Today's Topics

Wednesday, October 28, 2020 (Week 10, lecture 28) – Chapters 18, 19, 22.

A. Stellar statistics

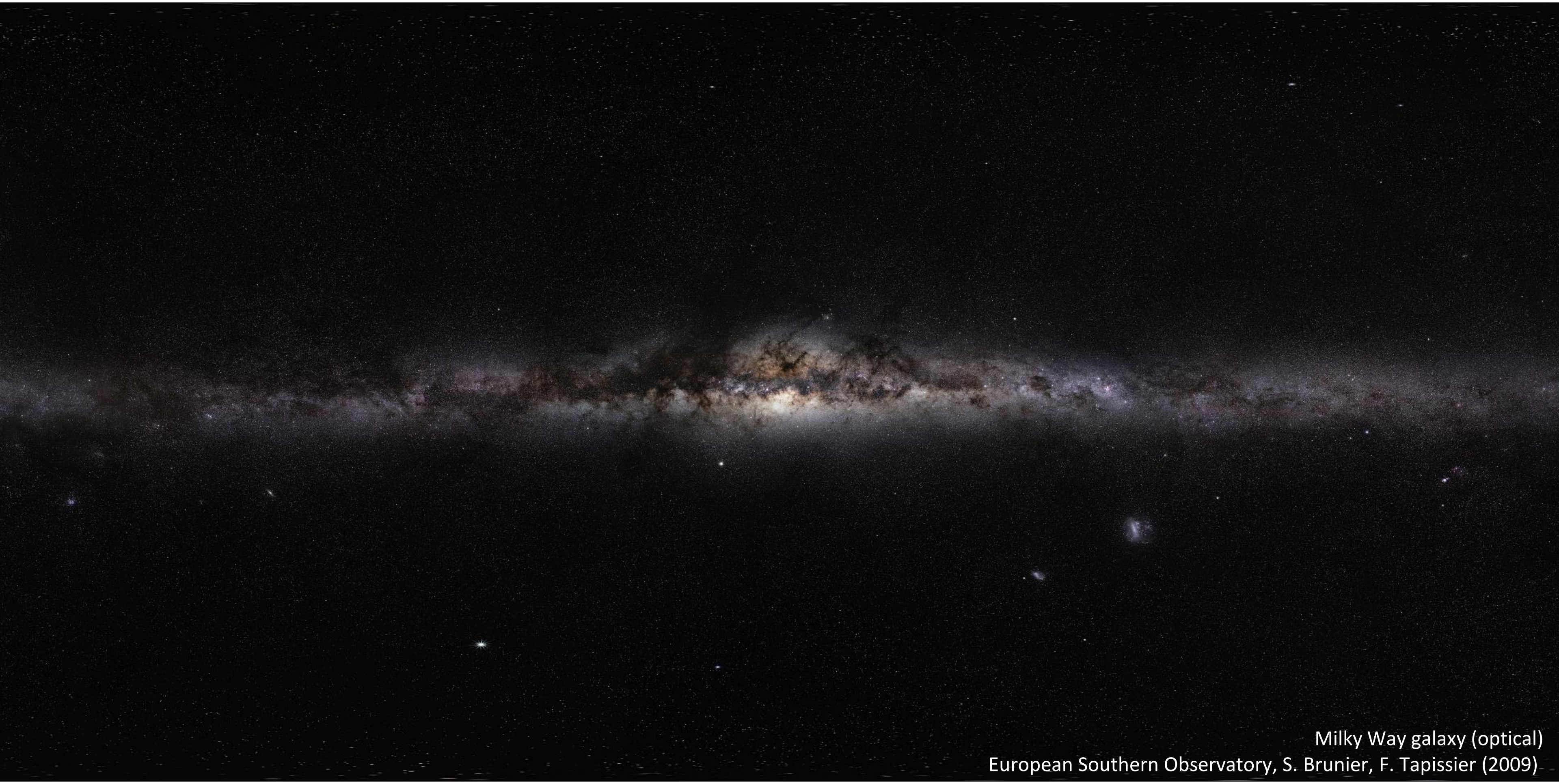
B. Luminosity vs mass

C. H-R diagram.

D. Stellar evolution: *Main sequence to red giants.*

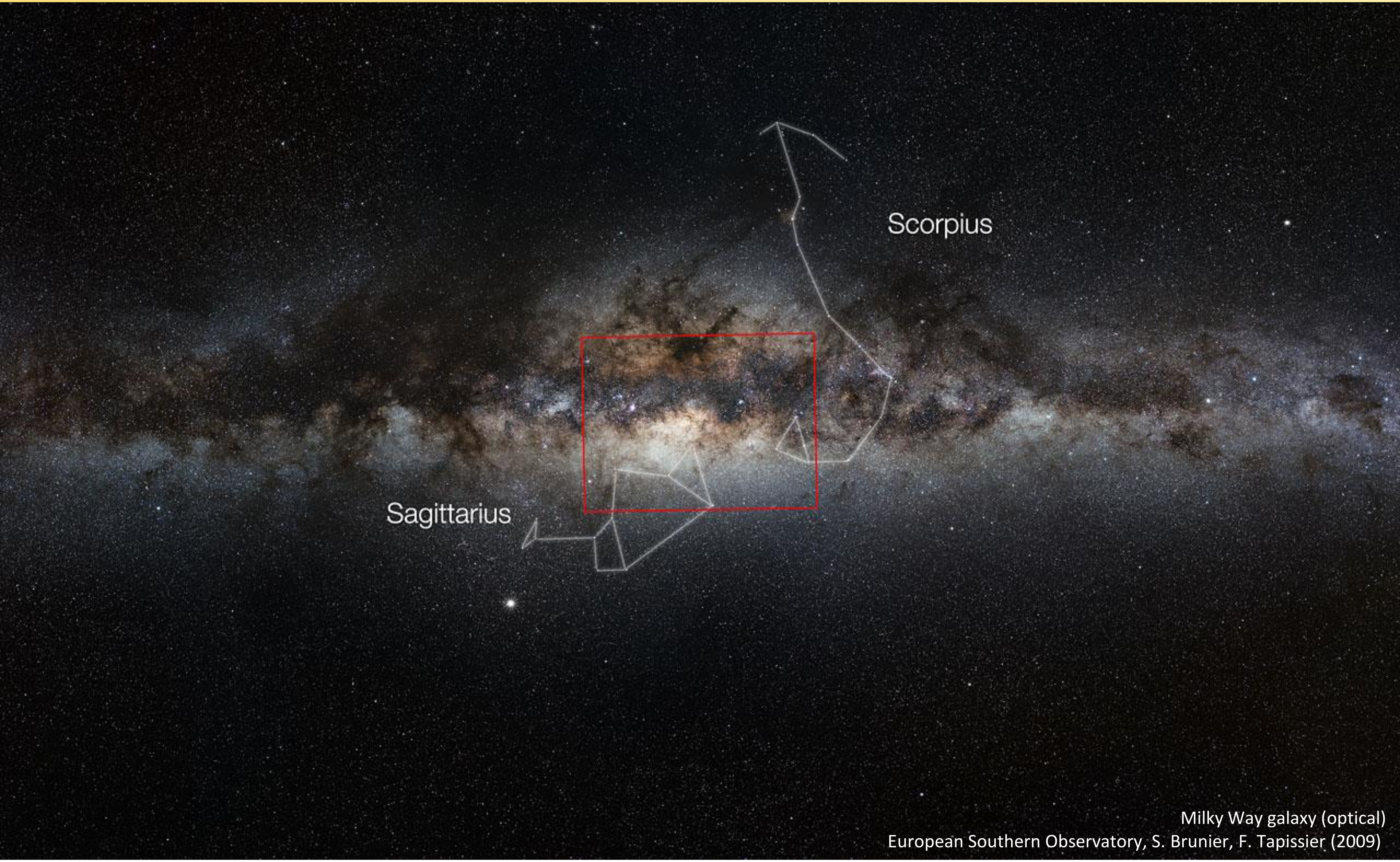
Stellar Census → Stellar Statistics

Our Milky Way galaxy has 100-400 billion stars → a statistical analysis of stars is feasible.


Milky Way galaxy (optical)
European Southern Observatory, S. Brunier, F. Tapissier (2009)

Milky Way galaxy: 360° view.

Stellar Census → Stellar Statistics

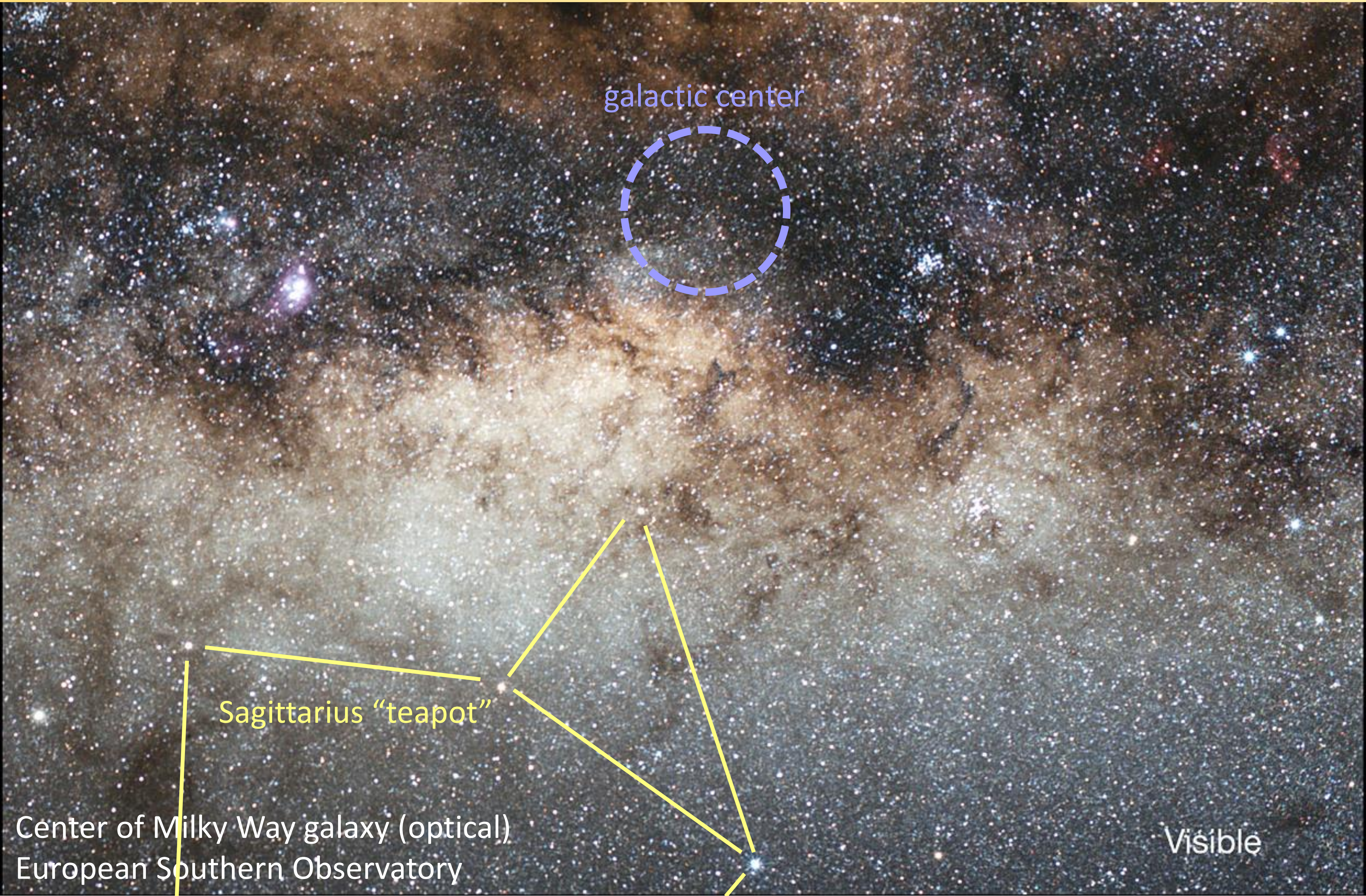


Milky Way galaxy (optical)
European Southern Observatory, S. Brunier, F. Tapissier (2009)

