STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

# Digital micromirror devices in space for Multi-Object spectroscopy in the ultraviolet

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for The STUF team

# The Landscape in the USA

NASA's Cosmic Origins Program Analysis Group (COAPG) report to NASA's Science Mission Directorate on flagship missions states that:

- A flagship mission offering … access to the **full range of wavelengths covered by HST** … is essential to advancing key Cosmic Origins science goals in the 2020s and 2030s
- detection and characterization of rocky planets, widefield astronomical imaging, and **high-throughput ultraviolet imaging and spectroscopy** [are all essential]
- ASTRO2020 will tell us whether these recommendations will be reflected in the plans for science and technology development in the next 10 years

# Scientific Motivation for UV-MOS

- Spectroscopy in the UV is crucial for probing a wide-range of gaseous environments, from the IGM to Exo-earths atmospheres.

- UV Single object spectrographs are or will be available (HST/COS, HST/STIS, CUTE, SPRITE), but there is no current UV-MOS capability

- Possible science cases requiring a UV-MOS:
    - protoplanetary disks in nearby star forming regions
    - massive star formation in the Local Volume
    - physics of the interstellar, circum-galactic and inter-galactic media
    - spatially resolved feedback throughout star-forming galaxies
    - Lyman escape photons in nearby star forming galaxies
    - AGN and their host galaxies
    - …and more

# Enabling space-based UV multi-object spectroscopy

## A technology gap: the object selection mechanism

- Technological advancements are required to improve the performance of space-based UV MOS

- A crucial component of a MOS is the object-selection device

- Digital Micromirror Devices (DMDs) are currently the only alternative to micro shutter arrays (MSAs) as slit selection mechanisms for space-based MOS

- Exploring this alternative could mitigate risks and reduce costs for future missions

# The Space Telescope Ultraviolet Facility (The STUF)

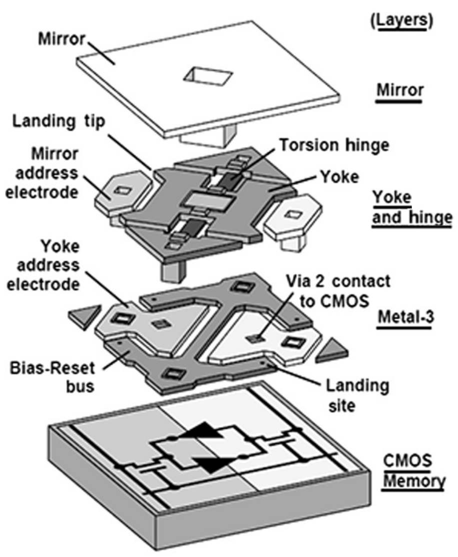
Initiative funded by the STScI director to:

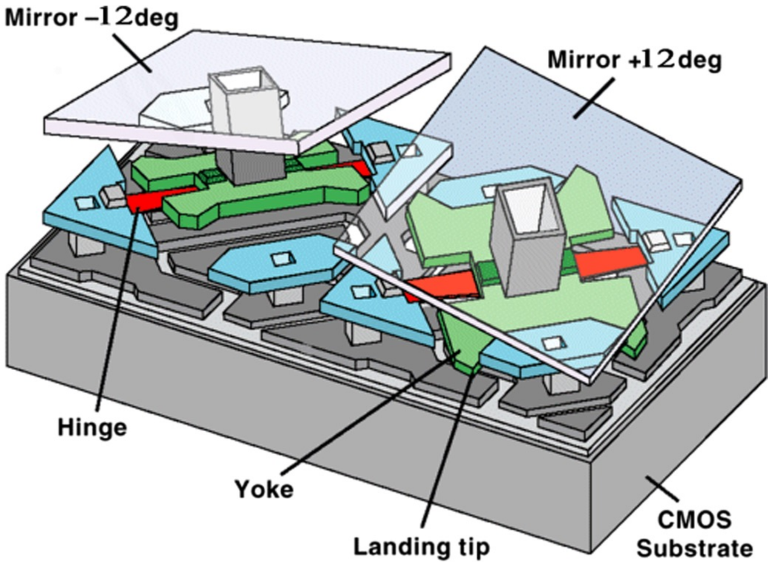
- Establish in-house capability for UV instrumentation R&D
- Advance technology readiness level for space based UV-MOS
    - Characterize the optical performance of DMDs in the UV
- Develop a conceptual design for a small UV-MOS mission

