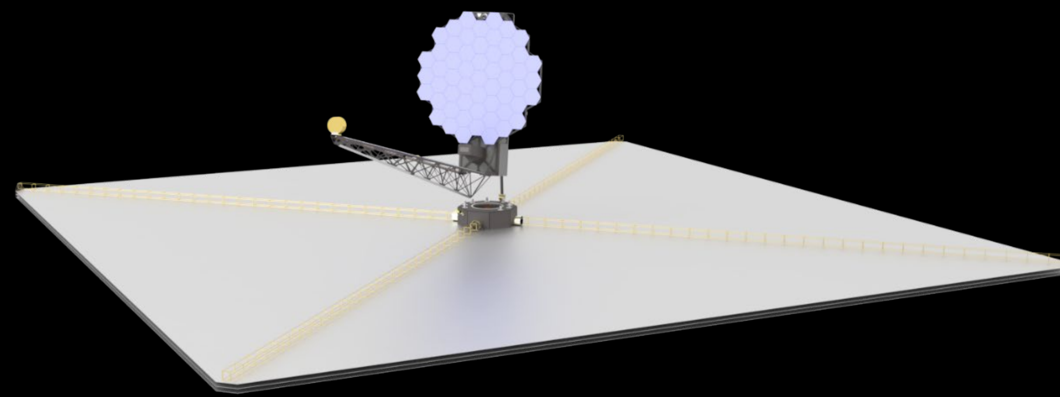


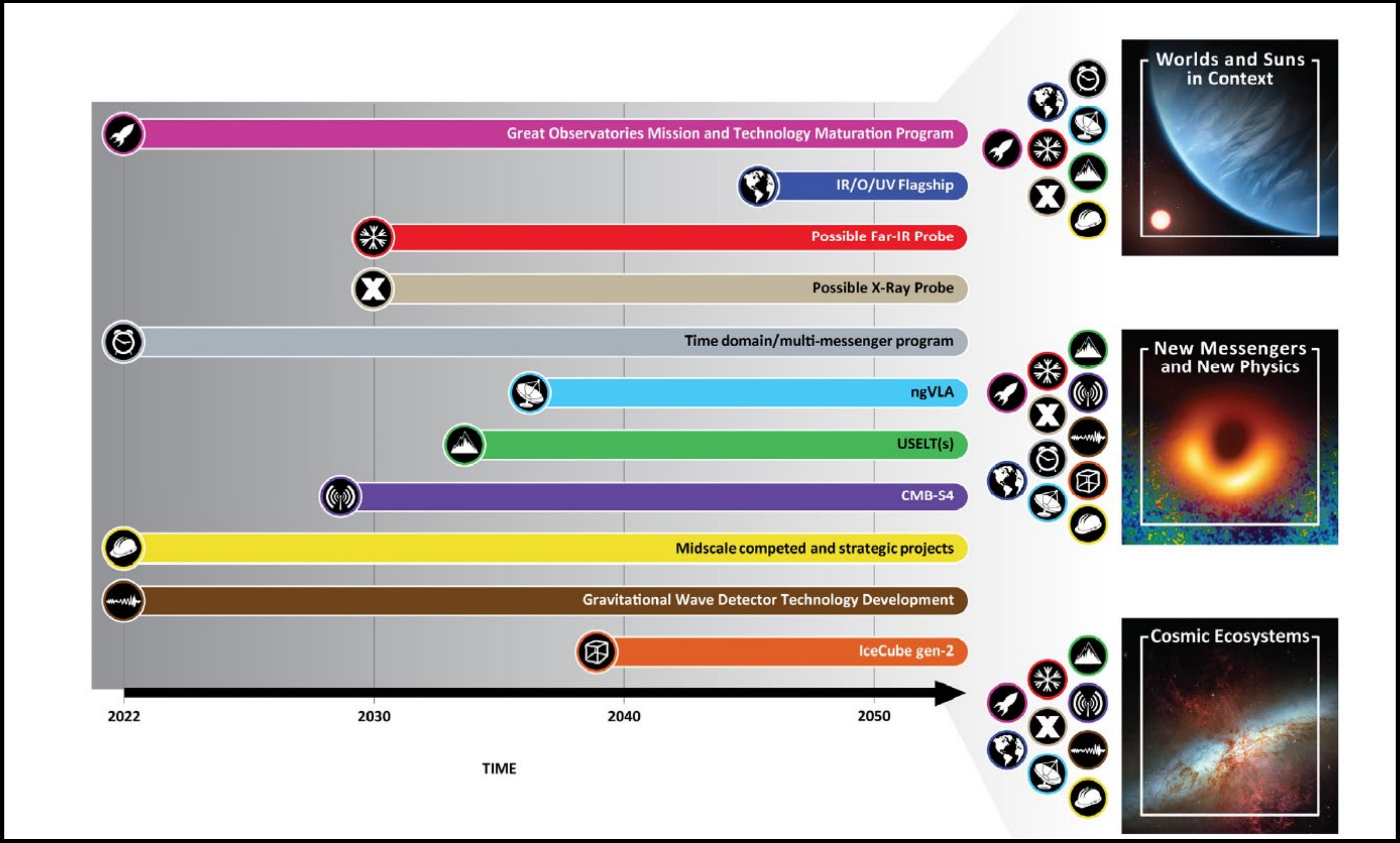
UV Multi-Object Spectroscopy with the Habitable Worlds Observatory

Kevin France – University of Colorado

AAS 241, 10 January 2023

CUSP

"THE SURVEY RECOMMENDS THAT THE FIRST MISSION TO ENTER THIS PROGRAM IS A LARGE (~6 M APERTURE) INFRARED/OPTICAL/ULTRAVIOLET (IR/O/UV) SPACE TELESCOPE."



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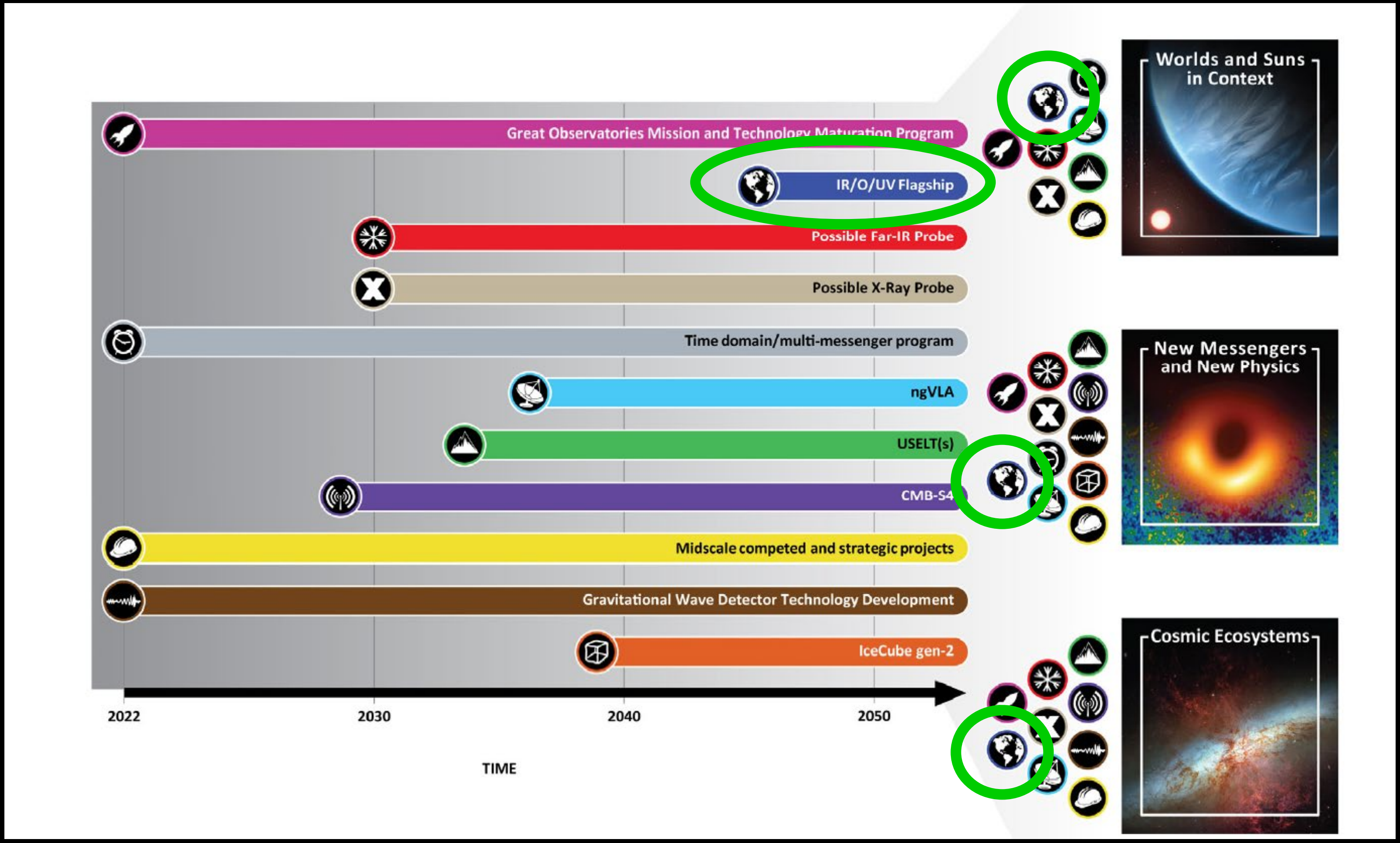
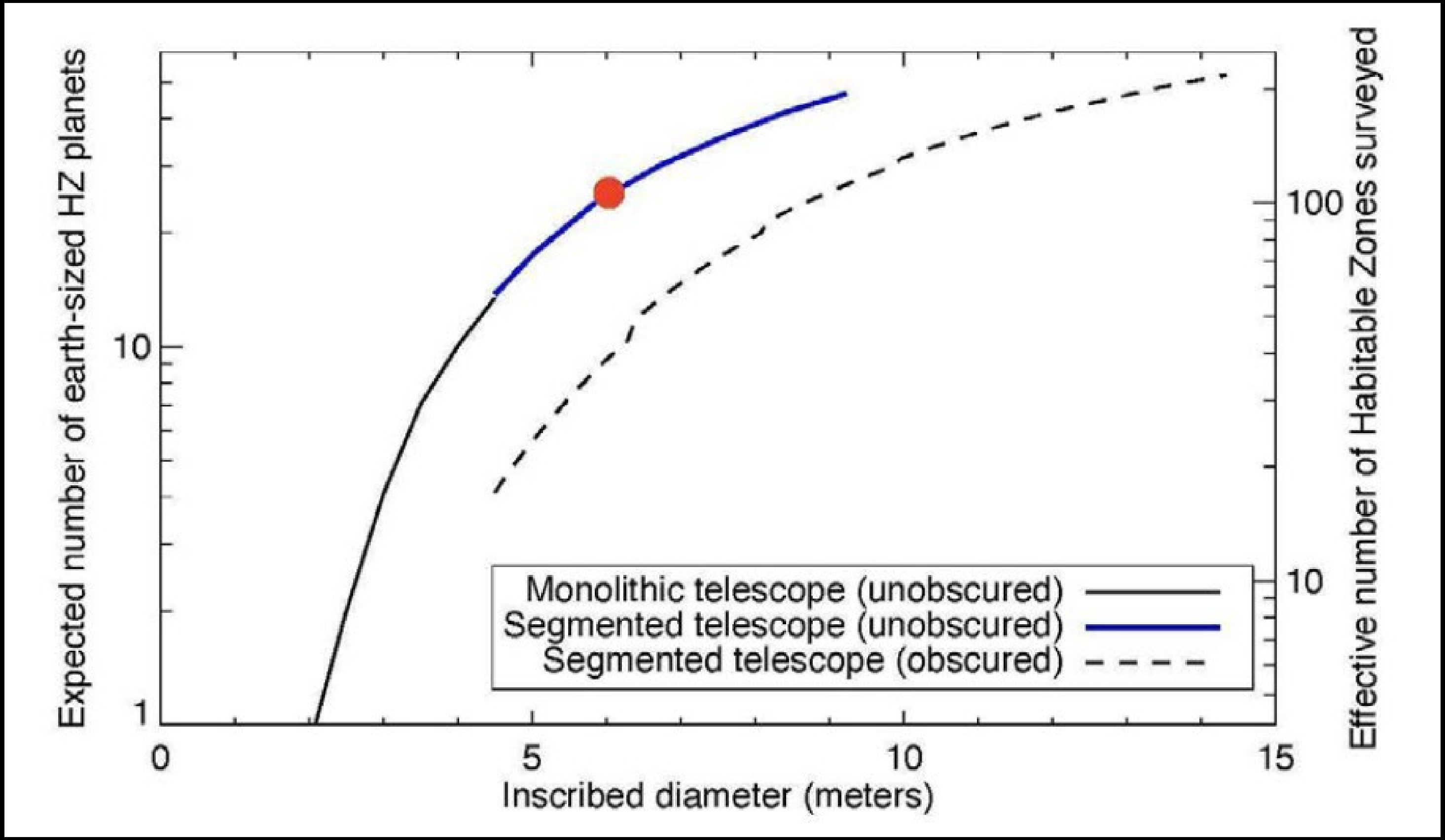


