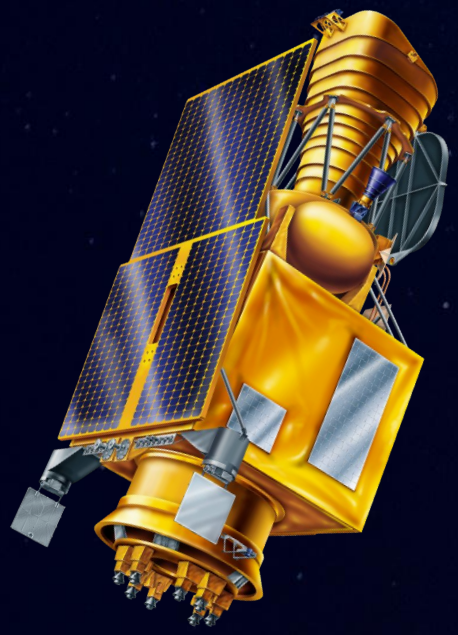
ULTRASAT:
A Wide-Field UV Space Telescope

Revolutionizing our view of the transient universe



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Funding partners
ISA
WIS
NASA
DESY

Industry partners
IAI
Elop
Tower

Yossi Shvartzvald | Weizmann Institute of Science

ULTRASAT's uniqueness

ULTRASAT
SKYLIGHT TO SPACE

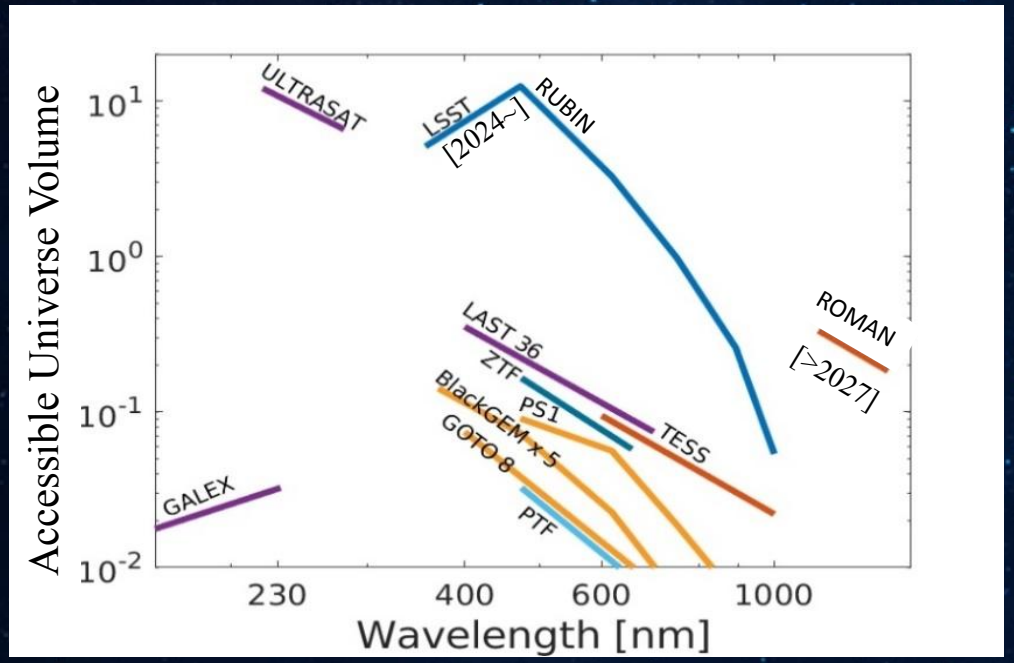
Key Properties

- Very large, 200 deg^2, field of view
- High UV (230-290nm) sensitivity:
  1.5 x 10^{-3} ph/cm^2 s (900s, 5σ)
  [m = 22.5]
- Geostationary orbit

Key Capabilities

- Monitor an unprecedentedly large volume of the Universe
- New window in wavelength (NUV) and in cadence (minutes - months)
- Real-time alerts to ground/space-based telescopes (GEO orbit), initiate world-wide follow-ups
- ToO: Instantaneous >50% of the sky in <15 min for >3 hr

Transient detection rates of leading surveys



Shvartzvald+ in perp.

ULTRASAT - Key Science Goals

ULTRASAT
SKYLIGHT TO SPACE

EM counterpart to GW sources

Starting 2026: ~ 10s NS-NS merger events per year

~100 deg^2 error boxes

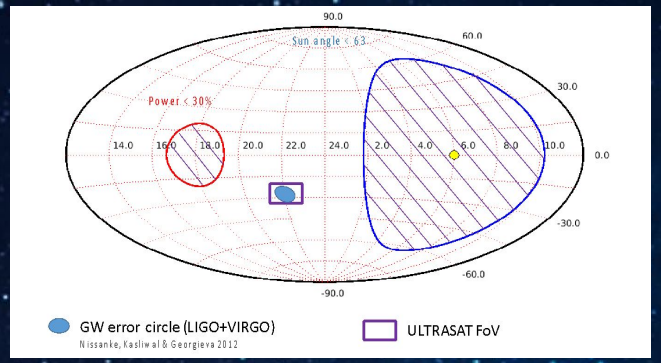
ULTRASAT will provide:

