


ALW.EXE         Astronomy Lab program
ALW.HLP         On-line Help File
STARS.DAT       Star Database
CITIES.DAT      City Location Database
COMMDLG.DLL     Common Dialog Boxes for Windows 3.0
```

```
               Users Only
README.WRI     Installation Instructions
```

1.6.   Registering Astronomy Lab

Astronomy Lab is shareware.   To register your copy, please send $15.00 US plus postage and handling to:

Personal MicroCosms
8547 E. Arapahoe Road
Suite J-147
Greenwood Village, CO   80112   USA

Postage and Handling:

US and Canada: $2.50   Overseas: $10.00 (for airmail delivery)

What you get for registering:

1.   Disk containing the latest version of Astronomy Lab.   Please specify disk type: 5 1/4" high density or 3 1/2" high density.

2.   Personal MicroCosms' customer support telephone number.

3.   Notification by mail when future versions of Astronomy Lab are available.

We Accept:

Checks in US funds drawn on a US bank
Registration on CompuServe ("GO SWREG")
International Postal Mail Orders
American Express International Money Orders
US Cash

2.1. Purpose

The purpose of this chapter is to rapidly acquaint you with many of the most important features of Astronomy Lab.   The topics introduced in this chapter will be discussed in greater depth in Chapter 3 and Chapter 4.

It is best to go through this tutorial in order, from the beginning to the end.   If you decide to quit the program before finishing this tutorial, you can quit Astronomy Lab as follows: Select the File menu and the Exit item (Alt,F,X).

2.2. On-Line Help

Astronomy Lab has a comprehensive on-line help system.   Press F1 to get on-line help.

Type Alt,H,G to read the on-line User's Guide.

To get help on a given menu item (e.g. the Printer Setup item), select the appropriate menu (e.g. Alt,F).
Then move to the item by typing the up and down arrow keys.   Then press F1 for help on the menu item.

To get help on a given dialog box, simply press F1 when the dialog box is displayed.

You can also get help by selecting an item from the Help menu.

2.3. Setting Your Location

Astronomy Lab produces reports, graphs, and movies that are customized for your latitude, longitude, time zone, and elevation.   Every date and time that you type into Astronomy Lab must be for your local time zone.   All results from Astronomy Lab will be for your local latitude, longitude, time zone, and elevation.

In order to use Astronomy Lab, you must first enter your latitude, longitude, elevation, and time zone with the Set Location command.   Select the Location menu and the Set Location item (Alt,L,S).

The location of your city may already be available in Astronomy Lab's city location database.   To find out, press the arrow at the right of the Location text box to open the drop-down list box.   If your city is in the list box, select it with the mouse and press the Save button.

If your city is not in the database,   type its name in the Location text box.   Go to the Latitude group box and enter your latitude in degrees, <u>minutes</u>, and <u>seconds</u>.   Press the North button if you live north of the equator, and press the South button otherwise.

Go to the Longitude group box and enter your longitude in degrees, <u>minutes</u>, and <u>seconds</u>.   Press the West button if you live West of Greenwich, England, and press the East button otherwise.

Go to the Elevation text box and enter your elevation above or below sea level in meters (to convert feet to meters, multiply feet by 0.3048).   If you live below sea level, enter a negative elevation.   Round your elevation to the nearest whole number.   If you don't know your elevation, enter 0.

Go to the Time Zone text box and enter your time zone.   For locations in the U.S.A., use the following table:

Table 2: U.S. Time Zones

```
Region      Time Zone

Eastern     -5
Central     -6
Mountain    -7
Pacific     -8
```

All times entered into Astronomy Lab and output by Astronomy Lab are standard time, not daylight savings time.   For further information on time zones, see <u>Universal Time and Time Zones</u>.

Now press the Save button and your location information will be saved in the city location database and will be automatically loaded when Astronomy Lab is run again.   Pressing the OK button will only save the location information until you exit the program.

2.4. Assigning Colors

Make sure that all objects drawn by Astronomy Lab will be visible and attractive by using the Assign Colors command.   For further information, see <u>Assign Colors</u>.

2.5. The Planetarium Movie

The Planetarium movie is an animated display of the <u>celestial sphere</u>, complete with the sun, moon, planets, and stars (see figure 1, below).

```
┌────────────────────────────────┐   Planetarium
│  .        .'           .     .'│
│     .                          │   Date: 07/07/1991
│       .                    .   │   Time: 18:52
│                                │   GST:  20:54
│  .      .        .         .   │   LST:  13:54
│                         .'.    │   Julian Date (UT)
│           .          .'  ▒▒▒   │    2448445.57
│    .    .    .          ▒▒Sun▒ │   RA:     8h37m02s
│  .    .        Mercury   ▒▒▒▒  │   DEC:  20°07'48"
│  .          Jupiter ●      .   │
│     . Mars       ● .         . │ . Alt:   20°45'20"
│    Venus                     . │   Azi:  279°24'37" (NW)
│    . ●       _           .     │   View Angle: 90.00°
│  .        .      .       .     │   Time Speed:    0
│         . .'  .       .        │   Turbo is Off
│       .         .       .   .  │   Tracking is On
│          .          .          │
│    .         .     .           │
│    .'   .      .               │
│    .              .            │
└────────────────────────────────┘
```
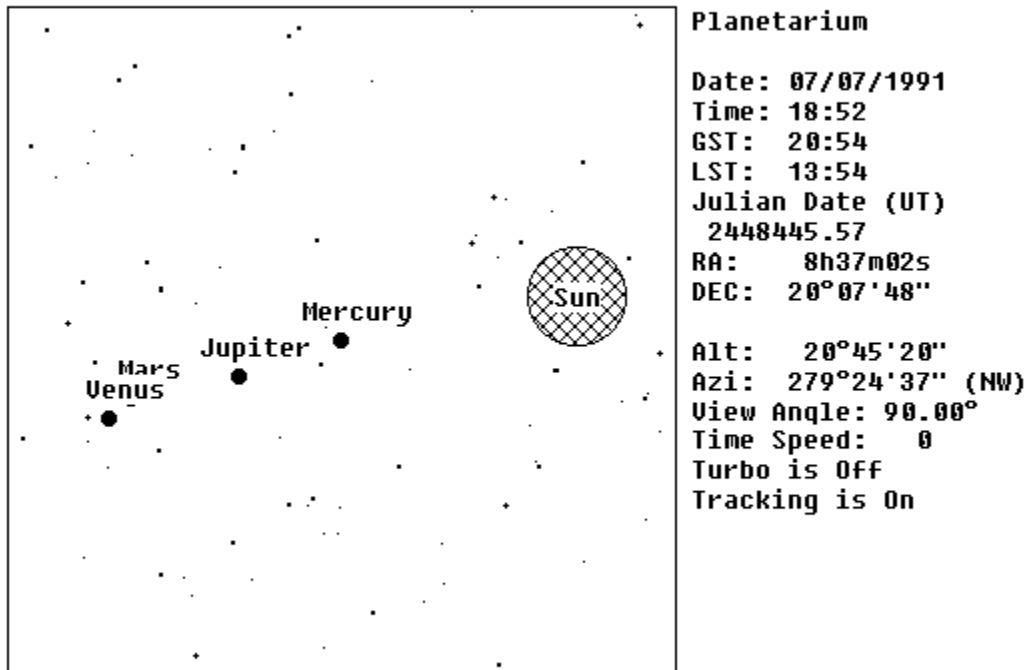
Figure 1:   Planetarium Movie Frame

2.5.1.   Starting the Planetarium Movie

To start the Planetarium movie, choose Movies Planetarium (Alt,M,P).   Enter the current date and time (in 24 hour format) for the movie.   SHORTCUT: to automatically enter the current date and time, press the Now button.

The time speed, which must be a whole number between -64 and 64, controls the rate at which the computer's clock changes between successive frames of a movie.   For example, a time speed of 64 will cause the computer's clock to move ahead by a large amount from frame to frame.   A time speed of 1 will cause the clock to move ahead by a much smaller value.   A time speed of 0 will cause the computer's clock to stay at the same time, and a negative time speed will cause the clock to move backwards.   Enter a time speed of 64.

Make sure that the Turbo check box is cleared.   Turbo mode will be discussed later.

The view angle, which is given in degrees (°), determines how much of the celestial sphere will appear in the movie.   The view angle must be between 5° and 90°.   A large view angle will cause a large portion of the celestial sphere to appear in the movie, and a small view angle will result in a small region appearing in the movie.   Enter a view angle of 90°.

Now you will need to decide which body will appear in the center of the screen when the movie begins - you can choose the sun, moon, a planet, or a star by pressing the appropriate button.   Choose the sun by pressing the Sun button.

At this point you've specified that the sun will initially appear in the center of the screen.   If you select the Track Body check box, the program will track the movement of the sun, and keep it in the center of the screen throughout the movie.   If you clear the Track Body check box, the sun will slowly move away from the center of the screen, just as it would if you were observing it through a stationary telescope.   Disable tracking by clearing the Track Body check box.

Now you will need to select which bodies will appear in the movie by going to the View group box and selecting and clearing the Sun/Moon, Planets, and Stars check boxes.   The more bodies that you select, the slower the movie will run.   If you're not interested in seeing a particular body, clear its check box. For this session, select the Sun/Moon, Planets, and Stars check boxes.   If you want planets labeled, select the Label Planets check box, otherwise clear it.   Press the OK button and the movie will run.

2.5.2.   Description of the Screen

Figure 1 is a Planetarium movie frame.   Note that the sun and moon appear as large disks with their names inside.   Stars appear as small circles.   The size of a star is proportional to its visual magnitude - a bright star will be large and a dim star will be small.   Planets appear as colored circles with their names beside them.

Information about the movie is displayed on the right of the screen.   The time, date, time speed, view angle, Greenwich sidereal time (GST), local sidereal time (LST), and Julian date of the movie are displayed.   Also, the position of the center of the screen is given in equatorial coordinates (RA and DEC) and horizon coordinates (altitude and azimuth).

2.5.3.   Changing the Planetarium Movie

You can change the time speed, view angle, and the portion of the celestial sphere displayed on the screen while the Planetarium movie is running.

To increase the time speed, choose Movies Speed Up (Alt,M,U or F2).   To decrease the time speed, choose Movies Slow Down (Alt,M,D or F3).   To reverse the time speed, choose Movies Reverse Time Speed (Alt,M,R or F4).

To decrease the view angle, choose Movies Zoom In   (Alt,M,I or F6).   To increase the view angle choose Movies Zoom Out (Alt,M,O or F7).

To explore other parts of the celestial sphere, move the horizontal and vertical scroll bars with the mouse, or type the arrow keys.   You can only move around the celestial sphere if you cleared the Track Body check box.

2.5.4. Turbo Mode

The time speed determines the amount of time that will pass between successive Planetarium movie frames.   However, if Turbo mode is enabled by selecting the Turbo check box, the amount of time that elapses between frames will be increased by a factor of 1000.   Turbo mode is useful for observing events that happen very slowly, over a period of days or months.   Turbo mode has one restriction: it requires that you track on a star or a planet.   Turbo mode is only available for the Planetarium movie.

2.5.5.   Stopping Movies

Any movie can be stopped at any time by pressing the Esc key.   After a movie is stopped in this manner you will be free to execute other commands.   When you have finished watching the Planetarium movie, stop the movie by pressing the Esc key.

This tutorial has discussed only the main points of the Planetarium movie.   Chapter 3 will show how to use the Planetarium movie to view the following astronomical phenomena:

*   Solar Eclipses
*   Lunar Eclipses
*   Transits of Mercury and Venus
*   Lunar Occultations of Stars and Planets
*   Planetary Occultations

2.6.   The Jupiter Moons Orbit Graph

The Jupiter Moons Orbit graph (see figure 2, below) shows the configurations of Jupiter's four bright moons over a given month.   The horizontal strip in the middle of the graph represents the width of Jupiter's disk.   Following traditional practice, east and west are reversed - therefore if a moon appears to the west on the graph, it will appear to the east when viewed with a non-inverting telescope or binoculars.

To generate a Jupiter Moons Orbit graph, choose Graphs Jupiter Moons Orbit (Alt,G,J).   Enter the year and month for the graph.   Select the check boxes for the moons that you want to appear in the graph, and clear the others.   Select the Number Moons check box if you want the moons numbered in the graph, otherwise clear it.   Press the OK button and the graph will be drawn.

Any graph can be stopped at any time by pressing the Esc key.   After a graph is stopped in this manner you will be free to execute other commands.
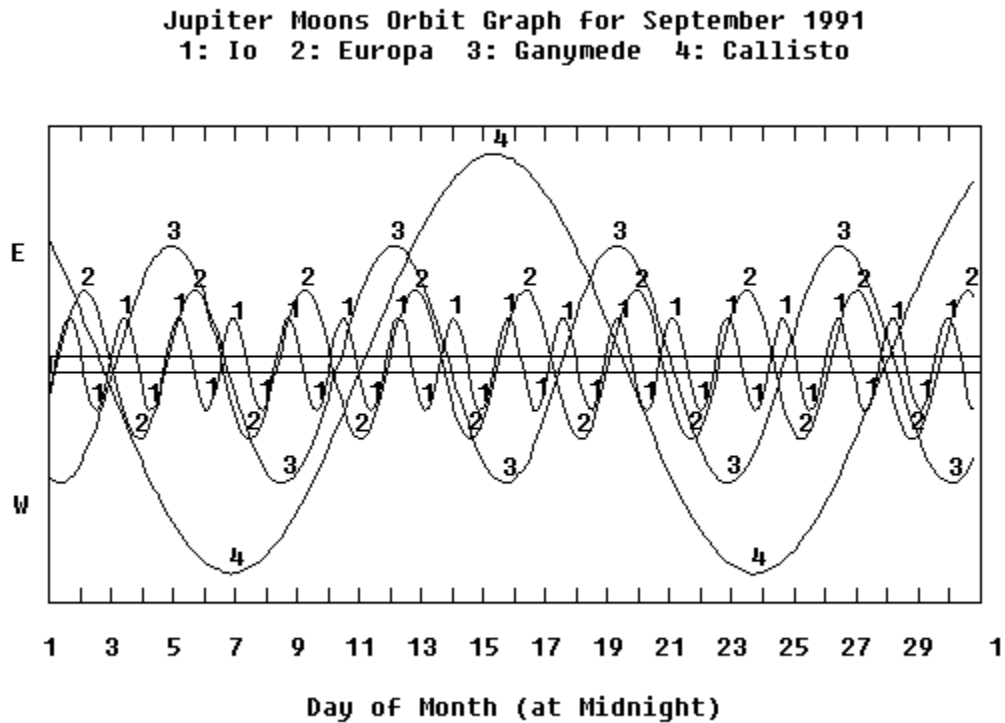
Figure 2:   Jupiter Moons Orbit Graph

2.7.   The Calendar Report

The Calendar report is a yearly calendar giving the times and dates of the following astronomical events:

*   Sun Rise and Set
*   Moon Rise and Set
*   Solar Eclipses
*   Lunar Eclipses
*   <u>Moon Phases</u>
*   <u>Equinoxes</u> and <u>Solstices</u>

To generate a Calendar report, first enter your location information with the Set Location command (Alt,L,S).   Then choose Reports Calendar (Alt,R,C).

Enter the year and start and stop month.   For example, if you enter a start month of 9 and a stop month of 11, a report will be generated for September to November of the specified year.   Press the OK button and the report will be generated.

NOTE: There are days in which the sun does not rise or set (in far northern and southern latitudes), and days in which the moon does not rise or set (everywhere).   In these cases a time of "None" is given.   All abbreviations used in the Calendar report are listed in <u>Appendix B</u>.

Any report can be stopped while it is running.   To stop a report, press the Esc key or select Stop Stop Command (Alt,S,S).   The report will stop, and you will be free to execute other commands.

2.8.   Congratulations!

You've just completed the tutorial.   Although new commands will be introduced in the following chapters, and the commands that you've already learned will be discussed in greater depth, you have already mastered many of the most important features of Astronomy Lab.

3.1. Purpose

The purpose of this chapter is to show how Astronomy Lab simulates several important astronomical phenomena, including eclipses, transits, occultations, and the orbits of Jupiter's moons.   This chapter also discusses the numerous reports and graphs produced by Astronomy Lab.   It is best to read this chapter from beginning to end since later sections build on knowledge introduced in earlier sections.

3.2. Solar Eclipses

WARNING: NEVER look directly at the sun, even for a moment - serious and permanent damage to
your vision could result.   For information about observing astronomical events involving the sun, consult
a textbook on astronomical observation.

Examine figure 3 (below) which is a diagram of a solar eclipse.   Notice that moon's shadow has two
components, an inner, dark region called the umbra, and an outer, lighter region called the penumbra.   A
total eclipse of the sun is visible at the point where the umbra and the earth's surface meet.   Observers in
the shade of the penumbra will observe a partial eclipse.
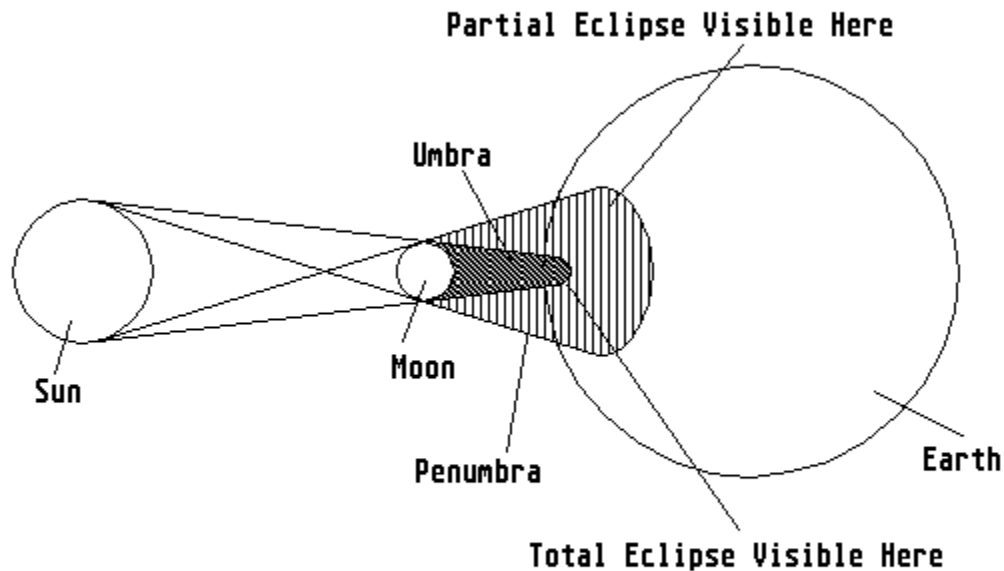
Figure 3:   Solar Eclipse

A total solar eclipse occurs when the moon moves between the earth and the sun, completely covering up
the sun.   An annular eclipse happens when the moon moves between the earth and the sun, but does
not completely cover up the sun.   During the middle of an annular eclipse a thin ring of the sun (called an
annulus) is visible behind the moon.   An annular-total eclipse will appear total to observers in some
locations, and annular to observers located elsewhere.   A partial eclipse takes place when the moon
covers up only a portion of the sun's disk.

Due to the elliptical orbit of the moon around the earth and the earth around the sun, sometimes the disk
of the moon appears larger than the disk of the sun (e.g.   during a total eclipse of the sun), and
sometimes the moon's disk appears smaller than the sun's (e.g.   during an annular eclipse).

Astronomy Lab can simulate all types of solar eclipses.   Table 3 contains the information necessary to
reproduce an example of each type of solar eclipse:

Table 3:   Data for Three Types of Solar Eclipses [1]

