New Technologies Developed for FORTIS*

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*Far-UV Off Rowland-circle Telescope for Imaging an Spectroscopy

Co-Is and Collaborators:

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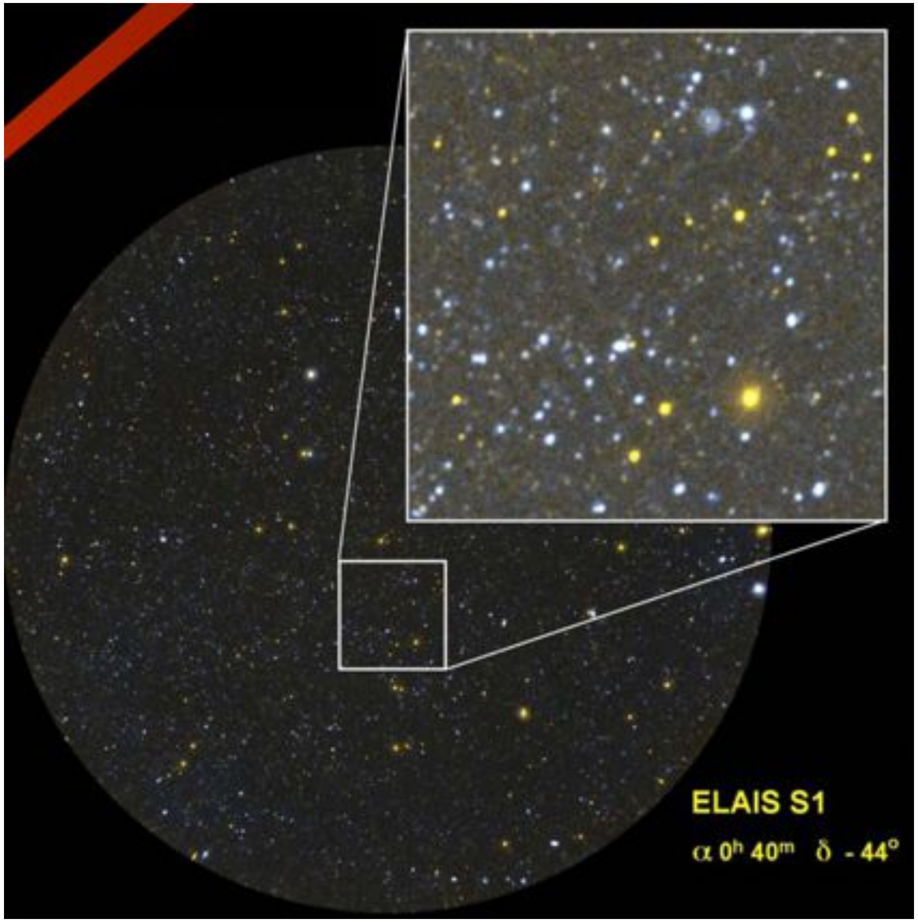
GSFC - Samuel H. Moseley, Alexander S. Kutyrev, Mary J. Li, David A. Rapchun, Jeffery Kruk

