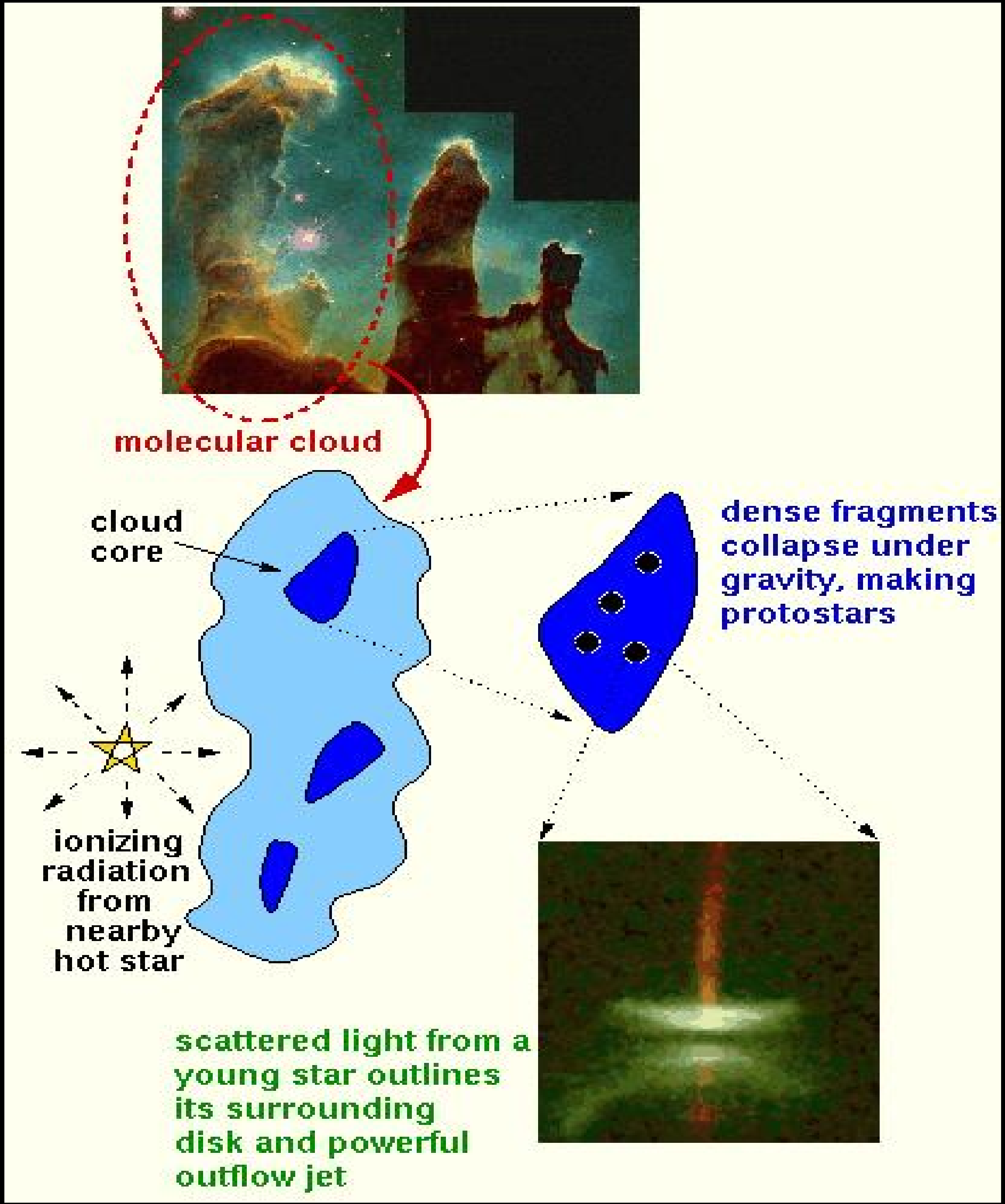
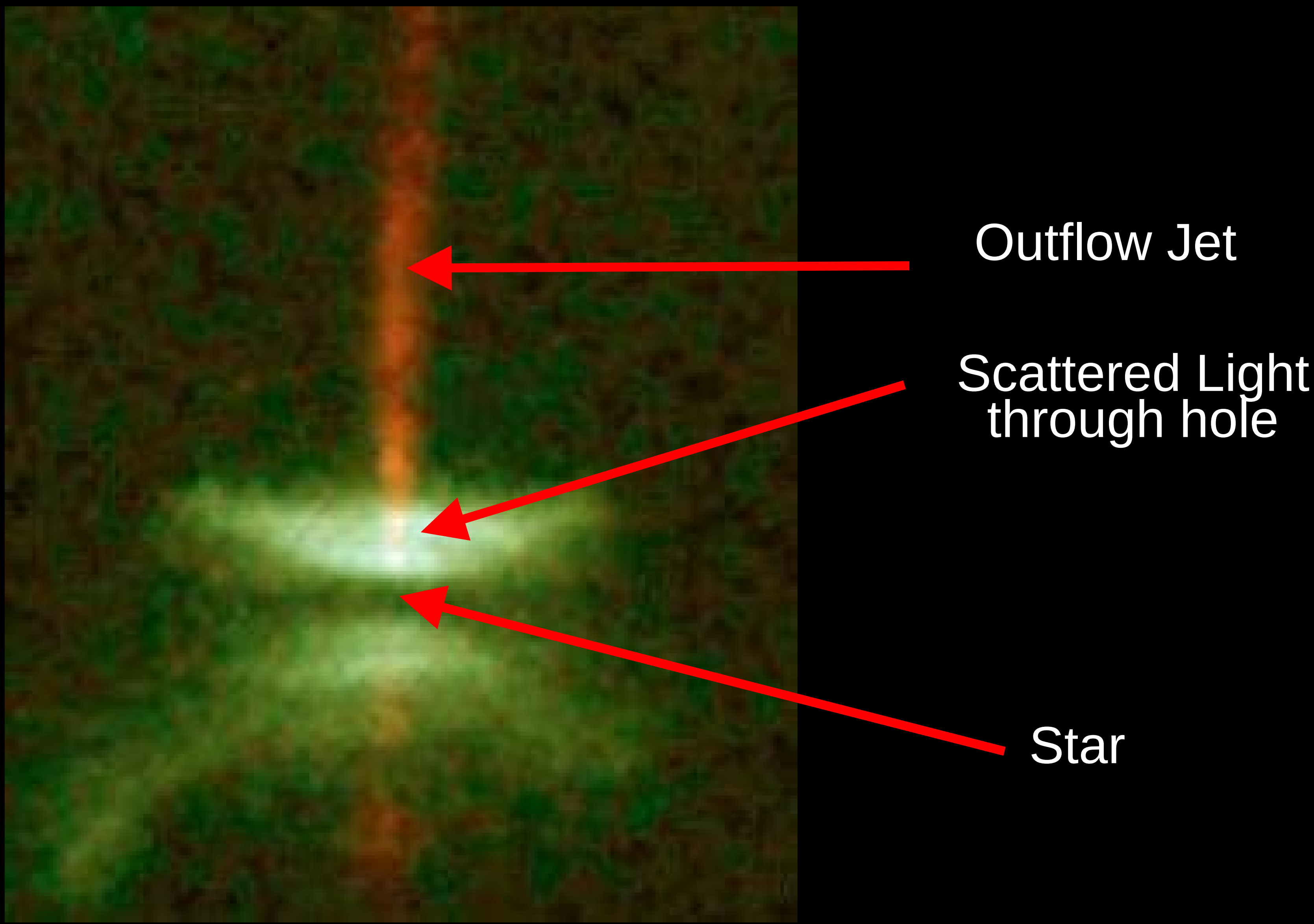
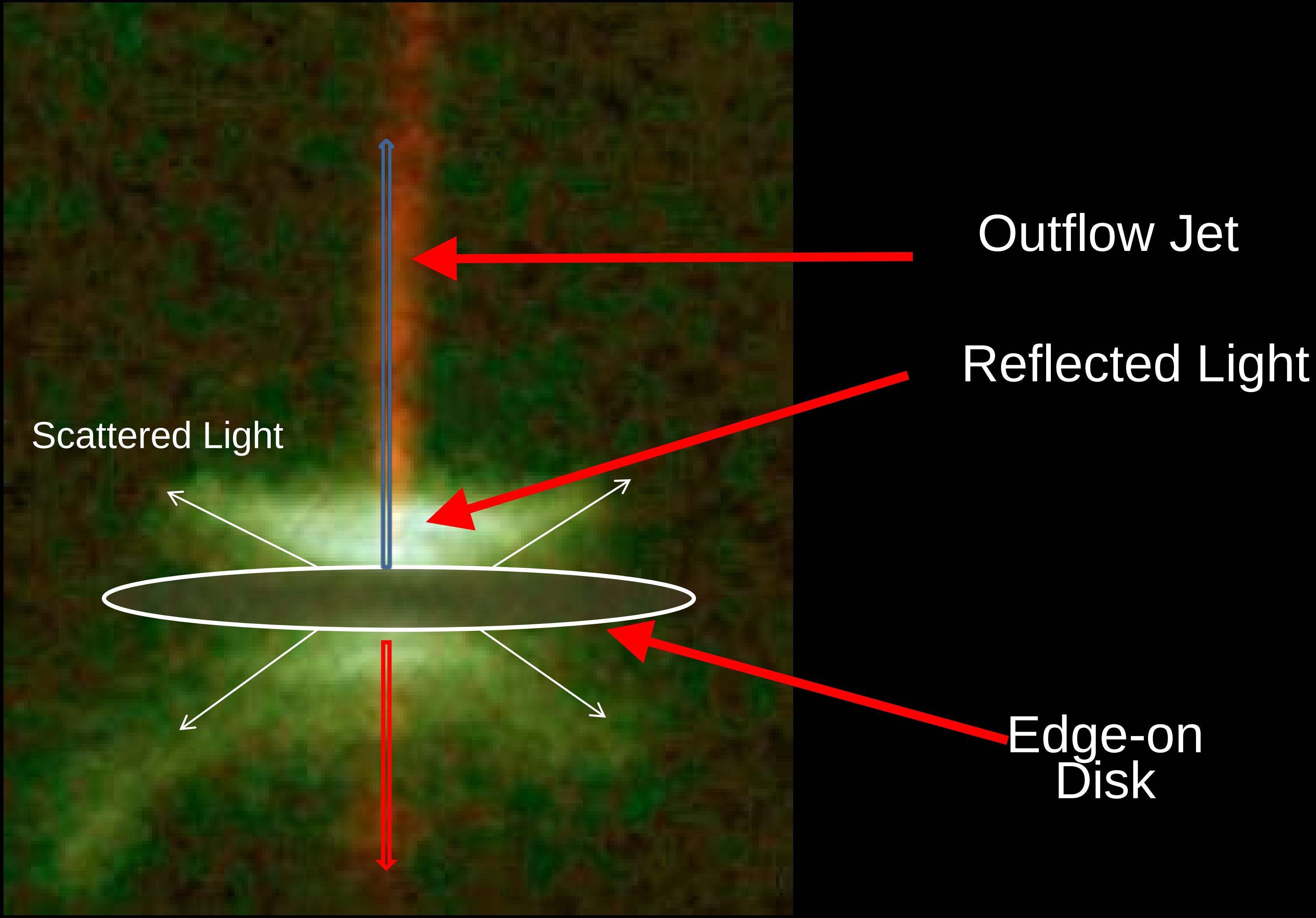
Basic Theory of Planet Formation

