UVOIR Technology Needs
(Cosmic Origins Program Analysis Group)

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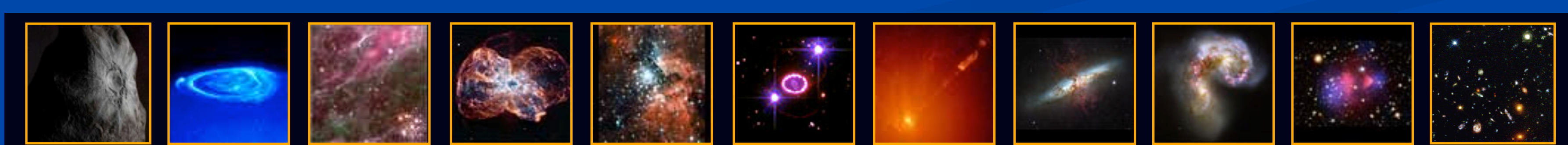
On behalf of the COPAG Executive Committee,

Chair: Chris Martin



COPAG Charge

- Identify a focused set of mission-enabling technologies relevant to Cosmic Origins future missions
- Provide a nucleus for the community to speak with a coherent voice in technology prioritization
- Provide input to Strategic Astrophysics Technology (intermediate TRL) NRA and selection process by end of 2011, for 2012+ proposal opportunities
- Provide input to APRA (low TRL) technology selection process
- Provide input to NASA and NRC Technology Roadmapping
- Make tough choices for highest-value efforts given limited resources

COPAG Tasks

- **Determine technology focus areas for a large UVOIR mission in the next decade**
  - Possible areas of investment
    - Detectors
    - Optical coatings
    - Gratings
    - Multiplexing elements / IFUs
    - Wavefront sensing and control
    - Lightweight mirrors
  - This activity was divided into two tasks – one to identify the needs for a standalone UVOIR Cosmic Origins mission, and one to identify the needs for a joint UVOIR Cosmic Origins / Exoplanet mission
- **Determine technology focus areas for future Far-IR instruments**
  - Not part of today's discussion

Task 1 Activity
(Independent of ExoPAG)

- Develop strawman reference mission concept as “target”
- Assess the TRL/maturity level of various technologies
- Determine time/$$/investment to reach necessary TRL level to support mission concept development
- Prioritize and develop a portfolio based on one or more Figures of Merit and supporting rationale
  - Ex. FOM: Expected increase in “Effective Telescope Aperture” by 2018

Task 2 Activity
(In Conjunction with ExoPAG)

- Develop strawman joint reference mission concept as "target", coordinating with ExoPAG
- Consider internal and external starlight suppression concepts
- Determine requirements for compatibility
  - E.g., Coatings: $R > R_{min}$, Variations < XX%
- Assess the TRL/maturity level of relevant technologies
- Determine time/$$/investment to reach necessary TRL level to support mission concept development
- Prioritize and develop a portfolio based on one or more Figures of Merit and supporting rationale

Selected Astro2010 White Papers

- Several key Astro2010 white paper references:
  - *Technology Investments to Meet the Needs of Astronomy at Ultraviolet Wavelengths in the 21st Century* (technology white paper #54 – Sembach et al.)
  - THEIA: Telescope for Habitable Exoplanets and Interstellar/ Intergalactic Astronomy (RFI #132 – Kasdin et al.)
  - Advanced Technology Large Aperture Space Telescope - ATLAST (RFI #13 – Postman et al.)

Key advances could be made with a telescope with a 4-meter-diameter aperture with large field of view and fitted with high-efficiency UV and optical cameras/spectrographs operating at shorter wavelengths than HST. This is a compelling vision that requires further technology development. The committee highly recommends a modest program of technology development to begin mission trade-off studies, in particular those contrasting coronagraph and star-shade approaches, and to invest in essential technologies such as detectors, coatings, and optics, to prepare for a mission to be considered by the 2020 decadal survey. A notional budget of $40 million for the decade is recommended.

Increasing Throughput

- The throughput of optical systems at ultraviolet wavelengths has considerable headroom for growth.
- Even Optical/IR designs can be improved via multiplexing.
- Technology investments can be traded against aperture size.