- Fast localization of NS-NS/BH mergers
  Rapid, <15min, access to 50% of the sky
  Cover GW error box in a single image
- UV light curves to measure ejecta properties

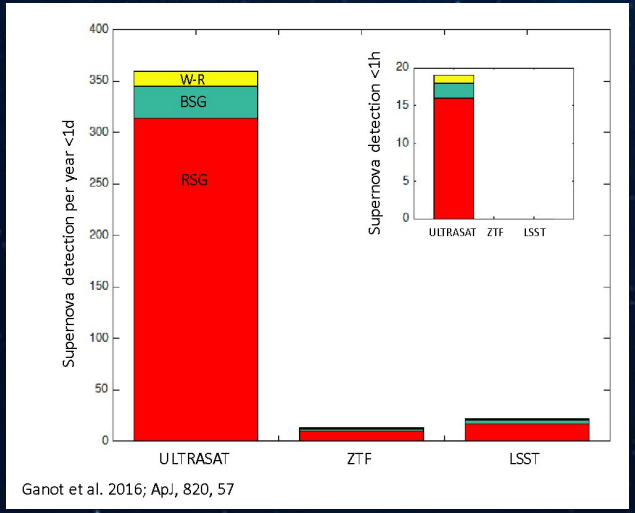
Death of massive stars

- High quality early high cadence UV data
  Rapid alerts for follow-ups,
  100's of SNe including rare types
- Measure properties of SNe progenitors
- Map progenitors to SNe types
- Reveal pre-explosion evolution and mass loss

ULTRSAT's ToO access



Rates of early detection of SNe



Ganot et al. 2016; ApJ, 820, 57

First detection of GW from a NS merger [GW170817]

- Very nearby, ~40 Mpc
  Light detected after 0.5 day, UV bright.

- ULTRASAT is far superior to other searches
  - Identifying light by searching over all galaxies within GW error volume- will be prohibitive, at ~300 Mpc - 1000's of galaxies.
  - Detection in other bands (infra-red, radio) will be highly challenging.

- Heavy elements beyond Iron – produced, How heavy (Germanium or Gold) – uncertain. More detections, with earlier light detection, are required.

Strong support to ULTRASAT

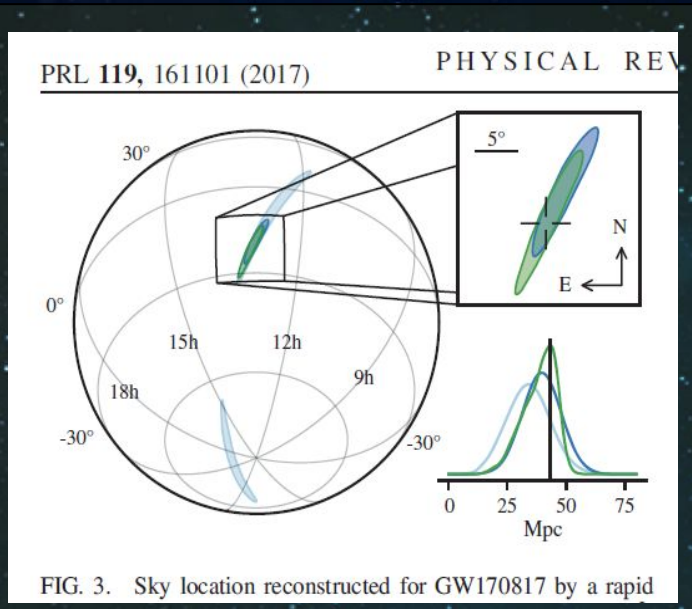
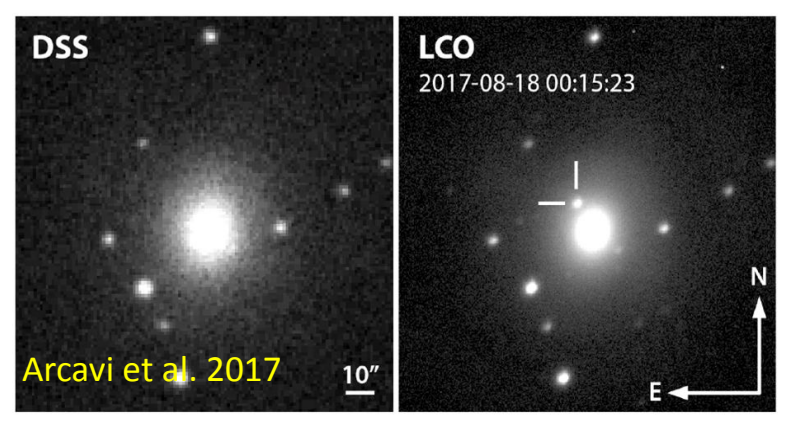


