Supplemental Material: The Character of M Dwarfs

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Abstract

This supplementary material to *The Character of M Dwarfs* includes three useful related items: (1) dossiers of the three nearest M dwarfs to the Sun, (2) a Table of 19 M dwarf spectral standards on the RECONS system, and (3) values for the luminosity and mass functions shown in Figure 4 of the main article.

1. SUPPLEMENTAL TEXT: DOSSIERS ON THE THREE NEAREST M DWARFS

1.1. Proxima Centauri

The nearest star to our Solar System, and most famous M dwarf is, of course, Proxima Centauri (GJ 551, M5.0V), the tertiary in the α Centauri system (A is type G2V and B is type K1V), found at a distance of only 1.3 pc. At $V = 11.13$, Proxima is not particularly bright, but given that it is the most local of all stars in the solar neighborhood, it has been the subject of scrutiny in both scientific studies and science fiction — a recent example of the latter is the eponymous novel *Proxima* by Stephen Baxter (2013). Proxima was discovered to be a "Faint Star of Large Proper Motion" just over a century ago by Innes (1915) and confirmed to be nearby two years later by Voûte (1917) with a parallax similar to that of α Centauri, noting that "it may be considered at the present moment the faintest star known." We now know that Proxima is not the lowest luminosity star known, although with $M_G = 13.41$ it remains among the smallest and coolest. It is a very slow rotator with a period of ~83 days (Benedict et al. 1998), yet it is one of the most variable red dwarfs known, as shown in the main article in the top left panel of Figure 8 and at the top of the plot in Figure 10*b*. One planet has been reported to orbit Proxima every 11 days, and it has a minimum mass a bit larger than the Earth (Anglada-Escudé et al. 2016). Two other possible planets have been reported in orbits of 5 days (Suárez Mascareño et al. 2020) and ~5 years (Damasso et al. 2020) — the short-period second planet is likely real but the long-period planet has not been confirmed. The planet(s) will experience one of the most inconsistent environments encountered among those with M dwarf hosts, so if there is life on an orbiting planet, it will be interesting life, indeed.

1.2. Barnard's Star

Barnard's Star (GJ 699, M3.5V, at 1.8 pc the 2nd nearest stellar system), the fastest moving star in the sky with a proper motion of $10\overset{\prime\prime}{.}4$/yr, was discovered over a century ago by Barnard (1916). Barnard's Star is the destination of Robert Forward's *The Flight of the Dragonfly*, describing a trip to a double planet in orbit around the red dwarf. Over many years, van de Kamp reported the star to have one or two jovian mass planets (although not a double planet). In van de Kamp (1982), he provided a detailed treatment spanning 44 years of astrometric observations that indicated planets having masses of 0.7 and 0.5 Jupiter masses with orbital periods of 12 and 20 years, respectively. However, using astrometry from *HST/FGS*, Benedict et al. (1999) ruled out companions of 2 Jupiter masses at a period of 50 days, down to 0.4 Jupiter masses at a period of 600 days. In addition, precise Doppler velocity measurements reported by Choi et al. (2013) spanning 25 years from 1987 to 2012 at a precision of 2–20 m/s eliminated the reported planets in all but the very unlikely case of nearly face-on orbits. The authors also eliminated smaller planets with $M sini$ greater than 2 Earth masses for orbital periods of a few hours to 10 days, greater than 3 Earth masses out to 100 days, and greater than 10 Earth masses out to 2 years. In 2018, a possible planet with minimum mass of 3.2 M_{Earth} in a 233 day orbit around Barnard's Star was announced (Ribas et al. 2018), but the signal in the radial velocity data has since been attributed to timing of the observations and stellar activity (Lubin et al. 2021).

