ASTR 511

Galactic Astronomy

Lecture 01

Introductions & Review

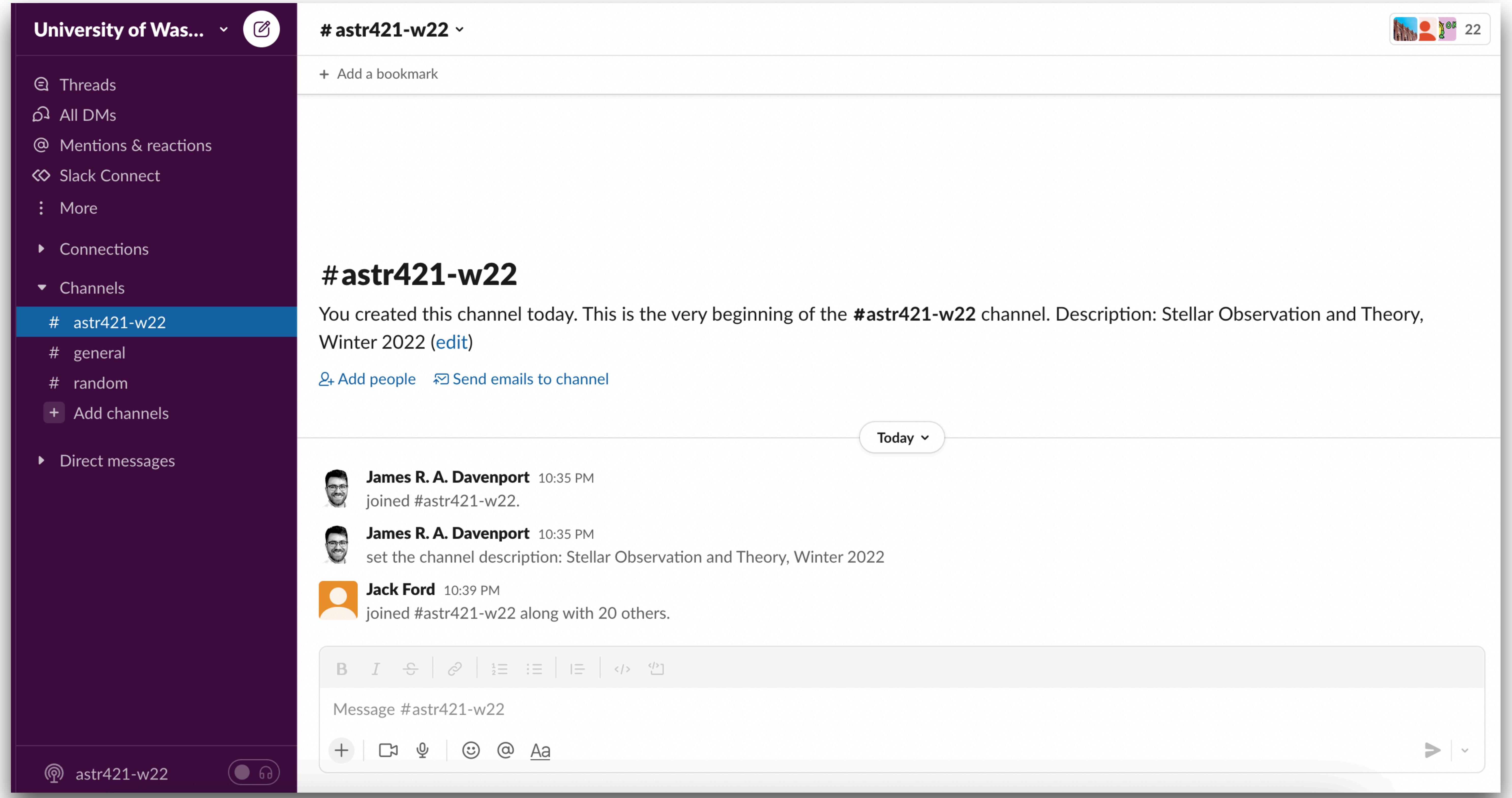
Prof. James Davenport (UW)

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

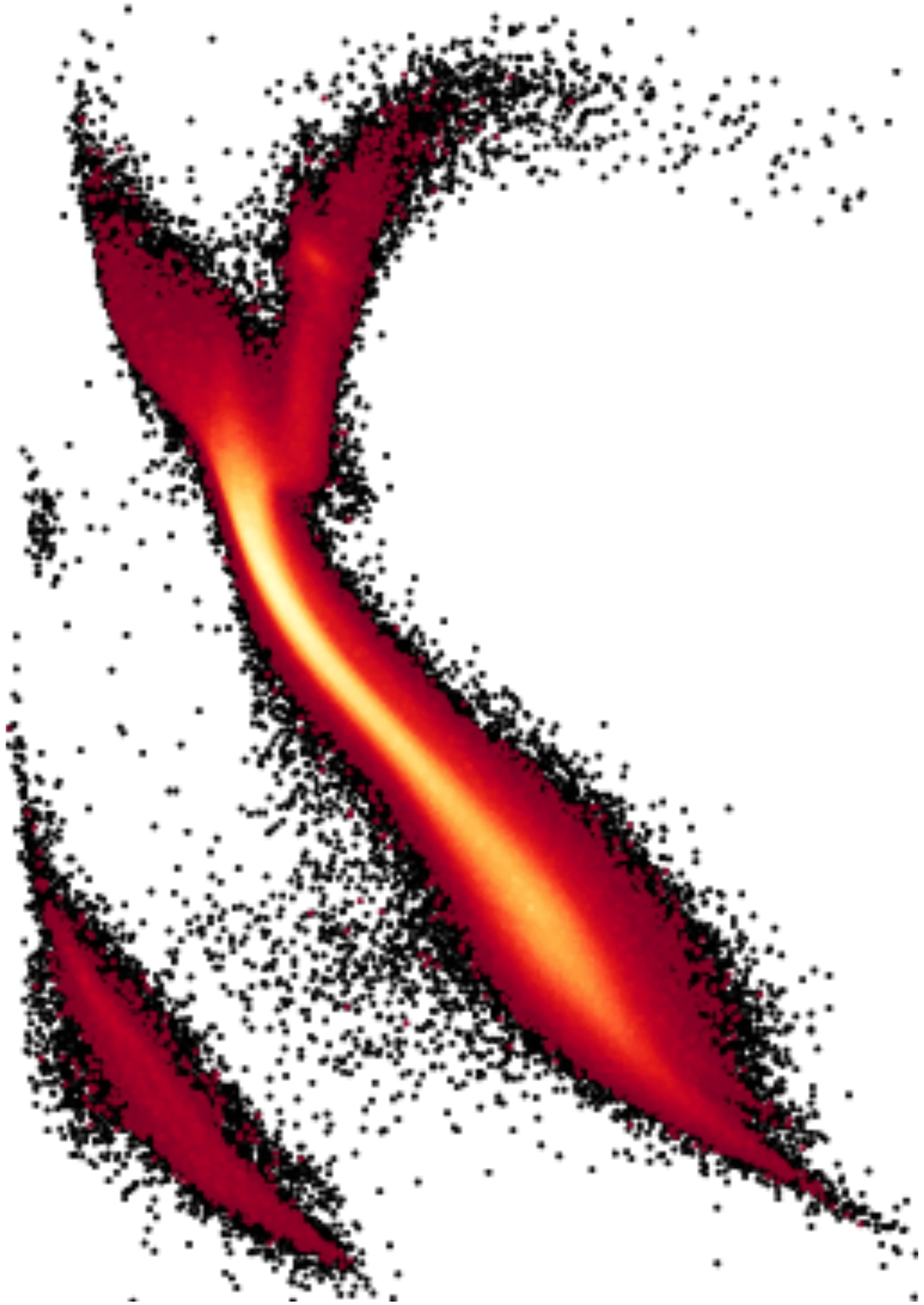
- **This class will not be held during AAS 241**
  - You will learn more there than I can teach you in 2 sessions.
- There is a (mostly fun) "scavenger hunt" assignment: **Homework 1**, posted now!
  - If you are not attending AAS, you can complete it using the arXiv.
- I'll make time on Thursday for 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.

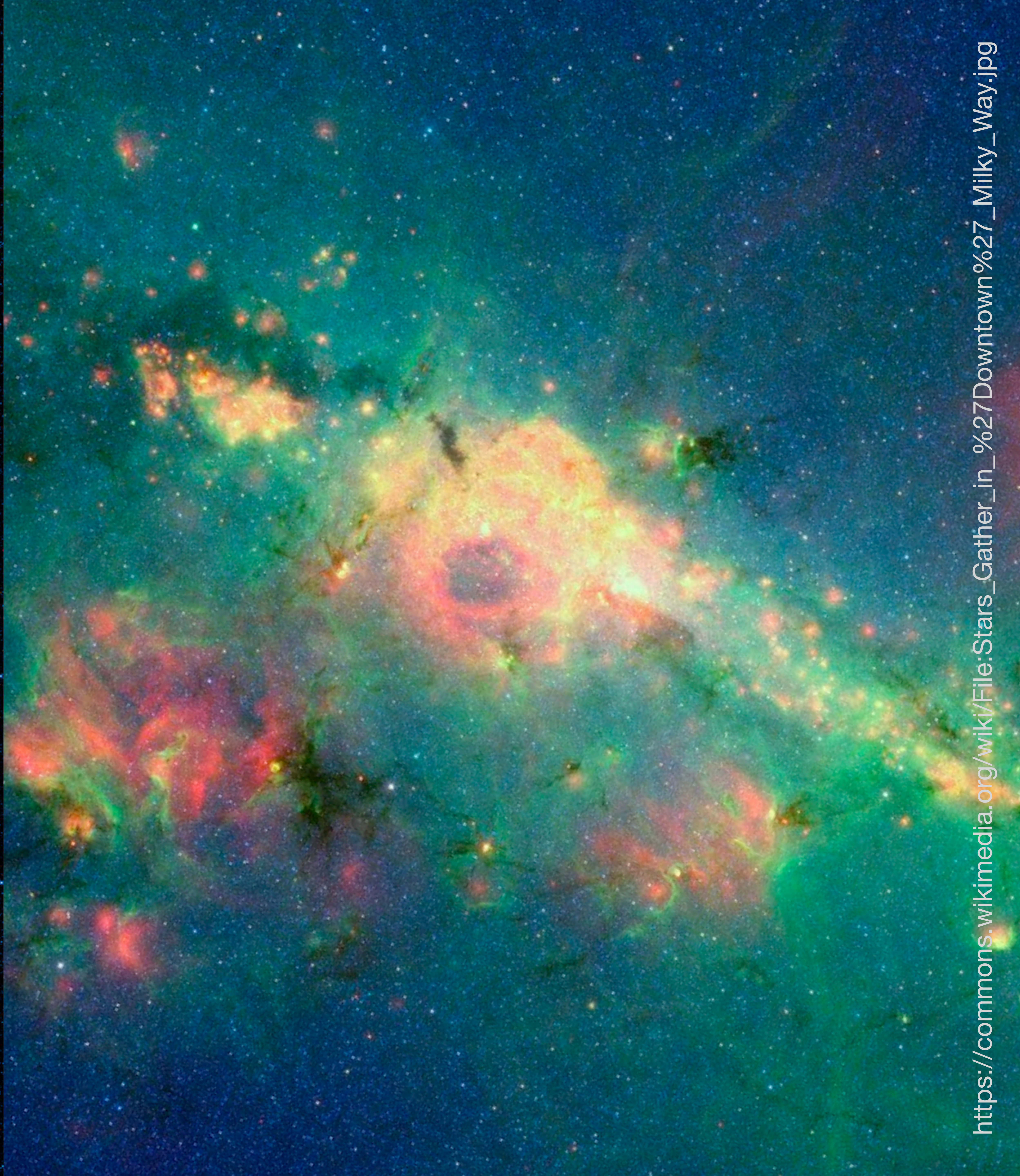
Version 5 from Feb 9, 2015

ASTR 511: Galactic Astronomy

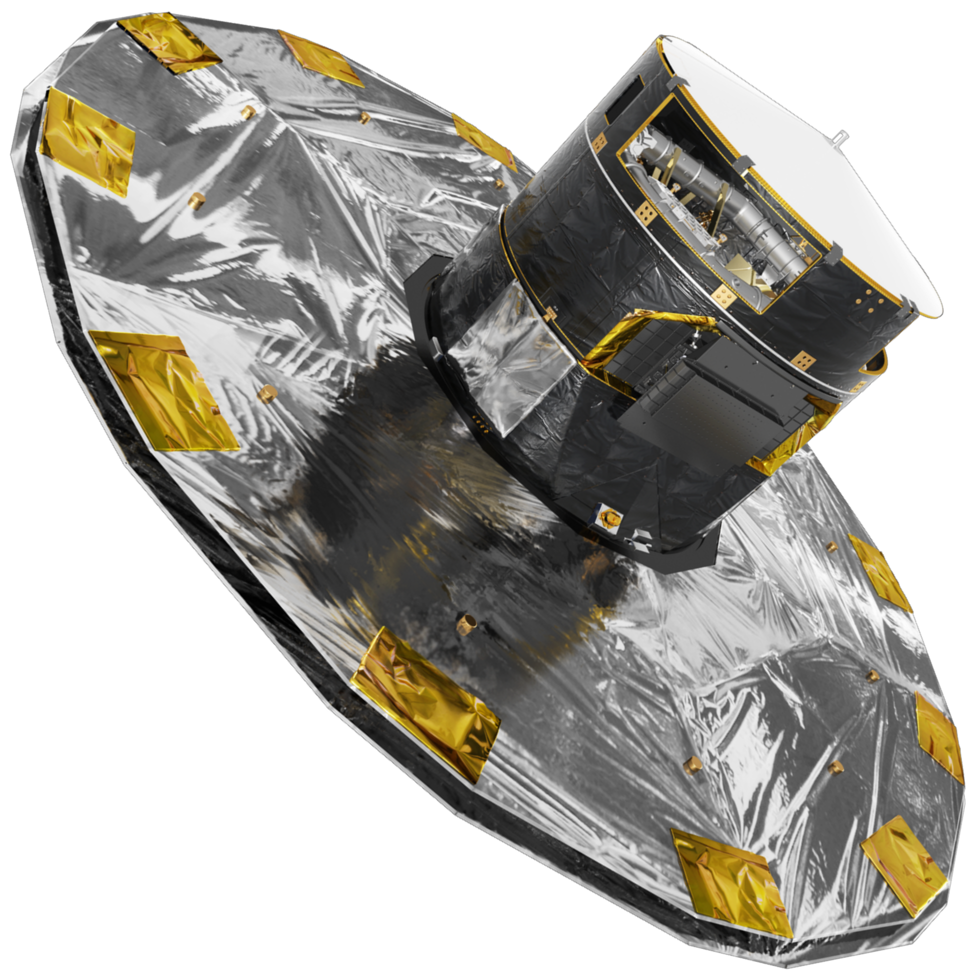
ASTR 511, Winter 2021: Galaxies as Galaxies

