TOOLS AND STRATEGIES FOR TRANSIENTS MULTI-MESSENGERS DETECTIONS

A French-Australian perspective

Dr. Karelle Siellez *[they/them]*

OzGrav

UNIVERSITY of TASMANIA

Artist credit: Karelle Siellez

MULTIMESSENGER ERA

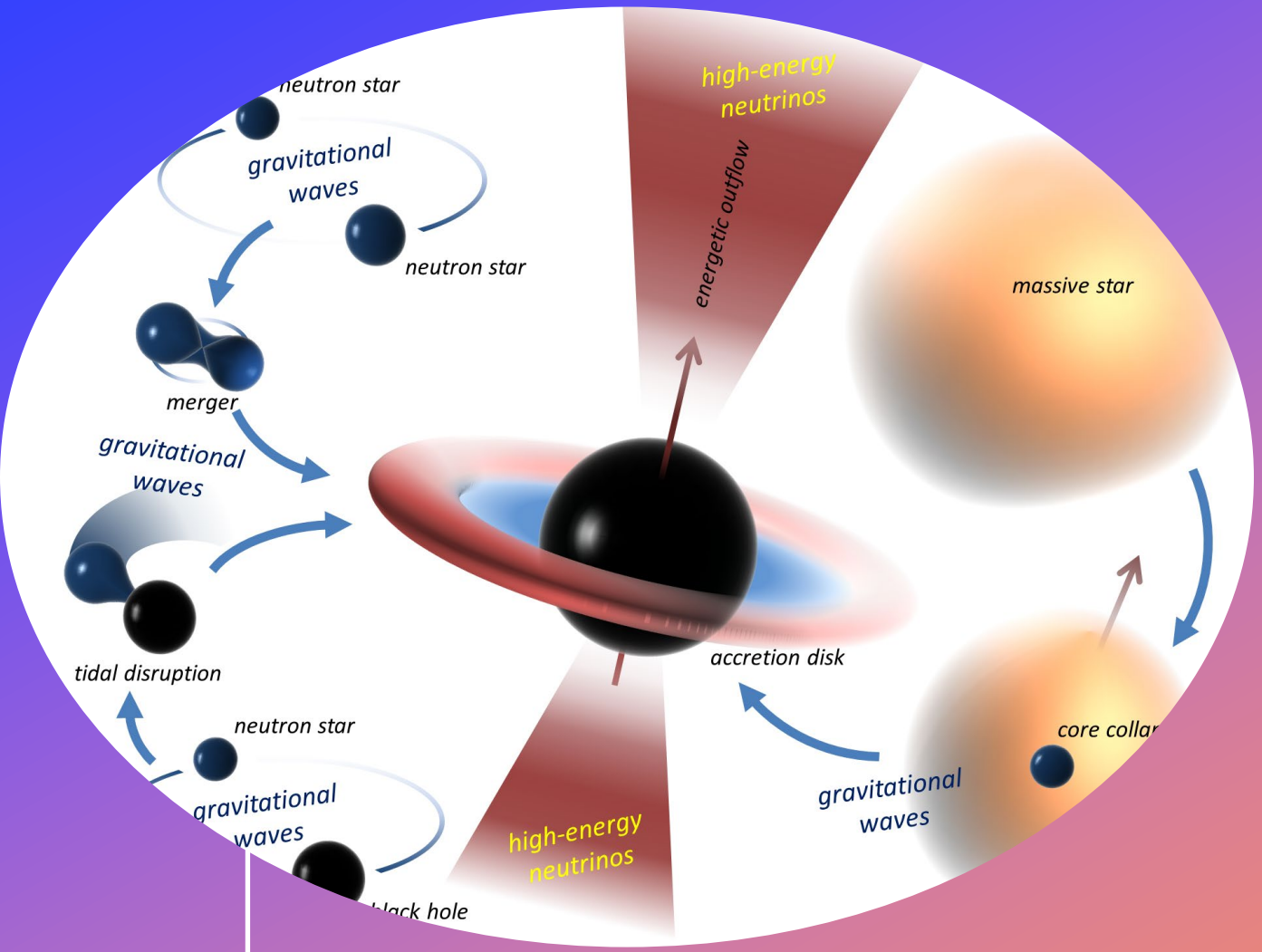


Image credit: Bartos/Based on arXiv:1212.2289

GWs

- Mass
- Spins
- Eccentricity
- NS compactness and tidal deformability
- System orientations
- Luminosity distance
- Compact object binary rate
- Explosion asymmetry

EM

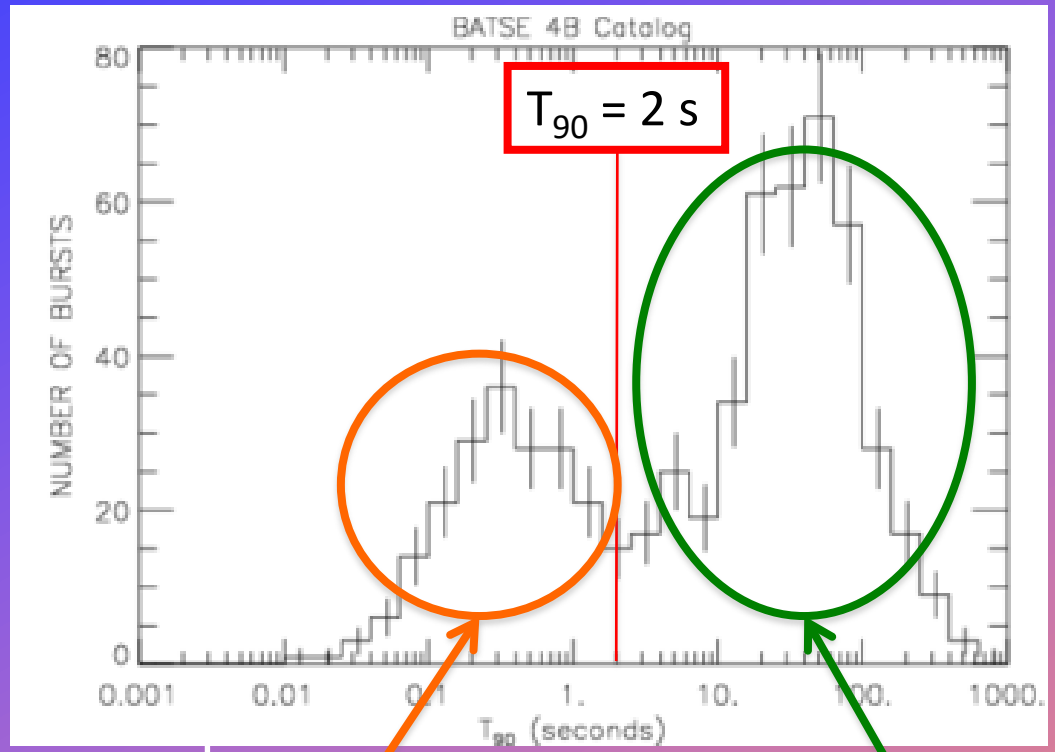
- Energetics
- Magnetic field strength
- Source geometry (beaming)
- Source environment
- Precise (arcsec) sky localization
- Host galaxy
- Redshift
- Nuclear astrophysics

- Confirmation about the progenitor
- Confidence of a GW detection
- sGRB as a trigger to detect fainter signal
- Early detection of sGRB with GW trigger
- Cosmological constant
- Knowledge about progenitors
- Rate of events and stellar evolution model

