

Tenth International Fermi Symposium

9th-15th October 2022

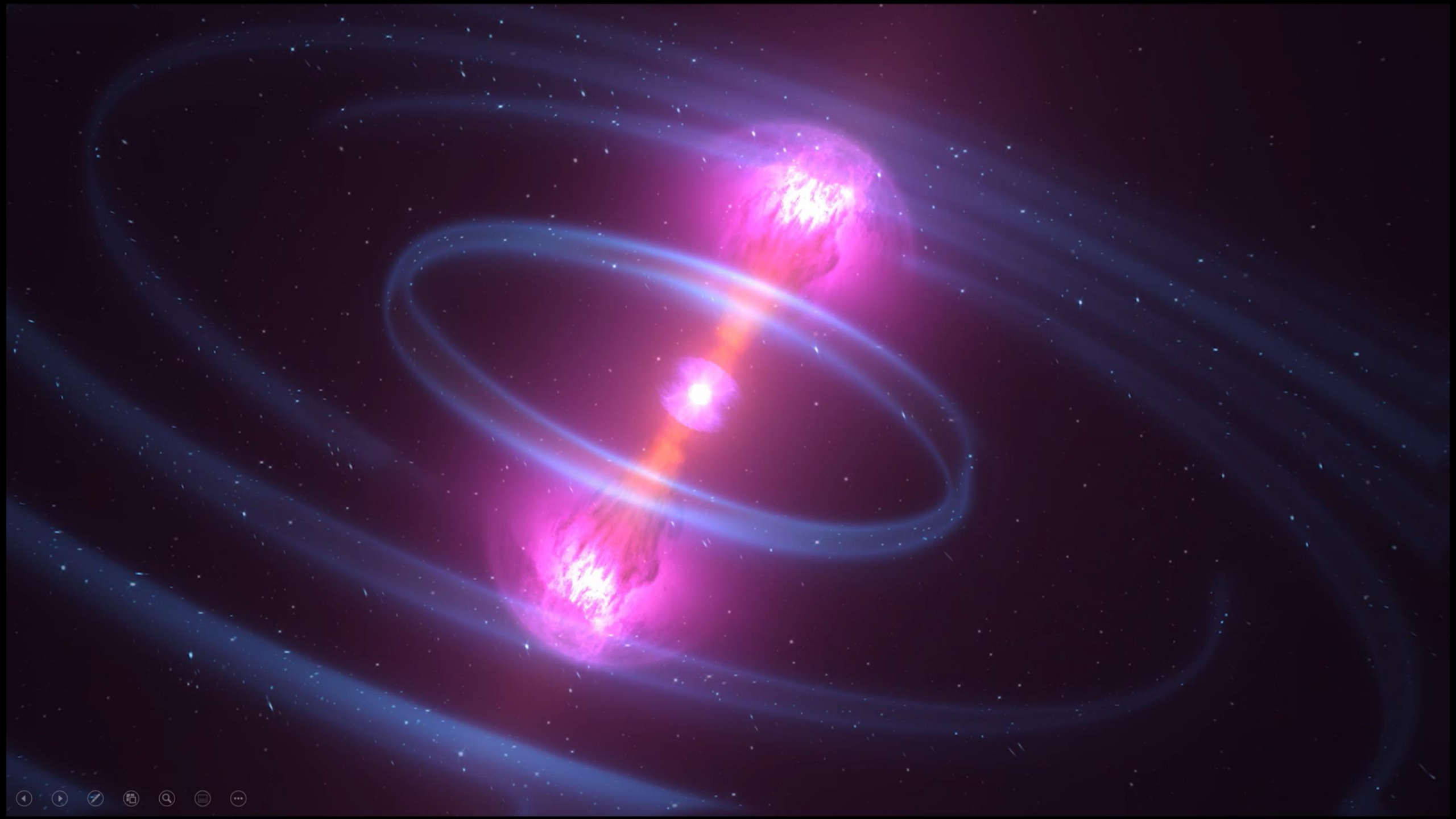


The GW-GRB Working Group and IPN in the O4 Observing Run

Eric Burns

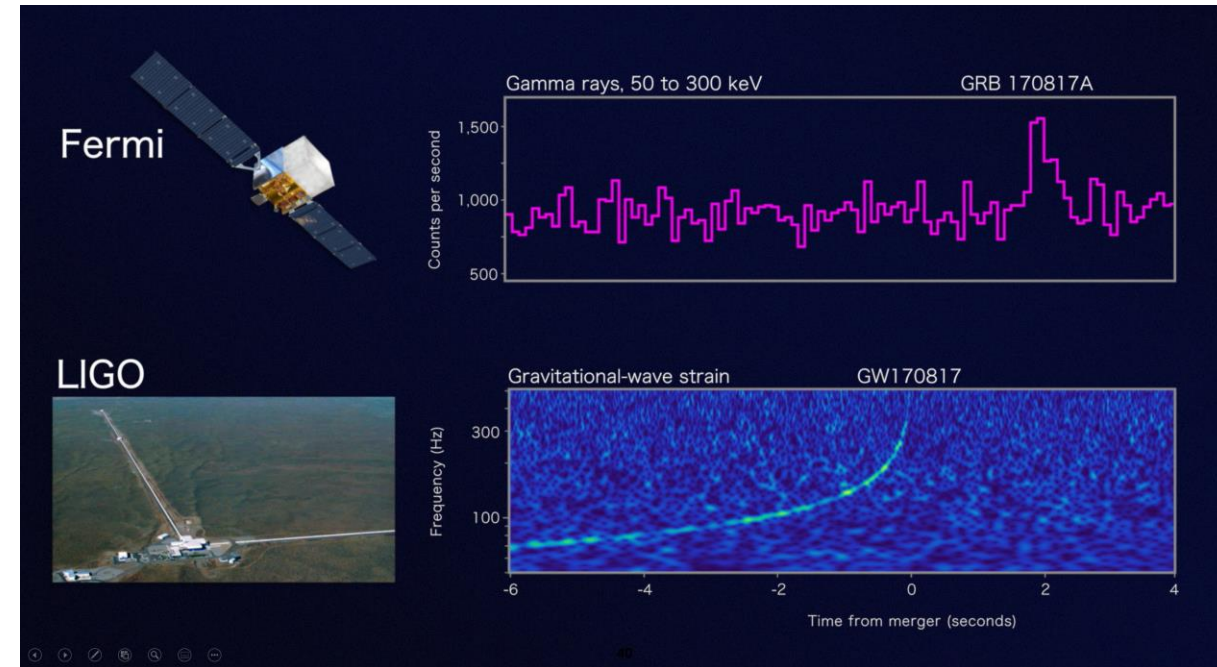
On behalf of the GW-GRB Working Group and the third
InterPlanetary Network

