Astronomy 405
Solar System and ISM

Lecture 13
The Pluto-Charon System, Comets

February 13, 2013

Pluto was dicovered by Clyde Tombaugh on Feb 18, 1930.

It was called a planet until Aug 2006. It was voted out by the General Assembly of the International Astronomical Union.

Because Tombaugh was born on a farm near the Illinois community of Streator.

RESOLVED, BY THE SENATE OF THE NINETY-SIXTH GENERAL ASSEMBLY OF THE STATE OF ILLINOIS,

that as Pluto passes overhead through Illinois' night skies, that it be reestablished with full planetary status, and that March 13, 2009 be declared "Pluto Day" in the State of Illinois in honor of the date its discovery was announced in 1930.

(SR0046 was adopted on 2/26/2009.)

Pluto's Orbit

248.5-yr orbit, inclined from the ecliptic by 17°

Eccentricity e = 0.25; at aphelion, 49.3 AU;
at perihelion, 29.7 AU, closer than Neptune.

But, 3:2 orbital resonance => won't collide with Neptune

The closest distance to Neptune is 17 AU, but only
11 AU to Uranus.

Pluto and Charon

Pluto’s mas and radius were better determined after Its moon Charon was discovered in 1978.

P = 6.39 day

Separation = 19,640 km

1/20 that from Earth to Moon

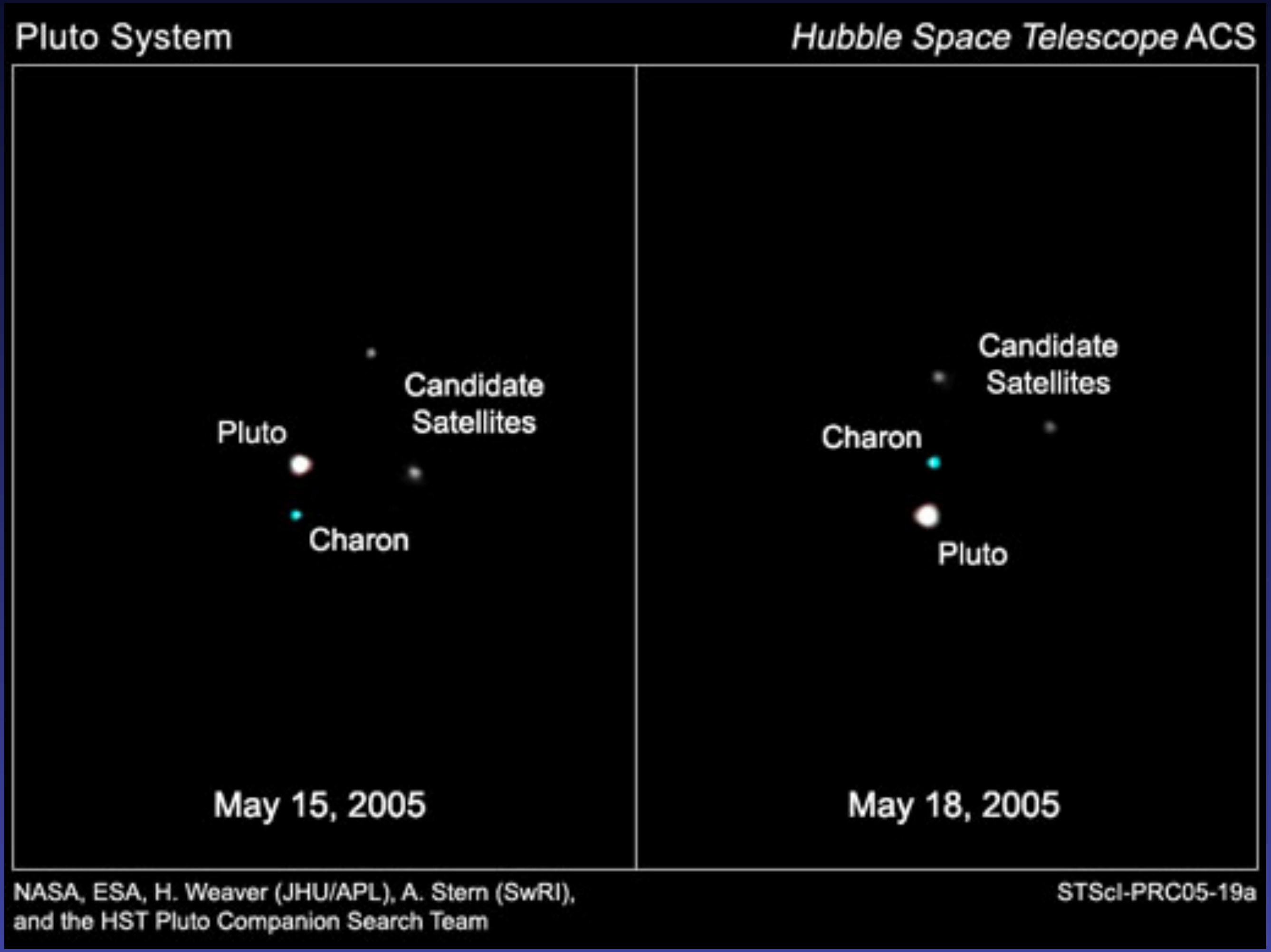
Total mass = 0.00247 $M_\oplus$

$M_C/M_P = 0.124$

$M_P = 1.3 \times 10^{22}$ kg

$M_C = 1.6 \times 10^{21}$ kg

$M_T = 2.1 \times 10^{22}$ kg

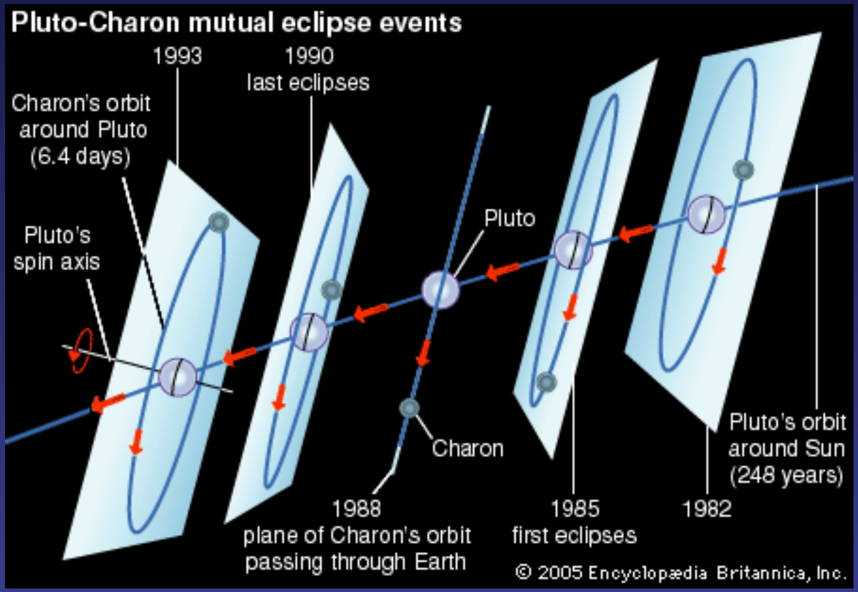


Pluto’s mass is similar to Triton’s mass.

Pluto and Charon

The orbital plane of Pluto+Charon is inclined 122.5° to their orbit around the Sun. From Earth we see the orbit edge-on only twice per orbit, i.e., every 124 years.

The last eclipses occurred between 1985 and 1990. Pluto was at perihelion in 1989.



Pluto's radius = 1137 km
Charon's radius = 600 km

Pluto's density = 2.11 g/cm^3
Charon's density = 1.77 g/cm^3
Triton's density = 2.05 g/cm^3

Frozen ices and rocks. Pluto has a higher proportion of rocks than most moons of giant planets.

