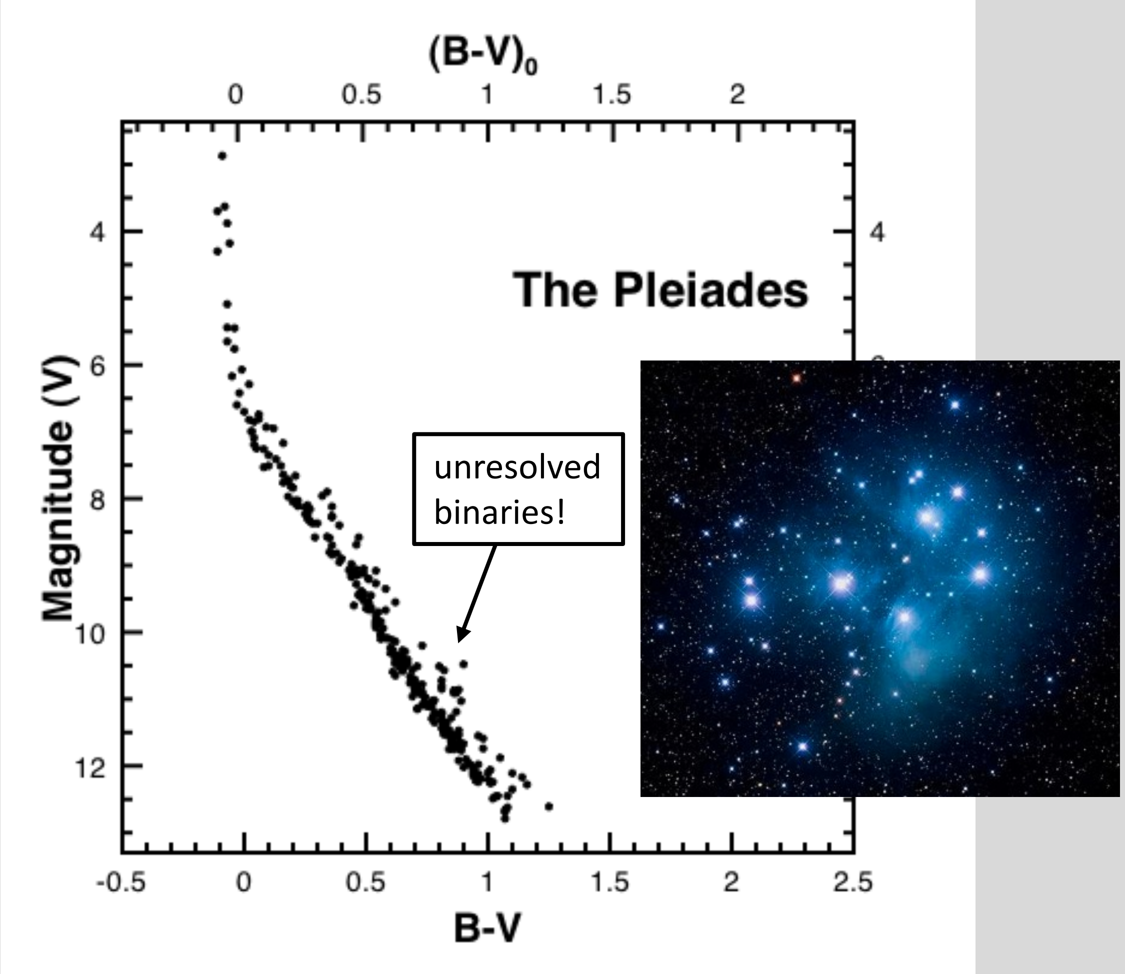
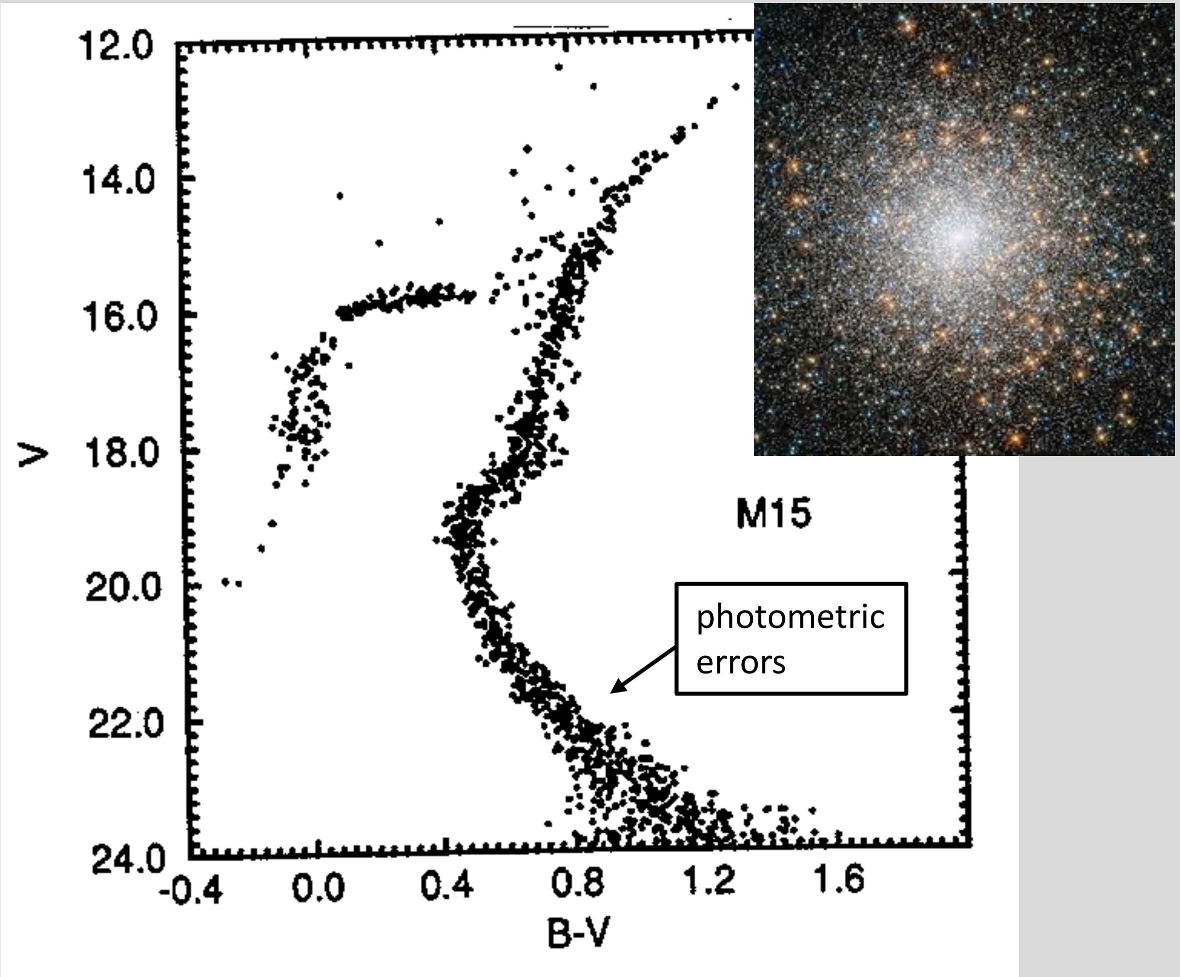
Star Clusters: Useful Little Buggers

