

images credit Paz Beniamini

LUCA LATRONICO, INFN TORINO

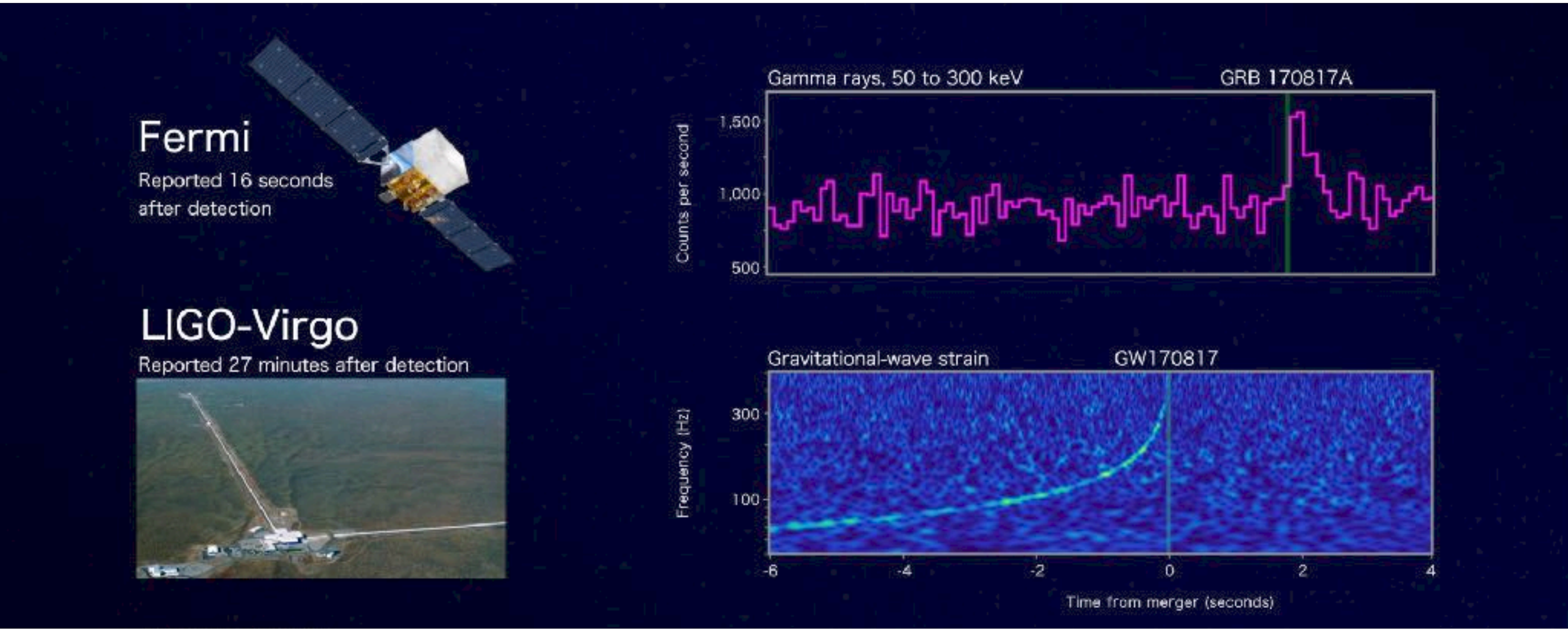
SIF - CONGRESSO 106

14 SETTEMBRE 2020

IL TELESCOPIO FERMI E L'ASTRONOMIA MULTI-MESSAGGERA

ASTRONOMIA MULTIMESSAGGERA - NASCITA

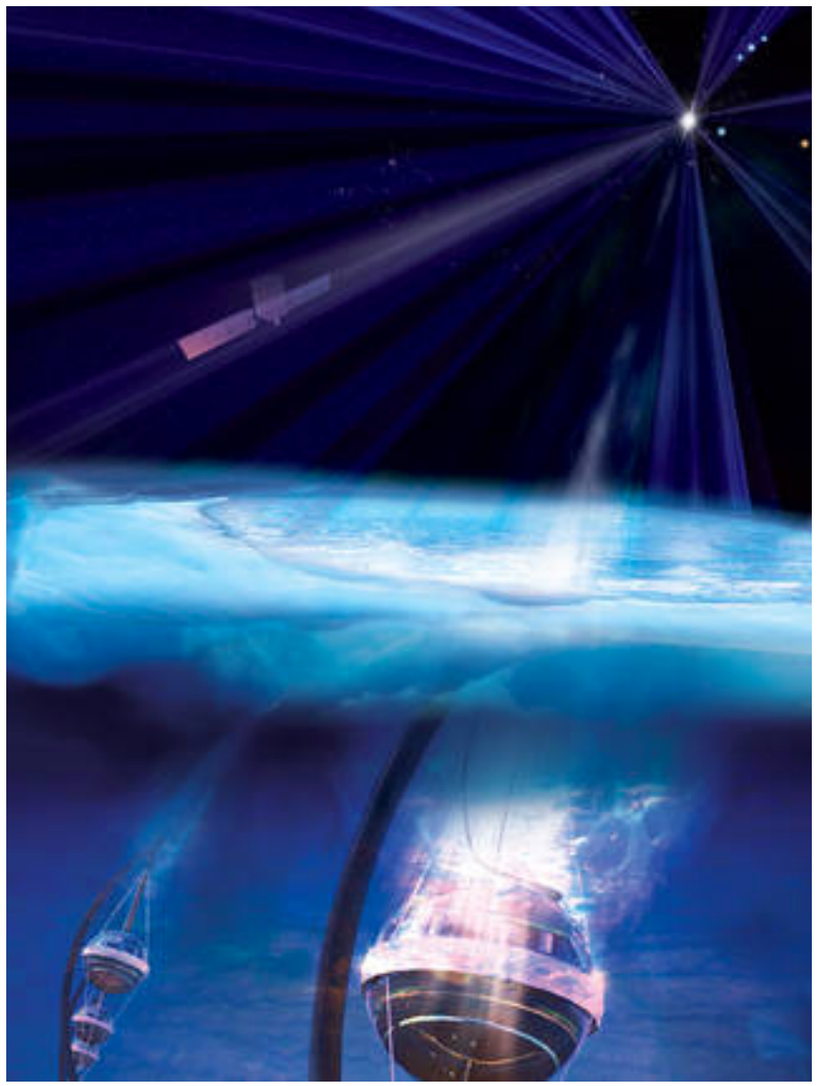
17 AUGUST 2017 – WAKE UP!

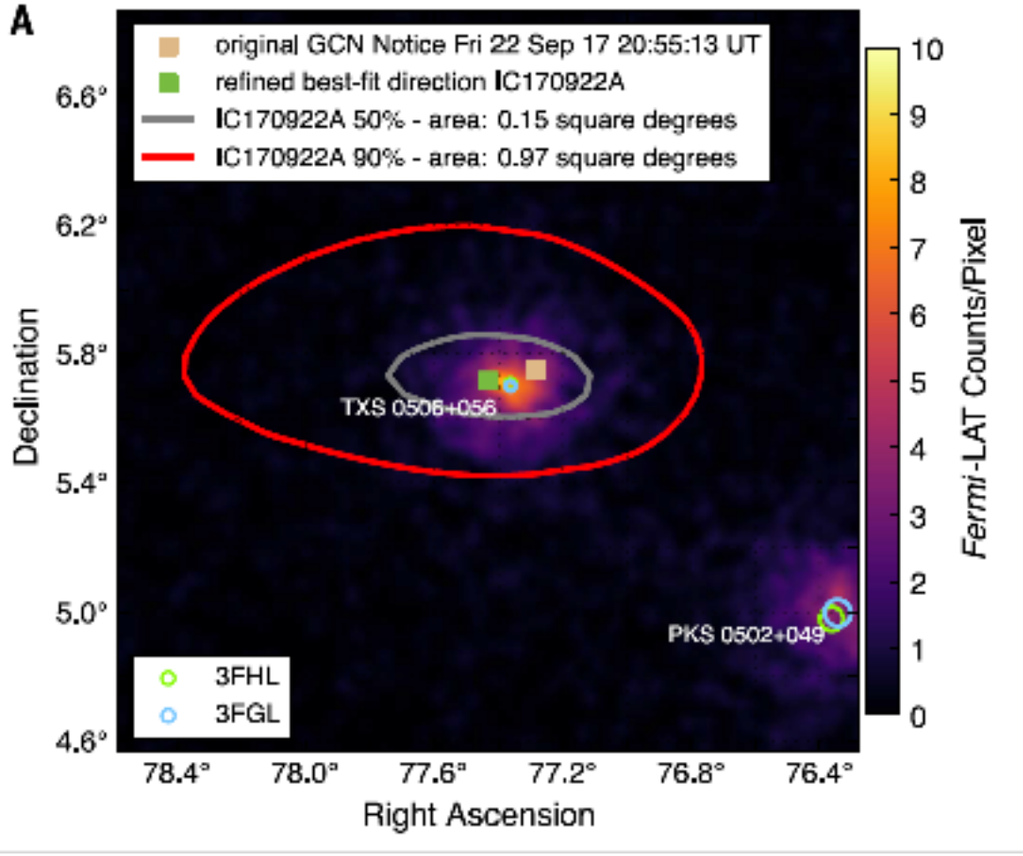


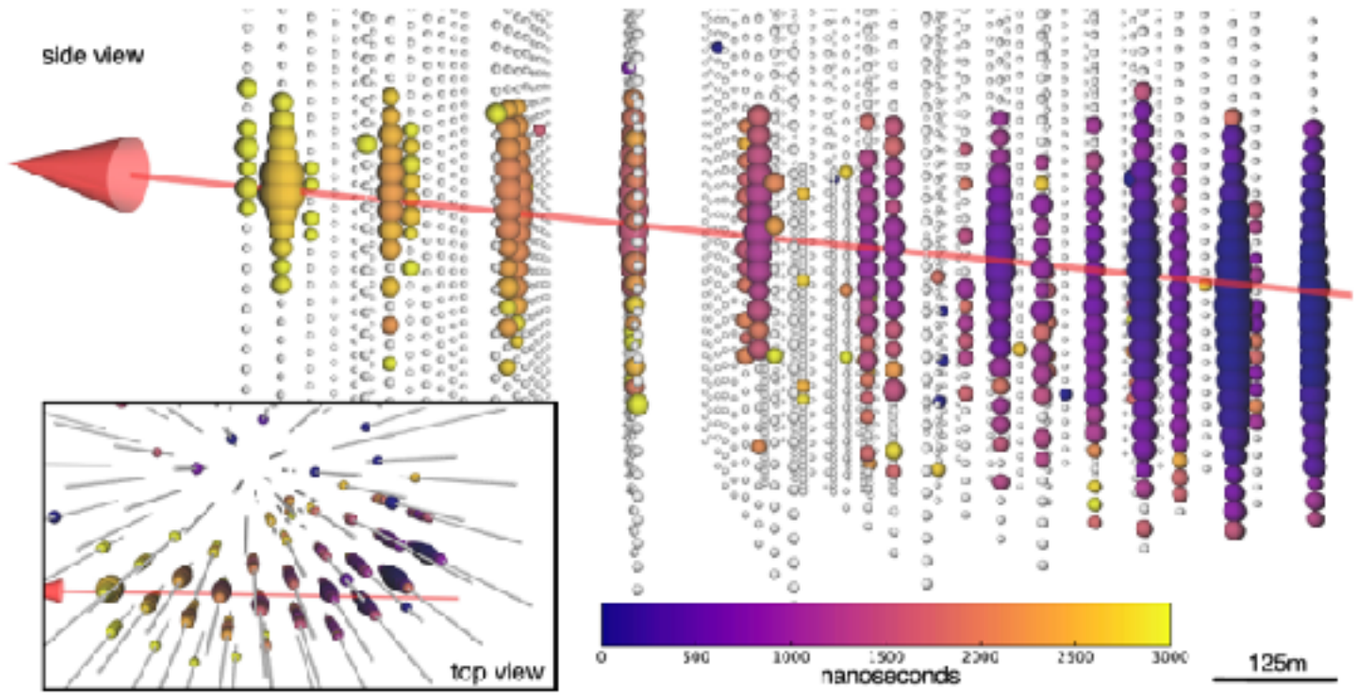
https://www.nasa.gov/centers/marshall/news/news/2017/fermi-gamma-ray-burst-monitor-wakes-the-world-to-smashing-neutron-stars.html