- 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!*

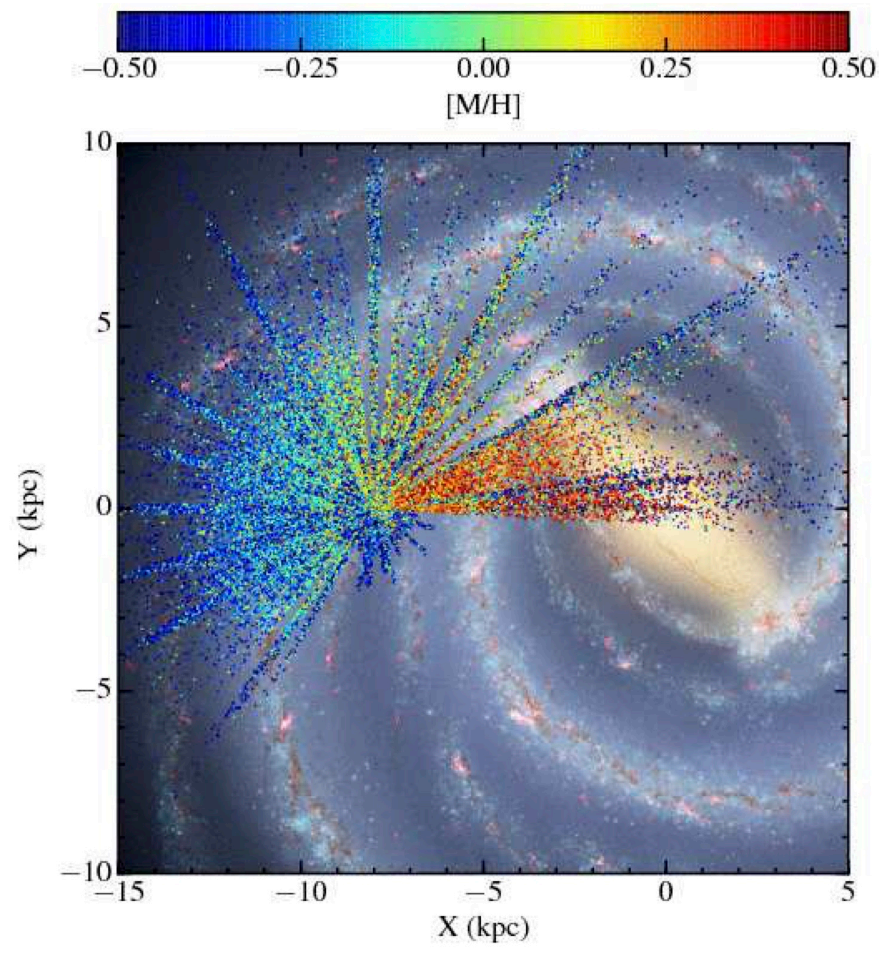
Course Goals

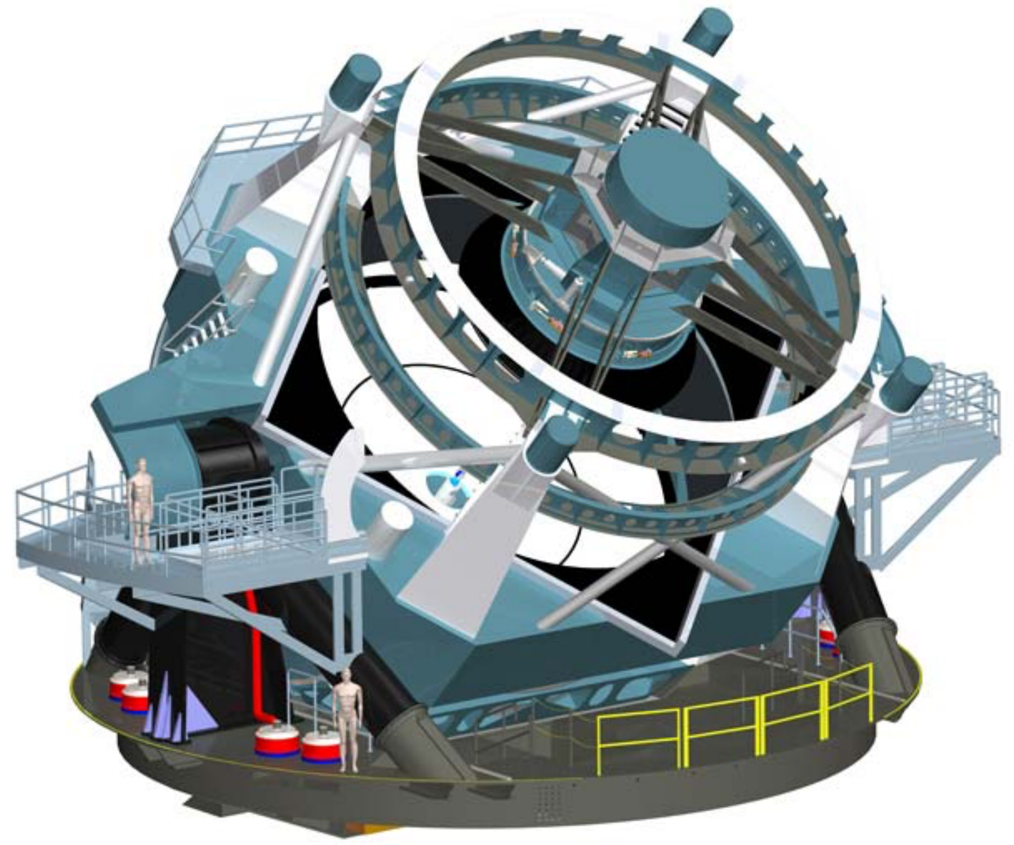


Course Goals



- 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**





https://www.sdss4.org/surveys/apogee/

Course Goals

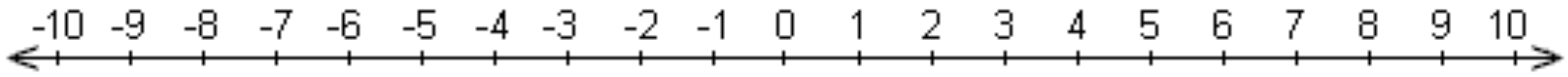
- Also an amazing time for theory!

https://www.tng-project.org/media/

Course Goals

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

Astro Jargon Review



- Magnitudes (apparent vs absolute) & flux
- Colors

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

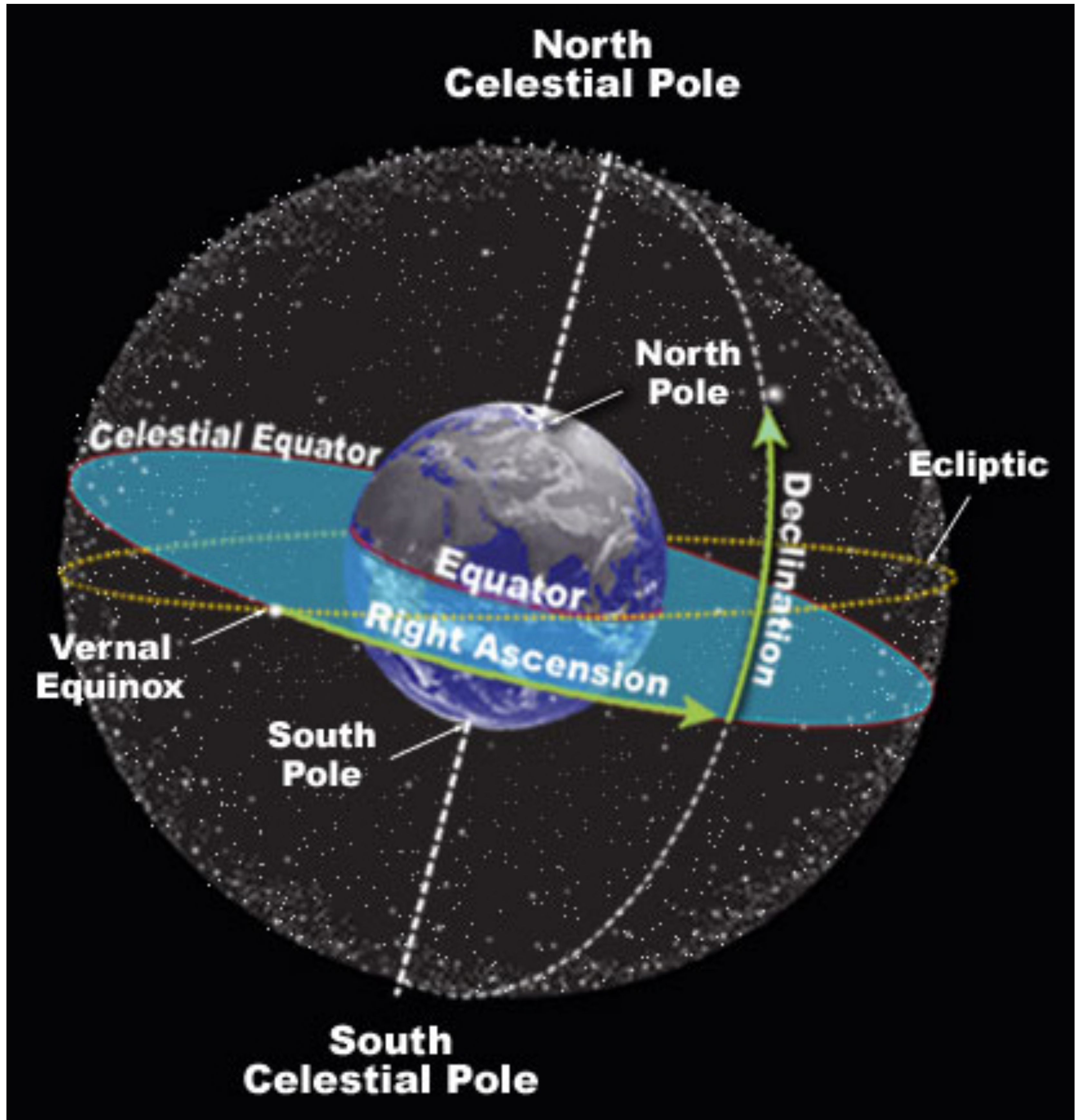
$$m - M = 5 \log_{10} d[pc] - 5$$

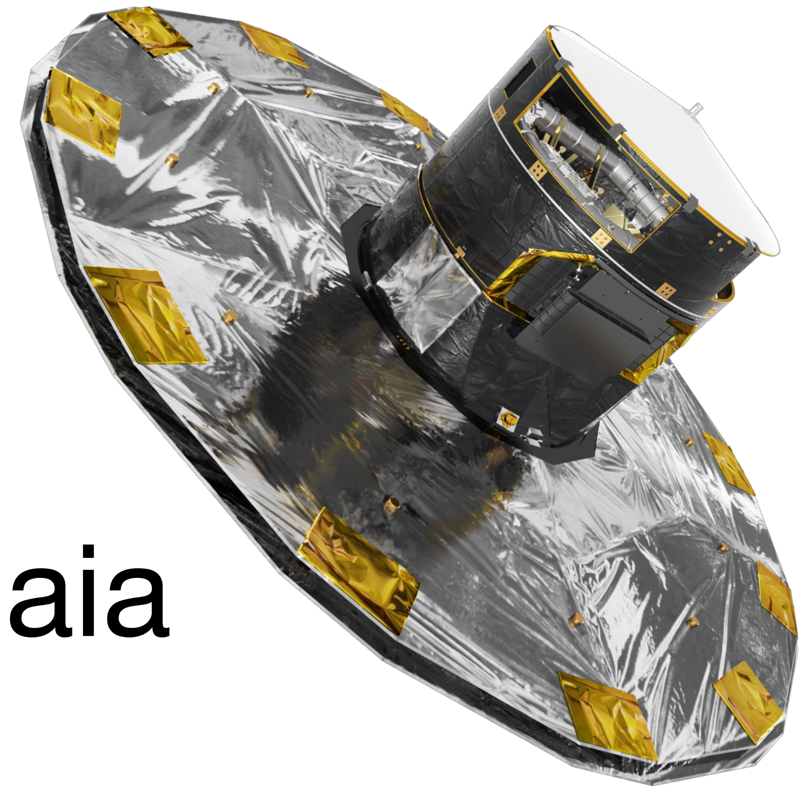
$$B - V \equiv m_B - m_V \equiv M_B - M_V$$

Bold statement: magnitudes are a good unit!

