QUASI-SIMULTANEOUS PHOTOMETRIC AND POLARIMETRIC OBSERVATIONS OF T TAU AND RY TAU

N.P. Red'kina
G.P. Chernova
Institute of Astrophysics
Dushanbe, 734670, U.S.S.R.

ABSTRACT

Quasi-simultaneous photometric and polarimetric observations of T Tau and RY Tau show that the proper polarization of these stars arises in the visual region in their gaseous emitting envelopes. The polarization of T Tau shows cyclic variations with a period of $5^{h}18$. That of RY has two different modes of variation at brightnesses $V > 11^{m}$ and $V < 11^{m}$; it is possibly connected with the suspected binary nature of this star.

INTRODUCTION

The nature of the polarization of T Tau type stars is subject to many controversies. Brager (1974) suggests scattering by dust particles, while Strom (1977) thinks scattering by electrons to be more acceptable. Abuladze et al., (1975) point out the difficulty of explaining the polarization variations at constant brightness of T and RY Tau in the frame of the dust cloud hypothesis.

Wavelength dependent linear polarization in the range 3560 to 8410 Å and in the narrow Hα interference filter region was observed by Bastien and Landstreet (1980) for T and RY Tau and V 866 Sco. They showed the polarization to originate in extended circumstellar dust envelopes. The considerable change of the wavelength dependent shape is explained as a result of changing dust particle dimensions.

The observations of linear polarization of RY Tau enabled Efimov (1980) to conclude that the star has a flattened gas and dust envelope. Efimov connects the wavelength dependent variation with the prevalence of Thomson scattering by electrons at a low brightness of the star.

Hough et al. (1981) found a considerable linear polarization in all six T Tau type stars investigated by them in the IR range 0.44 - 2.2 μm. T Tau (and possibly SU Aur) showed at 2.2 μm, a change of the polarization plane orientation by 90^{o}. The polarization spectrum

Z. Kopal and J. Rahe (eds.), Binary and Multiple Stars as Tracers of Stellar Evolution, 231–238.
Copyright © 1982 by D. Reidel Publishing Company.

https://doi.org/10.1017/S0252921100100569 Published online by Cambridge University Press

of T Tau is flattened, the mean degree of polarization P being about 1%. P drops to zero at 1.6 μm and then grows to 0.6% at 2.2 μm. To interpret the T Tau polarization in the optical region, Hough et al. (1981) involve small silicate grains with dimensions $<0.1\,\mu$m; an admixture of large particles ($>1.0\,\mu$m) helps to explain the IR polarization. The polarization vectors of particles of these two kinds are orthogonal, and so the inversion of the polarization sign should occur at some intermediate wavelength.

The peculiar behavior of RY Tau is explained by Nurmanova (1981) on the basis of her photometric and polarimetric observations as a consequence of the duplicity of this star.

The discrepancy in the interpretation of T Tau star polarization is perhaps due to the fact that most authors ignore the interstellar polarization.

PROPER POLARIZATION OF T TAU

To analyze our T TAU observations in the visual region (Red'kina et al., 1981) and the results obtained by other authors (Vardanian, 1964 ; Abuladze et al., 1975; Efimov, 1980), we took the effects of interstellar polarization into account, following Vardanian (1964) and Efimov (1980). T Tau shows seasonal variations of its proper polarization from 0.5% to 1.7% at almost constant light in V. Reciprocal correlations between long-term (several years) variations of the polarization and brightness predicted by the dust hypothesis, were not revealed.

The analysis of our simultaneous photometric and polarimetric observations of T Tau showed a direct correlation of the proper polarization P_V with the intensity in Hα , and a weak correlation with the brightness in V (Fig. 1a), indicating a connection of the polarization of the star with its gaseous emission envelope.

Such peculiarities as the direct correlation between P_V and the intensity in Hα, the absence of a correlation with the brightness in V and the essentially flat polarization spectrum of T Tau could hardly be explained by two kinds of scattering particles ($<$ o.1 μm and $>1\,\mu$m) in a dusty stellar envelope (Hough et al., 1981). It seems more realistic to suggest that at $\lambda < 1.6\,\mu$m, the polarization is due to scattering in the gaseous emissive shell. At the envelope regions where the Thomson scattering cross-section is greater than the braking radiation cross-section, the polarization spectrum does not depend on λ. The depression in the polarization spectrum at $\sim 1.6\,\mu$m is due to the enhanced braking absorption in the gas envelope.

