Today's Topics

Wednesday, November 13, 2019 (Week 11, lecture 27) – Chapters 17, 18, 19, 22.

1. Solar fusion

1. Overview of common stars

2. Luminosity vs mass

3. H-R diagram: main sequence stars

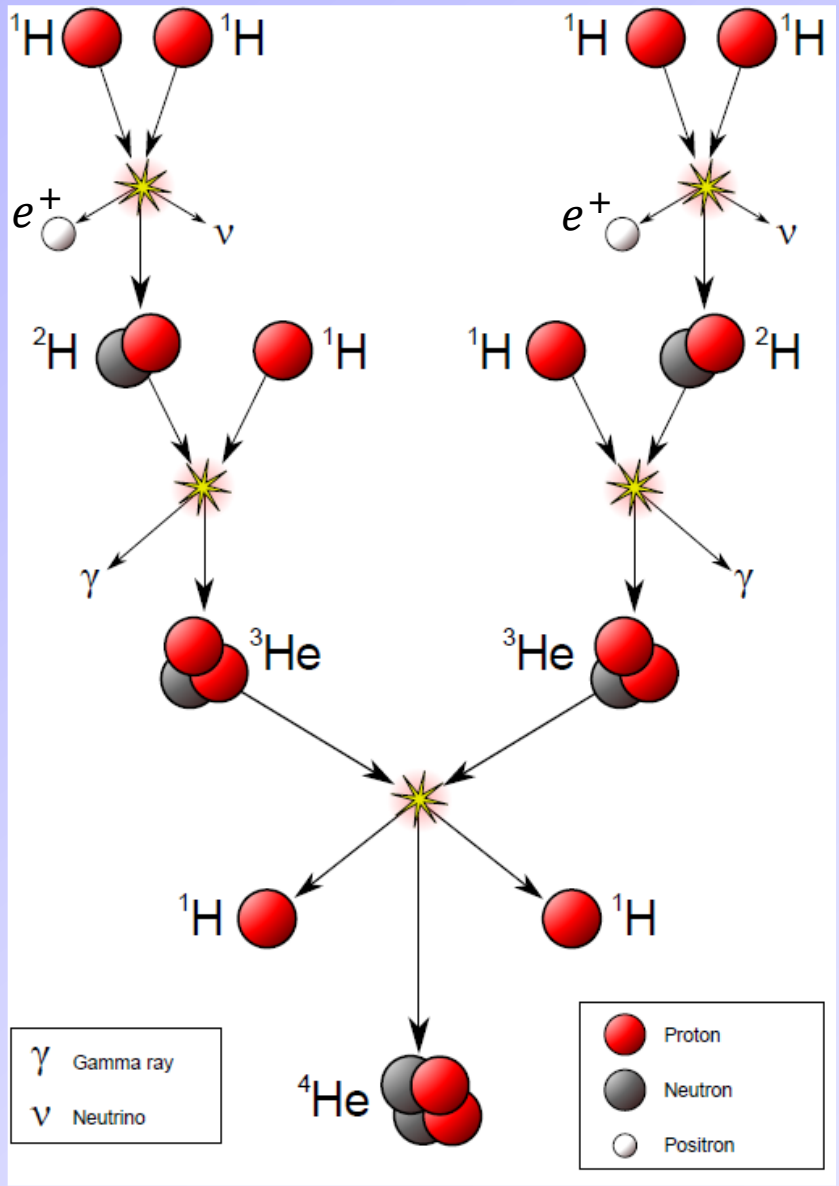
Reminder: Midterm on Monday, November 18, 2019.

Solar Fusion: proton-proton chain

9 billions years
weak force

4 seconds
strong force

400 years
strong force



(Note: 1 eV = 1.602×10^{-19} J)

2×1.442 MeV

$2 \times (0.42 + 2 \times 0.511)$ MeV
e^+ **mass**

\+ 2×5.49 MeV

\+ 12.86 MeV

= 26.7 MeV total

= 4.28×10^{-12} J

(see also Sept. 20 lecture)

Einstein: Mass & Energy

$$Energy = E = mc^2$$

mass

c = speed of light

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Example: Mass converted to energy in p-p fusion

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Mass of ^{4}He nucleus: $m_{He} = 6.6447 \times 10^{-27}$ kg

Note:

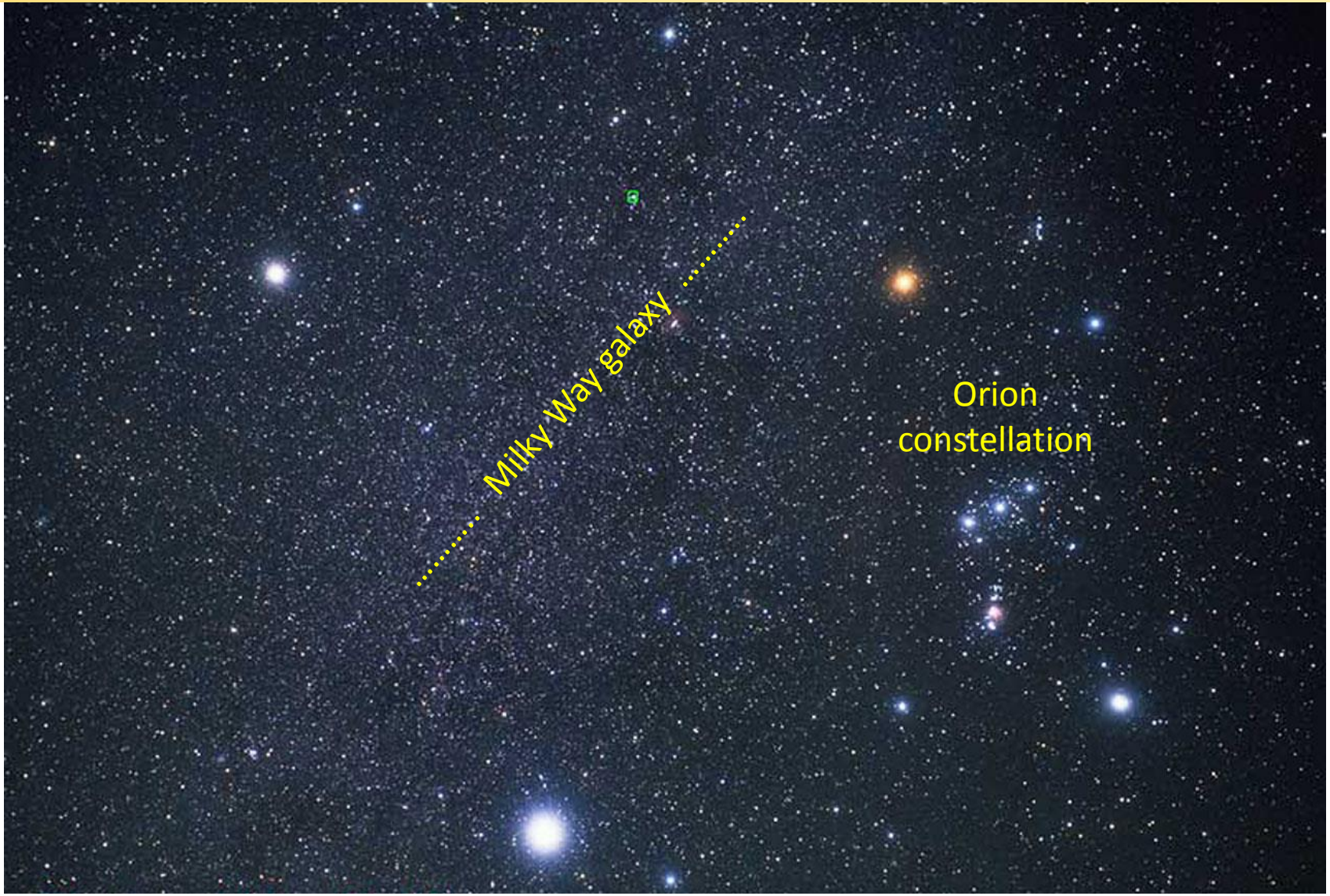
$4m_p - m_{He} = 4.65 \times 10^{-29}$ kg

difference is due to two positrons !

