2MASS J15460752-6258042: a mid-M dwarf hosting a prolonged accretion disc

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ABSTRACT
We report the discovery of the oldest (∼55 Myr) mid-M type star known to host on-going accretion. 2MASS J15460752-6258042 (2M1546, spectral type M5, 59.2 pc) shows spectroscopic signs of accretion such as strong Hα, Hei, and [Oi] emission lines, from which we estimate an accretion rate of ∼10⁻¹⁰ M⊙ yr⁻¹. Considering the clearly detected infrared excess in all WISE bands, the shape of its spectral energy distribution and its age, we believe the star is surrounded by a transitional disc, clearly with some gas still present at inner radii. The position and kinematics of the star from Gaia DR2 and our own radial velocity measurements suggest membership in the nearby ∼55 Myr-old Argus moving group. At only 59 pc from Earth, 2M1546 is one of the nearest accreting mid-M dwarfs, making it an ideal target for studying the upper limit on the lifetimes of gas-rich discs around low mass stars.

Key words: accretion, accretion discs – stars: late-type – stars: pre-main-sequence – open clusters and associations: individual

1 INTRODUCTION
Stars inevitably harbour discs in the early stages of the star formation process and the lifetime of such discs is one of the most important parameters for understanding early stellar evolution. Moreover, because gas giant planet formation must occur while the disc is gas-rich, the disc lifetime is also a crucial parameter in planet formation scenarios. By surveying young (2–30 Myr) clusters, Haisch et al. (2001) showed the lifetime of gas-rich discs is ∼2 Myr and ongoing accretion is rare beyond ages of ∼10 Myr. Mamajek (2009) noted that the disc dissipation timescale should be dependent on the mass and hence spectral type (temperature) of the host star, and Ribas et al. (2015) showed that high-mass (>2 M⊙) stars dispersed their discs up to twice as fast as lower mass stars.

Recently, several examples of circumstellar disc accretion at ages greater than ∼10 Myr have been identified (e.g., PDS 66- 20 Myr; Mamajek et al. 2002, HD 21197- 30 Myr; Moór et al. 2011, 49 Ceti- 40 Myr; Zuckerman & Song 2012, WISE J080822.18-644357.3- 45 Myr; Silverberg et al. 2016; Murphy et al. 2018, J0446A & B, J0949A & B; Silverberg et al. 2020), and they have been treated as unusual anomalies without delving into the problem of prolonged gas accretion at extreme ages. In spite of the small number of cases, such old pre-MS stars hosting accretion discs can be challenging to the hypothesis for the rapid planet formation (Pfalzner & Bannister 2019; Manara et al. 2018; Najita & Kenyon 2014; Greaves & Rice 2010) and provide the upper limit on the life times of gas-rich discs.

The young M5 star 2MASS J15460752-6258042 (hereafter 2M1546) was serendipitously found by us in a survey of low-mass moving group candidate members from Gaia DR2 (Lee et al. in preparation). 2M1546 was first observed spectroscopically and classified as a T Tauri star with strong Hα emission by Miszalski & Mikołajewska (2014) during their survey for new symbiotic stars selected from the AAO/UKST SuperCOSMOS Hα Survey. In this work, we analyse optical spectra of 2M1546, its IR excess and spectral energy distribution, and evaluate its age based on the kinematic membership of nearby young moving groups. From this analysis we conclude that 2M1546 is the oldest (55 Myr) and one of the nearest (59 pc) accreting M-type stars discovered to date.

2 SPECTROSCOPIC OBSERVATIONS AND DATA ANALYSIS
We observed 2M1546 using the Wide Field Spectrograph (WiFeS; Dopita et al. 2007) mounted on the ANU 2.3-m telescope at Siding Spring Observatory during June 2018
and February 2019. A summary of these observations is given in Table 1. The B3000 and R7000 gratings provided wavelength coverage of 3500–6000 Å ($\lambda/\Delta \lambda \sim 3000$) and 5300–7000 Å ($\lambda/\Delta \lambda \sim 7000$), respectively. The raw data were reduced using the PYTHON-based data reduction pipeline, Py-WiFeS (Childress et al. 2014). The reduction process includes bad pixel repair, bias, and dark current subtraction, flat fielding, wavelength calibration, flux calibration, and data cube creation. The wavelength calibration was performed using a series of Ne-Ar arc lamp exposures, taken throughout the night.