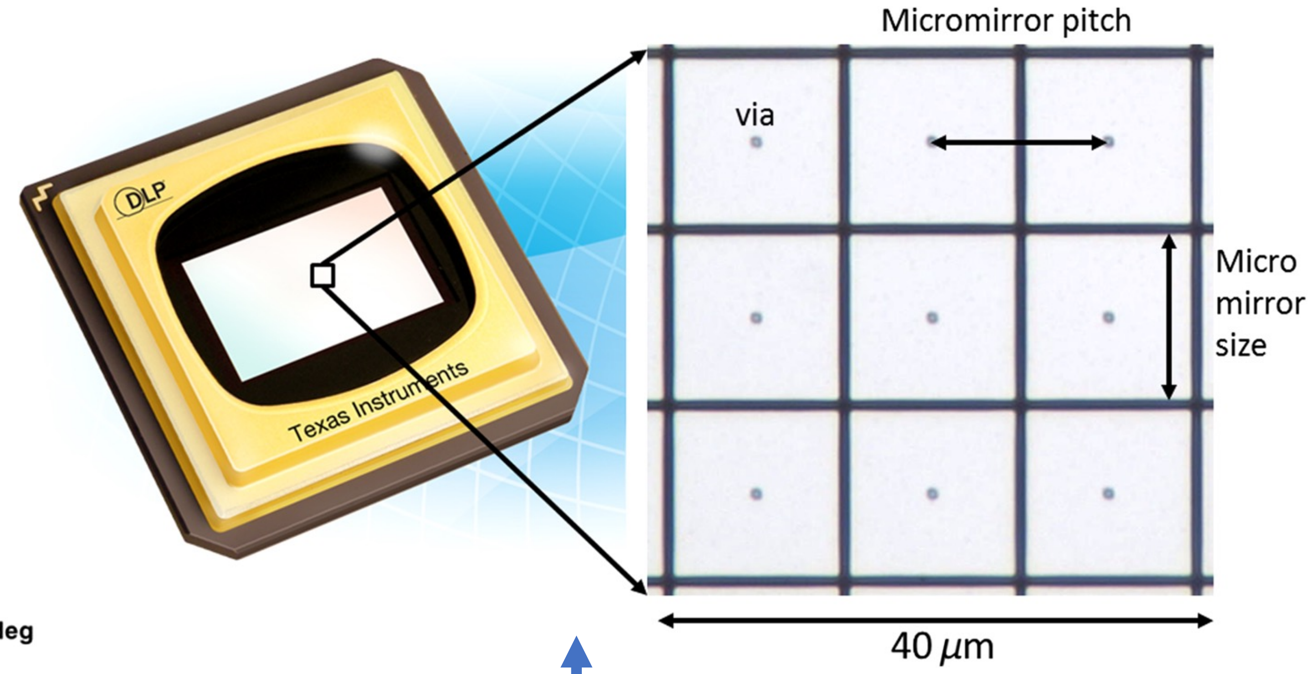
# A brief detour on COTS* Digital micromirror devices (DMDs)

