

# The Stellar Luminosity Function and Binary Stars

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**ABSTRACT:** If all stars within a small volume surrounding the sun are counted we obtain an approximation of the low-mass *single-star* luminosity function. Alternatively, deep photographic surveys cannot resolve most of the binary systems, and consequently we obtain an approximation to the *system* luminosity function. Comparing the single-star and system luminosity functions we derive the stellar mass function and constrain the properties of binary systems.

## 1. INTRODUCTION

The faint star luminosity function is interesting for researchers working on dark matter and star formation. Two, in principle, straightforward approaches have been implemented to estimate this function yielding discrepant results. The luminosity function derived by counting the stars within a distance of 5.2 pc has a different shape than the luminosity function determined from photographic surveys at distances of typically 100 – 200 pc. Dahn *et al.* (1986) raised the possibility that unresolved binary systems in the photographic surveys may be responsible for the difference between the number density of stars in both samples at  $M_V > 14$ . Also, photographic surveys which suffer much less from Poisson uncertainties, lead to luminosity functions with a pronounced peak at  $M_V \approx 12$  (see for example Stobie *et al.* 1989). The nature of this peak remained unknown, but may reflect either structure in the stellar mass function (e.g., Rana 1987), or alternatively may be the result of a minimum in the slope of the mass–absolute-visual-magnitude relation.

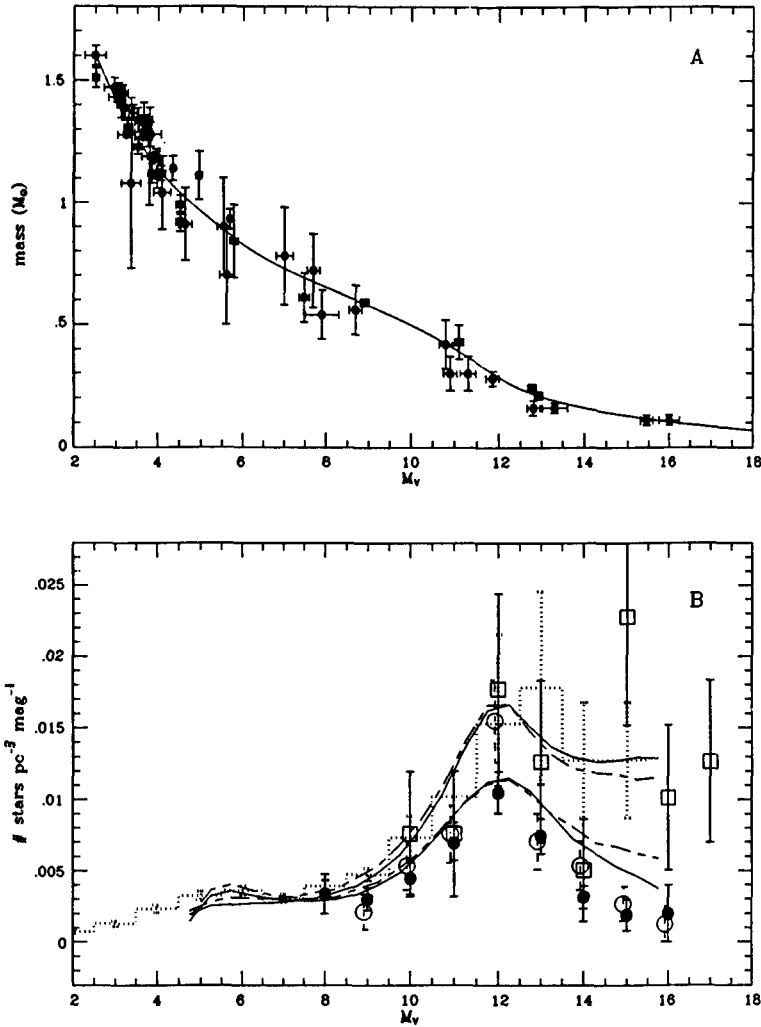
## 2. THE MASS–LUMINOSITY RELATION

Small scale structure in the luminosity function can be accounted for by structure in the mass–luminosity relation (Kroupa *et al.* 1990) as shown in Figure 1. The underlying mass function can be smooth and certainly need not be bimodal. In particular the effect of molecular hydrogen on the equation of state of fully convective stars causes a pronounced peak in the luminosity function at  $M_V \approx +12$  and the opacity of  $H^-$  ions causes the much more subtle dip at  $M_V \approx +7$ .

