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Update of FastCam, the lucky imaging instrument at the Observatorios de Canarias (OCAN).

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Abstract

FastCam is an instrument designed to obtain high spatial resolution images in the optical wave- length range from ground-based telescopes by using the Lucky Imaging technique. This technique is based on the idea of registering the instants of atmospheric stability, typically lasting just some milliseconds, using very short exposures. The instrument consists of a very low noise and very fast readout speed EMCCD camera capable of reaching the diffraction limit of medium-sized telescopes from 380 to 1000 nm. At the beginning of 2019, a new camera was commissioned. Now the instrument makes use of an Andor iXon DU-888U3-CSO#BV back-illuminated system containing a 1024x1024 pixel frame transfer CCD sensor from E2V Technologies. The pixel size is 13 microns and the camera allows up to 30 exposures per second. A new update of the camera acquisition software is currently being worked on. A complete characterization of the detector is also being carried out in order to better understand and exploit all the performances of the instrument, applying particular configurations for each scientific case. A standard reduction of the data is also being implemented in order to offer it to all users of the instrument. The first FastCam was an instrument jointly developed by the Spanish Instituto de Astrofísica de Canarias (IAC) and the Universidad Politécnica de Cartagena which started in 2006. Since then, the IAC assumed the instrument and tested it on several telescopes of the OOCC, among them the Nordic Telescope (NOT) where images were obtained in the optical domain diffraction-limited with high contrast, reaching a resolution of 0.1"/px. Currently FastCam is a common-user instrument at the Cassegrain focus of the 1.52-meter Carlos Sánchez Telescope (TCS, Teide Observatory) where observations are being made to calibrate the detector with sky tests. The idea is that in the near future it will be installed in the NOT to finish the commissioning process of the new camera and the whole acquisition system so that this instrument can be used by the international community.

1 Introduction

Fastcam is an instrument that uses the Lucky Imaging (LI) technique to obtain high spatial resolution images in the optical range. It has been developed by the Instituto de Astrofísica de Canarias (IAC) in collaboration with other institutions [1]. This technique is based on recording the instants of atmospheric stability through very short exposures (30-50 ms). The selection of those images minimally affected by turbulence allows to reach the resolution limit of the telescope in the optical range, offering results similar to those of space telescopes (Figure 1).

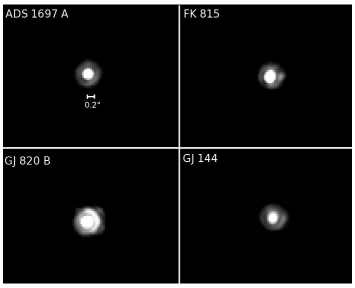

Figure 1: I-band images taken at the TCS showing the first Airy disc.

2 UPDATE OF THE INSTRUMENT

Fastcam consists of a commercial EMCCD (Electron Multiplying Charge Coupled Device) detector with fast-reading and low-noise together with an optical system and the acquisition, selection and process software packages. A new camera has been purchased and based on it we are carrying out a complete upgrade of the instrument and associated software (Figure 2).

3 A NEW CAMERA

The new Fastcam camera is an Andor iXon Ultra 888 detector, model DU-888U3-CS0-#BV (Back-illuminated, standard AR coated): 1024 x 1024 active pixels, 13 um pixel size, 30 MHz max readout time, $\ll$1 e- readout noise (with EM gain), 26 fps full frame, 93 fps at 512x512 (Cropped mode), $\gg$ 95% QE. Some features of the detector are the frame transfer mode. This option is a special acquisition mode that contains 2 areas of approximately equal size as shown below: 1. The Image Area, which is at the top and farthest from the readout register. This is the light sensitive area of the CCD. 2. The Storage Area is located between the Image Area and the readout register. This section is covered by an opaque mask, usually a metal film, and is therefore not sensitive to light. Frame transfer devices typically have faster frame rates than full frame devices, and have the advantage of a high duty cycle, meaning the sensor is always collecting light (Figure 3).