We compared the R7000 spectrum against the M-type spectral templates of Bochanski et al. (2007) that were generated by utilizing more than 4,000 M-dwarfs spectra from the Sloan Digital Sky Survey (SDSS; York et al. 2000). Visual comparison of the 2M1546 spectra against a set of M-dwarf template spectra shows the best match at M5. 2M1546 is located well outside of any molecular cloud and, at a distance of only 60 pc, it should have negligible interstellar extinction. Nevertheless, the accretion causes “veiling”, in which the accretion shock increases flux in the UV/optical, while the surrounding accretion disc produces additional flux to the photosphere in the IR (Vacca & Sandell 2011). Veiling can potentially affect our spectral type estimation because it will change the spectral shape (Herczeg & Hillenbrand 2008; Manara et al. 2013; Ingleby et al. 2014). However, in the case of the spectral shape due to veiling occurs usually over a wide wavelength range while our spectral type estimate is focused on rather narrow wavelength ranges of 100 to 200 Å (e.g., shaded regions of 1). Therefore, our estimate of M5 spectral type should not be far from the truth and appropriate for the discussion in this paper. A more robust, unambiguous spectral type estimate can be done in the future by using a high spectral resolution echelle spectrum by measuring line ratios of some temperature sensitive lines that are adjacent in wavelengths so that veiling effect can be negligible.

The Li 6708 Å absorption feature was strongly detected in both epochs of WiFeS spectra (EW of 430 and 600 mÅ). Considering a typical equivalent width measurement uncertainty (~50 mÅ) in our WiFeS spectra, the observed difference is likely a real variability of the Li 6708 line strength and related to a variable veiling. For an M5 star, the detected Li 6708 line strength indicates the undepleted level of Lithium in the atmosphere while a “normal” 55 Myr old M5 star should have depleted all Lithium already. An ongoing accretion must have replenished Lithium in the atmosphere so that the 6708 line was strongly detected in our observation.

### Table 1. Summary of ANU 2.3-m/WiFeS observations of 2M1546.

| UT date       | MJD      | Grating | SpT | RV (km s$^{-1}$) | $v_{\text{H}$
|              |          |         |     |                 | $\alpha$
|              |          |         |     | (km s$^{-1}$)   | [O\textsc{i}] 1\text{6678} | Li\textsc{i} 1\text{6708} |
|---------------|----------|---------|-----|------------------|----------------|----------------|
| 2018 Jun 4    | 58273.581 | R7000   | M5  | -4.4±0.9         | 366            | -210           | -1.6           | -3.6           | 0.43          |
| 2019 Feb 15   | 58529.685 | R7000 & B3000 | M5 | -3.5            | 310            | -120           | -0.8           | -3.8           | 0.60          |

*a Negative values are in emission.

2.1 Emission Lines

The magnetospheric accretion of the disc occurs from the inner edge of the disc onto the surface of the central source. This supersonic flow has nearly free-fall velocities, resulting in large line widths of some emission lines. In the region of the accretion shock, on the other hand, some narrow emission lines are more likely produced (Hartmann et al. 2016). The strength and/or shape of some lines such as hydrogen recombination lines and He i, Ca II, and Na I lines are known as accretion tracers (see e.g., Muzerolle et al. 1998; Antonucci et al. 2011; Biazzo et al. 2014). The observed spectra of 2M1546 cover Hα and He i lines.

Both WiFeS observations show strong Hα emission, with equivalent widths in excess of 100 Å. However, because of the contrast effect caused by the depression of the stellar continuum by molecular absorption, the equivalent widths of Hα lines (EW(Hα)) in non-accreting stars are typically enhanced at later spectral types (White & Basri 2003; Martin et al. 1998; Basri & Marcy 1995). Barrado y Navascues & Martín (2003) presented an EW(Hα) accretion criterion as a function of spectral type, where the upper limit for accretors is EW(Hα) ~ -20 Å at M5. This was corroborated by Duchêne et al. (2017) after an extensive analysis of known T Tauri stars. With equivalent widths of ~210 Å and ~120 Å, 2M1546 clearly exceeds this criterion.

