Giant Stars and How We Study Them

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About Me

- 2nd-year grad student at UF
- I love stars!
- From Johns Creek, GA
- Went to Georgia Tech
- I've worked at NASA
- I have a cat! Her name is Mavis :)

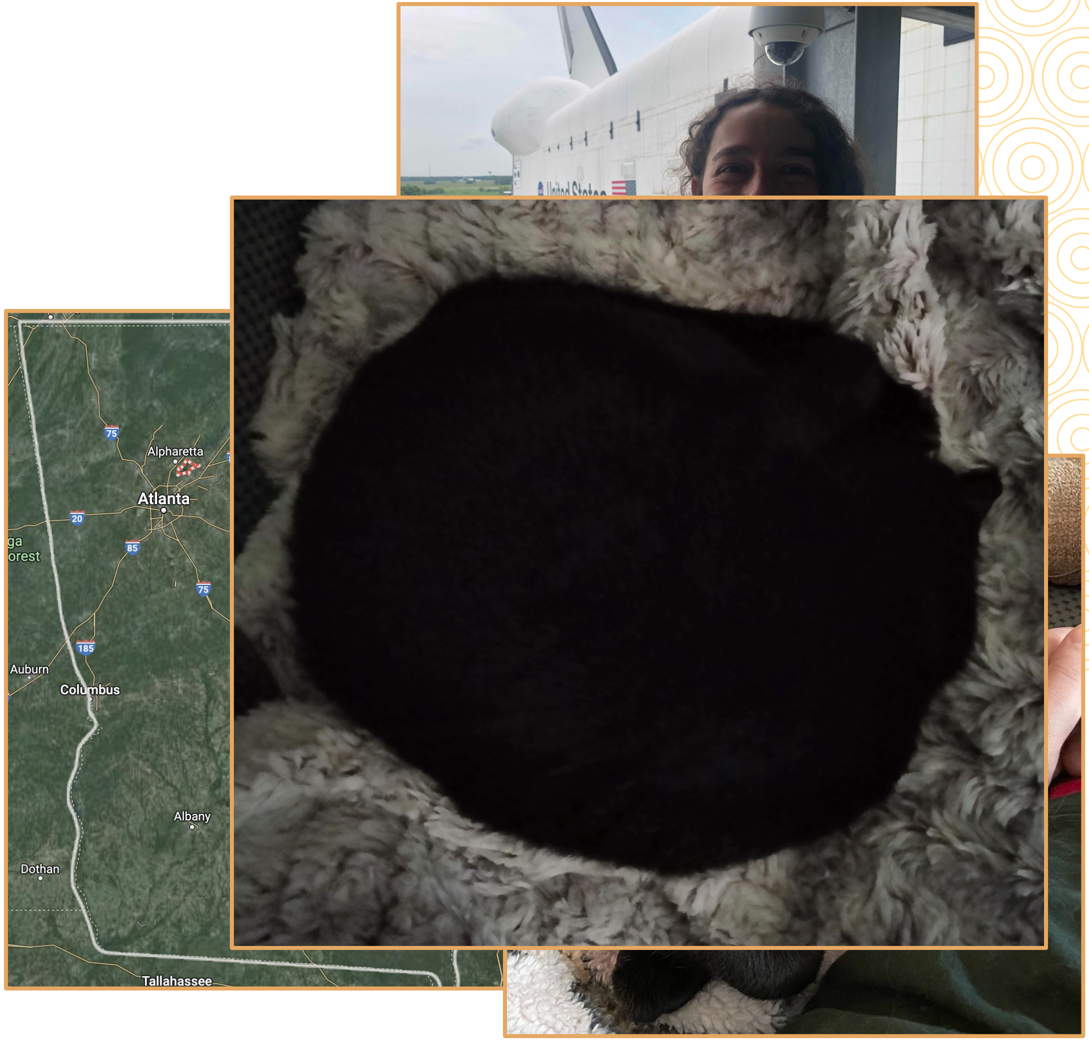
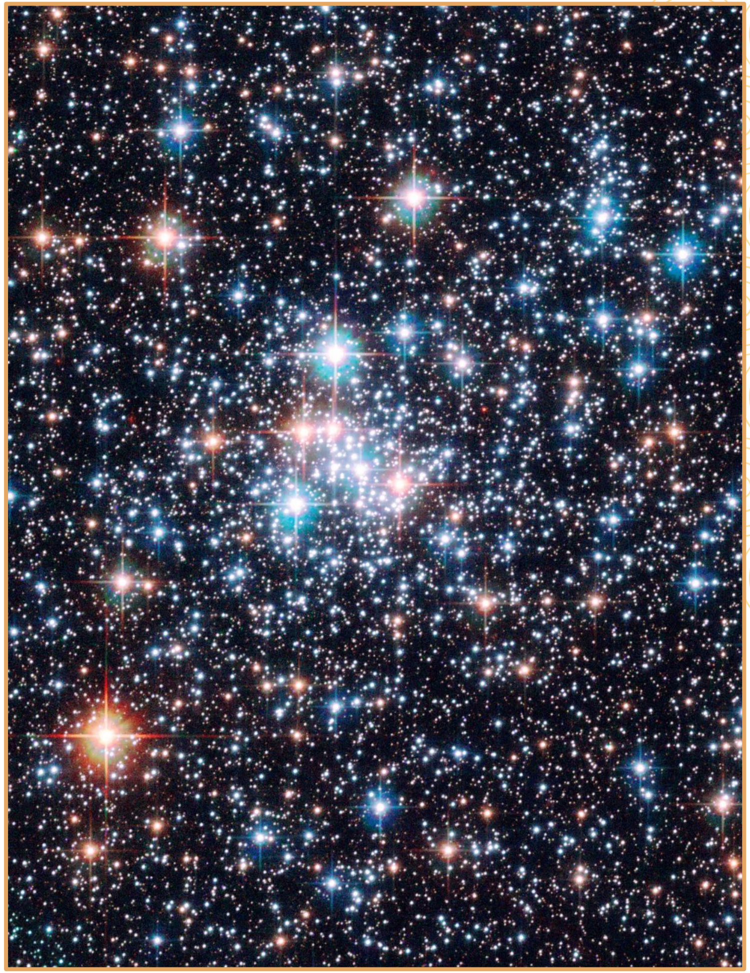


Table of Contents

Why Stars?

- Stars are the building blocks of the universe
- Make up galaxies and fundamental in planetary systems
- Essential to both planetary and galactic astronomy
    - Let us learn about the planets that orbit them
    - Tell us about how and when galaxies are formed and what they're made of
- Should learn as much as we can about them!



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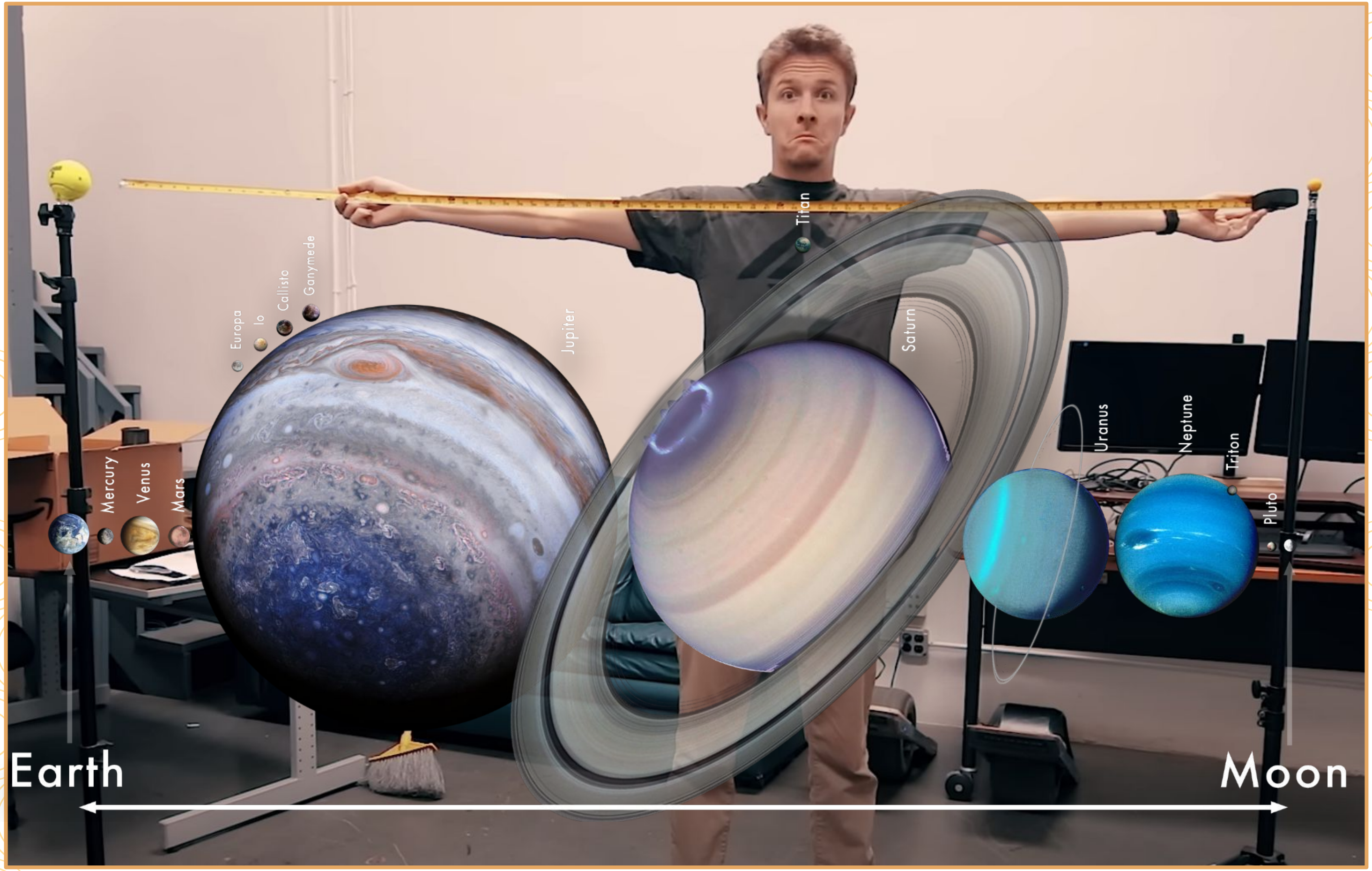
Scale of Giant Stars

How Big Are Giant Stars?
Space is huge! Let's shrink it down

How far away would they be?

