

Multi-Messenger Astronomy with Gravitational Waves

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Outline

Why EMGW

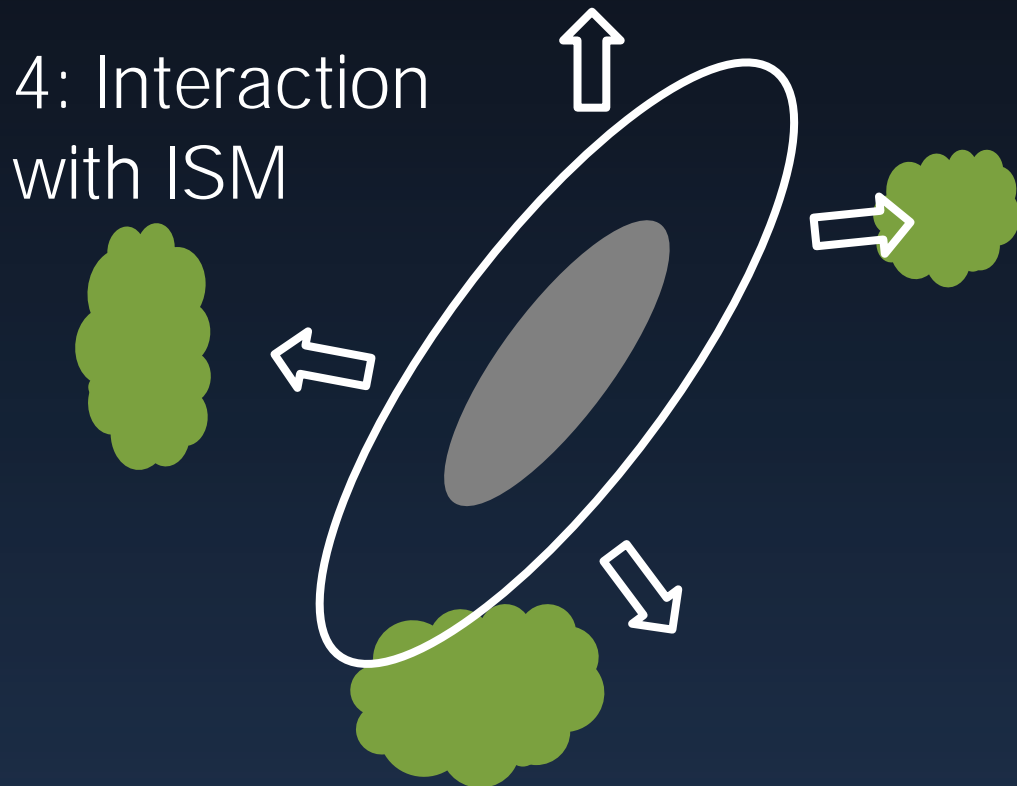
What and how: today

Tomorrow

Transient sources of GW

- Binary systems:
 - » Black hole + Black hole
 - » Black hole + Neutron Star
 - » Neutron Star + Neutron Star
- Core collapse supernovae
 - » If asymmetric explosion
- Unknowns!

Electromagnetic Counterparts



Complementary information

GW

- Masses
- Spins
- Geometric properties
 - » Position
 - » Distance
 - » Inclination angle...

