SYNOPTIC STUDIES OF THE T TAU RI STAR SU AUR

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ABSTRACT Eighty-three high resolution SU Aur H\alpha line profiles taken from Fall 1986 through 1989 are analyzed. The profiles are analysed for correlations among the profile parameters and for periodicity. Strong periodicity is found at 2.98 ± 0.4 days. A crude model is presented for the geometry of the emission region in terms of a wind emanating from a star surrounded by an accretion disk.

Keywords: T Tauri stars; H\alpha line profiles; stellar winds; accretion disks

INTRODUCTION

H\alpha in T Tauri stars (TTS) has been used as a diagnostic of circumstellar disks (for example see Basri and Bertout, 1989), and stellar winds (for example see Edwards et al., 1987, and Hartmann et al., 1990) These models have been very successful in accounting for the equivalent widths of the observed emission lines but the detailed line shapes do not account for all the observations.

TTS are known to be quite variable (for example see Mundt, 1984). SU Aur shows pronounced variation in its H\alpha profile and was selected for extensive study because of this. This should allow a determination of the constant properties of the line profile to be made and possibly interpreted in the context of one of the above models. It is also hoped that careful analysis of the variations in the line profile will help further constrain the nature of the H\alpha emitting region.

THE H\alpha PROFILES AND PERIOD ANALYSIS

The profiles were taken at Lick Observatory and Kitt Peak Observatory. Each profile was parameterized by fitting the profile to a function consisting of a flat-topped feature with from zero to five gaussian components superimposed on it. A gradient search algorithm was developed to optimize the fit. The profiles contain a clear flat top component which is slightly asymmetric with the blue side higher than the red with a smooth transition through line center on average. Eighty-one of the eighty-three profiles has a prominent absorption component, which often reaches below the stellar continuum, at about \( v = -40 \) km/s. Seventy-three of the profiles contain a central emission feature centered just red of line center with an average position of \( v = 20 \) km/s. The line profile often has an absorption feature at roughly \( v = -150 \) km/s and occasionally another absorption feature at roughly \( v = 130 \) km/s. The average observed H\alpha
profile is shown in Figure 1. The absorption at \( v = -40 \) km/s and the emission at \( v = 20 \) km/s are clearly visible and the absorption feature at \( v = -150 \) km/s can barely be seen.

![Graph showing a profile with peaks and valleys](image)

**Fig. 1:** The average SU Aur H\( \alpha \) profile.

With all the profiles parameterized as mentioned above, correlations were looked for among the profile parameters. The only correlation found is between the strength of the absorption component at \( v = -40 \) km/s and the strength of the emission component at \( v = 20 \) km/s. They correlate positively. The main absorption component does not appear to correlate in any way with the level of the flat top component.

Since the period of SU Aur is probably on the order of a few days, the period analysis was concentrated on stretches of data which have daily or better observations for several days. The best stretch of data for this purpose is shown in Figure 2 in a three dimensional surface plot. This figure clearly shows how variable the H\( \alpha \) profile is. Looking carefully at the blue side of the profile, it appears that this part of the profile varies periodically.

Periodogram analysis of the data confirm a period of \( 2.98 \pm 0.4 \) days in the blue side of the profile caused by variations in the \( v = -150 \) km/s absorption feature. This is taken to represent rotational modulation of mass outflow from near the stellar surface. The rotation period of SU Aur is then \( 2.98 \pm 0.4 \) days.

**A GEOMETRIC MODEL OF THE H\( \alpha \) EMISSION REGION**

From an analysis of the profiles, it is apparent that the majority of the H\( \alpha \) emission arises from the flat top feature. Optically thin, spherically symmetric stellar winds can easily produce broad flat emission features (Mihalas, 1978). Therefore, a simple model for computing line profile shapes for such winds was developed. Since SU Aur has a substantial IR and UV excess which indicates an active accretion disk is present (Bertout, Basri, and Bouvier, 1988), models were computed which have a circumstellar disk which operates as an opaque screen
blocking the receding flow. The volume is assumed to be quite optically thin so that each photon produced escapes.

![SU Aur Hα Profile](image)

Fig. 2: The SU Aur Hα profile for the 24 observations from Julian Date 2447199.66 to 2447213.68. For clarity, the first profile in this sequence has been highlighted.

The flat top component (profile minus a single gaussian absorption feature) of the least contaminated SU Aur Hα line profile is shown in Figure 3 along with the wind model fit. The wind emission in this model begins at \( r = 5R_\star \) and the model calculation is stopped at \( r = 10R_\star \). The velocity in the wind follows a \( r^{-1/2} \) law. Assuming that hydrogen is collisionally excited in such a wind, the source function was set equal to density squared. The model wind is assumed to have a constant mass loss rate with radius so the source function obeys a \( r^{-3} \) law. The asymmetry in the model is caused by the occulting disk. For an inclination of zero, the disk would block the entire redshifted half of the flow and the resulting profile would have only blue shifted emission. As the inclination increases, more and more redshifted material is on the observers side of the disk. The model shown has \( i = 73° \). The results are suggestive that the Hα line emission arises in an fast moving optically thin region of the outflow which is separated from the star. Since the wind is postulated to be very optically thin, the stellar absorption line should be apparent. The line profile would just be a G2 (solar) Hα line spun up to \( v \sin i = 68.5 \) km/s with a flat top feature added on making the level of the absorption feature higher than normal but still apparent. The wind can not be moving at escape velocity as soon as it leaves the star so there must be an acceleration region. The continuity equation then dictates there will be a high density (possibly enough to hide the stellar line), slow moving region of the wind near the star which may be much cooler than
the outer optically thin wind. The main absorption feature may form in this part of the wind and be seen through the optically thin, fast part of the wind.

![Graph showing relative intensity vs velocity (km/s)](image)

**Fig. 3:** SU Aur Hα line profile (solid line) and model fit (dotted line).

**CONCLUSION**

Analysis of the Hα profile seen in SU Aur indicates that the star rotates with a period of 2.98 ± 0.4 days. A model of the emission from SU Aur indicates that most of emission arises from a fast moving, hot, optically thin region a few stellar radii from the star. The lower velocity portion of the profile may arise from a low velocity, cool, dense, optically thick region inside the fast wind. Whatever accelerates the wind may also heat it.

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**REFERENCES**