Pluto and Charon
Asteroids and Comets

Assembled by
Dr. Harold Geller
Observatory Director
George Mason University
What I’m Going to Talk About

• Pluto and Charon
• Historical views
• Definitions and distinctions among comets et al.
• Misconceptions of comets, asteroids, etc.
• What these things look like
• Where these things come from
• The Damage Hazard and The Torino scale
• The saga of SL-9 and other close calls
• References and review
Pluto Statistics

• Orbital semi-major axis => 39.48 AU
  – Perihelion => 29.66 AU
  – Aphelion => 49.31 AU
• Orbital eccentricity => 0.249
• Mean orbital speed => 4.74 km/s
• Sidereal orbital period => 249 Earth years
• Orbital inclination to ecliptic => 17.15°
Pluto Stats (cont’d)

• Mass => $1.27 \times 10^{22}$ kg (0.0021 Earth mass)
• Equatorial radius => 1137 km
  – 0.18 Earth radius
• Mean density => 2.06 g/cc
• Surface gravity => 0.66 m/s$^2$ (1.2 km/s escape velocity)
• Rotation period => 6.4 days “retrograde”
• Axis tilt => 118$^0$
• Surface Temp => 40-60 K
Pluto Surprises

- It has moons
- Original moon discovered 1978
  - Charon (KAIR’ en)
- Now more
  - 2005 discovery of 2 additional moons
  - Named Nix and Hydra
Pluto’s History

• Planet X predicted
  – from perturbations in Uranus and Neptune orbit
• Discovered February 18, 1930
  – discovered by Clyde Tombaugh
    • accidental discovery (Neptune’s mass was wrong)
• First moon discovered 1978 (announced 7 July)
  – discovered by James Christy
• Spectroscopic studies
  – First attempt in ‘30s, first success in ‘70s
Spectral Analysis

• Compare with known samples

• First conclusions
  – methane ice
  – water ice
  – ammonia ice

• Develop models for surface to interior
  – based upon spectral analyses and density
Pluto’s Interior to Surface Model

• Model 1
  – partially hydrated rock core
  – water ice layer II
  – predominant water ice layer I

• Model 2
  – partially hydrated rock core
  – organics layer
  – predominantly water ice layer
Finding Charon

• Look at the light
  – light curves indicative of eclipsing binary
    • similar to light curves of binary stars
      – learn more about these in ASTR 113

• Look at details of photographs
  – “bump” on Pluto image
All about Charon

• Best images from Hubble Space Telescope
  – highest angular separation (resolution)
A Binary Like Earth?

• Size of Pluto compared to Charon
  – Some call it “binary planet”
    • What is origin of Charon
• Situation is similar to Earth and Moon
  – some consider Earth-Moon a binary planet
    • Moon was formed from Earth
Historical Views of Comets

• In 1902, Richard Proctor stated (regarding meteors and comets): “There are few more interesting chapters in the history of astronomy than that which deals with the gradual introduction of meteors into an important position in the economy of the solar system. Regarded for a long time as simply atmospheric phenomena (though many ancient philosophers held another opinion), it has only been after a long and persistent series of researches that they have come at length to be regarded in their true light.”

• He went on to say (specifically about comets): “We know that the dimensions of these objects are in many cases enormous. We know, further, that there must be many thousands of comets remaining undiscovered for each that our astronomers have detected. And, lastly, we are led to recognize the observed association between certain meteor-systems and certain comets as indicative of a general law by which, in some way as yet unexplained, comets and meteors are associated together.”
Definition of Comet

• Comet [according to Funk and Wagnalls Standard Desk Dictionary] - “A celestial body moving in an orbit about the sun and consisting of a nucleus of more or less condensed material, accompanied by a tenuous coma pointing away from the sun.”
Definition of Asteroid

• Asteroid [according to Funk and Wagnalls Standard Desk Dictionary] - “Any of several hundred small planets between Mars and Jupiter; also called planetoid.”
Definition of Meteor

• Meteor [according to Funk and Wagnalls Standard Desk Dictionary] - “A meteoroid that on entering the earth’s atmosphere at great speed is heated to luminosity and is visible as a streak of light; also called a shooting star.”
Definition of Meteoroid

• Meteoroid [according to Funk and Wagnalls Standard Desk Dictionary] - “One of the pieces of matter moving through outer space, that upon entering the earth’s atmosphere form meteors.”
Definition of Meteorite

- Meteorite [according to Funk and Wagnalls Standard Desk Dictionary] - “A portion of a meteor that has not been completely destroyed by combustion and has fallen to earth.”
Misconceptions about things that go boom

• [Adapted from David Levy’s book Comets: Creators and Destroyers]

• 1 - It can’t happen to us. Things won’t change after a major impact.