Pluto and Charon

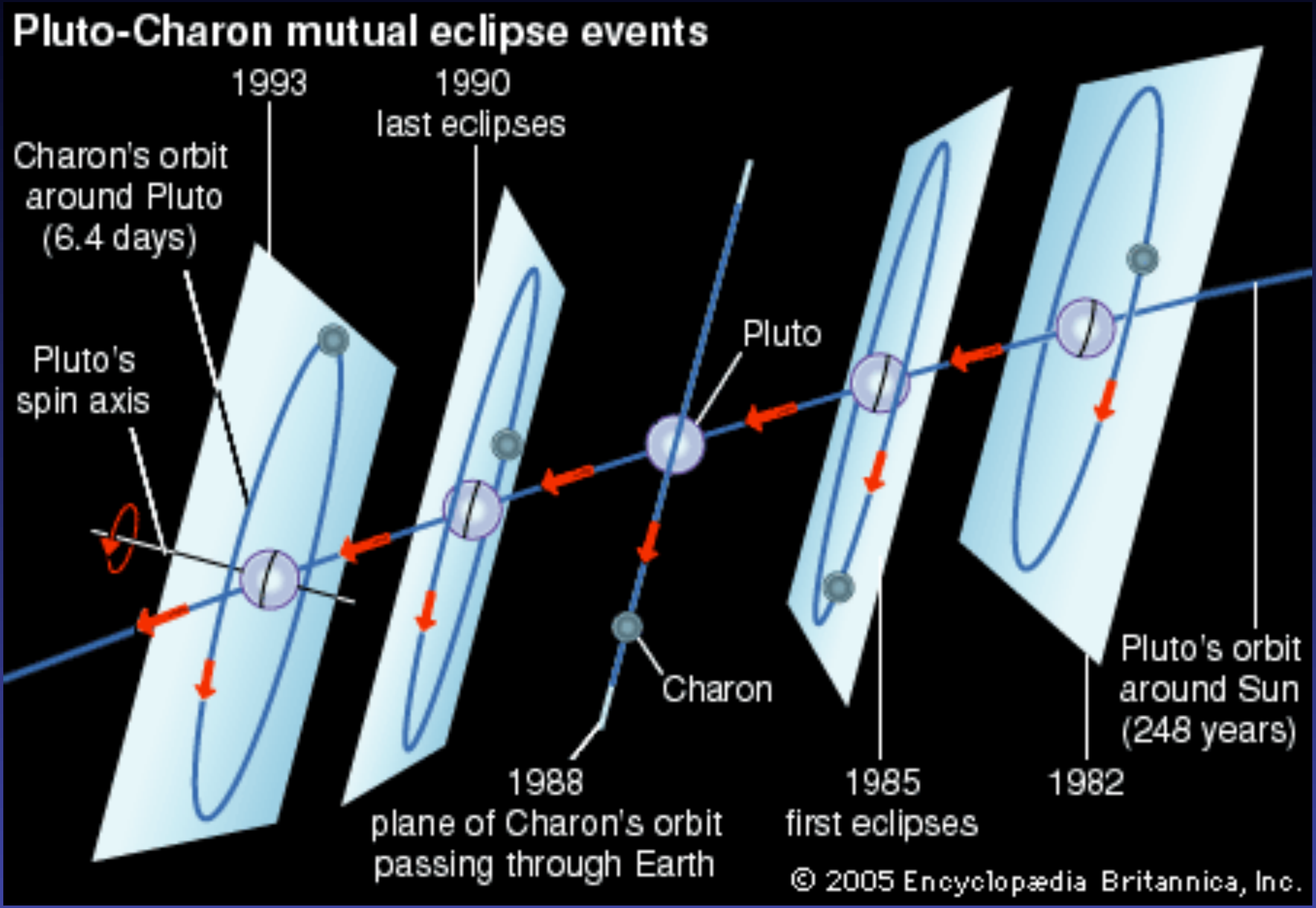
Charon’s mass is 1/8 that of Pluto
For comparion: Moon’s mass = 1/81 mass of Earth

Charon must have formed as a result of a large impact on Pluto. The two smaller moons may also have resulted from the same impact. The impactor had a mass between 0.2 and 1 M_P.

Pluto and Charon have rotation periods exactly the same as their orbital period. In order to have this fully locked synchronous rotation, the orbit of Charon has to be in the equatorial plane of Pluto.

The P-C orbit is inclined by 122.5° wrt their orbit around the Sun => retrograde rotation.

What Is Wrong in This Illustration?



Pluto's Atmosphere

1992 Tobias Owen used the United Kingdom IR Telescope to take spectra of Pluto.

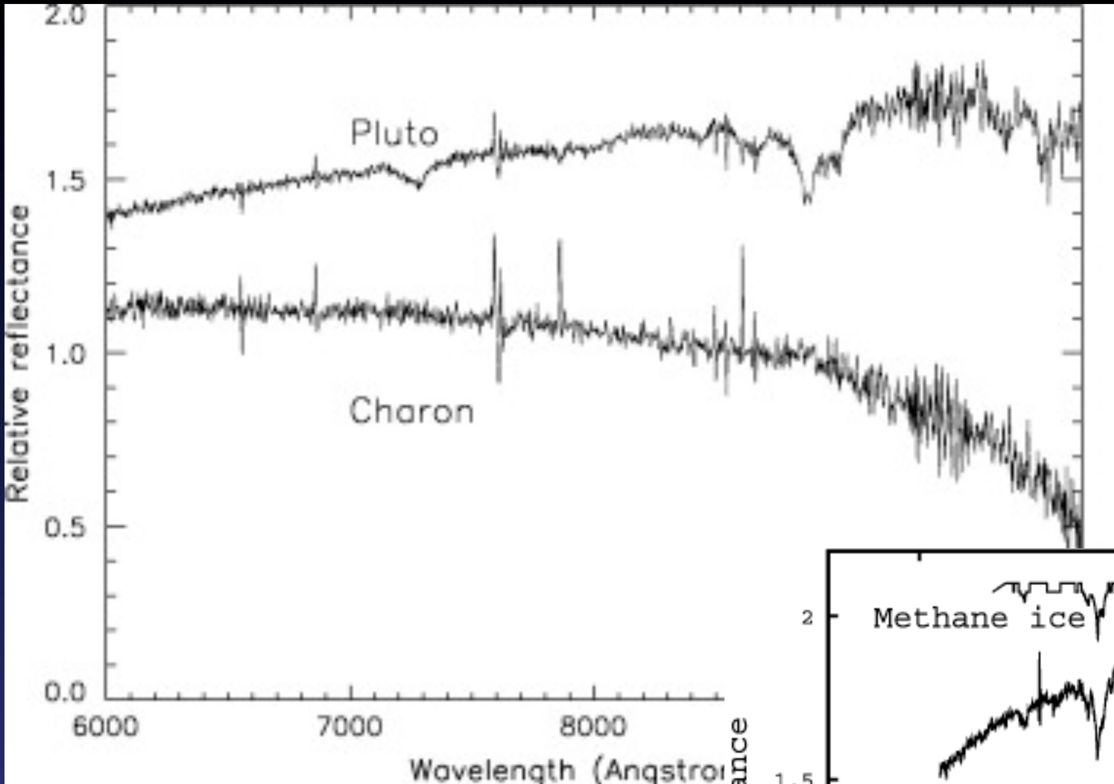
Frozen nitrogen (N_2) covering 97% of surface area
CO and CH_4 ice each accounting for 1-2%.
Similar to Triton.

