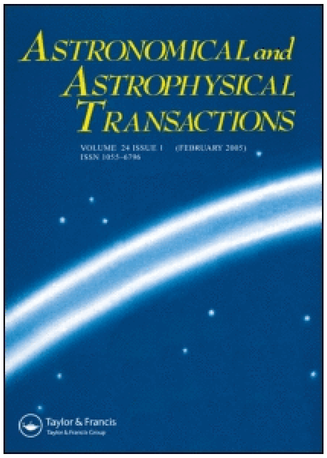

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THE FINE STRUCTURE OF LUMINOSITY FUNCTIONS OF YOUNG OPEN CLUSTER STARS

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The luminosity function (LF) of young open cluster stars has been studied for decades to obtain a slope of the initial mass function (IMF), which is important for understanding of star formation. Young open clusters contain a lot of pre-main-sequence (PMS) stars the positions of which in the H–R diagram deviate significantly from the main sequence and consequently the PMS mass–luminosity relation (MLR) differs from the ZAMS one. Such features of the MLR and related details of young open cluster LFs they produce are the subject of this poster. Three peaks have been studied: (1) the main peak (H-peak) — generated by PMS stars settling on the main sequence; (2) the R-peak — generated by inversion of the radius on the stellar birthline; the D-peak — generated by changes in the MLR and associated with deuterium burning. The evolution of these features with cluster age and possible application for young open cluster study are discussed.

KEY WORDS Luminosity function, initial mass function

1 LF MODELS CONSTRUCTION OF THEORETICAL LFs

The luminosity function for coeval star formation and cluster age t_0 is

$$\Phi(\log L) = \frac{dN}{d\log L} = f(m)\left|\frac{d\log m}{d\log L}\right|_{t_0}. \tag{1}$$

To calculate the LF Salpeter IMF $f(m) = m^{-x}$, $x = 1.35$ was used.

To construct the LF in some photometric band, e.g. in K, one should rewrite equation (1) like

$$\Phi(K) = \frac{dN}{dK} = 0.4f(m)\left|\frac{d\log m}{d\log L}\right|_{t_0}\left|\frac{dBC}{dK}+1\right|_{t_0}, \tag{2}$$

where $BC = M_{\rm bol} - M_K$.

Three sets of Population I PMS evolutionary star tracks (P, I and M) were used to calculate $d\log m/d\log L$. The I track system consists of Iben tracks (from $15M_\odot$ to $1.25M_\odot$ (Iben, 1965)) and D'Antona and Mazzitelli tracks (from $0.6M_\odot$ to $0.09M_\odot$ (D'Antona and Mazzitelli, 1985)), the P track system consists of Palla and Stahler tracks (from $8M_\odot$ to $0.6M_\odot$ (Palla and Stahler, 1993; Palla, private communication, 1995)). Maeder tracks (Maeder *et al.*, 1992) were used to complete the P and I systems with later stages (from the ZAMS). The M track system consists of D'Antona and Mazzitelli tracks (from $0.1M_\odot$ to $2.5M_\odot$ (D'Antona and Mazzitelli, 1994)) only and was used to study the D-peak.

2 THE MAIN MAXIMUM (H-PEAK)

Let us consider the behaviour of a typical isochrone with $\log t = 5.5$. The MLR valid for this isochrone can be divided into two parts: before ZAMS (for PMS stars) and in the ZAMS (for stars having masses greater than turn-on point mass) (see Figure 2). Slopes of these parts are different and the isochrone MLR slope rapidly changes between ZAMS and PMS evolution with the radiative envelope. These changes produce a maximum of the derivative $d\log m/d\log L$ and consequently of the LF (see equation (1)).

Figure 1 shows the LF H-peak which was produced both by P and I track systems. With age the H-peak position shifts from the bright end of the LF to the faint end, amplitude of H-peak decreases, and the H-peak disappears at 10^8 years since fully convective stars with masses smaller than $0.6M_\odot$ do not have a PMS evolution stage with increasing luminosity.

