Spectropolarimetric observations of the recurrent nova RS Ophiuchi

Yanko Nikolov, Radoslav Zamanov

Institute of Astronomy and NAO, Bulgarian Academy of Science

Introduction

- RS Ophiuchi (HD162214) is a symbiotic binary system in wich a near Chandrasekhar-mass white draft acretes material from a M2 III red giant companion (Mikolajewska & Shara 2017)

- The orbital period of the binary is 453,6 days and the obrit inclination is 49°-52° (Brandi at al. 2009)

- RS Oph undergoes novae eruptions approximately every 20 years (Schaefer 2010)

Observations

- Spectropolarimetric observations of RS Oph were secured with the 2-Channel-Focal-Reducer Rozhen (FoReRo2), attached at the Cassegrian focus of the 2.0m RCC telescope of the NAO Rozhen. We observed RS Oph ≈ 10 years after last recurrent nova outburst (Hirosawa et al. (2006))
- We obtained polarized spectra of RS Oph and standard stars with high degree of polarization (HD204827 and HD161056) and zero degree of polarization (HD212311 and HD154892). Polarimetric standard stars were observed with the same instrumental setup as RS Oph.
- We used standard stars with zero degree of polarization to correct for the instrumental polarization
- We used standard stars with high degree of polarization to correct for the position angle

Table 1 Journal of observations

Object	Data-obs yyyy-mm-dd	UT	Exp.time
RS Oph	2017-07-21	20:32:26	8*100 s
	2018-02-17	03:38:29	16*90 s
	2018-03-11	03:13:19	8*60 s

Data Analysis

Beam swapping technique

Polarized spectra are obtained at eight retarder angles : 0°, 22.5°, 45°, 67.5°, 90°, 112.5°, 135° and 157.5°. Beam swapping technique is used for polarimetric data processing. The values of $f(\lambda)^{\perp}$ and $f(\lambda)^{\parallel}$ are obtained at different retarder angles. The following formulas (Bagnulo et al. 2009) are used to calculate the Stokes parameters:

$$P(\lambda)_Q = \frac{1}{4}\left[\left(\frac{f(\lambda)^{\parallel}-f(\lambda)^{\perp}}{f(\lambda)^{\parallel}+f(\lambda)^{\perp}}\right)_{0^\circ} - \left(\frac{f(\lambda)^{\parallel}-f(\lambda)^{\perp}}{f(\lambda)^{\parallel}+f(\lambda)^{\perp}}\right)_{45^\circ}\right] + \frac{1}{4}\left[\left(\frac{f(\lambda)^{\parallel}-f(\lambda)^{\perp}}{f(\lambda)^{\parallel}+f(\lambda)^{\perp}}\right)_{90^\circ} - \left(\frac{f(\lambda)^{\parallel}-f(\lambda)^{\perp}}{f(\lambda)^{\parallel}+f(\lambda)^{\perp}}\right)_{135^\circ}\right] \quad (1)$$

$$P(\lambda)_U = \frac{1}{4}\left[\left(\frac{f(\lambda)^{\parallel}-f(\lambda)^{\perp}}{f(\lambda)^{\parallel}+f(\lambda)^{\perp}}\right)_{22.5^\circ} - \left(\frac{f(\lambda)^{\parallel}-f(\lambda)^{\perp}}{f(\lambda)^{\parallel}+f(\lambda)^{\perp}}\right)_{67.5^\circ}\right] + \frac{1}{4}\left[\left(\frac{f(\lambda)^{\parallel}-f(\lambda)^{\perp}}{f(\lambda)^{\parallel}+f(\lambda)^{\perp}}\right)_{112.5^\circ} - \left(\frac{f(\lambda)^{\parallel}-f(\lambda)^{\perp}}{f(\lambda)^{\parallel}+f(\lambda)^{\perp}}\right)_{157.5^\circ}\right] \quad (2)$$

where $f(\lambda)^{\parallel}$ and $f(\lambda)^{\perp}$ are the fluxes of the parallel and perpendicular beam of the Wollaston prism respectively. We reduced the Stokes parameter Q and U of RS Oph for the instrumental polarisation with Stokes parameter Q and U of standard star with zero degree of polarization. The degree of polarization is :

$$P(\lambda)_L = \sqrt{P(\lambda)_Q^2 + P(\lambda)_U^2}, \quad (3)$$

where $P(\lambda)_Q = \frac{Q(\lambda)}{I(\lambda)}$ and $P(\lambda)_U = \frac{U(\lambda)}{I(\lambda)}$.