LARGE, ≥ 6 M INSCRIBED



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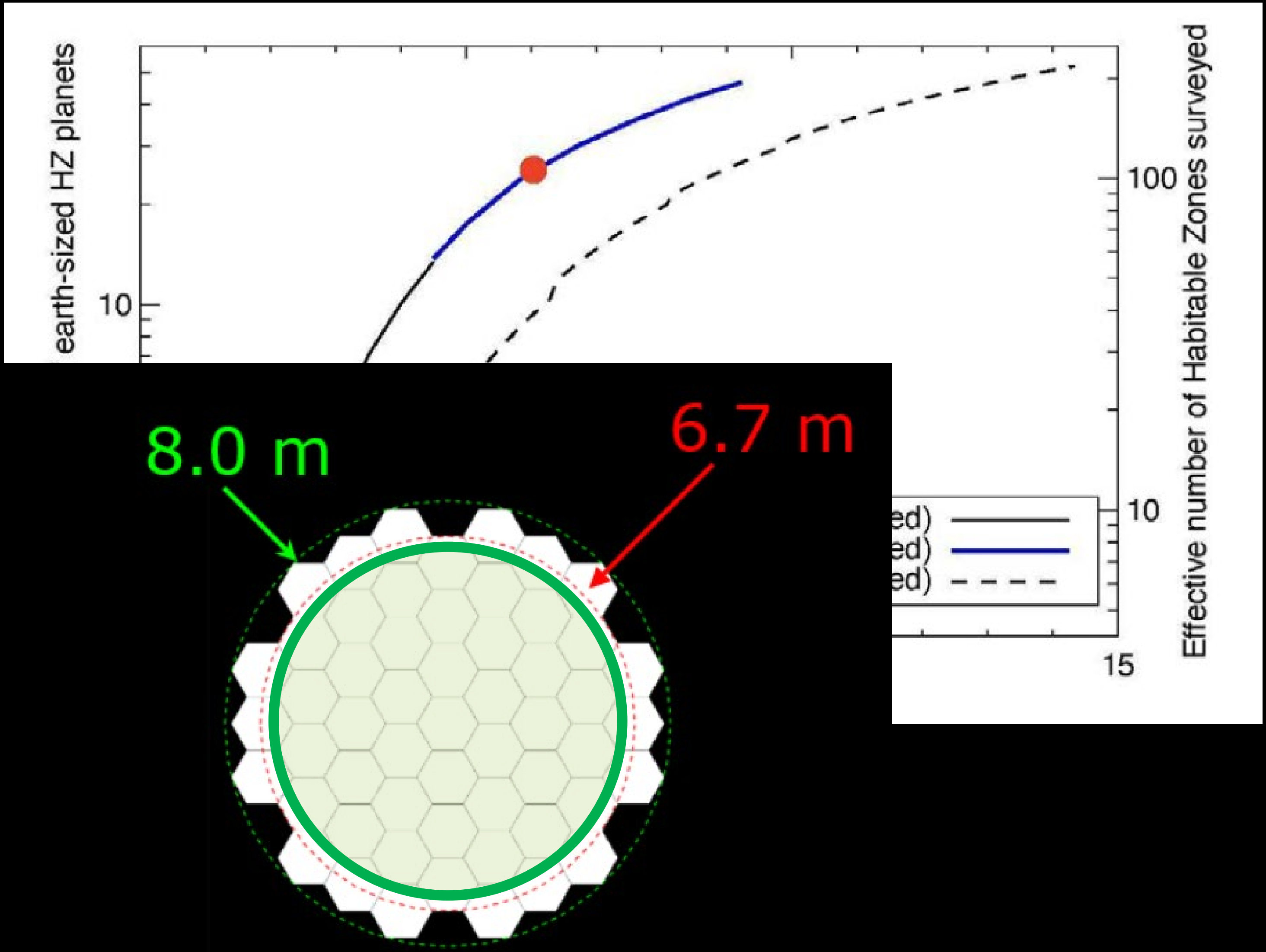
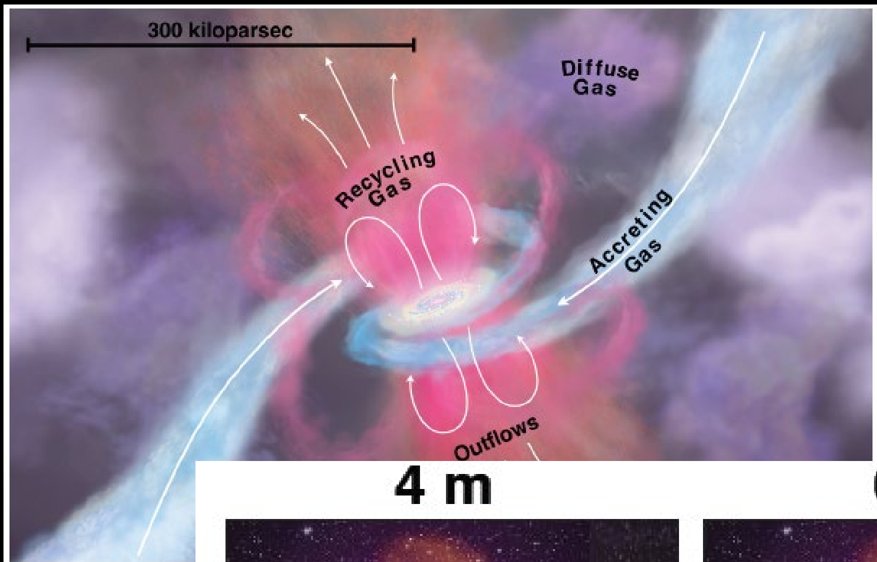
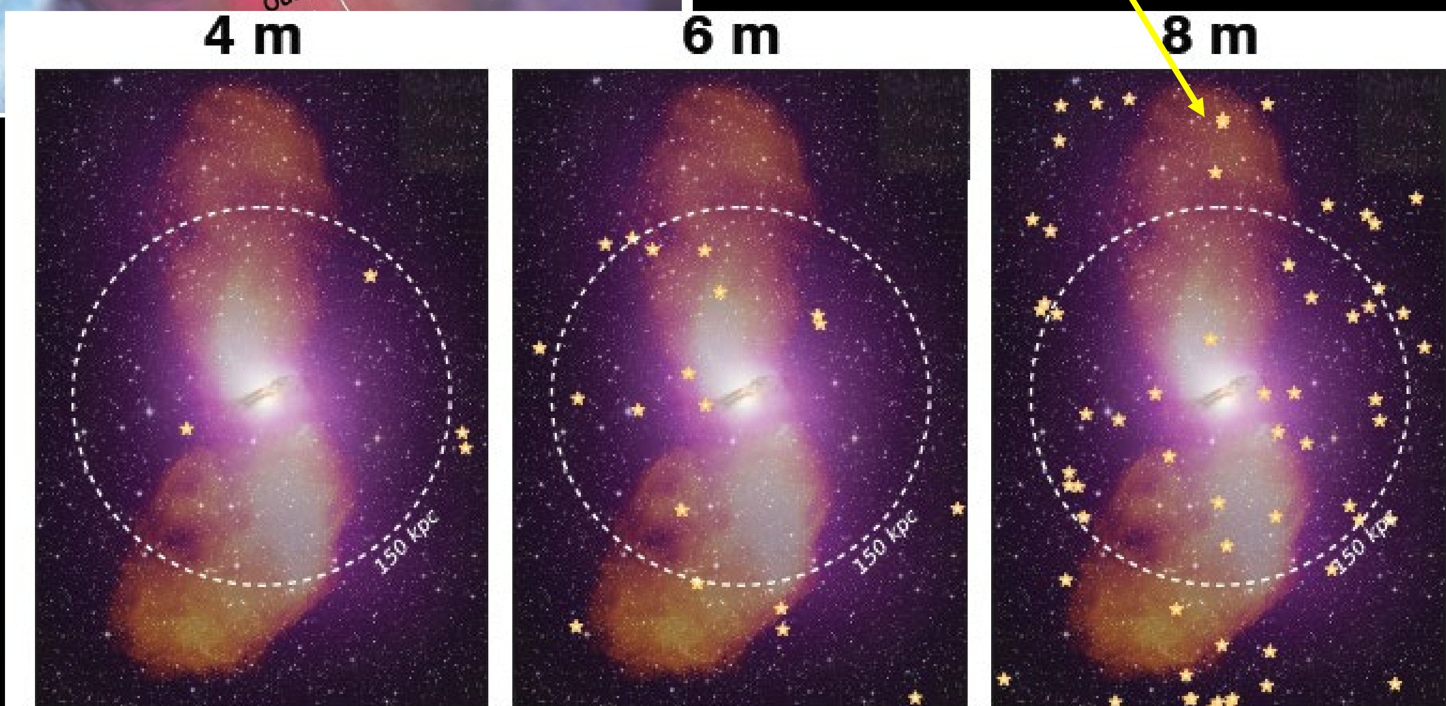


