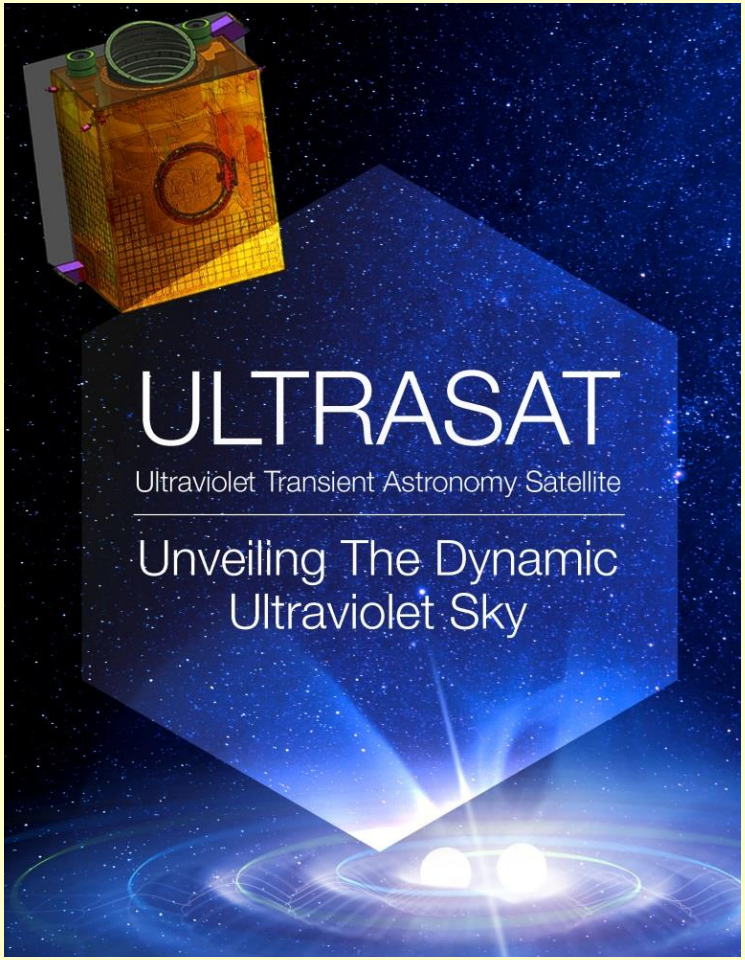
ULTRASAT: Ultra-Violet Space Telescope



Lead the research on the most exciting (astro)physics questions of the decade.

The study of Transient Cosmic Phenomena is taking Center Stage

An exciting frontier, many fundamental open questions

Sources	**Open questions**
Collisions and mergers of stars	- Where did the heavy elements, from Iron to Gold and Uranium, form? - 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?
Tidal disruption of stars 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 enables telescopes with very large fields of view,

Crucial for "catching" transient events.

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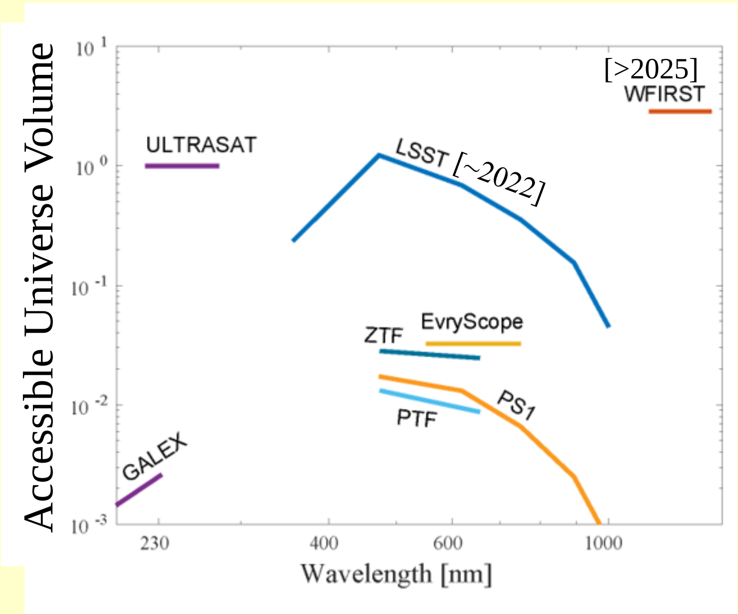
ULTRASAT will be unique and superior to all other missions.

