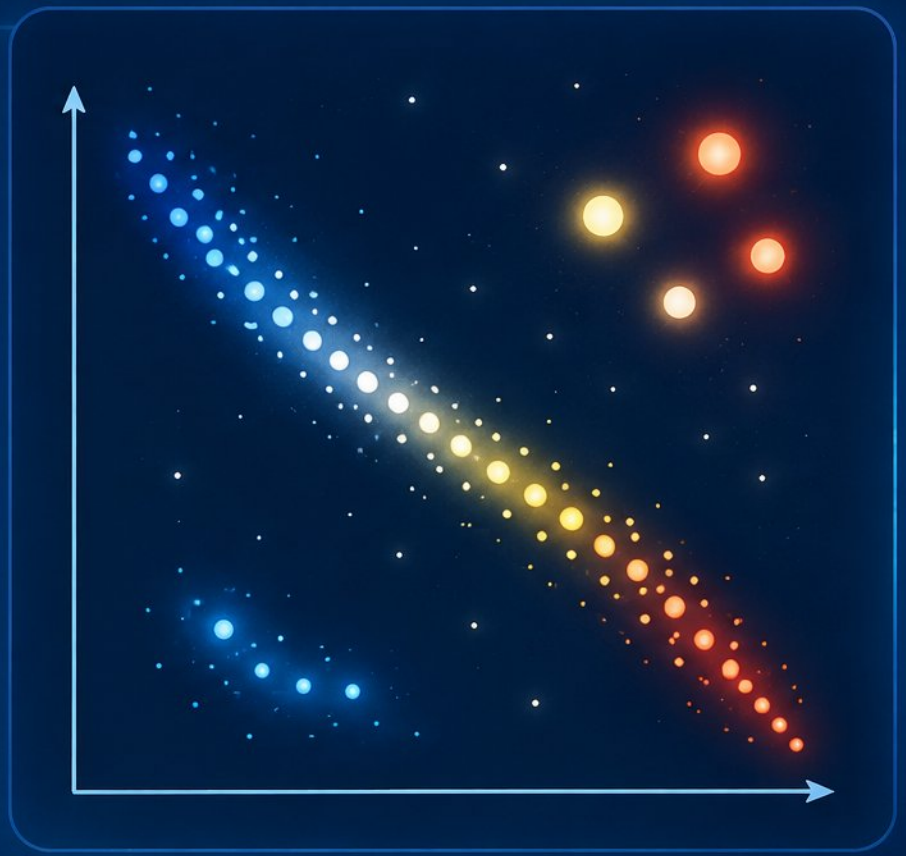
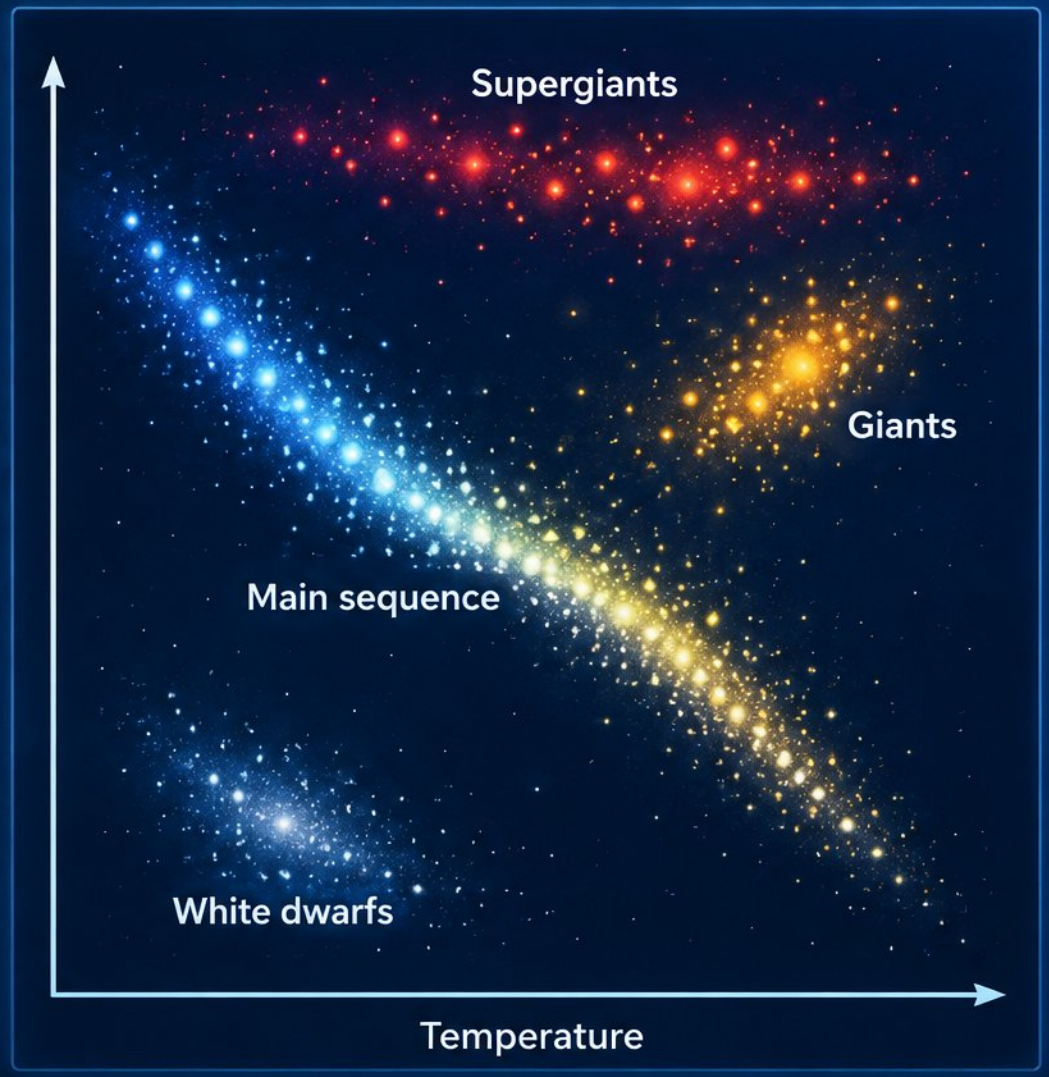
# Reading the H-R Diagram: Classifying Stars

