European Organisation for Astronomical Research in the Southern Hemisphere

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

VISITING ASTRONOMERS DEPARTMENT • Karl-Schwarzschild-Straße 2 • D-85748 Garching bei München • e-mail: visas@eso.org • Tel. : +49-89-32 00 64 73

Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of CoIs and the agreement to act according to the ESO policy and regulations, should observing time be granted

1. Title Category: **D–2**

The low-mass IMF in the Magellanic Clouds

2. Abstract

We propose to probe the field star Initial Mass Function (IMF) in the Large and Small Magellanic Clouds in the subsolar range down to 0.2 $M_{\odot}$. This mass interval has the great advantage of probing a segment of the IMF where it coincides with the Present-Day Mass Function (PDMF), and where pre-main sequence evolutionary timescales can be effectively neglected. Together with the fact that all the stars in the LMC and SMC can be considered to be at the same distance and that internal extinction is negligible in the infrared throughout most of their disks, these properties combine to provide the most robust, hypothesis-free determination of the IMF, in which the only ingredient needed is the main sequence luminosity-mass transformation. The determination of the low-mass IMF in the Magellanic Clouds will enable a direct comparison with the low-mass IMF in the solar vicinity determined by GAIA, revealing possible effects of metallicity on the universality of the IMF.

3.

Run	Instrument	Time	Month	Moon	Seeing	Sky Trans.	Obs.Mode
A	DLI	174h	dec	n	n	CLR	s

4. Principal Investigator: F. Comerón (ESO, ESO, fcomeron@eso.org)

CoI(s): H. Zinnecker (Potsdam, D)

5. Is this proposal linked to a PhD thesis preparation? State role of PhD student in this project

6. Description of the proposed programme

A) Scientific Rationale: The initial mass function is one of the main observational signatures of the complex interplay among the different processes leading to star formation (see e.g. Bonnell, Larson, and Zinnecker 2007, in Protostars and Planets V, Univ. of Arizona Press for a recent review). Although many observational signatures of the star formation process are lost as star forming aggregates disperse in phase space, the shape of the mass function in the field still encapsulates fundamental information on the processes that dominated the star forming history of the different structural components of the Galaxy, as can be appreciated from recent exhaustive reviews of the initial mass function (Chabrier 2003, PASP, 115, 763). At the same time, observationally populating the low-mass end of the temperature-luminosity diagram constrains the theoretical modeling of stellar and substellar interiors, structure, and evolution (e.g. Baraffe et al. 2003, A&A, 402, 701 for the lowest masses around the brown dwarf limit).

Dramatic improvements in the determination of the stellar and substellar initial mass functions have taken place in the last decades thanks to dedicated surveys and follow-up spectroscopic and astrometric observations (e.g. Reid et al. 1999, ApJ, 521, 613; Reid et al. 2002, AJ, 124, 2721). Substantial further improvements are expected in the next decade. On the one hand, deep, wide area imaging surveys like those to be carried out by VISTA will supply statistically significant numbers of objects at the faint end of the field luminosity function, revealed by the unusual infrared colors of L and T dwarfs. On the other hand, GAIA will provide an accurate, complete 3-D rendering of the solar neighborhood down to $V \simeq 21$ that will result in complete census of all the field stars above the substellar limit (0.075 $M_\odot$) up to a distance of 10 pc, and all the stars with masses above 0.1 $M_\odot$ up to 100 pc. Follow-up spectroscopy of the objects revealed by those surveys will enable accurate determinations of individual temperatures and metallicities, which are expected to result in robust determinations of the complete initial mass function and its possible evolution over the life of the Galaxy, at least at the low-mass end whose upper limit is defined by the turn-off mass of the main sequence at the present age of the Galaxy.

