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SN 1987A at high resolution

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Abstract. Handed the baton from *ROSAT*, early observations of SN 1987A with the *Chandra* HETG and the *XMM-Newton* RGS showed broad lines with a FWHM of $\sim 10^4$ km s^{-1}: the SN blast wave was continuing to shock the H II region around SN 1987A. Since then, its picturesque equatorial ring (ER) has been shocked, giving rise to a growing, dominant narrow-lined component. Even so, current HETG and RGS observations show that a broad component is still present and contributes ~ 20% of the 0.5–2 keV flux. SN 1987A's X-ray behavior can be modeled with a minimum of free parameters as the sum of two simple 1D hydrodynamic simulations: i) an on-going interaction with H II region material producing the broad emission lines and most of the 3–10 keV flux, and ii) an interaction with the dense, clumpy ER material that dominates the 0.5–2 keV flux. Toward the future, we predict a continued growth of the broad component but a drop in the 0.5–2 keV flux, *once* no new dense ER material is being shocked. When? Time, and new data, will tell.

Key words. Hydrodynamics – ISM: supernova remnants – Radiation mechanisms: thermal – Supernovae: individual: SN 1987A – Techniques: spectroscopic – X-rays: general

1. Introduction

X-rays from SN 1987A were detected by ROSAT and attributed to the shock reaching an H II region interior to the equatorial ring (ER); in agreement, an early *Chandra* HETG observation showed very broad lines (Michael et al. 2002). While monitored by *Chandra* (Park et al. 2006) and *XMM-Newton* (Haberl et al. 2006) the 0.5–2 keV flux dramatically increased as the shock reached parts of the visible ER (Sugerman et al. 2002). Observations with the *Chandra* LETG (Zhekov et al. 2005) were followed by further deep grating observations as more of the ER was shocked. Deep HETG observations (Dewey et al. 2012) show narrow and broad components, Figure 1; a growing broad flux is also seen in optical observations (Fransson et al. 2012). Continued X-ray observations are being made by *XMM-Newton* (Maggi et al. 2012) and *Chandra* (Helder et al. 2012).

SN 1987A can be coarsely modeled using two 1D hydrodynamic simulations (Dewey et al. 2012): one for the ER and one for the H II region. Calculating the X-ray spectra, as in Dwarkadas et al. (2010), gives good agreement and explains the broad component, Figure 1. A current schematic, Figure 2, shows that the forward shock in the out-of-plane H II region has now passed most of the visible ER.

Monitoring SN 1987A over the coming centuries will indeed be a worthwhile legacy project for Earthling astrophysics.

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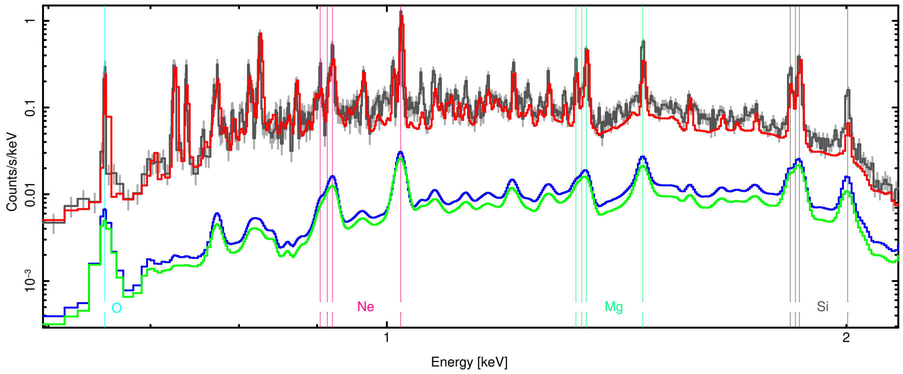

Fig. 1. SN 1987A's X-ray spectrum and the spectra of its hydro-model components. The HETG/MEG data from 2011 (histogram with error bars) is shown along with the modeled spectra from individual emission components. The spectrum from the dense clumpy equatorial ring is just slightly below the data and accounts for most of the emission in this range. The spectra from the out-of-plane H II region interactions, shocked CSM and reverse-shocked ejecta, contribute lower-flux but with very broad lines. In future, the shocked-ejecta emission is predicted to overtake the shocked-CSM so that at late times the ejecta and its abundances will dominate the very-broad H II component.

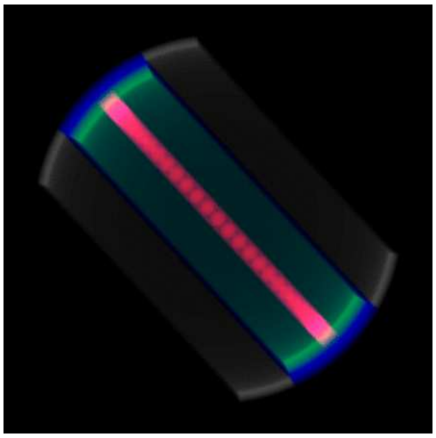

Fig. 2. Hydrodynamics-based geometric emission model of SN 1987A at the meeting epoch, 2012 October. In this "side" view north is up and the Earth is to the left. Four emission components are shown: the central bright emission is from the shocked, clumpy ER; just above/below the ER is the H II-shocked-CSM and reverse-shocked ejecta; finally at higher lattitudes radio emission is shown.

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