- Build practical skill reading the Hertzsprung-Russell (H-R) diagram
- Plot a star, read its position, identify luminosity class, infer stage
- Astronomy's central organizing tool for stars
- Developed independently by Hertzsprung (1911) and Russell (1913)
- For students, educators, and amateurs: no spectroscopy background needed



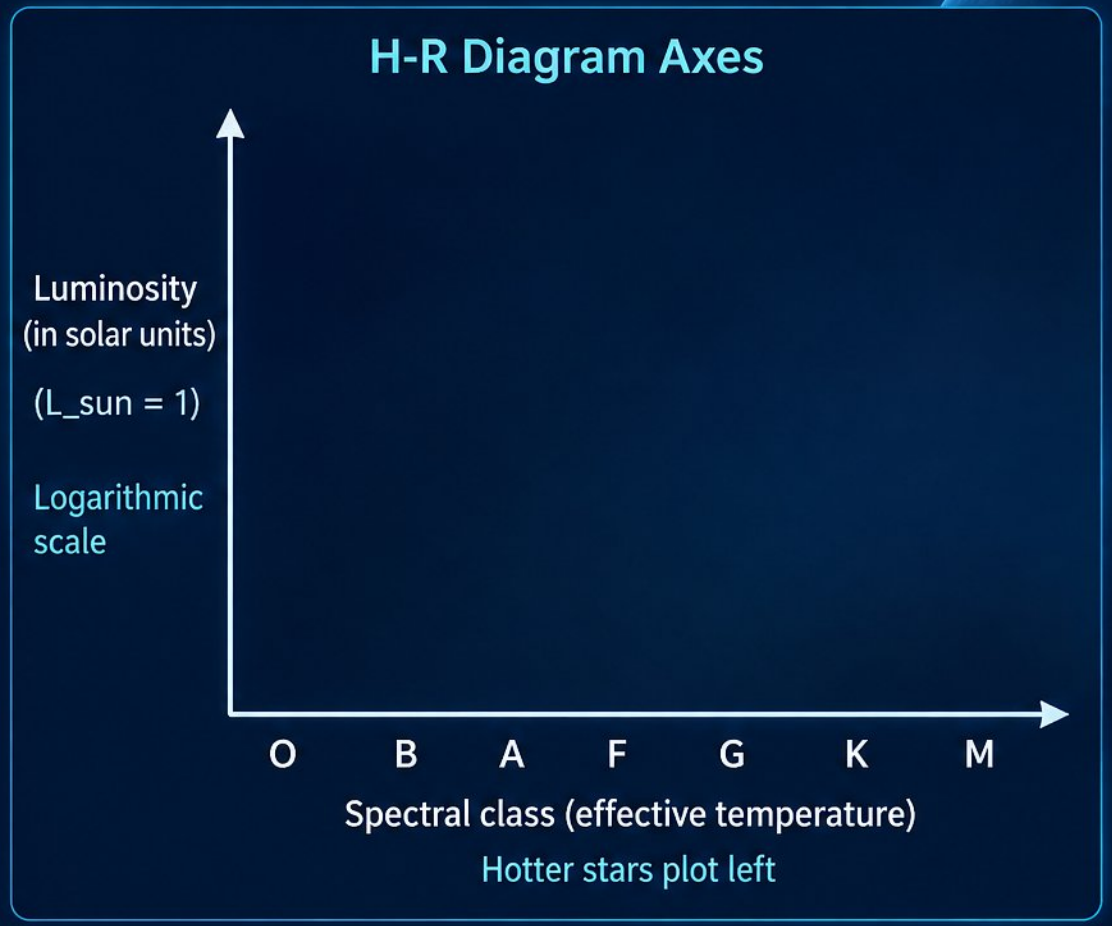
# Why Plotting Stars Reveals Structure

- Stars cluster into distinct populated regions, not random scatter
- Four main regions: main sequence, giants, supergiants, white dwarfs
- 80–90% of stars lie along the main-sequence band
- Position shows intrinsic physical state, not location in space
- 1911–1913: Hertzsprung and Russell revealed the giant/ main-sequence split



