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Research Article

DETERMINING THE ACCRETION CRITERION FOR YOUNG ACCRETING LATE-M DWARFS IN NEARBY ASSOCIATIONS

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ABSTRACT

Studying young accreting very low-mass objects (late-M and brown dwarfs) in nearby associations will shed lights into their formation mechanism at different stages. Therefore, the identification of these bona-fide accreting objects is the first important step for further studies. The 10% width of Hα emission profile with a value of about 200 km.s^{-1} has widely been used to detect young accreting brown dwarfs in star-forming regions. However, there has not been any independent criterion to verify the accreting and non-accreting nature of the detected objects, especially objects detected in young nearby associations. Based on the Wide Infrared Survey Explorer data, a small sample of previously identified accreting and non-accreting late-M and brown dwarfs in star-forming regions and young nearby associations was collected to construct their spectral energy distribution. The results of this study which were based on infrared excesses are aligned with the previous works. It is suggested that the Hα 10% velocity width at 200 km.s^{-1} could be applied for identifying accreting very low-mass objects in young associations.

Keywords: brown dwarfs; accretion phase; infrared excess; star formation; very low-mass stars

1. Introduction

One of the most important processes of star formation is accretion because the accretion timescale and rate will determine the final mass of a star. For very low-mass objects (brown dwarfs: masses below 0.075 M_{Sun}; late-M dwarfs: masses below 0.35 M_{Sun}) their formation is expected to be similar to low-mass stars (e.g., 1 M_{Sun}). However, it is still unclear how the accretion process occurs in these very low-mass objects at different stages (i.e., different ages).

The accretion phase in young stars usually occurs at ages younger than 5 Myr (Fedele et al., 2010). At 5 Myr, most of the stars have stopped accreting materials. However, some M dwarfs in young nearby associations with ages greater than 10 Myr that are still

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accreting have been detected, e.g., WISE J0808−6443 (M5.0, 45 Myr, Silverberg et al., 2016, Murphy et al., 2018), 2MASS 1239-5702 and 2MASS 1422-3623 (M5.0, ~10 Myr, Murphy et al., 2015). These detections have implied that the accretion process in very low-mass objects might last longer than that in higher mass stars. Therefore, the detection of accreting young BDs and late-M dwarfs at different ages, especially in young nearby associations, is important for better understanding their formation mechanism and the planet formation around them.

In accreting objects, the accretion disk provides more significant energy, thus it produces optical excess continuum emission (i.e., optical veiling) in optical spectra of these objects (Hartman, & Kenyon, 1990; Basri, & Batalha, 1990). Therefore, optical spectra have been used to distinguish between accreting and non-accreting objects. In an optical spectrum, the Hα emission line has been used to study accreting objects because the Hα emission line is prominent, and it is not affected by other absorption lines (Kirkpatrick et al., 1991). White and Basri (2003) proposed that objects with the 10% width of Hα emission line (i.e., the velocity full width at 10% of the peak flux) or v_{10} [Hα] > 270 km.s^{-1} are considered accreting objects, independent of their spectral types. The authors then applied this criterion to classify accreting late-M and brown dwarfs.

However, for the very low-mass regime, Jayawardhana et al. (2003) discussed that the v_{10} [Hα] cutoff criterion at 270 km.s^{-1} as proposed by White and Basri (2003) might discard some accreting late-M and brown dwarfs. This is due to the fact that the Stark broadening effect that can increase the width of the Hα profile is not significant in very low-mass objects that have very low accretion rates. Consequently, the authors have proposed the v_{10} [Hα] cutoff at 200 km.s^{-1} for accreting very low-mass objects. This cutoff value was determined based on some accreting very low-mass objects that show the typical broad O I and Ca II emission lines as seen in accreting low-mass stars (see Jayawardhana et al., 2003).

As the accretion disk produces excess emission not only in optical but also in infrared, therefore, the infrared excess could be used as an independent criterion to identify accreting objects although not all of them produce significant excess emission to be detectable (e.g., Boucher et al., 2016).

In this paper, we studied a sample of accreting and non-accreting late-M dwarfs in star-forming regions (ages <~5 Myr) and nearby associations (ages >~5 Myr). These objects have been classified based on the cutoff of the v_{10} [Hα] at 200 km.s^{-1}. We used the Wide Infrared Survey Explorer (WISE) data available since 2011 to verify infrared excesses of the accreting and non-accreting objects in the sample.

The sample will be presented in Section 2 and the detection of infrared excesses in Section 3 followed by discussion and conclusion in Section 4.