Observing the Stars

By Hubble European Space AgencyCredit: Akira Fujii - http://www.spacetelescope.org/images/heic0206j/ (watermark was cropped), Public Domain, https://commons.wikimedia.org/w/index.php?curid=5246351

Observing the Stars



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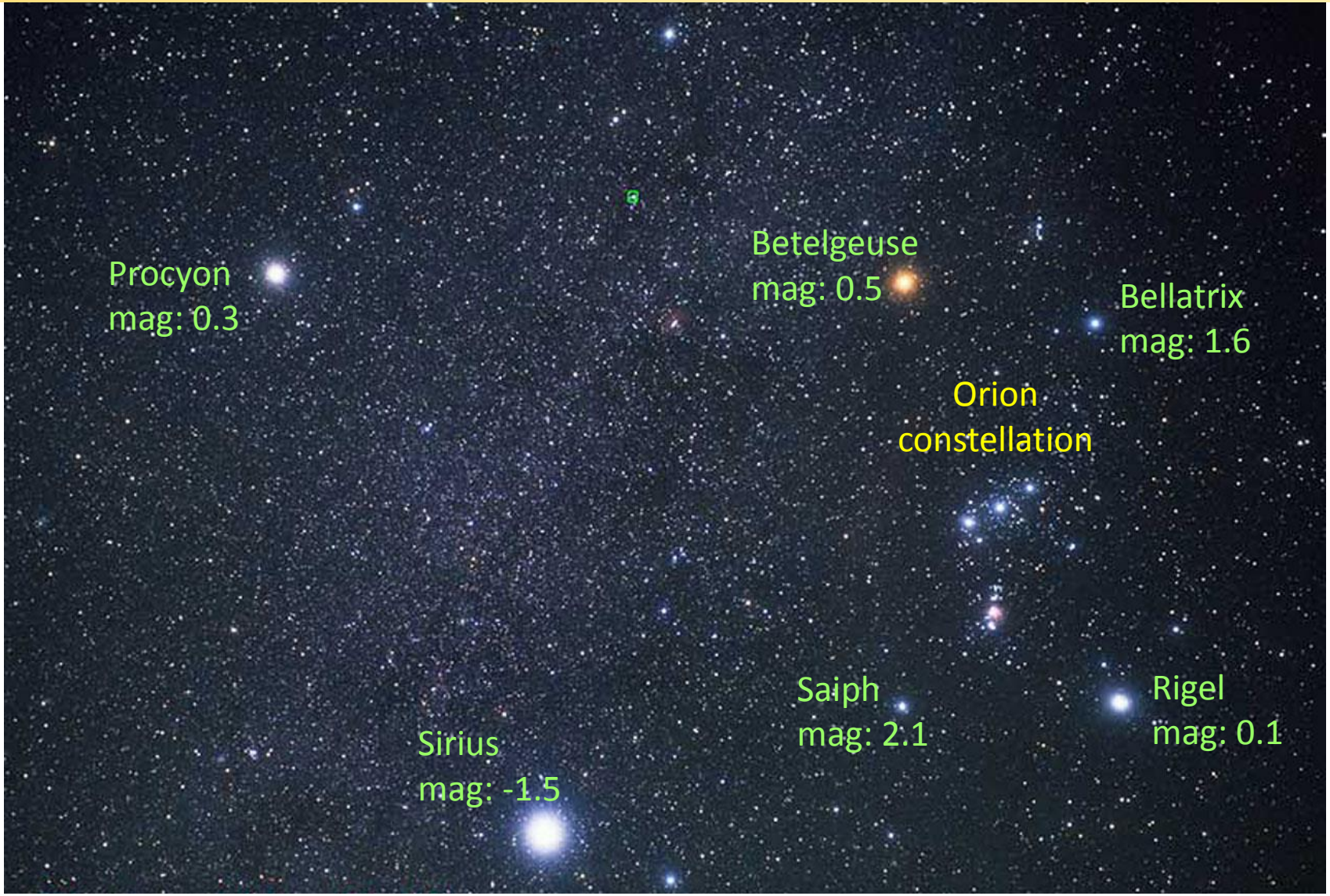

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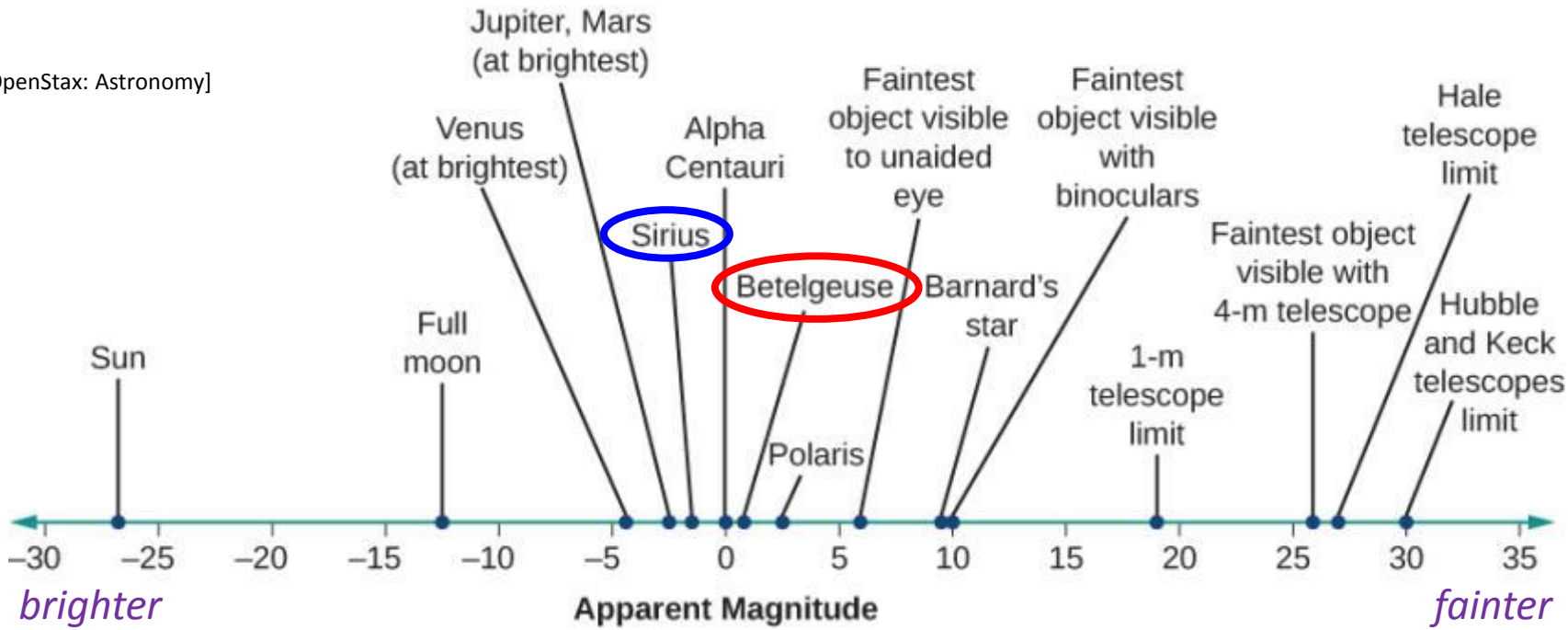
Apparent Magnitude

