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Research Article

STRONG BALMER EMISSION LINES IN YOUNG BROWN DWARFS

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ABSTRACT

The presence of Balmer emission lines is an indicator of magnetic activity in stars. This paper presents the spectroscopic observations at blue wavelengths of nearby young brown dwarfs with previously detected lithium. All targets show strong Balmer emission lines, indicating that these brown dwarfs are magnetically active. A forbidden emission line is marginally detected in DENIS2022-5645, implying that this young brown dwarf is still an accreting material.

Keywords: brown dwarfs; magnetic fields; spectroscopy

1. Introduction

Studying magnetic activities in the Sun, such as flares, prominences, coronal mass ejections, and sunspots is important to understand physical phenomena related to the magnetic field and the solar dynamo of generating the Sun's magnetic field. In very low-mass (VLM) stars with masses below 0.35 $M_\odot$ ($M_\odot$: solar mass) and brown dwarfs (BDs) with masses below 75 M_J (M_J: Jupiter mass), magnetic activities, such as flares have usually been studied by observing Balmer series and other emission lines in stellar chromospheres (e.g., Hawley et al., 1996).

Based on spectroscopic observations at red wavelengths, Phan-Bao et al. (2017) reported the detection of lithium in late-M dwarfs. Using Gaia trigonometric parallaxes, Phan-Bao and Bessell (2002) revised the masses estimated for these nearby (distances < 150 parsecs) late-M dwarfs, and the authors found that all of them are young BDs, except one as a VLM star. Their spectra also showed strong Hα emission lines at 6562.8 Å, indicating the magnetic activity in these young VLM objects. In this paper, I present the spectroscopic observation at blue wavelengths of these VLM objects. Section 2 presents the observations

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and data reduction. Section 3 presents the observational analysis. Section 4 summarizes the results.

2. Observations and data reduction

The targets were observed in 2008 and 2016 with the double-beam grating spectrograph (DBS) and the Wide Field Spectrograph (WiFeS) on the ANU 2.3-m telescope at Siding Spring Observatory. The observing logs are given in Table 1. For the DBS, the blue channel covers the wavelength range from 3250 Å to 5250 Å, and the 600 g/mm grating was used, providing a resolution of approximately 2.0 Å. For the WiFeS, the blue channel covers from 3400 Å to 6000 Å, and the R7000 grating was used with a resolution of approximately 1.0 Å. The signal-to-noise ratios of spectra are above 8 for all targets, except above 4 for DENIS0041-5621.

The data were reduced using the FIGARO software. The spectra were corrected for mean telluric absorption using a smooth spectrum star. A NeAr arc was used for the wavelength calibration. I then used the IRAF task *splot* to measure equivalent widths (EWs) of the Balmer emission lines, including Hβ (4861 Å), Hγ (4340 Å), and Hδ (4102 Å). In addition, I also measured EWs of forbidden emission lines (FELs) [S I] λ4069 and [S I] λ4076.

Table 1. *Observing logs for nearby young VLM objects*

DENIS name	Spectral type	Mass[a] (M_J)	Instrument	UT observing time
0041-5621	M6.5+M9.0	37+16[b]	WiFeS	2016-11-22
0144-4604	M5.5	54	WiFeS	2016-11-21
			DBS	2008-03-28
0518-3101	M6.5	41	WiFeS	2016-11-18
			WiFeS	2016-11-19
1538-1038	M5.0	47	DBS	2008-03-28
1809-7613	M5.0	81	DBS	2008-03-28
			WiFeS	2016-11-23
2022-5645	M5.5	49	DBS	2008-03-28

Notes: [a]*: Mass estimates taken from Phan-Bao and Bessell (2022) and Nguyen-Thanh et al. (2020)*

[b]*: Masses listed for components A (M6.5) and B (M9.0), respectively*

3. Results and discussions

Figure 1 shows the spectra of six nearby young VLM objects: five BDs and one VLM star (DENIS1809-7613). It should be noted that DENIS0041-5621 is a BD binary consisting of an M6.5 and an M9.0 (Reiners et al., 2010).