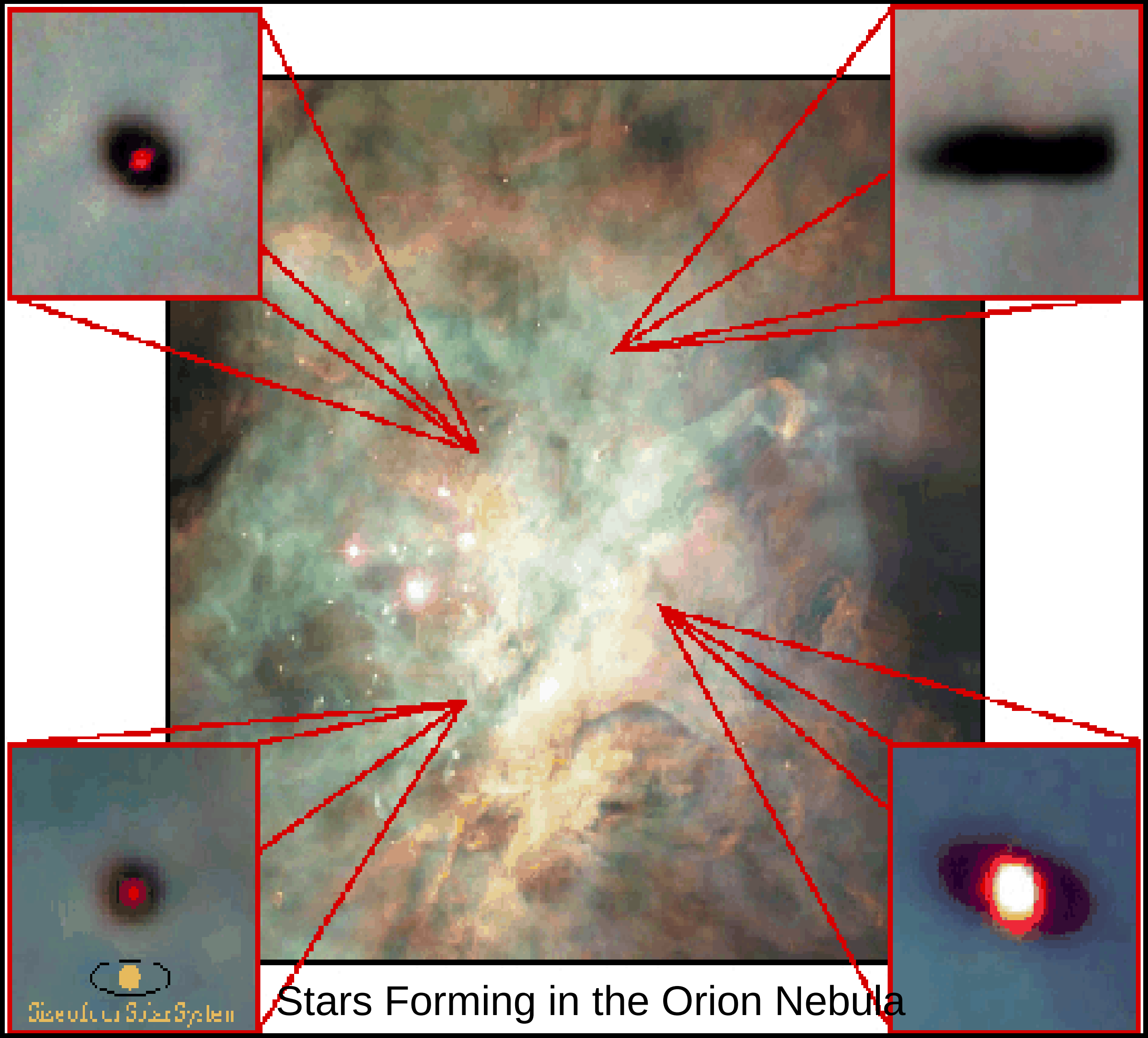
- How can we explain with a **single theory** how the varied kinds of objects in the Solar System formed?


molecular cloud
cloud core
dense fragments collapse under gravity, making protostars
ionizing radiation from nearby hot star
scattered light from a young star outlines its surrounding disk and powerful outflow jet

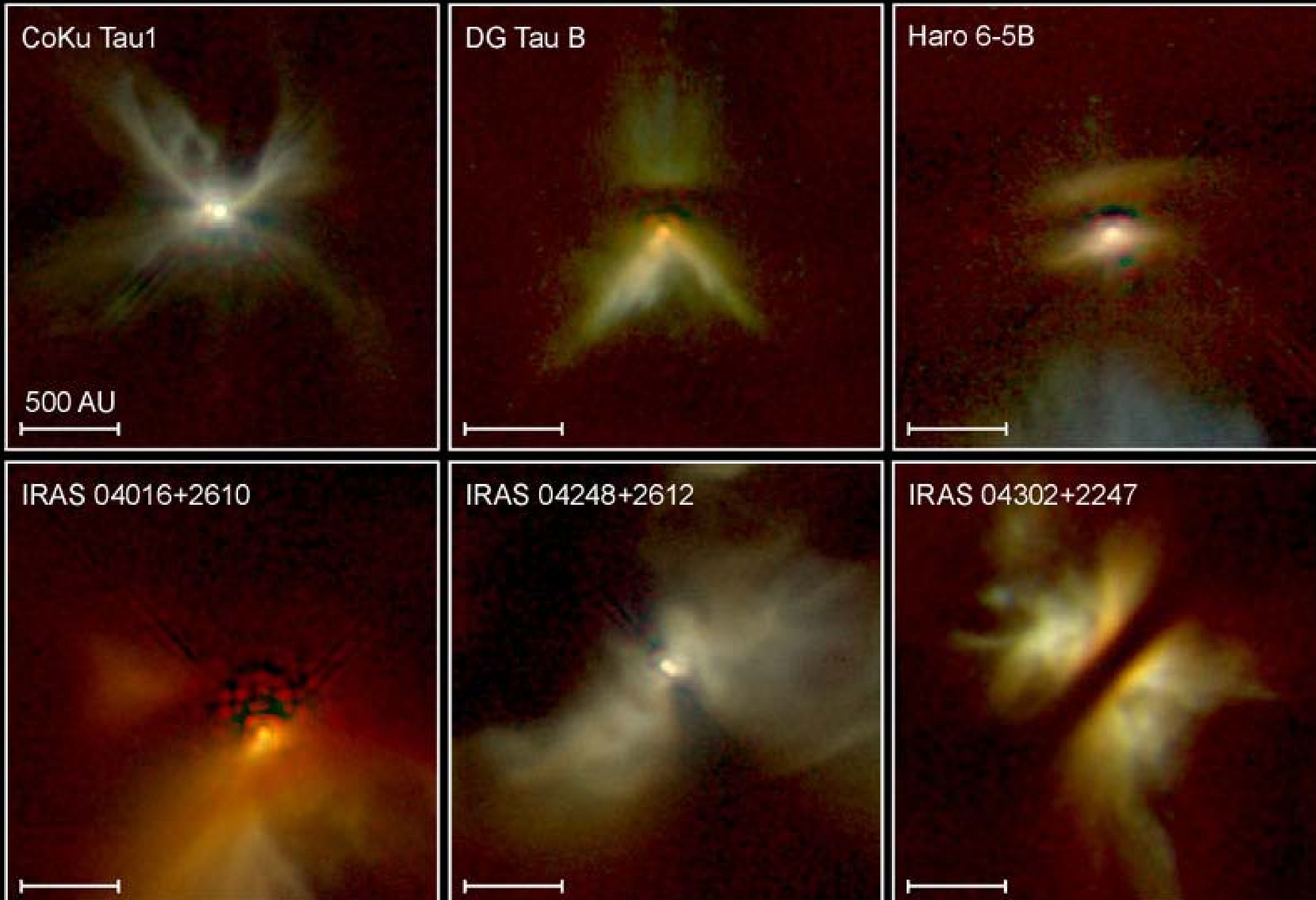

Outflow Jet
Scattered Light
through hole
Star


Outflow Jet
Reflected Light
Scattered Light
Edge-on
Disk

Protoplanetary Disks: Proplyds



Stars Forming in the Orion Nebula

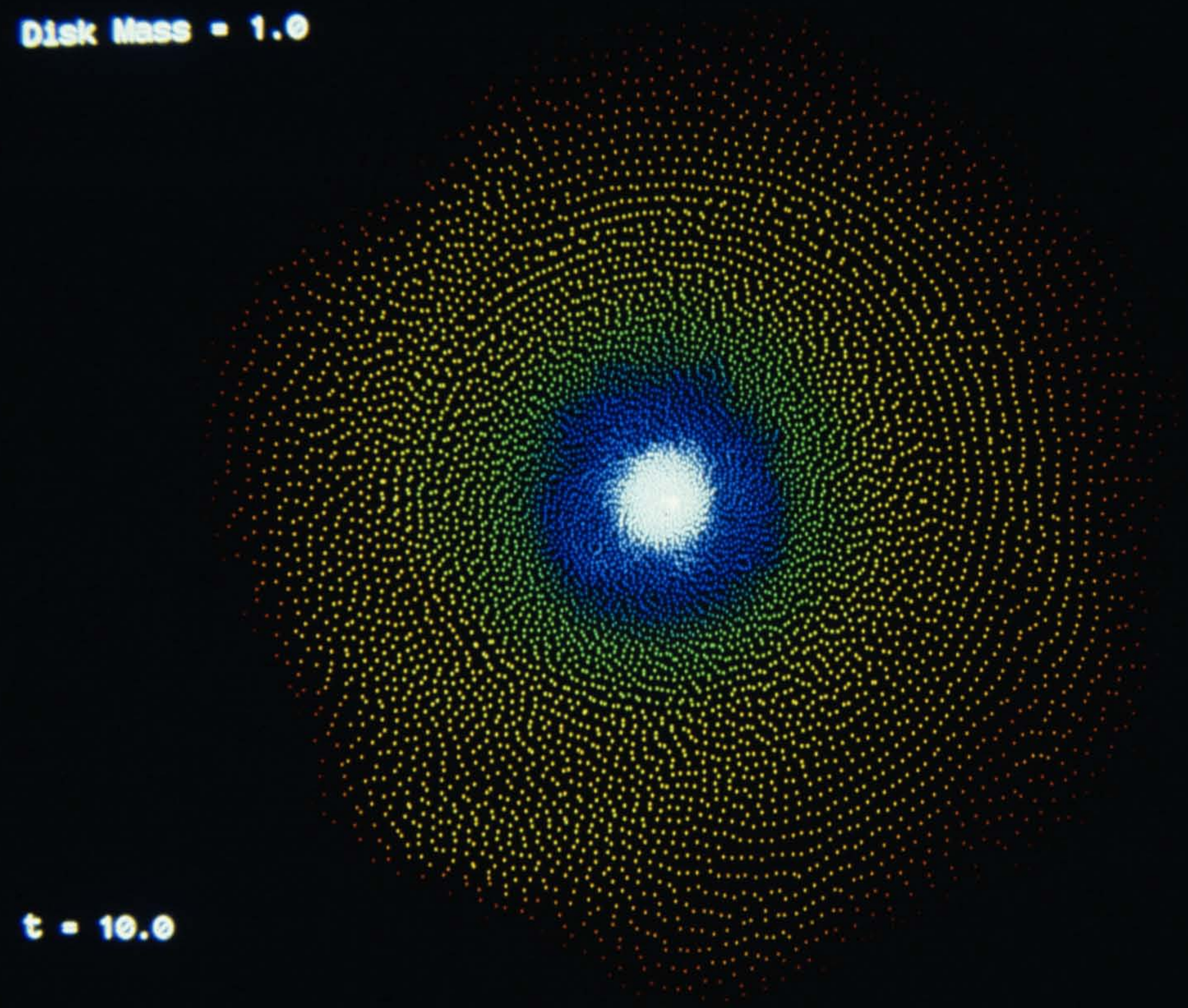


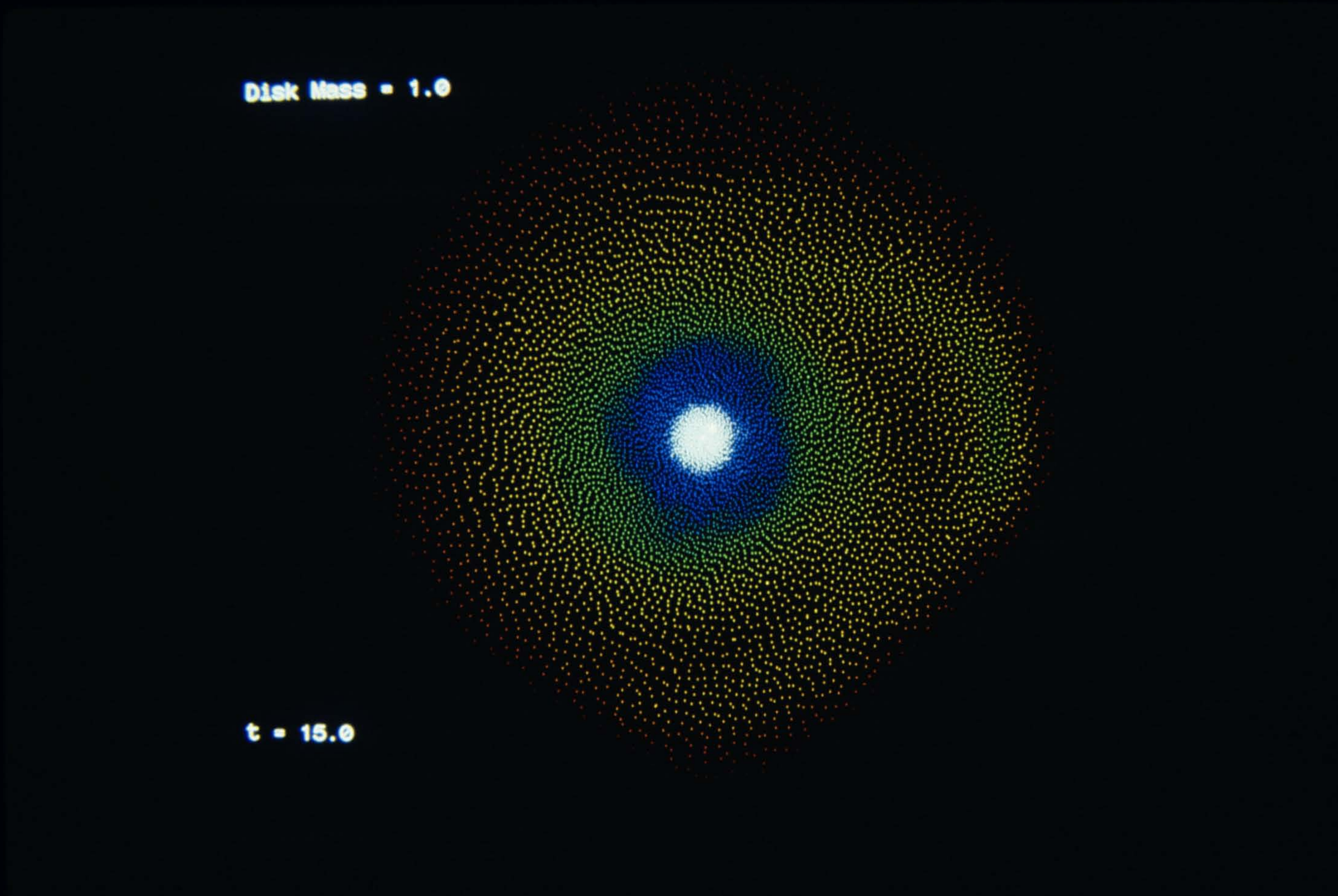
Young Stellar Disks in Infrared **HST • NICMOS**

