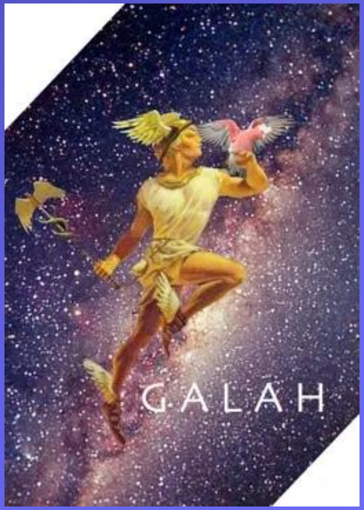
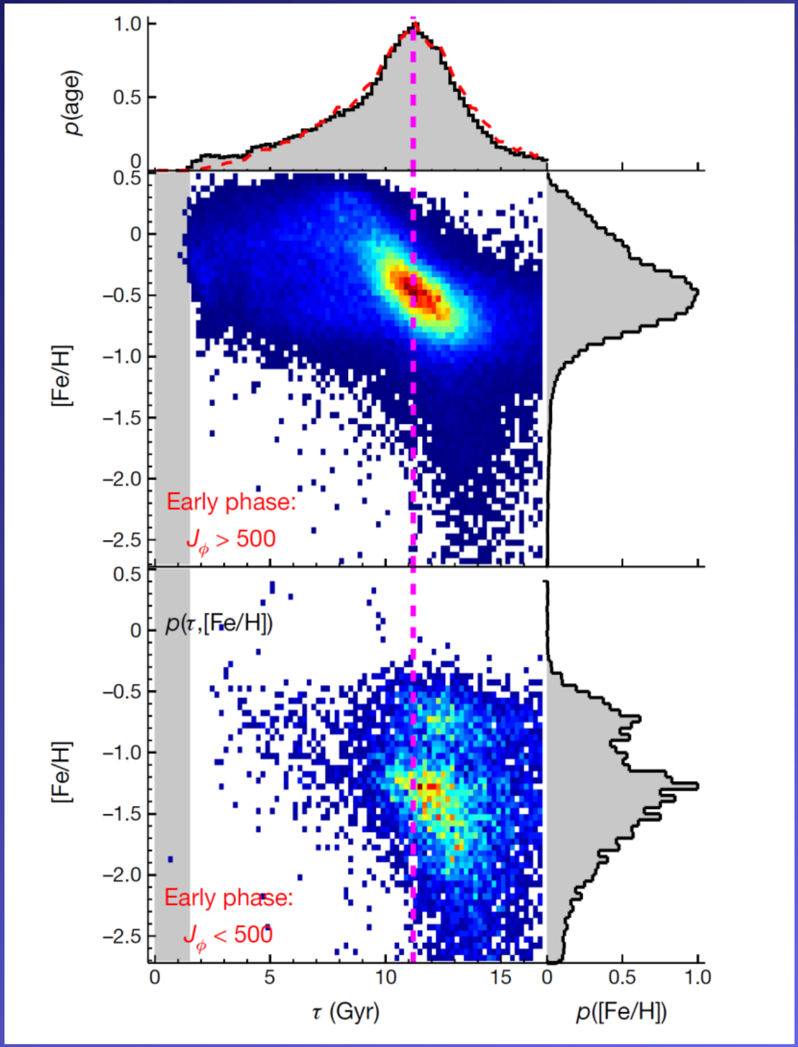
Know Thy Star, Roman Style

