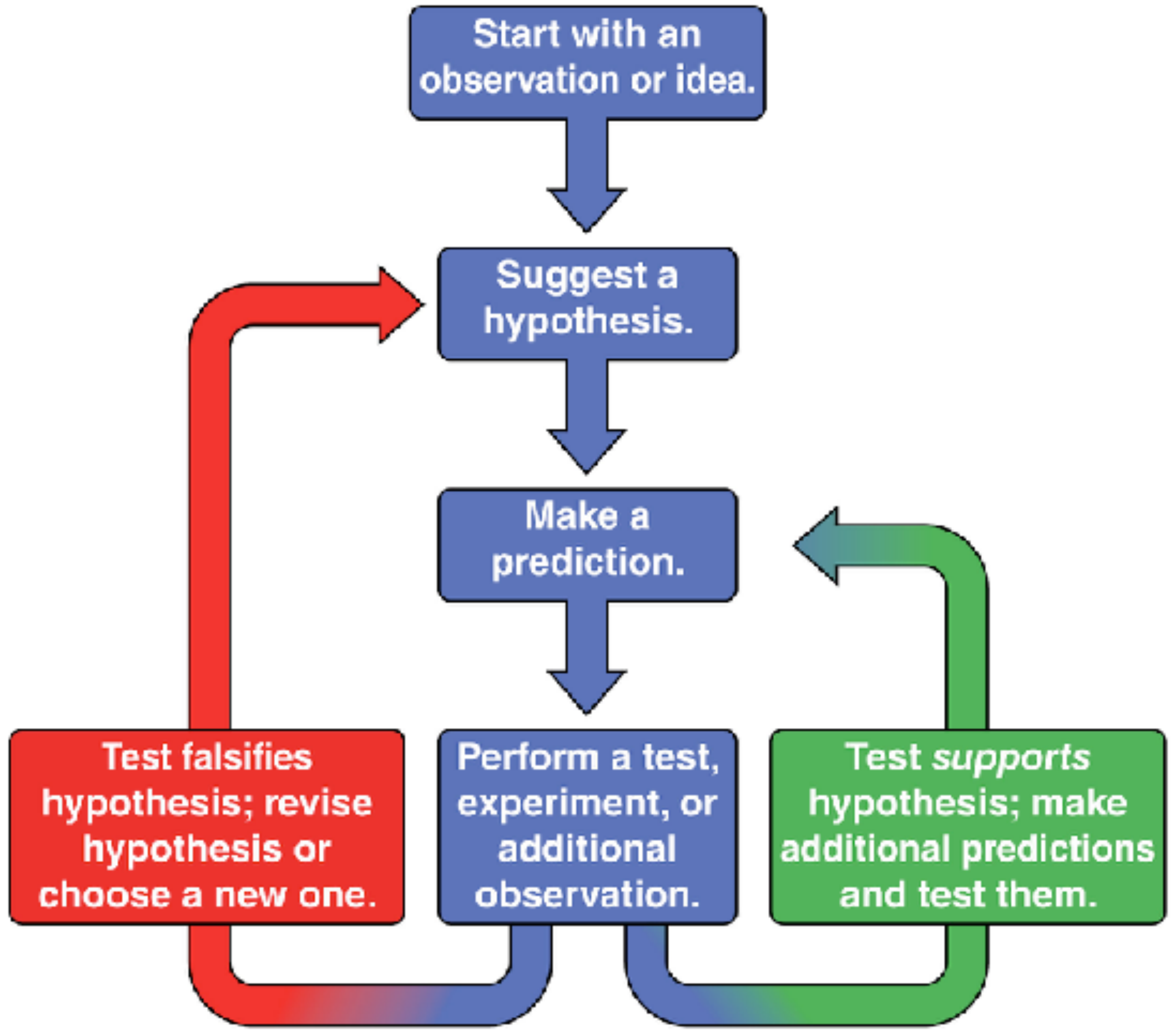
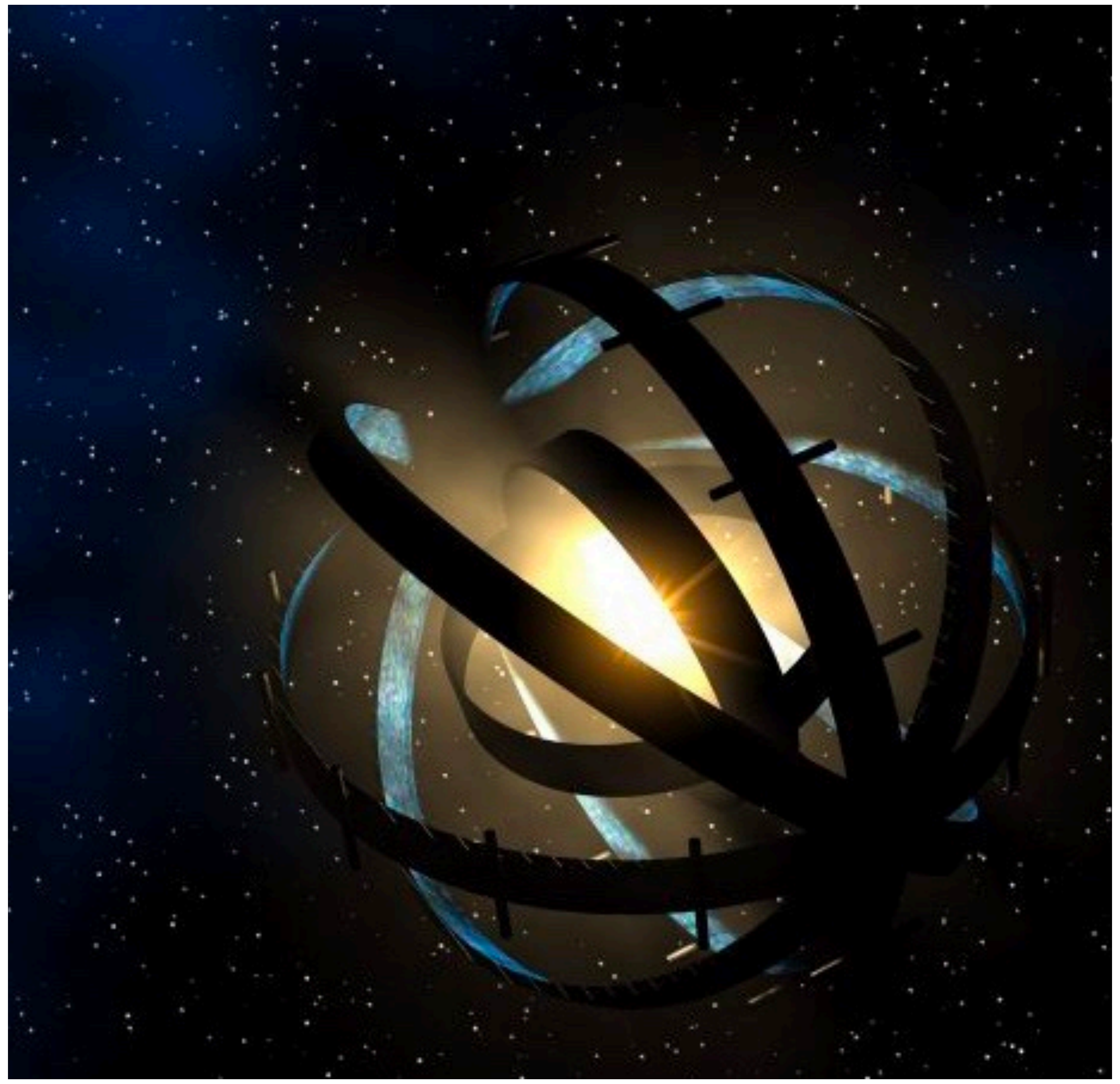

# Final Exam Review




December 9th
8:00am
JFB 101 (this room)

Pick up midterms from Mirna

TA-led review tomorrow from
3-6pm in AEB 320



# Exam Format

2hr time limit: 8:00-10:00am

counts 33% more toward your final grade than a midterm, so the exam will be roughly 33% longer (2hr should be plenty of time in other words)

Multiple Choice Questions

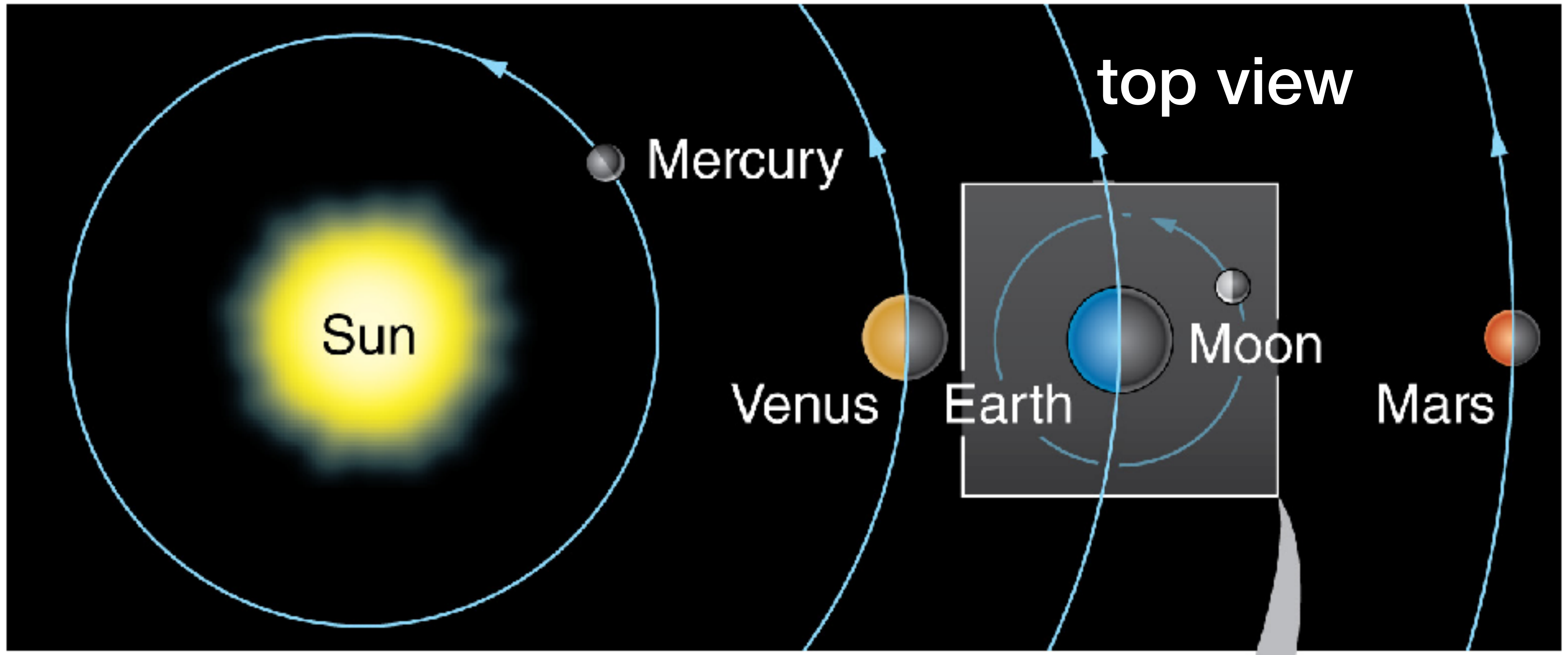
60-75% of total score

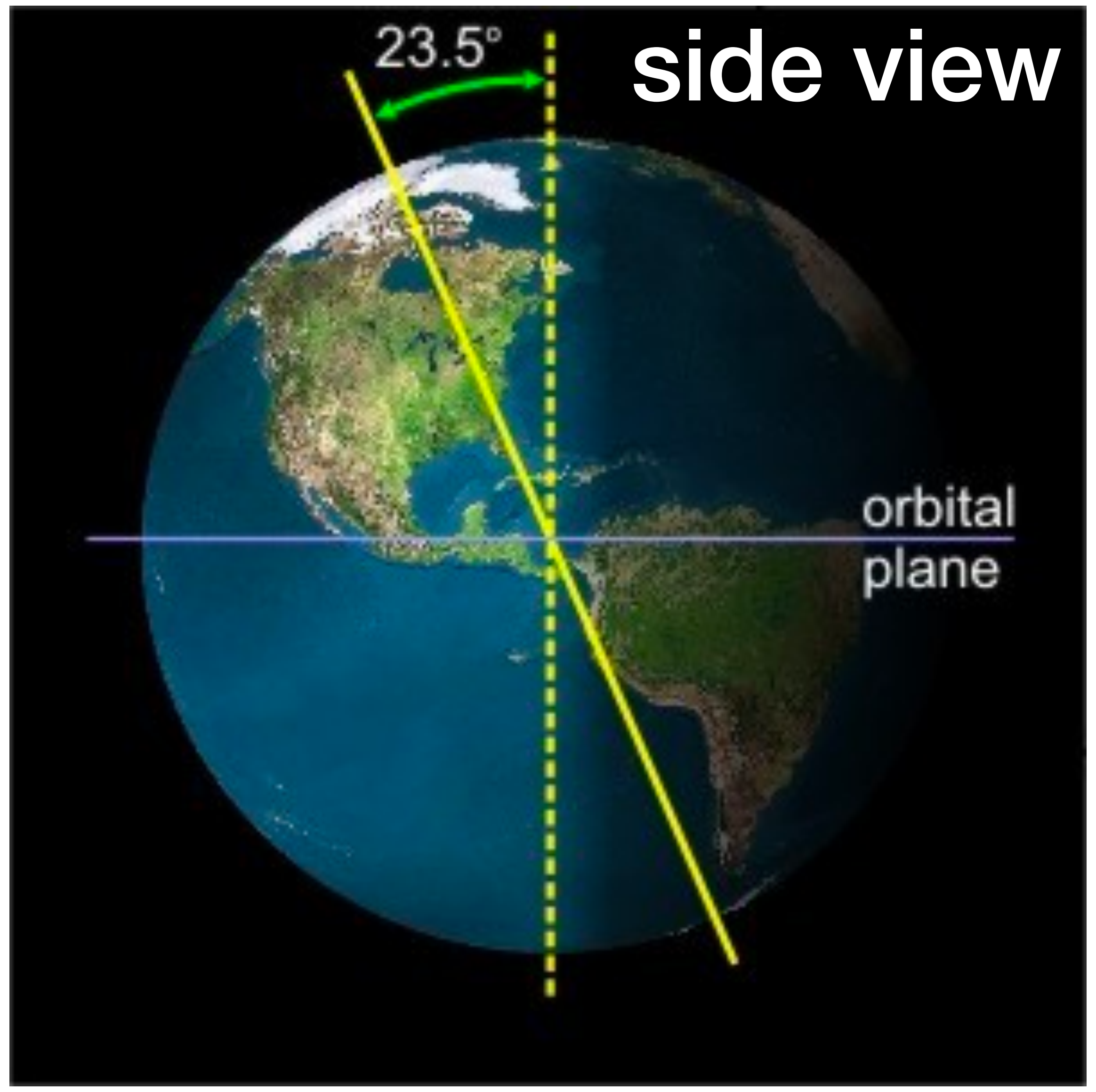
Short Answer Questions

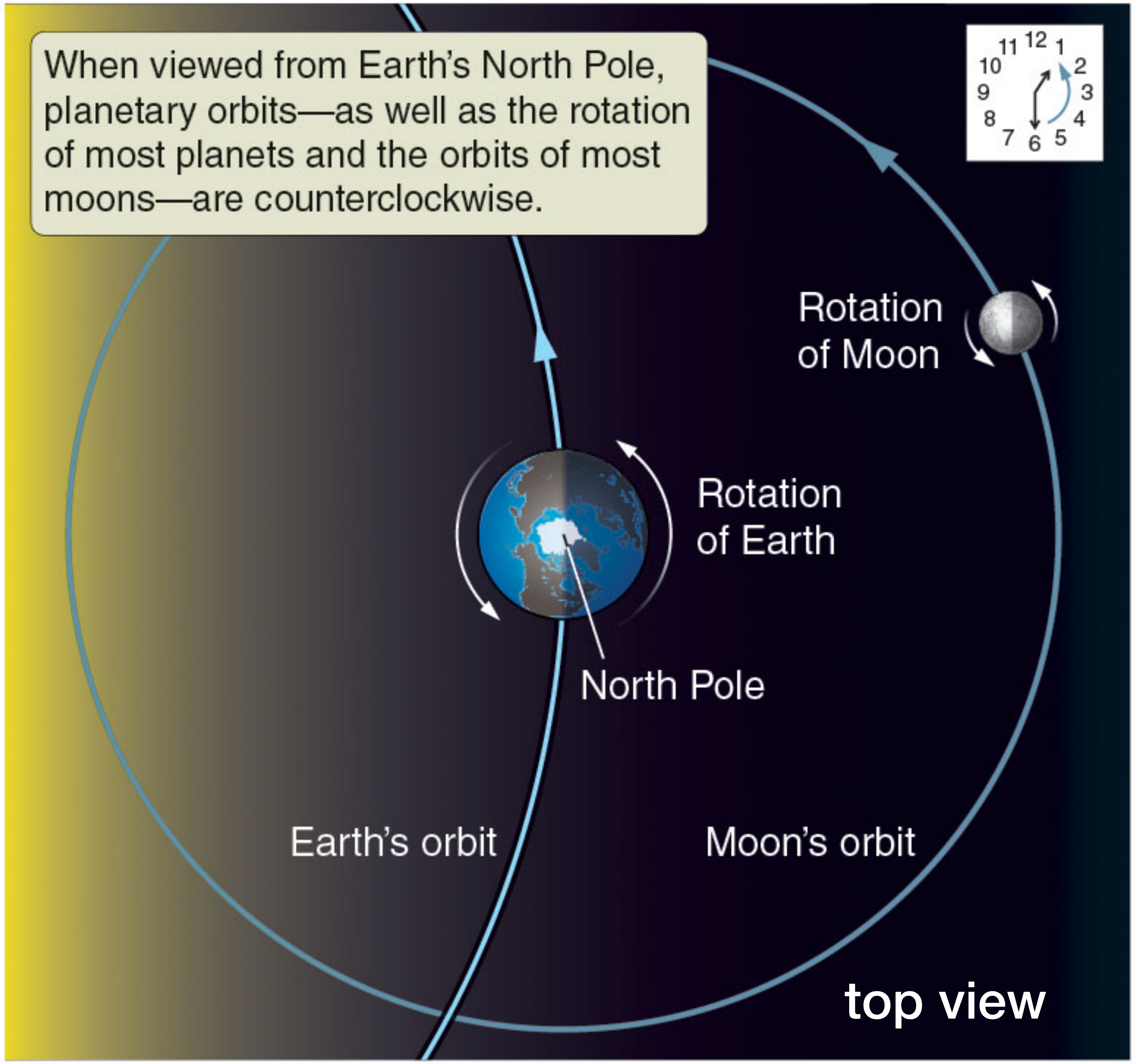
40-25% of total score

may require calculations, but calculators not needed (or allowed)

