Physics 231
Introductory Astrophysics

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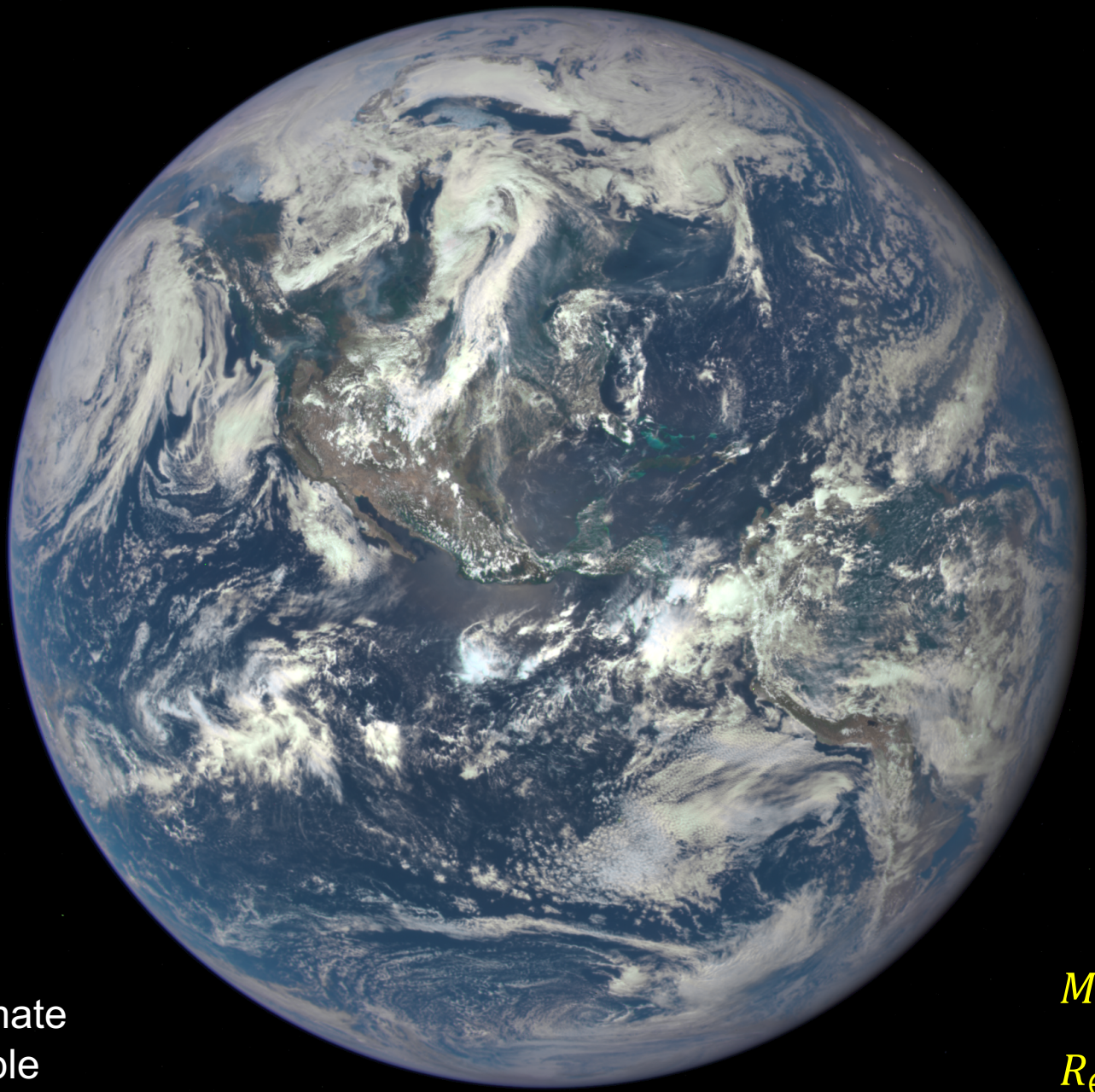
Course outline

- Length and mass scales in the universe
- Physical principles in astrophysics
- Stars and stellar evolution
- Stellar remnants
- Exoplanets?
- Galaxies
- Cosmology?



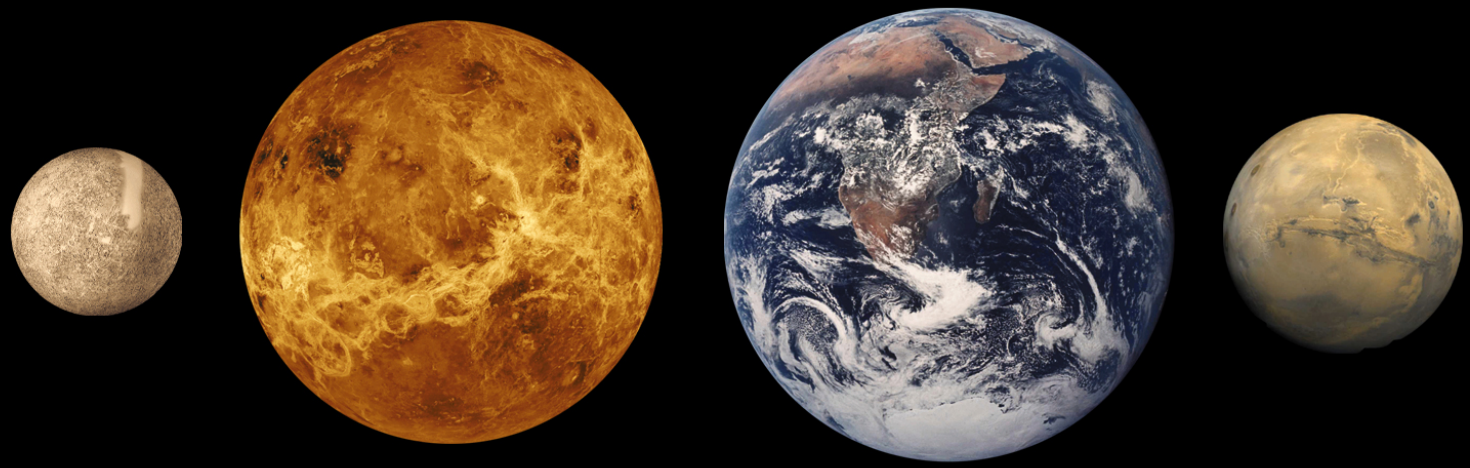
Earth
Deep Space Climate
Observatory/visible

