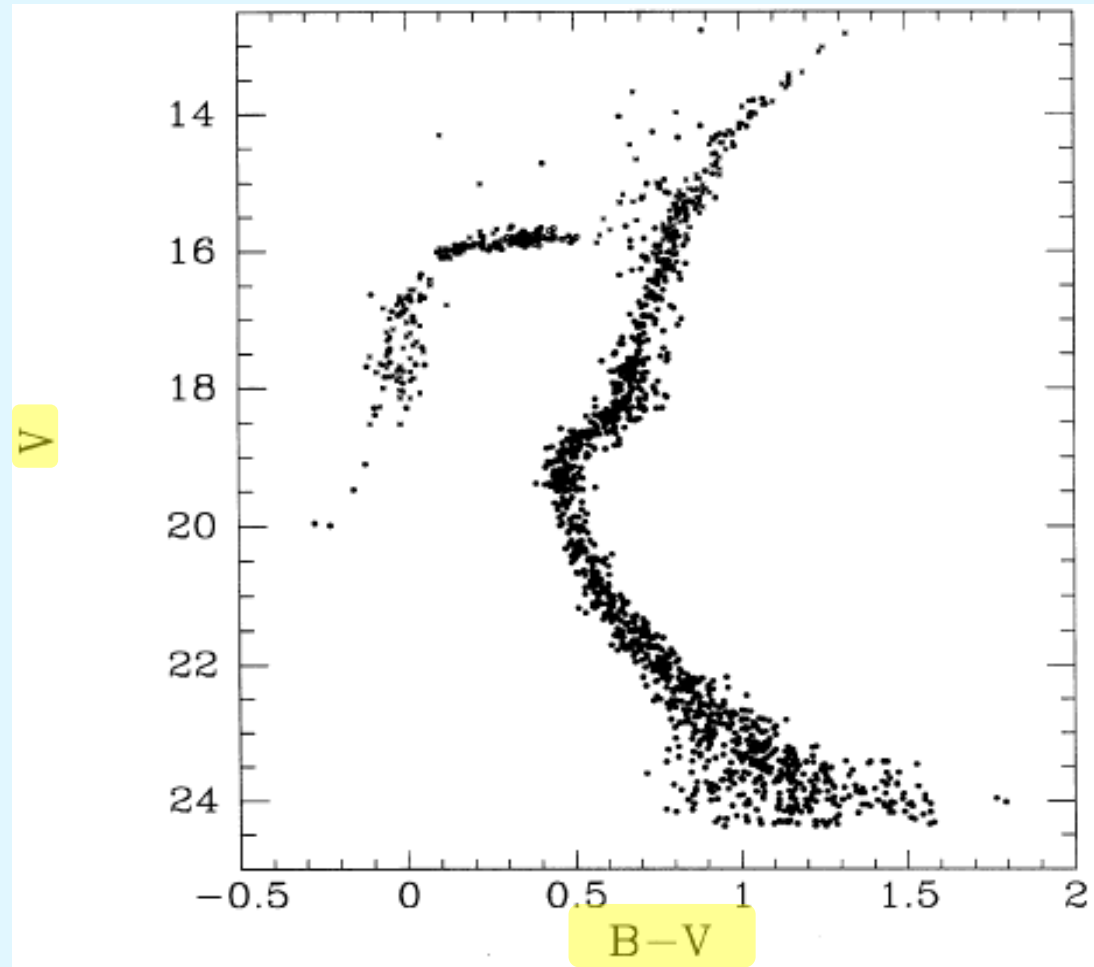# Main Sequence Fitting

Madison LeBlanc

What is it?

- Using an HR diagram to determine the distance to a cluster of stars

- Works because all of the stars in a cluster are about the same:
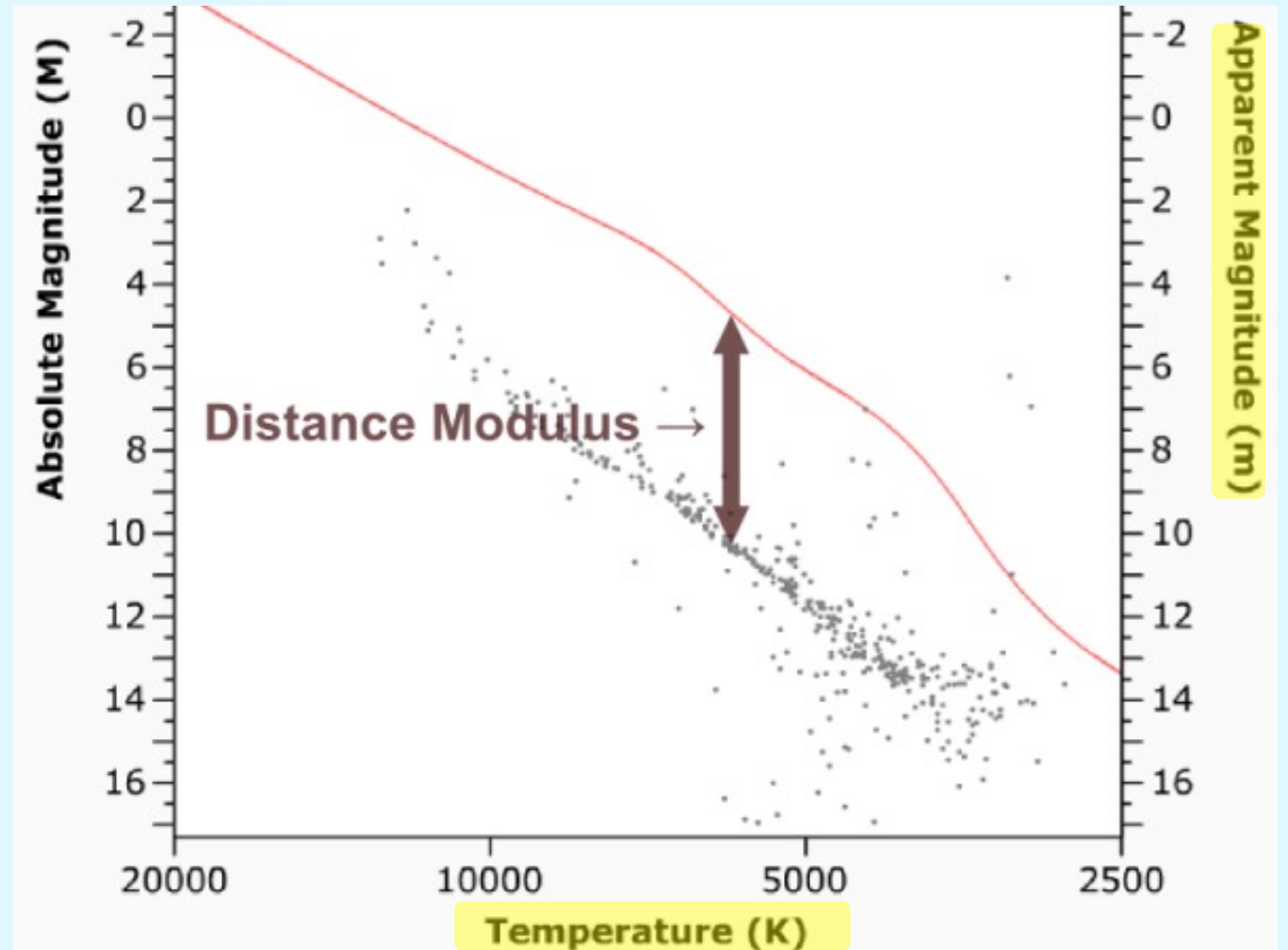 - Age
  - Metallicity
  - Distance!