LUVOIR-B

Cosmic Ecosystems

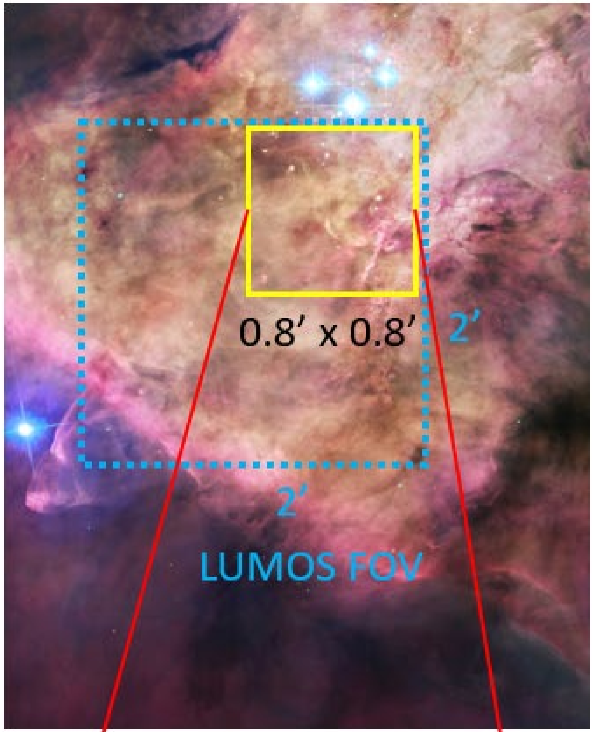


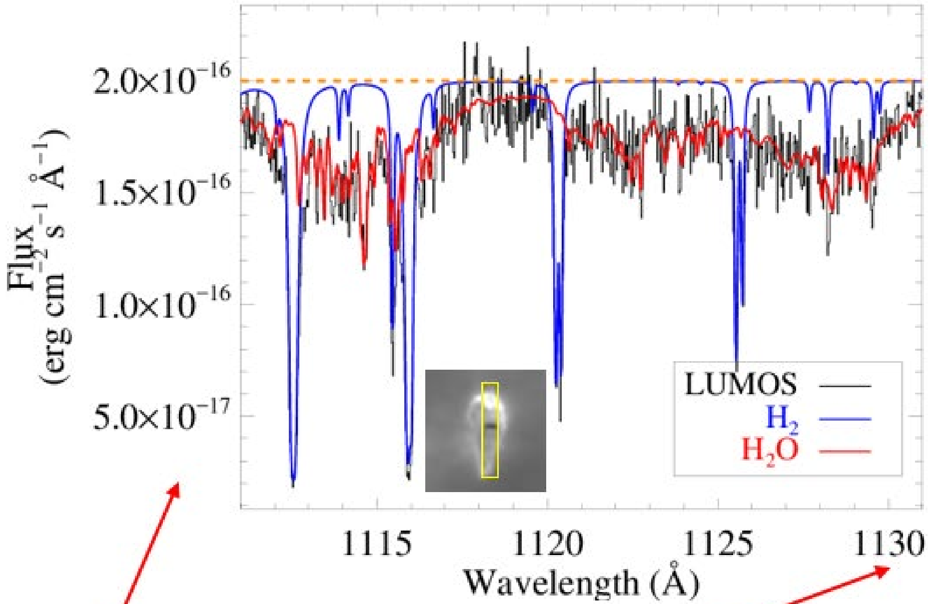
Background QSOs observed with S/N > 10 in FUV continuum in < 1 hour

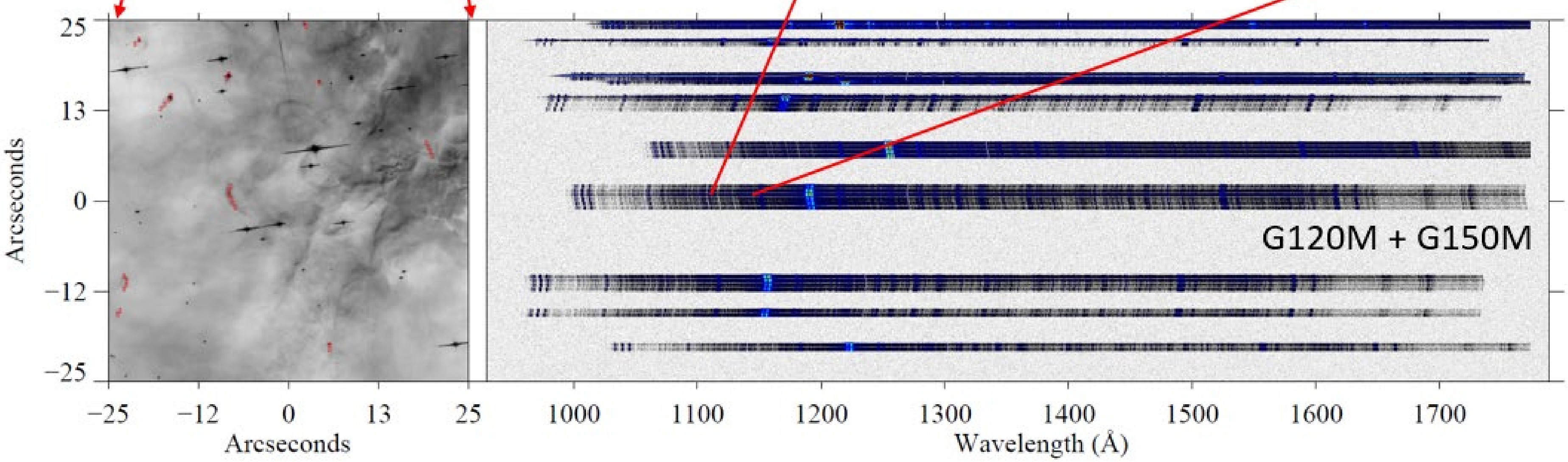


LUVOIR Final Report 2019

THE BIRTHPLACE OF STARS AND PLANETS







France et al. 2017; LUVOIR Final Report 2019

The HWO Instrument Recommendation from EOS-1

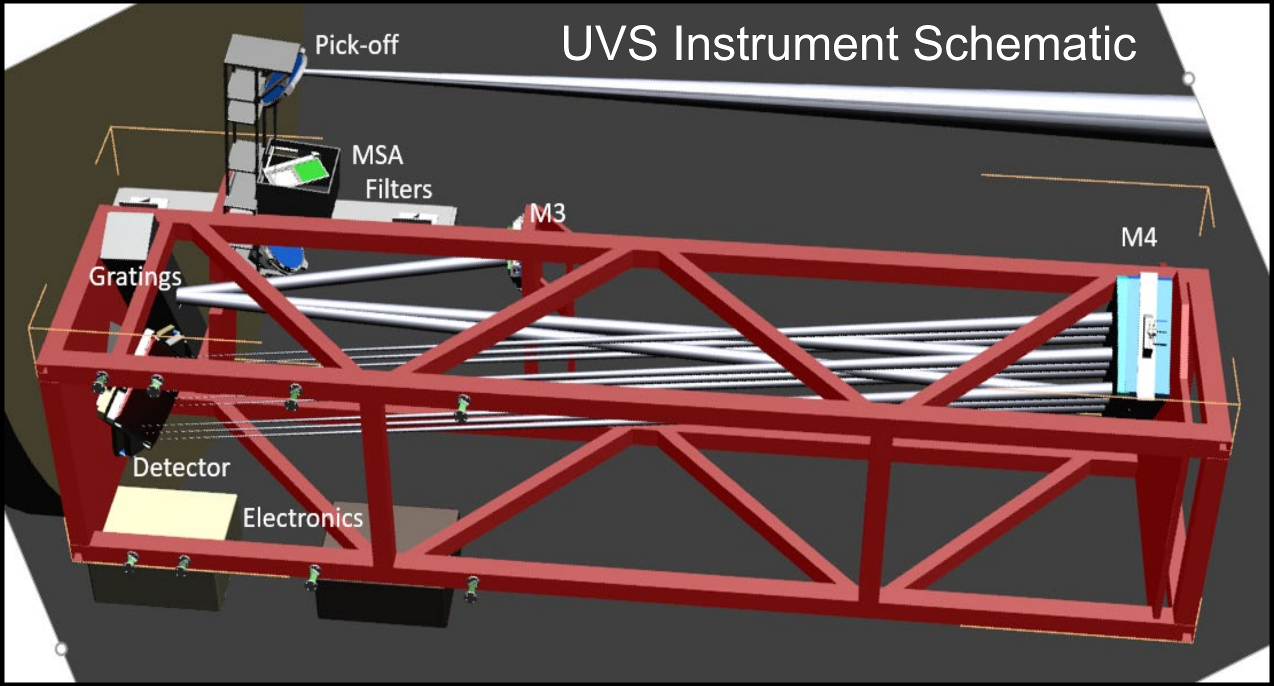
"The mission will also need focal plane instrumentation to acquire:

- images and spectra over the range of **100 nm** to 2 microns with
- parameters similar to cameras and spectrometers proposed for the Large Optical UV Infrared Telescope (LUVOIR) and the Habitable Exoplanet Observatory (HabEx)."

"These instruments would include:

- moderately wide-field **imaging at UV**, optical and near-IR wavelengths as well as
- **multi-object spectroscopy** over a similar wavelength range."

