Object information file

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Contents

Chapter 1

Object information file

1.1 Index of Additional Information

```
 Our Solar System
 ================
 "The Digital Universe" provides detailed information on the Sun, the 9
planets, and all 61 known moons in our solar system.  As well, you can read
information about asteroids, comets, meteors, and the interplanetary medium
(the space between the planets).

  The Sun
  Planets and their satellites
  Asteroids
  Comets
  Meteors
  Interplanetary medium
  Hypothetical objects          (things which were once thought to exist)
  Earth-orbiting satellites
  Spacecraft

 Elsewhere
 =========
 Detailed information is available for all of the Messier objects, some NGC and
IC objects, and several significant stars.

  Deep Sky Objects              (Messier, NGC, IC objects)
  Stars
```

1.2 Planets and their satellites

```
 Planets and their satellites
 ============================
  Mercury
  Venus
  Earth
         The Moon
  Mars
         Phobos     Deimos
```

```
Jupiter
       Ganymede   Amalthea   Pasiphae   Sinope
       Callisto   Himalia    Metis      Ananke
       Io         Thebe      Carme      Adrastea
       Europa     Elara      Lysithea   Leda
Saturn
       Titan      Hyperion   Pandora    1995 S1
       Rhea       Mimas      Atlas      1995 S2
       Iapetus    Phoebe     Helene     1995 S3
       Dione      Janus      Telesto    1995 S4
       Tethys     Epimetheus Calypso    1995 S5
       Enceladus  Prometheus Pan        1995 S6
       1995 S7
Uranus
       Cordelia   Cressida   Portia     Puck       Umbriel
       Ophelia    Desdemona  Rosalind   Miranda    Titania
       Bianca     Juliet     Belinda    Ariel      Oberon
Neptune
       Proteus    Despina    Thalassa   Triton
       Larissa    Galatea    Naiad      Nereid
Pluto
       Charon
```

1.3 Deep Sky Objects

```
Deep Sky Objects (Galaxies, Nebulae, and Clusters)
==================================================
 M1   (NGC 1952) - The Crab Nebula
 M2   (NGC 7089)
 M3   (NGC 5272)
 M4   (NGC 6121)
 M5   (NGC 5904)
 M6   (NGC 6405) - The Butterfly Cluster
 M7   (NGC 6475)
 M8   (NGC 6523) - The Lagoon Nebula
 M9   (NGC 6333)
 M10  (NGC 6254)
 M11  (NGC 6705) - The Wild Duck Cluster
 M12  (NGC 6218)
 M13  (NGC 6205) - The Keystone Cluster
 M14  (NGC 6402)
 M15  (NGC 7078)
 M16  (NGC 6611) - The Eagle Nebula
 M17  (NGC 6618) - The Swan, Omega, or Horseshoe Nebula
 M18  (NGC 6613)
 M19  (NGC 6273)
 M20  (NGC 6514) - The Trifid Nebula
 M21  (NGC 6531)
 M22  (NGC 6656)
 M23  (NGC 6494)
 M24  (NGC 6603)
 M25  (IC  4725)
 M26  (NGC 6694)
 M27  (NGC 6853) - The Dumbbell Nebula
 M28  (NGC 6626)
```

```
M29  (NGC 6913)
M30  (NGC 7099)
M31  (NGC  224) - The Andromeda Galaxy
M32  (NGC  221)
M33  (NGC  598) - The Pinwheel Galaxy
M34  (NGC 1039)
M35  (NGC 2168)
M36  (NGC 1960)
M37  (NGC 2099)
M38  (NGC 1912)
M39  (NGC 7092)
M40             - Double star, SAO 28353 & SAO 28355
M41  (NGC 2287)
M42  (NGC 1976) - The Great Orion Nebula
M43  (NGC 1982)
M44  (NGC 2632) - Praesepe, or the Beehive Cluster
M45             - The Pleiades
M46  (NGC 2437)
M47  (NGC 2422)
M48  (NGC 2548)
M49  (NGC 4472)
M50  (NGC 2323)
M51  (NGC 5194) - The Whirlpool Galaxy
M52  (NGC 7654)
M53  (NGC 5024)
M54  (NGC 6715)
M55  (NGC 6809)
M56  (NGC 6779)
M57  (NGC 6720) - The Ring Nebula
M58  (NGC 4579)
M59  (NGC 4621)
M60  (NGC 4649)
M61  (NGC 4303)
M62  (NGC 6266)
M63  (NGC 5055) - The Sunflower Galaxy
M64  (NGC 4826) - The Black Eye Galaxy
M65  (NGC 3623)
M66  (NGC 3627)
M67  (NGC 2682)
M68  (NGC 4590)
M69  (NGC 6637)
M70  (NGC 6681)
M71  (NGC 6838)
M72  (NGC 6981)
M73  (NGC 6994)
M74  (NGC  628)
M75  (NGC 6864)
M76  (NGC  650) - The Little Dumbbell, Barbell, or Cork Nebula
M77  (NGC 1068)
M78  (NGC 2068)
M79  (NGC 1904)
M80  (NGC 6093)
M81  (NGC 3031) - Bode's Nebula
M82  (NGC 3034)
M83  (NGC 5236)
M84  (NGC 4374)
M85  (NGC 4382)
```

```
M86  (NGC 4406)
M87  (NGC 4486)
M88  (NGC 4501)
M89  (NGC 4552)
M90  (NGC 4569)
M91  (NGC 4548)
M92  (NGC 6341)
M93  (NGC 2447)
M94  (NGC 4736)
M95  (NGC 3351)
M96  (NGC 3368)
M97  (NGC 3587) - The Owl Nebula
M98  (NGC 4192)
M99  (NGC 4254)
M100 (NGC 4321)
M101 (NGC 5457)
M102 (NGC 5457) - Messier's Error - duplicate entry of M101
M103 (NGC  581)
M104 (NGC 4594) - The Sombrero Galaxy
M105 (NGC 3379)
M106 (NGC 4258)
M107 (NGC 6171)
M108 (NGC 3556)
M109 (NGC 3992)
M110 (NGC  205)

IC   434        - The Horsehead Nebula
IC  5070        - The Pelican Nebula

NGC  206
NGC  891
NGC 1432        - The Maia Nebula
NGC 1435        - The Merope Nebula
NGC 1499        - The California Nebula
NGC 1977
NGC 2237        - The Rosette Nebula
NGC 2264        - The Christmas Tree Cluster, Cone Nebula
NGC 2346
NGC 2419
NGC 2440
NGC 2841
NGC 3115
NGC 3372        - The Keyhole, Eta Carinae Nebula
NGC 3628
NGC 4261
NGC 4388
NGC 4394
NGC 4402
NGC 4647
NGC 4945
NGC 5033
NGC 5139        - The Omega Centauri Cluster
NGC 5548
NGC 6164
NGC 6165
NGC 6240
NGC 6543        - The Cat's Eye Nebula
```

```
 NGC 6814
 NGC 7000        - The North American Nebula
 NGC 7252
 NGC 7331
```

1.4 Stars

```
Stars
=====
 Alcyone
 Aldebaran
 Algol
 Altair
 Asterope
 Atlas
 Betelgeuse
 Celaeno
 Electra
 Fomalhaut
 Maia
 Merope
 Pleione
 Polaris
 Sirius
 Sterope II
 Taygeta

 Alpha Centauri
 Beta Pictoris
 Epsilon Aurigae
 Eta Boötes

 SAO  69181
 SAO 100458
 SAO 226891
```

1.5 Earth-orbiting satellites

```
For information on interplanetary spacecraft, click here.

Earth-orbiting satellites
-------------------------
 Though there are literally thousands of satellites in orbit around the Earth,
descriptions of only a few hundred are provided with "The Digital Universe".
Most of the objects presented here are reasonably well-suited for visual or
binocular observation.

 Alouette 1
 Alouette 1 Rocket/Body
 Alouette 2 Rocket/Body
 AMPTE Rocket/Body
 Astro 3
```

```
Atmosphere 1
Atmosphere 2
Centaur 2
COBE
Comstar 1 Rocket/Body
Copernicus (OAO 3)
Copernicus (OAO 3) Rocket/Body
Cosmos 382
Cosmos 398
Cosmos 825-832 Rocket/Body
Cosmos 871-878 Rocket/Body
Cosmos 939-946 Rocket/Body
Cosmos 1051-1058 Rocket/Body
Cosmos 1076
Cosmos 1130-1137 Rocket/Body
Cosmos 1151
Cosmos 1171 Rocket/Body
Cosmos 1320-1327 Rocket/Body
Cosmos 1473-1480 Rocket/Body
Cosmos 1500
Cosmos 1522-1529 Rocket/Body
Cosmos 1602
Cosmos 1603
Cosmos 1635-1642 Rocket/Body
Cosmos 1697
Cosmos 1697 Rocket/Body
Cosmos 1745 Rocket/Body
Cosmos 1794-1801 Rocket/Body
Cosmos 1833
Cosmos 1833 Rocket/Body
Cosmos 1844
Cosmos 1844 Rocket/Body
Cosmos 1852-1859 Rocket/Body
Cosmos 1861
Cosmos 1900
Cosmos 1924-1931 Rocket/Body
Cosmos 1934 Rocket/Body
Cosmos 1943
Cosmos 1943 Rocket/Body
Cosmos 1954 Rocket/Body
Cosmos 1980
Cosmos 1980 Rocket/Body
Cosmos 2004
Cosmos 2004 Rocket/Body
Cosmos 2008-2015 Rocket/Body
Cosmos 2016
Cosmos 2016 Rocket/Body
Cosmos 2026
Cosmos 2026 Rocket/Body
Cosmos 2027
Cosmos 2034
Cosmos 2034 Rocket/Body
Cosmos 2037 Rocket/Body
Cosmos 2046
Cosmos 2056
Cosmos 2056 Rocket/Body
Cosmos 2058
```

```
Cosmos 2060
Cosmos 2061
Cosmos 2061 Rocket/Body
Cosmos 2064-2071 Rocket/Body
Cosmos 2074
Cosmos 2075 Rocket/Body
Cosmos 2082
Cosmos 2082 Rocket/Body
Cosmos 2084
Cosmos 2084 Rocket/Body
Cosmos 2098 Rocket/Body
Courier 1-B Rocket/Body
CRRES
Delta Star
DMSP 2-3
DMSP 2-4
DMSP 2-5
Echo 2 Rocket/Body
EGP/AJISAI
EGP Rocket/Body
ERBS
Exosat Rocket/Body
Feng Yun 1-A
Feng Yun 1-B
Feng Yun 1-B Rocket/Body
Fltsatcom 4 Rocket/Body
Gamma
Geosat
Goes 3 Rocket/Body
Goes 6 Rocket/Body
GPS 2-4 Rocket/Body
GPS 2-5 Rocket/Body
GPS 2-6 Rocket/Body
GPS 2-10 Rocket/Body
Hubble Space Telescope
Inmarsat 2-1 Rocket/Body
Intelsat 4-1 Rocket/Body
Intelsat 4A-1 Rocket/Body
Intelsat 5-1 Rocket/Body
Intelsat 5-3 Rocket/Body
Intelsat 6-3
Intercosmos 19 Rocket/Body
Intercosmos 24
Intercosmos 24 Rocket/Body
IRAS
IRAS Rocket/Body
JCSAT 2 Rocket/Body
LACE
Lacrosse 1
Lageos
Landsat 1
Landsat 2
Landsat 3
Landsat 4
Landsat 5
Leasat 1 Rocket/Body
Leasat 2 Rocket/Body
```

```
Leasat 3 Rocket/Body
Leasat 4 Rocket/Body
Leasat 5 Rocket/Body
MAO 1 Rocket/Body
Meteor 2-12
Meteor 2-13
Meteor 2-16
Meteor 2-16 Rocket/Body
Meteor 2-17
Meteor 2-17 Rocket/Body
Meteor 2-18
Meteor 2-19
Meteor 3-1
Meteor 3-2
Meteor 3-3
Mir Complex
Miranda Rocket/Body
MOS 1-A
MOS 1-B
MOS 1-B Rocket/Body
Nadezhda 1
Nadezhda 2
Nadezhda 2 Rocket/Body
Nimbus 2 Rocket/Body
Nimbus 6 Rocket/Body
Nimbus 7
NOAA 1 Rocket/Body
NOAA 7
NOAA 8
NOAA 9
NOAA 10
NOAA 11
OAO 1
OAO 1 Rocket/Body
OAO 2
OAO 2 Rocket/Body
Okean 1
Okean 2
Orizuru (Debut)
Pageos DA
Pageos H
Pageos Rocket/Body
Palapa 4 Rocket/Body
Palapa 6 Rocket/Body
Pegsat
Polar Bear
RME
Rosat
Rosat Rocket/Body
Sakura Rocket/Body
Satcom 6 Rocket/Body
Seasat
SERT 2
Sirio Rocket/Body
SME
SME Rocket/Body
Solrad 7A/Secor 1 Rocket/Body
```

```
 Solrad 7B/Secor 3 Rocket/Body
 Spot 2
 Spot 2 Rocket/Body
 Starlette
 Timation 1 Rocket/Body
 Timation 2 Rocket/Body
 Transit 2-A Rocket/Body
 Ulysses Rocket/Body
 UME 1
 UME 1 Rocket/Body
 UME 2
 UME 2 Rocket/Body
 Vanguard 1
 Vanguard 1 Rocket/Body
 Vanguard 3
 Westar 6 Rocket/Body
 Yuri Rocket/Body
```

1.6 The Sun

```
The Sun
=======
View picture

 Fast facts
 The Sun's power source
 Structure and Nuclear Processes
 Features visible from Earth
 The solar wind & solar flares
 The Solar Cycle
 Helioseismology
 Observing the Sun safely
 Solar Eclipses
 Exploration
 Nemesis - an unseen companion?
 Pictures

       Planets orbiting the Sun:
   Mercury
   Venus
   Earth
   Mars
   Jupiter
   Saturn
   Uranus
   Neptune
   Pluto
```

1.7 Mercury

```
Mercury
=======
```

```
View picture

 Fast facts
 Mythology
 Discovery
 Exploration
 A Strange Orbit
 Length of the Day
 Physical features
 Observing Mercury
 Pictures
```

1.8 Venus

```
Venus
=====
View radar picture

 Fast facts
 Mythology
 Discovery
 Exploration
 Runaway Greenhouse Effect
 Length of the Day
 Physical features
 Observing Venus
 Neith - Venus' mistaken moon
 Pictures
```

1.9 Earth

```
Earth
=====
View picture
```

Though a program such as this cannot even begin to describe what we currently know about our own planet, the following information is provided as a brief summary to compare the Earth against other objects in the solar system.

```
 Fast facts
 Structure of the Earth
 Atmosphere
 Pictures

 Satellite     Distance (km)     Radius (km)
 ---------     -------------     -----------
 The Moon      384,400           1738
```

1.10 The Moon

```
The Moon - Satellite of The Earth
=================================
View picture of lunar phases

 Fast facts
 Exploration
 Physical features
 The lunar day
 Phases of the Moon
 Do we have only one moon?
 Pictures & Audio clips
```

1.11 Mars

```
Mars
====
View picture

 Fast facts
 Mythology
 Discovery
 Exploration
 Physical features
 Is there life on Mars?
 Observing Mars
 Pictures

 Satellite     Distance (km)     Radius (km)
 ---------     -------------     -----------
 Phobos         9,378            13.5 x 10.8 x 9.4
 Deimos        23,459            7.5 x 6.1 x 5.5
```

1.12 Phobos

```
Phobos - Satellite of Mars
==========================
View Picture

 Fast facts
 Brief description
```

1.13 Deimos

```
Deimos - Satellite of Mars
==========================
View Picture

 Fast facts
 Brief description
```

1.14 Jupiter

```
Jupiter
=======
View picture

 Fast facts
 Mythology
 Discovery
 Exploration
 Physical features
 Jupiter's ring
 Observing Jupiter
 Collision with comet SL9
 Pictures

 Satellite     Distance (km)     Radius (km)
 ---------     -------------     -----------
 Metis            128,000          20
 Adrastea         129,000          12.5 x 10 x 7.5
 Amalthea         181,000         135 x 83 x 75
 Thebe            222,000          55 x 45
 Io               422,000        1815
 Europa           671,000        1569
 Ganymede       1,070,000        2631
 Callisto       1,883,000        2400
 Leda          11,094,000           8
 Himalia       11,480,000          93
 Lysithea      11,720,000          18
 Elara         11,737,000          38
 Ananke        21,200,000          15
 Carme         22,600,000          20
 Pasiphae      23,500,000          25
 Sinope        23,700,000          18
```

1.15 Ganymede

```
Ganymede - Satellite of Jupiter
===============================
View picture of a hemisphere of Ganymede
View picture of tectonics on Ganymede

 Fast facts
 Brief description
```

1.16 Callisto

```
Callisto - Satellite of Jupiter
===============================
View picture

 Fast facts
```

Brief description

1.17 Io

Io - Satellite of Jupiter
==========
View a portion of the surface of Io
View picture showing evidence of active volcanoes

Fast facts
Brief description

1.18 Europa

Europa - Satellite of Jupiter
==========
View picture

Fast facts
Brief description

1.19 Amalthea

Amalthea - Satellite of Jupiter
==========
View picture

Fast facts
Brief description

1.20 Himalia

Himalia - Satellite of Jupiter
==========
Fast facts
Brief description

1.21 Thebe

Thebe - Satellite of Jupiter
==========
Fast facts
Brief description

1.22 Elara

```
Elara - Satellite of Jupiter
============================
 Fast facts
 Brief description
```

1.23 Pasiphae

```
Pasiphae - Satellite of Jupiter
===============================
 Fast facts
 Brief description
```

1.24 Metis

```
Metis - Satellite of Jupiter
============================
 Fast facts
 Brief description
```

1.25 Carme

```
Carme - Satellite of Jupiter
============================
 Fast facts
 Brief description
```

1.26 Lysithea

```
Lysithea - Satellite of Jupiter
===============================
 Fast facts
 Brief description
```

1.27 Sinope

```
Sinope - Satellite of Jupiter
=============================
 Fast facts
 Brief description
```

1.28 Ananke

```
Ananke - Satellite of Jupiter
=============================
 Fast facts
 Brief description
```

1.29 Adrastea

```
Adrastea - Satellite of Jupiter
===============================
View picture

 Fast facts
 Brief description
```

1.30 Leda

```
Leda - Satellite of Jupiter
===========================
 Fast facts
 Brief description
```

1.31 Saturn

```
Saturn
======
View picture

 Fast facts
 Mythology
 Discovery
 Exploration
 Physical features
 Saturn's rings
 Observing Saturn
 Pictures

 Satellite     Distance (km)     Radius (km)
 ---------     -------------     -----------
 *1980 S35        118,000           5
 *1980 S36        118,000           8
 Pan              133,583          10
 1995 S1          137,450           ?
 Atlas            137,670          20 x 10
 Prometheus       139,353          70 x 50 x 40
 1995 S7          139,440          18
 1995 S2          139,700           ?
 1995 S6          139,910          19
```

1995 S5	140,060	26
1995 S3	141,050	?
Pandora	141,700	55 x 45 x 35
1995 S4	146,450	?
Epimetheus	151,422	70 x 60 x 50
Janus	151,472	110 x 100 x 80
Mimas	185,520	196
*1980 S12	186,000	5
*(unnamed)	210,000	2
Enceladus	238,020	250
Tethys	294,660	530
Telesto	294,660	17 x 14 x 13
Calypso	294,660	17 x 11 x 11
*1981 S10	350,000	6
Dione	377,400	560
Helene	377,400	18 x 16 x 15
*1981 S7	377,400	8
*1981 S9	470,000	8
Rhea	527,040	765
Titan	1,221,830	2575
Hyperion	1,481,100	250 x 130 x 110
Iapetus	3,561,300	730
Phoebe	12,952,000	110

NOTE: The satellites preceded by an asterisk (*) have been reported from single Voyager photographs. As two photographs are required for confirmation, they are likely to remain unnamed until future spacecraft study the Saturnian system.

1.32 1995 S5, 1995 S6, and 1995 S7

On August 10, 1995, a team led by Phil Nicholson of Cornell University used the Hubble Space Telescope to discover three potential new moons of Saturn. His findings were released in the IAU circular 6243, released on October 4, 1995.

At the time of discovery, Saturn’s rings were tipped nearly edge on to the Earth. Such an orientation makes the rings virtually invisible, allowing for faint moons orbiting near the rings to be seen.

The three moons range in magnitude from 17.1 to 17.8, and in size from 18 to 26 km. They all orbit in the vicinity of Saturn’s F-ring. 1995 S7 trails 1995 S2 by approximately 15 degrees, in the same orbit, whereas 1995 S5 and 1995 S6 lie in orbits significantly different from other known satellites.

Astronomers believe that these newly discovered objects may in fact be the remnants of recently shattered moonlets. If so, it is believed that they may have formed more recently than 1981, as the Voyager spacecraft should have been able to detect them when they flew past Saturn - but did not. They appear to be elongated or arc-like and may in fact be just large clouds of debris resulting from the destruction of such a moonlet. If the newly discovered objects are indeed the remnants from a shattered moonlet, they will help to provide astronomers with key insights into the formation of planetary ring systems.

See also 1995 S1, 1995 S2, 1995 S3, and 1995 S4.

1.33 1995 S1, 1995 S2, 1995 S3, and 1995 S4

View discovery photographs of 1995 S3

On July 27, 1995, Amanda S. Bosh and graduate student Andrew S. Rivkin of Lowell Observatory reported the discovery of four possible Saturnian moons in IAU circular 6192. Their findings were made with the Hubble Space Telescope, from images taken on May 22, 1995 when Saturn's rings were tilted edge-on to the Earth.

Twenty seven images taken at a wavelength of 8900 Angstroms with Hubble's Wide Field Planetary Camera revealed the satellites, ranging in magnitude from 16.3 to 18.3. They had been previously undetected due to the glare from Saturn's rings.

1995 S3 and 1995 S4 have been confirmed as new satellites, but the possibility exists that 1995 S1 may be Atlas or Pan, and that 1995 S2 may be Prometheus. The uncertainty arises because the orbits of these other satellites is not well known.

Since 1995 S3 lies just outside Saturn's F-ring, the possibility exists that it is an additional "shepherd moon", using its gravitational influence to keep the particles confined to the ring.

Astronomers believe that these newly discovered objects may in fact be the remnants of recently shattered moonlets. If so, it is believed that they may have formed more recently than 1981, as the Voyager spacecraft should have been able to detect them when they flew past Saturn - but did not. They appear to be elongated or arc-like and may in fact be just large clouds of debris resulting from the destruction of such a moonlet. If the newly discovered objects are indeed the remnants from a shattered moonlet, they will help to provide astronomers with key insights into the formation of planetary ring systems.

