RevMexAA (Serie de Conferencias), **42**, 81–83 (2013)

THE PROMISE OF CANARICAM

C. M. Telesco,[1] C. Packham,[1] F. Varosi,[1] D. Li,[1] J. G. Bennett,[1] E. Pantin,[2] C. Álvarez,[3] and S. Fernández Acosta[3]

RESUMEN

CanariCam proporcionará a la comunicad GTC con un instrumento excepcional de exploración del universo en el rango infrarrojo medio. Sus capacidades incluyen imagen, espectroscopía, polarimetría y coronografía. En este artículo resumimos el estado actual de CanariCam, que en la actualidad está siendo probado en el GTC. Mostraremos un ejemplo de la ciencia puntera que CanariCam permitirá llevar a cabo.

ABSTRACT

CanariCam will provide the GTC community with an outstanding mid-infrared capability with which to explore the Universe. Its capabilities include imaging, spectroscopy, polarimetry, and coronagraphy. Here we summarize the current status of CanariCam, which is now undergoing commissioning on the GTC, and we describe one example of the breakthrough science that CanariCam will enable.

Key Words: instrumentation: spectrographs — magnetic fields — protoplanetary disks

© 2013: Instituto de Astronomía, UNAM - Fourth Science Meeting with the GTC
Ed. C. Muñoz-Tuñón & J. M. Rodríguez-Espinosa

1. GENERAL

CanariCam is the GTC multi-mode, mid-infrared camera, a GTC facility instrument developed at the University of Florida for use by the entire GTC community. It uses a 320×240 pixel Raytheon blocked-impurity-band detector, which, with 0.08 arcsec pixels, provides diffraction-limited imaging across the 8.7–24 μm spectral region, Nyquist sampling of the point spread function, and a 26×19 arcsec field of view. CanariCam has four modes of operation: (1) imaging through a broad selection of spectral filters spanning the 8–12 μm and 16–24 μm atmospheric windows, (2) plane-grating, slit spectroscopy with approximate spectral resolving powers $R = \lambda/\delta\lambda =$ 100 and 1000, also in both atmospheric windows, (3) coronagraphy incorporating a 0.8-arcsec-radius occulting spot and rotating pupil masks, and (4) dual-beam imaging polarimetry for the 8–12 λm region, which may be extended to longer wavelengths upon later implementation of an appropriate half-wave plate. I refer the reader to the CanariCam link at the GTC website for much more complete information about CanariCam, its operation, and its anticipated performance.

2. THE PATH TO CANARICAM COMMISSIONING

CanariCam passed formal Acceptance Testing at the University of Florida in August 2007, and, in July 2008, it arrived in good working order at the GTC, where it awaited telescope completion. In November 2009 it was installed temporarily on the telescope for the first time to checkout all electrical, mechanical, and optical interfaces, and at that time it achieved 'first-light' on a star, although the telescope's primary mirror (M1) segments were not phased. CanariCam was installed permanently on the telescope in September 2010, with formal commissioning finally beginning in June 2011. At the time of this writing, GTC and University of Florida personnel are in the process of completing the commissioning of CanariCam. The imaging and low-resolution 10 μm (Lo-Res-10) modes have been offered for community use during GTC semester 2012A.

3. CANARICAM PERFORMANCE

On-telescope tests demonstrate that CanariCam provides diffraction-limited images. Of course, poor seeing or poor M1 phasing can degrade this performance, but it is clear at this time that CanariCam fulfills the requirements for excellent image quality in the mid-infrared. For example, in Figure 1 we show a stellar image made with a 1-second, on-source exposure at 12.5 μm. The FWHM of the profile is 0.3 arcsec, which essentially equals the diffraction-limited value of 0.26 arcsec. One also sees the first, and perhaps even the second, diffraction ring. To routinely achieve similar image quality for longer exposures of minutes-to-hours will require the use of so-called fast guiding, which is the small-amplitude, rapid tip-tilt of the secondary mirror (M2) to compensate in real

[1]Department of Astronomy, University of Florida, Gainesville, Florida 32611, USA (telesco@astro.ufl.edu).
[2]Service d'Astrophysique, CE Saclay, France.
[3]Gran Telescopio Canarias, Santa Cruz, La Palma, Spain.