Sensor Sciences - Oswald H. Siegmund, Adrian Martin, John V. Vallerga

My obsession started in 2004

(McCandliss et al. 2004) when >>>

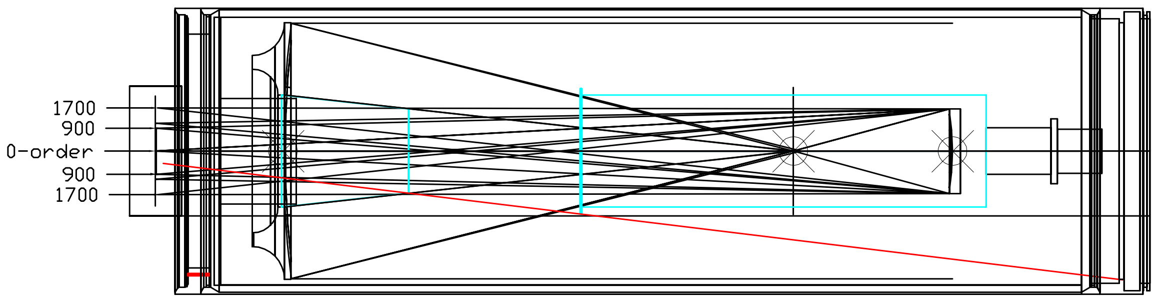


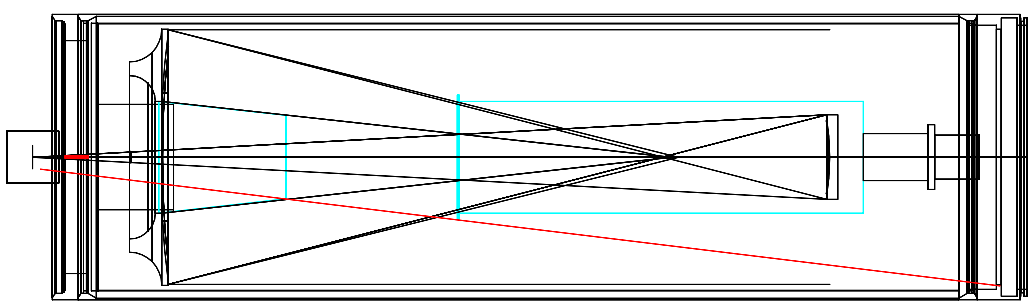
Graphic taken from T. K. Wyder, Moriond Conference, March 29, 2004, La Thuile, Italy

- ***GALEX*** **found lots of nearby faint "blue" star forming galaxies over large angular fields**
- **Science Questions: What fraction of these galaxies leak ionizing radiation? How efficient? Implications for epoch of reioniztion?**
- **Technology Need: Industrial approach to wide field multiobject spectroscopy in far-UV; moderate *R***

High Efficiency Spectro/Telescope Concept

Gregorian with a triaxially figured laminar grating as the secondary optic





Four New UV Science Thrusts

(McCandliss et al. 2010)

- Enabled by the development of wide-field multi-object spectroscopy in the UV
  - The Mystery of Lyman Continuum Escape and the Potential of a Lyα Proxy (McCandliss et al. 2008, 2009)
  - Search for the Epoch of He II Reionization
  - Baryon Acoustic Oscillation Probe of Dark Energy with Lyα Forest
  - Visualizing the Lyα Web

