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STRÖMGREN PHOTOMETRY OF THE T TAURI STAR SU AURIGAE: ECLIPSE-LIKE VARIABILITY AND AGE DETERMINATION

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SU Aurigae (HD 282624; G2 IIIe; $\langle V \rangle = +9.23$ mag; $\langle B-V \rangle = +0.83$) is one of the brightest archetypical classical T Tauri stars (CTTS). CTT stars are pre-main sequence stars with accretion disks. They have spectral types of typically F to K, exhibit weak Hα and Ca II emissions, have broad absorption lines (implying rapid rotation), and are located well above the main-sequence. From an analysis of the variability of its Hα line profiles, Giampapa *et al.* (1993) found a possible ~3.0 day periodicity which is attributed to the rotation period of the star. Also, Hartmann *et al.* (1986) report a projected rotational velocity of $v \sin i = 66.2 \pm 4.6$ km/s, which indicates rapid rotation.

The recently determined distance from Hipparcos (ESA, 1997) of $r = 151 \pm 40$ pc confirms that SU Aur is member of the Taurus-Auriga star-forming complex. Furthermore, AB Aur (HD 31293; A0pe; $V = +7.06$; $B-V = +0.13$), is a nearby bright companion to SU Aur. The two stars are separated by 3.5 arcmin and AB Aur is itself classified as an early-type T Tau star. Since AB Aur has a nearly identical parallax ($r = 144 \pm 20$ pc) and similar proper motions to its fainter companion, it appears that SU Aur and AB Aur are physically linked – perhaps a common proper motion pair, or are members of the same local star forming region. If we assume that they are at the same distance, then the two stars are separated by about 31,500 AU.

Although SU Aur is one of the brightest CTT stars, only a few concentrated photometric studies have been devoted to this interesting young star. Herbst *et al.* (1994) have published a catalogue of *UBVRI* photometry of T Tauri stars which includes SU Aur (as well as AB Aur). They classify SU Aur and AB Aur as early-type T Tauri stars (ETTS). They report a range of V-mag of +8.93 to +9.77 for SU Aur from photometry extending from JD 2439095 to JD 2447605. The light variations of SU Aur do not appear to be periodic. Also the light variations appear not to be accompanied by spectral changes (*i.e.* veiling effects).

Photoelectric photometry of SU Aur was made using the 0.8m Automatic Photoelectric Telescope (APT), located at Fairborn Observatory, Mt. Hopkins, Arizona. The photometry was made using intermediate-band filters very closely matched to the Strömgren *uvby* system. The observations reported here were made from November 1993 to March 1994. The photometry was made differentially with respect to the nearby comparison

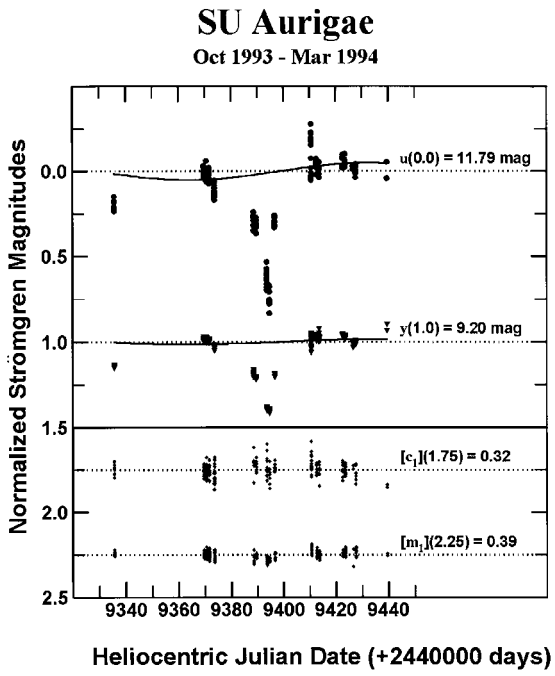

Figure 1. u and y light curves for SU Aur are shown in the top panel with the Strömgren $[c_1]$ and $[m_1]$ indices in the lower panel. Note that though there is a significant "eclipse-like" drop in light occurring around JD 2449390, the indices remain unaffected. This implies obscuration by dust with properties similar to ISM dust. We find the out-of-eclipse light levels to be 10.57 mag in v and 9.78 mag in b

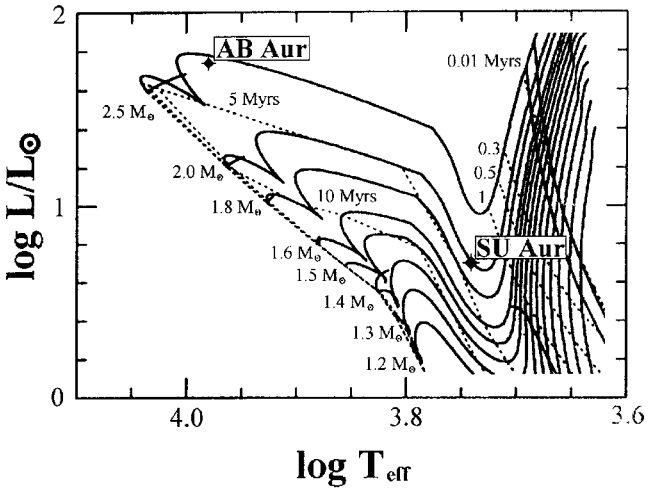

Figure 2. Theoretical Hertzsprung–Russell Diagram (HRD) from D'Antona & Mazzitelli (1994) showing the present positions of both SU and AB Aur. Isochrones are represented by dashed lines within the figure, and the solid lines represent different mass models. Especially noteworthy is their common age of approximately 4 Myrs. Since both stars have similar proper motions, they are most likely a coeval proper motion pair.

star, HD 31305 (A0 V; $V = +7.56$; $B-V = +0.11$). In addition to observing SU Aur, differential photometry of AB Aur was conducted at the same time that SU Aur was observed, but AB Aur was observed less frequently per night and showed only small light variations (± 0.07 in u and ± 0.03 in y).