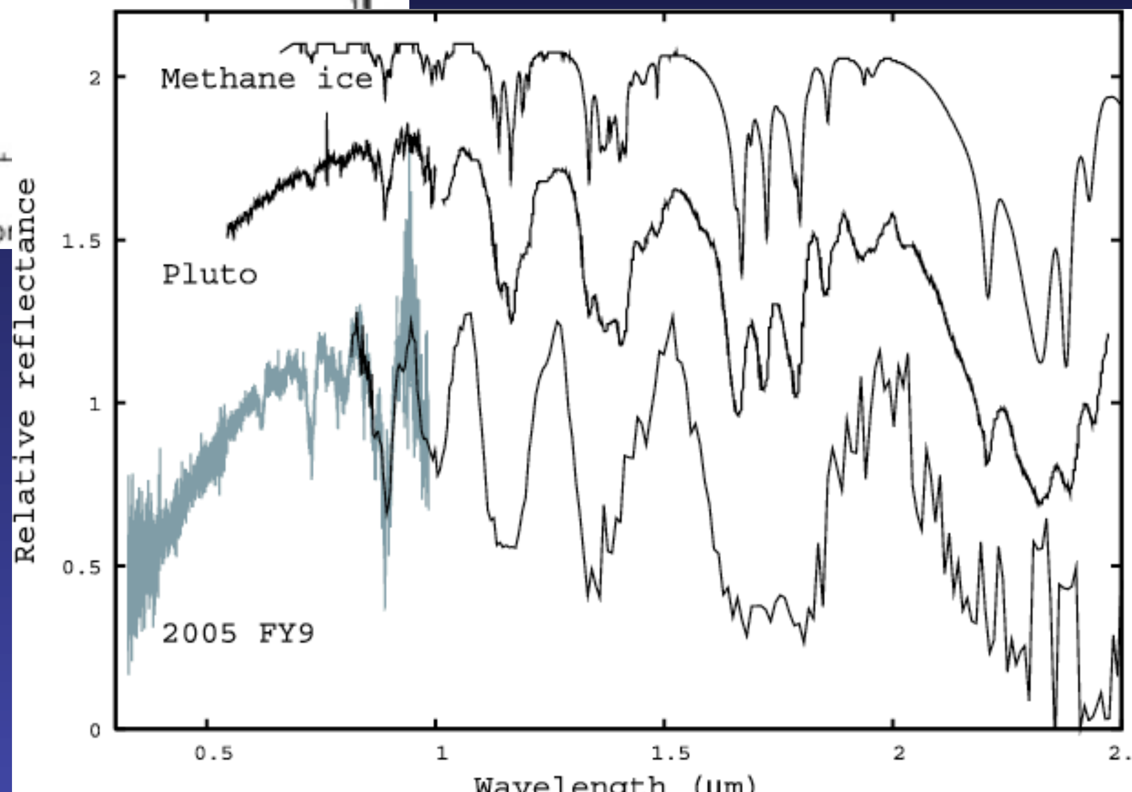
Charon's surface is composed primarily of water-ice.
No N_2, CO, or CH_4 ices or gas was detected.

