Microchannel Plate Detectors

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for UV Astronomy

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Outline

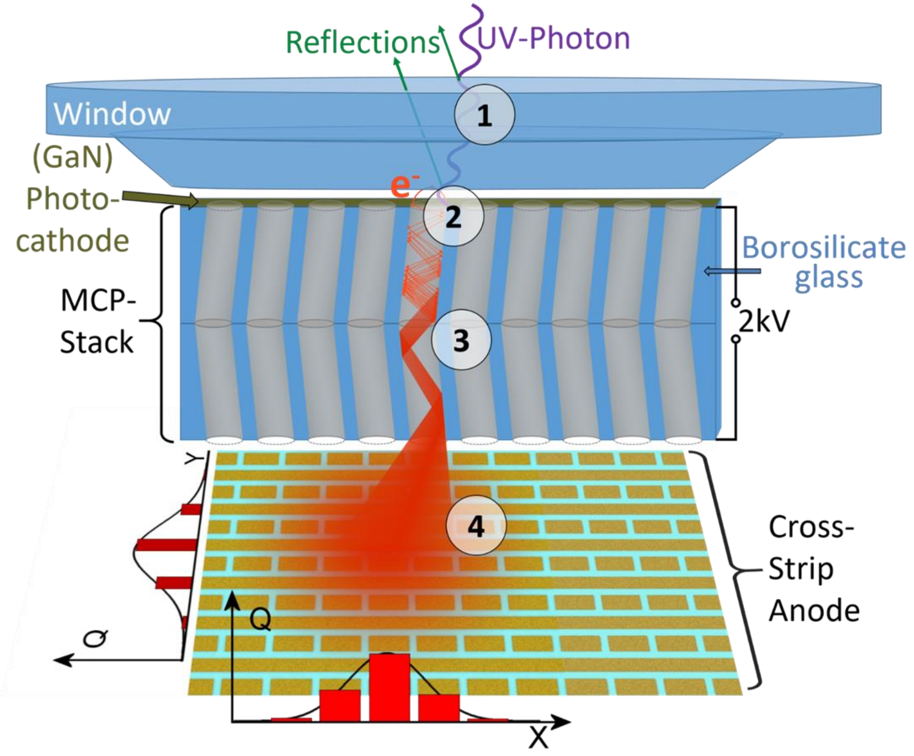
Detector Technology

Use cases and trade-offs for solid-state sensors vs. MCP detectors in the UV

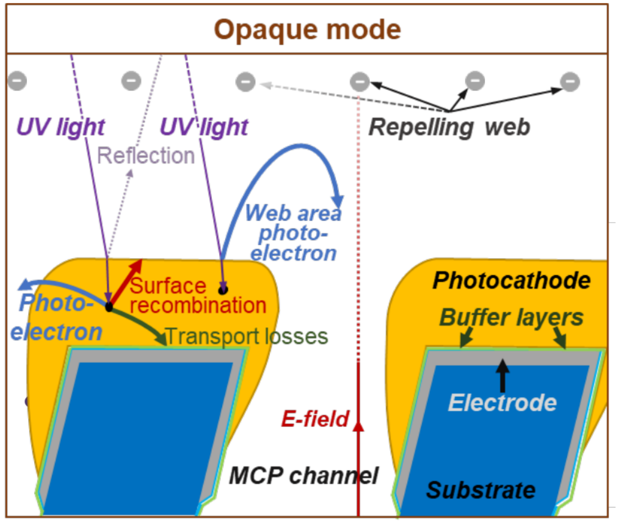
MCP Detector Development in Tübingen

Status and mission prospects

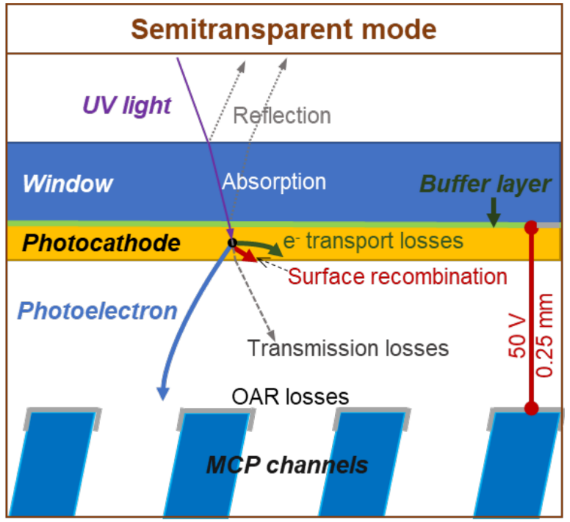
Principle of microchannel plate detectors for the UV