The usual observing pattern of *sky-comp-var-comp-sky* was employed. An integration time of 10-sec was used and typically the stars were observed several times a night over a 25-30 minute interval. The photometry was reduced in the usual way in that the UT times were converted to heliocentric Julian Day (HJD) and the differential magnitudes were corrected for atmospheric extinction. However, because of the close angular proximity of the stars, the extinction corrections were insignificantly small. Also, the differential Strömgren *uvby* magnitudes were converted to the standard system and Strömgren indices were computed. For the comparison star the following Strömgren magnitudes and indices were adopted: $y = +7.69$, $b-y = +0.06$, $v-b = +0.22$, and $u-v = +1.34$.

Figure 1 shows u(350nm) and y(550nm) light curves of SU Aur for the 1993/94 observing season plotted against Julian Day Number. Also included in the Figure are the Strömgren reddening-free $[c_1]$ and $[m_1]$ indices discussed below. Noteworthy is the large "eclipse-like" drop in light that occurs starting around JD = 2449370 (Jan. 17, 1994 UT) and ending about 40 days later. Also evident are smaller light variations that occur on shorter time-scales and a possible long-term, low amplitude undulation in brightness with time. There is a strong wavelength dependence during the large dimming event of 1994. For example, the magnitude range of the light decrease is 0.75 mag in u, 0.57 mag in v, 0.48 mag in b, and 0.40 mag in y.

To understand better the nature of this light decrease during the large dimming event of 1994, Strömgren reddening-independent $[c_1]$ and $[m_1]$ indices:

$$c_1 = (u-v)-(v-b) \quad and \quad m_1 = (v-b)-(b-y)$$

$$[c_1] = c_1 - 0.20(b-y) \quad and \quad [m_1] = m_1 + 0.32(b-y)$$

(Strömgren, 1966; Crawford & Mandwewala, 1976) were formed from the observations. When plots were made (see Figure 1) of the $[c_1]$ and $[m_1]$ indices versus HJD, no significant variations are seen during the dimming event. We find mean values of $[c_1] = 0.32 \pm 0.046$ and $[m_1] = 0.39 \pm 0.024$ mag. The constancy of the Strömgren indices through the dimming event indicates that the light decrease arises from the obscuration of the star by dust with scattering properties similar to ISM dust. The wavelength dependence of the dimming event as seen with the Strömgren indices appears to eliminate the possibility that the event was produced by a change in the mean temperature of the star from either pulsations or from the sudden growth and decay of large starspots on the star's surface. These other possibilities would have a different wavelength dependence than observed. Since CTTS have accretion disks, the dimming event could be caused by a concentration of matter orbiting in the outer regions of the disk that temporarily obscures the star and the central (hotter) regions of the accretion disk. It is also possible that a dust cloud condenses from ejected matter and temporarily obscures the star.

We also searched for possible short period modulations in brightness that could arise from the rotational modulation of light by starspots. Several T Tau stars have their rotation periods established this way (Bouvier *et al.*, 1995; Bouvier *et al.*, 1993; *cf* Herbst *et al.*, 1994). In particular, we searched for periodic light variability near the 3 day period indicated by Giampapa *et al.* (1993). No evidence for a period near this value was found within these data sets.

Using the Hipparcos parallax given above, we computed the absolute magnitudes of both SU Aur and its nearby companion AB Aur. The reddening correction for both stars was made assuming a value of $E(B-V) = 0.13$ derived from the color indices and spectral type of AB Aur. Using the standard relation $A_V = 3.2\ E(B-V)$, the mean values of $\langle V \rangle_{SU} = +9.23$ and $\langle V \rangle_{AB} = +7.08$, and the Hipparcos distances, we arrive at $M_V = +2.90$ and $(B-V)_0 = +0.70$ for SU Aur and $M_V = +0.87$ and $(B-V)_0 = 0.00$ for AB Aur. These values place SU Aur and AB Aur about 1.8 mag and 0.6 mag above the main-sequence for their respective unreddened colors (or spectral types). The two stars can be satisfactorily placed on PMS evolution tracks (D'Antona & Mazzitelli, 1994) for a common age of about 4 Myrs. Figure 2 shows the locations of SU Aur and AB Aur in the theoretical HRD. This clearly shows that both stars are more luminous than corresponding main-sequence stars. Furthermore, their locations indicate masses of $M_{AB} = 2.5 \pm 0.1\ M_\odot$ and $M_{SU} = 1.9 \pm 0.1\ M_\odot$.

We plan to discuss the photometry of AB Aur in a future paper. Strömgren photometry of both stars is being continued by us with the 0.8m APT. This research is supported by NSF/RUI Grant AST-93 15365, which we gratefully acknowledge.

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