Gaia EDR3 confirms a red dwarf companion of the nearby F1 star HD 105452 and reveals a new brown dwarf companion of the M4.5 dwarf SCR J1214-2345

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ABSTRACT

There are 88 stars which lack colours, but have measured parallaxes in Gaia EDR3 that place them within 20 pc from the sun. Among them we found two new common parallax and proper motion (CPPM) companions separated from their primaries by about 3 arcsec. The CPPM companion of a nearby \(d = 14.98\) pc F1 star, HD 105452 B, was already imaged with the Hubble Space Telescope and is now confirmed with Gaia data and photometrically classified by us as M4 dwarf. The other CPPM companion, SCR J1214-2345 B orbiting an M4.5 dwarf at \(d = 10.77\) pc, represents the faintest brown dwarf discovery made by Gaia so far. It was also imaged by the VISTA Hemisphere Survey and partly detected in the near-infrared. Our photometric classification led to an uncertain spectral type of T1±3 and needs to be confirmed by spectroscopic follow-up.

Keywords: Parallaxes – Proper motions – binaries: general – brown dwarfs – Stars: distances – solar neighbourhood

INVESTIGATED GAIA EDR3 20PC SUB-SAMPLE

The Gaia Early Data Release 3 (EDR3; Gaia Collaboration et al. 2020) provided parallax measurements for about 1.5 billion stars. Selecting only the nearest stars with the largest parallaxes taking into account their errors, we found 2756 stars with \((Plx + 3 \times e_{Plx}) > 50\) mas comprising the EDR3 20 pc sample. There are 88 stars without \(G-RP\) colour measurements among those 2756 stars. The majority (48) of them are very faint \((19.2 < G_{mag} < 20.9)\) objects in the Galactic plane \(|b| < 9\) deg, where Gaia measurements are problematic. Five objects were according to SIMBAD brown dwarfs with spectral types between L4.5 and L6.5, whereas the remaining 35 represented the fainter components of close common parallax and proper motion (CPPM) pairs in Gaia EDR3. These CPPM pairs with projected separations between 0.7 arcsec and 3.5 arcsec were mostly already known in the Washington Double Star (WDS) catalogue (Mason et al. 2001). They typically contained M dwarf secondaries, but also included an M3+L0 and an L1.5+L4.5 pair. With such small separations, the Gaia EDR3 proper motions of these nearby CPPM pairs disagreed to some extent because of the effect of orbital motion. Only three of the 35 CPPM pairs had no WDS entry. One of them contains the known DQ6 white dwarf (WD) GJ 86 B that did not have a Gaia DR2 parallax. Hence it was not yet included in the Gaia DR2 20 pc WD sample of 139 objects of Hollands et al. (2018, see their Table 4). The other two are described below.

CONFIRMED COMPANION OF A NEARBY F1 STAR

A relatively bright star Gaia EDR3 3489338019474046720, hereafter HD 105452 B \((G_{mag} \approx 11.70, Plx = 66.23 \pm 0.17\) mas, \(pmRA = +23.99 \pm 0.29\) mas/yr, \(pmDE = -59.66 \pm 0.45\) mas/yr), was measured at an angular separation of 3.1 arcsec from the known very bright F1 star (Gray et al. 2006) HD 105452 = Gaia EDR3 3489338019475637760 \((G_{mag} \approx 3.95, Plx = 66.77 \pm 0.18\) mas, \(pmRA = +96.98 \pm 0.18\) mas/yr, \(pmDE = -40.02 \pm 0.21\) mas/yr). Whereas the parallaxes almost agree within their errors, the relatively small proper motions are rather different. The total proper motion difference is about three times larger than the expected effect of orbital motion \((\approx 25\) mas/yr) if we assume a
system mass of two solar masses and a circular orbit in the plane of the sky (cf. Scholz et al. 2018). This may indicate that our simple assumptions are not correct or that the system is already dissolving. Because of the missing colour measurements in Gaia EDR3, HD 105452 B, with its absolute magnitude of $M_G = 10.80$ mag, could be a hot WD similar to Sirius B or a red dwarf.