Astro Jargon Review

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



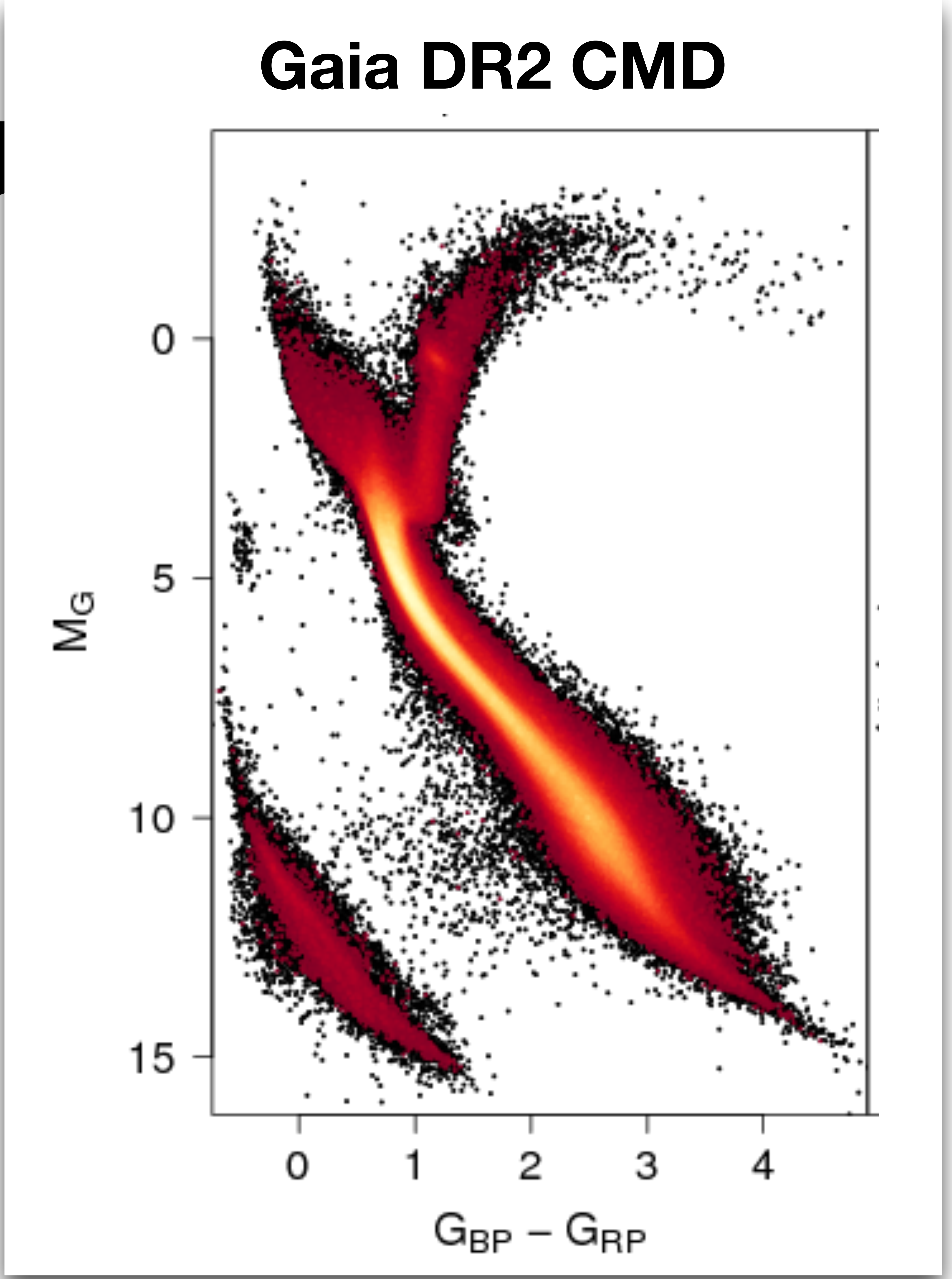


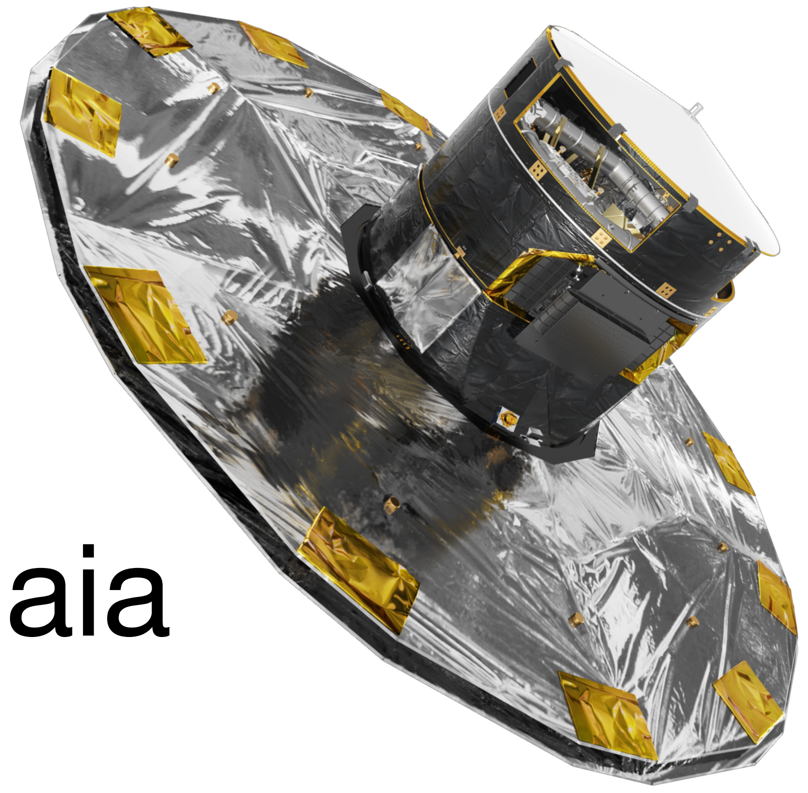
Gaia

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

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

Astro J





Gaia

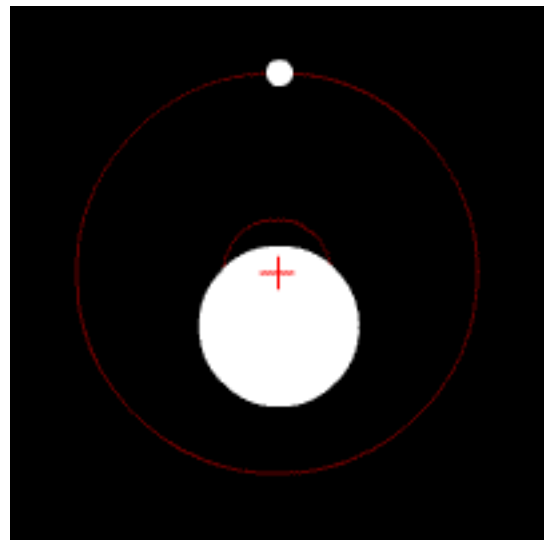
https://www.cosmos.esa.int/web/gaia/gaiadr2_hrd

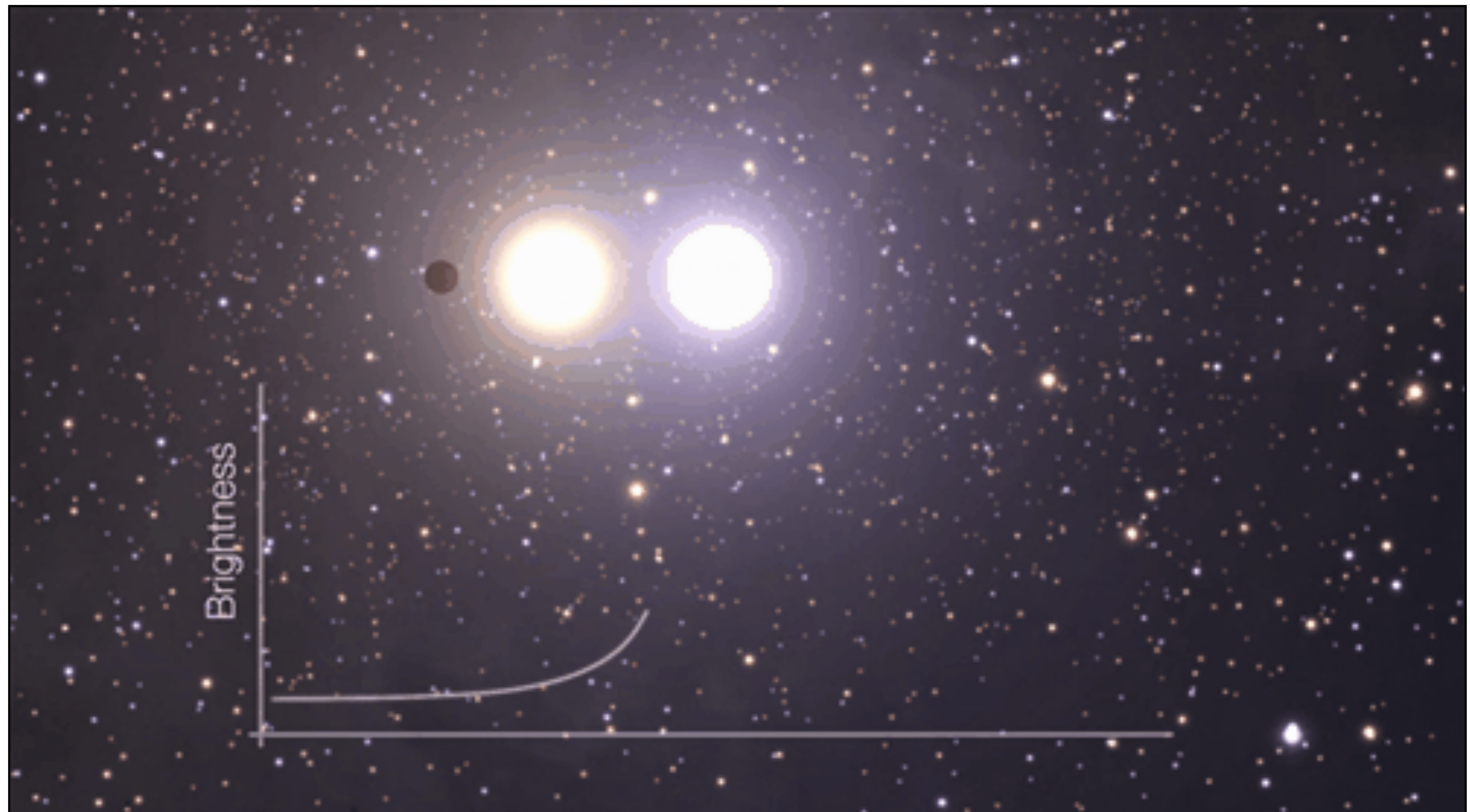
Stars

- 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

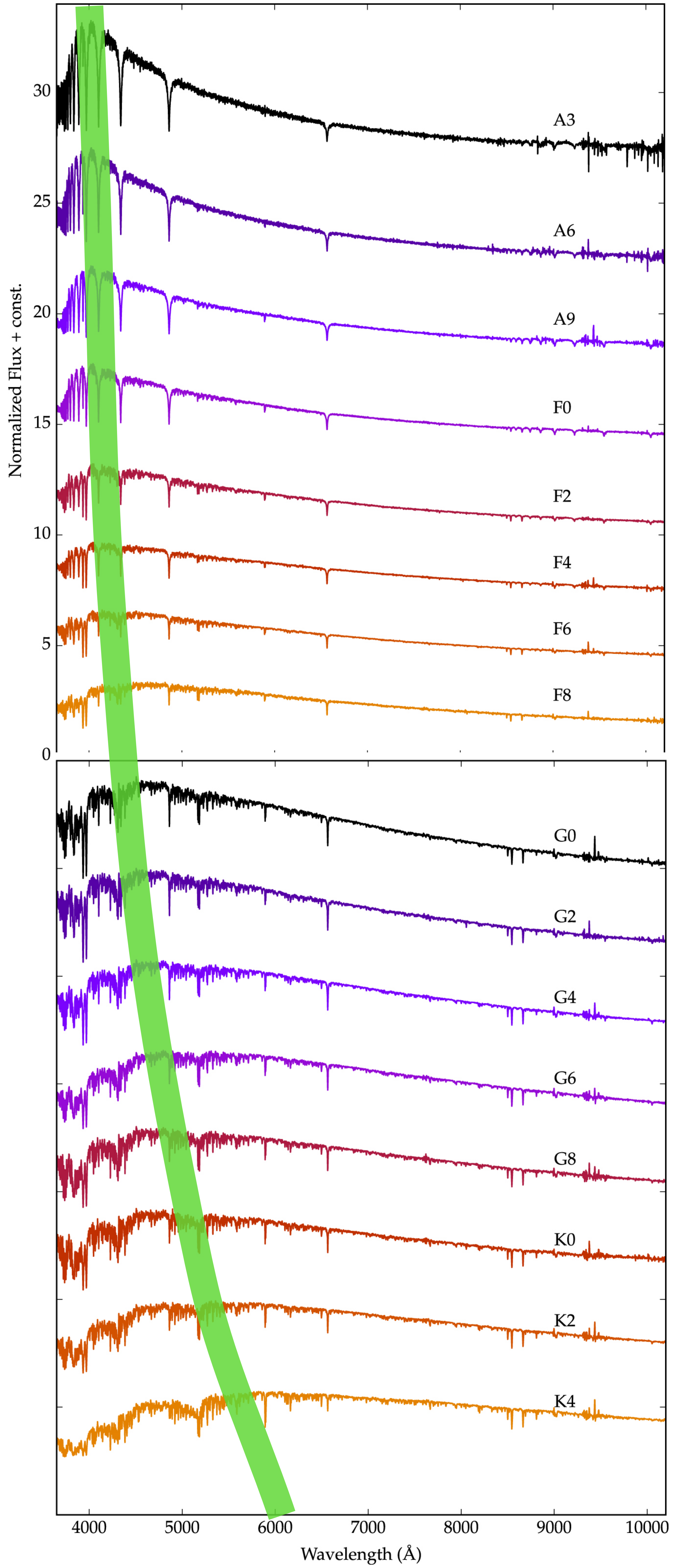
- **Mass is probably the most important/fundamental property for a star**
- It factors into all timescales at work, most other general properties (e.g. radius, temp, etc) are directly related to mass
- However, not much about the star itself is actually a direct measurement of mass
- This makes mass 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