EUV + FUV + NUV



FUV > 110 nm + NUV



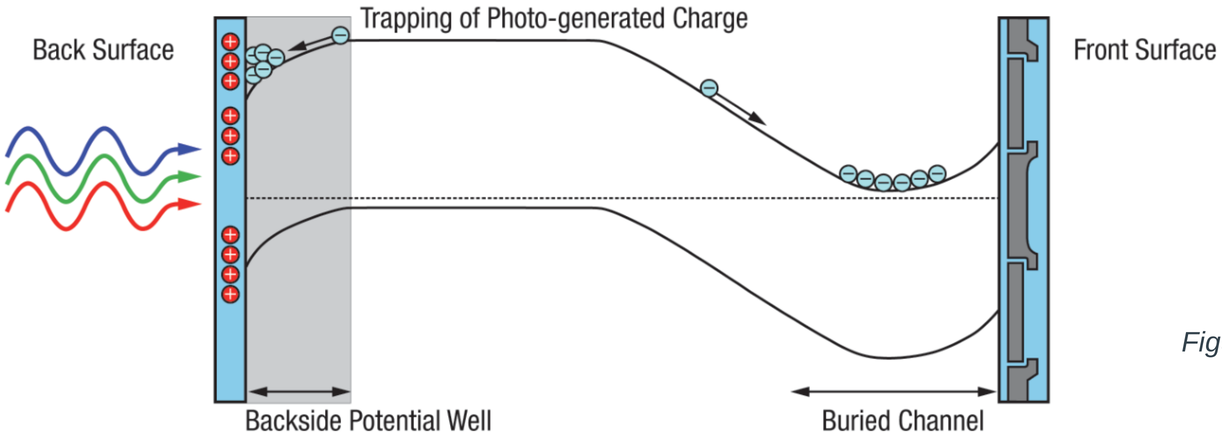
Considerations for solid-state (silicon) sensors in the UV

Quantum efficiency (QE)

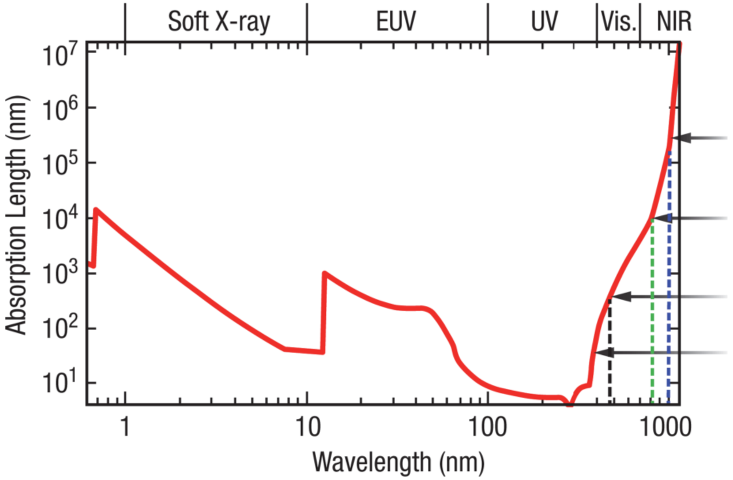
- Charge trapping near surface
(low QE + QE hysteresis)
- Indirect band gap at 1.1 eV becomes direct in the UV due to high energy levels