```
Type of  Date and Time of  Latitude     Longitude
Eclipse  Max. Ecl. (UT)

Total    8/21/2017 18:25   36°58'00"N   87°37'42"W
Annular  2/26/2017 14:53   34°41'36"S   31°08'24"W
Partial  3/ 7/1989 18:08   39°44'58"N  104°59'22"W
```

To view the above eclipses, first use the Set Location command (Alt,L,S) to enter the latitude and longitude from table 3.   Enter a time zone of 0 since the times are in UT.

Then choose Movies Planetarium (Alt,M,P).   Enter the date of the solar eclipse and a time about 1 hour before the maximum eclipse.   Type in a time speed of 64.   Disable Turbo mode by clearing the Turbo check box.   Type in a view angle of 5°.   Since the sizes of the disks of the sun and moon are exaggerated at view angles greater than 5°, a view angle of 5° must be specified in order to accurately observe eclipses, transits, and occultations.

Press the Sun button.   Specify that you want tracking done by selecting the Track Body check box.

Now select the bodies that will appear in the movie - in the View group box select the Sun/Moon check box and clear the others.   Press the OK button and a movie of the solar eclipse will run.


```
Planetarium

Date: 07/11/1991
Time: 12:11
GST:  14:28
LST:   7:28
Julian Date (UT)
 2448449.29
RA:    7h22m13s
DEC:  22°05'45"

Alt:  72°03'26"
Azi: 184°10'10" (SW)
View Angle:  5.00°
Time Speed:   0
Turbo is Off
Tracking is On
```
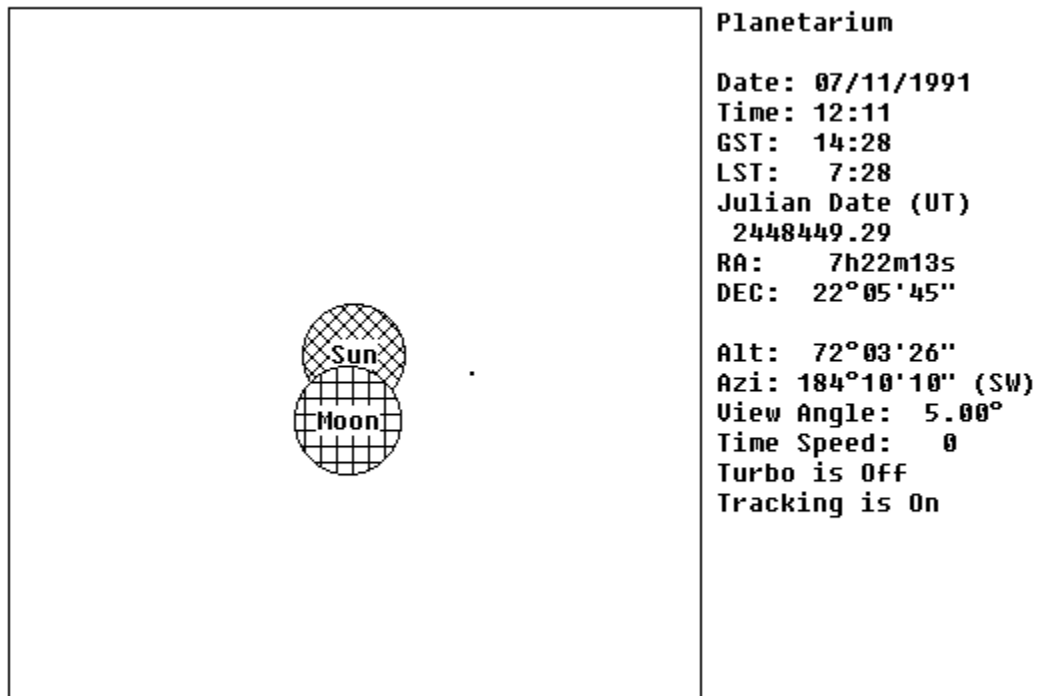
Figure 4:   Planetarium Movie of Partial Solar Eclipse

3.3. Lunar Eclipses

Like the moon's shadow, the earth's shadow has two components: a large conical shadow called the penumbra, and a smaller conical shadow called the umbra (see figure 5, below).   The umbra is much darker than the penumbra.
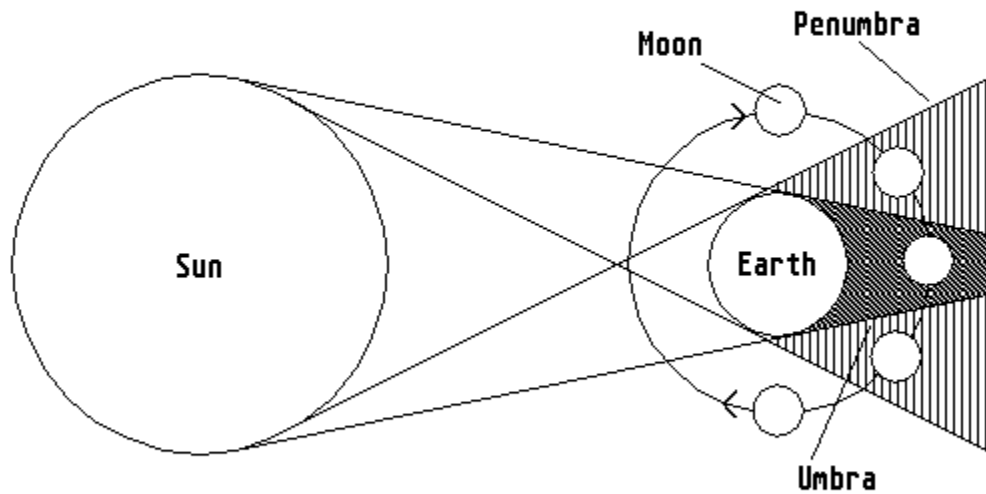
Figure 5:   The Earth's Shadow and Lunar Eclipses

A penumbral lunar eclipse occurs when the moon passes through the penumbra but does not enter the umbra.   An umbral eclipse happens when the moon passes through the umbral portion of the earth's shadow.   During an umbral eclipse, a dark shadow is cast on the surface of the moon.   In order to enter the umbra, the moon must first pass through the penumbra, consequently every umbral eclipse has a penumbral phase (when the moon first enters the penumbra) followed by an umbral phase (during which the moon is in the shade of the umbra), followed by another penumbral phase (when the moon leaves the umbra).

An umbral eclipse is total if the moon moves entirely inside the umbra.   During a partial lunar eclipse part of the moon's disk does not enter the umbra and will be visible during the entire eclipse.

Unlike the total phase of a solar eclipse which is only visible to observers located inside a small eclipse track, the total phase of a lunar eclipse can be viewed by anyone who can see the moon at the moment it becomes full.

Astronomy Lab can run movies of all types of lunar eclipses.   Table 4 can be used to simulate some past lunar eclipses:

Table 4:   Data for Three Types of Lunar Eclipses [2]

```
Type of          Date        Time of Max.  Umbral
Eclipse                      Eclipse       Magnitude
                             (ET)


Umbral/Total     5/ 4/1985   19:57         1.237
Umbral/Partial   8/27/1988   11:05         0.292
Penumbral        4/14/1987    2:20         undefined
```

To simulate a lunar eclipse, first enter your location and time zone (Alt,L,S).   Enter a time zone of 0 since the times in the above table are in Ephemeris Time (ET).   For further information about ET, see Ephemeris Time.

After setting your location, choose Movies Planetarium (Alt,M,P).   Enter the date of the eclipse from table 4, and a time about 1 hour before the maximum eclipse.   Specify a time speed of 64 and   make sure that Turbo mode is disabled by clearing the Turbo check box.   Specify a view angle of 5°.   Since the sizes of the disks of the sun and moon are exaggerated at view angles greater than 5°, a view angle of 5° must be specified in order to accurately observe eclipses, transits, and occultations. Select the Moon button.   Specify that you want tracking done by selecting the Track Body check box.

Now select the bodies that will appear in the movie - in the View group box select the Sun/Moon check box and clear the others.   Press the OK button and a movie of the lunar eclipse will run.   Check to see if the eclipse was visible from your location - if the altitude of the moon is positive, the eclipse was visible.


```
Planetarium

Date: 02/09/1990
Time: 10:54
GST:   3:12
LST:  20:12
Julian Date (UT)
 2447932.24
RA:     9h28m23s
DEC:  13°44'21"

Alt: -33°24'18"
Azi: 337°38'06" (NW)
View Angle:  5.00°
Time Speed:  64
Turbo is Off
Tracking is On
```
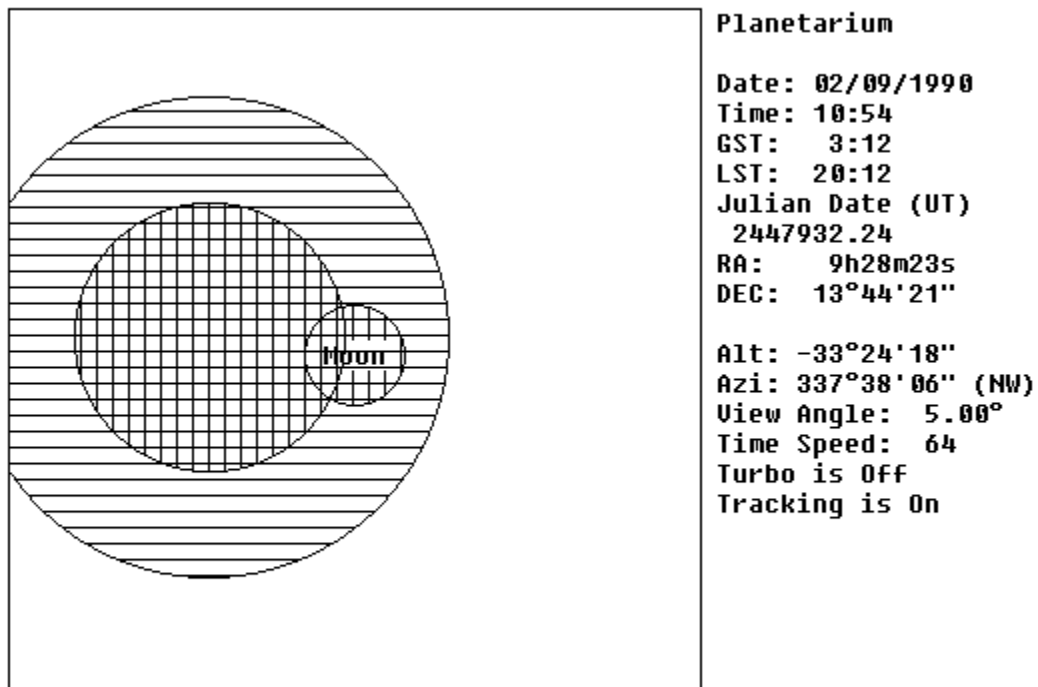
Figure 6:   Planetarium Movie of Lunar Eclipse

3.4.   Transits of Mercury and Venus

WARNING: NEVER look directly at the sun, even for a moment - serious and permanent damage to your vision could result.   For information about observing astronomical events involving the sun, consult a textbook on astronomical observation.

A transit occurs when an inner planet comes directly between the earth and the sun and appears as a black spot on the sun's disk.

Transits of Mercury and Venus occurred only one month apart in 1631.   The data for this pair of transits is given in table 5:

Table 5:   Data for Two Transits [3]

```
Planet     Date             Time Planet Closest to
                            Center of Sun's Disk (ET)


Mercury    11/7/1631       7:22
Venus      12/7/1631       5:18
```

The above table is provided so that you can simulate transits with Astronomy Lab.   To simulate a transit, first enter your location information with the Set Location command (Alt,L,S).   Enter a time zone of 0 since the times in the above table are in ET.

Now choose Movies Planetarium (Alt,M,P).   Enter the date and time of the transit from table 5.   Specify a time speed of 64 and disable Turbo mode by clearing the Turbo check box.   Specify a view angle of 5°. Since the sizes of the disks of the sun and moon are exaggerated at view angles greater than 5°, a view angle of 5° must be specified in order to accurately observe eclipses, transits, and occultations.

Select the Sun button.   Specify that you want tracking done by selecting the Track Body check box. Now you will need to select the bodies that will appear in the movie - in the View group box select only the Sun/Moon and Planets check boxes.   Press the OK button and a movie of the transit will run.

3.5. Lunar Occultations

A lunar occultation happens when the moon moves in front of a star or planet. If the occulted body is covered up by just the outer edge of the moon's disk, the occultation is called a grazing occultation. During a grazing occultation the occulted body will vanish behind lunar mountains and reappear behind lunar valleys as the moon moves by.

3.5.1. Lunar Occultation of a Star

Astronomy Lab simulates lunar occultations.   For example, you can simulate the occultation of the star
Regulus by the moon of October 6, 1988.   This occultation was visible in Denver (latitude 39°44'58"N,
longitude 104°59'22"W) and began with the star vanishing behind the moon at 20:46 UT [4] (see figure 7,
below).

To view this occultation, first enter the latitude and longitude of Denver with the Set Location command
(Alt,L,S).   Enter a time zone of 0 since the time of the occultation is given in UT.

Now choose Movies Planetarium (Alt,M,P).   Enter the date of the occultation.   To see the star before it is
occulted, enter a time about 30 minutes before the beginning of the occultation.   Enter a time speed of 64
and disable Turbo mode by clearing the Turbo check box.   Specify a view angle of 5°.   Since the sizes of
the disks of the sun and moon are exaggerated at view angles greater than 5°, a view angle of 5° must be
specified in order to accurately observe eclipses, transits, and occultations.

Select the Star button and select Leo/Regulus from the Star list box.   Specify that you want tracking
done by selecting the Track Body check box.   In the View group box, select only the Sun/Moon and Stars
check boxes, and then press the OK button.