Low Aeff

v

High Aeff

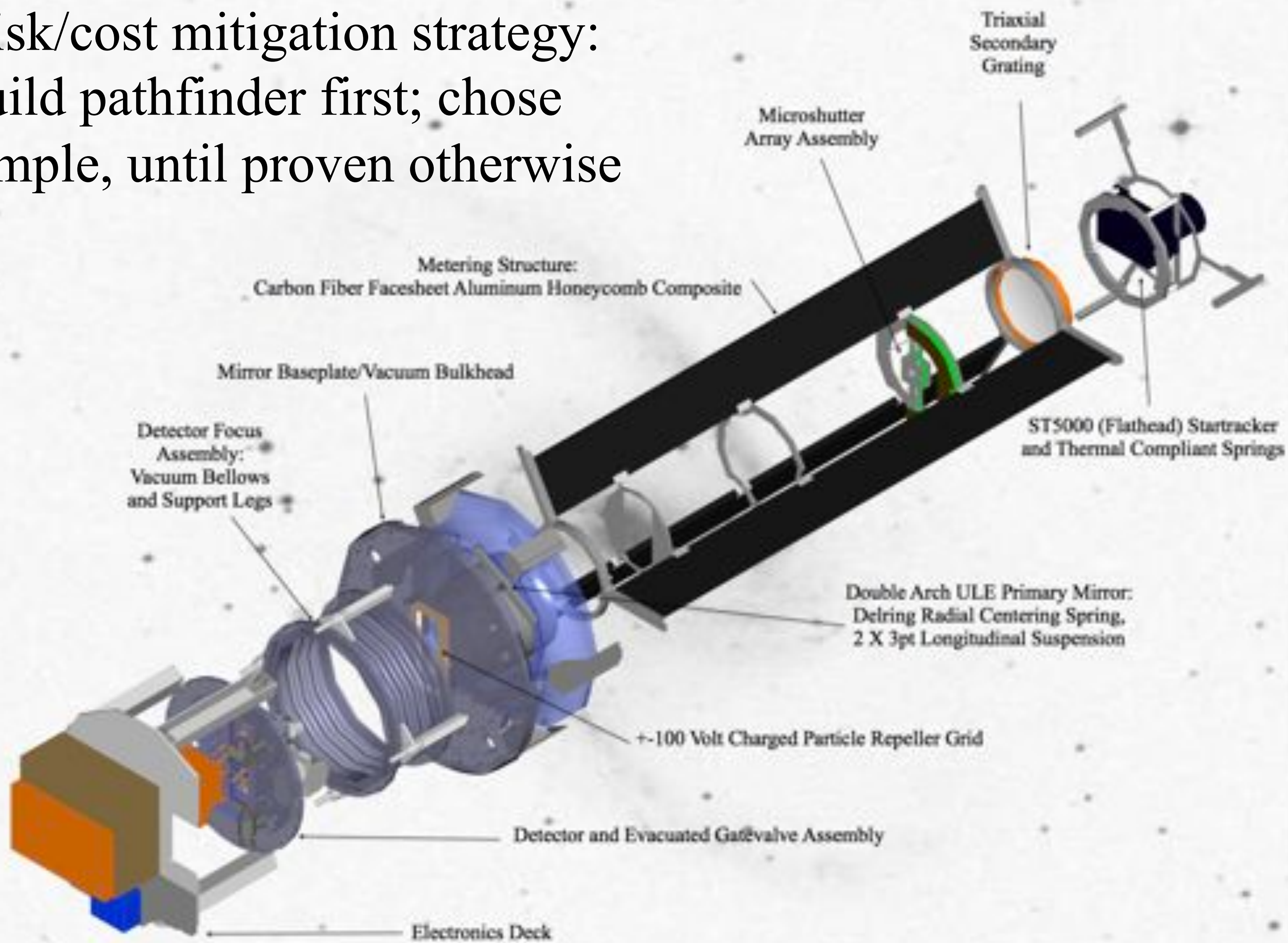
New Technologies

Developing with sounding rocket borne pathfinder:

Science - Lyman alpha escape fraction and gas-to-dust ratio

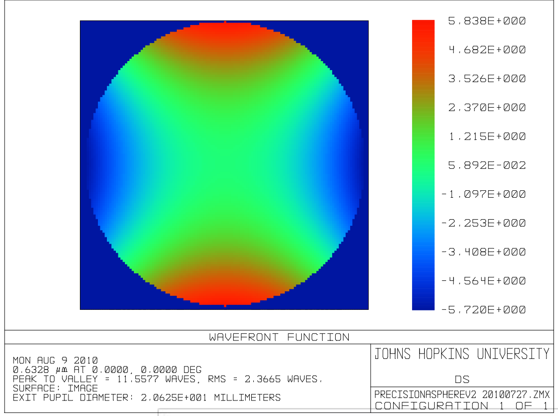
- Spectro/telescope
  - High efficiency “two-bounce” Gregorian design with two spectral and one imaging channel; requires triaxial figured secondary grating and cylindrical achromat
    - Ideal instrument for wide-field spectral imaging surveys
- Microshutter array (MSA) - (developed by GSFC for JWST)
  - Prototype is an array of 64 x 128 individually selectable slitlets
  - Placed at prime focus image to dissect image
    - Provides multi-object capability
- Autonomous targeting
  - Zero-Order Microshutter Interface (ZOMI)
    - Brightest targets are selected on-the-fly for spectral acquisition.

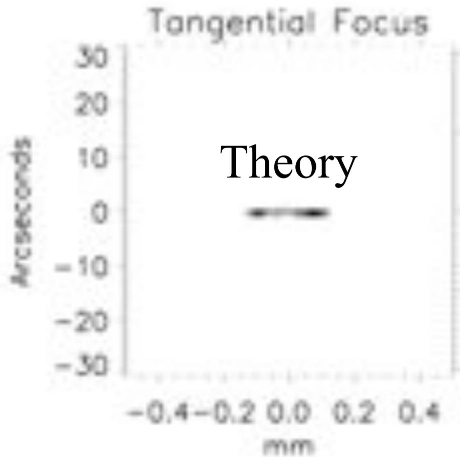
Risk/cost mitigation strategy: build pathfinder first; chose simple, until proven otherwise

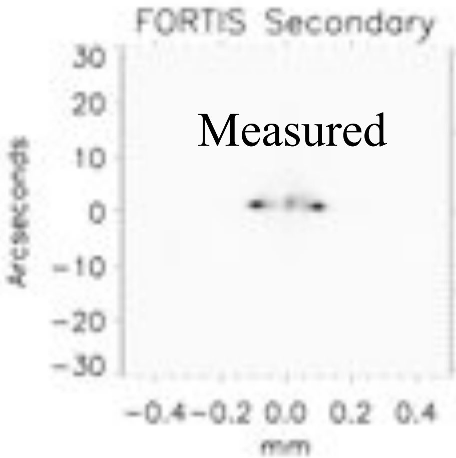


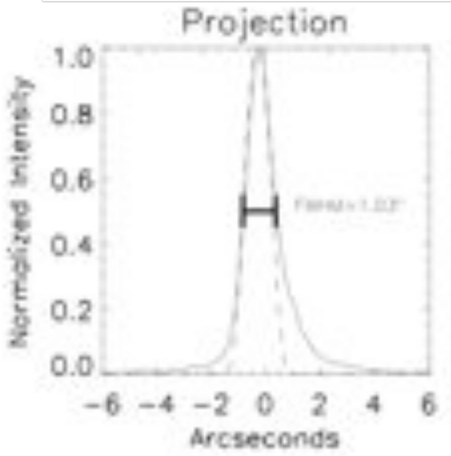
Triaxial ellipse

- Two secondary tri-axial ellipses delivered May 2010
- Two additional substrates delivered November 2010 (Precision Asphere)
- Delivered to Horiba Scientific (JY) Nov. 2010
  - Expected grating delivery Nov. 2011