2. Sample

Twelve late-M dwarfs with spectral types from M4.0 to M9.0 and ages from 2 to 45 Myr were selected. They are young objects in star-forming regions and nearby associations (see Table 1).

Table 1. *The Hα equivalent widths and the velocity widths at 10% of the Hα line of 12 young late-M dwarfs*

Object	Spectral type	EW [H_α] (Å)	v_{10} [H_α] ($km.s^{-1}$)	Age (Myr)	Accretor/ Non-accretor	Region	Ref
2MASS 0801-8058	M4.5	[6.0; 27.0]	[148; 346]	6	Non-accretor	η Cha	2
WISE 0808-6443	M5.0	[65.0, 125.0]	[298; 419]	45	Accretor	CAR	4
2MASS 0820-8003	M4.5	[15.0; 40.0]	[210; 425]	6	Accretor	η Cha	2
RECX 5	M4.0	[8.6; 35.0]	[194; 330]	6	Accretor	η Cha	4, 5
RECX 9	M4.5	[10.0; 11.7]	[300; 389]	6	Accretor	η Cha	4, 5
2MASS 1058-2346	M5.0	11.3	151	8	Non-Accretor	TWA	3
2MASS 1101-7718	M8.0	[12.0; 126.0]	[122; 232]	2	Non-Accretor	Cha I	6
TWA 26	M9.0	7.3	111	8	Non-Accretor	TWA	1
2MASS 1202-3328	M5.0	9.5	169	8	Non-Accretor	TWA	3
TWA 27	M8.0	[64.0; 387.0]	[209; 308]	8	Accretor	TWA	1, 6
2MASS 1239-5702	M5.0	[27.0; 63.0]	[238; 331]	10	Accretor	Sco – Cen	3
2MASS 1422-3623	M5.0	[33.0; 91.0]	[236; 341]	10	Accretor	Sco - Cen	3

In Table 1, we list the values of the 10% width of Hα line (v_{10} [Hα]) available in the literature, which are used to classify accretors and non-accretors. All v_{10} [Hα] values of WISE 0808-6443, RECX 5, RECX 9, 2MASS 0820-8003, TWA 27, 2MASS 1239-5702 and 2MASS 1422-3623 are well above the cutoff of 200 $km.s^{-1}$ as proposed by Jayawardhana et al. (2003). So, they are accretors (see Table 1). For 2MASS 0801-8058, 2MASS 1101-7718, these late-M dwarfs are at the boundary between accretors and non-accretors. Their v_{10}[Hα] values were generally below the cutoff of 200 $km.s^{-1}$, they could be classified as non-accretors. However, at some epochs, their v_{10}[Hα] values increased significantly and exceeded 200 km.s^{-1} to be classified as accretors. It is unclear that the significant increase in the width of the Hα line originates from accretion or flaring activity (Scholz & Jayawardhana, 2006). Its origin will be discussed in Section 4. For the three remaining late-M dwarfs, 2MASS 1058-2346, TWA 26 and 2MASS 1202-3328, they have previously been classified as non-accreting objects as their v_{10} [Hα] values well below the cutoff of 200 km.s^{-1}.

Figure 1 shows the v_{10} [Hα] versus spectral type diagram for the 12 late-M dwarfs.

3. Verifying the accreting and non-accreting nature of the late-M dwarfs in the sample using the WISE data

In this section, we constructed the spectral energy distribution (SED) of all 12 targets in our sample to detect infrared excesses. We used Deep Near Infrared Survey (DENIS), Two Micro All Sky Survey (2MASS) and the WISE photometry as well as NextGen model atmospheres for very low-mass stars and brown dwarfs (Chabrier, & Baraffe, 2000).

The best fitting of these models is found by the method of determining the minimum deviation. We then identified candidates with infrared excesses at WISE bands, especially for 12 μm and 22 μm. An examination of all WISE images for all candidates was carried out to confirm their real IR excess. The resulting SEDs of our targets are shown in Figure 2.

The infrared excess was detected in seven young late-M dwarfs that include WISE 0808-6443, RECX 5, RECX 9, 2MASS 0820-8003, TWA 27, 2MASS 1239-5702, and 2MASS 1422-3623. These objects show strong infrared excesses with detection levels above 3σ (1σ is the error bar) at 12 μm and 10σ at 22 μm. For some of these late-M dwarfs, WISE 0808-6443, RECX 5, RECX 9, 2MASS 1239-5702, and 2MASS 1422-3623 whose infrared excesses have previously been recognized (Murphy et al., 2015, 2018; Riviere-Marichalar et al., 2015). For 2MASS 0801-8058 and 2MASS 1058-2346, their SEDs likely show infrared excesses at 22 μm. However, our examination of their WISE images indicated that these excesses are false-detection. For the three remaining non-accreting objects, we did not find any infrared excesses.

