

Near-infrared Spectroscopy of Brown Dwarf and Planetary-Mass Members in Upper Scorpius

Nicolas Lodieu^{1,2}

¹ Instituto de Astrofísica de Canarias (IAC), Calle Vía Láctea s/n, E-38200 La Laguna, Tenerife, Spain

email: nlodieu@iac.es

² Departamento de Astrofísica, Universidad de La Laguna (ULL), E-38206 La Laguna, Tenerife, Spain

Abstract. In these proceedings, I present new VLT/X-shooter near-infrared spectroscopy of brown dwarf and planetary-mass candidates with masses below 30 Jupiter masses identified in a deep VISTA *ZYJ* survey of 13.5 square degrees in the Upper Scorpius (USco) association. These spectra represent new benchmarks at 5–10 Myr to compare with known and future discoveries of members in nearby moving groups and other young regions.

Keywords. Brown dwarfs — planetary-mass objects — surveys — photometry — spectroscopy

1. The Upper Scorpius association

USco is part of the nearest OB association to the Sun, Scorpius Centaurus, located at 145 pc from the Sun (de Bruijne *et al.* 1997). The combination of its close distance, young age (5–10 Myr; Preibisch & Zinnecker 1999; Pecaut *et al.* 2012; Song *et al.* 2012), and mean proper motion distinct from field stars makes it an ideal ground to search for cool brown dwarfs. Various groups have examined the association in X-rays and at optical and infrared wavelengths to identify bona-fide members. Spectroscopy of hundreds of stars and substellar members is now available, allowing us to characterise in-depth their binary and disk properties. The mass function of the association is very similar to the field mass function, from high-mass stars all the way to the substellar regime (Preibisch & Zinnecker 2002; Lodieu *et al.* 2011).

2. Photometric selection of brown dwarf member candidates

We conducted a deep *ZYJ* survey of 13.5 square degrees of USco with VISTA (Visible and Infrared Survey Telescope for Astronomy) in April/May 2012 in service mode under good conditions (Lodieu *et al.* 2013b). Our VISTA survey is 100% complete down to 22.0, 21.2, and 20.5 mag in *Z*, *Y*, and *J*, respectively. We complemented this dataset with additional *H* and *K* photometry as well as proper motions from the UKIDSS Galactic Clusters Survey (Lawrence *et al.* 2007). We identified 67 bona-fide *ZYJ* candidates in multiple colour-magnitude diagrams (Fig. 1) as well as five *YJ*-only candidates with *J*-band magnitudes in the 14–20 mag range, corresponding to masses between 30 and 5 Jupiter masses according to state-of-the-art atmospheric models. We concluded that the USco mass function in the planetary-mass regime might be flat or decreasing by counting the number of potential members in the 20–10 and 10–5 Jupiter mass bins.

