THE NEAR-INFRARED VARIABILITY OF CLASSICAL T TAURI STARS.

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Classical T Tauri stars (CTTSs) are pre-main sequence, low mass (M<2 $M_\odot$) stars still surrounded by an accretion disk. Mass accretion from that disk plays an important role in their visible continuum and line variability, which is due, mainly, to the hot spots generated at the bottom of the accretion columns.

The near-infrared (NIR) variability of CTTS stars was discovered during their first observations at this wavelength range (Mendoza 1966, 1968), at the same time that a strong NIR excess was found for many of them. Other NIR monitorings took place in the following years (e.g.Cohen & Schwartz 1976; Rydgren & Vrba 1983; Kilkenny et al. 1985) but it was not until 1996 that Skrutskie et al. and Liu, working on different samples of stars, suggested that changes in the disk accretion rate could be responsible for the NIR variability. The time sampling and coverage of the NIR (JHK) observations of Carpenter et al. (2001), in the Orion A region, led this group to propose that changes in both the mass accretion rate and in the inner disk structure could be responsible for the observed variability, with time scales of days and weeks. Our Fig. 1 and Fig. 2 show the light curves of two of the variable stars of their sample.

Nevertheless, unambiguous support to the disk hypothesis was only given by the simultaneous visible and NIR observations carried out by Eiroa et al. (2002), which showed for some stars uncorrelated light curves at both wavelength ranges. The spots on the stellar surface, that fit the observations at visible wavelengths, could only have a second order effect on the NIR variability and, therefore, another mechanism related to the disk was taking place simultaneously.

Changes in the disk inner rim

Following the work of Eiroa et al. (2002) we started in 2003 a project devoted to the simultaneous visible and NIR monitoring of several samples of CTTSs. As an example, Fig. 3 shows the visible (B band) and NIR (K_{cont} band) light curves of DL Tau obtained during one of the nights. From a careful analysis of the database of accretion disk models of D'Alessio et al. (2005), we have shown that the NIR variations should be related either to variations in the disk mass accretion rate or to changes in the disk inner rim (Fernández 2005). The disk inner rim had been successfully proposed by Natta et al. (2001) for the Herbig Ae stars (more massive counterparts of the T Tauri stars) as a narrow region of the disk where the temperature reaches the dust sublimation temperature; a dust free region would extend inwards from this limit, while matter at that distance and further from the star would be a mixture of gas and dust. The rim can be visualized as the wall of a cylinder whose height is that of the disk at the dust sublimation radius[1]. The accretion disks of the CTTSs seem also to follow this pattern and such disk inner rim has been incorporated by D'Alessio et at. (2005) into their accretion disk models.

We have analyzed the effect of changes in the disk inner rim, namely, in its distance to the star. We have assumed that a hot spot on the stellar surface, as they have been observed at visible wavelengths, UBVRI, (e.g. Fernández & Eiroa 1996), increases the stellar luminosity and therefore the temperature of the part of the disk that is looking to the spot. As a consequence, dust sublimates and the rim moves further from the star, increasing its surface. We are not able to change the circular shape of the rim (although this must be the case) but since we only detect the emission of the part of the rim that 'looks' to us, our (naive) calculations should be a good approximation. This is confirmed by the fit performed to the JHK light curves shown in Fig. 1 and Fig. 2: the solid line shows the computed brightness variations due to a rim that moves back and forth from the star (Fernández 2007). In this fit to the JHK light curves there is only one free parameter: the distance of the rim to the star. The time scale of the variations falls within the estimated time required for dust sublimation (Sorelli et al. 1996).

Previous evidences of such an *extra*-irradiated rim were found for DG Tau, for which Colavita et al. (2003) carried out Keck interferometric observations. They showed that the system was resolved at the K band and derived a radius that was $\sim$3 times larger than the dust sublimation radius inferred, assuming that the rim is irradiated by a central star that is not affected by accretion. D'Alessio et al. (2003) showed that if mass accretion is taken into account, results are consistent with the observed inner radius of DG Tau.