EM

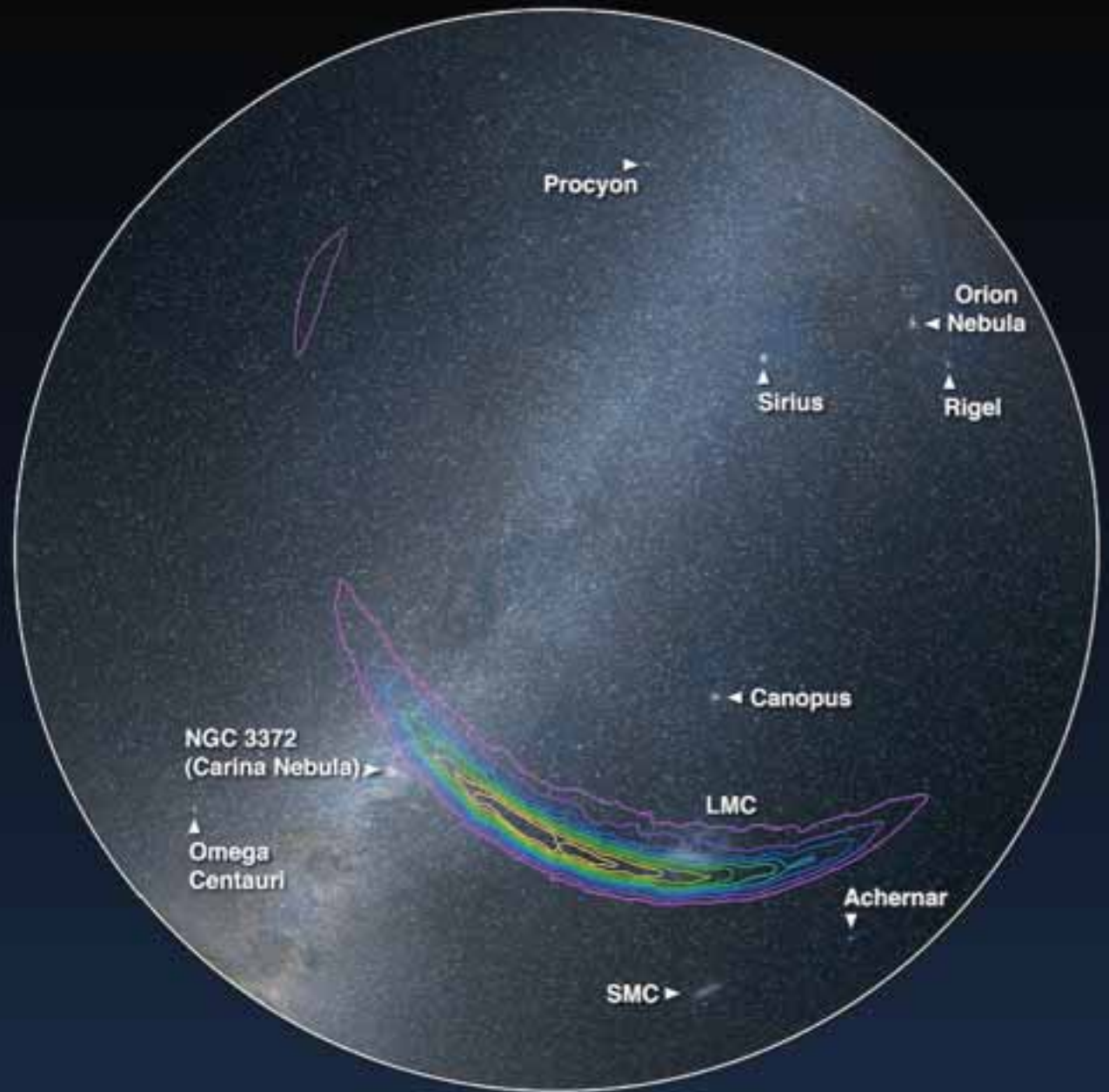
- Precise location
- Nucleosynthesis
- Ejecta properties
 - » Beaming
 - » Mass
 - » Velocity...
- Cosmology

Complete astrophysical picture

Large positional uncertainty

GW150914:
90% containment
region spans
630 square degrees

*(arXiv:1602.08492,
Abbott et al., including
V. Bhalerao)*



Credit: M. Zevin / Astrobites / LVC / arXiv:1602.03840

Localization

2 detectors
250 deg²

Typical
telescope:
15'

Ursa Major

~ 160 images

4 det
10 deg²

The complete story



Sound + images show Bailey was out in the India-Australia match on 12 Jan 2016.

