# ASTR 511

## Galactic Astronomy

# Lecture 01

## Introductions & Review

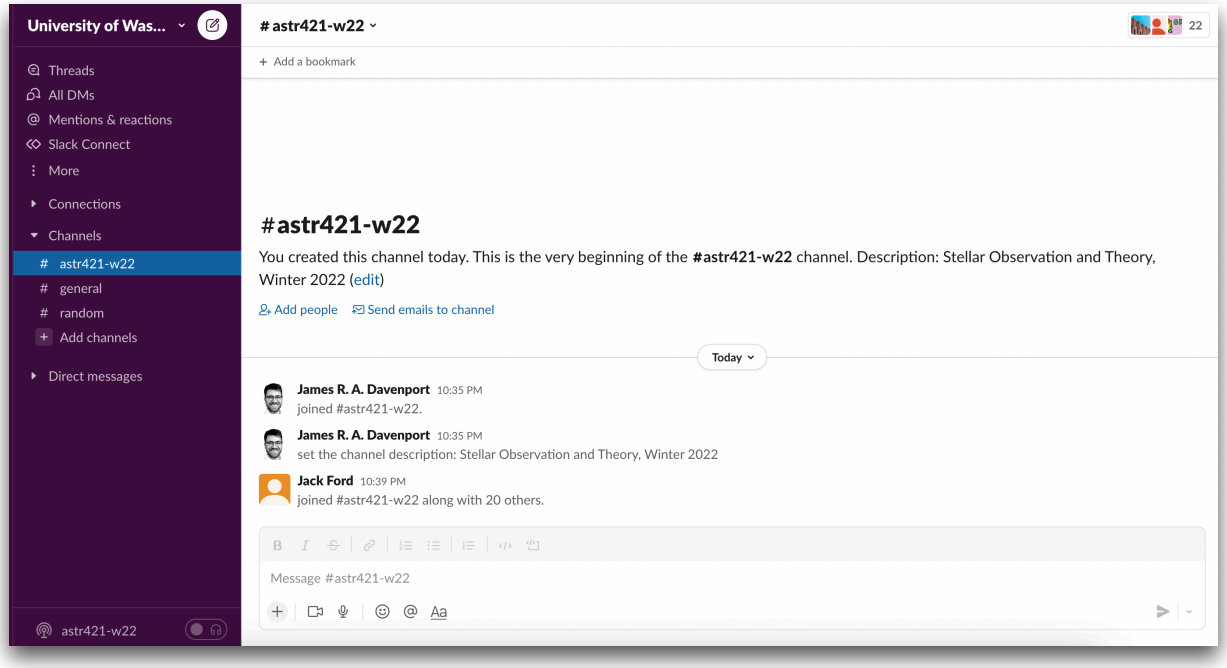
Prof. James Davenport (UW)

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?

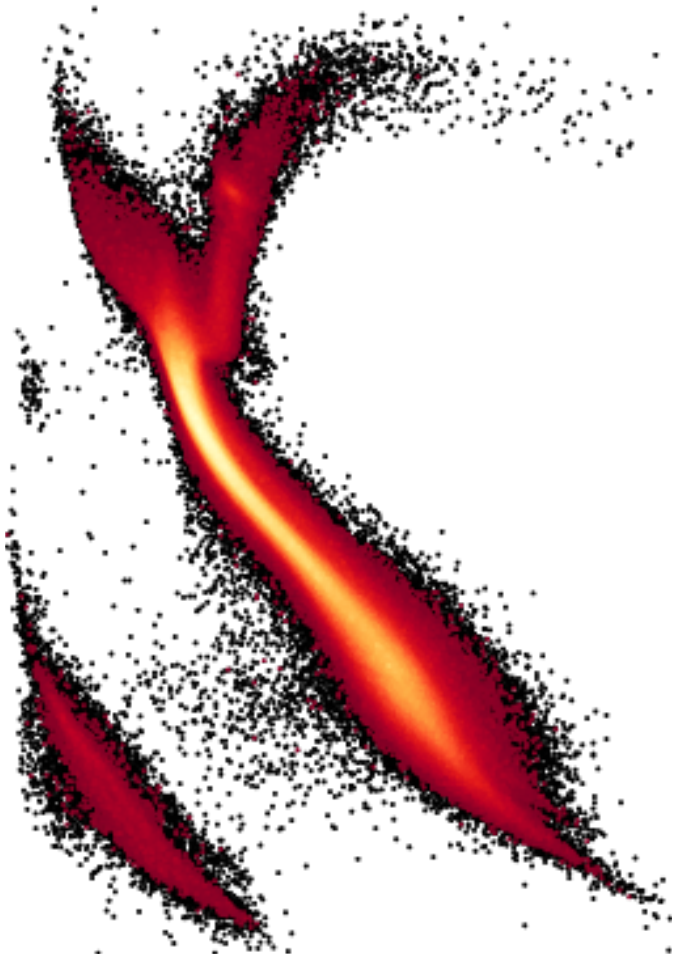
- **A word on teaching/course philosophy**
  - No book? Term paper?! Why do we have these lectures?

# One more thing…

**Let’s talk for a moment about a couple other semi-related things going on this Quarter**

# 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 called “Galactic Astronomy”, “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*