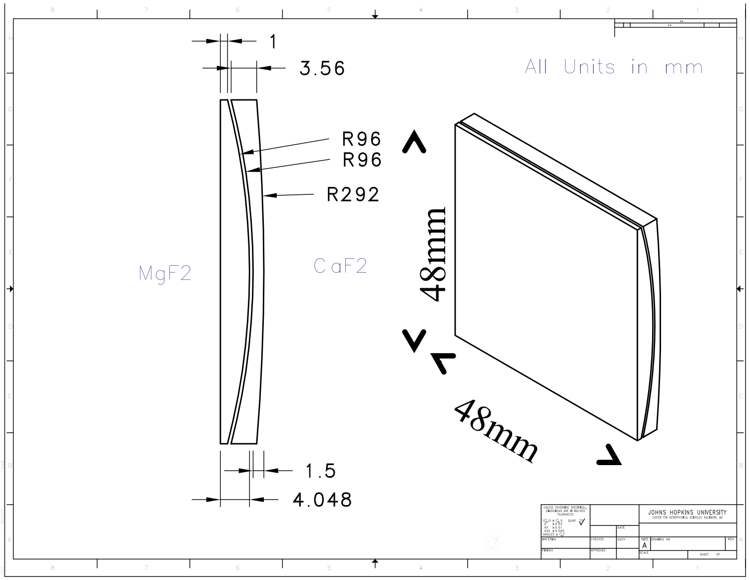


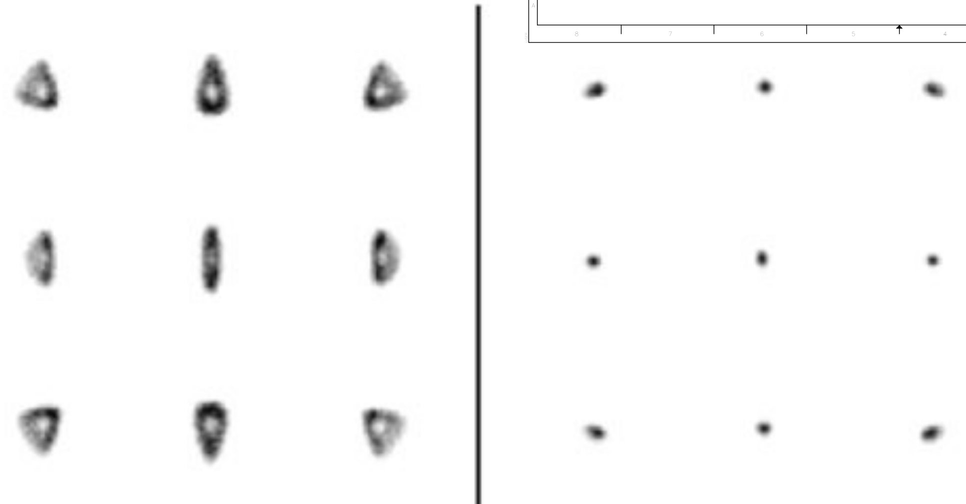




Corrective cylindrical doublet - achromat

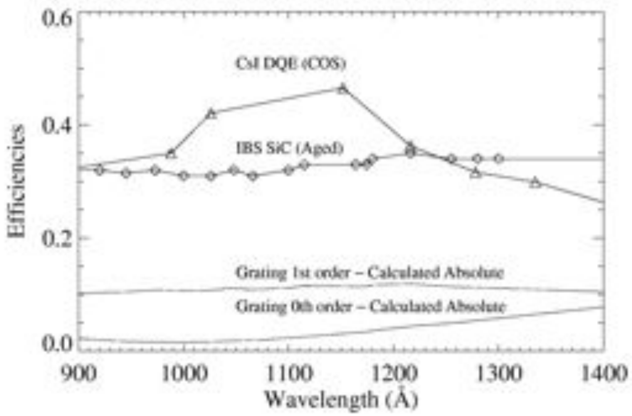
- CaF_2 / MgF_2
- Estimated Delivery in late fall 2011



