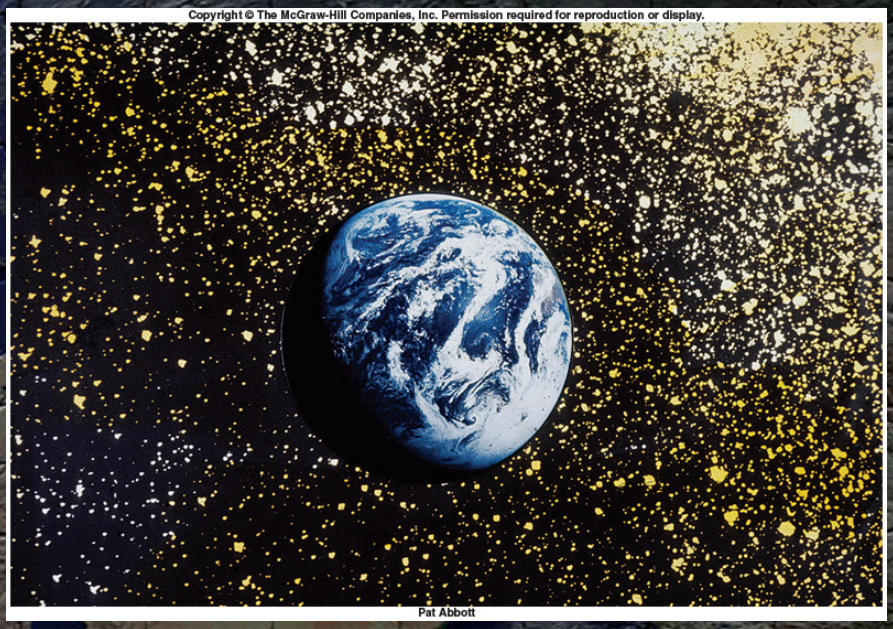
Topic 3: The Solar System – Part 2

https://geowiki.ucsd.edu/sio15



Pat Abbott

Monday For-Credit Test - Canvas

- open Sunday noon
- due Monday by 11:59 pm PDT
- topics 1– 3 (incl. lectures slide, notes, short videos)
- multiple choice
- only one answer correct
- 20 questions (0.25 pt each)
- 30 min (start any time, but you have only 30 min after start)
- you see only one question at a time
- you cannot go back
- you can take the test only once

- no need to have camera on during test
- no need to Zoom record your test
- do not 'screen shot' test questions (this is considered cheating)

Practice Quizzes - Geowiki

- anonymous; not monitored; take as often as you want
- don't ask for editing access!

Homework 1

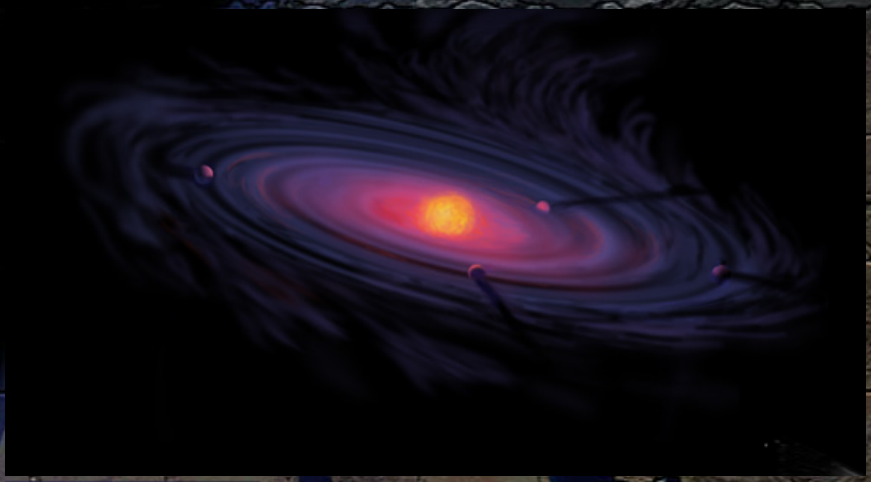
6) News Clip September 28, 2025:
   a) At the time of the news clip, tropical storm weather in the Atlantic affected islands in which area? (0.5 pt)
   b) Which name did this particular unnamed storm eventually get? (0.5 pt)
   c) What was the name of the other hurricane at the time? What was its category? (0.5 pt)
   d) Which specific areas did this storm threaten? Name 3 areas. (0.5 pt)
   e) At 5 pm EST how far was the unnamed storm from the Central Bahamas? Include units. (0.5 pt)
   (2.5 points total)

7) News Clips September 25 and 26, 2025:
   a) What was the name of the typhoon that battered countries in the western Pacific? (0.5 pt)
   b) Which four countries (not cities!) were most affected? (0.5 pt)
   c) As of 9/25/25, how many people lost their lives? (0.5 pt)
   d) At the time of its greatest strength, what was the highest sustained windspeed? Include units! (0.5 pt)
   e) What was its windspeed upon making landfall and what was its category by then? (0.5 pt)
   (2.5 points total)

as spelled out in the clip, and a recognized in the U.S.
for b) only, news clips sep 27 may help best

