

# A Search for Photometric Variability in Very Low Mass Stars and Brown Dwarfs

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## Abstract

We present here optical I-band photometric variability studies of few young very-low-mass stars (VLMs) in IC348 using 2m HCT and 1.3m DFOT telescopes. IC 348 is a star-forming region in Perseus Molecular Cloud having an age of 2-3 Myr. Our preliminary analysis shows prominent hours-scale variability features in young VLMs of IC 348. The I-band light curves analysis of these VLMs show the variability periods in the range 3.6 - 16 hours, which are attributed to the fast rotational period in this kind of young VLMs. We detect a flare-event in a M3 dwarf in one occasion of our observing run.

## Introduction

Very low mass star (VLMs) refers to a main sequence star with a spectral type from mid-K to late-M and a mass from about  $0.6 M_{\odot}$  down to the brown dwarf limit of  $0.075 M_{\odot}$  (Allard et al. 1997). Brown dwarfs (BDs) are sub-stellar objects with a mass below  $0.075 M_{\odot}$  and a spectral type L, T, or Y (Kirkpatrick 2005). They don't have enough mass to fuse the hydrogen inside the core. They burn deuterium instead, as the threshold energy for deuterium fusion is lower compared to the one of hydrogen fusion. Theoretical models are found challenging to explain the spectral features of these dwarfs (e.g., Allard et al. 2001; Marley et al. 2002; Helling et al. 2008)

Photometric variability studies of VLMs and brown dwarfs (BDs) is an important tool to probe the physical nature of their atmospheres. This is generally attributed to the presence of surface features like magnetic spots or dust clouds, which may cause optical modulation as the object rotates. Brown dwarfs, being rapid rotators having a period of few hours, variability can be observed within few nights of photometric monitoring using moderate-sized telescopes. We present here our preliminary results of optical I-band photometric variability of a few selected young VLMs and BDs in IC 348 having an age of few million years. IC 348 is a nearby (310 pc) star-forming region in Perseus Molecular Cloud.

## Observation & Data Reduction



Table 1. Observation Log for IC348

Date	Telescope	Instrument	FoV (arcmin <sup>2</sup> )	Run-Length (hours)
18.12.2016	1.3m DFOT	ANDOR 2Kx2K	18x18	3.77
19.12.2016	1.3m DFOT	"	"	1.85
20.12.2016	1.3m DFOT	"	"	6.13
27.10.2017	1.3m DFOT	"	"	6.99
28.10.2017	1.3m DFOT	"	"	4.64
10.11.2017	1.3m DFOT	"	"	6.16
14.11.2017	2m HCT	HFOSC	10x10	7.98
15.11.2017	2m HCT	"	"	9.08

Table: Observation log of IC348. Data was obtained with 1.3m Devasthal Fast Optical Telescope (DFOT), ARIES, Nainital and 2m Himalayan Chandra Telescope (HCT), IIA, Bangalore

Figure: The observed region IC348 obtained with 1.3 DFOT, ARIES in optical I band. RA: 03:44:34 (J2000), DEC: +32:09:48 (J2000) Age ~ 2 - 3 Myr; Distance ~ 310 pc

