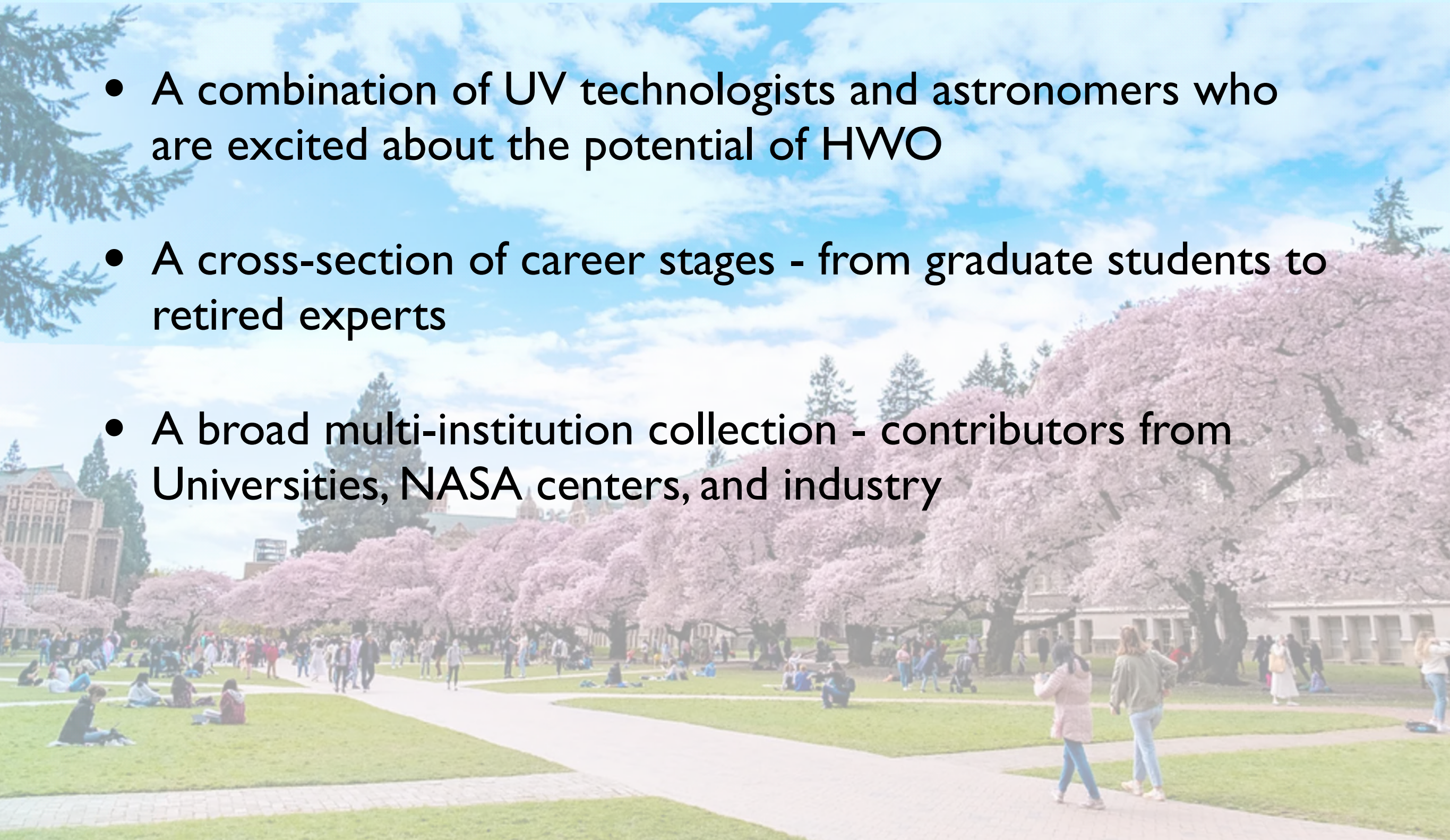


The Ultraviolet Hardware Path to HWO

Sarah Tuttle, University of Washington, Seattle
on behalf of the Cosmic Origins Program Analysis Group

Who are we?

- A combination of UV technologists and astronomers who are excited about the potential of HWO
- A cross-section of career stages - from graduate students to retired experts
- A broad multi-institution collection - contributors from Universities, NASA centers, and industry



Ultraviolet Technology To Prepare For The Habitable Worlds Observatory

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Why this working group?

- The road to HWO is both really long (work wise) and surprisingly short (time wise)
- Crucial to capture the current state of UV technology
- Want to document and address some past concerns & experiences
- Demonstrate current state of the art – and exciting development paths!
- Instrumentalists are surprisingly (not that surprisingly) mediocre at publishing things. Building things? Great. Documenting that? A... little less great.

4. Reflective Coatings

- 4.1. eLiF and XeLiF - Physical Vapor Deposition (PVD) Coatings
- 4.2. Atomic Layer Deposition (ALD) Coatings
- 4.3. Coating Performance
- 4.4. Polarization Sensitivity
- 4.5. Coating Development towards HWO

5. Detectors

- 5.1. Microchannel Plates
- 5.2. Solid State Detectors

6. Gratings

- 6.1. UV gratings with electron-beam lithography

7. Spectral Multiplexing Technologies

- 7.1. Microshutter Arrays
- 7.2. Digital Micromirror Devices
- 7.3. Integral Field Units

8. Contamination Reduction

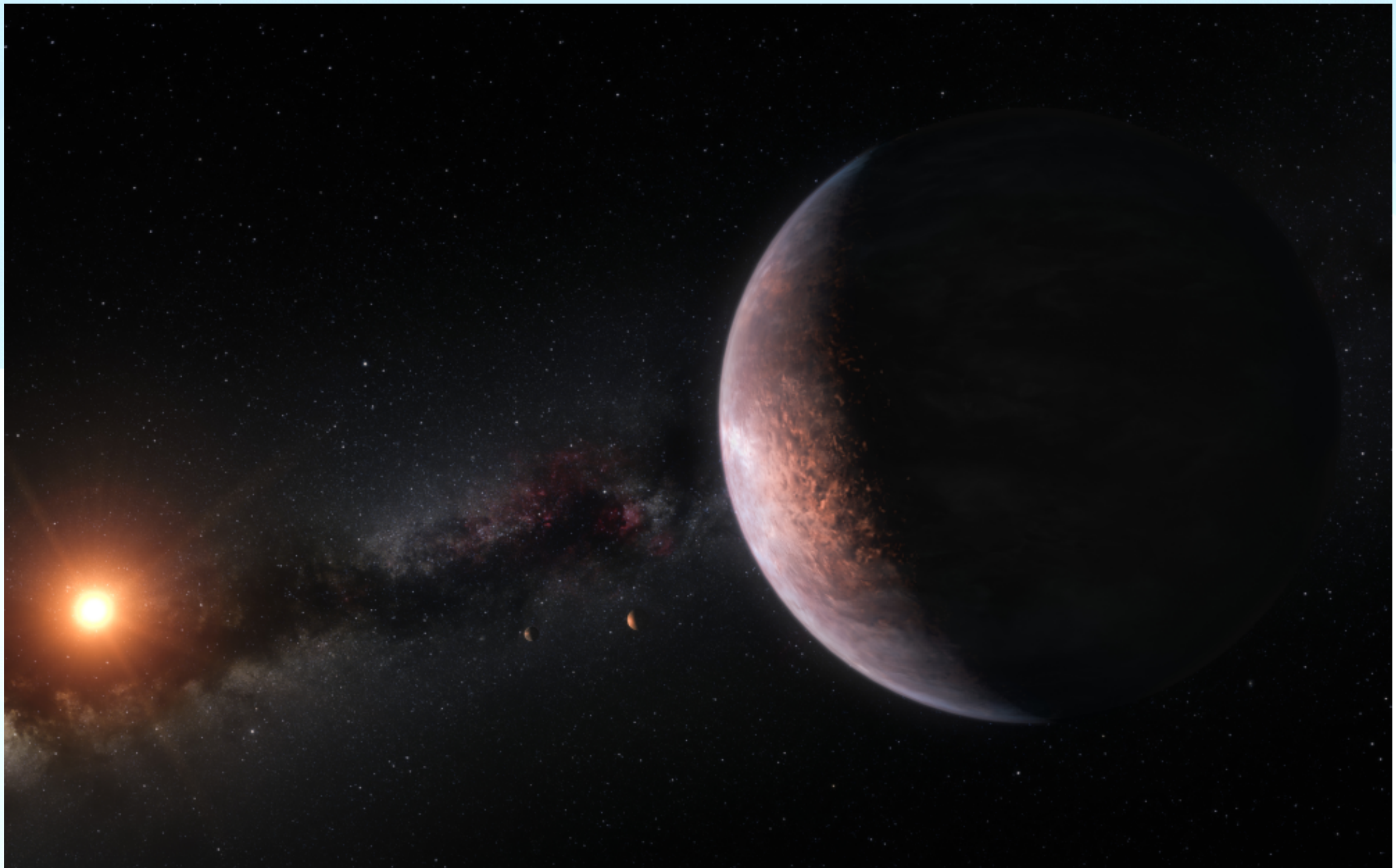
- 8.1. Contamination Budgets
- 8.2. Contaminants and their Effects
- 8.3. Contamination Controls
- 8.4. Maintenance Cleaning
- 8.5. Venting
- 8.6. Future Testing

