ULTRAVIOLET ASTRONOMY IN THE XXI CENTURY

e-Workshop 2020 – October 27-29

JcUVa

Progress on the Optical Design of a 1m Spectroscopic and Imaging UV space telescope for the CASTOR/INSIST mission

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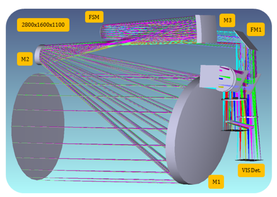
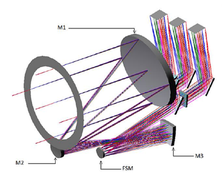
Overview:
In 2019 collaborative work between HAA (Herzberg Astronomy & Astrophysics) and IIA (Indian Institute of Astrophysics) began to develop a common optical design in preparation of a possible collaboration between the CASTOR and INSIST missions. India and Canada have been developing similar 1m aperture UV space missions, the Indian lead INSIST (Indian Spectroscopic Imaging Space Telescope) mission and the Canadian lead CASTOR (the Cosmological Advanced Survey Telescope for Optical and uv Research) mission. The common optical design is a 1-m off axis Korsh design with a 0.25 square degree field. There is simultaneous imaging in three band passes (UV, u, and g) via dichroic beam splitters. Image sampling is 0.1"/pixel with a required image quality over the field of <0.15" FWHM. In addition, a multi-object DMD (Digital Micro-Mirror) spectrograph, covering an adjacent field of view, will provide moderate to high-resolution UV spectroscope, while a wide-field, low-resolution spectroscopic capabilities will be provided by a grism. The instrument is designed to fit within the ISRO (Indian Space Research Organization) PSLV(Polar Satellite Launch Vehicle) and is constrained to cylindrical volume 4m long by 1.5m diameter. The progress on the common optical design is presented with preliminary performance and tolerancing calculations.

INSIST baseline design

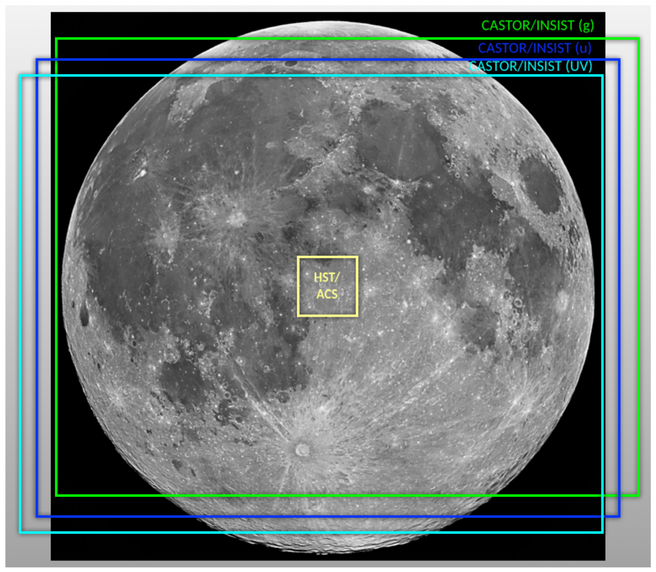


The baseline designs are both KORSH TMA design. A design effort as been needed to address new packaging requirement for the PSLV launch vehicle to fit the design in a 4m long by 1.5m diameter cylinder.