# Axes and Scales: Temperature, Luminosity, Magnitude

- Horizontal axis: effective temperature or spectral class; hotter stars plot left
- Spectral sequence O, B, A, F, G, K, M runs hot to cool
- Class ranges: O >30,000 K; B 10,000–30,000; A 7,500–10,000; F 6,000–7,500; G 5,200–6,000; K 3,700–5,200; M <3,700 K
- Vertical axis: luminosity in solar units (L_sun = 1) or absolute magnitude
- Logarithmic scales compress roughly eight orders of magnitude in luminosity
- Apparent magnitude is observed brightness; absolute magnitude is brightness at 10 parsecs

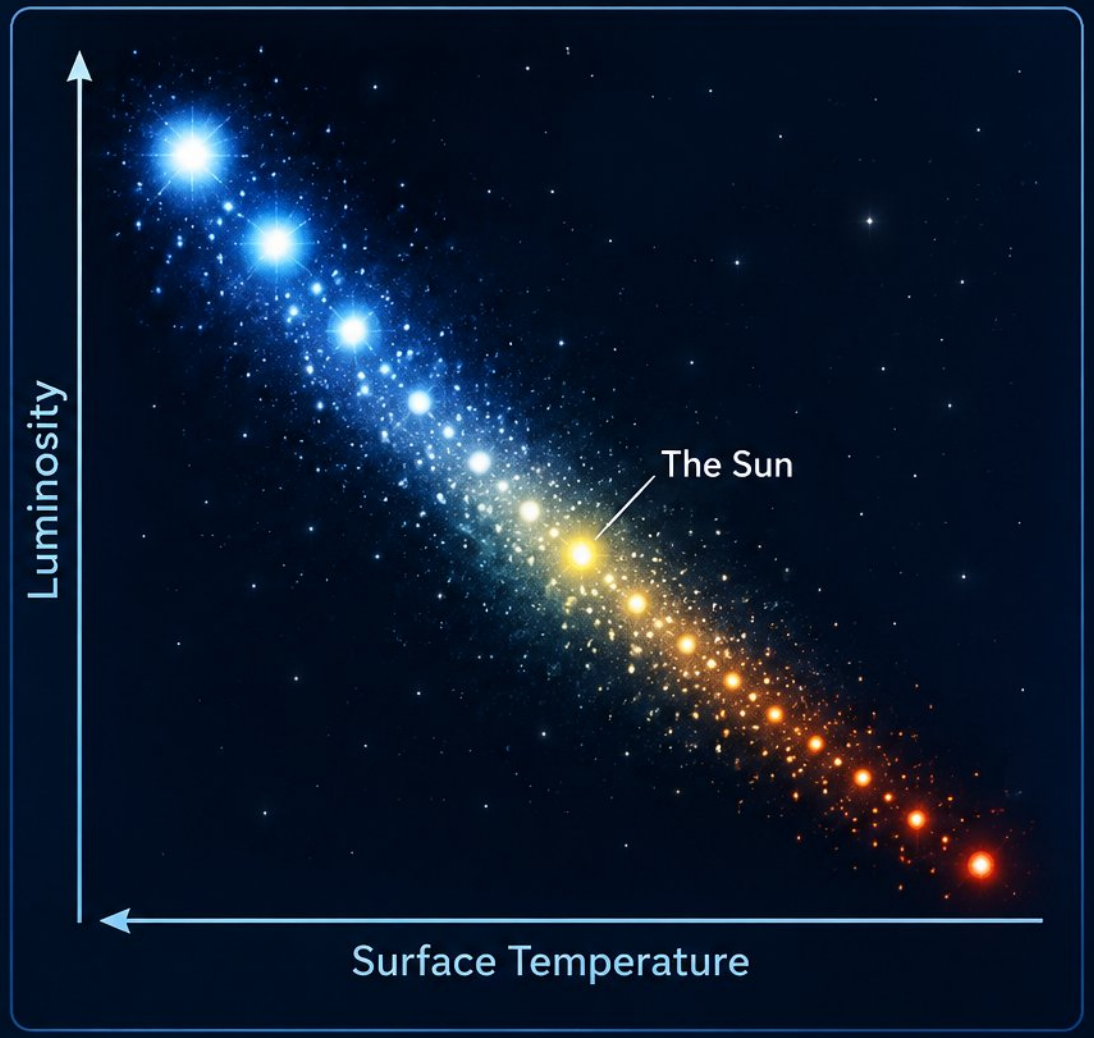





# Main Sequence Stars and the Mass-Luminosity Link

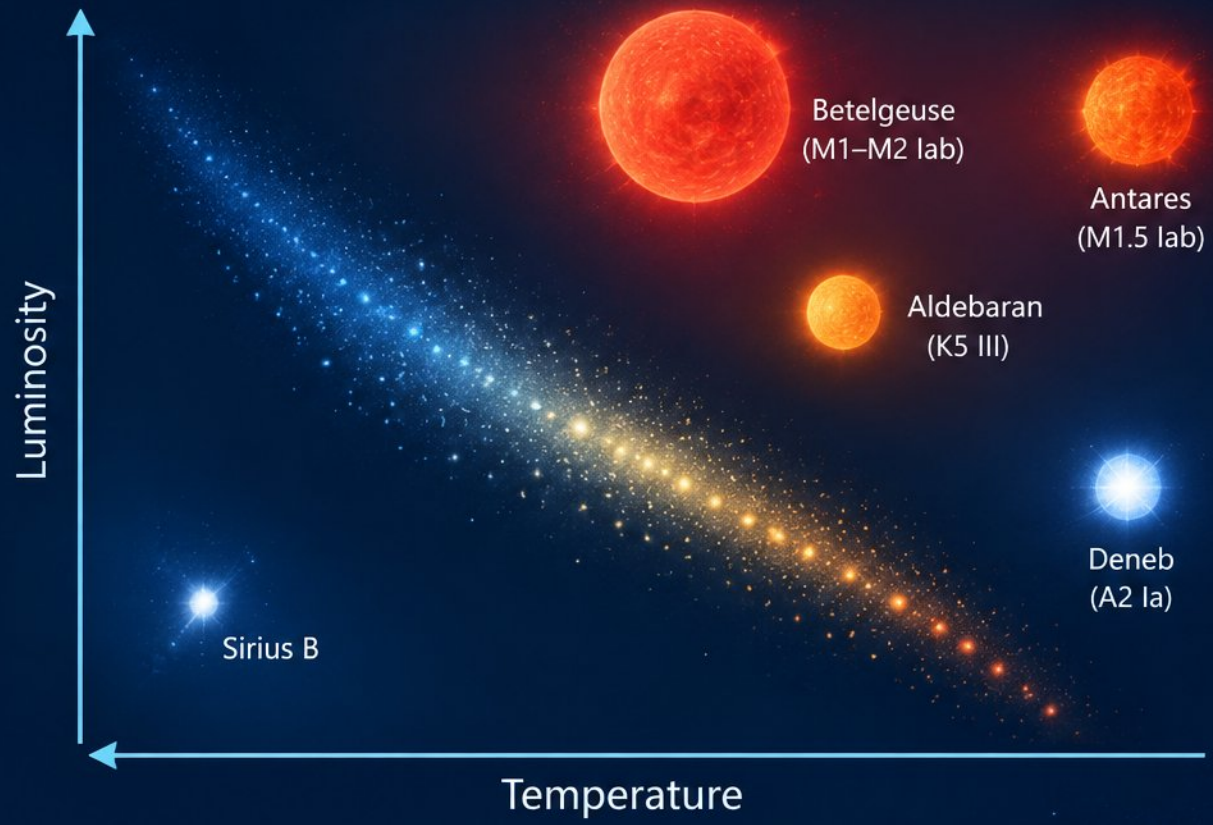
MASS DRIVES TEMPERATURE, LUMINOSITY, AND LIFETIME

- Main sequence: core hydrogen fuses into helium
- Position tracks mass: hot, massive stars upper left
