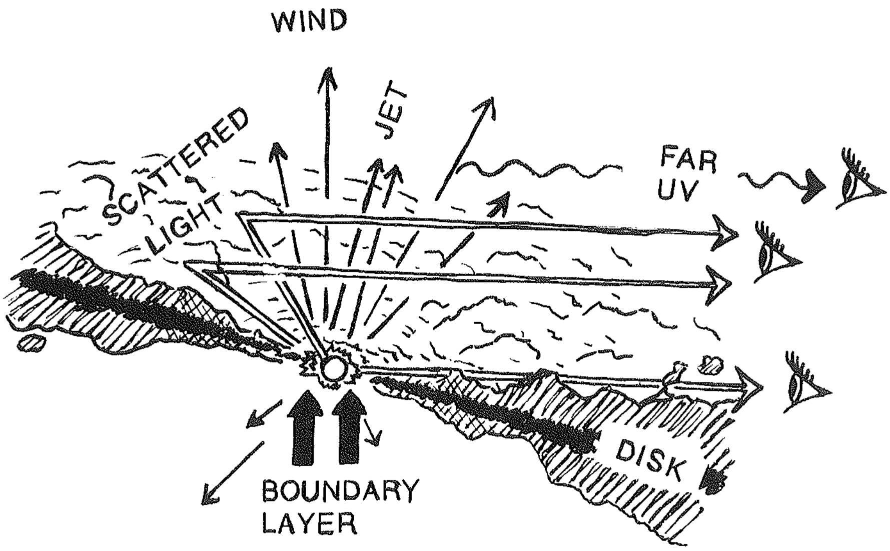

Figure 3: *The contours of a possible model of RY Lupi. The star is seen through the fluffy outskirts of an equatorial disk of dust which is inclined by 20 degrees to the line-of-sight. In the drawing the disk is cut in a plane through the star and directed to the observer to the right. On occasions, when the stellar light is almost totally blocked by foreground dust, the observer instead sees the light scattered or emitted from the extensive disk. The fluxes in the far-ultraviolet and in the emission lines stay relatively constant and must originate outside the star and the disk, like in a stellar wind or a jet. Rapid phenomena take place, possibly in the warm boundry layer between the star and the disk.*

trast. There is evidence that the flips sometimes reappear on a time-scale of close to 6 hours.

There are more peculiar things to be noted. For instance we have found evidence of a second period of about 19 hours in the light variations. The collected information on RY Lupi presents a complex but challenging picture. We cannot claim that we fully understand the unusual behaviour of this star. We have tried to bring together all pieces in what could be the contours of a model for RY Lupi. Some of the ideas can be tested by further specific observations.

In short, we find that the general pattern of variability is consistent with variable circumstellar extinction in the line-of-sight to the star. When the star fades to 13th magnitude in V, most of the stellar light is blocked and instead we see light emitted and/or scattered by circumstellar dust. Then RY Lupi must be a rare case among the T Tauri stars where the line-of-sight to the star happens to pass through the outer, fluffy regions of a flat equatorial disk of dust. On occasions the sight is clear and the star dominates the light. When the star is occulted by cloudlets of dust, we see the light from the remote side of the disk. The infrared emission from the dust grains stays constant in flux and the far-ultraviolet excess emission and the hydrogen line emission must be formed in regions outside the disk – like in a wind or jet perpendicular to the disk. These features are sketched in Figure 3.

The rapid flips are not flares on the stellar surface. They could be of circumstellar origin, like nebular flares which are discussed by cosmogonists in connection to local reheating of the early solar system material, or they are produced by instabilities in a wind or jet. Another possibility is that the flips result from scattered light from hot clumps which orbit around the star with high speed in a boundary layer between the star and the disk. The expected Keplerian orbital period close to the stellar surface is the same as the period found, namely 6 hours. It will be interesting to see if this period can be confirmed by future observers.

