

ASTR 511

Galactic Astronomy

Lecture 01

Introductions & Review

Prof. James Davenport (UW)

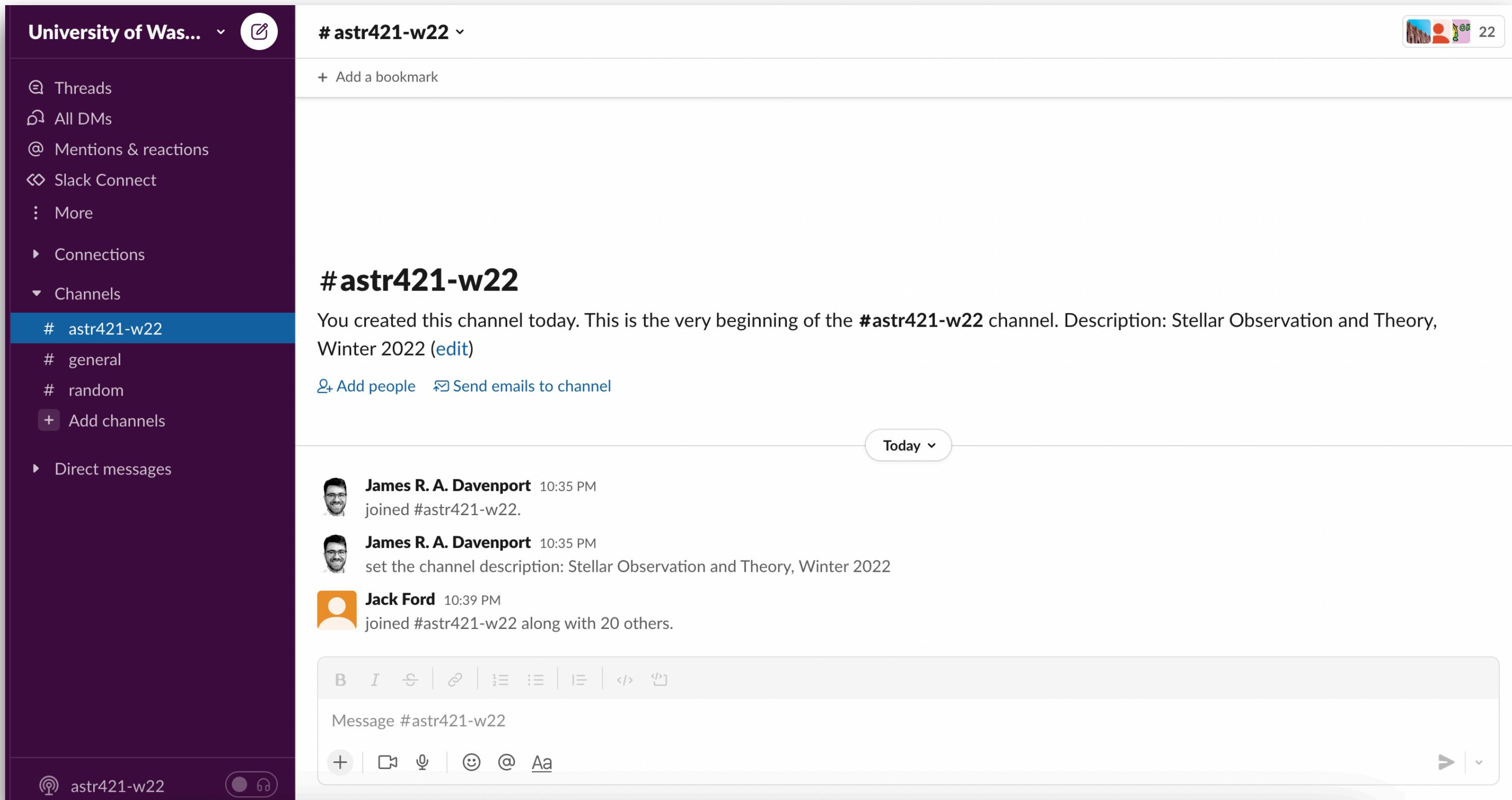
Winter 2023

Introductions

- Course Website: <https://jradavenport.github.io/astr511wi23/>
- Your instructor... me!
 - Prof. James Davenport
 - Associate Director of the DiRAC Institute @ UW Astro
 - I work on stars, SETI, big data, time domain astronomy, wacky ideas
 - I like coffee, gardening, the PNW,



Communication



- Zoom (obv)
 - Stable Zoom link all quarter (hopefully)
- Slack
 - Good for general Q's, asking for help
 - If you didn't get added, ping me!
- Email, b/c I'm old
- Course website
- Canvas: for grades only.

COVID protocols...

- **We will strive to be 1) safe, 2) empathetic, and 3) practical**
- If you get sick or may be exposed, please let us know as appropriate
- If you need to miss a class activity because of a COVID-related disruption, let me know
- I will strive to do the same... it happened last year!

Code of Conduct

- Absolutely no bullying, harassing, disruptive, rude, or exclusive behavior will be tolerated – both in-person & virtually.
- Work together, be kind
- No tool shaming
- <https://www.washington.edu/cssc/for-students/student-code-of-conduct/>
- <https://www.washington.edu/cssc/for-students/academic-misconduct/>

Evaluation

- Assignments (70%)
 - Turned in via **Dropbox links**
 - Planning for ~4 homeworks
- Final Project (30%)
- Notes about GROUP WORK
No extra credit

Most (all?) assignments will be coding-focused. We expect most people will use Python/Jupyter, but any language/tool that you want to use is OK!

Final Project term paper requires you to use LaTeX, and give a presentation

Next Week: AAS 241

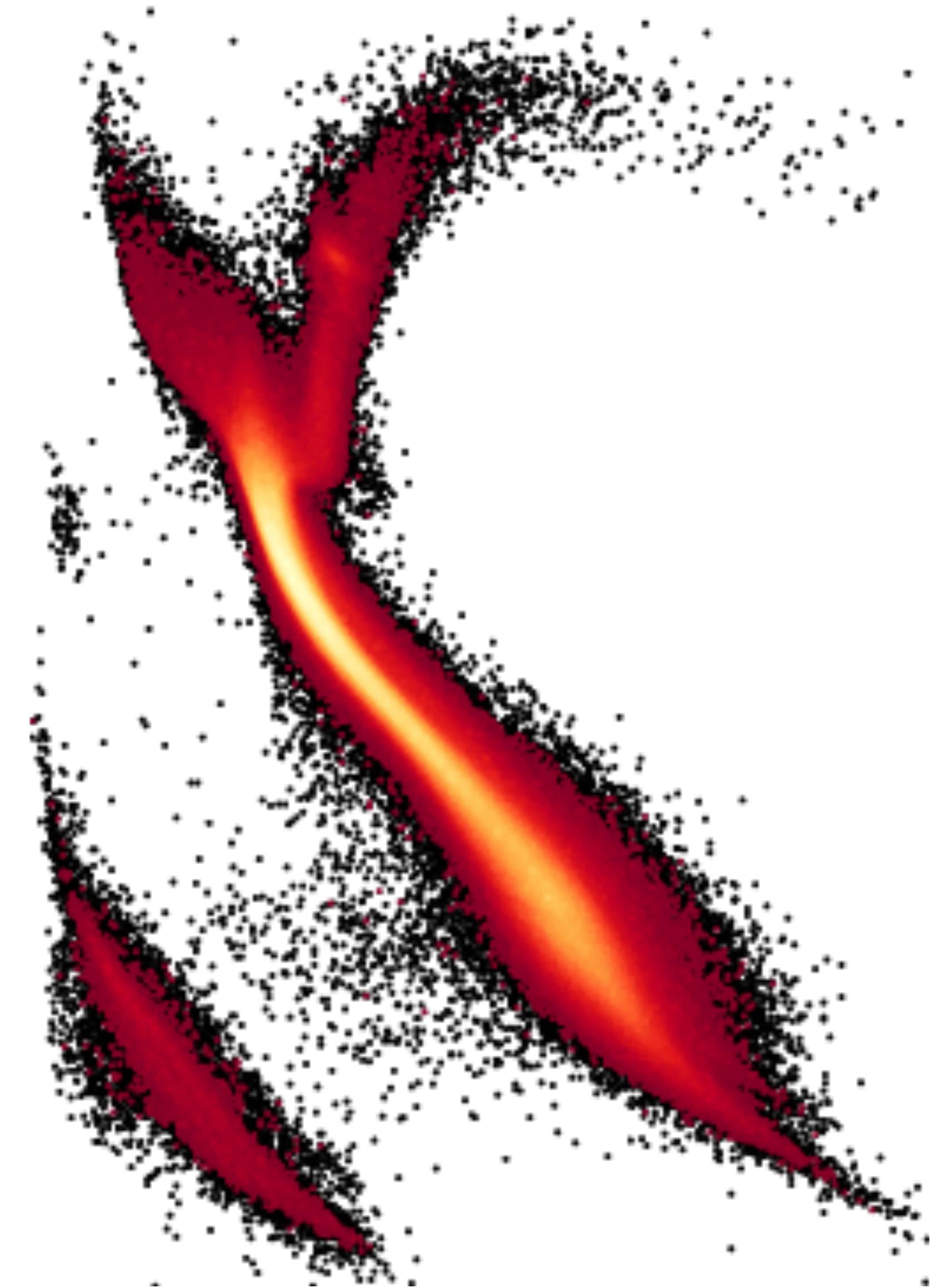
- **This class will not be held during AAS 241**
 - You will learn more there than I can teach you in 2 sessions.
- There is a (mostly fun) “scavenger hunt” assignment: [**Homework 1**](#), posted now!
- If you are not attending AAS, you can complete it using the arXiv.
- I’ll make time on Thursday for this also, but **are there any questions/thoughts/concerns you have about AAS?**

What's the point?

- **A word on teaching/course philosophy**
 - No book? Term paper?! Why do we have these lectures?

Read the syllabus

- All these details and more are in the syllabus.
- **Any questions? Let's take a moment...**



Introduce yourselves!

To make sure we all know each other, can you please share:

- Preferred Name & Pronouns
- Year & Advisor(s)
- Have you ever seen the Milky Way or any other galaxy? If so, when?

Now, on to Lecture 01!

Course Goals

- This course has been “Galactic Astronomy”, “Galaxies”, “Galactic Structure”...

ASTR 511 Galactic Structure (3)

Kinematics, dynamics, and contents of the galaxy. Spiral structure. Structure and evolution of galaxies.

Version 5 from Feb 9, 2015

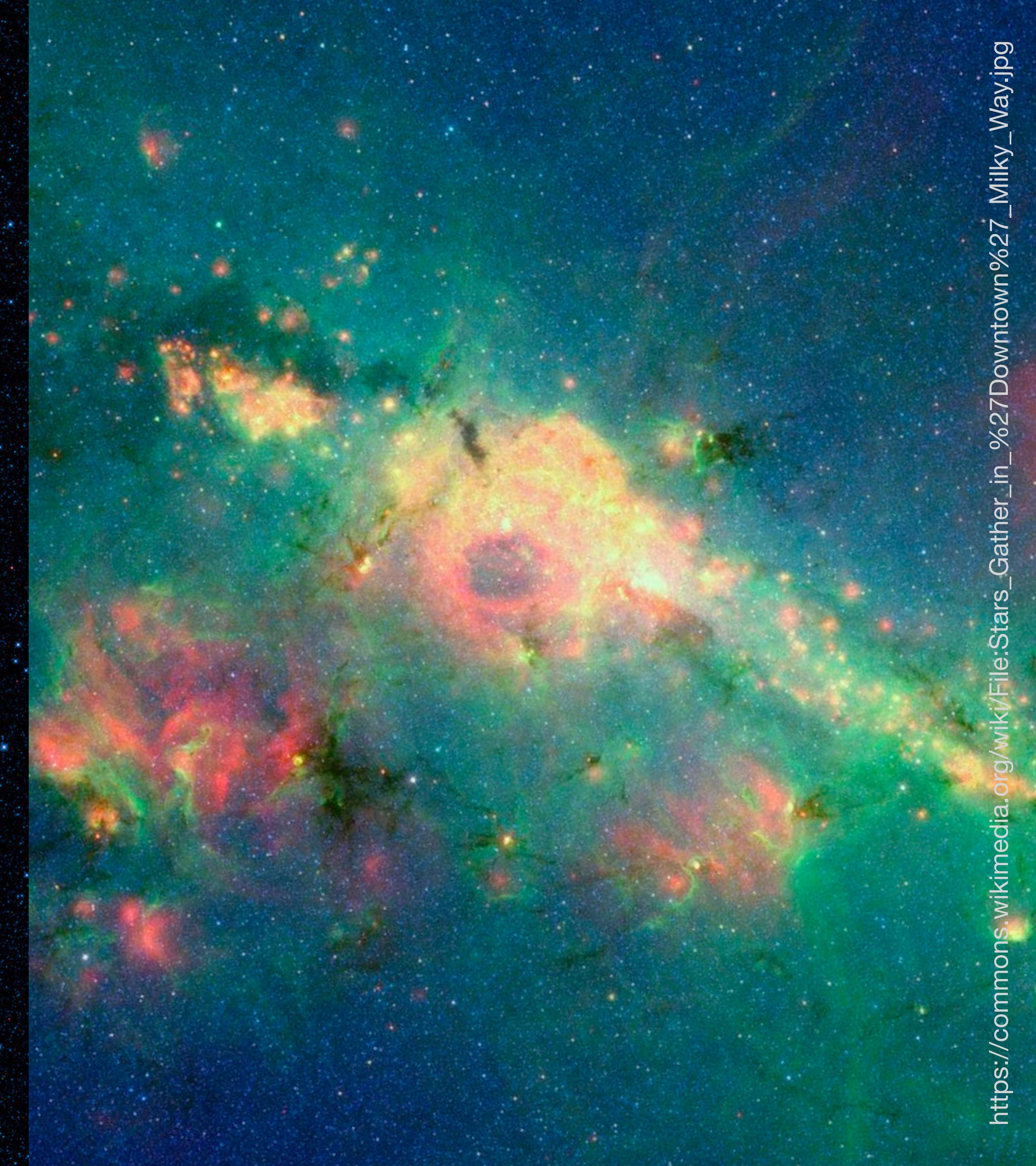
ASTR 511: Galactic Astronomy

ASTR 511, Winter 2021: Galaxies as Galaxies

- So, is this course about the history, contents, and structure of the Milky Way, or about the study of other galaxies?
- Some aspects are the same, some are *very different!*

