Using variability to identify young stars and search for planetary mass companions

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Introduction

- Young main sequence stars are often more intrinsically variable than older main sequence [Pace G, Pasquini L, 2004]. M dwarfs are also known to exhibit more variability [Khodachenko, Makim L, 2007]. Hence a variable M dwarf is likely to be young.

- A Brown dwarf is generally defined as an object between 13 and 80 M_J [David S. Spiegel et al 2011]. However, there is a class of Brown Dwarfs of 13 M_J and below called Sub-Brown dwarfs or planetary mass objects, which form via cloud collapse but don't fuse deuterium [Jose A.Caballero, 2018]. Hence in this project, planetary mass objects are used to refer to our targets.

- Brown dwarfs gradually cool down and contract in size over time and thus change spectral type. Brown dwarfs may start their life as an M-type, then transition to L-T-Y. Thus, a young L/T dwarf is expected to be lower mass, possibly a planetary mass object.

Importance

- Young, planetary mass Brown dwarfs are useful exoplanet analogues for studies in the formation and development of Gas Giants planets and in using spectroscopy to study atmospheres and cloud formation.

- Some L/T type companions are wide orbit exoplanets, such as COCONUTS-2b, a Gas Giant exoplanet with a spectral type of T9.5 ± 0.5, orbiting at 7,506 AU away from its primary M dwarf [Zhoujian Zhang et al 2021]. These objects are also very useful for atmospheric studies, and targets for the search for transiting exosatellites [Mary Anne Limbach *et al* 2021].

References

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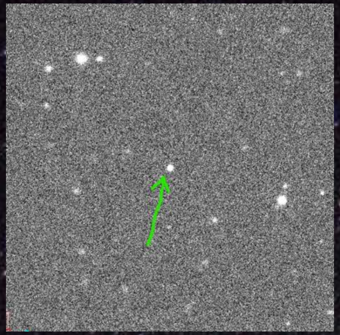

Figure 1: M7-L1 candidate, Z band image from the Dark Energy Survey

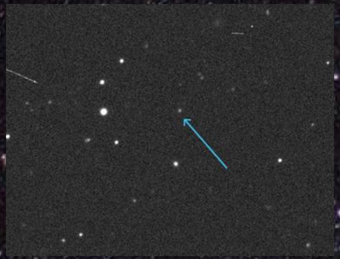

Figure 2: L6-T1 candidate, Z band image from the Dark Energy Survey

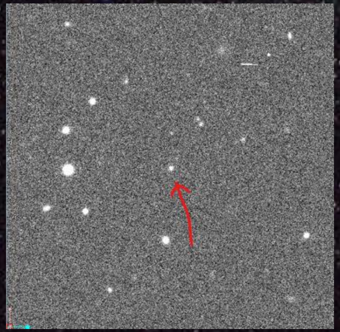

Figure 3: L2-L4 candidate, Z band image from the Dark Energy Survey

Method

- We crossmatch a catalogue of 36,898 M dwarfs [Cook, N.J, Pinfield, D.J 2016] with GAIA DR3, to obtain the parallax, and proper motion values, and calculated the distance in parsecs. We crossmatch those M dwarfs with catalogues of known variable stars [Stellar variability in GAIA DR3 and GAIA DR3: Crossmatch with known variable objects]

- We conduct a cone search of 20,000 AU around each M dwarf and crossmatch every point source with the ALLWISE catalogue.

- We crossmatch these potential companions, with UHS/VHS and Pan-STARRS, to obtain values for magnitudes and colours in the infrared. We use those values to select objects with a colours of an M7 object or cooler.

- Using the data obtained from crossmatching with various catalogues, we estimate; spectral type, significance of proper motion, common distance, and use space density estimates to calculate the chance alignment and the separation distance between the Primary M dwarf star and Brown Dwarf/Planetary mass candidate.

Results

- 3 candidates with: J mag values of 17.2, 20.02, 19.2, photometric spectral type ranges of M7-L1, L6-T1, L2-L4, and separation values of 29244, 1121, 5813 AU away from their primary star. All three candidates have a common distance, common proper motion and low probability of chance alignment.

Next Steps

- (Concurrent): repeat method, but for larger sample size, 440 694 M dwarfs [Cook, N.J, Pinfield, D.J 2016].
- Write observing proposal to SPEX (NASA IRTF) to spectroscopically confirm the companions as either: low-mass stars, Brown dwarfs or even exoplanets, and confirm the M dwarf as a young star.
- Search the TESS archives for lightcurves of the Primary M dwarf and look for any evidence of variability or exoplanet transits.