• 2 - Any object that hits the Earth could cause global devastation.

• 3 - To prevent an impact, we have to destroy the comet or asteroid.

[Adapted from David Levy’s book Comets: Creators and Destroyers]
Misconceptions about things that go boom

• 4 - The chance that a comet or asteroid that could damage the Earth’s ecosystem will land in our lifetime is virtually zero.

• 5 - Earth is just as much at risk now as it was in the past.

• 6 - Impacts are bad for life.

• 7 - Every mass extinction was caused by an impact.

[Adapted from David Levy’s book Comets: Creators and Destroyers]
Misconceptions about things that go boom

- 8 - An object the size of the dinosaur comet cannot threaten the Earth today.
- 9 - Life began on comets.
- 10 - Impacts are science fiction; they don’t really happen in the solar system.

[Adapted from David Levy’s book Comets: Creators and Destroyers]
Picture an Asteroid (Gaspara by Galileo)
Picture a Comet (Halley’s by Giotto)

[Source: Dr. Sten Odenwald
Astronomy Café]
Looking for Hale-Bopp?
Where did they come from?

- **Kuiper Belt**
  - Just beyond reaches of solar system, once thought to be location of origin of comets.
  - Likely source of “Jupiter family short-period comets.”

- **Oort Cloud**
  - Likely region of most comets, located far away from solar system (25,000 - 100,000 AU).
  - These comets were likely formed closer in, but their orbits were influenced by the Jovian planets.
  - Possible location of a Brown Dwarf (Matese, 1999).
New Oort Cloud Surveys

[Source: John J. Matese, Ph.D., with permission (submitted to Icarus, 1999).]
# Damage From Space

<table>
<thead>
<tr>
<th>Asteroid Size</th>
<th>Yield (megatons TNT)</th>
<th>Crater Diameter (kilometers)</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 meters</td>
<td>100</td>
<td>1.5</td>
<td>Land impacts destroy major metropolitan area, e.g. Washington, D.C or Paris</td>
</tr>
<tr>
<td>350 meters</td>
<td>5000</td>
<td>6.0</td>
<td>Destroys area the size of a small state. Ocean impact produce tsunamis.</td>
</tr>
<tr>
<td>700 meters</td>
<td>15,000</td>
<td>12.0</td>
<td>Land impact destroys areas the size of Virginia or Taiwan, and ocean impact produces major tsunami</td>
</tr>
<tr>
<td>1.7 kilometers</td>
<td>200,000</td>
<td>30.0</td>
<td>Land impact affects climate, ozone and tsunamis destroy coastal communities.</td>
</tr>
<tr>
<td>3.0 kilometers</td>
<td>1 million</td>
<td>60.0</td>
<td>Large nation destroyed. Widespread fires from ejecta. Major climate change.</td>
</tr>
<tr>
<td>7.0 kilometers</td>
<td>50 million</td>
<td>125</td>
<td>Mass extinction, global conflagration and long term climate change.</td>
</tr>
</tbody>
</table>

[Source: Dr. Sten Odenwald, Astronomy Café]
What Determines the Hazard

• Impactor flux (quantity, how destabilized)
• Fatalities determined by damaged target
  – high density population centers
  – oceans - can cause catastrophic tsunamis
• Damage determined by energy
• Energy equals \((1/2) \times \text{mass} \times \text{velocity}^2\)
• Mass determined by density / composition
• Velocity determined by orbit
  – long-period, short-period
# The Torino Scale