Although the contrast effect is considered, the evaluation of accretion based on Hα strength has a caveat. The chromospheric activity—typically enhanced for young stars—generates a strong Hα emission similar to the case of accretion. The line profile of Hα is used for distinguishing between accreting and nonaccreting objects: disc accretion generates broad and asymmetric Hα lines (Luhman et al. 2007). Fig. 2 shows the Hα velocity profiles for 2M1546, which are asymmetric in both two observations. The asymmetric feature can be explained by the inclination effects and/or absorption by an accompanying outflowing wind (Mohanty et al. 2005; Alencar & Basri 2000). A quantitative diagnostic value using Hα emission line profile is the full width of Hα at 10 per cent of the line peak ($v_{10}$) (White & Basri 2003; Mohanty et al. 2005). However, the broadened Hα line profile is not always explained by the accretion. Fast rotator and binarity can broaden the Hα emission line, which can be misdiagnosed as an accretor (Manara et al. 2013). In the opposite way, the inclination of the accretion disc can produce a narrower emission line along the line of sight, which can be misdiagnosed as a nonaccretor (Mohanty et al. 2005). Published $v_{10}$ accretion criteria vary from 200 < $v_{10}$ < 270 km s$^{-1}$ (Fang et al. 2013; Jayawardhana et al. 2003; White & Basri 2003), independent of spectral type. Measured $v_{10}$ values for 2M1546 are over 300 km s$^{-1}$ (Table 1), which exceeds the strictest accretion criterion (i.e., >270 km s$^{-1}$). Using the $v_{10}$ value and the accretion rate ($\dot{M}_{\text{acc}}$) relation...
of Natta et al. (2004), we estimate $M_{\text{acc}} = 1.3 \times 10^{-10} M_\odot$ yr$^{-1}$. Considering many M-type pre-MS stars found to have accretion rates as low as $\sim 2 \times 10^{-12} M_\odot$ yr$^{-1}$ (Alcalá et al. 2014; Herczeg et al. 2009), the rate we infer for 2M1546 suggests it is actively accreting from its inner disc.

From our SED fitting, we obtain the bestfit stellar radius ($0.461 R_\odot$), effective temperature (2940 K), and luminosity ($0.014 L_\odot$). We alert readers that this SED fitting ignores any effects from veiling and self-extinction so that they should be taken with caution. Based on Baraffe et al. (2015), these values are inconsistent with values from a 55 Myr old M5 star. These bestfit SED parameters are instead well matched for parameters of a 10 Myr old mid-M type star with mass of 0.1 $M_\odot$. For this mass, a typical mass accretion rate is expected to be $1.0 \times 10^{-10} M_\odot$ yr$^{-1}$ (Hartmann et al. 2016) which agrees well with our obtained accretion rate. As shown in the following section, 2M1546 is a highly likely member of the 55 Myr old Argus association. When a star has prolonged accretion, then it may be conceivable that such a star has stellar parameters of a younger star because of the accretion effect on its evolution. One needs higher spectral resolution data to confirm this possible effect of accretion by independently obtaining a spectral type not affected by veiling.

Emission in He$\alpha$ 6678 is also reasonably well correlated with accretion among very low mass stars and brown dwarfs (Mohanty et al. 2005; Alcalá et al. 2014, 2017). Gizis et al. (2002) showed that He$\alpha$ 6678 is generally present in low levels ([EW(He$\alpha$)]$<1$ Å) in older chromospherically-active stars. 2M1546 shows strong He$\alpha$ 6678 emission at both epochs (EWs of $-0.8$ Å and $-1.6$ Å), supporting the hypothesis of ongoing accretion (See Table 1 and Fig. 4). In addition to strong He$\alpha$, we also detect other Balmer line emission up to H17 (Fig. 3).

As shown in Figs. 1 and 4, we detect strong [O$\i$] emission at 6300 Å at both epochs. Studies investigating the prominent [O$\i$] 6300 emission toward young stellar objects suggest that jets, MHD winds, photoevaporative winds, and photodissociation of OH in the disc surface layers are the possible origins of the line (e.g., Banzatti et al. 2019; Natta et al. 2014; Rigliaco et al. 2013; Acke et al. 2005; Störzer & Hollenbach 2000). Störzer & Hollenbach (2000) predicts that [O$\i$] 6300 is dominated by OH photodissociation in the region with a line ratio [O$\i$] 6300/[O$\i$] 45577 smaller than 10. Our spectra show a potentially weak (1 Å) detection of [O$\i$] 45577 which results in the line ratio of about 3. This small line ratio favours the other explanations for the origin of OI emission such as from winds and/or jets.
3 CIRCUMSTELLAR DISC EMISSION

Dust emission from the circumstellar disc is observed as the IR excess of the spectral energy distribution (SED). The SED of 2M1546 was generated utilizing catalogue data from POSS-II (JFN; Cabanela et al. 2003), SkyMapper DR1 (griz; Wolf et al. 2018), Gaia DR2 (GBP, GRP, G), 2MASS (JHKs; Cutri et al. 2003), and AllWISE (W1 – W4; Cutri et al. 2014). Examinations of high angular resolution optical/near-IR images show no possible contaminating source within the spatial resolution of WISE images. Therefore, we conclude that there is no contamination and these photometric data are only from 2M1546. We fit synthetic photometry derived from BT-Settl (Allard et al. 2012) using our SED fitting technique described in Rhee et al. (2007). The resulting SED and the best-fitting model are presented in Fig. 5.

