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A Deep JI Survey of the Pleiades for Freely-Floating Superplanets and Brown Dwarfs at the Deuterium Burning Limit

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Abstract. We present preliminary results from a deep near-infrared J-band and I-band photometric survey of the Pleiades for freely-floating superplanets and brown dwarfs (BD) near the deuterium burning limit (DBL). With limiting magnitudes of J=20.5 and I=23.5, we have selected candidate Pleiads on the basis of evolutionary tracks, color-magnitudes, and I-J color lower limits (non-detections at deep I-band). Likelihoods of membership will be ultimately determined by a combination of image profile analysis, spectral energy distribution, proper motion, and low-resolution measurements of near-infrared water and/or methane absorption slopes. If confirmed, our faintest candidates are predicted to have made the transition from L to T spectral types with temperatures down to 820 K, and masses approaching 10 M_{Jup}.

1. Survey Specifications

Over the past several years we have conducted a dual J and I-band survey for faint Pleiades candidates to an unprecedented depth. The J-band(1.25μm) imaging was performed with two wide-field IR cameras: UCLA/GEMINI at the Lick/Shane 3-m telescope, and STEWARD/NICMOS at the Kitt Peak/Bok 2.2m telescope. The complementary I-band(0.83μm) data were obtained with LRIS in imaging mode at Keck and with the Prime Focus Camera at the Lick 3-m. We reached a typical J-band completeness limit of J=19.5 mags, and a limiting magnitude of J=20.5 mags (2 full mags fainter than any confirmed Pleiad) at which theoretical models by Burrows (2000) predict objects at the Pleiades age and distance to have masses between 10 and 20 M_{Jup}, and temperatures below the poorly constrained L/T spectral transition at ~1300 K. With typical I-band completeness limits of I=24 (LRIS) and I=23.5 (PFCAM), we are able to select faint, point-like cluster candidates with red colors (I-J$\geq$3), and magnitudes consistent with the latest pre-main sequence model tracks.

At the age of the Pleiades, BDs above 20 M_{Jup} are expected to have exhausted their supply of deuterium, whereas 10-20 M_{Jup} objects are predicted to exhibit a slight excess in luminosity while in the midst of their deuterium burning phase. Since it has been suggested that freely-floating superplanets be distinguished in name by an inability to ignite deuterium, we expect that our faintest confirmed candidates will probe the transition regime (~13 M_{Jup} in Burrows

et al. 1998) between deuterium-depleted BDs and deuterium-preserved super-planets down to ~820 K at J~21 mag. Thus by enumerating the lowest spur of the IMF in the Pleiades, we stand to generate a statistically significant sample of objects which can be subsequently analysed to place empirical constraints on evolutionary models of deuterium depletion in a prototypically adolescent star cluster. Our most promising candidate to date is a point-source at J=19.3 with a non-detection at I-band, and a 5σ lower-limit of I=23.8 (I-J$\geq$4.5), corresponding to a mass of 10-20 M_{Jup}, if membership can be confirmed.

2. Follow-Up Observations and Expected Yield

A first pass of real-time color-color and image profile analysis (under the typically excellent seeing conditions and plate scale with IRTF/SPEX in imaging mode) at J-band and K-band is our most efficient available means of discriminating between potentially false detections (low-sigma stellar-like reduction artifacts and ghosts), background objects (moderately compact galaxies and reddened late-type stars), and likely Pleiades members. Since the expected transition to methane-absorbing T spectral types should produce a prohibitively blue J-K color (Burrows et al. 1998) for K-band detection with IRTF/SPEX, we will only attempt to obtain K-band photometry and image profiles for our brighter candidates at first. Remaining candidates with mere lower limits at I-band will benefit from a Z-band detection to extend the long wavelength baseline, and further distinguish members from colors of background objects. We then hope to utilize H and K grism spectroscopy with IRTF/SPEX to estimate spectral types on our faintest candidates using methane and steam band slope analysis. Finally, in 3 years time, we will be able to ascertain proper motion consistency with good Mauna Kea seeing conditions using second epoch images with IRTF/SPEX.

Weather permitting, we hope to cover an additional ~600 arcmin^2, raising our full-depth J-band areal coverage to one quarter-square degree, ~900 arcmin^2. Recent photometric surveys for substellar Pleiades members (i.e., Martín et al., 2000, Moraux et al. 2001) show a frequency of one true BD member between 40 M_{Jup} and 80 M_{Jup} per ~150 arcmin^2 imaged, and a mass function which flattens modestly (logarithmic slope of -0.5) toward lower mass BDs. After correcting for reddened background objects, we expect to see ~6 such high-mass BDs and, assuming that the nearly-flat mass function (in logarithmic mass units) seen in these photometric surveys extends down to 10 M_{Jup}, we expect to see ~5 and ~4 more BDs in each progressively lower mass bin between 20 - 40 M_{Jup}, and 10 - 20 M_{Jup}, respectively. We estimate the foreground contamination from interloping L and T dwarfs to be only ~2 objects over our entire survey volume.

References

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