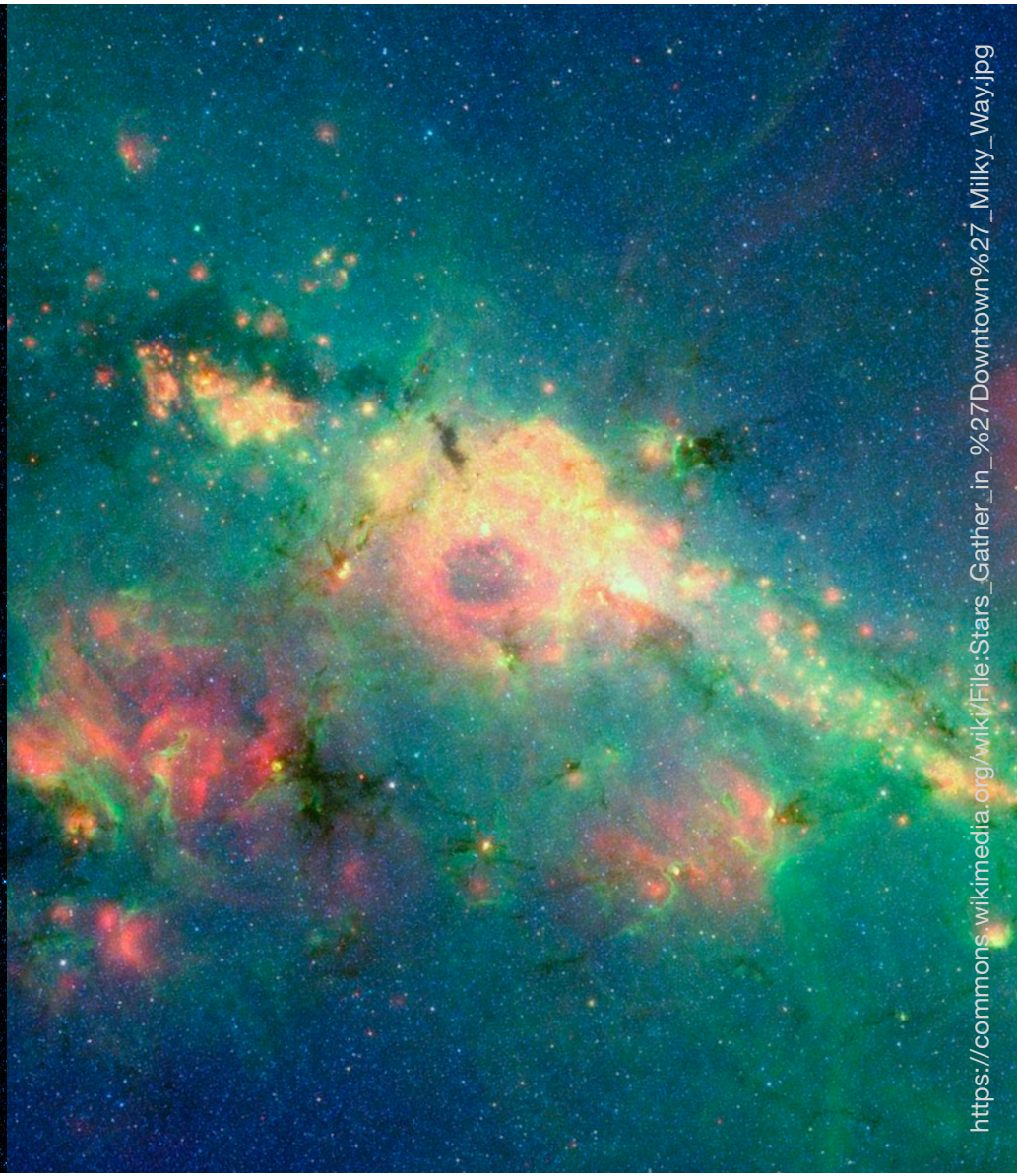
**ASTR 511: Galactic Astronomy**

**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!

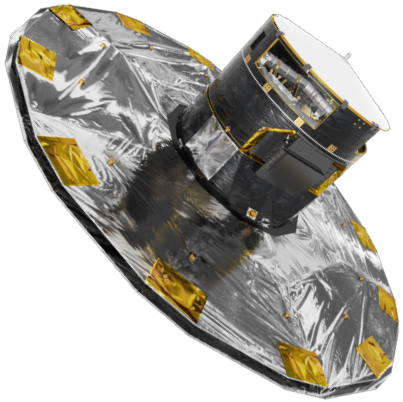
# Course Goals

https://commons.wikimedia.org/wiki/File:WISE-_Andromeda.jpg

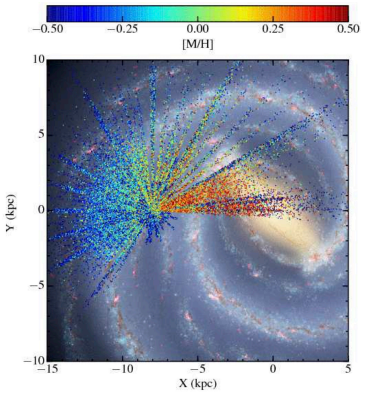


https://commons.wikimedia.org/wiki/File:Stars_Gather_in_%27Downtown%27_Milky_Way.jpg

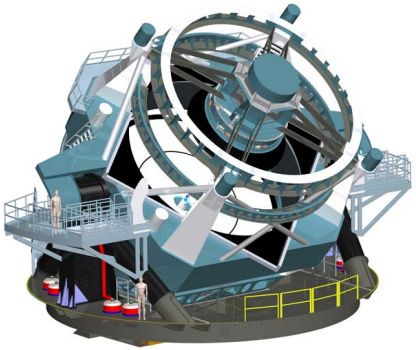
# Course Goals



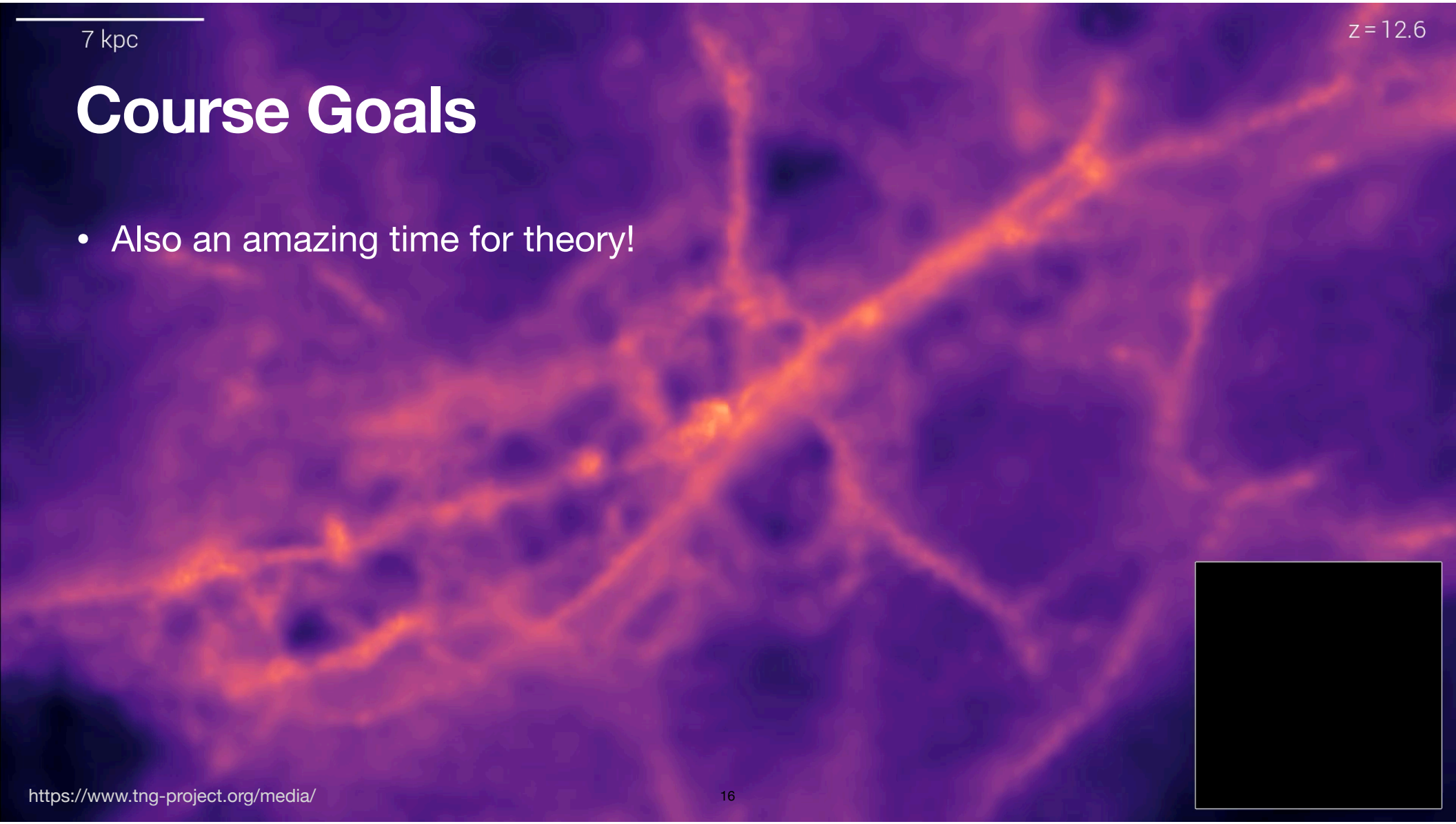
- Both… but with an emphasis on the Milky Way
  - Because I think about nearby things, and it is timely…
- **Now is a golden age for galactic astronomy observations**







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




# Course Goals

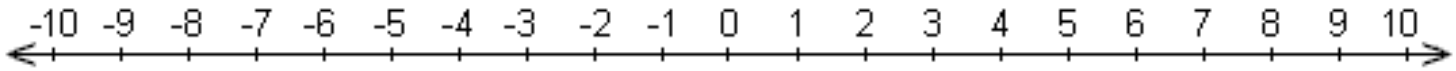
- Also an amazing time for theory!