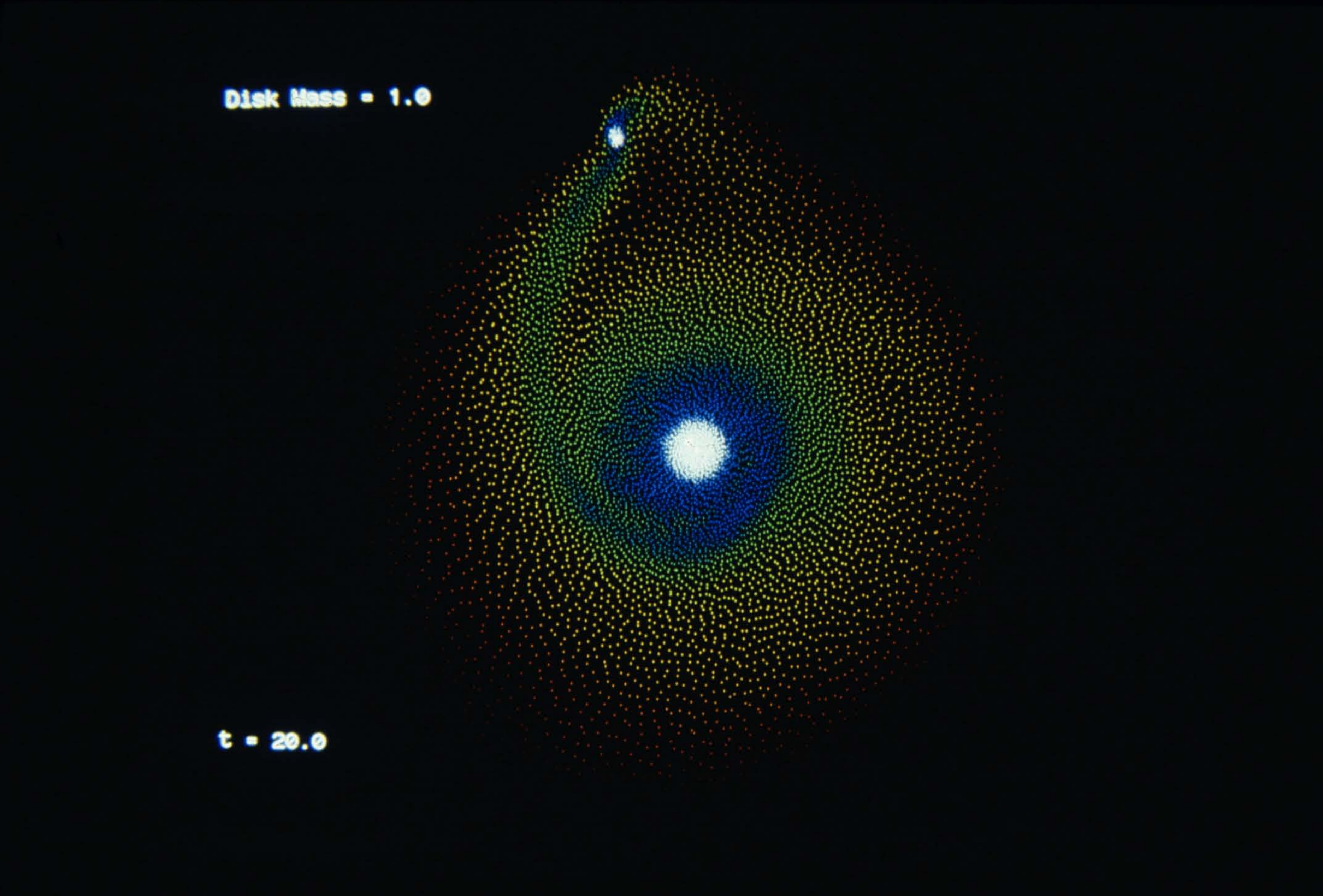
PRC99-05a • STScI OPO

D. Padgett (IPAC/Caltech), W. Brandner (IPAC), K. Stapelfeldt (JPL) and NASA

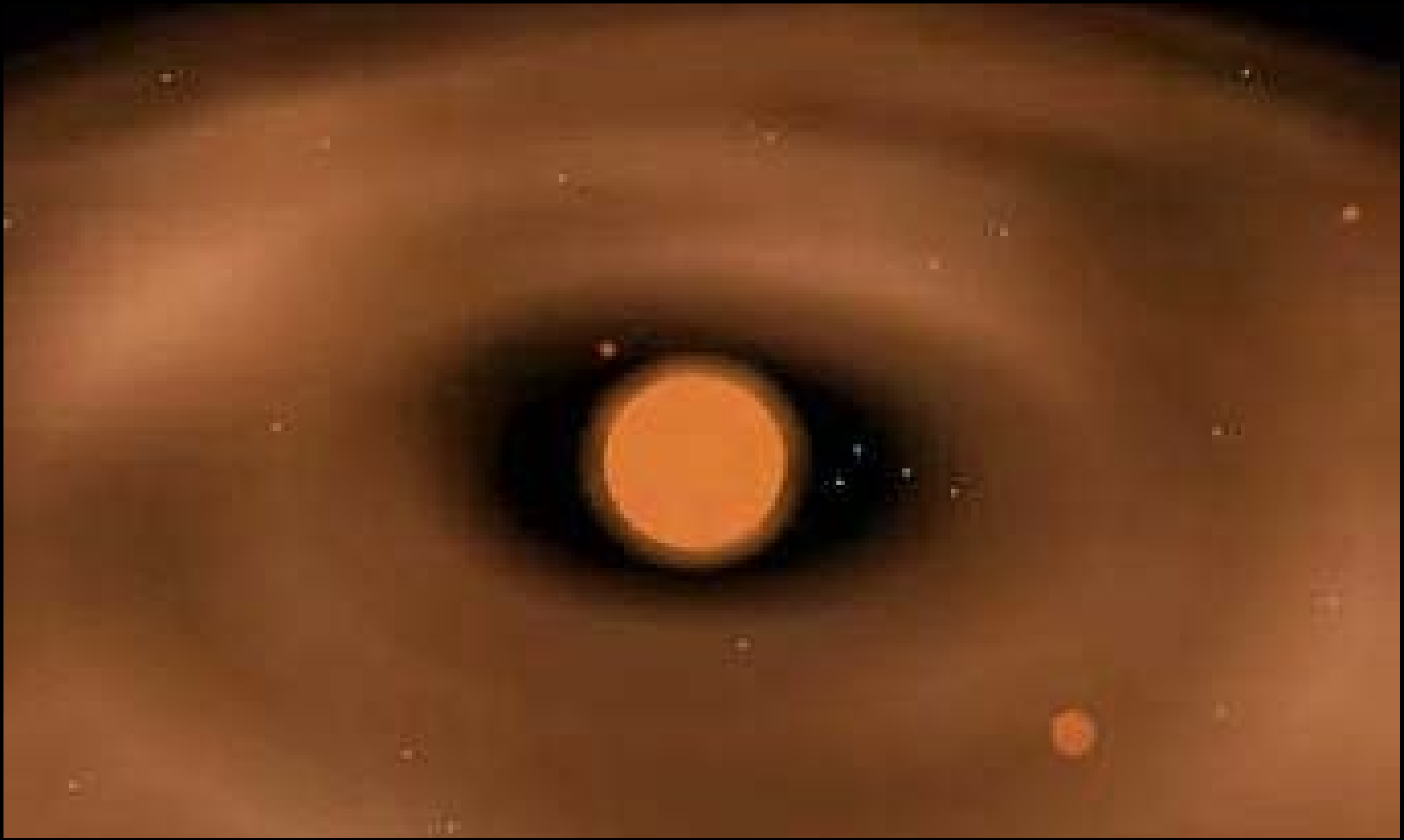
Planetesimal Theory

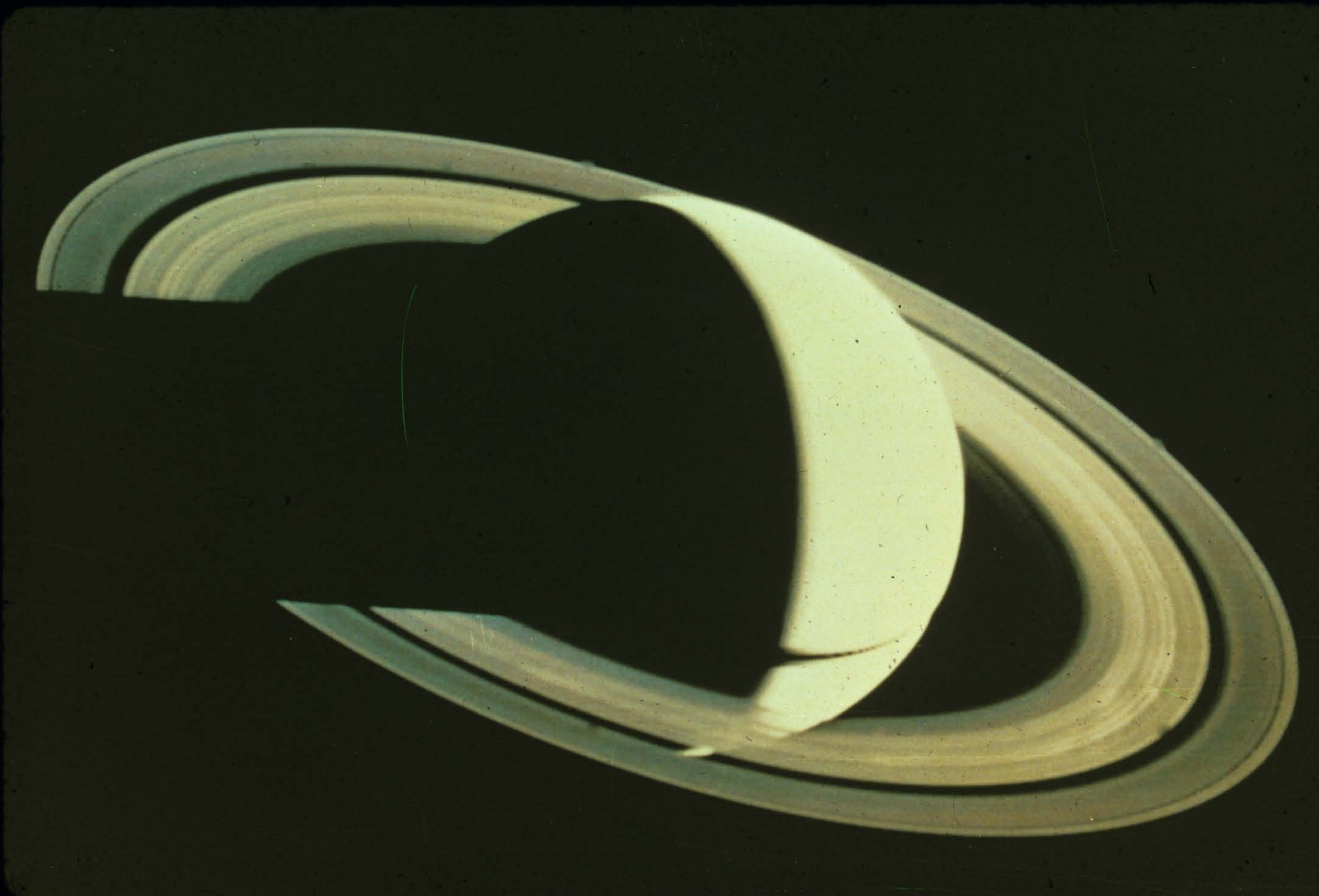