So far, the model outlined is very speculative and may be drastically refined by future work. Apparently, the star also changes its pattern of variability from time to time. During the period of a new series of observations, RY Lupi showed almost perfectly gray variations (only very small changes in colour). One of the problems is to understand the well established 3.75-day period. If this is a consequence of a regular structure in the rotating disk, then how could it be so stable over 52 years? Is there in fact a relation to the region of co-rotation between the star and the disk? Can stable spiral arms form in dusty disks?

All these question marks left make it exciting to continue the exploration of the T Tauri stars and their surroundings. There is still the feeling that the T Tauris also have something to tell us about the origin of our own solar system.

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Does the Mass Function of Galactic Globular Clusters Depend Upon Metallicity?

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Introduction

In the last three-four decades galactic globular clusters (GCs) have been known to constitute an excellent laboratory for the investigation of primordial star formation and chemical enrichment during the collapse of the parent galaxy. Until the advent of the CCDs, however, the study of the faint main-sequence stars, several magnitudes below the turn-off, has remained beyond our reach. The first

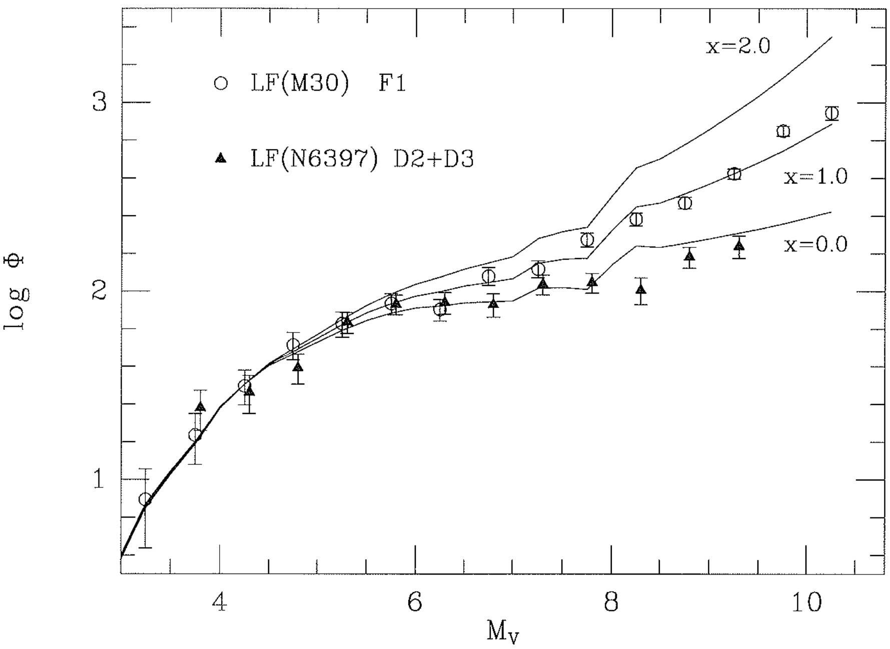

Figure 1: *Luminosity functions of the outer M30 region (light circles) and the composite luminosity function of NGC 6397 (filled triangles) plotted agianst the theoretical curves (solid lines) derived with McClure et al. (1987) mass-luminosity relation assuming a power law mass function and three values of the power index* x. *The error bars indicate Poisson uncertainties (in cluster and field stars).*

high-quality CCD became available at the ESO 1.54 m Danish telescope in the early 80's (followed by the detectors installed at the 3.6 m and 2.2 m telescopes). It provided the European astronomers with the unique opportunity to share the venture of exploring the faint main sequence stellar population of the galactic GCs, particularly numerous in the Southern sky.

The parallel development of *ad hoc* reduction packages (e.g. DAOPHOT, INVENTORY, ROMAFOT) has also permitted to carry on accurate photometry of single stars in the very dense fields closer and closer to the cluster centers. This modern software allows also numerical simulations with artificial stars to evaluate the incompleteness caused by crowding and/or very low signal-to-noise ratios.