Table 2. *Equivalent widths of Balmer series and FELs in nearby young VLM objects*

DENIS name	UT observing time	EW Hβ	EW Hγ	EW Hδ	EW [S I] λ4069	EW [S I] λ4076
0041-5621	2016-11-22	-17±2	-14±2	-12±2	>-2.0	>-1.2
0144-4604	2016-11-21	-49±5	-32±5	-21±5	>-0.4	>-0.8
0518-3101	2008-03-28	-17±1	-16±1	-10±1	>-0.5	>-1.0
	2016-11-18	-7±1	-5±1	>-1.0	>-1.0	>-1.0
1538-1038	2008-03-28	-15±1	-13±1	-11±1	>-0.5	>-0.5
1809-7613	2008-03-28	-7.0±0.5	-6.0±0.5	-5.6±0.5	>-0.2	>-0.1
	2016-11-23	-9.2±0.5	-12±1	-3.2±0.2	>-0.1	>-0.3
2022-5645	2008-03-28	-10±1	-10±1	-5±1	>-1.0	-4.0±1.0

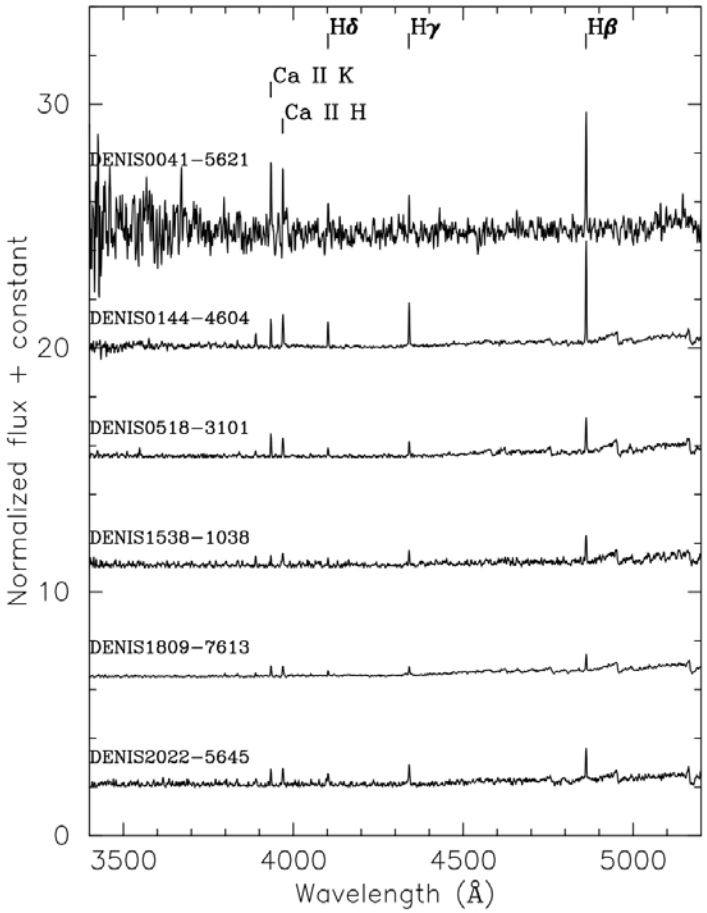

Figure 1. *Mid-resolution spectra at a blue wavelength of six nearby young very low-mass objects. The Balmer emission lines, Hβ, Hγ, and Hδ are indicated. The Ca II H λ3968 & K λ3933 are also shown*

All spectra of the VLM objects show the Balmer emission lines, Hβ, Hγ, and Hδ, as well as Ca II H λ3968 (blended with Hϵ at 3970 Å) and K λ3933, indicating chromospheric (magnetic) activities. Table 2 lists the measurements of EWs of the Balmer lines.