Stellar Census → Stellar Statistics

Center of Milky Way galaxy (optical)
European Southern Observatory

Stellar Census → Stellar Statistics

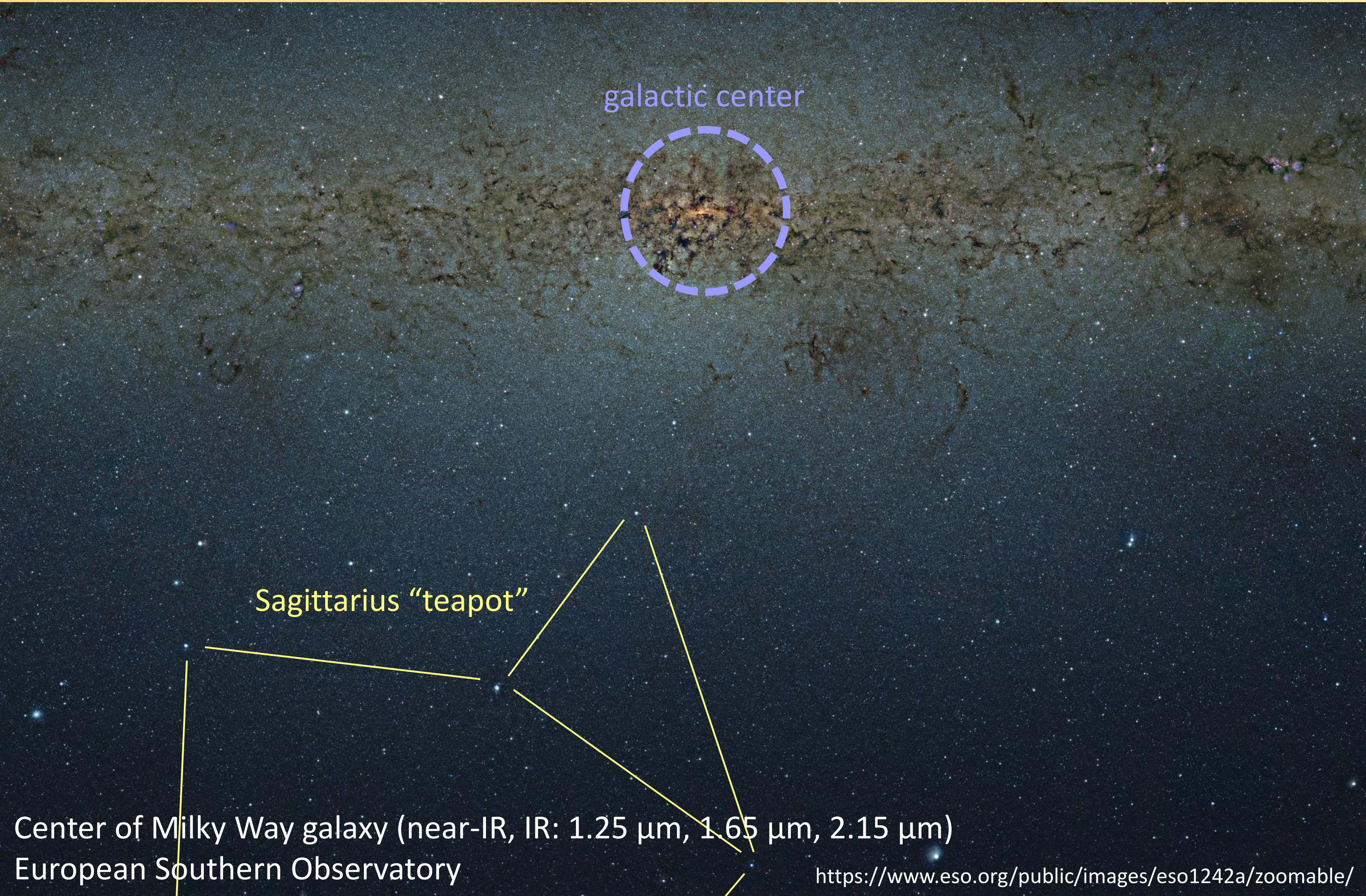


Stellar Census → Stellar Statistics

Center of Milky Way galaxy (near-IR, IR: 1.25 µm, 1.65 µm, 2.15 µm)
European Southern Observatory

https://www.eso.org/public/images/eso1242a/zoomable/

Stellar Census → Stellar Statistics



Center of Milky Way galaxy (near-IR, IR: 1.25 µm, 1.65 µm, 2.15 µm)
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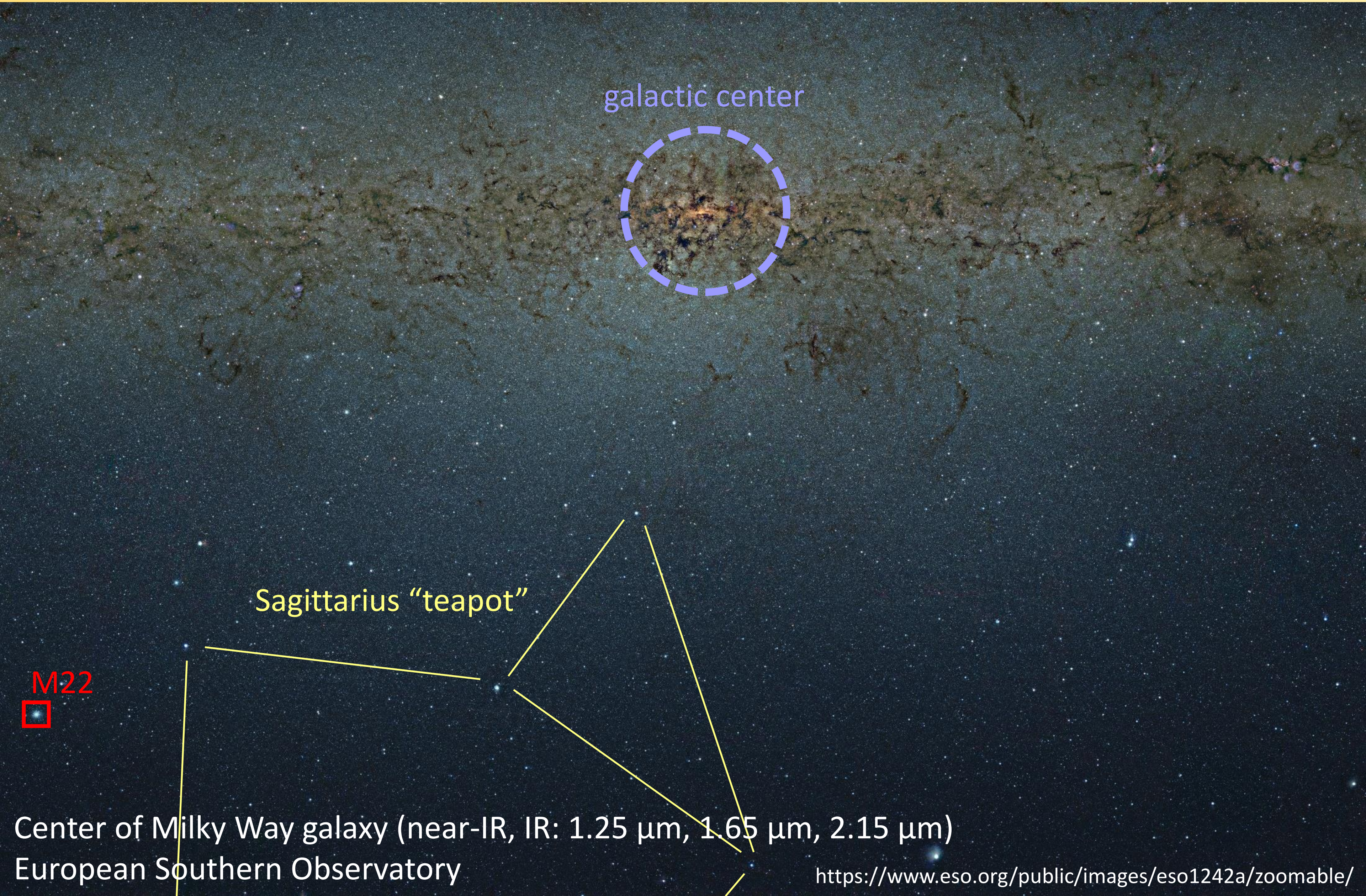
Stellar Census → Stellar Statistics



Center of Milky Way galaxy (near-IR, IR: 1.25 µm, 1.65 µm, 2.15 µm)
European Southern Observatory

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Stellar Census → Stellar Statistics