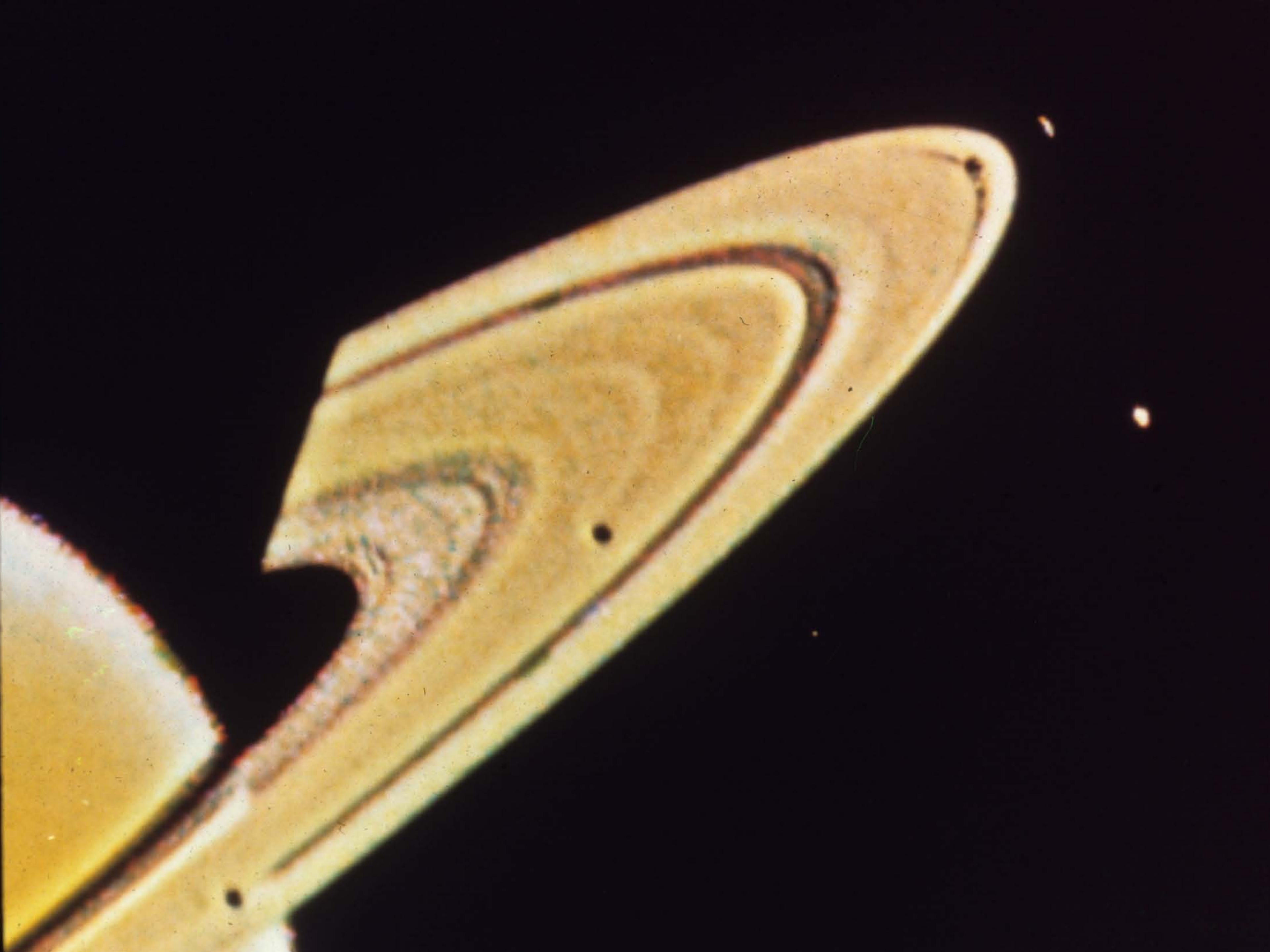

Disk Mass = 1.0
t = 15.0


Disk Mass = 1.0
t = 20.0

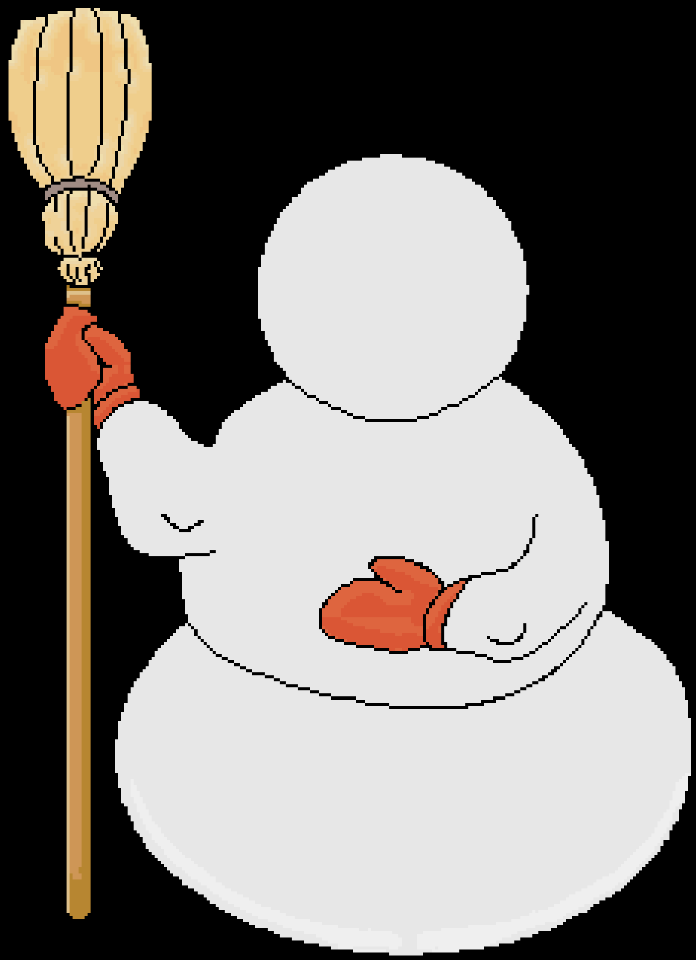
Movie



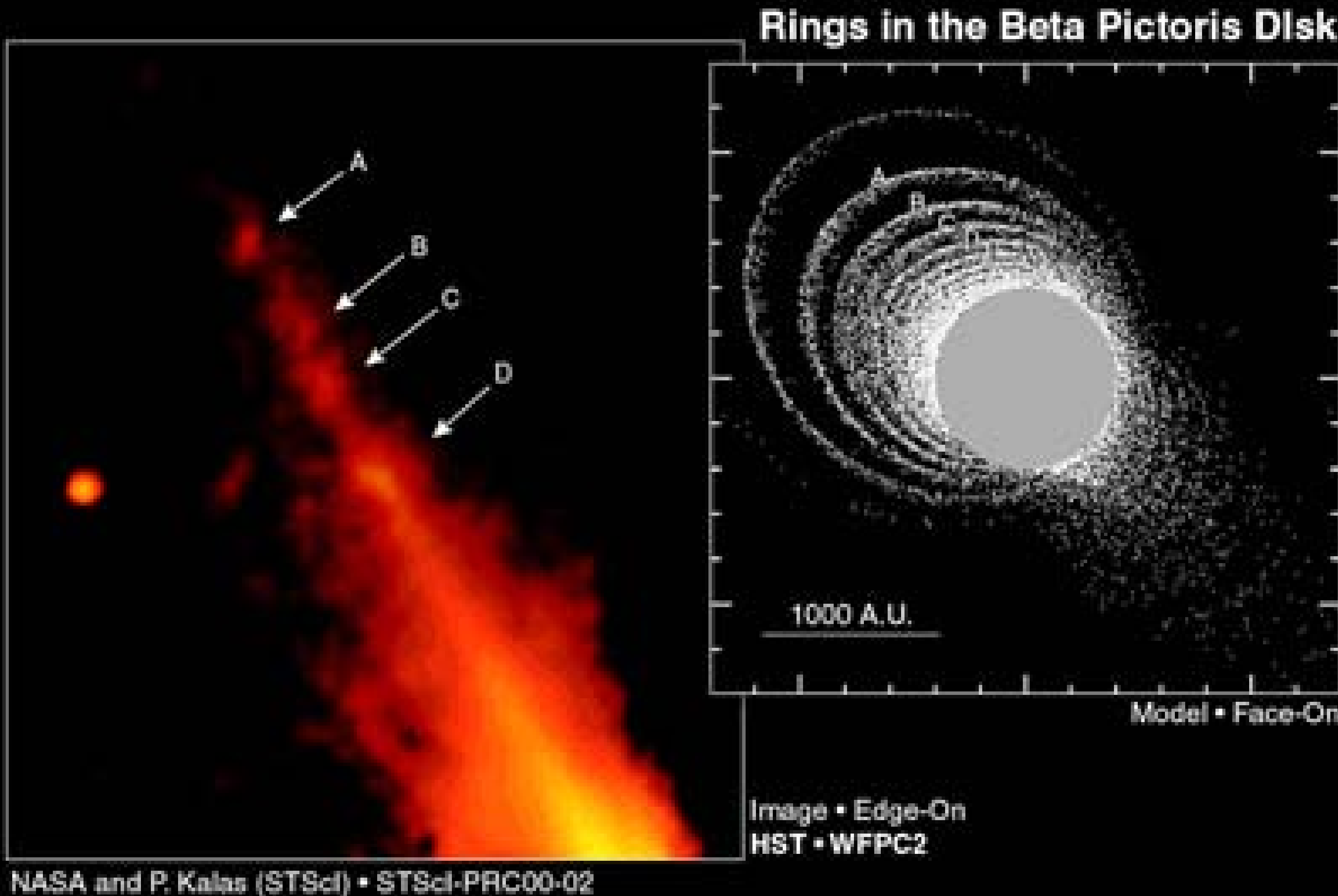


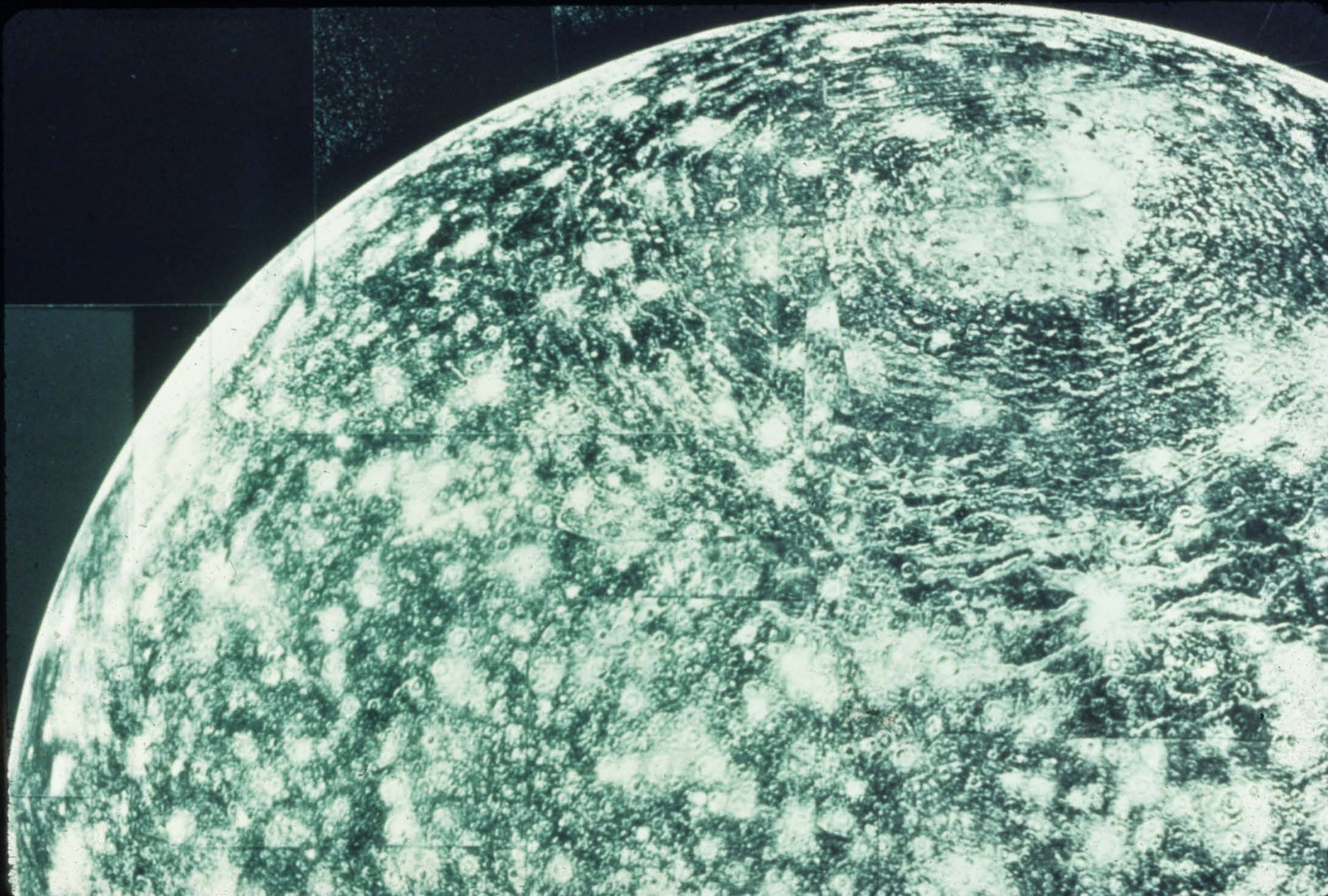


Planet Building…..



