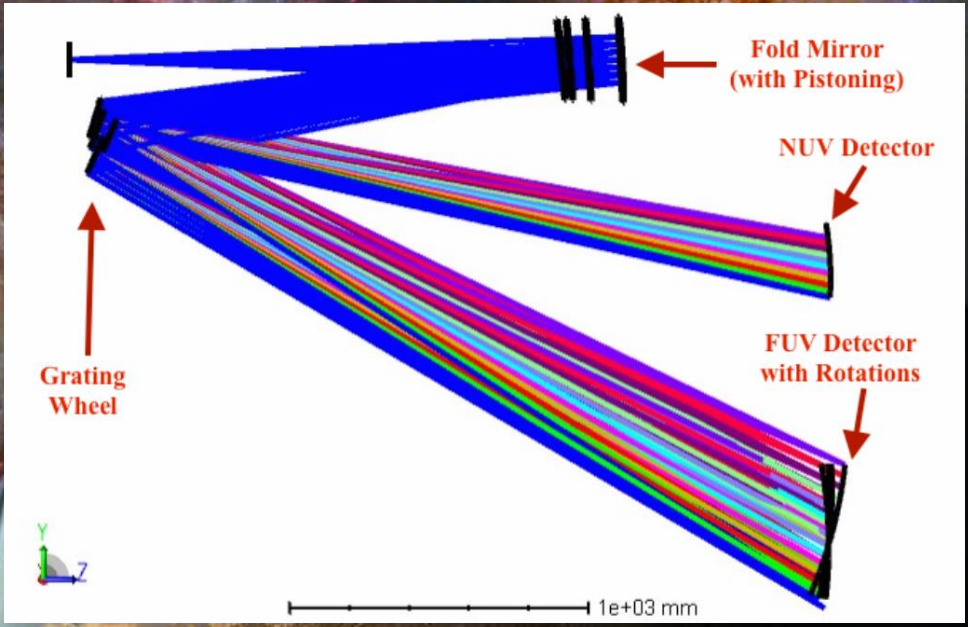
LUVOIR Ultraviolet Multi-object Spectrograph (LUMOS)



KEVIN FRANCE

UNIVERSITY OF COLORADO

FOR LUMOS SCIENCE WORKING GROUP

LUVOIR STDT F2F3 – 09 NOVEMBER 2016

LUMOS SCIENCE TEAM

Kevin France - Colorado

John O'Meara – St. Michael's

Jane Rigby – GSFC

David Schiminovich - Columbia

Walt Harris – Arizona

Leonidas Moustakas - JPL

Jason Tumlinson - STScI

Brian Fleming - Colorado

Steve McCandliss - JHU

1. LUMOS OVERVIEW

Multi-channel instrument:

1) High-resolution (echelle) point source spectrograph

2) Multi-object imaging spectrograph, medium- and low-resolution spectral modes.

3) Near-UV IFU and NUV+FUV imaging mode (under discussion)

2. LUMOS Instrument Requirements

Spectral Bandpass:
Target: 100 – 400 nm
(Stretch: 90 – 400 nm)

Spectral Resolving Power:
Target: “H” = 120,000
“M” = 15,000 – 50,000
“L” = 5,000 – 15,000
“LL”~ 500
(Stretch: H -> 250,000)

Temporal Resolution:
Target: 1 msec
(Stretch: 0.1 msec)

2. LUMOS Instrument Requirements

Multi-Object Field-of-View:
Target: 2’ x 2’
(Stretch: 3’ x 3’)

Angular Resolution in MOS mode:
Target: 50 mas
(Stretch: 30 mas)

Heritage/TRL: Design, technology, ConOps based on HST UV spectrographs, FUSE, and suborbital instrument designs and component level testing; NASA APRA and SAT programs (e.g., J. Vallerga, O. Siegmund , K. France, S. McCandliss, B. Fleming, S. Nikzad, M. Quijada, and others)

2b. LUMOS Technology – Current Laboratory and Flight Testing

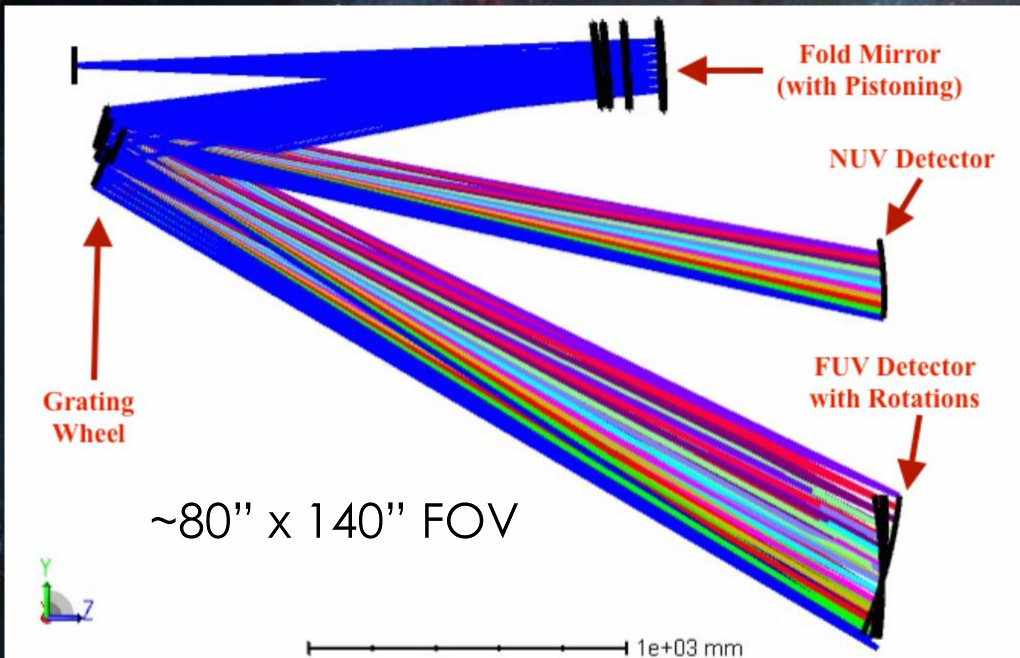
lumos

NASA CASA CU LASP
University of Colorado Boulder

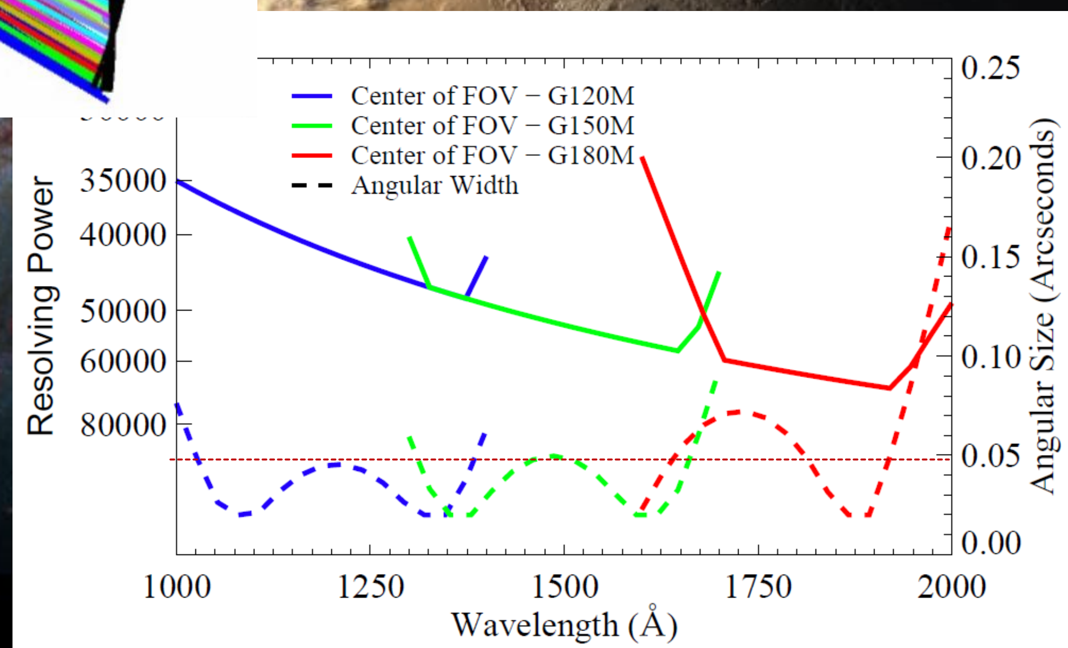
LUMOS Technology Development: Current Laboratory/Flight Programs

