Multi Messenger Astrophysics at NASA's Goddard Space Flight Center (GSFC)

https://science.gsfc.nasa.gov/astrophysics/

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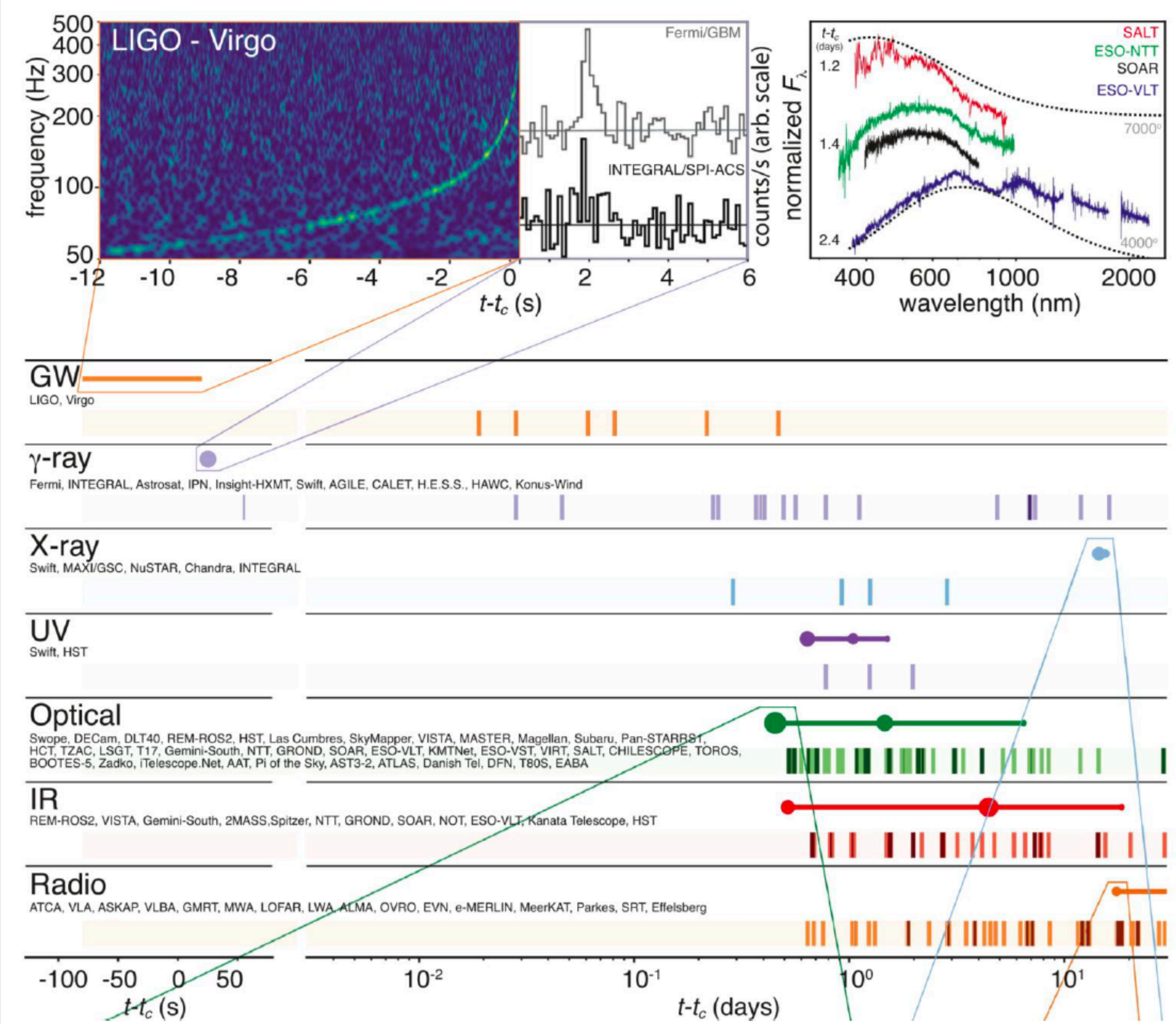
NASA and Multi-Messenger Astrophysics

GW 170817



Abbott et al. 2017, ApJL, 848, L12

Extragalactic Neutrinos: the "new" kid on the block

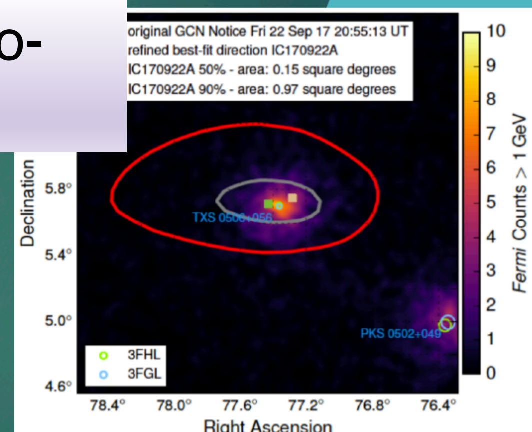
Cosmic neutrinos may originate in blazars - a first compelling neutrino candidate

IC 170922A & TXS 0506+056

>TeV neutrinos correlated with radio-loud quasars? (Plavin et al. 2020)

- High-energy neutrino event with >183TeV
- Flaring γ–ray blazar (Tanaka, SB+ Atel#10791)
- ~3σ post-trial chance coincidence correlation

- Lepto-hadronic models can adequately explain the observations (IC170922A)