Beta Pictoris ~19.3 pc away






Meteor Crater, AZ…not a place to be ~49,000 years ago….

e uppermost Stairway Sandstone.

The map pattern shows that successive strata do not describe continuous belts but occur in discrete plates, each

to a decreased perimeter requires some systematic pattern, but we offer no explanation why this particular pattern developed rather than any of the multi-

tion of reflectors with horizons penetrated by exploratory wells.

Interpretation of records is complicated by an increase of velocities from

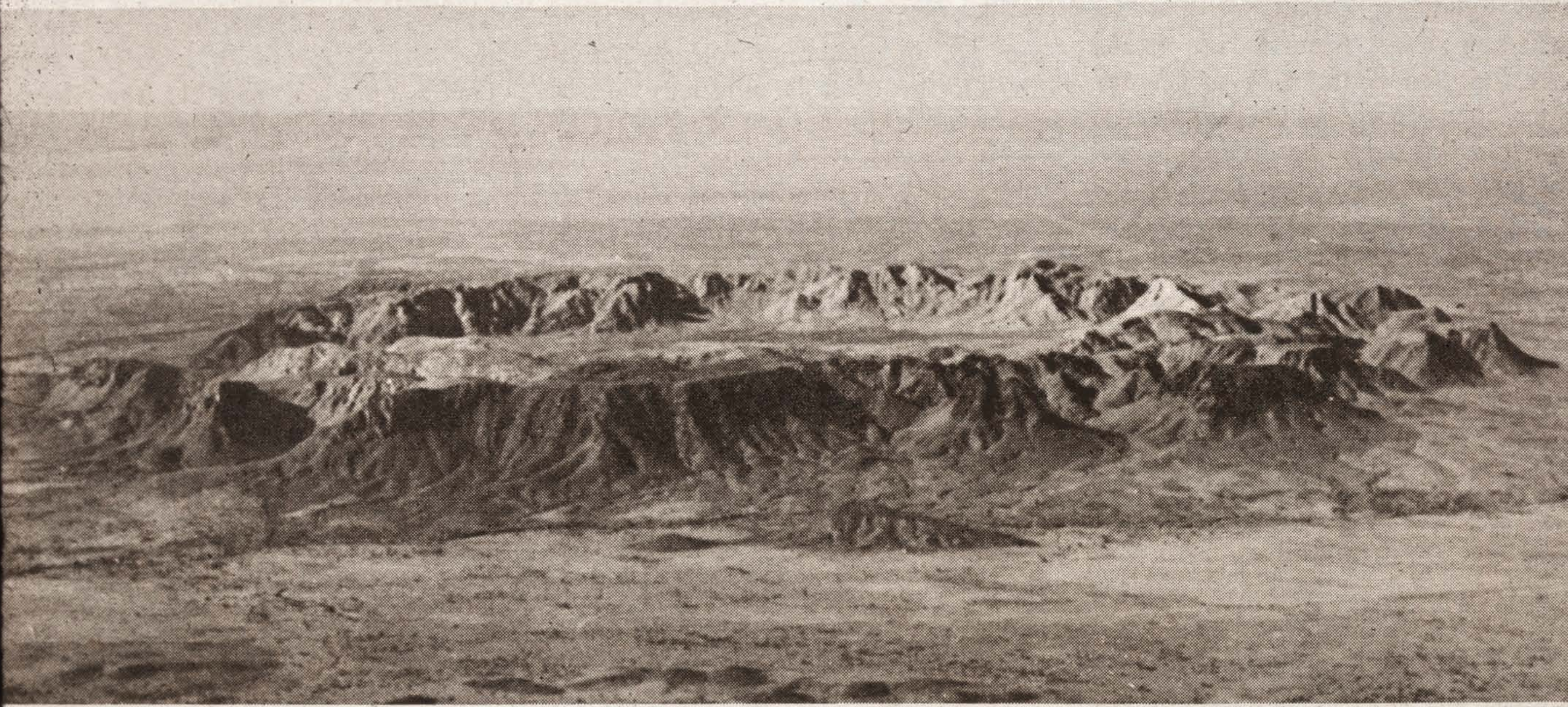
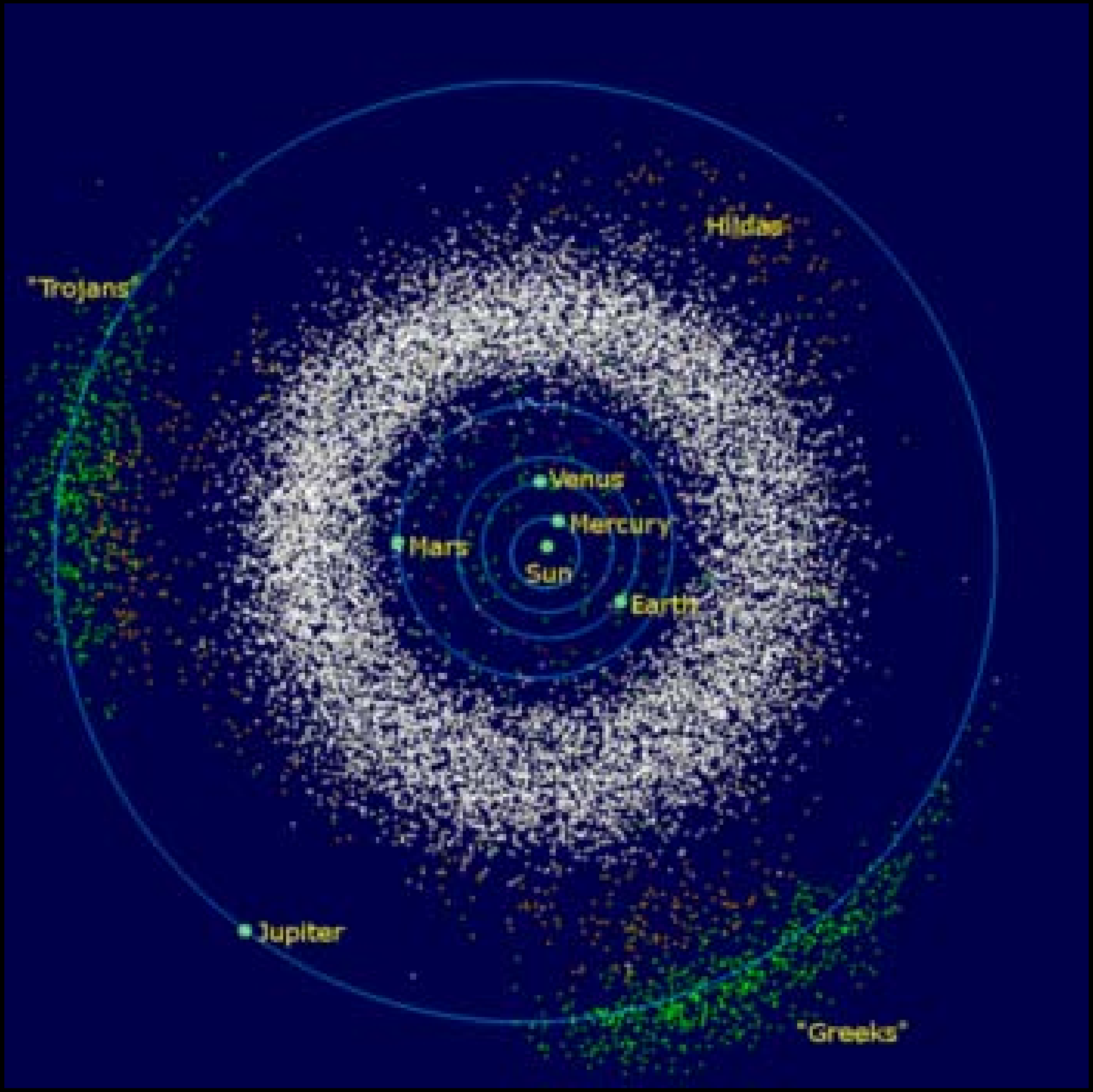
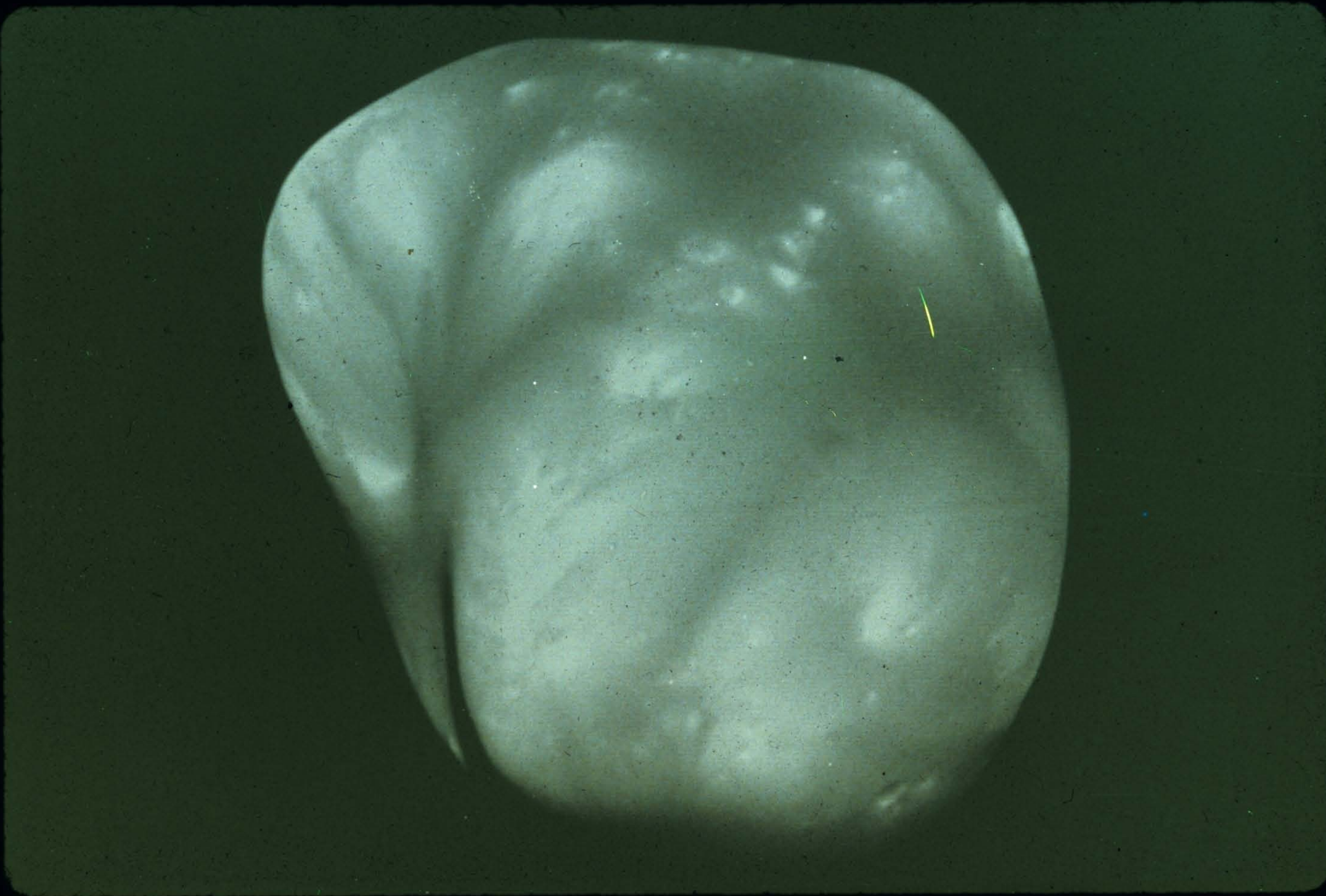


