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FLARES AT THE COOL END OF THE M DWARFS: THE CASE OF LHS 2065

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ABSTRACT

LHS 2065 is an M9 very low mass star at a distance of 8.5 pc. It was known to have Hα emission, but no other emission lines had been seen before. We observed it on 1998 December 12 and found a rich emission spectrum (He I, Na D, and Balmer series). Additional spectra were obtained after 1 hr, 2 hr, and 1 day. They showed progressively weaker emission lines. Using our data and a compilation of the literature, we find that, while strong flares in LHS 2065 are rare (their recurrence rate is ≤ 0.03 hr^{-1}), weak flares may be common (about 0.5 hr^{-1}). Our observations add to the growing evidence that many, if not all, of the coolest M dwarfs have flare activity.

Key words: stars: activity — stars: flare — stars: individual (LHS 2065) — stars: late-type

1. INTRODUCTION

The first observation of a flare in an ultracool dwarf (spectral type M7 or later) is usually credited to Herbig (1956), who noted the presence of extraordinarily bright Balmer and Ca II lines in a spectrum of VB 10 obtained on 1956 September 3. No emission was visible on repeat photographic spectrograms obtained on 7 and 8 September of the same year. The photographic plates could not be flux-calibrated, but these early observations already indicated that flares could be common among fully convective ultracool dwarfs. Herbig also noted an intriguing difference between VB 10 and the class of mid-M flare stars. VB 10 does not possess bright emission lines out of the flare, suggesting that the flare emerged from low-level quiescent chromospheric activity. VB 10 was the lowest-luminosity star known at that time (Van Biesbroeck 1944).

At a distance of 8.5 pc (Monet et al. 1992), LHS 2065 is one of the nearest ultracool dwarfs known. Bessell (1991) obtained optical spectra and noted that the T II, VO, and FeH bands of LHS 2065 were similar to those of LHS 2924, making it one of the coolest dwarfs known at that time. The lack of lithium in the atmosphere and the very late M spectral type (M9) indicate that it must be old (age > 0.5 Gyr) and the mass must be between 0.1 and 0.06 $M_{\odot}$ (Martín, Rebolo, & Magazzù 1994). Given the typical age of a disk star (a few gigayears), LHS 2065 would be a very low mass star rather than a massive brown dwarf. Gizis et al. (2000) suggest that brown dwarfs may be more inactive than stars, which is another hint that LHS 2065 could have a stellar mass. We observed LHS 2065 in 1998 as a spectral type standard and were surprised to find strong emission lines in the spectrum. A strong flare must have occurred during our observations. In this paper we report this flare and we compare it with observations of other very low mass dwarfs.

2. OBSERVATIONS AND RESULTS

Observations of LHS 2065 were obtained on the nights of 1998 December 12 and 13 using the Kast double spectrograph attached to the Cassegrain focus of the Shane 3 m telescope. We used only the red-optimized spectrograph without dichroic beam splitter. The 300/7500 grating gave a resolution of 11 Å in the spectral range 467.6–1003.6 nm. A standard reduction procedure was performed using IRAF tasks (debiasing, flat-fielding, extraction, wavelength calibration, and flux calibration using the standard HD 84937). The weather was not photometric, so we cannot derive absolute fluxes from the spectra.

We realized at the telescope that the first spectrum of LHS 2065 showed bright emission lines. Hence, we reobserved the object two more times during the same night and once the next night. Our series of spectra are shown in Figure 1, together with the spectrum of the same object observed by Kirkpatrick, Henry, & McCarthy (1991) at a resolution of 18 Å.

Equivalent widths of all visible emission lines were measured by direct integration of the profile with respect to the local pseudocontinuum. We used the IRAF task SPLOT. The measurements are presented in Tables 1 and 2. We have not attempted to derive emission fluxes because the pseudocontinuum was variable (it was bluer during the flare) and the weather was nonphotometric.

In Table 1 we compare the Hα emission measured by us with observations taken from the literature or unpublished data obtained from researchers working in the field. Our maximum equivalent width is more than a factor of 10 stronger than any previous value.