Short versus long GRBs

Difference between long and short GRB: temporal and spectral properties

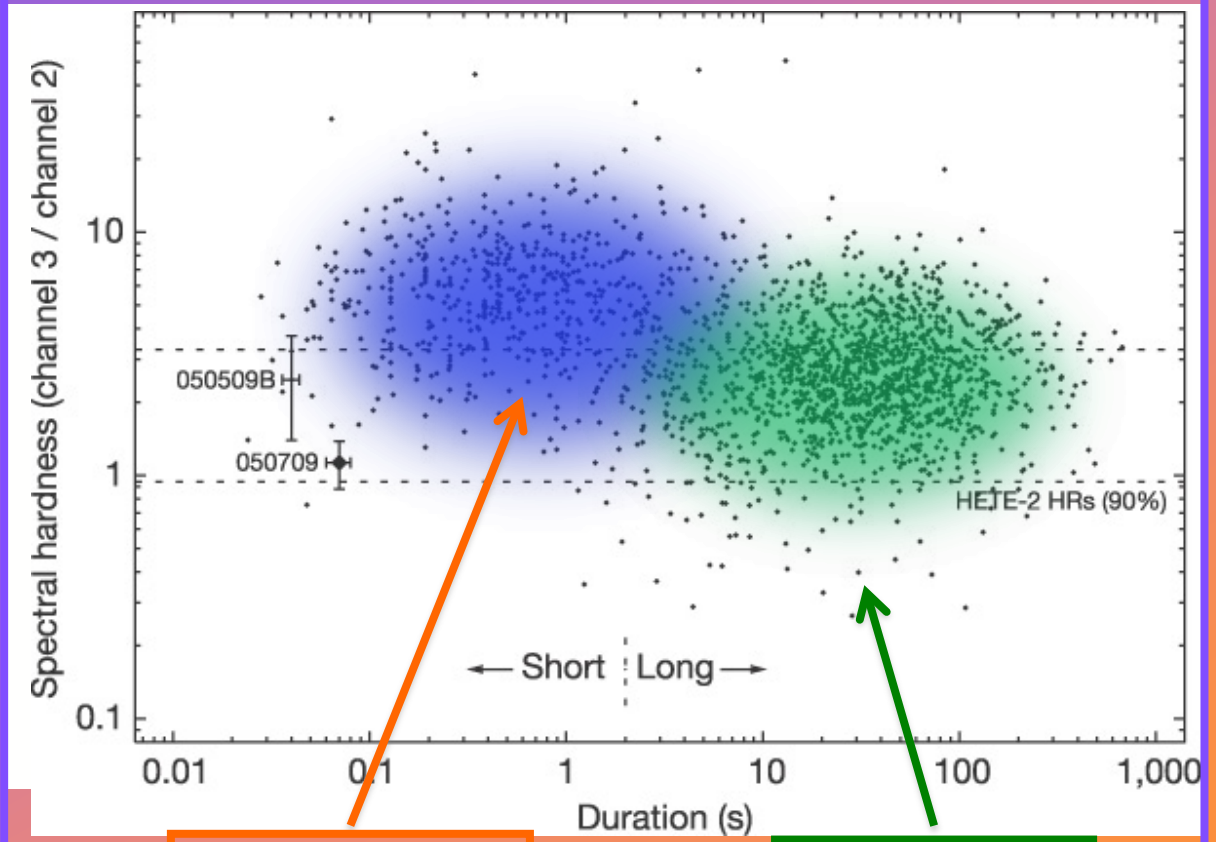
Temporal properties



T_{90} < 2s : sGRB

T_{90} > 2s : lGRB

Hardness ratio

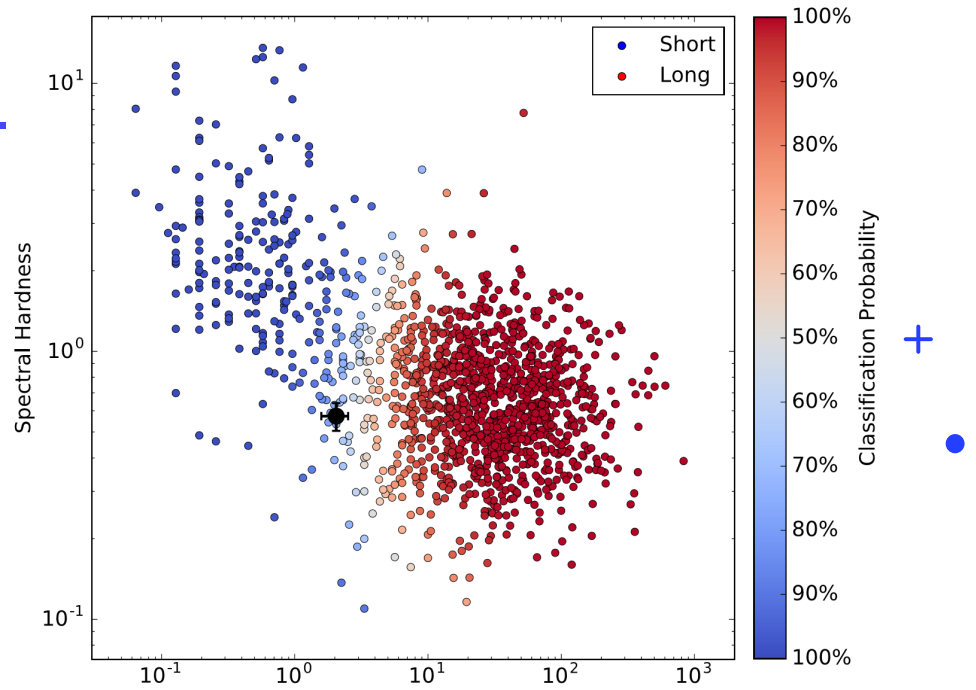


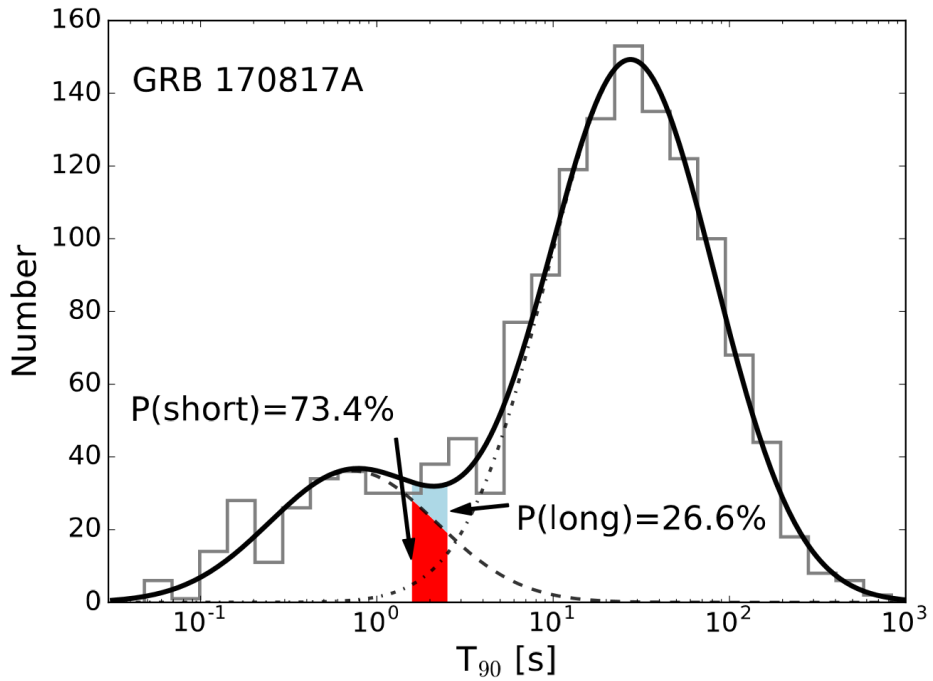
sGRB : harder

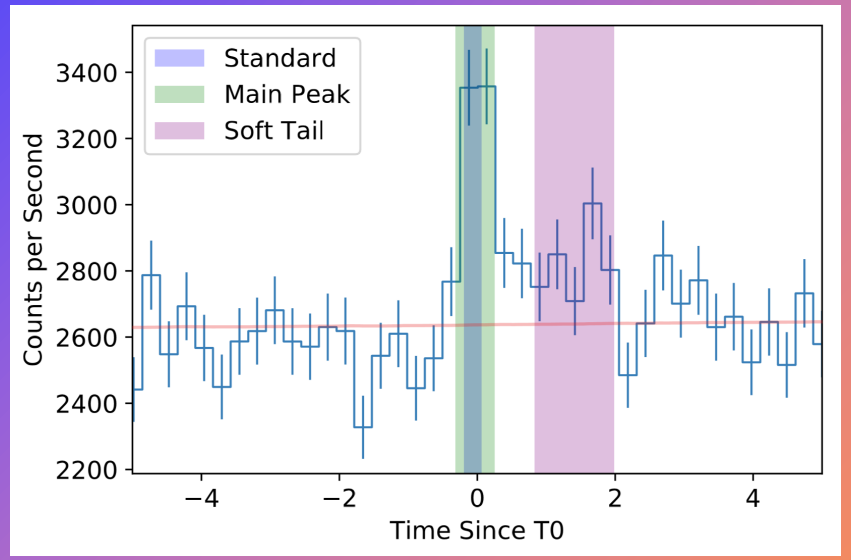
lGRB : softer

GRB 170817A

- GRB 170817A is 3 times more like to be a short GRB than a long GRB
- (excluding the soft tail makes this classification far more certain)



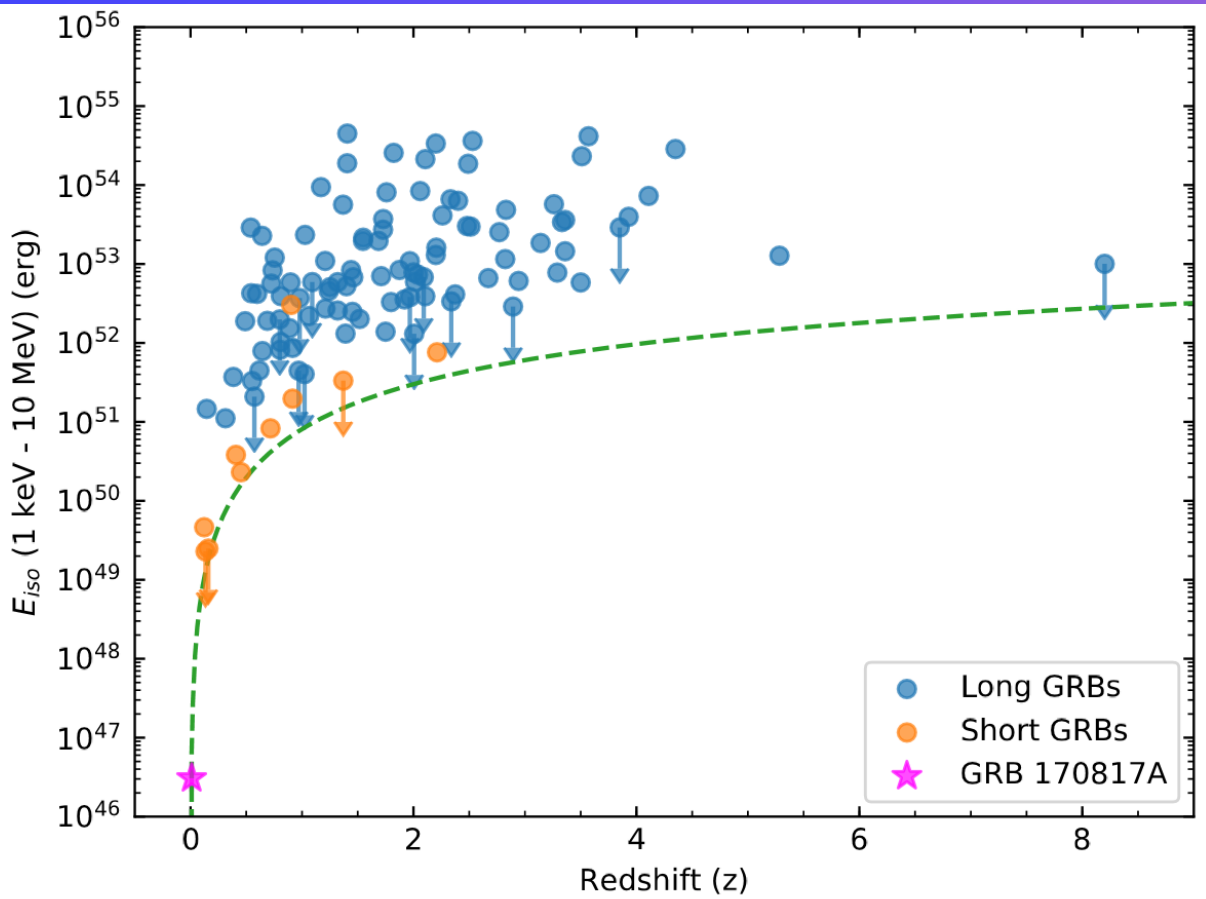


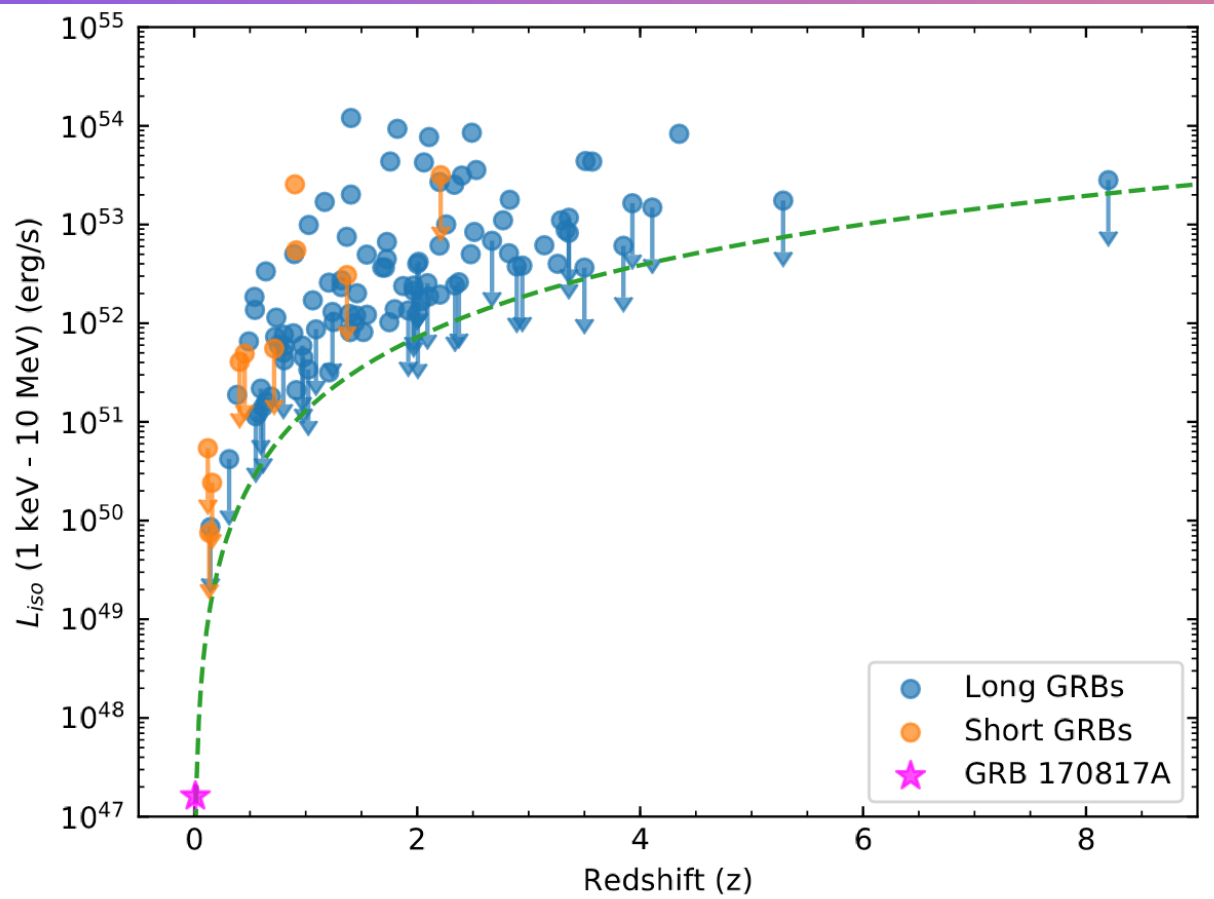


GRB 170817A – A normal short GRB ?