Ages of the Universe, Sun and Earth

Protoplanetary disk



Source: wikipedia

Moon Formation

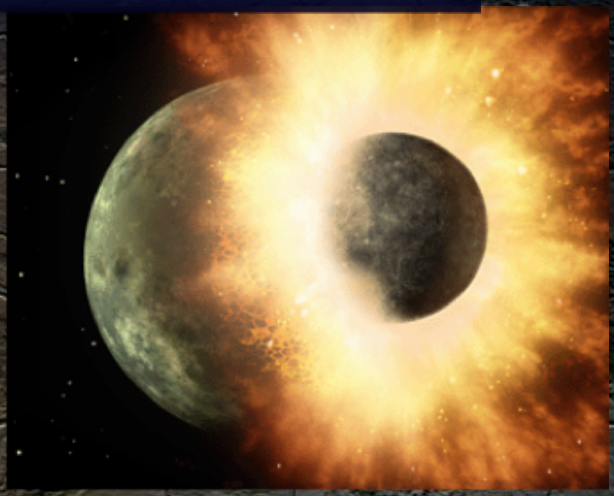


Fig 3.9

1) universe: ~ 13.8 billion years
2) solar system: ~ 4.5 billion years
3) sun and planets formed at same time
4) moon: ~ 4.4 billion years (Mars-size impactor on Earth)

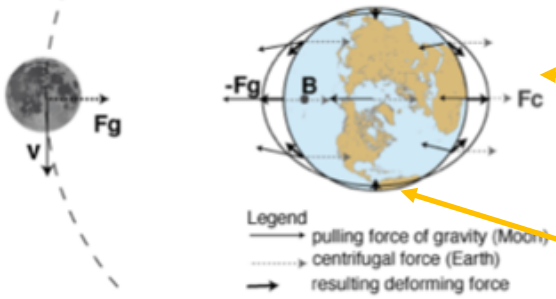
Earth Tides (Sun-Earth-Moon System)

high tide wherever Moon is 'overhead'

Moon orbits Earth

Gravitation and Tides

* Earth's surface feels the pull of the Moon on the near side more than on the far side.



... but also on the 'other side'

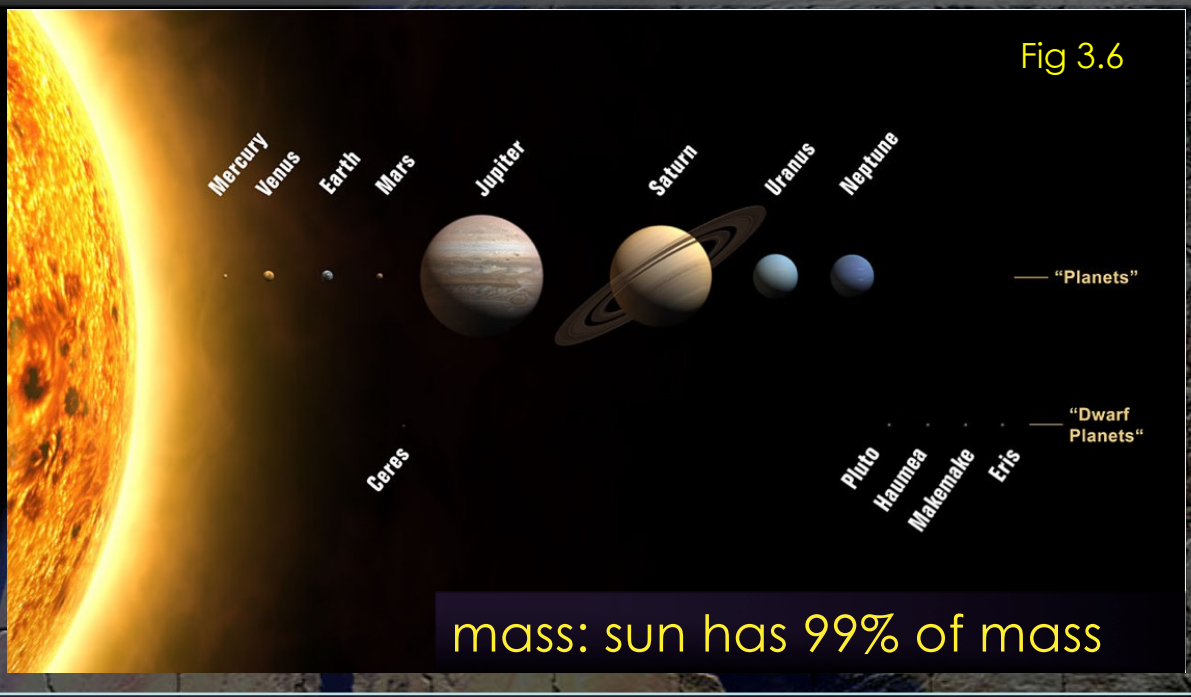
low tide at 90°

Fig. 2.15

Watch short Video on tides (3a,b)

SIO15: Chapter 2: Tides

Members of our Solar System - Planets



mass: sun has 99% of mass

terrestrial planets, inner p.: Mercury, Venus, Earth, Mars
(high density); rocky planets
giant planets, outer planets: Jupiter, Saturn (gas), Uranus, Neptune (ice)
(low density)