ASTRONOMIA MULTIMESSAGGERA - NASCITA

19 SEPTEMBER 2017

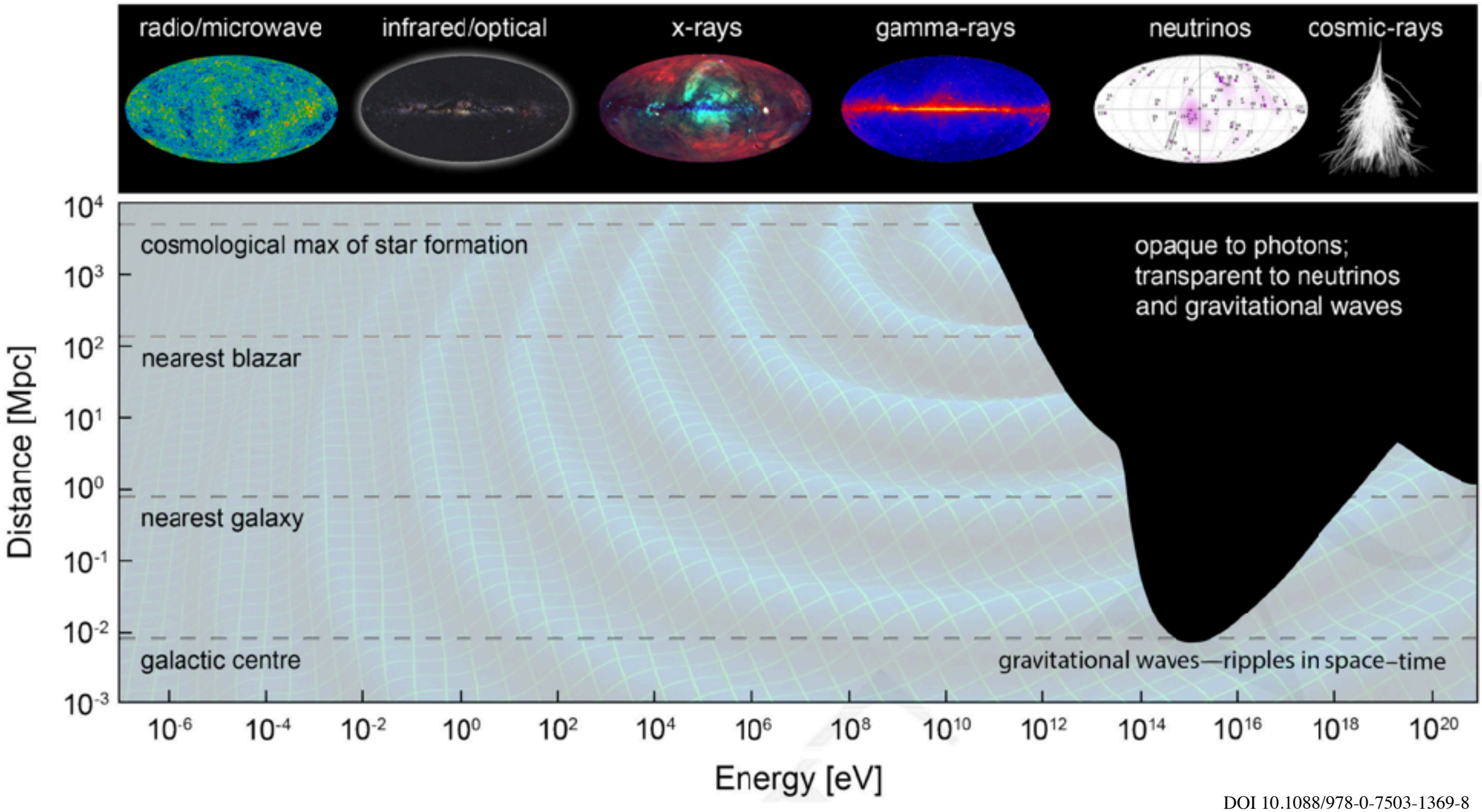




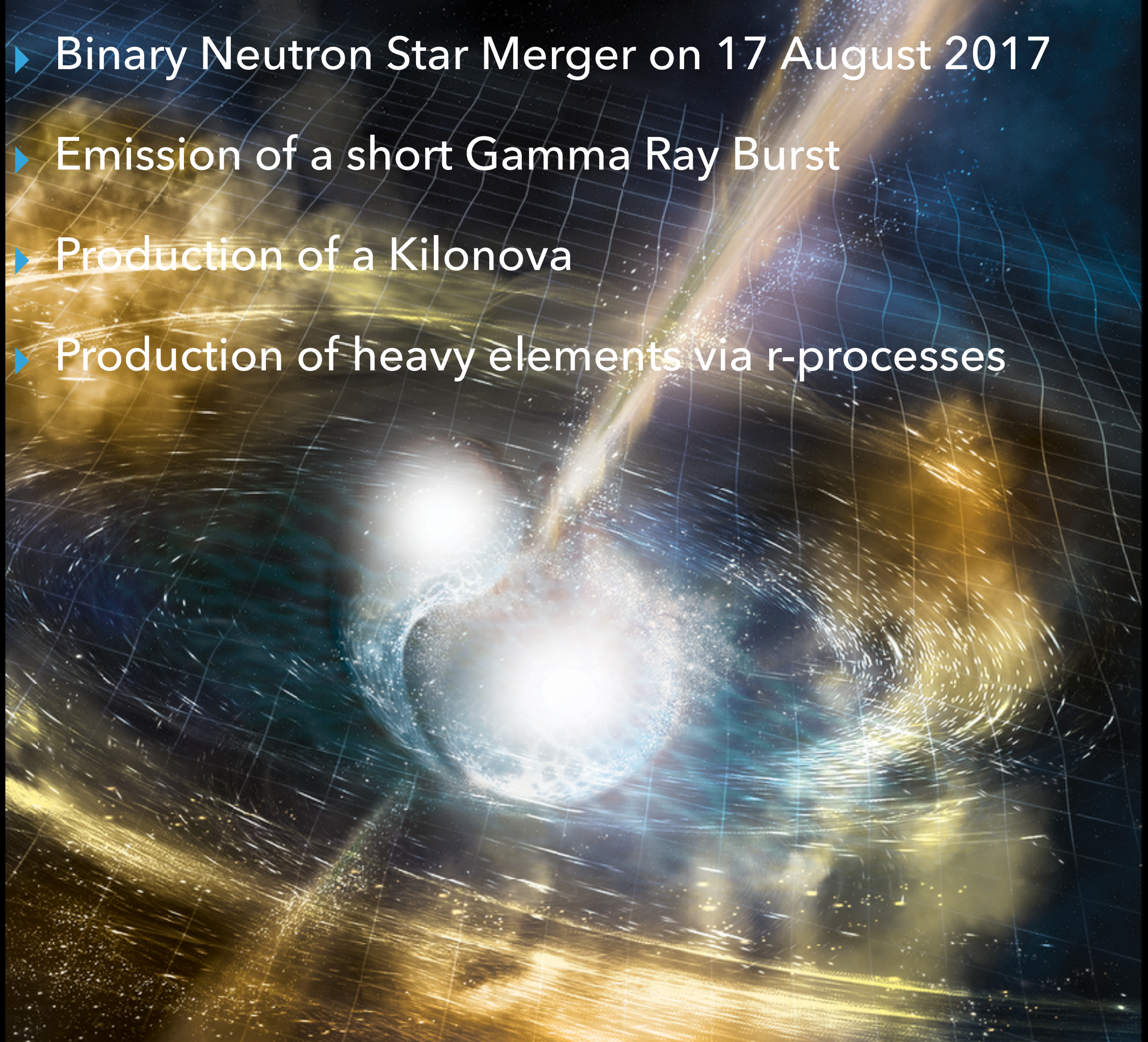


https://www.nasa.gov/press-release/nasa-s-fermi-traces-source-of-cosmic-neutrino-to-monster-black-hole

MESSENGERS

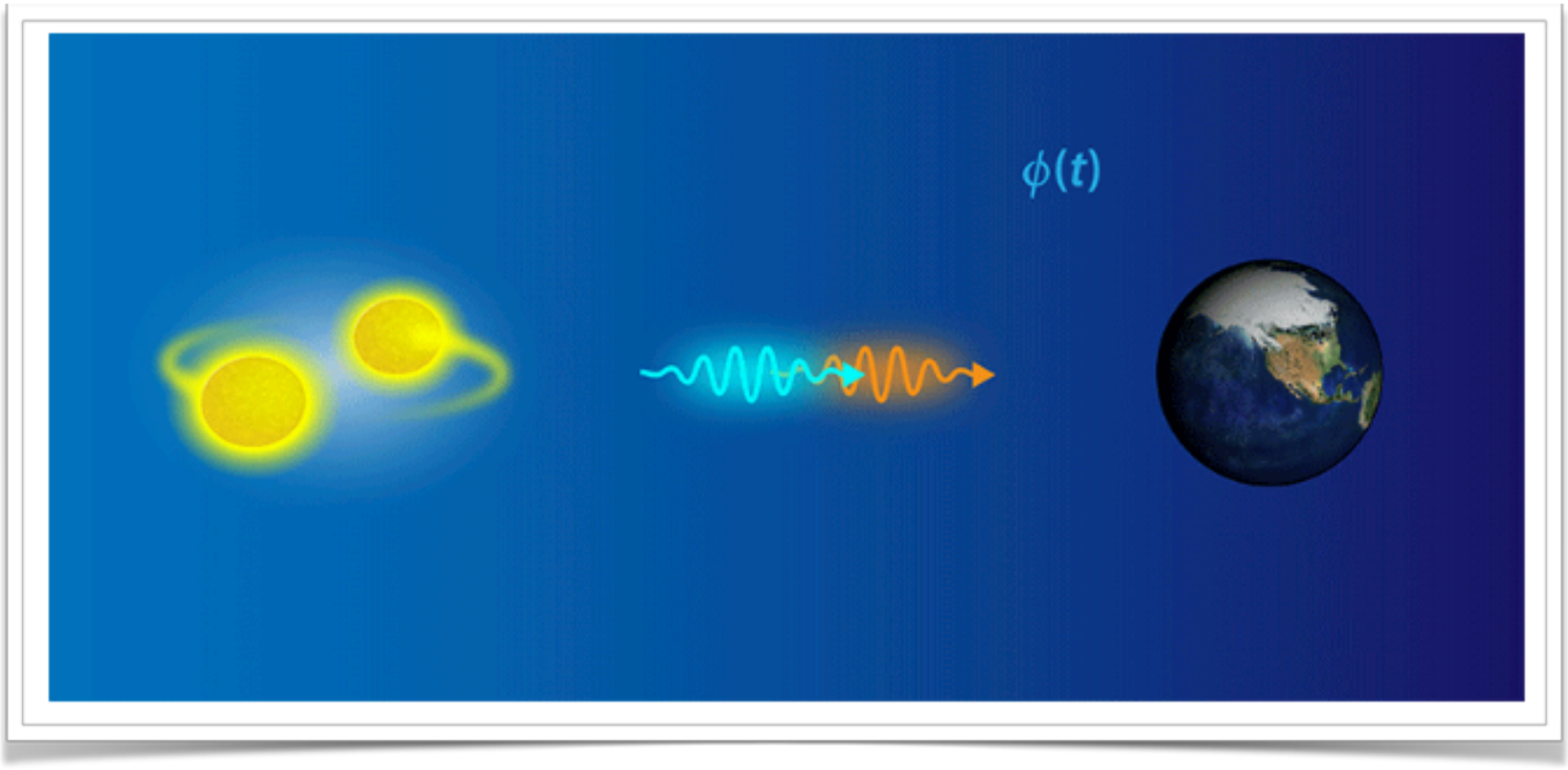


DOI 10.1088/978-0-7503-1369-8



- Binary Neutron Star Merger on 17 August 2017
- Emission of a short Gamma Ray Burst
- Production of a Kilonova
- Production of heavy elements via r-processes

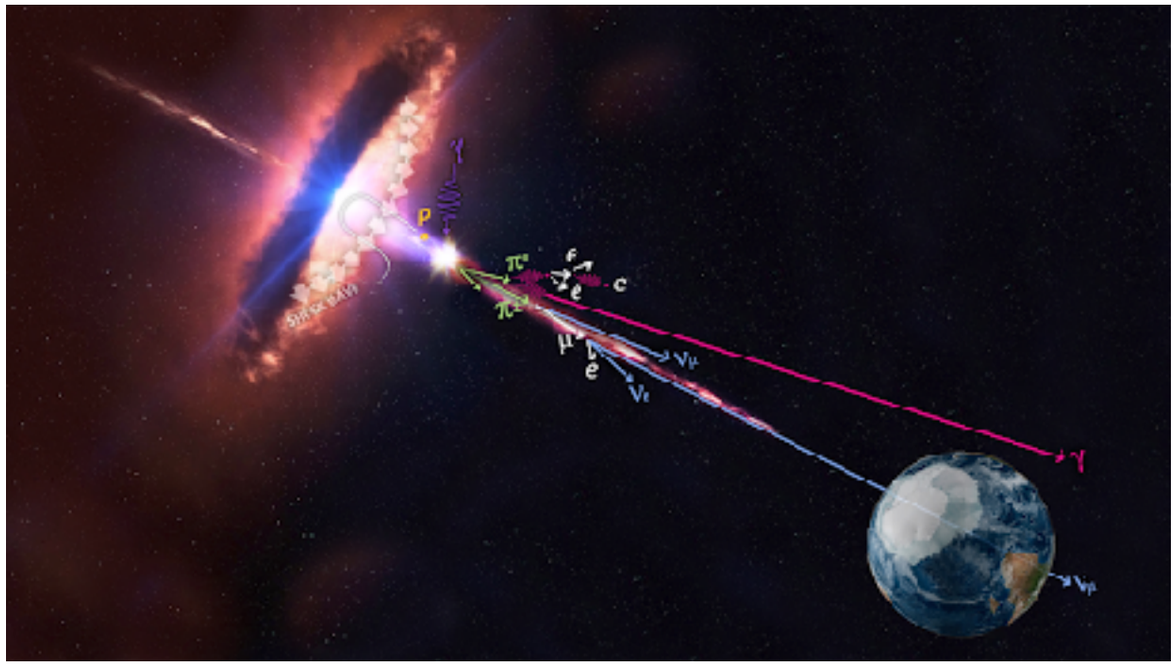
FUNDAMENTAL PHYSICS IMPLICATIONS

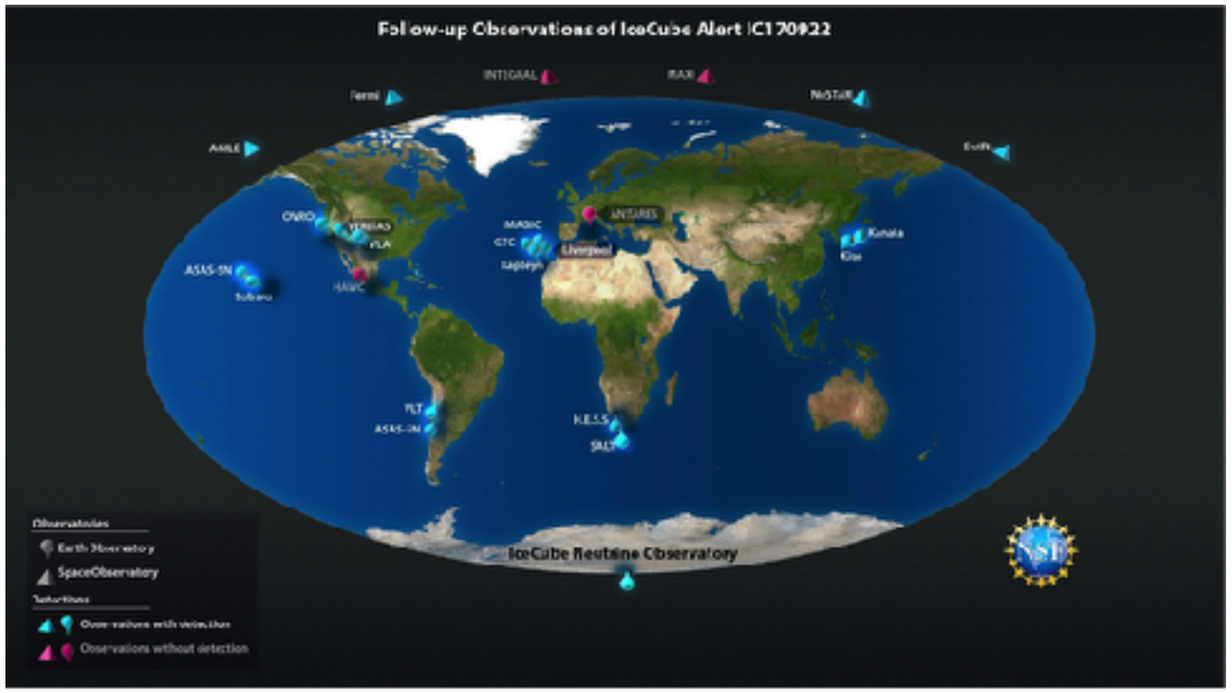


- GW and photons speed = c with ~1/10^{15} error (2s/130Mly)
  - Lorentz Invariance and Equivalence Principle verified (ApJL 848:L13, 2017)
  - limits to alternative cosmology other than GR + cosmological constant (https://physics.aps.org/articles/v10/134)

