THE CENTRAL OBJECT OF THE 30 DORADUS NEBULA, A SUPERMASSIVE STAR

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SUMMARY*

The 30 Doradus nebula is the brightest H II region in the local group. Radio continuum and Radio recombination line observations indicate that it is photoionized by the equivalent of ~100 O5 stars. Observations of the central object R136 made at low and high spectral resolution with the IUE reveal a peculiar hot object with a massive stellar wind. An outflow speed of 3500 kilometers per second and a temperature of approximately 60,000 K are indicated by the spectra. The bulk of the observed ultraviolet radiation must come from R136a, the brightest and bluest component of R136. Its absolute visual magnitude and observed temperature imply a luminosity about 10^8 times that of the sun. Most of the ionizations produced in 30 Doradus are provided by this peculiar object. If R136a is a dense cluster of very hot stars, about 30 stars of classes O3 and WN3 exist in a region estimated to have a diameter of less than 0.1 parsec. This is inconsistent with the ultraviolet line spectrum and the evidence for optical variability. An alternative interpretation of the observations is that the radiation from R136a is dominated by a single superluminous object with the following approximate properties: luminosity and temperature as given above, a radius 100 times that of the sun, a mass 2500 times that of the sun, and a loss rate of $10^{-3.5}$ solar masses per year. Model interior calculations for hydrogen-burning stars are consistent with these parameters. Such stars, however, are expected to be unstable, and this may account for the massive stellar wind.

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C. W. H. de Loore and A. J. Willis (eds.), Wolf-Rayet Stars: Observations, Physics, Evolution, 563–565.

DISCUSSION FOLLOWING CASSINELLI et al.

de Loore: The lifetime of such a 2000 $M_\odot$ star should be smaller than 10^6 year, and the star has to be unstable (according to Appenzeller, Ledoux). In order to stabilize it in a reasonable time we need a mass loss rate of the order of

$$\frac{2000\ M_\odot}{10^6 yr} \sim 2.10^{-3}\ M_\odot/yr$$

Hence could the mass loss rate not be higher? How good is the $\dot{M}$ determination?

Cassinelli: The mass loss rate estimate of $10^{-3.5\pm1}$ is very uncertain. Rough estimates from UV line profiles and He II 4686 give $\dot{M}$ from 10^{-3} to 10^{-4} $M_\odot/yr$. If we assume $\dot{M}$ is proportional to L, and use $\dot{M} \simeq 3.10^{-5}$ for WR stars, we get $\dot{M} \simeq 3.10^{-3}$. So the value you say is necessary for stability is certainly possible, but is on the high side.

Panagia: The IR measurements I have presented at this conference imply a mass loss rate of $\sim 3.10^{-4}$ $M_\odot/yr^{-1}$ if a photospheric radius of $\sim 80\ R_\odot$ is adopted. Therefore, your estimate of $\dot{M}$ obtained from an analysis of UV lines is confirmed.
It is worth noting that, unlike all WR stars, for R 136a the momentum carried by the wind ($\dot{M}v_\infty$) does not exceed L/c. This fact leads me to suggest that, as far as the internal structure and the evolutionary phase are concerned, R 136a is not a WR star (i.e. a highly evolved star) but is rather still in the H-burning phase. Within this frame, the WR characteristics can be the consequence of the very high mass loss rate which makes the wind very optically thick. Also, being able to observe such a rare object would not be unplausible because the star spends most of its lifetime in the H-burning phase, thus maximizing the detection probability.

Cassinelli: Yes, we also think that the star is showing WR emission line characteristics while it is on the H-burning main sequence.

Tutukov: The cocoon stage limits the mass of stars to 60-100 $M_\odot$ if the heavy element abundance is not 0. I would like to remind also that the theory of stellar evolution give to us still unused opportunity to get very high luminosity objects, possible S Dor, η Car like. (Tutukov, Yungelson, in proc. 1979, IAU Symp. no. 83).

Cassinelli: The upper limits of $\lesssim$ 100 $M_\odot$ that have been observed by Yorke and Kruegel, 1977, were based on conditions that may not be relevant to the central region of 30 Dor. The dust abundance there appears to be low. Also, because of the low density in high mass protostars, grains will be driven to much higher "terminal speeds" and may therefore be destroyed by sputtering. If so they would not reverse the collapse process. In regard to your second comment: no matter what the source of the energy the mass must be large so that the luminosity be less than the Eddington luminosity.

Renzini: Unlike our own Galaxy the Magellanic Clouds are still forming globular clusters. Youngest GC's in LMC are just a few million years old, have typical diameters of ~ 10 pc and the most massive ones have a mass of ~ $10^5 M_\odot$. If 30 Dor is a just forming GC with the above characteristics one would expect a central clump of massive stars.

Cassinelli: The major objection to such a cluster model is that you have to pack in about 30 O3 or WN3 stars within a small volume $\lesssim 1$ pc in diameter. And also have nothing in there but those stars, in order not to exceed the observed V magnitude of R 136a. So the luminosity function will be a δ-function peaked at the earliest spectral types.

Moffat: It is well known that the interstellar extinction law especially in the UV can vary considerably for different galactic stars, especially if connected with circumstellar material. This may influence the L-estimate of the 30 Dor core. (Even small changes in E_{B-V} could drastically affect T_{eff} and thus L derived using UV fluxes).

Cassinelli: Yes, we agree that the UV extinction is poorly known. However, our derivation of the luminosity of the star rests on the estimation of the temperature of the star and on the V magnitude. The UV fluxes are certainly consistent with the derived luminosity and temperature.