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# MEASUREMENT OF CFHT IMAGES I. IDENTIFICATION, PHOTOMETRY AND CLASSIFICATION

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RESUMEN

En este trabajo presentamos resultados preliminares de la medición y análisis de imágenes de la zona ecliptical obtenidas con la Cámara MegaCam instalada en el Canada-France-Hawaii Telescope (CFHT) ubicado en Mauna Kea (Hawaii). Se está evaluando la posibilidad de construir un catálogo astrométrico y fotométrico de las fuentes astronómicas identificadas en las mencionadas imágenes. En esta presentación se comentan y discuten los criterios empleados y procedimientos aplicados para la identificación, reducción fotométrica y clasificación de las fuentes astronómicas como estelares o extendidas.

ABSTRACT

In this paper we present preliminary results from the measurement and analysis of images of the ecliptic zone obtained with MegaCam at Canada-France-Hawaii Telescope (CFHT) located at Mauna Kea (Hawaii). We are evaluating the feasibility of constructing an astrometric and photometric catalogue with all the astronomical sources identified on those images. We comment and discuss the criteria and procedures for the identification of sources, the photometric reduction and their classification as stellar or extended objects.

*Key Words:* astrometry — methods: data analysis



## 1. INTRODUCTION

In the last year we have started a collaboration with the Laboratory SYRTE (Systèmes de Référence Temps-Espace, UM8630 of CNRS) at Paris Observatory for the exploitation of 1700 wide-field frames taken at the Canada-France-Hawaii Telescope (CFHT), each one covering a $1° \times 1°$ area with a mosaic of 36 CCD chips. These frames covering a large band of the sky along the ecliptic are already available as part of the CFHT Legacy Survey-Very Wide (CFHTLS-VW). The ultimate objective is the construction of a celestial catalogue called MEGACLIP much deeper and accurate than other existing catalogues in the region covered. For the same zone of the sky it will contain much more objects than these catalogues, as well as the output catalogue from GAIA (scheduled around 2017). Moreover the MEGACLIP catalogue, thanks to its high density and its accuracy with respect to the existing catalogues, will enable to determine GAIA's coordinates during its operational mission by giving the coordinates of reference stars with very good accuracy.

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## 2. IMAGES DESCRIPTION

The wide-field imager MegaCam of CFHT produces an image formed by 36 CCD frames of $2048 \times 4612$ 13.5-microns square pixels, covering a full $1° \times 1°$ field of view with a resolution of $0.187''$ per pixel to properly sample the $0.7''$ median seeing offered by the CFHT at Mauna Kea.

Images are part of the CFHTLS-VW covering a large fraction of the ecliptic plane within a band of $\pm 2°$. Images were taken with the filters ($g'/r'/i'$) of the AB photometric system.

Each image has a total of 340 megapixels having 16 bits digital resolution. Frames have a nominal separation of 70 $\mu$m in East-West direction and 430 $\mu$m in North-South direction. The image data file is a unique fits file 649 Mby, each frame has 34 Mby. Images are corrected for instrumental errors and they have rough astrometric and photometric calibrations. These calibrations were not taken into account in this work.

We began analyzing field 739523p centered in RA=10h 00m 29s.03; DEC=$2°12'05''$ (band $r'$), observing date 03/20/2004.

## 3. VISUAL INSPECTION OF IMAGES

We performed a preliminary visual inspection of the field 739523p. Tycho-2 (Høg et al. 2000) and UCAC3 (Zacharias et al. 2010) stars were visually

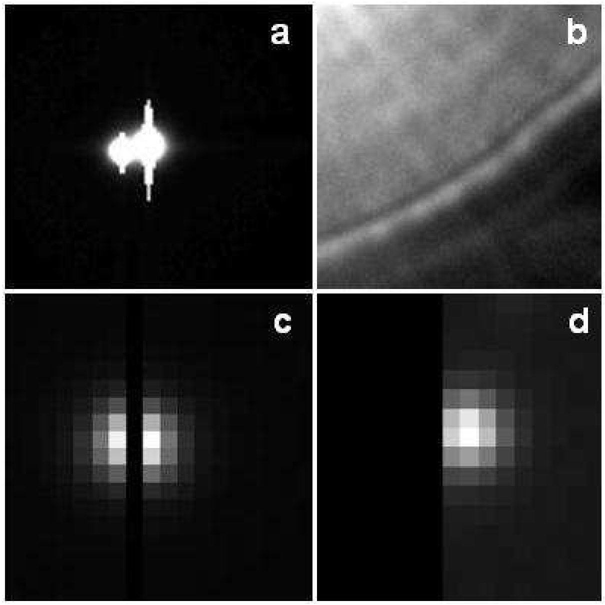


Fig. 1. See text for description.