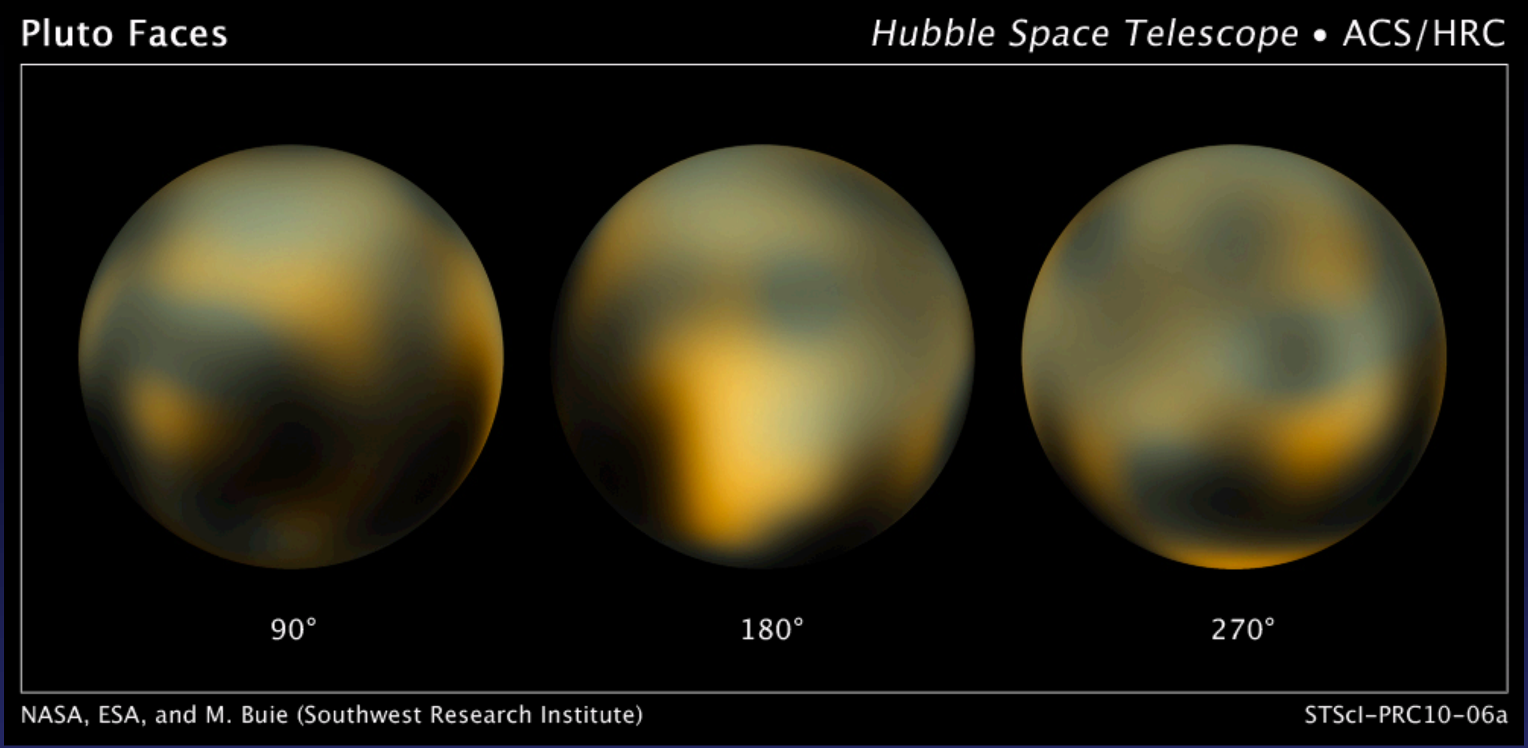
In 1988, when Pluto occulted a star, a very tenuous atmosphere was detected. 10^{-5} atm. Dominated by N_2 with CO and CH_4 making up ~0.2%. In 2002, the height of its atmosphere doubled.

