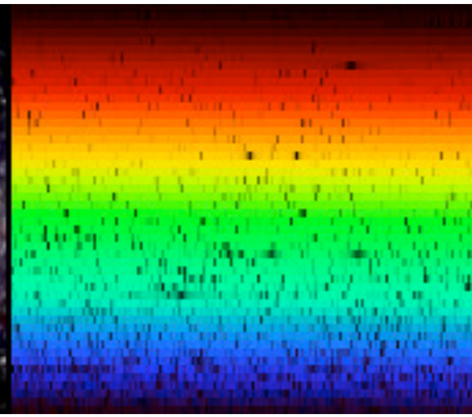
ASTR/PHYS 3070: Foundations Astronomy



Week 5 Thursday

Today's Agenda

- Telescopes
- Making measurements
- Group problem
- Observing "invisible" light
- Sun / Solar System ???

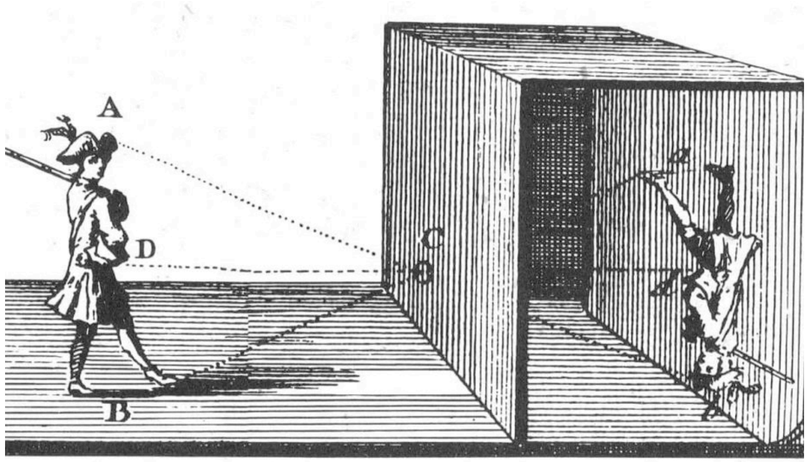
Connection details sent in class announcement

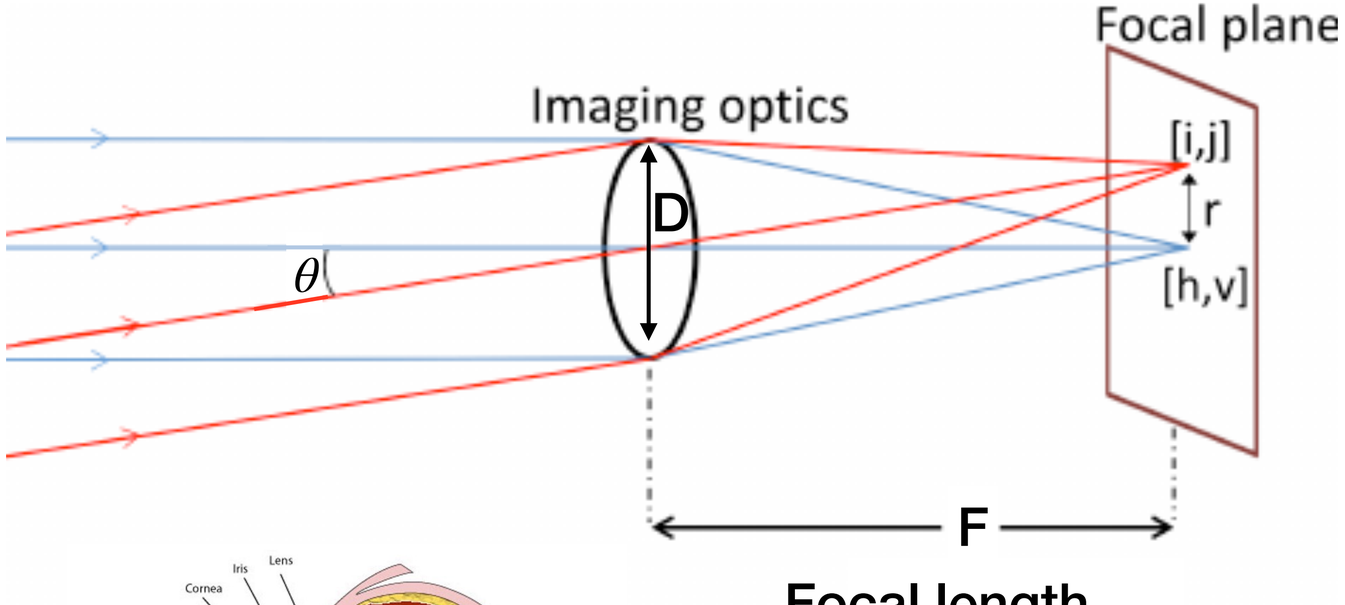
Announcements / Reminders

- Read Chapter 7.1, 8.1-2, 11.1-2
- HW 4 due September 24th (tomorrow!) at 11:59pm via Canvas upload

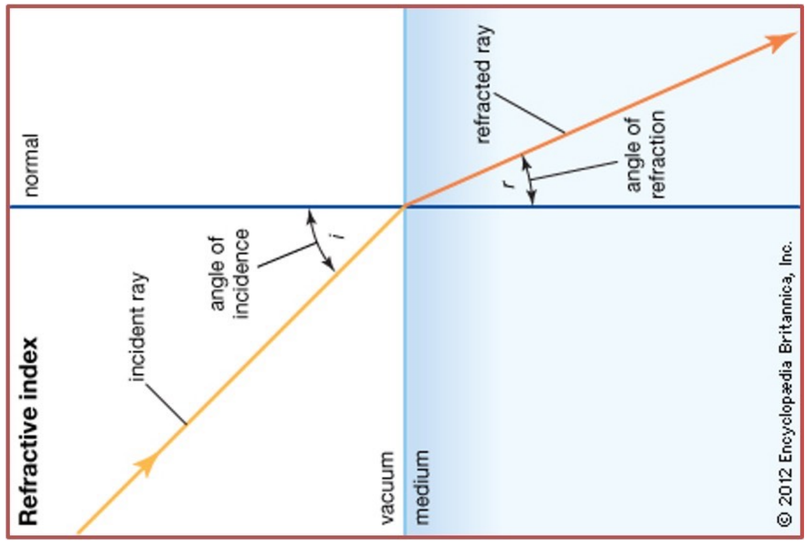
- HEAP talk at 4pm over Zoom (only)
  - Gravitational Wave detection with asteroids
- Colloquium at 2pm in JFB auditorium & Zoom
  - Deep Underground Neutrino Experiment (DUNE)

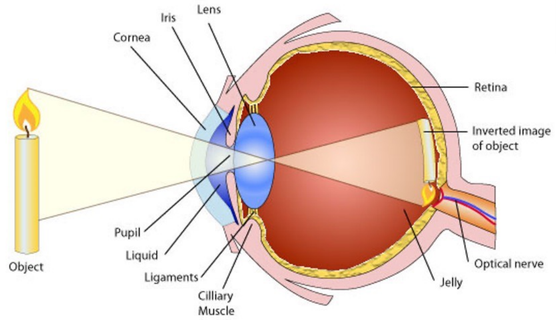
Telescopes collect (often by focusing) light





Focal length



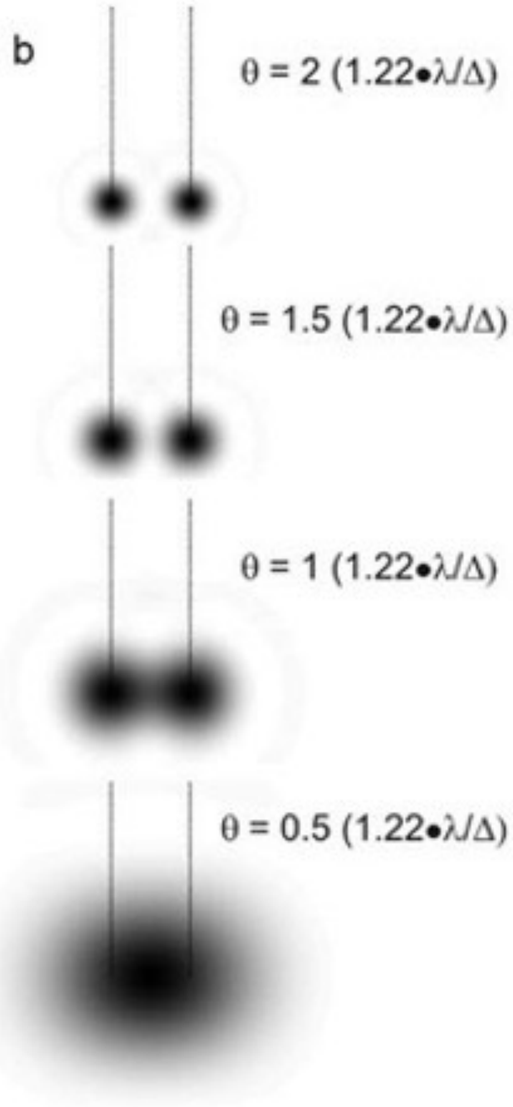


Our eyes are telescopes!

Plate scale = $\frac{\theta}{r}$ (arcsec/mm)

$$\theta_{\min} = 1.22\frac{\lambda}{D}$$

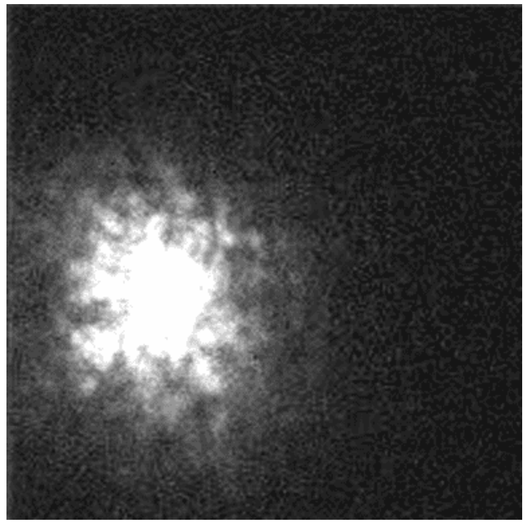
Image Resolution



$$\theta_{\min} = 1.22\frac{\lambda}{D}$$

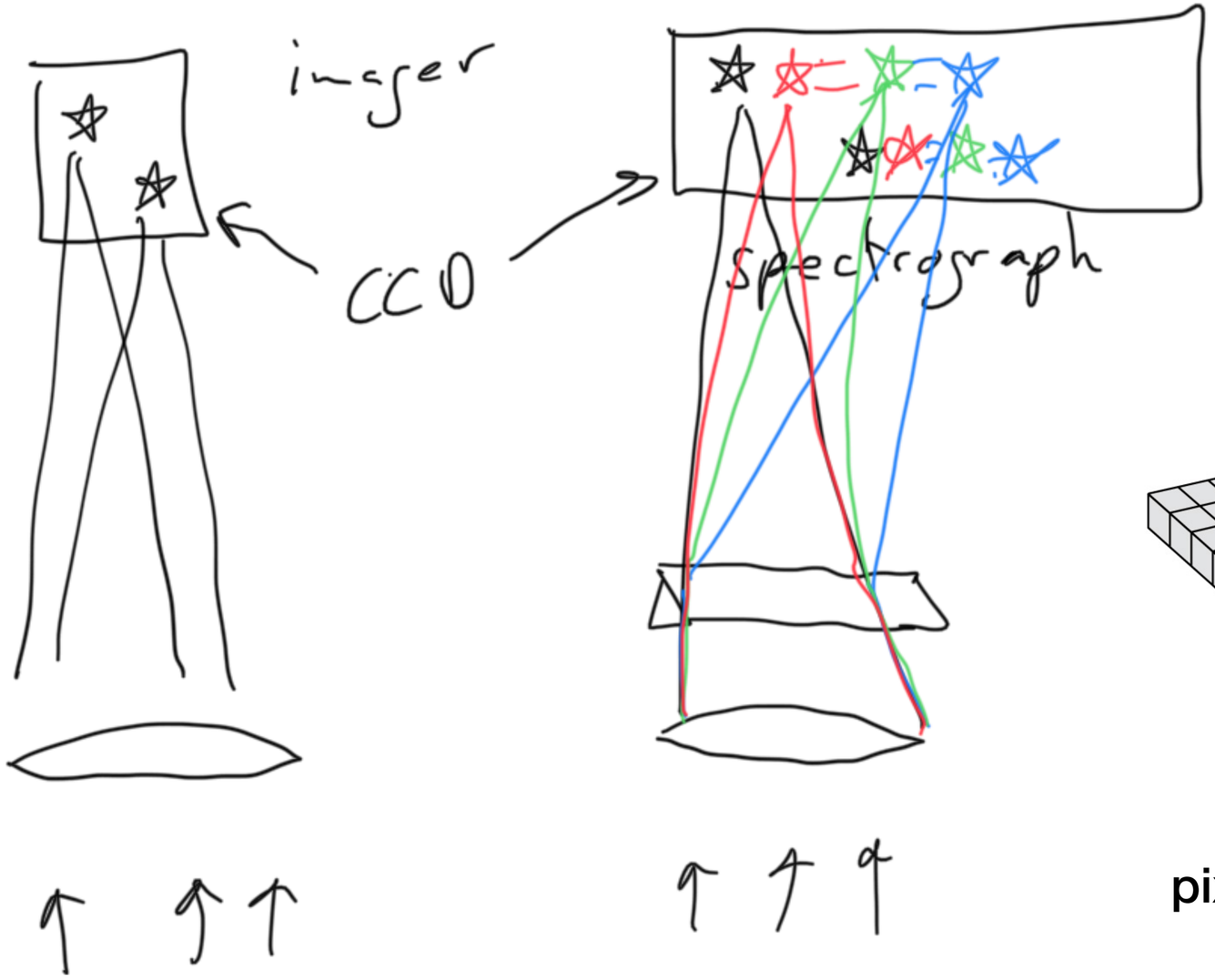
In ideal case, resolution determined by size of mirror

Often, mirror imperfections (misalignments, roughness) or atmospheric effects make the actual resolution worse