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

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

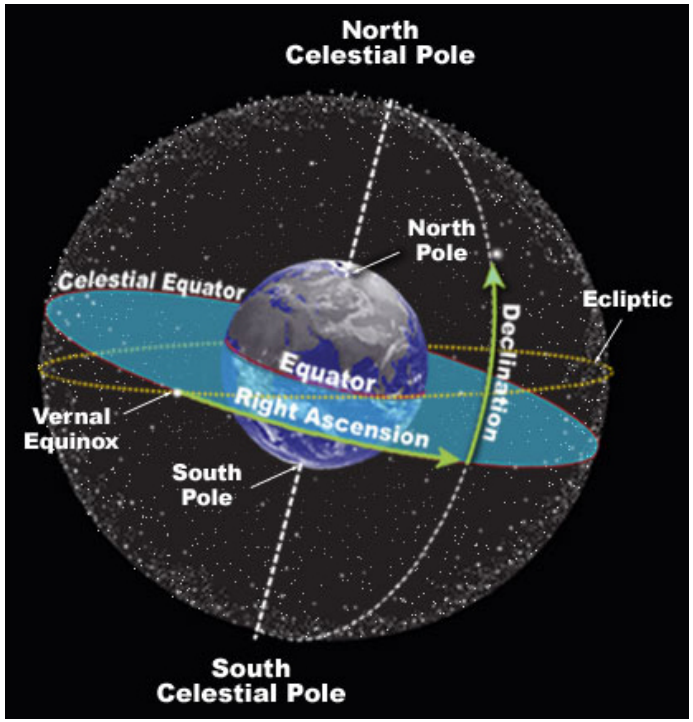
$$m - M = 5 \log_{10} d[pc] - 5$$

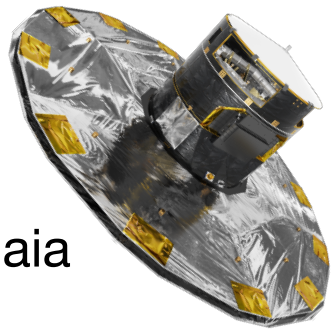
$$B - V \equiv m_B - m_V \equiv M_B - M_V$$

**Bold statement: magnitudes are a good unit!**

# Astro Jargon Review

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



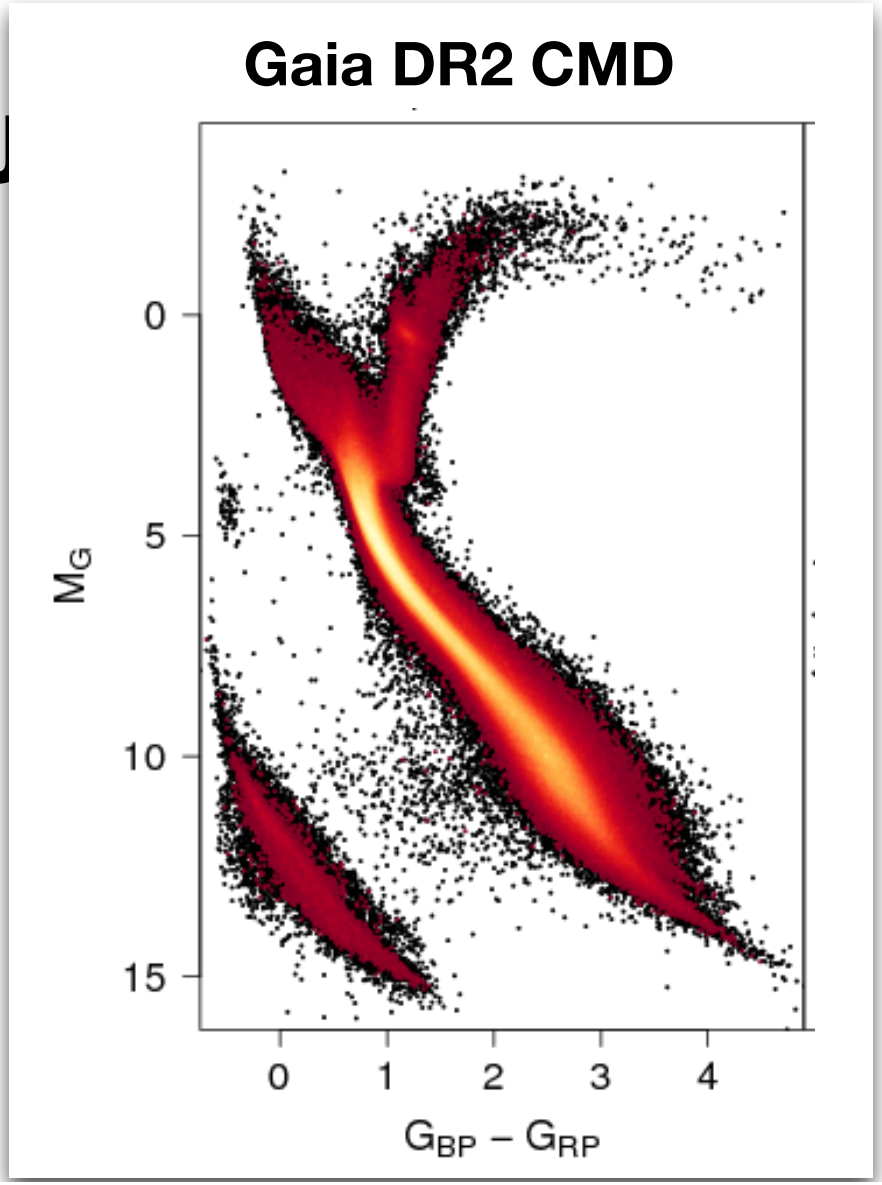



Gaia

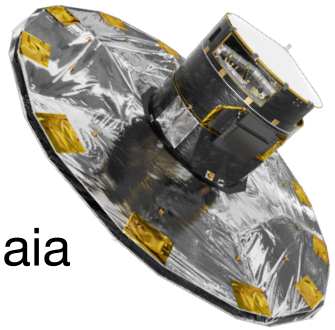
$$m - M = 5 \log_{10} d[pc] - 5$$

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

# Astro J




Gaia



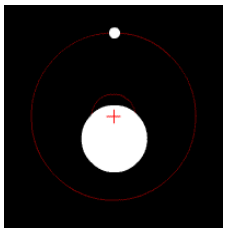
https://www.cosmos.esa.int/web/gaia/gaiadr2_hrd