From @CorridorCrew on YouTube



7 feet!

From @CorridorCrew on YouTube

How big would the Sun be?

From @CorridorCrew on YouTube

Giants!

From @CorridorCrew on YouTube

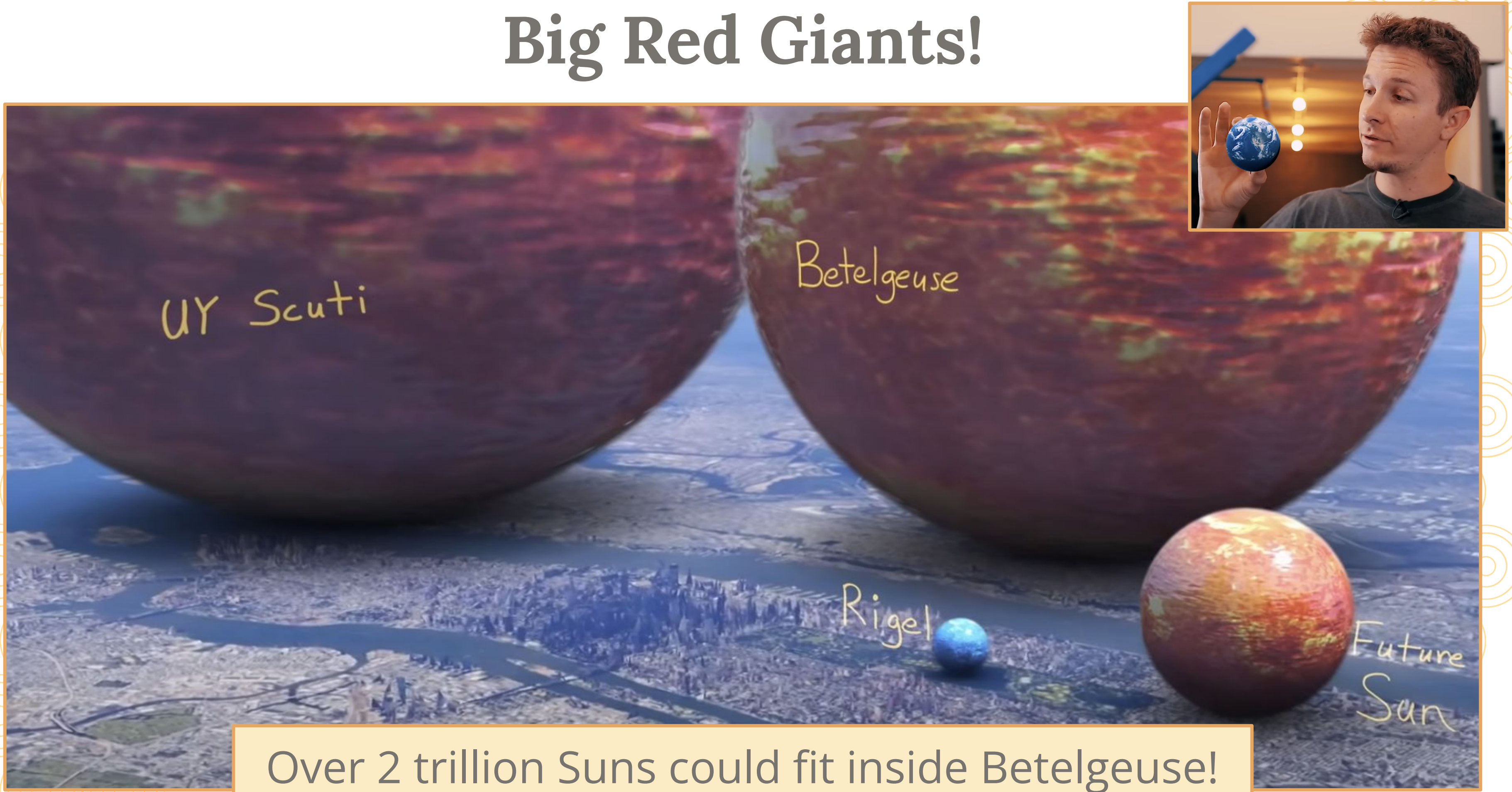
Red Giant!

From @CorridorCrew on YouTube

Big Red Giants!

From @CorridorCrew on YouTube

Big Red Giants!



Over 2 trillion Suns could fit inside Betelgeuse!

From @CorridorCrew on YouTube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Betelgeuse
Rigel
Future Sun
Arcturus
Rigel
Sun
Sirius

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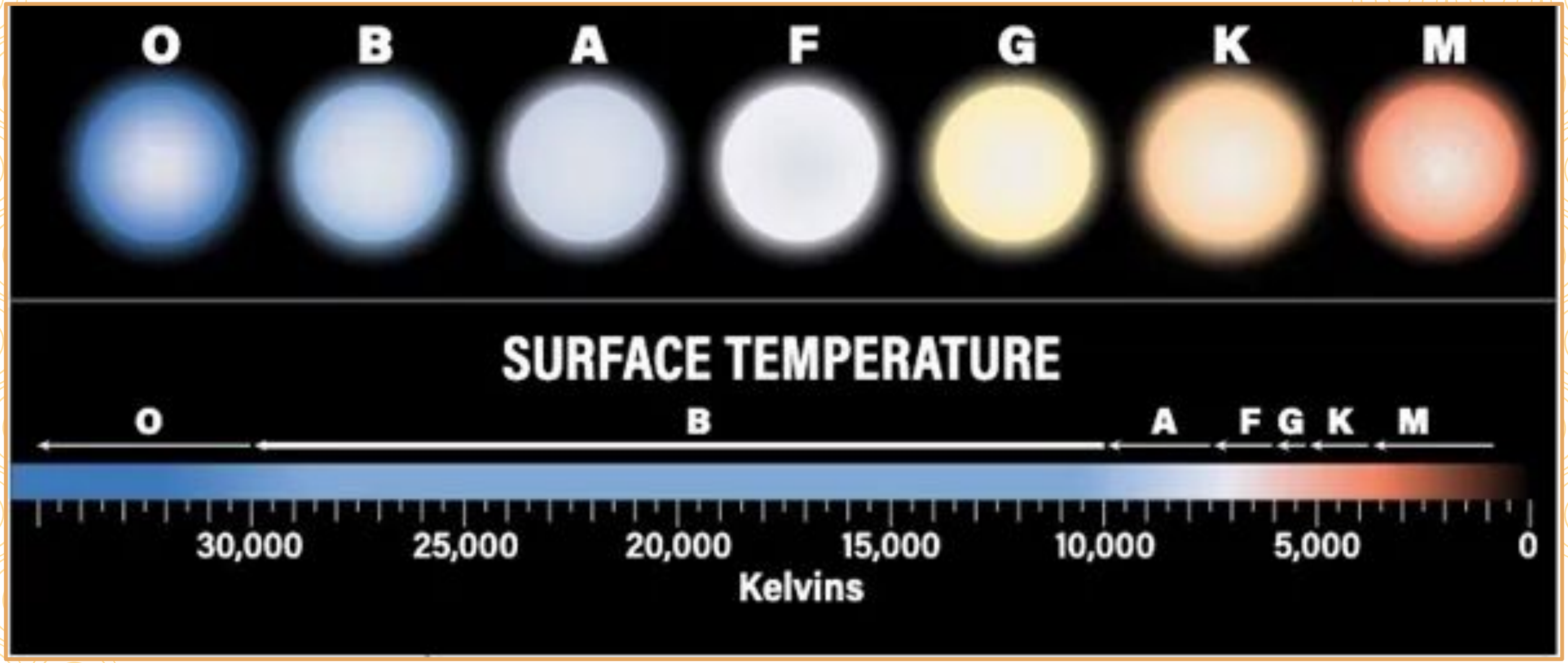
Stellar Classification

Stellar Classification History

- Developed by Harvard computers
  - Classified 100,000s of stars
- Williamina Fleming sorted the stars into classes A-Q
- Annie Jump Cannon simplified this system so that the stars were sorted based on colors (OBAFGKM)

Stellar Classification (Spectral Class)



Stellar Classification

Oh, Be A Fine Girl, Kiss Me!

What increases as the star becomes bluer?