Among the most recent and prestigious outcomes of the state-of-the-art photometric observations of galactic GCs are the deep luminosity functions (LFs) of the main sequence stars. Theoretical models have been developed which allow us to transform these LFs into the corresponding mass functions (MFs). The latter (giving the number of stars per mass interval) represent the result of the dynamical evolution applied to the initial mass function (IMF), i.e. the mass function which characterized a cluster stellar population at the epoch of formation (cf. Spitzer 1987).

In the last few years, deep main-sequence LFs for several nearby clusters have been obtained at ESO and elsewhere (CTIO, CFHT, KPNO). An important result of all these studies is that the slope of the MF of the GC stars is not a constant: if the MF is modelled by a power law $\zeta(m) = \zeta_o m^{-(1+x)}$, the index x is found to vary in the interval from $x = -0.5$ (M4 and 47Tuc) to $x = 2.5$ (M15). By collecting and analyzing the available data, McClure and collaborators (1986) pointed out the existence of a strong correlation between the index x and the cluster metallicity ([Fe/H]). If the relation is real, and if it reflects a property intrinsic to the IMF, it has important consequences in our understanding of the chemical enrichment and star-formation history of the galactic halo (e.g. Smith and McClure 1987).

Stimulated by these results, we began a survey tailored to the facilities of the European Southern Observatory. The results for our first two targets, the metal-poor clusters NGC 7099 (M30), and NGC 6397, are at variance with McClure et al. (1986) relation.

NGC 7099

M30 is a high-concentration cluster located at high galactic latitude. It is also one of the most metal-poor clusters of the Galaxy ([Fe/H] = −2.19, Webbink 1986). Using photographic material, Piotto et al. (1986) noted that the c-m diagram of this old object (age ~16 Gyr) is not reproduced by theoretical isochrones calculated for the nominal metallicity (VandenBerg and Bell 1985). They showed also that the data are better represented assuming that M30 has an oxygen over-abundance ([O/Fe] = 0.7). These findings are fully confirmed by a more recent study based on CCD material of the ESO 2.2 m and the CTIO 4 m telescopes (Piotto et al. 1989).

At the ESO Workshop on "Stellar Evolution and Dynamics in the Outer Halo of the Galaxy", Capaccioli, Ortolani, and Piotto (1987) reported that the LF of M30 was much flatter than the luminosity function of the only other metal-poor cluster, M15 ([Fe/H] = −2.05), whose MF was available at that time (McClure et al. 1986). Recently Piotto et al. (1989) have derived the slope $x = 1.0 \pm 0.2$ for the MF in an outer ($r = 4\overset{'}{.}4$) region of M30 observed with the ESO 2.2-m telescope (Fig. 1). However, the MF obtained in this way is just a *local* MF; its slope can be quite different from that characteristic of the whole set of stars (*global* mass function) due to the mass segregation consequent to the dynamical evolution of the cluster. In order to investigate the dependence on distance from the centre of the observed power law index x in a relaxed cluster, Pryor, Smith and McClure (1986) have calculated mass-segregation corrections for GC MFs using multimass King-Michie models with power law mass function. The aim of this work was to evaluate the mass-segregation corrections needed to recover the global power law index x_o

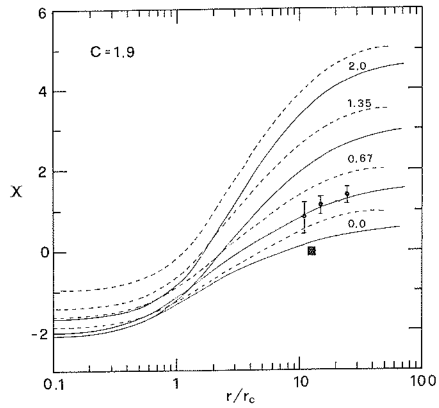

Figure 2: *Mass function power indexes (filled circles) for our three fields (the two inner fields are ESO data, while the outer one has been obtained from CTIO CCD frames) in M30 and for the composite NGC 6397 MF (filled triangle), compared with the theoretical predictions by a multi-mass King-Michie model with concentration parameter c = 1.9: solid lines are for isotropic models, dashed for anisotropic ones. The best estimate for the global power indexes is* $x_{0,M30} \simeq 0.7$, *and* $x_{0,NGC6397} \simeq -0.2$. *The trend of the data points for M30 is consistent with the occurrence of mass segregation. However, the effect to be measured is smaller than the errors.*