1) CHESS (CU): high dynamic-range MCPs (X-strip) echelle gratings, deformable mirror holographic recording
2) FORTIS (JHU): prototype MSAs
3) DEUCE (CU): large format photon-counting detectors (200mm x 200mm)
4) SISTINE (CU): Advanced UV coatings, large format high resolution MCPs, high angular and spectral res UV spectrograph design

3. LUMOS – Notional Design

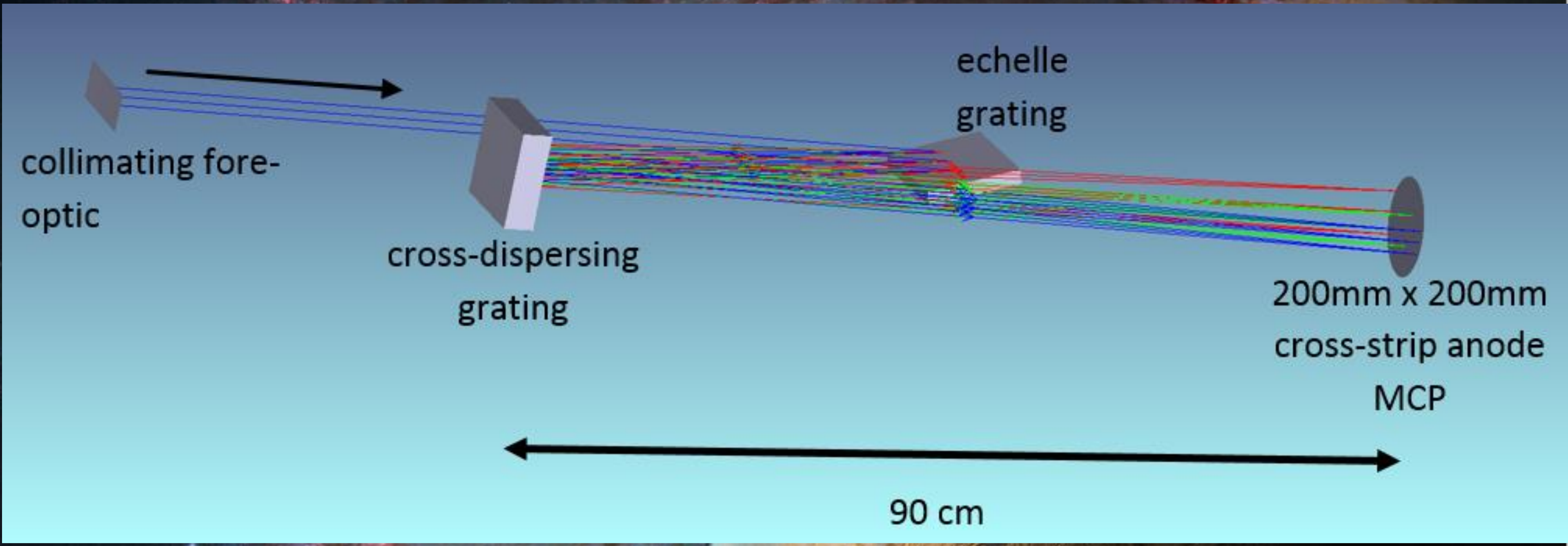


- "JWST-like" microshutter array Holographic grating
- Fold mirrors, grating wheel, detectors



NEED: stable advanced coatings, large-format detector arrays (~200mm x 200mm x 2)

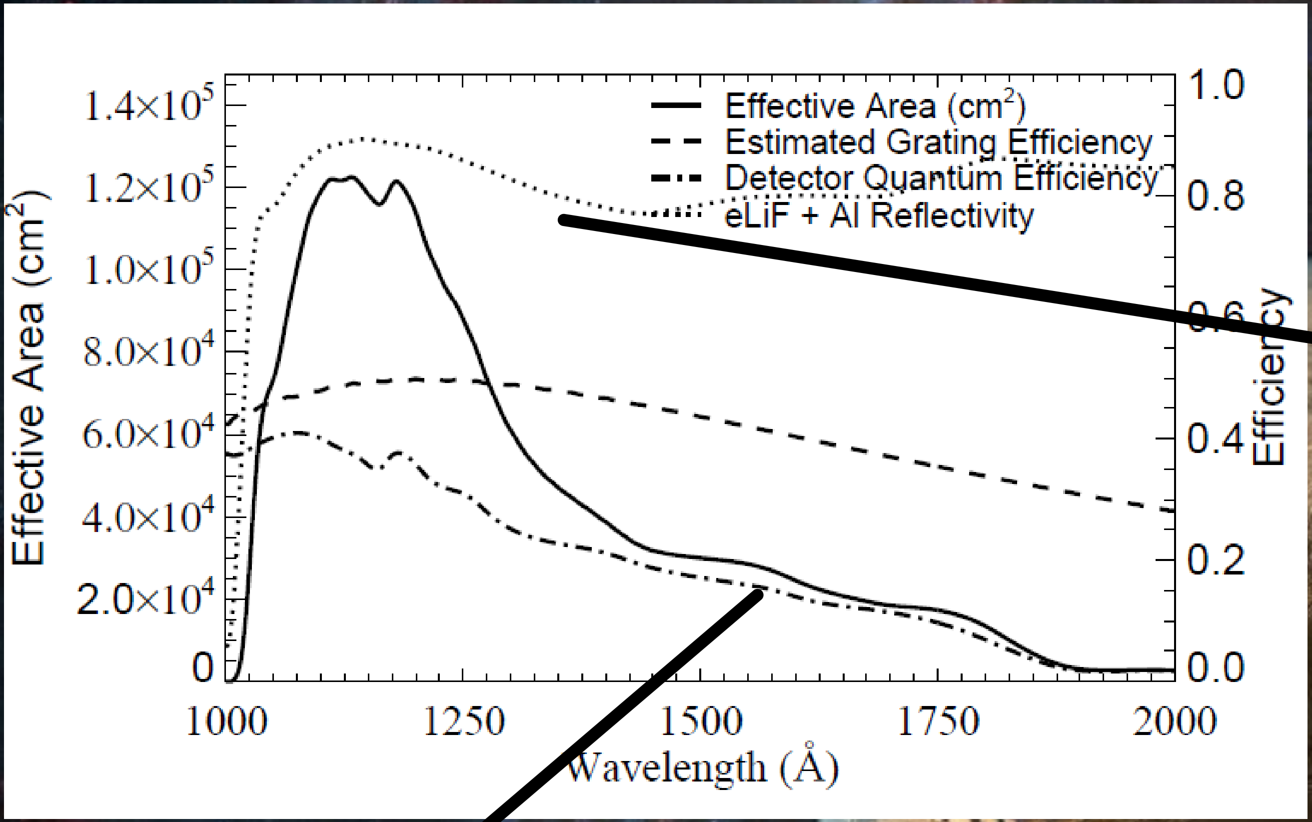
3. LUMOS – Notional Design



- Optical Telescope Assembly → collimator
- Echelle grating (mechanical: Richardson, e-beam: McEntaffer/PSU)
- Holographically ruled cross-dispersing/focusing grating

