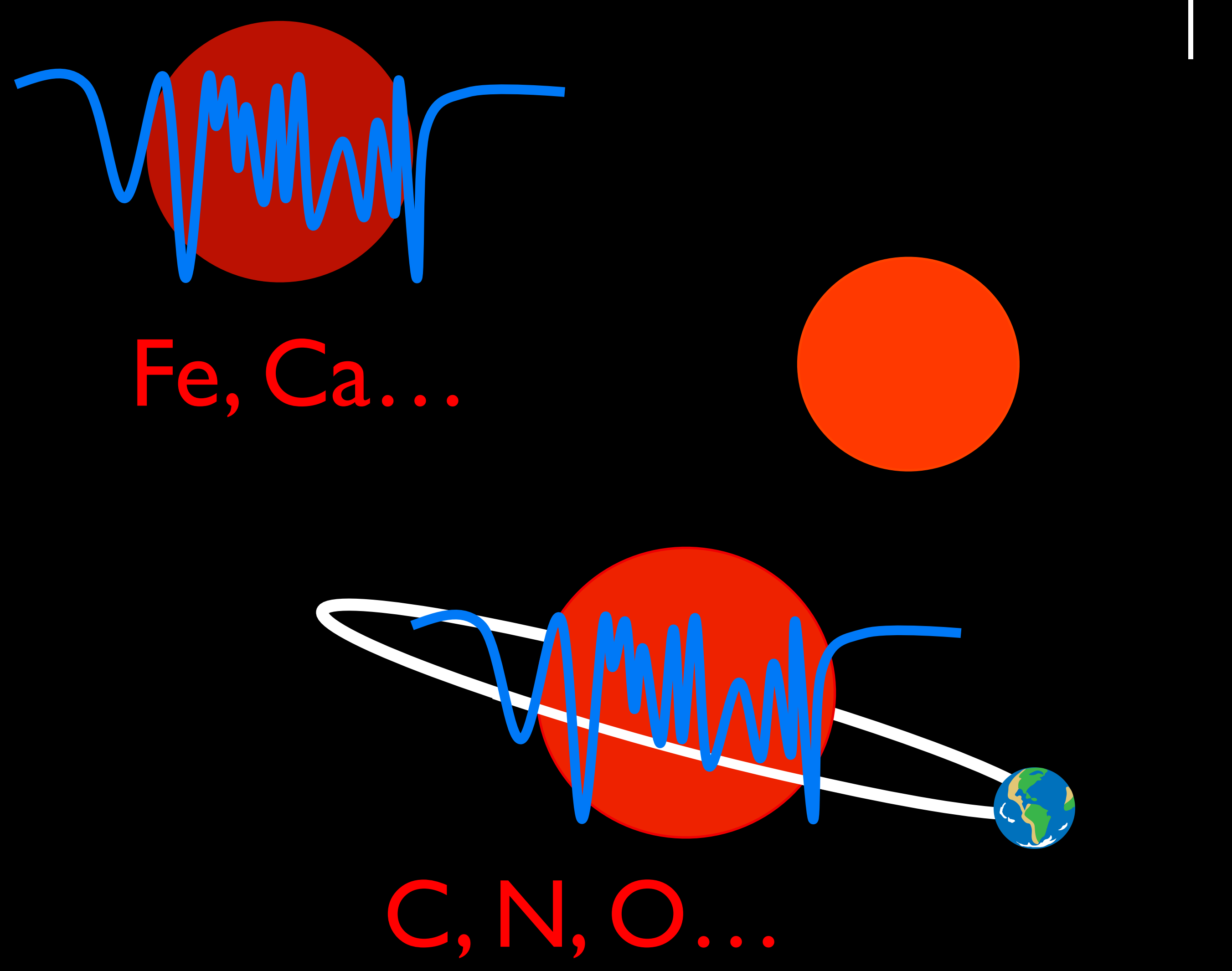
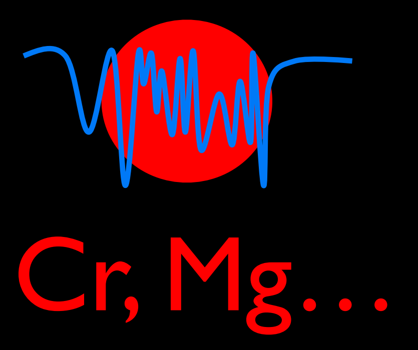
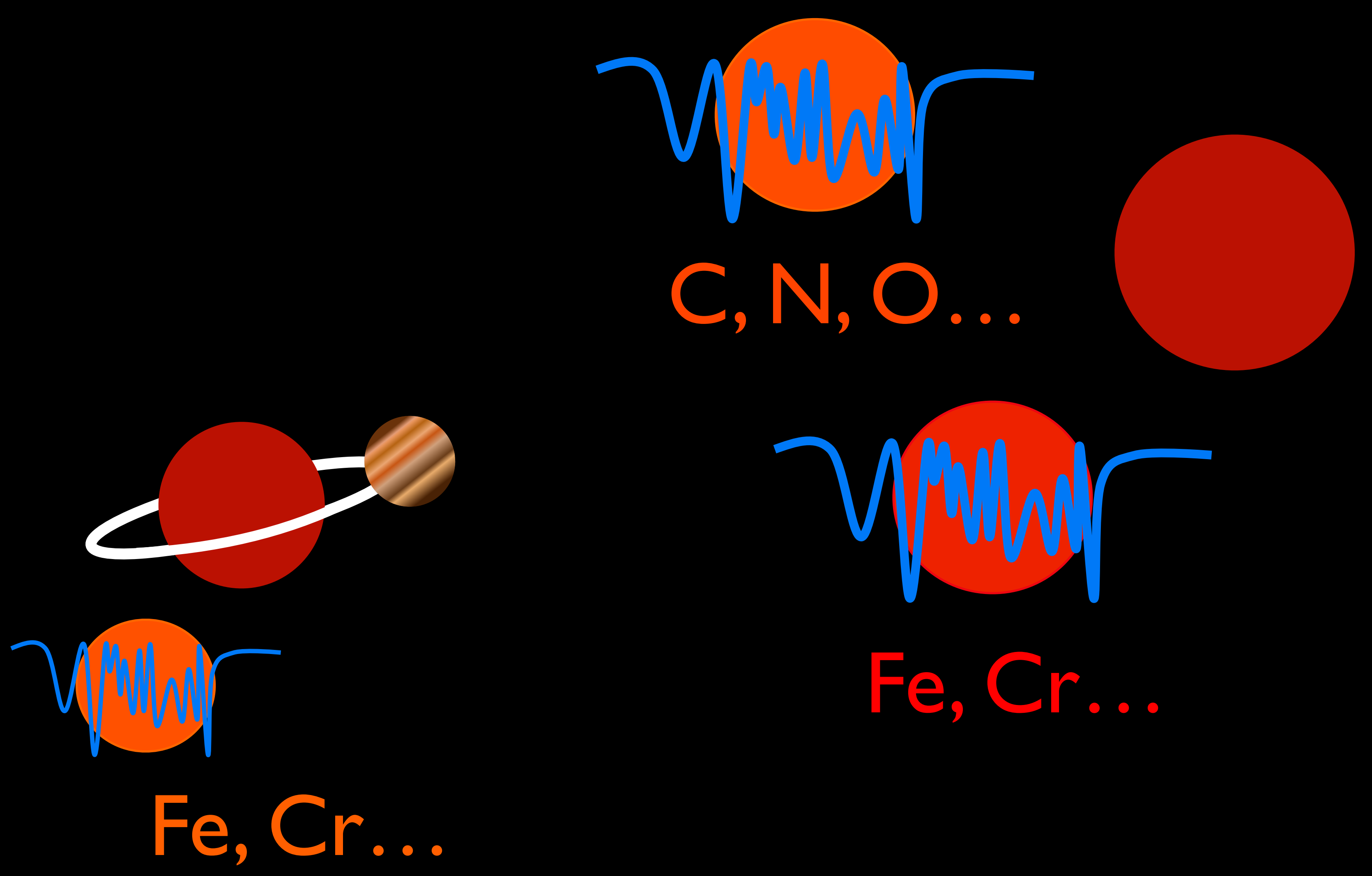
Many Elemental Abundances for ~17,000 ***M Dwarfs*** *in SDSS-V*

