JOINT DISCUSSION NO. 7

MASS LOSS PHENOMENA

(Commissions 29, 35, 36, 37 and 45)

Edited by Pik-Sin Thé

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EDDINGTON AND MASS LOSS

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ABSTRACT

This joint discussion is dedicated to the memory of Sir Arthur Eddington who was born 100 years ago. He laid the foundation of much work on stellar evolution, which was summed up in his book The Internal Constitution of the Stars (ICS) which appeared in 1926. Although he did no substantial work on mass loss from stars, the possibility of mass loss is mentioned in several places in ICS and I shall mention these and other aspects of Eddington's work which are relevant to our present interest.

Eddington had a particular interest in the role of radiation pressure. When his work started, it was not possible to derive accurate chemical compositions of stars. He believed that stars were largely made of heavy elements so that their mean molecular weight was nearer to 2.0 than to the 0.5 of pure hydrogen. This led to his incorrect belief that radiation pressure was beginning to dominate gas pressure in the most massive observed stars and he conjectured that more massive stars would be blown apart by radiation pressure. In passing he obtained an expression for what we now call the Eddington limit luminosity, which is the maximum luminosity of a star in radiative equilibrium if matter is not to be blown off by radiation pressure. He discussed how selective radiation pressure acting on heavy elements might cause them to rise in a star, while the lighter elements would sink to the centre. Having estimated that this might be an important effect, he then discounted it because his calculation of circulation caused by stellar rotation indicated that this would keep a star homogeneous and prevent the separation of elements. Near the end of ICS he discussed the possibility that radiation pressure might cause mass loss and said:

"There seems to be some possibility of escape of chromospheric atoms acted upon by intense radiation pressure but calculations are not as yet very definite. But in any case it is difficult to believe that loss by escaping atoms can be at all comparable with the loss of mass by

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radiation. The radiation of the Sun carries away a mass of 6 x 10^{-11} $gcm^{-2}s^{-1}$. We have found that the average density of the calcium chromosphere is of order $10^{-17}g\ cm^{-3}$; so that the whole chromosphere would have to move steadily outwards at 60 km s^{-1} in order to carry away as much mass as the radiation does."

It seems clear that had Eddington known of present observations of mass loss he would have attempted to explain it as a result of radiation pressure and probably by other mechanisms. He would also surely have been fascinated by the role of the Eddington limit luminosity in modulating accretion in some close binary systems. Eddington himself did early work on accretion but he believed that accretion could not influence stellar evolution.

Eddington was convinced for reasons which we now know to be incorrect that mass loss was very important in stellar evolution. Almost at the end of ICS when, as I have stated, he did not see how substantial mass loss could occur, but yet it must, he concluded:

"Somewhere in the present tangle of evolution and sources of energy I have been misled and my guidance of the reader must terminate with the admission that I have lost my way".

It is a pity that all authors are not equally frank. He was convinced of the importance of mass loss by his two beliefs that stars were homogeneous and made of heavy elements. Although the precise source of stellar energy was unknown, he knew that a homogeneous star composed almost entirely of heavy elements would remain in essentially the same place in the HR diagram even if its composition changed. As a result it would not evolve. The current belief was that stars started as giants and changed into dwarfs and the appropriate evolution only seemed possible with mass loss. Mass loss was implied not only because stars high on the main sequence were more massive than those lower down but also because it was then believed that giants were more massive than dwarfs. Eddington was also concerned with an explanation of the coexistence of giants and dwarfs in the same star clusters and he said:

"It will be seen that any modern theory of evolution is bound up with the question of the possibility of change of mass of a star."

We now know that mass loss is indeed very important in many stages of stellar evolution. However, many difficult theoretical and observational problems remain and it is likely to be some time before it is possible to predict the final mass of a star from its main sequence properties. In this respect we are still some way from achieving Eddington's aim of understanding "so simple a thing as a star".

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