- Main Peak (~0.5 s)
  - E_{peak} = (185 ± 62) keV
- Soft Tail (~few s)
  - $k_B T$ = (10.3±1.5) keV

GRB 170817A: EXCEEDINGLY DIM





GRB 170716A is 2 to 6 orders of magnitude less energetic than previously known SGRBs with firm redshifts

The Astrophysical Journal Letters, 863:L34 (9pp), 2018 August 20 https://doi.org/10.3847/2041-8213/aad813

Fermi GBM Observations of GRB 150101B: A Second Nearby Event with a Short Hard Spike and a Soft Tail

E. Burns[1], P. Veres[2], V. Connaughton[3], J. Racusin[1], M. S. Briggs[2,4], N. Christensen[5,6], A. Goldstein[3], R. Hamburg[2,4], D. Kocevski[7], J. McEnery[1], E. Bissaldi[8,9], T. Dal Canton[1], W. H. Cleveland[3], M. H. Gibby[10], C. M. Hui[7], A. von Kienlin[11], B. Mailyan[2], W. S. Paciesas[3], O. J. Roberts[3], K. Siellez[12], M. Stanbro[4], and C. A. Wilson-Hodge[7]

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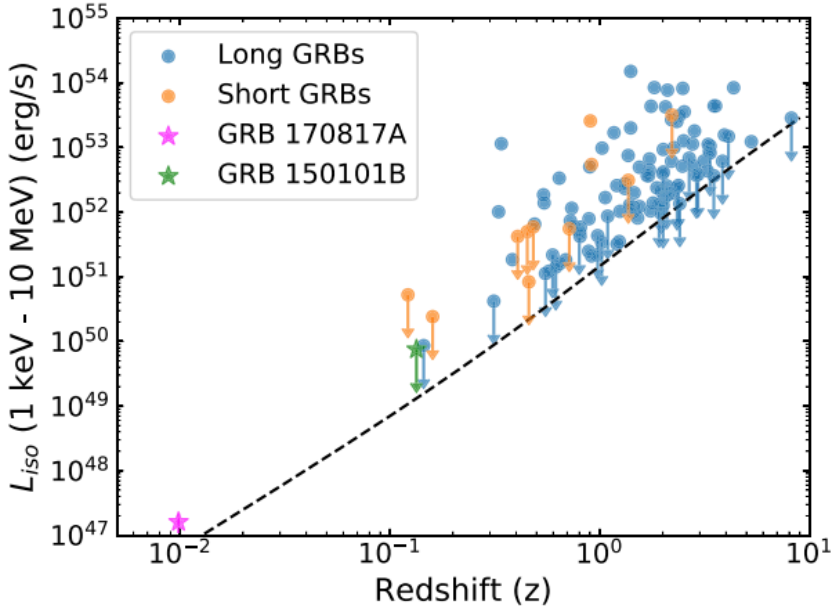
[12] Center for Relativistic Astrophysics and School of Physics, Georgia Institute of Technology, Atlanta, GA 30332, USA
Received 2018 July 13; revised 2018 August 3; accepted 2018 August 4; published 2018 August 17



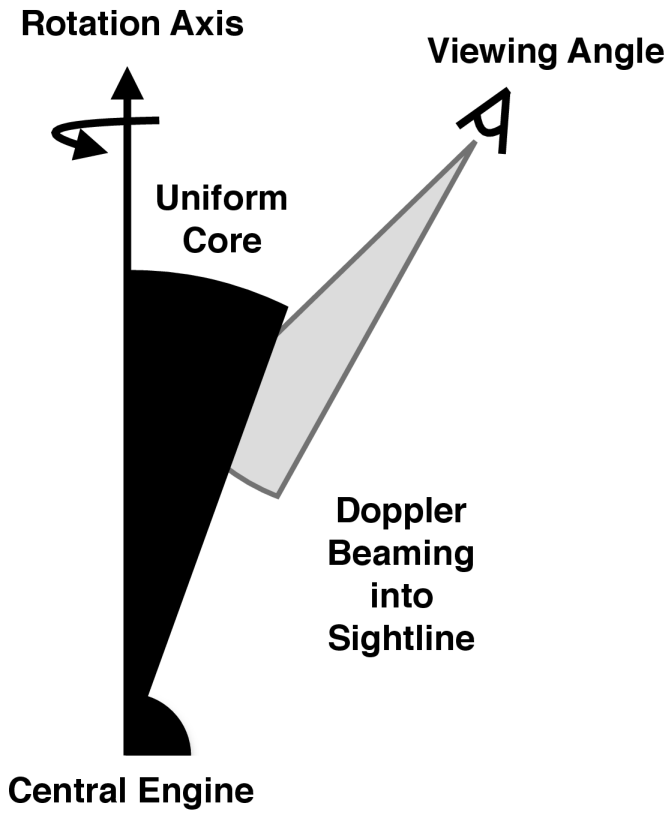
Abstract

In light of the joint multimessenger detection of a binary neutron star merger as the gamma-ray burst GRB 170817A and in gravitational waves as GW170817, we reanalyze the *Fermi* Gamma-ray Burst Monitor data of one of the closest short gamma-ray bursts (SGRBs): GRB 150101B. We find that this burst is composed of a short hard spike followed by a comparatively long soft tail. This apparent two-component nature is phenomenologically similar to that of GRB 170817A. While GRB 170817A was distinct from the previously known population of SGRBs in terms of its prompt intrinsic energetics, GRB 150101B is not. Despite these differences, GRB 150101B can be modeled as a more on-axis version of GRB 170817A. Identifying a similar signature in two of the closest SGRBs suggests that the soft tail is common, but generally undetectable in more distant events. If so, it will be possible to identify nearby SGRBs from the prompt gamma-ray emission alone, aiding the search for kilonovae.

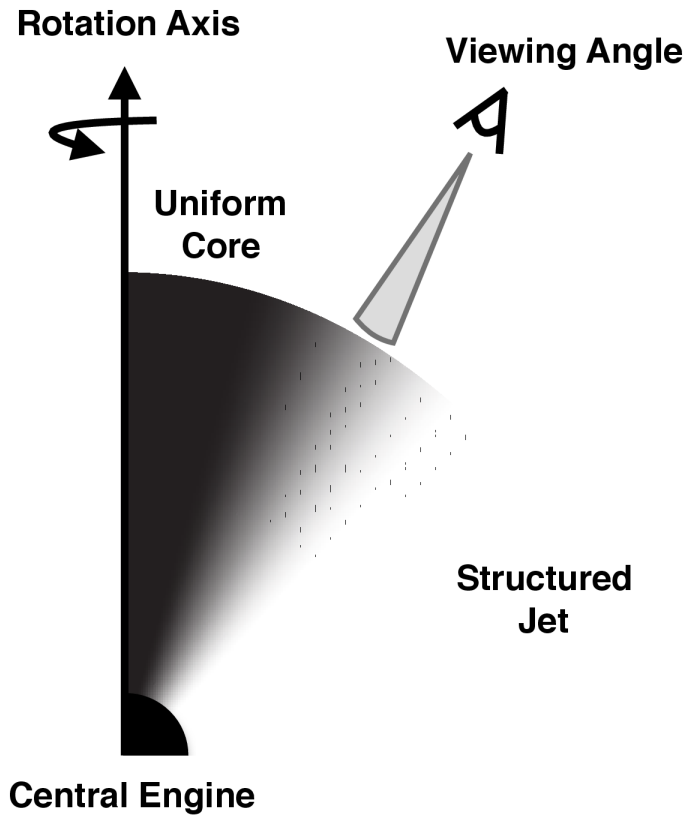
Key words: gamma-ray burst: general – gamma-ray burst: individual (GRB 150101B)

So little energy !!!

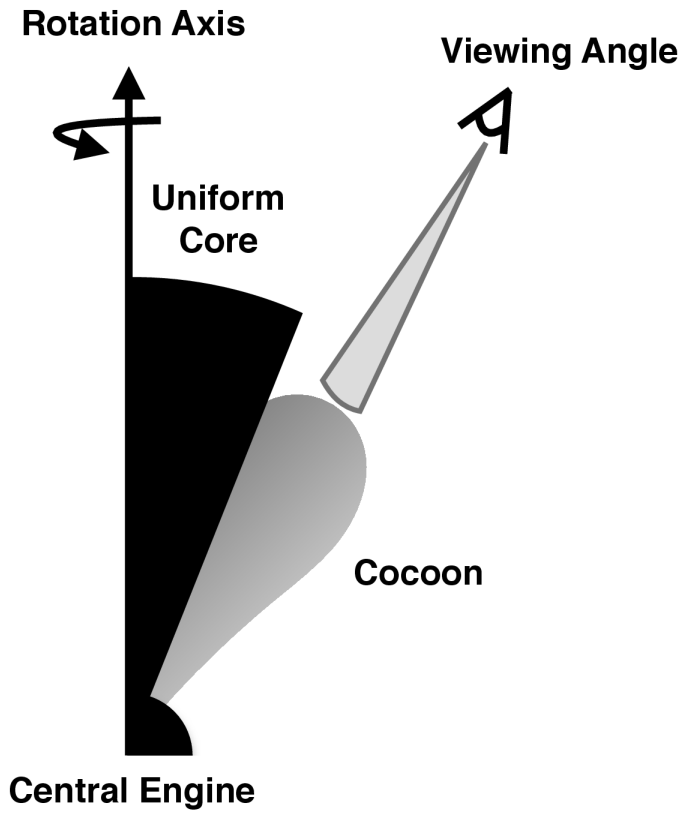
Scenario i: Uniform Top-hat Jet



Scenario ii: Structured Jet



Scenario iii: Uniform Jet + Cocoon



Coincidence rate estimation for AdV/aLIGO – EM satellites

Based on observations

Missions	Swift	FERMI	SVOM
F.o.V.	1.4 sr	9.5 sr	2 sr
Energy band	15-150 keV	8 keV – 40 MeV	2 – 80 keV
Estimated rate for O2 [O3] (events yr^{-1})	0.02±0.008 [0.87 ±0.39]	1.8±0.9 [7.5±3]	3.6 ±1.6