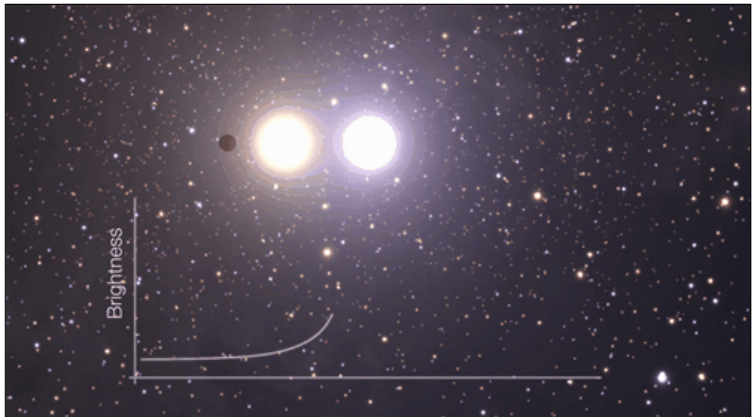
# Stars

- 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

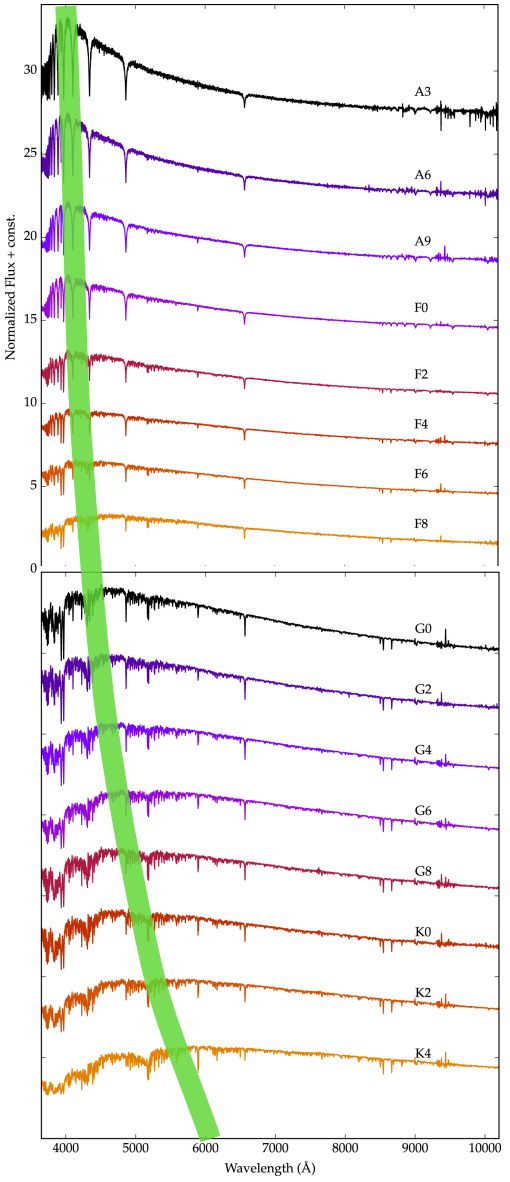
- **Mass is probably the most important/fundamental property for a star**
- It factors into all timescales at work, most other general properties (e.g. radius, temp, etc) are directly related to mass
- However, not much about the star itself is actually a direct measurement of mass
- This makes mass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





# Temperature ($T_{eff}$)

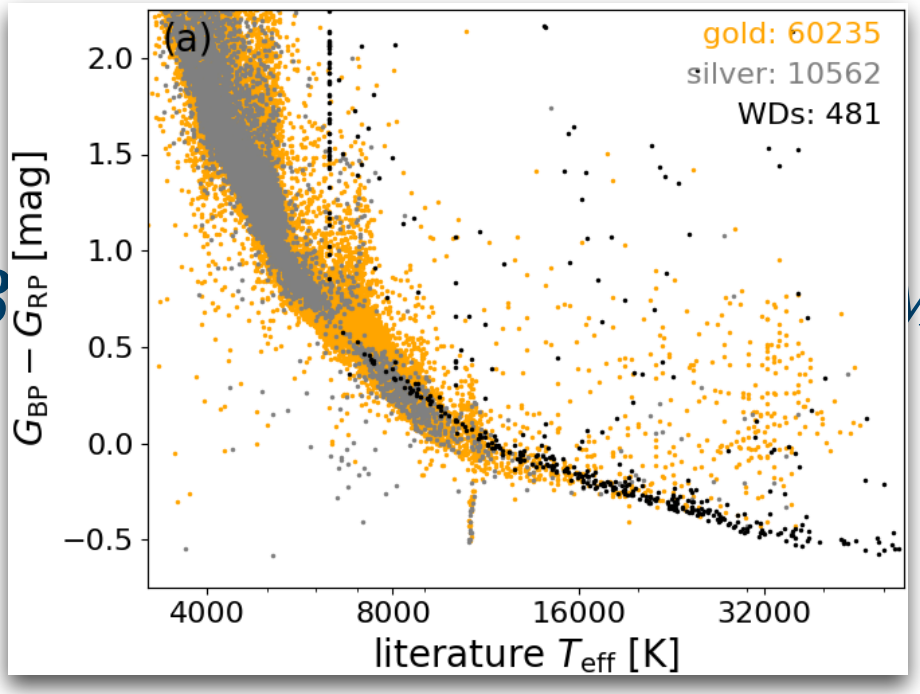
- Probably the most common property to measure
- Many ways to constrain!
- Spectroscopically (e.g. Wien's Law)
- The "effective temperature" is the Temp that a star would have if it were a perfect blackbody with the same luminosity $L = 4\pi R^2 \sigma_{SB} T^4$
  - Very close to the surface temp for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