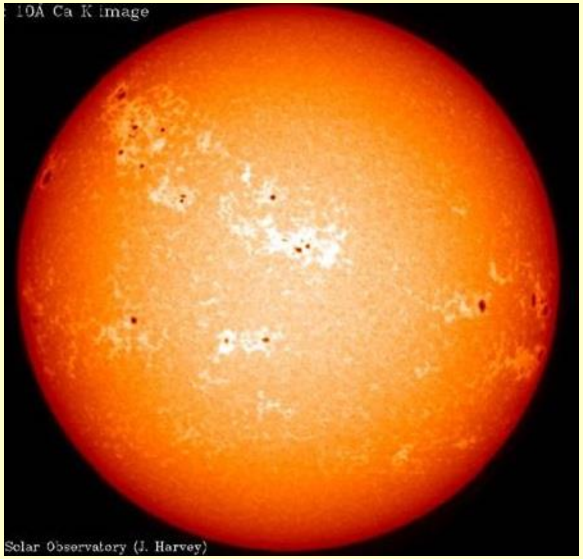
- Survey a volume of the universe that is A 100 times larger than current surveys, Comparable to that of the largest planned (>2022) ground based facility, LSST.
- Measure Ultra-Violet (UV) light, that cannot penetrate the atmosphere.
- Real-time alerts to ground/space-based telescopes, initiate world-wide follow-ups.



ULTRASAT Field of view:
200 squared degrees
=1000 times the full moon.
Hubble Space telescope:
1% of the moon.