FIG. 3. Sky location reconstructed for GW170817 by a rapid



ULTRASAT: A broad science impact

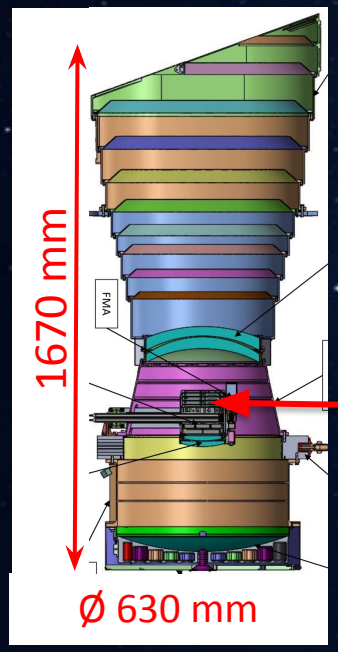
Source Type		# Events per 3 yr mission	Science Impact
Supernovae			
	Shock break-out and Early (shock cooling) of core collapse SNe	>40 >500	Understand the explosive death of massive stars
	Superluminous SNe	>250	Early evolution, shock cooling emission
	Type Ia SNe	>40	Discriminate between SD and DD progenitors
Compact Object Transients			
	Emission from Gravitational Wave events: NS-NS and NS-BH	~25	Constrain the physics of the sources of gravitational waves
	Cataclysmic variables	>25	Accretion and outburst physics
	Tidal disruption of stars by black holes	>250	Accretion physics, black hole demographics
Quasars and Active Galactic Nuclei			
	Continuous UV lightcurves	>7500	Accretion physics, BLR Reverberation mapping
Stars			
	M star flares	$>4\times10^5$	Planet habitability, magnetospheres
	RR Lyrae	>1000	Pulsation physics
	Nonradial hot pulsators, e.g., α Cyg, δ Scuti, SX Phe, β Cep etc. types	>250	Asteroseismology
	Eclipsing binaries	>400	Chromosphere and eclipse mapping
Galaxies and Clusters			
	All Sky Survey – galaxies	$>10^8$	Galaxy Evolution, star formation rate

ULTRASAT implementation

ULTRASAT
SKYLIGHT TO SPACE

Spacecraft: IAI

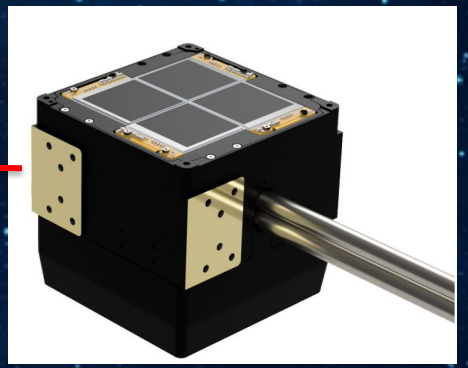
Telescope: Elop/Elbit



33-cm clear aperture

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

Sensors: Tower



Hosted launch to GTO: NASA

Launch Q2 2026
>3.5 year science mission (6 year fuel)

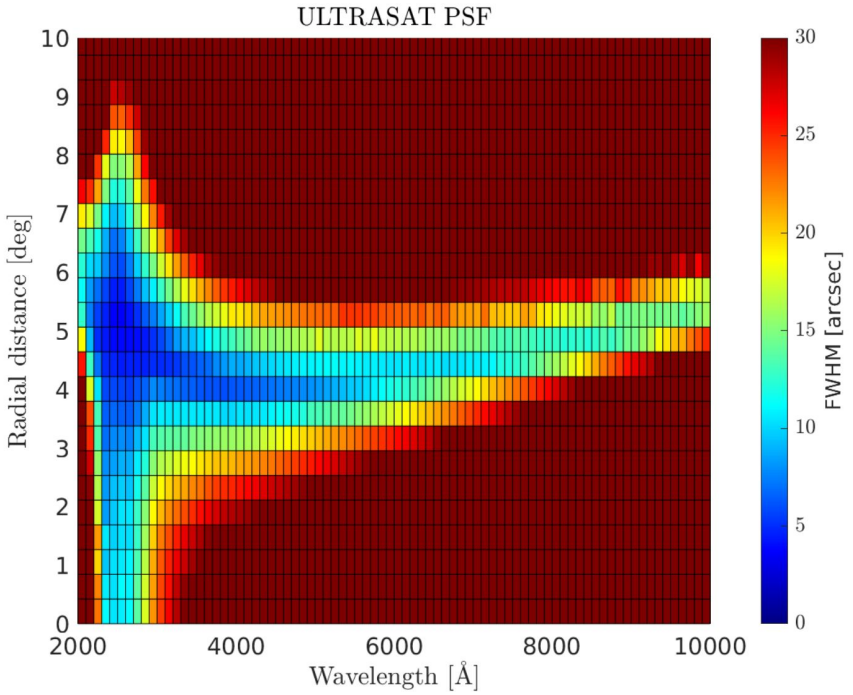
Dimensions: 1.5 x 1.9 x 3.6 (m^3)
Power: 500 W
Mass: 500 + 630 (Prop) kg

Optical Performance

Chromatic position-dependent PSF

Optimized for:

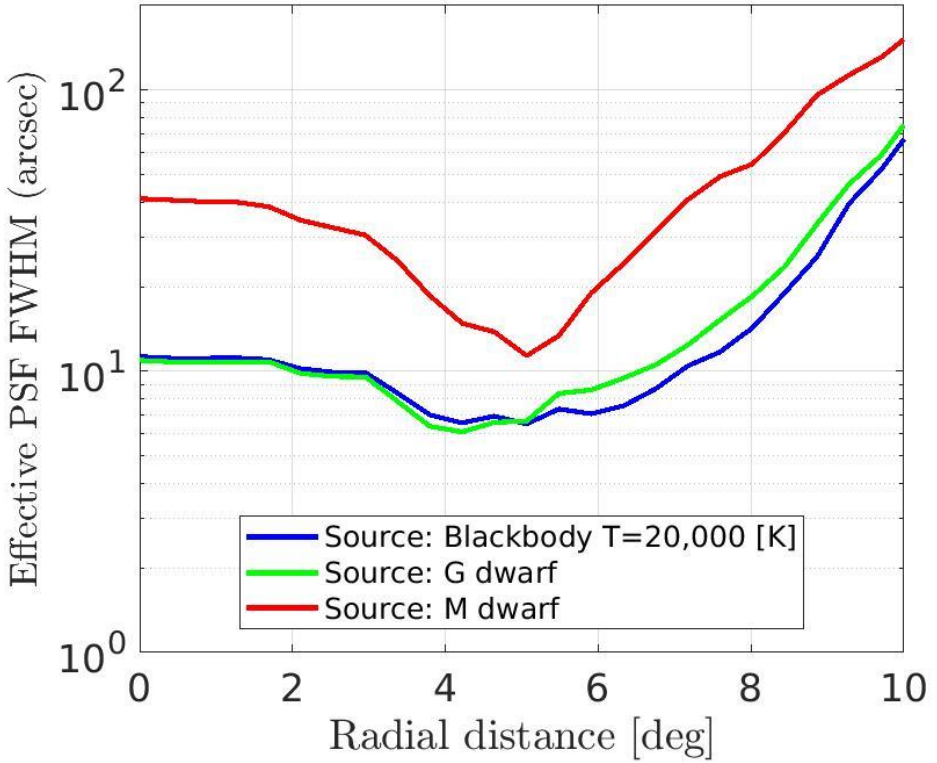
- ULTRASAT band: 230-290nm
- Central 170 deg^2



For more details see: Ben-Ami+2022

Effective PSF

Source and position dependent

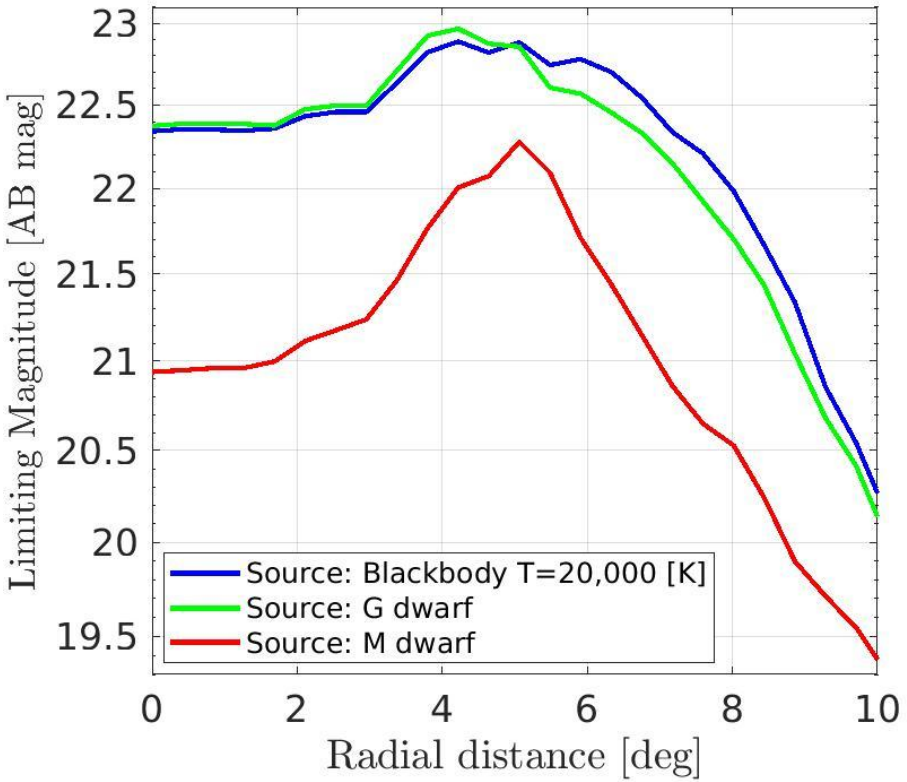


Shvartzvald+ in perp.