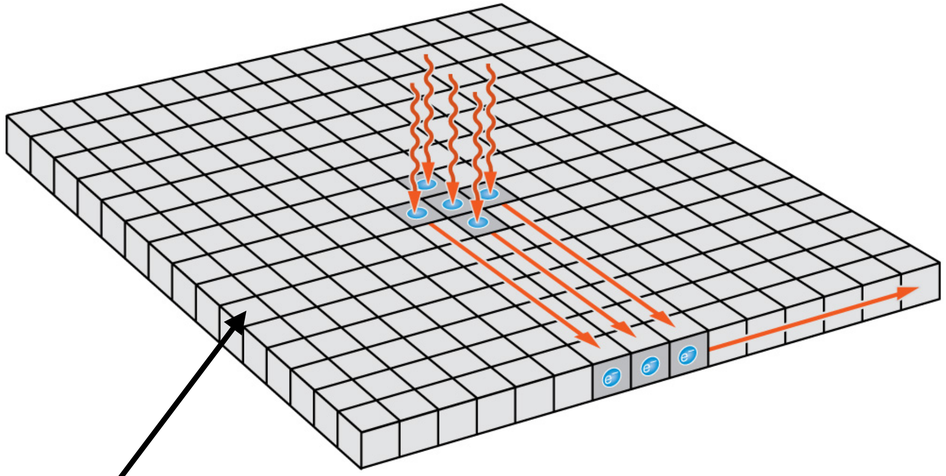


Why stars twinkle

Imaging versus Spectroscopy



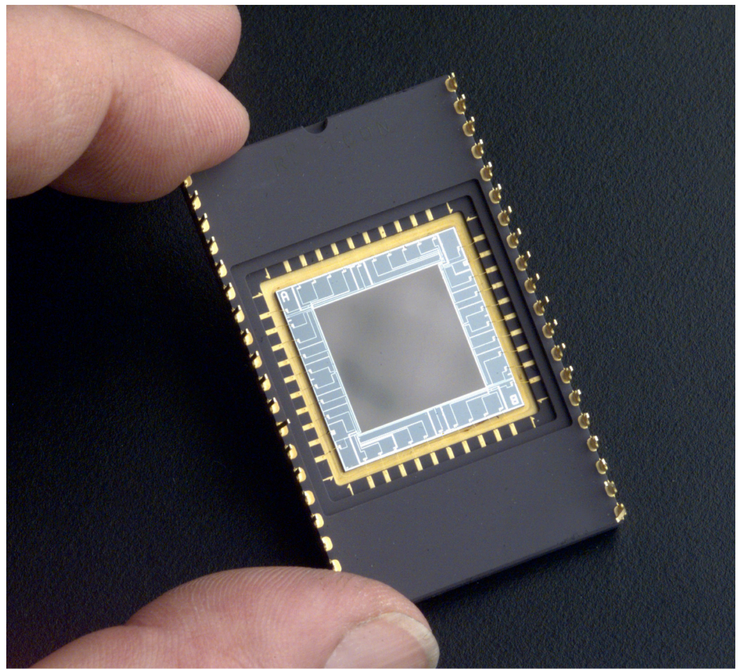
CCD
Charged Coupled Device



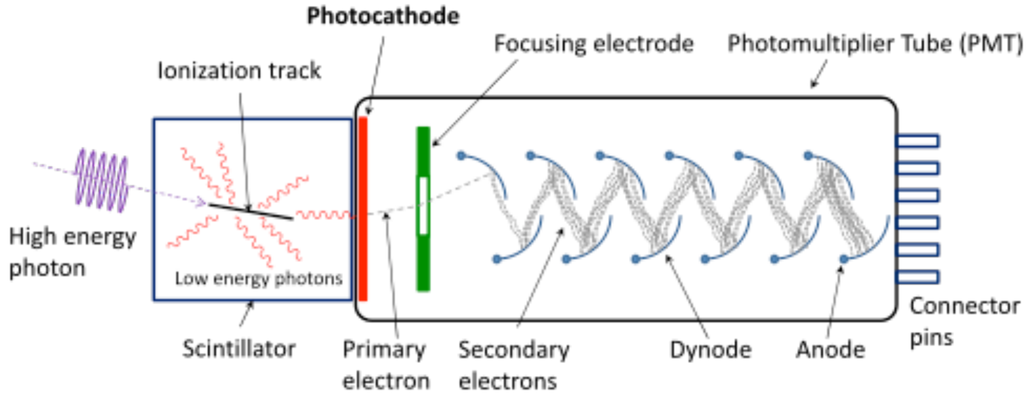
pixel (picture element)

Detectors

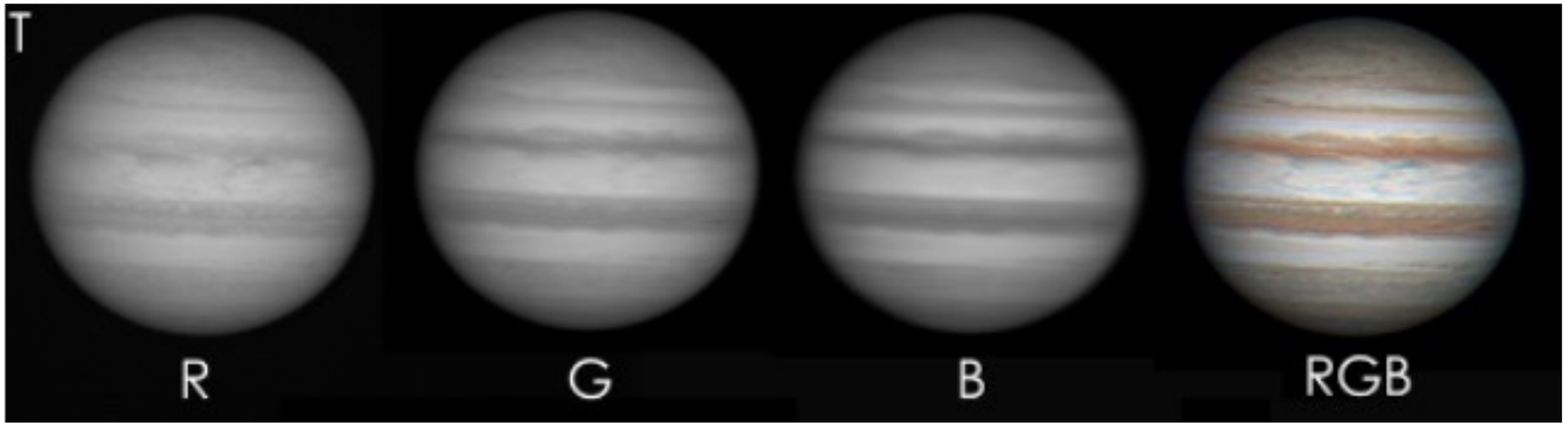
CCD

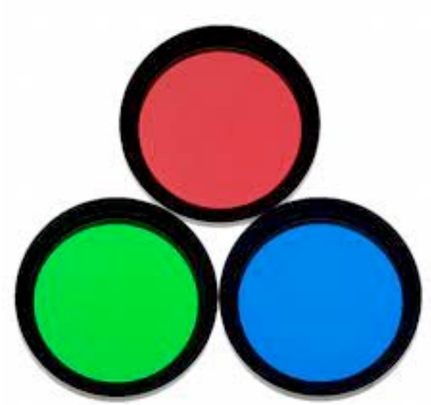


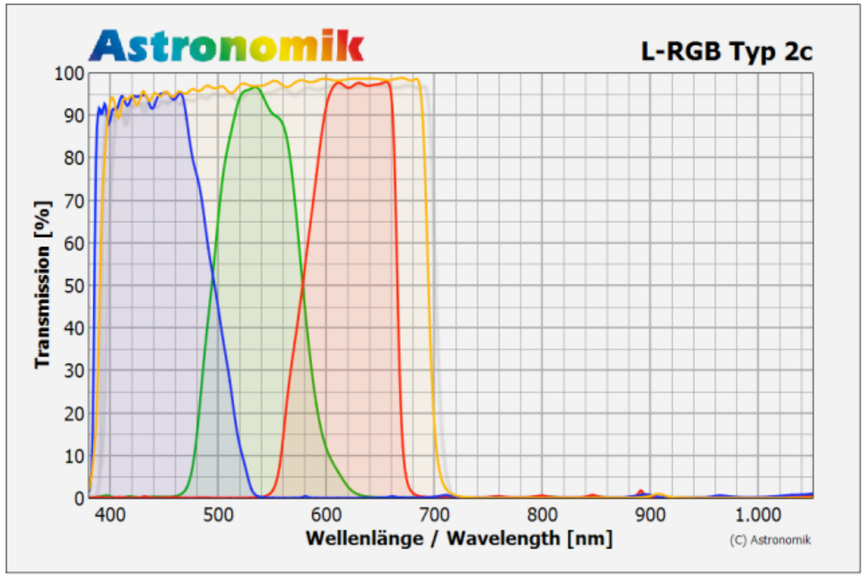
Photomultiplier tube

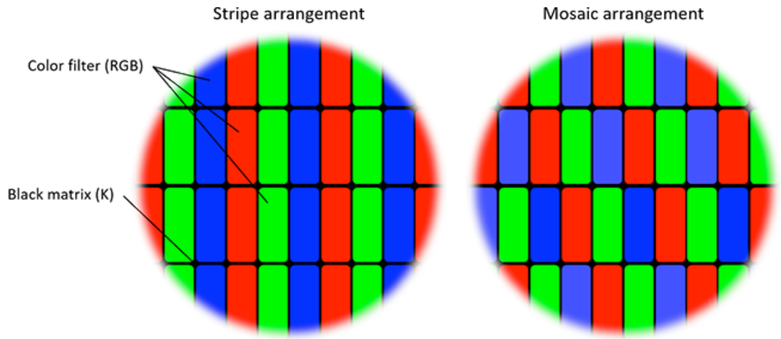


“Color” Imaging



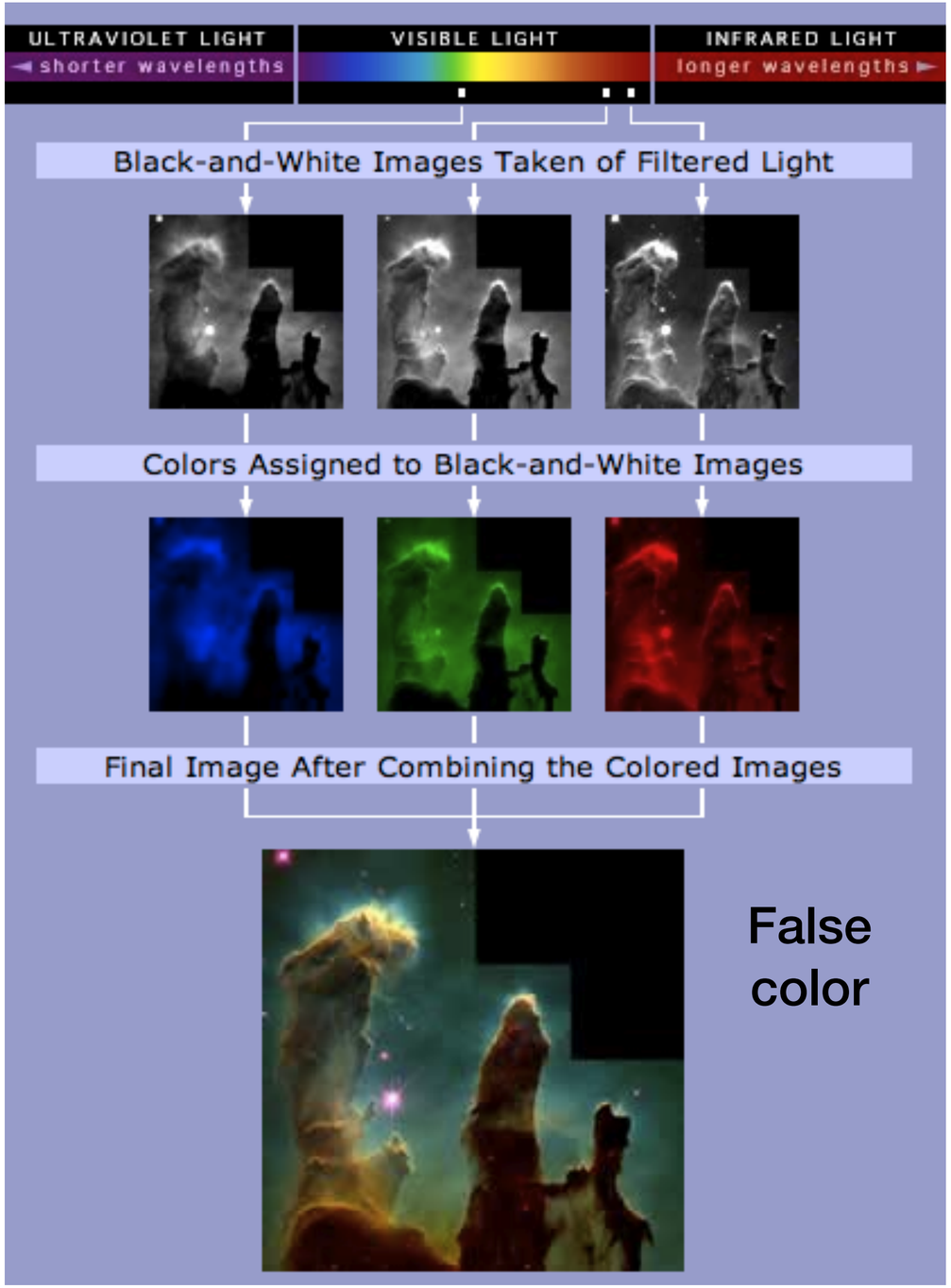






Phone Camera


ULTRAVIOLET LIGHT
shorter wavelengths
VISIBLE LIGHT
INFRARED LIGHT
longer wavelengths
Black-and-White Images Taken of Filtered Light
Colors Assigned to Black-and-White Images
Final Image After Combining the Colored Images
True color


ULTRAVIOLET LIGHT
shorter wavelengths
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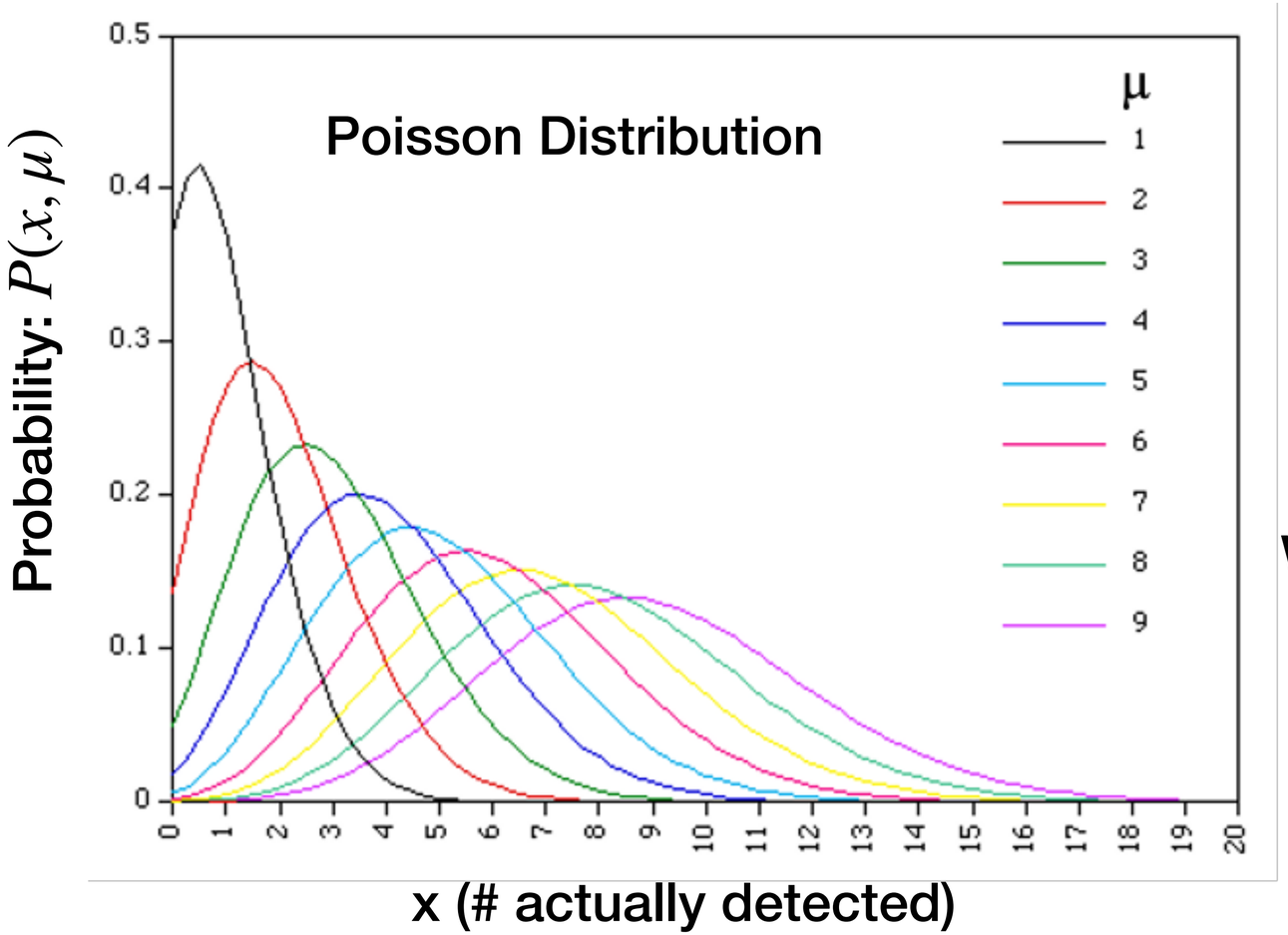
Black-and-White Images Taken of Filtered Light
Colors Assigned to Black-and-White Images
Final Image After Combining the Colored Images
False color

Making Measurements

Photons arrive randomly — # detected not necessarily # “should” detect



μ —> # “should” detect

$$P(x,\mu) = \frac{\mu^x}{x!} e^{-\mu}$$

Width of the distribution, which gives the uncertainty (or error) of the measurement, is $\sigma = \sqrt{\mu}$

What is the flux (and uncertainty) of this XRB?