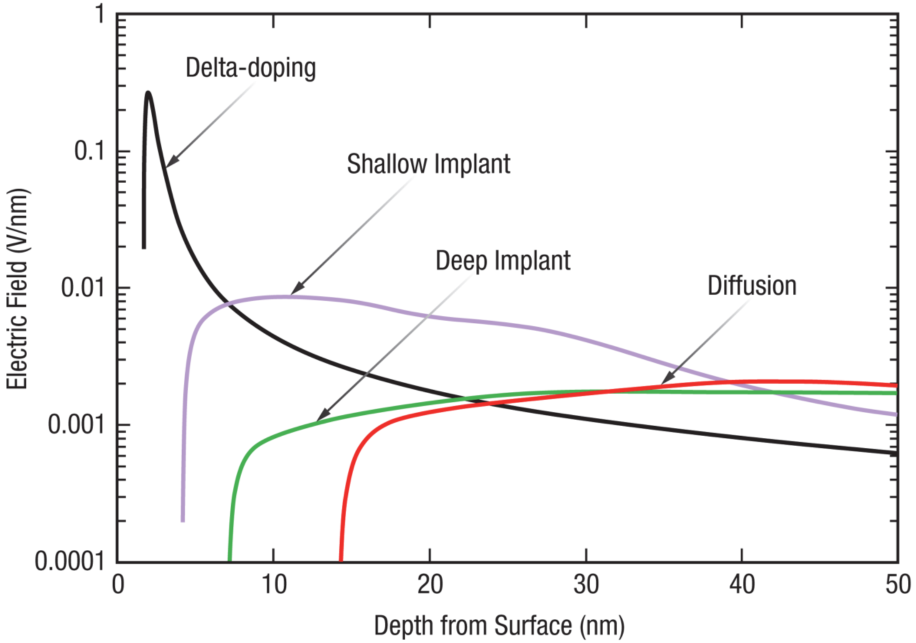
Measures to realize silicon UV sensors

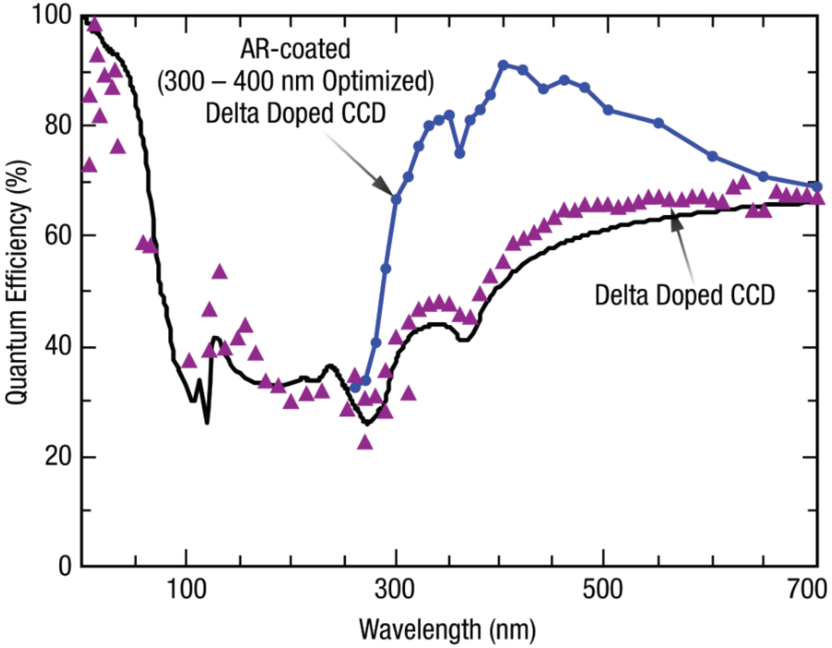
- Delta-doping by implanting or MBE
- AR coating



Figures by S. Nikzad, JPL, WSPC Handbook of Astronomical Instrumentation, 2021







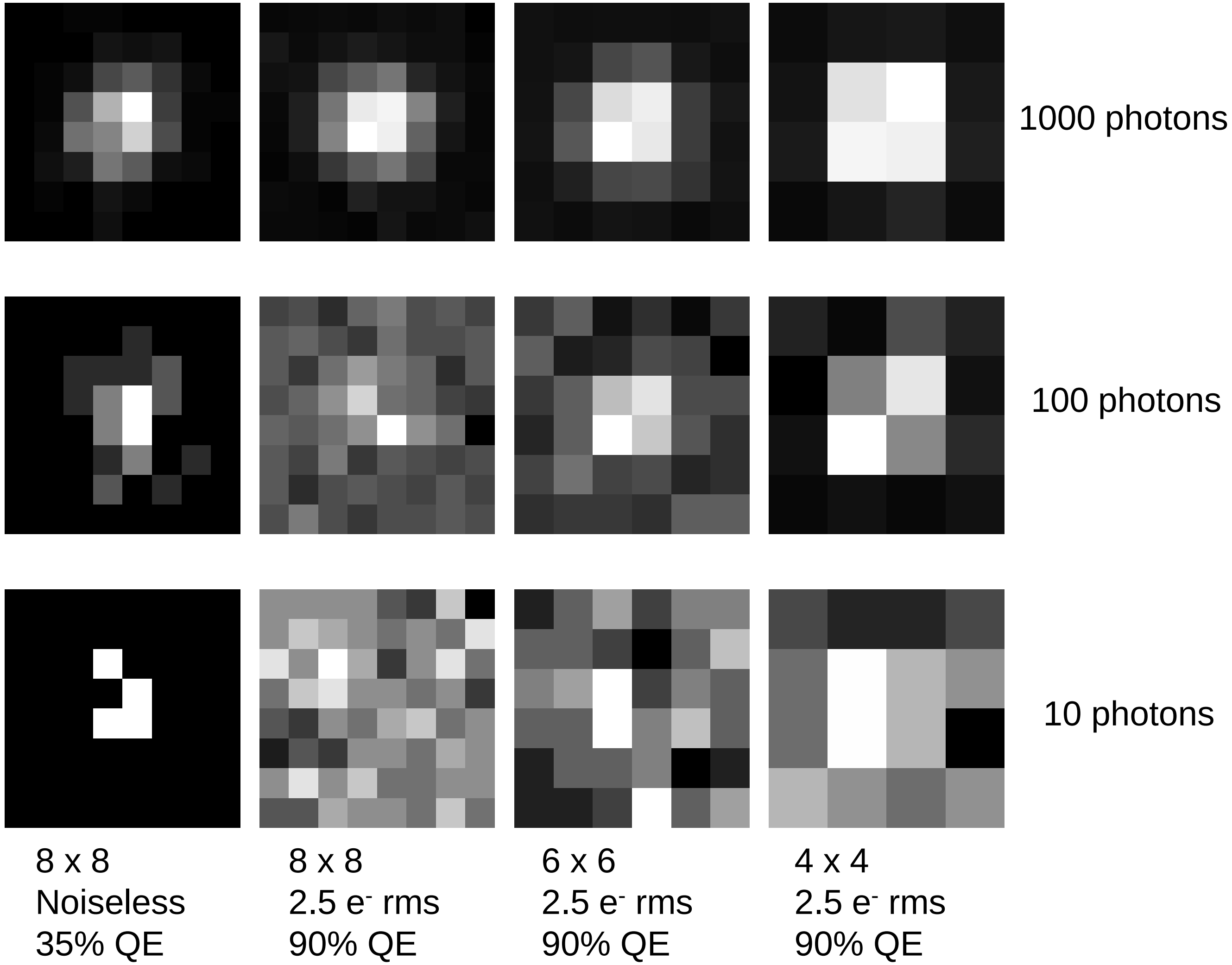
Trade-off between detector technologies

Comparison MCP vs. silicon (CCD, CMOS) technology

- Single photon-counting (time resolution <1 ms)
- No readout noise, but finite dark current
- Lower quantum efficiency (QE), particularly in the NUV
- Solar-/visible-blind (reduces straylight/background issues)
- High voltage required, but no cooling necessary

