Space-based Gamma-ray Astronomy in the Context of Astro2020

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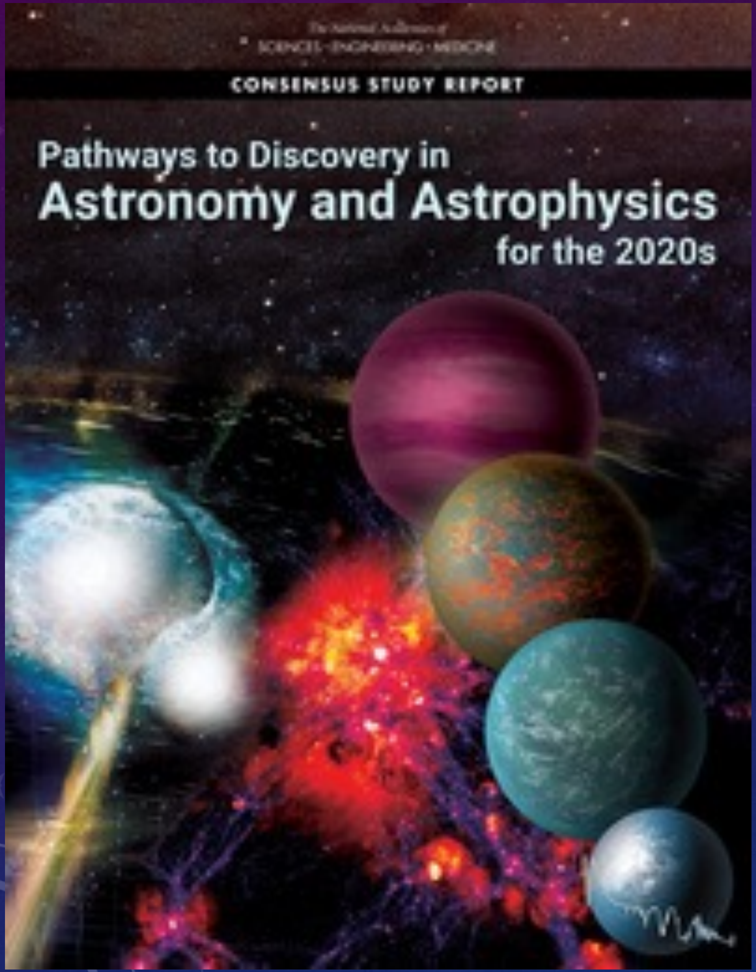
NASA GSFC

GRSIG, January 28, 2022

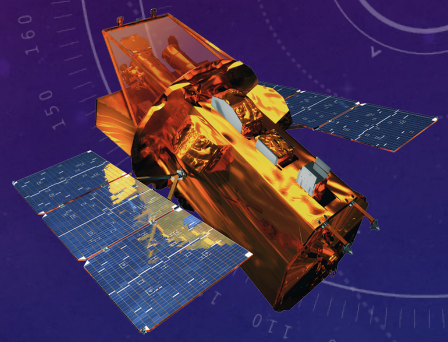
ASTRO2020 Themes and Priority Areas

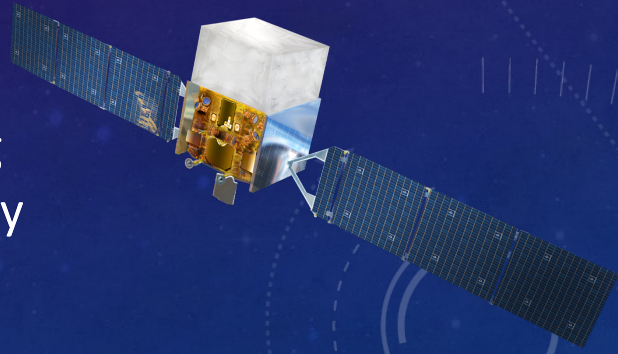


- **Worlds and Suns in Context**
  - **Pathways to Habitable Worlds**
- **New Windows on the Dynamic Universe**
  - **New Messengers and New Physics**
- **Cosmic Ecosystems**
  - **Unveiling the Drivers of Galaxy Growth**

