N. N. Chugaĭ. *Supernova in the Large Magellanic Cloud: first year of observations.* The supernova 1987A which exploded in the Large Magellanic Cloud (LMC) on February 23, 1987, provided a unique opportunity to solve the many unanswered riddles in supernova physics. First, the star had been carefully studied prior to its explosion. It was the blue supergiant labelled No. -69 202 in the Sanduleak catalogue. The absence of its signature in the ultraviolet spectrum SN1987A taken by the "Astron" [1] and IUE satellites leaves no doubt that this was indeed the star that became the supernova. According to photometric characteristics obtained by means of photography in different colors, the luminosity of this star prior to the explosion was 10^5 solar luminosities, its temperature was $(12–20)\cdot 10^3$ K, its radius was 30–60 solar radii. During the almost 100 years of LMC observation the star had exhibited no sign of variable behavior. An analysis of the radio-frequency SN1987A burst received for the first 10 days after the explosion[2] indicates that the rate of mass expulsion in the presupernova stage was 10^{-6}–10^{-5} $M_\odot$/year. It appears that for the 10^4 years prior to the explosion the star had been a red supergiant and mass expulsion proceeded faster. The nitrogen content of this material, discovered by the narrow ultraviolet lines in the SN1987A spectrum at the end of May, 1987, was an order of magnitude higher than normal (C. Fransson, private communication).

Supernova 1987A belongs to type II, since its spectrum contains strong hydrogen lines. However, in a number of ways this supernova is unique. First of all, its light curve has been unusual: the luminosity was low for the first two months and its rate of increase was slow, with peak luminosity reached after 86 days (rather than the usual one or two weeks). Currently there is no doubt that the peculiar behavior of SN1987A light curve has been due to the relatively small radius of the presupernova compared to the usual type II supernovae.[3] Another peculiar feature of SN1987A is the strong barium line BaII 6142 Å, which appeared in the spectrum three weeks after the flash. It has been suggested that the presence of this line is a consequence of a strong (order of magnitude) excess of barium over the normal content. A more careful analysis reveals this hypothesis to be unfounded. The observed line can be adequately fitted by the following parameters: envelope mass of 8 solar masses, barium content—1/3 of solar content, density distribution $\rho \propto \exp(-v/v_0)$ (where v_0 is a characteristic velocity set by the explosion energy of 10^{51} erg) (see Fig. 1). The above assumes single ionization of Ba. In typical type II supernovae, conditions in the envelope are probably such that barium is doubly ionized.

By far the greatest share of recorded SN1987A radiation in our time frame has been contained in a continuous spectrum of a shape nearly corresponding to the black-body curve at a temperature of 5000 K. The role of the emission lines grew with time, and 230 days after the explosion 25% of the radiated energy was comprised by these lines.[4] At a later stage ($t \gtrsim 100$ days) the frequency of received radiation was fixed by the energy of the $^{56}Co \rightarrow {}^{56}Fe$ radioactive decay (the lifetime of ^{56}Co is 111.2 days); ^{56}Co itself is a decay

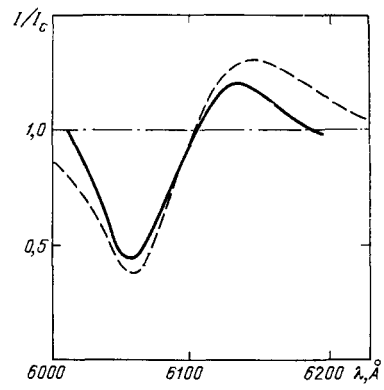

FIG. 1. The BaII 6142 Å line in the spectrum of SN 1987A on March 20, 1987. The solid line represents observations (R. M. Catchpole *et al.*), the dashed line is calculated for an envelope mass of 8 $M_\odot$ and a Ba content equal to 1/3 of solar.

product of ^{56}Ni (lifetime of 8.8 days). This radioactive luminosity mechanism of SN1987A was corroborated by measurements of the full luminosity flux recorded at the South-African observatory. During the 130–260 day interval, the integrated flux fell exponentially with a mean lifetime of 113 ± 0.6 days, which agrees quite well with the lifetime of ^{56}Co. In order to account for the luminosity of SN1987A during this interval the initial mass of ^{56}Ni in the envelope must have been 0.07–0.08 solar masses. The gamma line at 847 keV emitted by the ^{56}Fe nucleus during the $^{56}\mathrm{Co} \rightarrow {}^{56}\mathrm{Fe}$ decay has also been observed. According to the data of the SMM satellite, from August to October of 1987 the flux of the 847 keV line made up $(1.0 \pm 0.25) \cdot 10^{-3}$ quanta/cm^2 s.[5] This flux corresponds to 1% of all 847 keV quanta leaving the envelope without scattering. It is almost certain that the hard x-ray radiation recorded by the "Kvant" module in the "Mir" station during August of 1987 corresponds to the Compton-scattered gamma radiation emitted in the course of ^{56}Co decay in the envelope of SN1987A.[6]

Interestingly, the homogenous, spherically symmetric models of the envelope of SN1987A with central localization of ^{56}Ni predict a much later arrival of gamma radiation from the $^{56}\mathrm{Co} \rightarrow {}^{56}\mathrm{Fe}$ decay. In particular, the model which describes the flux of 847 keV quanta (envelope mass 11.3 M, explosion energy of 10^{51} erg) would have to assume the mixing of ^{56}Ni in more than six solar masses of envelope material. Another possibility is that the shape of the envelope deviates from the spherically symmetric. Here we should mention that polarization measurements have revealed significant linear polarization in the H_α, H_γ and NaI 5892 Å lines (up to 2%). This polarization is most easily explained by assuming a nonspherical envelope model of SN1987A (Yu. N. Gnedin, private communication).

A mysterious "red shift" of the emission lines has been observed in spectra from the later stage.[4] For different lines its magnitude varied in the 500–1500 km/s range. Some lines, for example [OI] 6300, 6364 Å, show no red shift at all. The simplest interpretation of this shift points to an asymmetric distribution of matter in the interior parts of the envelope. But a red shift is also possible in a symmetric model (for example, a "cocoon" with holes, which is brighter on the inside than on the outside). We note that in symmetrical models the red shift should disappear at a sufficiently late stage.

The observation of a CO molecule emission line at a wavelength of 2.3 μm 120 days after the explosion was a surprise.[4] This was the first ever observation of molecules in the envelope of a supernova. The excitation temperature of CO on day 230 was only 2000 K. Simultaneously, an HeI 10830 Å absorption line was visible in the spectrum. The excitation potential of this line is 20 eV which points to extreme nonequilibrium conditions in the envelope of SN1987A. We note that the presence of an HeI line in the spectrum of SN1987A was predicted on the basis of a radioactive luminosity model for the later stages of type II supernovae.[7]

New and interesting observational data from SN1987A should appear in the coming years. First of all, astrophysicists are anticipating effects related to the possible presence of a neutron star at the center of the envelope. The neutron star could manifest itself optically via injection of energy into the envelope of SN1987A; it could also appear directly in the x-ray spectrum. Another interesting effect, largely at radio frequencies, is expected when the outer regions of the SN1987A envelope collide with the dense circumstellar gas ejected during the presupernova stage of the red supergiant.

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