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NEAR-INFRARED SPECTROSCOPIC FOLLOW-UP OF GAIA ULTRA-COOL DWARFS CANDIDATES

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Abstract. Ultra-cool dwarfs are red, cool and low-luminosity objects, with spectral types later than M7. They encompass the stellar-substellar boundary, and their faintness make them an elusive population. In the solar neighbourhood, their census is incomplete, despite representing an important fraction of local objects in the Milky Way. Numerous new ultra-cool dwarfs candidates have been identified thanks to the Gaia survey, and have to be spectroscopically confirmed to complete a census.

We analyse the near-infrared spectra, obtained with the SOFI spectrograph between 0.93 and 2.5 microns (R∼ 600), of 61 ultra-cool dwarf candidates in the solar neighbourhood. We confirm that all are ultra-cool dwarfs from their spectral types, except one. Their near-infrared spectral types are close to what was expected from their photometric spectral types, derived using their absolute magnitude. We find that objects identified in previous surveys have similar published spectral types.

In our UCD sample, we detected binary candidates, from common parallaxes and proper motions. We also find unresolved binaries from features in their spectra, revealing the presence of a cool companion.

Keywords: Brown dwarfs, Stars: late-type, Stars: low-mass, Infrared: stars, surveys

1 Introduction

M dwarfs ($\lesssim 0.6$ M$_\odot$) are the most prominent stars in the Galaxy, and account for $\sim 60\%$ of the stellar budget in the solar neighbourhood (Bochanski et al. 2010; Reid & Gizis 1997; Reyl'e et al. 2021b). Objects with spectral types later than M7, with a temperature lower than 2800 K (e.g Rajpurohit et al. 2013) have been defined as Ultra-Cool Dwarfs (hereafter UCDs) by Kirkpatrick et al. (1999), a name used to designate the less massive stars, as well as brown dwarfs, encompassing the stellar-substellar transition.

UCDs form an elusive population, due to their faintness. Large photometric surveys of objects found red, cold, and low luminosity in colour-absolute magnitude diagrams allow to statistically study UCDs. Thanks to its complete sky coverage, the *Gaia* satellite permits to unveil the optical emissions of UCDs down to a G-magnitude of ~ 20.5. With *Gaia* Data Release 2, Reylé (2018) compiled a set of 14 200 UCD candidates, and additional candidates have been identified within the data release by Smart et al. (2019); Scholz (2020). The DR3 acquired new parallaxes and new candidates (Gaia Collaboration, Smart et al. 2021; Sarro et al. 2023).

The Spectral Energy Distribution of the candidates, together with stellar atmosphere and evolutionary models, permit to estimate their temperatures Filippazzo et al. (2015). Their space-density can be estimated using luminosity functions (Cruz et al. 2007; Reyl'e et al. 2010; Bochanski et al. 2010).

With the acquisition of UCD candidates spectra in the near-infrared, where the objects radiate most of their energy, we can determine their spectral types, and confirm their nature that was estimated from their *Gaia* G-band absolute magnitude. These new spectra also allow improving our understanding of the physics and atmospheric processes occurring in these cool objects, and to search for unresolved binaries.

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2 Method

Using the SOFI spectrometer (Moorwood et al. 1998, NTT, la Silla), we acquire near-infrared spectra of 61 *Gaia* UCD candidates that were found in Reylé (2018); Smart et al. (2019); Scholz (2020). The resulting spectra are low-resolution ($R \sim 600$), within the $0.90 - 2.53\,\mu$m wavelength range.

Using the *SpeX Prism Library Analysis Toolkit* (SPLAT, Burgasser & Splat Development Team 2017), we determine the spectral types of the SOFI spectra by comparing the SOFI spectra to spectra with spectral types already assigned from the SpeX Prism Library (SPL). The library includes standard objects, such as the ones defined by Kirkpatrick et al. (2010), but also peculiar ones : low and very-low gravity objects classified following β, γ indices of Cruz et al. (2009), or low metallicity subdwarfs (Lodieu et al. 2019).

We also search for binaries, by looking for objects with common parallaxes and proper motions (Smart et al. 2019; Reyl'e et al. 2021a), as well as objects showing signs of spectral (unresolved) binarity (Burgasser et al. 2010, 2011; Bardalez Gagliuffi et al. 2014).

