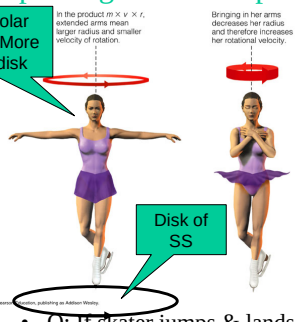
Asteroids–February 23

- Test 2
  - Mon, Feb 28
  - Covers
    - 6 questions from Test 1. Added to score of Test 1
    - Telescopes
    - Solar system
  - Format similar to Test 1
- Missouri Club
  - Fri 9:00 1415
  - Fri, last 10 minutes of class
- Homework 3 closes 3am Mon

- Recap SS formation
- Asteroids are old
- Age of solar system

Why is the solar system spinning & disk shaped?

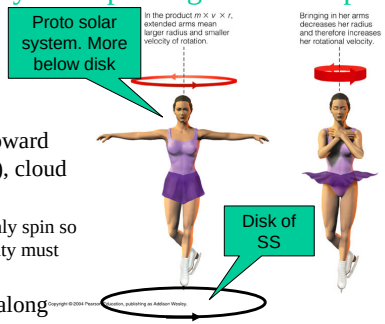
- Skater represents protosolar system
- Kepler's Law of Equal Areas, Conservation of Angular Momentum:
  L = m r v
  r is distance to rotation axis
  v is speed of rotating motion
- If skater pulls arms in (cloud shrinks horizontally), skater spins faster.



- Q: If skater jumps & lands (cloud collapses toward disk), skater spins a) faster, b) same, c) slower

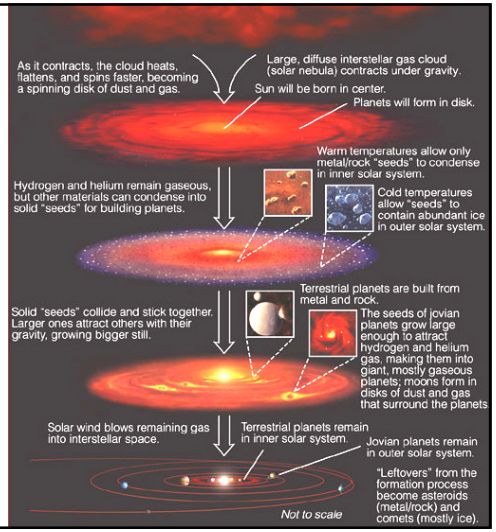
Why is the solar system spinning & disk shaped?

- Skater represents protosolar system
- If cloud shrinks toward axis (horizontally), cloud spins faster.
  - Real cloud can only spin so fast because gravity must hold gas in orbit.
- Cloud can shrink along spin axis without butting against angular momentum. Cloud can flatten.



The Solar Nebula

[Fig 6.27]

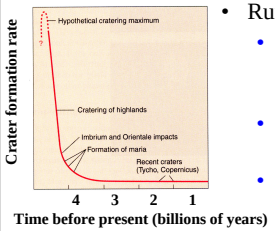


Progressive Buildup of the Planets

Before the Sun started to produce its own energy:

- Small "dust" grains condensed from nebula.
  - mm-sized.
- Clumped up into *planetesimals*
  - 10's of km in diameter.
  - comets and asteroids.
- Run away growth into *protoplanets*
  - larger bodies had more gravitational attraction
    - collected lots of smaller bodies.
  - ➔ a few Mercury/Mars-sized objects.
    - rapidly accreted further planetesimals.
  - Impacts heated interior of growing planet.
    - ➔ differentiation in molten interiors.

protoplanets



Giants vs. Terrestrials

- In inner solar system.
  - Lighter elements evaporated away.
  - Planetesimals contained only heavy elements.
  - Growth stopped at Earth-sized planets.
  - But continuing impacts with planetesimals altered the planets
    - Earth's moon
    - Reversal of Venus' rotation, etc.
    - Dumped much of atmospheres onto planets
- In outer solar system.
  - Ices as well as silicates available for solid bodies.
  - ➔Larger protoplanets.
  - These cores able to attract surrounding H, He gas in order to build giant planets.
  - Gravitational field of giant planets perturbed orbits of remaining planetesimals.
    - Most comets ejected into Oort Cloud
    - Somehow governs existence of asteroid belt.

Jovian buildup

The End Game

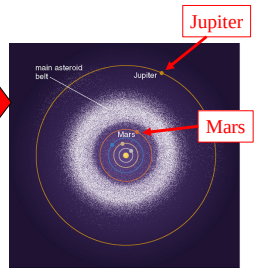
- The Sun became a star
  - *Solar wind* = high velocity particles streaming outwards from Sun.
  - Blew away the remaining H, He gas.
  - Left just protoplanets + remaining planetesimals to finish up their interactions.
  - Timescale to this point: only ~ 10 million years.

Asteroids [9.1]

- Small, rocky objects in orbit around the Sun.
  - Sizes up to hundreds of km.
  - 26 known ones with sizes > 200 km.
- 250,000 currently have designations.
  - + estimated > 1 million asteroids < 1 km in size.
- But total mass probably less than mass of Moon.

The Asteroid Belt

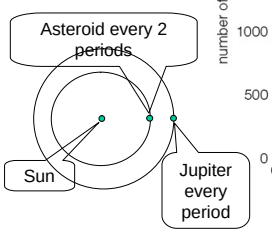
- semi-major axis 2.2 - 3.3 au.
- Between orbits of Mars and Jupiter
- Includes 75% of known asteroids.
- Mostly orbiting sun in same direction of planets, and in plane of solar system.