Fortunately, HD 105452 was selected by Duchêne et al. (2014) as a point spread function (PSF) reference star in their investigation of a debris disk around another star. They mentioned an apparent companion at a separation of 2.2 arcsec, when they observed HD 105452 with the Hubble Space Telescope (HST) advanced camera for surveys (ACS) using the high resolution channel (HRC). Figure 1a shows that this companion, marked as HD 105452 B, appeared relatively bright in the observation with the red F814W filter. Duchêne et al. (2014) noted problems caused by this obviously red companion in their applied PSF subtraction technique with the F814W filter, whereas these problems were less acute with the F435W and F606W filters. We conclude that HD 105452 B is not a WD but a red dwarf. According to Cifuentes et al. (2020, their Table 7), the average absolute magnitude of M4 dwarfs in Gaia DR2 was $M_G = 10.88$ mag. Therefore, we assign a photometric spectral type of M4V to HD 105452 B.

NEW BROWN DWARF COMPANION

The faint CPPM object Gaia EDR3 3489874340630661248, hereafter SCR J1214-2345 B ($G_{mag} \approx 20.58, P_lx = 94.18 \pm 1.08$ mas, $pmRA = +58.67 \pm 1.17$ mas/yr, $pmDE = +53.39 \pm 0.94$ mas/yr), was measured next (separation 3.5 arcsec) to the nearby M4.5 dwarf (Riaz et al. 2006) SCR J1214-2345 = Gaia EDR3 3489874340631095936 ($G_{mag} \approx 12.29, P_lx = 92.89 \pm 0.03$ mas, $pmRA = +44.18 \pm 0.03$ mas/yr, $pmDE = +84.32 \pm 0.04$ mas/yr). The parallaxes of this CPPM pair are in good agreement, and the total proper motion difference is not so large as in case of HD 105452 AB - only about 60% larger than the expected orbital motion effect of about 20 mas/yr for an assumed system mass of only 0.5 solar masses. An $RP$ magnitude was not given in Gaia EDR3, whereas the $BP \approx 20.4$ mag should be taken with caution as it was based on only two measurements and probably affected by the close primary.

Optical and near-infrared images of SCR J1214-2345 can be found in the VISTA Hemisphere Survey (VHS; McMahon et al. 2013). The extracted $1\times1\text{arcmin}^2 YJK_s$ images centered on the Gaia EDR3 position of SCR J1214-2345 B are shown in Figure 1b. The small proper motion can hardly be seen because of the epoch difference of less than two years. The VHS catalogue lists only $K_s = 12.83$ mag (AperMag3), but no $YJ$ magnitude measurements for SCR J1214-2345 B, although one can see its fainter counterparts in the images, where we also marked a background star with similar $K_s$ but brighter $YJ$ magnitudes for comparison. Using the relations between absolute magnitudes and spectral types given in Reylé (2018) led to a spectral type of T4-T5 from $M_G = 20.45$ mag but only L8 from $M_{K_s} = 12.70$ mag. Therefore, we can only provide a very uncertain photometric classification of SCR J1214-2345 B as T1±3 dwarf. However, it is an important addition to the 20 pc census of LTY dwarfs of Kirkpatrick et al. (2020) and the faintest new brown dwarf discovery from using Gaia data so far (cf. Scholz 2020).

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Figure 1. a) HST ACS/HRC images of HD 105452, used as PSF star in Duchêne et al. (2014), from the original observing program 10244 of Mark Wyatt (PI) extracted from https://archive.stsci.edu/hst/preview/. The three exposures with different filters (left: F435W, middle: F606W, right: F814W) were obtained with a coronographic mask of 1.8 arcsec. The positions of two objects detected in Gaia EDR3 are overplotted with blue open circles. In the left panel, their separation and $G$ magnitudes are overlaid. The red arrows in the right panel illustrate the proper motions of the two components over the time baseline of about 11 years, which are consistent with the Gaia EDR3 measurements and probably indicate orbital motion. b) from left to right: VHS $Y$, $J$, and $K_s$-band images (epoch 2014.3) centered on the Gaia EDR3 position (epoch 2016.0) of SCR J1214-2345 B. The VHS catalogue position of SCR J1214-2345 B is only 137 mas away from its Gaia EDR3 position and consistent with its proper motion. The measured VHS (AperMag3) magnitudes of SCR J1214-2345, SCR J1214-2345 B, and a background star are marked. However, 2MASS $J$ and $K_s$ magnitudes of (the unresolved) SCR J1214-2345 are given, because its VHS catalogue magnitudes appeared much too faint.

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