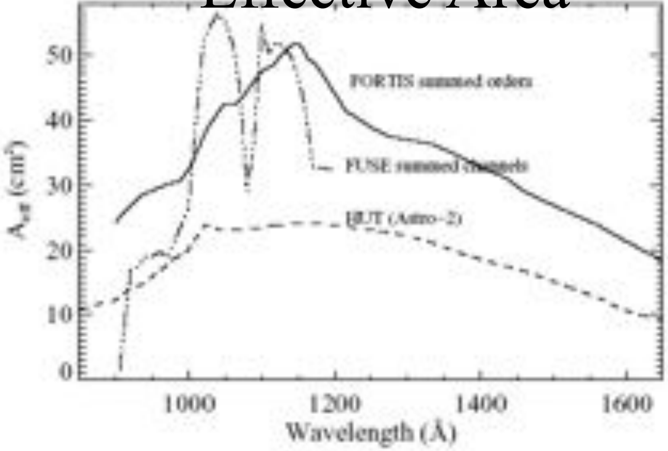


Fortis expected performance

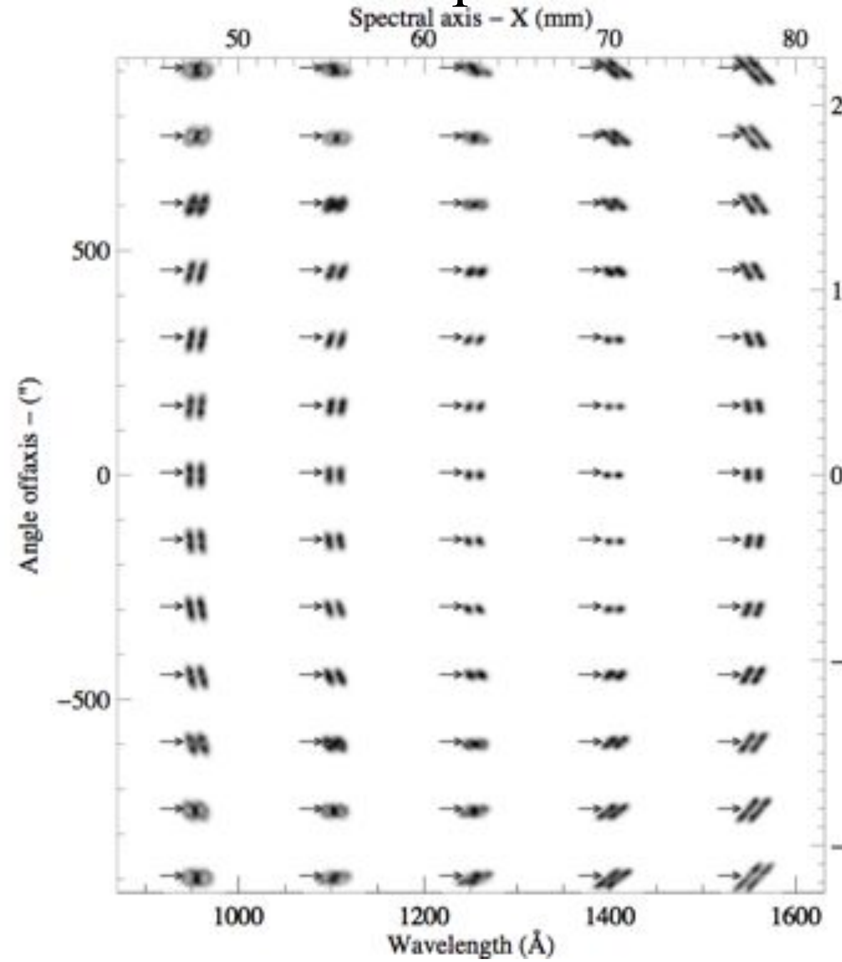
Component Efficiency



Effective Area

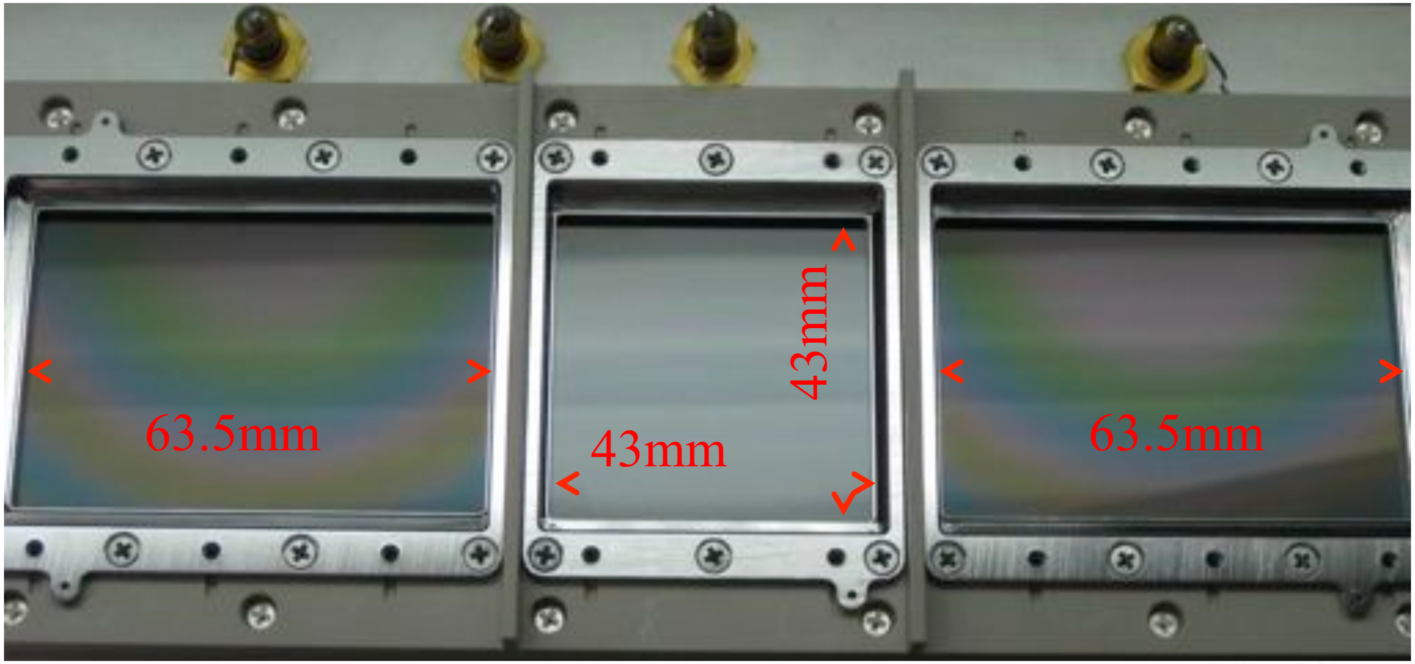


Point Spread Function



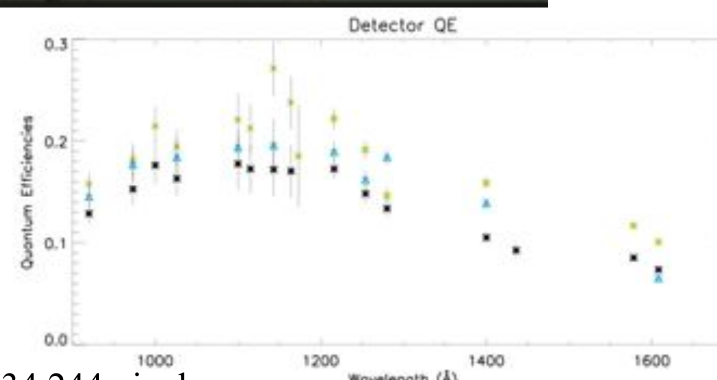
(wavelength pairs with 1 Å separation - X 10 magnification - 0.015mm sampling)