Temperature

Luminosity

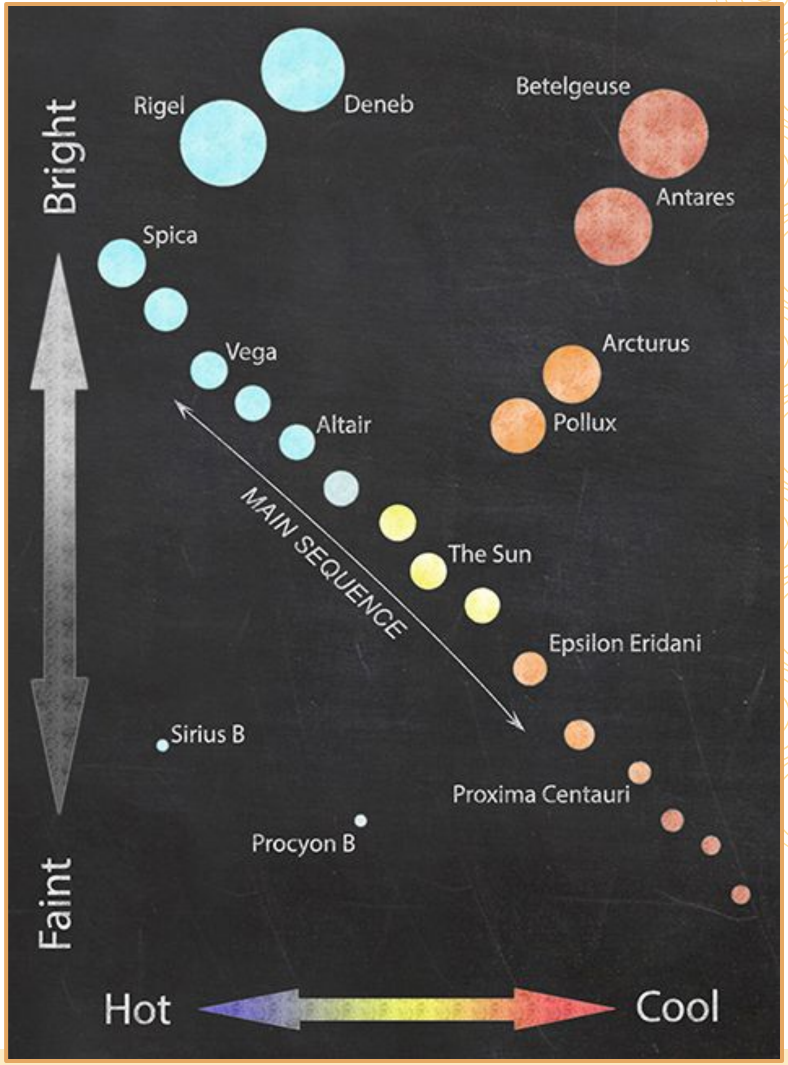
Size

Lifespan

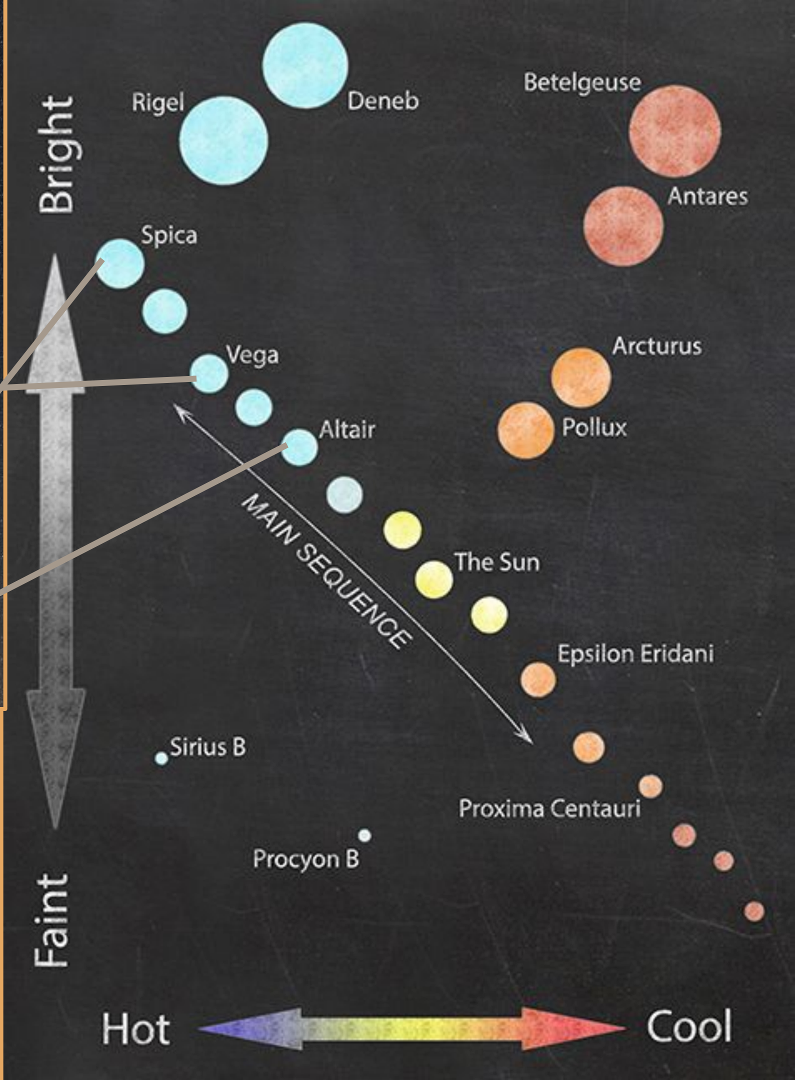
3

The HR Diagram

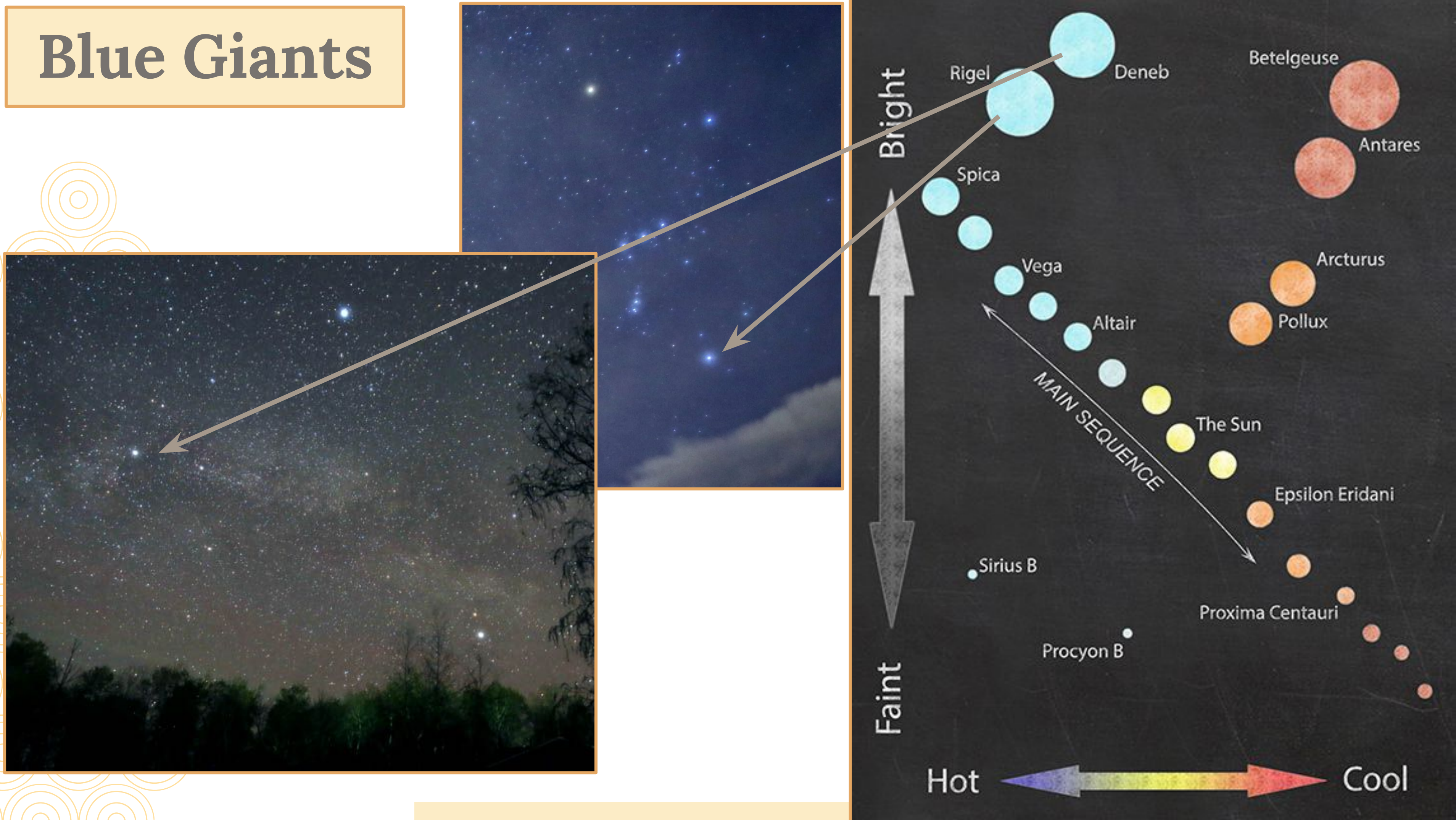
The Hertzsprung–Russell (HR) diagram



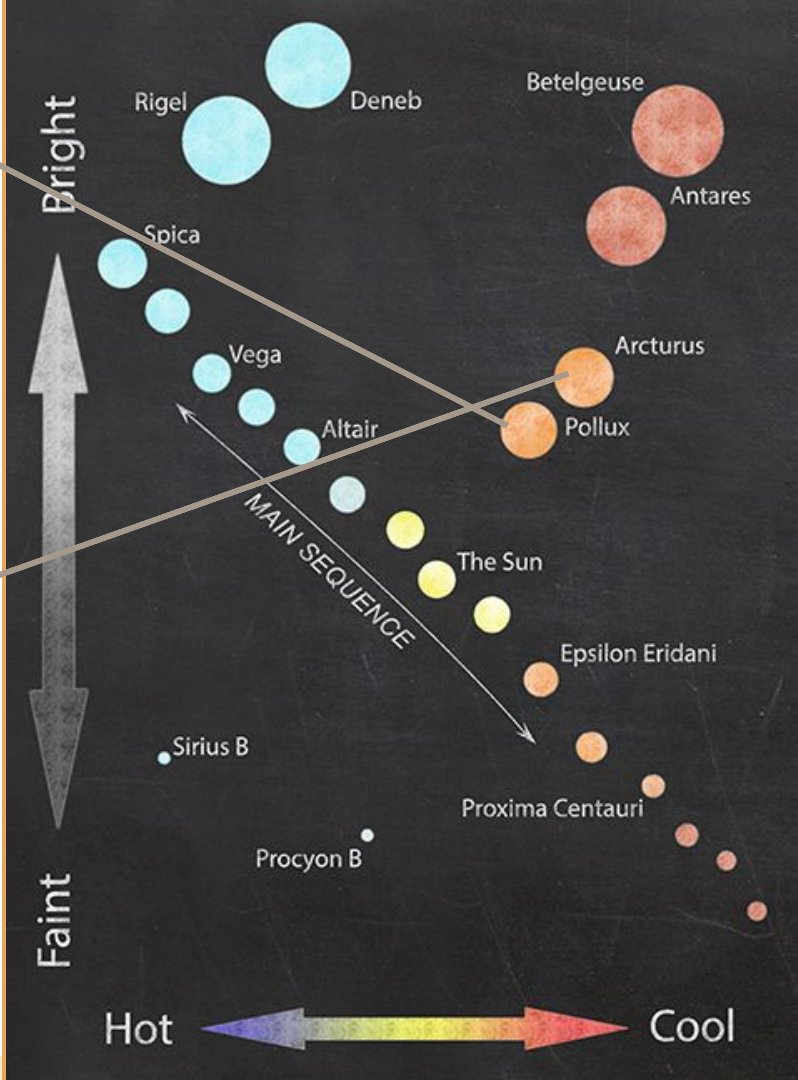
Main sequence



Blue Giants


Bright
Faint
Hot
Cool
Rigel
Deneb
Betelgeuse
Antares
Spica
Vega
Altair
Arcturus
Pollux
MAIN SEQUENCE
The Sun
Epsilon Eridani
Sirius B
Proxima Centauri
Procyon B