ASTRO2020: Current Missions

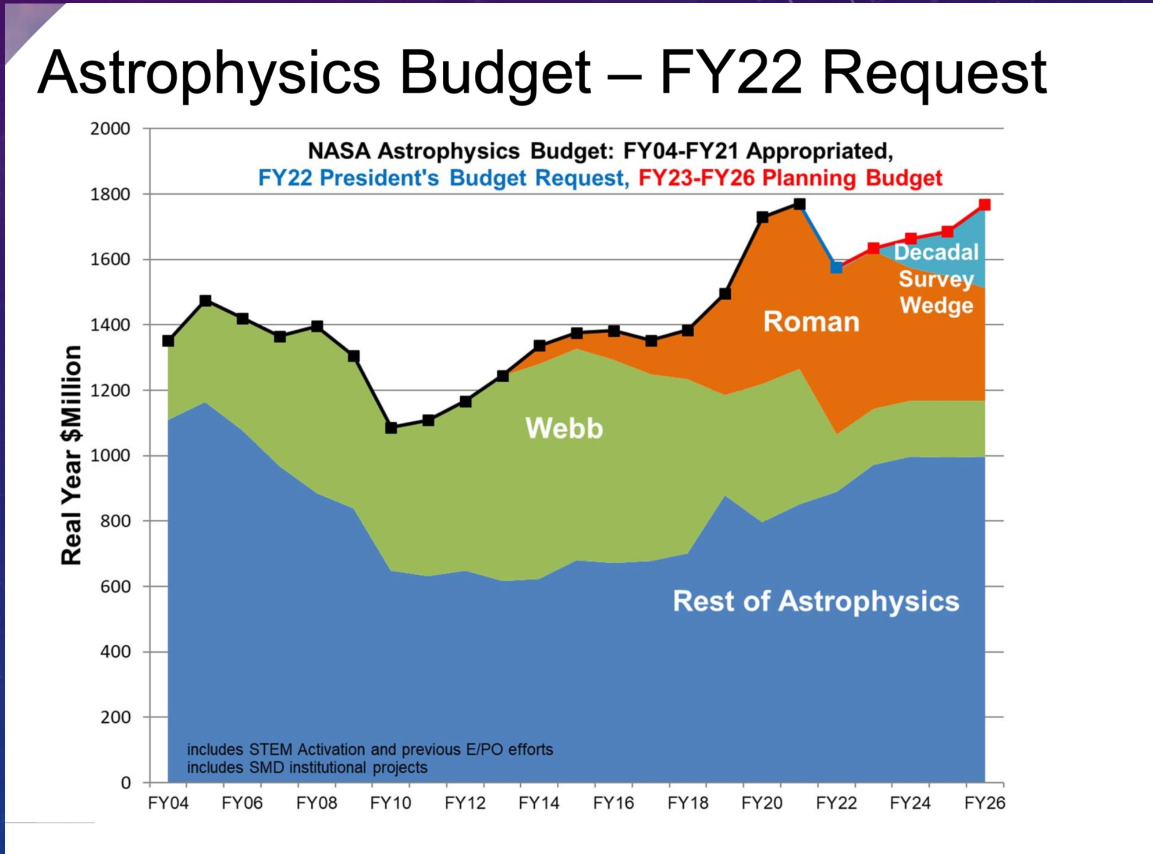
- “In addition, NASA’s workhorse hard X-ray and gamma ray transient facilities (Swift and Fermi, respectively) are aging and their longevity is uncertain.” (2-33)
- “In addition to the threats of lost capabilities resulting from the aging of Swift and Fermi, there are also potential new international opportunities to meet the scientific needs, such as the Space Variable Objects Monitor (SVOM). Contribution of instruments to international efforts is another possibility for achieving some elements of the program. The specific needs to sustain and enhance the optimum suite of space capabilities will change over the upcoming decade, and it is likely that these capabilities will be most effectively achieved by a complement of missions on different scales, including contributions to international efforts.” (7-18)
- “For rapid follow-up and correlation studies, continued support of *Swift* and *Fermi* spacecraft operations will be crucial until newer missions replace them.” (B-10)