IceCube, Fermi, MAGIC+ Science 361, 146 2018

Courtesy S. Buson

MMA Science Activities at GSFC

- Mission operations and GOFs: NICER, Fermi, Swift, NuSTAR, TESS
- **MMA missions in phase A and pre-phase A**
- **Theory, computation, and interpretation**
- GCN alert system & upgrades
- Data archiving in HEASARC
- Data analysis tools and interpretation
- Proposer support infrastructure

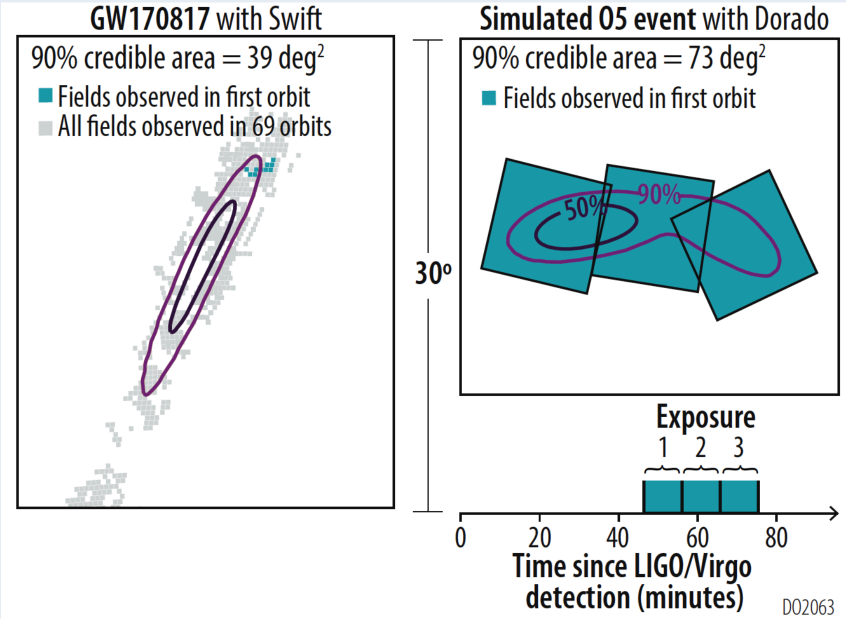
Bldg 34 at GSFC, home of ASD

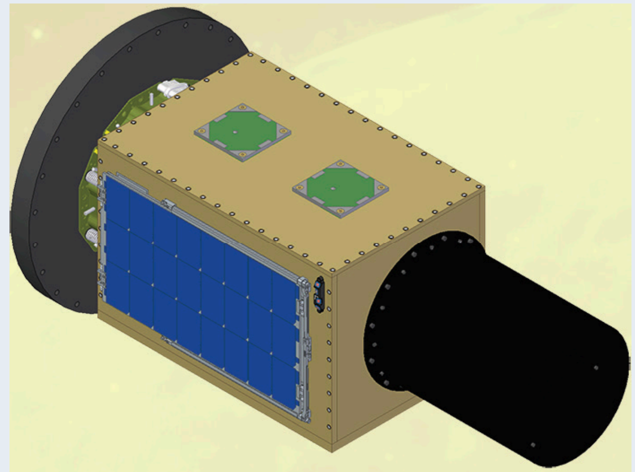
MMA Missions in development & Concept Studies

"Ensure continuity of capabilities in the next decade, especially large-field UV, X-ray, and Gamma-ray"

(GW-EM Task Force report, : https://pcos.gsfc.nasa.gov/gw-em-taskforce/GW-EM_Report_Final.pdf)

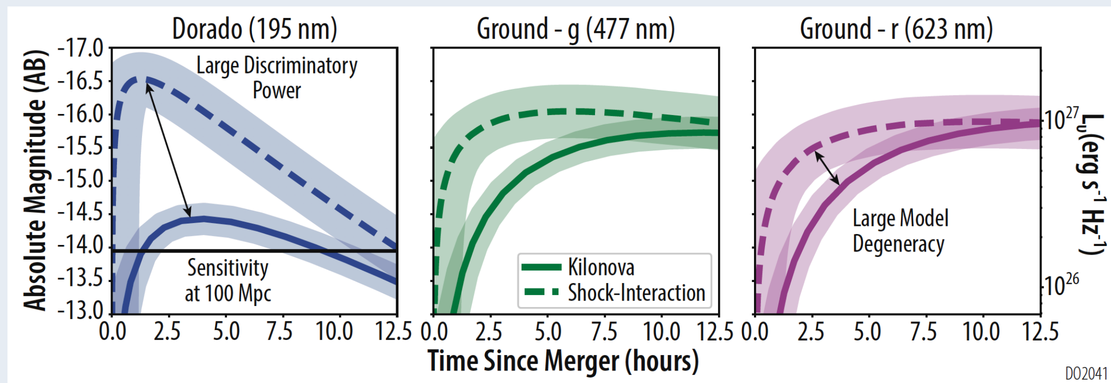
Dorado: Wide-Field UV Imaging SmallSat





FOV is 600x Swift UVOT

Prompt (< 2 hr) imaging of large-area GW localizations provides counterpart notification for follow-up with sensitive narrow-field facilities



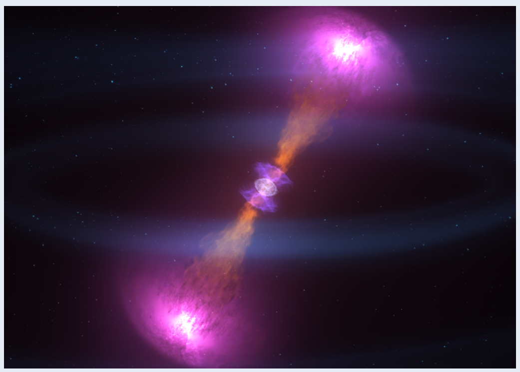
Powerful model discrimination to understand the origin of early blue-UV emission: radioactive nucleosynthesis (kilonova) vs. shock interaction