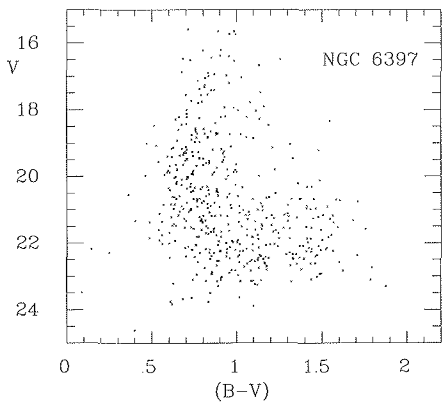

Figure 3: *Colour-magnitude diagram for the foreground/background stars towards NGC 6397.*

from the one observed at a given $\langle r \rangle$ (measured in units of core radius r_c). The models (computed for a set of concentration parameters $c = \log(r_t/r_c)$, where r_t is the tidal radius) predict an excess of the local (observed) MF exponent over the global exponent, x_o, at large distances from the centre: this is due to the fact that the most massive stars tend to concentrate towards the cluster centre. The effect is larger in models with steeper MF and higher central concentration. Assuming that M30 has r_t = 15′.8 and r_c = 15″, Piotto et al. (1989) have found an index x_o as small as 0.7, or even smaller if anisotropy in the outer velocity field is taken into account (Fig. 2). Note that Pryor et al. (1986) give x_o = 1.4 for the equally metal poor cluster M15.

The observed trend of the MF slopes at different radial distances is similar to that predicted by the multimass King-Michie models, though the differences between the indexes x found in the inner and outer regions are within 1 sigma (Fig. 2). In any case, Piotto et al. (1989) results seem to exclude the anomalous mass segregation in M30 suggested by Richer, Fahlman and VandenBerg (1988).

NGC 6397

NGC 6397 is one of the nearest globular cluster ($m-M \sim 12.5$). Being at low galactic latitude, its c-m diagram is strongly contaminated by the foreground/background (field) stars of the Galaxy. The c-m diagram of the (control) field stars is presented in Figure 3. Four cluster fields have been covered by B, V deep CCD exposures. We present here the preliminary results for two fields centred at 10′E and 7′W from the cluster centre. A detailed account will be given by Ortolani and Piotto in a forthcoming paper.

Figure 4a reproduces the c-m diagram of the outer region; the same diagram, after field star subtraction, is plotted in Figure 4b. The composite LF for the two regions is in Figure 1, together with the LF for M30 and the theoretical LFs, obtained using McClure, VandenBerg and Bell (1987) isochrones and a power law mass function with different slopes. The mass function for NGC 6397 is flat, with $x = 0$ or even smaller, in agreement with the conclusions of Alcaino et al. (1987) based on a smaller sample of stars. Adopting r_c = 0′.6 and c = 1.86 (Peterson and King 1975), and using the results of Pryor et al. (1986) calculations reproduced in Figure 2, we conclude that the global value of the slope of the mass function for NGC 6397 is $x \sim -0.2$.

Consequences

In Figure 5 we have plotted the observed (x) and global (x_o) power law indexes of the MFs of 10 GCs against their metal content [Fe/H]. It is evident that our new results cast some doubt on the McClure et al. (1986) relation. On the other hand it is not possible to explain the observed spread of the global power law index x_o just with observational errors, nor with the mass segregation alone (Pryor et al. 1986; note that their models tend to overestimate the mass segregation). Our new results do not change the picture.

There is no obvious interpretation for the apparently random behaviour of x. This might result from the combination of several factors, including the uncertainties of the models used to transform luminosity into mass functions (Renzini and Fusi Pecci 1989). It has been also speculated that the power law may not be a good representation of the MF.

