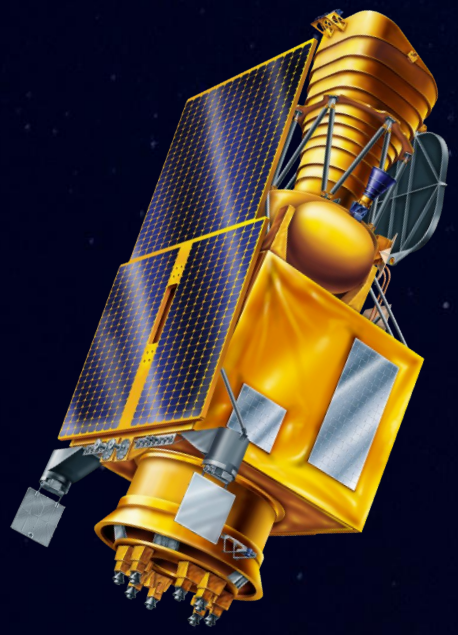
ULTRASAT:
A Wide-Field UV Space Telescope

Revolutionizing our view of the transient universe



PI	E. Waxman (WIS)
Program Manager	U. Netzer (ISA/WIS)
Deputy PI	A. Gal-Yam (WIS)
Camera PI	D. Berge (DESY)
Project Scientist	Y. Shvartzvald (WIS)
Science Lead	E. Ofek (WIS)
Payload Lead	S. Ben-Ami (WIS)
NASA Project Scientist	J. Rhoads (NASA)

Funding partners
ISA
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Yossi Shvartzvald | Weizmann Institute of Science

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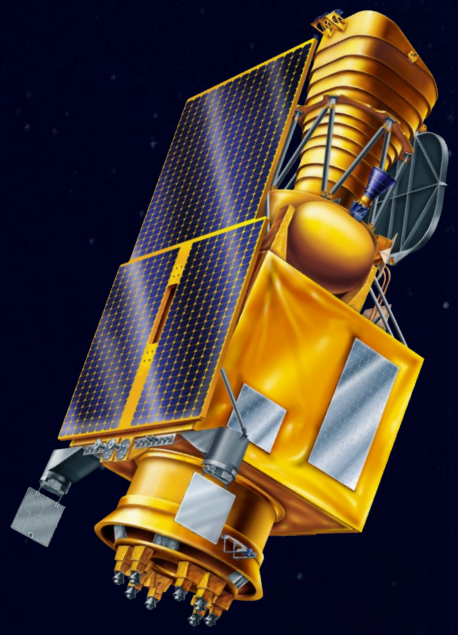

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The study of Transient Cosmic Phenomena is taking Center Stage

ULTRASAT
SKYLIGHT TO SPACE

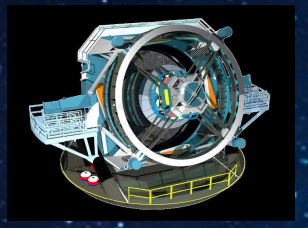
An exciting frontier, Many fundamental open questions

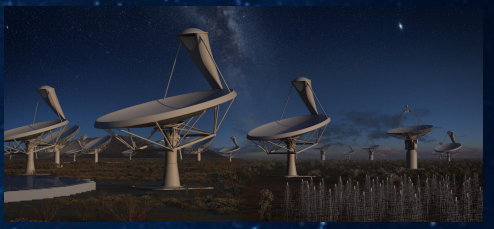
Sources	Open questions
Collisions and mergers of stars	• Where in the Universe are the heavy elements, from Iron to Gold and Uranium, produced? • What are the properties of matter at nuclear density? • How do black holes form? • What is the current expansion rate of the Universe?
Explosive deaths of massive stars	• How do massive stars explode and affect their environment? • What is the pre-explosion evolution & mass loss?
Tidal disruption of stars (TDEs) by super-massive black holes (SMBH)	• What is the SMBH “demographics”? • How do they affect their environment? • How is mass accreted onto BH?
…	…

Why now?

Technology developments enable:

- Wide Field of View surveys:
  Optical (LSST/Rubin), Radio (LOFAR, SKA),
  X/γ-ray (Fermi, SVOM; HAWC, CTA, LHAASO).





- Non-EM (“Multi-Messenger Astronomy”) detectors:
  Gravitational Waves (LIGO, Virgo, KAGRA)
  ν Neutrinos (IceCube, KM3NeT)