Angular Momentum

Fig 3.5

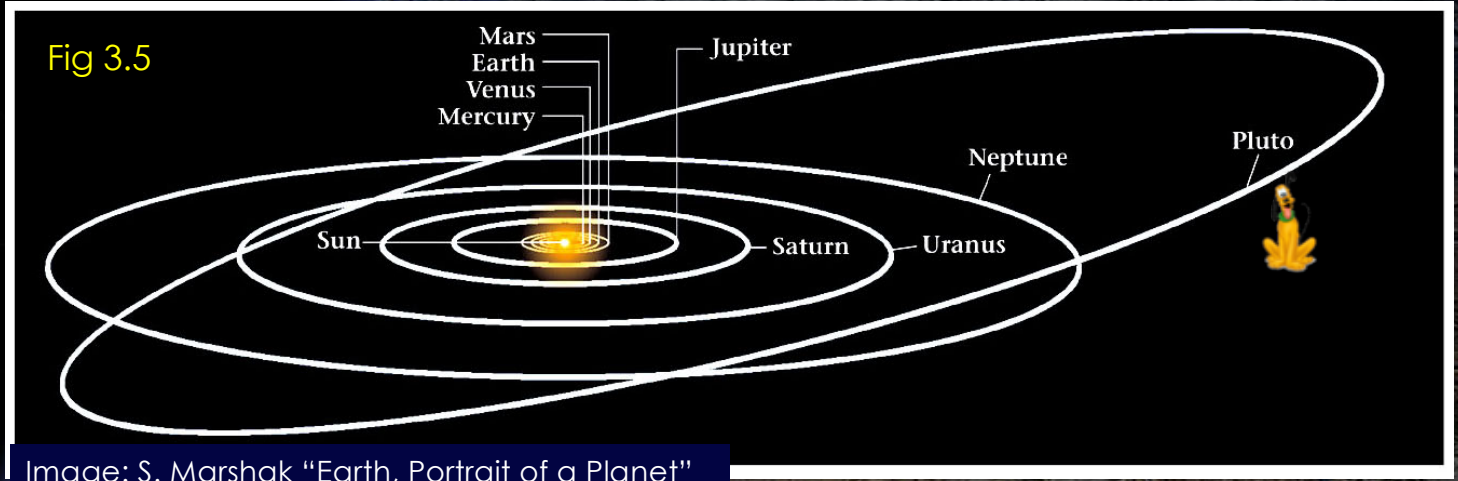


Image: S. Marshak "Earth, Portrait of a Planet"

momentum: $p = m*v$
angular momentum: $L = I*\Omega$

planets have 99% of angular momentum

comparable angular momentum
-> inner planets orbit faster than outer planets
(like skater tugging in arms)

Pluto

Fig 3.5

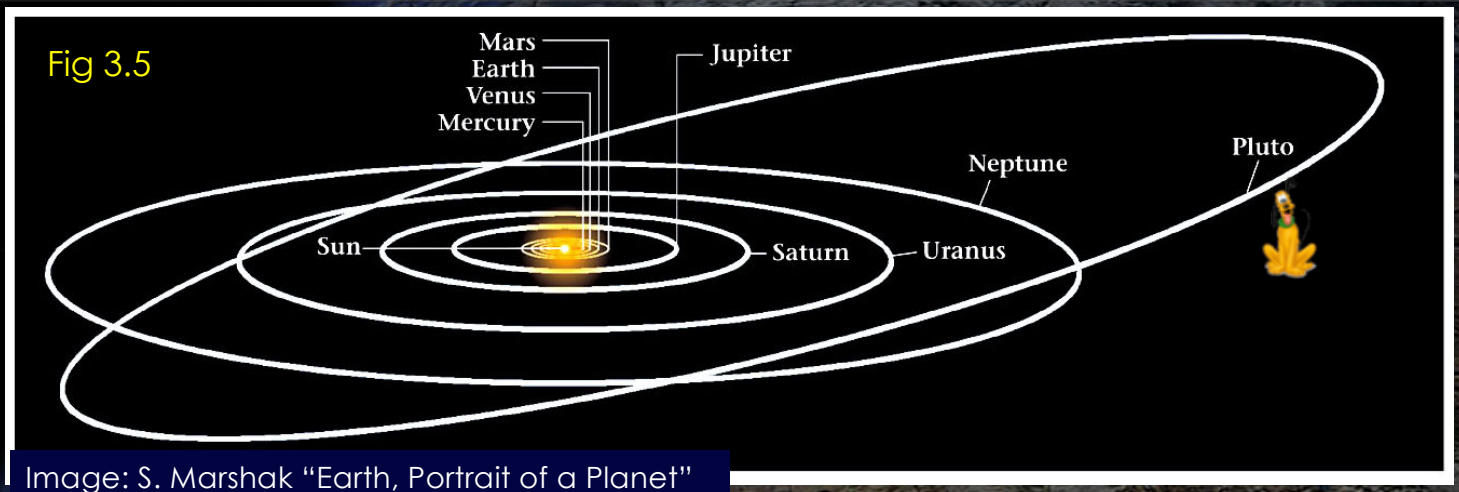


Image: S. Marshak "Earth, Portrait of a Planet"