Changes in the disk mass accretion rate predict the same kind of behaviour in the JHK bands as the changes in the rim, in the sense that the amplitude of the variability increases at longer wavelengths. Nevertheless, a detailed fit to the observational data cannot be performed because the grid of models has not enough resolution to allow small changes in the disk mass accretion rate (e.g. from $10^{-7} M_\odot$/yr to $2\times10^{-7} M_\odot$/yr).

Sample selection

An analysis of the JHK light curves of the 1235 variable stars observed by Carpenter et al. (2001) shows that for $\sim$10% of them the disk dominates the variability at the H and K bands. Only for $\sim$1% of the stars the disk dominates at the three bands; these are the stars we are interested on. For the other variable stars the JHK observations show either the effect of the stellar spots or of a mixture of the effects of the stellar spots and the disk.

[1] A detailed analysis of the shape of the rim is given by Isella & Natta (2005).

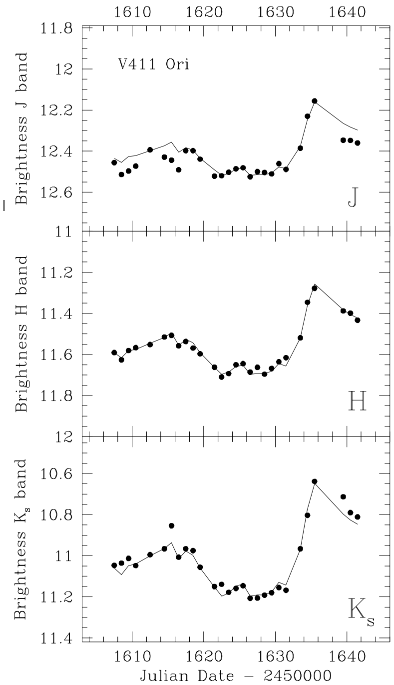

Figure 1: The near-infrared (JHK$_s$) light curves of one star observed by Carpenter et al. (2001). The solid lines represent the fit of a disk inner rim that changes its distance to the star, due to the presence of stellar hot spots (Fernández 2007).

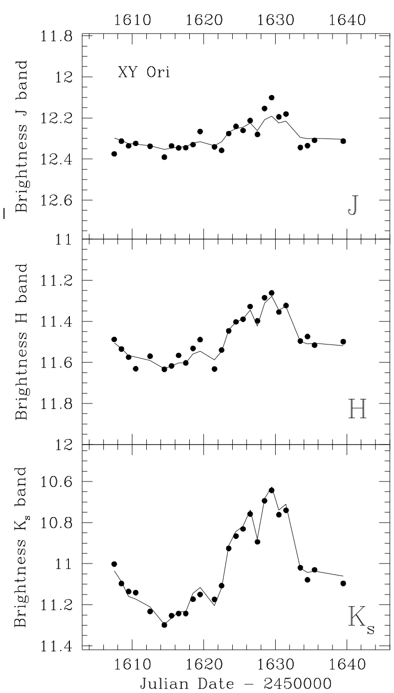

Figure 2: See caption of Fig.1.

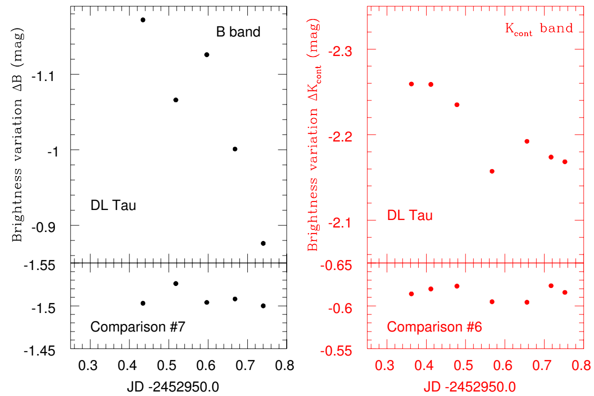

Figure 3: Simultaneous visible and near-infrared observations of DL Tau. *Left panel:* the light curve at the B band (4400 Å), *right panel:* the light curve at the K_{cont} band (2.2μm). The amplitude observed in the K_{cont} band is about one order of magnitude larger than what is expected to be the effect, at this wavelength, of the spot hat fits the B-band observations, for this reason the variability is attributed to the disk.

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