[Zoom-in of previous photo, (near/short-infrared)]

https://www.eso.org/public/images/eso1242a/zoomable/

M22 globular cluster, Milky Way galaxy

Stellar Census → Stellar Statistics

M22 globular cluster, Milky Way galaxy

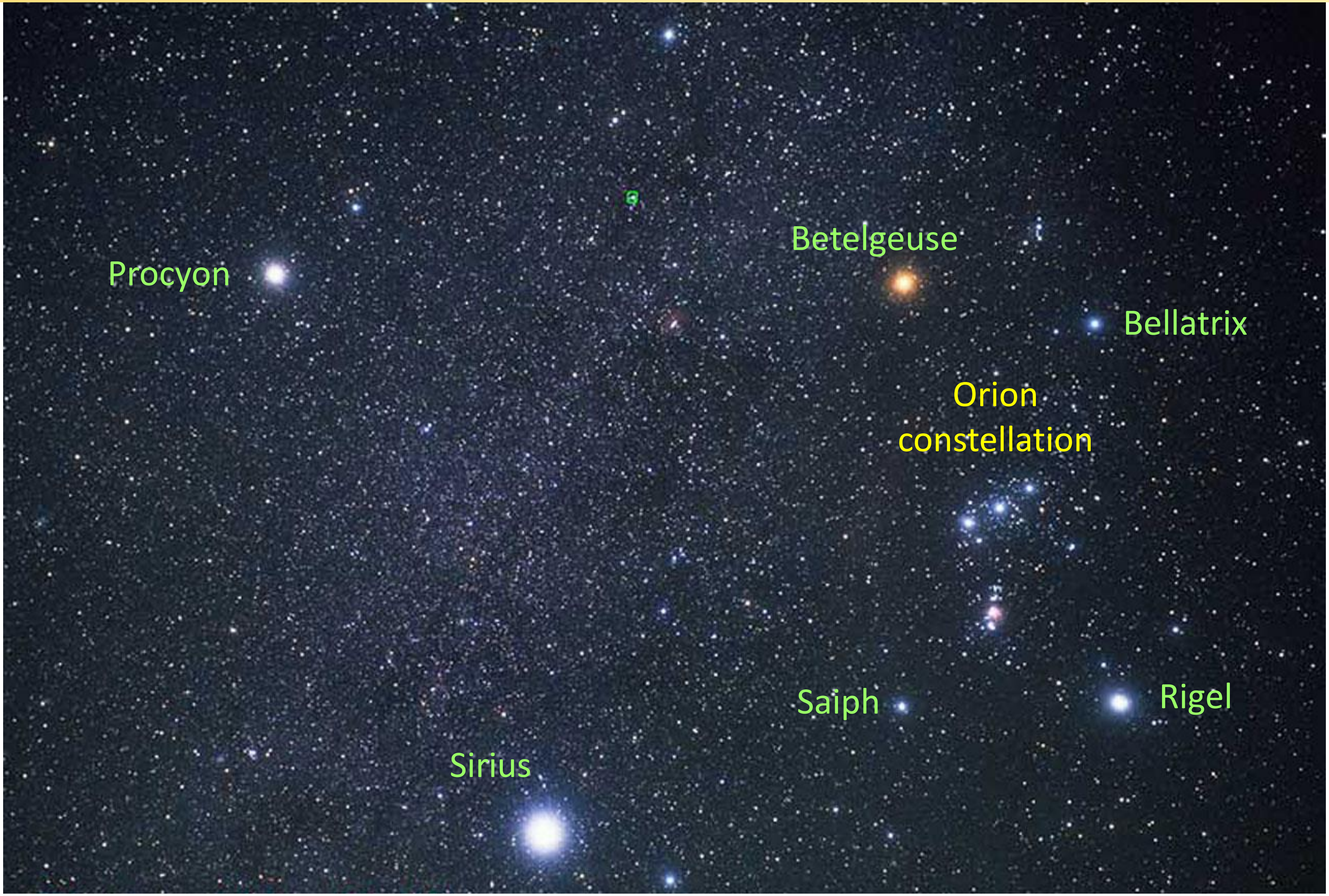
Mass-Luminosity Relation

- Luminosity can be determined by the brightness of star (as seen from Earth) and its distance.

  → *Reminder: distance can be measured by* ***parallax.***

- How do you determine the mass of a star?

About Half of "Stars" are Binary/Trinary 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

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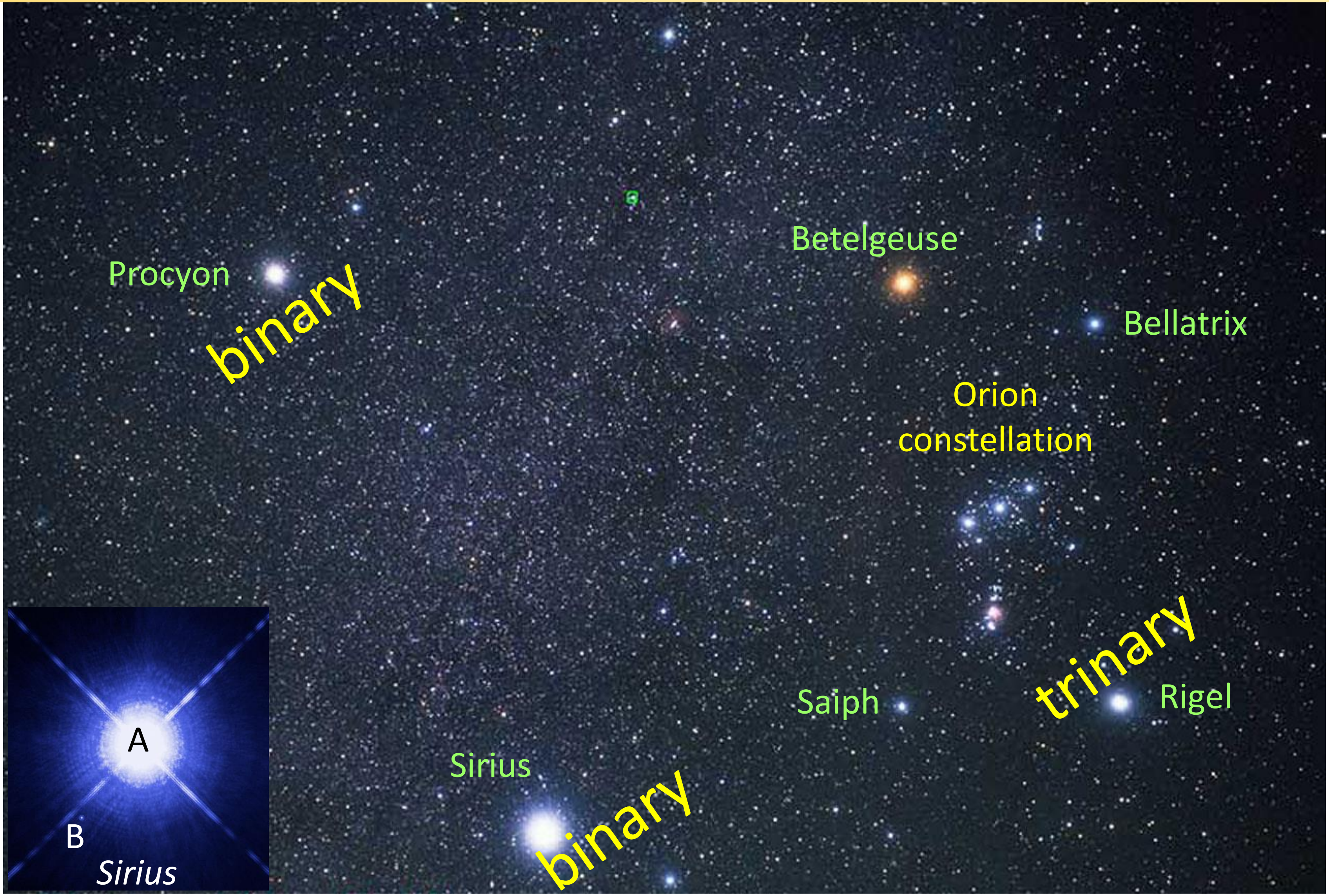


[By NASA, ESA, H. Bond (STScI), and M. Barstow (University of Leicester)]

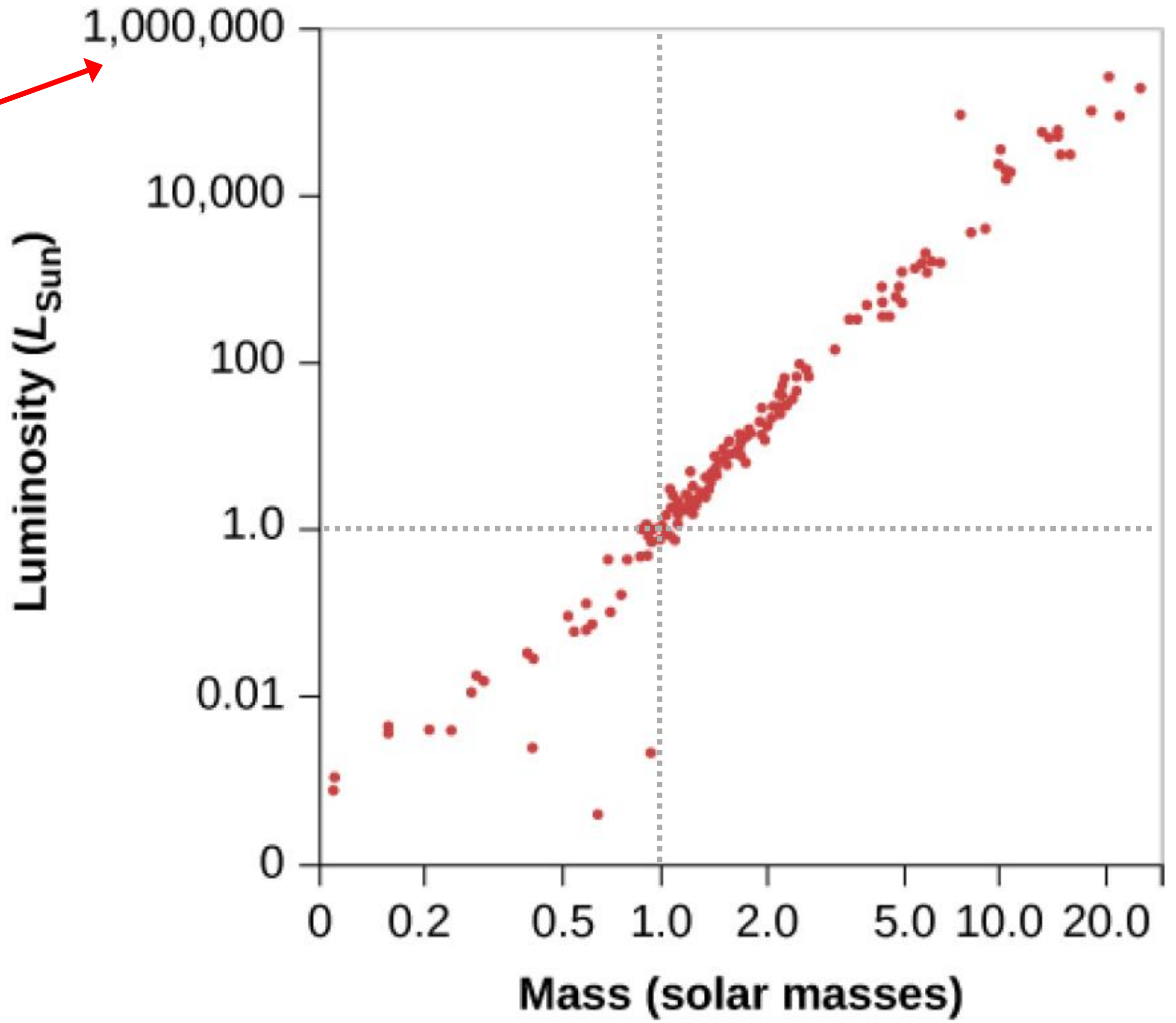
By Hubble European Space AgencyCredit: Akira Fujii - http://www.spacetelescope.org/images/heic0206j/ (watermark was cropped), Public Domain, https://commons.wikimedia.org/w/index.php?curid=5246351

How to Determine Stellar Mass ?