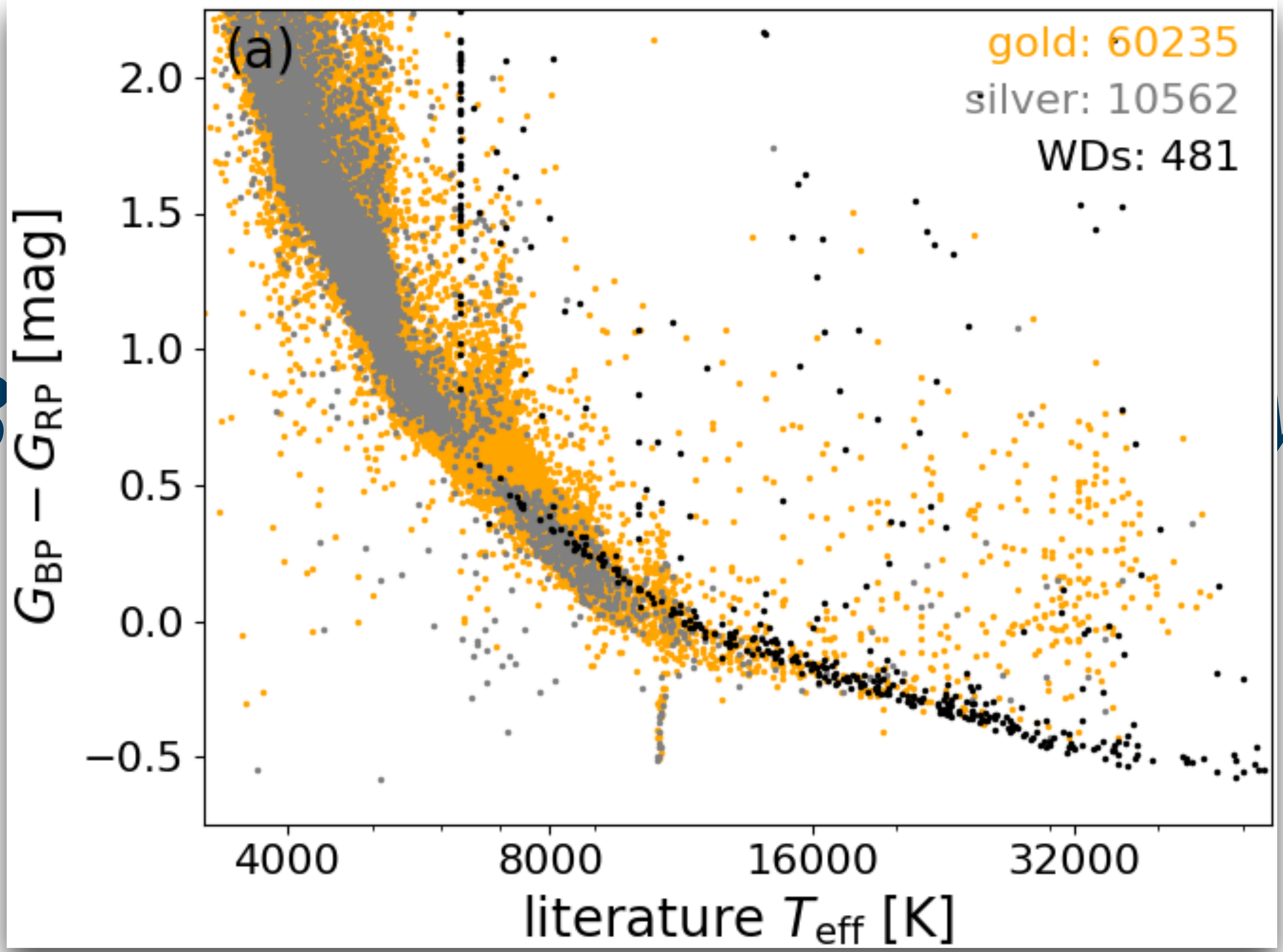


Kesseli+2017
https://arxiv.org/abs/1702.06957

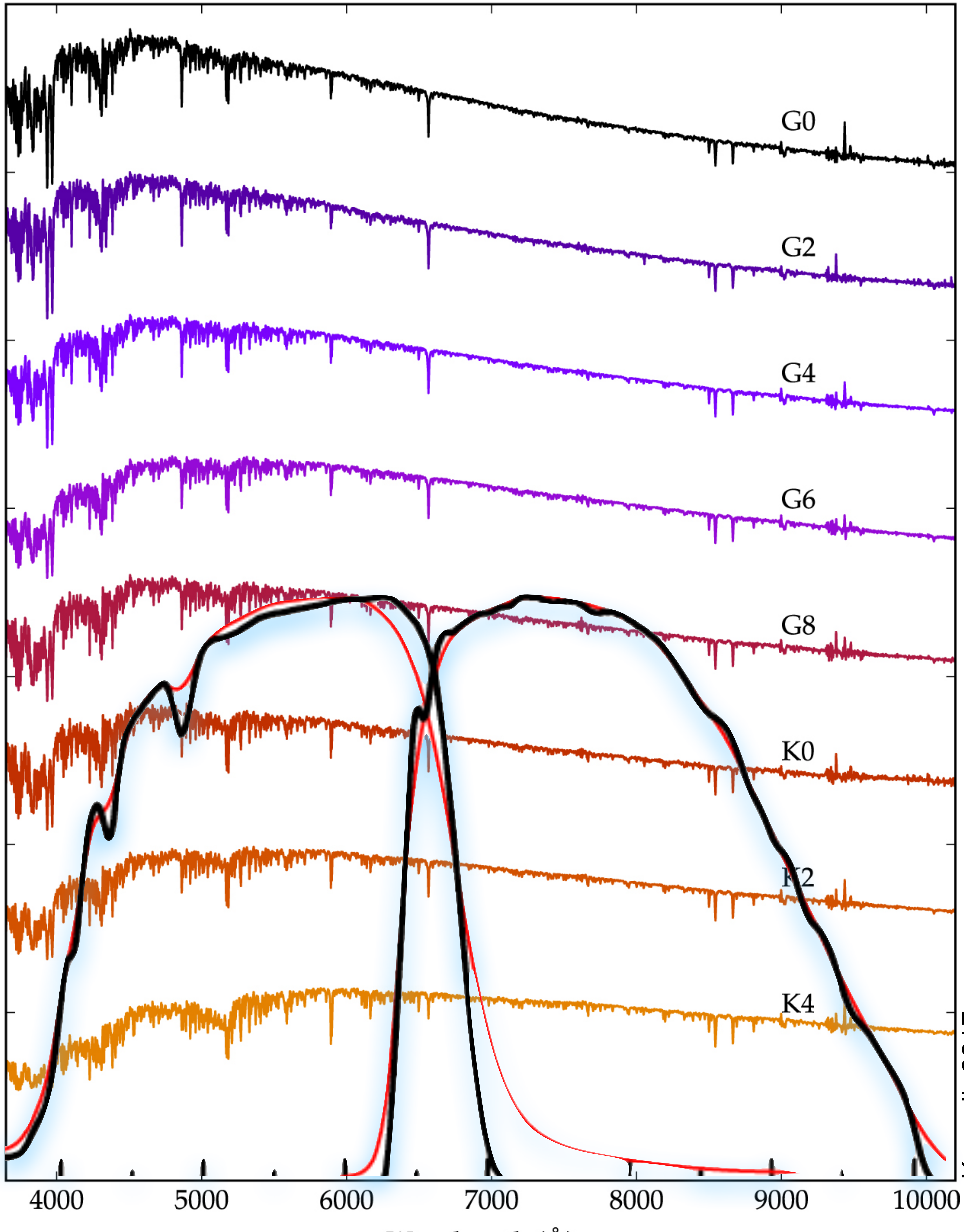
Temperature (T_{eff})

- Also can constrain with photometry via the “color”

B



M_V



Kesseli+2017
https://arxiv.org/abs/1702.06957

Luminosity

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

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

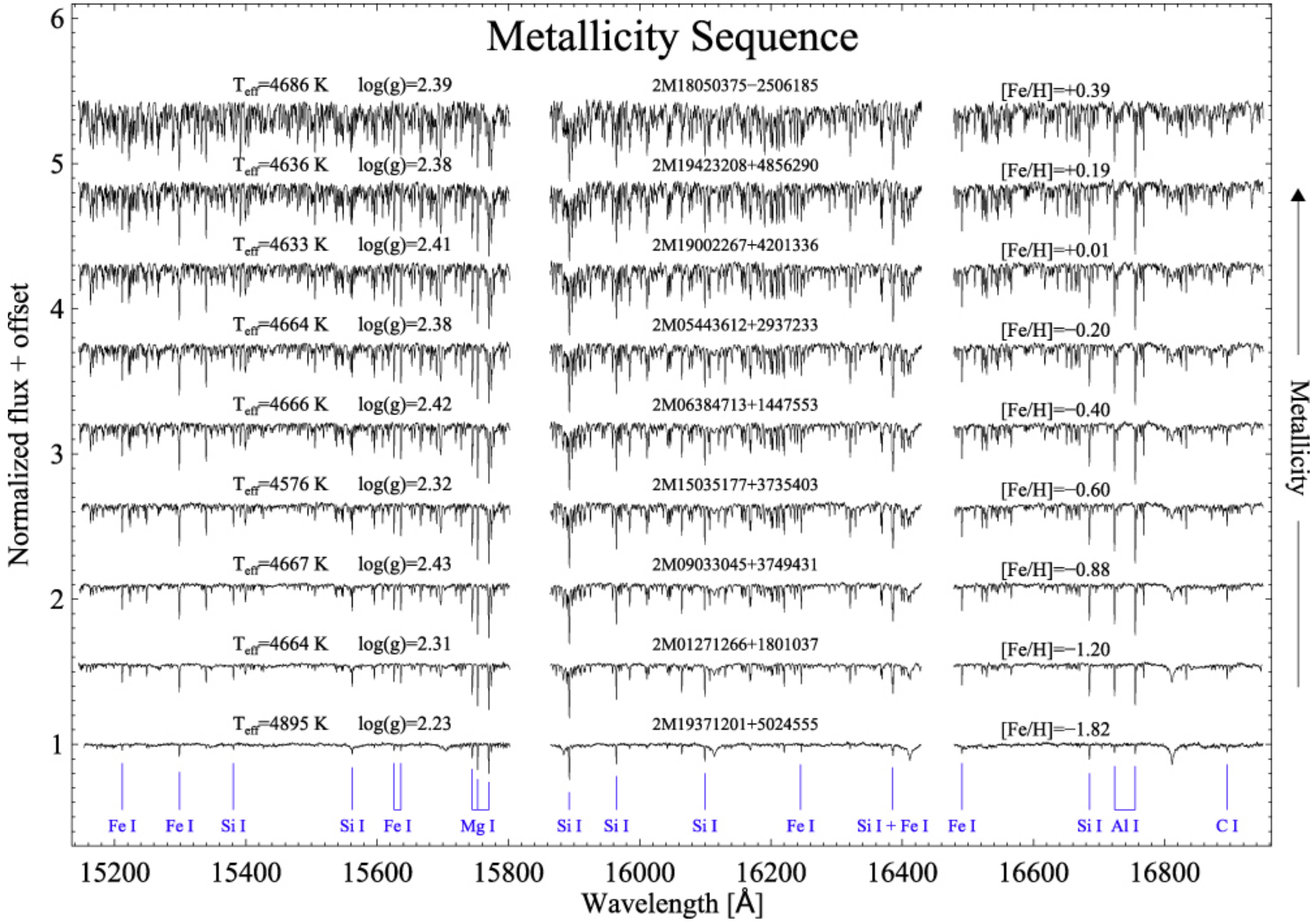
$$m_i = -2.5 \log_{10}\left(\frac{F_i}{F_0}\right)$$

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

- 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

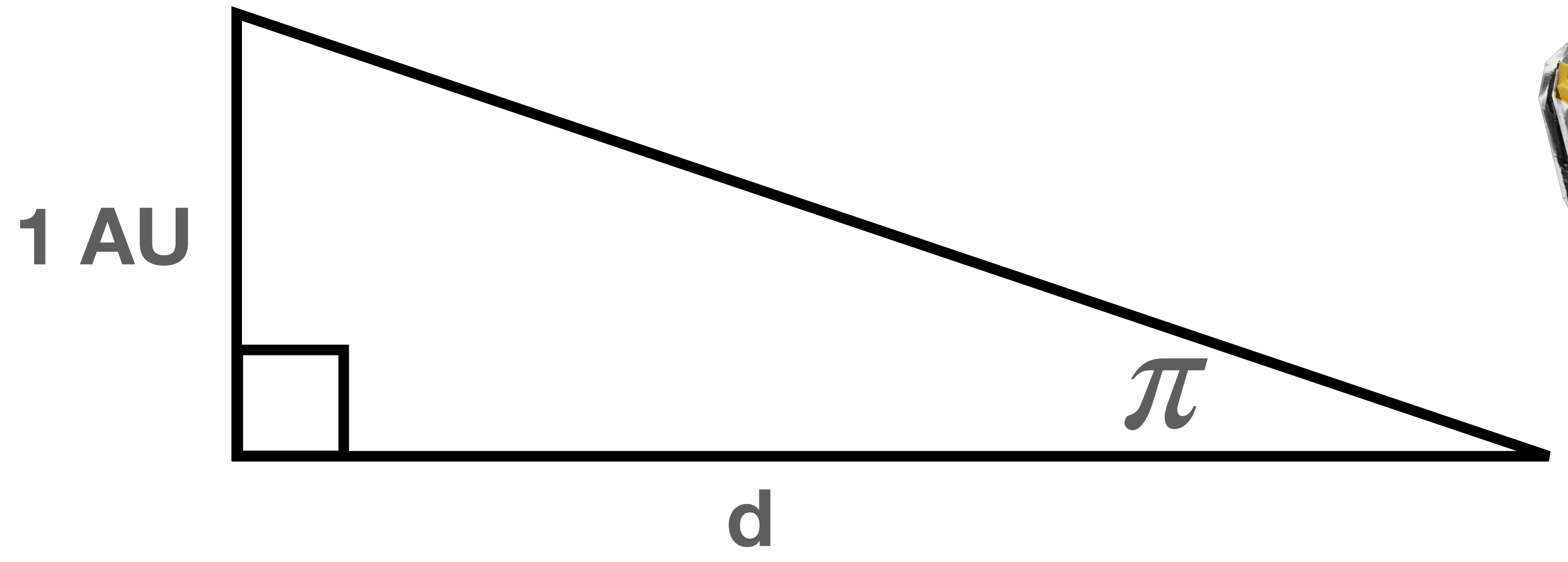
Composition (aka Metallicity)

