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CAMILA: INFRARED CAMERA/SPECTROGRAPH

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RESUMEN

Se describe el desarrollo del instrumento Cámara/Espectrógrafo Infrarrojo llamado CAMILA. Está basado en un detector NICMOS 3 de HgCdTe desarrollado por Rockwell, con respuesta espectral de 1–2.5 μm. La configuración inicial del sistema ha sido concluída y consiste de las siguientes componentes: crióstato, control del detector, cadena de amplificación, interface detector-PC y sistema operativo. Se presentan resultados preliminares del detector de calidad científica. La configuración óptica completa está en construcción y tendrá los siguientes modos de operación: imagen directa (12 filtros), polarimetría y espectroscopía en 3 modos de dispersión (baja, mediana y alta resolución). El proyecto es una colaboración de grupos del IAUNAM y UMASS (Amherst) y será utilizado principalmente en el telescopio de 2.1-m del OAN en San Pedro Mártir, B.C. (México).

ABSTRACT

The development of the Infrared Camera/Spectrograph called CAMILA is described. It is based on a NICMOS 3 HgCdTe detector developed by Rockwell with a spectral response of 1–2.5 μm. The initial configuration of the system was recently concluded and consists of the following components: detector cryostat, detector control, amplification board, detector-PC interface and operating system. Preliminary tests of the science grade chip are presented. The complete optical configuration is under construction and consists of the following modes of operation: direct imaging (12 filter positions), polarimetry and spectroscopy on 3 dispersion modes (low, medium and high resolution). The project is a collaborative effort of groups from IAUNAM and UMASS (Amherst) and will be used mainly at the 2.1-m telescope of OAN at San Pedro Mártir, B.C. (México).

Key words: **INSTRUMENTATION: SPECTROGRAPHS**

1. INTRODUCTION

Infrared cameras and spectrographs with 256×256 HgCdTe or InSb arrays have been developed over the ıst few years; some of these are now operational and others are under construction (e.g., IRAC2 at ESO: Aoorwood et al. 1992, OSIRIS: Atwood et al. 1993).

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The Infrared Camera/Spectrograph Camila has been designed and developed through a collaborative effc of groups of the Instituto de Astronomía (UNAM) and the Five College Astronomy Department (UMASS) wi the following goals:

1) Construct an instrument for the San Pedro Mártir (SPM) 2.1-m telescope to pursue several astronomi observing projects in the near-infrared using high sensitivity and low read-out noise current bidimensional arr As examples of current projects of interest: star formation (IR binaries, bright rims associated with IR sources, young embedded stellar clusters), circumnuclear regions of active galaxies, surface photometric stud of early and late type galaxies in clusters, star formation in galaxies, etc.

2) Develop an instrument capable of executing astronomical IR observations in different operational mod direct imaging, polarimetry, and spectroscopy (low, medium and high resolution).

3) Gain experience in development of modern IR instrumentation by full control in design and constructi (electronics + optics + mechanics + software).

4) Develop software routines that allows us to perform different reading modes to be applied depending the astronomical application.

The project has been divided into several phases depending on the operation modes. First, we developed t direct imaging capability which involved the design and construction of the detector readout and amplificati electronics and the control of the camera (§ 2). Second, the optical system was designed for the differe applications: direct imaging and spectroscopy (§ 3). In § 4 we present results of the observing run with t science grade NICMOS 3 detector.

2. DIRECT IMAGING

2.1. Detector

The core of the instrument is a NICMOS 3 detector developed by Rockwell Inc. with the followi characteristics:

Spectral Response	1–2.5 μm
Format	256×256 pixels, 4 quadrants
Pixel size	40 μm
Quantum efficiency	> 70 % at peak λ
Detector type	HgCdTe, photovoltaic
Operating temperature	60–80 K
Charge capacity	3×10^5 electrons
Linearity	90% (0.1% to 80% full wells)
Dark current	$< 800 e^-/s$ at 77 K; $< 2 e^-/s$ at 55 K

2.2. Control and Readout Electronics

The design philosophy of Camila's electronic system is based on a SUN computer that acts as a host a two slave computers (486 and 80C52SBC) that allow a full parallel multiple readout of the detector and programmable timing multisignal sequencer. The full electronic system is presented in the schematic diagra of Figure 1. The initial configuration consists of the following components: 1) Detector cryostat: mount, dew power sources, motor. 2) Timing control electronics: microcontroler software. 3) Amplificaction electronics a A/D conversion. 4) Detector-PC interface. 5) Acquisition computer: software, lecture modes.

(1) Detector Cryostat

It consists of a cryostat of LN_2 where the detector carrier is located along with a 12 position filter whe The NICMOS 3 detector is mounted on a printed circuit board (PCB) that contains electrical filtering a decoupling elements required for a low noise performance. The interconnection of the PCB and a 26-p vacuum connector is carried by low thermal transfer coaxial cables. The chip is radiation baffled and plac in a side-looking position, and mounted with an efficient thermal contact through a solid copper cold fing attached to the cold surface. The incident light passes into the dewar through a circular CaF_2 window. T filter wheel is moved with a shaft coupled to a stepper motor located outside the dewar, with a vacuum ferroflu seal.