Astro2020: Space Priorities

- IR/O/UV Large Strategic Mission
  - Technology Maturation Program after which missions begin development mid-late decade
  - 5 years - $11B
- Time-Domain Program
  - A program of competed missions and missions of opportunity to realize and sustain the suite of capabilities required to study transient phenomena and follow-up multi-messenger events.
  - Over decade - $500M-$800M
- Probes
  - Far-IR and X-ray to complement Athena
  - Technology maturation in second half of decade
  - 1 per decade - $1.5B/mission



From Paul Hertz's Townhall talk Jan 2022

Astro2020 Decadal Survey (Space) Priorities

- IR/O/UV Large Strategic Mission **NOT Gamma-ray**
  - Technology Maturation Program after which missions begin development mid-late decade
  - 5 years - $11B
- Time-Domain Program **Gamma-ray???**
  - A program of competed missions and missions of opportunity to realize and sustain the suite of capabilities required to study transient phenomena and follow-up multi-messenger events.
  - Over decade - $500M-$800M
- Probes **NOT Gamma-ray**
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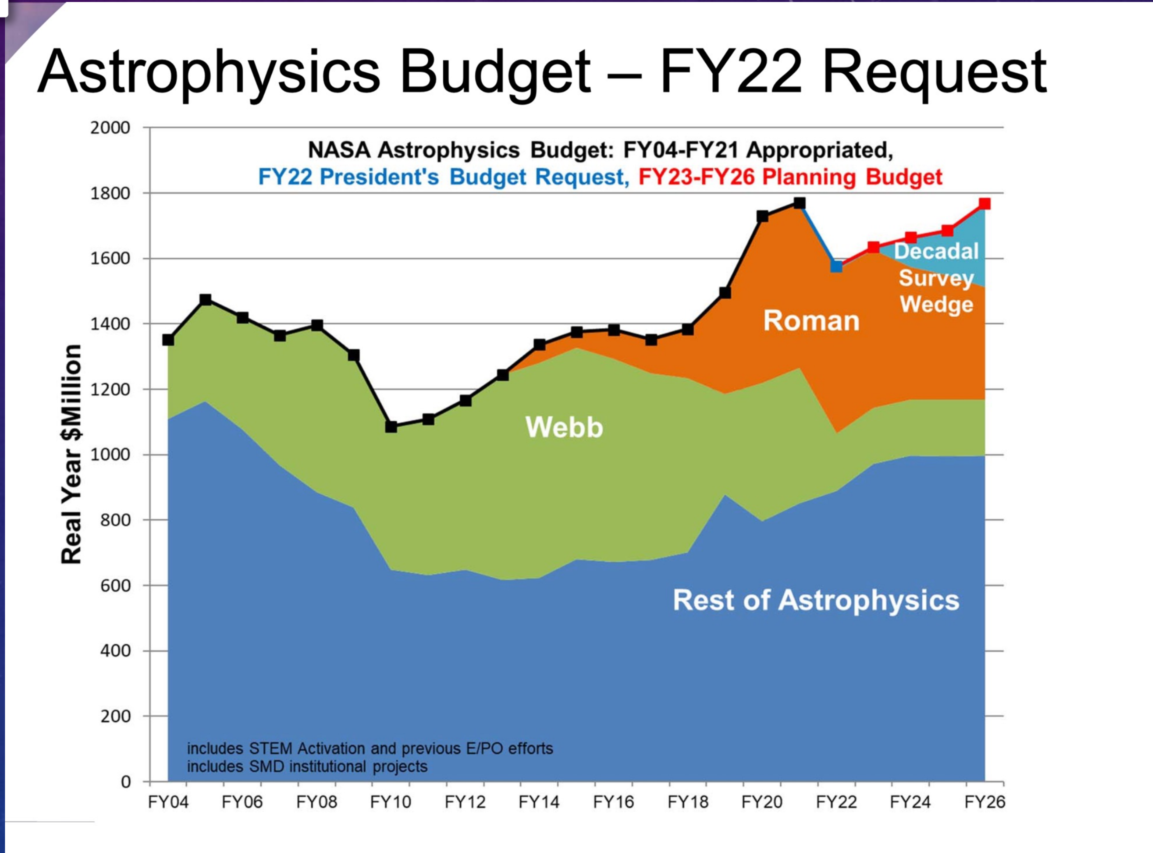


From Paul Hertz's Townhall talk Jan 2022

Is this the End for Gamma-ray Probes (HEX-P, TAP & AMEGO)?