LUVOIR/LUMOS and Habex/UVS: Roadmap UV instrument concepts for HWO

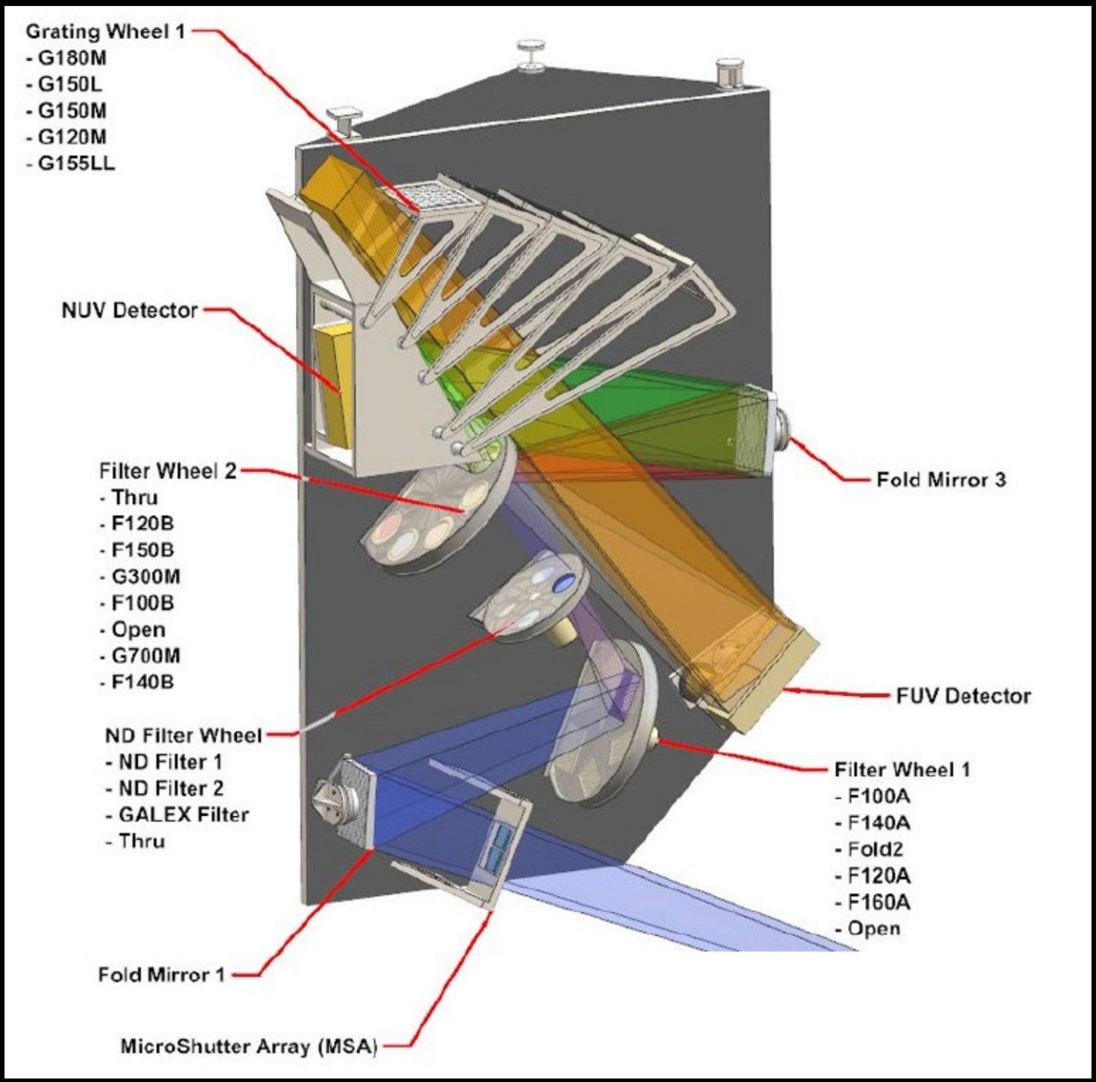


Instrument overview papers:

France et al. SPIE 2017
Scowen et al. SPIE 2019

LUVOIR and Habex final reports, 2019

LUMOS: three channels (FUV, NUV, optical imaging and spectroscopy)



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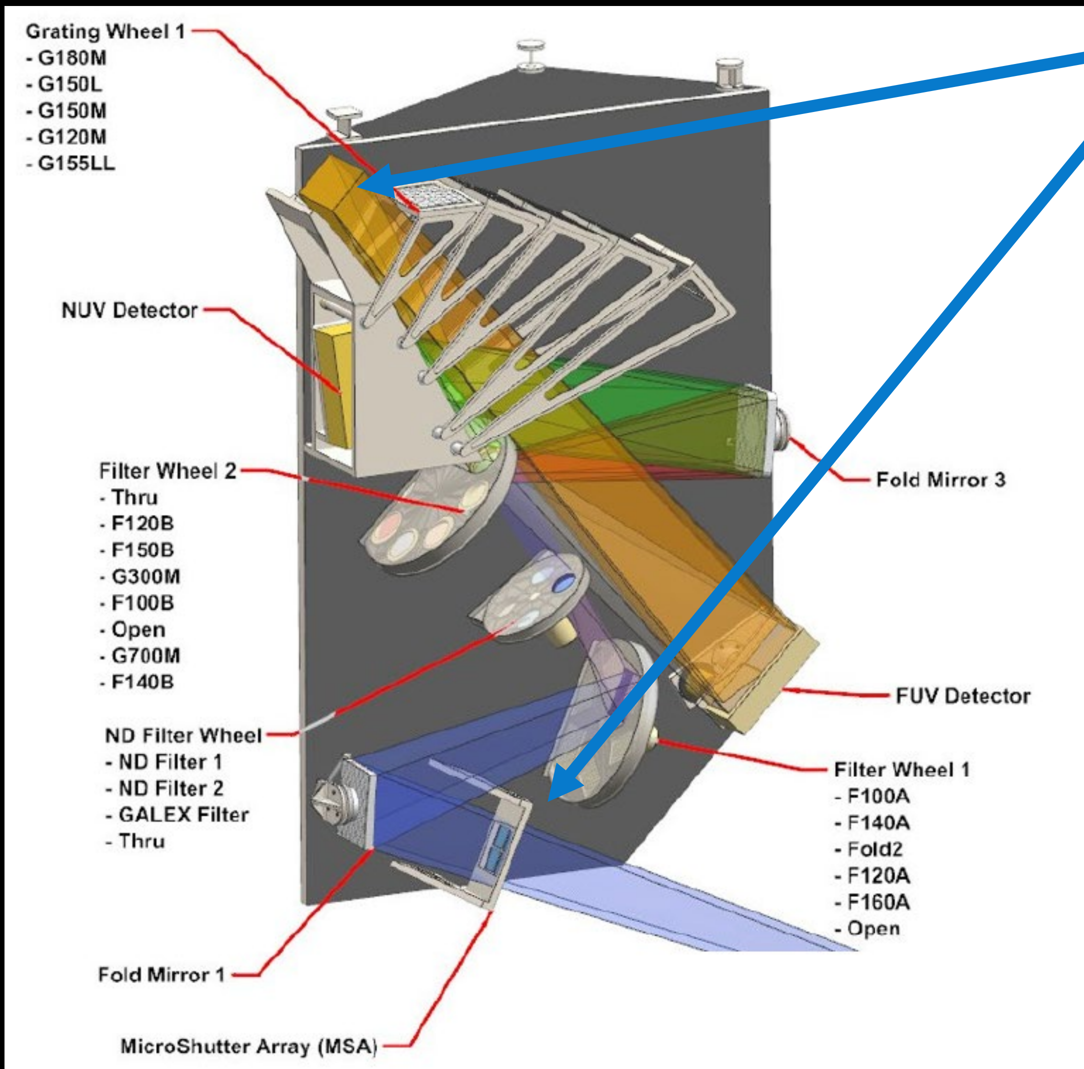

- Low/Med-res (R =500 -> 60K), FUV, NUV, optical **MOS**. FOV = 2’ x 2’

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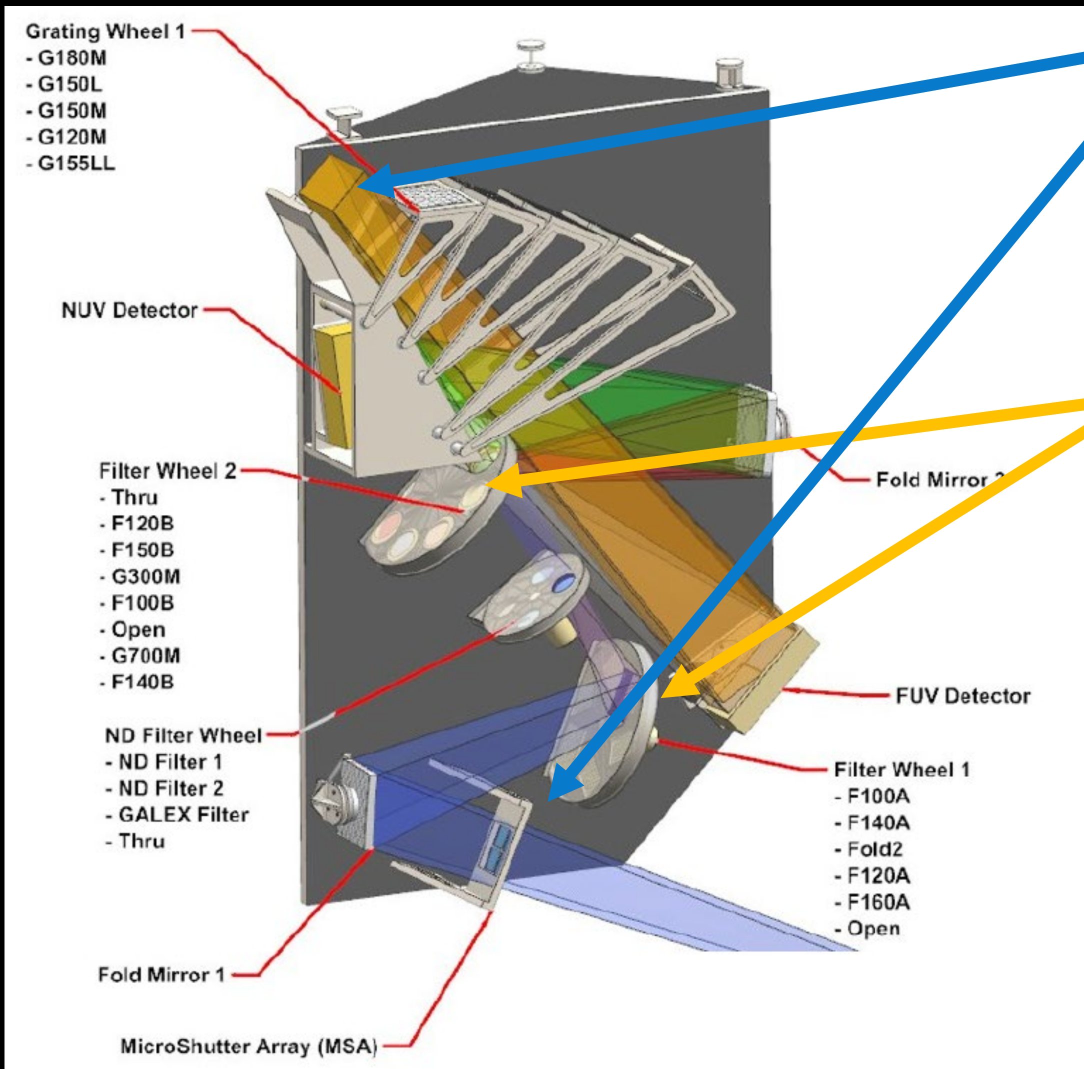