The peculiarities of the T Tau polarization listed can be explained by radiation scattering in a magnetized optically thin region of the gaseous envelope of the star. The proper polarization is

https://doi.org/10.1017/S0252921100100569 Published online by Cambridge University Press

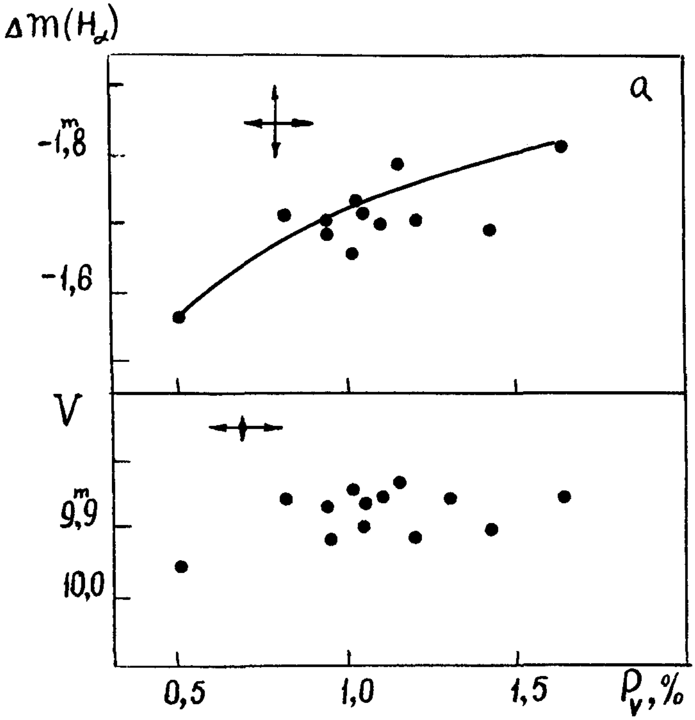
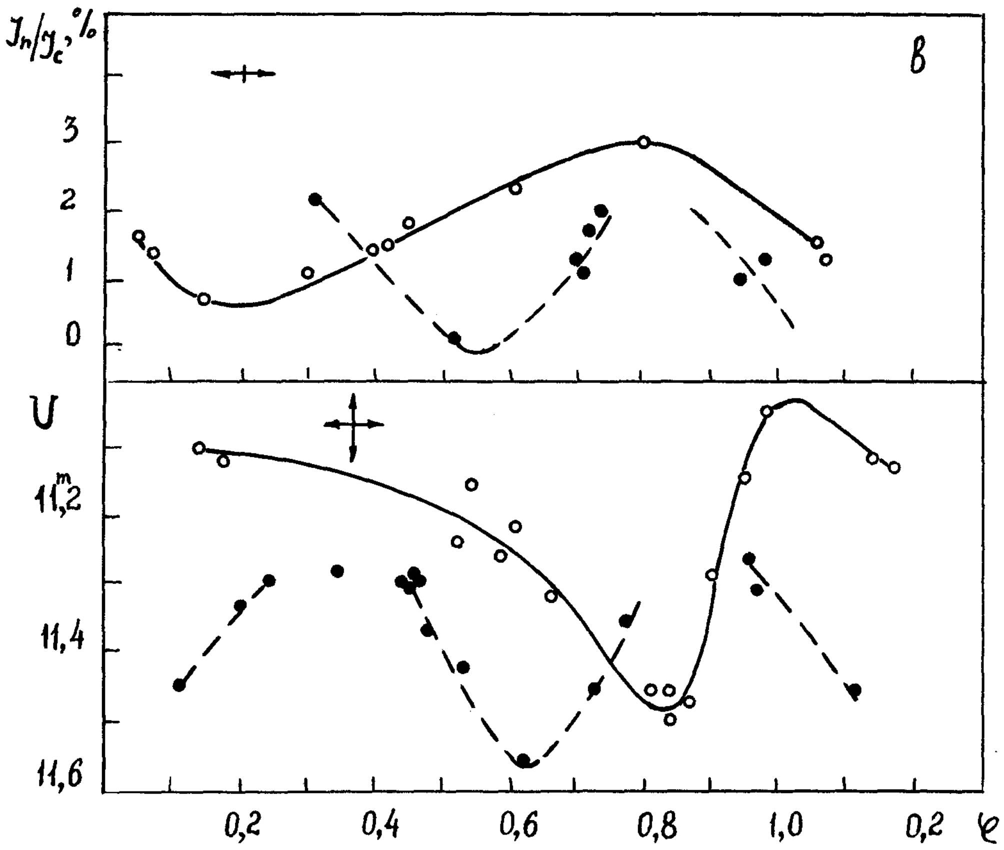


