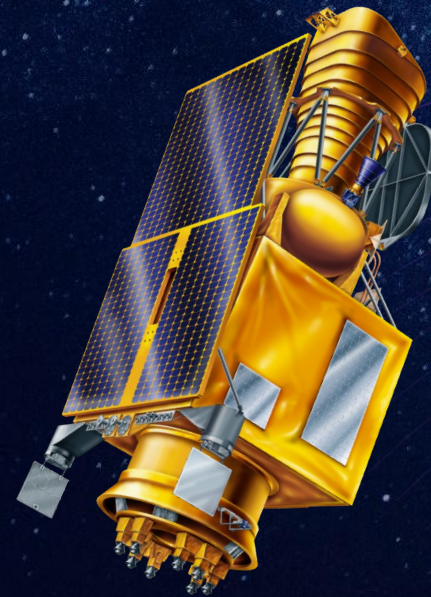


# ULTRASAT

## Performance and Capabilities

“Ultrasat introduction” session @ AAS 2023, Jan 11, 2023



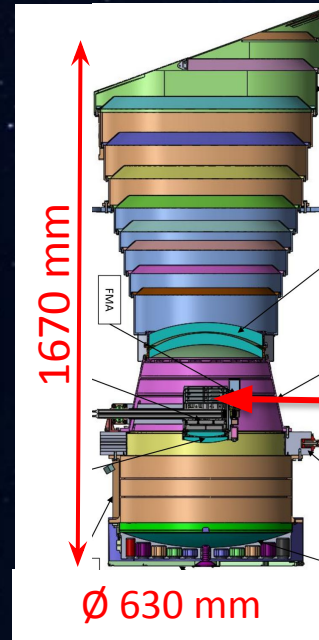
Yossi Shvartzvald | ULTRASAT Project Scientist | Weizmann Institute of Science

# ULTRASAT implementation

**Spacecraft: IAI**

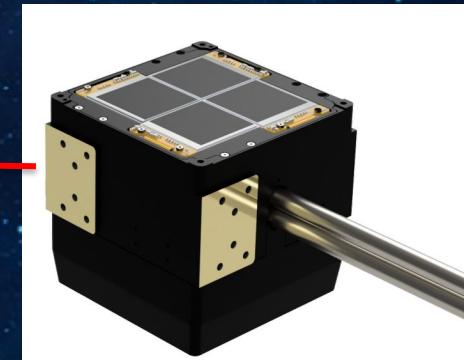


**Telescope: Elop/Elbit**



**Focal Plane Array  
("Camera"):  
DESY/Helmholtz**

**Sensors: Tower**



**Hosted launch to GTO: NASA**

**Launch Q1 2026**

**>3.5 year science mission (6 year fuel)**

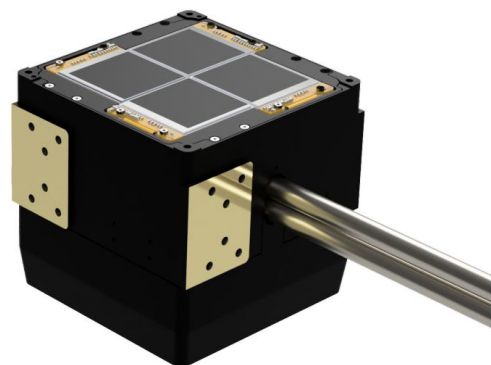
**Dimensions: 1.5 x 1.9 x 3.6 (m<sup>3</sup>)**

**Power: 500 W**

**Mass: 500 + 630 (Prop) kg**

# Focal Plane Array

- Developed and supplied by DESY
- BSI CMOS from TowerJazz - **production completed!**  
4 Tiles aligned to  $< 50 \mu\text{m}$
- High UV QE using:  
high-K dielectric coating  
Optimized anti-reflection coating
- Space qualified design (e.g., radiation hardness)
- Electronic design **passed full verification**
- Flight sensors diced and now are **being packaged**



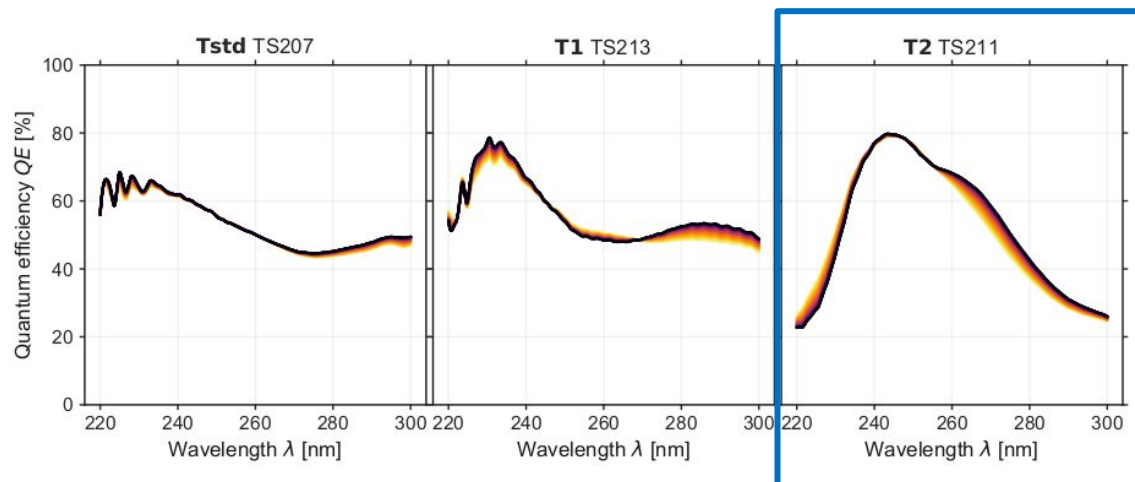
## Sensor main Spec.