P and I track systems differ in the position of the maximum at early ages (before 10^6 years) due to the birthline effect which has been taken into account in the P track system. The H-peak position on the LF is shifted from $\log L = 3.0$ for the I track system to $\log L = 2.5$ for the P track system due to the birthline effect (stars with masses greater than $8M_\odot$ do not have a visible PMS stage).

The position of the H-peak on the LF of a young open cluster can indicate the age of the cluster studied, so that the position of the H-peak–cluster age relation (PAR) can be constructed and used for clusters with accurate LFs. A comparison of theoretical relations for the P and I track systems with observational data is discussed below.

3 THE BIRTHLINE MAXIMUM (R-PEAK)

The luminosity function calculated with the use of the P track system differs from the I system LF in another respect also. Figure 1 shows the peak at the faint end of the P system LF near $\log L = 0$. This peak also shifts faintward with age, but unlike the H-peak does not move on the mass axis.

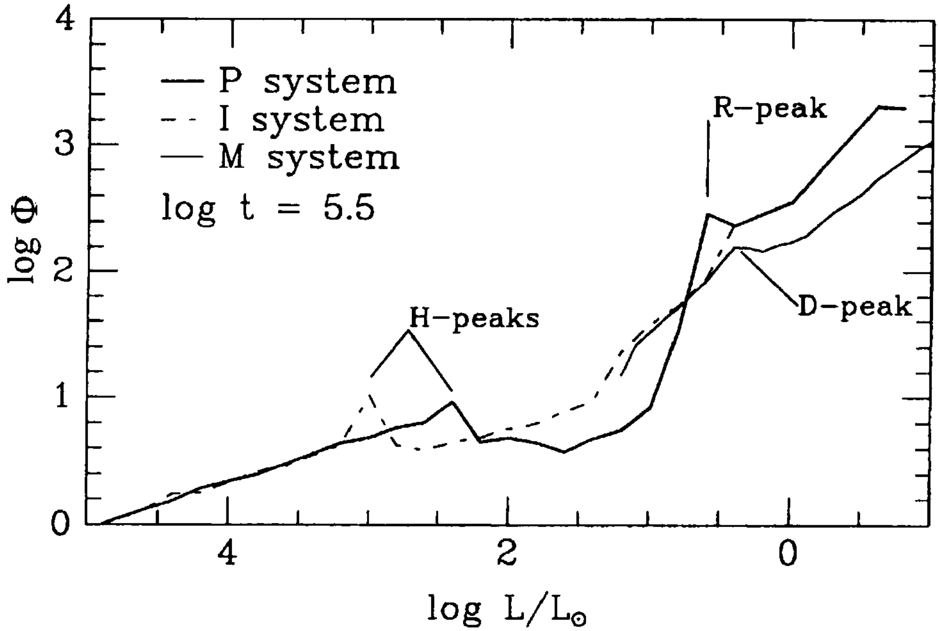

Figure 1 Theoretical luminosity functions.

