Astron. Astrophys. 229, 141–142 (1990)

ASTRONOMY AND ASTROPHYSICS

Research Note

Simultaneous radio and Hα observations of Be stars

K.M.V. Apparao [1], T.N. Rengarajan [1], S.P. Tarafdar [1], and K.K. Ghosh [2]

[1] Tata Institute of Fundamental Research, Homi Bhabha Road, Colaba, Bombay 400005, India
[2] Vainu Bappu Observatory, IIA, Kavalur, Alangayam 635701, India

Received June 6, accepted August 12, 1989

Abstract. We have observed 18 Be stars in the radio continuum at 2 cm wavelength with the VLA on 7th February 1987. We observed 12 of the stars the same night in the optical using an Hα filter and the rest subsequently. No radio emission was observed and 3σ upper limits of 0.4–1.0 mJy were obtained. The result is discussed.

Key words: Be stars – radio

1. Introduction

Be stars have been observed at infrared, optical, UV and X-ray wavelengths revealing several different and interesting phenomena (Doazan, 1982). Observation at a single wavelength will not, sometimes, give unambiguous information. For example, lack of observations at, say X-ray wavelengths, may either mean that there is no compact companion to the Be star or simply that the star is not in its Be phase. Recently, simultaneous observations at more than two wavebands have been undertaken with fruitful results (Taylor et al., 1987).

Upto now only a handful of Be stars have been detected in the radio band (Purton, 1976; Marsh et al., 1976; Taylor et al., 1987). Taylor et al. used the Very Large Array (VLA) of the US National Radio Astronomy Observatory to observe five Be stars at 6 cm wavelength. They found a finite flux from only one star, ψ Per. It was not, however, clear whether the other stars were in the Be phase or not. We therefore, decided to observe a large number of Be stars to increase the chance of detection. Since the radio emission is expected to be optically thick, we chose to observe at the short wavelength of 2 cm. To improve the chance of detection, we also used the infrared observations listed by Coté and Waters (1987) and selected 15 stars with V magnitude < 5 and colour excess $[V-(12)] > 1$ mag. Three other stars were also observed. We also observed these almost simultaneously in the Hα line. We present here the results of our study and their implications.

Send offprint requests to: K.MV. Apparao

2. Observations and results

The radio observations were carried out on 7th February 1988 at a wavelength of 2 cm using the VLA in the B/C hybrid configuration. The FWHM of the synthesized beam was about 2″. The 18 Be stars observed are listed in Table 1. Each star was observed for about one hour. The radio data were reduced with the "AIPS" program package. No radio flux was observed from any of the stars and we obtain 3σ upper limits in the range 0.3–1.0 mJy for the radio flux density at 2 cm. The upper limits for individual stars are listed in Table 1. Five of our sources have also been observed by Taylor et al. (1987) at 6 cm. In order to compare our results with theirs, we use a spectral index of 1.28, the same as the 1.1 mm–6 cm index observed for ψ Per (Taylor et al. 1987; Waters et al. 1989). Our 3σ upper limits then translate to 6 cm limits ranging from 0.11–0.15 mJy, which are in the same range as those of Taylor et al.. However, for ψ Per our implied 3σ upper limit of 0.12 mJy is only half of their reported flux density of 0.23 ± 0.036 mJy. It is not clear whether this discrepancy is due to time variation or implies that the radio spectral index in the cm region is flatter.

Twelve of the stars were observed during the same night when the radio observations were taken with a grating spectrograph attached to the 1 metre telescope at the Vainu Bappu Observatory, Kavalur, India. H-alpha line profiles and equivalent widths were obtained for all these. Subsequently, the remaining stars were observed, also in Hα in a similar fashion. The V magnitudes and the equivalent widths of the Hα line are given in Table 1. A negative equivalent width indicates emission, a positive one absorption. The observed stars range in spectral type from B0–B9.