Courtesy B. Cenko, NASA

AMEGO: A Probe Class Mission For Multimessenger Astrophysics

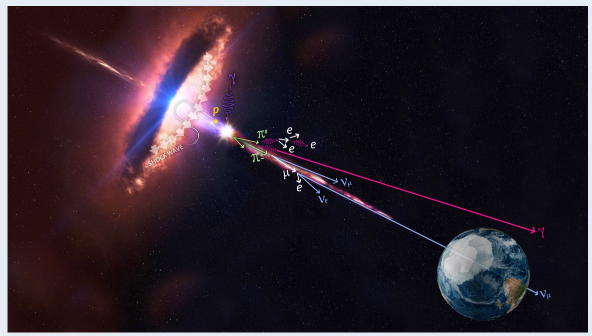
Groundbreaking gamma-ray spectroscopy, polarization and flux measurements of all known classes of multimessenger sources

Extreme Explosions – GW counterparts



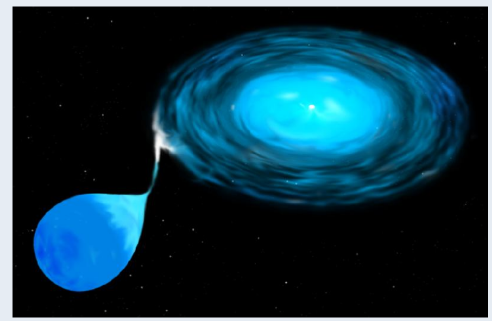
- High rate of well localized (~<1 deg) GRB
    - ~100 short GRB/year
    - ~450 long GRB/year
- Polarization probe GRB jets
- Direct observation of gamma-rays from nuclear processes in nearby kilonova

Extreme Accelerators – VHE Neutrino counterparts



- Gamma-rays are generated in the same physical process that produces neutrinos
- Continuous monitoring of hundreds of the most luminous blazars
- MeV flux good proxy for neutrino flux
- Polarization observations probe jet composition

Element formation – MeV Neutrino counterparts



- Gamma-ray line flux as function of time provides good measure of geometry and total mass of Ni in SN1A
- AMEGO will detect SN1A out to 50 Mpc

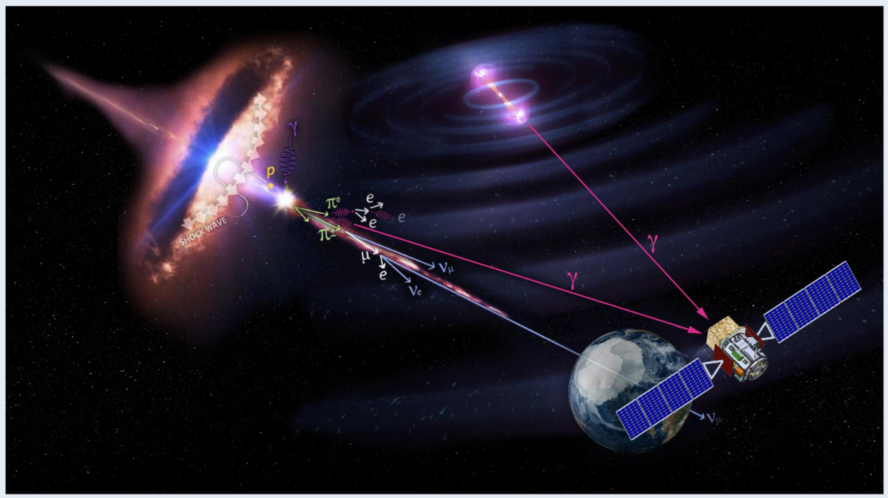
Courtesy J. McEnery, NASA

AMEGO-X: MIDEX Multimessenger Observatory

Gamma-ray observations played the critical discovery role in *all* major multimessenger discoveries in the past half decade

High-energy neutrinos + gamma rays:

Discovering one of the most extreme accelerators in the universe



Gravitational Waves + gamma rays:

Measuring fundamental parameters of spacetime

AMEGO-X will observe the band where they are the brightest

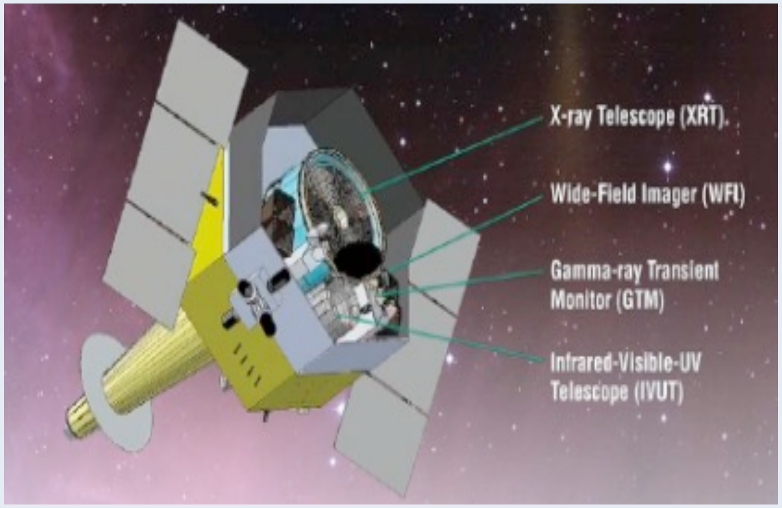
From stellar mass to supermassive black holes: multimessenger sources are gamma-ray sources