# Seasons and Moon Phases: it's all just perspective

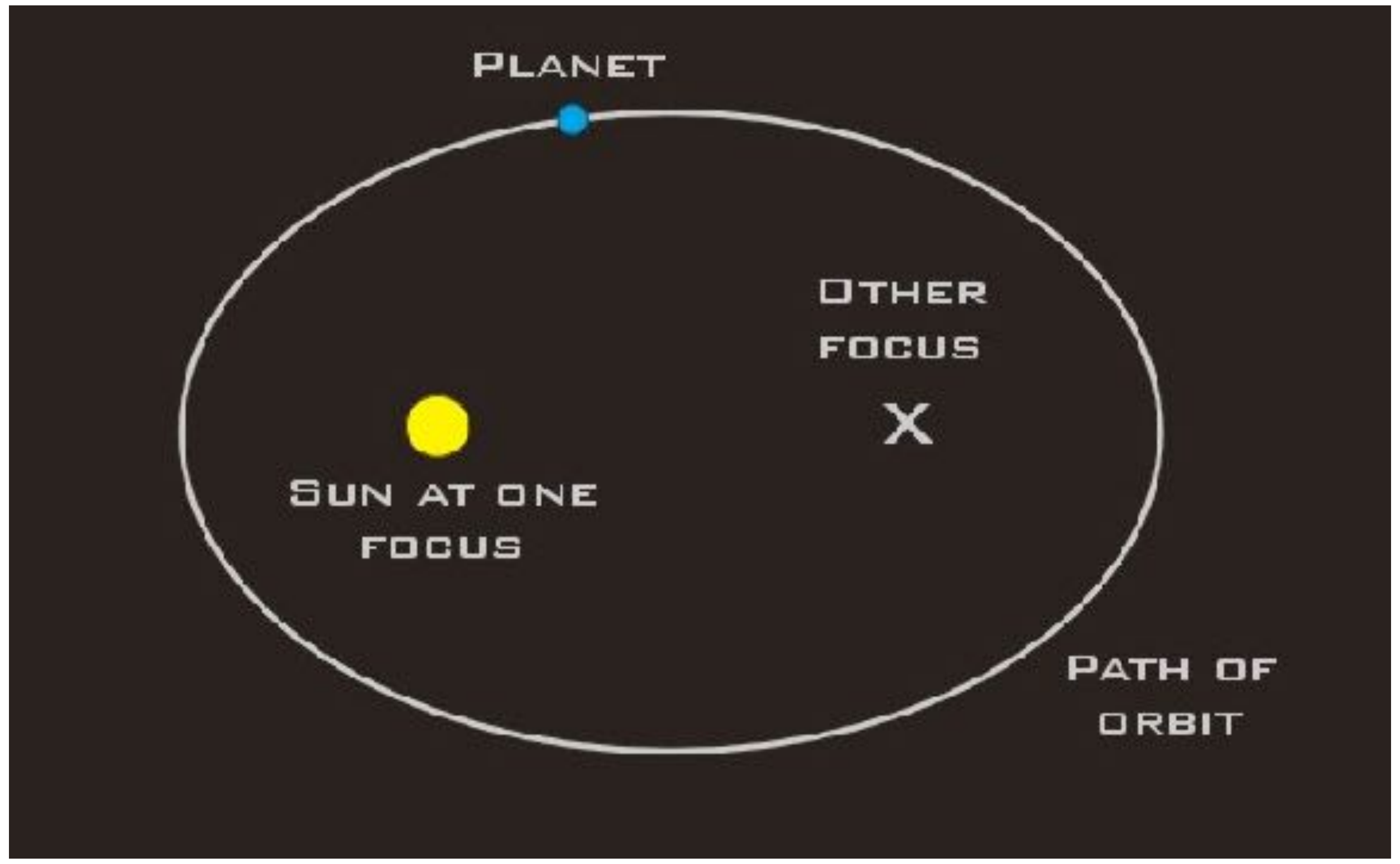


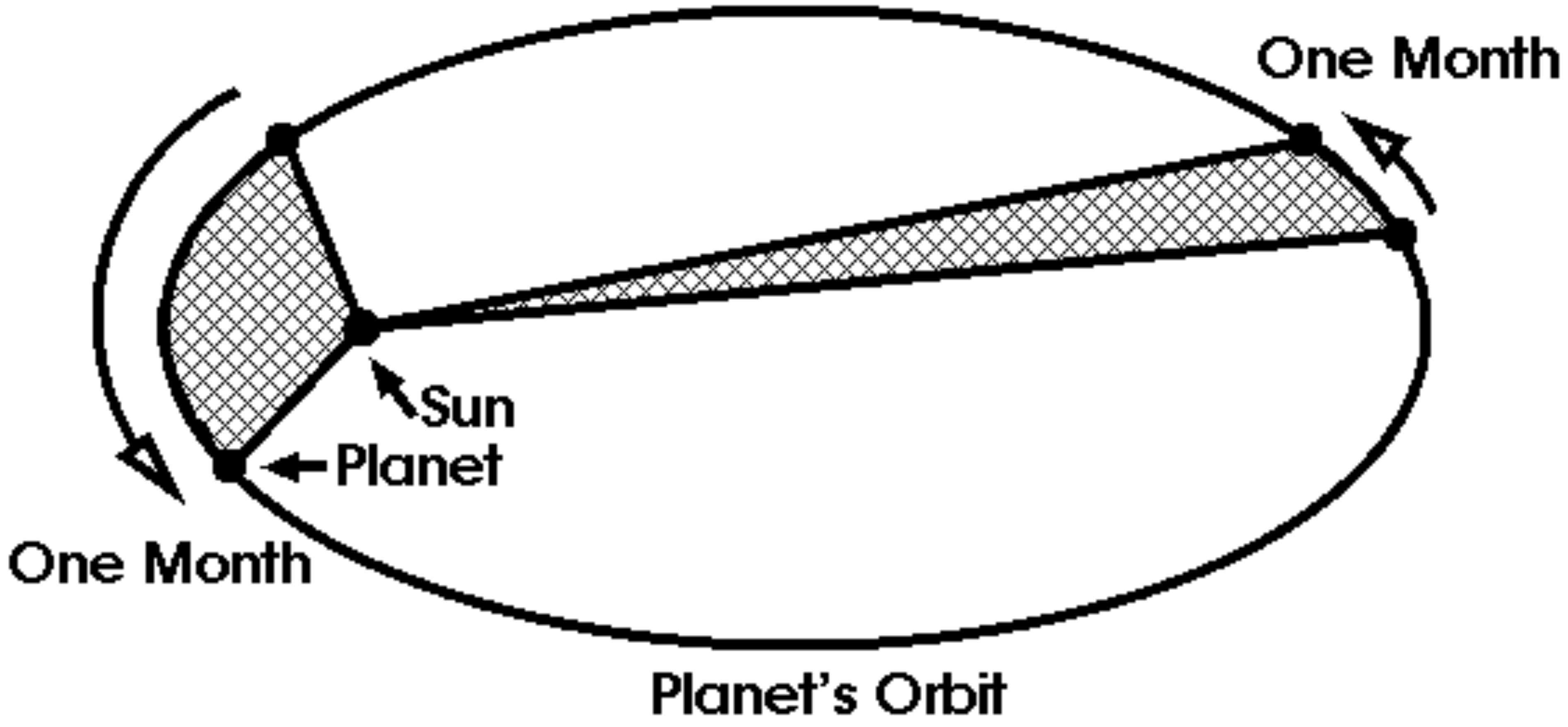



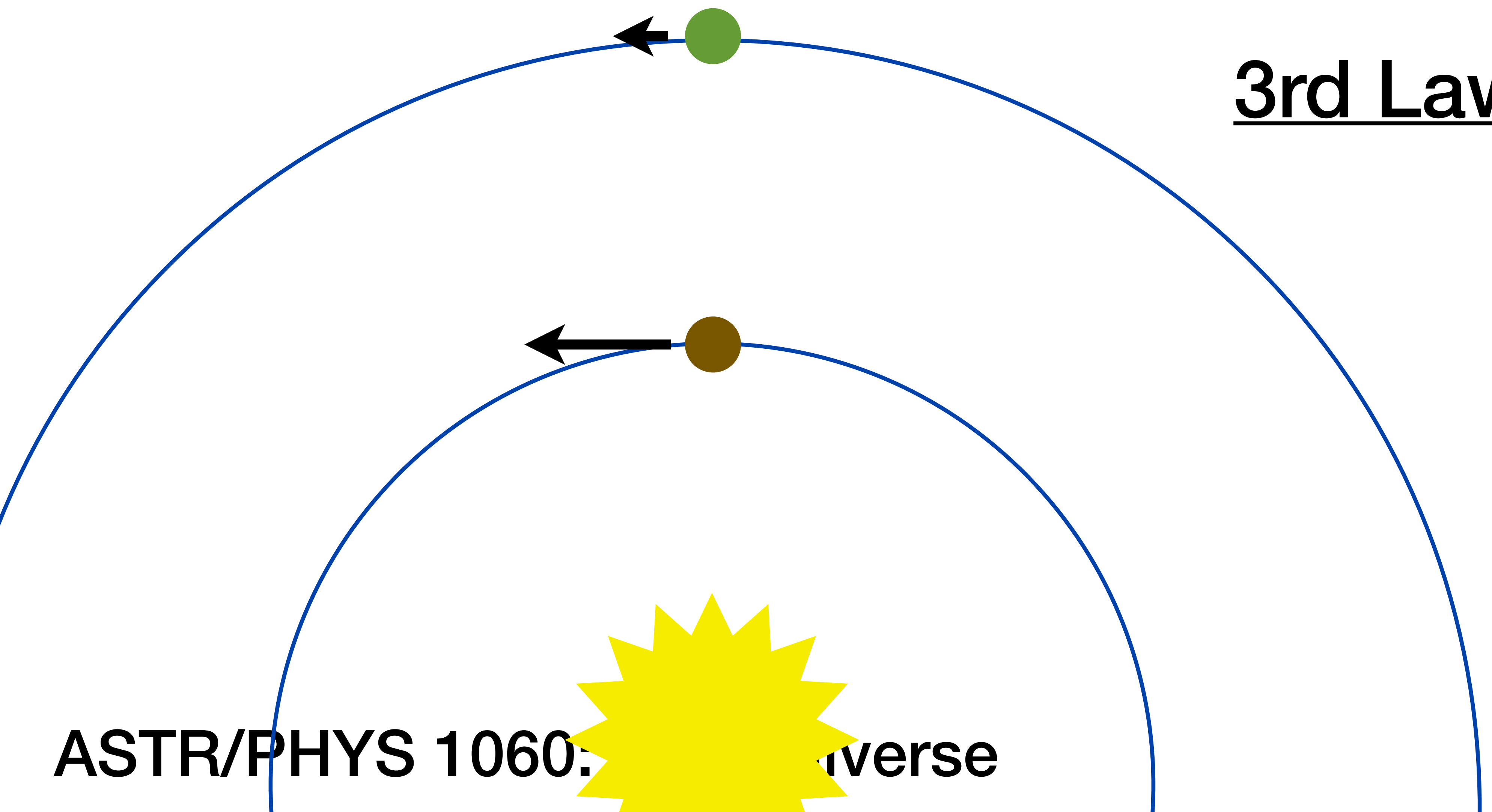
# Kepler's 3 Laws

<u>1st Law</u>: Orbits are elliptical




<u>2nd Law</u>: equal areas in equal times



<u>3rd Law</u>: period depends on distance

(Period of Planet [in years])$^2$

=

(Average Distance of Planet from Star [in AU])$^3$

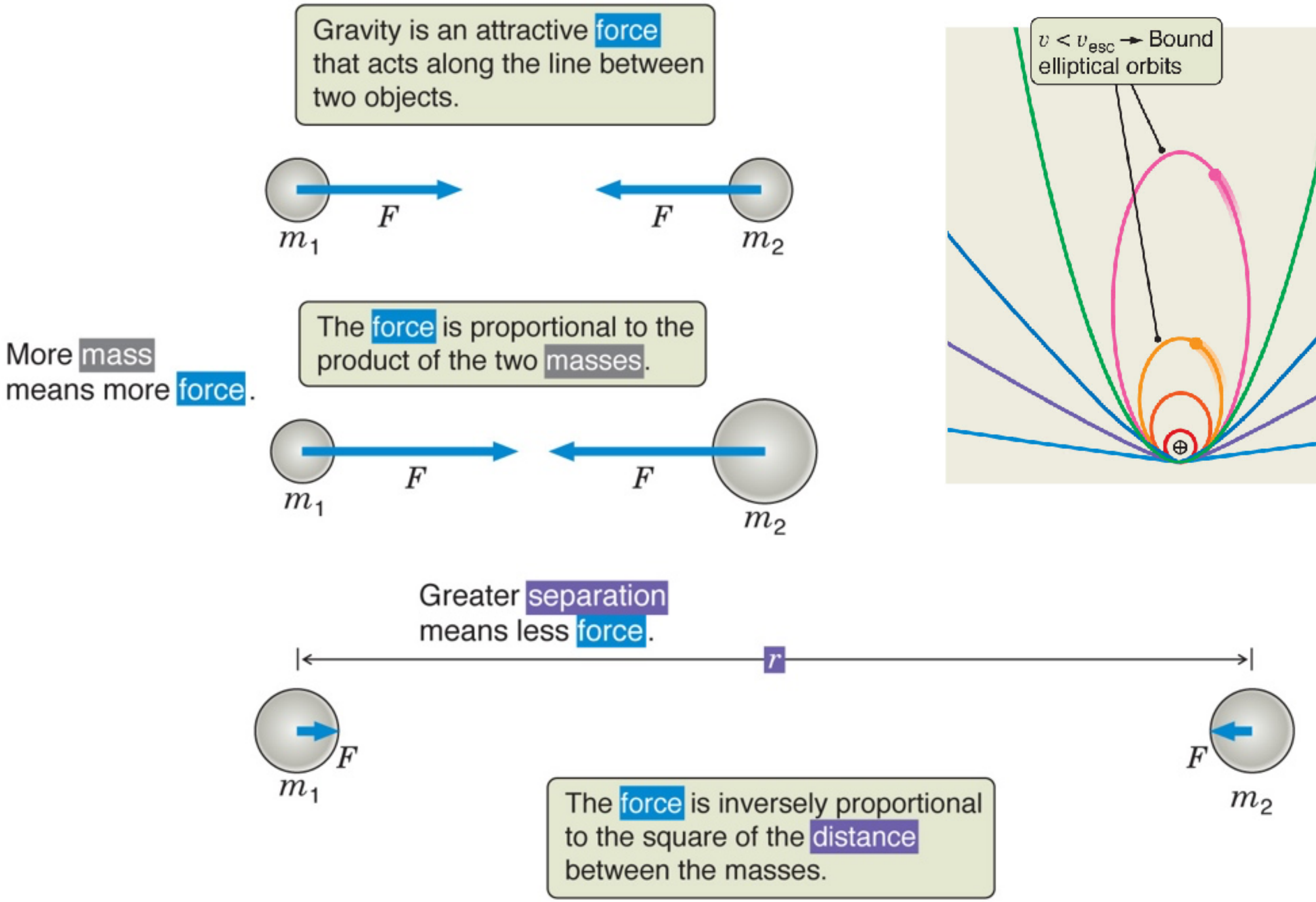
# Newton’s 3 Laws

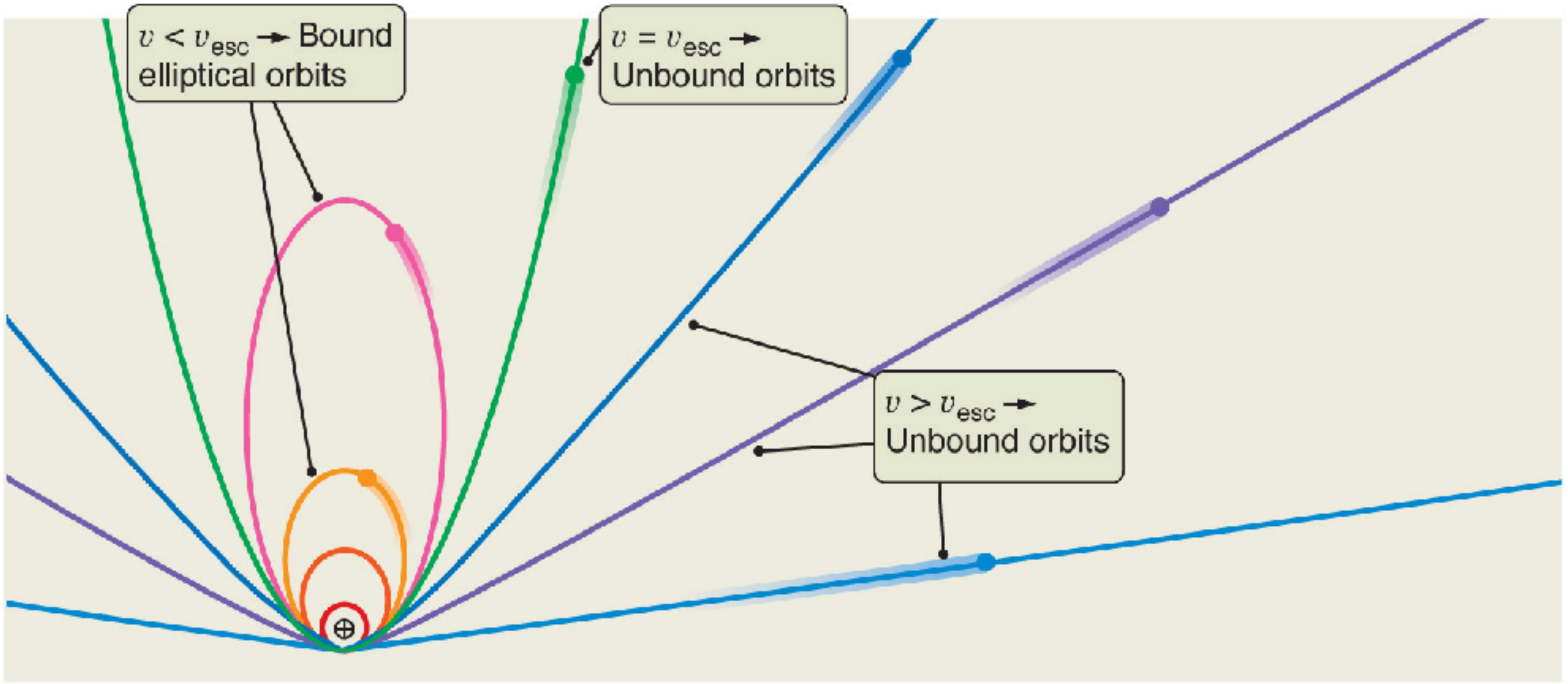
1) Law of Inertia: Objects at rest stay at rest, objects in motion stay in motion (Galileo figured this one out)

2) Motion is changed by unbalanced forces
   acceleration = force / mass

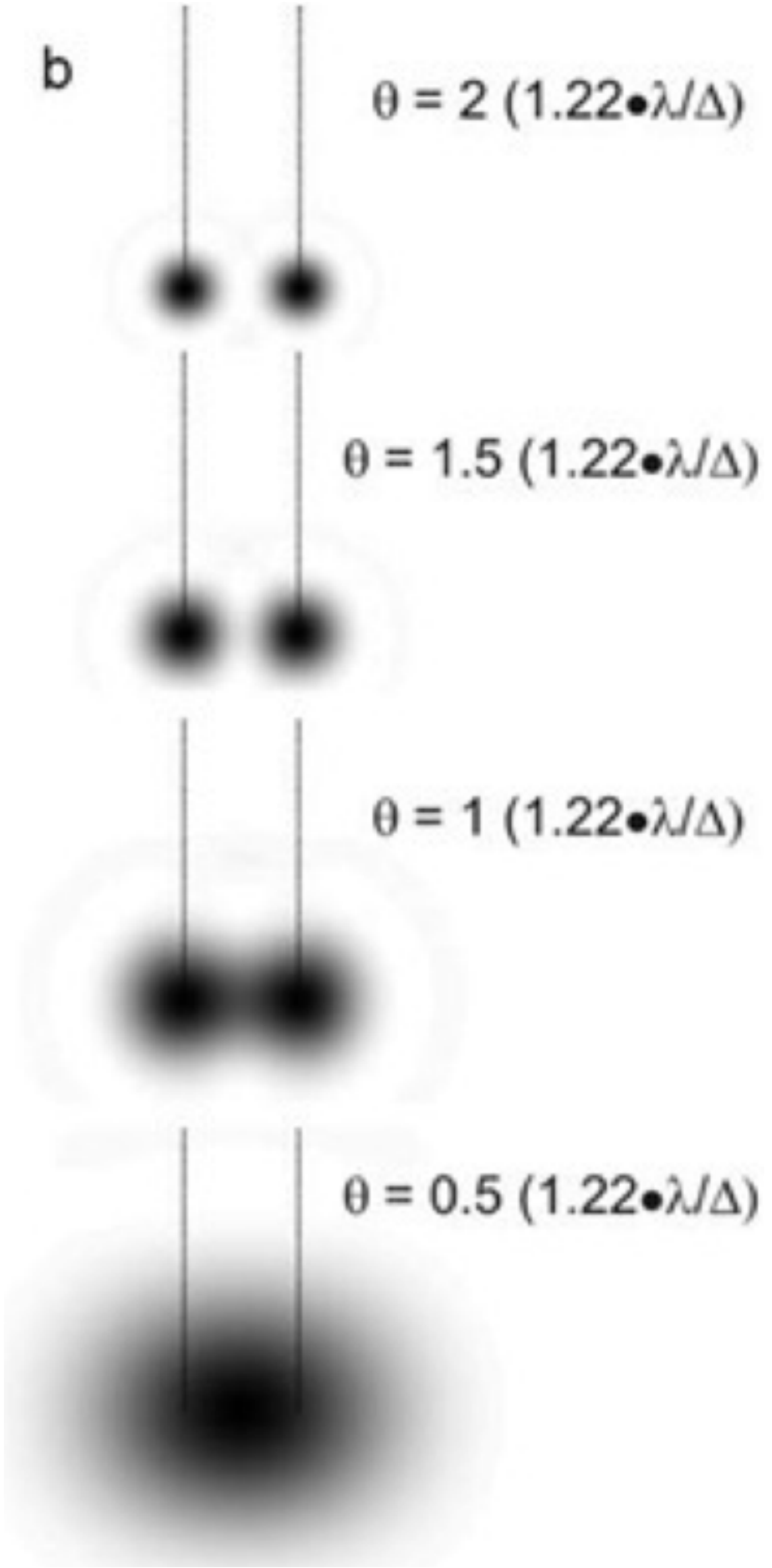
3) Forces always come in pairs and those pairs are always equal in strength but opposite in direction

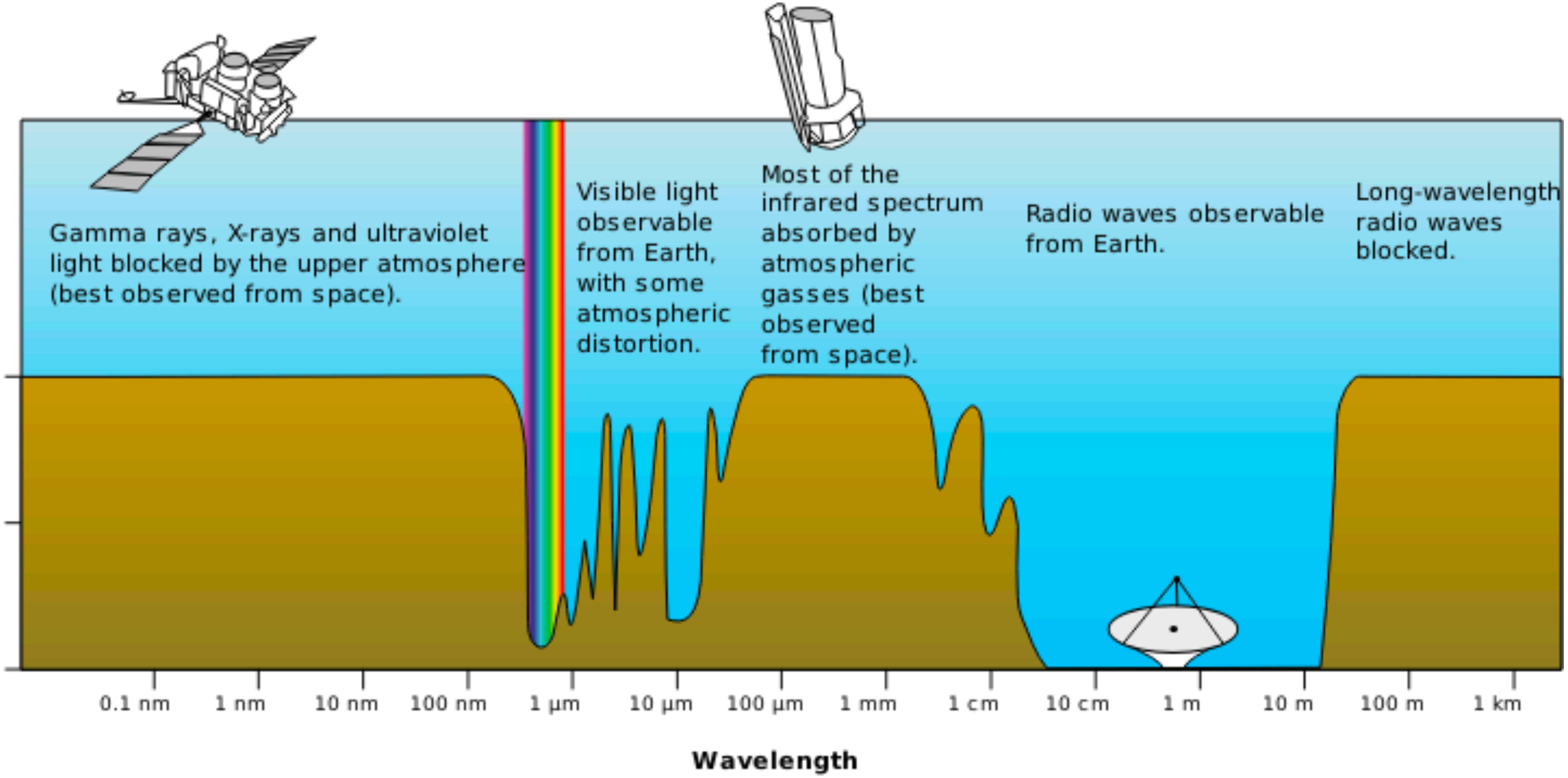
**Newton's Universal Law of Gravitation:** $F = G\frac{m_1 m_2}{r^2}$



# Electromagnetic Spectrum



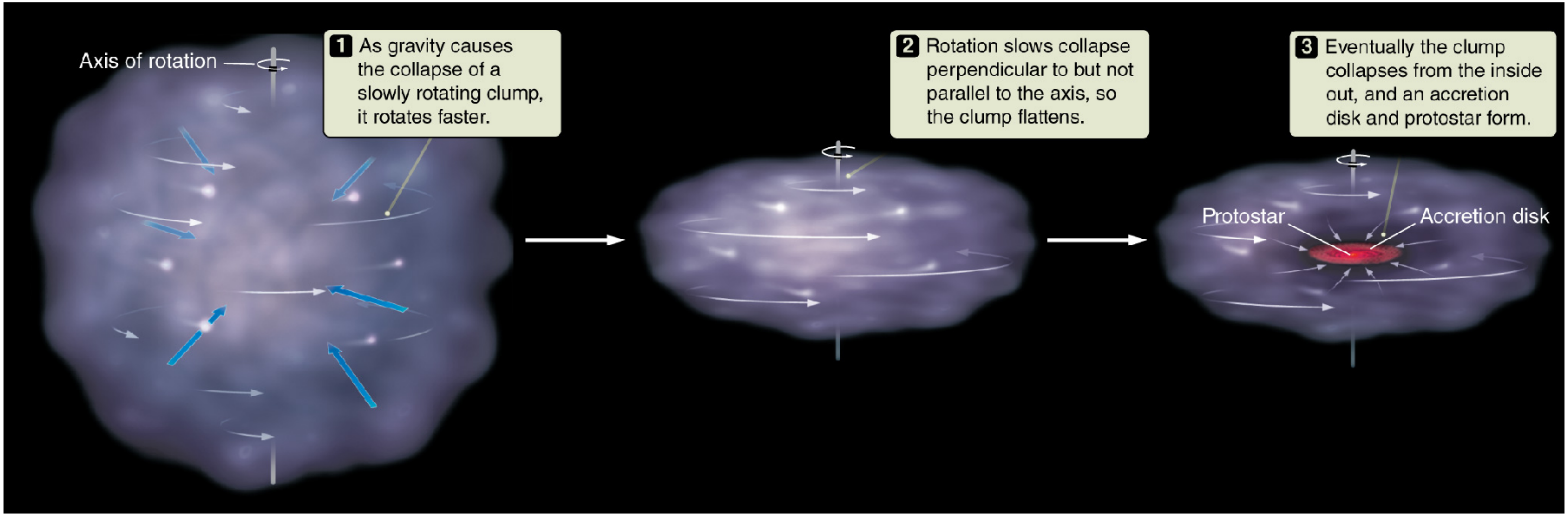




# Telescopes

$$\text{angular resolution} = 206265 \text{ arcseconds} \frac{\text{wavelength}}{\text{telescope diameter}}$$

$$\longrightarrow \quad \theta \propto \frac{\lambda}{D}$$

# Any small net spin of the collapsing cloud is amplified as it becomes smaller




Conservation of Angular Momentum: $L = m\,v\,r$

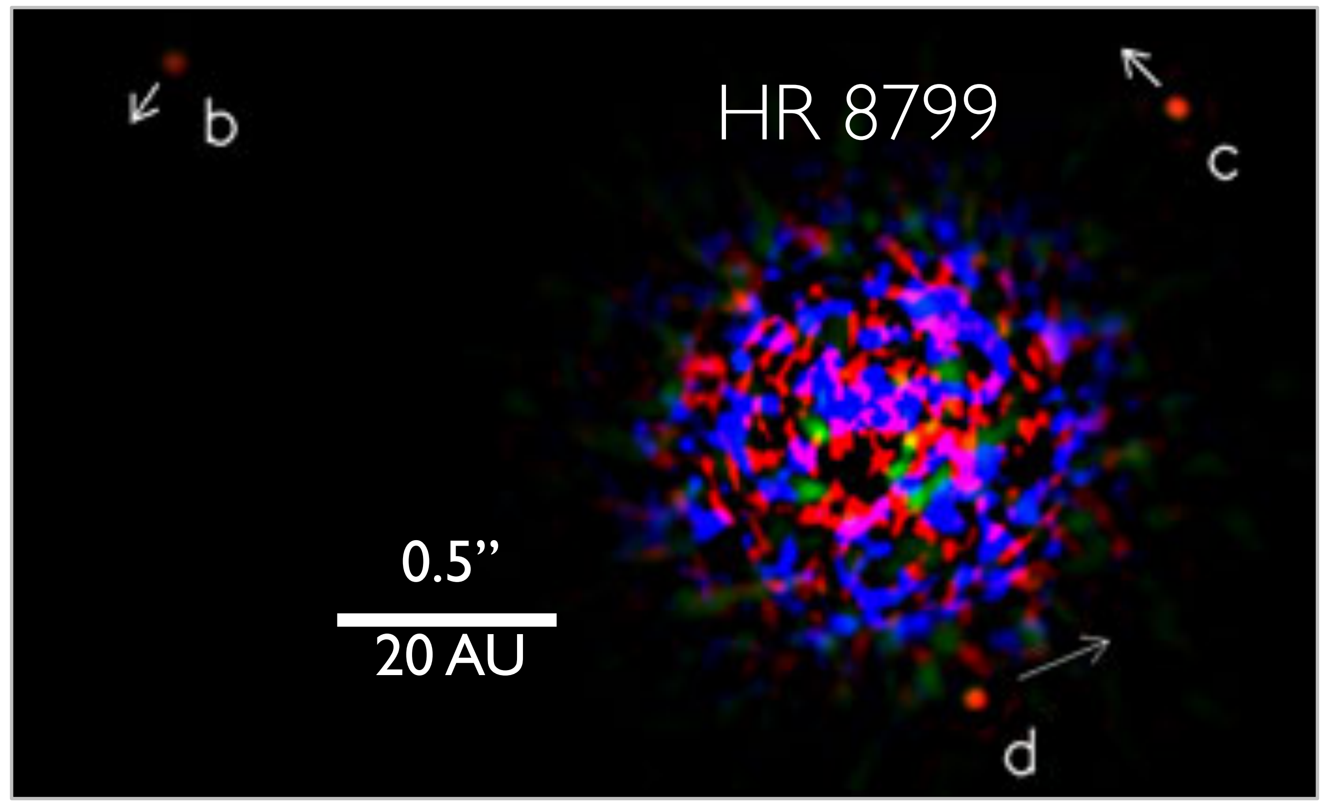
# Mass Distribution in the Solar System

Sun
99.85%

Outer Planets
0.134%

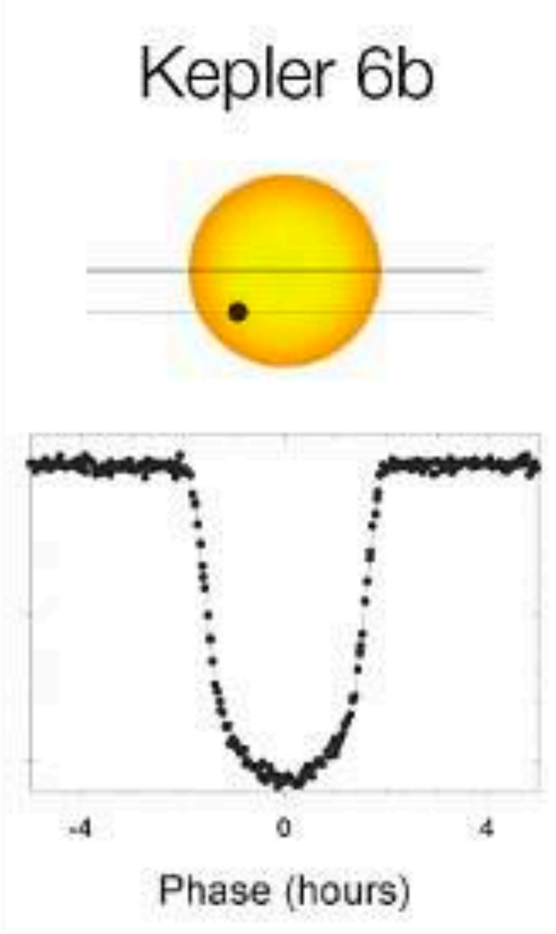
Terrestrial Planets
0.001%

# How to find planets




Direct Imaging

- Detect them directly
  - Image the planet
  - Detect its atmosphere in a spectrum