Fig. 1 a) Interrelation between the proper polarization P_V^*, Hα intensity (relative to the Hα intensity of the comparison star "c" in Abuladze et al., 1975) and V-brightness for T Tau.

https://doi.org/10.1017/S0252921100100569 Published online by Cambridge University Press



b) Presentation of T Tau polarized light I_n in the V band (relative to the light of the comparison star "c" in Abuladze et al., 1975) as a periodic function with periods $P=5^h_.18$ (open circles) or $P_1 = P/2$ (filled circles)

https://doi.org/10.1017/S0252921100100569 Published online by Cambridge University Press

determined in this case by the depolarization factor δ which according to the magnetic active plasma theory is determined by the formula (Dolginov et al., 1979):

$$\delta = \frac{1}{P^2}\left\{9.137\,\frac{(1-\mu^2)\,\varphi(\mu)}{H(\eta)}\right\}\cdot\frac{1}{\mu^2} \qquad (1)$$

$$\delta = 7.93.10^7\ \lambda^2 \cdot B \quad ,$$

where B is the magnetic field strength; $\mu = \cos\vartheta$ with ϑ the angle between the normal to the surface of the medium and the direction of the magnetic field; H (μ) and φ (μ) are the generalized Ambartsumian-Chandrasekhar functions; P is the linear polarization. The maximal (1.6%) and minimal (0.5%) values of P correspond at $\mu = 0.1$ to $\delta = 42.52$ and 143.81 and B=174 and 520 gauss, respectively. The magnetic fields can also have greater strengths since $\delta \to \infty$ when $\mu \to 0$.

The position angle of the polarization plane Θ remains practically unchanged in the visual region. This is shown by our 1979 and 1980 observations as well as by those of other authors (Efimov, 1980; Abuladze et al., 1975) and by the polarization spectrum from 0.44 to 1.6 μm (Hough et al., 1981). The symmetry axis of the scattering system of the star is supposed to remain fixed in space.

T Tau has possibly a disk-like gas and dust envelope. The jump of the position angle at 2.2 μm occurs most probably at the boundary between the two envelopes. This conclusion is supported by the intensity distribution of T Tau (Rydgren et al., 1976), where the Θ considered ($\lambda = 2.2\ \mu$m) is the mean of the radiation wavelength of the gas (free-free transition) and that of the dust envelope. The geometry of the system is as follows: the electric field vector of the scattered optical radiation vibrates perpendicular to the symmetry axis of the shell, the electric field vector of the IR radiation vibrates along the symmetry axis.

Goetz and Wenzel (1970) detected short period changes of the spectral type of T Tau with a period of $5^h\!.18$. When analyzing our own observations we found an analogous period for the amount of polarized light I_n. The conversion of the proper polarization P_v to I_n was made using the formula:

$$I_n\ (\varphi) = P\ (\varphi) \cdot I_o\ (\varphi) \circ 10^2 \ , \qquad (2)$$

where φ is the phase, I_o is the light intensity.