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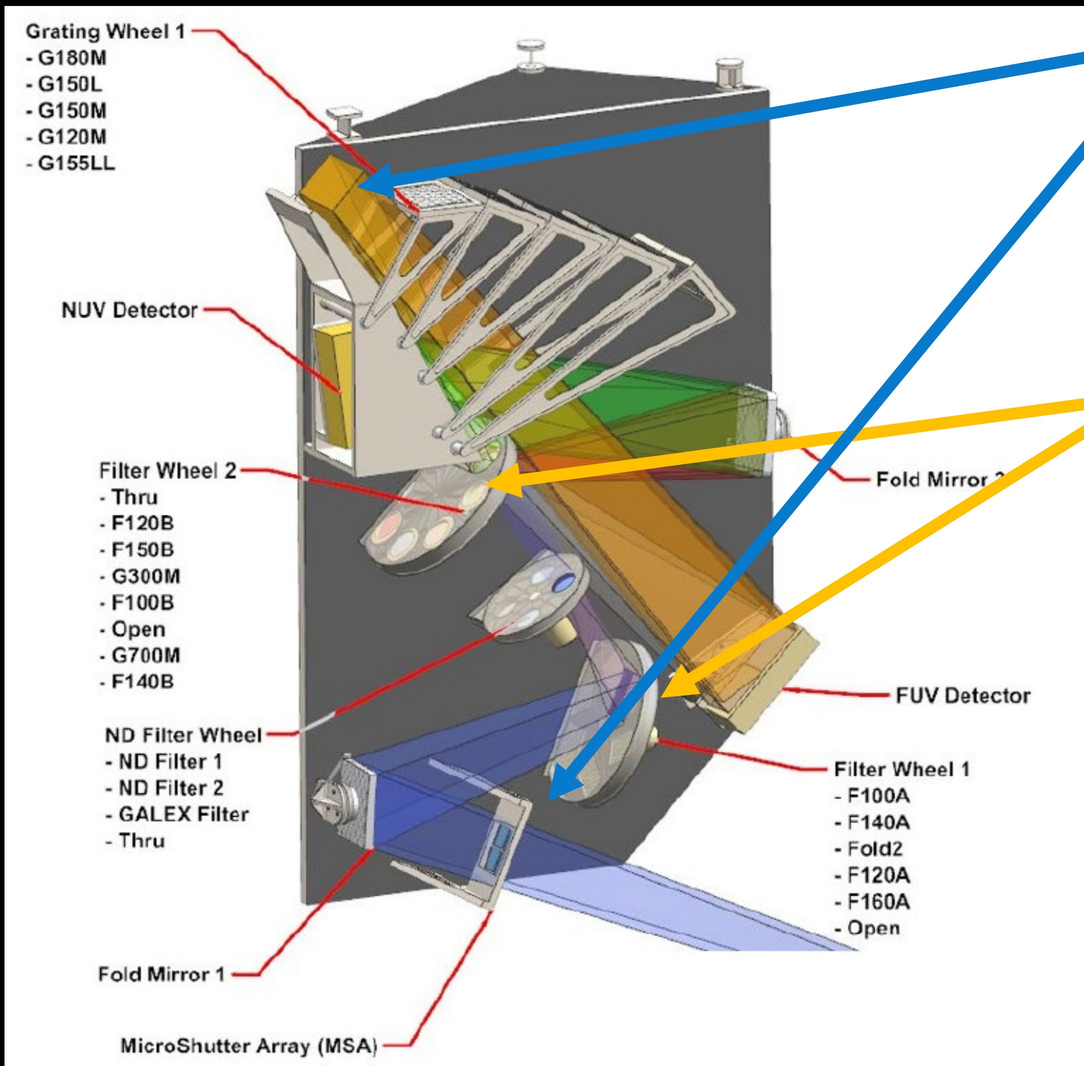

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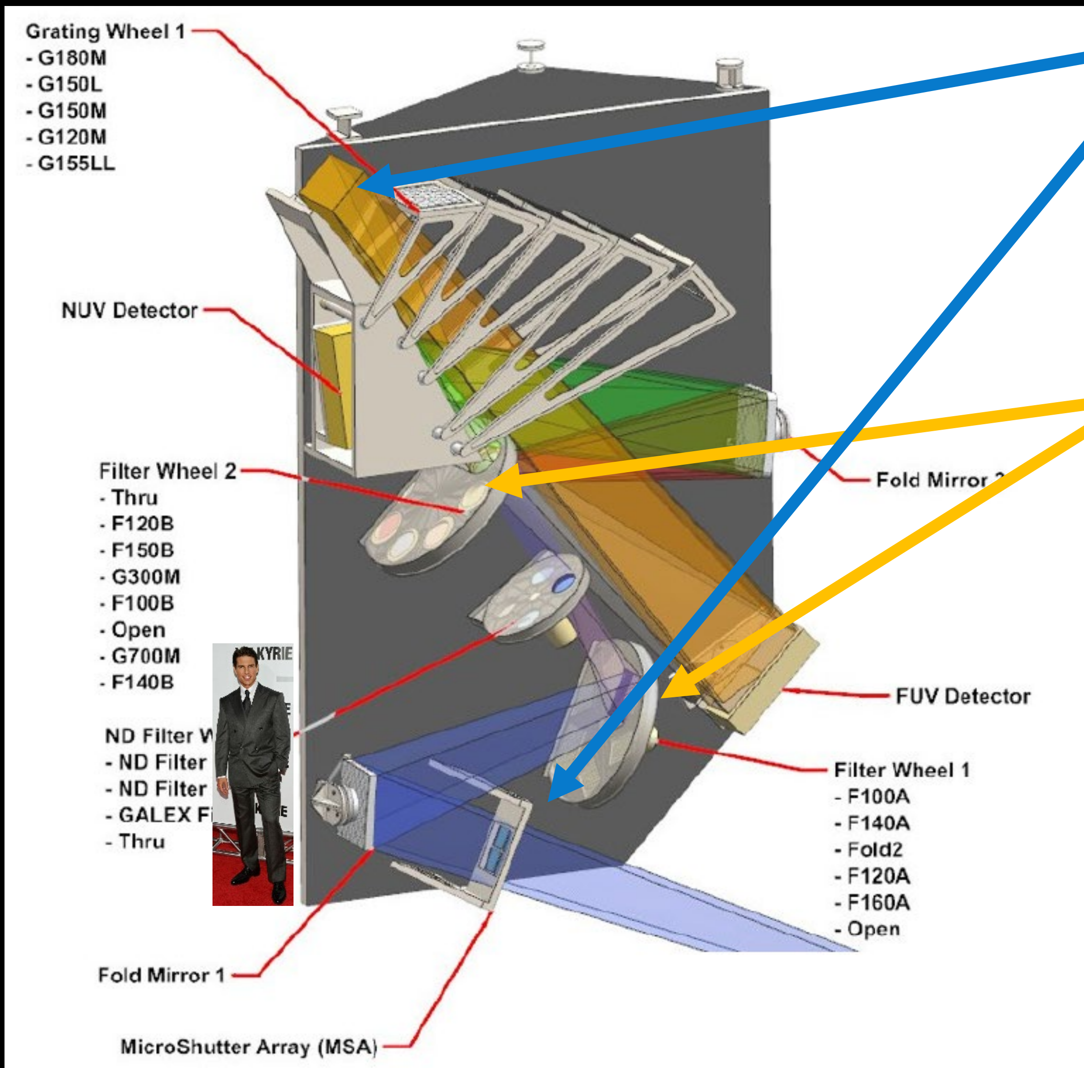

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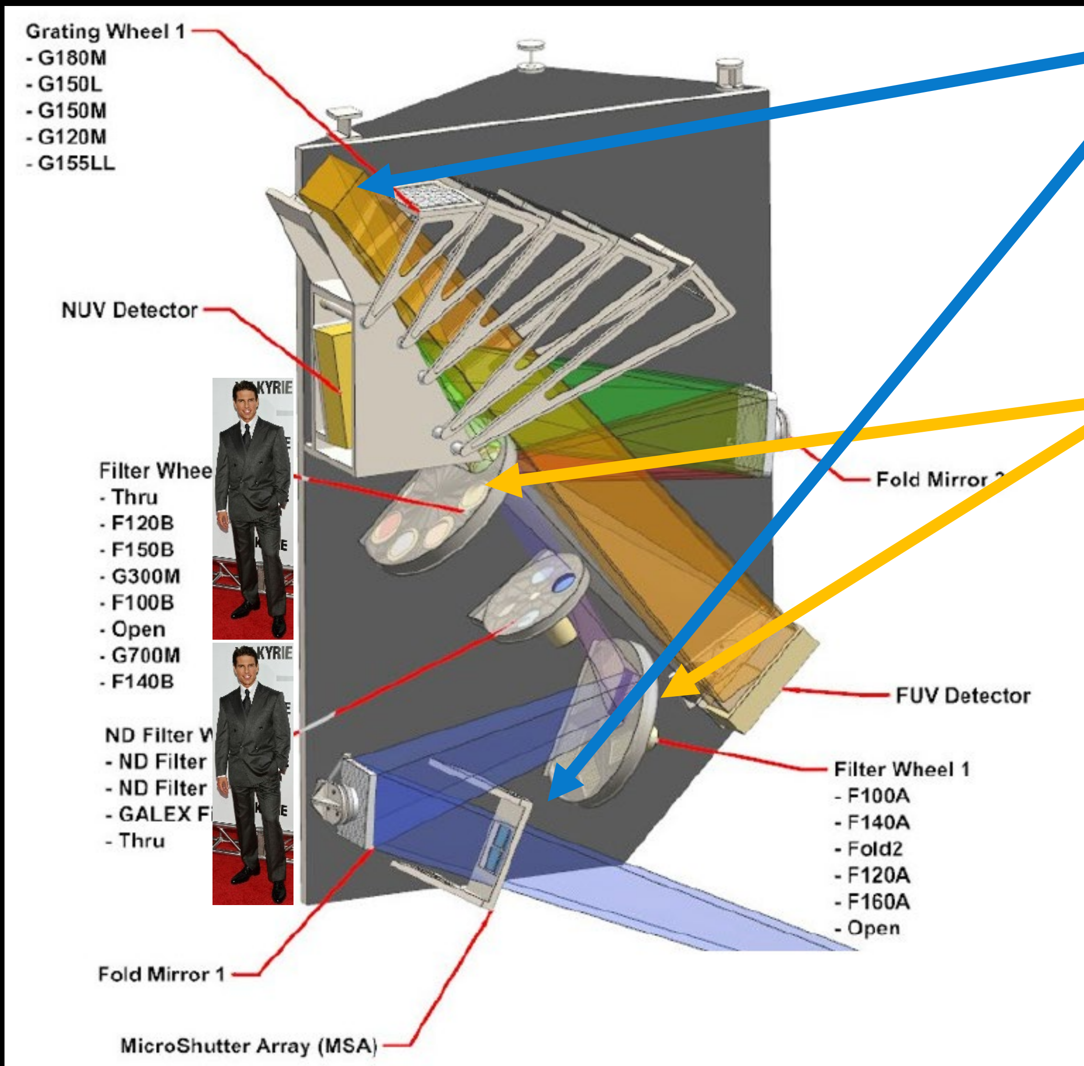

