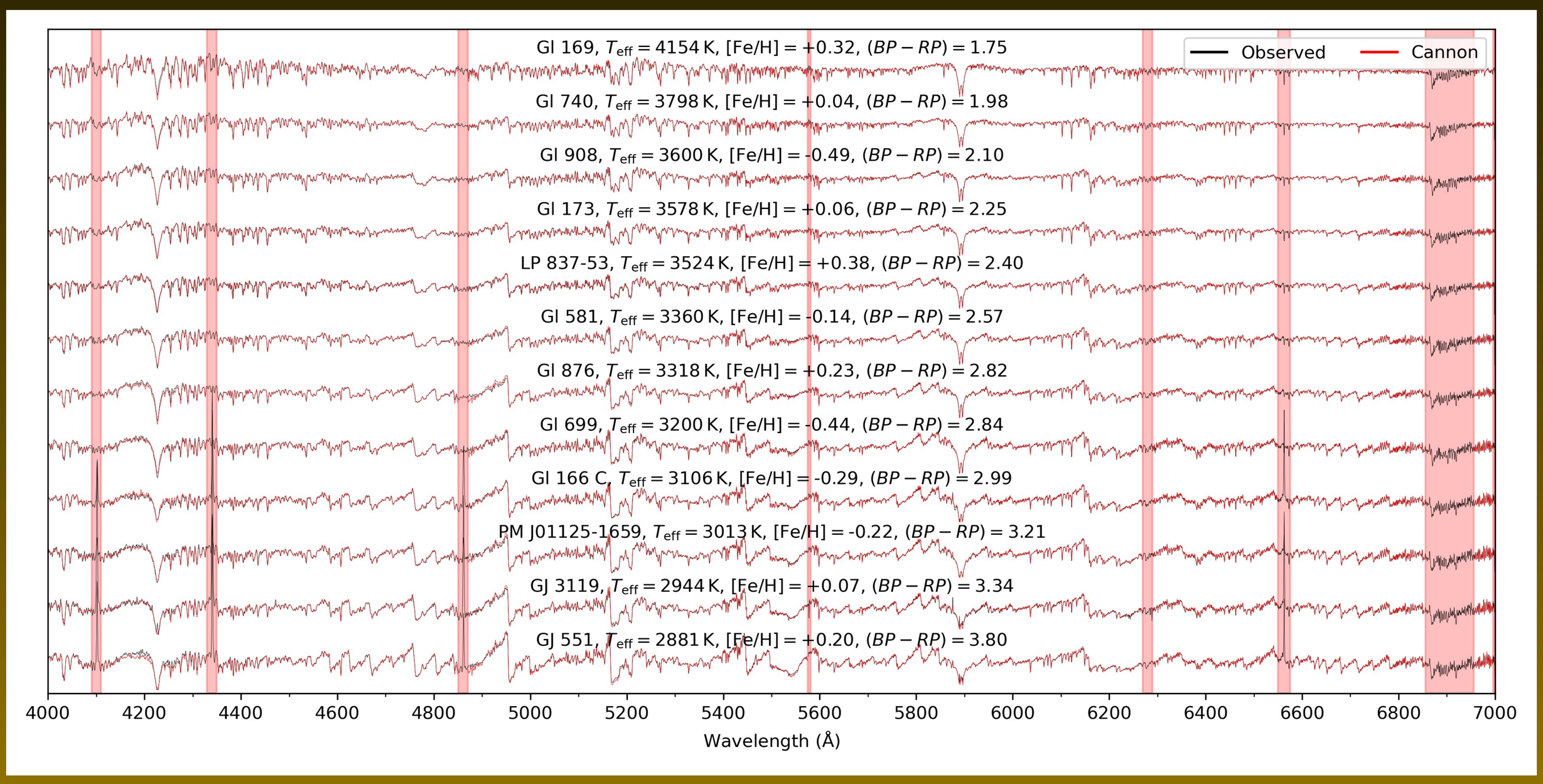
Data Driven Optical Cool Dwarf Chemistry & the Giant Planet–[Fe/H] Correlation