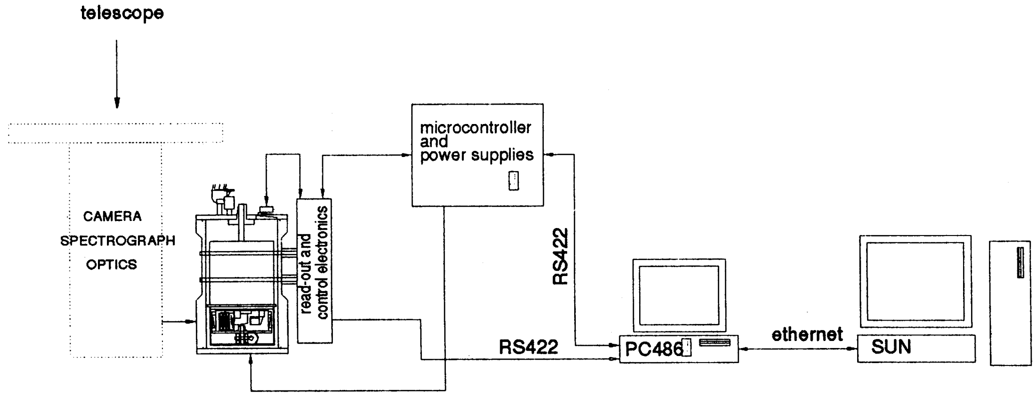

Fig. 1. Schematic Diagram of Electronic System

(2) Timing Control Electronics

The timing control is based on a single board micro-controller (SBC) using an 80C52 chip. The main function of the micro-controller is that of multisignal sequencer to provide erase, expose and readout operating functions. The timed signals are appropriately sent to the detector and the readout electronics. Other tasks accomplished by the micro-controller include the filter position control and the communication to an intel 486 acquisition computer.

(3) Amplification Electronics and A/D Conversion

The readout electronics is composed of 4 identical electronic chains coupled to each quadrant of the detector located on a single PCB. Each chain consists of one amplifier stage, a selectable dual gain integrator and a 14-bit A/D converter (ADC) that transmits data and clock signals in serial mode. In the PCB are also included the precision voltage reference sources and the line drivers that transmit signals from the ADC to the acquisition computer. The 4 quadrant transmission frame is sent in a parallel mode in $t \approx 0.49$ sec.

(4) Detector-PC Interface and Acquisition Computer

The 486 computer stores and performs preliminary data processing. It has a designed interface that receives the 4-quadrant serial data, converts to parallel and stores it temporarily in a buffer FIFO memory. This system is connected through an RS422 full duplex serial port with the SBC and loads the detector operating program. It performs the readout and execution commands for the image acquisition mode as well. The final data acquisition is carried out by a SUN workstation via an ethernet link to the intel 486 computer. The 486 software was developed in C^{++} and the SUN's software is based on an IRAF platform along with custom Fortran programs. The 486 software is capable of performing multiple readouts, the number depending on the signal in each pixel, such that each pixel can be read a number of times just before it reaches saturation, and then a line is fitted to the signal. With this two purposes are served: First, the read-out noise is diminished, first by a large factor (10) when at least two read-outs are performed, and then by a factor $\sqrt(N)$, N the number of read-outs. The other advantage is that the dynamic range is expanded by a factor of the number of read-outs, since the integration can be effectively stopped in bright regions of the image, while it continues in dimmer regions. Since the non-linearities of the detector can be larger than the read-out noise, a linearization process in real time is needed to perform more than two read-outs correctly. This linearization is carried out at the 486, although it is time consuming. For two read-outs or less, the linearization is carried out afterwards at the SUN computer.

3. OPTICAL DESIGN AND SPECTROGRAPH

The optics of CAMILA are based on the following specificactions:

1) Cold stop diameter 30 mm, located far from reflecting surfaces.

2) Design based in combination of a collimator and 3 cameras to be used with the f/13.5 secondary of the 2.1-m SPM telescope. These cameras will have the following characteristics: f/4.5 (5.25 arcmin^2, 0.87 arcsec/pix), f/13.5 (1.75 arcmin^2, 0.29arcsec/pix), f/47.25 (0.50 arcmin^2, 0.08 arcsec/pix), in parenthesis are the field of view and plate scale.

3) The distance from cold stop to detector should be constant for the 3 cameras.

4) Spectral coverage of design 1–2.5 μm.

5) Inexpensive optical materials frequently used, with a minimum number of elements that yield acceptabl images.

6) The optics will be placed in an optical bench cooled to −50 C by means of a refrigerating system.