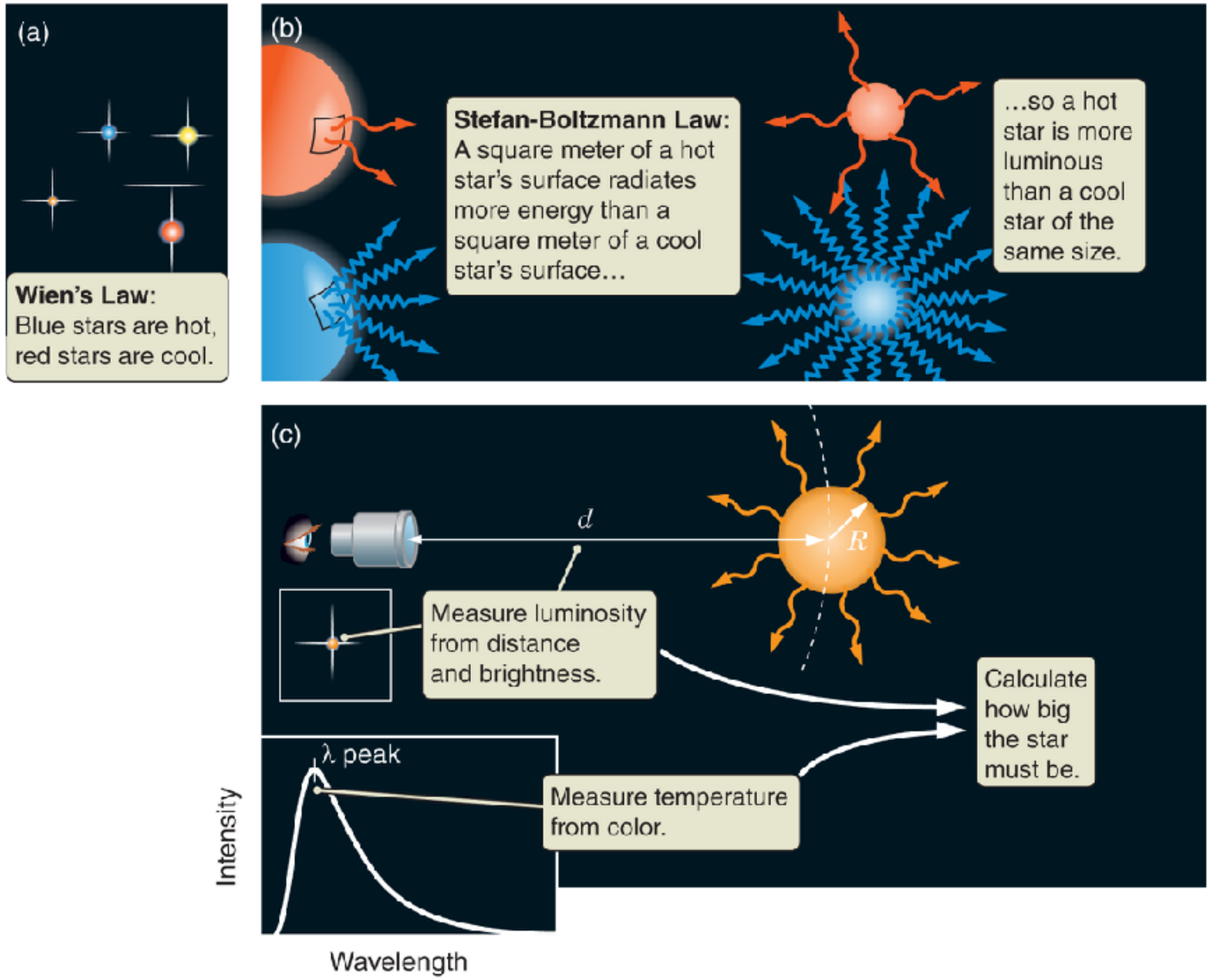

Transit Method

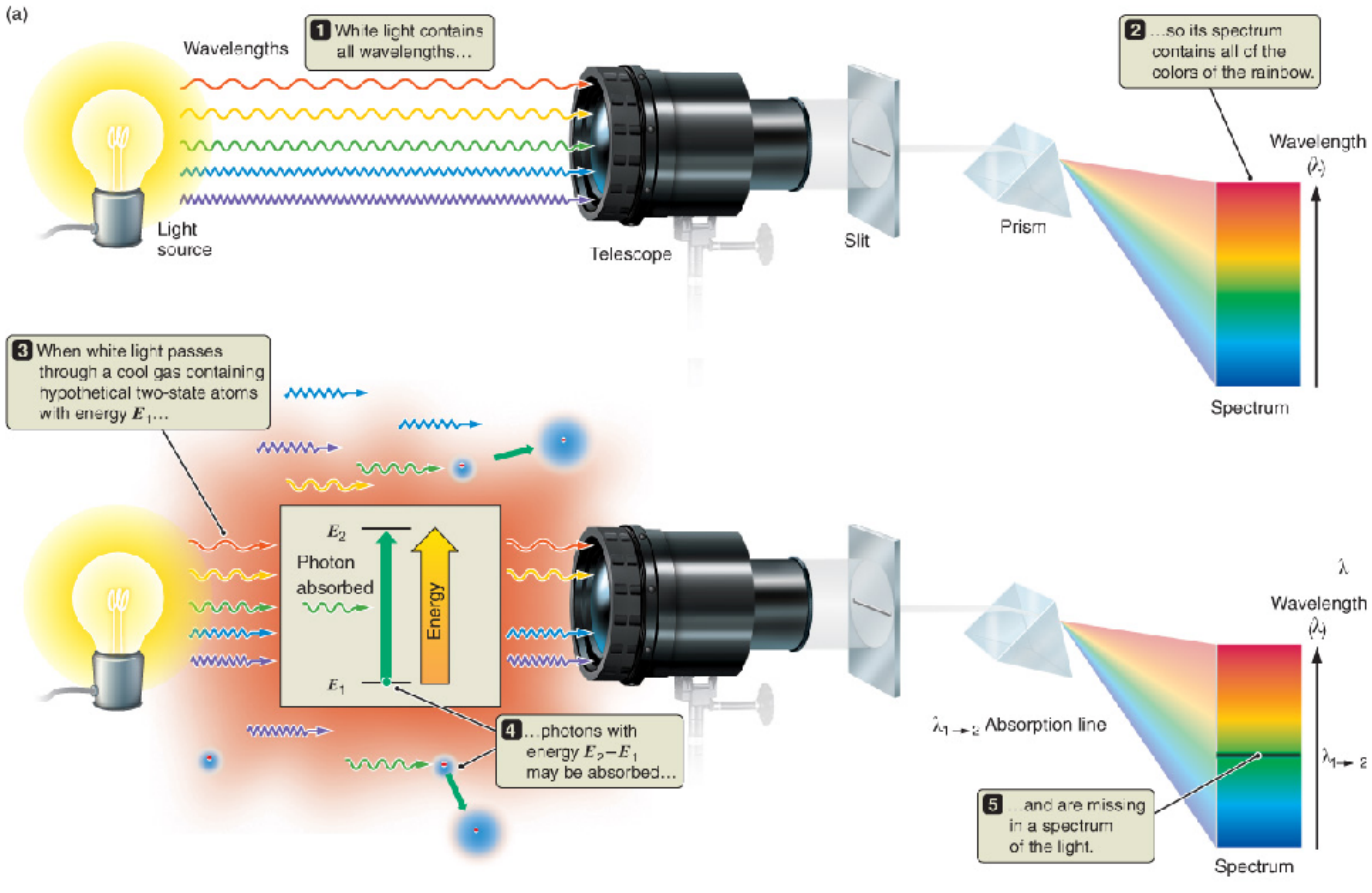
- Detect their influence on their star
  - Measure light blocked from the star when the planet eclipses it
  - Measure the star's motion due to the planet's gravity

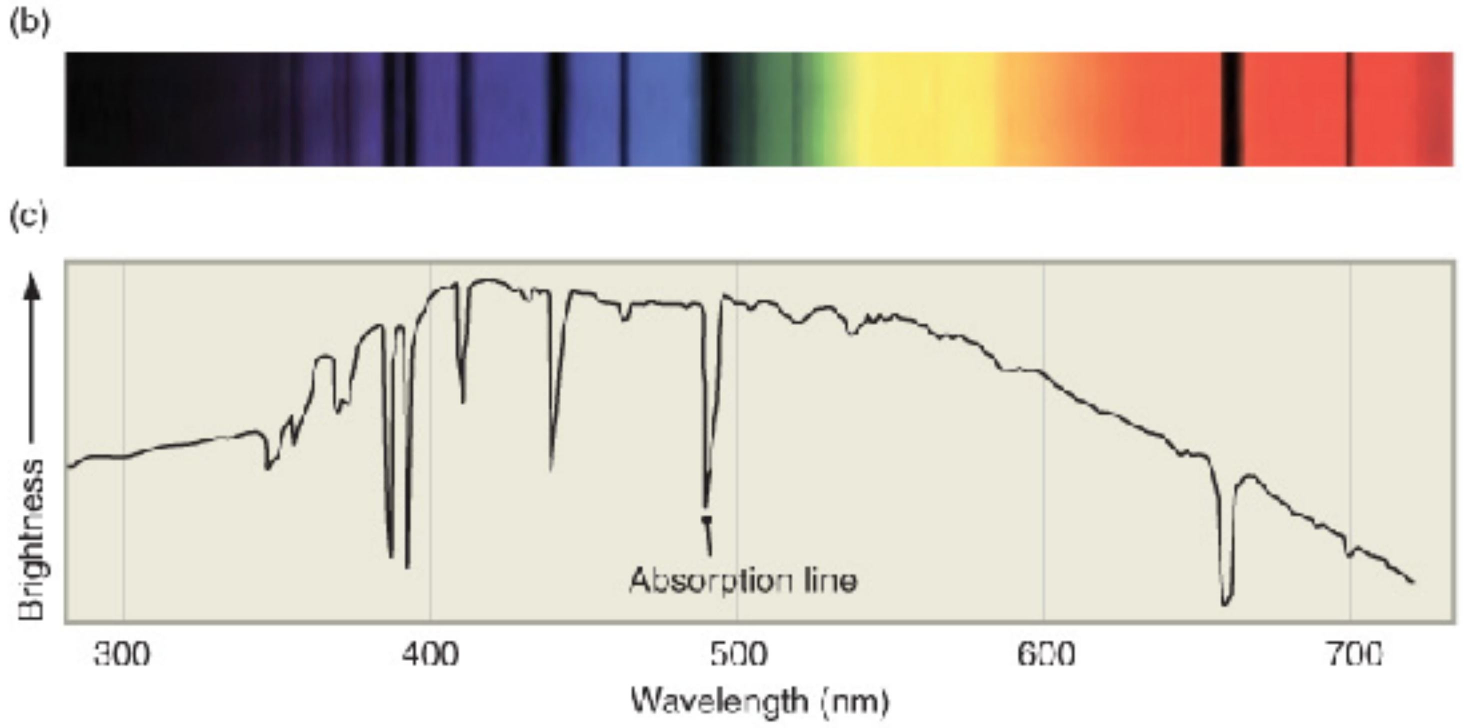
Radial Velocity Method

$$\frac{\lambda_{observed} - \lambda_{emitted}}{\lambda_{emitted}} = \frac{v}{c}$$

# Luminosity depends on Temperature AND Size

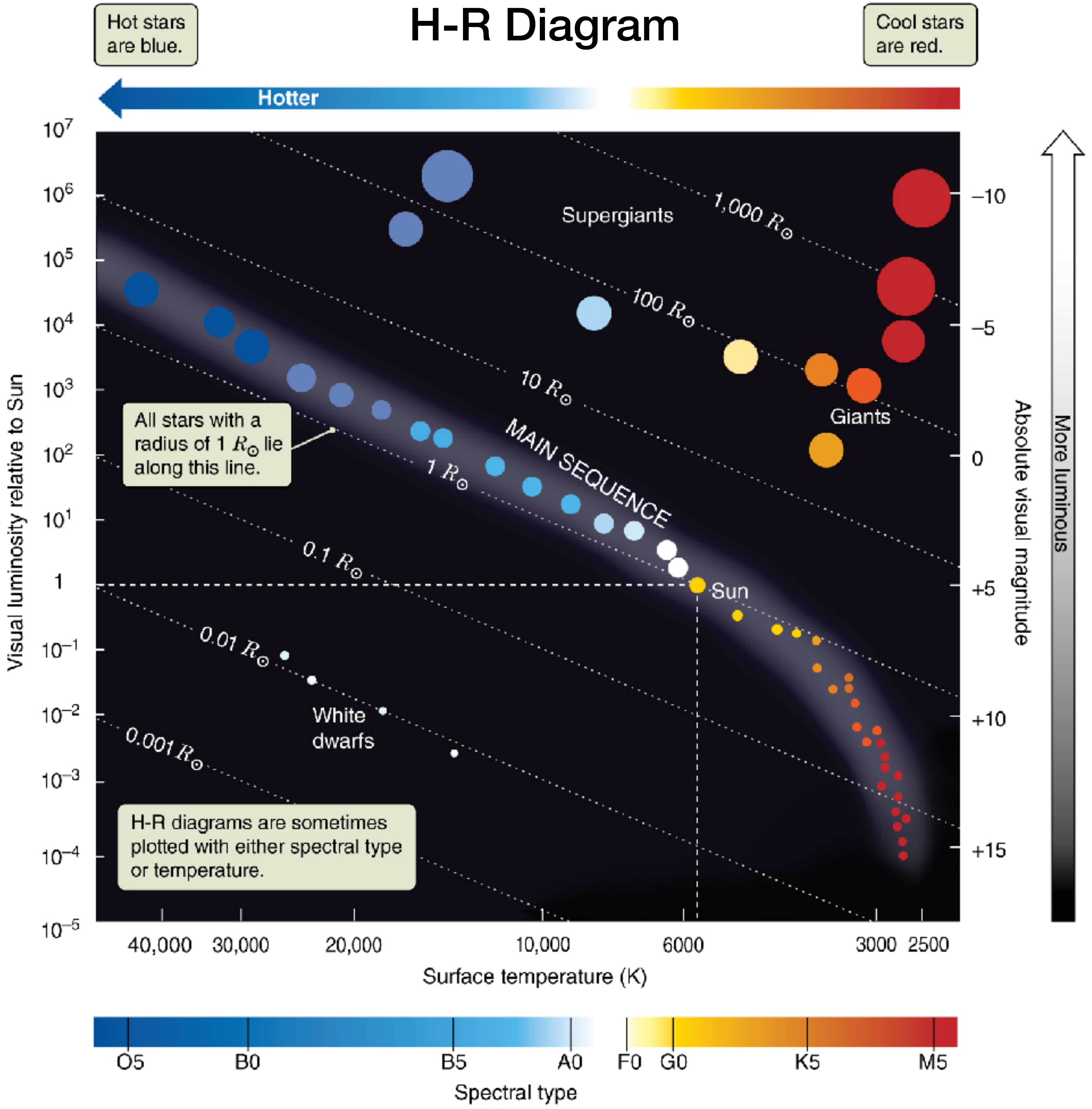


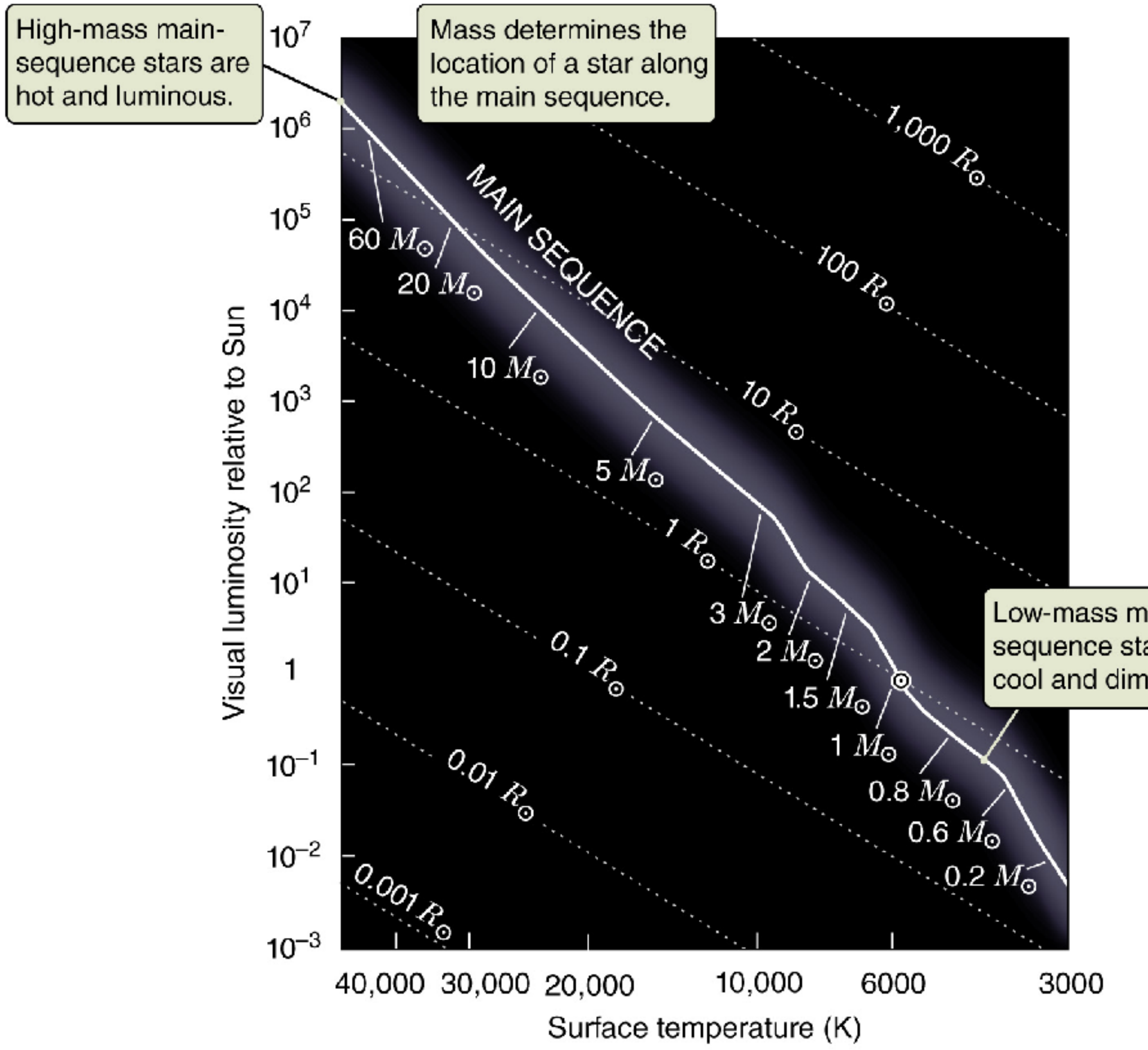



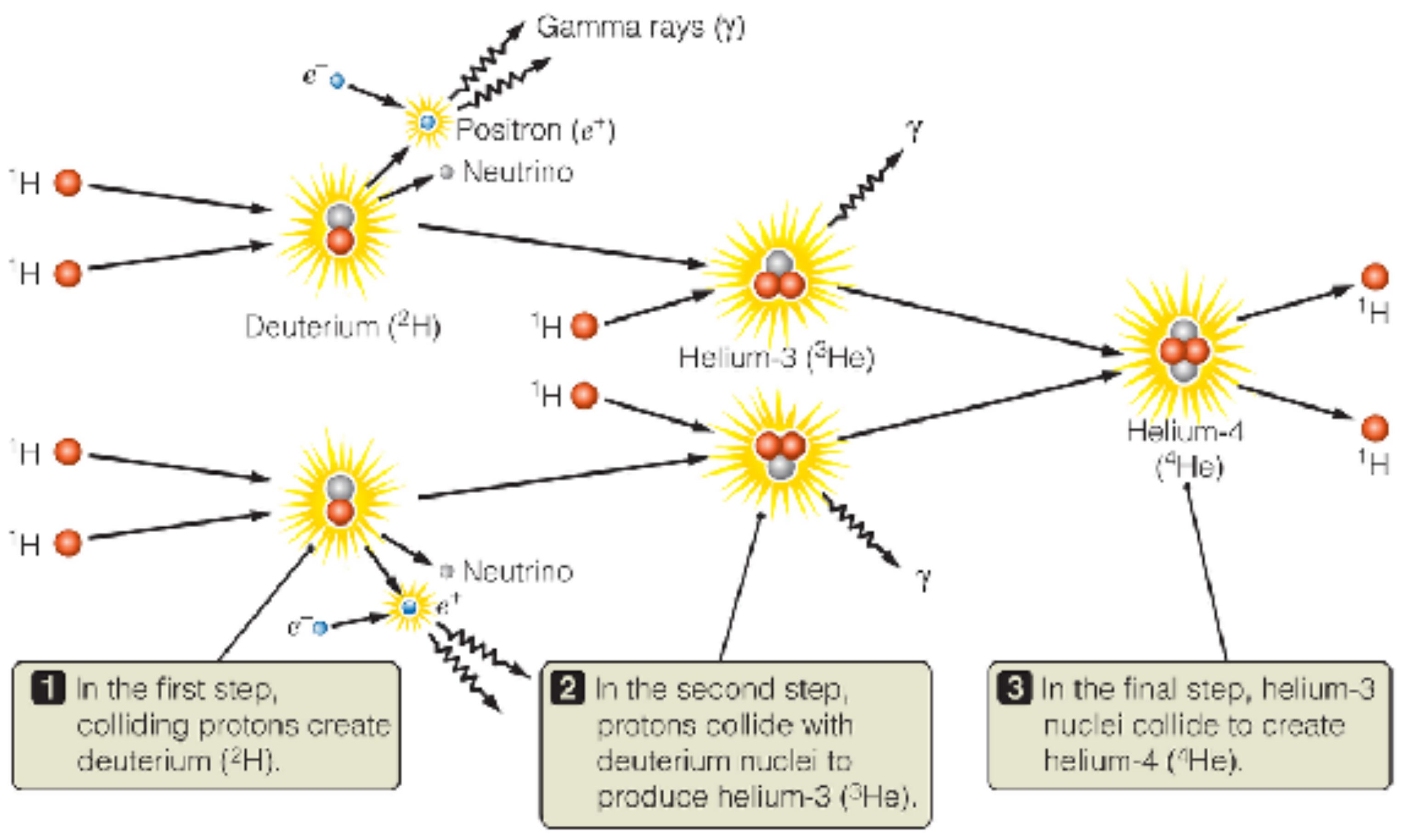

## Stellar Spectra: blackbody plus absorption lines

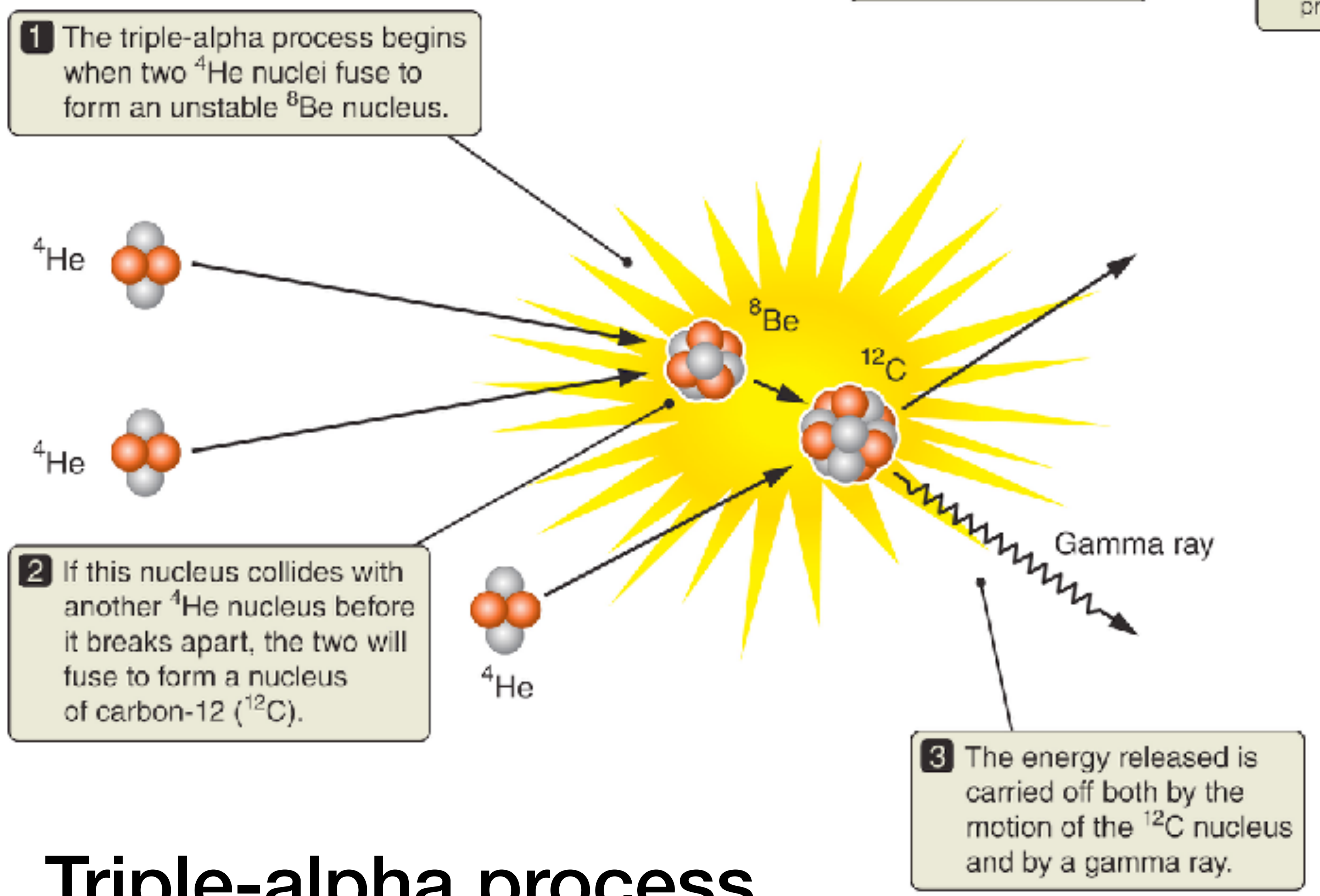
# H-R Diagram


Hot stars are blue.
Cool stars are red.
Hotter
Supergiants
Giants
MAIN SEQUENCE
White dwarfs
Sun
1,000 $R_{\odot}$
100 $R_{\odot}$
10 $R_{\odot}$
1 $R_{\odot}$
0.1 $R_{\odot}$
0.01 $R_{\odot}$
0.001 $R_{\odot}$
All stars with a radius of 1 $R_{\odot}$ lie along this line.
H-R diagrams are sometimes plotted with either spectral type or temperature.
Visual luminosity relative to Sun
$10^7$ $10^6$ $10^5$ $10^4$ $10^3$ $10^2$ $10^1$ 1 $10^{-1}$ $10^{-2}$ $10^{-3}$ $10^{-4}$ $10^{-5}$
Absolute visual magnitude
−10 −5 0 +5 +10 +15
More luminous
40,000 30,000 20,000 10,000 6000 3000 2500
Surface temperature (K)
O5 B0 B5 A0 F0 G0 K5 M5
Spectral type