The position angle is

$$\theta(\lambda) = \frac{1}{2}\arctan\frac{P(\lambda)_U}{P(\lambda)_Q} + \Theta_0, \quad (4)$$

Results

- Standard stars with zero degree of polarization – the observed degree of polarization p% represents instrumental polarization

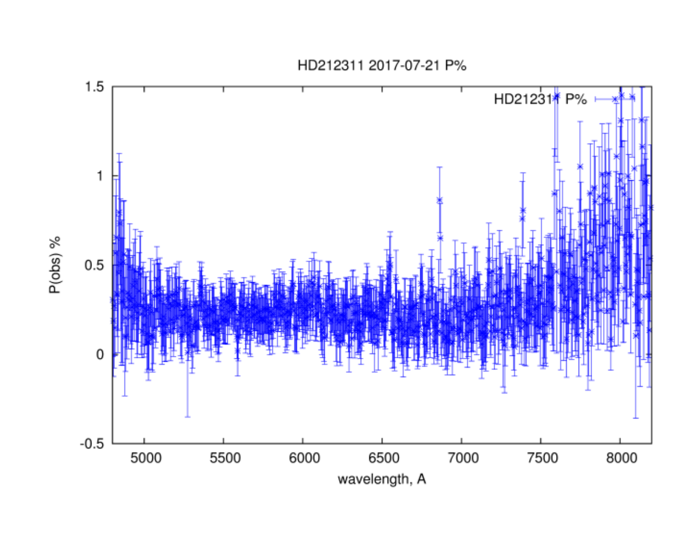
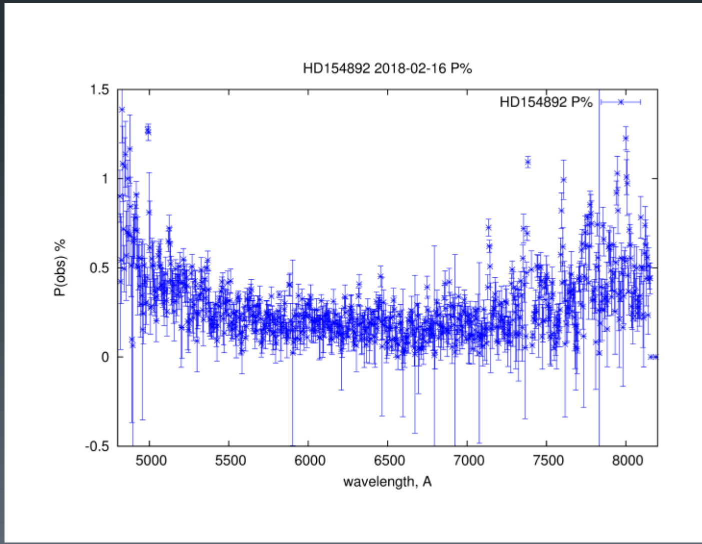
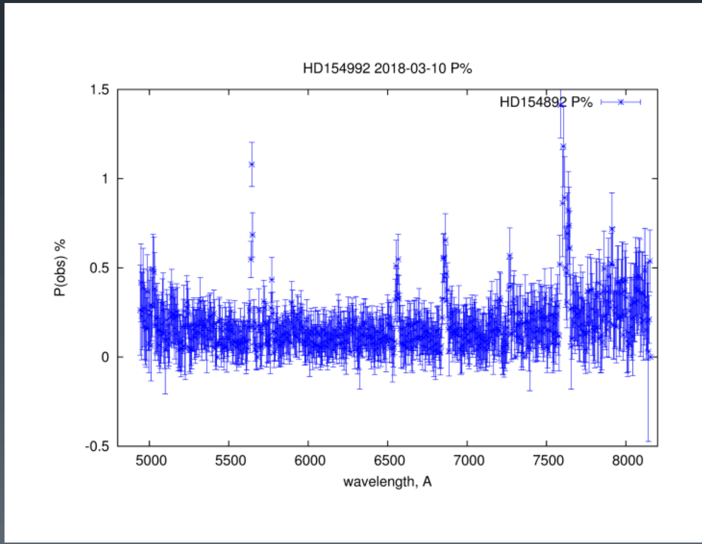


