Recap of last time

Photometry: Measuring light intensity

- Magnitude: Brightness measurement in a single filter
- Color: Difference of two magnitudes, sensitive to temperature

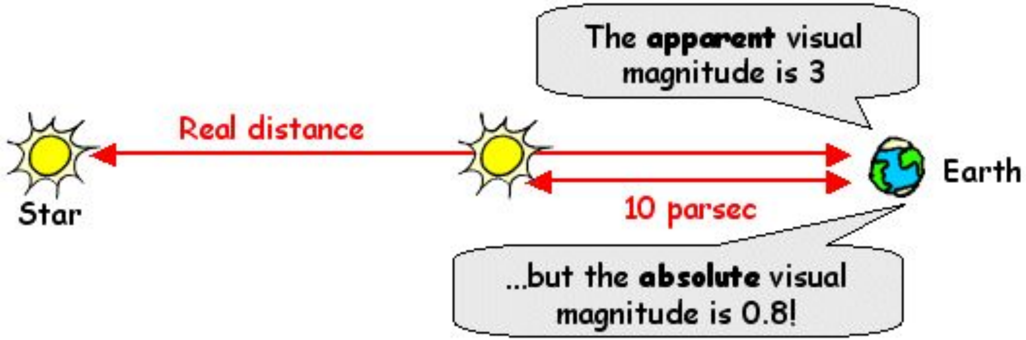
Astrometry: Measuring positions and motions (6D!)

- First 4 dimensions: Positions and velocities on the plane of the sky
- 5th dimension (distance): Derived from parallax measurements
- 6th dimension (radial velocity): Must be measured from spectra

Before we start with spectroscopy, a few extra details →

Absolute and apparent magnitudes

Objects have intrinsic brightnesses (**luminosity**), but their distance affects how bright or faint they appear to us here on Earth.



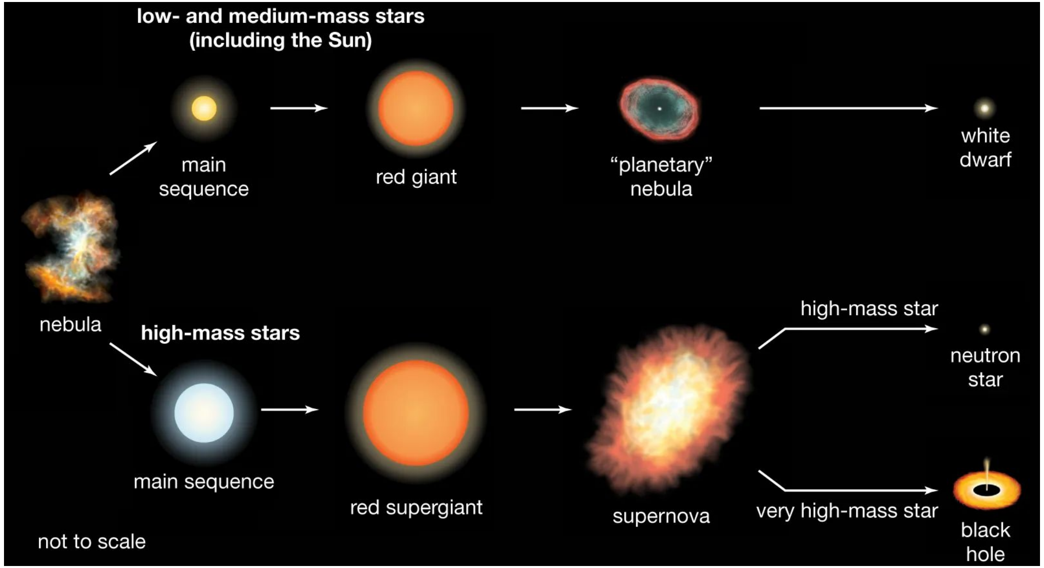
Absolute magnitude (M):
Brightness if the object were placed at 10 pc

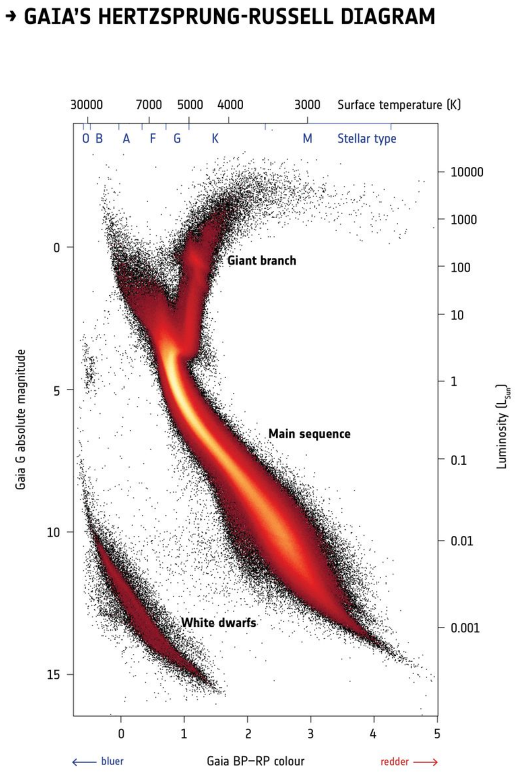
Apparent magnitude (m):
What we measure on Earth