3. Discussion

It is seen from Table 1 that 16 out of 18 Be stars are in emission phase, indicating the presence of an ionized gaseous envelope. In spite of this no radio flux was observed. The emission of radio flux from H II regions has been discussed by Olnon (1975) for various configurations of the emitting region. Using his formalism and taking the radius of the ionized gas envelope to be 10^{12} cm, an

Table 1. Properties of Be stars observed

HD	Name	V_{mag}	$V-(12)$	MK	$W(H\alpha)$ (Å)	Upper limit to radio flux (3σ) mJy
4180	o Cas	4.54	1.31	B 5 IIIe	−39.45[a]	0.78
5394	γ Cas	2.47	1.62	B 0 IVe	−24.40	0.48
10516	ϕ Per	4.07	2.24	B 2 Ve	−24.61	0.51
22192	ψ Per	4.23	1.70	B 5 Ve	−25.89	0.48
23302	17 Tau	3.70	0.95	B 6 IIIe	+ 3.28	0.45
25940	48 Per	4.04	1.46	B 3 Ve	−14.41	0.45
35439	25 Ori	4.95	1.43	B 1 Ve	− 8.24	0.42
37202	ζ Tau	3.00	1.27	B 4 IIIe	− 5.94	0.45
37490	ω Ori	4.51	0.75	B 2 IIIe	− 7.11	0.38
45725	β^1 Mon	4.57	1.95	B 4 Ve	−16.51	0.36
50013	k CMa	3.47	1.96	B 2 IVe	−13.90	0.42
63462	o Pup	4.48	1.53	B 1 IVe	− 7.77	0.37
109387	k Dra	3.87	1.38	B 6 IIIe	−15.74	0.46
112078	λ Cru	4.62	−0.55	B 4 Ve	+ 8.27	0.42
142983	48 Lib	4.88	1.37	B 5 IIIe	−14.83	0.84
148184	χ Oph	4.42	3.01	B 2 IVe	−44.67	0.57
164284	66 Oph	4.64	2.01	B 2 Ve	−51.38	0.63
191610	28 Cyg	4.93	1.20	B 2.5 Ve	−20.15	0.96

[a] Negative value implies emission

electron density of 10^{12} cm^{-3} and an electron temperature of 10^4 K, we find that the optical depth at 2 cm is much larger than unity and that the emitted spectrum therefore is that of a black-body. For a typical distance of 100 pc, the above parameters predict a flux density of only 2 μJy, much smaller than the observed upper limits. When the optical depth is large, the only way to get substantially higher radio emission is to increase the radius of the emitting region. For the radio flux density at 2 cm to be in the observable range, the radius has to be larger than $2\ 10^{13}$ cm. By the time the Hα emitting region expands to this size, the declining phase of Hα probably sets in. We conclude that for the observed Be stars, the ionized gas envelope was not sufficiently large during the period of our observations.

Acknowledgements. The National Radio Astronomy Observatory is operated by Associated University Inc. under contract with the U.S. National Science Foundation. We are thankful to them for observing time as well as for help during the observations.

References

Coté, J., Waters, L.B.F.M.: 1987, *Astron. Astrophys.* **176**, 93

Doazan, V.: 1982, B stars with and without emission lines, NASA SP-456, Part II

Marsh, K.A., Purton, C.R., Feldman, P.A.: 1976, *Astron. Astrophys.* **49**, 211

Olnon, F.H.: 1975, *Astron. Astrophys.* **39**, 217

Purton, C.R.: 1976, *Proc. IAU Symp.* **70**, ed. A. Slettebak, Reidel, Dordrecht, p. 157

Taylor, A.R., Waters, L.B.F.M., Lamers, H.J.G.L.M., Persi, P., Bjorkman, K.S.: 1987, *Monthly Notices Roy. Astron. Soc.* **228**, 811

Waters, L.B.F.M., Boland, W., Taylor, A.R., van de Stadt, H., Lamers, H.J.G.L.M.: 1989, *Astron. Astrophys.* **213**, L 19