Course Goals

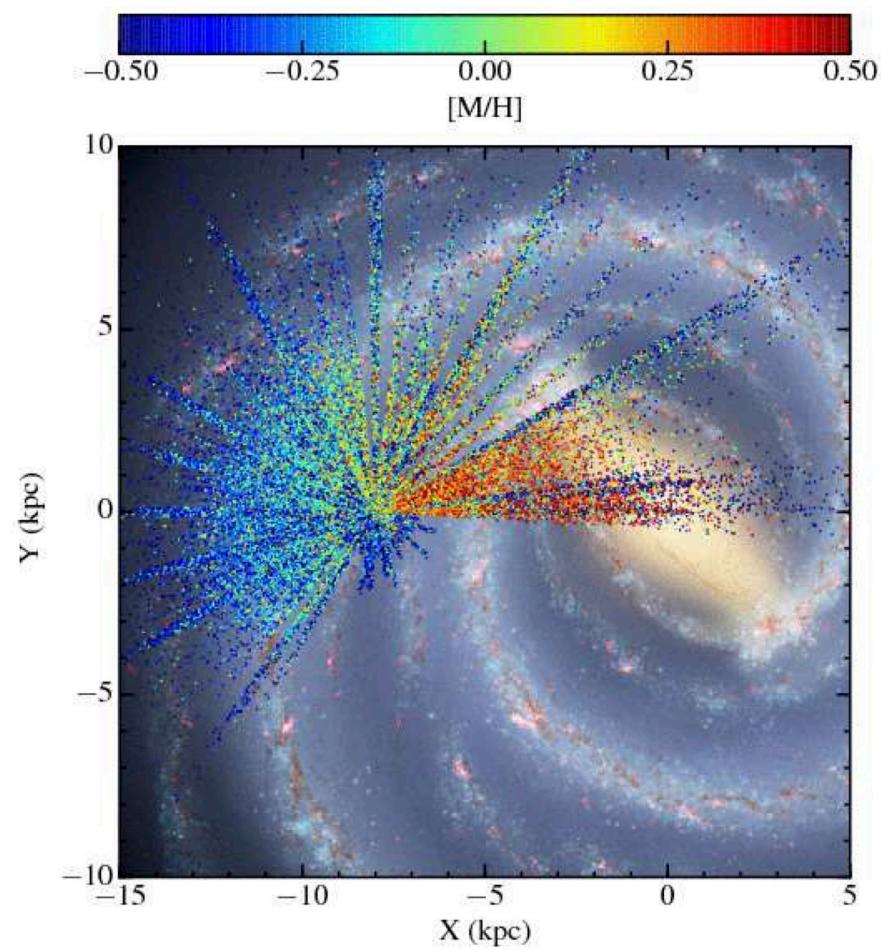
https://commons.wikimedia.org/wiki/File:WISE_-Andromeda.jpg



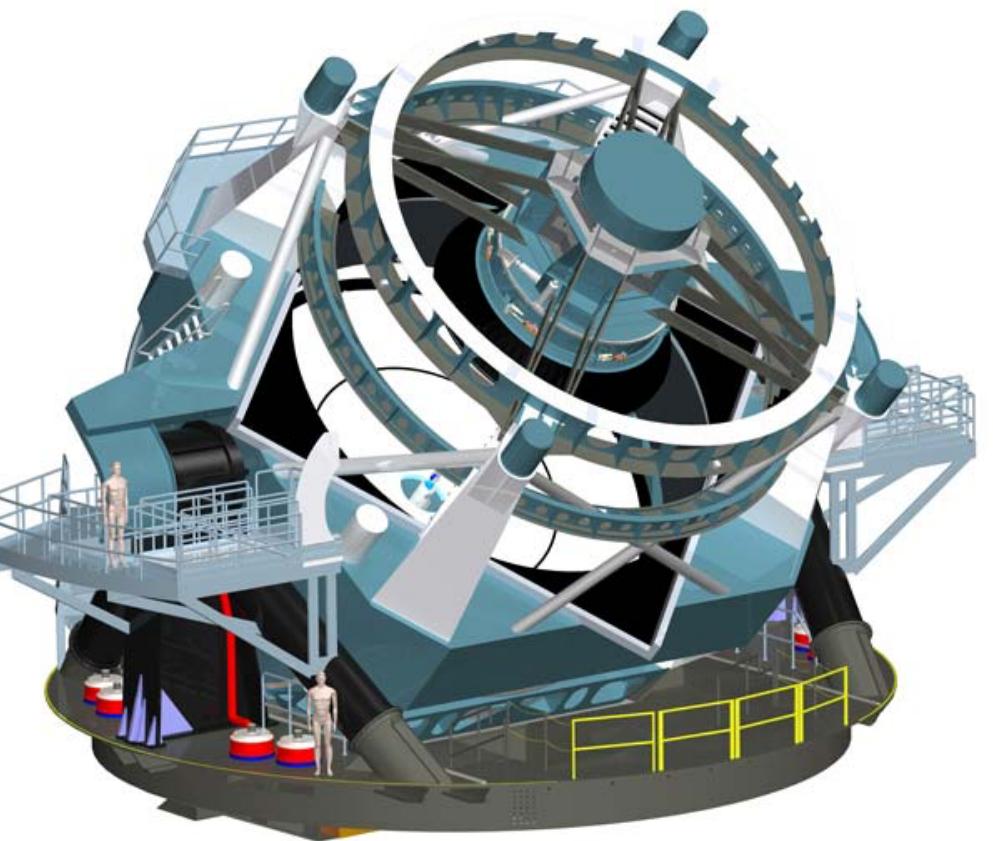
https://commons.wikimedia.org/wiki/File:Stars_Gather_in_Milky_Way.jpg

Course Goals

- Both... but with an emphasis on the Milky Way
 - Because I think about nearby things, and it is timely...
- **Now is a golden age for galactic astronomy observations**



SDSS-V



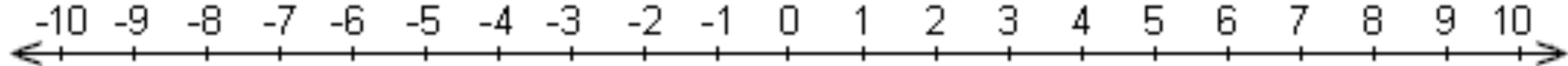
Course Goals

- Also an amazing time for theory!

Course Goals

- Going to (roughly) structure the course from **near to far**

Astro Jargon Review



- Magnitudes (apparent vs absolute) & flux
- Colors

$$m_i = -2.5 \log_{10} \left(\frac{F_i}{F_0} \right)$$

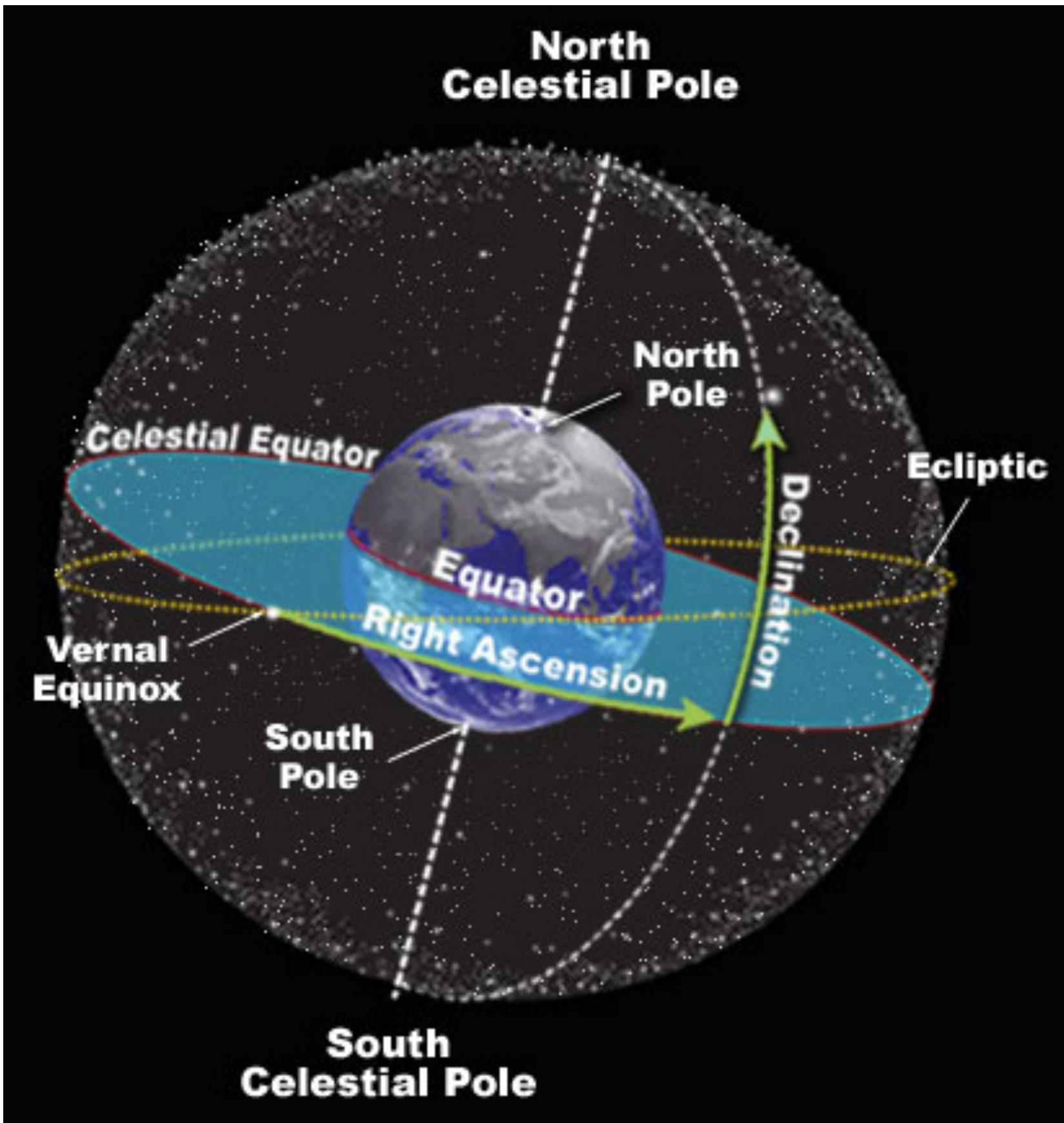
$$m - M = 5 \log_{10} d[pc] - 5$$

$$B - V \equiv m_B - m_V \equiv M_B - M_V$$

Bold statement: magnitudes are a good unit!