See also: 1995 S5, 1995 S6, and 1995 S7

1.34 Pan

Pan - Satellite of Saturn
==========
View picture

Fast facts
Brief description

1.35 Atlas

```
Atlas - Satellite of Saturn
===========================
View picture

 Fast facts
 Brief description
```

1.36 Prometheus

```
Prometheus - Satellite of Saturn
================================
View picture

 Fast facts
 Brief description
```

1.37 Pandora

```
Pandora - Satellite of Saturn
=============================
View picture

 Fast facts
 Brief description
```

1.38 Epimetheus

```
Epimetheus - Satellite of Saturn
================================
View picture

 Fast facts
 Brief description
```

1.39 Janus

```
Janus - Satellite of Saturn
===========================
View picture

 Fast facts
 Brief description
```

1.40 Mimas

```
Mimas - Satellite of Saturn
===========================
View picture

 Fast facts
 Brief description
```

1.41 Enceladus

```
Enceladus - Satellite of Saturn
===============================
View picture

 Fast facts
 Brief description
```

1.42 Tethys

```
Tethys - Satellite of Saturn
============================
View picture

 Fast facts
 Brief description
```

1.43 Telesto

```
Telesto - Satellite of Saturn
=============================
View picture

 Fast facts
 Brief description
```

1.44 Calypso

```
Calypso - Satellite of Saturn
=============================
View picture

 Fast facts
 Brief description
```

1.45 Dione

```
Dione - Satellite of Saturn
===========================
View picture

 Fast facts
 Brief description
```

1.46 Helene

```
Helene - Satellite of Saturn
============================
View picture

 Fast facts
 Brief description
```

1.47 Rhea

```
Rhea - Satellite of Saturn
==========================
View picture

 Fast facts
 Brief description
```

1.48 Titan

```
Titan - Satellite of Saturn
===========================
View picture

 Fast facts
 Brief description
```

1.49 Hyperion

```
Hyperion - Satellite of Saturn
==============================
View picture

 Fast facts
 Brief description
```

1.50 Iapetus

```
Iapetus - Satellite of Saturn
=============================
View picture

 Fast facts
 Brief description
```

1.51 Phoebe

```
Phoebe - Satellite of Saturn
============================
View picture

 Fast facts
 Brief description
```

1.52 Uranus

```
Uranus (pronounced YUR-uh-nus)
==============================
View picture

 Fast facts
 Mythology
 Discovery
 Exploration
 Physical features
 Uranus' rings
 Observing Uranus
 Pictures
```

Satellite	Distance (km)	Radius (km)
Cordelia	49,770	13
Ophelia	53,790	15
Bianca	59,170	21
Cressida	61,780	31
Desdemona	62,680	27
Juliet	64,350	42
Portia	66,090	54
Rosalind	69,940	27
Belinda	75,260	33
Puck	86,010	77
Miranda	129,390	240
Ariel	191,020	579
Umbriel	266,300	586
Titania	435,910	790
Oberon	583,520	762

1.53 Cordelia

```
Cordelia - Satellite of Uranus
==============================
View picture

 Fast facts
 Brief description
```

1.54 Ophelia

```
Ophelia - Satellite of Uranus
=============================
View picture

 Fast facts
 Brief description
```

1.55 Bianca

```
Bianca - Satellite of Uranus
============================
 Fast facts
 Brief description
```

1.56 Cressida

```
Cressida - Satellite of Uranus
==============================
 Fast facts
 Brief description
```

1.57 Desdemona

```
Desdemona - Satellite of Uranus
===============================
 Fast facts
 Brief description
```

1.58 Juliet

```
Juliet - Satellite of Uranus
============================
 Fast facts
 Brief description
```

1.59 Portia

```
Portia - Satellite of Uranus
============================
 Fast facts
 Brief description
```

1.60 Rosalind

```
Rosalind - Satellite of Uranus
==============================
 Fast facts
 Brief description
```

1.61 Belinda

```
Belinda - Satellite of Uranus
=============================
View picture

 Fast facts
 Brief description
```

1.62 Puck

```
Puck - Satellite of Uranus
==========================
View picture

 Fast facts
 Brief description
```

1.63 Miranda

```
Miranda - Satellite of Uranus
=============================
View picture

 Fast facts
 Brief description
```

1.64 Ariel

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Ariel - Satellite of Uranus
===========================
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1.65 Umbriel

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Umbriel - Satellite of Uranus
=============================
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 Fast facts
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1.66 Titania

```
Titania - Satellite of Uranus
=============================
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 Fast facts
 Brief description
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1.67 Oberon

```
Oberon - Satellite of Uranus
============================
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1.68 Neptune

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Neptune
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 Satellite     Distance (km)     Radius (km)
 ---------     -------------     -----------
 Proteus           48,200         218 x 208 x 201
 Larissa           50,000         104 x 89
 Despina           52,600          74
 Galatea           62,000          79
 Thalassa          73,600          40
 Naiad            117,600          29
 Triton           354,760        1353
 Nereid         5,513,400         170
```

1.69 Proteus

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Proteus - Satellite of Neptune
==============================
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1.70 Larissa

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Larissa - Satellite of Neptune
==============================
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 Fast facts
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```

1.71 Despina

```
Despina - Satellite of Neptune
==============================
View picture

 Fast facts
 Brief description
```

1.72 Galatea

```
Galatea - Satellite of Neptune
==============================
View picture
```

Fast facts
Brief description

1.73 Thalassa

Thalassa - Satellite of Neptune
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1.74 Naiad

Naiad - Satellite of Neptune
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Fast facts
Brief description

1.75 Triton

Triton - Satellite of Neptune
==========
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Fast facts
Brief description

1.76 Nereid

Nereid - Satellite of Neptune
==========
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Fast facts
Brief description

1.77 Pluto

Pluto
=====
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Satellite	Distance (km)	Radius (km)
Charon	19,600	593

1.78 Charon

Charon - Satellite of Pluto
==========
View picture

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1.79 M1, NGC 1952, The Crab Nebula

View Picture

Discoverer.....John Bevis, 1758
Distance.....6300 light years
True diameter.....6 light years

The Crab Nebula is one of the most conspicuous, and certainly the most famous known supernova remnant. It was discovered by John Bevis in 1731, but independently rediscovered by Messier in September of 1758. It was described as a "nebulosity above the southern horn of Taurus... It contains no star; it is a whitish light, elongated like the flame of a taper; discovered while observing the comet of 1758". It was the discovery of the Crab Nebula that prompted Messier to compile his catalogue of nebulae, galaxies, and clusters so that other observers would not confuse them with comets. See Messier, Charles for more information.

In a 3 or 4 inch telescope, M1 is detectable as a faint smudge. In a 6 inch telescope, it appears as an irregular oval, and by 10 inches or larger some hint of detail can be glimpsed. The best details are only revealed through long photographic exposures.

Expansion of the Crab Nebula, and its suspected origin

In 1921, C. O. Lampland detected motion within the cloud of the Crab Nebula. Though varying at different parts of the cloud, the nebula appeared to be expanding at a rate of about 0.2 arcseconds per year. At its estimated distance of 6300 light years, this expansion corresponds to a rate of about 360 km/sec. Allowing for the current size of the cloud, and the fact that the expansion rate seems to be increasing, an estimate of the age of the cloud appears to be

about 900 years. Thus, it is believed that the nova explosion creating the Crab Nebula might have occurred approximately in the year 1000 AD.

A very interesting account of a "guest star" appearing near Zeta Tauri on July 4, 1054 is given in the "Sung Shih", or Annals of the Sung Dynasty of China. It reads:

> "In the first year of the period Chih-ho, the 5th moon, the day chi-ch'ou, a guest star appeared approximately several inches south-east of Tien-Kuan. After more than a year it gradually became invisible."

There are no known European records of the nova, however it has been suggested that religious prejudices of the time may have forced astronomers to ignore the event. It was believed that the stars in the sky were changeless, and to suggest anything else was blasphemy.

There is evidence to suggest that North American Indians may have observed the event. Several pictographs show a crescent moon with a large "star" nearby and below. It can be calculated using "The Digital Universe" that on the morning of July 5, 1054, this is exactly how the sky would have appeared if the Crab Nebula were shining as a brilliant star. Since the regions in which the pictographs were found are believed to have been occupied between 1000 and 1200 AD, it is thought by many that these drawings were representations of the nova explosion producing the Crab Nebula.

If the distance estimate of 6300 light years is assumed, the nova would have had to attain an absolute magnitude of at least -17 to have produced the recorded observations. As a result, for a few weeks, the star was shining with the equivalent light of 400 million stars.

Structure of the Crab Nebula

Best seen on red-sensitive photographic plates, the inner part of the nebula consists of an intricate network of fine filaments. On blue-sensitive plates, a larger outer region may be observed with substantially less detail. It is suspected that this nebulous region may have 1/1000th the density of the inner region, which in turn is less than a trillionth the density of the Earth's atmosphere at sea level.

By studying the appearance of the inner filaments when photographs were taken through polarized filters, it became apparent that the light was indeed strongly polarized. This suggested a strong magnetic field within the Crab Nebula.

In 1948, the nebula was identified as a strong source of energy at radio wavelengths. In fact, it is the fourth "brightest" radio object in the sky. Additionally, later evidence revealed the nebula to be a strong source of X-rays and gamma rays as well. In the X-ray band of the electromagnetic spectrum, the nebula emits over 100 times as much energy as it does in the visual band.

A pulsar is discovered

It had long been suspected that the result of such a large stellar explosion may be a highly compressed remnant with a density several hundred million times

that of a normal star. In fact, such an object would be compressed to the point where its individual neutrons were in virtual contact with one another. This object, called a neutron star was first postulated by the Russian physicist L. Landau in 1932.

A star had been identified at the central regions of the Crab Nebula, which was believed to have been the remnants of the star which exploded. However, until the late 1960s it had not been proven that this star was in fact a neutron star.

The proof came rather indirectly. In 1967, J. Bell and A. Hewish, working at the Cambridge University Observatory detected a mysterious object near the visible star 2 Vulpeculae which was emitting regular pulses of radio energy at intervals of precisely 1.337301 seconds. It was believed that one possible mechanism for such a phenomenon was a rapidly rotating star with a magnetic field whose axis did not coincide with the axis of rotation. The magnetic field would cause energetic particles to be emitted near the north and south magnetic fields, resulting in two beams of particles and energy from the star. As the star rotated, the beams would sweep out a path through space, much like a lighthouse. If the Earth were located in the line of sight of one of these beams, the object would appear to pulsate at an extremely regular interval.

However, for a massive object such as a star to be able to rotate this quickly, it had to be amazingly small and dense. A neutron star fit the bill perfectly, and it appeared as though the object located near 2 Vulpeculae (denoted PSR1919+21) was a likely candidate for a spinning neutron star, or a pulsar as it came to be called.

By 1968, the object at the center of the Crab Nebula was observed to emit radio pulses at the extremely short period of 0.033089 seconds. Thus, it was established that the object was a pulsar rotating at a very high rate. It obtained the pulsar designation "PSR0531+21".

At the time of its discovery, the Crab Nebula pulsar was the only pulsar which was known to coincide with an optically visible object. Previous pulsars had only been detectable at radio wavelengths. As a result, an effort was launched to see if the object was optically variable as well. On January 15, 1969, W. J. Cocke, M. J. Disney, and D. J. Taylor detected such variations with precisely the same period. It was later shown that the X-ray output from the Crab Nebula had the same variation.

The pulsar within the Crab Nebula has been observed to go through occasional abrupt changes in its otherwise regular period. Such changes are believed to be caused by a sudden shrinkage in the size of a neutron star. It is calculated that a shrinkage of a thousandth of a centimeter in the radius of the pulsar would produce a measurable change in its rotation period. In addition to these sudden changes, the rotational period is slowly increasing by a slight amount. It is not yet definitely known what could be causing this "braking" effect.

1.80 M2, NGC 7089

View Picture

Discoverer.....Maraldi, 1746

```
 Distance.....................50,000 light years
 True diameter................150 light years
 Number of stars..............100,000
```
M2 is a globular cluster, first seen by Maraldi in 1746, and rediscovered by Charles Messier in 1760. It is easily visible with small optical instruments. Binoculars reveal the object to appear as a hazy "star", while a 2 inch or larger telescope reveals the object to have a definite size. With a 8 inch telescope or larger, some stars can be resolved.

M2 lies approximately 50,000 light years away, with a diameter of about 150 light years. It is estimated that more than 100,000 stars populate the cluster with red and yellow giants making up the brightest members.

The majority of the variable stars located in M2 are those of short period known as RR Lyrae, or "cluster" variables.

1.81 M3, NGC 5272

View Picture

```
 Discoverer..................Charles Messier, 1764
 Distance.....................40,000 light years
 True diameter................220 light years
 Number of stars..............>500,000
```
M3 is one of the most spectacular globular clusters in the sky. It appears as a hazy "star" in binoculars, but even a small telescope shows a round fuzzy object about 10 arcminutes in diameter. A 4 inch telescope will partially resolve the outside edges.

Modern photographs reveal obscuring dark patches in the central mass (though these features are more obvious in M13). However, since globular clusters are thought to contain virtually no dust or gas, several astronomers believe that these dark nebulae are foreground objects. Globular clusters just provide a good backdrop to view the nebulae.

M3 contains thousands of stars from magnitude 11 and dimmer. More variable stars have been detected in M3 than in any other globular cluster. The total luminosity of the system is about 160,000 times that of the Sun, while the mass is about 140,000 times that of the Sun. Most of the mass is accounted for by vast numbers of faint stars.

There is substantial evidence to indicate that M3, and other similar globular clusters is comprised mainly of very old stars. Several are observed to have passed from the "hydrogen fusion" to the "helium fusion" stages in their development. It is believed that M3 may be 10 billion years old.

1.82 M4, NGC 6121

View Picture

```
 Discoverer..................P. L. de Cheseaux, 1746
 Distance.....................5,700 light years
```

```
 True diameter.................20 light years
 Number of stars..............>10,000
```
This is one of the largest and nearest globular clusters. It is located quite easily in binoculars and can even be detected with the naked eye under good sky conditions. It is a somewhat loose cluster, showing no great condensation of stars towards its center. A 4 inch telescope will begin to partially resolve individual stars. A rather bright linear chain of 11th magnitude stars makes the cluster appear oblate in smaller telescopes. However, larger telescopes show that the cluster is in fact quite spherical.

The cluster is observed to be receding from us at a velocity of 65 km/sec. In 1975, G. Alcaino arrived at an estimated distance of 5700 light years.

1.83 M5, NGC 5904

View Picture

```
 Discoverer...................Gottfried Kirch, May 5, 1702
 Distance.....................27,000 light years
 True diameter.................80 light years
 Number of stars..............>500,000
```
This globular cluster competes with M3 and M13 for the role of most impressive cluster visible from the northern hemisphere. Discovered by Gottfried Kirch in 1702, it was rediscovered by Charles Messier in May 1764, when he mistakenly described M5 as "a fine nebula which I am sure contains no star".

With binoculars, and under ideal sky conditions, M5 will appear as a hazy star of about 7th magnitude. In a 3 inch telescope, it appears as a bright nebula about 5 arcminutes in size. Resolution of the cluster into individual stars starts with telescopes 4 inches and larger. The cluster is not completely circular, but is somewhat elliptical with the shorter axis some 10% smaller than the longer. M5 contains an unusually large number of variable stars - the vast majority of which are of the RR Lyrae type with periods of around half a day.

M5 appears to be receding from us at a rate of about 50 km/sec.

In 1917, Harlow Shapley used the variables in M5 to check a theory which postulated that the velocity of light might vary slightly with wavelength. By measuring the time of maxima of the stars in both blue and yellow light, he demonstrated that if there was a variation, it would have to be less than one part in 20,000,000,000. It is now agreed that light of all frequencies travels at the same speed in space - namely 299,792,458 m/s.

By studying the colors and spectral types of the stars in M5, it has been demonstrated that the age may be as much as 13 billion years - making it one of the most ancient clusters known.

1.84 M6, NGC 6405, The Butterfly Cluster

View Picture

```
 Discoverer..................P. L. de Cheseaux, 1746.
 Distance....................1,200 light years
 True diameter...............20 light years
 Number of stars.............80
```
M6, and its close companion M7 are two of the largest and brightest open clusters, beautiful even with little optical aid. To the naked eye it appears as a nebula, but even binoculars start to resolve individual stars. With some imagination, the asterism appears to take on the shape of a butterfly with open wings.

Though the discovery is usually attributed to P. L. de Cheseaux, there is substantial evidence to indicate that it, along with M7, was mentioned in the catalogue of Ptolemy.

The age of the cluster is estimated at about 100 million years.

1.85 M7, NGC 6475

View Picture

```
 Discoverer..................Ptolemy, AD 150
 Distance....................800 light years
 True diameter...............12 light years
 Number of stars.............80
```
M7, and its close companion M6 are two of the largest and brightest open clusters, beautiful even with little optical aid. It is easily visible to the unaided eye, with several stars approaching naked eye visibility individually. It is believed that the cluster is some 260 million years old.

1.86 M8, NGC 6523, The Lagoon Nebula

View Picture

```
 Discoverer..................LeGentil, 1747
 Distance....................5200 light years
 True diameter...............115 light years
```
The Lagoon Nebula is a diffuse nebula visible to the naked eye as a fuzzy patch lying just off the main stream of the Milky Way in Sagittarius. Its discovery is usually attributed to LeGentil in 1747, though there is some evidence that it was observed by Flamsteed in 1680 and de Cheseau in 1746.

Though visible as a diffuse mass to the eye and small telescopes, long exposure photographs reveal the nebula to contain intricate detail. Its most prominent feature is a dark dust lane about two arcminutes wide extending from the NE to the SW. In addition to this feature, there are numerous other smaller dust clouds apparent against the bright background.

It appears as though the star 9 Sagittarii is the chief source of illumination for the nebula, though it is thought that several hot stars lie within the cloud.

A curious feature apparent in good photographs of the Lagoon Nebula is the

existence of tiny circular dark nebulae known as "globules". These nebulae have diameters of between 7000 to 10000 AU, and are thought to be contracting clouds in the process of forming a new star.

Studies of the redshift of stars associated with the nebulae seem to indicate that the system is moving away from us at about 9 km/sec.

1.87 M9, NGC 6333

View Picture

```
 Discoverer..................Charles Messier, May 1764
 Distance....................26,000 light years
 True diameter...............60 light years
 Number of stars.............thousands
```

M9 is a small globular cluster discovered by Messier in May 1764. It is one of the nearest such clusters to the nucleus of the Milky Way, located about 7500 light years from the Galactic Center. It is estimated to have a total luminosity of about 60,000 times that of the Sun. Several variable stars have been identified in the cluster.

Through an analysis of the redshift of stars within the cluster, it is estimated that the system is receding from us at a rate of approximately 220 km/sec.

1.88 M10, NGC 6254

View Picture

```
 Discoverer..................Charles Messier, May 1764
 Distance....................20,000 light years
 True diameter...............70 light years
 Number of stars.............thousands
```

This is a bright and rich globular cluster, easily visible in binoculars. With a 6 inch telescope or larger, some individual stars begin to be resolved. Only a few stars within the cluster have been identified as being variable.

M10 has a rather low radial velocity in comparison with other similar clusters; it is receding from us at approximately 70 km/sec.

1.89 M11, NGC 6705, The Wild Duck Cluster

View Picture

```
 Discoverer..................Gottfried Kirch, 1681
 Distance....................5,500 light years
 True diameter...............60 light years
 Number of stars.............900
```

M11 was listed by Messier as "a cluster of a great number of small stars which can be seen in a good telescope. In a 3 foot (focal length) instrument it

looks like a comet. The cluster is mingled with a faint light; 8 magnitude star in cluster". Many observers have also reported that the cluster appears to be divided into several sections.

In binoculars, this object resembles a globular cluster. There is a brighter star near the center, but no true nucleus. A ten inch or larger telescope resolves hundreds of stars.

The probable mass of the system is equivalent to approximately 2900 times that of our Sun, with a combined luminosity 10,000 times greater. The cluster is believed to be approximately 500 million years old. It is quite tightly packed, with some 83 stars per cubic parsec near the center (implying an average separation of less than a light year).

1.90 M12, NGC 6218

View Picture

```
 Discoverer..................Charles Messier, May 1764
 Distance....................20,000 light years
 True diameter...............80 light years
 Number of stars.............~100
```

This bright globular cluster was discovered by Messier in May 1764. As it has a rather loose structure, individual stars are easier to resolve in smaller telescopes. It has a rather low radial velocity, approaching us at the rate of about 16 km/sec.

1.91 M13, NGC 6205, The Keystone Cluster

View Picture

```
 Discoverer..................Edmond Halley, 1715
 Distance....................25,000 light years
 True diameter...............200 light years
 Number of stars.............>1,000,000
```

This is widely considered to be the most spectacular globular cluster visible from the northern hemisphere. Easy to find with a good pair of binoculars, it may even be glimpsed with the naked eye under ideal sky conditions. In a small telescope, it appears as a bright roundish nebula, while a 4 to 6 inch telescope begins to resolve individual stars. Messier was rather mistaken when he classified the object as "a nebula which I am sure contains no star". It is now believed that over a million stars inhabit the cluster, with an average density suspected of being approximately one star per cubic light year.

The total luminosity of M13 is over 300,000 times that of the Sun, with a mass greater by a factor of 500,000. The brightest members of the cluster, with a luminosity of about 2000 suns each, are red giants appearing at 11th magnitude. Only a few variable stars have been detected. The cluster is receding from us at a velocity of approximately 250 km/sec.

1.92 M14, NGC 6402

View Picture

```
 Discoverer..................Charles Messier, 1764
 Distance....................70,000 light years
 True diameter...............200 light years
 Number of stars.............>100,000
```

This globular cluster was discovered by Messier in June 1764. It lacks a sharp condensation towards the center, with only a gradual tapering off near the edges. A 10 inch telescope or larger is required to be able to resolve the cluster into individual stars, as the magnitudes of the brightest lie at around 15.5.

A large number of variable stars have been detected in the cluster, which is moving towards us at a velocity of 130 km/sec.

In 1938, a nova was detected in M14. There are only two cases of novae known to occur in globular clusters; the other occurred in 1860 in M80.

1.93 M15, NGC 7078

View Picture

```
 Discoverer..................Maraldi, September 1746
 Distance....................40,000 light years
 True diameter...............150 light years
 Number of stars.............>100,000
```

This globular cluster appears as a fuzzy object in binoculars, with partial resolution being attained with telescopes of 8 inches and above. The central region has a slight elliptical shape to it, though the cluster as a whole is quite spherical. The core of the cluster is tightly packed, with nearly 7,000 stars in an area just 0.8 light years across (more than a million times more populated by stars than our location in the Milky Way).

A rather large number of variable stars have been discovered in M15, most of which are of the RR Lyrae class. The brightest stars are red giants with an absolute magnitude of -2.0. The total luminosity of the cluster is approximately 200,000 times that of our Sun, and it is approaching us at a velocity of approximately 110 km/sec.

In 1974, it was discovered that M15 is a source of X-rays. As a result, it was suspected that the cluster might be the home to one or more supernova remnants, or even more interestingly, black holes. However, images taken by the Hubble Space Telescope of the core of the cluster in 1990 do not reveal the sharp concentration of stars that would be expected if a black hole was present.

In 1991, Brian W. Murphy of the University of Utrecht reported finding emissions from ionized calcium in spectrae of the center of the cluster. It is suspected that these spectral lines come from rapidly rotating stars, which stimulate activity in their chromospheres.

Then in 1992, Guido De Marchi and Francesco Paresce of the Space Telescope

Science Institute (STScI) observed M15 at ultraviolet wavelengths with the Hubble Space Telescope. They were surprised to find 15 extremely hot, blue stars at its center (with surface temperatures in excess of 30,000 degrees C). Since heavier stars tend to collect near the core of clusters, usually relatively cool red giants are observed there. The astronomers believe that the stars detected were actually red giants which have lost their outer layers due to the gravitational effects of other stars passing nearby. If this happened, regions nearer to their core would be exposed, resulting in the high observed temperatures.

1.94 M16, NGC 6611, The Eagle Nebula

View Picture

Discoverer.....P. L. de Cheseaux, 1746
Distance.....8,000 light years
True diameter.....70 light years

M16 is a beautiful star cluster nestled within a huge diffuse nebula. Due to its remarkable appearance in long exposure photographs, it may be initially disappointing to the visual observer. It appears as a scattered cluster of reasonably bright stars, with the first hint of nebulosity appearing in a 6 inch telescope.

The prominent dark dust lane extending through the bright nebulosity is 6 light years long. Within the nebula, new stars are condensing out of the gas and being formed. The star cluster itself consists of a large number of young O- and B-type giants. These stars have a particularly high luminosity and temperature. An average age of the stars appears to be about 800,000 years, though star formation is still occurring.

M16 is visible at radio wavelengths in addition to optical.

1.95 M17, NGC 6618, The Swan, Omega, or Horseshoe Nebula

View Picture

Discoverer.....P. L. de Cheseaux, 1764
Distance.....5,700 light years
True diameter.....40 light years

The Swan Nebula is one of the most prominent diffuse nebulae. The main feature is a bright streak across its northern edge. Long exposure photographs reveal a multitude of filaments in the nebula.

Though most of the stars appearing in the field with M17 simply lie in the foreground and can not be associated with the nebula, there is evidence to suggest that at least some are in its vicinity. It is believed that the stars which light up the nebula are hidden behind thick clouds of dust.

M17 is visible at radio wavelengths in addition to optical.

1.96 M18, NGC 6613

View Picture

```
 Discoverer..................Charles Messier, June 1764
 Distance.....................4,900 light years
 True diameter................13 light years
 Number of stars..............~12
```
This rather unimpressive cluster was discovered by Messier in June 1764. It was described as "a cluster of small stars, a little below M17; surrounded by a slight nebulosity. Easier to see than M16." Approximately 12 stars make up the group. The slight nebulosity reported by Messier was undoubtedly the myriad of unresolved dimmer stars making up the background of the field, but unassociated with the cluster.

1.97 M19, NGC 6273

View Picture

```
 Discoverer..................Charles Messier, June 1764
 Distance.....................25,000 light years
 True diameter................100 light years
 Number of stars..............~100,000
```
M19 is one of the most elliptical globular clusters known, with the non-spherical outline visible even in small telescopes. It is an impressive sight when viewed against the background of countless dimmer stars in the Milky Way. Only a few variable stars have been identified within M19.

The cluster is quite near to the center of our galaxy - located some 3000 light years distant. It is receding from us at a rate of approximately 100 km/sec.

1.98 M20, NGC 6514, The Trifid Nebula

View Picture

```
 Discoverer..................LeGentil, 1747
 Distance.....................8,000 light years
 True diameter................70 light years
```
Though discovered by LeGentil in 1747, John Hershel was the first to describe its appearance as anything other than an unimpressive cluster of faint stars. Calling the object "The Trifid Nebula", he described it as "consisting of 3 bright and irregularly formed nebulous masses, graduating away insensibly externally, but coming up to a great intensity of light at their interior edges where they enclose and surround a sort of 3-forked rift or vacant area, abruptly and uncouthly crooked and quite void of nebulous light. A beautiful triple star is situated precisely on the edge of one of these nebulous masses just where the interior vacancy forks into two channels". This structure is quite easy to detect in an 8 inch telescope under good conditions. Each of the three dust lanes measures about 45 arcseconds in width.

Though hot stars hidden in the dust may contribute towards the nebula’s illumination, it appears as though SAO 186145 is the primary source of light.

In fact, SAO 186145 is merely the brightest of 6 stars in a multiple system.

Since M20 was first photographed, no evidence of any changes has been observed. However, it appears that Hershel's 150 year old drawings may have indicated a small motion of the central star from the center of the dark lanes to the tip of one of the luminous regions as it appears today.

1.99 M21, NGC 6531

View Picture

```
 Discoverer..................Charles Messier, June 1764
 Distance....................2,200 light years
 True diameter...............17 light years
 Number of stars.............hundreds
```
Messier found this object while studying the Trifid Nebula. The cluster consists of a group of dim stars surrounding six stars of 8th magnitude. The brightest stars are giants, of spectral type B0.

1.100 M22, NGC 6656

View Picture

```
 Discoverer..................Abraham Ihle, 1665
 Distance....................9,600 light years
 True diameter...............50 light years
 Number of stars.............>500,000
```
This is an impressive globular cluster, surpassed in the northern sky only by M13. It is an easy object to resolve, with the brightest stars of 11th magnitude. An 8 inch telescope can pick out hundreds of stars.

M22 appears distinctly elliptical. Many RR Lyrae type variable stars have been detected in the cluster. This cluster is currently moving towards us at a rate of 150 km/sec.

1.101 M23, NGC 6494

View Picture

```
 Discoverer..................Charles Messier, June 1764
 Distance....................2,200 light years
 True diameter...............15 light years
 Number of stars.............150
```
This loose cluster is composed of stars ranging from 9th to 13th magnitude, scattered evenly throughout. The majority of its members seem to be reddened stars on the main sequence, with the brightest being of spectral type B9.

1.102 M24, NGC 6603

View Picture

```
 Discoverer..................Charles Messier, June 1764
 Distance....................16,000 light years
 True diameter...............20 light years
 Number of stars.............hundreds
```
There is some confusion as to the identify of M24. NGC 6603 lies in the northern portion of a large star cloud. Some people attribute M24 to NGC 6603, while others believe the designation refers to the entire cloud. The statistics given above pertain just to NGC 6603.

NGC 6603 is a group of several hundred stars of magnitude 14 and dimmer. As such, an 8 inch telescope (or larger) is required to see the cluster as anything but a little nebulous patch.

Though large and visible to the naked eye, the star cloud was not mentioned until catalogued by Messier in 1764. It is roughly rectangular in shape, measuring 1 x 2 degrees, oriented with the longer axis NE to SW. Several dark nebulae border the cloud along its northwest edge. The dark nebula "B92" is prominent, located near Gamma Sagittarii. It is a massive cloud of dust and gas, blocking the light from stars behind it.

The star cloud is 560 light years across its longest dimension.

1.103 M25, IC 4725

View Picture