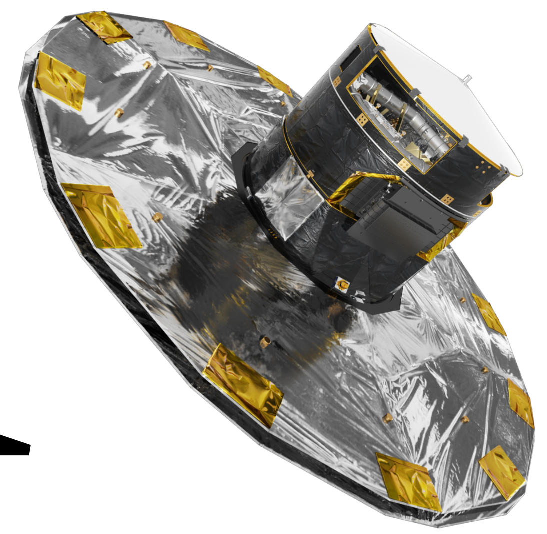
- Typically summed up as [Fe/H], i.e. the log ratio of Fe/H *relative* to the solar amount
  - Also abundances of individual elements are studied, as well as groups (e.g. [α/Fe])
- Primarily determined via spectroscopy, modeling atomic absorption lines
  - High resolution VERY helpful



Majewski+2017 (APOGEE)

Distance





Gaia

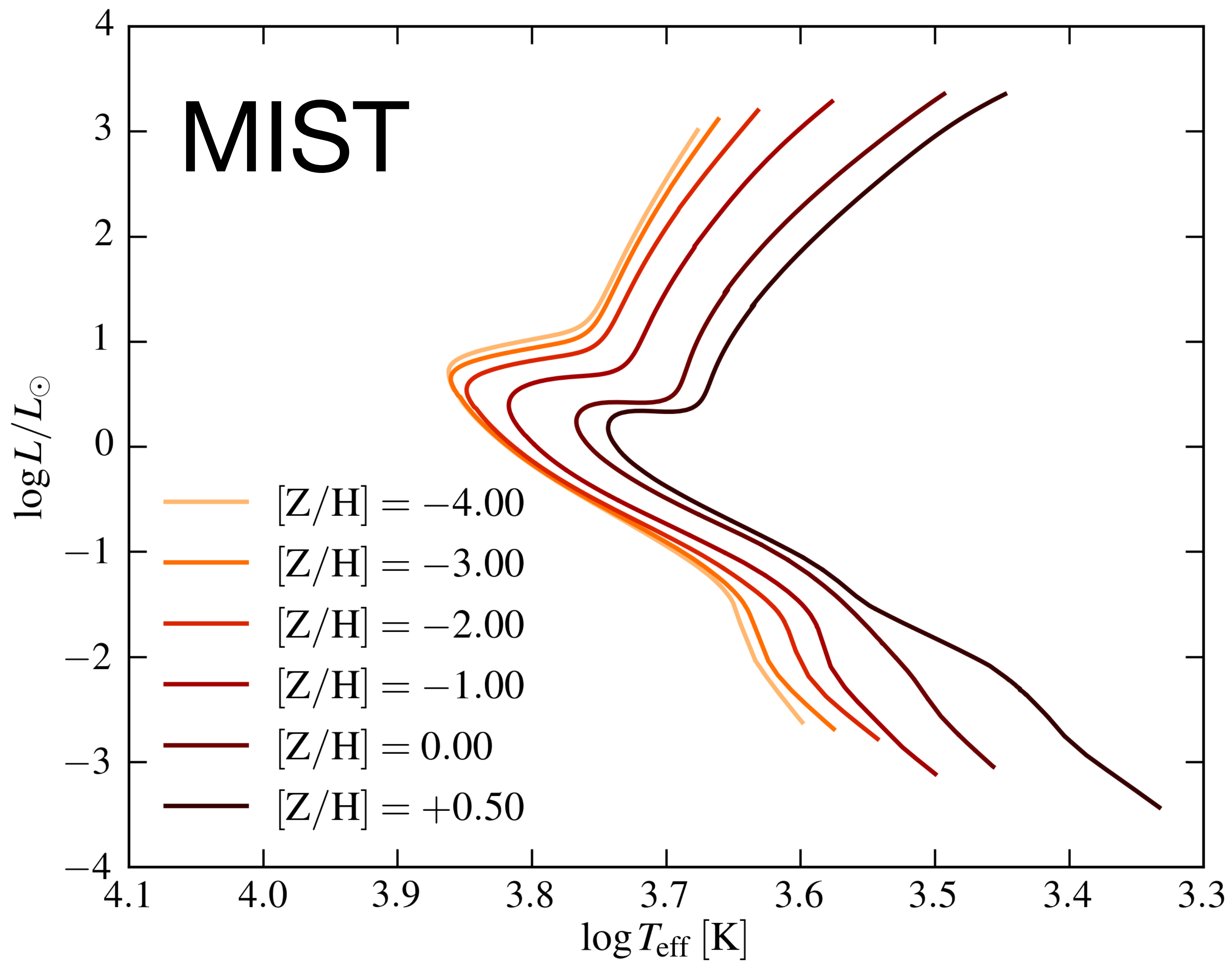
- Parallax! The best! But only for nearby stars
  (Gaia is making this *better, +1Billion stars*, but not perfect!)

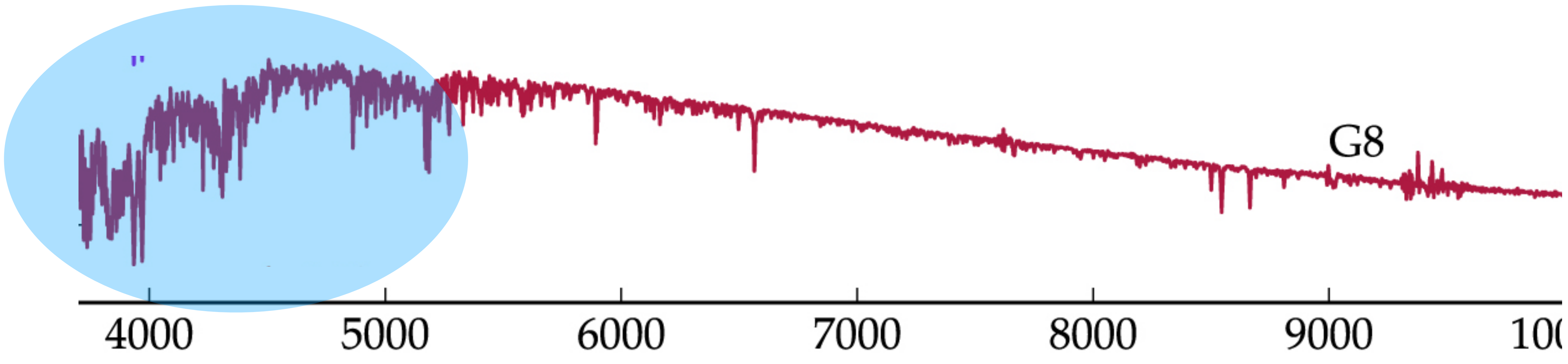
- Many other clever ways:
  - Stellar clusters $m - M = 5\log_{10} d[pc] - 5$
  - RR Lyr, standard candles, the "distance ladder", etc…
  - Eclipsing binaries
    - e.g. LMC distance to 2% Still the benchmark [Pietrzyński et al. (2013)]

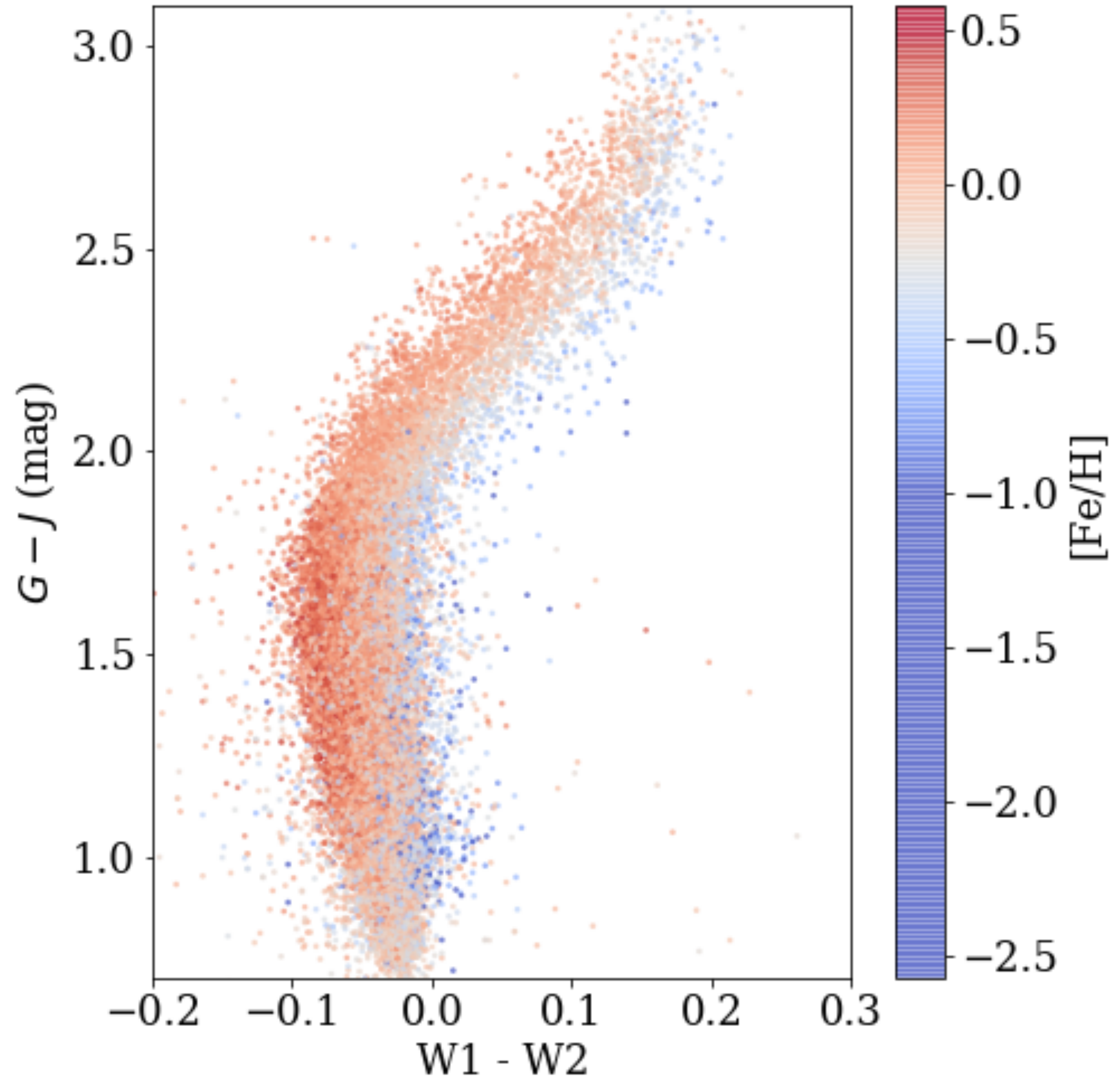
- Can be estimated for a star if you assume it is main sequence
  (e.g. "photometric parallax") or take a spectrum

Composition (aka Metallicity)