How?

- Need 2 things:
  - apparent magnitude
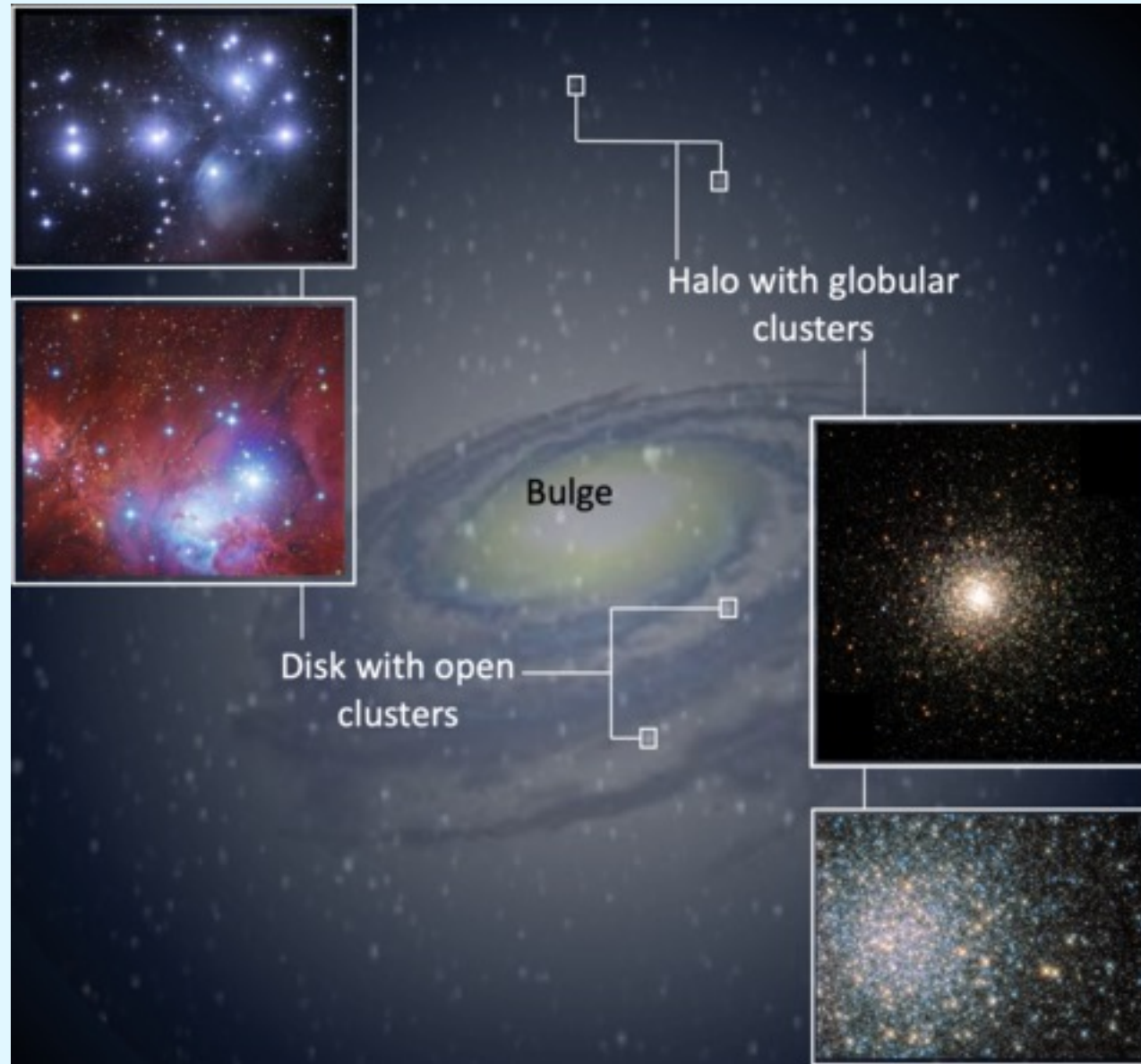 - color (e.g. B-V) ***OR*** spectral types* (temps)

How?

- Need 2 things:
  - apparent magnitude
  - color (e.g. B-V) **OR** spectral types* (temps)

- Distance modulus!
  - m-M = 5*log(d[pc]/10 pc)