Star clusters represent a group of stars with common distance, age, and metallicity. Many stars to define an observed color-magnitude diagram, compare to calibrated color-magnitude diagrams to measure distance, age, metallicity, etc.



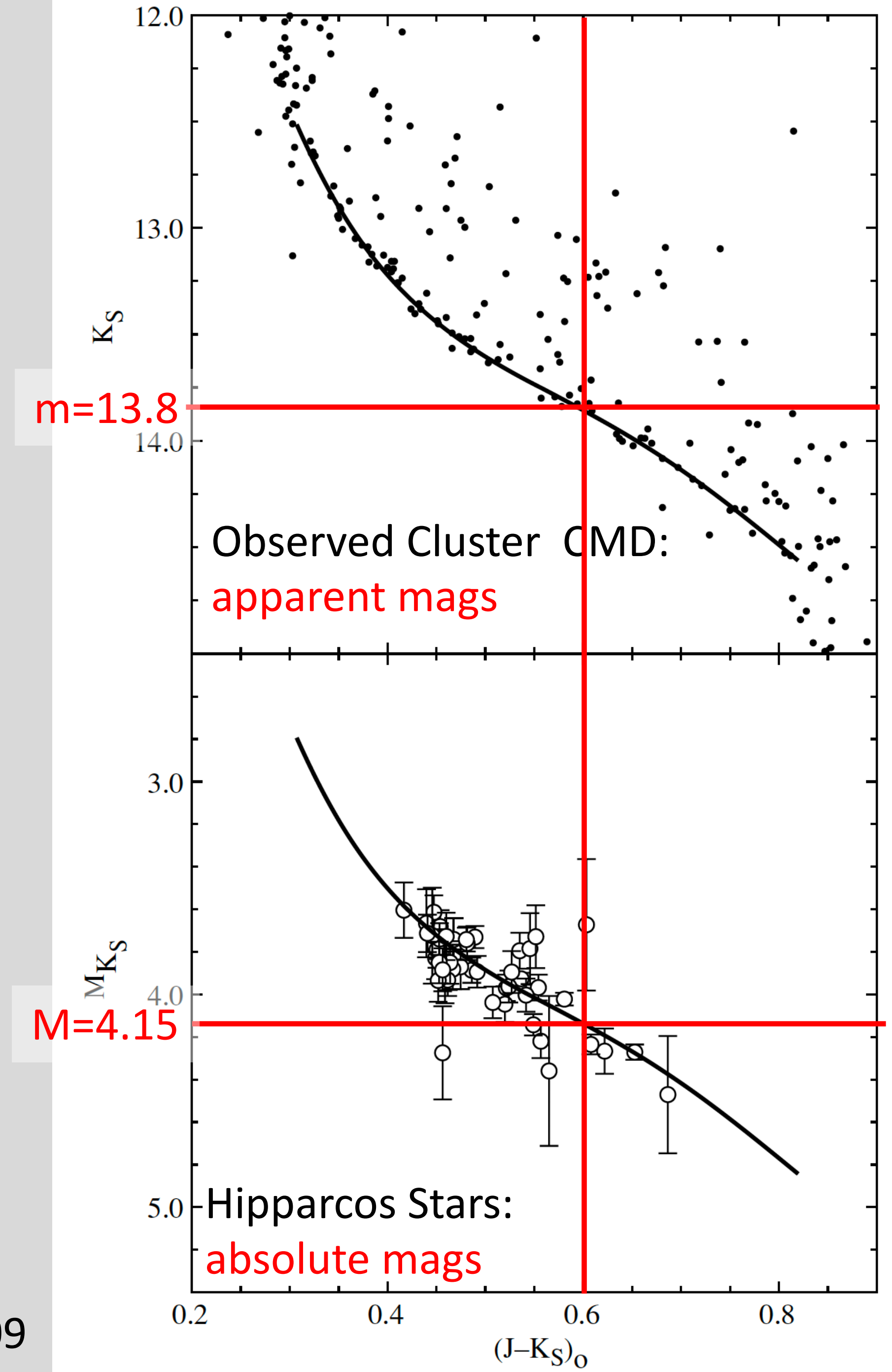


Star Clusters: Useful Little Buggers

Let's figure out the distance to the open cluster M67.

Solving for distance:

$$m - M = 5\log d - 5$$
$$13.8 - 4.15 = 5\log d - 5$$
$$9.65 = 5\log d - 5$$
$$d = 850\ pc$$