TABLE J.2 EOS2-Related Probe-Scale Mission Concepts

Mission Concept	Lead Author	Closest Predecessor	Science Capabilities	Spectral Coverage
FARSIDE	Burns	N/A	z > 10 neutral hydrogen and SETI search on lunar far side; exoplanets; heliophysics	200 kHz–40 MHz
PICO	Hanany	Planck	CMB polarization anisotropy	21–799 GHz
CMB Spectral Distortions	Kogut	FIRAS	CMB spectral distortions	10–6000 GHz
GEP	Glenn	Spitzer, Herschel	Star formation and SMBH growth over cosmic time	400–10 μm
TSO	Grindlay	N/A	UV–mid-IR time domain astronomy follow up	5.0–0.3 μm
AXIS	Mushotzky	Chandra, Athena	Growth and fueling of SMBHs; transient universe; galaxy formation and evolution	0.3–10 keV
STROBE-X	Ray	RXTE	Compact objects; X-ray counterparts; time domain astronomy	0.2–50 keV
HEX-P	Madsen	NuSTAR	Accreting compact objects; extreme environments around black holes; neutron stars	2–200 keV
TAP	Camp	Swift	Time-domain astrophysics	0.4 keV–1 MeV
AMEGO	McEnery	Compton, Fermi	Multi-messenger; γ-ray studies of neutron star mergers; supernovae; flaring AGN	200 keV–10 GeV
POEMMA	Olinto	N/A	Ultra high-energy cosmic rays and cosmic neutrinos from space	Cosmic rays > 2 × 10^{19} eV Neutrinos > 20 PeV
MFB	Michelson	N/A	Fills gaps in frequency coverage between LIGO and LISA	Gravitational waves 10 mHz–1 Hz

EOS2 Panel, J-16

Highest Priority in Space: TDA MMA (aka TDAMM)

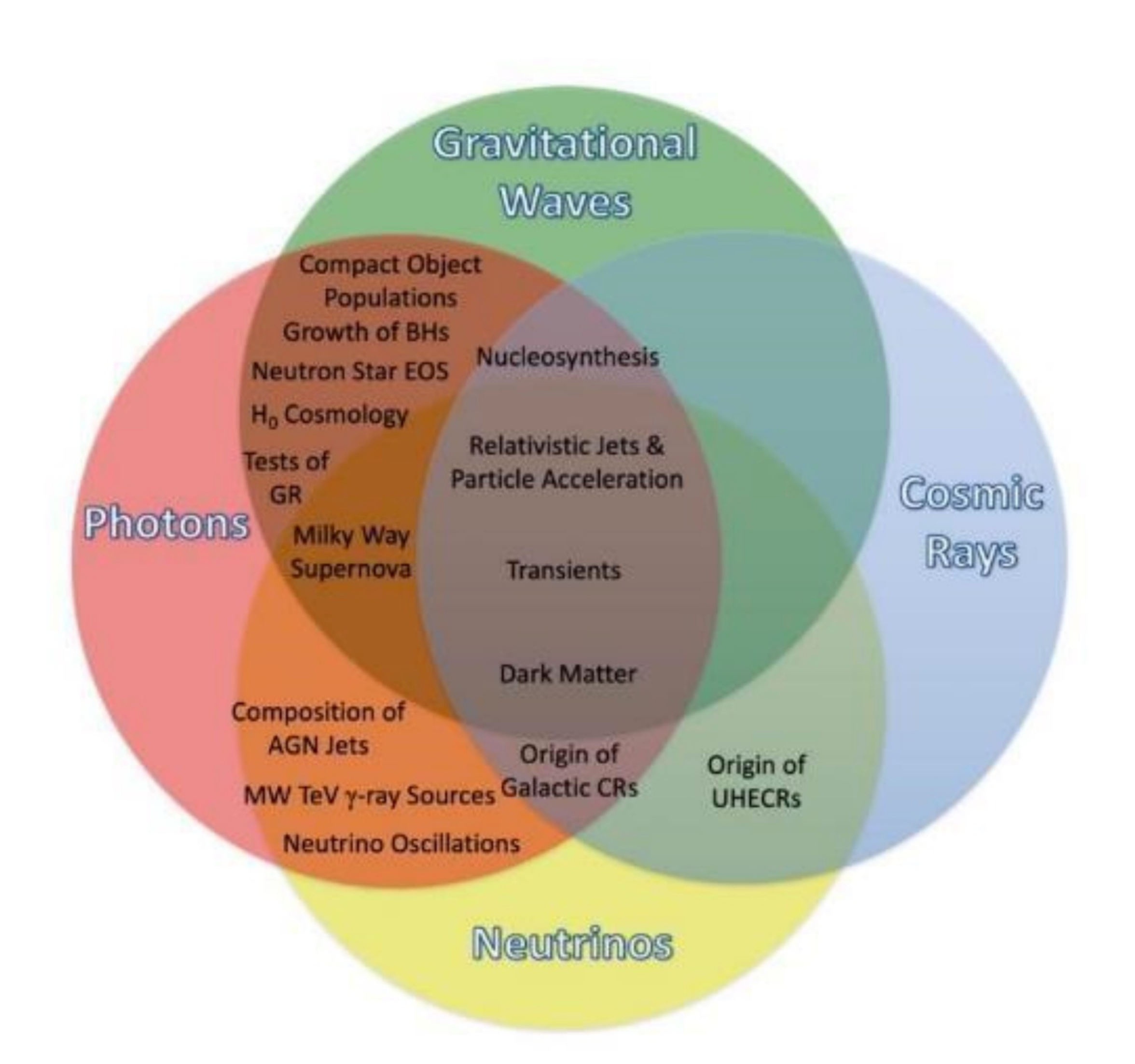
- “Exploring the cosmos in the multi-messenger and time domains is a key scientific priority for the coming decade”
  - “maintain and expand space-based time-domain and follow up facilities in space”
  - “Explorer-scale platforms, or possibly somewhat larger”
  - “time-domain program is therefore recommended as an augmentation [to Explorer program] .. competed calls in broad, identified areas.”
  - (1-17)