Courtesy R. Caputo, NASA

Transient Astrophysics Probe

- TAP comprises *wide-field* X-ray, Gamma-ray, and Infrared telescopes designed to address two major Frontier Discovery Areas of the 2010 Decadal Survey
  - EM Counterparts to Gravitational Waves
  - Time-Domain Astrophysics

- Telescopes: UV, IR, X-ray, γ-ray
  - Wide-field, high sensitivity
  - Multi-wavelength
  - Rapid response



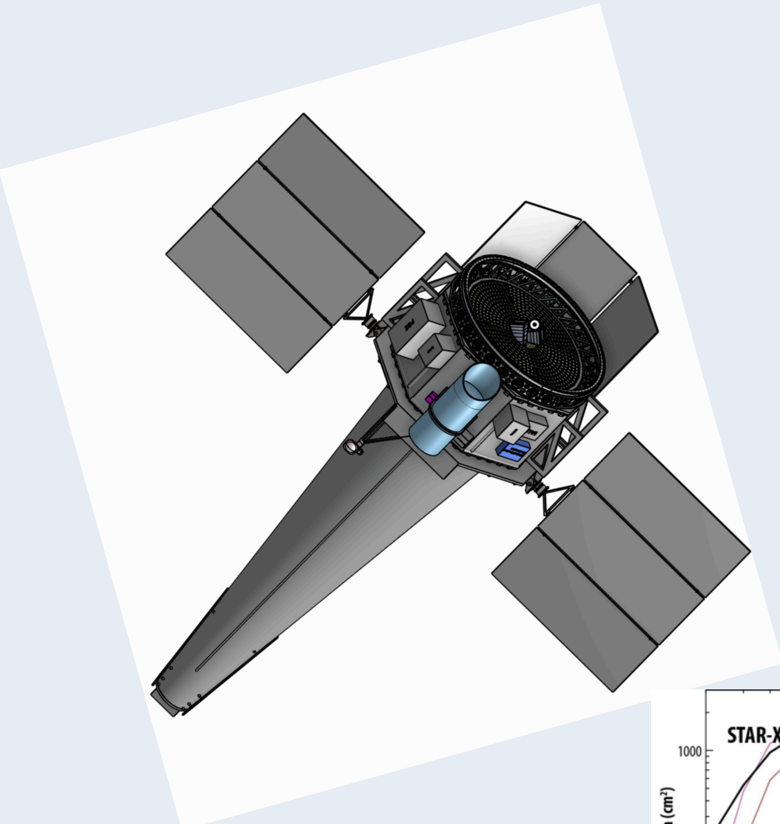
Science Goals:

- EM Counterparts to GWs
  - BNS (LIGO): UV, IR, g-ray
  - Possibly Supermassive BH Binaries (LISA and PTA): X-ray

- Time-Domain Astrophysics: multiwavelength scan of TDEs, AGN and Rubin targets follow-up

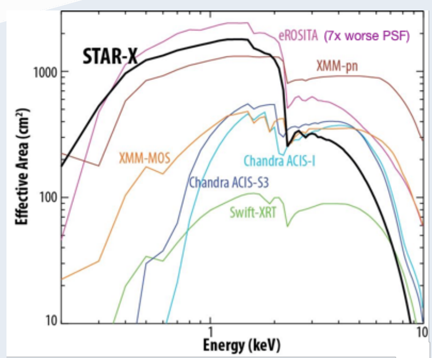
Courtesy J. Camp, NASA

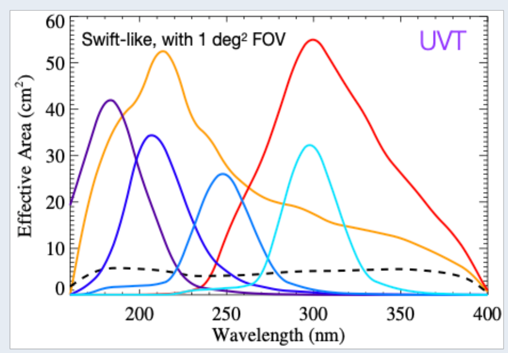
***STAR-X: S**urvey and **T**ime-domain **A**strophysical **R**esearch E**X**plorer*

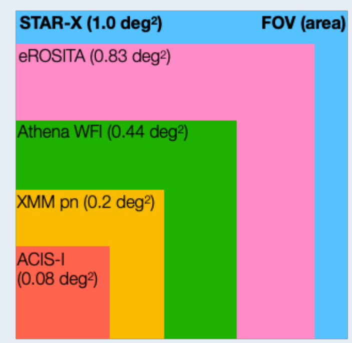


	X-ray Telescope (XRT)	UV Telescope (UVT)
PSF	2.5” on-axis 10” 0.5° off-axis	4.5”
FOV	1 deg^2	1 deg^2
Band width	0.5 – 5 keV	160 – 350 nm
Effective Areas	@1keV: 1,800 cm^2 on-axis 900 cm^2 0.5° off-axis	7 different filters: 25 - 55 cm^2
TOO Response	~60 minutes	
Field of Regard	80% of the sky every 90 minutes	