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The GW-GRB Working Group: Overview

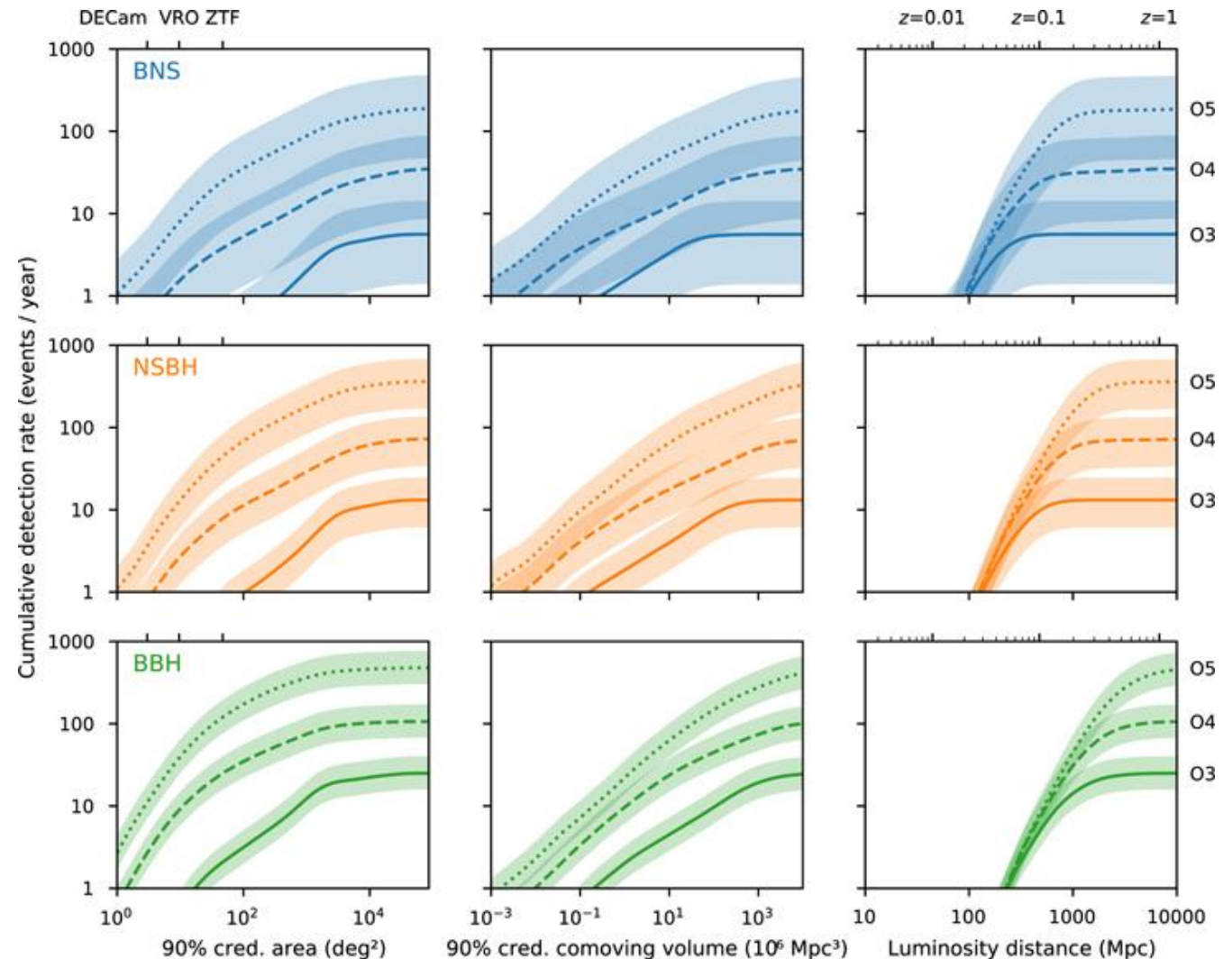
- 1 decade old; ~40 active members
 - 2012 – 2017; Organizers: Valerie Connaughton, Jordan Camp
 - Members: LIGO, Fermi-GBM
 - 2017 – 2022; Organizers: Eric Burns, Nelson Christensen
 - New Members: Virgo, Swift-BAT/GUANO
 - 2022 – ; Organizers: Rachel Hamburg, Tito dal Canton
 - New Members: KAGRA, BurstCube
 - Future members: GlowBug, StarBurst, COSI, MoonBEAM?
- Outputs:
 - >7000 citations
 - 10 lead papers, contributions to several more
 - Multiple papers in development
 - Combined prompt alert streams
 - Multimessenger association formalisms
 - Successful predictions proven with GRB 170817A



