Searching for Binary Y dwarfs with the Gemini GeMS Multi-Conjugate Adaptive Optics System

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Abstract. The NASA Wide-field Infrared Survey Explorer (WISE) has delivered an exceptional harvest of new ultra-cool Y-type brown dwarfs. We present results from a diffraction-limited study of the binary status of a sample of Y dwarfs observed with the Gemini GeMS Multi-Conjugate Adaptive Optics System. We report no evidence of equal mass/luminosity binaries at separations larger than $\sim$ 0.5-2.0 AU for five Y dwarfs.

1. Introduction

The discovery of the coolest brown dwarfs have extended the spectral classification system to the Y spectral type and enable the study of the properties of objects in the temperature gap between the coolest previously known sub-stellar objects ($T_{eff} \sim 500$ K) and gas-giant planets ($T_{eff} \sim 124$ K). Currently eighteen Y dwarfs are known (Cushing et al. 2011; Kirkpatrick et al. 2012; Tinney et al. 2012; Liu et al. 2012; Kirkpatrick et al. 2013; Cushing et al. 2014; Pinfield et al. 2014), as well as three candidates awaiting spectroscopic confirmation (Liu et al. 2011; Luhman et al. 2011; Luhman 2014) The latest atmospheric models (Morley et al. 2012) are consistent with the majority of these Y dwarfs absolute magnitudes. However, some Y dwarfs (Leggett et al. 2013; Tinney et al. 2014) show disagreements between their luminosities and colors. These inconsistencies suggest either binarity or the presence of condensates clouds. Here we present a diffraction-limited study to determine the binary status of five Y dwarfs using the Gemini GeMS Multi-Conjugate Adaptive Optics System.In Section 2, observations and data reduction are detailed. In Section 3 the binary status of

Y dwarfs is confirmed and luminosity and separation limits for non-detection of companions are determined. Finally in Section 4 a conclusion is established.

2. Observations and Data Reduction

We observed five Y dwarfs: WISE J035934.06–540154.6 (W0359), WISE J053516.80–750024.9 (W0535), WISE J071322.55–291751.9 (W0713), WISE J154151.66–225025.2 (W1541) and WISE J163940.83–684738.6 (W1639). Our images were recorded with the Gemini South Adaptive Optics Imager (GSAOI) and corrected for atmospheric aberrations by the Gemini Multi–Conjugate Adaptive Optics System (GeMS). GSAOI has an image scale of 0.02"/pix and offers access to a field of view of 85"x85". The observations were obtained between March 2013 to January 2014 and delivered a typical FWHM of 85 mas in the CH_4S passband (1.486–1.628 μm). Data processing was performed using a version of the GSAOI pipeline which creates and subtracts averaged dark, flat field and sky frames and then mosaics them to produce a final image (See Fig. .1). Coordinates from the WISE All-Sky Release, photometry and spectral type are displayed in Table .1 for all our targets.

Target	J3 (mag)	Spectral Type	Ref
WISE J035934.06–540154.6	21.40 ± 0.09	Y0	1,3
WISE J053516.80–750024.9	22.09 ± 0.07	≥ Y1	1,3
WISE J071322.55–291751.9	19.42 ± 0.03	Y0	1,3
WISE J154151.65–225024.9	20.99 ± 0.03	Y0.5	1,2
WISE J163940.83–684738.6	20.57 ± 0.05	Y0	1,4

Table .1: Coordinates and photometry from the WISE All-Sky Release for our five targets. Magnitudes in the J3 passband are from [1]Tinney et al. (2014). Spectral type sources are from: [2]Cushing et al. (2011), [3]Kirkpatrick et al. (2012), [4]Tinney et al. (2012).

3. Upper Limits on Binarity

3.1 Looking for Companions

Photometry was performed using the DAOPHOT II package implemented within the Starlink environment. Unsaturated stars were selected and used to determine the Point Spread Function (PSF). Finally this PSF was used to fit and subtract all identified stars within the image. This process did not reveal any companions within the halos of the Y dwarf targets.

3.2 Simulations

Simulations were performed to determine the magnitude and separation limits for the non-detection of companions. We injected synthetic binaries with a variety of separations and

component magnitudes spanning 0.02-0.2 and a flux ratio of 0.2-1.0 into the observations to reproduce each object, where m_1 is the magnitude of the primary, m_2 is the magnitude of the secondary and m_T refers to the magnitude of the system in total. The magnitude and separation limits established by visual confirmation are displayed in Fig. .2

4. Conclusion

We conclude that none of these Y dwarfs are equal mass/luminosity binaries at separations larger than 0.5-2.0 AU. Our best data is for W1639 and W0713 and shows no evidence for binarity to limits $\sim \triangle$m = 2.0 mag in CH_4S at separations beyond 0.5 AU.