```
Planetarium

Date: 10/06/1988
Time: 20:15
GST:  21:17
LST:  14:17
Julian Date (UT)
 2447441.34
RA:   10h07m46s
DEC:  12°01'29"

Alt:  28°43'52"
Azi: 261°22'56" (SW)
View Angle:  5.00°
Time Speed:  64
Turbo is Off
Tracking is On
```
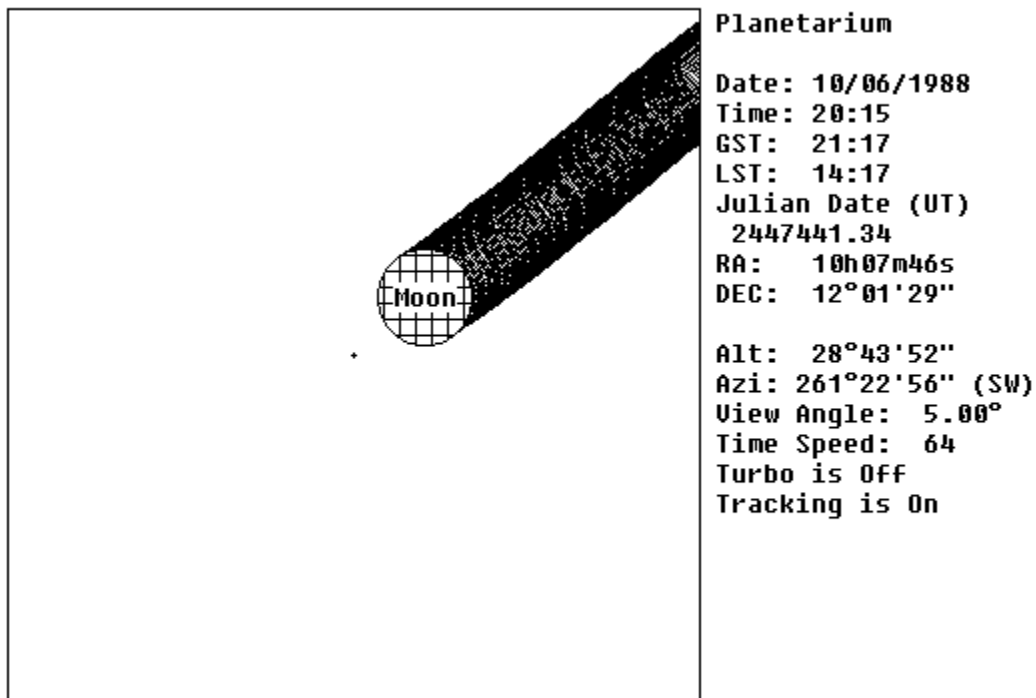
Figure 7:   Lunar Occultation of Regulus

3.5.2. Lunar Occultation of a Planet

A lunar occultation of a planet is a very rare event.   The moon occulted the planet Uranus in 1832 (see figure 8, below).   Table 6 contains the data that you'll need to watch a movie of the occultation:

Table 6:   Data for a Lunar Occultation of Uranus [5]

```
Date         Start (UT)  Latitude      Longitude

10/4/1832  21:00        35°00'00"S   20°00'00"E
```

To view the occultation, first use the Set Location command (Alt,L,S) to type in the latitude and longitude from table 6.   Specify a time zone of 0 since the time is given in UT.

Then choose Movies Planetarium (Alt,M,P).   Type in the date of the occultation, and enter a time about 1 hour before the beginning of the occultation (so that you will see the planet before it is occulted by the moon).   Enter a time speed of 64 and disable Turbo mode by clearing the Turbo check box.   Specify a view angle of 5°.   Since the sizes of the disks of the sun and moon are exaggerated at view angles greater than 5°, a view angle of 5° must be specified in order to accurately observe eclipses, transits, and occultations.

Press the Uranus button and select the Track Body check box.   In the View group box select only the Sun/Moon and Planets check boxes.   Press the OK button and the movie of the occultation will begin.
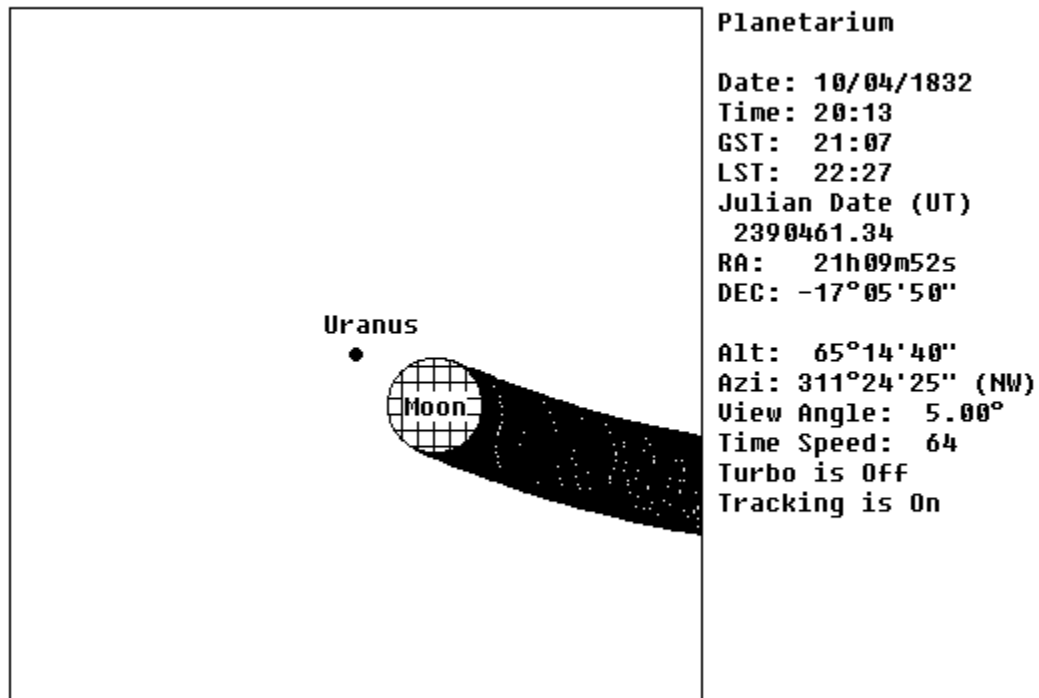
Figure 8:   Planetarium Movie of Lunar Occultation of Uranus

3.6. Planetary Occultations

Like the moon, planets can occult stars and other planets.   On July 14, 1708 at 13:02 ET, Mercury occulted Uranus [6] (see figure 9, below).   To view this occultation, first use the Set Location command (Alt,L,S) and type in your location.   Enter a time zone of 0 since the time of the occultation is given in ET.

Now choose Movies Planetarium (Alt,M,P).   Enter the date of the occultation.   Enter a time of 10:00 so that you'll be sure to see both planets before the occultation.   Enter a time speed of 64 and make sure that Turbo mode is disabled by clearing the Turbo check box.   Specify a view angle of 5°.   Since the sizes of the disks of the sun and moon are exaggerated at view angles greater than 5°, a view angle of 5° must be specified in order to accurately observe eclipses, transits, and occultations.

Press the Uranus button.   Specify that you want tracking done by selecting the Track Body check box. In the View group box, select the   Planets check box and clear the rest.   Press the OK button and a movie of the occultation will run.

```
Planetarium

Date: 07/14/1708
Time:  1:33
GST:  21:01
LST:  22:21
Julian Date (UT)
 2345088.56
RA:     9h16m59s
DEC:   16°32'05"

Alt: -66°37'27"
Azi: 138°05'57" (SE)
View Angle:  5.00°
Time Speed:    1
Turbo is On
Tracking is On
```
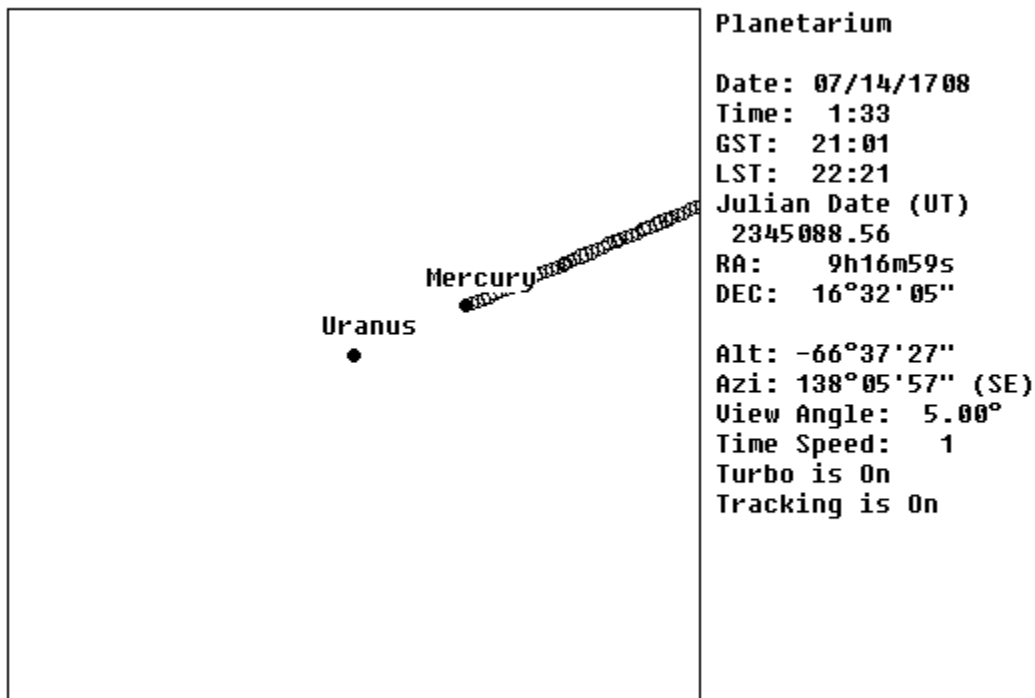
Figure 9:   Planetarium Movie of Planetary Occultation

Table 7 contains predictions of all mutual planetary occultations before the year 2100:

Table 7:   Mutual Occultations of Planets: 2000 - 2100 [7]

Date	Time (ET)	Occulting Planet	Occulted Planet
11/22/2065	12:47	Venus	Jupiter

```
 7/15/2067  11:57      Mercury    Neptune
 8/11/2079   1:30      Mercury    Mars
10/27/2088  13:46      Mercury    Jupiter
 4/ 7/2094  10:46      Mercury    Jupiter
```

4.1. Purpose

The purpose of this chapter is to present activities that will help you to learn important astronomical concepts in greater depth.

4.2.   The Saros Cycle

In this activity you will learn how to predict future solar and lunar eclipses without even using a calculator, by using an ancient method discovered thousands of years ago.

A saros is a length of time approximately equal to 18 years, 11 days, and 8 hours. Solar eclipses are cyclic: given the date and time of a solar eclipse, another solar eclipse will tend to occur approximately one saros later.   The same holds true for lunar eclipses.

This cycle was apparently discovered by various ancient civilizations after centuries of careful eclipse observations and accurate record-keeping.   The saros cycle exists because "... the various periods of the sun and moon's motion all beat together at that frequency [i.e. once every saros]." [8]

You can use knowledge of the saros cycle to predict eclipses without even using a calculator.

4.2.1. Predicting a Solar Eclipse

To predict a solar eclipse, just add one saros to the time and date of a known solar eclipse. At the resulting time and date another solar eclipse is very likely to happen.

For example, take the solar eclipse of 3/7/1989 at 18:06 UT.   Adding one saros (i.e. 18 years, 11 days, and 8 hours) to this date and time gives a date and time of 3/19/2007 at 2:06 UT.   Checking a Solar Eclipses report confirms the prediction: a solar eclipse will take place on 3/19/2007 at about 2:31 UT.

Take the dates and times of the other solar eclipses in table 3 and predict the solar eclipses that are likely to happen one saros later.   Verify your results by generating Solar Eclipses reports. Were all of your predictions accurate?

4.2.2.   Predicting a Lunar Eclipse

To predict a lunar eclipse, just add one saros to the time and date of a known lunar eclipse. At the resulting time and date another lunar eclipse is very likely to happen.

For example, take the lunar eclipse of 5/4/1985 at 19:59 UT.   Adding one saros to this date and time gives a date and time of 5/16/2003 at 3:59 UT. Checking a Lunar Eclipses report confirms the prediction: a lunar eclipse will take place on 5/16/2003 at about 3:43 UT.

Take the dates and times of the other lunar eclipses in table 4 and predict the lunar eclipses that are likely to happen one saros later.   Verify your results by generating Lunar Eclipses reports. Were all of your predictions accurate?

Because some years are leap years, your solar and lunar eclipse predictions may be off by a day or two. Also, an eclipse is not always followed by another eclipse one saros later.

For further information on the saros cycle, see "Commensuration for Astronomical Prediction". [9]

4.3. Space Exploration

Every 175 years the outer planets (i.e. Jupiter, Saturn, Uranus, and Neptune) line up so that a space probe launched from earth can easily visit each planet, one after the other.   The scientists of the Voyager II project took advantage of this alignment, which happened in 1977. [10]

Figure 10 shows the positions of earth and the Outer Planets on August 20, 1977, the date of Voyager II's launch. Voyager II followed a spiral path, bringing the craft to Jupiter in 1979, Saturn in 1981, Uranus in 1986, and Neptune in 1989. After visiting Neptune Voyager II continued on beyond the solar system.
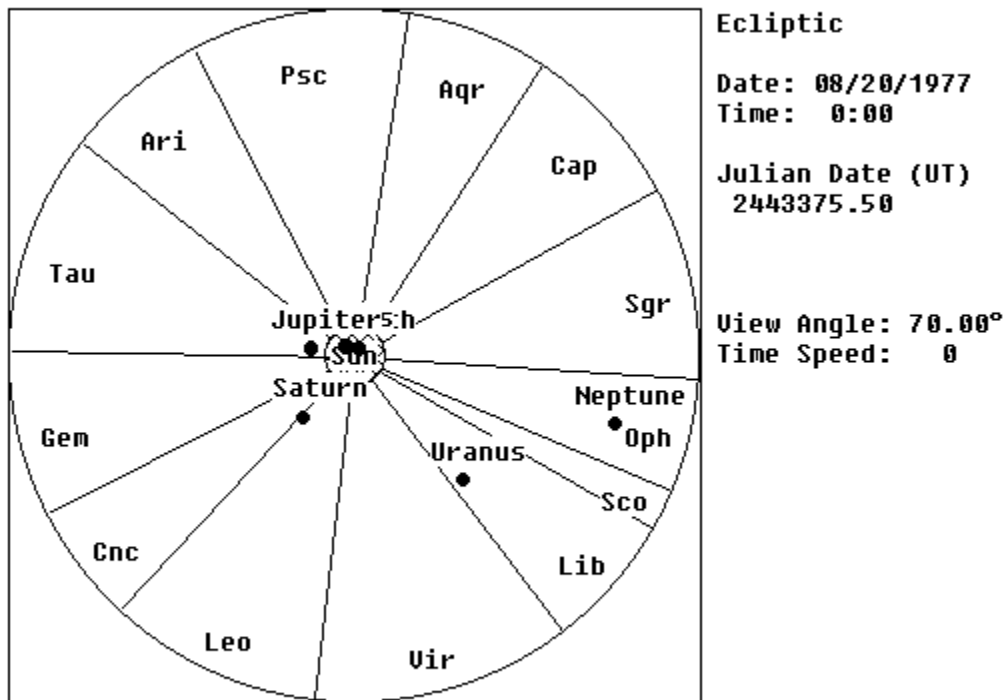
Figure 10:   Outer Planets at Launch of Voyager II

To observe the periodic alignments of the outer planets, run an Ecliptic Top movie for the years 2327, 2502, 2677, and 2852.   When you run the movie, select a view angle of 90° (so that all of the planets will be visible), and select the buttons for the earth, Jupiter, Saturn, Uranus, and Neptune.

4.4. Inclination

By definition, the earth is the only planet that is always on the ecliptic. All other planets spend some of their time above the ecliptic, and the rest of the time below (see figure 11, below). The reason for this is that the orbital planes of all planets except the earth are at an angle with respect to the ecliptic. This angle is called a planet's inclination.

A planet passes through the ecliptic at two points, called the nodes of the planet's orbit. A planet passing through the ecliptic going up is at its ascending node. A planet passing through the ecliptic going down is at its descending node.
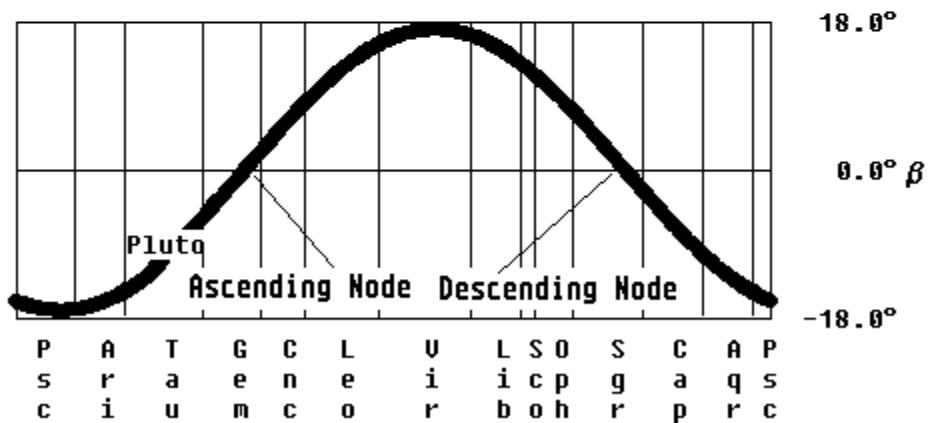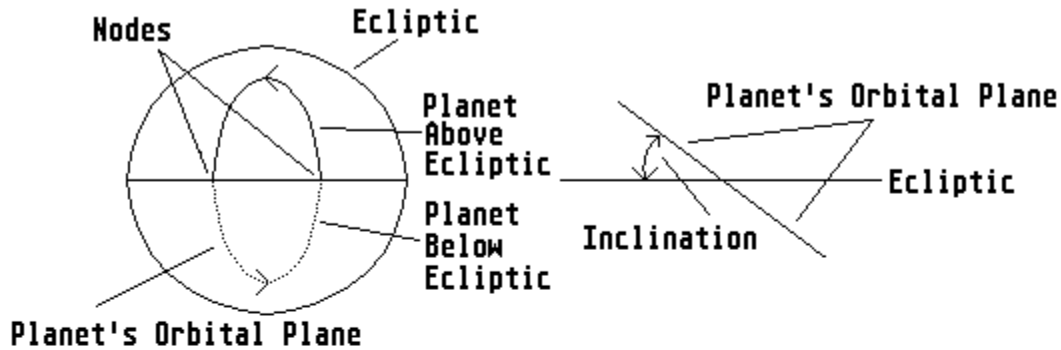
Figure 11:   Inclination

The Ecliptic Side movie can be used to view the effects of inclination: Select Jet Trails (Alt,M,T).   Then run an Ecliptic Side movie, specify a time speed of 4, and select only Mercury.

Notice that Mercury's angle above or below the ecliptic is constantly changing (consequently the planet rises and falls during the movie).   Since the inclination of Mercury is about 7°, the planet rises half way to the top of the rectangle and sinks half way to the bottom of the rectangle. The planet crosses the middle of the rectangle when it is at one of its nodes (and its angle with respect to the ecliptic is 0°).

Run an Ecliptic Side movie for other planets and observe how their inclinations compare to Mercury's.

4.5. Planetary Retrograde Motion

The motion of a planet with respect to the stars can be from west to east (called direct motion) or from east to west (called retrograde motion).   Figure 12 shows Mars' movement over a period of several months: at first Mars moves eastward (direct motion), then it reverses its direction and moves westward (retrograde motion). Finally it reverses its direction again, and moves eastward.