*Sometimes called spectroscopic parallax

The Nebraska Astronomy Applet Project

Good for open clusters AND globular clusers

Halo with globular clusters

Bulge

Disk with open clusters

DISTANCES: ~40 pc to 10 kpc

NASA/HST/STScI/AURA

Hyades

NASA
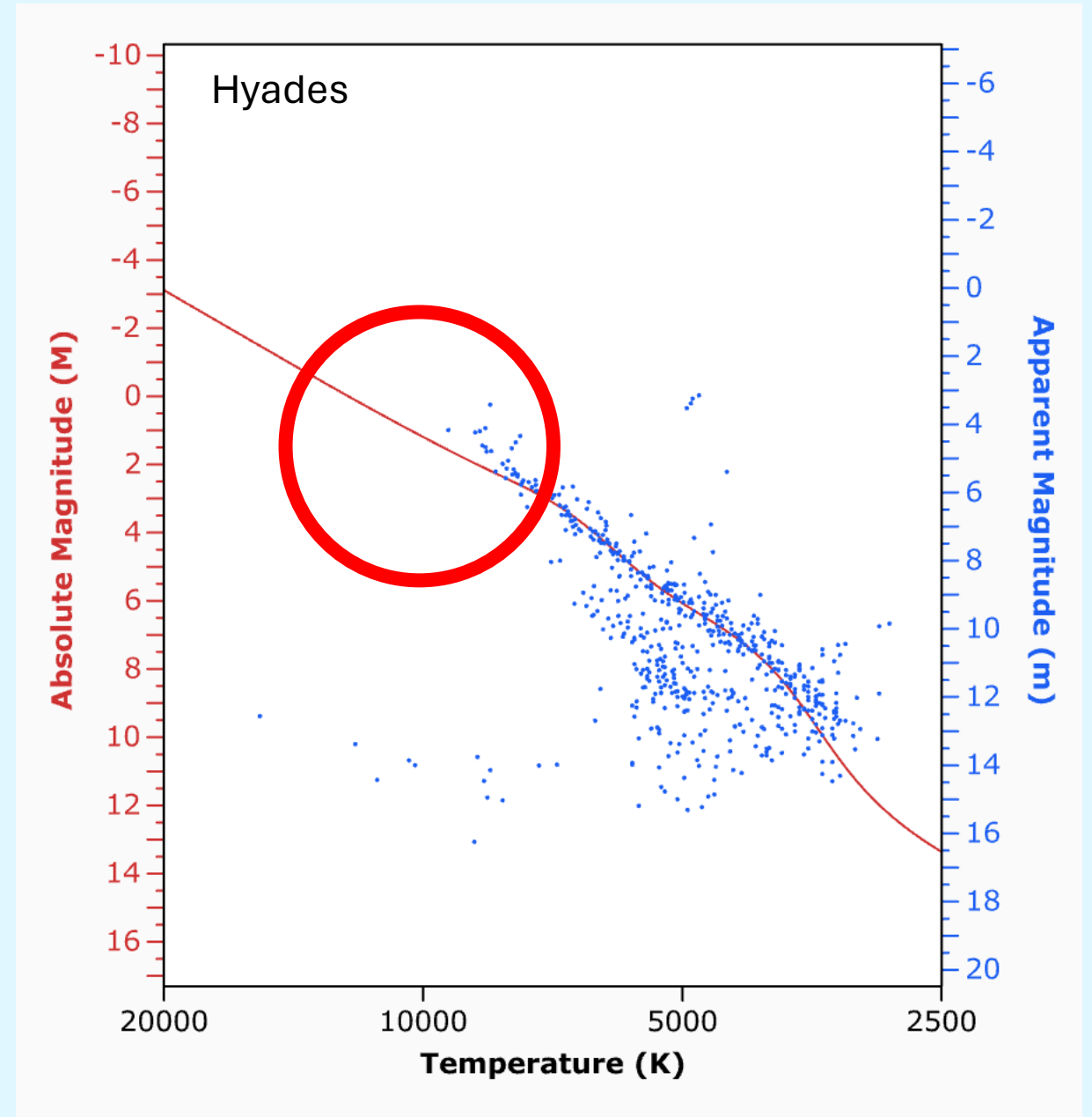
Calibration

- Need a closer cluster to calibrate apparent to absolute magnitudes

- Hyades
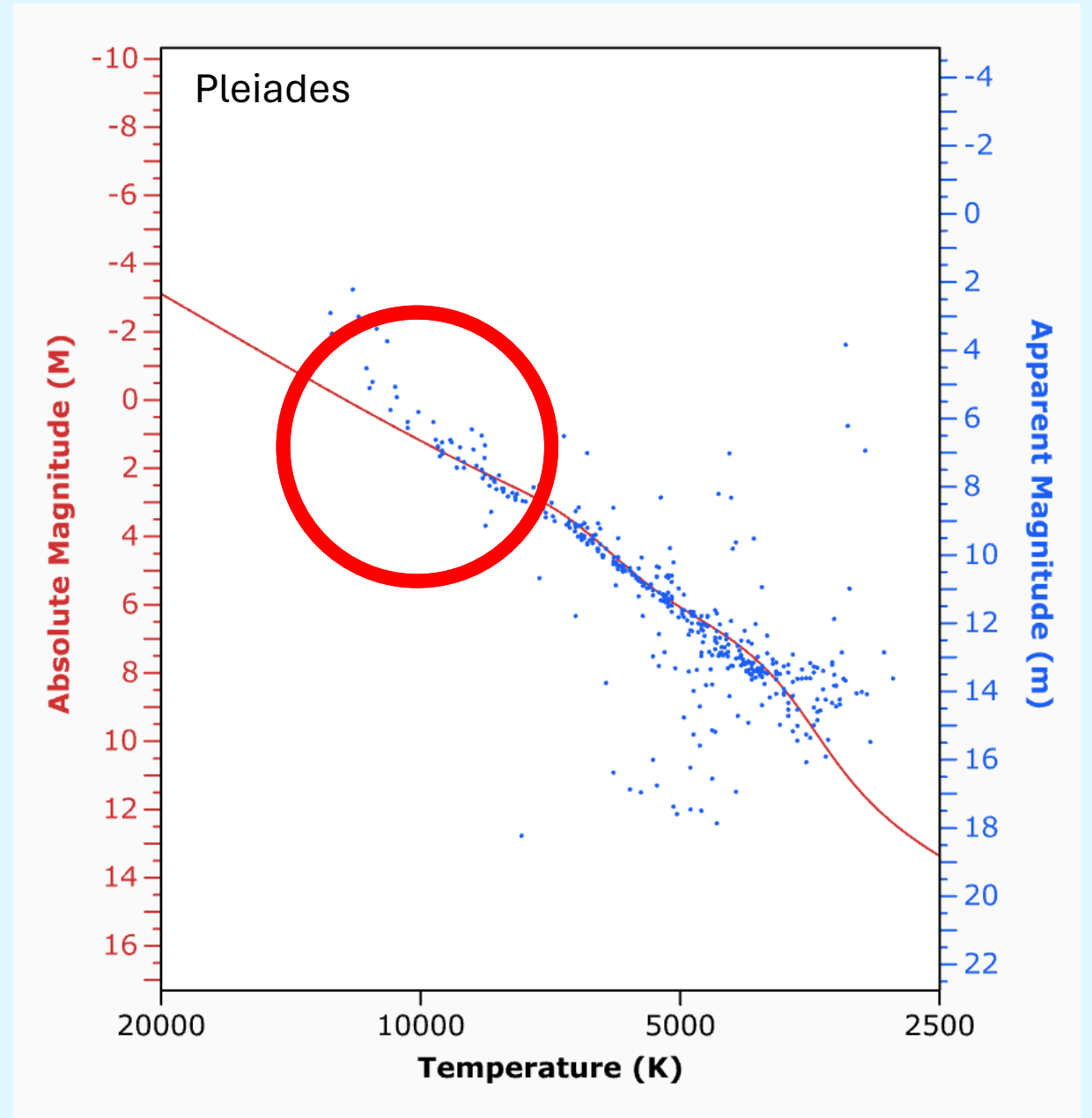 - We can get the distance with parallax
  - 47 pc away