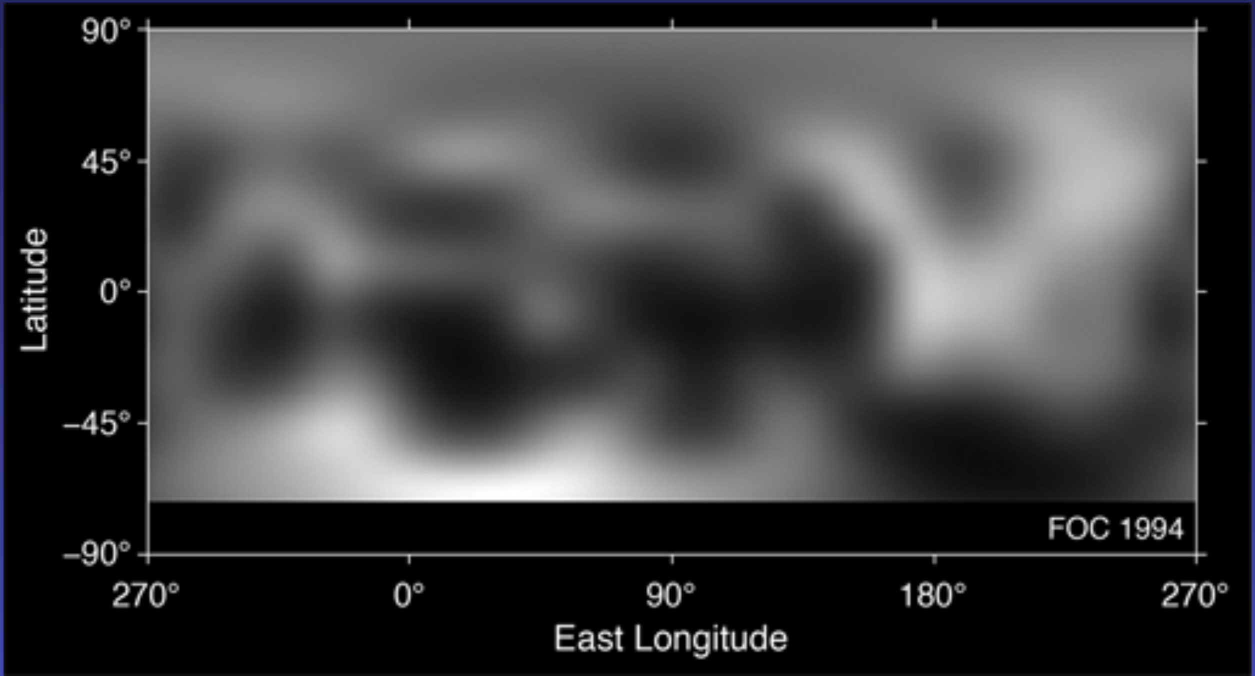
At perihelion ~40 K => partial sublimation

At aphelion => atmosphere freezes out


Pluto
Charon
Relative reflectance
2.0
1.5
1.0
0.5
0.0
6000
7000
8000
Wavelength (Angstror

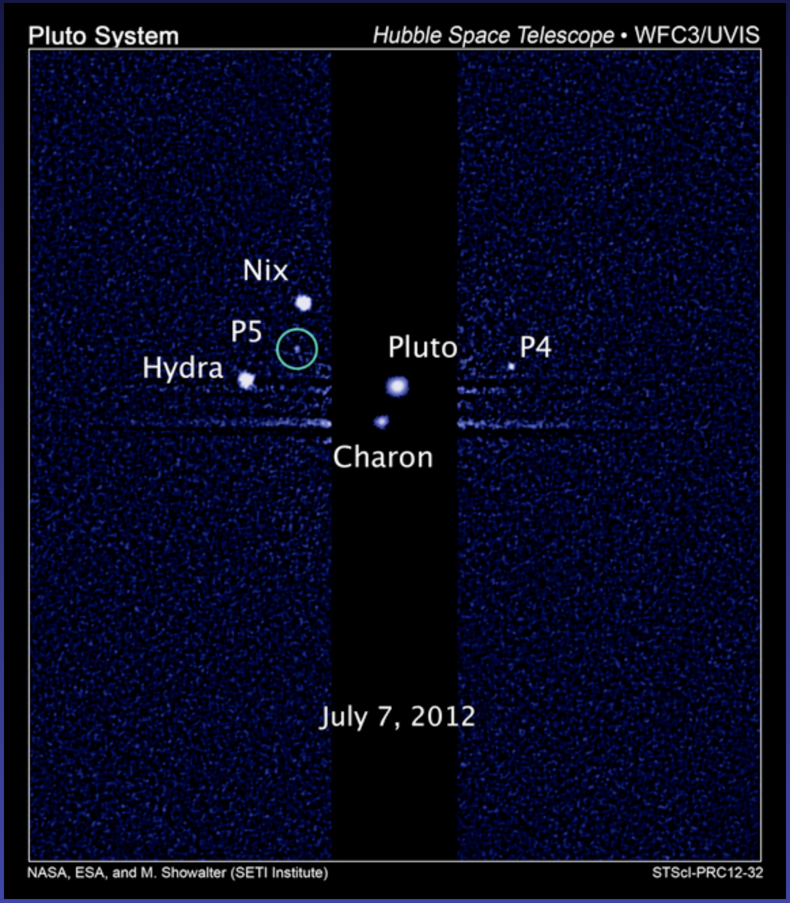

Methane ice
Pluto
2005 FY9
Relative reflectance
2
1.5
1
0.5
0
0.5
1
1.5
2
2.5
Wavelength (μm)