Suggested use cases for MCP detectors

- Small to medium class missions
  - less photons
  - less stable platform
  - less funds
  - higher potential for straylight issues
- Need for flatter response than AR coated Si
- FUV (90 – 120 nm)
- Larger “pixel” size affordable

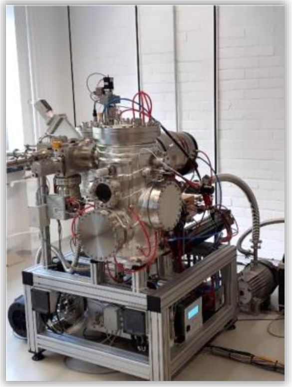


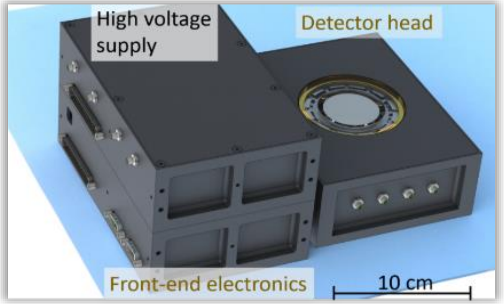
Simulations by J. Vallerga, SSL

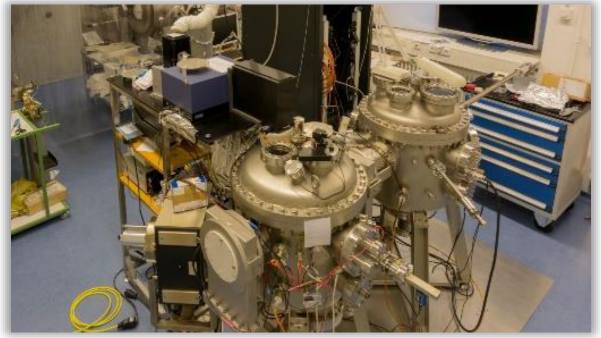
UV MCP detector development at IAAT

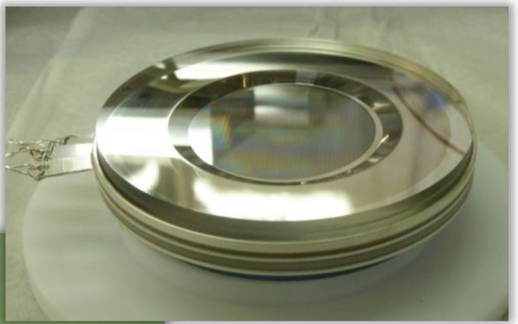
Goals and realization

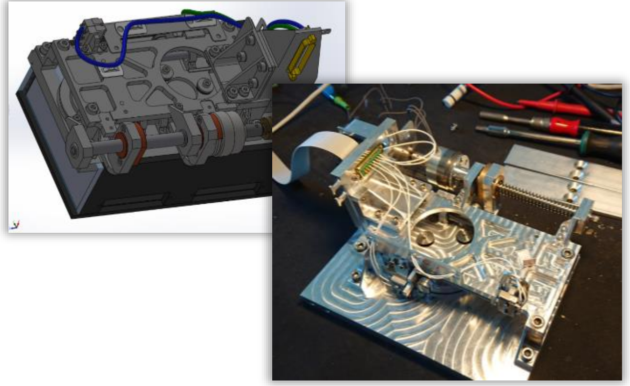
- Enhanced QE and adjustable band pass
  ⟶ *(Al)GaN photocathode*
- Higher count rate and lower dark current
  ⟶ *FPGA-based electronics, ALD MCPs*
- Enhanced lifetime
  ⟶ *ALD MCPs, XS anode*
- Low power consumption (<15 W)
  ⟶ *BEETLE pre-amp chip, FPGA-based readout*
- Lower mass (3 – 5 kg) + smaller envelope
  ⟶ *Highly integrated sealed tube/lightweight door mechanism*