Photosensitive area ( <b>single tile</b> )	45 x 45 mm <sup>2</sup> <b>7.14 x 7.14 deg<sup>2</sup></b>
Pixel size Pixel scale	9.5 $\mu\text{m}$ 5.4''
Mean QE at 230-290nm	>60%
Operation temperature	200 $\pm$ 5 °K
Dark current @ 200 °K	<0.03 e <sup>-</sup> /sec
Readout noise @ High-gain	<3.5 e <sup>-</sup> /pixel
Electronic cross-Talk	<0.01%
Readout time	<20 sec
Pixel sampling scheme	Rolling shutter + Dual gain

For more details see: Asif+2021  
Bastian-Querner+2021  
Liran+2022

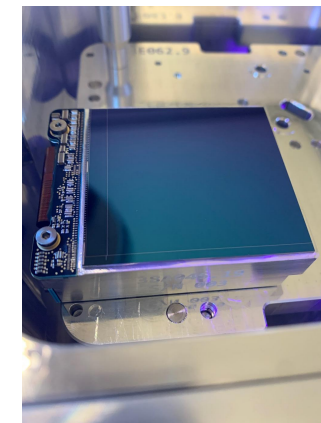
# Focal Plane Array

## “Scouts” QE measurements: Optimal ARC selection

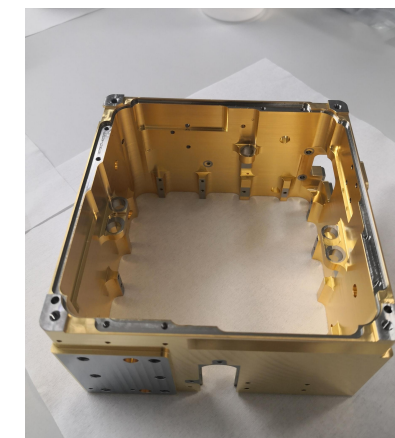
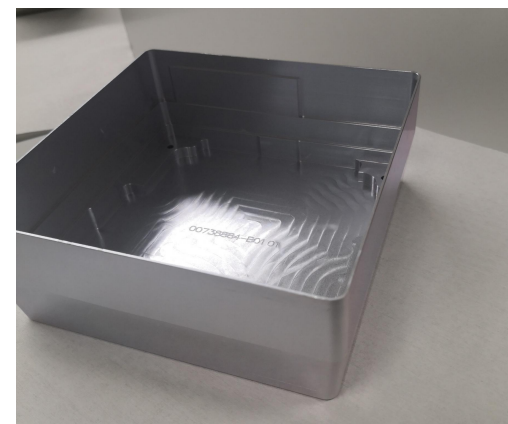


For more details see: Asif+2021  
Bastian-Querner+2021  
Liran+2022

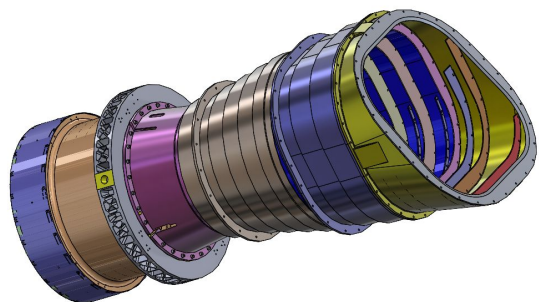
## First Sensor Tile



## Development camera structure

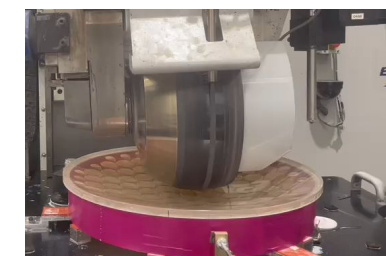
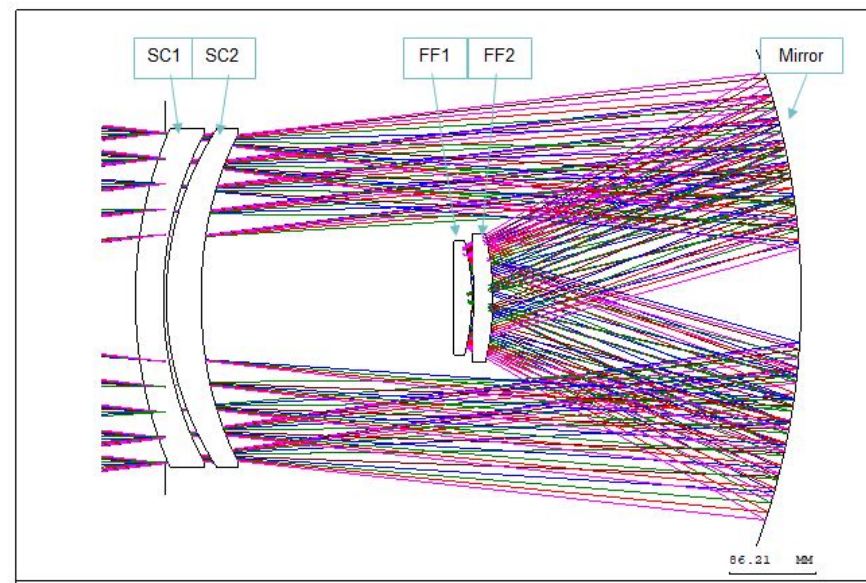
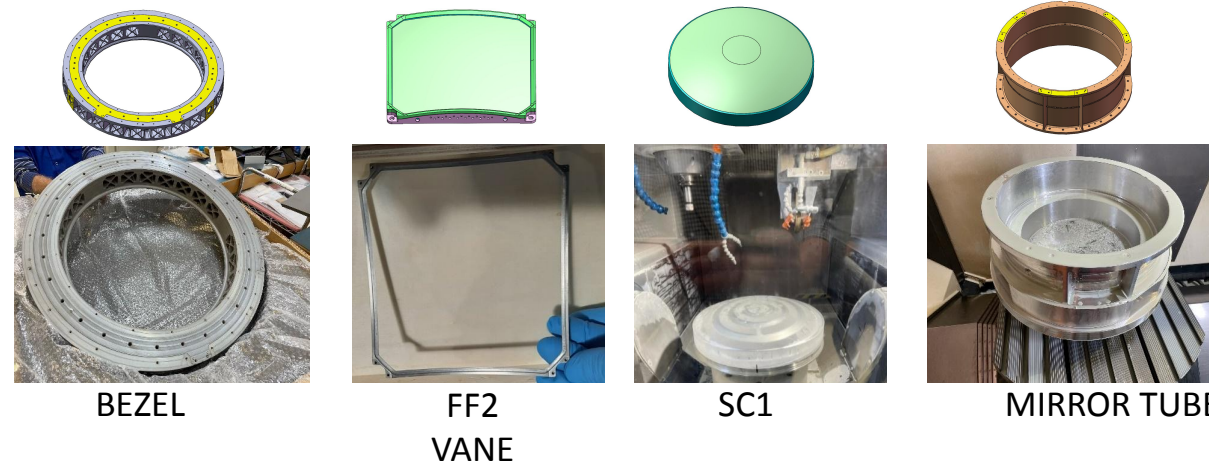


