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RECENT OUTBURST OF U SCORPII

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ABSTRACT

A photoelectric scan of Hβ and a photographic spectrum between $\lambda\lambda$ 4500-7000 obtained during the 1979 outburst of the recurrent nova U Sco have been studied. The electron density and the mass of ionized hydrogen in the nova shell on June 28.77 U.T. as derived from the photoelectric observations are $N_e = 6.63 \times 10^{6}\ r_{kpc}\ cm^{-3}$ and $M_{HII} = 4.41 \times 10^{-7}\ r_{kpc}\ M_{\odot}$ where r_{kpc} is the distance to the nova in kpc.

Key words : U Sco Recurrent novae—spectroscopy

1. Introduction

U Scorpii was discovered by Pogson (1887) in 1863 at Madras. Subsequent outbursts recorded at Harvard by Thomas (1940) in 1906 and 1936 have accorded it the status of a recurrent nova. It eluded detection at its minimum until Webbink (1977) identified it with a $19^m.2$ star. Its large amplitude of outburst (~10 mag.) and fast decay (3 magnitudes in 4-5 days) render it an interesting object among the known recurrent novae. A detailed study of this object has so long been hampered by the absence of spectroscopic data.

No spectroscopic data exist for the previous outbursts of U Sco. Hill *et al.* (1979) have reported spectroscopic observations on July 2 and July 3, 1979 during the recent outburst. The results that we report herein are based on a photoelectric scan of the Hβ region on June 28 and an unwidened slitless spectrum covering $\lambda\lambda$ 4500-7000 on June 29.

2. Observations

Both the observations reported are obtained with the 102cm reflector of Kavalur Observatory. The Hβ region ($\lambda\lambda$ 4760-5260) was scanned with the automated spectrum scanner (Bappu, 1977) on June 28.77 U.T. A band pass of 25Å was employed and 58 Aql served as a spectrophotometric standard.

The spectroscopic observations were obtained on June 29.72 using an objective transmission grating of 150 l mm^{-1} in parallel beam and an F/3.5 camera equipped with a Varo 8605 image intensifier tube. The resultant dispersion was 380Å mm^{-1}.

We show in Figure 1, the instants of these observations relative to the light curve. The latter is obtained by superposing visual estimates of magnitudes during the recent outburst, published in IAU circulars along with the observations of previous outbursts by Pogson (1908) and Thomas (1940). The observations of Pogson and Thomas are shifted so as to match the maxima. The epochs of our observations clearly fall at the transition from the "Orion" to the "Nebular" phase. The nova had faded to ~ 12^m by this time.

The reduced photoelectric scan is shown in Figure 2 and a microdensitometric tracing of the spectrum in Figure 3. The observations are noisy due to the intrinsic faintness of the nova. Nevertheless FeII $\lambda\lambda$ 4924, 5018, 5169 and 5235 are seen in the photoelectric scan. The photographic observations show besides Hα and Hβ, the $\lambda\lambda$ 4640-4650 complex which is stronger than Hβ. The major contribution to this feature in the early stages is NII and OII (McLaughlin, 1944) while in the later stages NIII and CIII become stronger. HeII λ4686 appears blended with this feature. Among the fainter lines we could identify FeII $\lambda\lambda$ 4924, 5018 and 5991, NII $\lambda\lambda$5667 and 5710, [NII] λ5755, HeI λ5876 and [OI] λ6300. The line of [OI] λ6363 is not visible due to a blemish in the fibre optic face plate of the image tube. The spectrum compares well with the Orion to Nebular transition stage (compare with Δ m = 3.8 of McLaughlin, 1944).

