FORTIS: A Rocket-Borne Far-UV Spectro-Telescope

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Abstract

The Far-Ultraviolet Off-Rowland Telescope for Imaging and Spectroscopy (FORTIS) is a rocket-borne spectro-telescope designed to investigate Lyman alpha (Lyα) escape from nearby star-forming galaxies and to quantify its relationship to the local gas-to-dust ratio. By operating in the 900 – 1700 Å wavelength bandpass and incorporating a GSFC microshutter array at the prime focus, the FORTIS instrument enables simultaneous observations of both Lyα and the far-UV continuum of the brightest HII regions of low redshift starforming galaxies. A primary ground-based optical spectroscopy of the target will provide the necessary Balmer line to calculate the Lyα escape fraction (Fleming et al. 2010).

We present the optical design and capabilities of the FORTIS instrument, the first flight of which is currently scheduled for April of 2011 to observe the galaxy cluster Abell 1367.

Primary Science Objectives

Star-forming galaxies are currently believed to be the dominant sources of the ionizing radiation responsible for re-ionization at z ~ 6, however, the fraction of ionizing radiation (Lyman continuum, LyC) that escaped from the first galaxies is currently unknown. Due to increasing HI opacity at redshifts z > 3, direct observation of escaped LyC radiation in the earliest galaxies is considered to be effectively impossible. Lyman alpha (Lyα), which in star-forming galaxies is dominantly produced by the recombination of ionized hydrogen, is a potential proxy for LyC as the Lyα intensity is effectively a measure of the number of LyC photons which do not escape. If a quantitative relationship between escaping Lyα and LyC emission can be established in low-z analogs, then the easily observed Lyα could be used to estimate the contribution of star-forming galaxies to the meta-galactic ionizing background over time.

The primary science goal of the FORTIS instrument is to measure Lyα escape fraction (fLyα) and the gas-to-dust ratio as a function of position in nearby resolved star-forming galaxies. We seek to determine whether the observed fLyα is correlated to the gas-to-dust ratio and ultimately if the same factors which govern fLyα also determine the amount of LyC escape. The FORTIS instrument is designed to carry out these objectives within the scope of a sounding rocket mission. A full scale program to fully examine the LyC escape fraction and fLyα could then be completed within the parameters of an orbital mission.

FORTIS Overview

The FORTIS spectro-telescope design is Gregorian telescope (concave primary and secondary mirrors) with a diffraction grating holographically ruled on the secondary. The diffraction secondary provides two off-axis spectrally dispersed channels to either side of an on-axis imaging channel all in the same plane. This two-bounce design expands the efficiency, angular coverage, and spectral multiplexing capability of FORTIS in comparison to that of a traditional long-tube three-bounce far-UV Rowland circle spectrograph and telescope. Astigmatism in the spectral orders is controlled by slightly altering the radius of curvature of the secondary mirror in the direction perpendicular to the dispersion, making the secondary mirror into the form of a triaxial ellipsoid. Correcting for astigmatism in the spectral channels introduced astigmatism into the imaging channel. A cylindrical doublet is used to remove this aberration.

The FORTIS optical system consists of a parabolic primary mirror, a diffractive secondary triaxial ellipse, a zero-order C2F6 and MgF2 cylindrical doublet to correct for astigmatism in the imaging focal plane, and an optical bench. We recently accepted delivery of two astigmatic secondary ellipses and have shipped them to the grating vendor.

Optical Elements

FORTIS will initially launch with all of the shutters in the MSA closed. The flight of a rocket will be an unknown number of failed shutters in the “open” position which will provide a minimum backup in case of addressing failure. When the telescope has slewed onto target, the payload shutter plane will open and a motor driven latching shutter will scan the face of the MSA, transitioning into the “all open” configuration. The imaging (zero-order) MCP will observe the target for ~30 seconds while an onboard National Instruments (NI) FPGA will accumulate the accumulated image on the fly to determine the brightest “pixel” (shutter) in each row of shutters. Only one shutter per row may be open during spectral acquisition to reduce confusion. A command sent from the ground will order the magnet to rescan the array and the latching voltages will be applied in such a way that only the brightest shutter in each row remains open. It will remain in this configuration for the duration of the flight.

Detector System

The FORTIS detector array consists of three Csl coated microchannel plate (MCP) stacks read out by a charged detector readout system. The detector is housed in a vacuum vessel with a vacuum door that will be opened during flight.

Microshutter Array

The MSA consists of a 20 array of closely packed clear aperture slits, each with an independently selectable shutter (Kutyrev et al. 2004). An array is composed of a thin shutter membrane and light shield mounted to a 100 μm × 200 μm pitch of rectangular holes. The matching shutter array is machined into a silicon nitride membrane 0.5 μm thick. An individual shutter blade is suspended from the shutter frame by a torsion flexure. The shutters are coated with a layer of high permeability magnetic material to allow for rotation of the shutters by a passing magnet. Electrodes, deposited on one of the interior walls of the shutter support grid and the shutters themselves, allow for electrostatic latching and release.

Multi-object capability is provided by an array of microshutters at the focus of the primary. The FORTIS microshutter arrays (MSA) are small prototype devices of the larger arrays developed at Goddard Space Flight Center (GSFC) for use in the Near Infrared Spectrograph (NIRSpec) on JWST. FORTIS will provide the first flight opportunity for this device, which is ideally suited to far-UV applications because the shutters are clear apertures devoid of material. In spectral acquisition mode only one shutter per row is open to reduce spectral confusion. Targets are selected on the fly using the zero-order imaging channel to determine the brightest regions of the targets in the far-UV.

FORTIS Parameters

Table 1 shows the values of the parameters that describe the FORTIS design. All values are in mm, unless otherwise noted. The FORTIS detector area is ~ 45 mm2 and the two adjacent spectral areas are 45 mm × 62.5 mm.

References

Fleming, B. et al. 2010, this issue.

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