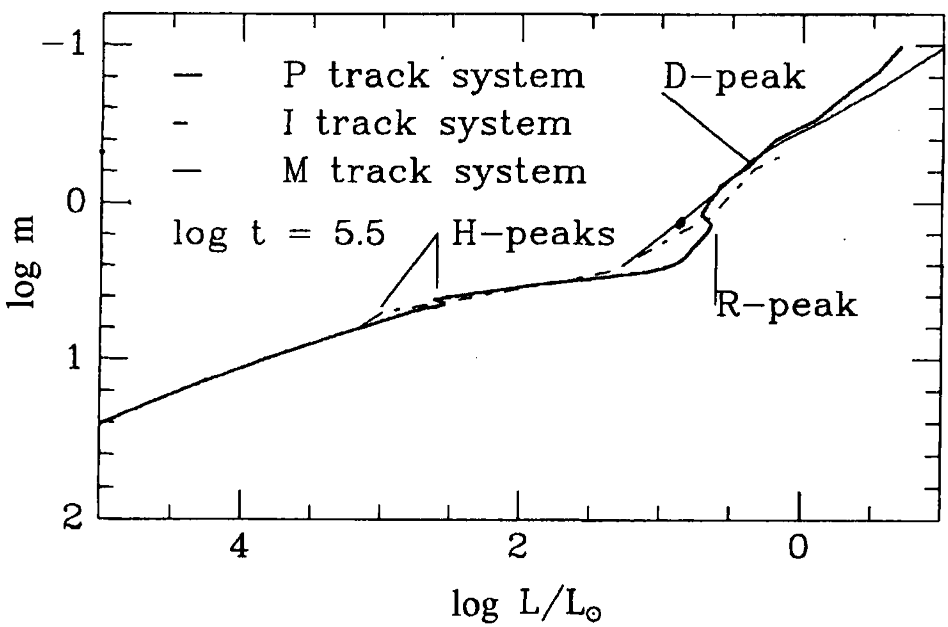

Figure 2 Mass–luminosity relations.

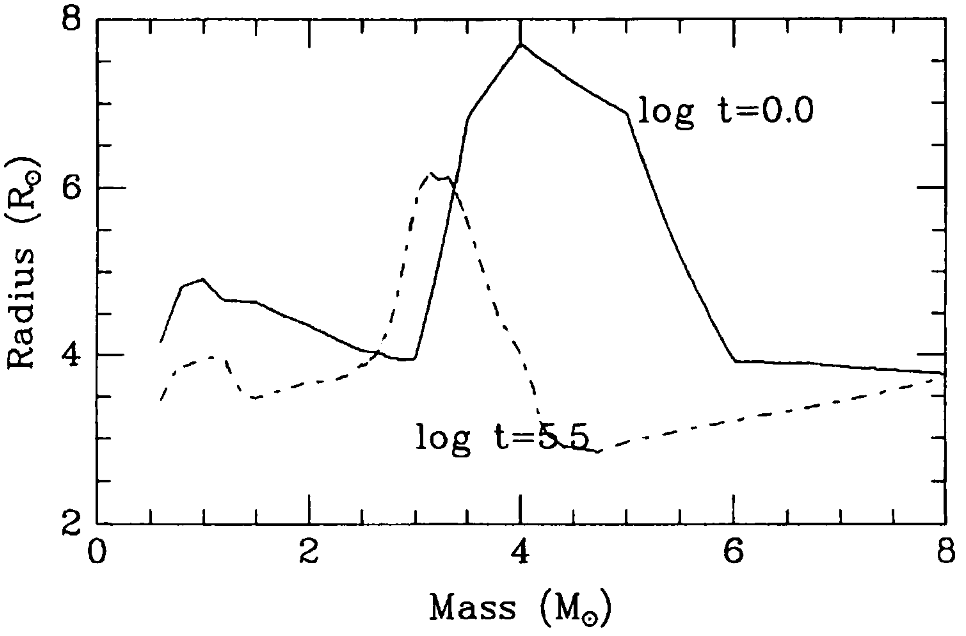

Figure 3 Mass–radius relation for the P system.