ASTRONOMIA MULTIMESSAGGERA - RISULTATI

19 SEPTEMBER 2017

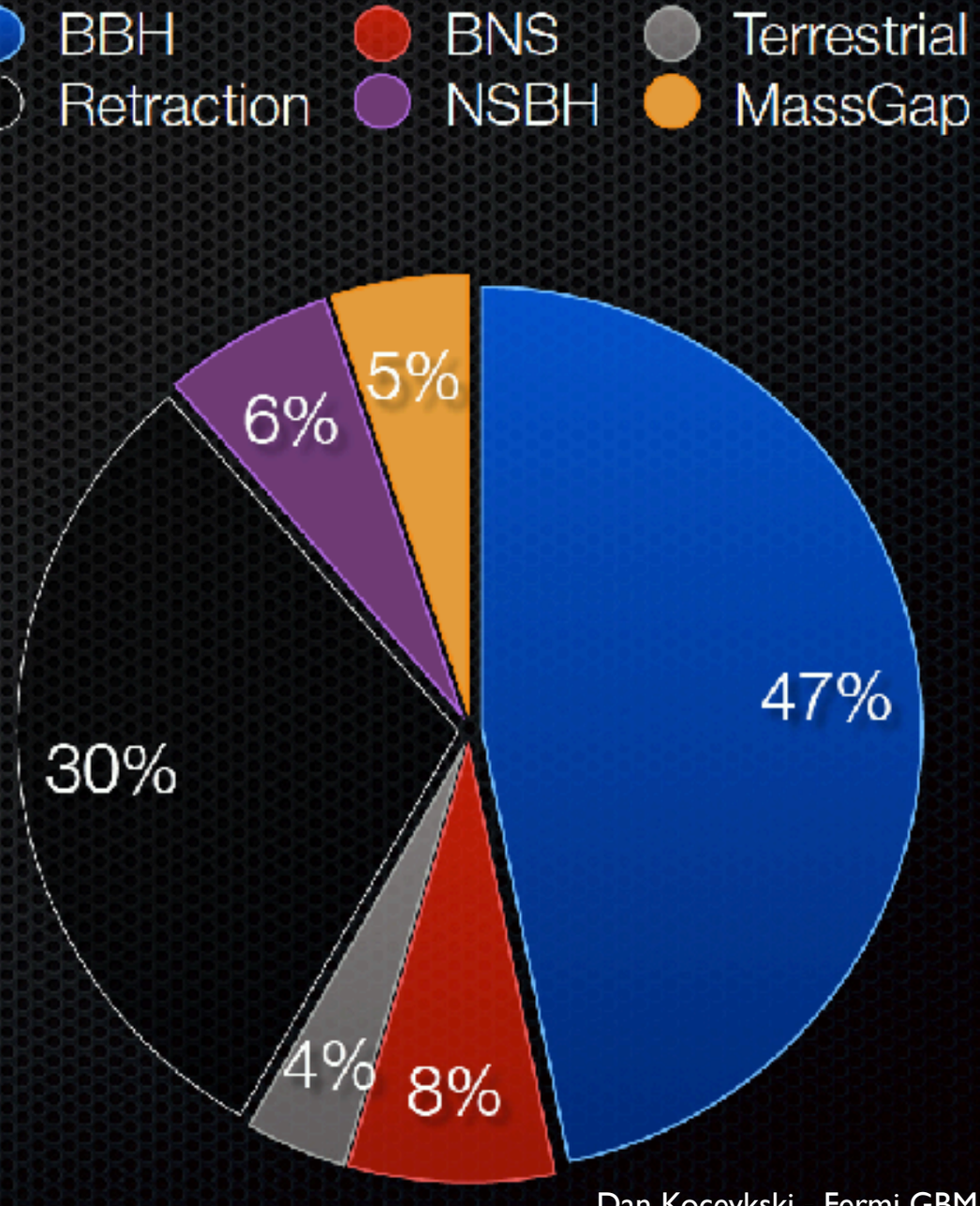




- Blazar accelerate protons
- A world-wide network of observatories can perform multi-messenger followups

GW OBSERVATIONS AND FERMI FOLLOWUPS

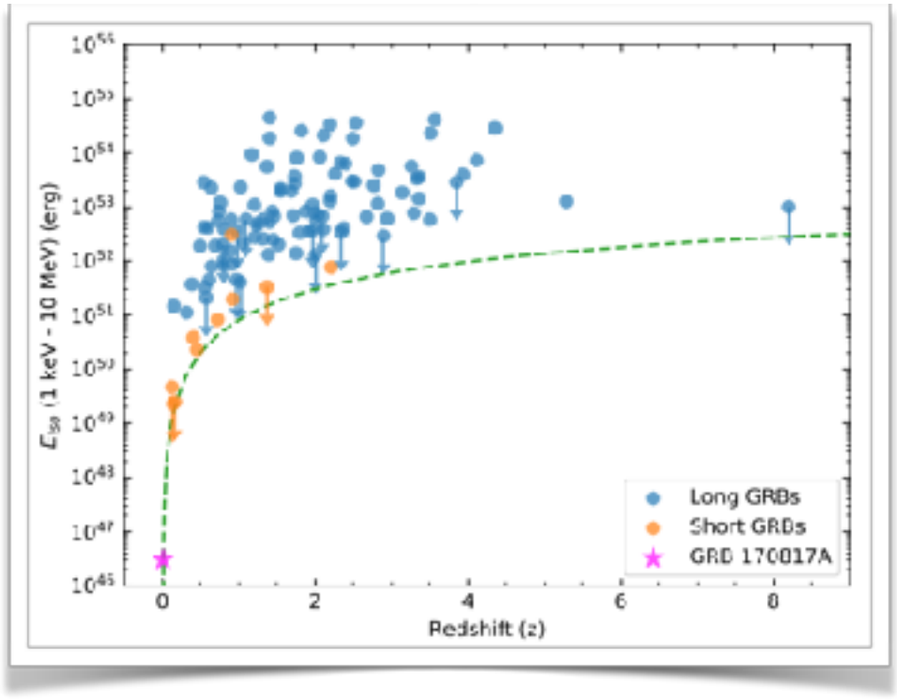
- LVC issued 80 public detection alerts via GCN since April 5th, 2018
  - 37 BBH
  - 6 BNS
  - 5 NSBH
  - 4 MassGap
  - 3 Terrestrial?
  - 24 Retractions
- Ferm was in SAA for 9 of 55 un-retracted triggers, or roughly 16% of the time



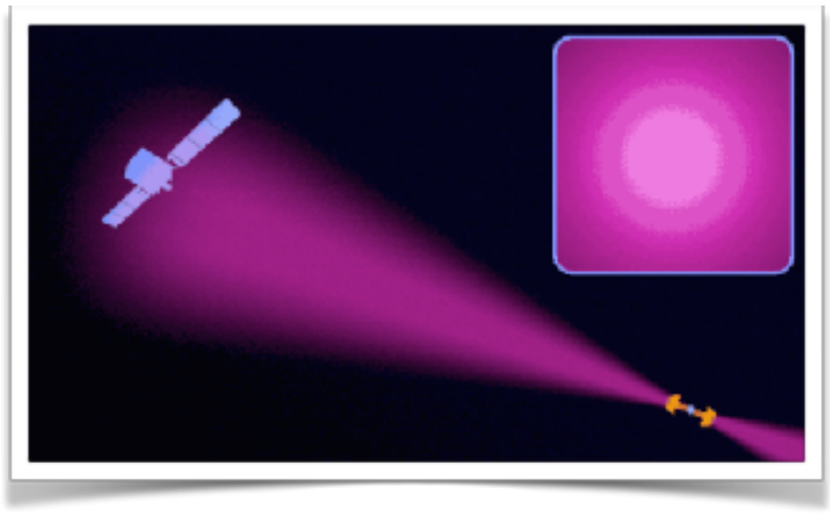
Dan Kocevkski - Fermi GBM Team

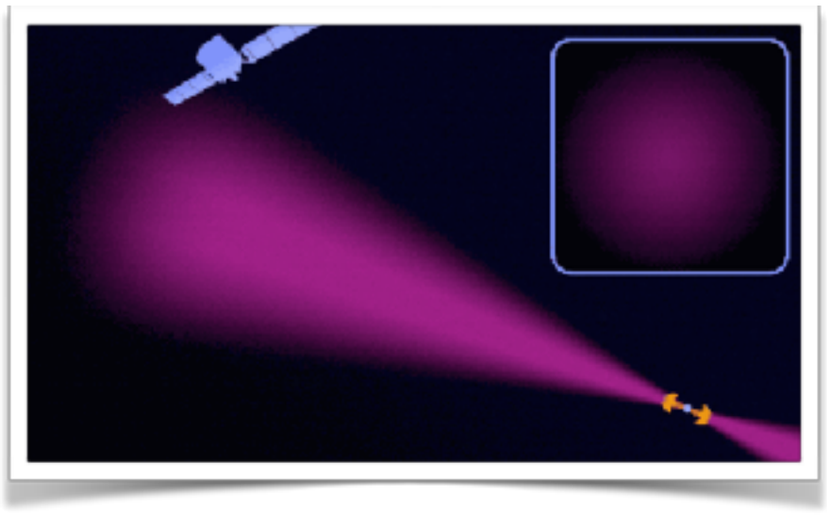
GRB170817 – A SPECIAL EVENT?

- ~10^4 dimmer than ordinary GRBs
- Circumstantial evidence of a jet seen off axis
- long term multi-wavelength observations and jet modeling to assess this picture



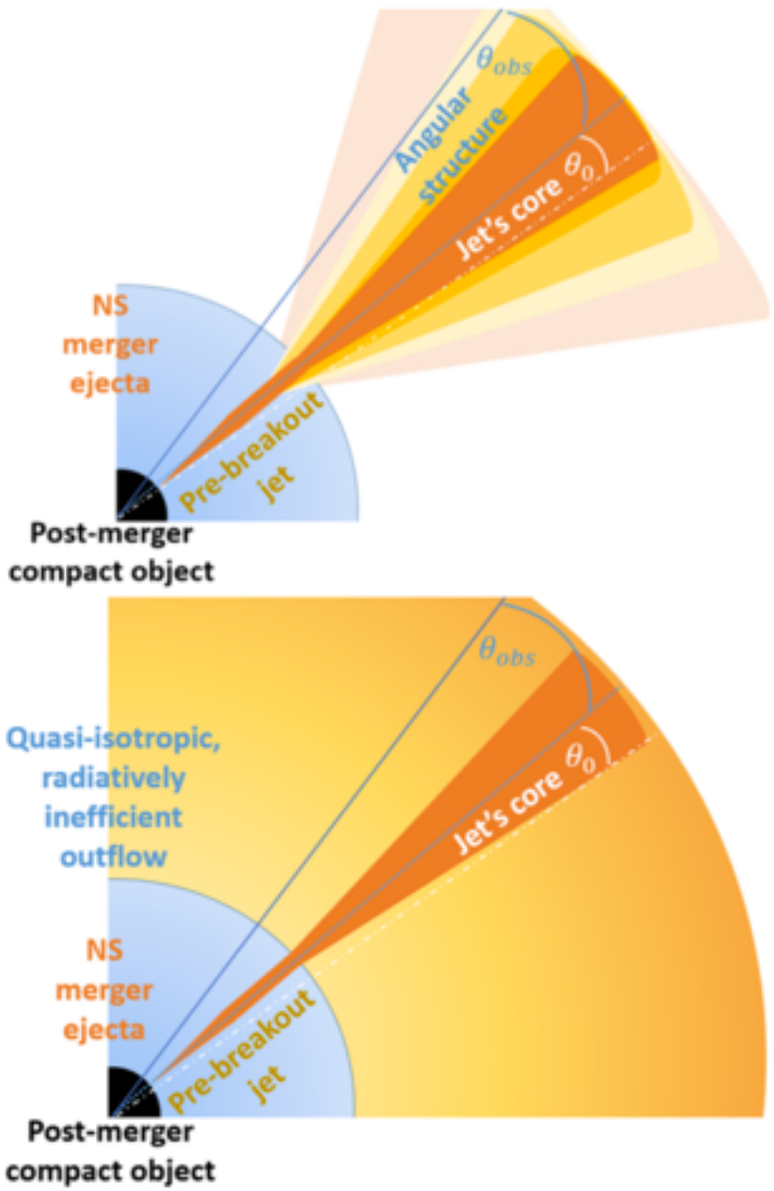
Abbott et al, 2017, arXiv:1710.05834





GRB170817 EMISSION MODELS

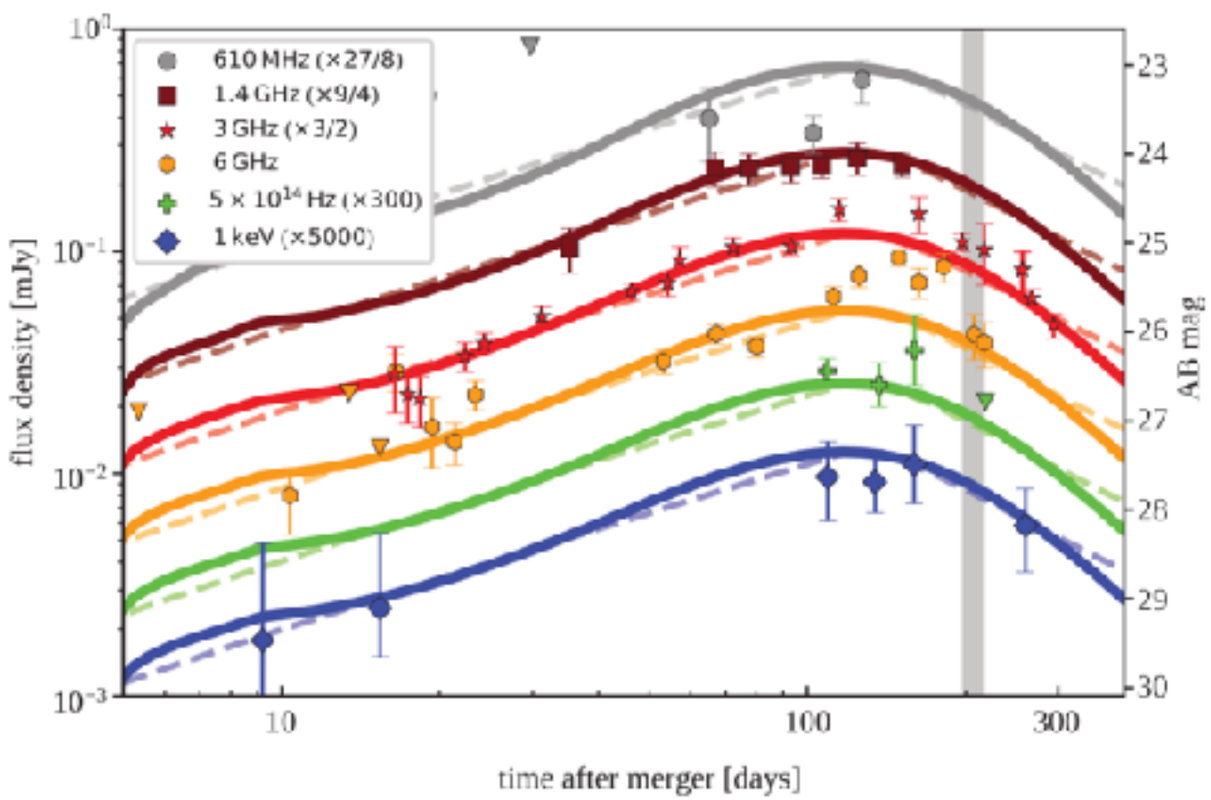
- Top: **structured jet**
  - jet with core luminosity (power-law / gaussian) breaks the ejecta
  - observer sees dimmer / less energetic emission
- Bottom: **choked cocoon**
  - jet with radiatively inefficient outflow



