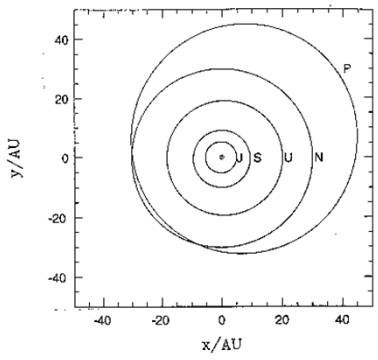
Kuiper Belt—21 Feb

- Orbit of Pluto
- Discovery of objects beyond Neptune
- Orbits of trans Neptune objects
- Kuiper Belt and Oort Cloud

- Answer to preclass question for today is wrong.
- No preclass questions for Fri.
- Read about Kepler's Laws for Friday.
  - Textbook §4.4 & Carroll & Ostlie §2.1-2.3
- Midterm exam next week
  - Mon. Missouri (Ask Me State) Club
  - No late Homework 5 after Mon. Answers will be on angel.
  - Send me equations to put on cheat sheet before 8:00am, Fri, 4 March
  - Test on Fri, 4 March
- After Spring Break
  - Formation of the Kuiper Belt

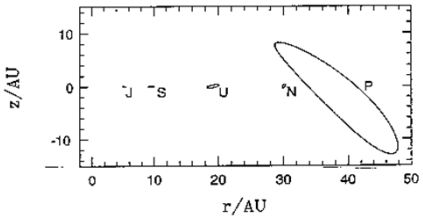
Pluto's orbit

- 3:2 resonance with Neptune
  - $P_{Pluto}/P_{neptune}$ = 248yr/165yr = 3/2
- At perihelion, Pluto is inside Neptune's orbit.
- Neptune affects Pluto's orbit.
  - Why does Pluto survive in resonance when the asteroids in the 3:2 resonance with Jupiter did not.
  - What happened to create this arrangement?

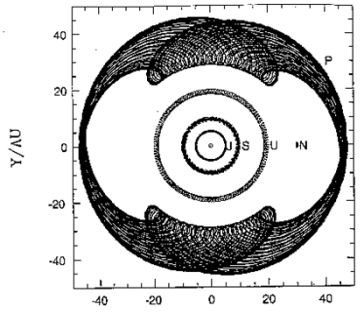


3-d positions

1. When Pluto is closest to Neptune, it is in danger of colliding with Neptune.
   A. True
   B. False
2. When Pluto is closest to Neptune, they are not really close because
   1. The distances to the sun are not close.
   2. Pluto is high above the ecliptic.



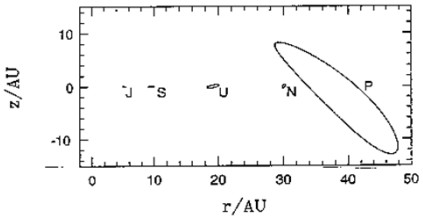
z component of planet's position vs. simultaneous distance from Sun.



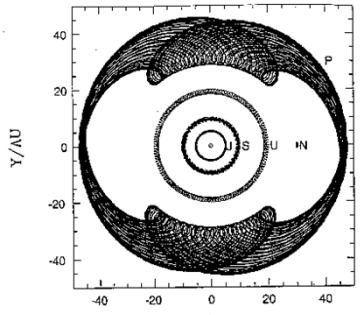
Planet's orbit relative to Neptune, projected into plane of solar system.

3-d positions

- When Pluto is closest to Neptune, they are not really close because
  - Pluto is high above the ecliptic.
- At perihelion, where Pluto is inside Neptune's orbit,
  - Pluto is above the ecliptic
  - Neptune is 50° behind Pluto
- One Pluto year later,
  - Neptune has moved 1.5 periods. 180-50=130° ahead of Pluto



z component of planet's position vs. simultaneous distance from Sun.



