

Rotational periods of very young brown dwarfs in Cha I

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Abstract. A photometric monitoring campaign of brown dwarfs in the Cha I star forming region in the *i* and *R* band revealed significant periodic variations of the three M6.5–M7 type brown dwarf candidates Cha H α 2, 3 and 6 (Joergens et al. 2002). These are the first rotational periods for very young (1–5 Myr) brown dwarfs and among the first rotational periods for brown dwarfs at all. The relatively long periods of 2.2 to 3.4 days as well as $v \sin i$ values (Joergens & Guenther 2001) indicate that our targets are moderately fast rotators in contrast to very rapidly rotating old brown dwarfs. The periods for the Cha I brown dwarf candidates provide valuable data points in an as yet, in terms of rotational characteristic, almost unexplored region of the age-mass diagram. A comparison with rotational properties of older brown dwarfs indicates that most of the acceleration during the contraction phase takes place within the first 30 Myr or less of the lifetime of a brown dwarf. We have also determined periods for the two M5–M5.5 type very low-mass stars B 34 and CHXR 78C.

Key words: Stars: low-mass, brown dwarfs – Stars: formation – Stars: late-type – Stars: activity – Stars: rotation – starspots – Stars: individual: Cha H α 1 to 12, B 34, CHXR 73, CHXR 78C

1. Data acquisition and period search

Photometric *i* and *R* band data have been obtained with DFOSC at the Danish 1.5 m telescope at ESO. We performed aperture photometry and calculated differential magnitudes by means of carefully chosen reference stars in the field.

A search for periodicity in the obtained light curves has been performed with the string-length method (Dworetzky 1983). This method is ideally suited for unevenly spaced data as in our case. The algorithm phase folds the data with a trial period and calculates the string length between successive data points. This is done for all periods within a given period range. The period which generates the minimum string length is the most likely period.

2. Tracing the rotation by means of spots

Young stars are known to exhibit often prominent cool spots on their surface, analog to sunspots but of much larger size. They are thought to form as magnetic flux tubes rise to the atmosphere and suppress convective energy transport. Appearance and disappearance of spots due to stellar rotation modulates the total brightness of the star and leads to periodic light vari-

Table 1. First rotation rates of very young brown dwarfs. Rotational periods P_{rot} (Joergens et al. 2002) and measurements of the projected rotational velocity $v \sin i$ based on UVES (VLT) spectra (Joergens & Guenther 2001) for bona fide and candidate brown dwarfs in Cha I with an age of 1–5 Myr. Spectral types SpT from Comerón et al. (2000).

object	SpT	P_{rot} [d]	$v \sin i$ [km/s]
Cha H α 1	M7.5	–	7.6 ± 2.2
Cha H α 2	M6.5	2.8	12.8 ± 1.2
Cha H α 3	M7	2.2	21.0 ± 1.6
Cha H α 4	M6	–	18.0 ± 2.3
Cha H α 5	M6	–	15.4 ± 1.8
Cha H α 6	M7	3.4	13.0 ± 2.8
Cha H α 7	M8	–	≤ 10
Cha H α 8	M6.5	–	15.5 ± 2.6
Cha H α 12	M7	–	25.7 ± 2.6

ations. The measured photometrical period of a spotted star is therefore a direct tracer of its rotational period.

