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Missing Mass from Low-Luminosity Stars [and Discussion]

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Missing mass from low-luminosity stars

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Results from a deep photometric survey for low-luminosity stars show a turnup to the luminosity function at faint magnitudes, and reopen the possibility that the missing mass in the solar neighbourhood is made up of stars after all.

Among the wide range of distance scales for which evidence for 'missing' mass has been found, perhaps the most puzzling is that of the solar neighbourhood. About twenty years ago, Oort (1965) pointed out the discrepancy, by about a factor of two, between the local mass density as deduced from the kinematics of stellar populations, and the integrated mass from directly observable matter. The most obvious candidates for this unseen material were low luminosity stars, and much effort was subsequently put into measuring the stellar luminosity function, especially at the faint end. The large-scale proper-motion survey by Luyten (1968) provided a benchmark for this work, and he found a broad maximum centred on $M_V = 12$, followed by a steady decline to $M_V = 15$, although his results for the faintest stars were severely limited by small numbers. Subsequent surveys by Wielen (1974) and Sanduleak (1976) largely confirmed this picture, and there seemed little reason to believe in a subsequent rise in numbers at faint magnitudes. More recently, Reid & Gilmore (1982), on the basis of a photometric survey, put upper limits on the existence of a population of low luminosity stars and claimed that the local missing mass does not reside in such stars.

The present results are the outcome of the unexpected discovery of some very red stars in a proper-motion survey from deep R-band U.K. Schmidt plates. The existence of these stars appeared to contravene the limits set by Reid & Gilmore (1982), and so a photometric survey was carried out using deep R- and I-band plates, to construct the luminosity function to the faintest attainable magnitude. The use of R-band plates in place of the V-band plates used by Reid & Gilmore enabled the survey to be pushed to about one and a half magnitudes fainter, and all stars in the sample were measured in the two passbands. The absolute magnitudes for the sample members were obtained from the (R–I) against M_R relationship for parallax stars, and the sample confined to stars within 100 pc†. Figure 1 shows the resulting luminosity function, open circles representing the same data rebinned by a half a magnitude.

Before interpreting figure 1, checks were carried out to establish the reality of the rise in space density at the faint end. Several of the faintest stars were observed in the infrared JHK bands, and these colours confirmed the luminosities obtained from the (R–I) colours. Finally, a FORS spectrum of the reddest star was obtained on the AAT, which showed a very cool star of similar temperature to VB8, and was completely consistent with the optical and infrared photometry.

Figure 1 is best interpreted by comparison with model luminosity functions based on theoretical cooling tracks for low mass stars, such as those of Staller & de Jong (1981). Most

† 1 pc ≈ 30857 × 10^{12} m.

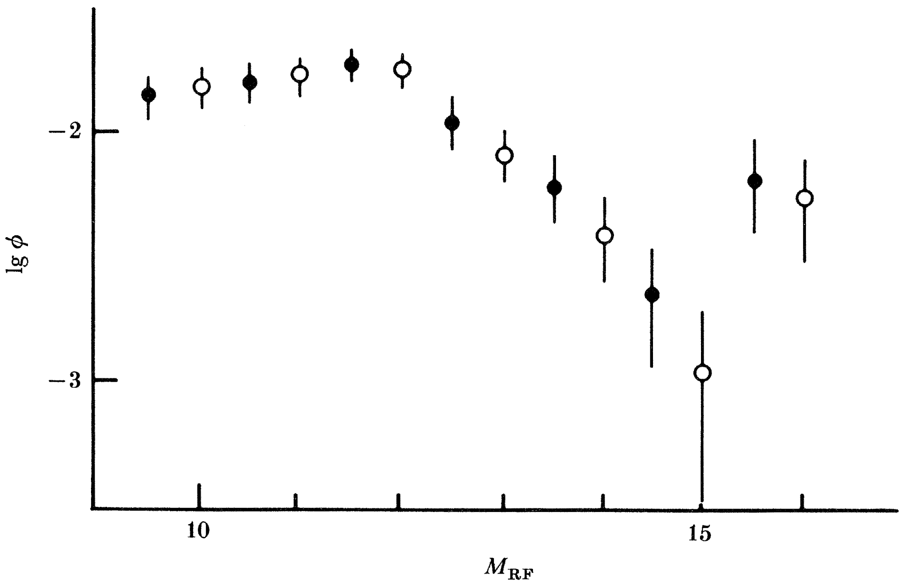

FIGURE 1. Luminosity function for M-stars within 100 pc of the sun. Closed circles show logarithmic space density, and open circles are the same data rebinned by half a magnitude.

of their models show a qualitatively similar shape to the function in figure 1, although the rise to fainter magnitudes is somewhat more gentle. The decline and subsequent increase in space density is associated with the cessation of hydrogen burning, and the appearance of a population of 'brown' dwarfs in a degenerate cooling phase. These features are present more or less regardless of the shape of the initial mass function. This interpretation has important consequences for the missing mass problem. Earlier surveys suggested that the luminosity function dropped to vanishingly small space densities below $M_V = 16$, giving little reason to believe that the missing mass might be in the form of low luminosity stars. The present observations imply an upturn in the space density, as predicted by the theoretical models, giving new hope that the local missing mass might be in the form of stars after all. It goes without saying that the stars detected so far are not in themselves sufficient to make up the deficit, and it is necessary to integrate the mass function to an appropriate lower limit, set by fragmentation processes. If this is done with reasonable parameters for the mass function, the missing mass can be accounted for in this way.

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Discussion

R. J. Tayler (*Astronomy Centre, University of Sussex*). Surely the first 'back of envelope' estimate, if one believes that the observed stars are no more than 10^9 years old, is to multiply their mass by a factor of about 10 or 15 and see whether that roughly accounts for everything.

M. R. S. Hawkins. The observed stars count for very little. The question really is whether they are the 'tip of the iceberg'. I do not know at present of any way of answering that question definitively.

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