```
 Discoverer..................de Cheseaux, 1746
 Distance....................2,000 light years
 True diameter...............20 light years
 Number of stars.............~100
```
This is a loose open cluster. It contains about 50 stars brighter than 12th magnitude, and about as many fainter members.

The brightest stars are of spectral type B4, and there are a few G-type giants as well. M25 is moving away from us at a velocity of about 4 km/sec.

A bright Cepheid variable star, denoted U Sagittarii, is part of the cluster. It ranges in magnitude from 6.3 to 7.1, over a period of 6.744925 days, while its spectral type ranges from F5 to G1. Cepheid variables are rare in open clusters, with only a few examples known. U Sagittarii is also a double star, with a companion 66.5 arcseconds (40,000 AU) distant, at a position angle of 253 degrees.

1.104 M26, NGC 6694

View Picture

```
 Discoverer..................Le Gentil, prior to 1750
```

```
 Distance.....................4,900 light years
 True diameter................12-16 light years
 Number of stars..............~100
```
This open cluster is located in a rich section of the Milky Way. In small telescopes, it appears as a tight group, with the brightest star (11th magnitude) in the southwest corner.

With a 6 inch telescope (or larger), about 25 stars can be resolved.

1.105 M27, NGC 6853, The Dumbbell Nebula

View Picture

```
 Discoverer...................Charles Messier, July 1764
 Distance.....................~900 light years
 True diameter................2.5 light years
```
M27 is a planetary nebula, considered to be the brightest in the sky. Shining with an integrated magnitude of 8, it is visible in large binoculars and small telescopes. "The Dumbbell Nebula" was so called because of its characteristic shape - see the picture for details.

M27 was the first planetary nebula mentioned by Messier in his list. Planetary nebulae consist of gas ejected from a dying star, but this particular nebula does not have a 'typical' appearance. Normally, when the star sheds its gas, it does so more or less symmetrically, generating an expanding spherical shell of gas in the process. The result looks like a 'ring' around the star which exploded (See M57, The Ring Nebula). However, when the star creating M27 exploded, it did so asymmetrically, and a 'ring' did not appear.

The distance to the nebula is not precisely known, with best estimates ranging around 900 light years. If this is indeed the case, then M27 is one of the largest planetary nebulae known, with a diameter of 2.5 light years. The nebula is still expanding, at a rate of 30 km/sec. If this expansion has been going on at a continuous rate, astronomers calculate that its age would be about 48,000 years.

The star from which the nebula originated has been detected, shining at magnitude 13.5 near its centre. It is a blue dwarf star, with an incredibly high surface temperature of 85,000 degrees C. It appears to be part of a double system, with a yellow 17th magnitude companion 6.5 arcseconds distant, at a position angle of 214 degrees.

1.106 M28, NGC 6626

View Picture

```
 Discoverer...................Charles Messier, July 1764
 Distance.....................15,000 light years
 True diameter................65 light years
 Number of stars..............hundreds
```
This globular cluster does not appear very striking in the average amateur telescope. Composed of stars dimmer than 14th magnitude compressed into a

small region, it is often described as a fuzzy round spot.

M28 is moving slowly away from us at the rate of 1.5 km/sec. Several variable stars have been detected, most of which are of RR Lyrae type. A Population II Cepheid variable with a period of 12.937 days was detected, as was an RV Tauri variable with a period of 90 days, undergoing a change in brightness of 2 magnitudes.

1.107 M29, NGC 6913

View Picture

Discoverer.....Charles Messier, July 1764
Distance.....7,200 light years
True diameter.....15 light years
Number of stars.....~20
This is a small cluster in a crowded area of the Milky Way. At the center, there is a tight arrangement of 8th-9th magnitude stars. It appears, however, that the region of our galaxy in which M29 lies has a density of dust particles 1000 times greater than average. This dust tends to dim the cluster by 3 magnitudes.

The brightest stars are of spectral type B.

1.108 M30, NGC 7099

View Picture

Discoverer.....Charles Messier, August 1764
Distance.....40,000 light years
True diameter.....100 light years
Number of stars.....hundreds
This globular cluster is slightly elliptical in shape, with a dense central nucleus. Several variable stars are found in the cluster, as well as a Dwarf Nova variable resembling U Geminorum.

The bright star "41 Capricorni" is very near the cluster, appearing just 25 arcminutes east. M30 is moving towards us at the rapid rate of approximately 180 km/sec.

1.109 M31, NGC 224, The Andromeda Galaxy

View Picture

Discoverer.....Al Sufi, 905 AD
Distance.....2,200,000 light years
True diameter.....110,000 light years
Number of stars.....>300,000,000,000
M31 is the brightest galaxy in our night sky. In fact, it is so bright that it can be seen by the naked eye, appearing as a small, elongated, fuzzy cloud.

When using a telescope to view the object, use a low power, wide field eyepiece. The galaxy is large enough that higher powers will only show the condensation in its nucleus. Even with larger telescopes, the galaxy reveals few features, appearing as a smooth glow gradually brightening towards the centre. Long exposure photographs are required to show more than just a hint of detail.

The Andromeda Galaxy appears to have been known at least as far back as 905 AD, when it was mentioned by the Persian astronomer Al Sufi as the "Little Cloud". It was first observed telescopically by Simon Marius in 1611 or 1612, who considered it a nebula. It wasn't until much later that spectroscopic observations revealed it to be composed of a great number of individual stars. In 1923, several Cepheid variables were discovered in the galaxy. This was significant since they would enable astronomers to approximate its distance. Prior to the discover of the Cepheids, astronomers considered it a cluster associated with nebulosity, within the Milky Way. Dr. E. Hubble calculated its distance to be about 900,000 light years, placing it outside the confines of our own galaxy. Through more accurate measurements in later years, and the realization that there were at least two different types of Cepheid variables, with different mass-luminosity relationships, its distance was adjusted to the present-day value of 2,200,000 light years.

The Andromeda Galaxy, like our Milky Way, consists of billions of individual stars. It has a spiral structure that classifies it as a type 'Sb' galaxy. M31 is more or less circular in shape, though it appears elongated since it is viewed at an angle of only 15 degrees from edge-on. Like all spiral galaxies, it is in slow rotation, with the inner regions orbiting around the galactic center in 11 million years, and the outermost in 200 million years. Studies of the Andromeda Galaxy have conclusively proved that the arms in spiral galaxies trail, rather than lead, in the galaxy's rotation.

Telescopes 100 inches or larger are required to resolve individual stars in the galaxy. Even then, it should be remembered that only the extremely bright stars can be resolved. At the distance of the Andromeda Galaxy, our Sun would shine at an extremely feeble magnitude of 29.1, beyond the range of any of our current telescopes.

Though the entire galaxy spans a distance of at least 110,000 light years, the nucleus is a condensed region containing more than 10,000,000 stars in a sphere only 50 light years across. In such tight concentrations, it is expected that stellar collisions may periodically occur.

Approximately 140 globular clusters and several planetary nebulae have been detected in the Andromeda Galaxy.

M31 is approaching us at a rate of about 35 km/sec. It is thus unique in that it does not appear red shifted like most of the other galaxies.

It is estimated that approximately 30 stars in the Andromeda Galaxy go nova every year, though they typically only reach magnitudes of 15 to 19 as they are at a vast distance from us. When corrections for this distance are made, they turn out to be about the same brightness as novae in our Milky Way. However, in 1885, astronomers observed a star flare up to an apparent magnitude of 5.4. At its distance, it would have to be 1.6 billion times as bright as the Sun. The object, denoted "S Andromedae", had turned out to be the first observation of a supernova in another galaxy.

In 1950, H. Brown and C. Hazard at the Jodrell Bank in England detected that M31 was a source of radio energy at 158.5 MHz.

On July 20, 1993, Tod R. Lauer (National Optical Astronomy Observatories) and Sandra M. Faber (University of California) used the Hubble Space Telescope to make observations of the central regions of M31. To their surprise, the images revealed a double nucleus. It is still unknown as to whether the observation indicates two separate condensations of stars, or whether there is a single nucleus divided by a dust lane.

1.110 M32, NGC 221

View Picture of M32
View Picture showing relationship with M31

Discoverer.....Le Gentil, 1749
Distance.....2,200,000 light years
True diameter.....2,400 light years
Number of stars.....millions

M32 is a companion elliptical (type 'E2') galaxy to the Andromeda Galaxy, M31. It is easily visible, even in binoculars, and appears as a 9th magnitude fuzzy 'smudge' just 24 arcminutes south of the center of M31.

1.111 M33, NGC 598, The Pinwheel Galaxy

View Picture

Discoverer.....Charles Messier, August 1764
Distance.....2,400,000 light years
True diameter.....42,000 light years
Number of stars.....billions

This is the second nearest spiral galaxy, only the Andromeda Galaxy being closer. But it is nowhere near as easy to observe, with its low brightness spread over a large area similar in size to the Moon. More important than the size of the telescope, a wide field with low power is required to see it. Binoculars may prove the most useful instrument in locating this galaxy.

M33 is classified as an "Sc" spiral galaxy, and is rather loosely structured. High luminosity stars of spectral type O and B have been found, as well as open clusters, globular clusters, Cepheid variables, irregular variables, novae, and nebulae. Because of the spectrae of the supergiant stars found within, M33 appears more blue than many other galaxies.

M33 is slowly rotating clockwise, with stars near the edge of the galaxy completing one orbit in 200,000,000 years. Like the Andromeda Galaxy, the Pinwheel Galaxy is not receding from us, but rather approaching at a rate of about 12 km/sec. This is unusual in that most galaxies show us a red shift and are moving away from us.

1.112 M34, NGC 1039

View Picture

 Discoverer..................Charles Messier, August 1764
 Distance....................1500 light years
 True diameter...............18 light years
 Number of stars.............~80
This is a bright open cluster visible to the naked eye under good conditions. Composed of stars from magnitude 8 to 13, it appears most spectacular in a low power, wide field view.

The brightest stars in the cluster are of spectral type B8. Color-magnitude studies imply that the age of the stars is slightly over 100 million years.

1.113 M35, NGC 2168

View Picture

 Discoverer..................de Cheseaux, 1745
 Distance....................2200 light years
 True diameter...............30 light years
 Number of stars.............hundreds
This open cluster is bright enough to be visible by binoculars, or even by the unaided eye during exceptional viewing conditions. Small telescopes reveal this cluster to appear somewhat like a nebula, while 6 inch or larger telescopes reveal a multitude of stars at the more or less uniform magnitude of 7.5.

Spectral types of stars in the cluster range from B3 to G0, as well as several orange and yellow giants. The brightest is of spectral type B3.

1.114 M36, NGC 1960

View Picture

 Discoverer..................Le Gentil, 1749
 Distance....................4100 light years
 True diameter...............14 light years
 Number of stars.............hundreds
This open cluster contains about 60 stars ranging from magnitude 9 to 14. As the central condensation measures about 10 arcminutes in diameter, use eyepieces with low power and a wide field to view it.

M36 is a fairly young cluster, with no red giants. All its members are of spectral type B, including main sequence stars and subgiants.

1.115 M37, NGC 2099

View Picture

 Discoverer..................Charles Messier, August 1764

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 Distance.....................4600 light years
 True diameter................25 light years
 Number of stars..............>500
```
This is a large and bright open cluster, considered by many to be one of the finest in the sky. In telescopes larger than 2 inches, some of the individual stars should be able to be resolved. 150 stars brighter than magnitude 12.5 are visible. It is believed that the cluster is approximately 200,000,000 years old.

The cluster is roughly triangular in shape, and includes a prominent yellow-orange star. It is cut into sections by dark lanes.

Though the cluster is composed mostly of main sequence stars with spectral type A, several dozen red giants may be seen as well. Particularly prominent is one such red giant near the center of the cluster, shining at magnitude 9.5.

1.116 M38, NGC 1912

View Picture

```
 Discoverer..................Le Gentil, 1749
 Distance.....................4200 light years
 True diameter................25 light years
 Number of stars..............>100
```
This is a scattered open cluster about 20 arcminutes in diameter. It is composed of stars of a wide variety of spectral types, ranging from B5 to G. The brightest star is a yellow G0 giant shining at an apparent magnitude of 7.9.

The stars are arranged in the rough outline of the Greek letter "Pi".

1.117 M39, NGC 7092

View Picture

```
 Discoverer..................Le Gentil, 1750
 Distance.....................800 light years
 True diameter................7 light years
 Number of stars..............~30
```
Though its discovery is generally attributed to Le Gentil in 1750, there is evidence to suggest that M39 was mentioned by Aristotle as long ago as 325 BC. Visible to the naked eye under good sky conditions, this open cluster is an easy target in binoculars. Since the brightest members span a region more than 30 arcminutes in diameter, only low power eyepieces should be used when observing through a telescope.

M39 is approaching us at a rate of about 15 km/sec. Virtually all stars in the cluster are on the main sequence, though some show evidence of beginning to move to ‘giant’ status.

1.118 M40, Double star - SAO 28353 & SAO 28355

View Picture

M40 is one of the two mistakes in Messier's Catalogue. No nebula, galaxy, or cluster exists at the site; instead only a double star can be found. In 1660, the astronomer Hevelius listed the object as a nebula. When Messier later tried to find this object in 1764, he stated that he "looked for the nebula which is above the back of the Great Bear... I found by means of this position, two stars, very close together and of equal brightness, about 9th magnitude,... They are difficult to distinguish with an ordinary telescope of 6 feet... It is presumed that Hevelius mistook these two stars for a nebula..."

However, despite Messier's realization that the object was only a double star, he included the object in his catalogue. There is a faint galaxy (NGC 4290) located in the field, but it is unlikely that it could have been seen by Messier or Hevelius, as it is a faint barred spiral galaxy of magnitude 12.7.

See also: M102

1.119 SAO 28355

See SAO 28353.

1.120 M41, NGC 2287

View Picture

```
 Discoverer..................Aristotle, 325 BC
 Distance....................2350 light years
 True diameter...............20 light years
 Number of stars.............>100
```

This bright open cluster is visible to the naked eye under good conditions. Binoculars and small telescopes are capable of resolving individual stars. Covering an area about 30 arcminutes in diameter, 25 bright stars (including a prominent orange star near the center) and numerous fainter ones can be seen. Magnitudes range from 7 to 13.

M41 is moving away from us at a speed of approximately 30 km/sec.

1.121 M42, NGC 1976, The Great Orion Nebula

View Picture

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 Discoverer..................Nicholas Peiresc, 1611
 Distance....................1700 light years
 True diameter...............30 light years
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M42, or the Great Orion Nebula, is one of the most spectacular and interesting objects in the sky. Plainly visible even to the naked eye, it may be observed

in binoculars as a faint mist near four stars known as "The Trapezium", or Theta 1 Orionis. Small telescopes reveal this mist to be greenish in color. A larger telescope (and particularly, long exposure photography) allows the observer to view detail unmatched by any other deep sky object in the heavens. Best observations are done with low power, wide field eyepieces.

Since the Orion Nebula is so obvious to all but the most casual observers, it is surprising that the first mention of it did not occur until 1611. In 1880, M42 became the first nebula to be photographed, when it was captured by Henry Draper with an 11 inch telescope, and an exposure time of 51 minutes.

The nebula itself consists of an extremely tenuous cloud of gas and dust. It has a density a million times smaller than that of a good laboratory vacuum, yet its massive size contains enough material to form 10,000 stars like the Sun. In fact, stellar formation is occurring within the nebula, as the cloud condenses into "pockets" which eventually become dense and hot enough for nuclear fusion to initiate.

The composition of the Orion nebula is believed to be as follows:

Element	Concentration (atoms per cubic metre)
Hydrogen	880,000,000
Helium	88,000,000
Carbon	530,000
Oxygen	220,000
Nitrogen	180,000
Sulphur	32,000
Neon	8,800
Chlorine	1,800
Argon	1,300
Fluorine	110

The "Trapezium", or the multiple system of four bright stars designated as Theta 1 Orionis is estimated to be only 23,000 years old. This is one of the best indications to prove that the Orion Nebula is indeed a star forming region. In addition, photographs taken in 1947 and 1954 showed changes in the appearance of condensation regions in the nebula. These regions are suspected to be protostars still in the process of accumulating enough matter for fusion to begin.

Studies done with the 27-disk VLA (Very Large Array) radio telescope in New Mexico in 1990 have revealed the existence of bright filaments surrounding the Trapezium. Visual evidence had hinted to such structures, but they are much more obvious with the radio data. Astronomers do not yet know what they are. They may be the edges of gas ‘bubbles’ inflated by stellar winds. Other possibilities include their being condensations of cooling interstellar gas, or regions where expanding gas bubbles encounter abrupt changes in the density of the interstellar medium.

In 1994, C. Robert O’Dell (Rice University) and Zheng Wen (University of Kentucky) used the Hubble Space Telescope to study stars near the Trapezium to see if they could detect any disks of gas and dust surrounding them (thought to be planetary systems in the making). They were surprised to find that 56 of the 110 stars they surveyed had such disks. Because the stars are so young, the disks have not yet had time to condense into planets, however the data indicates that planetary formation may be a common occurrence in the universe.

More than 50 variable stars have been detected in M42. One of the most interesting is designated as "T Orionis". This irregular variable 5.2 arcminutes south and 9 arcminutes east of the Trapezium stays at a magnitude of about 9.4 for several months. Then, it rapidly and unpredictably fluctuates in brightness, on occasion becoming as dim as magnitude 12.6. Astronomers are not sure what causes these variations.

As a whole, M42 is moving away from us at a rate of about 30 km/sec, although the cloud is quite turbulent, and different portions are receding at different rates. In addition, it is measured to be expanding at the rate of about 10 km/sec in the inner regions and 7 km/sec in the outer.

There is some evidence to suggest the existence of a black hole in the Orion nebula. Strong X-rays from a source designated 2UO525-06 (near Theta 2 Orionis) were detected in 1976.

In 1992, C. Robert O'Dell of Rice University used the Hubble Space Telescope to identify 15 disks of gas and dust surrounding newly formed stars. These disks are believed to contain a mass 15 times greater than that of Jupiter, and it is thought that they may condense into planets in the future. Based on his data, O'Dell believes that up to 40% of the newly formed stars in the Orion nebula may be surrounded by these 'protoplanetary' disks.

1.122 M43, NGC 1982

View Picture
View M43 and its relationship to M42

Discoverer.....Nicholas Peiresc, 1611
Distance.....1700 light years
True diameter.....6 light years
M43 is a detached portion of the Great Orion Nebula, located just to the north of it. It is illuminated by its own 8th magnitude star.

For more information, see M42.

1.123 M44, NGC 2632, Praesepe, or the Beehive Cluster

View Picture

Discoverer.....unknown
Distance.....525 light years
True diameter.....40 light years
Number of stars.....>350
This is one of the largest, nearest, and brightest open clusters. Visible to the naked eye, binoculars are sufficient to resolve individual stars. If a telescope is used, ensure that you use a low power, wide field eyepiece to be able to see the entire cluster in your field of view.

Since it is visible to the naked eye, M44 has been known since ancient times (at least as long ago as 260 BC). It was used to forecast the weather - if it was not visible on an an otherwise clear night, a violent storm was said to be

approaching. Known as the "Little Cloud", or "Little Mist", it wasn't recognized as a cluster of stars until Galileo viewed the object with his telescope.

Most of the stars in the cluster are of spectral types ranging from A2 to K6. Several orange giants and white dwarfs have been detected. A Dwarf Eclipsing Variable denoted TX Cancri is in the cluster, with a period of 0.38 days, undergoing a small magnitude change from 10.5 to 10.8.

The cluster is moving away from us at a rate of about 42 km/sec. It is estimated to be about 400,000,000 years old.

1.124 M45, The Pleiades

View Picture

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 Discoverer...................unknown
 Distance.....................410 light years
 True diameter................20 light years
 Number of stars..............~500
```

This famous open cluster was not given an NGC designation, but was listed by Messier in his catalogue. It is sometimes called "The Seven Sisters" since seven stars can be seen by the naked eye under good conditions (though observers with exceptionally keen eyesight have reported seeing up to 16).

Binoculars or telescopes with a very wide angle, low power eyepiece are essential to see the hundreds of stars which make up the cluster. Do not use high magnifications, or the Pleiades (spanning 1 degree) will not fit entirely into the field of view. With small instruments, up to 100 stars may be seen. Long exposure photographs with large telescopes have revealed over 2000 stars in the vicinity of the cluster, though only 1/4 are believed to be associated with the cluster (the rest merely lie along the line of sight).

The Pleiades consists mostly of stars on the main sequence, with no red giants. It is believed to be only about 20 million years old, and is moving away from us at a rate of about 8 km/sec.

The star named Pleione (also designated 28 Tauri or BU Tauri) is a rather interesting variable star. In addition to changing its brightness by 0.5 magnitudes, it rotates at the high rate of 3 times per day (about 100 times faster than our Sun). In addition, it seems to eject gas into space from time to time. Some astronomers think that this may occur at least in part due to the star's rapid rotation.

A faint reflection nebula surrounds the stars composing the Pleiades. Observers typically need a telescope 6 inches or larger to detect the nebula, though it might be visible under extremely good sky conditions with smaller instruments. As with most things in astronomy, long exposure photography is required to see any detail but the faintest smudge. The nebula is divided into two NGC objects - NGC 1432 (The Maia Nebula) and NGC 1435 (The Merope Nebula).

The named stars in the Pleiades include Pleione, Atlas, Alcyone, Merope, Electra, Maia, Taygeta, Celaeno, Sterope I (Asterope), and Sterope II.

1.125 M46, NGC 2437

View Picture

```
 Discoverer..................Charles Messier, February 1771
 Distance....................5400 light years
 True diameter...............30 light years
 Number of stars.............~500
```
This open cluster is visible in small telescopes as a tiny circular grouping of stars. It is quite dim, with the magnitudes of stars ranging from 10 to 13.

The small planetary nebula NGC 2438 appears within M46, but the relationship is believed to only be "line-of-sight", since they are not located at the same distance from us.

1.126 M47, NGC 2422

View Picture

```
 Discoverer..................Charles Messier, February 1771
 Distance....................1500 light years
 True diameter...............16 light years
 Number of stars.............45
```
M47 is a bright, though sparse open cluster. Though the brightest star is magnitude 6, the large number of fainter stars require a telescope 8 inches or greater. All the brighter stars are of spectral type B or A. In larger instruments, you can see several star chains and dark lanes radiating outwards from a dark nucleus.

No object can be found at the position cited by Messier for M47. However, his description of the cluster matches the appearance of nearby NGC 2422, so it is thought that he simply published an erroneous position.

1.127 M48, NGC 2548

View Picture

```
 Discoverer..................Charles Messier, February 1771
 Distance....................1700 light years
 True diameter...............20 light years
 Number of stars.............~50
```
This open cluster is easily visible in binoculars, and can be seen with the naked eye under good sky conditions. There are about ten stars brighter than 11th magnitude in the cluster. Three yellow giants of spectral type G or K make their home in the cluster, as do several main sequence stars of spectral type A.

No object can be found at the position cited by Messier for M48. However, his description of the cluster closely matches the appearance of nearby NGC 2548. It is thought that he simply published an erroneous position.

The cluster shines with a light approximately equal to 1400 times that of the

Sun.

1.128 M49, NGC 4472

View Picture

```
 Discoverer..................Charles Messier, February 1771
 Distance....................48,000,000 light years
 True diameter...............50,000 light years
 Number of stars.............billions
```

M49 is a slightly elliptical galaxy, one of the brighter members of the Virgo Cluster of galaxies. It is usually classified as an 'E3' type galaxy, and is one of the largest such objects known. It is moving away from us at a velocity of approximately 1000 km/sec.

It is incredibly massive, thought by most astronomers to be 5 times larger than the Milky Way.

1.129 M50, NGC 2323

View Picture

```
 Discoverer..................Jean Cassini, before 1711
 Distance....................2,000 light years
 True diameter...............9 light years
 Number of stars.............~200
```

M50 is a bright open cluster which can be easily seen in binoculars. Under the best sky conditions, some observers have reported seeing it with the naked eye.

A red giant star of spectral type M is prominent 7 arcminutes south of the center. The majority of stars are on the main sequence having spectral types ranging from B8 to A0. The cluster emits about 1600 times more light than our Sun.

1.130 M51, NGC 5194, The Whirlpool Galaxy

View Picture

```
 Discoverer..................Charles Messier, October 1773
 Distance....................35,000,000 light years
 True diameter...............18,000 light years
 Number of stars.............billions
```

M51 is an type 'Sc' spiral galaxy, visible as a faint smudge in instruments as small as binoculars under good sky conditions. Telescopes as large as 8 or 10 inches are required before a hint of the spiral structure of the galaxy is revealed. Long exposure photography reveals a wealth of features in its structure, including narrow dust lanes delineating the spiral arms.

In the July 22, 1993 issue of "Nature", Dennis Zaritsky (Carnegie Observatory), Hans-Walter Rix (Institute for Advanced Study), and Marcia Rieke (University of

Arizona) reported on infrared images that they obtained with the 2.3 metre reflector on Kitt Peak. They found that the two primary spiral arms of the galaxy are detectable almost up to the very core of the galaxy. This discovery cannot have been made with visible light, since the nucleus is obscured by dust.

M51 is receding from us at a rate of about 570 km/sec.

A bright galaxy known as NGC 5195 is apparently associated with M51. Computer simulations carried out in 1990 by Sethanne Howard (of Georgia State University) and Gene G. Byrd (of the University of Alabama) indicate that the two galaxies apparently brushed past each other 70 million years ago. Tidal effects of the close encounter appear to have produced a great amount of the detail seen in the outer arms of M51. NGC 5195 is now observed to orbit the Whirlpool with a period of 500 million years, inclined at an angle of 50 degrees to the plane of the larger galaxy. The two galaxies are drawing nearer together, and should merge within the next few billion years.

On April 2, 1994 Tim Puckett and Jerry Armstrong of Atlanta, Georgia discovered a supernova near the center of this galaxy. Designated SN1994I, the star brightened to magnitude 13 before fading. Astronomers think that it may have been a rare type of supernova explosion (called 'Type Ic') in which the star had already shed its outer layers.

1.131 M52, NGC 7654

View Picture

Discoverer.....Charles Messier, Sept. 7, 1774
Distance.....5,400 light years
True diameter.....12 light years
Number of stars.....~200

This open cluster is visible in binoculars or small telescopes. It is rather compressed, with a distance of less than 1 light year separating stars in the center. The brightest stars on the main sequence are blue giants of spectral type B7, whereas the brightest stars overall are F9 and G8 yellow giants.

1.132 M53, NGC 5024

View Picture

Discoverer.....Bode, February 1775
Distance.....65,000 light years
True diameter.....250 light years
Number of stars.....~50,000

This bright, condensed globular cluster is visible in a telescope of 3 inches in size, but resolving individual stars requires a telescope 6 inches or larger. It is composed of stars of 11th magnitude and fainter. Several variable stars have been found in M53. As a whole, the cluster emits 200,000 times more energy than our Sun. It is observed to be moving towards us at the rate of 120 km/sec.

1.133 M54, NGC 6715

View Picture