- Use binary star systems.
- Use Kepler's 3rd law (Newton's version) to determine M1 + M2.
- Use observation of center-of-mass of to obtain M1/M2.
  (or use Doppler velocimetry)

Mass-Luminosity Relation

logarithmic scale

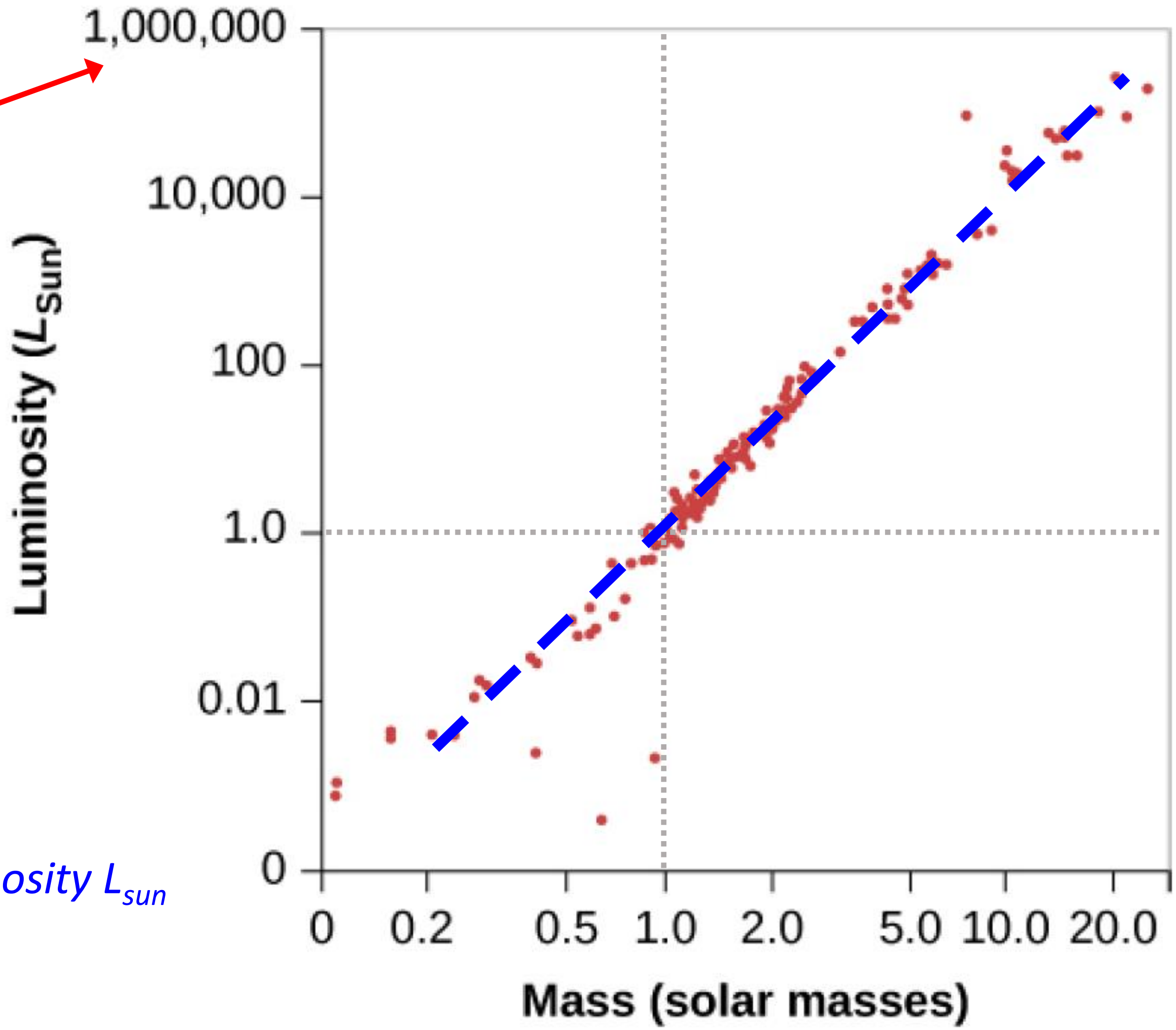


Main sequence stars (not white dwarfs or re giants)

logarithmic scale

Mass-Luminosity Relation

logarithmic scale



Main sequence stars (not white dwarfs or re giants)

logarithmic scale

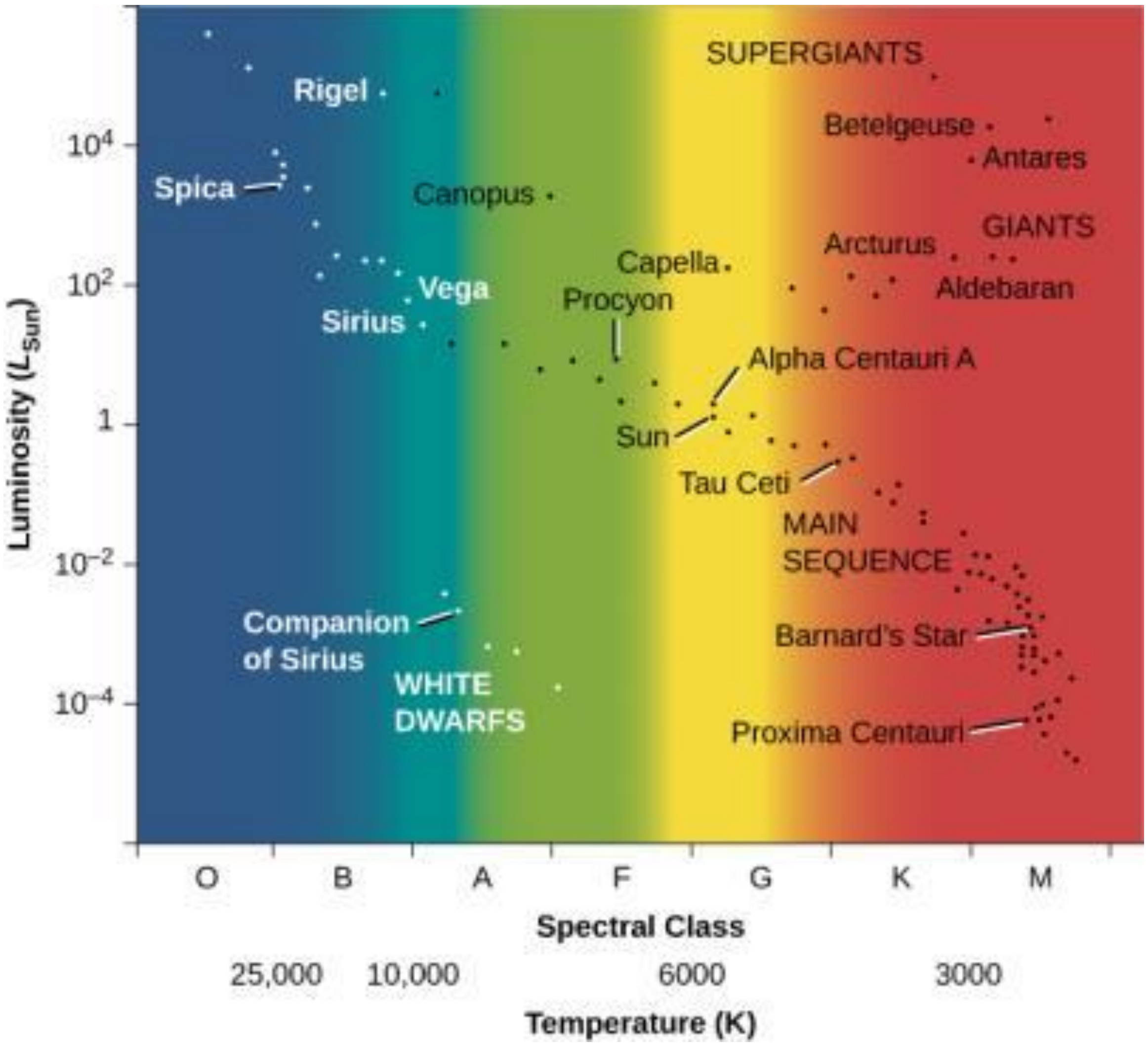
Units: Solar Luminosity L_{sun}

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

Units: Solar Mass M_{sun}

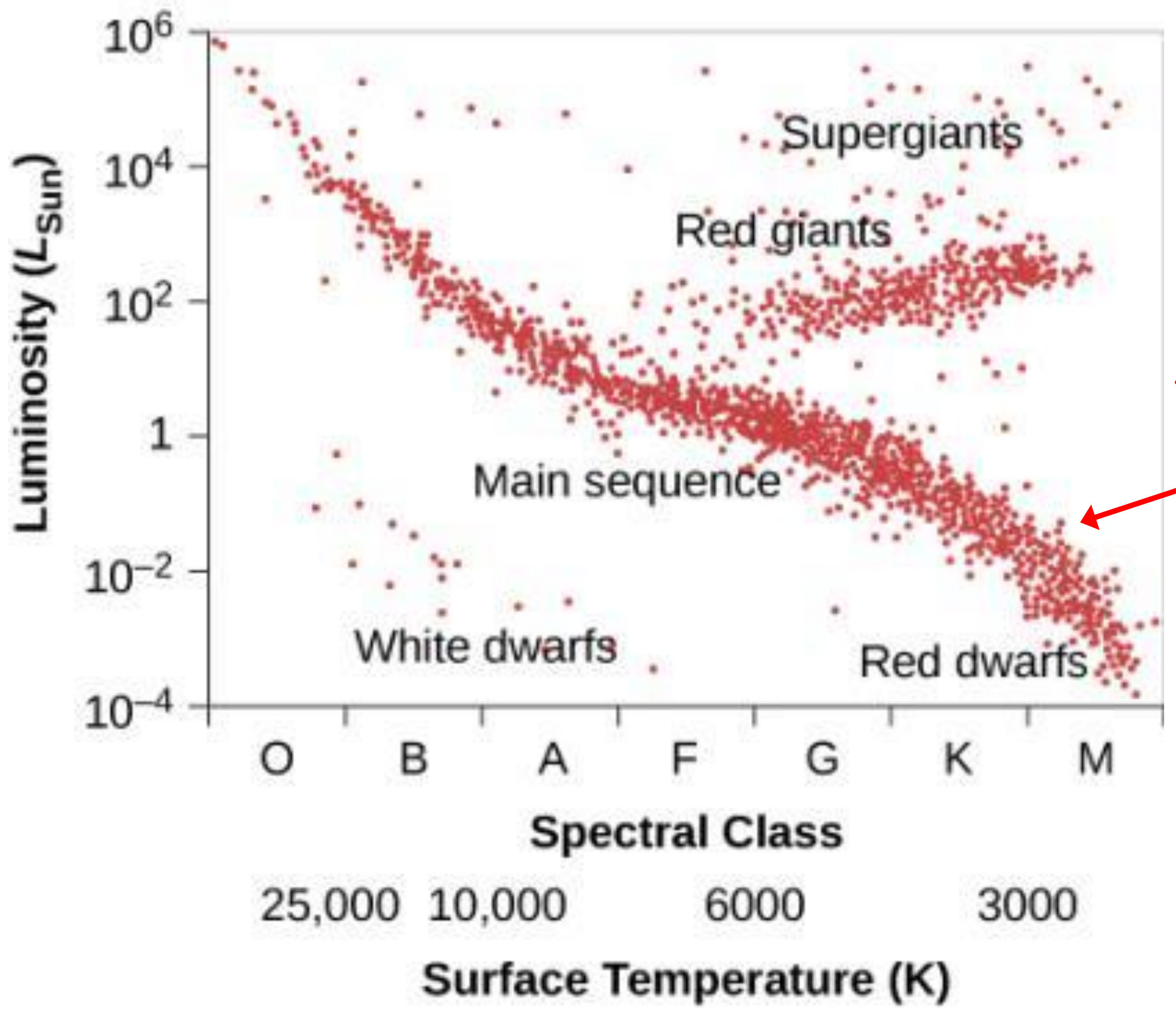
Temperature-Luminosity Relation
H-R diagram