Astro Jargon Review

- Parallax & distance modulus
- 3D positions (ra,dec,distance)

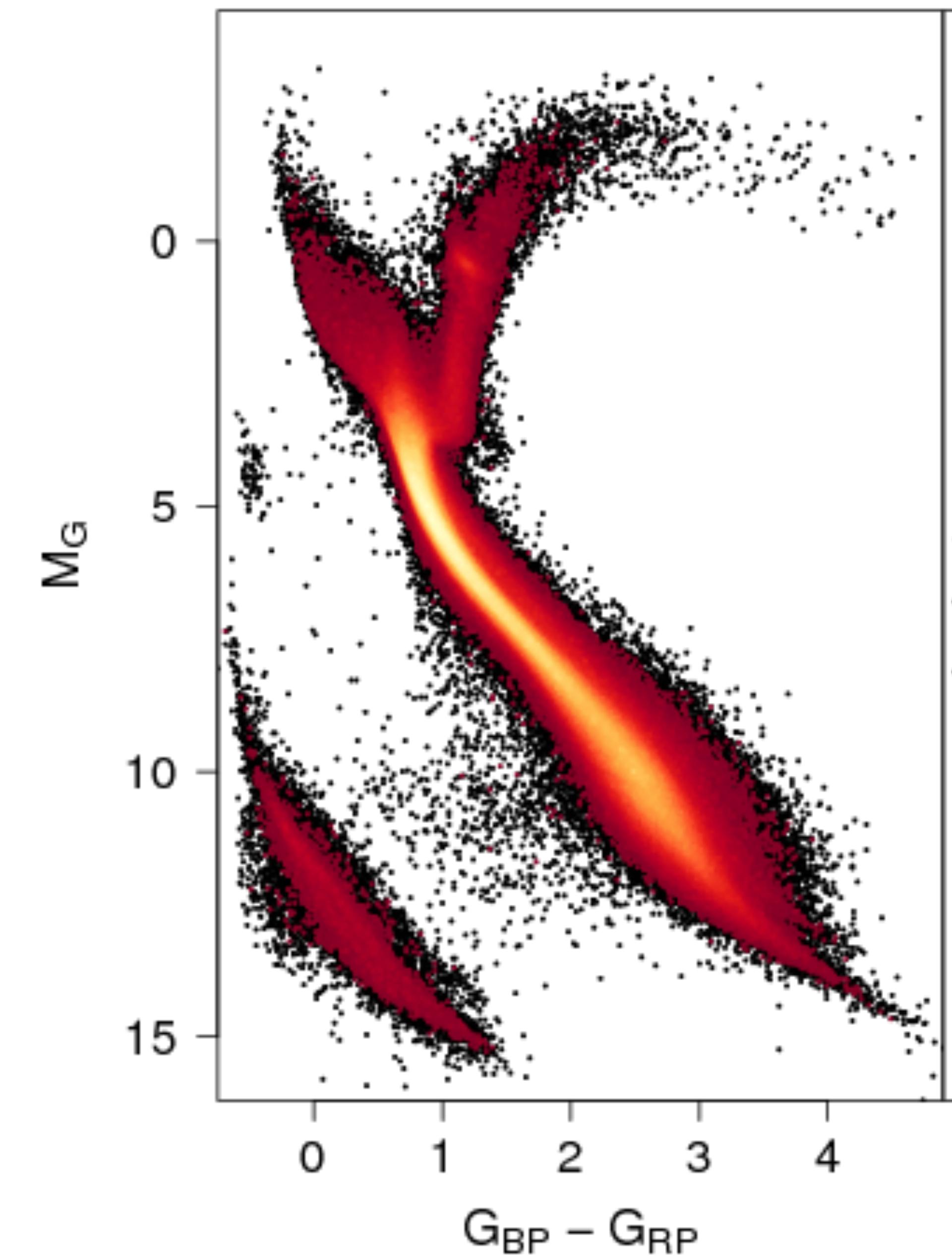


$$m - M = 5 \log_{10} d[pc] - 5$$

$$m - M = 5 \log_{10}(1/\pi) - 5$$

Astro J

Gaia DR2 CMD

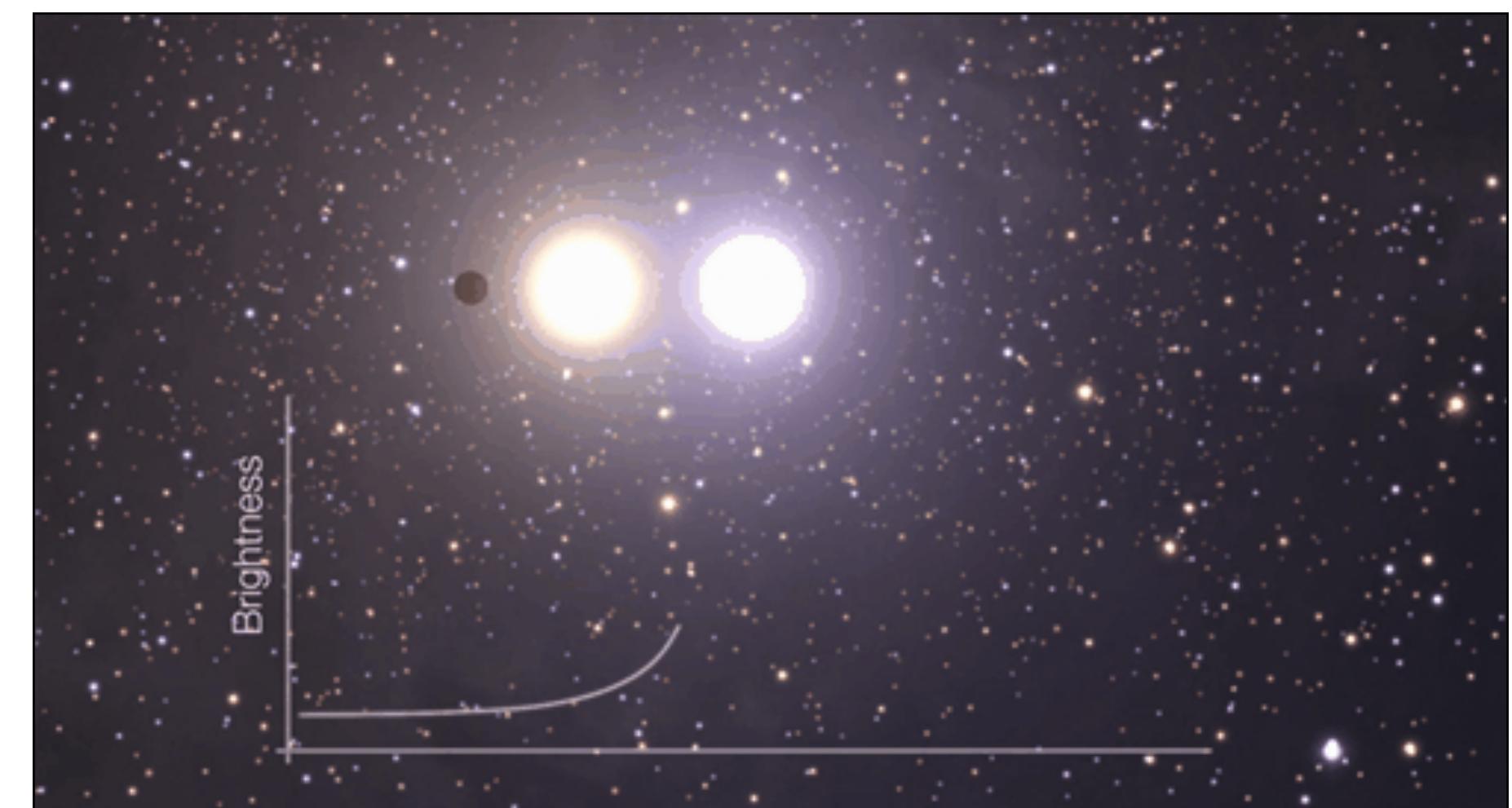
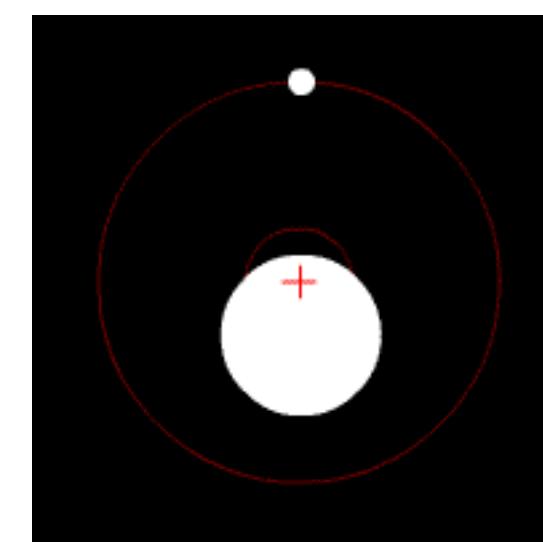


Stars

- Since they are one of the primary ways we understand the structure and history of our galaxy, let's start with a quick refresher, all of which you should probably know

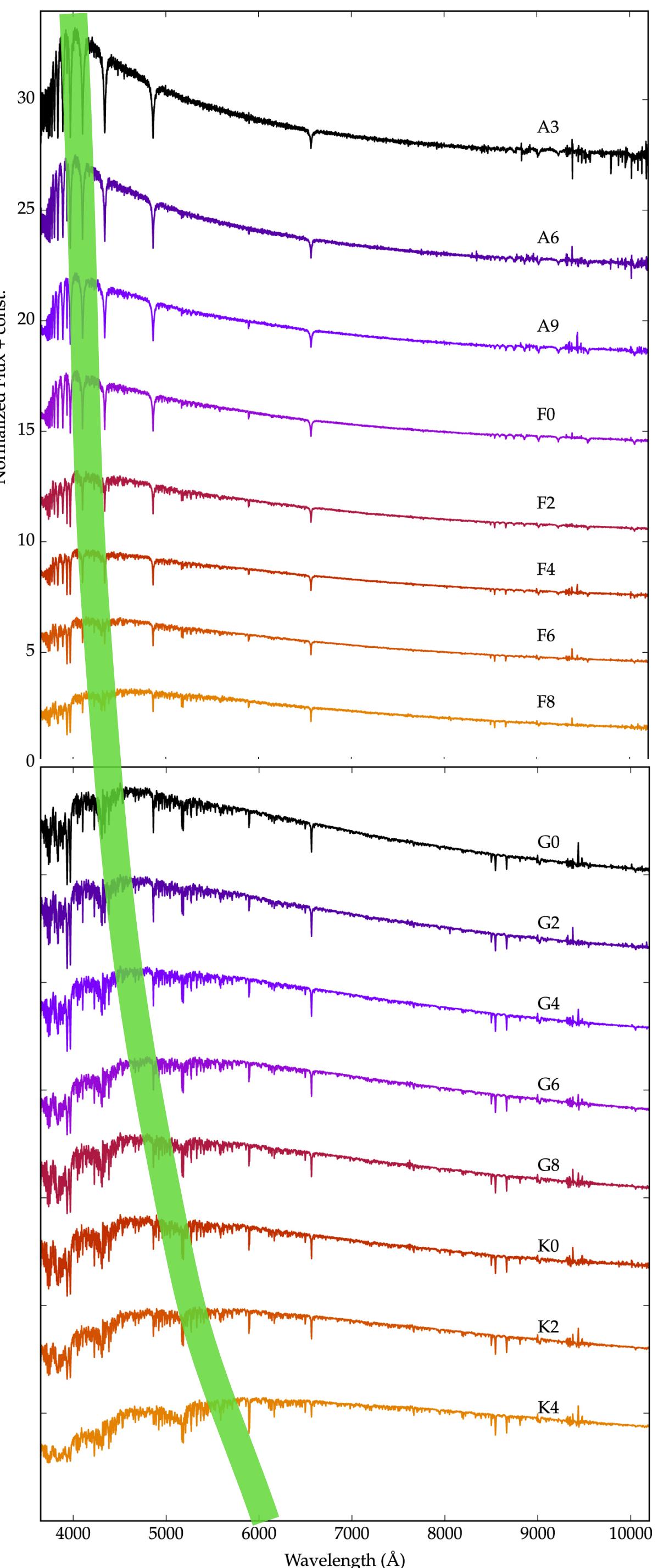
Mass

- **Mass is probably the most important/fundamental property for a star**
- It factors into all timescales at work, most other general properties (e.g. radius, temp, etc) are directly related to mass
- However, not much about the star itself is actually a direct measurement of mass
- This makes mass relatively easy to estimate by proxy, and difficult to directly measure.
- Enter: Kepler's laws (esp. eclipsing binary stars & exoplanets)
- Also useful: lensing!



