G. S. Bisnovatyĭ-Kogan. *Gravitational collapse, neutrino radiation, and supernova light curves*. Collapse-induced supernova explosions are the last stage in the life of massive ($\geqslant 8\ M_\odot$) stars. The total energy liberated during the collapse is approximately 20 times greater than the energy loss during the steady evolution of the star. Less massive stars with $M < 8\ M_\odot$ lose most of their mass during steady evolution and become white dwarves. The main evolutionary stages of a massive star are: hydrogen burning in the core (main sequence); helium burning in the core and hydrogen burning in the shell (supergiant stage); and rapid evolution either towards the formation of an iron core and the subsequent hydrodynamic collapse (for $M > 10\ M_\odot$), or towards neutronization in the core from $O^{16} + Ne^{20} + Mg^{24}$ reaction, also followed by collapse (see review article, Ref. 1).

Collapse computations in the spherical symmetry approximation, ignoring rotation and magnetic fields, have been carried out for over 20 years. The main question concerns the mechanism by which enough kinetic and radiant energy ($\sim 10^{51}$ erg) is liberated to explain the observed supernova explosions. The most fullest accounting of all the factors, carried out by Nadezhin in 1978 and by foreign scientists in subsequent studies, answered in the negative, i.e., no explosion should follow the collapse. The collapse is strongly inhomogenous. First, over a period of $\sim 10^{-3}$ s, a neutron core forms, followed by the accretion of remaining matter onto this core over ~ 20 s accompanied by neutrino radiation (see Ref. 2). The intense neutrino flux slows the accretion of matter and hinders rebounding. The complexity of the problem is such that further refinements could overturn the current conclusion that no explosion is possible, and so work in the field continues.

The discovery of pulsars demonstrated that neutron stars rotate and exert strong ($\sim 10^{12}$ G) magnetic fields. The magnetic field-assisted transformation of rotational energy into explosive energy has been proposed in Ref. 3 to explain supernova explosions. In the course of a magnetorotational explosion (MRE) the collapse produces a neutron core surrounded by a differentially rotating envelope. The differential rotation twists the magnetic lines of force which connect the core and the envelope. Momentum is transferred to the outlying regions and magnetic pressure increases. This leads to the creation of a compression wave, which then becomes a shock wave. One-dimensional calculations have shown[4] that $\sim 5\%$ of the original rotational energy $E_{\rm rot}$ turns into the energy of envelope expulsion. Then, if $E_{\rm rot} = 10^{53}$ erg, there should be sufficient energy for an explosion. There is current research into two-dimensional calculations.

Neutrino radiation during collapse does not depend on the subsequent explosion or lack thereof. For ~ 20 s the binding energy of a neutron star $E_{\nu,\rm tot} = (3 + 6)\cdot 10^{53}$ erg is radiated away in the form of neutrinos. The neutrino light curve was studied by D. K. Nadezhin and others (see review article, Ref. 2). Calculations taking into account all types of neutrinos were carried out in Ref. 5. All 6 neutrino types (counting antiparticles) carry away an approximately equal amount of energy. The average energies of the different types of neutrinos are as follows: $\langle \varepsilon_{\nu_e} \rangle = 15$ MeV, $\langle \varepsilon_{\bar{\nu}_e} \rangle = 16$ MeV, $\langle \varepsilon_{\nu_\mu} \rangle = \langle \varepsilon_{\bar{\nu}_\mu} \rangle = \langle \varepsilon_{\nu_\tau} \rangle = \langle \varepsilon_{\bar{\nu}_\tau} \rangle = 33$ MeV. Of the four signals observed at four neutrino observatories on February 23, 1987, the day of the SN1987A supernova flash, three can be attributed to the neutrinos radiated during the gravitational collapse.[6]

The supernova light curves are calculated by solving hydrodynamic equations simultaneously with expressions for either radiant thermal conductivity or radiation transfer. The initial conditions include the initial distributions of mass, velocity, instantaneous liberated energy, additional energy sources in the form of a young pulsar or radioactive decay in the $\mathrm{Ni}^{56} \to \mathrm{Co}^{56} \to \mathrm{Fe}^{56}$ chain. These initial conditions are selected with the goal of matching the theoretical luminosity curves, spectra at various stages and luminosities in the x-ray and gamma-ray regions with the available data on SN1987A. Work in this direction continues. A light curve cannot be computed directly from the preceeding collapse calculations because of the enormous difficulties involved. We note that the observed exponential decay in the light curve is typical not only for radioactive decay, but also for pulsar radiation.[7]

Radiowave radiation from SN1987A exhibited some unusual properties. It was recorded only during the ~ 10 days immediately following the explosion, appeared soon after or simultaneously with the optical flash, and was anomalously weak compared to the total radiant energy $E_{\rm r,tot} \approx 10^{39}$ erg. Possibly this was related to the generation of fast positrons by the anti-neutrino $\bar{\nu}_e$ pulse, leading to plasma oscillations. These, in turn, could give rise to radiowave radiation at the observed frequencies near 1 GHz at $n_e = 10^9$–10^{10} cm^{-3}.[8] If so, such radiowave radiation could indicate an optically invisible gravitational collapse, for example at the center of the Galaxy, and should correlate with neutrino signals. The materials of this report have been published in Refs. 3, 4, 6, 8.

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Translated by A. Zaslavsky