Missing: UV

ULTRASAT's uniqueness

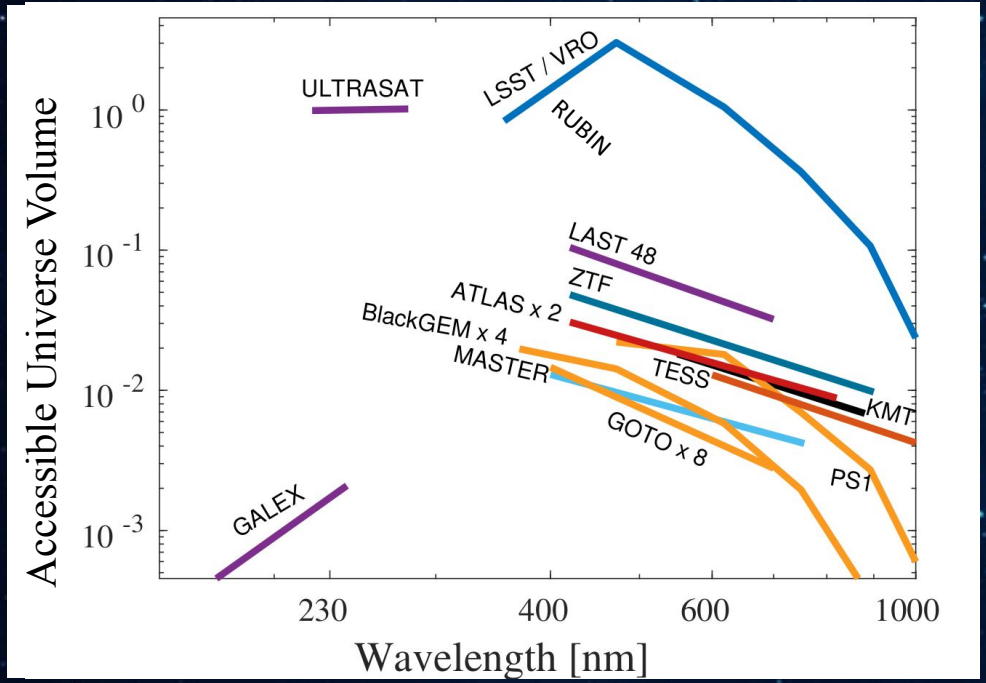
<u>Key Properties</u>

- 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

<u>Key Capabilities</u>

- 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



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ULTRASAT - Key Science Goals

ULTRASAT
SKYLIGHT TO SPACE

<u>EM counterpart to GW sources</u>

Starting 2027: ~ 10's NS-NS merger events per year

~100 deg^2 error boxes

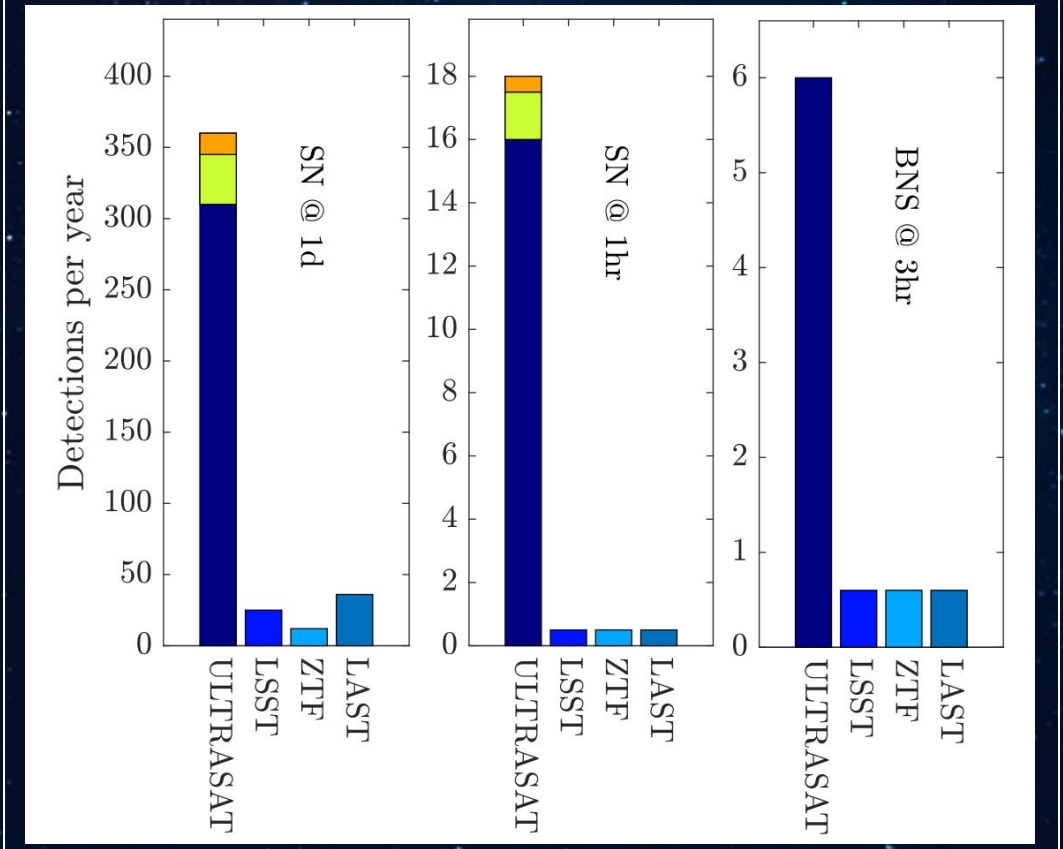
ULTRASAT will provide:

- 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

<u>Death of massive stars</u>

- 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

Annual early detection of SNe & GW/BNS EM counterparts



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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	> 1000	Discriminate between SD and DD progenitors, dust reddening
Compact Object Transients		
Emission from Gravitational Wave events: NS-NS and NS-BH	~ 25	Constrain the physics of the sources of gravitational waves
Tidal disruption events	> 300 (high-cadence) > 4500 (low-cadence)	Accretion physics, black hole demographics
Quasars and Active Galactic Nuclei		
Continuous UV lightcurves	> 7500	Accretion physics, BLR reverberation mapping, lensed quasars
AGN-related flares & transients	> 100	Accretion physics
Stars & Exoplanets		
Active & Flaring stars	$> 4 \times 10^5$	Planet habitability, high-energy flare frequency, stellar magnetic structure, gyrochronology, magnetospheres
White dwarfs	$> 3 \times 10^4$	Planetary systems, debris accretion, rotation-related variability
RR Lyrae	> 1000	Pulsation physics
Nonradial hot pulsators, e.g., α Cyg, δ Scuti, SX Phe, β Cep types	> 250	Asteroseismology
Eclipsing binaries	> 400	Chromosphere and eclipse mapping
Galaxies and Clusters		
All Sky Survey – galaxies	$> 10^8$	Galaxy Evolution, star formation rate
Gamma Ray Bursts		
GRBs occurring in-field	~ 30	Prompt emission & afterglow physics, dust reddening
Orphan Afterglows	> 30	Fireball Γ and opening angle distributions
Solar System		
Asteroids and other small bodies	$> 10^4$	Asteroid classification, origin

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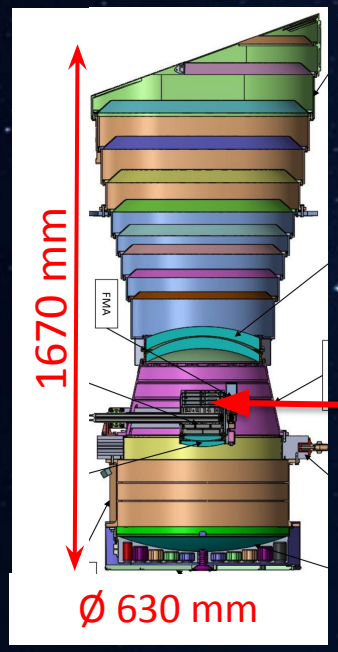
ULTRASAT implementation