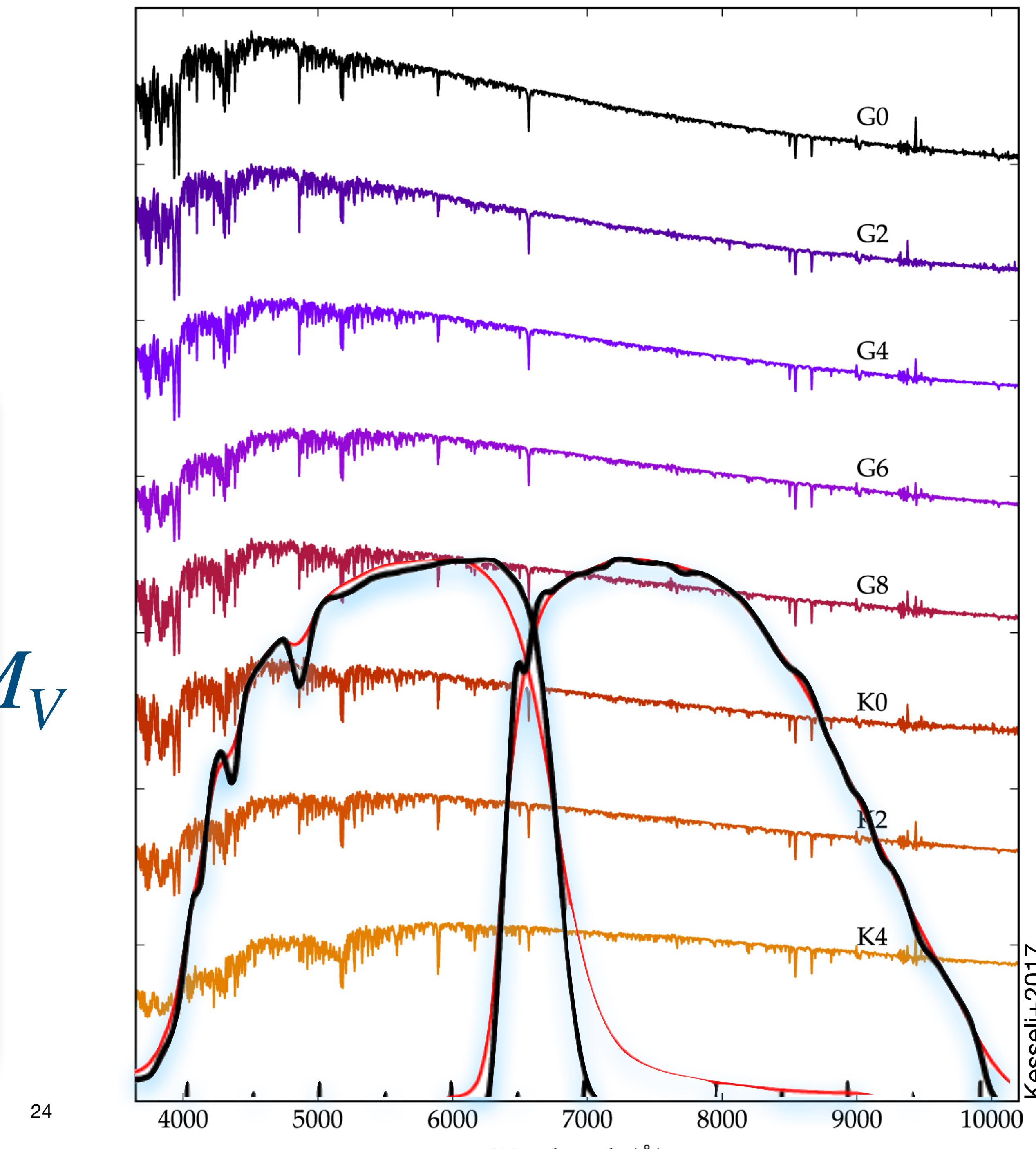
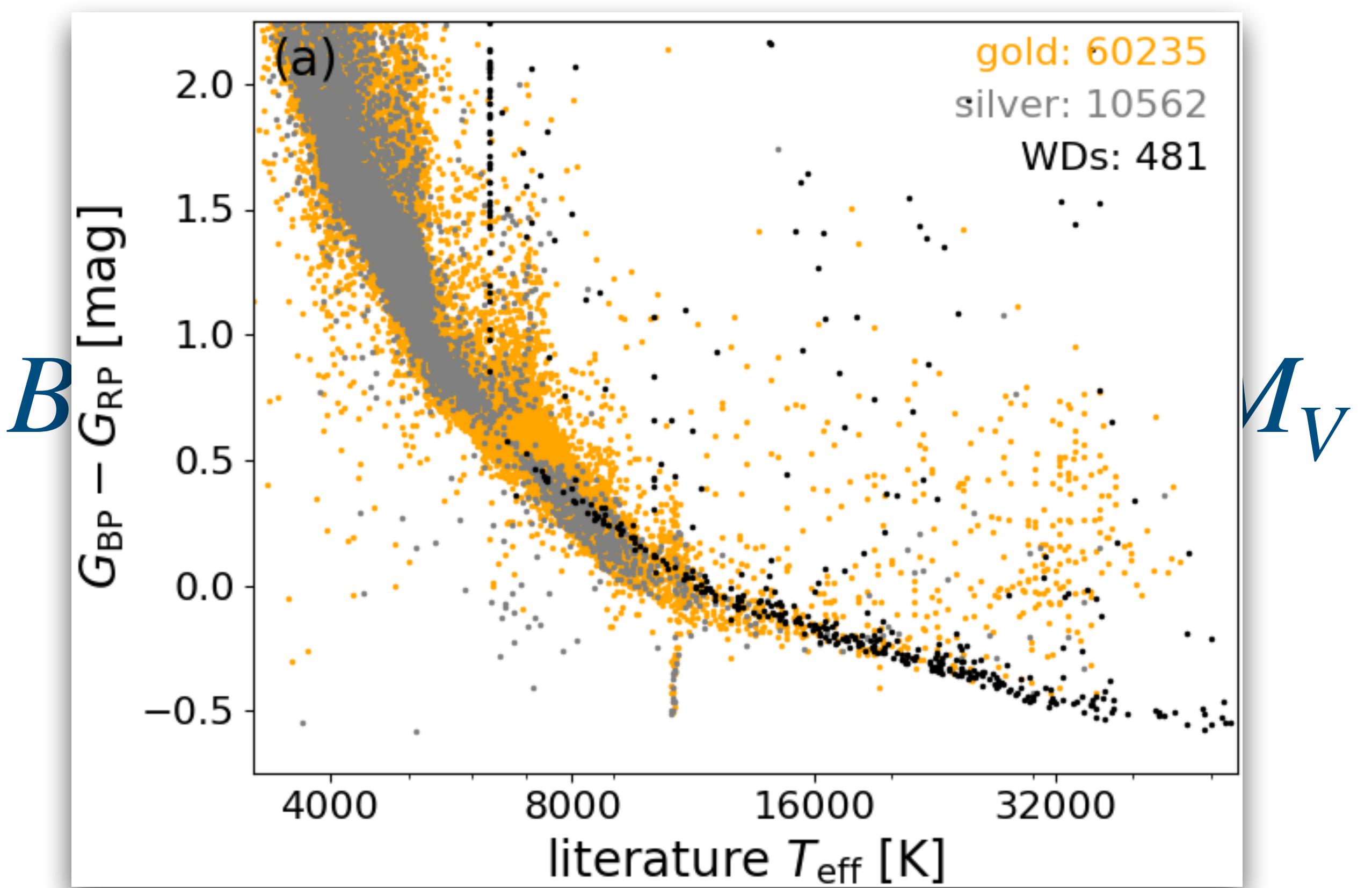
Temperature (T_{eff})

- Probably the most common property to measure
 - Many ways to constrain!
 - Spectroscopically (e.g. Wien's Law)
 - The “effective temperature” is the Temp that a star would have if it were a perfect blackbody with the same luminosity
- $$L = 4\pi R^2 \sigma_{SB} T^4$$
- Very close to the surface temp for some stars
 - Harder to estimate for cool stars



Temperature (T_{eff})

- Also can constrain with photometry via the “color”



Luminosity

$$L = 4\pi R^2 \sigma_{SB} T^4$$

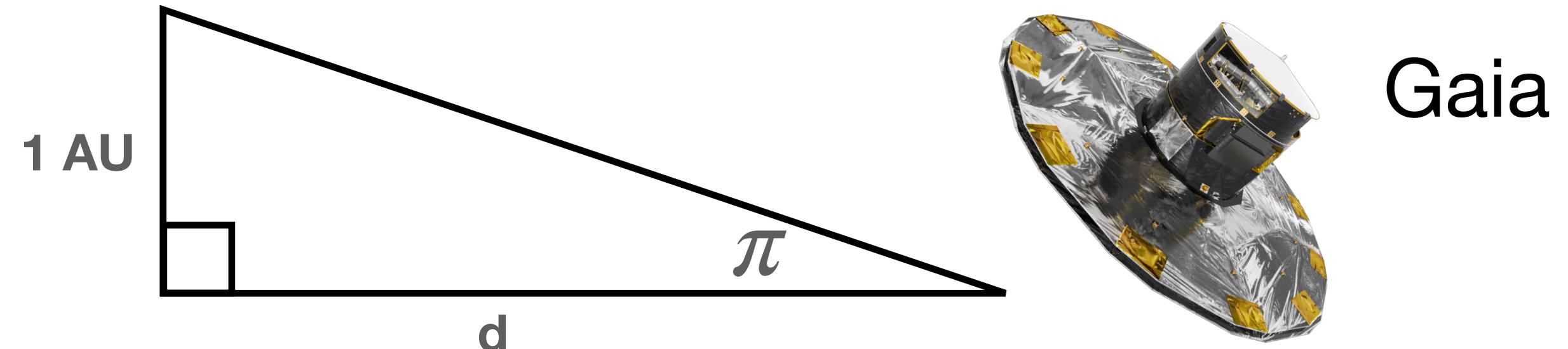
- Easy to constrain, difficult to directly measure
- **Usually need to know distance**

$$m_i = -2.5 \log_{10} \left(\frac{F_i}{F_0} \right)$$

$$m - M = 5 \log_{10} d[pc] - 5$$

- The total luminosity @ all wavelengths, known as “bolometric” luminosity (or absolute magnitude)
 - Typically you estimate luminosity in a given band, and then add a “bolometric correction”
- $M_{bol,\odot} \approx 4.74$ https://www.iau.org/static/resolutions/IAU2015_English.pdf

Distance

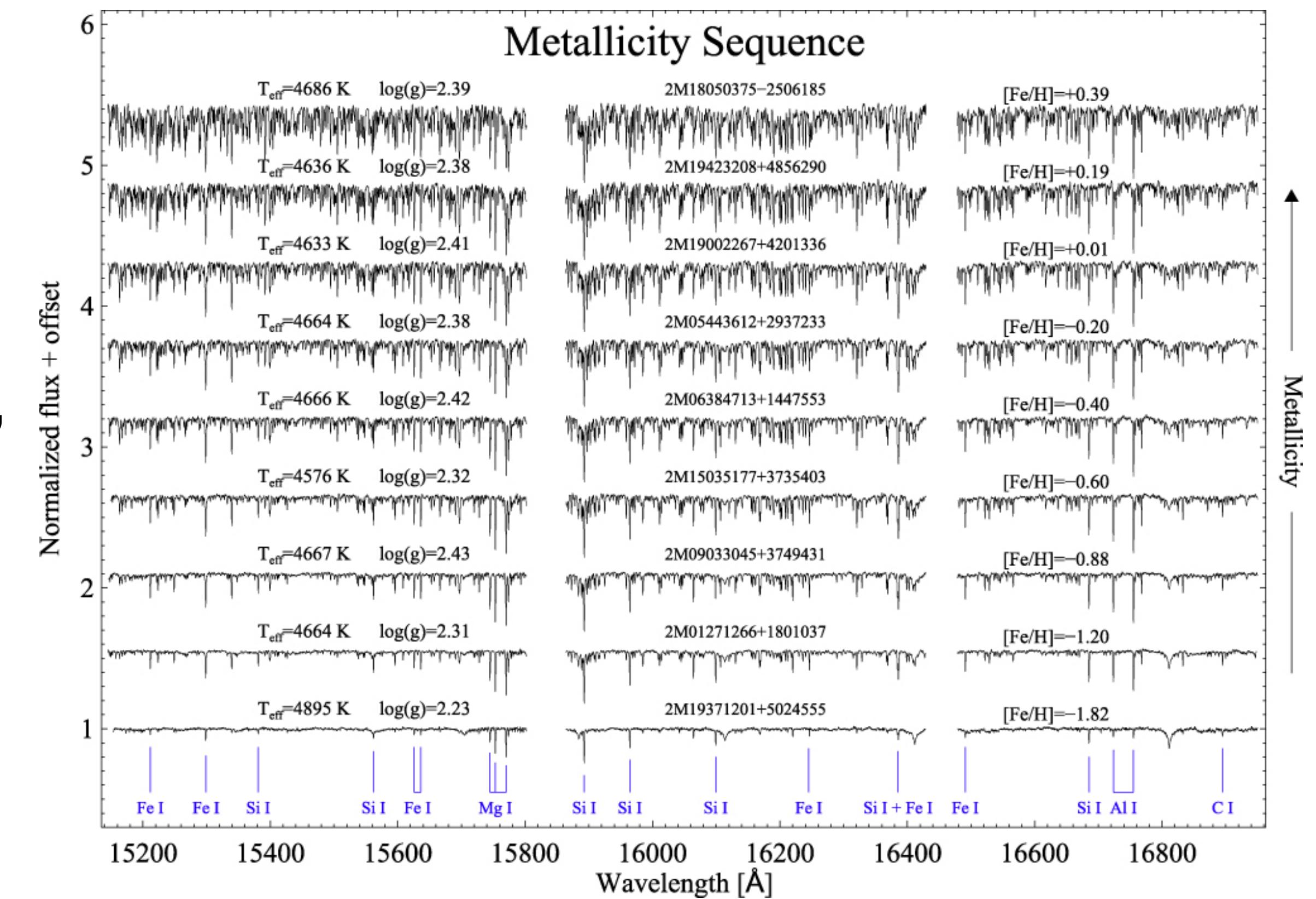


- Parallax! The best! But only for nearby stars
(Gaia is making this *better*, *+1Billion stars*, but not perfect!)
- Many other clever ways:
 - Stellar clusters $m - M = 5 \log_{10} d[pc] - 5$
 - RR Lyr, standard candles, the “distance ladder”, etc...
 - Eclipsing binaries
 - e.g. LMC distance to 2% Still the benchmark [Pietrzynski et al. \(2013\)](#)
 - Can be estimated for a star if you assume it is main sequence (e.g. “photometric parallax”) or take a spectrum

Composition (aka Metallicity)