- Mass range ~0.08 to 100+ solar masses
- $L \propto M^{3.5}$: a 10x mass gain means ~3000x luminosity
- Massive stars burn fast and die young; low-mass stars last far longer
- The Sun (G2V, ~5,772 K, 1 $L_{sun}$) sits mid-band



# Giants, Supergiants, and White Dwarfs

- Giants and supergiants: cool yet highly luminous, in the upper right
- White dwarfs: hot but faint, in the lower left
- Stefan-Boltzmann relation: $L = 4\pi R^2 \sigma T^4$ links luminosity, radius, temperature
- Luminosity classes I–V: supergiants, bright, giants, giants, subgiants, main sequence
- Examples: Betelgeuse (M1–M2 Iab), Aldebaran (K5 III), Antares (M1.5 Iab), Sirius B, Deneb (A2 Ia)



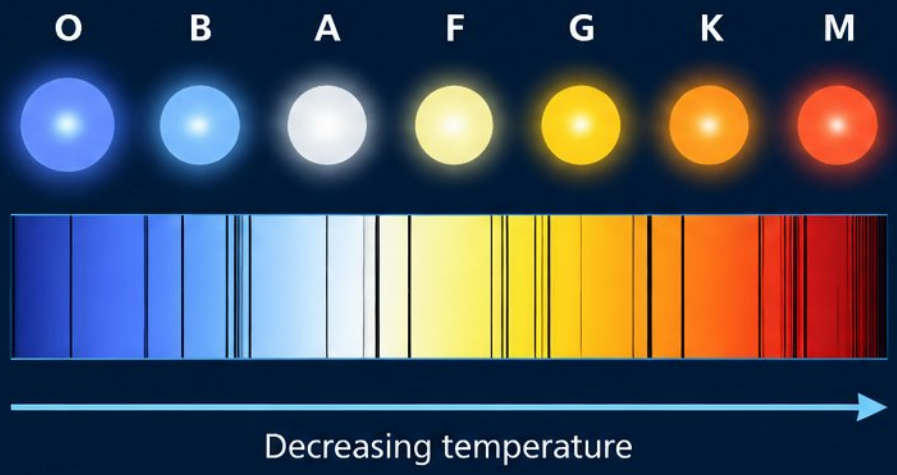

**Luminosity Classes (I–V)**

| | |
|---|---|
| I | Supergiants |
| II | Bright giants |
| III | Giants |
| IV | Subgiants |
| V | Main sequence |