```
Planetarium

Date: 03/02/1991
Time: 20:00
GST:   6:40
LST:  23:40
Julian Date (UT)
 2448318.33
RA:     3h44m19s
DEC:  24°05'06"

Alt:   36°58'47"
Azi:   92°11'20" (SE)
View Angle: 50.00°
Time Speed:   8
Turbo is On
Tracking is On
```
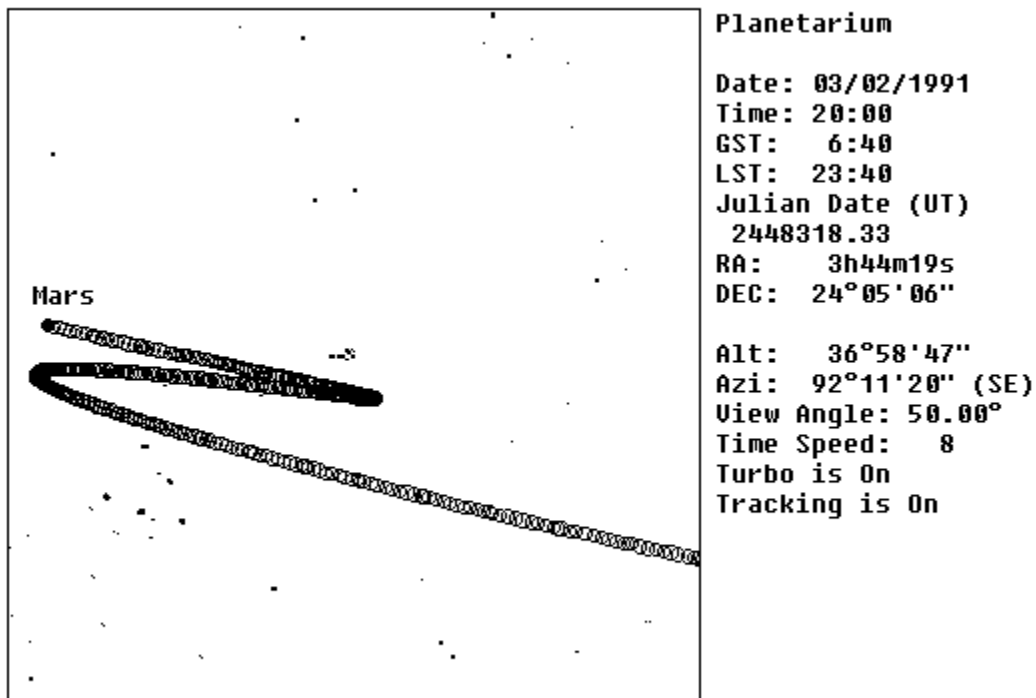
Figure 12:   Motion of Mars, July 1990 - March 1991

To early astronomers, the ability of planets to reverse their apparent directions was a complete enigma. This puzzle was solved in 1543, when "... Copernicus explained retrograde motion by showing that it is an effect of perspective.   It occurs when   the earth passes Mars, as both planets orbit the sun." [11]   Figure 13 shows how retrograde motion happens: when the earth and Mars move from points 1 to 2, Mars appears to undergo direct motion.   When both planets move from points 2 to 4, Mars appears to reverse its direction and undergo retrograde motion.   Finally, as both planets move from points 4 to 5 Mars appears to reverse its direction again and undergo direct motion.
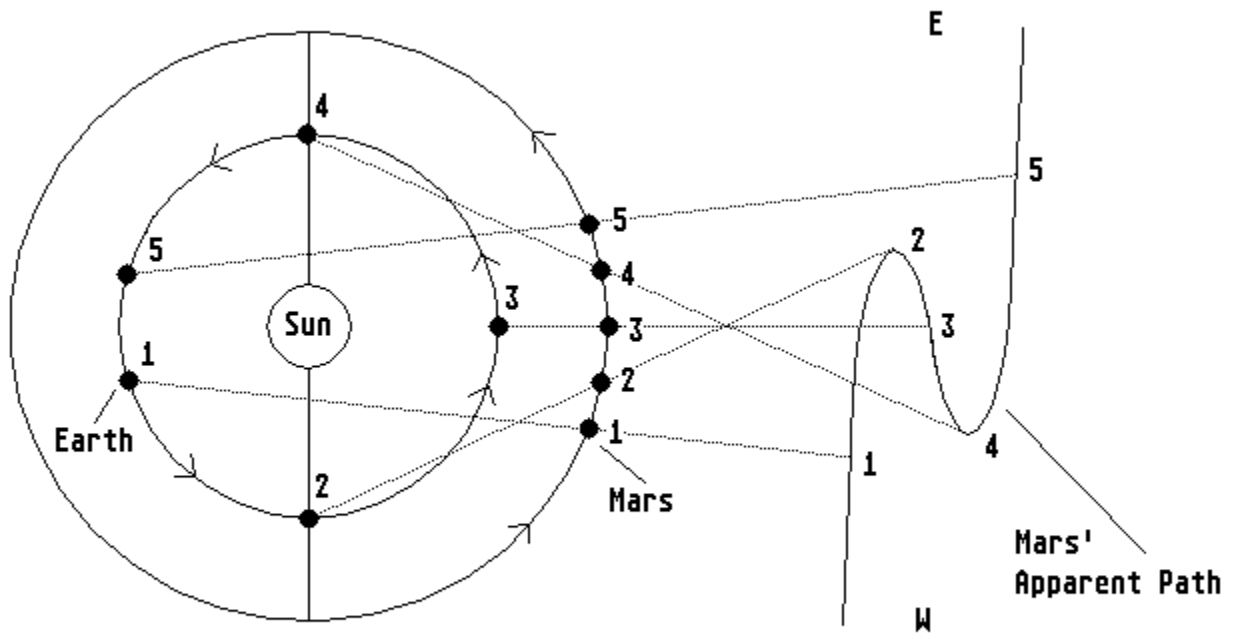
Figure 13:   How Retrograde Motion Happens [12]

4.5.1. Planetarium Movie

To see Mars undergo <u>retrograde motion</u> in 1990, first select Movies Jet Trails (Alt,M,T or F8).   Then run a Planetarium movie.

Specify a date of 8/1/1990 and a time of 0:00.   Enter a time speed of 64 and select the Turbo check box. Enter a view angle of 50°.

Select the Star button, and select the Track Body check box.   Select the star Tau/Electra (p) from the Star list box.   In the View group box, select only the Planets and Stars check boxes and press the OK button.

As the movie runs, you will first see Mars undergo <u>direct motion</u> as it moves towards the left edge of the screen. Then the planet will undergo <u>retrograde motion</u> as it moves to the right.   Finally the planet will return to <u>direct motion</u> as it moves to the left.

4.5.2. Planet Orbit Graph

In addition to watching retrograde motion with the Planetarium movie, you can easily detect the retrograde motions of planets in a Planet Orbit graph.   Generate a Planet Orbit graph for Mars in 1984. The graph will show Mars' right ascension increasing until April, decreasing from April to July, and then increasing once again.

Planets other than   Mars also exhibit retrograde motion.

4.5.3. Planet View Info Report

Retrograde motion can also be found by examining a   Planet View Info report.   To look for retrograde motion in a Planet View Info report,   examine the   column   labeled   RA (right ascension).   If the right ascension is decreasing, the planet is experiencing retrograde motion.   If the right ascension is increasing, the planet is experiencing direct motion.

4.6.   Equinoxes

At either equinox the sun will rise at the point due east on the horizon, and set due west on the horizon. Verify this by using your Calendar report and the Planetarium movie. Due east corresponds to an azimuth of 90°, and due west corresponds to an azimuth of 270°.

4.7. The Length of a Day

Generate Day Length graphs for the north and south poles.   Notice that a year at one of the poles has only one night, which lasts half the year, and one day, which lasts for the remaining half of the year.

Regions far north of the equator experience "midnight sun" during the northern hemisphere's summer, and regions far south of the equator experience midnight sun during the southern hemisphere's summer.

Midnight sun shows up in the Day Length graph as a day lasting 24 hours. Generate some Day Length graphs to determine the minimum latitude (in either hemisphere) necessary to have midnight sun.

Question: For your location, how much longer is a day at the June <u>solstice</u> than a day at the December <u>solstice</u>?

Question: What would a Day Length graph for the equator look like? Why?   After answering these questions,   Generate a Day Length graph to verify your answers.

4.8.   The Horizon Calendar

Some American Indian tribes used a <u>horizon calendar</u> to keep track of the date for agricultural purposes. A <u>horizon calendar</u> is a drawing of the eastern horizon, with the position of the sun at sunrise marked for various dates, used to ascertain the current date.

Use a Sunrise graph to draw a <u>horizon calendar</u> for your area.

4.9.   The Date of Easter

Examine a Calendar report.   Can you determine the date of Easter (see <u>Dates of Easter</u>)   just by looking at the information in the calendar?   Calculate the date of Easter, and then check your results with the Dates of Easter report.

4.10.   Ocean Tides

Ocean tides are caused by the gravitational attractions of both the moon and the sun (the moon provides about 70% of the attraction, and the sun provides about 30%).

When the sun and moon line up (at syzygy, i.e. new or full moon) their tidal forces add together, producing tides for which the difference in elevation between high and low tides is especially large. These tides are called spring tides (and have nothing to do with springtime).   When the sun and moon are at right angles (during first or last quarter moons), the tidal forces of the two bodies tend to cancel each other out, resulting in tides for which the difference in elevation between high and low tides is especially small, called neap tides.

About once every year, a full moon happens near the time of perigee, and about once a year a new moon happens near perigee.   The resulting spring tides are especially high since the moon's gravitational force is at its maximum.

Using Calendar and Moon Apsides reports, predict the dates of these exceptionally high spring tides (hint: find dates of perigees occurring near syzygy).   If you have access to tidal records of your location, verify your predictions.

5.1. Purpose

The purpose of this chapter is to describe all of Astronomy Lab's features.   Features are presented in the order that they appear in the program's menu structure.

5.2.1. Print (Alt,F,P)

Selecting the Print item prints the current report, graph, or movie frame.   You may want to setup the printer before printing.   See <u>Print Setup</u>.

5.2.2. Print Setup (Alt,F,r)

Select the Print Setup item to choose and configure a printer before printing.

5.2.3. Set Font (Alt,F,F)

Select the Set Font item to choose the font that will be used for printing reports.

5.2.4. Exit (Alt,F,x)

Select the Exit item to quit Astronomy Lab.

5.3.1. Copy (Alt,E,C)

Reports, graphs, and movie frames generated by Astronomy Lab can be copied into the Windows Clipboard and subsequently pasted into another Windows program (e.g. a word processor or paint program).

After generating a report, graph, or movie frame, select the Copy item to copy the item into the Clipboard. Then go to another Windows program, select the Paste item from the Edit menu, and the item will be pasted into the program, provided it can paste text or graphics from other programs.

5.4.1. Set Location (Alt,L,S)

The Set Location item is covered in the Tutorial.   See <u>Setting Your Location</u> for further information.

Table 8:   Commands affected by the Set Location Item

Reports	Graphs	Movies
Calendar	Jupiter Moons Orbit	Planetarium
Seasons	Planet Angle	Jupiter Moons Side
Lunar Eclipses	Day Length	Jupiter Moons Top
Solar Eclipses	Sun Angle	Ecliptic Top
Planet View Info	Analemma	Ecliptic Side
Planet Apsides	Sunrise	Day/Night
Planet Conj/Opp	Moon Angular Speed	
Moon Apsides	Moon Illum. Frac.	
Meteor Showers		
Twilight		
Almanac		

5.5.1. Customizing a Report For a Location

Most reports are customized for the location specified with the Set Location command.   For further information, see <u>Setting Your Location</u>.

5.5.2. Scrolling Report Text

After a report has been generated, the report text can be scrolled vertically or horizontally with the scroll bars.   Pressing the Home key will go to the beginning of the report, and pressing the End key will go to the end.   Pressing the Page Up or Page Down will scroll the text up or down one page.   Pressing the up or down arrow keys will move the text up or down one row.   Pressing the left or right arrow keys will move the text one column to the left or right.

5.5.3. Printing a Report

A report can be printed after it has been generated.   See <u>Print</u> for further information.

5.5.4. Copying a Report

A report can be copied into other Windows programs after it has been generated.   See <u>Copy</u> for further information.

5.5.5. Stopping a Report

Any report can be stopped by pressing the Esc key or by choosing Stop Stop Command (Alt,S,S). After stopping a report in this manner you will be free to run other commands.

5.5.6. Introduction (Alt,R,I)

The Introduction report summarizes the most important information needed to interpret reports generated by Astronomy Lab.

5.5.7. Calendar (Alt,R,C)

The Calendar report is described in the Tutorial.   See <u>The Calendar Report</u> for further information.

5.5.8. Seasons (Alt,R,n)

The Seasons report gives the times and dates of <u>equinoxes</u> and <u>solstices</u>, and the lengths of the seasons for a range of years.

5.5.9.   Dates of Easter (Alt,R,E)

Easter is defined as "...   the Sunday after the first full moon immediately after the Spring equinox". [13]
Easter will always fall between March 22 and April 25, inclusive. [14]   The Dates of Easter report gives
the dates of Easter for a given range of years.

5.5.10.   Lunar Eclipses (Alt,R,u)

The Lunar Eclipses report gives predictions of all umbral lunar eclipses that occur in a given range of years.   For further information on lunar eclipses, see <u>Lunar Eclipses</u>.

5.5.11. Solar Eclipses (Alt,R,S)

The Solar Eclipses report gives predictions of all solar eclipses that occur in a given range of years.
NOTE: eclipses predicted in this report may or may not be visible in your area.   To find out, use the
Planetarium movie.   For further information on solar eclipses, see <u>Solar Eclipses</u>.

5.5.12. Planet View Info (Alt,R,V)

The Planet View Info report gives information useful for observing the planets.   The report lists the following information at weekly intervals: the planets' times of rising and setting, equatorial coordinates, elongation, illuminated fraction, and the distance from the earth to the planet in Astronomical Units (AU).

5.5.13. Planet Apsides (Alt,R,A)

All planets (including the earth) move in elliptical orbits around the sun.   The point in a planet's orbit closest to the sun is called <u>perihelion</u>, and the point farthest from the sun is called <u>aphelion</u>.   The Planet Apsides report gives the dates of <u>apsides</u> (i.e.   <u>perihelion</u> and <u>aphelion</u>) for Mercury, Venus, Mars, Jupiter, Saturn, and the earth for a given range of years.

5.5.14. Planet Conj/Opp (Alt,R,P)

The Planet Conj/Opp report gives the times of <u>conjunction</u> and <u>opposition</u> of a set of planets during one year.   Since an inner planet can <u>transit</u> the sun when it is at <u>inferior conjunction</u>, the report predicts <u>transits</u> of Mercury and Venus.   A planet can be occulted by the sun when it is at superior <u>conjunction</u>. Even though this kind of <u>occultation</u> is not visible, it appears in this report.

5.5.15. Planet Data (Alt,R,D)

The Planet Data report gives physical data about the planets.

5.5.16.   Moon Apsides (Alt,R,M)

The moon orbits the earth in an ellipse.   The point in the moon's orbit closest to the earth is called perigee, and the point farthest from the earth is called apogee.   The Moon Apsides report gives the dates and times of the moon's apsides (i.e.   perigee and apogee) together with the moon's angular diameter at the apsides.

5.5.17.   Meteor Showers (Alt,R,h)

The Meteor Showers report predicts the major meteor showers that will occur over a given range of months.

In order to describe this report, some terminology is required: the <u>radiant</u> of a meteor shower is the location on the <u>celestial sphere</u> where the meteors appear to originate.   The <u>zenithal hourly rate (ZHR)</u> is the number of meteors seen every hour under ideal conditions.

The Meteor Showers report gives the following information for each shower: the approximate date when the shower will be at its peak, the shower's name, the <u>ZHR</u>, the epoch 2000 <u>equatorial coordinates</u> of the <u>radiant</u>, the <u>illuminated fraction</u> of the moon, and the <u>ecliptic longitude</u> of the shower.   The moon's <u>illuminated fraction</u> is included because of its effect on viewing conditions - a <u>new moon</u>, with an <u>illuminated fraction</u> of 0.0, will tend to yield the best conditions.

5.5.18.   Twilight (Alt,R,T)

The Twilight report gives the times of astronomical, nautical, and civil twilight over a specified range of months.   In the report, "----" indicates continuous twilight.

The three types of twilight are summarized by the following table:

Table 9:   Types of Twilight