(Hertsprung-Russell diagram)



Temperature-Luminosity Relation
H-R diagram

(Hertsprung-Russell diagram)



90% of stars are on "main sequence"

Temperature-Luminosity Relation
H-R diagram

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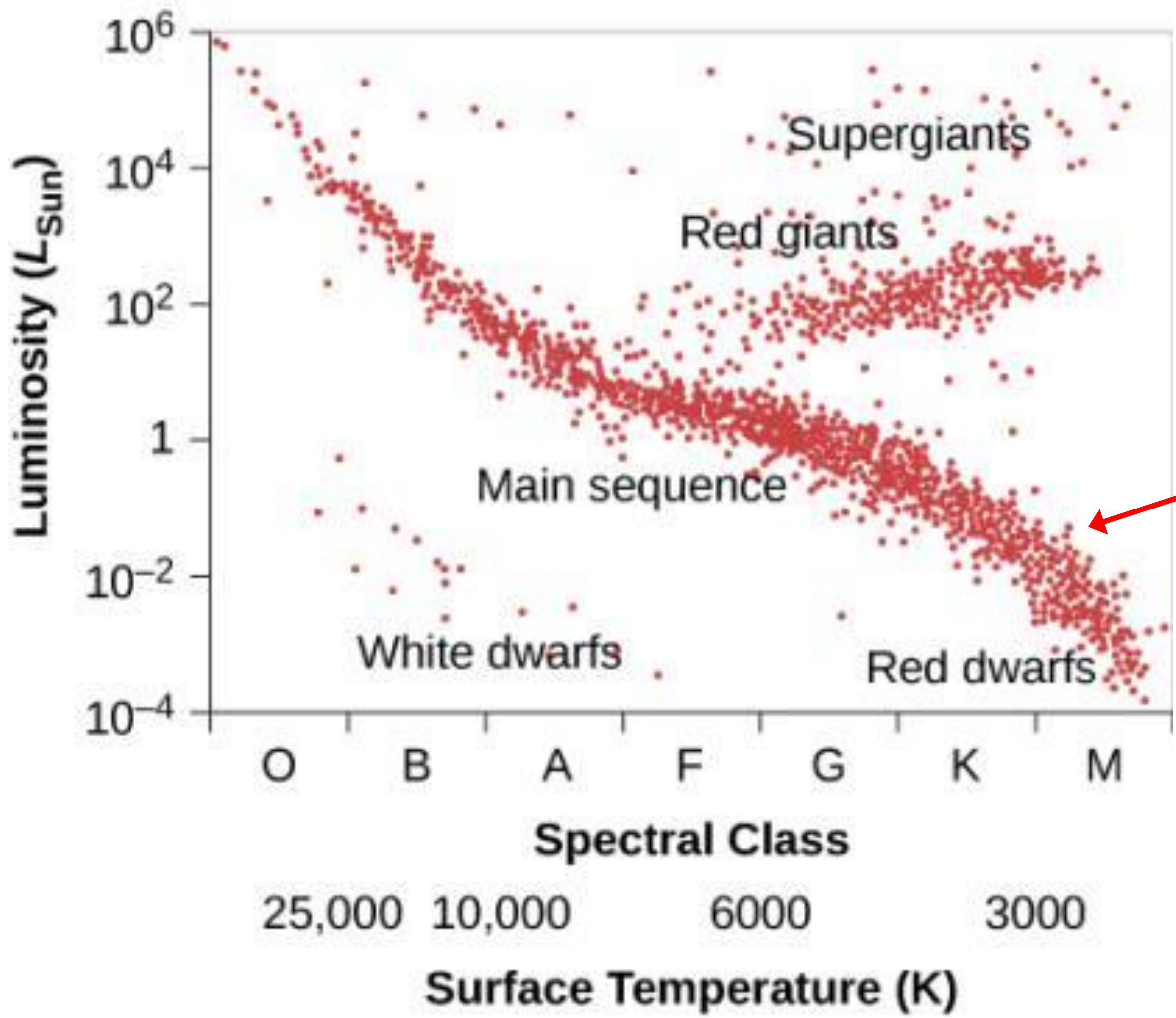
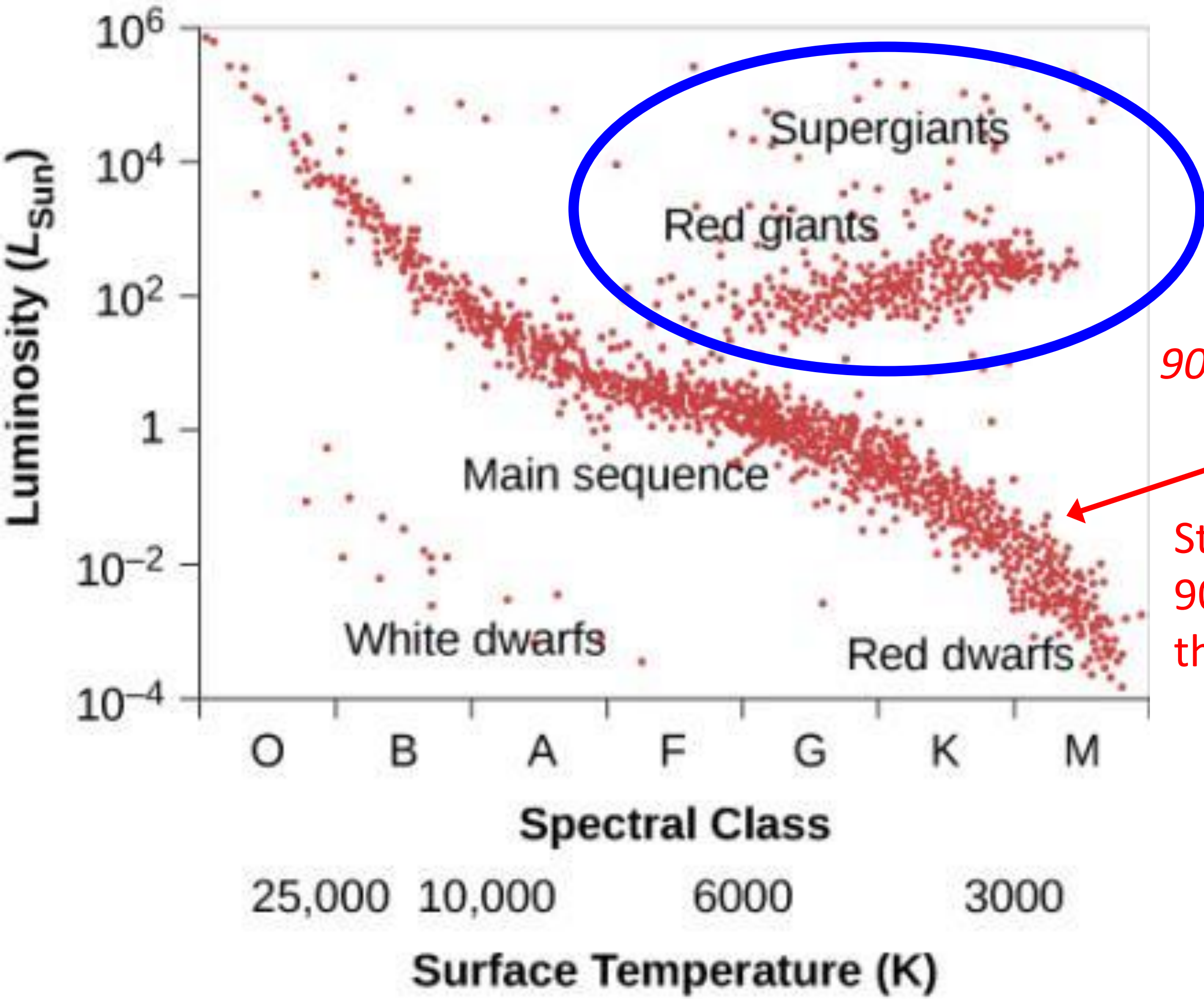


90% of stars are on "main sequence"

Stars spend about 90% of their "life" on the main sequence.

Temperature-Luminosity Relation
H-R diagram

(Hertsprung-Russell diagram)



These stars are in their end stage of "star life."