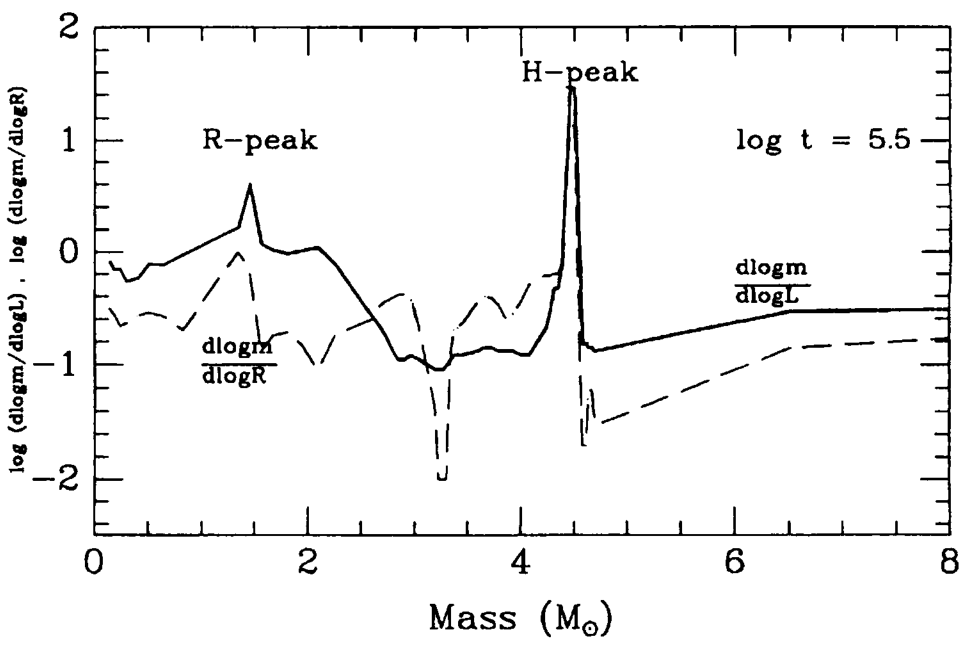

Figure 4 Mass–radius and mass–luminosity relation derivatives (P system).

Let us rewrite the LF as

$$\Phi(\log L) = \frac{dN}{d\log L} = \frac{dN}{d\log m}\left|\frac{d\log m}{d\log R}\right|_{t_0}\left|\frac{d\log R}{d\log L}\right|_{t_0}, \quad (3)$$

and note that a maximum of the derivative $d\log m/d\log R$ is responsible for this LF peak (R-peak). The mass–radius relation (MRR) strongly influences the behaviour of the birthline in the H–R diagram. The inversion of radius between $1M_\odot$ and $3M_\odot$ (see Figure 3) produces a knee of the birthline, and the maximum of the MLR derivative $d\log m/d\log L$ in this mass region (see Figure 4). Isochrones of the P track system retain the birthline behaviour until 10^6 years and the R-peak remains on the LF until this moment also.

4 THE DEUTERIUM MAXIMUM (D-PEAK)

The D maximum was studied first by Zinnicker and McCaughrean (1991).

We reconstruct the D-peak on the basis of the M system. The D-peak occurs from 5×10^5 until 10^6 years and evolves from $\log L = 0.5$ to $\log L = -1.0$ with age (see Figure 1 for $\log t = 5.5$). It is strongly associated with the finishing of the D burning stage and arises due to the faster decrease in luminosity after this stage.

No D-peak was obtained with the use of the P track system since this system has tracks with masses greater than $0.6M_\odot$ and for a star of $0.6M_\odot$ D-burning occurs only during 10^3 years after the birthline. Tracks with smaller masses are required to discuss the problem of the D-peak with the P system LF.

5 OBSERVATIONAL DATA AND POSSIBLE USE OF FINE LF FEATURES

In order to verify the PAR for the H-peak a literature search was performed to compile a list of young open clusters suspected to have LFs with H-peaks. Altogether 18 young open clusters were found as a result. The oldest one is Pleiades with the peak position at $M_V = +5^m$. Theoretical calibrations along with observational data on maximum positions and corresponding cluster ages are plotted in Figure 5 for the V-band. Cluster ages were taken from original papers.

Note that age obtained from the PAR calibration must differ from age obtained with the use of the turn-off point, since the latter is usually defined via the lifetime scale representing the upper limit of cluster age, meanwhile the former corresponds to the average age of a cluster's stars.

We plan to complete the observed data for these and other open clusters to obtain ages with this new method. The theoretical curve like one plotted on Figure 5 could be obtained for near IR photometric bands (H, K, etc.) as well. Some young open clusters have photometry in the K-band so their ages may be found from their luminosity functions. Figure 6 shows an example of theoretical calibrations and observational data for the K-band.