```
Type of Twilight         Position of Sun's Center
                         Below Horizon at
                         Beginning and End

Civil                     6°
Nautical                 12°
Astronomical             18°
```

Twilight happens twice a day.   Morning twilight ends at sunrise and evening twilight begins at sunset.

5.5.19. Almanac (Alt,R,I)

The Almanac report allows you to generate all of Astronomy Lab's reports at one time.

5.6.1. Customizing a Graph for a Location

Most graphs are customized for the location specified with the Set Location command.   For further information, see Setting Your Location.

5.6.2. Colors

The colors of items graphed by Astronomy Lab can be set with the Assign Colors command.   For further information, see <u>Assign Colors</u>.

5.6.3. Grid Lines and Tick Marks

Graphs can be drawn with tick marks or grid lines.   For further information, see <u>Grid Lines</u> and <u>Tick Marks</u>.

5.6.4. Printing a Graph

A graph can be printed after it has been generated.   See <u>Print</u> for further information.

5.6.5. Copying a Graph

A graph can be copied into other Windows programs after it has been generated.   See <u>Copy</u> for further information.

5.6.6. Stopping a Graph

Any graph can be stopped by pressing the Esc key or by choosing Stop Stop Command (Alt,S,S).   After stopping a graph in this manner you will be free to run other commands.

5.6.7. Jupiter Moons Orbit (Alt,G,J)

The Jupiter Moons Orbit graph was described in the Tutorial. See <u>Jupiter Moons Orbit Graph</u> for further information.

5.6.8. Planet Orbit (Alt,G,O)

The Planet Orbit graph is simply a graph of right ascension (alpha) over time.   This graph provides a wealth of information about the planets and their positions in the sky during a year.

Since constellation abbreviations are drawn on the right side of the graph, you can determine the constellation in which a planet will be on a given date.   In the Planet Orbit graph, each planet's curve is connected to its name with a vertical line.

In order to make the best use of the Planet Orbit graph, some new terminology must be introduced.   Two bodies are in conjunction if they have the same right ascension.   When an inner planet (i.e.   Mercury or Venus) is in conjunction, this conjunction will be inferior if it is in front of the sun, or superior if it is behind the sun.   Two bodies are in opposition if their right ascensions differ by 12 hours.

Knowing the times that a planet is in conjunction and opposition is important: a planet in or near conjunction will not be visible.   A planet in opposition will be visible the entire night and its disk will be fully illuminated.

The thick diagonal curve extending from the graph's bottom left corner to the top right corner represents the sun's right ascension during the year.   When a planet's curve crosses this line, that planet is in conjunction with the sun.   The other two thick diagonal lines represent the sun's right ascension + 12 hours, thus a planet's curve will cross one of these lines when it is in opposition.

5.6.9. Planet Magnitude (Alt,G,M)

Astronomers use a special visual magnitude scale to express the brightness of a celestial body.   The brighter an object is, the smaller its magnitude.   The brightest star has a magnitude of about 1 and a star that is barely visible to the naked eye has a magnitude of about 6. [15]

The magnitude scale is logarithmic.   If a body's magnitude increases by 1, its brightness will increase by about 2.5.   If the magnitude increases by 2, the brightness will increase by about (2.5) ^ 2.   If the magnitude increases by 3, the brightness will increase by about (2.5) ^ 3, etc.

The Planet Magnitude graph shows the visual magnitudes of a set of planets over a given year.

5.6.10. Planet Illum. Frac. (Alt,G,F)

The Planet Illum. Frac. graph shows the <u>illuminated fractions</u> of a set of planets over a given year. A celestial body's <u>illuminated fraction</u> is the fraction of the body's <u>disk</u> illuminated by the sun.

5.6.11. Planet Diameter (Alt,G,D)

The Planet Diameter graph shows the <u>angular diameters</u> of a set of planets over a given year.   A body's <u>angular diameter</u> is the angle subtended at an observer's location by two points on opposite sides of a body's <u>disk</u>.   In the graph the <u>angular diameters</u> of planets are expressed in <u>seconds</u>.

5.6.12. Planet Distance (Alt,G,s)

The Planet Distance graph shows the distances of a set of planets from the sun or earth over a given year.   The distances are expressed in <u>Astronomical Units (AU)</u>.

5.6.13. Planet Angle (Alt,G,A)

The Planet Angle graph shows the angle between one planet and a set of other planets over a given month.

5.6.14. Equation of Time (Alt,G,q)

The Equation of Time graph shows the equation of time for a given year.

Background: see Mean Time.

5.6.15. Day Length (Alt,G,L)

The Day Length graph shows the length of a day over a given year.

5.6.16. Sun Angle (Alt,G,n)

The Sun Angle graph shows the angle at which the sun's rays strike the earth over a given year. The graph shows the angle of the sun at <u>local apparent noon</u>.

5.6.17. Analemma (Alt,G,e)

The Analemma graph shows the underlined analemma for a given year.

BACKGROUND: Because of the equation of time and the changing apparent position of the sun, if the position of a shadow on the ground at 12:00 mean time were recorded, it would form a figure-8, called an analemma.   Since the mid-day sun appears highest in the sky near the June solstice (for the northern hemisphere), the shadow is shortest near this time.   At the December solstice the mid-day sun is lowest in the sky (for the northern hemisphere), thus the shadow is longest near this time.

When the sun's shadow is above the north-south line that runs through the middle of the analemma, the real sun is slow relative to the mean sun.   When the shadow is below the line, the real sun is fast compared to the mean sun.   Since the equation of time is 0 four times a year, the analemma crosses the north-south line at four points.

5.6.18.   Sunrise (Alt,G,r)

The Sunrise graph shows the <u>azimuth</u> of the sun at sunrise for an entire year.

5.6.19. Moon Angular Speed (Alt,G,g)

The Moon Angular Speed graph shows the speed at which the moon moves through the <u>ecliptic</u> over a given year.

BACKGROUND: The moon orbits the earth in an ellipse tilted about 5° with respect to the <u>ecliptic</u>.   The speed at which the moon moves through the <u>ecliptic</u> is constantly changing - the moon speeds up when it is closest to the earth (at <u>perigee</u>), and slows down when it is most distant from the earth (at <u>apogee</u>). Also, the moon's speed increases at <u>new</u> or <u>full moon</u> (at <u>syzygy</u>).

5.6.20. Moon Illum. Frac. (Alt,G,u)

The Moon Illum. Frac. graph shows the <u>illuminated fraction</u> of the moon over a given month.   A celestial body's <u>illuminated fraction</u> is the fraction of the body's disk illuminated by the sun.

5.6.21. Eclipses (Alt,G,E)

The Eclipses graph shows the dates of lunar and solar eclipses over a given range of years.   Lunar and solar eclipses are drawn in the color assigned to the moon and sun, respectively (see <u>Assign Colors</u> for further information).

5.6.22. Tick Marks (Alt,G,T)

When the Tick Marks item is selected, graphs are drawn with tick marks on the axes. Tick marks are generally more attractive than grid lines.

5.6.23.   Grid Lines (Alt,G,i)

When the Grid Lines item is selected, graphs are drawn with grid lines.

5.7.1. Customizing a Movie for a Location

Most movies are customized for the location specified with the Set Location command.   For further information, see <u>Setting Your Location</u>.

5.7.2. Time Speed

The time speed of a movie determines how much time passes on the computer's clock between successive movie frames.   The time speed does not change the rate at which movie frames are displayed on the screen.   The time speed can be changed while a movie is running.   For further information, see <u>Speed Up</u>, <u>Slow Down</u>,   <u>Rev. Time Speed</u>, and <u>Pause</u>.

5.7.3. View Angle

The view angle of a movie determines the field of view.   A large view angle works like a wide angle lens, allowing you to see many objects crowded together.   A small view angle works like a telephoto lens, zooming in on the objects in the center of the screen.   The view angle can be changed while a movie is running.   For further information, see Zoom In and Zoom Out.

5.7.4. Colors

The colors of items appearing in movies can be set with the Assign Colors command. For further information, see <u>Assign Colors</u>.

5.7.5. Printing a Movie Frame

A movie frame can be printed after it has been generated.   See <u>Print</u> for further information.

5.7.6.   Copying a Movie Frame

A movie frame can be copied into other Windows programs after it has been generated.   See <u>Copy</u> for further information.

5.7.7. Stopping a Movie

Any movie can be stopped by pressing the Esc key or by choosing Stop Stop Command (Alt,S,S).   After stopping a movie in this manner you will be free to run other commands.

5.7.8. Planetarium (Alt,M,P)

The Planetarium movie was described in the Tutorial.   See <u>The Planetarium Movie</u> for further information.

5.7.9.   Jupiter Moons Side (Alt,M,J)

The planet Jupiter has several moons, four of which can be seen with binoculars.   The Jupiter Moons Side movie shows the orbits of these moons as they would appear to an observer on the earth.

The larger disk in the middle of the screen is Jupiter and the smaller disks are Jupiter's 4 bright moons. When a moon moves behind one side of the planet, the moon will disappear and then reappear later on the other side.

In the Jupiter Moons Side movie the orbits of the moons are approximately horizontal.   In reality, they would appear tilted with respect to the observer's horizon.

Table 10:   Names and Numbers of Jupiter's 4 Bright Moons

```
Moon          Number

Io            1 (I)
Europa        2 (II)
Ganymede      3 (III)
Callisto      4 (IV)
```

5.7.10. Jupiter Moons Top (Alt,M,M)

The Jupiter Moons Top movie shows the orbits of Jupiter's 4 bright moons as they would appear to an observer above Jupiter's north pole.

5.7.11. Ecliptic Side (Alt,M,E)

The earth orbits around the sun in a plane called the <u>ecliptic</u>.   The orbits of the other planets are approximately in this plane.   The Ecliptic Side movie is an animated display of the orbits of the earth and planets around the sun in the <u>ecliptic</u>, as seen from the side.

5.7.12. Ecliptic Top (Alt,M,I)

The Ecliptic Top movie shows the planets in their orbit in the <u>ecliptic</u>, seen from above the <u>ecliptic</u>.

5.7.13. Day/Night (Alt,M,y)

The Day/Night movie shows where on the earth it is day and where it is night.   The Day/Night movie can be run in real time.   This will cause the sunlit portion of the earth to move at the same rate in the movie that it does in real life.   If you would prefer to see the movie run faster, you can specify that 1 hour, 1 day, 1 week, or 1 month elapse between successive movie frames.

5.7.14. Binary Star (Alt,M,B)

The Binary Star movie shows the orbits of binary star systems.   A binary star consists of a main star and its companion, both orbiting around a common center of gravity.   In the Binary Star movie the main star appears in the center of the screen, with its companion orbiting around it.

The apparent position angle (theta) and angular distance (rho) are given on the right of the screen.   The apparent position angle is the angle between north and the companion, measured counterclockwise.   The angular distance is proportional to the apparent distance between the two stars.

5.7.15. Speed Up (Alt,M,U or F2)

The Speed Up item increases the time speed of the currently running movie.

5.7.16. Slow Down (Alt,M,D or F3)

The Slow Down item decreases the time speed of the currently running movie.

5.7.17. Rev. Time Speed (Alt,M,R or F4)

The Reverse Time Speed item changes the sign of the time speed, causing a movie to reverse direction.

5.7.18.   Pause (Alt,M,a or F5)

The Pause item pauses the current movie.   To pause a movie, select this menu item.   To resume the movie, select it again.

5.7.19.   Zoom In (Alt,M,I or F6)

The Zoom In item decreases the view angle of the currently running movie.

5.7.20. Zoom Out (Alt,M,O or F7)

The Zoom Out item increases the view angle of the currently running movie.

5.7.21. Jet Trails (Alt,M,T or F8)

The Jet Trails item causes moving objects in movies to leave trails on the screen.

5.8.1. Assign Colors (Alt,C,A)

To change the color of any objects displayed by Astronomy Lab, select the Assign Colors item.   Then select an object from the Objects list box, and select its new color.   When all the objects have the correct color, press the Save button and the color information will be saved in a disk file and loaded when Astronomy Lab is run again.   Pressing the OK button will only save the color information until you exit the program.   If you change your mind and decide not to change any colors, press the Cancel button.

NOTE: Since objects are drawn with pure rather than dithered colors, the color used by Astronomy Lab may differ slightly from the color you select.

5.9.1. Stop Command (Alt,S,S or Esc)

To stop the current report, graph, or movie, select the Stop Command item.   Then you will be free to run other commands or quit the program.

5.10.1. Index (Alt,H,I or F1)

Displays the Astronomy Lab Help index.   Press Tab to move to the topic you want, and then press Enter.
With the mouse, click the name of the topic you want.

5.10.2. Keyboard (Alt,H,K)

Gives information about using keyboard keys in Astronomy Lab.

5.10.3. Commands (Alt,H,C)

Gives help on all of Astronomy Lab's commands.

5.10.4. Using Help (Alt,H,U)

Gives information about getting on-line help with Astronomy Lab.

5.10.5. User's Guide (Alt,H,G)

Allows the user to read the on-line User's Guide for Astronomy Lab.

5.10.6. How to Register (Alt,H,R)

Gives information about registering Astronomy Lab.

5.10.7. About Astronomy Lab (Alt,H,A)

Displays a dialog box that tells you which version of Astronomy Lab you are using.

5.11.   Customizing Date, Time, and Number Format

The format of every date, time, and floating point number displayed by Astronomy Lab is specified in the International section of the Control Panel.   To change the way Astronomy Lab displays dates, go to the Control Panel, select the International section, and change the Short Date Format settings.   To change the way times are displayed, change the Time Format settings.   To change the way floating point numbers are displayed, change the Number Format settings.

A.1. Purpose

The purpose of this appendix is to explain the basic astronomical concepts that you will need to know to make the best use of Astronomy Lab.

A.2.   The Celestial Sphere

To a person observing the celestial sphere, the stars, moon, and planets appear to be points on an enormous sphere, known as the celestial sphere.   An observer in the northern hemisphere will notice that throughout the night all stars appear to rotate about a point near Polaris, the north pole star (see figure 14, below).   If a camera is aimed at the north celestial pole and a time exposure is taken, stars will leave circular trails on the photograph.

Observers in the southern hemisphere will see a similar rotation about a point near mu Octantis, the south pole star.   The entire celestial sphere rotates about the celestial axis, which is simply an extension of the earth's axis of rotation.   The apparent rotation of stars and planets about the celestial axis is caused by the rotation of the earth on its axis - to an observer the celestial sphere appears to rotate in a direction exactly opposite to the rotation of the earth.