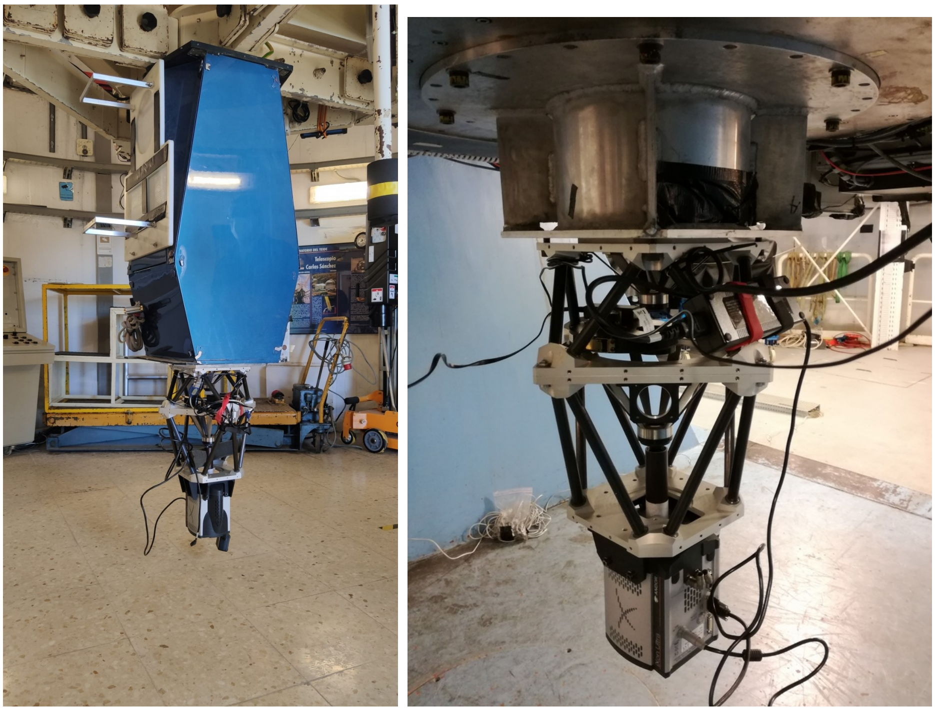

Figure 2: Left image: Fastcam at TCS, Right image: Fastcam at NOT

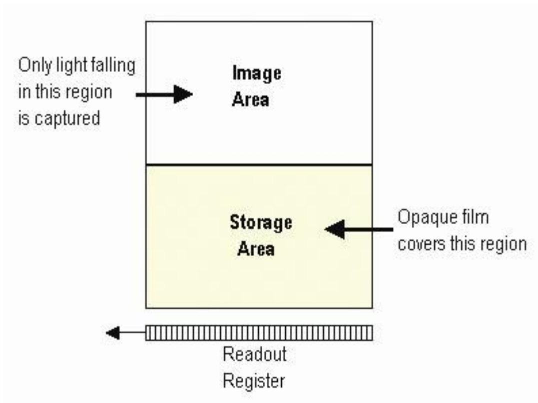

Figure 3: Frame transfer mode.

4 DETECTOR CHARACTERISATION

In addition to the new hardware, we are carrying out a complete characterization of the system both in the laboratory and in test nights at the Carlos Sanchez Telescope. Basically, the new generation of this type of optical detectors has the great advantage of performing the electron multiplication of the signal before the readout of the detector, which means that, proportionally, the readout noise can be significantly reduced in each pixel compared to useful signal, down to 1 e- rms. Using Electron Multiplication, the iXon is capable of detecting single photons, therefore the actual detection limit of the camera is set by the number of 'dark' background events. These events consist of thermally generated residual electrons and Clock Induced Charge (CIC) electrons (also referred to as Spurious Noise), each appearing as random single spikes above the read noise floor. This total characterization of the system will allow optimization of the camera configurations according to the scientific objective (Figure 4).