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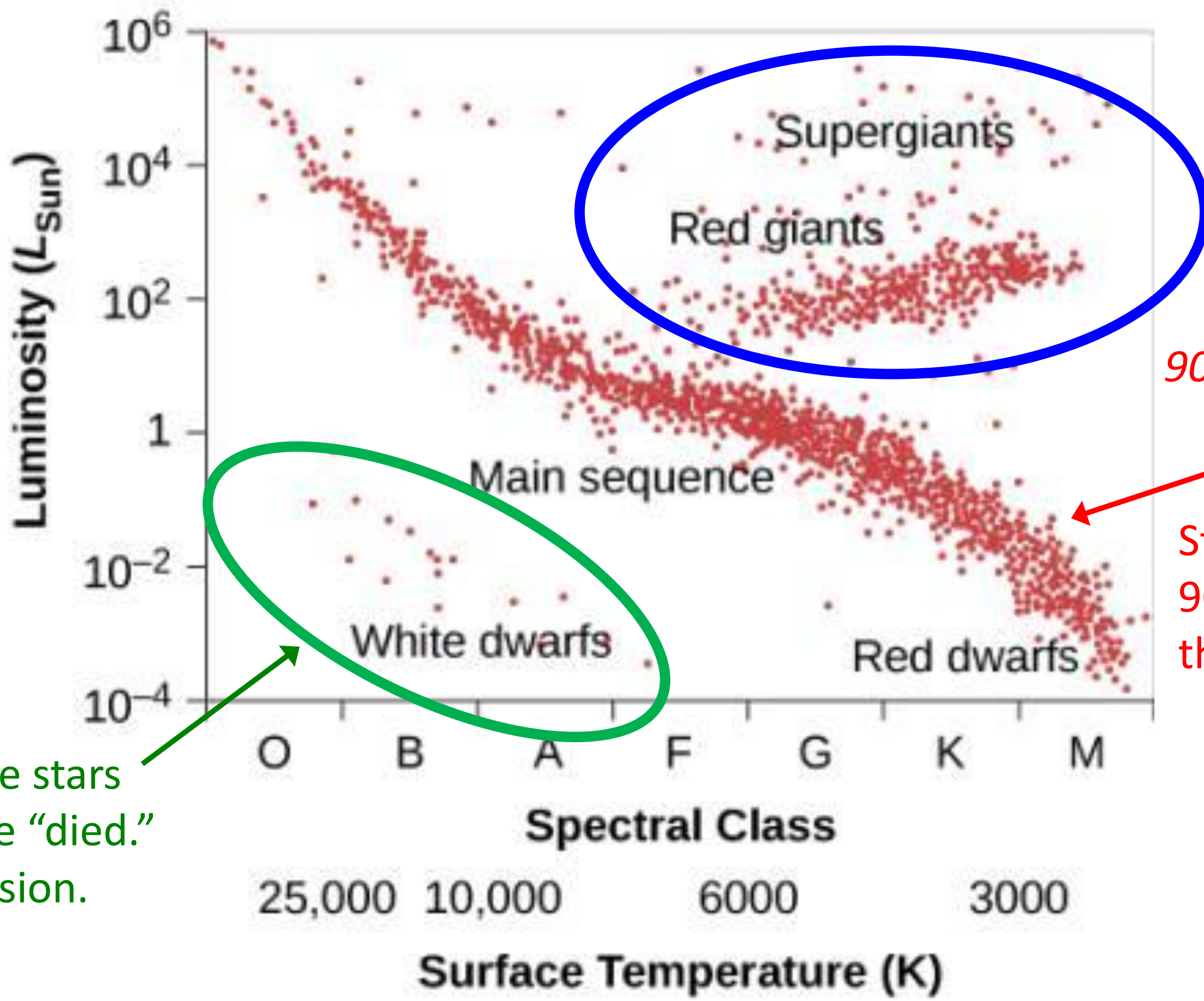
Temperature-Luminosity Relation
H-R diagram

(Hertsprung-Russell diagram)



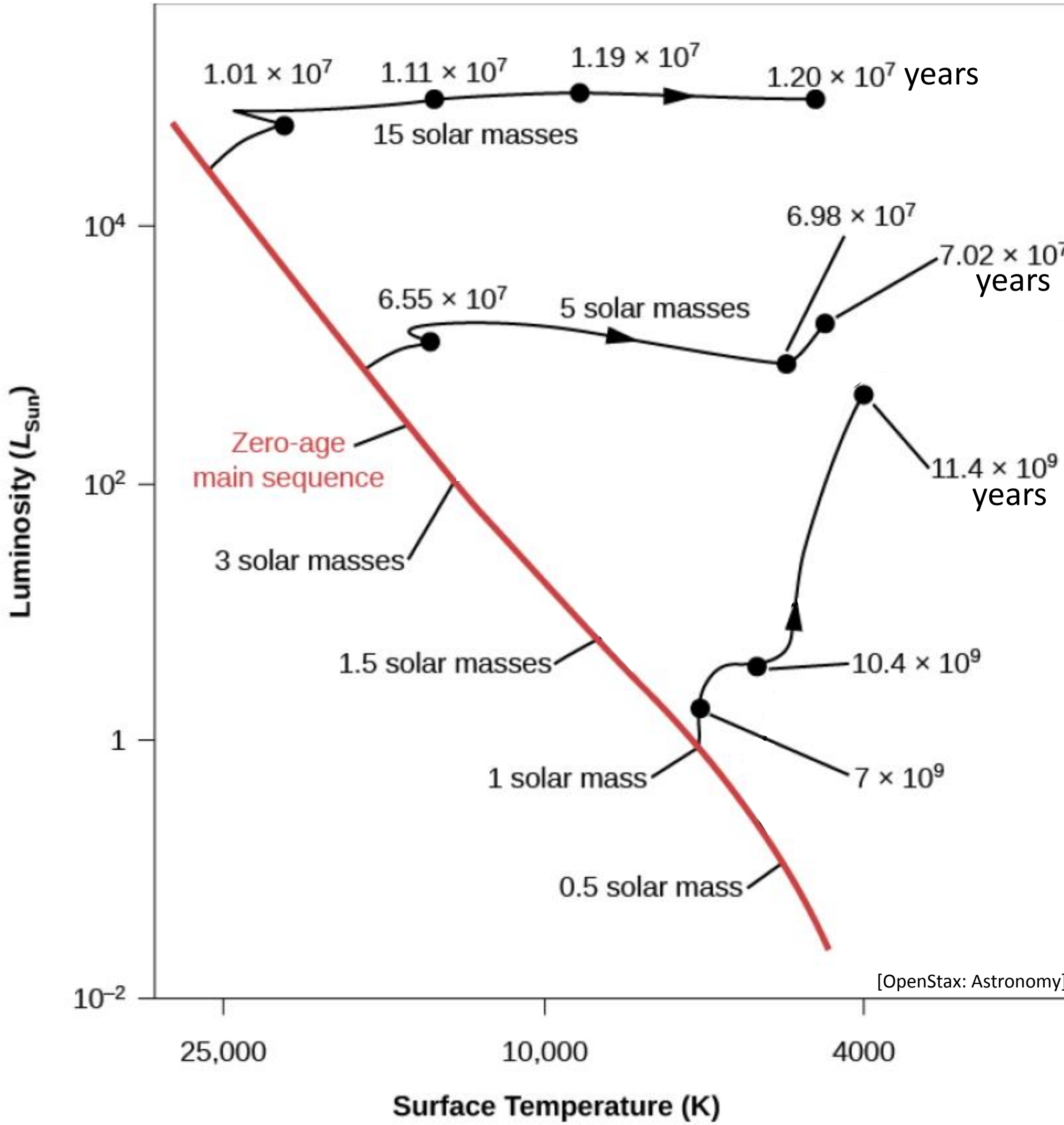
These stars are in their end stage of "star life."

90% of stars are on "main sequence"

Stars spend about 90% of their "life" on the main sequence.

These are stars that have "died." → No fusion.

Stellar Evolution: on the H-R Diagram



Stellar Evolution: on the H-R Diagram

Heavy stars

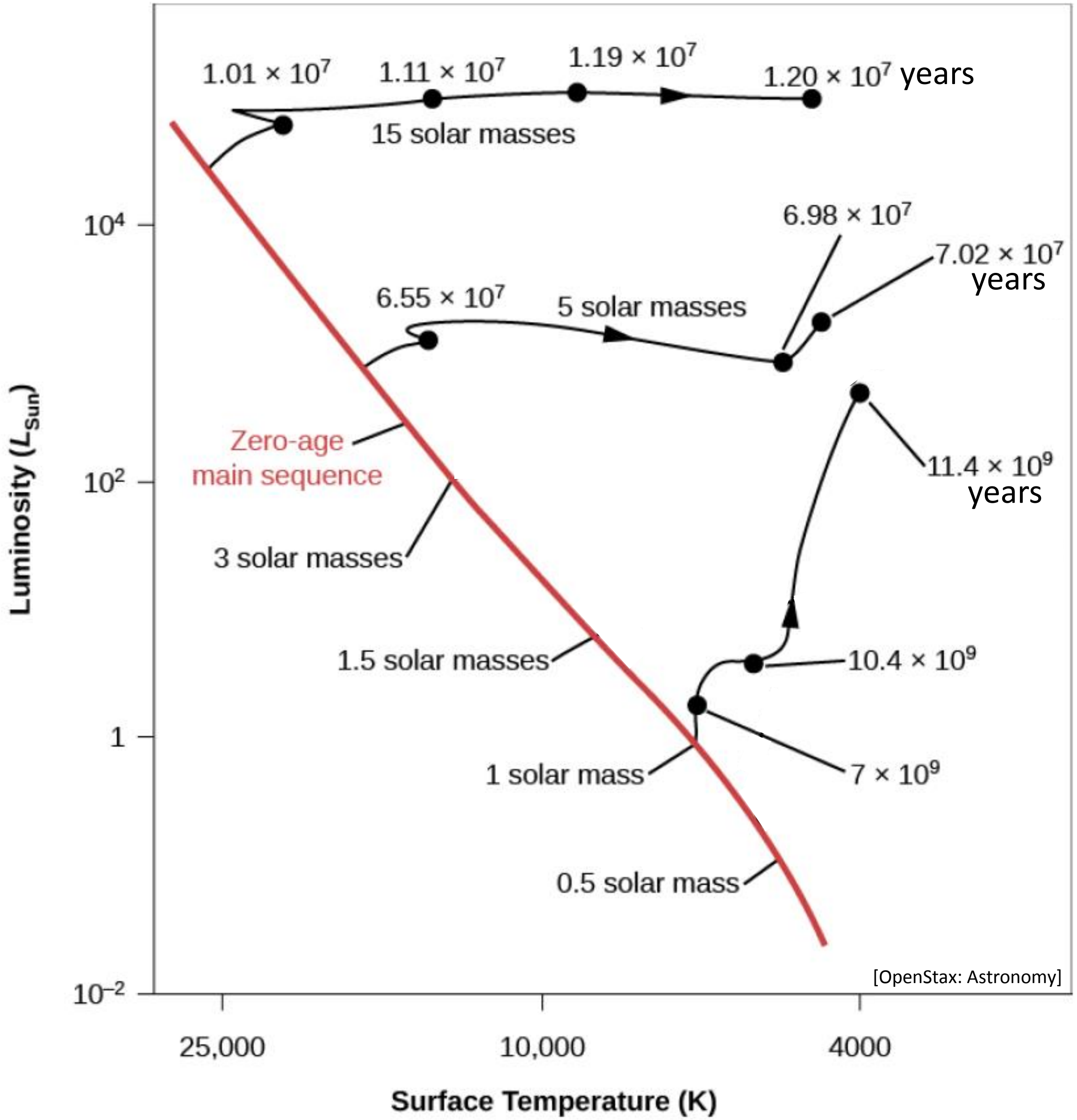
- Blue-ish color.
- Hot and very luminous
- Very short lived.

  → < 1-10 million years

Light stars (sun-like & smaller

- Yellow and red color.
- cooler and dimmer.
- Long lived.

  → > 10 billion years.