Siellez et al., 2014, MNRAS, Vol. 437, Issue 1

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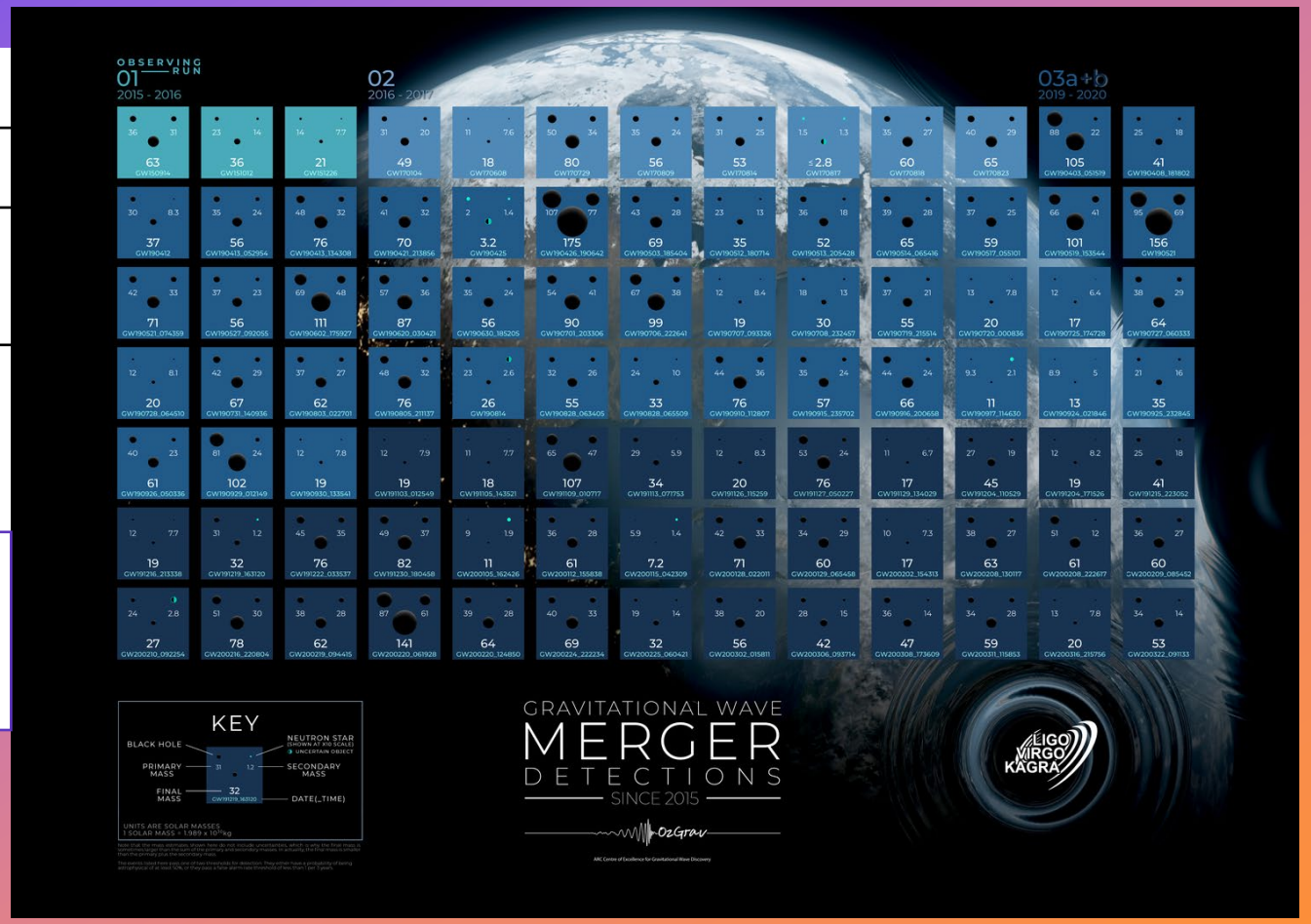
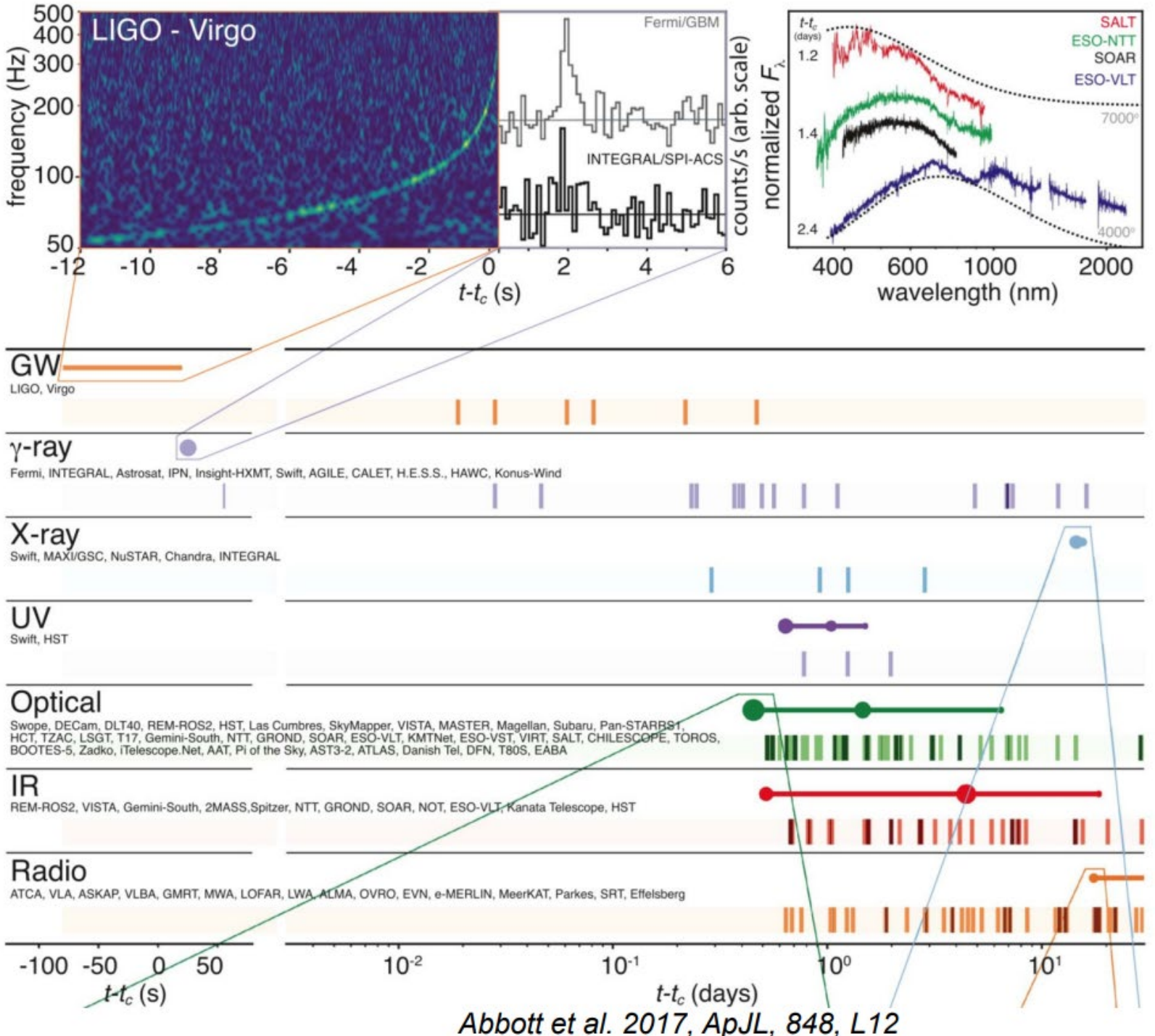
Actual Coincident events	0 [0]	1 [0]



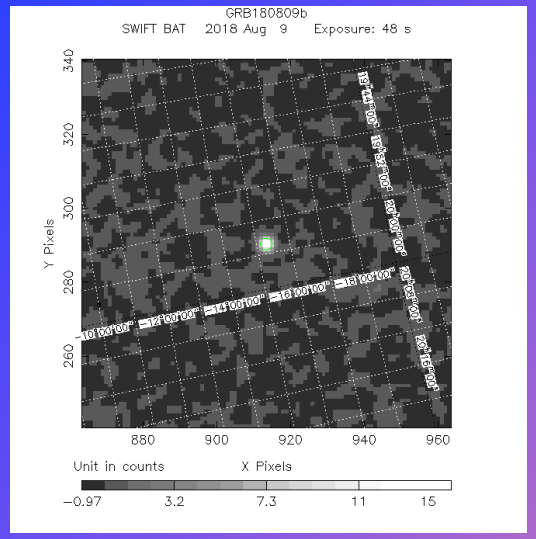
WHERE ARE THE COINCIDENCES?

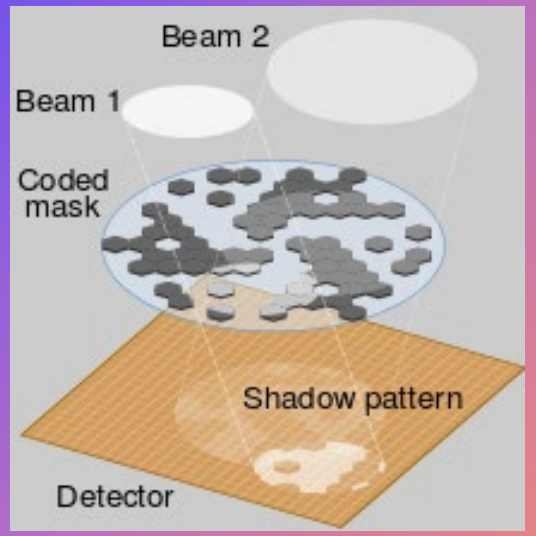
70 observatories working together

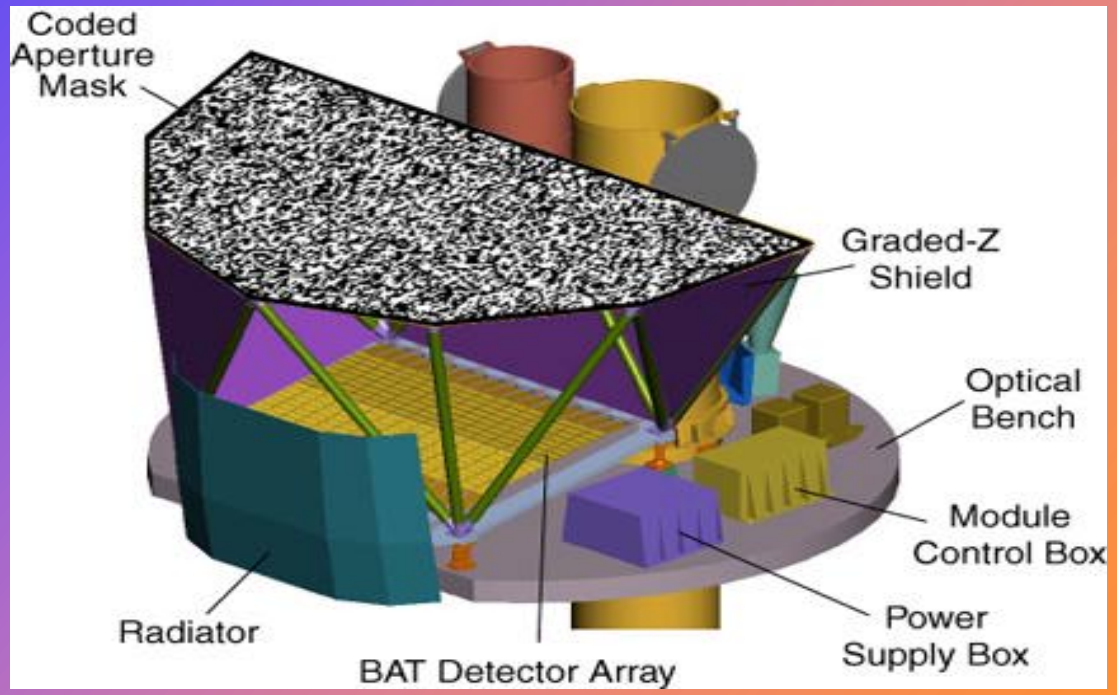


HOW TO FIND MORE KILONOVAE???

GET MORE GAMMA RAY BURSTS !!







Nitrates and GUANO for Swift

- Hard X-rays (15-350 keV)
- 1/6 of the whole sky (~2 sr.) FoV
- Localizes ~100 GRB/yr onboard
- Prompt Arc-minute localization

https://github.com/Swift-BAT/NITRATES

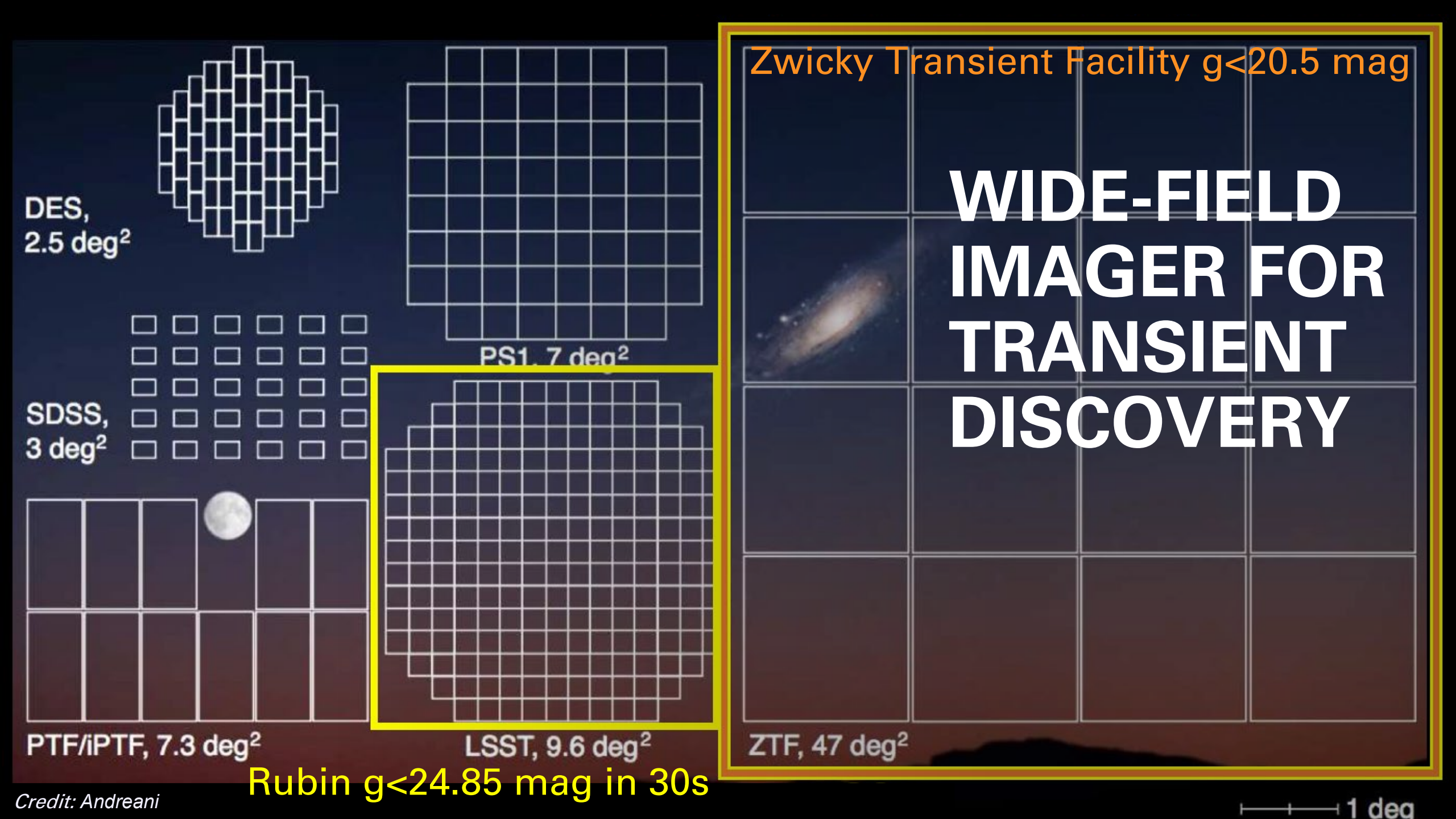
THE SVOM MISSION

SVOM "Space-based multi-band astronomical Variable Objects Monitor"