Key Science Goal 1: Mergers of Neutron Stars

Stars



Sun

M = 1 M_{sun}

R = 670,000 km

Density ~ 1 g/cc

Supported by Thermal pressure

T~10 Million degrees K

Burns (fusion) H to He

Earth

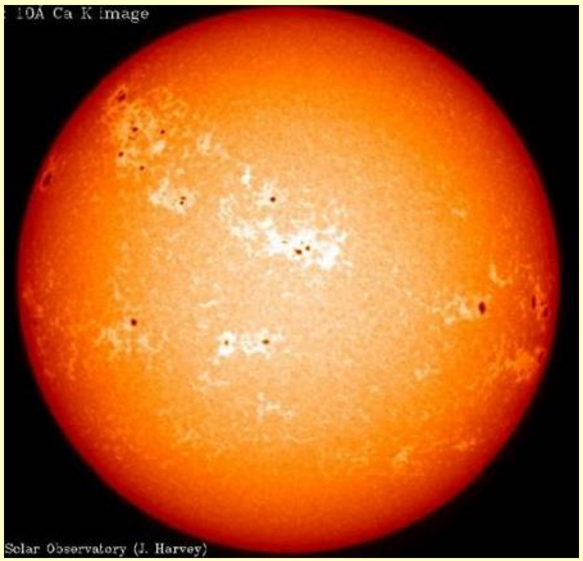
M_{sun}/Million

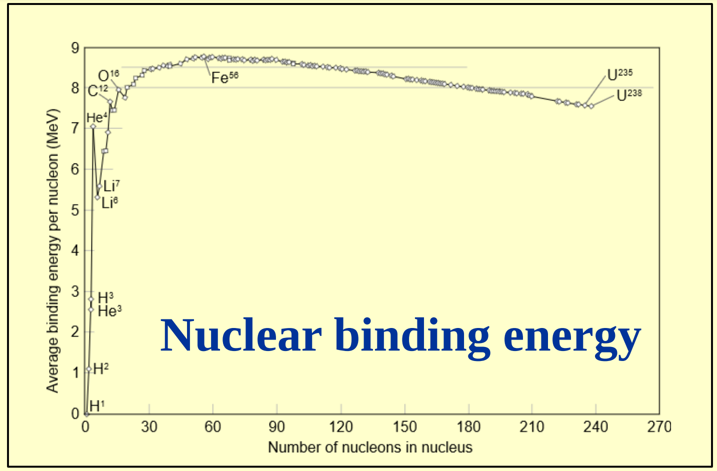
6,400 km

1 g/cc

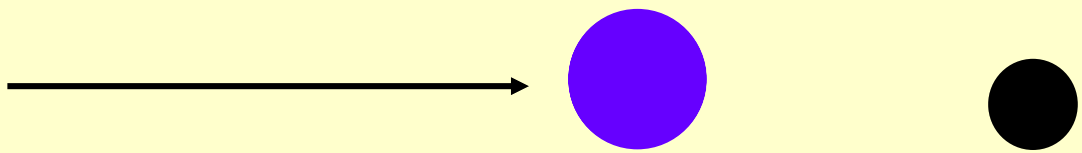
Electrostatic forces

The life of Massive stars





"Dead" remnants of massive stars



Massive Stars
M ~ 10 x M_{sun}

Neutron Star
1 M_{sun}
10 km
10^{14}g/cc

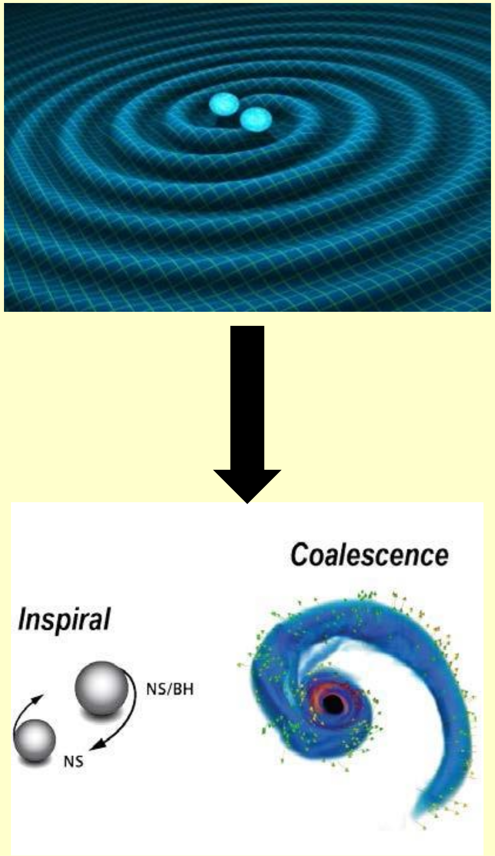
Black Hole
1 M_{sun}
3 km

Burn H → He → C/O → Si → Fe

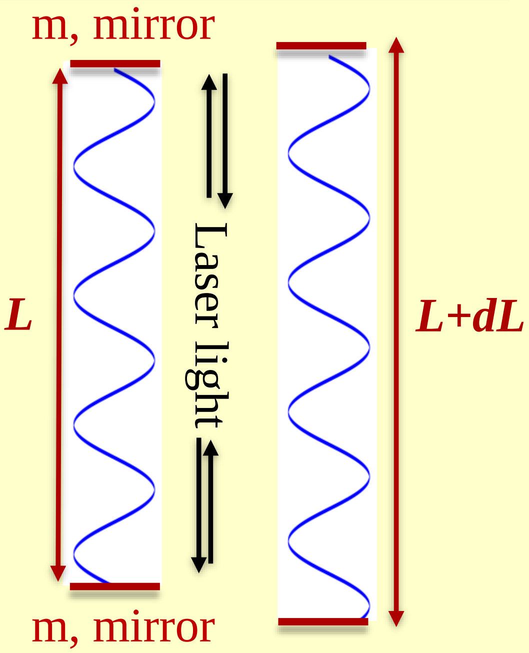
- And then, collapse and explode as Supernova- how?
- How are elements beyond Fe produced?