```
 Discoverer..................Charles Messier, July 1778
 Distance....................50,000 light years
 True diameter...............70 light years
 Number of stars.............hundreds
```
This tiny globular cluster is rather difficult to see with smaller instruments. In telescopes smaller than 10 inches, expect nothing more than a round, fuzzy spot. Telescopes larger than 10 inches are capable of resolving a few stars if they are used during excellent sky conditions.

About 100 variable stars have been detected in M54, most of which are of the RR Lyrae type. The cluster is moving away from us at a velocity of about 130 km/sec.

1.134 M55, NGC 6809

View Picture

```
 Discoverer..................Lacaille, 1752
 Distance....................20,000 light years
 True diameter...............80 light years
 Number of stars.............thousands
```
This large globular cluster is visible in binoculars, appearing as a somewhat hazy 'star'. In small telescopes, the haze will seem like a roughly circular nebula, with resolution into individual stars being reserved for larger instruments.

The cluster is composed of a few stars of magnitude 13 to 14, and several thousand at magnitude 17 and beyond. Several RR Lyrae variable stars have been detected in M55. It is moving away from us at a velocity of about 175 km/sec, and is thought to be one of the nearest globular clusters.

1.135 M56, NGC 6779

View Picture

```
 Discoverer..................Charles Messier, Jan. 19, 1779
 Distance....................46,000 light years
 True diameter...............60 light years
 Number of stars.............thousands
```
M56 is a globular cluster showing little evidence of central condensation. Though visible as a faint smudge in small telescopes, a 6 inch telescope is required to resolve individual stars. Several variable stars have been found in the cluster.

Approaching us at the rate of about 150 km/sec, M56 as a whole shines with a light equal to 90,000 times that of our Sun.

1.136 M57, NGC 6720, The Ring Nebula

View Picture

```
 Discoverer..................Antoine Darquier, 1779
 Distance.....................1,400 light years
 True diameter................0.5 light years
```

This is probably the most famous of all planetary nebulae. Planetary nebulae are caused by a star shedding its outer layers of gas. But since this gas is rather thinly distributed, it is easiest to observe if a substantial portion intersects our line of sight. When looking at the shell of expanding gas, we are only able to see it clearly near the edges, since here our line of sight is blocked most. As a result, a symmetrically expanding shell appears to us as a 'ring' around the star from which it originated. This feature is plainly evident in M57, the Ring Nebula.

The Ring Nebula is visible in telescopes 4 inches or larger in size, though a 6 inch telescope is typically needed to be able to see the ring structure. The central star (from which the nebula originated) was discovered by F. Von Hahn around the year 1800. Detection of this star requires very large amateur telescopes, as it is quite dim. There is evidence to suggest that it may be variable, ranging between magnitudes 14 and 16. It is thought to be a blue dwarf star, with a density several thousand times that of the Sun, and a surface temperature 20 times greater. It may be entering the white dwarf stage.

The composition of M57 is believed to be as indicated in the following table. Astronomers think that other planetary nebulae contain a similar relative proportion of ions.

Ion	Concentration (atoms per cubic metre)
Hydrogen	9,300,000,000
Helium	730,000,000
Oxygen	5,400,000
Nitrogen	2,700,000
Neon	820,000
Sulfur	500,000
Argon	70,000
Chlorine	20,000
Fluorine	2,000

Though there may seem to be a large number of atoms per cubic metre in the nebula, in fact it is more than 1000 times better than a good laboratory vacuum.

The Ring Nebula appears to be expanding at a rate of about 20 km/sec. If it has been expanding at a continuous rate, it would have begun its life a mere 20,000 years ago to attain its present size.

1.137 M58, NGC 4579

View Picture

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 Discoverer..................Charles Messier, April 1779
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 Distance.....................48,000,000 light years
 True diameter................56,000 light years
 Number of stars..............billions
```
This barred spiral (type 'SBb') galaxy, part of the Virgo Cluster of galaxies, is rather difficult to see without a medium to large sized telescope. An 8 inch telescope is required to see the 'bar' in its structure.

M58 is moving away from us at the rate of about 1700 km/sec.

1.138 M59, NGC 4621

View Picture

```
 Discoverer...................J. G. Koehler, April 1779
 Distance.....................48,000,000 light years
 True diameter................28,000 light years
 Number of stars..............billions
```
This is an elliptical galaxy of type 'E4'. It is believed to contain enough mass to form 250 billion stars the size of our Sun. A supernova reaching magnitude 12 appeared in this galaxy in May 1939.

The galaxy is quite dim, and requires a medium to large-sized telescope to be visible.

M59 is located in the Virgo Cluster of galaxies, and is moving away from us at a velocity of about 350 km/sec.

1.139 M60, NGC 4649

View Picture

```
 Discoverer...................J. G. Koehler, April 1779
 Distance.....................48,000,000 light years
 True diameter................42,000 light years
 Number of stars..............billions
```
This elliptical galaxy, of type 'E1', is incredibly massive. It is believed to contain enough matter to make 1,000,000,000,000 stars the size of our Sun.

Generally, a telescope of at least 4 inches in diameter is required to see this galaxy. M60 is located in the Virgo Cluster of galaxies, and appears to be receding from us at a velocity of 1400 km/sec. It appears to be associated with the spiral galaxy NGC 4647.

1.140 M61, NGC 4303

View Picture

```
 Discoverer...................B. Oriani, May 1779
 Distance.....................48,000,000 light years
 True diameter................70,000 light years
```

 Number of stars.....billions
M61 is an 'Sc' spiral galaxy appearing face-on from our vantage point on the Earth. It is one of the larger galaxies in the Virgo Cluster, containing a mass of 50 billion times that of our Sun. It is visible in 4 inch telescopes under good sky conditions, though a much larger telescope and/or long exposure photography is required to show a hint of detail.

The galaxy is interesting in that the spiral arms do not curve smoothly away from the nucleus. Instead, they exhibit sharp 'kinks', or bends.

Supernovae in M61 were detected in 1926, 1961, and 1964.

1.141 M62, NGC 6266

View Picture

 Discoverer.....Charles Messier, June 1771
 Distance.....26,000 light years
 True diameter.....50 light years
 Number of stars.....thousands
This is a fairly dim globular cluster, with the average magnitude of the 25 brightest stars being a mere 15.9. If you only have a small telescope, excellent viewing conditions are required to see this object.

M62 has a markedly irregularly outline, with an uneven distribution of stars throughout (there seems to be more stars in the north end of the cluster). A telescope 12 inches or larger is required to resolve the individual stars.

About 100 variable stars have been found in the cluster, almost all of which are of RR Lyrae type. M62 is approaching us at a rate of about 77 km/sec.

1.142 M63, NGC 5055, The Sunflower Galaxy

View Picture

 Discoverer.....P. Mechain, 1779
 Distance.....35,000,000 light years
 True diameter.....90,000 light years
 Number of stars.....billions
M63 is a reasonably bright 'Sb' spiral galaxy, oriented about 30 degrees from appearing 'edge-on'.

This galaxy is interesting in that it seems to have two distinct sets of spiral arms. Adjoining the small nucleus are tightly wound arms extending to an apparent distance of 50 arcseconds. Then, a second set of spiral arms, less tightly wound, extend the remaining distance. The resulting appearance is reminiscent to some as a sunflower, hence the name.

M63 shines with a total light 10 billion times greater than that of our Sun, and contains 115 billion times more mass.

1.143 M64, NGC 4826, The Black Eye Galaxy

View Picture

```
 Discoverer..................Bode, April 4, 1779
 Distance....................20,000,000 light years
 True diameter...............48,000 light years
 Number of stars.............billions
```
This 'Sa' spiral galaxy is visible in good binoculars or small telescopes, though it will appear as nothing more than a faint wisp of light. Larger telescopes are required to see any features.

Though the arms of M64 are smooth with no unusual features, the nucleus of the galaxy is unique. In a telescope 6 inches or larger, a dark nebula can be seen extending the length of the nucleus.

M64 is receding from us at a rate of about 375 km/sec, and shines with a total light 13 billion times stronger than that of our Sun.

Observations made in the early 1990s by Robert Braun of the "Netherlands Foundation for Research in Astronomy" with the Very Large Array (VLA) in New Mexico have showed that neutral hydrogen within 3000 light years of the center of the Black Eye Galaxy rotates in the opposite direction from the hydrogen in the outer regions. At the boundary point between the two zones, the gas molecules smash together, lose their angular momentum, and fall towards the galactic nucleus.

Braun believes that this behaviour could have arisen from two galaxies rotating in opposite directions that merged long ago.

1.144 M65, NGC 3623

View Picture

```
 Discoverer..................P. Mechain, March 1780
 Distance....................30,000,000 light years
 True diameter...............60,000 light years
 Number of stars.............billions
```
This spiral galaxy, classified as either 'Sa' or 'Sb', can be seen by binoculars under excellent sky conditions, though a larger telescope is required to see detail in its structure. It is thought to be part of the Virgo Cluster of galaxies.

M65 is quite symmetrical, with its arms following a classic spiral pattern. It is tipped at a viewing angle of about 14 degrees from edge-on, and is moving away from us at a rate of about 630 km/sec.

1.145 M66, NGC 3627

View Picture

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 Discoverer..................P. Mechain, March 1780
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```
 Distance.....................30,000,000 light years
 True diameter................50,000 light years
 Number of stars..............billions
This spiral galaxy, classified as 'Sb', can be seen by binoculars under
excellent sky conditions, though a larger telescope is required to see detail
in its structure.  It is thought to be part of the Virgo Cluster of galaxies.

Several large dust lanes may be seen between the spiral arms of M66.  The
galaxy is moving away from us at a rate of about 630 km/sec.
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1.146 M67, NGC 2682

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View Picture

 Discoverer...................unknown
 Distance.....................2,500 light years
 True diameter................12 light years
 Number of stars..............~500
This open cluster contains approximately 500 stars, ranging in magnitude from
10 to 16, and in spectral type from B9 to K4.  The composition of its stars
makes M67 resemble a globular cluster, thought to be about 10 billion years
old.
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1.147 M68, NGC 4590

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View Picture

 Discoverer...................Charles Messier, 1780
 Distance.....................46,000 light years
 True diameter................100 light years
 Number of stars..............>100,000
This globular cluster is visible in small telescopes, though a 6 inch
instrument is required to resolve individual stars. A great deal of faint stars
are visible in the cluster, making it appear spectacular in large telescopes.

Approximately 50 variable stars have been detected in the cluster, which is
approaching us at a rate of about 120 km/sec.
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1.148 M69, NGC 6637

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View Picture

 Discoverer...................Lacaille, 1752
 Distance.....................36,000 light years
 True diameter................70 light years
 Number of stars..............thousands
M69 is a small globular cluster, composed of stars of magnitude 14 and fainter.
A large telescope is required to resolve individual stars.

Several variable stars have been detected in the cluster, with at least two
```

long period variables that fluctuate in brightness over a 200 day period.

M69 is one of the most metal-rich globular clusters known. It is moving away from us at a velocity of about 100 km/sec.

1.149 M70, NGC 6681

View Picture

Discoverer.....Charles Messier, August 1780
Distance.....65,000 light years
True diameter.....80 light years
Number of stars.....thousands
This small globular cluster has a bright, condensed center, and is composed of stars from 14th to 17th magnitude. A 6 inch telescope is required to resolve individual stars.

A few variable stars have been discovered in the cluster, most of which are of type RR Lyrae. M70 is moving away from us at a velocity of about 205 km/sec.

1.150 M71, NGC 6838

View Picture

Discoverer.....J. G. Koehler, 1775
Distance.....18,000 light years
True diameter.....30 light years
Number of stars.....thousands
This cluster of stars is visible as a faint patch of light in telescopes smaller than 4 inches. The stars range from magnitude 11 to 17, and include several red giants as well as stars on the main sequence.

The classification of M71 is subject to some debate. It exhibits characteristics representative of both globular and open clusters.

M71 is moving toward us at a rate of about 80 km/sec.

1.151 M72, NGC 6981

View Picture

Discoverer.....P. Mechain, August 1780
Distance.....60,000 light years
True diameter.....85 light years
Number of stars.....thousands
M72 is an unimpressive globular cluster, visible only as a faint haze of light in all but the largest telescopes. It is more 'open' than most globulars, consisting of stars dimmer than magnitude 15. Resolving individual stars requires telescopes typically larger than 12 inches.

About 50 variable stars have been located in this cluster, most of which are RR Lyrae variables. The system is approaching us at a velocity of about 270 km/sec.

1.152 M73, NGC 6994

View Picture

Discoverer.....Charles Messier, October 1780
Number of stars.....4
This object should not really be considered as a true deep sky object, since it is merely a gathering of four dim stars of magnitudes 10.5, 10.5, 11.0, and 12.0. Messier, however, thought he detected some nebulosity associated with the stars, and so included it in his catalogue.

Modern photographs of the stars reveal no such nebula.

1.153 M74, NGC 628

View Picture

Discoverer.....P. Mechain, September 1780
Distance.....40,000,000 light years
True diameter.....100,000 light years
Number of stars.....billions
This is a large 'Sc' spiral galaxy visible to us from a viewing angle that is almost perfectly face-on. Unfortunately, it is one of the faintest of the Messier objects, and extremely difficult to find. It is easiest to see in large telescopes with a wide field, low power eyepiece.

In long exposure photography, dust lanes can be seen delineating the spiral arms, and running almost entirely to the center of the galaxy. It is of comparable mass to our Milky Way, but the stars in it seem dimmer, on average.

M74 is receding from us at a velocity of about 710 km/sec.

1.154 M75, NGC 6864

View Picture

Discoverer.....P. Mechain, August 1780
Distance.....95,000 light years
True diameter.....125 light years
Number of stars.....thousands
M75 is a small, rich globular cluster, visible in smaller telescopes as only a faint patch of light. It is resolvable into stars only with larger instruments.

This cluster is one of the most compressed known, although the stars within it appear quite dim from our vantage point on Earth (since it is also one of the

furthest known). The 25 brightest stars have an average apparent magnitude of only 17, though the brightest one reaches 12.5. As a whole, the cluster shines with a light of 160,000 suns.

Several variable stars have been detected in the cluster. It is moving towards us at a rate of about 205 km/sec.

1.155 M76, NGC 650, The Little Dumbbell, Barbell, or Cork Nebula

View Picture

Discoverer.....P. Mechain, September 1780
Distance.....2,000 light years
True diameter.....1 light year

M76 (also known as the Little Dumbell, the Barbell, or the Cork Nebula) is a faint planetary nebula, irregular in shape. It is extremely dim and difficult to see, visible only with larger telescopes using wide field, low power eyepieces.

The central star of the nebula has been detected, and is of magnitude 16.5. It is extremely hot, with a surface temperature of about 60,000 degrees C. The system is approaching us at a rate of about 25 km/sec.

1.156 M77, NGC 1068, 3C71

View Picture

Discoverer.....unknown
Distance.....60,000,000 light years
True diameter.....100,000 light years
Number of stars.....billions

This is a small, bright 'Sb' spiral galaxy. Though visible in smaller telescopes as a faint mist of light, a larger telescope is usually required to see some of the details.

M77 is interesting in that it contains three different sets of spiral arms. The inner set is the brightest, and is full of small 'knots' of condensation where stars cluster together. Outside the inner spiral structure, the arms become fainter and more spread out. Finally, a large, dim ring around the entire system can be detected.

M77 is one of the first galaxies measured to have a large red shift, providing some of the initial evidence indicating the expansion of the universe. It is currently moving away from us at the rate of over 1030 km/sec.

The galaxy is believed to contain the mass of 100 billion suns, and in total emits 30 to 40 billion times more light than our Sun. It is a Seyfert galaxy, and is also known as a radio source with the designation '3C71'. Clouds of dust and gas 10 million times more massive than our Sun are being ejected from the nucleus at speeds of up to 600 km/sec. Astronomers do not have a clear idea of what could be providing the energy.

1.157 M78, NGC 2068

View Picture

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 Discoverer..................P. Mechain, 1780
 Distance....................1,600 light years
 True diameter...............3 light years
```
M78 is a diffuse nebula, visible in small telescopes as a faint patch of light. It is one of the brighter portions of a huge nebula covering much of the constellation of Orion. Very little detail can be seen, even with larger instruments.

Two stars of 10th magnitude and spectral type B are found within the nebula.

1.158 M79, NGC 1904

View Picture

```
 Discoverer..................P. Mechain, October 1780
 Distance....................50,000 light years
 True diameter...............110 light years
 Number of stars.............thousands
```
This globular cluster is rather dim, and can only be seen with difficulty in smaller telescopes. 8 inch telescopes can begin to resolve the outer edges into stars of 14th magnitude, while the center remains a tightly packed mass.

M79 shines with a light 90,000 times greater than our Sun. Few variable stars have been detected. This galaxy is receding from us at a velocity of about 200 km/sec.

1.159 M80, NGC 6093

View Picture

```
 Discoverer..................Charles Messier and P. Mechain, January 1781
 Distance....................36,000 light years
 True diameter...............50 light years
 Number of stars.............thousands
```
This is a bright globular cluster. It is visible in smaller telescopes as a mist of light, whereas instruments 6 inches or larger begin to resolve individual stars. It looks most spectacular in large telescopes with wide angle, lower power eyepieces, shining with the light of 190,000 suns.

Relatively few variable stars have been found in this galaxy, though these include two long period variables denoted 'R' and 'S' Scorpii. They have periods of 223 and 117 days respectively, and vary in magnitude from 9.8 to 15.5.

In May 1860, a bright star in M80 went nova, reaching magnitude 7. Within 11 days, the star had dimmed to magnitude 9, reaching its previous level of brightness in a few months. Novae have been detected in only two globular clusters - M80 and M14.

1.160 M81, NGC 3031, Bode's Nebula

View Picture

```
 Discoverer...................J. E. Bode, December 1774
 Distance.....................12,000,000 light years
 True diameter................36,000 light years
 Number of stars..............billions
```

This 'Sa' spiral galaxy is one of the brightest in the sky, even visible in a large pair of binoculars. In smaller instruments, it appears as a patch of light, but larger telescopes can view the bright nucleus as well as a hint of spiral arms. Long exposure photography reveals dust lanes delimiting the spiral structure.

M81 is called "Bode's Nebula" by some, even though it is a spiral galaxy and not a nebula at all. This is because J. E. Bode originally entered the object as a nebula in his logs.

Doppler shifts of spectral lines have revealed that the outer portions of the galaxy are moving at 300 km/sec in orbit around the nucleus. A mass of about 250 billion suns is contained within M81, and since it is not exceptionally large, it is one of the densest galaxies known.

A large number of variable stars have been observed, including irregular variables, Cepheids, and novae. M81 is moving away from us at a velocity of about 80 km/sec.

On March 28, 1993, Francisco García discovered a supernova in M81, which became known as SN1993J. The discovery was significant for a number of reasons. First, the supernova was discovered early. Usually, supernovae are discovered after they have already reached their maximum brightness. This enabled astronomers to see how the light varies as the object brightens.

Second, astronomers had taken detailed pictures of M81 within the last ten years, which allowed them to identify the star which exploded. It happened to be a red supergiant 10 to 20 times more massive than our Sun, as astronomers expected. Third, the supernova was well-placed for observations from the northern hemisphere. Since more of the world's observatories lie north of the equator, scientists were given an unprecedented opportunity to view the supernova.

Eight months after the outburst, Juan-Maria Marcaide at the University of València in Spain detected a shell of gas hurtling outward from the site of the explosion. This detection provided a glimpse of the youngest supernova remnant yet observed.

The remnant was primarily symmetrical, indicating a rather uniform explosion. Using doppler measurements to derive an estimate of the shell's rate of expansion, scientists can combine the information with the time it has been expanding to get an estimate of its true size. By then measuring the apparent diameter of the shell (0.00116 arcseconds in November 1993), the distance to the shell (and hence M81 itself) has been determined to be 12,000,000 light years. The value obtained by this method is in close agreement with that obtained from the observation of Cepheid variable stars observed with the Hubble Space Telescope.

Using the Hubble Space Telescope in 1991, Gary A. Bower of the Space Telescope Science Institute (STScI) found that stars were heavily concentrated toward the centre of the galaxy's nucleus. He feels that this may indicate the existence of a black hole.

In 1994, Min Sun Yun and Paul T. P. Ho of the Harvard-Smithsonian Center for Astrophysics, and Kwok-Yung Lo of the University of Illinois observed M81 with the Very Large Array (VLA) radio telescope in New Mexico. Their images revealed previously unseen filaments of atomic hydrogen bridging the gap between M81 and nearby galaxies M82 and NGC 3077. The finding indicates that the galaxy is interacting with its neighbours.

1.161 M82, NGC 3034

View Picture

```
 Discoverer...................J. E. Bode, December 1774
 Distance.....................7,000,000 light years
 True diameter................16,000 light years
 Number of stars..............billions
```

This is a reasonably bright irregular galaxy, visible in small telescopes as a long patch of light. Some dust lanes are visible in telescopes more than 10 inches in size, but long exposure photography is usually required to reveal the most detail.

Outer filaments particularly rich in hydrogen have been observed. 5 million times more massive than the Sun, they are travelling outwards at a rate of 1000 km/sec. Light coming from these regions is strongly polarized, suggesting an intense magnetic field. In addition, M82 is a reasonably strong radio source.

This evidence seems to suggest that a violent explosion of some kind occurred within the galaxy 1.5 million years ago. Scientists do not know what may have triggered the event.

Astronomers believe that a great deal of star formation, hidden behind a huge cloud of dust, is occurring within M82. Brilliant light is reflected by massive nebulae from a site near the center of the galaxy. The location of this source happens to coincide with a region powerful in radio and infrared emissions.

In the March 1, 1991 issue of the "Astrophysical Journal", Charles Telesco at NASA's Marshall Space Flight Center reports that M82 is actually a barred spiral galaxy, the bar only visible in infrared light. This bar is several thousand light years long and believed partially responsible for the star forming activity, stirring up gas as it rotates in the galaxy.

M82, containing enough mass to create 50 billion stars the size of our Sun, is moving away from us at a velocity of about 400 km/sec.

In 1994, Min Sun Yun and Paul T. P. Ho of the Harvard-Smithsonian Center for Astrophysics, and Kwok-Yung Lo of the University of Illinois observed M82 with the Very Large Array (VLA) telescope in New Mexico. Their images revealed previously unseen filaments of atomic hydrogen bridging the gap between M82 and nearby galaxies M81 and NGC 3077. The finding indicates that the galaxy is

interacting with its neighbours.