9. Development Priorities

10. Path to HWO

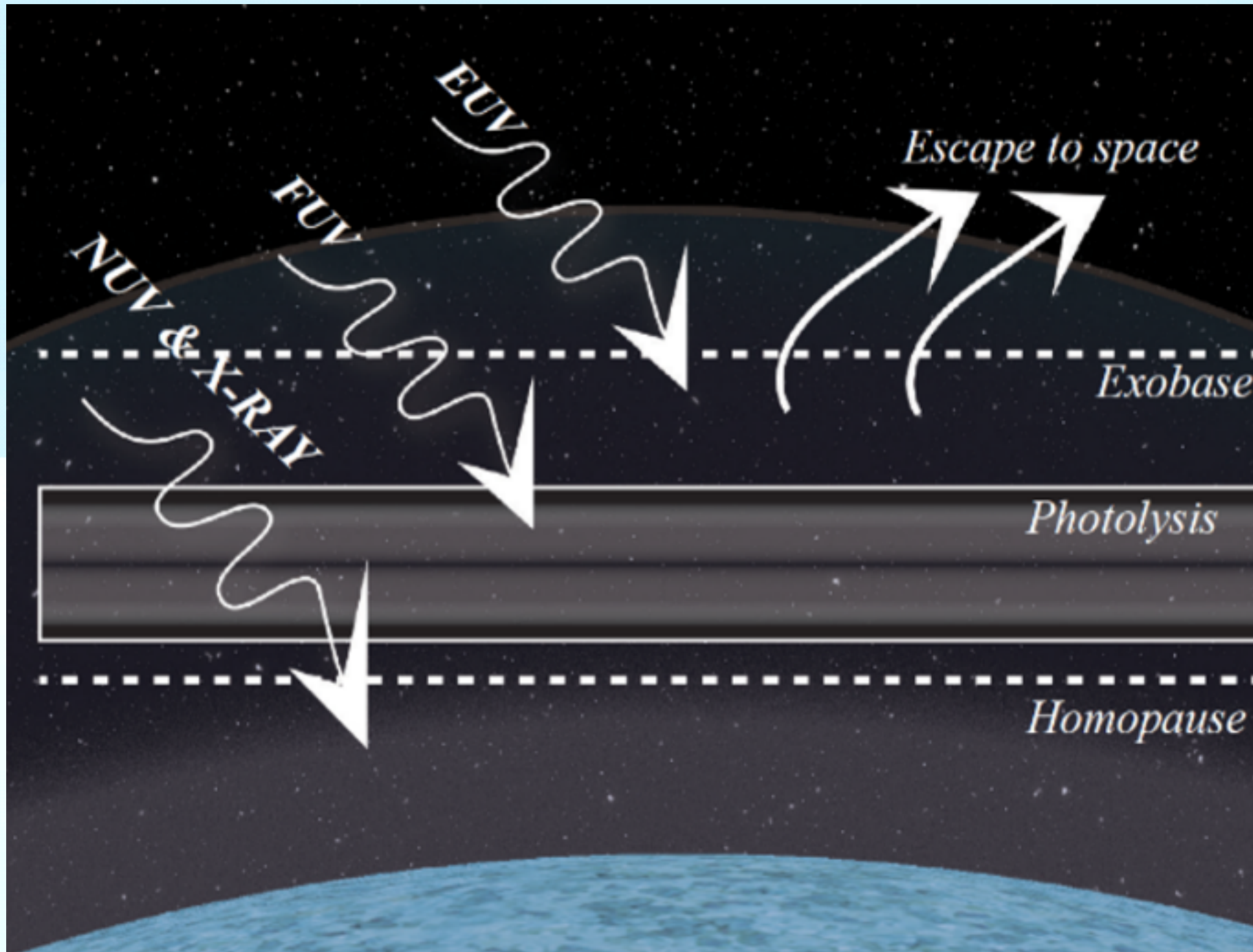
- 10.1. Training
- 10.2. Smallsats for Accelerated Technology and Workforce Maturation

Worlds & Suns in Context



UV drives exoplanet photochemistry

100 - 320nm



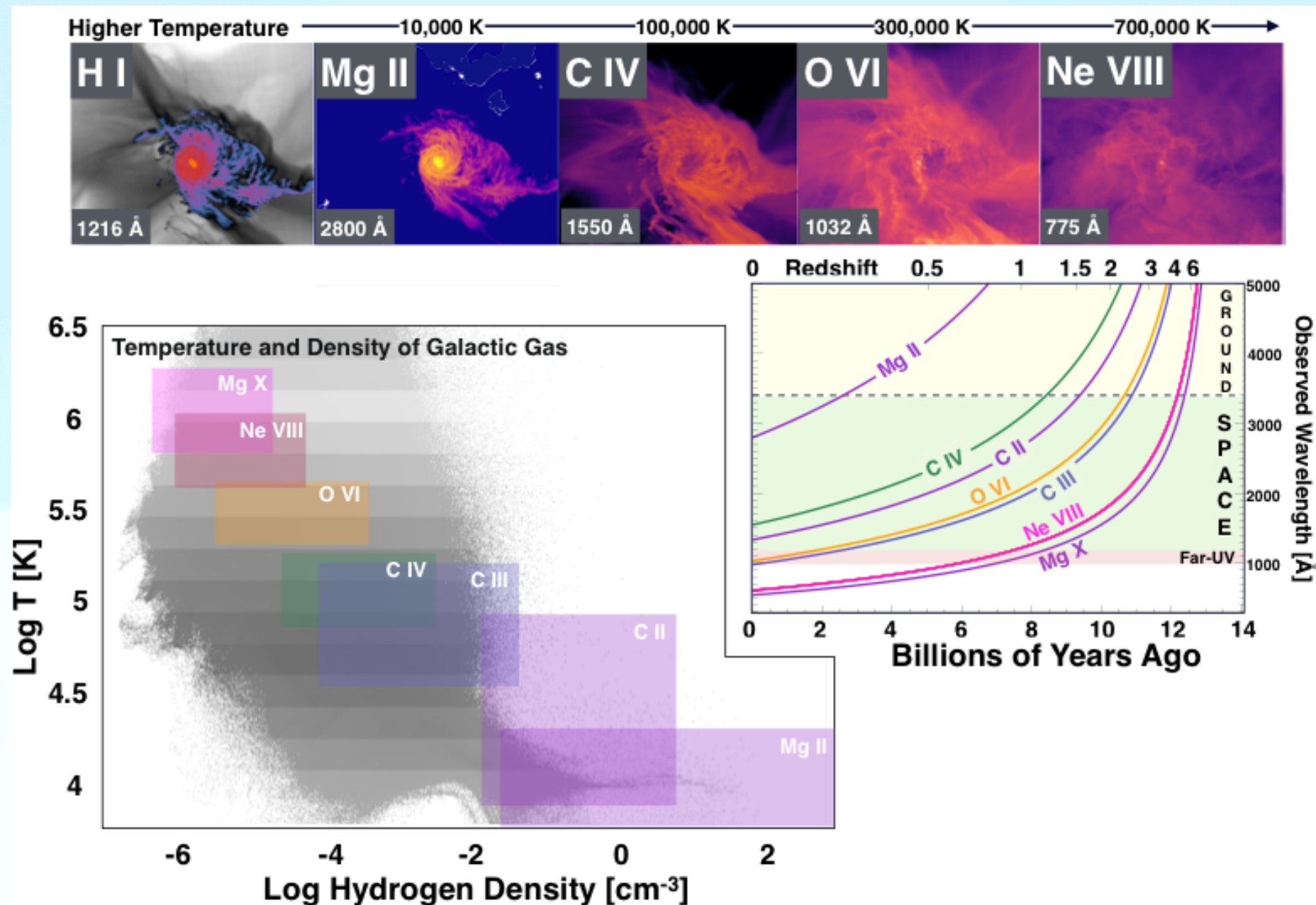
100 - 115nm
provide
temperature and
abundance
diagnostics