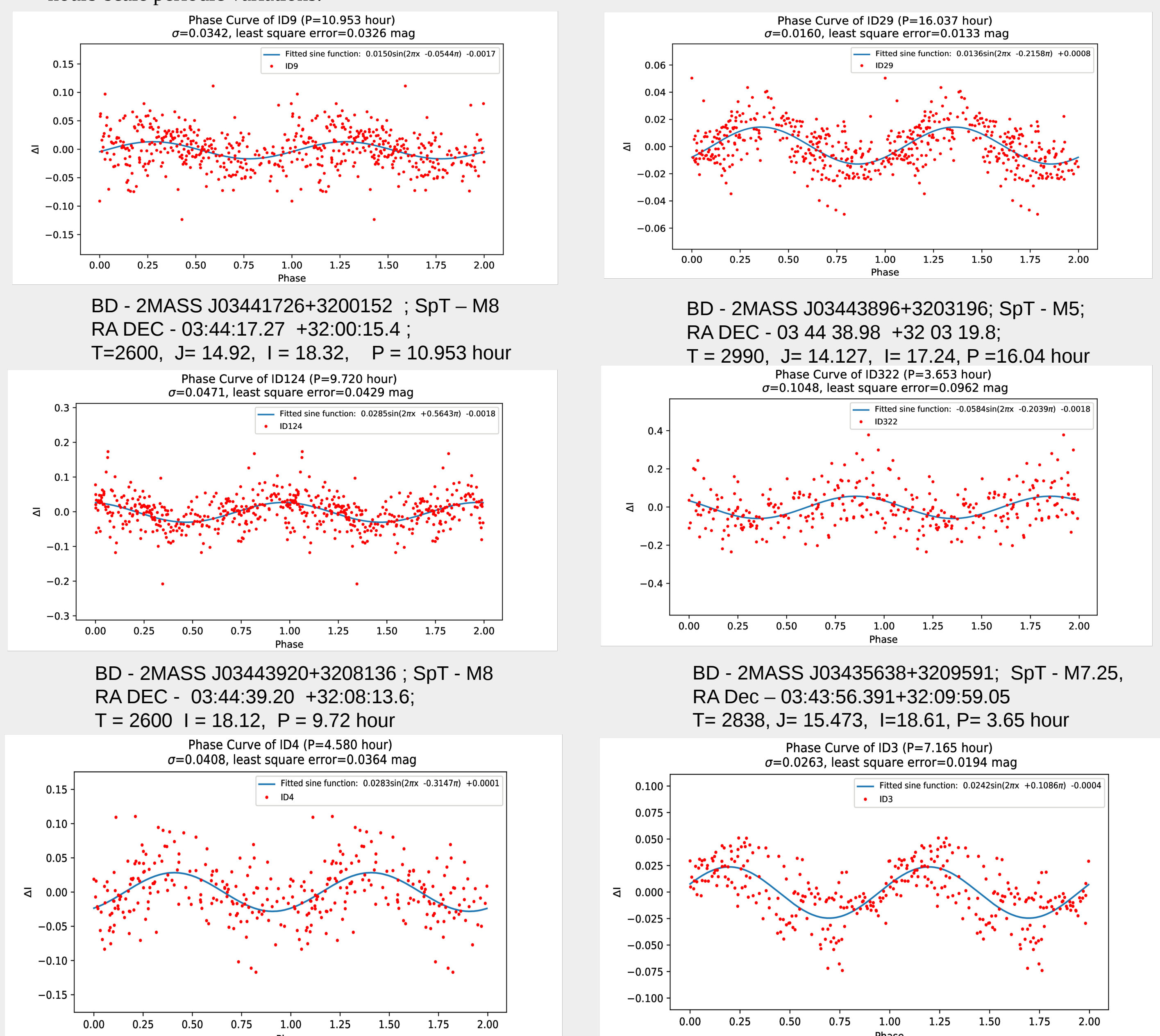
1. We have reduced the data using IRAF and used differential photometry to form zero averaged light curve over the nights. We checked for any variability present in those sources comparing with non-varying reference stars in each night.
2. Lomb-Scargle (LS) Periodogram (Lomb1976; Scargle1982) analysis is used to find a significant periodic signal in the stacked light curves and constructing the phase curves.
3. It is a well-used algorithm to find a periodic signal in unevenly spaced time-series data and is common in observational astronomy.
4. We haven't used the CLEAN algorithm (Roberts et al.1987) in our data because the data is unevenly spaced whereas the algorithm is based on classical FFT analysis which would only happen if the data were evenly spaced (VanderPlas 2018).
5. We have formed phase curves from the Period (LS Algorithm) using all nights' data. (Results)

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## Results

The phase light curves of four Brown dwarfs and two very low mass stars (M dwarf) from our studies, which are members in IC 348. Their light curves are folded by the most significant period found through LS periodogram analysis and show hours-scale periodic variations.



BD - 2MASS J03441726+3200152 ; SpT - M8  
RA DEC - 03:44:17.27 +32:00:15.4 ;  
T=2600, J= 14.92, I= 18.32, P = 10.953 hour

BD - 2MASS J03443896+3203196; SpT - M5;  
RA DEC - 03 44 38.98 +32 03 19.8;  
T = 2990, J= 14.127, I= 17.24, P =16.04 hour

BD - 2MASS J03443920+3208136 ; SpT - M8  
RA DEC - 03:44:39.20 +32:08:13.6;  
T = 2600 I = 18.12, P = 9.72 hour

BD - 2MASS J034435638+3209591; SpT - M7.25,  
RA Dec - 03:43:56.391+32:09:59.05  
T = 2838, J= 15.473, I=18.61, P= 3.65 hour

M dwarf - [AMB2013] CFHT-IC 348 17 ;  
RA Dec - 03:44:49.427 & +31:58:44.27;  
J = 15.598, I= 17.91, P = 4.58 hours

M dwarf - 2MASS J03443379+3158302; SpT - M3.75;  
RA Dec - 03:44:33.646 +31:58:29.09;  
T = 3270 K, J = 13.488, I = 16.04, P = 10.54 hour

## A Flare-event in 2MASS J03441857 +3212530

RA DEC: 03:44:18.579 +32:12:53.08

Temp	J mag	I mag	SpT	Luminosity(L)	E.D (hour)
3451	13.816	15.924	M3	0.14L <sub>*</sub>	1.0195

\* Uncertainty in L = 0.4L<sub>\*</sub> (Faherty et al.2013, Luhman et al.2003)