<u>**NEED**</u>: stable advanced coatings (reflectivity ≥ 85% at $\lambda >$ 1000 Å, large-format detector array (~200mm x 200mm)

3. LUMOS – Notional Design

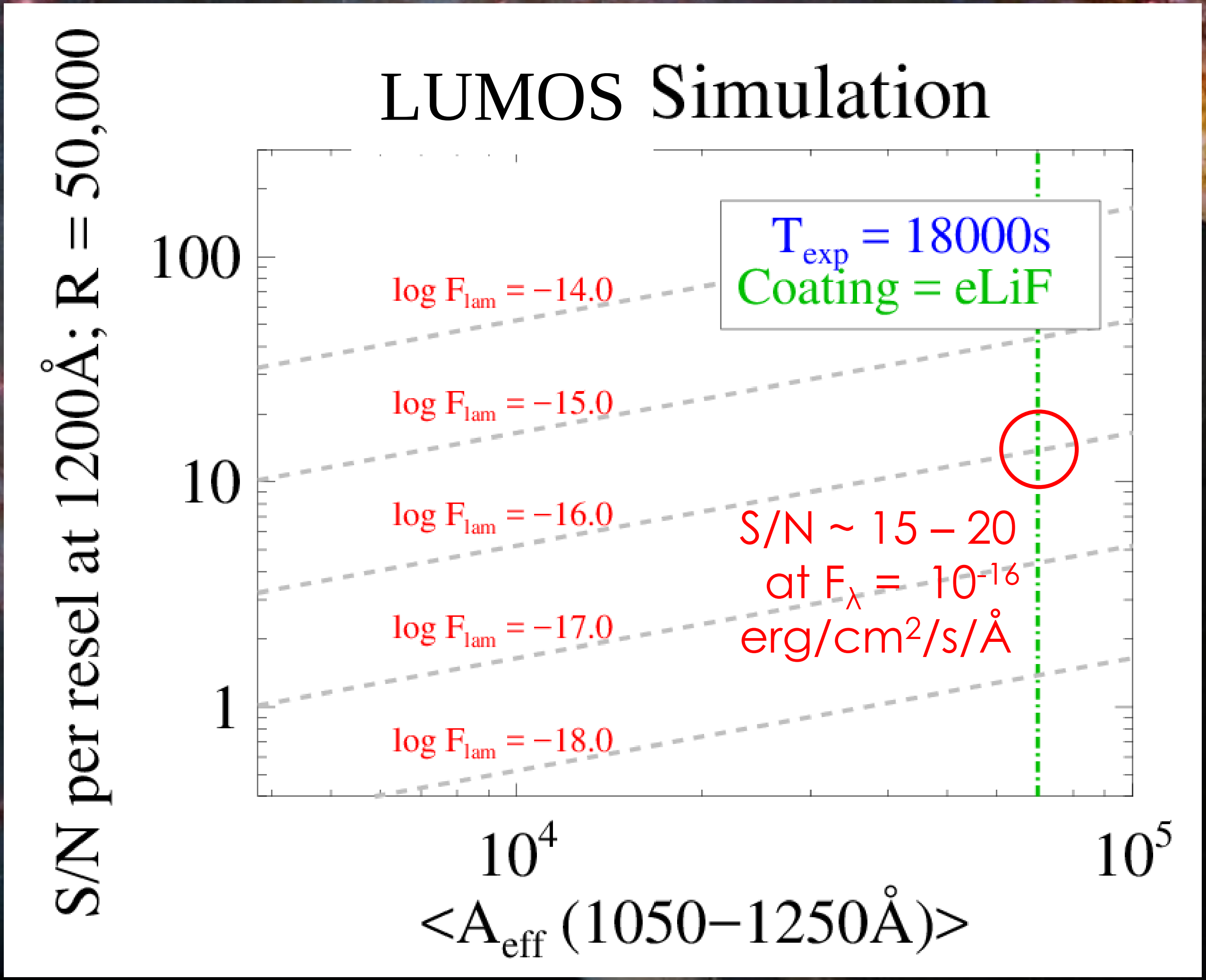


-Quijada et al. 2014;
-Fleming et al. 2016;
-Hennessey et al. 2016
-Balasubramanian et al. 2015

