



UvA-DARE (Digital Academic Repository)

Observational evidence for a prograde one-armed density structure in the equatorial disc of a Be star

Telting, J.H.; Heemskerk, M.H.M.; Henrichs, H.F.; Savonije, G.J.

Publication date

1994

Published in

Astronomy & Astrophysics

[Link to publication](#)

Citation for published version (APA):

Telting, J. H., Heemskerk, M. H. M., Henrichs, H. F., & Savonije, G. J. (1994). Observational evidence for a prograde one-armed density structure in the equatorial disc of a Be star. *Astronomy & Astrophysics*, 288, 558-560.

General rights

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

Observational evidence for a prograde one-armed density structure in the equatorial disc of a Be star

J. H. Telting, M. H. M. Heemskerk, H. F. Henrichs, and G. J. Savonije

Astronomical Institute Anton Pannekoek, University of Amsterdam, and Center for High Energy Astrophysics, Kruislaan 403, NL-1098 SJ Amsterdam, The Netherlands

Received 5 February 1994 / Accepted 18 February 1994

Abstract. We discuss the implications of the observations of the Be star β^1 Mon, as presented by Cowley & Gugula (1973), for the theory of one-armed density perturbations in the equatorial discs of Be stars. This theory aims to describe the nature of the long-term (cycles of a few to several years) V/R variations of the Balmer and other emission lines of these stars (Okazaki 1991 and Papaloizou et al. 1992). From the observations of β^1 Mon we infer that a one-armed density structure revolved around the star in the same direction as the nearly Keplerian orbits of the disc material. We conclude that these observations are consistent with a model which predicts *prograde* precession of a one-armed density perturbation.

Key words: stars: emission-line, Be – circumstellar matter – individual: β^1 Mon

1. Introduction

Long-term variability (time scales of 2–15 years) in the ratio of the intensity of the violet and red peaks of the Balmer emission lines (V/R variation) is commonly observed in the spectra of Be stars (Dachs 1987; Mennickent & Vogt 1991). Based on more than 60 years of observations of β^1 Mon Cowley & Gugula (1973) concluded that the cyclic V/R variations of this star can be explained by the presence of a non-axisymmetric envelope which slowly rotates around the star with the period of the V/R variations (approximately 12 years). Other stars of which the long-term V/R variations have been modelled by a non-axisymmetric flattened envelope are e.g. EW Lac (Suzuki & Kogure 1985) and HD184279 (Ballereau & Chauville 1989). Furthermore, Telting et al. (1993) and Telting & Kaper (1994) concluded that the model which best describes the V/R behaviour of the Be star γ Cas and also its IR continuum and UV spectral variations consists of a star surrounded by a rotating non-axisymmetric, disc-like wind, which is seen at a moderate inclination angle.

Send offprint requests to: John Telting

After the suggestion by Kato (1983) that low-frequency one-armed modes may occur in semi-Keplerian non-self-gravitating discs, Okazaki (1991) considered these modes in relation to the V/R phenomenon. He constructed semi-Keplerian disc models in which pressure forces cause one-armed ($m = 1$) density waves to precess in the direction opposite to the Keplerian rotation with periods in the range of the observed V/R cycle times. By producing locally enhanced emission these slowly precessing modes may give rise to the V/R variations. Papaloizou et al. (1992) extended the semi-Keplerian disc models of Okazaki (1991) by including the effect of the quadrupole contribution to the external potential of the rotationally distorted (i.e. oblate) Be-star on the modal precession. They concluded that this effect can naturally explain the observed cycle times, rather independent of the adopted size and structure of the disc. For not too hot discs, in which pressure effects become dominant, the fundamental $m = 1$ modes (and their first overtones) precess in the same direction as the Keplerian rotation and are naturally confined to within a few stellar radii from the Be-star (see also Savonije & Heemskerk 1993).

Studies of the observational appearance of global disc oscillations and studies of observational evidence for the occurrence of such oscillations have been presented by Hanuschik et al. (1994) and Okazaki (1994). Furthermore, Hummel & Hanuschik (1994) compared results of a 3D radiative line transfer code, including one-armed disc perturbations, with observations of β^1 Mon and concluded that these observations are consistent with the presence of a *retrograde* one-armed density perturbation in the disc.

In this paper we concentrate on the directional sense of the precession of the disc perturbations with respect to the Keplerian rotation. In the following section we argue that the observations of β^1 Mon favour a model which predicts *prograde* revolution of a one-armed density perturbation in the disc.