```
Planetarium

Date: 08/12/1991
Time: 10:50
GST:    8:12
LST:    1:12
Julian Date (UT)
 2448480.95
RA:     2h32m37s
DEC:  89°13'25"

Alt:  46°17'04"
Azi:  0°23'16" (NE)
View Angle: 90.00°
Time Speed:   64
Turbo is Off
Tracking is Off
```
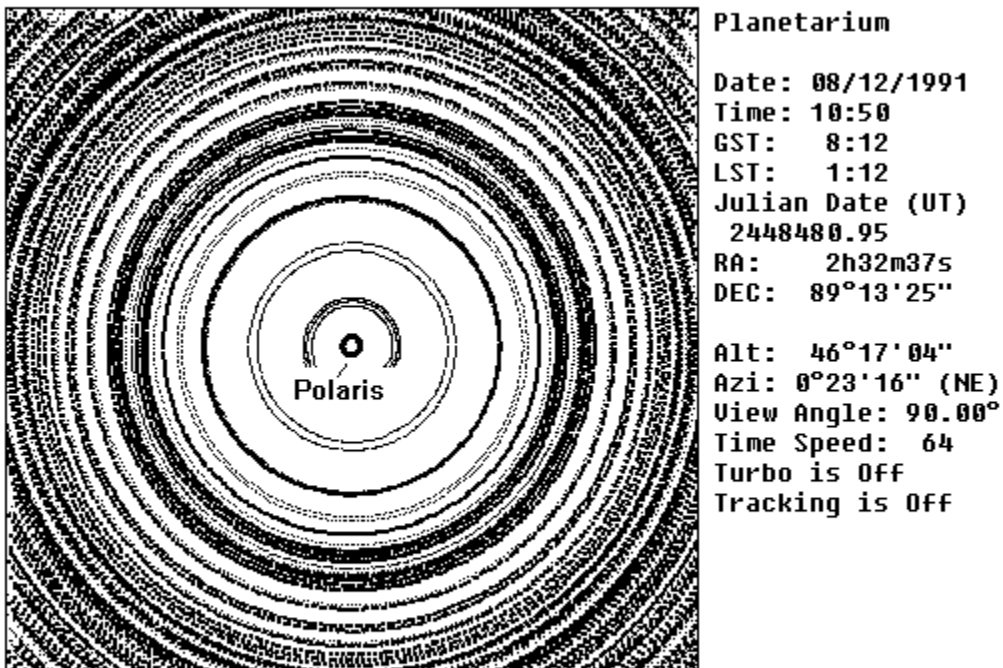
Figure 14:   "Time Exposure" of Stars near the North Celestial Pole

Although ancient peoples believed that the stars, moon, and planets were contained in a sphere, this is an optical illusion caused in part by the vast distances between the earth and other celestial bodies. Even though the celestial sphere is an illusion, it is often a convenient framework to use in discussing the positions of celestial objects.   Modern-day astronomers use coordinate systems based on the celestial sphere.

The time necessary for the celestial sphere to make a complete rotation about its axis is called a sidereal day.   Since the apparent rotation of the celestial sphere is caused by the rotation of the earth, one would expect that a sidereal day would be exactly 24 hours in length.   However, a sidereal day is about 4 minutes shorter - although the earth completes one rotation in 24 hours, during that time it also moves

about 1° in its annual orbit around the sun.

A.3. The Equatorial Coordinate System

The celestial sphere is the basis for the equatorial coordinate system.   This coordinate system expresses the location of a celestial body in terms of two angles, right ascension (alpha) and declination (delta). Right ascension is analogous to longitude on a globe of the earth, and declination is analogous to latitude. Right ascension is usually expressed in hours.   Declination is usually expressed in degrees.

The celestial equator is the intersection of the plane containing the earth's equator and the celestial sphere.   The declination of a body is the angle subtended at an observer's location by the point on the celestial equator directly above or below the body and the body.   The north celestial pole has a declination of 90° and the south celestial pole has a declination of -90°.

The first point of Aries is the point on the celestial equator where the sun will appear at the instant of the March equinox.   The right ascension of a body is the angle subtended at an observer's location by the first point of Aries and the point on the celestial equator directly above or below the body.   The first point of Aries has a right ascension of 0 hours.

One of the chief advantages of the equatorial coordinate system is that it is not tied to a particular location on the earth or a particular instant in time.   A disadvantage of this coordinate system is that the equatorial coordinates of a celestial body do not directly specify the body's position in the celestial sphere.

A.4. The Ecliptic

The ecliptic is the plane of the earth's orbit around the sun.   The moon and planets move in orbits very close to the ecliptic.   Just as the celestial sphere is the basis for the equatorial coordinate system, the ecliptic is the basis for the ecliptic coordinate system.   In this system, a celestial body's position is expressed as two angles, ecliptic longitude (lambda) and ecliptic latitude (beta).

The ecliptic longitude of a body is the angle subtended at the sun by the first point of Aries and the point on the ecliptic directly above or below the body.

The ecliptic latitude of a body is the angle subtended at the sun by the point on the ecliptic directly above or below the body and the body.   A body's ecliptic latitude will be positive if the body is above the ecliptic, and negative if the body is below the ecliptic.   A body's ecliptic coordinates do not directly specify the position of the body in the celestial sphere.

A.5. The Horizon Coordinate System

The horizon coordinate system expresses a body's location as two angles, azimuth (A) and altitude (a).

The azimuth of a body is the angle subtended at an observer's location by the point on the horizon due north of the observer and the point on the horizon directly above or below the body.

The altitude of a body is the angle subtended at an observer's location by the point on the horizon directly above or below the body and the body.   A body above the horizon will have a positive altitude, and a body below the horizon will have a negative altitude.

The point directly above an observer is called the zenith.   The point directly below an observer is called the nadir.   Unlike equatorial and ecliptic coordinates, a body's horizon coordinates directly specify where the body will be found in the sky.   To aim a telescope at a body whose horizon coordinates are known, simply point the telescope in the direction corresponding to the azimuth, and then tilt the telescope upwards to the correct altitude.

A celestial body's horizon coordinates depend on an observer's location and the current time.   The horizon coordinates of a body are constantly changing because of the rotation of the earth and the motion of the body itself.

A.6. Universal Time and Time Zones

Universal Time (UT) (formerly called Greenwich Mean Time) is the local time zone for Greenwich, England which has a longitude of 0° and lies on the Prime Meridian.   Local time at other regions of the earth is usually equal to UT + 1 hour for each 15° east of the Prime Meridian, or UT - 1 hour for each 15° west of the Prime Meridian.   Since UT is often used in astronomy, it is important to know how to convert between your local time and UT.

In order to use Astronomy Lab, you must specify the number of hours that your local time differs from UT. To do this, use the Set Location command (see Setting Your Location).   The Set Location command requires that you enter a time zone.   This time zone is simply the number of hours that your local time differs from UT.   If your local time is earlier than UT (if you live west of Greenwich), make the time zone negative.   Leave the time zone positive otherwise.   For example, since the local time of Denver, Colorado is 7 hours earlier than UT, Denver requres a time zone of -7.

The following table gives the time zones for users living in the continental United States:

Table 11: U.S. Time Zones

```
Region      Time Zone

Eastern     -5 hours
Central     -6 hours
Mountain    -7 hours
Pacific     -8 hours
```

Users living in other places should consult an atlas to determine the proper time zone value.

If you would like Astronomy Lab to accept dates and times in UT, and generate all results in UT, run the Set Location command and enter a time zone of 0.

A.7. Daylight Savings Time

All times entered into Astronomy Lab and output by Astronomy Lab are standard time, not daylight savings time.

A.8. Sidereal Time

Greenwich sidereal time (GST) is a time system based on the sidereal day.   Greenwich sidereal time is equal to Universal Time (UT) at the September equinox.   After that, GST runs faster than UT (since a sidereal day is about 4 minutes shorter than an earth day).   In exactly one year (at the time of the next September equinox) GST is exactly 24 hours ahead of UT, thus GST and UTd are equal once again. [16] GST is used to describe observations made at the Prime Meridian - for other meridians Local Sidereal Time (LST) is used.

To convert a time in GST to LST:

If meridian is west of Greenwich: LST = GST - longitude / 15

If meridian is east of Greenwich: LST = GST + longitude / 15

A.9. Ephemeris Time

Universal Time (UT) is based on the rotation of the earth on its axis.   This rotation is not uniform and is subject to currently unpredictable fluctuations.   Since UT is bound to the earth's rotation, it suffers from the same lack of uniformity.   The concept of Ephemeris Time (ET) was invented to provide scientists with a uniform time system.   ET is based on the motion of the moon and is assumed to be uniform.   For the present day and for dates not too far into the past or future ET and UT are reasonably close.   Therefore UT may be substituted for ET for the astronomical phenomena whose times are given in ET described in this User's Guide.

A.10. Mean Time

Since the sun appears to make a complete circuit around the earth in 24 hours, one could use the sun as a clock and determine the time based on how far the sun has traveled around the earth.   However, this apparent motion of the sun around the earth is not uniform - it speeds up and slows down at various times during the year.   This non-uniformity is due to two factors.   First, the earth speeds up near perihelion and slows down near aphelion.   Second, the fact that the earth's axis of rotation is tilted with respect to the celestial axis contributes to the lack of uniformity. [17]

In order to have a more uniform time system, the concept of the mean sun was invented.   The mean sun appears to move at a uniform rate around the celestial equator at a constant speed equal to the average speed of the real sun as it appears to move in the ecliptic.   The time measured by the real sun in its apparent orbit around the earth is called apparent time.   The time measured by the mean sun in its orbit around the celestial equator is called mean time.   Our watches and clocks measure mean time, and most sundials measure apparent time.

The difference between mean time and apparent time is called the equation of time.   The equation of time is the amount of time that a sundial is in error.   When the equation of time is negative (as it is between January 1 and about April 16) the real sun is lagging behind the mean sun and sundials run slow.   When the equation of time is positive (as it is between about April 16 and June 14), the real sun is ahead of the mean sun and sundials run fast.

The equation of time is 0 (i.e.   mean time is equal to apparent time) four times every year at approximately April 16, June 14, September 2, and December 25. [18]

A.11. The Julian Date

The Julian date for a given date and time is simply the number of days between Greenwich mean noon 4713 B.C. and the date and time in question.   For example, the Julian date for 0:00 March 2, 1963 (UT) is 2438090.5.   Julian dates are often used in astronomy because they are convenient to use in calculations.   Julian dates are unrelated to the Julian calendar.

A.12. The Seasons

The earth's equator is tilted with respect to the ecliptic.   This tilt is approximately 23°27' and is called the obliquity of the ecliptic.   This tilt together with the earth's annual orbit around the sun has the greatest effect on the changing of the seasons on earth (see figure 15, below).   The distance between the earth and sun has a much smaller effect on the seasons - in fact the earth reaches perihelion (the point in its orbit closest to the sun) in the middle of winter in the northern hemisphere.