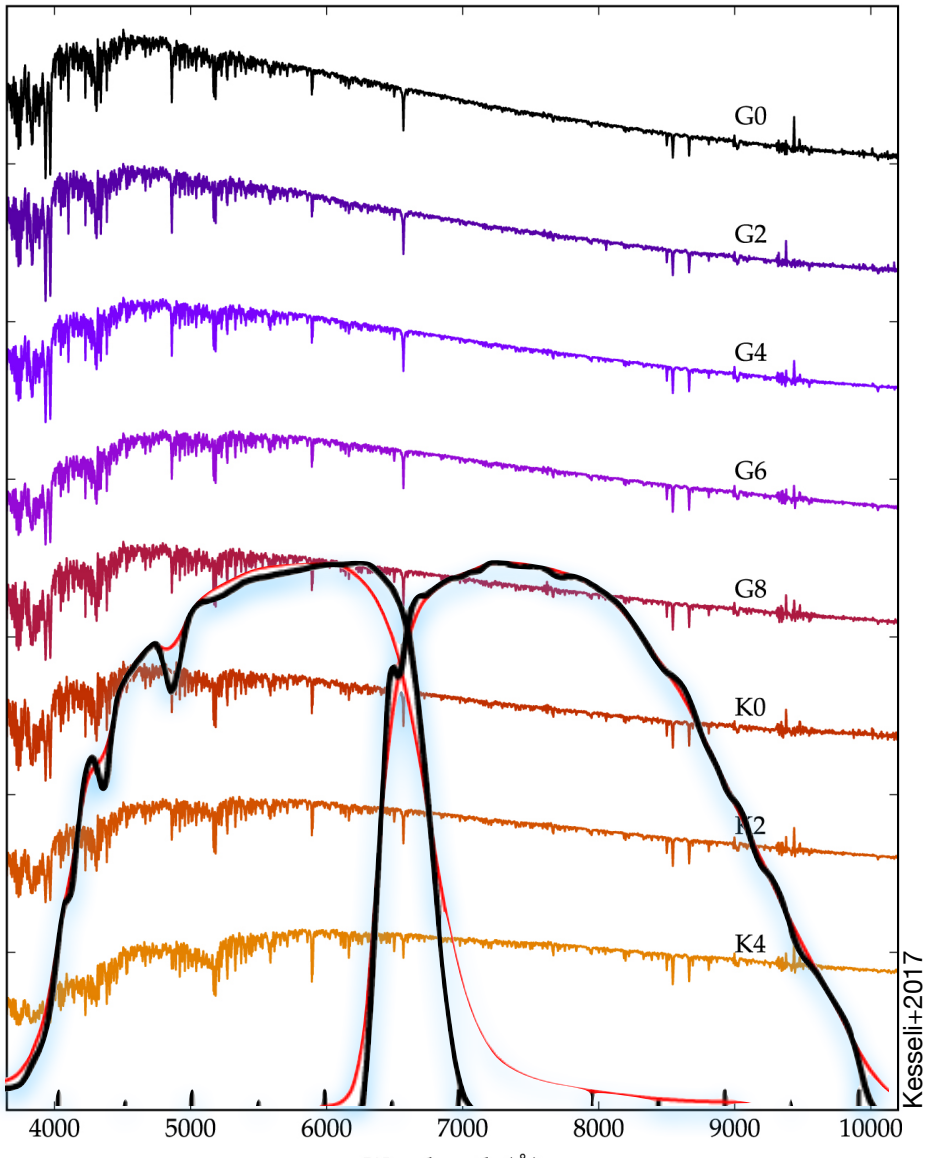

Kesseli+2017
https://arxiv.org/abs/1702.06957

# Temperature ($T_{eff}$)

- Also can constrain with photometry via the “color”




$B$ $V$




Kesseli+2017
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# Luminosity

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

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

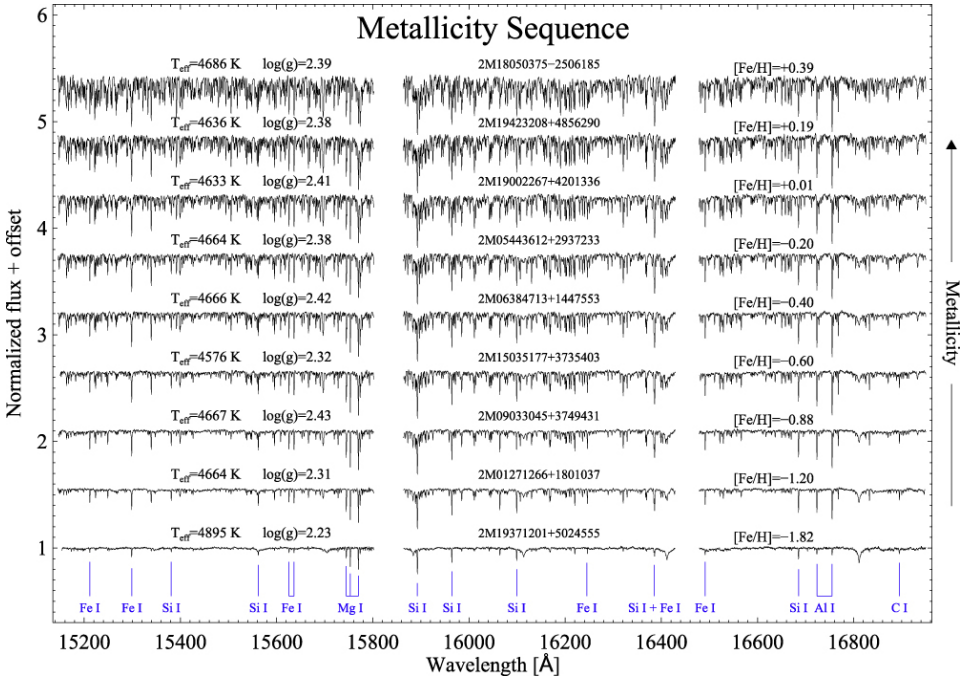
$$m_i = -2.5 \log_{10}\left(\frac{F_i}{F_0}\right)$$

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

- 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

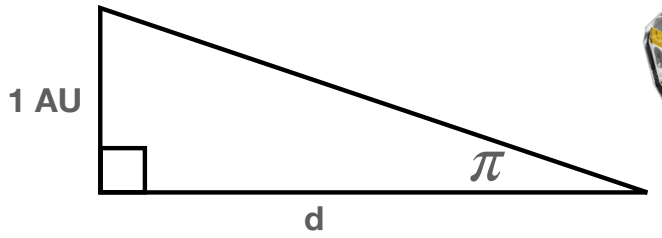
# Composition (aka Metallicity)

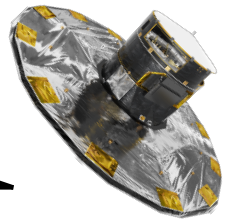
- Typically summed up as [Fe/H], i.e. the log ratio of Fe/H *relative* to the solar amount
  - Also abundances of individual elements are studied, as well as groups (e.g. [$\alpha$/Fe] )
- Primarily determined via spectroscopy, modeling atomic absorption lines
  - High resolution VERY helpful




Majewski+2017 (APOGEE)