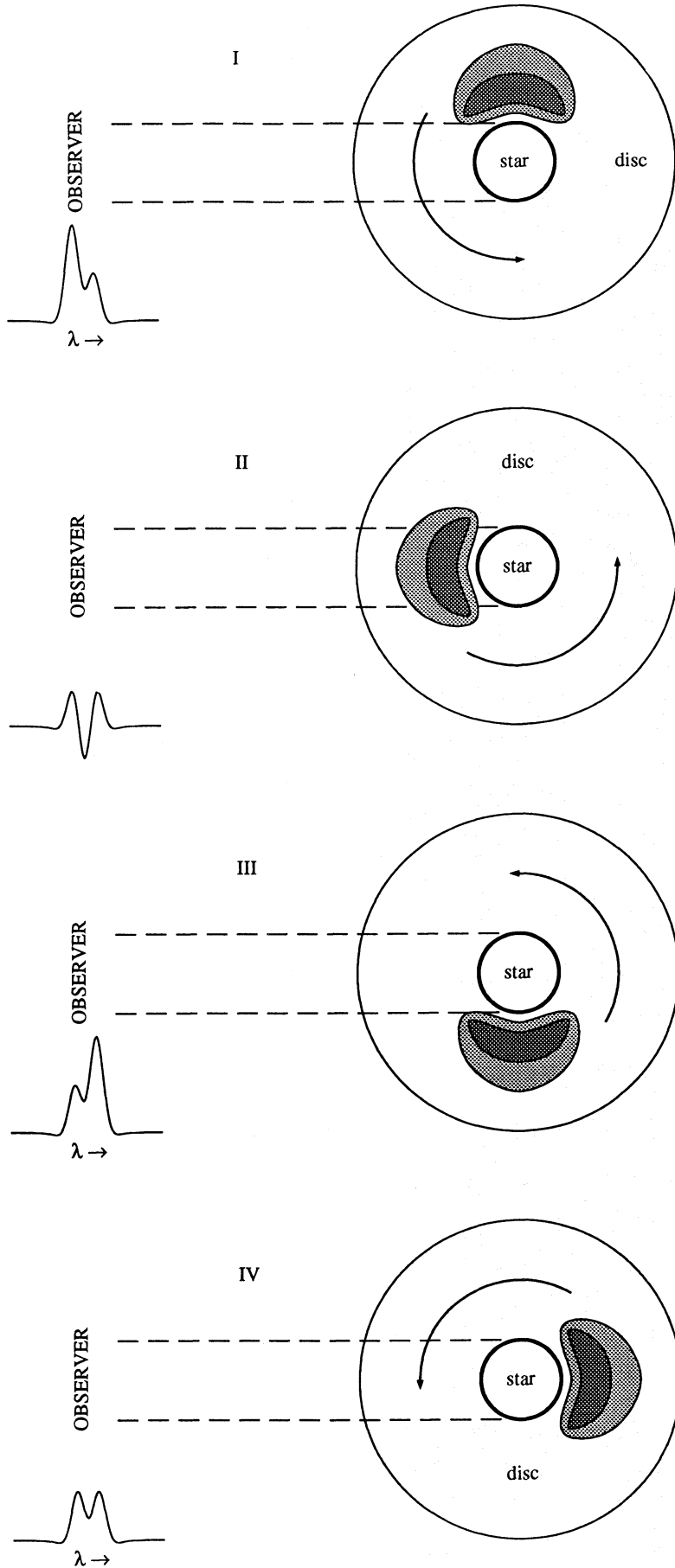


Fig. 1. Schematic model for V/R variations in the spectra of β^1 Mon. We show a pole-on view of the equatorial disc. The curved arrow indicates the direction of the nearly Keplerian motion of the gas in the disc. The grey areas in the disc represent the high-density part of a one-armed oscillation of the disc. This high-density part revolves around the star *in the prograde sense* on the time scale of the V/R variations of the emission lines. For four positions of the high-density part of the one-armed perturbation we indicate the expected $H\beta$ profile for an observer which sees the disc (nearly) edge-on. Note that the displayed sequence of $H\beta$ profiles (I \rightarrow II \rightarrow III \rightarrow IV \rightarrow I) is the same as for the observed spectra of β^1 Mon. **I)** The gas in the high-density part of the equatorial disc moves towards the observer; the emission lines have $V > R$. **II)** The high-density part of the equatorial disc is in front of the star; the emission lines have maximum shell absorption and $V = R$. **III)** The gas in high-density part of the equatorial disc moves away from the observer; the emission lines have $V < R$. **IV)** The high-density part of the equatorial disc is behind the star. Since the star is partly obscuring the extra emission the emission lines are not much different from the situation without a one-armed perturbation; the emission lines have $V = R$. These expected line profile changes are consistent with the calculations of Hummel & Hanuschik (1994)

2. Observational discrimination between prograde and retrograde precession of global disc perturbations

β Monocerotis is a visual triple system which consists of three Be stars of which β^1 Mon (HR2356, HD45725, $V \approx 4.6$ mag, spectral type B3Ve, $v \sin i \approx 346$ km/s) is the brightest (Hoffleit & Jaschek 1982; Cowley & Gugula 1973). The high $v \sin i$ of β^1 Mon makes it likely that the star is viewed at a large inclination angle, i.e. nearly edge-on.

Cowley & Gugula (1973) report results of more than 60 years of optical spectroscopy. They found that from ~ 1930 to ~ 1966 the V/R ratio of the H β line showed a quasi-periodic behaviour over three cycles with a period of approximately 12 years. The long-term variations of the H γ and H δ line were practically indistinguishable from those of the H β line. During the transition from $V > R$ to $V < R$ they observed relatively strong central absorption (shell line) in the profile, whereas they observed relatively weak central absorption as the peak ratio changed from $V < R$ to $V > R$.