Merging Binary Neutron Stars / Black Holes

- Most stars "live" in binaries
- Massive star binaries may lead to the formation of binary Neutron Star / Black Hole systems
- "Tight" NS/BH binaries, separation < 1 Million km, can merge by emitting Gravitational Waves (GW).
- Detection of GW from a merger - Fundamental test of Einstein's Gravity (1916)

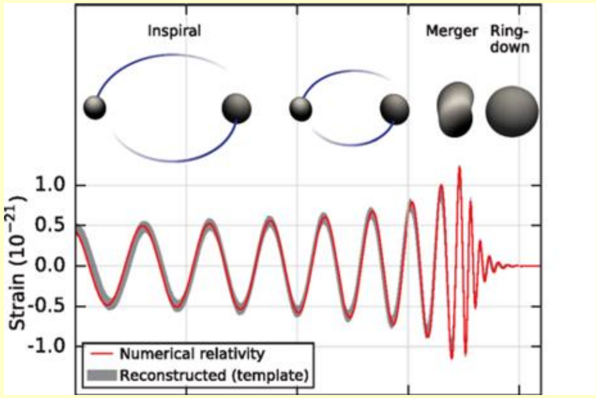


First direct detection of Gravitational Waves [2016]



- 2016:
  LIGO detects a 2x 30 solar mass BH binary merger.
- Distance ~ 1 Billion light years.

- 2017 Physics Nobel Prize
  R. Weiss, B. Barish, K. Thorne.

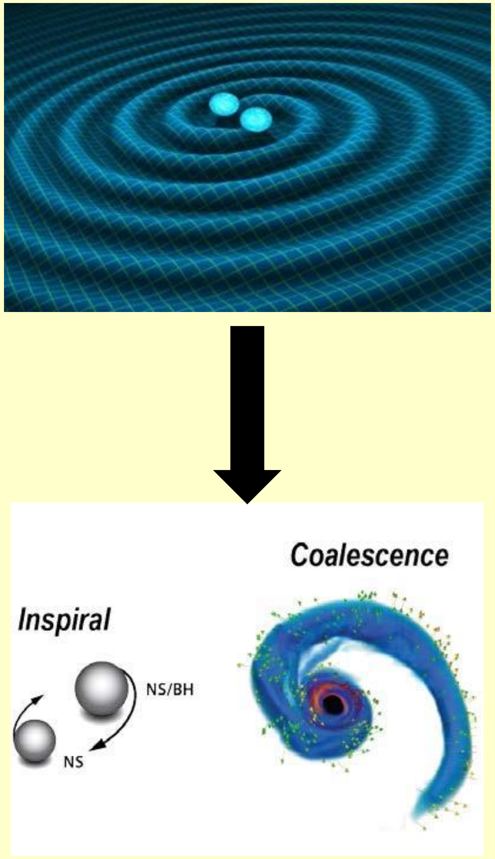


Detecting GW and light from NS-NS/BH mergers

- Nuclear density radioactive material torn and ejected at close to light speed. May be the source of the heavy elements, beyond Iron (up to Gold & Uranium).

- Detecting light, from radioactive material, following GW, is (one of) the major goals of astronomy in the coming decade:

- Identify the origin of heavy elements
- Study the properties of material at nuclear density
- Study the formation of Black Holes
- Accurately localize the merger, identify host galaxy Measure the expansion rate of the Universe

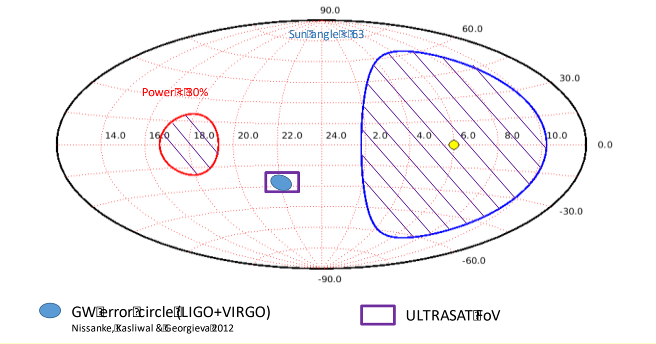


Key Science Goal 1: Mergers of Neutron Stars

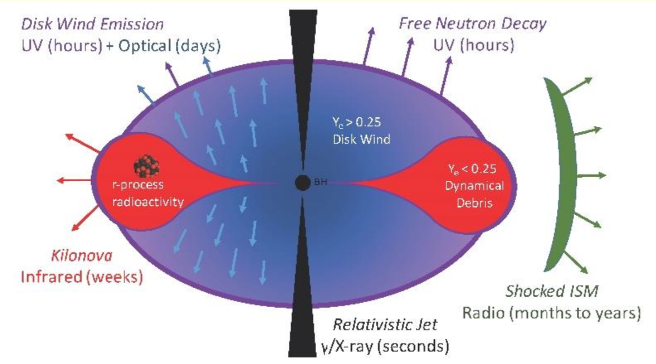
- Starting ~2024, GW detectors will improve detection horizon to ~ 1 Billion light years, provide ~ 10 NS-NS merger events per year, with ~100 squared degree error box. (Until then - a few in total.)