Problems: Calibration

- Hyades is kind of old ☹
  - 47 pc away ☺
  - 700 Myr old ☹

Hyades

The Nebraska Astronomy Applet Project

Problems: Calibration

- Hyades is kind of old ☹
  - 47 pc away ☺
  - 700 Myr old ☹

- We can use the Pleiades also!
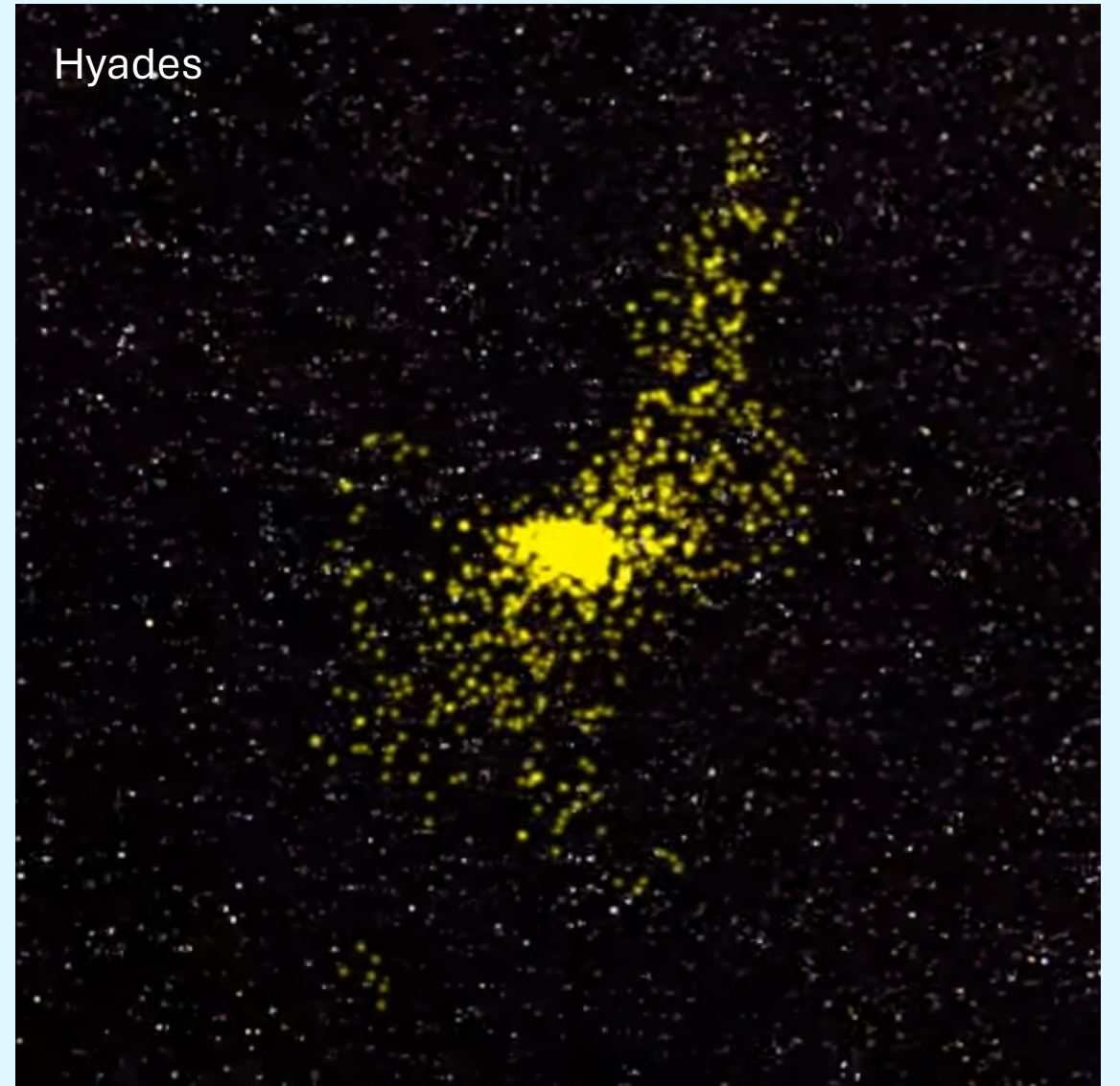 - Next closest cluster (~135 pc) 😕
  - 120 Myr old ☺

NGC 3603

Problems: Age

- Young clusters still have a lot of gas and dust!

- NGC 3603 ~1Myr old and ~7,000 pc away

- Hard to get good colors with stuff in the way ☹

Other Problems:

- ## What's what?

  - It can be hard to tell what is and isn't part of the cluster.

  - Proper motions can help to distinguish members from background stars

Hyades

ESA

Other Problems:

- ## What's what?
  - It can be hard to tell what is and isn't part of the cluster.
 - Proper motions can help to distinguish members from background stars

- ## Where do you draw the line?
  - Evolved stars (post turn-off) and blue stragglers can make fitting the main sequence difficult.
 - Some clusters only have bright stars