Table 2 Catalogue value

Ref. Turnshek, D.A. et al. 1990

Object	V	P(%)
HD212311	8.10	0.028±0.025
HD154892	8.0	0.05±0.03





Results

- Standard stars with high degree of polarization after correction for instrumental polarization

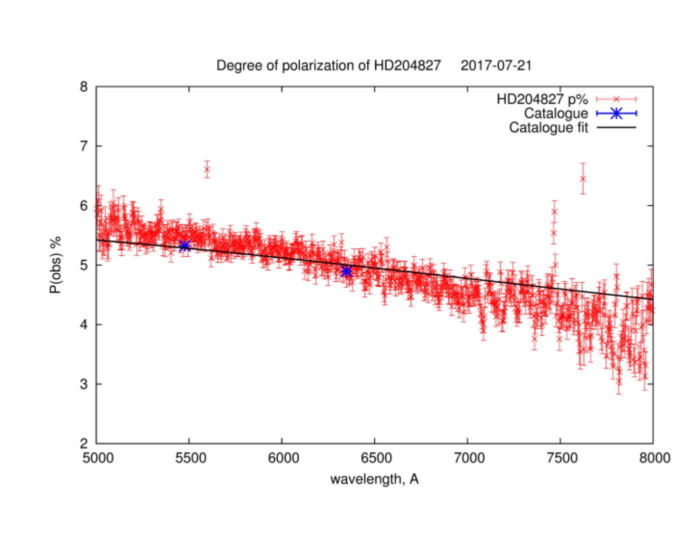
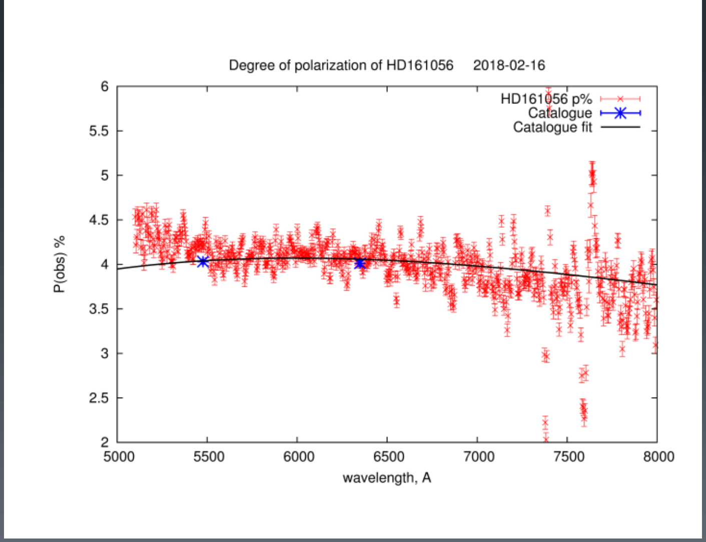
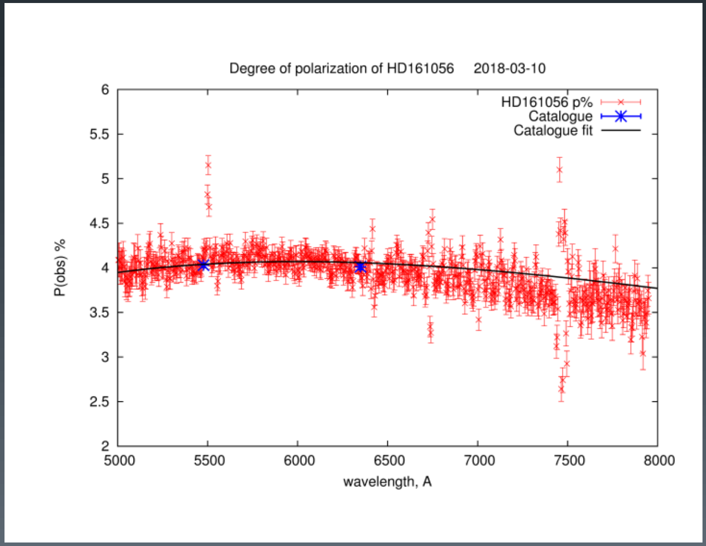