Logarithmic brightness scale

[OpenStax: Astronomy]



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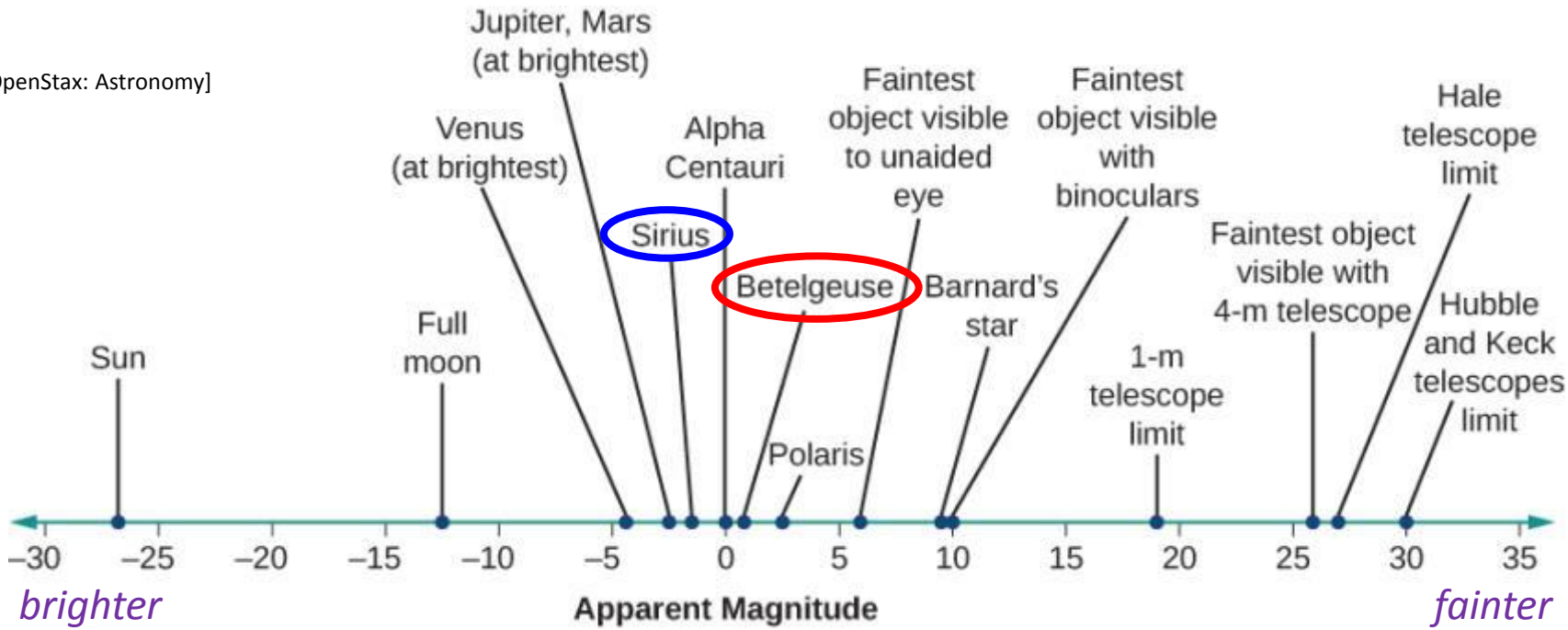

Apparent **brightness** is proportional to optical energy/power incident on detector/eye.

Human eyes are **logarithmic** detectors of brightness, so they measure **magnitude**.

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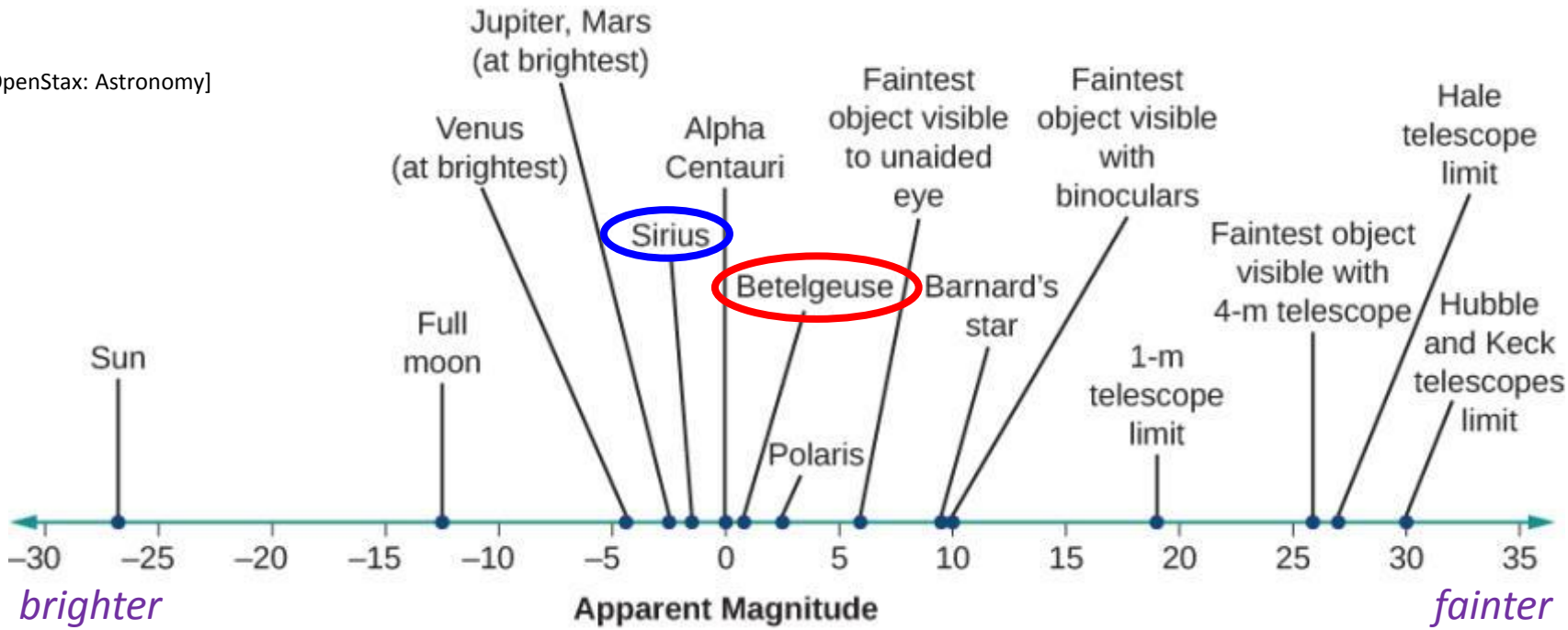