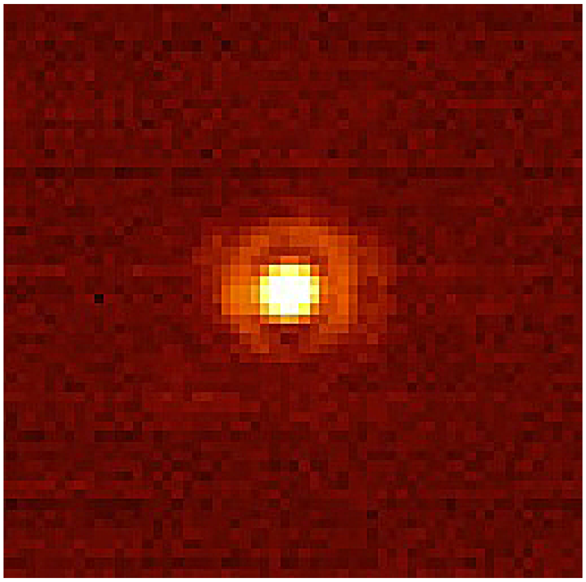

Fig. 1. A stellar image made with CanariCam during commissioning. This 1-s exposure at 12.5 μm has a full-width at half-maximum (FWHM) intensity of about 0.3 arcsec, essentially the diffraction limit. Note the first Airy ring and a hint of the second.

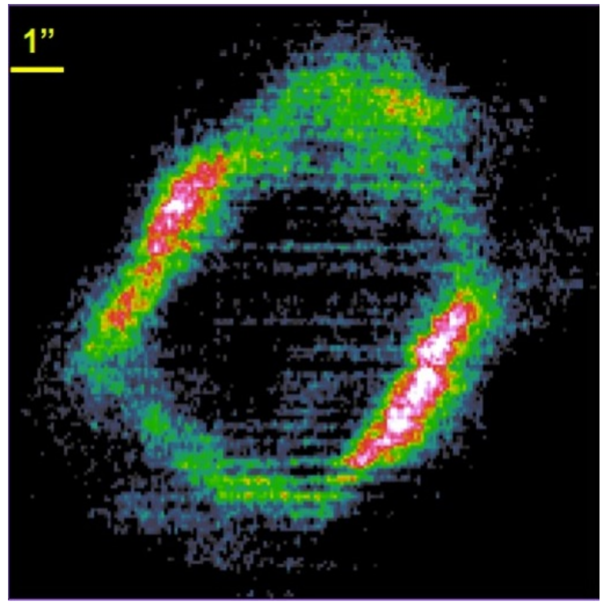

Fig. 2. A CanariCam commissioning image of the planetary nebula NGC 7027. This image is the difference image between an image made through a narrow-band filter centered on the NeII-12.8 μm line and an image through a filter centered on the adjacent continuum emission. Thus, this is essentially the an image of the distribution of the line emission.

time for arcsec and sub-arcsec image motion due to seeing; this fast-guiding motion should not be confused with the much larger amplitude (typically >10 arcsec) oscillation, or 'chopping', of M2 to permit thermal-background subtraction. If there is a strong point source in the field, image shift-and-add prior to co-adding individual image frames can be used to compensate partially for the lack of fast guiding corrections, but for extended sources, such as the planetary nebula NGC 7027 shown in Figure 2, this is generally not possible; fast guiding is then crucial in order to achieve the image-quality goals. We are hoping that fast guiding will be implemented on GTC in 2012. Another crucial indicator of CanariCam performance is sensitivity. A full discussion of the CanariCam sensitivity is beyond the scope of this paper. However, we can say that early commissioning results imply that the CanariCam sensitivity within the 10 μm atmospheric window is comparable to, or better, than that achieved for T-ReCS on Gemini South as indicated on the sensitivity tables available at the Gemini website (note that C. Telesco, the PI of CanariCam, was also the PI of T-ReCS). Commissioning tests of the spectroscopic, polarimetric, and coronagraphic modes of CanariCam are still in progress, but all results so far imply that CanariCam will satisfy its performance requirements.