Table 3 Catalogue value

Ref. Turnshek, D.A. et al. 1990 and Schmidt, G.D. et al. 1992

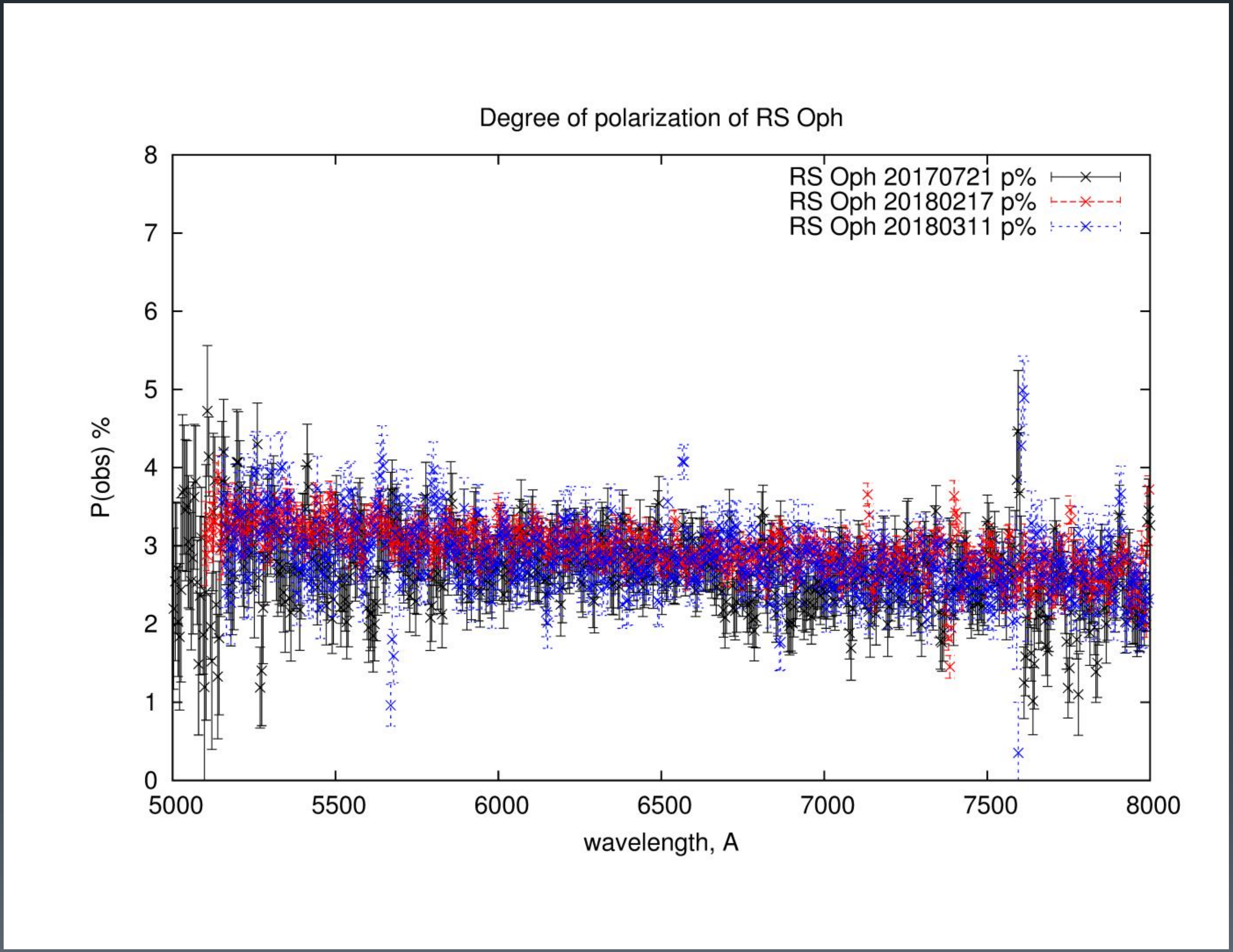
Object	V	P %	angle
HD204827	7.93	V 5.322±0.08 R 4.893±0.024	V 58.73±0.08 R 59.10±0.17
HD161056	6.32	V 4.030±0.025 R 4.012±0.032	V 66.93±0.18 R 67.33±0.23





