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 x 10²² kg (0.0021 Earth mass)
- Equatorial radius => 1137 km
  - 0.18 Earth radius
- Mean density => 2.06 g/cc
- Surface gravity => 0.66 m/s² (1.2 km/s escape velocity)
- Rotation period => 6.4 days “retrograde”
- Axis tilt => 118°
- Surface Temp => 40-60 K

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

Pluto Surprises

- It has moons
- Original moon discovered 1978
  - Charon (KAIR’ en)
- Now more
  - 2005 discovery of 2 additional moons
    - Named Nix and Hydra
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 and Its Moon?
• 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 or 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.”
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 Destriers]

Errata for the book Comets: Creators and Destriers by David Levy

• 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 Destriers]

Picture an Asteroid (Gaspara by Galileo)

[Source: Dr. Sten Odenwald Astronomy Café]

Picture a Comet (Halley’s by Giotto)

[Source: Dr. Sten Odenwald Astronomy Café]

Looking for Hale-Bopp?

[Source: Dr. Sten Odenwald Astronomy Café]

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>Estimated Impact Size</th>
<th>Estimated Damage (Kilometers)</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small asteroid</td>
<td>10</td>
<td>Land impact destroys major metropolitan area, e.g. Washington, D.C.</td>
</tr>
<tr>
<td>Medium-sized asteroid</td>
<td>60</td>
<td>Destroys area the size of a small state. Ocean impact produces tsunamis.</td>
</tr>
<tr>
<td>Large asteroid</td>
<td>120</td>
<td>Land impact destroys areas the size of Virginia or Taiwan, and ocean impact produces major tsunami.</td>
</tr>
<tr>
<td>Extraterrestrial object</td>
<td>300</td>
<td>Land impact affects climate, ozone and tsunamis destroy coastal communities.</td>
</tr>
<tr>
<td>Very large asteroid</td>
<td>2,000</td>
<td>Large nation destroyed. Widespread fires from ejecta. Major climate change.</td>
</tr>
<tr>
<td>Massive asteroid</td>
<td>5,000</td>
<td>Mass extinction, global climate change, 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) (mass) (velocity²)
• Mass determined by density / composition
• Velocity determined by orbit
  – long-period, short-period

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Coming to a Theater Near You

<table>
<thead>
<tr>
<th>Meteor shower</th>
<th>Peak dates</th>
<th>Magnitude</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-August 14</td>
<td>15</td>
</tr>
<tr>
<td>Perseids</td>
<td>July 29-August 18</td>
<td>40</td>
</tr>
<tr>
<td>Draconids</td>
<td>Oct 10</td>
<td>7</td>
</tr>
<tr>
<td>Orionids</td>
<td>Oct 17-24</td>
<td>15</td>
</tr>
<tr>
<td>Taurids</td>
<td>Oct 20-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-Dec 6</td>
<td>7</td>
</tr>
<tr>
<td>Geminids</td>
<td>Dec 8-15</td>
<td>50</td>
</tr>
<tr>
<td>Ursids</td>
<td>Dec 19-Dec 22</td>
<td>12</td>
</tr>
<tr>
<td>Arietids</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