4. Discussion and conclusion

All seven late-M dwarfs that have been classified as accreting objects based on the v_{10} [Hα] criterion of 200 km.s^{-1} show strong infrared excesses at 12 μm and 22 μm. For 2MASS 0801-8058 and 2MASS 1101-7718, the upper values of the Hα 10% velocity width of these dwarfs are 324 km.s^{-1} and 232 km.s^{-1} (see Table 1), well above the cutoff of 200 km.s^{-1}. However, our SEDs and the examination of their WISE images as discussed in Section 3 indicate that they are non-accreting objects. We conclude that the high values of v_{10} [Hα] (>200 km.s^{-1}) at some epochs in these objects were probably from strong flares and not from accretion. For 2MASS 1058-2346, TWA 26 and 2MASS 1202-3328, our non-detection of infrared excesses is consistent with the previous classification based on the Hα 10% velocity width criterion.

In this paper, we used the infrared excess as an independent criterion to verify the presence of accretion disks in late-M dwarfs that have been classified based on the cutoff of the Hα 10% velocity width at 200 km.s^{-1} for young late-M dwarfs in star-forming regions and nearby associations. Our results are aligned with the results of previous studies.

We therefore concluded that this criterion is also applicable for detecting accreting very-low mass objects in nearby associations.

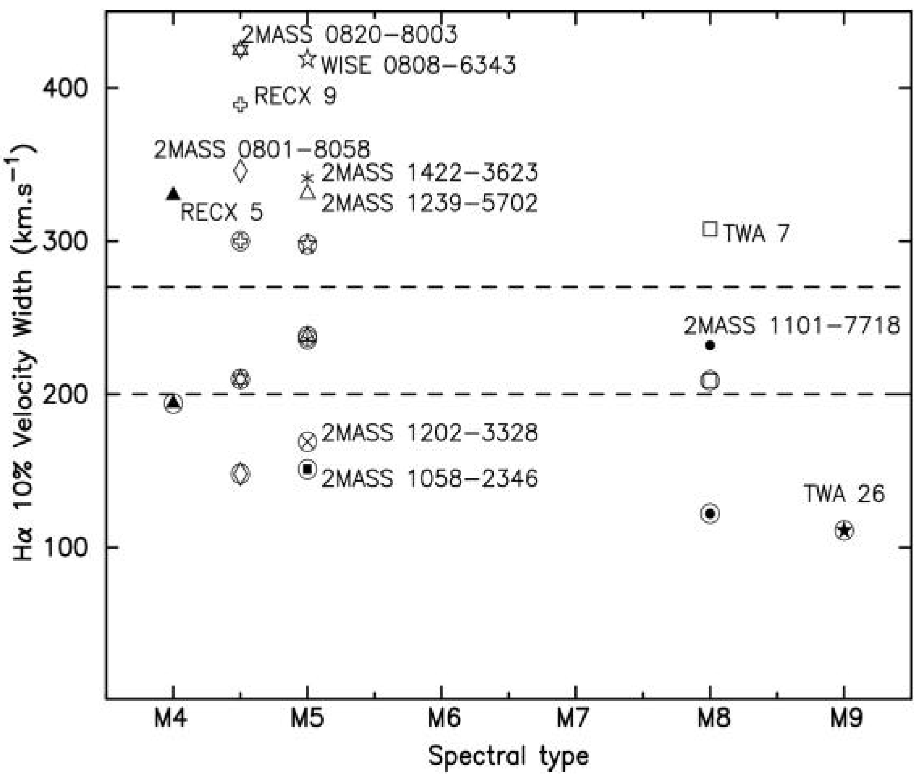
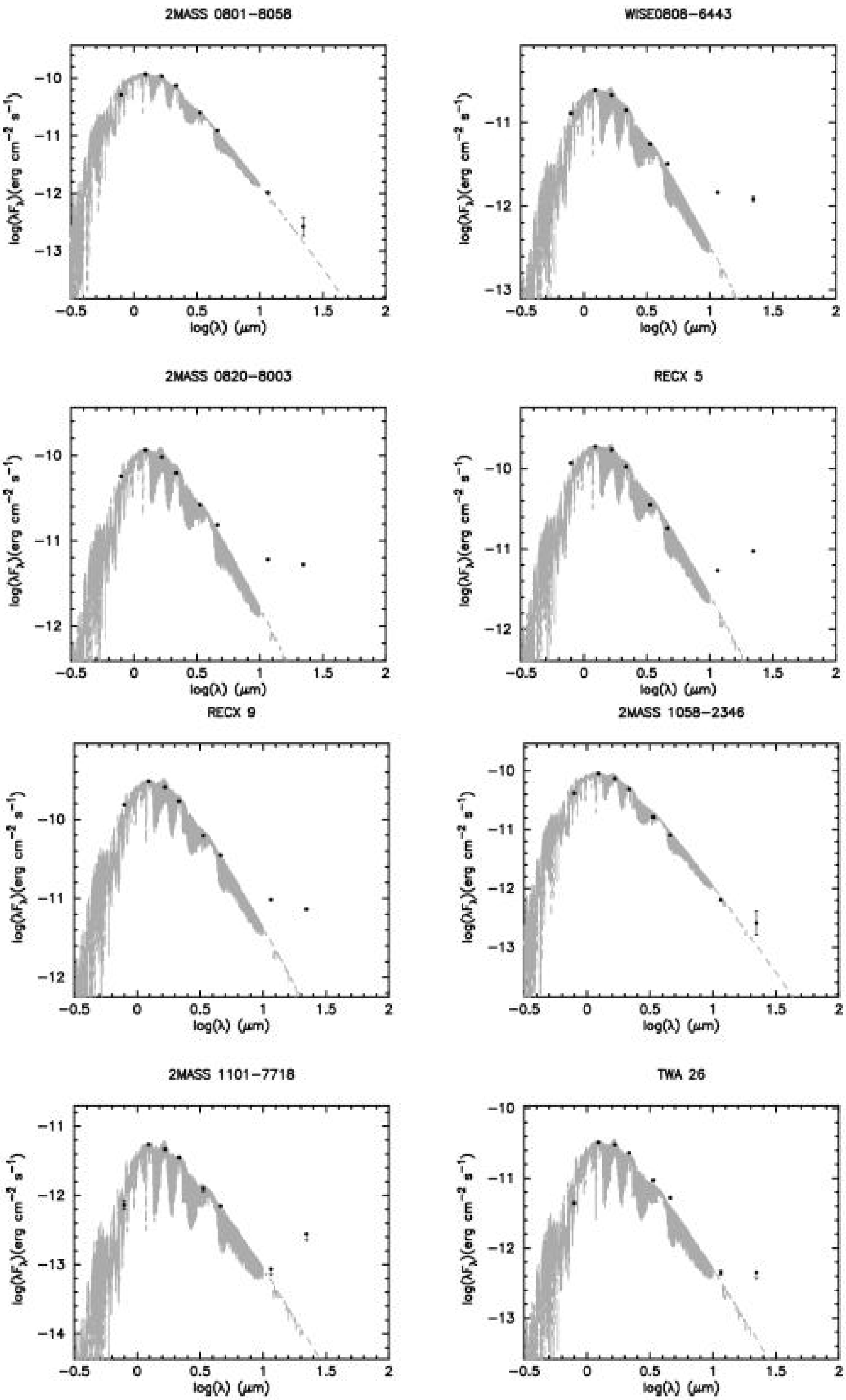


Figure 1. *The Hα velocity width at 10% peak intensity (v_{10}) versus spectral type diagram for young late-M dwarfs. For objects with an upper value and a lower v_{10} [Hα] value available in the literature, we use the same symbols. The v_{10} [Hα] cutoff at 270 km.s^{-1} and 200 km.s^{-1} are also plotted* (White, & Basri, 2003; Jayawardhana et al., 2003)


2MASS 0801-8058
WISE0808-6443
2MASS 0820-8003
RECX 5
RECX 9
2MASS 1058-2346
2MASS 1101-7718
TWA 26
log(λF_λ)(erg cm^-2 s^-1)
log(λ) (μm)