Marc Pinsonneault
Ohio State

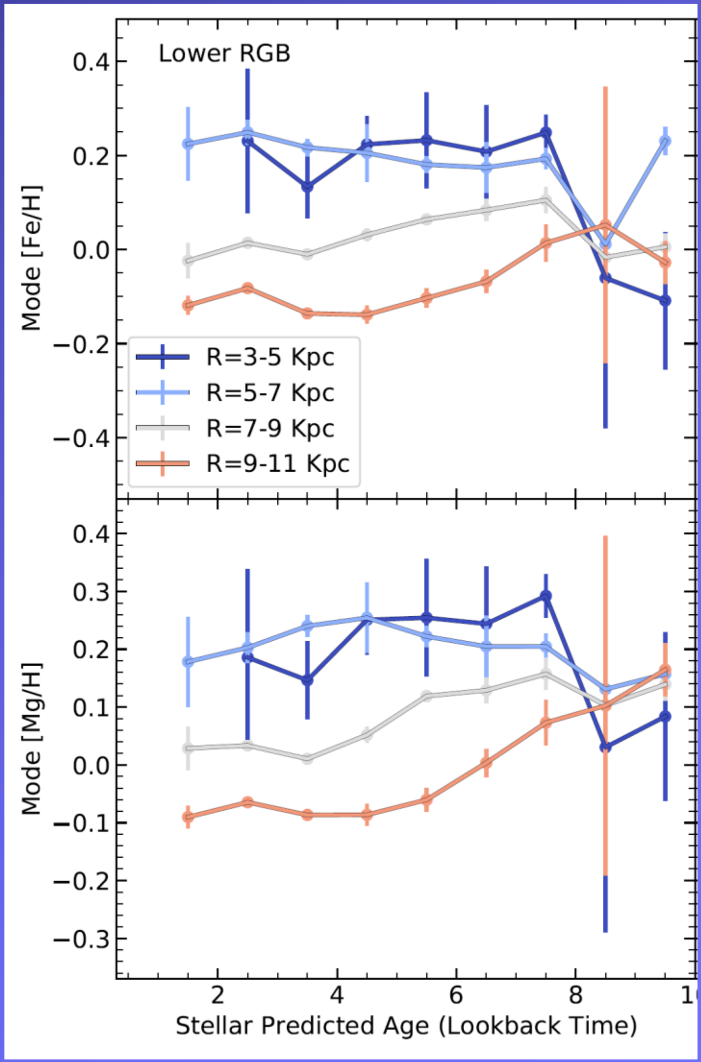
The Survey Revolution



The Power of Understanding Stars I: Galactic Archeology

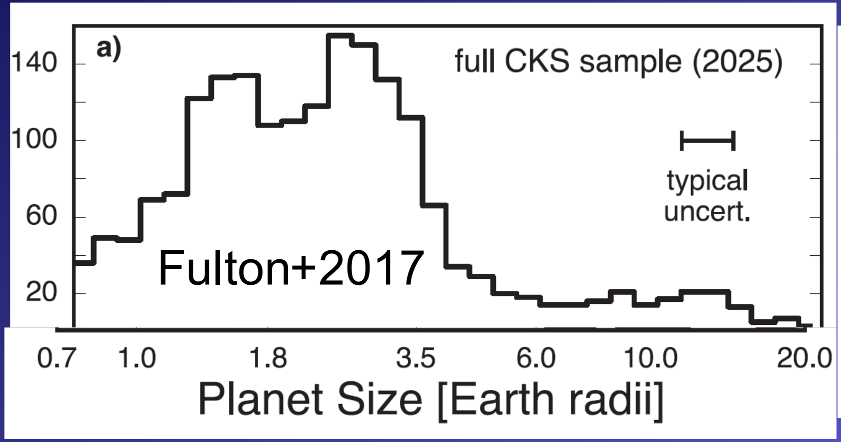


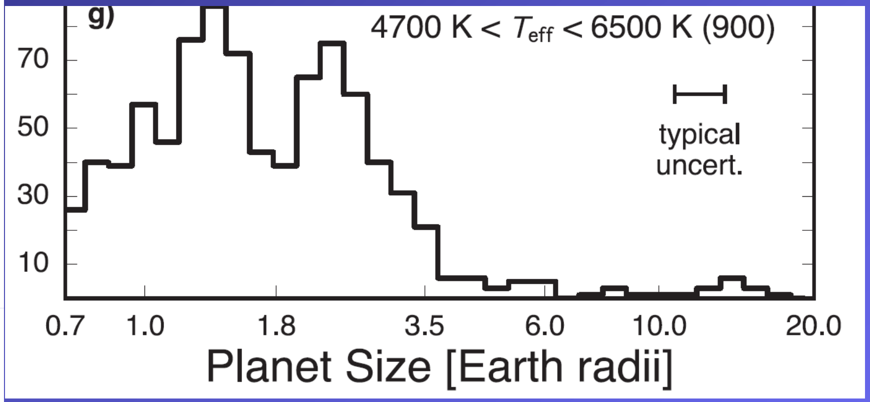
Subgiants: Xiang & Rix 2022

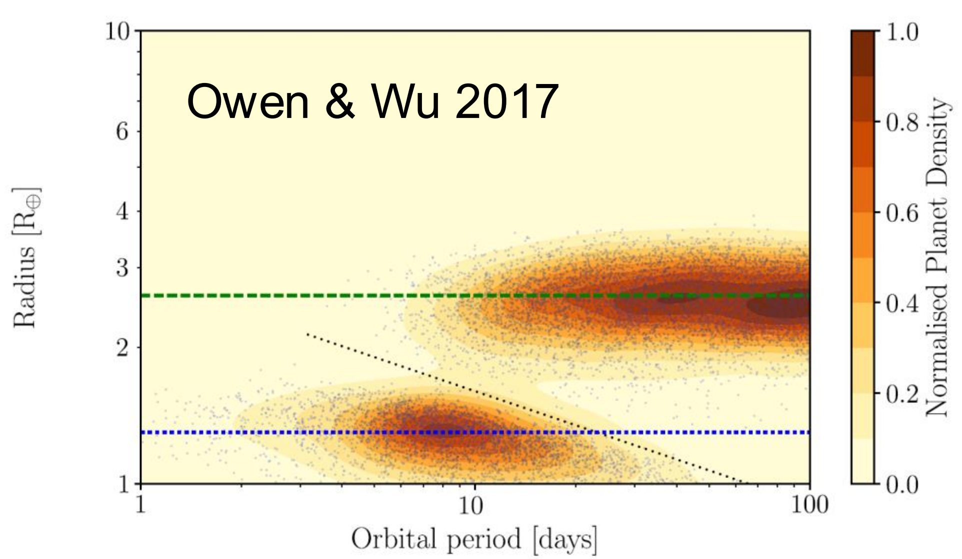


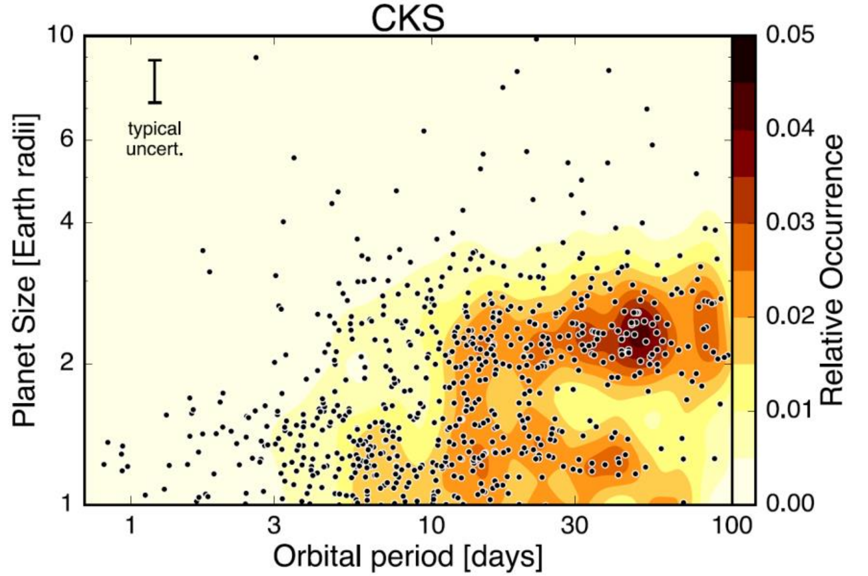
Red Giants: Roberts+2026

The Power of Understanding Stars II: The Planet Radius Valley





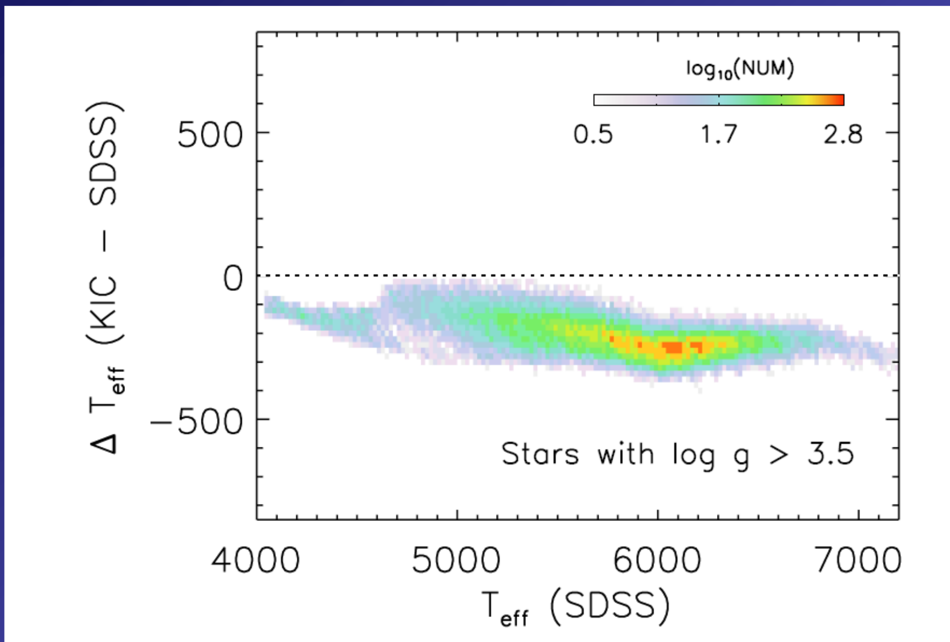




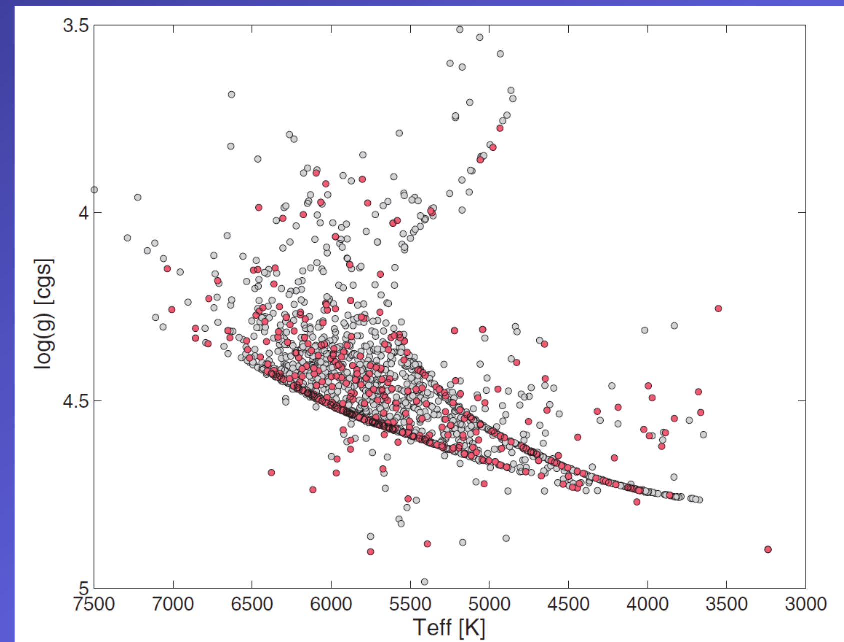
How We Did It

- Modern surveys have revolutionized planetary and stellar astrophysics
- Unleashing their full power has required a dizzying array of tools employed at scale:
  - Spectroscopy
  - Photometry
  - Astrometry
  - Time domain surveys

Flashback: the KIC

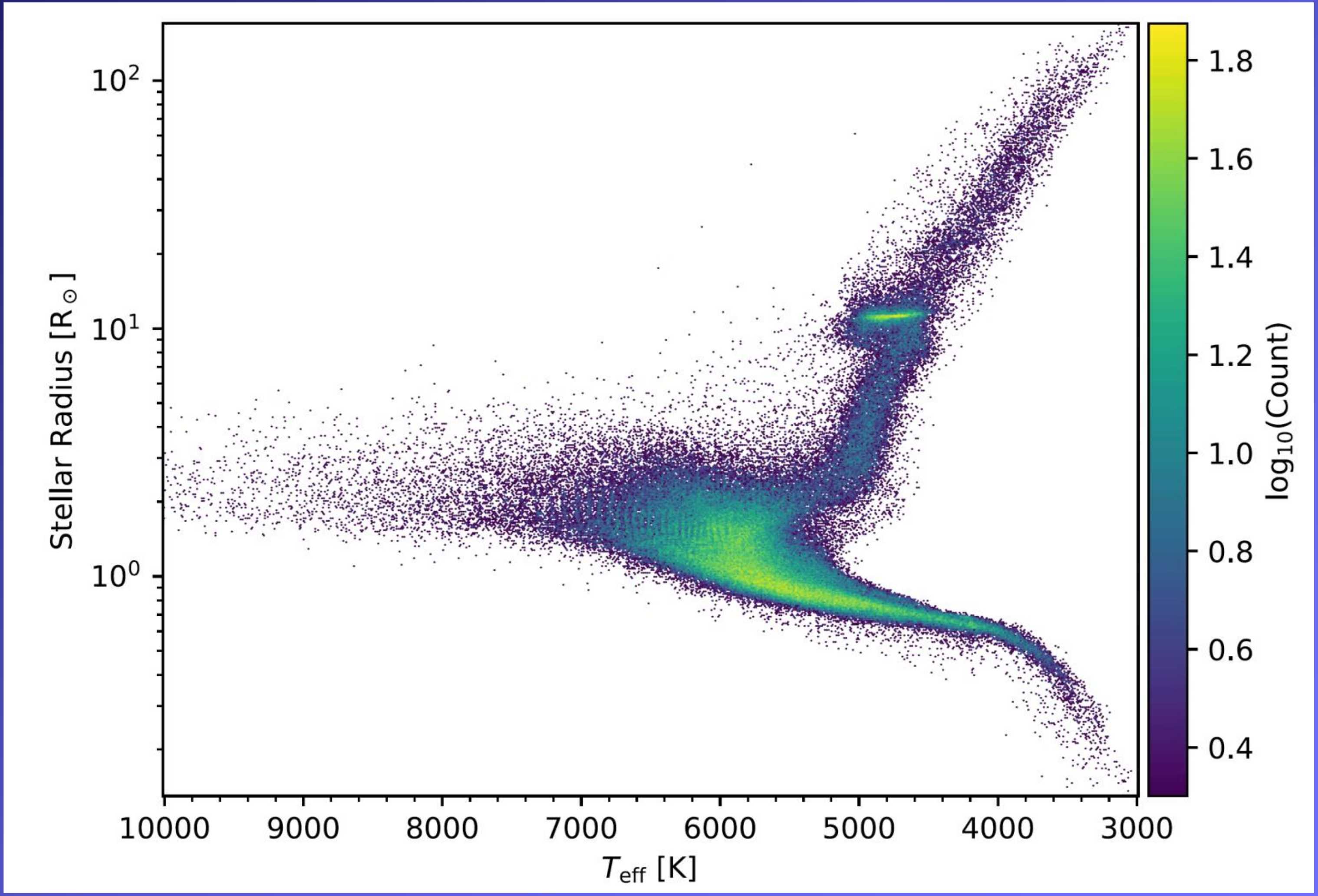


Pinsonneault+2012:
Mapping the original KIC onto the IRFM

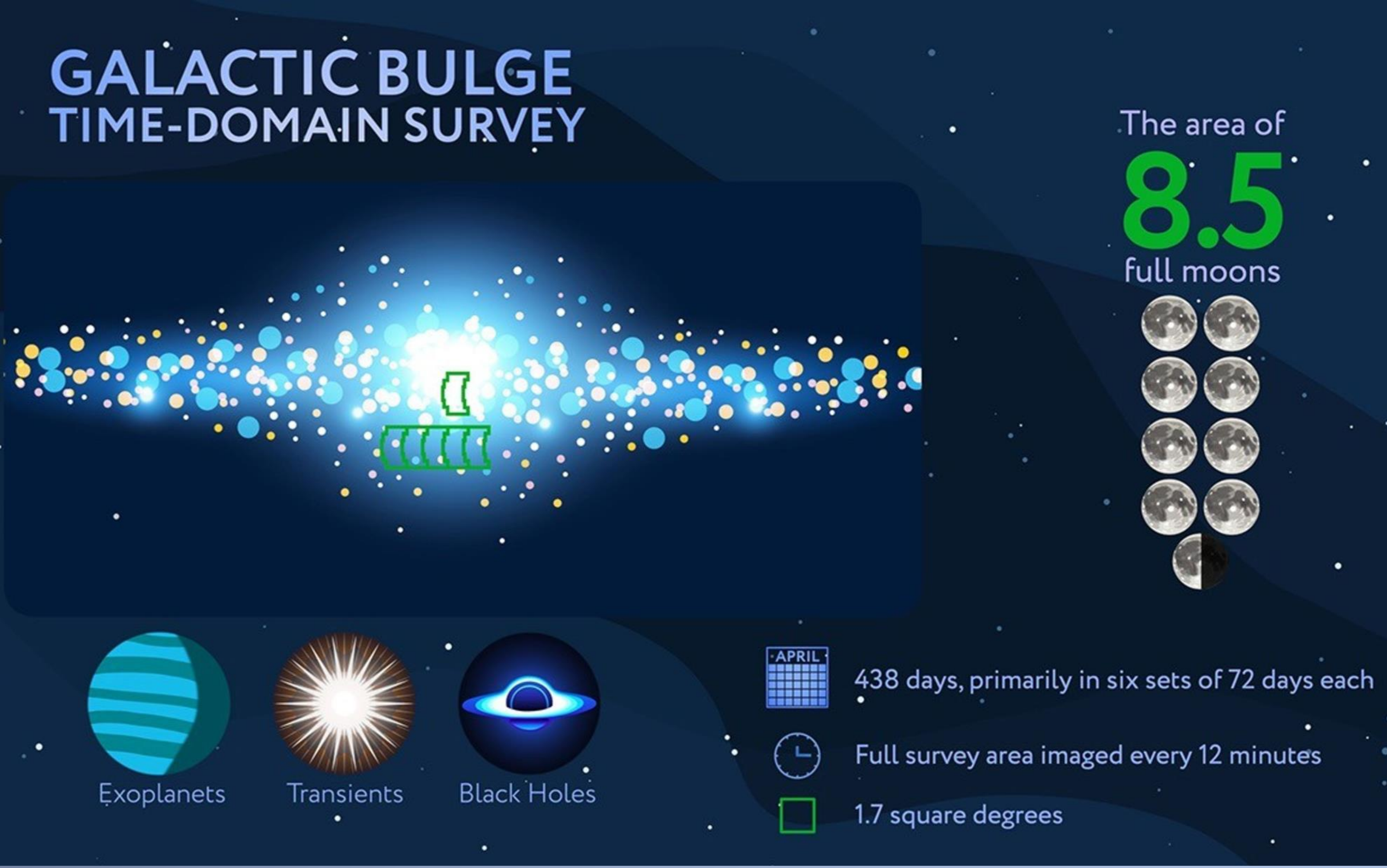


Burke+2014: Stellar properties of *Kepler* planetary hosts
(Pinsonneault+2012 KIC properties)