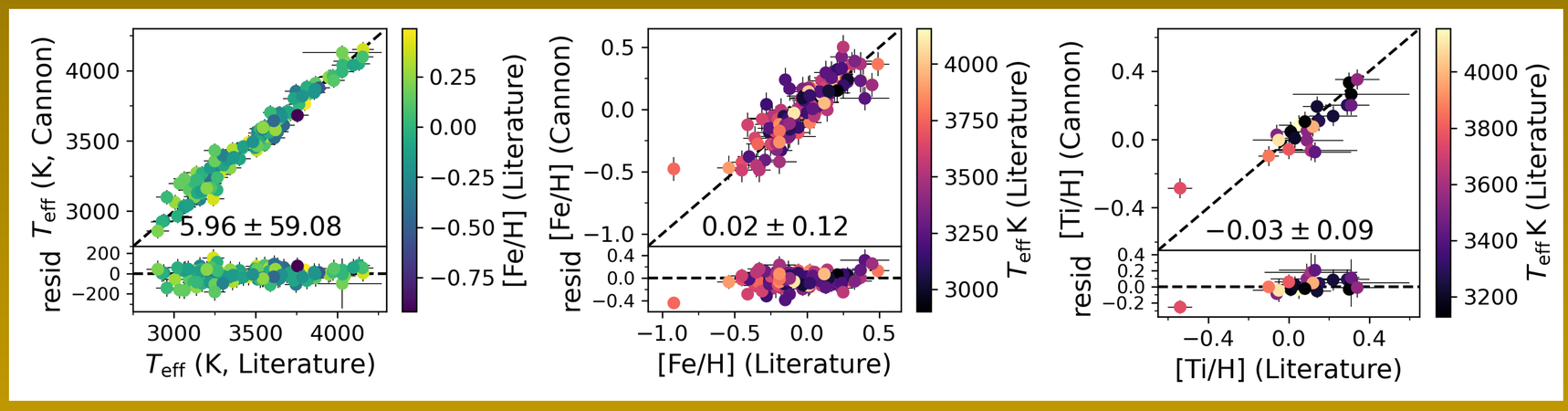
Adam D. Rains[1,2], Thomas Nordlander[2,3], Andrew R. Casey[3,4], Maruša Žerjal[2,5], Michael J. Ireland[2], Michael S. Bessell[2]

[1]Department of Physics and Astronomy, Uppsala University, Box 516, 75120 Uppsala, Sweden
[2]Research School of Astronomy and Astrophysics, Australian National University, Canberra, ACT 2611, Australia
[3]ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D)
[4]School of Physics & Astronomy, Monash University, Wellington Road, Clayton 3800, Victoria, Australia
[5]Instituto de Astrofísica de Canarias, E-38205 La Laguna, Tenerife, Spain

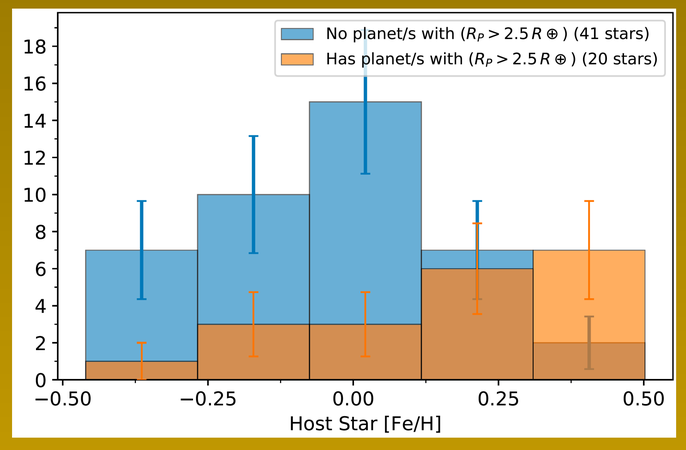
Detailed chemical studies of Solar-type stars have long been routine in stellar astrophysics, making possible studies in Galactic chemodynamics and exoplanet demographics. However, a similar understanding of the chemistry of M and late-K dwarfs—the most common stars in the Galaxy and most likely to host planets—has been greatly hampered by the complex molecular chemistry of their cool atmospheres. Here we present a new implementation of the Cannon, a data-driven model widely used in stellar spectroscopy, developed here for optical cool dwarf spectra. Our novel four-parameter model in T_{eff}, log g, [Fe/H], and [Ti/H] handles both label uncertainties and missing labels, and is trained on 121 cool dwarf benchmarks—21 of which have literature [Ti/H] measured from a warmer binary companion. Under leave-one-out cross-validation we recover T_{eff}, [Fe/H], and [Ti/H] with precisions of 2%, ±0.12 dex, and ±0.09 dex respectively, allowing insight into the giant planet–[Fe/H] correlation for our sample of 61 TESS candidate planet hosts.



Cannon performance for combined ANU 2.3 m Telescope/WiFeS blue (4000 < λ< 5400 Å, R~3000) and red (5400 < λ< 7000 Å, R~7000) arm spectra showing superior flux recovery at blue wavelengths compared to current generation grids of synthetic spectra (see Rains+2021, MNRAS, 504, 5788). Vertical red bars correspond to telluric features, stellar emission, or detector artefacts not included in the model.



Cross validation performance for label recovery in T_{eff}, [Fe/H], and [Ti/H] for our 121 stellar benchmarks consisting of stars with interferometric or fundamentally calibrated T_{eff}, abundance measurements from a wide binary companion of spectral type F/G/K, or [Fe/H] determined from empirical relations based on low-resolution NIR spectra. The precision of our [Ti/H] recovery hints at optical spectra of cool stars being a powerful and as-yet-untapped resource for studying the chemistry of our Galaxy and the demographics of planets.



Histogram of stellar [Fe/H] for confirmed and candidate exoplanet hosts for stars both with and without large (R_P > 2.5 $R_\oplus$) planets detected by TESS. Each bin has Poisson uncertainties overplotted.

Contact:
adam.rains@physics.uu.se
@AdamDRains