The design of the spectrograph was concluded in June 1993. The optical designs for the collimator and cameras (f/4.5 y f/13.5) were revised and sent to Janos for construction. The design of the f/30 or f/40 camera applicable for speckle and small field imaging, is not yet satisfactory but we expect to conclude it soon. Th required parts for the spectrograph are being ordered and we plan to test a configuration of $R = 3000$ at th end of the year. The spectrograph will have the following modes of operation: low resolution ($R \approx 400$ medium resolution ($R \approx 2760$) and Echellete ($R \approx 12800$).

4. ASTRONOMICAL CHARACTERIZATION

The initial configuration was tested with the engineering grade chip in April 1993 at the 2.1m telescope c SPM. Quadrant 3 of the chip was dead (gold wire inside chip loose). Unfortunately, we had bad weather an we got little data. Nevertheless, the full electronics configuration worked well. We decided to install the scienc grade chip in June 1993 and tested it in July at the telescope. We obtained the following results:

1) Linearity. Due to the non-linear response of the detector, the linearity was tested taking sky frames a various integration times. The non-linearity of the detector is 12% at 1000 counts, 5% at 5000–10 000 count and 12% at 15 000 counts. The images will be linearized by a function $Q = y_{linear}/y_{observed}$, where Q is polynomial of 2nd order in $y_{observed}$. This linearization will be performed a posteriori when working in 1 or read-outs mode, and in real time for a multiple read-out scheme.

2) Read out Noise. The read out noise is excellent: $40 - 50e^{-}$, hence, we are dominated by backgroun noise in direct imaging. For spectroscopy (low background) we expect to diminish the readout noise increasin the number of readings (by $1/\sqrt{N}_{readout}$).

3) Limiting Magnitudes. Due to poor weather, so far we can only make rough estimates: $J = 18$ i 60 s. We expect to reach: $H = 19$ at 5σ in 60 s and $K = 18$ at 5σ in 40 s.

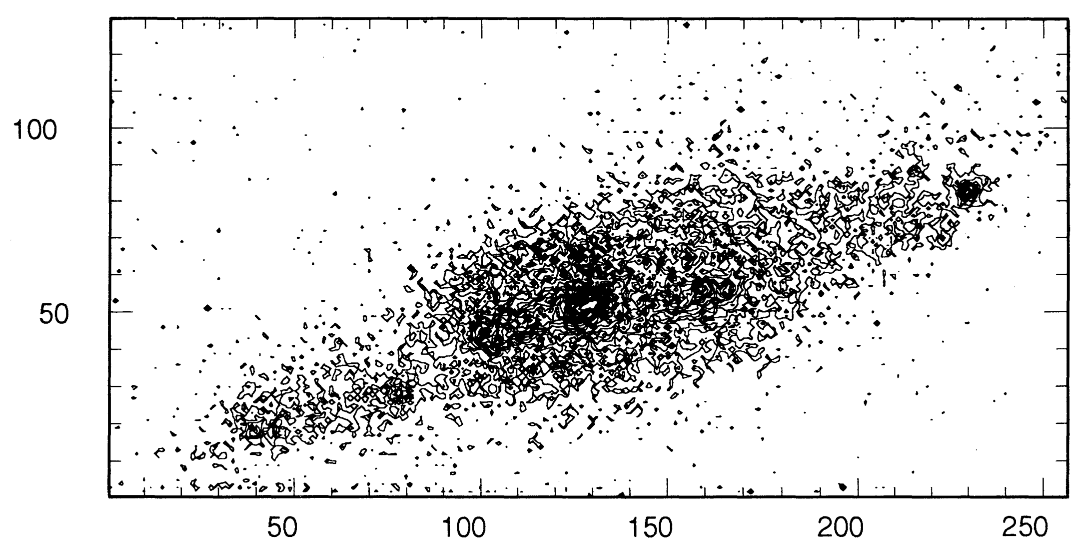

Fig. 2. Image of the galaxy M82 taken at Br γ (2.166 μm).

The IR Camera/Spectrograph CAMILA described in this paper will become fully operational in 199 Next winte we expect to obtain astronomical images, to test the optics at the telescope and to test th spectrograph capabilities at $R = 3000$. A full description of the instrument, together with the technical report is in preparation.

The mechanical work was done at IAUNAM and UMASS, we thank the technicians for their excellent work.)ur thanks to R. Langarica for the drawings. Finally, our appreciation to many colleagues for encouragement ,nd support, especially to A. Serrano and S. Strom. This work was supported by grant IN-300789 DGAPA, JNAM.

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DISCUSSION

)ostero: Does the non-linearity repeat in a stable manner?. If so, to what degree?

)ruz-González: The linearity is stable.

Iissen: Is it normal to have such high values of non-linearity for these kinds of IR detectors?

)ruz-González: Yes.

Iannings: Is the instrument designed only for the 2.1-m telescope in SPM? Have you thought in using another elescope also to give the instrument "more working" time?

)ruz-González: It can be used in any telescope with an f/15 secondary.

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