I also searched for FELs in the range of observed wavelengths, which are only emitted in an interstellar region of low-density gas. The origin of the FELs relates to the accretion and outflow processes in star formation (e.g., Herczeg & Hillenbrand, 2008; Nguyen-Thanh et al., 2020). According to theoretical models, such as the one by Gomez de Castro and Pudritz (1993), the accretion and outflow processes create shocked gas that produces FELs when the shocked gas cools down. The measurements of EWs of FELs [S I] at wavelengths of 4069 Å and 4076 Å are given in Table 2. Among the six VLM objects, only DENIS2022-5645 shows FEL [S I] λ4076 (see Figure 2) with an EW of -4.0$\pm$1.0 Å. The presence of the FEL implies that DENIS2022-5645 is still accreting material from its gas reservoir. However, the detection level of this FEL is at only about 4. Therefore, further observations are needed to confirm this detection.

It is noted that DENIS1538-1038 did not exhibit any FELs during the observations presented in this paper. However, the source is a sporadic and intense accreting BD as previously reported by Nguyen-Thanh et al. (2020). The non-detection of FELs is probably because the source was in a quiet phase of accretion.

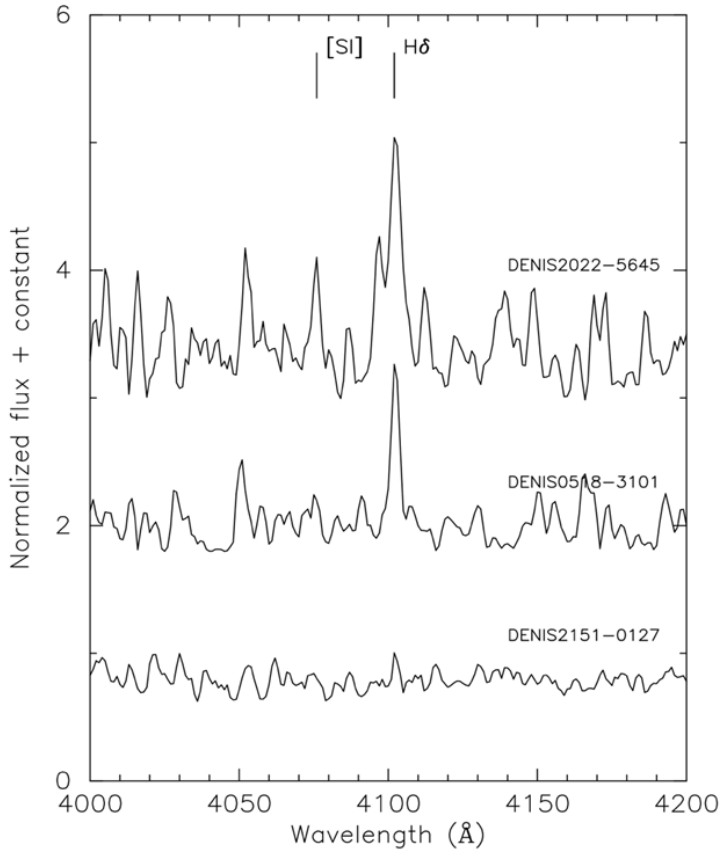

Figure 2. *The forbidden emission line [S I] at 4076* Å *is marginally detected at a signal-to-noise ratio of about four in the young brown dwarf DENIS2022-5645. The spectra of the young brown dwarf DENIS0518-3101 and the old M dwarf DENIS2151-0127 without the detection of [S I] at 4076* Å *are also shown for comparison.*