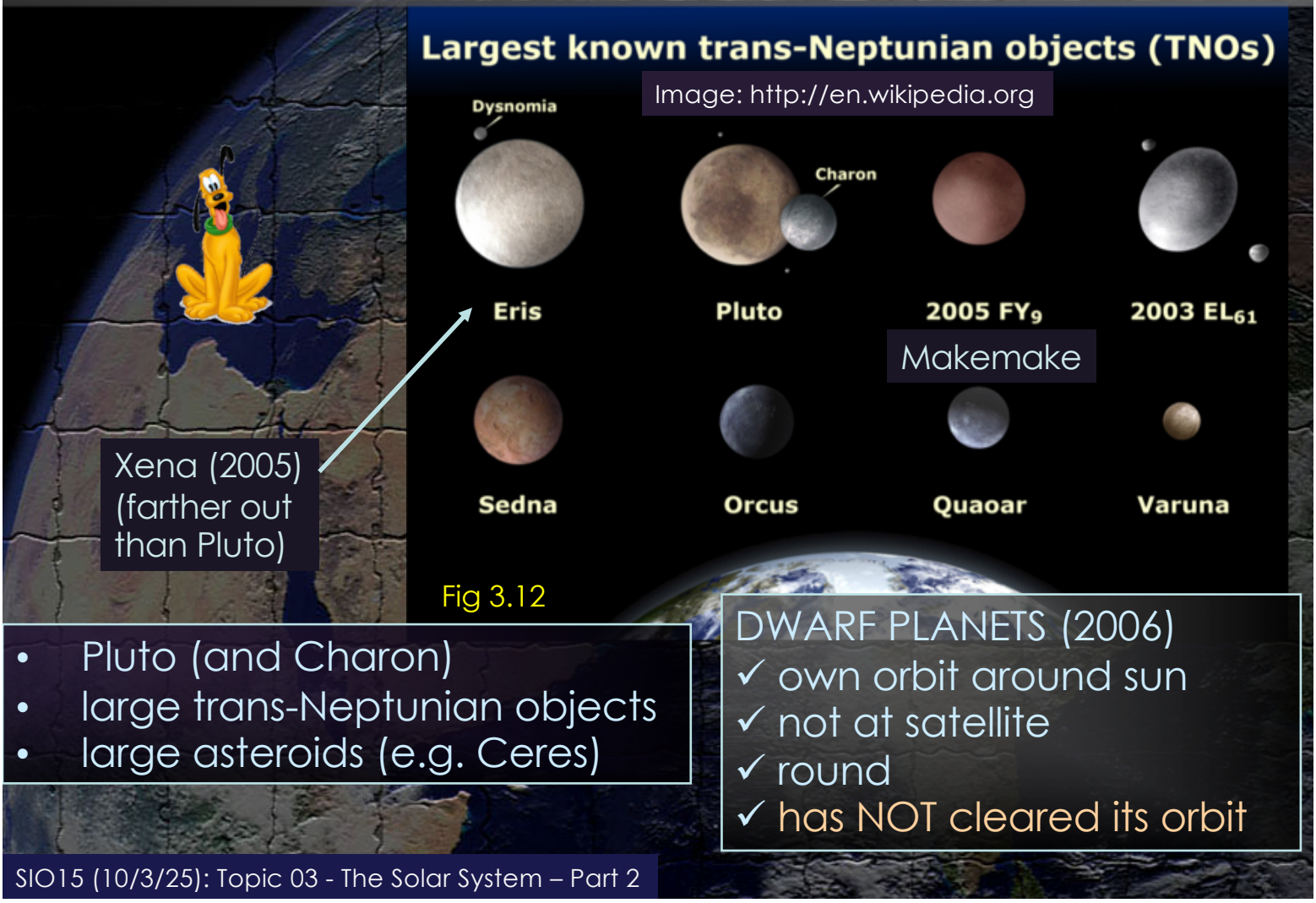
Orbit

- highly elliptical
- Tilted with respect to ecliptic

- discovered in 1930
- Only 2/3 of Moon
- Weird orbit
- large satellite (Charon)
- Smaller than Xena (2005)

Renamed: Eris

Dwarf Planets



Xena (2005) (farther out than Pluto)