NGC 3293
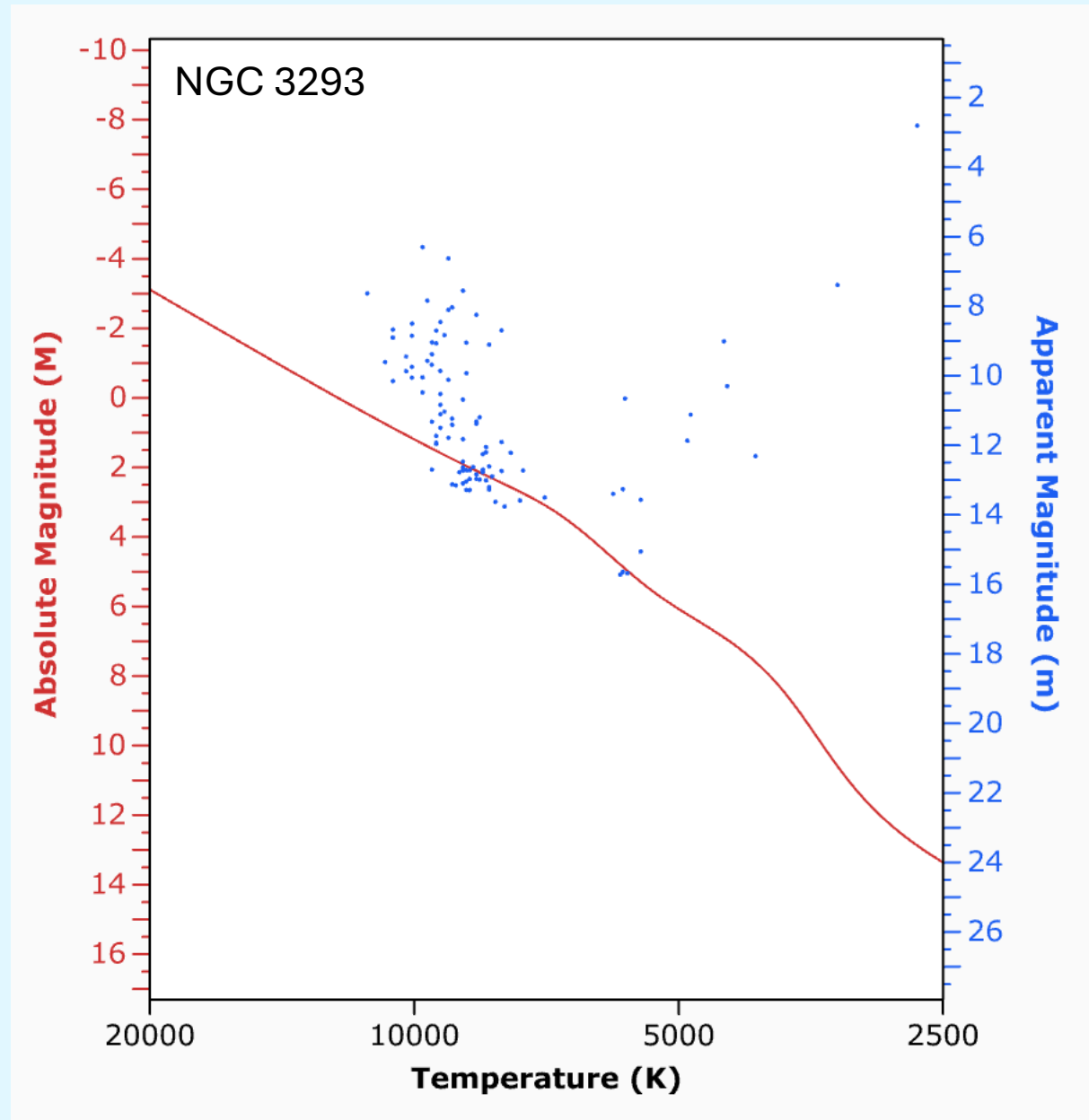
Farther?

- Hipparcos had really good parallax measurements (basically Gaia in the 90s)

- People thought "let's MS fit a clusters near the LMC to get the distance"
  - ~50 kpc

NGC 1866

age = 140, 160 Myr

Z=0.007 Y=0.24

$(m-M)_v = 18.50$

$E(V-I) = 0.08$
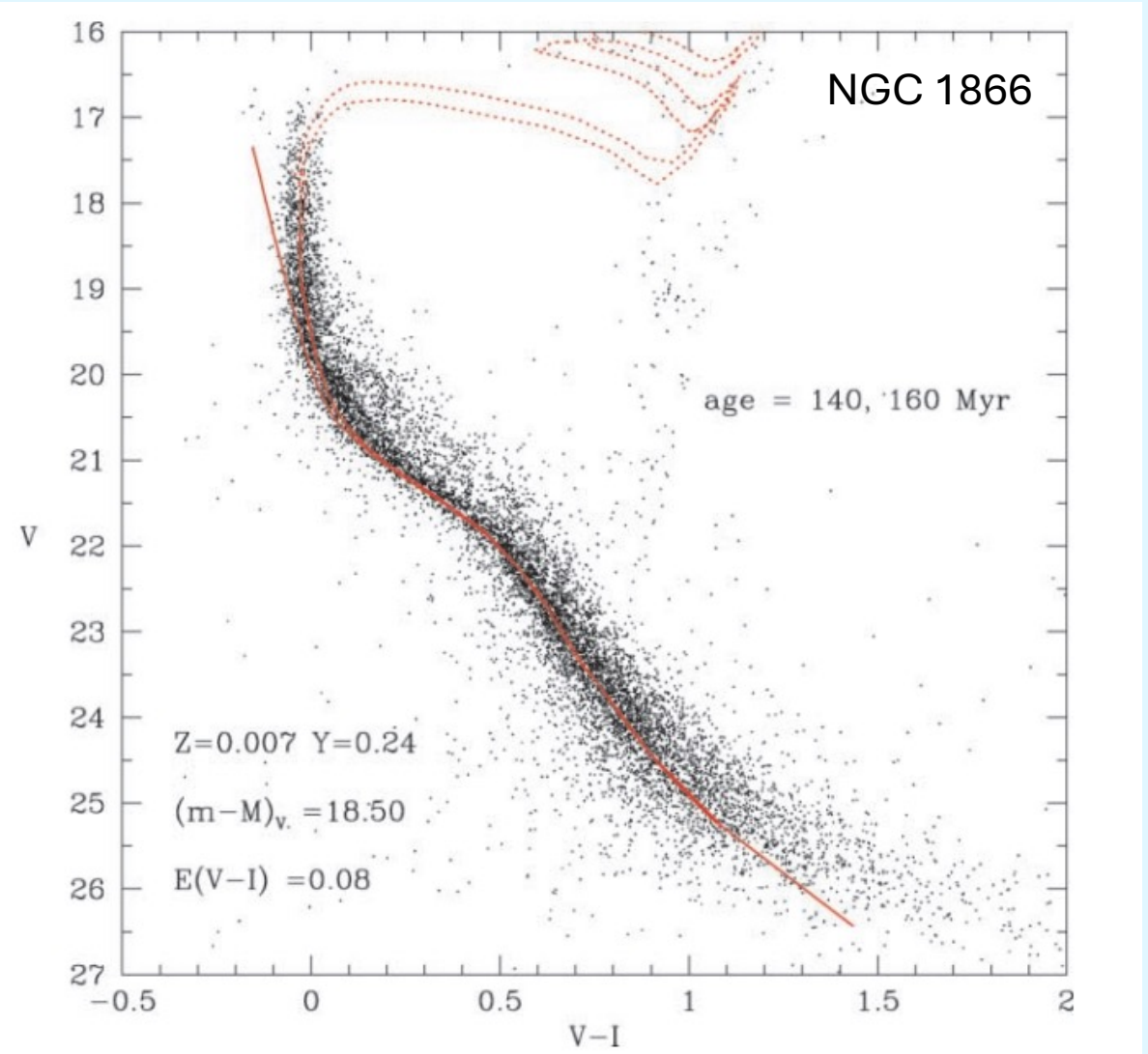
Walker et al. (2001)