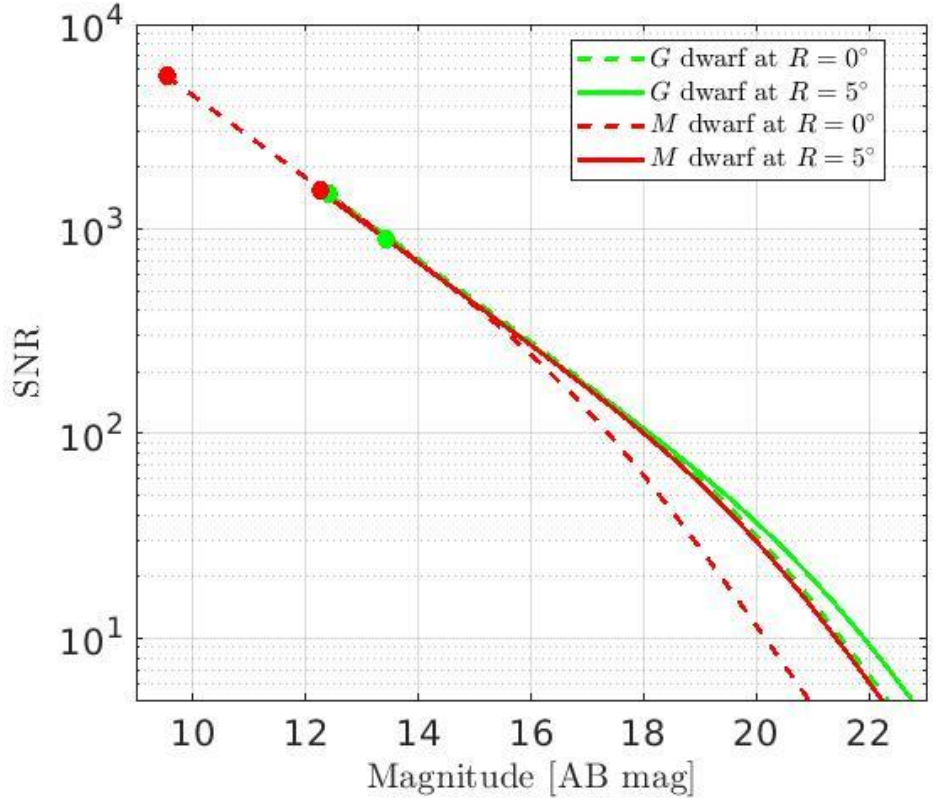
Optical Performance

Limiting magnitude

- Source and position dependent



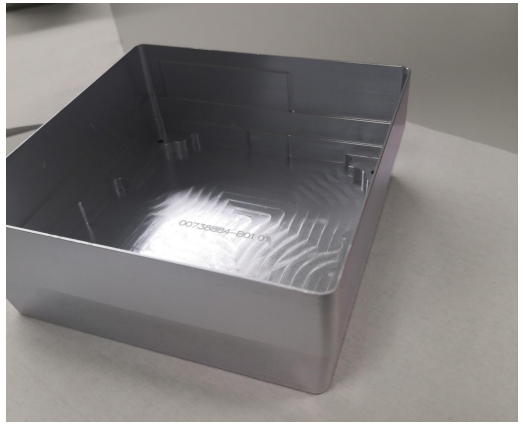
Sensitivity

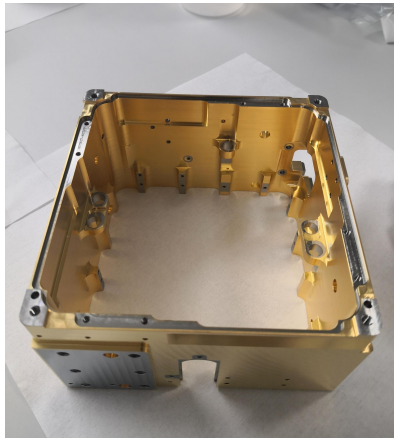


Shvartzvald+ in perp.