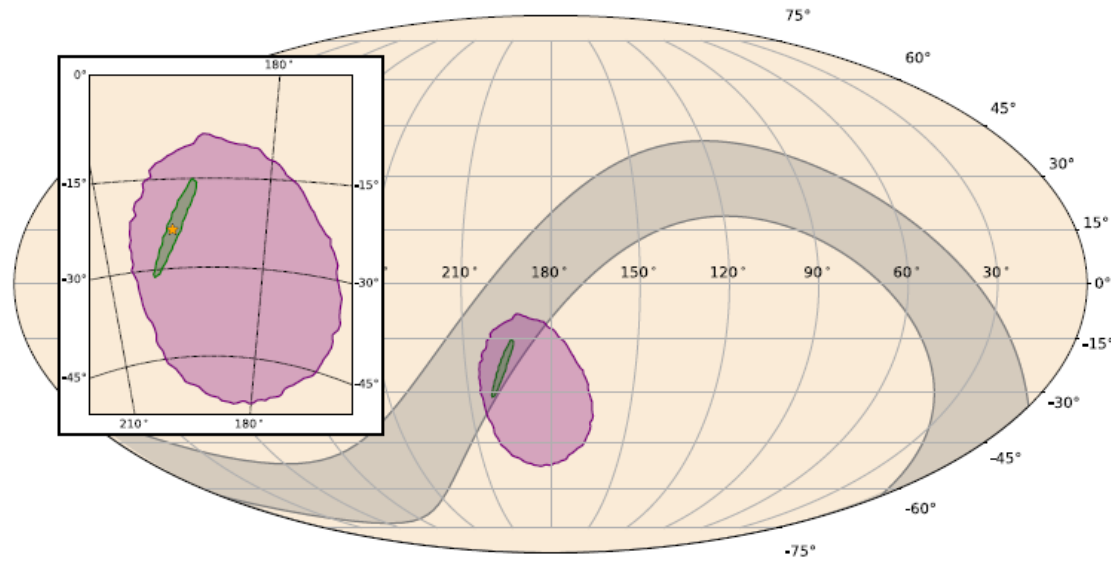
The GW-GRB Working Group: Joint Localizations

Petrov et al. ApJ 924 2 (2022)

- GW localizations improve, but less than previously thought
- This is due to adapting reporting criterion from the GW Network
- GW-GRB Events will be systematically further away, and thus more poorly localized



The GW-GRB Working Group: Joint Localizations



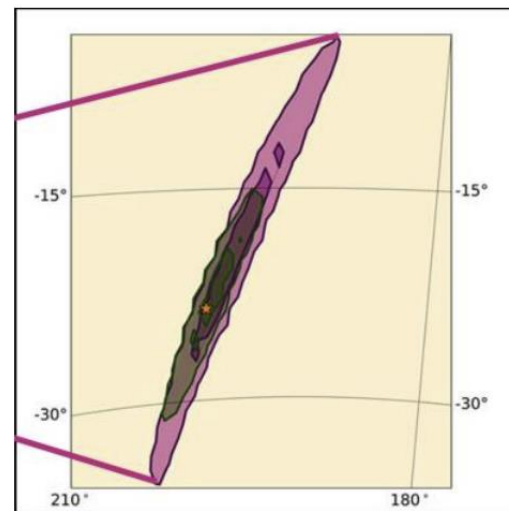
Fermi+INTEGRAL Annulus

Fermi-GBM

LIGO+Virgo

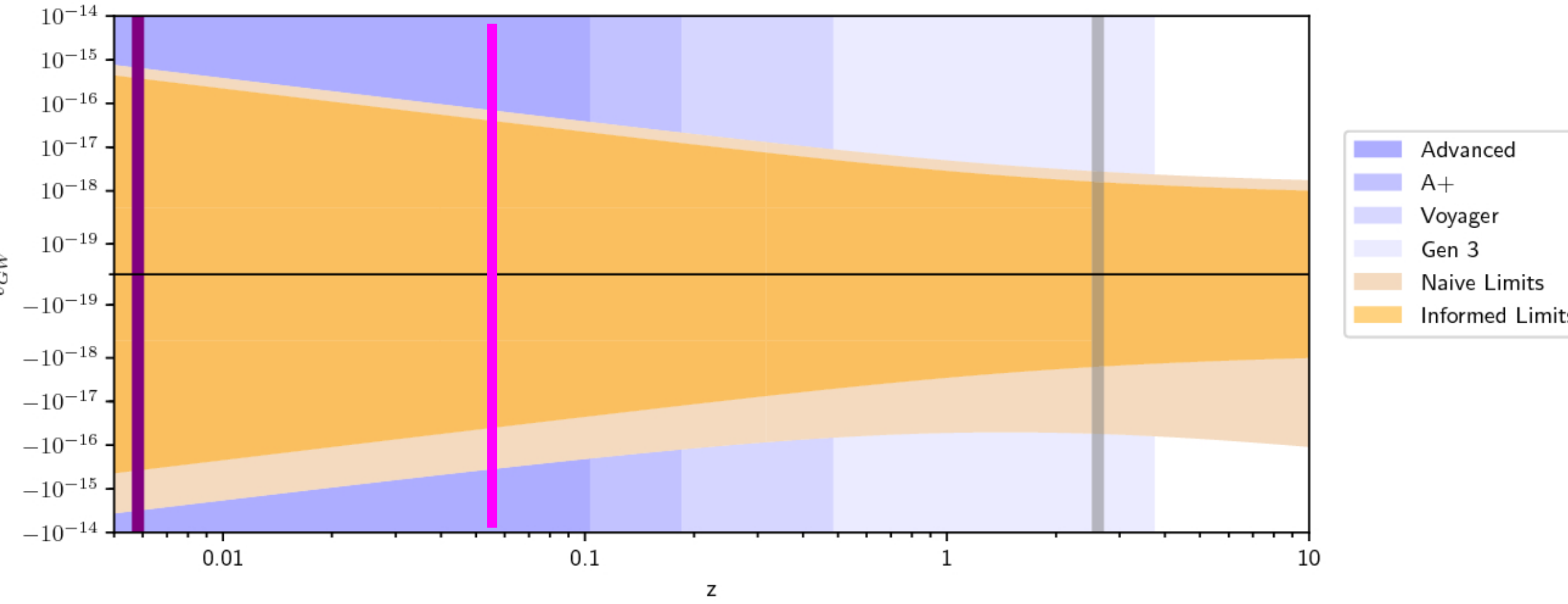
LVK alerts will be automatically associated to Fermi-GBM and Swift-BAT triggers in O4, the localizations combined, and distributed through the LVK alert stream