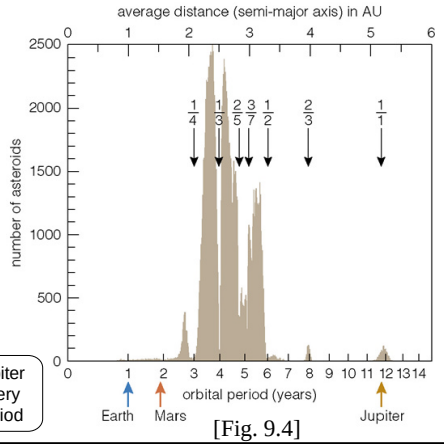


[Fig. 9.3]

Jupiter prevented planet from forming

- Gaps in asteroid belt correspond to resonances with orbital period of Jupiter
  - 2:1 resonance

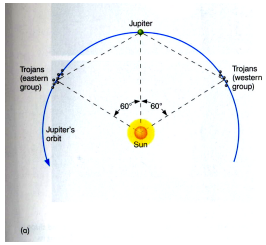


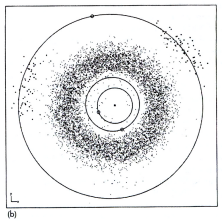


[Fig. 9.4]

Trojan Asteroids

- In same orbit as Jupiter, but leading or trailing Jupiter by 60º
  - Gravitationally stable position.



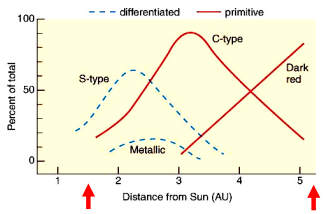


- Similar case exists for Mars.
  - also perhaps for Venus and Earth.
- Also, a few asteroids are known in outer solar system.

Most Asteroids are "Dark"

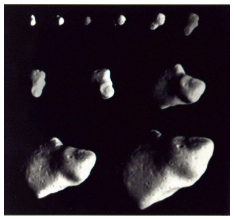
- Low reflectivity (3-4%)
- Primitive bodies
  - chemically unchanged since initial formation of Solar System
- Most are carbon-rich "C-type"
- Also stony "S-type",
  - dark carbon compounds missing.
- A few metal-rich "M-type"
  - Especially reflective at radar wavelengths.
  - Remnants of a differentiated body.
  - Collisions with Earth ➔ giant iron/nickel deposits.

Where Different Types of Asteroids are Found



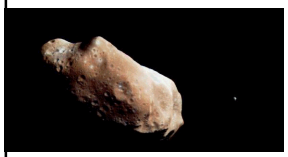
Asteroids seen from Galileo

Gaspra compared to Phobos & Diemos (the 2 moons of Mars)



Gaspra
19x12x11 km.
Rotation: 7 hrs.
Orbit: 1.4 AU
Composition: S-type

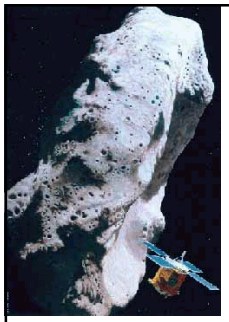
Few craters
➔ recently formed from breakup of larger body.



Ida and Dactyl
52 km long.
Rotation: 4.5 hrs
Orbit: 1.8 AU
Composition: S type.

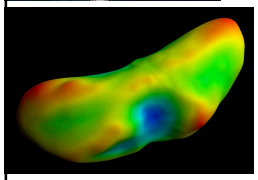
Dactyl (Ida's little companion)

- Member of group resulting from breakup of heavier body.
- Heavy cratering ➔ happened long ago.



433 Eros

- Near Earth asteroid: 1.13 to 1.78 AU
- S-type
- 35 x 15 x 13 km (size of Lansing)
- You would weigh 3 oz on Eros (little bag of potato chips)
- 20 mph speed limit
- NEAR spacecraft orbited for 1 year, then landed Feb. 2001.
  - NEAR found that Eros is not differentiated.



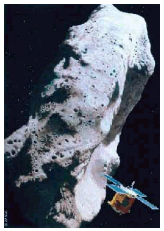
Colors show elevation (blue=low)

124 km orbit movie

- Q1 Hypothetical discovery: NEAR finds Eros has significant amounts of water. Would this be a surprise?
  a. Yes
  b. No

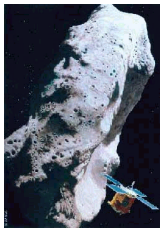
- Q1 Hypothetical discovery: NEAR finds Eros has significant amounts of water. Would this be a surprise? Yes
- Q2 If that were an actual discovery, how would you change the theory of Eros' formation?

- Near Earth asteroid: 1.13 to 1.78 AU
- 35 x 15 x 13 km (size of Lansing)
- You would weigh 3 oz on Eros



- Q2 If that were an actual discovery, how would you change the theory of Eros' formation?
- Q3 Which theory can be disproved?
  a. Form near Jupiter; then collide to put it near earth
  b. Formed as a comet; collided
  c. Formed in astreoid belt; collisiion

- Near Earth asteroid: 1.13 to 1.78 AU
- 35 x 15 x 13 km (size of Lansing)
- You would weigh 3 oz on Eros



Chemical composition of primitive meteorites

- H, He, C, N, O, Ne, Ar under-abundant relative to atmosphere of Sun.
  - The lightest elements did not condense
- More lithium than in sun ➔ sun has destroyed some of its lithium.
- 16 amino acids in Murchison carbonaceous meteorite
  - Equal numbers of right, left-handed.
  - Life on Earth uses only left-handed.
  - Shows that amino acids in Murchison meteorite are extra-terrestrial in origin.