A. V. Tutukov and A. G. Masevich. ***The evolution of massive close binary stars.*** The steadily increasing interest of astrophysicists in the study of binary stars is due to a number of circumstances. 1. Investigation of binary-star orbits is essentially the only way to determine such theoretically important characterists of the stars as their masses and radii. 2. The discovery of x-ray sources has shown that their nature is, in all probability, related to exchange of matter in close binary systems. 3. Progress in the theory of stellar evolution has made it possible to compute the evolution of system components with exchange of matter between them. 4. Statistical analysis of the distribution of the parameters of binary stars in our Galaxy gives a direct indication as to the evolutionary process of binary stars.

Massive stars with masses M greater than 10 sun masses ($M_{\odot}$) are of special interest for the theory of stellar evolution, since the evolutionary processes in these objects unfold comparatively rapidly and intensively and their evolution terminates in a supernova outburst, generally with formation of neutron stars. About half of the known massive stars are close binary stars the components of which are usually indicated by observations to have had initial masses about equal to or greater than 10 $M_{\odot}$. Figure 1 shows the general scheme that we propose for the evolution of such stars: it indicates the lifetimes T of the stars in various stages and the numbers N of stars of the corresponding types in our Galaxy.

The system consists initially of two Main Sequence stars (1.1); the more massive component is the first to fill the Roche lobe, it transfers the greater part of the matter of its envelope to the companion (1.2), and is transformed into a Wolf-Rayet helium star (1.3). Exhaustion of the nuclear fuel in the interior of the helium star inevitably results in its explosion as a supernova, with formation of a neutron star or black hole, depending on its initial mass. The system does not disintegrate, but acquires a spatial velocity of up to 100 km/sec (1.4). Accretion of part of the stellar-wind matter lost by the O-B component (which nearly fills the Roche

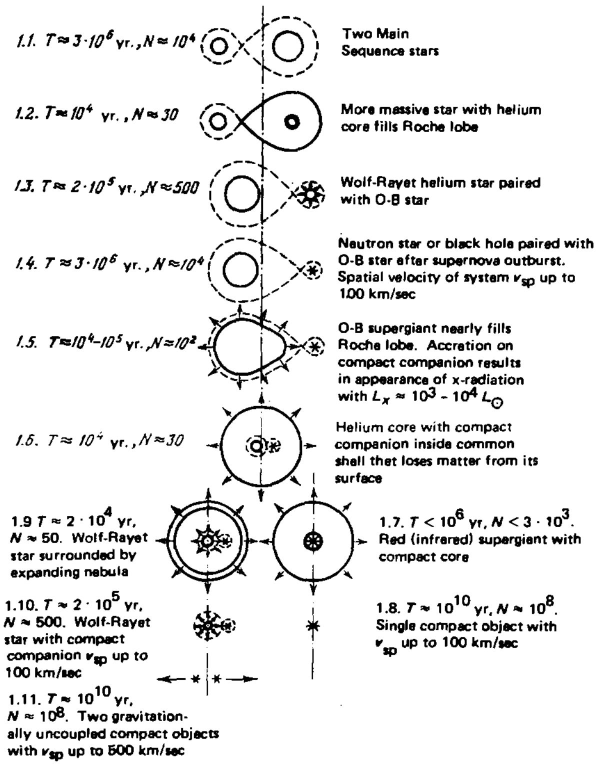

FIG. 1. Evolution of massive stars.

lobe) of the neutron star leads to the appearance of an x-ray source with a luminosity of $10^3 - 10^4 L_\odot$ (1.5). Filling of the Roche lobe by the massive component causes the formation of a common envelope around the helium core with the neutron star (1.6). As a result, the neutron star may be decelerated and transformed into the core of a red (infrared) supergiant, which loses matter at a rate greater than $10^{-5} - 10^{-4} M_\odot$/year (1.7). It is possible that stars of the type ot η Car, S Dor, and P Cyg are in this stage. In this case the end product of evolution would be a single neutron star or a black hole with a spatial velocity v_{sp} of up to 100 km/sec.

If the orbital period of the system was large enough before formation of the common envelope, the envelope will be lost before the cores "merge". Remnants of the common envelope may be observed for some time around the Wolf-Rayet star, which, as a rule, appears to be single (1.9) owing to the large mass ratio. Dispersal of the envelope leaves a "single" Wolf-Rayet star with a high spatial velocity (1.10). A second supernova outburst in the system will result in decay of the system and the appearance of two single neutron stars with spatial velocities up to 500 km/sec (1.11). Thus, some radiopulsars may be products of the evolution of massive close binary stars, which explains their spatial distribution and velocities. Thus, this scheme, which was obtained from calculations of evolutionary sequences with masses from 10 to 60 sun masses on the basis of the current theory of internal stellar structure and observations of massive stars in a broad range of wavelengths, makes it possible to cover a number of basic massive-star classes with a unified evolutionary theory.

The results on which this paper was based were published as follows:

A. V. Tutukov and L. R. Yugel'son, Nauchnye informatsii No. 27, 58 (1973).
A. G. Massevitch, A. V. Tutukov, and L. R. Yugelson, Astrophys. Space Sci. 40, 115 (1976).
A. G. Massevitch and L. R. Yugelson, In: Nonstationary Evolution of Close Binaries. Warszawa, 1978, p. 11.