ULTRASAT
SKYLIGHT TO SPACE

Spacecraft: IAI

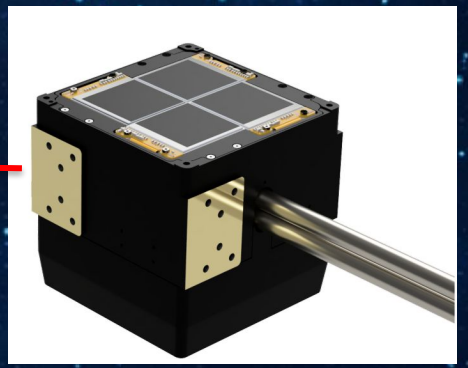
Telescope: Elop/Elbit



33-cm clear aperture

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

Sensors: Tower



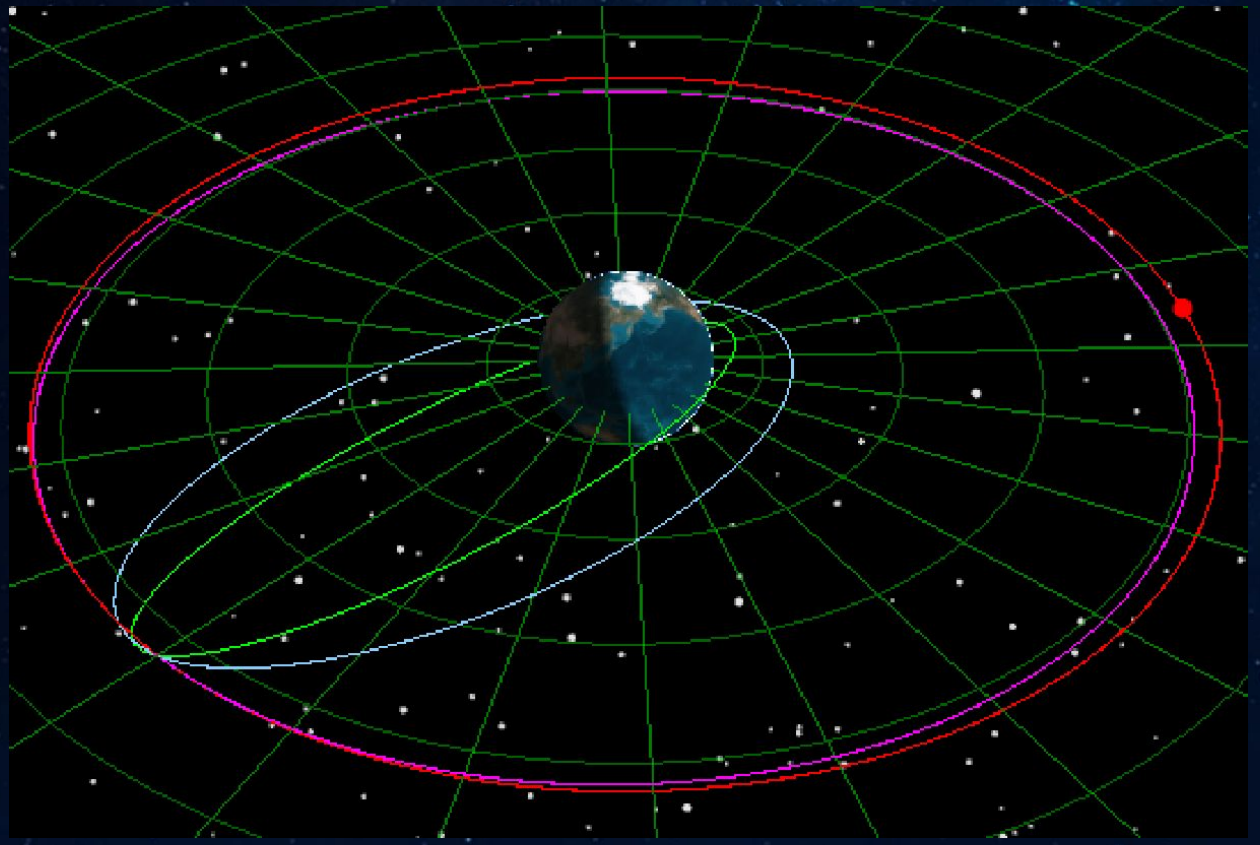
Hosted launch to GTO: NASA

Launch Q3/Q4 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

GTO to Geo Orbit

- Launch to Geo-Transfer-Orbit (GTO)
- GTO to Geostationary (GEO) maneuvers
- Main Mission: 3-6 years



<u>GEO advantages</u>

- Continuous communication:
  - Real-time data download
  - Instantaneous slewing
- Sky accessibility

  >50% of the sky at any given moment
- Avoiding O2 photo-dissociation line

ULTRASAT: Mission Profile

SURVEY (→ Key goal 2)

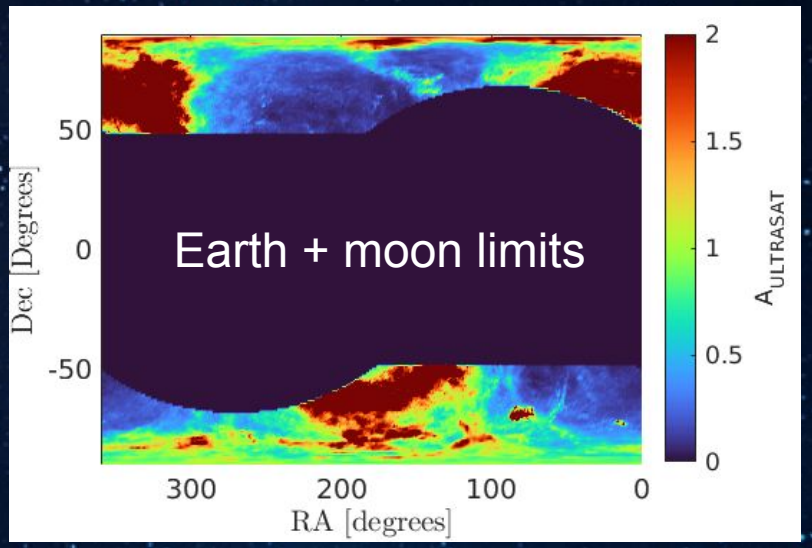
- High cadence - 200 deg^2 with 5 min cadence (21 hr/day)
- Low cadence - 8000 deg^2 with 4 day cadence (3 hr/day)
- Real-time data download and analysis -
  Alerts <15min of observations

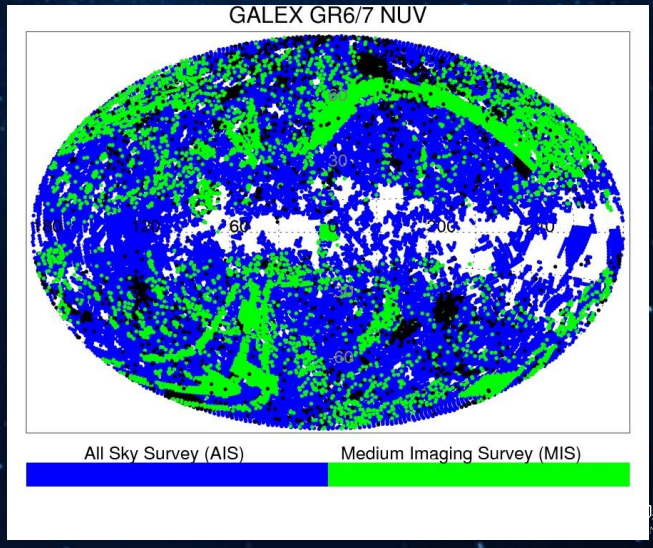
TARGET OF OPPORTUNITY (ToO's; → Key goal 1)