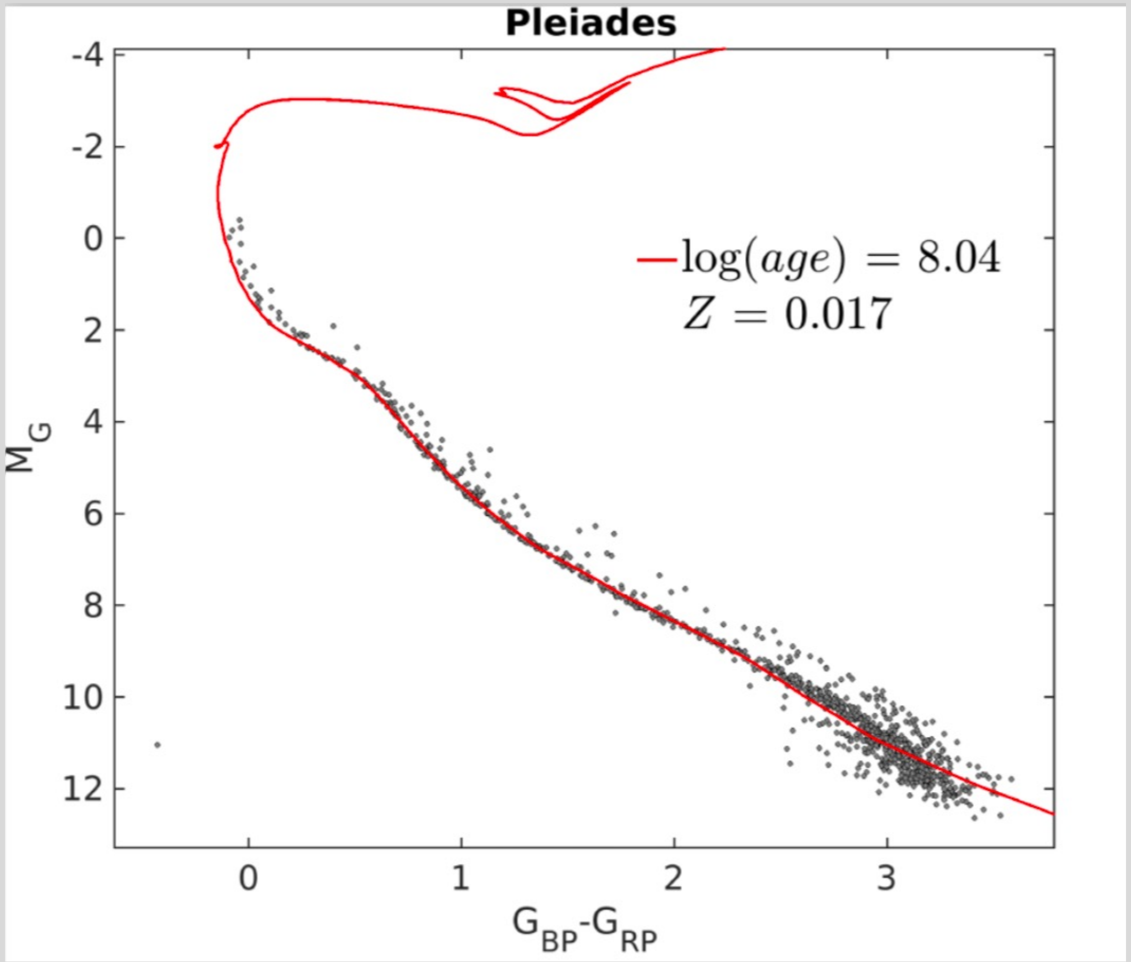
Sarajedini+ 09

Star Clusters: Useful Little Buggers

Compare observed CMDs (using apparent magnitudes) to parallax-calibrated CMDs (which have absolute magnitudes) and stellar models to derive distances, ages, metallicities.

Complications:

- Dust (reddens and dims the apparent magnitudes)
- Metallicity (need calibrated CMDs and stellar models matched in metallicity)
- Contamination (interloper stars not part of the cluster)
- Sparseness of the CMD
- Photometric uncertainty (problematic at faint end of sequences)
- Model uncertainties (not always great at late stages of evolution)