-Siegmund et al. 2014;
-Nikzad et al. 2012;
-Vallerga et al. 2016

$A_{eff} \sim 0.9 * (\pi\ (12m/2)^2) * (R_{coat})^4 * (G_{grat}) * DQE_{det}$

3. LUMOS – Notional Design



3. LUMOS – Exposure Time Calculator (Jason Tumlinson)

http://www.jt-astro.science/luvoir_simtools/spec_etc.html

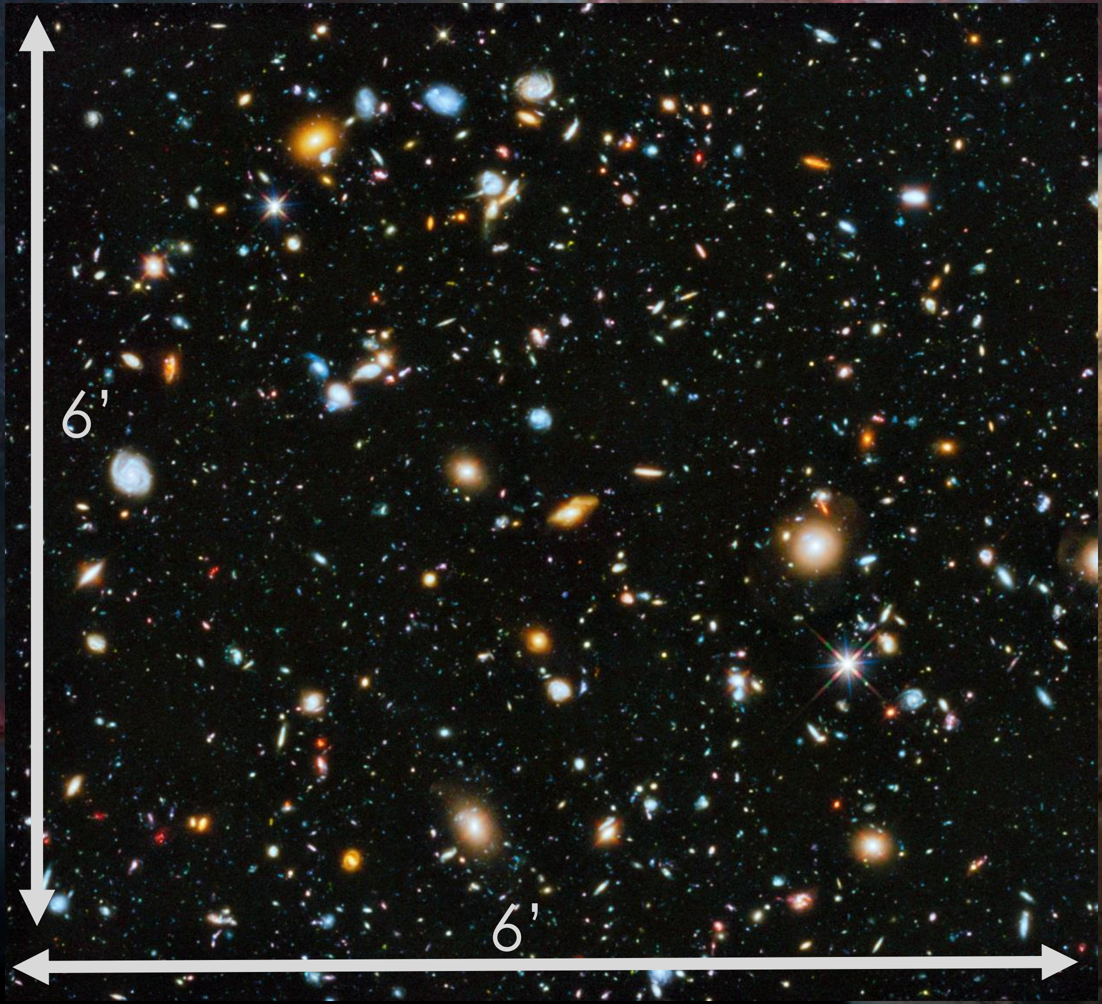
3. LUMOS – Notional Design

Comparison with HST-STIS

Instrument Parameter	STIS G140M	LUMOS FUV (Imaging Modes)
Spectral Resolving Power	10,000	8,000 – 50,000 (NUV: 20k – 40k)
Total Spectral Bandpass	1140 – 1740 Å	1000 – 2000 Å (NUV: 2000 – 4000 Å)
Spectral Bandpass per Exposure	50 Å	450 – 1000 Å (NUV: 1600 Å)
Number of Exposures to Cover Spectral Bandpass	12	1 (Low Res) 3 (Med Res) (NUV: 1 – 2)
Imaging Field-of-View	0.2” x 28”	~80” x 140” (OTA-dependent)
Spectrograph Throughput	1.2%	10.5%

4. LUMOS Concept of Operations

What can we do with LUVOIR + LUMOS?

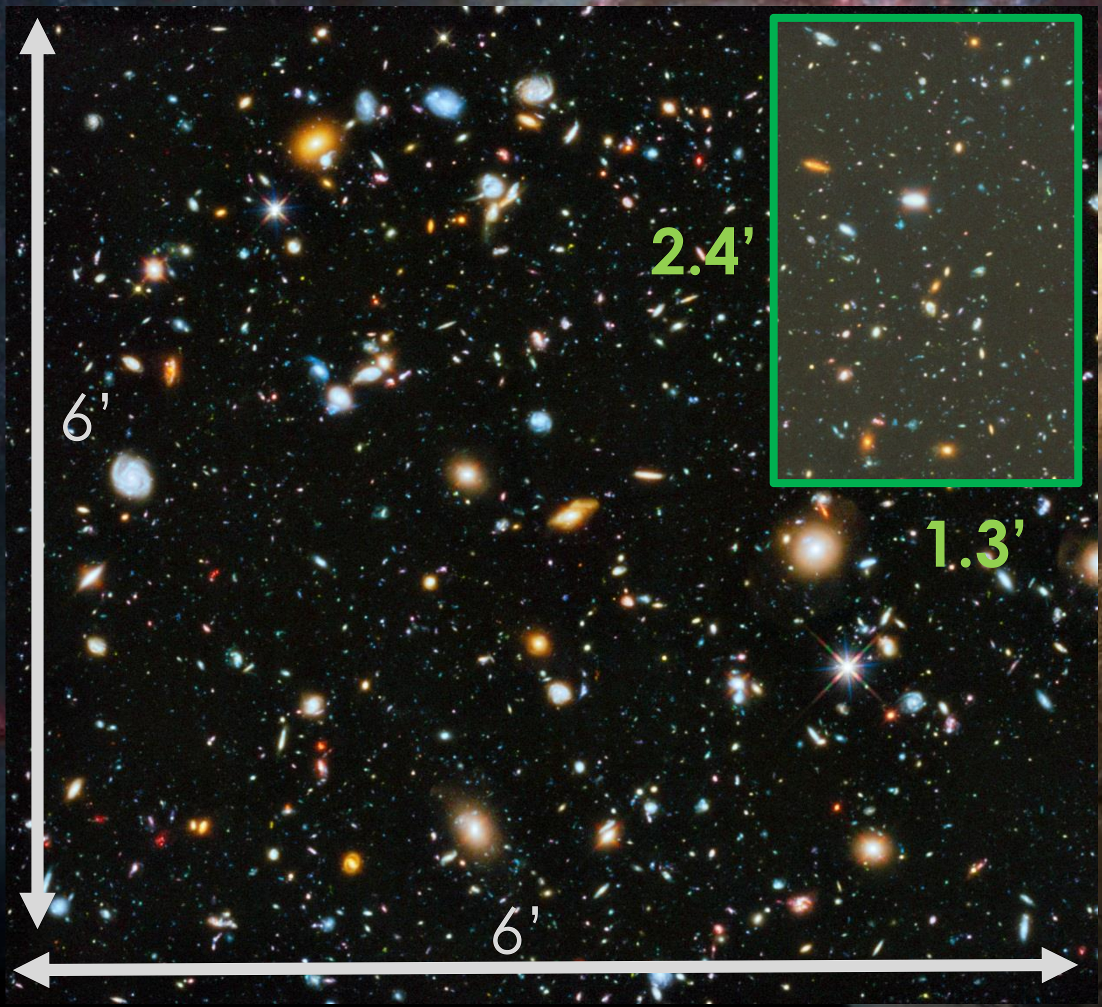


Deep fields will be produced automatic via parallel observations during coronagraphy

Spectroscopic observations of low/intermediate redshift galaxies and CGM/IGM

4. LUMOS ConOps

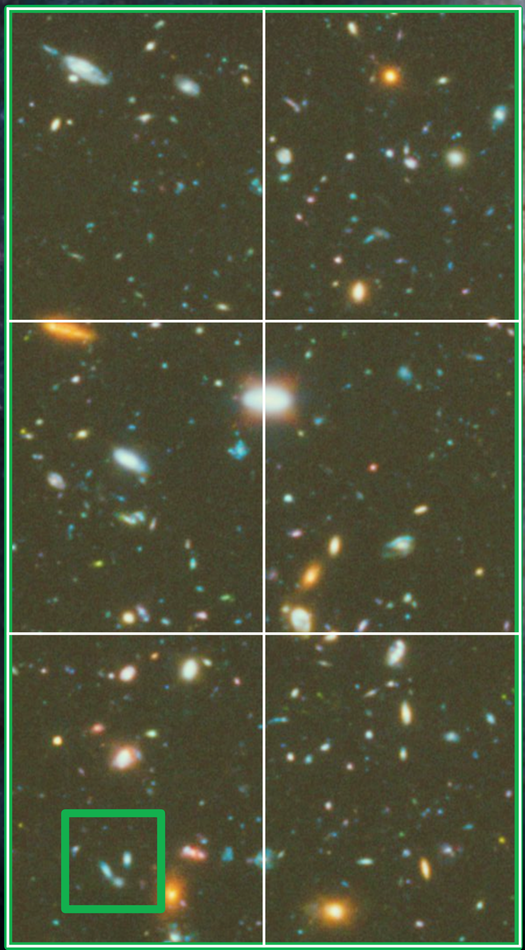
What can we do with LUVOIR + LUMOS?