Stellar populations other than those of GCs do not seem to present this large spread in the MF slopes. Scalo (1986) concludes that the differences in the index x among most galaxies are less than ±0.5. No systematic trends of the LF with the morphology of the parent galaxy or metallicity appear in the data, at least for stellar masses $m > 10 \div 20\ M_\odot$. At smaller masses, the LFs in several regions of the Large Magellanic Cloud agree with each other and with the solar neighbourhood LF, suggesting similar IMFs down to about 2 $M_\odot$. For the stars in the vicinity of the Sun, the value of x is likely between +1.3 and +2.4 for $m > 10\ M_\odot$, and x = +1.7 for lower stellar masses ($2 < m < 10\ M_\odot$). Up to now, no significant differences

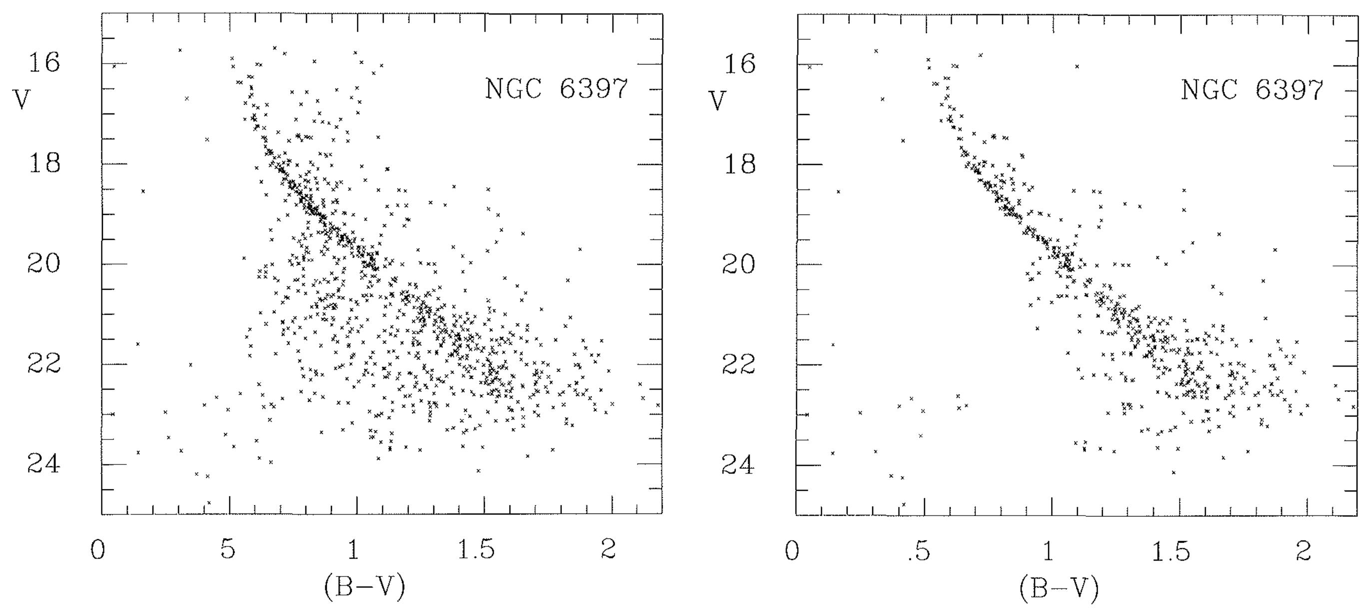

Figure 4: *Colour-magnitude diagram for the outer region of NGC 6397: a) original; b) after field stars subtraction.*