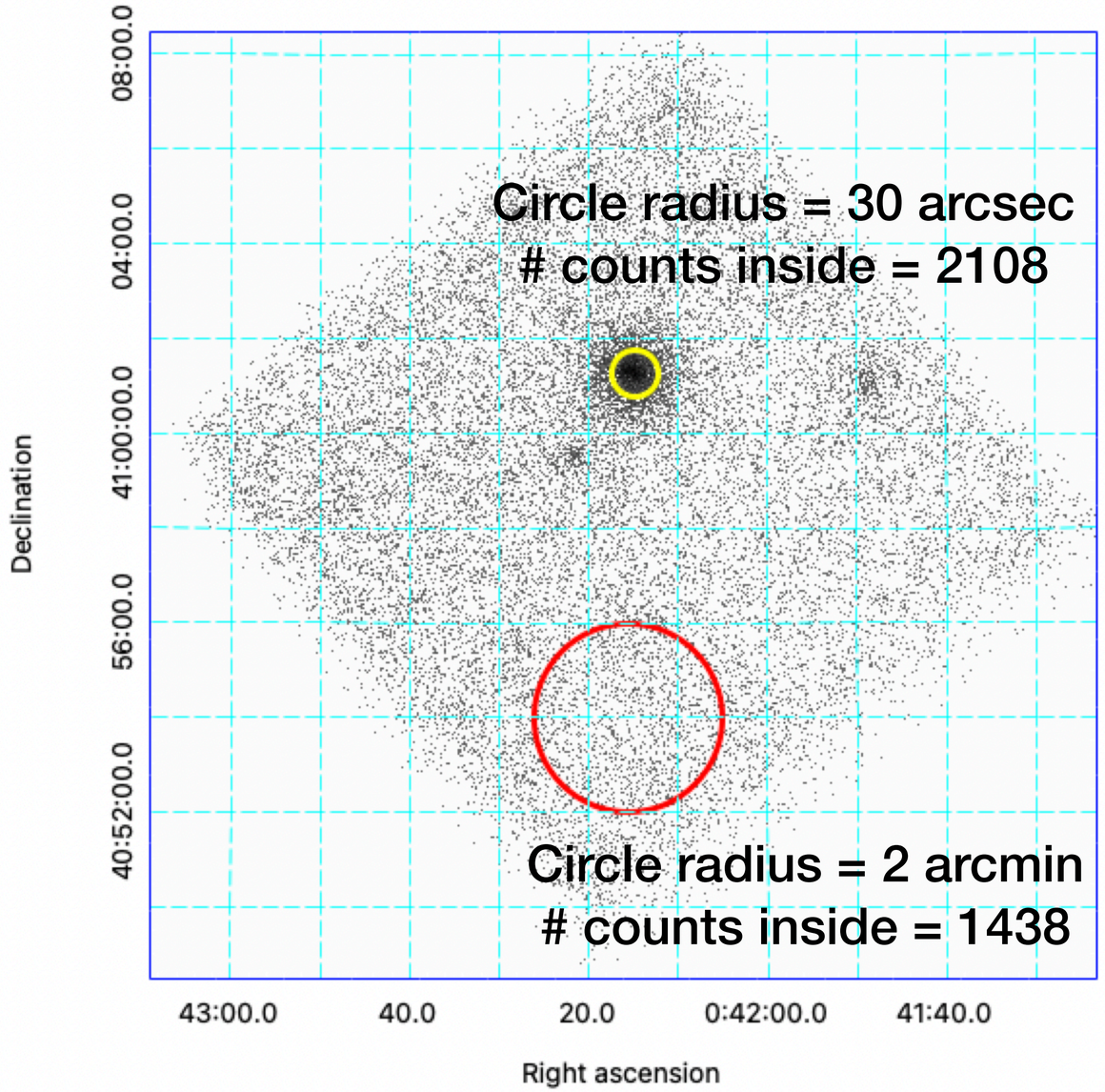


Image from the *NuSTAR* X-ray Observatory

(4-25 keV; $1\ \mathrm{keV} = 1.602 \times 10^{-16}\ \mathrm{J}$)

Exposure time of image = 37,547 s

XRB is in the Andromeda galaxy, 780 kpc away

($1\ \mathrm{kpc} = 3.086 \times 10^{19}\ \mathrm{m}$)

<u>Telescope Properties</u>:

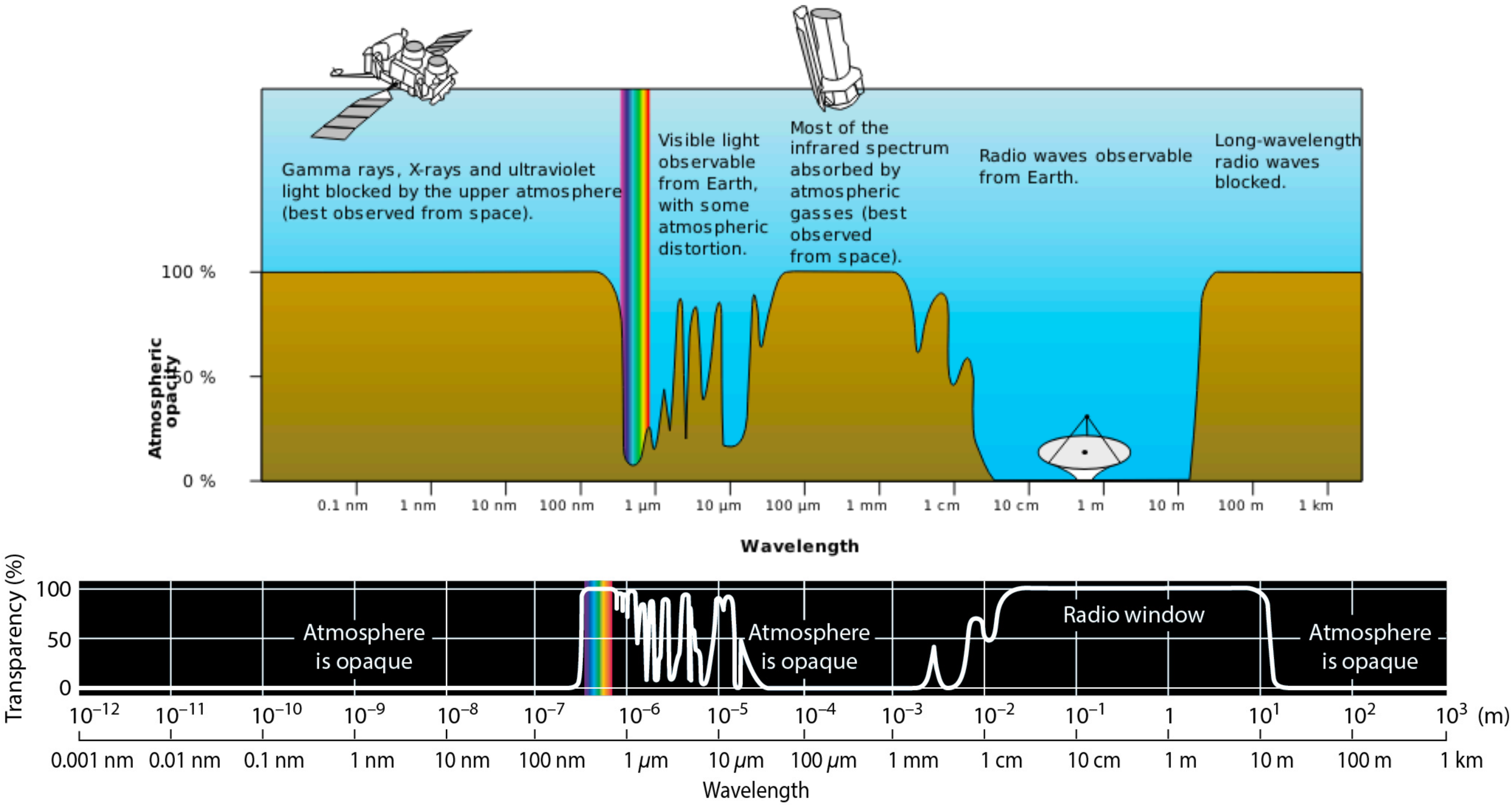
Collecting area = 400 cm^2

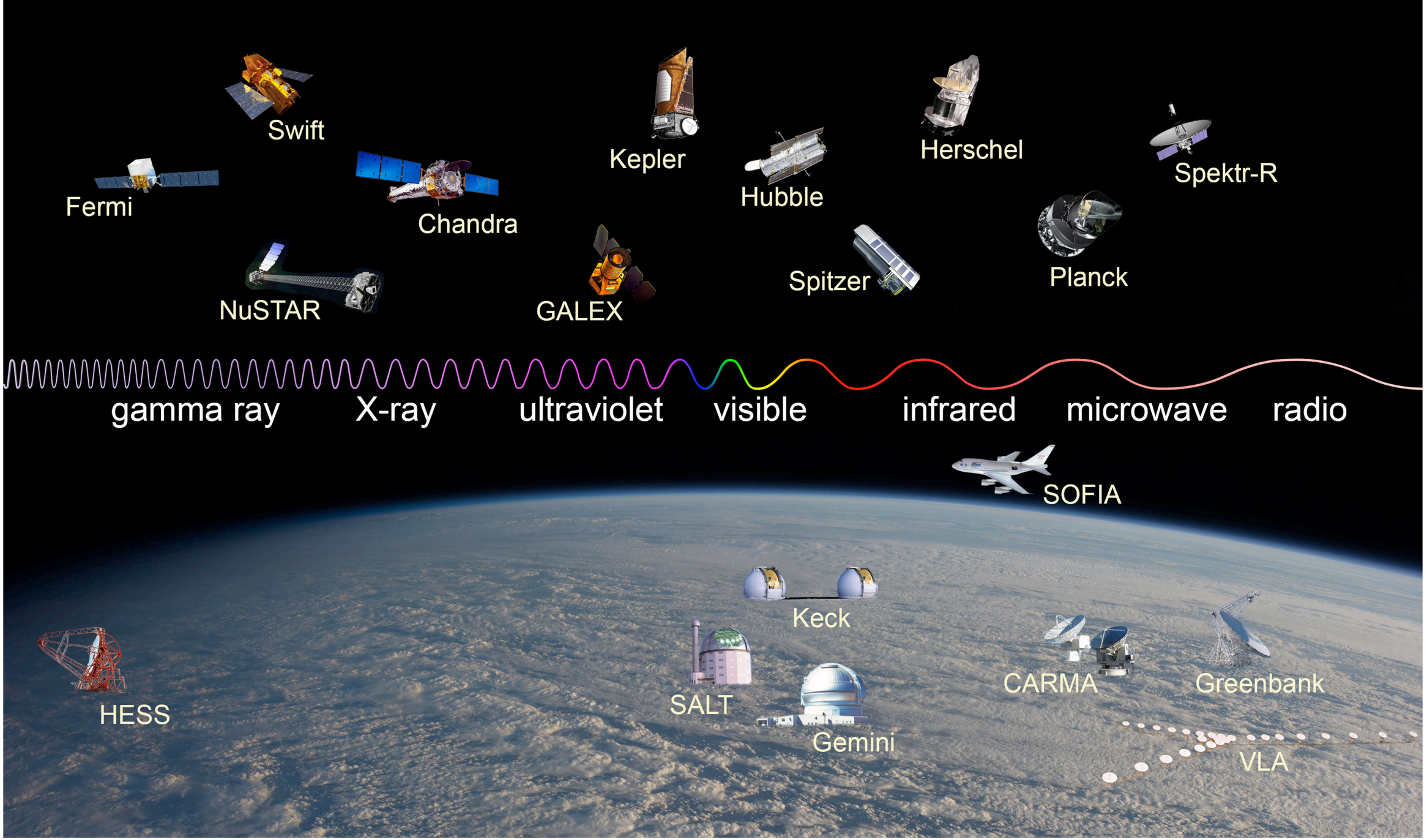
Focal length = 10.15 m

PSF FWHM = 18 arcsec

PSF HPD = 1 arcmin

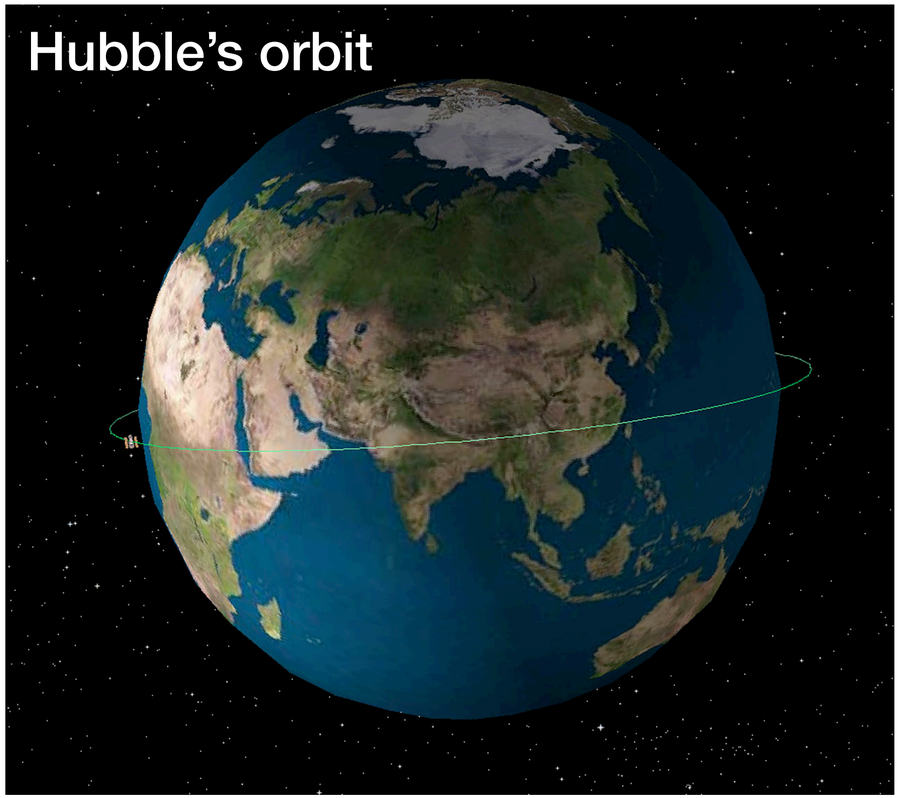
1. Calculate the *total* number of source counts S
2. Convert S to flux (units of $\mathrm{J/m^2/s}$)
3. Convert flux to luminosity
4. Calculate the S/N ratio of the XRB
5. Convert the uncertainty in total S and flux

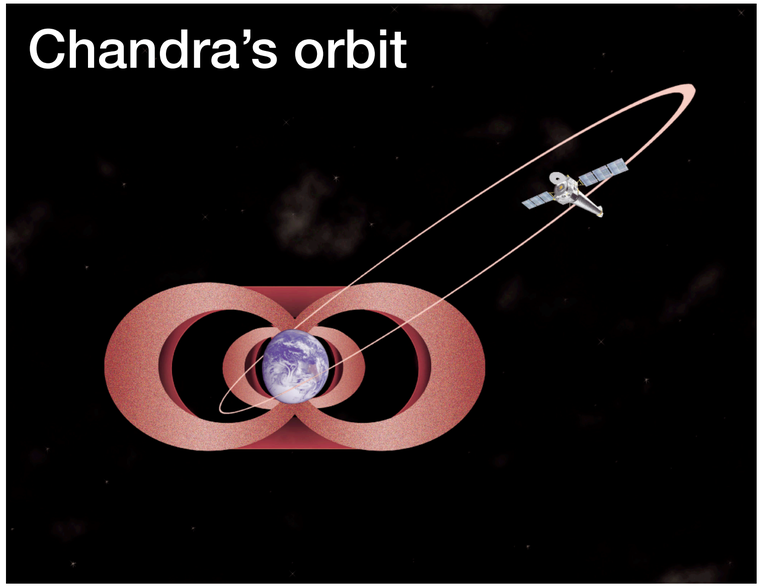

Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).
Visible light observable from Earth, with some atmospheric distortion.
Most of the infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio waves observable from Earth.
Long-wavelength radio waves blocked.
100 %
50 %
0 %
Atmospheric opacity
0.1 nm
1 nm
10 nm
100 nm
1 μm
10 μm
100 μm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength
Transparency (%)
100
50
0
Atmosphere is opaque
Atmosphere is opaque
Radio window
Atmosphere is opaque
10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10^{1} 10^{2} 10^{3} (m)
0.001 nm 0.01 nm 0.1 nm 1 nm 10 nm 100 nm 1 μm 10 μm 100 μm 1 mm 1 cm 10 cm 1 m 10 m 100 m 1 km
Wavelength


