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ITANET CCD camera for Near-Earth Objects photometric observations

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Abstract. In the framework of the Near-Earth Objects (NEOs) observational research programme undertaken at the Department of Physics and Astronomy of Catania University, a CCD camera was developed to be used at the 41/61-cm Schmidt telescope of M.G. Fracastoro station. The camera, equipped with BVRI Johnson filters and mounting a bare, front-illuminated 2048×2048 Kodak KAF-4202 CCD with 9 μm pixel-size, was realised at the Catania Astrophysical Observatory Laboratory for Detectors (COLD). The optimisation of the operating conditions of both electronics and cryogenics and the CCD characterisation are presented.

Key words. Instrumentation: detectors – Methods: laboratory – Asteroids: NEOs

1. Introduction

Near-Earth Objects (NEOs) are all the small objects in the Solar System (e.g. asteroids, short-period comets, source bodies for meteroites) which have a perihelion distance $q \leq 1.3$ AU. Due to their orbits, NEOs could pass close to the Earth and, therefore, they are capable of striking our planet.
The mere detection of NEOs is not enough to safeguard the Earth against large scale catastrophes. After the discovery, it is necessary to follow up the NEOs with continuous astrometric and photometric observations. While continuous astrometric observations allow to compute accurately their orbit and ephemeris, photometric observations supply the measurements useful to determine the taxonomic type and the physical parameters, i.e. surface characteristics, absolute magnitude, rotational period, shape, spin axis direction, size. Such information are important both for understanding the origin and collisional evolution of NEOs population, and for assessing their potential hazard for the Earth. Despite the increase in the discovery rate of NEOs, physical information are known only for less than the 20% of all discovered objects.
Since a long time the Department of Physics

Send offprint requests to: D. Gandolfi and Astronomy of Catania University has carried out systematic asteroid photometric observations using a photon-counting photoelectric photometer. Recently, it has been involved in the ITANET Italian national research program, whose main goal is the discovery and the study of NEOs. In this framework the role of the Department of Physics and Astronomy is to perform systematic CCD photometric observations devoted to study of NEOs rotational and physical properties. Observations will be caried out at the 41/61-cm Schmidt telescope of M.G. Fracastoro station using the ITANET multi-band CCD camera, developed and realised at the INAF-Catania astrophysical Observatory Laboratory for Detectors (COLD).

2. The ITANET camera

The potentiality of M.G. Fracastoro station of Catania Astrophysical Observatory has promoted the design and construction of a CCD camera, named ITANET camera, planned to be placed at the 41/61-cm Schmidt telescope (Bonanno et al. 1999). Due to the optical configuration of the Schmidt telescope, that requires the camera mounted at the primary focus as replacement of the corrective photographic plate, the housing has been designed to be very compact (diameter 230 mm). The used detector is a bare, front illuminated, 2048×2048 pixels, Kodak KAF-4202 CCD (class 1) manufactured in Multi Pinned Phase (MPP) technology. The 41/61-cm Schmidt telescope plate scale of 169″/mm together with the selected 9 μm pixel-size of the Kodak CCD allows a resolution of about 1.5″/pixel and a field of view of about 1 squared degree. In order to carry out wide band photometric observations the camera is equipped with a set of BVRI Johnson filters manufactured by Schott.

2.1. CCD controller

The CCD controller used to operate the detector is the same developed for the italian national telescope Galileo. It is based essentially on transputers and Digital Signal Processing (DSP) modules. The overall controller is made of two fundamental components: the host PC and the remote controller. The host PC has installed inside a special interface able to hold various transputer modules. The remote controller consists of a preamplifier, a sequencer that provides the logical signals, an analog board that provides for biasing, clocking and video processing. The last board is able to process and convert independently 4 video-channels in 16 bit data by using the correlated double sampling technique. All the voltage levels are programmable and their values can be monitored by telemetry. Furthermore the sequencer provides shutter and temperature controller handling as well as support for 8 digital inputs and 8 digital outputs fully programmable. Eight temperatures can be monitored and one of them is controlled. We used the input-output lines for controlling and monitoring the movable filter mechanical system. An appropriate software procedure has been written to manage all the movements and place the filter in front of the CCD.