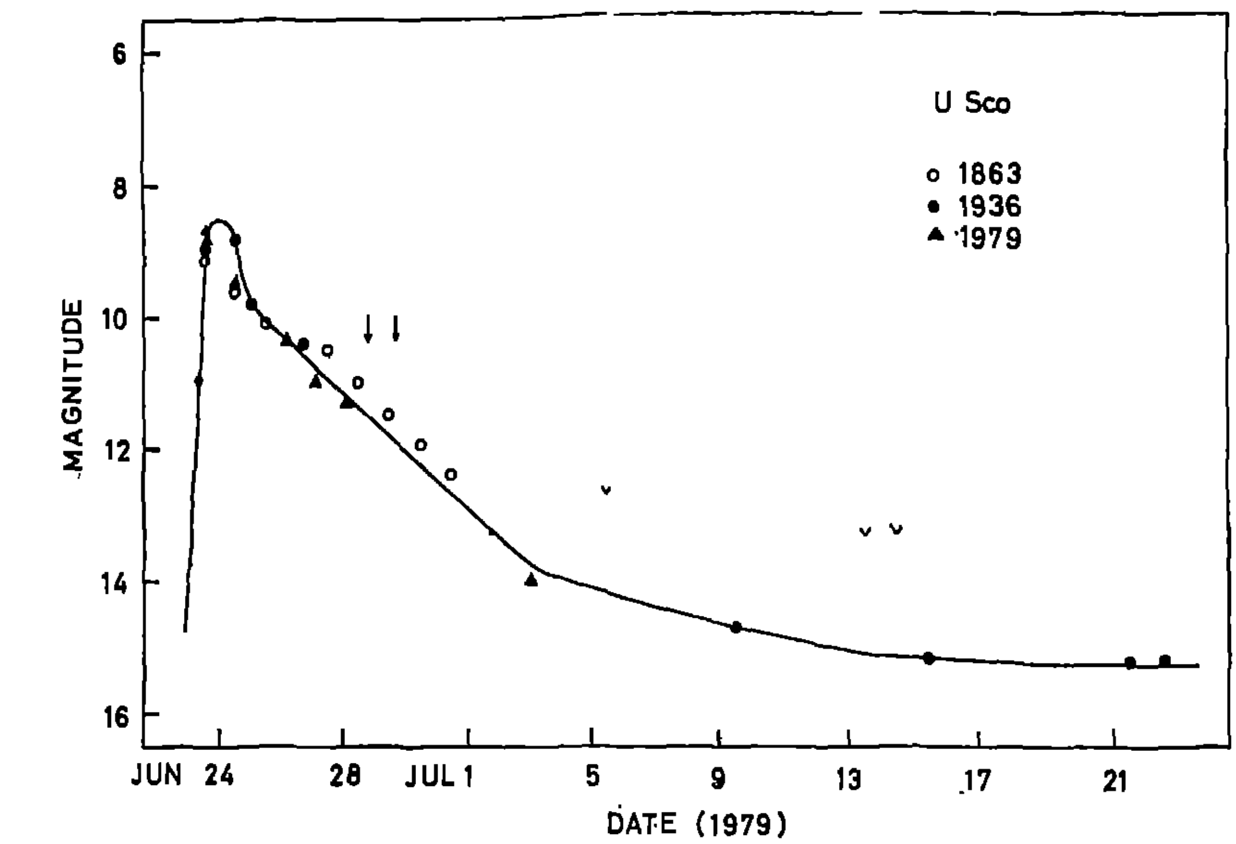

Fig. 1 The light curve of U Sco. Open circles are Pogson's observations of 1863 outburst. The V marks are Pogson's upper limits. Closed circles are the Harvard observations of the 1936 outburst. The filled circles are the visual estimates of the 1979 outburst published in the IAU Circulars. The abscissae are the dates of the present outburst while the observations of the previous outbursts are shifted to match the light curve. The arrows indicate the times of our spectrophotometric observations.