1.3. Wolf 359

Wolf 359 (GJ 406, M5.5V, at 2.4 pc the 3rd nearest stellar system) is one of the many nearby M dwarfs revealed by Wolf, who measured its large proper motion of $4''\!.8$/yr in 1917 and included it in his 1919 catalog of proper motion stars (Wolf 1919). As with several of the nearest stars, Wolf 359 has become notorious among science fiction fans, in this case as the location of the *Star Trek* battle with the Borg. RECONS photometric data from the CTIO/SMARTS 0.9m indicate that the star varies in the R filter by $\sim$20 mmag, with a likely spot cycle lasting perhaps 9 years. At $V = 13.61$, the star is fainter than Proxima ($V = 11.13$) and Barnard's Star ($V = 9.54$), so planet searches are more difficult. No worlds have yet to be reported orbiting Wolf 359, although given its proximity, it will undoubtedly be a key target for future exploration.

Supplemental Table 1 M Dwarf Spectral Standards on the RECONS System

Spectral Type	Name	RA (2000.0)	DEC (2000.0)	V	M_G
M0.0V	GJ 784	20 13 53	−45 09 50	7.95	8.29
M0.5V	GJ 678.1	17 30 23	+05 32 55	9.30	8.50
M1.0V	GJ 514	13 30 00	+10 22 38	9.05	8.80
M1.5V	GJ 382	10 12 18	−03 44 44	9.29	8.90
M2.0V	GJ 176	04 42 56	+18 57 29	9.97	9.11
M2.5V	L 591-042	04 36 41	−27 21 18	12.25	9.31
M3.0V	LHS 2634	12 47 10	−03 34 18	12.60	9.87
M3.5V	GJ 1207	16 57 06	−04 20 56	12.25	11.21
M4.0V	LP 876-010	22 48 04	−24 22 08	12.62	11.72
M4.5V	LHS 3799	22 23 07	−17 36 26	13.30	12.25
M5.0V	GJ 1093	06 59 29	+19 20 56	14.94	13.33
M5.5V	GJ 406 (Wolf 359)	10 56 29	+07 00 53	13.61	14.13
M6.0V	LHS 2090	09 00 24	+21 50 05	16.11	14.39
M6.5V	LHS 292	10 48 13	−11 20 10	15.78	14.55
M7.0V	GJ 644 C (VB 8)	16 55 35	−08 23 41	16.85	14.75
M7.5V	LP 775-031 AB[a]	04 35 16	−16 06 57	17.72	14.49
M8.0V	GJ 752 B (VB 10)	19 16 58	+05 09 02	17.54	15.44
M8.5V	SCR 1845-6357	18 45 05	−63 57 47	17.40	16.00
M9.0V	LHS 2065	08 53 36	−03 29 32	19.14	16.20

[a] close binary that increases M_G value

Supplemental Table 2 Luminosity and Mass Function Values (Figure 4)

M_G Range (mag)	# stars	LF Value (N pc^{-3} mag^{-1})		Mass Range ($M_\odot$)	# stars	MF Value (N pc^{-3} $M_\odot^{-1}$)
8.10–8.98	84	0.0049		0.575–0.605[a]	37	0.0379
8.98–9.86	154	0.0090		0.525–0.575	35	0.0359
9.86–10.75	187	0.0109		0.475–0.525	45	0.0461
10.75–11.63	207	0.0121		0.425–0.475	71	0.0728
11.63–12.51	184	0.0107		0.375–0.425	76	0.0780
12.51–13.39	122	0.0071		0.325–0.375	78	0.0799
13.39–14.27	65	0.0038		0.275–0.325	99	0.1015
14.27–15.15	44	0.0026		0.225–0.275	127	0.1302
15.15–16.04	23	0.0013		0.175–0.225	142	0.1456
16.04–16.92	26	0.0015		0.125–0.175	197	0.2020
16.92–17.80	15	0.0009		0.075–0.125	204	0.2091

[a] The adopted K/M dwarf cutoff at M_G = 8.10, M_V = 8.88 results in mass 0.605 $M_\odot$ for the highest mass M dwarf.

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