

RATE OF MASS LOSS BY STARS OF DIFFERENT CLASSES

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The present communication contains mainly the discussion of the problem of mass loss by stars of early classes. The investigations show that the loss of mass by the Sun may proceed in different ways. In the atmospheres of O stars different mechanisms of ejection of gases must also exist: thermal dissipation of gases, the ejection of prominences (electromagnetic mechanisms), the ejection of atoms by radiation pressure, the ejection of atoms from active regions which may exist in the atmospheres of O-Stars, a very rapid rotation of stars etc. However our present knowledge on the mechanisms of ejection of gases from the surface of stars of early types is extremely scanty. Therefore it seems that there exists only one way to estimate the rate of mass loss by O-stars. This is the investigation of those effects which can be produced by gases ejected from the star.

The first case. The gases which are being ejected from the star will create around it some sort of envelope. The latter will produce bright lines in the spectrum of the star. However computations show [1], that the effects expected here are small even for the line $H\alpha$. This is due to the fact that the density of matter inside of such an envelope diminishes rather rapidly with the growing distance from the star (roughly as R^{-2}). Therefore the extension of the envelope cannot be great and the emission in spectral lines will be lost in the background of the bright star. Therefore we must investigate those effects which may be observed at a sufficiently great distance from the star.

The second case. Immediately after the "birth" of an O-star there begins an ejection of corpuscles from it. These corpuscles (or clouds of corpuscles) will begin to drive away from the star the gas medium, in which this star is embedded. In result of this an envelope will be created, the density of which will be greater, than the density of the gas medium [1], [2]. This envelope will move away from the star and its mass will grow. The equation of motion of such an envelope may be received from the general equation of motion :

$$\frac{d(mv)}{dt} = P. \quad (1)$$

The equation of motion may also be obtained if the gases outside the envelope will be considered as a resisting medium. In this case the equation of motion may be written as :

$$\frac{dv}{dt} = \frac{P-Q}{m}.$$

Both equations are equivalent. The force P is determined by the atoms ejected from the star which overtake the envelope and transfer part of their momenta to it. The force Q is determined by the surrounding exterior gases, which retard the moving envelope.

The mass of the envelope will continually increase, first of all because the atoms ejected from the star penetrate into the envelope and remain in it, secondly because the envelope in its motion carries away the exterior gas medium.

The equation of motion of the envelope was worked out [1] and solved for a great number of different cases. The integration of the equation was carried out with the help of an electronic computing machine. From the analysis of these computations the following conclusions are made :

a) The errors in the adopted initial conditions of integration of the equation of motion do not influence the derived results, if we deal with sufficiently large values of t and R_a , where t is time and R_a is the radius of the envelope.

b) It was found that for relatively small intervals of time (for various cases from 10^4 to 10^6 years) the envelope is sufficiently extensive to be registered by observations.

c) For a given value of H_0 , where H_0 is the mass lost by the star per second, the size of the envelope depends only slightly on the adopted values of v_0 and n_c ; v_0 is the velocity of atoms ejected from the star and n_c is the concentration of particles in the interstellar medium, or in the gaseous nebula surrounding the star.

d) The total mass of the envelope, all the way out from the star, is determined mainly not by the atoms, which are ejected by the star, but by the atoms which are captured by the envelope from the interstellar medium (or the diffuse nebula).

The possibility of detecting the above discussed envelope by optical observations is considered. Since only very hot stars are concerned, the envelope must have a form similar to that of a planetary nebula. The analysis of the problem shows that the brightness of such an envelope depends considerably on the so far unknown quantity $R_a/\Delta R$ where ΔR is the thickness of the envelope. However even for the smallest possible value of $R_a/\Delta R$, equal to two, the envelope must be visible, of course, if it is not projected on a very bright diffuse nebula.

The second possibility of detecting the envelope is connected with the fact that the envelope drives away all the matter from the star and therefore the space between the star and the envelope must be relatively empty. The gases ejected by the star are sufficiently dense only in the immediate vicinity of the latter. All this means that the envelope created by the corpuscular radiation from the star must deform, or even destroy the H II regions around O and B-stars.

Observations do not confirm the existence of the above-mentioned optical effects around O and B stars. In particular the bright rims observed around some O and B stars [3], [4] are evidently produced by a completely different phenomenon [5], [6]. Therefore the results of the present investigations do not seem to confirm the existence of a powerful outflow of gases from the surface of O and B stars. However, these results are of a preliminary character and are in need of further discussion.

For the Sun the loss of mass is relatively small [7], [8]. The loss of mass from the solar corona owing to thermal dissipation of atoms [9], [10] is about 6×10^{17} gm/year. The mass loss determined by the ejection of prominences from the sun is about 10^{17} gm/year, see [7], [8]. The mass loss owing to the ejection of the corpuscles from the plages is about 10^{17} gm/year, see [7], [8]. The mass loss owing to the ejection of corpuscles from the chromospheric flares amounts to 10^{18} gm/year, see [11]. All these values are considerably smaller than the value of mass loss, according to the equation $E = mc^2$, due to the stars luminous output.

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Discussion

Question : Where are the arguments that the envelope investigated by you is stable?

Mustel : This problem is not of importance. The principal point here is that from the dynamical considerations the gases ejected from the star must drive away the gases surrounding the star and therefore certain condensation of gases at a distance R_a from the star must arise and this condensation must be visible. Moreover H II regions must be deformed.

Question : With which velocity (greater or less than the velocity of the sound) is the envelope moving inside the interstellar matter?

Mustel : At the beginning this velocity is greater than the velocity of sound, later it is less.