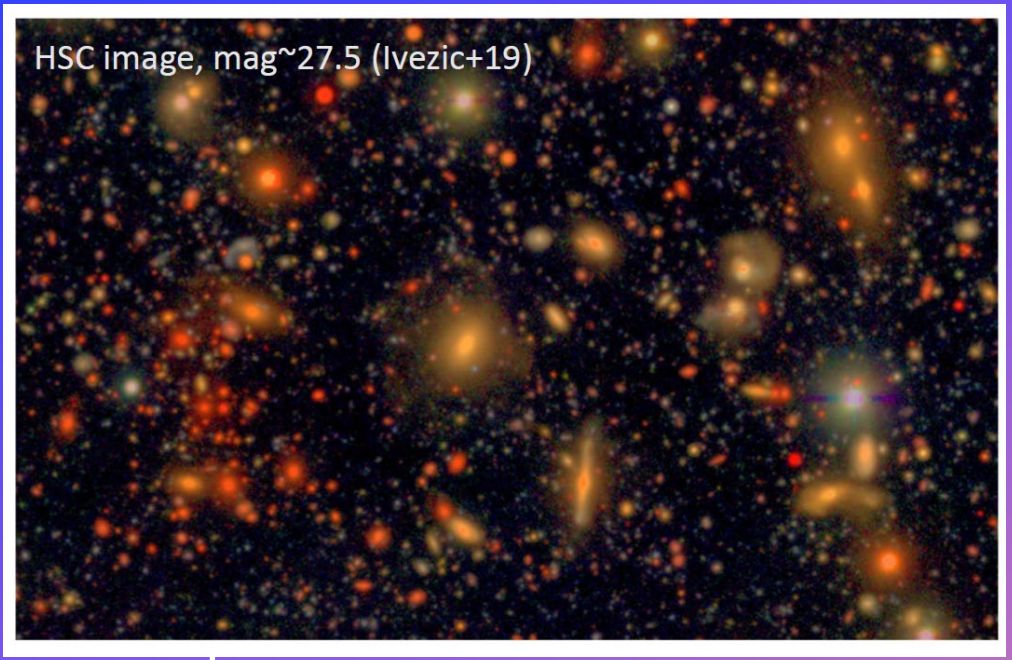
a Sino-French mission dedicated to GRBs and transient sources to be launched end 2023, duration 3+2 years

HOW TO FIND MORE KILONOVAE???

GET WIDE/DEEP FIELD SURVEY !!