FORTIS MCP Detectors



Future Borosilicate Testbed

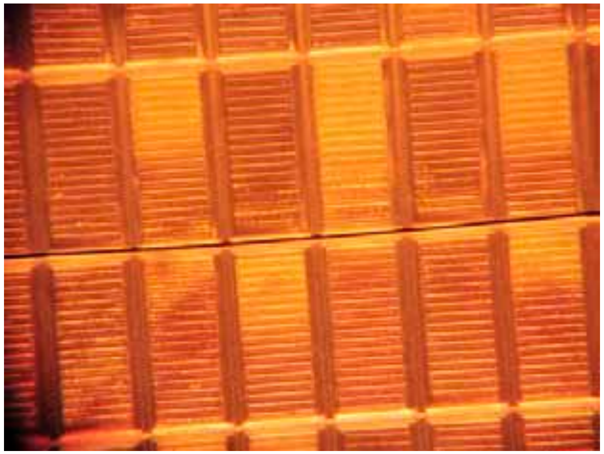
- +1/0/-1 Orders
  - Three cross delaylines
  - CsI Photocathodes
  - Area (mm x mm): 63.5 x 43, 43 x 43, 63.5 x 43 = 170 x 43
  - Pixel size X(µm), Y(µm): 10.6, 7.8; 13.4, 13.7; 11.4, 7.5
  - Pixel count: 5991 x 5513 + 3209 x 3139 + 5570 x 5733 = 75,034,244 pixels