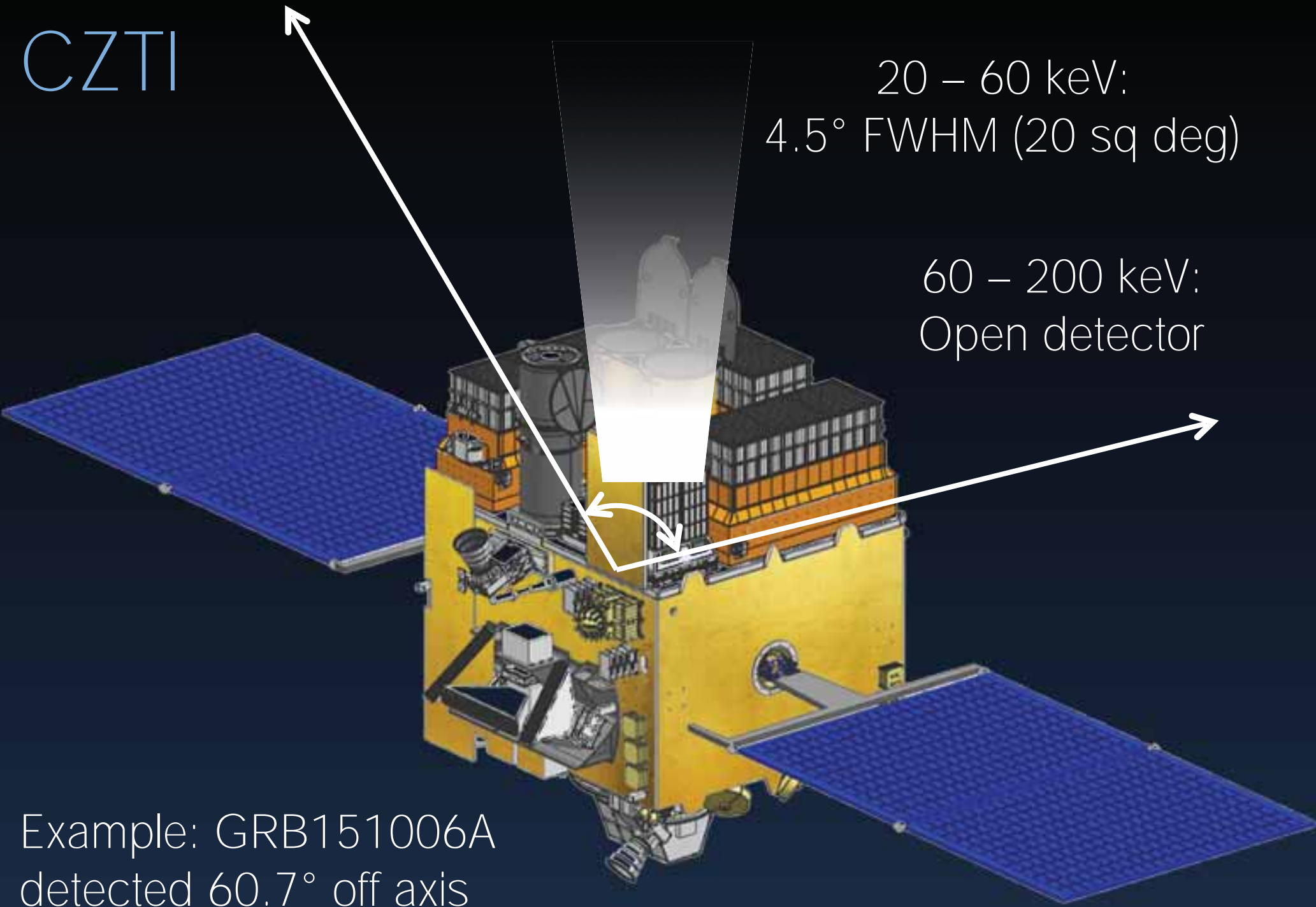
Image credit: Rediff / Fox news / Twitter

Electromagnetic follow up: the Indian context

CZTI

20 – 60 keV:
4.5° FWHM (20 sq deg)