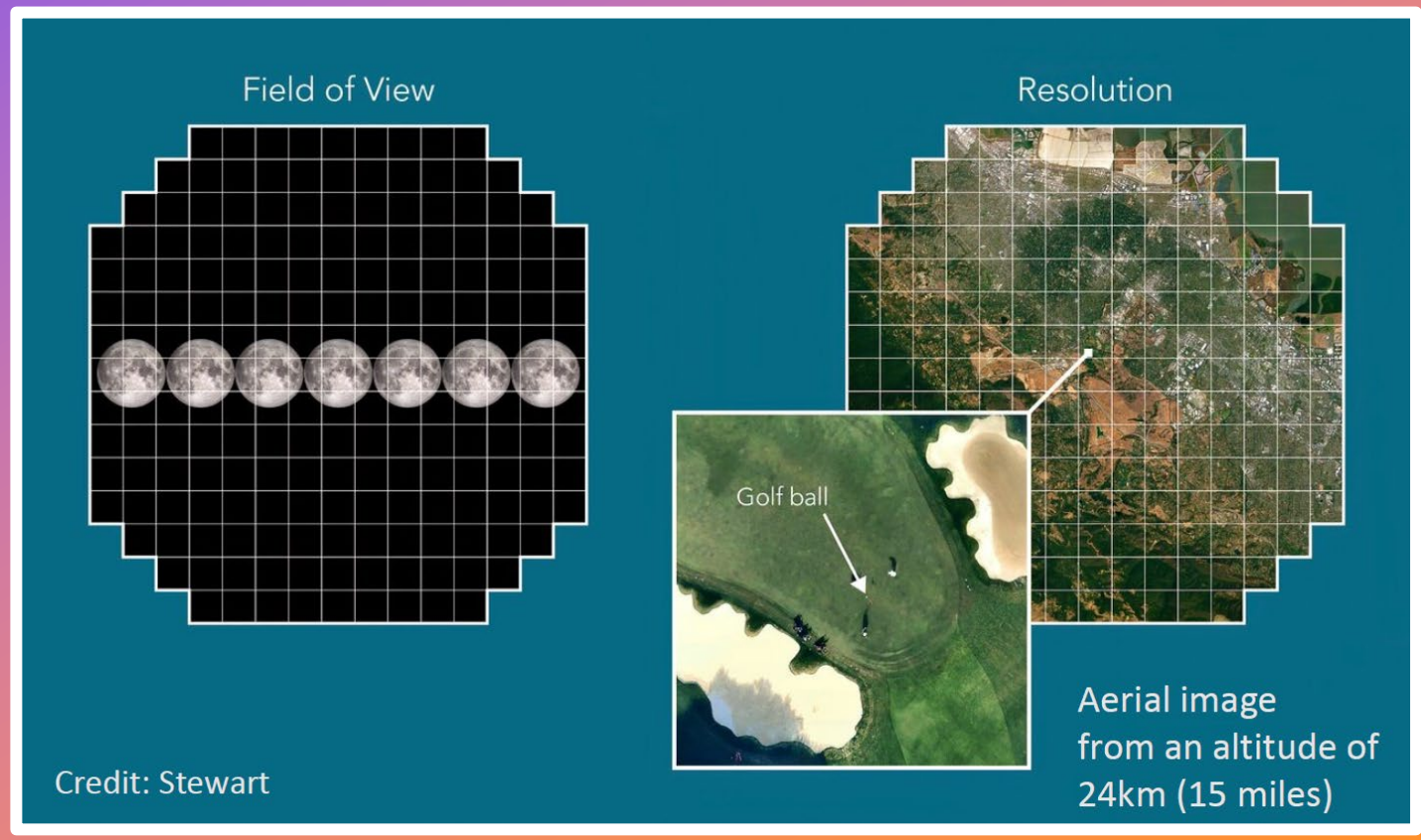


Credit: Andreani



RUBIN: A KEY DIFFERENCE FOR OPTICAL DISCOVERIES

- Field of View: 9.6 deg^2
- u-g-r-i-z-y filters
- 0.2 arcsec / pixel



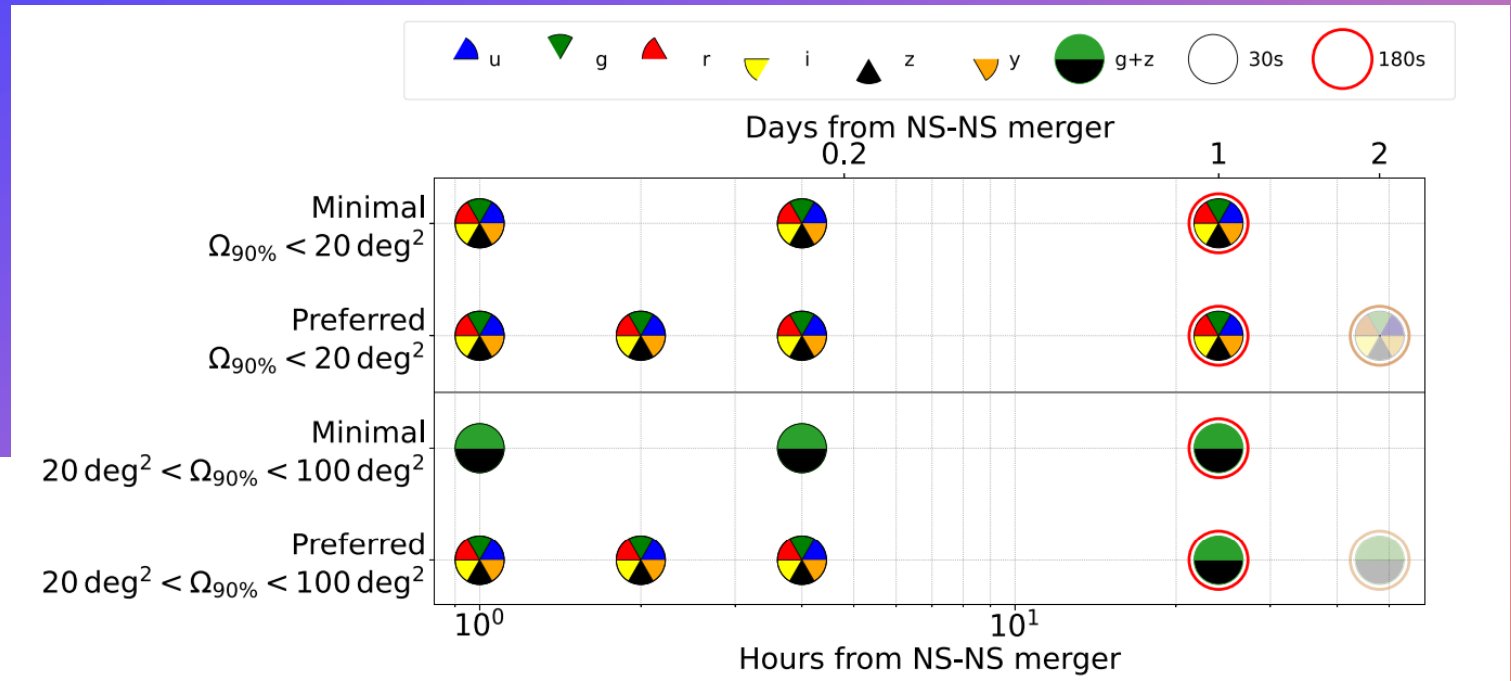
STRATEGY FOR NS-NS MERGER FOLLOW-UP

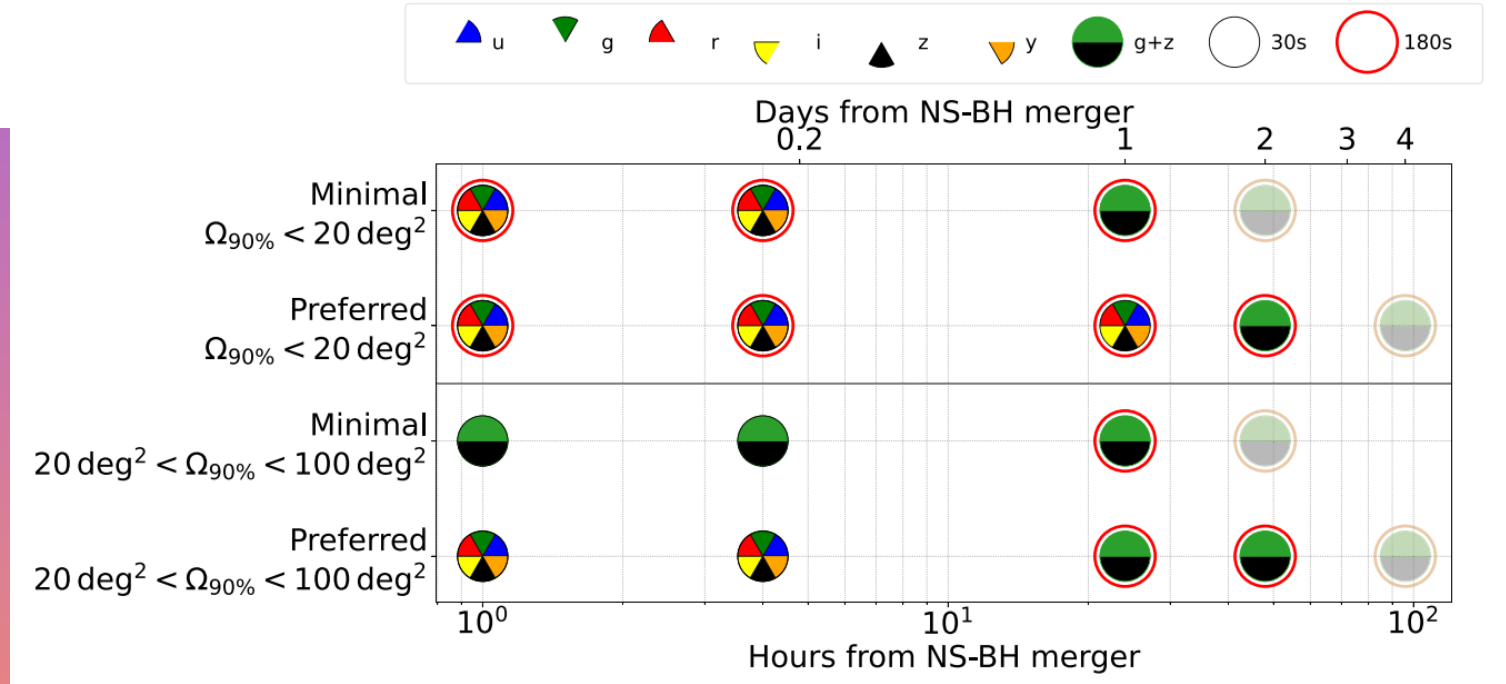
The Astrophysical Journal Supplement Series, 260:18 (17pp), 2022 May https://doi.org/10.3847/1538-4365/ac617c

Target-of-opportunity Observations of Gravitational-wave Events with Vera C. Rubin Observatory

Igor Andreoni[1,2,3,50], Raffaella Margutti[4], Om Sharan Salafia[5,6], B. Parazin[7], V. Ashley Villar[8,9,10], Michael W. Coughlin[11], Peter Yoachim[12], Kris Mortensen[13], Daniel Brethauer[4], S. J. Smartt[14], Mansi M. Kasliwal[15], Kate D. Alexander[16], Shreya Anand[15], E. Berger[17], Maria Grazia Bernardini[5], Federica B. Bianco[18,19,20,21], Peter K. Blanchard[16], Joshua S. Bloom[4,22], Enzo Brocato[23,24], Mattia Bulla[25], Regis Cartier[26], S. Bradley Cenko[1,3], Ryan Chornock[4], Christopher M. Copperwheat[27], Alessandra Corsi[28], Filippo D'Ammando[29], Paolo D'Avanzo[5], Laurence Élise Hélène Datrier[30], Ryan J. Foley[31], Giancarlo Ghirlanda[5], Ariel Goobar[32], Jonathan Grindlay[17], Aprajita Hajela[16], Daniel E. Holz[33], Viraj Karambelkar[15], E. C. Kool[25], Gavin P. Lamb[34], Tanmoy Laskar[35], Andrew Levan[35,36], Kate Maguire[37], Morgan May[38], Andrea Melandri[5], Dan Milisavljevic[39], A. A. Miller[16], Matt Nicholl[40], Samaya M. Nissanke[41], Antonella Palmese[42,51], Silvia Piranomonte[23], Armin Rest[43,44], Ana Sagués-Carracedo[32], Karelle Siellez[45], Leo P. Singer[46], Mathew Smith[47], D. Steeghs[48,49], and Nial Tanvir[34]

White paper
Margutti et al. 2018



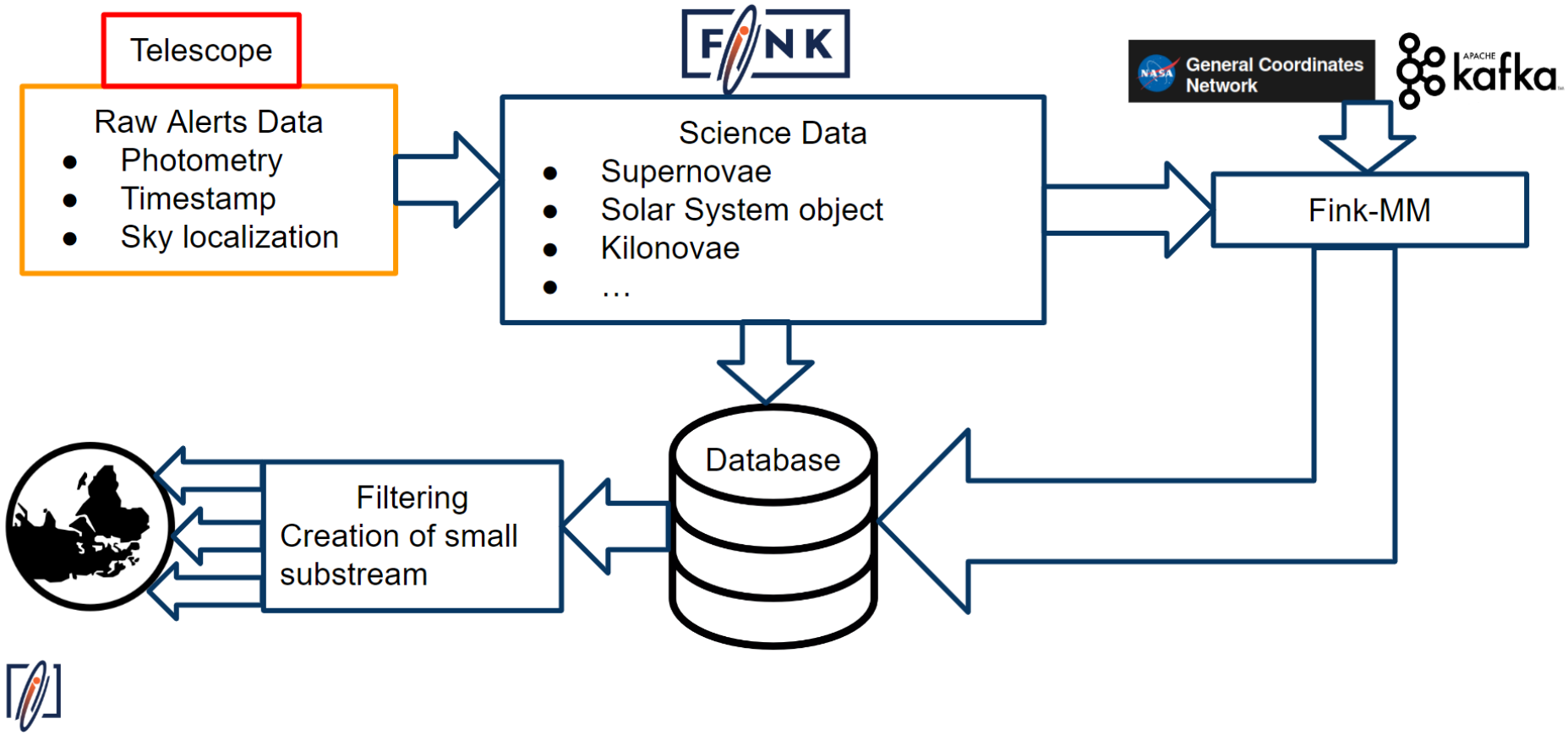


Deeper, Wider, Faster survey
Led by Jeff Cooke and the team!
(Jim, Tasha, Mark, Dougal, Simon, Renee…)

HOW TO FIND MORE KILONOVAE???

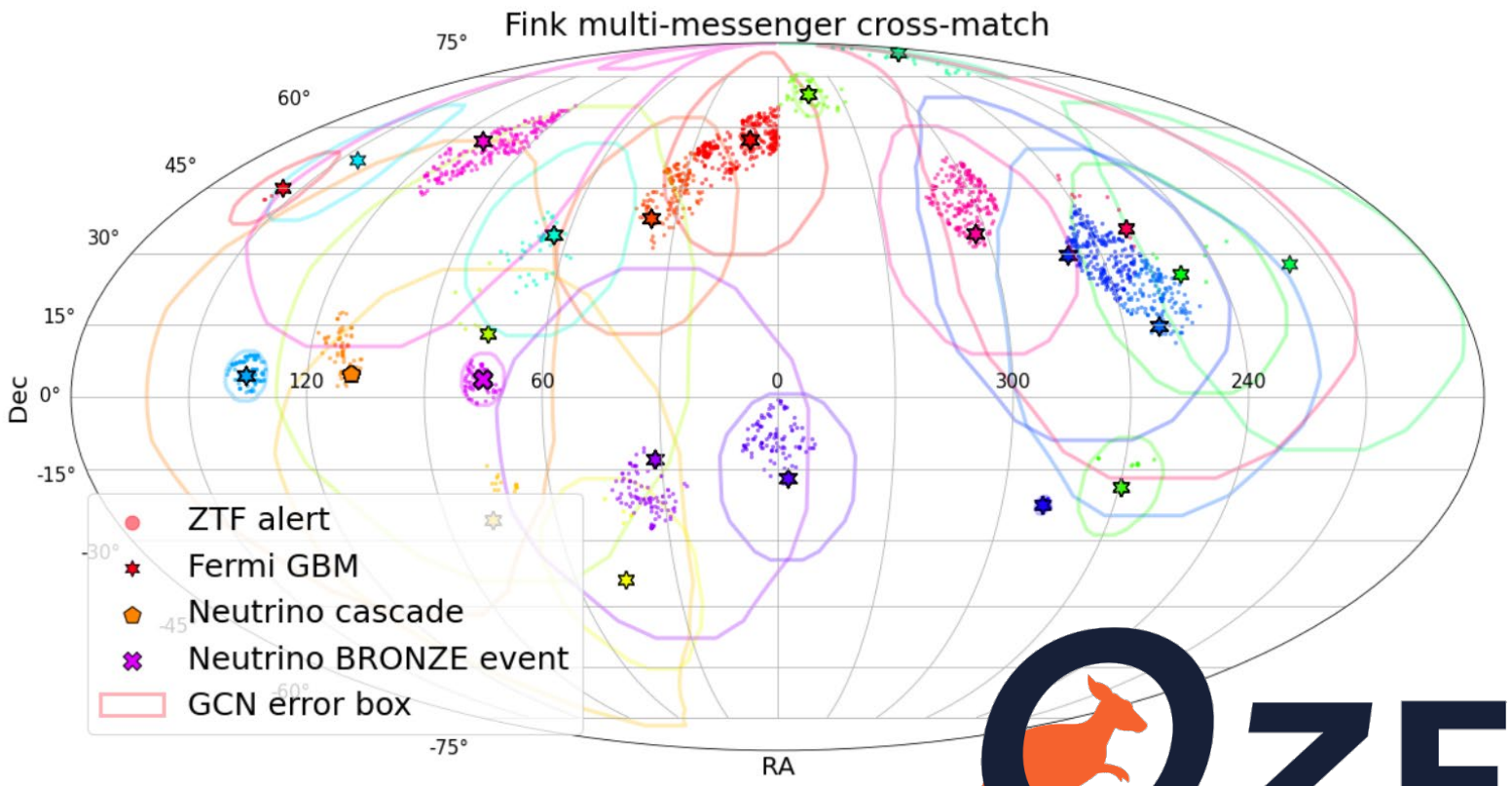
DEVELOP OPEN SOURCE TOOLS to understand all those DATA!!