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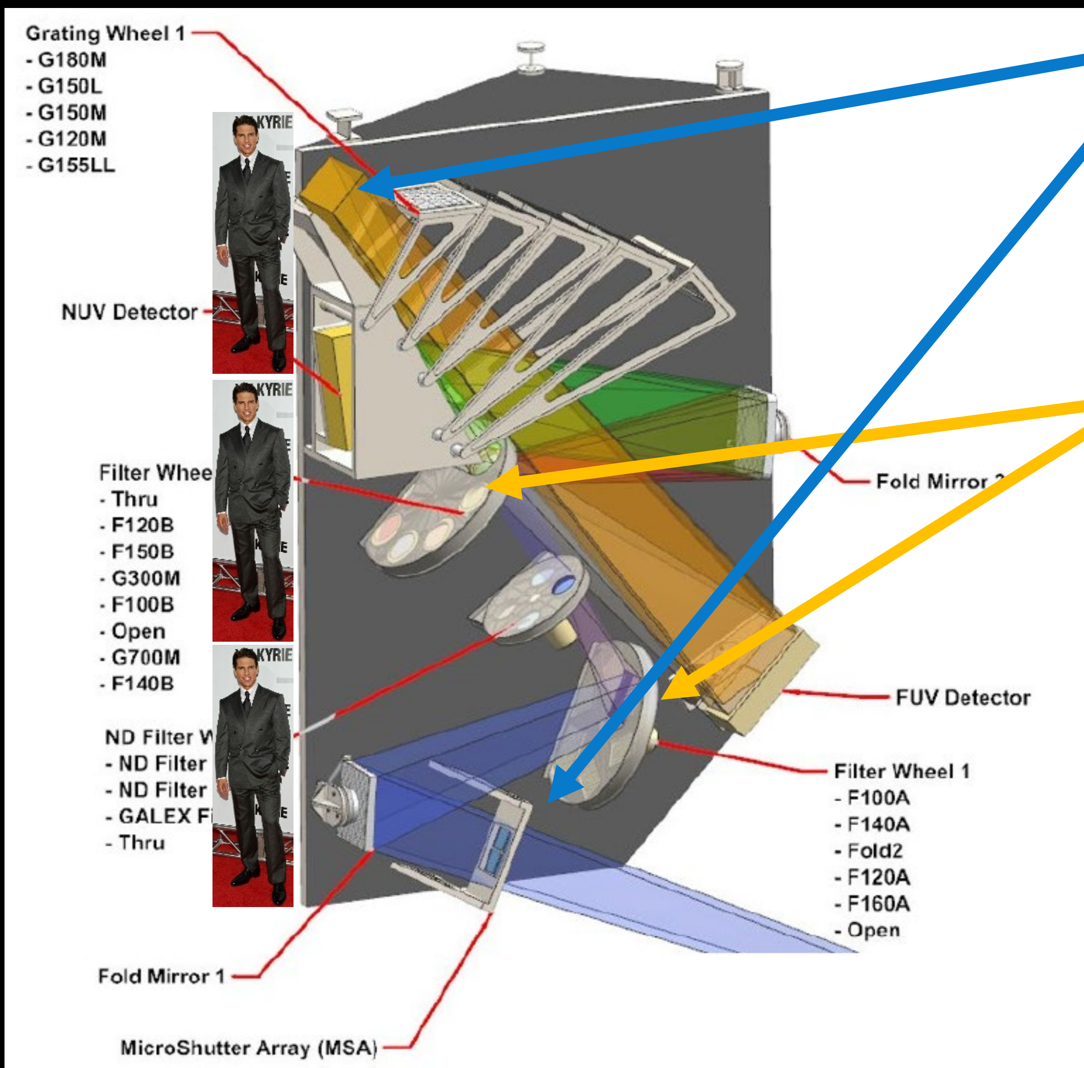

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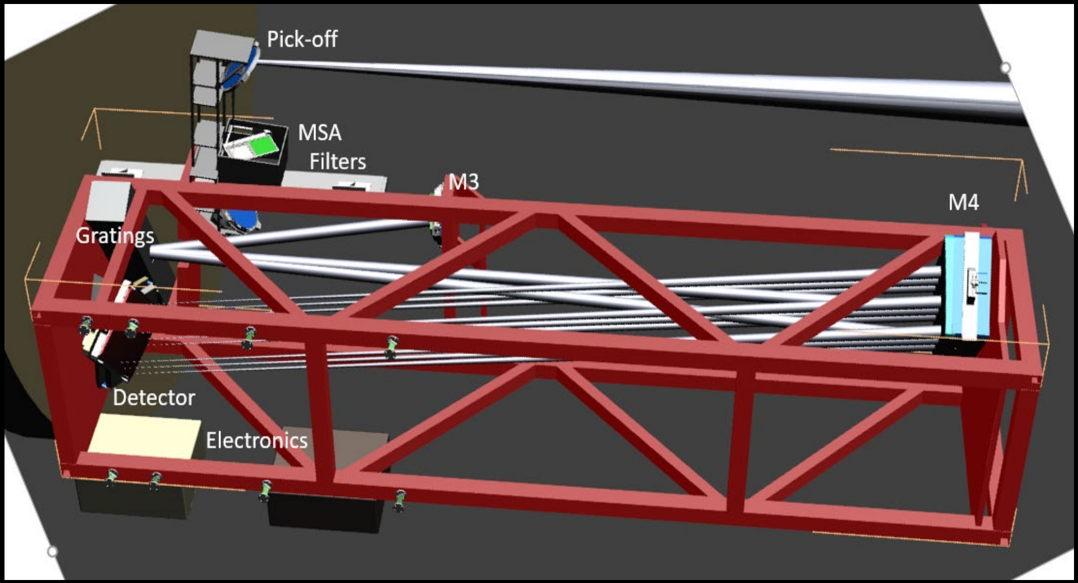
UVS vs LUMOS:



- Low/Med-res (R =500 -> 60K), greater number of grating resolution settings for FUV and NUV spectroscopy; **MOS**. FOV = 3' x 3'
- NUV **imager**. FOV = 3' x 3'; broad/medium/narrow band filters.
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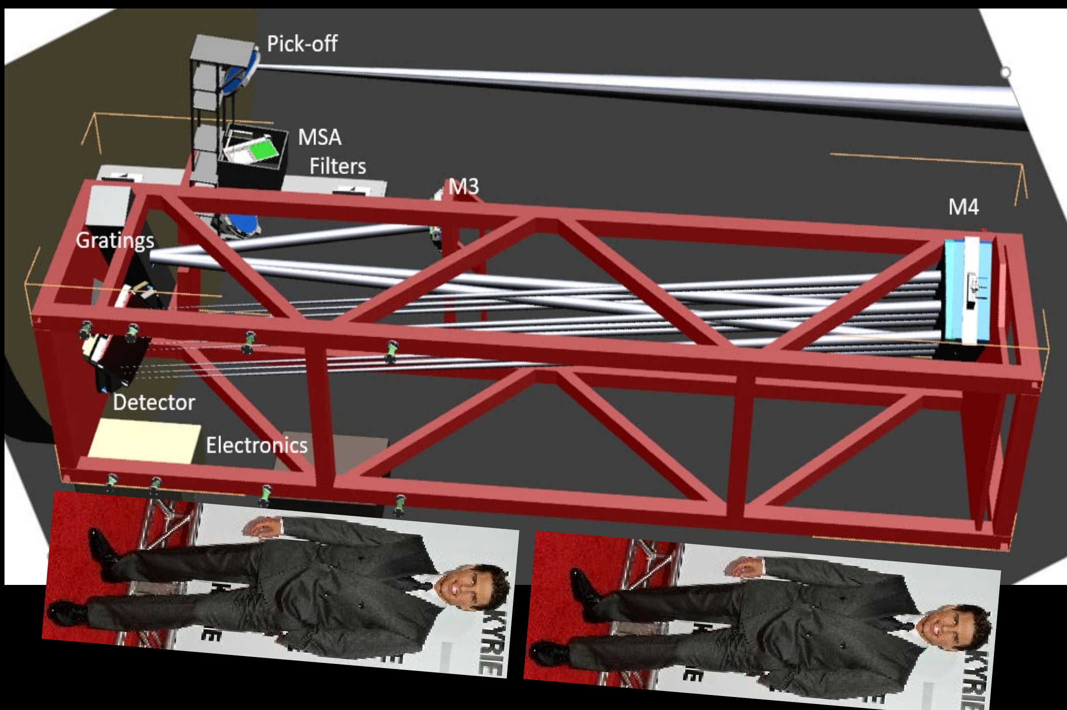