Farther?
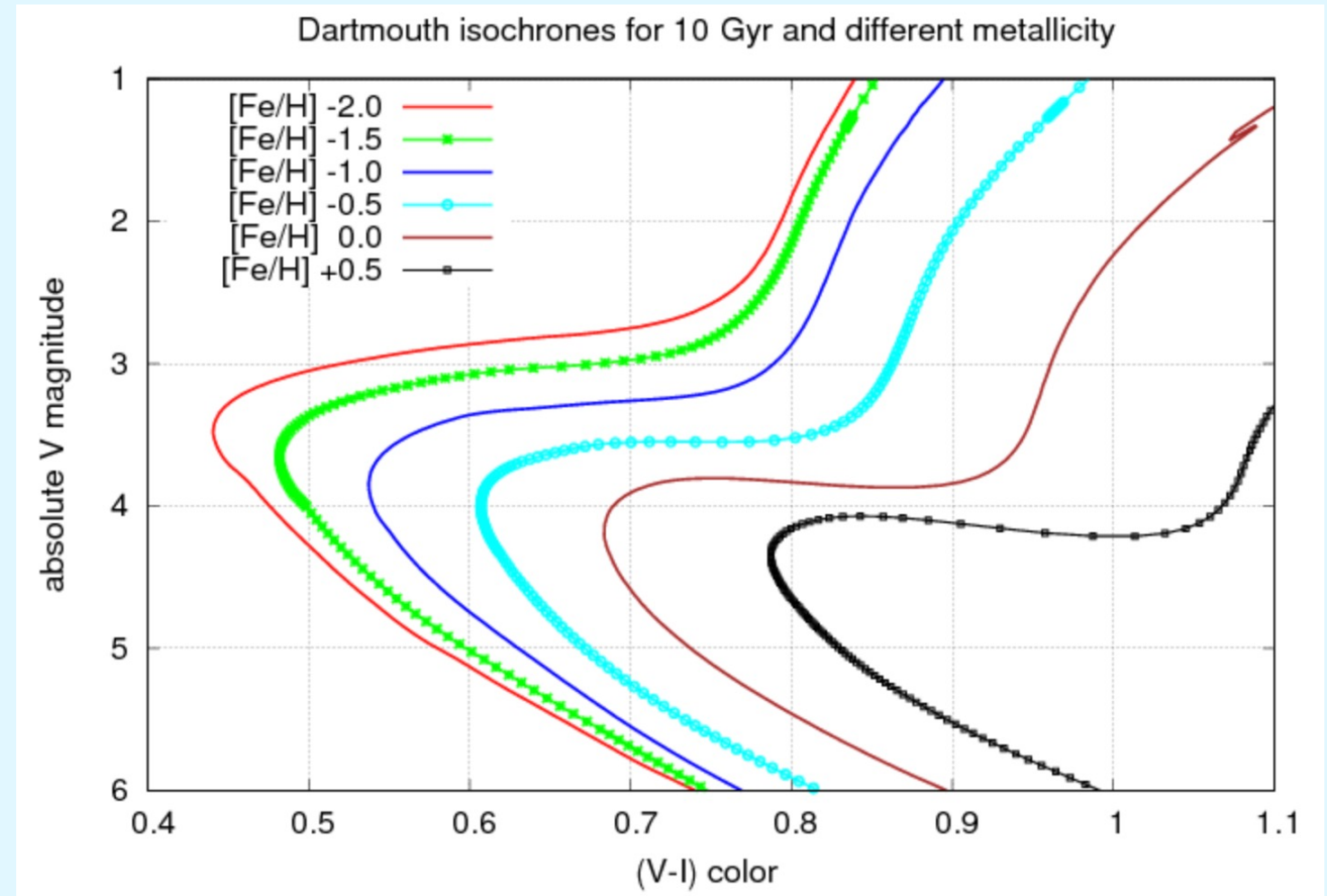
- Hipparcos also had good distances to red clump stars
  - RC → weak luminosity dependence on metallicity/age
  - RC in LMC = distance to LMC

- Comparing the red clump fit to the MS fit didn't work that well ☹
  - Something is wrong