recognized. All Tycho-2 and many UCAC3 stars are saturated (Figure 1a). Their haloes and spikes affect objects around them (Figure 1b). CCDs inactive columns affect images of objects formed on them resulting in two objects instead of one (Figure 1c). Objects near the edge of CCD chips lose some pixels and hence their measured centroids will not be correct (Figure 1d). These last three issues must be taken into account because they will produce spurious detections. The FWHM measured for stellar images in this field was ≈6 px (1.1″), but smaller values were measured in other fields.

## 4. DETECTION AND CENTERING OF OBJECTS

We considered two possibilities for detection and centering of possible astronomical sources. One of them was to use IRAF-DAOFIND (Stetson 1987)the other was to use SExtractor (Bertin & Arnouts 1996). DAOFIND is based on the convolution with an elliptical Gaussian, which requires *a priori* fixing a value for FWHM of the PSF, a background noise, an axis ratio and a position angle. For this reason we adopted SExtractor that is a non-parametric algorithm. It requires only fixing a minimum signal/noise threshold of detection and a minimum area of connected pixel. This amount represents the minimum possible area corresponding to the image of a *true astronomical* source and it is related to the measured seeing on the image. SExtractor produces a catalogue of measured properties of detections: central coordinates of centroids with their errors, instrumental photometric magnitudes, shape parameters (FWHM, second order momenta, position angle, elipticity, elongation, etc.) and a classification parameter (CLASS) useful for the classification of detections into different types of objects: stellar or extended.

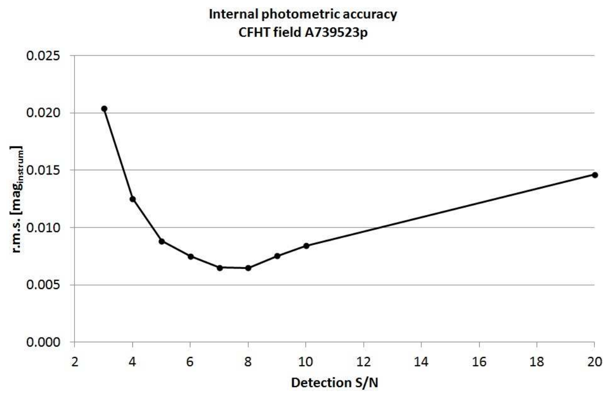


Fig. 2. R.m.s deviation from average instrumental magnitude at different S/N detection levels.

## 5. OPTIMAL SIGNAL TO NOISE DETECTION THRESHOLD

We observed a slight variation of errors of centroid coordinates according to the selected S/N threshold for detections. This will affect the results of astrometric reduction. We tried to find an optimal working S/N threshold, i.e. the threshold that minimizes the errors. The optimal value found was S/N=7. More details at this respect can be seen in Bustos Fierro & Calderón (2013). We found that not only errors in centroids of coordinates were minimized at S/N=7 but also errors in instrumental magnitudes have their minima as can be seen in Figure 2.

We have also considered how detection threshold affects the number of detected sources. We observed that sources with CLASS $\geq 0.7$ have stellar appearance, therefore sources with CLASS $\geq 0.7$ will hereafter be considered as *stars*. Results for field 739523p can be seen in Table 1. Finally we adopted S/N=7 to obtain data for calibrations and S/N=3 to produce a deep enough catalogue. Note that the increase of the number of *non-stars* is larger than that of the number of *stars* when decreasing S/N.

## 6. PRELIMINARY PHOTOMETRIC CALIBRATION

We performed a preliminary photometric calibration in order to have an estimation of the limiting magnitude of the images. We used as reference data for calibration the magnitudes from the

TABLE 1

NUMBER OF DETECTED OBJECTS AT DIFFERENT S/N THRESHOLDS

| S/N | Stars | Non-stars | All |
|---|---|---|---|
| 3 | 4709 | 14220 | 18929 |
| 4 | 4106 | 10623 | 14729 |
| 5 | 3695 | 8648 | 12343 |
| 6 | 3385 | 7227 | 10612 |
| 7 | 3169 | 6247 | 9416 |
| 8 | 2971 | 5565 | 8536 |
| 9 | 2823 | 4933 | 7756 |
| 10 | 2687 | 4444 | 7131 |