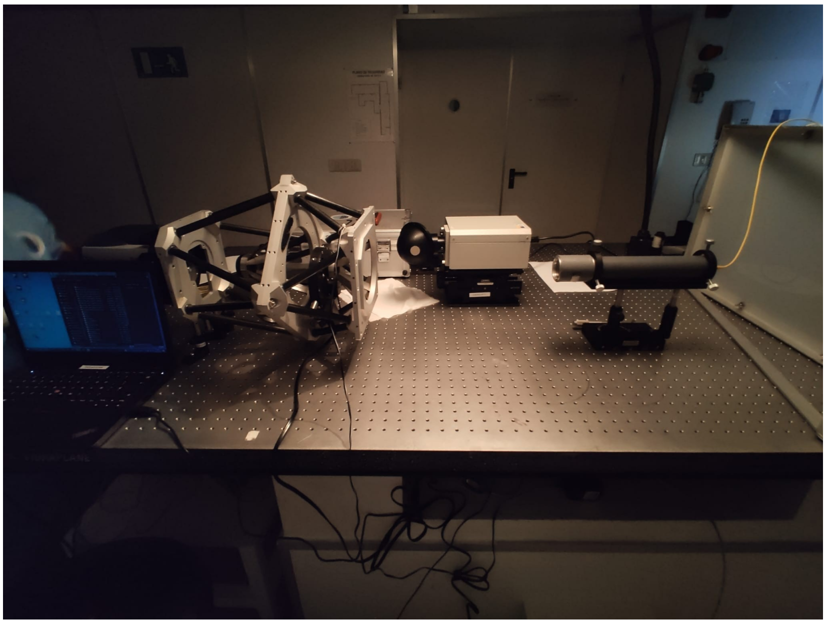

Figure 4: The system in the laboratory for a complete characterization.

5 SOFTWARE UPGRADE

Finally, we are carrying out a complete upgrade of the following software packages: New acquisition and control software. More robust user interface. Optimisation of the reduction software. In the LI algorithm, the images that suffered less atmospheric distortion are detected according to a quality criterion, then re-centered and added together into a single image [2]. A limitation of the LI technique is that a corrected image of a star shows a diffraction-limited central core with a residual halo corresponding to the atmospheric turbulence that could not be corrected as it can be seen in the figure. The new COELI algorithm (COvariancE of Lucky Images) [3, 4] has been designed to overcome that improving the detectability of faint objects falling inside the residual halo by analyzing the correlation between the peak pixel and the rest of the pixels of each lucky image (Figure 5).

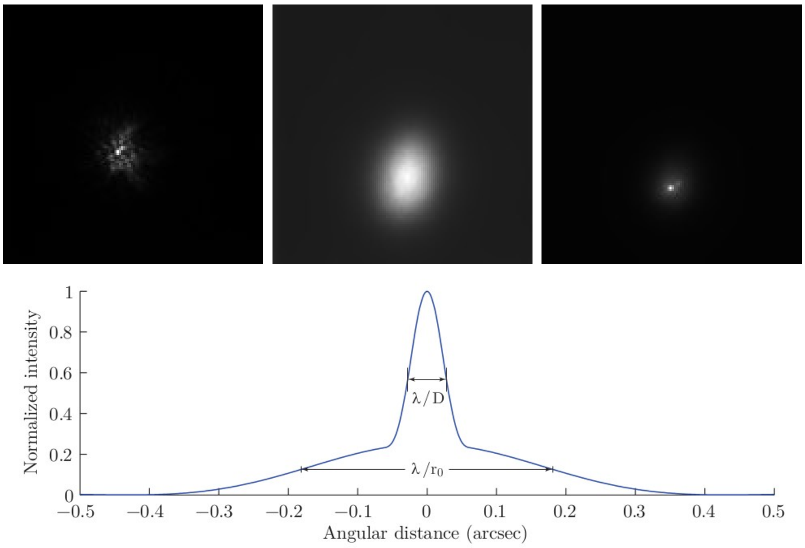

Figure 5: Left images: a 30ms exposure; natural seeing; 1% of 4,000 aligned and averaged images. Bottom image: profile of a partially corrected image of a star, showing a diffraction-limited central core and the residual halo..

6 CONCLUSIONS AND FUTURE WORK

The project started in March 2006 and, since then, FastCam has been successfully tested on different OCAN telescopes and the theoretical diffraction limit of the following telescopes has been reached in the I band (850nm), 0.17 at TCS, 0.10 at NOT and 0.07 arcsec at WHT, and similar resolutions have been also obtained in the V and R bands. For this update process we are performing observations that help us in the commissioning of the instrument to define the most appropriate configuration for each scientific case. The instrument can offer competitive observations in multiple fields of astronomy: Solar System with asteroids and comet; Exoplanets; Studies of stellar formation and dynamics; Multiplicity of stars in a wide range of masses and evolutionary states; Extragalactic resolution studies (quasars, AGNs, etc). Fastcam is a common-user instrument at TCS since 2008 and will be offered for installation at NOT in the near future.

References

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