51 kpc

46 kpc
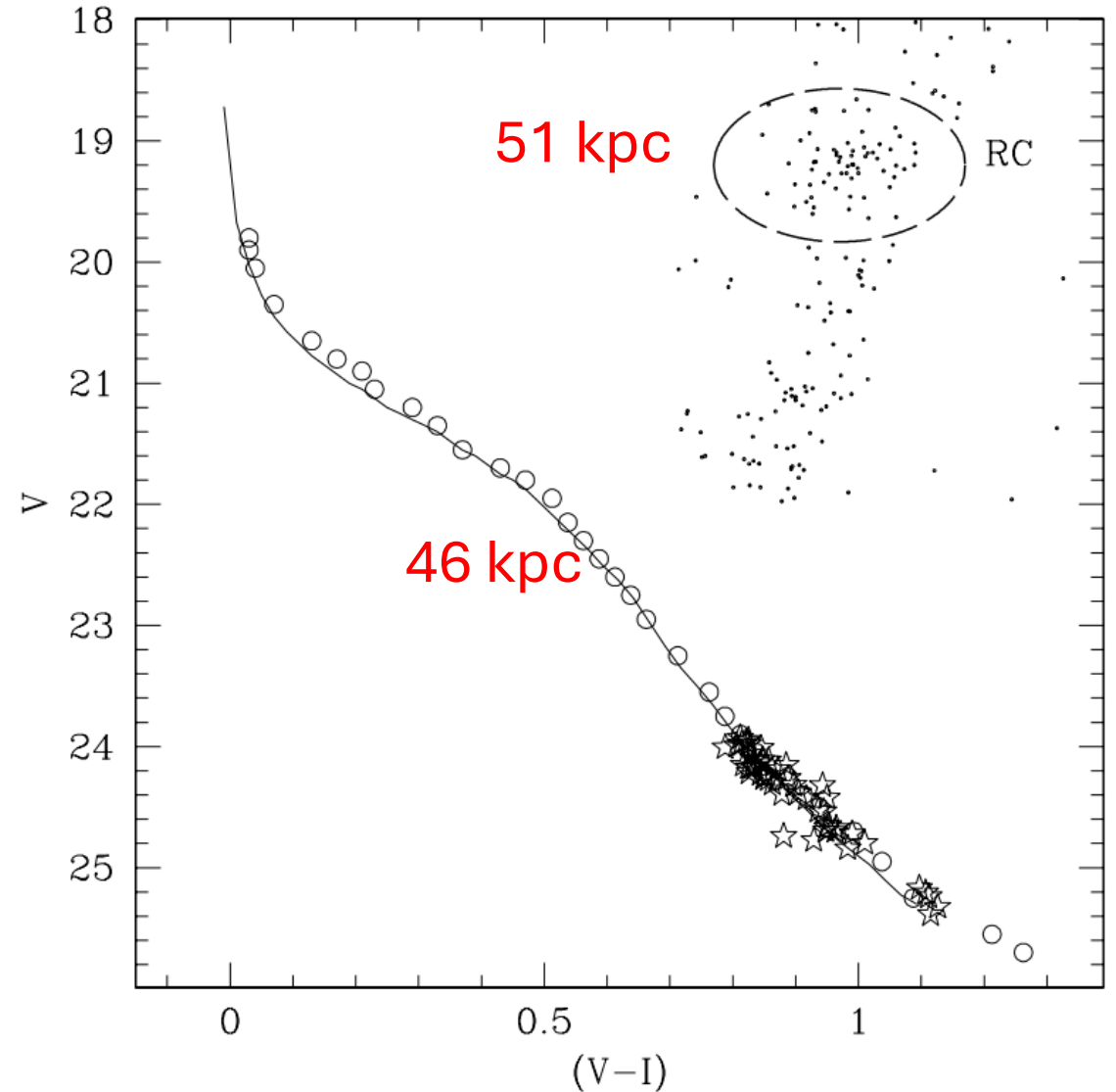
Salaris et al. (2003)

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Sources of Error

- Photometry
  - The MS used for calibration needs VERY high-precision parallaxes

- Systematic errors:
  - Metallicity/Age
  - Reddening

Dartmouth isochrones for 10 Gyr and different metallicity

[Fe/H] -2.0
[Fe/H] -1.5
[Fe/H] -1.0
[Fe/H] -0.5
[Fe/H] 0.0
[Fe/H] +0.5

absolute V magnitude

(V-I) color

Accounting for Errors

THE DISTANCES TO OPEN CLUSTERS FROM MAIN-SEQUENCE FITTING. IV. GALACTIC CEPHEIDS, THE LMC, AND THE LOCAL DISTANCE SCALE

DEOKKEUN AN, DONALD M. TERNDRUP, AND MARC H. PINSONNEAULT

- Series of papers accounting for various systematic errors in MS fitting (~2007)

- Extend Hyades templates to Pleiades to get hotter stars

- Calibrated isochrones to clusters with Cepheids to get distances, reddening, and abundance
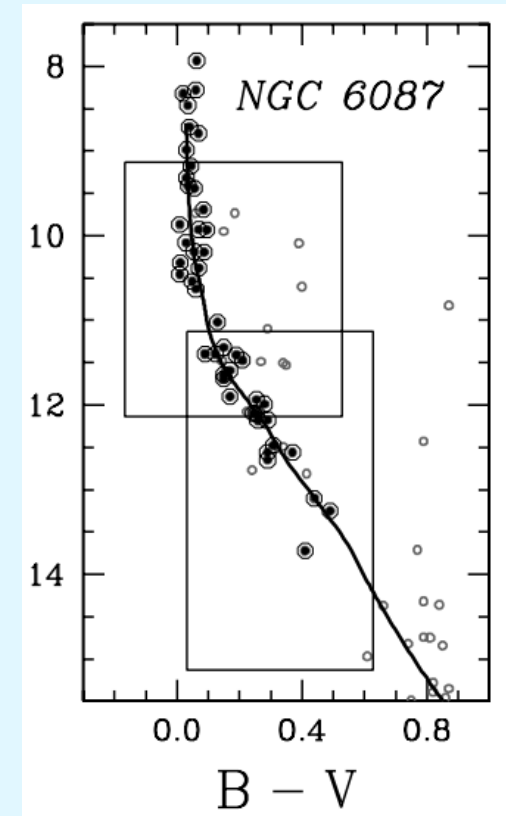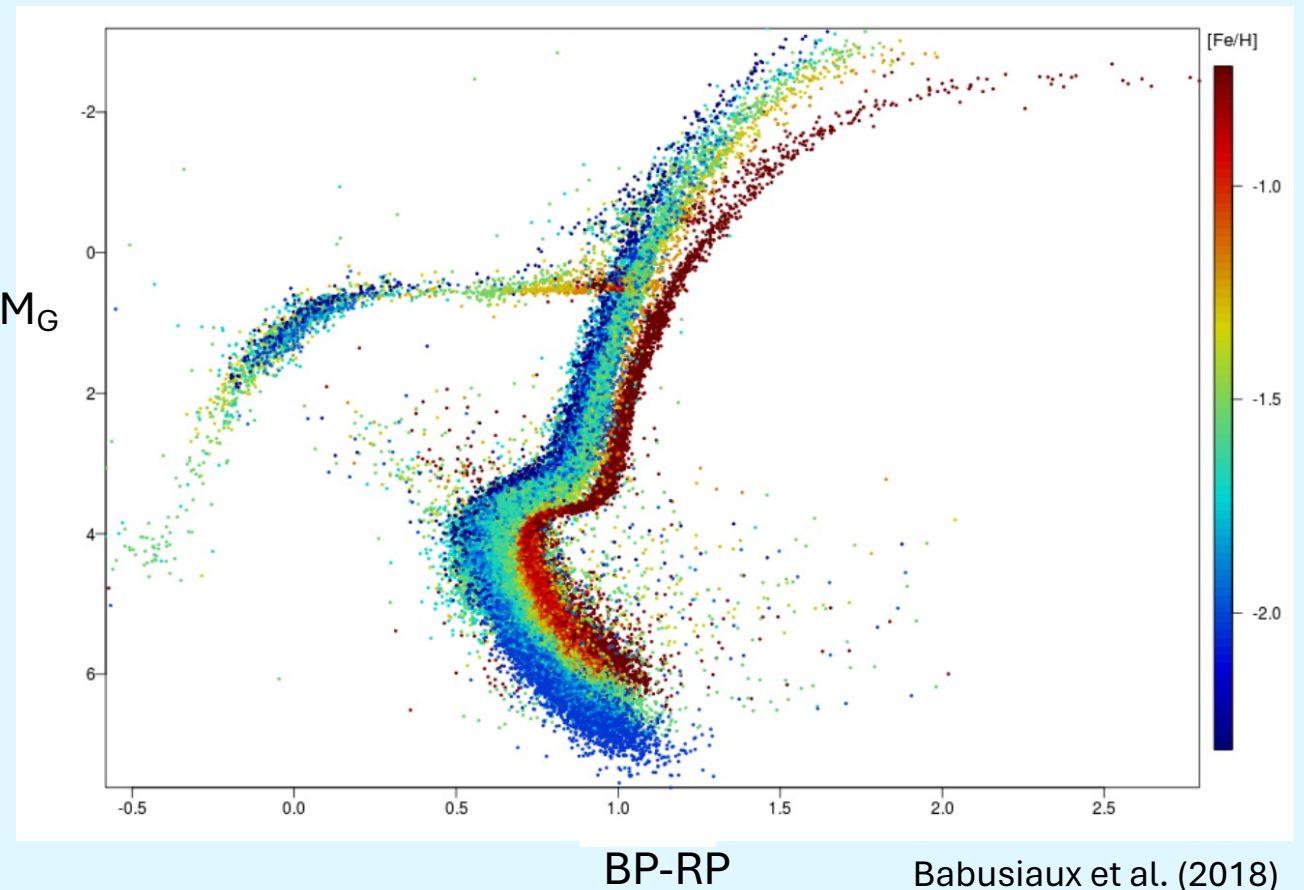

