Photometric Determination of the System-IMF of the 25 Orionis Stellar Group

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Abstract

We present advances towards the construction of the photometric system IMF of the 25 Orionis stellar group (25 Ori) from optical and near-infrared photometry from DECam and CIDA Deep Survey of Orion, as well as the public UCAC4, VISTA and 2MASS catalogs. Selection of the 25 Ori photometric member candidates was made on the basis of their positions in the Ic vs $Ic-J$ color-magnitude diagram with an estimated efficiency of 82% (Downes *et al.* 2014). The mass range covered by this study goes from 9 M_{jup} up to 12.9 $M_\odot$, according to the models of Baraffe *et al.* (2015) and Marigo *et al.* (2017).

Introduction

The IMF is one of the most important functions in modern astrophysics because it is an essential input to many astrophysical studies. There are a large number of studies of the IMF in different stellar populations (e.g. Bastian et al. 2013), however, only few of those cover the whole stellar mass range in spatially complete surveys (e.g. Peña et al. 2012).

In this work we present the advances toward the construction of the system IMF of 25 Ori, first with photometric candidates and then, in an ongoing study, with a statistically complete sample of spectroscopically confirmed members covering the estimated stellar mass range of the group ($0.01< m/M_\odot < 10$; Downes *et al.* 2014).

25 Ori is an ideal group to carry out this study due to the following properties: *i*) distance of 330-360 pc, *ii*) $7-10$ Myr old, *iii*) extinction of $\bar{A}_V \approx 0.30$ mag and *iv*) a radius of $\approx 1.0°$ (Kharchenko *et al.* 2005, Briceño *et al.* 2005, 2007, Downes *et al.* 2014, Brown *et al.* 2016, Suárez *et al.* 2017). Downes *et al.* (2014) determined the IMF of 25 Ori with photometric candidates in the mass range $0.03< m/M_\odot < 0.80$. In this ongoing study we extend the mass range coverage of the 25 Ori IMF down to the planetary mass domain and including the massive members of the group.

Photometric Data

Optical:
- DECam (PI. G. Suárez)
- CDSO (Downes *et al.* 2014)
- UCAC4 (Zacharias *et al.* 2013)

Near-infrared (NIR):
- VISTA (Petr-Gotzens *et al.* 2011)
- 2MASS (Skrutskie *et al.* 2006)

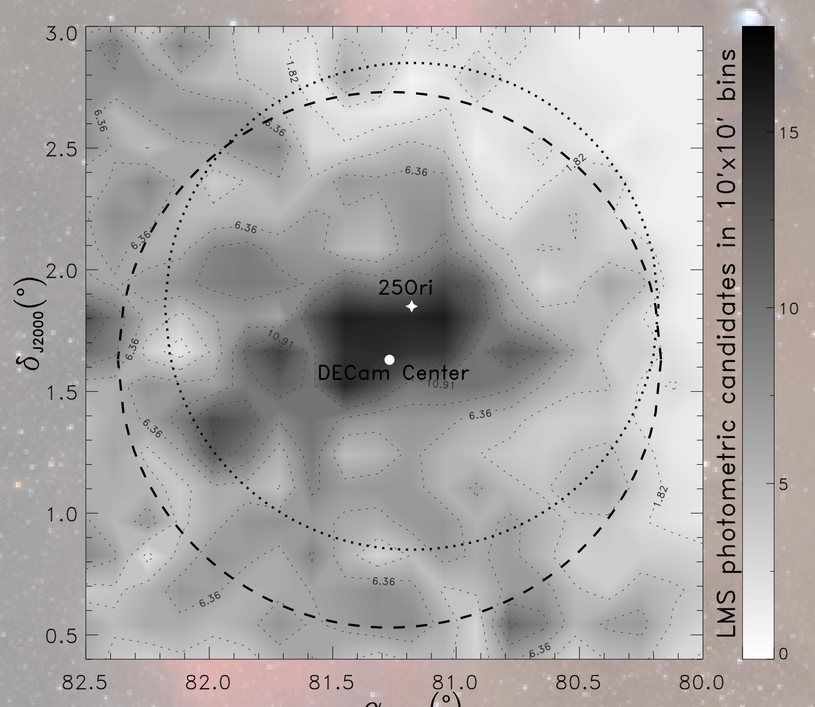


Figure 1 : *Spatial coverage of the photometry considered in this work. The dashed and dotted circles represent the FOVs of the optical and NIR photometry toward 25 Ori and the estimated area of 25 Ori (∼ 1° radius; Briceño et al. 2005, 2007), respectively. The gray background map indicates the LMS and BD photometric candidate density in 10'x10' bins from Downes et al. (2014).*