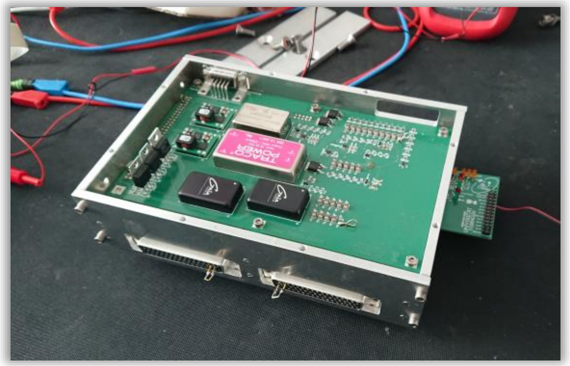


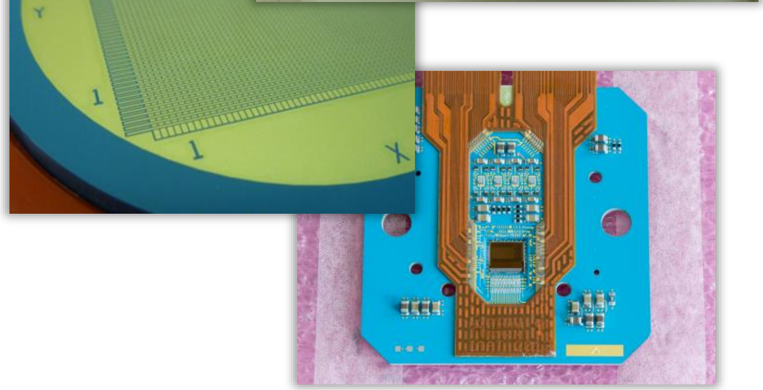












TINI – Tuebingen IIA Nebula Explorer

The TINI instrument

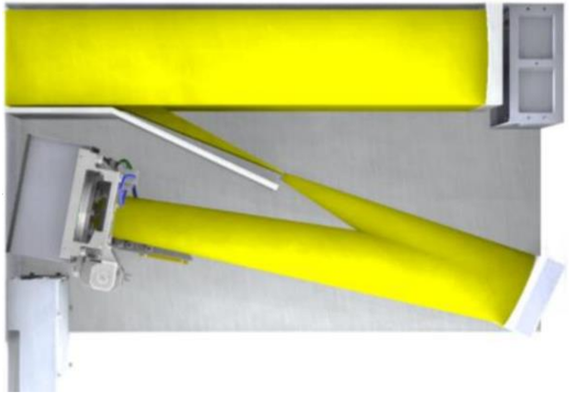
- Imaging spectroscopy in the FUV (90 – 180 nm)
- Wide FoV 0.7° with 13” spatial resolution
- 12U cubesat package, planned as piggyback

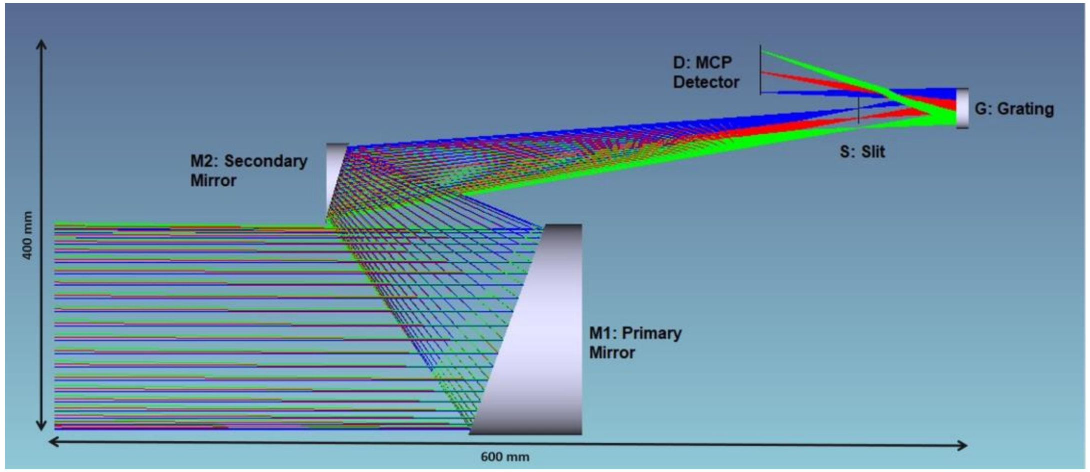
Mission situation

- Indian led mission with German contribution
- PI: formerly J. Murthy, since 2022 R. Mohan
- Proposed to ISRO in 2019 and 2022, no decision yet
- Detector development funded by DLR, but AIV only with launch perspective

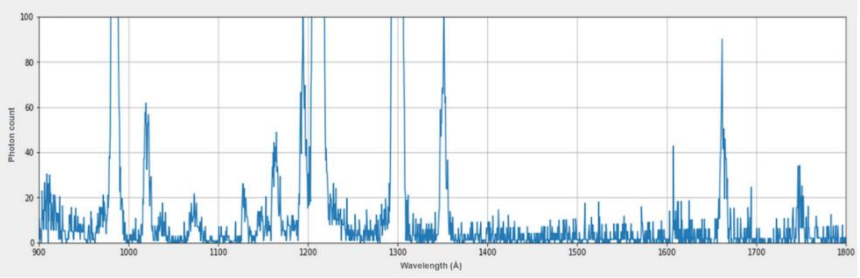
Hardware status

- Prototype instrument completed except for the final grating
- Detector prototype currently finalized