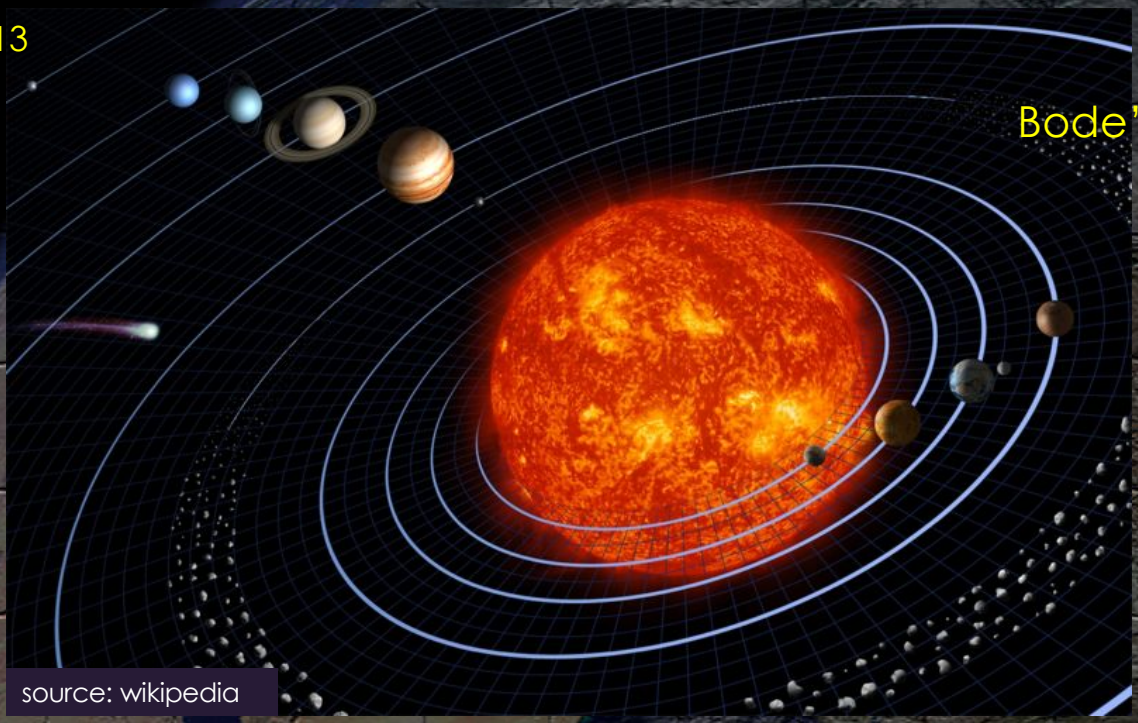
Fig 3.12

- Pluto (and Charon)
- large trans-Neptunian objects
- large asteroids (e.g. Ceres)

DWARF PLANETS (2006)
- ✓ own orbit around sun
- ✓ not at satellite
- ✓ round
- ✓ has NOT cleared its orbit

The Asteroid Belt

Fig 3.13



source: wikipedia

Bode's Law

see course book!

- asteroid belt between Mars, Jupiter (tug of Jupiter prevented planet formation)
- source of some impactors

Fig 3.14

Asteroids

- rocky
- low density

IDA; 56km long + Dactyl

source: wikipedia/NASA

Ceres; 940 km across
dwarf planet

source: wikipedia/NASA

most too small to be rounded
3 large > 500km diameter (Ceres, Pallas, Vesta)
some have Earth crossing orbits: Apollos
(Amors: Mars-crossing)

Fig 3.14

Apollos - Near-Earth Asteroids

101955 Bennu

source: wikipedia/NASA

discovered 11 Sep 1999
may impact 24 Sep 2182 ± 6 years
mean radius 245 m

OSIRIS-Rex mission 2016
returned samples to Earth (1 cup?) 9/24/23
opened 1/13/24 (122 g/4.3 oz)

1) what are they really made of?

DART - Double Asteroid Redirection Test

- Launch: Nov 2021 (SpaceX Falcon 9), Vandenberg, CA
- Refrigerator size (372 kg) (NASA)
- Dimorphos, moon of Didymos
- Impact: Mon 9/26/22 (equivalent of 5 tons TNT); 150 m crater
- analyzed data for next 6 months
- Purpose: deflect Dimorphos/shorten orbit by 73 s
- actual: shortening by 32 min!

2) can we prevent impact?

ESA follow-up launch of Hera 2024 to arrive 2026

2020 Comet NEOWISE

NEOWISE Program
"find NEOs"
(Near-Earth Objects)

- brightest comet in N. hemisphere since 97 Hale-Bopp
- discovered 3/27/20 (NEOWISE mission/space telescope)
- long-period comet
- perihelion 7/3/20
- visible with naked eye (??)

Comets

"dirty snowballs"

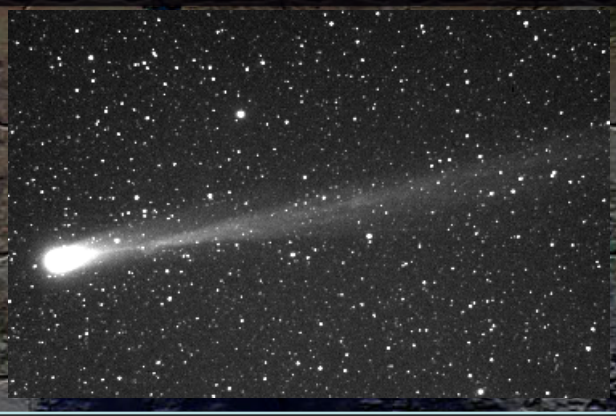
- icy (frozen volatiles)
- rocky core (few km across)
  (Halley comet: 40km)
- sunlight and solar wind