The best-fitting temperature ($T_{\text{star}} = 2940$ K) is consistent with the pre-MS temperature scale for young (10–30 Myr) stars derived by Pecaut & Mamajek (2013) for a spectral type of M5. We can satisfactorily fit the WISE W3 (12 µm) and W4 (22 µm) excesses with a single blackbody of temperature $T_{\text{dust}} \sim 200$ K. With little excess emission at $\lambda < 5$ µm and a significant excess at $\lambda > 10$ µm we classify 2M1546 as having a transitional disc (Strom et al. 1989; Williams & Cieza 2011), with clearly some material in the inner disc remaining to drive the accretion we observed.

Murphy et al. (2018) investigated the disc surrounding the M5 Carina member WISE J080822.18-644357.3 (hereafter WISE J0808), which has a similar SED and accretion characteristics to 2M1546. They found a cold disc component which was well fitted by a ~240 K blackbody resulting from populations of small dust grains released by sublimating planetesimals. Flaherty et al. (2019) recently observed WISE J0808 with the Atacama Large Millimetre/sub-millimetre Array (ALMA) but did not detect any CO gas, indicating WISE J0808 may be at an evolutionary state between a gas-rich transition disc and a gas-poor second-generation debris disc. Considering the
similarities between WISE J0808 and 2M1546, the latter is also probably a borderline transition/debris disc accreting the last of its inner gas on to the star. More observations, including from ALMA, are required before definitively assessing the evolutionary stage of the disc around 2M1546.

4 AGE ESTIMATION BASED ON MOVING GROUP MEMBERSHIP PROBABILITY

One of the key parameters for constraining disc models is stellar age and, for young nearby stars within 150 pc, one of the most reliable age-dating methods is to test whether the star is a member of one of several young moving groups in the solar neighborhood with well determined ages (e.g. Zuckerman & Song 2004; Torres et al. 2008). Although the absolute age scales from these moving groups should not be overinterpreted, relative age ordering of several major moving groups is secure and can be used to derive ages of member stars at much higher precision than possible for an isolated star. The relative age rank for major moving groups are: TWA < BPMG < Columba/Carina < Argus < AB Dor (Zuckerman & Song 2004; Torres et al. 2008; Gagné et al. 2014; Bell et al. 2015). We note that the existence of the Argus group was challenged by Bell et al. (2015) and Riedel et al. (2017), but Zuckerman (2019) reaffirm the Argus moving group.

There are several moving group membership probability calculation tools available in the literature (e.g. BANYAN II & Σ and BAMG 1 & 2; Gagné et al. 2014, 2018; Lee & Song 2018, 2019). The main differences between these tools are their internal membership lists and how they calculate the structural properties (mean XYZ positions, UVW velocities and their distributions) of each moving group. BAMG 2 is the most recent code for calculating kinematic memberships and was developed to be self-consistent with respect to group memberships (Lee & Song 2018). For this reason we adopt membership probabilities from it over those from other tools.

Table 2 presents membership probabilities using our two measured RV values. BAMG 2 evaluates 2M1546 as an Argus member while the two BANYAN models provide a very small Argus membership probability, with the star most likely being a field object. If 2M1546 was an old field star, then its ongoing accretion is even more interesting yet more challenging to understand. If an isolated accreting pre-MS star, then 2M1546 belongs to a rare group of nearby (<60 pc) youngest stars such as some accreting TWA members. Fig. 6 compares the heliocentric position (XYZ) and velocity (UVW) of 2M1546 to the moving group models used by BAMG 2. The position and velocity of 2M1546 are well matched to the ~55 Myr-old Argus group, as expected from the membership probabilities in Table 2.