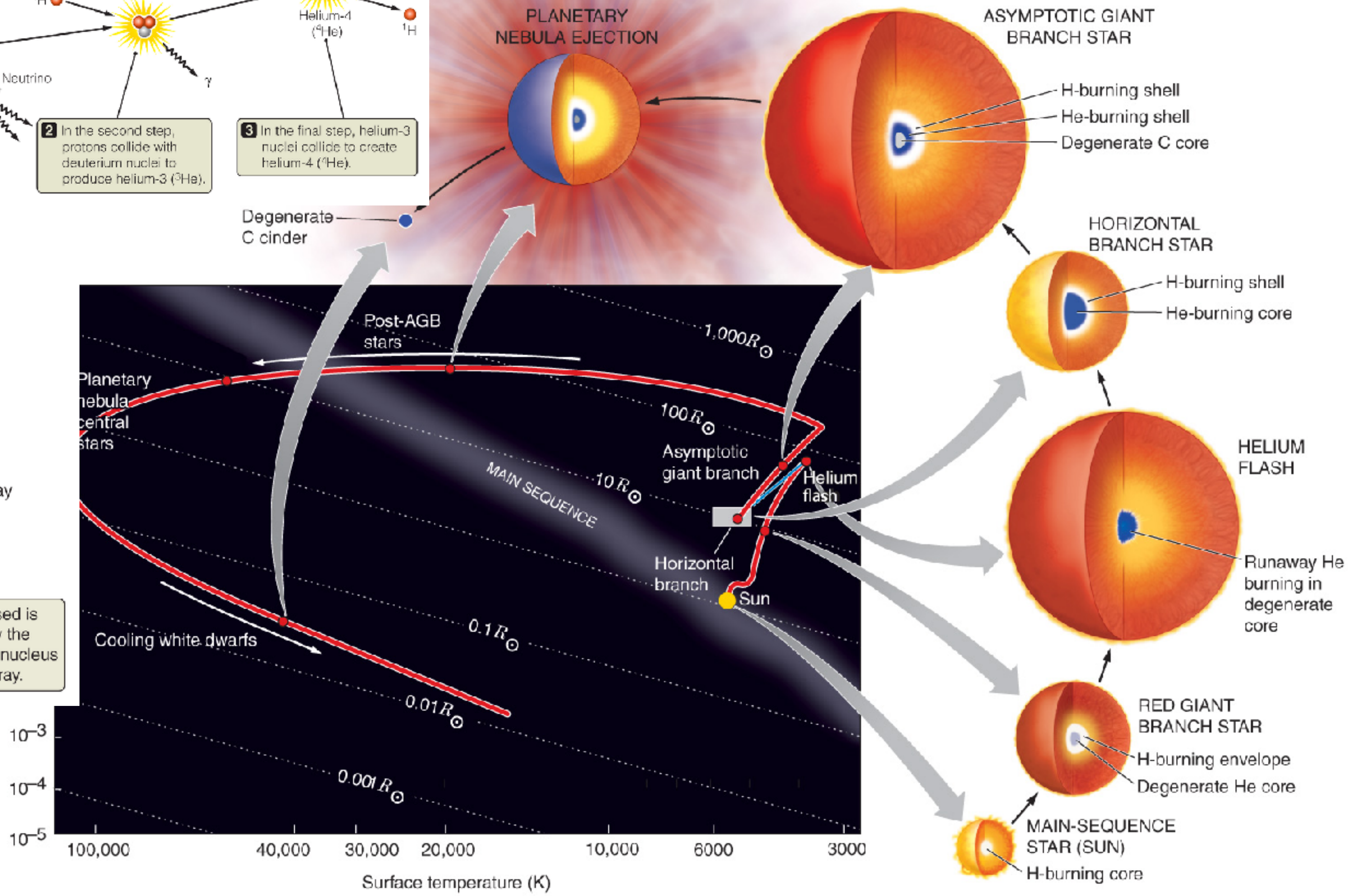

High-mass main-sequence stars are hot and luminous.
Mass determines the location of a star along the main sequence.
Low-mass m
sequence sta
cool and dim
MAIN SEQUENCE
60 $M_{\odot}$
20 $M_{\odot}$
10 $M_{\odot}$
5 $M_{\odot}$
3 $M_{\odot}$
2 $M_{\odot}$
1.5 $M_{\odot}$
1 $M_{\odot}$
0.8 $M_{\odot}$
0.6 $M_{\odot}$
0.2 $M_{\odot}$
1,000 $R_{\odot}$
100 $R_{\odot}$
10 $R_{\odot}$
1 $R_{\odot}$
0.1 $R_{\odot}$
0.01 $R_{\odot}$
0.001 $R_{\odot}$
Visual luminosity relative to Sun
$10^7$ $10^6$ $10^5$ $10^4$ $10^3$ $10^2$ $10^1$ 1 $10^{-1}$ $10^{-2}$ $10^{-3}$
40,000 30,000 20,000 10,000 6000 3000
Surface temperature (K)

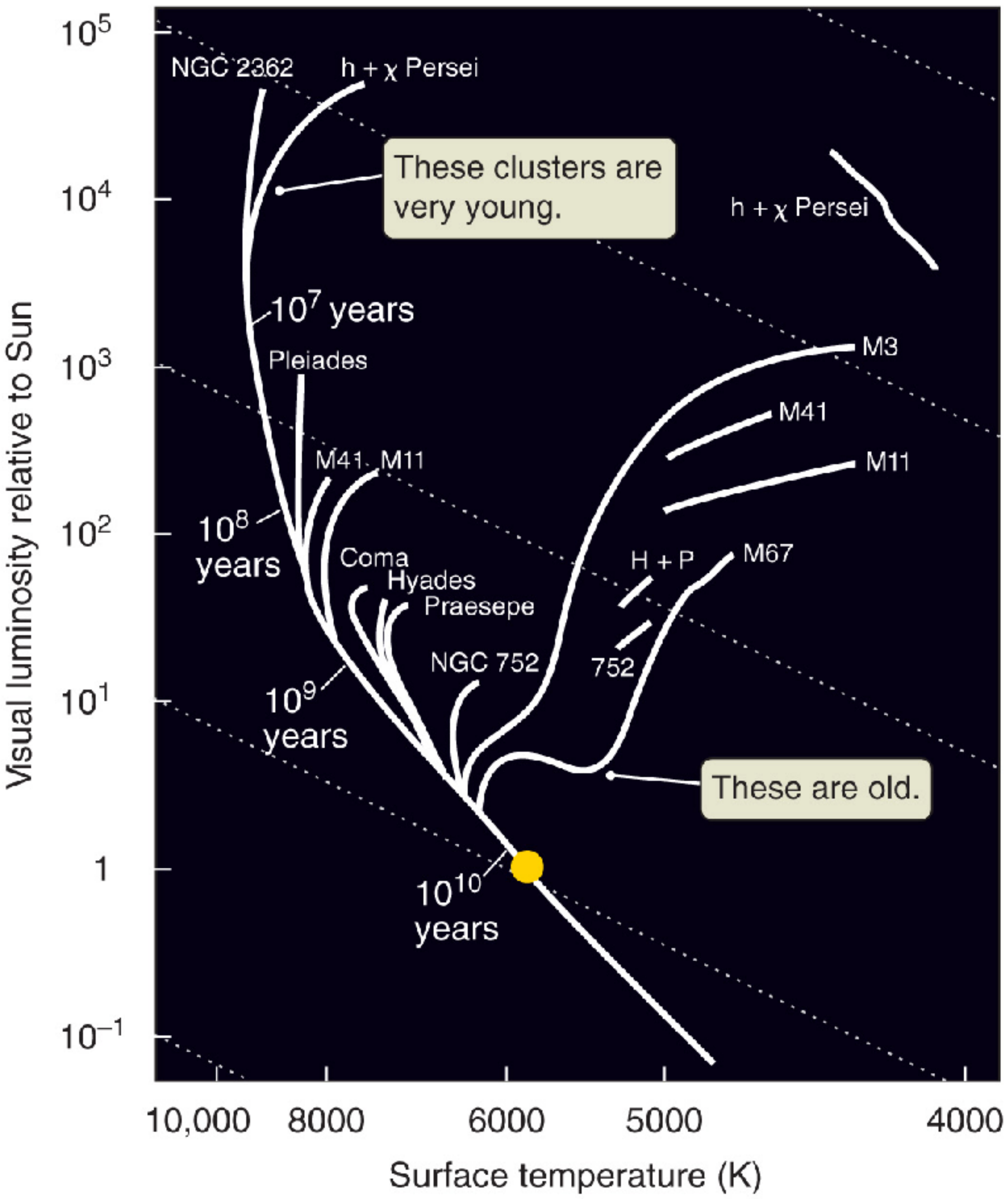
proton-proton chain burns H —> He, releasing neutrinos and positrons (gamma rays)



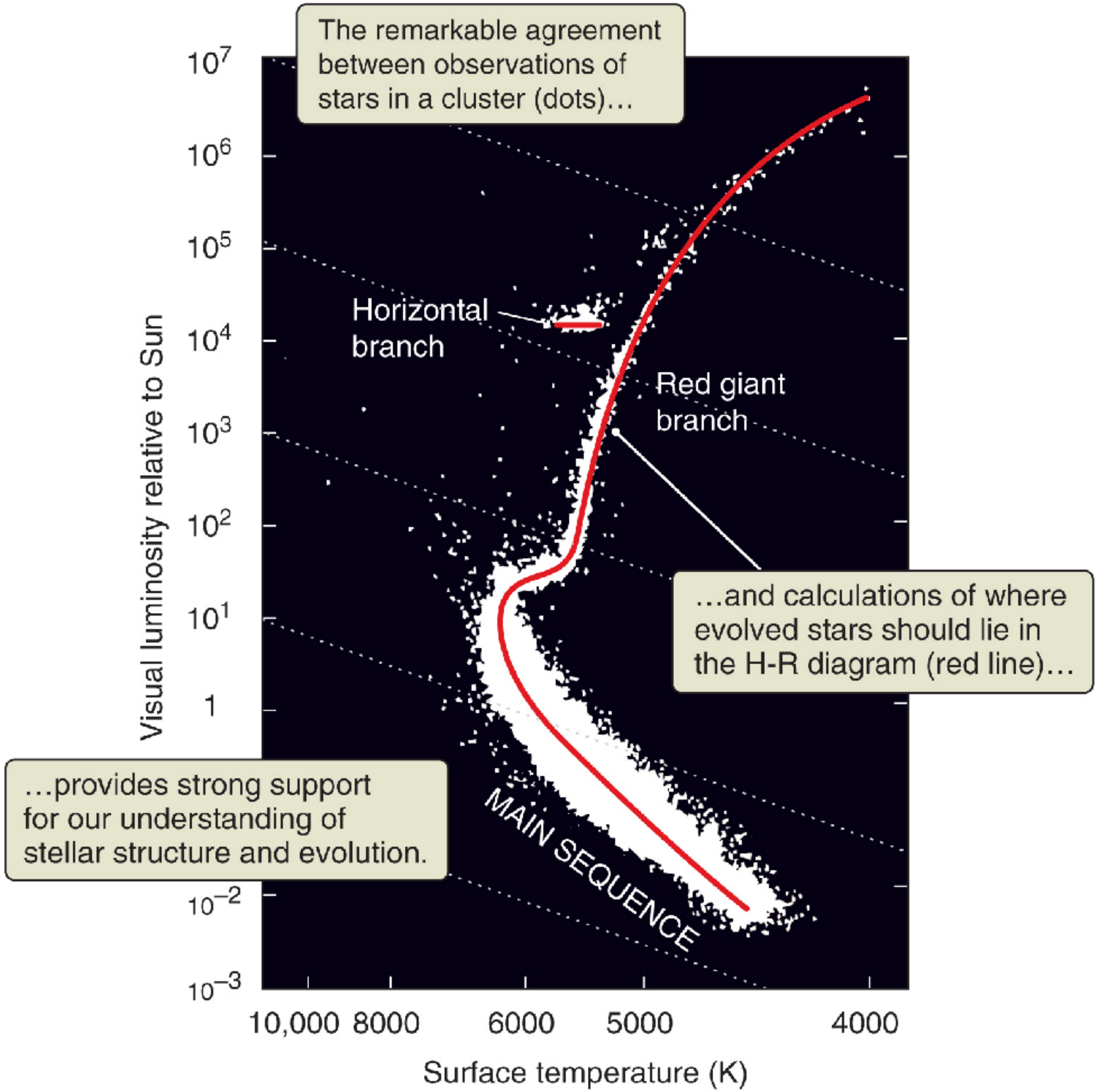




Triple-alpha process, burns He —> C in Horizontal Branch phase



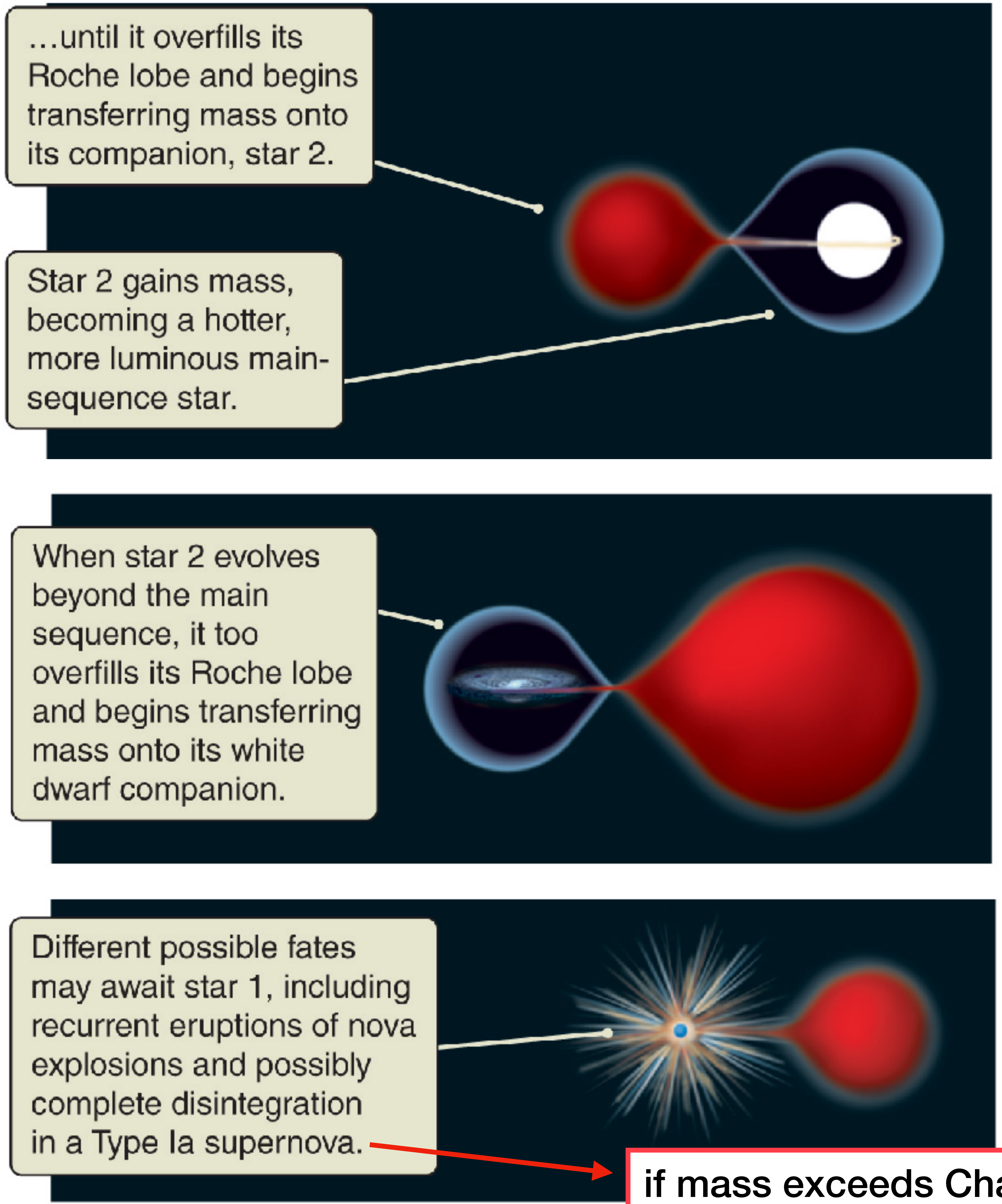


NGC 2362
h + χ Persei
These clusters are very young.
h + χ Persei
$10^7$ years
Pleiades
M3
M41
M41, M11
M11
$10^8$ years
Coma
Hyades
Praesepe
H + P
M67
NGC 752
752
$10^9$ years
These are old.
$10^{10}$ years
Visual luminosity relative to Sun
Surface temperature (K)

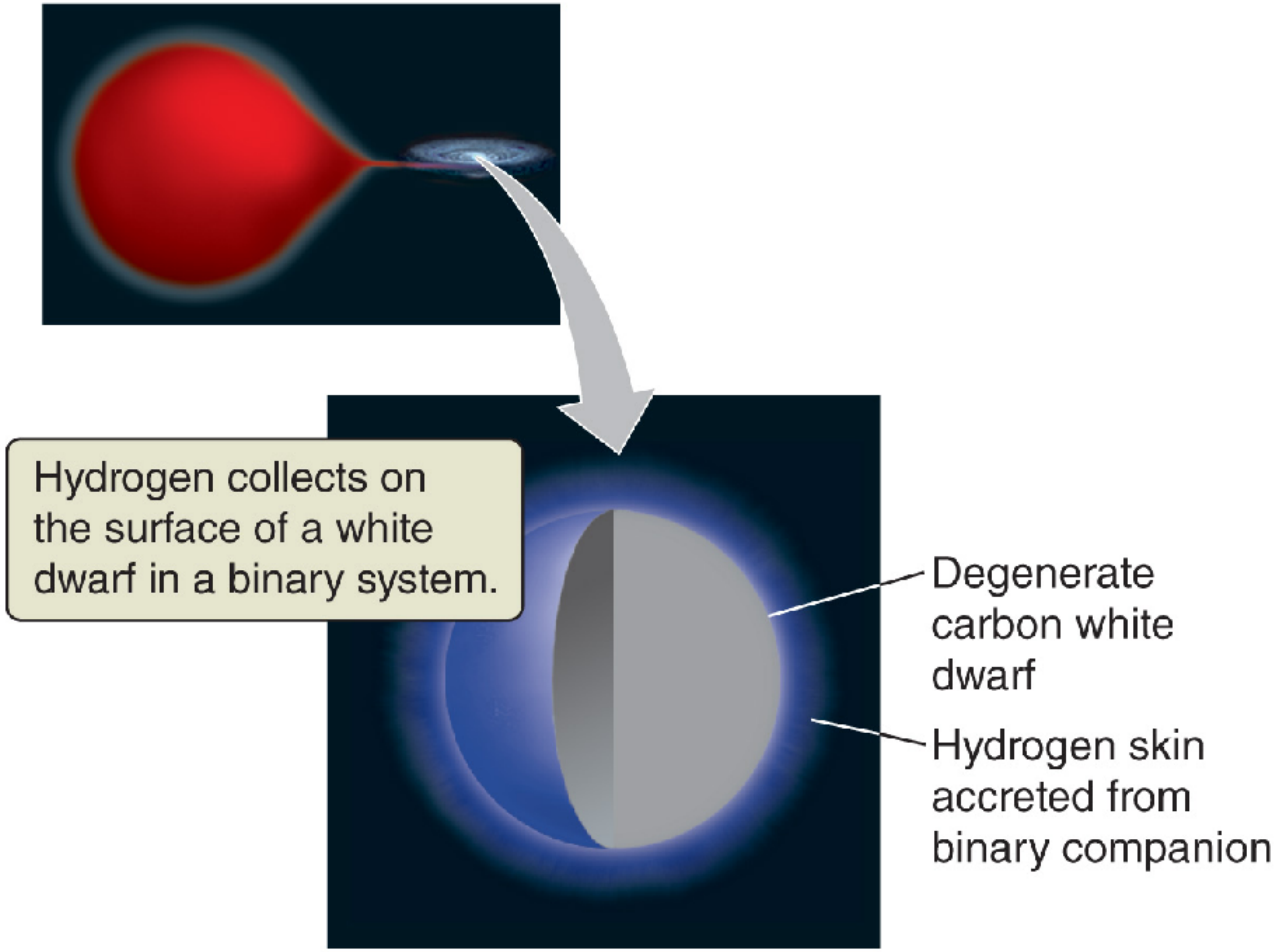



The remarkable agreement between observations of stars in a cluster (dots)…
Horizontal branch
Red giant branch
…and calculations of where evolved stars should lie in the H-R diagram (red line)…
…provides strong support for our understanding of stellar structure and evolution.
MAIN SEQUENCE
Visual luminosity relative to Sun
Surface temperature (K)

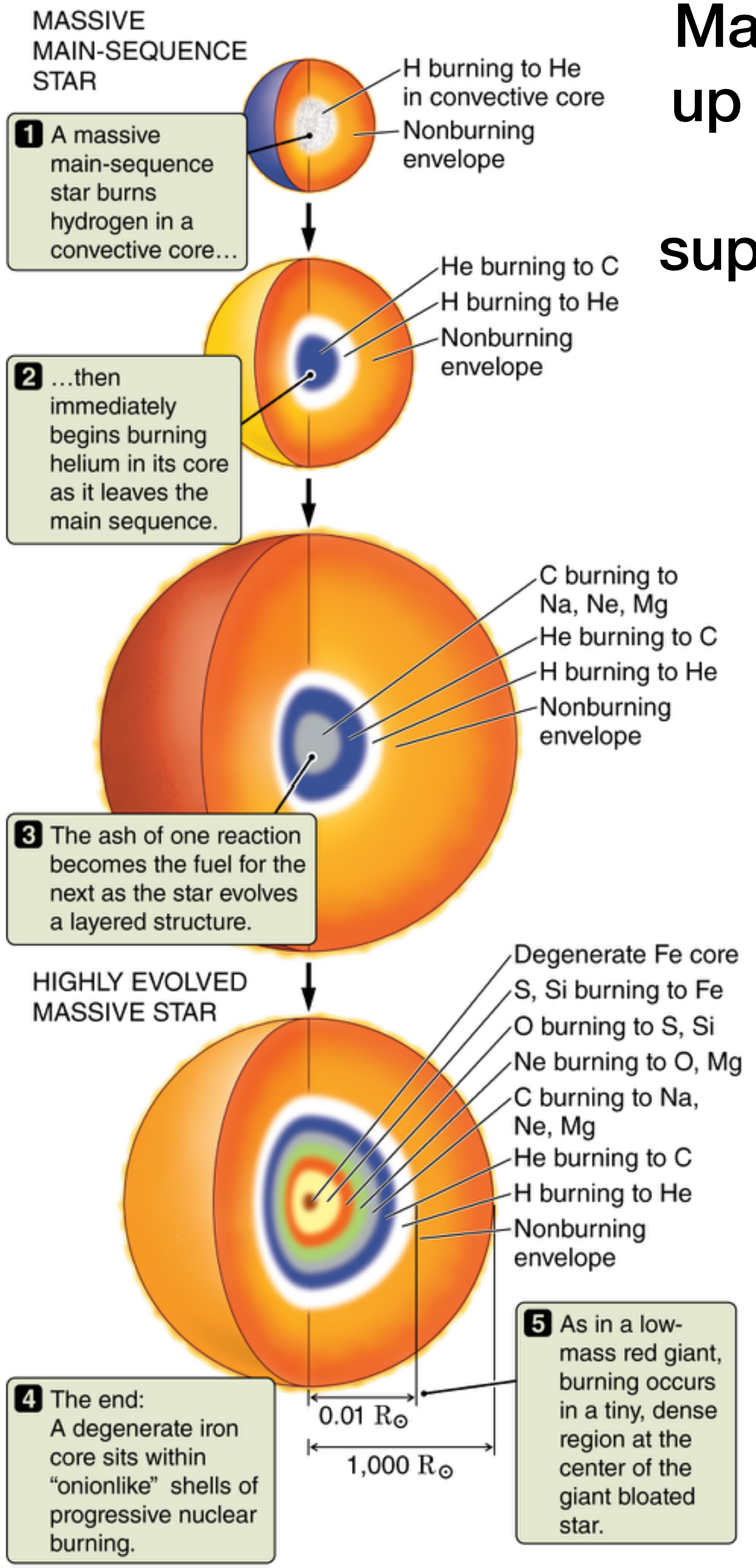
## White Dwarf <—> electron degeneracy pressure

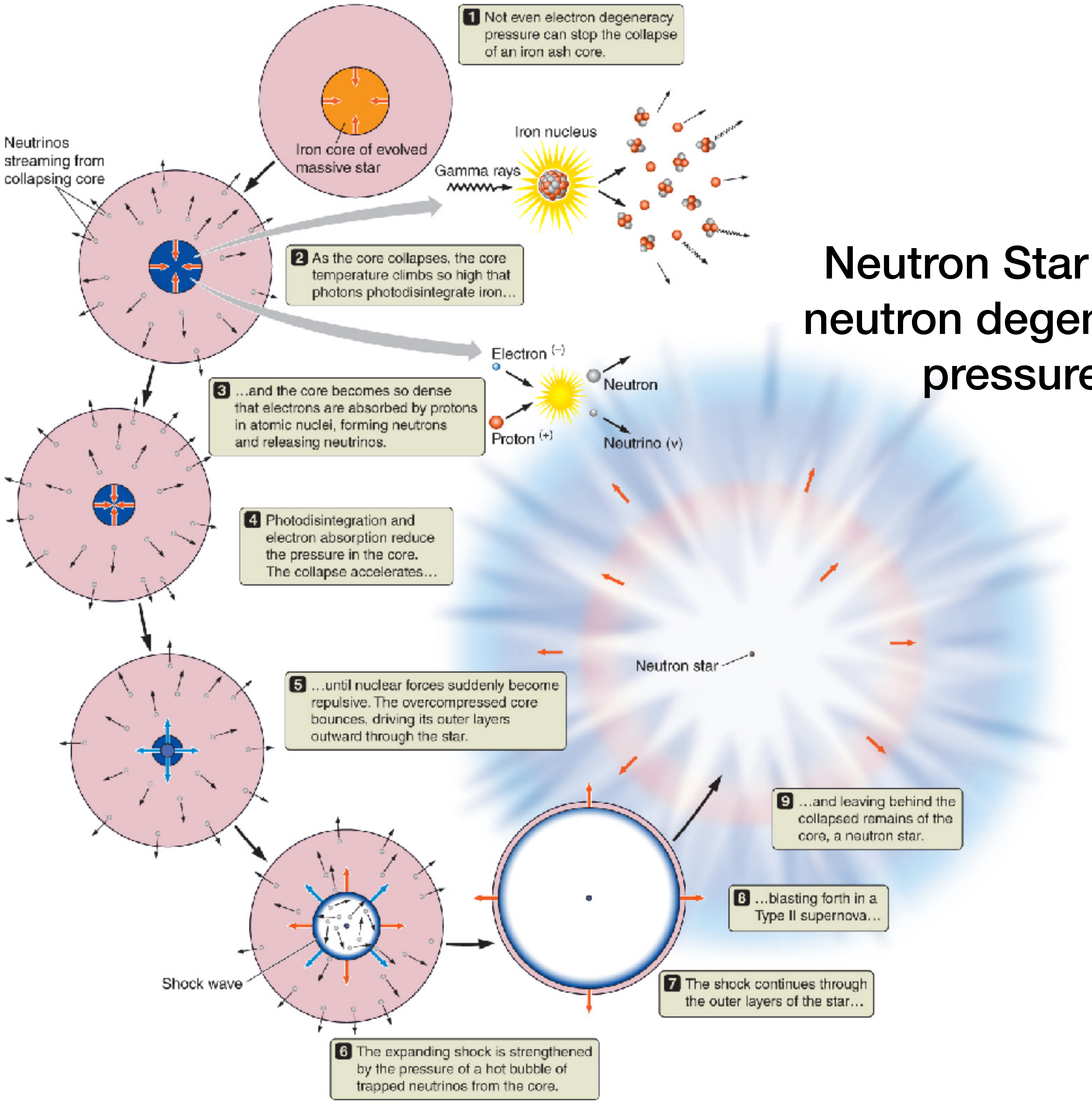



if mass exceeds Chandrasekhar limit (1.4 $M_{sun}$)

