12. LOCAL RATE OF STAR FORMATION

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There can be little doubt that the formation of stars has a profound influence on the evolution of galaxies. Unfortunately, the physics of star formation is still a mystery, and a property such as the distribution of stellar masses at birth is essentially not understood. Salpeter (1955) derived the mass distribution at birth from the field luminosity function and life times computed for evolving star models; he assumed a constant rate of star formation. The small percentage of gas present in the Galaxy and in the Andromeda nebula make the assumption of a constant formation rate rather unlikely.

As one obviously needs gas to form stars, it seemed reasonable to assume that the rate of star formation depends on the gas density. Usually it was taken, then, that the rate of formation varies with a power n of the gas density. Salpeter (1959) considered the case of $n = 1$ for our Galaxy as a whole. Schmidt (1959) discussed the value of n and concluded that $n = 2$ was the most likely value. These investigations essentially assumed that the dependence of star formation on gas density is a physical law, i.e. that it applies also elsewhere in the Galaxy, off the galactic plane, etc.

A new discussion of the value of n was published recently by Schmidt (1963). It was assumed that the rate of star formation decreases with time, and in such a fashion that it varies proportional to the n-th power of the gas density. The discussion of the value of n was *not* based on a physical relation between formation rate and gas density. Also, the value of n was taken to be a function of the stellar mass; it was arbitrarily assumed that $n = n_1 + q \log M$ for stars with mass M exceeding one solar mass, and $n = n_1$ for those less than one solar mass. It is not possible to repeat the discussion of the values of n_1 and q here and reference has to be made to the original paper (Schmidt, 1963). A considerable number of assumptions has to be introduced and the result is correspondingly uncertain.

It may be of interest to discuss briefly some properties of one or two models of the evolution of the solar neighborhood that are admitted by the above-mentioned discussion. The values of the parameters are $n_1 = 1$, and $q = 1$ to 2. The total mass density was assumed to be 75 $M_\odot$ per pc^2, the present gas density 15 $M_\odot$ per pc^2. With these values of n_1 and q, the initial rate of formation of stars of one solar mass was five times the present rate, while that of 10 solar mass stars started at 25 to 125 times their present rate (ranges given correspond to $q = 1$ to 2). The present rate of formation per interval of 1 magnitude is:

$M_v = -5$: 0·001 per square pc per billion years,
0 : 0·04
+5 : 0·08
+10 : 0·2

Stars over one solar mass now form at a rate of one solar mass per billion years, while less massive stars form at a mass rate of two solar masses per billion years. Assuming that each star with a mass exceeding that of a white dwarf throws off the excess mass, the present rate of ejection is 1 to 1.7 solar masses per pc^2 per billion years. The total amount of gas used in forming stars over the full 10^{10} years is 110 to 230 solar masses per pc^2, and the total mass ejected is 50 to 170 solar masses per pc^2.

In problems involving the gradual enrichment of metals in the interstellar gas due to ejecta from evolving stars, a quantity of interest is the average number of times an average particle of the present interstellar medium has passed through a star. With the values of n_1 and q under discussion this average number of passages is around 1 to 4. This means that the average metal abundance of the material ejected by evolving stars in the past would have to be equal to or less than the present metal abundance of the interstellar gas. The variation of the metal abundance in the solar neighborhood at present would be 6 to 3 per cent per billion years. At the time of the Sun's formation the abundance was 64 to 80 per cent of the present metal abundance.

A rough estimate of the rate of change of luminosity and color of the solar neighborhood has only been made for a case resembling $n_1 = 1$, $q = 2$ (Schmidt, 1962). The visual luminosity decreased by $0\overset{m}{.}08$ per 10^9 years, while both $B-V$ and $U-B$ increased by $0\overset{m}{.}03$.

Finally, it should be stressed again that the above properties represent just one perhaps possible model of the evolution of the solar neighborhood. Substantial improvement in these evolution models may be expected once we have much more detailed information about the late evolution stages of stars, about the nature of that part of the local mass that is not yet accounted for in terms of known objects, and about the large-scale dynamics of the interstellar gas.

REFERENCES

Salpeter, E. E. *Astrophys. J.*, **121**, 161, 1955; **129**, 608, 1959.
Schmidt, M. *Astrophys. J.*, **129**, 243, 1959; *Symposium on Stellar Evolution* (La Plata: Astronomical Observatory), 1962; *Astrophys. J.*, **137**, 758, 1963.

DISCUSSION

Van Woerden. In these calculations the evolution of the solar neighbourhood was considered independent of other regions in the Galaxy. What would be the effects of mixing in the interstellar gas?

Schmidt. The effects of mixing on a 1 kpc scale would be quite small. In fact, in the model continual immediate mixing on a small scale was assumed.

Varsavsky. There appear to be stars of all ages having all sorts of composition. Also, what are your views on the helium problem?

Schmidt. The poor correlation between age and composition indicates that the interstellar medium is not well-mixed. The helium problem is very severe; there is no evidence of low helium abundances anywhere.

Zwicky. I am at a loss to understand how you expect to produce a realistic theory of star formation by starting from the not very profound assumption that it is a function of time and by endowing this function with mathematical characteristics which admittedly have no relation to any known physico-chemical phenomena. Real progress in our understanding of star formation can probably be made only if physically possible processes of condensation in a wide variety of extended formations of matter are investigated in dependence upon realistically chosen initial conditions.

Schmidt. The present work only considers star formation as a function of time, and the gas density—itself a function of time—has just been used as a convenient parameter.