$$m - M = 5\log\left(\frac{d}{10}\right)$$

distance (pc)

Color-magnitude diagrams





CMDs allow us to distinguish the different stages of stellar evolution just with photometric information

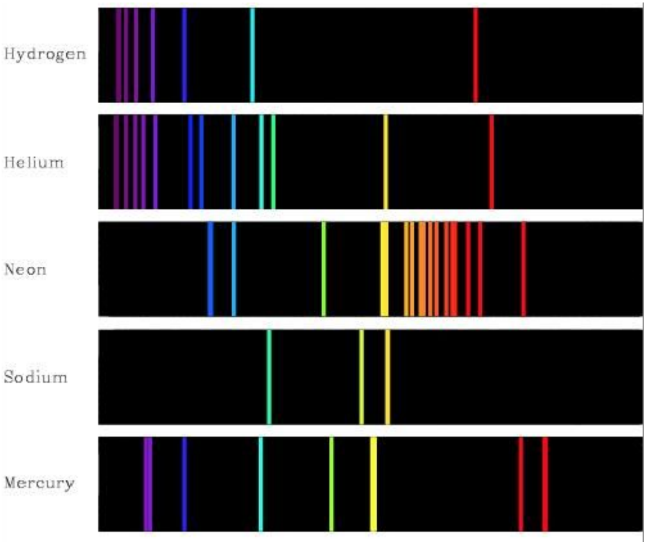
Spectroscopy

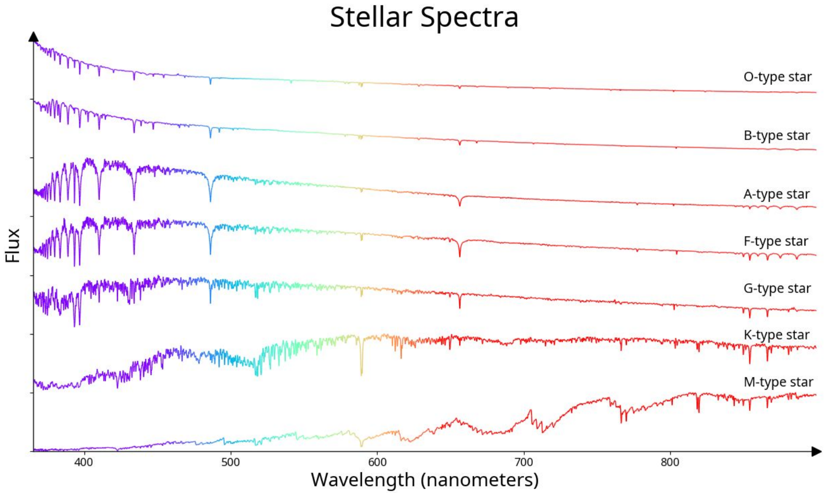
ASTR 2910 ⭑ Week 8