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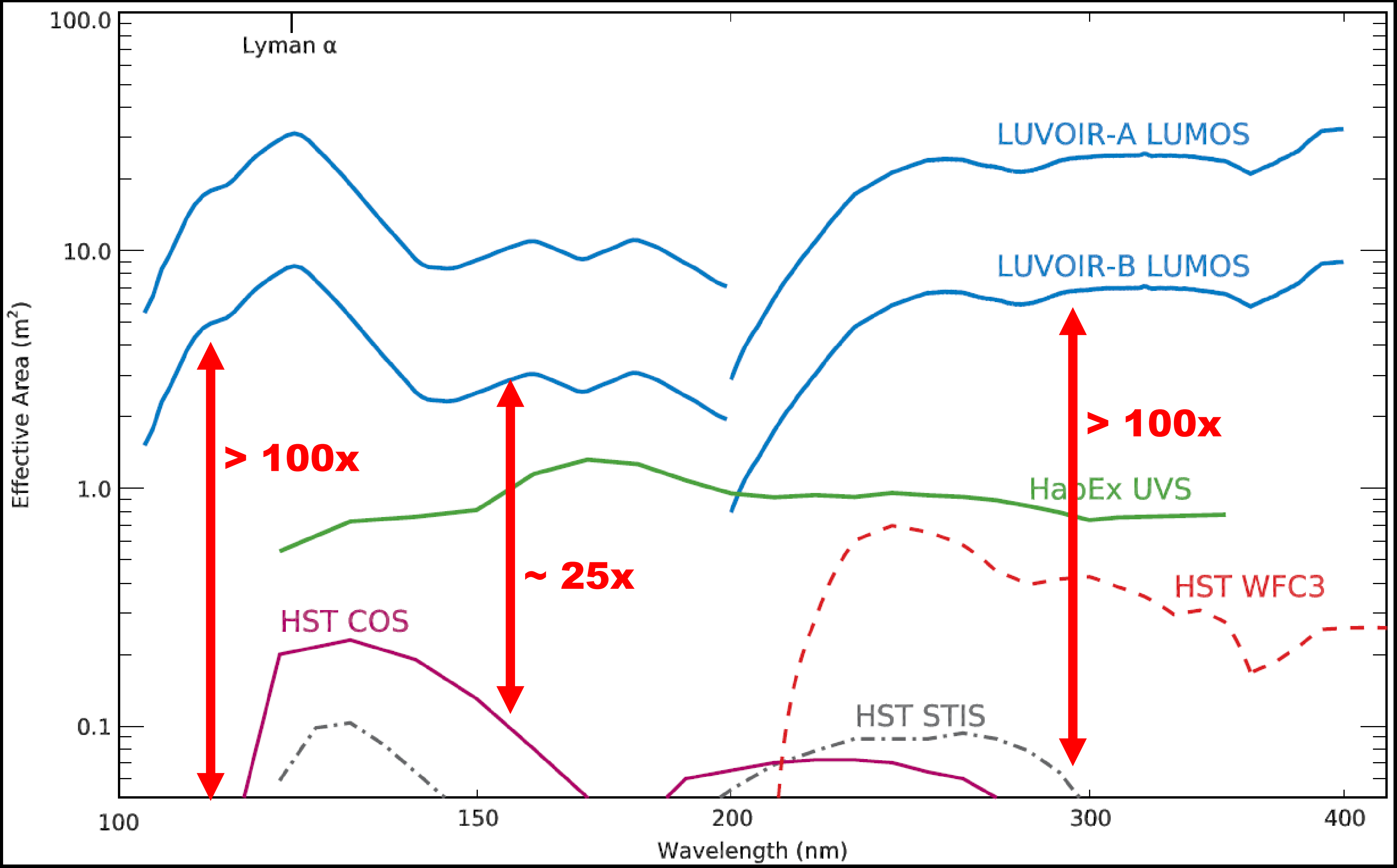
Target Sensitivity Performance (LUMOS-B)

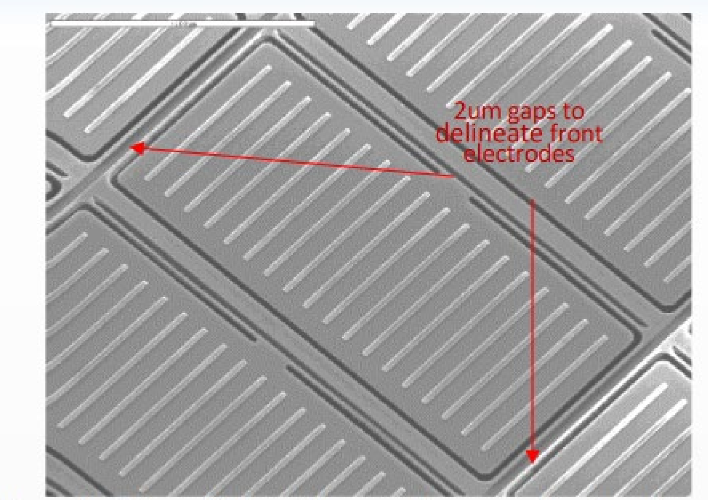


Courtesy of Eric Lopez, NASA/GSFC

LUMOS-B Performance

Mode	Peak Sensitivity Band (nm)	Res Pow (best 1'x1' of FOV)	Ang Res (best 1'x1' of FOV, mas)
G120M	100-140	40K	31
G150M	130-170	52K	32
G180M	160-200	59K	33
G155L	100-200	17K	39
G145LL	100-200	530	23
G300M	200-400	33K	23
G700M	400-1000	28K	41
FUV Img	100 - 200	N/A	40

Multi-object selection with micro-shutter arrays (MSAs), development work led at NASA/GSFC



Front side of shutter: column electrodes

~ 800 shutters available per exposure in M & L MOS modes

Each microshutter is ~110 mas (clear) in height, so each is a "long slit" aperture (~2-5 XD resols/shutter).

LUMOS-B Performance

G150M: λ ~ 111-189 nm
<R> = 52K, <θ> = 32mas

Mode	Peak Sensitivity Band (nm)	Res Pow (best 1'x1' of FOV)	Ang Res (best 1'x1' of FOV, mas)
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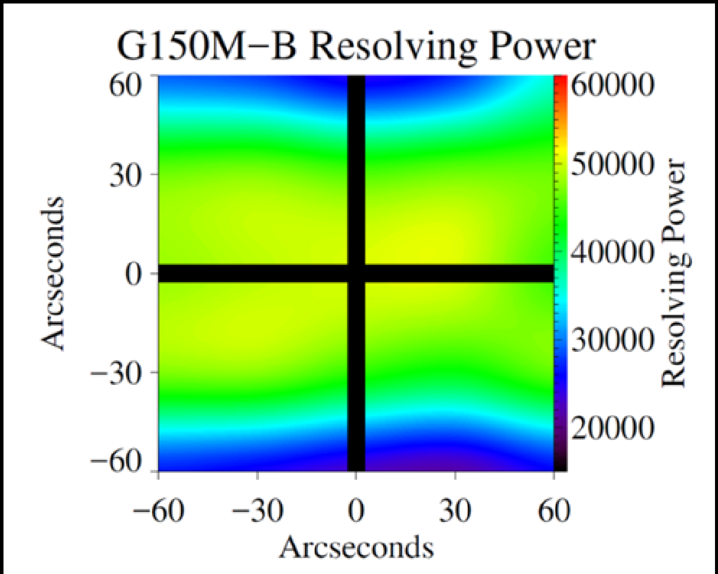

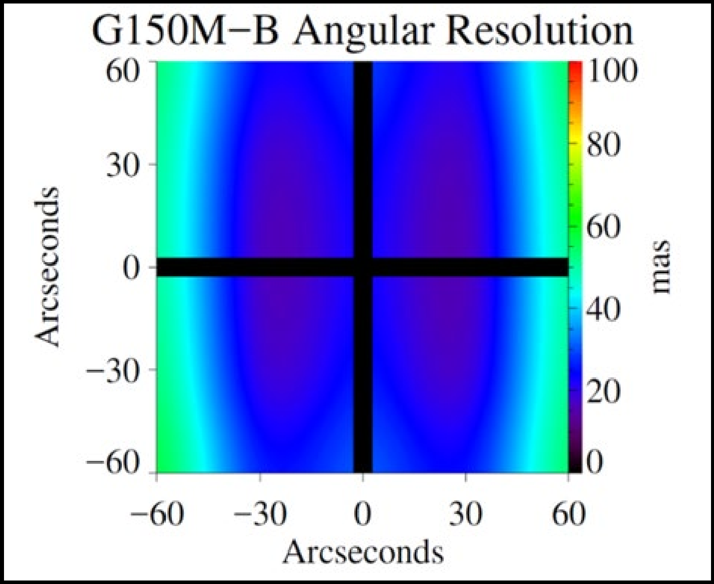

UV technology needs for future flagship missions:

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Requirements:

1) High-efficiency spectrograph designs that deliver high angular & spectral performance over ‘wide’ fields

2) Large-format (100 - 200 mm), photon-counting detectors with high global/local rate capability (~5 MHz) and high spatial resolution (20 - 25 µm)

3) Optical Coatings with > 50% reflectance at 103nm, high reflectance into the visible/NIR

4) Multi-object selection mechanisms (e.g., microshutter or micromirror), 420x840 elements, 2 side buttable, 1E-5 scatter at Lyα

5) Band-selecting UV filter technology with ≤ 1% transmission at Lyα

6) Low-scatter, high-efficiency (> 60% peak order) diffraction gratings

3) Optical Coatings with reflectance > 50% at 103nm, high reflectance into the visible/NIR

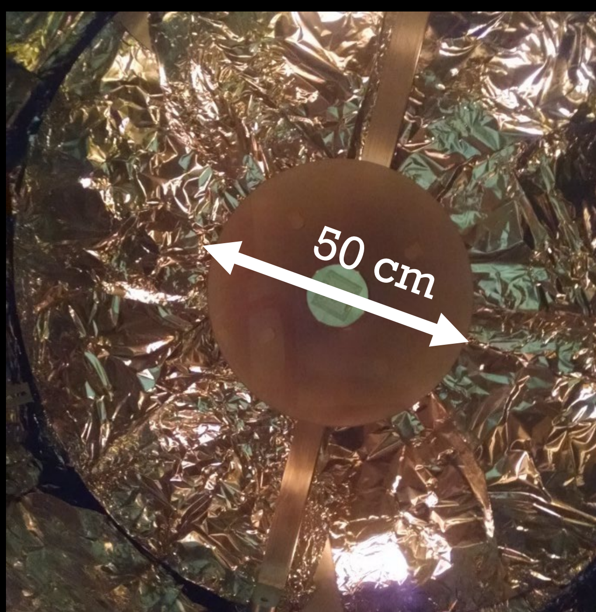
Instrumental needs:	Prior/Ongoing investments
broadband 100 – 2000nm coatings (protected enhanced Al+LiF), > 50% at 103nm, > 80% over 115-200 nm, > 88% over 200 - 850 nm	SAT/APRA - JPL and GSFC programs (PIs – Nikzad, Hennessy, Quijada), Roman Technology Fellowship - (PI – Fleming), APRA - rocket and cubesat instrument applications (PIs – France, Fleming)
scaled to ~1m optics	APRA – 0.5m rocket mirrors (PI – France, Fleming)