LIGO + Fermi-GBM
LIGO+Virgo



- Swift-BAT localizations are $\sim 3'$
- Fermi-GBM localizations vastly reduce \sim half of LVK localizations in O4
- Expect ~ 1 joint detection

The GW-GRB Working Group: Speed of Gravity



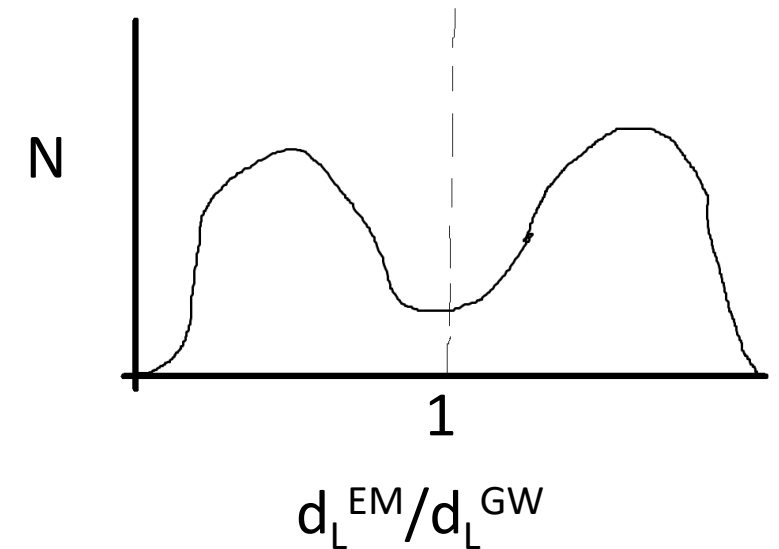
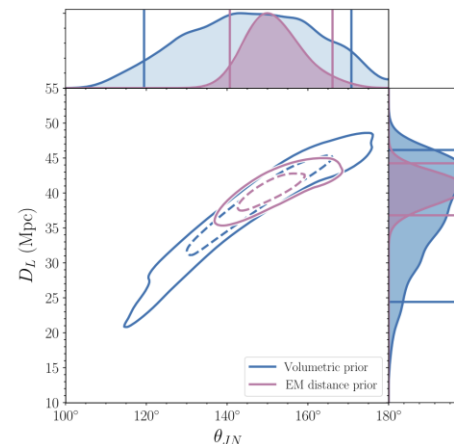
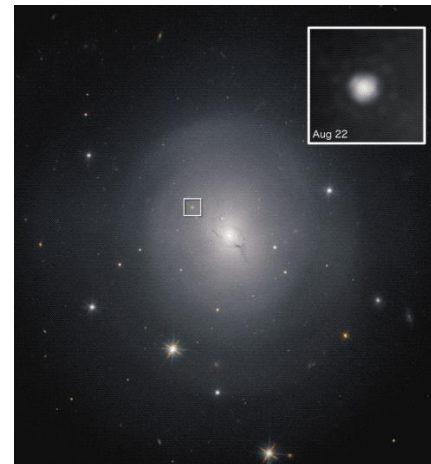
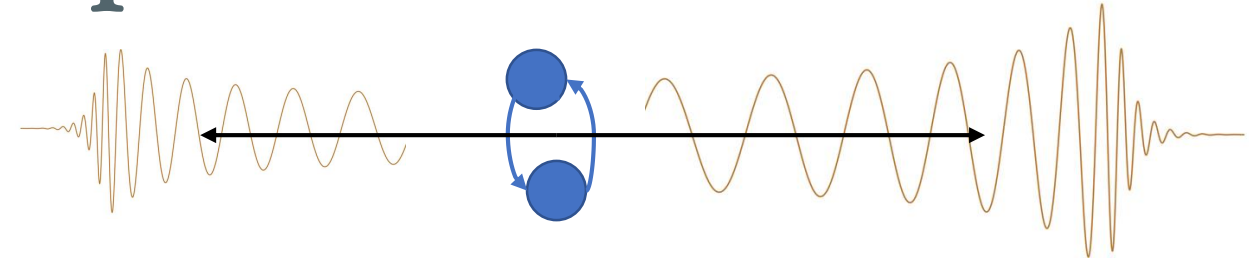
Burns *Living Reviews in Relativity* 23 4 (2020)