Fig. 2. Aerial view of Gosses Bluff from the north. [Photograph by C. Zawartko]

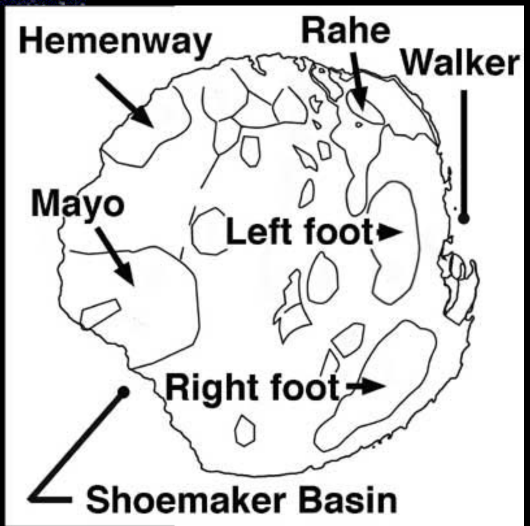
Ateroids

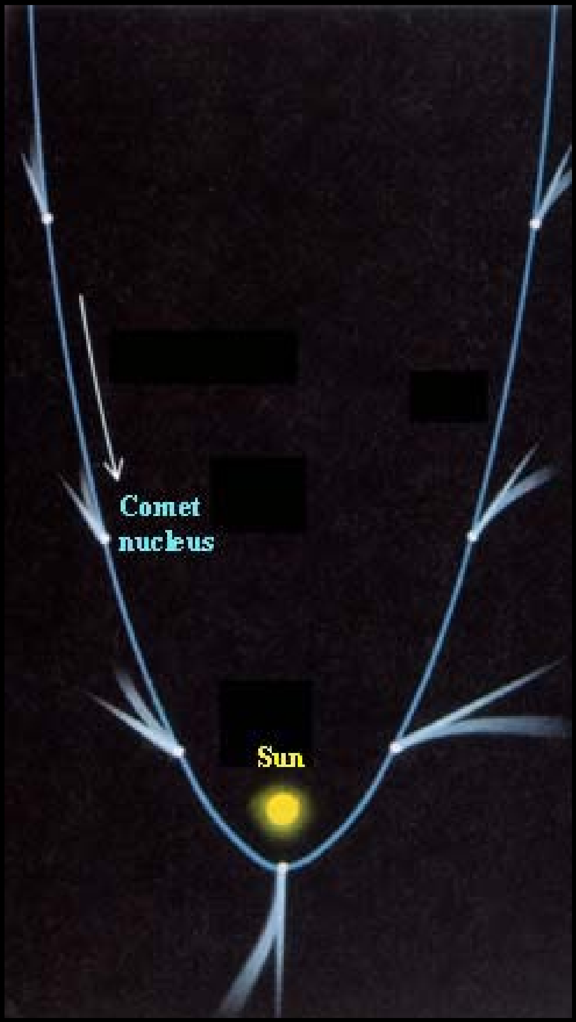


"Trojans"
Hildas
Venus
Mercury
Mars
Sun
Earth
Jupiter
"Greeks"



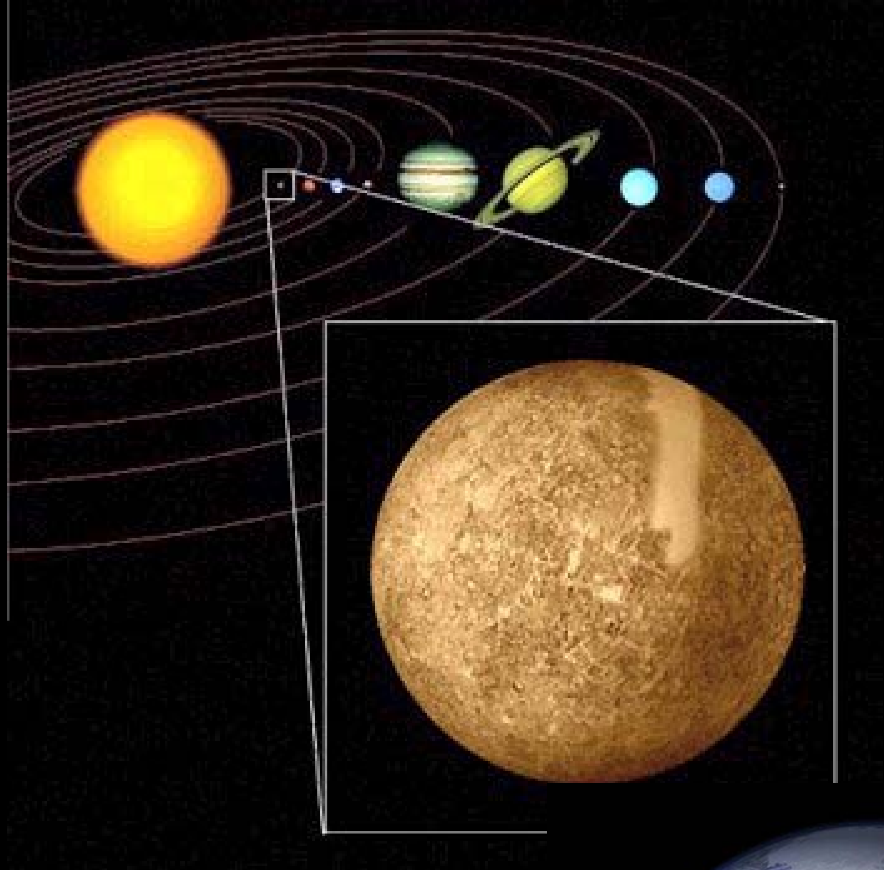
Comets – dirty snowballs of the outer solar system

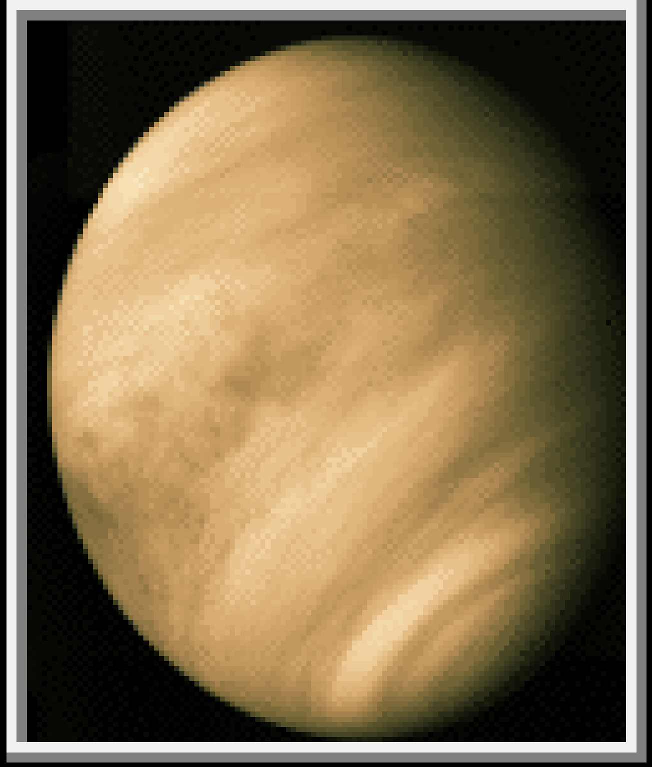




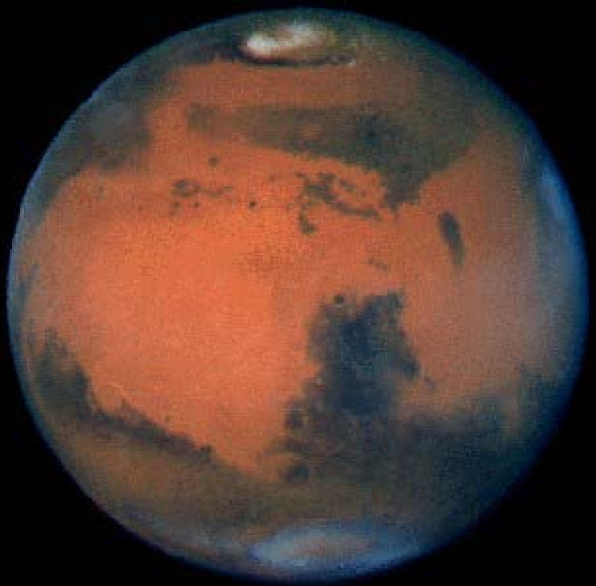
Comets Crashing on YouTube…

http://www.youtube.com/watch?v=16IlnQSY1ZQ





Terrestrial
planets
…inner Solar System



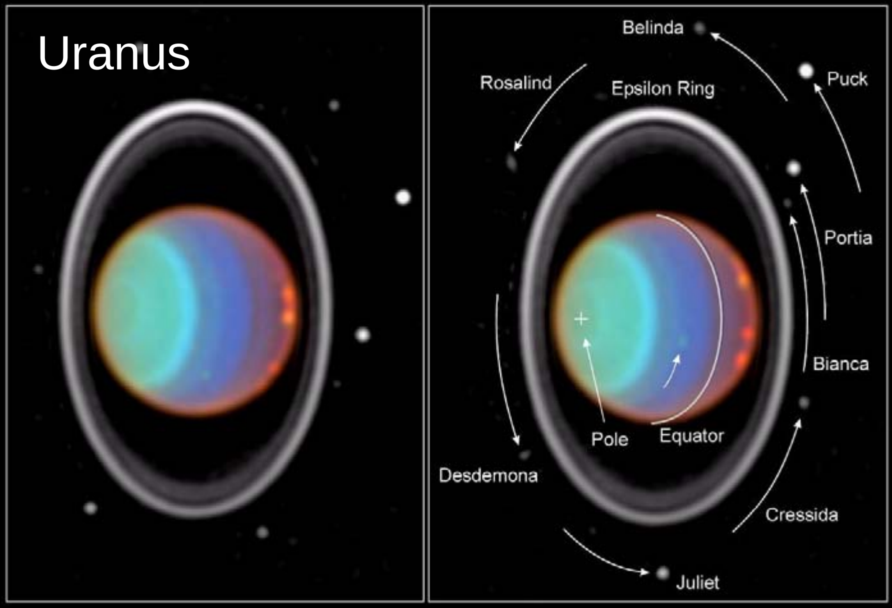
Mars • Syrtis Major • March 10, 1997 HST • WFPC2

Jovian Planets

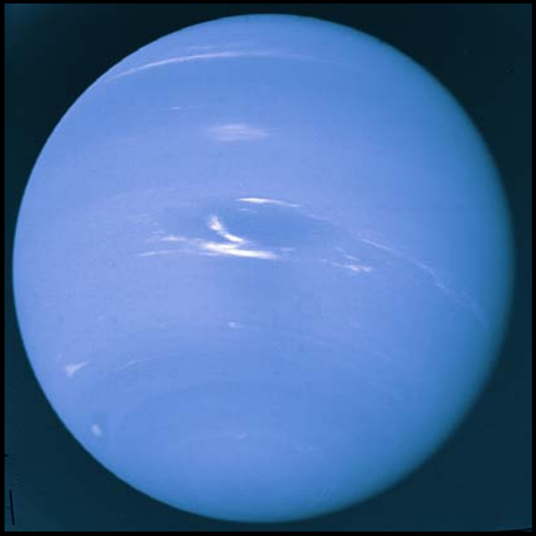
…different, why?