- 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°)



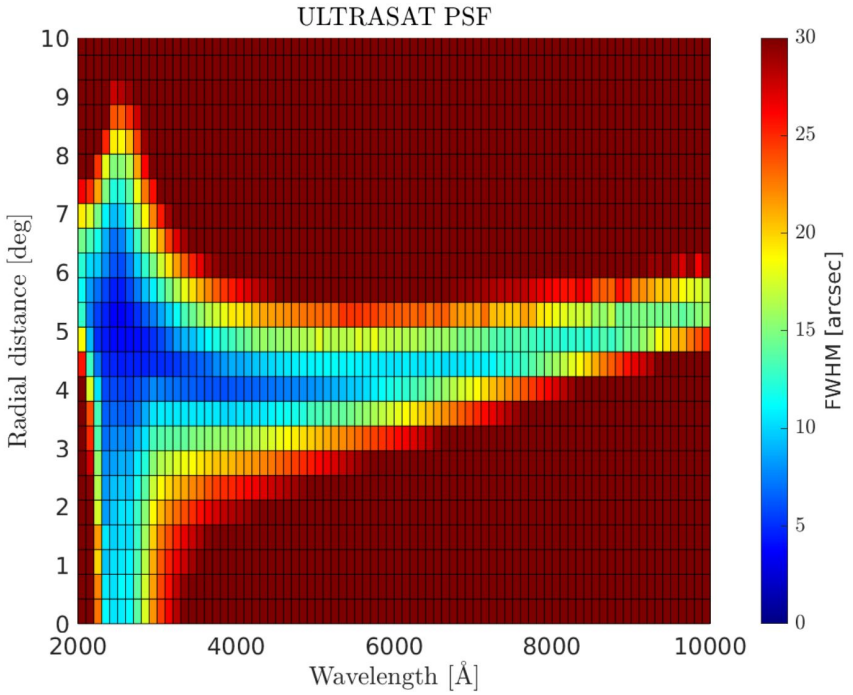


Optical Performance

Chromatic position-dependent PSF

Optimized for:

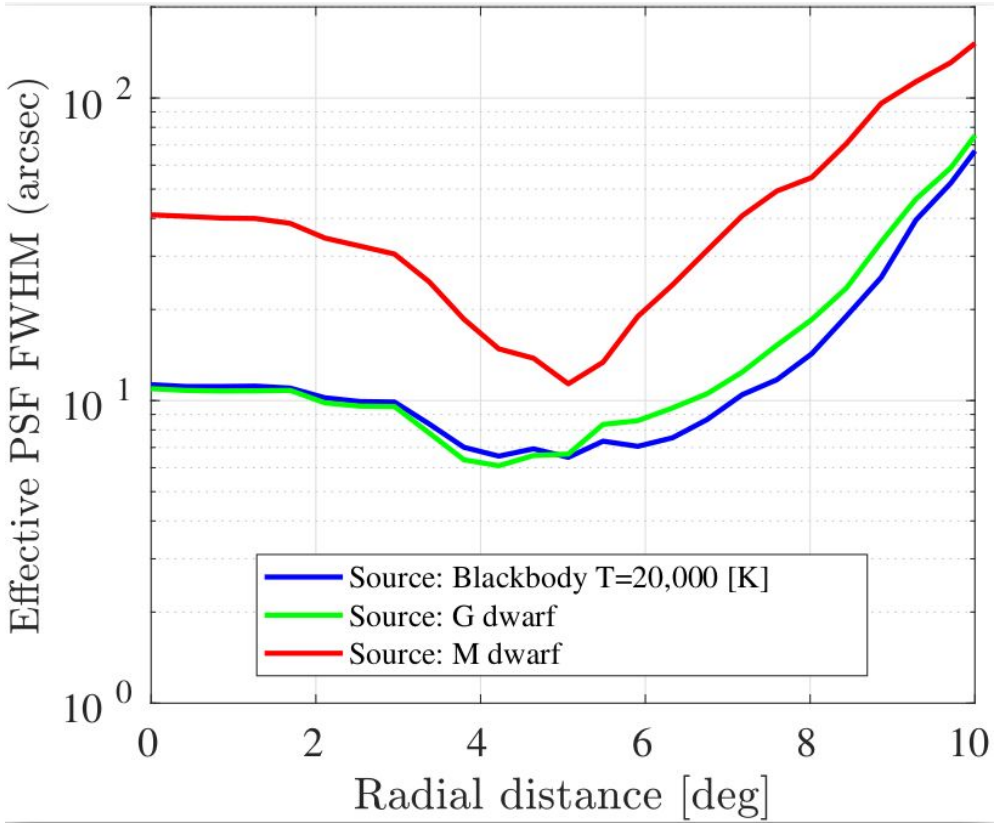
- ULTRASAT band: 230-290nm
- Central 170 deg^2