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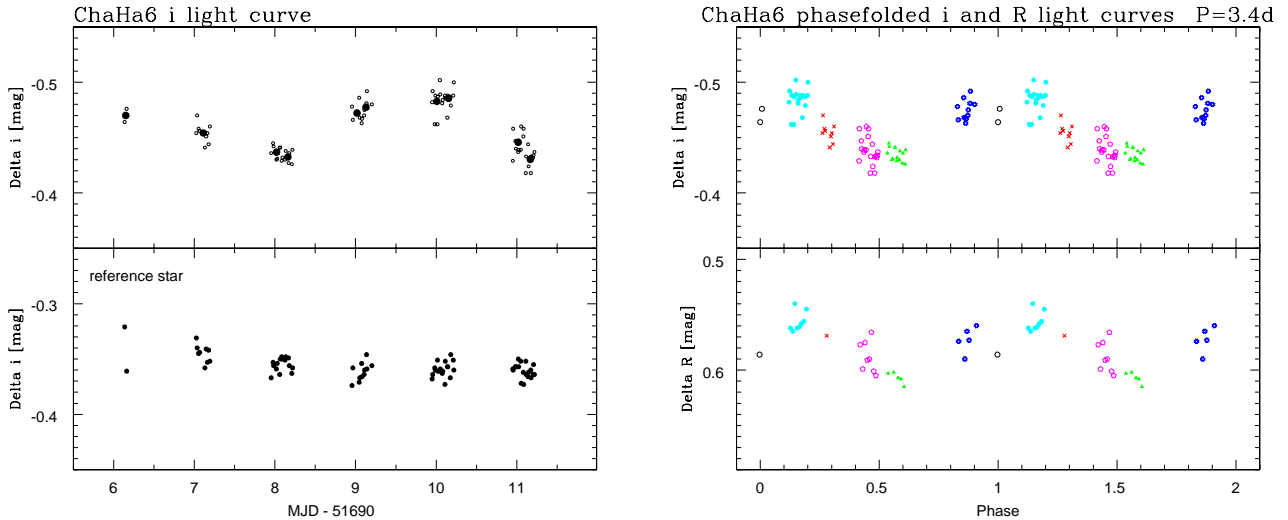


Fig. 1. Phasefolded as well as unphased i-band light curve of Cha H α 6 (M_7 , $\sim 0.05 M_\odot$, $\sim 0.68 R_\odot$)

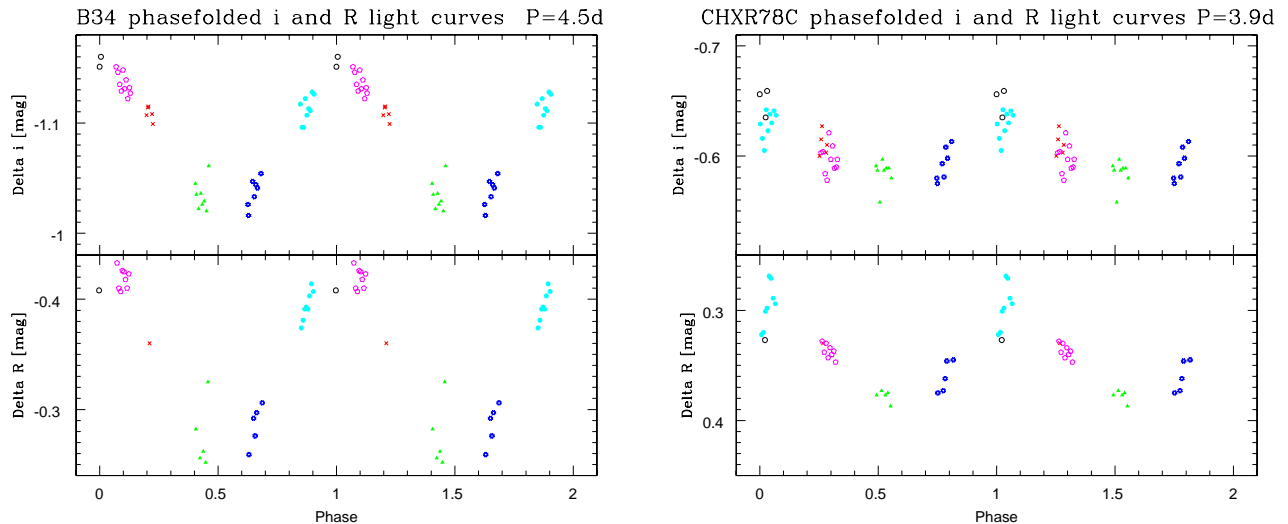


Fig. 2. Phasefolded light curves of the very low-mass T Tauri stars B34 (M_5 , $\sim 0.12 M_\odot$, $\sim 0.93 R_\odot$) and CHXR 78C ($M_{5.5}$, $\sim 0.09 M_\odot$, $\sim 0.94 R_\odot$).

3. Results

We have measured significant periods for three brown dwarf candidates (Cha H α 2, 3, 6) as well as for two very low-mass T Tauri stars (B 34, CHXR 78C) within the range of 2.2 d to 4.5 d and with i band amplitudes between 0.06 mag and 0.14 mag (Joergens et al. 2002). See Table 1 for periods and $v \sin i$ measurements of the targets as well as Fig. 1, 2, 3 for the phasefolded light curves.