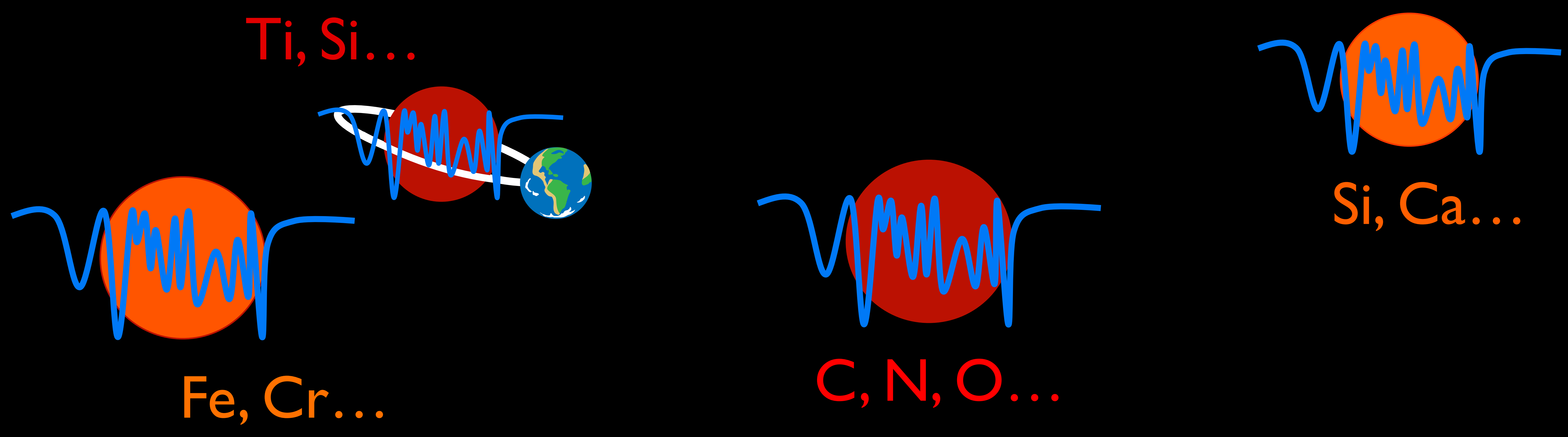


Aida Behmard*

+ Melissa Ness, Andy Casey, Ruth Angus, Katia Cunha, Diogo Souto, Lucy Lu







* = Center for Computational Astrophysics, Flatiron Institute

*M dwarfs are **very** important (for planets!)*

Most common stars:
~70% of Solar neighborhood

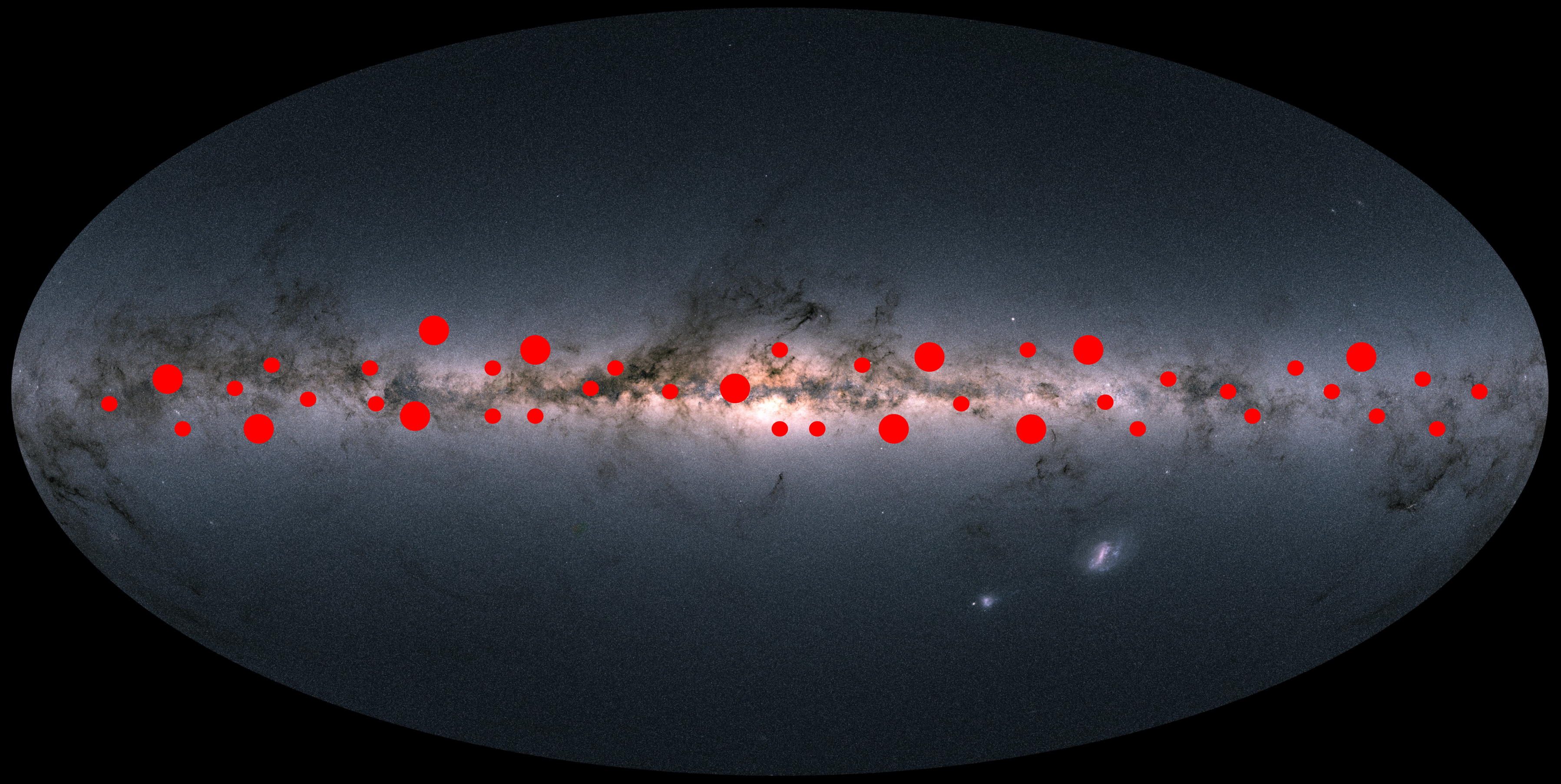
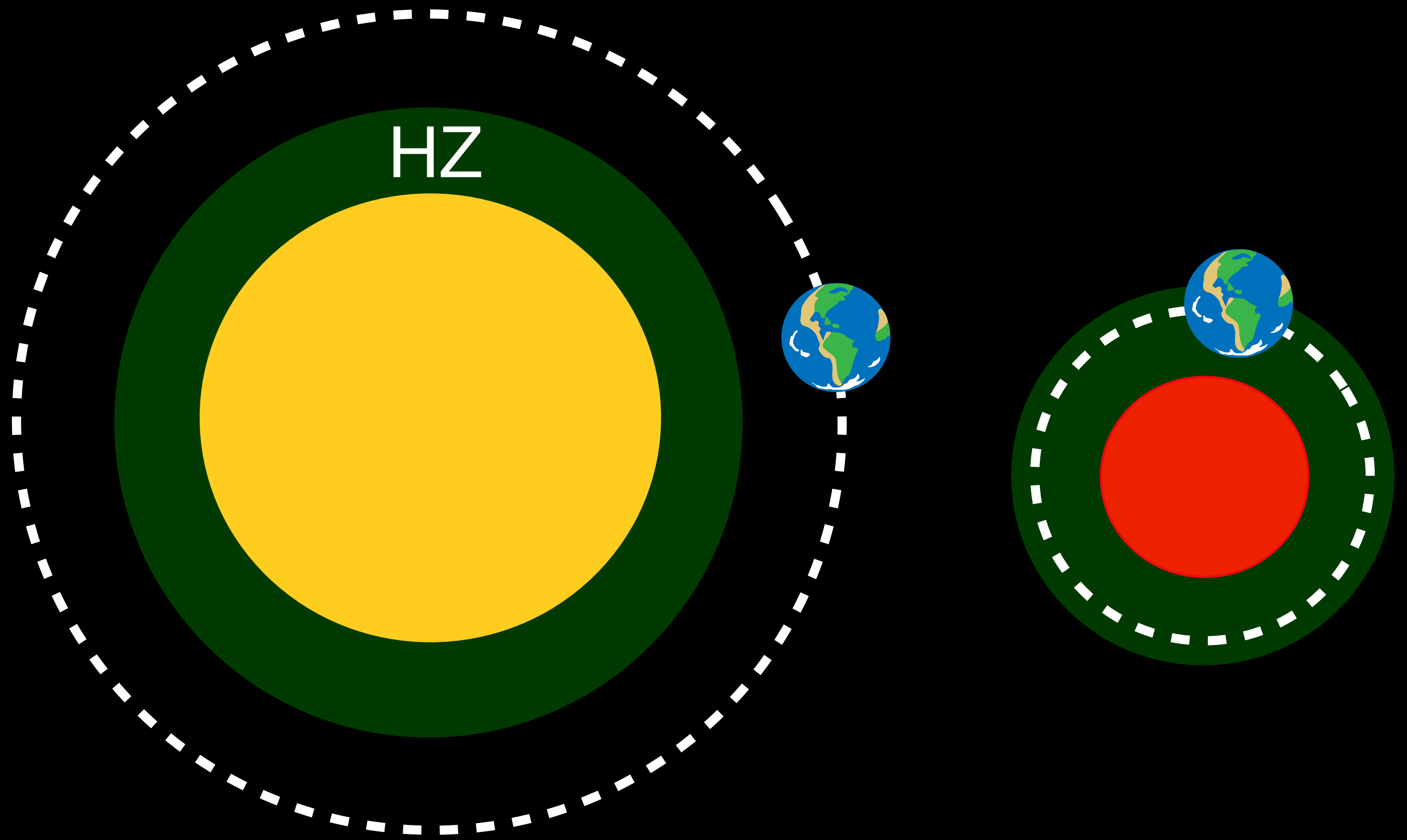


Image Credit: ESA/Gaia/DPAC

Best for detecting and characterizing (Earth-like) planets

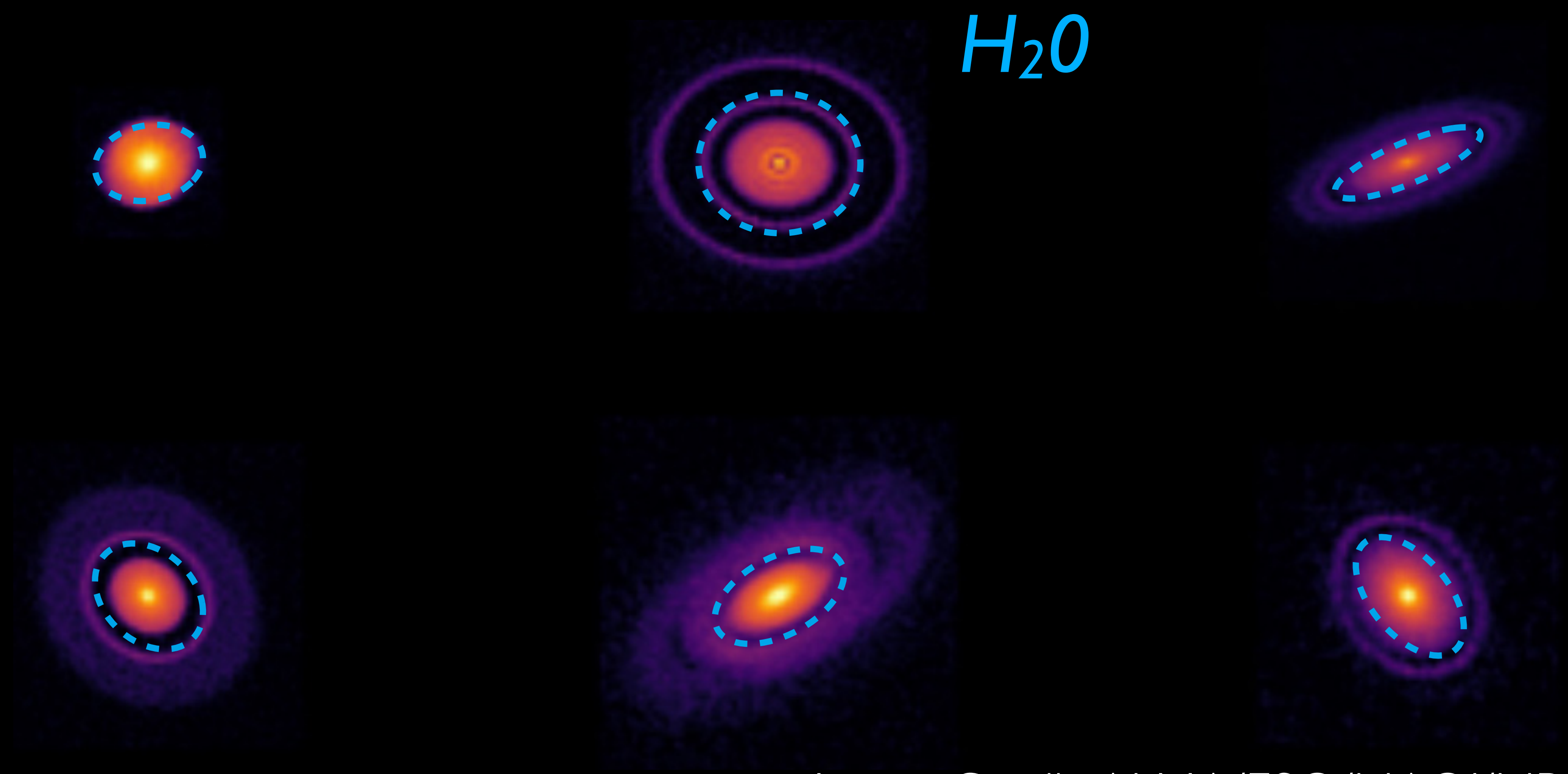


…popular TESS targets,
~100 M dwarfs in JWST (Cycles 1-3)

To characterize planets, it's important to measure M dwarf chemistry!

planet bulk densities to compositions

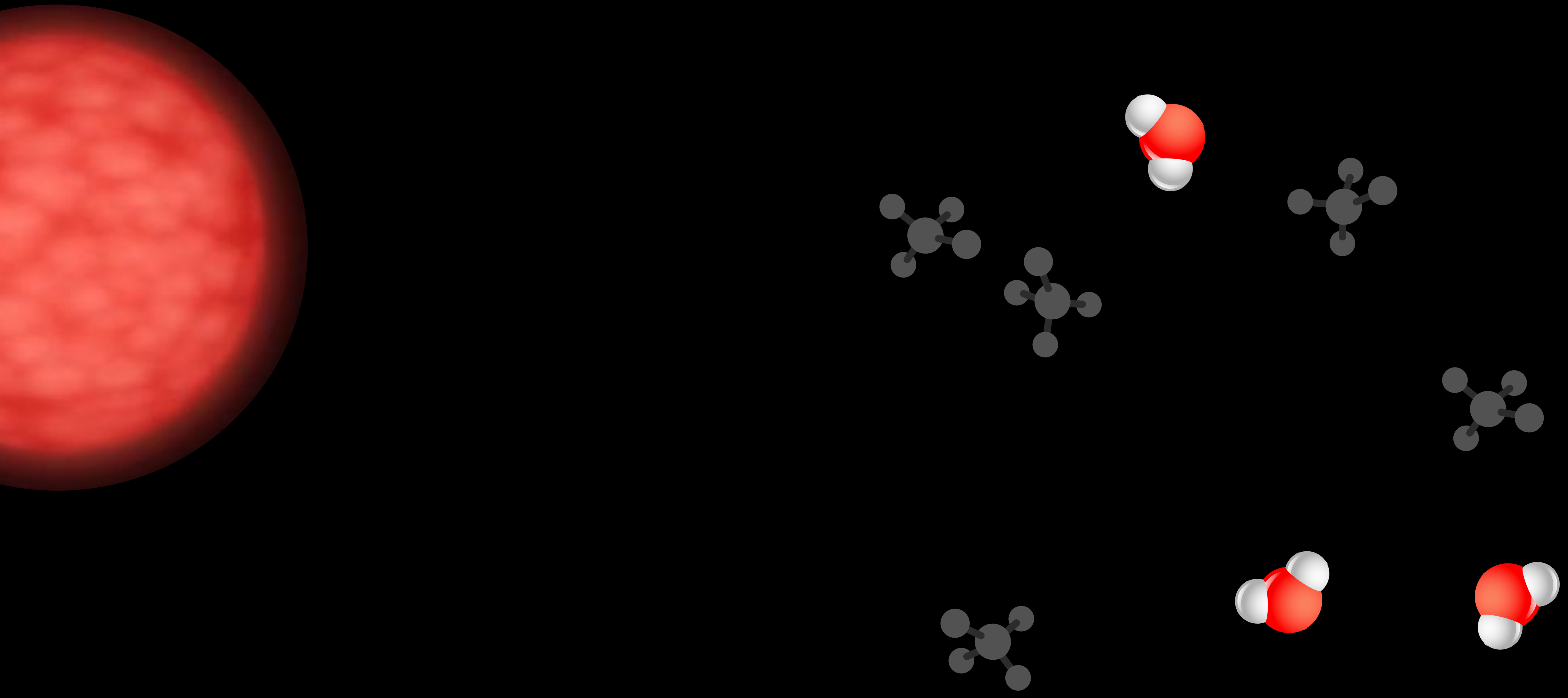
TRAPPIST-1: Si, Fe, Mg…



Planetary atmosphere compositions (e.g., C/O) to formation pathways

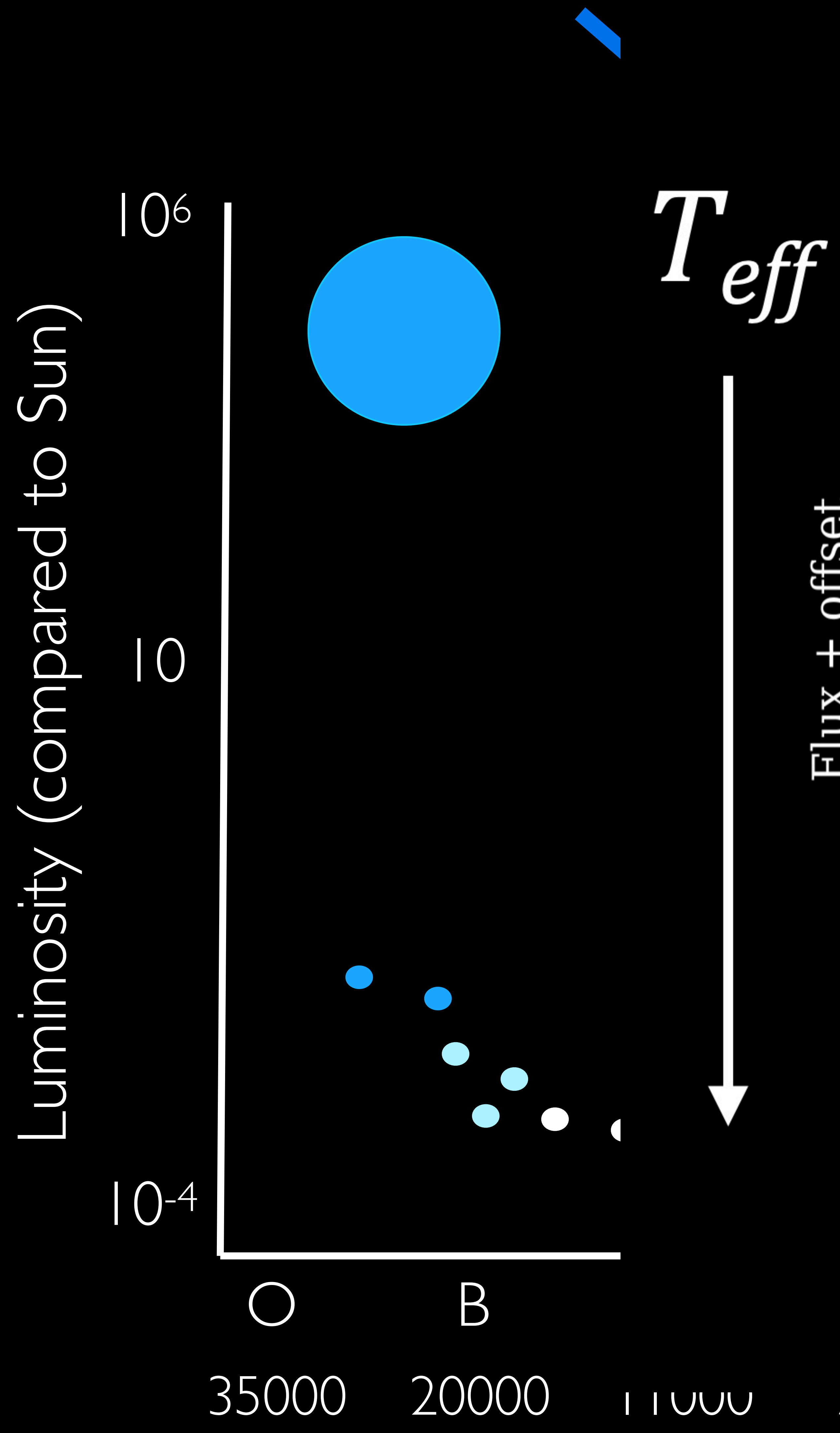
Image Credit: ALMA/ESO/NAOJ/NRAO/S. Andrews et al./AUI/ NSF/S. Dagnello