5 DISCUSSION AND CONCLUSIONS

We summarize the important properties of 2M1546 from the literature and this work in Table 3. The proximity (59 pc), late spectral type (M5), old age (55 Myr), mid-IR excess emission, and ample evidence of on-going accretion observed in 2M1546 make it an interesting laboratory for studying prolonged disc accretion. It is the oldest known accreting star to date, and can therefore be used for studying the upper limit on the lifetimes of gas-rich discs. The kinematic properties of the star are consistent with the Argus moving group and its estimated age of ~55 Myr.

Over the past several years, several mid-M type accretors at various ages have been reported in the literature (Table 4). All of the stars in Table 4 show strong mid-IR excess emission at W3 and W4 and signs of ongoing accretion. Among these sources, WISE J0808 appears to be the most similar to 2M1546, with v10 velocity widths in excess of 300 km s−1. 2MASS J1239–5792 and 2MASS J1422–3623 have slightly weaker Hα equivalent widths and v10 values comparable to 2M1546. However, they are believed to be younger (10–17 Myr) members of LCC or UCL subgroups of the Sco-Cen OB association (Murphy et al. 2015). While LDS 5606A+B are also actively accreting sources, they are binaries and hence their accretion might have been affected by their companions. 2MASS J1337–4736 is claimed to be accreting based on its asymmetric Hα profile and WISE excess (Rodriguez et al. 2011; Schneider et al. 2012b). Zuckerman (2015) found that this star has a distant companion. While not having a measured v10 value, TWA 31 has a strong EW(Hα) value and significant excess at W3 and W4, supporting an accretion hypothesis (Schneider et al. 2012a; Zuckerman 2015). The remaining three stars seem to show marginal signs of accretion. 2MASS J0844–7833 and 2MASS J0508–2101 barely exceed the lower limit for accretion criterion in terms of v10 and/or EW(Hα). Compared to other accretion sources, 2MASS J0501–4337 also has a significantly lower EW(Hα) and a v10 width that barely exceeds the accretion criterion of Barrado y Navascués & Martín (2003).

With the exception of WISE J0808, the inferred ages for these stars are all smaller than the age of the β Pic Moving Group (≤ 25 Myr). Therefore, the slightly prolonged accretion at these stars could have been accepted as an unusual phenomenon seen in some rare outliers. Now, we see at least a handful of adolescent mid-M type stars with clear signs of ongoing accretion, suggesting that accretion can be maintained for several tens of million years around low-mass stars under certain conditions. The discovery of these older M-type accretors could eventually reveal a less efficient process of removing circumstellar gas and dust around low-mass stars. We note that the plethora of M5 accretors at ages of 30–55 Myr coincides with the mass boundary at which stars become fully convective in their interiors.

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Table 2. Kinematic membership probabilities.

| Membership probability: Group (per cent) | RV (km s$^{-1}$) | SpT | X (pc) | Y (pc) | Z (pc) |
|------------------------------------------|------------------|------|--------|--------|--------|
| 100 per cent                             | $-4.4 \pm 0.9$   | M7   | 45.9, -36.7, -6.7 | 15.8, -13.1, -5.7 | k m s$^{-1}$ |
| 50 per cent                              | $-3.5 \pm 1$     | M5   |         |        |        |

Note. Since only groups with membership probabilities >2 per cent are presented here, the sum of probabilities is smaller than 100 per cent.

Figure 6. Accreting mid-M type stars and models of NYMGs in the XXYZUVW spaces.

Table 3. Summary of 2M1546 parameters.

| Parameter         | Value | Units |
|-------------------|-------|-------|
| R. A.             | 15:46:07.52$^a$ | hh:mm:ss.ss |
| Dec.              | -62:58:04.2$^a$  | dd:mm:ss.s |
| SpT               | M5     |       |
| $\mu_{\alpha}\cos\delta$ | $-42.7 \pm 0.1$  | mas yr$^{-1}$ |
| $\mu_{\delta}$    | $-61.5 \pm 0.1$  | mas yr$^{-1}$ |
| Distance          | 59.2 $\pm$ 0.3 | pc     |
| RV                | $-4.4$, $-3.5$ | k m s$^{-1}$ |
| $T_{\text{eff}}$  | 2940   | K      |
| $\log(L/L_\odot)$| $-1.83$ | dex    |
| $M_{\text{acc}}$  | $1.31^{-10}$ | M$_\odot$ yr$^{-1}$ |
| Mass              | 0.11   | M$_\odot$ |
| Age               | 55     | Myr    |
| $X, Y, Z$         | 45.9, -36.7, -6.7 | pc |
| $U, V, W$         | $-16.5, -12.5, -5.0$ | k m s$^{-1}$ |
|                  | $-15.8, -13.1, -5.7$ | k m s$^{-1}$ |