-> comet ejects ionized gases and dust

-> tail

McNaught, 2007
Lovejoy, 2011

Hale-Bopp, 1997

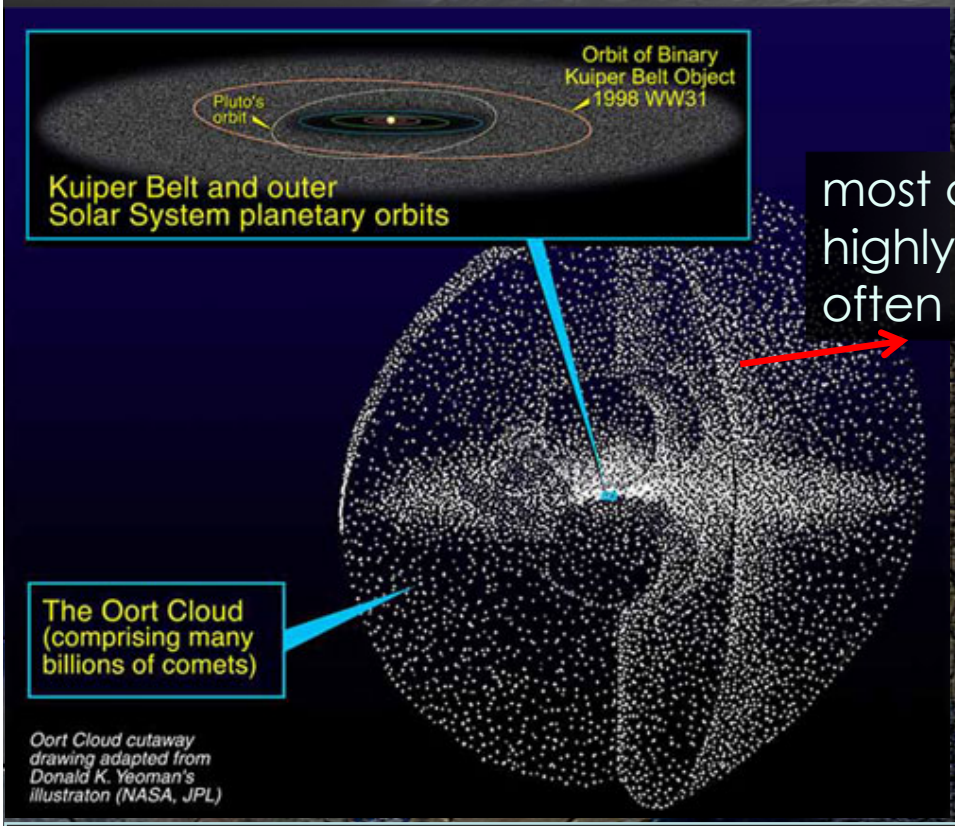


Hyakutake, 1996

- Kuiper belt beyond Neptune: short-period comets
- Oort cloud: long-period comets

Comets

Fig 3.17



most comets are long-period
highly elongated orbit
often not discovered until late

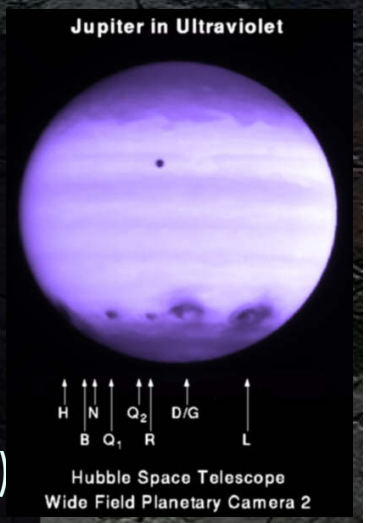
- Kuiper belt beyond Neptune: short-period comets (recurrence < 200 yrs)
- Oort cloud: long-period comets

1994: Comet Shoemaker-Levy 9

Fig 3.20

source: NASA/wikipedia

UV Hubble Image taken 21 July1994



- first observation of an extraterrestrial impact
- discovered 24 March 1993 at Palomar Obs.
- probably captured by Jupiter 20-30 years earlier
- fragmentation during July 1992 encounter
- impact 16 – 22 July 1994
- scientists argued whether impact would be seen at all
- captures by Jupiter not uncommon (19 July 2009) ("cosmic vacuum cleaner")

Hubble Image taken 17 May 1994

crater chain on Ganymede

Comets – Where does Earth's water come from?

currently a matter of great debate

9/29/15

- ✧ comets
- ✧ primordial

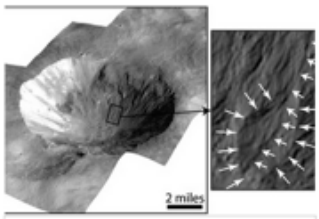
some have organic compounds

Earth
Europa
Enceladus
Mars??

water #1 condition for life to form

Surprise! Water Once Flowed on Huge Asteroid Vesta

by Mike Wall, Space.com Senior Writer | January 27, 2015 11:00am ET



Cornelia Crater lies on the large

Liquid water apparently flowed on the surface of the huge asteroid Vesta briefly in the relatively recent past, a surprising new study suggests.

"Nobody expected to find evidence of water on Vesta. The surface is very cold and there is no atmosphere, so any water on the

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LIQUID WATER FOUND ON MARS

Finding could have big implications for possibility of microscopic life-forms existing on Earth's next-door neighbor

BY KENNETH CHANG

Scientists have for the first time confirmed liquid water flowing on the surface of present-day Mars, a finding that will add to speculation that life, if it ever arose there, could persist now.

"This is tremendously exciting," James Green, the director of NASA's planetary science division, said during a news conference Monday. "We haven't been able to answer the question, 'Does life exist beyond Earth?' But following the water is a critical element of that. We now have, I think, great opportunities in the right locations on Mars to thoroughly investigate that."