Equivalent Duration (E.D.)= 1.0195 hour = 3670.2 seconds

The duration of flare = 5.714 - 4.553 = 1.161 hour  
Rising Phase = 0.189 hour = 11 min 20.4 seconds  
Decaying Phase = 0.972 hour = 58 min 19.2 sec

Energy of Flare = E.D. × Luminosity = 3670.2 × 0.14L<sub>\*</sub>  
= 513.83 L<sub>\*</sub> = 1.973 × 10<sup>36</sup> ergs

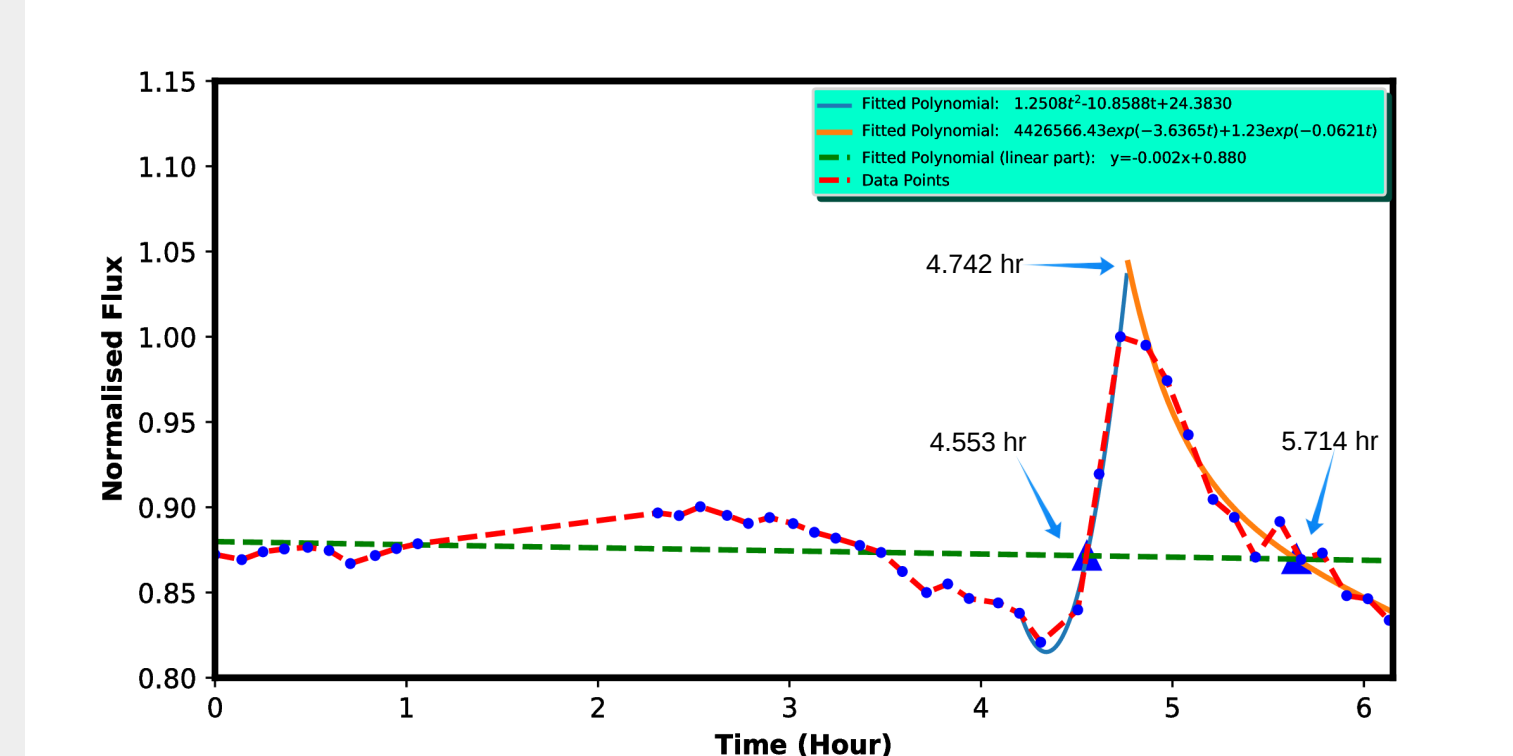


Fig: Normalised Flux variation with time. The normalised flux is fitted with straight line (upto the rising phase starts). The flare rising region is fitted with polynomial while the decaying part is fitted with exponential function.

## Summary

1. We aim here to observe short-term optical variability in hours to days timescales in young brown dwarfs and low mass stars. We found six low-mass sources show hour-scale variability.
2. It was observed that some sources are not varying in all observed nights and their degree of variations are changing night to night. One probable cause might be the dynamical evolution of brown dwarf's atmosphere (in timescales of days).
3. We observed a flare-event in young M3 dwarf, which is a member of IC 348.

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