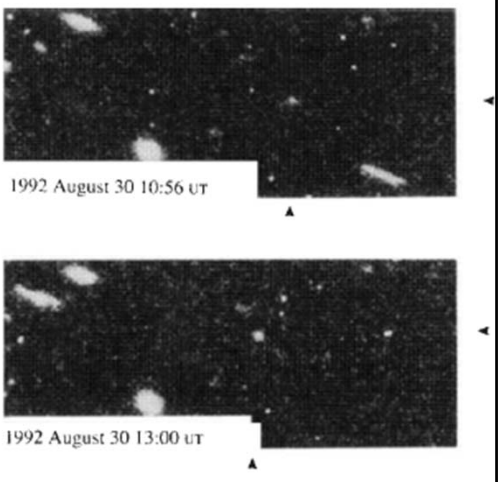
Planet's orbit relative to Neptune, projected into plane of solar system.

Are there other objects beyond Neptune?

- Are other objects locked with Neptune or are their orbits independent of Neptune?
- Searches in 1992

Discovery of second object beyond Neptune

- Jewitt & Luu, 1993, Nature 362, 730.
- 1992 QB1
  - P=289.225 yr
  - a=43.7AU
  - a_{Pluto}=39.5
  - D=160km
  - D_{Pluto}=2330km

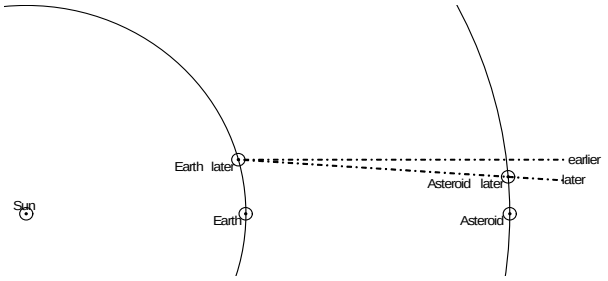


Discovery images. Note the streak, an asteroid

Determining semi-major axis

- Determining the semi major axis, a.

$$\frac{d\theta}{dt} = 148\text{arcs/hr}(1 - a^{-\frac{1}{2}})/(1 - a)$$



Earth and asteroid at two times. The dashed lines show the directions of the asteroid as viewed from earth at two times. (Hwk 4)

More Kuiper Belt objects keep being discovered.

CNN
Oct. 7, 2002

The spherical planetoid, half the size of Pluto, is the biggest found in the solar system since astronomers

The object, dubbed Quaoar, further strengthens the theory that Pluto is not a conventional planet but rather a Kuiper Belt object.

Biggest object since Pluto found in solar system

By Richard Stenger (CNN)
Monday, October 7, 2002 Posted: 12:54 PM EDT (1654 GMT)

(CNN) -- A newly discovered body in the outer reaches of the solar system is larger than all the objects in the asteroid belt combined, astronomers announced Monday.

The spherical planetoid, half the size of Pluto, is the biggest found in the solar system since astronomers detected the ninth planet in 1930.

Artist's concept of Quaoar

a distance of (6.4 billion
er region known
ring of thousands of primordial icy, rocky chunks beyond the planets that date back to the origins of the solar system.

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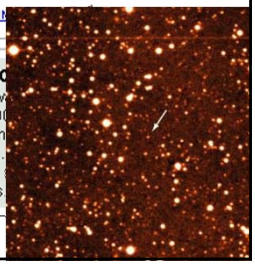
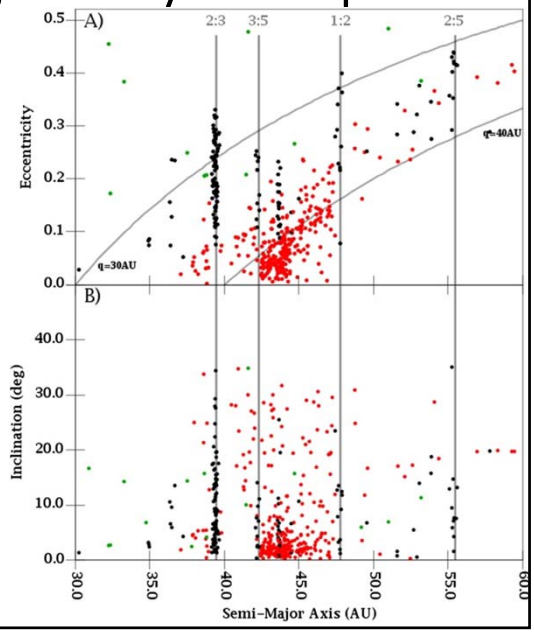
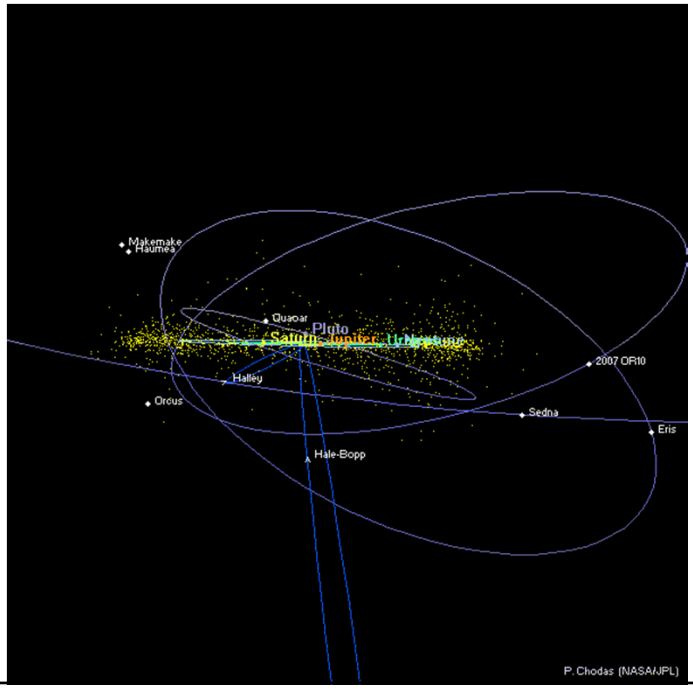


