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X-rays from SN1993J in M81

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Abstract. *XMM-Newton* observed SN1993J in April 2001. The spectrum between 0.3 and 11 keV is best fitted by a 2-component thermal emission model adopting ionization equilibrium, but shock models also provide acceptable fits. In the light of the standard SN model of Chevalier (1982) the development of the X-ray temperatures over the first 8 years after the explosion is discussed. The long term X-ray lightcurve shows a general decline of the luminosity with $L_x \propto t^{-0.30}$ as well as dips and rises that appear to correlate with the expansion velocity derived from radio observations.

1. Introduction

The evolution of the X-ray emission from SN1993J in M81, at a distance of 3.26 Mpc, has been followed since its detection 6 days after the explosion (Zimmermann et al. 1993). *XMM-Newton* was pointed in April 2001 for 132 ksec on the center of M81. For our analysis we used data from the EPIC PN camera, run in small window mode, and the MOS2 camera in imaging mode. After background screening data from about 70 ks remained in both instruments.

2. X-ray lightcurve

The long term X-ray lightcurve of this SN with the recent *XMM* data point (Fig. 1) suggests a general decline in luminosity with time as $t^{-0.3}$. From that we can deduce that the density of the circumstellar matter, assumed to be dominated by the stellar wind material of the progenitor, decreases with increasing radius as $r^{-1.65}$. The general decline is overlayed by dips and rises in intensity. There appears to exist a correlation of the dips and rises with the expansion velocity of the SN shell, deduced from high resolution radio images (Bartel et al. 2002). The times of rises in the X-ray lightcurve agree surprisingly well with times of maximum decelaration in the SN expansion curve. We suggest that each dip in the X-ray lightcurve indicates a region, where the shock wave runs into sufficiently low density material, where the matter heated so far will simply expand. If some time later the shock wave encounters a sudden jump to higher densities, the emission measure and thus the X-ray luminosity will rise. Dips and rises appear to show some repetitive pattern. Whether this characterizes the stellar wind activity of the progenitor star remains to be seen.

3. X-ray spectrum

The *XMM* spectrum of the SN (Fig. 2), taken with the PN camera, shows emission lines of Mg, Si, S, Ar, Ca and of Fe. We tested fits with both thermal emission and shock models. A 2-temperature thermal emission model

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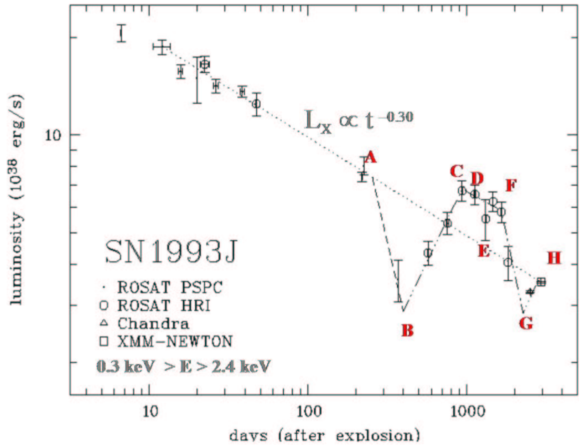

Fig. 1. The X-ray lightcurve of SN1993J shows dips and bumps on a general decline profile.

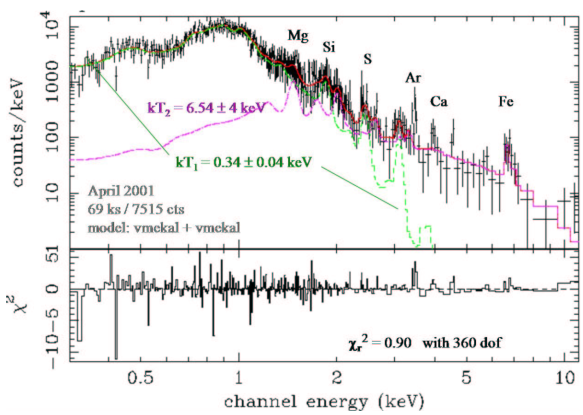

Fig. 2. The X-ray spectrum of the SN, taken with the PN camera, and the best fit 2-component thermal emission model.

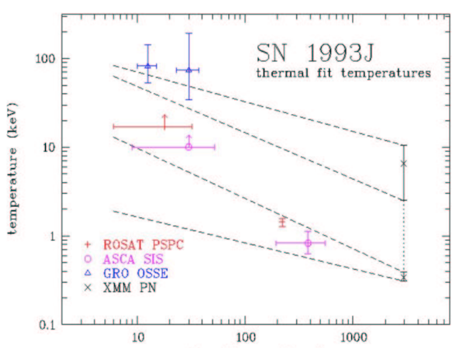

Fig. 3. Development of the X-ray temperatures and comparison to standard SN model predictions.

(vmekal) with $kT_1 = 0.34 \pm 0.04 keV$ and $kT_2 = 6.5 \pm 4 keV$ allows a good fit over the whole energy band between 0.3 up to about 11 keV. The abundances of C, N, O and Mg in the low temperature component are found to be subsolar, while abundances of heavier elements and of the elements in the high temperature component result overabundant (Zimmermann & Aschenbach 2003).

4. Temperature development

If we take the wind density profile as derived from the X-ray lightcurve and assume that the 2 temperatures from the fit to the *XMM* spectrum represent the temperatures in the forward and reverse shock regions, we can use the similarity solution of the standard SN shock model (Fransson et al. 1996) in order to extrapolate the temperatures from the *XMM* observation backwards in time up to the temperatures determined from the early ROSAT, ASCA and GRO data (Fig.3). Although the standard model is no more fully applicable at these late times, the extrapolation is not incompatible with what has been observed. Even though we do not take this as a final proof that the observed X-ray temperatures really demonstrate the existence of both a forward and a reverse shock region.

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