1.162 M83, NGC 5236

View Picture

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 Discoverer..................Lacaille, 1752
 Distance....................10,000,000 light years
 True diameter...............30,000 light years
 Number of stars.............billions
```

M83 is a bright 'Sc' type spiral galaxy. It is visible in small telescopes as a patch of light, and larger telescopes reveal some of its spiral structure. With long exposure photography, dust clouds can be seen delimiting the spiral arms and reaching almost to the center of the nucleus.

At least 4 supernovae have been observed in this galaxy since 1923. This number is remarkably high, since it is expected that the average galaxy has one star go supernova every few hundred years.

M83 is moving away from us at a velocity of about 330 km/sec.

1.163 M84, NGC 4374

View Picture

```
 Discoverer..................Charles Messier, March 1781
 Distance....................48,000,000 light years
 True diameter...............25,000 light years
 Number of stars.............billions
```

This is a bright 'E1' elliptical galaxy near the center of the Virgo Cluster of galaxies. There is some evidence to support that a dusty ring surrounds the nucleus. If this is so, it would be more aptly classified as an 'S0' galaxy.

This galaxy is a source of radio emissions. In May 1957, a supernova appeared, reaching a maximum apparent magnitude of 12.5.

There is enough matter in M84 to create 500 billion stars the size of our Sun.

1.164 M85, NGC 4382

View Picture

```
 Discoverer..................P. Mechain, 1781
 Distance....................44,000,000 light years
 True diameter...............40,000 light years
 Number of stars.............billions
```

This is an 'S0' elliptical galaxy, appearing rather unremarkable through the telescope. It is part of the Virgo Cluster of galaxies.

M85 is moving away from us at a rate of about 750 km/sec, and contains 100

billion times more mass than our Sun. In 1960, a supernova was observed within the galaxy.

1.165 M86, NGC 4406

View Picture

Discoverer.....Charles Messier, March 1781
Distance.....20,000,000 light years
True diameter.....40,000 light years
Number of stars.....billions

M86 is a bright 'E3' elliptical galaxy appearing near the center of the Virgo Cluster of galaxies. There is evidence to suggest, however, that it is not a true member of the Virgo group, but merely a foreground object lying along our line of sight.

This galaxy is interesting in that it is approaching, rather than receding from us. Since the universe is thought to have begun from an initial 'explosion' called "The Big Bang", almost all galaxies appear to be moving away from us. M86 approaches at a rate of about 470 km/sec.

M86 is about 130 billion times more massive than our Sun.

1.166 M87, NGC 4486, 3C274

View Picture

Discoverer.....Charles Messier, March 1781
Distance.....45,000,000 light years
True diameter.....40,000 light years
Number of stars.....billions

This interesting object is a large 'E1p' elliptical galaxy in the Virgo Cluster. It is visible in small telescopes as a nebulous patch of light. It is one of the largest known galaxies, with a total mass of 790 billion times that of the Sun.

Long exposure photographs of M87 reveal a number of globular clusters surrounding the galaxy. By some estimates, there may be as many as 4000 globular clusters in the system. The Milky Way, by comparison, is only known to have slightly over 100.

M87 is the 5th 'brightest' source of radio energy in the sky, designated as the radio source '3C274'. It is also a strong source of X-rays. This activity may be associated with a peculiar 'jet' of gas and dust 4100 light years long, visible within the galaxy. Light from the jet is strongly polarized, suggesting that it is enveloped in an intense magnetic field.

John A. Biretta and Frazer N. Owen of the National Radio Astronomy Observatory (NRAO) took several high resolution radio images of the jet emanating from M87 over the course of eleven years (starting in 1982). Throughout this period, 'blobs' in the stream were observed to move a tiny, though measurable amount. From this motion, matter in the stream was calculated to have the incredible

velocity of up to 90% that of light. They suspect that a supermassive black hole within M87 may be powering the jet.

Observations in 1991 by researchers at the European Southern Observatory in Chile, and La Palma in the Canary Islands have yielded evidence of a faint 'counterjet' on the opposite side of the galaxy. This feature was long suspected by theoreticians but was only visible by electronically subtracting light from stars in the galaxy.

On May 25, 1994, Holland Ford (Johns Hopkins University) and Richard J. Harms (Applied Research Corp.) presented additional evidence that a black hole lies at the centre of M87. Using the Hubble Space Telescope, they obtained images revealing a thin disk of gas 500 light years in diameter. Near the center of the disk, doppler measurements show that the gas is orbiting a central body at the incredible speed of 800 km/sec. To remain in orbit at such a speed, the central body must be 2 to 3 billion times more massive than the Sun. A black hole seems the only plausible solution.

M87 is moving away from us at a velocity of about 1300 km/sec.

1.167 M88, NGC 4501

View Picture

Discoverer.....Charles Messier, March 18, 1781
Distance.....41,000,000 light years
True diameter.....60,000 light years
Number of stars.....billions
This 'Sb' spiral galaxy is moderately bright, though a larger telescope and/or long exposure photography is required to see much detail. This member of the Virgo Cluster is oriented about 30 degrees from an edge-on view.

M88 is traveling away from us at the rapid rate of 2130 km/sec.

1.168 M89, NGC 4552

View Picture

Discoverer.....Charles Messier, March 1781
Distance.....40,000,000 light years
True diameter.....23,000 light years
Number of stars.....billions
This 'E0' elliptical galaxy is quite faint and requires a medium sized telescope to observe. M89 is believed to contain the mass of 250 billion suns, making it larger than The Milky Way.

It is thought to be a member of the Virgo Cluster, though its relatively slow speed of recession (220 km/sec) implies that it may be one of the nearer members.

1.169 M90, NGC 4569

View Picture

```
 Discoverer..................Charles Messier, March 1781
 Distance....................42,000,000 light years
 True diameter...............80,000 light years
 Number of stars.............billions
```
M90 is a relatively bright ‘Sb’ spiral galaxy. Though faintly visible in smaller telescopes, long exposure photography with large instruments is required to see any details.

This galaxy is believed to contain a mass equivalent to 80 billion times that of our Sun. It is currently moving away from us at a velocity of about 925 km/sec.

1.170 M91, NGC 4548

View Picture

```
 Discoverer..................Charles Messier, March 1781
 Distance....................40,000,000 light years
 True diameter...............47,000 light years
 Number of stars.............billions
```
There is much controversy over which object should be given the designation of M91. In Messier’s catalog, he described an object at 12h 35.0’ right ascension, and 14deg 02’ declination which appeared as "a nebula without star...its light even fainter than M90". However, no object can be detected near these coordinates which is bright enough for Messier to have seen.

There are many theories about what happened. Some people believe that Messier had unknowingly seen a comet. Others believe that the position he gave for M91 was in error. As a result, several candidate objects have been proposed - including NGC 4571, NGC 4548, or a mistaken reidentification of M58.

"The Digital Universe" treats NGC 4548 as M91, though it is likely that the mystery will never be solved. NGC 4548 is a faint ‘SBb’ barred spiral galaxy, whose details are only visible in long exposure photography with large telescopes.

1.171 M92, NGC 6341

View Picture

```
 Discoverer..................J. E. Bode, December 1777
 Distance....................35,000 light years
 True diameter...............80 light years
 Number of stars.............thousands
```
M92 is a bright globular cluster which is easily visible in binoculars as a fuzzy, starlike object. Resolution of individual stars in the cluster is possible even with smaller telescopes.

Several variable stars have been detected in the cluster, most of which are of RR Lyrae type (though at least one dwarf eclipsing variable has been found). Most of the brightest stars in the cluster are red giants.

The cluster emits 250,000 times more light than the Sun, and is approaching us at a rate of about 122km/sec.

1.172 M93, NGC 2447

View Picture

```
 Discoverer..................Charles Messier, March 1781
 Distance.....................3,400 light years
 True diameter................18 light years
 Number of stars..............~70
```

M93 is a bright open cluster, visible in binoculars. If you use a larger telescope to view the cluster, ensure that you have a reasonably wide field, low power eyepiece, as the cluster covers an area of the sky 18 arcminutes in size (more than half the size of the full moon).

The brightest stars in M93 are blue giants of spectral type B9.

1.173 M94, NGC 4736

View Picture

```
 Discoverer..................P. Mechain, 1781
 Distance.....................20,000,000 light years
 True diameter................33,000 light years
 Number of stars..............billions
```

M94 is a bright 'Sb' spiral galaxy seen from a nearly face-on position. It is visible even in small telescopes, though larger instruments are required to see the fainter spiral arms.

In fact, there are two sets of spiral arms associated with the galaxy. The innermost is quite distinct in long exposure photography, and tightly wound. The outermost is less well defined, and substantially fainter.

M94 shines with the light of 8 billion suns, and is moving away from us at a velocity of about 350 km/sec.

1.174 M95, NGC 3351

View Picture

```
 Discoverer..................P. Mechain, March 1781
 Distance.....................29,000,000 light years
 True diameter................34,000 light years
 Number of stars..............billions
```

This 'SBb' barred spiral galaxy is quite bright, and visible in moderate sized

telescopes.

M95 is moving away from us at a rate of about 700 km/sec.

1.175 M96, NGC 3368

View Picture

 Discoverer.....P. Mechain, March 1781
 Distance.....29,000,000 light years
 True diameter.....51,000 light years
 Number of stars.....billions
M96 is a bright 'Sa' spiral galaxy, visible in moderate telescopes. Larger instruments are required to bring out the detail in the spiral arms.

This galaxy is moving away from us at a rate of about 700 km/sec.

1.176 M97, NGC 3587, The Owl Nebula

View Picture

 Discoverer.....P. Mechain, 1781
 Distance.....3,000 light years
 True diameter.....3 light years
The Owl Nebula is one of the largest planetary nebulae visible in the night sky. Unfortunately, it is not very bright and large amateur telescopes are usually required for it to be seen. The central star (from which the nebula originated) is of magnitude 12. It has a high surface temperature of about 85,000 degrees C, and is quite possibly a white dwarf.

1.177 M98, NGC 4192

View Picture

 Discoverer.....P. Mechain, 1781
 Distance.....35,000,000 light years
 True diameter.....80,000 light years
 Number of stars.....billions
M98 is an 'Sb' spiral galaxy, visible from a nearly edge-on position. It is quite faint, and a moderate sized telescope is typically required for a positive identification. With amateur instruments, long exposure photography is necessary to show the spiral arms.

The galaxy is rather interesting in the fact that although it is located 35,000,000 light years distance, it is approaching us at a velocity of about 210 km/sec. Astronomers believe that the universe originated from an 'explosion' known as the Big Bang. The resulting expansion is still going on today, and in general, the further an object is from us, the faster it is receding. Since M98 is in fact approaching, it demonstrates that there are exceptions to this rule.

M98 contains enough mass to make 130 billion stars the size of our Sun.

1.178 M99, NGC 4254

View Picture

```
 Discoverer...................P. Mechain, 1781
 Distance.....................50,000,000 light years
 True diameter................50,000 light years
 Number of stars..............billions
```
This is an 'Sc' spiral galaxy requiring a medium sized telescope for observation. It appears nearly face-on, and has a very well defined structure. Dust lanes delimiting the spiral arms are readily visible in long exposure photographs.

M99 contains the mass equivalent of 50 billion suns, and is moving away from us at the high velocity of 2500 km/sec.

1.179 M100, NGC 4321

View Picture

```
 Discoverer...................P. Mechain, 1781
 Distance.....................56,000,000 light years
 True diameter................150,000 light years
 Number of stars..............billions
```
This is a large 'Sc' spiral galaxy, though difficult to see with smaller telescopes. Long exposure photography reveals an intricate spiral structure, with dust lanes visible reaching to the nucleus.

Supernovae have been observed in M100 in 1901, 1914, and 1959. It contains the mass of 160 billion suns, and shines with a light 20 billion times greater than our own Sun.

In 1994, Wendy Freedman of the Carnegie Observatory in Pasadena, California discovered several Cepheid variable stars in M100 which could be used to accurately determine its distance. Her findings determined that M100 is located 56,000,000 light years away, but more significantly, provided data to help astronomers calculate the approximate age of the universe. The findings were surprising, and will likely change the ways in which we view some of the processes taking place within. For further details, see
Our Expanding Universe.

M100 is moving away from us at a velocity of 1600 km/sec.

1.180 M101, M102, NGC 5457

View Picture

 Discoverer..................P. Mechain, 1781
 Distance....................15,000,000 light years
 True diameter...............90,000 light years
 Number of stars.............billions
It is suspected that Messier made two mistakes in his catalogue: M40 and M102. Whereas it is generally accepted that Messier accidentally listed a double star in the case of M40, it is unknown what he was referring to with M102. It is suspected that M102 is simply an accidental additional reference to M101. In some of Messier's later writings, there is evidence to suggest that M102 may be equated to NGC 5866, but this has not been confirmed.

M101 is one of the best examples of an 'Sc' type spiral galaxy viewed from face on. Discovered by P. Mechain in 1781, it was described by Messier as "A nebula without star, very obscure and pretty large, 6 or 7 arcminutes in diameter between the left hand of Boötes and the tail of the Great Bear."

It exhibits "mottled nebulosity", and in fact some of these clusters of condensation eventually became known as individual NGC objects (5449, 5450, 5451, 5453, 5455, 5458, 5461, and 5462).

The computed mass of M101 is approximately equivalent to 16 billion suns, making it only about 10% as massive as the Milky Way. Since a great deal of the light comes from hot Population I stars in the spiral arms, it is one of the bluest galaxies known. It radiates a light 5 billion times stronger than the light of our Sun.

M101 is moving away from us at a rate of almost 400 km/sec.

1.181 M103, NGC 581

View Picture

 Discoverer..................P. Mechain, 1781
 Distance....................8,000 light years
 True diameter...............15 light years
 Number of stars.............40
M103 is an open cluster, visible in binoculars under a dark night sky. The cluster is about 1/4 as large as the full moon, so if you are using a large telescope, ensure that you have a wide field, low power eyepiece.

It is a fairly compact cluster, with the brightest stars being of spectral type B3. In addition, it contains a red giant, of spectral type gM6 and magnitude 10.8.

1.182 M104, NGC 4594, The Sombrero Galaxy

View Picture

 Discoverer..................P. Mechain, May 1781

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 Distance.....................40,000,000 light years
 True diameter................130,000 light years
 Number of stars..............billions
```
The Sombrero Galaxy is an ‘Sa’ spiral galaxy. It is seen only 6 degrees from edge-on, and is surrounded by a spectacular ring of dust. This dust is faintly visible on dark nights with telescopes 10 inches or larger, but is clearly revealed with long exposure photography.

This galaxy has a mass 1,300,000,000,000 times greater than our Sun, making it one of the most massive known. Stars near the edges of the galaxy take 25 million years to complete one rotation around the nucleus.

Several globular clusters have been detected surrounding M104. It is moving away from us at a velocity of 1200 km/sec.

1.183 M105, NGC 3379

View Picture

```
 Discoverer...................unknown
 Distance.....................29,000,000 light years
 True diameter................17,000 light years
 Number of stars..............billions
```
M105 is an ‘E1’ elliptical galaxy. It is quite faint, and a medium sized telescope is typically required to see it.

1.184 M106, NGC 4258

View Picture

```
 Discoverer...................unknown
 Distance.....................25,000,000 light years
 True diameter................140,000 light years
 Number of stars..............billions
```
M106 is a rather large ‘Sb’ spiral galaxy, visible even in small telescopes as a faint patch of light. Larger telescopes are required to reveal the more subtle details.

There is evidence for the existence of a supermassive black hole in M106. Images obtained by Makoto Miyoshi of Japan’s National Astronomical Observatory revealed a thin ring of gas surrounding the core. Only 1.5 light years in diameter, doppler measurements reveal that it is orbiting the core at an incredible speed of 1000 km/sec. Calculations show that to be moving at this speed, it must be orbiting a mass 36 million times that of the Sun.

This mass cannot be simply a dense concentration of stars, since Miyoshi has shown that at the required density they would have all collided with one another within 100,000,000 years. Thus, he feels that the most likely candidate for this mass is a large black hole. Miyoshi and his team reported his findings at the January 1995 meeting of the American Astronomical Society and in the January 12, 1995 issue of "Nature".

1.185 M107, NGC 6171

View Picture

```
 Discoverer..................unknown
 Distance.....................10,000 light years
 True diameter................12 light years
 Number of stars..............thousands
```
M107 is a rather faint globular cluster, requiring a moderate sized telescope to be seen. It is composed of stars magnitude 11 and dimmer.

1.186 M108, NGC 3556

View Picture

```
 Discoverer..................P. Mechain, 1781
 Distance.....................25,000,000 light years
 True diameter................57,000 light years
 Number of stars..............billions
```
M108 is an 'Sc' spiral galaxy, appearing nearly edge-on from our point of view. It is quite dim, and a moderate sized telescope is required to reveal its presence as a faint patch of light. Long exposure photography is required to bring out details in its mottled appearance.

1.187 M109, NGC 3992

View Picture

```
 Discoverer..................unknown
 Distance.....................25,000,000 light years
 True diameter................47,000 light years
 Number of stars..............billions
```
This 'SBb' barred spiral galaxy is reasonably bright and easily seen through a moderate-sized telescope. As with all deep sky objects, long exposure photography is required to bring out details.

1.188 M110, NGC 205

View Picture

```
 Discoverer..................unknown
 Distance.....................2,200,000 light years
 True diameter................5,400 light years
 Number of stars..............millions
```
This 'E6' elliptical galaxy is visible in telescopes 3 inches or larger in size. It is just northwest of the Great Andromeda Galaxy, and is linked gravitationally to it.

1.189 IC 434 - Background illumination for the Horsehead Nebula

View Picture

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 Discoverer..................E. Pickering, 1889
 Distance....................1,500 light years
 True diameter...............26 light years
```

The Horsehead Nebula is probably one of the most famous nebulae in the sky. This fame is brought about by its spectacular appearance in long exposure photographs of the region. Unfortunately, a very large telescope is required to see the nebula if photography is not used.

The appearance of the Horsehead is made possible by two separately designated nebulae. IC 434 is a bright nebula (appearing red in the picture) providing background illumination to silhouette B33, the dark Horsehead itself.

IC 434 is believed to be illuminated by the nearby star Zeta Orionis. It is suspected that new stars are currently being formed in the nebula.

1.190 IC 5070 - The Pelican Nebula

View Picture

```
 Discoverer..................unknown
 Distance....................1,600 light years
 True diameter...............37 light years
```

This nebula is faint in small telescopes. It is quite reddish in color, and thus shows up best on red sensitive photographic plates. A large number of dark dust lanes can be seen stretching across the face of the nebula in good photographs.

The Pelican Nebula is a detached part of the North American Nebula.

1.191 NGC 206

View Picture

```
 Discoverer..................unknown
 Distance....................2,200,000 light years
 True diameter...............2900 x 1400 light years
 Number of stars.............thousands
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NGC 206 is a prominent star cluster within M31, the Andromeda Galaxy. It is so bright that it is classified as a separate entry in the NGC catalog. It can be detected by an 8 inch telescope under good sky conditions, and contains a few hundred stars over 10,000 times brighter than our Sun.

1.192 NGC 891

View Picture

 Discoverer.....unknown
 Distance.....43,000,000 light years
 True diameter.....120,000 light years
 Number of stars.....billions
NGC 891 is a faint 'Sb' spiral galaxy, viewed from almost a perfect edge-on orientation. A clear dark night, with a telescope 6 inches in size or larger is required to see this object. Of course, long exposure photography reveals far more structure than can be seen otherwise. Photographs show a long lane of dust encircling the galaxy.

This galaxy shines with the light of 1,500,000,000 suns.

1.193 NGC 1432, The Maia Nebula

See The Pleiades.

1.194 NGC 1435, The Merope Nebula

See The Pleiades.

1.195 NGC 1499, The California Nebula

View Picture

 Discoverer.....unknown
 Distance.....1,000 light years
 True diameter.....44 light years
The California Nebula is a faint reflection nebula, illuminated by the star Xi Persei. The object is quite diffuse and difficult to see, even in moderate sized telescopes. Long exposure photography is typically required to show details of the nebula.

Some astronomers believe that the nebula has been the birthplace of some of the stars in the vicinity. If so, it is likely that star formation is still occurring there.

1.196 NGC 1977

View Picture

 Discoverer.....unknown
 Distance.....1,700 light years
 True diameter.....20 light years
NGC 1977 is a small nebula, associated with The Great Orion Nebula. It is quite a bit fainter than its bright neighbour, and difficult to see with smaller telescopes.

1.197 NGC 2237 - The Rosette Nebula

View Picture

```
 Discoverer..................unknown
 Distance....................2,600 light years
 True diameter...............55 light years
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NGC 2237 is a large nebula surrounding an open cluster (the cluster is designated NGC 2244). To view this object, you require a lot of light gathering power coupled with a low magnification, as it is quite faint and is almost three times larger than the full moon. In fact, a large pair of binoculars often works better than a small telescope. As with all deep sky objects, long exposure photography is required to bring out the exquisite detail associated with this nebula.

The Rosette is one of the most massive nebulae known, with estimates at around 11,000 times the mass of our Sun. It is believed that stars are being born within.

1.198 NGC 2264, Cone Nebula, Christmas Tree Cluster

View Picture

```
 Discoverer..................unknown
 Distance....................2,600 light years
 True diameter...............20 light years
 Number of stars.............hundreds
```

NGC 2264 is a loose open cluster, surrounded by nebulosity. Its shape is reminiscent of a christmas tree, hence the name.

The 20 brightest stars range from magnitude 4.6 to 9.3, and their spectral types vary between O and K (a substantial range). Radio emissions have been detected from the cluster and surrounding nebula.

NGC 2264 is one of the youngest star clusters known (2 million years old), and the area is likely still a region of active star formation.

There are two primary nebulae associated with the cluster. A dark nebula (the Cone Nebula) is silhouetted against a much brighter background reflection nebula.

1.199 NGC 2346

This planetary nebula is reasonably easy to see in moderate sized telescopes. An 11th magnitude star can be seen near the center, from which the nebula is thought to have originated. However, the star is not bright enough to make the nebula shine as much as it does. For a long time, astronomers suspected that another, much brighter star, was hidden within the gas and dust, causing the nebula to appear as bright as it does.

Such an object was seen by the International Ultraviolet Explorer satellite (IUVE) in the early 1980s. Then, in 1981-1982, the central star gradually

became variable, with a light curve seeming to indicate that an object was periodically eclipsing it. By 1985, the brightness variations were 3.5 magnitudes, but by 1987 they had virtually stopped.

Astronomers think that gas and dust was expelled by the hot star in the nebula, and as the cloud orbited the central star, it periodically eclipsed it. Over time, the cloud gradually dispersed until its effects were no longer clearly visible.

1.200 NGC 2419

Discoverer.....William Herschel
Distance.....180,000 light years
True diameter.....380 light years
Number of stars.....100,000
NGC 2419 is one of the Milky Way's most distant globular clusters. It is nearly opposite the galactic center where most of the other globular clusters are found. It is extremely dim, with the brightest stars being of magnitude 18.

Several variable stars have been found in the cluster, most of which are of RR Lyrae type.

It is moving away from us with a velocity of about 20 km/sec.

1.201 NGC 2440

In 1992, the Hubble Space Telescope studied this planetary nebula. In the center, they found a 16th magnitude white dwarf star from which the nebula originated. It is one of the hottest stars ever observed, with a surface temperature of 200,000 degrees C, or more than 35 times that of the Sun.

1.202 NGC 2841

View Picture

NGC 2841 is a rapidly spinning 'Sb' spiral galaxy. It is visible in moderate sized telescopes, and reveals an exquisite amount of detail when photographic methods are used to record its structure.

1.203 NGC 3115, Spindle Nebula

Discoverer.....unknown
Distance.....45,000,000 light years
True diameter.....50,000 light years
Number of stars.....billions
This is a bright 'S0' galaxy, which is rather bright but difficult to locate since it is in a relatively empty area of the sky. Unlike most deep sky

objects, this galaxy's appearance does not improve much with long exposure photography.

This galaxy is about 7 billion times more luminous, and about 24 billion times more massive than our Sun.

In the early 1990s John Kormendy of the University of Hawaii used the CFHT (Canada-France-Hawaii Telescope) to take images of NGC 3115. He found that the orbital velocity of stars increases rapidly as the core of the nucleus is approached. Near the centre, stars are travelling at the incredible speed of 300 km/sec. This implies that a great mass must exist at the core. Since relatively little light is emitted from the core, he feels that a likely candidate for this matter is a black hole calculated at one billion times more massive than our Sun.

NGC 3115 is moving away from us at a velocity of about 430 km/sec.

1.204 NGC 3372, The Keyhole Nebula, Eta Carinae Nebula

View Picture

Discoverer.....unknown
Distance.....3,700 light years
True diameter.....65 light years
The Keyhole Nebula is a large diffuse nebula associated with the irregular variable star Eta Carinae. It is unknown whether the nebula was formed as a result of eruptive events with the star, or if the star formed from the nebula. In any case, when the star went nova in April 1843, it emitted a shell of gas that is currently expanding into the rest of the nebula.

Though the star is no longer visible to the naked eye, it is the brightest infrared source in the sky (other than objects in our solar system). Radio observations of the star indicate that it has an extremely strong "stellar wind", one of the fastest known.

1.205 NGC 3628

View Picture

NGC 3628 is an 'Sb' spiral galaxy viewed from a nearly edge-on position. It is fairly large, though faint, requiring a moderate sized telescope with a wide field, low power eyepiece. A prominent dust lane cutting across the galaxy is evident in photographs.

1.206 NGC 4261

NGC 4261 is an 'E2' elliptical galaxy in the Virgo Cluster of galaxies. It is quite dim, and a medium to large telescope is required to see it.

With the Hubble Space Telescope, astronomers have taken an interesting picture

of the galaxy's core. It reveals a dust accretion disk 400 light years across, believed to be circling a black hole 10 million times more massive than the Sun. Jets of material 88,000 light years long, visible at radio wavelengths and originating from the core, provide additional evidence for the existence of a black hole.

View Picture of center of NGC 4261

1.207 NGC 4388

View Picture

NGC 4388 is an 'SBc' barred spiral galaxy, viewed from a nearly edge-on position. It is quite dim, and a large telescope and/or long exposure photography is required to see it.

1.208 NGC 4394

View Picture

NGC 4394 is a faint 'SBb' barred spiral galaxy. It is visible only with larger telescopes, or through the use of long exposure photography.

1.209 NGC 4402

View Picture

NGC 4402 is an 'Sb' spiral galaxy viewed from nearly edge-on. It is very faint, and a large telescope is typically required to see it.

Long exposure photography reveals a belt of dust running across the galaxy.

1.210 NGC 4647

View Picture

NGC 4647 is a faint 'Sc' spiral galaxy, visible only through large telescopes. It appears to be associated with the elliptical galaxy M60.

1.211 NGC 4945

View Picture

NGC 4945 is a moderately bright galaxy, classified as either type 'Sc' or 'SBc'. It is seen from a nearly edge-on position.

This galaxy can be seen with small telescopes, providing that you are observing in good seeing conditions from a dark sky location.

1.212 NGC 5033

View Picture

NGC 5033 is a moderately dim 'Sb' spiral galaxy, viewed from an angle halfway between edge-on and face-on. A medium-sized telescope is required to see the object.

1.213 NGC 5139, The Omega Centauri Cluster

View Picture

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 Distance.....................17,000 light years
 True diameter................350 light years
 Number of stars..............>1,000,000
```

Omega Centauri is the brightest globular cluster in the sky, visible even to the naked eye. Without optical assistance, the cluster is too tightly packed to appear as anything but a star, but binoculars or telescopes reveal a spectacular structure. Make sure that you use a wide field, low power eyepiece so that the entirety of the cluster can be seen in the field of view.

The Omega Centauri Cluster is believed to contain a mass 5,000,000 times greater than that of our Sun. Near the center, the density of stars increases dramatically until they are only 0.1 light years apart from one another, on average.

Many variable stars have been located in the cluster. Most of these are of RR Lyrae type, though Cepheids, long period, and irregular variables have been detected as well.

The cluster is moving away from us at a velocity of about 230 km/sec.

1.214 NGC 5548

NGC 5548 is a faint 'Sa' spiral galaxy, visible only through larger telescopes.

Data obtained in the early 1990s by D. Michael Crenshaw and James H. Blackwell "provides direct evidence that the central engine is a supermassive object, presumably a black hole". Measurements from the International Ultraviolet Explorer (IUVE) satellite indicate that clouds of gas near the center of the galaxy are falling rapidly inwards. It is estimated that the attracting mass would be 10 million times greater than the mass of our Sun.

1.215 NGC 6164, NGC 6165 & SAO 226891

View Picture

Astronomers have obtained evidence to show that the star designated as SAO 226891 (the brightest member of a triple system) is continuously losing its outer layers of gas. Vigorous outbursts in the past are believed to have created the faint symmetric shells of nebulosity surrounding the star, designated as NGC 6164 and 6165.

1.216 NGC 6165

See NGC 6164

1.217 NGC 6240

NGC 6240 is a pair of colliding galaxies 300,000,000 light years away.