$M_\oplus$ = 6 x 10^{24} kg

$R_\oplus$ = 6,400 km

10^4 km

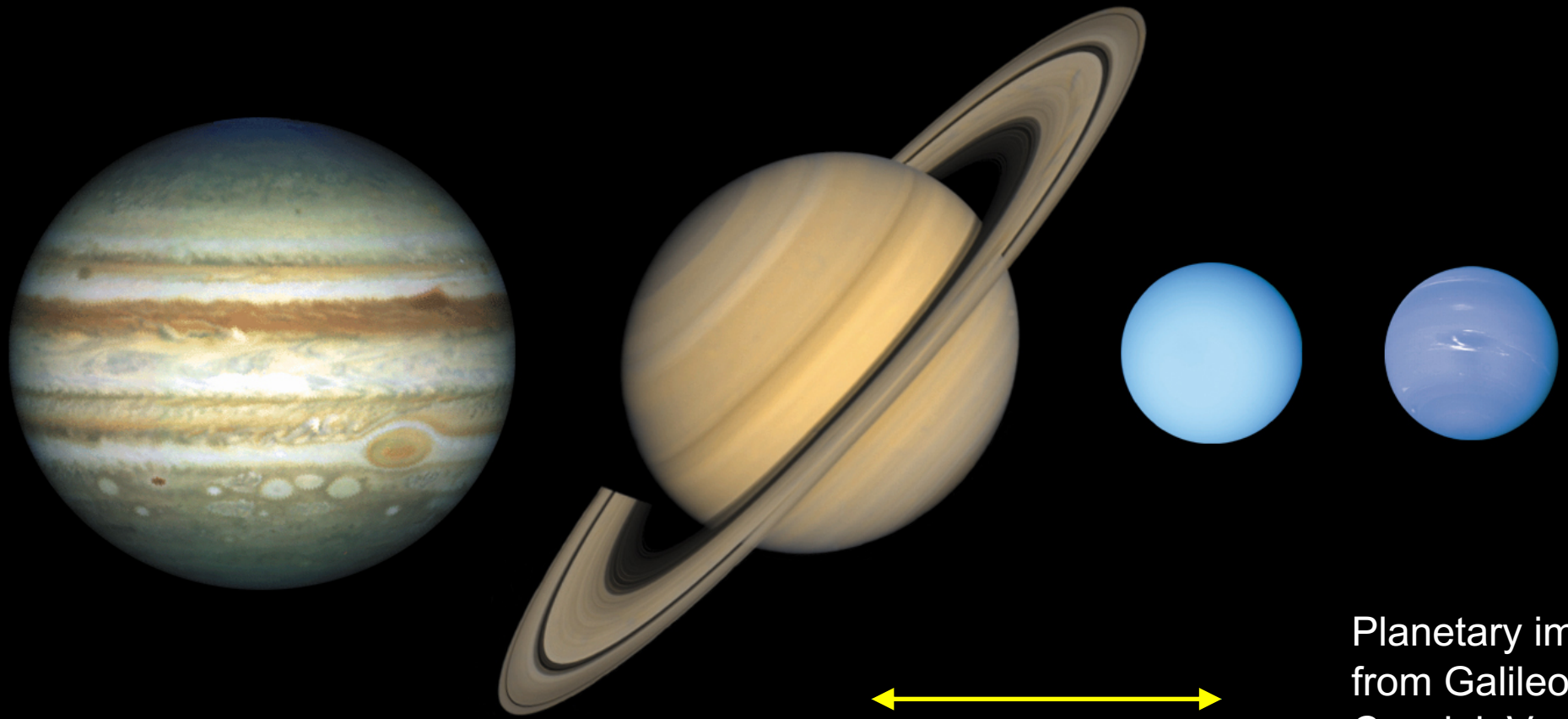
The Terrestrial Planets



10^4 km

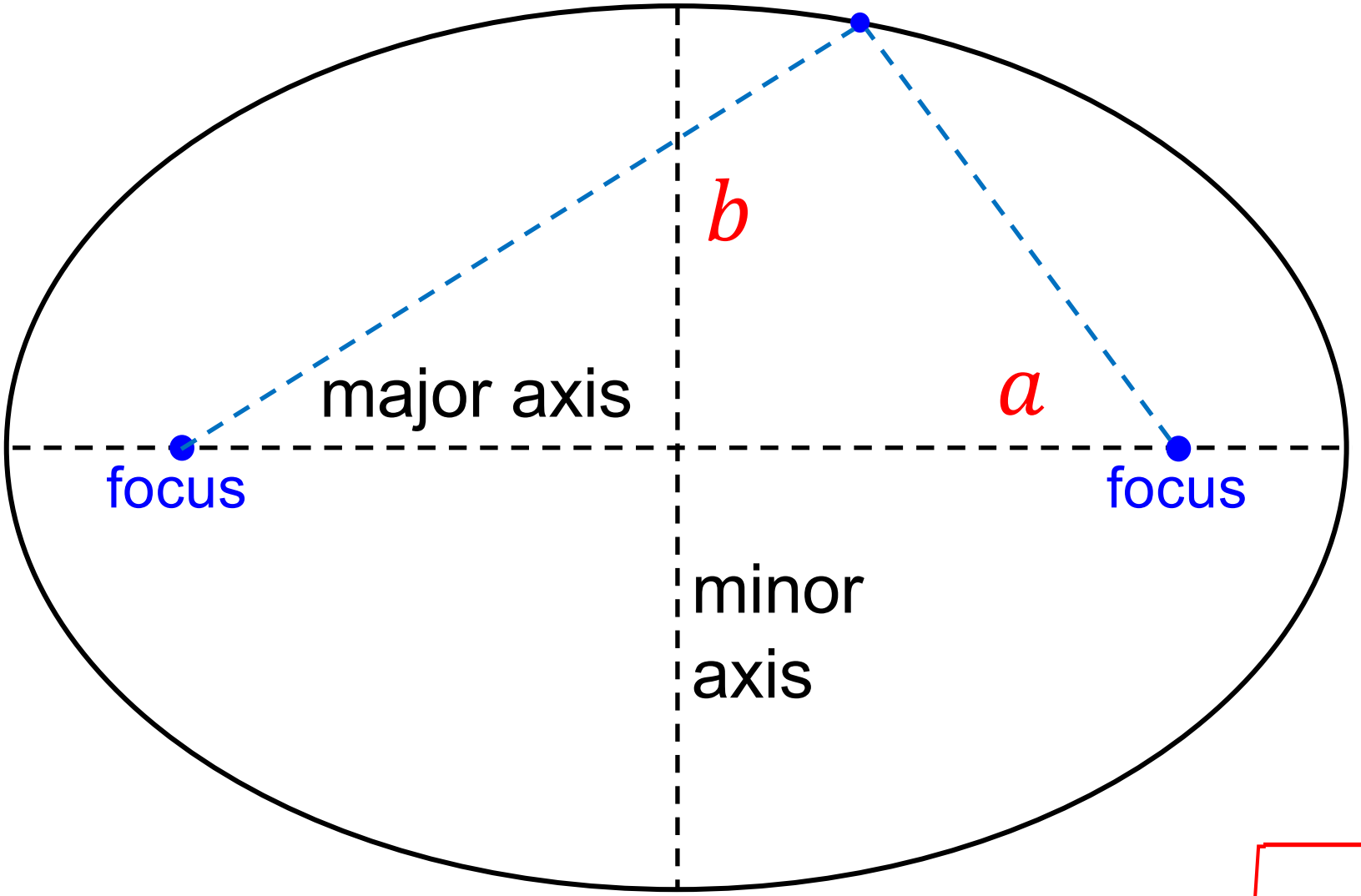
Planetary images from Messenger, Magellan, EPIC, Viking

The outer planets



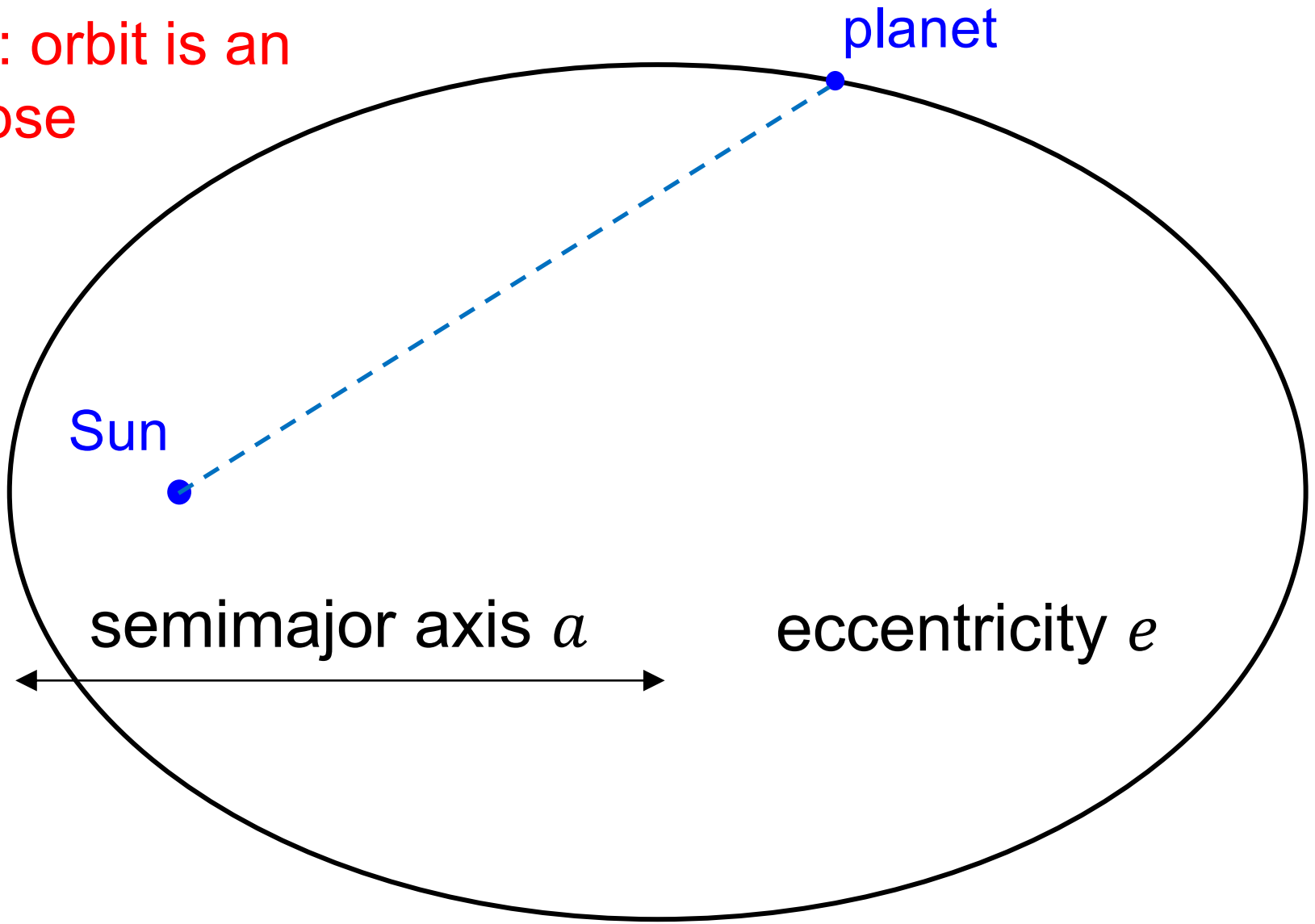
10^5 km

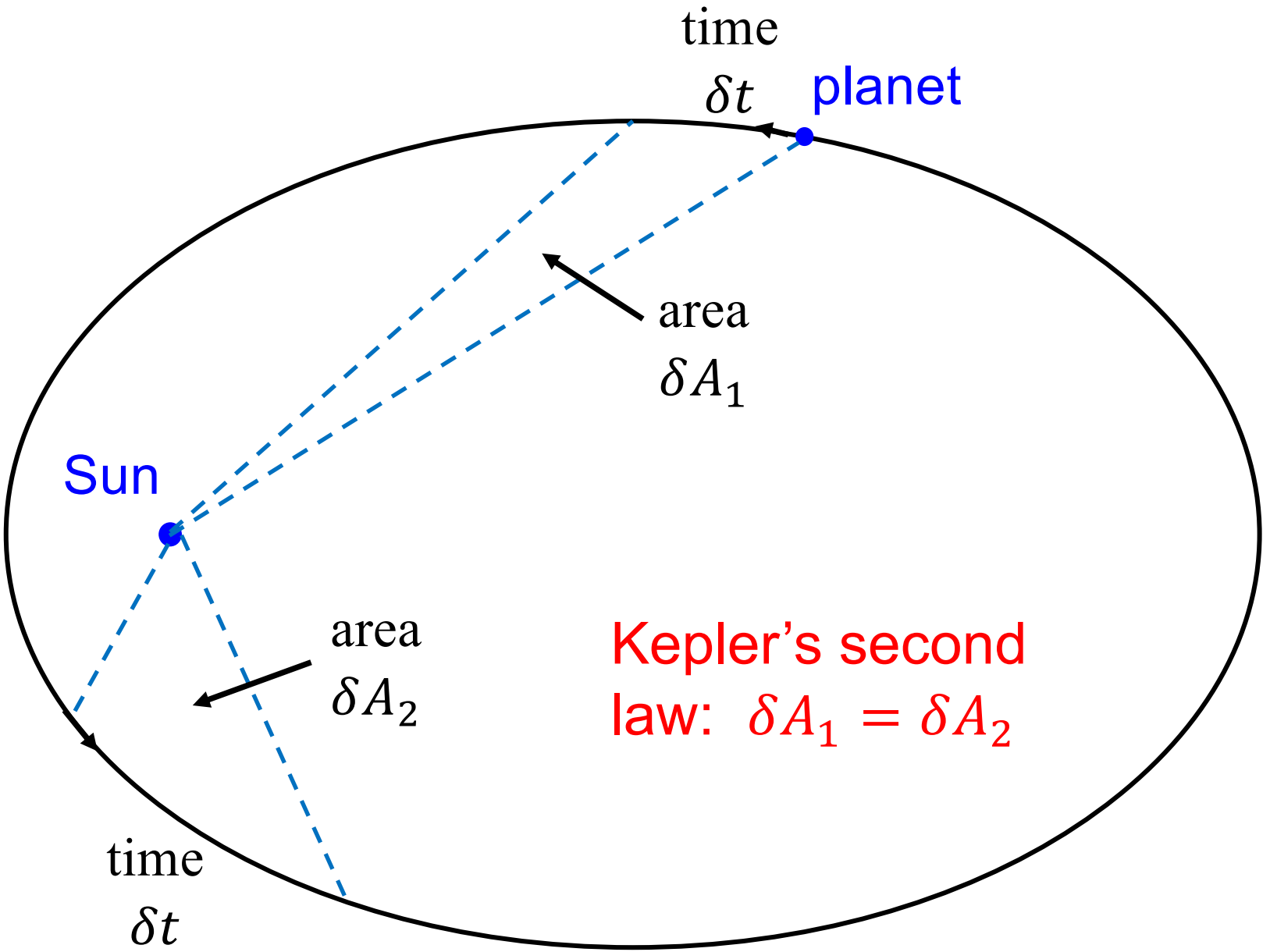
Planetary images from Galileo, Cassini, Voyager