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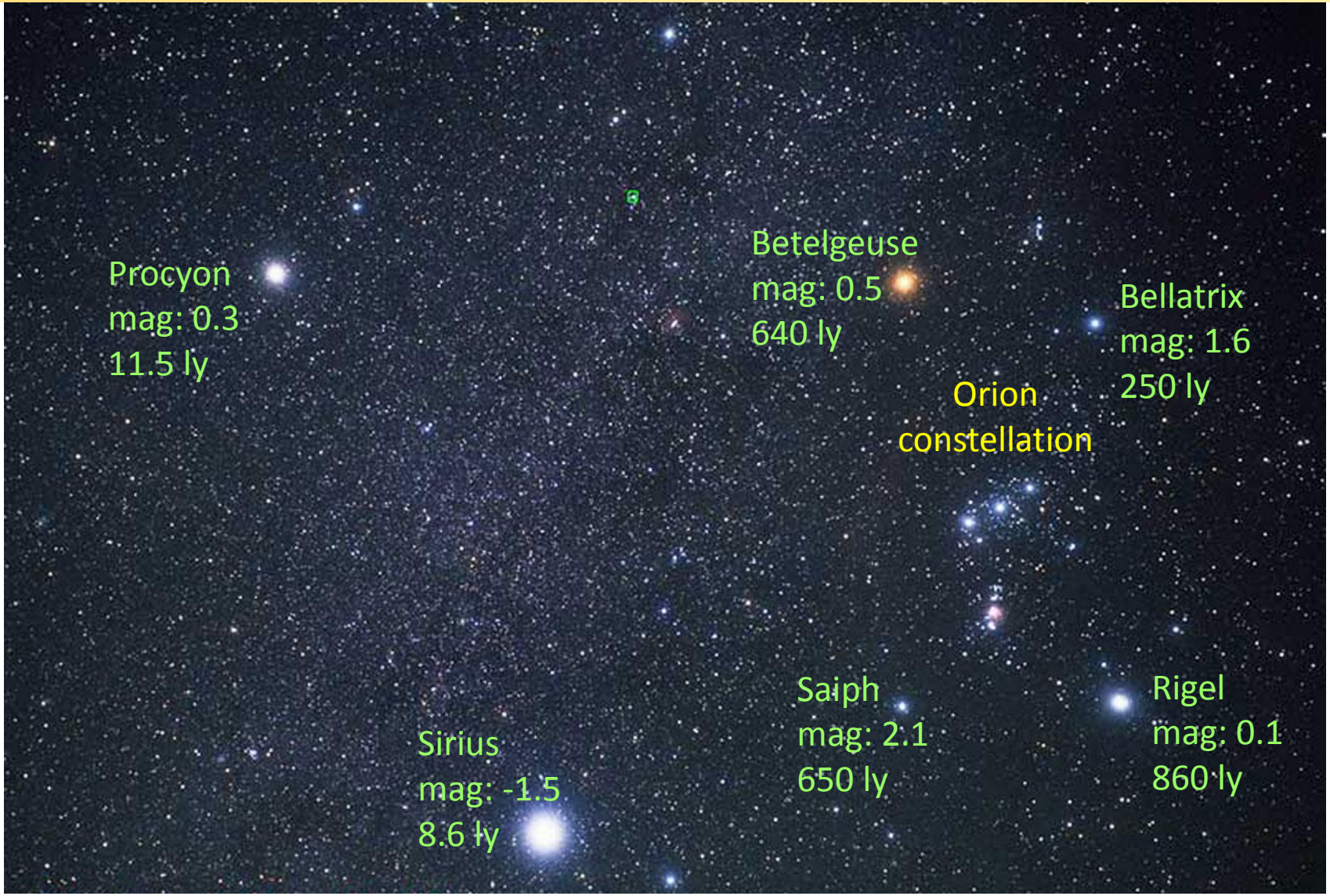
Δmagnitude = m_1-m_2 = 1 corresponds to a factor of 2.512 change in brightness

$$\Delta brightness = \frac{b_2}{b_1} = 2.512^{\Delta m} = 2.512^{(m1-m2)}$$

Observing the Stars



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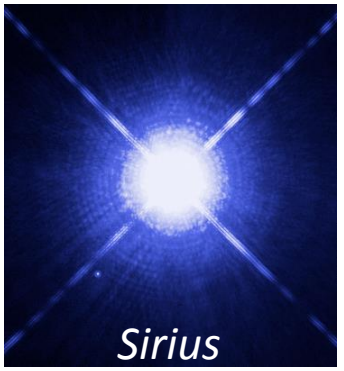
Apparent Brightness vs Luminosity

Luminosity *(definition)*

Total **power** output of a star.

energy per second



[By NASA, ESA, H. Bond (STScI), and M. Barstow (University of Leicester)]

Distance of Star: The farther away a star is, the dimmer it will appear.

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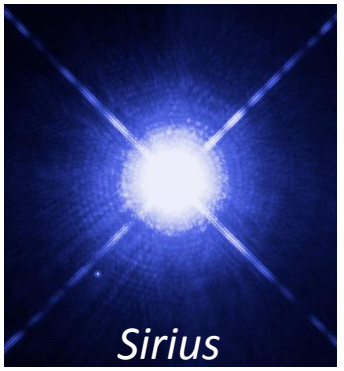

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$$apparent\ brightness \propto \frac{Luminosity}{distance^2}$$

Dim Stars

A star may appear **dim** because it has **low luminosity**, or/and because it is **further away**.

Bright Stars

A star may appear **bright** because it has **high luminosity**, or/and because it is **closer** to us.

Star Color

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Star Color = Temperature

Star Color	Approximate Temperature	Example
Blue	25,000 K	Spica
White	10,000 K	Vega
Yellow	6000 K	Sun
Orange	4000 K	Aldebaran

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Star light is blackbody radiation

Star color follows roughly from Wien's law for peak wavelength: $\lambda_{max,\,nm} = \frac{2.9 \times 10^6}{T}$

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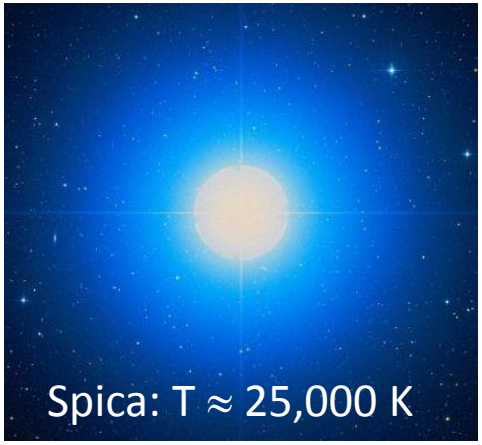
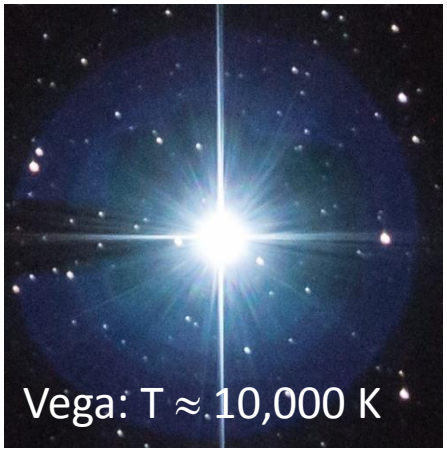
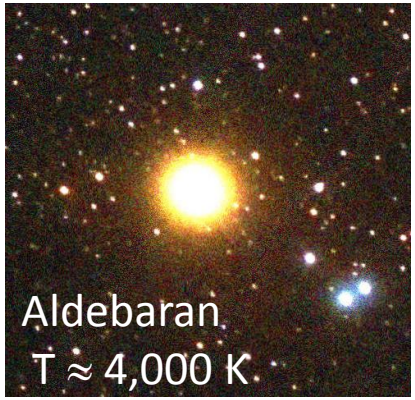