CASTOR baseline design



CASTOR vs. Hubble: Field of View



In this re-design Packaging effort we have two candidate designs:

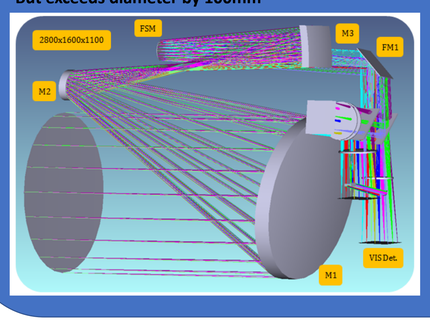
Design -1 (D1)

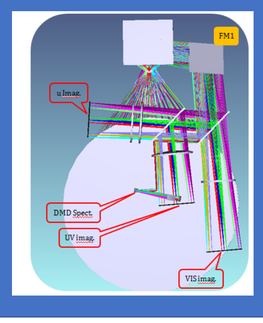
Tertiary –Located in Off-Axis direction

Lower distortion – more telecentric

But exceeds diameter by 100mm

Primary (f/2.35)–Secondary : f/6.1
System: f/20
Sec-Tertiary: 1998mm
2800mm x 1600mm x 1000mm





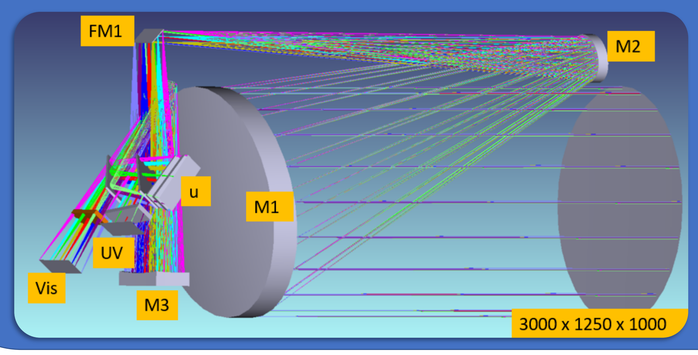
Design -2 (D2)

Tertiary –Located behind Primary

Greater distortion – less telecentric

meets volume constraint

Primary (f/2.3)–Secondary : f/12
System: f/20
Sec-Tertiary-: 3265mm
3000mm x 1250mm x 1000mm



Design trade –

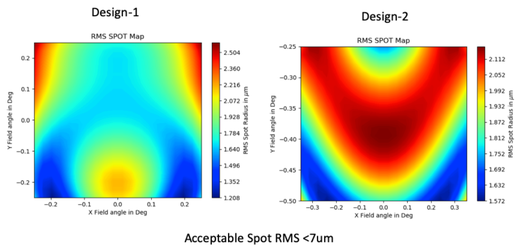
	D1	D2
Image Quality	Exceeds requirement	Exceeds requirement
Position sensitivity of secondary	dY < 15um, dZ < 5um	dY < 13um, dZ < 5um
	Both very similar!	
Distortion	~0.2" Max distortion 0.02%	~2" Max distortion 0.65%
Telecentricity	2.6 degrees	7.6 degrees
Volume constraint	diameter 100mm over requirement	Meets all requirements

DESIGN BASELINE

Primary aperture	1m off-axis, un-obscured primary
Lifetime	5 years minimum, with possible extended lifetime.
Orbit	Low-earth, sun-synchronous, polar terminator orbit (circular, ~800 km, 98 degrees inclination)
Operational modes	(1) wide field imaging in three channels simultaneously. (2) slit-less spectroscopy in UV and u channels, simultaneously (full field). (3) multi-slit, medium resolution UV spectroscopy in parallel field.
wide-field imaging	
Imaging field of view	0.44˚ x 0.56˚ = 0.25 deg^2 (rectangular to accommodate detector format)
Plate scale	0.1" = 10um (f/20.6 system)
Image quality	FWHM = 0.15" in all channels
Baseline detector	2x2 array of 8Kx10K with 10 um pixels for each photometric channel
Photometric channels	UV (150-300 nm), u (300-400 nm), g (400-550 nm) (uv-dark / u wide band passes under consideration)
Slit-less spectroscopy in UV and u imaging channels (single grism option)	
Spectroscopic field	0.44˚ x 0.56˚ = 0.25 deg^2 [full imaging field of view]
Spectroscopic channels	UV (150-300 nm), u (300-400 nm)
Resolving Power	1. R~300 to 500 (tbd) in UV channel, Δλ over 2 px, 1 px = 10 µm 2. R~500 in u channel, Δλ over 2 px, 1 px = 10 µm
PSF	FWHM < 0.3" in both channels
Multi-slit, UV spectroscopy in parallel field (DMD MOS option)	
Spectroscopic field	213" x 121", offset by ~3'-4' from the edge of the imaging field.
Spectroscopic channels	UV (150-300 nm)
Resolving Power	R=1000
Spectral Multiplexing	~500 maximum (i.e., 2 pixels height per spectrum, with 2 pixel gap between spectra) ~200"long slit