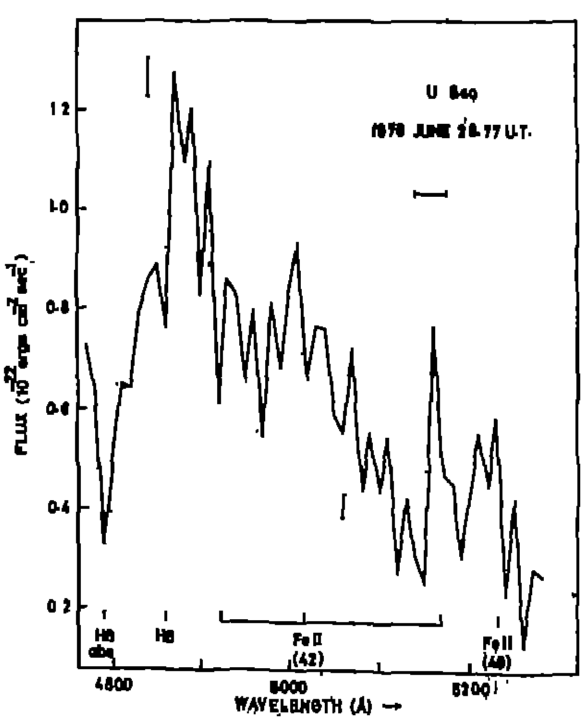

Fig. 2 Reduced photoelectric spectrum scan of the Hβ region of U Sco on June 28.77 U.T. The rest wavelength of Hβ, and FeII λλ 4924, 5018, 5169 (RMT 42) and 5235 (RMT 49) are shown. Hβ absorption is also indicated. The horizontal bar in the top right corner indicates the band pass (25 Å) and the two vertical bars indicate the estimated errors in the flux.

3. The Nebular Shell of U Sco

The photographic observations yield a half width at zero intensity for the Hα and Hβ profiles as 5350 km s^{-1} and 6610 km s^{-1} respectively. These values are likely to be higher than the true values due to poor seeing. A value corrected for 3 arc sec seeing agrees with the estimate of 5000 km s^{-1} reported by Hill *et al.* (1979) four days later. Also the photoelectric scan of June 28 indicates an absorption feature at -4300 km s^{-1} (resolution 1500 km s^{-1}). We assume a value of 5000 km s^{-1} as the expansion velocity for an estimation of the radius of the shell.

The total flux in Hβ enables us to determine the electron density and the mass of ionized hydrogen in