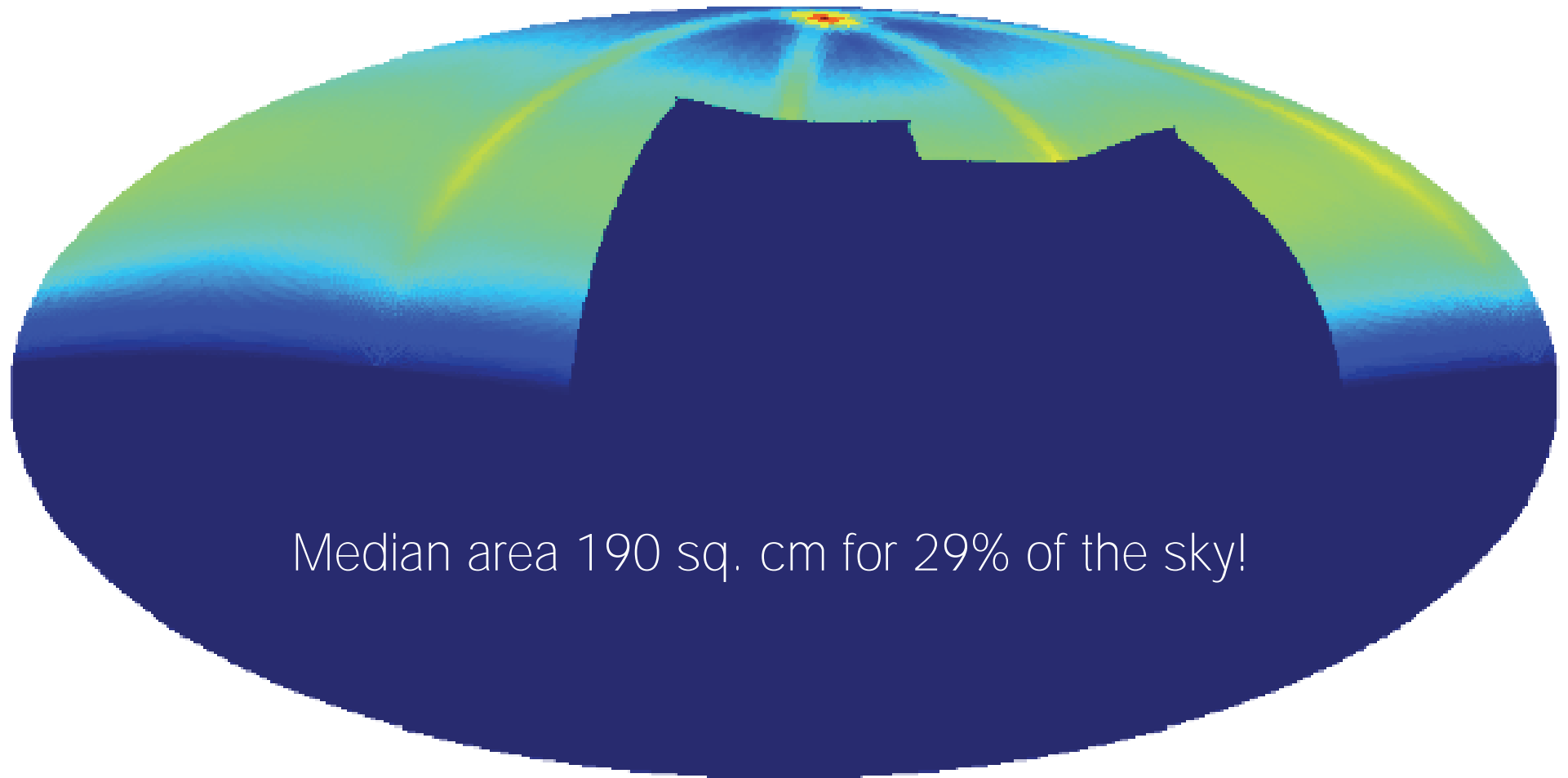
60 – 200 keV:
Open detector



Example: GRB151006A
detected 60.7° off axis
Bhalerao et al., 2015, GCN 18422