[OpenStax: Astronomy]

Stellar Evolution Summary Table

Spectral Type	Mass (Sun=1)	Radius (Sun=1)	Luminosity (Sun=1)	Temperature	Lifetime (yrs) on main seq.
G0	1.1	1.1	1.4	6,000 K	9 billion

Table based on data in Tables 18.3 & 22.1 (OpenStax: Astronomy)

Stellar Evolution Summary Table

Spectral Type	Mass (Sun=1)	Radius (Sun=1)	Luminosity (Sun=1)	Temperature	Lifetime (yrs) on main seq.
F0	1.7	1.4	5	7,500 K	2.7 billion
G0	1.1	1.1	1.4	6,000 K	9 billion
K0	0.8	0.8	0.35	5,000 K	14 billion

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Stellar Evolution Summary Table

Spectral Type	Mass (Sun=1)	Radius (Sun=1)	Luminosity (Sun=1)	Temperature	Lifetime (yrs) on main seq.
A0	3.3	2.5	55	10,000 K	0.5 billion
F0	1.7	1.4	5	7,500 K	2.7 billion
G0	1.1	1.1	1.4	6,000 K	9 billion
K0	0.8	0.8	0.35	5,000 K	14 billion
M0	0.4	0.6	0.05	3,500 K	200 billion

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Stellar Evolution Summary Table

Spectral Type	Mass (Sun=1)	Radius (Sun=1)	Luminosity (Sun=1)	Temperature	Lifetime (yrs) on main seq.
O5	40	18	700,000	40,000 K	0.001 billion (1 million)
B0	16	7	270,000	28,000 K	0.01 billion (10 million)
A0	3.3	2.5	55	10,000 K	0.5 billion
F0	1.7	1.4	5	7,500 K	2.7 billion
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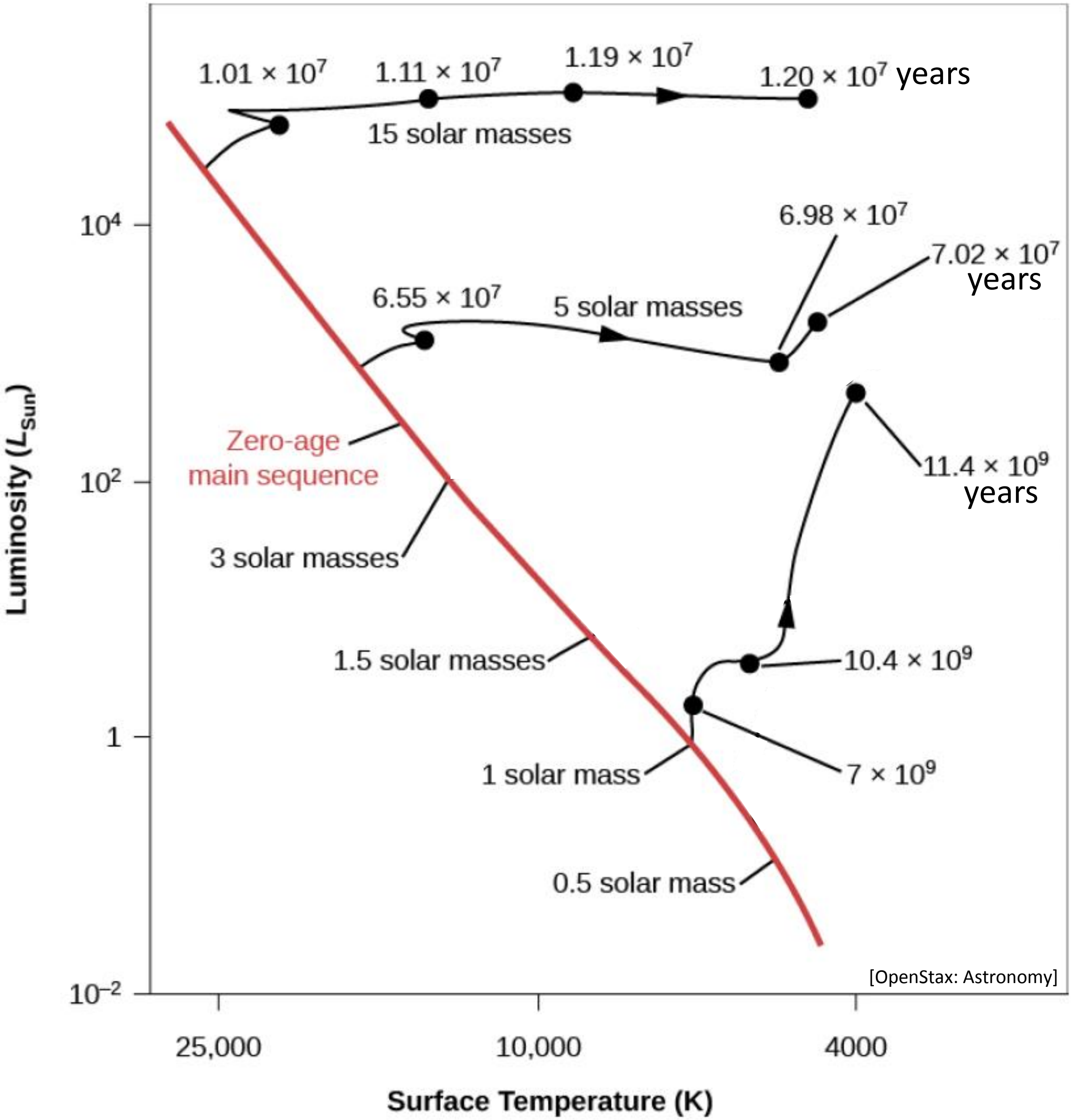

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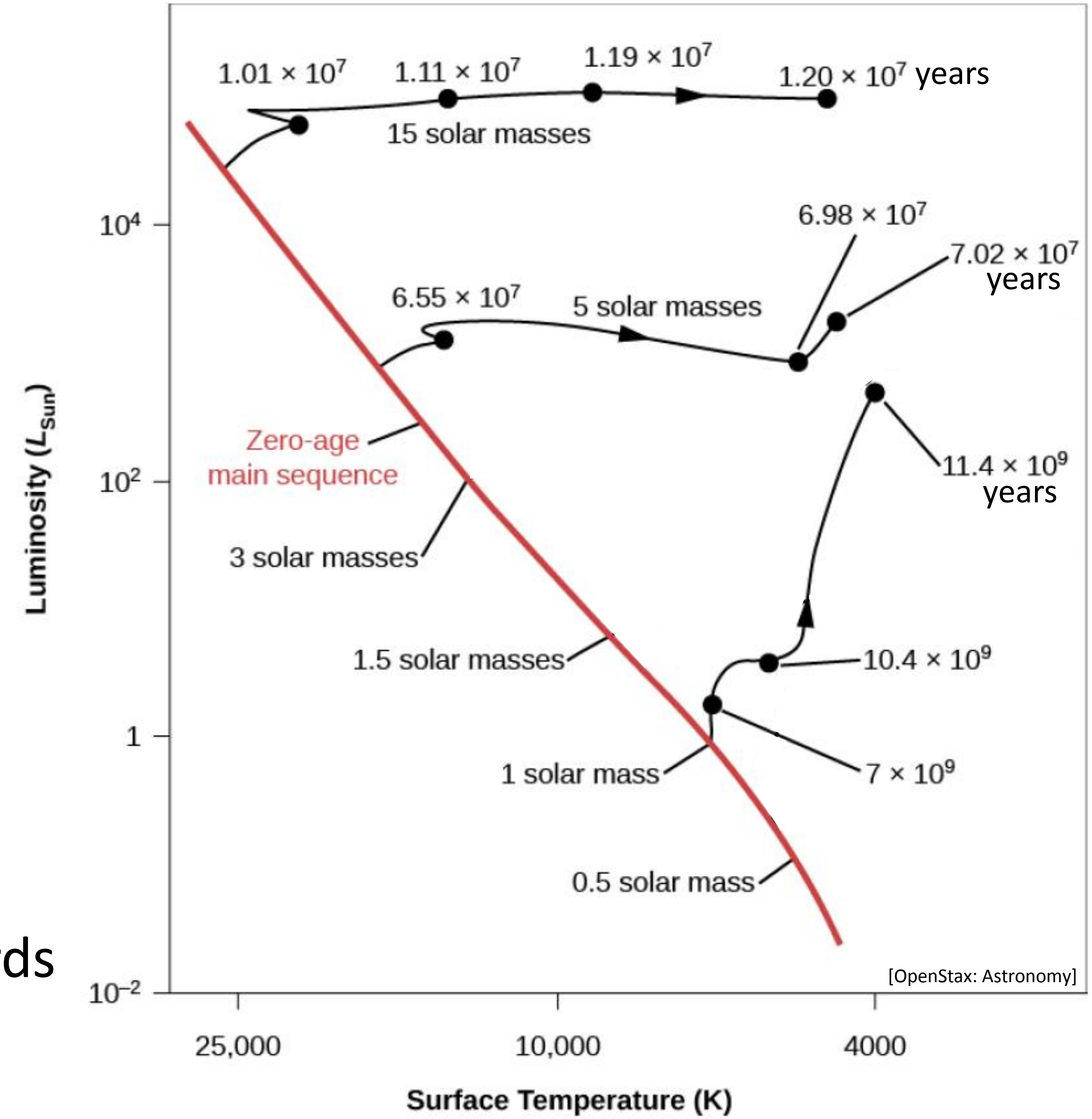
Old age

Stars evolve quickly towards the upper right corner.

→ More luminous, but cooler.



