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This is only an upper limit, of course. The characteristic time t for civilizations of the terrestrial type does not exceed several characteristic times τ. Consequently, $t \ll t_{cr}$ and contact is practically impossible. Incidentally, from (2) and (3) and from the condition that $p \ll 1$, it follows that the number of civilizations existing simultaneously in the Galaxy is much less than $4\cdot 10^3$.

[1)]It is also possible that the absence of "miracles" is connected with a loss of interest in the search for one's fellows. Our experience shows, however, that such loss is unlikely in the exponential stage of development,[5] and hence such a possibility does not affect our arguments to follow.

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R 136*a*1: superstar or stellar cluster?

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The high-luminosity object R 136*a*1 in the Large Magellanic Cloud may not, in principle, be a single supermassive star ($M \approx 2000\ M_\odot$) but a compact stellar cluster with a short lifetime ($\sim 10^2$–10^4 years) or a multiple hierarchical system of four to six very massive stars ($M_* \approx 300\ M_\odot$).

The object R 163 in the Large Magellanic Cloud has often attracted interest.[1] It is the central optical object of the very young stellar cluster NGC 2070, located at the center of the giant Tarantula emission nebula (30 Dor). R 136 is resolved into three components, a, b, and c, separated by distances of 2-3". The brightest and bluest of them is R 136a. This source, in turn, consists of at least eight components. The three brightest of these are separated by 0".10 and 0".48 (Ref. 2). They are just the ones responsible for the ionization of gas in the Tarantula. The object R 136a1, the brightest of the unresolved sources in this group, is of particular interest for investigators of massive stars and young stellar clusters. Its bolometric luminosity is estimated as $L = (5\text{-}7)\cdot 10^7\ L_\odot$. If it is a single supermassive star, then from considerations of equilibrium of the forces of gravity and light pressure, its mass (the Eddington mass M_E) is estimated as 1500-2000 $M_\odot$. Obviously, this is the lower limit of the object's mass: The possibility of supercritical luminosity is low.

The properties of the object R 136a1 are inconsistent. On the one hand, there are signs of a supermassive star: a high surface temperature ($\geq 6\cdot 10^4$ K), a spectrum of type O3 or even earlier, and a strong stellar wind ($\dot{M} = 3\cdot 10^{-4}\ M_\odot$/yr, $V \approx 4000$ km/sec). The absence of optical variability, however, and the theoretical indications of the unsteadiness of supermassive stars compel us to assume that the object R 136a1 has a composite makeup. In fact, this could be a system of several O stars or a normal cluster containing stars of different masses. It is simplest of all to "construct" such a cluster from N identical stars, the optical characteristics of which are consistent with observations of R 136a1. Obviously, these must be stars close to the spectral class O3. In this case, $10 \leq N \leq 100$. What are the observational and dynamic limits on the parameters of such a stellar system?

The age limit follows from the size (r = 10 pc) and expansion velocity (v = 25 km/sec) of the cavity formed in the interstellar gas by the pressure of the stellar wind from R 136a (Ref. 3), $t_{min} = r/v = 4\cdot 10^5$ yr.

Photographic measurements[4] yield an absolute upper limit of $R_0 = 0''.1$ (= 0.025 pc) on the radius of the source R 136a1. Speckle-interferometric measurements[5] of the same quantity reliably yield a value $R_1 = 0''.04$ (= 0.01 pc) and, less reliably, a value $R_2 = 0''.01$ (= 0.0025 pc).

Considering the object's high density (see Table I), we can conclude that external factors of dynamic evolution – tidal influence on the part of clusters, clouds, etc. – are unimportant in this case. Therefore, let us consider the three main internal dynamic factors: dissipation of the cluster as a result of star–star relaxation, mutual collisions of stars, and mass loss in the form of gas.

According to classical stellar dynamics,[6] for $N \approx 10^2$ the time of dissipation of a cluster is

$$t_{dis} = 39 t_{rel} \cong \frac{N}{5}\left(\frac{R^3}{GM}\right)^{1/2},$$

where t_{rel} is the relaxation time, N is the number of stars, and R and M are the radius and mass of the cluster.