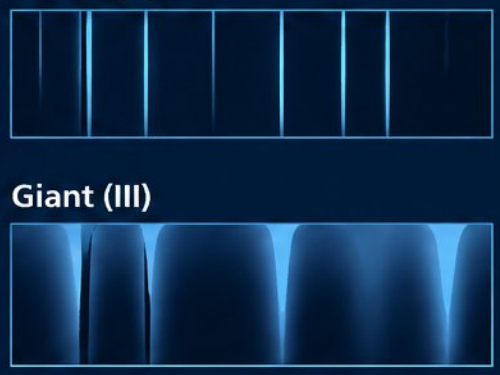
# Spectral Lines and the MK Luminosity Classes

- Spectral lines encode temperature, composition, and surface pressure
- Harvard sequence OBAFGKM orders stars by decreasing temperature
- MK system (Morgan-Keenan-Kellman, 1943) adds a second dimension: luminosity class
- Pressure broadening separates dwarfs from giants at the same temperature
- Full types: Sun G2V, Sirius A1V, Betelgeuse M2 Iab, Arcturus K0 III

## The Harvard Spectral Sequence




## Pressure Broadening at the Same Temperature




Higher surface pressure in dwarfs produces broader spectral lines.

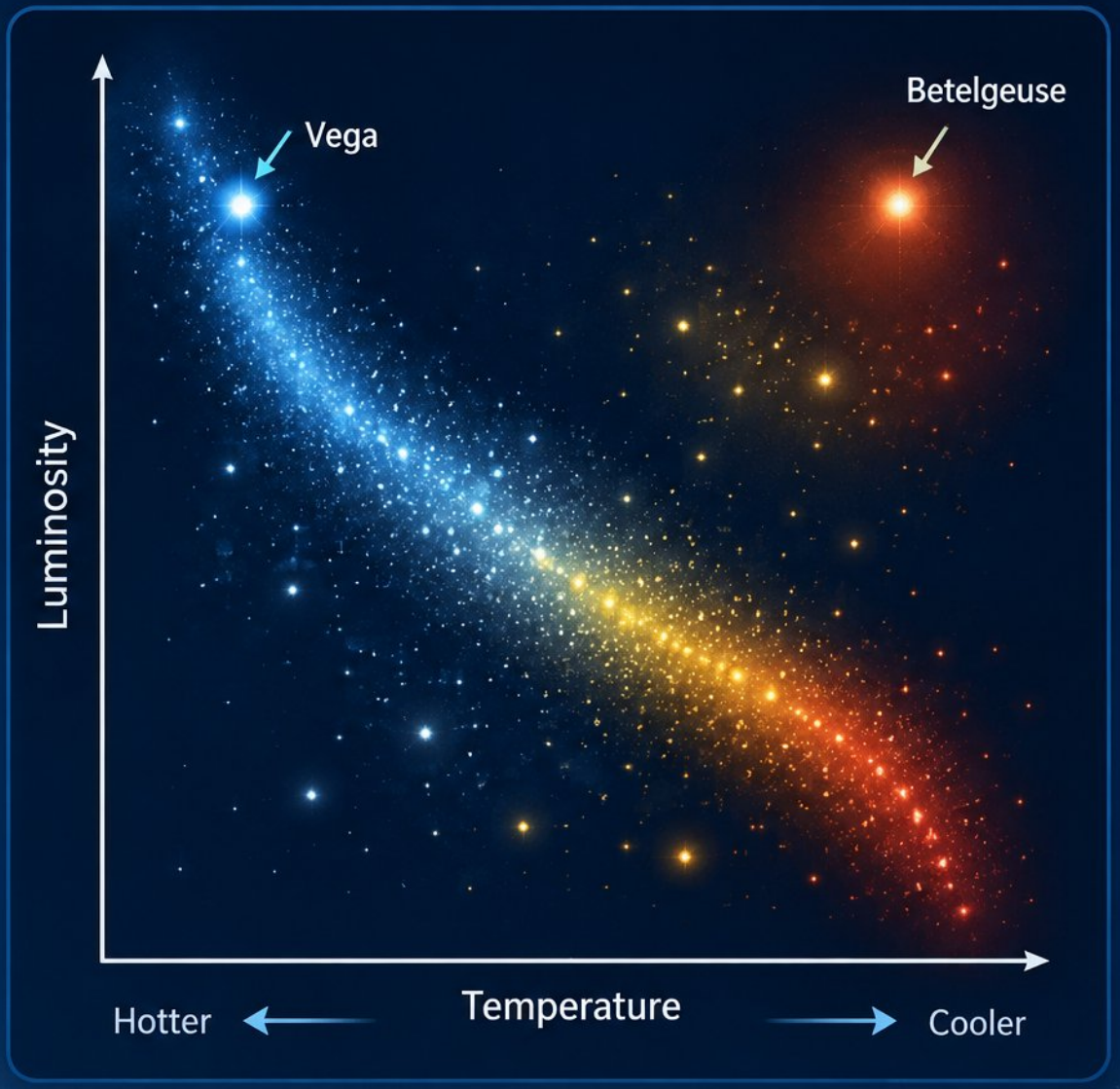
## MK Luminosity Classes

| | |
|---|---|
| I | Supergiants |
| II | Bright giants |
| III | Giants |
| IV | Subgiants |
| V | Main-sequence dwarfs |
| VI | Subdwarfs |
| VII | White dwarfs |

