Accurate, Precise, and Homogeneous Exoplanet Host Star Parameters Across the Whole Sky

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One of the largest obstacles to the accomplishment of the “Worlds and Suns in Context” theme of the Astro2020 Decadal Survey is the lack of accurate, precise, and homogeneous host star parameters and elemental abundances for both exoplanet host stars and stars searched for exoplanets. The fifth phase of the Sloan Digital Sky Survey (SDSS-V) is currently collecting high-resolution, high signal-to-noise ratio Apache Point Observatory Galactic Evolution Experiment (APOGEE) spectrograph H-band spectra for all known exoplanet host stars, as well as all stars searched for exoplanets using the astrometric, direct imaging, and Doppler techniques across both the northern and southern skies. Utilizing Milky Way Mapper (MWM) spectra from optical BOSS (Baryon Oscillation Spectroscopic Survey) data and infrared APOGEE data, Astra leverages a suite of pipelines to derive fundamental stellar parameters and abundances. Of particular importance to the exoplanet community, the continued release of high-quality carbon, nitrogen, and oxygen abundances will be crucial for placing exoplanetary formation mechanisms into context. Moreover, the dispersion of C/O and N/O abundance ratios (Figure 1) highlights the necessity of considering non-solar abundance ratios when analyzing exoplanet atmospheres.

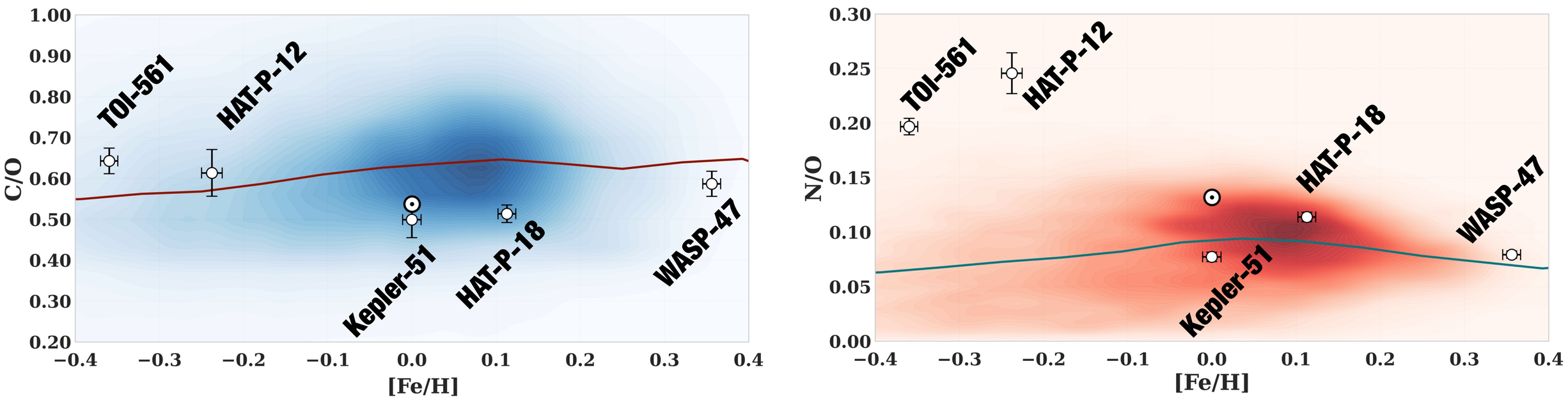
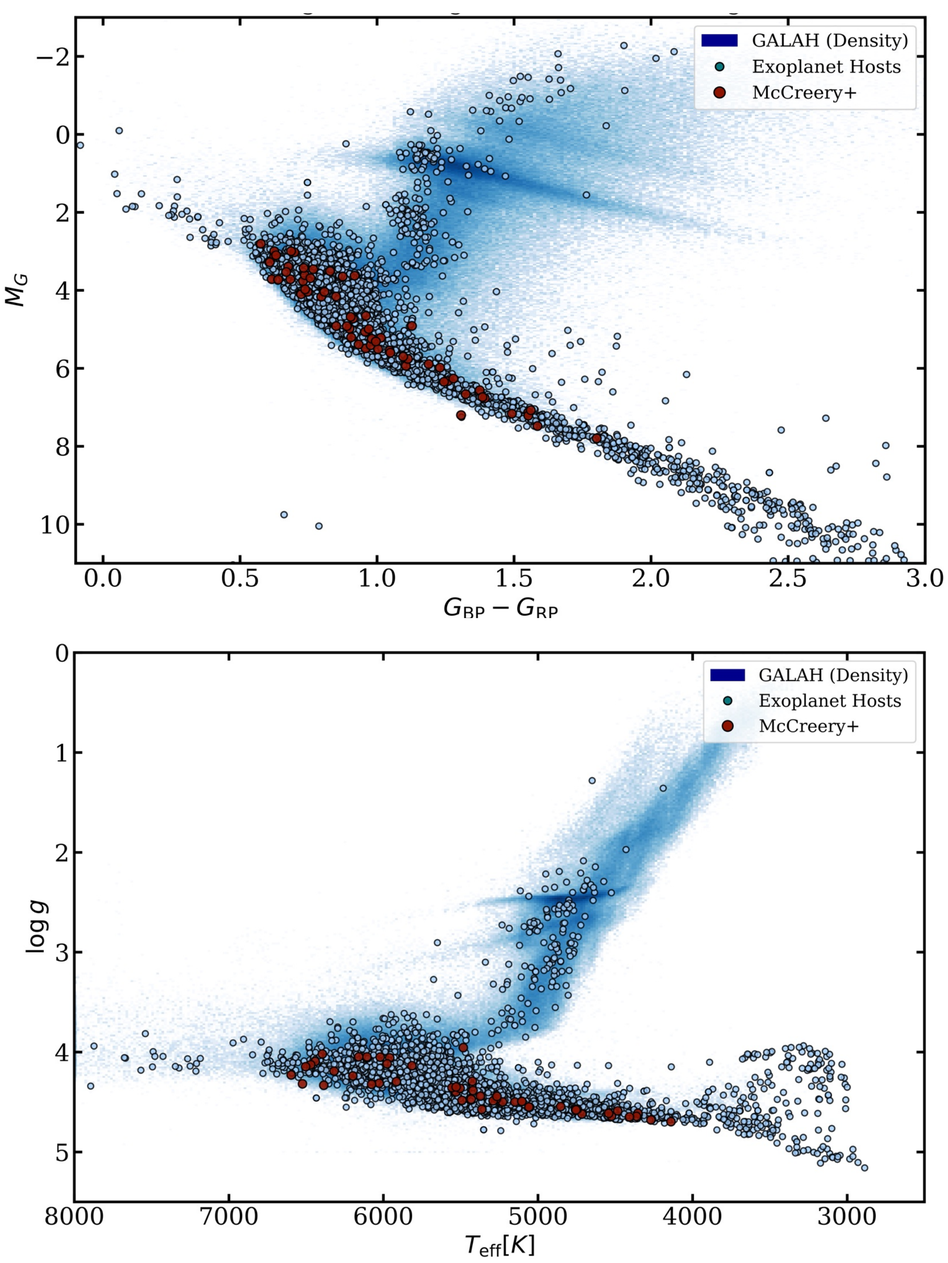


