GROUND-BASED SURVEYS FOR LOW-LUMINOSITY STARS

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1. Introduction

Most of what we know about the luminosity and mass function of low-mass stars has been derived from analysis of ground-based photometric and astrometric surveys. A major uncertainty in the interpretation of such surveys lies in the appropriate correction for unresolved binaries and in the use of a reliable colour-magnitude relation. Various new surveys are now uncovering large numbers of objects which should rapidly ameliorate these ambiguities.

The recent discovery of brown dwarfs and planets has highlighted the importance of low-luminosity stars. Once we understand their spectra and colours and have statistically significant samples, it will be important to use them to reliably constrain theories of star formation and chemical evolution as well as to use them as a probe of galactic structure and to reliably ascertain their contribution to baryonic dark matter. In this brief review I shall focus on ground-based field searches. Hambly (1997) reviews the very successful searches that have recently been carried out in nearby clusters.

Until the 1970s, most work on the faint-star luminosity function was based on proper-motion searches primarily by Dutch researchers, in particular Luyten (e.g. 1938, 1979). The last 20 years have seen a switch from astrometric to photometric surveys employing plate-scanning machines or CCD cameras. Combined with substantial increases in computing power these technologies have led to the discovery of large numbers of very low-luminosity stars.

2. Problems & Progress

Surveys for low-mass stars have usually being made in two near-optical bands. However low-mass stars release most of their energy in the infrared, furthermore large numbers of low-mass stars are only found in the faintest bins. In addition the near-optical relationships between colour, luminosity and mass are not smooth and are not well calibrated. This has lead to newer surveys moving to longer wavelengths and obtaining more calibration data. A problem which all surveys have to overcome is Malmquist bias. Unless corrected for unresolved binary systems beyond the designated survey volume will be erroneously included as single stars because of their apparent brightness. The treatment of Malmquist bias and other biases are described in detail by Stobie, Ishida & Peacock (1989) and Kroupa, Tout & Gilmore (1993).

A major aim of most surveys is to probe the stellar luminosity and mass functions with good statistics. Early work broadly supported the Salpeter hypothesis of a power-law. As statistics improved, e.g., Reid & Gilmore (1982) structure became apparent. A number of studies have improved the statistics and extended such findings to fainter stars, though, the broad trend of a maxima in the photometric luminosity function ($\psi_{\rm phot}$) around $M_{\rm v} \sim 12$ ($M_{\rm bol} \sim 10$) with a decline at fainter magnitudes has remained. However, this apparent lack of faint stars is not seen in luminosity functions constructed from nearby stars samples ($\psi_{\rm near}$), typically within 5 or 8 pc, which show a much flatter distribution. One explanation for this might be a local overdensity. However the stars which define $\psi_{\rm near}$ have a velocity dispersion of ~ 50 kms which means that within 4 Myr they would have dispersed over ~ 200 pc. Dahn et al. (1986) suggested that the apparent deficit of faint stars in the photometric surveys might arise from the non-detection of low-mass companions, which in studies of nearby stars can be resolved as separate from bright primaries. Kroupa and collaborators (e.g. 1993, 1995) and Mera et al. (1996) have used the binary fraction of 49 % and the companion mass

J. Andersen (ed.), Highlights of Astronomy, Volume 11A, 421–422.

ratios based on the G and K dwarf sample of Duquennoy & Mayor (1991) to model the contribution of unresolved binaries to $\psi_{\rm phot}$. Using a model where both primary and secondary are drawn from the same initial mass function they find that unresolved binaries are sufficient to solve the deficit of faint objects in $\psi_{\rm phot}$. However Reid & Gizis (1997) have failed to re-produce these results and contest that the Duquennoy & Mayor sample is appropriate for use with M dwarfs. Reid & Gizis's 8-pc sample of M dwarfs and the work of Mazeh et al. (1992) indicates that the binarity fraction and distribution fraction for M dwarfs is quite different from that of G and K dwarfs. Rather than a smooth tendency to produce large binary mass ratios, Reid & Gizis find that M dwarfs show a strong propensity toward near-equal mass binary systems. Reid & Gizis model unresolved binarity using a binary fraction of 36% and find that the shape of $\psi_{\rm phot}$ is altered little by correcting for unresolved binaries. They propose that the discrepancy between $\psi_{\rm phot}$ and $\psi_{\rm near}$ is rectified by using an $M_{\rm v}(V-I)$ relation which is constructed using only objects with high quality photometry. The clear clarification of this issue requires

- M dwarf multiplicity to be thoroughly quantified for a large sample and
- further work on colour-luminosity-mass relations.

Even without these essential large scale observational efforts, research would benefit from the use of the same nearby star sample and from using bolometric luminosities rather than $M_{\rm v}$ magnitudes. Although it is easier to make accurate measurement in one photometric band, disk low-luminosity stars show very significant colour variations which are not yet understood in terms of their spectra, age or metallicity (e.g. Tinney et al. 1995). Furthermore the slow cooling (> 1 Gyr) of very low-mass objects onto the main sequence means that analyses need to take age into account. The necessary observational work is already being tackled by a number of large-scale projects. New surveys are now producing large numbers of nearby M dwarfs and brown dwarf candidates which are expected to clarify the appropriate corrections to apply to $\psi_{\rm phot}$.

TABLE 1. Some of the new candidates which have been discovered. References are DEN97 - Delfosse et al. 1997a, KBS97 - Kirkpatrick et al. 1997, O97 - Oppenheimer 1997, F97 - Fleming 1997, D97 - Delfosse et al. 1997b, R97 - Ruiz 1997, T96 - Thackrah 1996 and H97 - Hawkins et al. 1997.

Technique & Survey	Recent Highlights	Reference
Large area IR	Brown dwarf + 3 excellent candidates	DEN97, KBS97
e.g. DENIS and 2MASS	+ many M dwarfs within 25 pc	
Coronographic	Brown dwarf + ~5 M dwarfs within 25 pc	O97
ROSAT all-sky	55 M dwarfs with 25 pc	F97
Radial velocities	lots of planets + 12 M dwarfs within 9 pc	D97
Photographic searches	Brown dwarf + many candidates	R97, T96, H97
	+ many M dwarfs within 50 pc	

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