```
                                    N   September
                                     \   Equinox
      December                        ⊘
      Solstice                        |
      N                               S           June
       \                                  ↙      N   Solstice
        ⊘                                         \
        |                                          ⊘
   ←—Sun's Rays—   (Sun)   —Sun's Rays—→          |
        |            N                             S
        S             \
         \             ⊘
          \            |       ↗
           \      March \
            Ecliptic  Equinox   S
```
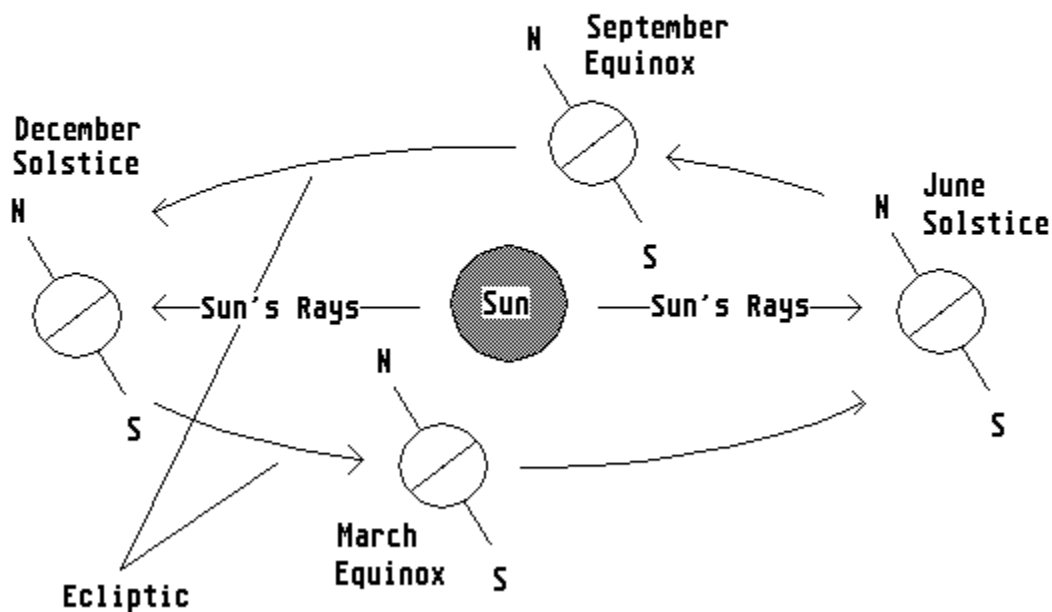
Figure 15:   The Seasons

A solstice occurs when the sun's declination is at a maximum or minimum.   An equinox occurs when the sun appears to cross the celestial equator (and has a declination of 0°).   At an equinox, the lengths of day and night are most nearly equal, at a solstice they are most unequal.

The word solstice comes from a Latin word meaning "sun-standing" since the sun appears to stand still before reversing its direction at a solstice.   The word equinox comes from a Latin word meaning "equal night", since the lengths of night and day are most nearly equal at an equinox.

Northern Hemisphere: At the June solstice the sun's rays strike the earth most directly, causing summer to occur.   At the December solstice the sun's rays strike the earth least directly, leading to winter there.   Spring begins at the March , summer at the June solstice, autumn at the September equinox, and winter at the December solstice.

Southern Hemisphere: At the June solstice, the sun's rays strike the earth least directly, causing winter to occur there.   At the December solstice, the sun's rays strike the earth most directly, leading to summer there.   Autumn begins at the March equinox, winter at the June solstice, spring at the September

equinox, and summer at the December <u>solstice</u>.
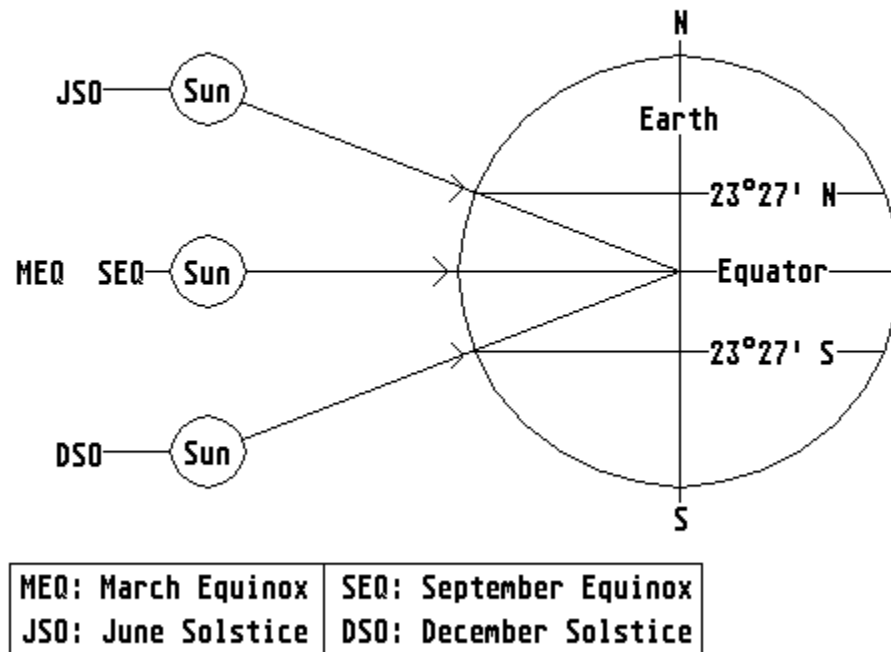
Figure 16:   Equinoxes and Solstices

Appendix B - Abbreviations

ABBR	Abbreviation
ALT	Altitude
ANG	Angle, Angular
AQR	Aquarius
ARI	Aries
AU	Astronomical Unit
AZI	Azimuth
CAP	Capricornus
CNC	Cancer
CONJ	Conjunction
CONST	Constellation
CONT	Continue
D	Degrees
DD	Day
DEC	Declination
DIST	Distance
DSO	December Solstice
E	East
ECL	Eclipse
ELEV	Elevation
EQN	Equation
ET	Ephemeris Time
FM	Full Moon
FQ	First Quarter Moon
GEM	Gemini
GST	Greenwich Sidereal Time
H	Hours
ILLUM, ILLUM. FRAC.	Illuminated Fraction
JSO	June Solstice
K	Kilobyte
KM	Kilometers
LE	Lunar Eclipse
LEO	Leo

LIB	Libra
LQ	Last Quarter Moon
LST	Local Sidereal Time
M	Meters, Minute
MAG	Magnitude
MAX	Maximum
MED	Medium
MEQ	March Equinox
MM	Month
MR	Moon Rise
MS	Moon Set
N	North
NE	North East
NW	North West
NM	New Moon
OPH	Ophicus
OPP	Opposition
PSC	Pisces
RA	Right Ascension
RES	Resolution
S	South, Seconds
SCO	Scorpius
SE	Solar Eclipse, South East
SEC	Seconds
SEQ	September Equinox
SGR	Sagittarius
SR	Sun Rise
SS	Sun Set
SW	South West
TAU	Taurus
UT	Universal Time
VIR	Virgo
W	West
°	Degrees

C.1. Purpose

Every effort has been made to make Astronomy Lab easy to use and free of errors. However, if you encounter a problem, this section will help you solve it.

C.2. Objects are Invisible in Graphs or Movies

Use the Assign Colors command (Alt,D,A) to ensure that Astronomy Lab's color settings are visible and attractive.   See Assign Colors for further information.

C.3. Insufficient Memory

Astronomy Lab requires 1 megabyte of available memory.   To determine the amount of available memory, go to the program manager and select the About Program Manager item in the Help menu (Alt,H,A).

Symptoms:

If there is insufficient memory, Astronomy Lab may not be able to run certain commands, save screen bitmaps properly, copy reports or images to the Clipboard, etc.   Astronomy Lab may exit with a fatal error message.

Solution:

If you have insufficient memory to run Astronomy Lab, free memory by closing other large programs, or reduce the amount of memory allocated to programs (e.g. disk caches, ram disks, etc).

C.4. Cannot Load the Star Database

When Astronomy Lab starts running, it loads its star database from a disk file.   If this file is missing or has become corrupted, the Planetarium movie will not run.

Symptoms:

When Astronomy Lab is run, the following error message is given: "Cannot load star database".

Solution:

Go inside the directory containing Astronomy Lab.   If the file "STARS.DAT" is present, delete it.   Get your distribution disks (the disks that came with Astronomy Lab) and copy the file named "STARS.DAT" into the directory that contains Astronomy Lab.   After you've done this, the Planetarium movie should run without problems.

C.5. Cannot Load the City Location Database

When Astronomy Lab starts running, it loads its city location database from a disk file.   If this file is missing or has become corrupted, the Set Location command will not allow you to choose cities from the city location database.

Symptoms:

When the Set Location command is run, there are no city names in the Location drop-down list box.

Solution:

Go inside the directory containing Astronomy Lab.   If the file "CITIES.DAT" is present, delete it.   Get your distribution disks (the disks that came with Astronomy Lab) and copy the file named "CITIES.DAT" into the directory that contains Astronomy Lab.   After you've done this, the city database should be accessible by the Set Location command.

C.6. Values are not Exact

All astronomical calculations performed by a computer are approximations.   Also, the calculations used by Astronomy Lab are optimized for the present day.   As a result, values in movies, reports and graphs generated by Astronomy Lab are approximate, and may differ slightly from the actual values.   Values for dates near the present day will tend to be more accurate than values for dates far into the past or future.

C.7. Astronomy Lab Gives Unexpected Results

Unexpected results are usually caused by the following oversights:

* Improper Location Information has been Entered

The proper location information must be specified with the Set Location command (Alt,L,S).   If the wrong location or time zone is given, the results will be accurate, but for the wrong location.

* Some Phenomena Require a View Angle of 5°

Since the sizes of the disks of the sun and moon are exaggerated at view angles greater than 5°, a view angle of 5° must be specified in order to accurately observe eclipses, transits, and occultations.

* Time and Date Must be Correct

If Astronomy Lab produces unexpected results, make sure that the time and date are accurate.   Also make sure the time zone specified with the Set Location command is accurate.   Remember that times are specified in 24 hour format.   For example, if you want to see a movie of the celestial sphere at 7 p.m., enter a time of 19:00.

All times entered into Astronomy Lab and output by Astronomy Lab are standard time, not daylight savings time.

C.8. Printouts Printed Incorrectly or Unattractively

In order to print correctly and attractively, the printer must be properly configured.   See <u>Print Setup</u> for further information.

C.9. Windows 3.1 or Later Required

Astronomy Lab requires Windows 3.1 or later.

C.10. Customer Support

If you experience a problem that is not corrected by the above solutions, please contact:

Personal MicroCosms
8547 E. Arapahoe Road
Suite J-147
Greenwood Village, CO   80112   U.S.A.

Registered users can call the customer support telephone number.   For further information, see Registering This Shareware Program.

D.1. Purpose

This appendix lists a variety of books and magazines about astronomy that you may find useful.

D.2. General Astronomy

Donald H. Menzel and J. M. Pasachoff, *Stars and Planets*, published by Houghton Mifflen, 1983

Stars and Planets will benefit anyone interested in astronomy. Persons interested in astronomical observation will appreciate the detailed star maps and month-by-month observing information. This book will help novice astronomers learn the basic concepts of astronomy.

Ian Ridpath, editor, *Norton's 2000.0 Star Atlas and Reference Handbook*, Eighteenth Edition, published by John Wiley & Sons, 1989

Norton's is a beautiful storehouse of essential astronomy information including a complete star atlas.

Patrick Moore, *Guiness Book of Astronomy*, published by Guiness Publishing, 1988

The *Guiness Book of Astronomy* is packed with interesting astronomical facts, data, photographs, and maps.

Chet Raymo, *365 Starry Nights*, published by Prentice Hall Press, 1982

365 Starry Nights will be useful to everyone interested in the stars. In addition to covering many of the basic concepts of astronomy, *365 Starry Nights* includes much of the fascinating folklore about the heavens.

Guy Ottewell, *The Astronomical Companion*, published by Astronomical Workshop, Furman University, 1988

This book contains many innovative drawings that clarify many important concepts of astronomy. Highly recommended.

George Gamow, *A Planet Called Earth*, published by Bantam Books, Inc., 1970

A Planet Called Earth is a good introduction to our planet.

Kim Long, *The Moon Book*, published by Johnson Books, 1988

The Moon Book is a worthwhile book about our nearest neighbor.

David and Carol Allen, *Eclipse*, published by Allen & Unwin, 1987

Eclipse not only describes how eclipses and transits happen, but contains a wealth of historical information about past eclipses and scientific experiments.

D. Tattersfield, *Projects and Demonstrations in Astronomy*, published by John Wiley & Sons, 1979

Projects and Demonstrations in Astronomy contains several activities for those wishing to broaden and deepen their understanding of astronomy. This book shows how to build working versions of ancient astronomical instruments.

Carl Sagan, *Cosmos*, published by Ballentine Books, 1980.

Carl Sagan is one of today's great popularizers of Astronomy. Cosmos will be a useful book for any astronomy enthusiast.

D.3. Magazines

"Astronomy", 21027 Crossroads Circle, P.O. Box 1612   Waukesha, WI 53187-1612, USA

"Astronomy Now", Intra Press, Intra House, 193   Uxbridge Road, London W12 9RA, Great Britain

"Sky and Telescope", P.O. Box 9111, Belmont, MA   02178-9918, USA

"Southern Astronomy",   116   Bronte   Road,   Bondi   Junction   2022, Sydney NSW, Australia

All of the above magazines contain excellent   information about current events in astronomy and space science.   Since the magazines cover upcoming astronomical   events   (e.g.   eclipses, transits, etc) they are invaluable to astronomical observers.

D.4. Astronomical Observation

Ray L. Bishop, editor, *The Observer's Handbook*, published yearly by the Royal Astronomical Society of Canada

The Observer's Handbook contains information about   every astronomical event that one is likely to want to see during the year.   This book will be   indispensable to anyone   interested in astronomical observation.   The   information in this book is for observers in Canada and the U.S.A.

D.5. Astronomy Education

John Paul Rossie, *Handbook for Aerospace Education*, published by The Aerospace Educational Development Program, 1989

The Handbook for Aerospace Education is a reference book listing educational resources for science educators.   The book includes a short listing of educational astronomy software.

John Paul Rossie, editor, *Handbook Two for Aerospace Education*, published by Prakken Publications, 1991

The *Handbook Two for Aerospace Education* is a guide to projects and applications for science educators.

Gregory L. Vogt, Susan Kies   Roth, and Malcom V. Phelps, *Software for   Aerospace   Education*, Second Edition, published by NASA Educational Technology Branch, n.d.

Software for Aerospace Education is a comprehensive database of educational Astronomy and Aerospace software.

D.6. Archaeoastronomy

Kenneth Brecher and Michael Feirtag, editors, *Astronomy of the Ancients*, published by The MIT Press, 1981

J. McKim Malville and Claudia Putnam, *Prehistoric Astronomy in the Southwest*, published by Johnson Books, 1989

Anthony Aveni, *Empires of Time*, published by Basic Books, 1989

Anthony Aveni, editor, *Archaeoastronomy in the New World*, published by Cambridge University Press, 1982

Anthony Aveni, editor, *World Archaeoastronomy*, published by Cambridge University Press, 1989

All of these thought-provoking books will be appreciated by anyone interested in archaeoastronomy, a field which combines archeology and astronomy.

D.7. History of Astronomy

J. L. E. Dreyer, *A History of Astronomy from Thales to Kepler*, published by Dover Publications, 1953

Arthur Berry, *A Short History of Astronomy*, published by Dover Publications, 1961

A. Pannekoek, *A History of Astronomy*, published by Dover Publications, 1989

These classic texts give a comprehensive history of the early days of astronomy. Berry's and Pannekoek's books are especially recommended.

Albert Van Helden, editor and translator, *Sidereus Nuncius or the Sidereal Messenger*, published by University of Chicago Press, 1989.

Sidereus Nuncius recounts Galileo's first telescopic discoveries in his own words. This book allows the modern reader to share the excitement of his discovery of craters on the moon, Jupiter's four bright moons, and stars never seen before. Van Helden's is an excellent edition, complete and unabridged.

D.8. Computational Astronomy

Jean Meeus, *Astronomical Algorithms*, published by Willmann-Bell, 1991

Peter Duffett-Smith, *Practical Astronomy with Your Calculator*, Third Edition, published by Cambridge University Press, 1988

Peter Duffett-Smith, *Practical Astronomy with Your Personal Computer*, published by Cambridge University Press, 1985

Jean Meeus, *Astronomical Formulae for Calculators*, Third Edition, published by Willmann-Bell, 1985

Jean Meeus, *Transits*, published by Willmann-Bell, 1989

Oliver Montenbruck, *Practical Ephemeris Calculations*, (translated by A. H. Armstrong), published by Springer-Verlag, 1989

Oliver Montenbruck and Thomas Pfleger, (translated by Storm Dunlop) *Astronomy on the Personal Computer*, published by Springer-Verlag, 1991

Agnes Acker and Carlos Jaschek (translated by Chris Kitchin), *Astronomical Methods and Calculations*, published by John Wiley & Sons, 1986

Almanac for Computers, published yearly by the Nautical Almanac Office of the United States Naval Observatory

T. C. Van Flandern and K. F. Pulkkinen, *Low Precision Formulae for Planetary Positions*, published by Willmann-Bell, 1979

Pierre Bretagnon and Jean-Louis Simon, *Planetary Programs and Tables from -4000 to +2800*, published by Willmann-Bell, 1986

Laurence G. Taff, *Computational Spherical Astronomy*, published by John Wiley and Sons, 1981

W. M. Smart, *Textbook on Spherical Astronomy*, Sixth Edition, published by Cambridge University Press, 1986

Many of the above books will be useful to people interested in calculating astronomical phenomena with a computer. *Astronomical Algorithms* and *Astronomy on the Personal Computer* are essential for anyone interested in computational astronomy. *Practical Astronomy with Your Calculator* and *Astronomical Formulae for Calculators* are also highly recommended.

D.9. Sundials

Albert E. Waugh, *Sundials: Their Theory and Construction*, published by Dover Publications, Inc., 1973

R. Newton Mayall   and   Margaret W. Mayall, *Sundials*, published by Sky Publishing, 1973

Robert Adzema and   Mablen   Jones, *The Great Sundial Cut-Out Book*, published by Hawthorn Books, 1978

Sundial design can be an enjoyable, creative experience, and a good way to learn more about astronomy. *Sundials: Their Theory and   Construction* and *Sundials* show how to design and build several different types of sundials.   *The Great Sundial   Cut-Out   Book* contains several different sundials that can be cut out of the book.

D.10. Reference

Jean Meeus, *Astronomical Tables of the Sun, Moon, and Planets*, published by Willmann-Bell, 1983

Astronomical Tables of the Sun, Moon, and Planets contains detailed information on just about every upcoming astronomical event of importance.

Fred Espenak, *Fifty Year Canon of Solar Eclipses: 1986 - 2035*, NASA Reference Publication 1178 Revised, published by Sky Publishing, 1987

The *Fifty Year Canon of Solar Eclipses* contains concise data and diagrams for all solar eclipses between 1986 and 2035.

Almanacs

Most almanacs contain descriptions of the most important upcoming astronomical events.

Appendix E - Also by the Author

The Astronomy Lab (Atari ST version) published by The ST Club, 49 Stoney Street, Nottingham NG1 1LX, Great Britain.

Astronomy Lab (MS-DOS version), published by Personal MicroCosms, 8547 E. Arapahoe Road Suite J-147, Greenwood Village, CO   80112   USA

"Software for Astronomy Education", published in *Handbook Two for Aerospace Education*, edited by John Paul Rossie, published by Prakken Publications, Inc., 1991.

"Books for Astronomy Programming", published in "Monthly Notes of the Astronomical Society of Southern Africa" (MNASSA), August 1990, and in "Southern Stars" (Journal of the Royal Astronomical Society of New Zealand), March, 1991.

"Commensuration for Astronomical Prediction", published in "Southern Astronomy", January/February, 1991.

"Date Management", published in "Computer Language", December 1990 (also see the Feedback column in "Computer Language", April 1991).

"A Call-Tree Generator for C Programs", published in "The C User's Journal", October, 1991.

Glossary

Altitude: Part of a celestial body's position specified in the <u>horizon coordinate system</u>. The altitude (a) of a body is the angle subtended at an observer's location by the point on the horizon directly above or below the body and the body.

Analemma: The figure-8 path followed by a shadow on the ground observed every day at 12:00 <u>mean time</u> for one year.