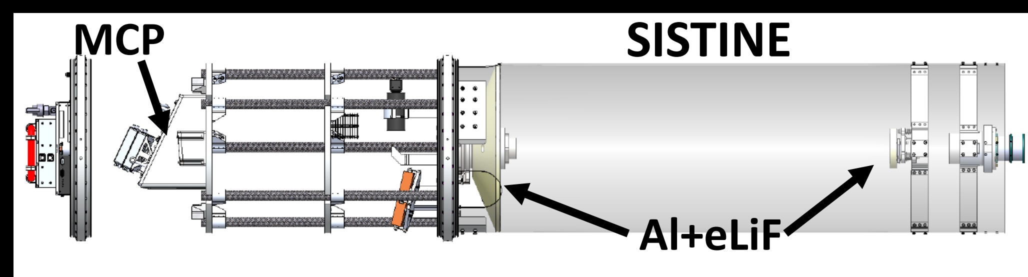
3) Optical Coatings with reflectance > 50% at 103nm

SISTINE Pathfinder Spectrograph:

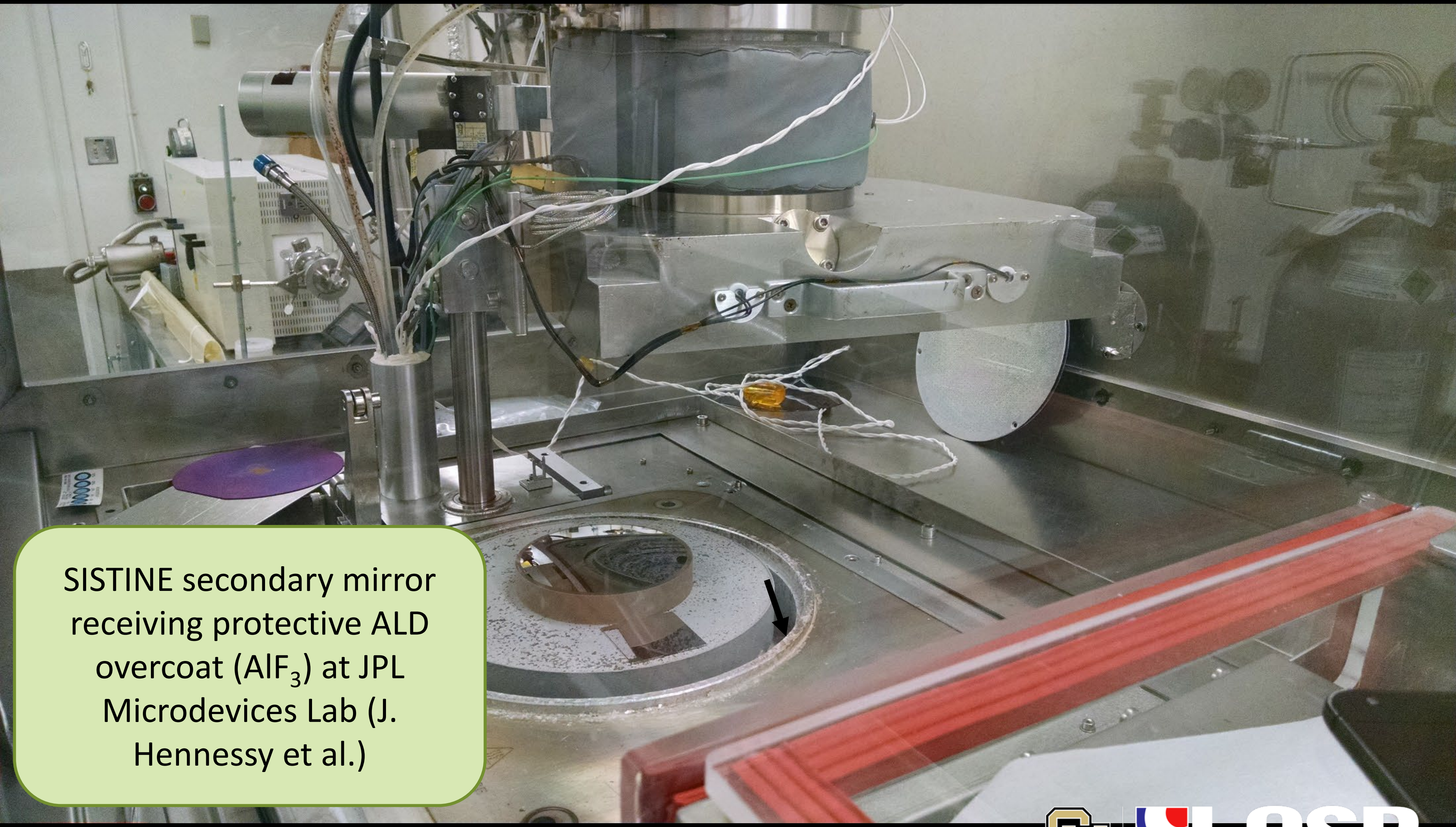
--**Al+eLiF coatings on shaped mirrors, up to 0.5m**

--first time these coatings have been deposited on large (> 2”) and shaped optics



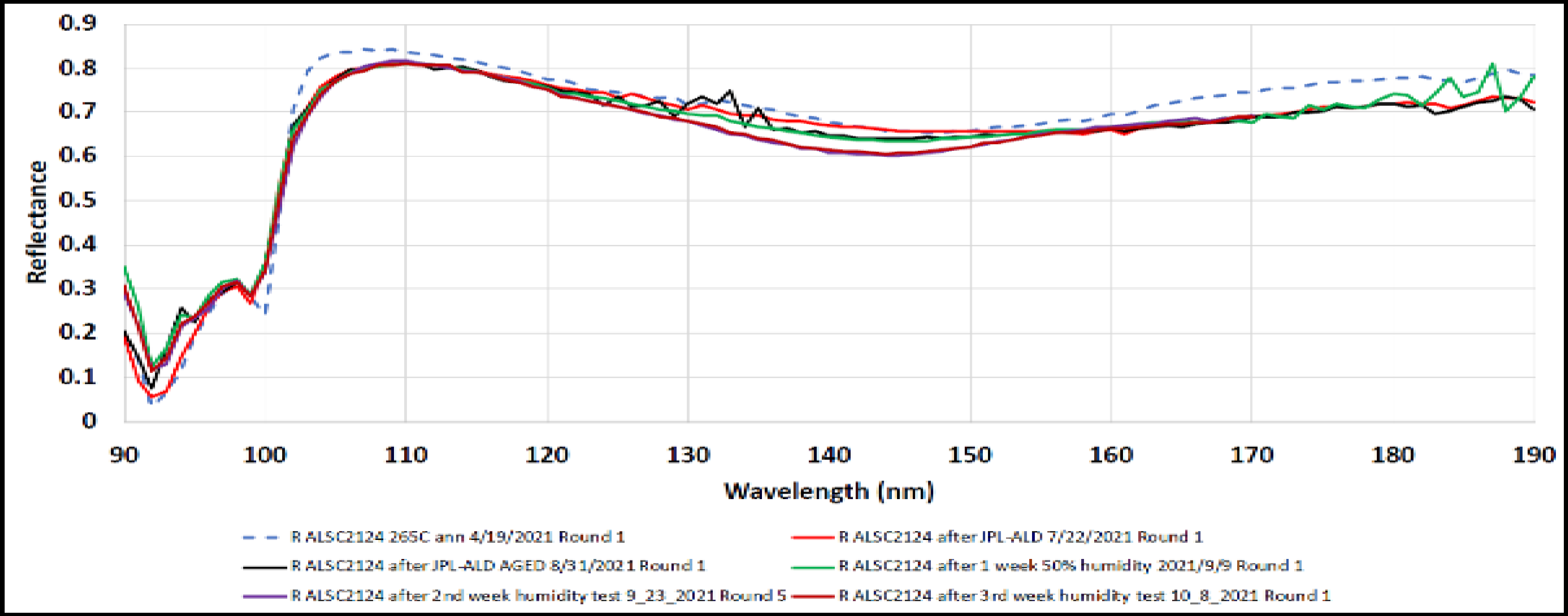


Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**



SISTINE secondary mirror receiving protective ALD overcoat (AlF_3) at JPL Microdevices Lab (J. Hennessy et al.)

3) Optical Coatings with reflectance > 50% at 103nm



SPRITE Cubesat:

--Plot of the SPRITE humidity test sample after coating with just eLiF (blue dashed line), and then after the MgF_2 overcoat (solid lines). The colored curves show no degradation from 103 - 115 nm after four weeks of aging at 50% and 60% relative humidity.

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People for future missions –

People for future missions – NASA's Suborbital Program

PIs:


Profs. Kevin France, Brian Fleming (CUTE, SPRITE cubesats, HST/COS, STAR-X/UVT, and numerous rocket missions)

Research Scientists:

Dr. Ambily Suresh


Dr. Dolon Bhattacharyya

Dr. Dmitry Vorobiev

Dr. Briana Indahl

Junior Engineers: Dana Chafetz, Stefan Ulrich, Nick DeCicco



Emily Witt

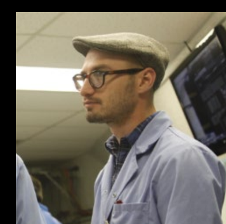

Dr. Nick Kruczek

Ph.D. and M.S. Students:

Arika Egan

Prof. Keri Hoadley

Fernando Cruz-Aguirre

Nico Nell (AE)

Dr. Chris Moore

Robert Kane (ME)


Emily Farr

Mattie Bowen

Dr. Allison Youngblood

Summary: UV Instruments for HWO

Many of the driving science cases in Cosmic Ecosystems and Worlds and Suns in Context require UV imaging and spectroscopic capabilities that far exceed what is possible with existing observatories, including

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Many of the driving science cases in Cosmic Ecosystems and Worlds and Suns in Context require UV imaging and spectroscopic capabilities that far exceed what is possible with existing observatories, including

- 100 – 1,000 nm spectral range
- R ~ 500 – 60,000 MOS over full spectral range (≥ 2’ x 2’)
- R > 100,000 point source spectroscopy, 100 – 170nm
- < 50 mas FUV and NUV imaging (≥ 2’ x 2’; multiple filters)
- > 25-100x effective area of HST-COS, imaging spectroscopy, hundreds of objects at a time.

The path to the Habitable worlds Ultraviolet Multi-object Spectrograph (HUMS)

kevin.france@colorado.edu

The path to the Habitable worlds Ultraviolet Multi-object Spectrograph (HUMS)

Our charge for the next 5 years: to advance the required technologies through a combination of laboratory and flight experiments that simultaneously bring early-career scientists and engineers into this field, invest in these technologies to scale them to the size/level required for HWO.

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