Gaia 2018

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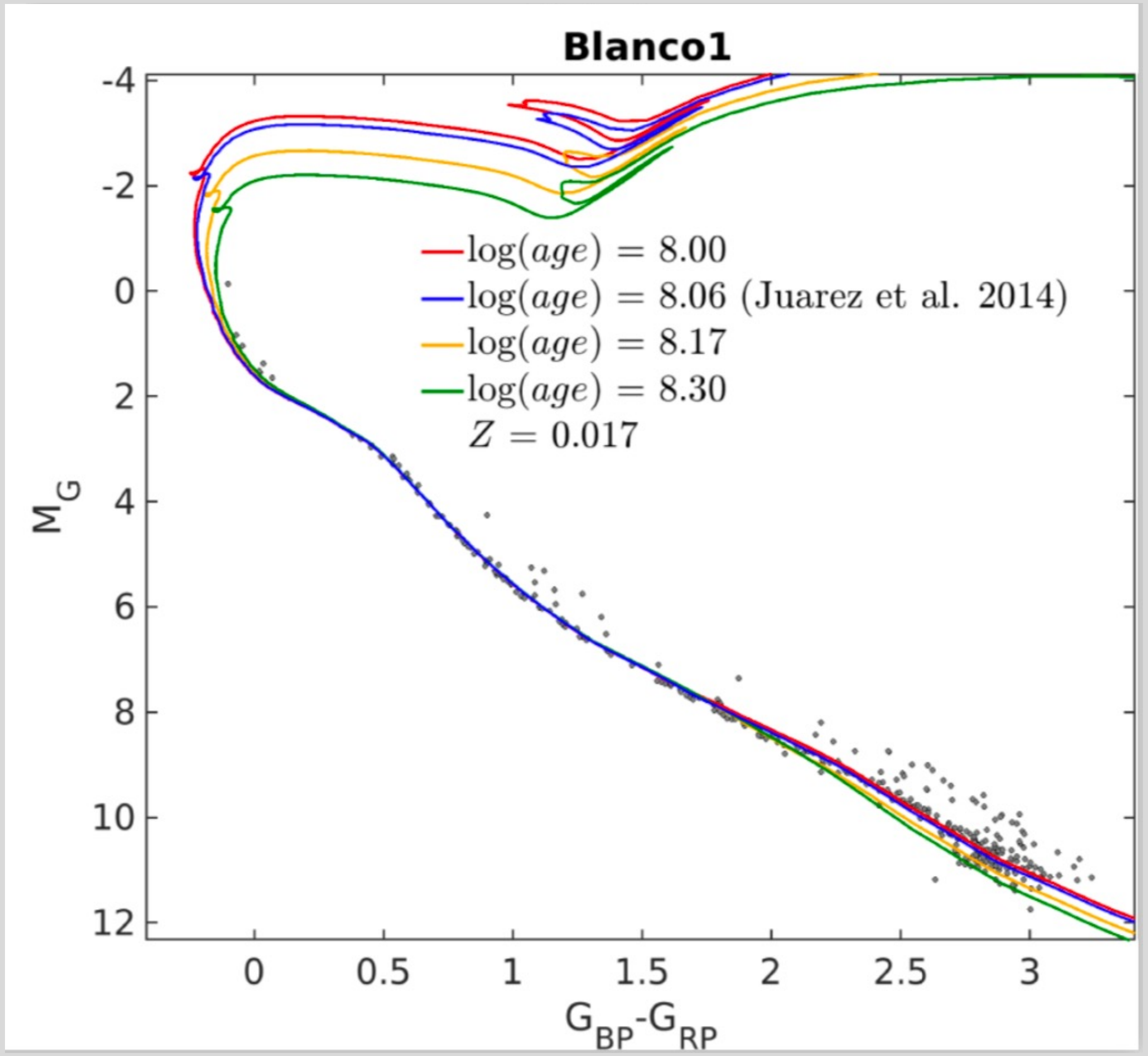
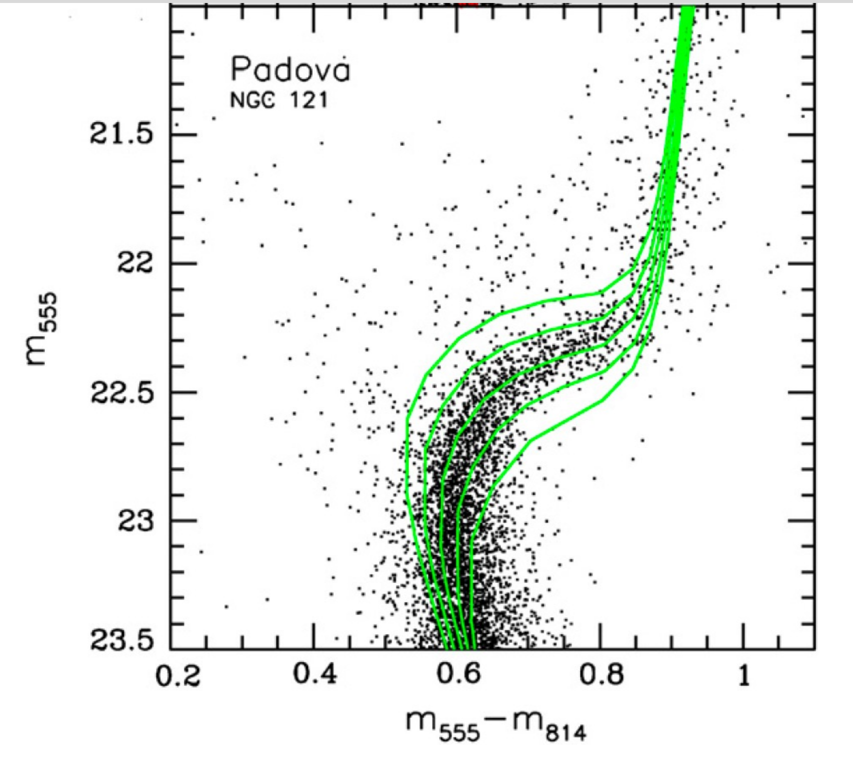
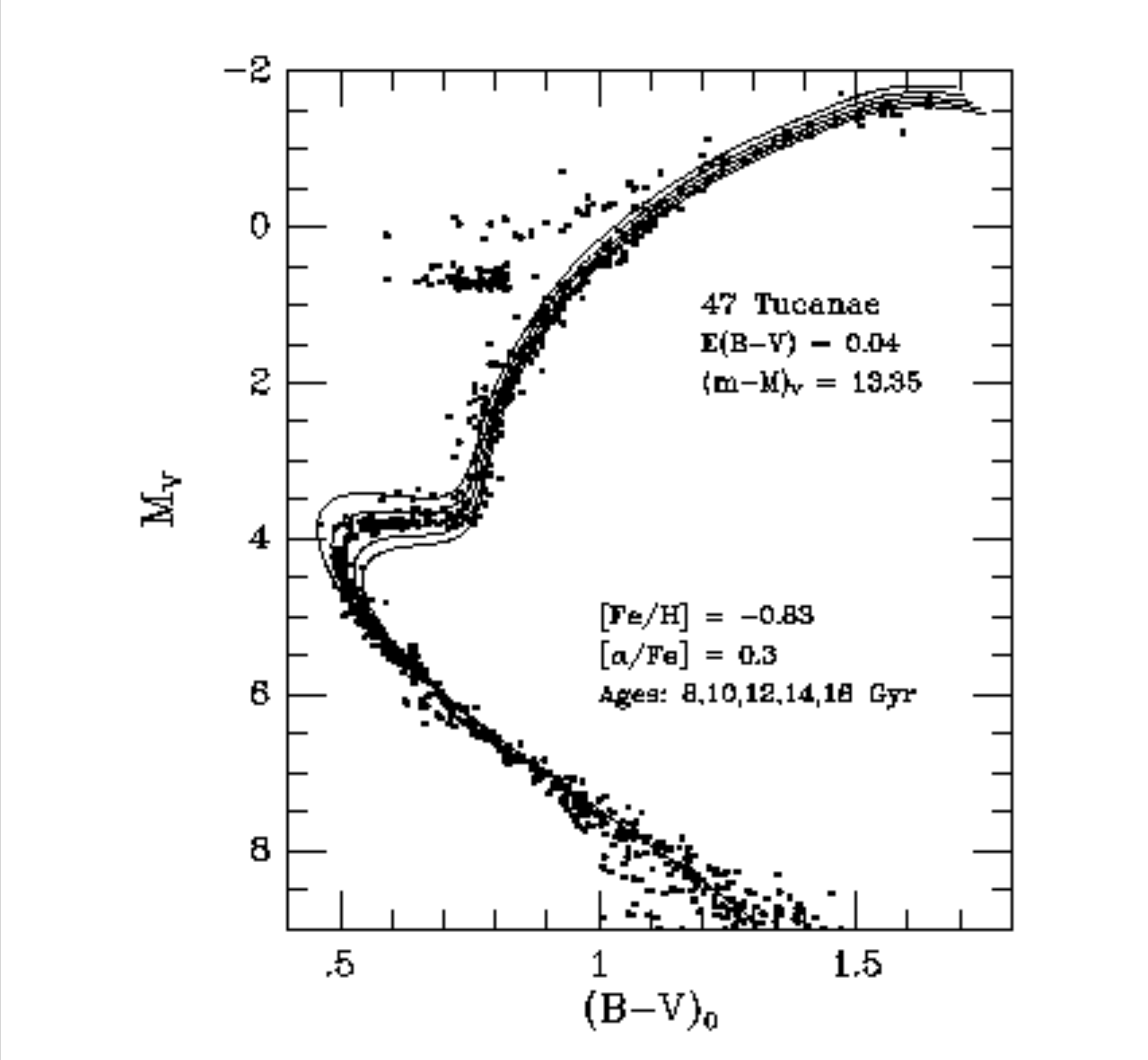


Gaia 2018

Globular Clusters: Old Populations



NGC 121 (Glatt+08)
ages: 10, 10.9, 11.8, 12.6, 13.5 Gyr



Varying Parameters: Old Populations

Isochrones depend on many parameters:

- Age
- Metallicity
- Distance
- α-abundances

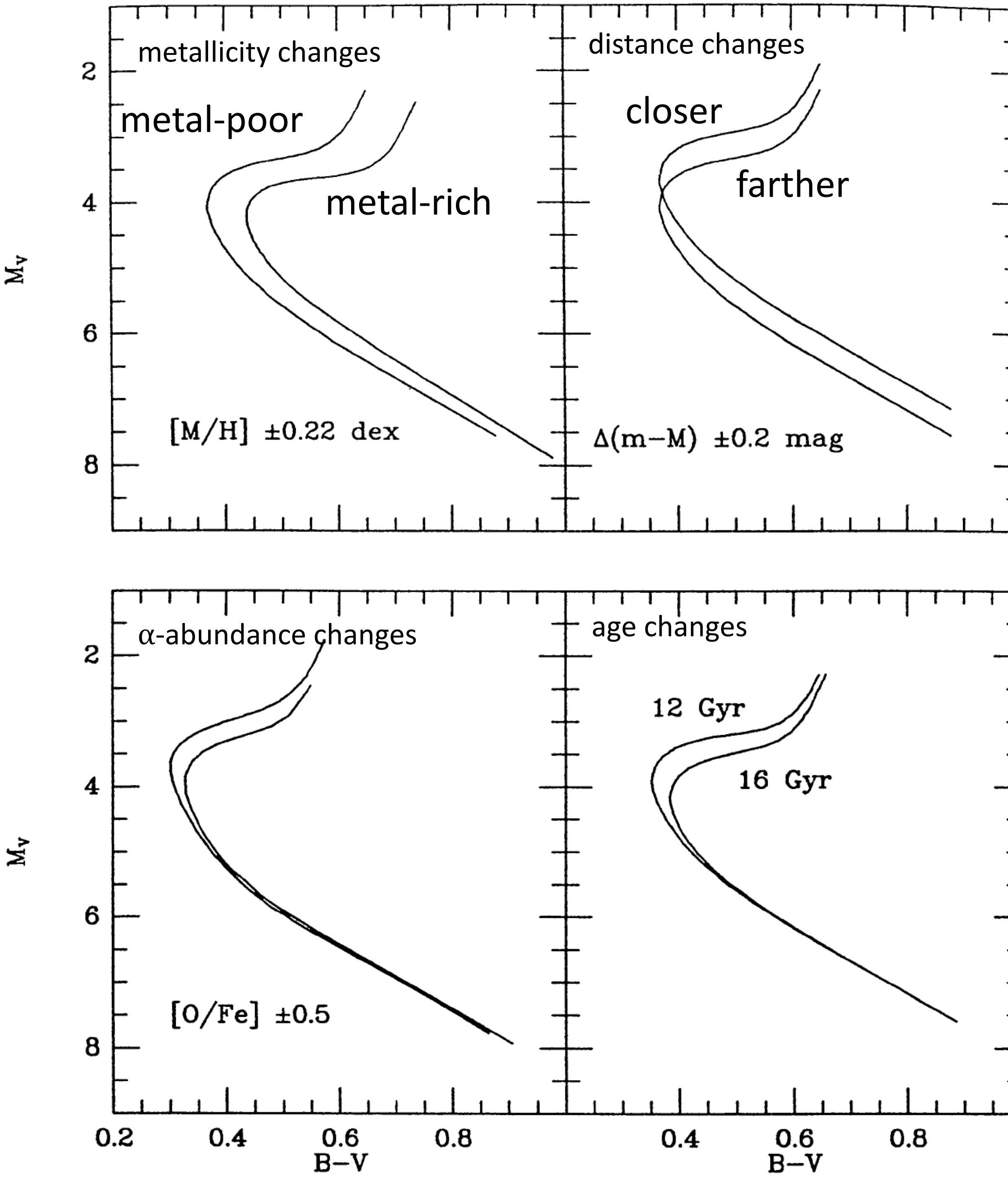
All contribute to uncertainties.

Additional data can reduce uncertainties:

- Parallax gives distance
- Spectroscopy can contrain metallicity, α-abundance

How parameter variations change CMD shapes

☞



Bolte 1990

Individual Stars: Much more problematic!

Lets say we have photometry for an individual star:

app mag, color: m_B, B-V

What can we say about its absolute magnitude?

How good is this estimate?

How can we tell if a star is a dwarf or a giant if we don't know the distance? Can we figure out luminosity some other way?