Red Giants


Rigel
Deneb
Betelgeuse
Antares
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Spica
Vega
Arcturus
Altair
Pollux
MAIN SEQUENCE
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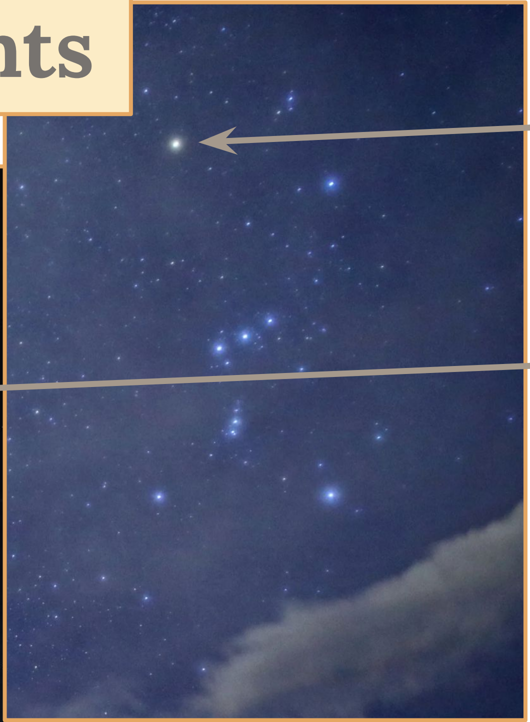
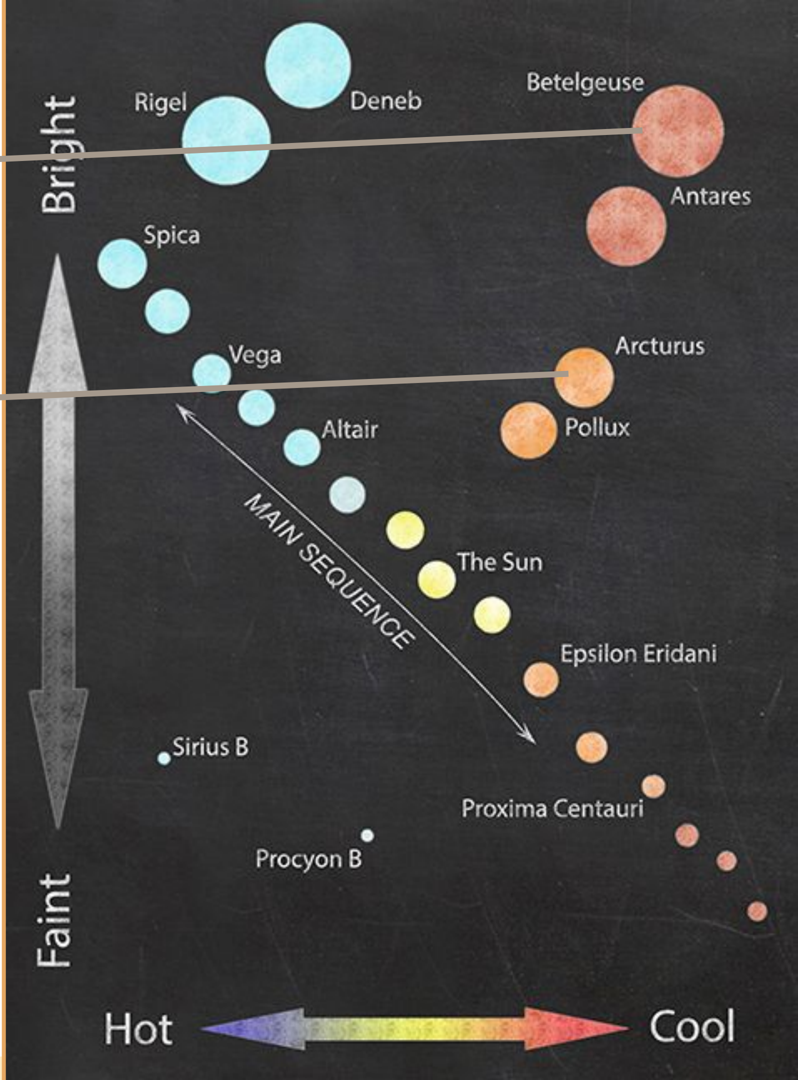
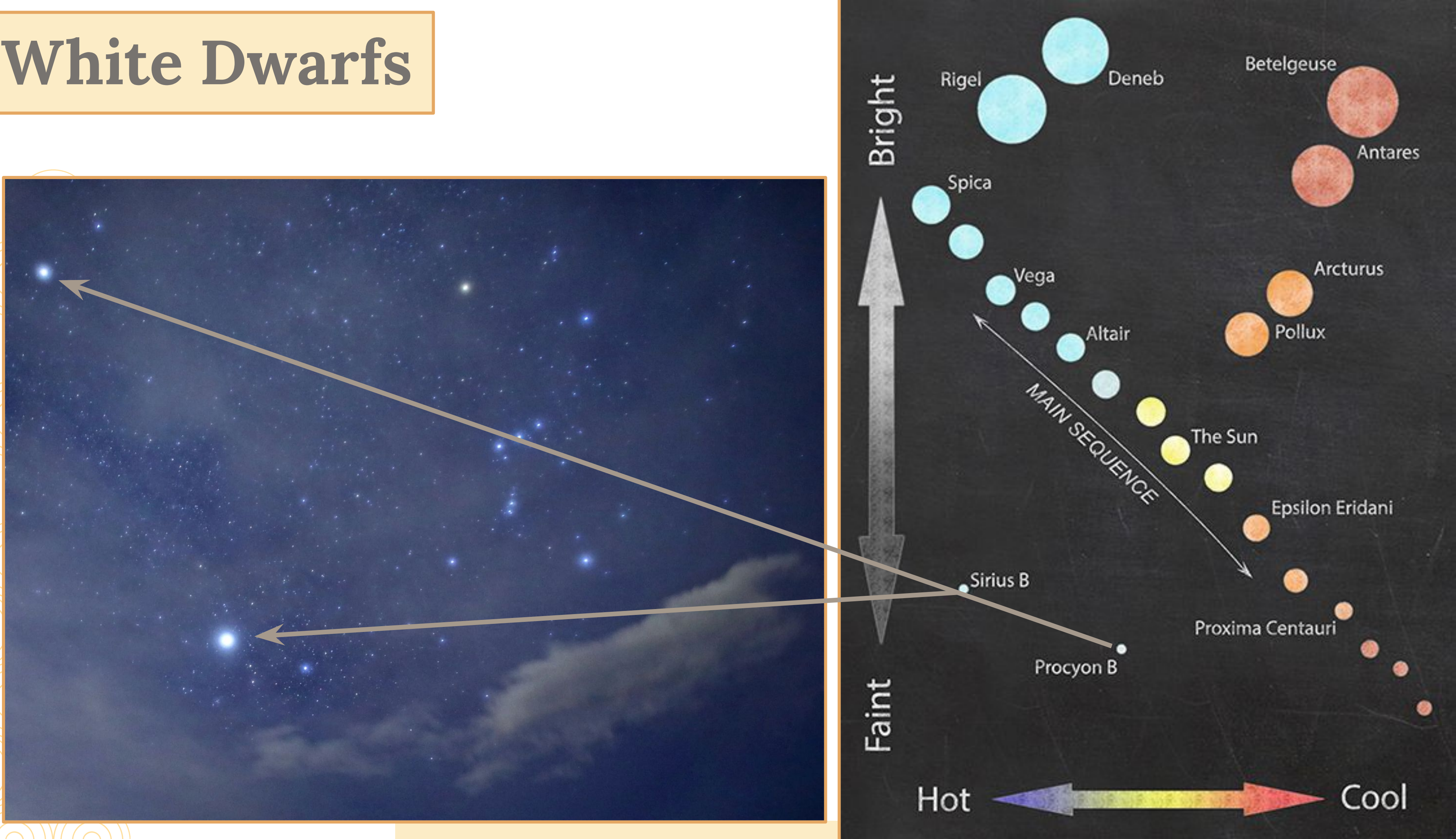
Epsilon Eridani
Sirius B
Proxima Centauri
Procyon B
Faint
Hot
Cool