Cosmic Ecosystems

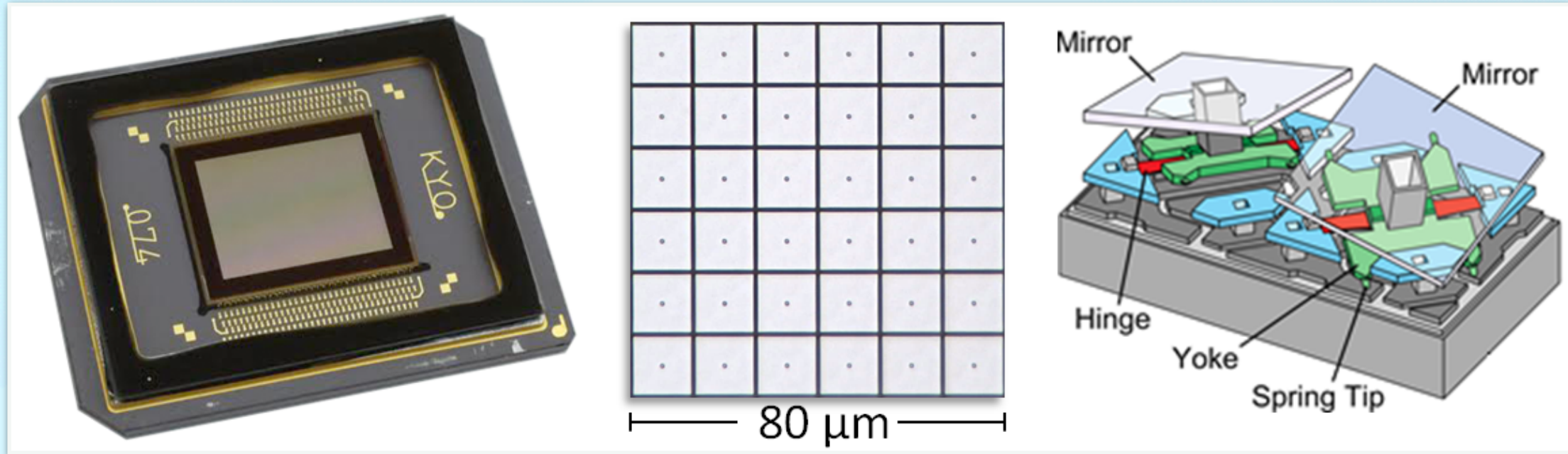


Key Science

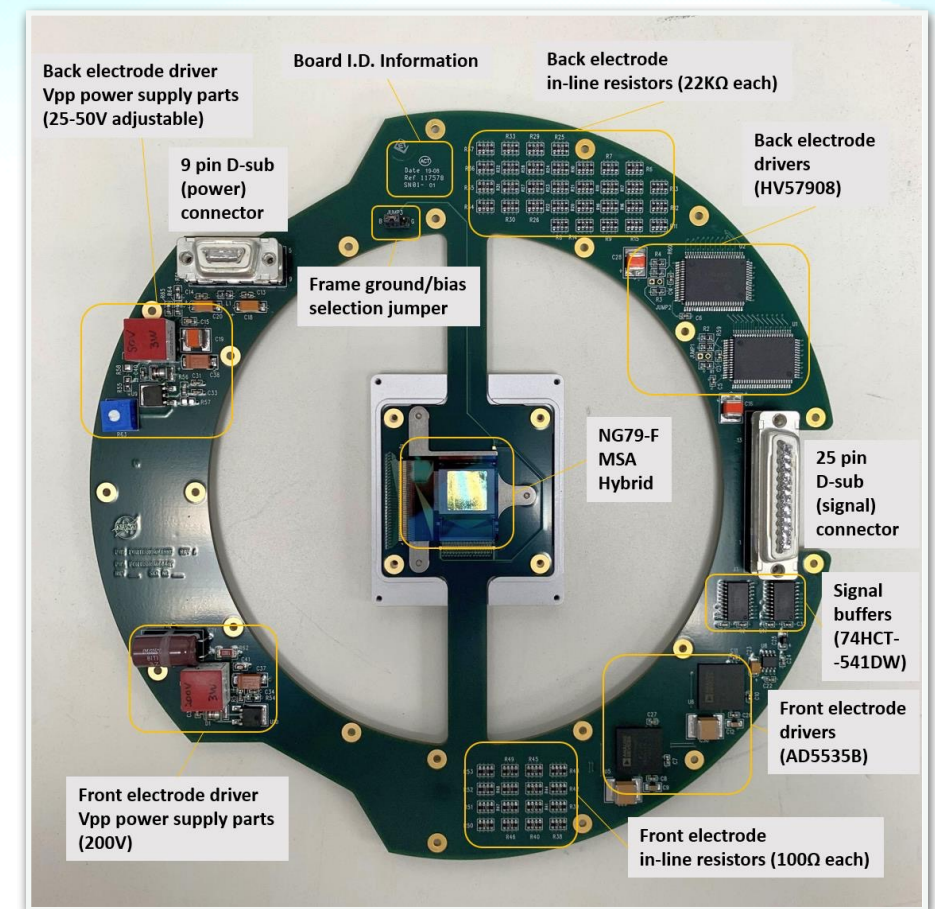
Observing the Circumgalactic Medium (CGM)



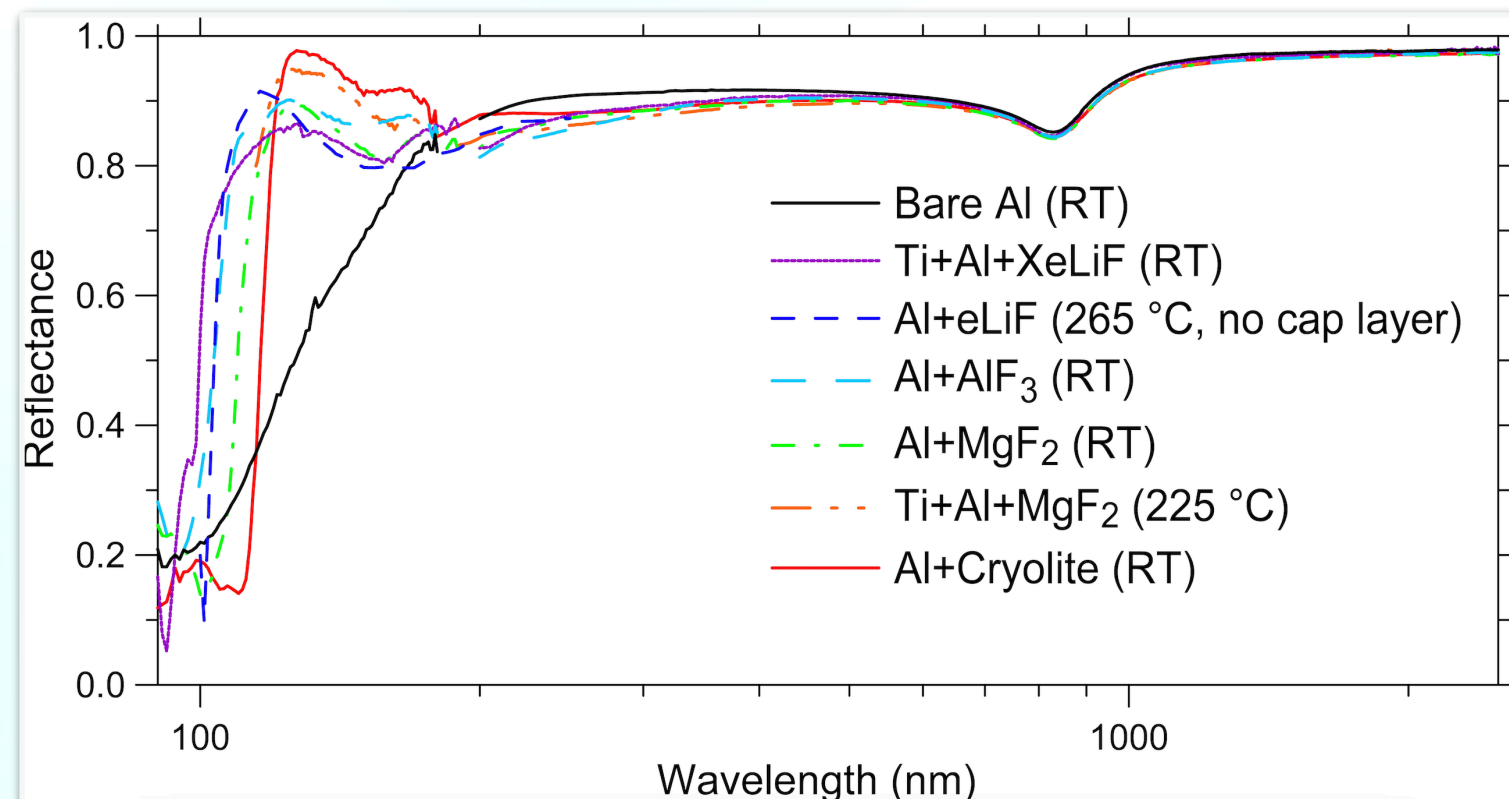
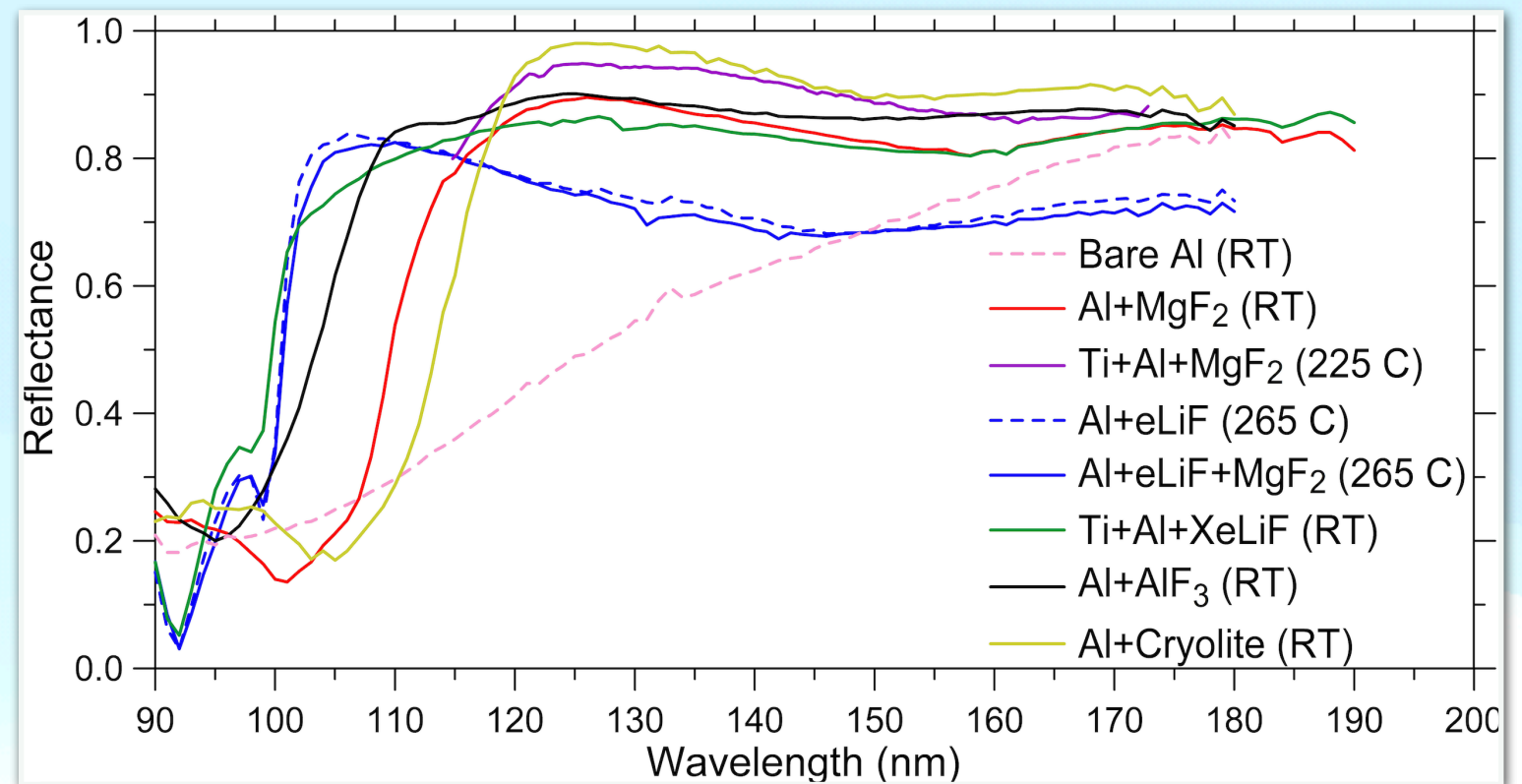
100 - 120 nm captures OVI (103.2nm) at $z > 0.1$
and Ne VIII and Mg X at $z > 0.5$



