

Radio Insight into the Nature of Type IIb Progenitors

Christopher J. Stockdale¹, S. D. Ryder², A. Horesh³, K. W. Weiler⁴,
N. Panagia⁵, S. D. Van Dyk⁶, F. E. Bauer⁷, S. Immler⁸,
R. A. Sramek⁹, D. Pooley¹⁰, J. M. Marcaide¹¹, and N. Kassim¹²

¹Marquette University
Dept. of Physics, P.O. Box 1811, Milwaukee, WI 53201, USA
email: chris.stockdale@mu.edu

²Australian Astronomical Observatory
P.O. Box 296, Epping, NSW 1710, Australia

³California Institute of Technology
Cahill Center for Astrophysics, Pasadena, CA, 91125, USA

⁴Computational Physics, Inc.
8001 Braddock Rd., Suite 210, Springfield, VA 22151, USA

⁵Space Telescope Science Institute
3700 San Martin Drive, Baltimore, MD 21218, USA

⁶Spitzer Science Center/Caltech
Mailcode 220-6, Pasadena, CA 91125, USA

⁷Pontificia Universidad Católica de Chile
Departamento de Astronomía y Astrofísica, Casilla 306, Santiago 22, Chile

⁸Center for Research and Exploration in Space Science and Technology
NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

⁹National Radio Astronomy Observatory
P.O. Box O, Socorro, NM 87801 USA

¹⁰Sam Houston State University
Department of Physics, Farrington Building, Suite 204, Box 2267, Huntsville, TX 77341 USA

¹¹Universidad de Valencia
Departamento de Astronomía, 46100 Burjassot, Spain

¹²Naval Research Laboratory
Code 7210, Washington, D.C. 20375, USA

Abstract. We present the results of over two decades of radio observations of type IIb Supernovae with the Very Large Array and the Australia Telescope Compact Array. These radio studies illustrate the need for multi-wavelength follow-up to determine the progenitor scenario for type IIb events.

1. Overview

Type IIb Supernovae often have very similar optical spectra initially and frequently evolve into type Ib Supernovae. The optical classification IIb was invented to describe the spectral characteristics of type II SN 1987K, distinguished by its weak hydrogen absorption lines and a weak HeI emission line (Filippenko 1988). The recent SNe 2011dh (Horesh *et al.* 2011a; Horesh *et al.* 2011b; Soderberg *et al.* 2011; Krauss *et al.* 2012) and 2011hs (Ryder *et al.* 2011) bring the total type IIb SNe detected in the radio to eight, including SNe 1993J (Weiler *et al.* 2007), 2001gd (Stockdale *et al.* 2007), 2001ig (Ryder

et al. 2004), 2003bg (Soderberg *et al.* 2006), 2008ax (Stockdale *et al.* 2008a; Roming *et al.* 2009), and 2008bo (Stockdale *et al.* 2008b).

SN 1993J is the best studied case of a radio-loud supernova, (Weiler *et al.* 2007; Marti-Vidal *et al.* 2011; and references therein) reaching maximum radio light at 6 cm near 150 days after explosion and declining with a power-law time decay index of -0.73 and a spectral index of -0.81. SN 2001gd had a similar radio evolution to SN 1993J with both SNe showing no clear signs of short-term variability (Stockdale *et al.* 2007). However both show unexpected declines in their radio light curves that are interpreted as abrupt changes in the mass-loss rates of their progenitors. For SN 1993J, this change implies that its progenitor star underwent an abrupt increase in its mass-loss rate from 3×10^{-6} up to 7×10^{-6} solar masses yr^{-1} between 10,000 and 7,000 yrs prior to explosion, with a nearly linear decline in mass-loss rate to $\sim 10^{-6}$ solar masses yr^{-1} just prior to explosion.

Radio emission from another excellent example of this type IIb class, SN 2001ig, shows a periodic oscillation in the radio light curve of 150 days, while SN 2008ax exhibits an approximate periodicity of 80 days in its radio emission. The periodicity observed in SNe 2001ig (Ryder *et al.* 2004), 2003bg (Soderberg *et al.* 2006) and 2008ax (Roming *et al.* 2009) can be explained by a binary companion that influenced the wind-established CSM of the SN progenitor star to create spiral density fluctuations that the SN blastwave later shocks (e.g. SN 1979C Weiler *et al.* 1992; Schwarz & Pringle 1996).

2. Implications

These studies demonstrate that the radio properties can effectively allow us to distinguish between two possible progenitor scenarios which have nearly indistinguishable optical spectra: 1) a single massive star which has shed most of its hydrogen as a function of normal evolution and 2) a less massive star whose hydrogen envelope is being influenced and depleted by a binary companion. The prevailing evidence appears to lean toward most type IIb SNe being binary systems with varying degrees of interaction (Van Dyk *et al.* 2011; Chevalier & Soderberg 2010).

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