Red Supergiants



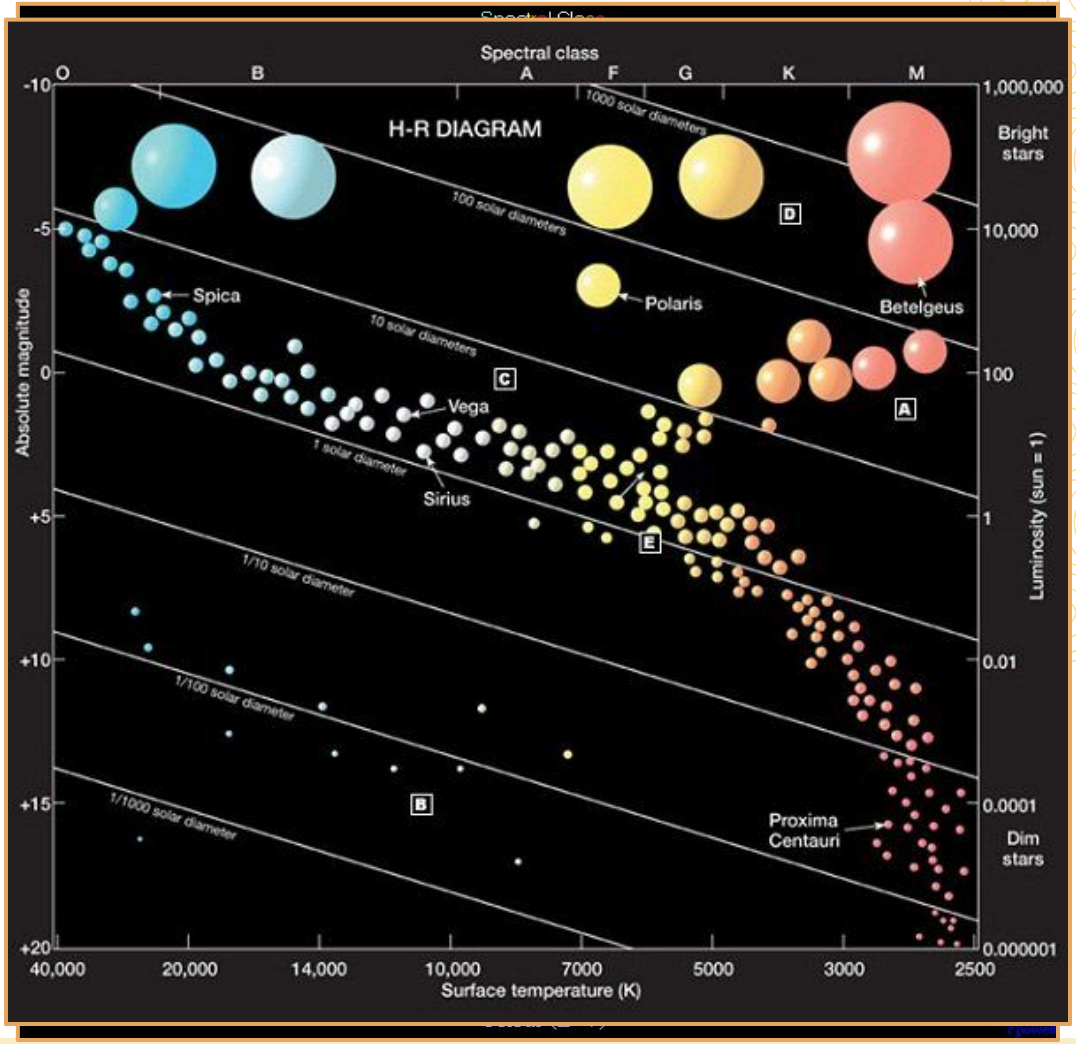


White Dwarfs

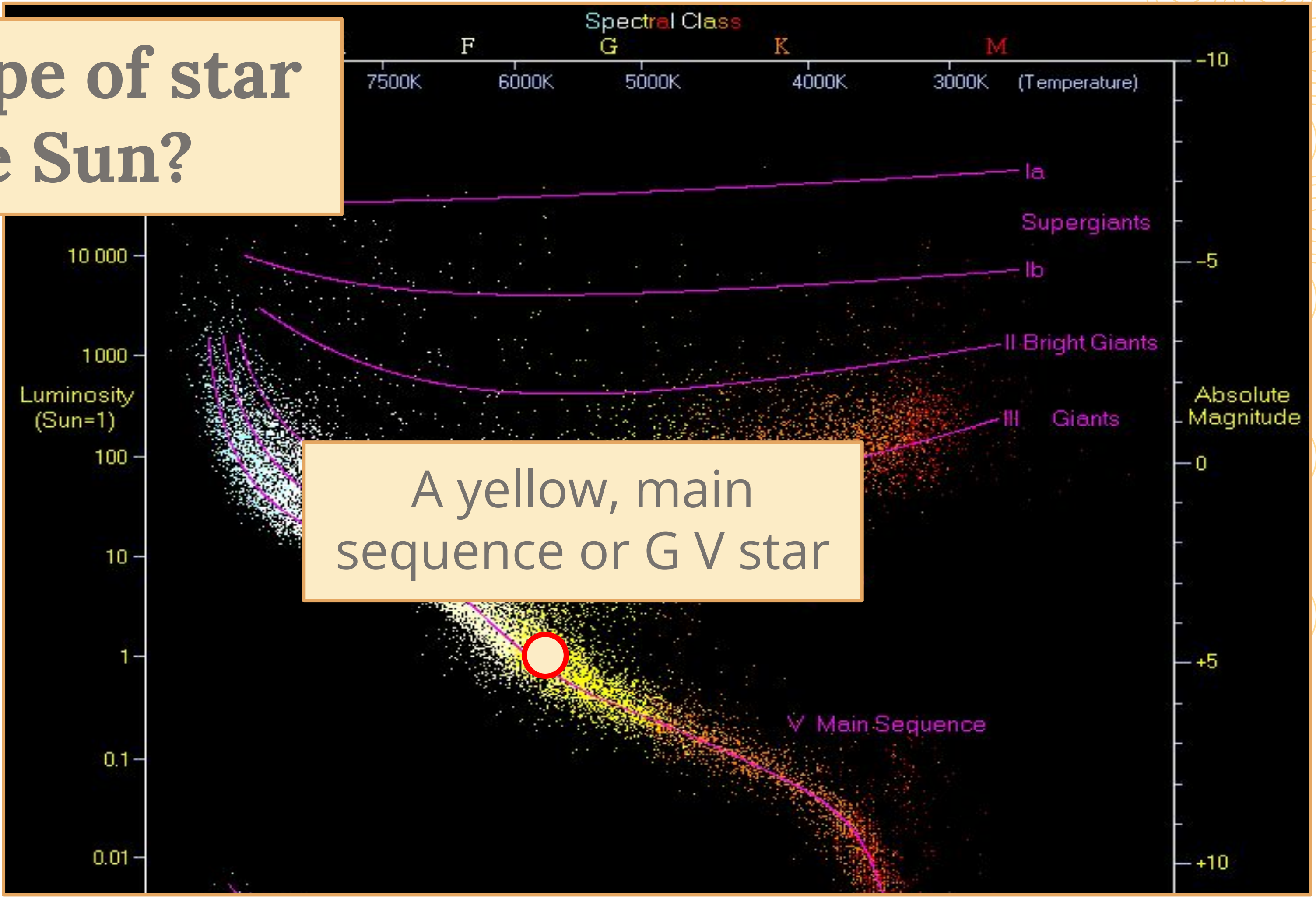


The Hertzsprung–Russell (HR) diagram

- V - Main sequence
- IV - Subgiants
- III & II - Giants
- Ia & Ib - Supergiants
- 90% of stars are on the MS, but over half of the brightest stars in the night sky are giants!



What type of star is the Sun?



A yellow, main sequence or G V star

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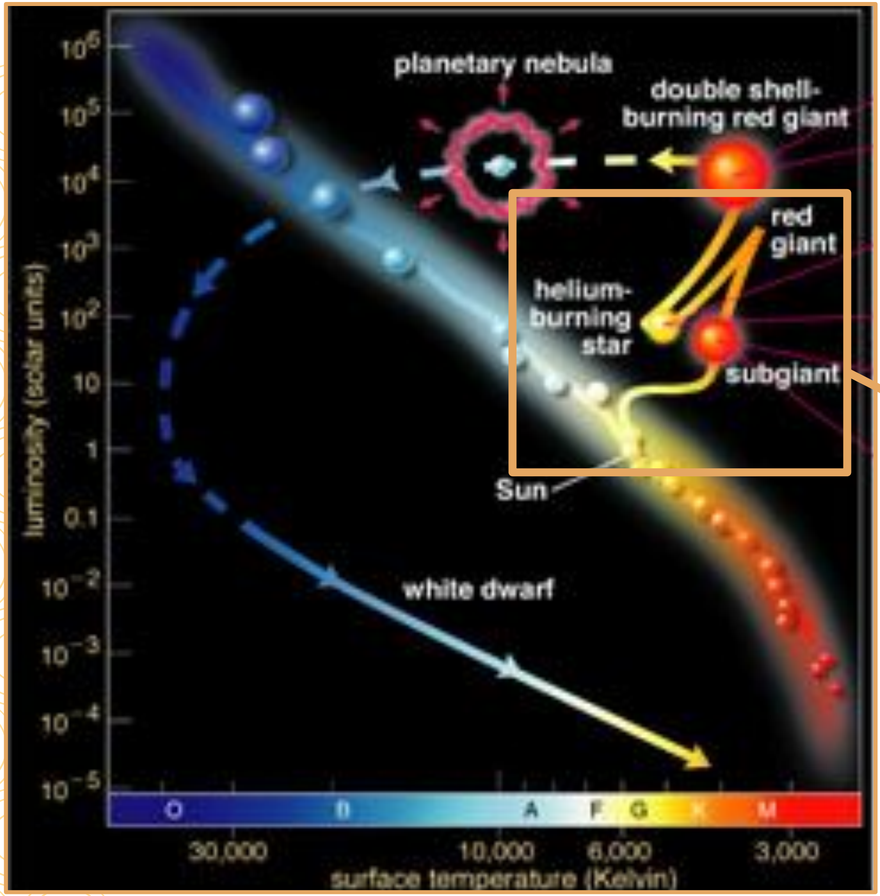
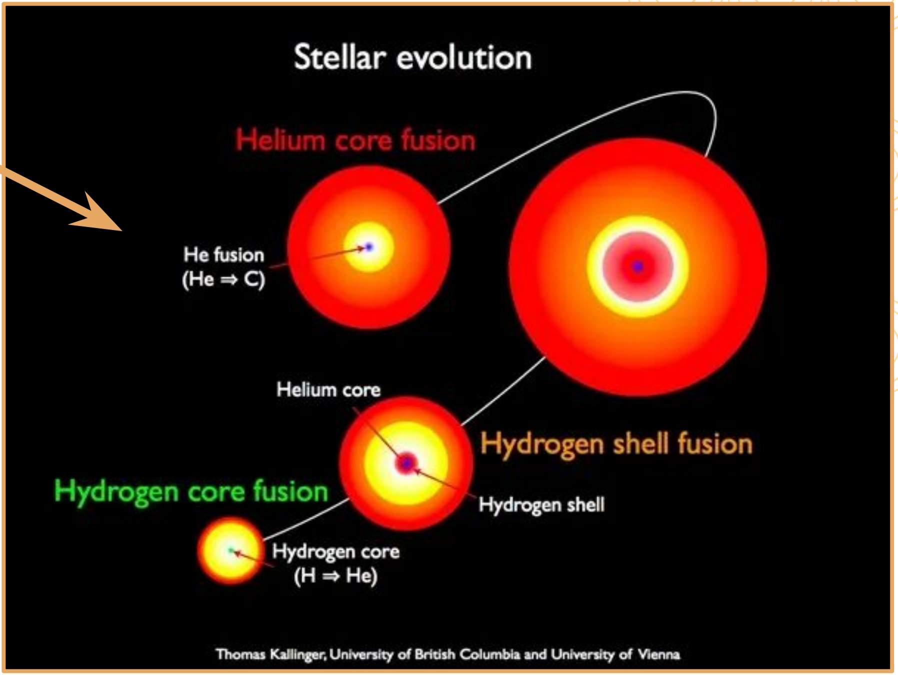
Stellar Evolution