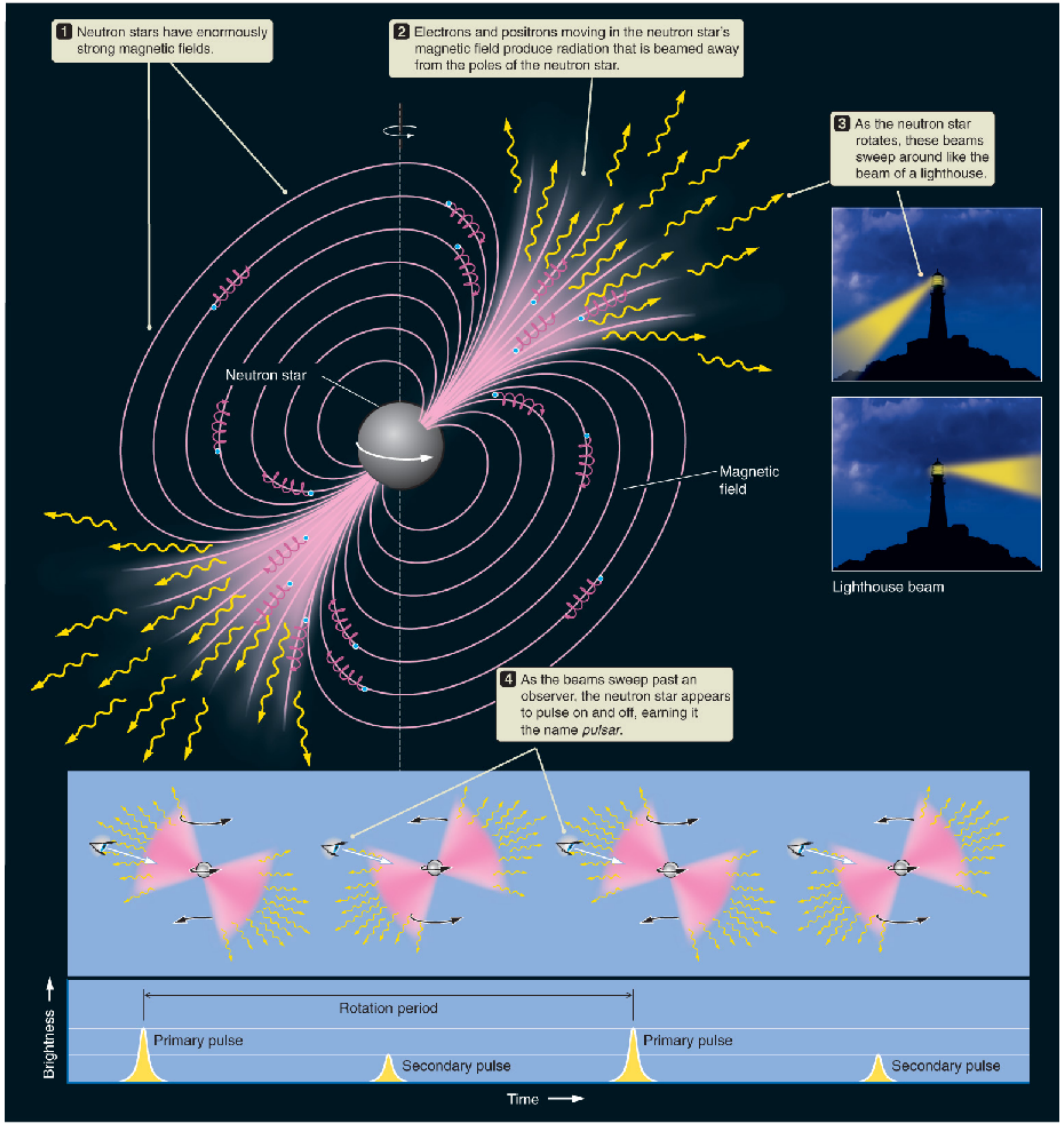


# Massive stars burn up to Fe (iron) in its core, then go supernovae (Type II)



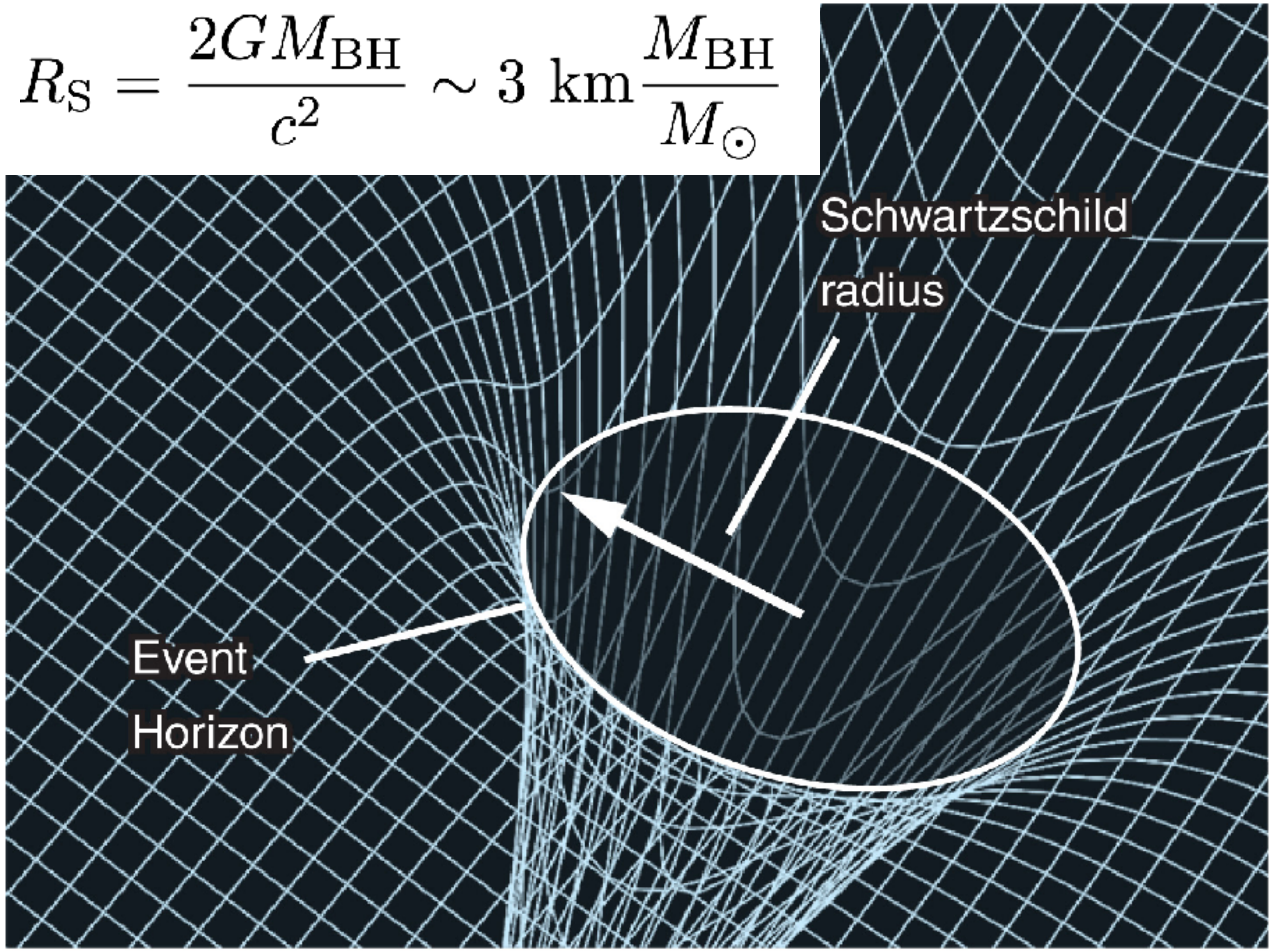

## Neutron Star <—> neutron degeneracy pressure

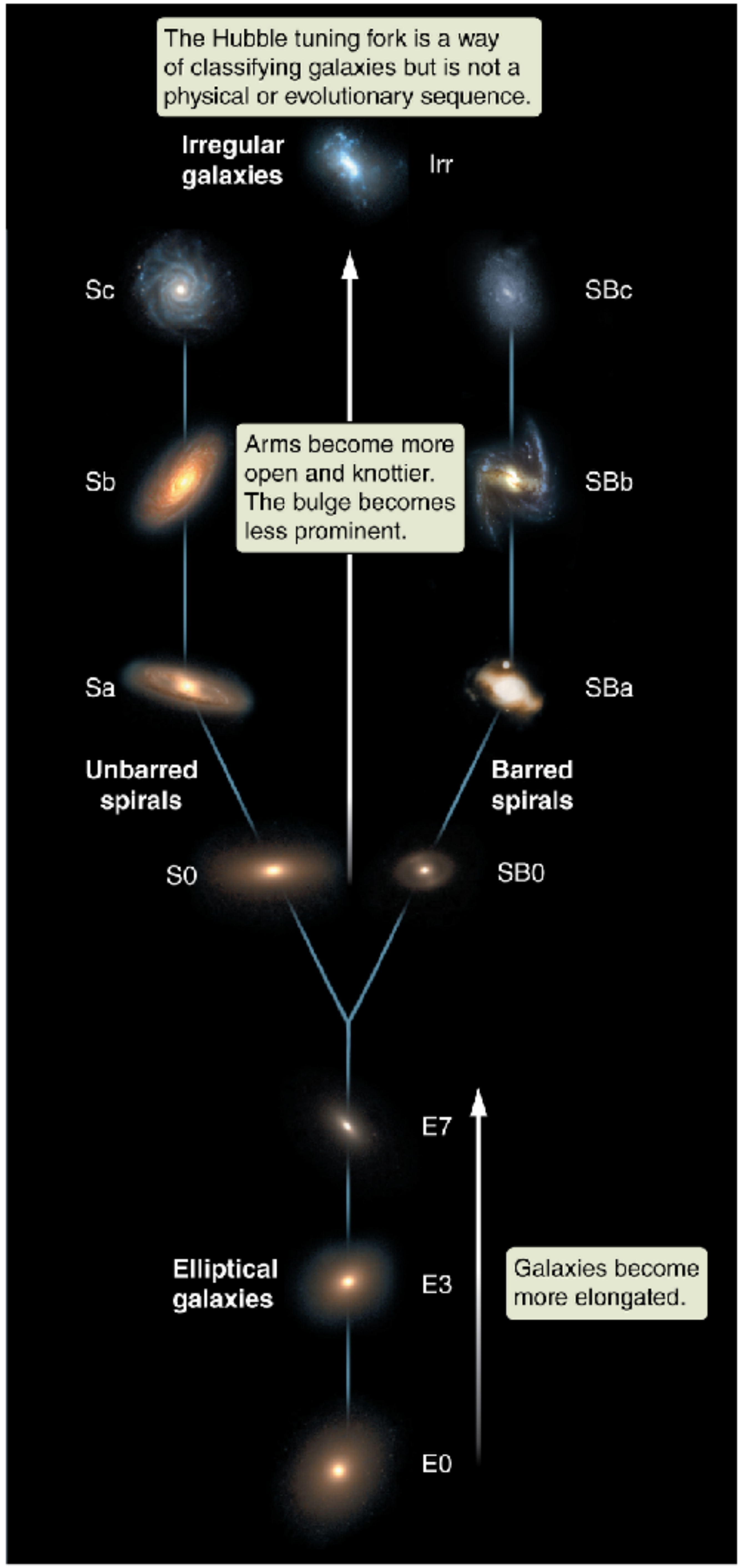


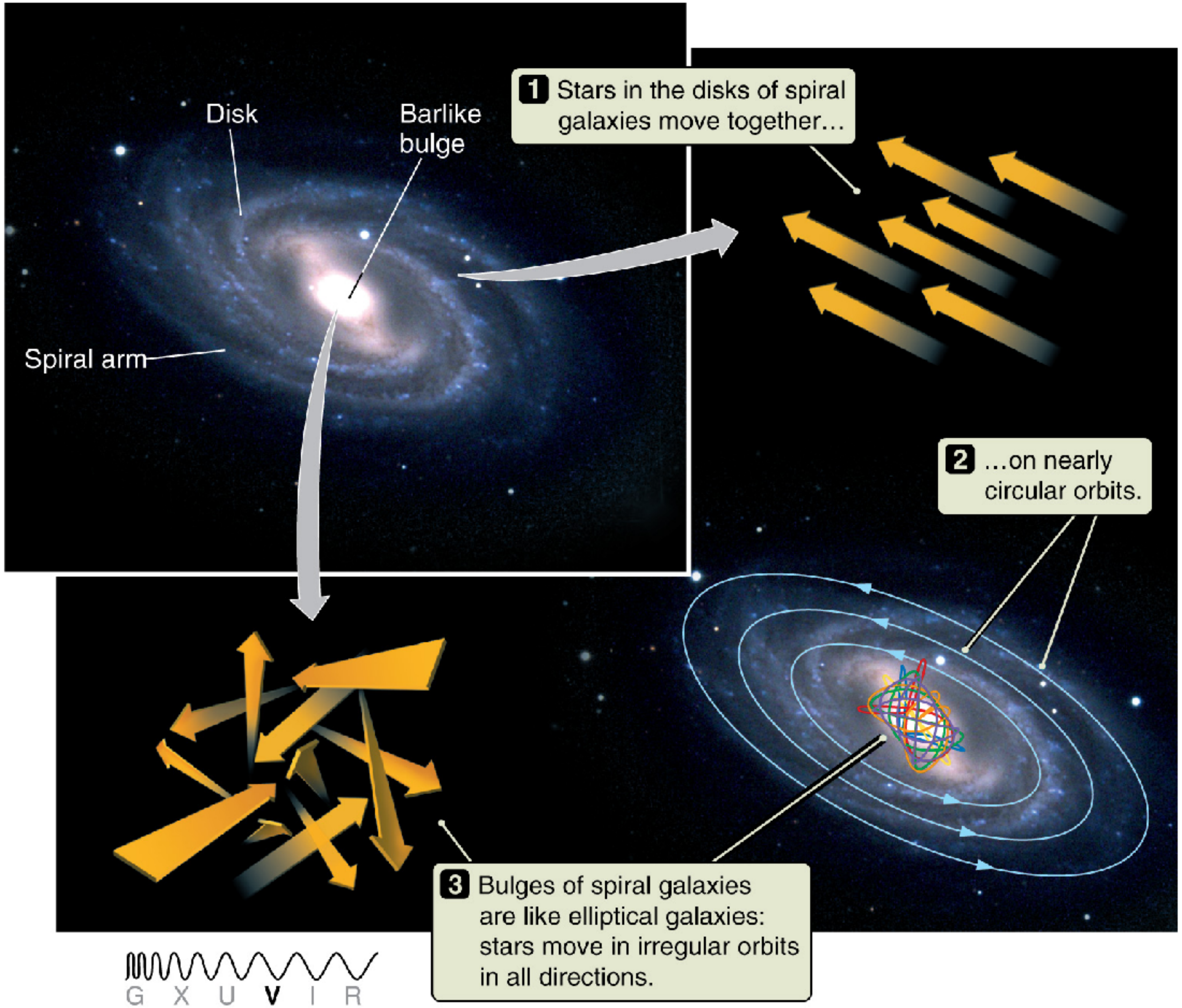

# Neutron Stars

# Black Holes

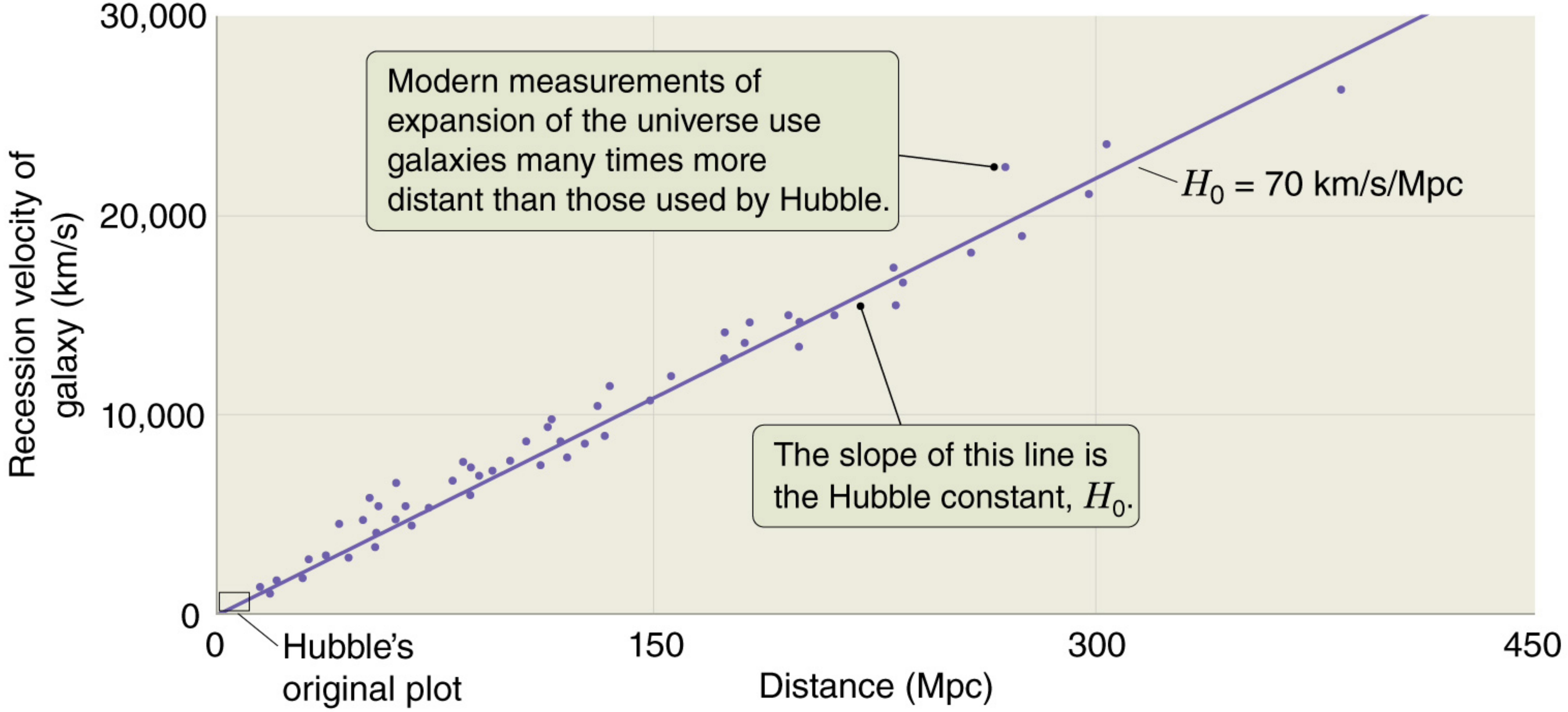
$$R_S = \frac{2GM_{BH}}{c^2} \sim 3\ \mathrm{km}\frac{M_{BH}}{M_\odot}$$




The Hubble tuning fork is a way of classifying galaxies but is not a physical or evolutionary sequence.
Irregular galaxies
Irr
Sc
SBc
Sb
Arms become more open and knottier. The bulge becomes less prominent.
SBb
Sa
SBa
Unbarred spirals
Barred spirals
S0
SB0
E7
Elliptical galaxies
E3
Galaxies become more elongated.
E0

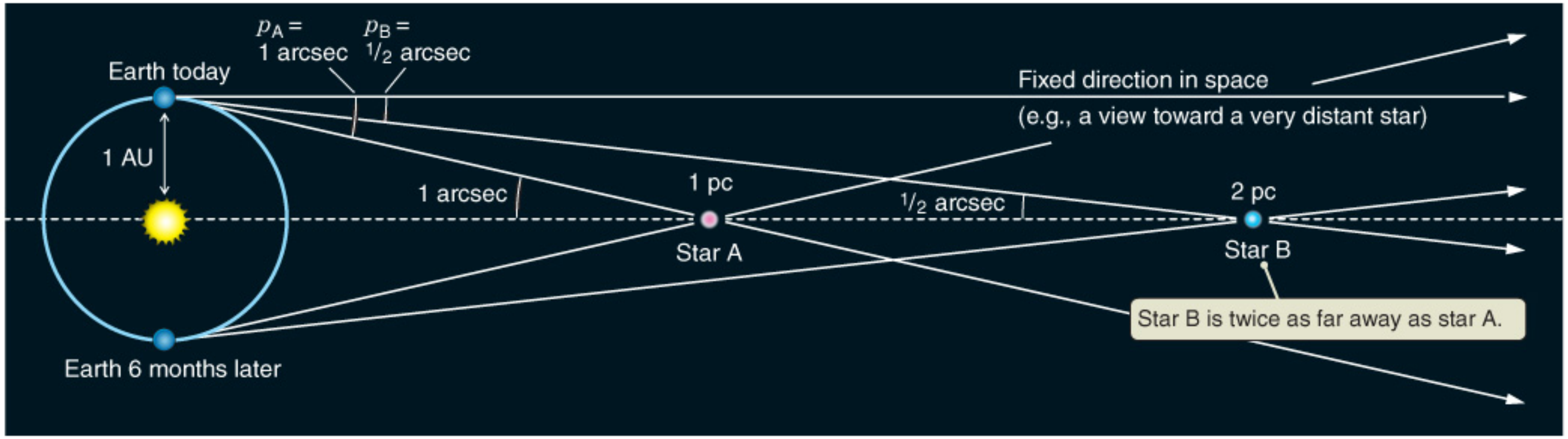

Disk
Barlike bulge
1 Stars in the disks of spiral galaxies move together…
Spiral arm
2 …on nearly circular orbits.
3 Bulges of spiral galaxies are like elliptical galaxies: stars move in irregular orbits in all directions.
G X U V I R