Beniamini et al, 2018, arXiv:1808.04831

GRB170817 – MULTIFREQUENCY OBSERVATIONS

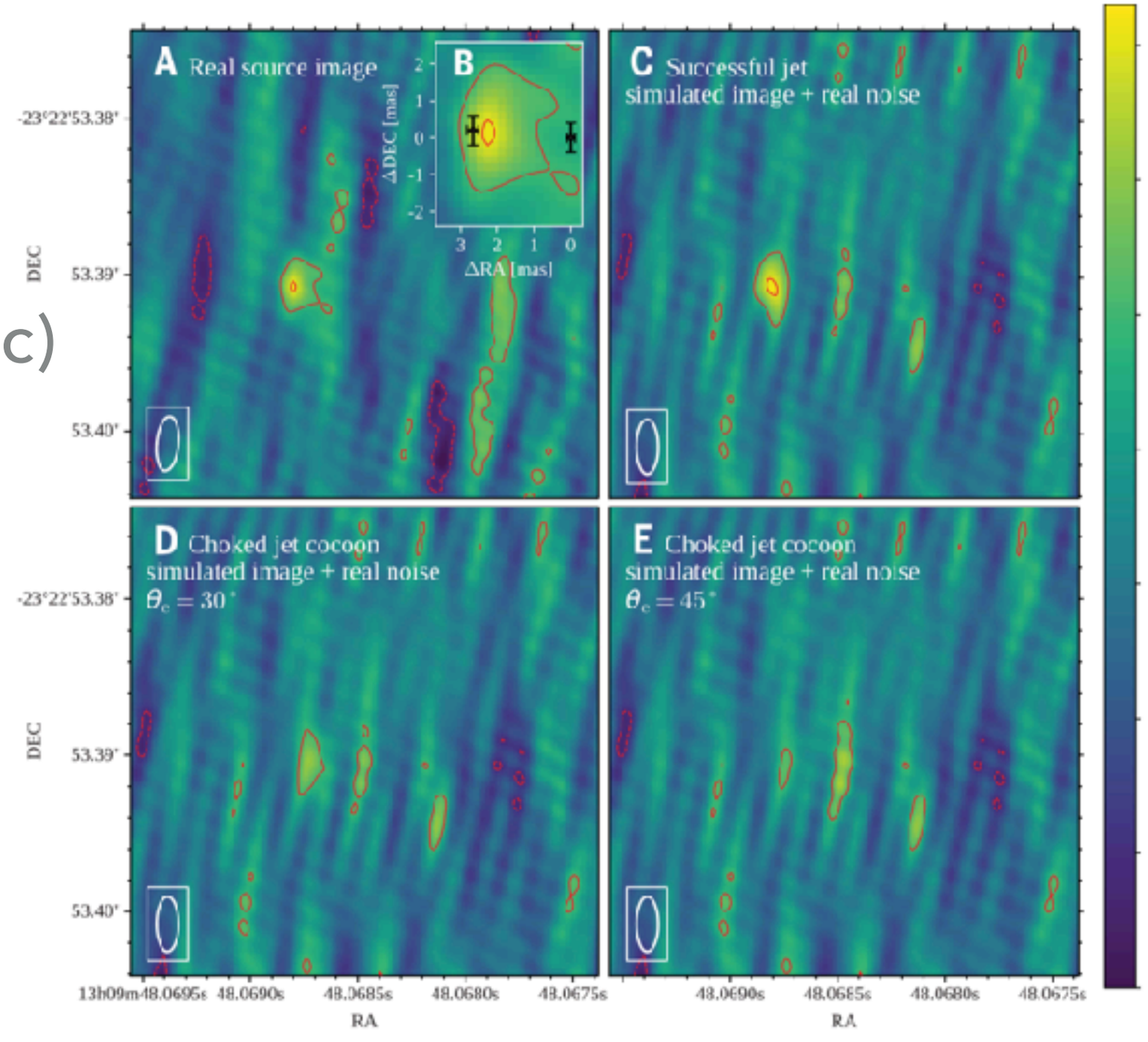
- Long-term observations of the multifrequency emission confirm non thermal emission
- Flux information compatible with a structured jet (solid lines) as well as with a choked cocoon (dashed)



Ghirlanda et al, 2019, Science 363, 968-971

GRB170817 – RADIO VLBI OBSERVATIONS – JET IMAGING

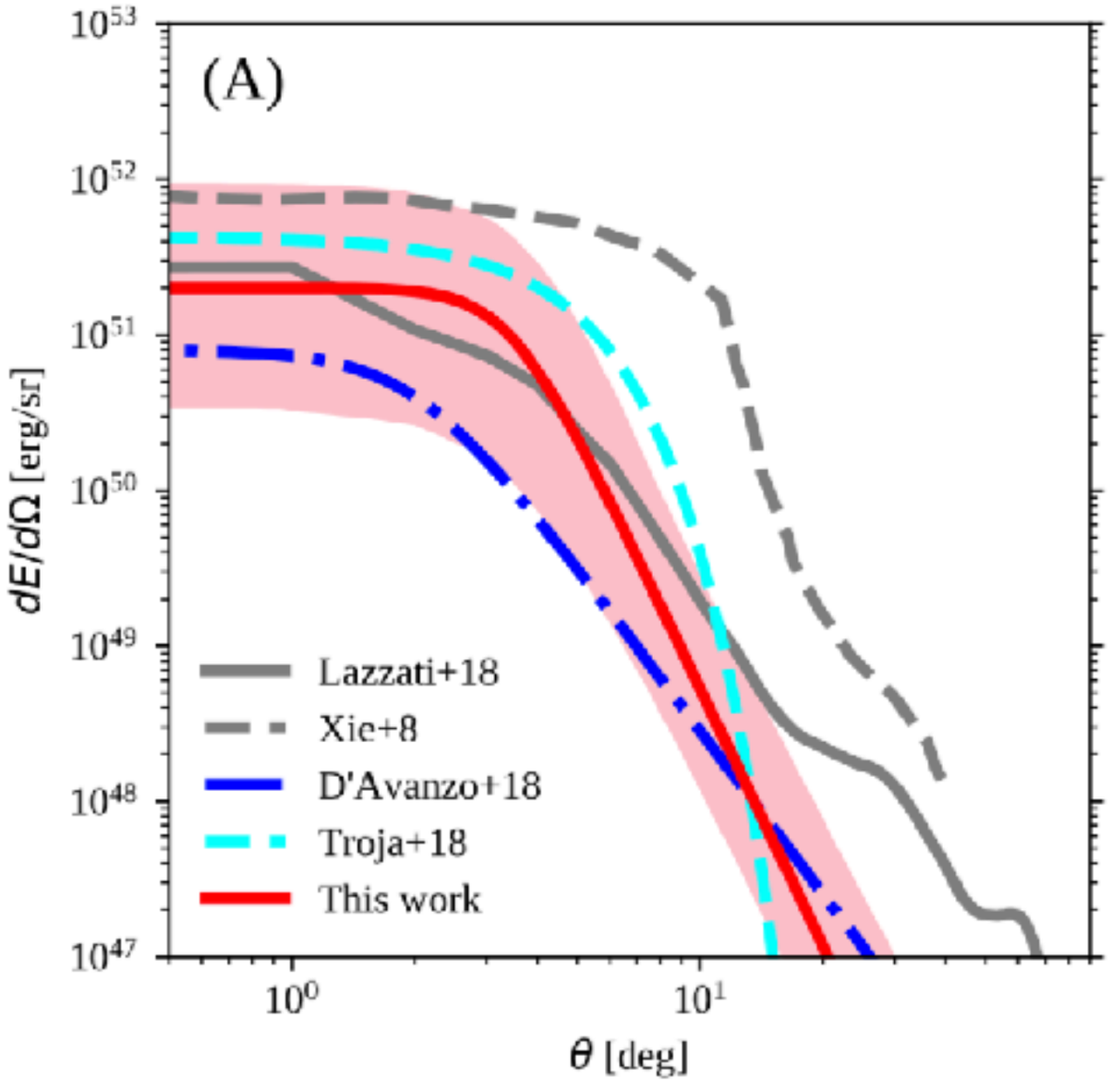
- Structured jet preferred to chocked cocoon
  - **compact** (<~2marcsec)
- peaked brightness



Ghirlanda et al, 2019, Science 363, 968-971

GRB170817 – RADIO VLBI OBSERVATIONS – JET ENERGETICS

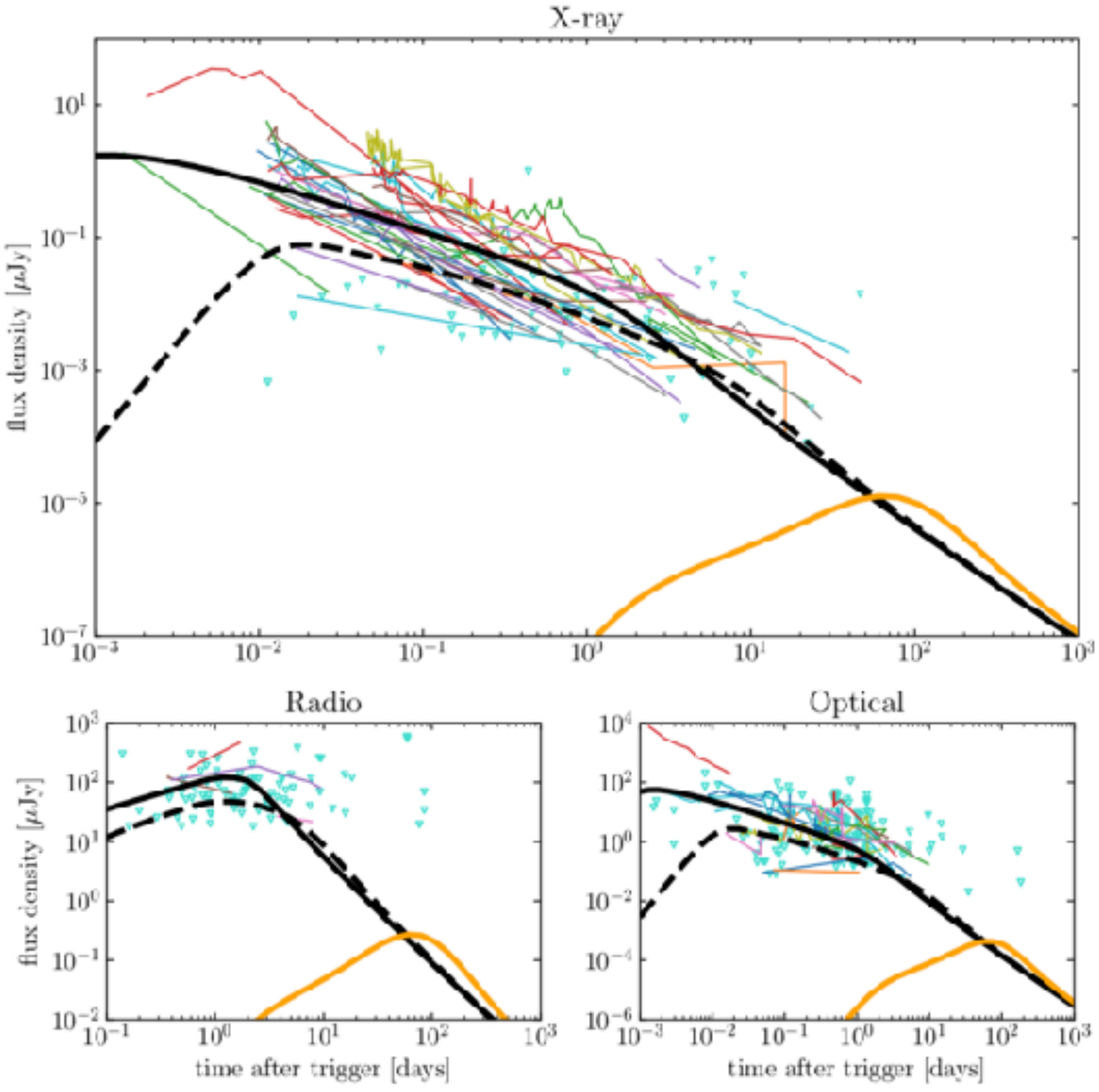
- Structured jet preferred to chocked cocoon
  - compact (<~2marcsec)
  - **peaked brightness**



Ghirlanda et al, 2019, Science 363, 968-971

A UNIVERSAL SHORT-GRB JET STRUCTURE ?