Population sensitivity scales as \sqrt{N}

The GW-GRB Working Group: Science

Other future measurement areas

- Behavior of speed-of-light jets
- Origin of the elements
- Neutron star equation of state
 - Maximum NS mass
- Standard Siren cosmology
 - Hubble constant
 - Nature of neutrinos
- Fundamental physics
 - Lorentz Invariance
 - GW polarization
 - Extra large dimensions
 - **Gravitational parity**

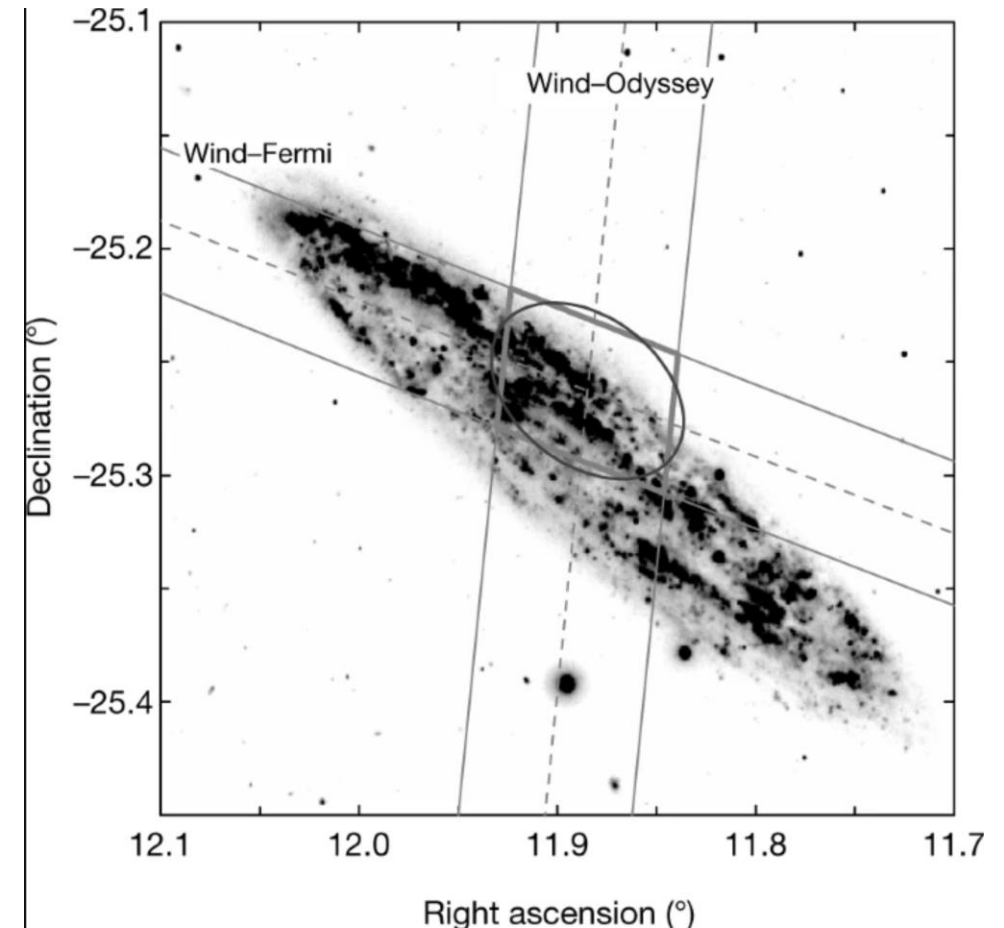


The GW-GRB Working Group: Other Works

- Fermi-GBM GRBs with characteristics similar to GRB 170817A
- GRB 150101B as an analogue of GRB 170817A
- Isolation of magnetar giant flares from the broader short GRB sample
- Exploration of magnetar flares as sources of GWs and fast radio bursts
- Providing tools and formalisms for IPN modernization
- Forthcoming papers:
 - GBM and BAT follow-up of GWTC-3 - Cori Fletcher (USRA), Josh Wood (NASA Marshall) for GBM; Milena Crnogorčević (UMD) for BAT; Tyson Littenberg (NASA Marshall)
 - Joint sub-threshold GW-GRBs, GBM - Marion Pillas (Universite Paris-Saclay), Tito Dal Canton, Cosmin Stachie, Brandon Piotrkowski (UW-Milwaukee), Fergus Hayes (University of Glasgow)
 - Joint sub-threshold GW-GRBs, BAT – methods - Aaron Tohuvavohu (U Toronto), Rebecca Ewing (PSU), Brandon Piotrkowski (UW-Milwaukee)
 - Joint sub-threshold GW-GRBs, BAT – results - Gayathri Raman (PSU)
 - Swift-BAT Biased Pointing; Swift-BAT Early Warning Response -Aaron Tohuvavohu (U Toronto)

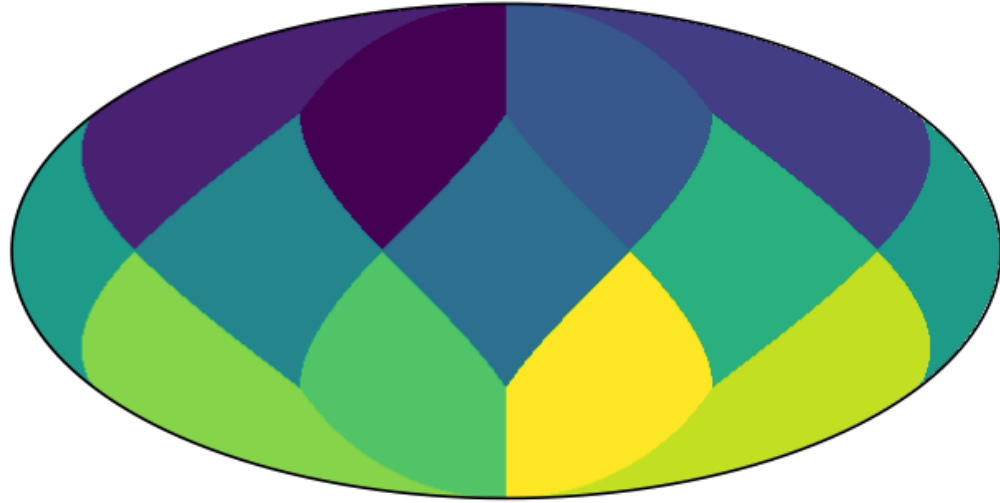
The InterPlanetary Network (IPN): Past and Present