4. A SCIENCE PROGRAM

It is certain that magnetic fields (B-fields) in protoplanetary disks have a broad impact on the disk evolution and the process of planet formation, and yet there are virtually no observations of disks that can constrain the B-field morphologies and intensities across the planet-forming regions of disks, namely the central few hundred AU. B-fields are implicated in, for example, the generation of disk viscosity (and therefore turbulence), deceleration of disk collapse (thus setting the disk-formation timescale), and the creation of over-dense (and under-dense) regions that might result in accelerated planet formation. CanariCam's polarimetric mode offers the opportunity of exploring and characterizing these B-fields. In one widely accepted scenario, the 'ambient' B-field embedded in the collapsing protostellar clump is dragged toward the center of the collapse by the partially ionized gas that is accreting onto the star and disk (Figure 3, from Pudritz 1985). The picture must become very complicated as the evolution proceeds, since one expects twisting of the B-field due to the disk's differential rotation, as well B-field coupling among the gas clumps in different Keplerian orbits, which will lead to turbulence

© 2013: Instituto de Astronomía, UNAM - Fourth Science Meeting with the GTC
Ed. C. Muñoz-Tuñón & J. M. Rodríguez-Espinosa

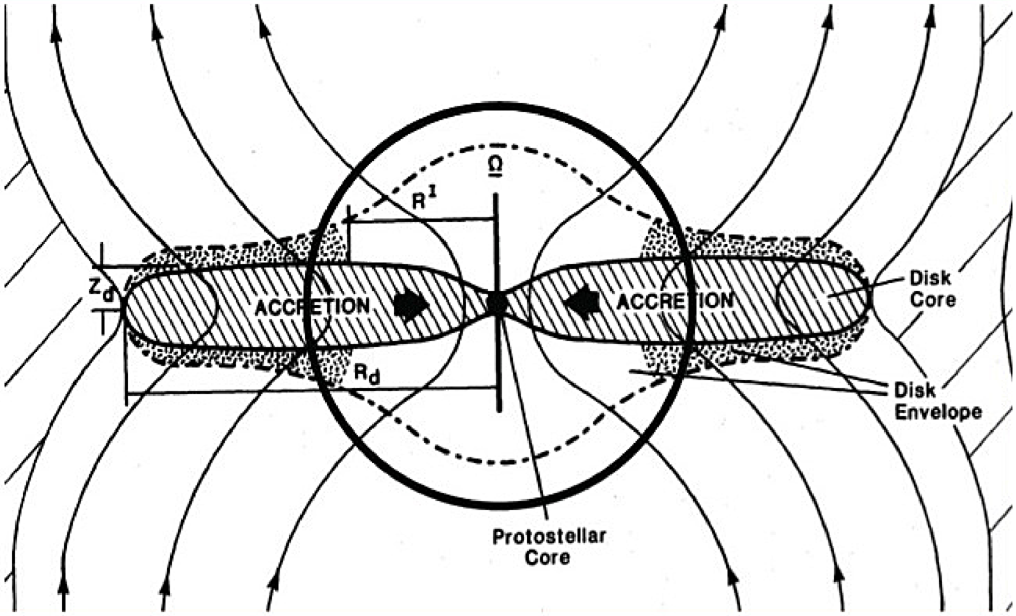

Fig. 3. During the formation of a star and its associated disk, the original 'primordial' B-field is dragged inward with the accreting material, thus taking on the hour-glass morphology, as indicated in this figure from Pudritz (1985). In reality, the B-field morphology must be much more complicated than this.

© 2013: Instituto de Astronomía, UNAM - Fourth Science Meeting with the GTC
Ed. C. Muñoz-Tuñón & J. M. Rodríguez-Espinosa

and radial angular momentum transfer (e.g., Balbus & Hawley 1998). By carrying out mid-infrared imaging polarimetry, we plan to explore the large-scale B-field morphology in protoplanetary disks (see Aitken et al. 2002). The idea is that non-spherical, spinning dust particles assume a preferential orientation in a B-field. The absorption and emission of mid-infrared radiation by these non-spherical particles will be polarized, and we can infer the B-field morphology by 2-D imaging of the mid-IR polarization. (Generally, we expect polarization by scattering to be small compared to that by emission and absorption.) Multi-wavelength polarimetric imaging permits one to separate the emission and absorption components of the polarization. Exploring B-fields in disks and star-forming regions has enormous potential, and we are on the verge of realizing that potential with CanariCam.

C. Telesco wishes to acknowledge the support of NSF grants AST-0908624 and AST-0903672. We also wish to acknowledge the outstanding support of numerous scientists, engineers, and managers at both the GTC and the University of Florida who have helped make CanariCam a reality.

REFERENCES

Pudritz, R. E. 1985, ApJ, 293, 216
Balbus, S. A., & Hawley, J. F. 1998, Rev. Mod. Phys., 70, 1
Aitken, D. K., Efstathiou, A., McCall, A., & Hough, J. H. 2002, MNRAS, 329, 647