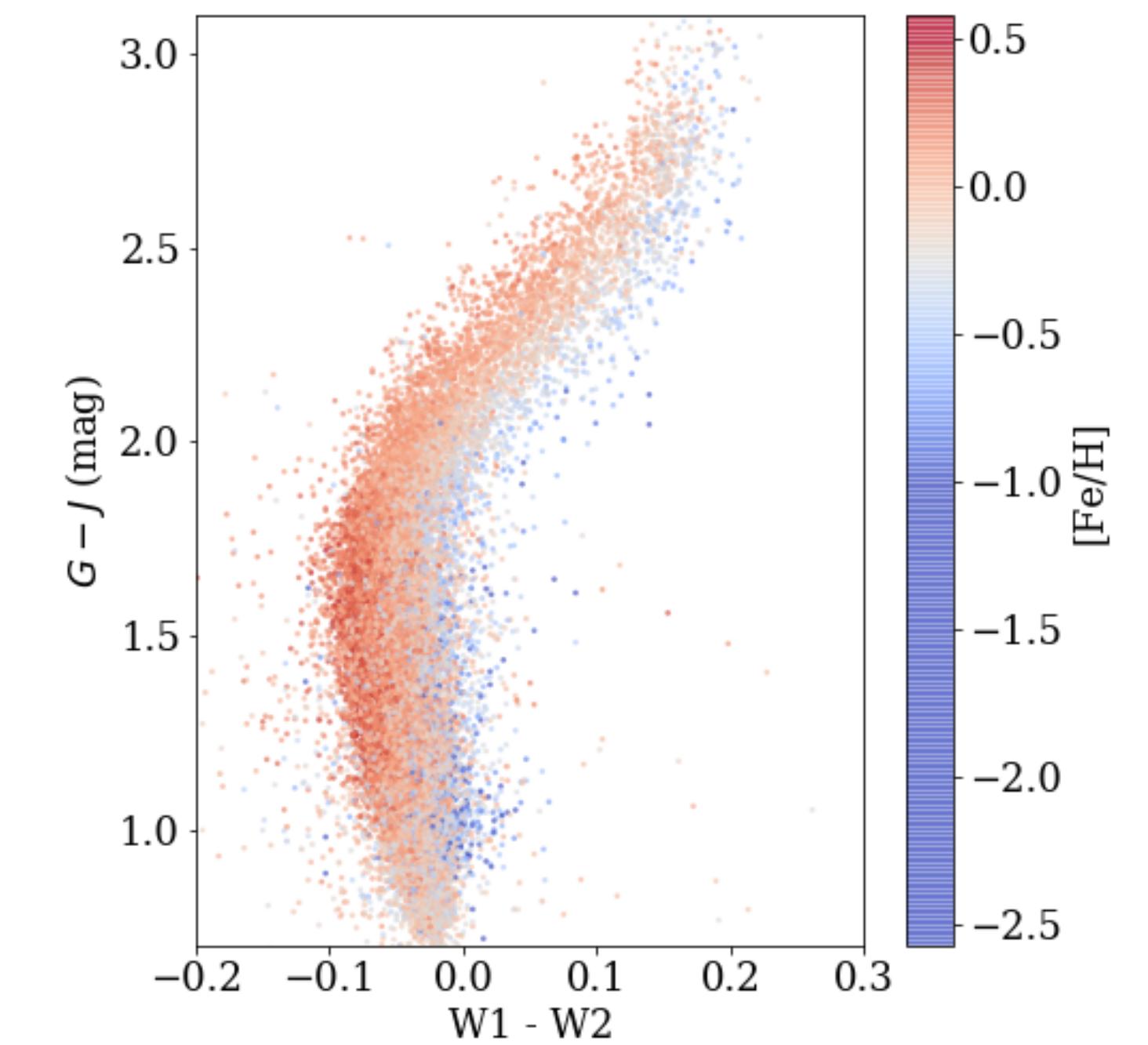
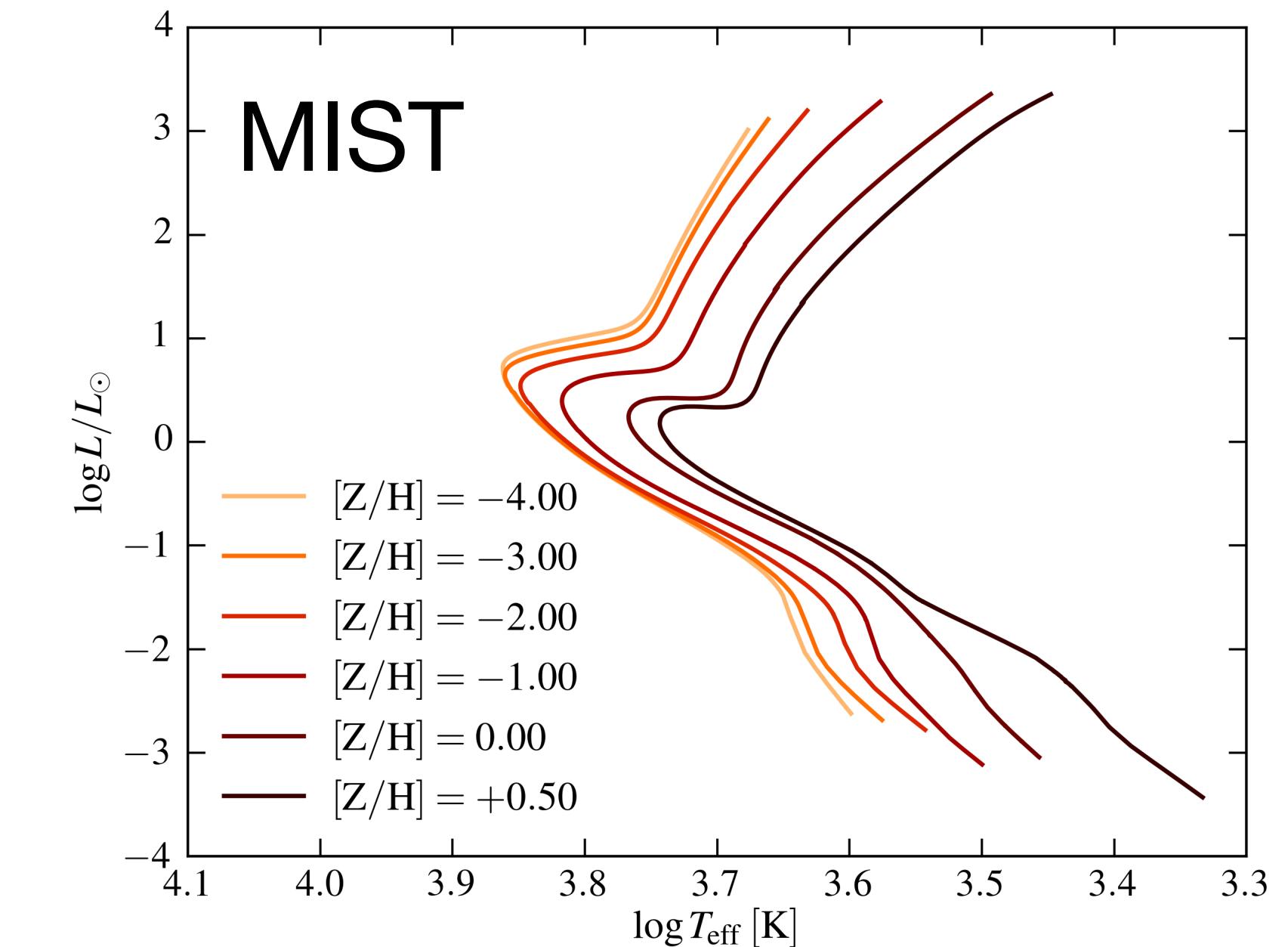
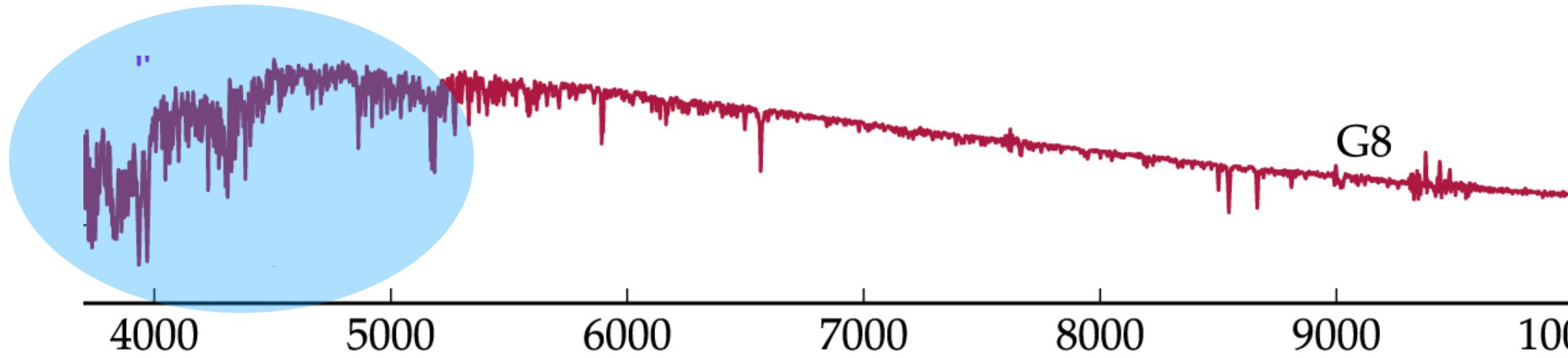
- Typically summed up as [Fe/H], i.e. the log ratio of Fe/H *relative* to the solar amount
 - Also abundances of individual elements are studied, as well as groups (e.g. $[\alpha/\text{Fe}]$)
- Primarily determined via spectroscopy, modeling atomic absorption lines
 - High resolution **VERY** helpful

Majewski+2017 (APOGEE)



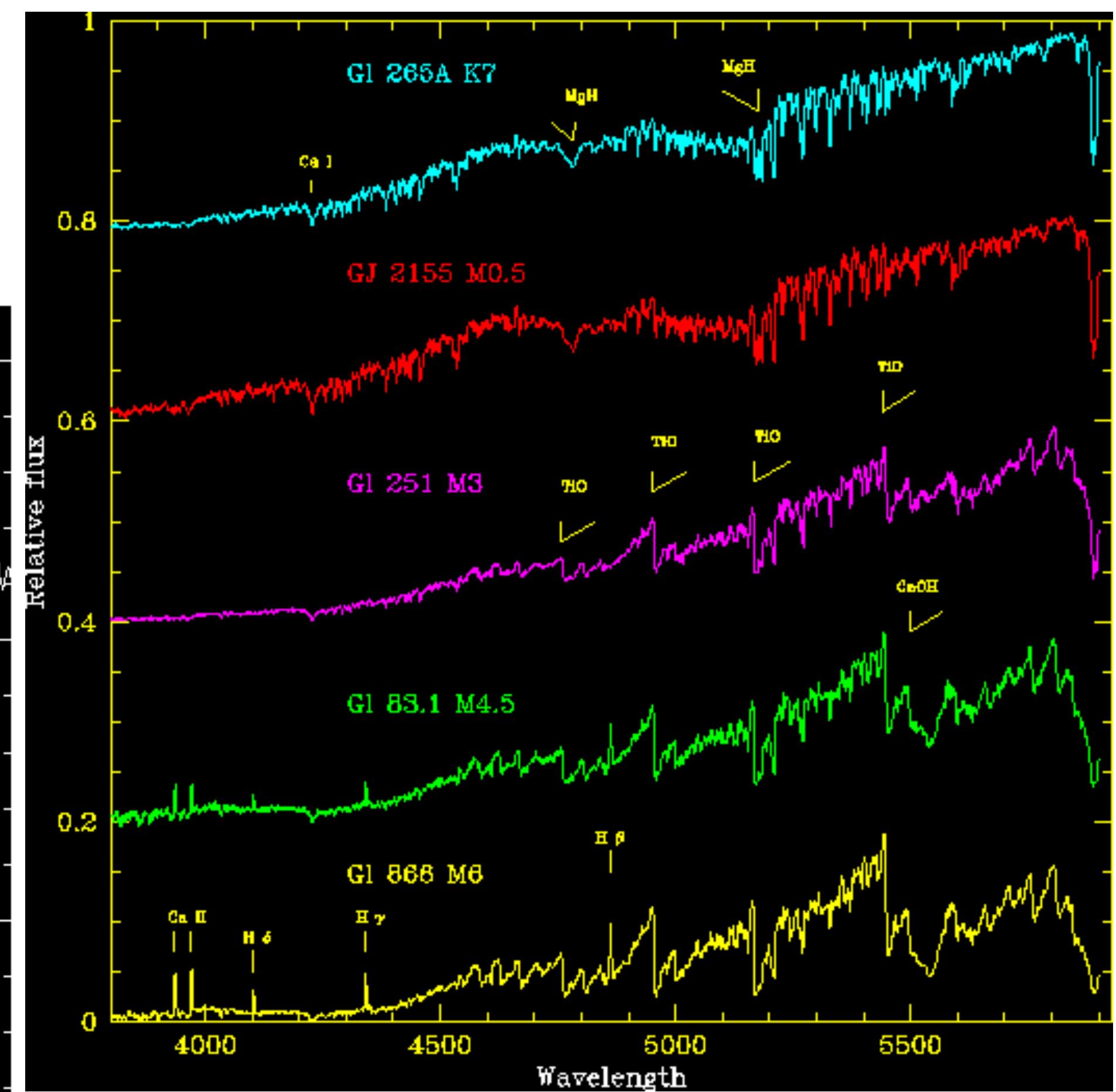
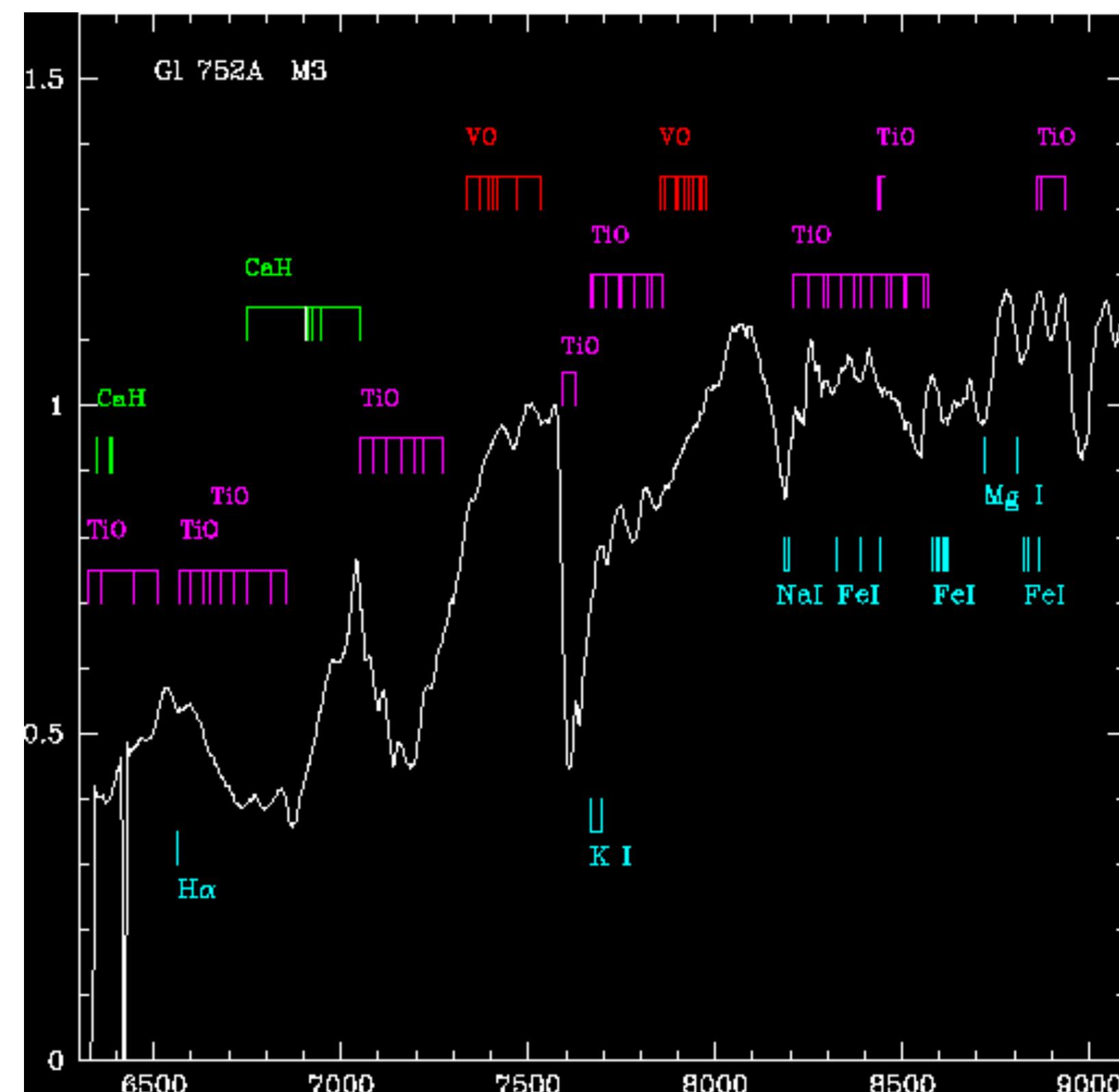
Composition (aka Metallicity)