The characteristic time between direct (physical) collisions of stars is

$$t_{col} = (\sigma n v)^{-1} = \left[4\pi r_*^2\left(1 + \frac{v_\infty^2}{v^2}\right)\frac{3Nv}{4\pi R^3}\right]^{-1} \cong \frac{R}{6r_*}\left(\frac{R^3}{GM}\right)^{-1},$$

where r_* and M_* are the radius and mass of a star, $v = \sqrt{GM/R}$ is the characteristic velocity of stars in

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TABLE I. Parameters of a Stellar Cluster Modeling the Object R 136a1 Assuming $M = 2000\ M_\odot$.

R, ang. sec	R, pc	n, $M_\odot/pc^3$	v, km/sec	t_{dis}, yr (N = 50)
0.1	0.025	$3\cdot10^7$	19	$1.3\cdot10^4$
0.04	0.01	$5\cdot10^8$	30	$3\cdot10^3$
0.01	0.0025	$3\cdot10^{10}$	60	$4\cdot10^2$

the cluster, and $v_\infty = \sqrt{2GM_*/r_*}$ is the parabolic velocity at the surface of a star ($\sim 10^3$ km/sec). In our case, $v_\infty > v$ always.

For main-sequence stars we can take[7] $r_* = R_\odot(M_*/M_\odot)^{2/3}$. Then

$$\frac{t_{dis}}{t_{col}} \cong \frac{Nr_*}{R} < \frac{Nr_*(M_*=2000M_\odot)}{R_2} < 1 \quad \text{for} \quad N<10^3.$$

The characteristic time of mass loss in the form of gas, if the observed intensity of stellar wind is maintained, is

$$t_{gas} \geqslant M_E/\dot{M} \approx 10^7 \text{ yr}.$$

Thus, $t_{dis} < \min\{t_{col}, t_{gas}\}$. Hence the dominant dynamic process, for all plausible values of N, is the process of star-star relaxation leading to dissipation of a cluster.

Generally speaking, a consistent model of a cluster of O stars ($N \approx 50$) imitating the main observational characteristics of the object R 136a1 can be constructed, although such a cluster will be without analogs in its parameters (see Table I). Such high spatial densities (n) and dispersions of the velocities (v) of stars as the theory indicates are characteristic for the nuclei of globular clusters in the period of their collapse. Young open clusters are usually far from this stage of evolution. Moreover, its future duration ($t_{dis} \approx 10^2$-10^4 yr) is considerably shorter than the preceding stage of evolution of the object R 136a ($t_{min} = 4\cdot10^5$ yr). Such a situation seems improbable, although it is possible, in principle. The value of t_{dis} increases somewhat if we assume that there are a considerable number of stars of intermediate and low masses in the cluster besides the massive stars. True, in this case the cluster approaches the nuclei of Seyfert galaxies[8] in its parameters, while the inequality $t_{dis} < t_{min}$ is still preserved.

The variant of a multiple stellar system with an hierarchical structure (2 + 1, 2 + 2, etc.) appears to be the most promising multicomponent model for the object R 136a1, in our view. Such a system can be formed as a result of the evolution of a stellar cluster (after the dissipation of the majority of its members) and, in contrast to a cluster, will have a long lifetime.[9] A system containing four to six components with individual masses $M_* \approx 300\ M_\odot$ could explain the observed characteristics of the object R 136a1 without becoming explicitly inconsistent with stellar dynamics and the theory of the internal structure of stars.

CONCLUSION

Two possibilities exist for constructing a multicomponent model of the object R 136a1: 1) a compact cluster of several dozen O stars and 2) a multiple hierarchical system of four to six very massive stars ($M_* \approx 300\ M_\odot$). The first model has a short lifetime because of dissipation, while the second has a complicated spatial structure. Both models look artificial to a considerable extent and demand a further study of the possibility of the stable evolution of supermassive stars with $M_* \approx 2000\ M_\odot$.

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