# Telescope components



## Telescope structure and optics

- **Baffle**
- **Schmidt Correctors**
  - **33 cm clear aperture**
  - Fused Silica & CaF<sub>2</sub>
  - Reduce Spherical aberration
- **Mirror 50 cm Zerodur**
- **Field Flattener lenses**
  - Fused Silica & CaF<sub>2</sub>
  - Focus mechanism
  - Reduces Field Curvature
- **Out-of-band Sapphire filter**
- **Focal Plane array**



MIRROR

For more details see: Ben-Ami+2022

# Baffle

## Stray light

- Pointing limits:
  - No Sunlight enters at any time
  - Earth light required suppression
  - No direct moonlight hit the corrector
- **Enables >50% sky accessibility at any given moment**

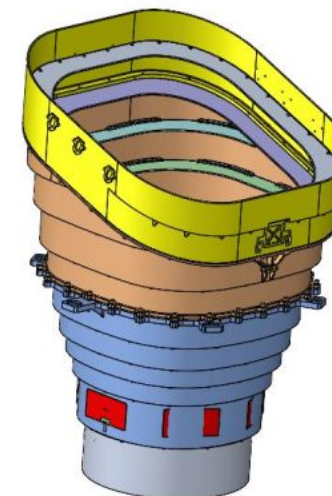
## Trapped electrons propagating through the corrector

- Reduce Cerenkov radiation - the dominant background noise source!
- Reduce transmission degradation

For more details see: Ben-Ami+2022  
Shvartzvald+ in perp.

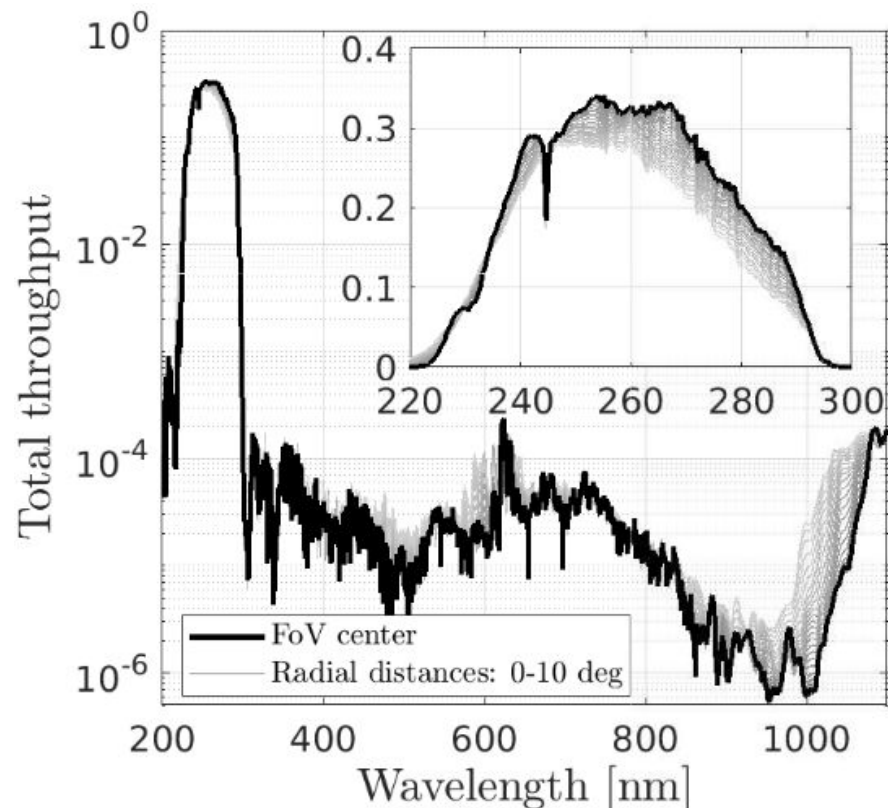
## Baffle main Spec.