STARS TELL STORIES
IN THEIR SPECTRA

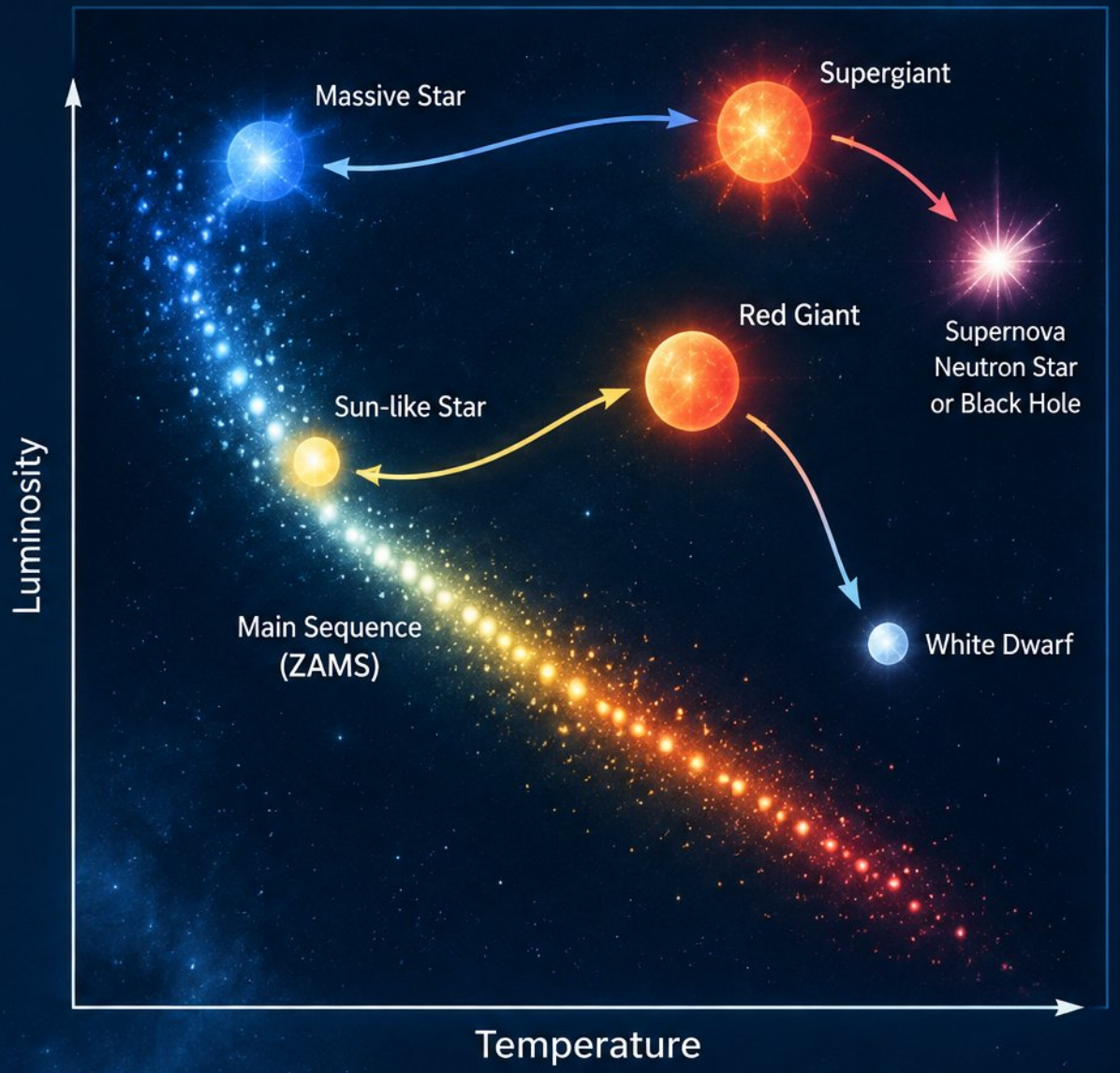
# Demo: Placing a Star on the Diagram

- Given temperature, luminosity, or spectral type: locate the star and infer its class
- Reverse reading: position → temperature, luminosity, radius, and likely stage
- Vega (A0V, ~9,600 K, ~44 L,sun): hot main-sequence star, upper left
- Betelgeuse (~3,500 K, ~10↑5 L,sun): cool supergiant, upper right
- Sanity-check against anchors: Sirius, Rigel, Aldebaran, Proxima Centauri
- Fix common misreads: reversed hot/cool sides; apparent brightness vs. luminosity