- Can be studied (coarsely) with photometry
 - Big error bars, but big samples
- In general, metal-poor: bluer (hotter T_{eff})
metal-rich, more lines, redder
- Typically use blue (e.g. u -band) filters
BUT, some sensitivity in the IR too



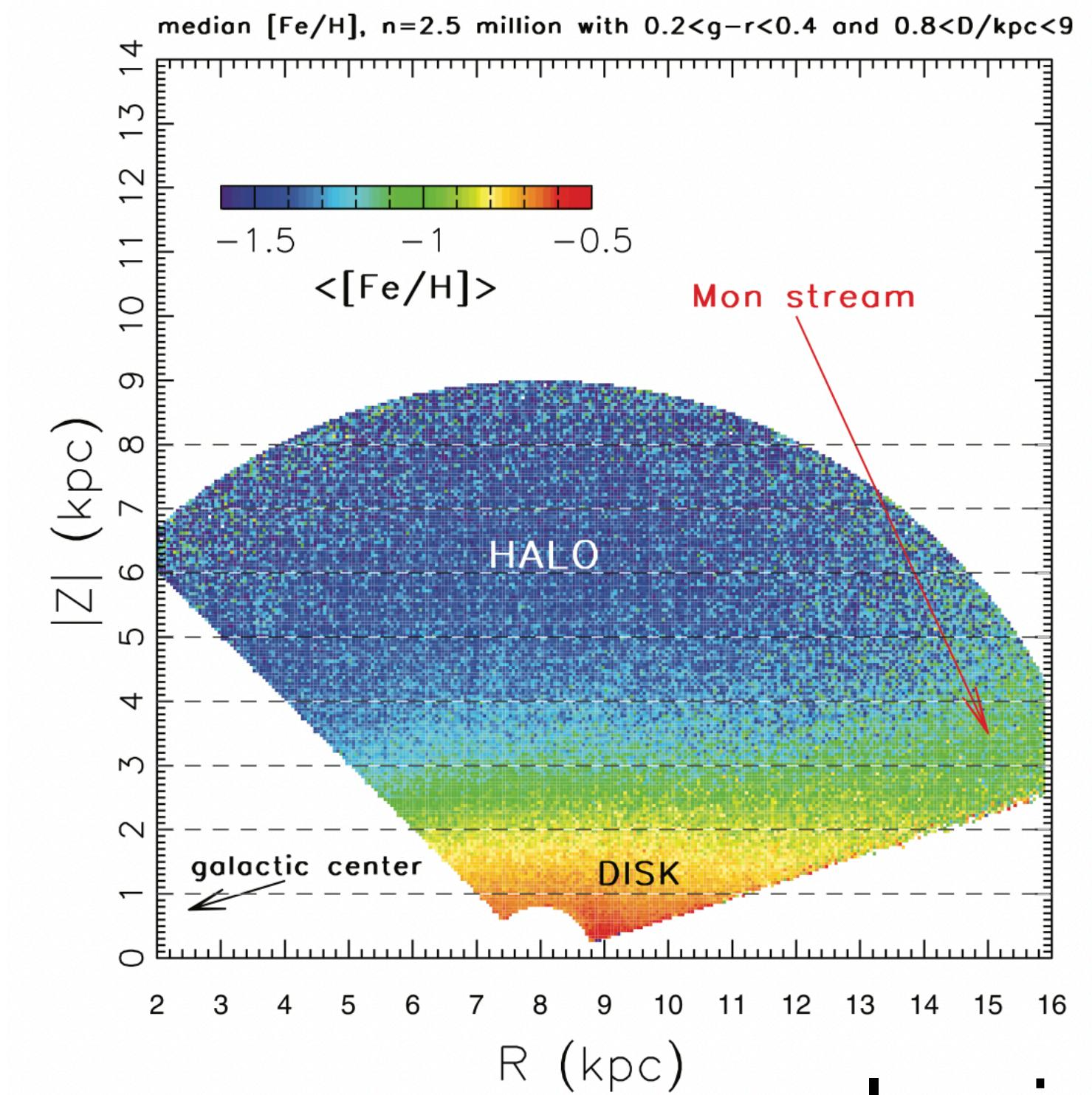
Composition (aka Metallicity)

- The situation is... more difficult for low-mass stars
- Cool temperature, spectra dominated by *molecules*
- Molecules are *wild...*



Composition (aka Metallicity)

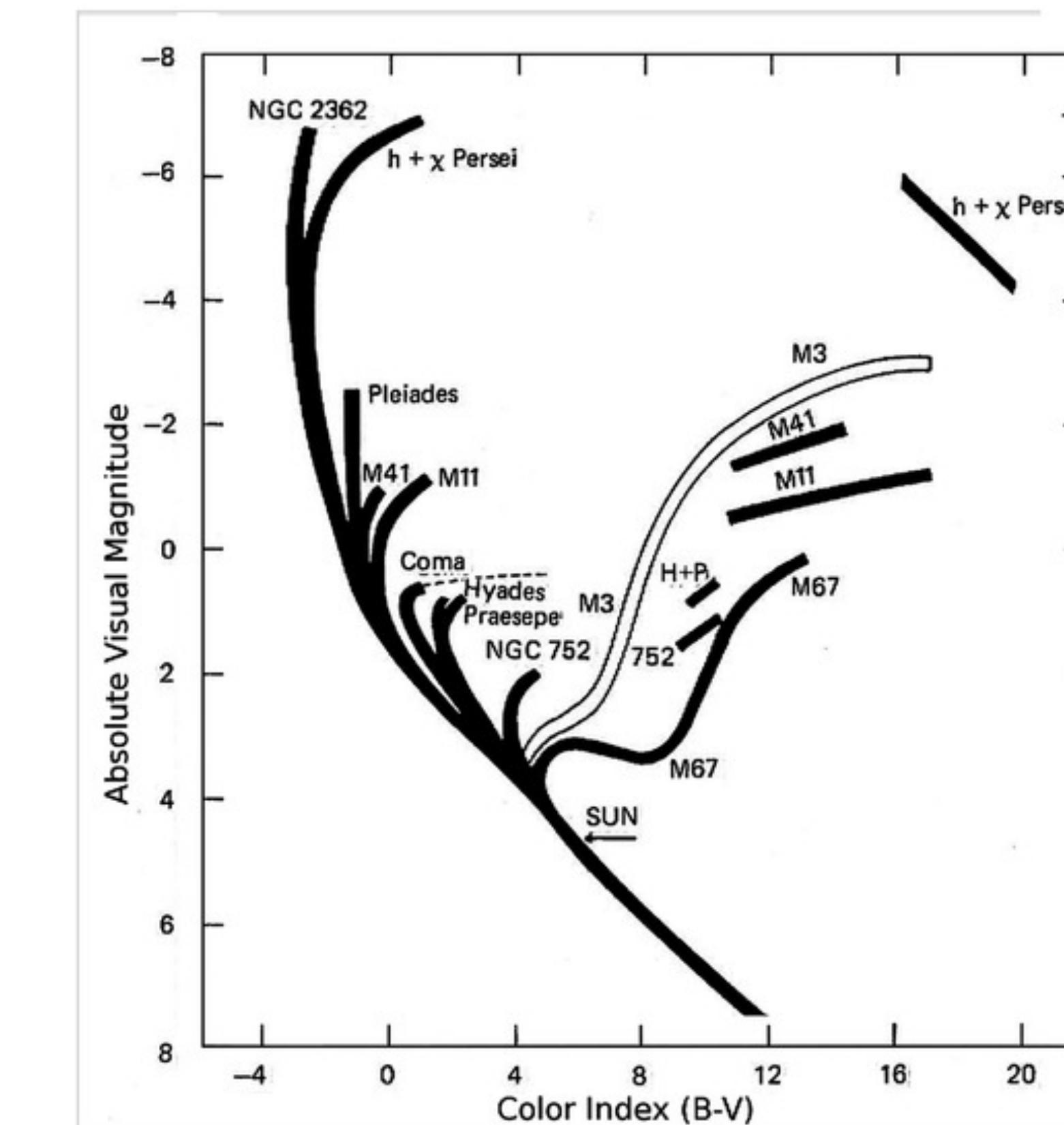
- Doing this for hundreds of thousands (or even millions) of stars enables new studies of the composition of our galaxy!
- Wonderful new term: chemical cartography



Ivezic+2008

Age

- For main sequence stars, incredibly difficult to constrain, cannot be “measured” directly...
- 10% uncertainty considered very good!
- A good review: [Soderblom \(2010\)](#)
- Cluster ages (open and globular) a critical historical benchmark, still key!
 - Mostly information in the “turn off”