# Distance



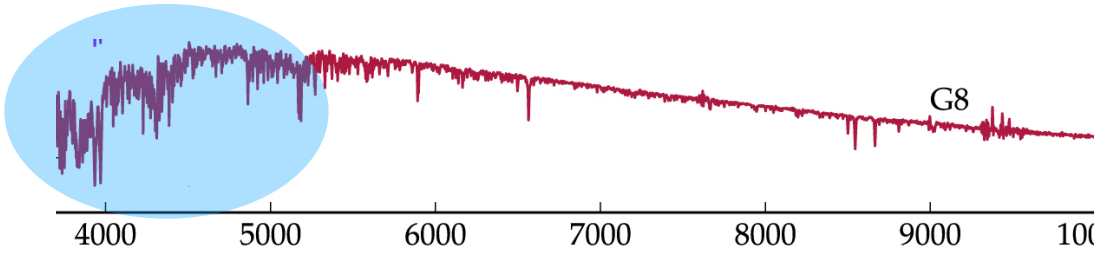



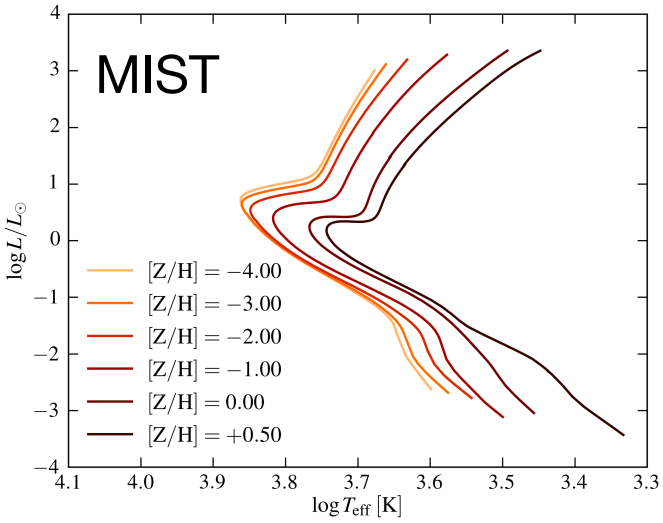
Gaia

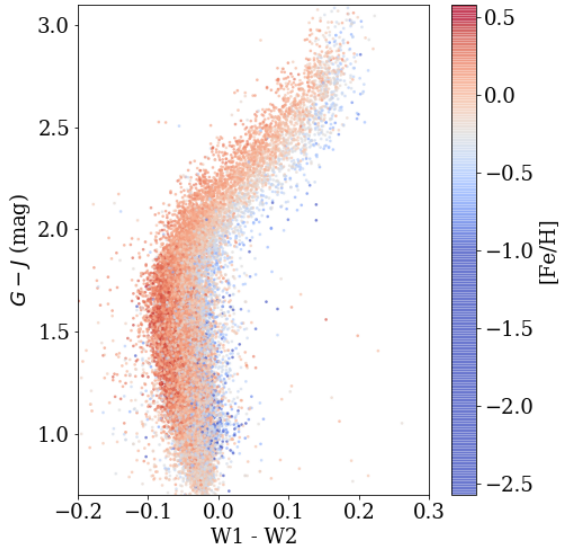
- Parallax! The best! But only for nearby stars
  (Gaia is making this *better, +1Billion stars*, but not perfect!)
- Many other clever ways:
  - Stellar clusters $m - M = 5 \log_{10} d[pc] - 5$
  - RR Lyr, standard candles, the “distance ladder”, etc…
  - Eclipsing binaries
    - e.g. LMC distance to 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



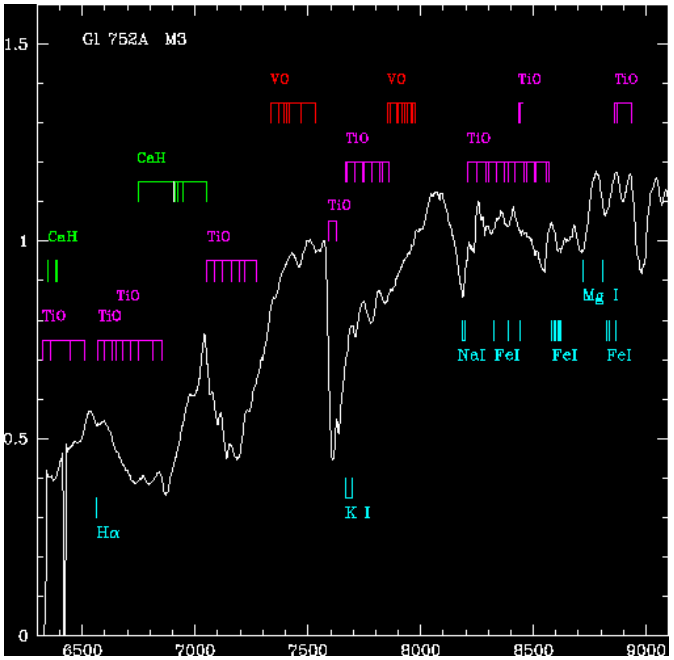



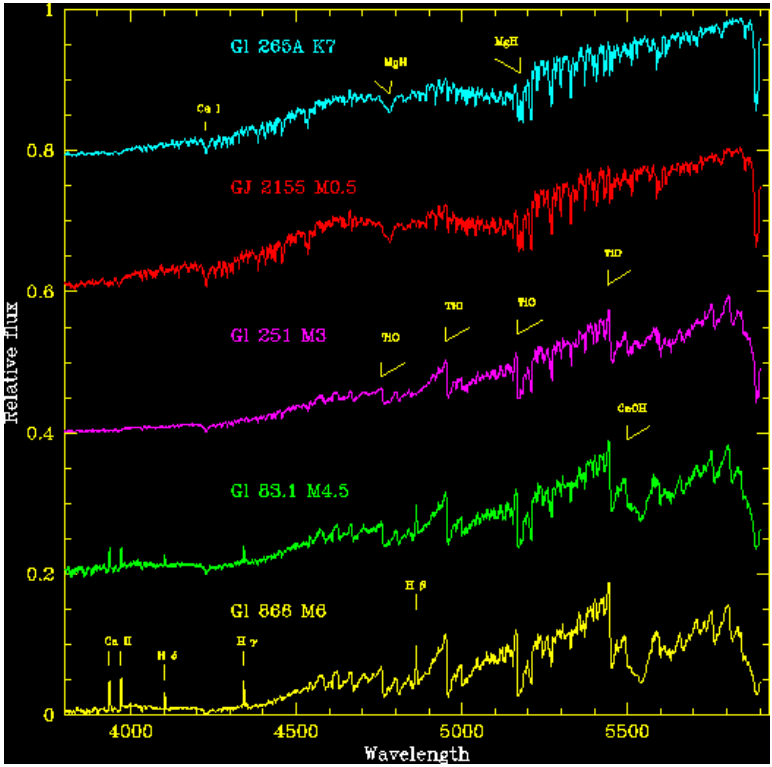




Davenport & Dorn-Wallenstein

# Composition (aka Metallicity)

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

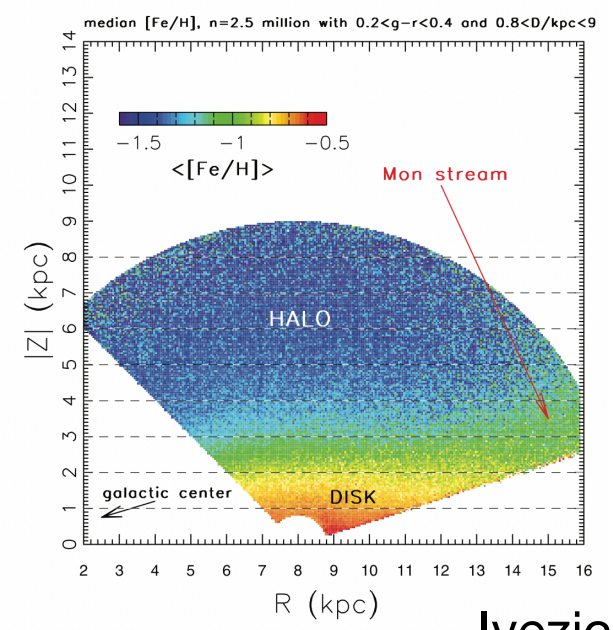



N. Reid

# 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

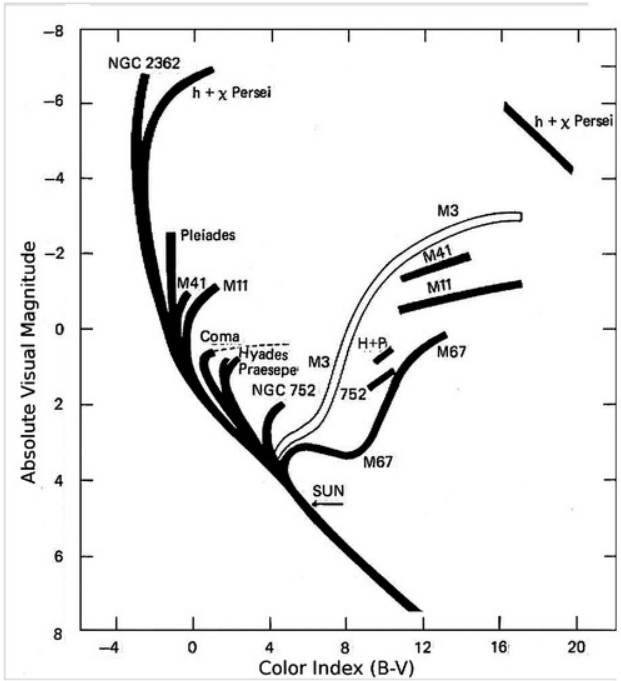



Ivezic+2008

# Age

- For main sequence stars, incredibly difficult to constrain, cannot be "measured" directly…