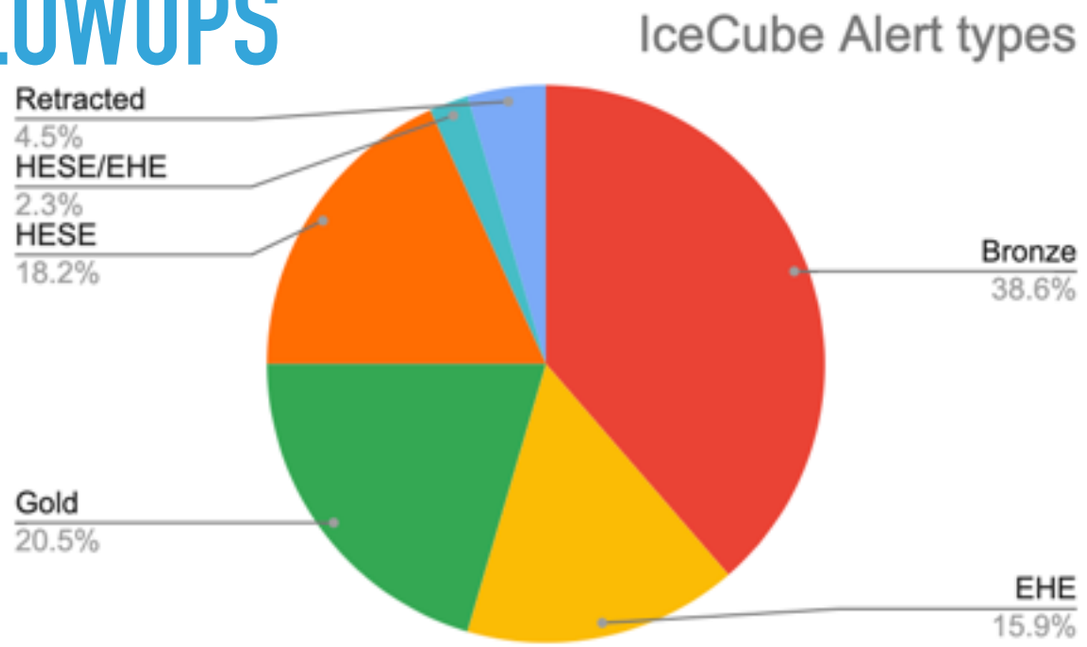
- sGRBs afterglows: archival data for ordinary GRBs with a GRB170817-like structured jet seen on-axis (black lines) or off-axis (orange line)
- diversity of sGRB afterglows attributed to external properties

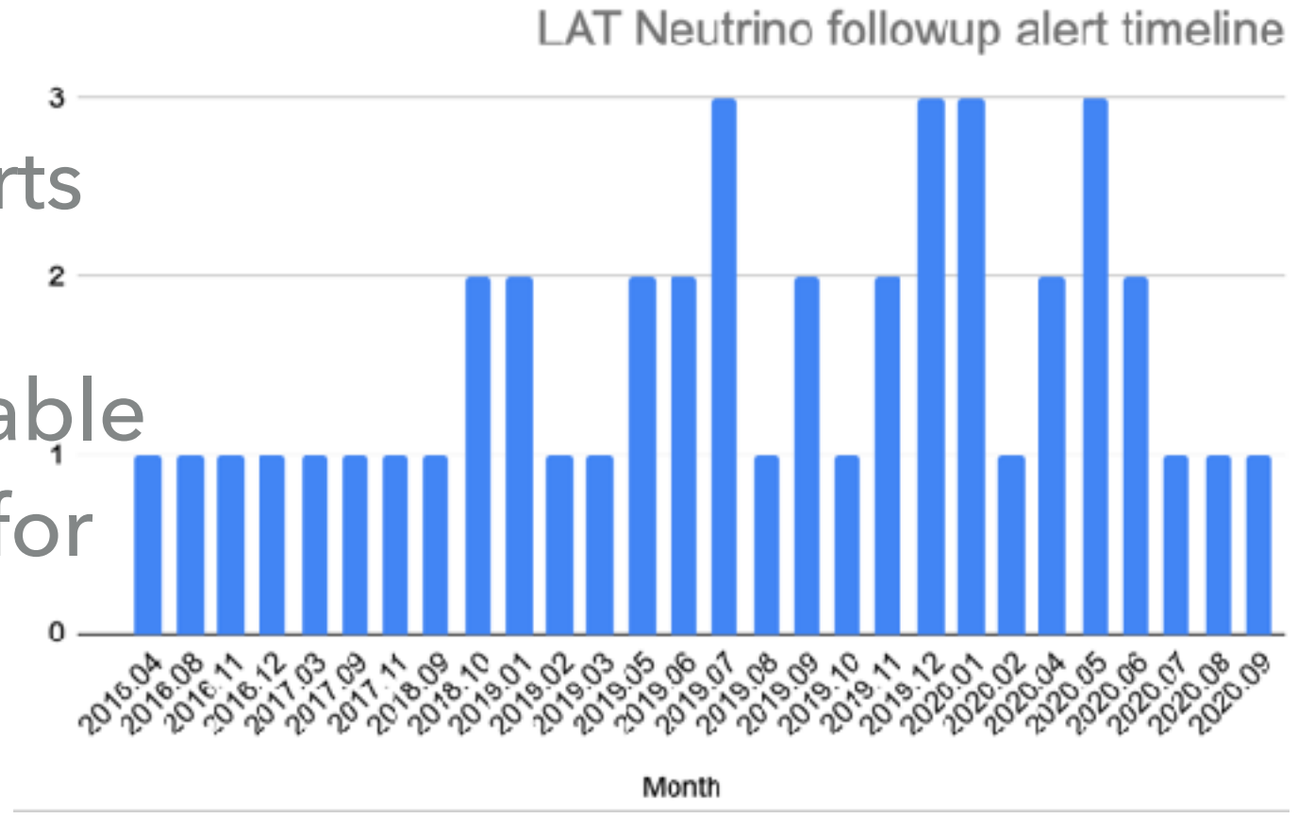


Salafia et al, 2019, MNRAS, arxiv 1905.01190

NEUTRINO ALERTS AND FERMI FOLLOWUPS

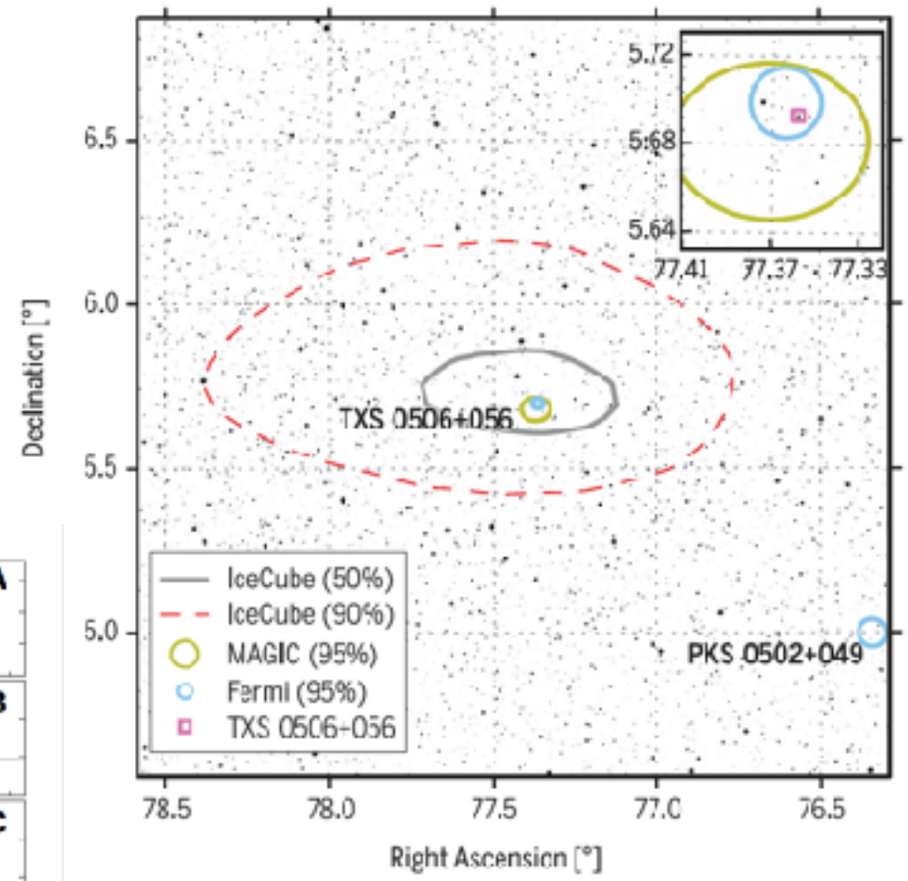
- IceCube issued 46 alerts in 66 months
- alert definition changed in 2018 (EHE/HESE -> Bronze/ Gold)
- LAT followed with GCN alerts with one association for IC170922A and no remarkable gamma-ray activity except for all other events

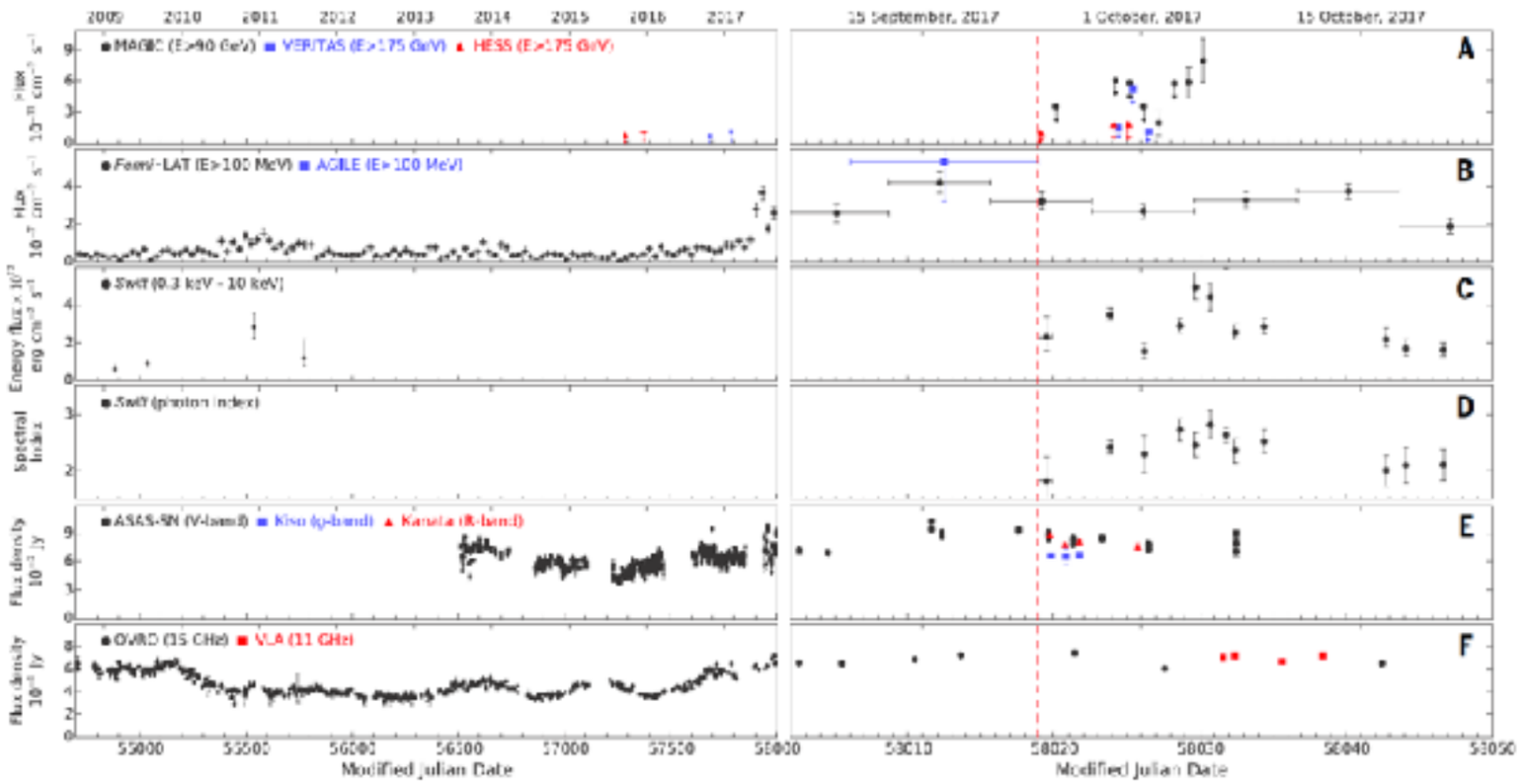




NEUTRINO SOURCES ?

- TXS 0506+056 and IceCube 170922A association inferred from positional coincidence and concurrent high energy flare

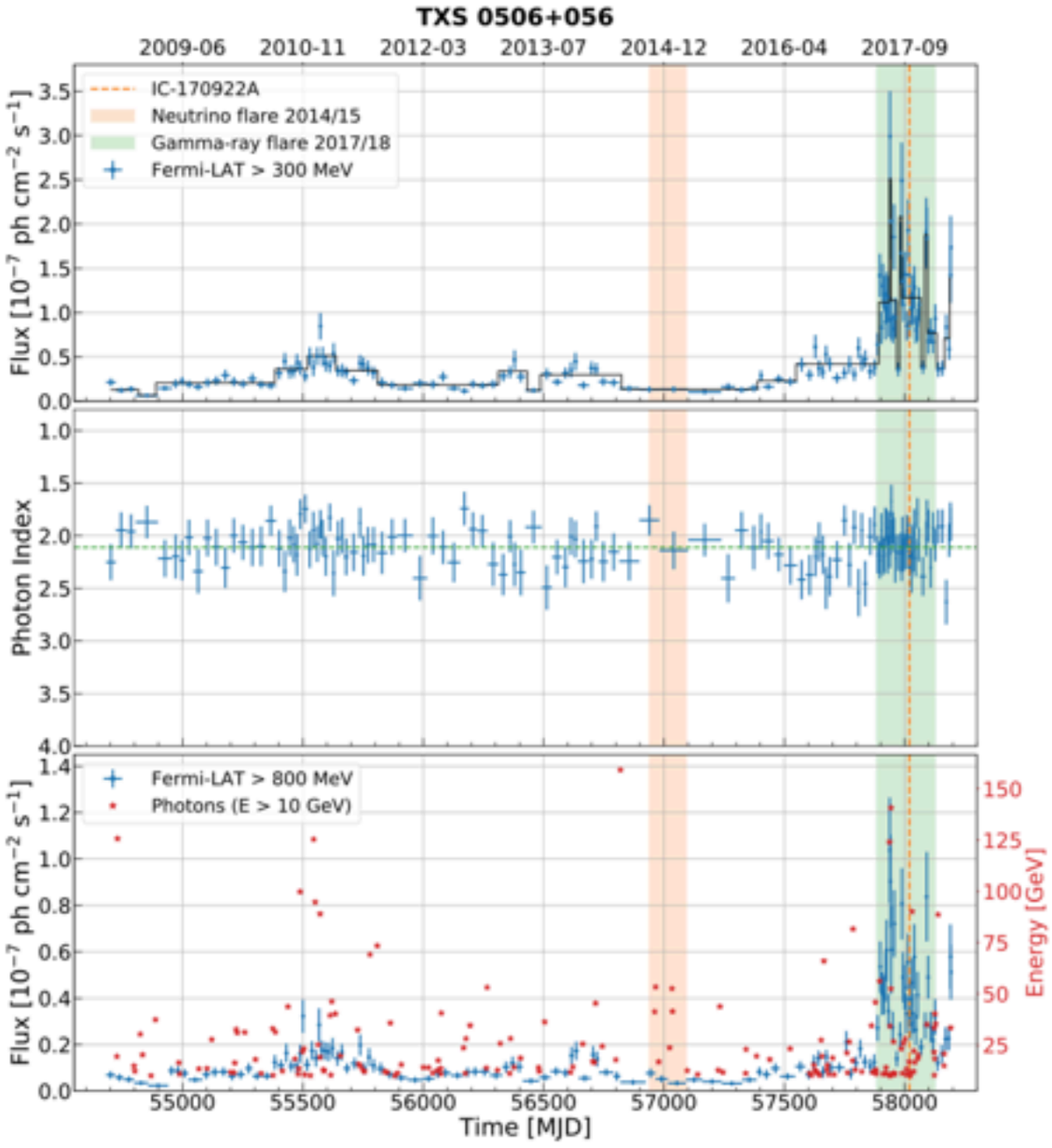




IceCube, Fermi, MAGIC et al, Science 361 (6398), eaat1378

NEUTRINO SOURCES ?