3 Results

On Fig. 1, we present the distribution of spectral types of observed objects. We confirm that 57 objects have a spectral type later than M7, and that 3 have a spectral type of M6 or M6.5, compatible with being UCDs. The last object, that was expected to be a M8, is found to be a M4. This unexpected spectral type could be caused by a pointing error, or by a *Gaia* photometry error that led to the selection of this object as a UCD candidate. The overall agreement between the photometric spectral types published by Reylé (2018) and those derived in this study, which agree by less than one subtype, gives confidence in the nature of the objects detected by *Gaia*, even without spectroscopic follow-up.

Amongst the observed objects, two to four objects are potential low-metallicity subdwarfs, as they have blue colours or are similar to already-classified low-metallicity UCDs. We find seven that have common parallaxes and proper motions with brighter objects or other UCDs. One of them is in a binary system with a white dwarf spotted by *Gaia*, *Gaia* DR2 4757030391786232576. We also find spectra that show indices of unresolved binarity. Analysing these spectra following the method proposed by Bardalez Gagliuffi et al. (2014), we find seven sources that are likely to be unresolved UCDs accompanied by even cooler companions, T-dwarfs.

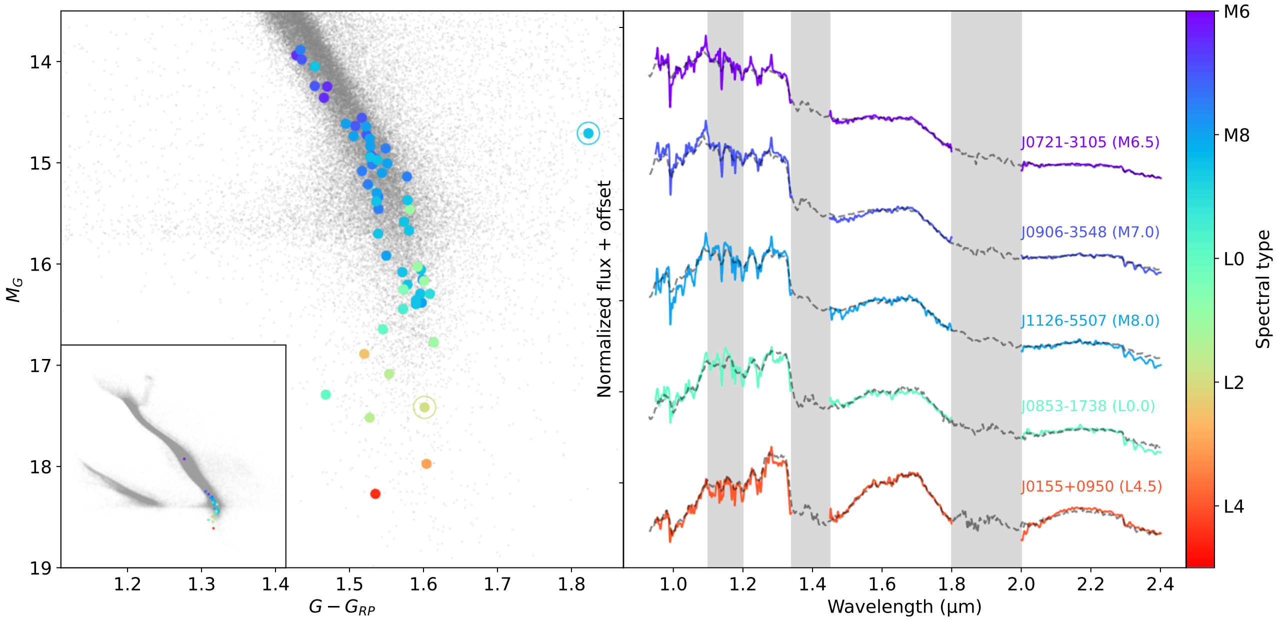

Fig. 1. Left: Observed UCD candidates on a zoomed *Gaia* M_G - $G - G_{RP}$ diagram. UCDs are coloured by their obtained spectral type. The two circled UCDs have peculiar colours due to poor photometry or partially resolved binarity. Right: Example spectra issued from our observed sample, coloured by their spectral type. In dashed grey, we present the best matching standard used to derive the classification. The shaded area are telluric absorption regions of the Earth atmosphere.

This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www. cosmos.esa.int/web/gaia/dpac/consortium). This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France. Based on observations collected at the European Organisation for Astronomical Research in the Southern Hemisphere under ESO programmes 106.214E.001 and 108.22G4.001. This research has been supported by the Centre National d'Etudes Spatiales (CNES) PhD grant 2021-262, and a PhD grant from the Région Bourgogne-Franche-Comté.

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