PI: William W. Zhang
DPI: Ann Hornschemeier





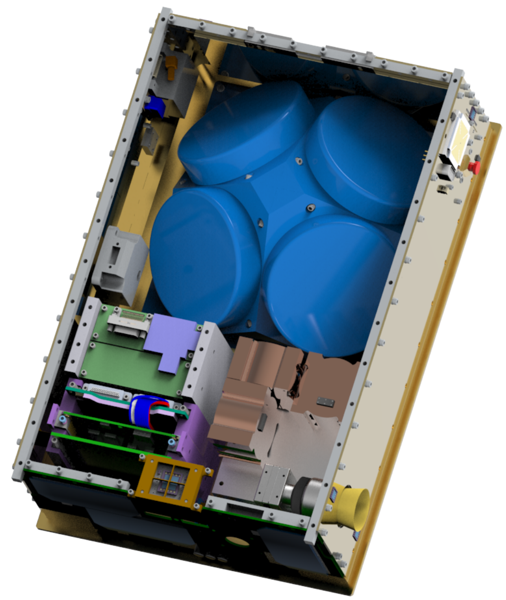


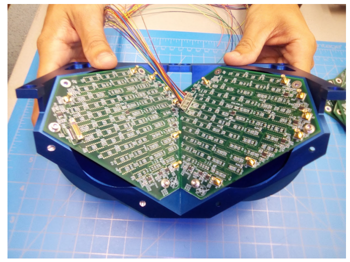
Surveying the Ever-Changing Universe

Courtesy W. Zhang, NASA

BurstCube: A CubeSat for Gravitational Wave Counterparts

- A **6U CubeSat** that will d**etect, localize, and characterize** Gamma-ray Bursts (**GRBs**):
  - Focus on **short GRBs** (binary neutron star mergers) that are the counterparts of gravitational wave sources.
  - Will detect ~100 long GRBs and ~20 short GRBs.
- Will detect these with **four CsI** scintillators coupled to arrays of **Silicon photomultipliers**.
- Complement to existing multi-messenger facilities (*Swift*, *Fermi*) and could be an **interim multi-messenger instrument** before next generation missions fly.
- Flight **assembly is underway** (as of Jan. 2021) and **launch readiness is in Jan. 2022** with a 1 year mission expected.



