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OPTIMIZATION OF SOURCE EXTRACTION & GALAXY LUMINOSITY FUNCTION OF THE CLUSTER OF GALAXIES ABELL 85

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Abstract. Observational astronomy is characterized by an increasing number of large surveys from which catalogs of several tens of millions of celestial objects are extracted. For this reason, astronomical image analysis should be performed with fast automatic tools such as SExtractor (Bertin & Arnouts 1996). We present here an optimization of the extraction parameters of SExtractor from simulated images (using SkyMaker by E. Bertin). We implemented it on deep multiband images of the cluster of galaxies Abell 85 obtained with the MegaPrime/MegaCam imaging facility at the CFHT. Using the optimized parameters, we reach both a completeness and a reliability of 90% at $i = 24.5$, which means a gain of 0.5 to 1 magnitude in galaxy extraction. Moreover, we introduce here two filters to reduce artefacts. This should allow to derive its galaxy luminosity function (GLF) deeply.

1 Introduction

Extraction of celestial objects from astronomical images is not as easy as one could think. Indeed, it often happens that people need to extract numbers of objects and for that, they use automatic tools such as the popular SExtractor (Bertin & Arnouts 1996). Nevertheless, there are several parameters that must be tuned and for a given configuration it can miss many objects or on the opposite extract a lot of artefacts. We will illustrate these difficulties on the measurement of the galaxy luminosity function (hereafter GLF) of the cluster of galaxies Abell 85 which shows characteristics of recent mergers (Durret et al. 2005). The reason why it is important to detect faint objects for this kind of measurement is that in clusters, galaxies undergo many physical and dynamical interactions which modify their properties and affect the GLF. Particularly, Popesso et al. found in 2006 a steeper faint end in cluster GLF than in the field. It is thus interesting to see if Abell 85, which is not relaxed, has the same GLF. Whatever the results, they will constrain the formation of faint galaxies.

2 SExtractor parameters

SExtractor is a software developed by Bertin & Arnouts (1996) that creates a catalog of objects from an astronomical image. It passes twice through the entire image. During the first pass, it builds a background and a root mean square map and, in the second pass, it performs the detection and photometry measurement on the filtered, background subtracted image using a threshold. The **filter** as well as the **threshold** can be chosen by the user. It is clear that the lower is the signal to noise ratio, the wider should be the filter and the higher the threshold. But what is the relation between these quantities, if it exists, and what are the effects of the seeing and crowding?

Moreover, if the chosen parameters are too low and noise is detected, then priors can be used to select the most probable objects from the catalog. For instance, it can be assumed that elongated detections with very thin **semi-minor axes** (typically less than one pixel) are artefacts. An other prior is related to the **windowed coordinates** given by SExtractor. They are gaussian weighted barycenters instead of standard barycenters. These positions should not be very different from one another for real sources (except the brightest - and largest - galaxies), but we observe great deviations for some faint detections ($i > 24$), as shown in Fig. 1.

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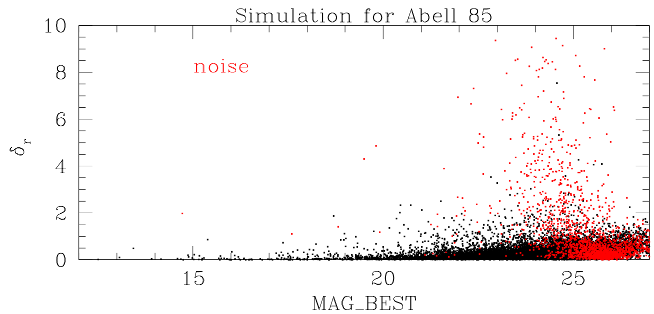


Fig. 1. Distance δ_r between the weighted and standard barycenters of each object versus i-band magnitude. This allows to distinguish between true (black) and fake (red) objects. We see that many artefacts have large δ_r.