Improving the KIC: Spectroscopy, Astrometry, Asteroseismology



Berger+2020

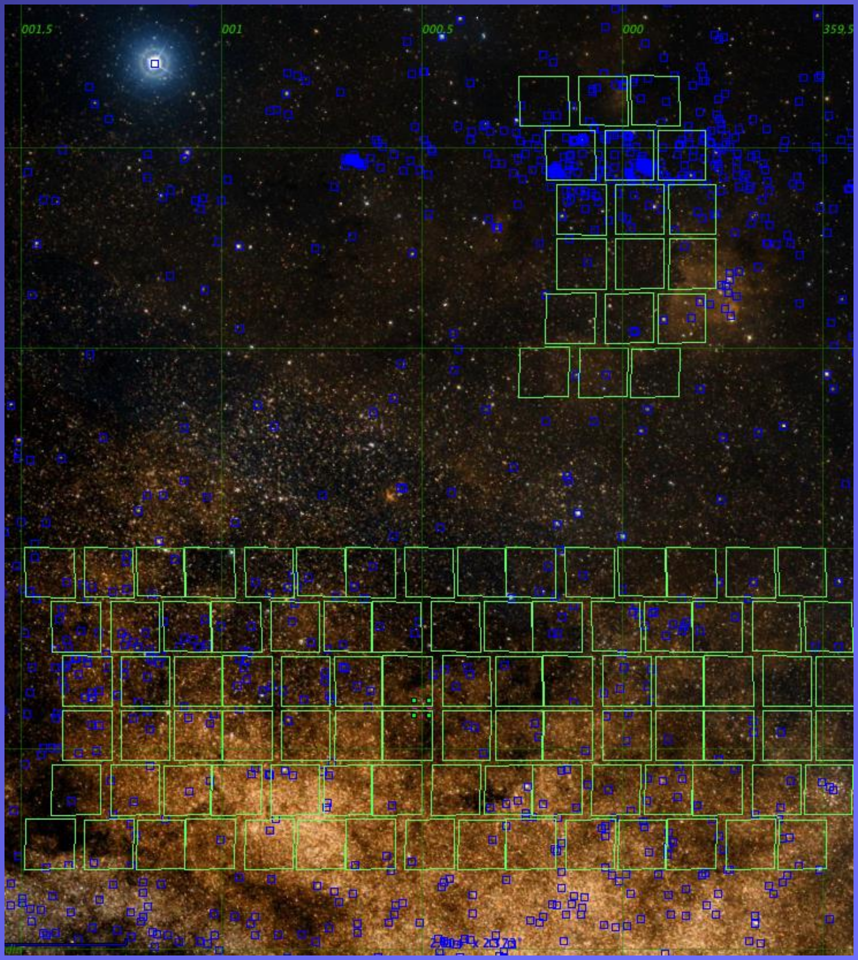


Launch Date: August 30, 2026!

Plus:
- Galactic Plane Survey
- General astrophysics observations: ~25% of the prime mission
- Coronagraphic observations

The GBTDS Challenge

- Stars are too faint in the optical for reliable parallaxes
- We lack high-res spectra
- Extinction is far more severe than the *Kepler* case



Back to Basics: How Can We Measure Fundamental Properties Without Spectra and Parallaxes?

- T_{eff} is a defined, exact quantity that can be precisely and accurately correlated with photometry
- Metallicity and extinction can also be inferred reliably from their impact on colors
- There are practical challenges that will require dedicated effort to overcome!

What Is the Best Way to Measure T_{eff}?

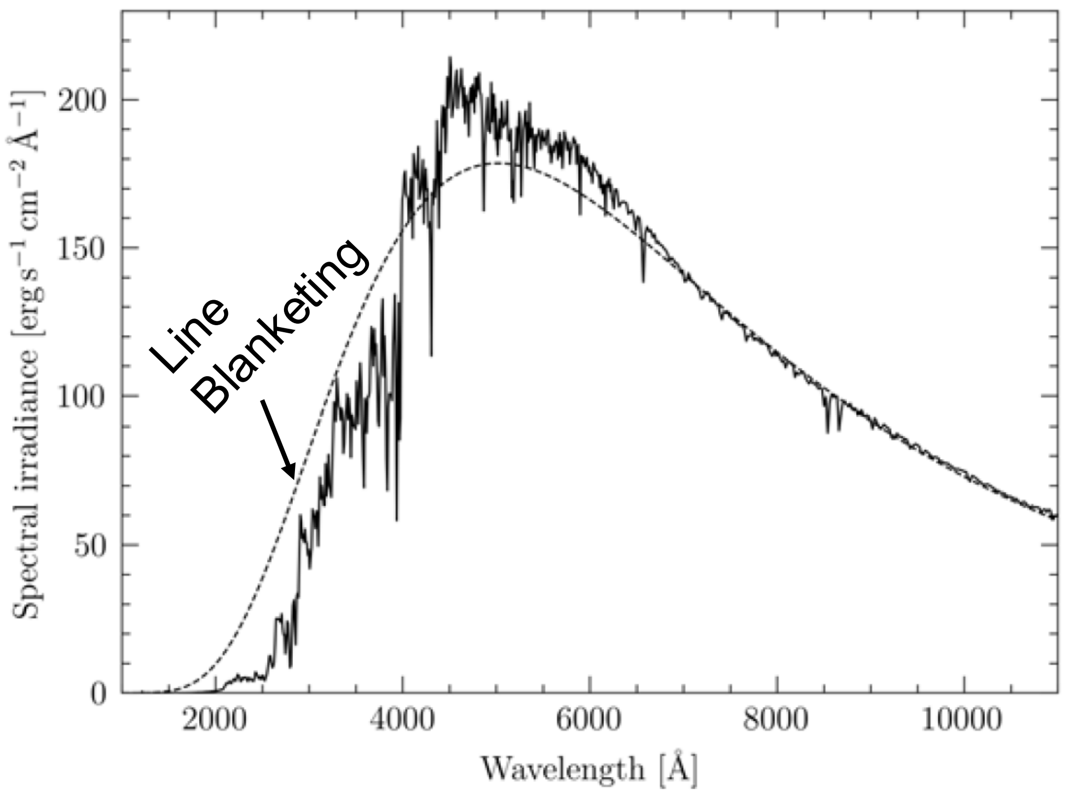
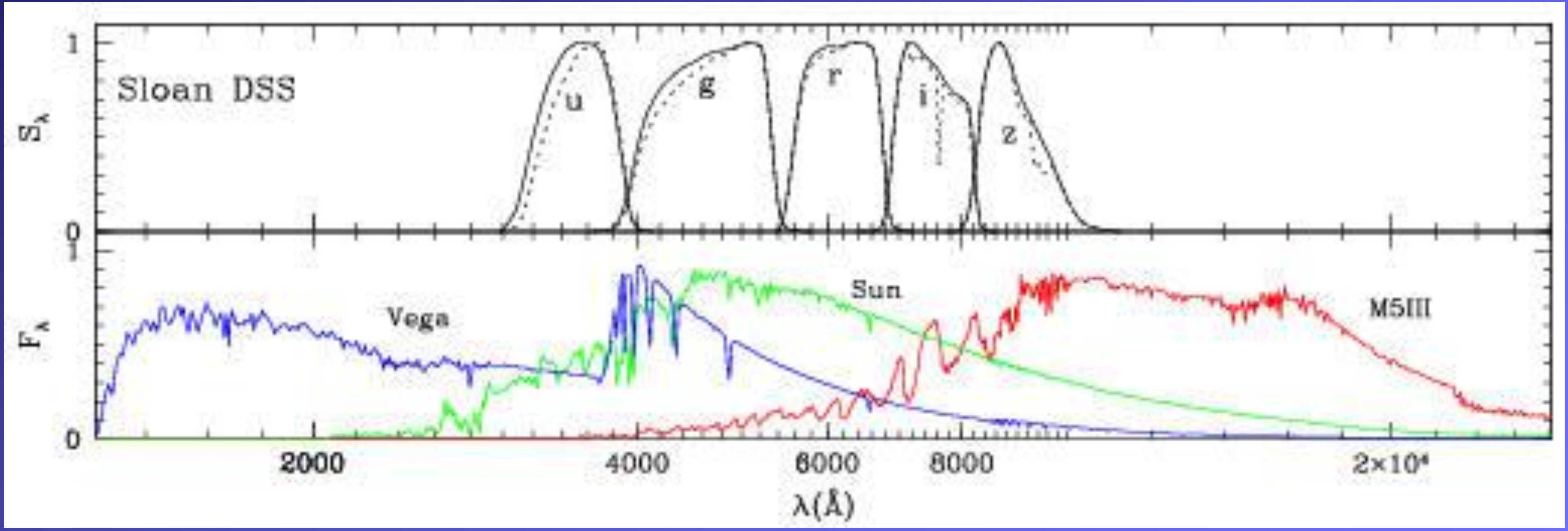


Figure 1.3 The solar spectrum as seen 1 au from the Sun, without filtering by the Earth's atmosphere. The dashed line shows a blackbody spectrum with a temperature 5772 K. [ASTM E-490-00 solar spectrum]