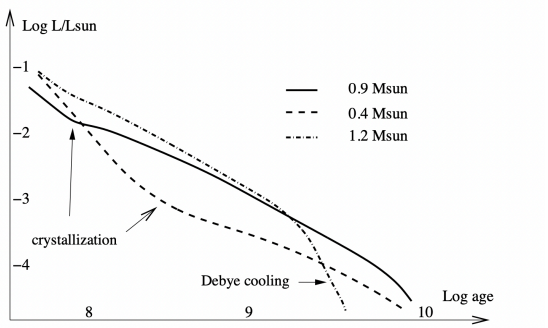
- 10% uncertainty considered very good!
- A good review: Soderblom (2010)
- Cluster ages (open and globular)
  a critical historical benchmark, still key!
  - Mostly information in the "turn off"




Sandage (1957)

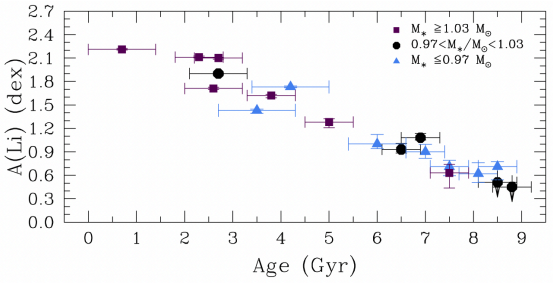
# Age

- 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

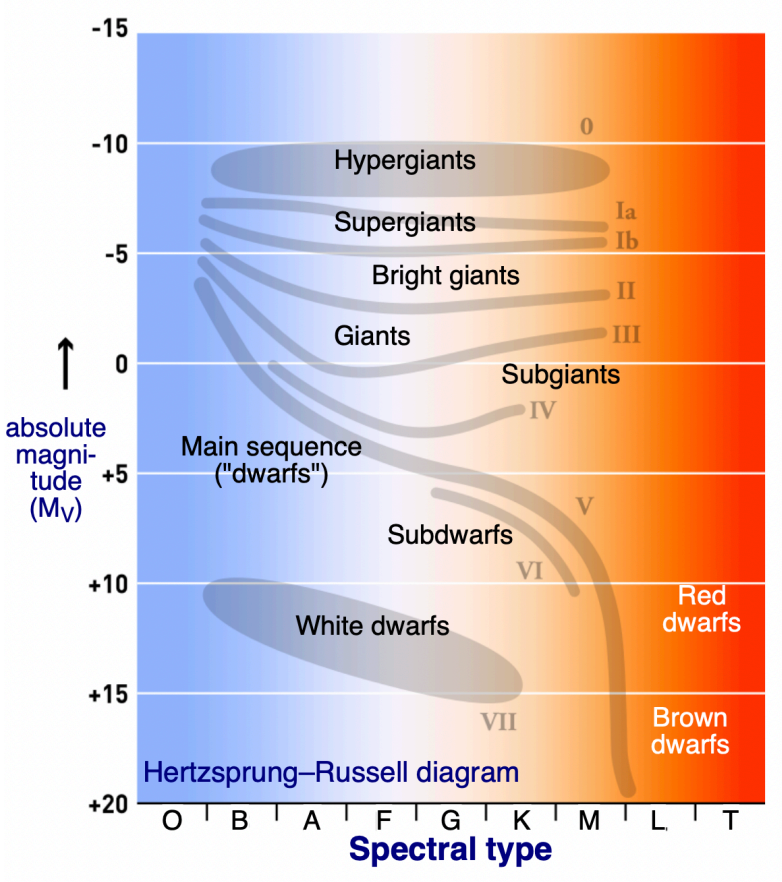
- Radius
- Density
- Surface Gravity
- Binarity

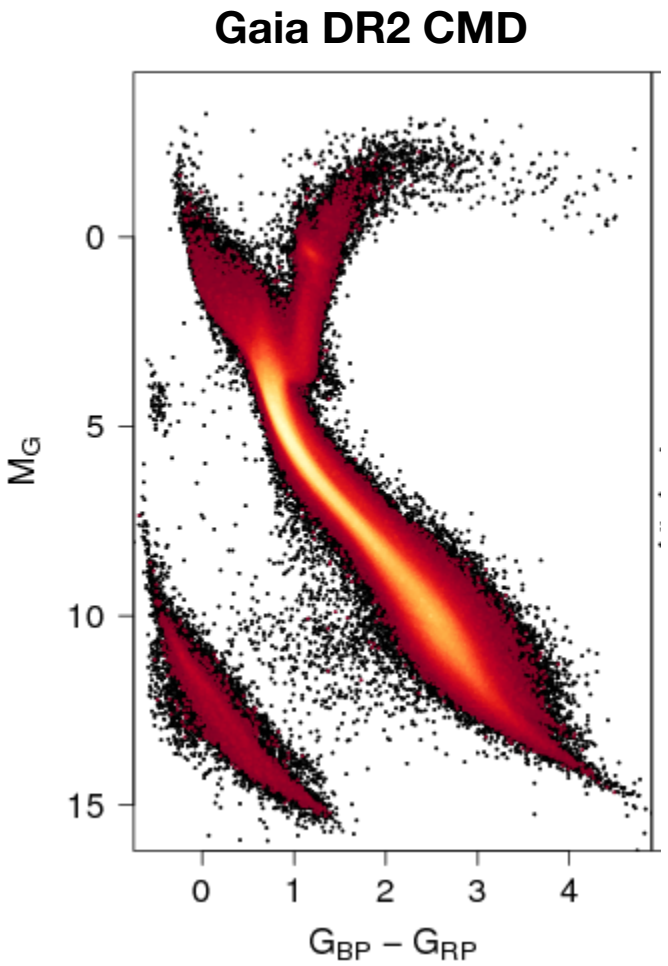
**Very interesting, but not critical for Galactic Astronomy**