**Left:** Exploded view of a single mirror

**Right:** 2 adjacent mirrors in opposite states



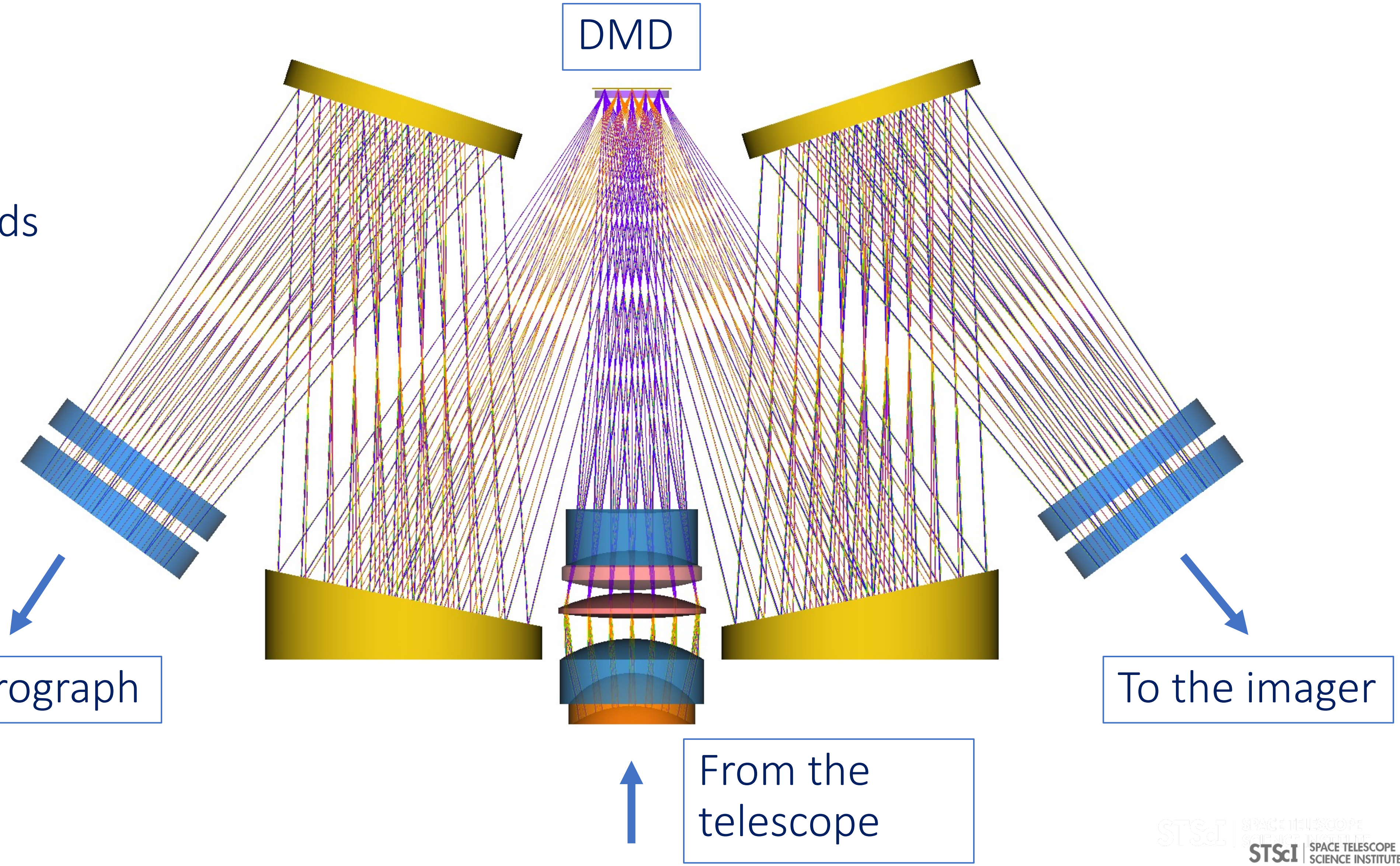

DMD chipset from Texas Instrument and zoomed-in view of a small part of the array

*Commercial off the shelf

# DMDs as slit selectors in multi-object spectrographs

## SAMOS layout:

DMDs can be used to reflect the light towards two paths/channels



# Results of NASA-funded tests towards DMD use in space

- **Radiation:** DMDs are extremely resilient to radiation:
  - long-term robustness
  - operationally robust against single-event upsets
- **Vibrations:** DMDs experience no damage under NASA GEVS tests:
  - no mirror failure
  - no window seal break
- **Cryo-tests:** DMDs have been successfully operated at 78K
- **Optical performance enhancements:** DMDs have been operated successfully
  - After replacing the protective window with UV-transparent materials
  - After recoating the mirrors themselves with Al and Al + protective overcoat