Pinsonneault & Ryden 2023

The Power Of Photometry



UV

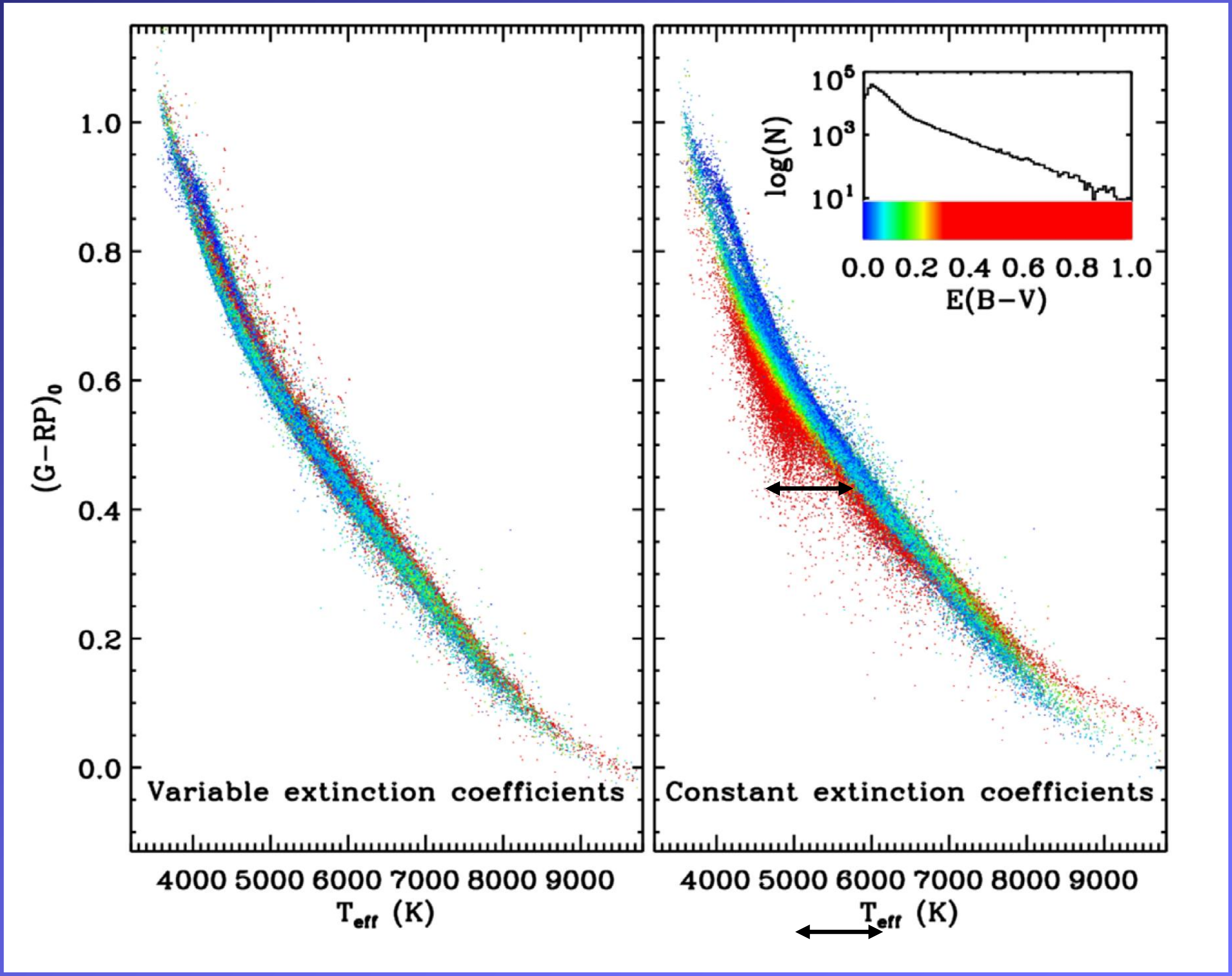
Visible

IR

Better Living Through Photometry

Correlate fundamental T_{eff} with colors

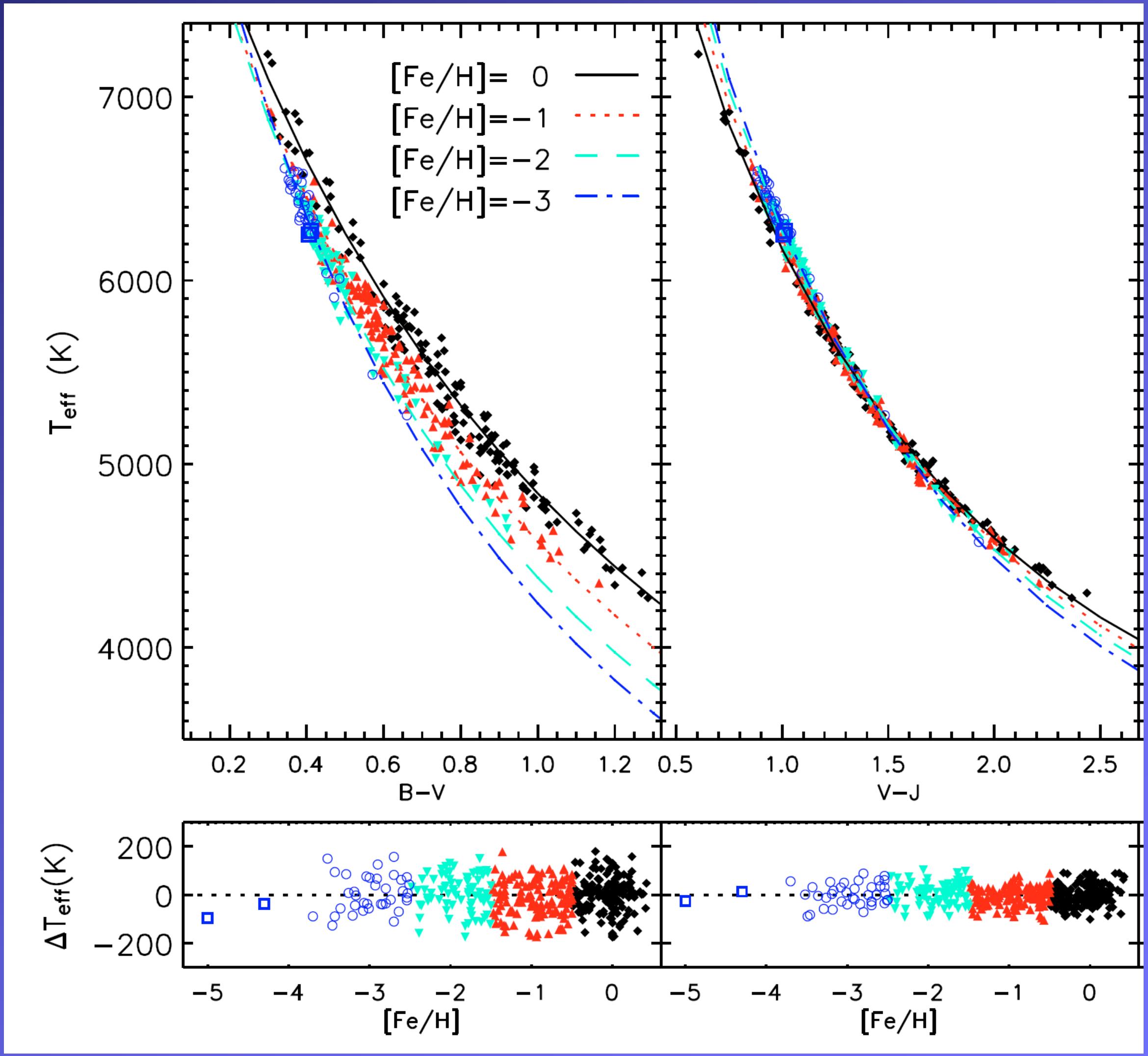
Note: Reddening Is Very Important!



Casagrande+2026

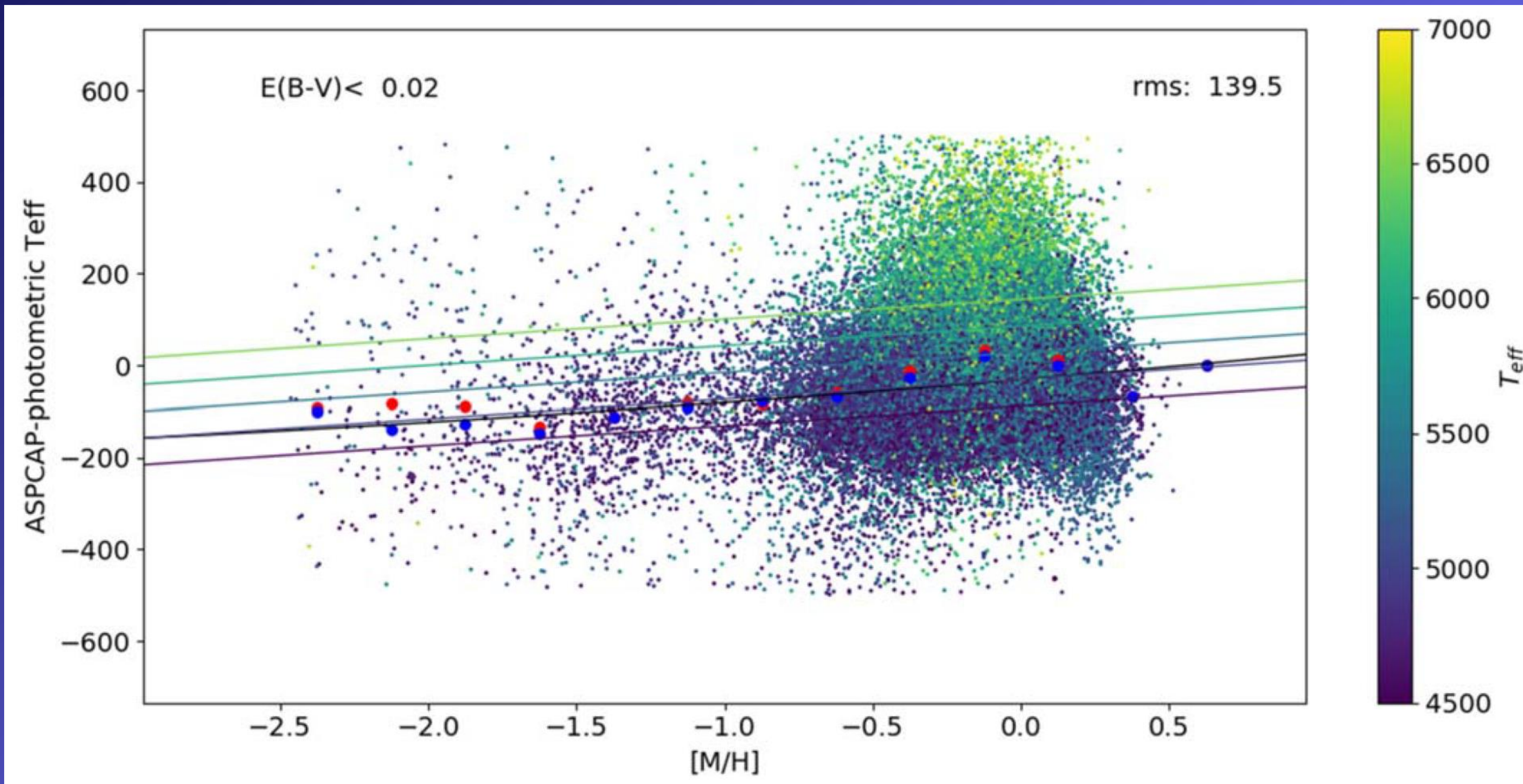
Metallicity Impacts Photometry

Color-color Consistency Can Be Used To Infer [Fe/H]



Casagrande+2010

Note: Spectroscopy is Anchored Using Photometry!