M dwarfs have lots of molecules…

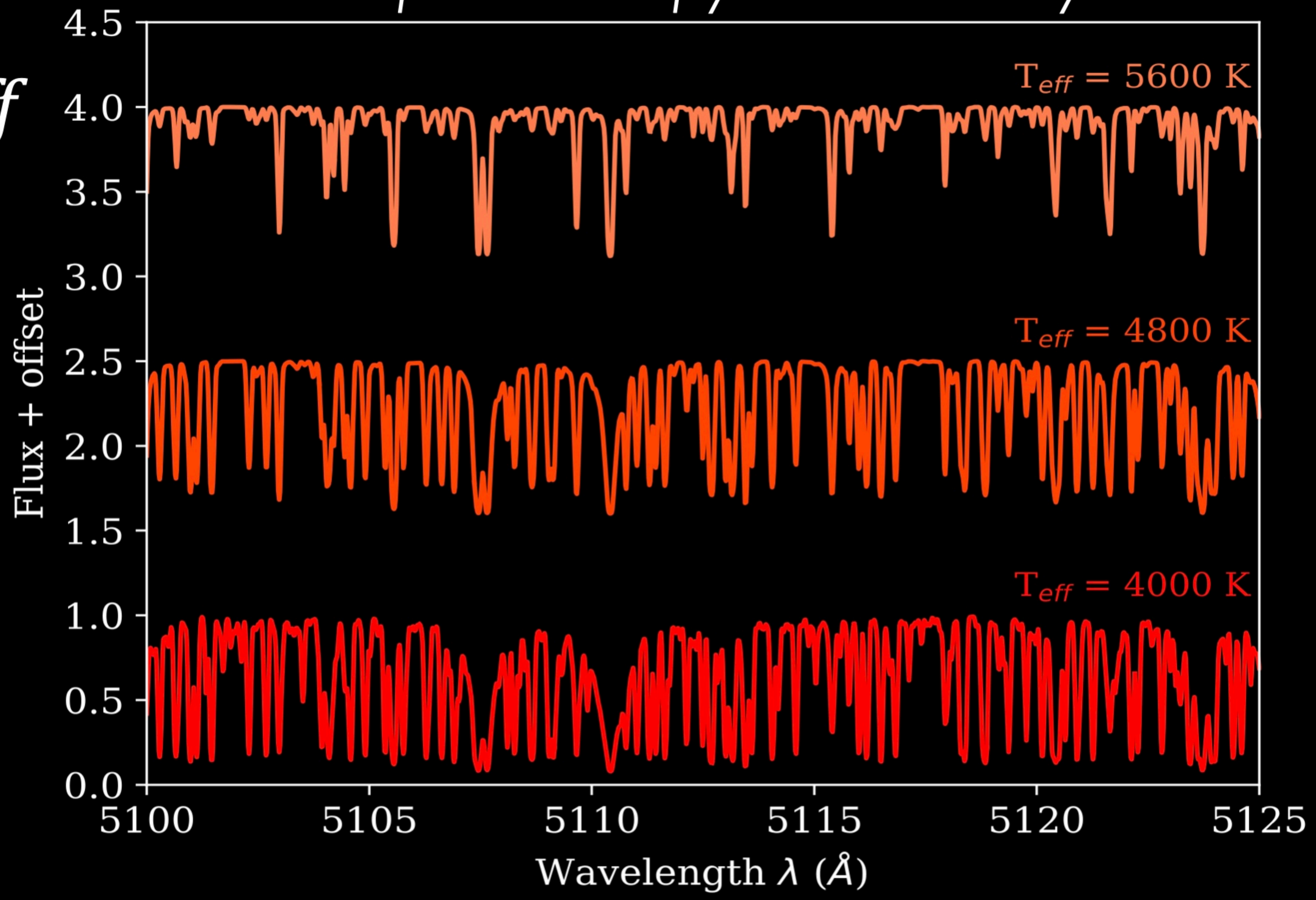


Molecules make it hard to measure M dwarf chemistry

Solar-like stars



Spectroscopy Made Easy Code

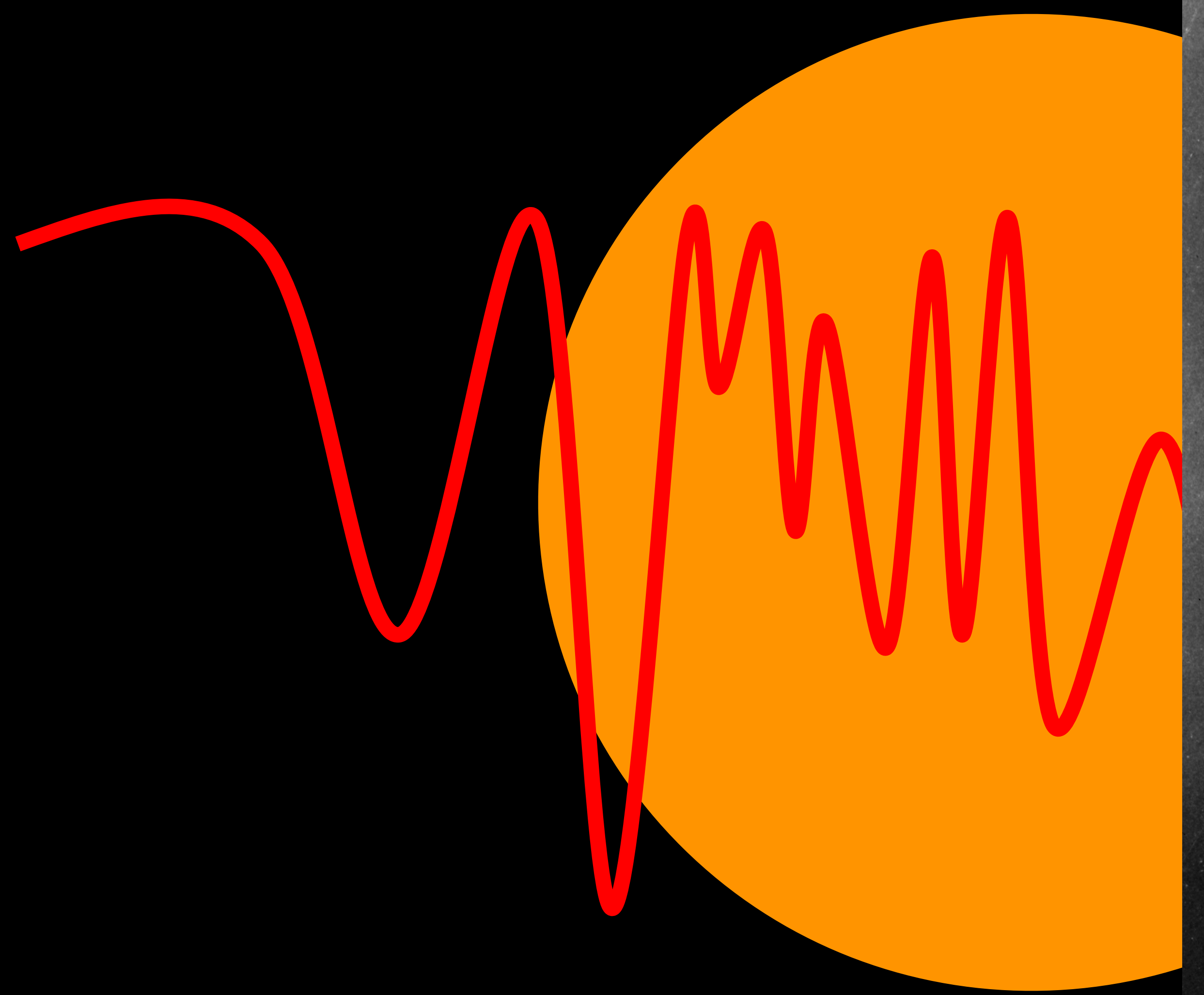


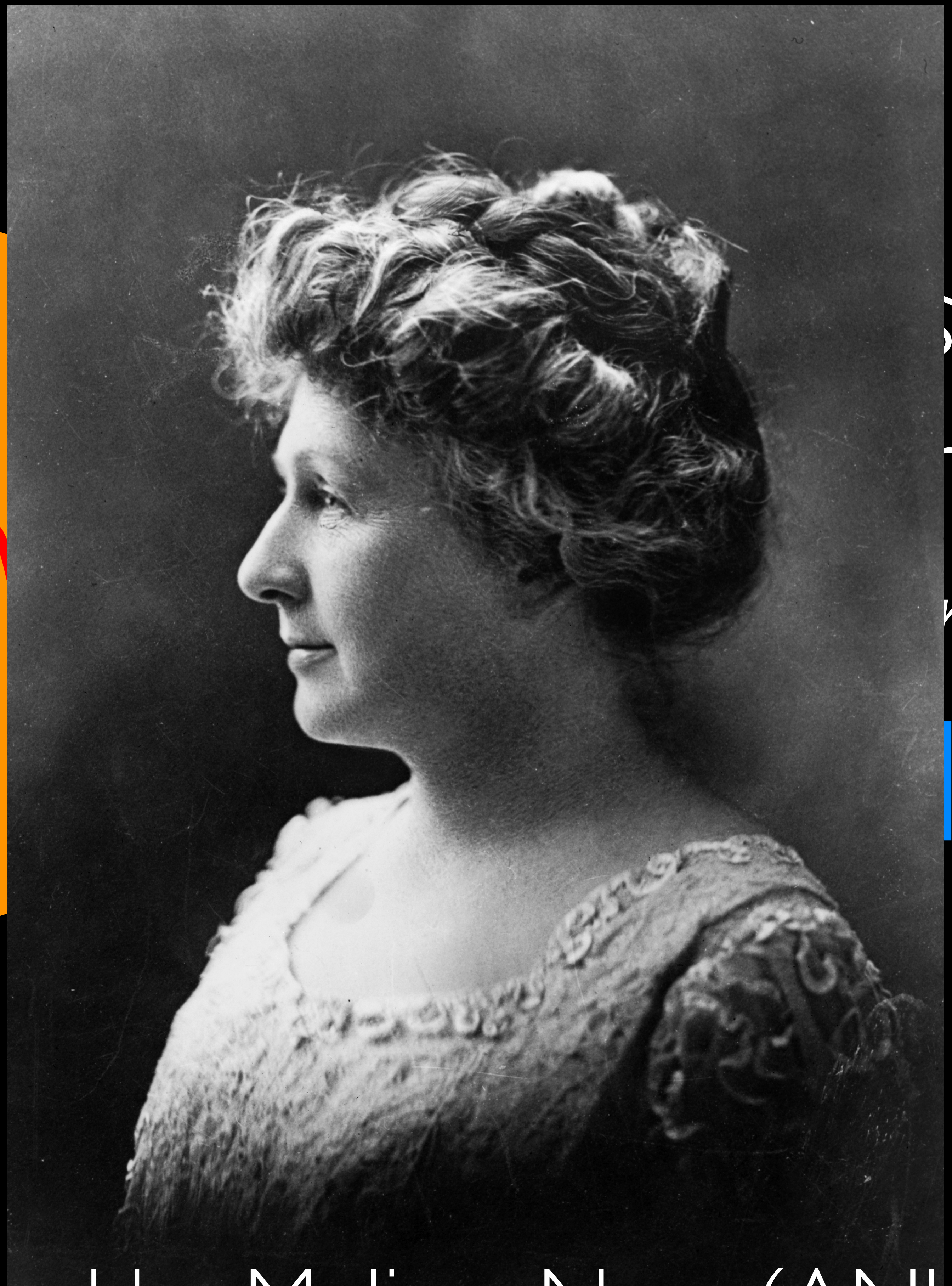
Behmard et al. (2019)

rfs are

The Cannon

Data-driven approach for inferring stellar "labels" from spectra—does not use physical stellar models!