# Evolution Across the Diagram

- Stars evolve: protostar track moves down-left to the zero-age main sequence (ZAMS)
- Low-mass stars swell to red giants, then fade to white dwarfs
- High-mass stars become supergiants, then supernovae, neutron stars, or black holes
- Main-sequence turnoff marks cluster age: lower turnoff means older cluster
- Open clusters turn off high and young; globulars turn off near 0.8 M_sun, over 12 billion years
- The diagram maps stellar life stages, not a fixed snapshot



# Observing with the Diagram: Color and Brightness

- Blue-white stars are hot; orange-red stars are cool
- Orion anchors: Betelgeuse (red supergiant) versus Rigel (blue supergiant)
- Seasonal anchors: Aldebaran in Taurus, Vega in Lyra, Arcturus in Boötes
- Color index B−V: negative for blue stars, positive for red stars
- Separate apparent brightness from intrinsic luminosity using distance



# Teaching Activities and Interactive Tools

- Predict-then-plot cycles build real diagram-reading skill
- NAAP H-R Diagram Explorer: change temperature and luminosity interactively
- Star in a Box animates stellar life tracks across masses
- SDSS SkyServer project plots cluster data in spreadsheets
- Spot-the-inconsistent-star claims make quick, assessment-friendly checks



# Common Misconceptions and How to Fix Them



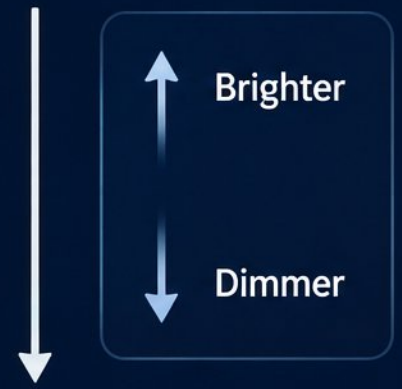
- Reversed temperature axis is deliberate, not a plotting error



- Diagram shows intrinsic properties, not positions in the sky



- Apparent brightness ≠ luminosity; use absolute magnitude for the diagram




- Magnitude runs backward: lower or negative numbers mean brighter



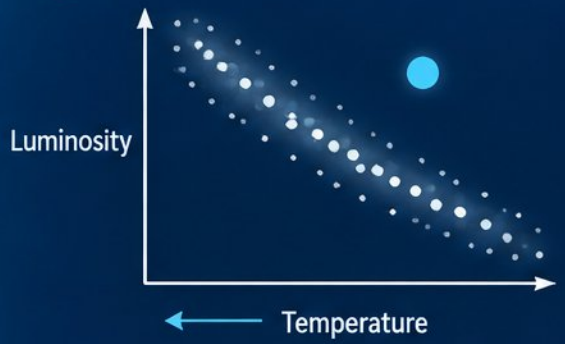
- Main-sequence stars vary by mass, from cool dim to hot luminous

# Practice Set: Read, Classify, and Check

- Position → region, temperature range, and luminosity class
- Spectral type: place F5 IV-V or K5 III and describe the star
- Spot bad claims: a ‘cool, faint supergiant” fails
- Use $L = 4\pi R^2 \sigma T^4$ to estimate radius from L and T
- Answers include explanations and a self-check for common errors




## 1 Classify the star’s position




Determine the star’s region, temperature range, and luminosity class.

## 2 Spectral type

Place F5 IV-V or K5 III and describe the star.




## 3 Spot the bad claim

A star is described as a “cool, faint supergiant.” Why does this claim fail?

“cool, faint supergiant”

## 4 Estimate the radius

Use $L = 4\pi R^2 \sigma T^4$ to estimate the radius from L and T.