## Hubble's law demonstrates that the universe is expanding

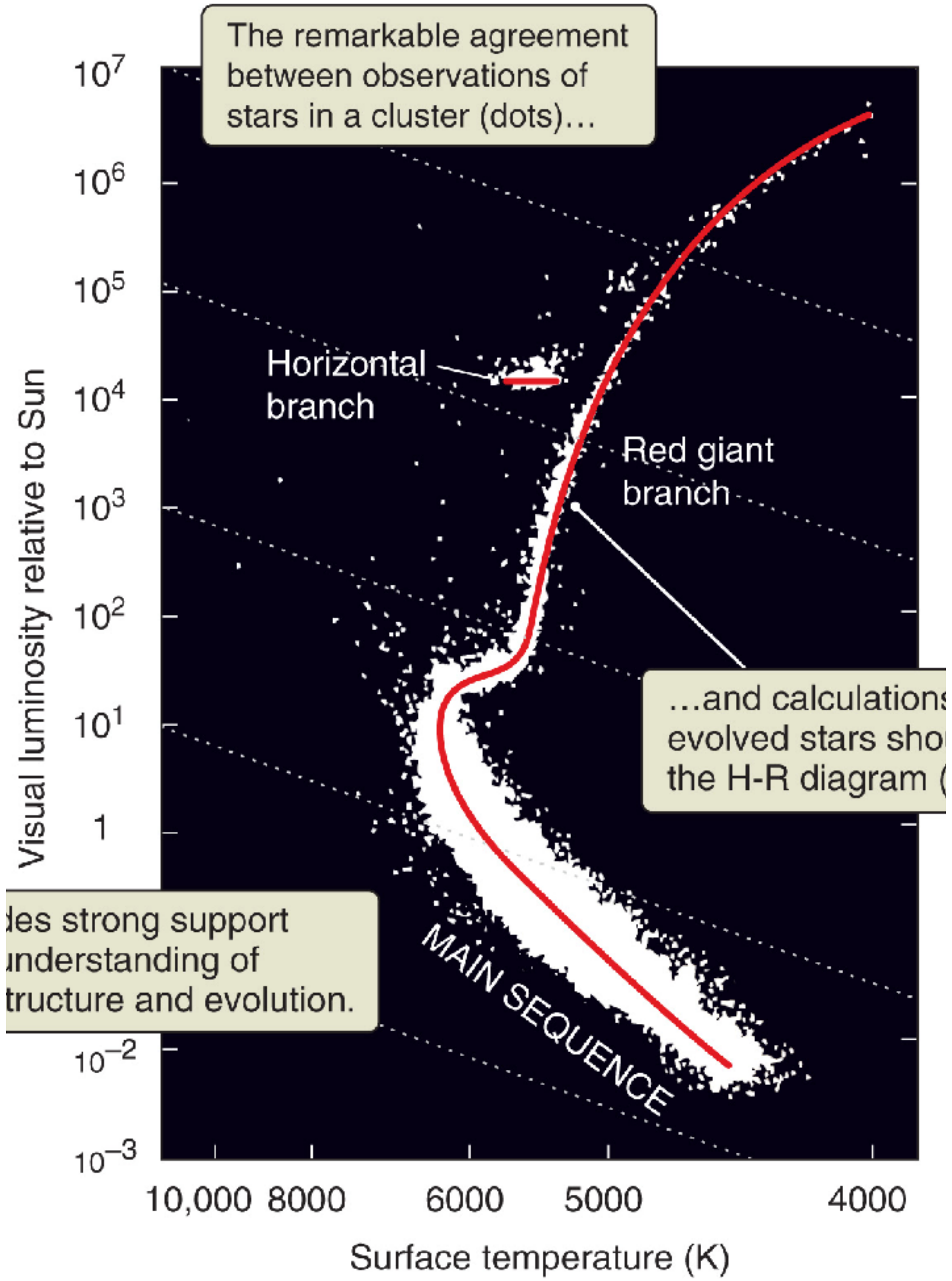


# Distance Ladder

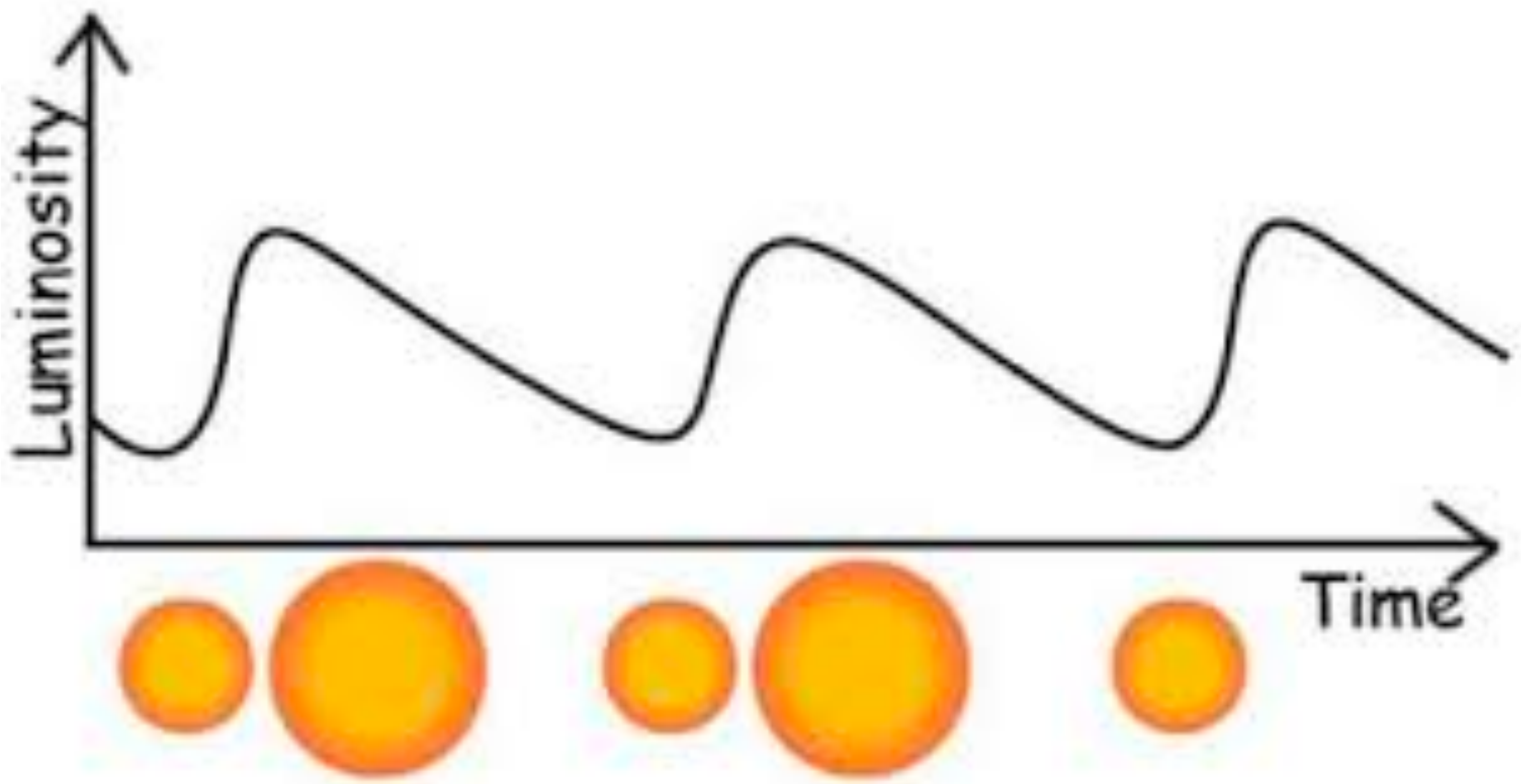
## Parallax



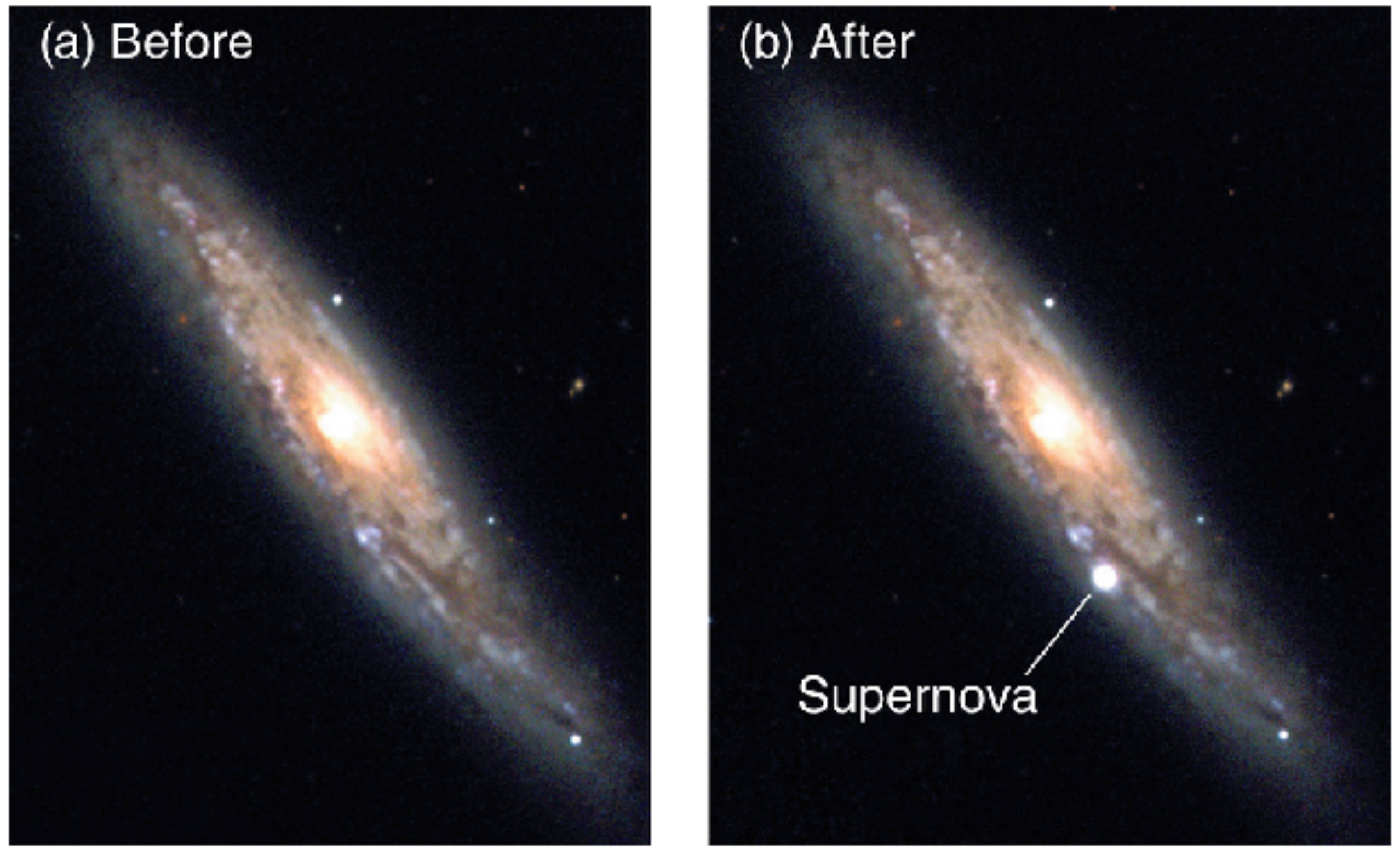

## Spectroscopic Parallax



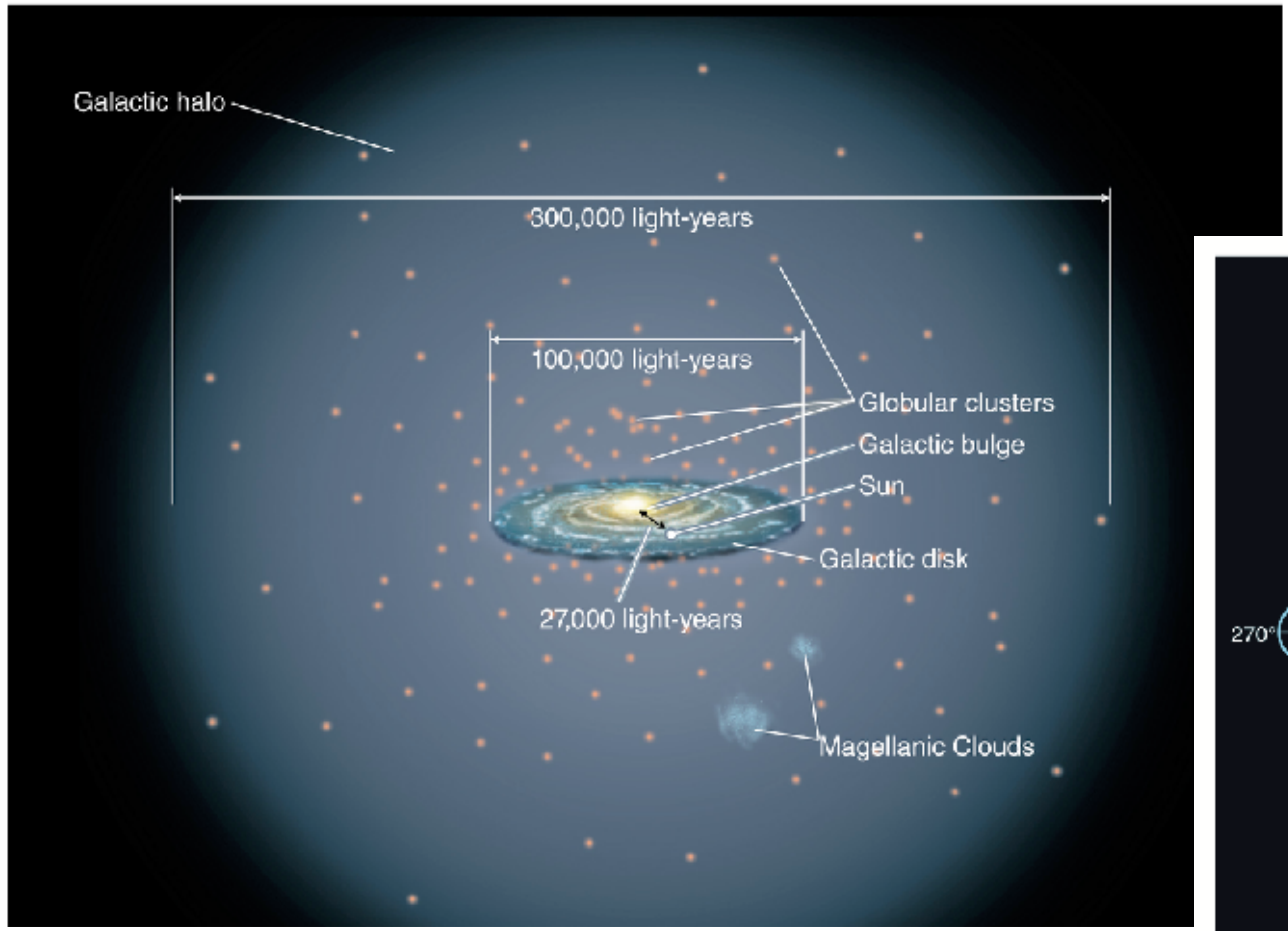

## Cepheid Variables



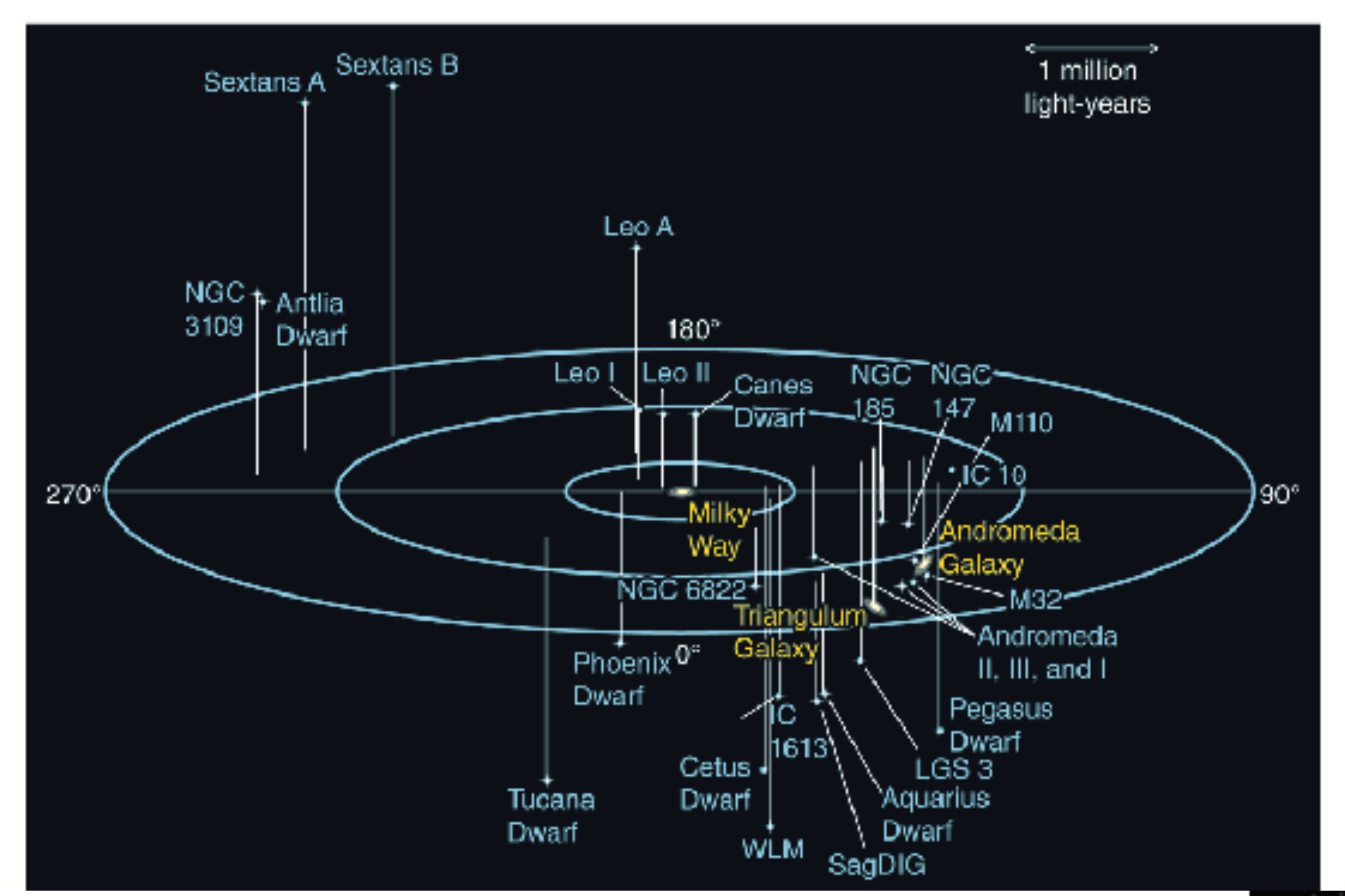

## Type Ia SNe



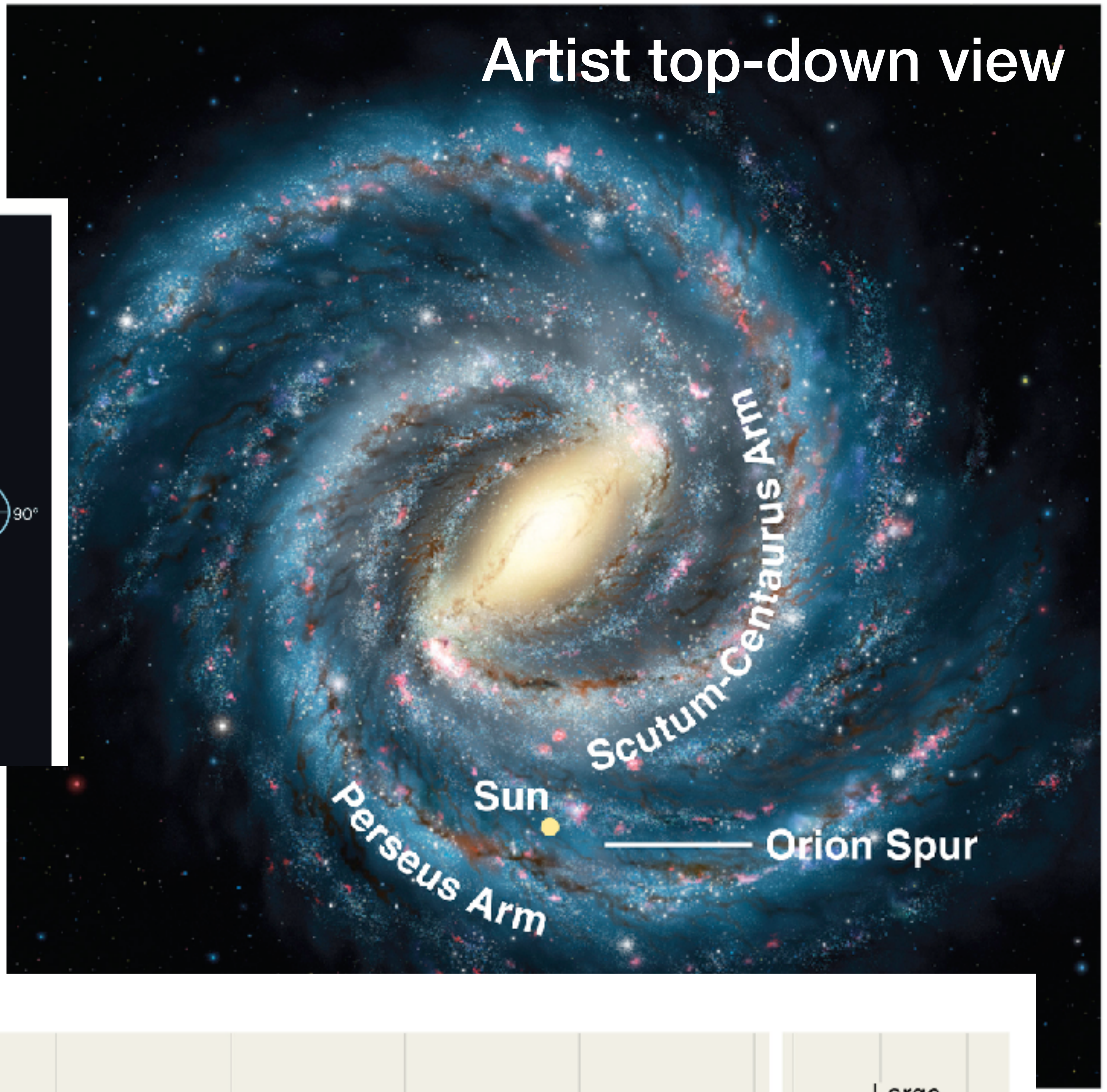
# Milky Way



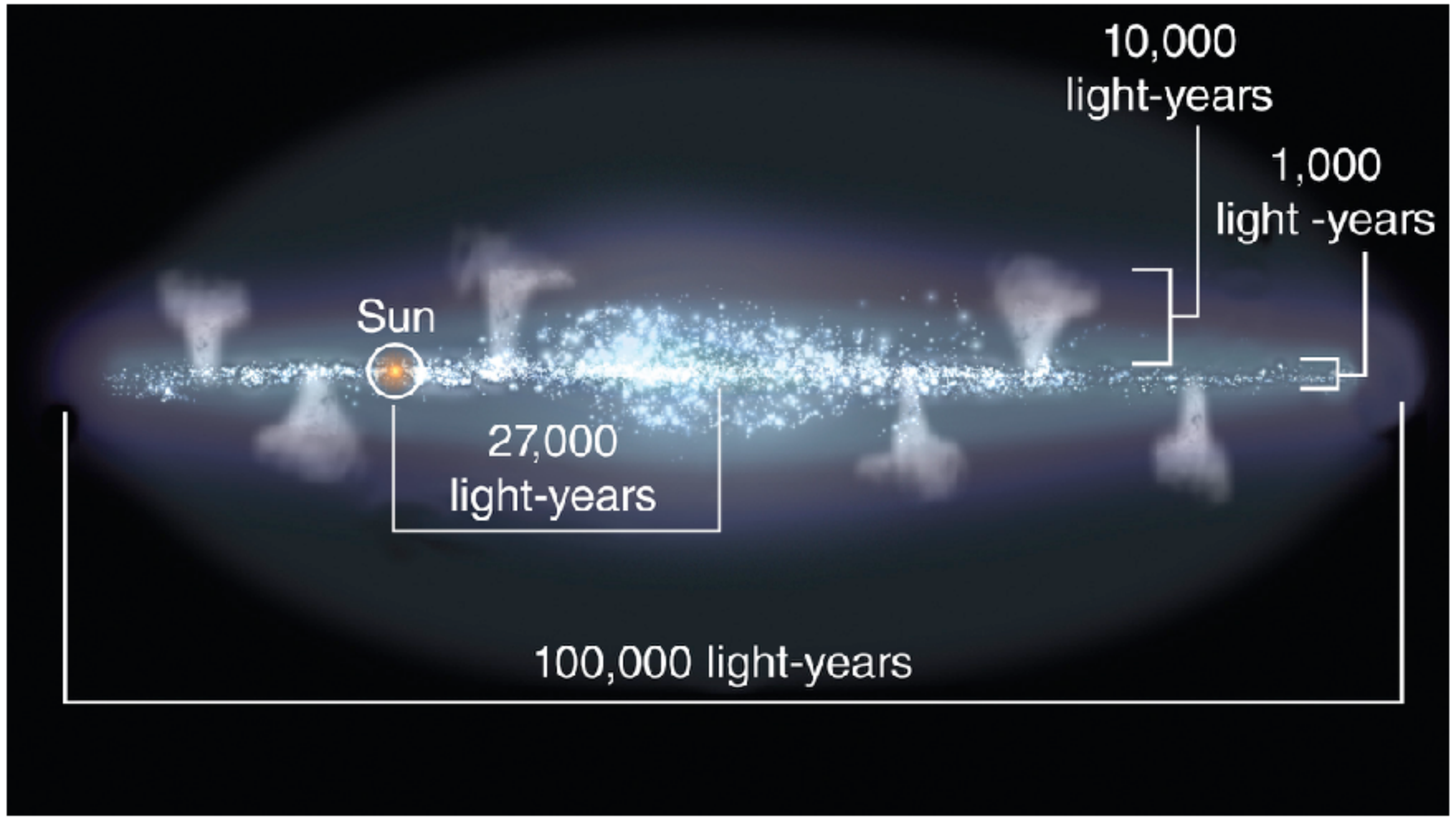
Galactic halo
300,000 light-years
100,000 light-years
Globular clusters
Galactic bulge
Sun
Galactic disk
27,000 light-years
Magellanic Clouds

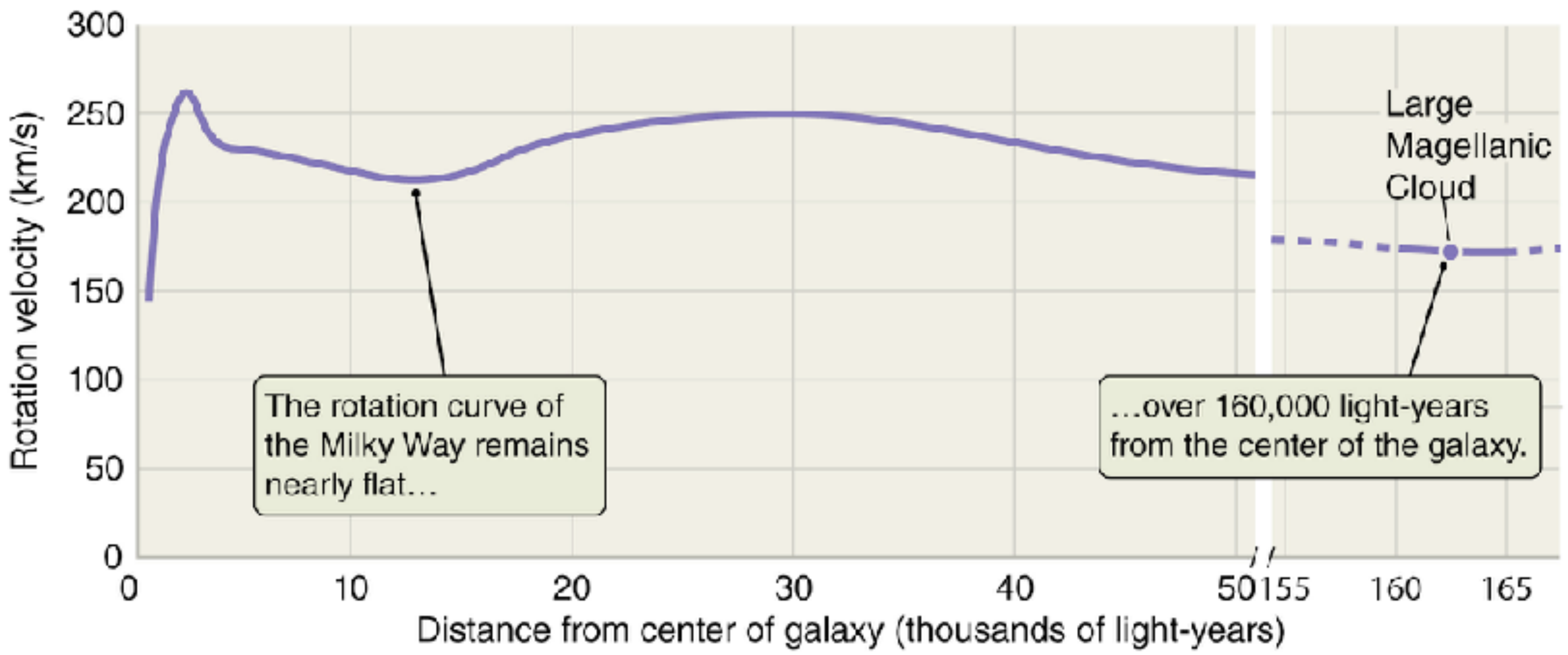
Sextans A
Sextans B
1 million light-years
Leo A
NGC 3109
Antlia Dwarf
180°
Leo I
Leo II
Canes Dwarf
NGC 185
NGC 147
M110
IC 10
270°
90°
Milky Way
Andromeda Galaxy
NGC 6822
M32
Triangulum Galaxy
Andromeda II, III, and I
Phoenix Dwarf
0°
Pegasus Dwarf
IC 1613
Cetus Dwarf
LGS 3
Aquarius Dwarf
Tucana Dwarf
WLM
SagDIG