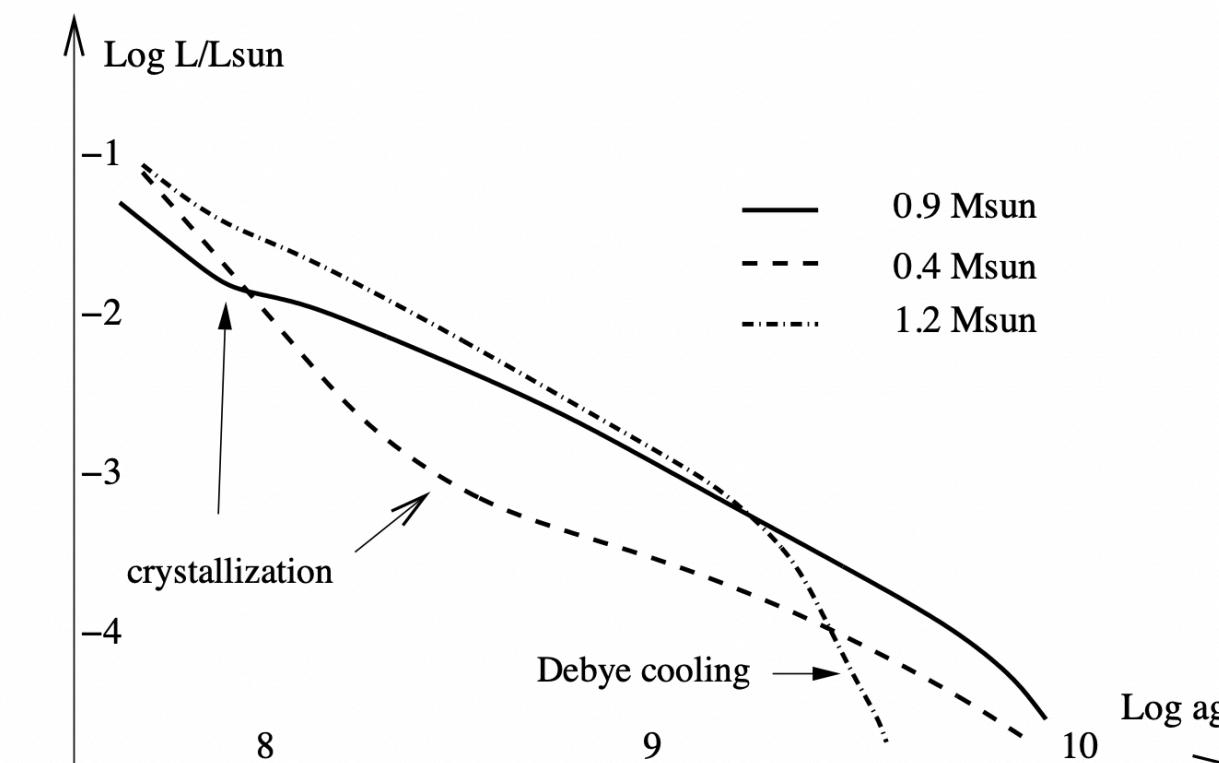
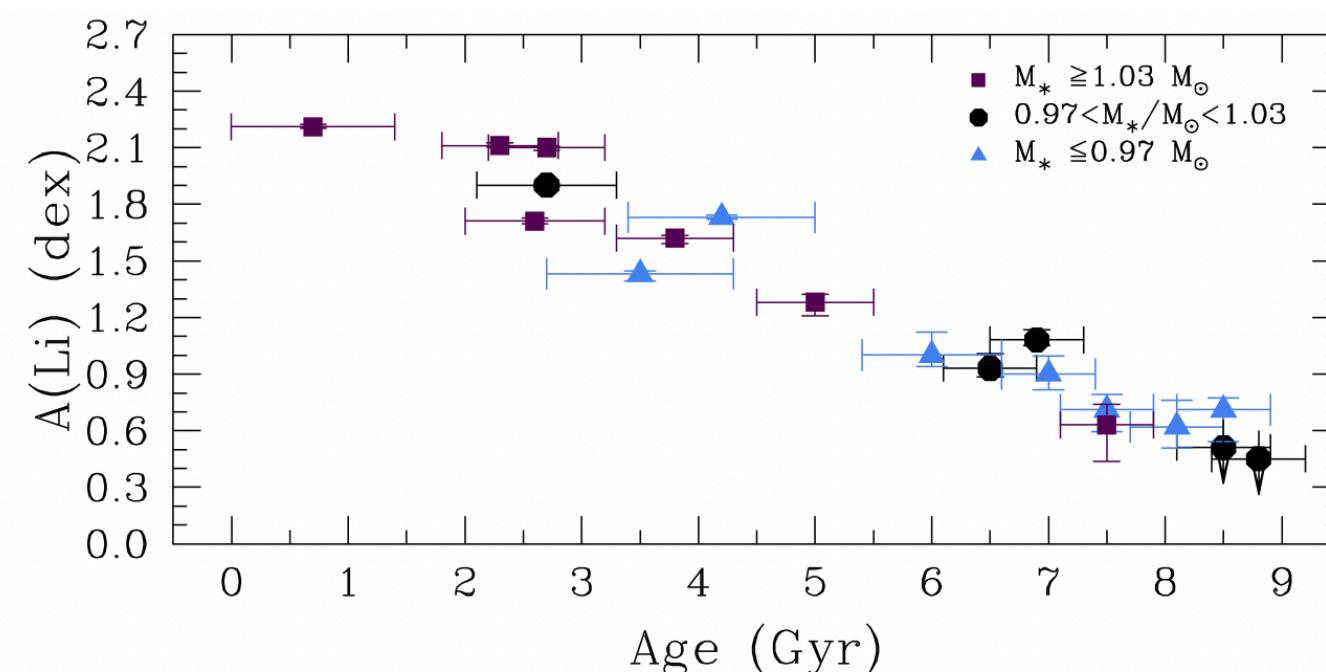


[Sandage \(1957\)](#)

Age

- A few other ways to estimate ages, none work for all stars/timescales:
 - White-dwarf cooling sequence

[Althaus+2010](#)



[Carlos+2016](#)

- “Gyrochronology” - i.e. a spin-clock
Stars lose angular momentum over time, perhaps predictably*
Key paper establishing this idea: [Skumanich \(1972\)](#)

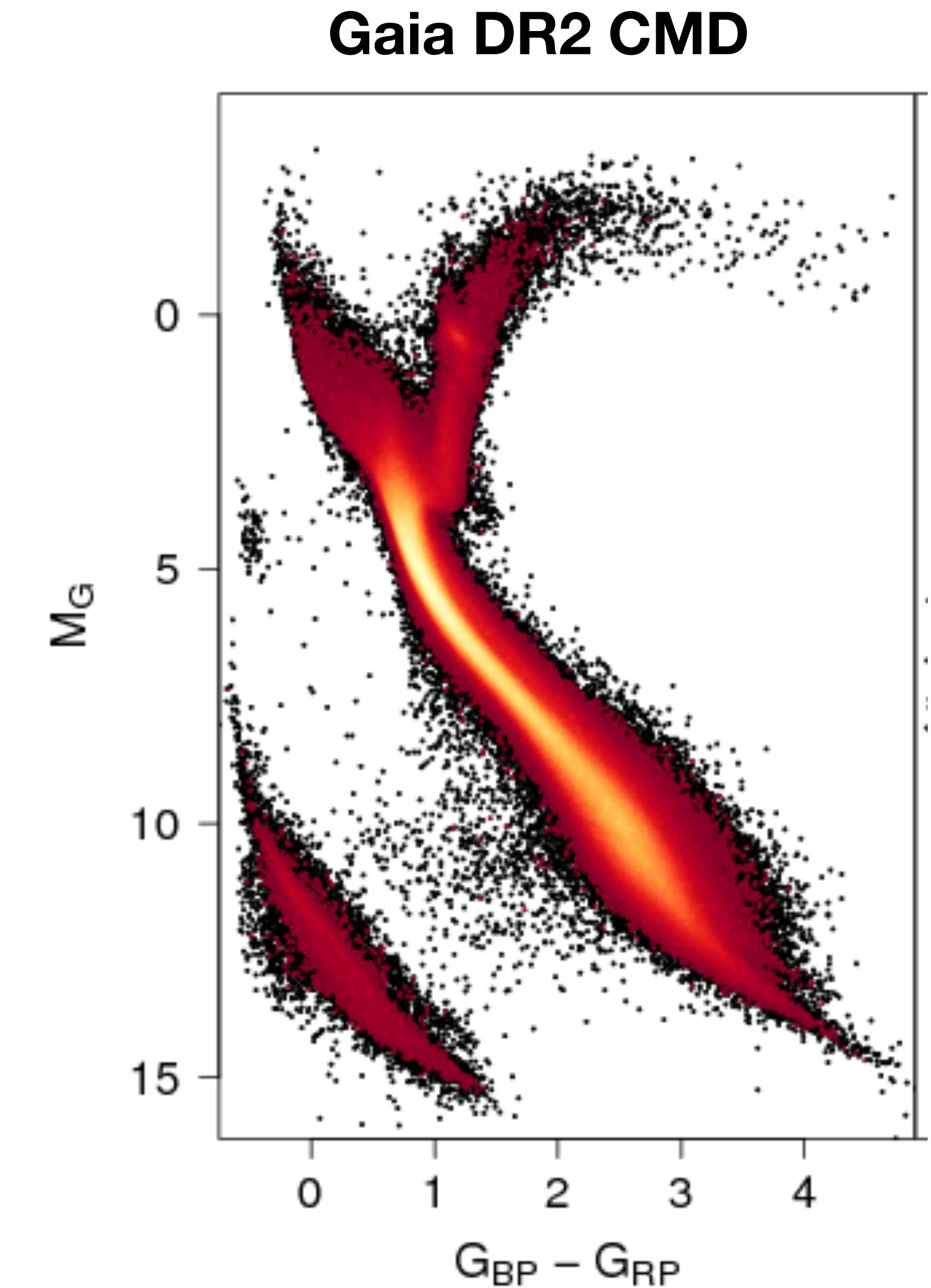
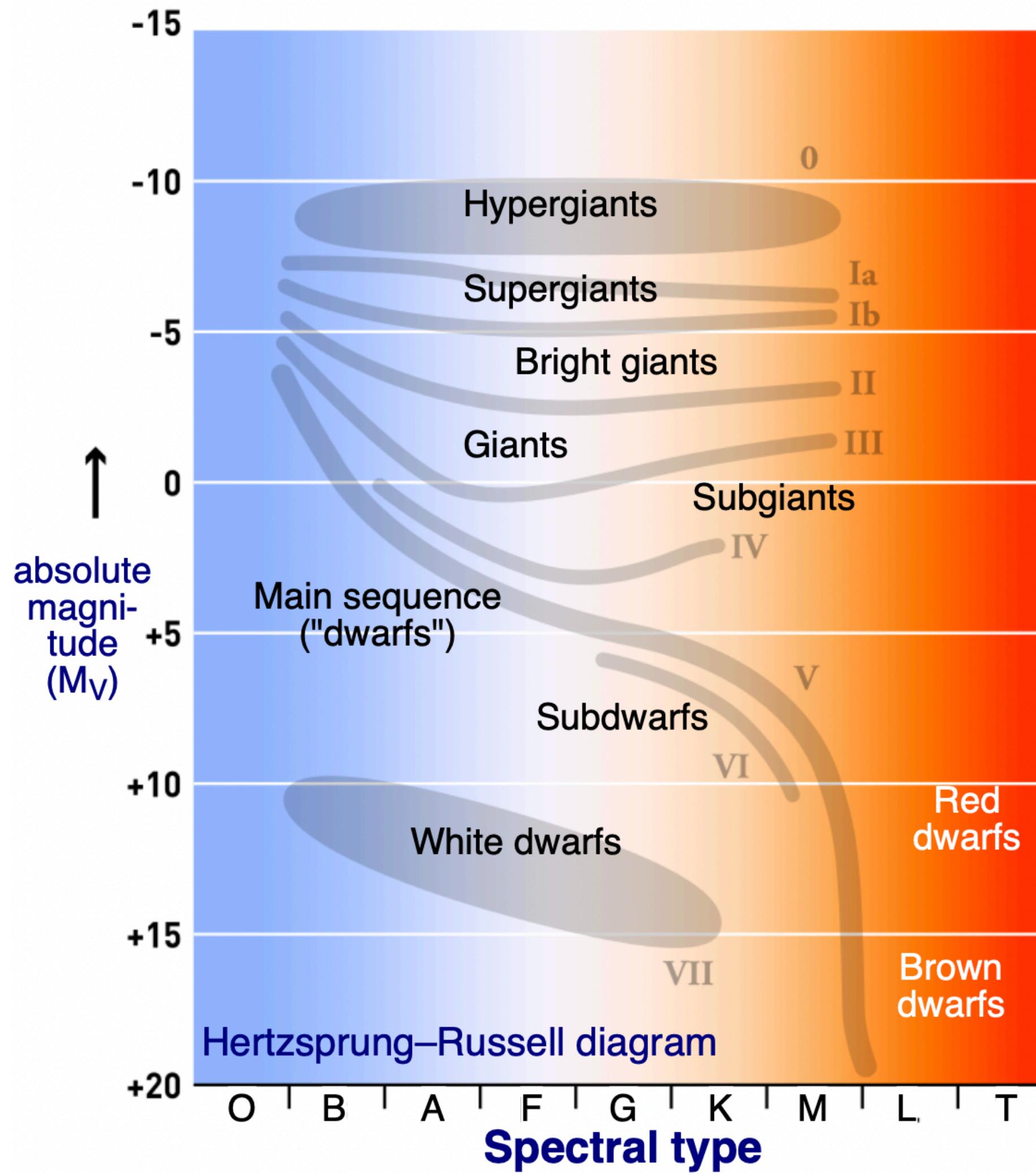
Other Properties