The APOGEE T_{eff} corrections

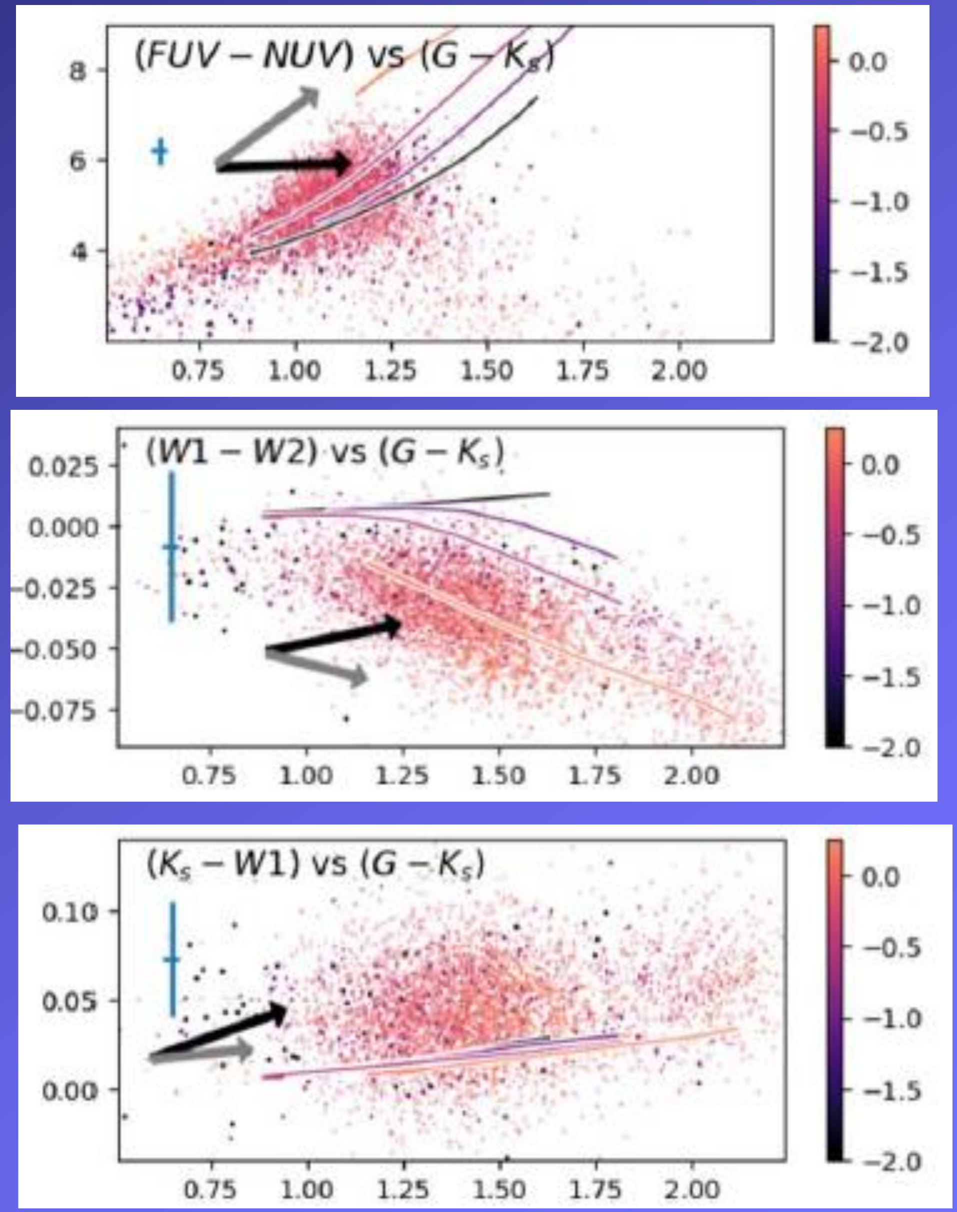
Jonsson+2020

Sleuthing Extinction

Nataf+ 2024

Extinction

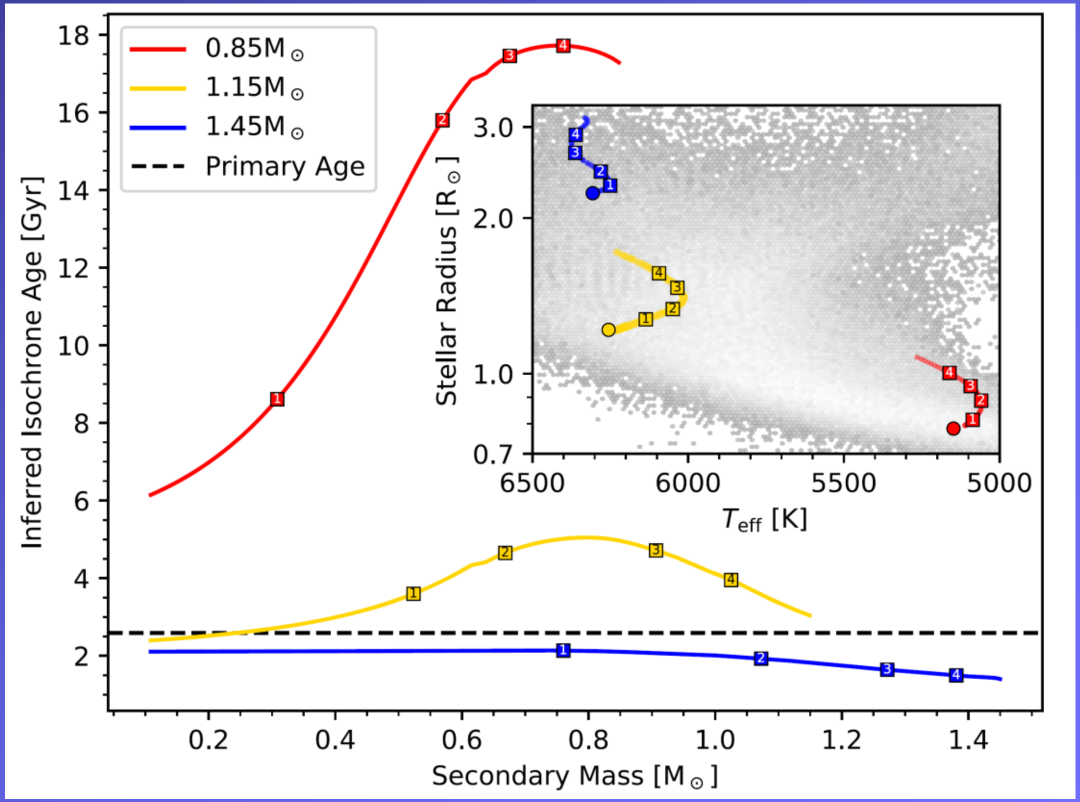
Temperature



- *In principle well-posed*
- *Quite sensitive to assumptions about the nature of dust…*

Complications and Annoyances: Binaries and Blends

- 4% of KIC stars are photometric blends
- GBTDS: 0.1” = 800 AU at 8 kpc…so many binaries will be unresolved
- Severe problem in hot subgiants



Unresolved binaries: Berger+2020

Complications and Annoyances: Extinction and Reddening

- Nataf talk earlier!
- The extinction, *and the extinction law*, can vary as a function of depth and position
- Early going – the lack of parallaxes will limit 3D maps
- Best prospects – the unevolved lower MS, and the evolved stars

Two Paths to Enlightenment

Theoretical Models

- Use model atmospheres to generate synthetic colors and magnitudes for stars across the HRD
- Flexible, but subject to significant systematic errors

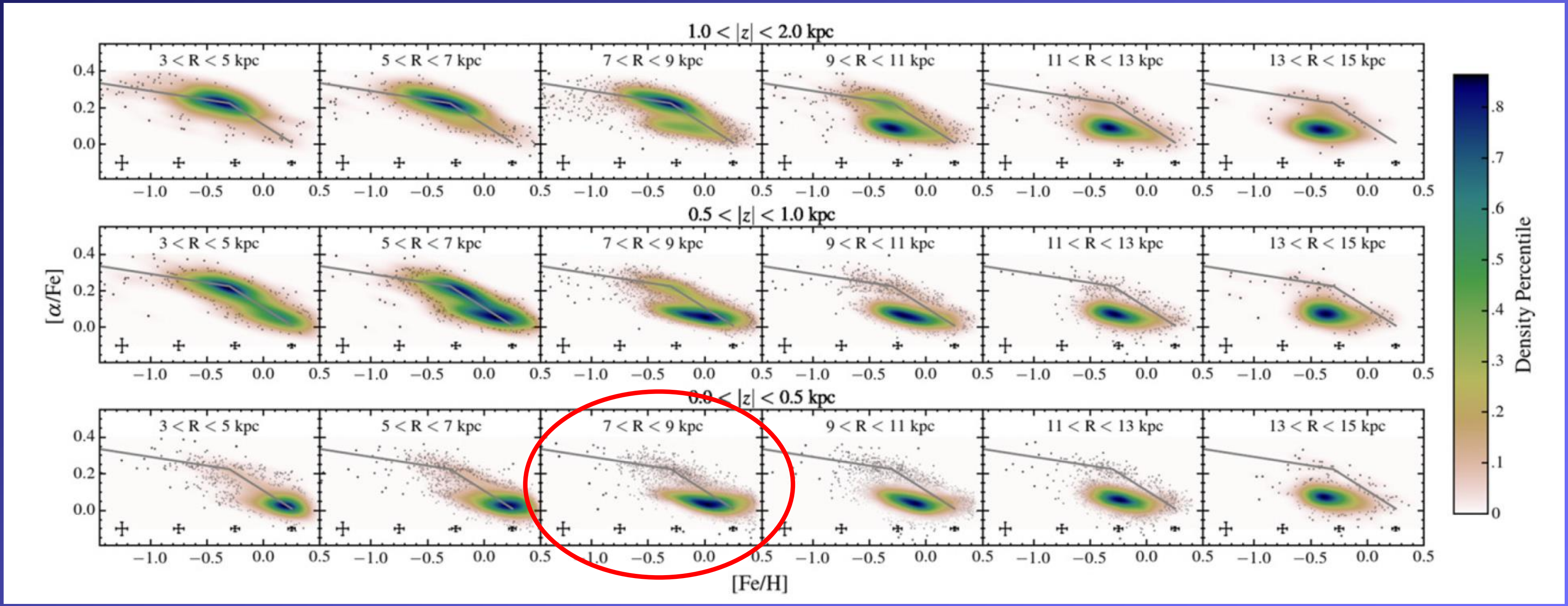
Empirical Models

- Use high-resolution metallicity and fundamental T_{eff} and data to define a training set
- Can correlate with all information (spectra, photometry, astrometry…)
- Cons: abundances not truly fundamental, have systematics; local samples may not be representative

Enter the Machine Gods

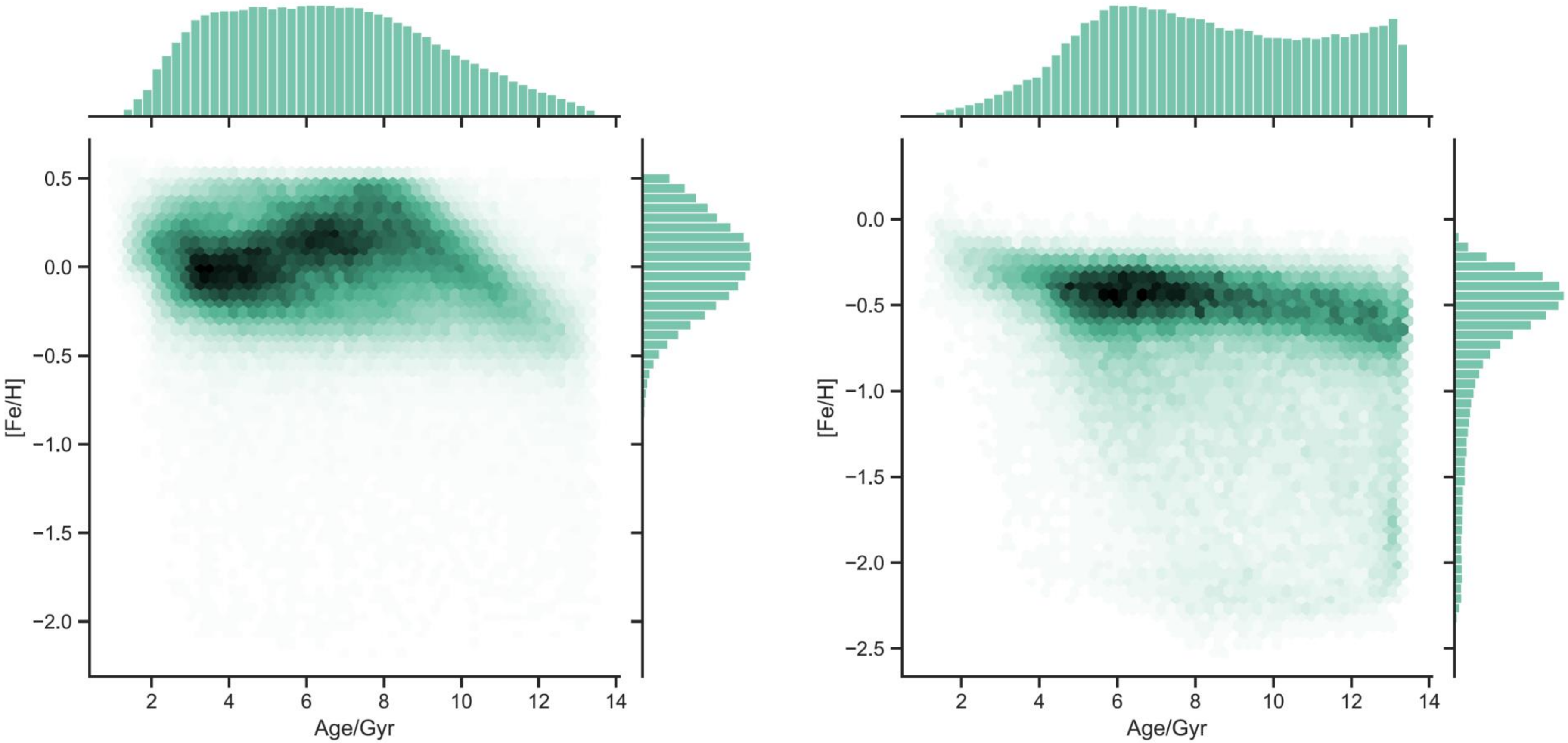
Why Collect New Data?

Geography Matters!