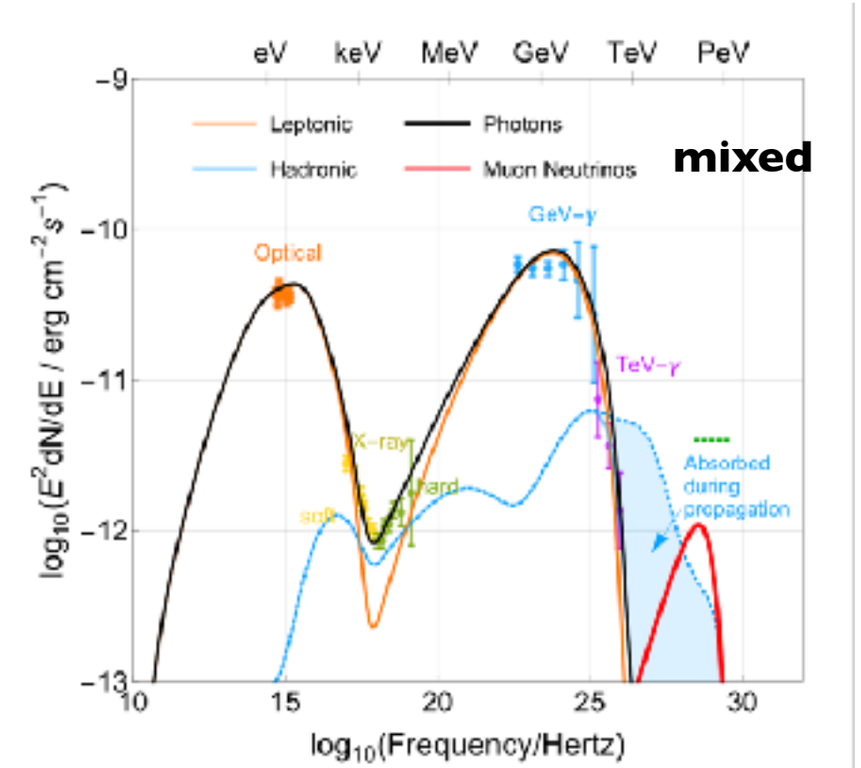
- Absence of gamma-ray emission with archival neutrino flare 2014/2015

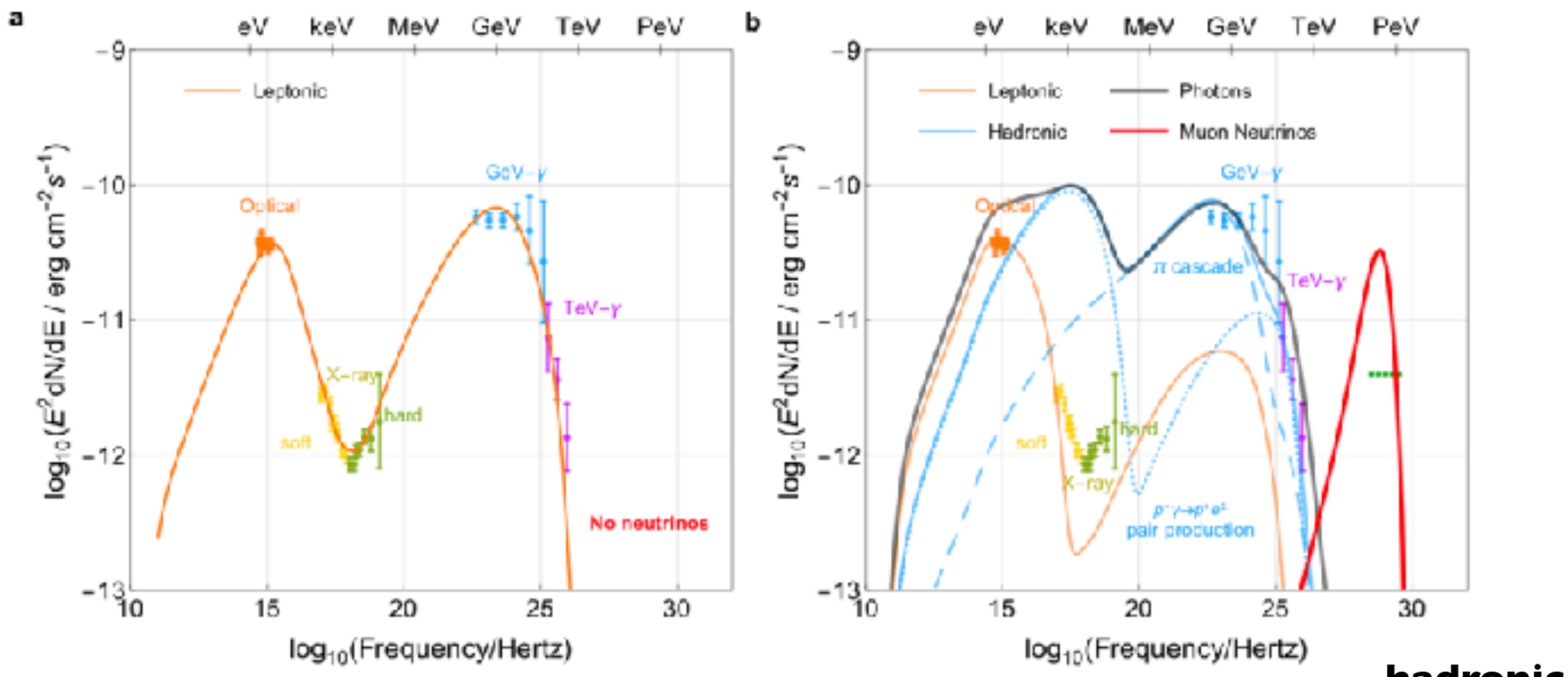


Garrappa et al, 2019, ApJ 880 103

NEUTRINO SOURCES ?

- Difficulties in reproducing photon and neutrino measured fluxes with simple models



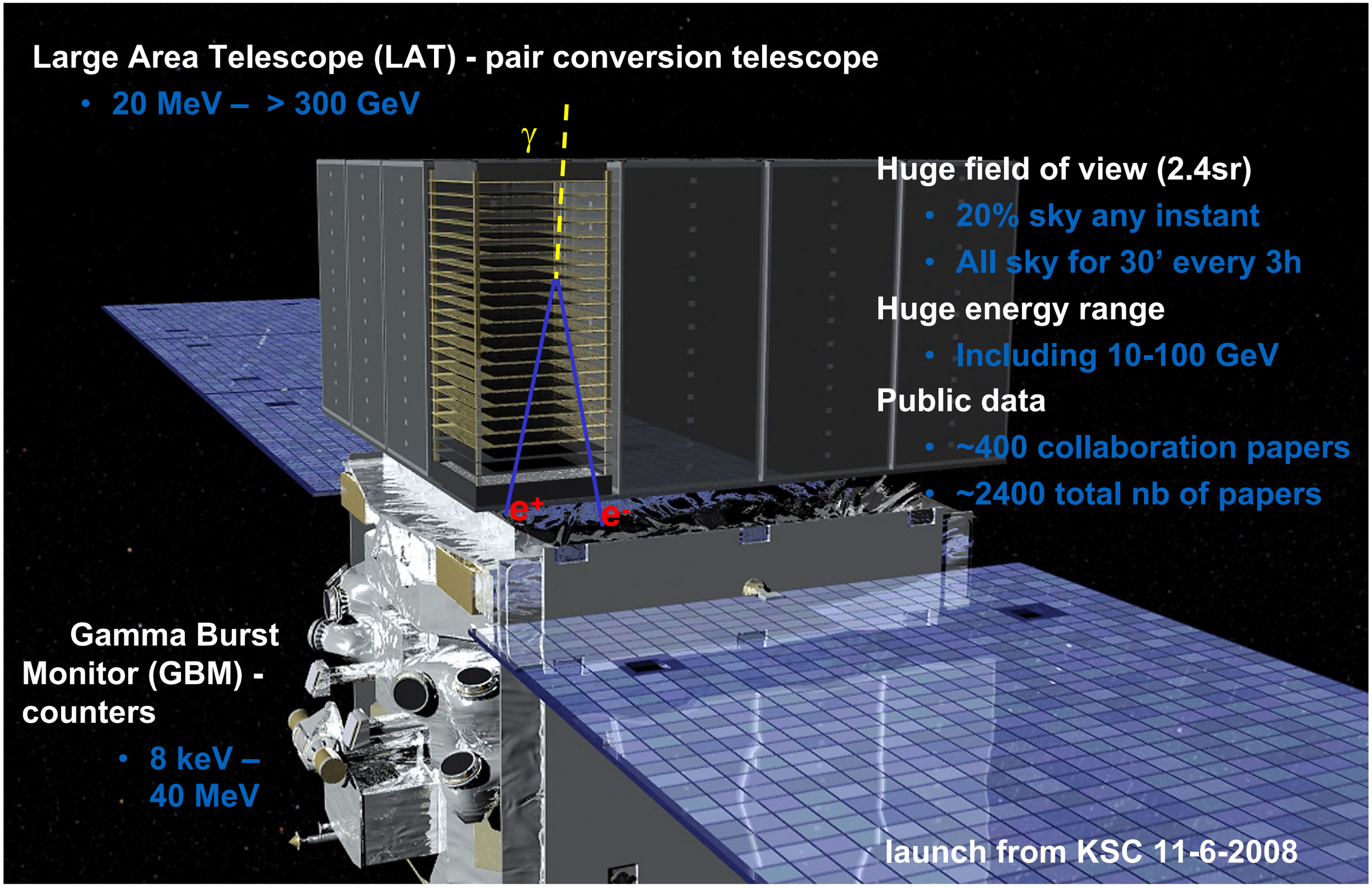


Gao et al, 2018, Nature Astronomy, arxiv 1807.04275

REMARKS

- Observatories
  - complex systems, decades long operations, multipurpose
- Multiple experimental techniques and operating environments
  - multi-decades R&D programs
- Complementary communities
  - Particle physics, Astrophysics, Cosmology
- Open questions
  - how do Black Holes work ?
  - what are the sources of Cosmic Rays and how are they accelerated ?
  - what is the nature of Dark Matter ?

FERMI - IL TELESCOPIO

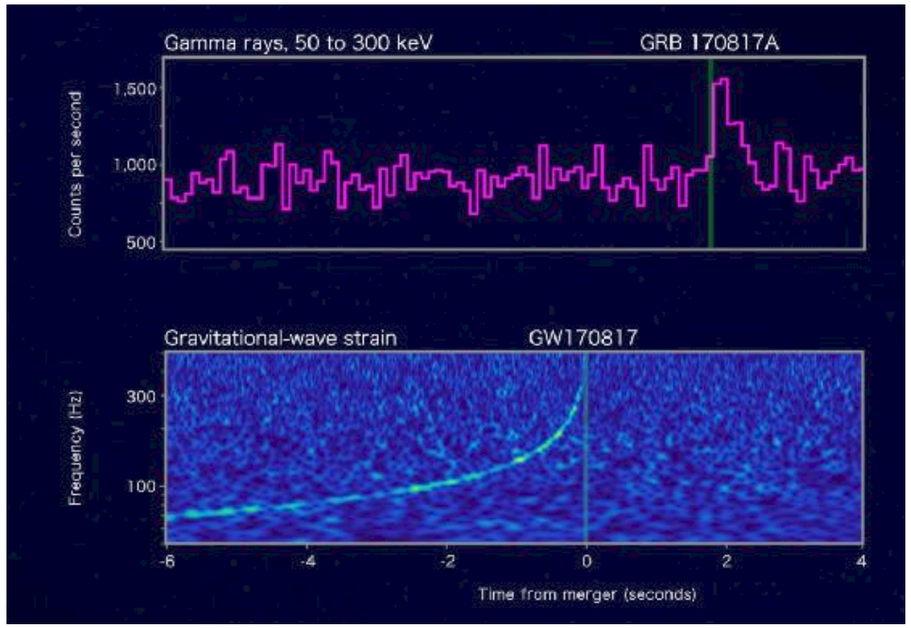


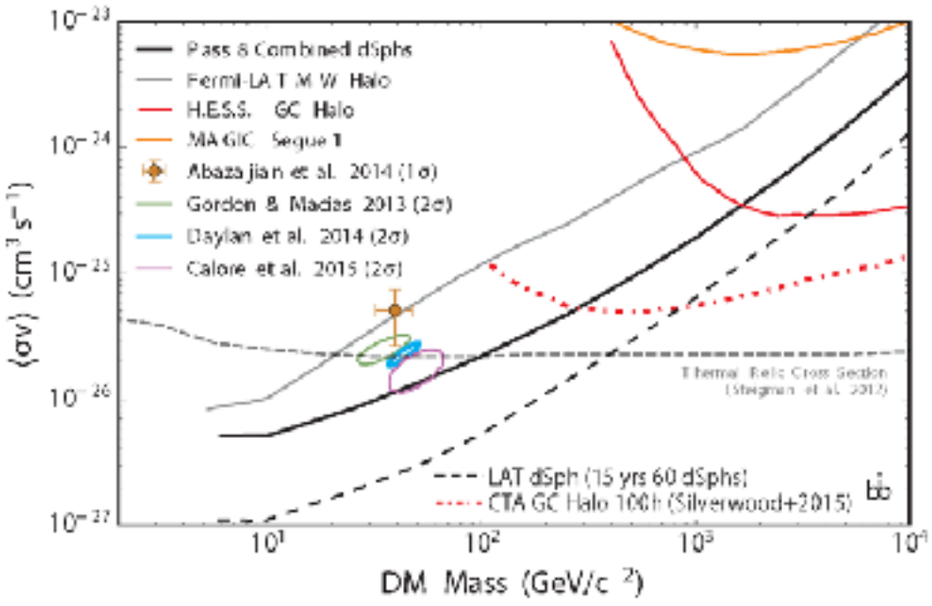
SCIENCE – TOP HIGHLIGHTS

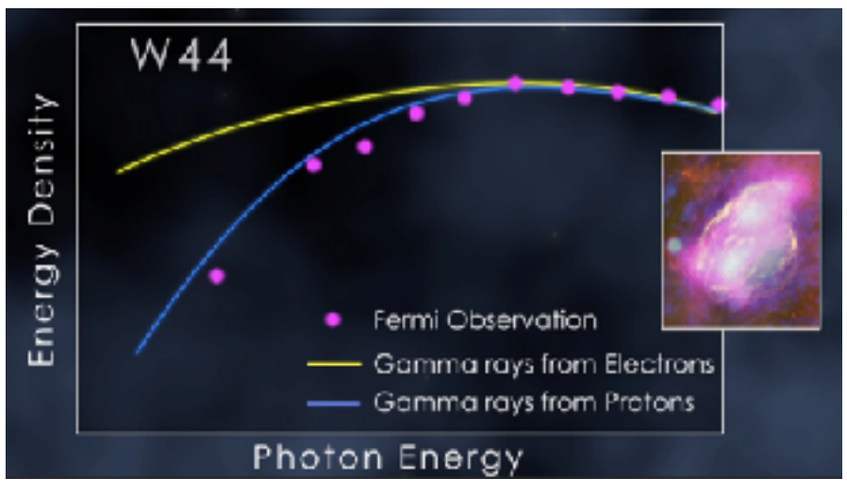
- Deep, high resolution, new view of the gamma-ray sky
  - more than 5k sources of many different types plus diffuse emission
- Cosmic rays origin and acceleration
  - unexpectedly energetic galactic electrons
  - evidence of proton acceleration in supernovae
  - Fermi bubbles
- Birth of Multimessenger astrophysicsGravitational Waves (GW)
  - with Gravitational Waves: first detection of electromagnetic emission after binary neutron star mergers
  - with Neutrinos: first association of extreme energy neutrino with gamma-ray flaring galaxy
- Dark Matter
  - most stringent limits on generic particle candidate (WIMP)