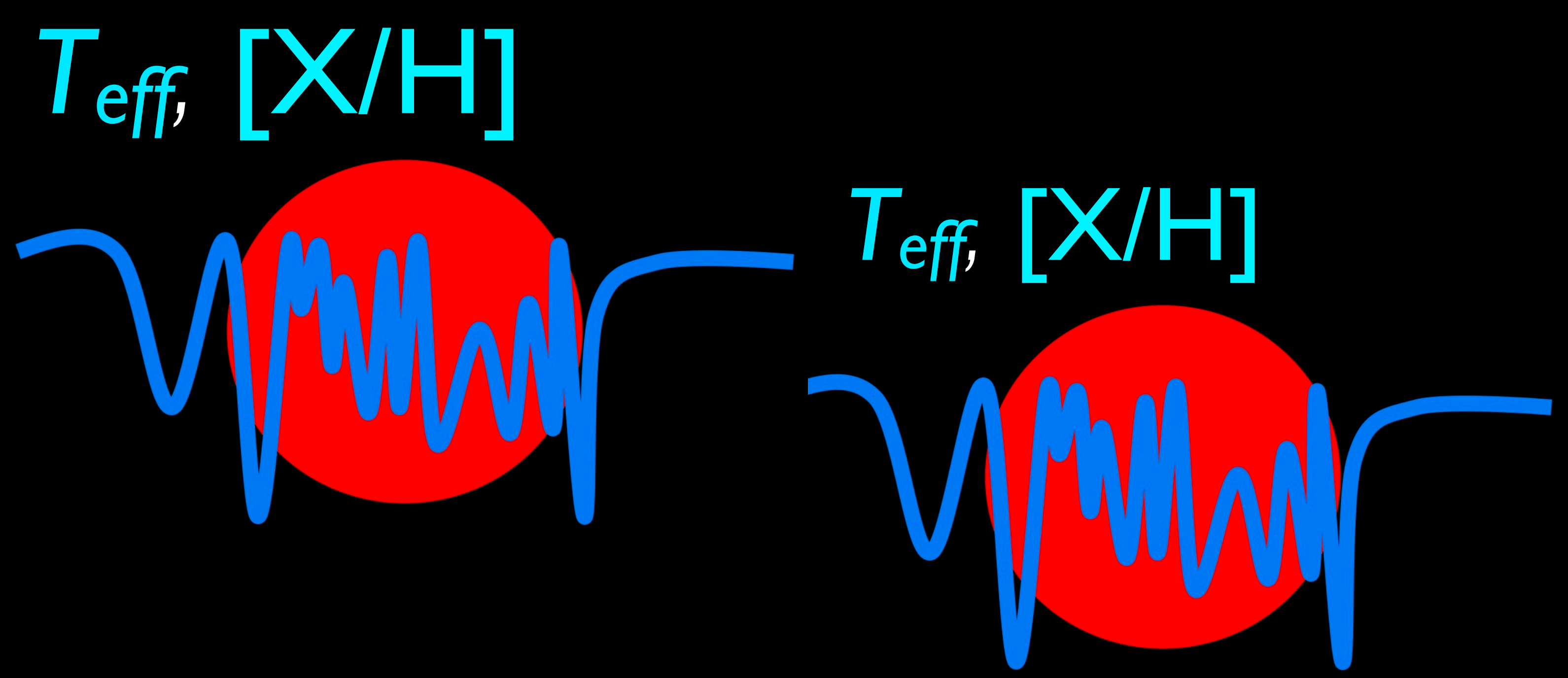
s can be physical
*neters (e.g., T_{eff}, **logg**),*
r chemical abundances

The Cannon was developed by Melissa Ness (ANU), Andy Casey (Monash U.)

The Cannon

Works via a 2-step process:

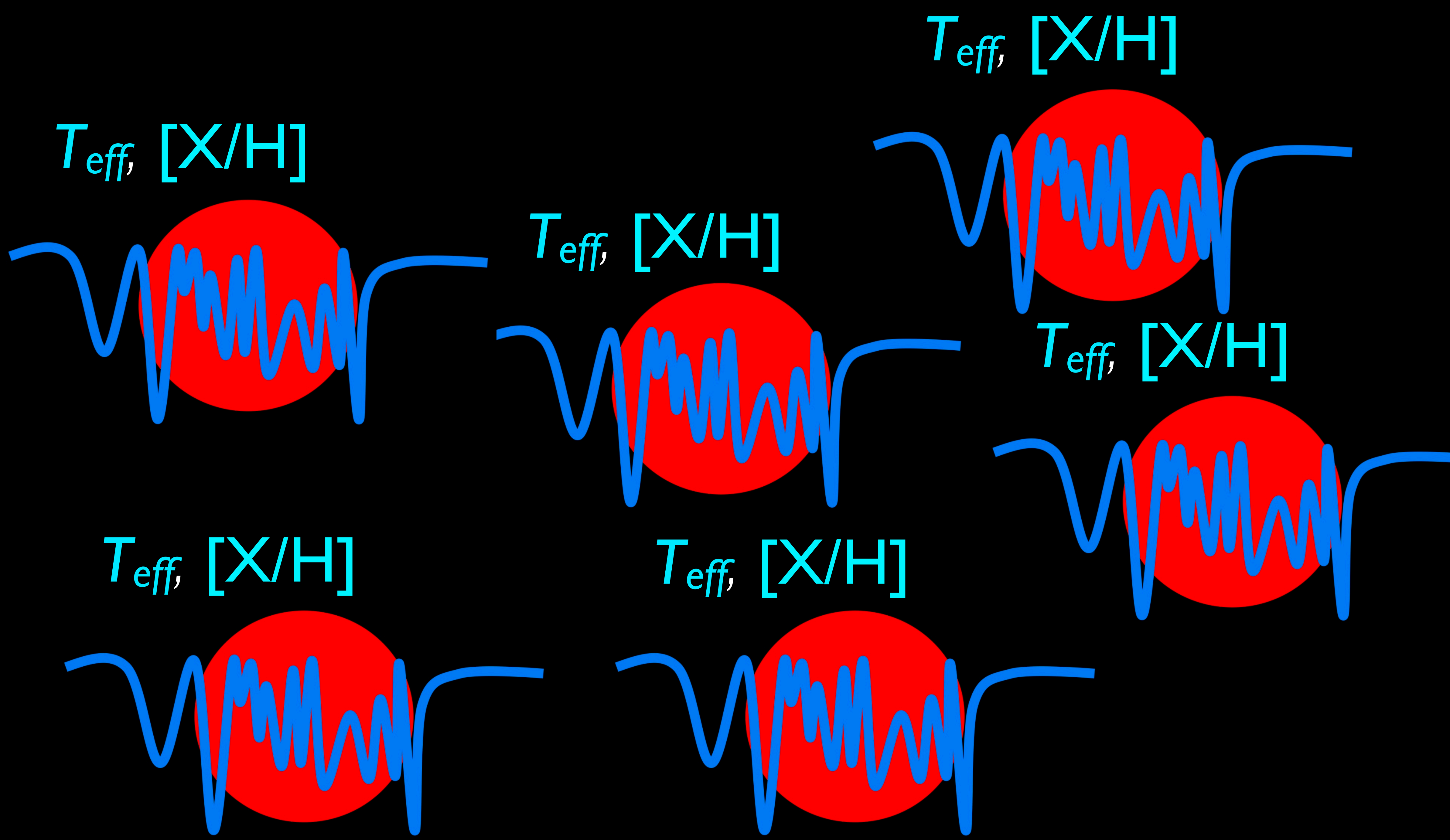
"Training Step"



Use training set spectra and labels to construct flux models

"Test Step"

Apply flux models to test set spectra—derive test labels

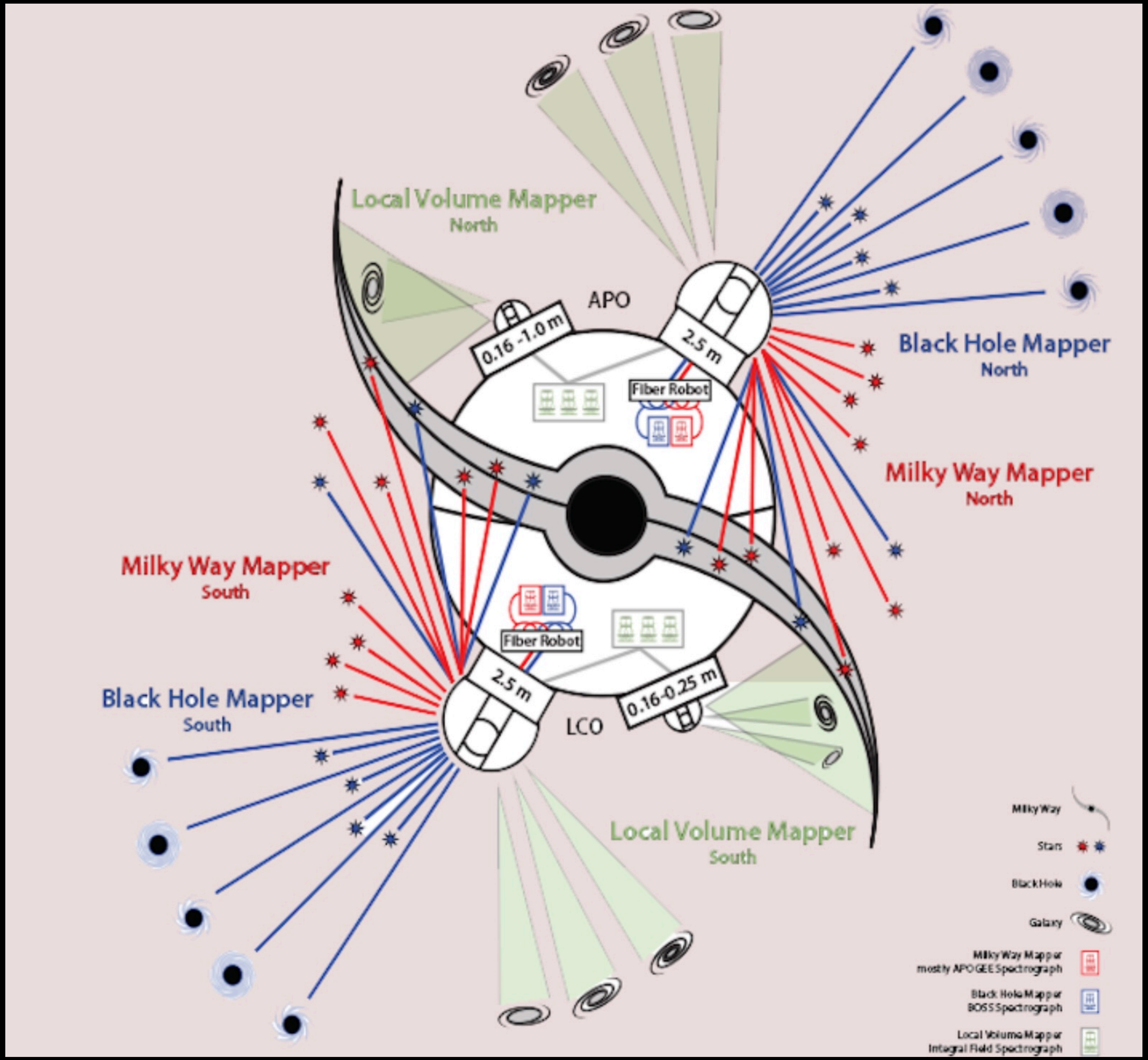


Sloan Digital Sky Survey (SDSS-V)

3 sub-surveys: BHM, LVM, MWM

We use Milky Way Mapper (MWM):
H-band, R ~22,500

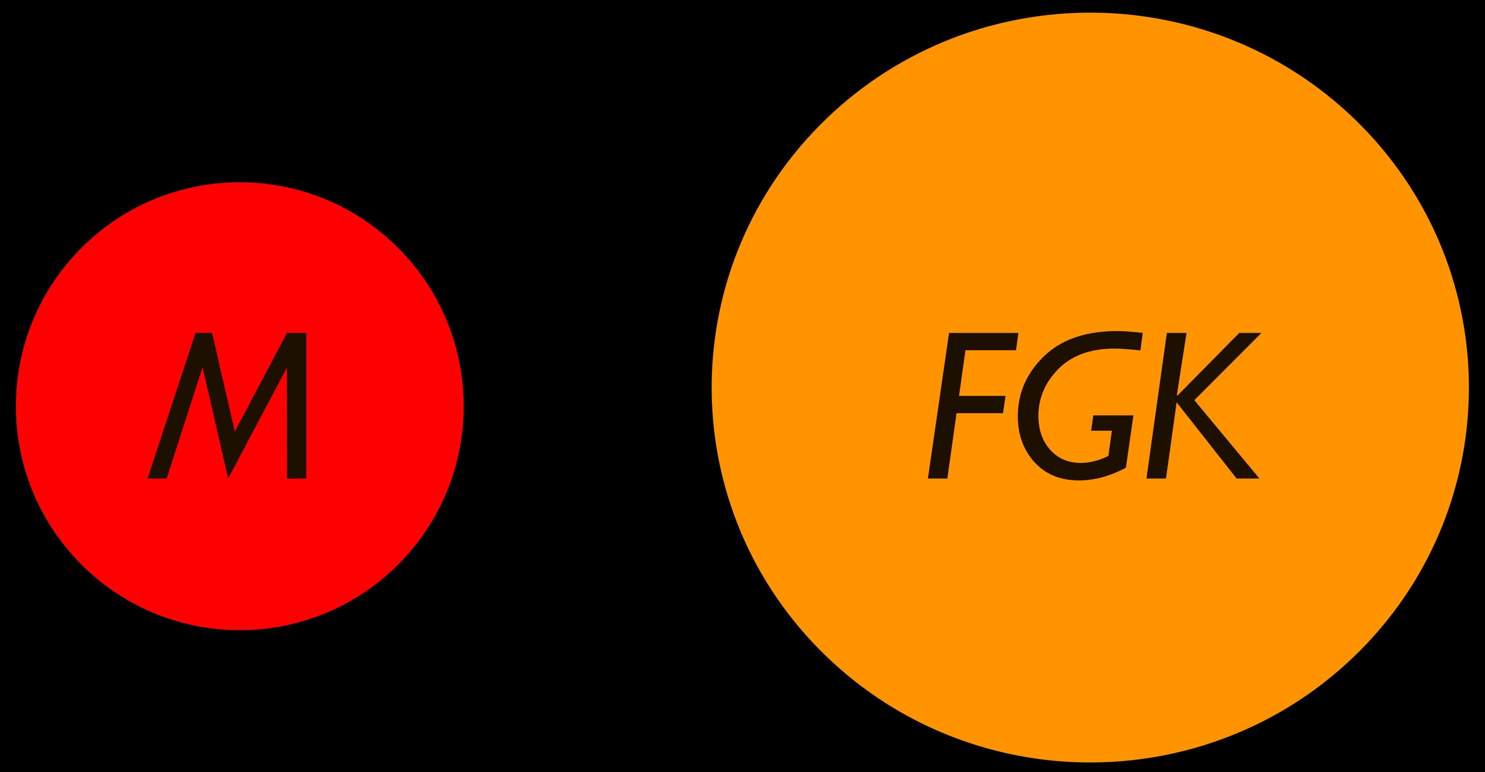
SDSS abundance pipeline (ASPCAP)
relies on stellar models:
only good >4500 K