Existing data (esp. Kepler) is largely in the solar circle Hayden+2015

A Worked Example: Gaia Subgiants



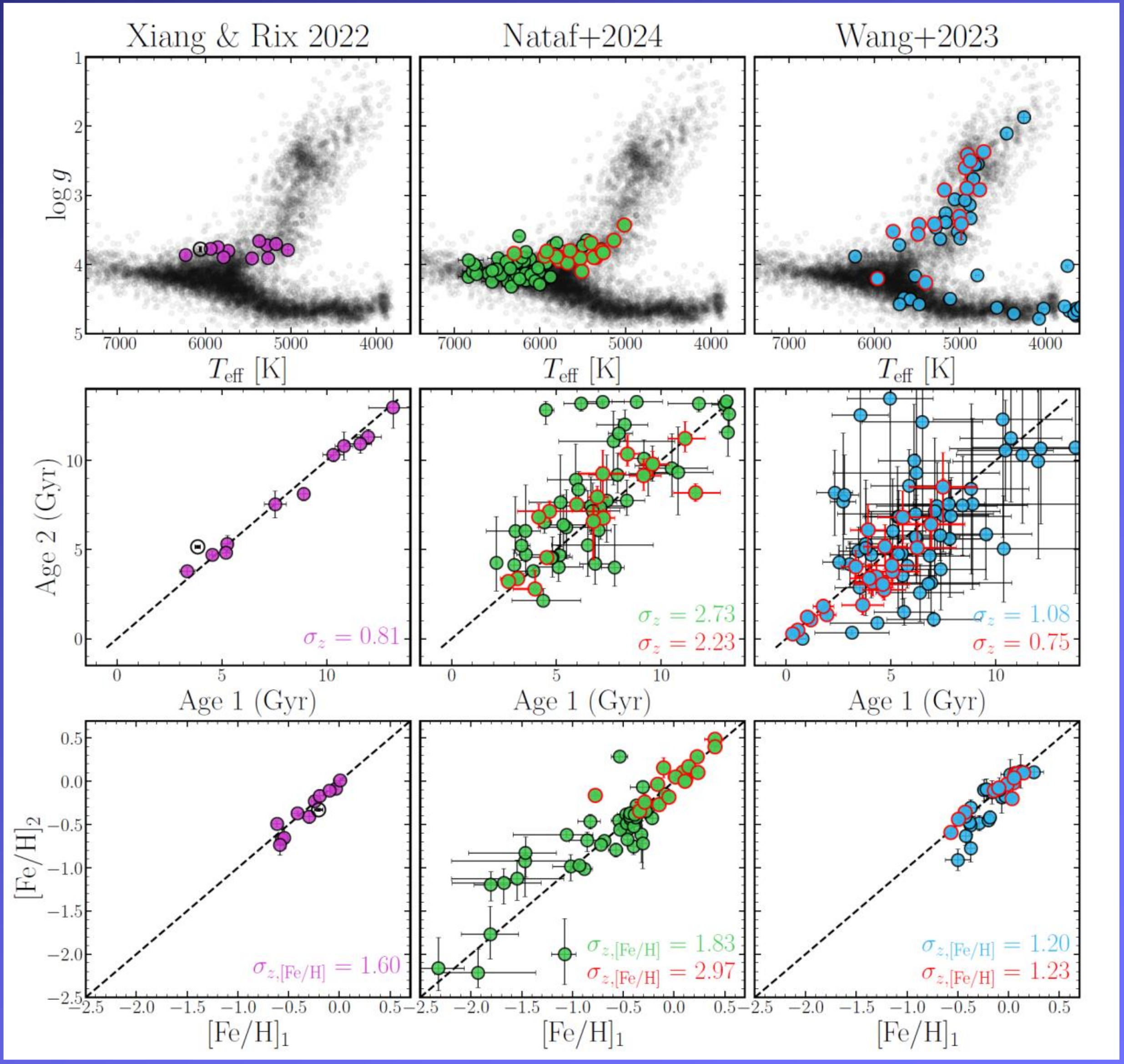
Nataf+2024

- Note: metallicities may be more difficult for the GBTDS

Systematics Matter!

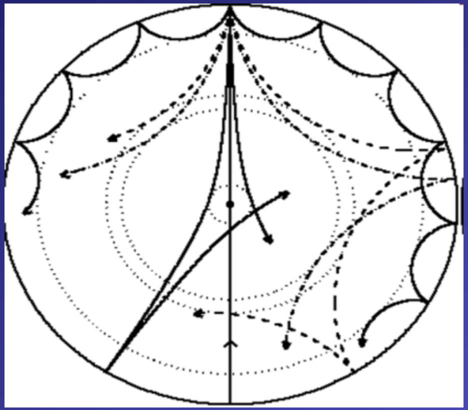
Shariat+2026

Used wide binaries
to test recovery for age
and metallicity



Asteroseismology Summarized

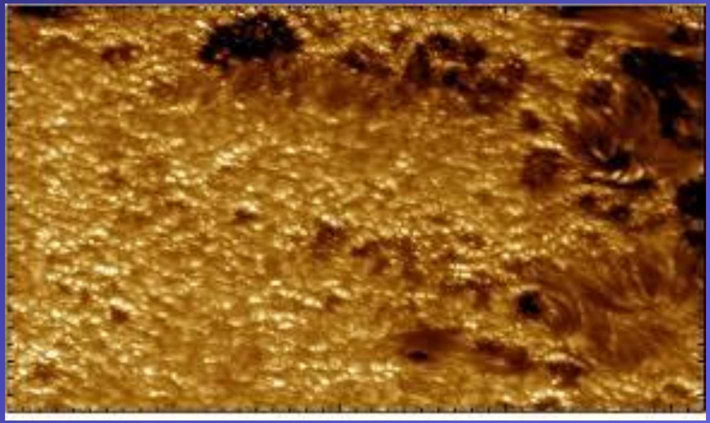
STANDING
WAVES

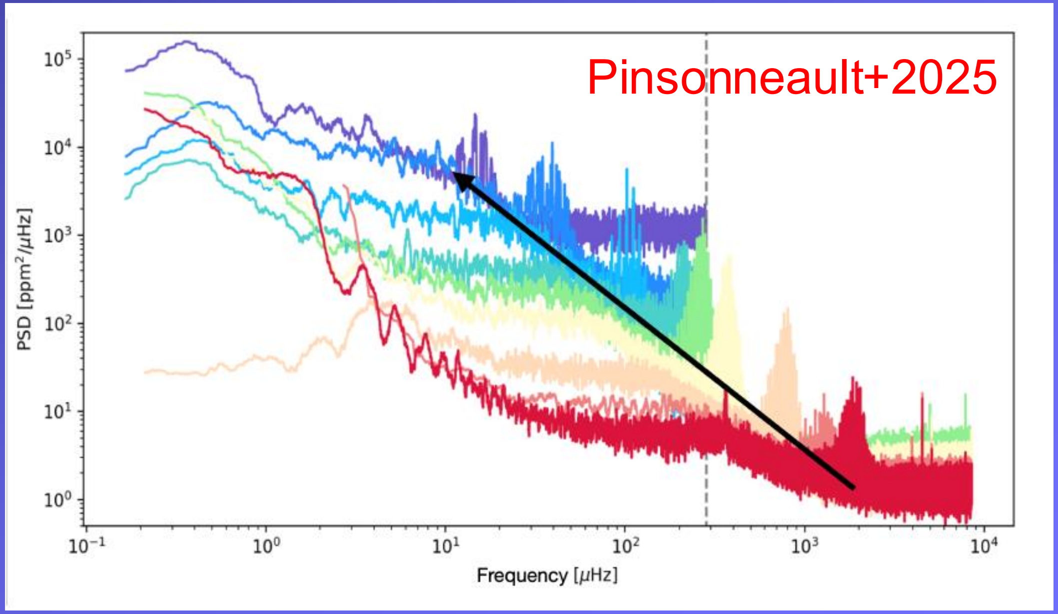


→ BRIGHTNESS VARIATIONS

Oscillation Frequencies That
Depend Sensitively on Mass and Radius!

TURBULENCE

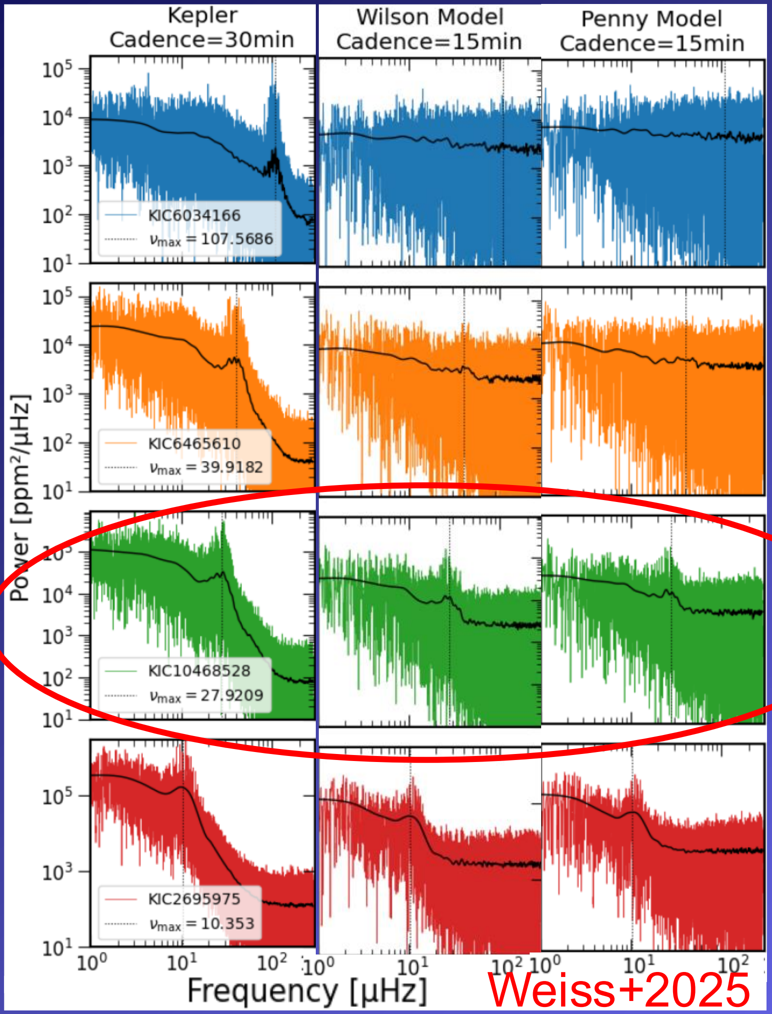




Why Do Asteroseismology With Roman?

- Red giants are luminous oscillators, and the GBTDS can detect these oscillations
- We can use asteroseismology to infer ages, important for understanding μlensing planet yields and MW galaxy formation