- 5* decades old, ~70 members
 - 1967 – Vela triangulation
 - ~1978 – 1992; Organizers: Kevin Hurley
 - 1992 – 2021; Organizers: Kevin Hurley, Russian Scientists
 - Key Members: AGILE, **Bepi-Colombo**, CALET, CGRO, Fermi, GECAM, Insight, INTEGRAL, Konus, Mars Odyssey, MESSENGER, RHESSI, Swift, Suzaku
 - 2022 - ; Organizers: Eric Burns, Russian Scientists
 - Future instruments: StarBurst, COSI, **Psyche**, **MEGANE**
- Discoveries
 - >3500 direct citations, thousands more enabled
 - Separation of GRBs, soft gamma-ray repeaters (SGRs)
 - Anisotropy of SGRs, association with supernova remnants
 - Discovery of magnetars
 - Separation of short GRBs from neutron star mergers from extragalactic magnetar giant flares



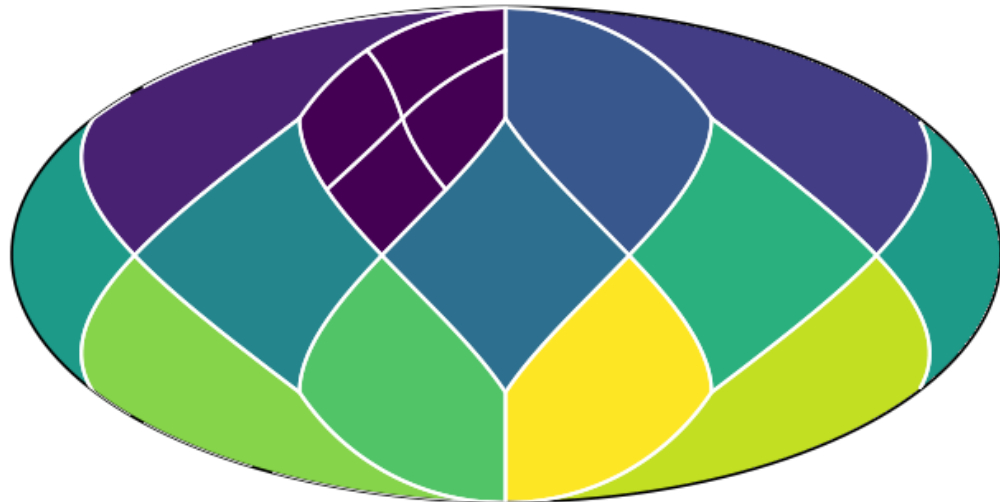
Svinkin et al. 2021 Nature 589 221

The IPN: Recent and Future Progress



Ease of access to localization information

- Multi-resolution healpix maps
 - mhealpy as a lightweight version; MartinezCastellanos et al. 2022 AJ 163 259
 - New IPN localizations are being distributed with healpix maps



