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The radio morphology of the LBV IRAS 18576+0341

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Abstract. Multi-frequency, sub-arcsecond resolution radio observations of IRAS 18576+0341 have revealed an extended, asymmetric and quite structured radio nebula allowing us to locate the central core of this highly obscured new galactic Luminous Blue Variable. The analysis of radio properties of IRAS 18576+0341 has provided estimates of important physical parameters of the central star. In particular, an effective temperature of $T_{\rm eff} \sim (2.6 \pm 0.2) \times 10^4$K, corresponding to a B0-B0.5 supergiant, and the current day mass-loss ($\dot{M} = 3.7 \times 10^{-5} M_{\odot}{\rm yr}^{-1}$), have been derived.

Key words. circumstellar matter – Stars: winds, outflows – Stars: mass-loss – Radio continuum: stars – Stars: individual:(IRAS 18576+0341, AFGL 2298)

1. Introduction

Luminous Blue Variables (LBVs) are luminous, massive stars quite rare in our Galaxy. This is mainly due to the very short timescales involved in this transition phase of stellar evolution leading to the Wolf-Rayets stage and to the presence of thick circumstellar envelope that makes observations of the central object quite difficult. A review of their characteristics can be found in Humphreys & Davidson (1994).

The infrared source IRAS 18576+0341, originally classified as a Planetary Nebula, is now recognized as new LBV, on the basis of the observed strong photometric and spectroscopic variability and of its position in the HR diagram (Pasquali & Comeron 2002; Clark et al. 2003).

The presence of an extended dusty circumstellar shell have been reported by Ueta et al. (2001) , who mapped the source at 10.3 and 18.0 μm. Radio observations have been proven to be very important in the study of LBVs as they allow to probe the gaseous component lying inside the dust shells and because they provide a powerful tracer for $\dot{M}$.

In this paper we present the first set of multi-frequency and subarcsec angular resolution VLA radio observations of IRAS 18576+0341.

2. Observations

We observed IRAS 18576+0341 with the VLA[1], in two different array configurations,

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[1] The Very Large Array is a facility of the National Radio Astronomy Observatory which is

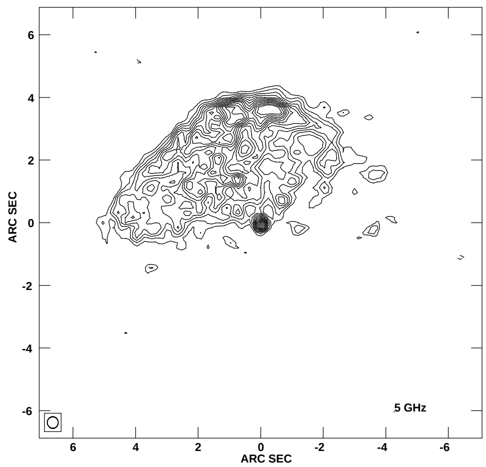

Fig. 1. Contour plot of 5 GHz cm VLA-A image. Levels are -3, 3, 4, 5, 6, 7, 8, 10, 12, 15, 20, 25, 30, 40, 45, 50, 60, 70, 80, 90 times 0.09 mJy/beam

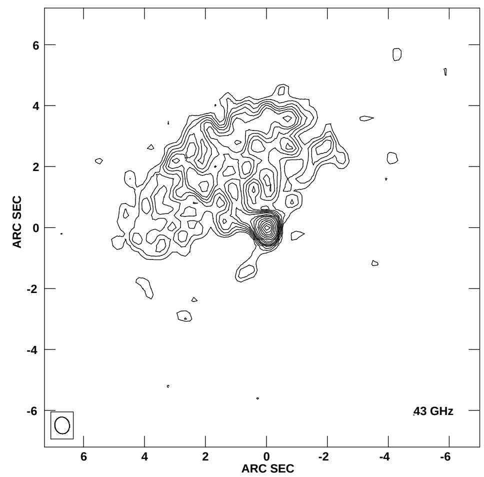

Fig. 2. Contour plot of 43 GHz VLA-C image. Levels are -3, 3, 4, 5, 6, 7, 8, 10, 12, 15, 20, 25, 30, 40, 45, 50, 60, 70, 80, 90 times 0.15 mJy/beam