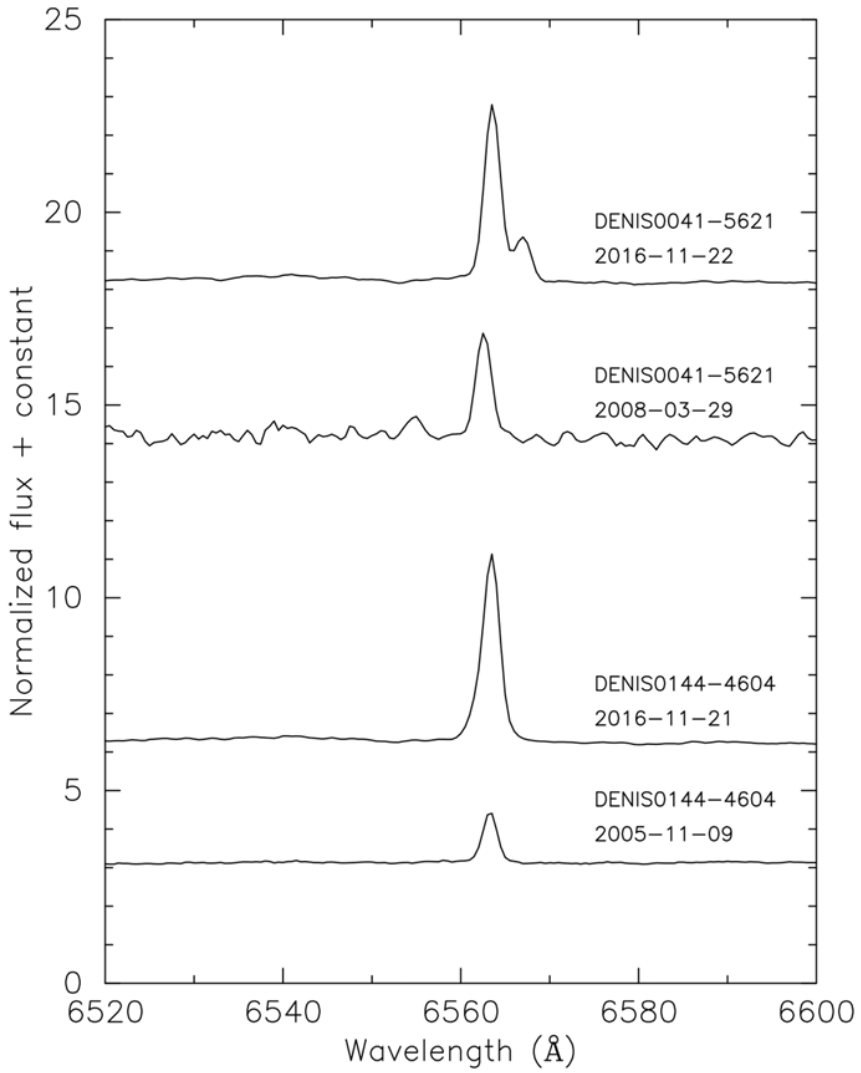

Figure 3. *DENIS0041-5621 and DENIS0144-4604 were in strong flaring levels with strong Hα emission lines observed in 2016 and lower levels of magnetic activity observed in 2008 and 2005, respectively. The Hα profile of DENIS0041-5621 observed in 2016 shows two peaks, indicating that DENIS0041-5621 is a binary system M6.5+M9.0 as reported by Reiners et al. (2010)*

Strong flares were also observed in DENIS0041-5621 and DENIS0144-4604 during the observations obtained in 2016 when compared with those obtained in 2008 and 2005 (see Figure 3).

4. Summary

This paper presents the spectroscopic observations at blue wavelengths of six nearby young VLM objects. All targets show strong Balmer emission lines, Hβ, Hγ, and Hδ, and thus they are magnetically active. The strong flares were also observed in DENIS0041-5621 and DENIS0144-4604. The FEL [S I] λ4076 is marginally detected in DENIS2022-5645, implying that the young BD is still an accreting material. Further observations are needed to confirm the detection of the FEL in DENIS2022-5645.

❖ ***Conflict of Interest:*** *Author have no conflict of interest to declare.*

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BỨC XẠ BALMER Ở CÁC SAO LÙN NÂU TRẺ

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TÓM TẮT

Sự xuất hiện các vạch bức xạ Balmer là một chỉ số về hoạt động từ trường ở các sao. Bài báo này giới thiệu quan sát phổ quang học ở các bước sóng xanh của các sao lùn nâu trẻ với phát hiện lithium đã được báo cáo trước đây. Tất cả các sao lùn nâu được quan sát đều phát các vạch bức xạ mạnh Balmer, chỉ ra rằng các sao lùn nâu này đều có hoạt động từ trường. Một vạch bức xạ cấm cũng được phát hiện ở DENIS2022-5645, cho thấy sao lùn nâu trẻ này vẫn đang hút vật chất.

Từ khóa: sao lùn nâu; từ trường; quang phổ