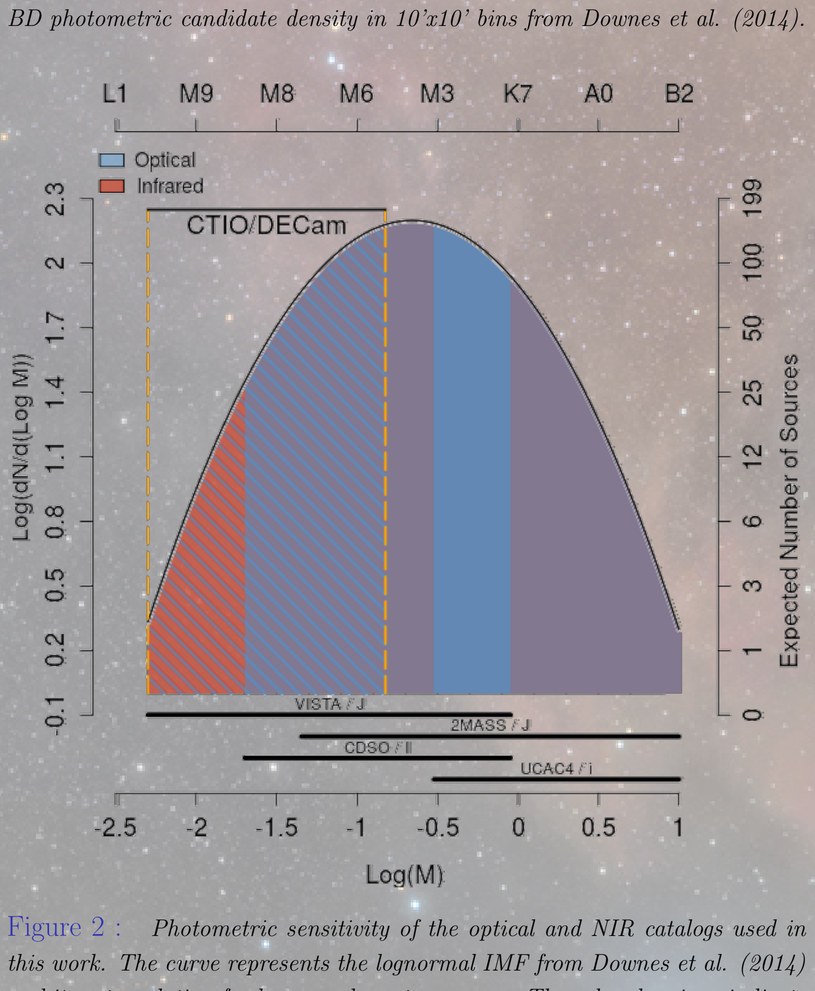


Figure 2 : *Photometric sensitivity of the optical and NIR catalogs used in this work. The curve represents the lognormal IMF from Downes et al. (2014) and its extrapolation for lower and greater masses. The colored regions indicate the mass range covered by the different photometric catalogs. We have optical and NIR photometry in the whole stellar mass range of 25 Ori. Note that when the sensitivities of the catalogs overlap the colors in the plot are combined.*

Spatial Completeness and Photometric Sensitivity.

Survey	Photometric Band	Area [%]	Saturation (mag)	Completeness (mag)	Limiting (mag)
DECam	Ic	≈ 75	16.0	24.0	25.0
CDSO	i	100	13.0	20.0	21.5
UCAC4	i	100	6.0	15.0	16.0
VISTA	J	100	4.0	16.0	17.0
2MASS	J	100	12.0	20.5	21.5

Selection of Photometric Candidates

The sources falling inside a locus defined in the Ic vs $Ic-J$ diagram, according to the previously confirmed members, were selected as 25 Ori photometric member candidates. To remove the contamination in our candidate sample we subtracted the objects inside the membership locus obtained *i*) from an observed control field at the same galactic latitude and *ii*) from a simulation of the expected galactic population in the 25 Ori field performed with the Besançon model (Robin et al. 2003).