namely C and A, providing a typical beam size at 8.4 GHz of ∼ 2.3′′, and ∼ 0.3′′, respectively. The observations were carried out at six frequencies, namely 1.4 (L-Band), 4.8 (C-Band), 8.4 (X-Band), 14.9 (U-Band), 22.0 (K-Band) and 43.0 (Q-band) GHz with VLA-C and at three frequencies, 1.4, 8.4 and 4.8 GHz, with VLA-A. In particular, the use of two configurations allows to obtain comparable resolutions at both lower and higher frequencies in order to compare radio structures at different scales. The data processing was performed using the standard programs of the NRAO **A**stronomical **I**mage **P**rocessing **S**ystem (AIPS).

3. The radio properties

IRAS 18576+0341 is an extended radio source, whose morphology consists of a compact, slightly resolved source, embedded in a structured extended ionized shell. The same kind of morphology has been observed in other LBVs. Figure 1 and 2 show the images obtained at 5 and 43 GHz but using a different configuration to obtain a comparable angular resolution ∼ 0.4′′.

The limited angular resolution of the C configuration prevented the identification of the core component at lower frequencies, but allowed a good determination of the radio flux coming from the extended, highly clumpy nebula. To quantify the contribution of the two components (central object and nebula) to the observed flux density we have then reconstructed the radio spectrum (central object plus nebula).

3.1. The core component

¿From the higher frequency , where the angular resolution allows us to clearly distinguish the compact component, the position, flux density and angular size of the central source have been derived by fitting a two dimensional Gaussian brightness distribution to the map. For the core component a stellar wind behavior was derived, which is characterized by a 0.8 ± 0.1 spectral index. ¿From the radio flux density observed at 43 GHz ($F_\nu = 6.2 mJy$), assuming as stellar wind velocity a value of $v \sim 200$ km s^{-1}, (Crowther 1997), a temperature of the wind of 10^4K and a distance of 10 Kpc (Ueta et al. 2001), we derive a cur-

operated by Associated Universities, Inc. under cooperative agreement with the National Science Foundation rent day mass loss rate for the LBV of $\dot{M} = 3.7 \times 10^{-5} M_{\odot} \mathrm{yr}^{-1}$.

3.2. The extended nebula

To get an estimate of the radio flux density due only to the extended nebula, at the higher frequencies we directly subtracted, from the total flux density, the contribution of the core component, as derived by the Gaussian fit. For the lower frequencies the contribution of the core component was evaluated from the extrapolation of the stellar wind spectrum down to 1.4 GHz, leading to a typical free-free radio spectrum, which is optically thin for frequencies higher than 4.8 GHz.

It is, therefore, possible to derive the excitation parameter ($U_{\rm exc}$) required to account for the measured radio flux. Following Spitzer (1978) we found that to maintain the nebula ionized the flux of Lyman continuum photons of a B0-B0.5 supergiant is necessary.

This corresponds to an effective temperature of $T_{\rm eff} \sim (2.6 \pm 0.2) \times 10^4$K (Panagia 1973).

4. Conclusions and future work

We have obtained the first high resolution, multi-frequency radio images of the newly recognized galactic LBV IRAS 18576+0341, which have revealed the core compact component, assumed to be coincident with the LBV, embedded in a more extended, highly structured nebula.

The radio properties of the extended nebula have allowed the estimates of important physical parameters of the source. In particular, the detection of radio emission from a stellar wind associated to the central core of IRAS 18576+0341 have provided the possibility to get accurate estimates of the current day $\dot{M}$.

The most striking characteristics of the radio nebula is its asymmetry, as the nebula lying all well in the N-E part with respect to the central object. A small degree of asymmetry was also evident in the mid-IR map obtained by Ueta et al. (2001), but the dust emitting region has essentially a toroidal morphology. While the explanation of the radio morphology and its relation with the mid-IR images is beyond the scope of this paper and needs further, more focused observations, it appears that the binary model evocated in the case of other LBVs may be not valid in the present situation as the temperature map obtained from mid-IR observations by Ueta et al. (2001) indicates a single, central, heating source.

The comparison between our high resolution radio maps with more sensitive mid-IR images, in both continuum and spectral lines (SPITZER), will strongly improve our knowledge of this very intriguing source.

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