[astronomytrek.com/star-facts-spica]



[Wikipedia: Stephen Rahn]

[Wikipedia: Skatebiker]



[Wikipedia: Giuseppe Donatiello]

Luminosity = Output Power

Stellar luminosity is given by

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$$Intensity = \sigma T^4$$

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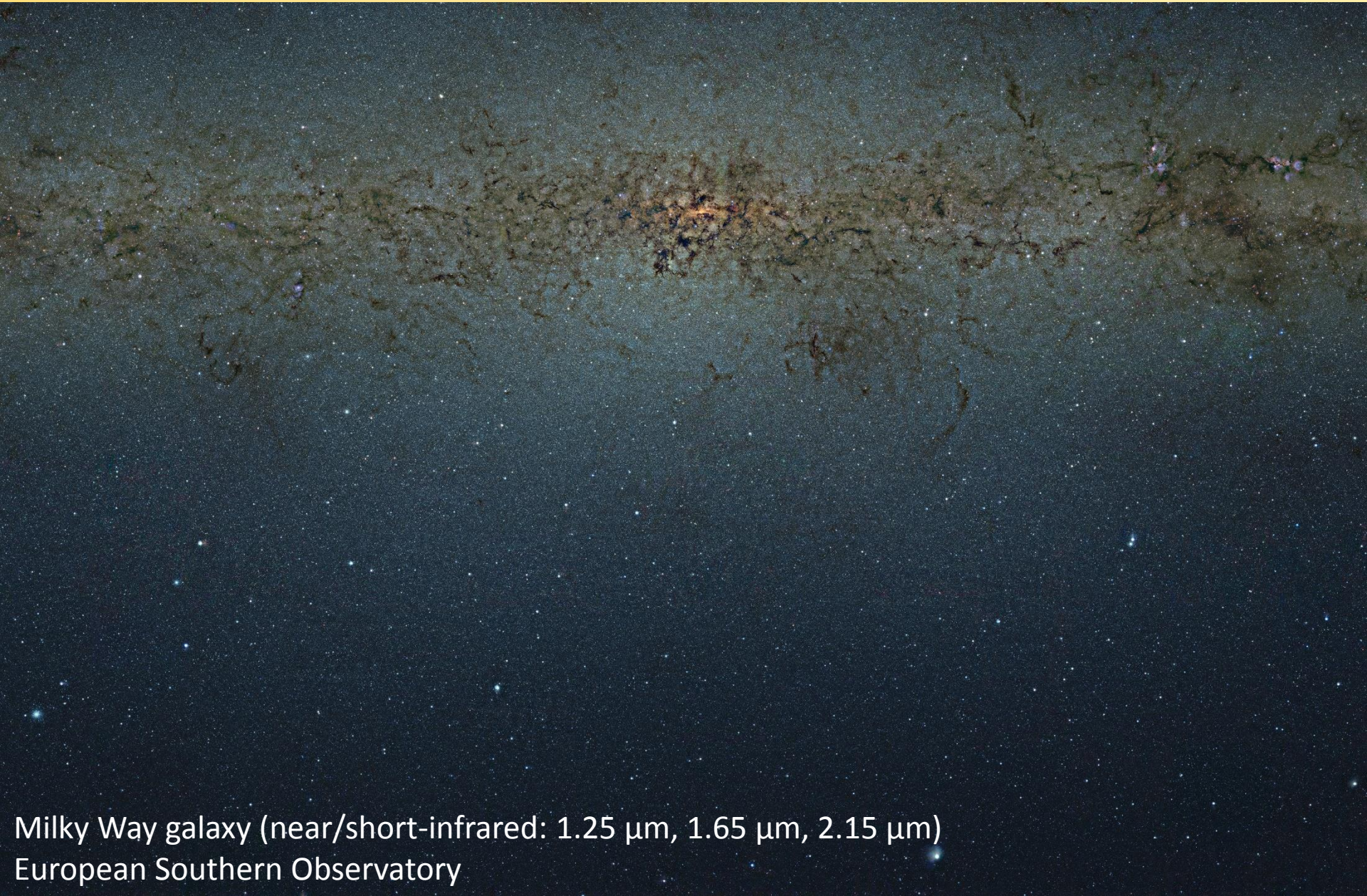
→ A hot star is more luminous

- The surface area of a star is related to its radius, i.e. size:

$$Surface\ Area = 4\pi R^2$$

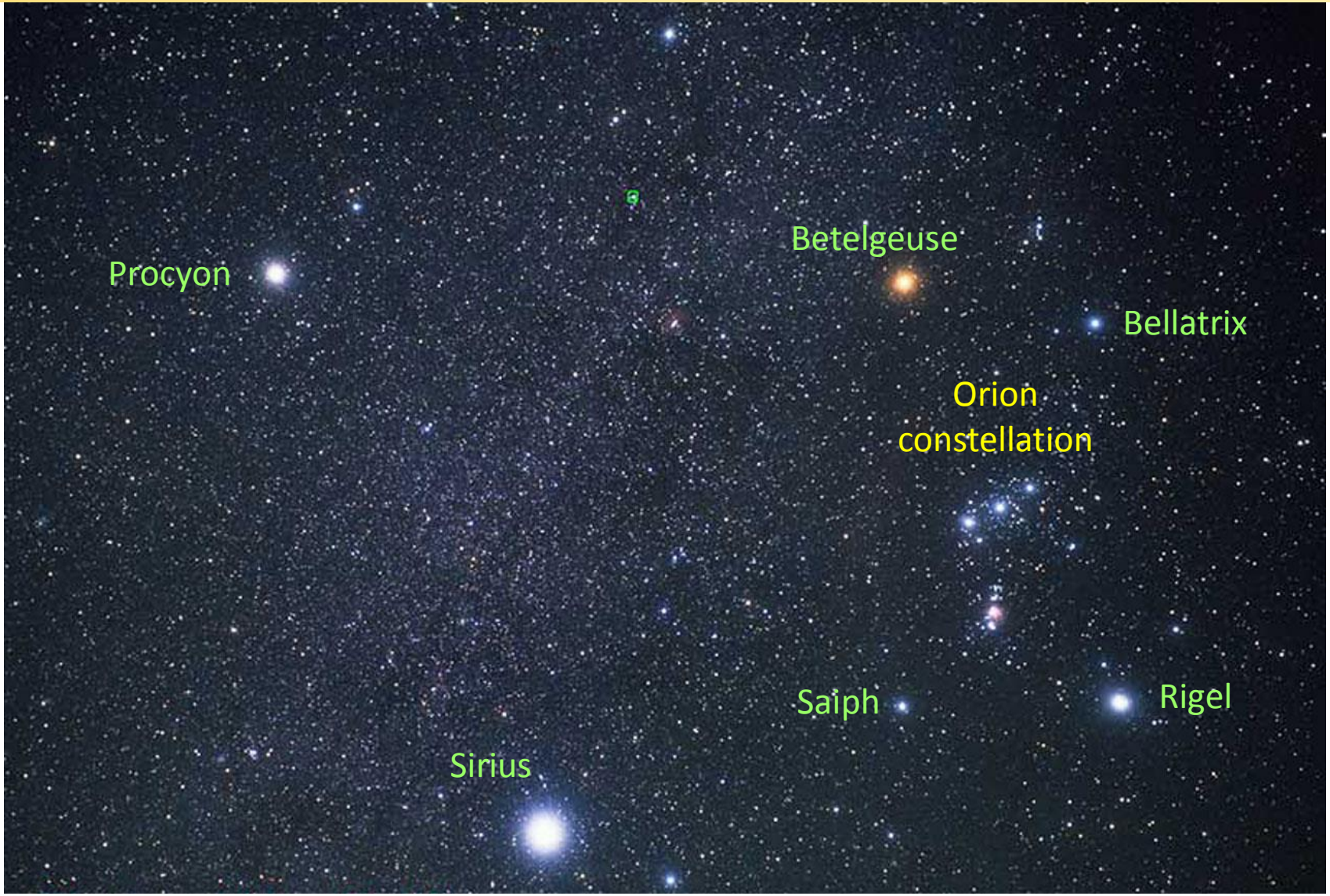
→ A large star is more luminous

Stellar Census → Stellar Statistics



Milky Way galaxy (near/short-infrared: 1.25 μm, 1.65 μm, 2.15 μm)
European Southern Observatory

About Half of “Stars” are Binary/Trinary Stars



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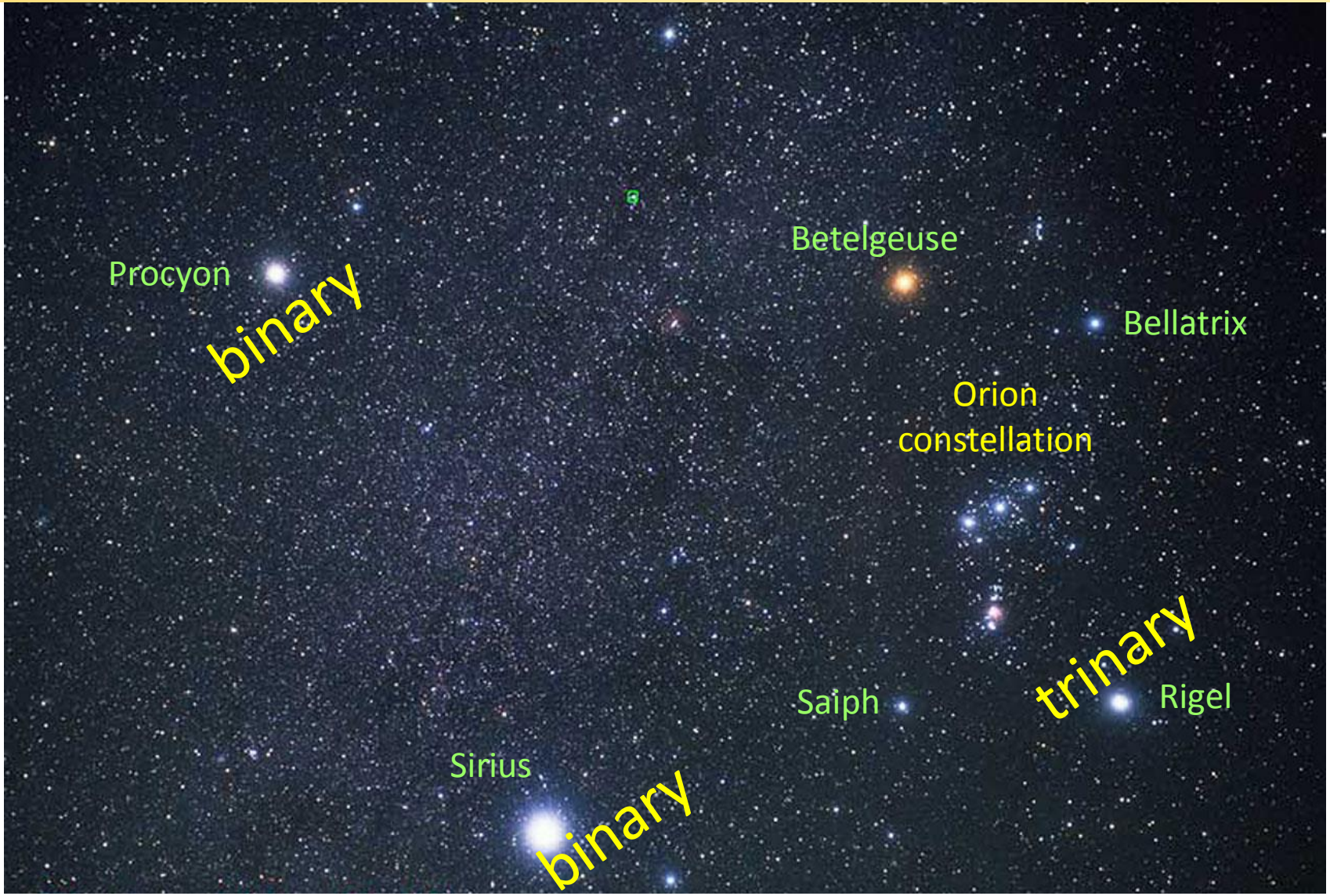