Figure 1. Density plots showing the C/O and N/O abundance ratios as a function of [Fe/H] for Astra ASPCAP (APOGEE Stellar Parameter and Chemical Abundances Pipeline) data from to-date, SDSS-V DR19 data reductions. Overlaid are solar composition values (⊙) and the compositions of a sample of JWST-target exoplanetary host stars from Astra ASPCAP. The median C/O and N/O ratios against [Fe/H], plotted in red (top) and green (bottom), illustrate their relationship with metallicity.



JWST Target Host Star Analysis

The dispersion of stellar composition of exoplanet host stars makes it essential to directly characterize their fundamental parameters and detailed photospheric abundances. Following the methodology of Reggiani et al. (2022), which combines high-resolution optical spectroscopy with available photometry, we can robustly determine stellar effective temperatures, surface gravities, metallicities, and key elemental abundance ratios.

Systematically applying this framework to James Webb Space Telescope (JWST) exoplanet host stars enables the derivation of homogeneous, self-consistent, and precise stellar photospheric C/O ratios across a wide range of planetary systems. These stellar C/O ratios provide direct constraints on the composition of the protoplanetary disks from which exoplanet atmospheres formed. By comparing the C/O ratios inferred from stellar spectroscopy to those retrieved from JWST exoplanet atmosphere observations, we can test models of disk chemistry and migration, as well as refine our understanding of planet formation processes in the era of high-precision JWST spectroscopy.

Figure 2. Top: Gaia color–magnitude diagram showing the GALAH survey sample, the NASA Exoplanet Archive sample, and the McCreery et al. (in prep.) sample. Bottom: Effective temperature–surface gravity diagram comparing stellar parameters inferred from the GALAH survey, the Exoplanet Archive, and the final Teff and log g values derived from our analysis.

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