Proposed Process

- Standing committee to "advise NASA about what the critical needs are to maintain and expand a vibrant and effective system of time-domain and transient follow-up observatories … through targeted calls" in APRA or Explorer program
- "wide-field gamma-ray and X-ray monitoring, and rapid and flexible imaging and spectroscopic follow-up in the X-ray, ultraviolet (UV), and far-infrared (far-IR) … access much of the sky at any given time, essential for the study of short-lived transients or rapidly variable sources"
- "many of the necessary observational capabilities can be realized on Explorer-scale platforms (Missions of Opportunity (MoO), Small Explorers (SMEX) and Medium-class Explorers (MIDEX), while others could require larger efforts, but still less than half the scope of a Probe Mission"
- "Optimum suite of space capabilities … most effectively achieved by a complement of missions on different scales, including contributions to international efforts." (7-18)

Gamma-rays are TDAMM

- Gamma rays are key to science overlapping with all the other messengers
- “most of the known and anticipated sources of gravitational waves, neutrinos, and cosmic rays are also time variable or transient electromagnetic sources (e.g., neutron star mergers, gamma-ray bursts, black hole jets, and stellar explosions). Combining information from all messengers can unravel the physics at the heart of these objects, as was demonstrated so spectacularly in the case of the binary neutron star merger GW170817” (2-25)



NASA's Implementation of TDAMM?

Time Domain & Multi-Messenger Program

Actions are being developed to address Time Domain Astrophysics and Multi Messenger (TDAMM) recommendations of the 2020 Decadal Survey; NASA's current thinking is

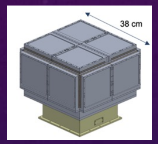
- A panchromatic, multi-messenger program enabled by current and upcoming ground- and space-based facilities will require coordination and broad community involvement
- In addition to new flight missions, the program must involve multi-mission, interagency, and international coordination in the areas of data archives, data standards, transient alerts, and community research opportunities
- Existing and future (in development) NASA missions will continue to make valuable contributions to TDAMM, and upcoming NASA missions and partnerships promise to do likewise
- This will be a program with extensive international cooperation, shaped using broad community input
- NASA has invited its international partners and NSF to participate in the necessary cooperation