For more details see: Ben-Ami+2022

Effective PSF

Source and position dependent



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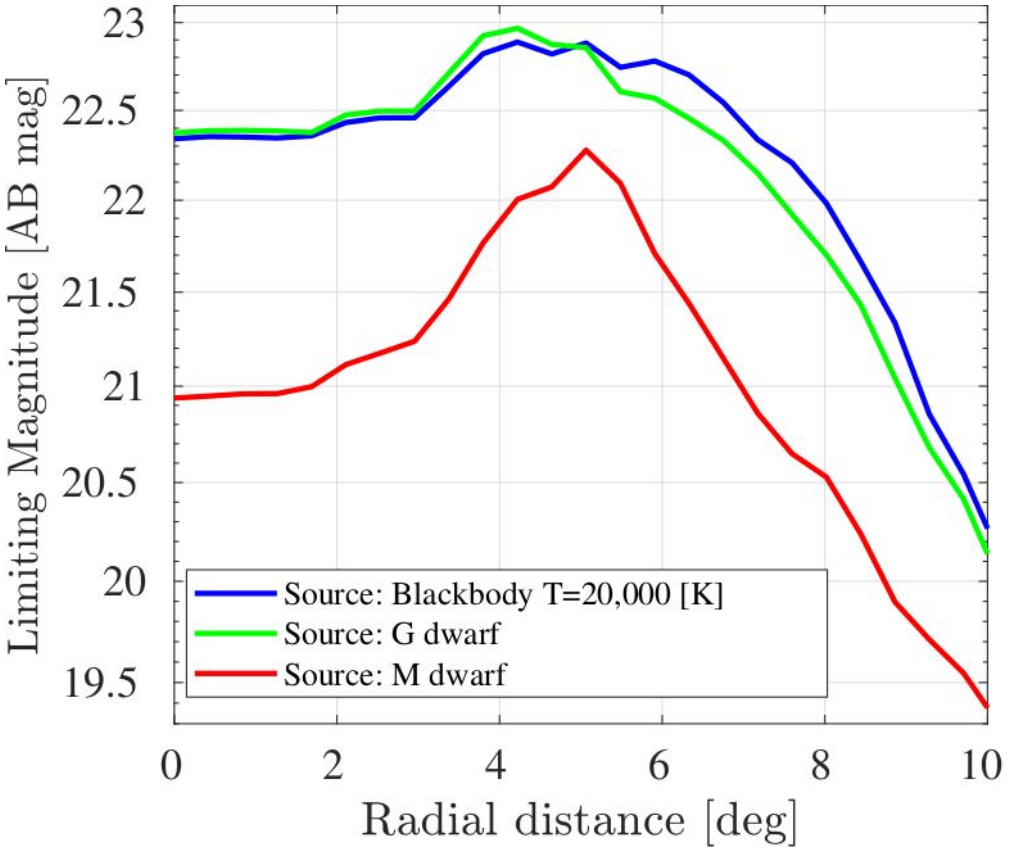
Optical Performance

Limiting magnitude

- Source and position dependent



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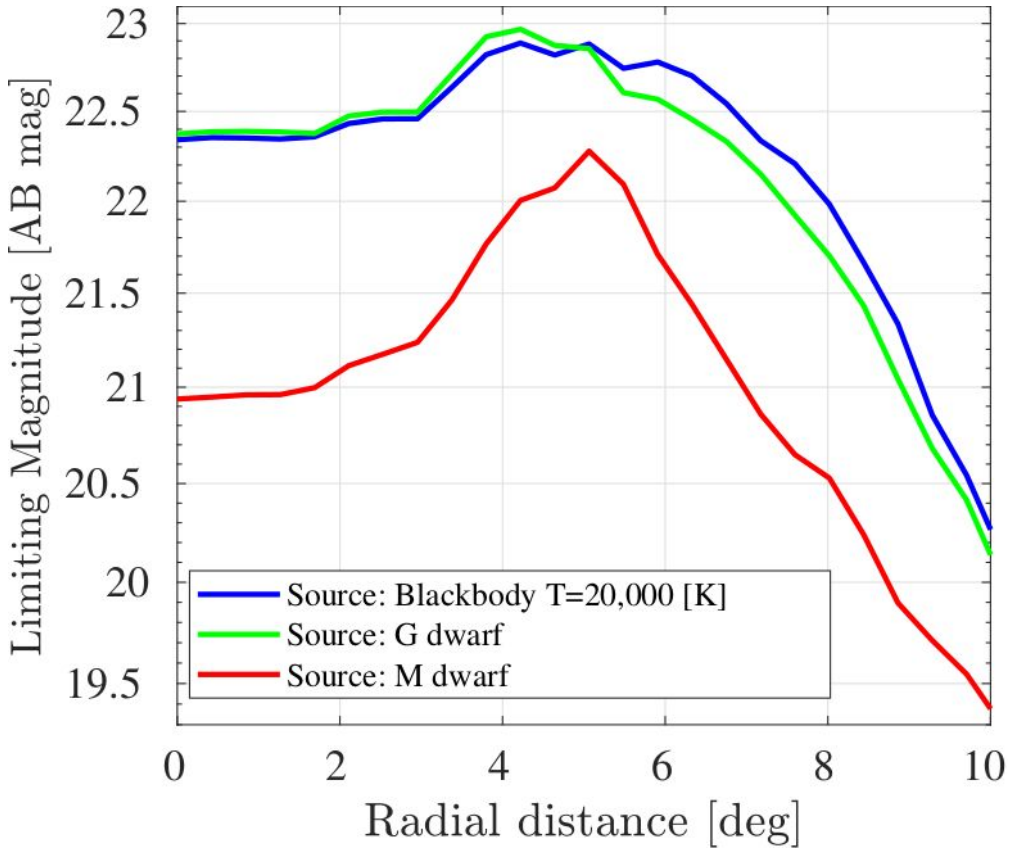
Background Noise