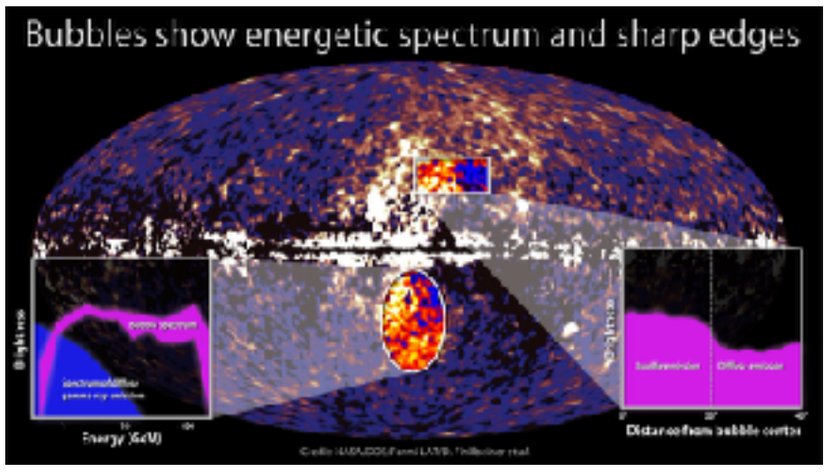
FERMI - L'OSSERVATORIO

SCIENCE HIGHLIGHTS GALLERY



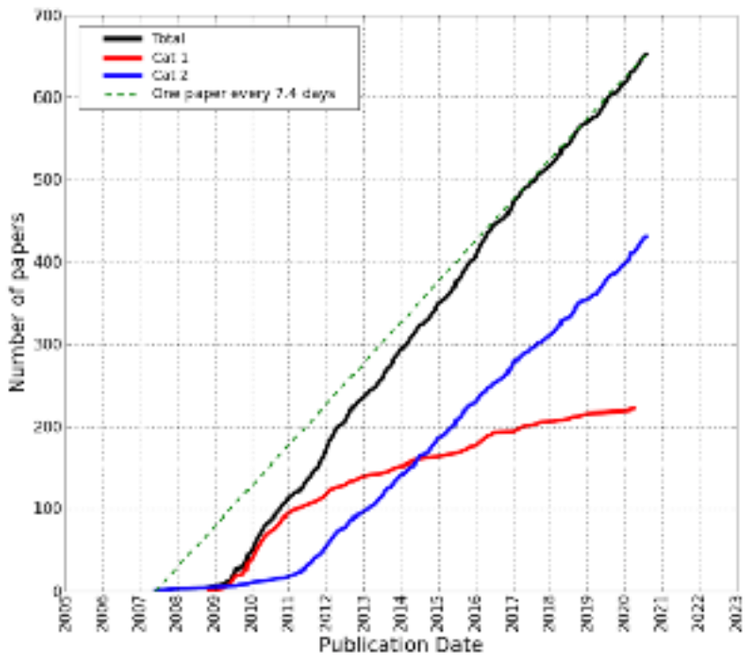


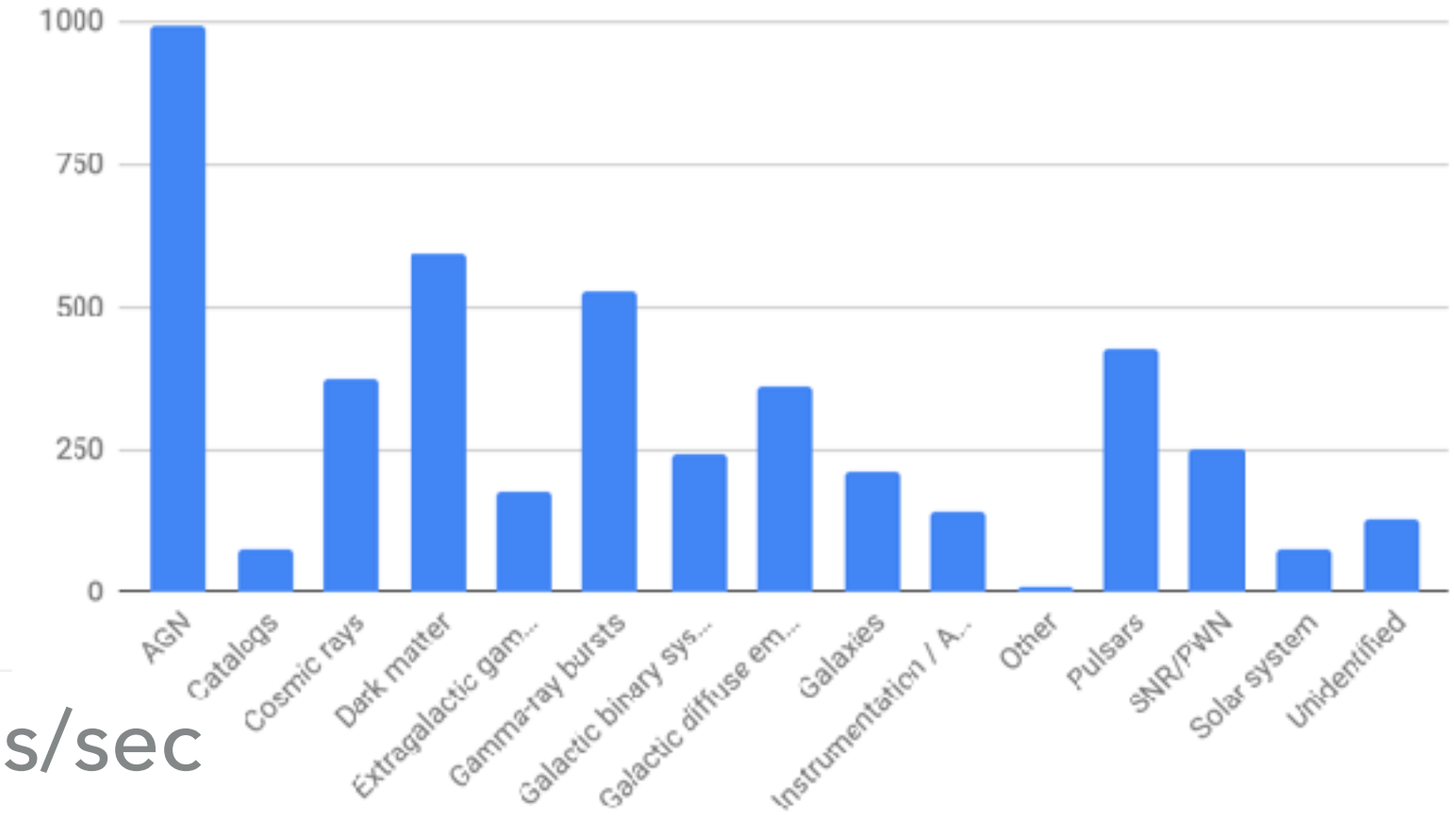




https://www-glast.stanford.edu/cgi-bin/pubpub

SCIENCE HIGHLIGHTS





- Fermi data - 4photons/sec
  - 3.13B public photons, 1.19B source-class photons
- Fermi products - 1 LAT Collaboration paper/week
  - 3438 papers, 129667 citations, 563 LAT papers

https://www-glast.stanford.edu/cgi-bin/pubpub
https://fermi.gsfc.nasa.gov/cgi-bin/bibliography_fermi

OPERATIONAL CONTEXT

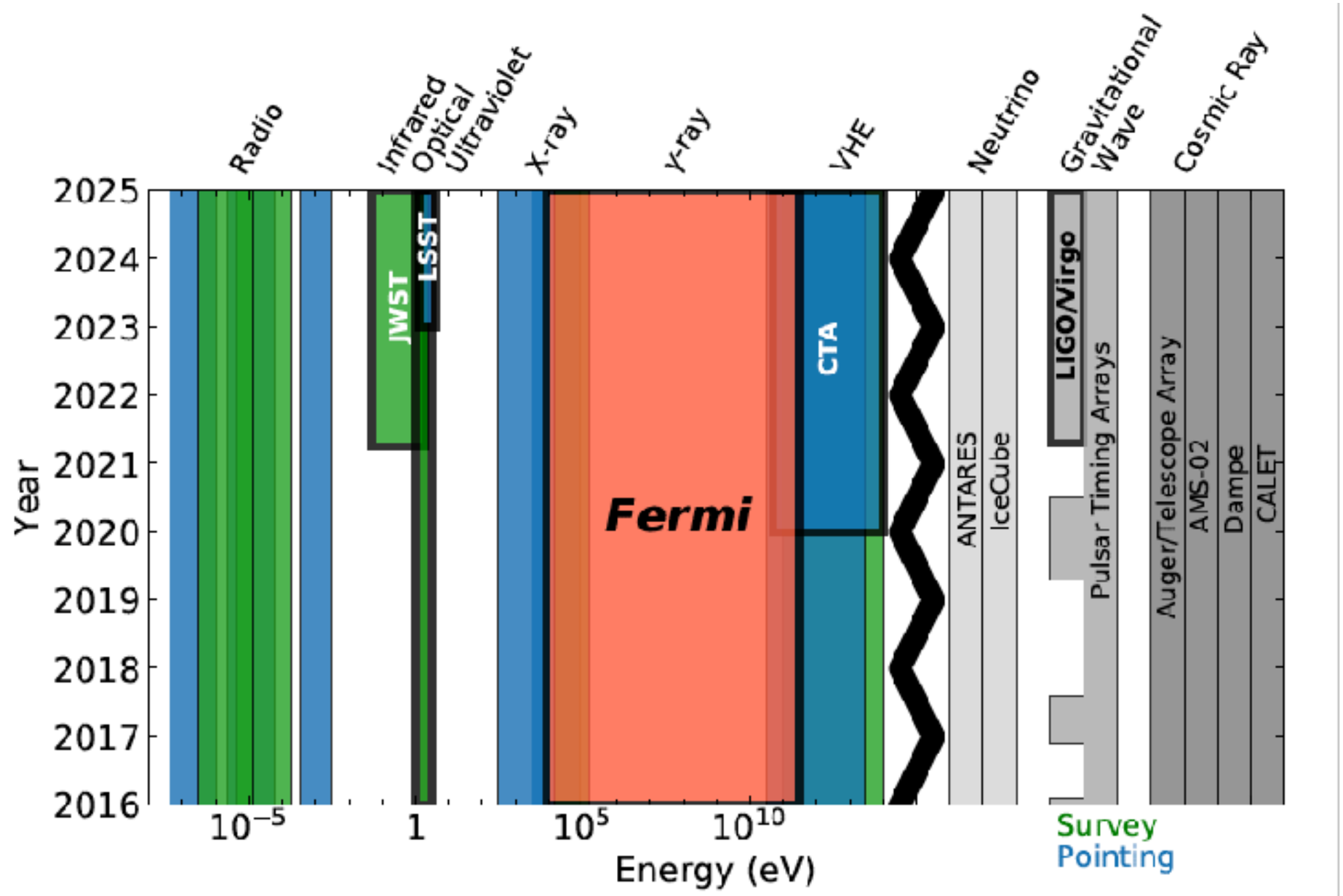
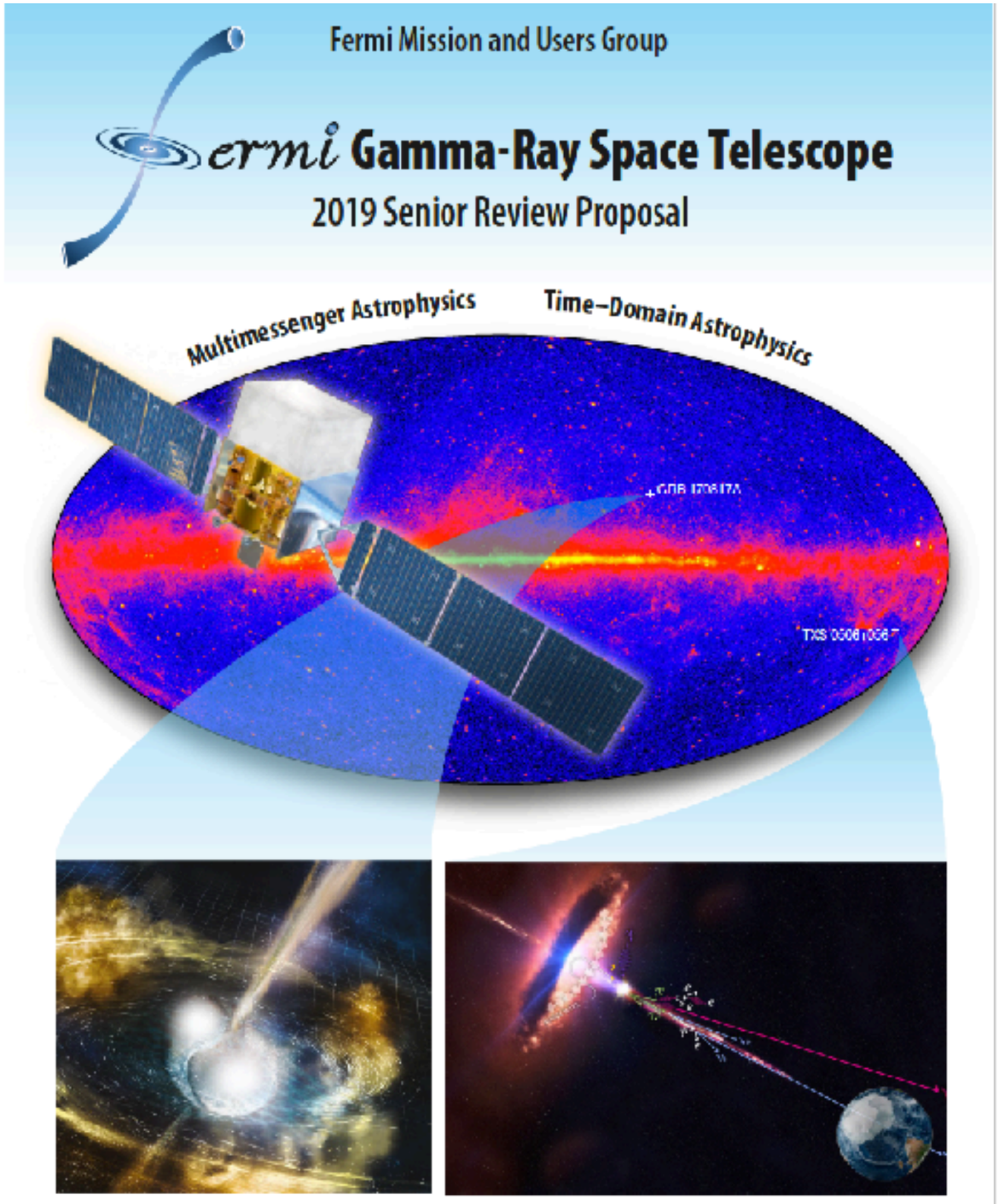


Figure 7: *Fermi* fills a unique part of the electromagnetic spectrum, especially vital in the coming years as new or enhanced facilities (bold outlined) come online presenting new opportunities in cooperation with *Fermi*.