An et al. (2007)

Future?

- MS fitting is hard and has a LOT of systematic errors

- *Gaia* has been able to get good parallaxes to globular and open clusters

"The results from the *Gaia* mission… will surely eliminate the need to use theoretical color shifts to determine MS templates at a generic [Fe/H]"
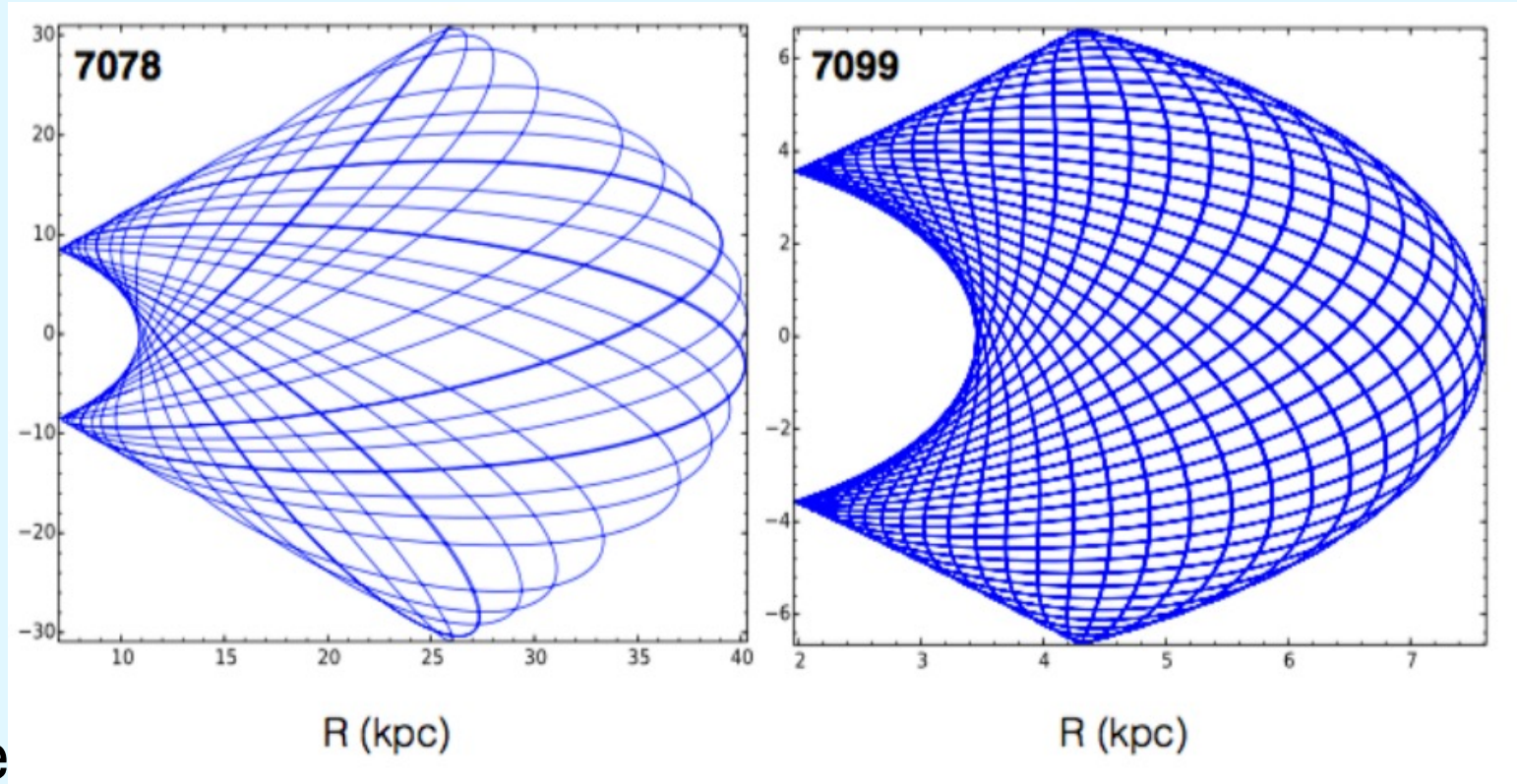
              - Salaris (2011)

14 Globular Clusters in *Gaia* DR2

M_G BP-RP

Babusiaux et al. (2018)

Orbits and Ages

- Used Gaia DR1 data
  - <u>Metal poor</u> subdwarfs
  - Calibrate models for GCs

- Distances and Ages to GCs
  →Orbits!

- Most GCs are found in the outer Halo

O'Malley et al.(2017)

Questions?