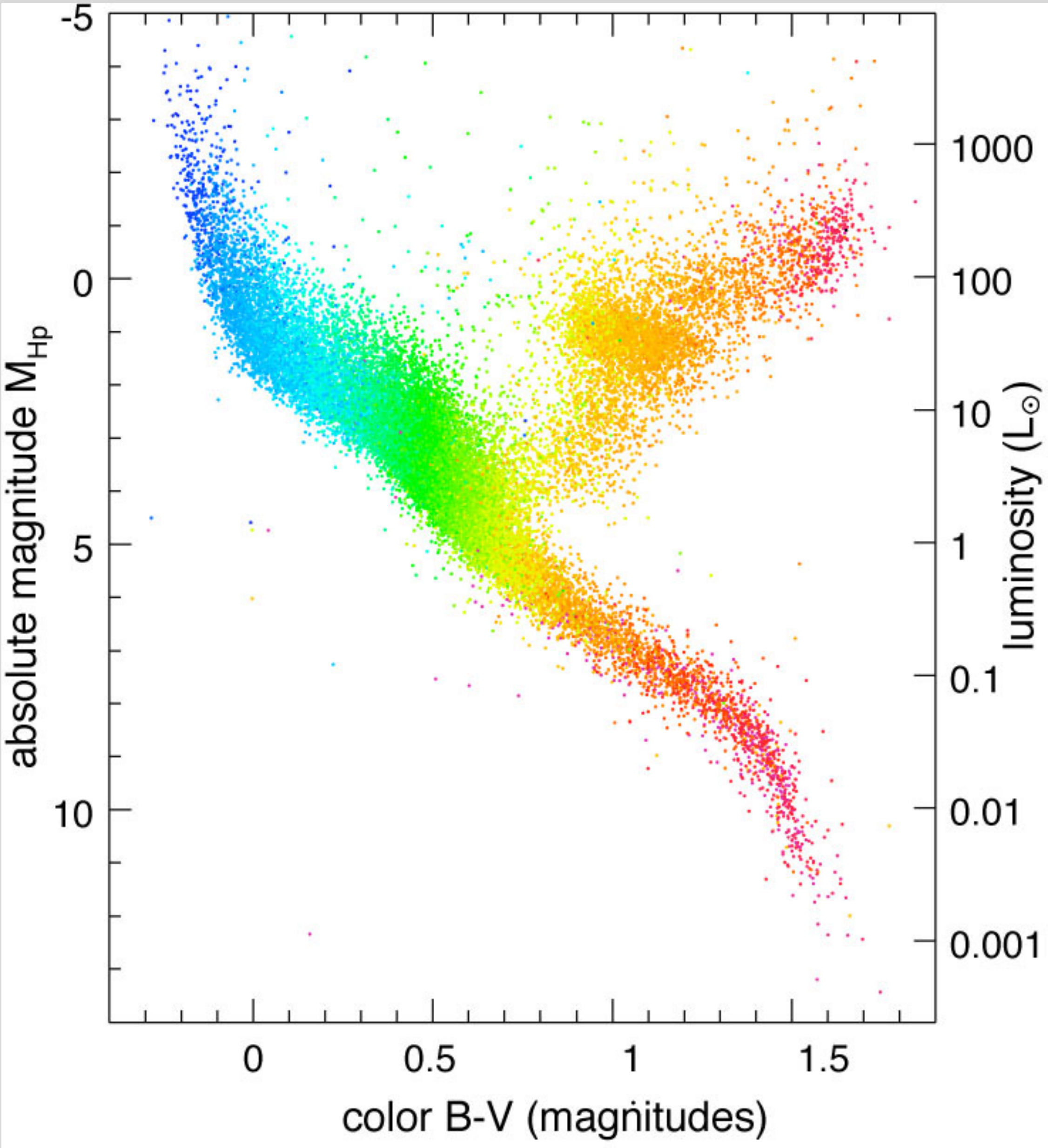


Fig 2.2 (F. van Leeuwen) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Luminosity information: Spectral Signatures

Giants and (*main sequence*) dwarfs have very different "**surface gravities**"

$$g = GM/r^2$$

typically expressed as **log(g)**

Giant stars: very extended, low surface gravity, low density atmospheres

Main sequence dwarfs: smaller, higher g, denser

Pressure broadening:

Collisions blur the energy levels of an atom, broadening the lines. Much stronger at higher densities/pressures, so giants have narrow lines, dwarfs have broader lines.

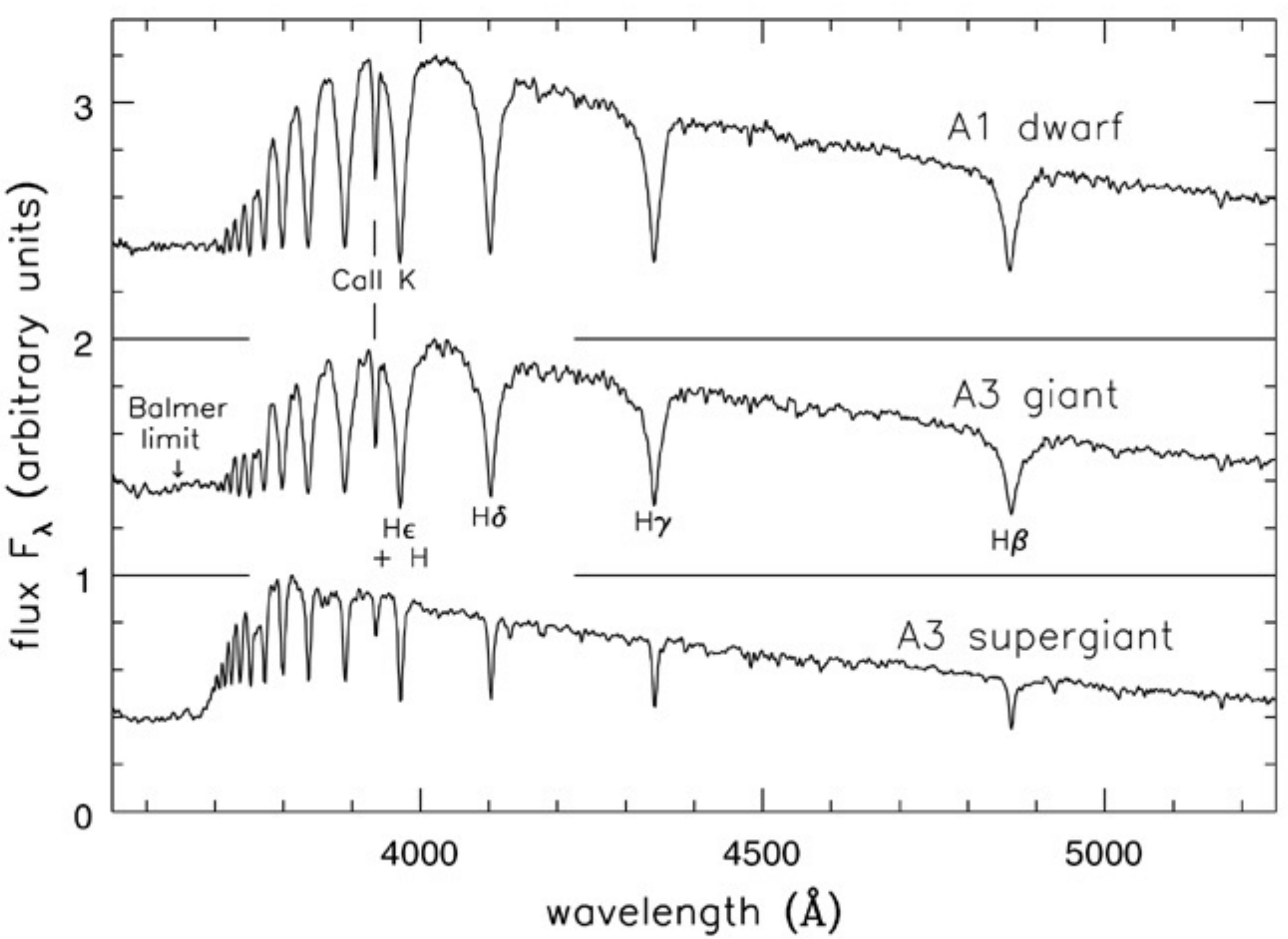


Fig 1.2 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Luminosity information: Spectral Signatures

Molecule formation

Easier to form molecules at higher densities, so *atmospheres of dwarfs have more molecules.*

Molecules are good at creating broad absorption bands, for example magnesium hydride (MgH).

So, MgH absorption is a good discriminator between dwarfs and giants.