Spectroscopic observations of low/intermediate redshift galaxies and CGM/IGM

4. LUMOS ConOps

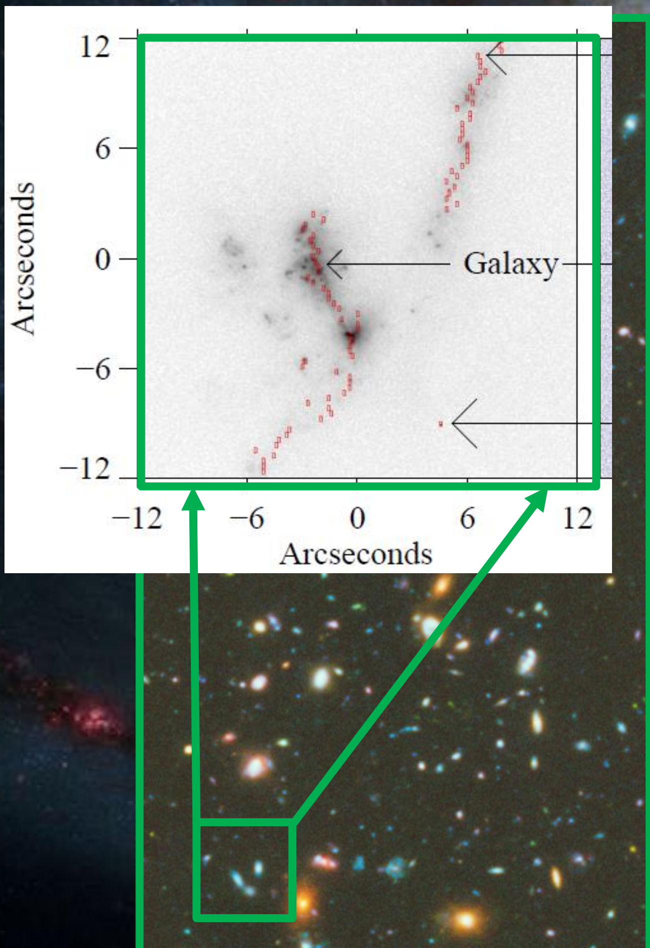
What can we do with LUVOIR + LUMOS?



- 3 x 2 microshutter arrays, 100 x 200 micron slits
- < 0.05" spectral imaging across most of FOV
  - (0.03" – 1.0" spectral imaging across full FOV)

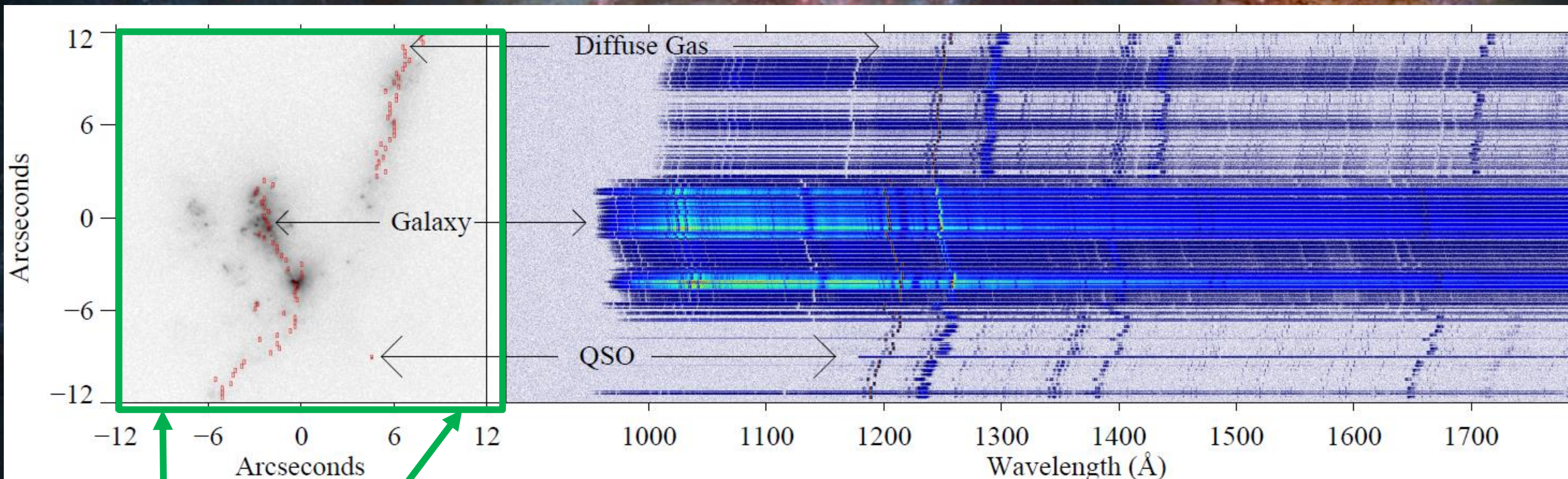
4. LUMOS ConOps

What can we do with LUVOIR + LUMOS?



4. LUMOS ConOps

What can we do with LUVOIR + LUMOS?

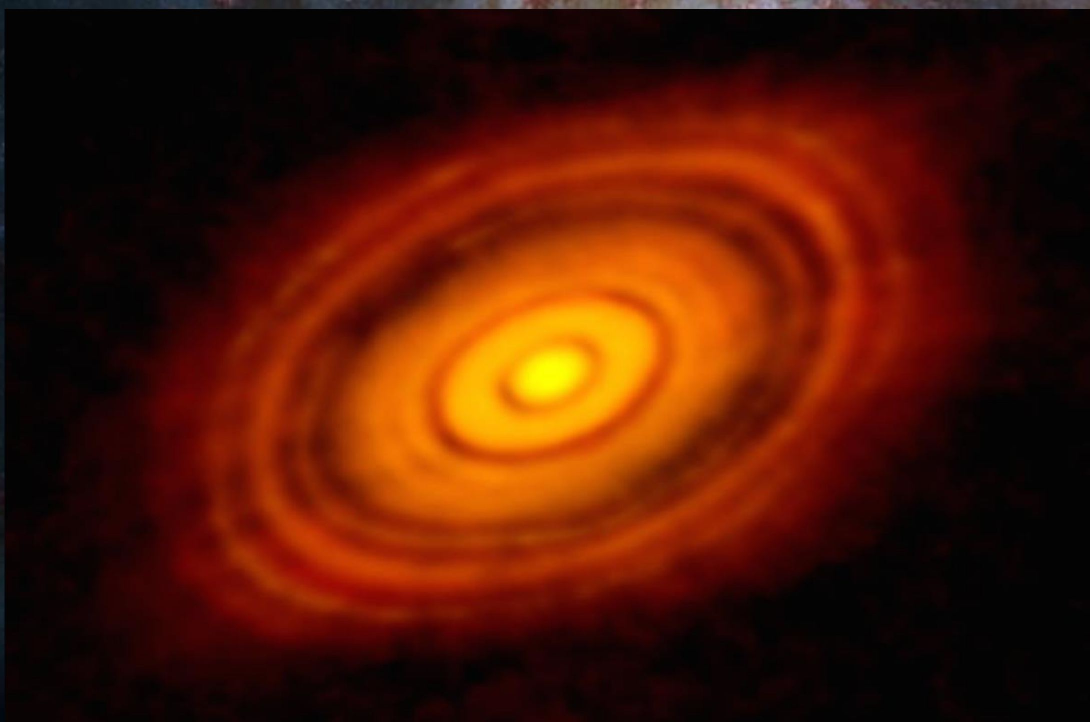


R > 8,000 1000 – 2000 Å spectroscopy of hundreds of objects *simultaneously*.