2.2. Camera cryogenic set-up

To operate the CCD at a temperature of about $-40°$ C , the cooling system has been designed to work under vacuum conditions. It is based on the use of a two stage Thermo Electric Cooler module (TEC). In addition, a chiller with closed circulating refrigerant liquid has been used to cool the TEC hot-plate. In order to optimise the vacuum conditions the device is mounted inside a stainless steel cryogenic housing and it is vacuum sealed with copper rings and steel bolts. During the camera's set up, we considered the problem of preserving vacuum integrity into the CCD housing. In order to adsorb contaminating molecules (e.g. water molecules and hydroxide iones) and succeeding to slow down the pressure increase we used 5A Zeolite, a hydrophilic material. Zeolites are micro-porous crystalline solids with well-defined structures; generally they contain silicon, aluminum and oxygen in their framework and cations, water and other molecules within their pores (in this case, 5A zeolite has a pores diameter of 5 Å). The binding energy for water in zeolite is so

Table 1. Main characteristics of Kodak KAF-4202 CCD. All measurements were made cooling the detector down to a temperature of about −40° C.

Sensitive area	2032×2044 *px*
Pixel-size	$9\ \mu m$
Full Well	$\sim 10^5\ e$
Dark Current	$2.5\ e^-/px/h$
CTE	0.99997
Gain	$1.65 \pm 0.02\ e^-/ADU$
r.o.n. (50 kpx/sec)	$8.4\ e^-$ ($r.m.s.$)
Linearity	< 1 %

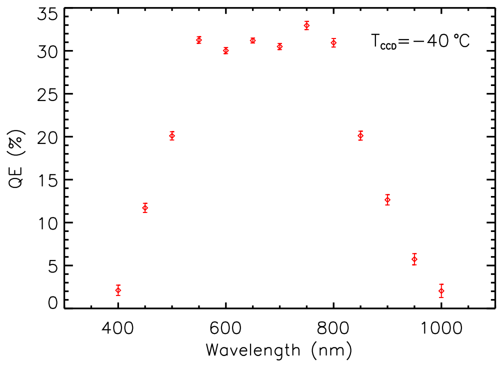

Fig. 1. Quantum efficiency of Kodak KAF-4202 CCD.

high that, at room temperature, adsorbed water is essentially permanent. It is possible to remove water from pores backing zeolite at about 200° C for several hours, without any change in the form of zeolite crystal lattice. As a result, molecules of different gasses with diameter less or equal than 5 Å, can easily occupy the spaces left vacant by the removal of water. The used 5A zeolite, whose pores diameter is about 5 Å, is therefore excellent hydrophilic material able to adsorb the excess of out-gassing water inside the cryostat.
Due to the small volume of ITANET CCD camera, three small stainless steel canisters filled with 10 g of 5A Zeolite were used.

2.3. CCD characterisation

The COLD laboratory has developed a facility that allows the full electro-optical characterisation of bi-dimensional detectors. The main component of the facility is the instrumental apparatus to measure the quantum efficiency (QE) of detectors in the wavelength range from 125 nm to 1100 nm (Bonanno et al. 1996). This apparatus allowed us to measure the CCD's QE illuminating the detector with monochromatic radiations and comparing its response to that of a calibrated photodiode. For gain and linearity measurements, the CCD was uniformly illuminated using a stable light source and a 8 inches integrating sphere. All the CCD characterization and relative measurements were made cooling the detector down to a temperature of −40° C. The main results are listed in the Tab. 1. The measured QE is also shown in Fig. 1.

3. Conclusion

Due to mechanical refurbishment of the 41/61-cm Schmidt telescope, the photometric tests of the ITANET camera were performed with the 67/92-cm Schmidt telescope of Padova Astronomical Observatory (Blanco et al. 2004). Some asteroid photometric observations were carried out using the same telescope (Gandolfi et al. 2005). When the refurbishment of the 41/61-cm Schmidt telescope will end the NEOs photometric observational campaigns will cover half of the allocated observational time. In the meanwhile, the ITANET camera has been employed in the RATS project, whose main goal is the discovery of giant planet transiting solar type stars (Scuderi et al. 2005).

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