Swift
Kepler
Herschel
Spektr-R
Fermi
Chandra
Hubble
Planck
Spitzer
NuSTAR
GALEX
gamma ray
X-ray
ultraviolet
visible
infrared
microwave
radio
SOFIA
Keck
HESS
SALT
Gemini
CARMA
Greenbank
VLA

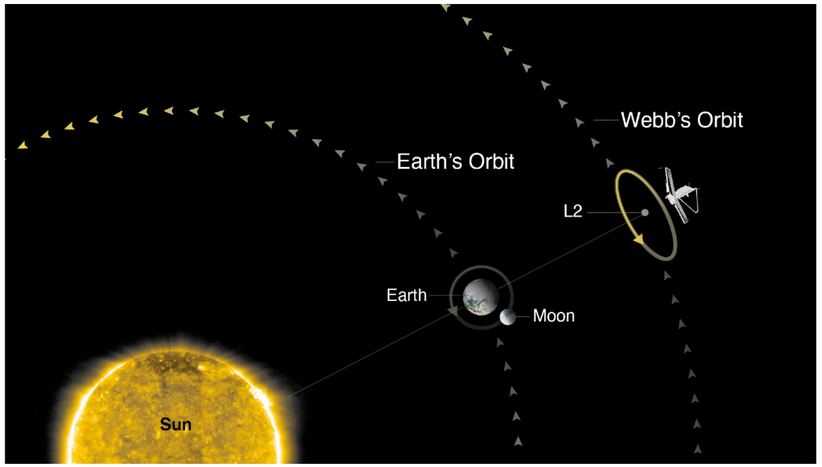
3 Misconceptions about Telescopes in Space

- From space, objects can be observed continuously, even during the day
- The sky is much darker in space than on the Earth
- Observations from space are not affected by weather