Training set: FGK-M binaries in SDSS-V

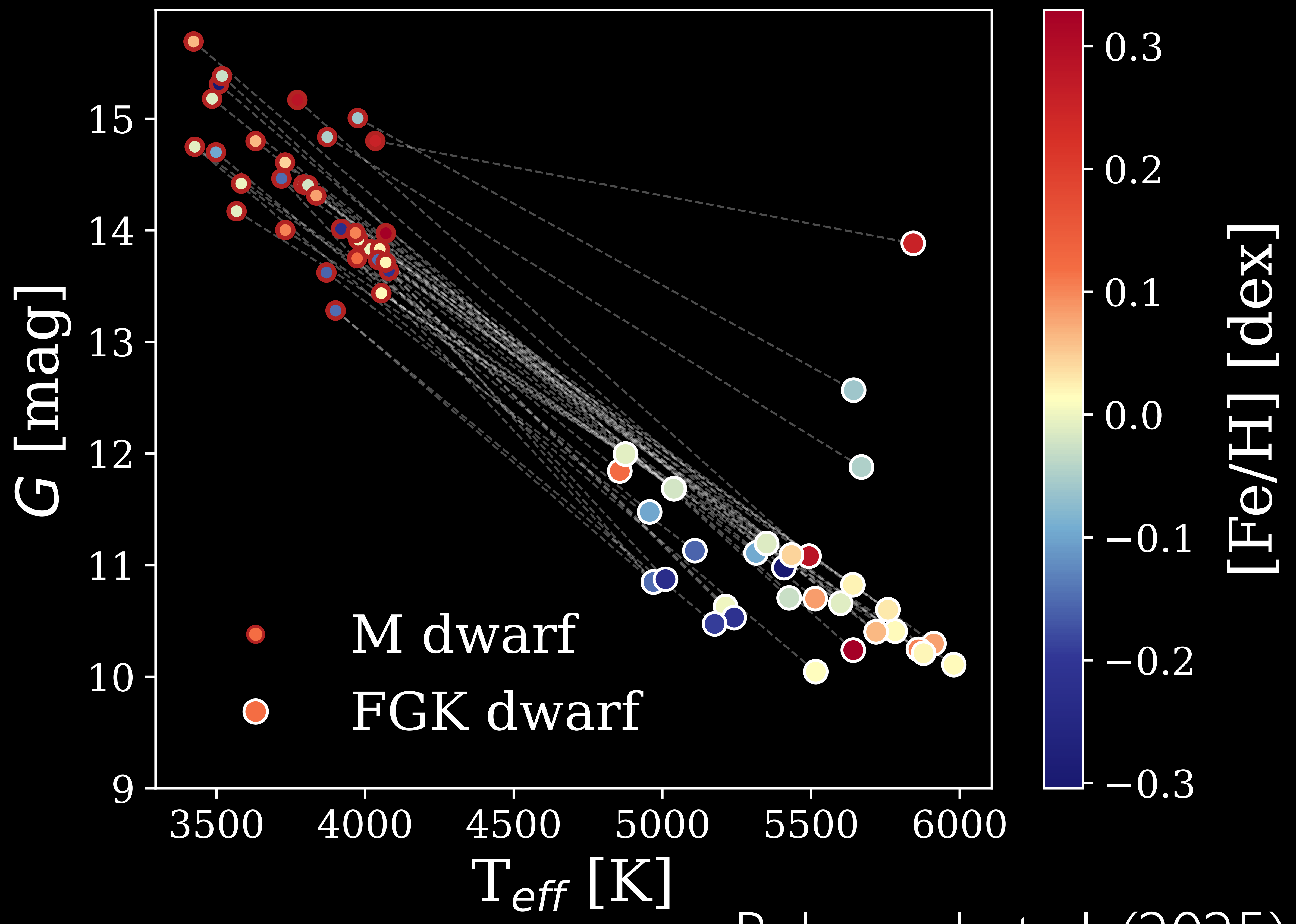
ASPCAP is reliable for solar-like stars

binary companions:
chemically homogeneous



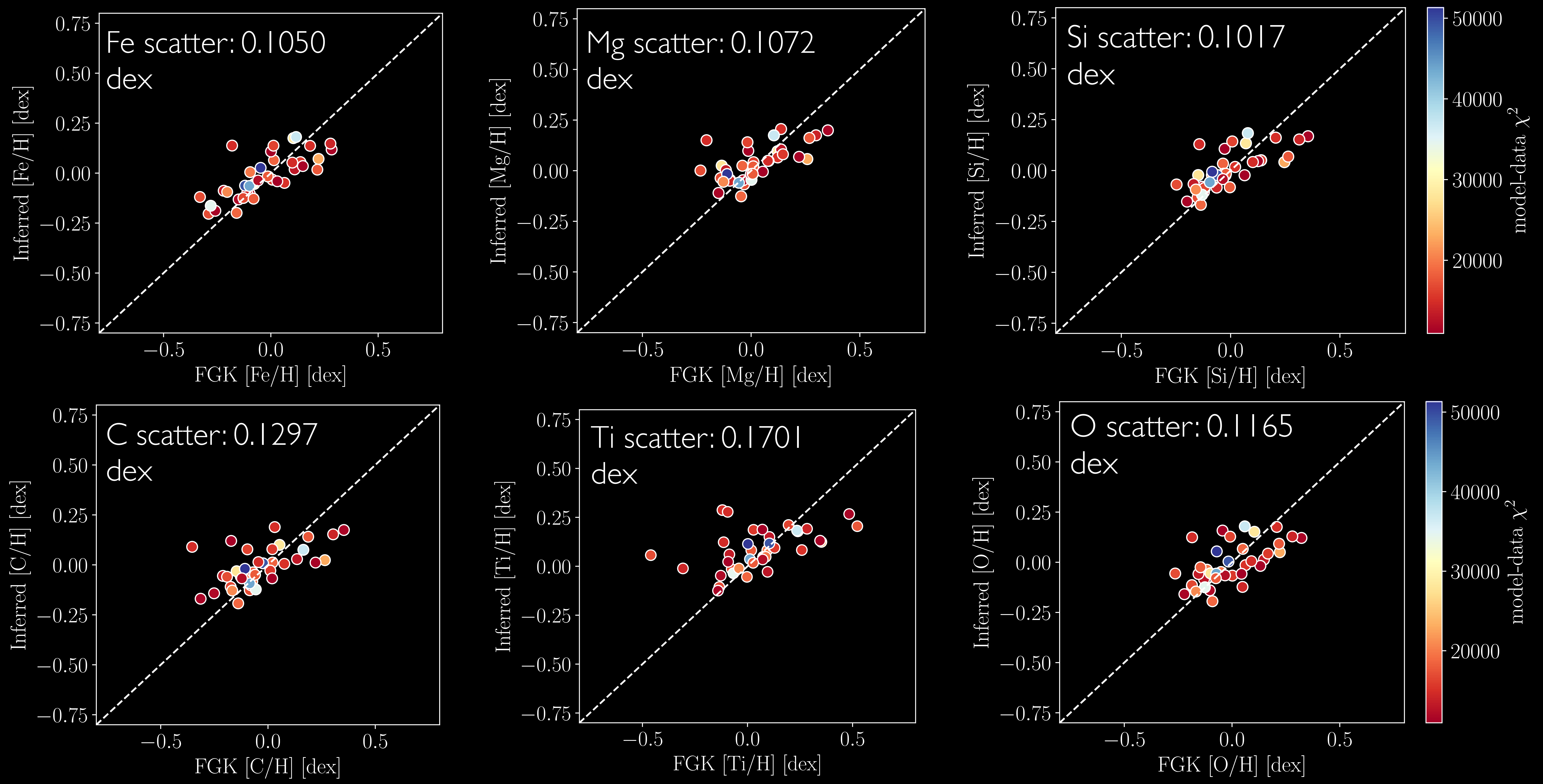
Fe, C, N, O… = *Fe, C, N, O…*

~80 pairs FGK-M pairs



Behmard et al. (2025)

Leave-one-out cross-validation

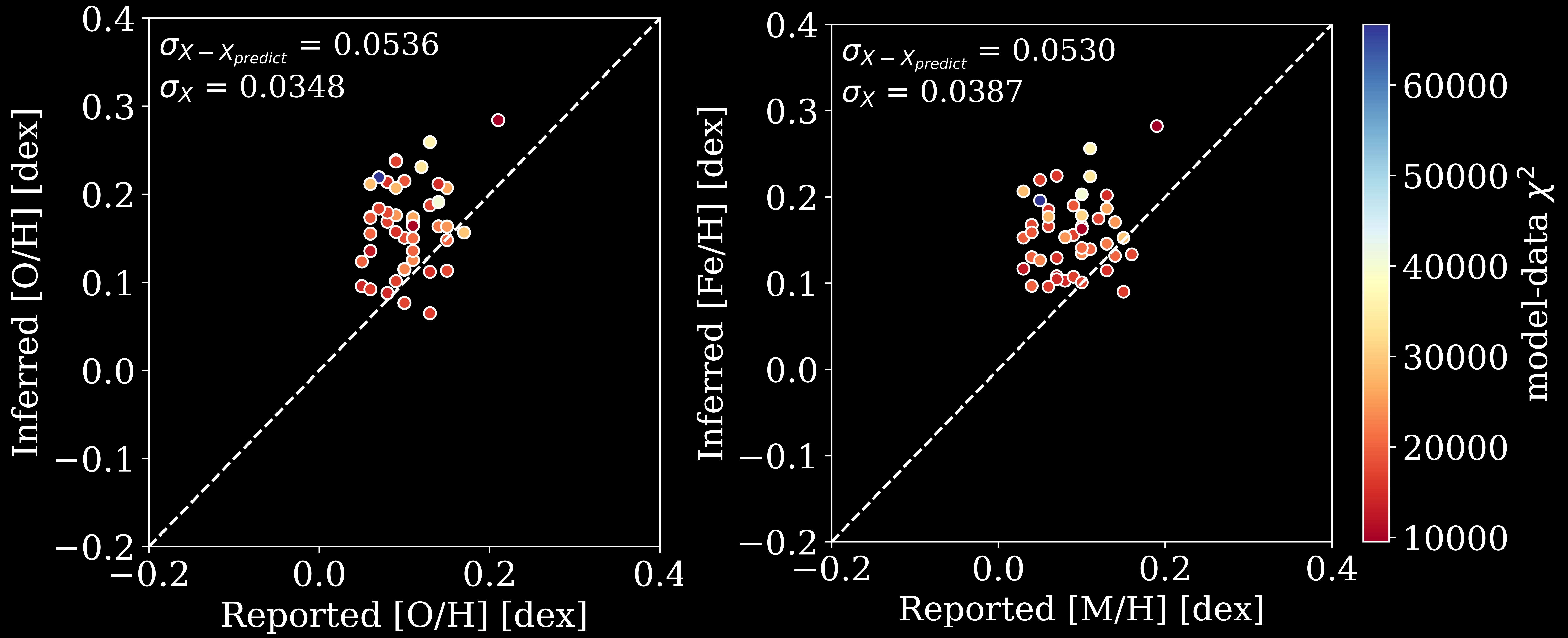


Behmard et al. (2025)