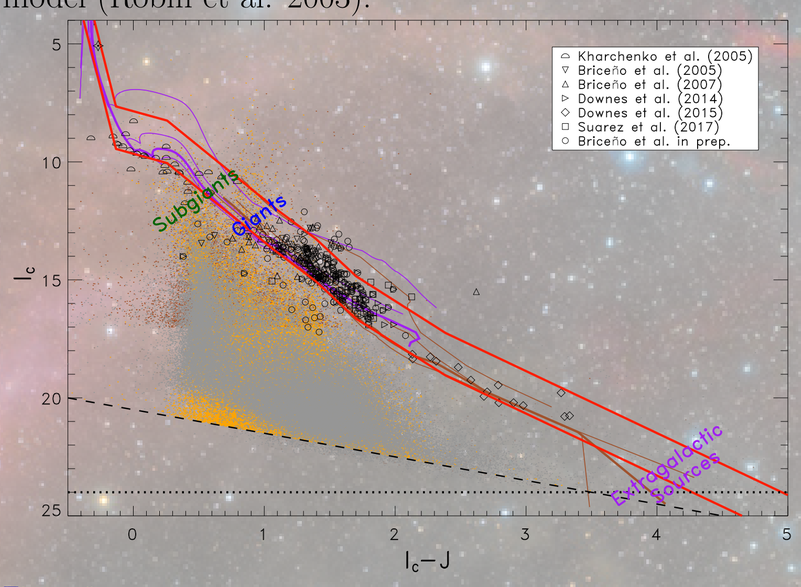


Figure 3 : *CMD used to select the photometric candidates to 25 Ori members. The confirmed members (see label) trace a clear sequence shown by the red lines. The dotted and dashed lines represent the completeness limits of the DECam and VISTA catalogs, respectively. The 1, 5, 8 and 10 Myr isochrones from Baraffe et al. (2015) and Marigo et al. (2017) are indicated by the purple and brown curves, respectively. The gray, brown and orange points show, respectively, the observations toward 25 Ori, the observation in a control field and the field stars simulated by the Besançon models (Robin et al. 2003).*

Sources Inside the Locus.

Origin	Number of sources	Ic range (mag)
25 Ori FOV	1295	[5.08, 24.85]
Control Field FOV	656	[8.16, 23.3]
Besançon Model	428	[8.07, 18.0]

LF and system IMF

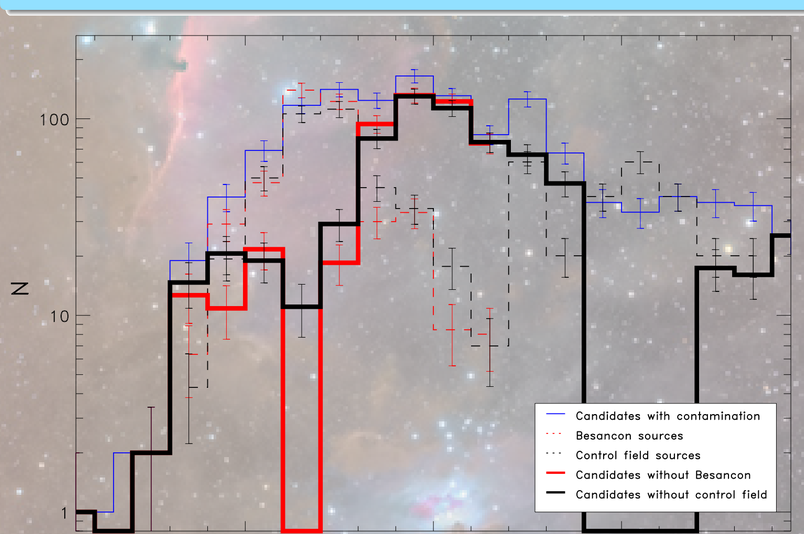
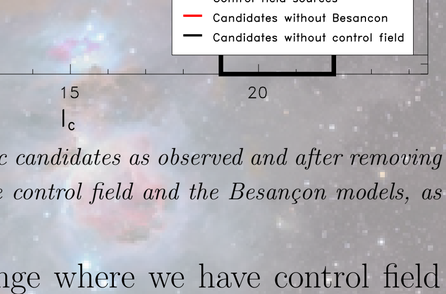


Figure 4 : *LFs of the photometric candidates as observed and after removing the contamination according to the control field and the Besançon models, as indicated in the label.*

Within the brightness range where we have control field and Besançon model sources, the estimated source counts are consistent within the Poisson uncertainties, except in the intervals where the subgiant and giant star branches cross the 25 Ori locus (see Figure 3). In this narrow mass interval the system IMF remains undetermined. Membership confirmation is needed for such determination.
Using the Baraffe *et al.* (2015) and Marigo *et al.* (2017) models we interpolated the Ic brightness of the sources inside the locus to estimate their masses. The mass range covered by our photometric candidates goes from 9 M_{jup} to 12.9 $M_\odot$.