Sun pointing limit	>70°
Earth (center) pointing limit	>56°
Moon pointing limit	>34°
Stray light suppression factor	< 2 x 10 <sup>-11</sup>
Electron suppression (Cerenkov)	< 1/6

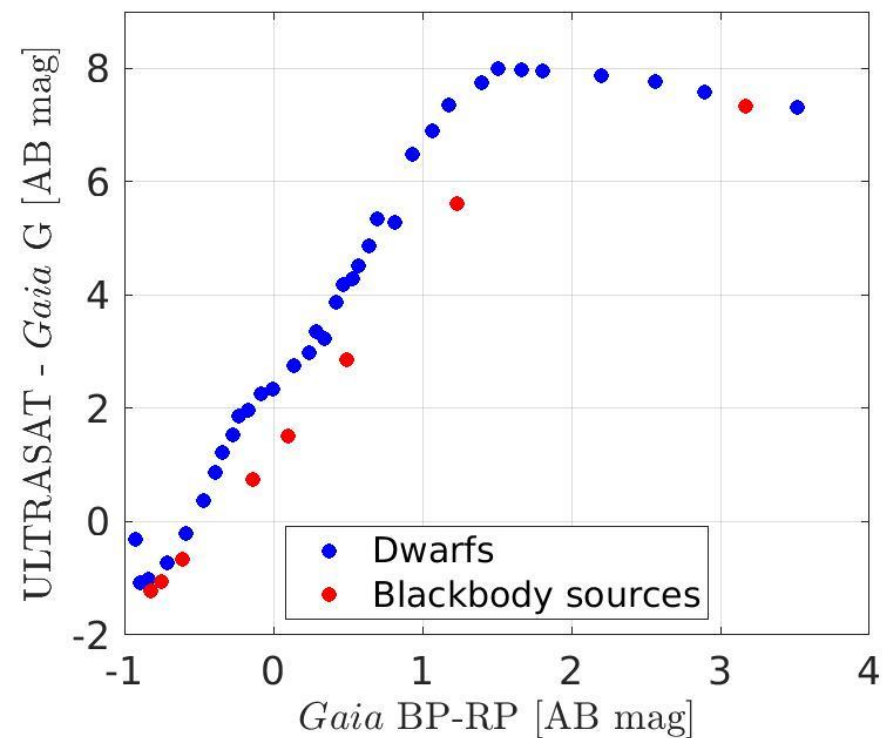


# Optical Performance

Total throughput



Colors



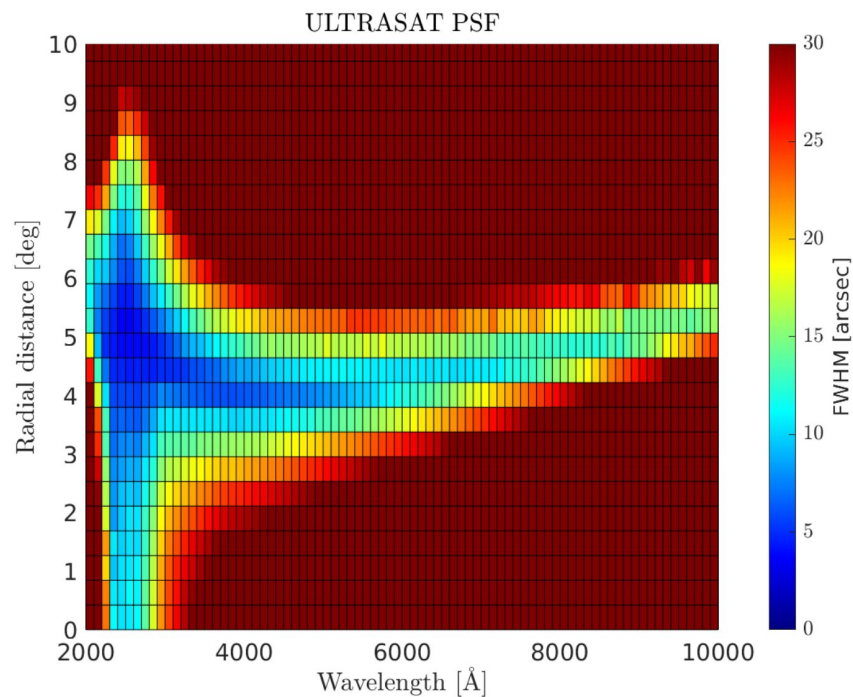
Shvartzvald+ in perp.

# Optical Performance

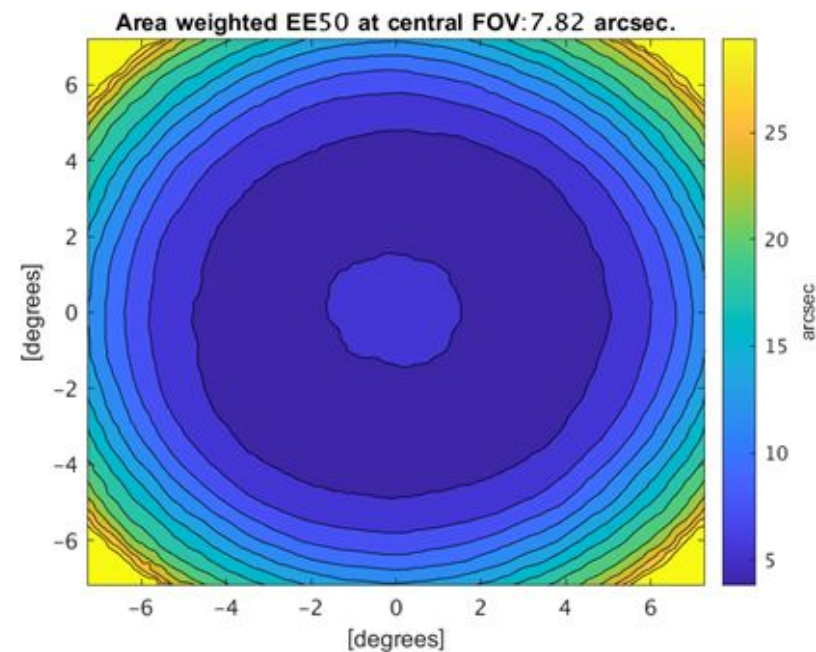
## Chromatic position-dependent PSF

Optimized for:

- ULTRASAT band: 230-290nm
- Central 170 deg<sup>2</sup>



## PSF



For more details see: Ben-Ami+2022

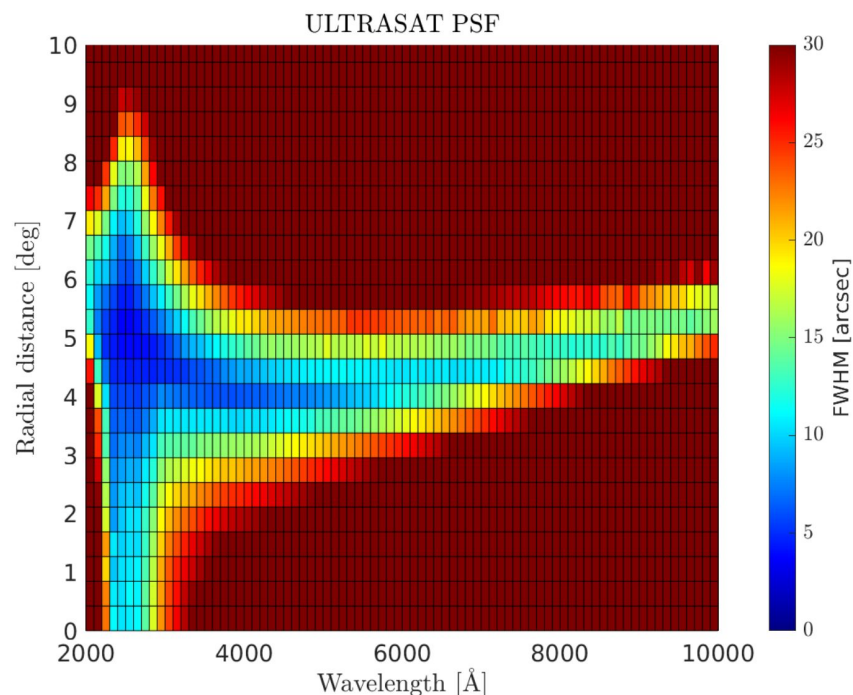


# Optical Performance

## Chromatic position-dependent PSF

Optimized for:

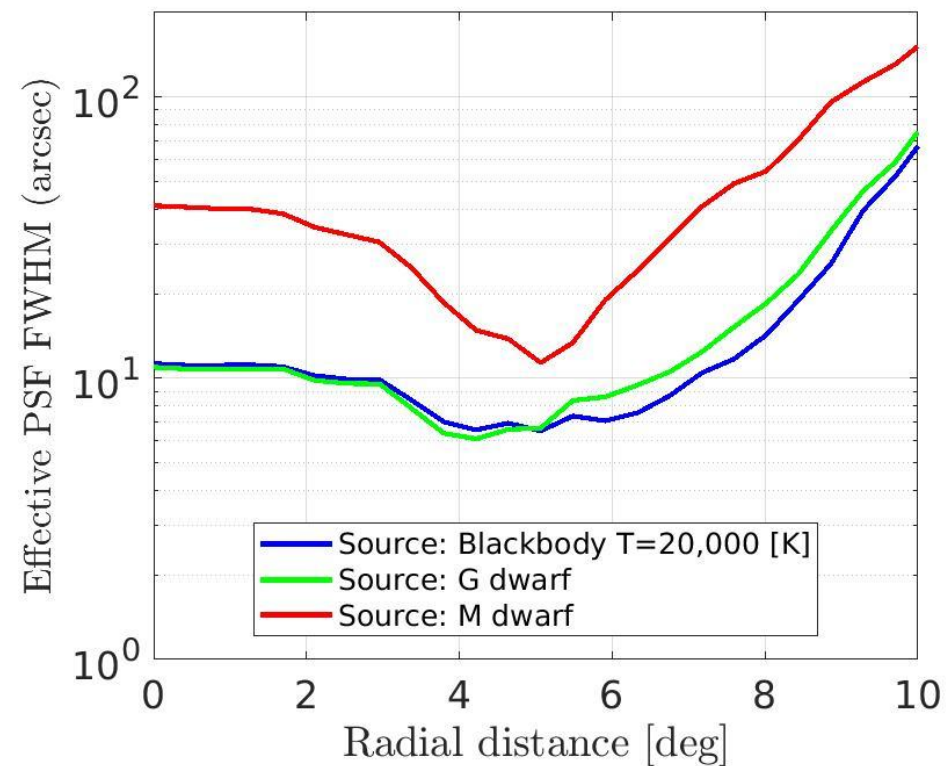
- ULTRASAT band: 230-290nm
- Central 170 deg<sup>2</sup>



For more details see: Ben-Ami+2022

## Effective PSF

Source and position dependent

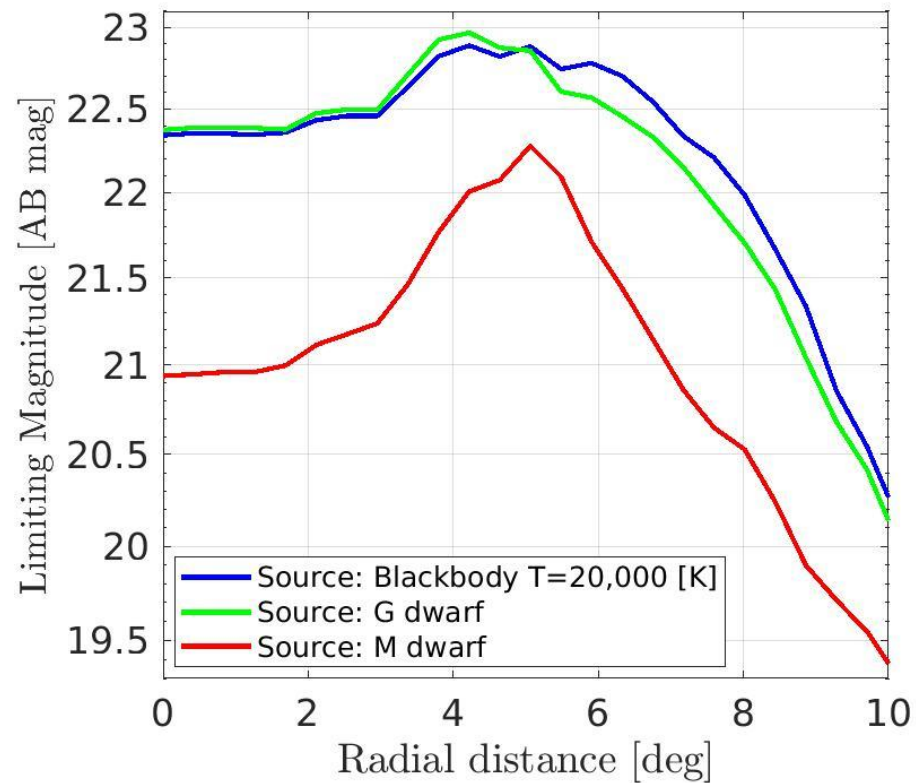


Shvartzvald+ in perp.

