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FRIDA: THE FIRST INSTRUMENT FOR THE ADAPTIVE OPTICS SYSTEM OF GTC

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RESUMEN

FRIDA (in**FR**rared **I**mager and **D**issector for the **A**daptive optics system of the Gran Telescopio Canarias) se está diseñando como un instrumento con óptica limitada por difracción con capacidades de imagen de banda ancha y angosta y espectroscopía integral de campo para operar en el intervalo de longitudes de onda de 0.9 – 2.5 μm. FRIDA es un proyecto de colaboración entre los socios principales de GTC; a saber, España, México y Florida. Las principales características de diseño de FRIDA se describen en esta contribución.

ABSTRACT

FRIDA (in**FR**rared **I**mager and **D**issector for the **A**daptive optics system of the Gran Telescopio Canarias) is being designed as a diffraction limited instrument with broad and narrow band imaging and integral field spectroscopy capabilities to operate in the wavelength range 0.9 – 2.5 μm. FRIDA is a collaborative project between the main GTC partners, namely, Spain, México and Florida. The main design characteristics of FRIDA are described in this contribution.

Key Words: **INSTRUMENTATION: ADAPTIVE OPTICS**

1. INTRODUCTION

GTC will shortly be the single largest operating optical / infrared telescope in the world and as such, it will have two distinct advantages in the study of faint objects in the local and distant universe. The first is that the light grasp of a telescope scales as D^2, the square of the diameter, and so GTC will gather more photons than any other optical / infrared telescope. The second is that the angular resolution of a telescope is proportional to λ D, and so once the adaptive optics system is operating, the GTC will have the finest resolution of any infrared telescope. Furthermore, when observing point sources in the background limit, the combination of light grasp and diffraction limit will give GTC a D^4 advantage over smaller telescopes. FRIDA will use diffraction-limited optics to avoid degrading the hard-won image quality delivered by the adaptive optics system of GTC. FRIDA will be sensitive in the near infrared regime, where the highest Strehl ratios are achieved, and will deliver high quality imagery in broad and narrow bands and spatially resolved spectroscopy with the use of an integral field unit. FRIDA is being designed to be installed at the Nasmyth platform, behind the adaptive optics system, it will use a single 2048 × 2048 Hawaii 2 Rockwell detector. The same detector will be used for the imaging and IFS operating modes.

2. SCIENTIFIC CASE

FRIDA will reveal astrophysical phenomena on angular scales as small as 0.020 arcsec and at high spectral resolution. The operating wavelength range of FRIDA will expose dusty environments and will probe a spectral range rich in absorption and emission lines from many different species and gas phases. With these characteristics FRIDA will be able to tackle a large number of astrophysical problems. The interest for FRIDA in the GTC community is broad, the scientific cases range from solar system bodies to high-redshift galaxies, including resolved stellar populations, close binary systems, young stellar objects and star formation environments, circumstellar phe-

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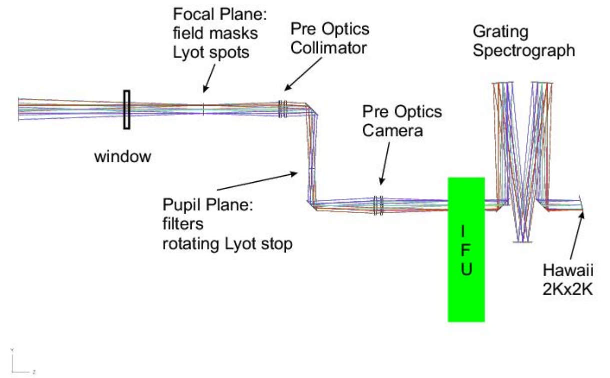

Fig. 1. The basic Frida layout. The pre-optics collimator and camera are CaF2 and FTM16 doublets. The spectrograph performs as a 1:1 imager when replacing the diffraction grating by a mirror. The spatial scale is selectable from the pre-optics camera.

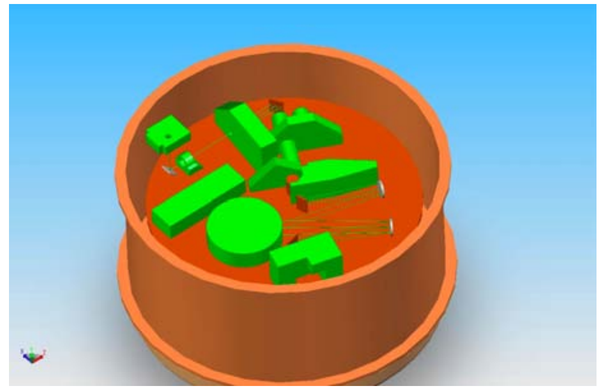

Fig. 2. Volumetric general overview of the instrument. The incoming beam from the AO system enters at the top on the left side of the figure and after the first focal plane it is redirected by a fold mirror to the pre-optics collimator and the first pupil (filters) plane. A second fold mirror redirects the beam to the camera wheel, the second focal plane and the IFU. The sliced field then enters the spectrograph to finally reach the detector.

nomena in advanced stages of stellar evolution and active galactic nuclei.

3. BASIC LAY-OUT

The current basic optical scheme of FRIDA is shown in Figure 1. Light from the GTC adaptive optics system (Devaney et al. 2004) enters from the left through the dewar window. The optics forms a dual re-imaging system. The spatial scale is selected by changing the pre-optics. In the imaging mode the beam avoids the integral field unit (slicer or dissector) and it is redirected into the IFU for the spectroscopic mode. Figure 2 shows a volumetric general overview of the instrument with its folded optics. The incoming beam from the AO system enters from the top on the left side of the image in this representation.

