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OBSERVATION OF A $V = R$ TRANSITION IN THE Be STAR 66 Oph[1]

As part of our long-term high resolution spectroscopic monitoring programme of Be stars, we have repeatedly observed the interesting equatorial Be star 66 Oph = HR 6712 (B2 IV-Ve, $v \sin i = 240$ km s^{-1}). During the past two decades, its Hα emission strength has been observed to steadily increase from $F_\alpha = 3F_c$ in 1973 (Gray & Marlborough 1974) to 8–10F_c in 1992–1994 (see Table 1). This latter value corresponds to equivalent width $W_\alpha \approx 50 - 60$Å, thus presently making 66 Oph one of the brightest Be stars at Hα.

We have mainly investigated the Hα and the Fe II λ5317 emission lines. Our data cover the epoch 1989–1994 and have been measured at ESO 1.4m Coudé Auxiliary Telescope (observers: Hanuschik, Hummel), at the 2.2m telescope at the German-Spanish Observatory DSAZ on Calar Alto/Spain (observers: Hummel, Vrancken), and at the 2.0m Ondřejov telescope (observer: Štefl). Resolution $R = \lambda/\Delta\lambda$ has been around 50 000, except for the Ondřejov data (15 000). The signal-to-noise ratio is usually several hundred except for some of the Fe II profiles shown here. Profile parameters are collected in Table 1.

Our profile survey in Fig. 1 demonstrates that in 1989–April 1993, and since June 1994 again, 66 Oph has shown asymmetric single or double-peak profiles at Hα, and extremely asymmetric, so-called steeple profiles in Fe II. Especially striking is the inversion of asymmetry from $V > R$ (in 1989) to $R > V$ (1992) back to $V > R$ (1994).

The steeple-type Fe II profile shape and the cyclic V/R asymmetry are two connected phenomena, both being produced by a large-scale density inhomogeneity. This structure is likely to be a *global density wave*, slowly precessing under the influence of the centrifugally flattened B star (Hanuschik et al. 1995).

In 1988, 66 Oph showed a sudden onset of cyclic V/R variability, after at least 15 years of symmetric double-peak structure ($V \approx R$). Its present full V/R cycle time is only 5 years, rather short if compared to other such Be stars which have typical cycle duration of about 10 years. With this cycle time, the first $V = R$ transition must have occurred in early-1991, but escaped detection. In 1993, we have been fortunate enough to observe the second $V = R$ transition, both in Hα and Fe II (see Fig. 2). This transition occurred in November 1993 and appears to have lasted only a few months, as a comparison of our data from September 1993 (Hα: $R > V$), November 1993 ($R = V$), and June 1994 ($V > R$) clearly shows.

The transition appears quite smooth, with a gradual decrease in asymmetry in 1993 from April over September to November, and a new increase, with opposite sign, to 1994 August. The overall time of observed $V = R$ shape is only a few months, a small fraction of the full cycle time. Such temporal behaviour agrees well with the expectation that the slope of the V/R evolution is sinusoidal, with much longer periods of V/R asymmetry than with $V = R$.

[1] Based on observations obtained at the European Southern Observatory, La Silla, Chile; at the German-Spanish Observatory DSAZ, Calar Alto, Spain; and at the Ondřejov Observatory, Czech Rep.