Jupiter

Saturn

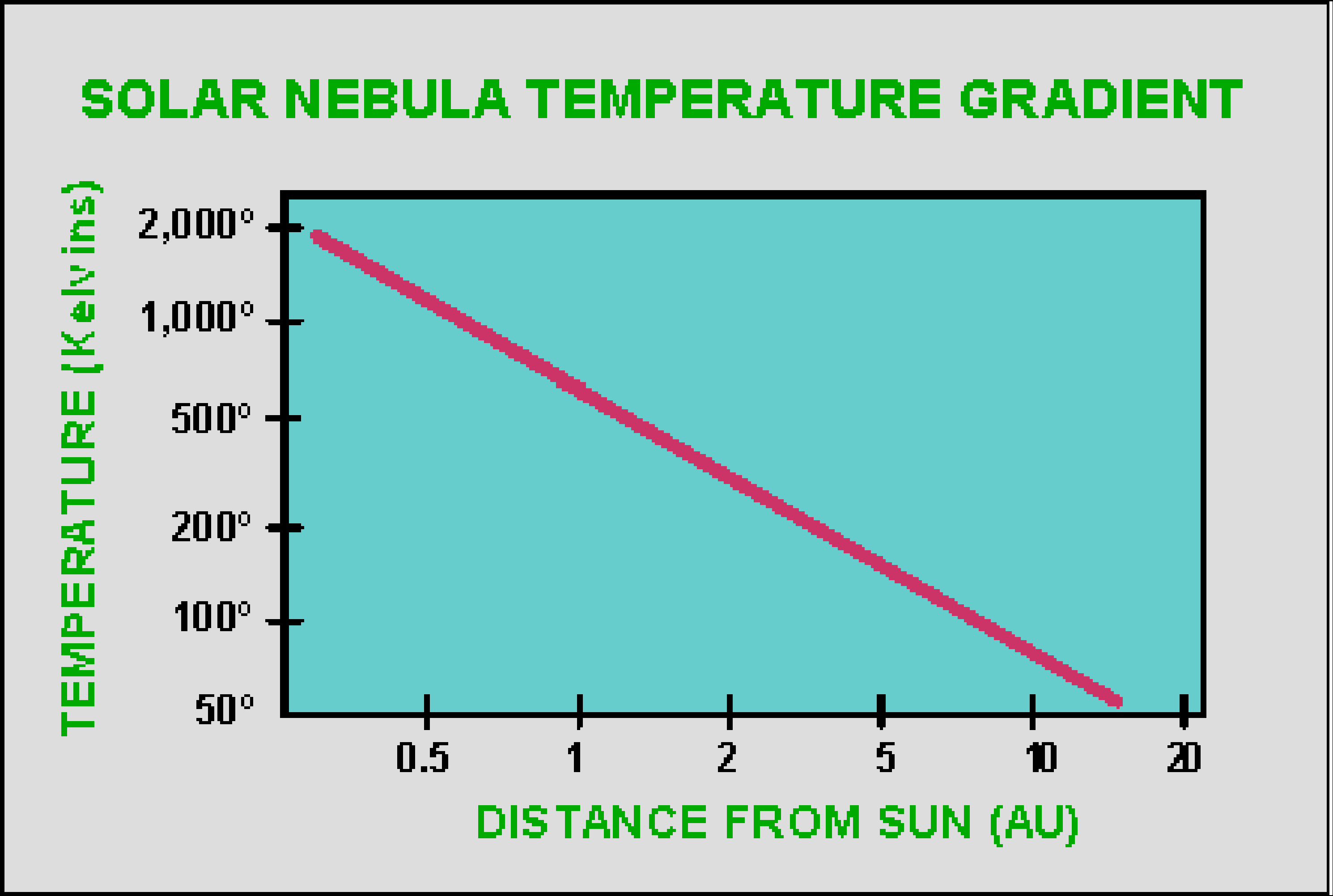


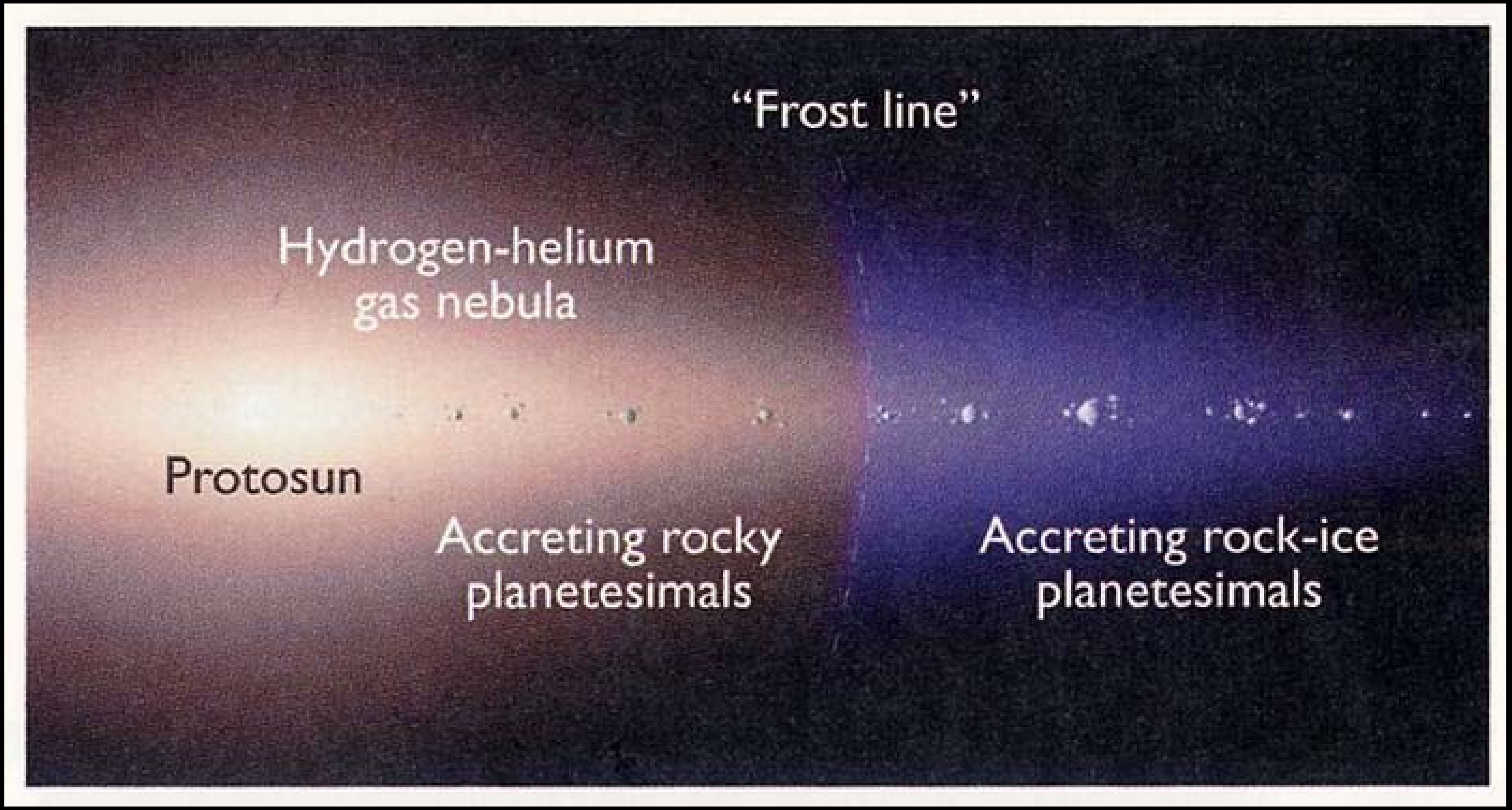
Neptune



…outer Solar System

Temperature Profile in Solar Nebula





"Frost line"
Hydrogen-helium
gas nebula
Protosun
Accreting rocky
planetesimals
Accreting rock-ice
planetesimals

Common Planet forming materials

Gases

Hydrogen (H)
Helium (He)
Neon (Ne)

Ices (condense @100-300K)

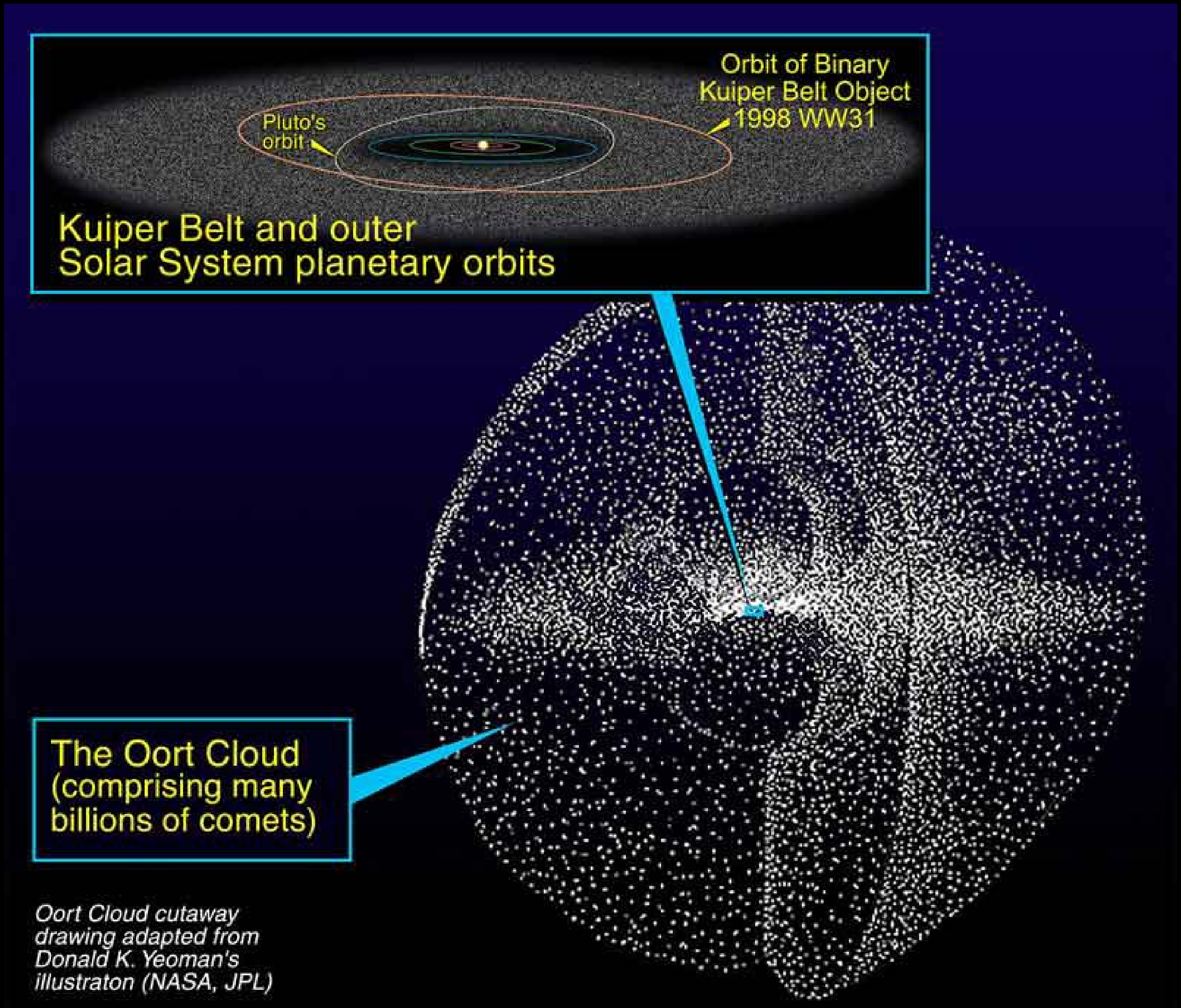
Water (H_2O)
Methane (CH_4)
Ammonia (NH_3)
Carbon Dioxide (CO_2)

Solids (condense ~1400K)

Iron (Fe)
Iron Sulfide (FeS)
Olivine ($(MgFe)SiO_4$)
Pyroxine ($CaMgSi_2O_6$)

Formation of Jovian Planets

- Formation is similar to the smaller rocky terrestrial planets, but they can also accumulate ICE!   (frost line)
- Once they get to ~15 times Earth's mass, they can gravitationally attract hydrogen and helium gas too!
- Thus we get massive gas-giant planets in the outer Solar System
- Leftovers are comets, asteroids (Kuiper Belt and Oort Cloud)