# The H-R Diagram

- Theorists:
  Temp, Lum
  or
  Temp, log g

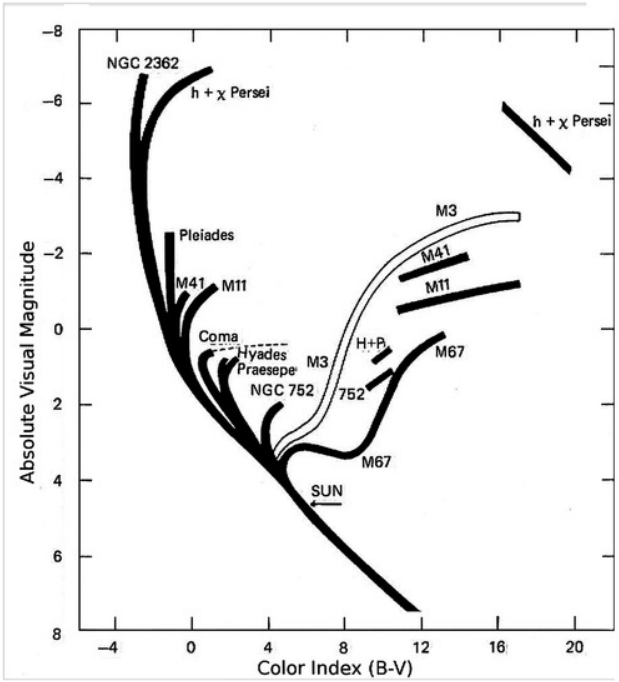
- Observers:
  Color, Mag

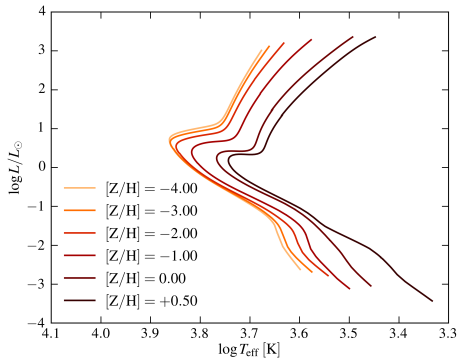


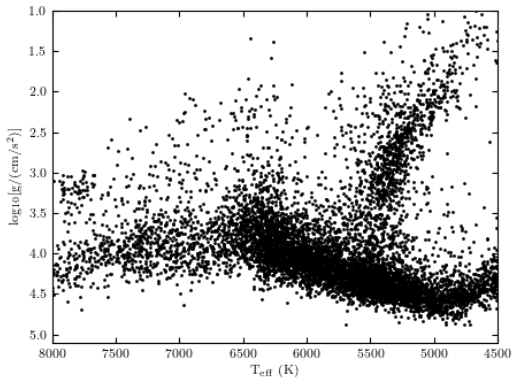



# The H-R Diagram

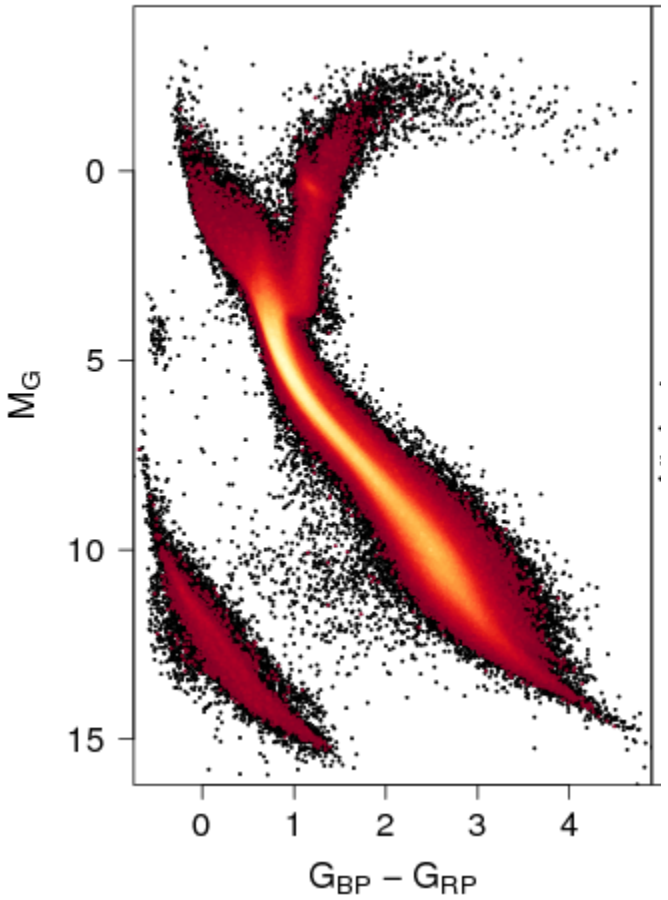
A Rosetta Stone for understanding the lives & properties of stars



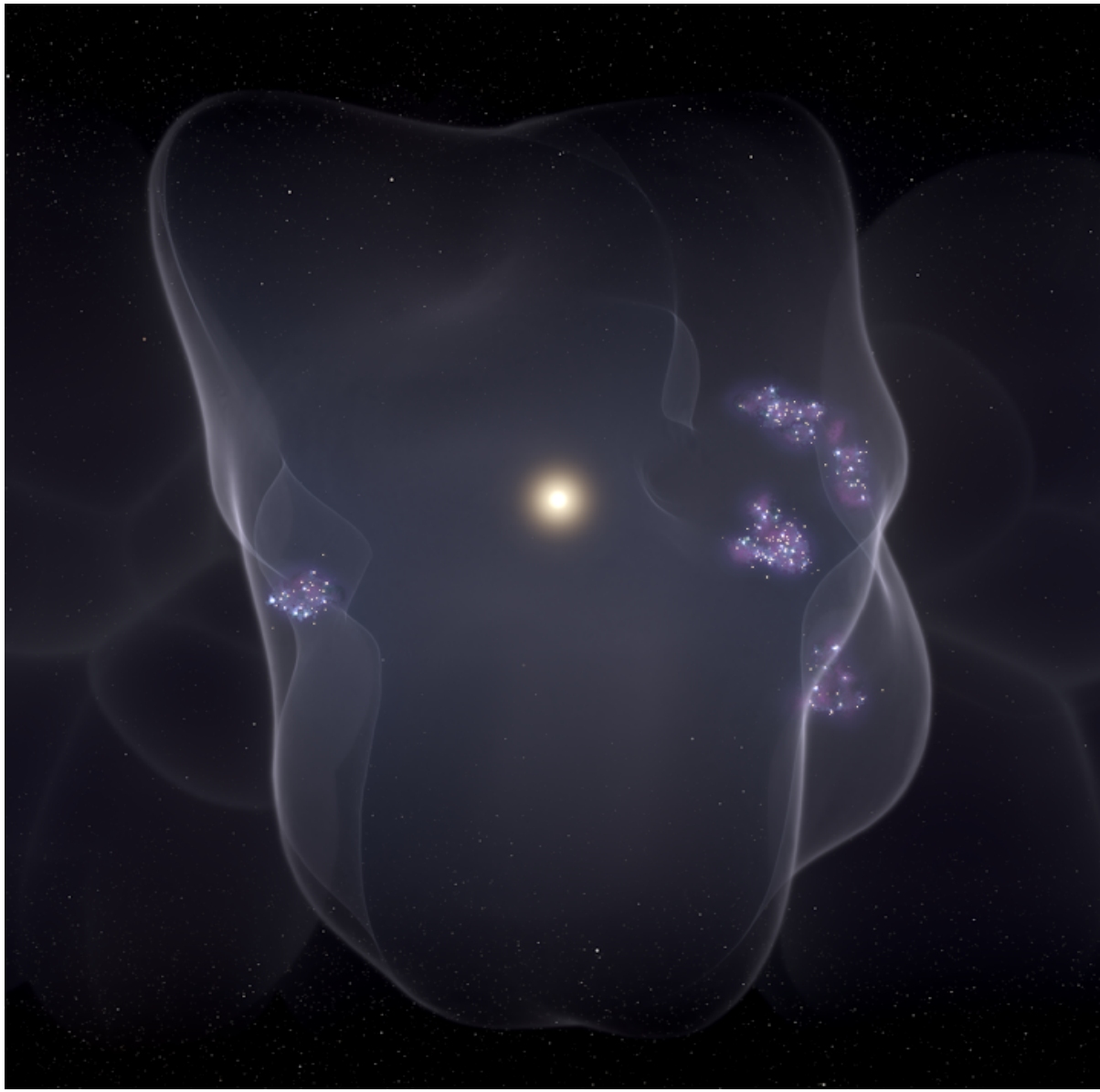




**Gaia DR2 CMD**



# Next time:

- **The Solar Neighborhood**



# FRIDAY!

- Suzanne Hawley is retiring, having a small farewell event at 12-1 pm
  - **Dubs** is scheduled to attend!!!!!!!!!