Young Stars & Planets Near the Sun
Proceedings IAU Symposium No. 314, 2015
J. H. Kastner, B. Stelzer, & S. A. Metchev, eds.
© International Astronomical Union 2016
doi:10.1017/S1743921315006407

Toward Direct Imaging of Low-mass Gas-Giant Planets with the *James Webb Space Telescope*

J. E. Schlieder[1], C. A. Beichman[2], M. R. Meyer[3], & T. Greene[4]

[1]NASA Postdoctoral Program Fellow, NASA Ames Research Center
email: joshua.e.schlieder@nasa.gov
[2]NASA Exoplanet Science Institute/Caltech, [3]ETH Zürich, [4]NASA Ames Research Center

Abstract. In preparation for observations with the *James Webb Space Telescope* (*JWST*), we have identified new members of the nearby, young M dwarf sample and compiled an up to date list of these stars. Here we summarize our efforts to identify young M dwarfs, describe the current sample, and detail its demographics in the context of direct planet imaging. We also describe our investigations of the unprecedented sensitivity of the *JWST* when imaging nearby, young M dwarfs. The *JWST* is the only near term facility capable of routinely pushing direct imaging capabilities around M dwarfs to sub-Jovian masses and will provide key insight into questions regarding low-mass gas-giant properties, frequency, formation, and architectures.

Keywords. stars: low-mass, stars: imaging, techniques: high-resolution

1. Introduction

M dwarfs, low-mass stars ($\leqslant$0.6 $M_\odot$) cooler than the Sun ($\leqslant$3900 K), are the most common stars in the Galaxy (~75%). The youngest M dwarfs in the Solar neighborhood (d$\leqslant$100 pc) are members of loose associations having common Galactic kinematics and ages ~10–130 Myr; young moving groups (YMGs, Zuckerman & Song 2004). Due to their proximity, youth, and intrinsically low-luminosities, M dwarf YMG members are prime targets for direct exoplanet imaging. Additionally, a sizable population of ~Jupiter to ~Neptune mass planets is detected at moderate separations (~1–10 AU) around M dwarfs by gravitational micro-lensing surveys (Cassan *et al.* 2012). For these reasons, many dedicated searches to identify the missing M dwarf members of YMGs have been undertaken, e.g. Kraus *et al.* (2014), and several surveys to directly image their planets are ongoing (Bowler *et al.* 2015). Despite the identification of several hundred likely new M dwarf YMG members and high-contrast imaging observations of a sizable fraction of that sample, YMGs still lack the large numbers of M dwarfs expected (Kraus *et al.* 2014) and only a few planetary-mass companions on wide orbits have been imaged. To probe the known population of low-mass gas-giants around M dwarfs via direct imaging, more members of the nearby young sample must be identified and facilities with greater sensitivity are required.

2. A Search For Nearby Young M Dwarfs and the Current Sample

We have identified nearly 400 candidate M dwarf YMG members using a selection algorithm that hinges on proper motion, photometry, and activity (see Schlieder *et al.* 2012). For the last 3 years we have pursued an all-sky, spectroscopic, follow-up program to identify true YMG members in the sample that we call *CASTOFFS* (Schlieder *et al.* 2015). We have observed ~$\frac{3}{4}$ of our candidates using high-resolution optical (MPG 2.2m/FEROS,

https://doi.org/10.1017/S1743921315006407 Published online by Cambridge University Press

CAHA 2.2m/CAFE) or medium-resolution near-IR (IRTF 3.0m/SpeX) spectroscopy and our analyses continue. Our high-resolution optical spectra have so far revealed more than 50 new M dwarf YMG members, several isolated young field M dwarfs, and a dozen spectroscopic binaries. Our analyses of the near-IR spectra are just beginning and young M dwarfs with low surface-gravity features are already apparent in the data.

We have compiled an up to date list of young, low-mass stars within 100 pc from the literature and added to it our new identifications from *CASTOFFS*. We primarily include stars having both spectroscopic confirmation of youth and at least partial kinematics (proper motion and RV) consistent with YMG membership. A few well characterized, young field stars are also included. From more than 30 literature references over the last ∼15 years and our new results, we find 440 ∼K5–M9 systems (338 known or presumed single, 102 multiples) with ages ∼10–400 Myr at distances $\lesssim$100 pc. This is nearly a factor of five increase over the M dwarf YMG sample from Torres *et al.* 2008. Only $\sim\frac{1}{3}$ of the sample has measured parallaxes, the remaining distances are kinematic or photometric estimates. There are fewer stars within 25 pc than anticipated and the population falls off very quickly beyond ∼M4 type and distances $\gtrsim$50 pc, indicating the potential for more discoveries with ongoing, dedicated searches.

3. *James Webb Space Telescope* Survey Simulations and Future Work

The *James Webb Space Telescope* will provide unprecedented imaging sensitivity. Observing at ∼4.5 μm with a coronagraph, the NIRCam instrument is expected to provide a contrast of 10^{-5} at $1''$ separations with a very low background limit. To explore these capabilities in the context of M dwarfs, we have performed imaging survey simulations on our young M dwarf sample using the Monte Carlo methods described in Beichman *et al.* (2010). Young planet magnitudes were taken from extended COND03 models (Baraffe *et al.* 2003) covering 0.1–5 $M_{\rm Jup}$. The simulated survey results reveal routine imaging sensitivity to planets <0.5 $M_{\rm Jup}$ at >50 AU separations. In the best cases, the simulations predict *JWST*/NIRCam will detect ∼0.1 $M_{\rm Jup}$ (∼2 $M_{\rm Nep}$) planets at <10 AU, directly probing the known micro-lensing population.

Our preliminary simulations indicate that *JWST*/NIRCam imaging can routinely detect sub-Jovian mass planets around nearby, young M dwarfs. However, further work is warranted. New constraints on the M dwarf planet population are available and new planet evolution and atmosphere models will provide better predictions of young, low-mass planet luminosities. We plan to include these new results in our future simulations. Our continuing *CASTOFFS* survey and improved survey simulations will provide high priority targets for early *JWST* GTO and GO proposals and pave the way for the first direct images of low-mass gas-giant planets.

References

Baraffe, I., *et al.* 2003, *A&A*, 402, 701
Beichman, C. A., *et al.* 2010, *PASP*, 122, 162
Bowler, B., *et al.* 2015, *ApJS*, 216, 7
Cassan, A., *et al.* 2012, *Nature*, 481, 167
Kraus, A. L., *et al.* 2014, *ApJ*, 147, 146
Schlieder, J. E., *et al.* 2012, *AJ*, 143, 80
Schlieder, J. E., *et al.* 2015, *Proceedings of CS18*, Editors: G. van Belle and H.C. Harris, 919
Torres, C. A. O., *et al.* 2008, *HSFR*, Editor: Bo Reipurth, 2, 757
Zuckerman, B. & Song, I. 2004, *ARA&A*, 42, 645

https://doi.org/10.1017/S1743921315006407 Published online by Cambridge University Press