Stars: some basic characteristics
Stars!

How bright are they?  What are the different types?
How massive are they?  How long do they live?
How hot are they?
Stellar brightness and luminosity

- The **apparent brightness** (or just the brightness) of an object is how bright it appears to us, or how much radiative energy we receive.
- The **luminosity** of an object refers to how intrinsically bright an object is, or how much total radiative energy it gives off.

The apparent brightness decreases with distance, whereas the luminosity is an intrinsic quantity.
Stellar brightness and luminosity

What is the relationship between the apparent brightness of an object at some distance, and its luminosity? We can figure it out easily using the conservation of energy.
Stellar brightness and luminosity

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- If you imagine a sphere centered on the object, the total radiative energy incident on that sphere will be the same regardless of the sphere’s radius.
- The surface area of a sphere is $4\pi d^2$. So the energy per unit area on that sphere decreases as $1/4\pi d^2$.

\[
\text{apparent brightness} = \frac{\text{luminosity}}{4\pi \times \text{distance}^2}
\]
Stellar brightness and luminosity

We can measure a star’s apparent brightness, and if we also know how far away that star is (for instance by measuring it’s parallax) then we can figure out how luminous it is.

- The most luminous stars are 1 million times more luminous than the Sun \((10^6 L_{\text{sun}})\).
- The faintest stars are one ten-thousandth as luminous as the Sun \((10^{-4} L_{\text{sun}})\).
Q: Two stars have the same luminosity, but one star is bluer than the other. Which star is hotter?

A. The bluer star
B. The redder star
C. We need more information
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The thermal spectrum

Dense objects emit a thermal spectrum based on their temperature. Hotter objects are give off more light per unit surface area at all wavelengths, and peak and a shorter wavelength.
Q: Two stars in a binary system have the same apparent brightness, but one is bluer. Which star is larger?

A. The bluer star

B. The redder star

C. We need more information
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How can we estimate stellar temperatures?

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- Hotter stars are also more luminous at a given size. But a large and cool star can be more luminous than a hot and small star.
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Apparent brightness depends on distance, but color does not. So you can estimate the temperature without knowing anything about the distance!
Spectral types

Stars have absorption line spectra — there is a bright thermal continuum with absorption lines due to the cooler stellar atmospheres
Spectral types

A well-known astronomy professor, Edward Pickering, employed a group of female astronomers to analyze and classify the spectra for huge numbers of stars. He called them “computers”
Spectral types

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O B A F G K M
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(Oh Be A Fine Girl/Guy, Kiss Me)

(1863-1941)
Spectral types
Spectral types

But what causes the difference in the absorption features?

• Recall that the emission/absorption features can be taken as chemical fingerprints: for instance, if there is a strong Hydrogen absorption feature, then you would expect that there is a lot of hydrogen in the star.

• But actually it isn’t that simple!
Spectral types

In her PhD thesis, Cecilia Payne-Gaposchkin showed that actually all stars consist almost entirely of hydrogen and helium. There are only trace amounts of the heavier elements.
Spectral types

The reason that O- and B-type stars have few absorption lines is that they are very hot. There is so much thermal energy in their atmospheres that most of the elements become ionized; if the electrons aren’t attached to nuclei, then they can’t transition between energy levels and so they can’t absorb photons.
Spectral types

The reason that O- and B-type stars have few absorption lines is that they are very hot. *There is so much thermal energy in their atmospheres that most of the elements become ionized;* if the electrons aren’t attached to nuclei, then they can’t transition between energy levels and so they can’t absorb photons.

In contrast, K- and M- type stars are relatively cool. So there are a lot of atoms and molecules in their atmospheres that still have their electrons, and those electrons absorb photons.
Hotter stars have bluer spectra, and have no absorption features.

Cooler stars are redder and have lots of absorption features.
The Hertzsprung-Russell diagram

If you plot stars on a graph of luminosity versus temperature, then you see some very clear patterns emerge.
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The Hertzsprung-Russell diagram

Most stars, including the Sun, are on the "main sequence"
The Hertzsprung-Russell diagram

Stars on the upper left of the main sequence are hotter. They are also more luminous; this is partially because they are hotter, but also because they are larger.
Giants and supergiants are very luminous, but have relatively low temperatures. So we know that they must be very large.
The Hertzsprung-Russell diagram

So stars of a given spectral type/temperature might be normal main sequence stars, or they might be giants!
The famous star cluster Omega Centauri
• https://www.youtube.com/watch?v=jiSN95WX1NA
If you zoom way in, you can see that the brightest objects are all very blue or very red. The blue ones are mostly hot O- and B- type stars (or “horizontal branch” stars), and the red ones are cool giants.
If you zoom in even more, you see that some of the fainter stars are blueish or white, and the faintest stars are red
Q: Two stars have the same spectral type but one of them has 100 times fainter apparent brightness. How much further is that star than the other?

A. 100 times closer
B. 10 times closer
C. 10 times further
D. 100 times further
E. We don’t have enough information
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B. 10 times closer
C. 10 times further
D. 100 times further
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Q: Two main sequence stars have the same spectral type but one of them has 100 times fainter apparent brightness. How much further is that star than the other?

A. 100 times closer
B. 10 times closer
C. 10 times further
D. 100 times further
E. We don’t have enough information
Q: Two stars on the main sequence have the same spectral type but one of them has 100 times fainter apparent brightness. How much further is that star than the other?

A. 100 times closer  
B. 10 times closer  
C. 10 times further  
D. 100 times further  
E. We don’t have enough information