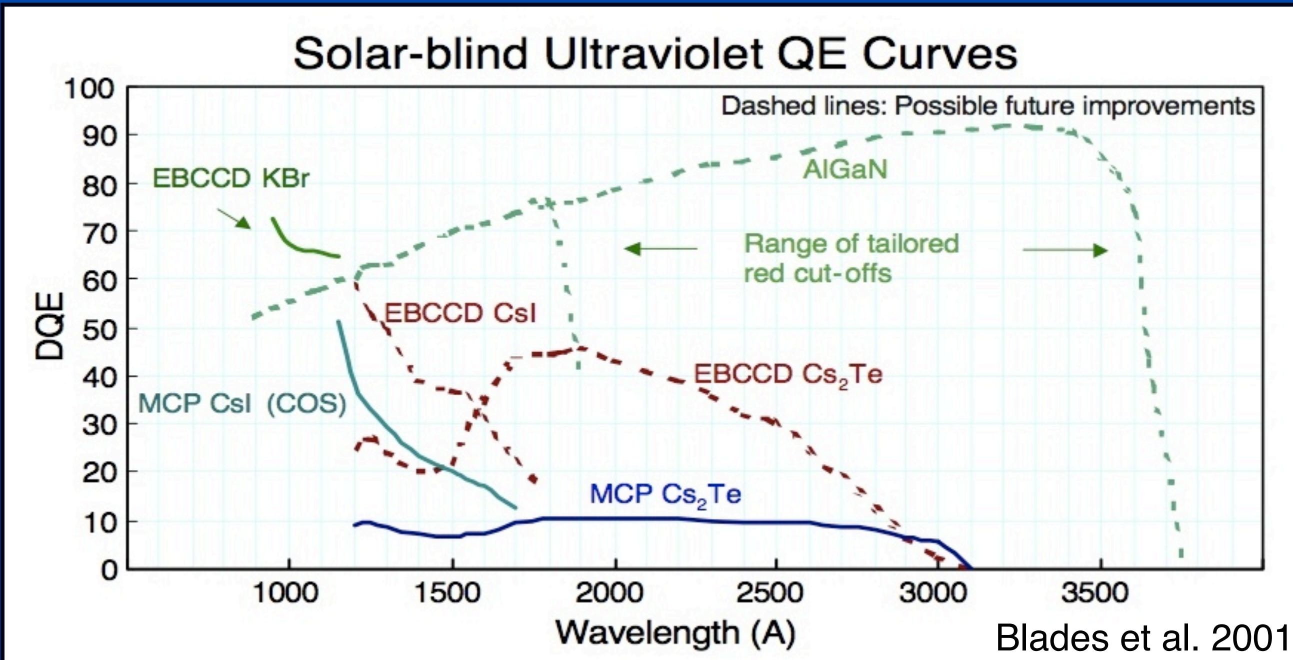
Table 1: Exposure Times for Telescopes With and Without New Technology Investments

Flux (erg cm^{-2} s^{-1} $Å^{-1}$)	GALEX FUV (mag)	Exposure Time to Reach S/N =10 at R = 20,000			
		HST / COS	4m HST or Optimized 2m	8m HST or Optimized 4m	16m HST or Optimized 8m
$1x10^{-15}$	19.2	9.8 ksec	3.6 ksec	900 sec	220 sec
$1x10^{-16}$	21.7	115 ksec	39 ksec	9.1 ksec	2.2 ksec
$1x10^{-17}$	24.2	2.9 Msec	700 ksec	110 ksec	24 ksec

Calculations assume a 2-mirror OTA with 12% secondary linear obscuration, feeding a single reflection spectrograph with a detector dark count rate of $2.7x10^{-4}$ cnt s^{-1} per resolution element.
Optimized telescope configurations assume a factor of 4 improvement in system throughput compared to existing (Hubble) technology.

Detectors (1/3)

- Improving quantum efficiency is a key issue
  - Particularly, band-averaged values
  - Matching to optical λs is important for data quality uniformity when exposing for similar times