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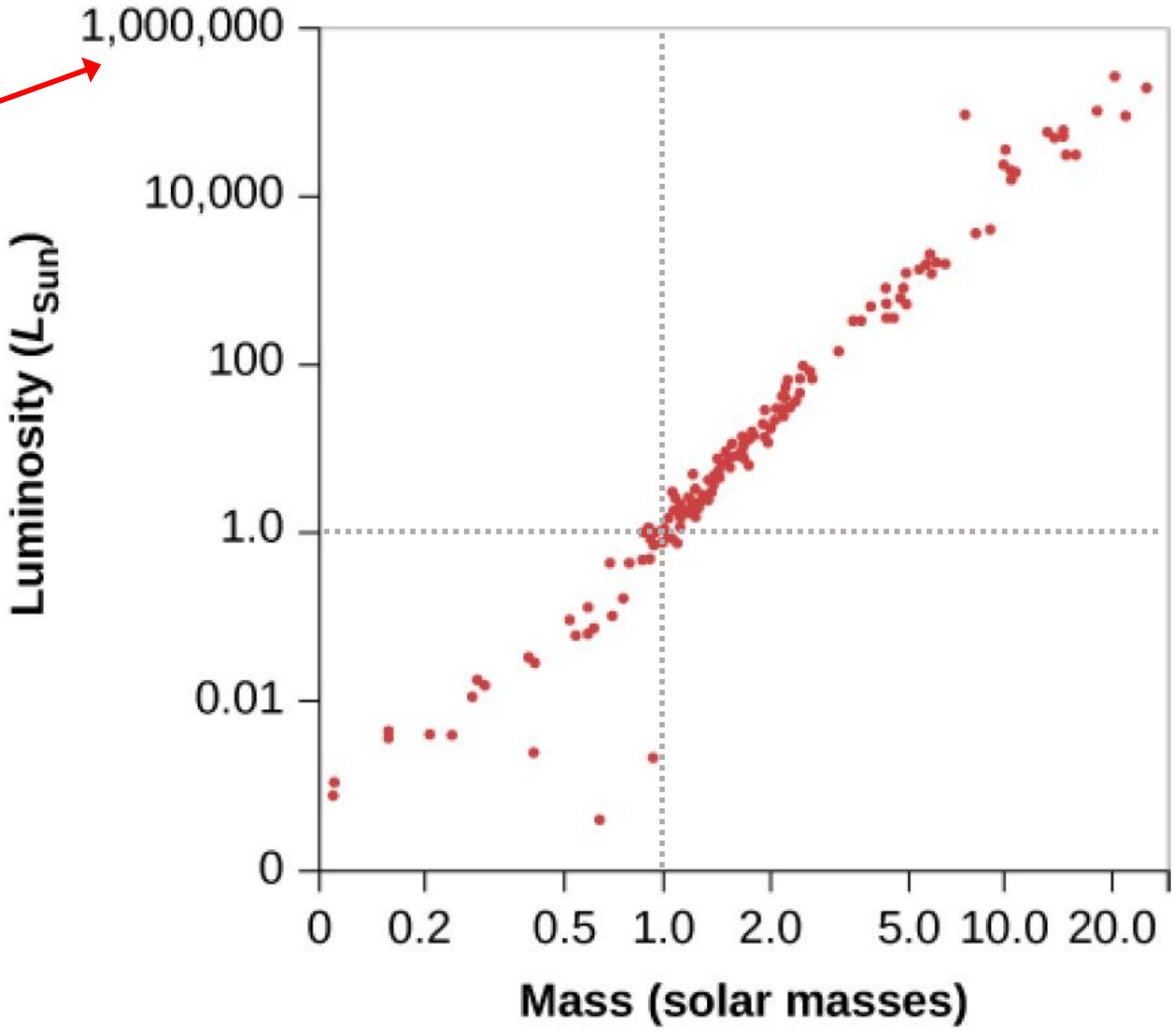
Mass-Luminosity Relation



logarithmic scale

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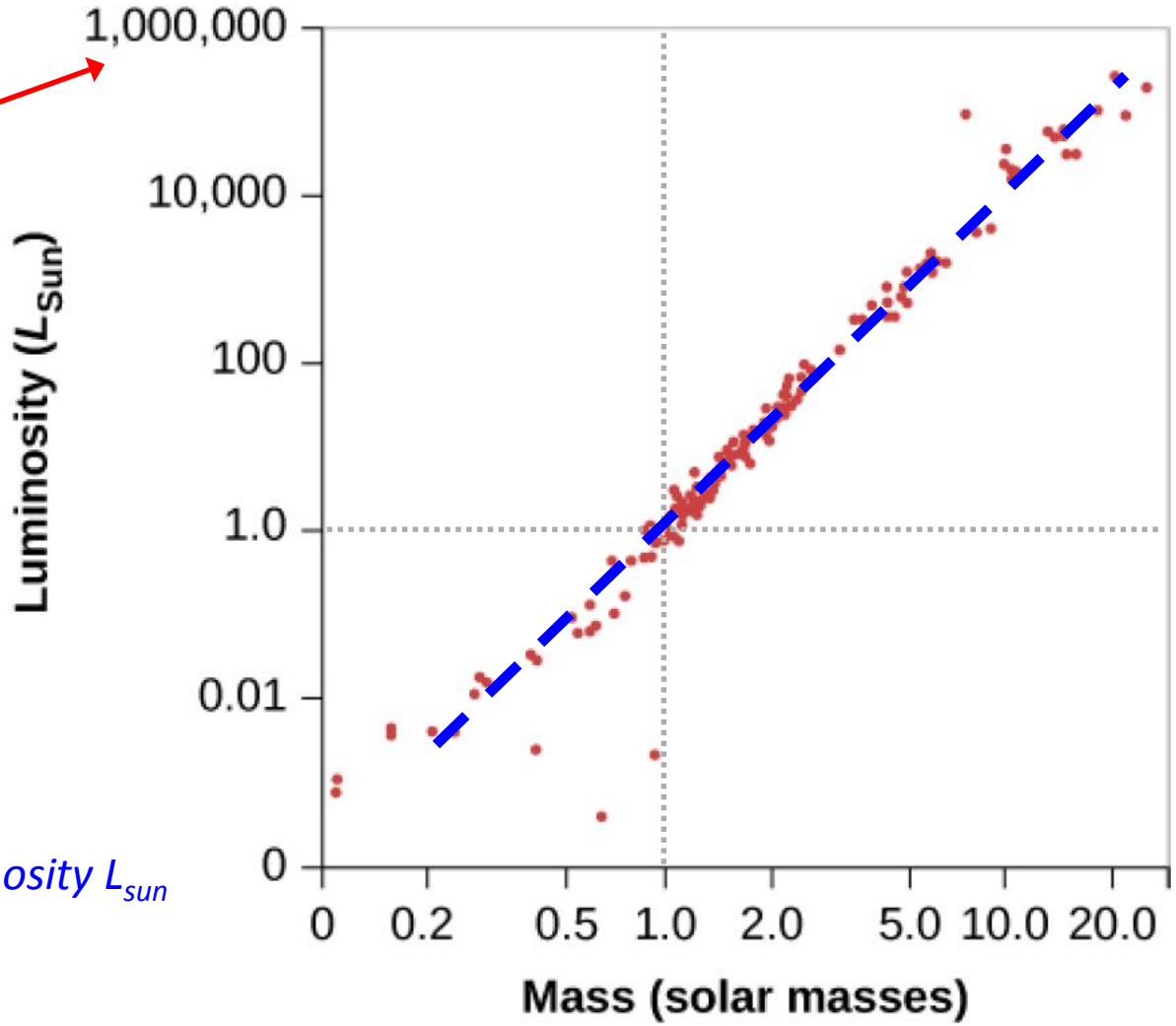