Angular Diameter: See Diameter, Angular.

Annulus: The ring-shaped portion of the sun's <u>disk</u> visible during the middle of an annular solar eclipse.

Aphelion: The point in a planet's orbit most distant from the sun.

Apogee: The point in the moon's orbit most distant from the earth.

Apparent Time: The time measured by the sun in its apparent orbit around the earth.

Apsides: The points in a body's orbit in which the distance of the body from its center of attraction is at a maximum or minimum. The singular of "apsides" is "apsis".

Apsis: See Apsides.

Astronomical Unit (AU): A unit of distance equal to the average distance between the earth and the sun (149,598,770 kilometers).

AU: See Astronomical Unit.

Azimuth: Part of a celestial body's position specified in the <u>horizon coordinate system</u>. The azimuth (A) of a body is the angle subtended at an observer's location by the point on the horizon due north of the observer and the point on the horizon directly above or below the body.

Calendar, Horizon: A drawing of the eastern horizon, with the position of the sun at sunrise marked for various dates, used to ascertain the current date.

Celestial Equator:	Consider the plane containing the earth's equator. The celestial equator is the intersection of this plane with the <u>celestial sphere</u>.
Celestial Axis:	The axis about which the <u>celestial sphere</u> appears to rotate once every <u>sidereal day</u>.
Celestial Sphere:	An imaginary sphere containing the stars, moon, and planets. Also the basis for the <u>equatorial coordinate system</u>.
Conjunction:	Two bodies are in conjunction if they have the same <u>right ascension</u>. When an inner planet is at conjunction with the sun, the conjunction will be inferior if the planet is in front of the sun, and superior if the planet is behind the sun.
Coordinate System, Ecliptic:	A coordinate system based on the <u>ecliptic</u>, which specifies a celestial body's position in terms of two angles, <u>ecliptic longitude (lambda)</u> and <u>ecliptic latitude (beta)</u>.
Coordinate System, Equatorial:	A coordinate system based on the <u>celestial sphere</u> which specifies a celestial body's position in terms of two angles, <u>right ascension (alpha)</u> and <u>declination (delta)</u>.
Coordinate System, Horizon:	A coordinate system which specifies a celestial body's position in terms of two angles, <u>azimuth (A)</u> and <u>altitude (a)</u>.
Declination:	Part of a celestial body's position specified in <u>equatorial coordinates</u>. Declination (delta) is analogous to latitude on a globe of the earth. Declination is usually specified in degrees, from -90° to 90°.
Diameter, Angular:	The angle subtended at an observer's location by two points on opposite sides of a body's disk.
Direct Motion:	A west-to-east movement of a planet with respect to the stars.
Disk:	The circular portion of a moon or planet facing an observer.
Ecliptic:	The plane containing the earth in its annual orbit around the sun. Also the basis for the <u>ecliptic coordinate system</u>.

Ecliptic Coordinate System:	See Coordinate System, Ecliptic.
Ecliptic Latitude:	Part of a celestial body's position specified with <u>ecliptic coordinates</u>. A body's ecliptic latitude (beta) is the angle subtended at the sun by the point on the ecliptic directly above or below the body and the body.
Ecliptic Longitude:	Part of a celestial body's position specified with <u>ecliptic coordinates</u>. A body's ecliptic longitude (lambda) is the angle subtended at the sun by the <u>first point of Aries</u> and the point on the <u>ecliptic</u> directly above or below the body.
Ecliptic, Obliquity of:	The tilt of the earth's axis with respect to the <u>ecliptic</u>. The obliquity of the ecliptic is about 23°27'.
Elongation:	The elongation of a body is the angle subtended at the center of the earth by the body and the center of the sun.
Ephemeris Time (ET):	A uniform time system based on the motion of the moon. Ephemeris Time is usually abbreviated as ET.
Equation of Time:	The difference between <u>mean time</u> and <u>apparent time</u>.
Equatorial Coordinate System:	See Coordinate System, Equatorial.
Equinox:	An equinox occurs when the sun appears to cross the <u>celestial equator</u>.
ET:	See Ephemeris Time.
First Point of Aries:	The point on the <u>celestial equator</u> where the sun will appear at the instant of the March <u>equinox</u>. The First Point of Aries is a reference point for the <u>equatorial</u> and <u>ecliptic</u> coordinate systems.
Galilean Moons:	Jupiter's four brightest moons, discovered by Galileo in 1610. These moons are named Io, Europa, Ganymede, and Callisto. The Galilean moons can be viewed with a good pair of binoculars or a low-power telescope.
Horizon Calendar:	See Calendar, Horizon.

Horizon Coordinate System:	See Coordinate System, Horizon.
Hour:	A unit of angular measure equal to 15°.
Inclination:	The angle between a planet's orbital plane and the ecliptic.
Illuminated Fraction:	The fraction of a body's disk illuminated by the sun.
Inner Planets:	Mercury and Venus, whose orbits are closer to the sun than the earth's.
Julian Date:	The number of days between Greenwich mean noon 4713 B.C. and a given date and time.
Local Apparent Noon:	The instant that the sun crosses a location's meridian.
Magnitude, Visual:	The brightness of a celestial body. Astronomers use a special logarithmic magnitude scale to express the brightness of a celestial body. The brighter an object is, the smaller its magnitude. The brightest star will have a magnitude of about 1 and a star that is barely visible to the naked eye will have a magnitude of about 6.
Mean Sun:	A fictitious sun that appears to move at a uniform rate around the celestial equator at a constant speed which is equal to the average speed of the real sun as it appears to move in the ecliptic.
Mean Time:	The time measured by the mean sun in its apparent orbit around the earth.
Meridian:	A semicircle on the earth starting at the north pole and ending at the south pole. All points on a meridian have the same longitude. Also an imaginary north-south line in the sky directly above an observer.
Minute:	A unit of angular measure equal to 1 / 60 of 1°.
Nadir:	The point directly below an observer.

Neap Tides:	See Tides, Neap.
Node:	The points of intersection between a planet's orbital plane and the ecliptic are called the nodes of the planet's orbit.
Obliquity of the Ecliptic:	See Ecliptic, Obliquity of.
Occultation:	The disappearance of a body behind the disk of another body.
Opposition:	Two bodies are in opposition if their right ascensions differ by 12 hours (180°).
Penumbra:	The outer, lighter region of the shadow cast by a body.
Perigee:	The point in the moon's orbit closest to the earth.
Perihelion:	The point in a planet's orbit closest to the sun.
Prime Meridian:	The semicircle on the earth for which the longitude is 0°. The Prime Meridian passes through Greenwich, England.
Radiant:	The location on the celestial sphere where meteors appear to originate during a meteor shower.
Retrograde Motion:	An east-to-west movement of a planet with respect to the stars.
Right Ascension:	Part of a celestial body's position specified in equatorial coordinates. Right ascension (alpha) is analogous to longitude on a globe of the earth. Right ascension is usually specified in hours, from 0 to 24.
Saros:	A period of time approximately equal to 18 years, 11 days, and 8 hours. Given one solar eclipse, another solar eclipse is likely to occur approximately one saros later. The same holds true for lunar eclipses.
Second:	A unit of angular measure equal to 1 / 3600 of 1°.
Sidereal:	Relating to the stars (often relating to a celestial body's position relative to the stars).

Sidereal Day:	The time necessary for the <u>celestial sphere</u> to make a complete rotation about its axis.
Sidereal Time:	A time system based on the <u>sidereal day</u>.
Solstice:	A solstice occurs when the sun's angle with the <u>celestial equator</u> is at a maximum.
Spring Tides:	See Tides, Spring.
Syzygy:	The instant that the moon is full or new.
Tides, Neap:	Ocean tides for which the difference in elevation between high and low tides is especially small. Neap tides happen near the time of first or last quarter moon.
Tides, Spring:	Ocean tides for which the difference in elevation between high and low tides is especially large. Spring tides happen near the time of <u>new</u> or <u>full moon</u>.
Transit:	The apparent journey of an <u>inner planet</u> across the <u>disk</u> of the sun, or of a planet's moon across the planet's <u>disk</u>.
Umbra:	The inner, darker region of the shadow cast by a body.
Universal Time (UT):	The local time zone for Greenwich, England which has a latitude of 0° and lies on the <u>Prime Meridian</u>.
UT:	See Universal Time.
Zenith:	The point directly above an observer.
Zenithal Hourly Rate:	The number of meteors seen every hour under ideal conditions. Abbreviated as ZHR.
ZHR:	See Zenithal Hourly Rate

Altitude: Part of a celestial body's position specified in the horizon coordinate system.   The altitude (a) of a body is the angle subtended at an observer's location by the point on the horizon directly above or below the body and the body.

Analemma: The figure-8 path followed by a shadow on the ground observed every day at 12:00 mean time for one year.

Annulus: The ring-shaped portion of the sun's disk visible during the middle of an annular solar eclipse.

Aphelion: The point in a planet's orbit most distant from the sun.

Apogee: The point in the moon's orbit most distant from the earth.

Apparent Time: The time measured by the sun in its apparent orbit around the earth.

Apsides: The points in a body's orbit in which the distance of the body from its center of attraction is at a maximum or minimum.   The singular of "apsides" is "apsis".

Astronomical Unit (AU):   A unit of distance equal to the average distance between the earth and the sun (149,598,770 kilometers).

Azimuth: Part of a celestial body's position specified in the horizon coordinate system.   The azimuth (A) of a body is the angle subtended at an observer's location by the point on the horizon due north of the observer and the point on the horizon directly above or below the body.

Calendar, Horizon: A drawing of the eastern horizon, with the position of the sun at sunrise marked for various dates, used to ascertain the current date.

Celestial Equator: Consider the plane containing the earth's equator.   The celestial equator
is the intersection of this plane with the celestial sphere.

Celestial Axis: The axis about which the celestial sphere appears to rotate once every sidereal day.

Celestial Sphere: An imaginary sphere containing the stars, moon, and planets.   Also the basis for the equatorial coordinate system.

Conjunction: Two bodies are in conjunction if they have the same right ascension. When an inner planet is at conjunction with the sun, the conjunction will be inferior if the planet is in front of the sun, and superior if the planet is behind the sun.

Coordinate System,

Ecliptic: A coordinate system based on the ecliptic, which specifies a celestial
                                   body's position in terms of two angles, ecliptic longitude (lambda) and
                                   ecliptic latitude (beta).

Coordinate System,

Equatorial: A coordinate system based on the celestial sphere which specifies a celestial body's position in terms of two angles, right ascension (alpha) and declination (delta).

Coordinate System,

Horizon: A coordinate system which specifies a celestial body's position in terms of two angles, azimuth (A) and altitude (a).

Declination: Part of a celestial body's position specified in equatorial coordinates.
                Declination (delta) is analogous to latitude on a globe of the earth.
                Declination is usually specified in degrees, from -90° to 90°.

Diameter, Angular: The angle subtended at an observer's location by two points on opposite sides of a body's disk.

Direct Motion: A west-to-east movement of a planet with respect to the stars.

Disk: The circular portion of a moon or planet facing an observer.

Ecliptic: The plane containing the earth in its annual orbit around the sun.   Also the basis for the ecliptic coordinate system.

Ecliptic Latitude: Part of a celestial body's position specified with ecliptic coordinates.   A body's ecliptic latitude (beta) is the angle subtended at the sun by the point on the ecliptic directly above or below the body and the body.

Ecliptic Longitude: Part of a celestial body's position specified with ecliptic coordinates.   A body's ecliptic longitude (lambda) is the angle subtended at the sun by the first point of Aries and the point on the ecliptic directly above or below the body.

Ecliptic, Obliquity of: The tilt of the earth's axis with respect to the ecliptic. The obliquity of the ecliptic is about 23°27'.

Elongation: The elongation of a body is the angle subtended at the center of the earth by the body and the center of the sun.

Ephemeris Time (ET):   A uniform time system based on the motion of the moon.   Ephemeris
                         Time is usually abbreviated as ET.

Equation of Time: The difference between mean time and apparent time.

Equinox: An equinox occurs when the sun appears to cross the celestial equator.

First Point of Aries: The point on the celestial equator where the sun will appear at the instant of the March equinox.   The First Point of Aries is a reference point for the equatorial and ecliptic coordinate systems.

Galilean Moons: Jupiter's four brightest moons, discovered by Galileo in 1610.   These moons are named Io, Europa, Ganymede, and Callisto.   The Galilean moons can be viewed with a good pair of binoculars or a low-power telescope.

Hour: A unit of angular measure equal to 15°.

Inclination: The angle between a planet's orbital plane and the ecliptic.

Illuminated Fraction: The fraction of a body's disk illuminated by the sun.

Inner Planets: Mercury and Venus, whose orbits are closer to the sun than the earth's.

Julian Date: The number of days between Greenwich mean noon 4713 B.C. and a given date and time.

Local Apparent
Noon: The instant that the sun crosses a location's meridian.

Magnitude, Visual: The brightness of a celestial body.   Astronomers use a special
logarithmic magnitude scale to express the brightness of a celestial body.
The brighter an object is, the smaller its magnitude.   The brightest star
will have a magnitude of about 1 and a star that is barely visible to the
naked eye will have a magnitude of about 6.

Mean Sun: A fictitious sun that appears to move at a uniform rate around the celestial equator at a constant speed which is equal to the average speed of the real sun as it appears to move in the ecliptic.

Mean Time: The time measured by the mean sun in its apparent orbit around the earth.

Meridian: A semicircle on the earth starting at the north pole and ending at the south pole.   All points on a meridian have the same longitude.   Also an imaginary north-south line in the sky directly above an observer.

Minute: A unit of angular measure equal to 1 / 60 of 1°.

Nadir: The point directly below an observer.

Node: The points of intersection between a planet's orbital plane and the ecliptic are called the nodes of the planet's orbit.

Occultation: The disappearance of a body behind the disk of another body.

Opposition: Two bodies are in opposition if their right ascensions differ by 12 hours (180°).

Penumbra: The outer, lighter region of the shadow cast by a body.

Perigee: The point in the moon's orbit closest to the earth.

Perihelion: The point in a planet's orbit closest to the sun.

Prime Meridian: The semicircle on the earth for which the longitude is 0°.   The Prime Meridian passes through Greenwich, England.

Radiant: The location on the celestial sphere where meteors appear to originate during a meteor shower.

Retrograde Motion: An east-to-west movement of a planet with respect to the stars.

Right Ascension: Part of a celestial body's position specified in equatorial coordinates.
                                Right ascension (alpha) is analogous to longitude on a globe of the earth.
                                Right ascension is usually specified in hours, from 0 to 24.

Saros: A period of time approximately equal to 18 years, 11 days, and 8 hours. Given one solar eclipse, another solar eclipse is likely to occur approximately one saros later. The same holds true for lunar eclipses.

Second: A unit of angular measure equal to 1 / 3600 of 1°.

Sidereal: Relating to the stars (often relating to a celestial body's position relative to the stars).

Sidereal Day: The time necessary for the celestial sphere to make a complete rotation about its axis.

Sidereal Time: A time system based on the sidereal day.

Solstice: A solstice occurs when the sun's angle with the celestial equator is at a maximum.

Syzygy: The instant that the moon is full or new.

Tides, Neap: Ocean tides for which the difference in elevation between high and low tides is especially small.   Neap tides happen near the time of first or last quarter moon.

Tides, Spring: Ocean tides for which the difference in elevation between high and low tides is especially large.   Spring tides happen near the time of new or full moon.

Transit: The apparent journey of an inner planet across the disk of the sun, or of a planet's moon across the planet's disk.

Umbra: The inner, darker region of the shadow cast by a body.

Universal Time (UT):   The local time zone for Greenwich, England which has a latitude of 0° and lies on the Prime Meridian.

Zenith: The point directly above an observer.

Zenithal Hourly Rate: The number of meteors seen every hour under ideal conditions. Abbreviated as ZHR.

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Moon Phases
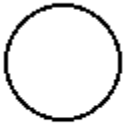
New Moon   First Quarter   Full Moon   Last Quarter