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CANARICAM: THE GTC'S MULTIMODE MID-INFRARED CAMERA FOR DAY ONE

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RESUMEN

Este trabajo describe las características generales de CanariCam, la cámara para el infrarrojo medio del GTC. CanariCam proporcionará una extraordinaria sensibilidad en cuatro modos de operación científicos distintos: imagen limitada por difracción, espectroscopía de red con resolución moderada, polarimetría de doble haz y coronografía.

ABSTRACT

We describe the general features of CanariCam, the mid-infrared camera for the GTC. CanariCam will provide outstanding sensitivity in four different science modes of operation: diffraction-limited imaging, moderate resolution grating spectroscopy, dual-beam polarimetry, and coronography.

Key Words: **INSTRUMENTATION: INFRARED CAMERAS — METHODS: OBSERVATIONAL**

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1. INTRODUCTION

CanariCam is the GTC's Day One mid-in (MIR) camera being developed by the Infrare trophysics Group in the Department of Astrc at the University of Florida, with key partici of several members from other institutions, dicated in Table 1. The goal has been to p the GTC astronomy community with an out ing "workhorse" multimode instrument for use atmospheric windows near 10 μm (extending about 8 to 14 μm) and 20 μm (extending fr to roughly 30 μm). The detector, an arsenic- silicon blocked-impurity-band (BIB, or IBC) from Raytheon, has peak quantum efficiency in the 8–25 μm region and a $26'' \times 19''$ field o spanned by 320×240 pixels. CanariCam wil vide imaging, spectroscopic, polarimetric, and nagraphic capabilities for science, as well as imaging and window imaging modes for engin assessment and monitoring.

2. BASIC CONFIGURATION AND OPTIC DESIGN

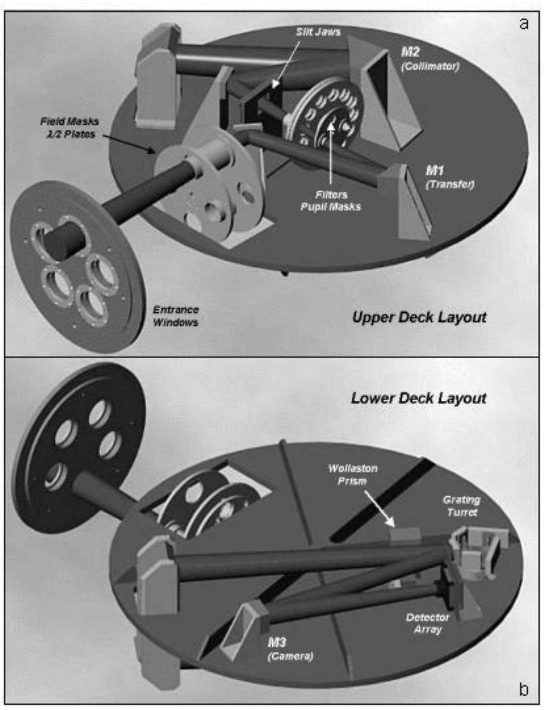

Fig. 1. The CanariCam enclosure, or dewar, illustrating the locations of the optical bench, coldhead, and window turret.

The CanariCam optics and detector are encased in a hexagonally shaped dewar to which is attached a coldhead capable of cooling the detector to its operating temperature near 8 K and the optics and interior hardware to appropriately low temperatures to minimize thermal background. No liquid cryogens are used in CanariCam. The CanariCam instrument is illustrated in Figure 1. Note particularly the window turret, which permits one to select in real time from among a number of entrance windows to permit optimization of the window material for specific science goals and observing conditions. As discussed further below, the detector and all optical compo-

TABLE 1

THE CANARICAM TEAM

Name	Role	Affiliation
Charles Telesco	Principle Investigator	Univ. Florida (USA)
Chris Packham	Deputy PI, Optics	
Roger Julian	Project Manager	
James French	Mechanical Engineer	
Jeff Julian	Mechanical Engineer	
Frank Varosi	Software Engineer	
Kevin Hanna	Electronics Engineer	
David Ciardi	Optics	
Robert Piña	(Consultant: systems, detectors)	
Dan Cawlfield	Electronics Technician	
James Hough	Polarimetry Design	Univ. Hertfordshire (UK)
Christ Ftaclas	Coronography Design	Univ. Hawaii (USA)
Mark Kidger	Calibration, Spanish Liaison	IAC (Spain)

nents and associated mechanisms are attached to the rigid internal optical bench, which is thermally isolated from the radiation shields and outer case by several bands, or cylinders, of G-10 fiberglass standoffs.

