Today's Class: Pluto & The Kuiper Belt

1. Exam 3 on Monday. Covers topics from Oct. 26 to Nov. 20.
2. Homework #6 is due by 5 pm today.

Earth, Moon & Pluto

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ESA Greenlights ARIEL Exoplanet Surveying Mission

Presented by Jacob Clark

ARIEL – Atmospheric Remote-sensing Infrared Exoplanet Large-survey

- Primary mission is "to understand the links between a planet's chemistry and its environment" by studying what exoplanets are made of, how they form and how they evolve.
- Planned to survey 1000 extra-solar planets simultaneously in infrared and visible wavelengths
- Mission will focus on planets which are unlikely to host life as we know it
- 4+ year planned mission scheduled to launch in 2029
- ARIEL's destination is Sun – Earth Lagrange Point 2 (L2)
- ARIEL will be equipped with a primary elliptical primary mirror dimensioned 1.1 x 0.7 meters along with instrumentation to continuously cover 0.5 to 7.8 microns in wavelength

Question:
Why do you think that ARIEL will be focusing on exoplanets that are less likely to harbor life as we know it?

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Last Class

- Overview of asteroids
  - Asteroid moons & calculating densities
  - Orbits & Locations of asteroids
  - Origin of the asteroid belt
- OSIRIS-REx sample return

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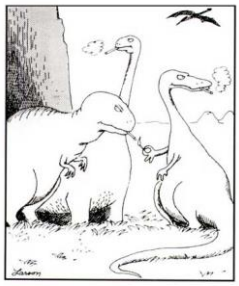
Class Exercise

Suppose the asteroid impact from 65 million years ago had not occurred. How do you think the Earth would be different today? Would mammals still dominate the planet?



The real reason dinosaurs became extinct

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This Class

- Overview of Pluto & the Kuiper Belt
- Pluto & dwarf planets
- The New Horizons Mission to Pluto & Kuiper Belt object
  - Science goals
  - Trajectory & closest approach
  - Spacecraft & instruments
  - What have we learned about Pluto?

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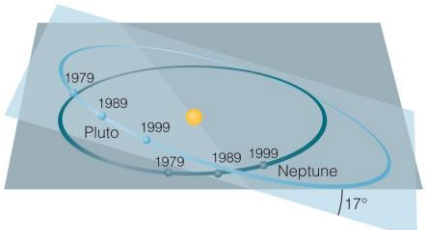
Pluto's Orbit



- Pluto will never hit Neptune, even though their orbits cross, because of their 3:2 orbital resonance.
- Neptune orbits three times during the time Pluto orbits twice.

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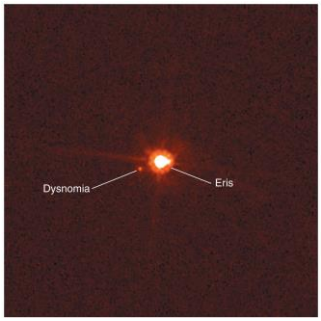
Kuiper Belt Objects



- These large, icy objects have orbits similar to the smaller objects in the Kuiper belt that become short period comets.
- So are they very large comets or very small planets?
- Pluto is one of the largest members of the Kuiper Belt.

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What is Pluto like?

- Its moon Charon is nearly as large as Pluto itself (probably made by a major impact).
- Pluto is very cold (40 K).
- Pluto's density is only 2 gm/cm^3 whereas as Mercury is 5.4 gm/cm^3.
- Pluto has a thin nitrogen atmosphere that will refreeze onto the surface as Pluto's orbit takes it farther from the Sun.
- *New Horizons* has revealed a surprisingly active geology.

Clyde Tombaugh discovered Pluto in 1930

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Pluto and Eris

- Pluto's size was overestimated after its discovery in 1930, and nothing of similar size was discovered for several decades.
- Now other large objects have been discovered in Kuiper belt, including Eris.
- The International Astronomical Union (IAU) now classifies Pluto and Eris as ***dwarf planets***.
- Dwarf planets have **not** cleared most other objects from their orbital paths.

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Is Pluto a Planet?

- Much smaller than the terrestrial or Jovian planets
- Not a gas giant like other outer planets
- Has an icy composition like a comet
- Has a very elliptical, inclined orbit
- Has more in common with comets than with the eight major planets

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NASA Administrator Weighs in on Pluto as the Ninth Planet

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Other Icy Bodies

- There are many icy objects like Pluto on elliptical, inclined orbits beyond Neptune.
- The largest of these, Eris, was discovered in summer 2005, and may be even larger than Pluto.