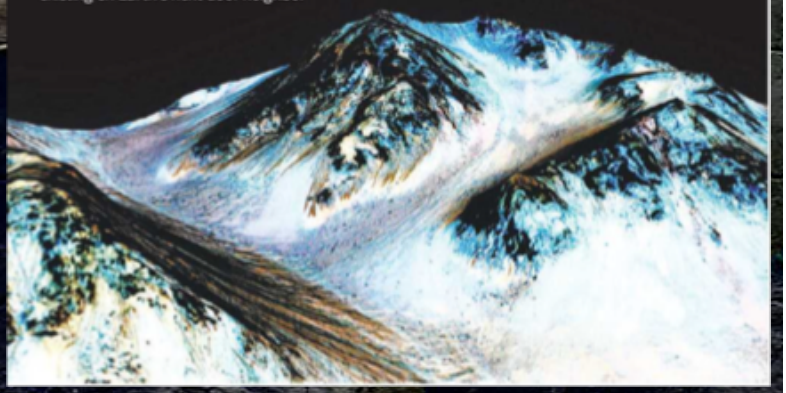
That marks a shift in tone for NASA, where officials have played down the notion that the dusty and desolate landscape of Mars could be inhabited today.

But now, John Grunsfeld, NASA's associate administrator for science, talked of sending a spacecraft in the 2020s to one of these regions, perhaps with experiments to

SEE MARS • A7

"Mars is not the dry, arid planet that we thought of in the past."

James Green
director of NASA's planetary science division

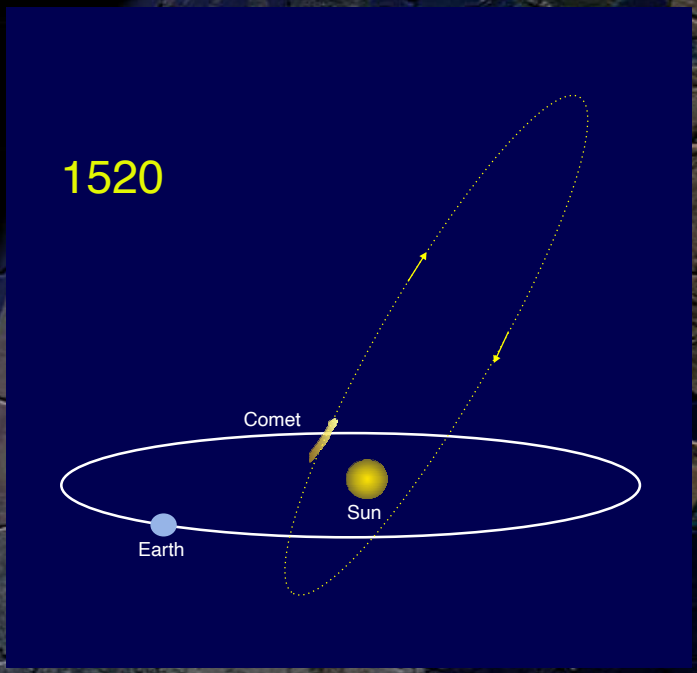


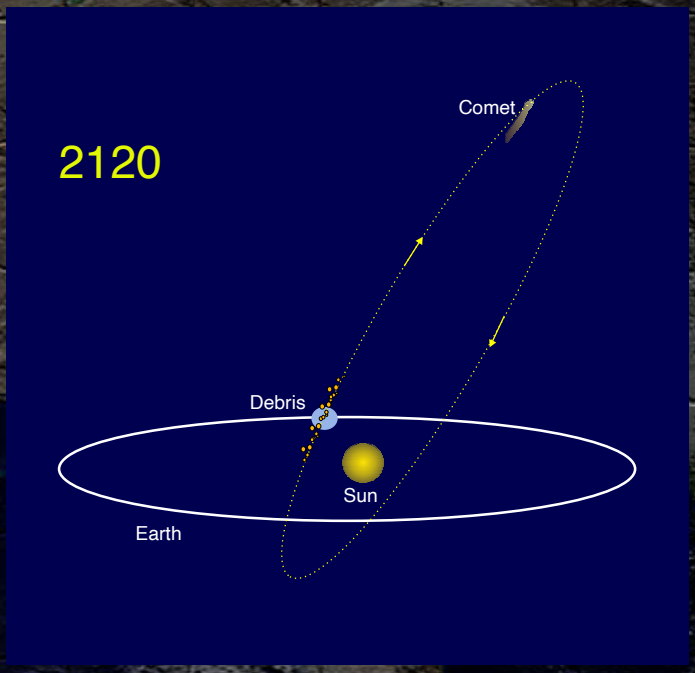
Source: San Diego U-T

Comets & Meteor Showers

Fig 3.19

Meteor Shower: comet dust burning up in atmosphere
remnant tail/debris field of ancient Earth-crossing comet





shows at same time every year
whenever Earth moves through debris field

Meteorites

Fig 3.19

- Meteoroid: object entering Earth's atmosphere
  comet, asteroid or similar
- Meteor: phenomenon seen in sky (shooting star)
- Meteorite: piece(s) left on Earth's surface after impact

Willamette meteorite

Meteors, shooting stars

fragments of asteroids and comets that impacted on Earth
- ❖ stony meteorite (less likely to survive)
- ❖ iron meteorite (from core of differentiated asteroids)