# Optical Performance

## Limiting magnitude

- Source and position dependent



Shvartzvald+ in perp.

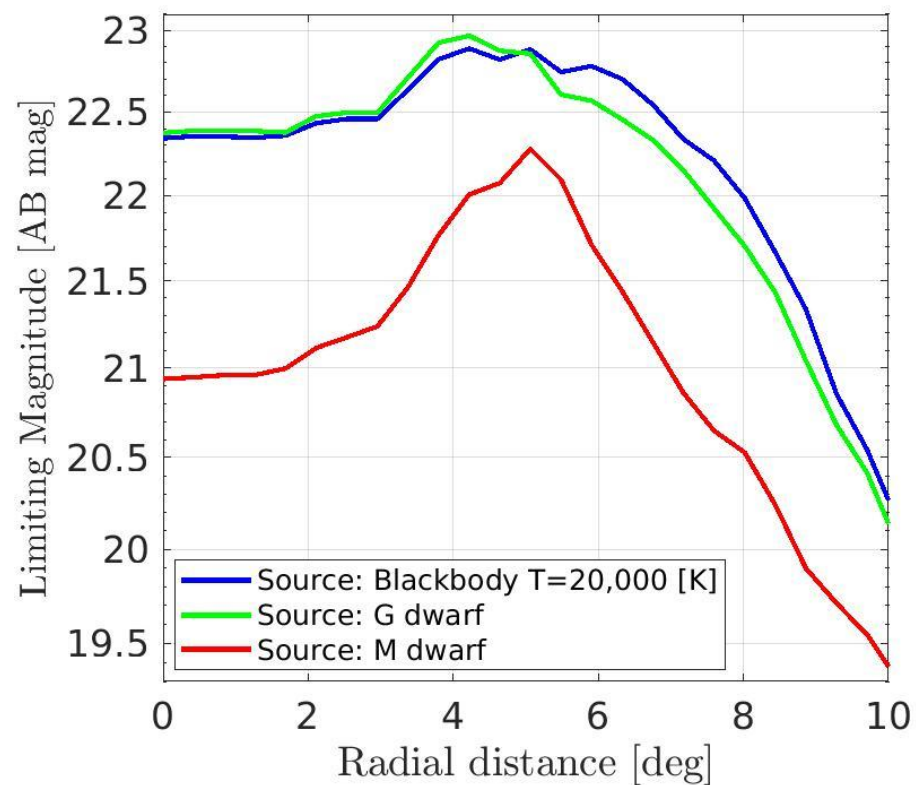
## Background Noise

Source	Variance (e <sup>-</sup> /pix)
Zodiac (Survey)	27
Cerenkov (75%)	15
Stray light (max)	12
Dark current	12
Readout noise [ <sup>2</sup> ]	6
Electronic Crosstalk	2
Gain	1
Quantum Yield	<1
<b>Total</b>	<b>75</b>

# Optical Performance

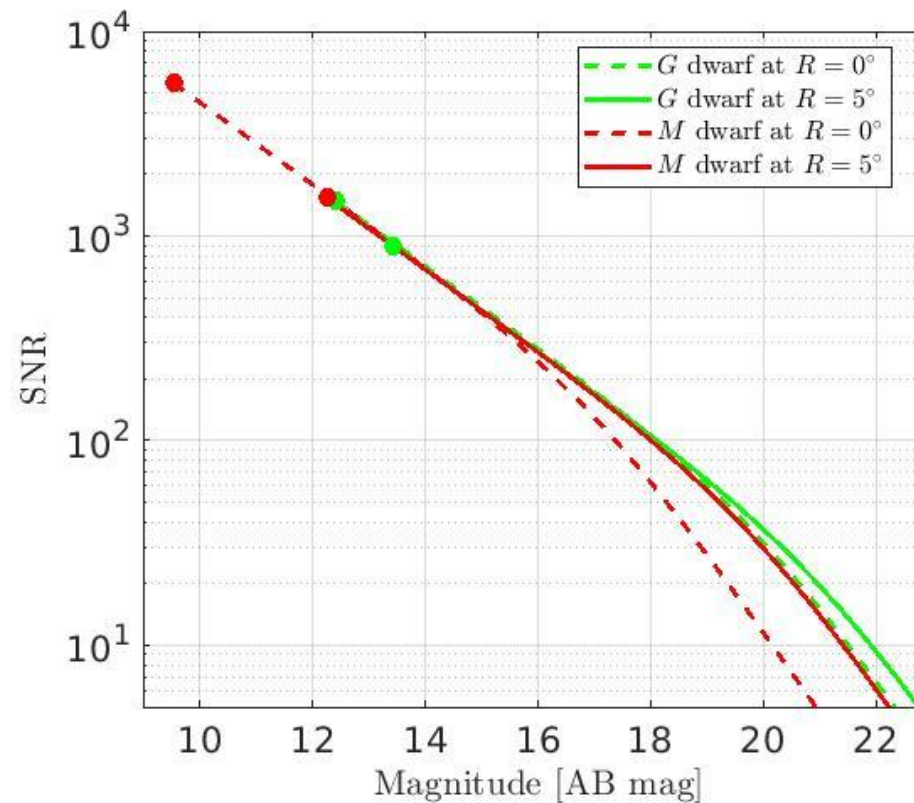
## Limiting magnitude

- Source and position dependent



Shvartzvald+ in perp.