$$e = \sqrt{1 - \frac{b^2}{a^2}}$$

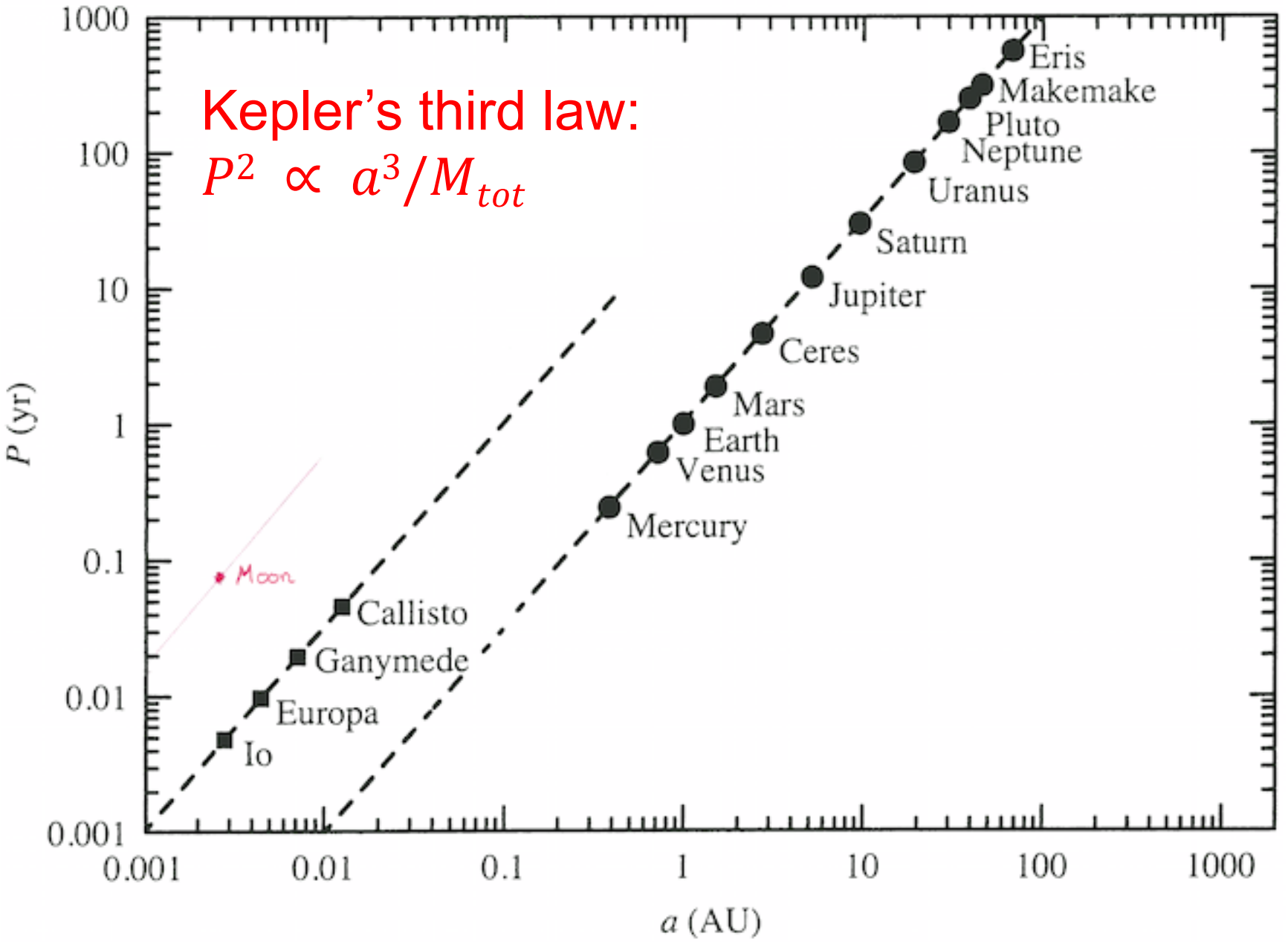
Kepler's first law: orbit is an ellipse

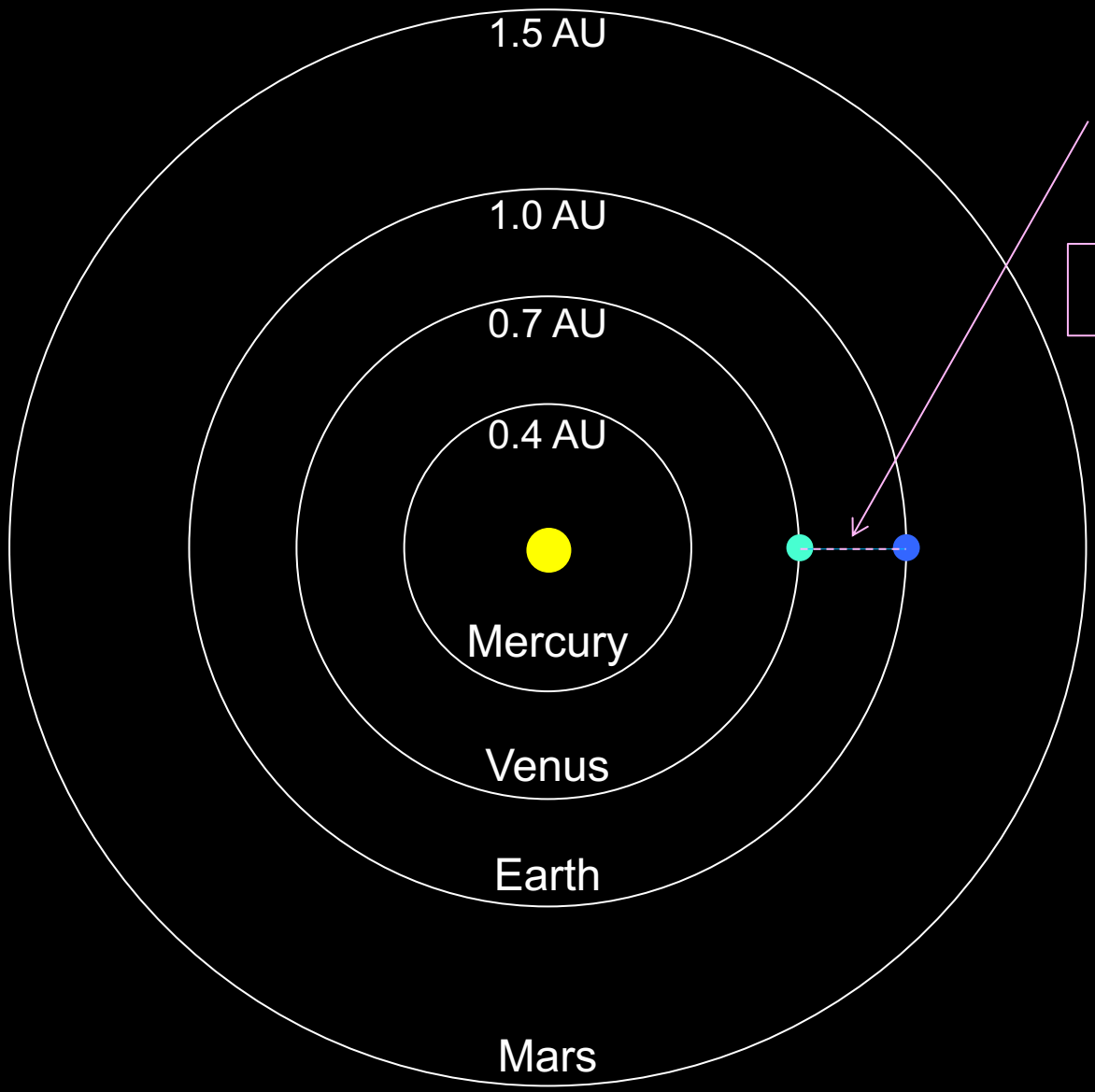



time
δt
planet
area
δA_1
Sun
area
δA_2
Kepler's second
law: $\delta A_1 = \delta A_2$
time
δt

Some Planetary Properties

Planet	semimajor axis (AU)	period (yr)	eccentricity	inclination (degrees)	mass (Earth)	radius (Earth)
Mercury	0.387	0.241	0.206	7	0.0553	0.383
Venus	0.723	0.615	0.0068	3.4	0.815	0.95
Earth	1	1	0.0167	0	1	1
Mars	1.52	1.88	0.0934	1.9	0.107	0.532
Jupiter	5.2	11.9	0.0485	1.3	318	11
Saturn	9.54	29.5	0.0557	2.5	95.2	9.14
Uranus	19.2	84	0.0472	0.77	14.5	3.98
Neptune	30.1	165	0.00858	1.8	17.2	3.87