Background quasars, numerous galactic regions, circumgalactic halo

4. LUMOS ConOps

What can we do with LUVOIR + LUMOS?



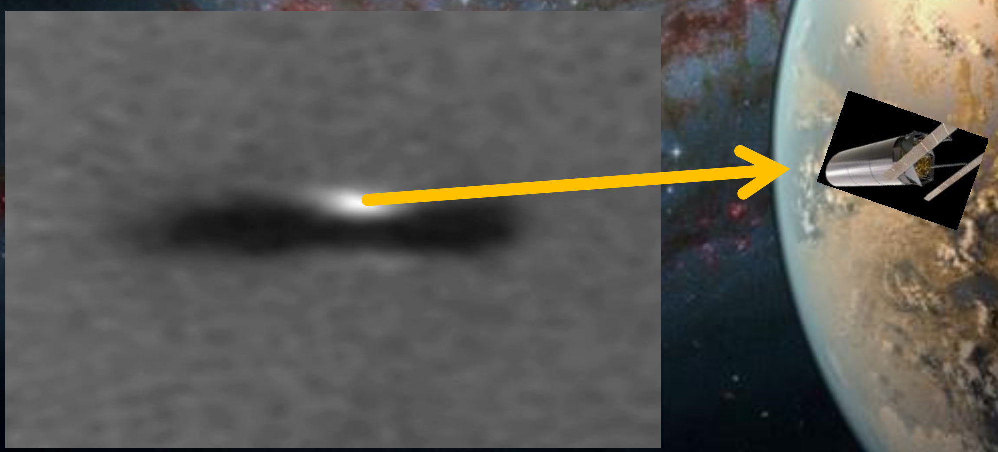
Protoplanetary Disks – where COR and EXO meet

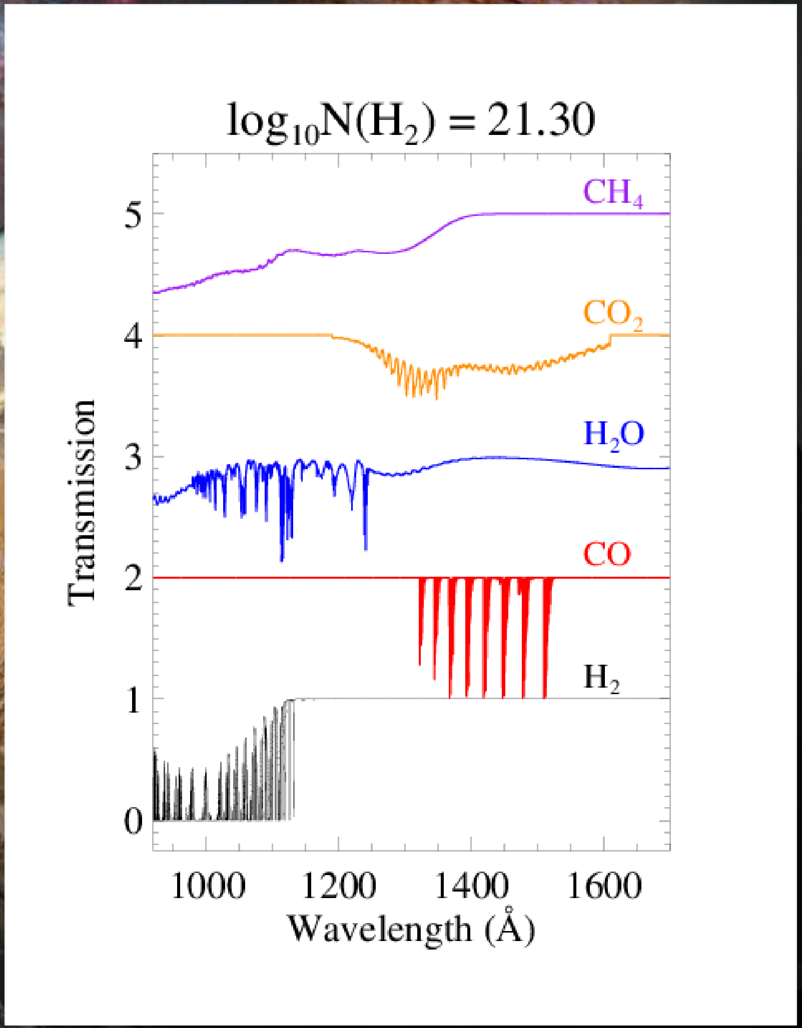
'End product' of CGM/galaxy connection. Composition of planet forming region, connection to eventual bulk composition of exoplanets and their atmospheres.