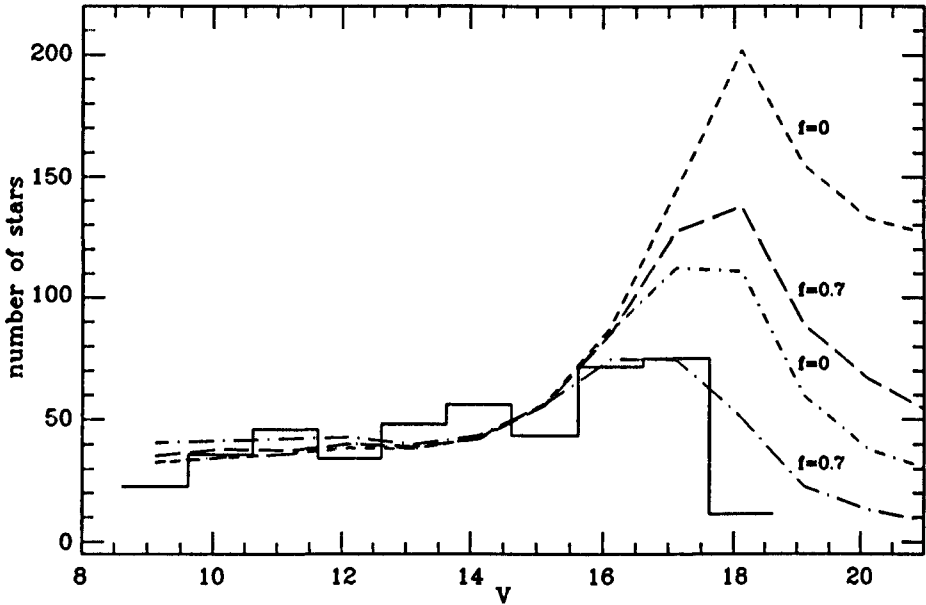
## 3. BINARY STARS

We find that a large proportion of unresolved binary systems can explain the difference between photographically determined luminosity functions and the nearby luminosity function (Kroupa *et al.* 1991, Kroupa 1992), as shown in Figure 1. The following mass function provides a good solution to both luminosity functions:

$$\xi(m) = \begin{cases} 0.035 m^{-\alpha}, & \text{if } 0.08 \leq m \leq 0.5; \\ 0.019 m^{-2.2}, & \text{if } 0.5 < m \leq 1.0, \end{cases}$$



**FIGURE 1.** Panel A: The mass–luminosity relation (Kroupa 1992). Filled circles are observational data compiled by Popper (1980). Panel B: The luminosity function based on data within 20 pc compiled by Wielen *et al.* (1983) is shown as a dotted histogram. Open squares represent the determination based on data within 5.2 pc (Kroupa 1992 and references therein). Two examples of photographically determined luminosity functions towards the south galactic pole (Reid & Gilmore 1982) and the north galactic pole (Stobie *et al.* 1989) are shown as open and solid circles, respectively. The upper curves depict our single–star Galactic–field models and the lower curves the system luminosity functions for  $f = 0.2$  (short–long dashed line) and  $f = 1.0$  (solid line), where  $f$  is the proportion of binary systems with two hydrogen burning components the masses of which are chosen independently from the mass function, and  $1 - f$  is the fraction of systems composed of one main–sequence star (and possibly a dark component). The models are maximum likelihood solutions for  $\alpha$  and the disc–scale height  $h$ . We obtain  $\alpha = 1.1$ ,  $h = 280$  pc for  $f = 0.2$  and  $\alpha = 1.3$ ,  $h = 270$  pc for  $f = 1$  (Kroupa 1992).



**FIGURE 2.** Luminosity function for Praesepe: The histogram is the observed data (Jones & Stauffer 1991) and is incomplete for  $V > 16$ . The dashed lines are for a mass function with  $\alpha = 1.1$ , and the dash-dot-dashed lines for  $\alpha = 0$ .

where  $m$  is the stellar mass in solar units,  $\alpha \approx 1.2$  and  $\xi(m) dm$  is the number of stars per  $\text{pc}^3$  in the mass range  $m$  to  $m + dm$ . The hydrogen-burning limit is taken to be  $0.08 M_{\odot}$ . By studying the luminosity function for main-sequence stars and assuming all 'stars' consist of two components we can in principle constrain the mass function for masses smaller than  $0.08 M_{\odot}$ . The data remain too poor to allow a more precise conclusion than that the best models have 100% unresolved duplicity with uncorrelated main-sequence stellar component masses chosen from the same mass function. Our Monte-Carlo simulations include a detailed model of the dispersion about the colour-magnitude relation (Kroupa 1992). This dispersion complicates the distance estimation substantially and smears out features in the luminosity function (see also Kroupa, this Colloquium).

Stars in an open cluster lie at the same distance and have the same age and chemical abundance. The effects of binary systems on the stellar luminosity function thus become very apparent at magnitudes fainter than  $M_V \approx 13$  (Kroupa *et al.* 1992, Kroupa 1992), as shown in Figure 2.

#### 4. CONCLUSIONS

1. The dip at  $M_V \approx 7$  and the peak at  $M_V \approx 12$  in the stellar luminosity function can be explained by structure in the mass-luminosity relation.
2. Binary systems have a significant effect on the shape of the faint-star luminosity function.

3. Comparison of the single-star and system luminosity functions allows the derivation of the mass function and constrains the mass-ratio distribution.

## 5. REFERENCES

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