From Kepler to Roman



Low L,
low amplitude
high frequency

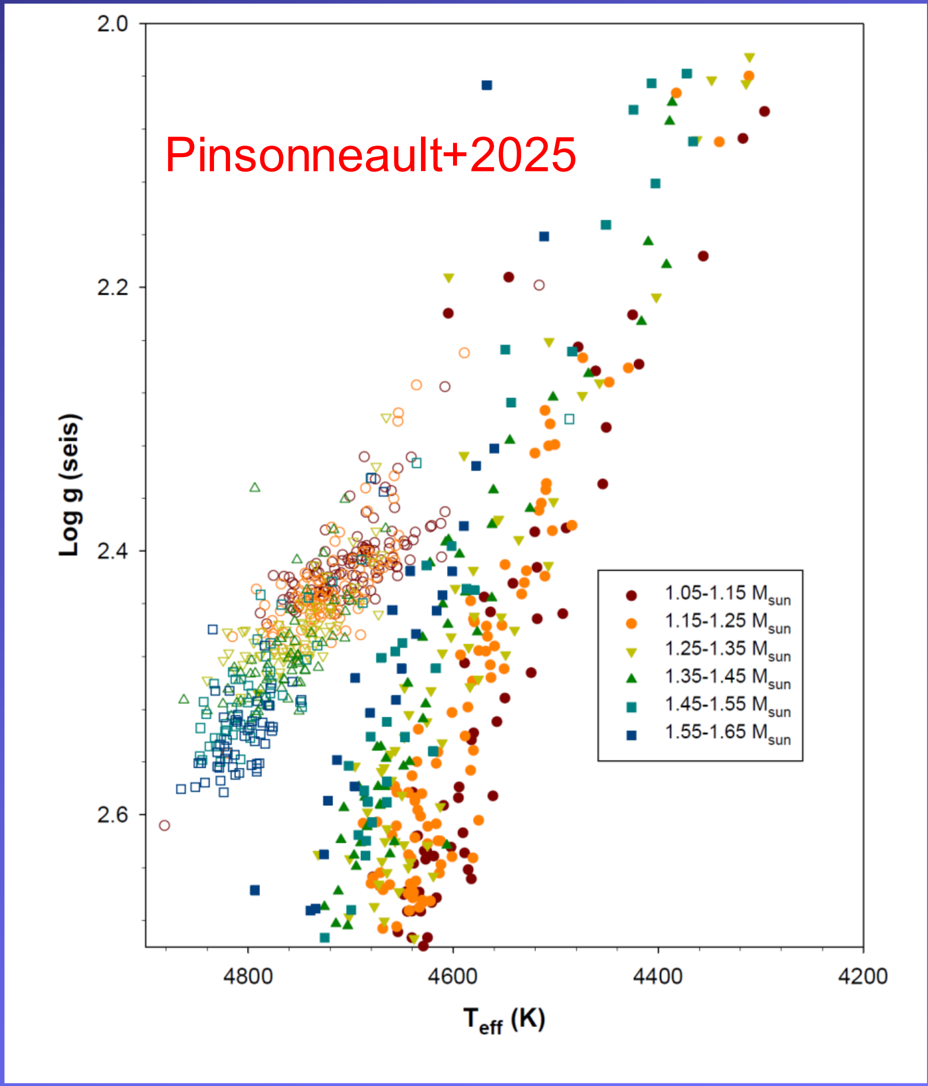
216 days of data Feb 27 – Apr 28

Our Key Target: the Red Clump

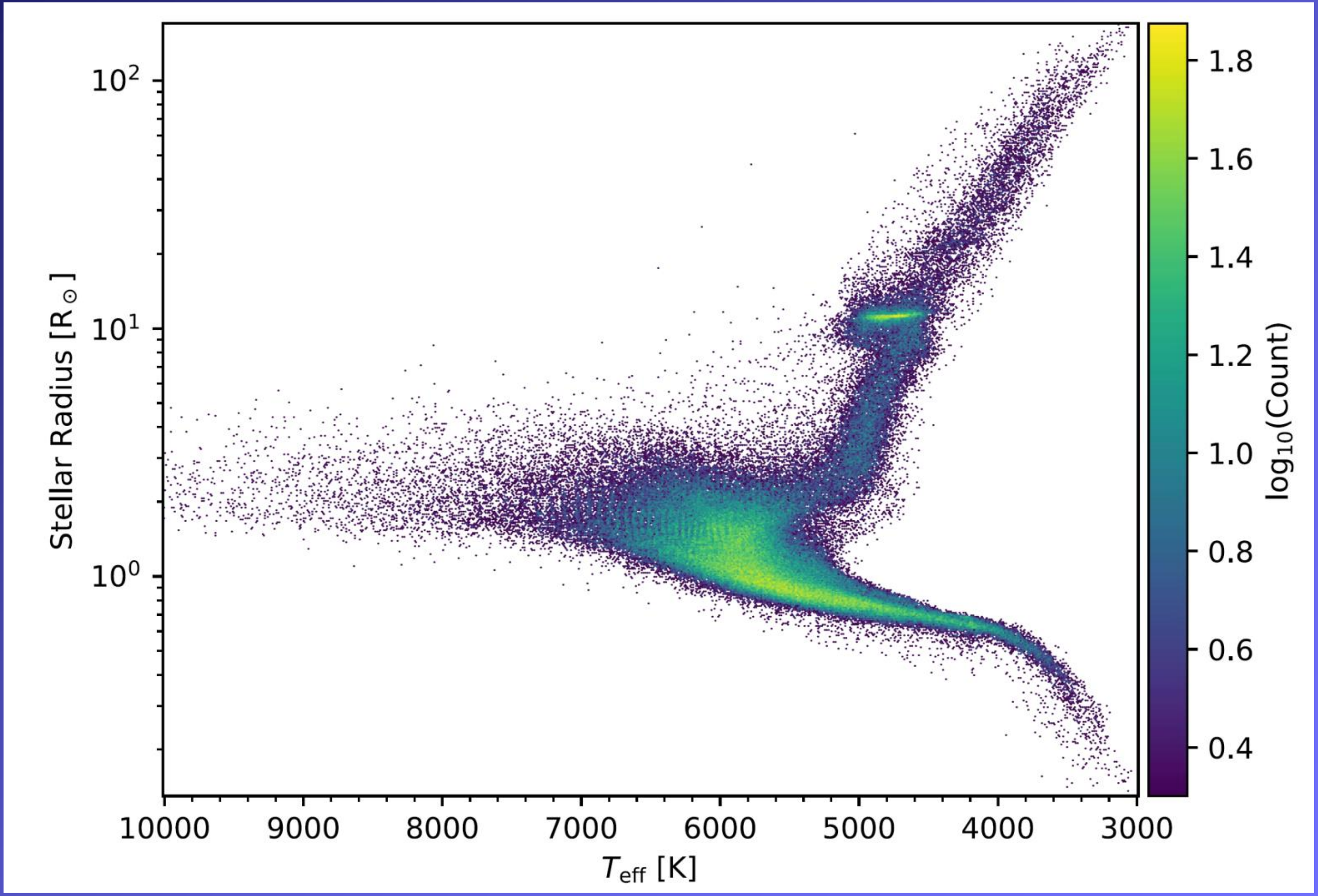
High L,
high amplitude,
low frequency

The Red Clump: A Powerful Population Diagnostic

- *With asteroseismology we can infer masses, and ages, of this common population*

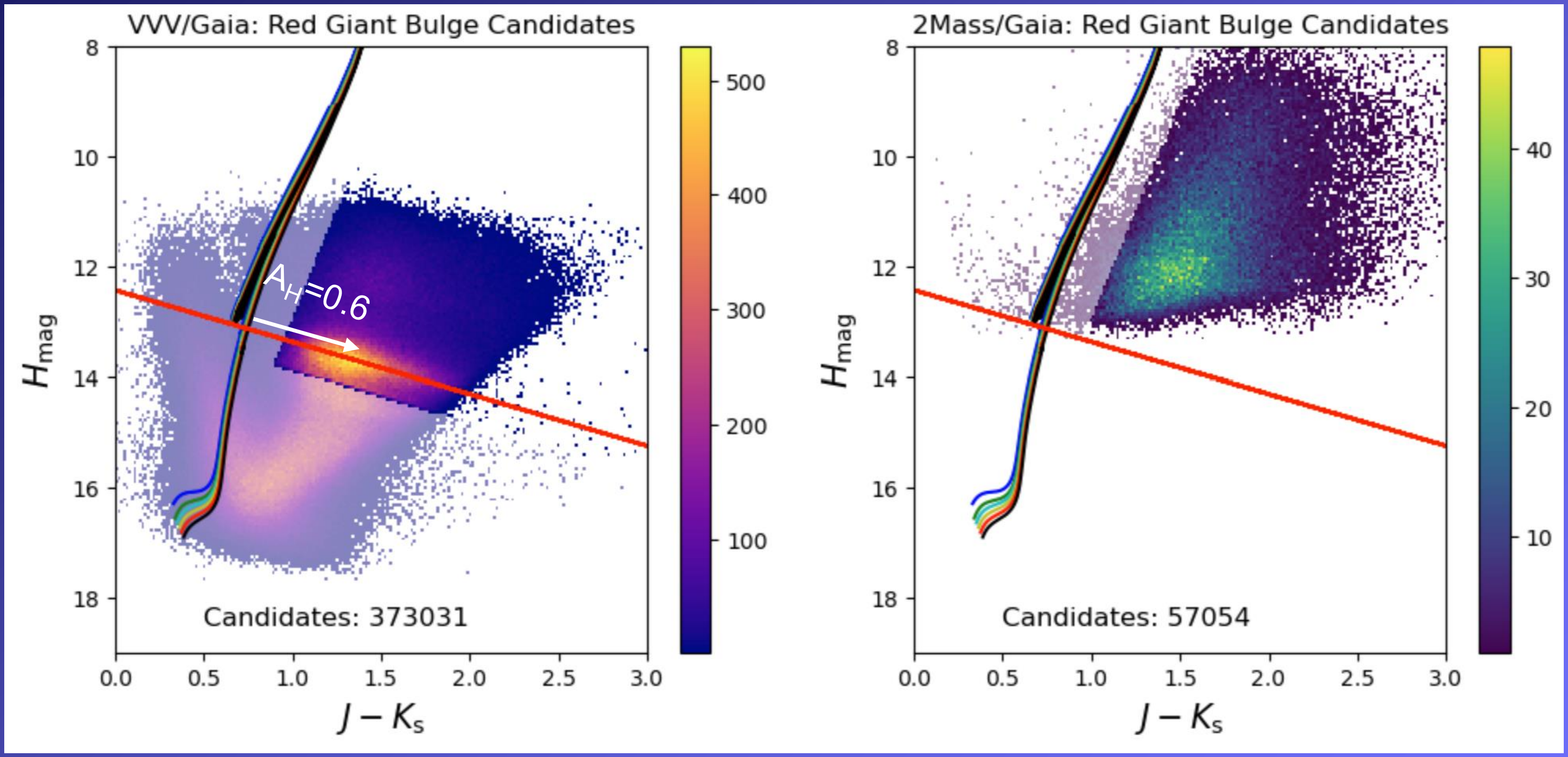


The Red Clump: Standard Candle, Standard Crayon



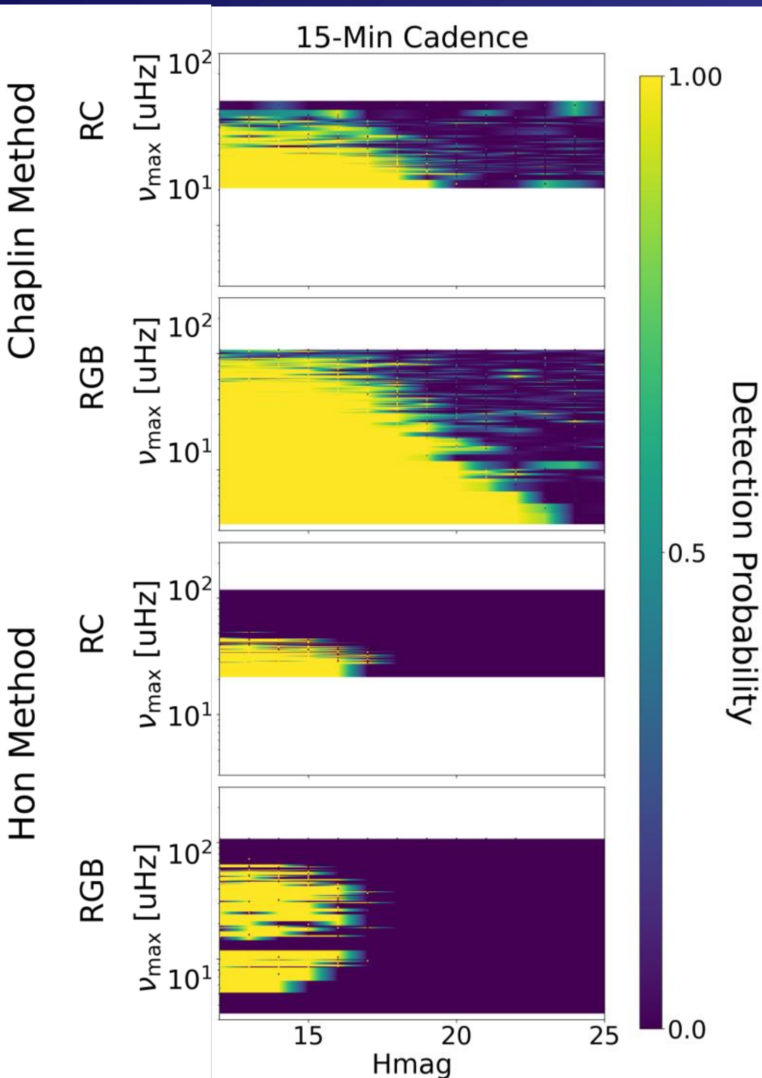
Berger+2020

An Asteroseismic Target List

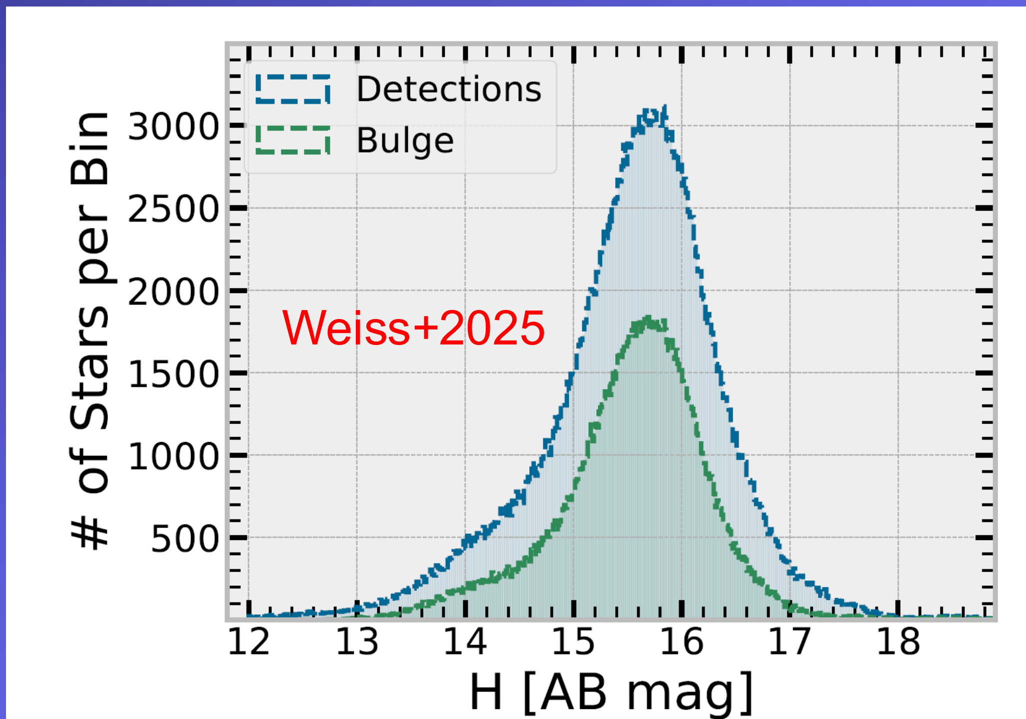


MP, Ballas, Howell (OSU)