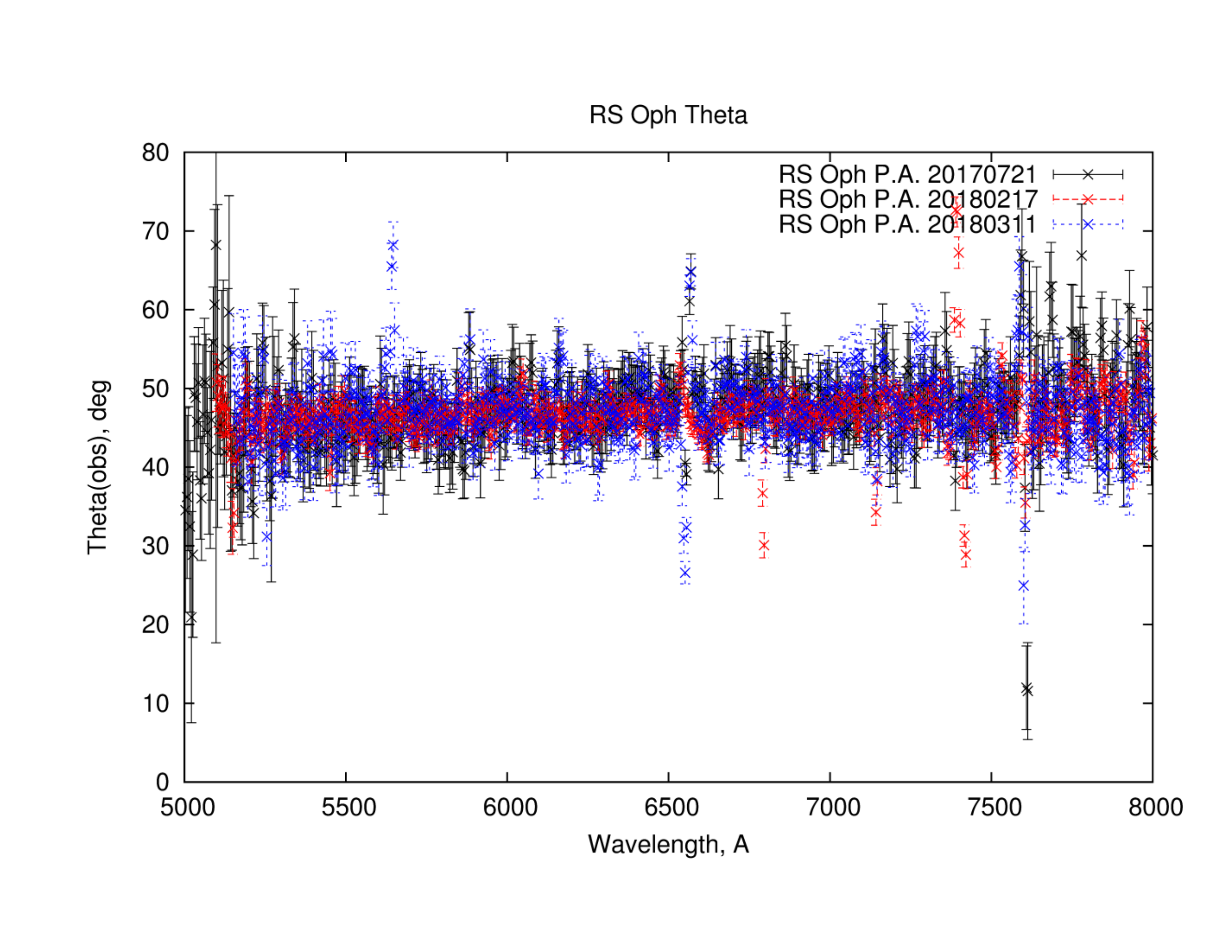
Results

- Spectropolarimetric observation of RS Oph – Degree of polarization



Results

- Spectropolarimetric observation of RS Oph – position angle



Discussion

- Position angle θ

Table 4. Position angle θ

θ	note	reference
46.6°±4.5 44.2°±1.4	P.A. of nine field stars P.A. of 488 day after outbursts	Cropper 1990 Cropper 1990
78.7°±5.1	?	Somero et al. 2016
47.2°±0.5		This work

Our value obtained for P.A. is similar in value to that obtained from Cropper (1990) and differs from that obtained from Somero et al. (2016)

Interstellar polarization

The interstellar polarization is produced by dichroic absorption by magnetically aligned aspherical dust grains existing between the object and the earth. In the optical region the degree of interstellar polarization is a function of wavelength (Serkowski et al. 1975):

$$P_{ISP}(\lambda) = P_{max}\ \exp(-K \ln^2 \frac{\lambda_{max}}{\lambda}),$$

where P_{max} is the peak of the interstellar polarization at wavelength λ_{max}.

Table 5 The results of the fit with Serkowski law

$P(\lambda_{max})$(%)	K	λ_{max} (Å)	Reference
2.60	1.15	5900	Cropper 1990
2.75	1.69	5867	Somero et al. 2016
2.83	1.91	5760	This work

Interstellar polarization toward RS Oph

Observed polarization is generally expressed as a vectorial sum of the intrinsic polarization and the interstellar polarization (ISP), i.e.,