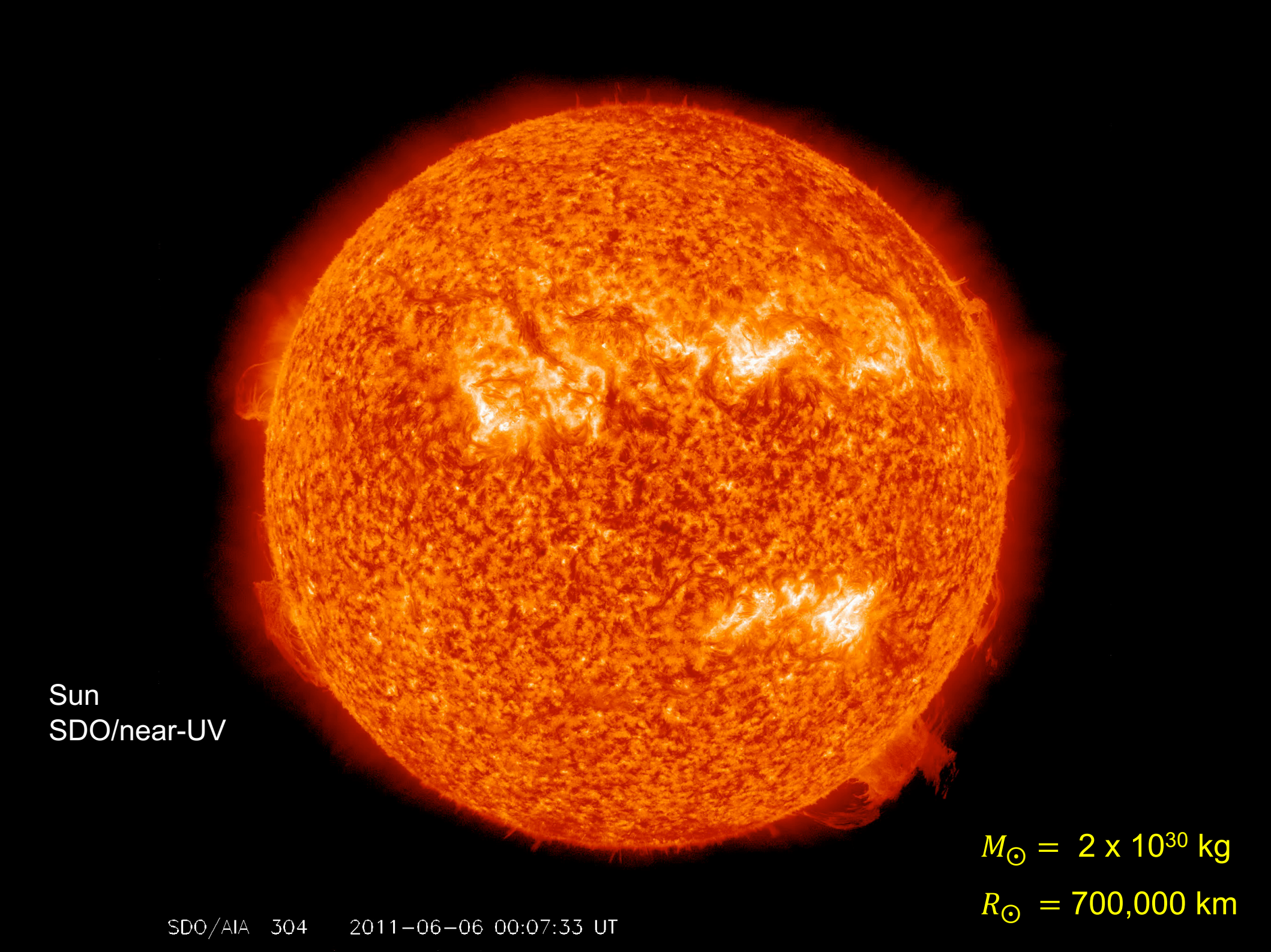

Kepler's third law:
$P^2 \propto a^3/M_{tot}$
1000
100
10
1
0.1
0.01
0.001
P (yr)
0.001
0.01
0.1
1
10
100
1000
a (AU)
Eris
Makemake
Pluto
Neptune
Uranus
Saturn
Jupiter
Ceres
Mars
Earth
Venus
Mercury
Moon
Callisto
Ganymede
Europa
Io

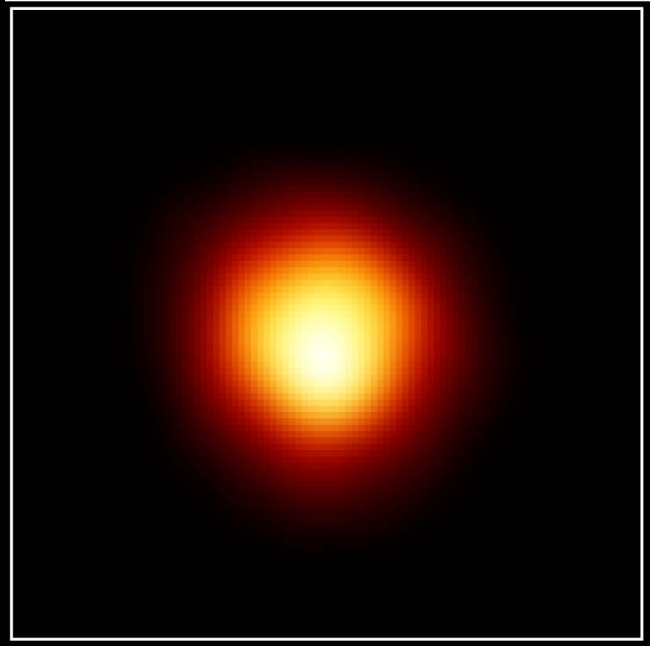


Radar ranging:

0.3 AU = 150 light sec
= 4.5×10^7 km

1 AU = 1.5×10^8 km

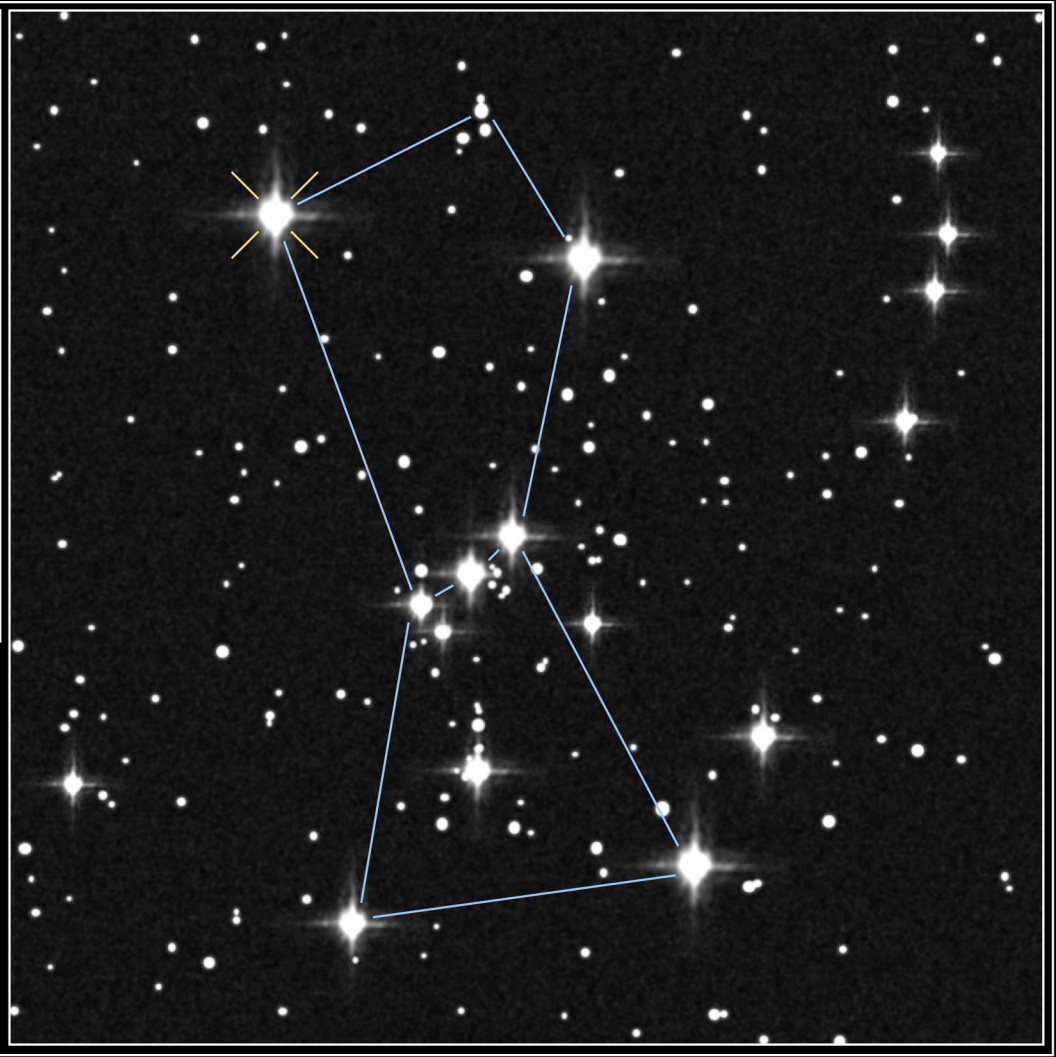

Sun
SDO/near-UV
SDO/AIA 304 2011-06-06 00:07:33 UT
$M_\odot$ = 2 x 10^{30} kg
$R_\odot$ = 700,000 km