Compared to our detailed knowledge of the galactic stellar and substellar mass function, very little is known about the low mass contents of the Magellanic Clouds near or below one solar mass. Recent HST observations carried out with WFPC2 and ACS, reaching down to or near ~ 0.7 $M_\odot$ (Gouliermis, Brandner, and Henning 2005, ApJ, 623, 846; Gouliermis, Brandner, and Henning 2006, ApJ, 641, 838; Chiosi and Vallenari, 2007, A&A, 466, 165; Sabbi et al. 2008, AJ, 135, 173), have made possible to investigate for the first time the subsolar IMF in both the LMC and the SMC. One of the main drivers of these studies is the observational detection of possible differences in the initial mass function between the Magellanic Clouds and the solar neighborhood. Such differences may arise from the star formation processes taking place in environments of overall lower metallicity of the interstellar gas (40% solar for the LMC, 15% solar for the SMC; Hunter et al. 2007, A&A, 466, 277).

The results of these studies hint at possible differences between the initial mass function in at least some regions of the LMC and the solar vicinity. Indeed, Gouliermis et al. (2005) report indications of a steeper IMF in young Lucke/Hodge associations. However, the IMF near young associations may be biased by assumptions on the history of star formation or by foreground or background contamination by stars in the same galaxy. The reality of such biases is supported by observations of other fields, since no such differences are found in the observations of three moderately young clusters in the SMC (Chiosi & Vallenari 2007), in NGC 346 also in the SMC (Sabbi et al. 2008), nor in the observations of the LMC field population outside the bar carried out by Gouliermis et al. (2006). Both studies report initial mass functions consistent with the solar neighborhood one, at least down to the moderately subsolar masses probed. However, the absence of evidence for a metallicity-dependent IMF from those studies cannot be interpreted as evidence of the universality of the IMF independently of the metallicity. In the first place, the portion of the IMF sampled by those observations only barely enters the regime where the observed present-day mass function (PDMF) coincides with the IMF, and star formation history effects thus need to be corrected for, with the subsequent uncertainty. Such corrections are particularly difficult for dwarf galaxies such as the Magellanic Clouds, where ample evidence exists showing that major bursts of star formation took place at irregular intervals (see Skillman et al. 2003, ApJ, 596, 253 for a typical example). In fact, evidence for such bursts in their observed fields is discussed in the work by Chiosi & Vallenari (2007). In addition, metallicity effects may play an increased role towards lower masses as the stellar mass approaches the Jeans mass in the interstellar medium out of which the stars form. It would thus be premature to conclude from those studies alone that the entire field IMF in the Magellanic Clouds is indistinguishable from the solar vicinity IMF or, more generally, that the shape of the IMF is insensitive to the metallicity.

The project proposed here attempts to test the universality of the faint end of the IMF in the Magellanic Clouds probing down to a mass as low as 0.2 $M_\odot$, as the analysis and interpretation of the results is greatly simplified and made more robust in this domain. Below the mass corresponding to the main sequence turnoff of the oldest stars in the Magellanic Clouds the PDMF and the IMF coincide, and the IMF becomes insensitive to the star formation history or to background or foreground contamination by stars of the same galaxy. Pre-main sequence evolution is not an issue, since the evolution toward the main sequence is essentially complete within 100 Myr at the lower end of the mass range, and is even faster for higher masses. By choosing a region free from extinction and nebulosity (the nearly face-on view of the Clouds from our vantage points makes differential dust extinction effects negligible, especially at the near infrared wavelengths where we propose to carry out our

6. Description of the proposed programme (continued)

observations), the luminosity function is derived simply by star counts as a function of the apparent magnitude, as all the stars in each of the Clouds can be considered to lie at the same distance for any practical purposes. This luminosity function can be translated into the low-mass field stellar IMF and be compared with the corresponding distributions in the solar neighborhood (e.g. Reid et al. 2002. AJ 124, 2721), since all the stars can be safely assumed to have reached the main sequence, and the transformation from luminosity to mass is straightforward and free from any evolutionary effects. A comparison between the field star luminosity function in the LMC and SMC will be extremely valuable given their substantially different metallicities, which could offer unique clues as to whether metallicity effects are important in low-mass star formation. This part of the project thus aims at producing the most direct determination possible of a complete low-mass initial mass function over a relatively broad but still limited mass range, even overcoming effects that are unavoidable in the solar neighbourhood.