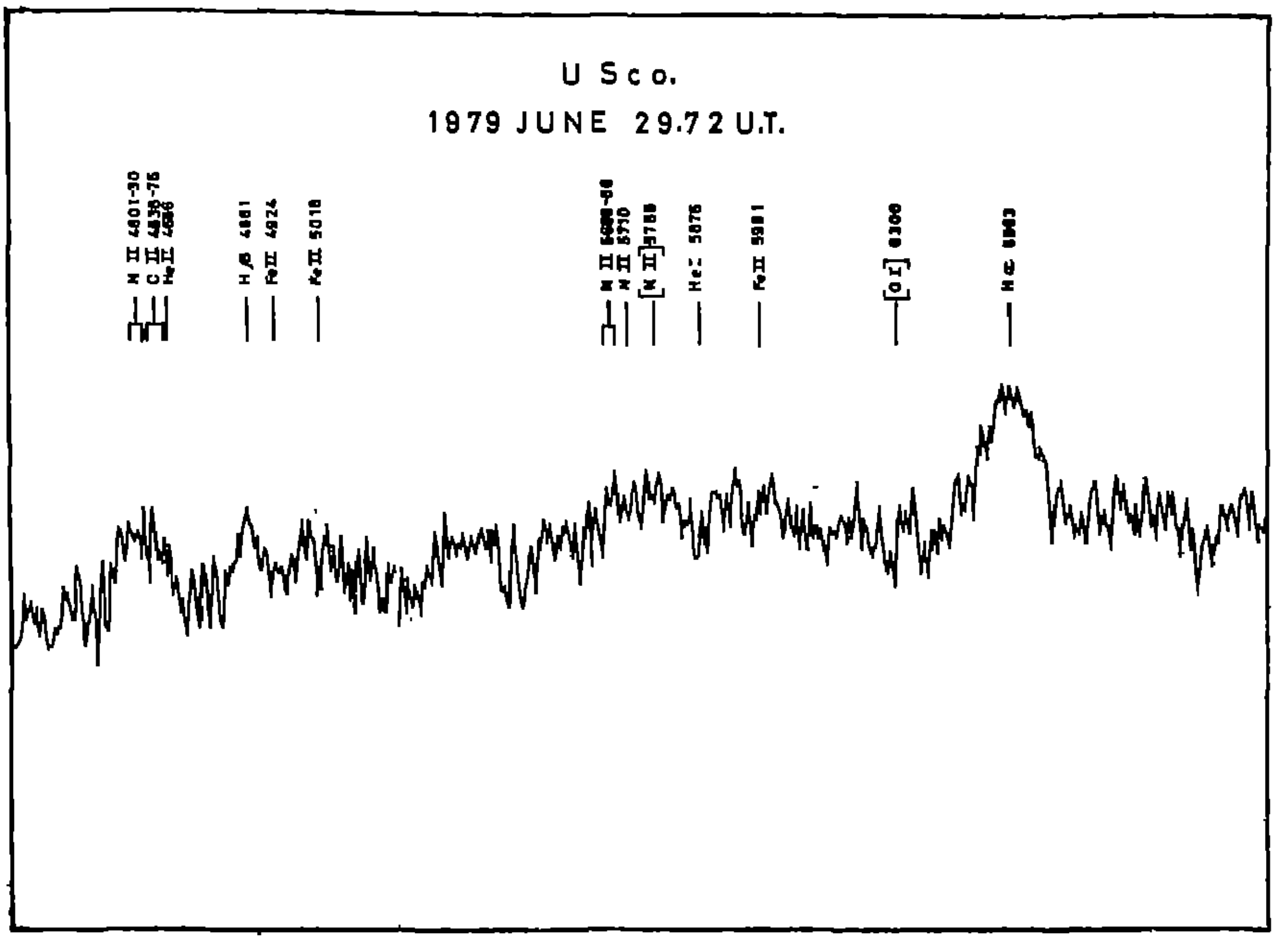

Fig. 3 A microdensitometric scan of the photographic spectrum of U Sco on June 29.72 U.T. Various emission features are identified

the shell, if the distance to the nova and the interstellar absorption are known. We assume a value of $A_v = 0.6$ following Webbink (1977). The corrected value of flux at $H\beta$ is 4.95×10^{-10} erg cm^{-2} s^{-1}. The uncertainty in the determination of the continuum and also in estimating the correction for the absorption profile limits the accuracy of this value to within a factor of two.

It is not known with certainty whether one may use the absolute magnitude-rate of decline relationship established for novae in the case of recurrent novae too (Warner, 1976). With the assumption of its validity, Payne-Gaposchkin (1957) derives a value of 13.6 kpc as the distance to U Sco. Webbink (1977), with an improved relation due to Pfau (1976), obtains a minimum distance estimate of 22 kpc and a maximum one of 95 kpc. We have evaluated the electron density and the mass of ionized hydrogen in the shell assuming both of the distance estimates 13.6 and 22 kpc.

The light curve shown in Figure 1 yields the time of maximum as June 24.05 U.T. With a velocity of 5000 km s^{-1}, we obtain the radius of the expanding shell as $R = 16.4$ A.U. The thickness of the shell is limited by the sound speed to a value

$$\Delta R = 3\, at \text{ (Pottasch, 1959).}$$

With a value of 10 kms^{-1} for a (Malakpur, 1973), we obtain $\Delta R = 0.098$ A.U. The volume of the shell is thus 1.108×10^{42} cm^3. Assuming an emmisivity of $\epsilon_{H\beta} = 1.22 \times 10^{-25}$ ergs cm^{-3} s^{-1} for $T_e = 10^4$ °K (Kaplan and Pikelner, 1970), in the expression for N_e namely,

$$N_e^2 = 4\pi F_{H\beta} r^2 / (\epsilon_{H\beta} V)$$

we obtain

$$N_e = 6.83 \times 10^8 \, r_{kpc} \, cm^{-3}$$

where r_{kpc} is the distance to the nova in kpc. At distances of 13.6 kpc and 22 kpc the values of

Table 1

Observed and derived parameters of U Sco.