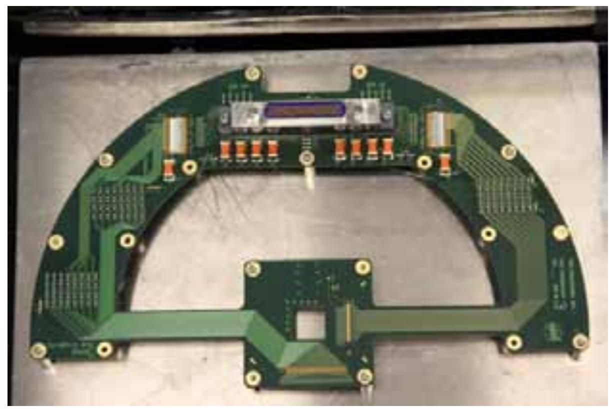


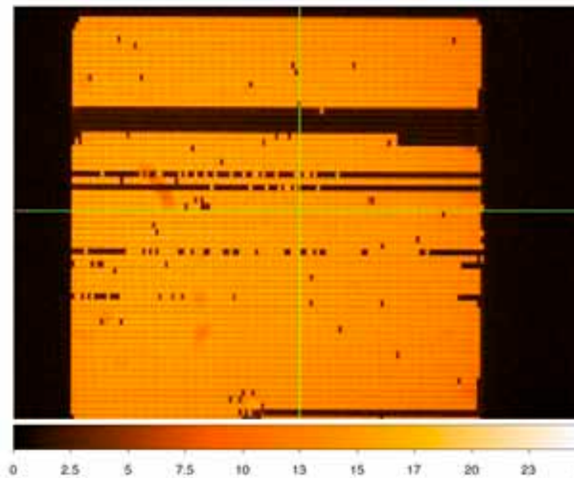
Microshutter Arrays

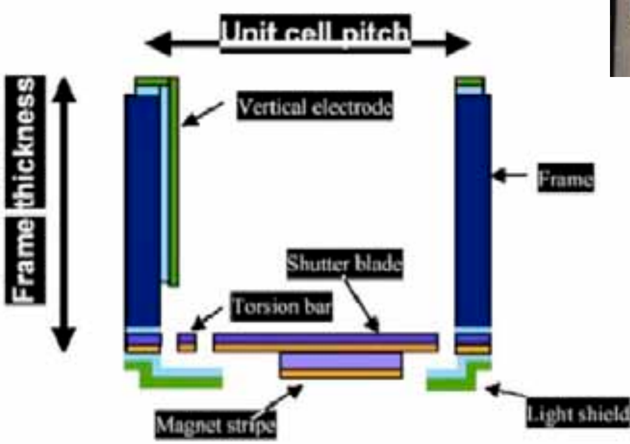
Latched open!

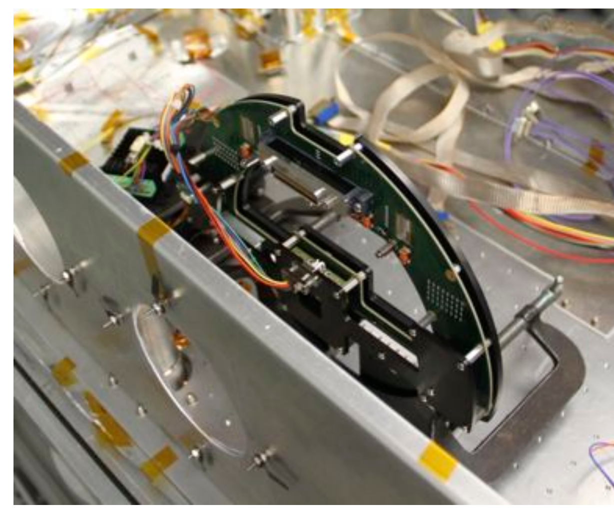
- *JWST NIRSPEC* prototype
  - 128 x 64 shutters