- Radius
- Density
- Surface Gravity
- Binarity

**Very interesting,
but not critical for
Galactic Astronomy**

The H-R Diagram

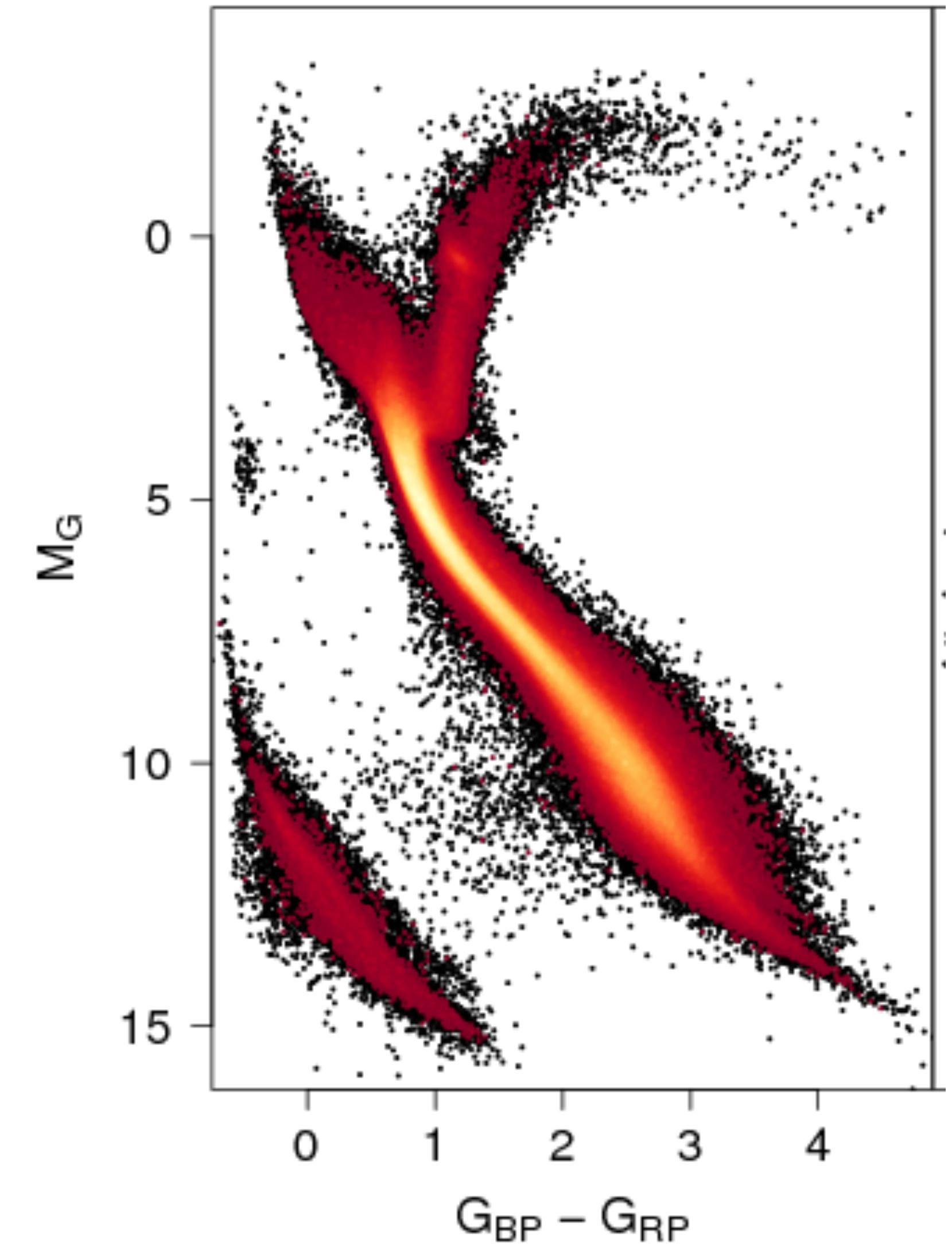
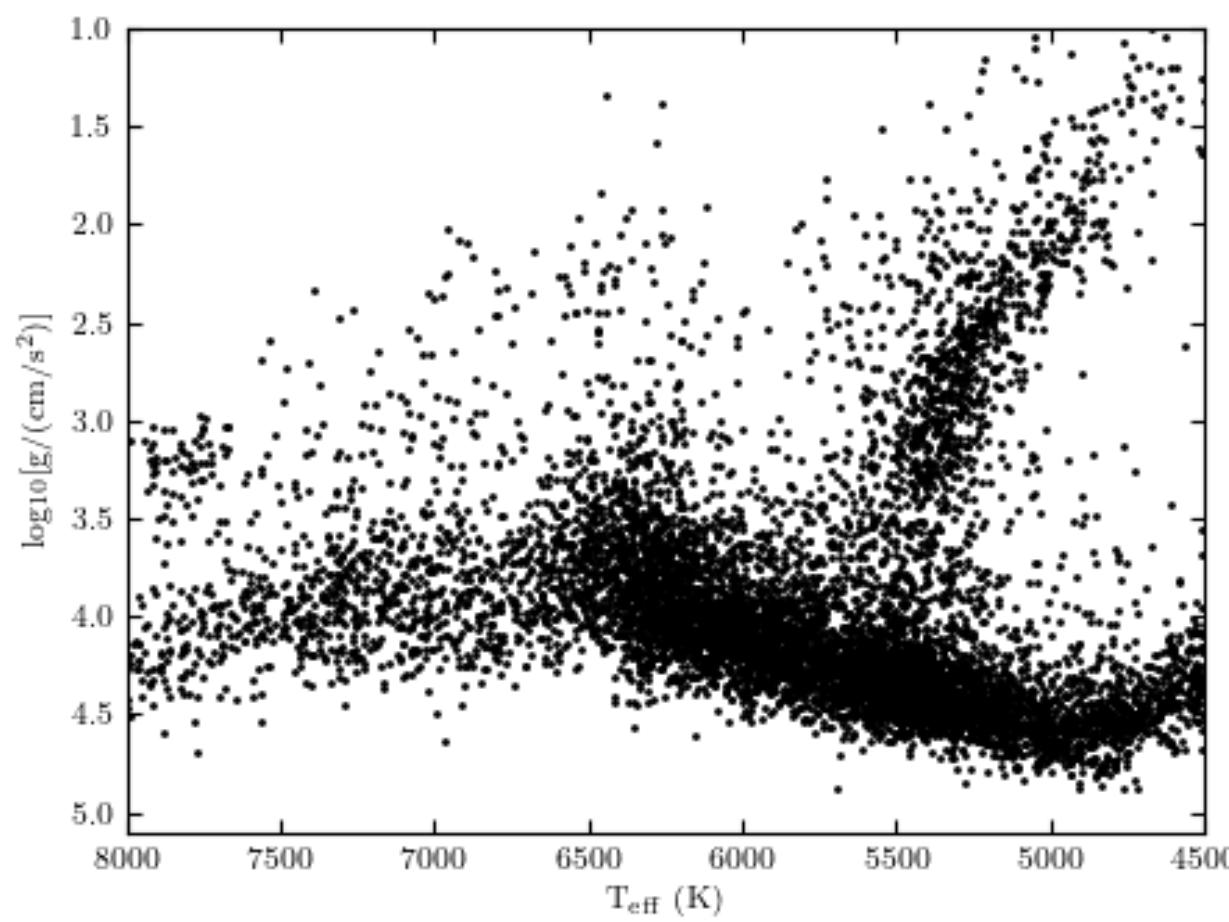
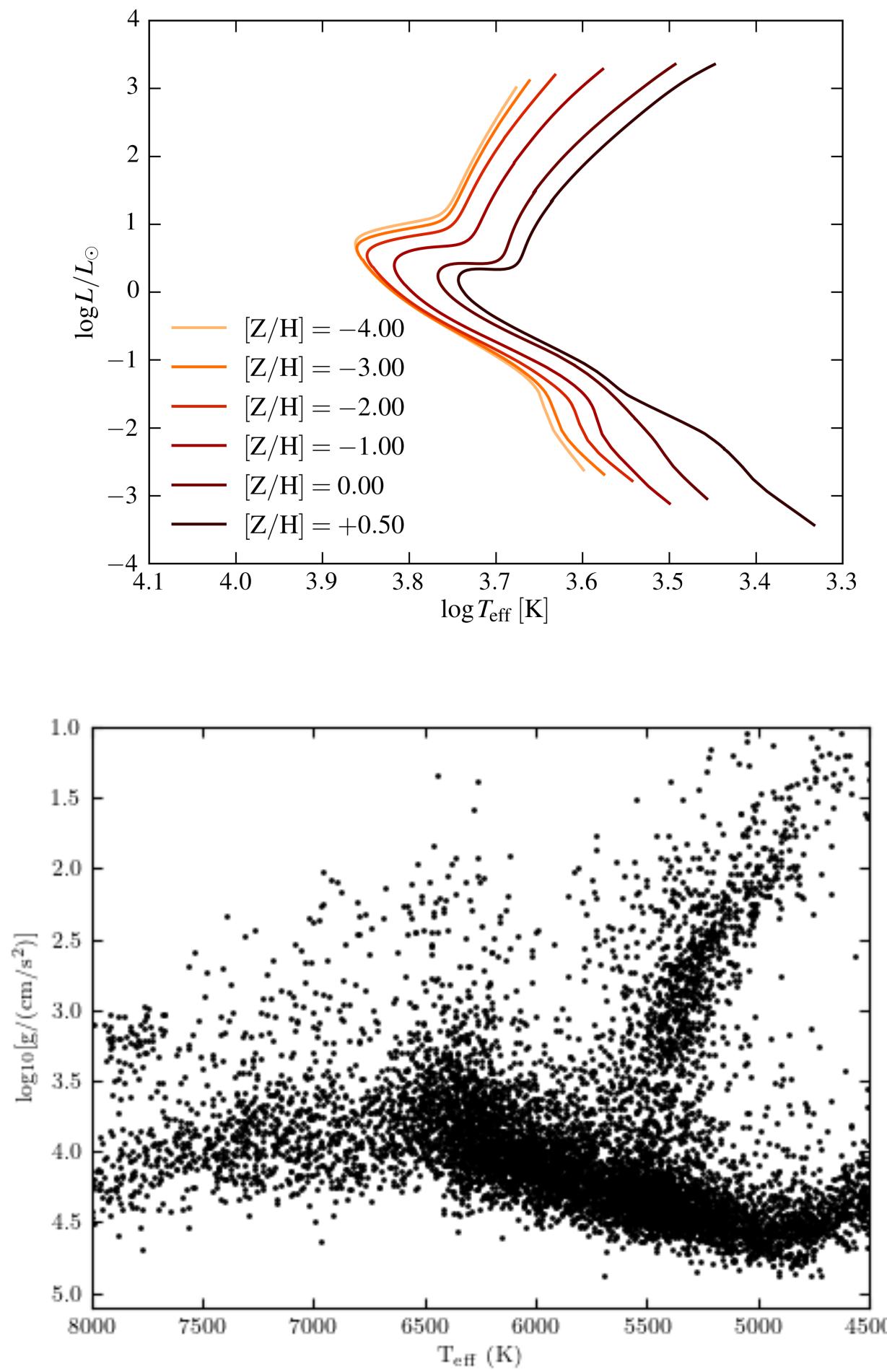
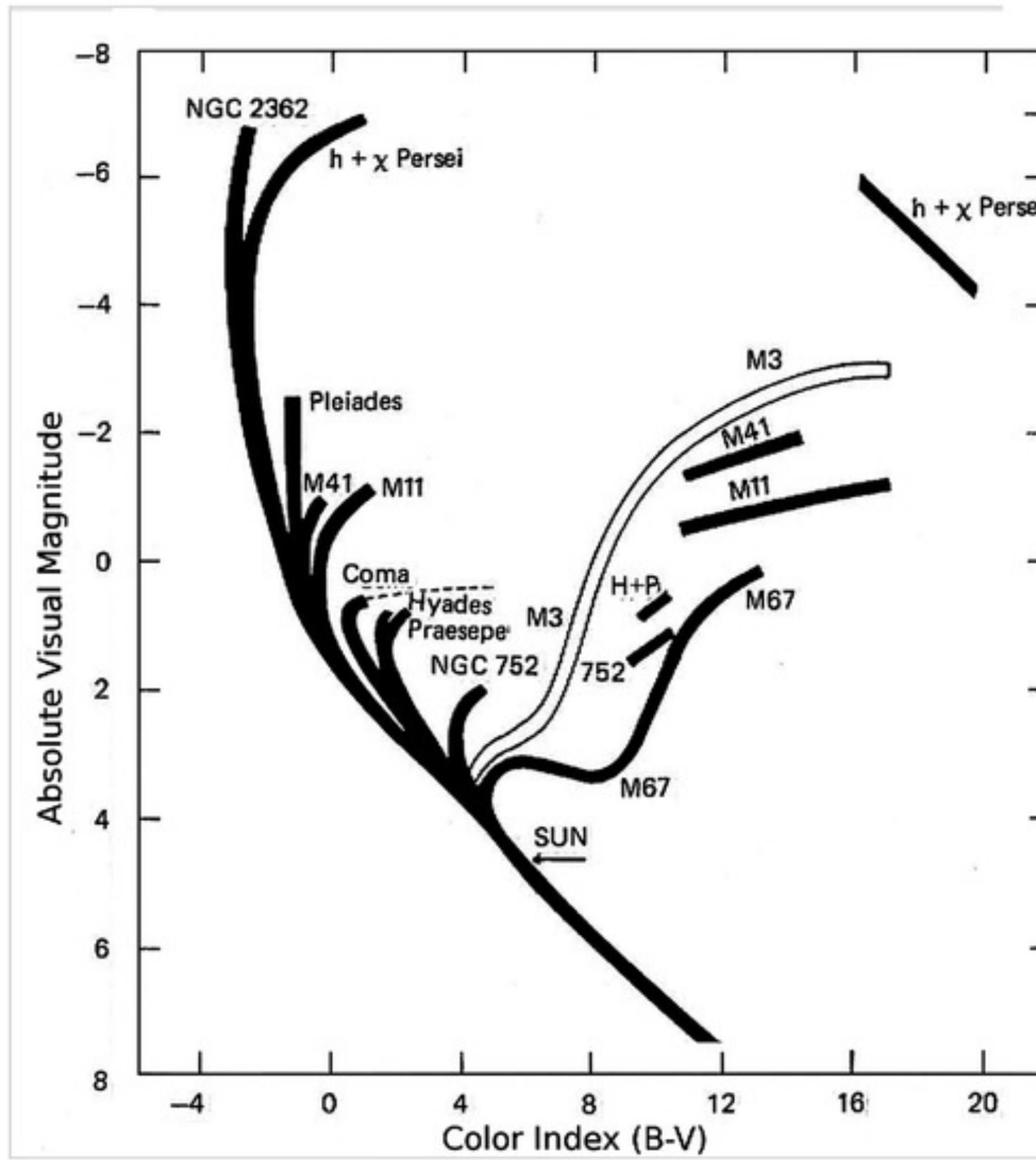
- Theorists:
Temp, Lum
or
Temp, log g
- Observers:
Color, Mag



The H-R Diagram

A Rosetta Stone for understanding the lives & properties of stars

Gaia DR2 CMD



Next time:

- The Solar Neighborhood