$$q_{\rm obs}(\lambda) = q_{\rm int}(\lambda) + P_{\rm ISP}(\lambda)\cos 2\theta_{\rm ISP},$$

$$u_{\rm obs}(\lambda) = u_{\rm int}(\lambda) + P_{\rm ISP}(\lambda)\sin 2\theta_{\rm ISP},$$

where $(q_{\rm obs}, u_{\rm obs})$ and $(q_{\rm int}, u_{\rm int})$ are the Stokes parameters of the observed polarization and the intrinsic polarization, respectively. $P_{\rm ISP}$ and $\theta_{\rm ISP}$ are the degree of the ISP and its position angle, respectively.

The relantionship between polarization and extinction has been studied by Fosalba et al. 2002. We use Eq.3 by these autors to estimate the interstellar polarization towards RS Oph:

$$P_{max,ISM(\%)} = 3.5E(B-V)^{0.8}. \qquad (3)$$

For RS Oph we have estimated $E(B-V) = 0.69 \pm 0.07$ and consequently $P_{max,ISM}(\%) = 2.6 \pm 0.2$. Somero et al. (2017) determined only interstellat polarization towards RS Oph with $P_{(\lambda_{max})}(\%) = 2.75 \pm 0.02$ at $\lambda_{max}(\AA) = 5867.94 \pm 37.41$

Discussion

- "During its 1985 outburst, RS Oph developed intrinsic linear polarization with a position angle aligned with the radio jet structure seen in VLBI observation" Cropper 1990. The degree of intrinsic polarization of RS Oph, obtained by Cropper(1990) are presented in table 4.
- Our results of degree of polarization of RS Oph represent interstellar polarization.