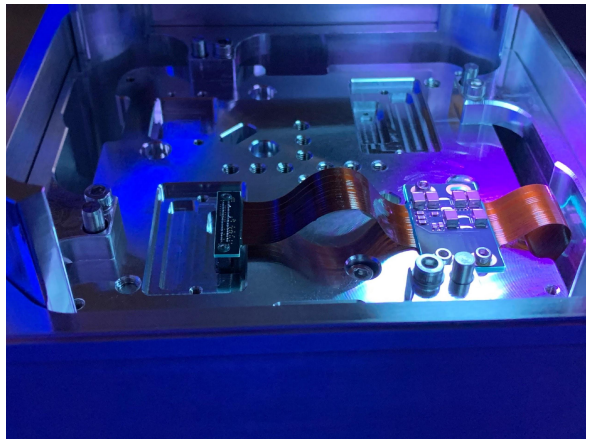
Moving into production phase

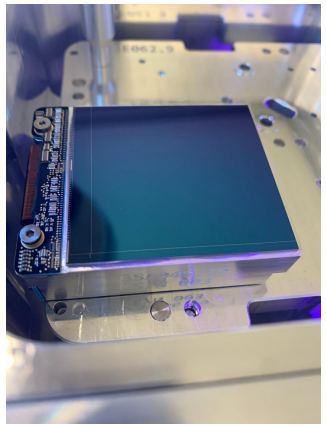
Development camera structure





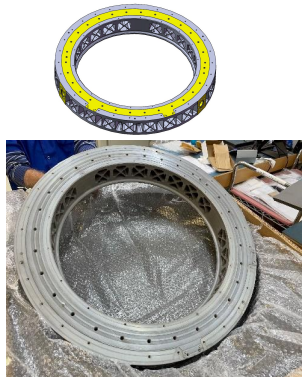
First Sensor Tile



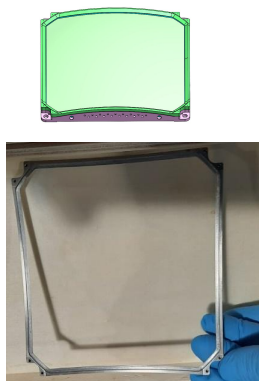


Telescope structure and optics

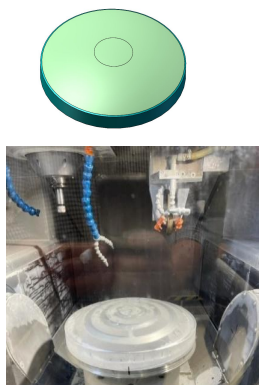
MIRROR



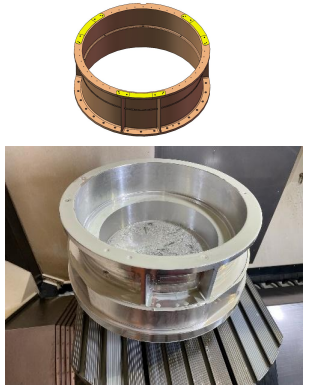
BEZEL



FF2
VANE



SC1



MIRROR TUBE

ULTRASAT: Mission Profile

SURVEY (→ Key goal 2)

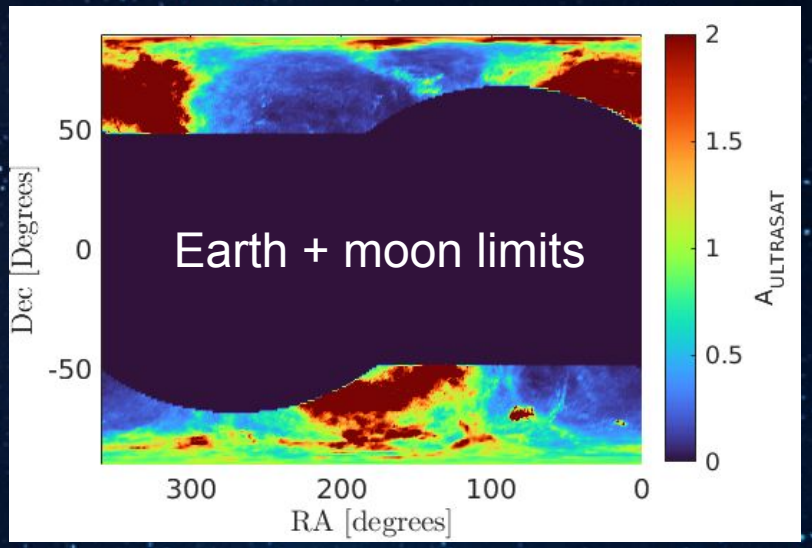
- High cadence - 200 deg^2 with 5 min cadence (21 hr/day)
- Low cadence - 8000 deg^2 with 4 day cadence (3 hr/day)
- Real-time data download and analysis -
  Alerts <15min of observations

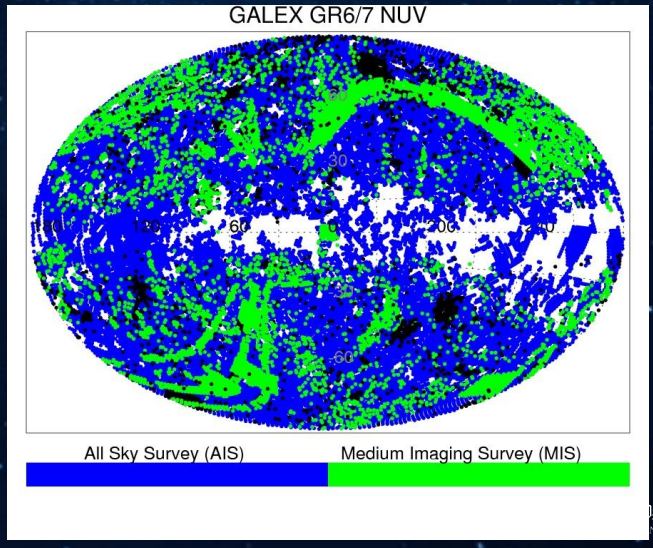
TARGET OF OPPORTUNITY (ToO's; → Key goal 1)

- 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
- 10x deeper than current state-of-the-art (GALEX)
  (>23.5 AB limiting mag @ |b|>30°)