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**

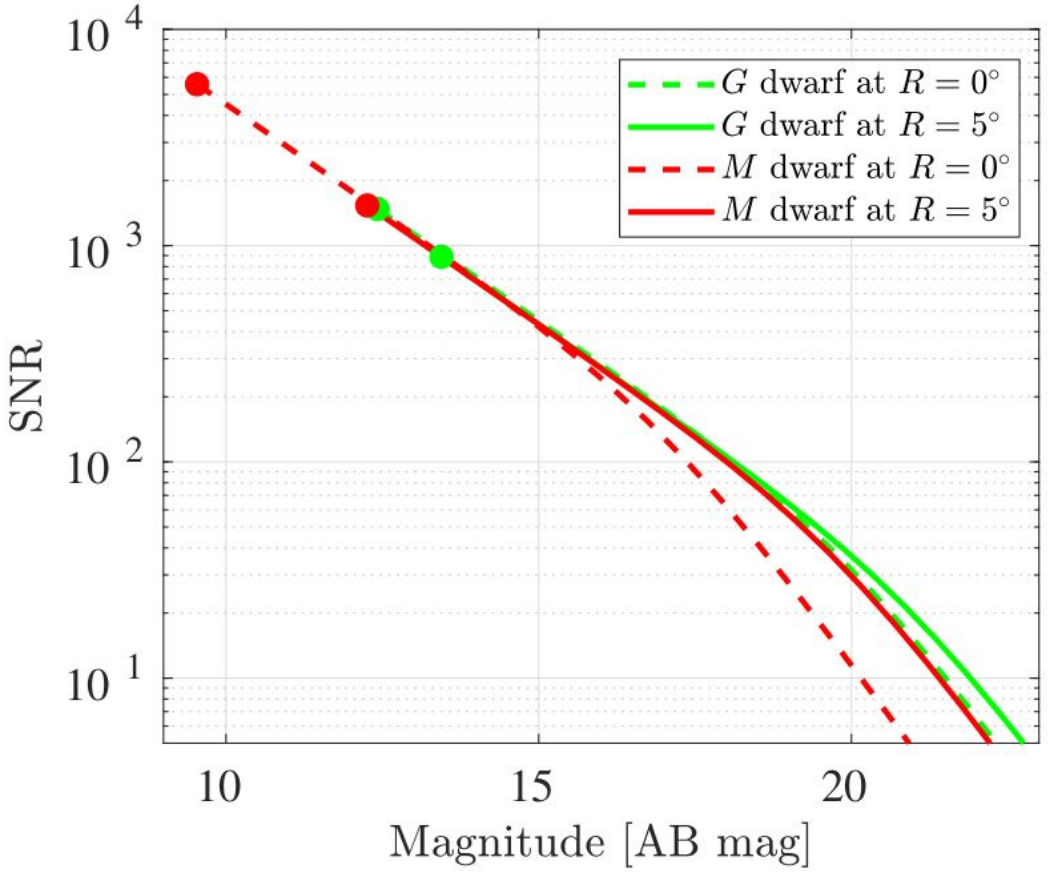
Optical Performance

Limiting magnitude

- Source and position dependent



Sensitivity



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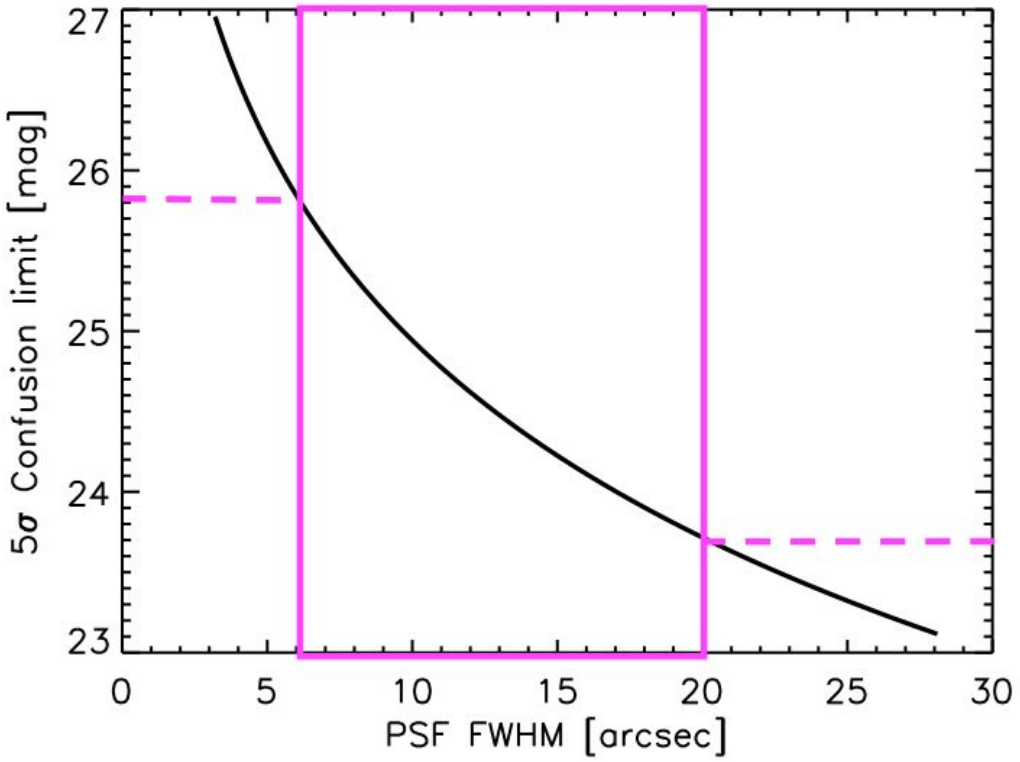
Optical Performance