Joss Bland-Hawthorn (of Rice University), Andrew S. Wilson (of the University of Maryland), and R. Brent Tully (of the University of Hawaii) published evidence suggesting a huge black hole at the center of this galaxy, in the April 10, 1991 "Astrophysical Journal Letters". They detected two spinning disks of swirling gas in the pair of galaxies. It is rotating so fast that it must be orbiting an object containing as much matter as The Milky Way, but in a volume 10,000 times less. If this object is a black hole, it would be 10 to 100 times more massive than any other yet observed.

1.218 NGC 6543, The Cat's Eye Nebula

View Picture

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 Discoverer..................unknown
 Distance....................3,000 light years
 True diameter...............0.3 light years
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The Cat's Eye Nebula is a bright planetary nebula, visible even in small telescopes as a hazy patch of light. In larger instruments, it appears to have a bluish-green shade.

If we would have had telescopes 1000 years ago, it is thought that we might have seen the event causing the central star to cast off the cloud of gas. In actuality, the event would have happened 4000 years ago, since the light has taken 3000 years to reach us. The central star is of spectral type O, and has a temperature of 35,000 degrees C. It is 100 times brighter than our own Sun.

1.219 NGC 6814

NGC 6814 is an 'Sb' spiral galaxy, oriented nearly face-on to us.
Unfortunately, it is quite faint, visible only through larger telescopes.

Studies of the galaxy's nucleus in 1990 revealed a variable X-ray source with an extremely short period (sometimes the intensity doubles in less than a minute). This suggests that the source is less than 15 million kilometers across. With this and a variety of other evidence, it is felt that a thick accretion disk lies at the core of NGC 6814 surrounding a mass of about 1.4 million Suns. The density required would imply the existence of a black hole.

1.220 NGC 7000, The North American Nebula

View Picture

Discoverer.....unknown
Distance.....1,600 light years
True diameter.....45 light years
This is a reasonably bright nebula, barely visible to the naked eye. On a clear and dark night, binoculars reveal a shape reminiscent of the North American continent, after which it was named. Small telescopes give a good view of the nebula, though if an eyepiece with a narrow field of view is used, the whole object cannot be seen at once.

Many stars in the region are thought responsible for illuminating this reflection nebula, though Deneb is likely the largest contributor.

The Pelican Nebula lies adjacent to the North American Nebula.

1.221 NGC 7252

This object is classified as a peculiar elliptical 'Ep' galaxy. From pictures through ground-based telescopes, astronomers have long known that the object appeared to be two galaxies in the process of collision.

Recent observations by the Hubble Space Telescope have revealed a spiral structure in the core, despite the galaxy's outwardly elliptical appearance. This feature is only 10,000 light years across and rotates in an opposite direction to the rest of the galaxy. Bradley Whitmore of the Space Telescope Science Institute (STScI) believes that this may indicate that the elliptical galaxy was formed by the collision of two spirals.

1.222 NGC 7331

View Picture

Discoverer.....unknown
Distance.....50,000,000 light years
True diameter.....140,000 light years
NGC 7331 is a moderately bright 'Sb' spiral galaxy, viewed from an orientation

20 degrees away from edge-on. It is thought to have a mass 140 billion times as much as our Sun, and shine with a light 50 billion times as great.

In 1959, a supernova appeared in the galaxy, reaching a magnitude of 12.7. The galaxy is moving away from us at a velocity of about 1100 km/sec.

1.223 Alcyone

See The Pleiades.

1.224 Aldebaran

High resolution spectrae taken from the Hubble Space Telescope (HST) and the International Ultraviolet Explorer (IUE) reveal that Aldebaran has a chromosphere rich in ionized carbon, cobalt, iron, and nickel. In addition, gas in the chromosphere is extremely turbulent, moving around at average velocities of 24 km/sec.

1.225 Algol, Beta Persei

Algol is the most famous eclipsing binary. Though there are vague historical references that may be interpreted as a record of this star's variability, the first concrete statement was made by the Italian astronomer Geminiano Montanari in 1667. Several astronomers then observed the star, but since their studies were not made on a regular basis, the period was not noticed until 1782. At that time, John Goodricke suggested that the periodic dimming might best be explained by eclipses of the bright star by a darker companion. In 1889, H. C. Vogel used spectroscopic analysis to prove the hypothesis to be correct.

Algol is bright and easy to see with the naked eye. It is a popular variable star, since the brightness changes by more than one magnitude. Normally at magnitude 2.1, the star is eclipsed every 2.8673075 days. The eclipse lasts about 10 hours, with the star fading to magnitude 3.4. A tiny dip in the light curve is noticed exactly midway between the primary eclipses, as the dim star is eclipsed by the brighter one.

The Julian Dates for the Universal Times of minimum brightness may be estimated by the equation:

JD=2449836.409+2.8673075*E

where E is an integer

1.226 Altair

Altair is a bright, white star of magnitude 0.77. It is located 16 light years away, and is approaching us at a rate of about 27 km/sec.

The most interesting fact about Altair is its rapid rotation. Spectral studies indicate that the star rotates in about 6.5 hours. This rapid rotation has likely flattened Altair into an ellipsoidal shape so that its equatorial diameter is twice as large as its polar diameter.

1.227 Asterope, Sterope I

See The Pleiades.

1.228 Atlas

See The Pleiades.

1.229 Betelgeuse

Betelgeuse (pronounced BAY-tel-jooz) is a bright red giant star in the constellation of Orion. Its name is believed to have come from the Arabic 'Beit Algueze', meaning the "Armpit of the Giant".

This star is an irregular variable, with a period roughly 5.7 years long. The star has been measured at magnitudes between 0.4 and 1.2 in recent history, but the brightness variations are quite irregular. Spectroscopic studies show that during periods of maximum brightness, the diameter of the star may actually increase to a size 60% larger than its size when faint. The star is so large that if it were to replace our Sun, it will engulf Mercury, Venus, Earth, and Mars. During periods of its maximum size, Jupiter would be in jeopardy as well.

Betelgeuse is believed to be located about 520 light years away. To shine as brightly in our skies as it does, astronomers infer that it must be 10,000 times more powerful than our Sun.

1.230 Celaeno

See The Pleiades.

1.231 Electra

See The Pleiades.

1.232 Fomalhaut

Fomalhaut (pronounced FOE-ma-low) is named from the Arabic "Fum al Hut", meaning "The Mouth of the Fish" (due to its location in the constellation of Pisces Austrinus). It is located about 22 light years from us, and is believed to be about twice as large and 14 times brighter than our Sun.

On March 30, 1993, S. Alan Stern (Southwest Research Institute), Michel C. Festou (Observatoire Midi-Pyrénées), and David A. Weintraub (Vanderbilt University) used a 30 meter radio telescope in France to observe Fomalhaut. Their data indicated the presence of a disk of gas and dust surrounding the star measuring 400 AU in diameter.

It is believed that such clouds of dust give us a glimpse of what our solar system may have looked like in its early history. Many astronomers believe that our planets condensed out of such a cloud after the formation of our Sun. Planets may be forming in the Fomalhaut system at this very moment.

Such clouds are extremely difficult to see from our viewpoint on Earth, due to their vast distances from us. Though astronomers suspect that they may be common features at some point in a star's history, only two such clouds have been discovered associated with main sequence stars (around Beta Pictoris and Fomalhaut).

1.233 Maia

See The Pleiades.

1.234 Merope

See The Pleiades.

1.235 Pleione

See The Pleiades.

1.236 Polaris - the North Star

Polaris is a Cepheid variable - a variable star which brightens and fades as it alternately swells and shrinks. Though its period has remained roughly constant at about 3.97 days, the amplitude has been greatly decreasing. At the turn of the century, Polaris varied by about 0.1 magnitudes, while by 1992 the variation was only 0.01 magnitudes. This trend led some Canadian astronomers to predict that Polaris would quit pulsating altogether by 1993.

However this never happened. Martin Krockenberger at the Harvard-Smithsonian Center for Astrophysics obtained several high resolution spectrae of Polaris

throughout 1994, and has concluded that it is pulsating as much as ever. In fact, the average variation in 1994 was as much as 0.03 magnitudes, above that observed in 1992.

1.237 Sirius

Sirius is the brightest star in the sky (other than our Sun, of course), shining at magnitude -1.46. It is 23 times brighter than our Sun, 1.8 times larger, and 2.35 times as massive. It shines a brilliant bluish-white, having a surface temperature of about 10,000 degrees C.

Between 1834 and 1844, F. W. Bessel noticed that Sirius had a "wavy" motion in its path through space. He used this observation to theorize the existence of an unseen massive companion. In January 1862, Alvin G. Clark discovered this object orbiting Sirius once every 49.98 years. Though the star has a a reasonably bright magnitude of 8.65, its proximity to the much brighter Sirius makes it an extremely difficult object to observe. With telescopes 10 inches or larger, a good observer may find it possible to detect Sirius' companion, known as Sirius B.

Sirius B is an interesting object, about as massive as the Sun, but only giving off 0.25% of the light. From spectral studies, the surface temperature was deduced to be about 8500 degrees C. This makes its surface about 4 times brighter than the Sun, so to shine as faintly as it does, it must have a diameter some 50 times less. Thus, its density must be 100,000 times more than the Sun. It is a white dwarf, with a cubic centimeter of its material weighing as much as 125 kg.

Sirius is located about 8.7 light years away from us, making it the 5th nearest star known.

1.238 Sterope II

See The Pleiades.

1.239 Taygeta

See The Pleiades.

1.240 Alpha Centauri

Alpha Centauri is a triple star system, famous for containing the nearest star to us other than our own Sun. It is only 4.34 light years away.

The two brightest stars in the system are denoted A and B (or alpha1 and alpha2) and appear to lie quite near each other. The third star, called "Proxima Centauri", or simply 'C', is quite faint (magnitude 10.7) and 0.21

light years from the others, but it is this star that is the closest to the Earth (4.25 light years). It is more than 13,000 times fainter than our own Sun.

Proxima Centauri is a flare star, a red dwarf which suddenly changes in brightness at unpredictable intervals, lasting only a few minutes. The exact cause of these periodic brightenings is not well known, but is similar in intensity and believed to be related to solar flares occurring on our own Sun.

In the March 15, 1993 issue of the "Monthly Notices of the Royal Astronomical Society", Robert Matthews and Gerard Gilmore presented evidence indicating that Proxima Centauri may not actually be in orbit about the other two stars. Their data indicates that this dimmer star may be travelling too fast to remain within the multiple system. If it is in orbit, it would circle the bright inner stars in a period of more than a million years. More evidence is required to definitively state whether Proxima Centauri is actually a permanent part of the system.

1.241 Alpha Centauri 2

See Alpha Centauri.

1.242 Beta Pictoris

In 1984, astronomers detected a disk of matter surrounding Beta Pictoris. The disk, 2000 AU in diameter and seen nearly edge-on, is believed to be no more than a few hundred million years old - very young when compared with the age of the universe. Many scientists feel that they may be witnessing a solar system in the making, as the planets surrounding our Sun are thought to have condensed out of a similar cloud of matter billions of years ago.

Such clouds are extremely difficult to see from our viewpoint on Earth, due to their vast distances from us. Though astronomers suspect that they may be common features at some point in a star's history, only two such clouds have been discovered associated with main sequence stars (around Beta Pictoris and Fomalhaut).

The following photograph shows this disk of matter, in false colour. The star itself is near the center of the image, though blocked out by a small circular mask. This mask prevented the star's light from saturating the image, allowing the much fainter disk of material to be seen.

View picture

In the June 23, 1994 issue of "Nature", Pierre Olivier Lagage and Eric Pantin of the Astrophysical Service of Saclay, presented evidence which may indicate that at least one planet has already accreted out of the disk. At a distance of about 30 AU from the star, the density of material in the disk is about 10 times less than elsewhere. The astronomers suggest one possible explanation is that a planet the size of Uranus has swept the region clear.

1.243 Epsilon Aurigae

Epsilon Aurigae is a 3rd magnitude variable star whose exact nature has eluded astronomers for quite some time. Every 27.1 years, it appears to be eclipsed by a dark object for months on end.

Previous efforts to determine the nature of this object, based on measured light curves of the star, have failed. Then in 1990, Sean Carroll (of the Harvard-Smithsonian Center for Astrophysics) and Edward Guinan (of Villanova University) realized that a thin, tilted disk with a partially transparent inner region and a clear zone in the center may be the form of the eclipsing body.

This is significant because the general shape predicted by these researchers matches that expected of a cloud of gas around a star condensing into planets. If their theory is correct, astronomers studying Epsilon Aurigae may actually be seeing indirect evidence of a solar system in the process of formation.

1.244 Eta Boötes

This star is one of the Sun's nearer neighbours, at a distance of about 38 light years. It has a luminosity approximately 7 times greater than our own Sun, and is moving towards us at the rather leisurely rate of 0.2 km/sec.

In the March 1995 issue of the "Astronomical Journal", Hans Kjeldsen and his colleagues from Aarhus University in Denmark and the European Southern Observatory (ESO) in Germany reported tiny temperature fluctuations in the star. They found that the temperature varies by a few hundredths of a degree in complex, yet periodic patterns. They believe that the fluctuations are caused by a "ringing" effect, similar to that observed in the Sun. See Helioseismology for more information.

1.245 SAO 69181

In 1971, the satellite "Uhuru" detected a strong source of X-rays coming from a location near the star SAO 69181. The source varied irregularly, and as a result, it was considered unlikely to be a neutron star. The object became known as "Cygnus X-1".

Some astronomers suggested that the energy might originate from a black hole in the vicinity. Though energy cannot leave a black hole, matter is predicted to radiate strongly in X-rays as it is drawn into one.

Close studies of SAO 69181 revealed that it was a binary star, circling an unseen companion in 5.6 days. From the nature of the orbit, it was calculated that this companion would have to be 5 to 8 times more massive than the Sun. Since it is too massive to be a white dwarf or neutron star, this evidence suggested further that the object was indeed a black hole.

In addition, SAO 69181 seems to be entering the red giant stage of its life. It is therefore likely that matter would be moving from the visible star to its unseen companion, producing an accretion disk around the black hole generating

the observed X-rays.

Cygnus X-1 is one of the first objects discovered likely to be a black hole.

1.246 SAO 100458

During the 1980s, astronomers David Latham, Robert Stefanik, Richard McCrosky, and Robert Davis of the Smithsonian Astrophysical Observatory took several high resolution spectra of SAO 100458 in an effort to create a definition of a "standard" star of constant velocity against which other stars could be compared. However, instead of finding a constant velocity, they found that the star's velocity varied by 533 metres/second over a period of 84.2 days. This can be best explained by the gravitational influences of a large planet orbiting the star.

The astronomers feel that a planet ten times more massive than Jupiter can best explain their data. It is likely orbiting the star at a distance roughly equivalent to that of Mercury from our Sun.

1.247 SAO 226891

See NGC 6164

1.248 Comet Halley

In 1705, Edmund Halley noticed that comets observed in 1456, 1531, 1607, and 1682 followed remarkably similar paths through the sky. In addition, he observed that 76 years, on average, separated the sightings. He used this information to postulate that the sightings were actually of the same comet, returning to view every 76 years. He then successfully predicted its reappearance in 1759, though he died before it returned.

Nevertheless, Halley had succeeded in doing what nobody had done before. He had proved that comets were actually part of our solar system, orbiting the Sun. Sightings of comets as long ago as 239 BC (and possibly 1059 BC) have been attributed to Comet Halley (pronounced HAL-lee). It is also depicted in the famous Bayeux Tapestry, having been visible in 1066 right before the Battle of Hastings.

Though on average, the orbit of Comet Halley is 76 years, gravitational perturbations on its orbit by the larger planets in our solar system cause it to fluctuate from 76 to 79.3 years. In addition, gases boiling off the nucleus of the comet act like tiny rocket motors to alter its orbit, though to a lesser extent than the perturbations.

When Comet Halley made its latest close approach to the Earth in 1986, scientists were ready to explore it with spacecraft. The following probes flew to the comet for a closer look (sorted by launch date):

Vega 1 - Dec. 15/84

Vega 2 - Dec. 21/84
Sakigake - Jan. 7/85
Giotto - Jul. 2/85
Suisei - Aug. 18/85

They revealed the nucleus to have dimensions of about 16x8x8 km - "peanut shaped", according to one astronomer. Before the encounter, scientists expected the nucleus to be quite bright. Instead, it was found to have an albedo of only 0.03, making it one of the darkest objects in the solar system. Its density was an incredibly low 0.1 g/cm^3. This indicates that it is likely porous. Subsequent analysis of the images returned by the various spacecraft has yielded evidence to support that the nucleus of the comet rotates around its axis every 7.1 days.

Disappointingly, Comet Halley's latest appearance was not as spectacular as it had been in 1835 and 1910. Though it was visible to the naked eye if one knew where to look, it wasn't an obvious feature in the sky.

Comet Halley is predicted to return in the year 2061.

View nucleus of Comet Halley, as imaged by Vega 2.

1.249 951 Gaspra

For information on 951 Gaspra, click here.

1.250 243 Ida

For information on 243 Ida, click here.

1.251 Vanguard 1

The following information was written by William F. Hagen.

5 VANGUARD 1: The second USA satellite (after Explorer 1) and the oldest satellite still in orbit from any nation. Vanguard 1 is very faint visually, between tenth and fifteenth magnitude depending on its distance and illumination.

See also: Vanguard 1 Rocket/Body.

1.252 Vanguard 1 Rocket/Body

The following information was written by William F. Hagen.

16 VANGUARD 1 ROCKET/BODY: The oldest RB in orbit, and with the Vanguard 1 payload, the oldest object still in orbit from any nation. The Vanguard RB is much brighter than its payload, sometimes as bright as seventh magnitude on very favorable passes.

1.253 Vanguard 3

The following information was written by William F. Hagen.

20 VANGUARD 3: This satellite was never separated from its rocket/body, so it is unusually bright for the early payloads still in orbit. At perigee it can reach sixth magnitude, although it spends most of its time at much higher altitudes.

1.254 Transit 2-A Rocket/Body

The following information was written by William F. Hagen.

57 TRANSIT 2-A ROCKET/BODY: From the 1960 launch of an early Transit navigation satellite.

1.255 Courier 1-B Rocket/Body

The following information was written by William F. Hagen.

59 COURIER 1-B ROCKET/BODY: This is the rocket/body from the launch of the very early low-orbit Courier 1-B communications satellite. Launched in October 1960, three years to the day after Sputnik 1, there are only 22 objects (counting payloads, R/Bs and debris) that have been in orbit longer than NORAD catalog number 59. And at a reliable sixth magnitude this satellite is an easy object to spot in binoculars.

1.256 Alouette 1

Most of the following information was written by William F. Hagen.

424 ALOUETTE 1: An eighth magnitude Canadian satellite that investigated the ionosphere. This is the oldest non-USA satellite in Earth orbit, older than any Soviet satellite in Earth orbit. There are two older Soviet spacecraft in heliocentric orbit.

Alouette 1 was launched at 6:05 UTC on September 29, 1962. Upon reaching orbit, it had a mass of 145.70 kg.

It was equipped with an ionospheric sounder, a VLF receiver, an energetic particle detector, and a cosmic noise experiment. Two dipole antennas were shared by three of the spacecraft's experiments. The satellite was spin-stabilized at about 1.4 RPM after the antennae had been extended. After about 500 days, the satellite had slowed to about 0.6 RPM. This was faster than expected, and as a result the spacecraft lost its orientation. It is believed that the satellite gradually progressed towards a "gravity gradient" stabilization with the longer antenna pointing towards the Earth. In September 1972, the Alouette 1 mission was declared to be officially over.

See also: Alouette 1 Rocket/Body

1.257 Alouette 1 Rocket/Body

The following information was written by William F. Hagen.

426 ALOUETTE 1 ROCKET/BODY: A fifth magnitude Agena-B rocket/body from Thor-Agena TA-1, launched in September 1962 from Vandenberg. The payload was Alouette 1, a Canadian satellite that investigated the ionosphere.

1.258 Centaur 2

The following information was written by William F. Hagen.

694 CENTAUR 2: This is the first Centaur rocket ever to enter space, on the Atlas/Centaur 2 rocket launched in November 1963 from pad 36-A at the Cape Canaveral Air Force Station. A/C-1 failed due to an Atlas malfunction. Centaur 2 was an engineering test for the Centaur program, under development for the Surveyor lunar landing probes. Visually Centaur 2 is a very interesting satellite. It is tumbling with a period of 20 seconds, with a three magnitude swing from maximum to minimum. It is also in a very eccentric orbit, ranging from 500 to 1,500 kilometers, which makes Centaur 2 appear very different depending on its altitude. At perigee it ranges from first to fourth magnitude every 20 seconds, and at apogee the swing is between fourth and seventh magnitude. Centaur 2 is the most easily seen satellite launched before the mid-60s. This is one of the three Centaurs in low orbit.

1.259 Solrad 7A/Secor 1 Rocket/Body

The following information was written by William F. Hagen.

727 SOLRAD 7A / SECOR 1 ROCKET/BODY: A multiple-payload fifth magnitude rocket/body, probably an Agena. The payloads were the scientific satellites Solrad 7A and Greb, the store/dump LEO comsat Secor 1, and Gravity Gradient 1.

1.260 Echo 2 Rocket/Body

The following information was written by William F. Hagen.

741 ECHO 2 ROCKET/BODY: This is the Agena upper stage from the Thor-Agena TA-2 rocket that boosted the famous Echo 2 balloon satellite into a 1,000 kilometer high orbit from Vandenberg in January 1964. Echo 2 was a 135-foot diameter mylar balloon that served as a passive line-of-sight communications relay, and brilliant visual satellite, until its decay in June 1969 due to a combination of solar radiation pressure and atmospheric drag. The R/B is about sixth magnitude, still in the precise orbit that the brilliant Echo 2 once followed (the R/B has a much higher density and was unaffected by solar radiation pressure), today only an echo of Echo.

1.261 Solrad 7B/Secor 3 Rocket/Body

The following information was written by William F. Hagen.

1245 SOLRAD 7B / SECOR 3 ROCKET/BODY: A multiple-payload fifth magnitude rocket/body, probably an Agena. The payloads were the scientific satellites Solrad 7B and Greb, the store/dump LEO comsat Secor 3, Gravity Gradient satellites 2 and 3, Surcal, and the amateur radio satellite Oscar 3.

1.262 Alouette 2 Rocket/Body

The following information was written by William F. Hagen.

1807 ALOUETTE 2 ROCKET/BODY: The Agena rocket/body from the dual launch of Alouette 2 and Explorer 31. The R/B has a wide magnitude range and a period of 40 seconds.

1.263 OAO 1

The following information was written by William F. Hagen.

2142 OAO 1: Orbiting Astronomical Observatory 1 failed after two days in orbit due to a battery failure. OAO 1 has been reported as bright as magnitude -1 during one flare, although it is typically closer to fifth magnitude. All three OAOs have had flashes into the negative magnitudes, probably due to the highly reflective telescopic mirrors.

See also: OAO 1 Rocket/Body.

1.264 OAO 1 Rocket/Body

The following information was written by William F. Hagen.

2144 OAO 1 ROCKET/BODY: Agena-B rocket/body from the launch of Orbiting Astronomical Observatory 1 (OAO 1) in April 1966. In the fifth magnitude range.

1.265 Nimbus 2 Rocket/Body

The following information was written by William F. Hagen.

2174 NIMBUS 2 ROCKET/BODY: Agena TA-6 rocket/body from the 1966 launch of a Nimbus polar weather satellite aboard a Thor-Agena rocket. In a sun-synchronous orbit with evening passes near sixth magnitude.

1.266 Pageos Rocket/Body

The following information was written by William F. Hagen.

2255 PAGEOS ROCKET/BODY: Agena TA-7 rocket/body from the launch of the Pageos mylar balloon. In a 4,000 kilometer high orbit, the R/B is quite faint near ninth magnitude. It has been reported to have a flash period of 18.6 seconds.

1.267 Timation 1 Rocket/Body

The following information was written by William F. Hagen.

2826 TIMATION 1 ROCKET/BODY: From launch of a navigation satellite.

1.268 OAO 2

The following information was written by William F. Hagen.

3597 OAO 2: Orbiting Astronomical Observatory 2 was launched on Atlas/Centaur 16 in December 1968. OAO 2 ran a very successful ultraviolet astronomy program. All three OAOs have been reported to flash into the negative magnitudes on occasion, probably due to their highly reflective telescopic mirrors.

See also: OAO 2 Rocket/Body.

1.269 OAO 2 Rocket/Body

The following information was written by William F. Hagen.

3598 OAO 2 ROCKET/BODY: Centaur stage from Atlas/Centaur 16, launched in December 1968 from pad 36-B at the Cape Canaveral Air Force Station. The payload was the astronomical telescope Orbiting Astronomical Observatory 2. OAO 2 R/B is a very easily seen, if somewhat visually unpredictable, satellite. It is generally in the third magnitude range, but it is sometimes up to three magnitudes off prediction in either direction. This is one of the three Centaurs in low orbit.

1.270 Timation 2 Rocket/Body

The following information was written by William F. Hagen.

4159 TIMATION 2 ROCKET/BODY: From launch of a navigation satellite.

1.271 SERT 2

The following information was written by William F. Hagen.

4327 SERT 2 (Space Electric Rocket Test): This was an engineering test for ion propulsion in space. The ion engine fired a one-ounce thrust for eight months, but the engines shut down before their design lifetime and the mission was officially considered unsuccessful.

1.272 MAO 1 Rocket/Body

The following information was written by William F. Hagen.

4392 MAO 1 ROCKET/BODY: The RB from the first Chinese launch, of the 'East is Red' satellite, in April 1970.

1.273 Cosmos 382

The following information was written by William F. Hagen.

4786 COSMOS 382: This is by far the largest piece from the Cosmos 382 satellite, which apparently made some separations during its operational lifetime. C-382 was an engineering test for the 1971 Soviet missions to Mars, which included the first soft landing ever made on that planet. Unfortunately the 1971 spacecraft fleet arrived during a major dust storm that obscured the planet's surface from view and made conditions on the surface inhospitable to the Soviet lander, which went silent seconds after touchdown. C-382 is a rather large satellite in a fairly high orbit, making it relatively easy to locate visually. It has been reported to have a flash period of under five seconds.

1.274 NOAA 1 Rocket/Body

The following information was written by William F. Hagen.

4794 NOAA 1 ROCKET/BODY: Delta rocket/body from the launch of the NOAA 1 polar weather satellite in December 1970 from Vandenberg. Sun-synchronous orbit, flash period reported of 3.5 seconds.