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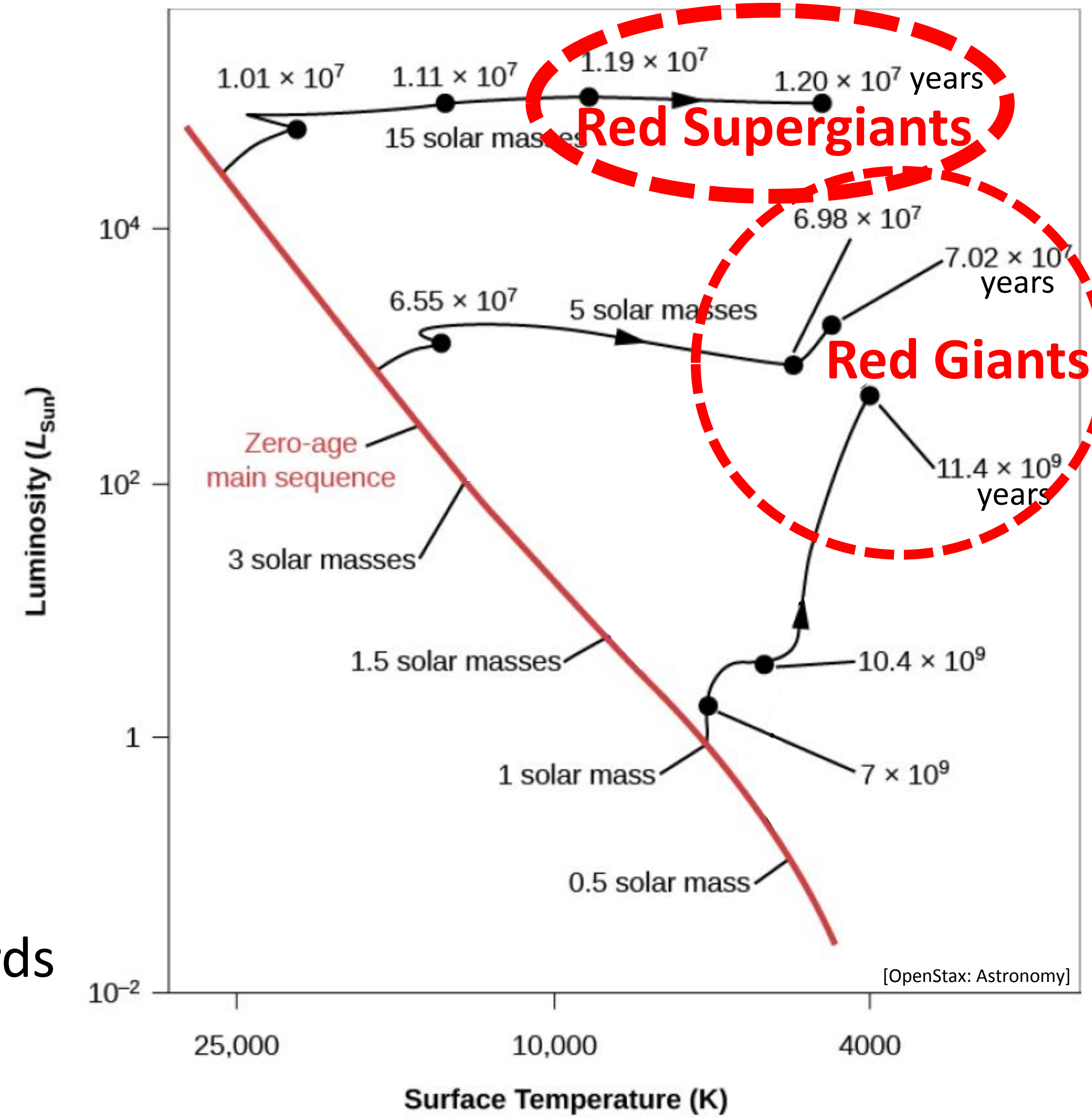
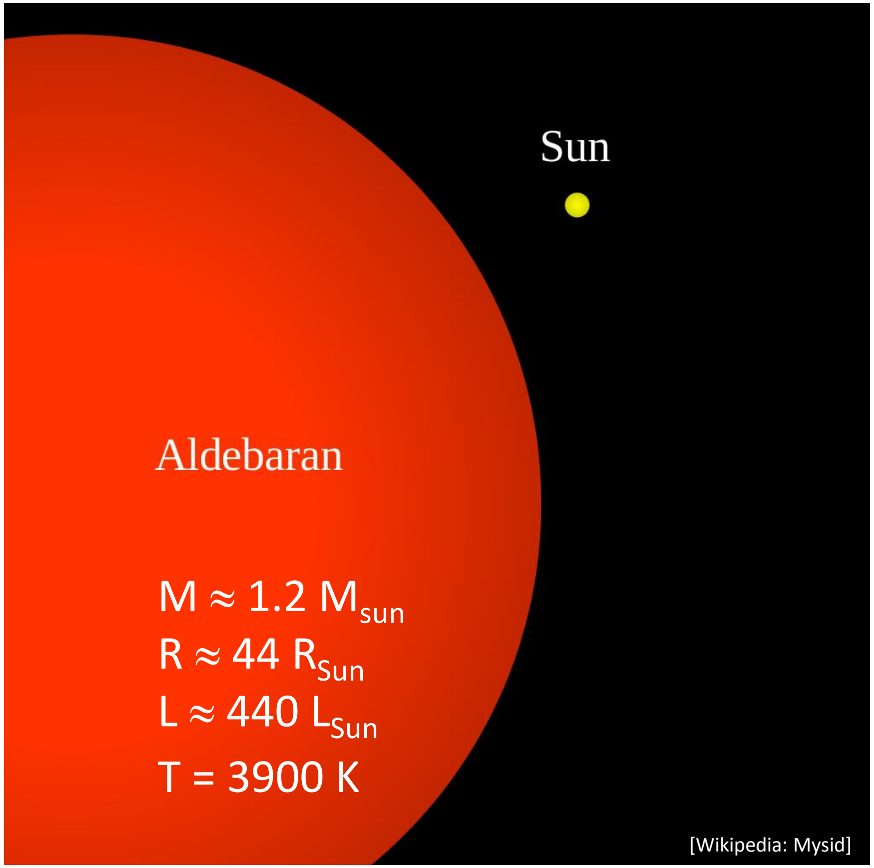


Red Giants & Supergiants

Red Giants

End-of-life stars with masses of $0.6\text{-}10\ M_{Sun}$.



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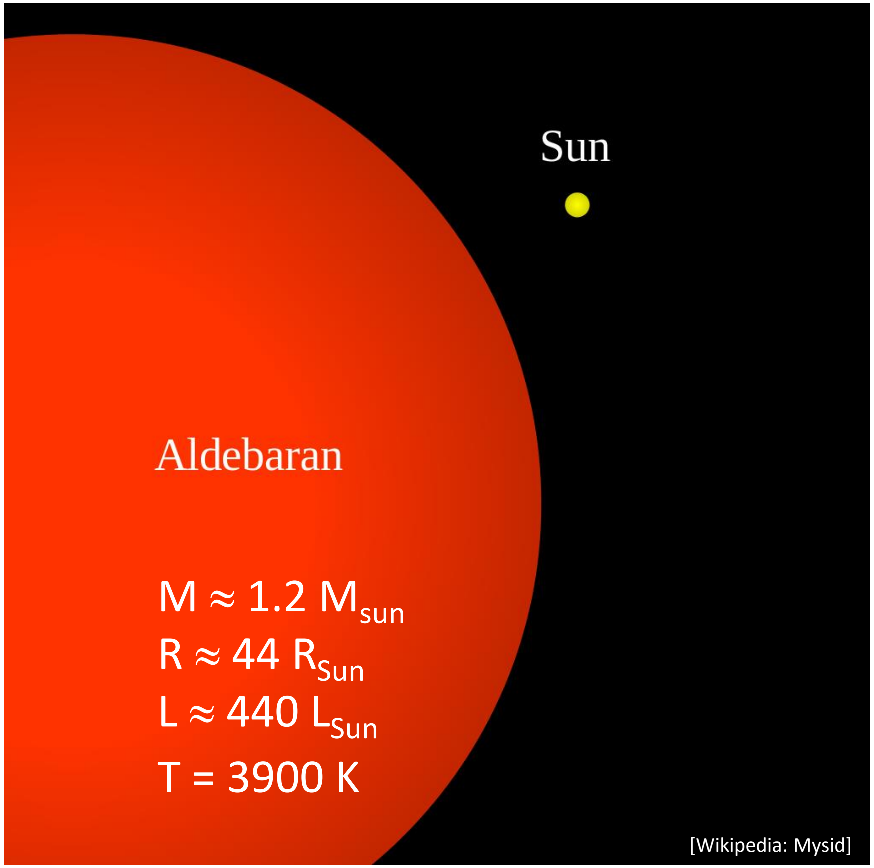
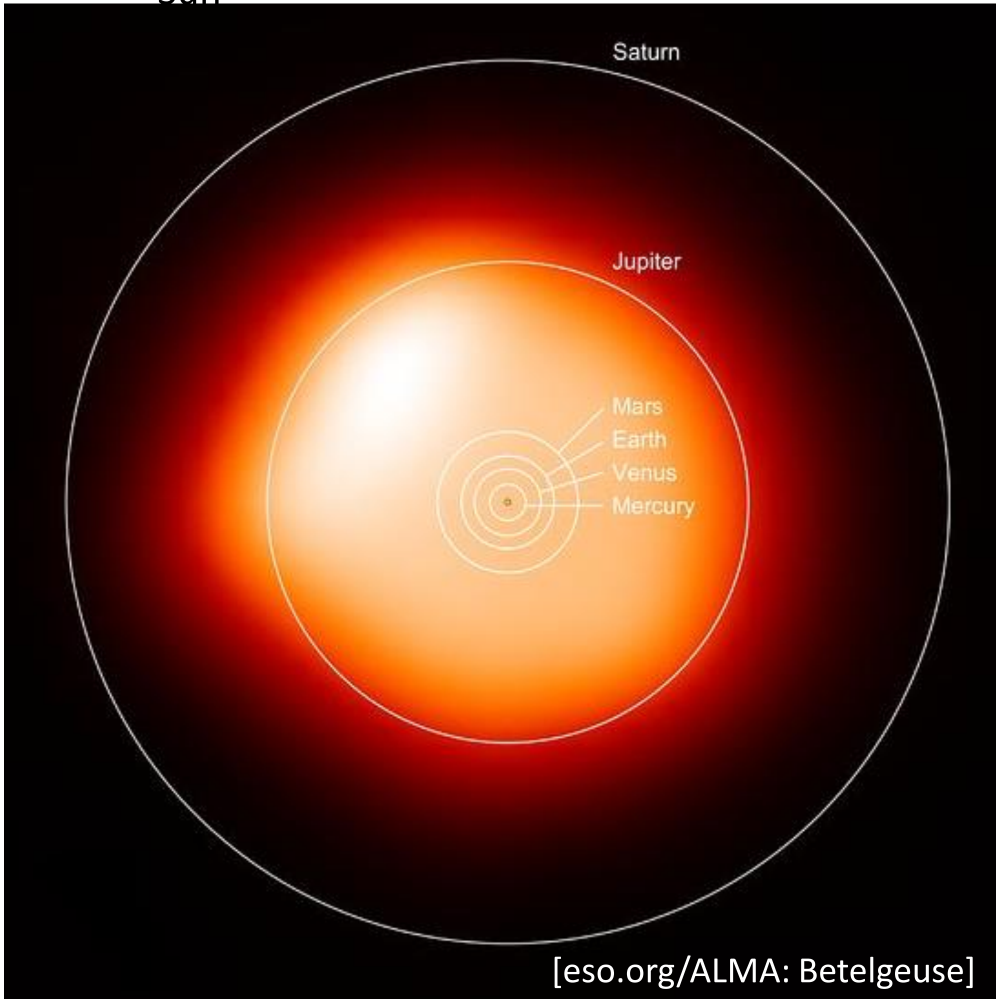


[Wikipedia: Mysid]

Red Supergiants

End-of-life stars with masses of 10-40 M_{Sun}.



[eso.org/ALMA: Betelgeuse]

Aldebaran & Betelgeuse in the Sky