Diebold+, Proc. SPIE, 2022



SIRIUS – a mission for the EUV

Proposed as ESA S and F class mission

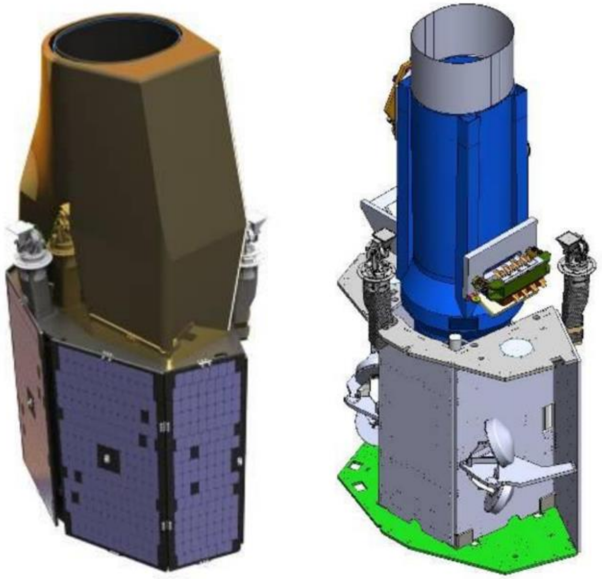
- UK-led (PI: M. Barstow)
- Contributions from Belgium, Germany, Spain
- Slitless, narrow-band EUV spectroscopy

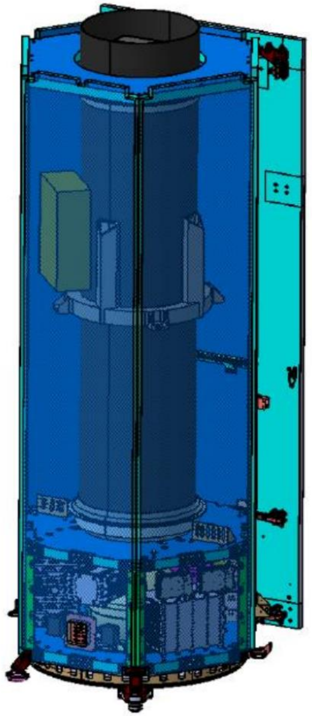
Upcoming UKSA call for a bi-lateral mission

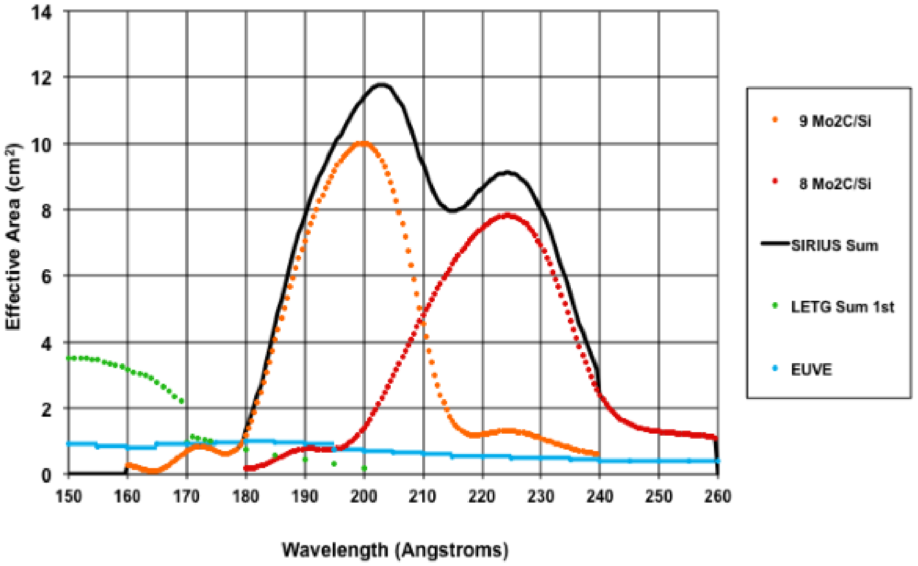
- Expected in late 2023
- Interest by the *SIRIUS* F2 instrument team

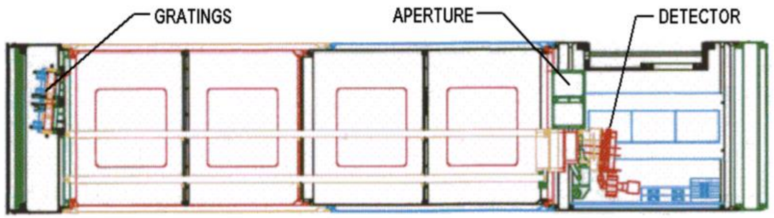
Planned contribution from IAAT

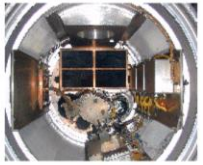
- Open MCP detector (GaN or KBr, need for photon-counting)
- Lyman-Alpha blocking filter



