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Finding the Youngest Exoplanets

Lisa Prato (1,2), Christopher Johns-Krull (3), Joe Llama (1), Daniel Jaffe (4), Larissa Nofi (1,5), Laura Flagg (3), Cathie Clarke (6), Patrick Hartigan (3), Lauren Biddle (1,2), Brian Skiff (1), Gregory Mace (4), Adolfo Carvalho (3)
(1) Lowell Observatory, Flagstaff, USA (lprato@lowell.edu), (2) Northern Arizona University, Flagstaff, USA, (3) Rice University, Houston, USA, (4) University of Texas, Austin, USA, (5) Institute for Astronomy, Manoa, USA, (6) Cambridge University, Cambridge, UK

Abstract

In spite of the diverse wealth of data provided by the identification of thousands of planets spanning a broad parameter space, we know little about young (<few Myr old) planets. To advance our understanding of the processes governing planet formation and evolution, we need to find and characterize young planets themselves. Given the extreme activity inherent in young stars, particularly those with active, primordial accretion disks, this is a challenging undertaking.

1. Motivation

Exoplanets orbit a vast range of stars, from the hypercompact Trappist-1 to the decades- and centuries-long orbits of the HR 8799 planets, and everything in between. Intriguingly, however, although exoplanetary systems are found around a veritable zoo of hosts, almost nothing is known about planets around young stars. Consequently, our planet formation paradigm is largely inferred from models based on data from billion year old systems, and the balance of nature versus nurture, i.e. to what degree planetary systems reflect formative versus evolutionary processes, is unknown. Astronomers have little knowledge of precisely when and at what distances from the parent star planets form, with what frequency they form, how rapidly they migrate or are disrupted and/or ejected, and at what age planetary systems acquire stable configurations.

There are good reasons for the gap in our knowledge of young planets. The assembly of exoplanet systems takes place around the youngest stars, with ages of <a few Myr; even the closest star forming regions are located at >120 pc, and thus their stellar members are correspondingly faint. Classical T Tauri stars, surrounded by the circumstellar disk material from which planets form, demonstrate complex and extreme behavior. Systems in which disk material is actively accreting onto the central stars manifest large IR excesses, strong veiling, prominent hydrogen emission line spectra, and often extreme, irregular photometric variability. Similarly, young systems which show no evidence for disks also demonstrate high levels of typically more regular but still dramatic variability caused by giant star spot complexes and energetic flares

2. The Era of Young Exoplanets

In spite of these obstacles, the last 3 years have ushered in the era of young exoplanet detections. In 2016 we published the discovery of an 11 M_{Jup} object in a 9 day period orbiting at the inner edge of an optically thick disk around a classical T Tauri star, the ∼2 Myr CI Tau (Johns-Krull et al. 2016a). This finding was the result of 10 years of optical and infrared (IR) high-resolution spectroscopic observations to measure the stellar radial velocities (RVs) and to determine and confirm the fundamental properties of this important young planet. This one detection alone provides important challenges to planet formation models, but other recent results also push the envelope of our theoretical understanding. Mann et al. (2016) and David et al. (2016) describe transits of a few Neptune size planet around the 5−10 Myr old star K2-33 in the Upper Scorpius region. Furthermore, Donati et al. (2016) and Yu et al. (2017) present evidence for hot Jupiters around two weak-lined, diskless T Tauri stars, V830 Tau and TAP 26. Johns-Krull et al. (2016b) observed a candidate hot Jupiter on a ∼half day orbit that, if confirmed, may represent a disintegrating exoplanetary system.

3. CI Tau b Beyond RVs

In addition to the RV results of Johns-Krull et al. (2016), we used the high-cadence photometry of *K2* to identify signals in the CI Tau power spectrum with the same periodicity as the planet, consistent with planet-disk interactions, in addition to a the distinct signature from stellar rotation (Biddle et al. 2018). In Clarke et al. (2018; Figure 1), we demonstrated the likelihood of a family of giant planets carving gaps in the outer regions of the CI Tau primordial circumstellar disk. Most recently, Flagg et al. (2019) used our high-resolution IR spectra to **directly detect CO in the atmosphere of CI Tau b**, confirming the planet at the ephemeris expected from the stellar reflex motion.

4. Current Survey

Starting in late 2016, our team negotiated the unique and unprecedented opportunity to use the high-resolution Immersion Grating Infrared Spectrograph (IGRINS; Park et al. 2014) on Lowell Observatory's 4.3-meter Discovery Channel Telescope (DCT) to mount an intensive observing campaign to survey our entire sample of ~140 T Tauri stars for the youngest giant exoplanets and to determine their frequency and characteristics. With IGRINS, we have obtained ~1200 spectra inclduing 3–4 observations of every target in the survey sample, and dozens of observations of a subsample of targets suspected of hosting young exoplanets. These include classical T Tauri systems with primordial, active accretion disks identified in *K2* data as likely displaying planet–disk interactions. Analysis of the most promising candidate exoplanets is currently underway.

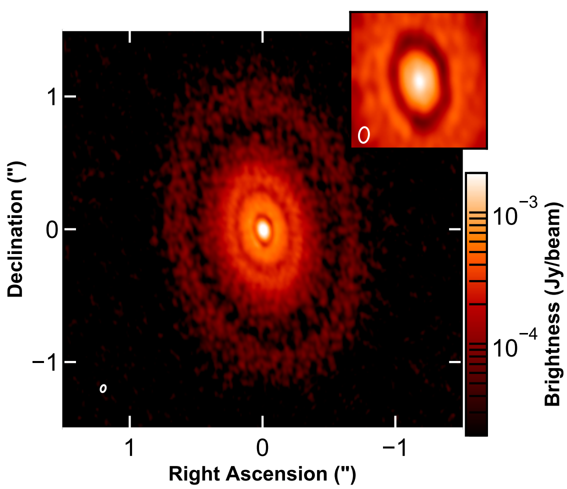

Figure 1: ALMA image of CI Tau (Clarke et al. 2018).

5. Summary

The relatively short-period giant planets we are sensitive to are of fundamental importance in part because of their role in the dynamics of the inner 1 AU, the terrestrial planet-forming region. Detections of planets around stars with primordial disks are especially interesting because they provide a direct link between the host disk and the exoplanet properties. This poster will describe the status of our RV survey, observations of the CI Tau exoplanet, and report on recent results.

Acknowledgements

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