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

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

From Paul Hertz’s Townhall talk Jan 2022
## Upcoming Gamma-ray TDAMM Missions

### In Development:

<table>
<thead>
<tr>
<th>BurstCube</th>
<th>Glowbug</th>
<th>StarBurst</th>
<th>COSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI: Jeremy Perkins</td>
<td>PI: Eric Grove</td>
<td>PI: Dan Kocevski</td>
<td>PI: John Tomsick</td>
</tr>
<tr>
<td>(GSFC)</td>
<td>(NRL)</td>
<td>(MSFC)</td>
<td>(Berkeley, SSL)</td>
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<tr>
<td>6U Cubesat</td>
<td>ISS Payload</td>
<td>Pioneer SmallSat</td>
<td></td>
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<tr>
<td>Early 2023</td>
<td>Early 2023</td>
<td>2025</td>
<td></td>
</tr>
<tr>
<td>Wide-field Scintillator</td>
<td>50 keV-1 MeV</td>
<td>Wide-field Scintillator</td>
<td>30 keV-2 MeV</td>
</tr>
</tbody>
</table>

### Proposed:

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

+ 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