$^a$ Gaia Collaboration et al. (2018)

$^b$ Using RV = $-4.4$ km s$^{-1}$

$^c$ Using RV = $-3.5$ km s$^{-1}$

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Table 4. Accreting mid-M type stars from the literature.

| Name                  | SpT  | Dist. (pc) | RV (km s⁻¹) | EW(Hα) (Å)  | v纮(Hα) (km s⁻¹) | Age from Lit. (Myr; group) | Age from this work* (Myr; group) | Refs. |
|-----------------------|------|------------|--------------|-------------|------------------|---------------------------|---------------------------------|-------|
| 2MASS J08440915−7833457 | M4.5 | 98         | −            | 60          | 212              | 8−14 (η Cha)              | 7−13 (TWA)                      | 1     |
| TWA 31                | M4.2 | 81         | 10.5±0.4     | 115         | −                | 7−13 (TWA)                | 7−13 (TWA)                      | 2     |
| 2MASS J13373839−4736297 | M3.5 | 126        | −            | 13.7        | −                | 10−17 (LCC)               | 10−17 (LCC)                     | 3, 4  |
| 2MASS J13293212−5702400 | M5   | 180        | 16±2         | 27−63       | 238−331          | 10−17 (LCC)               | 10−17 (LCC)                     | 5     |
| 2MASS J14224981−3623009 | M5   | −          | 9±2          | 33−91       | 236−341          | 10−16 (UCL)               | 10−16 (UCL)                     | 5     |
| 2MASS J05082729−2101444 | M5   | 49         | 24.9±0.9     | 25          | 197              | 12−25 (BPMG)              | 30−44 (Columbia)                | 1     |
| LDS 5606 A            | M5   | 84         | 14.9±0.8     | 99−135      | 250              | 12−25 (BPMG)              | 30−44 (Columbia)                | 6, 7  |
| LDS 5606 B            | M5   | 84         | 14.9±0.4     | 25          | 135              | 12−25 (BPMG)              | 30−44 (Columbia)                | 6, 7  |
| 2MASS J05010082−4337102 | M4.5 | −          | −            | 7.6         | 210              | 30−44 (Columbia)          | 30−44 (Columbia)                | 8     |
| WISE J080822.18−644357.3 | M5   | 90±1      | 22.7±0.5     | 65−125      | 300−350          | 30−49 (Carina)            | 30−49 (Carina)                  | 9     |
| 2MASS J15460752−6258042 | M5   | 59−4.4,−3.5| 120−210      | 310−366     | −                | 30−44 (Carina)            | 30−44 (Carina)                  | 9     |
| J0446A                | M6   | 82         | 26.7±16.8    | 10.4        | 210              | 30−44 (Carina)            | 30−44 (Carina)                  | 11    |
| J0446B                | M6   | 82         | 29.8±16.8    | 16.8        | 239              | 30−44 (Carina)            | 30−44 (Carina)                  | 11    |
| J0949A                | M4   | 79         | 22.4±16.7    | 110         | 367              | 30−49 (Carina)            | 30−49 (Carina)                  | 11    |
| J0949B                | M5   | 78         | 20.5±16.8    | 24          | 305              | 30−49 (Carina)            | 30−49 (Carina)                  | 11    |

* Ages are obtained based on the moving group membership probabilities calculated using BAGM 2 except where marked.

b η Cha, LCC, and UCL are not included in BAGM 2. BANYAN Σ suggests that 2MASS J0844−7833, J1337−4736, J1329−5702, and J1422−3623 are likely members of η Cha (P = 62 per cent), LCC (P = 63 per cent), LCC (P = 52 per cent), and UCL (P = 84 per cent), respectively.

c Since a Gaia proper motion for this star not exist, the Bayesian membership probability cannot be calculated.

d Kinematic distance based on membership in Carina (Murphy et al. 2018).

Notes. References for group age: η Cha- Bell et al. 2015; TWA-Bell et al. 2015; LCC- Song et al. 2012, Pecaut & Mamajek 2016; UCL- Song et al. 2012, Pecaut & Mamajek 2016; BPMG- Song & Zucker 2003, Bell et al. 2015; Columbia- Torres et al. 2008, Bell et al. 2015; Carina- Torres et al. 2008, Bell et al. 2015, Zucker et al. 2015

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