Massive Stars Near and Far
Proceedings IAU Symposium No. 361, 2024
J. Mackey, J. S. Vink, & N. St-Louis, eds.
doi:10.1017/S1743921322002058

Low-frequency radio view of a fast-blue optical transient - AT 2018cow

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Abstract. We present low-frequency (0.40 − 1.25 GHz) radio observations and modeling of a Fast Blue Optical Transient (FBOT), AT2018cow (Nayana & Chandra 2021). Our data are best modeled as an inhomogeneous synchrotron emitting region expanding into an ionized circumstellar medium. We estimate the mass-loss rate of the progenitor star and shock parameters at multiple epochs post-explosion and find that the progenitor has gone through an enhanced phase of mass-loss close to its end-of-life.

Keywords. supernovae: individual: AT2018cow, radio continuum: general, stars: mass loss

1. Introduction

Fast Blue Optical transients (FBOTs) are characterised by high optical luminosities ($\gtrsim 10^{43}$ erg s^{-1}), rapid rise times to optical maxima ($t < 10$ days), and blue colors (Drout et al. 2014). The short rise time and high peak luminosities can be explained in a scenario where the optical light curves are hydrodynamically powered (not radioactively) with small ejecta masses; $M_{\rm ej} \lesssim 10^{-1}$ (Lyutikov 2022).

AT 2018cow was discovered on 2018 June 16.44 UT in the galaxy CGCG 137−068 at a distance of 66 Mpc (Smartt et al. 2018). The event was classified as an FBOT based on the characteristics of the optical light curve and spectra (Prentice et al. 2018). Radio emission was detected from AT 2018cow (Nayana & Chandra 2018, Margutti et al. 2019, Ho et al. 2019) and was found to be synchrotron radiation from a shock ($v \sim 0.1$ c) created due to the interaction of the ejecta with the dense surrounding medium (Ho et al. 2019, Margutti et al. 2019). Modelling the early time ($t \sim 5 - 81$ days) radio observations, Ho et al. (2019) estimated the mass-loss rate of the progenitor to be $\dot{M} \sim 4 \times 10^{-4}$ $M_\odot$ yr^{-1}.

Late-time low-frequency radio observations of FBOTs will probe a longer period of mass-loss in the progenitors' life prior explosion. We present upgraded Giant Metrewave Radio telescope (uGMRT) observations of AT 2018cow up to $t \sim 570$ days at frequencies 0.40−1.25 GHz, and study the properties of its environment. Our findings are published in (Nayana & Chandra 2021) and here we summarize the main results presented in Nayana & Chandra (2021).

2. uGMRT observations and modeling

We observed AT 2018cow with the uGMRT during $t = 11 - 570$ days at frequencies 0.40, 0.75, and 1.25 GHz in the standard continuum mode. The radio light curves are shown in Fig. 1. We model the radio data as synchrotron radiation from a shock created

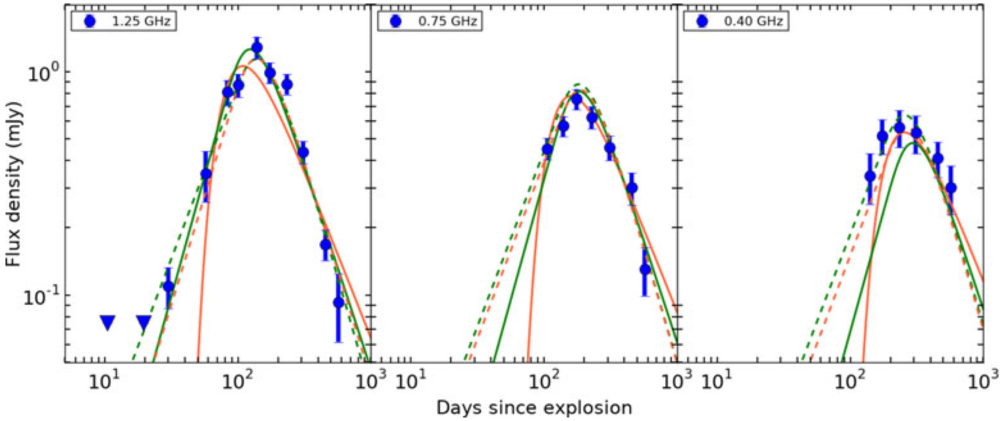

Figure 1. The best-fit homogeneous FFA (red solid lines), SSA (green solid lines), inhomogeneous FFA (red dotted lines), and inhomogeneous SSA models (green solid lines) are shown. The blue filled circles denote the observed flux densities at 0.40, 0.75 and 1.25 GHz. Figure reproduced from (Nayana & Chandra 2021).

due to the interaction of the ejecta from the explosion with the circumstellar medium, initially suppressed by free-free absorption (FFA; Chevalier 1982) or synchrotron self-absorption (SSA; Chevalier 1998). We model the data using standard homogeneous FFA and SSA models as well as inhomogeneous FFA and SSA models and find that the data is best represented by an inhomogeneous SSA model (see Fig. 1). The best-fit 1.25, 0.75 and 0.40 GHz light curves peak with flux densities $F_{\rm peak}$ = 1.1, 0.9 and 0.6 mJy at $t_{\rm peak}$ = 138, 182 and 257 days, respectively.

3. Results

We estimate shock radius (R) and magnetic field (B) at $t_{\rm peak}$ using equations 13 and 14 of Chevalier (1998). We also derive the mass-loss rates at multiple epochs using magnetic field scaling relation; $\frac{B^2}{8\,\pi} = \epsilon_{\rm B}\frac{\dot{M}}{4\pi R^2 v_{\rm w}}v^2$ (Chevalier 1998). We assume the fraction of shock energy distributed to magnetic fields to be $\epsilon_{\rm B} = 0.33$ and a wind velocity $v_{\rm w} \sim 1000$ km s^{-1}. The derived physical parameters are $R \sim$ (6.1, 9.3, 14.4) $\times$ 10^{16} cm, $B \sim$ 0.11, 0.07, 0.04 G, and $\dot{M} \sim$ (0.4, 0.3, 0.2) $\times$ 10^{-5} $M_\odot$ yr^{-1}, at $t_{\rm peak}$ = 138, 182 and 257 days (19 $-$ 46 years prior explosion), respectively. These $\dot{M}$ values are $\sim$ 100 times smaller than the $\dot{M}$ values derived at $t_{\rm peak}$ = 22 days ($\sim$ 2 years prior explosion; Ho et al. 2019), indicating the presence of a dense shell in the viscinity of AT 2018cow.

Acknowledgements

Nayana A.J. acknowledges DST- INSPIRE Faculty Fellowship (IFA20-PH-259) for supporting this research. P.C. acknowledges the support of the Department of Atomic Energy, Government of India, under project no. 12-R&D-TFR-5.02-0700.

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