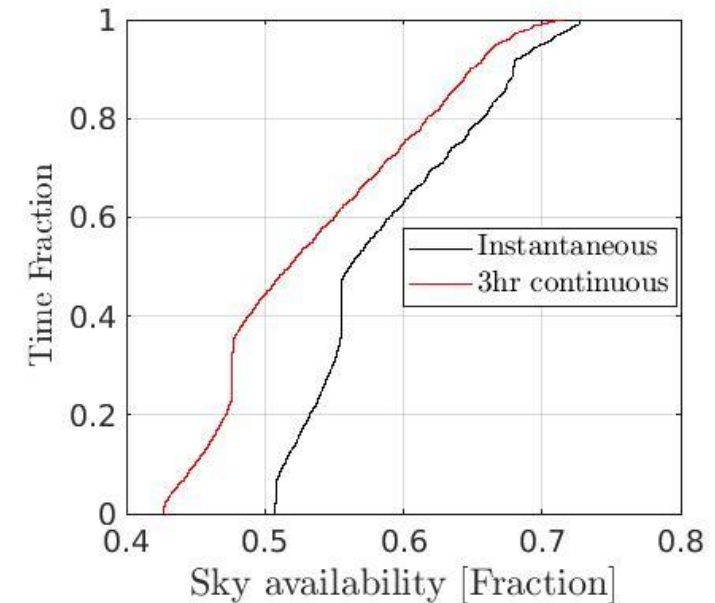
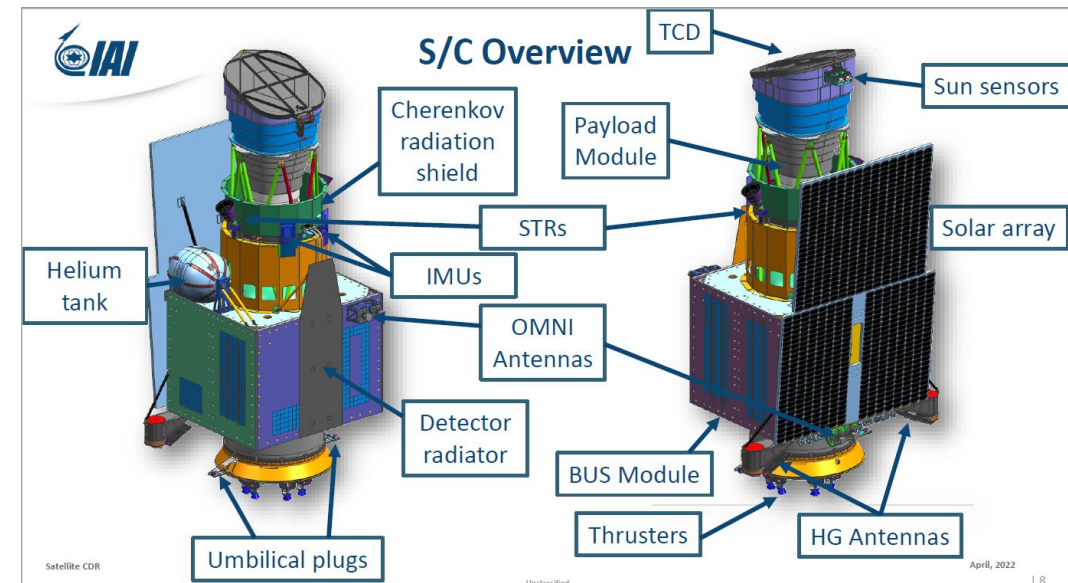
## Sensitivity



# Spacecraft

- Launch (provided by NASA) into GTO orbit
  - Self propulsion to GEO orbit
  - Final orbit – Slot 4-West
  - Full Station Keeping
- **Continuous transmission** to the ground
- **Instantaneous >50% of the sky in <15 min**
- No limit on number of ToO's, except for max 25/yr with negative energy balance ("Hard ToO")
- Duration of Hard ToO: >3 h

Mission lifetime	>3 years
Kinematic lifetime	6 years
Science observations availability	>90%
Pointing stability	<3.0" over 300s (3 $\sigma$ )
Data Downlink rate	>5 Mbps
Pointing slew agility	>30°/min