Majewski+00

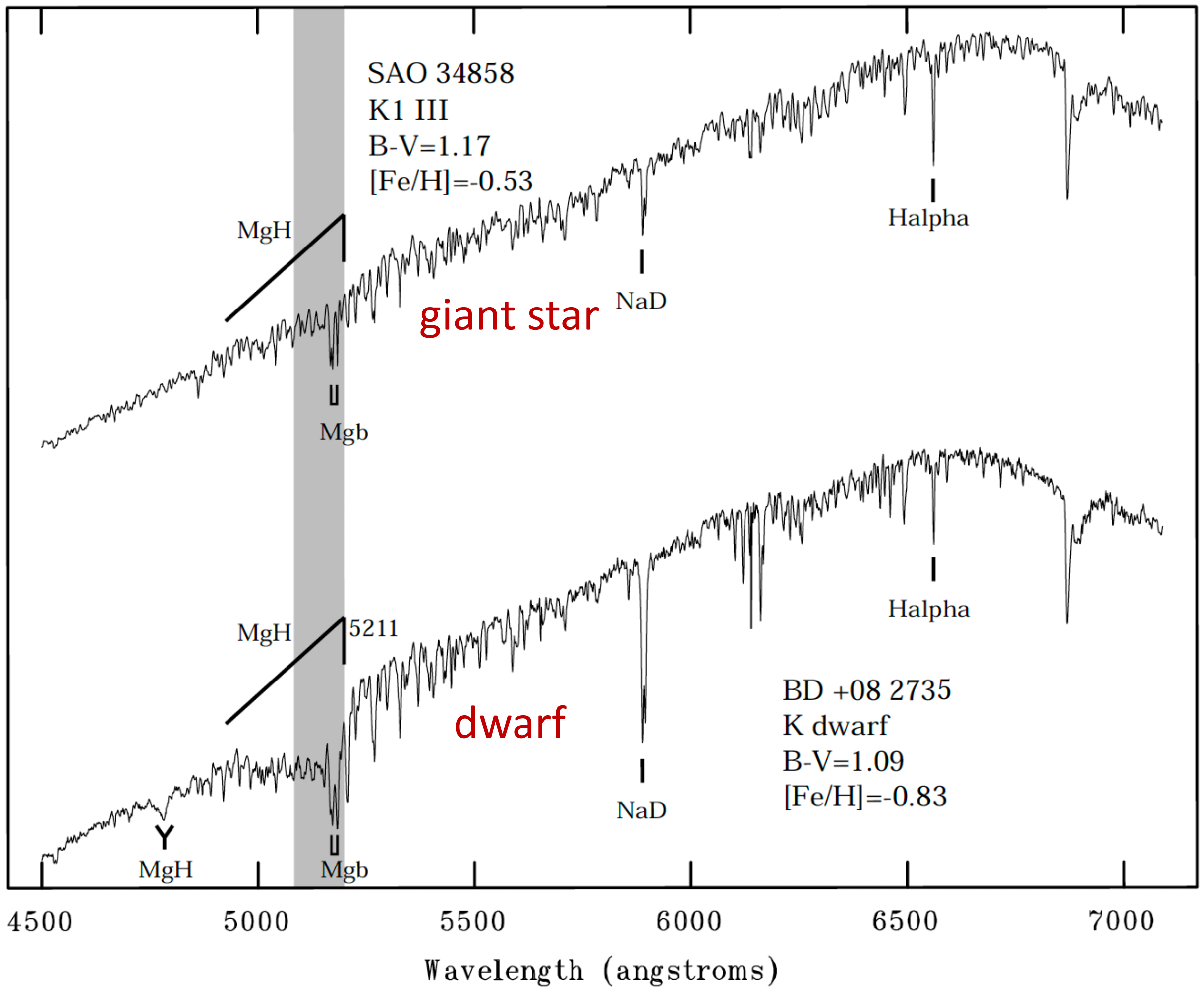


FIG. 1.—Comparison of spectra for K giant and dwarf stars of similar color and abundance, illustrating the dependence of the MgH + Mgb triplet on luminosity class. The location of the DDO51 filter bandpass is indicated by the shaded region. Note also the gravity-sensitivity of both the MgH band near 4850 Å as well as the NaD doublet (Tripicchio et al. 1997).

Individual Stars: Spectroscopic Parallax

Now we have more information

m_B, B-V, luminosity class, metallicity

Now what can we say about its absolute magnitude?

How good is this estimate?

This technique is called “spectroscopic parallax”, but
IT 👏 HAS 👏 NOTHING 👏 TO 👏 DO 👏 WITH 👏 PARALLAX