**Also have: Al, N, Ca, Cr, Ni - galactic archaeology!*

Other tests to verify M dwarf abundances…

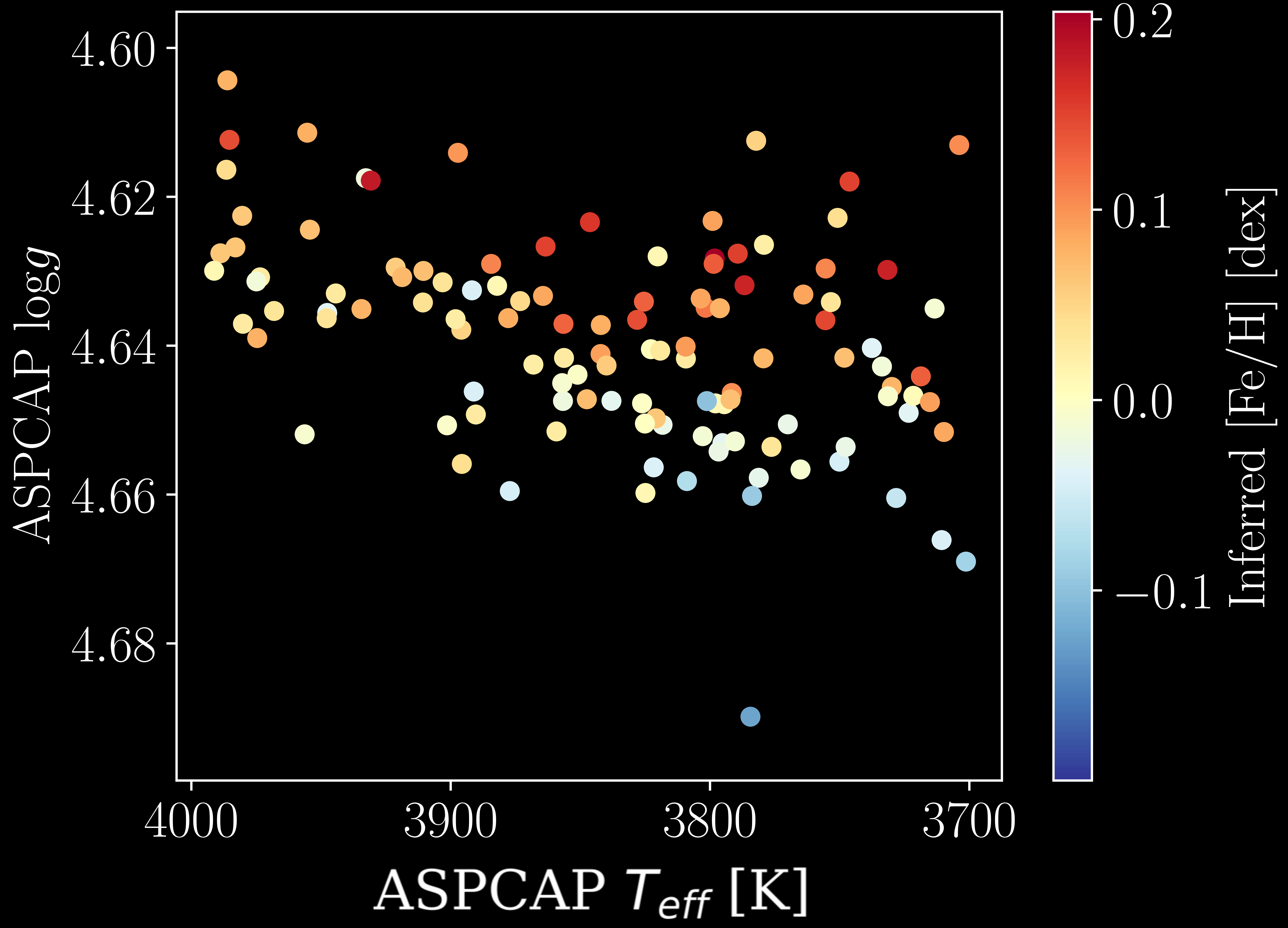
Reproduces known abundances of Hyades cluster M dwarfs

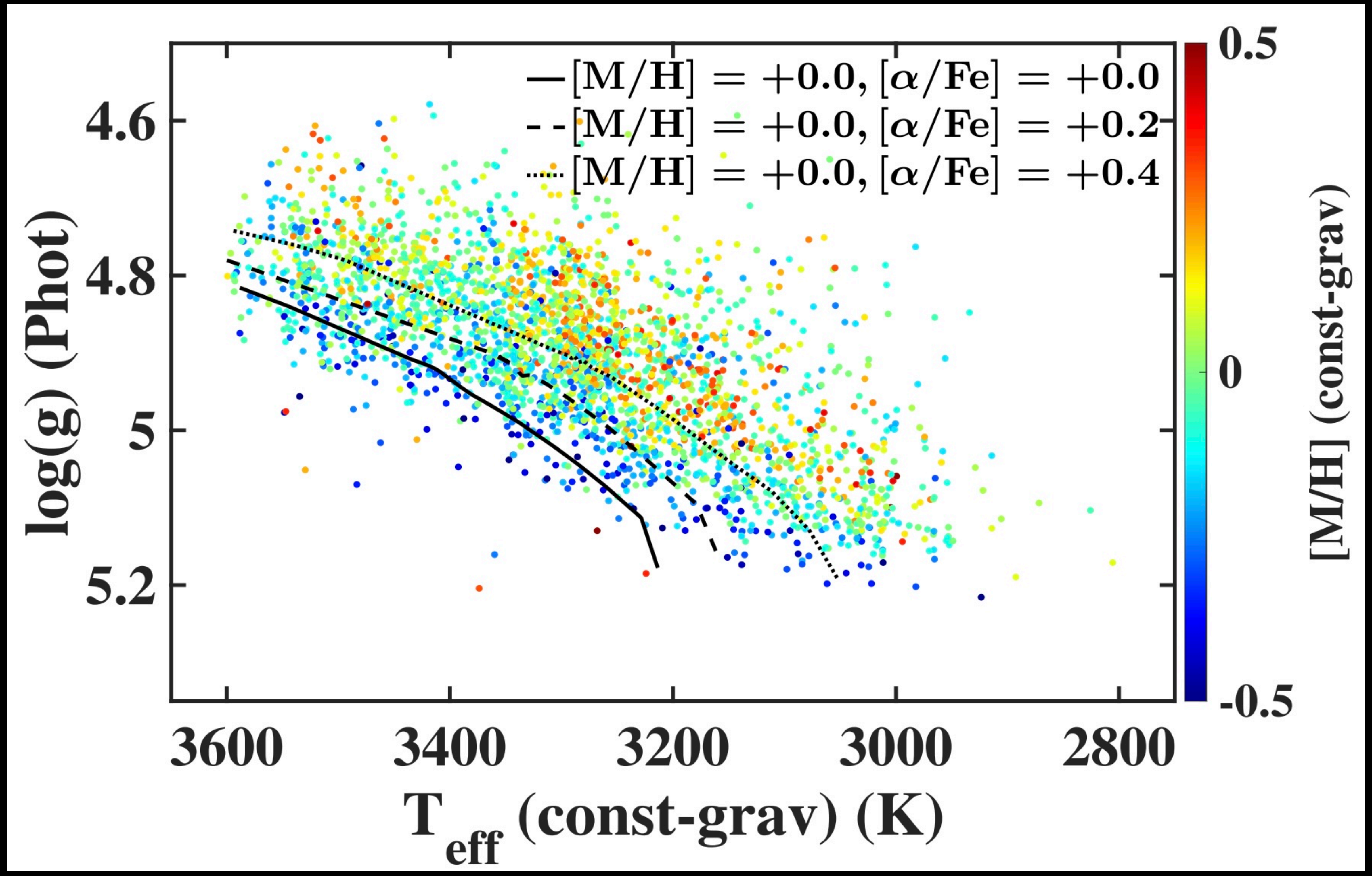


Behmard et al. (2025)

M dwarf metallicities reproduce expected tracks from stellar evolution

Our catalog



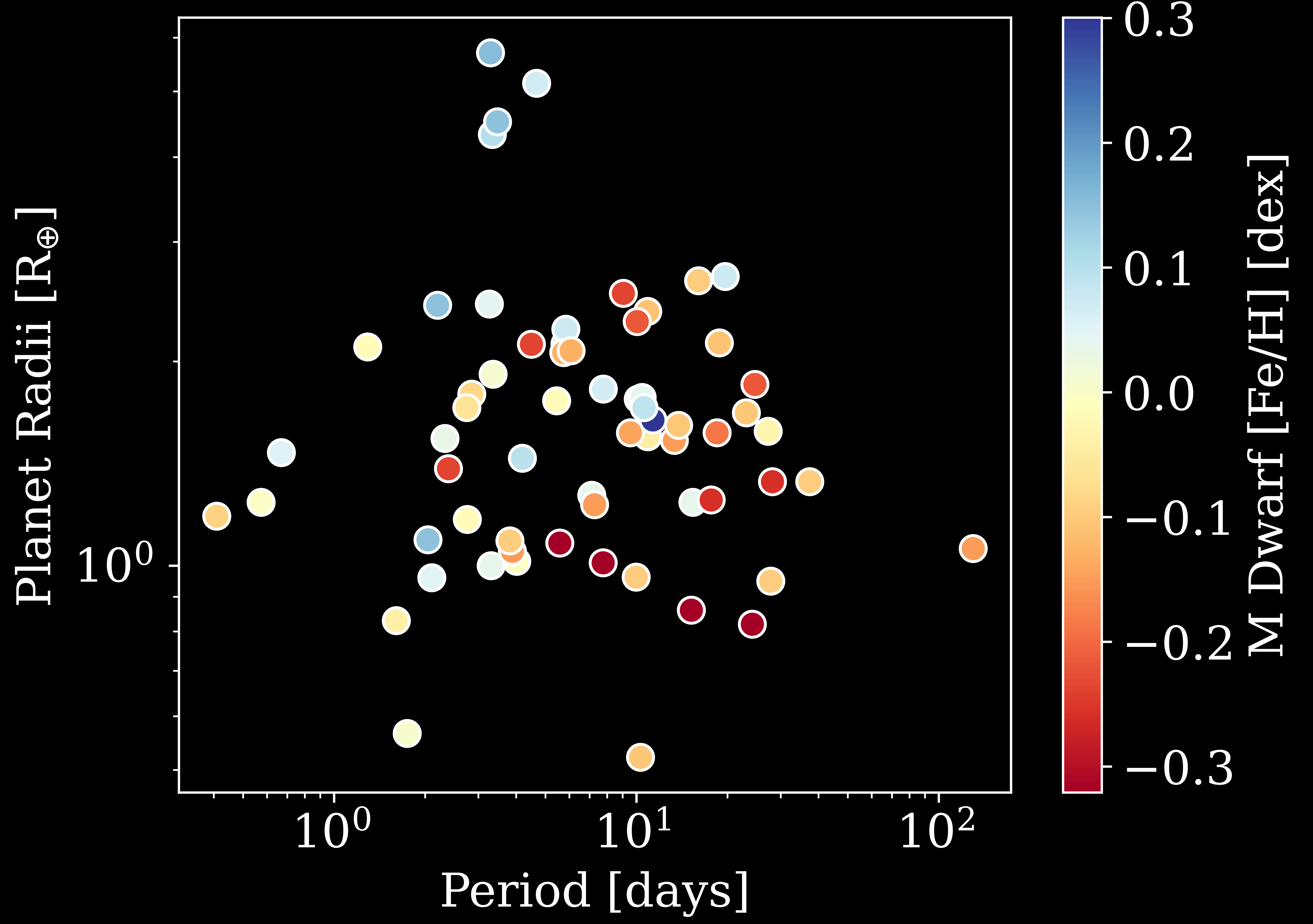


Hejazi et al. (2022)

Behmard et al. (2025)

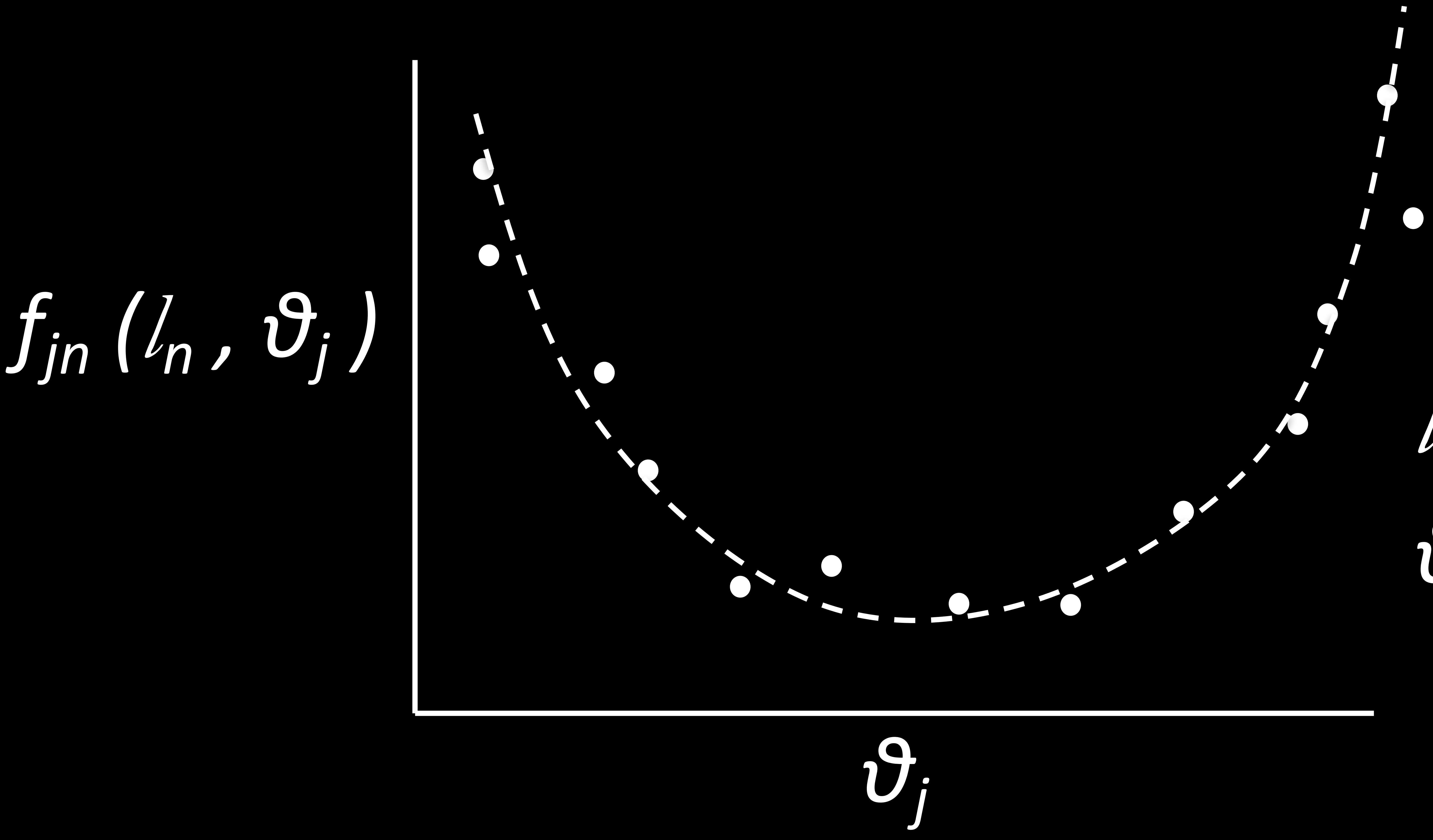
Summary

- *Used **The Cannon** to infer M dwarf abundances for many elements*
- *Catalog of ~17,000 M dwarfs, ~90 confirmed planets*
- *Valuable in era of large surveys (e.g., SDSS)*
- *Can be used for examining star/planet formation*