Bolides/Fireballs

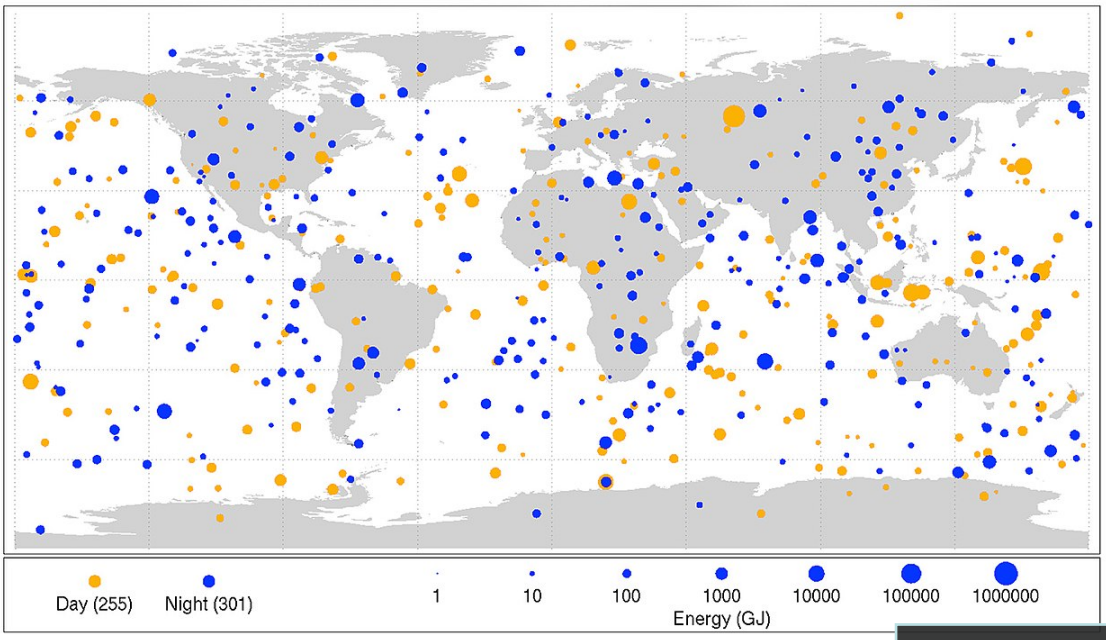
Fig 3.19

extremely bright meteors

- no day/night difference
- geographically random

Bolide events 1994-2013

(Small asteroids that disintegrated in the Earth's atmosphere)



source: wikipedia

most meteoroids burn up in Earth's atmosphere

The 1908 Tunguska Event

mass exploded <10 km high in atmosphere?

source: wikipedia

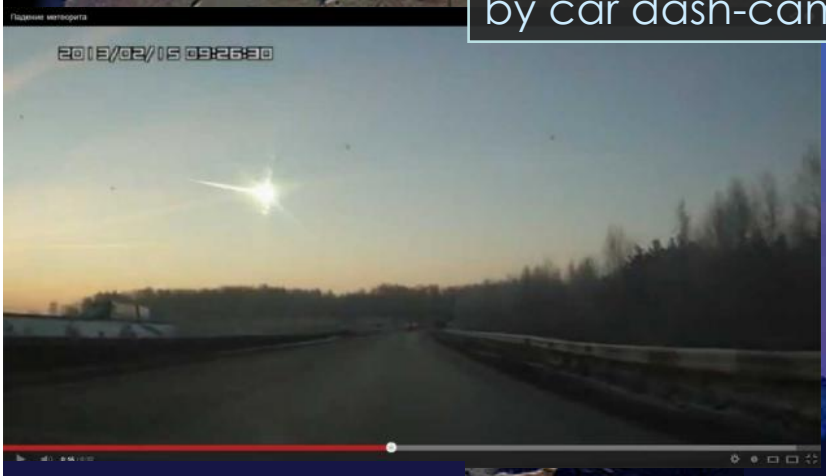
felled trees
no radioactivity
blast = 12-15 megatons (Bikini Atoll Bomb)
light phenomenon 200 km away
people knocked off their feet from shock wave
pressure fluctuations in Britain
volcanic area

remains from Comet Encke???

The 15 Feb 2013 Chelyabinsk Meteor

source: wikimedia

very well documented by car dash-cams !!



source: nationmultimedia

source: wordpress

The 15 Feb 2013 Chelyabinsk Meteor

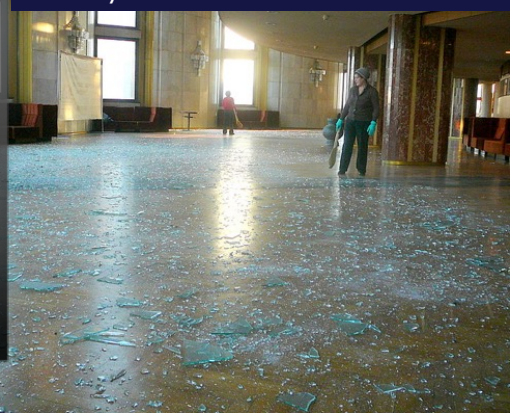
mass exploded ~25km high in atmosphere?

remains from 30-m asteroid 2012 DA_{14} 16h later??

Chelyabinsk Zinc Factory

source: wikipedia

Chelyabinsk Drama Theater



blast = <1 megaton (Tunguska 10x larger!)
(20-30 Hiroshima bomb)
light phenomenon 200 km away
large number of small meteorites
roof of zinc factory collapsed (from shock wave?)
injuries due to blown-out windows (7,200 buildings)
ground movement recorded 4000 km away