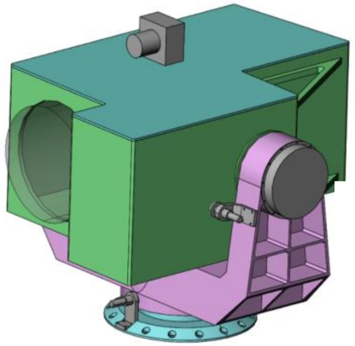


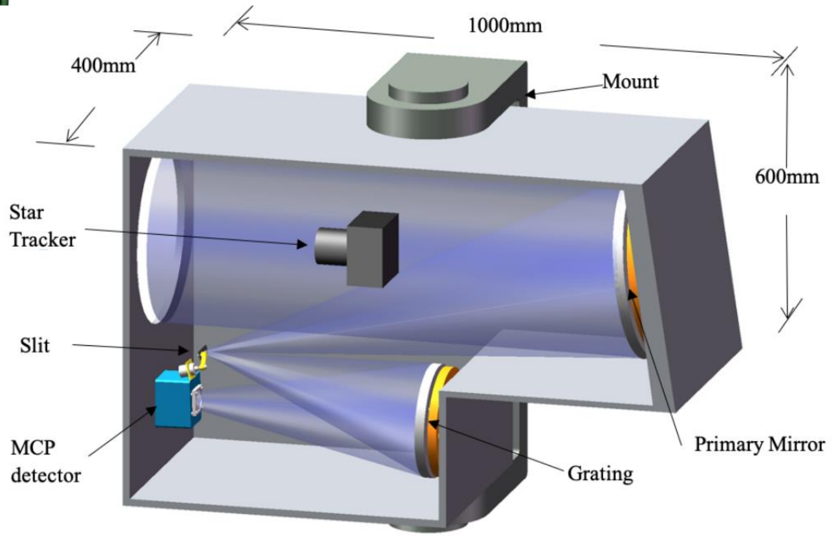






CAFE + LyRIC





Missions proposed to CAS

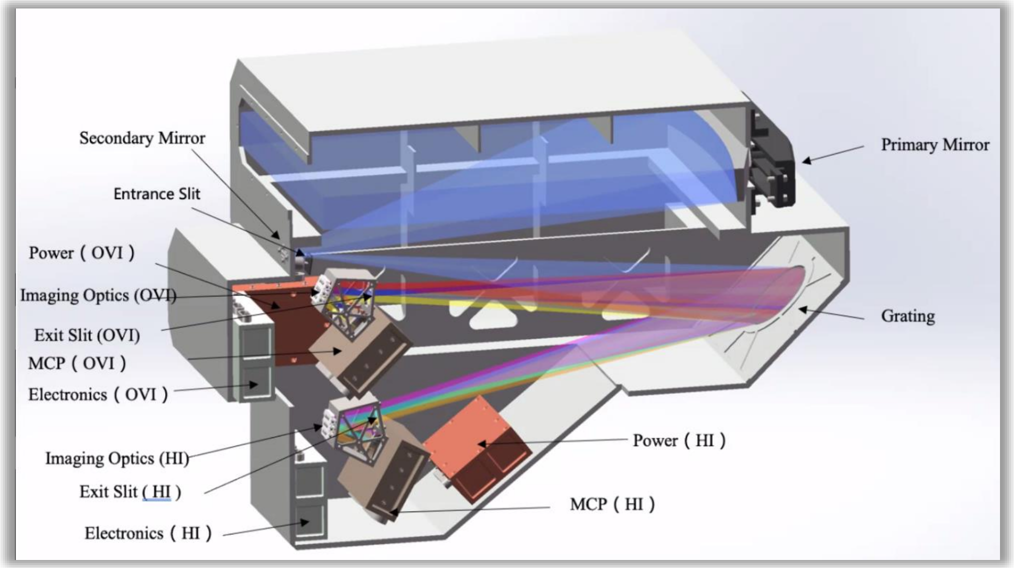
- PI: Li Ji, Purple Mountain Observatory, Nanjing
- Both instruments are tailored for IAAT MCP detectors

***LyRIC** (Lyman uv Radiation from Interstellar and Circum-galactic medium)*

- Long-slit spectrograph for the FUV range (91 – 115 nm)
- Designed for operation from the Chinese Space Station

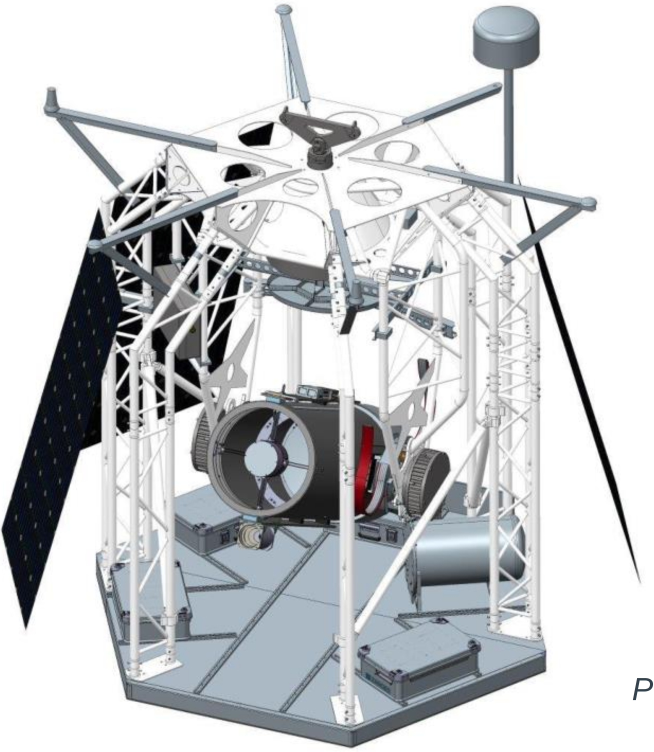
***CAFE** (Census of warm-hot intergalactic medium, Accretion, and Feedback Explorer)*

