A COMMENT ON THE INTERSTELLAR H_2 ABUNDANCE

by

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The abundance of interstellar molecular hydrogen has been recently discussed and various processes of production and destruction have been investigated. Gould and Salpeter concluded that the density of molecular hydrogen is probably comparable with the density of atomic hydrogen. This result is based upon the assumption that molecular hydrogen is formed on interstellar grains.[1]

A recent study by Meydenberg, Knaap, Beenakker and van de Hulst has shown that for ice grains this is not very probable at temperatures above $8^{o}K$.[2] Since the temperature of ice grains is presumed to be on the order of $25^{o}K$ it is of interest to examine the amount of H_2 produced by other mechanisms in order to establish a lower limit to the H_2 abundance. McDowell established a firm lower limit from the reaction

$$H + e \rightarrow H^-$$

$$H^- + H \rightarrow H_2^- \rightarrow H_2 + e.$$ [3]

McDowell's value for the formation rate of H_2 by this reaction is 10^{-5} that of the rate of formation on grains. In this note we wish to point out that there is another process which may build up significant concentrations of H_2.

The loss of mass from late type giant and super-giant stars has been recently reviewed by Deutsch and by Weymann.[4,5]

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The observational evidence appears to be in favor of a cool flow of matter from the star and a mechanism for this has recently been proposed by Wickramasinghe, Donn, and Stecher.[6] Assuming that cool flow does indeed take place it would constitute a source of molecules for the interstellar media.

The number of H_2 molecules per second introduced into the interstellar medium near the sun will be the product of the mass loss of molecular hydrogen times the space density of M giants. Deutsch has compared the mass loss of α Herculis (3×10^{-8} $M_\odot$/yr) with that required by stellar evolution assuming that Herculis was typical of all M giants and using Becker's value of the space density of M giants (2.2×10^{-5} pc^{-3}) and found them comparable.[4] Using these values for the mass loss and the space density and assuming all the mass lost is molecular hydrogen we obtain a supply rate of 4.2×10^{-19} H_2 mol $cm^{-3}s^{-1}$ which can be considered an upper limit.

We may now compare this with McDowell's production rate. If we take as typical values for an HI cloud $n_H = 10$ cm^{-3}, $N_e = 2 \times 10^{-3}$ and $T = 100^{\circ}K$ the rate in the cloud is 1.8×10^{-20} $cm^{-3}s^{-1}$. Assuming that the clouds occupy 6% of the volume the average production rate is 1.0×10^{-21} H_2 mol $cm^{-3}s^{-1}$.

The upper limit for the H_2 source rate from the red giants is therefore 420 times greater than that expected from the H_2^- process. This factor of 420 must be reduced by the fractional amount of helium and heavier elements The ratio of atomic to molecular hydrogen depends upon the temperature of the outermost layers of the star. Deutsch has suggested that the later type M stars provide most of the mass ejected. The boundary temperature for such stars is below $2000^{\circ}K$ so that most of the hydrogen coming out of the star is in the molecular form.

The most efficient method of destroying molecular hydrogen found by Gould and Salpeter is the ultraviolet radiation from a hot star during a chance encounter. For the galactic plane they give a dissociative rate constant of 3 x 10^{-16} s^{-1}. This combined with the upper limit for the supply rate from M giants gives an average steady-state concentration of ~10^{-3} H_2 mol cm^{-3}. It would then appear that, based on the assumptions that α Herculis has a typical rate of mass loss, that all the mass lost is H_2, and that the ejection process is a cold one, one quarter of one percent of the interstellar hydrogen is in molecular form, excluding any produced on interstellar grains. It might be noted that the red giants will release other molecules in proportion to their thermodynamical equilibrium abundance in the outermost layers of the star.

Observable inhomogeneities in the concentration of certain molecules may occur if the rate of mass loss is considerably greater; say, 10^{-6} $M_\odot$/yr. This would be particularly noticable if the mass ejection is into a HI cloud and the life time of a particular molecule is on the order of 10^6 years which would increase the contrast by lowering the mean density.

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