Confusion Limit

- Condon (1974) analytic formula
- Confirmed by simulated images



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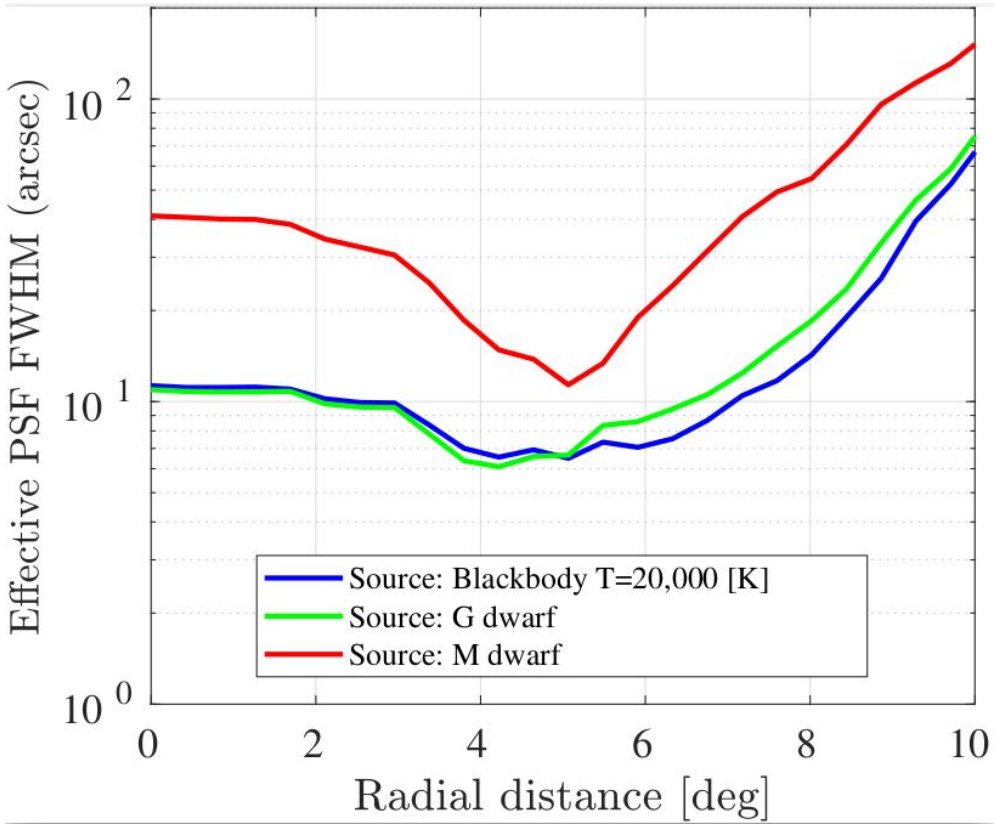
Source and position dependent



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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