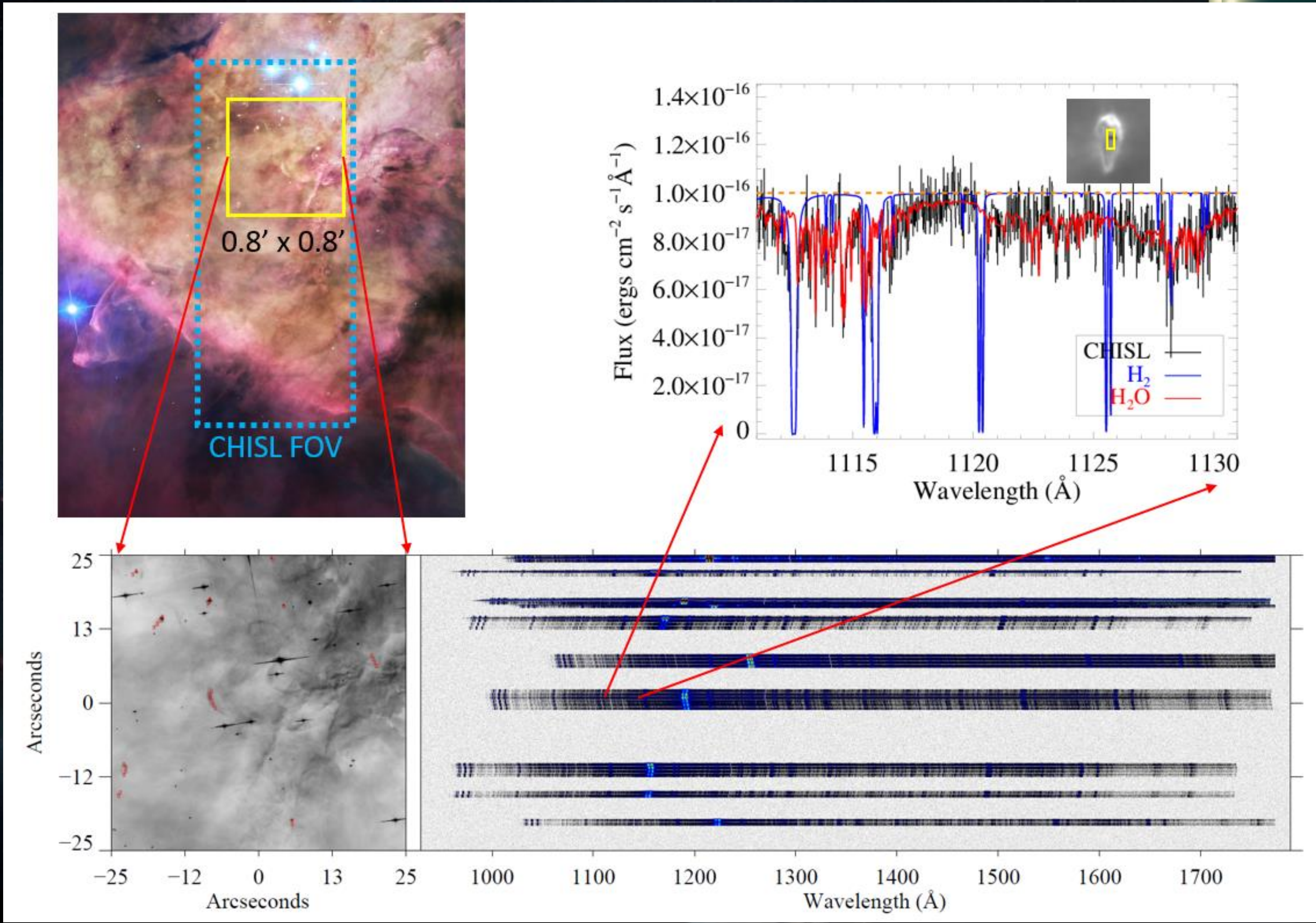
4. LUMOS ConOps

What can we do with LUVOIR + LUMOS?

- High sensitivity + high-resolution far-UV absorption line spectroscopy of CO, H_2, and H_2O enable quantitative compositional analysis of planet-forming disks







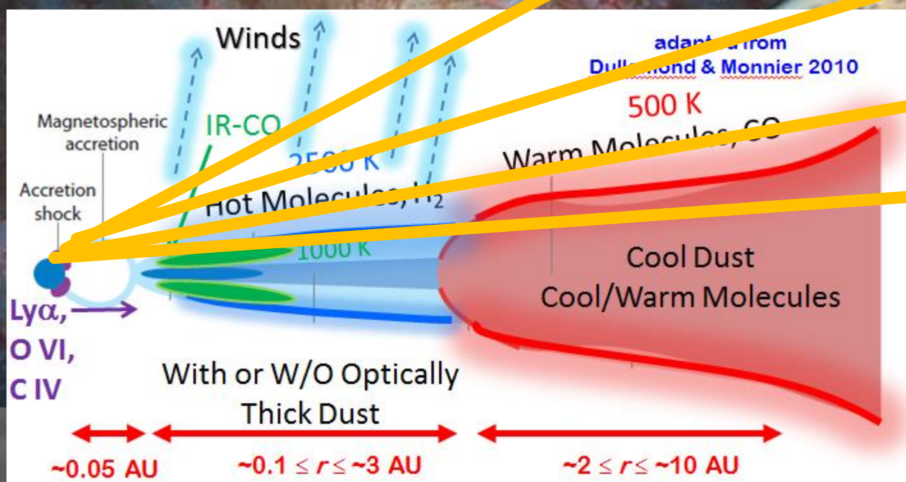
0.8′ x 0.8′
CHISL FOV
Flux (ergs cm^{-2} s^{-1} Å^{-1})
Wavelength (Å)
CHISL
H_2
H_2O
Arcseconds
Arcseconds
Wavelength (Å)

4. LUMOS ConOps

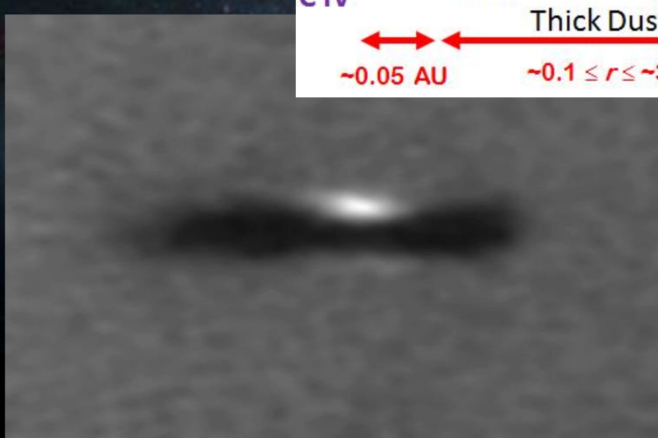
Photoevaporative wind

Warm H_2 Atm

Molec Surface Layer



Complex Chemistry Region and Grain Growth



- ***Distribution of inclination angle and ages allows 4-D mapping of disks [r,h,t (age),λ (composition)]***

SUMMARY

<u>LUMOS</u>: UV SPECTROGRAPH CONCPT FOR LUVOIR

1) High-resolution (echelle) point source spectrograph, [$R \geq 10^5$]

2) Imaging / multi-object spectrograph over 'a few' square arcminutes FOV (2 – 3 $'^2$) at low and medium res [R = 500 - 50,000]

3) Development and Flight-Testing happening today to support LUVOIR-like mission in the next decade


FIN

2b. LUMOS Technology – Current Laboratory and Flight Testing

- Colorado UV Rocket Program
  - High-resolution spectroscopy of the local ISM (**CHESS**); Imaging Spectroscopy of Nearby Galaxies and Exoplanet Host Stars (**SISTINE**)
  - **Hardware Development**:
    1. UV/visible optical coatings
    2. UV Detectors
    3. Diffraction Grating Technology