# Other developments – electronics control (at JHU/STScI)

- Commercial DMDs are meant to be operated a very high speed.
- Proprietary technology does not allow re-programming of the chipset.
- Large amount of data-transfer for video applications implies a large use of power
  - Bad for IR
  - Bad for space

# What is still missing

## GSF-IRAD grant to:

- Establish full end-to-end *clean* process to re-window and recoat DMDs and demonstrate their long-term functionality
- Study of the mechanical effects on the mirrors due to recoating

## The STUF grant:

- Characterize UV-rated DMDs both ”in isolation” (basic optical properties) and in an instrument-like setup (effective properties)

## Yet-to-be approved:

- Develop space-rated control electronic
- DMD small space-mission to demonstrate the technology can work in space and can obtain meaningful science results

# The STUF Proposed effort

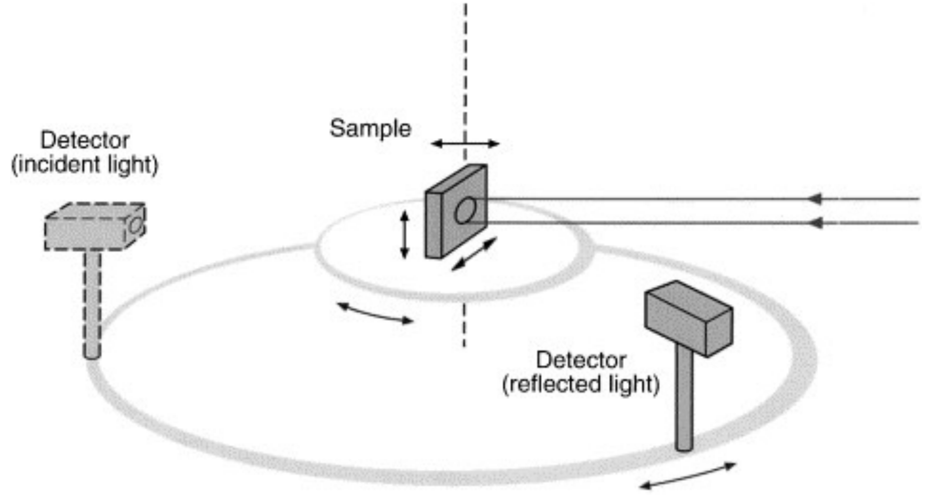
## High-level list of deliverables

# 1. Create a Near-UV setup to measure DMDs properties (@Makidon Lab)

Measure scattering and diffraction as a function of λ and angle of incidence in the Near-UV (160-350 nm).

A basic step towards:

- characterizing DMD performances (e.g. contrast, total throughput)
  - Re-windowed DMDs (RIT)
  - Re-coated DMDs (GSFC)
- controlling and operating DMD in house using custom software and electronics