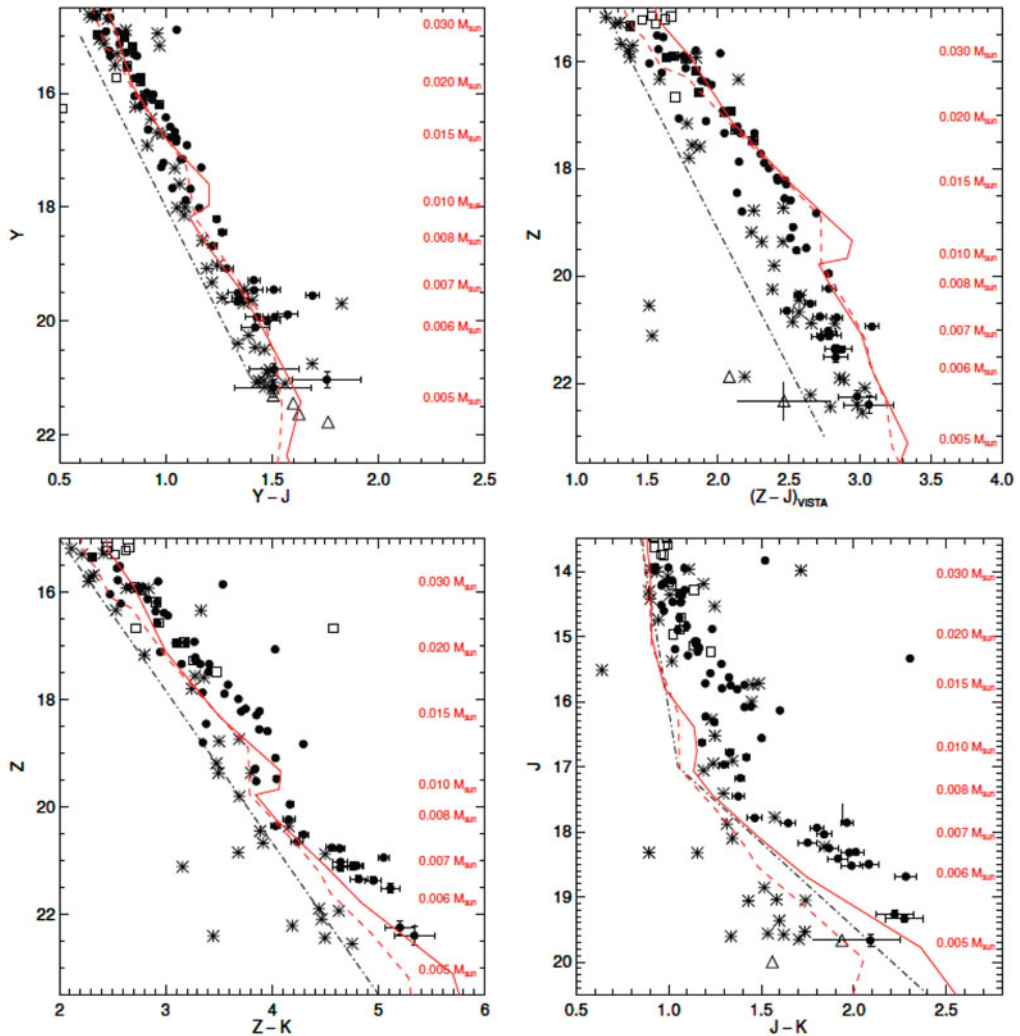


Figure 1. Colour-magnitude diagrams used to identify brown dwarf members of the USco association combining photometry from our deep VISTA ZYJ survey and public HK photometry from the UKIDSS Galactic Clusters Survey (Figure from Lodieu *et al.* 2013b).

3. VLT/X-shooter near-infrared spectroscopy

We obtained near-infrared (1.0–2.4 microns) intermediate-resolution ($R \sim 3900$) spectroscopy with the X-shooter instrument on the Very Large Telescope (VLT) on 10–14 April 2015 in visitor mode. We observed 15 USco candidate members with $J = 17$ –19.5 mag, equivalent to masses below the deuterium-burning limit. Moreover, half of the candidates with $J = 15$ –17 mag (i.e. masses in the ~ 20 –10 Jupiter mass range) identified in our deep VISTA survey are already confirmed members with optical spectral types (Luhman & Mamajek 2012). Those candidates have also VLT/X-shooter spectra available from the European Southern Observatory archive from an independent programme. All spectra show weak alkali lines and peaked H -band, signs of youth (Fig. 2). We also observe a diversity among the near-infrared spectra of these new members. We estimate preliminary spectral types in the L3–L7 range by comparison with known young members of nearby association and clusters (e.g. Lafrenière *et al.* 2010; Zapatero *et al.* 2014).

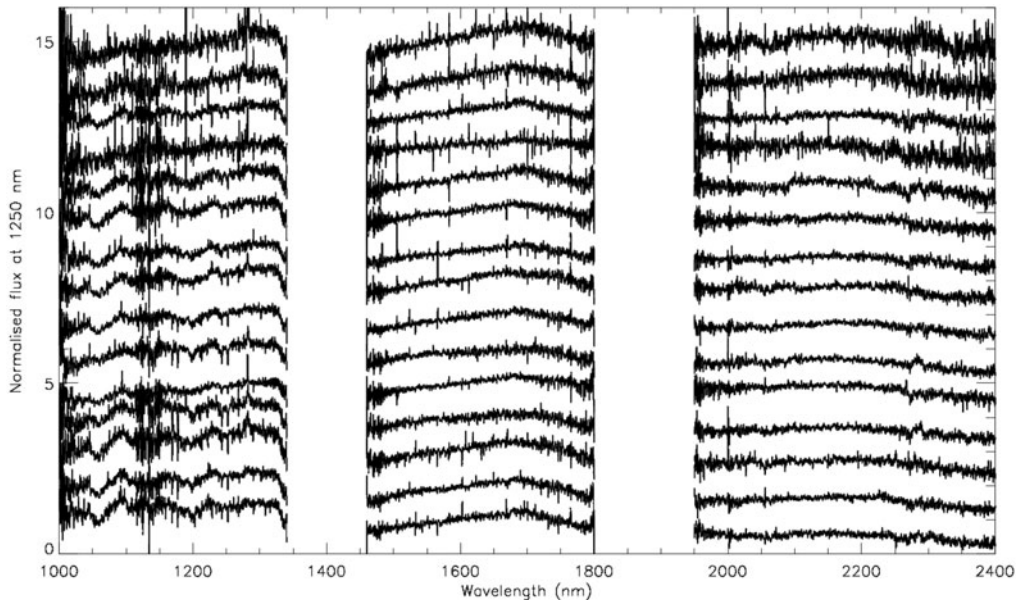


Figure 2. VLT/X-shooter near-infrared of 15 USco member candidates confirmed spectroscopically.

We compared our spectra to intermediate-age and very low gravity members of moving groups, suggesting that the latter might have dusty atmospheres or harbour discs. These results will be presented in more details in a future paper (Lodieu *et al.* 2015, in prep).

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Acknowledgements

My current contract is funded by the Ramón y Cajal fellowship number 08-303-01-02. I also acknowledge funding from an IAC internal project and another project financed by the Spanish Ministry of Economy and Competitiveness (MINECO).

Discussion

L. MALO: You should measure radial velocities before claiming that these sources are members of the USco association

AUTHOR: These candidates are selected in the central region of USco. We selected them photometrically using 5-band photometry (*ZYJHK*) and proper motions. The sequence is well-separated from the field stars in this part of the association not affected by reddening. The weak alkali lines and peaked *H*-band confirm their youth. We are pretty confident that they are bona-fide members of USco. Nonetheless we will attempt to measure radial velocities from our X-shooter spectra comparing with the latest models available to us. This will be presented in a future paper (Lodieu *et al.* 2015, in prep).

M. LIU: Do you observe any difference in the sequence of members that might be due to age spread in the USco association?

AUTHOR: We did not look into this. The VISTA survey covers only 13.5 square degrees in the central part of the association so we do not expect much spread. However, this is a good idea to check using our latest list of member candidates over the full association (Lodieu 2013a) once the map generated by Pecaut & Mamajek is published.