Size of Star

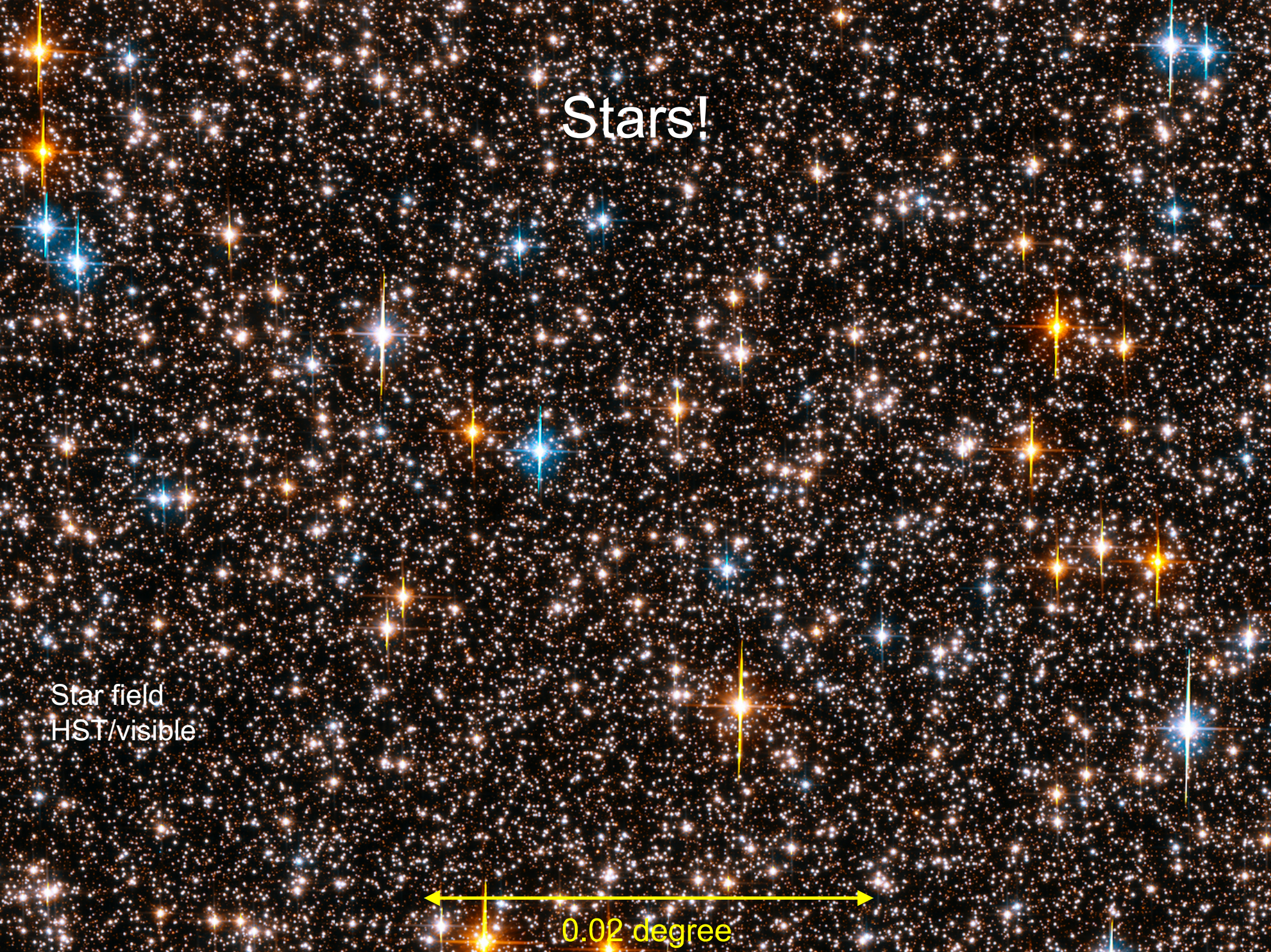
Size of Earth's Orbit

Size of Jupiter's Orbit

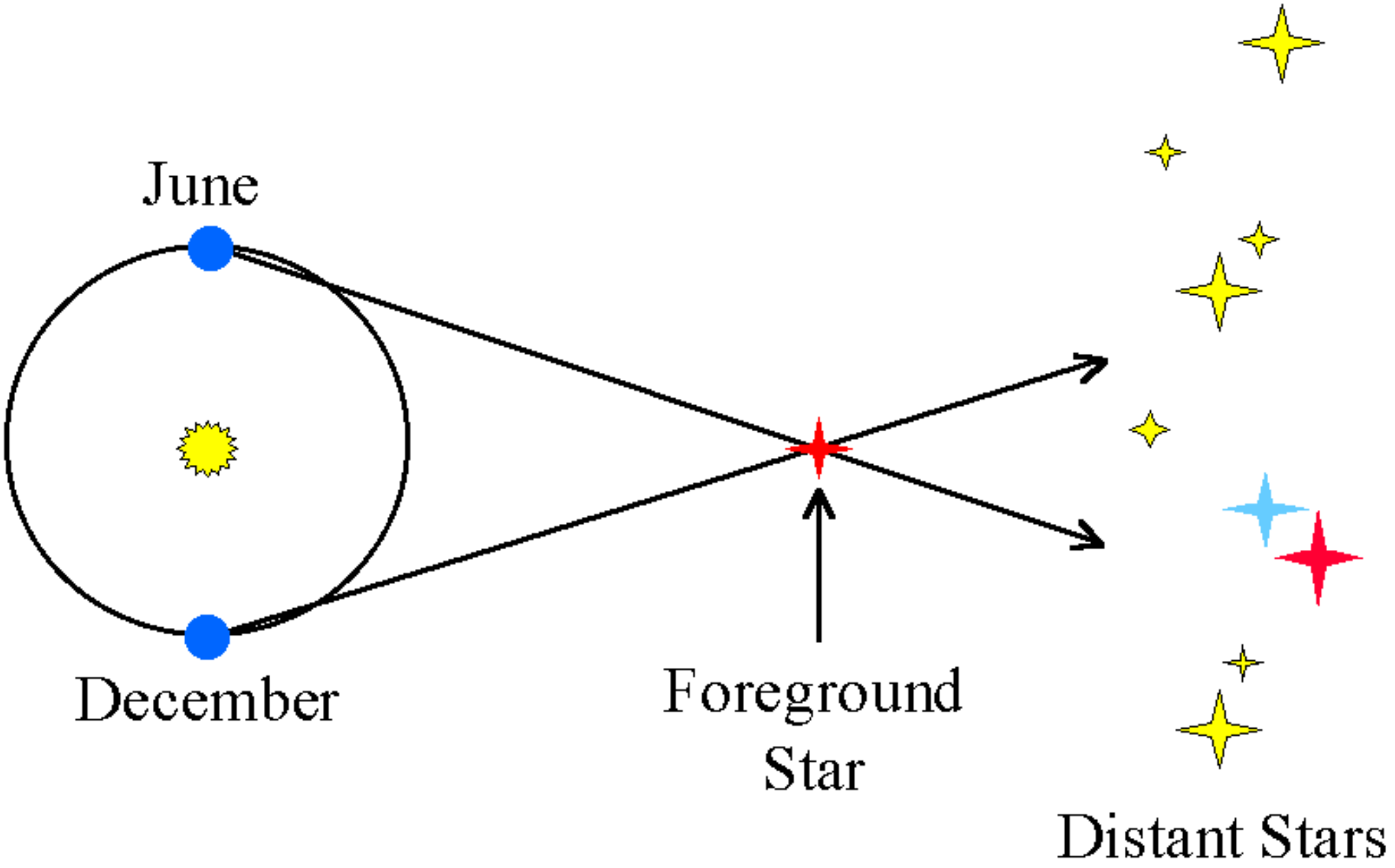


Atmosphere of Betelgeuse · Alpha Orionis

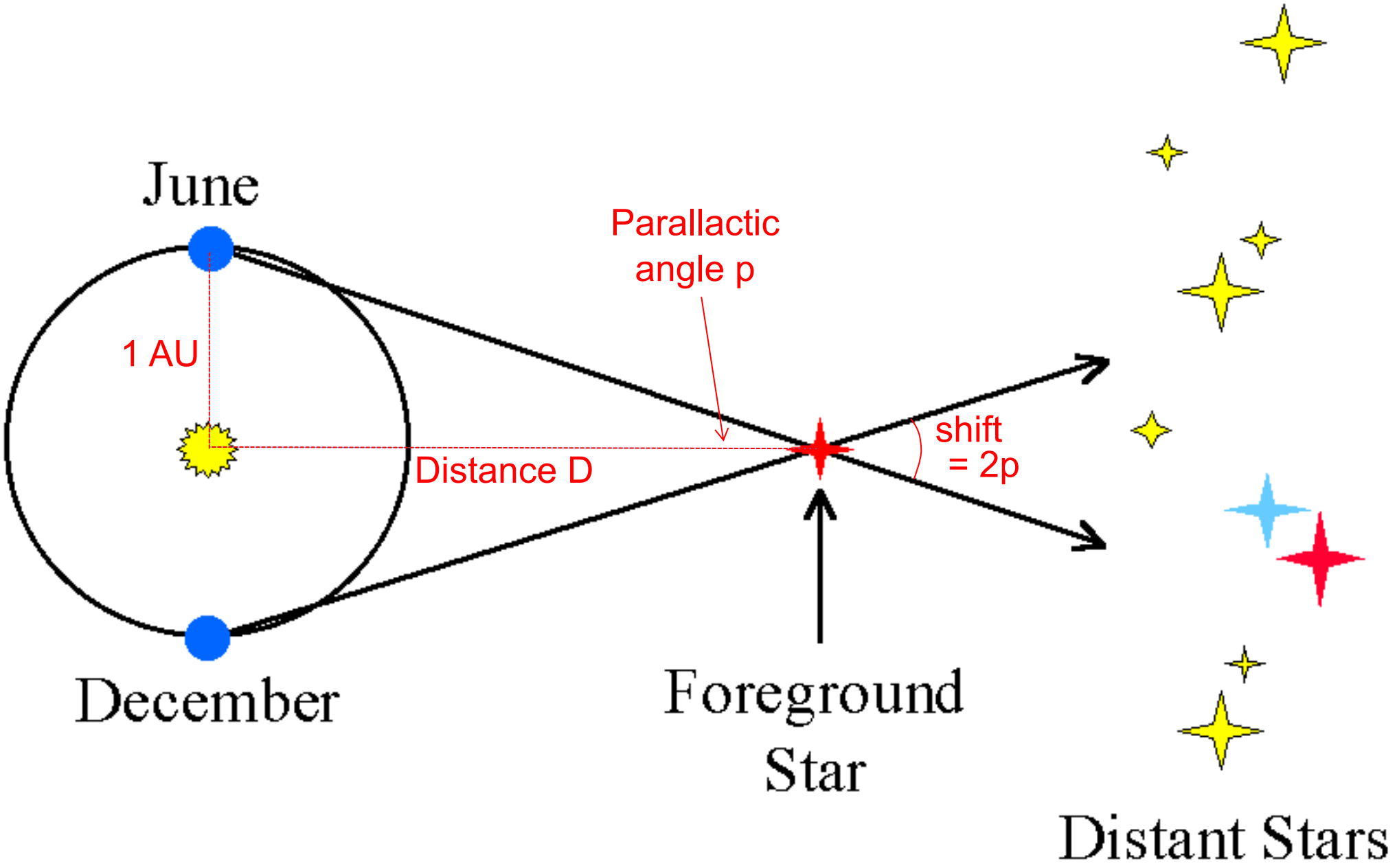
Hubble Space Telescope · Faint Object Camera

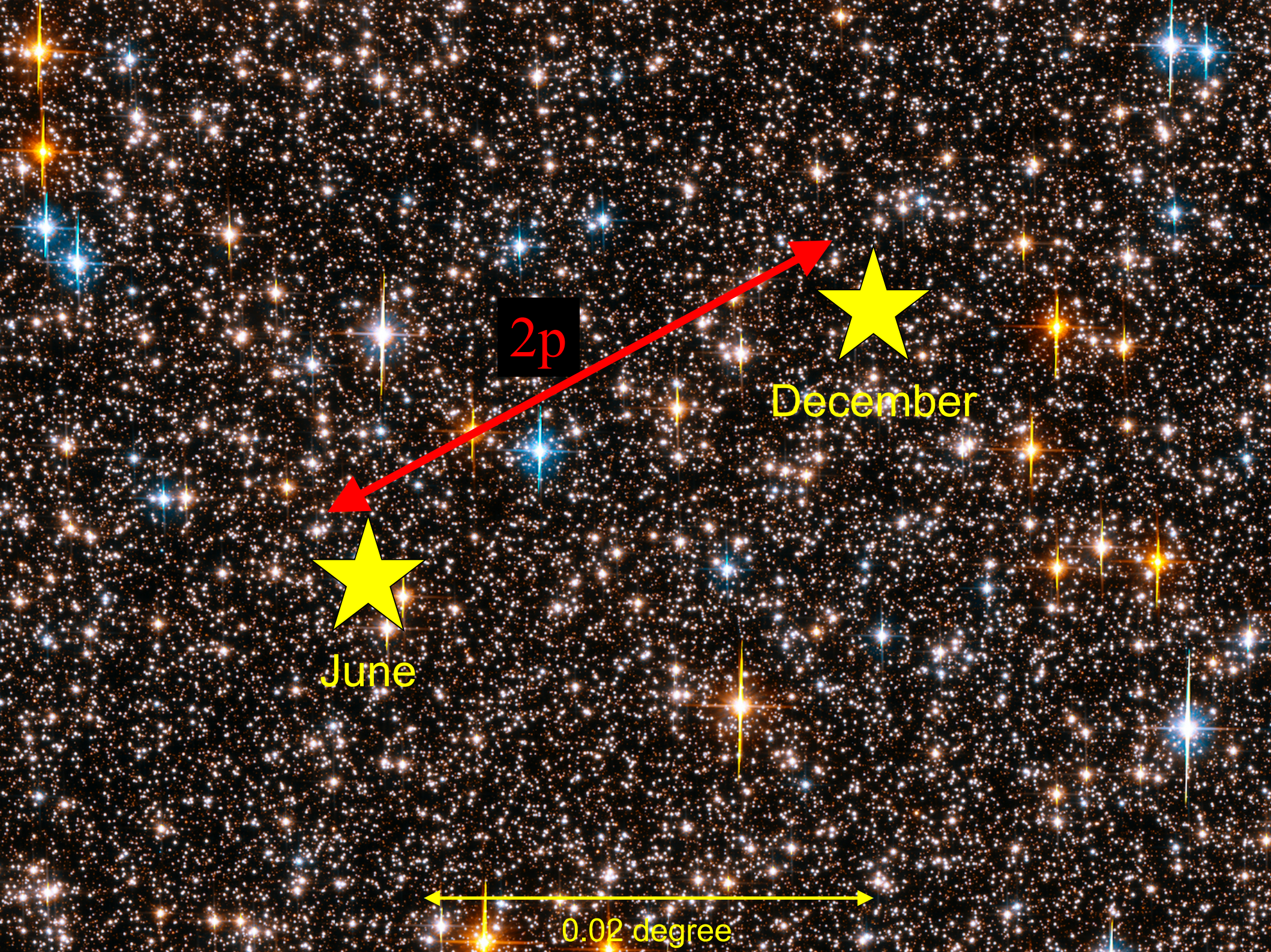

Stars!
Star field
HST/visible
0.02 degree

Parallax



Parallax


June
Parallactic
angle p
1 AU
shift
= 2p
Distance D
December
Foreground
Star
Distant Stars