CZTI as a wide angle monitor

CZTI effective area at 180 keV

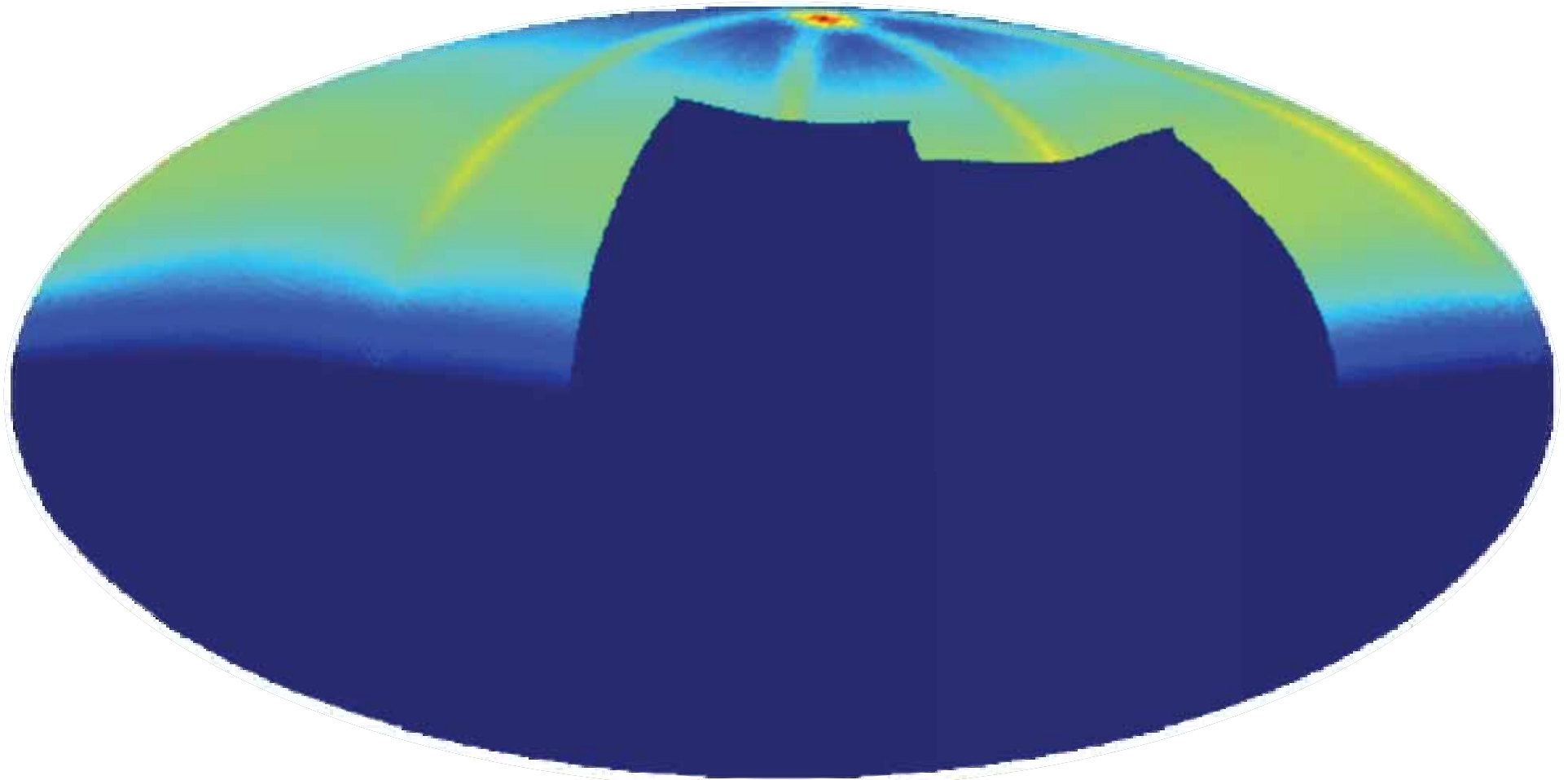


Median area 190 sq. cm for 29% of the sky!