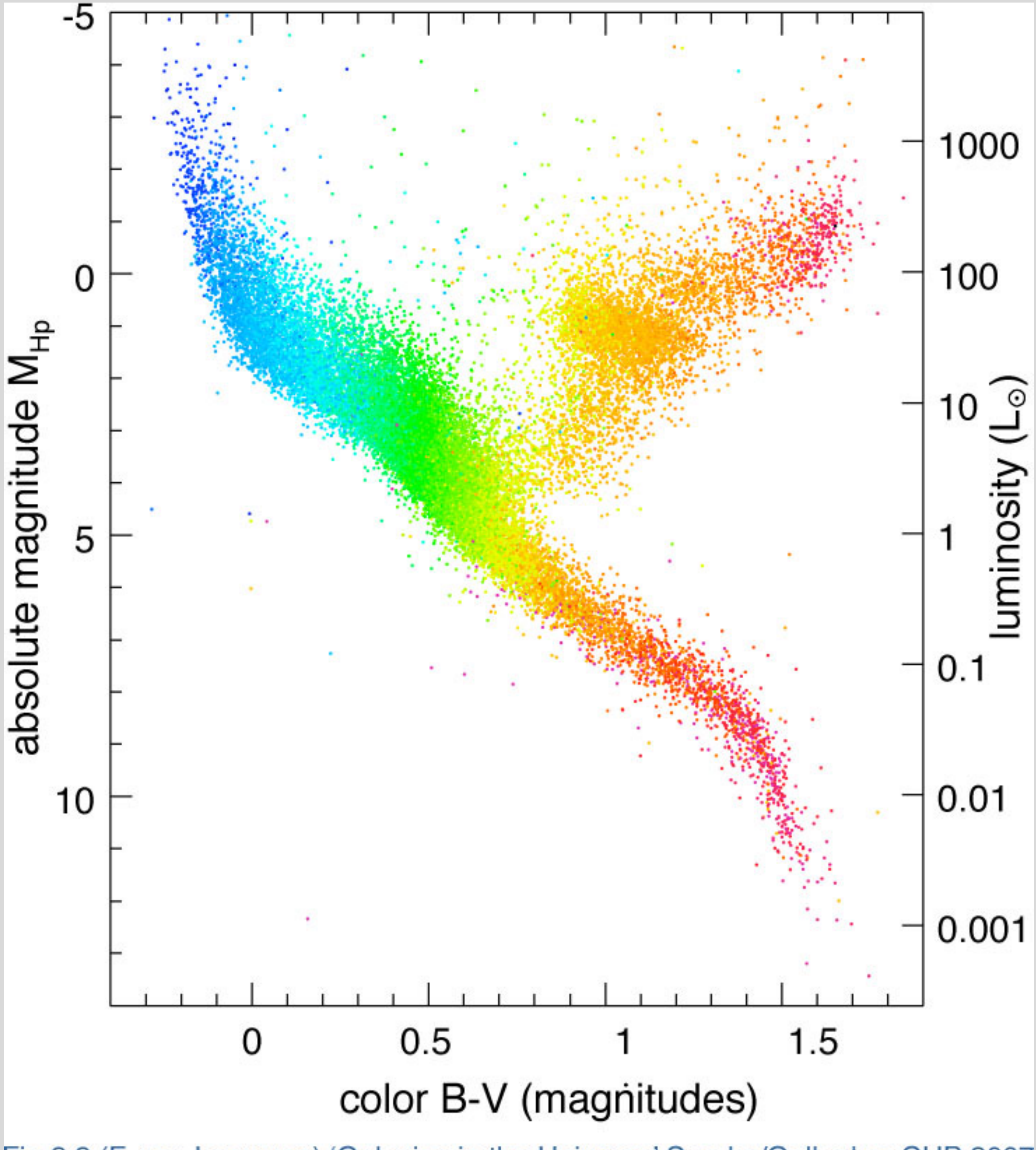


Fig 2.2 (F. van Leeuwen) ‘Galaxies in the Universe’ Sparke/Gallagher CUP 2007

Stellar Ages

Ages of *individual* stars are very hard to estimate.

If you have a good estimate of its physical properties, compare to theoretical evolutionary tracks on the CMD.

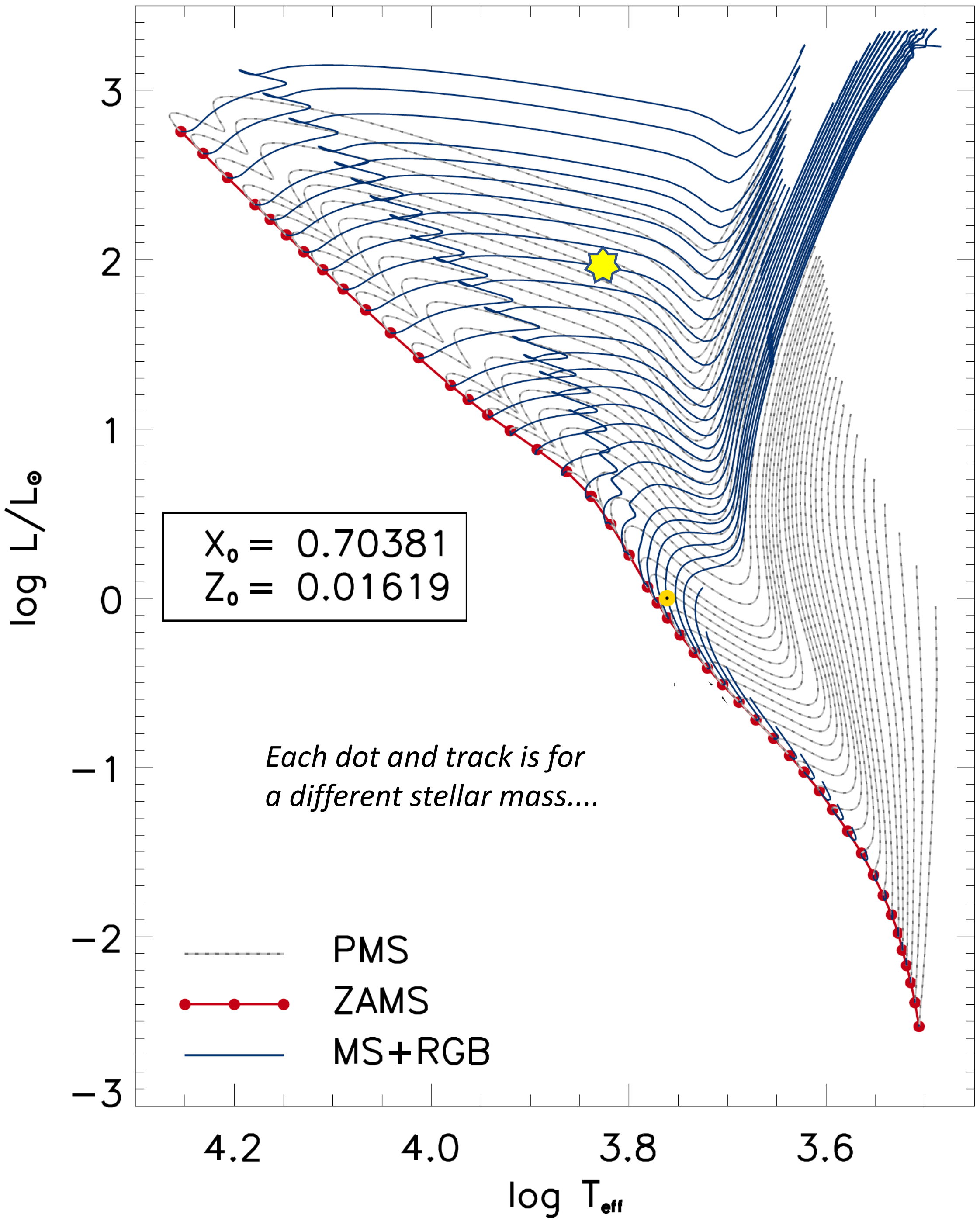
Need very good data: distance, photometry, metallicity.

Need very good models that cover all relevant parameters.

Need good transformation between observables and models:

- magnitude and colors ⟺ L_{bol} (bolometric mag = total luminosity)
- colors or spectra ⟺ T_{eff} (surface temperature)
- metallicity, α ⟺ X, Y, Z (chemical composition)

If done carefully, gives you both mass and age.



Yale-Potsdam Isochrones
Mass range: 0.86–5 M⊙
Spada+17