The corresponding brightness in U varies in opposite phases relative to the I_n (φ) curve. Fig. 2 shows the possible existence of vibrations with a period two times shorter than $5^h\!.18$.

https://doi.org/10.1017/S0252921100100569 Published online by Cambridge University Press

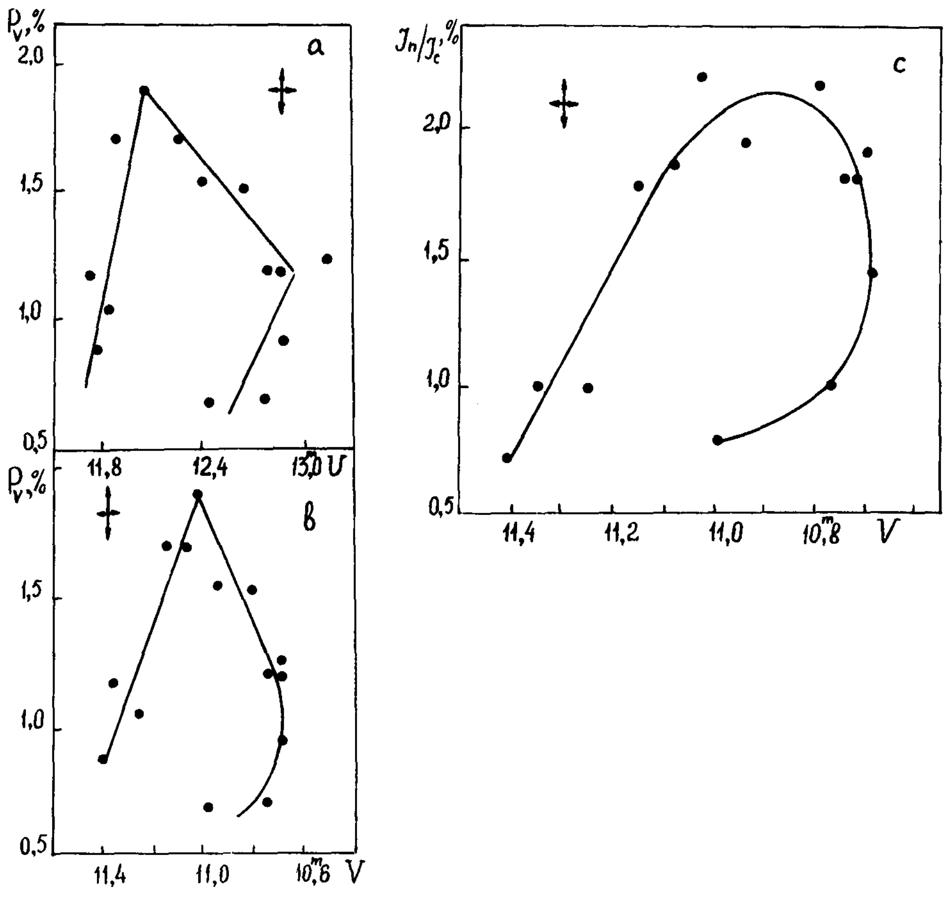


Fig. 2 RY Tau proper polarization as a function of brightness in U (a) and V(b). RY Tau polarized light amount I_n (relative to the light I_c of the comparison star "f" in Zaitseva et al., 1974) as a function of V-brightness (c).

https://doi.org/10.1017/S0252921100100569 Published online by Cambridge University Press

The following interesting peculiarity should be noticed; I_n has its maximum at $\varphi = 0.8$ possibly indicating an inhomogenity of the temperature distribution over the disk of the star. A proof of this through more extensive observations is desirable.

The cyclic variation of physical characteristics of T Tau stars is supported by the recent work by Worden et al., (1981). The analysis of observations in the U band showed the flares of T Tau stars to be a superposition of many solar-like flares. These flares are more frequent and more powerful (in separate cases up to 10^3 times) than solar flares. The index of the flare activity β ($\sim f^{-\beta}$, where f is the frequency) changes considerably, and a variable flare activity resembling the solar cycles is possible.

PROPER POLARIZATION OF RY TAU

RY Tau possesses, in the region studied ($V=10^m.68 \div 11^m.4$), two different types of P_V -V dependency, the critical brightness level being $\sim 11^m$. At $V > 11^m$ (Fig. 2 a,b) P_V increases with increasing V and U. The position angle Θ lies between 3^o and 59^o. The amplitude of the brightness variation grows towards the red end of the spectrum. At $V < 11^m$, the P_V -V and P_V -U relations become undefined. The position angle varies between 119^o and 153^o. The amplitude of the brightness variation grows towards the blue spectral region. The whole relation considered has a loop-like appearance (Fig. 2 a,b,c). This implies different polarization mechanisms at the minimal and maximal brightness levels, corresponding to different physical states of the star.