The observed periodic variations are interpreted as modulation of the flux at the rotation period by magnetically driven surface features on the basis of consistency with $v \sin i$ values as well as (R-i) color variations typical for spots. Furthermore, the temperatures even of the brown dwarfs in our sample are relatively high (> 2800 K) because they are very young. Therefore, the atmospheric gas should be sufficiently ionized for the formation of spots and the temperatures are too high for significant dust condensation and hence variability due to clouds.

4. Evolution of angular momentum in the sub-stellar regime

Old brown dwarfs are very rapid rotators having rotational velocities $v \sin i$ up to 60 km s^{-1} (e.g. Basri et al. 2000) and rotational periods shorter than one day (Bailer-Jones & Mundt 2001, Martín et al. 2001, Eislöffel & Scholz 2001 and Clarke et al. 2002). This can be explained by the fact that after the acceleration caused by contraction on the Hayashi track, there is no braking due to winds at the low masses of brown dwarfs, in contrast to stars. However, our measurements showed that extremely young brown dwarfs have significantly longer rotational periods (2 to 3 days) indicating that they are still in an early contracting stage and/or they have suffered until very recently a braking due to their interaction with an accretion disk. A comparison of our rotation periods at 1–5 Myr and those in the literature at > 36 Myr suggests that most of the acceleration takes place in the first 30 Myr or less of the lifetime of a brown dwarf. (The mark

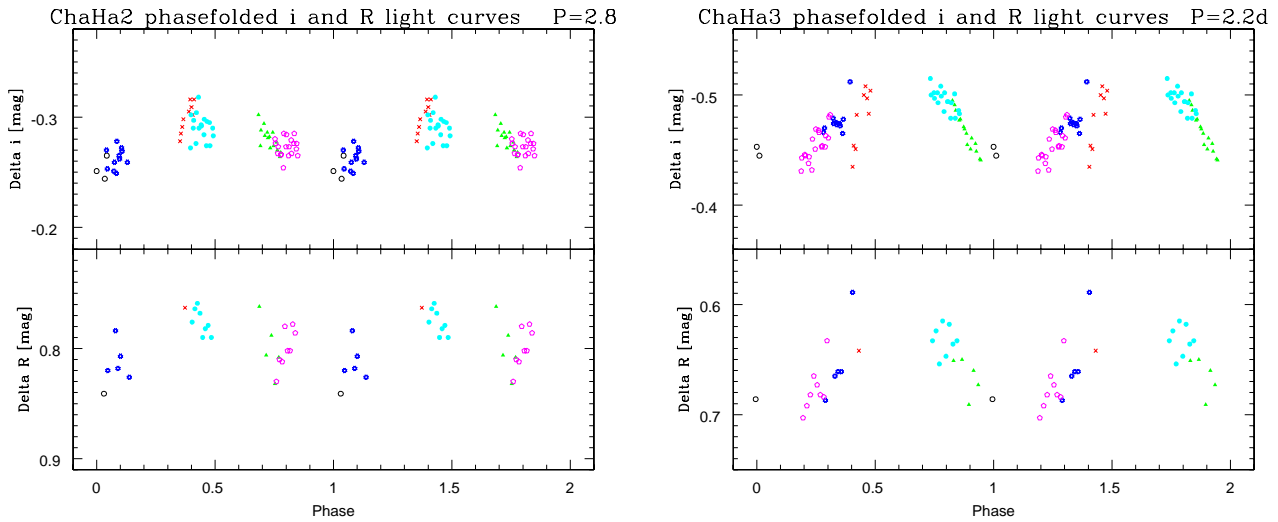


Fig. 3. Folded light curves of the brown dwarf candidates Cha H α 2 (M6.5, $\sim 0.07 M_{\odot}$, $\sim 0.73 R_{\odot}$) and Cha H α 3 (M7, $\sim 0.06 M_{\odot}$, $\sim 0.77 R_{\odot}$)

at 36 Myr is set by rotational periods for brown dwarf candidates in the cluster IC 4665 by Eislöffel & Scholz 2001.)

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