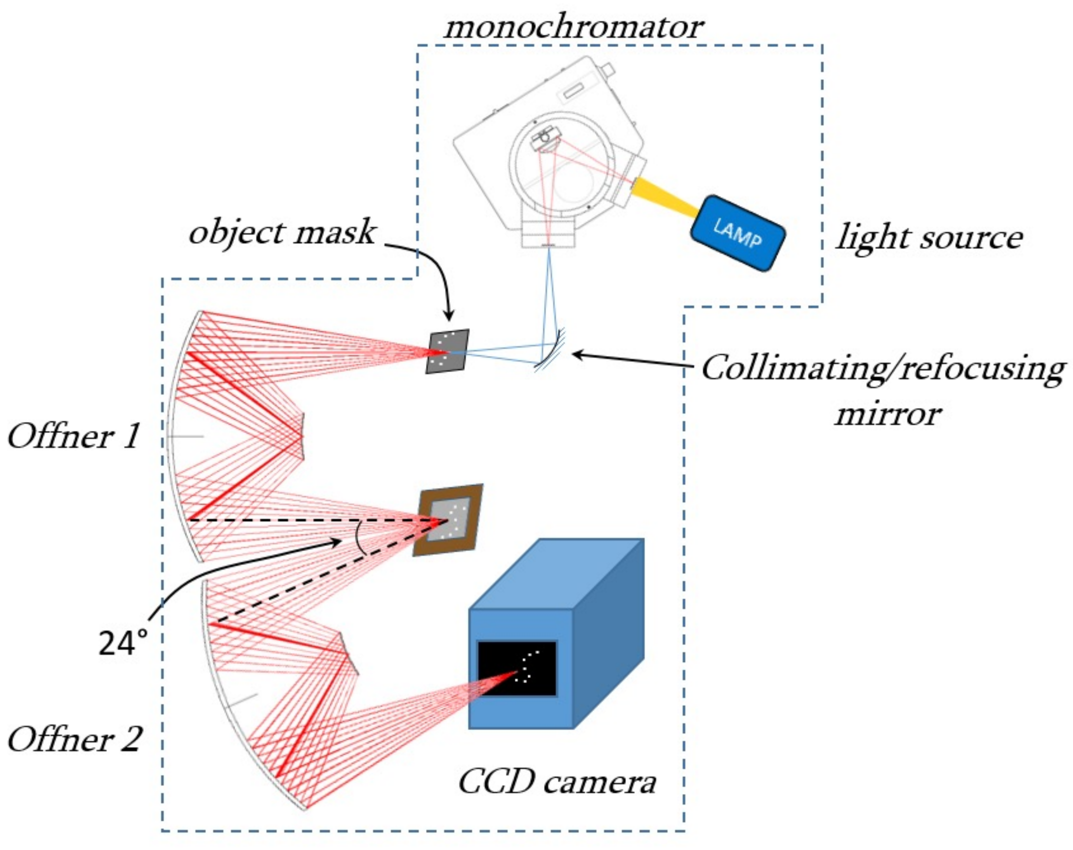



Cartoon schematics of a reflectometer setup

# 2. Build a bench-top spectrograph-like setup in the Near-UV

A realistic instrument-like setup allows an end-to-end assessment of the expected performances of a MOS:

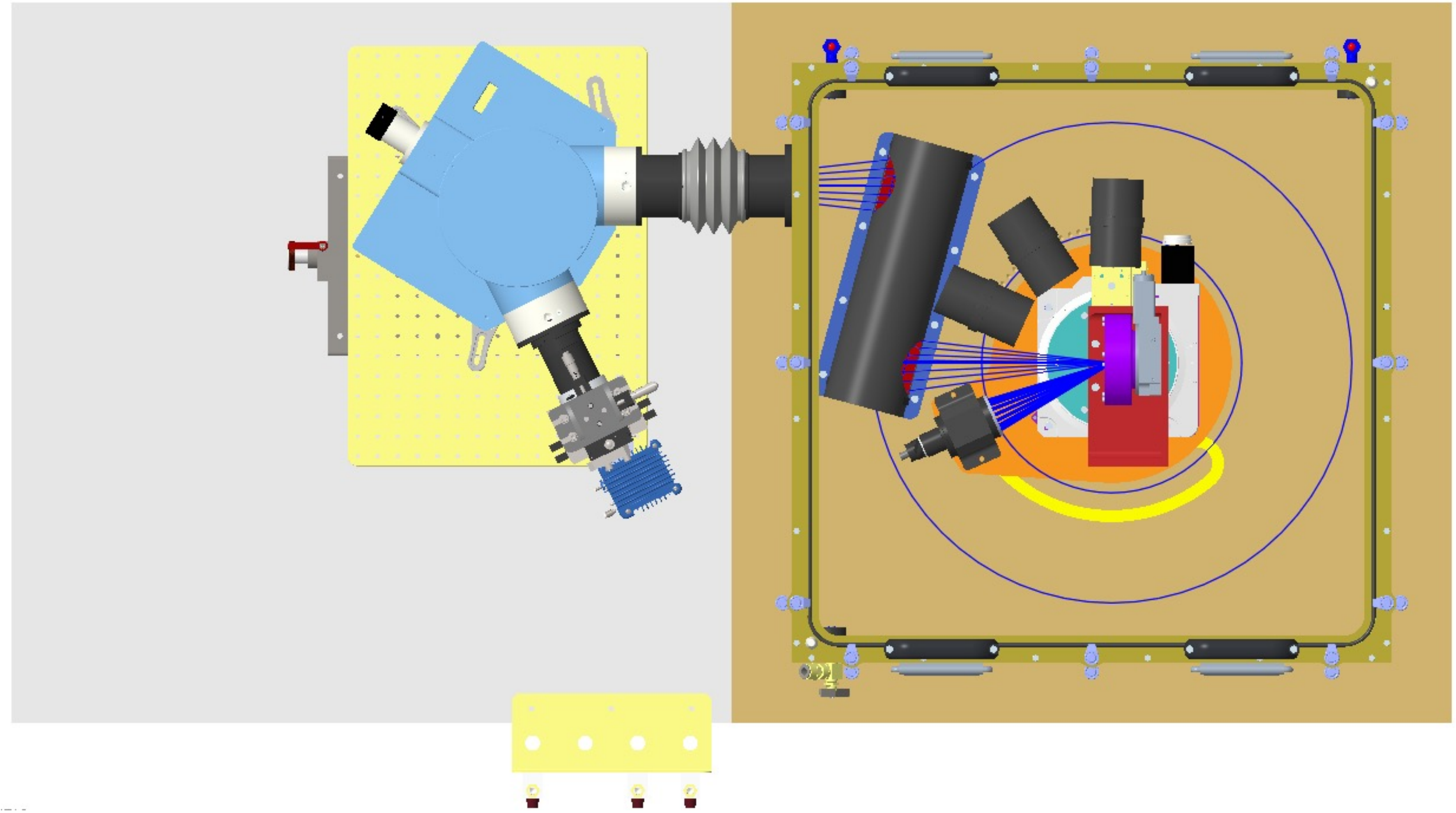
- Source-like illumination pattern (point-source / pin-holes)
- re-imaging optics (collecting photons at given f/#)
- diffraction grating
- 2D detector

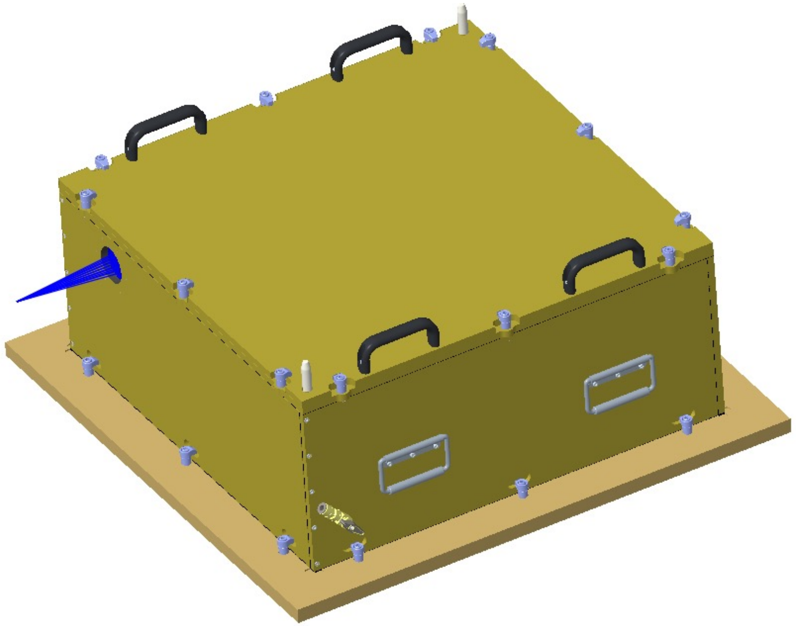



Cartoon schematics of a bench-top imager/spectrograph (D. Vorobiev)