In Fig. 1 we present a schematic representation of our picture of the β^1 Mon system. The H β line profiles are drawn to match the photographic spectra as presented by Cowley & Gugula (1973). The presence of a one-armed density enhancement gives rise to extra emission/absorption depending on its position with respect to the star. Following the observed sequence $V > R$ (I) \rightarrow strong central absorption (II) $\rightarrow V < R$ (III) \rightarrow weak central absorption (IV) $\rightarrow V > R$ (I) we conclude that the one-armed density enhancement of the disc must revolve around the star in the prograde direction:

- When the density enhancement is on the side of the star where the nearly Keplerian motion of the gas is directed towards the observer we expect to see enhanced emission at the blue side of the profile: $V > R$ (I).
- When the density enhancement is in front of the star, and the inclination is large enough, we expect to see shell absorption: strong central absorption due to the eclipse of the star by the density enhancement (II).
- When the density enhancement is on the side of the star where the motion of the gas in the disc is directed away from the observer we expect to see extra emission at the red side of the profile: $V < R$ (III).
- When the density enhancement is located behind the star, the star obscures significant amounts of the extra emission if the inclination is large. The emission lines appear as they would without the presence of a one-armed mode: weak central absorption, hardly extra emission (IV).

These expected line profile changes are consistent with the calculations of Hummel & Hanuschik (1994).

Here we stress that retrograde revolution of a mode would give rise to the reverse of the above mentioned sequence: (IV) \rightarrow (III) \rightarrow (II) \rightarrow (I) \rightarrow (IV), which in the case of β^1 Mon is not observed. Hence we conclude that the Balmer-line observations of β^1 Mon are consistent with a model of a *prograde* one-armed density perturbation in the equatorial disc. This directional sense is in agreement with the prediction of the model by Papaloizou

et al. (1992), and could therefore mean that the effect of the oblateness of the star is important.

Since the $v \sin i$ value of β^1 Mon is not exceptional for Be stars, the long-term V/R variations of other Be stars may also be due to prograde one-armed density waves. However, only for Be stars seen at large inclination angles (edge-on) we can observationally distinguish between prograde and retrograde disc modes due to the expected effects of disc-star eclipses (see Fig. 1). Further constraints on the density profile and velocity fields in the disc and on the one-armed modes can be obtained by careful comparison of the observations with line profiles generated by a three dimensional radiative transfer model with as input a non-axisymmetrical disc-like geometry. Promising results of this method have been presented by Hummel & Hanuschik (1994). However, these authors derived from the same observations as are discussed in the present paper, using the same argumentation as we do, an opposite, and incorrect directional sense of the precession of the density perturbation in the disc.

Acknowledgements. We thank Thomas Augusteijn, Wolfgang Hummel, Lex Kaper, Jan van Paradijs and Rens Waters for discussions, many helpful suggestions and careful reading of the manuscript.

This research is supported by the Netherlands Foundation for Research in Astronomy (NFRA) with financial aid from the Netherlands Organization for Scientific Research (NWO).

References

- Ballereau, D., Chauville, J. 1989, A&A, 214, 285
 Cowley, A.P., Gugula, E. 1973, A&A, 22, 203
 Dachs, J. 1987, in: IAU Colloquium 92, Physics of Be stars, ed. A. Slettebak and T.P. Snow, Cambridge University Press, p. 150
 Hanuschik, R.W., Hummel, W., Dietle, O., Dachs, J., Sutorius, E. 1994, in: Proc. IAU Symp. 162 'Pulsation, rotation and mass loss in early type stars', ed. L. Balona, H.F. Henrichs and J.-M. LeContel, Kluwer
 Hoffleit, D., Jaschek, C. 1982, The Bright Star Catalogue, Yale University Observatory
 Hummel, W., Hanuschik, R.W. 1994, in: Proc. IAU Symp. 162 'Pulsation, rotation and mass loss in early type stars', ed. L. Balona, H.F. Henrichs and J.-M. LeContel, Kluwer
 Kato, S. 1983, PASJ, 35, 249
 Mennickent, R.E., Vogt, N. 1991, A&A, 241, 159
 Okazaki, A.T. 1991, PASJ, 43, 75
 Okazaki, A.T. 1994, submitted to PASJ
 Papaloizou, J.C., Savonije, G.J., Henrichs, H.F. 1992, A&A, 265, L45
 Savonije, G.J., Heemskerk, M.H.M. 1993, A&A, 276, 409
 Suzuki, M., Kogure, T. 1985, Ap&SS, 119, 69
 Telting, J.H., Waters, L.B.F.M., Persi, P., Dunlop, S. 1993, A&A, 270, 355
 Telting, J.H., Kaper, L. 1994, A&A 284, 515

This article was processed by the author using Springer-Verlag L^AT_EX A&A style file version 3.