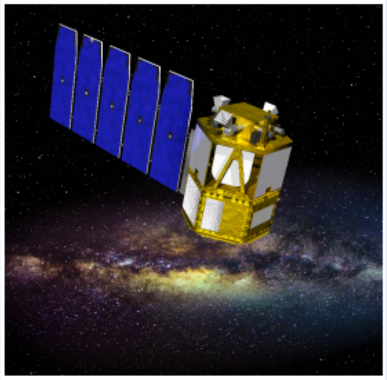


Courtesy J. Perkins, NASA

Partnerships

COSI SMEX

PI: J. Tomsick, Berkeley

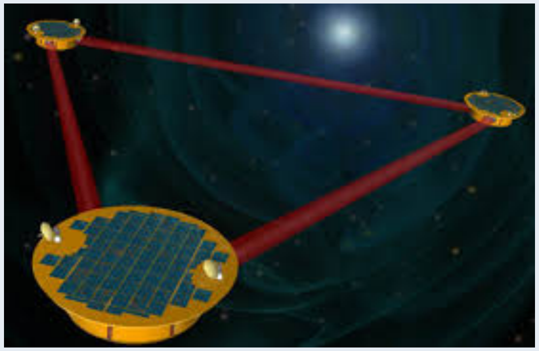


GSFC Contributions to the thermal system – cryocooler and heat pipes

Courtesy T. Brandt, NASA

LISA

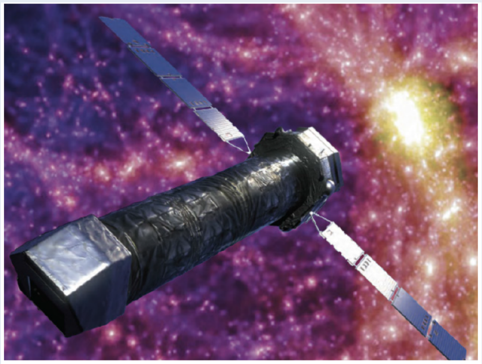
ESA-led with NASA partnership

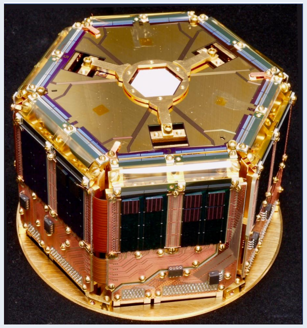


Courtesy ESA/I.Thorpe, NASA

Athena

ESA-led with NASA partnership



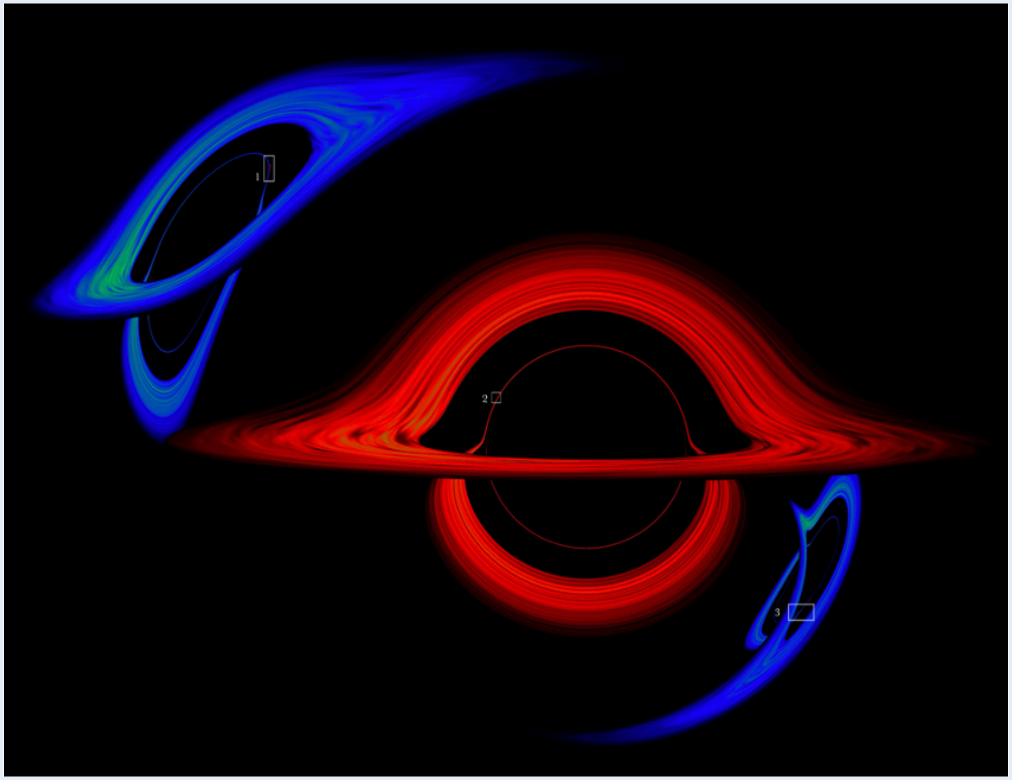


Courtesy ESA/S. Bandler, NASA

MMA Theory and Computation

… at the heartbeat of new missions

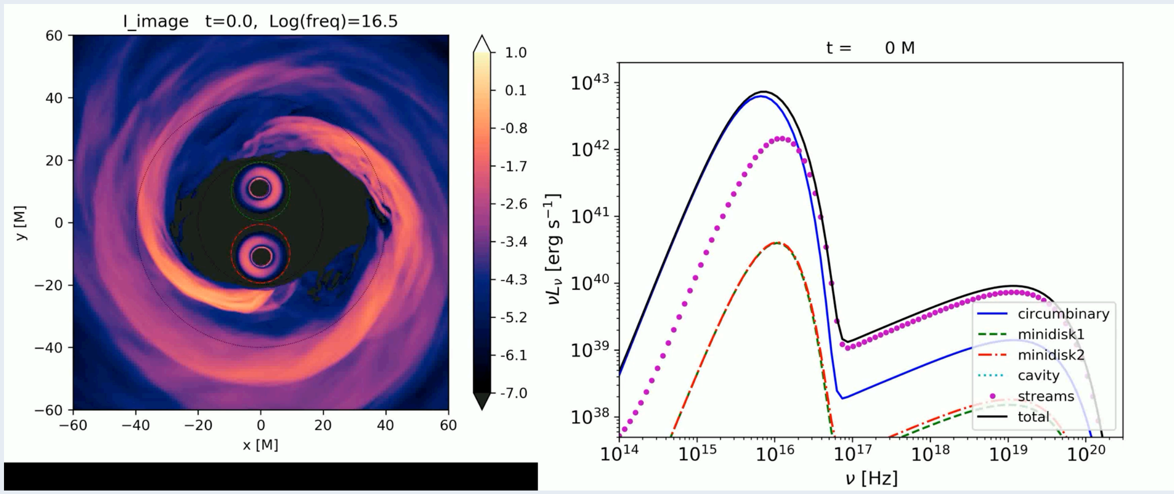
Binary Black Holes

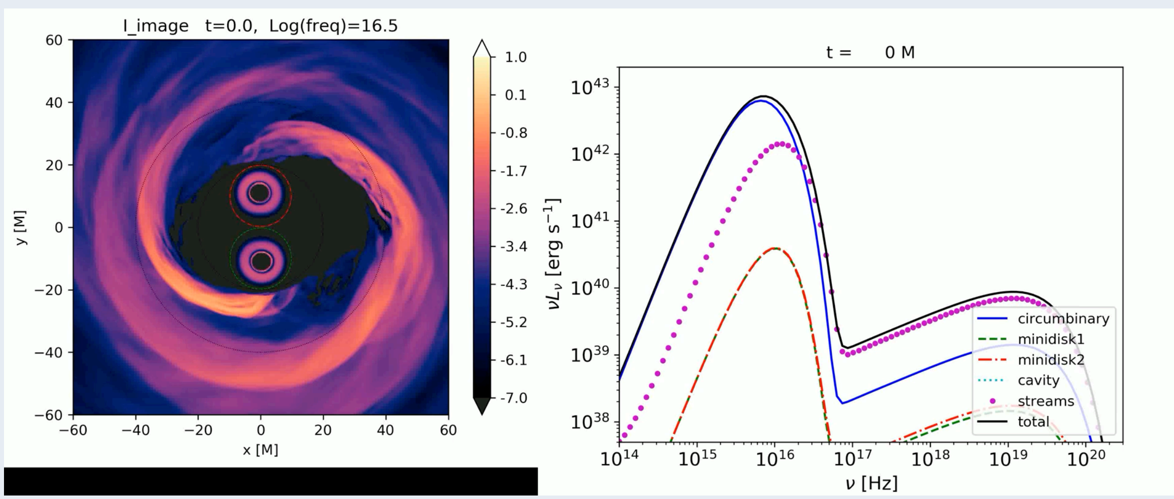


A simulated view of a binary black hole with mass ratio 1:2, as seen by an observer inclined 85deg to the orbital axis.