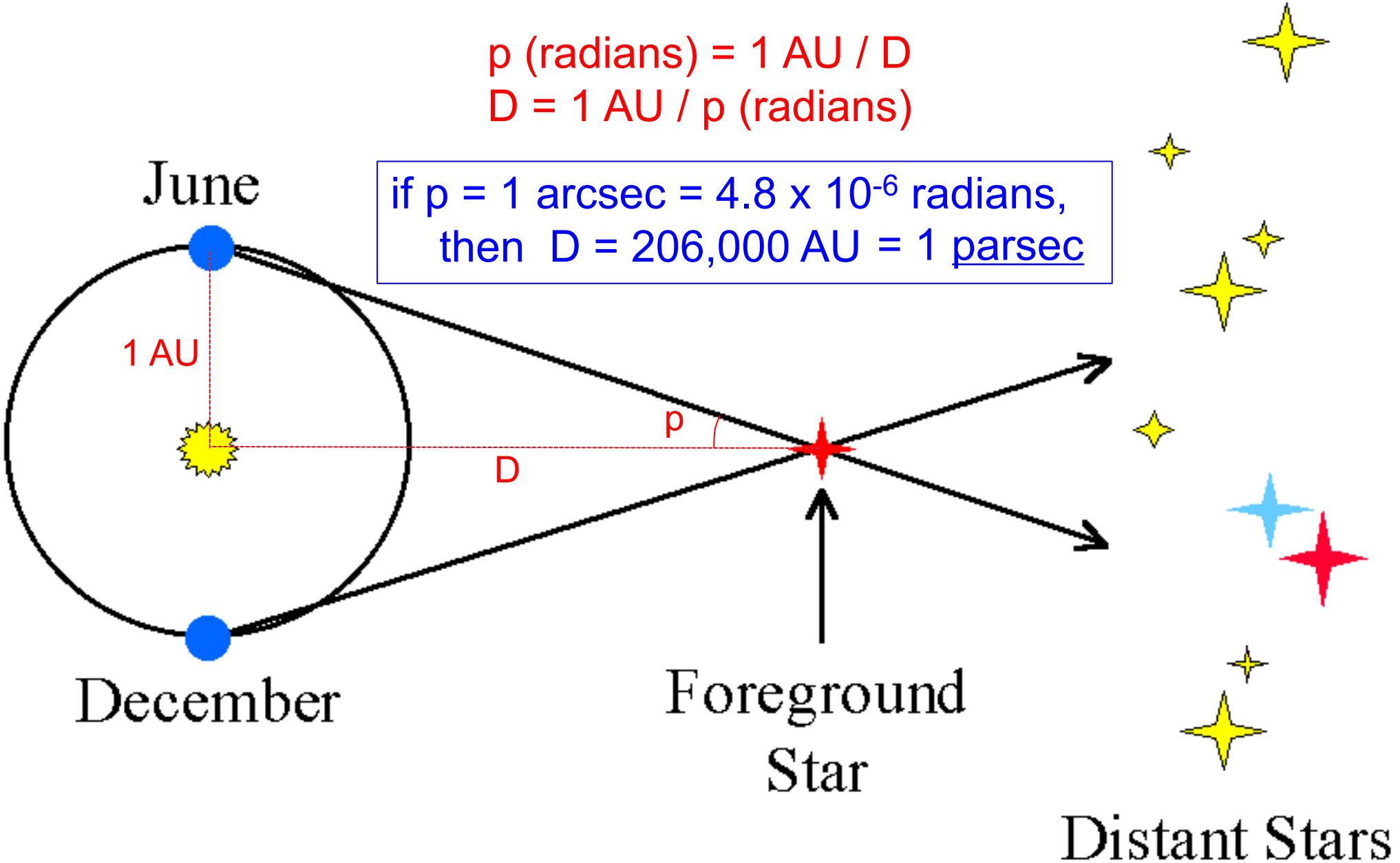

2p
December
June
0.02 degree

Parallax

p (radians) = 1 AU / D

D = 1 AU / p (radians)

if p = 1 arcsec = 4.8 x 10^{-6} radians,
then D = 206,000 AU = 1 parsec

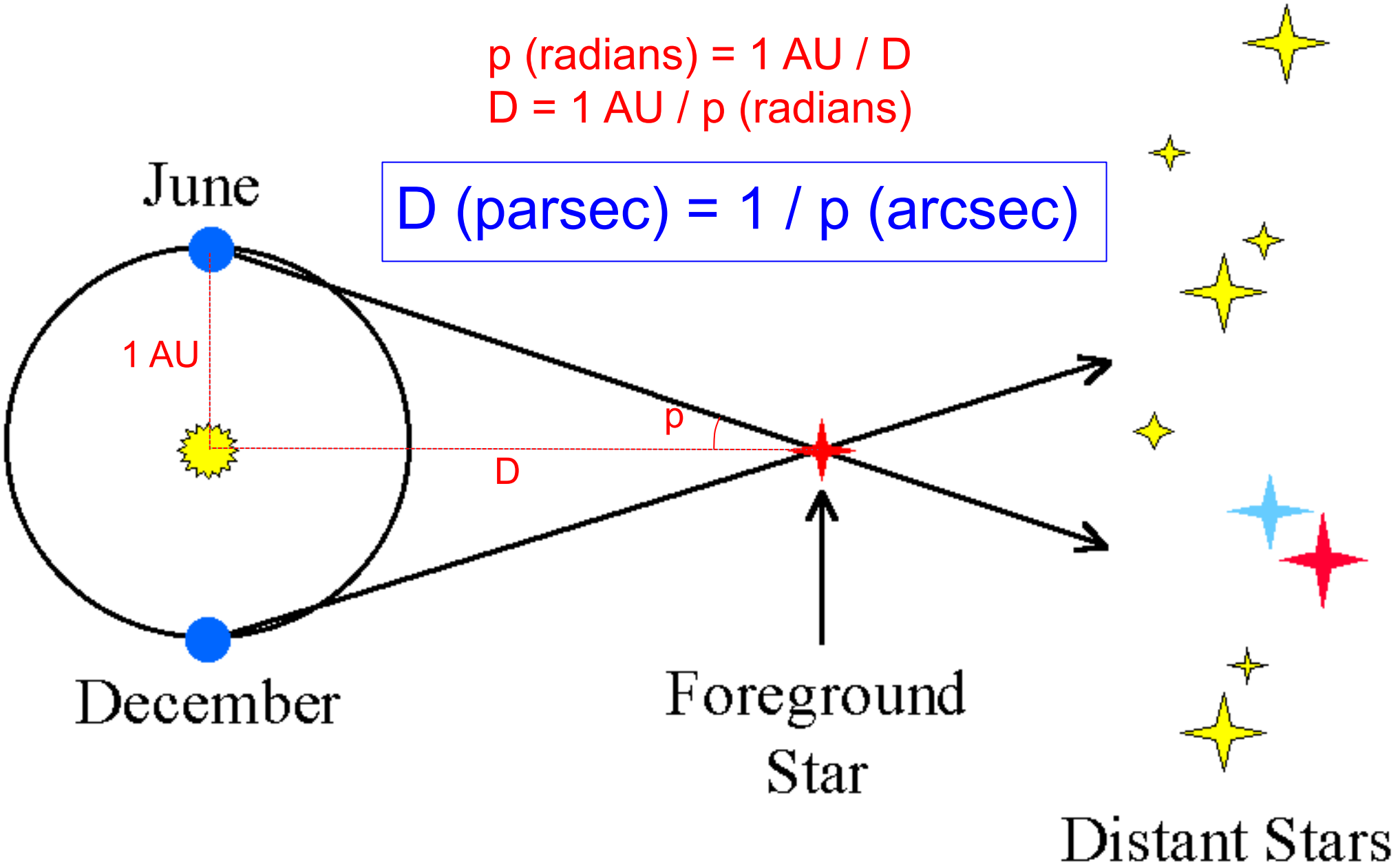


Parallax

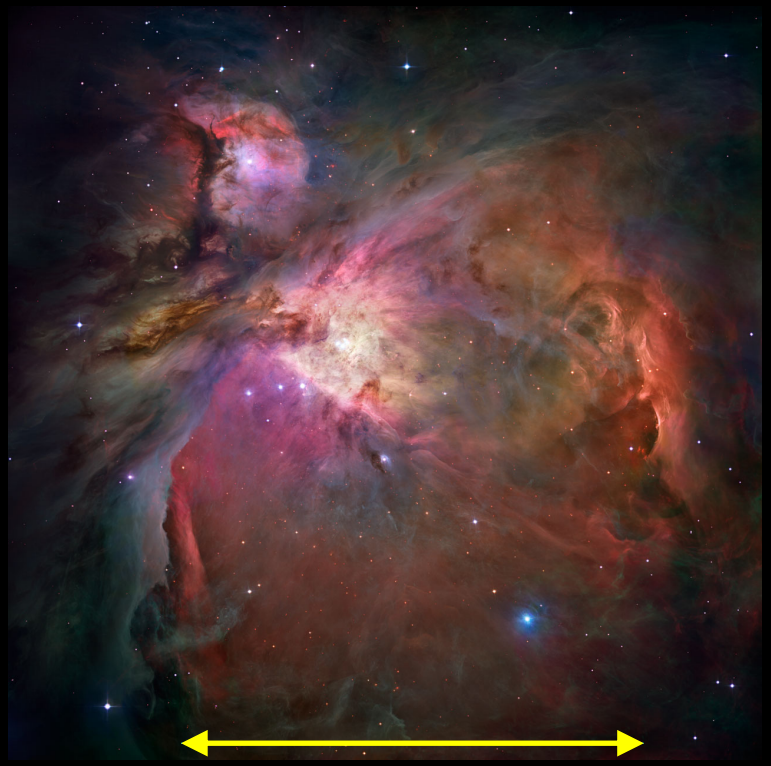
p (radians) = 1 AU / D

D = 1 AU / p (radians)