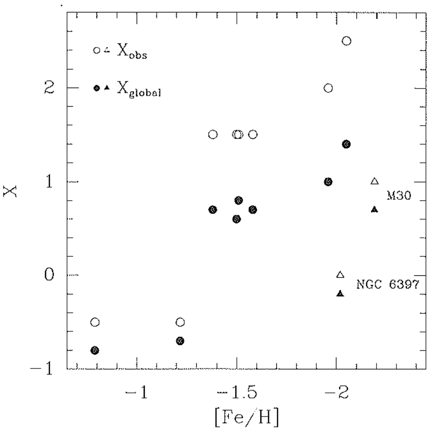

Figure 5: *Observed (light circles) and mass-segregation corrected (filled circles) power law exponents plotted versus metallicity. Note that the present sample seems to exclude any dependences of the MF slopes upon metallicity.*

have been found between the IMFs of disk and halo stars over the range $0.3 < m < 0.8\ M_\odot$. However, we shall note that these investigations consider heterogeneous samples of stars and regions of a vast stellar system which may have experienced a different evolution.

For all these reasons we have started a long-range project aimed at investigating the luminosity functions in different stellar populations. In the present phase we are studying GCs with different structure parameters, with a particular attention for the clusters with low concentration or long relaxation times (such as NGC 1261, M55 and M4), where the amount of mass segregation is expected to be small, and a few irregular galaxies resolved in stars.

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Molecular Hydrogen Emission from Star-forming Regions in the Large Magellanic Cloud

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1. Introduction

Molecular hydrogen is probably the most abundant molecule of the interstellar medium. Giant molecular clouds consist mainly of H_2. There are limited possibilities for direct observations of the H_2 molecule.

Within the ground electronic state, all rotation-vibration transitions are forbidden for electric and magnetic dipole transitions. The electronic transitions in the Lyman and Werner bands of the H_2, which occur in the UV range of the spectrum, can be observed in absorption against the continuum spectrum of bright stars. Due to the strong interstellar extinction in the ultraviolet, such observations are limited to nearby, low-density interstellar clouds. In giant molecular clouds the extinction prevents such observations. The excitation of the electric quadrupol transitions in the near infrared around 2 μm requires high excitation temperatures (≥ 1000 K). Such high excitation temperatures can be obtained by collisional excitation in regions behind shock fronts (Shull and Beckwith, 1982) or intense ultraviolet radiation from bright massive stars (Black and van Dishoeck, 1987).

The first detections of near-infrared H_2 quadrupol emission from star-forming regions in the Magellanic Clouds were reported from Koornneef and Israel (1985) and Israel and Koornneef (1987).

Compared to spiral galaxies, the Magellanic Clouds have, like other irregular galaxies, a lower metallicity, a low dust content and very weak CO line emission. Direct observations of the H_2 molecule can help to clarify whether these characteristics imply a considerable underabundance of H_2 or not.

2. Observations and Reduction

At the beginning of January 1988, we used the cooled infrared grating spectrometer IRSPEC (cf. Moorwood et al. 1986) attached to the ESO 3.6 m telescope to search for H_2 emission from star-forming regions in the Large Magellanic Cloud. The entrance aperture was 6″ × 6″ and the spectral resolution about 2000. For the flux calibration, flat fielding and cancellation of atmospheric absorption, the object spectra were divided by the spectrum of a standard star that has been observed at a similar air mass with the same instrument settings. The sky background was cancelled by chopping 60″ in declination. The total on-source integration times were 30 to 40 minutes.

The observed H_2 spectra were calibrated with the spectrum of the standard star HR 2015. The infrared magnitudes for this star and the absolute flux densities for zero magnitude are given by Koornneef (1983 a, b). The flux density distribution of HR 2015 in the photometric K-band window (1.9–2.5 μm) is given by

$$F\lambda\ (\mathrm{W\ cm^{-2}\ \mu m^{-1}}) = 8.43\ 10^{-16}\ \lambda^{-3.75} \quad (1)$$

We observed two compact infrared sources of non-stellar nature within the H II regions N 160 A and N 10, found by Jones et al. (1986). N 160 A is located in a molecular cloud (see Figs. 3 and 4) that itself belongs to an extremely large complex of molecular clouds extending south from 30 Doradus for over 2000 pc (Cohen et al., 1987). N 10 is also embedded in a molecular cloud complex (see Fig. 5). The CO observations have been carried out later than the H_2 observations. The beam size was 43″. We find