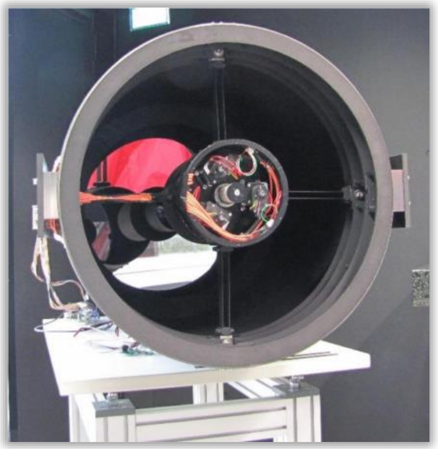
- Imaging spectroscopy in the FUV
- Two narrow channels around OVI (~103 nm) and LyA (~121 nm)



Ji+, PMO, Proc. SPIE, 2020

ESBO – European Stratospheric Balloon Observatory





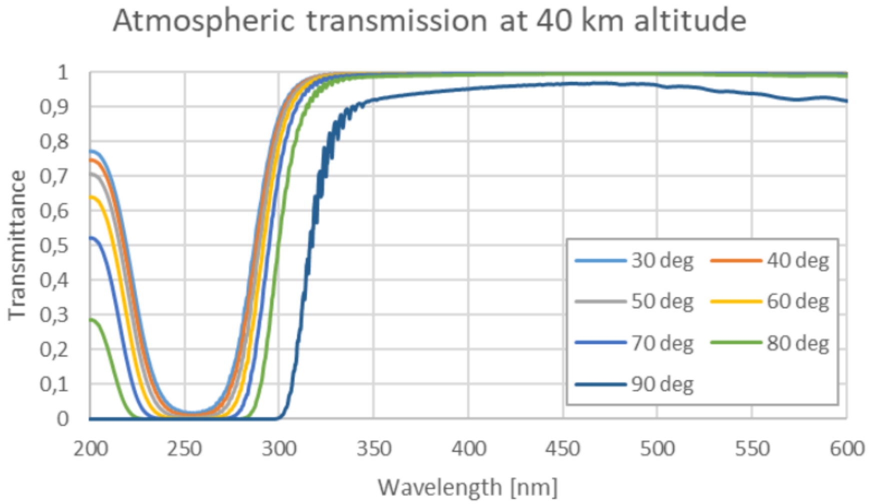
Pahler+, IRS, Proc. SPIE, 2022

ESBO-DS

- EU-Horizon funded design study concluded in 2021
- *STUDIO* instrument
  (Stratospheric UV Demonstrator of an Imaging Observatory)
- Looking for funding opportunities for a commissioning flight and science flights

Science goals for the *STUDIO* instrument

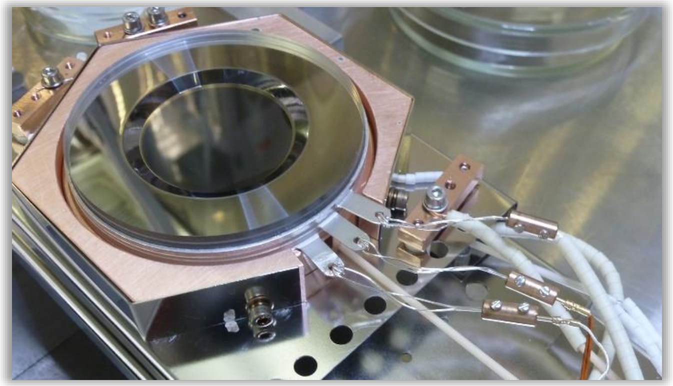
- Search for variable hot compact stars
- Detection of flares from cool dwarf stars
- Study of solar system objects



Conclusions

Detector technology

- MCP was the dominating technology in the whole UV range for decades
- Solid-state silicon technology caught-up and took over for several use-cases
- Still a careful technology trade-off is necessary to reach an optimal SNR



MCP detector development at IAAT

- Semi-transparent (Al)GaN photocathodes are routinely produced, optimization is ongoing
- Opaque (Al)GaN photocathodes on MCPs under development
- First sealed MCP detector head with XS anode successfully produced
- Readout electronics hardware for the XS anode is fully completed

Mission prospects

- Several European and international projects are on the horizon
  (TINI, SIRIUS, LyRIC, CAFE, ESBO …)

Thank you