- 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



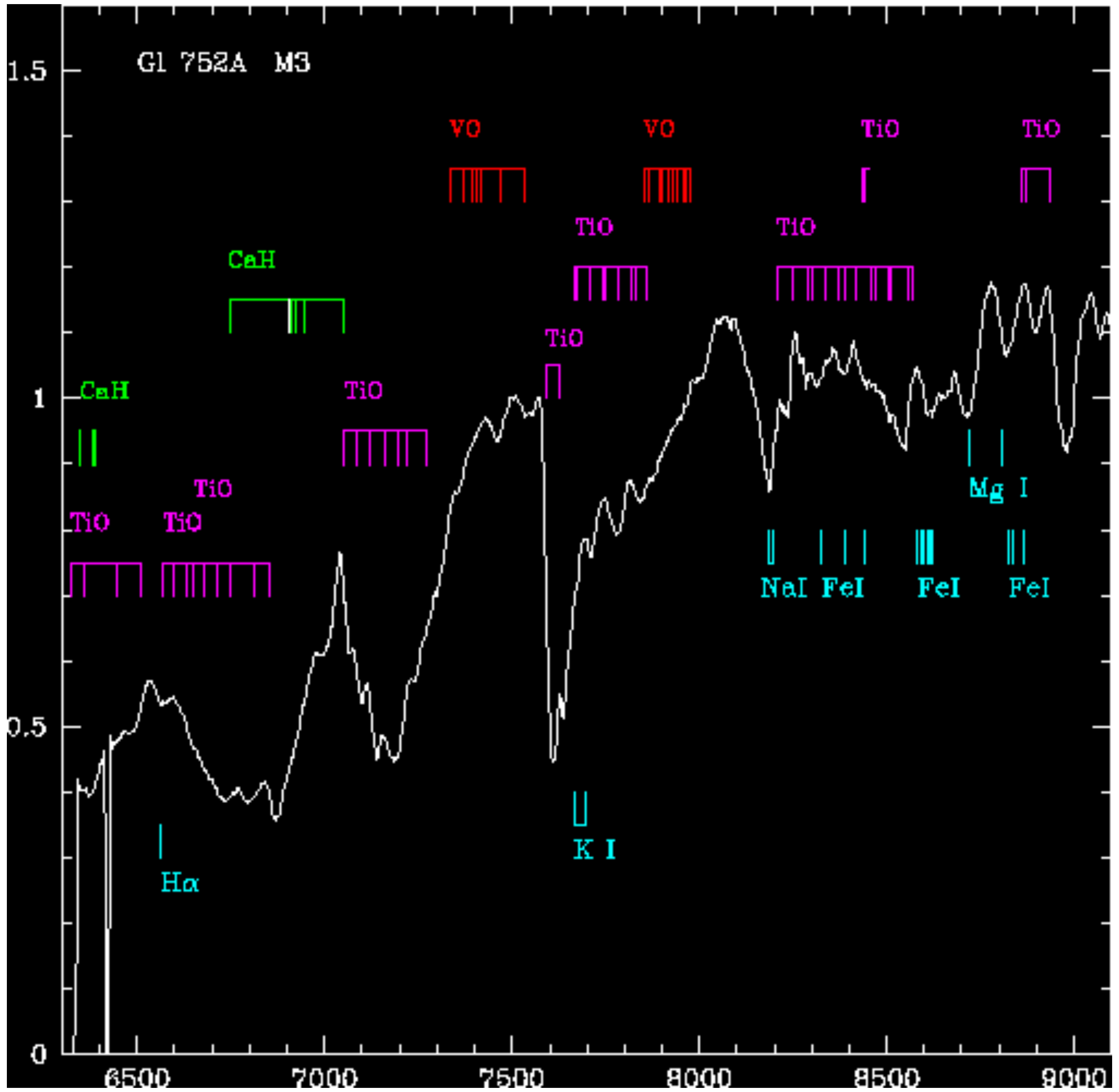


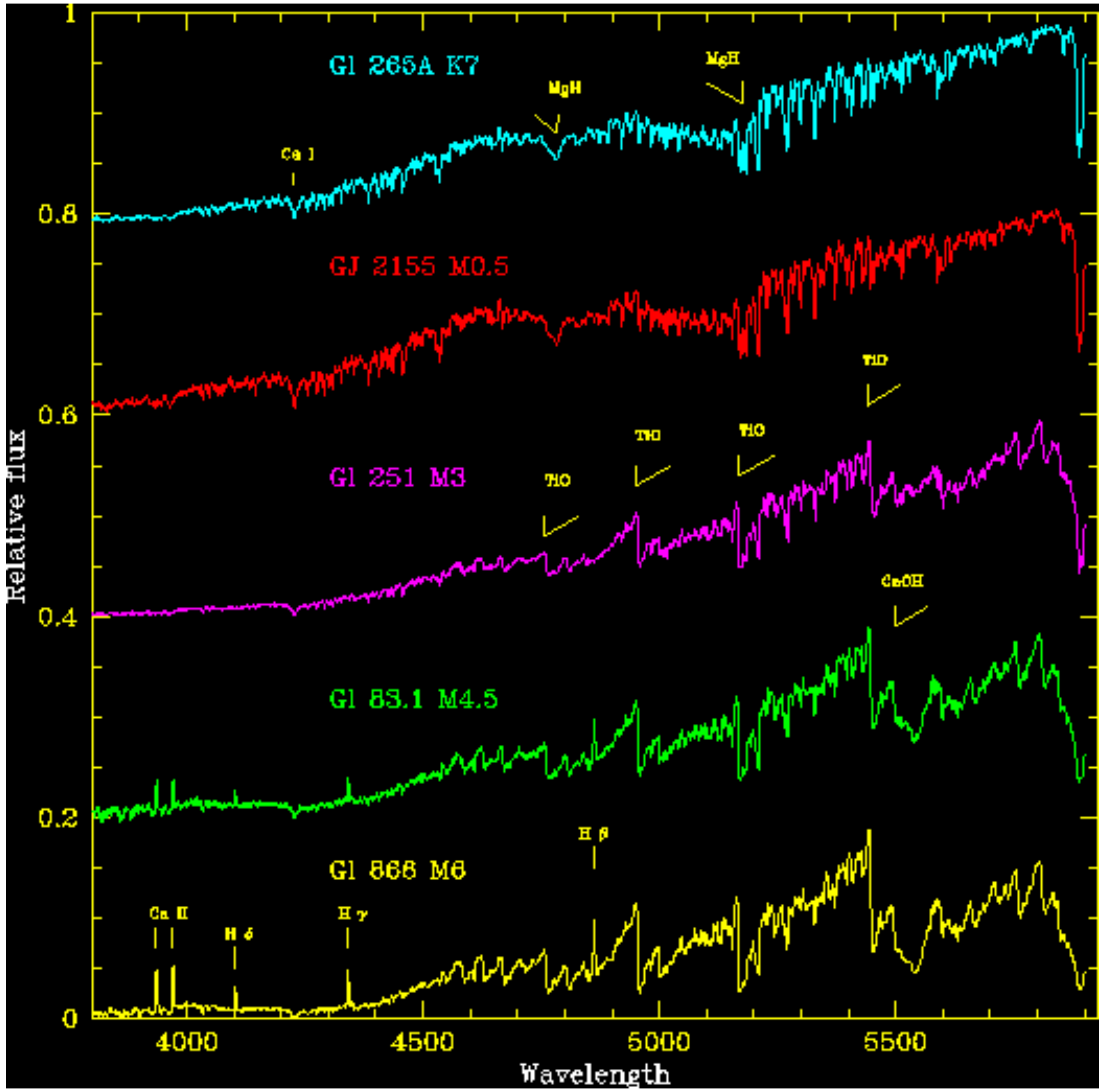


Davenport & Dorn-Wallenstein

Composition (aka Metallicity)

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



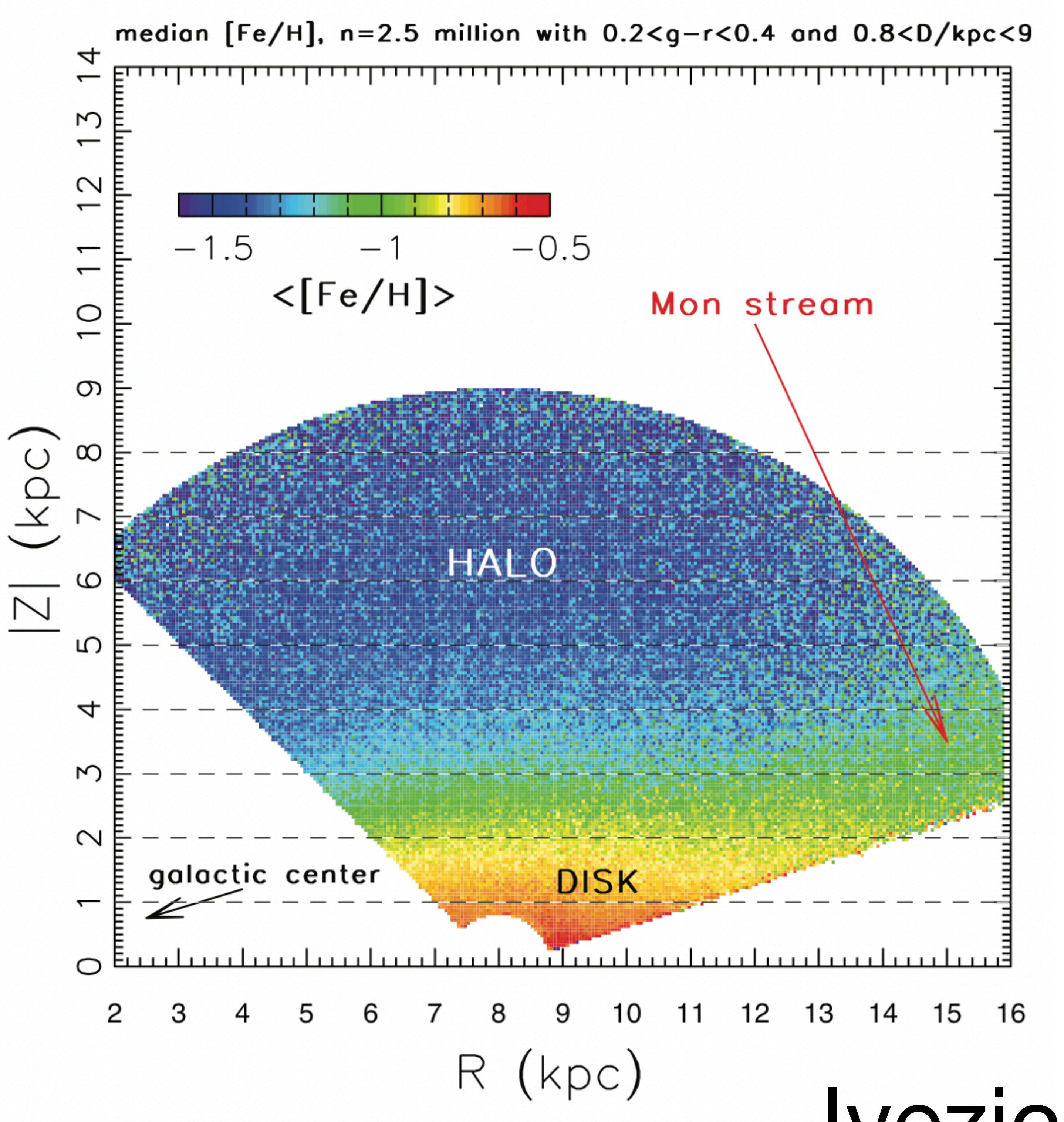


[N. Reid]

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

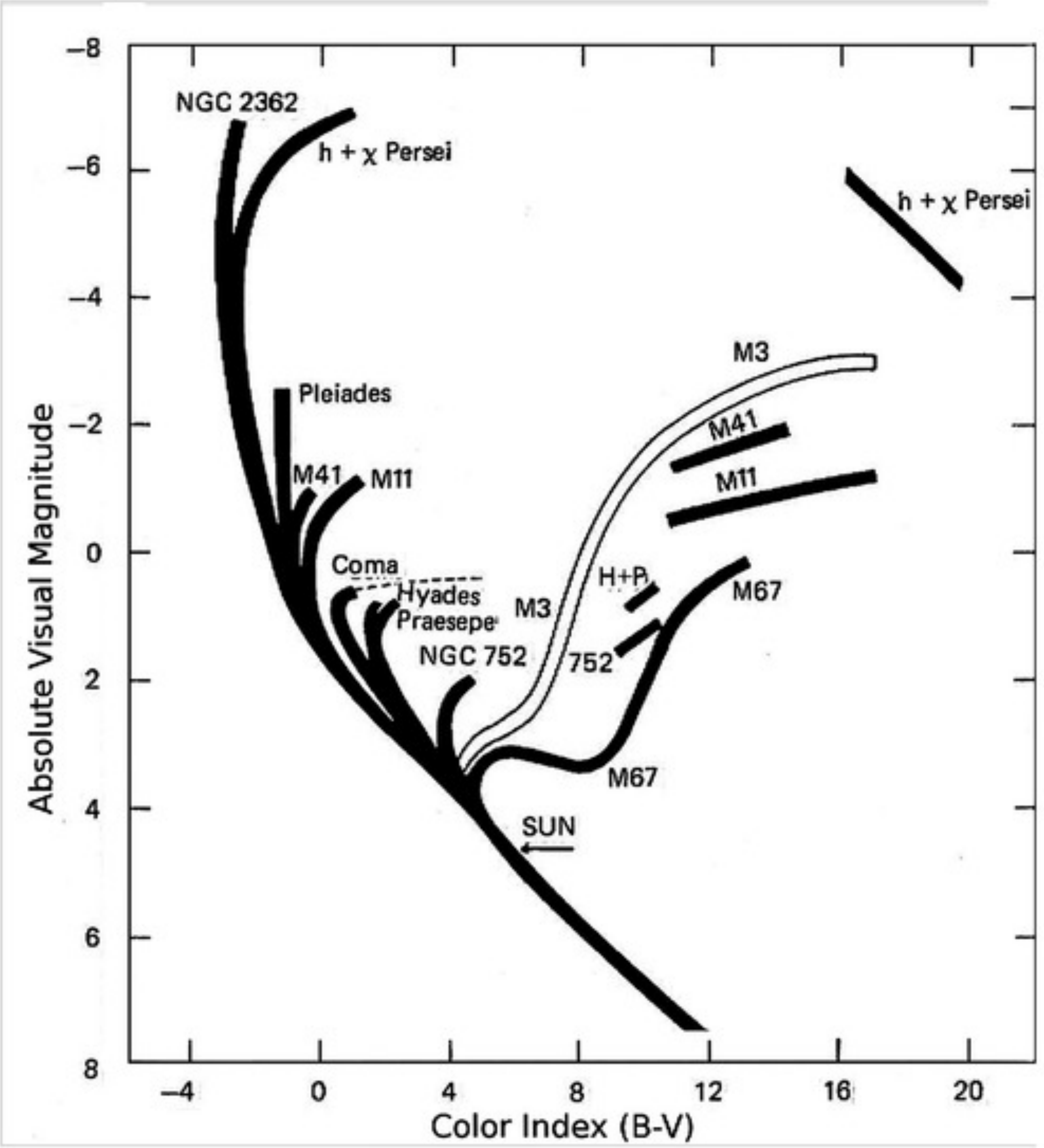


Ivezic+2008

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”