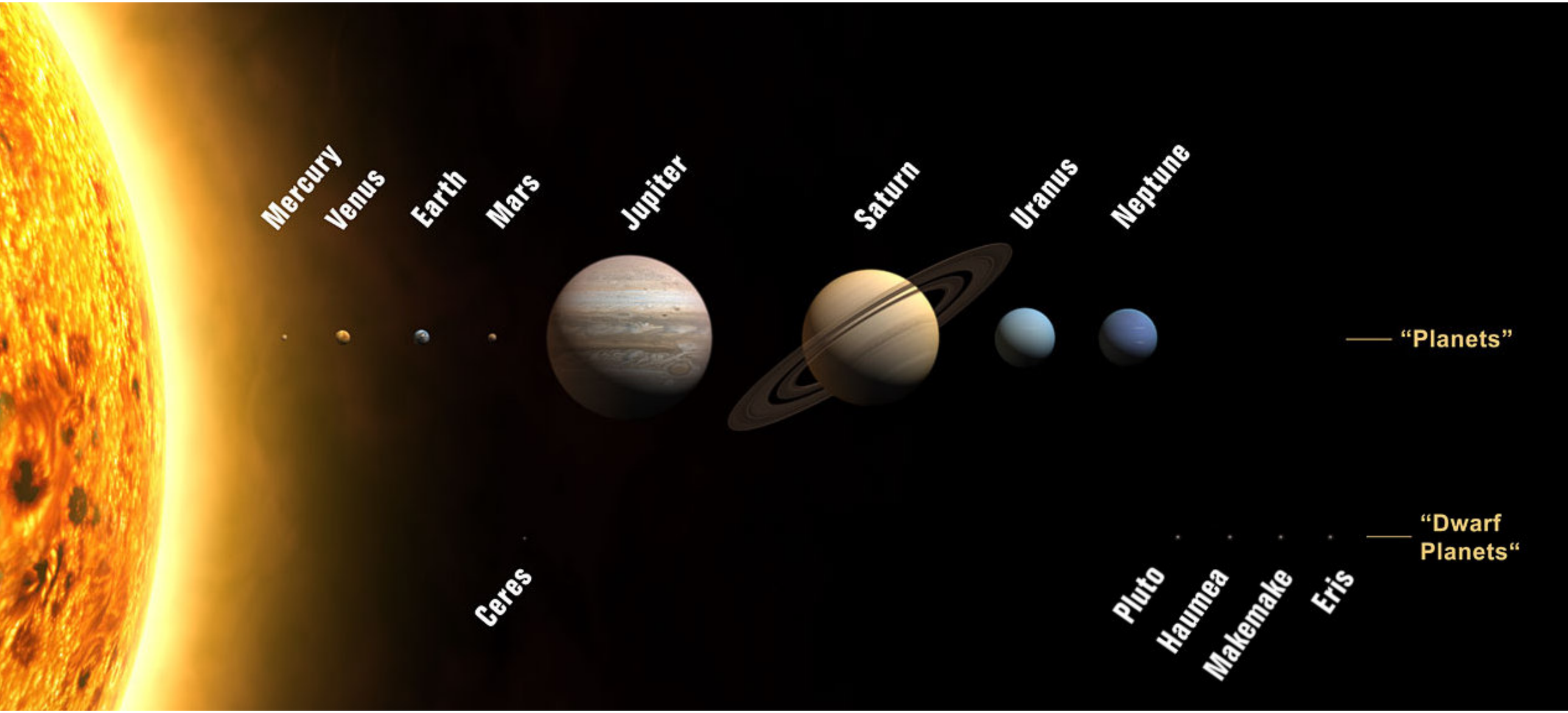


JWST's orbit

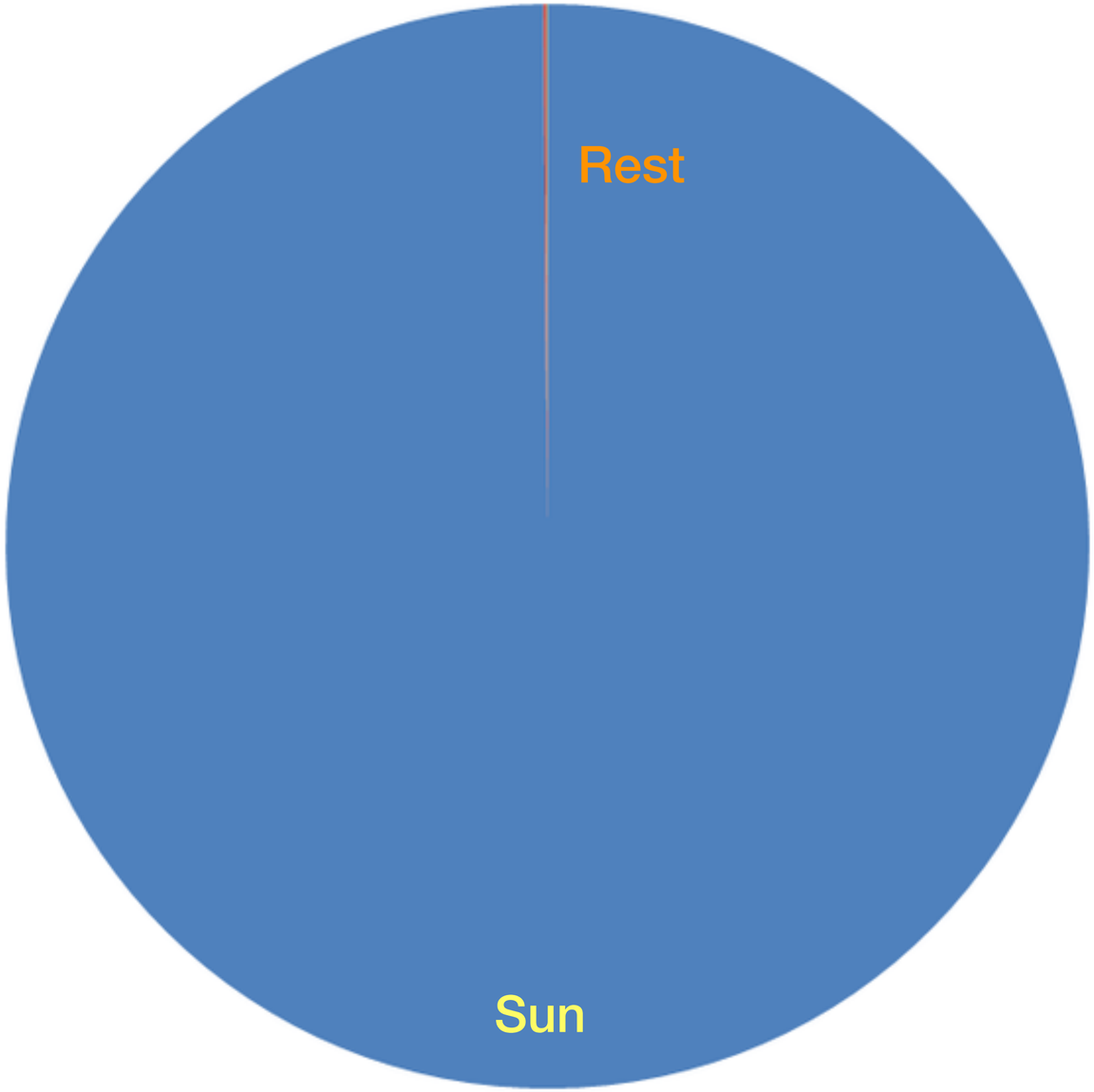


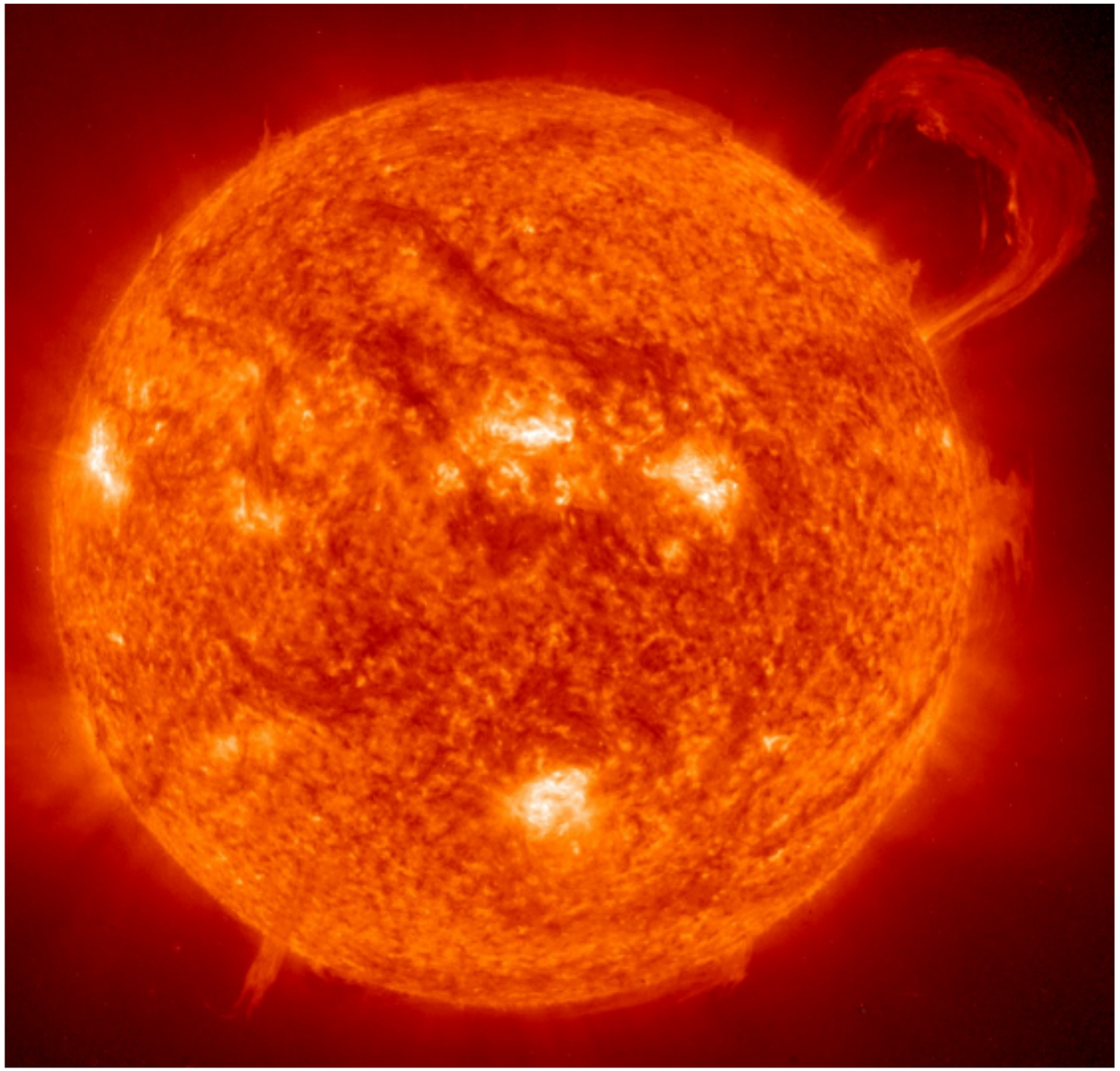
Sun / Solar System

Solar System

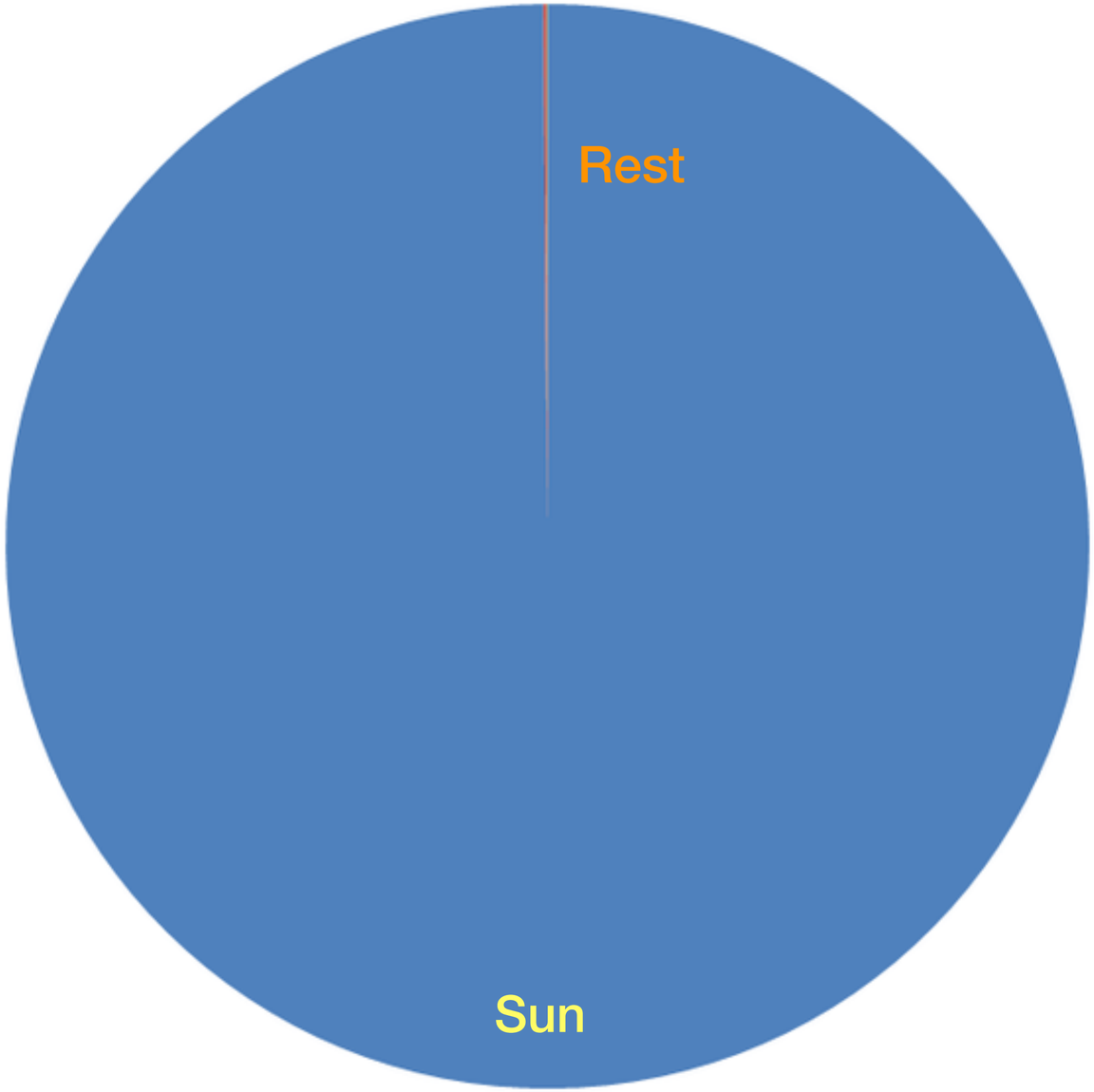


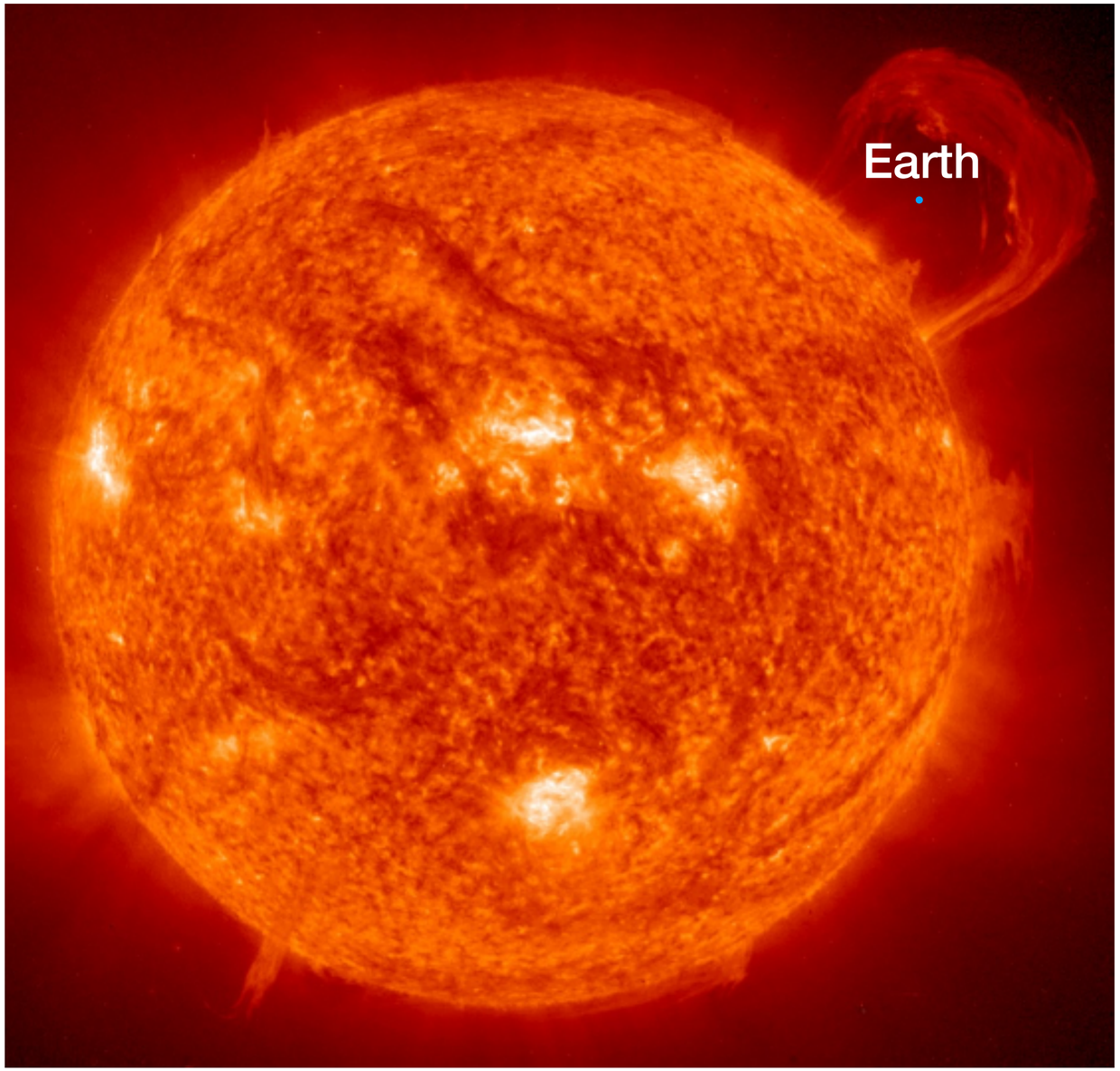
Mass Fractions





Mass Fractions



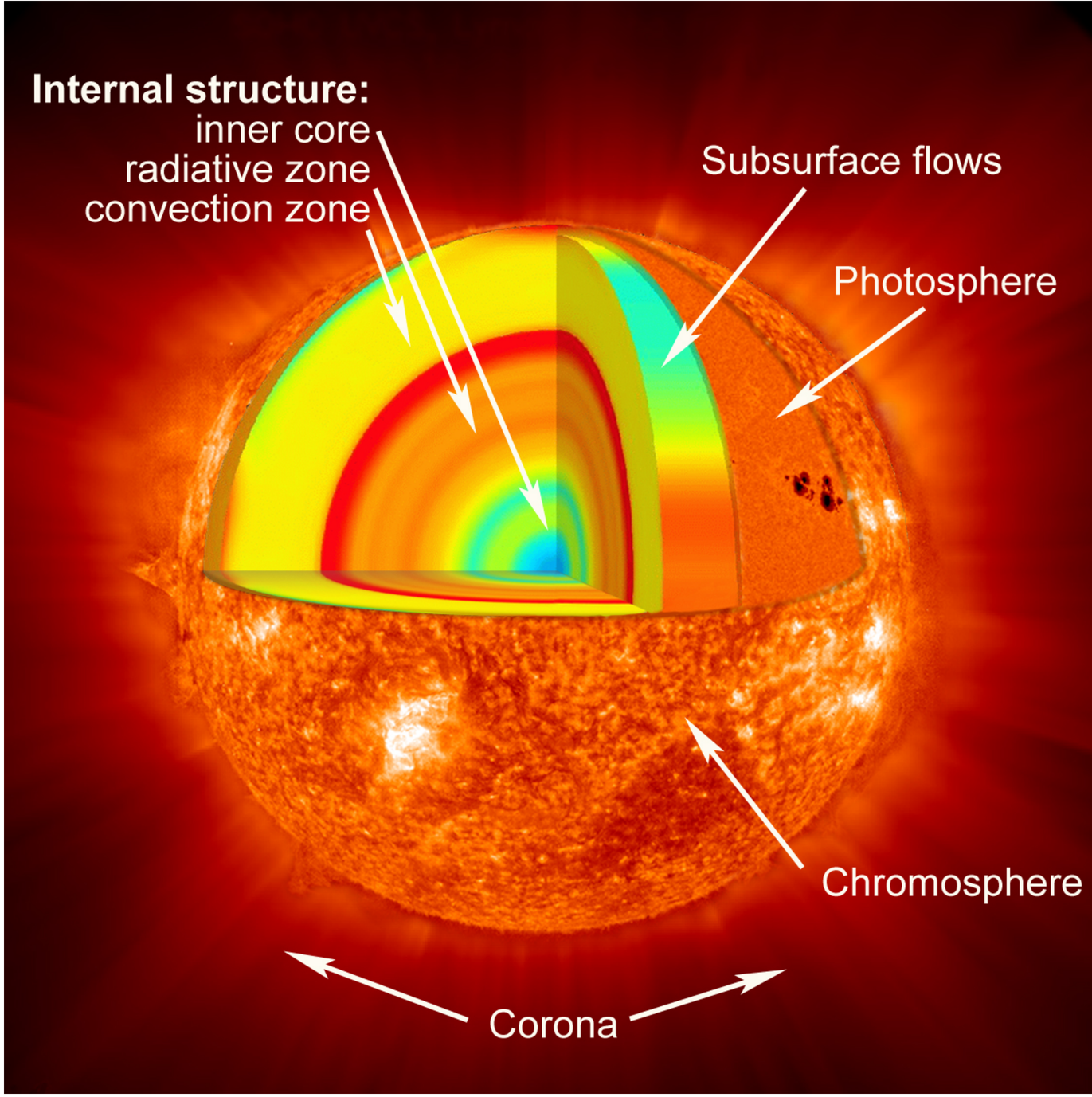


Structure of the Sun

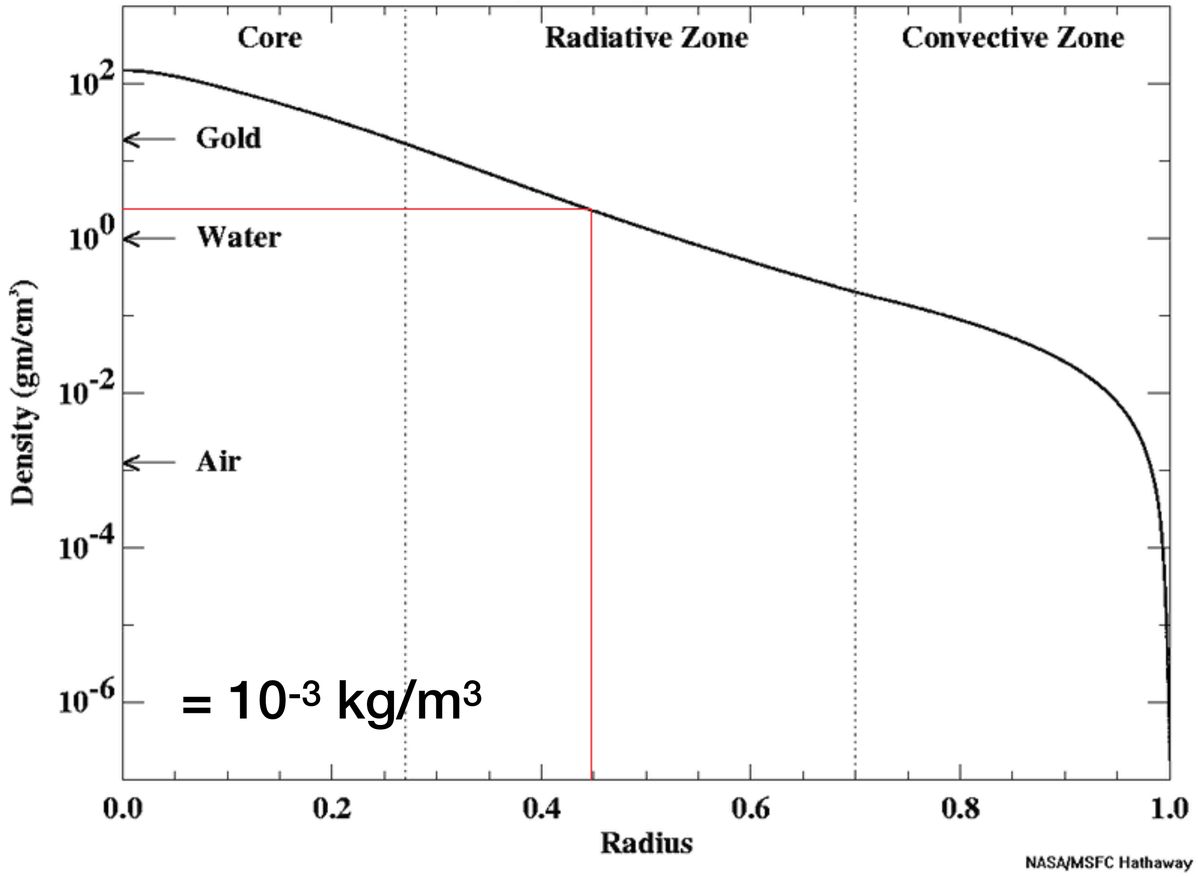
Core:
~15 million K
H —> He fusion produces Sun's photons

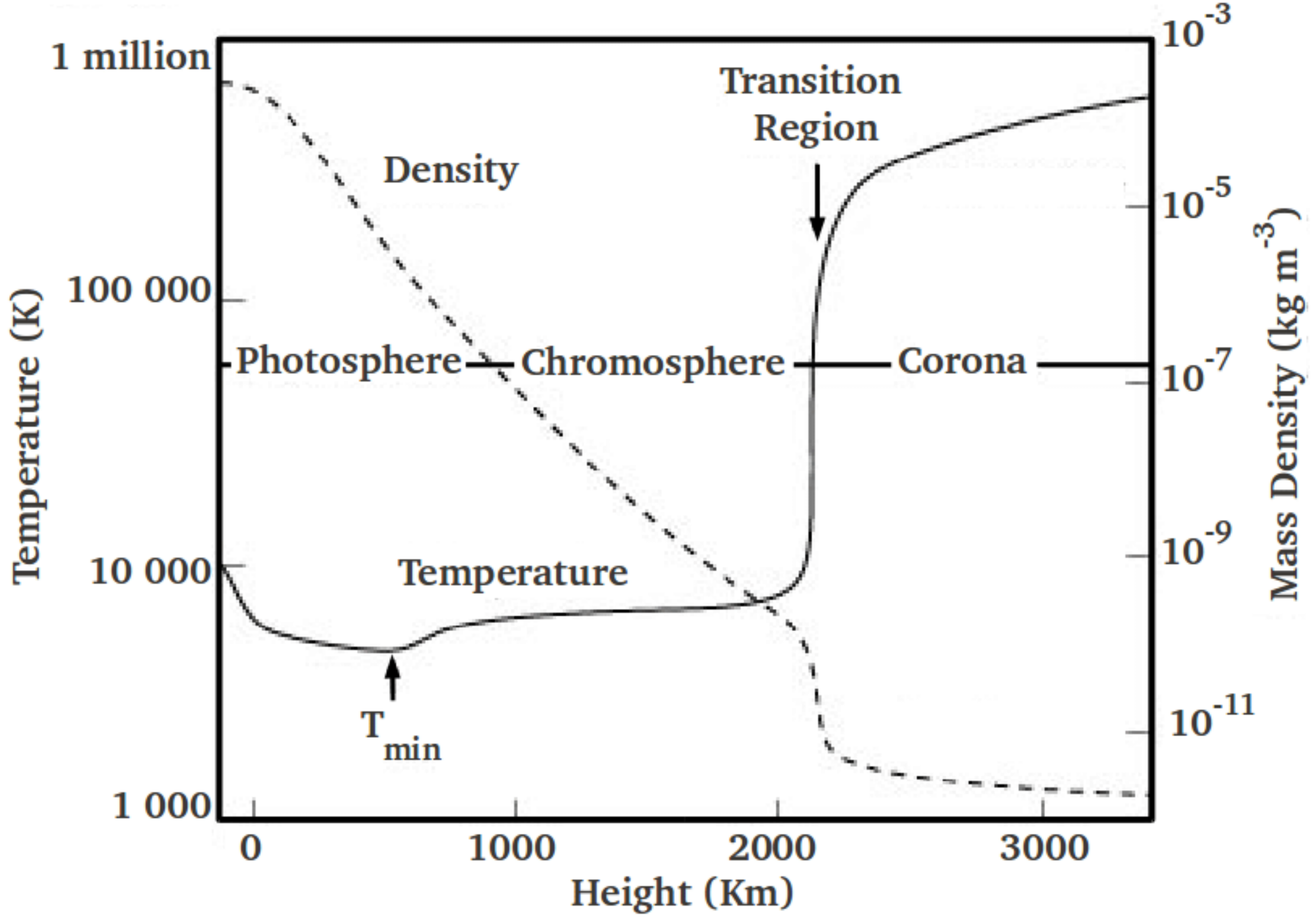
Photons take ~100,000 years to travel through the Sun, then take 8 min to reach the Earth

Temperature decreases outside the core until it falls to 5780 K at the "surface"

