THE LUMINOSITY FUNCTION AND STELLAR EVOLUTION

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- ABSTRACT

The luminosity function for main-sequence stars in the solar neighborhood is studied.
The rate of star formation as a function of stellar mass is calculated.

- INTRODUCTION

Studies of stellar evolution has been a growing field.
A lot has been learned by studying Population II systems.

<u>For studying Population II stars:</u>
Particularly, studies of globular clusters H-R diagrams, that suggest that most of the stars in a cluster are formed around the same time.
Since for magnitudes brighter than 3.5 there are basically no stars in the H-R diagram, and by estimating the time that it takes for a star (with $M_V = 3.5$ and $M = 1.3\ M_{\odot}$) to burn 12% of its mass from hydrogen to helium, the age of the cluster can be estimated (5 billion years).

<u>For studying Population I stars:</u>
Studies of the solar neighborhood.
Stars have larger range of masses.
Using large data of the solar neighborhood stars, the luminosity function can be calculated to an acceptable accuracy.
The luminosity function depends on three factors:
- $\xi(\mathfrak{M})$: relative probability for the creation of stars of mass near $\mathfrak{M}$ at a particular time
- rate of creation of stars as a function of time since the formation of our galaxy
- evolution of stars of different masses after they have burned out an appreciable fraction of their hydrogen mass and have left the main sequence

Since they cannot derive these factors from the luminosity function, then what the author can do is test that the assumptions they are taking, are actually compatible with the observed luminosity function:
- SFR in the solar neighborhood has remained the same since the beginning of the galaxy
- $\xi(\mathfrak{M})$ varies smoothly with $\mathfrak{M}$ and is independent of time
- Stars do not change their mass (just in last stages)
- Most stars are poorly mixed and move off the MS when 12% of their mass has burned into helium.

- OBSERVATIONAL DATA

The luminosity function gives the number of stars (or galaxies) per luminosity interval. – Given a luminosity as input, the luminosity function essentially returns the abundance of objects with that luminosity (specifically, number density per luminosity interval).

The total luminosity function $\phi_t(M_V)$, is defined as:

$$dN = \phi_t(M_V)dM_V$$

Number density (stars per pc^3) of stars with absolute visual magnitude M_V between $M_V + dM_V$

Salpeter is only considering the luminosity function in the range $M_V = -4.5$ to $+ 13.5$.

Salpeter is not considering the detailed luminosity-spectral type function, $\phi(M, Sp)$, but he's only considering the luminosity function for MS stars, separated from giants (however, the resolving power of this data is not sufficiently high to give a clear separation between main sequence and subgiants).

Table 1, basically shows the fraction of stars of each spectral class that are MS stars.

Salpeter defines the luminosity function for the MS alone as $\phi(M_V) = f\phi_t(M_V)$, with a correction for white dwarfs in ϕ_t.

Also, they need values for the average mass $\mathfrak{M}$ and absolute bolometric magnitude M_b as a function of M_V for MS stars.

- THE "ORIGINAL MASS FUNCTION"

In Figure 1, the luminosity function values (shown in Table 2) are plotted.

There is a significant change in the slope of the function, being steeper in the brighter end.
This change is more significant for the MS stars.
The change occurs somewhere between $M_V = +1$ and $M_V = +5$.

This change in slope for population I star may be explained similarly to the globular cluster HR diagram: there are no stars older than T_0 (the age of the galaxy), stars of visual magnitude M_L (limiting magnitude) burn 12% of their hydrogen mass in this time, therefore stars fainter than M_L have burned less and are still on the MS. For brighter stars, only those that are young enough to have burned less than 12% of H into He, are still on the MS, hence the rapid decline of MS stars with increasing brightness (for $M_V < M_{L,V}$)

Salpeter defines the "original mass function", $\xi(\mathfrak{M})$, as:

$$dN = \xi(\mathfrak{M})\, d(\log_{10}\mathfrak{M})\, \frac{dt}{T_0}$$

Where dN is the number of stars in the mass range $d\mathfrak{M}$ created in the time interval dt per pc^3.

the initial mass function (IMF) is an empirical function that describes the initial distribution of masses for a population of stars.

Its corresponding “original luminosity function”, $\psi(M_V)$, is:

$$\psi(M_V) = \xi(\mathfrak{M}) \frac{d(\log_{10}\mathfrak{M})}{dM_V}$$

The “original” functions correspond to what we would observe if stars where to stay on the MS forever.

Considering a MS star with absolute visual magnitude $M_{L,V}$, average mass $\mathfrak{M}_L$, bolometric luminosity L_L, and bolometric magnitude $M_{L,b}$. The time T spent on the MS by a brighter star than the limiting magnitude $M_{L,V}$ is

$$T = T_0 \left(\frac{\mathfrak{M}}{L}\right)\left(\frac{L_L}{\mathfrak{M}_L}\right)$$

The relation between the original luminosity function and the observed one is

$$\log\phi(M_V) = \begin{cases} \log\psi(M_V) + 0.4\left(M_b - M_{L,b}\right) + \log\left(\frac{\mathfrak{M}}{\mathfrak{M}_L}\right), & \text{for} \quad M_V < M_{L,V} \\ \log\psi(M_V), & \text{for} \quad M_V > M_{L,V} \end{cases}$$

Because the data is not very accurate to determine the value of the limiting magnitude, Salpeter uses the turning point for the globular clusters HR diagrams: +3.5

Using this value, and the observed luminosity function, and so on… they derive $\psi(M_V)$, and then derive $\xi(\mathfrak{M})$.

- DISCUSSION

ψ and ξ are smoothly varying functions.

For masses between $0.4\mathfrak{M}_\odot$ and $10\mathfrak{M}_\odot$, the "original mass function" is approximated reasonably well with

$$\xi(\mathfrak{M}) \approx 0.03\left(\frac{\mathfrak{M}}{\mathfrak{M}_\odot}\right)^{-1.35}$$

Equation 6:
Left side: total mass per pc3 of <u>all stars</u> created at <u>any time</u> since the origin of the galaxy, with $M_V < M_{L,V} = 3.5$ (most of which are no longer on the MS)
Right side: total mass per pc3 contained in all stars with $M_V < M_{L,V} = 13.5$ which exist at present

> the total mass which has been in the form of main- sequence stars once but has taken on different form by now is of the same order of magnitude as the total mass of present stars

Equation 7:
Left side: total number of burned-out stars
Right side: total number of MS stars

> roughly 10 per cent of existing stars should be white dwarfs, which agrees well with observational estimates of the abundance of white dwarfs

If the hypotheses that the author stated from section 1, turn out to be true, it would be logic to think that an appreciable fraction of the interstellar gas has been in the interior of stars at some point.

However, there are many sources of error for the calculations.