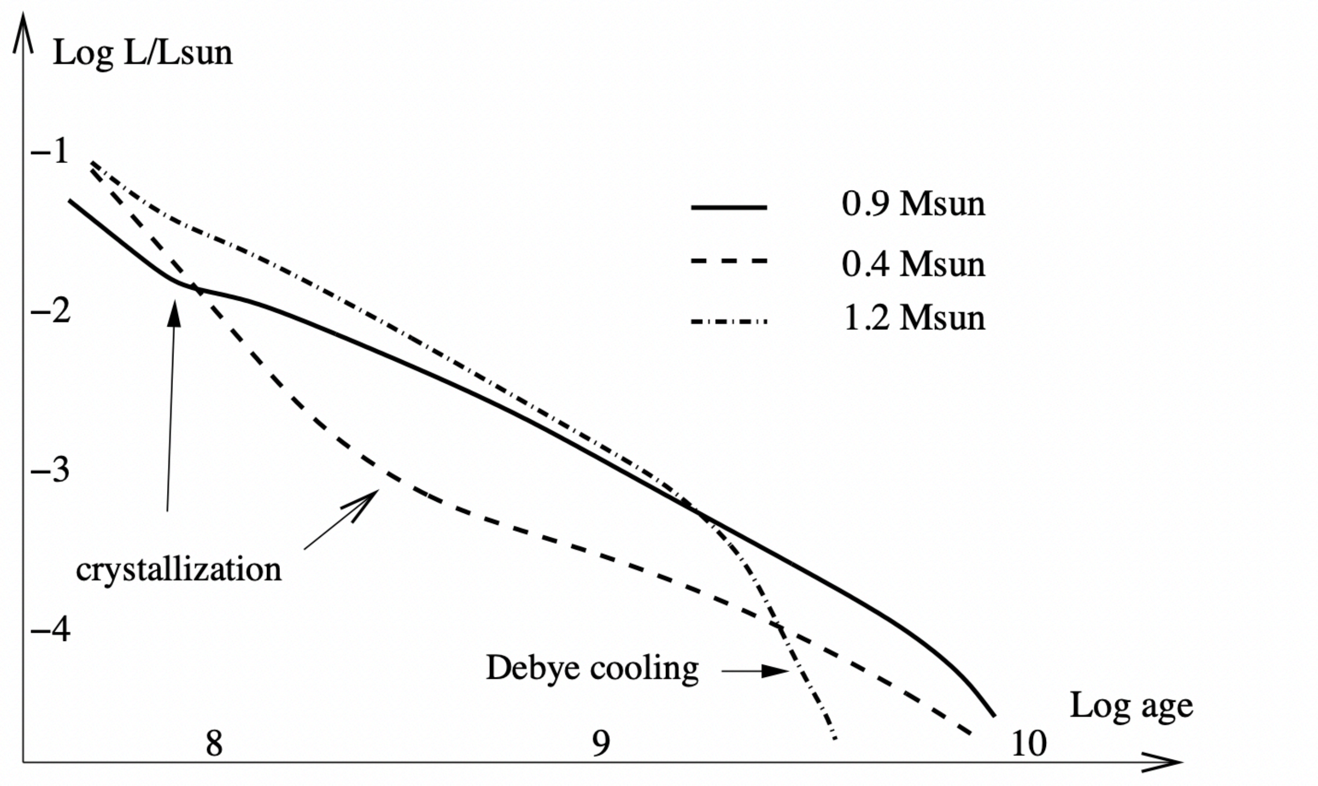


Sandage (1957)

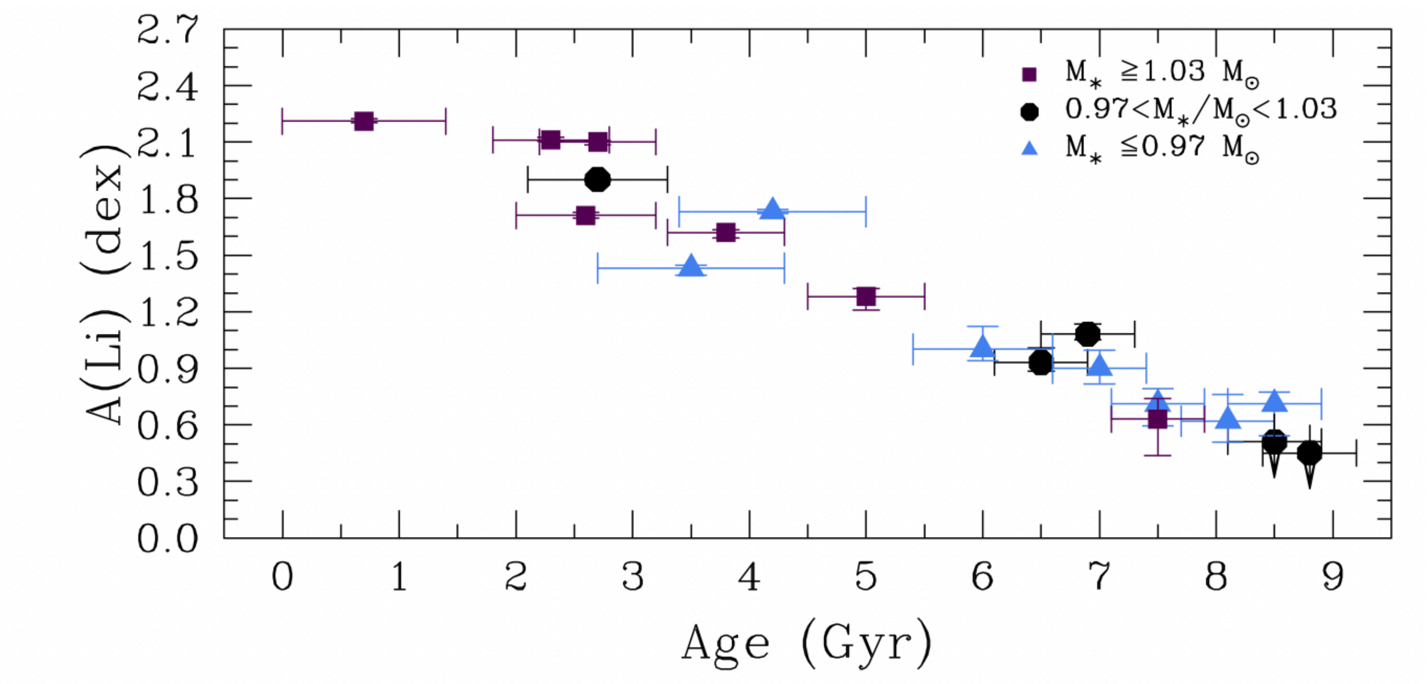
Age

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

Althaus+2010



  - Lithium abundance



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

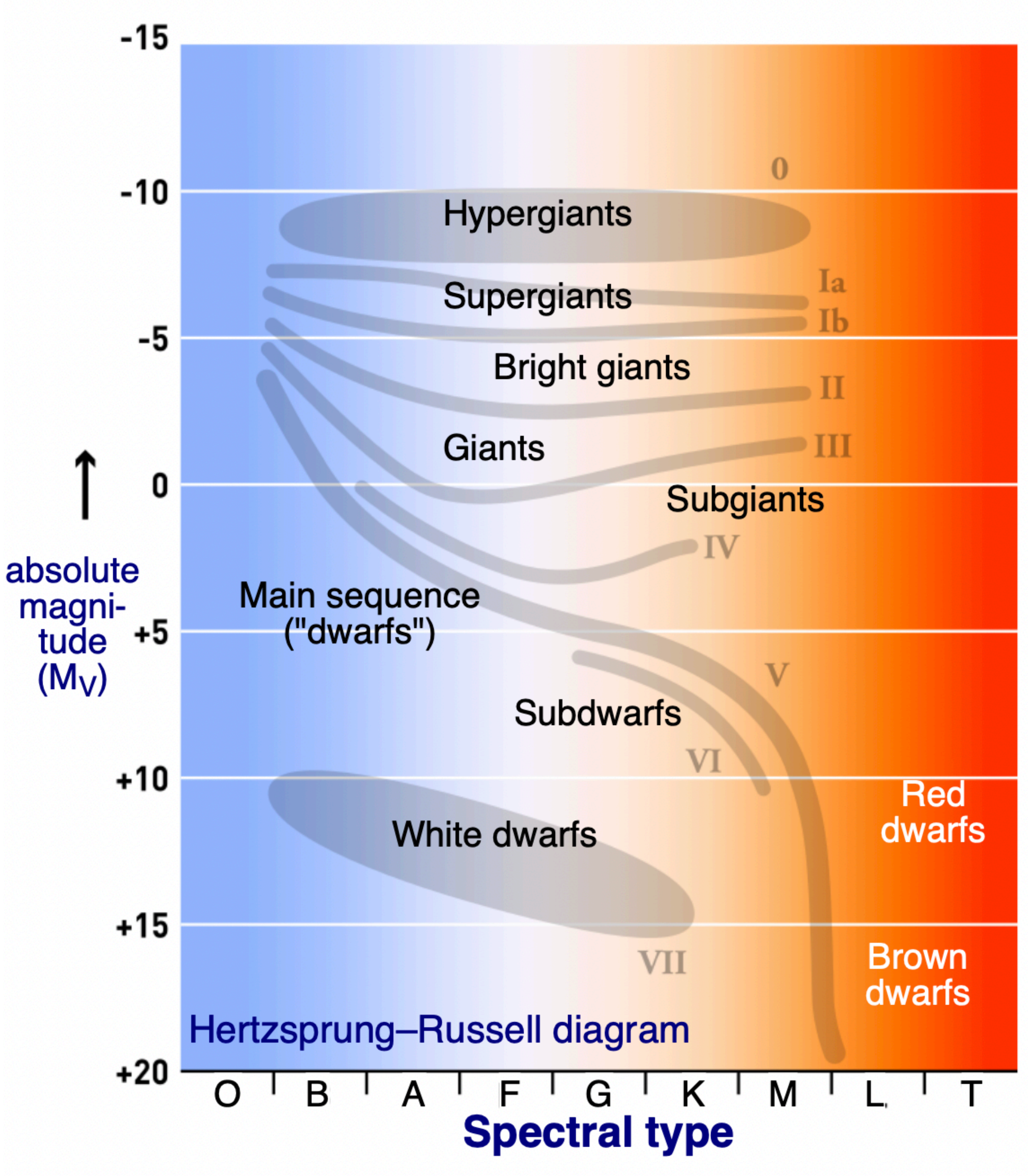
- Radius
- Density
- Surface Gravity
- Binarity