B) Immediate Objective: We propose to take deep adaptive optics images in the JHK_S bands in several fields in the LMC and the SMC, clear of extinction and nebulosity, to infer the luminosity function of low-mass main sequence stars with masses between 1 and 0.2 $M_\odot$. Near-infrared is preferred, as the target stars are red and adaptive optics works best in the near-infrared. Using the stellar density above 0.7 $M_\odot$ measured by Gouliermis et al. (2005) at the transition region between the LMC bar and the disk, and extrapolating using the galactic IMF down to 0.2 solar masses, we expect an angular surface density of about one star per arcsec^2 down to 0.2 $M_\odot$. The quantity is highly uncertain due to the present lack of determinations of the low-mass IMF in the LMC and SMC, which is the goal of this project. In a $20'' \times 20''$ image, there will be some 400 objects for which we need to obtain good near-infrared photometry (3% accuracy). Depending on the actual AO performance the observed LMC field could be selected either closer to the bar or in the outer disk, so as to increase or decrease the expected surface density, respectively. We expect less severe crowding problems at the SMC due to its lower surface density. We want to reach stars with masses as low as 0.2 $M_\odot$, which have absolute K magnitudes $M_K = 7.5$ (Baraffe et al. 1998, A&A, 337, 403). Given a distance modulus of 18.5 mag to the LMC, our faintest stars to be measured should be around $K = 26$ (J magnitudes up to 1 mag fainter). We will have to choose fields with a bright field star for wavefront sensing, which could be a foreground galactic star. GLAO will be used due to the need to have a good, and above all uniform, image quality over a field of view a few tens of arcsecond across. The instrument to be used as a reference should be the LTAO/MCAO diffraction-limited imager, used in GLAO mode.
Regarding simulations, this project is similar to those aiming at the study of resolved stellar populations in a very crowded field. The color range (and the physical properties) of the targets, and more importantly their luminosity distribution, vary. The performance of GLAO determines the target field: simulations at different distances from the most crowded regions of each galaxy (represented by different stellar surface densities) will show which is the largest amount of crowdedness that can be accepted while the mass function is still completely probed over the whole desired mass interval. The input to be provided to the simulations is a detailed monochromatic luminosity function and color distribution based on realistic expectations on the IMF, leaving the actual stellar surface density as a free parameter to be explored. The simulations should then verify the recoverability of the photometry of the faintest objects at different stellar surface densities.

C) Telescope Justification: Ground-based observations with current instrumentation cannot go to the required levels of depth.

D) Strategy for Data Reduction and Analysis: This is straightforward, GLAO-assisted imaging. The most challenging part will be the photometry of the faintest sources, but no analysis techniques other than those already in use for extragalactic resolved populations studies are necessary.

7. Justification of requested observing time and lunar phase

Lunar Phase Justification: This is imaging in the infrared, so any lunar phase is acceptable.

Time Justification: (including seeing overhead) JHK_S imaging down to $J = 27$, $H = 26.5$, $K_S = 26$ at S/N=10 at that magnitude limit is desired. The minimal requirement is one field in the LMC and another in the SMC. ETC estimates for the GLAO-assisted case are 13h at J, 35h at H, and 40h at K_S. This would require about 87h per field, or 174h for two fields. In practice it would desirable to probe several fields at different location in each galaxy, thus multiplying the 87h per field by the number of fields.

Calibration Request: Standard Calibration

8. Instrument requirements

Diffraction-limited imager:
Wavelength range required: from 1.2 μm to 2.4 μm.
Field of view of at least $20'' \times 20''$.
GLAO imaging, no diffraction-limited performance needed.

9. List of targets proposed in this programme

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
A	LMC	05 20 00	-69 00 00	20				
A	SMC	00 50 00	-73 00 00	20				

Target Notes: Fields selected in the general area of each galaxy.