# The reflectometer experiment

# Optical and optomechanical design (passed PDR, under construction)





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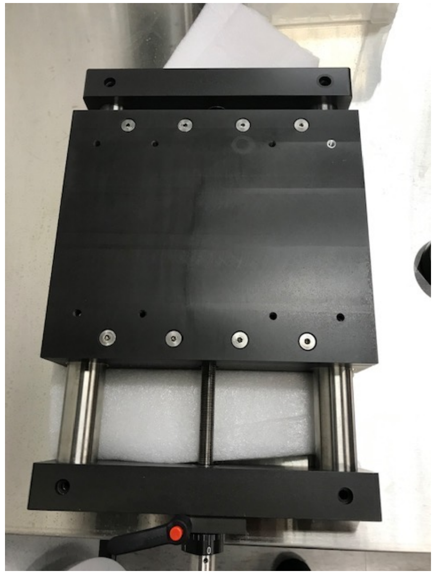


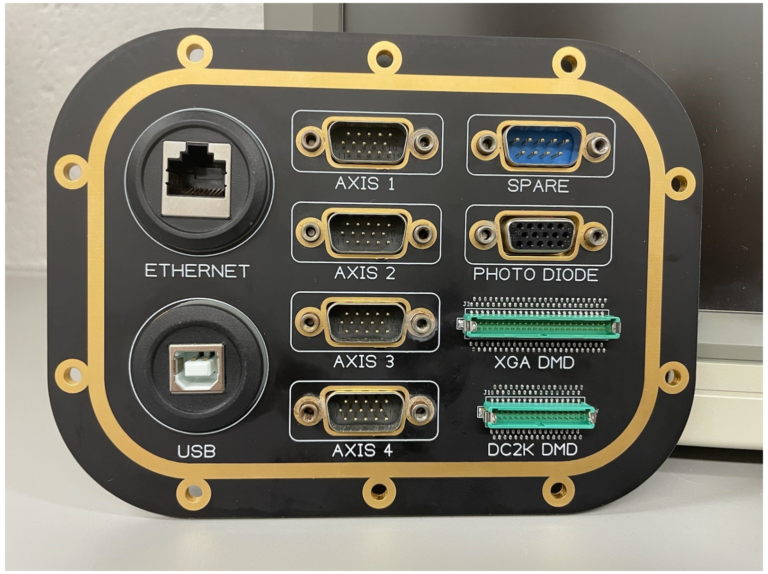


# Summary & Conclusions

# DMDs as a valid option for MOS in space

- DMDs are a robust commercial technology
- 2nd-generation Ground based applications (SAMOS, MIRA, BATMAN) will soon go beyond a "technology-demonstration" phase and really start yielding exciting science
- Technology advancement studies demonstrate DMDs potential for space application in, but not limited to the UV
- Relative minor investments in the next 3-5 years could bring this technology to full fruition for the astronomical community (and lower the risk of probe and flagship class missions)
- DMDs are not the only answer. Non-reflective options (MSA) remain incredibly useful e.g for the far-UV.

# The team

# The people that do stuff for The STUF

## STScI

- Alessandra Aloisi
- Gisella De Rosa
- Susana Deustua
- Bethan James
- Susan Kassin
- John MacKenty
- James Noss
- Cristina Oliveira
- Marc Postman
- Massimo Robberto
- Swara Ravindranath
- Julia Roman-Duval
- Elena Sabbi
- Remi Soummer
- Jason Tumlinson

## JHU

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- Aidan Gray
- Al Harding
- Randy Hammond
- Steve Hope
- Stephen McCandliss
- Jack Piotrowski
- Steve Smee

## CU/LASP

- Brian Fleming
- Kevin France
- Dimitri Vorobiev

## GSFC

- Javier Del Hoyo
- Luis Rodriguez De Marcos
- Manuel Quijada

## RIT

- Zoran Ninkov
- Kate Oram

## OSU

- Brad Peterson

Thanks for your kind attention