HARD X-RAYS AND GAMMA-RAYS FROM SN 1987A

M. Itoh[2], S. Kumagai[1], T. Shigeyama[1], K. Nomoto[1], and J. Nishimura[2]

[1]Department of Earth Science and Astronomy, University of Tokyo, Tokyo
[2]Institute of Space and Astronautical Science, Tokyo

Gamma-rays originating from radioactive decays of ^{56}Ni and ^{56}Co and hard X-rays due to Compton degradation of γ-rays have been predicted to emerge when the supernova becomes sufficiently thin. The X-ray detections by Ginga (Dotani et al. 1988) and Kvant (Sunyaev et al. 1988) and more recent report of γ-ray detections by SMM (Matz et al. 1988) were much earlier than the theoretical predictions. (See Itoh et al. 1987 and references therein.)

These observations would give important constraints on the distribution of the heavy elements and ^{56}Co in the ejecta. We adopted the hydrodynamical model 11E1Y6 (Nomoto et al. 1988) and carried out Monte Carlo simulation for photon transfer. A step-like distribution of ^{56}Co was assumed where the mass fraction of ^{56}Co in the layers at $M_r \leq 4.6\ M_\odot$, 4.6 - 6 $M_\odot$, 6 - 8 $M_\odot$, and 8 - 10 $M_\odot$ are $X_{\rm Co}$ = 0.0128, 0.0035, 0.0021, and 0.0011, respectively. Other heavy elements were distributed with mass fractions in proportion to ^{56}Co.

Our calculation can consistently account for the early emergence and the subsequent light curves of γ- and hard X-rays and the spectral evolution (see Nomoto et al. 1988 for the light curves).

Figures 1a, b show the hard X-ray and γ-ray spectra for the above model at t = 200 and 250 d as compared with the Ginga and Kvant observations at t = 200 d and the balloon borne observations (Wilson et al. 1988) at t = 250 d. The calculations clearly show that the spectrum becomes harder as the ejecta expands and the number of Compton scattering decreases. The power law spectra, $E^{-\alpha}$, at 30 - 200 keV with the index $\alpha \sim 1.3$ (200 d) and 1.1 (250 d) are in reasonable agreement with observations.

The most important improvement compared with the earlier models (M. Itoh et al. 1987 and references therein) is that the flux at 16 - 30 keV is consistent with the observations around t = 200 d. This is because more X-rays below 30 keV are absorbed by the enhanced amount of heavy elements which are mixed into the envelope.

As a prediction for future observations, X-ray and γ-ray spectra at t = 400 d and 600 d are shown in Figures 1c, d. The spectrum will become harder as the column depth of the ejecta decreases. Comparison with the observations will inform us more detailed abundance distribution and the clumpiness of the ejecta.

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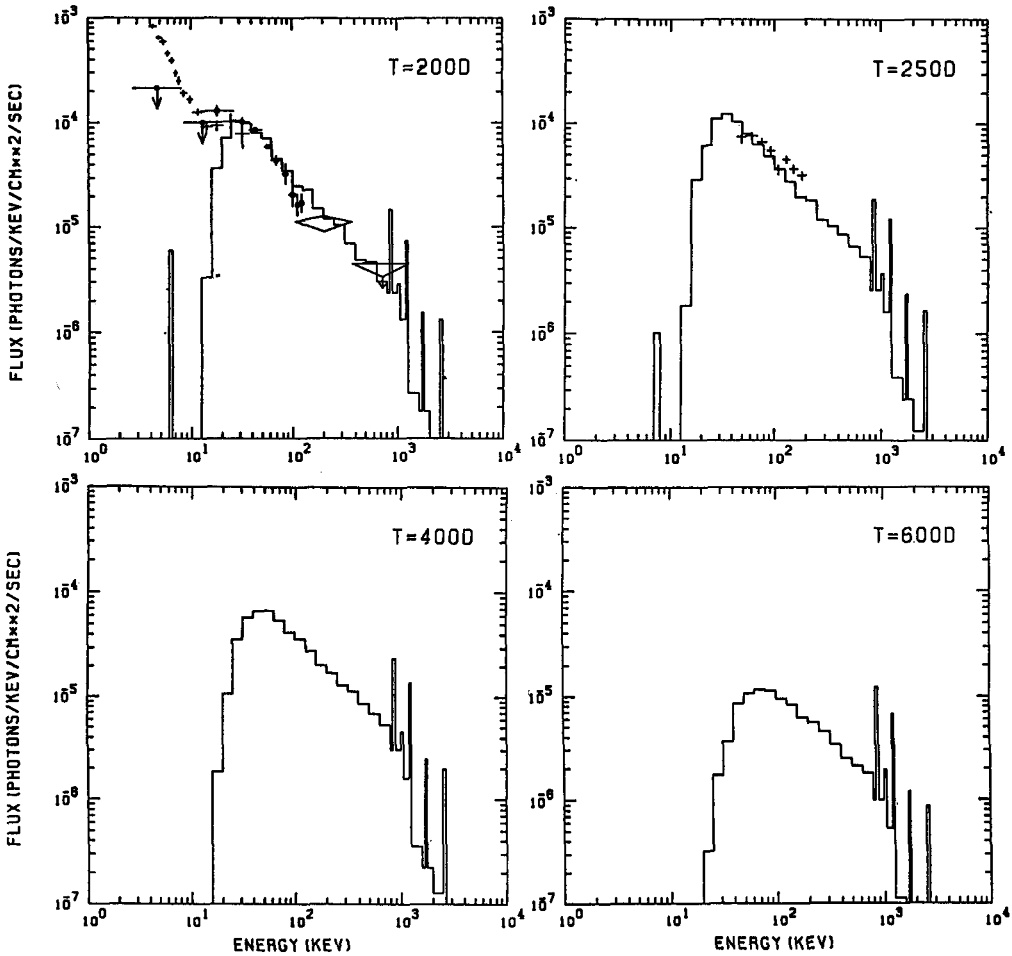

Figure 1: The calculated hard X-ray and γ-ray spectra for the the hydrodynamical model with $E = 1 \times 10^{51}$ erg and $M_{\rm env} = 6.7\ M_\odot$ at a) $t = 200$ d, b) $t = 250$ d, c) $t = 400$ d, and d) $t = 600$ d. At $t = 200$ d, the crosses indicate the spectrum observed by Ginga and the open circles and the diamonds are obtained by Kvant. At $t = 250$ d, balloon-borne observation (Wilson et al. 1988) is shown.