The present design introduces a series of modifications in the spatial scales in the imaging mode, eliminates anamorphic scales in the IFU mode and modifies the slicer format described in Cuevas et al. (2006) but otherwise it keeps the same main design architecture and operational modes philosophy.

4. IMAGING

In imaging mode FRIDA will provide broad-band and narrow-band filters and two selectable spatial scales that provide adequate Nyquist sampling of 0.010 arcsec/pixel and 0.020 arcsec/pixel with corresponding field of view 20.48×20.48 arcsec and 40.96×40.96 arcsec. The finer scale will provide adequate sampling of the almost limited core in J and H bands and the coarser scale will provide adequate sampling in the the K band.

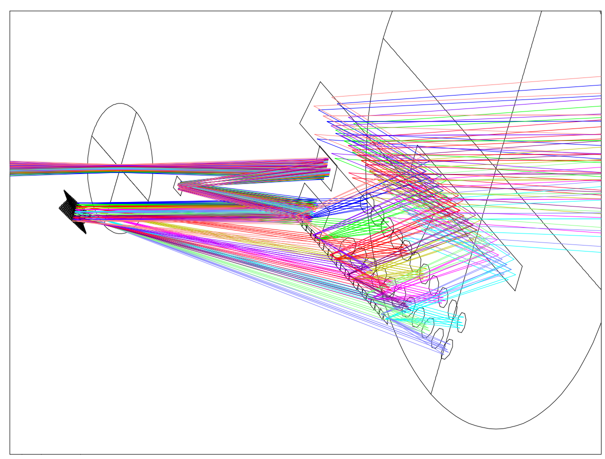

Fig. 3. The optical model for the FRIDA image slicer designed with the Zemax Non Sequential Components mode.

5. INTEGRAL FIELD SPECTROSCOPY

FRIDA will provide an integral field spectroscopy mode using an image slicer. The IFU design is based on FISICA (Eikenberry et al. 2004). The selectable spatial scales parallel to the slices will be 0.010 arcsec/pixel and 0.020 arcsec/pixel and the corresponding scales perpendicular to the slices will be 0.020 arcsec/slice and 0.040 arcsec/slice. Each slice will project to two pixels in the spectral direction. For an image slicer with thirty slices these scales yield

TABLE 1

SUMMARY OF MAIN PARAMETERS FOR FRIDA

Working location	Nasmyth A platform, after GTC AO system
Wavelength range	0.9 to 2.5 micron, performance optimized for 1.1 to 2.4 microns
Observing modes	Imaging and Integral Field Spectroscopy
Array format	2048 × 2048 HgCdTe Hawaii 2, Rockwell
Imaging mode scales	0.010 and 0.020 arcsec/pixel
Field of View	20.48 × 20.48 arcsec and 40.96 × 40.96 arcsec
IFS mode scales	0.010 arcsec/pixel ×0.020 arcsec/slice
	0.020 arcsec/pixel × 0.040 arcsec/slice
Field of View	0.65 × 0.60 arcsec and 1.30 × 1.20 arcsec
Spectral resolutions	R ≈ 1500, 4000 and 30000

fields of view of 0.65 × 0.60 arcsec and 1.30 × 1.20 arcsec. The available spectral resolutions will be R ≈ 1000, R ≈ 5000 and R ≈ 30,000. The combination of high spectral resolution and high spatial resolution will be a unique capability of FRIDA. The optical model for the IFU is shown in Figure 3. Light entering from the left first goes through a relay optics system before reaching the image slicer. The sliced field is then projected onto a set of pupil and field mirrors before forming the pseudo slit. Ray tracing has been designed with the Zemax Non Sequential Components mode.

6. PERFORMANCE

The expected performance of FRIDA has been modeled for imaging and spectroscopy of point and resolved sources with continuum and emission line spectra. The model includes sky background, OH supression, thermal background from the telescope and the AO system, the transmission of the instrument, the efficiency of the detector and the expected Strehl ratio delivered by the AO system. The figure of merit for imaging and spectroscopy is the magnitude at which a signal to noise ratio of 10 per resolution element is reached in the core. The 1 hour limiting magnitudes for a signal to noise ratio of 10 in direct imaging of point sources are 25.5 in Z, 25.1 in J, 24.2 in H and 23.0 in Ks. The corresponding one hour continuum point-source limiting magnitudes per resolution element for R = 5000 with the fine scale are 19.5 in Z, 19.4 in J, 19.3 in H and 18.6 in Ks and for the coarse scale 20.2 in Z, 20.1 in J, 20.0 in H and 18.8 in Ks.

7. SUMMARY

FRIDA will be a diffraction limited instrument, fully cryogenic, operating in the near infrared 0.9 – 2.5 μm regime (Table 1). It will provide narrow and broad imaging capabilities with scales of 0.010 and 0.020 arcsec/pixel and corresponding fields of view of 20.48×20.48 arcsec and 40.96×40.96 arcsec. Using the same detector, FRIDA will also provide integral field spectroscopy at low, intermediate and high spectral resolutions, the latter will be a unique capability among integral field spectrographs operating in 8 − 10 m class telescopes. Since the AO system is located upstream of FRIDA, the double pupil design provides adequate shielding from parasite radiation and together with the double focal plane design it allows to consider a future upgrade path for coronography and long-slit spectroscopy. FRIDA is in the preliminary design stage and currently some optimization to the spectrograph design and pupil size is being studied. FRIDA is being built as a collaboration among the main GTC partners, namely Spain, Florida and México. FRIDA shall be at the telescope by the end of 2010, after the GTC- AO system has been commissioned.

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