2019 NASA SENIOR REVIEW

- Fermi successful proposal focused on multi-messenger and time-domain astrophysics after first BSN observation and association of flaring AGN with high energy neutrino

- https://science.nasa.gov/astrophysics/2019-senior-review-operating-missions

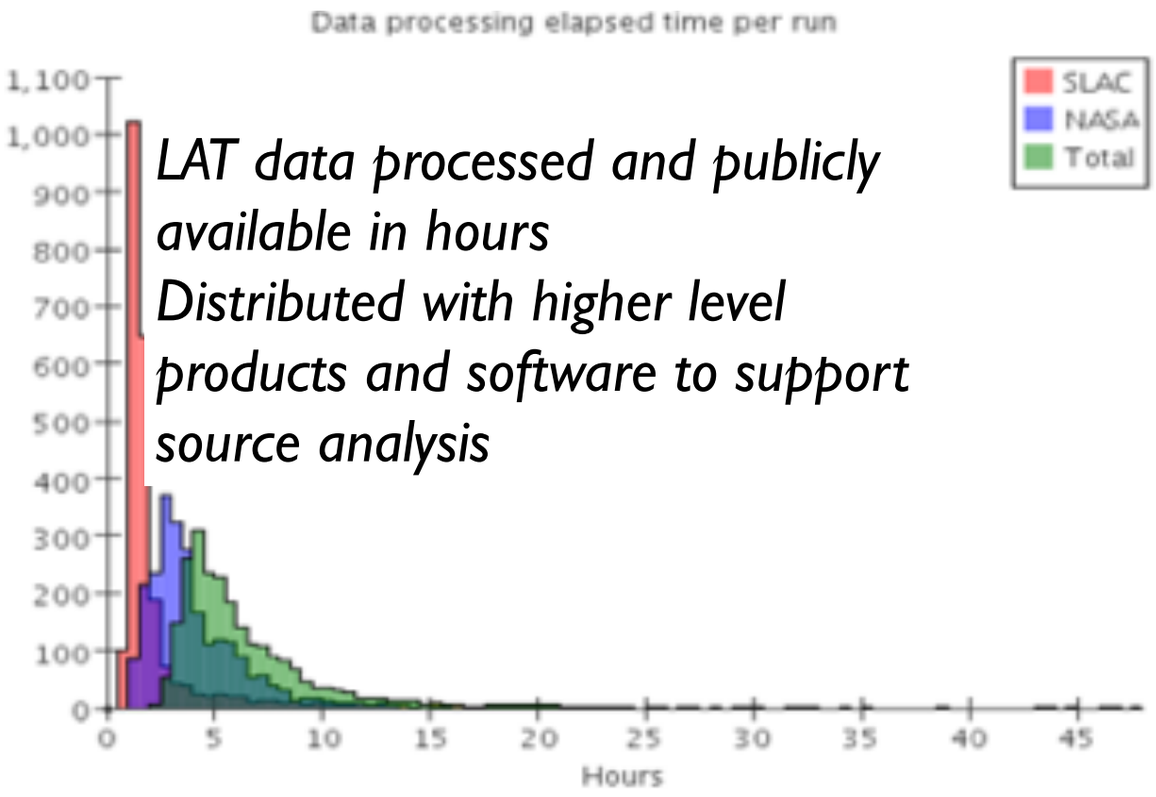


MISSION STATUS

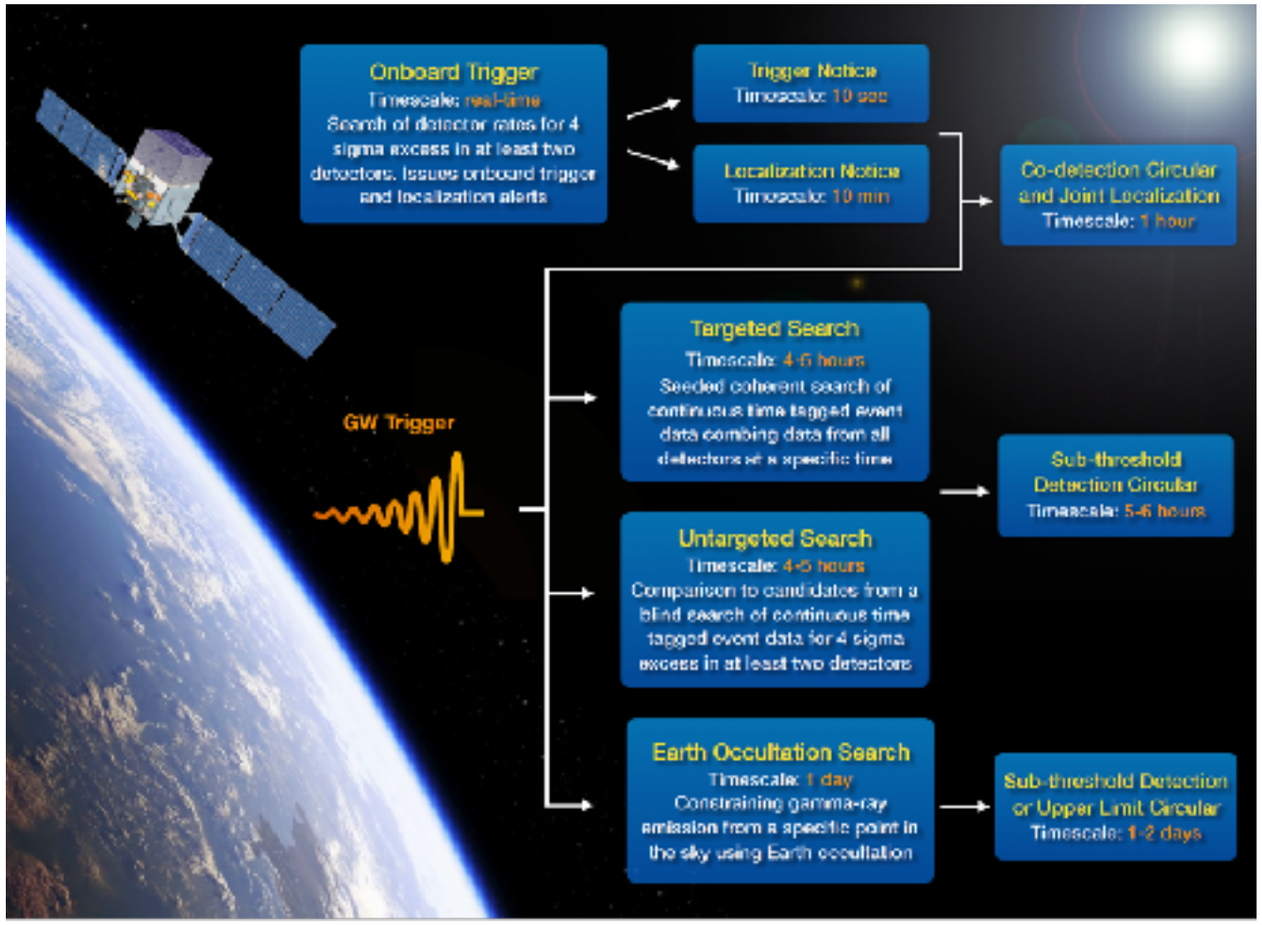
- Observatory running smoothly in 4410 days, 98.7% uptime
  - one solar array drive damaged in March 2018, since then oriented at fixed position
  - modified rocking profile to recover exposure uniformity
- All LAT subsystems working with no degradation
  - CAL light output reduced by ~6% for irradiation (expected)
  - TKR has only 0.07% strips masked (vs 2% requirement)

CHALLENGES FOR MULTI-MESSENGER ASTRONOMY

- Open data, smooth continuous operations, quick sky analysis and alert distribution



LAT data processed and publicly available in hours
Distributed with higher level products and software to support source analysis

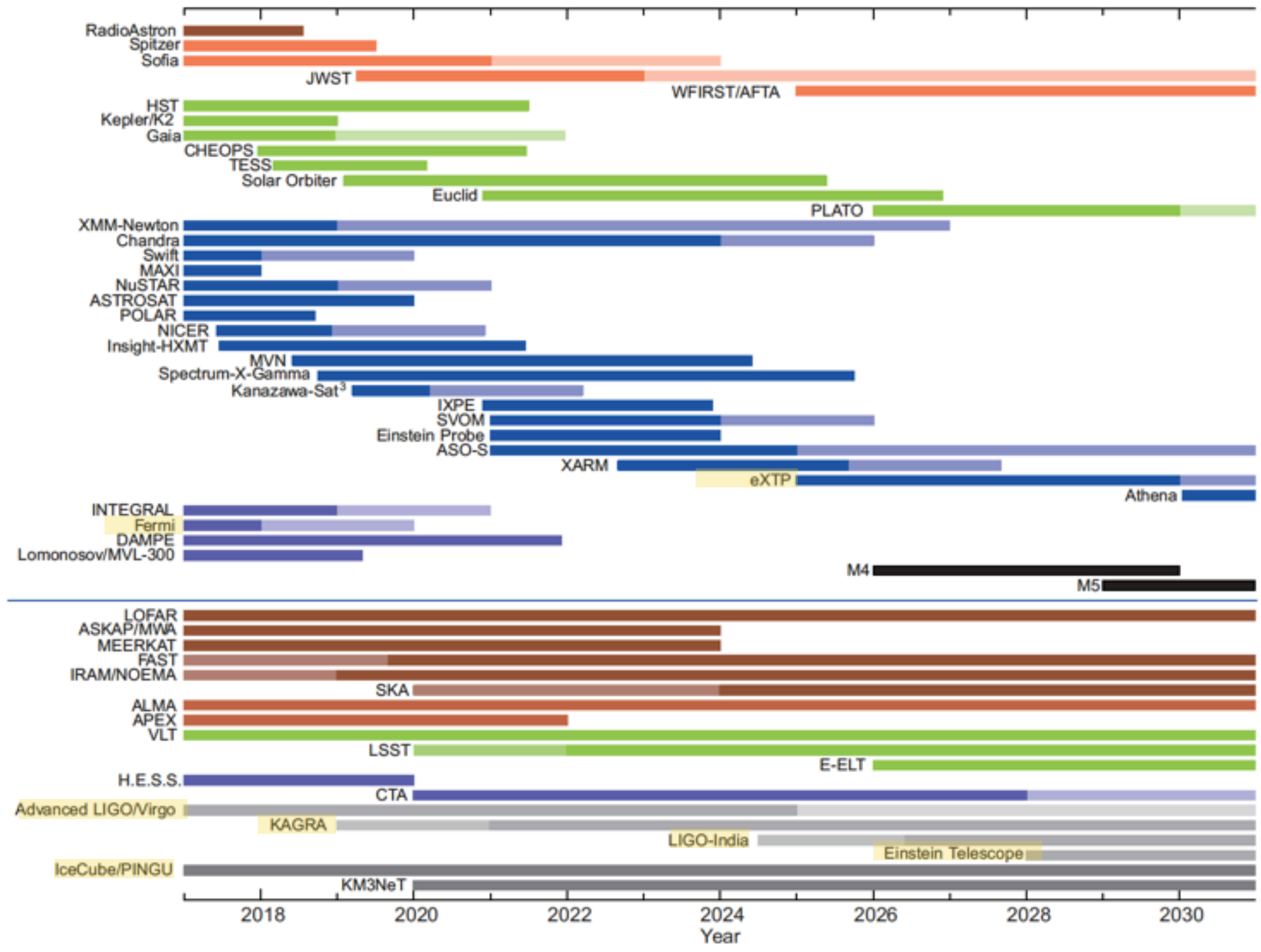


FERMI NEL PANORAMA MULTI-MESSAGGERO

OBSERVATORIES

Space

Ground



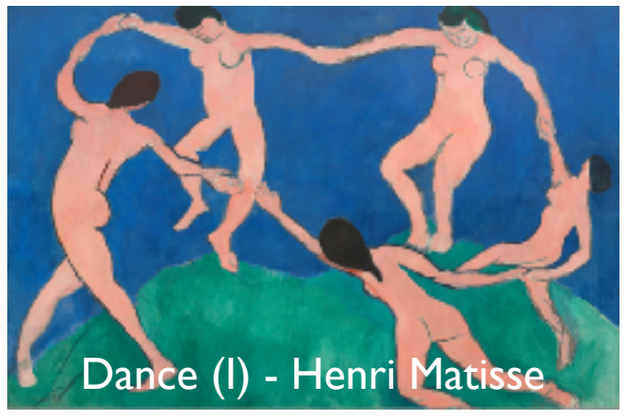
Dark - funded
Light - lifetime

Red - radio
Green - OIR
Blue - X
Purple - gamma
Grey - GW nu

Survey - large FOV

eXTP Observatory Science - doi 10.1007/s11433-017-9186-1

CONCLUDING REMARKS


Dance (I) - Henri Matisse

- Observational multi-messenger astronomy starts in 2017
  - still only two concurrent observations of major events
- Progress comes from a new interdisciplinary community
  - data from many observatories must continue to flow
    - requires dedicated efforts and investments
  - complementary scientific backgrounds and cultures are key
    - to complete the broad picture from major events and non concurrent multi-messenger data

FERMI AND THE LAT COLLABORATION ARE READY FOR THE CHALLENGE