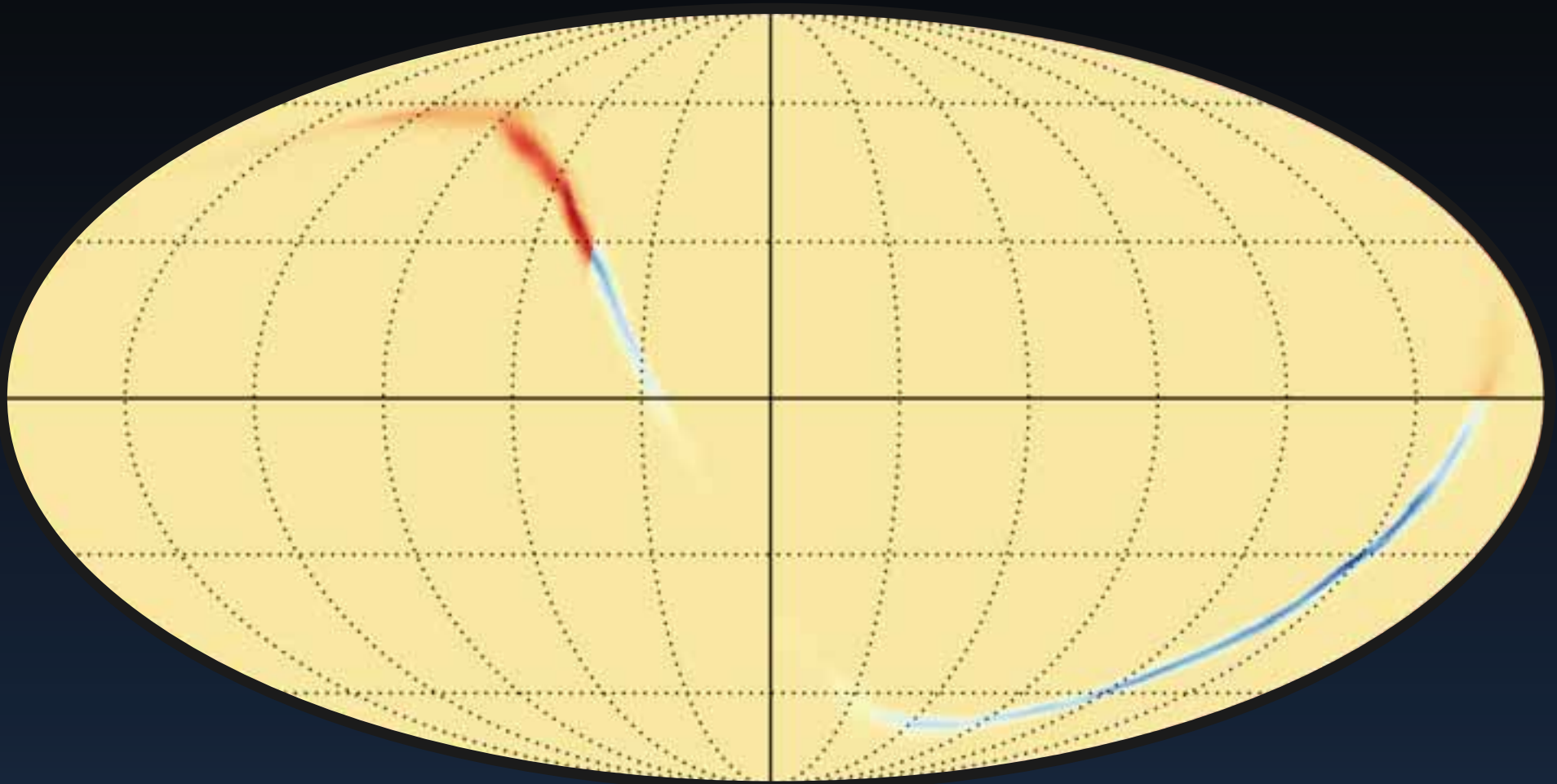
Coverage for GW151226

CZTI effective area at 180 keV



Skymap plotted using data provided by LSC.

Coverage for GW151226



CZTI observed 30% of the localisation of GW151226 and placed strong upper limits on an X-ray counterpart