The ratio of Hα to Hβ equivalent width (Tables 1 and 2) is consistent with the Balmer decrement of unsaturated chromospheric emission, such as observed in LHS 3003 (Ruiz et al. 1990) and PC 0025+0447 (Schneider et al. 1991).

3. DISCUSSION

We have combed the literature for previous observations of LHS 2065. Adding up all data available to us, we find that the Hα spectral region of LHS 2065 has been observed for 21.9 ks (6.08 hr), as summarized in Table 1. We consider 19.8 ks for estimating the rate of strong flares because we exclude our monitoring after the flare. We obtain a rate of 0.03 strong flares per hour. We consider this an upper limit because there could be more unpublished observations that we are not aware of, and they would have not been reported because they would not have shown any unusual emission. We conclude that LHS 2065 spends $\leq 3\%$ of the time in a strong flare.

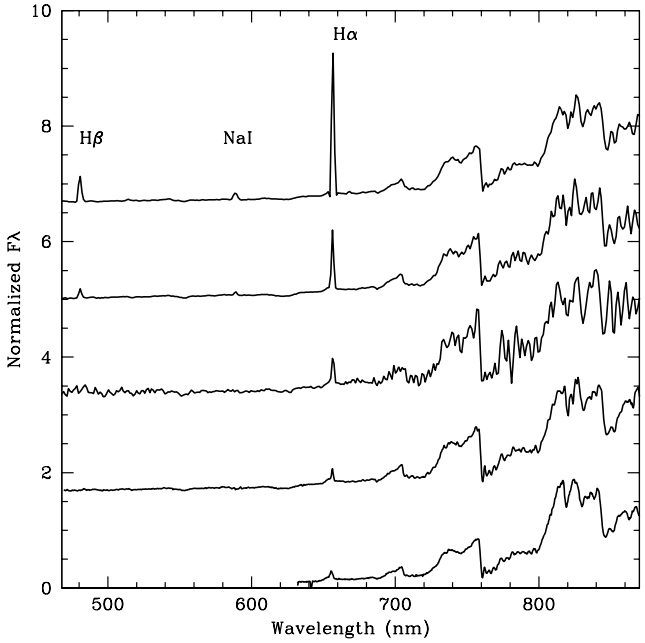


FIG. 1.—*Top to bottom*: Four Lick 3 m spectra of LHS 2065 in order of increasing universal time and the spectrum of Kirkpatrick, Henry, &Mc Carthy (1991) for comparison.

TABLE 1

Hα DATA FOR LHS 2065

Observed (UT)	τ (s)	EW (Å)	Source
1990 Jan 21.....	1500	13.5[a]	1
1992 Oct 17	1200	18.8	2
1993 Jan 21.....	1800	7.5	3
1993 Jan 22.....	1800	20.3	3
1994 Feb 7.....	5400	24.9	4
1994 Nov 24.....	3000	8.4	5
1994 Dec 30	600	10.5	6
1998 Dec 12	600	261	7
1998 Dec 12	900	99	7
1998 Dec 12	600	43	7
1998 Dec 13	600	11.0	7
1998 Dec 23	300	16.4	8
1999 Mar 7.....	1800	11.0	9
1999 Dec 6	1800	15.0	10

[a] Equivalent width measured by the authors from the digital spectra made available by D. Kirkpatrick.

REFERENCES.—(1) Kirkpatrick et al. 1991; (2) Reid, Tinney, & Mould 1994; (3) Martín et al. 1994; (4) Tinney 1998; (5) G. Basri 2001, private communication; (6) Martín, Rebolo, & Zapatero Osorio 1996; (7) this work; (8) Luhman 1999; (9) I. N. Reid 2001, private communication; (10) L. Hillenbrand 2001, private communication.