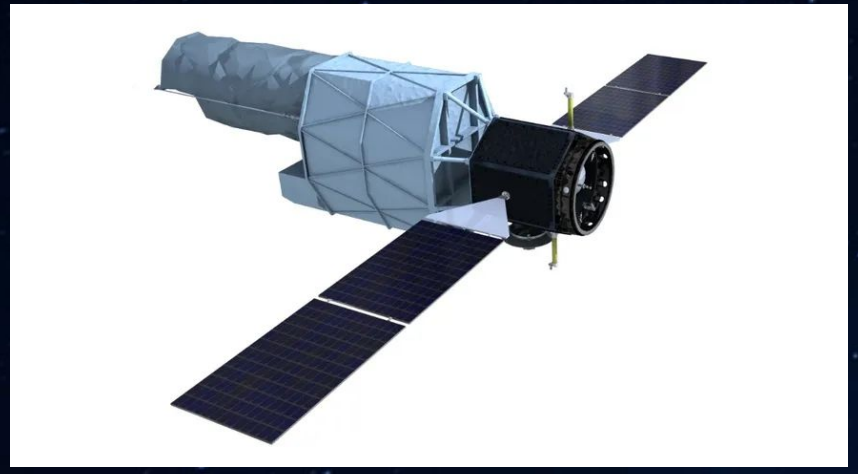
Possible synergies with UVEX

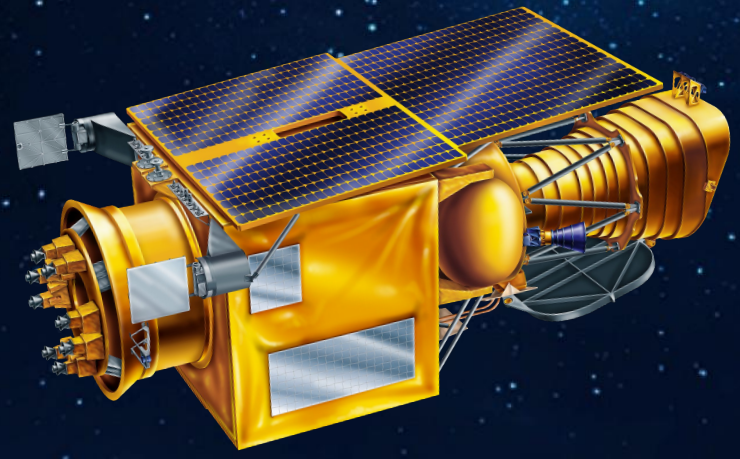
ULTRASAT all-sky map and variable source catalogs (precursor work)

- UVEX NUV band photometric calibration
- Targets for spectroscopic/FUV study

TDAMM science (overlapping operational time)

- Spectroscopic and FUV follow up of ULTRASAT transients
- Specifically, spectroscopy of GW sources





ULTRASAT: Science impact

Revolutionize our view of the hot transient Universe:

- Discovery volume 300 X GALEX
- Continuous (min-mon cadence) in a new window (NUV)
- Real-time alerts to ground/space-based telescopes

A broad impact:

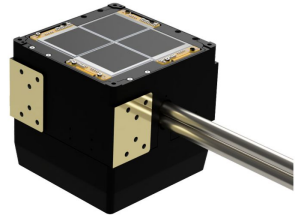
GW sources, SNe, variable and flare stars, AGN, TDEs, compact objects, galaxies.

Groundbreaking science with an affordable satellite mission

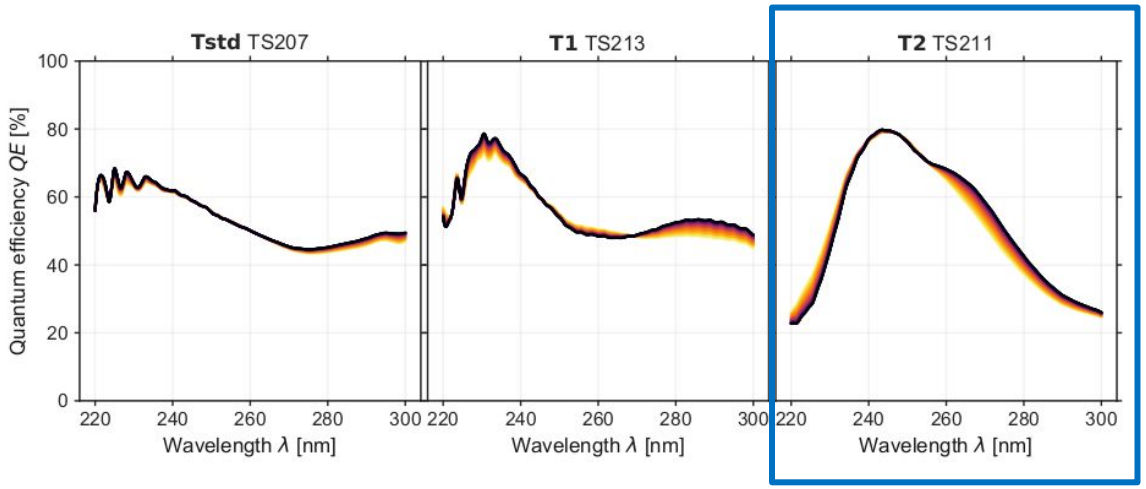
ULTRASAT Participating Scientist Program for US PIs
ROSES 2022 ULTRASAT PSP Element D.19
submission deadline March 31

Backup slides

Focal Plane Array



"Scouts" QE measurements: Optimal ARC selection



- Developed and supplied by DESY
- BSI CMOS from TowerJazz - **production completed!**
- Electronic design **passed full verification**
- Flight sensors diced and now are **being packaged**

Sensor main Spec.