Prompt GRB Catalog

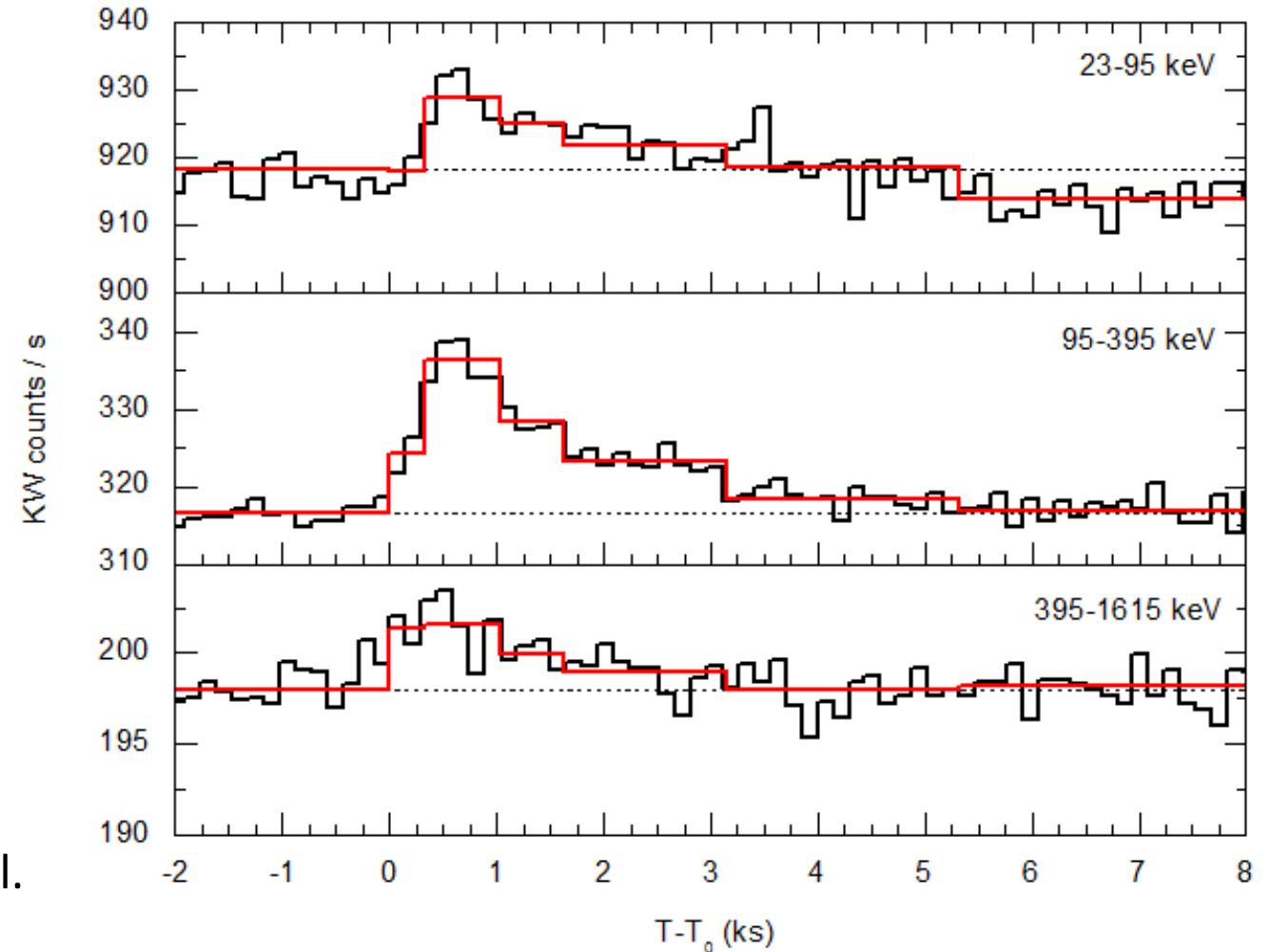
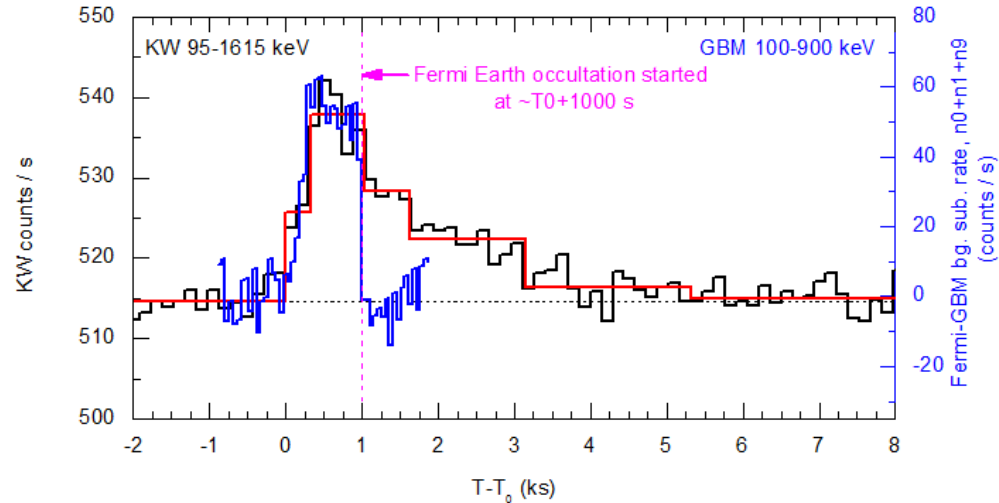
- All prompt GRB detections back to 1967
- Localization info combined into healpix format
- Additional duration and spectral parameters
- Designed for community contribution

The IPN: Recent and Future Progress

KONUS-WIND GRB 220525B

$T_0 = 13447$ s UT (03:44:07)