Cropper 1990

4.2 The intrinsic polarization

By subtracting the day 488 white light linear polarization, 2.49 per cent at 44.2°, from that measured during days 80–114, 2.81 per cent at 49.9°, the intrinsic and interstellar components can be separated. This produces a value for the intrinsic polarization, during days 80–114, of 0.62 per cent at 76° (with a fairly large uncertainty).

Using VLBI techniques at 1.7 GHz, Porcas, Davis & Graham (1987) found that RS Oph was elongated into a structure consisting of a core with diametrically opposed radio jets. Interestingly, the position angle of the intrinsic polarization agrees favourably with that of these jets (~84°), suggesting that there is an underlying structure which is responsible for both the intrinsic polarizations and the jets.

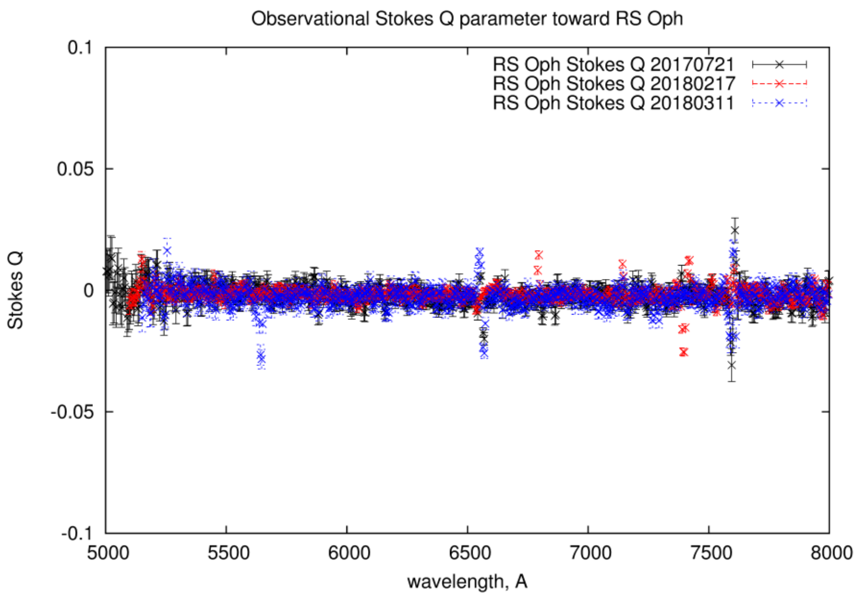
Cropper 1990

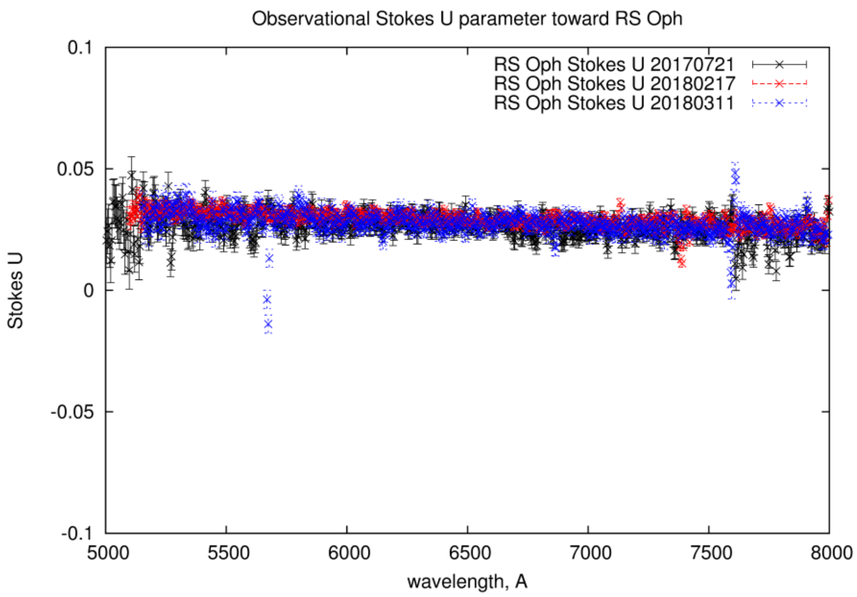
Table 4. Intrinsic linear polarization of RS Oph in per cent after subtracting a Serkowski (1973) interstellar law with P_{max}=2.60 per cent and λ_{max}=5900 Å with a 5.7° position angle difference determined from the white light polarizations.

