SIMULTANEOUS SPECTROSCOPIC AND POLARIMETRIC OBSERVATIONS OF π Aqr*

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Simultaneous spectroscopic and polarimetric observations of about 40 bright southern Be stars have been carried out by Dr. Pöllitsch and myself with the ESO 1.5m coudé spectrograph and with the ESO two channel polarimeter.

From our measurements we can conclude that the continuum polarization seems to be much more stable than the emission spectrum: Whereas several stars changed from an emission to an absorption spectrum and vice versa within a relatively short time interval, no dramatic variations of the polarization could be observed. however, if we measure by means of interference filters the polarization shortly before and after the Balmer jump and determine the difference of these two measurements (the socalled Balmer jump of polarization), then this jump is remarkably different from zero only for those stars which exhibit a pronounced emission. Since the difference is independent of interstellar polarization, it can be used to determine the intrinsic polarization of the star. This has been pointed out already by Poeckert et al. (1979). The most important result of our work is that the observed emission line profiles of Hα and Hβ of all our programme stars can be reproduced best by a shell which is not a disc but rather a sphere extending 5 to 6 photospheric radii. The shell rotates differentially and probably with conservation of angular momentum and continuous mass flow. The density is proportional to $1/r^2$.

Though this model is extremely simple, it reproduces the observed line profiles better than other more complicated models. However, it conflicts of course with the usual interpretation of the observed intrinsic polarization of Be stars. This contradiction becomes evident, if we consider the results of our measurements of π Aqr in 1977. This star exhibits the highest polarization of all stars measured during our campagne.

M. Jaschek and H.-G. Groth (eds.), Be Stars, 95–99.

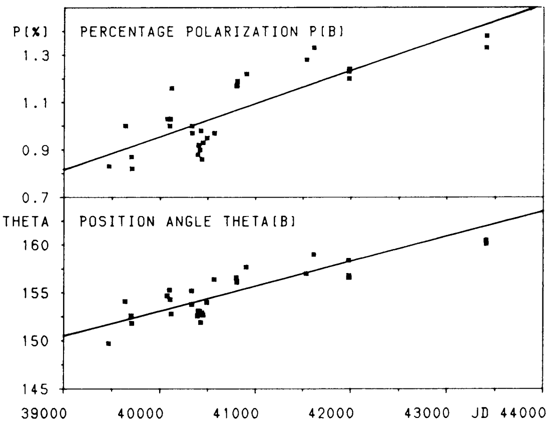

Fig. 1: The increasing polarization of π Aqr in the blue colour observed over a period of 12 years by different authors.

Fig. 1 shows its polarization compiled from measurements of several authors during 12 years. After an elimination of the interstellar component the resulting intrinsic polarization was 1.3% in 1977.

To explain such a strong polarization in the usual way, a disc with a radius at least 3 to 5 times its thickness would be necessary. On the other hand we have the contrary spectroscopic results (see fig. 2).

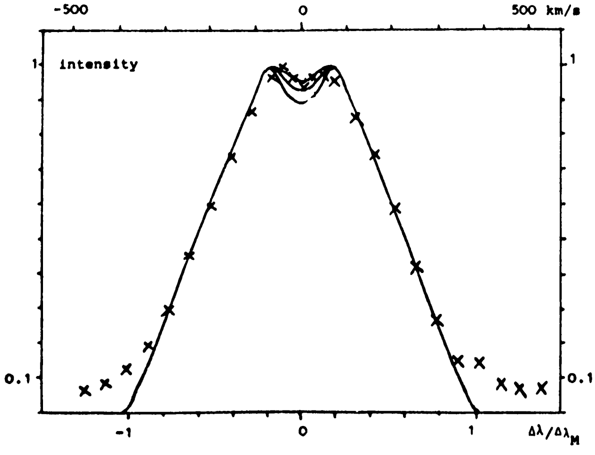

Fig. 2: Measured Hα profile of π Aqr normalized to intensity 1 for maximum emission (1977, Sept. 19, ESO 1.5m coudé, 3.3 A/mm). Solid lines derived from model calculations.