Very interesting, but not critical for Galactic Astronomy

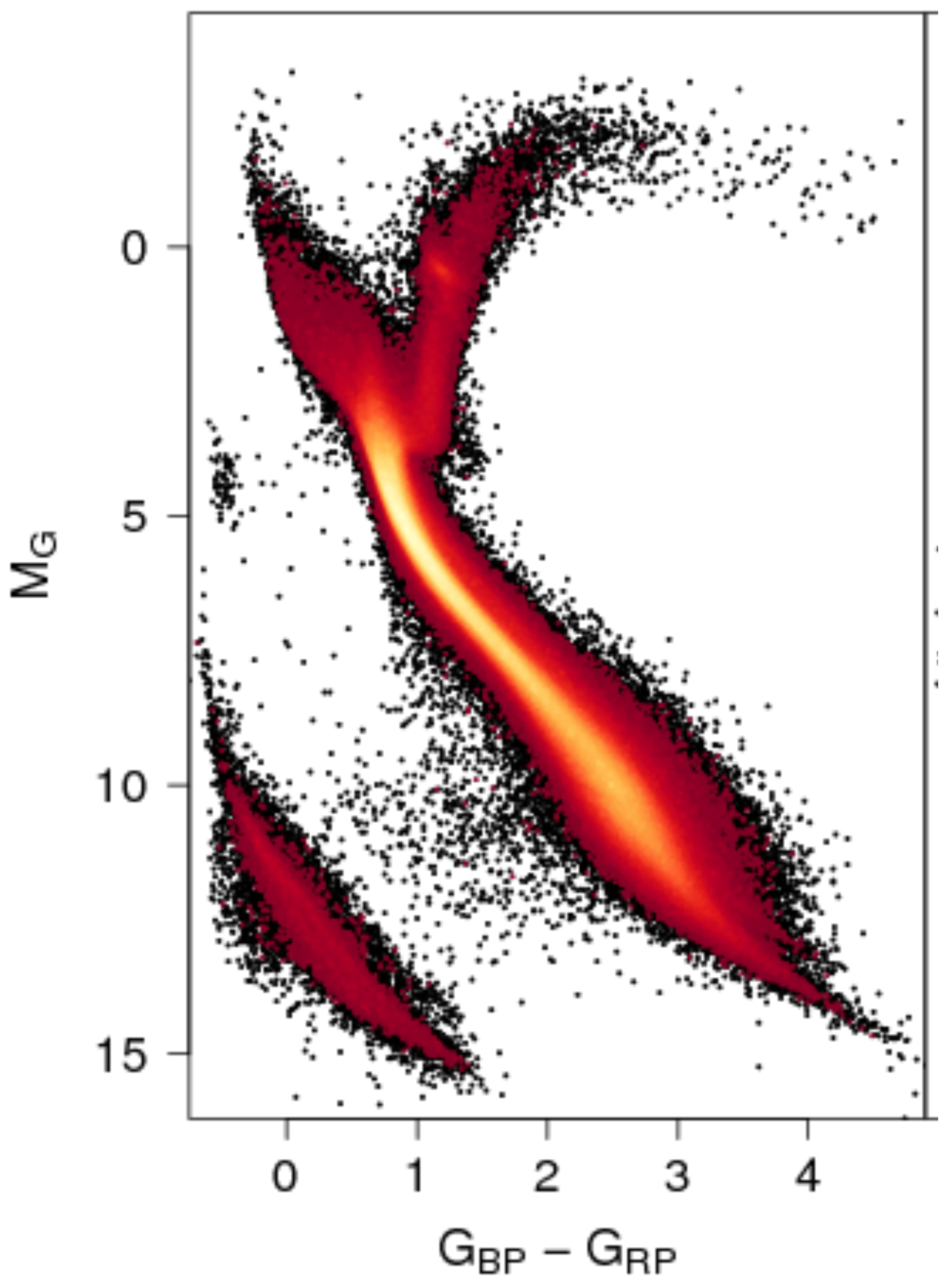
The H-R Diagram

- <u>Theorists</u>:
  Temp, Lum
  or
  Temp, log g

- <u>Observers</u>:
  Color, Mag

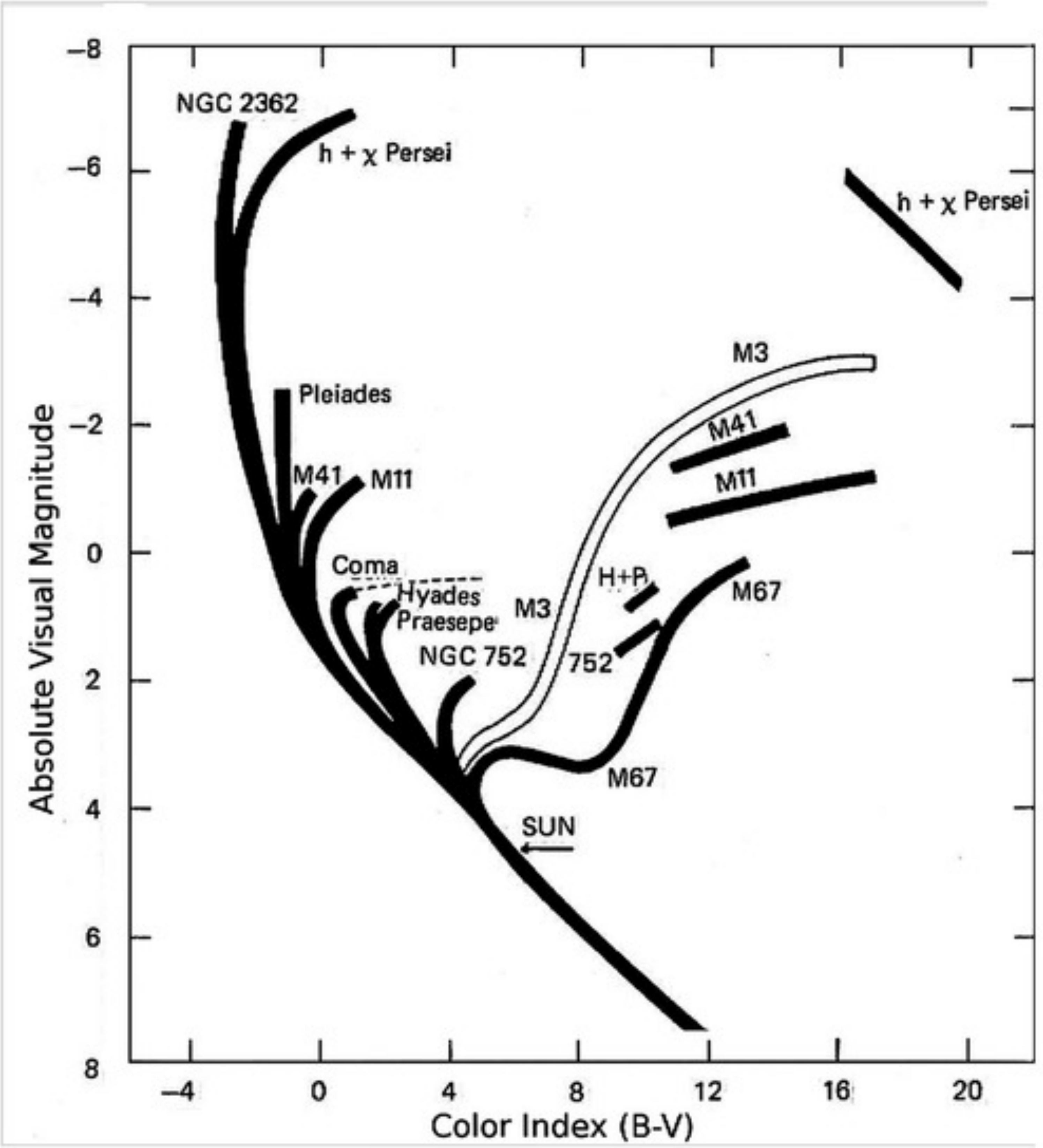


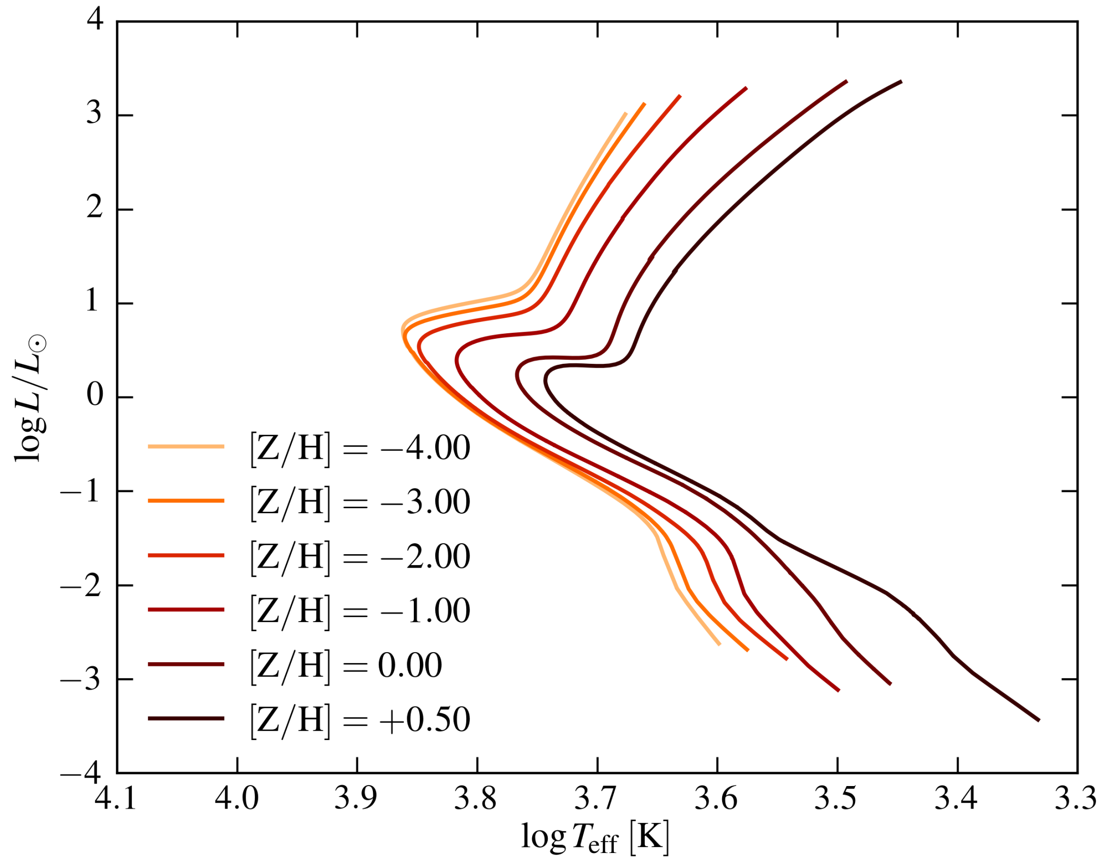
Gaia DR2 CMD

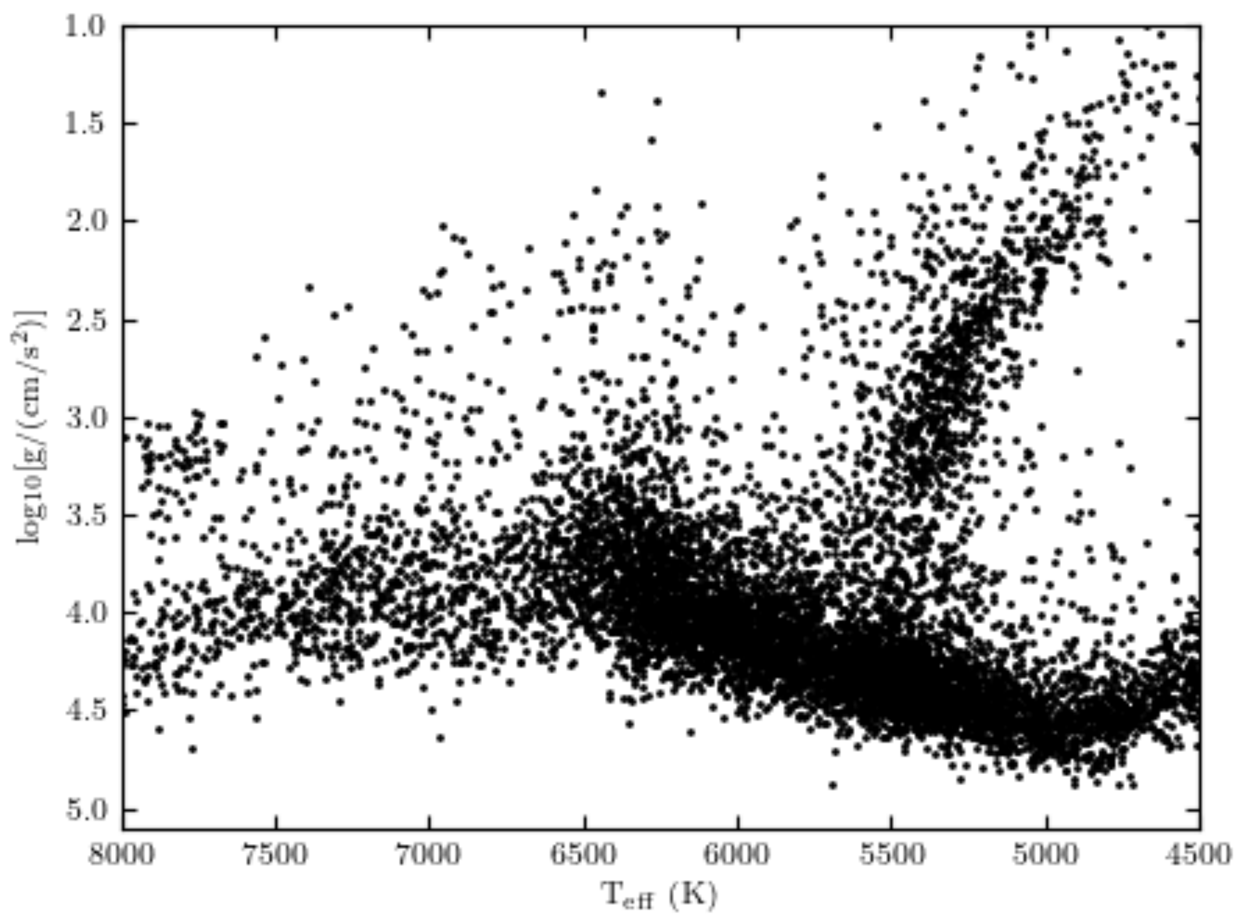


The H-R Diagram

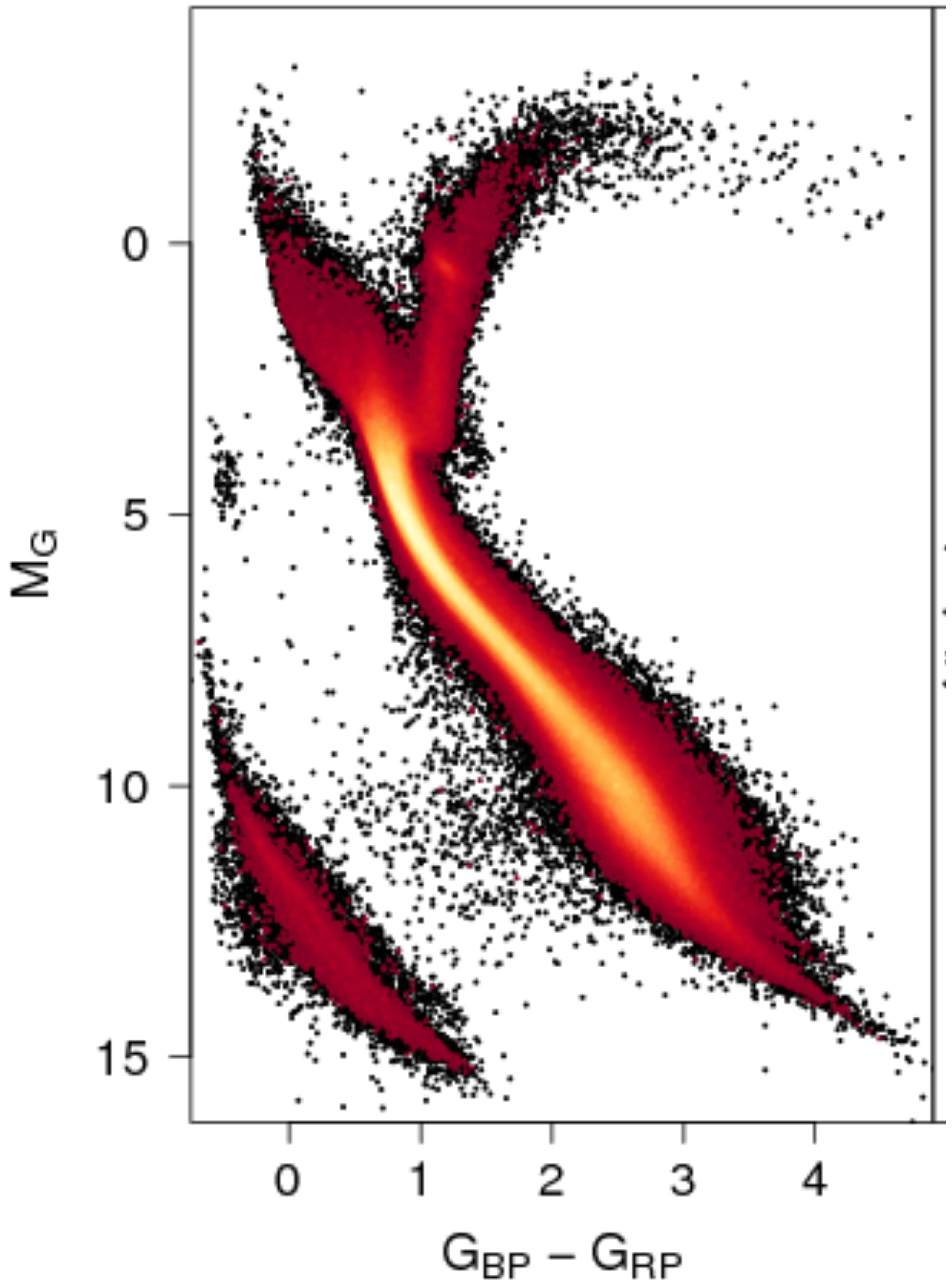
A Rosetta Stone for understanding the lives & properties of stars







Gaia DR2 CMD



Next time:

- The Solar Neighborhood