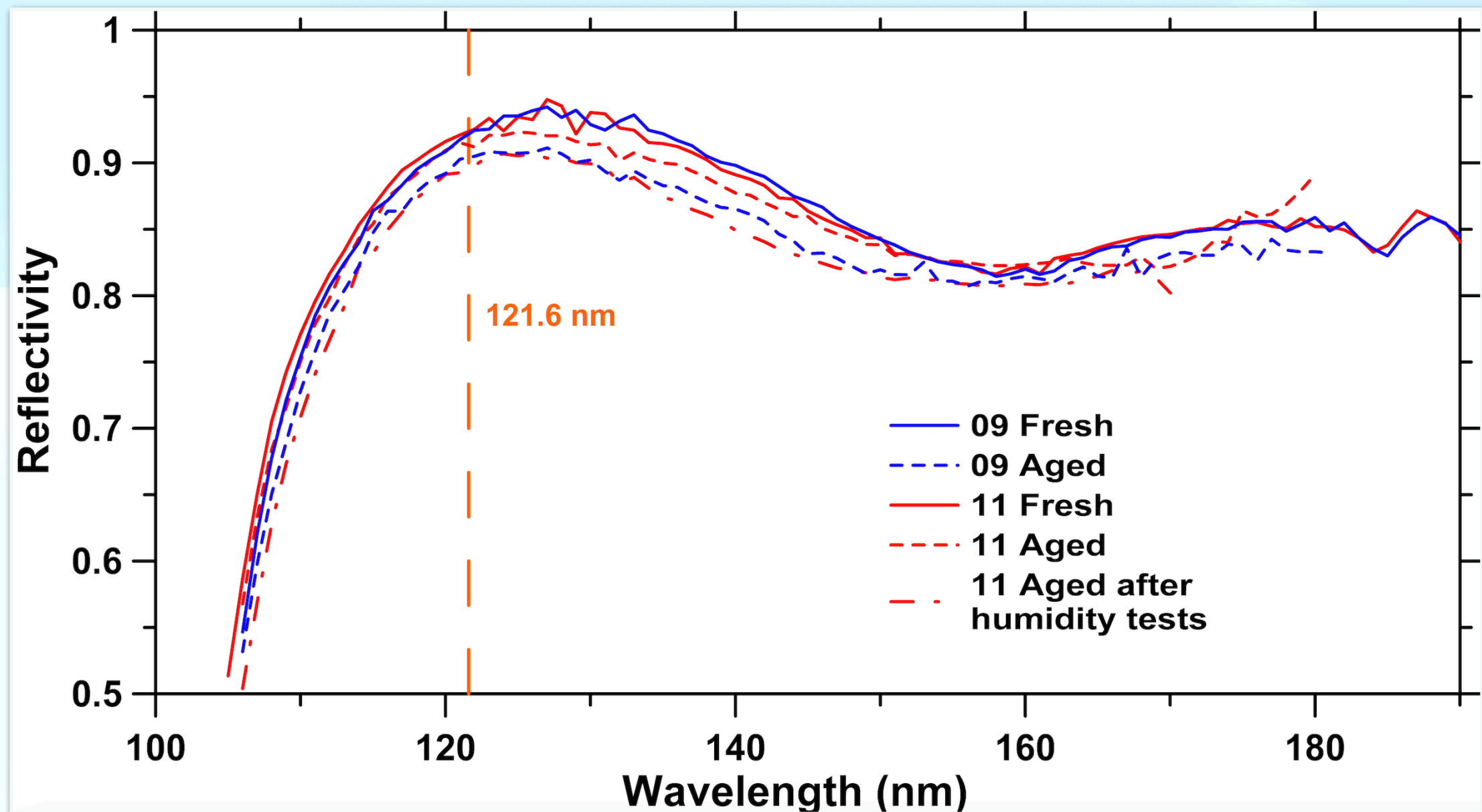
Hardware & Processes



UV & Optical Coating Performance



Reflective Coatings - XeLiF

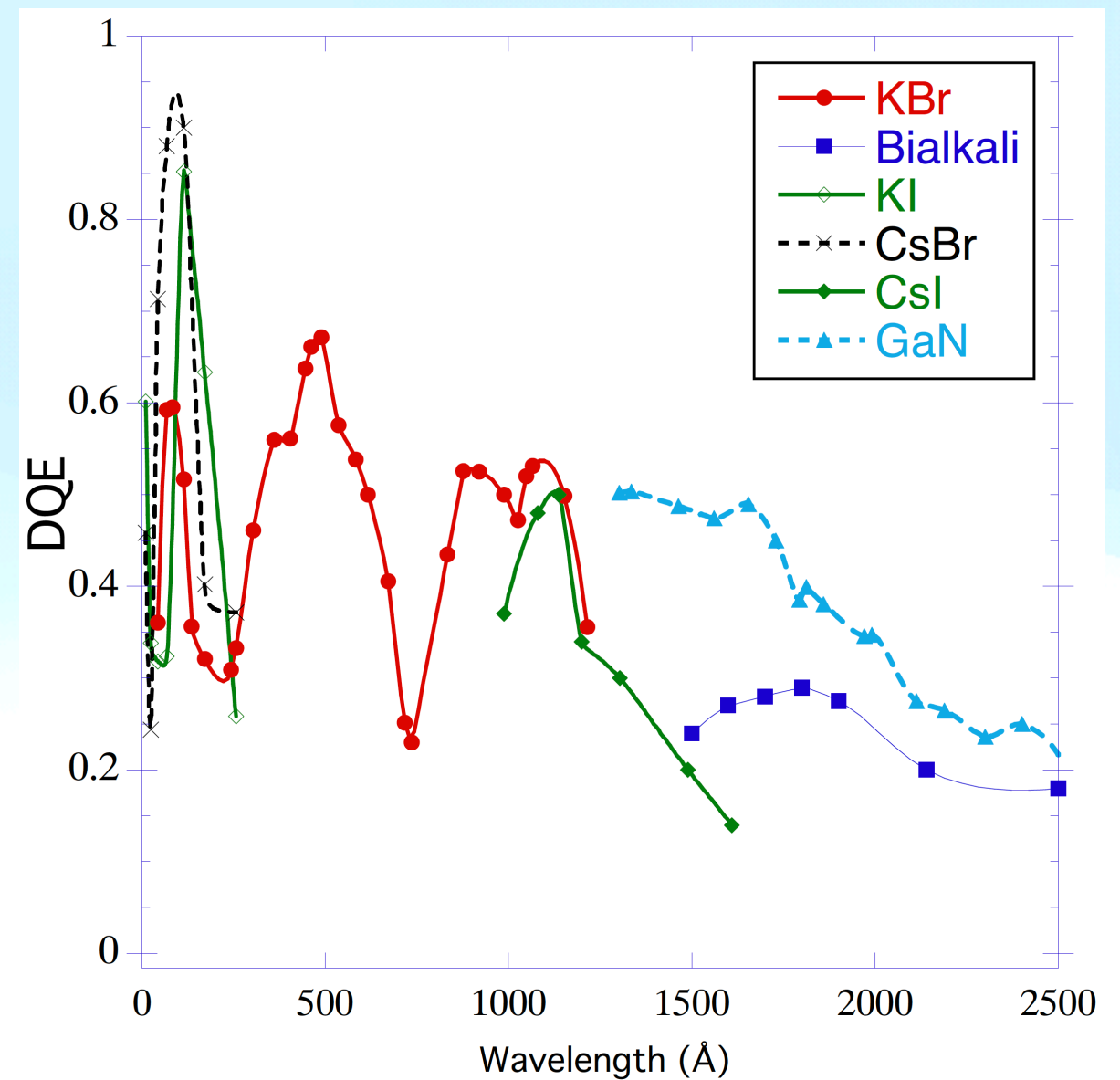


Reflective Coatings

Coating Technology	Coating Properties						
	λ Value @ R>60%	TRL	Largest Optics Coated	Elevated Substrate Temperatures Required?	Max. Relative Humidity for Coating Stability	Dielectric Layer Deposition Process	μ -roughness
Bare Al	>150 nm	6	> 1 meter	No	~70-100%	-	~0.78 nm