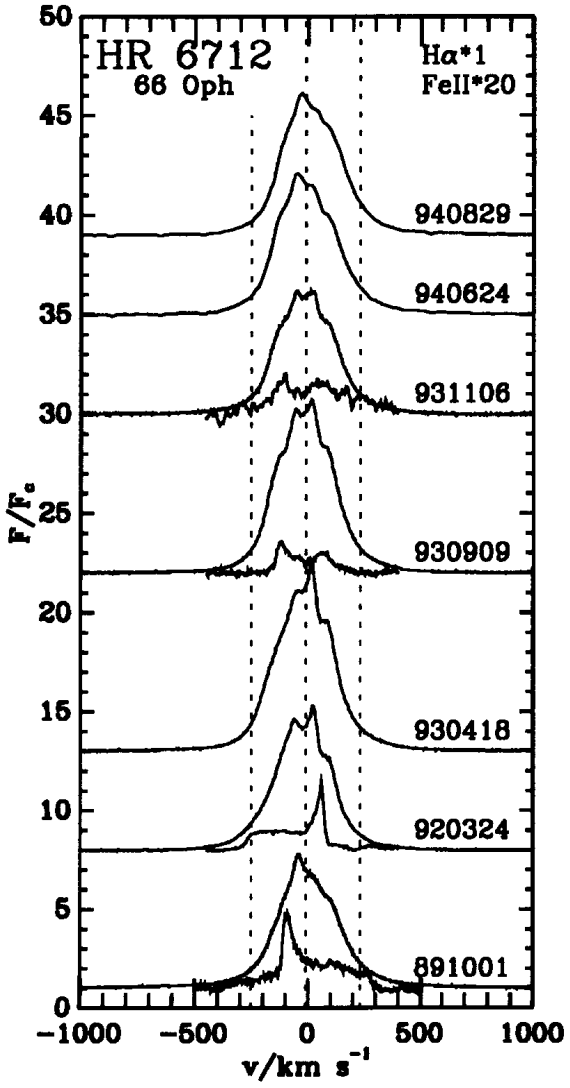

Figure 1. Hα and Fe II emission line profiles in 66 Oph (left), both on a common heliocentric velocity scale. The flux scale of the Fe II lines is expanded by a factor of 20.

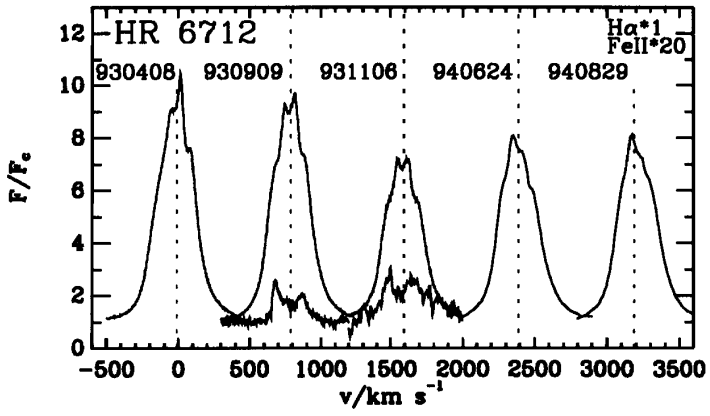

Figure 2: Comparison of the 1993 and 1994 profiles of 66 Oph, demonstrating the $V < R \rightarrow V > R$ transition in November 1993.

Table 1. Line parameters for Hα and Fe II

Date[a]	Hα			Fe II λ5317		
	W_λ/Å	V/R[b]	$F_\mathrm{p}/F_\mathrm{c}$[c]	W_λ/mÅ	V/R	$F_\mathrm{p}/F_\mathrm{c}$
891001	45.9	> 1	7.78	680	3.78	1.189
920324	46.6	0.911	7.95	391	0.241	1.174
930418	59.7	0.852	9.80			
930909	59.1	0.944	9.47	227	1.59	1.063
931106	44.6	1.00	7.16	500:	≈ 1	1.09:
940624[d]	50.5	1.10	7.82			
940706	49.8	1.11	7.73			
940803[e]	48.7	1.14	7.76			
940815	49.5	1.14	7.64			
940829	49.9	1.15	7.66			

[a] 891001 = 1989 October 1
[b] $V/R = [F(V) - F_\mathrm{c}]/[F(R) - F_\mathrm{c}]$
[c] average intensity if two peaks exist
[d] averaged from 7 measurements on June 23, 24, and 25
[e] averaged from 3 measurements

An interesting observation is that shortly before the $V = R$ transition, Hα and Fe II profiles showed slightly opposite V/R behaviour: in September 1993, $V < R$ in Hα, $V > R$ in Fe II. This may be partly due to the fact that in a certain critical parameter range, the superposition of different line broadening mechanisms (causing the winebottle-type inflections and the profile peaks) causes slightly inverse V/R ratios in Hα and the Fe II line. Alternatively, this may be indicative of a certain time lag between the $V = R$ transition in both lines due to very different optical depth and therefore different contributing disk regions. Thus these measurements contain valuable information for the modelling of the density wave.

A very pronounced decrease in equivalent width occurred in November 1993 (by 25 %), after the star had shown a stable value of 59 Å for almost half a year before. Half a year later, W_α was again observed at higher values, remaining constant thereafter for at least two months. Such rather strong variability seems to be uncommon in this star. However, we are not fully sure that the sudden decrease is not a mere chance coincidence. If it is physically related to the $V = R$ transition, then this observation may be interpreted as result of the relatively small velocity gradient (averaged across the whole emitting disk) at the moment of symmetry ($V = R$), as compared to the situation shortly before and after the transition when the velocity gradient becomes larger again.

We strongly encourage other observers to continue to monitor this interesting Be star at high spectral resolution, in order to follow up its V/R behaviour and to furthermore document its emission strength variability pattern.

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