- Light detection- ULTRASAT:
  - Instantaneous >50% of sky in <5 min. (10 times better than ground based).
  - Cover GW error box in a single image.
  - Sensitive out to >1 Billion light years.

ULTRSAT's ToO access



Bright, Early (hr) UV emission expected



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Must be in space by 2024

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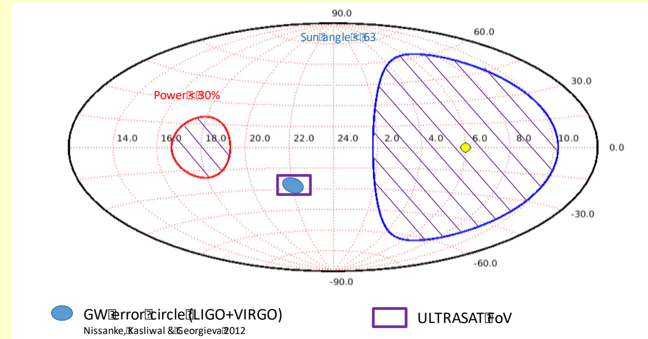

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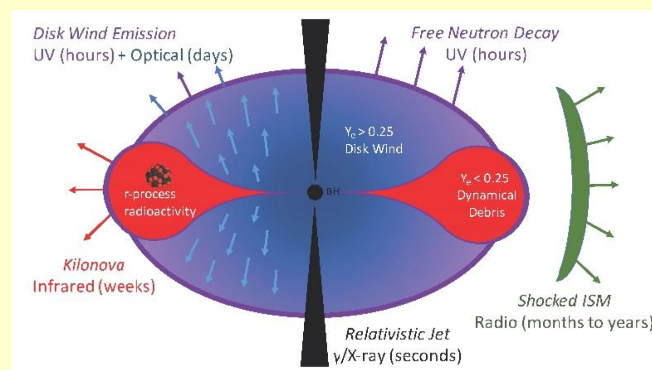

First detection of GW from a NS merger [2017]

- Very nearby, ~ 120 million light years.
  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 1 Billion light years- 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.

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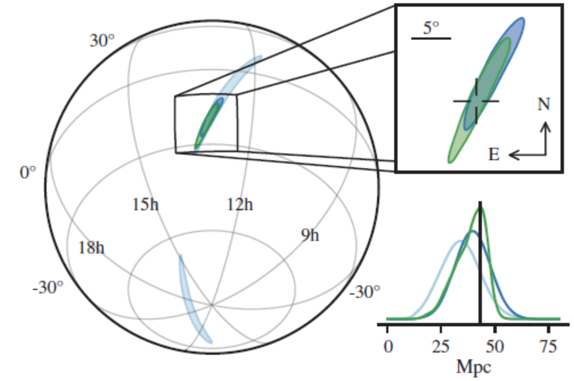
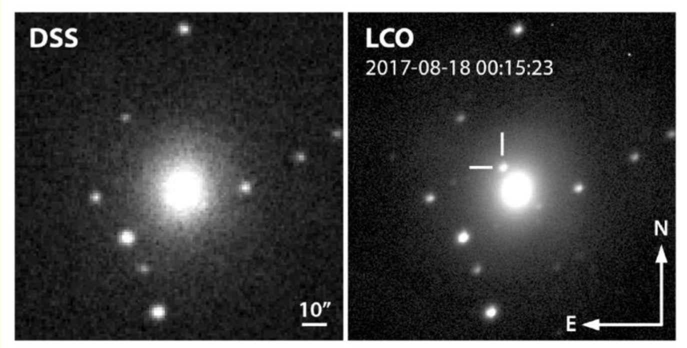