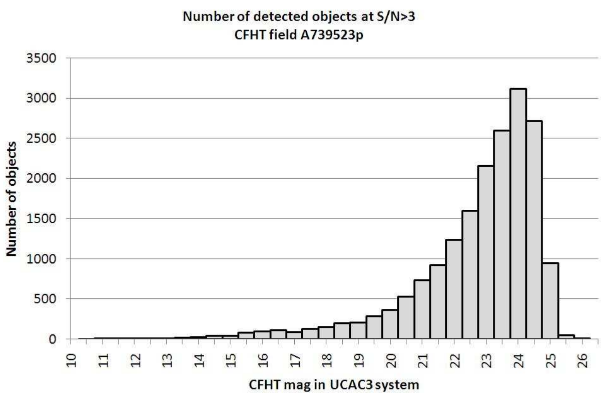


Fig. 3. R.m.s deviation from average instrumental magnitude at different S/N detection levels.

UCAC3 catalogue. We are aware that the UCAC3 magnitudes are not photometric standards but they were useful as a starting point. *We apologize to photometrists*. For the relation between UCAC3 magnitudes ($m_{\rm UCAC3}$) and instrumental magnitudes ($m_{\rm Inst}$) we proposed a linear fit: $m_{\rm UCAC3} = a \times m_{\rm Inst} + b$.

We have applied an iterative method in order to improve the correlation coefficient of the fit. Resulting limiting magnitudes can be seen in the histogram in Figure 3.

We also made a comparison of the number of detected objects and limiting magnitude with the catalogue USNO-B1 (Monet et al. 2003). See Figure 4.

## 7. CLASSIFICATION

We analyzed the results of automatic SExtractor classification. The parameter CLASS provided by SExtractor has values between 0 and 1. Low values of CLASS indicate extended appearance objects, high values indicate objects of stellar appearance.

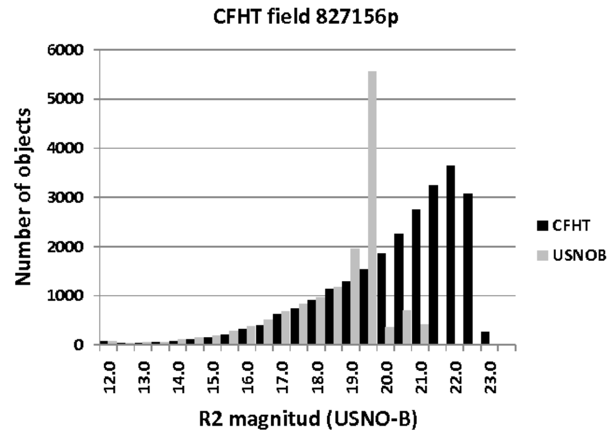


Fig. 4. R.m.s deviation from average instrumental magnitude at different S/N detection levels.

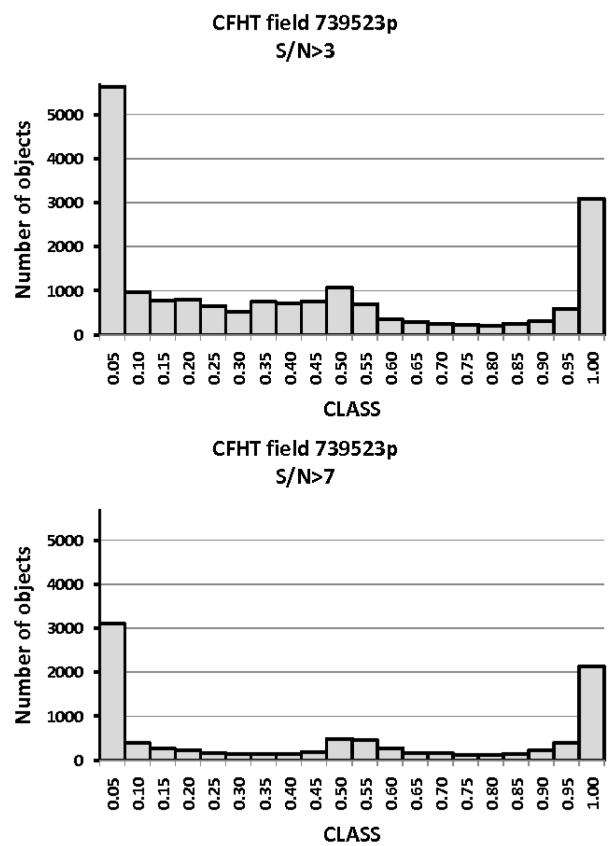


Fig. 5. See text for description.