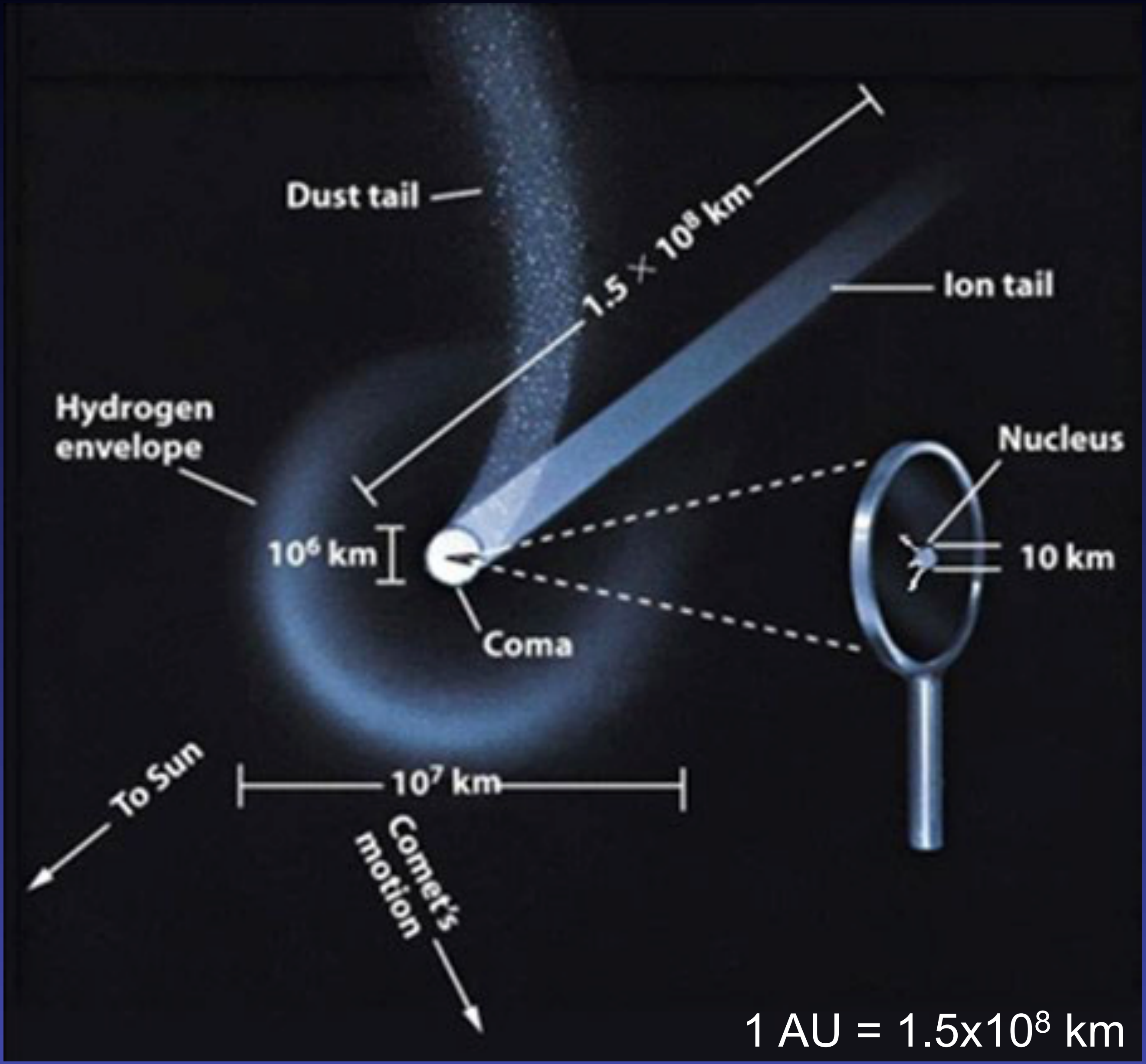
HST view of Pluto has similar linear resolution as naked eye view of the Moon. Features Are like

NASA's New Horizon,
launched in 2006,
is half way to Pluto.
It is expected to arrive
in 2015.