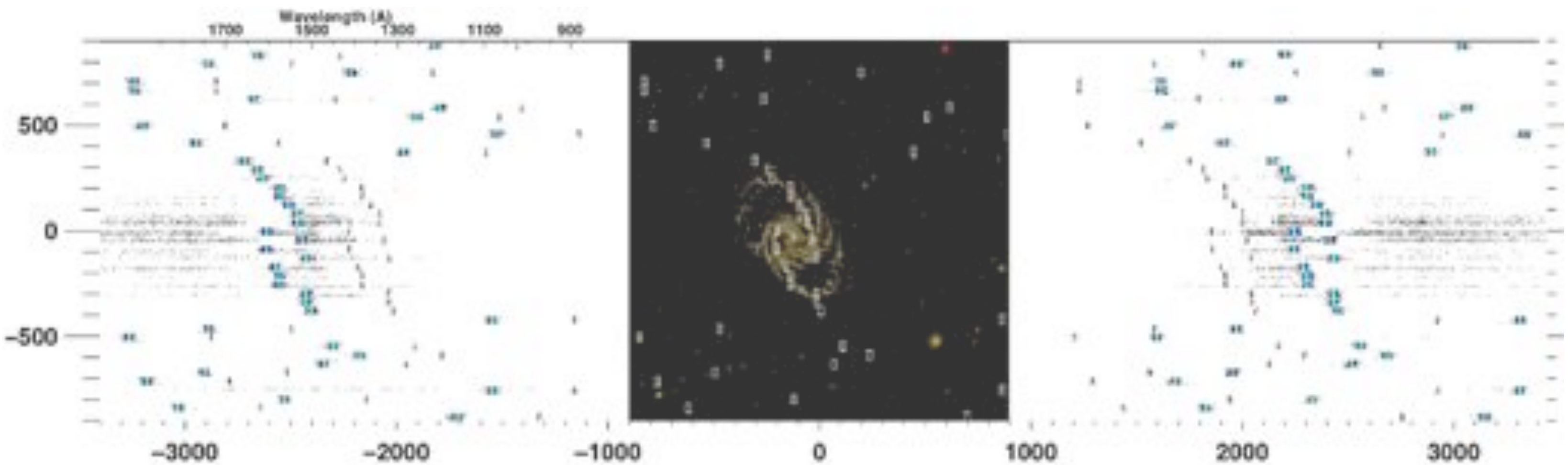
Targeting - two stages

- Stage 1 – Zero Order target imaging
  - Settle on target, send “All Open” command
    - Magnet scans MSA
    - Latching voltage locks all shutters open
  - Acquire image through open shutters
    - Integrate light through each shutter
    - Use NI cRIO running labview to select brightest region of galaxy in each row of microshutters (Zero Order Microshutter Interface - ZOMI)
- Stage 2 – Acquire spectra of target
  - ZOMI sends addresses to MSA electronics
  - Magnet scans MSA again
    - Closing coincides with a grounding of the latching voltage for a given row
    - Column latching the voltage of selected shutter remains on
  - Remain on target acquiring data through open shutters for duration of flight

Putting it all together;

the FORTIS spectral imaging plane –

brightest slit per row targeting algorithm



Technology Readiness Levels

System provider	Subsystem	Components	Heritage	TRL Heritage	TRL FORTIS at present *
Detector •Sen. Sci. •JHU	Head	CsI MCPs and X-delayline anodes	FUSE, COS, SRs	9, 9, 7	6
	Electronics	TAC, A/D, parallel multiplexer	FUSE, COS, SRs	9, 9, 7	6
	Vac door	Motor drive, linear bearing slide, TDC seal	FUSE, COS	9, 9	6
MSA •GSFC •JHU	Array	64x128 Array, Si Carrier, Optical/Mag. Mount	JWST Proto	6	5
	Electronics	HV Serial Register, addresser	JWST Proto	6	4
	Magnet Scanner	Precision slide, linear drive motor	JWST Proto	6	5
Optics •JHU •JY •Vanguard	Primary	F/2 Parabola, 0.5m, double arch, ULE glass	HUT, SRs	9	5
	Secondary	Diffractive, dual-order asphere	SR-LIDOS	7	4
	Image Corrector	Achromatic cylindrical doublet CaF2/MgF2	HST	9	4
	Bench	CF/Al composite metering, Al mirror baseplate	HST, FUSE	9, 9	4
Targeting •JHU •GSFC	Computer	RIO FPGA, Imager interface	JWST Proto	6	5
	Software	Brightest shutter per row algorithm	JWST Proto	6	4

* The first flight of FORTIS is expected in Winter 2012, after which TRL FORTIS = 7.

Summary

	Current/Future Performance	Implementation/ Operational Risk	Cost/Time to TRL-6; Leverage	Relevance/Impact
Spectro/Imager MCP	Current:75Mpix, DQE =20%, Dark < 1 cnt/ cm^2/s Future: >=300Mpix DQE=?, Dark < 0.1 cnt/ cm^2/s Anticoincidence can lower still.	Robust evolvable design. Some PC fabrication risk. Mitigate with generous T&E margin.	Currently at TRL-6. Leverage in form of extensive and successful flight history. Vendor has cross-agency funding. New high efficiency PC require investment.	Workhorse of UV astronomy. Steady improvement in performance. Produces high impact science.
Dual Order Triaxial ellipse	Current: 165 mm, OD Future: ~ 400 mm, OD feasible	Sensitivity to alignment and mounting stress unknown. Foreign vendor swamped with work.	Large (> 300 mm) holographic gratings have flown and tend to be expensive.	Enables industrial strength high efficiency spectral imaging surveys and NEW UV science.
MSA	Current formats 128x64 & 175x385; 100 x 200 micron pitch Future formats will depend on demand.	Magnet scan required for latching. Current funding in place to implement "resonant" alternative.	Requires large, sophisticated fab facilities. Resonant latching alternative maybe key to commercial acceptance.	Drastic reduction in background compared to slitless designs. May find use as programmable pupil mask for exoplanet observations.
Targeting Algorithms	Currently: immature and untested	Resting in live fight environment required for confident implementation.	Depends on desired level of sophistication?	The work is relevant to future implementation by JWST.