The Cannon flux model fitting:

For each pixel in the wavelength range of the spectra:



$l_n = [\,1, T_{eff}, [\mathrm{Fe/H}] \ldots\,]$

ϑ_j = *coefficients*

The Cannon flux model fitting:

"complex vectorizer" function ↓ *model coefficients* ↓

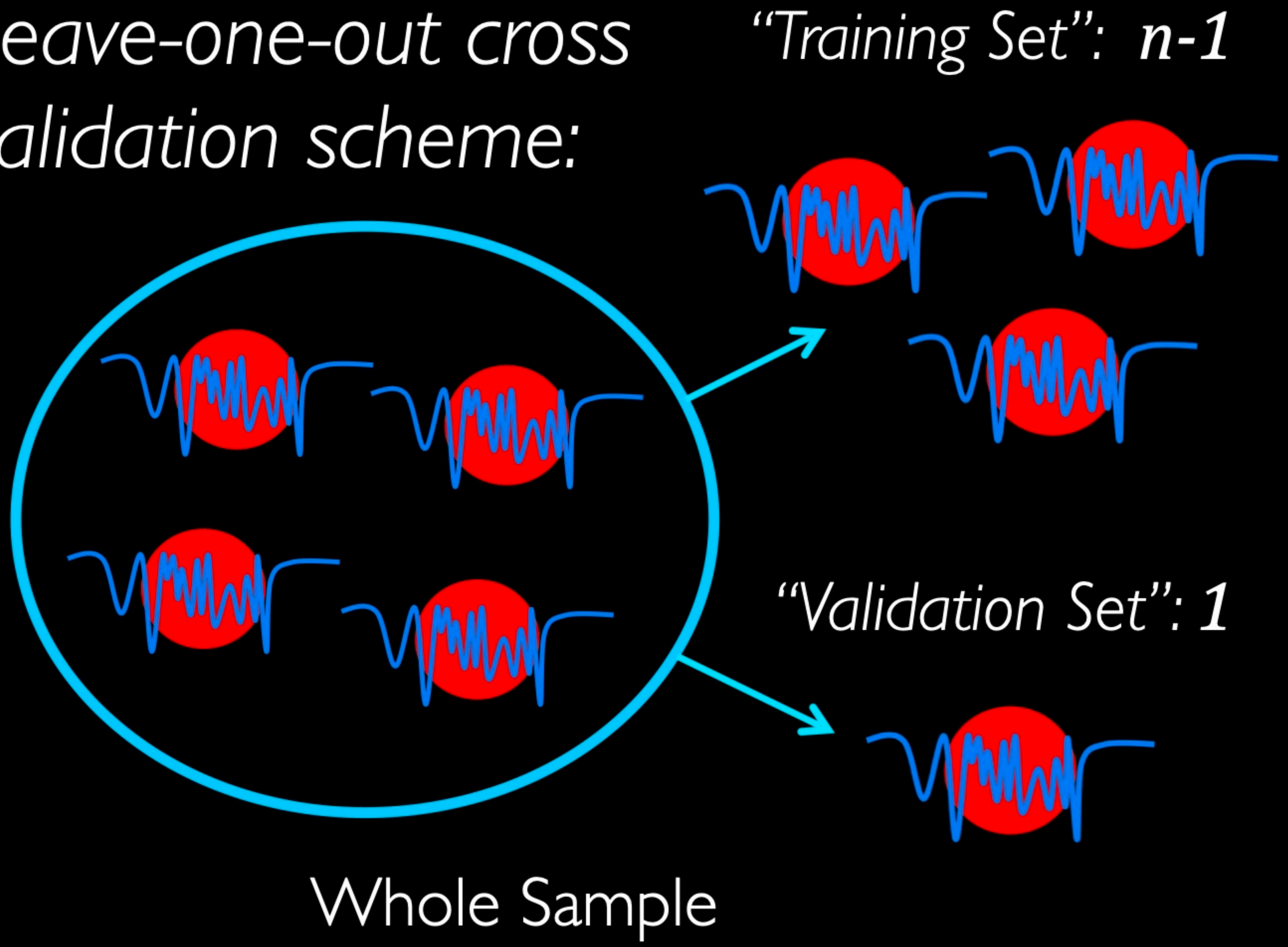
$$f_{jn} = V(l_n) \cdot \vartheta_j + noise$$

$$l_n = [\ 1,\ T_{eff},\ [Fe/H]\ \ldots\ ]$$

"Training Step" : fit for model coefficients ϑ_j *for each flux model*

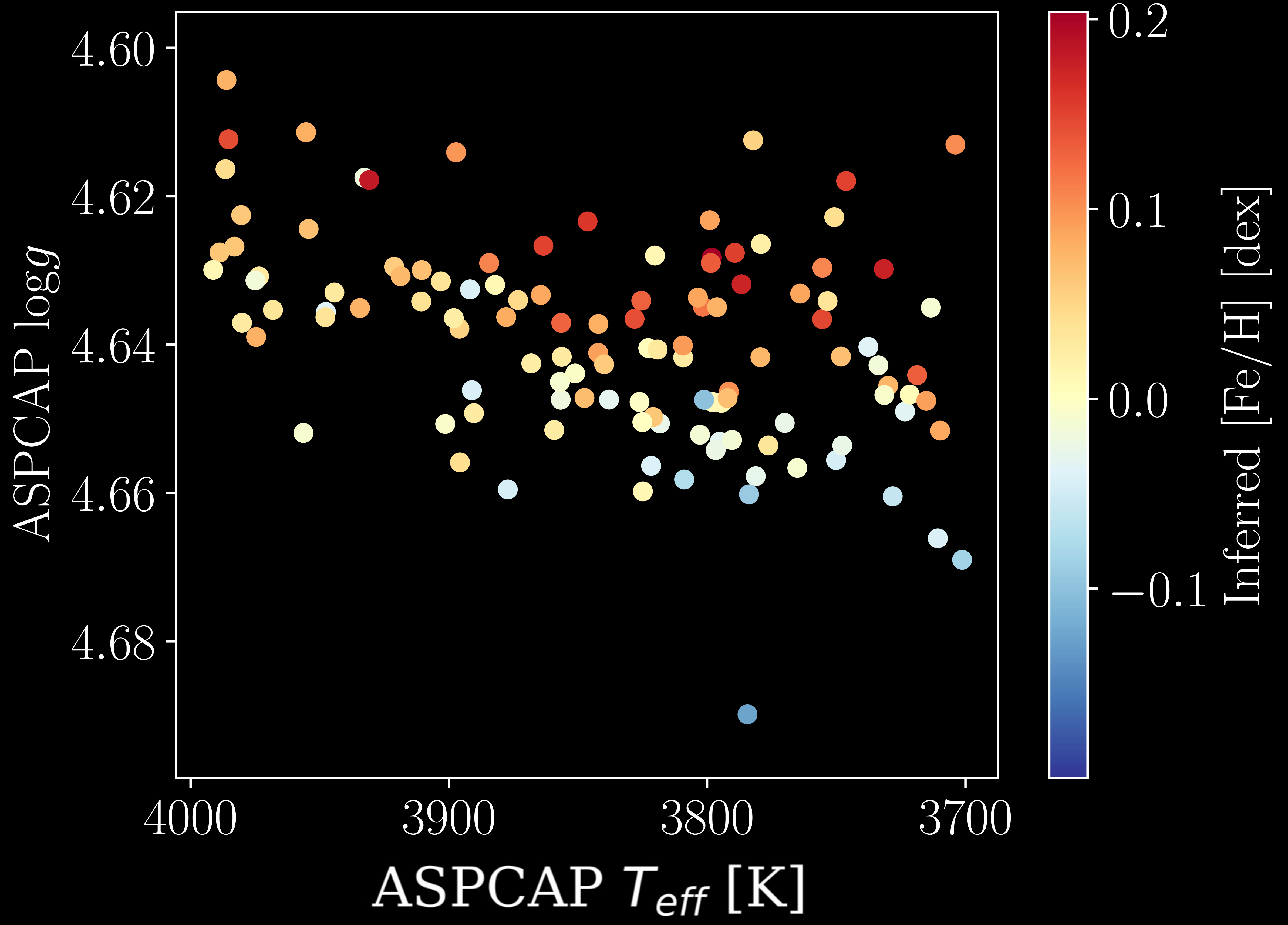
"Test Step" : fit for labels l_n *for each star in the test set that best reproduces empirical flux*

Leave-one-out cross validation scheme:

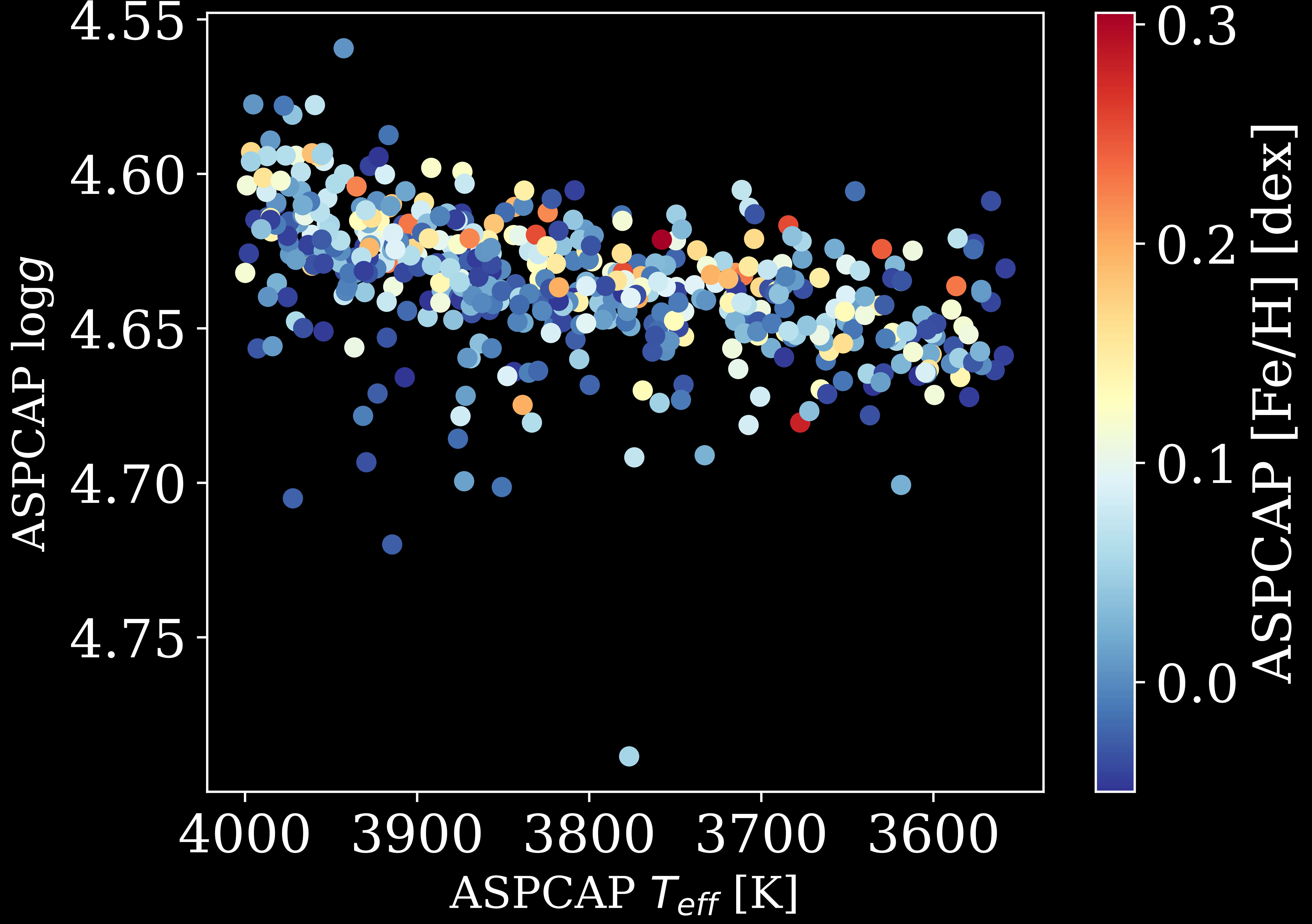


ASPCAP metallicities don't!