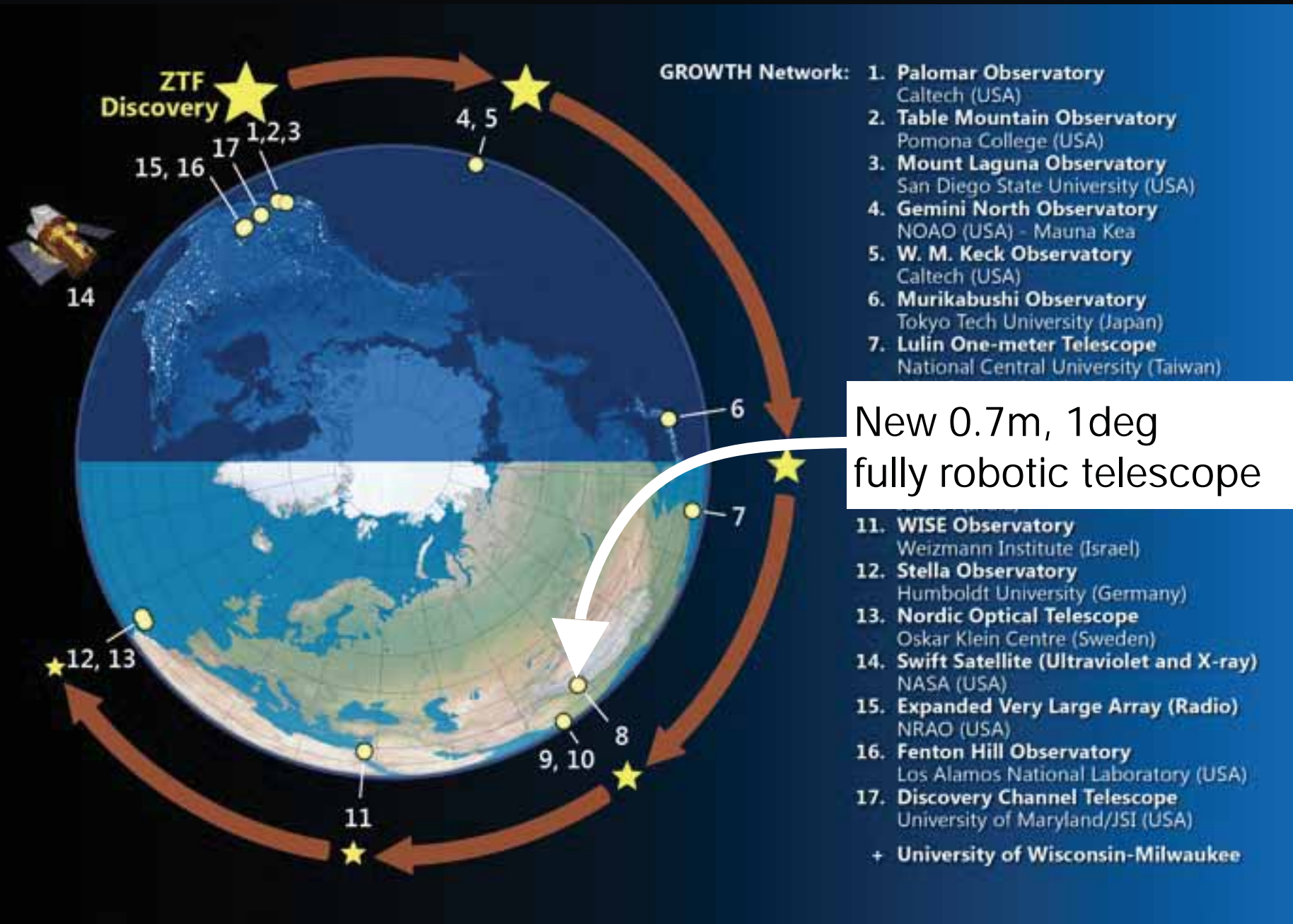
Skymap plotted using data provided by LSC.

Ground-based searches

- Distribute task among multiple telescopes
- Coordinated follow-up observations around the world
- Counterparts could be short-lived / rapidly evolving
 - » Eg: GRB afterglows

Global Relay of Observatories

Watching Transients Happen



What's next?



A decade from now...

- Increased LIGO sensitivity
 - » Find sources further away
- More detectors
 - » Smaller search regions
- More complete galaxy catalogs
 - » Cherry-pick targets
- Pre-merger triggers
 - » Advance warning to point telescopes

Deeper searches

- Devasthal 3.6m, Mt. Abu 2.5m
- Indian ten-meter class telescope?
- SALT / other partner programs
- Thirty Meter Telescope
 - » A proposal for EMGW already submitted!

- Radio followup:
 - » uGMRT
 - » SKA



Specialized instruments

- Meter-class telescopes can still make an impact in niche areas
- Specialized instruments and programs
 - » Multi-band monitoring
 - » Low resolution spectrography
 - » Robo-AO
- Automation of telescopes and processing!

Lots of space in outer space

- All sky monitors: Swift? iWF-MAXI? SSM
- Continuous wide angle coverage
- Soft + Hard X-rays, Gamma rays?
- Quick re-pointing abilities
 - » Spacecraft capabilities
 - » Communication links
- Need a network of satellites !