All of CanariCam's powered optics used in the science modes are reflective. Indeed, the imaging, spectroscopic, and coronagraphic modes are fully reflective except for the entrance window and filters. The polarimetric mode employs a half-wave plate and a Wollaston prism, both of which are transmissive. The nearly all-reflective design is achromatic and minimizes scattering and, therefore, stray light. Except for the entrance window, all of the optical components and associated mechanisms are attached to the optical bench. These optics and mechanisms are distributed on either side of the bench with a fold, which diverts the beam through the bench. In the following description we refer to Figure 2, which shows the optical bench and the associated optical components.

The telescope beam passes through the dewar entrance window (which is also the pressure window) and comes to a focus immediately inside the dewar. Between the entrance window and the telescope focal plane, half-wave plates for the polarimetric mode or a lens assembly for the window imaging mode can be inserted. The half-wave plates are also rotatable. A selection of aperture stops (including occulting masks for coronography and polarimetry) is installed in a wheel at the location of the telescope focus. The diverging beam is then incident on the powered transfer mirror, M1, which forms an image of the telescope pupil and an image of the telescope focal plane. Pupil stops are on a rotating assembly at the pupil image, and a double filter wheel is very close to this position. The rotating pupil stop assembly permits rotation of the complex pupil mask between integration sets (e.g., telescope nods) in order to provide maximum throughput and stray light rejection. One can insert a dual-lens assembly in this region in order effect the pupil imaging mode. An open hole for imaging or a selection of spectroscopic slits for spectroscopy can be inserted at the re-imaged telescope focal plane. As indicated in Figure 2, a slit jaw assembly was part of the preliminary design. However, as a result of the Critical Design Review (CDR), those jaws have been replaced by a slit-wheel assembly. The beam is then incident on the collimator, M2, which forms a pupil image near the position where the gratings (for spectroscopy) and a flat mirror (for all other modes) are mounted on a turret. A Wollaston prism can be inserted between M2 and the turret. After the turret the beam is incident on the camera mirror, M3, which images the astronomical field onto the detector array.

3. OBSERVING MODES

CanariCam has four science modes and two engineering modes. The science modes are: 1) imaging, 2) low and moderate spectral resolution spectroscopy, 3) coronography, and 4) polarimetry. While the addition of modes obviously complicates the design and implementation, the basic principle is

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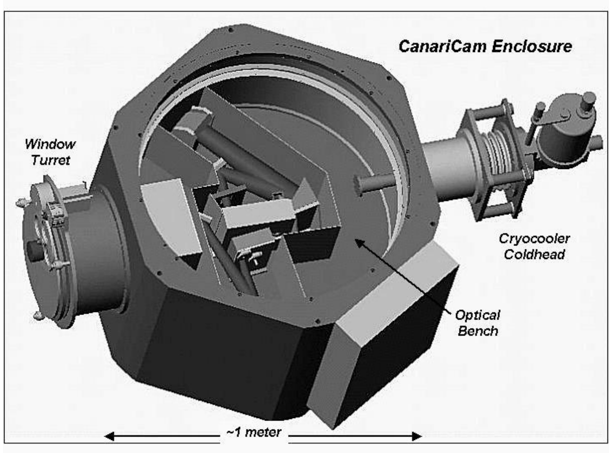

Fig. 2. The CanariCam optical layout shown attached to the optical bench.

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that the imaging mode is most important and fundamental, and implementation of the other modes cannot diminish the performance of the imaging mode. The two engineering modes are pupil imaging and window imaging, which facilitate system set-up, for monitoring the observatory thermal environment insofar as it effects CanariCam performance, and for monitoring the cryostat entrance window status. We give here a brief overview of each of the science modes.

3.1. *Imaging*

The key feature of the imaging mode is that it will permit diffraction-limited imaging at $\lambda \geq 8\mu$m over the full 19 arcsec $\times$ 26 arcsec field of view. Here, we take diffraction-limited performance to mean that for a point source at 8 μm, the energy enclosed within a square of pixels at the final image shall be at least 80% of that expected for the telescope alone. In fact, CanariCam will be much better than that. The image distortion will be less than two pixels center-to-corner for a 320 $\times$ 240 pixel array centered on the optical axis. The plate scale is such that each pixel subtends 0.08 arcsec, and the point spread function (PSF) at 8 μm is Nyquist sampled (two pixels per (λ/D). The maximum operational wavelength is set by the QE cut-off, and is near 25 μm. The QE is roughly constant between 8 and 25 μm, and falls off rapidly a shorter wavelengths. However, some sensitivity till exists at 2 μm, and thus some near-infrared filters are provided to use that spectral region for engineering purposes such as focus analysis.