The crosses represent the measured Hα profile. Solid lines are derived from model calculations of shells with a ratio of polar to equatorial diameter between 1 (line above) and 0.6 (line below). The ratio 1 fits the observed profile better than the ratio 0.6. From the line width of Hα we get a projected radial velocity of about 430 km/sec and this is very precisely the same value, which we can derive from the photospheric absorption line He Iλ4472. The consequence is that the emitting region begins very close to the stellar photosphere. Further the measured velocity is not too far from the critical break up velocity of the star and this indicates that we observe π Aqr nearly edge on.

A star rotating near the break up velocity and viewed edge on provides exactly the asymmetry which is necessary to produce a net polarization even for a complete spherical shell: Dependent on the angular velocity, the star will be rotationally distorted. In consequence of the resulting geometry the outgoing flux is stronger in polar directions and produces therefore an excess polarization with an angle of vibration perpendicular to the axis of rotation. This effect will be very essentially enhanced according to the Von Zeipel theorem which predicts a flux directly proportional to the local gravity.

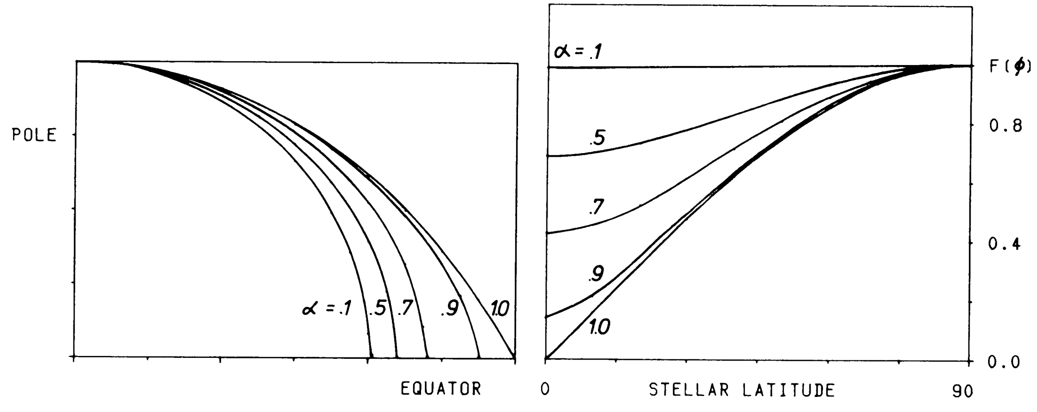

Fig. 3: a) The shape of a star rotating with ω/ω_{cr}= 0.1, 0.5, 0.7, 0.9, 1.0.
b) Theoretical surface flux F(ϕ) as a function of stellar latitude ϕ for ω/ω_{cr}= 0.1, 0.5, 0.7, 0.9, 1.0 (according to Von Zeipel).

In fig. 3 the shape and local fluxes of stars, rotating with different velocities, are plotted. As can be seen the difference of fluxes in polar and equatorial directions is a steep function of $\alpha = \omega/\omega_{crit}$.

For a quantitative determination of the resulting polarization of the system, the corresponding scattering angle for each point of the surface of the star and the envelope as well has to be calculated. Further the different local flux according to Von Zeipel and the dilution factor have to be determined. Finally it has to be checked which points of the shell are hidden by the star. Altogether this procedure needs several hours computer time even at a fast computer and therefore double scattering or the wavelength dependent absorption within the shell has not been included. For the numerical integration a stellar radius of 5 solar radii, an electron density of 10^{12} at the inner limit of the shell and an outer radius of the shell in the order of 5 stellar radii has been taken.