Multiwavelength/Multimessenger pipeline



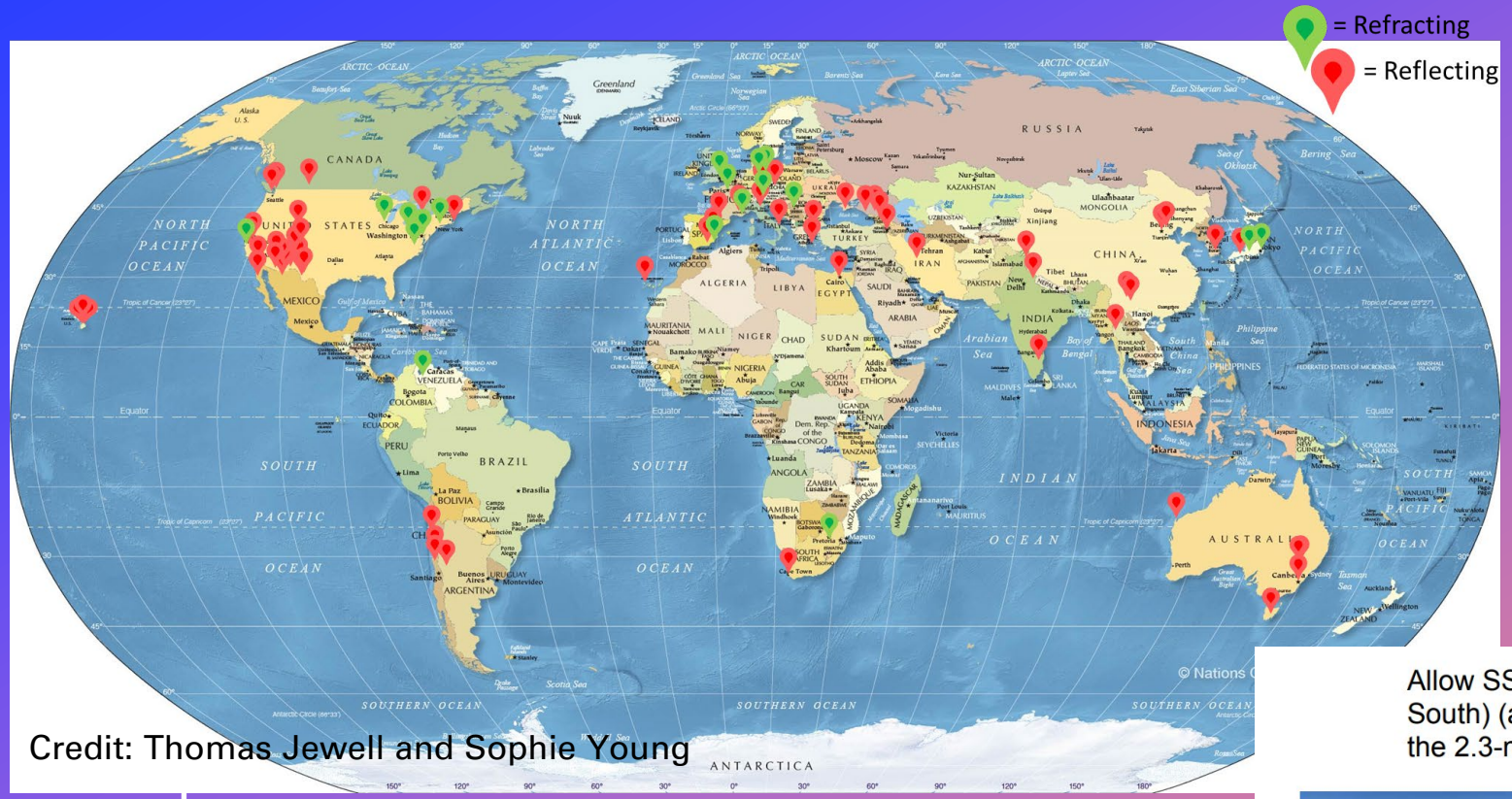
Tools for Afterglow / KN fitting: https://github.com/nikhil-sarin/redback/

Multiwavelength/Multimessenger module



HOW TO FIND MORE KILONOVAE???

WORK INTERNATIONALLY TOGETHER on OPEN SOURCE DATA with OPEN SOURCE tools

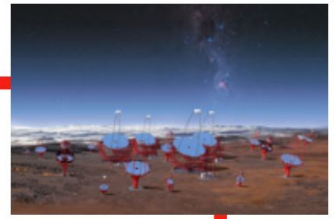


Credit: Thomas Jewell and Sophie Young

Allow SSO wide field imaging facilities (e.g. DREAMS and GOTO South) (and eventually other facilities) to trigger observations on the 2.3-metre without human intervention

CTA Credit: ESO

GOTO South with the APT (DREAMS) in the background



FINK

VRO

2.3-metre

Transients Down Under

Mon Jan 29 - Fri Feb 2, 2024 @ Swinburne Institute of Technology, Melbourne, Australia.

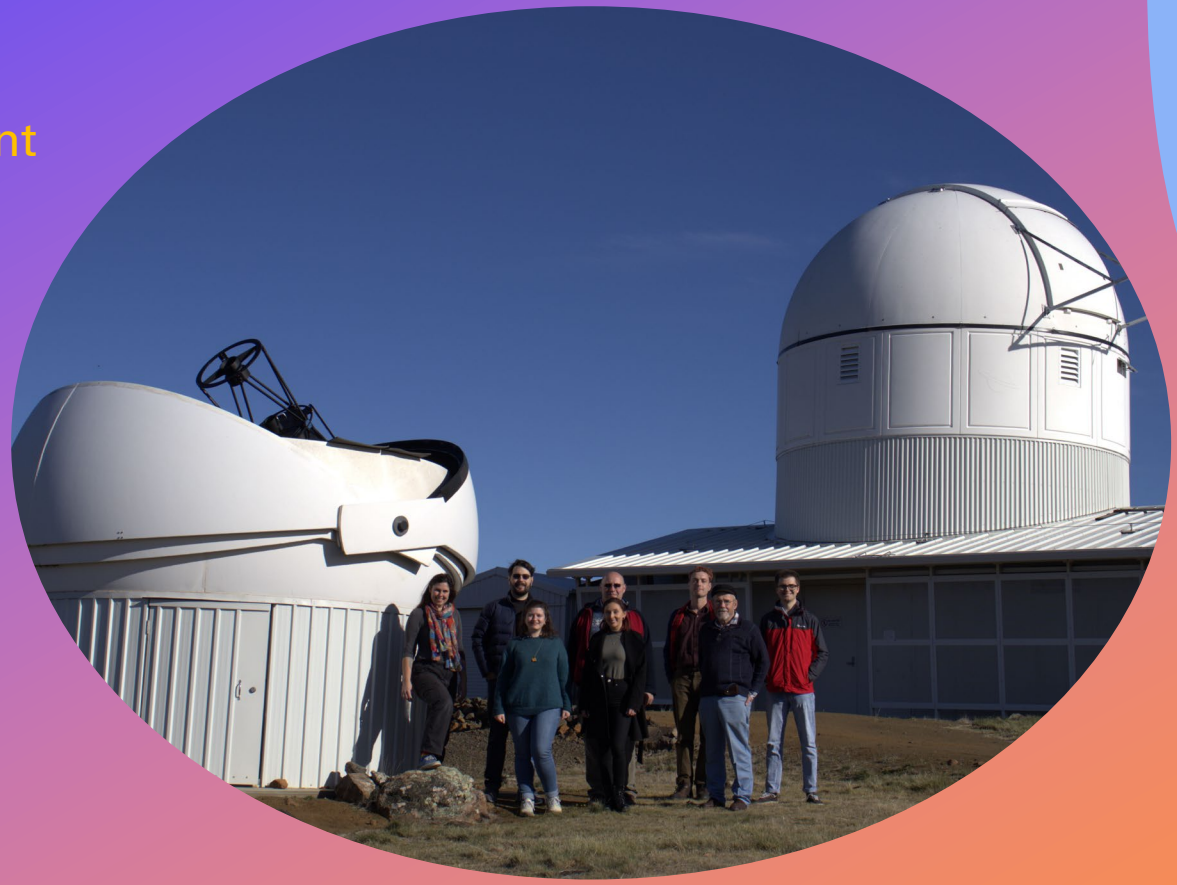
Background image: Vela supernova remnant. Image credit: ESO/VPHAS+ team. Acknowledgement: Cambridge Astronomical Survey Unit

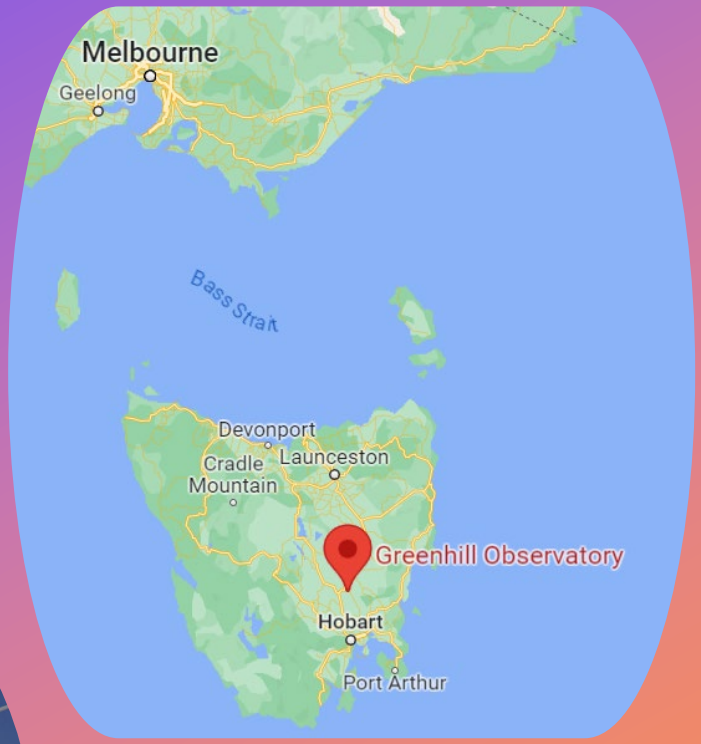
We are excited to announce the “Transients Down Under” conference to be held on 29 January - 02 February 2024 at Swinburne University of Technology in Melbourne, Australia. The conference is during summertime in Australia and the aim is to start off the year by gathering international experts in transient astronomy at all wavelengths, messengers, and timescales.

Conference website: https://transientsdownunder.github.io/

THE GREENHILL OBSERVATORY

Optical Telescopes:
- 50cm with fast mount
- 1.3m !





Dr. Karelle Siellez &
Prof. Andrew Cole

University of Tasmania

Thank you!