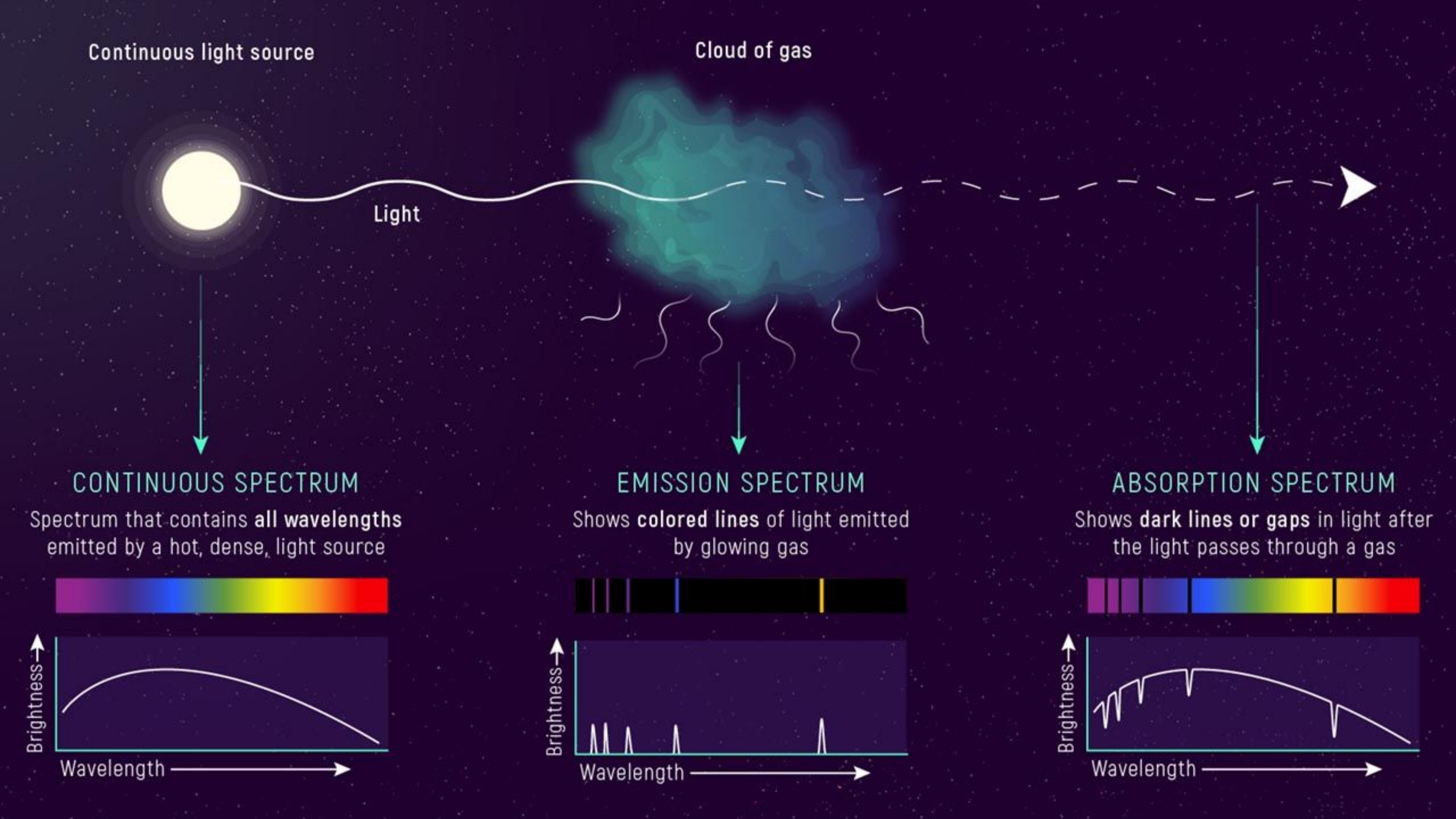
What is a spectrum?

Measurement of the flux (# photons/time) received at different wavelengths.

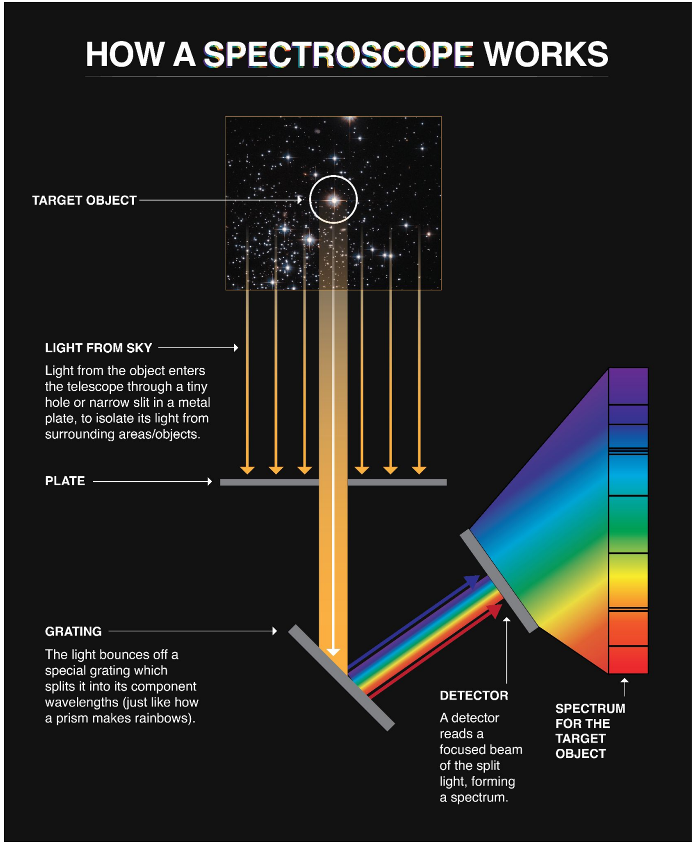
Spectral lines correspond to specific energy transitions within atoms. Each element on the periodic table has a unique spectral "fingerprint."