U	*B*	*V*	R_C	I_C
0.98	0.93	0.91	0.53	0.69

Conclusions

- Our result of spectropolarimetric observations of RS Oph most likely represented Stokes parameter Q and U of interstellar polarization. Our result is in argement with earlier observation by Cropper (1990) where they detected intrinsic polarization only during the outburst





Discussion

- Degree of linear polarization

Cropper 1990

RS Oph during its 1985 outburst 147

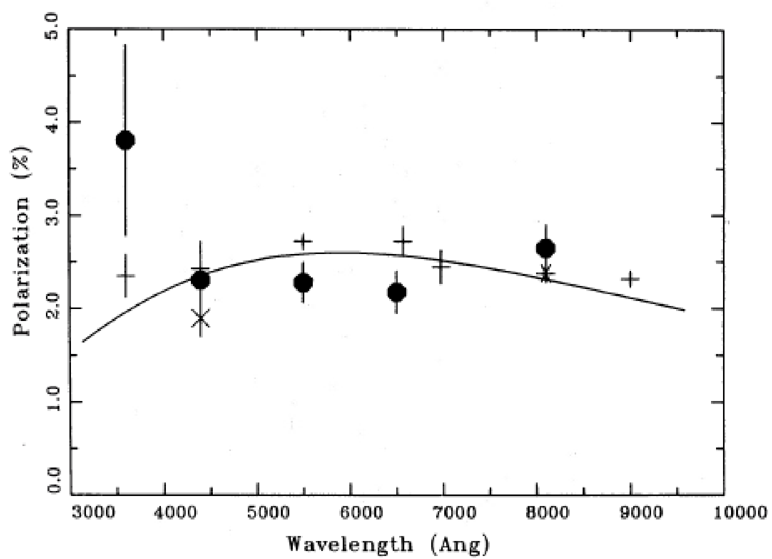


Figure 2. The interstellar polarization of RS Oph. Mean values for days 19 and 20 are shown plotted as ● symbols, the late-time I_C band observation is shown as an ∗ symbol, the mean of the Serkowski (1970) *B* band observations away from outburst is plotted as a × symbol and the Schulte-Ladbeck (1985) observations as + symbols. A Serkowski (1973) interstellar fit with $P_{max} = 2.60$ per cent and $\lambda_{max} = 5900$ Å is shown superimposed.

Somero et al. 2016

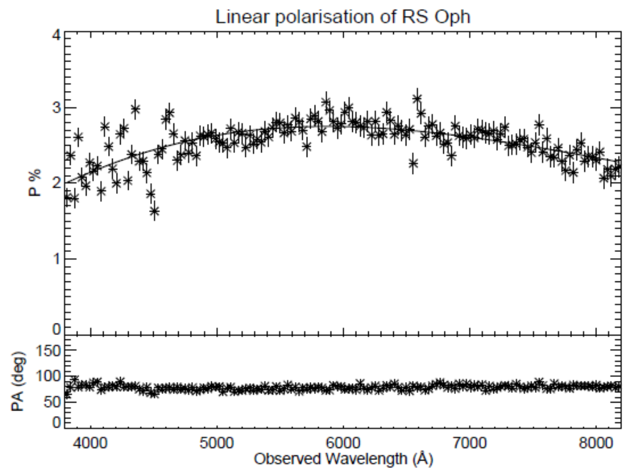


Figure 8. Polarisation spectrum of RS Oph (+) and the Serkowski law fit. Upper panel shows the binned spectrum, lower panel shows the position angle.