Wenzel (1970) suggested RY Tau to have an IR source associated with the dust envelope. Its radiation maximum lies near 1 μm and its short wavelength wing is seen in the optical region.

Nurmanova (1981) thinks RY Tau to be an eclipsing binary system. This suggestion explains the different properties of RY Tau at $V > 11^m$ and $V < 11^m$, including different dependencies between U and V (Nurmanova, 1981), between the intensity in Hα and the color index U-B at $V=10^m.5$ and $V=11^m$ (Zaitseva et al., 1974); different polarization mechanisms at different brightness levels; changes of the wavelength dependency.

SUMMARY

On the basis of our investigations we conclude that the optical radiation polarization of T Tau and RY Tau arises in the gaseous emissive envelopes of these stars due to radiation scattering on free electrons. Further simultaneous photoelectric and polarimetric observations would be of value to confirm the cyclical behavior of the flare activity of T Tau type stars.

https://doi.org/10.1017/S0252921100100569 Published online by Cambridge University Press

The peculiar change of the proper polarization and brightness of RY Tau suggests the binary nature of this star.

REFERENCES

Abuladze, O., Vardanian, R.A., Kovalenko, V.M., Kumsishvili, Ja., Melikian, J.A., Mironov, A.V., Oshchepkov, V.A., Stepanian, J.A., Totachava, A., Cherepashchuk, A.M., Shanin, G.I., Shpychka, I.V., Shcherbakov, A.G., 1975. Results of Observations of the T Tauri Type Stars under 1973 Joint Program. Variable Stars, 20, 47-61.
Bastien, P., and Landstreet, J.D.: 1979, Polarization Observations of the T Tauri Stars RY Tauri, T Tauri, and V866 Scorpii. Ap. J. Letters, 229, L137-L140.
Brager M.: 1974. Pre-main sequence stars. III. Herbig Be/Ae stars and other selected objects. Ap. J., 188, 53-58.
Dolginov, A.Z., Gnedin Ju.N., Silant'ev, N.A.: 1979. Radiation Propagation and Polarization in Space. Moscow, Nauka, 131-149.
Efimov, Ju.S.: 1981. Polarization Observations of RY Tau and T Tau. Variable Stars, 21, No. 3, 273-284.
Goetz, Von W., Wenzel, W.: 1970. Photoelektrische und Objektiv-Prismen-Beobachtungen an T Tauri. NVS, 5, 117-125.
Hough, J.N., Bailey, J., Cunningham, E.C., McCall, A., Axon, D.J.: 1981. Linear Polarization of T Tauri Stars. Mon. Not. R. Astr. Soc., 195, 429-436.
Nurmanova, U.A.: 1981. On the Duplicity of RY Tauri. Variable Stars, (in press).
Red'kina, N.P., Zubarev, A.V., Chernova, G.P.: 1981. Photoelectric and Polarimetric Observations of T Tauri. Astronom. Zirkuliar, No. 1149, 6-7.
Rydgren, A., Strom, S.E., Strom, K.M.: 1976. The Nature of Objects of Joy: A Study of the T Tauri Phenomenon. Ap. J., Suppl., 30, 307-336.
Strom, S.E.: 1977. Star Formation. Ed. T. de Jong and A. Maeder. (Dordrecht: Reidel), p. 179.
Vardanian, R.A.: 1964. The Polarization of T and RY Tau. Soobsch. Bjurak. Obs., 35, 3-23.
Wenzel, W.: 1970: Photoelektrische Beobachtungen an RY Tauri. NVS, 5, 117-125.
Worden, S.P., Schneeberger, T.J., Kyhn, J.R.: 1981. Flare Activity on T Tauri Stars, Africana J.L., 244, 520-527.
Zajtseva, G.V., Ljuty, V.M., Cherepaschuk, A.M.: 1974. Photoelectric Observations of Intensity Variability of Hα Emission Line and Continuum in the Spectrum of RY Tau. Astroph. Russ. J., No. 10, 357-364.

https://doi.org/10.1017/S0252921100100569 Published online by Cambridge University Press