Temporal and Spectral Modelling of Intermediate Luminosity type Ib Supernova SN 2015ap.

Amar Aryan1,2, S. B. Pandey1,2, Weikang Zheng3, Alexei V. Filippenko3, Joszef Vinkó4, Ryoma Ouchi5 et al.

1. Aryabhata Research Institute of observational sciences (ARIES), Nainital, India.
2. Deen Dayal Upadhyaya Gorakh University, Gorakhpur, Uttar Pradesh, India.
3. Dept. of Astronomy, Univ. of California, Berkeley, CA 94720-3411, USA.
4. Dept. of Astronomy, Univ. of Texas at Austin, TX, USA
5. Dept. of Astronomy, Kyoto Univ., Kyoto 606-8502, Japan

amar@aries.res.in, amaranayan411@gmail.com

Abstract

In this paper, we present the observed photometric and spectroscopic properties of a type Ib supernova (SN) SN 2015ap. Our aim in this work is to model a core-collapse progenitor, which can undergo core-collapse and explain the observed properties of this SN. Initially, this SN shows some broad-lined features like SN2008D, and later it shows features matching with normal type Ib supernova (SNeIb). We tried to synthetically reproduce the explosion. For this purpose, we modeled a 12 M☉ zero-age main sequence (ZAMS) star and evolved it until the onset of core-collapse using the stellar evolution code MESA. Thereafter, synthetic explosions are produced using SNEC and STELLA, which provide properties such as bolometric luminosity, blackbody radius, photospheric temperature, and velocity of the photosphere. We compare the observed parameters of SN 2015ap with those produced by synthetic explosion and find satisfactory agreement with each other supporting a 12 M☉ progenitor for SN 2015ap.

Introduction

Supernovae (SNe) are the final fates of stars. These are bright and extremely powerful explosions that mark the death of stars. Type Ib SNe lack prominent Hydrogen-features in their early spectra but display strong Helium features. Two progenitor scenarios have been proposed for these catastrophic events. The first case involves a relatively low mass progenitor (≥12 M☉) in a binary system, where the primary star lost its H-envelope through the transfer of mass to the companion star. The second case considers massive Wolf-Rayet (WR) star (> 20 to 25 M☉) that lost mass via stellar winds. For the case of SN 2015ap, based on literature and also from our analyses, we choose a 12M☉ ZAMS model as the possible progenitor. The outcomes of the synthetic explosion of such a progenitor model agree satisfactorily with the observed properties.

Photometric Properties

The left panel of fig.1 shows the UVBR data with BVRI data taken with the KAIT telescope and U band data taken from Swift UVOT at SOUSA (Brown et al. 2014). The top plot of right panel shows the bolometric light curve and the remaining three plots show the photospheric temperature, radius and velocity features.

Spectroscopic Properties

The left panel of fig.2 shows the SYN++ modeling of the spectra of SN 2015ap at various epochs easily producing the typical He I features of a type Ib SN. The 12, 13, and 17 M☉ model spectra from Jerkstrand (2015) are plotted over the SN 2015ap spectrum at +98.75 days since explosion. The 12 and 17 M☉ spectra match nicely the SN 2015ap spectrum (fig.2: right panel), indicating a range of 12-17M☉ progenitor for SN 2015ap, agreeing with Gangopadhyay et al. (2016).

Results and Conclusions

1) The photometric and spectroscopic analysis of SN 2015ap have been performed.
2) Based on these studies, a 12 M☉ ZAMS model is evolved up to the onset of core-collapse and synthetic explosions are produced using SNEC and STELLA.
3) The SNEC/STELLA produced parameters satisfactorily agree with the observed ones (calculated using Amert's model).
4) Although, magnetar model explains the observed properties much better than Ni-Co model (fig. 7), but the parameters of magnetar model are unphysical (e.g. slow rotation indicated by initial rotation period of ~70 ms, low magnetar rotational energy ~10^53 ergs and very high progenitor radii ~1200 Rsun).

References & Acknowledgments