Artist top-down view
Scutum-Centaurus Arm
Sun
Orion Spur
Perseus Arm

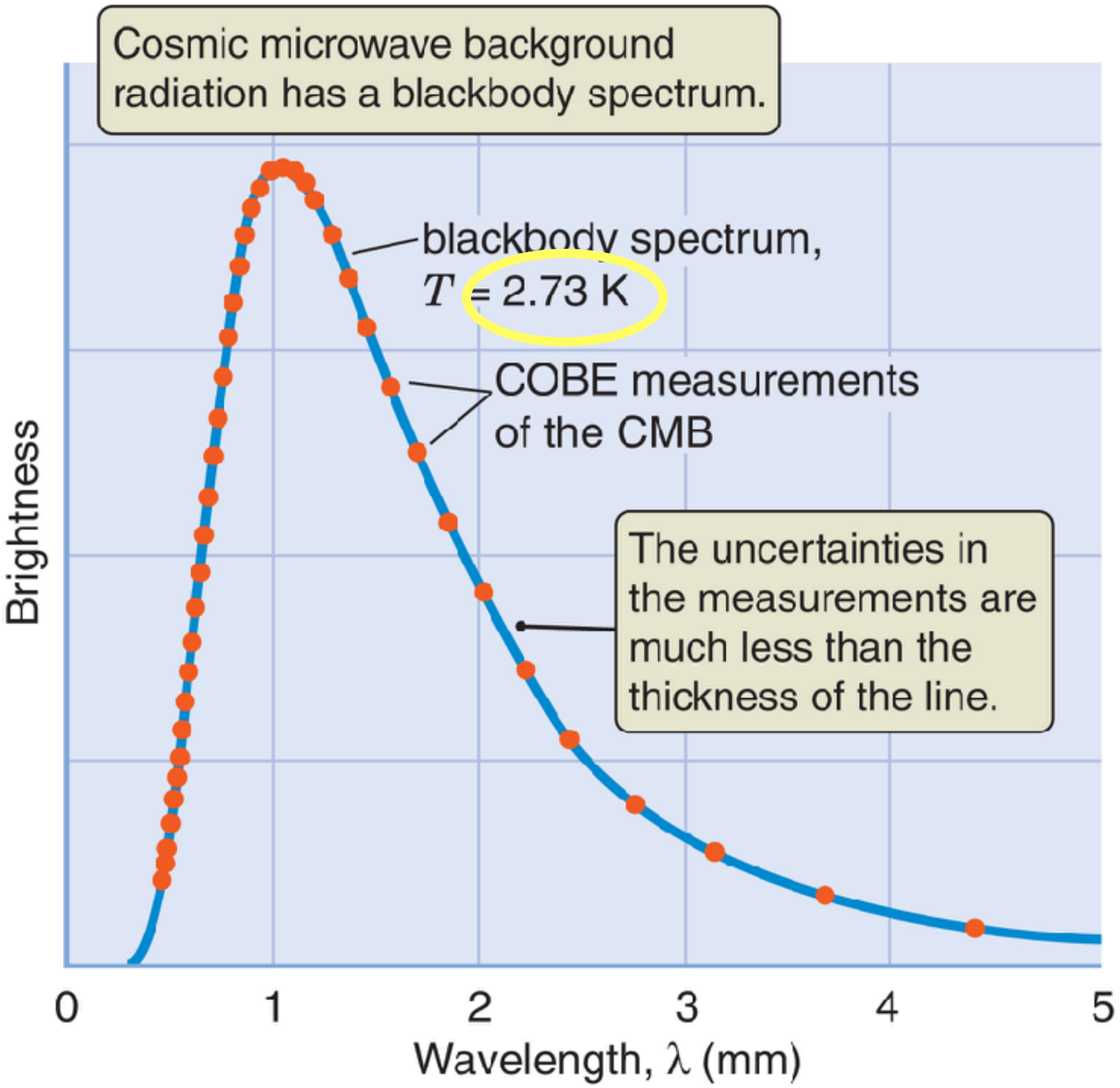



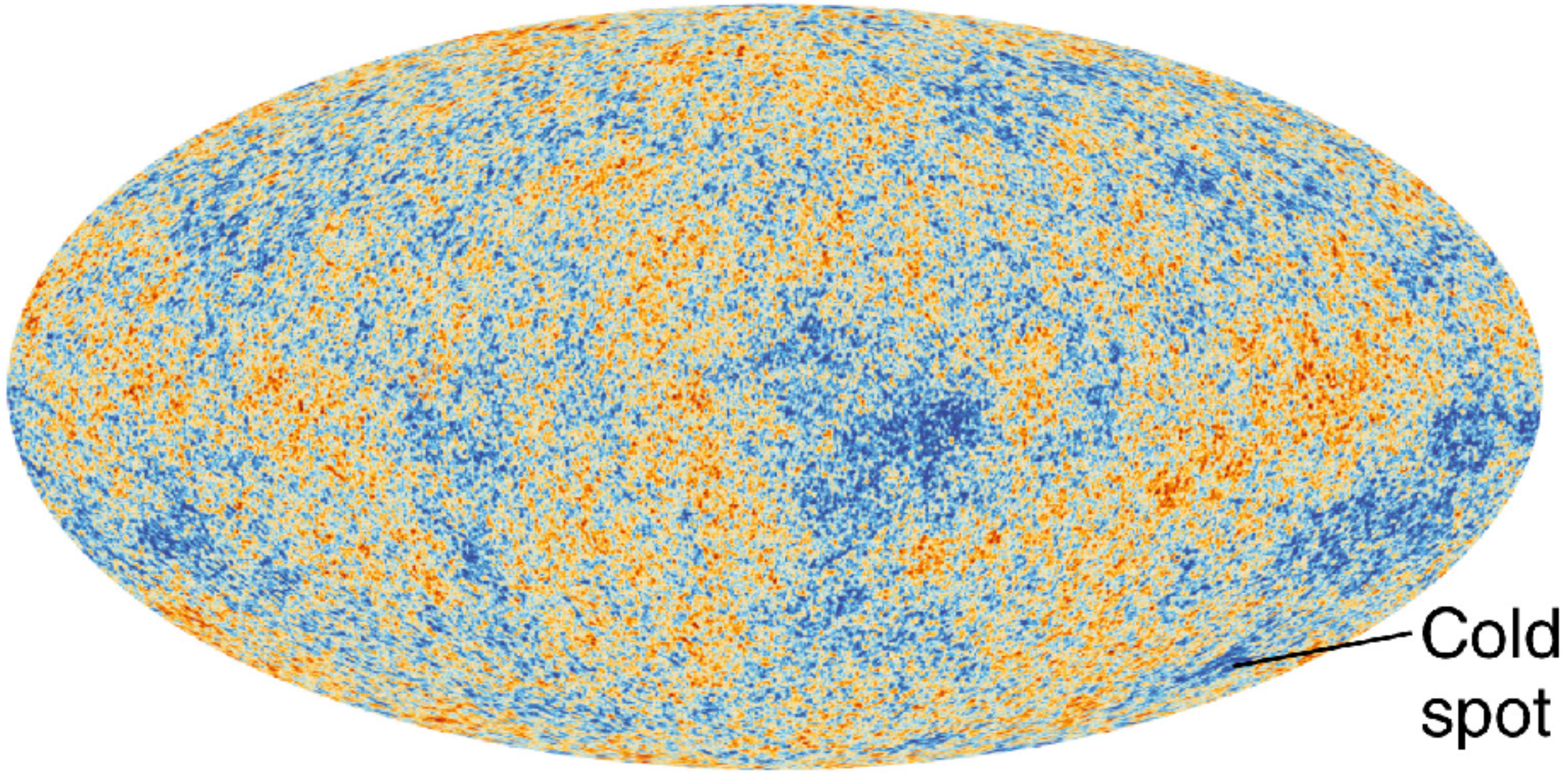
10,000 light-years
1,000 light -years
Sun
27,000 light-years
100,000 light-years

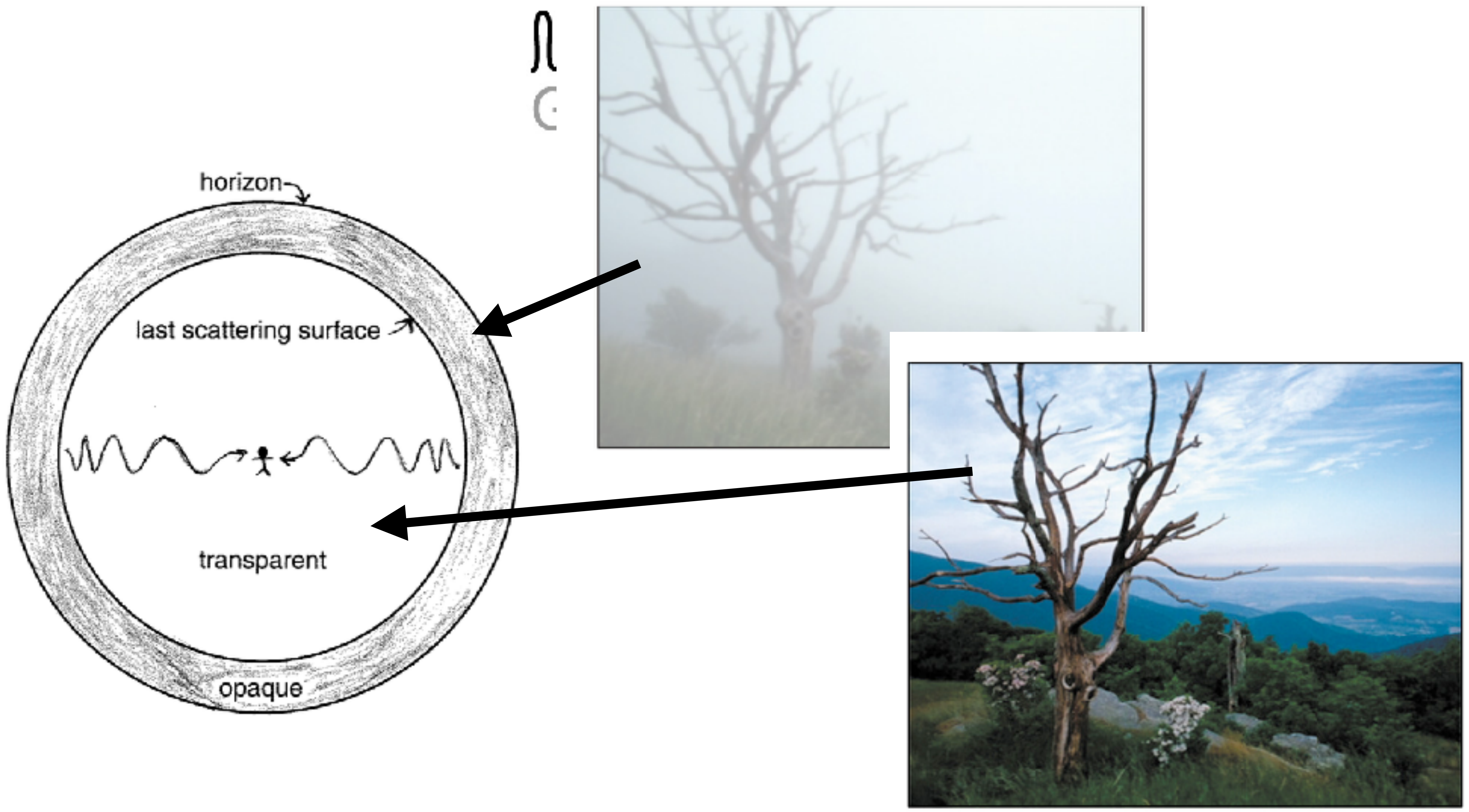



Rotation velocity (km/s)
300
250
200
150
100
50
0
Large Magellanic Cloud
The rotation curve of the Milky Way remains nearly flat...
...over 160,000 light-years from the center of the galaxy.
0
10
20
30
40
50
155
160
165
Distance from center of galaxy (thousands of light-years)

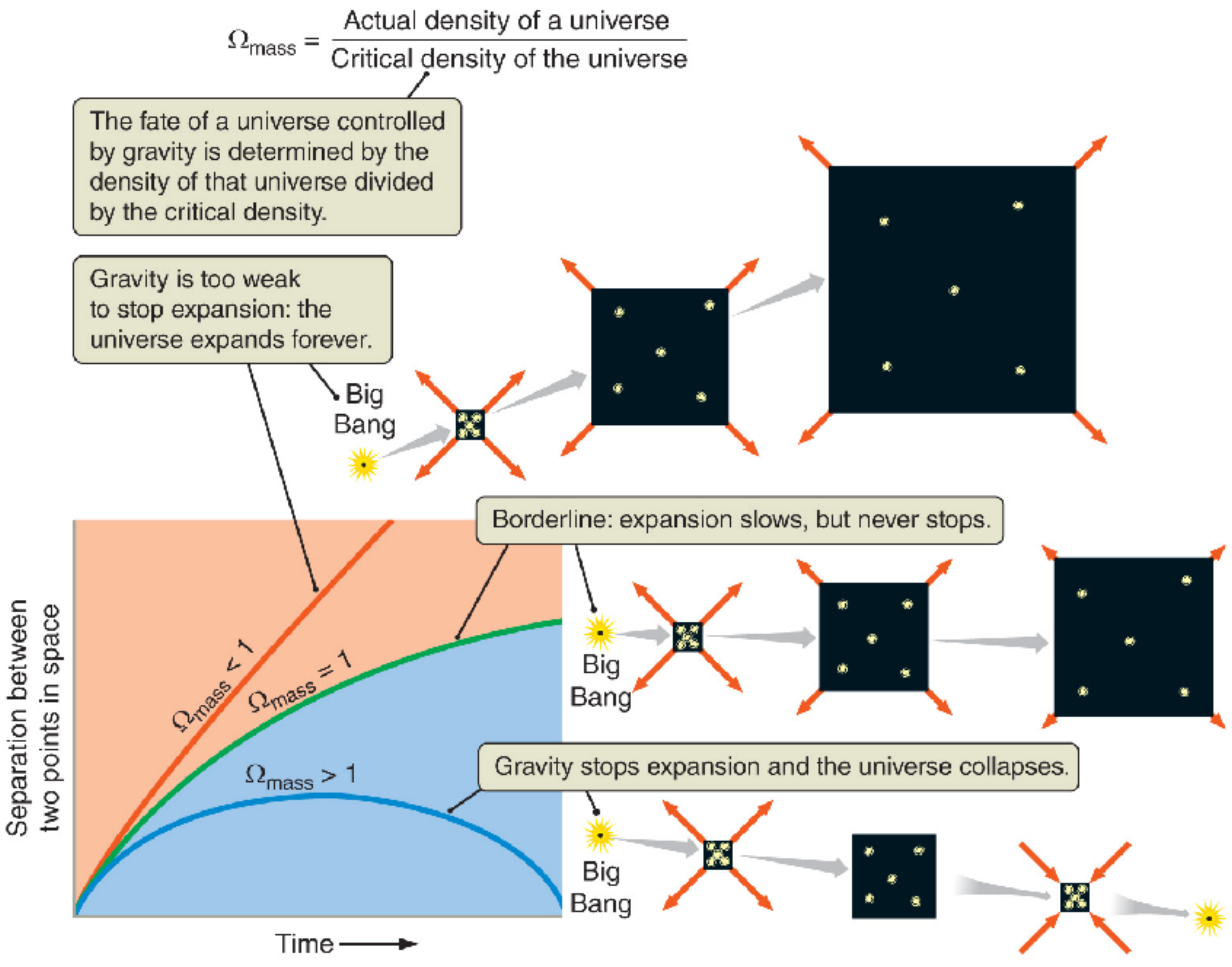
# Cosmic Microwave Background - leftover radiation from the big bang