The distributions of CLASS on the same field at two different S/N detection thresholds are shown in Figure 5. As seen in the histograms there is a continuous range of values without evident separation between stellar and extended objects.

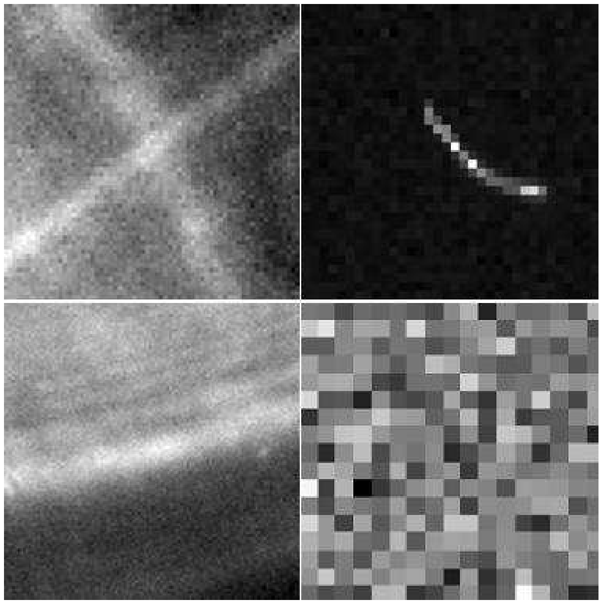

Fig. 6. See text for description.

From visual inspection of a random sample consisting of 20% of detections we found that there are some extended sources with CLASS $\geq 0.7$ and some stellar-like sources with CLASS $< 0.7$. Information about how CLASS is calculated by SExtractor is not available (or we cannot access it); thus we were not able to attack this matter using CLASS only. We performed statistic diagrams for classification taking into account the shape parameters provided by SExtractor, namely elongation, FWHM, position angle and the size of the minor axis. We also noticed an increase in the ellipticity of stellar images when increasing distance to the center of the field.

## 8. SPURIOUS DETECTIONS

We consider as spurious those detections whose image does not correspond to an astronomical source as well as those which correspond to distorted images of astronomical sources, as seen in Figure 1. From another analysis of the sample mentioned in § 7 we found a number of spurious detections with a wide range of values in CLASS and in shape parameters. Figure 6 shows some examples, two of them resulting from the haloes of bright stars, and two of them of unknown origin. In every case the center of the image is the position of the centroid provided by SExtractor, and the width is five times the largest between FWHM and major axis.

## 9. CONCLUSIONS

Visual inspection of the field showed images of a number of astronomical sources that are affected by distortions of instrumental origin (edges and cold columns) and by the glare of bright stars. In addition we observed a number of detections that do not correspond to any astronomical source.

SExtractor resulted to be more adequate than DAOFIND to perform detections in these images. It allows to identify objects that are not necessarily stars. It also provides many parameters useful to describe and classify the detections.

The best photometric accuracy with SExtractor is achieved with the detection threshold at S/N=7 but the number of detections is about half the number at S/N=3. Therefore we propose to perform the astrometric and photometric calibrations with S/N=7 and to construct a deeper catalogue with S/N=3.

From the preliminary photometric reduction we could estimate a limiting magnitude ~23–24, two or more magnitudes fainter than USNO-B1 and the expected limit of GAIA.

We found that the parameter CLASS is a good starting point for stellar/extended object classification, but it is not enough. Further analysis, taking into account other parameters and techniques, is in process. Similar problems occur with the identification of spurious detections.

This work is based on observations obtained with MegaPrime/MegaCam, a joint project of CFHT and CEA/DAPNIA, at the Canada-France-Hawaii Telescope (CFHT) which is operated by the National Research Council (NRC) of Canada, the Institut National des Science de l'Univers of the Centre National de la Recherche Scientifique (CNRS) of France, and the University of Hawaii. This work is based in part on data products produced at TERAPIX and the Canadian Astronomy Data Centre as part of the Canada-France-Hawaii Telescope Legacy Survey, a collaborative project of NRC and CNRS.

This research has made use of the VizieR catalogue access tool, CDS, Strasbourg, France.

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