Courtesy J. Schnittman, NASA

Light Curves from Accretion of Plasma onto Spinning BBHs





Courtesy S. Noble, NASA

BH mergers in dense plasma environments

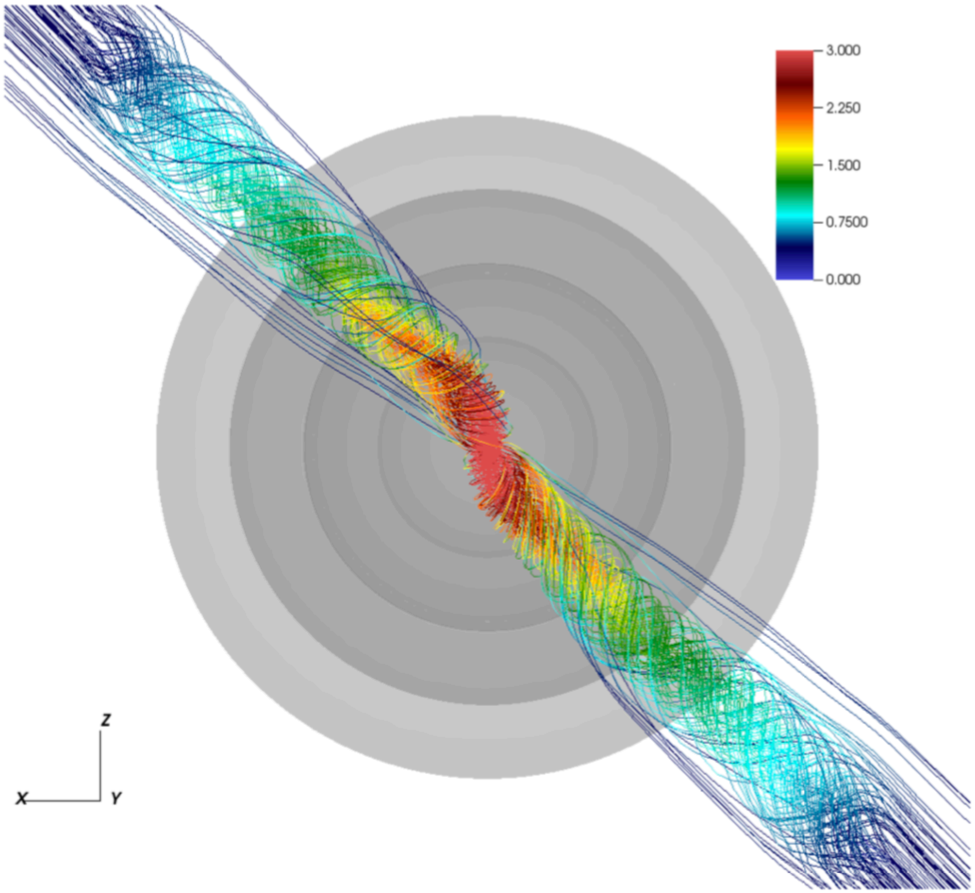
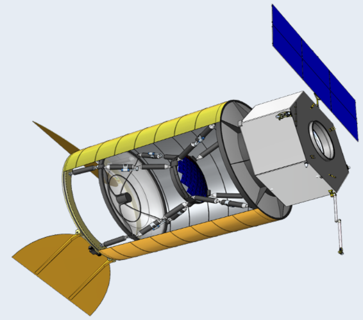


FIG. 4. B-field stream lines in the vicinity of the BH (spinning in the $\hat{k}$ direction) at time $t \approx 2{,}000M$ for a magnetic field initially uniform in strength, and everywhere pointing along $\hat{i} + \hat{k}$, 45° off the BH spin direction (configuration `KS_B45deg`). Grey shells indicate coordinate radii $R \in \{30M, 50M, 70M, 90M\}$.