# ULTRASAT: Mission Profile



## SURVEY (→ Key goal 2)

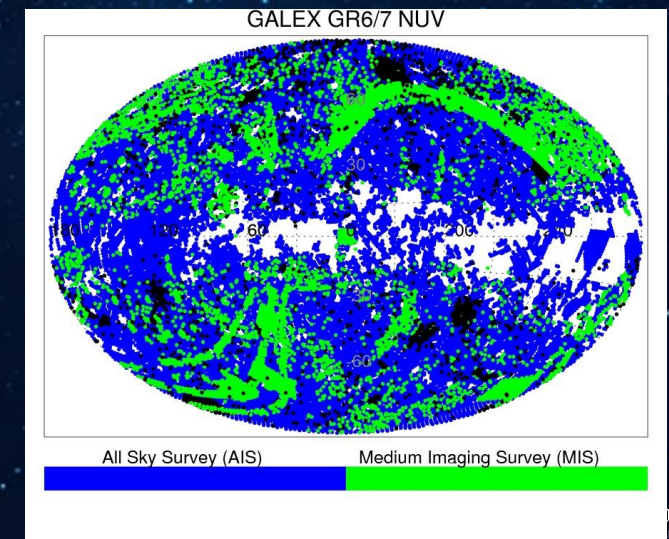
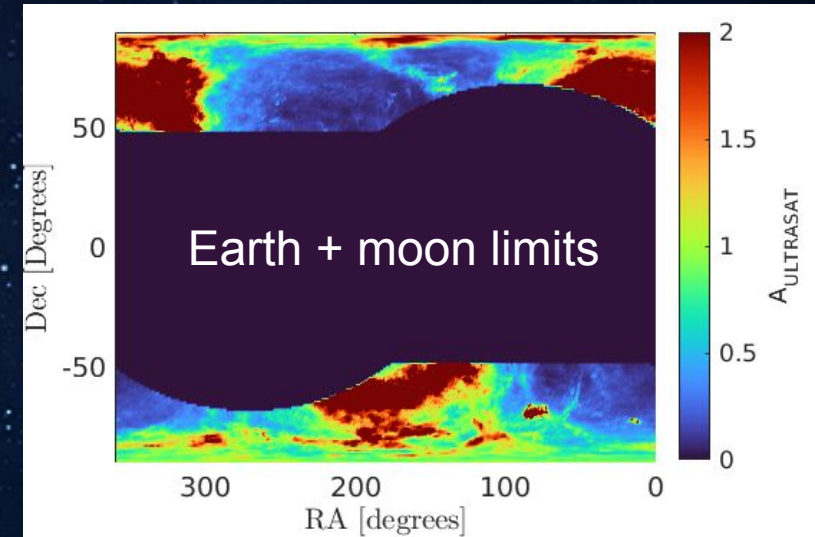
- High cadence - 200 deg<sup>2</sup> with 5 min cadence (21 hr/day)
- Low cadence - 8000 deg<sup>2</sup> with 4 day cadence (3 hr/day)
- Real-time data download and analysis - Alerts <15min of observations

## TARGET OF OPPORTUNITY (ToO's; → Key goal 1)

- Instantaneous >50% of the sky in <15 min for >3 h
- No limit on ToO number, except for max 25/yr with negative power balance (33%)
- Continuous transmission to the ground

## UV ALL SKY MAP

- 3hr/day during the first 6 months
- 7x deeper than current state-of-the-art (GALEX)  
(>23 AB limiting mag @ |b|>30°)



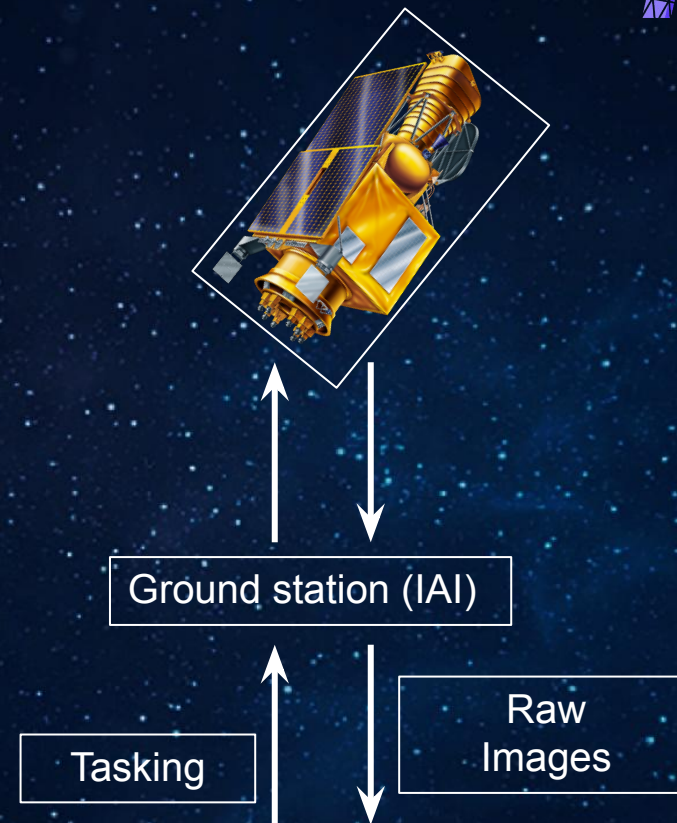
# Operations

## Ground Control Station (@ IAI):

- Command & Control, Telemetry Processing
- Immediate ToO tasking
- Receive imagery data, deliver to WIS (SOC)
- Perform ranging for orbit determination

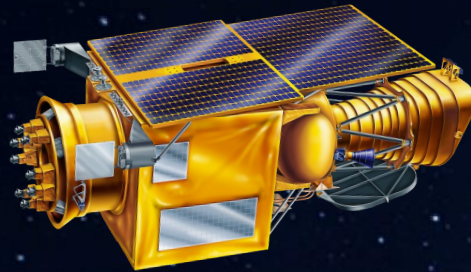
## Science Operation Center (@ WIS) :

- Observation planning
- Image and Data processing
- Scientific Data Products archiving
- Ultrasat Alerts generation



# Data Policy

- ULTRASAT real-time alerts - publicly available immediately
- All other ULTRASAT data products:
  - Periodic public data releases (DRs), after full calibration and verification
  - Proprietary period - 12 months
- Members of the ULTRASAT collaboration and the science working groups will have immediate access to all ULTRASAT data products



### Performance summary:

- Very large 200 deg<sup>2</sup> FOV
- Operation waveband 230-290 nm
- Mean PSF FWHM 8.5"
- Mean limiting mag 22.5 (5 $\sigma$ , 3x300s)
  
- Orbit: GEO
- Launch mass ~1100 kg, Dimensions 1.5x1.7x3.4 m<sup>3</sup>
  
- Transient alert after observation time: <15 min
- Observation start after ToO trigger: <15min

### Modes of operation:

- Survey modes:
  - **High cadence** (~21 hours/day)  
1 field: 200 deg<sup>2</sup>, 5 min cadence
  - **Low cadence** (~3 hours/day)  
40 fields: 8000 deg<sup>2</sup>, 4-day cadence
- Target of opportunity (ToO's)...
- UV All-sky map + building ref images  
3 hr/day during first 6 months

**Collaboration workshop: July 11-13, 2023**

**ULTRASAT Prize Fellowship @ WIS:  
submission deadline in 4 days (Jan 15)**