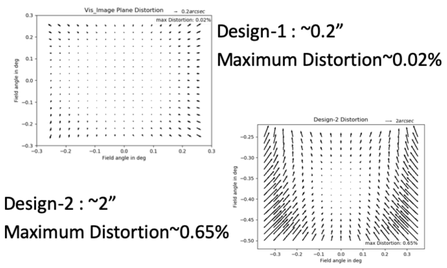
Spot map

(both exceed requirement)



Acceptable Spot RMS <7um

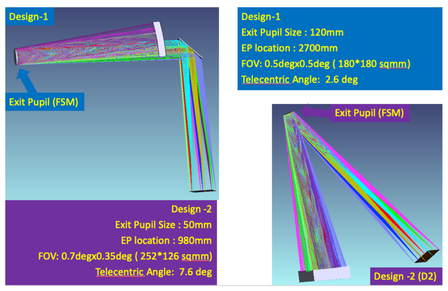
Distortion



Design-1 : ~0.2"
Maximum Distortion~0.02%

Design-2 : ~2"
Maximum Distortion~0.65%

Telecentricity

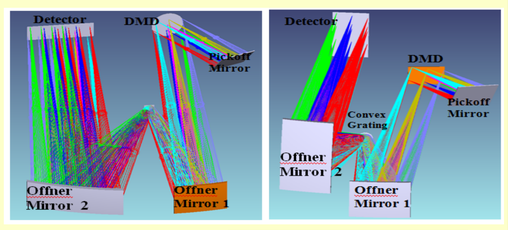


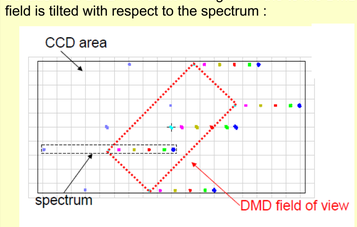
Multi-Object DMD Spectrograph:

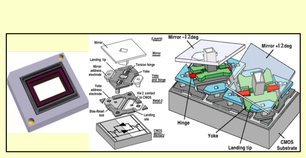
A multi-object DMD (Digital Micro Mirror) spectrograph is proposed for the NUV-band and will be located adjacent to the imaging field of view. A TI-DMD device with an Offner relay with a grating on the convex mirror is proposed.

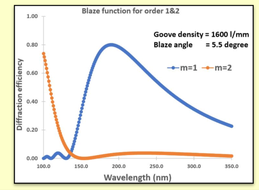
The preliminary specifications for the spectrograph are as follows:
- NUV-band 150-303nm, located adjacent to NUV detector.
- Field – as limited by the DMD size – of 20.7 x 11.7mm (213" x 121")
- Spectral resolution: R ≈ 1000 at 0.2" effective slit size.
-10um detector with 0.1" sampling (1:1 spectrograph magnification).

The Order layout on the detector with respect to the DMD Is shown below, because the DMD mirror tilt 45 degree to the to the DMD array the DMD field is tilted with respect to the spectrum :









Summary –

Both designs are very similar in performance with the exception of distortion and telecentricity. The D1 design has more favorable distortion and telecentricity, unfortunately it exceeds the volume constraint by 100mm. The telecentricity impacts the grism performance for higher resolutions. We are currently evaluating the D2 design grism image quality and the impact of higher distortion on the science.