Figure 5 : *Mass-Ic relation used to calculate the masses of the 25 Ori photometric candidates, control field sources and simulated stars falling inside the locus on the basis of their Ic magnitudes. The relation corresponds to an age of 8 Myr and is a combination of the Baraffe et al. (2015) and Marigo et al. (2017) models.*



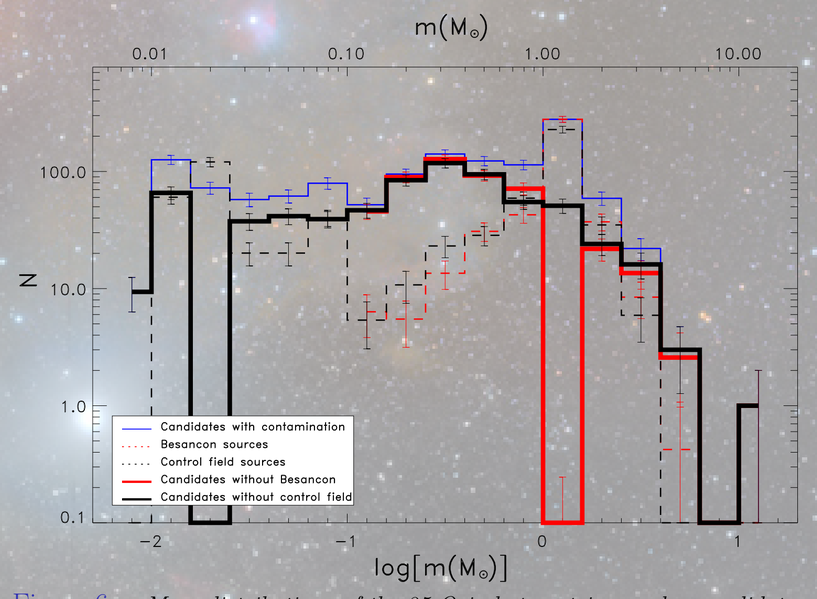


Figure 6 : *Mass distributions of the 25 Ori photometric member candidates.*

The peak of the resultant IMF is close to 0.3 $M_\odot$, which is consistent with the study of Downes *et al.* (2014). For mass values above the IMF peak, the change of the slope occurs at ~ 1 $M_\odot$, as predicted by Kroupa *et al.* (1993). The shape of the system IMF in the planetary mass domain ($m < 20 M_{jup}$) is still affected by the contamination from extragalactic sources. Its correction in this unprecedentedly deep observations of this low extinction region is still ongoing work.

Follow-up Spectroscopy

To confirm the membership of the photometric candidates and to determine their physical parameters (effective temperature, extinction, bolometric luminosity, age and mass), we have obtained spectra for about 80% of the candidates in our sample, taking advantage of several spectrographs to cover different mass ranges.

