Stellar Abundances as a Window on Planetary Properties and Habitability. Patrick A. Young[1] Michael Pagano[1] and Amanda Truitt[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287 (patrick.young.1@asu.edu, mpagano@asu.edu, atruitt@asu.edu)

Introduction: Chemical composition has a profound impact upon the evolution of stars and the properties of their planets. Direct measurements of planetary chemical properties is a daunting prospect, especially for the solid bodies of terrestrial planets. Accurate and complete chemical abundances for host stars are therefore extremely valuable for modeling their evolution and time-dependent habitable zones [1] as well as providing our first clues about the makeup of the planets themselves. This perspective will help choose the most interesting systems for later followup.

We present the results and analysis of a 458 star abundance survey. Stellar abundances are considered in terms of geological ternary diagrams and compared to solar system bodies. An in depth analysis of the τ Ceti system as a case study for characterization of habitability from a chemical point of view is presented.

Abundance Survey: We find abundances for up to 27 elements in a survey of 458 FGK dwarfs observed with MIKE at the Magellan telescope for the Carnegie planet survey. Of these, twenty-four are known to have planets or planet candidates. The survey covers a factor of eight in [Fe/H], from -0.49 to 0.4.

Though planets are more common at higher metallicity, as expected [2], they are present at all [Fe/H], including our most Fe-poor star at [Fe/H]=-0.49. In general trends for the abundances of elements with [Fe/H] are similar to Galactic Chemical Evolution models [3], but it should be emphasized that there is a large scatter around these values. The abundance of individual elements can very widely, even at a constant [Fe/H]. For most elements the abundance ratio to Fe [X/Fe] is similar between known hosts stars and the overall sample. Mg, Al, Ca, Ni, however, have systematically higher [X/Fe} in planet hosts than in the general sample. C/O ratios are on average slightly lower than the sun at 0.36, slightly higer for planet hosts, but range to extremely low values (~0.1). Only a few percent are near or above C/O >0.8, the theoretical cutoff where carbide-dominated planets are expected to be possible [4]. The mean Mg/Si = 1.22, higher than solar. Few stars are found with Mg/Si < 1. Two stars have Mg/Si > 1.75. Approaching Mg/Si ~2 planets may transition to mantles dominated by olivine and ferropericalse, with viscosities two orders of magnitude lower than Earth's mantle [5]. Based on the ternary analysis, low C/O and high Mg/Si planets may have systematically larger Fe cores.

In order to gain insight into which stars may host planets with exotic mineralogy, we plot ternary diagrams for O/C/Fe and Mg/Si/Fe with solar, terrestrial, CI chondrite, and Earth mantle values for comparison.

τ Ceti as a Case Study of Chemical Characterization: τ Ceti (HD10700), a G8 dwarf with mass 0.78M, is a close (3.65 pc) sun-like star where 5 possibly terrestrial planet candidates (minimum masses of 2, 3.1, 3.5, 4.3, and 6.7 M) have recently been reported. We provide abundances of 23 elements using spectra from the MIKE spectrograph on Magellan. We find [Fe/H] = −0.49 and T = 5387 K.

Using stellar models from the TYCHO code [6] with the abundances determined here, we calculate the position of the classical habitable zone with time. At the current best fit age, $7.63^{+0.87}$ Gy, up to two planets (e and f) may be in the habitable zone, depending on atmospheric properties.

The Mg/Si ratio of the star is found to be 1.78, which is much greater than for Earth (~1.2). With a system that has such a high Mg to Si ratio it is possible that the mineralogical make-up of planets around τ Ceti could be significantly different from that of Earth, with possible oversaturation of MgO, resulting in an increase in the content of olivine and ferropericlase compared with Earth. The increase in MgO would have a drastic impact on the rheology of the mantles of the planets around τ Ceti.

References: [1] Young, Liebst, & Pagano (2012) *ApJL, 755,* 31. [2] Fischer & Valenti (2005) *ApJ, 622,* 1102. [3] Timmes & Clayton (1996) *ApJ, 472,* 723. [4] Bond, O'Brien, & Lauretta (2010) *ApJ, 715,* 1050. [5] Young et al. (2014) *Astrobiology 14,* 603. [6] Young & Arnett (2005) *ApJ, 618*, 908

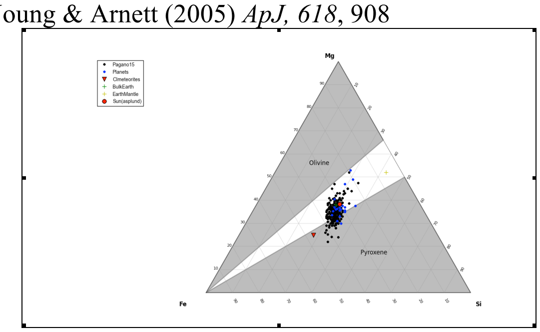

Figure 1: Ternary diagram for Mg/Si/O. Planet hosts are in blue, the full sample of 458 stars in red. Values for bulk Earth, Earth's mantle, CI chondrites, and the Sun are indicated. Regions dominated by olivine (upper grey) and pyroxene (lower grey) are indicated.