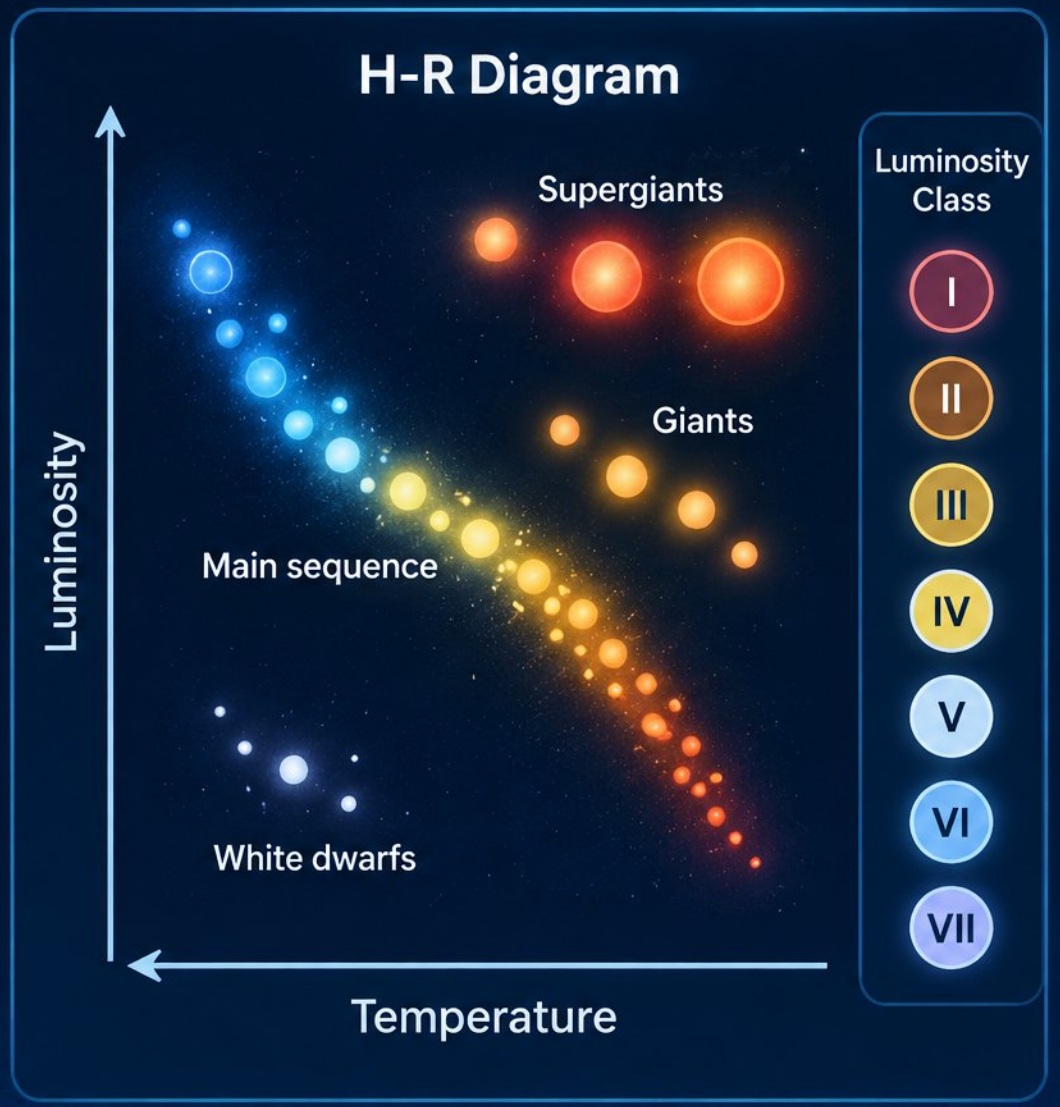
$$L = 4\pi R^2 \sigma T^4$$

Solve for R:

$$R = _____$$

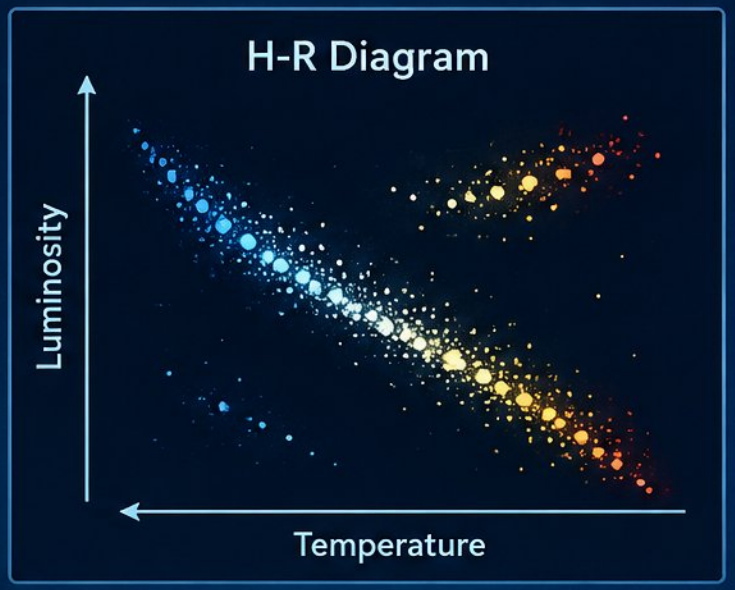
# Five Core Moves for Reading Any H-R Diagram

1. **Move 1:** Orient the axes — temperature increases leftward, luminosity upward
2. **Move 2:** Locate the region — main sequence, giants, supergiants, or white dwarfs
3. **Move 3:** Read temperature and luminosity separately before combining them
4. **Move 4:** Infer radius and evolutionary stage from position
5. **Move 5:** Cross-check with spectral type and luminosity class labels



# Key Takeaways and Next Steps

- The H-R diagram organizes stars by intrinsic temperature and luminosity
- Spectral type plus luminosity class (e.g., G2V) gives a compact physical description
- Position implies radius and evolutionary stage; cluster turnoffs imply age
- Next-step resources: OpenStax Astronomy, NAAP H-R Explorer, Star in a Box, SDSS SkyServer
- Practice further by plotting real stars from catalog data




OpenStax Astronomy

NAAP H-R Explorer

Star in a Box

SDSS SkyServer

PersonWise.

PersonWise • AI digital-human course platform

Scan the code or click anywhere to watch this course live, with voice Q&A

personwise.ai/t/2d724f00/public