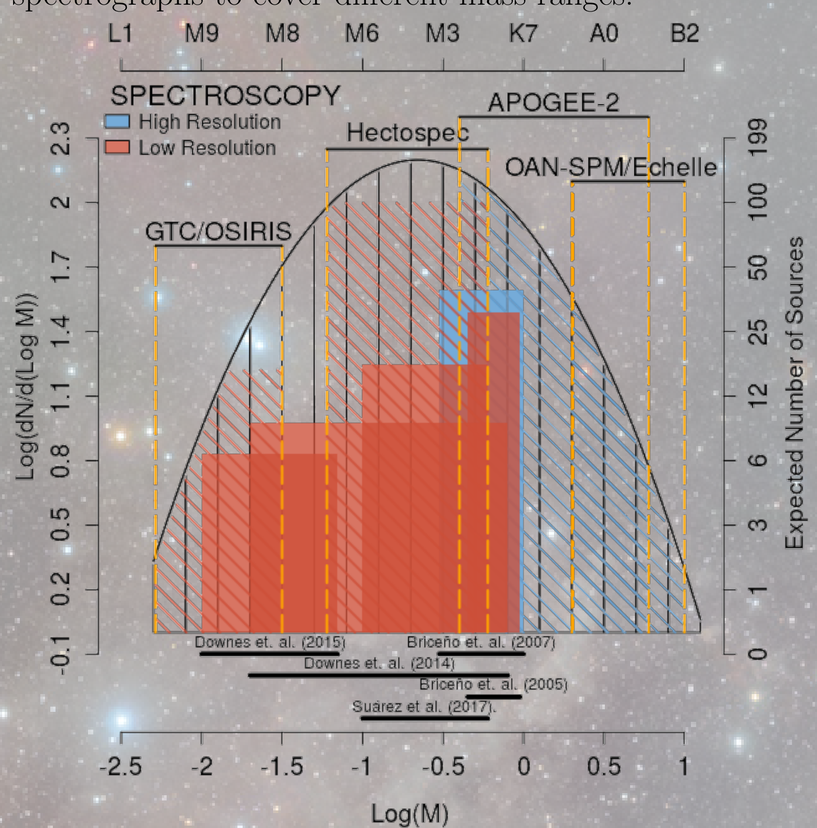


Figure 7 : *Completeness of our spectroscopic follow up of the photometric member candidates of 25 Ori. The curve is the same as in Figure 2. The colored histograms represent the spectroscopic completeness achieved with several facilities in specific mass ranges.*

As a first result of this spectroscopic follow up, we have used SDSS-III/BOSS spectra to confirm 50 new low-mass stars as members of 25 Ori and Orion OB1a on the basis of the H_α emission, LiIλ6708 absorption and weak NaI$\lambda\lambda$8183, 8195 doublet youth indicators and analyzed their H-R diagrams and spectral energy distributions (Suárez *et al.* 2017).

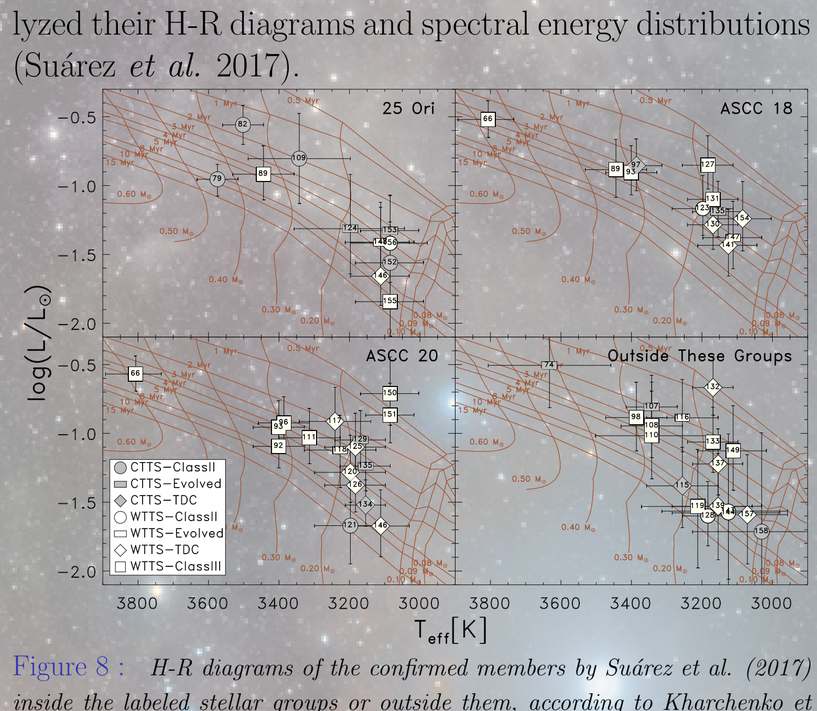


Figure 8 : *H-R diagrams of the confirmed members by Suárez et al. (2017) inside the labeled stellar groups or outside them, according to Kharchenko et al. (2013). The gray curves represent the PMS Baraffe et al. (2015) models.*

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References

Baraffe *et. al.* 2015, A&A, 557, A42
Bastian *et. al.* 2012, ARAA, 48, 339
Brown *et. al.* 2016, A&A, 595, A2
Briceño *et. al.* 2007, ApJ, 129, 907
Briceño *et. al.* 2005, ApJ, 661, 1119
Downes *et. al.* 2014, MNRAS, 444, 1793
Downes *et. al.* 2015, MNRAS, 450, 3490
Kharchenko *et. al.* 2005, A&A, 440, 403
Kharchenko 2013, A&A, 558, A53
Kroupa 1993, MNRAS, 262, 545 Marigo *et. al.* 2017, ApJ, 835, 77
Peña *et. al.* 2012, ApJ, 754, 30
Petr-Gotzens *et al.* 2011, The Messenger, 145, 29
Robin *et. al.* 2003, A&A, 409, 523
Skrutskie *et al.* 2006, AJ, 131, 1163
Suárez et al. *et. al.* 2017, AJ, in press arVix: 1705.02722
Zacharias *et al.* 2013, AJ, 145, 44