Al+MgF ₂	>111 nm	6	> 1 meter	No	~70%	PVD	~1.84 nm
Al+LiF	>101 nm	6	~0.5 meter	No	< 30%	PVD	Fresh 1.5-2.5 nm Aged >3 nm
Al+eLiF+MgF ₂	>102 nm	~5-6	~ 0.3 meter	Yes	~60 %	eLiF (PVD) MgF ₂ (ALD)	1.5-2.5 nm
Al+XeLiF	>103 nm	~3	5x5 cm ²	No	~60%	Reactive PVD	~1-1.5 nm
Al+AlF ₃ (e-beam)	>105 nm	~4	5x5 cm ²	No	~60%	E-beam Plasma	~0.81 nm

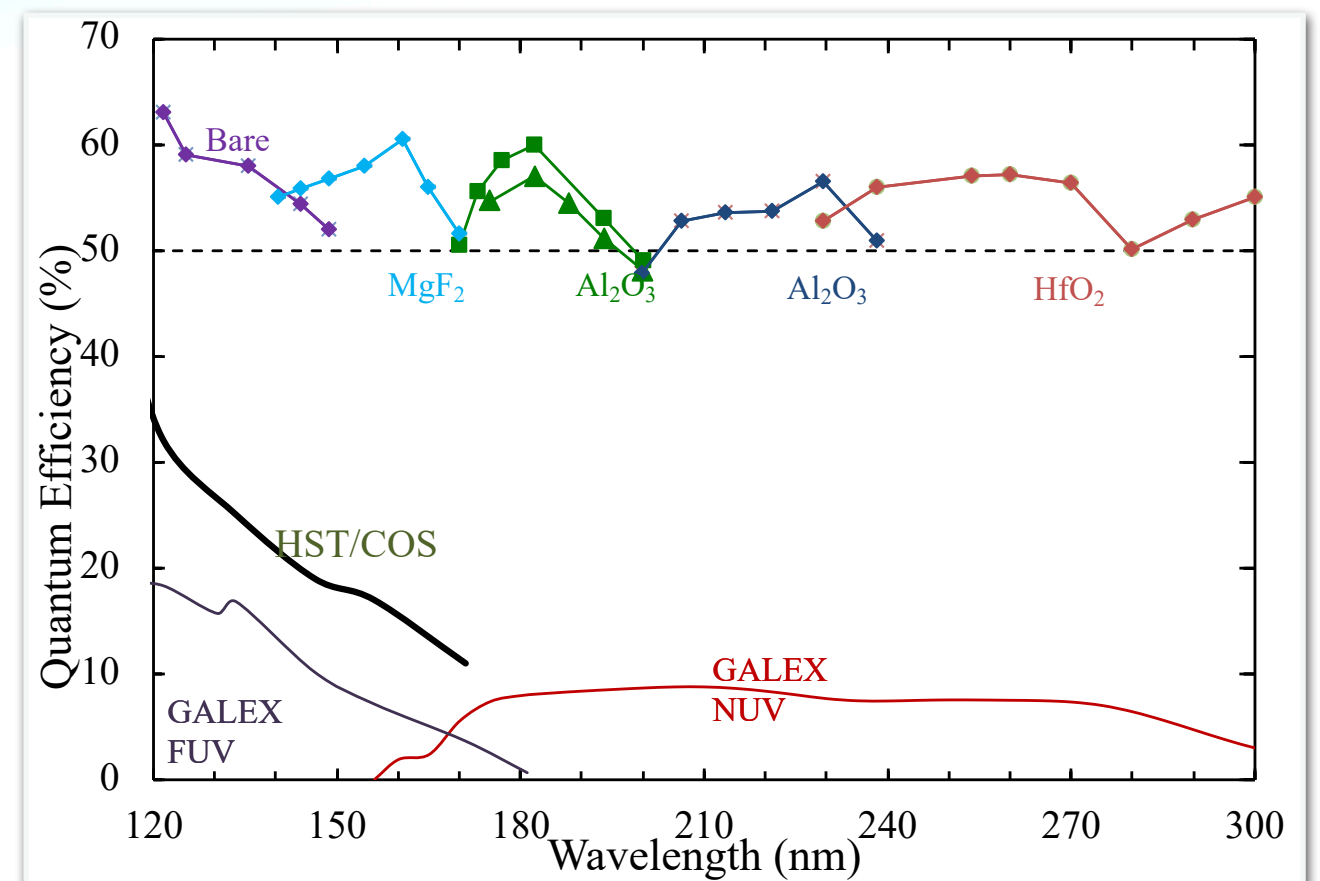
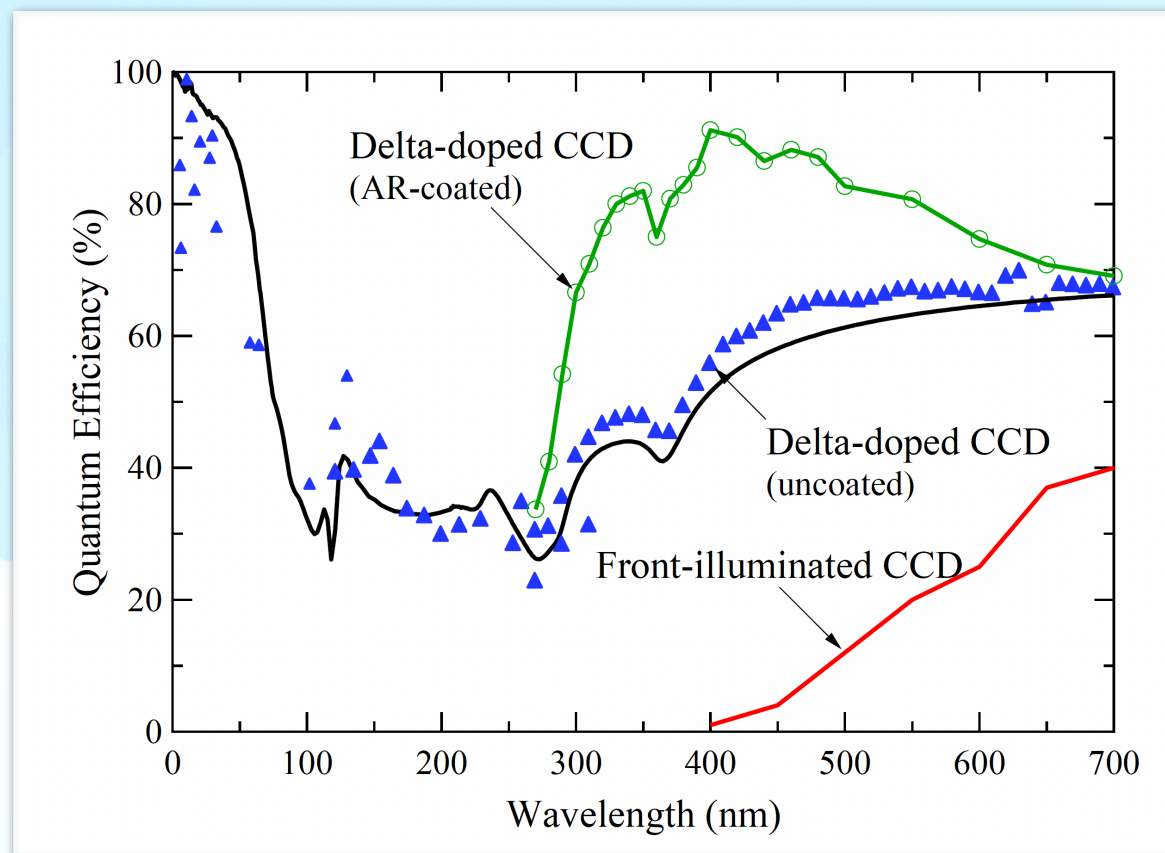
Next push - scaling optics upward

