A SEARCH FOR PERIODICITIES IN BALMER LINE PROFILES OF 6 T TAURI STARS

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ABSTRACT We analyze repeated observations of 6 T Tauri stars (TTS) to search for periodic behavior in their line profile variations. Three of the 6 stars show evidence for periodicity in some portion of their line profiles. In SU Aur the detected periodicity is in good agreement with the rotation period of the star. The source of periodicity in the other 2 stars (DF Tau and DR Tau) is unclear.

INTRODUCTION

The geometry of the excess emitting region in TTS remains unclear despite years of effort by a host of researchers. It is clear that a wind is present in TTS systems (see for example Mundt, 1984 and Edwards et al., 1987). Models for Alfvén wave driven winds originating from the star (Hartmann et al., 1990) and winds originating from the disk (see for example Saifer, 1993) have been calculated. Hartmann et al. (1993) have also proposed that the majority of Balmer emission arises from accretion along dipole magnetic field lines.

Shu et al. (1993) have proposed a generalized magnetocentrifugally driven flow model in which both a wind and accretion along magnetic field lines originates at the point where stellar field lines intersect the disk at a radius where the Keplerian angular velocity is equal to that of the star. In both this model and in the Alfvén wind model, any non-axisymmetric field structures might give rise to periodic profile variations with a period equal to the stellar rotation period. Any periodicity in the disk winds would be at some other period characteristic of Keplerian rotation unless the wind is preferentially launched from the point in the disk proposed by Shu et al.

We analyze multiple spectra of 6 TTS to look for periodicity in the line profile variations. All the data were collected at Lick Observatory using the Hamilton Echelle spectrometer. The spectral resolution is approximately 48,000. Most of the observations were made with the 0.6-m Coudé Auxiliary Telescope feeding the spectrograph, while a few were made using the 3-m Shane telescope.

PERIODOGRAM ANALYSIS OF H\textalpha AND H\textbeta IN SU AUR

In February 1988 we obtained nightly or better observations of SU Aur for a 14 day period. The photometric rotation period of SU Aur is \(~ 3\) days (Herbst et al. 1987, Bouvier et al. 1993). The periodogram (referred to here as a two
dimensional array made up of the power spectra computed at each wavelength bin in the line profile during the aforementioned time series) shows a peak at a period of 3 days and a velocity of $\sim -130$ km s$^{-1}$. The single wavelength bin false alarm probability for this peak, determined from a Monte Carlo test of 5000 synthesized random time series, is 0.0018 and the total false alarm probability is estimated to be $\sim 10^{-21}$, following the prescription of Catala et al. (1991) which allows us to multiply false alarm probabilities in adjacent wavelength bins which show power at the same period. This peak is caused by variations of a blue-shifted absorption feature centered at $v \sim -150$ km s$^{-1}$. This appears to be evidence for a rotationally modulated wind. For a complete discussion of H$\alpha$ variations in SU Aur see Giampapa et al. (1993).

Over this same period we have H$\beta$ line profiles for SU Aur. The periodogram of H$\beta$ is weaker than H$\alpha$, but shows a peak centered near $\sim -110$ km s$^{-1}$ with a period of 3 days. Again, a variable blue-shifted absorption feature is present at these velocities in the H$\beta$ line profiles. The single channel false alarm probability of this peak is 0.0146 and its total false alarm probability is estimated to be $\sim 10^{-20}$. The periodogram shows another peak in the velocity range of a variable red-shifted absorption feature. The period of the peak is slightly longer than 3 days but is the same as the blue side to within the error that we can actually determine the period. The single channel false alarm probability for the red side is 0.0688 which would not be considered reliable by itself. As opposed to the previous cases we have considered, the period found in adjacent velocity bins is not the same as found in the peak though they are equal to within the errors of the period determination. If we assume that these period differences can be ignored and estimate a total false alarm probability for this peak we find it to be $\sim 10^{-10}$. We interpret this as tentative evidence for rotationally modulated infall which exists simultaneously with a wind.

PERIODOGRAM ANALYSIS OF H$\alpha$ IN OTHER TTS

The periodogram of DF Tau is computed from 37 H$\alpha$ profiles collected in the Fall 1992 which was the only time our data was sampled well enough to detect periods longer than about 3-4 days. The peak of the periodogram is located at a period of $\sim 7.3$ days and a velocity of $\sim 40$ km s$^{-1}$. The resulting single wavelength bin false alarm probability is 0.0064 and we estimate the total false alarm probability for this power peak to be $\sim 10^{-13}$. The photometric rotation period of DF Tau is 8.5 days (Bertout et al. 1988).

The periodogram for DR Tau is based on 31 H$\alpha$ line profiles collected in the Fall 1992. A peak in the periodogram occurs at a period of $\sim 5.1$ days and a velocity of $\sim 50$ km s$^{-1}$. The single wavelength bin false alarm probability for this peak is 0.0134, but its total false alarm probability we estimate to be $\sim 10^{-19}$. This value is smaller than the total in DF Tau because the peak in DR is broader in wavelength than the peak in DF Tau. Photometric periods of 2.8 and 7.3 days (Bouvier et al. 1993) as well as a possible 9.0 day (Richter et al. 1992) have been reported. Since DR Tau is an extreme TTS in which the optical veiling can be as much as four times the photospheric light (Basri and Batalha, 1990), it does not follow that any one of the reported photometric periods is the stellar rotation period.
Periodogram analysis of the Hα line profile variations in RW Aur, RY Tau, and T Tau did not reveal any significant periodicity, though the amplitude of their profile variations is of the same order as the other stars in the sample.

DISCUSSION

We have analyzed line profiles of 6 TTS and found potentially periodic behavior in 3 of them. In only SU Aur is the detected profile periodicity equal to the stellar rotation period.

The simultaneous existence of rotationally modulated outflow and infall in SU Aur appears to fit nicely the recently proposed generalized model of magnetocentrifugally driven flows from young stars by Shu et al. (1993). The other stars are problematic. T Tau may show no periodicity because of its likely polar geometry. In RW Aur and RY Tau it may be that their winds are so optically thick that we can not see the region where the magnetic field controls the flow of material. DF Tau and DR Tau are more problematic since they both appear to show periodicity on the red side of the profile, but neither one is certain to be displaying line profile variability with the same period as the stellar rotation period. However, Bouvier (1993, private communication) indicates that the periods detected here are close to recently observed photometric periods. Further success in understanding TTS emission lines would be helped by line profile calculations of the Shu et al. (1993) model to see what kind and range of profile shapes it can produce.

REFERENCES