Stellar Evolution on the HR Diagram



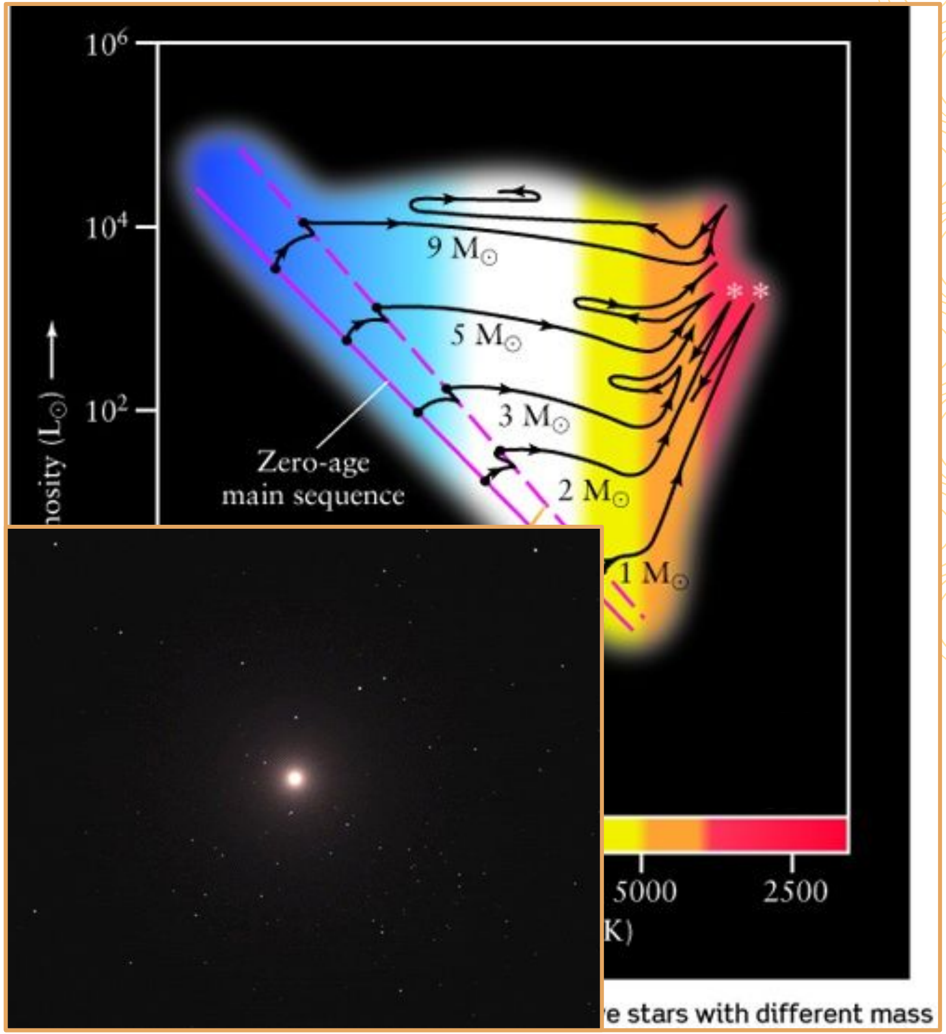
Stars generate energy by turning hydrogen into helium ("hydrogen-burning")



Stellar Evolution on the HR Diagram

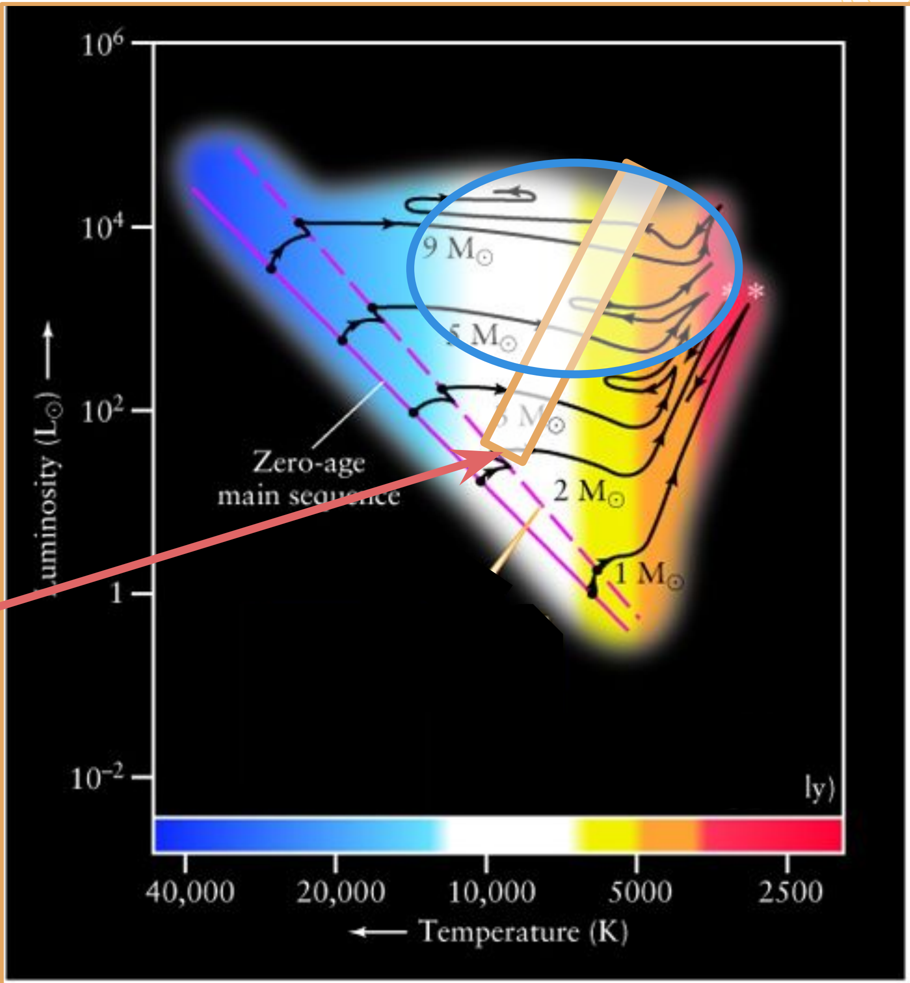
- Depends on mass
- With stronger gravity, high-mass stars continue to burn until it runs out of fuel
- Then, they go supernova

This makes yellow supergiants!



What Are Yellow Supergiants?

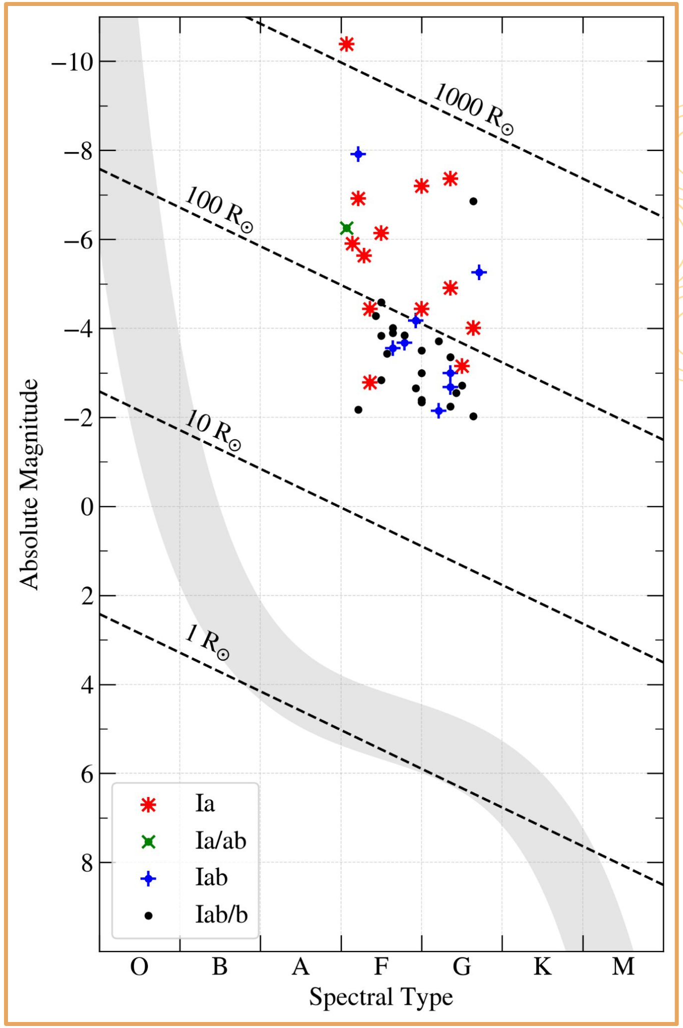
- Rarest type of star
  - Brief stage in stellar evolution (~1,000 yrs)
- Mostly high-mass stars in the blue loop
  - Instability strip - most are variables!
- The north star is one!
- Some astronomers from the 1st century BC described Betelgeuse as yellow, so it might have been a YSG then