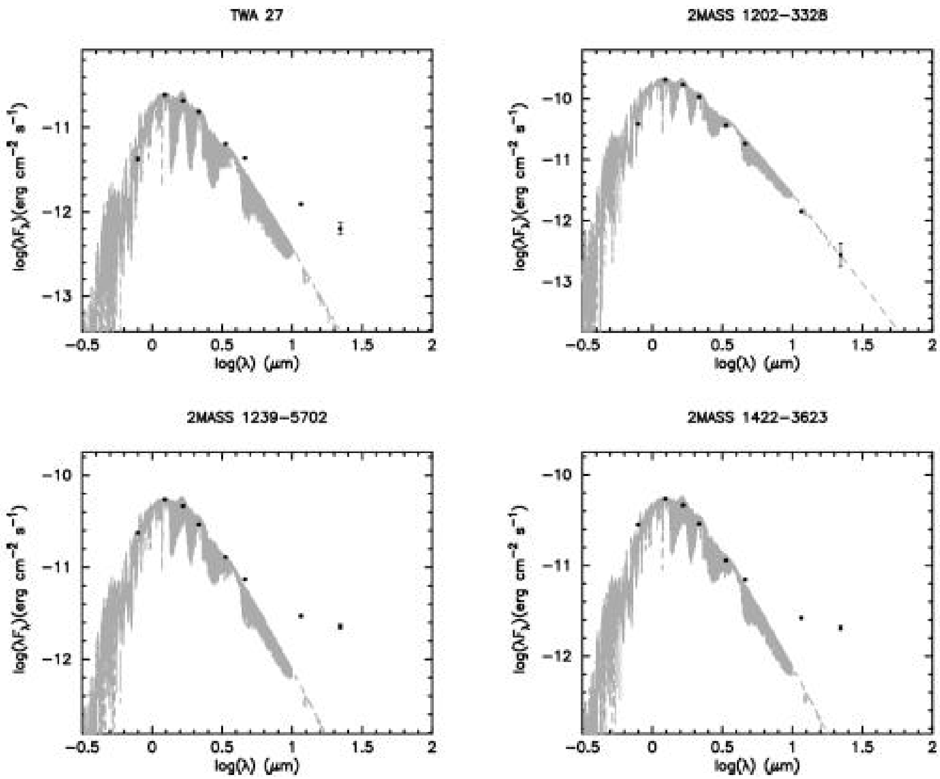


Figure 2. *SEDs of the 12 young late-M dwarfs. The grey curve represents the best-fit model to the observed data points from DENIS, 2MASS and WISE (solid circles). The infrared excesses at 12 μm and 22 μm are found in WISE 0808-6443, RECX 5, RECX 9, 2MASS 0820-8003, TWA 27, 2MASS 1239-5702 and 2MASS 1422-3623. 2MASS 0801-8058 and 2MASS 1058-2346 likely show an infrared excess at 22 μm but they are false-detection (see Sect. 3). 2MASS 1101-7718, TWA 26 and* 2MASS 1202-3328 *show no IR excess.*

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

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XÁC ĐỊNH TIÊU CHÍ HÚT VẬT CHẤT CHO CÁC SAO LÙN TRẺ CÓ KIỂU PHỔ M TRỄ Ở NHỮNG ĐÁM SAO LÂN CẬN MẶT TRỜI

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TÓM TẮT

Nghiên cứu về các vật thể có khối lượng rất thấp (sao lùn có kiểu phổ M trễ và sao lùn nâu) đang trong giai đoạn hút vật chút ở những đám sao trẻ lân cận Mặt Trời giúp chúng ta hiểu rõ hơn về cơ chế hình thành của chúng trong những giai đoạn khác nhau. Do đó, việc định dạng các vật thể đang ở giai đoạn hút vật chất là bước quan trọng đầu tiên cho những nghiên cứu sâu hơn. Tiêu chí 10% độ rộng vạch Hα với giá trị tương đương vận tốc 200 km.s^{-1} *thường được dùng để phát hiện các sao lùn nâu ở giai đoạn hút vật chất ở những vùng hình thành sao. Tuy nhiên, chưa có một tiêu chí độc lập nào khác để xác nhận hiện tượng hút vật chất và không hút vật chất ở các vật thể được phát hiện, đặc biệt là với các vật thể được phát hiện ở các đám sao trẻ lân cận Mặt Trời. Dựa trên dữ liệu của WISE, chúng tôi đã lựa chọn một mẫu nhỏ gồm các sao lùn có kiểu phổ M trễ và sao lùn nâu đã được xác nhận có hoặc không có hiện tượng hút vật chất từ trước ở những vùng hình thành sao và đám sao trẻ lân cận Mặt Trời, sau đó xây dựng mô hình phân bố phổ năng lượng của chúng. Kết quả nghiên cứu của chúng tôi dựa trên hiện tượng bức xạ hồng ngoại dư phù hợp với các kết quả nghiên cứu trước đó. Do đó, chúng tôi đề nghị rằng tiêu chí 10% độ rộng vạch Hα có thể được áp dụng để xác nhận các vật thể có khối lượng rất thấp đang trong giai đoạn hút vật chất ở những đám sao lân cận Mặt Trời.*

Từ khóa: sao lùn nâu; quá trình hút vật chất; bức xạ hồng ngoại dư; sự hình thành sao; sao có khối lượng rất thấp