From Paul Hertz's Townhall talk Jan 2022

- Does this mean new proposal opportunities?
- Paul expressed some surprise that the Decadal weighed TDAMM so highly
  - See also 2019 GW-EM Task Force report (https://pcos.gsfc.nasa.gov/gw-em-taskforce/gw-em-taskforce.php)
- TDAMM science advisory group will be formed following broad community, interagency, and international input regarding the pressing science questions to be addressed in TDAMM over the next decade
- TDAMM workshop in August 2022
- https://science.nasa.gov/science-pink/s3fs-public/atoms/files/AstrophysicsDivTown%20Hall_Jan_11_2022_Q&A.pdf

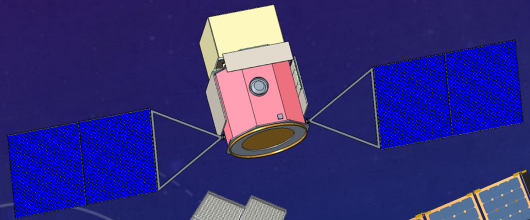
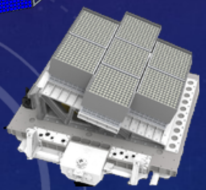
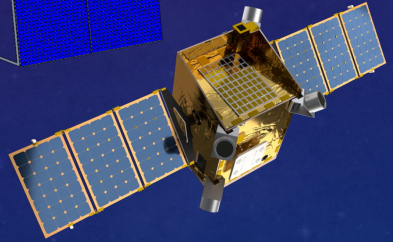
Upcoming Gamma-ray TDAMM Missions

In Development:


BurstCube	Glowbug	StarBurst	COSI
PI: Jeremy Perkins (GSFC)	PI: Eric Grove (NRL)	PI: Dan Kocevski (MSFC)	PI: John Tomsick (Berkeley, SSL)
6U Cubesat Early 2023	ISS Payload Early 2023	Pioneer SmallSat 2025	SMEX 2025
Wide-field Scintillator 50 keV-1 MeV	Wide-field Scintillator 30 keV- 2 MeV	Wide-field Scintillator 30 keV-2 MeV	Compton Telescope 0.2-5 MeV

Proposed:

AMEGO-X	MoonBEAM	LEAP	Others?
PI: Regina Caputo (GSFC)	PI: Michelle Hui (MSFC)	PI: Mark McConnell (UNH)	
MidEx 2028	SmallSat MoO 2027	ISS MoO 2027	
Compton & Pair Telescope 100 keV – 10 GeV	Wide-field Scintillator in Cislunar orbit 10 keV- 5 MeV	GRB Polarimeter 10 keV-5 MeV	

+ several balloons in various stages of development

TDAMM Infrastructure

- “Strong software ... ensure easy user access to the wealth of data on the dynamic universe” (1-7)
- “formats, tools, and alert standards that could be adopted by many projects.” (L-24)
- Transient Alert System
  - TACH/GCN Kafka-based system in development (https://heasarc.gsfc.nasa.gov/tachgcn)
  - SCiMMA NSF-funded system (scimma.org)
- Coordinated Follow-up Observations
  - e.g. efforts like Treasuremap.space
- Interoperable Open Data Archives
- Theory and Simulations

Future of the Interplanetary Network (IPN) (an aside from the Decadal)

- IPN provides time-delay localization of gamma-ray transients using instruments throughout the solar system
  - Key to localization of sources including: GRB 170817A, first extragalactic magnetar giant flare, galactic magnetars, etc.
- Current contributing missions
  - Non-LEO: Konus-Wind, Mars-Odyssey, MESSENGER, INTEGRAL
  - LEO: Fermi, Swift, AGILE
- Operated since 1976 in many different configurations
- Especially with recent loss of Kevin Hurley, discussions starting on the future of IPN
  - Realtime operations continuing for time-being by Dmitry Svinkin et al.
  - IPN archive at HEASARC
  - Many new GRB instruments coming, is it time for a change in approach? (e.g. more automation, machine readable localizations)
  - If you have input, please let John Tomsick know