1.275 Cosmos 398

The following information was written by William F. Hagen.

4966 COSMOS 398: This satellite, close to re-entry, is thought to have been an engineering test related to the Soviet manned lunar landing program.

1.276 Pageos DA

The following information was written by William F. Hagen.

5994 PAGEOS DA: This is one of the two large pieces of the Pageos balloon satellite still in orbit. Pageos is a 100-foot diameter mylar balloon, nearly identical to the Echo satellites, launched into a very high polar orbit from Vandenberg. Pageos' orbital altitude was initially near 4,000 kilometers, but the satellite was still second magnitude despite the very great distance. This combination of great altitude and great size made Pageos one of the most interesting visual satellites ever launched. Due to its great surface area and low mass, Pageos was subjected to intense solar sailing due to the radiation pressure of sunlight. In 1975 Pageos broke up in orbit, possibly due to weakening from micrometeoroid impacts, into about 75 pieces. Only five remain in orbit, and only two of these are large pieces (5994 and 8074). These two satellites are still active solar sailers. Solar radiation pressure has, over time, made the orbits of 5994 and 8074 very elliptical. Their perigees are under 1,000 kilometers, and their apogees are nearly 7,000 kilometers. Since they have very low densities, their perigee altitudes are dangerously low and they will probably re-enter within the next few years. This is the same fate that brought down the similar Echo balloons - solar sailing down the perigee, and atmospheric drag finishing the job. Both 5994 and 8074 are quite bright and easily seen objects, normally seen in intermediate altitudes near fourth to sixth magnitude. Due to their large surface area and irregular shape their brightness can be unpredictable. 5994 was mistakenly catalogued by NORAD as one of the Westford Needles deployed from the Midas 6 satellite, which were in a similar orbit to Pageos, but it is clearly a Pageos fragment.

1.277 Landsat 1

The following information was written by William F. Hagen.

6126 LANDSAT 1: USA earth resources satellite. For information on the Landsat program, see Landsat 5.

1.278 Copernicus (OAO 3)

The following information was written by William F. Hagen.

6153 COPERNICUS (OAO 3): The third Orbiting Astronomical Observatory, renamed Copernicus in orbit, was launched on Atlas/Centaur 22 in August 1972 from pad 36-B. It ran a very successful ultraviolet and X-ray astronomy program. Visually Copernicus is one of the most interesting satellites in orbit. It has a complex light curve that repeats every minute. It will be very faint, in the seventh magnitude range, and slowly increase brightness over almost a minute to third magnitude. Then it will rapidly increase brightness and flash in the magnitude zero to -2 range. The magnitude drop after the flash is very rapid as it sinks back to seventh magnitude. All three OAOs have flashed into the negative magnitudes, although Copernicus is the only one to do so regularly. These flashes are probably caused by their very reflective telescopic mirrors. Despite its brilliant flashes Copernicus can be a difficult satellite to observe because it is nearly invisible at minimum.

See also: Copernicus (OAO 3) Rocket/Body.

1.279 Copernicus (OAO 3) Rocket/Body

The following information was written by William F. Hagen.

6155 COPERNICUS (OAO 3) ROCKET/BODY: Centaur stage from Atlas/Centaur 22, launched in August 1972 from pad 36-B at the Cape Canaveral Air Force Station. Copernicus R/B is fairly easily seen, typically near third magnitude, but its brightness is somewhat unpredictable like 3598. This is one of the three Centaurs in low orbit.

1.280 Miranda Rocket/Body

The following information was written by William F. Hagen.

7228 MIRANDA ROCKET/BODY: The Scout solid-fuel upper stage from the launch of the British experimental satellite Miranda. In the seventh to eighth magnitude range.

1.281 Landsat 2

The following information was written by William F. Hagen.

7615 LANDSAT 2: USA earth resources satellite. For information on the Landsat program see Landsat 5.

1.282 Intelsat 4-1 Rocket/Body

The following information was written by William F. Hagen.

7902 INTELSAT 4-1 ROCKET/BODY: Information on the Intelsat-4 rocket/body series is very similar to the Intelsat 4-A rocket/body series; see Intelsat 4A-1 Rocket/Body.

1.283 Starlette

The following information was written by William F. Hagen.

7646 STARLETTE: French geodetic satellite, 25 centimeters diameter, passive laser reflector. Probably not a good candidate for visual observation.

1.284 Nimbus 6 Rocket/Body

The following information was written by William F. Hagen.

7946 NIMBUS 6 ROCKET/BODY: Delta upper stage from the 1975 launch of a Nimbus weather satellite. In a sun-synchronous orbit with evening passes near fifth magnitude.

1.285 Pageos H

The following information was written by William F. Hagen.

8074 PAGEOS H: Large fragment of the Pageos balloon. See Pageos DA for details.

1.286 Intelsat 4A-1 Rocket/Body

The following information was written by William F. Hagen.

8331 INTELSAT 4A-1 ROCKET/BODY: Centaur stage from the launch of an Intelsat 4A international communications satellite. The Centaur stages in Geosynchronous Transfer Orbit (GTO) have bright repeating glints that can be seen in binoculars at fairly high altitudes. The perigee altitudes of the five Intelsat 4A, seven Intelsat 4 and four Comstar rocket/bodies are high enough to avoid significant atmospheric drag; the three Intelsat 5 and the FltSatCom 4 rocket/bodies have a very low perigee that makes their positions somewhat uncertain. These GTO Centaur objects have a very unique appearance, due to their size, tumble and eccentric orbit, that make them interesting satellites to observe.

1.287 UME 1

The following information was written by William F. Hagen.

8709 UME 1: Japanese ionospheric sounding satellite also known as ISS-A. Flash period of 3.5 seconds.

See also: UME 1 Rocket/Body.

1.288 UME 1 Rocket/Body

The following information was written by William F. Hagen.

8710 UME 1 ROCKET/BODY: Japanese N-1 rocket/body from launch of Ume-1.

1.289 Lageos

The following information was written by William F. Hagen.

8820 LAGEOS: (Laser Geodynamics Satellite) A 900-pound sphere with a diameter of 2 feet, Lageos is in a very high altitude very highly stable orbit for precise geodetic mapping. The satellite is a passive reflector for laser beams. Because of its small size and great altitude, Lageos is certainly not visible to amateur trackers.

1.290 Comstar 1 Rocket/Body

The following information was written by William F. Hagen.

8840 COMSTAR 1 ROCKET/BODY: Information on the Comstar rocket/body series is very similar to the Intelsat 4A rocket/body series; see Intelsat 4A-1 Rocket/Body.

1.291 Cosmos 825-832 Rocket/Body

The following information was written by William F. Hagen.

8897 COSMOS 825-832 ROCKET/BODY: Flash period of 30 seconds

1.292 Cosmos 871-878 Rocket/Body

The following information was written by William F. Hagen.

9598 COSMOS 871-878 ROCKET/BODY: Soviet R/B in a 1,500 kilometer high orbit, very sharp glints every 4.17 seconds.

1.293 Cosmos 939-946 Rocket/Body

The following information was written by William F. Hagen.

10293 COSMOS 939-946 ROCKET/BODY: Flash period of 31.8 seconds

1.294 Sirio Rocket/Body

The following information was written by William F. Hagen.

10295 SIRIO ROCKET/BODY: Delta upper stage from the launch of the Italian communications satellite Sirio-1 (translation to Sirius)

1.295 Sakura Rocket/Body

The following information was written by William F. Hagen.

10517 SAKURA ROCKET/BODY: Delta upper stage from the launch of the Japanese experimental geostationary communications satellite Sakura-1

1.296 UME 2

The following information was written by William F. Hagen.

10674 UME 2: Japanese ionospheric sounding satellite also known as ISS-B.

See also: UME 2 Rocket/Body.

1.297 UME 2 Rocket/Body

The following information was written by William F. Hagen.

10675 UME 2 ROCKET/BODY: Japanese N-1 rocket/body from launch of Ume-2, flash period of 2.7 seconds.

1.298 Landsat 3

The following information was written by William F. Hagen.

10702 LANDSAT 3: USA earth resources satellite. For information on the Landsat series see Landsat 5.

1.299 Yuri Rocket/Body

The following information was written by William F. Hagen.

10793 YURI ROCKET/BODY: Delta upper stage from the launch of the Japanese experimental direct-broadcast communications satellite Yuri-1

1.300 Goes 3 Rocket/Body

The following information was written by William F. Hagen.

10954 GOES 3 ROCKET/BODY: Delta upper stage from the launch of the GOES-6 geostationary civilian weather satellite.

1.301 Seasat

The following information was written by William F. Hagen.

10967 SEASAT: This polar-orbiting and slightly retrograde satellite was launched from Vandenberg to study the oceans. The solar arrays are mounted on the Agena upper stage, which was maintained as part of the Seasat structure. It came to a premature failure after a few months in orbit, partly due to errors made in the ground operation of the spacecraft. Despite its short life it produced a great deal of valuable data on the oceans and on the capabilities of synthetic aperture radar orbital mapping, a technique later used on the Magellan Venus orbiter and the Lacrosse spy satellite. Visually Seasat is around third magnitude, although it can get as bright as zero magnitude on rare passes.

1.302 Nimbus 7

The following information was written by William F. Hagen.

11080 NIMBUS 7: USA civilian weather satellite in sun-synchronous orbit. Passes near noon and midnight. Visually can be seen over the pole near the summer solstice.

1.303 Cosmos 1051-1058 Rocket/Body

The following information was written by William F. Hagen.

11136 COSMOS 1051-1058 ROCKET/BODY: Flash period of 6.82 seconds

1.304 Cosmos 1076

The following information was written by William F. Hagen.

11266 COSMOS 1076: Soviet oceanographic satellite

1.305 Intercosmos 19 Rocket/Body

The following information was written by William F. Hagen.

11286 INTERCOSMOS 19 ROCKET/BODY: Soviet R/B, tumbler, with a 40 second period. Maximum can be in the second magnitude range.

1.306 Cosmos 1130-1137 Rocket/Body

The following information was written by William F. Hagen.

11546 COSMOS 1130-1137 ROCKET/BODY: Flash period of 15.47 seconds

1.307 Cosmos 1151

The following information was written by William F. Hagen.

11671 COSMOS 1151: Soviet oceanographic satellite, flash rate of five seconds

1.308 Cosmos 1171 Rocket/Body

The following information was written by William F. Hagen.

11751 COSMOS 1171 ROCKET/BODY: Flash period of 25.8 seconds

1.309 Fltsatcom 4 Rocket/Body

The following information was written by William F. Hagen.

12069 FLTSATCOM 4 ROCKET/BODY: Centaur stage from AC-57 launch of military comsat. Flash period of 5.15 seconds; the glints are fairly bright, rising a couple of magnitudes above the predicted brightness.

1.310 Intelsat 5-1 Rocket/Body

The following information was written by William F. Hagen.

12497 INTELSAT 5-1 ROCKET/BODY: Centaur stage from AC-56 launch of an international communications satellite. Flash period of five seconds.

1.311 NOAA 7

The following information was written by William F. Hagen.

12553 NOAA 7: This polar-orbiting weather satellite is now tumbling, and has frequent glints as bright as second magnitude on favorable passes. The flash pattern is very regular and predictable. NOAA 7 is in a sun-synchronous orbit that has seasonal visibility windows. Because of the brightness of the glints it is often visible at low elevations, making it possible to see the satellite even in seasons when there are no favorable passes.

1.312 SME

The following information was written by William F. Hagen.

12887 SME: Solar Mesosphere Explorer science satellite studies atmosphere, sunlight and their interaction. Flash period of 2 seconds.

See also: SME Rocket/Body.

1.313 SME Rocket/Body

The following information was written by William F. Hagen.

12889 SME ROCKET/BODY: Delta rocket/body from launch of Solar Mesospheric Explorer (SME) and amateur radio satellite Uosat Oscar-9.

1.314 Cosmos 1320-1327 Rocket/Body

The following information was written by William F. Hagen.

12983 COSMOS 1320-1327 ROCKET/BODY: Flash period of 14.9 seconds

1.315 Intelsat 5-3 Rocket/Body

The following information was written by William F. Hagen.

13007 INTELSAT 5-3 ROCKET/BODY: Centaur stage from AC-55 launch of an international communications satellite. Flash period of 4.7 seconds.

1.316 NOAA 8

The following information was written by William F. Hagen.

13923 NOAA 8: USA civilian weather satellite, no longer operational

1.317 Landsat 4

The following information was written by William F. Hagen.

13367 LANDSAT 4: USA earth resources satellite. For information on the Landsat program see Landsat 5.

1.318 IRAS

The following information was written by William F. Hagen.

13777 IRAS (InfraRed Astronomical Satellite): IRAS, the best infrared telescope ever launched, is one of the most famous satellites in orbit. It eventually ceased operation when the liquid helium used to cool the telescope evaporated from solar warming. IRAS is a joint USA, UK and Netherlands project, and was launched on a Delta rocket from the Vandenberg Air Force Base in California. Visually IRAS is typically in the fifth magnitude range, but it can sometimes flare up to second magnitude. It is in a sun-synchronous orbit so its visibility is seasonal.

See also: IRAS Rocket/Body

1.319 IRAS Rocket/Body

The following information was written by William F. Hagen.

13778 IRAS ROCKET/BODY: The Delta rocket/body from the launch of IRAS.

1.320 Satcom 6 Rocket/Body

The following information was written by William F. Hagen.

13985 SATCOM 6 ROCKET/BODY: Delta rocket/body from the launch of the Satcom-F1R communications satellite

1.321 Goes 6 Rocket/Body

The following information was written by William F. Hagen.

14051 GOES 6 ROCKET/BODY: Delta upper stage from the launch of the GOES-6 geostationary civilian weather satellite

1.322 Exosat Rocket/Body

The following information was written by William F. Hagen.

14096 EXOSAT ROCKET/BODY: Delta rocket/body from the launch of the European X-Ray Observation Satellite

1.323 Cosmos 1473-1480 Rocket/Body

The following information was written by William F. Hagen.

14179 COSMOS 1473-1480 ROCKET/BODY: Flash period of 43.5 seconds

1.324 Cosmos 1500

The following information was written by William F. Hagen.

14372 COSMOS 1500: Soviet oceanographic satellite

1.325 Cosmos 1522-1529 Rocket/Body

The following information was written by William F. Hagen.

14612 COSMOS 1522-1529 ROCKET/BODY: Flash period of 39.14 seconds

1.326 Palapa 4 Rocket/Body & Westar 6 Rocket/Body

The following information was written by William F. Hagen.

14693 PALAPA 4 ROCKET/BODY and 14694 WESTAR 6 ROCKET/BODY: Two PAM upper stages that were intended to boost their commercial communications satellite payloads into geostationary orbit. They were launched aboard the space shuttle Challenger and deployed into an identical parking orbit, but identical malfunctions stranded the satellites in low orbit. The payloads were recovered on a later shuttle mission and relaunched in 1990 aboard unmanned launch vehicles, but the failed PAM stages remain in low orbit, where they can be visually seen in the third to sixth magnitude range depending on altitude. This provides a unique opportunity for the observation of a PAM stage at close range.

See also: Palapa 6 Rocket/Body.

1.327 Westar 6 Rocket/Body

See Palapa 4 Rocket/Body & Westar 6 Rocket/Body.

1.328 Landsat 5

The following information was written by William F. Hagen.

14780 LANDSAT 5: Fifth in the USA series of earth resources satellites. Also known as ERTS (Earth Resources Technology Satellites). The Landsat series is the primary civilian USA source for global imaging of the Earth's surface. Landsat images can show the current land use and the potential natural resources. Landsats 1-3 are near sixth magnitude, and the more advanced 4 and 5 satellites are near fourth magnitude.

1.329 AMPTE Rocket/Body

The following information was written by William F. Hagen.

15202 AMPTE ROCKET/BODY: Delta upper stage from the launch of three satellites forming the Active Magnetosphere Particle Tracer Explorer constellation. The three satellites (CCE [USA], IRM [West German] and UKS [UK]) were boosted beyond the Delta's parking orbit into very highly eccentric orbits for the study of the magnetosphere. The Ampte RB ranges from fourth to eighth magnitude depending on altitude.

1.330 Leasat 2 Rocket/Body

The following information was written by William F. Hagen.

15244 LEASAT 2 ROCKET/BODY: Leasat 2 was launched aboard the space shuttle Discovery in August 1984 on mission STS 41-D. For generic information on the Leasat RBs, see Leasat 5 Rocket/Body.

1.331 Cosmos 1602

The following information was written by William F. Hagen.

15331 COSMOS 1602: Soviet oceanographic satellite.

1.332 Cosmos 1603

The following information was written by William F. Hagen.

15333 COSMOS 1603: Soviet Electronic Intelligence (ELINT) satellite. Made a dramatic series of orbital manoeuvers after launch, changing both altitude and orbital plane.

1.333 ERBS

The following information was written by William F. Hagen.

15354 ERBS (Earth Radiation Budget Satellite): ERBS was launched aboard the space shuttle Challenger (mission STS 41-G) in October 1984. Its mission is to study the Earth's radiation budget, i.e. the solar energy received and the reradiated energy from Earth. ERBS compliments similar experiments flown on several polar-orbiting NOAA weather satellites. Visually ERBS is in the fifth magnitude range.

1.334 Leasat 1 Rocket/Body

The following information was written by William F. Hagen.

15390 LEASAT 1 ROCKET/BODY: Leasat 1 was launched aboard the space shuttle Discovery in November 1984 on mission STS 51-A. For generic information on the Leasat RBs, see Leasat 5 Rocket/Body.

1.335 NOAA 9

The following information was written by William F. Hagen.

15427 NOAA 9: USA civilian weather satellite in low polar sun-synch orbit.

1.336 Meteor 2-12

The following information was written by William F. Hagen.

15516 METEOR 2-12: Soviet weather satellite. Visually near sixth magnitude.

1.337 Geosat

The following information was written by William F. Hagen.

15595 GEOSAT: USA Geodynamic Earth and Oceans Satellite.

1.338 Cosmos 1635-1642 Rocket/Body

The following information was written by William F. Hagen.

15625 COSMOS 1635-1642 ROCKET/BODY: Flash period of 40.25 seconds

1.339 Leasat 4 Rocket/Body

The following information was written by William F. Hagen.

16001 LEASAT 4 ROCKET/BODY: Leasat 4 was launched aboard the space shuttle Discovery in August 1985 on mission STS 51-I. For generic information on the Leasat RBs, see Leasat 5 Rocket/Body.

1.340 Cosmos 1697

The following information was written by William F. Hagen.

16181 COSMOS 1697: Soviet Electronic Intelligence (ELINT) satellite.

See also Cosmos 1697 Rocket/Body.

1.341 Cosmos 1697 Rocket/Body

The following information was written by William F. Hagen.

16182 COSMOS 1697 ROCKET/BODY: Soviet SL-16 Zenit booster from launch of ELINT satellite. For generic Zenit information see Cosmos 2082 Rocket/Body.

1.342 Meteor 3-1

The following information was written by William F. Hagen.

16191 METEOR 3-1: Soviet weather satellite. Visually sixth-seventh magnitude.

1.343 Leasat 3 Rocket/Body

The following information was written by William F. Hagen.

16229 LEASAT 3 ROCKET/BODY: Leasat 3 was launched aboard the space shuttle Discovery in April 1985 aboard mission STS 51-D. Due to a malfunction on the satellite the upper stage that became 16229 was never commanded to ignite, and the Leasat was stranded in a low orbit until a later shuttle rescue repaired the problem. A solar reflector was installed on the upper stage to try to warm the solid fuel. After several months in drift mode the booster was ignited and the Leasat entered the intended orbit. For generic information on the Leasat RBs, see Leasat 5 Rocket/Body.

1.344 Meteor 2-13

The following information was written by William F. Hagen.

16408 METEOR 2-13: Soviet weather satellite. Visually near sixth magnitude.

1.345 Mir Complex

View picture

Most of the following information was written by William F. Hagen.

16609 MIR COMPLEX: This is mankind's only operational space station. The Soviet complex consists of the Mir core, two Kvant modules, and one Kristall module, all launched separately and docked in orbit. Cosmonauts are launched to the Mir complex and return to Earth aboard Soyuz spacecraft. When manned the Mir includes the crew's Soyuz craft. The normal Mir crew size is two, although it is typically five for a short time when the old crew hands over to the new crew. There are frequent launches of unmanned Progress cargo supply spacecraft to Mir when manned, and there is normally one Progress docked to the complex. The primary purposes of the Mir are life-sciences experiments to determine the effect of long-duration weightless conditions on the human body and 'microgravity' commercial industrial experiments. Visually Mir is in the zero magnitude range and is easily the brightest artificial satellite in orbit. Because of frequent manoeuvering to compensate for atmospheric drag, and occasional major orbital changes during rendezvous with Soyuz and Progress spacecraft, Mir will often be much earlier or later than predicted by satellite tracking software.

The picture of Mir provided by the link at the beginning of this entry was taken at a distance of 165 feet from the cargo bay of the shuttle during the STS-63 mission. One of the primary tasks of the mission was to practice rendezvous maneouvers with the space station in preparation for STS-71, which docked with Mir.

1.346 Cosmos 1745 Rocket/Body

The following information was written by William F. Hagen.

16728 COSMOS 1745 ROCKET/BODY: Flash period of 11.02 seconds

1.347 EGP/AJISAI

The following information was written by William F. Hagen.

16908 EGP/AJISAI: This Japanese satellite is the most distinctive object in orbit. EGP (Experimental Geodetic Payload), also known as EGS (Experimental Geodetic Satellite) or Ajisai (Hydrangea flower), was launched on the first test flight of the H-1 rocket in August 1986. EGP is a sphere with a diameter

of seven feet, and is covered with mirrors and corner-cube reflectors. The latter are used to reflect laser beams and are invisible to amateur observers, but the mirrors are spectacular. They are designed to reflect sunlight so the satellite can be photographed by ground stations for precise geodetic surveying measurements. The glints are probably in the third magnitude range but are visible to the naked eye only in very dark skies under good conditions. The brief flashes are too short to be noticed by the naked eye. In binoculars EGP resembles the strobe of an airplane but the flash pattern is more complex than a strobe light. Because of the extremely high orbital altitude of 1,500 kilometers, EGP is often visible closer to midnight than other satellites, and can frequently be seen on as many as four orbits during a single overnight observing session.

See also: EGP Rocket/Body.

1.348 EGP Rocket/Body

The following information was written by William F. Hagen.

16910 EGP ROCKET/BODY: Upper stage from the H-1 rocket that launched the EGP satellite and a small amateur radio secondary payload Fuji 1 / Oscar 12 (FO-12). The R/B is quite large and, therefore, bright (fifth magnitude) for its altitude of 1,500 kilometers. It does not appear to be tumbling and is fairly constant in its brightness.

1.349 NOAA 10

The following information was written by William F. Hagen.

16969 NOAA 10: Active USA civilian weather satellite in low polar sun-synch orbit. Passes near sunrise and sunset, sometimes visible in evening skies near sixth magnitude. APT radio transmissions can be received on 137.500 MHz.

1.350 Polar Bear

The following information was written by William F. Hagen.

17070 POLAR BEAR: USA NNSS navigation satellite with auroral studies. Was restored from display at the Smithsonian in Washington, DC.

1.351 Cosmos 1794-1801 Rocket/Body

The following information was written by William F. Hagen.

17146 COSMOS 1794-1801 ROCKET/BODY: Flash period of 19 seconds

1.352 Astro 3

The following information was written by William F. Hagen.

17480 ASTRO 3: Japanese X-ray astronomy satellite, also known as 'Ginga'.

1.353 MOS 1-A

The following information was written by William F. Hagen.

17527 MOS 1-A: Japanese Maritime Observation Satellite

1.354 Cosmos 1833

The following information was written by William F. Hagen.

17589 COSMOS 1833: Soviet Electronic Intelligence (ELINT) satellite.

See also: Cosmos 1833 Rocket/Body.

1.355 Cosmos 1833 Rocket/Body

The following information was written by William F. Hagen.

17590 COSMOS 1833 ROCKET/BODY: Soviet SL-16 Zenit booster from launch of ELINT satellite. For generic Zenit information see Cosmos 2082 Rocket/Body.

1.356 Cosmos 1844

The following information was written by William F. Hagen.

17973 COSMOS 1844: Soviet Electronic Intelligence (ELINT) satellite.

See also: Cosmos 1844 Rocket/Body.

1.357 Cosmos 1844 Rocket/Body

The following information was written by William F. Hagen.

17974 COSMOS 1844 ROCKET/BODY: Soviet SL-16 Zenit booster from launch of ELINT satellite. For generic Zenit information see Cosmos 2082 Rocket/Body.

1.358 Cosmos 1852-1859 Rocket/Body

The following information was written by William F. Hagen.

18121 COSMOS 1852-1859 ROCKET/BODY: Flash period of 40 seconds

1.359 DMSP 2-3

The following information was written by William F. Hagen.

18123 DMSP 2-3: Military weather satellite. For general information on the DMSP series see DMSP 2-5.

1.360 Cosmos 1861

The following information was written by William F. Hagen.

18129 COSMOS 1861: Soviet system-1 navigation satellite. Carries RS/10-11 amateur radio package onboard. Visually near sixth magnitude.

1.361 Meteor 2-16

The following information was written by William F. Hagen.

18312 METEOR 2-16: Soviet weather satellite. Visually near sixth magnitude.

See also: Meteor 2-16 Rocket/Body.

1.362 Meteor 2-16 Rocket/Body

The following information was written by William F. Hagen.

18313 METEOR 2-16 ROCKET/BODY: Soviet Tsyklon (Cyclone) rocket/body. Launched Meteor 2-16 weather satellite.

1.363 Cosmos 1900

The following information was written by William F. Hagen.

18665 COSMOS 1900: This is the nuclear reactor from the Cosmos 1900 naval reconnaissance satellite. The satellites, which operate in very low orbits, are supposed to jettison their nuclear reactors into a higher stable orbit at the end of their operational mission. Twice the separation systems failed resulting in the re-entry of the nuclear fuel, once into the NWT in Canada, and

once into the Indian Ocean. C-1900 failed in orbit and came very close to re-entering before the separation and boost systems activated, keeping the 110 pounds of uranium in orbit as the rest of the spacecraft plunged to Earth. The C-1900 satellite is about fourth magnitude and has a flash period of 10 seconds.