While the flare reported in this paper is clearly the strongest episode of activity recorded in this object, there are significant changes in Hα in previous data. The flare of VB 8 reported by Martín (1999) displayed a change of a factor of 2 in Hα equivalent width. Taking the lowest floor of Hα emission ever observed in LHS 2065 (EW = 7.5 Å) indicates that it could spend ∼50% of the time with Hα emission equivalent width more than a factor of 2 higher than the most quiescent level. LHS 2065 could experience frequent weak flares, or perhaps it has magnetic cycles that change the quiescent level of Hα emission. Strong flares, however, are rare. They could be a high-energy manifestation of normal flares in the coolest M dwarfs.

The flare of LHS 2065 displayed emission lines other than the Balmer series (Table 2) but it did not show a strong blue continuum veiling the molecular features. Bessell (1991) observed a dramatic flare in the M8 dwarf LHS 2397a in less than 10 minutes. That flare displayed strong Hα emission and blue veiling. Liebert et al. (1999) observed blue veiling and a rich emission spectrum in the M9.5 dwarf 2MASSW J0149+29. In LHS 2065, we have seen neither the blue veiling nor any of the strong lines reported by

TABLE 2

OTHER EMISSION LINES OBSERVED IN LHS 2065

Date (UT)	Observed (UT)[a]	EW(Hβ) (Å)	EW(Na ID) (Å)	EW(He I) (Å)
1998 Dec 12.....	120327	570 ± 20	61 ± 2	4 ± 1
1998 Dec 12.....	130723	200 ± 10	21 ± 1	<1
1998 Dec 12.....	141718	<40	<10	<2
1998 Dec 13.....	111929	≤10	6[c]	<1

[a] Universal time at the beginning of the exposure.
[b] He I line at 668.0 nm.
[c] Emission reversal at the core of a broad absorption line.

TABLE 3

FLARE DATA IN ULTRACOOL DWARFS

Name	Sp.	Minimum EW(Hα)	Source	Maximum EW(Hα)	Source
VB 8	M7	3.7	TR98	20.4	TR98
LP 475-855.....	M7	7	G00	40.5	G00
VB 10.....	M8	4.1	M99	[a]	H56
LHS 2243	M8	1.3	M94	44	G00
LHS 3003	M8	4.1	TR98	33	R90
LHS 2397a	M8	15	G00	[a]	B91
LHS 2065	M9	7.5	MA01	261	MA01
BRI 0021-0214.....	M9.5	<0.2	BM95	18.2	R99
2MASSW J0149+29.....	M9.5	11	L99	300	L99
2MASSW J2234+23.....	M9.5	4.4	G00	20	G00

[a] Not available.

REFERENCES.—(B91) Bessell 1991; (BM95) Basri & Marcy 1995; (G00) Gizis et al. 2000; (H56) Herbig 1956; (L99) Liebert et al. 1999; (M99) Martín 1999; (MA01) this paper; (M94) Martín et al. 1994; (R90) Ruiz et al. 1990; (R99) Reid et al. 1999; (TR98) Tinney & Reid 1998.

Liebert et al. (1999), such as the Ca II infrared triplet. Martín (1999) also did not notice blue veiling in VB 8.

Table 3 summarizes the flares in ultracool dwarfs known to the authors. We do not include PC 0025+0447, which is difficult to classify as a flare star because it seems to stay in a permanently high state of chromospheric activity, although the level of activity is variable (Schneider et al. 1991; Martín, Basri, & Zapatero Osorio 1999). Burgasser et al. (2000) have found a T dwarf that also displays a steady strong Hα emission line. They suggested that both the T dwarf and PC 0025+0447 could be short-period binaries. Basri & Martín (1999) found a flare in the short-period brown dwarf binary PPl 15 when the objects were approaching (near perihelion), suggesting interaction between magnetospheres.

Our observations of LHS 2065 add to the increasing evidence that many dwarfs, if not all, at the bottom of the M class could experience flares. On the other hand, no flares in L dwarfs have been reported yet. This could be another manifestation that magnetic activity dies with the cooler temperatures of L dwarfs, which overall have less Hα emission than M dwarfs (Gizis et al. 2000).

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