Detectors - Microchannel Plates

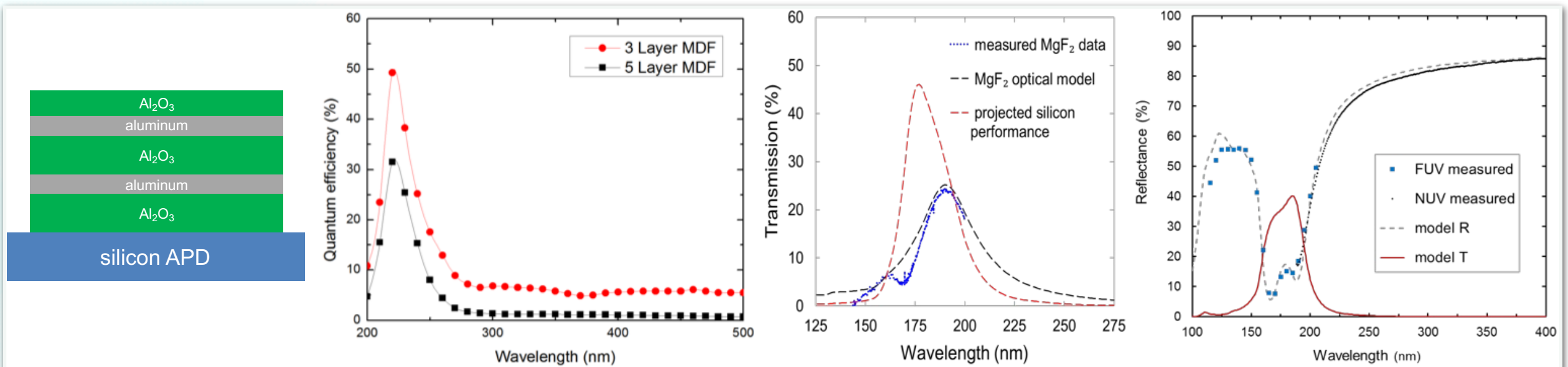
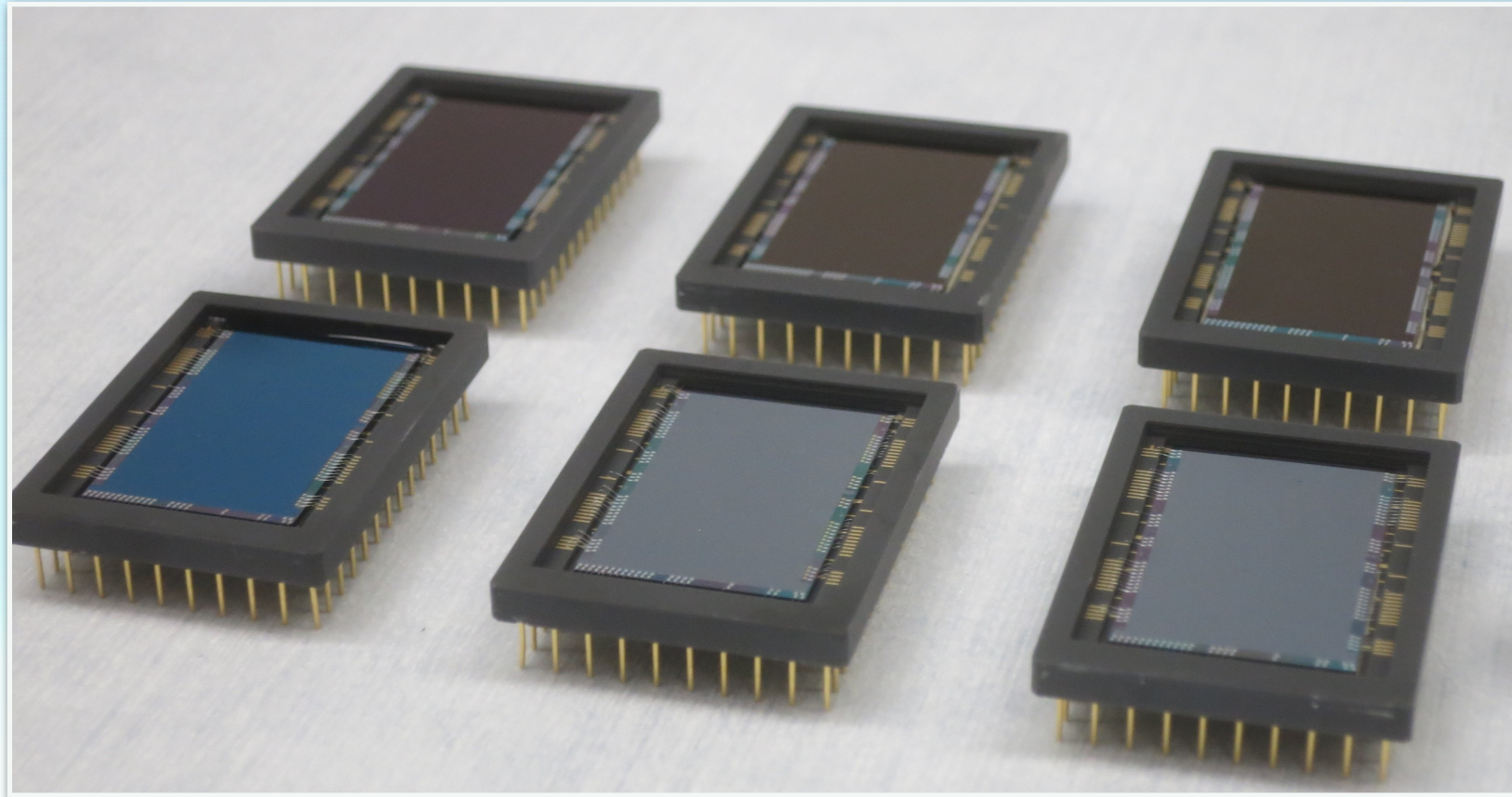