(a) Post-main-sequence evolutionary tracks of five stars with different mass

Yellow Supergiants on the HR Diagram

- <0.03% of stars in the Michigan Spectral Catalog
  - 45/161,000
- Careful study can shed light on a rare stage of stellar evolution



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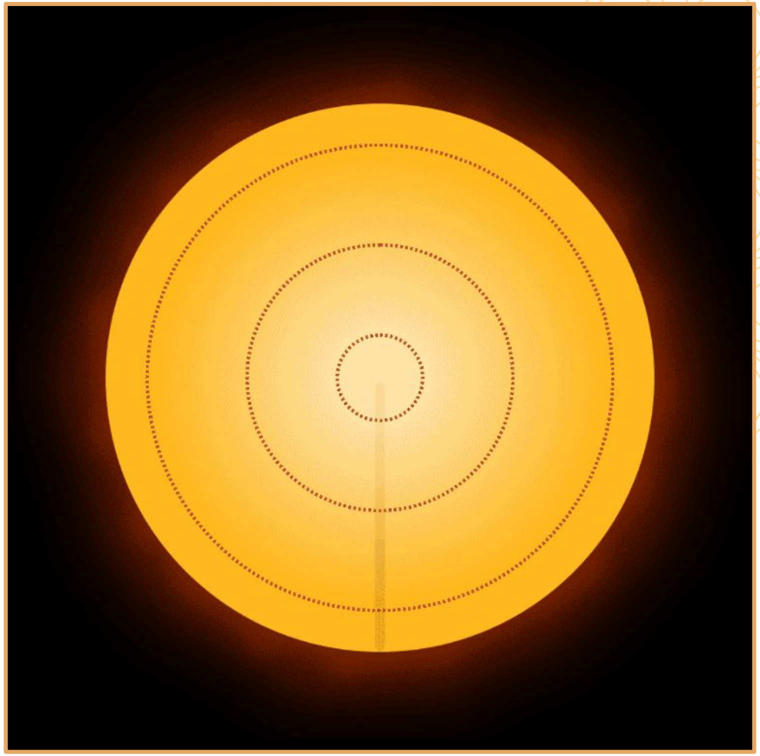
Asteroseismology

Why Do Masses and Ages Matter?

- Could tell when different galactic regions were formed
- Could tell if a star is old enough for planetary systems and better estimate their habitability

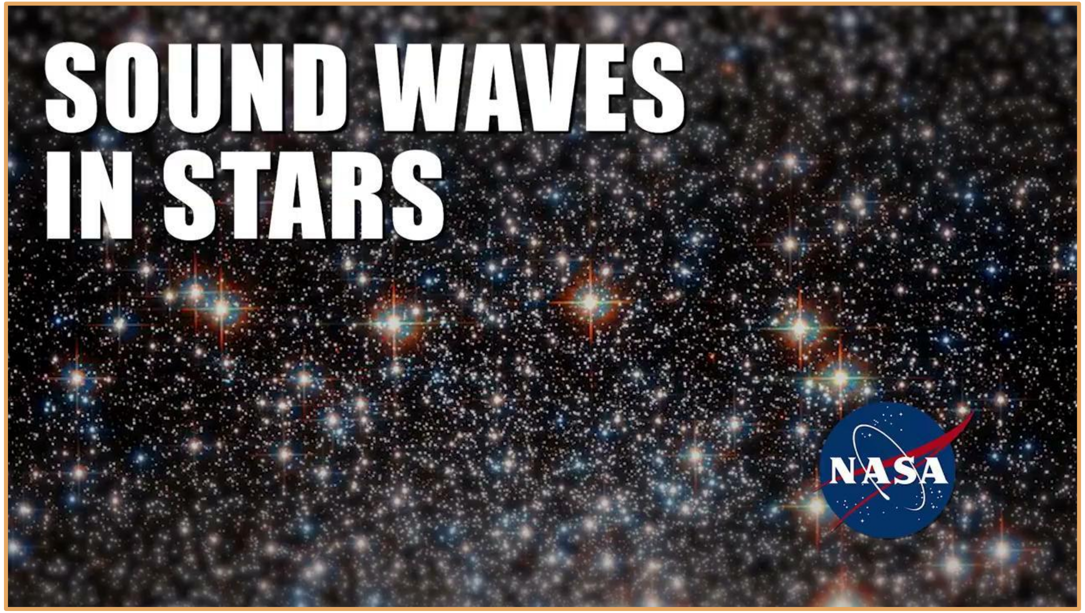
What is Asteroseismology?

- Asteroseismology is the study of stellar interiors through the observation of a star's oscillations
- First used on a large sample of stars just over 10 years ago
- Stars pulsate and create “starquakes”, causing seismic waves that we see as small changes in brightness



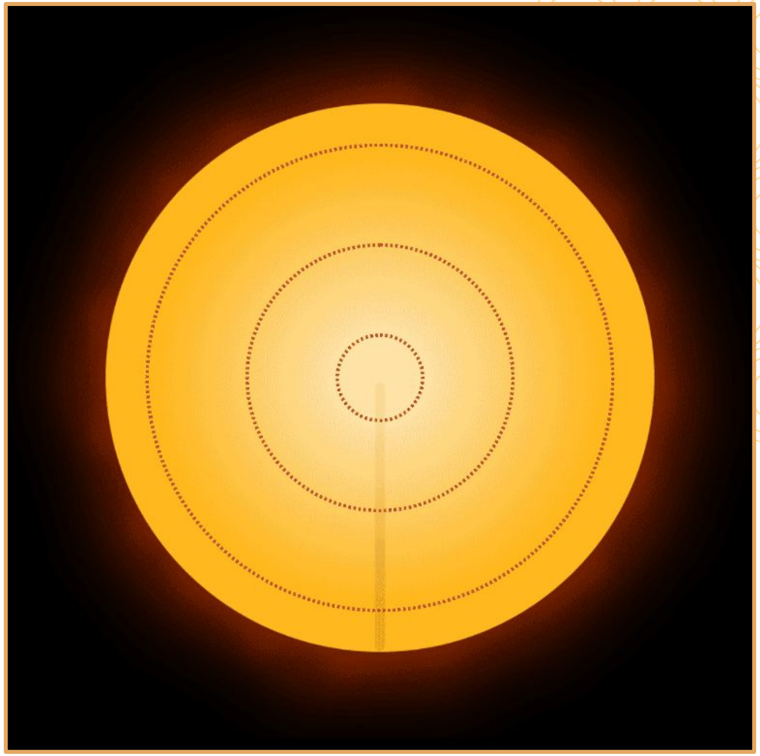
What is Asteroseismology?

Seismic waves are comparable to sound waves, so this is often called "listening" to the music of stars



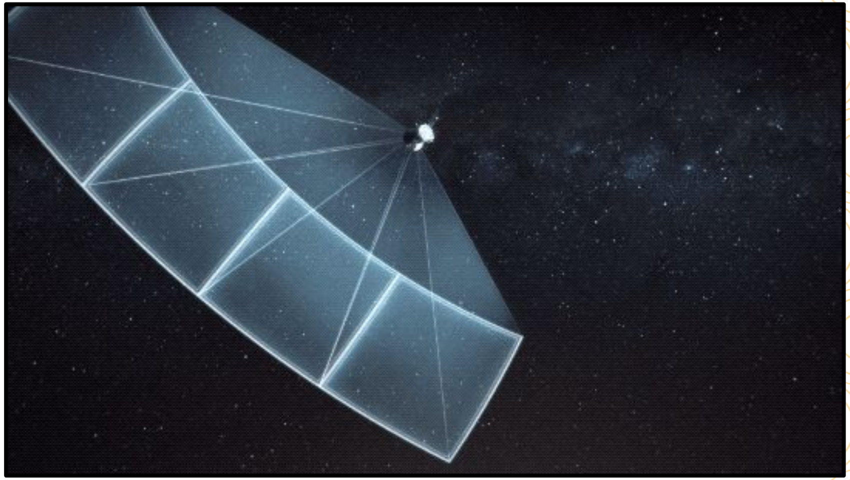
What is Asteroseismology?

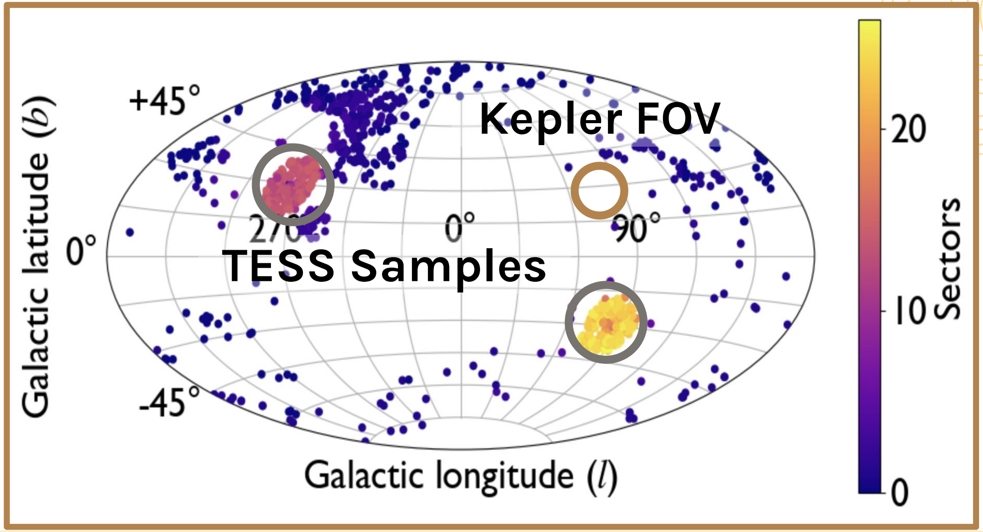
- These waves provide insight into the star's internal structure and composition
- Can help determine age, mass, and radius
- Ages notoriously difficult to measure, especially for metal-poor (old) stars, but could be extremely useful
- Expected to calculate ages with 10-20% accuracy, a large improvement over older methods of age determination (35-40%)



Why TESS?