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New Horizons Team (2004)

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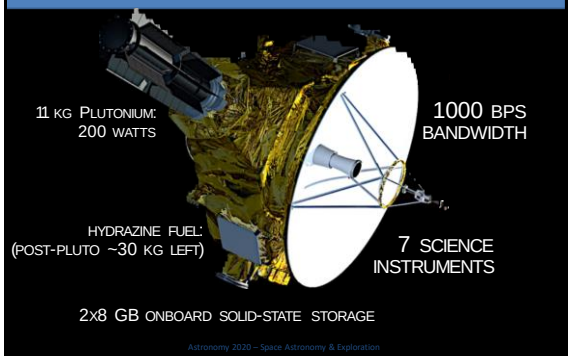
New Horizons



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New Horizons at the Cape

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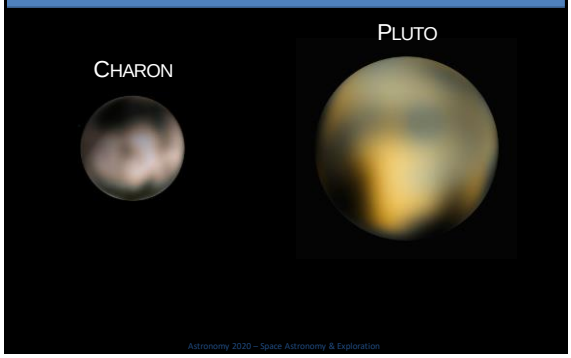
Before NASA's New Horizons



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After NASA's New Horizons

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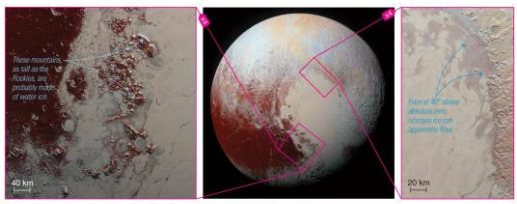
New Horizons at Pluto



a Pluto, with enhanced color to identify different regions. The bright, heart-shaped region is called Tombaugh Regio after Pluto's discoverer.

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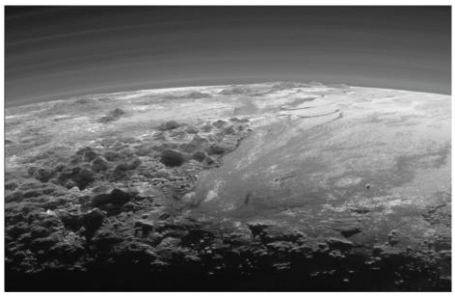
New Horizons at Pluto



Pluto's thin atmosphere

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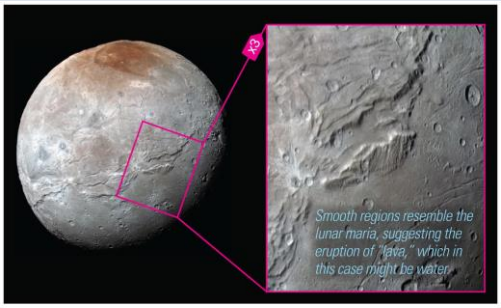
New Horizons at Charon



b Global and close-up images of Pluto's largest moon, Charon.

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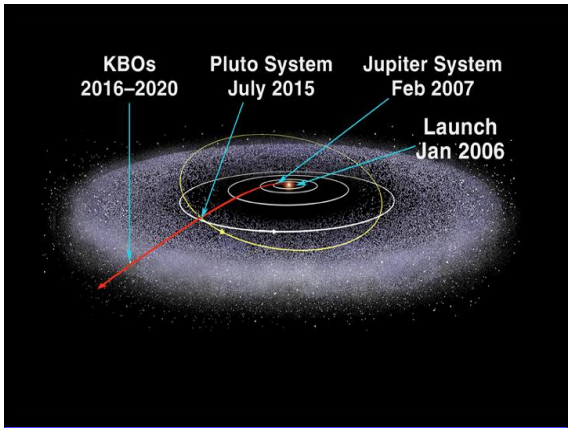

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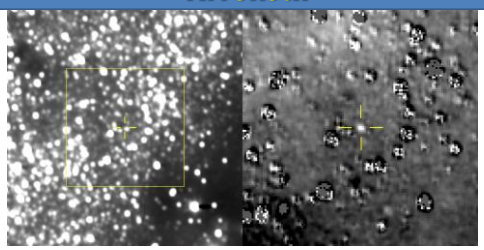
New Horizons Second Encounter: Arrokoth



The figure on left is a composite image produced by adding 48 different exposures, each with an exposure time of 29.967 seconds, taken on Aug. 16, 2018. The predicted position of Arrokoth is at the center of the yellow box, and is indicated by the yellow crosshairs. At right is a magnified view of the region in the yellow box, after subtraction of a background star field "template. At the time of these observations, Arrokoth was 107 million miles (172 million kilometers) from the New Horizons spacecraft and 4 billion miles (6.5 billion kilometers) from the Sun.

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New Horizons at Arrokoth (MU69)

- Fly-by on Jan. 1, 2019.
- Farthest exploration in history – 6.6 billion km from Earth.
- 38 km long, contact binary
- What caused loss of angular momentum leading to merging of 2 bodies?
- Reddish hue caused by modification of organic materials. Evidence for methanol, water ice, and organic molecules found on surface.

video

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What have we learned?

- **What is Pluto like?**
  - An icy world with mysterious active geology.
- **Why is there a Kuiper belt?**
  - Made up of leftovers from planet formation era.
  - Shaped by interactions with jovian planets.

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