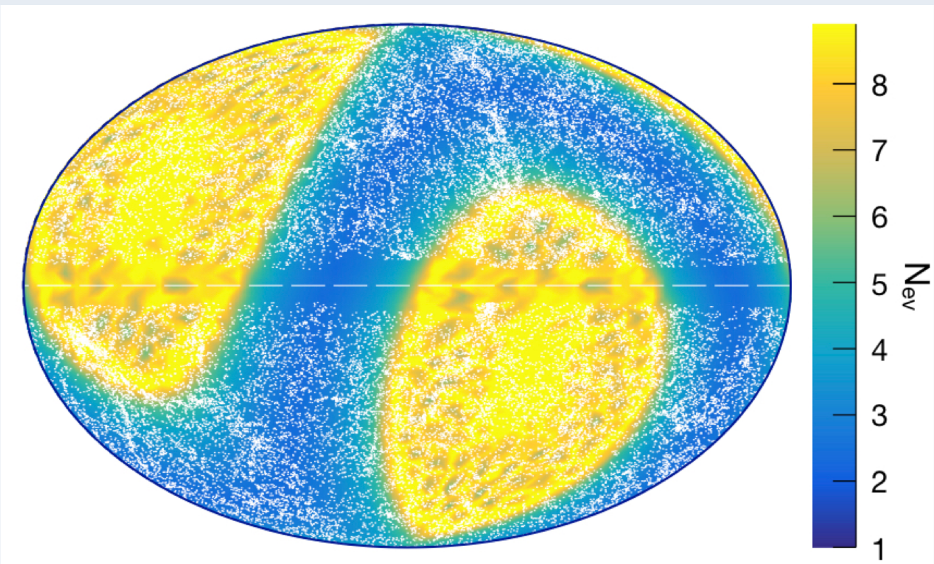
Kelly et al. 2020

POEMMA and tau neutrinos



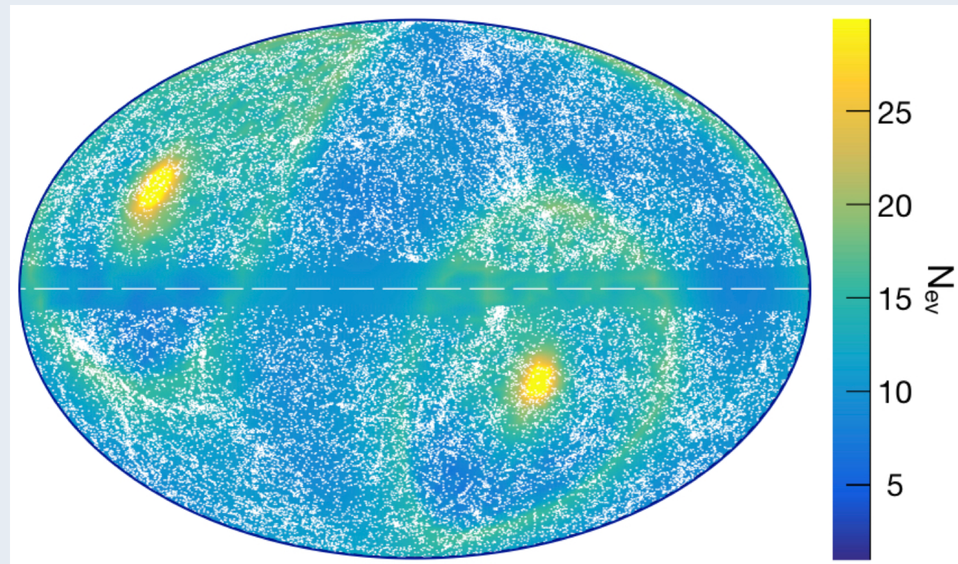
PI A. Olinto, Univ. of Chicago

Short Transient



- Skyplot of expected number of ν_τ events for sGRB scenario at 40 Mpc

Long Transient



- Skyplot of expected number of ν_τ events for BNS scenario at 5 Mpc

Courtesy T. Venters, NASA

Final Thoughts

(waiting for the 2020 Decadal report)

So much to do

- GW-EM Task Force report: https://pcos.gsfc.nasa.gov/gw-em-taskforce/GW-EM_Report_Final.pdf
- The MMA SAG report: https://pcos.gsfc.nasa.gov/sags/mmasag/MMA_SAG_Final_Report_R3.pdf

- Ensure continuity of capabilities in the next decade, especially large-field UV, X-ray, and Gamma-ray
- Invest in improved sensitivity for GW and neutrino detectors
- Make all data available immediately to everyone
- Improve communication spacecraft-ground (sc-to-sc) for prompter response to mergers
- Promote more NASA-NSF collaboration for R&A programs
- Provide dedicate funding for infrastructure development and theory
- Revisit data archives structures to optimize MMA needs
- Incorporate lessons learned from Big Data sciences
- …. *More* ….

Redefining the MMA community

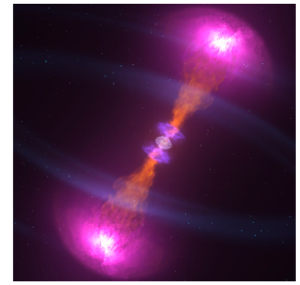
- MMA is by definition interdisciplinary and collaborative, and success is contingent on effective communication and inclusion of **<u>all</u>** parties
- MMA community is much, much larger than research scientists
- Ex.: TOO brokers, software/infrastructure scientists, obs. planners, archival scientists, optical comm engineers, communication professionals, and more
- Each comes with its own separate culture and funding
- Challenge is how to coordinate and integrate different cultures and standards (e.g., data proprietary time)

An MMA "Nation"

Giving Recognition

- MMA science is enabled by those working behind the scenes: software developers, observation planners, TOO brokers, telescope operators, archival scientists, etc.
- In the MMA Nation, credit must be given to them in a way that furthers their professional career
- We need to devise the best ways for our colleagues to be recognized

Conclusions



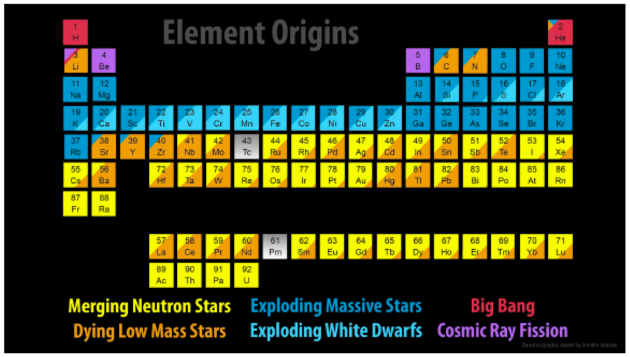
Credit: NASA SVS

- MMA has great promise – but optimizing its science yield depends on enhanced Communication, Collaboration, and Cooperation (C3) among all parties

- Inclusion and recognition of the entire Team

- Goddard looks forward to working with its partners (academia, NASA Centers, institutions, other Agencies, industry) to realize the potential of MMA at its fullest

THANK YOU



redit: Jennifer Johnson/SDSS / CC BY 2.0 (modified)