logarithmic scale

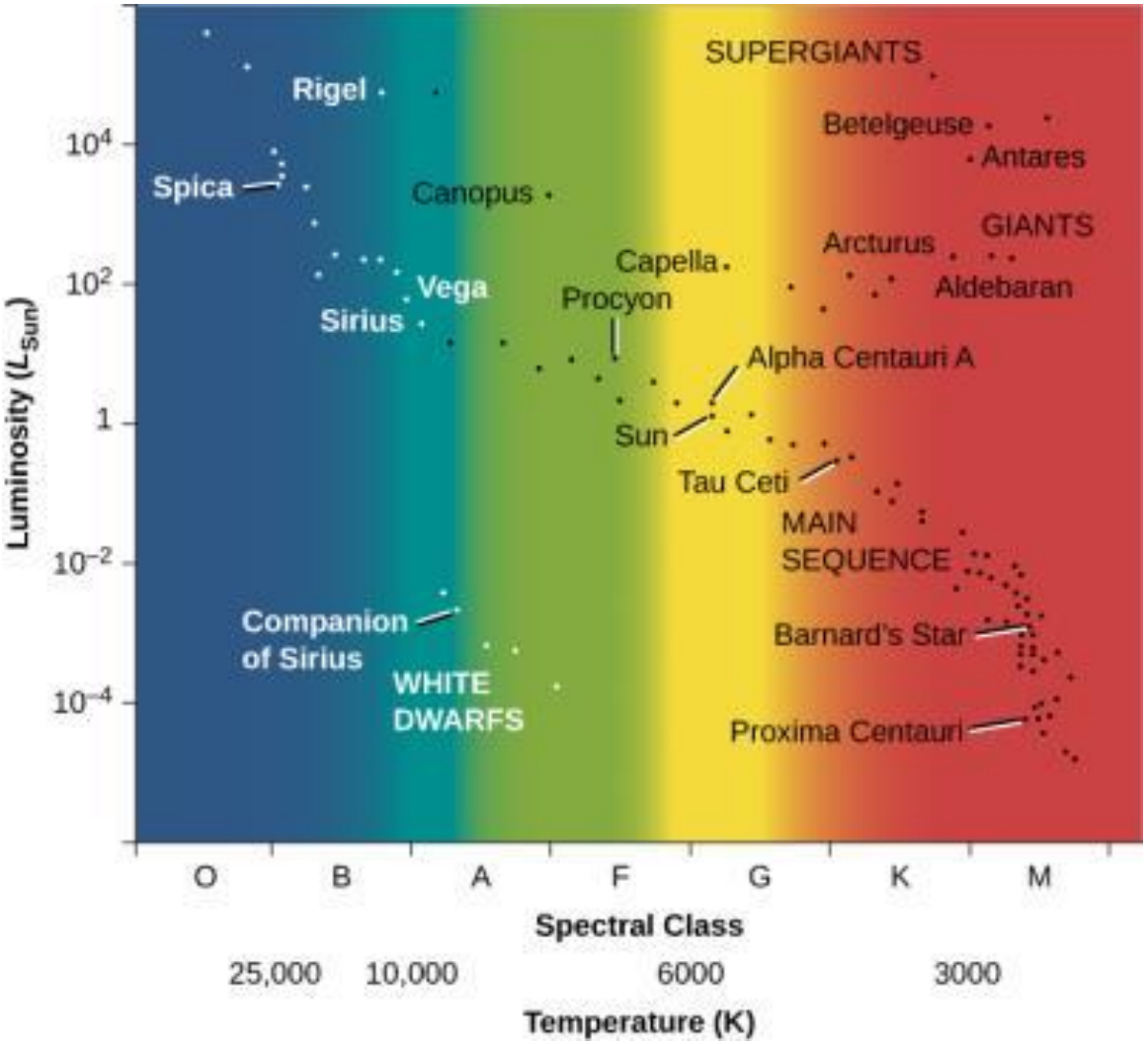
Units:
Solar Luminosity L_{sun}

$$Luminosity \sim Mass^{3.9}$$

Units: Solar Mass M_{sun}

Temperature-Luminosity Relation
H-R diagram

(Hertsprung-Russell diagram)



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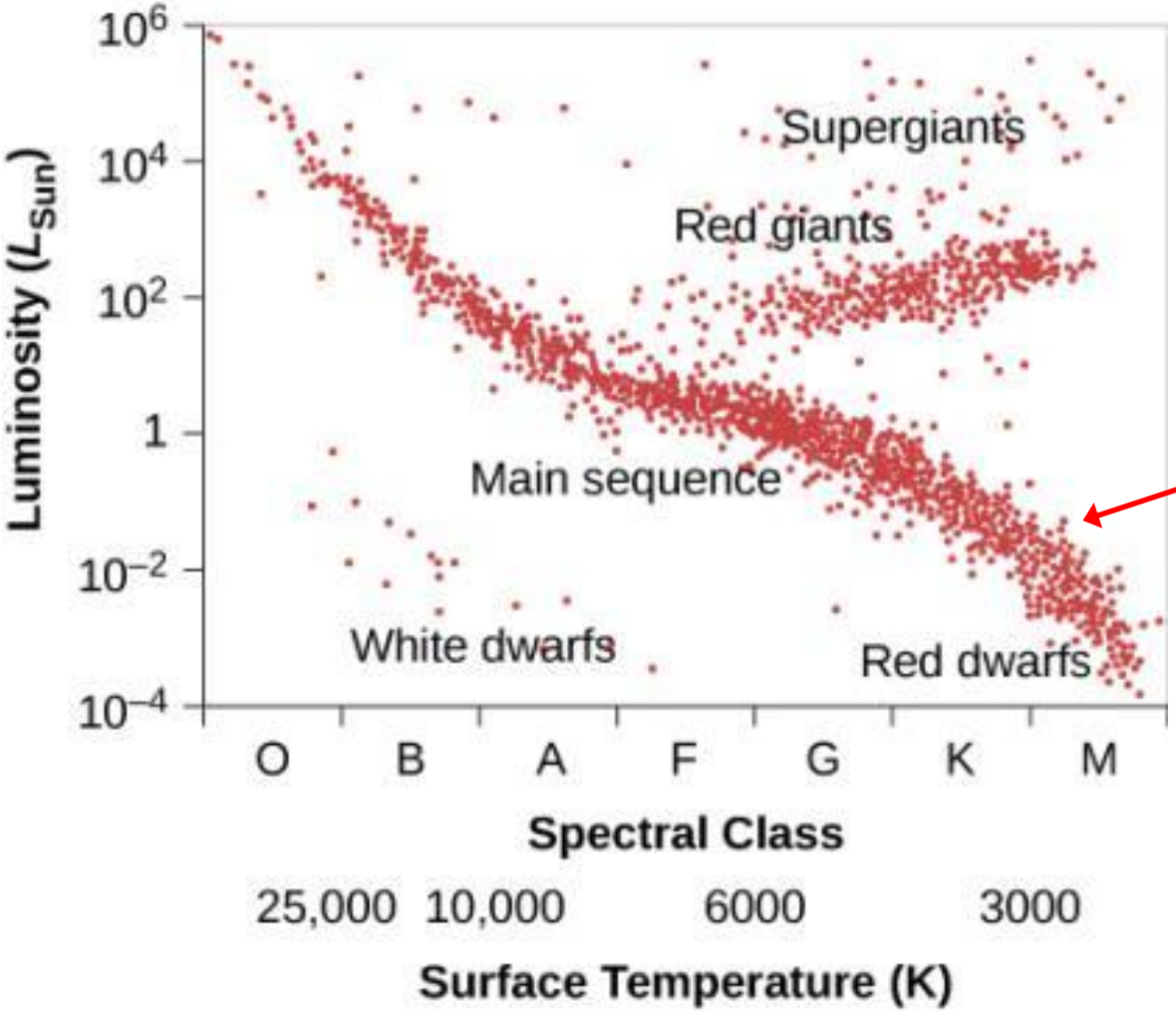
(Hertsprung-Russell diagram)



90% of stars are on "main sequence"