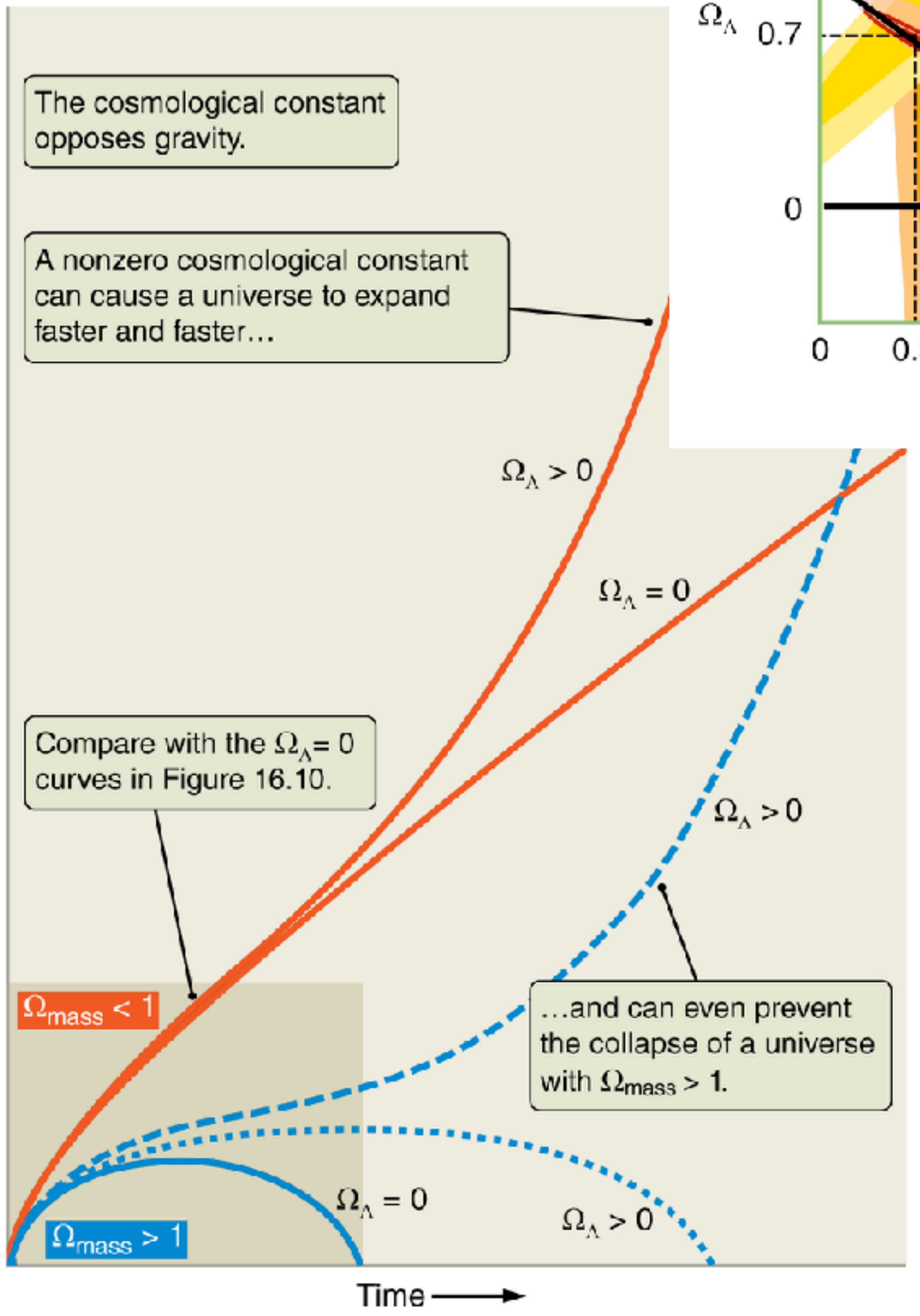


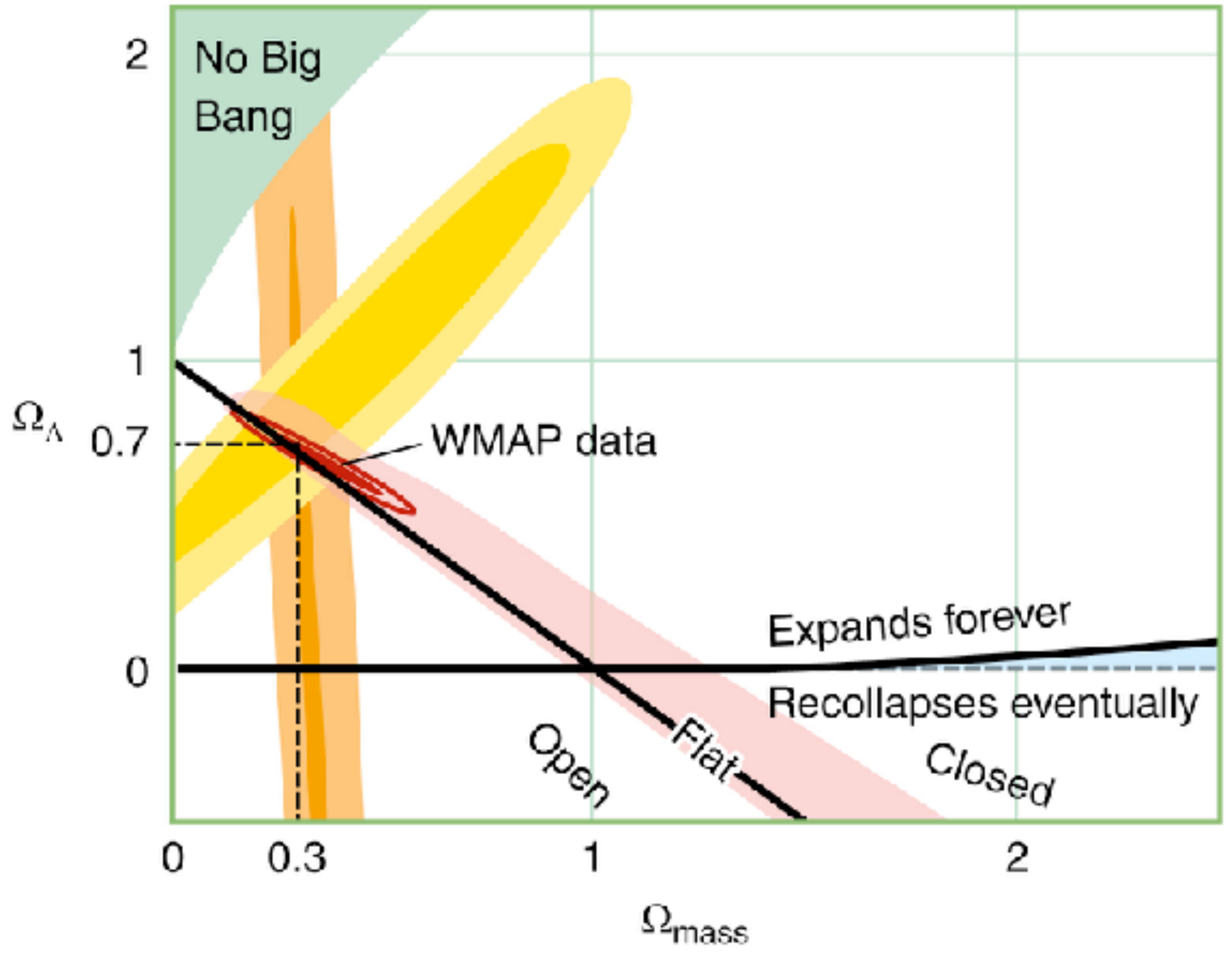



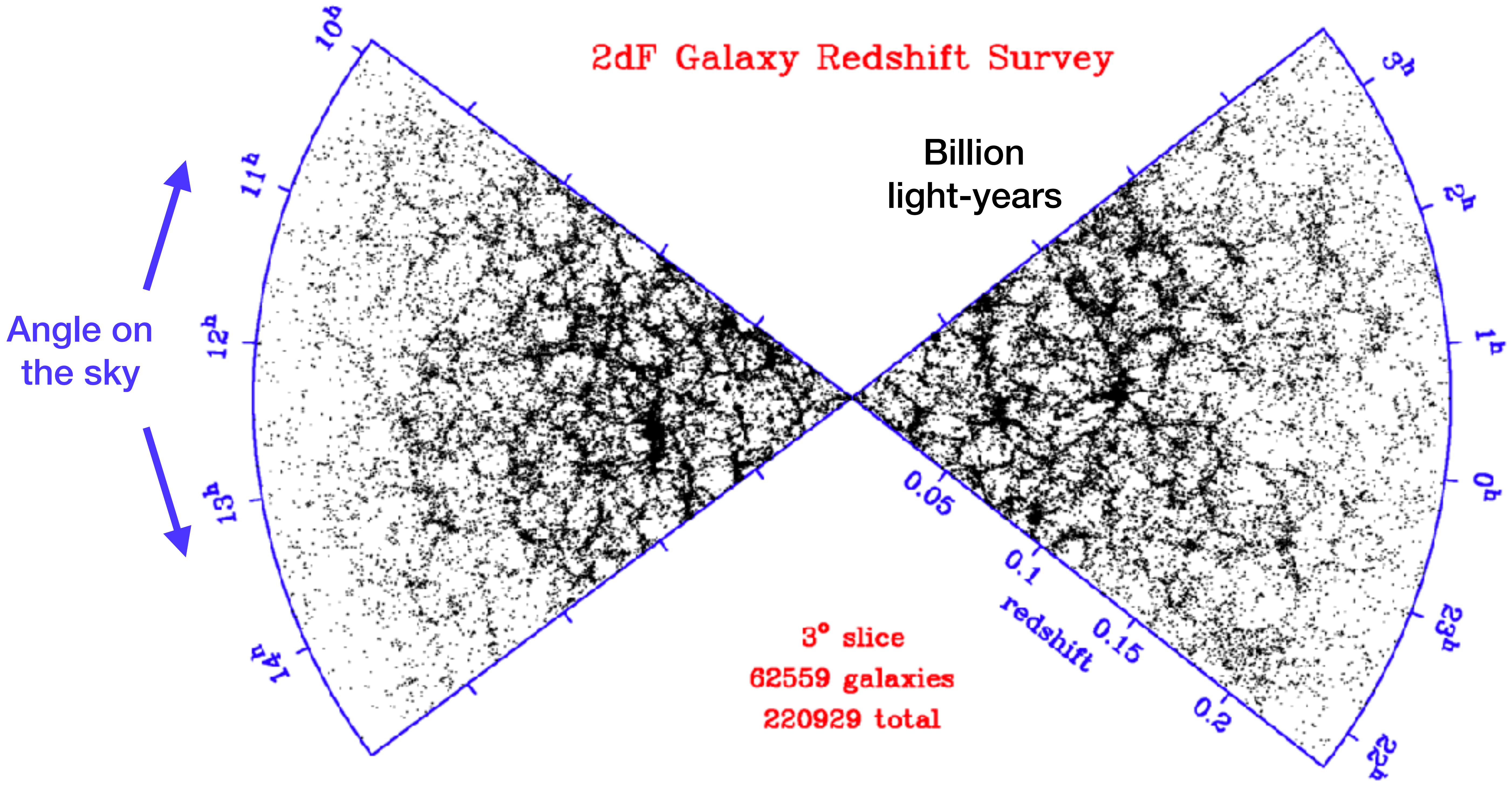



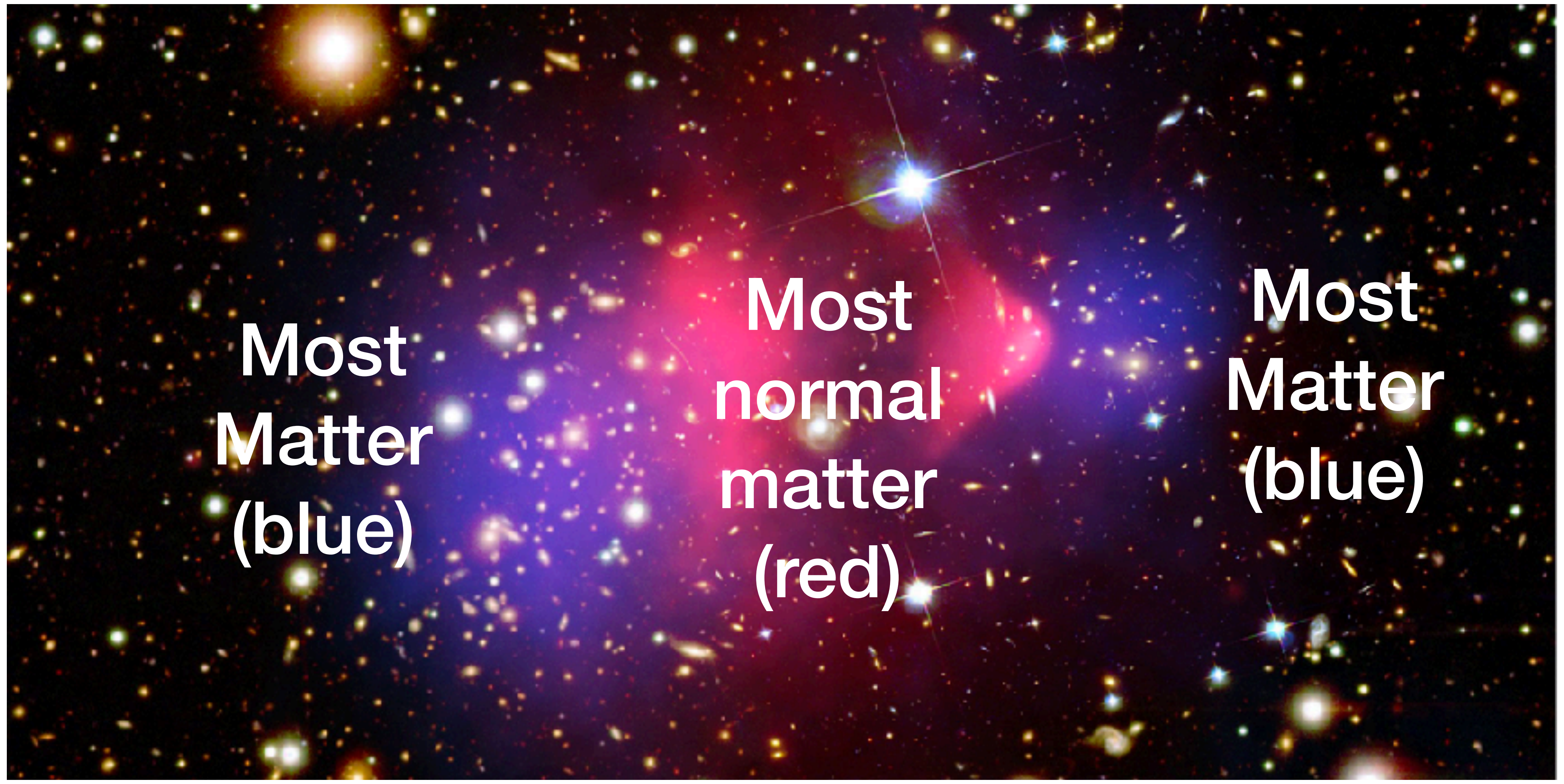
# Expansion History of Space

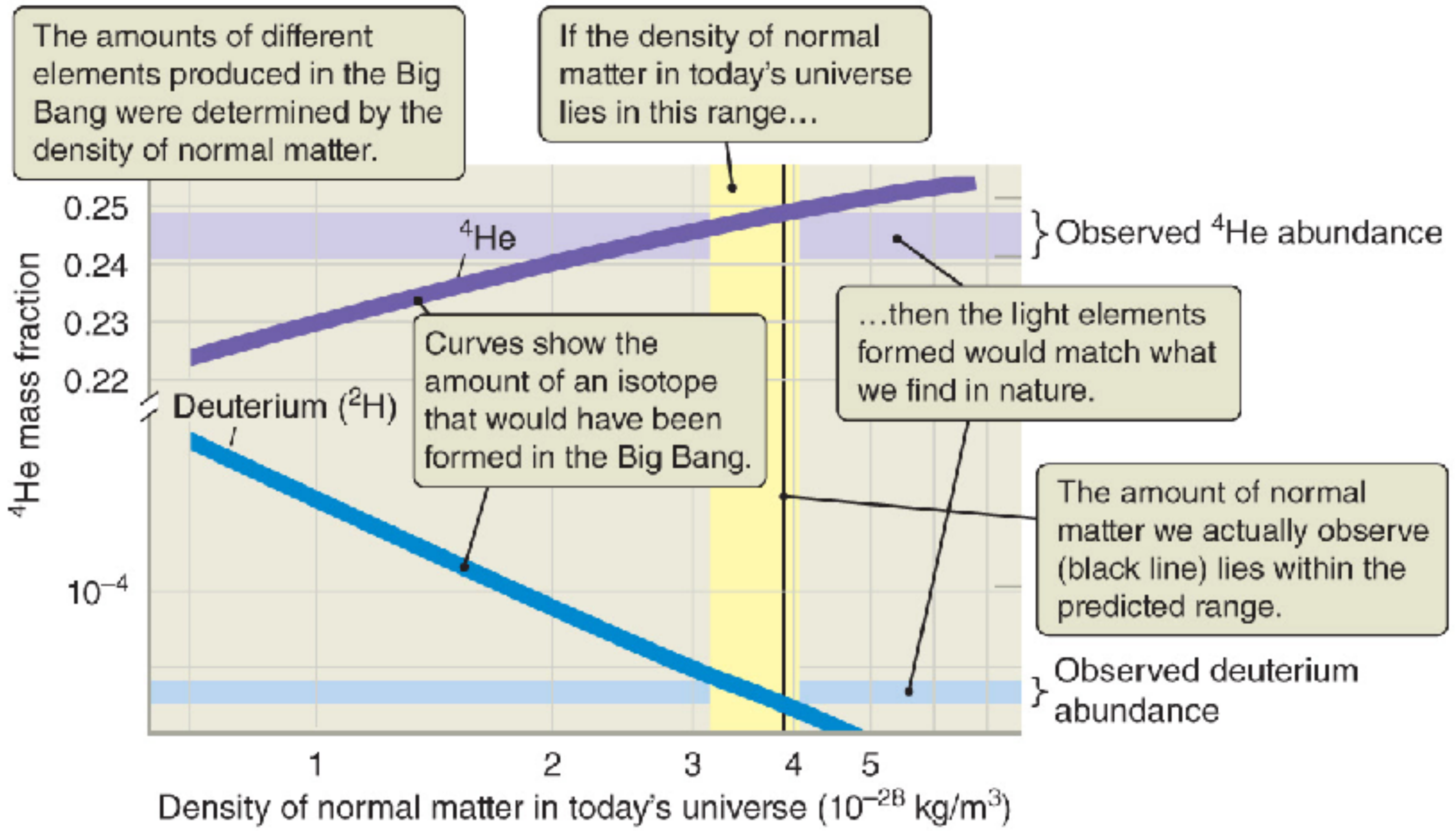


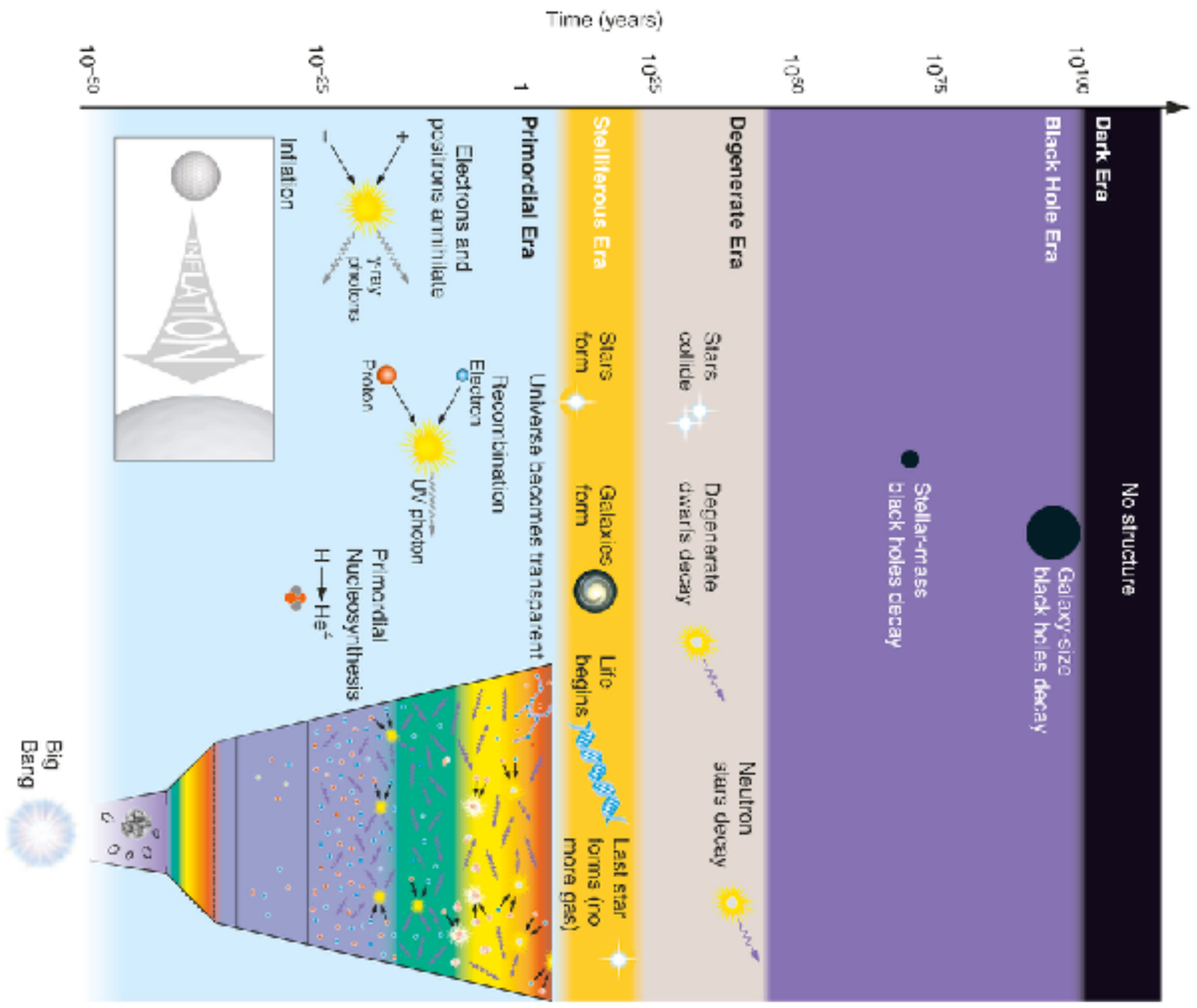



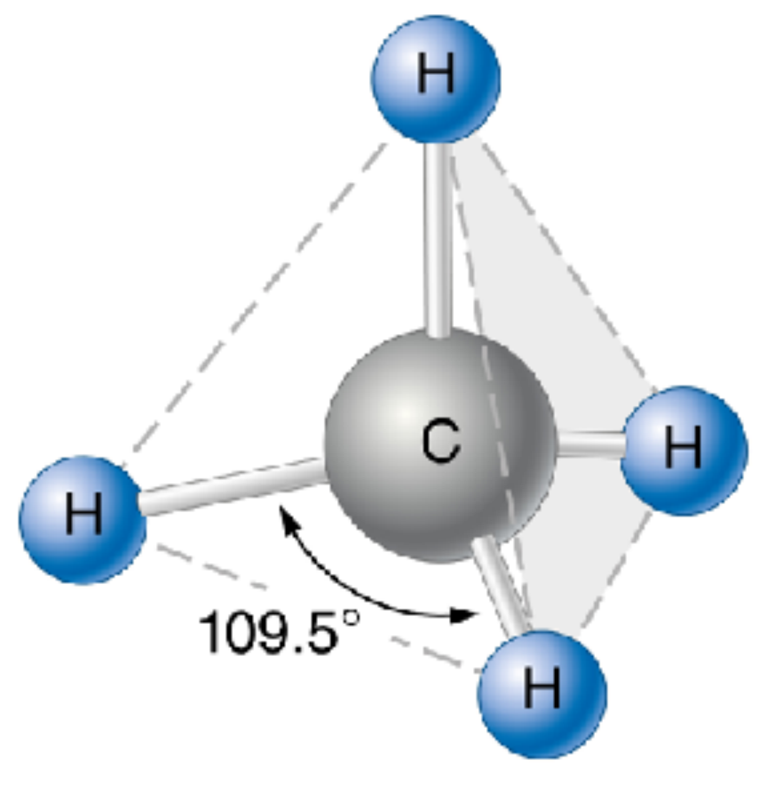




2dF Galaxy Redshift Survey
Billion light-years
Angle on the sky
3° slice
62559 galaxies
220929 total
redshift
0.05
0.1
0.15
0.2

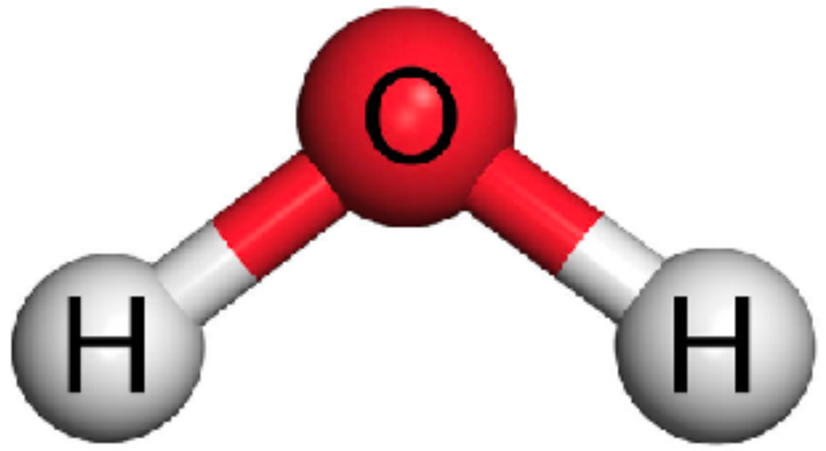

Most Matter (blue)
Most normal matter (red)
Most Matter (blue)

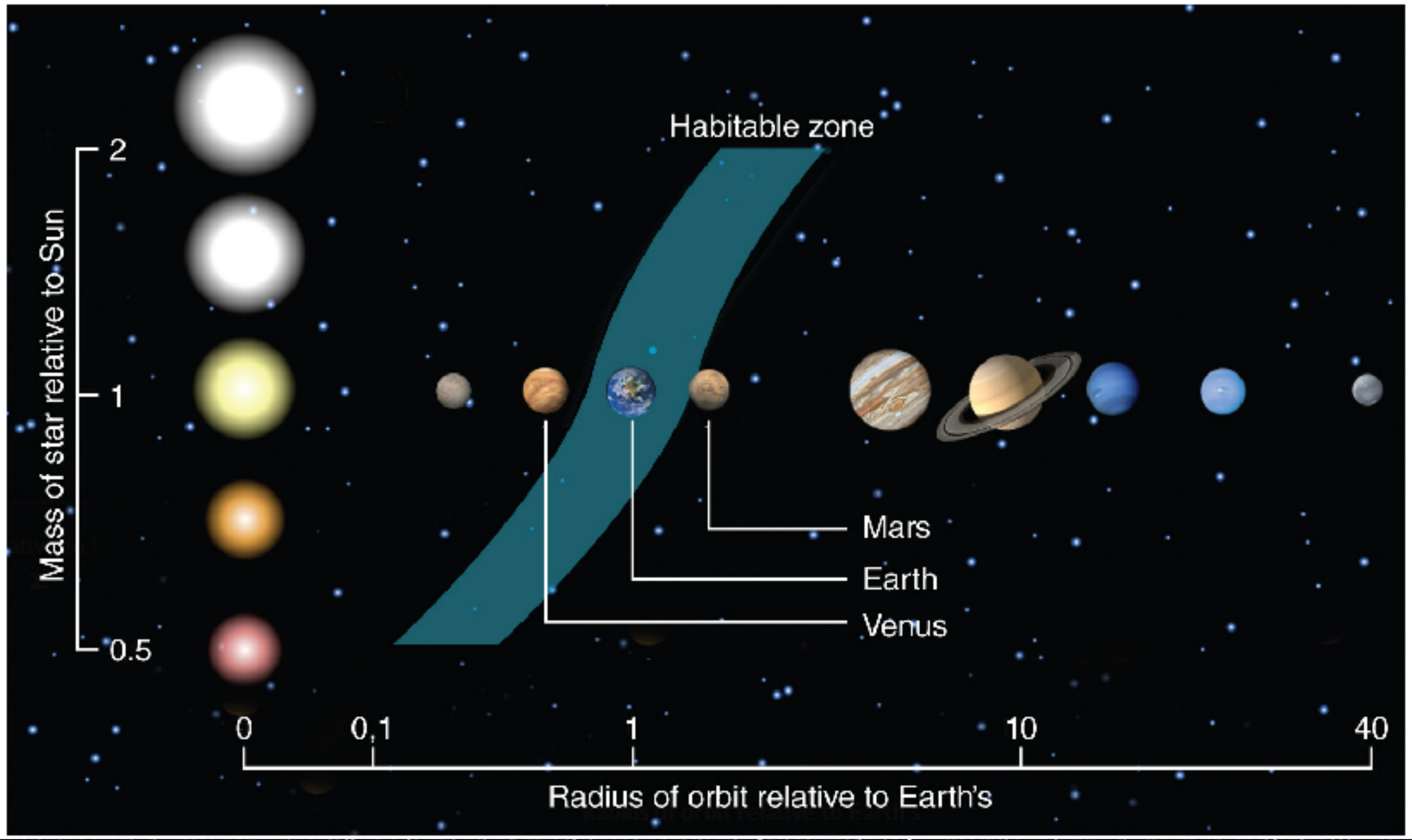

The amounts of different elements produced in the Big Bang were determined by the density of normal matter.
If the density of normal matter in today's universe lies in this range...
...then the light elements formed would match what we find in nature.
Curves show the amount of an isotope that would have been formed in the Big Bang.
The amount of normal matter we actually observe (black line) lies within the predicted range.
Observed $^4$He abundance
Observed deuterium abundance
$^4$He
Deuterium ($^2$H)
$^4$He mass fraction
Density of normal matter in today's universe ($10^{-28}$ kg/m$^3$)

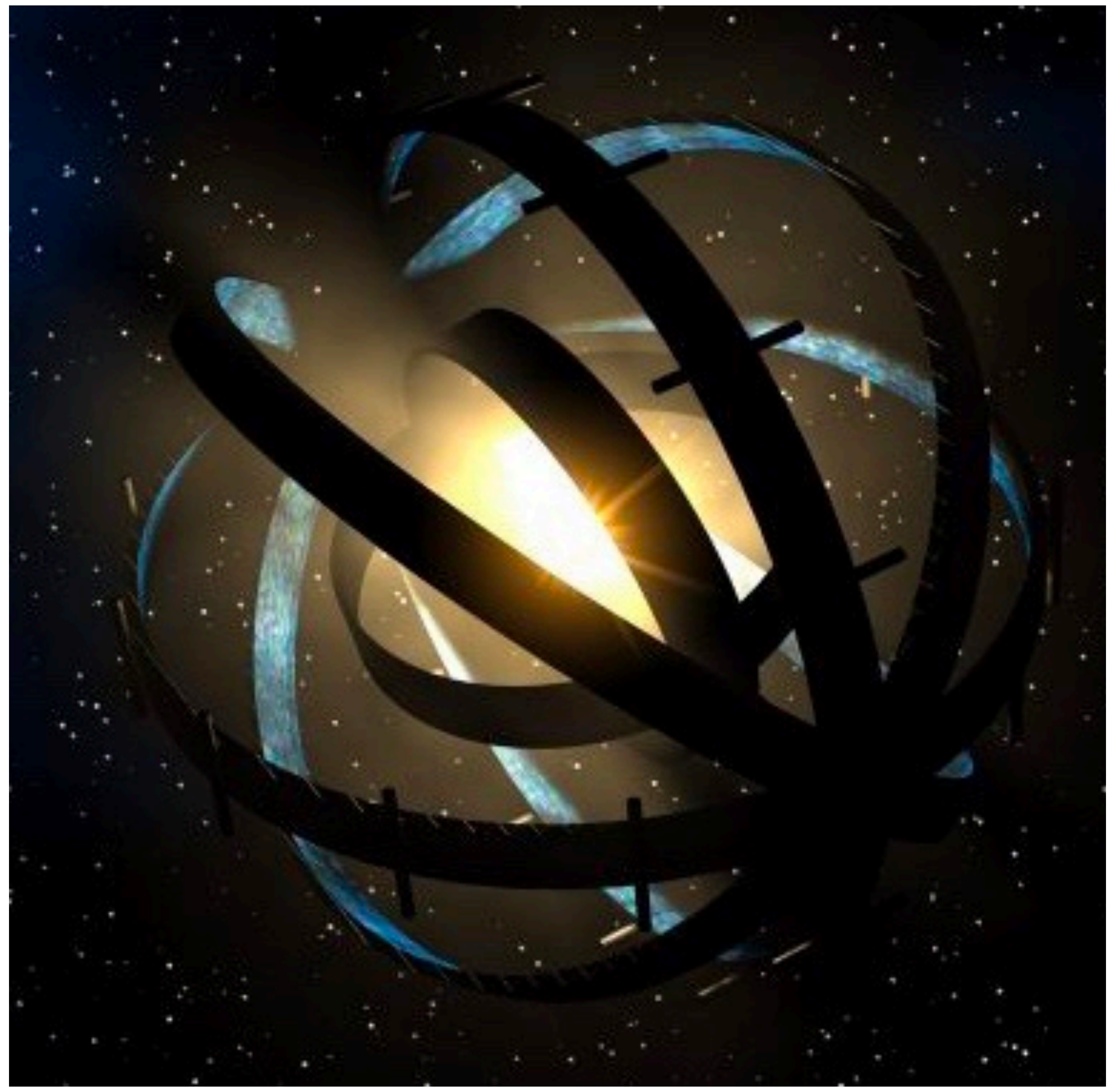

Time (years)
Primordial Era
Stelliferous Era
Degenerate Era
Black Hole Era
Dark Era



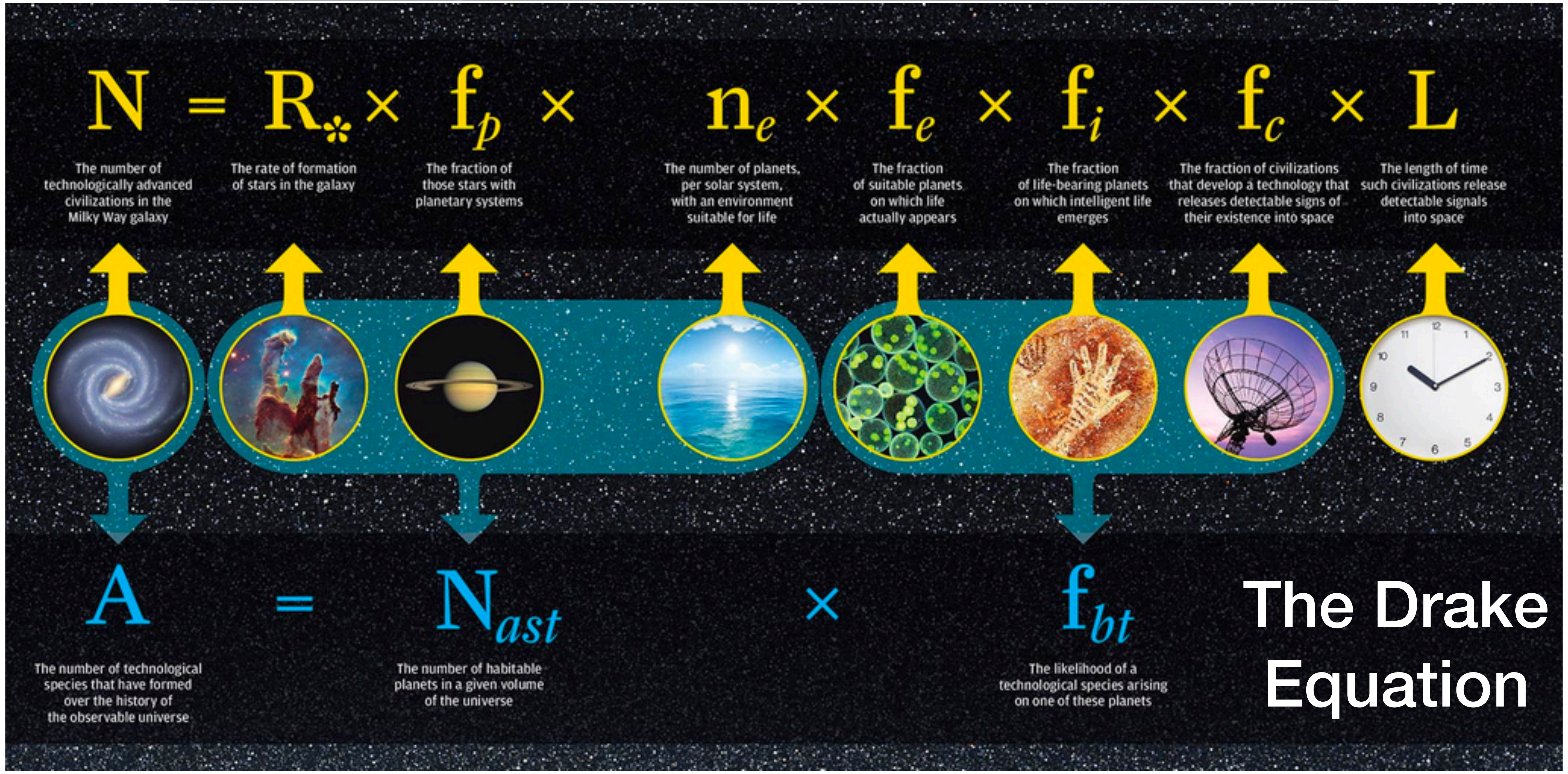

Methane tetrahedron



Dyson Spheres




Life needs:

- organic molecules
- water
- energy