1.364 Meteor 2-17

The following information was written by William F. Hagen.

18820 METEOR 2-17: Soviet weather satellite. Visually near sixth magnitude.

See also: Meteor 2-17 Rocket/Body.

1.365 Meteor 2-17 Rocket/Body

The following information was written by William F. Hagen.

18821 METEOR 2-17 ROCKET/BODY: Soviet Tsyklon (Cyclone) rocket/body. Launched Meteor 2-17 weather satellite.

1.366 DMSP 2-4

The following information was written by William F. Hagen.

18822 DMSP 2-4: Military weather satellite. For general information on the DMSP series see DMSP 2-5.

1.367 Cosmos 1924-1931 Rocket/Body

The following information was written by William F. Hagen.

18945 COSMOS 1924-1931 ROCKET/BODY: Flash period of 20.1 seconds

1.368 Cosmos 1934 Rocket/Body

The following information was written by William F. Hagen.

18986 COSMOS 1934 ROCKET/BODY: Flash period of 16.8 seconds

1.369 Cosmos 1943

The following information was written by William F. Hagen.

19119 COSMOS 1943: Soviet Electronic Intelligence (ELINT) satellite

See also: Cosmos 1943 Rocket/Body.

1.370 Cosmos 1943 Rocket/Body

The following information was written by William F. Hagen.

19120 COSMOS 1943 ROCKET/BODY: Soviet SL-16 Zenit booster from launch of ELINT satellite. Visually, a tumbler with a period of 20 seconds. For generic Zenit information see Cosmos 2082 Rocket/Body.

1.371 Cosmos 1954 Rocket/Body

The following information was written by William F. Hagen.

19257 COSMOS 1954 ROCKET/BODY: Flash period of 48 seconds

1.372 Okean 1

The following information was written by William F. Hagen.

19274 OKEAN 1: Soviet oceanographic satellite

1.373 Meteor 3-2

The following information was written by William F. Hagen.

19336 METEOR 3-2: Soviet weather satellite. Visually sixth-seventh magnitude.

1.374 Feng Yun 1-A

The following information was written by William F. Hagen.

19467 FENG YUN 1-A: Chinese weather satellite in low polar sun-synch orbit

1.375 NOAA 11

The following information was written by William F. Hagen.

19531 NOAA 11: Active USA civilian weather satellite in low polar sun-synch orbit. Passes near noon and midnight, sometimes visible over the pole in summer near sixth magnitude. APT radio transmissions can be received on 137.650 MHz.

1.376 Cosmos 1980

The following information was written by William F. Hagen.

19649 COSMOS 1980: Soviet Electronic Intelligence (ELINT) satellite.

See also: Cosmos 1980 Rocket/Body.

1.377 Cosmos 1980 Rocket/Body

The following information was written by William F. Hagen.

19650 COSMOS 1980 ROCKET/BODY: Soviet SL-16 Zenit booster from launch of ELINT satellite. Visually, a tumbler with a period of 40 seconds. For generic Zenit information see Cosmos 2082 Rocket/Body.

1.378 Lacrosse 1

The following information was written by William F. Hagen.

19671 LACROSSE 1: This 'dark' Department of Defense satellite is actually ruby red. The first Lacrosse satellite was launched aboard the space shuttle Atlantis (mission STS-27) in December 1988 from launch pad 39-B at the Kennedy Space Center. Lacrosse is a radar imaging satellite similar to the Magellan Venus orbiter, but with a much higher resolution. It is considered one of the most important USA military spacecraft. Lacrosse was, at one time, known by the code name Indigo. Visually Lacrosse is, after EGP, the most distinctive satellite in orbit. It is very bright, second magnitude, and a very strong shade of red. At that magnitude the eye can easily see color making the effect even more obvious. Lacrosse is also in the rather high orbit of 670 kilometers, at least high for something so large, so that the combination of color, brightness and apparent speed make it instantly recognizable. Because it is a classified satellite there are no NORAD orbital elements available, but it is quite easy to keep track of the satellite without official help. Its red color was seen while still in Atlantis' cargo bay on mission 27, and it was seen one orbit later after deployment as a red satellite co-orbital with the shuttle. Since that time it has been 'lost' for only a very short period of time, just after launch. Lacrosse is one of the most interesting satellites to observe.

1.379 Cosmos 2004

The following information was written by William F. Hagen.

19826 COSMOS 2004: Soviet System-2 navigation satellite.

See also: Cosmos 2004 Rocket/Body.

1.380 Cosmos 2004 Rocket/Body

The following information was written by William F. Hagen.

19827 COSMOS 2004 ROCKET/BODY: From launch of navigation satellite. Tumbler, with a flash period of 40.6 seconds.

See also: Cosmos 2004.

1.381 Meteor 2-18

The following information was written by William F. Hagen.

19851 METEOR 2-18: Soviet weather satellite. Visually near sixth magnitude.

1.382 Cosmos 2008-2015 Rocket/Body

The following information was written by William F. Hagen.

19910 COSMOS 2008-2015 ROCKET/BODY: Tumbler, flash period of 6.35 seconds

1.383 Delta Star

The following information was written by William F. Hagen.

19911 DELTA STAR: This is a 'gray' Department of Defense satellite which NORAD releases orbital data on. It is a research and development satellite for the Strategic Defense Initiative, better known as Star Wars. The name is derived from its Delta launch vehicle.

1.384 Cosmos 2016

The following information was written by William F. Hagen.

19921 COSMOS 2016: Soviet System-2 navigation satellite.

See also: Cosmos 2016 Rocket/Body.

1.385 Cosmos 2016 Rocket/Body

The following information was written by William F. Hagen.

19922 COSMOS 2016 ROCKET/BODY: From launch of navigation satellite. Tumbler, with a flash period of 17.2 seconds.

See also: Cosmos 2016.

1.386 Cosmos 2026

The following information was written by William F. Hagen.

20045 COSMOS 2026: Soviet System-2 navigation satellite.

See also: Cosmos 2026 Rocket/Body.

1.387 Cosmos 2026 Rocket/Body

The following information was written by William F. Hagen.

20046 COSMOS 2026 ROCKET/BODY: From launch of navigation satellite. Tumbler, with a flash period of 23 seconds.

See also: Cosmos 2026.

1.388 Cosmos 2027

The following information was written by William F. Hagen.

20064 COSMOS 2027: Soviet Electronic Intelligence (ELINT) satellite

1.389 Nadezhda 1

The following information was written by William F. Hagen.

20103 NADEZHDA 1: Soviet navigation satellite. The satellite is named (translation=Hope) for an onboard COSPAS/SARSAT package that locates emergency beacons.

1.390 Cosmos 2034

The following information was written by William F. Hagen.

20149 COSMOS 2034: Soviet system-2 navigation satellite

See also: Cosmos 2034 Rocket/Body.

1.391 Cosmos 2034 Rocket/Body

The following information was written by William F. Hagen.

20150 COSMOS 2034 ROCKET/BODY: From launch of navigation satellite. Tumbler, with a lighthouse appearance, flash period of 4.7 seconds.

See also: Cosmos 2034.

1.392 Cosmos 2037 Rocket/Body

The following information was written by William F. Hagen.

20197 COSMOS 2037 ROCKET/BODY: From launch of Soviet geodetic satellite. Tumbler, flash period of 0.8 seconds.

1.393 Cosmos 2046

The following information was written by William F. Hagen.

20259 COSMOS 2046: Soviet Electronic Ocean Reconnaissance Satellite (EORSAT); very bright first-magnitude satellite.

1.394 Intercosmos 24

The following information was written by William F. Hagen.

20261 INTERCOSMOS 24: Joint Soviet / eastern block scientific satellite to study the magnetosphere and the propagation of low radio frequencies.

See also: Intercosmos 24 Rocket/Body.

1.395 Intercosmos 24 Rocket/Body

The following information was written by William F. Hagen.

20262 INTERCOSMOS 24 ROCKET/BODY: Soviet Tsyklon (Cyclone) third stage rocket/body from launch of Intercosmos 24 and Magion subsatellite.

1.396 GPS 2-4 Rocket/Body

The following information was written by William F. Hagen.

20303 GPS 2-4 ROCKET/BODY: Delta-II second stage from launch of fourth block-2 GPS-Navstar navigation satellite. The GPS (Global Positioning System) series is a USA Department of Defense constellation of navigation satellites in circular 12-hour orbits. The primary use of GPS is for military navigation, but civilian users are allowed limited use of the satellites. The block-2 GPS-Navstar satellites are launched on the new Delta-II rocket. The second stage from the Delta remains in an eccentric parking orbit near 400x1000 km for some launches, depending on the payload's destination orbital plane. On some launches the parking orbit perigee is much lower and the second stage quickly decays. Visually the GPS RBs are fairly predictable in brightness, in the third to sixth magnitude range depending on altitude and solar illumination. They do not appear to be tumbling and maintain a steady brightness during a pass. The second stage is actually blue-green, and carries the GPS, McDonnell Douglas and USAF logos, but any color is very hard to detect in orbit.

1.397 Meteor 3-3

The following information was written by William F. Hagen.

20305 METEOR 3-3: Soviet weather satellite. Visually sixth-seventh magnitude.

1.398 COBE

The following information was written by William F. Hagen.

20322 COBE (COsmic Background Explorer): COBE's mission is to explore the residual background radiation from the big bang. It has measured the smoothness of the background and shown that the early universe was homogeneous to a degree beyond the measuring capability of any previous instrument. COBE was launched on a Delta rocket from Vandenberg Air Force Base in California. Visually COBE is a rather erratic satellite, often in the fourth magnitude range, but under certain lighting conditions it will be near first magnitude. These changes seem unrelated to the illumination phase. When it is bright its magnitude cycles between about first and third magnitude as COBE spins. Under most conditions COBE's spin does not appear to create a light curve. COBE is in a sun-synchronous orbit.

1.399 GPS 2-5 Rocket/Body

The following information was written by William F. Hagen.

20362 GPS 2-5 ROCKET/BODY: Delta-II second stage from the launch of the fifth block-2 GPS-Navstar navigation satellite in December 1989 from the Cape Canaveral Air Force Station. For general information on GPS RBs see GPS 2-4 Rocket/Body.

1.400 JCSAT 2 Rocket/Body

The following information was written by William F. Hagen.

20406 JCSAT 2 ROCKET/BODY: The modified Minuteman-III third stage, similar to the Leasat RBs, used as an upper stage for the Japanese communications satellite JCSAT. Launched from CCAFS pad 40 aboard the first commercial Titan rocket on new year's eve 1989.

1.401 Leasat 5 Rocket/Body

The following information was written by William F. Hagen.

20411 LEASAT 5 ROCKET/BODY: The Leasat R/Bs are modified Minuteman-III third stages used as a perigee kick motor for the Leasat (also known as Syncom) communications satellites. Leasat 5 was launched in January 1990 aboard the space shuttle Columbia on mission STS-32, a flight that included the recovery of the LDEF satellite. Visually the R/B has a firefly appearance in the fourth magnitude range at perigee. The Leasat RBs are in eccentric GTO orbits and are only good visual targets when close to perigee.

1.402 Cosmos 2056

The following information was written by William F. Hagen.

20432 COSMOS 2056: Soviet store/dump communications satellite.

See also: Cosmos 2056 Rocket/Body.

1.403 Cosmos 2056 Rocket/Body

The following information was written by William F. Hagen.

20433 COSMOS 2056 ROCKET/BODY: From launch of store/dump comsat. Flash period of 4.1 seconds.

1.404 Spot 2

The following information was written by William F. Hagen.

20436 SPOT 2: European commercial earth resources satellite in polar sun-synch orbit; launched on Ariane rocket.

See also: Spot 2 Rocket/Body.

1.405 Spot 2 Rocket/Body

The following information was written by William F. Hagen.

20443 SPOT 2 ROCKET/BODY: Ariane rocket/body from launch of Spot 2 earth resources satellite and six small amateur radio satellites.

1.406 GPS 2-6 Rocket/Body

The following information was written by William F. Hagen.

20453 GPS 2-6 ROCKET/BODY: Delta-II second stage from the launch of sixth block-2 GPS-Navstar navigation satellite from the Cape Canaveral Air Force Station. GPS 2-6 was launched just after sunset on January 24, 1990, and broke into daylight during ascent. For general information on GPS RBs see GPS 2-4 Rocket/Body.

1.407 Cosmos 2058

The following information was written by William F. Hagen.

20465 COSMOS 2058: Soviet Electronic Intelligence (ELINT) satellite

1.408 MOS 1-B

The following information was written by William F. Hagen.

20478 MOS 1-B: Japanese Maritime Observation Satellite.

See also: MOS 1-B Rocket/Body.

1.409 Orizuru (Debut)

The following information was written by William F. Hagen.

20479 ORIZURU (DEBUT): Japanese Deployable Boom and Umbrella Test. Technology development satellite.

1.410 MOS 1-B Rocket/Body

The following information was written by William F. Hagen.

20491 MOS 1-B ROCKET/BODY: Japanese H-1 rocket/body from launch of MOS 1-B, Orizuru and a small Fuji amateur radio satellite

1.411 LACE

The following information was written by William F. Hagen.

20496 LACE: USA Laser Atmospheric Compensation Experiment launched on Delta rocket with RME. A star wars test satellite for development of laser technology. Visually in the fourth magnitude range with a slightly reddish hue.

1.412 RME

The following information was written by William F. Hagen.

20497 RME: USA Relay Mirror Experiment launched on Delta with LACE. Carries a 2-foot diameter mirror for star wars testing.

1.413 Nadezhda 2

The following information was written by William F. Hagen.

20508 NADEZHDA 2: Soviet navigation satellite. The satellite is named (translation=Hope) for an onboard COSPAS/SARSAT package that locates emergency beacons.

See also: Nadezhda 2 Rocket/Body.

1.414 Nadezhda 2 Rocket/Body

The following information was written by William F. Hagen.

20509 NADEZHDA 2 ROCKET/BODY: Tumbler with a flash period of 20.5 seconds.

See also: Nadezhda 2.

1.415 Okean 2

The following information was written by William F. Hagen.

20510 OKEAN 2: Soviet oceanographic satellite

1.416 Intelsat 6-3

The following information was written by William F. Hagen.

20523 INTELSAT 6-3: This international communications satellite was left stranded in low orbit when its booster, the second Commercial Titan rocket (similar to the Titan-III), failed to separate the satellite from the second stage. The Titan/Intelsat combination was in a very low parking orbit so the only way to save the payload was to order spacecraft separation from the Intelsat's third stage perigee kick motor. The Titan second stage refused all commands to separate from the third stage, which is not part of the Titan launch vehicle and is considered to be payload at that stage in the launch process. The Intelsat was separated from the third stage and moved into a higher parking orbit where it can compensate for atmospheric drag by using its onboard manoeuvering fuel. The burned-out Titan second stage, and the Intelsat's third stage which was still firmly bolted to the Titan, re-entered 14 days after launch. Intelsat 6-3 is awaiting a shuttle rescue, presently scheduled for the first flight of the new orbiter Endeavour in 1992. The shuttle will carry a new third stage to Intelsat and place it on the satellite so that it will reach its operational geostationary orbit. Until it is rescued, satellite observers have a very rare opportunity to see a geosynch communications satellite at close range - some 60 times closer, and nine magnitudes brighter, than its intended orbit. Intelsat 6 satellites are spin stabilized, and Intelsat 6-3 goes through a very noticeable light curve from most perspectives. Its theoretical magnitude is third, but it is more often either brighter or fainter than predicted. From some angles it goes through some very bright glints. It normally gives only three or four flashes before its orbital motion takes it away from that angle. If the satellite is observed on the following days, it will almost always produce a similar series of flashes in the same part of the sky.

1.417 Cosmos 2060

The following information was written by William F. Hagen.

20525 COSMOS 2060: Soviet Electronic Ocean Reconnaissance Satellite (EORSAT); very bright first-magnitude satellite.

1.418 Cosmos 2061

The following information was written by William F. Hagen.

20527 COSMOS 2061: Soviet system-2 navigation satellite

See also: Cosmos 2061 Rocket/Body.

1.419 Cosmos 2061 Rocket/Body

The following information was written by William F. Hagen.

20528 COSMOS 2061 ROCKET/BODY: From launch of navigation satellite. Flash

period of 17.9 seconds.

See also: Cosmos 2061.

1.420 Pegsat

The following information was written by William F. Hagen.

20546 PEGSAT: This is the rocket/body, with an attached payload, from the first orbital rocket ever launched from the air. The privately developed Pegasus booster is dropped from a B-52 over the Pacific Ocean and then fires itself into orbit. A chemical release payload is attached to the spent rocket casing, and a small Department of Defense GLOMR satellite was deployed into a separate orbit. Pegsat is visually an interesting satellite, with a very large magnitude range from maximum to minimum, and a 2-second period to complete an entire cycle. Pegsat is in a sun-synchronous orbit.

1.421 Cosmos 2064-2071 Rocket/Body

The following information was written by William F. Hagen.

20557 COSMOS 2064-2071 ROCKET/BODY: Flash period 12.4 seconds.

1.422 Palapa 6 Rocket/Body

The following information was written by William F. Hagen.

20571 PALAPA 6 ROCKET/BODY: Delta second-stage from the relaunch of the Indian Palapa satellite stranded (see Palapa 4 Rocket/Body) and recovered by the shuttle.

1.423 Cosmos 2074

The following information was written by William F. Hagen.

20577 COSMOS 2074: Soviet system-2 navigation satellite

1.424 Hubble Space Telescope

View picture

The following information was written by William F. Hagen.

20580 HUBBLE SPACE TELESCOPE (HST): HST was launched aboard the space shuttle Discovery (mission STS-31) in April 1990 from launch pad 39-B at the Kennedy

Space Center. HST is mankind's best optical telescope despite the serious spherical aberration that has left it unable to achieve its theoretical capabilities. HST is scheduled to be revisited by the shuttle several times during its 15-year orbital life. The purpose of these visits, planned long before the spherical aberration was discovered, are to boost HST's orbit and replace the scientific instruments with more advanced designs. HST has no onboard propellant at all and is purely ballistic; it does not have the ability to boost its orbit periodically to compensate for atmospheric drag. The reason for this is that any residual propellants in HST's orbit could damage its optical instruments. HST must be revisited by the shuttle every few years to reboost it to its original altitude of over 600 kilometers; otherwise it will be destroyed on reentry, as happened to Skylab and Solar Max, and could have happened to LDEF. It has been expected that better instruments could be built for HST during its 15-year lifetime, so NASA planned to make use of the revisit missions to swap some of the scientific experiments while the shuttle was there. This capability will be utilized to partially 'fix' HST on the first revisit mission by replacing the primary camera with a replacement that will compensate for the spherical aberration. Visually HST is rarely fainter than third magnitude on favorable passes, and is more frequently in the first magnitude range. Each of the two solar panels is as large as the telescope itself, and these are held perpendicular to the Sun, so the illumination phase of HST is very important in predicting its brightness. When HST is seen at a high phase (in the east after sunset or the west before sunrise) there are sometimes very brilliant glints off the solar panels, sometimes as bright as magnitude -4. HST's orbital inclination of 28 degrees means it never passes directly over most of the United States, but it can be seen in binoculars even at elevations of 10 degrees, so it can be seen by ambitious observers in very northern latitudes.

NOTE: Since this description was written, NASA has sent up a successful mission to repair Hubble. The improved optical system has been operating perfectly.

1.425 Cosmos 2075 Rocket/Body

The following information was written by William F. Hagen.

20582 COSMOS 2075 ROCKET/BODY: Flash period of 4 seconds

1.426 Cosmos 2082

The following information was written by William F. Hagen.

20624 COSMOS 2082: Soviet Electronic Intelligence (ELINT) satellite.

See also: Cosmos 2082 Rocket/Body.

1.427 Cosmos 2082 Rocket/Body

The following information was written by William F. Hagen.

20625 COSMOS 2082 ROCKET/BODY: This SL-16 Zenit rocket boosted a Soviet ELINT spacecraft. The R/B is a very rapid tumbler, with a flash period of 1.3 seconds, and slowing due to interaction with the magnetic field. The Zenit boosters are among the largest objects in orbit and easily naked-eye, often close to second magnitude at maximum.

1.428 Rosat

The following information was written by William F. Hagen.

20638 ROSAT: The Rosat (Roentgen Satellite) is a German X-ray telescope launched on a Delta-II rocket from the Cape Canaveral Air Force Station in June 1990. Rosat is the most advanced X-ray telescope ever launched. It was initially planned for a shuttle launch and the reconfiguration to an unmanned launch vehicle delayed its flight by several years. There is significant American and British involvement in Rosat. Visually Rosat has a very strong yellow-gold hue because of the insulation that covers almost all of the spacecraft. It is typically in the fourth magnitude range but has been seen as bright as first magnitude.

See also: Rosat Rocket/Body.

1.429 Rosat Rocket/Body

The following information was written by William F. Hagen.

20639 ROSAT ROCKET/BODY: Delta second-stage from launch of Rosat.

1.430 Cosmos 2084

The following information was written by William F. Hagen.

20663 COSMOS 2084: This is a Soviet satellite intended for a Molniya orbit which was left stranded in a 600-kilometer altitude orbit due to a booster failure (see 20664). C-2084 is believed to be an early-warning military spacecraft. Observers of this satellite have a unique opportunity to observe a Molniya-orbit satellite at close range. Visually it is in the fourth magnitude range.

See also: Cosmos 2084 Rocket/Body.

1.431 Cosmos 2084 Rocket/Body

The following information was written by William F. Hagen.

20664 COSMOS 2084 ROCKET/BODY: This is the fourth stage perigee kick motor that was to have boosted Cosmos 2084 from its parking orbit into a Molniya orbit. It apparently shut down shortly after ignition and then separated from the payload, leaving it in a useless but stable low orbit. As with the payload, observers have here a unique opportunity to observe the upper stage at close range. Visually it is a tumbling object, easily naked-eye at maximum.

1.432 Meteor 2-19

The following information was written by William F. Hagen.

20670 METEOR 2-19: Soviet weather satellite. Visually near sixth magnitude.

1.433 Gamma

The following information was written by William F. Hagen.

20683 GAMMA: Large Soviet gamma-ray astronomical telescope. Second magnitude satellite.

1.434 CRRES

Most of the following information was written by William F. Hagen.

20712 CRRES: Joint NASA/USAF Combined Release and Radiation Effects Satellite. The NASA program is a series of chemical releases of Barium and Lithium into the magnetosphere; the unclassified USAF program is research and development testing of new materials and electronic parts to determine the effects of the space environment for future spacecraft design.

CRRES was launched at 19:21 UTC on July 25, 1990. Upon achieving orbit, it had a mass of 4383 kg. Its chemical releases were monitored from ground-based stations to measure the bulk properties and movement of the expanding clouds of photo-ionized plasma along field lines after the releases occurred.

In order to study the magnetosphere at different local times during the mission, the orbit of CRRES was designed to precess with respect to the Earth-Sun line so that the local time at apogee decreased by 2.5 minutes per day.

1.435 Cosmos 2098 Rocket/Body

The following information was written by William F. Hagen.

20775 COSMOS 2098 ROCKET/BODY: Flash period of 2.3 seconds

1.436 Feng Yun 1-B

The following information was written by William F. Hagen.

20788 FENG YUN 1-B: Chinese weather satellite in low polar sun-synch orbit

See also: Atmosphere 1 & Atmosphere 2, Feng Yun 1-B Rocket/Body.

1.437 Atmosphere 1 & Atmosphere 2

The following information was written by William F. Hagen.

20789 ATMOSPHERE 1 and 20790 ATMOSPHERE 2: These are two passive balloons launched by China as piggyback payloads on the Feng Yun 1-B rocket in September 1990. The satellites are about 10 feet in diameter. Their mission is to measure the density of the upper atmosphere at orbital altitudes by observing the air's drag effect on their orbits. Atmosphere 1 is near re-entry, but Atmosphere 2 is still safely in orbit. The two are in the fourth magnitude range and starting to show unstable brightnesses as the balloons start to deform.

1.438 Atmosphere 2

See Atmosphere 1 & Atmosphere 2.

1.439 Feng Yun 1-B Rocket/Body

The following information was written by William F. Hagen.

20791 FENG YUN 1-B ROCKET/BODY: This Chinese booster exploded in orbit, well after deploying the Feng Yun 1-B weather satellite and two small balloon secondary payloads. None of the payloads were damaged by the explosion, which produced about 75 pieces of debris large enough to be tracked by NORAD. The largest piece of the R/B, 20791, now has a very complex light curve. This is visually one of the most interesting satellites in orbit. The flash period, that is, the time for the brightness variations to repeat, has been measured at three seconds. Some of the glints can get fairly bright when seen from a good perspective.

See also: Feng Yun 1-B.

1.440 Ulysses Rocket/Body

The following information was written by William F. Hagen.

20843 ULYSSES ROCKET/BODY: The IUS (Inertial Upper Stage) first-stage from the launch of the Ulysses interplanetary spacecraft, en route to Jupiter for a

gravity assisted plane change to enter the intended polar heliocentric orbit for study of the Sun's magnetic field. 20843 has remained in Earth orbit, in GTO, and is an interesting historic object to sight at perigee. Ulysses was launched in October 1990 aboard the space shuttle Discovery on mission STS-41.

1.441 Inmarsat 2-1 Rocket/Body

The following information was written by William F. Hagen.

20919 INMARSAT 2-1 ROCKET/BODY: Delta-II second stage from the launch of the first dedicated Inmarsat communications satellite (previous Inmarsat payloads have piggybacked on other comsats). The launch vehicle was the 200th Delta rocket.

1.442 GPS 2-10 Rocket/Body

The following information was written by William F. Hagen.

20960 GPS 2-10 ROCKET/BODY: Delta-II second stage from the launch of the tenth block-2 GPS-Navstar navigation satellite from the Cape Canaveral Air Force Station. This was the first flight of a Delta with the uprated larger solid boosters, and the increased payload capacity was partly used to reduce the inclination of the parking orbit to 21 degrees. For general information on GPS RBs see GPS 2-4 Rocket/Body.

1.443 DMSP 2-5

The following information was written by William F. Hagen.

20978 DMSP 2-5: Military weather satellite (Defense Meteorology Support Program). The DMSP satellites are in low polar sun-synch orbits and similar in size to the civilian NOAA weather satellites. Their orbits are not classified. Visually DMSP satellites are in the sixth magnitude range.