3.2. *Spectroscopy*

CanariCam will have a high quality spectroscopic mode that can be straightforwardly accessed by inserting any one of four plane gratings into the beam by rotating a small circular turret near the second pupil image. Two low resolution settings are provided, one spanning 7.4–13.5 μm ("the 10 μm atmospheric window") in a single setting and the other spanning 15.7–25.3 μm ("the 20 μm atmospheric window") in a single setting. A high resolution setting is provided in each of these atmospheric windows, with the gratings being adjustable to center on the detector at any wavelength within that window. The spectral resolving power is $\geq$ 100 at the center of the 10 μm atmospheric window for the low resolution setting and $\geq$ 60 at the center of the 20 μm atmospheric window for the low resolution setting. The resolving power is $\geq$ 1300 for the high resolution setting in the 10 μm atmospheric window and $>$ 700 at the center of the 20 μm atmospheric window for the high resolution setting. Prior to the CDR, slit jaws were planned, but, because of CDR discussions, a slit-wheel containing a selection of slits of different widths will be located at the first re-mage of the telescope focal plane.

3.3. *Polarimetry*

CanariCam permits dual-beam measurement of source linear polarization by insertion of half-wave plates, a field mask, and a Wollaston prism. The inserted half-wave plate, inside the cryostat and slightly upstream from the telescope focal plane, can be rotated, which results in the rotation (relative to the Wollaston prism and detector) of the plane of polarization. The Wollaston prism, consisting of a birefringent crystal of sulfur-free CdSe, separates the two planes of polarization (the ordinary and extraordinary rays), which are subsequently imaged on

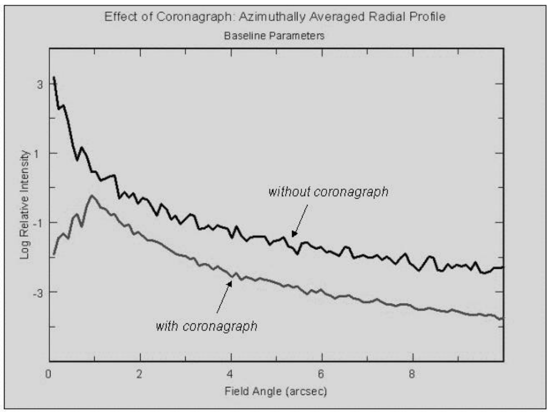

Fig. 3. Comparison of the azimuthal averages associated with the point source intensities for normal imaging mode (“without coronagraph”) and coronagraphic mode, as described in the text.

the detector. The focal-plane mask prevents overlap of the orthogonally polarized images for extended sources. This dual-beam design should permit polarization measurements of exceptional efficiency and quality.

3.4. *Coronography*

The key goal of a coronagraph is to suppress the emission in the PSF wings of a bright source so that a faint object can be detected nearby. In the CanariCam coronagraph, this suppression is accomplished by using an occulting mask at the telescope focal plane and a rotating pupil mask matched closely to the first pupil image. The basic design consists of: 1) a hard-edged (top-hat), low reflectivity mask 0.83 arcsec in radius located at the telescope focal plane; 2) a hard-edged, rotating Lyot stop with a spider mask with widths 20 times the spider image width. The rotating Lyot stop is roughly hexagonal and scaled from the input pupil so that the outer hexagonal edge is 90% the size of the image of the original. A central hard-edged, hexagonal mask blocks out the secondary mirror/obscuration; that mask is 140% the size of the image of the original. The purpose of this mask is to suppress the bright regions of scattered and diffracted light located primarily near the edge of the pupil image. The plate scale is the same as that for the imaging mode. Although the field of view is the full imaging field of view (except for that portion of the field covered by the occulting mask), superior results will be obtained for the central $\sim$10 arcsec centered on the occulted point source. As indicated in Figure 3, the intensity in the coronagraphic mode at positions more than about 1 arcsec from the occulted point source is at least a factor of 10 lower than it is in normal (i.e., non-coronagraphic) imaging mode.

4. EXPECTED PERFORMANCE

The performance on the GTC will be outstanding. This point is illustrated well by considering the point source sensitivity when imaging on a very good night in the broad band N filter centered at about 10.5 μm ($\Delta\lambda = 5$ μm). For telescope and atmosphere emissivities of 6% and 2%, respectively, we estimate that, for one hour of chopped integration, a signal-to-noise ratio of unity will be achieved on a point source (integrating over 6 $\times$ 6 pixels) with a 10 μm flux density of 0.04 mJy (i.e., 40 microjansky). One way to consider the significance of this number is to note that one will be able to detect circumstellar debris disks like those around the archetypal β Pictoris (at 19 pc, with flux density 1.1 Jy) and HR 4796A (at 67 pc, with flux density 0.04 Jy) as unresolved sources out to a distance of 1 kpc with a signal-to-noise ratio of five. When one realizes that the number of main-sequence A stars measured by *Hipparcos* to be within just 100 pc is about 1500, then the it becomes clear that an outstanding new vista of research will be opened up with CanariCam on the GTC.

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