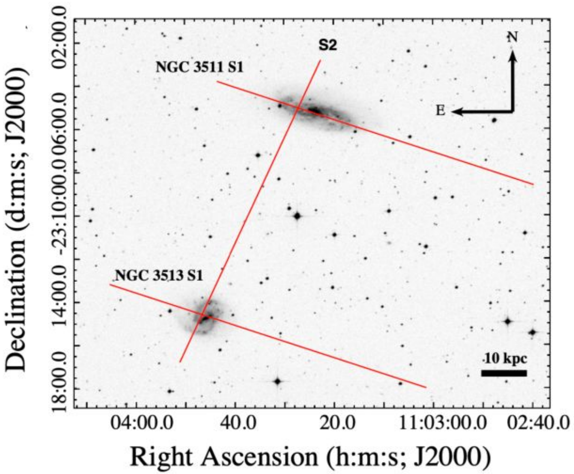

Continuous light source
Cloud of gas
Light
CONTINUOUS SPECTRUM
Spectrum that contains **all wavelengths** emitted by a hot, dense, light source
Brightness
Wavelength
EMISSION SPECTRUM
Shows **colored lines** of light emitted by glowing gas
Brightness
Wavelength
ABSORPTION SPECTRUM
Shows **dark lines or gaps** in light after the light passes through a gas
Brightness
Wavelength

How do we get spectra?



Light enters through slit → split up by diffraction grating or prism → recorded by detector

Different gratings have different wavelength ranges and resolutions.



Slits are narrow, but have different lengths; some are long enough to lie across whole galaxies!

What information does a spectrum give us?

- Chemical composition
- Surface gravity
- Radial velocity
- Temperature
- And more…

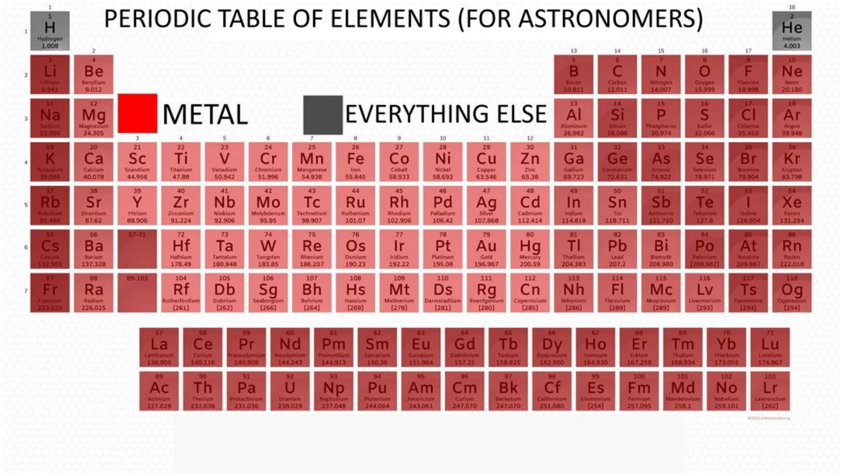
Hard to get with photometry!

Stellar spectra tell you the composition of the star's atmosphere

"Integrated" spectra of galaxies tell you about the stellar populations and the activity level of the central black hole

Spectra of diffuse objects (e.g. planetary nebulae) can tell you what they are/how the gas was heated

Metallicity and abundances



Metallicity (Z)

- Amount of elements heavier than H
- Often reported as [Fe/H]: ratio of iron to hydrogen, normalized to the value in the Sun (so $[Fe/H]_{\odot} = 0$)

Abundances (for any element X)

- Amount of that element that is present in a given object
- Usually reported as [X/Fe] (also normalized to solar values)

How do we get that information?

Stronger lines = more of that element

Other properties come from fitting the width of lines, determining the position of the lines (redshift/blueshift), etc.

In essence: fitting complicated models

GALAH

GALAH = **GAL**actic **A**rchaeology with **H**ERMES =

- High-resolution spectroscopic survey
- Running since 2013
- Main science goal: Survey one million stars in the Milky Way to trace its history
- DR4 (October 2024): ~917,000 stars
- Provides spectra and derived properties, including over 30 (!) elemental abundances

Let’s explore some GALAH data!