Wide companions to M and L subdwarfs with Gaia DR2 and the Virtual Observatory

J. González-Payo[1], M. Cortés-Contreras[2], N. Lodieu[3,4], E. Solano[2], Z. Zhang[5], M.C. Gálvez-Ortiz[2]

[1] Universidad Complutense de Madrid (UCM), Madrid, Spain
[2] Departamento de Astrofísica, Centro de Astrobiología (CSIC-INTA), ESAC Campus, Villanueva de la Cañada, Madrid, Spain
[3] Instituto Astrofísico de Canarias (IAC). La Laguna, Tenerife, Spain
[4] Departamento de Astrofísica, Universidad de La Laguna, La Laguna, Tenerife, Spain
[5] School of Astronomy and Space Science, Nanjing University, Nanjing, China

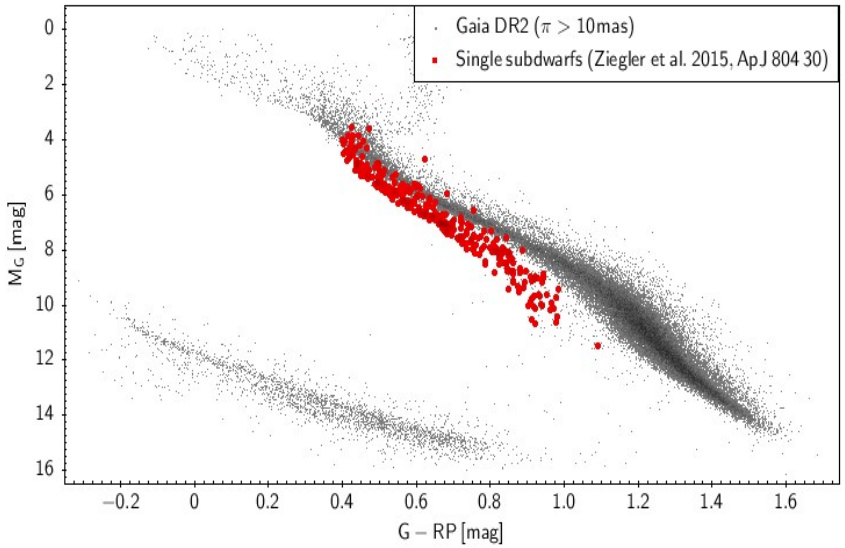
We performed a search for common proper motion companions to a sample of 217 spectroscopically confirmed M and L subdwarfs using Virtual Observatory tools, the Gaia DR2 catalogue and large-scale public photometric and astrometric surveys. After compiling some data from Gaia DR2 and estimating other ones if not available, we present five candidate systems with M primaries and projected physical separations between 0.007 and 2.6 pc.

We found two M+M systems, one confirmed spectroscopically as metal-poor, and one with solar metallicity. We also identified three M+L wide binary systems (just one M+L extreme subdwarf system has been reported to date by *Zhang et al. 2019, 2018MNRAS.479.1383Z*). None of the non-confirmed four systems can be discarded based on current astrometry and photometry, so they require spectroscopy follow-up.

The binary fraction in our sample is of 3.1% among our sample of M subdwarfs with separations between 0.007 and 2.6 pc. We found no companion candidates around the extreme or ultra subdwarfs in our sample.

Context

- Subdwarfs are population II dwarfs which appear bluer than solar metallicity stars due to the dearth of metals in their atmospheres.
- There are different subclasses of subdwarfs based on the metallicity index: subdwarfs (sd), extreme subdwarfs (esd) and ultra subdwarfs (usd).
- The esdM and usdM subdwarfs are usually halo members, and sdM mostly are thick disk members. They belong to the first generations of stars, being important tracers of the chemical enrichment history of the Galaxy.