Photosensitive area (**single tile**)	45 x 45 mm^2 **7.14 x 7.14 deg^2**
Pixel size **Pixel scale**	9.5 μm **5.4"**
Mean QE at 230-290nm	>60%
Operation temperature	200±5 °K
Dark current @ 200 °K	<0.03 e^-/sec
Readout noise @ High-gain	<3.5 e^-/pixel
Electronic cross-Talk	<0.01%
Readout time	<20 sec
Pixel sampling scheme	Rolling shutter + Dual gain

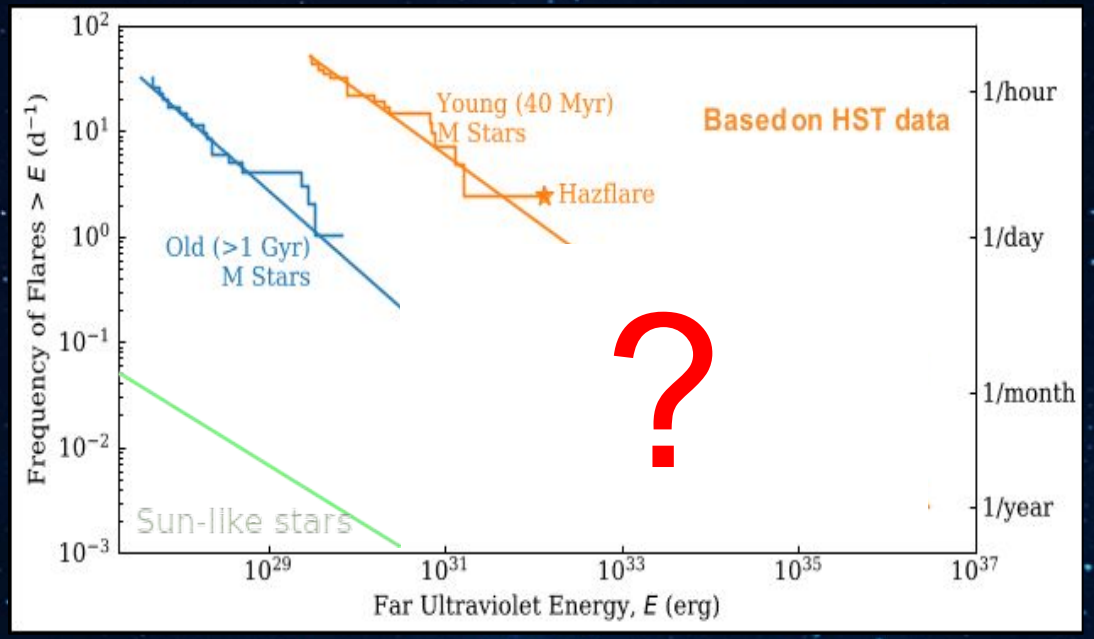
For more details see: Asif+2021
Bastian-Querner+2021
Liran+2022

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

Additional science goal: Planet habitability

- UV flares and Coronal Mass ejections:
  - May **limit habitability**,
  - May **allow prebiotic chemistry**,
  - May produce **false positive biomarker** signatures
    (O_3 from photo-dissociation of H_2O & CO_2).



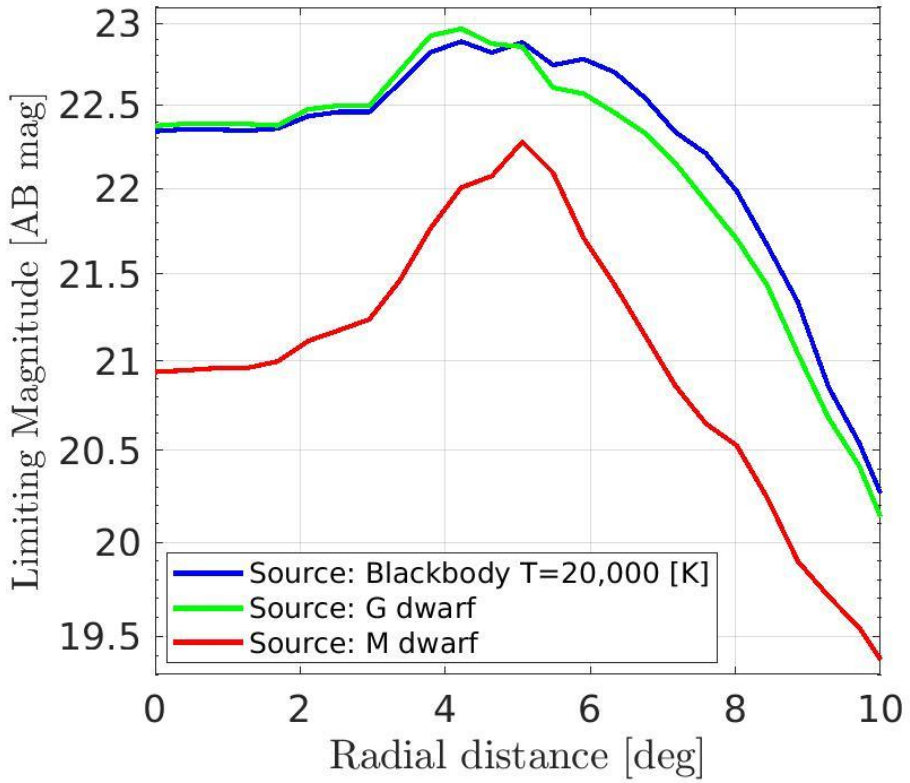
- Flare rates **unknown**.

- ULTRASAT will monitor ~10^6 stars,
  - Measure NUV flare frequency and luminosity distributions
  - Determine best habitable planet candidates (e.g., from TESS) for expensive spectroscopic bio-marker searches, e.g. by JWST.

Optical Performance

Limiting magnitude

- Source and position dependent



Background Noise

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

Shvartzvald+ in perp.

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