FIG. 3. Sky location reconstructed for GW170817 by a rapid



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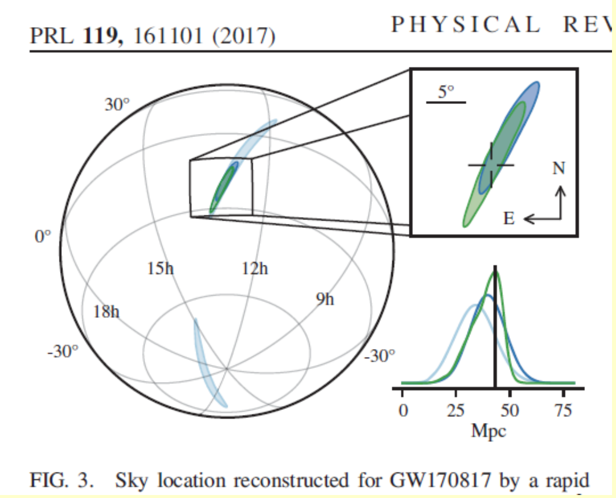
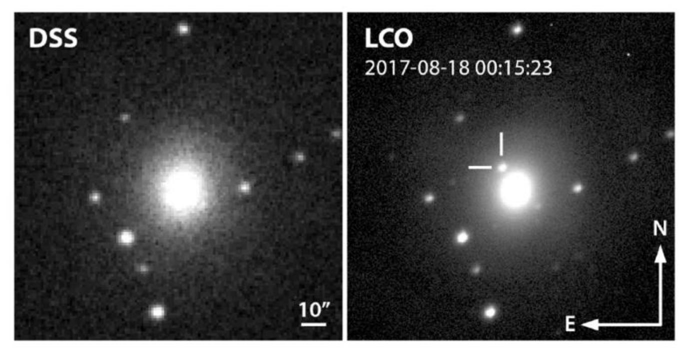




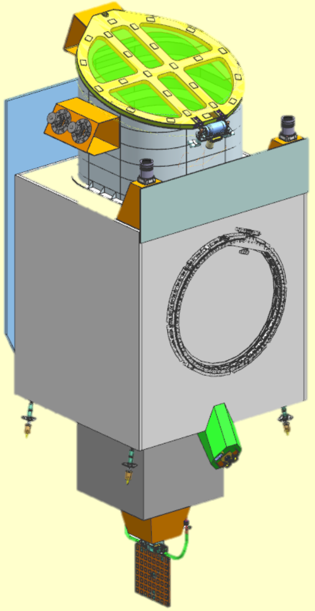
Strong support to ULTRASAT

ULTRASAT: Science highlights

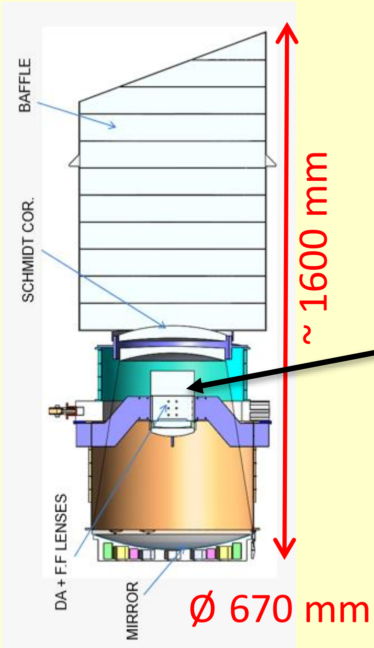
Source Type		# Events	Science Impact
Supernovae			
	Shock break-out and Early (shock cooling) of core collapse SNe	>30 >400	Understand the explosive death of massive stars
	Superluminous SNe	>200	Early evolution, shock cooling emission
	Type Ia SNe	>30	Discriminate between SD and DD progenitors
Compact Object Transients			
	Emission from Gravitational Wave events: NS-NS and NS-BH	~20	Constrain the physics of the sources of gravitational waves
	Cataclysmic variables	>20	Accretion and outburst physics
	Tidal disruption of stars by black holes	>200	Accretion physics, black hole demographics
Quasars and Active Galactic Nuclei			
	Continuous UV lightcurves	>6000	Accretion physics, BLR Reverberation mapping
Stars			
	M star flares	$>3\times10^5$	Planet habitability, magnetospheres
	RR Lyrae	>800	Pulsation physics
	Nonradial hot pulsators, e.g., α Cyg, δ Scuti, SX Phe, β Cep etc. types	>200	Asteroseismology
	Eclipsing binaries	>300	Chromosphere and eclipse mapping
Galaxies and Clusters			
	All Sky Survey – galaxies	$>10^8$	Galaxy Evolution, star formation rate