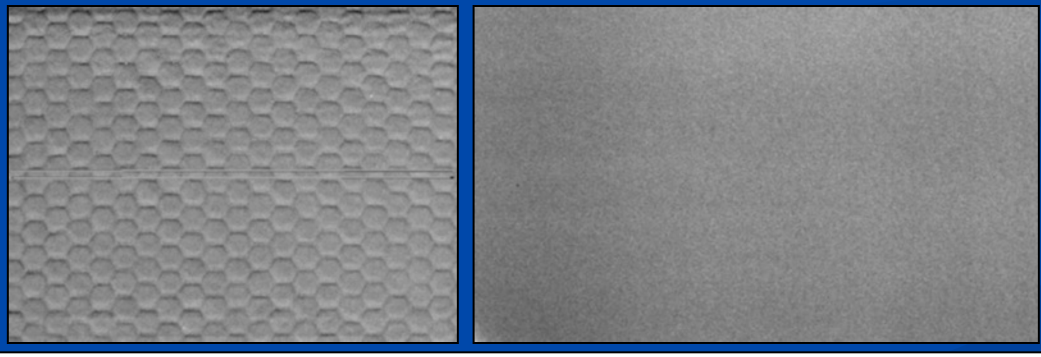


Blades et al. 2001

COS FUV MCP	
1216 Å	~34%
1300 Å	~30%
1400 Å	~23%
1500 Å	~20%
1600 Å	~13%
1750 Å	~ 10%
COS NUV MAMA	
2000 Å	~10%
2500 Å	~9%
3000 Å	~4%

Detectors (2/3)

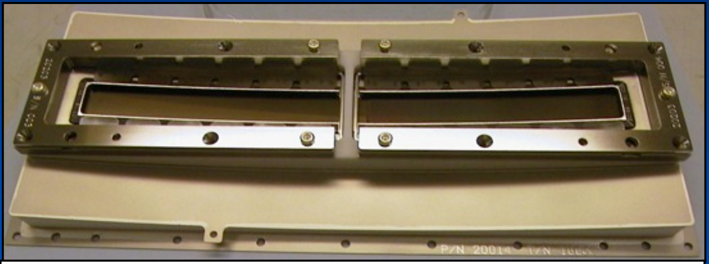
- Other key detector issues
  - Better photocathode materials are needed
    - Example: AlGaN, GaN show great promise (QEs > 70% at 122 nm) but have high dark noise and are not yet suitable for large formats
    - Considerable work is needed to extend results to semi-transparent mode or to use in opaque mode on microchannel plates
  - Flatfields



(Left) HST-COS flat field image of a 10 x 13 mm area of the far-ultraviolet MCP detector. The fiber bundles imprint an obvious fixed-pattern noise features in the image. (Right) A new glass process MCP flat field for a similar image area, demonstrating the absence of fixed-pattern noise (Siegmund et al. 2007).

Detectors (3/3)

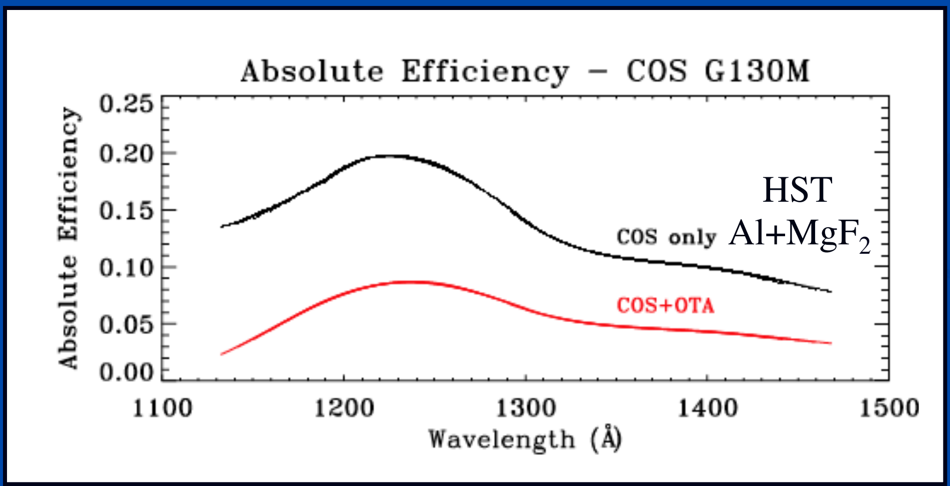
- Other key detector issues
  - Format
    - Long MCP detectors (1st order apps)
    - Large-format CCDs (echelle apps)
  - Backgrounds (photon counting)
  - Radiation hardness
    - Charge transfer efficiency primarily an issue for large CCDs in space
    - p-channel vs. n-channel can help
    - CMOS (or APS) devices hold great promise but have higher read noise and lower QE than conventional CCDs; need development
  - Operation at "room" temperature
    - Contamination of UV optics and detectors is a major concern at cryogenic temperatures



HST-COS far-ultraviolet detector showing the two abutting microchannel plate detector segments (each 85 x 10 mm) curved to the focal plane of the spectrograph.