CHESS Payload

X-strip MCP bulkhead

Echelle Al disk

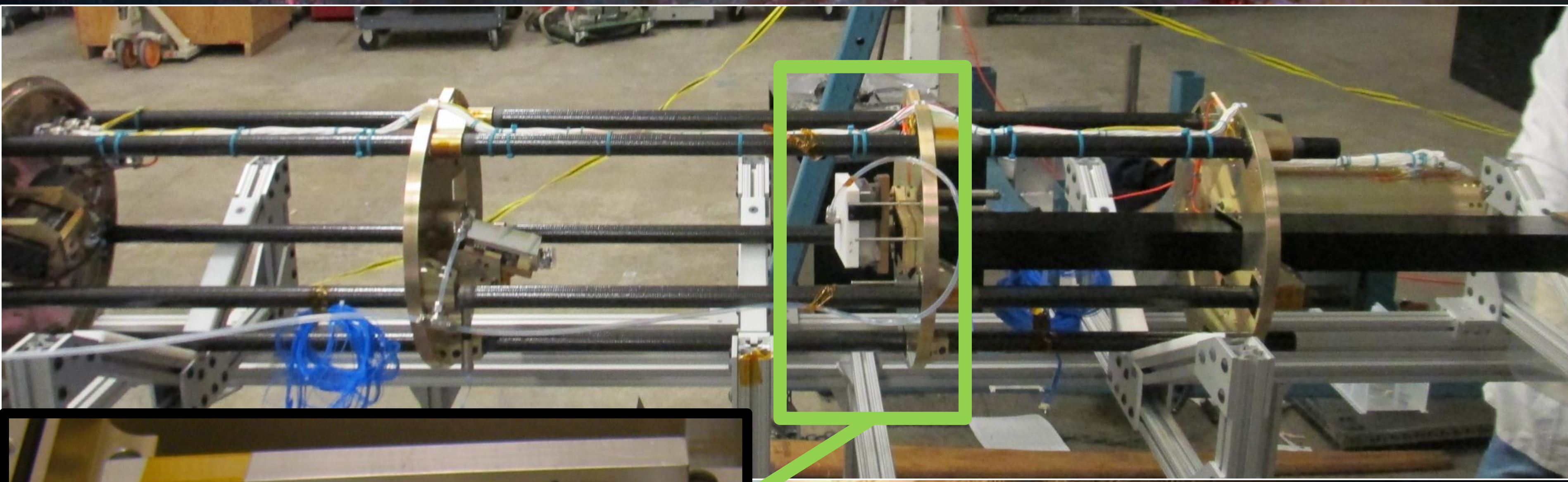
Cross disperser Al disk

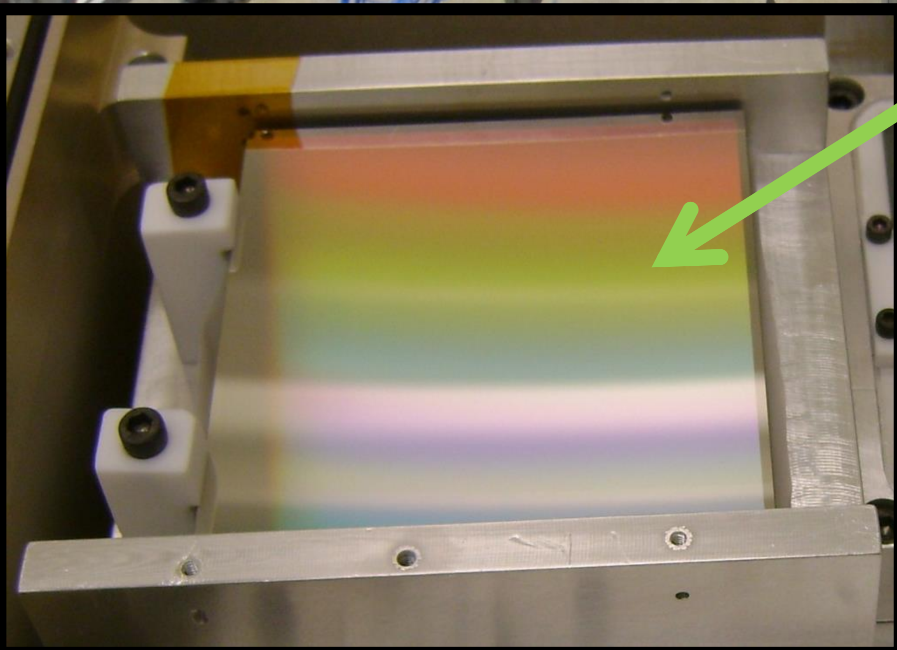
Mechanical collimator Al disk

Carbon fiber mechanical structure

France et al. 2012
Hoadley et al. 2014
France et al. 2016

CHESS Payload





Cross Disperser (HORIBA Jobin-Yvon):

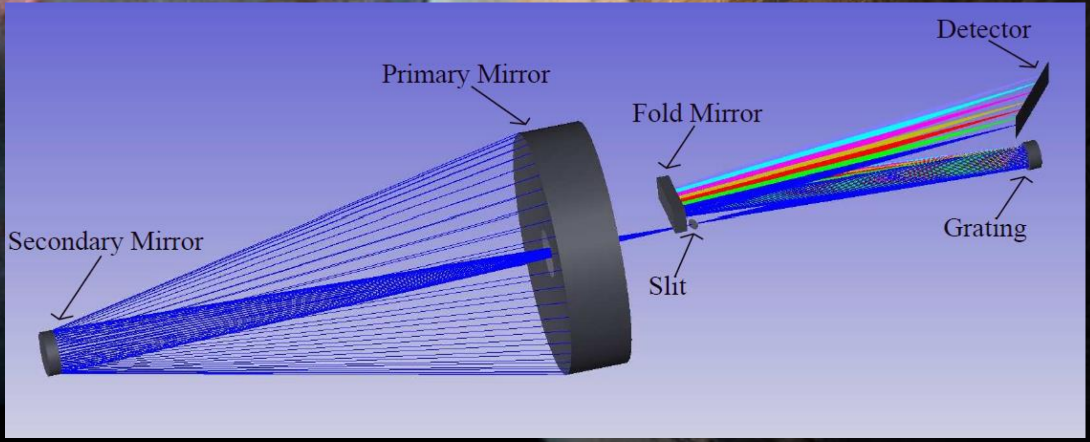
100 x 100 x 30 mm fused silica substrate
Holographically-ruled, 351 grooves/mm

5. LUMOS Technology – Current Laboratory and Flight Testing

CHISL Technology Development

1) CHESS: (see Keri Hoadley's poster today/tomorrow, 9905-138)

2) SISTINE: (see Brian Fleming's Talk this afternoon, 9905-9). *R* ≈ 10,000, sub-arcsecond imaging spectrograph, 1000 – 1600 Å



1. LUVOIR ORIGIN → SCIENCE

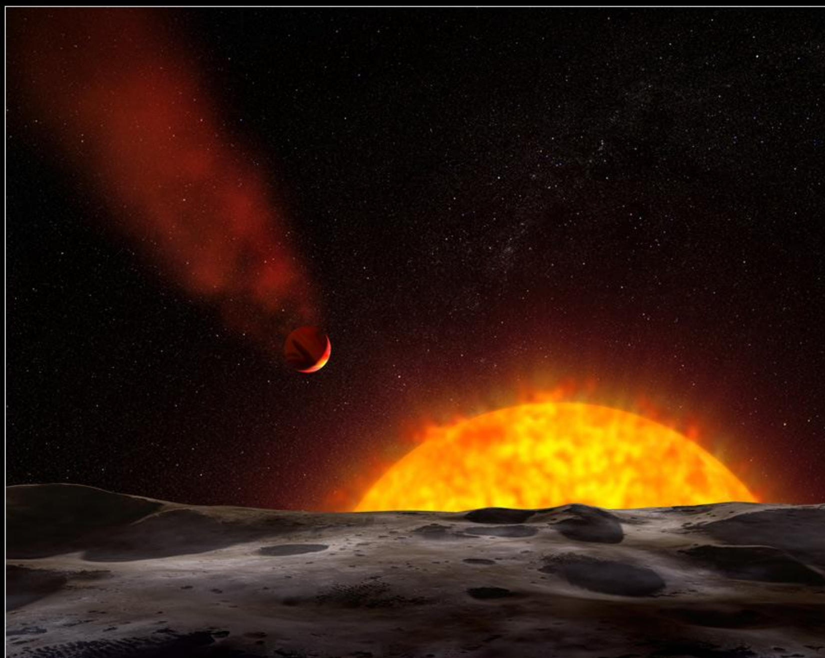
6.4 Science Summary

	Formative Era					Visionary Era			
	GW Surveyor	CMB-pol Surveyor	FIR Surveyor	LUVOIR Surveyor	X-ray Surveyor	GW Mapper	Cosmic Dawn Mapper	ExoEarth Mapper	Black Hole Mapper
Demographics of planetary systems				1					
Characterizing other worlds				2					
Our nearest neighbors and the search for life				3					
The origins of stars and planets				4					
The Milky Way and its neighbors				5					
The history of galaxies				6					
The origin and fate of the universe									
Extremes of matter and energy									
Ripples of space-time									

Primary Goals

Secondary Goals

Earth-mass Planets around M and K dwarfs: The Production of (and c "Biomar



Artist's View of Extrasolar Planet HD 209458b

NASA, ESA, and G. Bacon (STScI) ▪ STScI-PRC10-21

- Hot Jupiter Transits: FUV transmission spectroscopy the best technique for observations of atmospheric mass-loss outside the solar system. Currently limited by data quality.