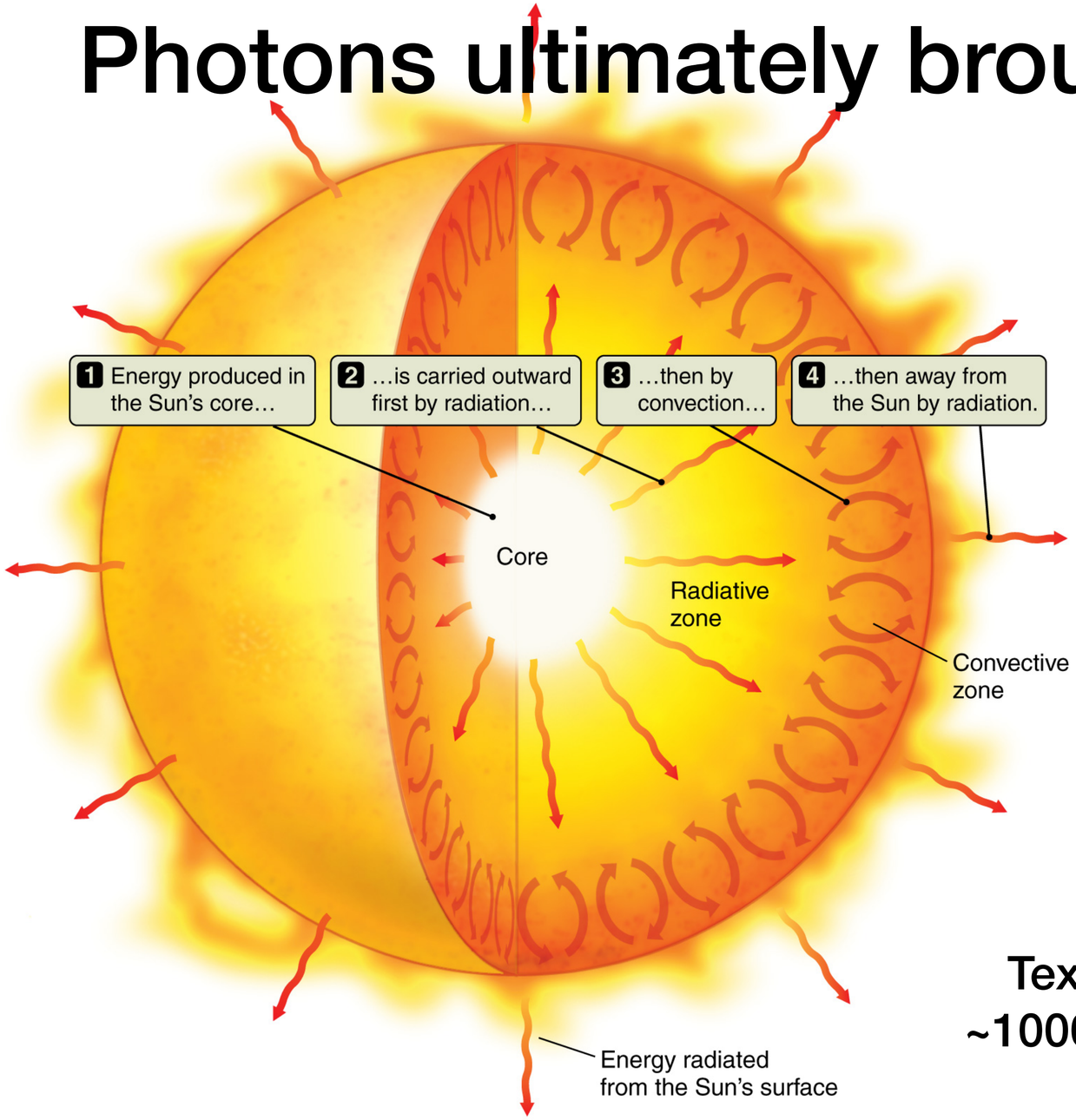


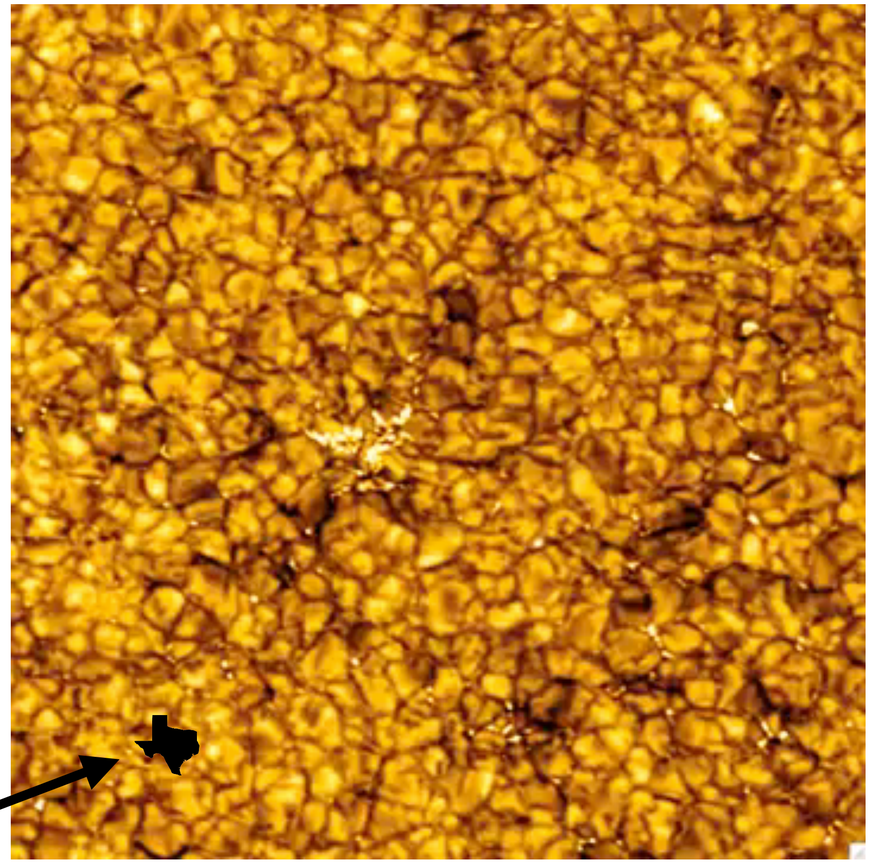
Temperature & Density Profiles of the Sun





Photons ultimately brought by convection cells





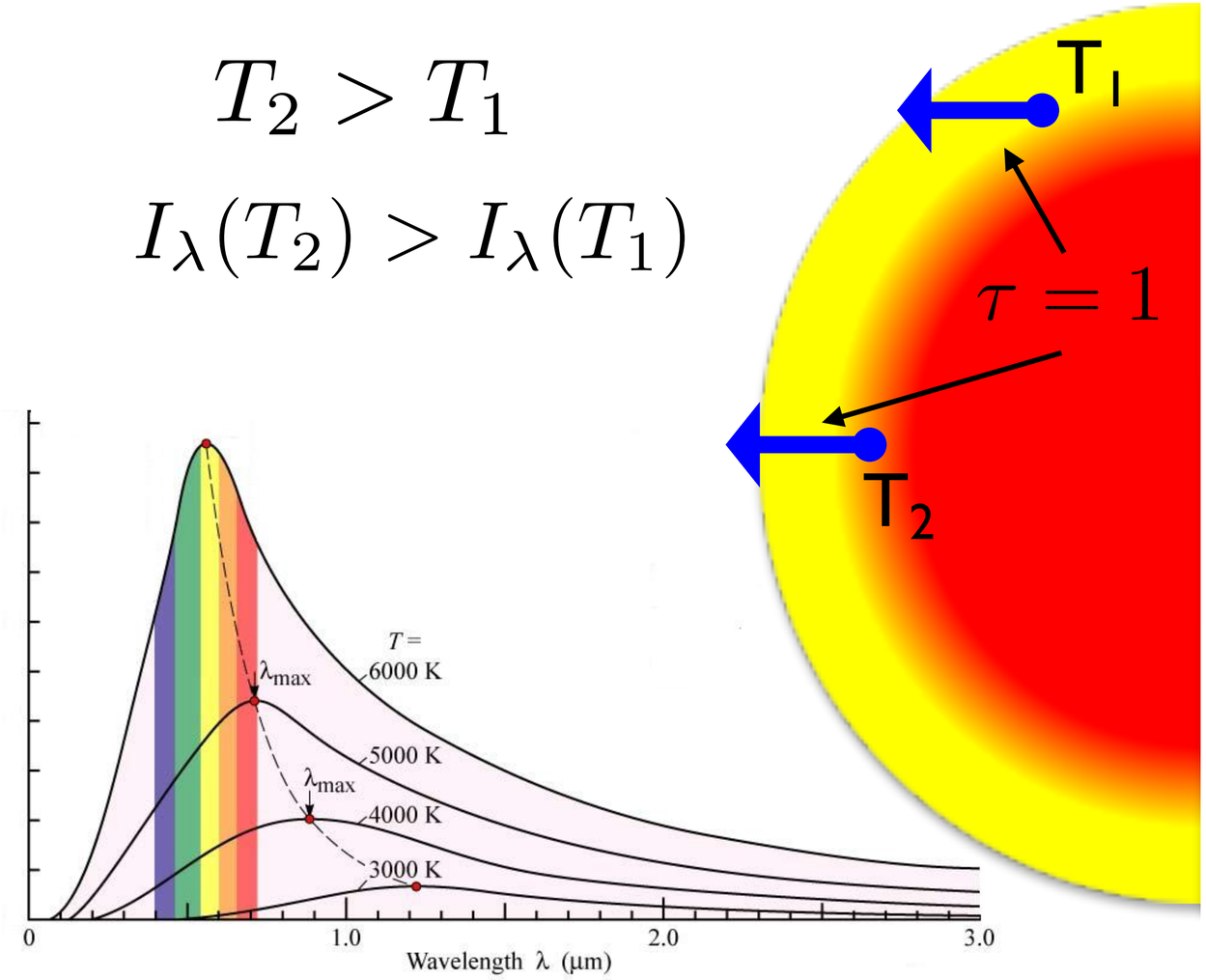
Texas
~1000 km

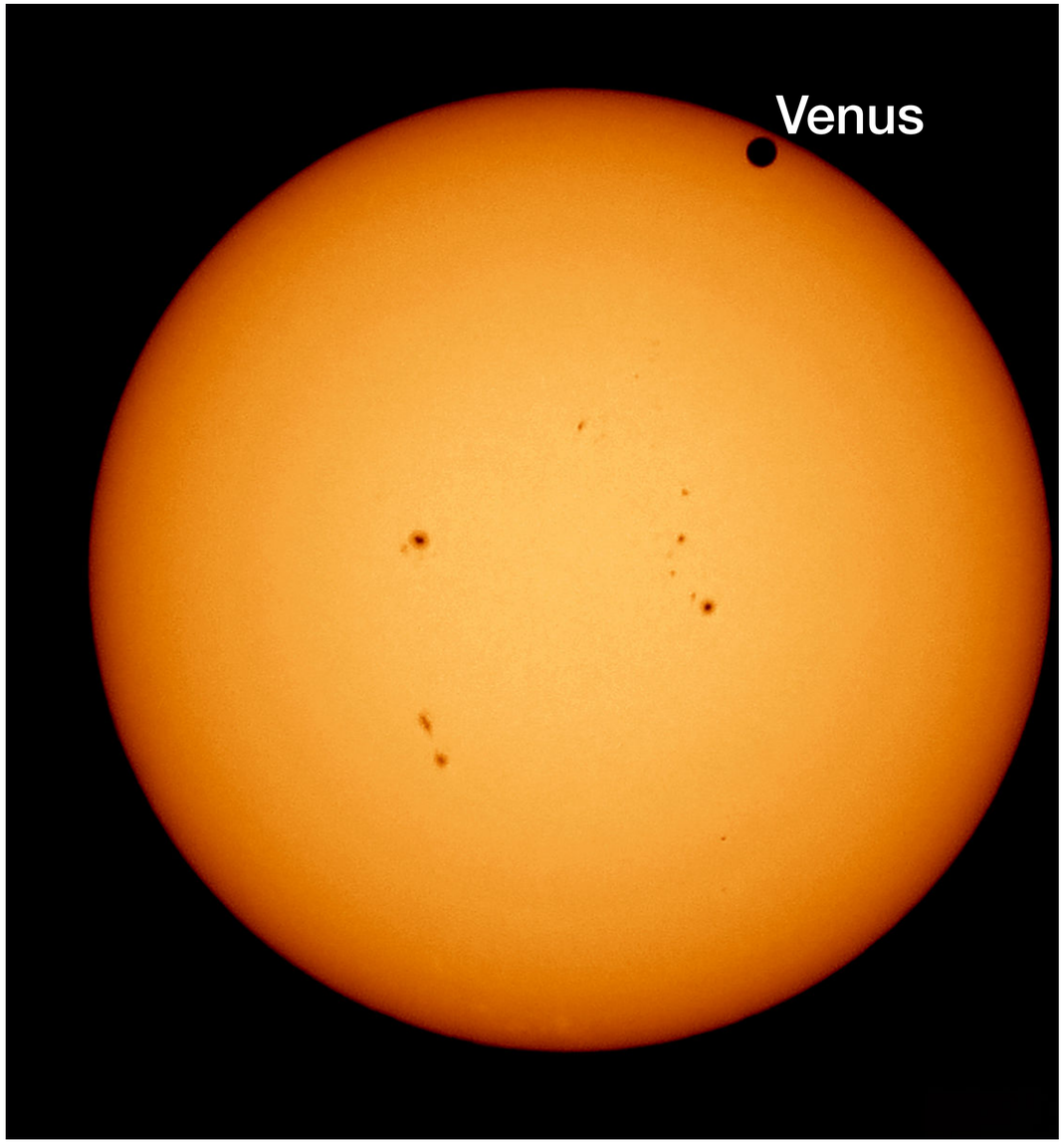
https://www.youtube.com/watch?v=W_Scoj4HqCQ