Spacecraft: New Horizons
Launch Vehicle: Lockheed Martin Atlas V
Launch Location: Cape Canaveral Air Force Station, Fla.
Launch Pad: Space Launch Complex 41
Launched: Jan. 19, 2006
Launch Time: 2:00.00 p.m. EST

The Anatomy of a Comet



Coma 10^9 m

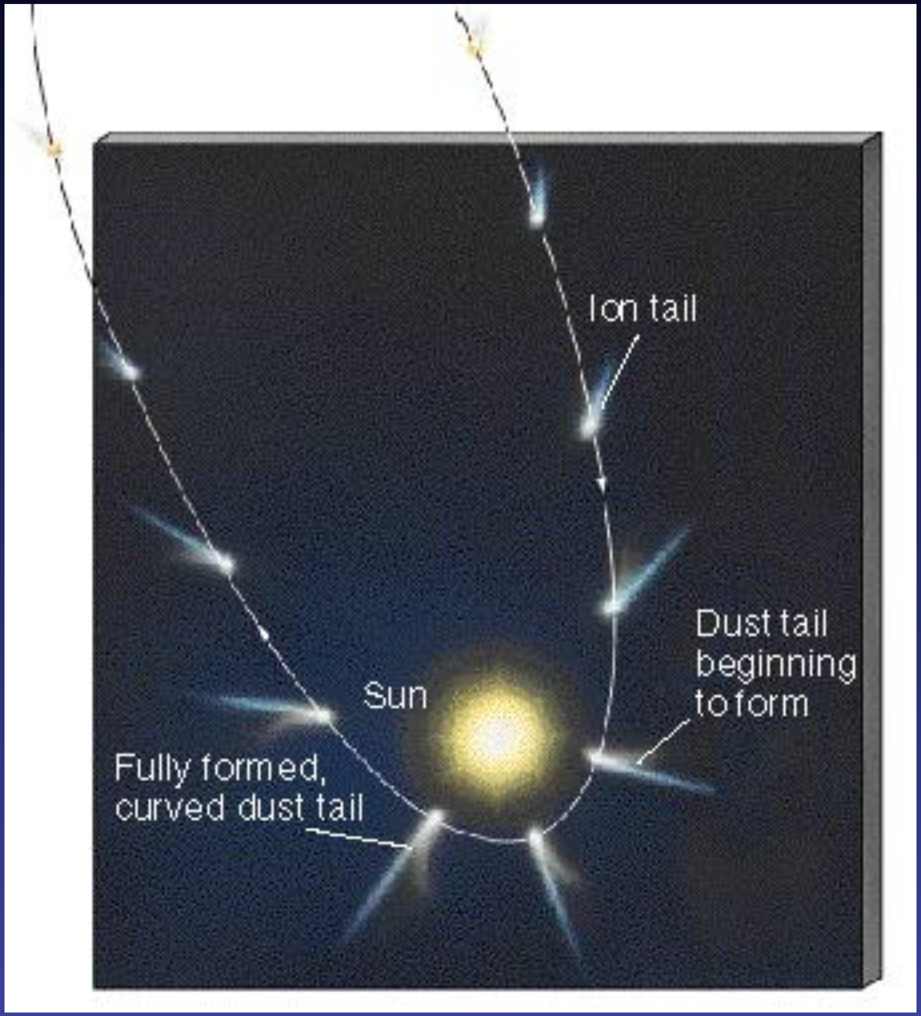
Nucleus 10 km

Halo 10^{10} m

Tails > 1 AU

Comet Hale-Bopp

Dynamics of Comet Tails



Gas (ion) tails
- interact with the solar wind
- point away from the Sun.

Dust tails
- pushed by radiation pressure,
- lagging behind the radial direction

Radiation Pressure on Dust Grains

$$F_{\mathrm{rad}} = \frac{\langle S \rangle \sigma}{c} = \frac{L_\odot}{4\pi r^2} \frac{\pi R^2}{c}$$

F = dp/dt *and*
p = E/c for photons
p: momentum; E: energy
σ*: cross section*

$$F_g = \frac{G M_\odot m_{\mathrm{grain}}}{r^2} = \frac{4\pi G M_\odot \rho R^3}{3r^2}$$

R : grain radius
r : distance to Sun

$m = \rho\,(4\pi R^3/3)$

$$\frac{F_g}{F_{\mathrm{rad}}} = \frac{16\pi G M_\odot R \rho c}{3L_\odot}$$

Gravitational force balances the force due to radiation pressure.

$$R_{\mathrm{crit}} = \frac{3L_\odot}{16\pi G M_\odot \rho c}$$

R_{crit} : blow-out radius
Smaller grains will be blown out

For $\rho = 3$ g/cm^3,
R_{crit} = 191 nm = 0.19 μm

Small dust grains will be blown out of the solar system.

The situation is more complicated because…
R_{crit} is 191 nm.
The Sun's radiation peaks near 500 nm.
R_{crit} is comparable to the wavelength of sunlight, small Grains cannot absorb sunlight efficiently.
Dust scatters light depending on the dust composition and geometry, and the wavelength.

Large dust grains orbits around the Sun, but the Poynting-Robertson effect makes the large grains to spiral in toward the Sun:

$$t_{\mathrm{Sun}} = \frac{4\pi\rho c^2}{3L_\odot} R r^2$$