- Ultracool subdwarfs have effective temperatures under 3100 K (spectral types later than ~M5).
- M dwarfs are prime targets for planet search with the radial velocity and transit methods, which take advantage of the relatively large planet-to-star mass and radius ratios, respectively.
- It has been noticed a direct correlation between the metallicity of a star and the probability of having a planet orbiting around it. However, the estimate of the metallicity of M dwarfs is difficult.
- This work was therefore motivated by the finding of high-mass physically bound companions to our M and L low metallicity sample which metal content is well determined.

Methodology

1. Proper motion and distance compilation/computation
2. Definition of the search radius (r) for each source using a minimum binding energy:

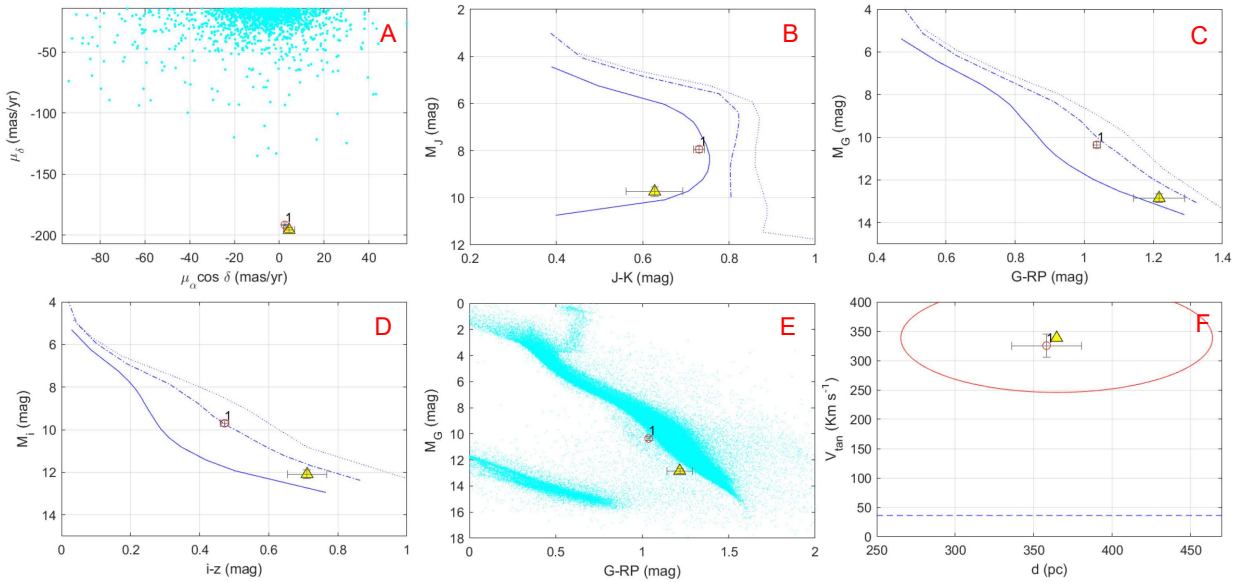
$$W = G\frac{m_1 m_2}{r} = 10^{33} J$$

3. Search of companion candidates applying proper motion and distance criteria:

$$\mu\alpha_{sd} - 3\sigma_{\mu\alpha-sd} \leqslant \mu\alpha_{comp} \leqslant \mu\alpha_{sd} - 3\sigma_{\mu\alpha-sd}$$
$$\mu\delta_{sd} - 3\sigma_{\mu\delta-sd} \leqslant \mu\delta_{comp} \leqslant \mu\delta_{sd} - 3\sigma_{\mu\delta-sd}$$
$$d_{sd} - 3\sigma_{d-sd} \leqslant d_{comp} \leqslant d_{sd} - 3\sigma_{d-sd}$$

4. Analysis of proper motion, colour-magnitude, tangential velocity diagrams, and HRDs
5. SED analysis of the systems using VOSA (*Bayo et al. 2008*)
6. Spectroscopic confirmation, if possible