3 Data

The extraction was performed on images of the cluster Abell 85. The observations were done with the MegaPrime/MegaCam imaging facility at the CFHT in October 2004. Images were then bias corrected, flat-fielded and astronomical centered by the TeraPix data center at the IAP. We get one stacked image in each of the four bands u, g, r, i. But as the seeing was best in the i-band ($0.85''$compared to about $1.3''$ in the other bands), we chose to perform the detection on the i image, and photometry in all bands using the two-image mode of SExtractor. For that reason, we only show here the optimization we did for the extraction on the i image. Furthermore, as we aim to build the GLF of Abell 85, we need to subtract field galaxies. For that, we use the four i-band CFHTLS Deep fields, on which optimization was done as well.

4 Criteria and simulation

The idea of the optimization is to run SExtractor on the same image with different sets of parameters (filter width, threshold, minimum semi-minor axis and maximum separation of weighted and standard barycenters) and select the ones which give the best extraction. The goodness of each extraction is computed as a combination of completeness $\mathcal{C}$ and reliability $\mathcal{R}$ defined as follows:

$$\mathcal{C} = \frac{N_{\rm true,detected}}{N_{\rm true}} \qquad \mathcal{R} = \frac{N_{\rm true,detected}}{N_{\rm detected}}$$

where $N_{\rm true}$ is the number of real sources up to a magnitude limit, $N_{\rm detected}$ the number of detections up to the same magnitude and $N_{\rm true,detected}$ the number of real detections. As we attach the same importance to both completeness and reliability, we minimize:

$$\mathcal{F} = (1-\mathcal{C})^2 + (1-\mathcal{R})^2.$$

Nevertheless, completeness and reliability cannot be measured on extractions over real images as real source positions are unknown, at least for the faintest ones.

To solve this problem, we simulate images using SkyMaker (version 3.0.2 E. Bertin). For relevant completeness and reliability measurements, we create images with the same point spread function and the same signal to noise ratio as on the real one. The input catalog is composed of a double Schechter GLF for the cluster (Popesso et al. 2006), a single Schechter GLF for the field (Blanton et al. 2003) and a star catalog generated by the Besançon model (Robin et al. 2003). Furthermore, in order to be more realistic, we modified SkyMaker to produce not only exponential and De Vaucouleurs profiles but also more general Sérsic profiles.

5 Optimization and results

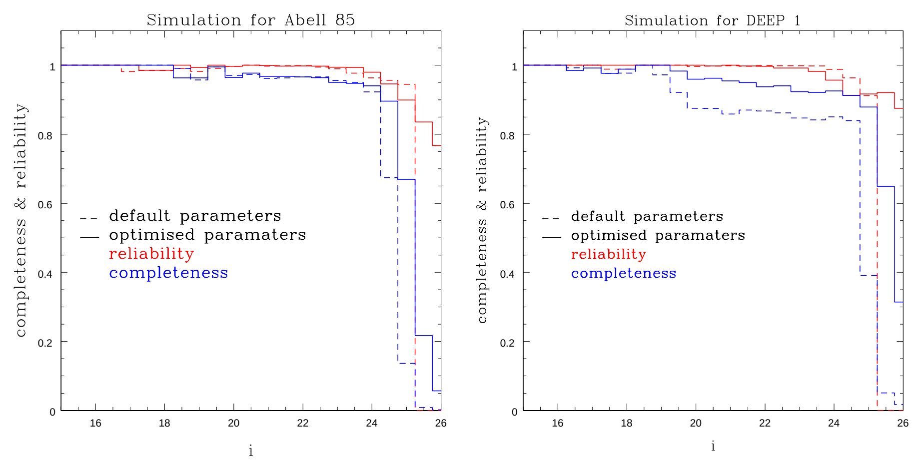
The optimization was done using the Powell algorithm (Numerical Recipes) on simulated images of Abell 85 and of the four Deep fields. Those images are 10000×10000 pixels to have enough statistics. The optimum parameters are listed in Table 1. As the four Deep fields are deeper than the image of Abell 85, i.e. the signal

image	filter FWHM	threshold	semi-minor axis	δ_r
Deep1	1.00	4.60	0.63	2.64
Deep2	1.03	5.74	0.29	3.07
Deep3	1.00	6.60	0.30	2.88
Deep4	1.00	5.85	0.36	2.90
A85	2.13	2.60	0.77	2.40