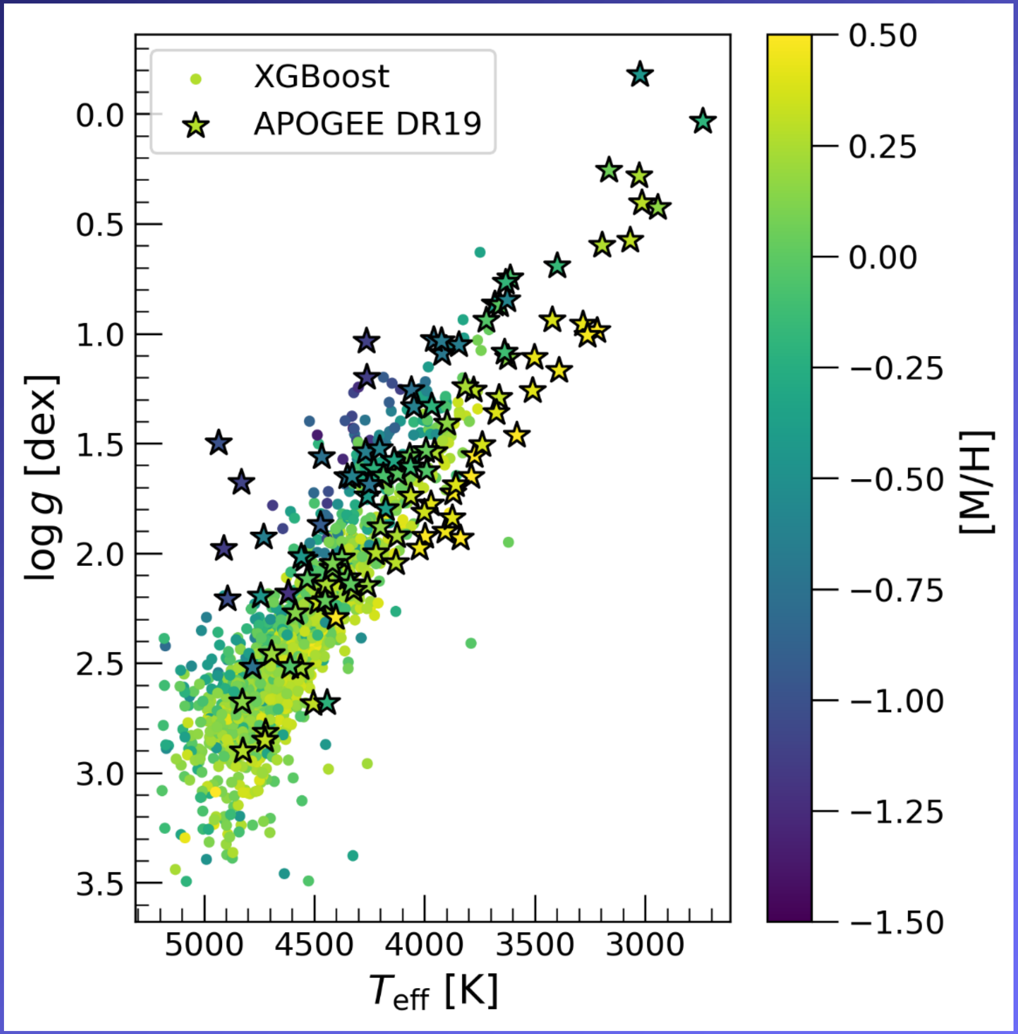
GBTDS, stars with reliable parallaxes removed



Predictions:
290,000 detections
185,000 in Bulge



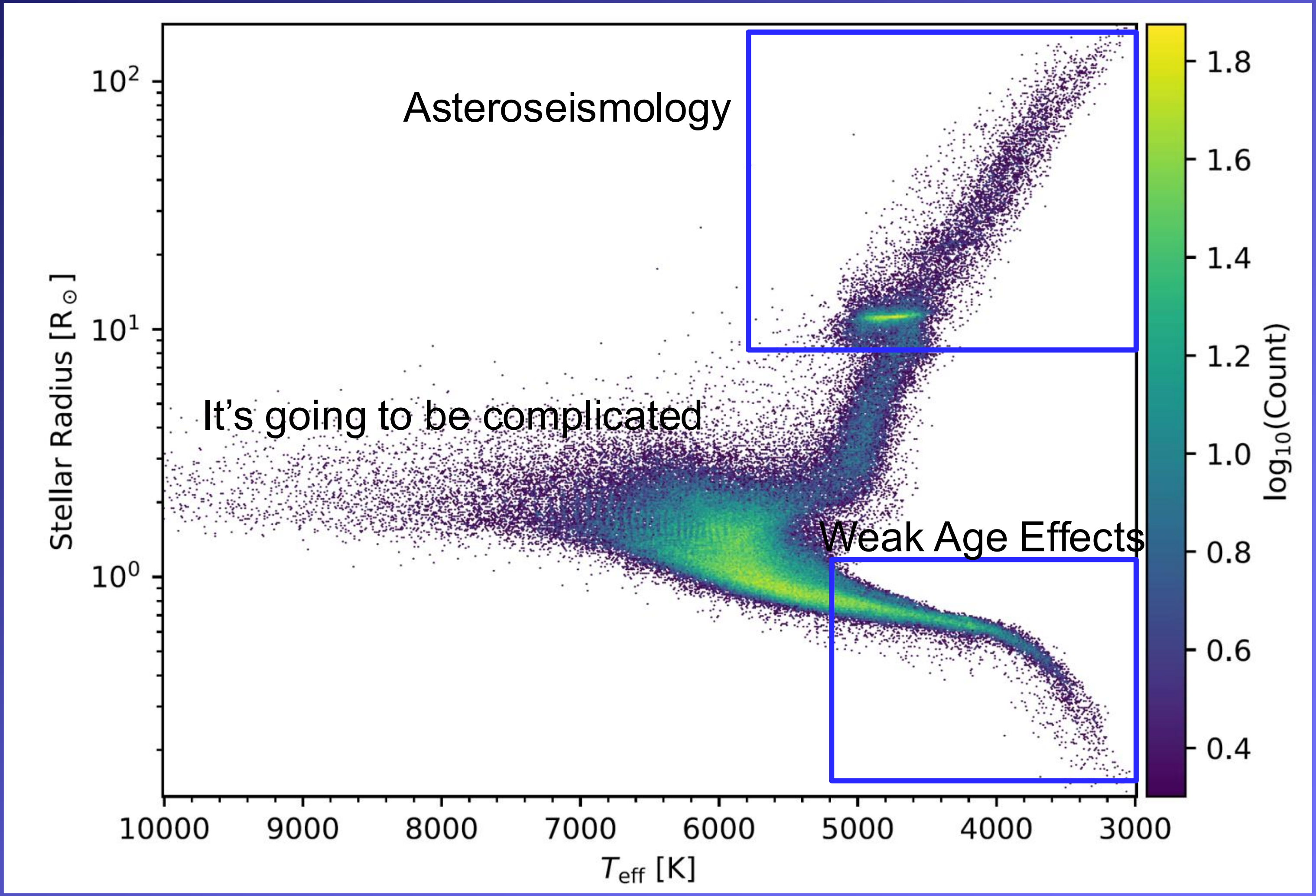
A potential training set



MP, Howell (OSU)

GBTDS, overlap with low and high-res spectra

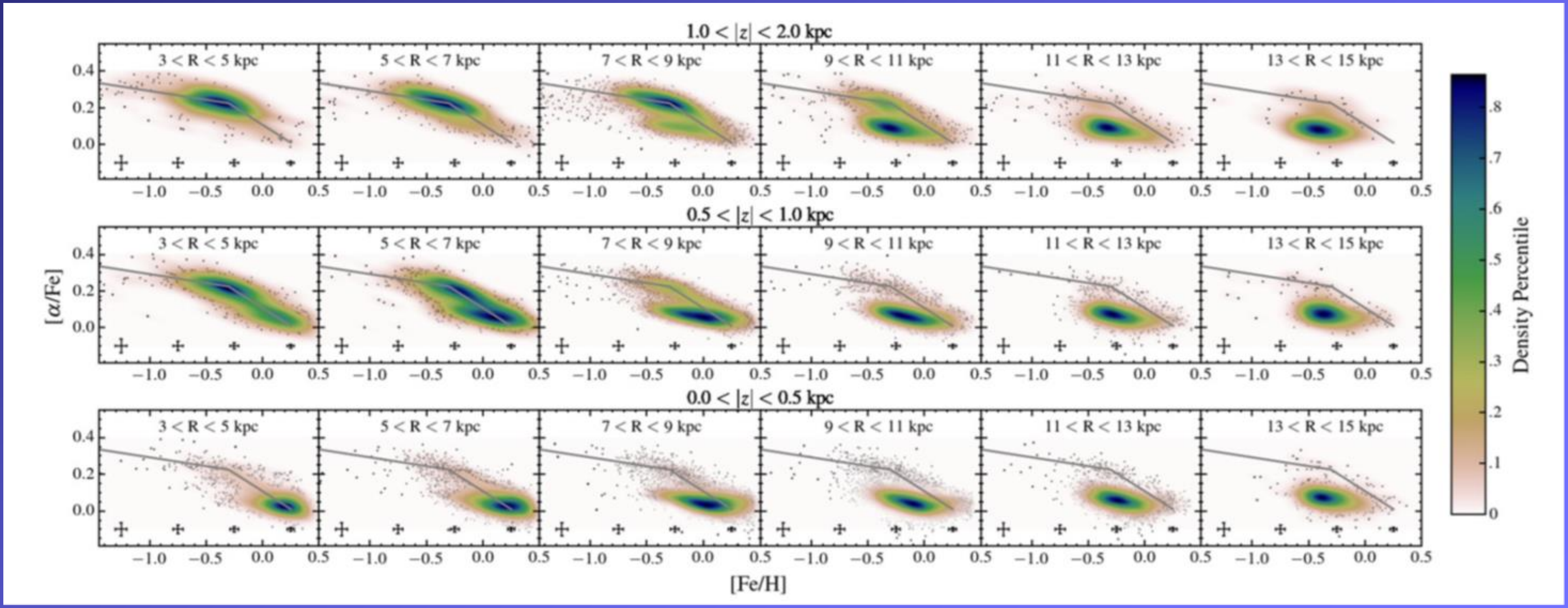
Different Domains, Different Prospects



Berger+2020

The Mixture Challenge

- Potential Problem: The mix of heavy elements and the mean populations could be very different from the solar neighborhood
- This will be very hard to test without deep high-res spectra; the giants will be our first clue



The Good News: We Will Have a Lot of Tools

HST!

LSST

Roman Photometry!

Roman Spectra?

Gaia

2MASS/ VVV

Roman Astrometry?