- Need a space-based telescope that observes stars for long periods of time
- Covers much more of the sky compared to Kepler
- Better chance of observing metal-poor (old) stars
- Still relatively new (~4 years of data)
- Not much asteroseismology has been done with metal-poor stars due to the lack of sufficient data



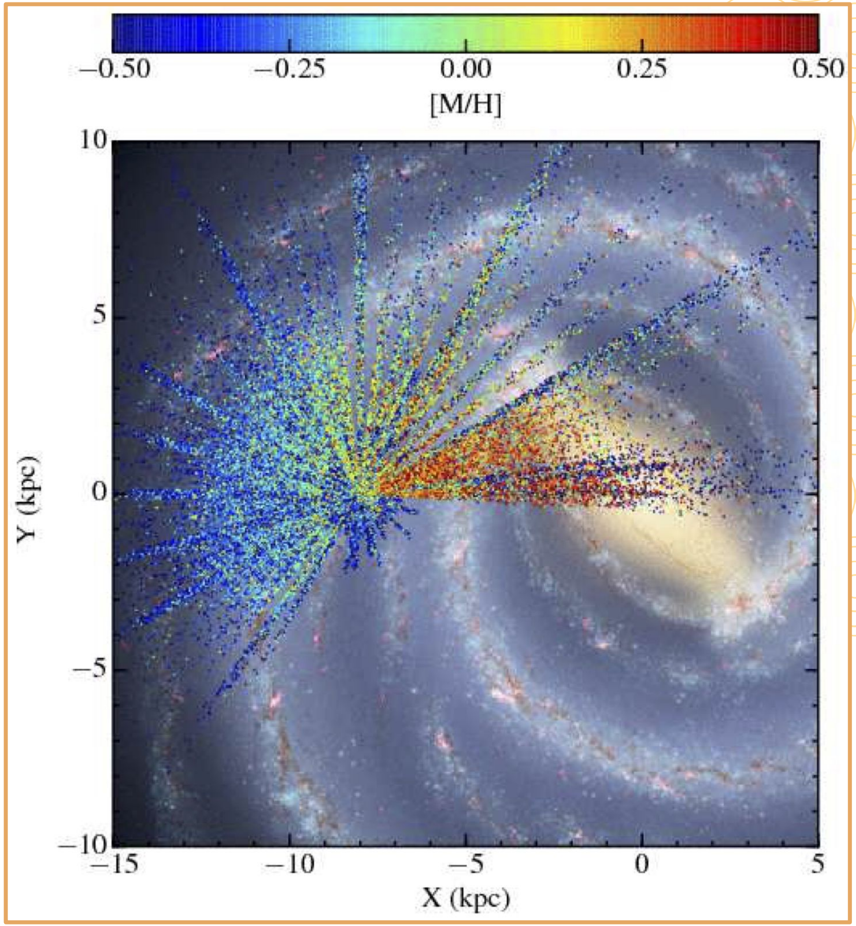


Who cares?

- First asteroseismic study to calculate masses and ages of a large group of low-metallicity stars from TESS (and therefore stars outside the Kepler field)
- Especially difficult with TESS because much less data than Kepler, but necessary to observe a larger sample of metal-poor stars
- Also difficult with low-metallicity stars because asteroseismic equations are solar-scaled
- Signals are also weaker due to their composition

The Stars

- APOGEE DR17 - A survey of red giants in the Milky Way
  - Includes stellar parameters (chemical abundances, temperatures, etc.)
- Only studying low-metallicity stars
  - Should be older
- Left with ~500 stars

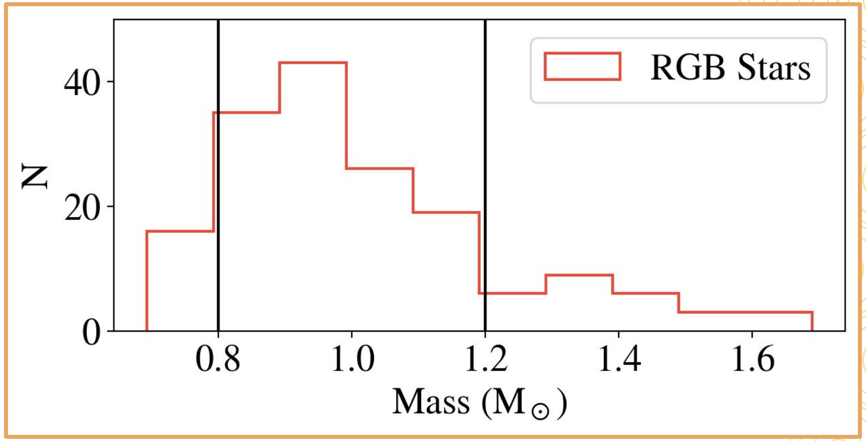


APOGEE DR17

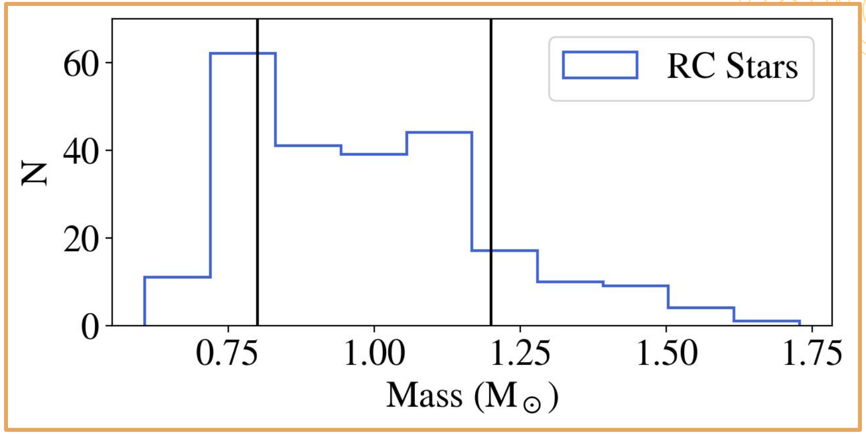
Mass Results

- Most masses are within expected limits
- Both peak at low masses, which is good because these are metal-poor and should have lower masses
- RGBs almost follow a Gaussian
- RCs peak at lower and higher masses
  - Likely due to mass loss from RGB to RC stage and/or binary mergers, which are more common in RC stars

Pre-He burning



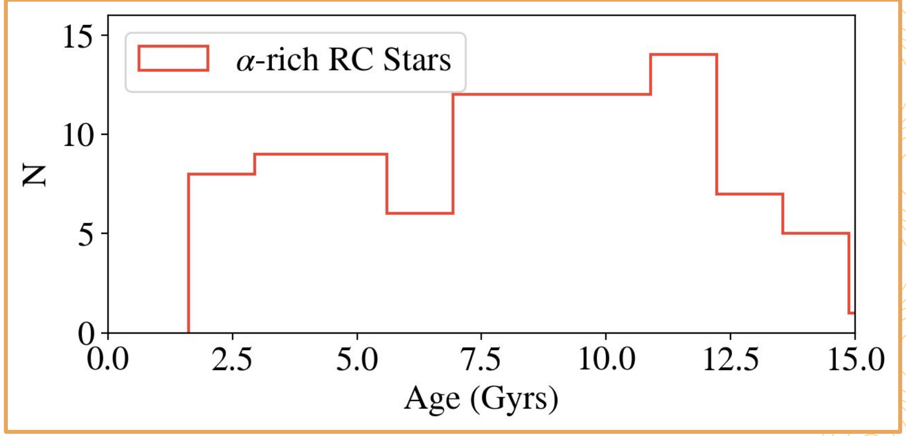
Post-He burning



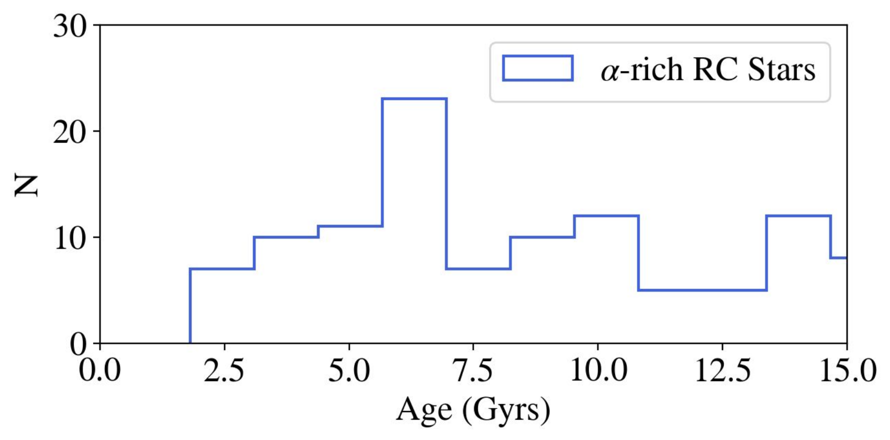
Age Results

- Much more dispersion than with masses, but appear correct
- The RGB stars peak at approximately the expected age; the lower bump is likely due to a known, yet mysterious, population of young stars with the metallicities of old stars
- The RC ages are skewed either low or high, which is similar to the trend from the mass plot

Pre-He burning



Post-He burning



Conclusions

- Now have the masses and ages of the Milky Way's oldest stars
- We can successfully use asteroseismology on metal-poor stars from TESS!
- Next, hope to create an asteroseismic age map of metal-poor stars in the Milky Way using Kepler, K2, and TESS data

Quick Recap

1. Scales of giant stars
2. Stellar classification and the HR Diagram
3. The stages of stellar evolution
4. Asteroseismology and its applications

Mobile Planetarium Plug

Let me know if you are interested in bringing the mobile planetarium to your/your child's school!

Follow @UF_CTO on Twitter (X?) for public nights and other events!

Thank you!

DO YOU HAVE ANY QUESTIONS?

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