Table 1. Optimized SExtractor extraction parameters obtained for simulated images of Abell 85 and the four Deep fields up to a magnitude limit $i = 25$. Smoothing filters are gaussian and the full width at half maximum is given in pixels. Detection thresholds given here are relative to the standard deviation of smoothed images. Minimum semi-minor axes and upper limits of distances δ_r between positions measured by SExtractor are given in pixels.

to noise ratio is higher, it is less necessary to smooth and detection thresholds are higher. In all cases, the lower limit on the semi-minor axis is a fraction of a pixel and the distance δ_r between the two positions measured by SExtractor is around three pixels.

Comparisons of the completeness and reliability in bins of magnitude between extractions with default and optimal parameters are given in Fig. 2. It can be checked that using optimal parameters, one can go between one half and one magnitude deeper in completeness while being more reliable.



(a) Abell 85. (b) CFHTLS Deep field.

Fig. 2. Completeness and reliability before and after optimization measured for Abell 85 and a CFHTLS Deep field on simulated images.

Using these optimized parameters, the GLF of Abell 85 is obtained by subtracting the median of the Deep field counts from the cluster image counts. The resulting GLF is shown in Fig. 3. Figure 3 displays a dip around $i = 18$ and a fall towards $i = 22$ whereas the completeness reaches $i = 24.5$. Because of cosmic variance, it is not clear whether this fall is real or not. For that reason, work is on progress to subtract the mean of the 59 subfields of the CFHTLS wide field survey. Conclusions will be more reliable only after this work.

6 Conclusion

Simulated images allow to measure completeness and reliability of galaxy extractions. They also allow to improve extraction parameters to gain between one half and one magnitude towards faint objects. Nevertheless this algorithm is time consuming and it would be efficient to find relations between the optimal parameters and the characteristics of images such as seeing, signal to noise ratio and crowding.

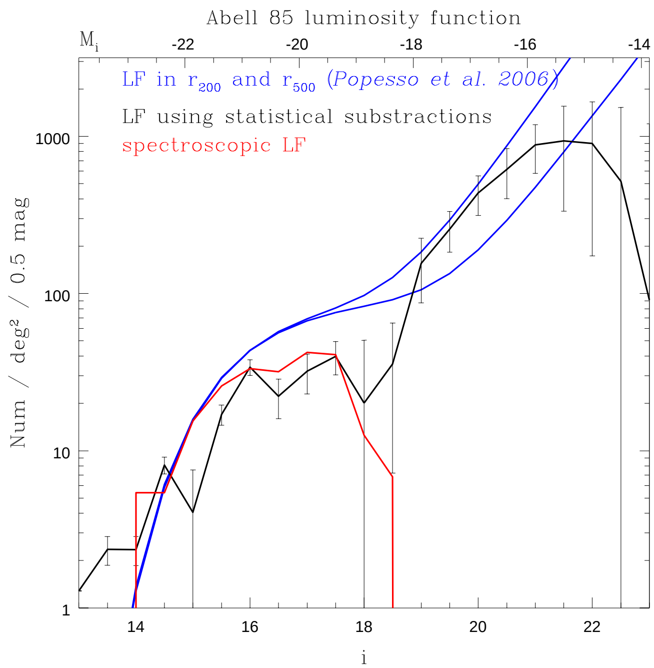


Fig. 3. GLF of Abell 85 obtained with optimized parameters using a statistical subtraction of the median of the four CFHTLS Deep fields. Superimposed (blue) are the GLFs (with arbitrary normalizations) given by Popesso et al. (2006) and galaxy counts obtained from a spectroscopic catalog in red. Error bars represent the cosmic variance measured as the standard deviation of the four Deep galaxy counts. Absolute magnitudes are computed assuming $H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and no peculiar velocity for Abell 85.

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