Detectors - Solid State Detectors

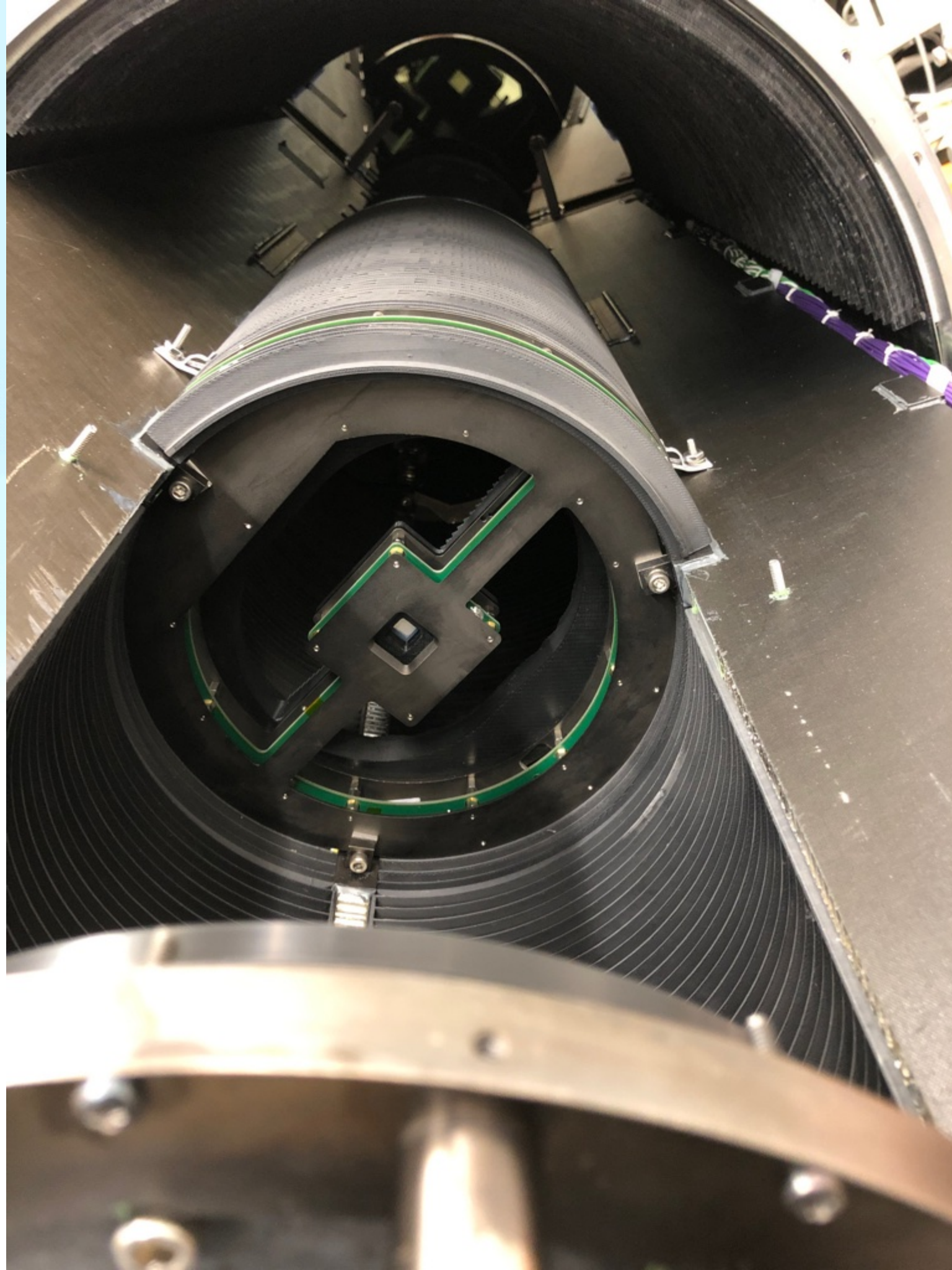
Delta Doped CCDs



Detectors - Solid State Detectors



Developing Systems



Take aways

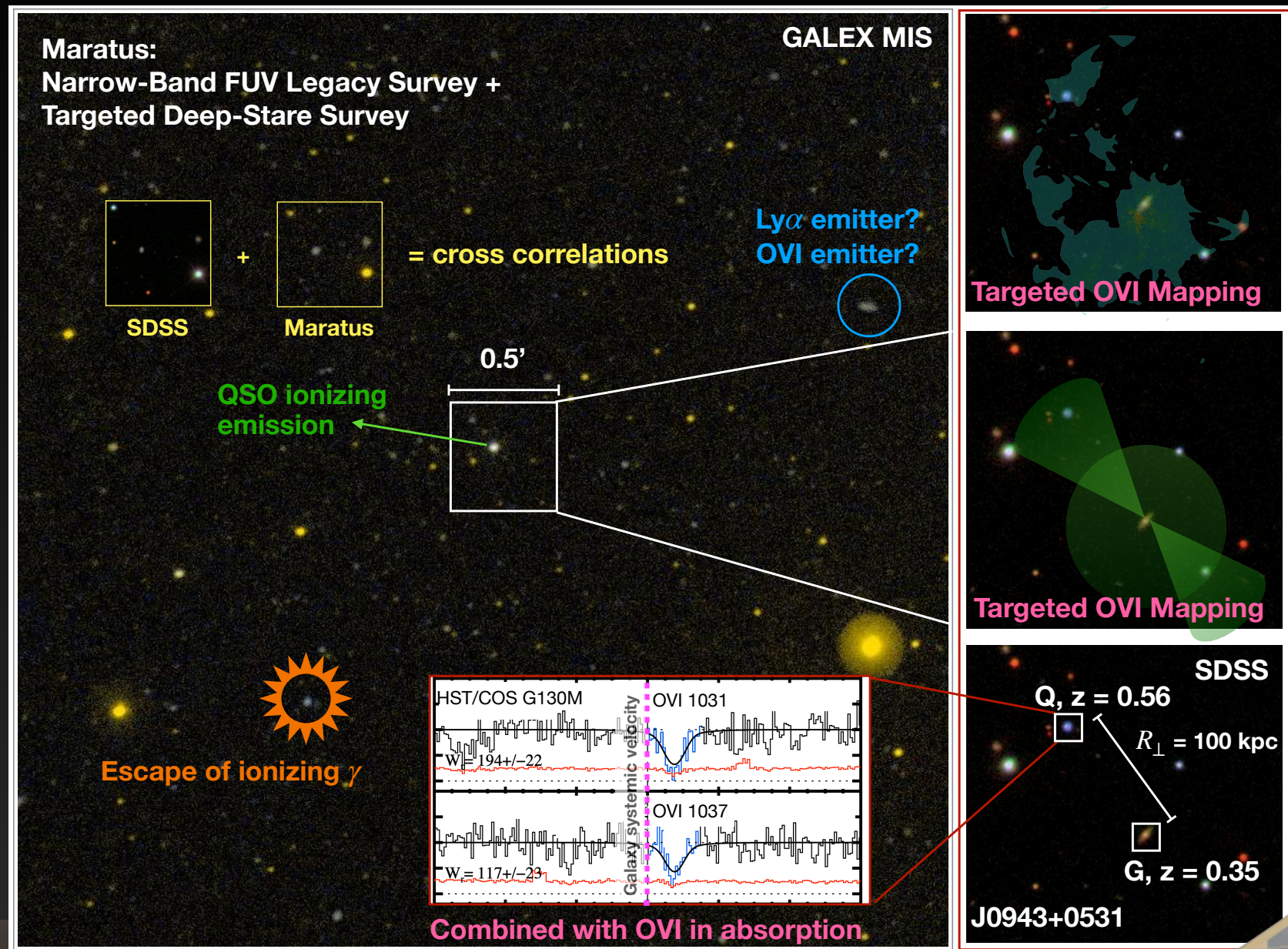
- Both planetary characterization and the circumgalactic medium (key science drivers) require pushing down to the 100nm cutoff.
- Current coatings reach nominal desired values in the UV.
- Electron-beam lithography is our most promising UV grating technology and has been tested sub-orbitally.
- Several mature UV detector technologies are available and flight qualified (with several more in the wings). There is room for performance improvement - this will especially benefit the transformational astrophysics goal of HWO.
- Contamination must be controlled at the systems level and the component level. We capture the wealth of knowledge on this topic to provide a strong start for HWO.
- Several multiplexing technologies have been space qualified. When combined with UV coating development, there is a very exciting path to a multiplexed UV instrument.

What comes next?

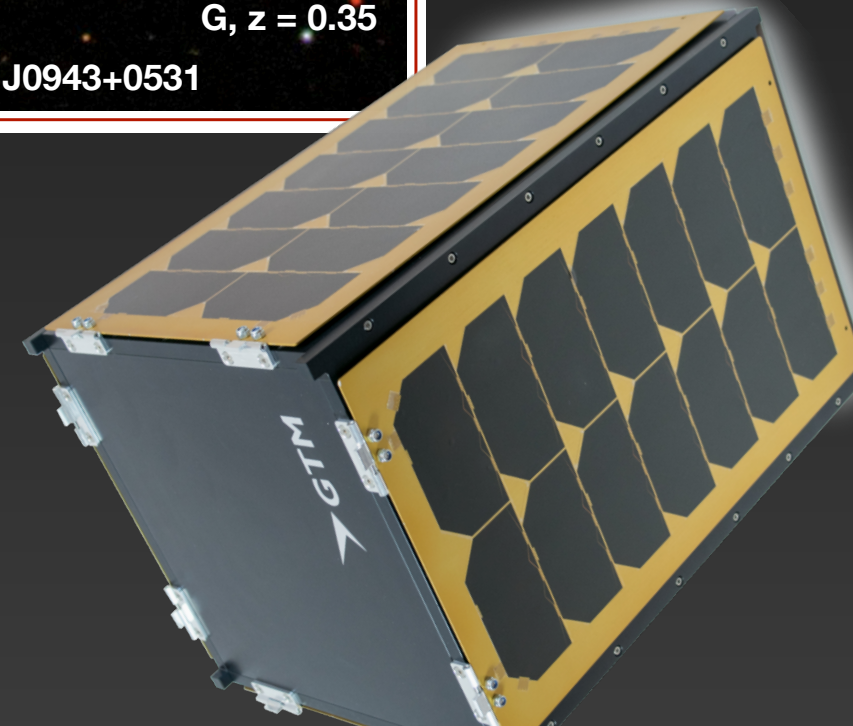
We suggest.....