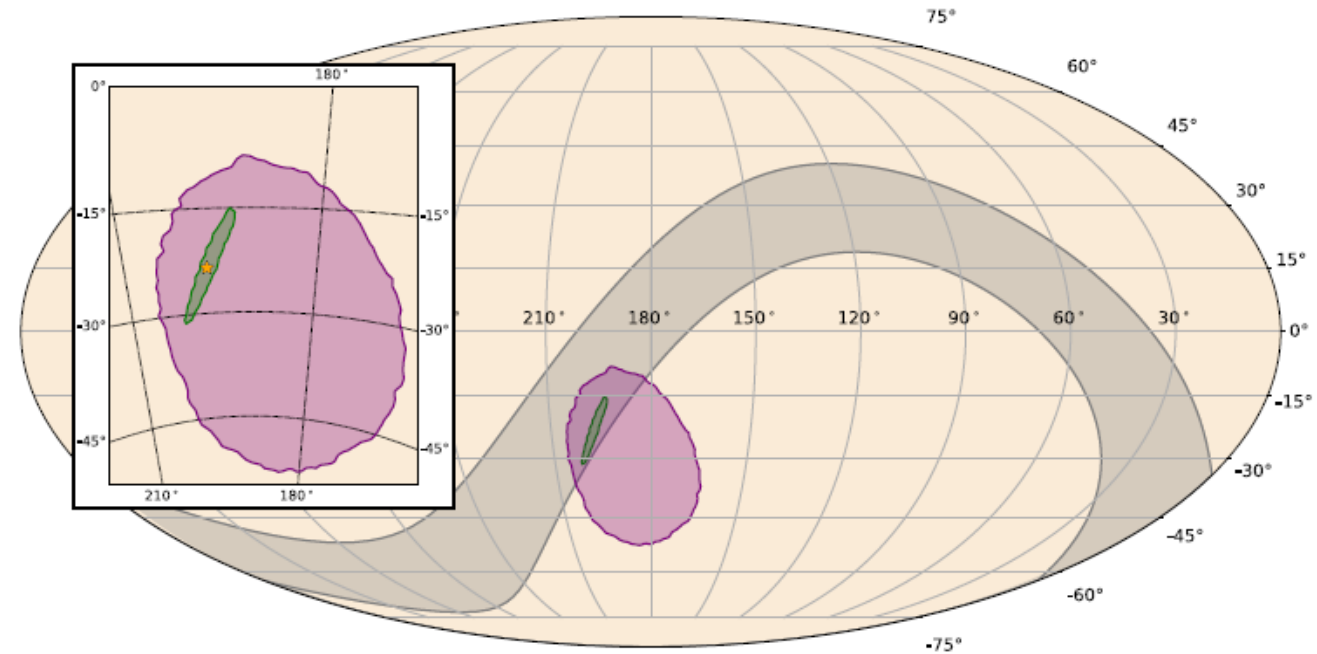
S1



- Identification of ultra-long GRBs
- Identification of a sub-class of ultra-long GRBs?
 - GRB 220525B – GCN 32591 Svinkin et al.
 - No LAT detection
 - The third of its kind in ~ 30 years

Putting it together: a combined GRB alert stream

- Automatic association of reported GRB triggers
- Automatic combination of autonomous localizations
- Automatic annuli calculation immediately after data is available
 - Likely limited to manual at O4 start
- Distribution to wider community with coherent information
- **Prioritization ranking**



Fermi+INTEGRAL Annulus

Fermi-GBM

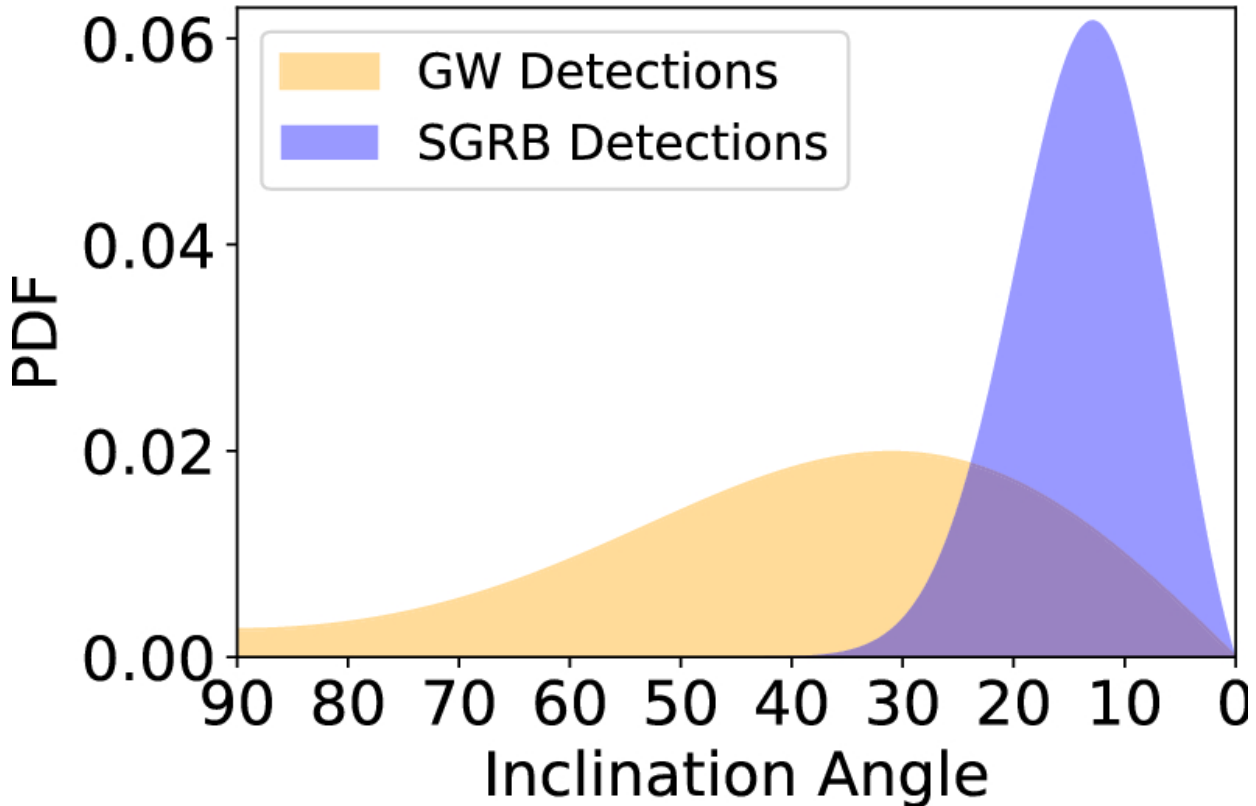
LIGO+Virgo

Predicted GW-GRB (Fermi-GBM) Rates for O4

- Limitations:
 - GW interferometer sensitivity
 - GRB monitor sensitivity
- Benefits:
 - Face-on events are louder in GWs
 - ~x2 gain in searchable volume using seeded (targeted) searches
- One estimate for BNS GW-GRBs from LVK arXiv: 2111.03608:

$$R_{\text{GW-GRB}}^{\text{O4}} = 1.04^{+0.26}_{-0.27} \text{ yr}^{-1}$$

0-2 w/ Poisson uncertainty, neglects sub-threshold detections



Burns 2020 LRR 23 4
Pulling from:
Schutz 2011 CQG 28:125023
Fong et al. 2015 ApJ 815 102

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Thank you for your attention!

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