Photosphere: Limb Darkening

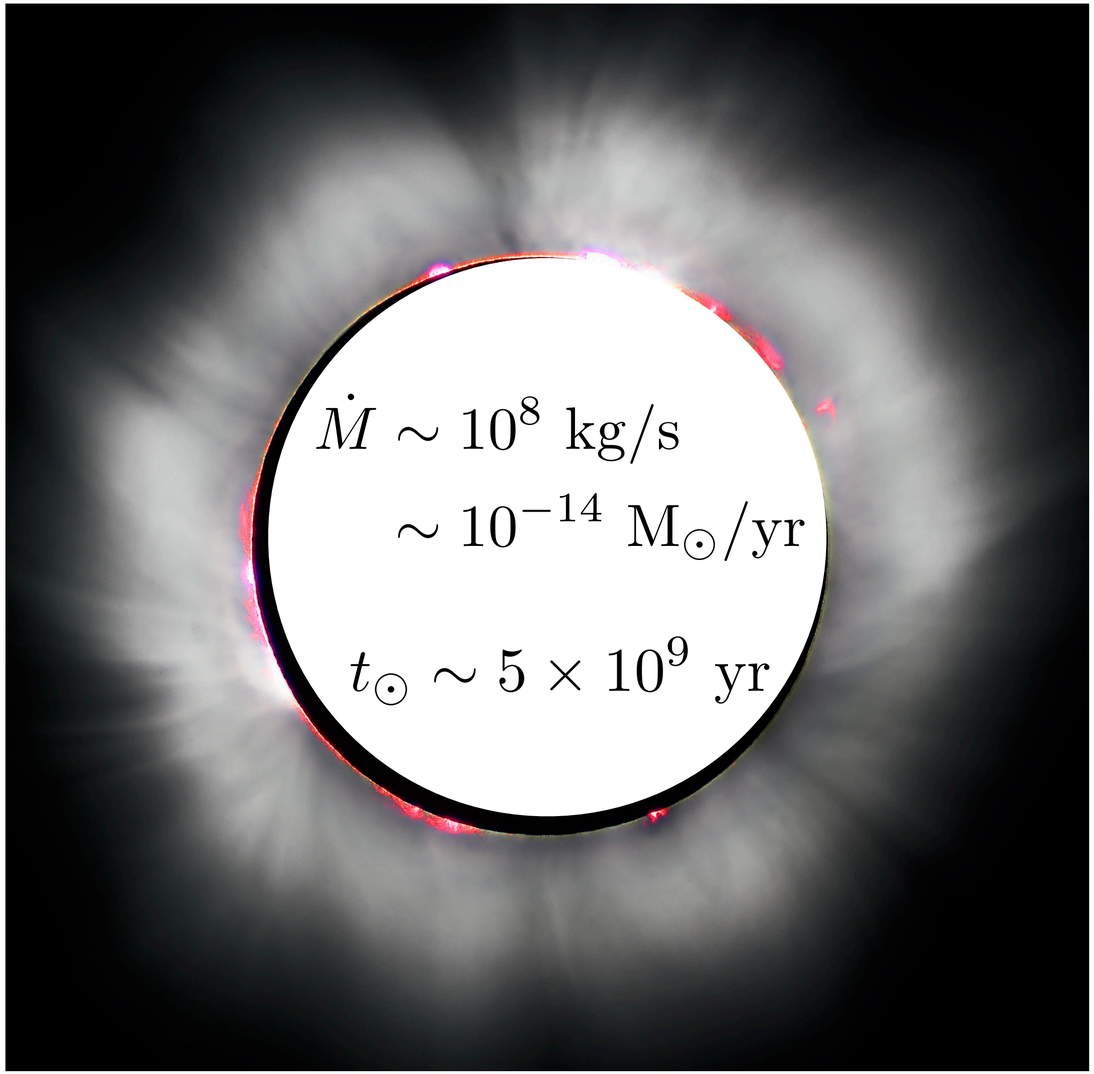
$$T_2 > T_1$$

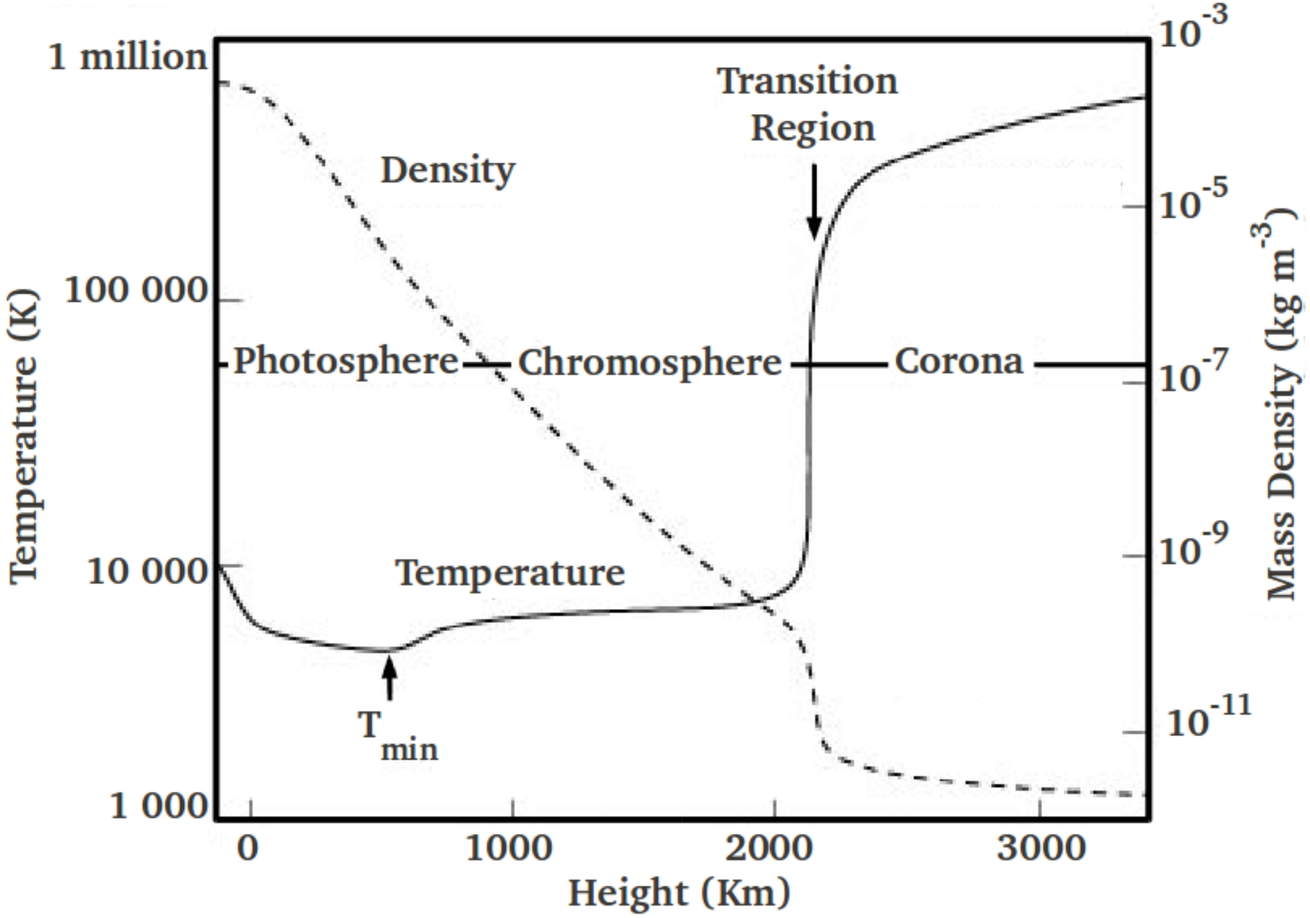
$$I_\lambda(T_2) > I_\lambda(T_1)$$



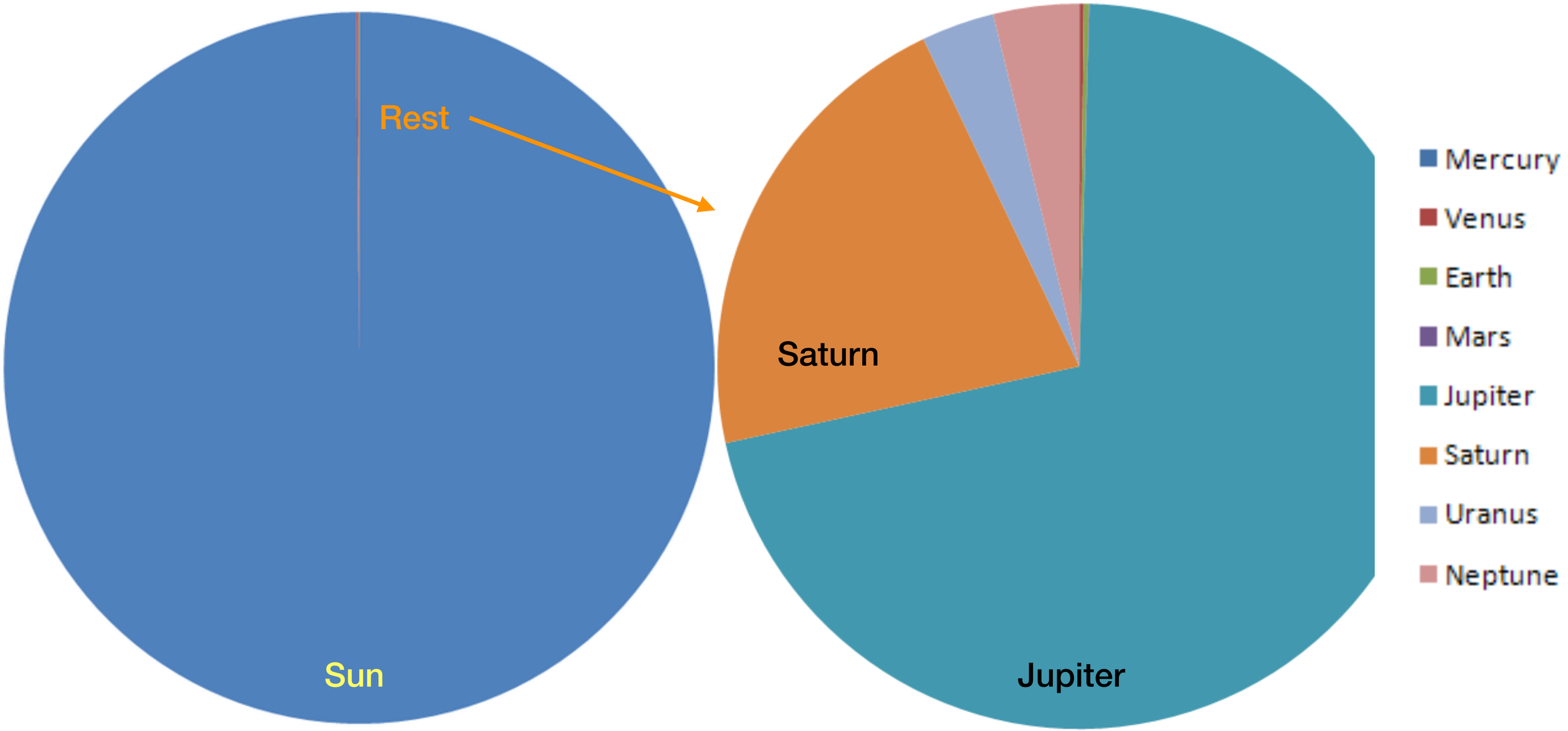


Corona: high T allows particles to reach v_{esc}





Mass Fractions



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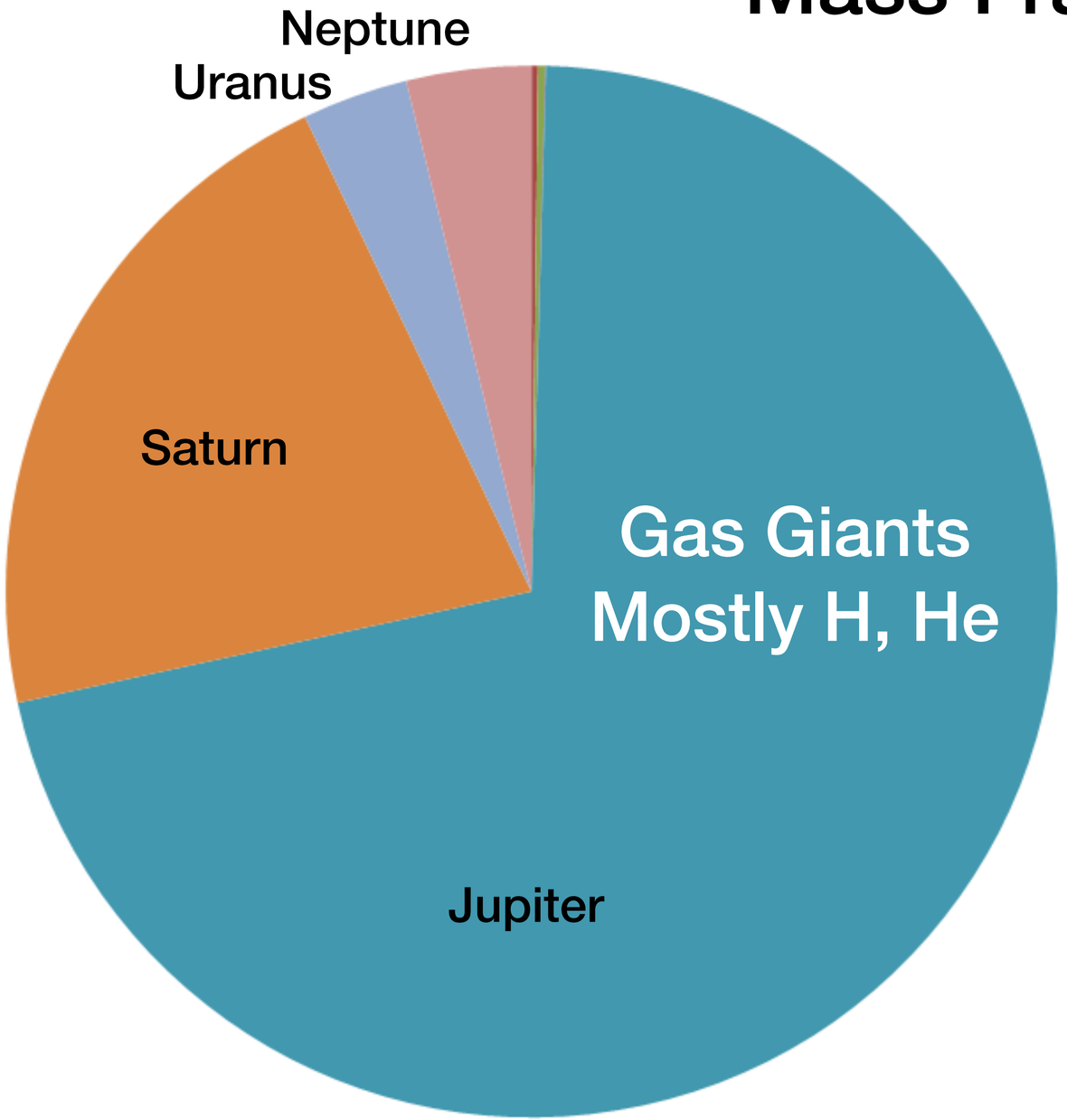
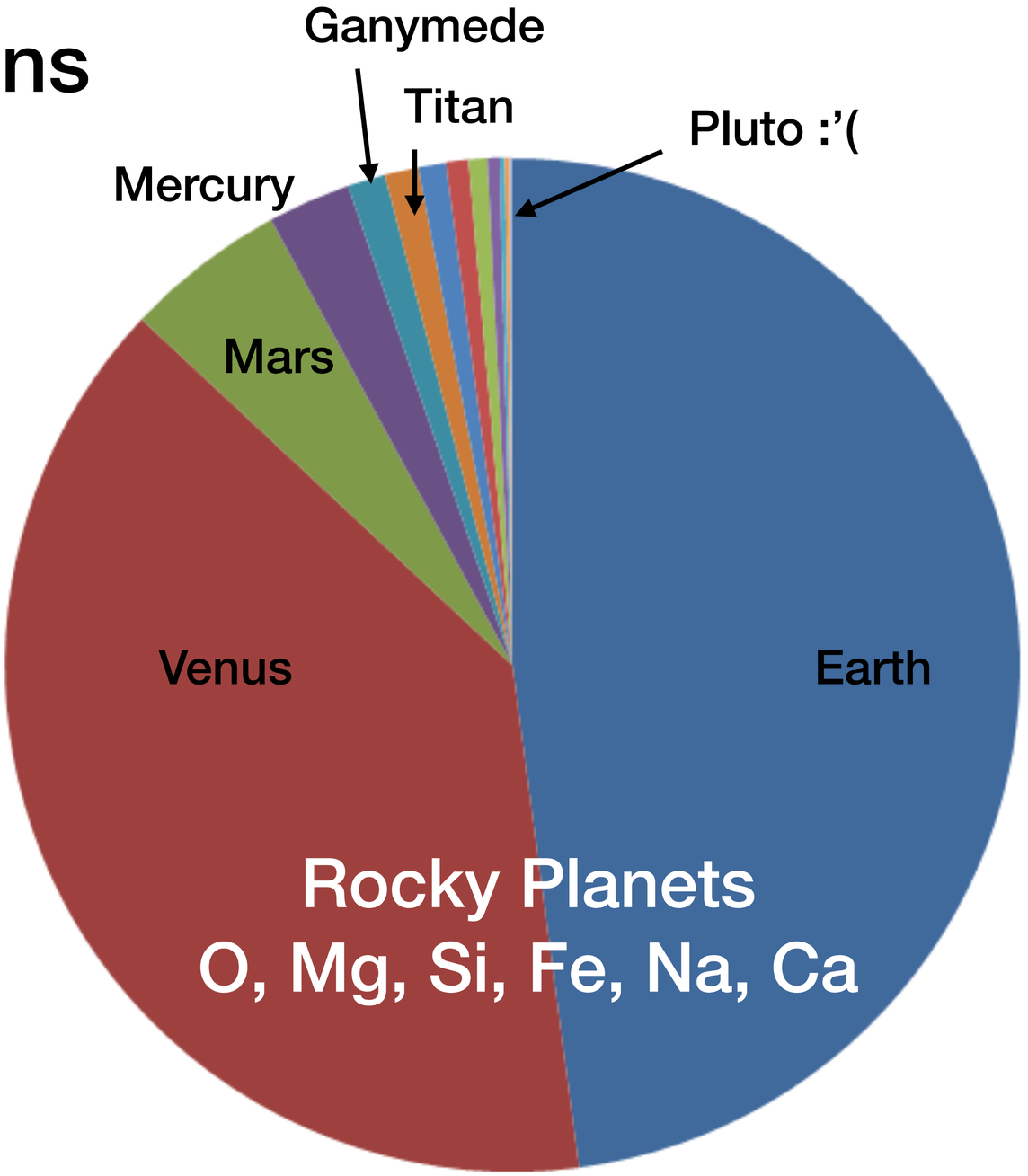
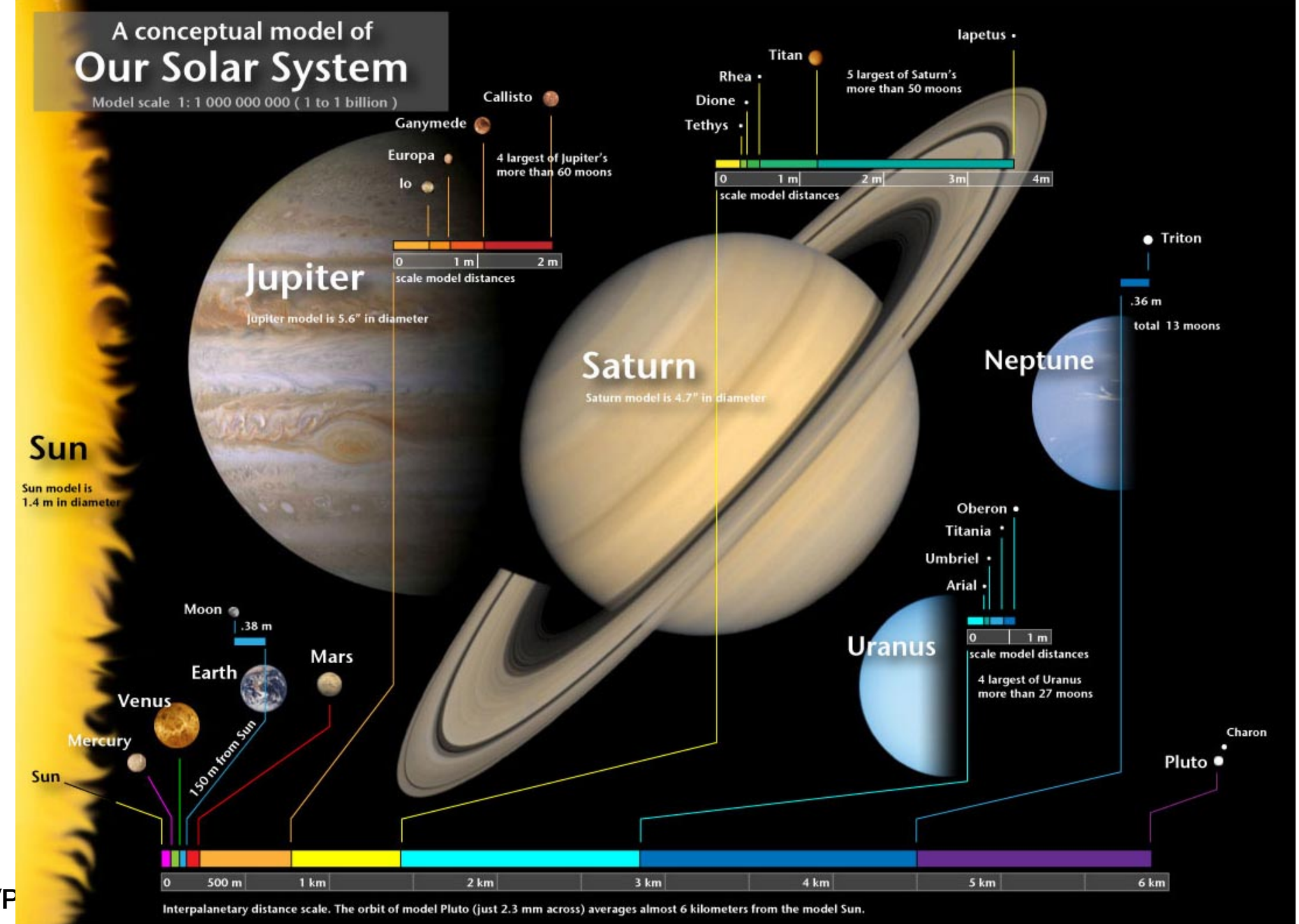
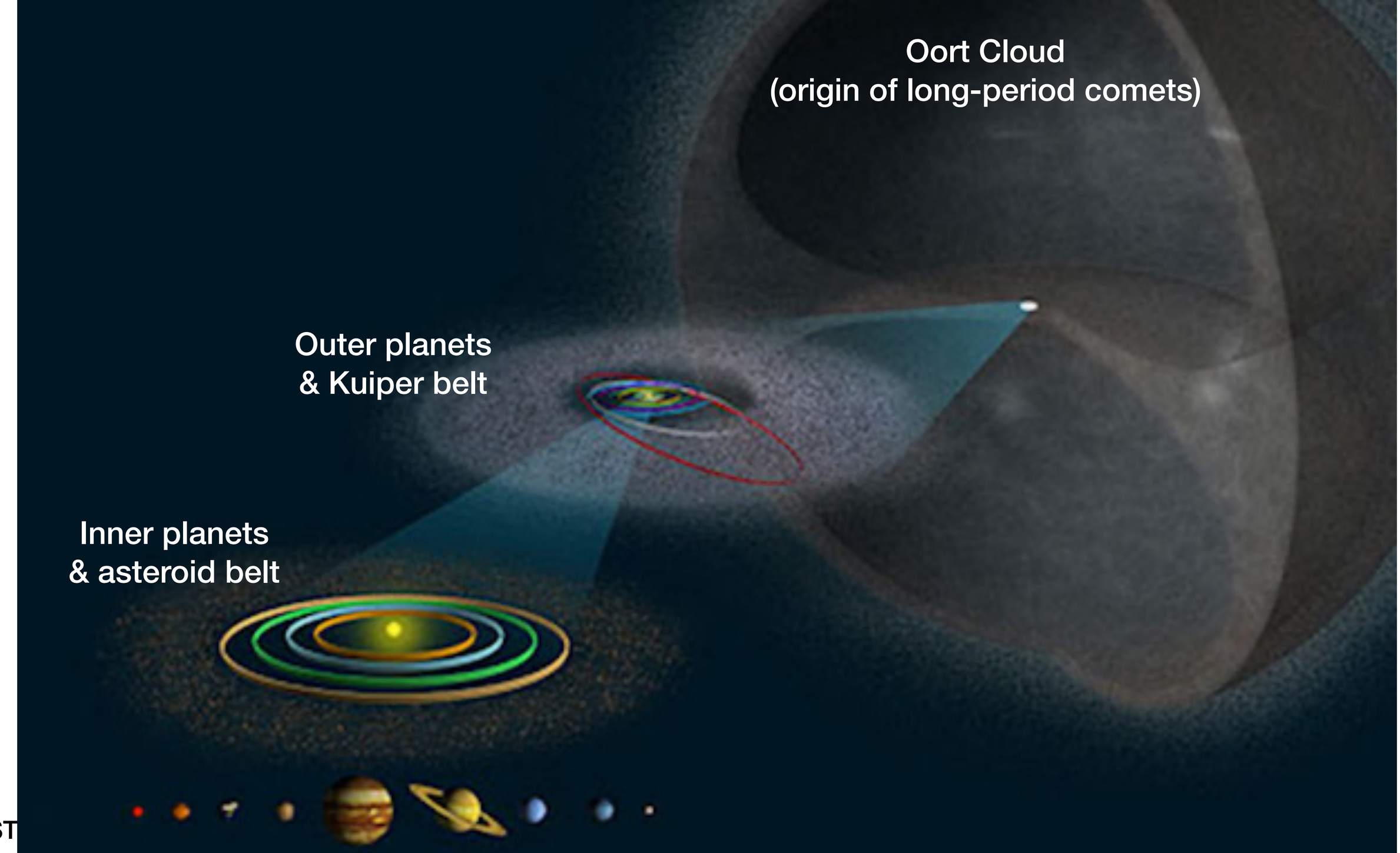
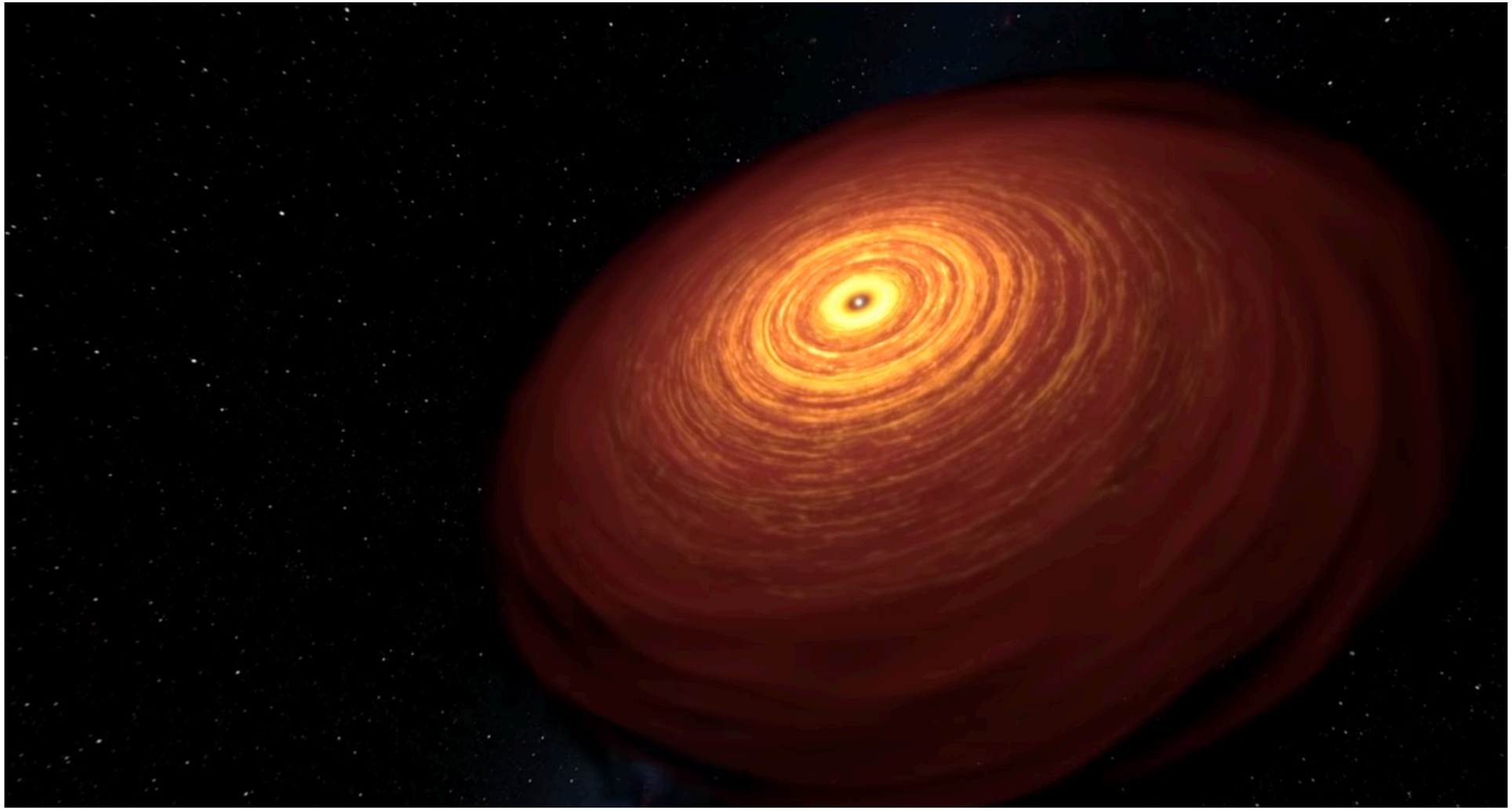




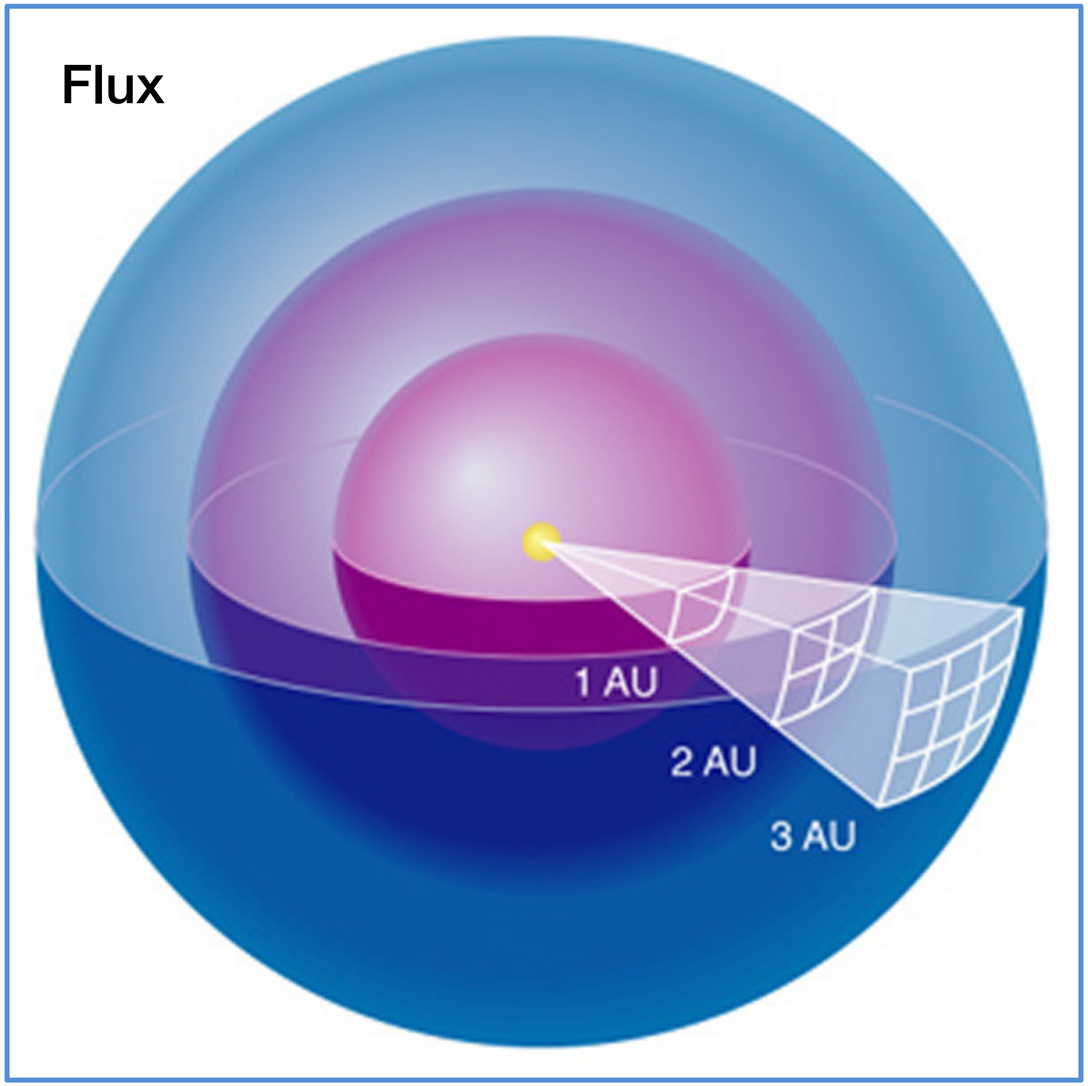

A conceptual model of
Our Solar System
Model scale 1: 1 000 000 000 (1 to 1 billion)
Sun
Sun model is 1.4 m in diameter
Jupiter
Jupiter model is 5.6" in diameter
Callisto
Ganymede
Europa
Io
4 largest of Jupiter's more than 60 moons
0 1 m 2 m
scale model distances
Saturn
Saturn model is 4.7" in diameter
Titan
Rhea
Dione
Tethys
Iapetus
5 largest of Saturn's more than 50 moons
0 1 m 2 m 3m 4m
scale model distances
Neptune
Triton
.36 m
total 13 moons
Uranus
Oberon
Titania
Umbriel
Arial
0 1 m
scale model distances
4 largest of Uranus more than 27 moons
Pluto
Charon
Moon
.38 m
Earth
Mars
Venus
Mercury
Sun
150 m from Sun
0 500 m 1 km 2 km 3 km 4 km 5 km 6 km
Interpalanetary distance scale. The orbit of model Pluto (just 2.3 mm across) averages almost 6 kilometers from the model Sun.


Oort Cloud
(origin of long-period comets)
Outer planets
& Kuiper belt
Inner planets
& asteroid belt

https://www.youtube.com/watch?v=yXq1i3HlumA&feature=youtu.be



How do we learn about solar system objects?



Albedo