- Process level (material physics) development (polarimetry performance of coatings, for example)
- Technologies need to scale up in aperture. We need to support facility to begin testing these larger scale components.
- Shifting modes from proving components to developing production lines and systems development and testing.
- Development of laboratory prototype testbed instruments
- Investment beyond APRA (sub-orbital) missions
- Technology Demonstration Missions (smallsats/pathfinders) to do systems level testing and provide early-career mission training

Maratus: Mapping the CGM in the FUV

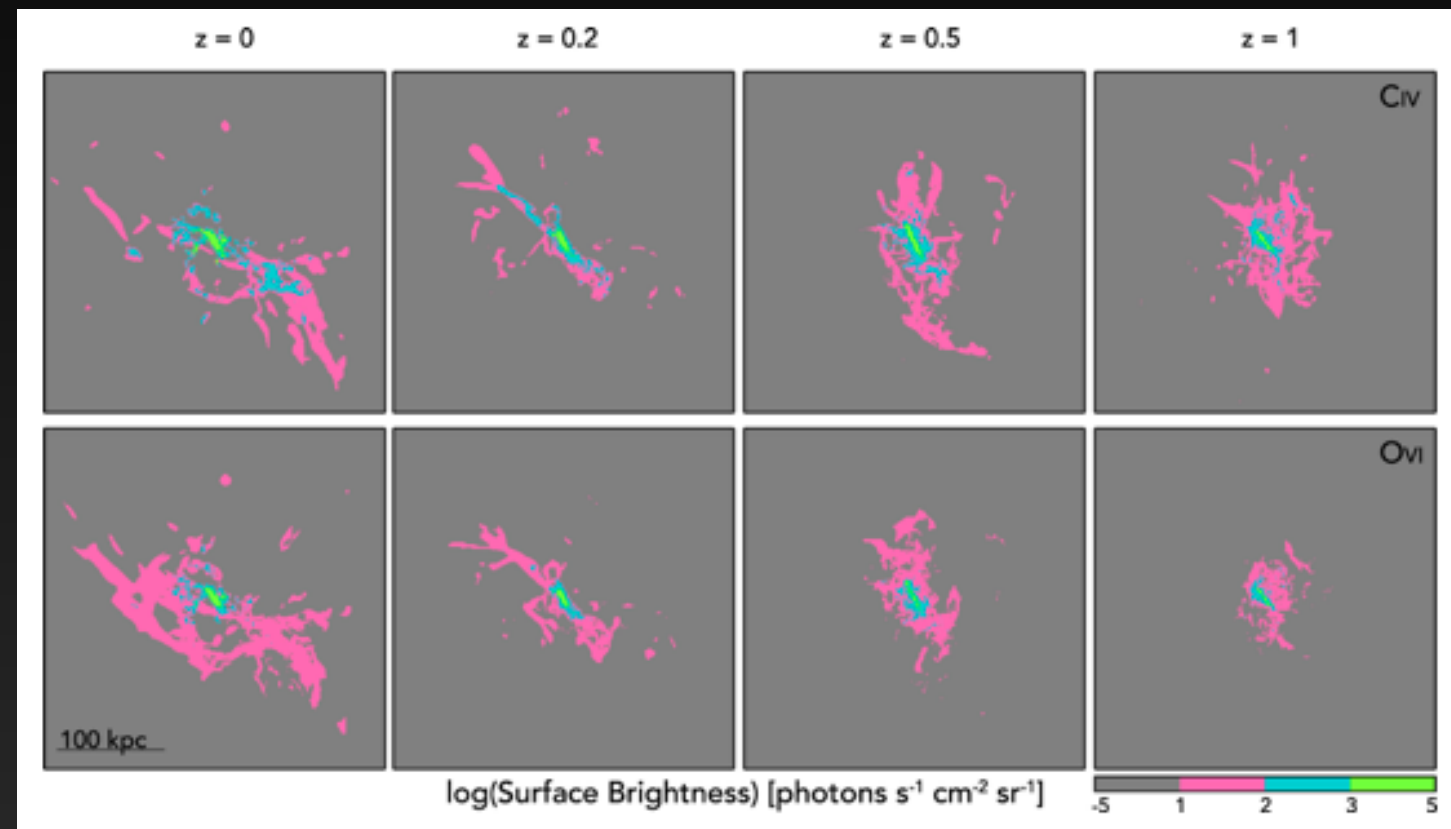


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(CU), Jason McPhate (UCB)

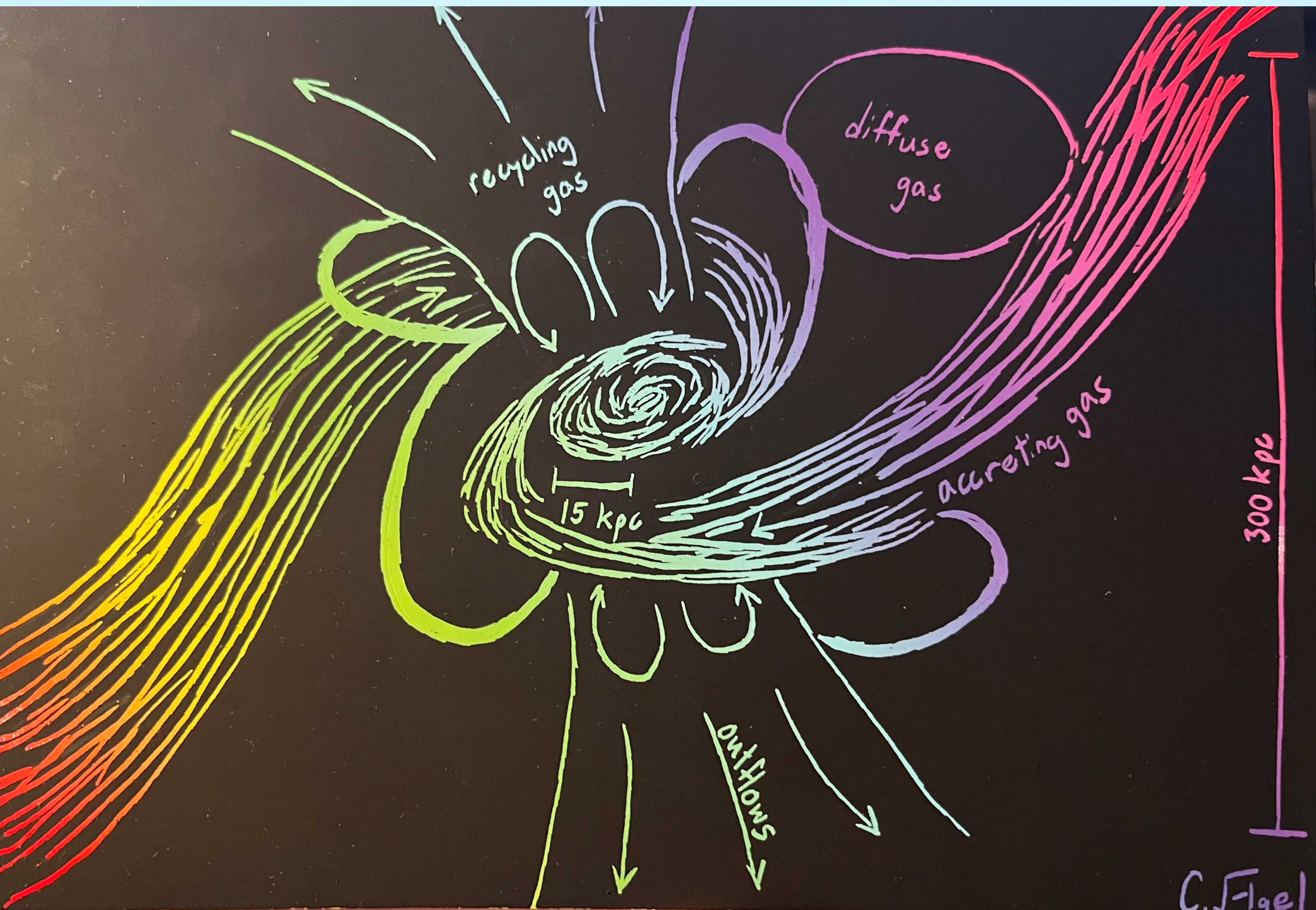


Mapping the Circumgalactic Medium

OVI at $z \sim 0.3$



- ✱ Predictions (from multiple simulations)
- ✱ Constraints from past projects (FIREBall1 & 2)
- ✱ Absorption measurements (COS-HALOs etc.)



C. Fiegel