D (parsec) = 1 / p (arcsec)



Local Galaxy Residents

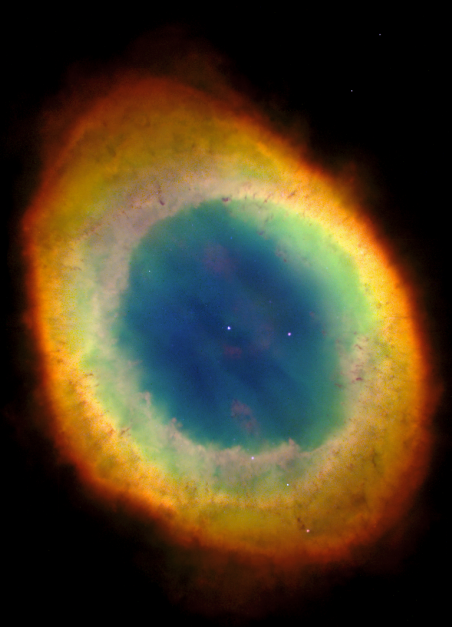


5 pc

M42, the Orion Nebula,
a star forming region
distance 410 pc
HST/visible

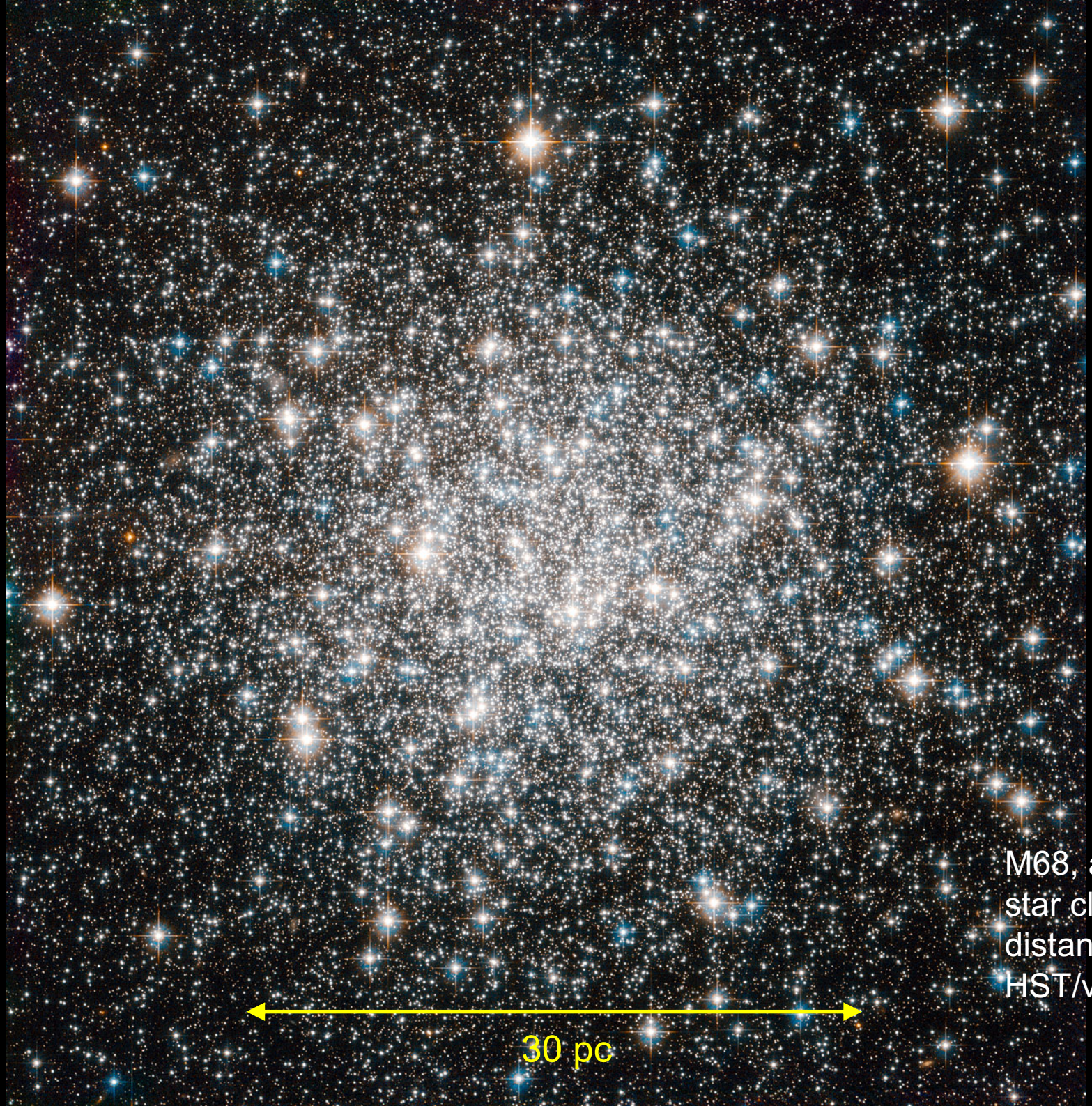
2 pc

M45, the Pleiades young
star cluster
distance 140 pc
visible light



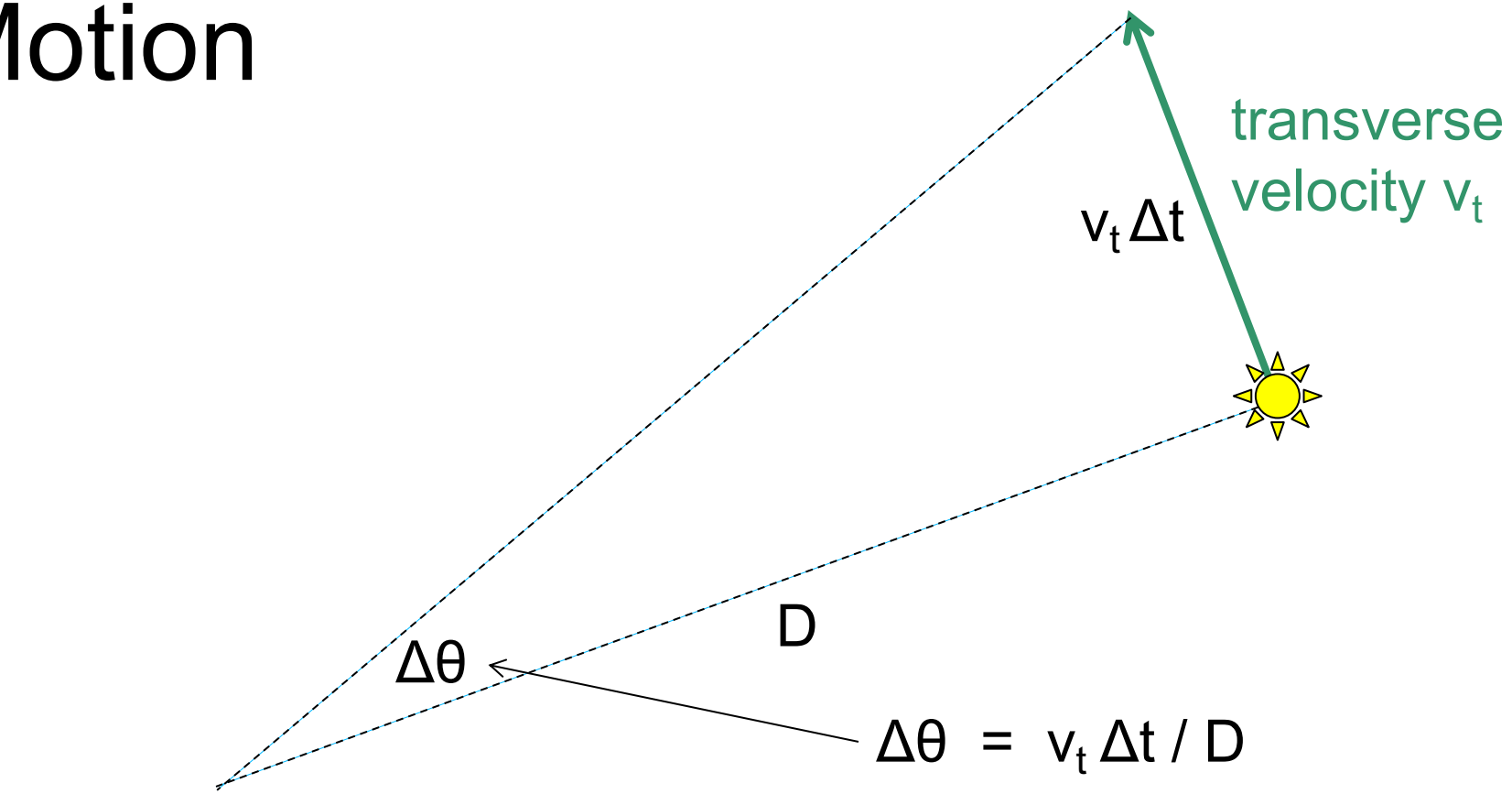
0.25 pc

M57, the Ring Nebula,
a planetary nebula
distance 700 pc
HST/visible



M68, a globular star cluster
distance 10 kpc
HST/visible

Proper Motion

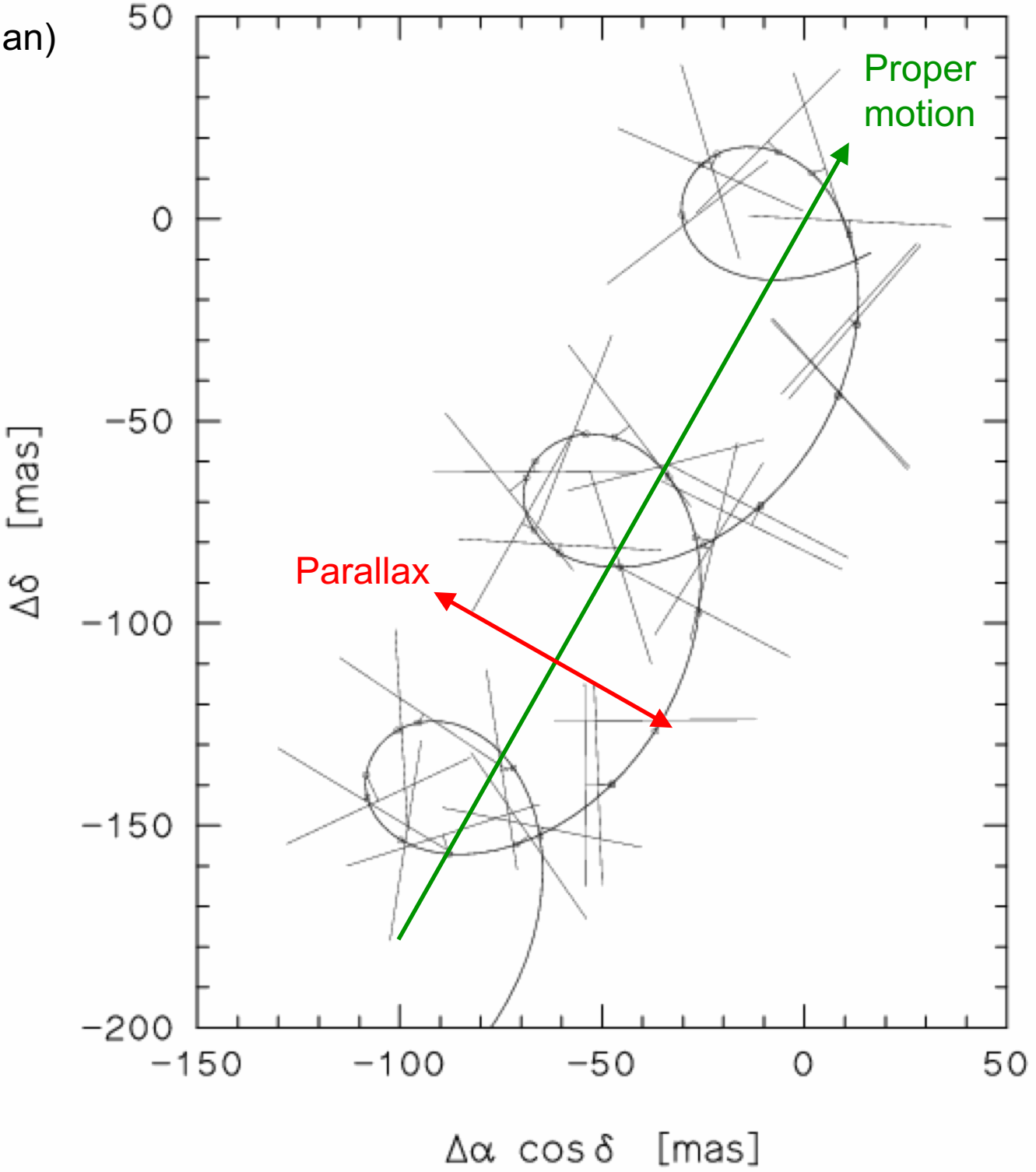