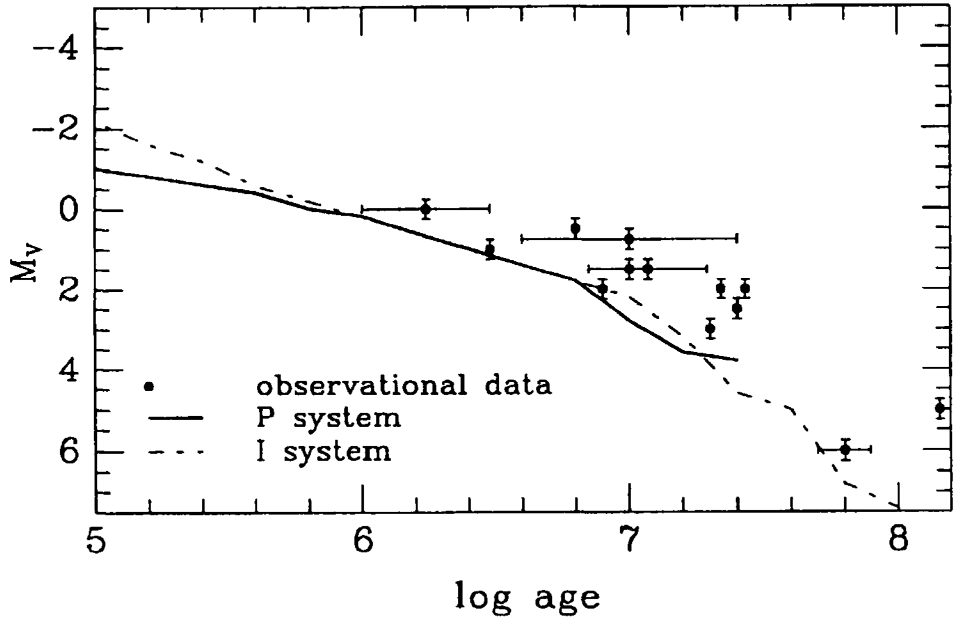

Figure 5 Theoretical H-peak – cluster age relation versus observational data in the V-band.

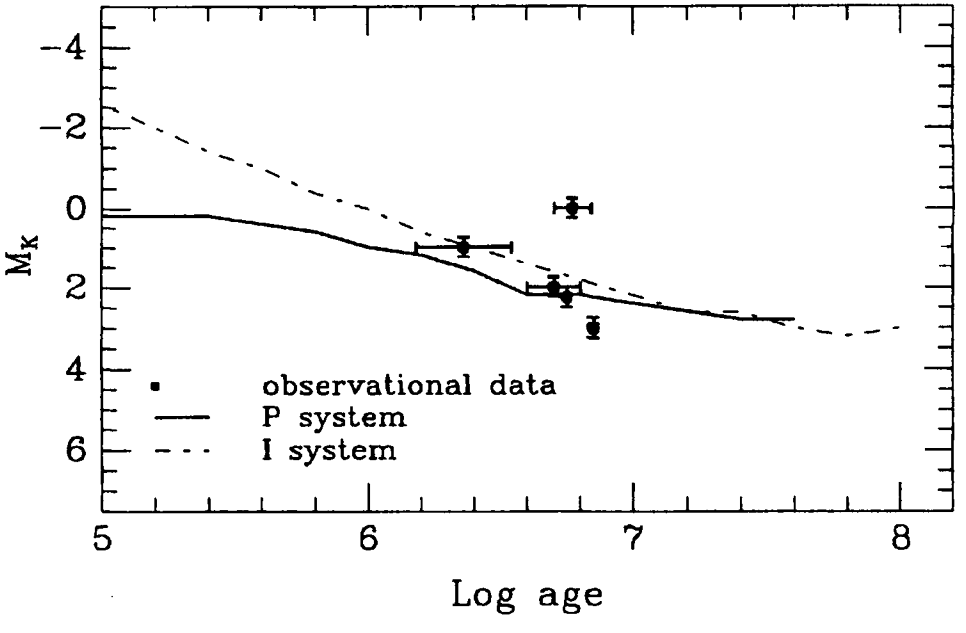

Figure 6 Theoretical H-peak – cluster age relation versus observational data in the K-band.

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