Karelle.Siellez@utas.edu.au

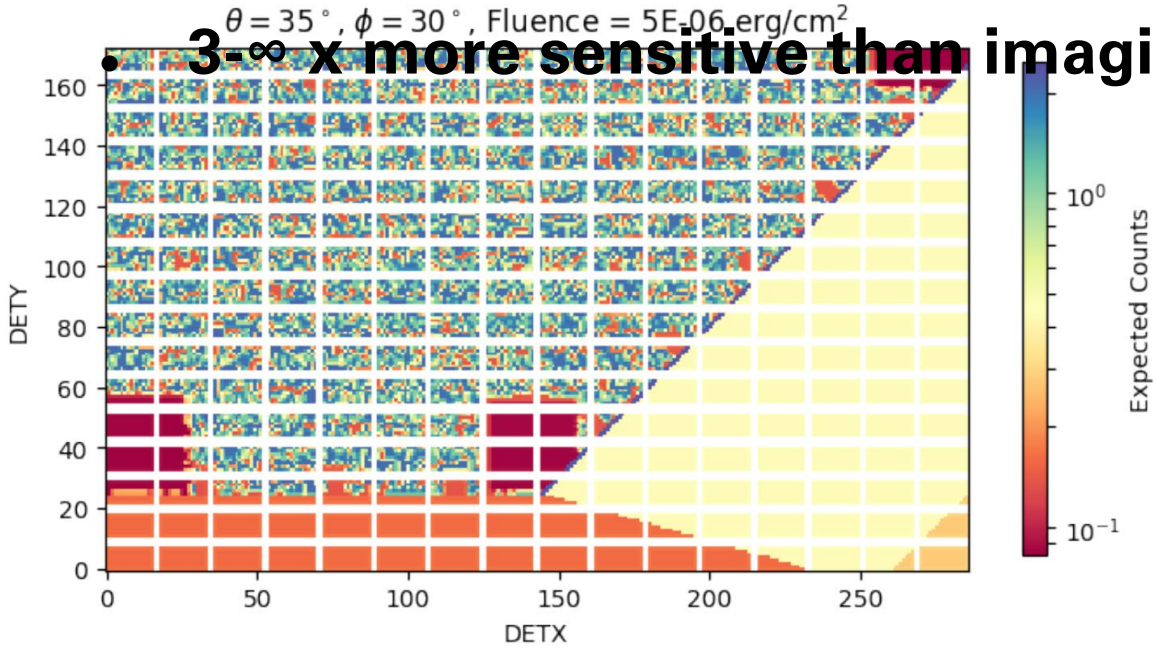
https://transientsdownunder.github.io/

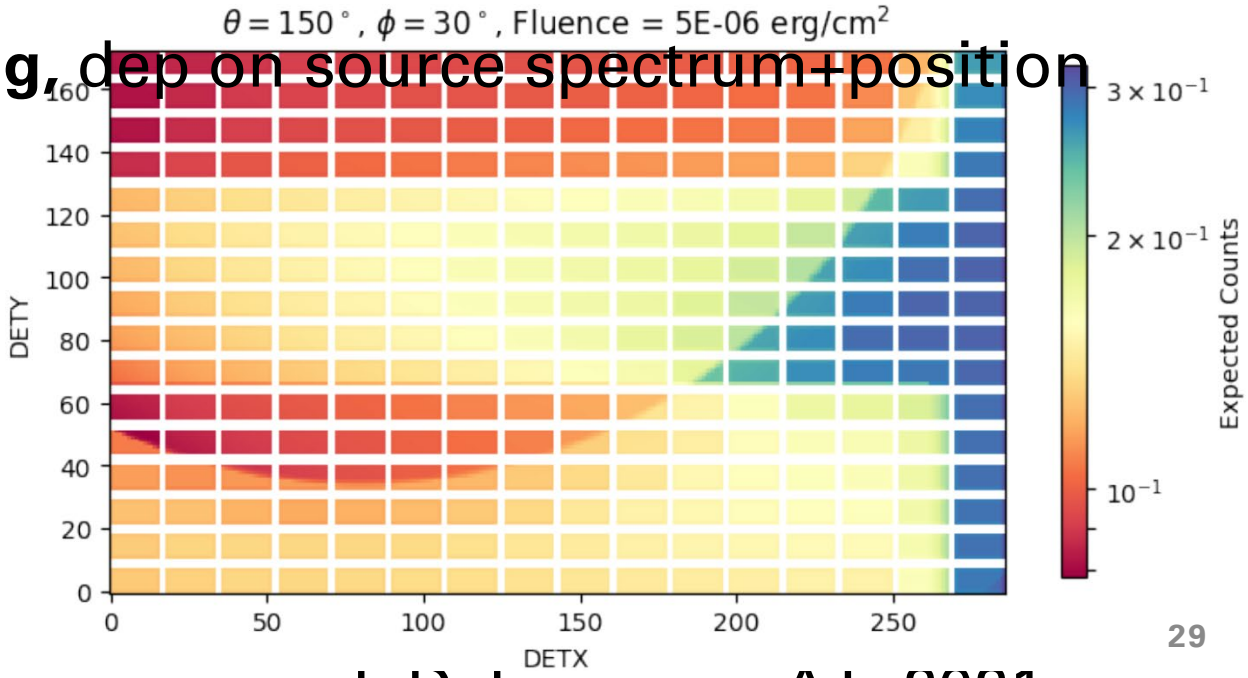
Supplements

NITRATES (Non-Imaging Transient Reconstruction And TEmporal Search):

A new maximum likelihood Analysis Framework for BAT data

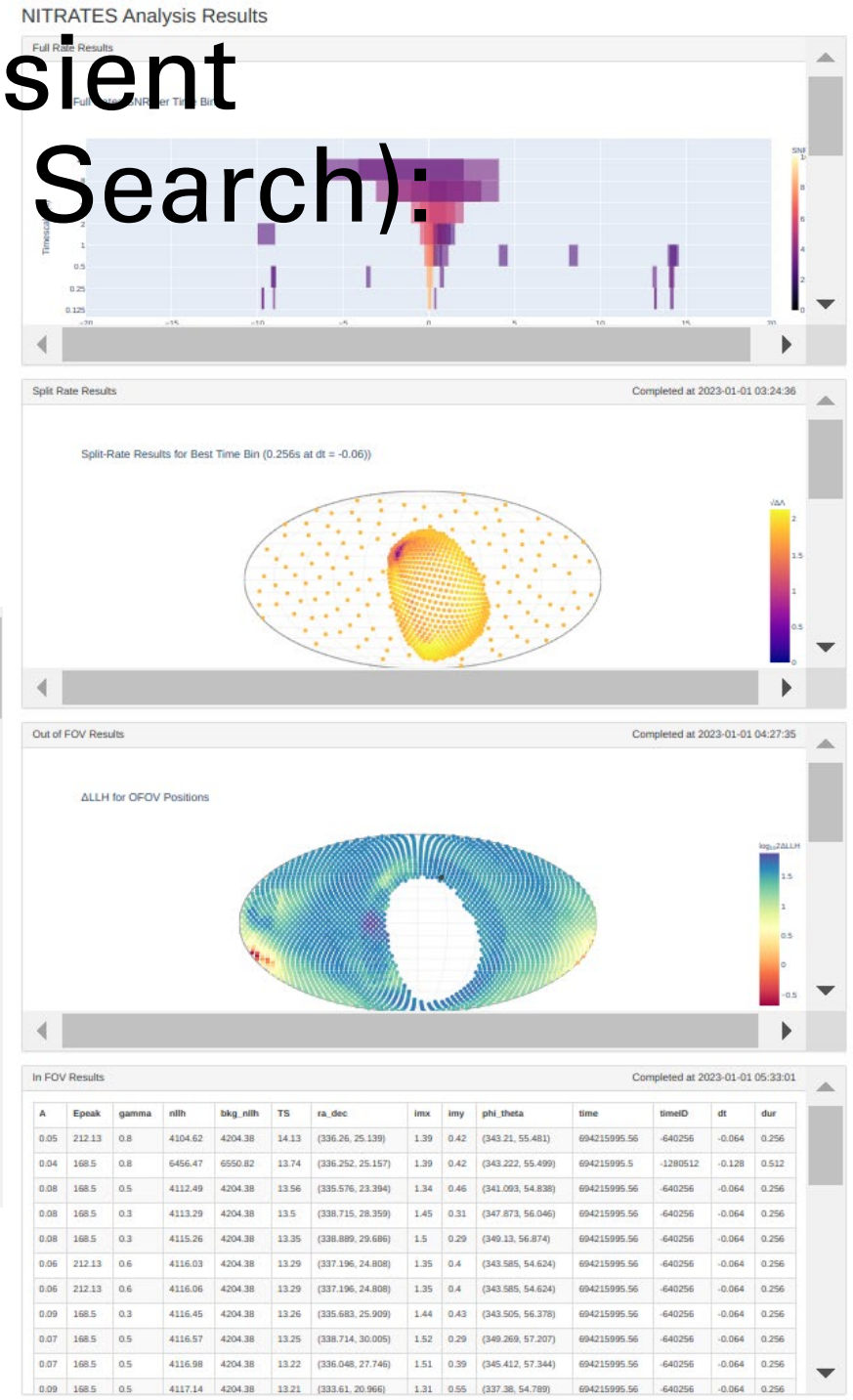
- Using the GUANO data, and bursts with known positions and spectra, we calibrate the BAT out-of-FoV response for the first time.
- GRBs are fully forward modelled through the instrument response, and resultant shadowgrams are produced
- These data models are compared to the observed data with a likelihood test
- **3-∞ x more sensitive than imaging,** dep on source spectrum+position





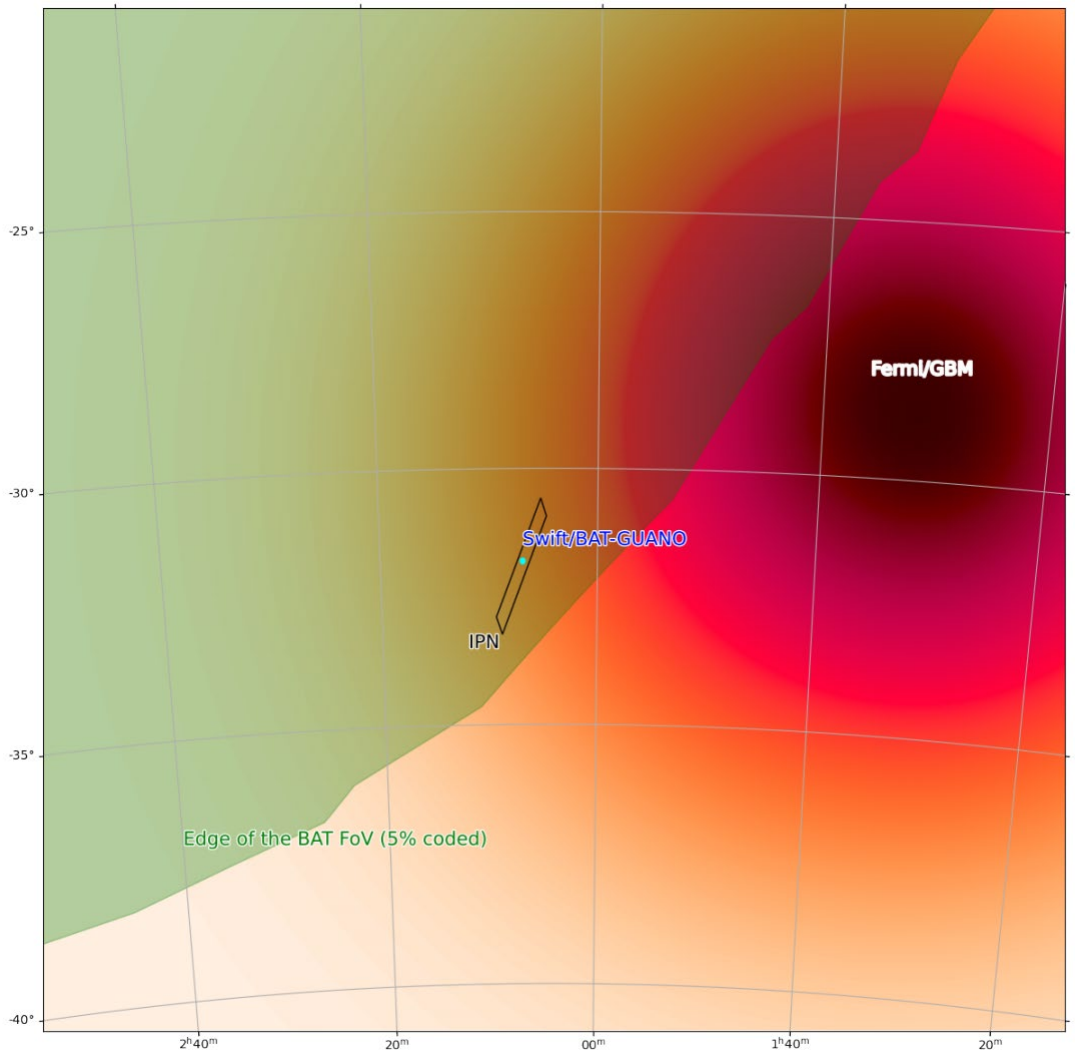
J. DeLaunay + AT, 2021

NITRATES (Non-Imaging Transient Reconstruction And TEmporal Search):



External GRB triggered search results:

- Since Feb 2020: Triggering on GRBs detected by Fermi, INTEGRAL, CALET, HAWC
- These GRBs have either large (~100-1000 deg^2) or no localizations
- GUANO has recovered **arcminute localizations for 34 GRBs** to date (~1/month).
  - **>15% of all arcmin localized GRBs.**
- Higher short GRB recovery fraction
  - 25% vs 10% for BAT onboard
- Localizations distributed to community for follow-up in O(hours) via GCN
  - 23 of 34 got prompt follow-up
  - **15 afterglows discovered**



Many localizations unrecoverable with conventional imaging