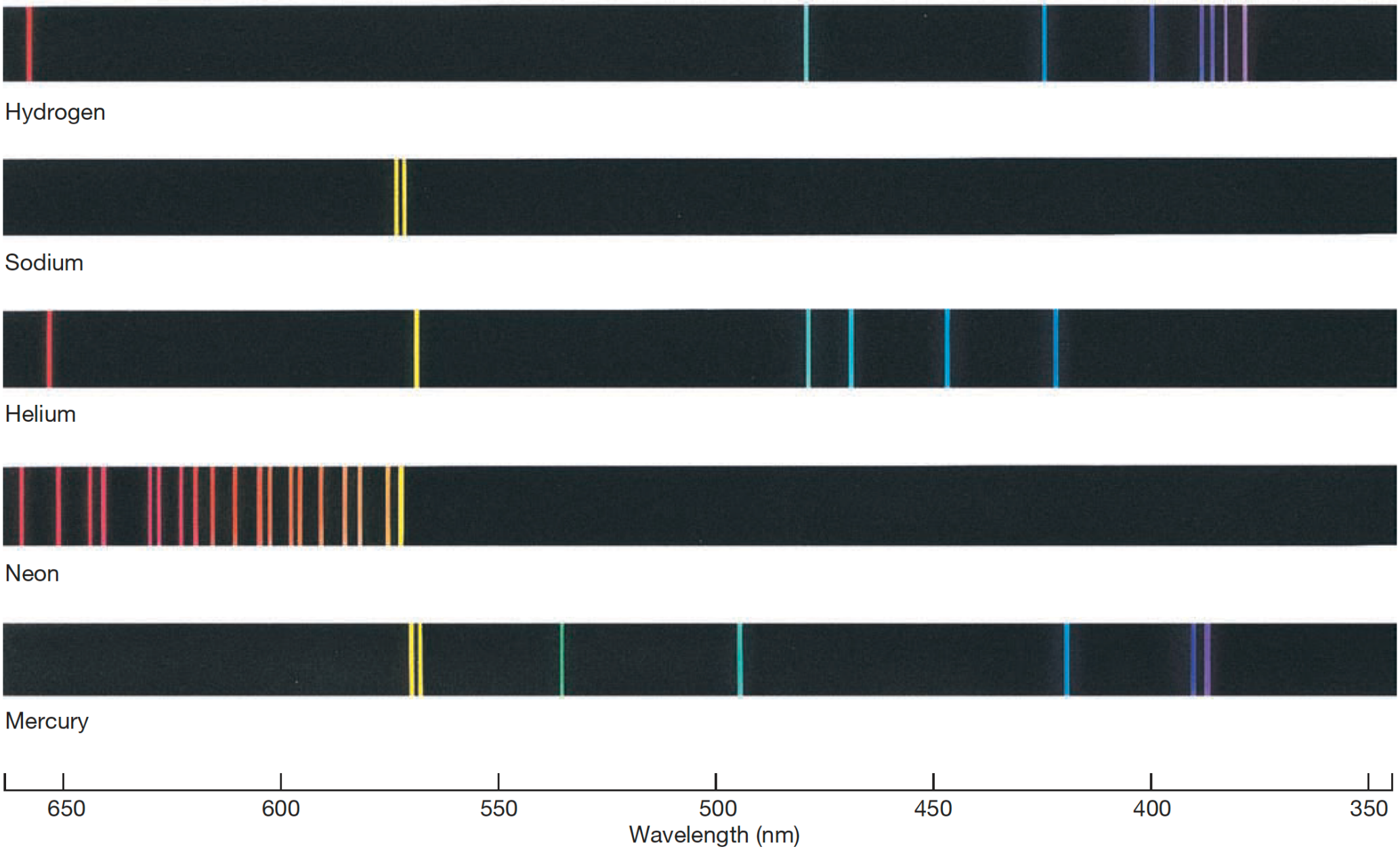
$\Delta\theta = v_t \Delta t / D$

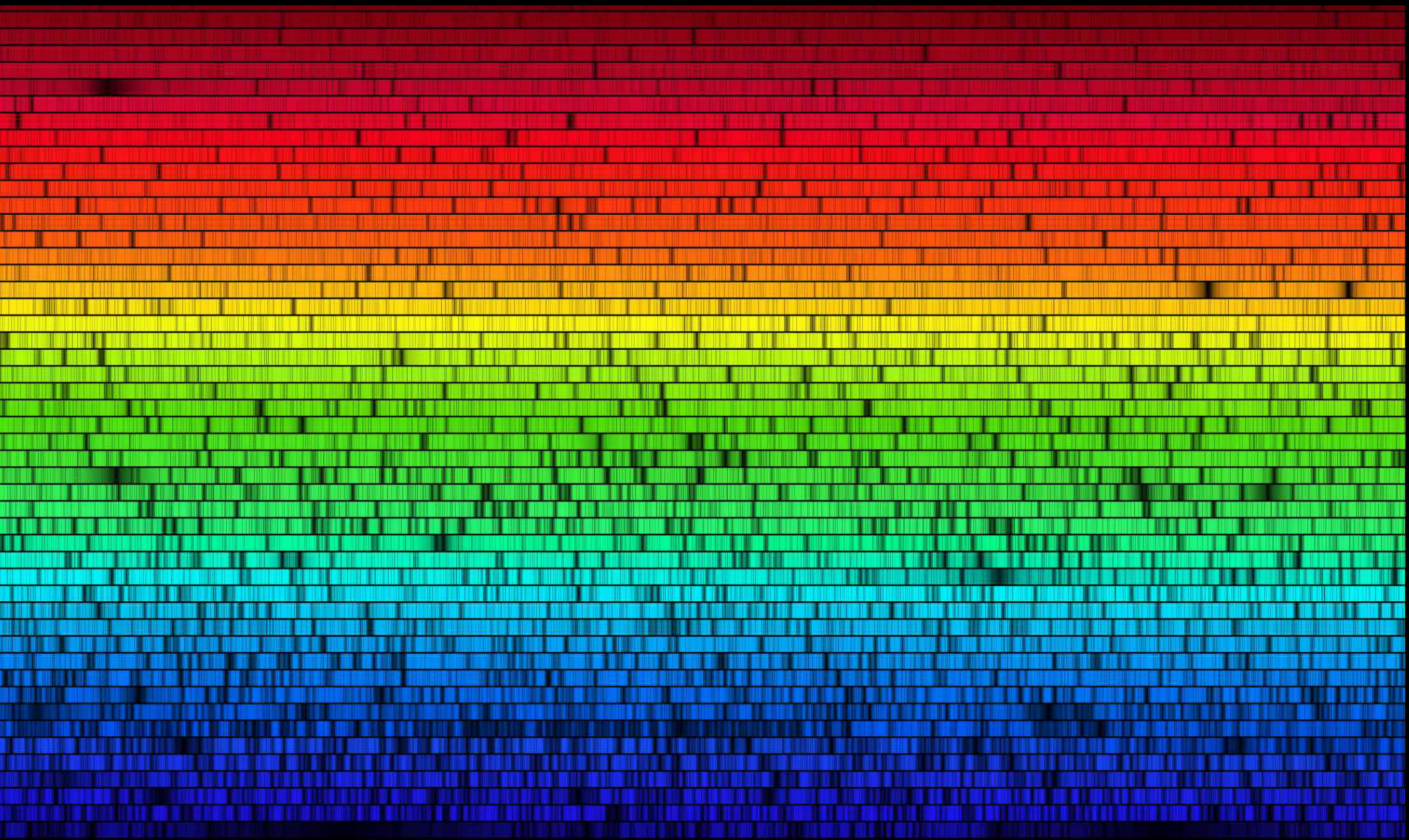
μ (arcsec/yr)
$= v_t$ (km/s) / 4.74 D (pc)


- 2008 August 26
- 2007 June 23
- 2006 August 8
- 2005 July 23
- 2004 May 29
Barnard's Star

(M. Perryman)


Proper
motion
Parallax
50
0
−50
−100
−150
−200
−150
−100
−50
0
50
Δδ [mas]
Δα cos δ [mas]


Hydrogen
Sodium
Helium
Neon
Mercury
650
600
550
500
450
400
350
Wavelength (nm)



Doppler Effect

$$\frac{\Delta f}{f} = -\frac{v}{c}$$

Lower frequency

$$\frac{\Delta f}{f} = \frac{v}{c}$$

Higher frequency