Optical Coatings

- Technological "tall poles"
  - Smoothness, surface quality/uniformity, polarization
  - High reflectivity (>90%) coatings over large bandpasses (100 nm – 1μm)
    - Compatibility with use at UV wavelengths is highly desirable
    - Coatings like Al+LiF may be difficult to handle on large optics

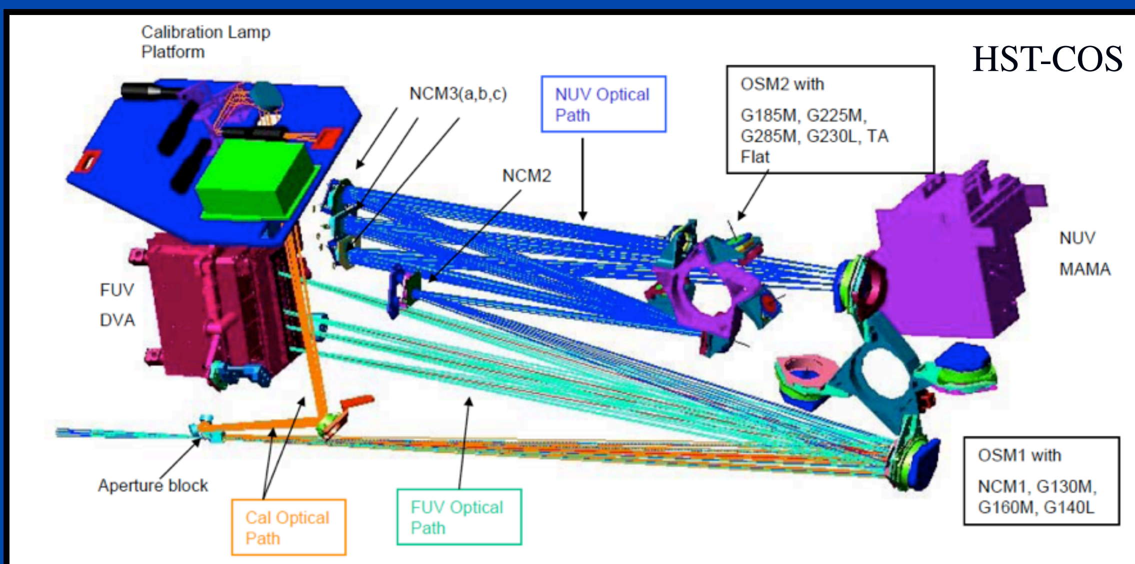


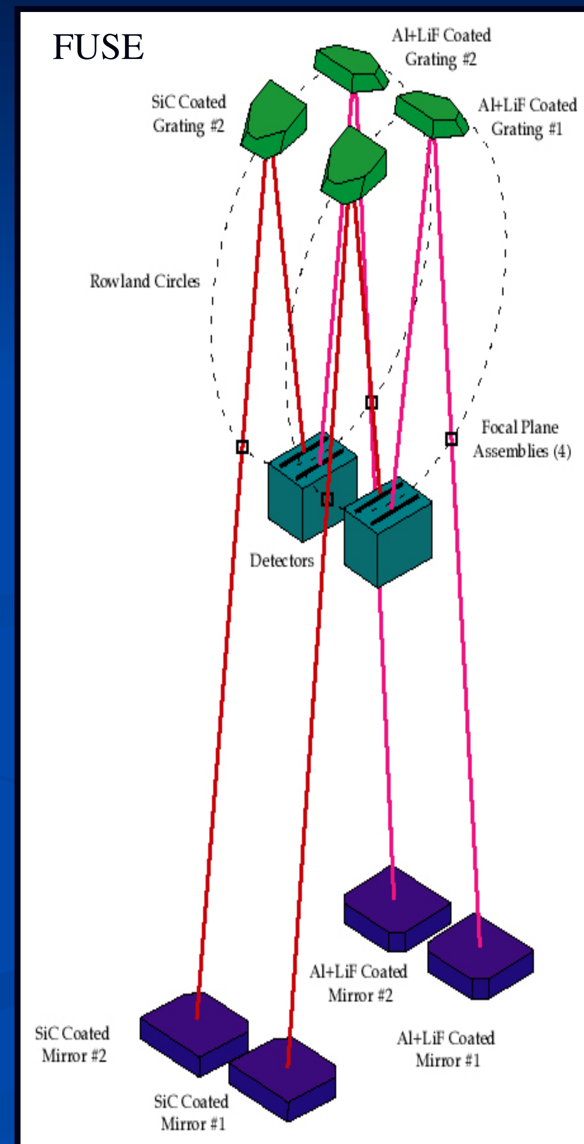
HST OTA	
1150 Å	26%
1200 Å	41%
1500 Å	41%
2000 Å	49%
2500 Å	60%
3000 Å	61%