Assessing Asteroid and Comet Impact Hazard Predictions in the 21st Century

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Events Having No Likely Consequences</td>
<td>0</td>
<td>The likelihood of a collision is zero, or well below the chance that a random object of the same size will strike the Earth within the next few decades. This designation also applies to any small object that, in the event of a collision, is unlikely to reach the Earth's surface intact.</td>
</tr>
<tr>
<td>Events Meriting Careful Monitoring</td>
<td>1</td>
<td>The chance of collision is extremely unlikely, about the same as a random object of the same size striking the Earth within the next few decades.</td>
</tr>
<tr>
<td>Events Meriting Concern</td>
<td>2</td>
<td>A somewhat close, but not unusual encounter. Collision is very unlikely.</td>
</tr>
<tr>
<td>Threatening Events</td>
<td>3</td>
<td>A close encounter, with 1% or greater chance of a collision capable of causing localized destruction.</td>
</tr>
<tr>
<td>Threatening Events</td>
<td>4</td>
<td>A close encounter, with 1% or greater chance of a collision capable of causing regional devastation.</td>
</tr>
<tr>
<td>Threatening Events</td>
<td>5</td>
<td>A close encounter, with a significant threat of a collision capable of causing regional devastation.</td>
</tr>
<tr>
<td>Threatening Events</td>
<td>6</td>
<td>A close encounter, with a significant threat of a collision capable of causing a global catastrophe.</td>
</tr>
<tr>
<td>Certain Collisions</td>
<td>7</td>
<td>A close encounter, with an extremely significant threat of a collision capable of causing a global catastrophe.</td>
</tr>
<tr>
<td>Certain Collisions</td>
<td>8</td>
<td>A collision capable of causing localized destruction. Such events occur somewhere on Earth between once per 50 years and once per 1000 years.</td>
</tr>
<tr>
<td>Certain Collisions</td>
<td>9</td>
<td>A collision capable of causing regional devastation. Such events occur between once per 1000 years and once per 100,000 years.</td>
</tr>
<tr>
<td>Certain Collisions</td>
<td>10</td>
<td>A collision capable of causing a global climatic catastrophe. Such events occur once per 100,000 years, or less often.</td>
</tr>
</tbody>
</table>

[Copyright (c) 1999 Richard P. Binzel, Massachusetts Institute of Technology. Permission is hereby granted to reproduce Torino Scale figures and text for educational and news reporting purposes.]
Predicted Close Calls Between now and 2004 AD:

<table>
<thead>
<tr>
<th>Asteroid</th>
<th>Distance (kilometers)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1863 Antinous</td>
<td>565,000</td>
<td>April 1999</td>
</tr>
<tr>
<td>1999 XF11</td>
<td>937,000</td>
<td>October 2028</td>
</tr>
<tr>
<td>2340 Hathor</td>
<td>970,000</td>
<td>October 2069</td>
</tr>
<tr>
<td>1991 IX</td>
<td>980,000</td>
<td>June 1999</td>
</tr>
<tr>
<td>2101 Adonis</td>
<td>1,060,000</td>
<td>February 2177</td>
</tr>
<tr>
<td>1986 PA</td>
<td>1,064,000</td>
<td>April 2001</td>
</tr>
<tr>
<td>1980 WF</td>
<td>1,155,000</td>
<td>January 2001</td>
</tr>
<tr>
<td>4660 Nereus</td>
<td>1,180,000</td>
<td>February 2060</td>
</tr>
<tr>
<td>1992 FE</td>
<td>1,218,000</td>
<td>March 2000</td>
</tr>
<tr>
<td>3362 Khufu</td>
<td>1,288,000</td>
<td>January 2001</td>
</tr>
<tr>
<td>4179 Toutatis</td>
<td>1,530,000</td>
<td>September 2004</td>
</tr>
<tr>
<td>4581 Asclepius</td>
<td>1,800,000</td>
<td>March 2051</td>
</tr>
<tr>
<td>2100 Ra-Shalom</td>
<td>2,114,000</td>
<td>September 2000</td>
</tr>
<tr>
<td>4660 Nereus</td>
<td>2,200,000</td>
<td>February 2071</td>
</tr>
<tr>
<td>1990 OA</td>
<td>2,200,000</td>
<td>July 2070</td>
</tr>
<tr>
<td>3361 Orpheus</td>
<td>2,450,000</td>
<td>April 2194</td>
</tr>
<tr>
<td>4183 Cuno</td>
<td>3,390,000</td>
<td>June 1998</td>
</tr>
<tr>
<td>4179 Toutatis</td>
<td>3,640,000</td>
<td>September 2004</td>
</tr>
<tr>
<td>1990 Os</td>
<td>8,750,000</td>
<td>November 2003</td>
</tr>
</tbody>
</table>

Observed Recent Close Calls:

<table>
<thead>
<tr>
<th>Asteroid</th>
<th>Distance (kilometers)</th>
<th>Date</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994 XM1</td>
<td>102,900</td>
<td>12-9-1994</td>
<td>9 meters</td>
</tr>
<tr>
<td>1993 KA2</td>
<td>147,000</td>
<td>5-20-1993</td>
<td>6</td>
</tr>
<tr>
<td>1994 ES1</td>
<td>162,000</td>
<td>3-15-1994</td>
<td>7</td>
</tr>
<tr>
<td>1991 BA</td>
<td>160,000</td>
<td>1-18-1991</td>
<td>7</td>
</tr>
<tr>
<td>1995 FF</td>
<td>426,000</td>
<td>5-27-1995</td>
<td>18</td>
</tr>
<tr>
<td>1996 JA1</td>
<td>440,000</td>
<td>5-19-1996</td>
<td>220</td>
</tr>
<tr>
<td>4581 Asclepius</td>
<td>576,000</td>
<td>3-22-1989</td>
<td>280</td>
</tr>
<tr>
<td>1994 WRI2</td>
<td>705,000</td>
<td>11-24-1994</td>
<td>140</td>
</tr>
<tr>
<td>1937 Hermes</td>
<td>720,000</td>
<td>10-30-1937</td>
<td>900</td>
</tr>
</tbody>
</table>

[Source: Dr. Sten Odenwald Astronomy Café]
### Coming to a Theater Near You

<table>
<thead>
<tr>
<th>Meteor Shower</th>
<th>Dates</th>
<th>Estimated Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadrantids</td>
<td>January 2-4</td>
<td>30</td>
</tr>
<tr>
<td>Lyrids</td>
<td>April 20 - 22</td>
<td>8</td>
</tr>
<tr>
<td>Eta Aquarids</td>
<td>May 2 - 7</td>
<td>10</td>
</tr>
<tr>
<td>Delta Aquarids</td>
<td>July 20 to Aug 14</td>
<td>15</td>
</tr>
<tr>
<td>Perseids</td>
<td>July 29 to Aug 18</td>
<td>40</td>
</tr>
<tr>
<td>Draconids</td>
<td>Oct 10</td>
<td>?</td>
</tr>
<tr>
<td>Orionids</td>
<td>Oct 17-24</td>
<td>15</td>
</tr>
<tr>
<td>Taurids</td>
<td>Oct 20 to Nov 25</td>
<td>8</td>
</tr>
<tr>
<td>Leonids</td>
<td>Nov 14-19</td>
<td>6</td>
</tr>
<tr>
<td>Andromedids</td>
<td>Nov 15 to Dec 6</td>
<td>?</td>
</tr>
<tr>
<td>Geminids</td>
<td>Dec 8 - 15</td>
<td>50</td>
</tr>
<tr>
<td>Ursids</td>
<td>Dec 19 - 22</td>
<td>12</td>
</tr>
<tr>
<td>Ariertids</td>
<td>May 29 - June 17</td>
<td>40</td>
</tr>
<tr>
<td>Zeta Perseids</td>
<td>June 1-15</td>
<td>30</td>
</tr>
<tr>
<td>Beta Taurids</td>
<td>June 23 - July 7</td>
<td>20</td>
</tr>
</tbody>
</table>

[Source: Dr. Sten Odenwald, Astronomy Café]
Shoemaker-Levy 9

- Cometary impact on Jupiter
  - Changed views about possibilities of such an impact on Earth
A Quick Review of Asteroids

• Categorized as family of objects
  – between the orbits of Mars and Jupiter
  – can be in other inner solar system orbits
• A part of our solar system
• Can go boom if you bump into them
• Of interest in study of primordial stuff
  – inner solar system stuff, rocky material
  – have been found with satellites of their own
A Quick Review of Comets

- Observed by humans for generations
- Originally considered as signs of bad fate
- The source of common meteor showers
- A part of the solar system
- Kuiper Belt and Oort Cloud parking lots
- Can cause a “boom” in the night (or day)
- Of interest for primordial matter studies
References

• Some Books of Interest
References

• Web URLs of interest
  – http://comets.amsmeteors.org/
  – http://www.solarviews.com/eng/comet.htm
  – http://encke.jpl.nasa.gov/
  – http://pbs.org/wgbh/nova/spacewatch/weaver.html
  – http://www.ucs.usl.edu/~jjm9638/matese.html