ULTRASAT: Implementation

Spacecraft: IAI



Telescope: Elop/Elbit



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

Components contribution: ESA

Hosted launch to GEO: NASA

>3 year science mission

Dimentions: 1 x 1 x 1.7 (m^3)
Power: <300 W
Mass: <300 kg

ULTRASAT: Impact

- Provide groundbreaking high profile science
  with a small, affordable satellite.

- Put Israel at the forefront of Observational Astrophysics.

- Put Israeli industry at the forefront of a global movement to explore the Universe with small, affordable satellites.

- Enhance international collaborations with leading Agencies and Industries.
  NASA & ESA are joining an Israeli led Science project.

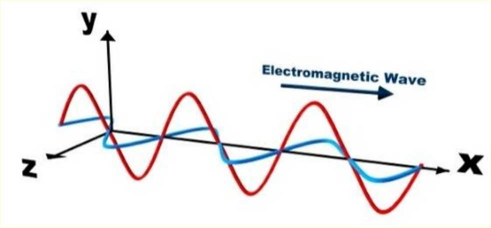
- Draw Israeli students to science and technology studies.

Gravitational Waves

Electro-Magnetic Transmitter

Accelerating electric charge (dipole) → **EM Wave** →

e⁻



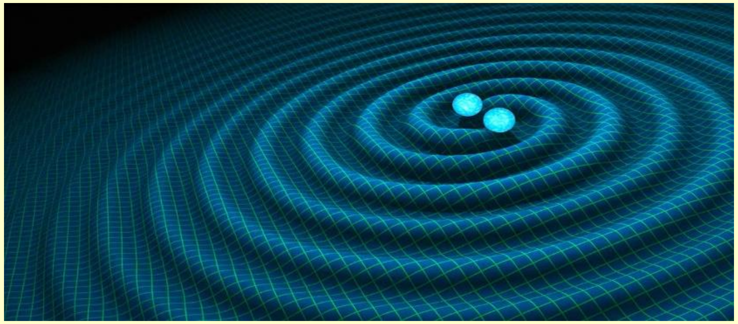
Receiver

Accelerating electric charge

e⁻

Gravitational "Transmitter"

Accelerating mass → **GW** →



Gravitational Antenna

Accelerating mass

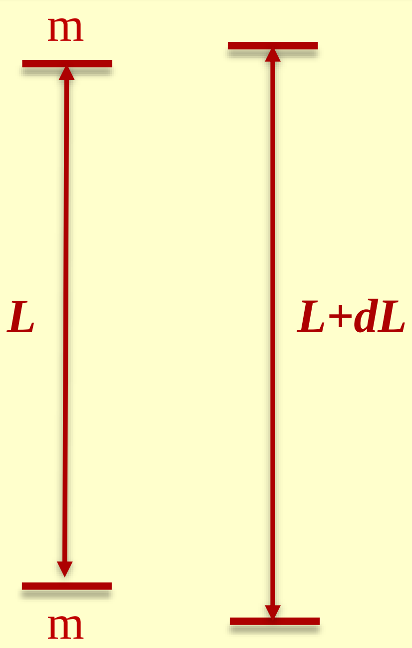
m

Detecting Gravitational Waves: The Challenge

- Predicted by Einstein's theory of gravity in 1916

- Challenge: $\frac{dL}{L} = \frac{1}{1{,}000{,}000\ldots000}$

  ←→ 21 zeros



Must be in space by 2024

- Be ready for the GW detector upgrade.
- Beat emerging competition.