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References

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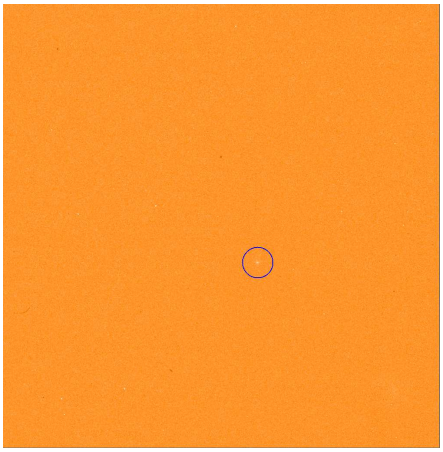
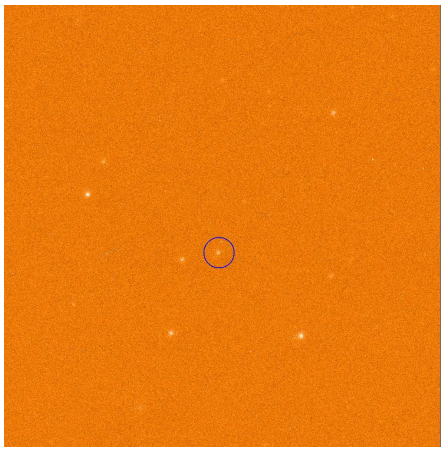


(a) WISE J035934.06-540154.6



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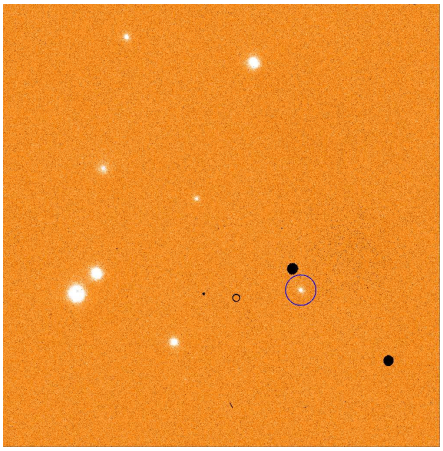
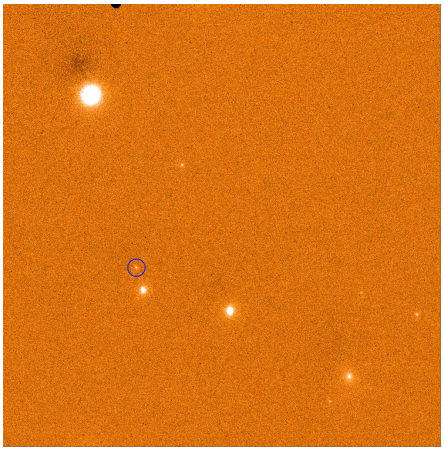
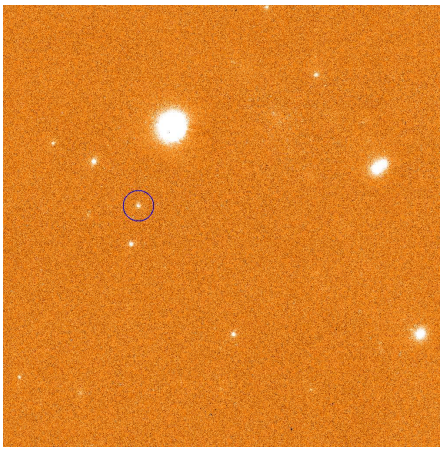


(c) WISE J071322.55-291751.9



(d) WISE J154151.66-225025.2



(e) WISE J163940.83-684738.6

Figure .1: Images of our five Y dwarfs taken in the CH_4S filter after the standard reduction processing. Each image shows a 20"×20" region.

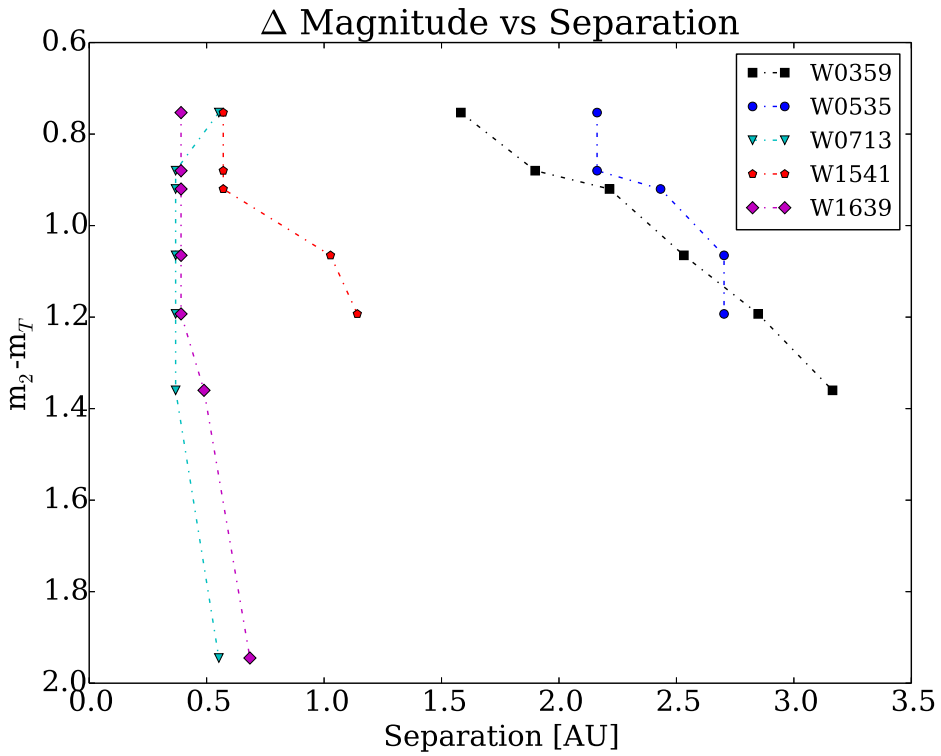


Figure .2: The magnitude and separations limits for six Y dwarfs: W0359, W0535, W0647, W0713, W1541, W1639. m_2 represents the magnitude of the secondary and m_T refers to the magnitude of the system in total.