Our catalog

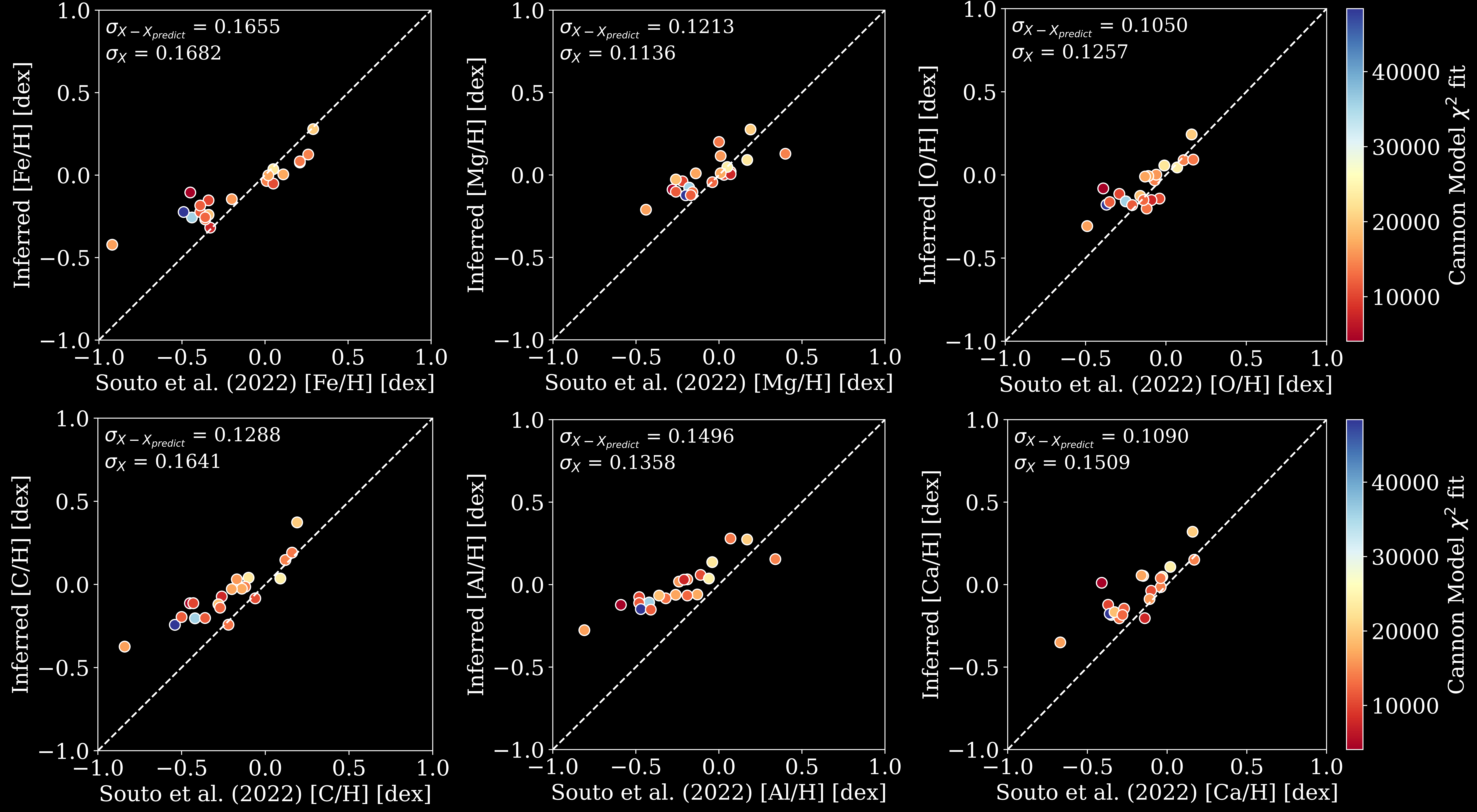


M dwarf ASPCAP



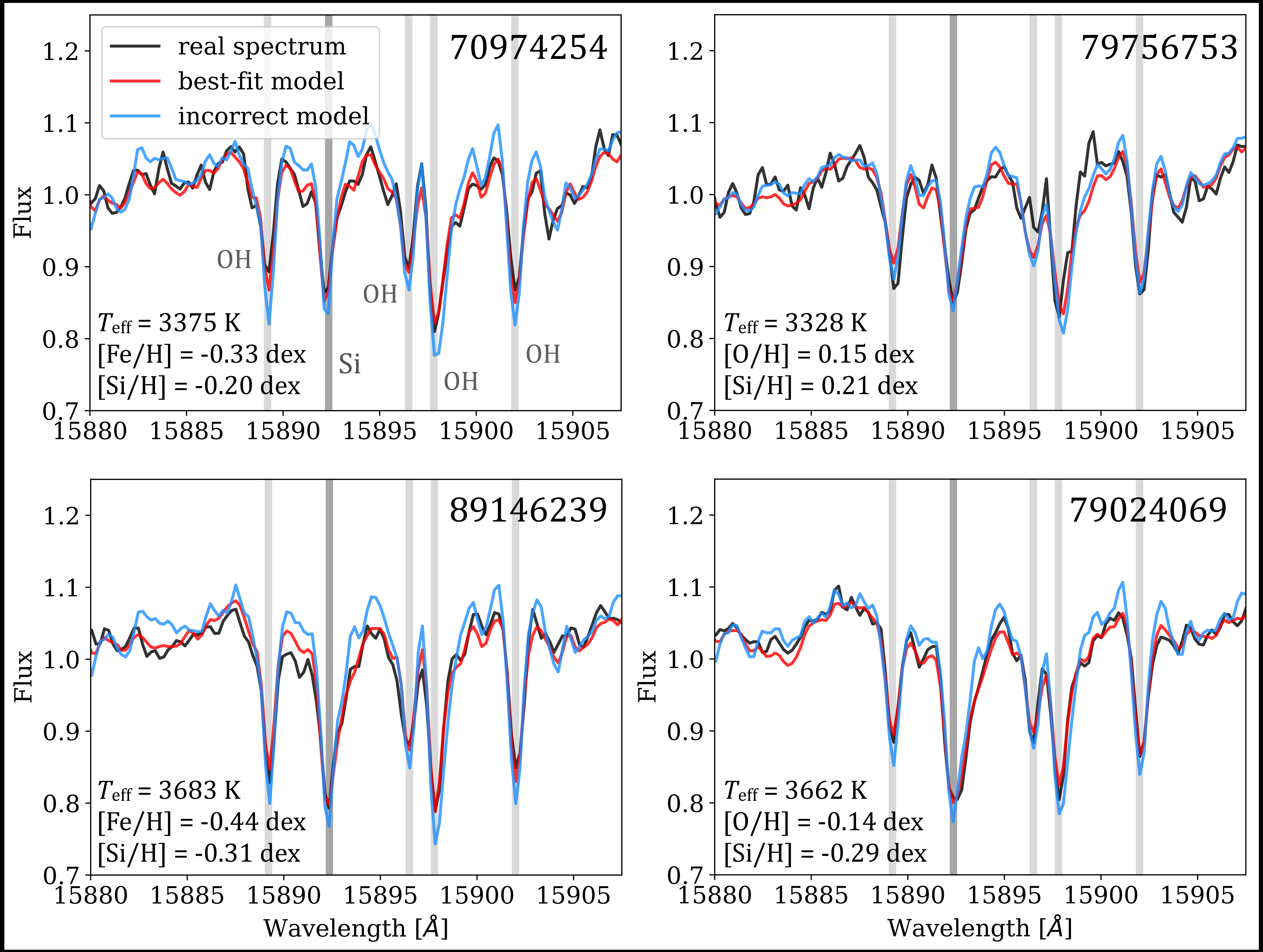
Behmard et al. (2025)

Performance against Souto et al. (2022) results



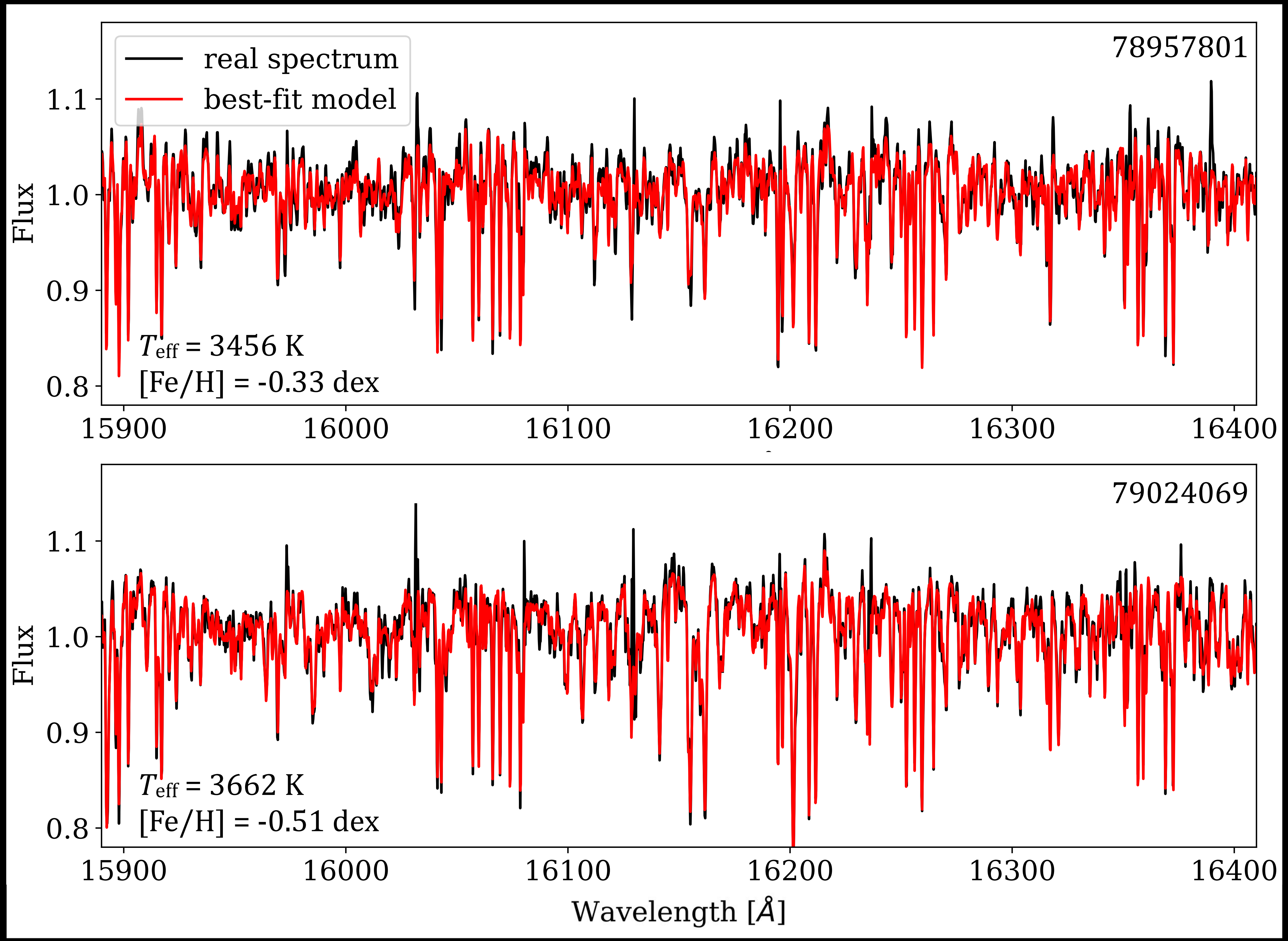
Behmard et al. (2025)

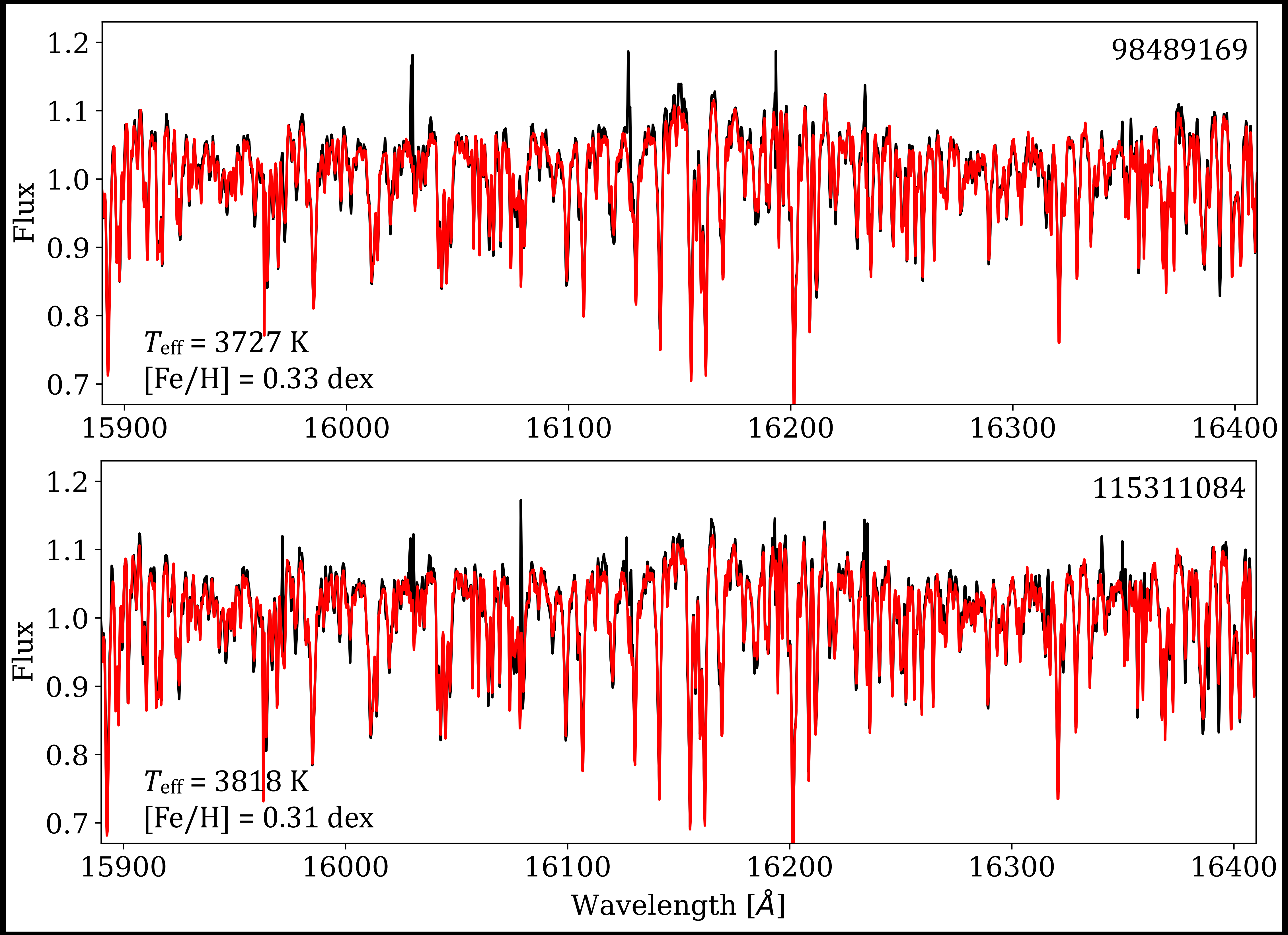
Flux model fit examples



Behmard et al. (2025)

Flux model fit examples





Behmard et al. (2025)