Light loss from Three 70% reflections = Ten 90% reflections = Twenty-One 95% reflections

Optics

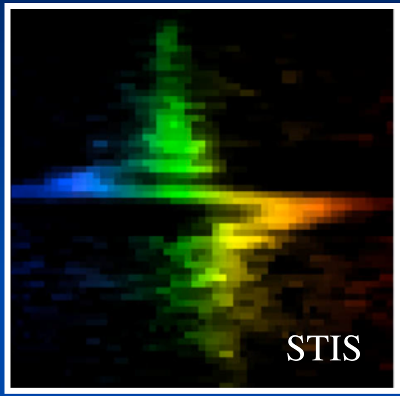
- Design complexity can improve as optics and coatings improve
- Needs
  - Large lightweight optics with areal densities of <20 kg/m^2 (and supporting pointing accuracy/stability)
  - Large aberration-correcting diffraction gratings
  - Fast optics for some applications (off-axis telescope designs – e.g., FUSE)





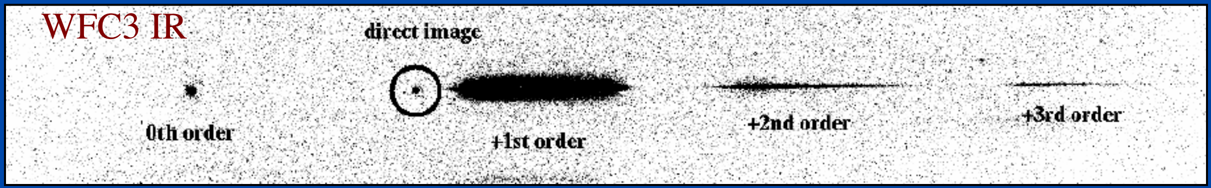
Optical Designs

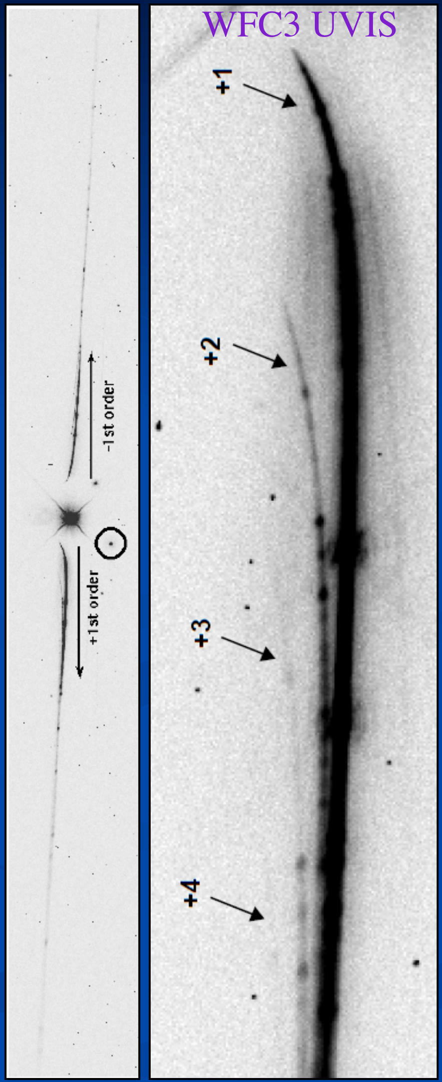
- Multiplexing can improve efficiency by orders of magnitude
  - Slitless spectroscopy
  - Multi-object aperture arrays
  - Integral field units
    (even all-reflecting IFUs in UV)



- JWST is taking advantage of spectroscopic multiplexing

- Grism spectroscopy with HST-WFC3 is being applied to fields ranging from ExoPlanets to Cosmology





Key Points

- Improvements in throughput present new science opportunities
  - Bringing UV throughput on par with optical/NIR wavelengths will require better detectors and optical coatings
- Improvements in UV throughput can be cost effective
  - Factor of 4 should be achievable (equivalent to doubling primary)
- Detectors need dedicated investment strategy
  - QE improvements, photon-counting, large formats, environmental tolerance
- Optics and coatings need to be improved as well
  - Reflections (currently) cost dearly in the ultraviolet
  - Instrument design possibilities abound with higher reflectivity