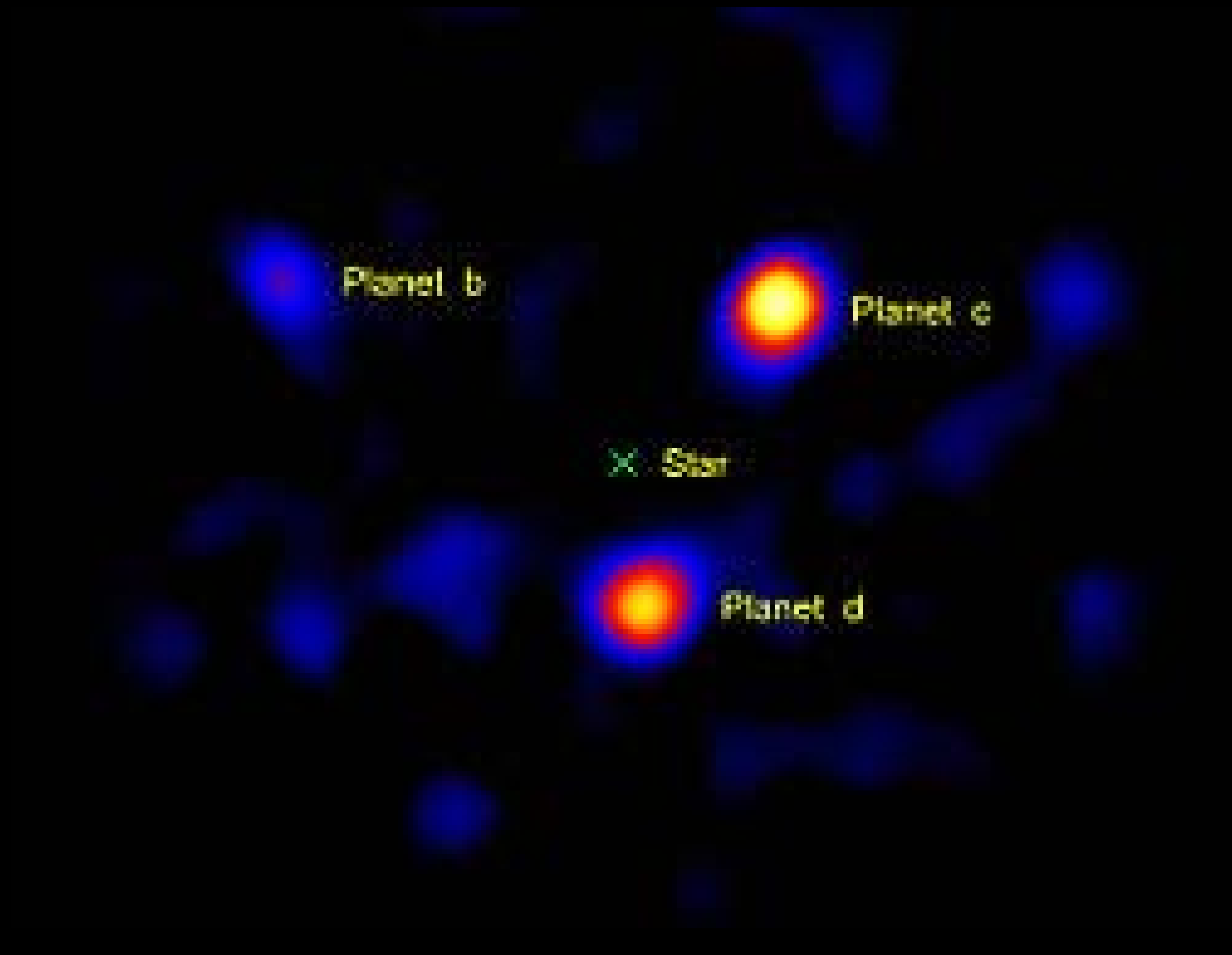


Oort cloud – pieces of the primordial Solar Nebula in a “Deep Freeze”... home of most comets

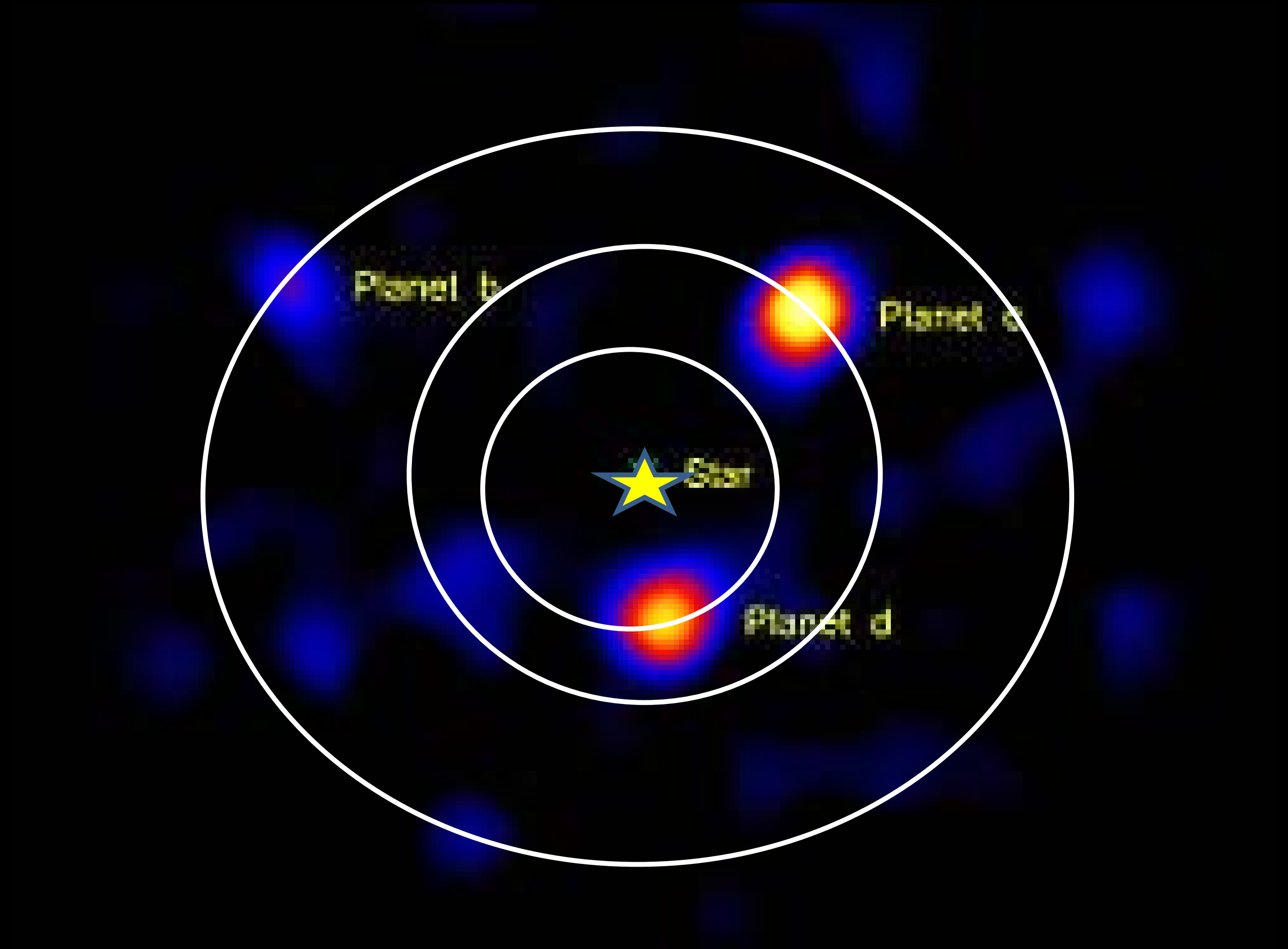
How can we detect planets?

- Direct Imaging
- Astrometry
- Doppler Spectroscopy
- Transit Technique
- Gravitational Microlensing

Direct Imaging: HR8799

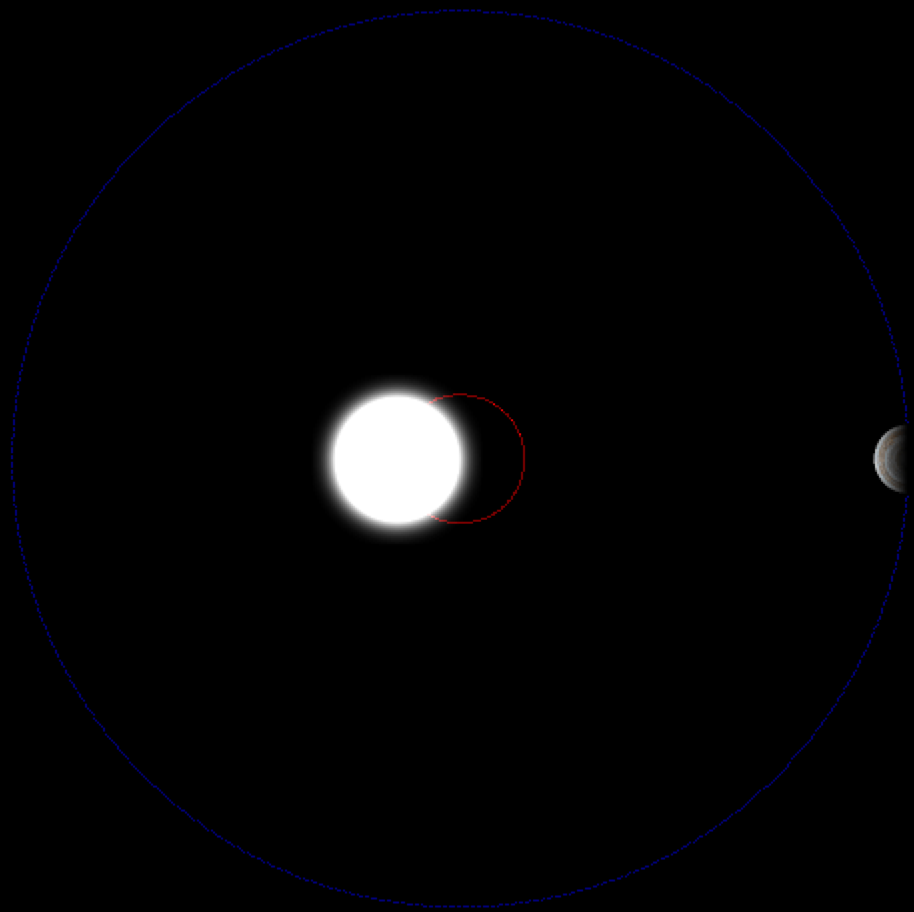


Direct Imaging: HR8799

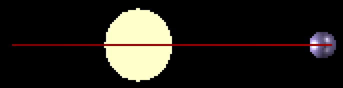


Astrometry

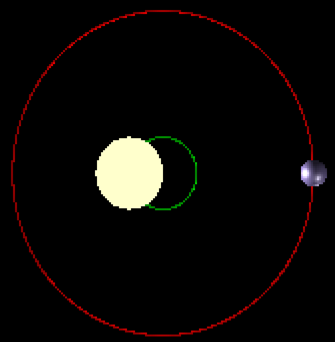
Face-on
Good



Doppler Spectroscopy

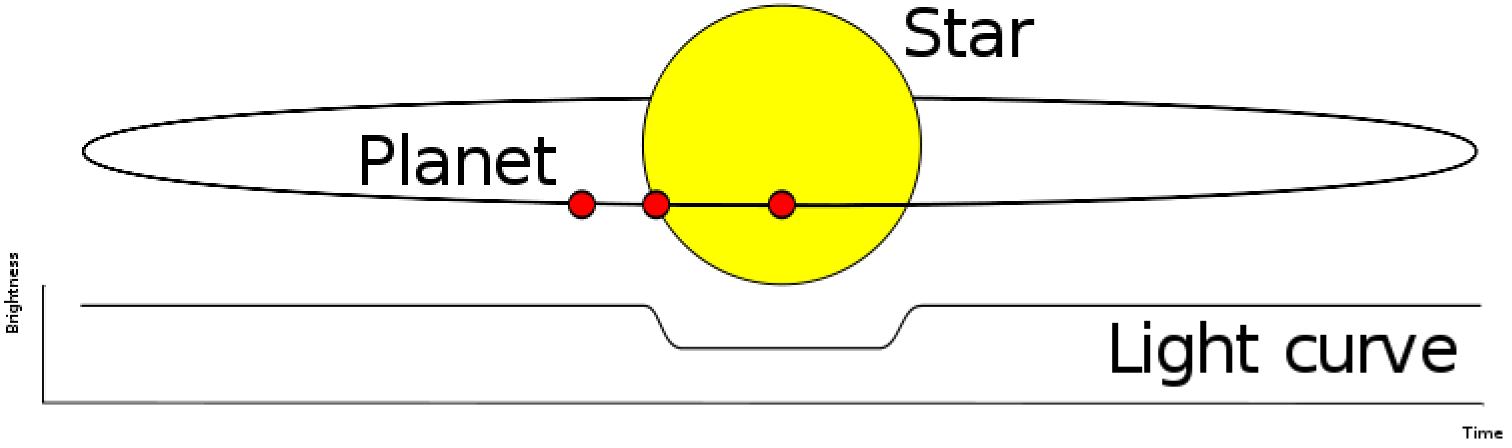


Edge-on
Good…



Face-on
Bad….

Transit Technique



Gravitational Microlensing

How many planets have been discovered?

How many planets have been discovered?

490!

Terrestrial Planet Finder