Population of objects beyond Neptune

- Kuiper belt
  - a>30 AU
  - Inclination is not high
- Largest
  - Eris 2700km
  - Pluto 2300km



Kuiper Belt objects
Black: Resonant objects
Green: Unstable. Colliding with Neptune
Red: Stable, non resonant
Line shows constant perihelion q
Levinson et al 2008, Icarus, 196, 258



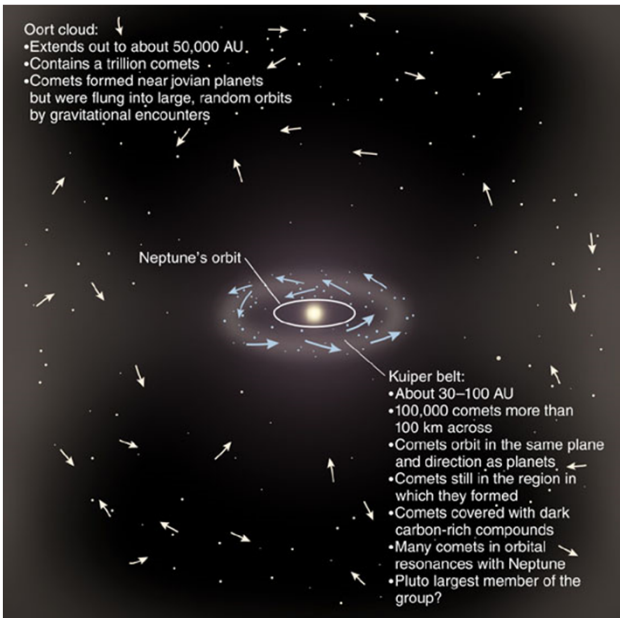
Kuiper Belt & Oort Cloud Comets

- Short period comets
  - small inclinations
  - prograde orbits.
  - belong to Kuiper Belt
- Long period orbits
  - large inclinations
  - retrograde and prograde orbits
- Oort 1950, BAN, 11, 910.
  - Distribution of semimajor axis peaks at 20,000AU
  - Comets last a short time relative to age of the solar system.

Distribution of original semi-major axes
(a in Astronomical Units)

$1/a$	n
$< .000\ 05$	10
$.000\ 05 - 10$	4
10 – 15	1
15 – 20	1
20 – 25	1
25 – 50	1
$.000\ 50$ – 75	1
$> .000\ 75$	0

Kuiper Belt and Oort Cloud



Oort Cloud

- 10^{11} - 10^{12} comets in loosely bound solar orbits at 50,000AU
- Ejected by Jupiter into random directions
- Gravitational perturbations occasionally deflect one in.
- Guesstimate: 1 trillion (10^{12}) comets total

  x 10^{-10} earth-mass/comet = 10^{2} earth masses total.