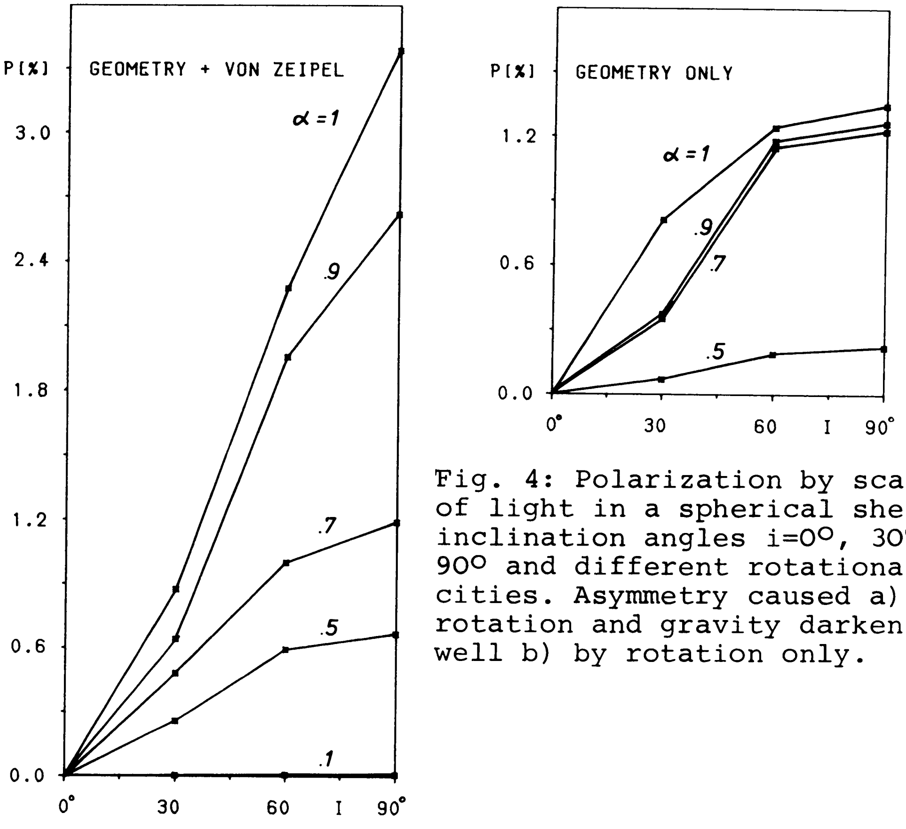

Fig. 4: Polarization by scattering of light in a spherical shell for inclination angles i=0°, 30°, 60°, 90° and different rotational velocities. Asymmetry caused a) by rotation and gravity darkening as well b) by rotation only.

The result is that a high polarization as observed in π Aqr can be produced by our model even for angles of inclination relevantly smaller than 90° and also for rotational velocities quite different from the break up velocity. This holds especially, if we apply the Von Zeipel theorem.

* Based on observations obtained at the European Southern Observatory, La Silla.

References

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Metz, K., Pöllitsch, G. (1979), ESO Messenger 18, 19.

DISCUSSION

Fehrenbach: Le spectre de π Aqr est variable. En décembre 1980 le contour de H_α comporte 3 absorptions et non pas une centrale.

Metz: In our model the lack of a central absorption only indicates that the dimensions of the shell are greater than 5 stellar radii.

Snow: This object is one of the Be stars whose mass-loss rate I have attempted to deduce from the analysis of the ultraviolet line profiles, to be reported later in the symposium. In this regard it is also unusual, with a high mass-loss rate compared to most of the rest of my sample stars.

Poeckert: What is the resolution of your data for H_α? The $H\alpha$ line in π Aqr is highly variable and one should perhaps be careful in aplying your model to all Be stars.

Metz: The dispersion was 3.3 A/mm. The time resolution was about 90 min. With our model we could reproduce the observed H_α profiles of stars which exhibit fairly symmetric lines.

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