1979 June 28.77 :	
Corrected Hβ flux F_{H}	$= 4.95 \times 10^{-10}$ ergs cm^{-2} s^{-1}
Electron density N_e	$= 6.63 \times 10^{8}$ r_{kpc} cm^{-3}
	$= 9.02 \times 10^{8}$ cm^{-3} ($r_{kpc} = 13.6$)
	$= 14.6 \times 10^{8}$ cm^{-3} ($r_{kpc} = 22$)
Mass of ionized Hydrogen M_{HII}	$= 4.41 \times 10^{-7}$ r_{kpc} $M_{\odot}$
	$= 6.00 \times 10^{-6}$ $M_{\odot}$ ($r_{kpc} = 13.6$)
	$= 9.70 \times 10^{-6}$ $M_{\odot}$ ($r_{kpc} = 22$)
1979 June 29.72 :	
Equivalent width of Hα	= 556 Å
Hβ	= 222 Å
Half width at zero intensity (Mean of *Hα* and *Hβ*)	= 5000 kms^{-1}

electron density would be 9.02×10^{9} cm^{-3} and 1.46×10^{10} cm^{-3} respectively.

We may proceed to obtain the mass of the ionized hydrogen in the shell. Assuming that there are 1.4 electrons per hydrogen atom (Pottasch, 1959) we obtain,

$$M_{HII} = 4.41 \times 10^{-7}\, r_{kpc}\, M_{\odot}$$

where r_{kpc} is again the distance in kpc. For the two values of r_{kpc} one obtains the masses as 6.00×10^{-6} $M_{\odot}$ ($r_{kpc} = 13.6$) and 9.70×10^{-6} $M_{\odot}$ ($r_{kpc} = 22$).

The photographic observations yield a value of $W_{H\alpha}/W_{H\beta} = 2.5$. for the ratio of the equivalent widths in Hα and Hβ. This value agrees with the observations of other novae. Since the continua of novae increase, in general, steeply to the red, the actual ratio of fluxes in Hα and Hβ would be much higher than these values.

The observed and derived parameters for U Sco are listed in Table 1.

4. Conclusions

The spectrum of U Sco as observed by us compares well with the synthetic spectrum of a typical nova (McLaughlin, 1944) 4^{m} below the maximum. The electron density and the mass of the ionized hydrogen also agree well with the values for a typical nova within the uncertainties of the distance estimates.

References

Bappu, M. K. V. 1977 *Kodaikanal Obs. Bull. Ser. A*, 2, 64

Hill, P.W., Pringle, J. E., Whelan, J. A. J. 1979, *IAU Circ.* 3376.

Kaplan, S. A. Pikelner, S. B. 1970 *'The Interstellar Medium'*, Harvard University Press, Cambridge, Massachusetts.

Malakpur, I. 1973 *Astr. Astrophys.* 24, 125.

McLaughlin, D. B. 1944 *Pop. Astr.* 52, 109.

Payne-Gaposchkin, C 1957 *'The Galactic Novae'*, North-Holland, Amsterdam.

Pfau, W 1976 *Astr. Astrophys.* 50, 113

Pogson, N. R 1887 *'Results of observations of the Fixed Stars with the Meridian Circle at the Government Observatory, Madras in the years* 1862, 1863 and 1864.'

Pogson, N. R 1908, *Mem. R. Astr. Soc.* 58, 92.

Pottasch, S 1959 *Ann. Astrophys.* 22, 394.

Thomas, H. L. 1940 *Harvard Obs. Bull.* 912, 10.

Warner, B 1976 IAU Symp. 73, 85.

Webbink, R. F. 1978 *Pub. Astr. Soc. Pacific*,90, 57.