Results (1/2): Properties of found systems



Example: Pair 148/148-1

- A: Proper motion diagram
- B, C, D: Colour-magnitude diagram
- E: Hertzprung-Russell diagram
- F: Tangencial velocity diagram
- △ Source of our sample
- ○ Companion candidate
- Light blue dots in A represent fiel stars, an in B represent Gaia DR2 sources with p>10 mas
- Blue solid, dashed and dotted lines are *Bt-Settl* isochrones for metallicities -2, -0.5 and 0.0

Physical parameters of the proposed systems

Id	Name	SpT	T_{eff} (K)	Mass ($M_\odot$)	$\mu_\alpha \cos\delta$ (mas/yr)	μ_δ (mas/yr)	Distance (pc)	Separation (pc)	Separation (arcmin)	W (10^{33} J)
11	ULAS J011824.89+034130.4	sdL0.0	2600	~0.075	19.9 ± 29	−33.8 ± 27	176.2 ± 13.7			
11-17	Gaia DR2 2562996857437494528	sdM7.0	3000	~0.090	41.2 ± 1.2	−45.1 ± 0.6	177.1 ± 17.7	0.69	13.4	0.08
71	SDSS J10465793-0137464	dM4.5	3100	~0.170	−25.2 ± 1.0	−9.8 ± 0.8	572.5 ± 175.6			
71-1	Gaia DR2 3802720750608315392	dM0.5	3600	~0.550	−22.4 ± 0.4	−10.1 ± 0.3	860.9 ± 159.7	2.64	15.9	0.30
105	ULAS J124104.75-000531.4	sdL0.0	2600	~0.075	−42.9 ± 8	−26.2 ± 6	196.5 ± 15.3			
105-1	Gaia DR2 3695978963488707072	sdM5.5	3200	~0.120	−36.9 ± 0.3	−20.7 ± 0.1	177.8 ± 3.7	0.62	10.9	0.12
148	Gaia DR2 3720832015084722304	sdM5.5	3000	~0.120	4.4 ± 2.5	−195.9 ± 2	364.6 ± 33.1			
148-1	Gaia DR2 3720832010789680000	sdM1.5	3600	~0.250	2.5 ± 0.4	−191.7 ± 0.3	358.2 ± 22.2	0.007	3.8[a]	36.7
188	ULAS J154638.34-011213.0	sdL5.0	2200	~0.075	−49.9 ± 8.6	−107.1 ± 7.6	61.1 ± 6.0			
188-1	Gaia DR2 4404197733205321216	sdM7.0	3000	~0.090	−52.8 ± 0.2	−122.7 ± 0.1	69.8 ± 0.4	0.16	8.9	0.36

Notes. [a] This value in arcsec.

Results (2/2): Multiplicity conclusions

We found the following results of multiplicity searching in a maximum radius of 3.6 pc in a sample of spectral types between M4.5 and L8.0:

- 2.3% in the whole sample with the pairs separated by 0.007 – 2.64 pc. The pairs have sources with SpT between M4.5 – L5.0
- 3.1% M subdwarfs. Found M4.5 – M5.5 separated 0.007 – 2.64 pc in (our sample was M4.5 – M9.5)
- 0% of L+L pairs in the range L0 – L8
- 0% of L+T pairs in the range L0 – L8: There was one pair previously known not detected in our survey due to the faintness of the T companion.
- 0% of extreme subdwarfs M, and 0% of ultra subdwarfs M

We obtained similar results to described into the found literature, but with different separations. We confirm also a low multiplicity fraction compared to the solar metallicity counterparts.

Impact and prospects for the future

The main results of our study are:

- *Use of Virtual Observatory tools for the search*
- *Search for candidates in Gaia DR2 catalogue*
- *Search for candidates in a very wide separation compared to other works*
- *We identified three NEW possible M+L pairs*

An article with these results is currently in preparation (*González-Payo et al, 2020*) and will be submitted shortly to *Astronomy & Astrophysics* journal.

For the future, we suggest to increase the amount of sources into the sample, including not only ultracool subdwarfs, but ultracool dwarfs, and any type of star with planets.