

Future Large Gamma-ray Mission Concepts Science Analysis Group

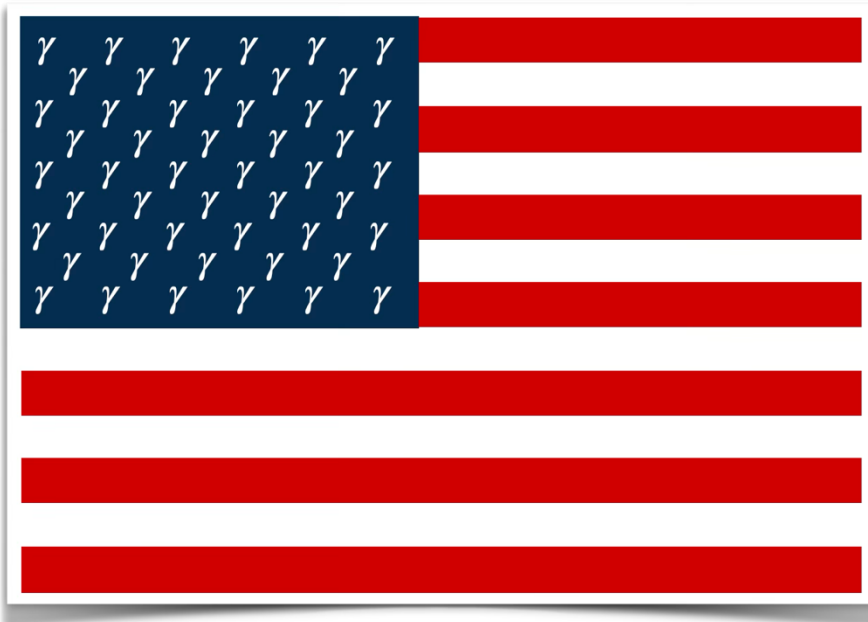
Community inputs on Probe-class and Flagship-class gamma-ray mission
concepts in the 2030s

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Members: All of you!

FLAG SAG survey of large mission capabilities

- Community-wide survey captured 21 submissions on capabilities, technologies and concepts for future large gamma-ray space missions.
- Report will summarize and synthesize inputs, identifying primary science goals and key science questions that concepts can address.
 - Secondary goal: highlight key areas where technical development in the next decade will have a big impact.



<https://science.nasa.gov/astrophysics/programs/physics-of-the-cosmos/community/flag-sag/>

Astrophysics Science Drivers for Future Gamma-ray Observations

- **Understand relativistic jets, how and where they emerge, how they are sustained and how they ultimately decline.**
- **Determine the growth and formation of supermassive black holes.**
- **Reveal the origins and mechanisms of cosmic explosions.**
- **Understand element formation and the energetic role of Cosmic Ray outflows.**
- **Probe extreme environments, underlying populations, and the intervening Universe.**

Advantages of Gamma-ray Space Telescopes

- Relatively **broad spectral bands** using single instruments or even broader with several instruments or techniques in combination – decade to multi-decade in energy/frequency.
- **Very-wide-field observations** possible in single instruments or in distributed configurations
 - Good for coverage and tracking of rare, rapid events. Also allows measurement of persistent emission over very large regions of the sky with some techniques.
- Gamma-ray band contains **electron-positron annihilation and nuclear lines** that carry information about explosions and progenitors.
- Gamma-ray detection interactions are **polarization sensitive**.
- Timing can be extremely precise. Allows studies over a very broad range of **variability from microseconds to years**. Enables novel studies of higher energy pulsar emission.
- Technology progress in partnership with particle physics, nuclear physics, and medical physics communities.

General Challenges for Gamma-ray Telescopes

- Angular resolution (location, location, location!)
- Collection area -- science can depend on how quickly or how many photons can be collected
- Large backgrounds (see above.)
- Rapid detection and communication for transients
- Spectral measurements alone typically do not distinguish non-thermal emission mechanisms
- Calibration often relies on indirect or simulation-based methods
- Relatively high information volume translates into high throughput acquisition/processing/high-bandwidth comms. (Often the ultimate limit for deep data studies.)

Expanding Technical Horizons for Gamma-ray Telescopes in the 2030s

Themes from community survey of concepts and capabilities

- **Improved rapid localization for gamma-ray transients** in addition to monitoring capability with very large to all-sky coverage.
- Wide-field and narrow-field instruments allow science trades between **survey and targeted operational concepts**.
- **Angular resolution improvements** under study -- enhance signal sensitivity, localizations, and mapping capabilities.
 - New studies explore feasibility of focusing gamma-ray telescopes.
- **Spectroscopy concepts** provide moderate or high-precision spectroscopy options to open window on gamma-ray line measurements.
- **Pathfinders for polarization measurements** aim to probe jet composition and distinguish mechanisms.
 - Get a first look of both of the above with COSI in 2027.
- Suborbital flights of the 2020s are **testing performance of particle tracking capabilities** – e.g., gas-based, solid-state, fiber-based approaches provide options to optimize science performance.
- **Novel architectures and orbits** considered in submitted concepts.

Common emphasis among many concepts on improved performance for MeV-band observations.

Gamma-ray Capabilities to Enable Astrophysics

- Observational Capability Categories Drawn from Community Inputs
 - All-sky MeV Transient Monitoring
 - Wide-field MeV to GeV Imaging Spectroscopic Surveys
 - MeV Nuclear Line Spectroscopy over Wide Fields
 - MeV and GeV Polarimetry
 - Large Grasp GeV Surveys with usec Timing
 - Arcminute Hard X-ray and Soft Gamma-ray Imaging
 - Pointed High-resolution Line Spectroscopy
 - Rapid Multiwavelength Follow Up

Gamma-ray Capabilities to Address High-Priority Astrophysical Questions

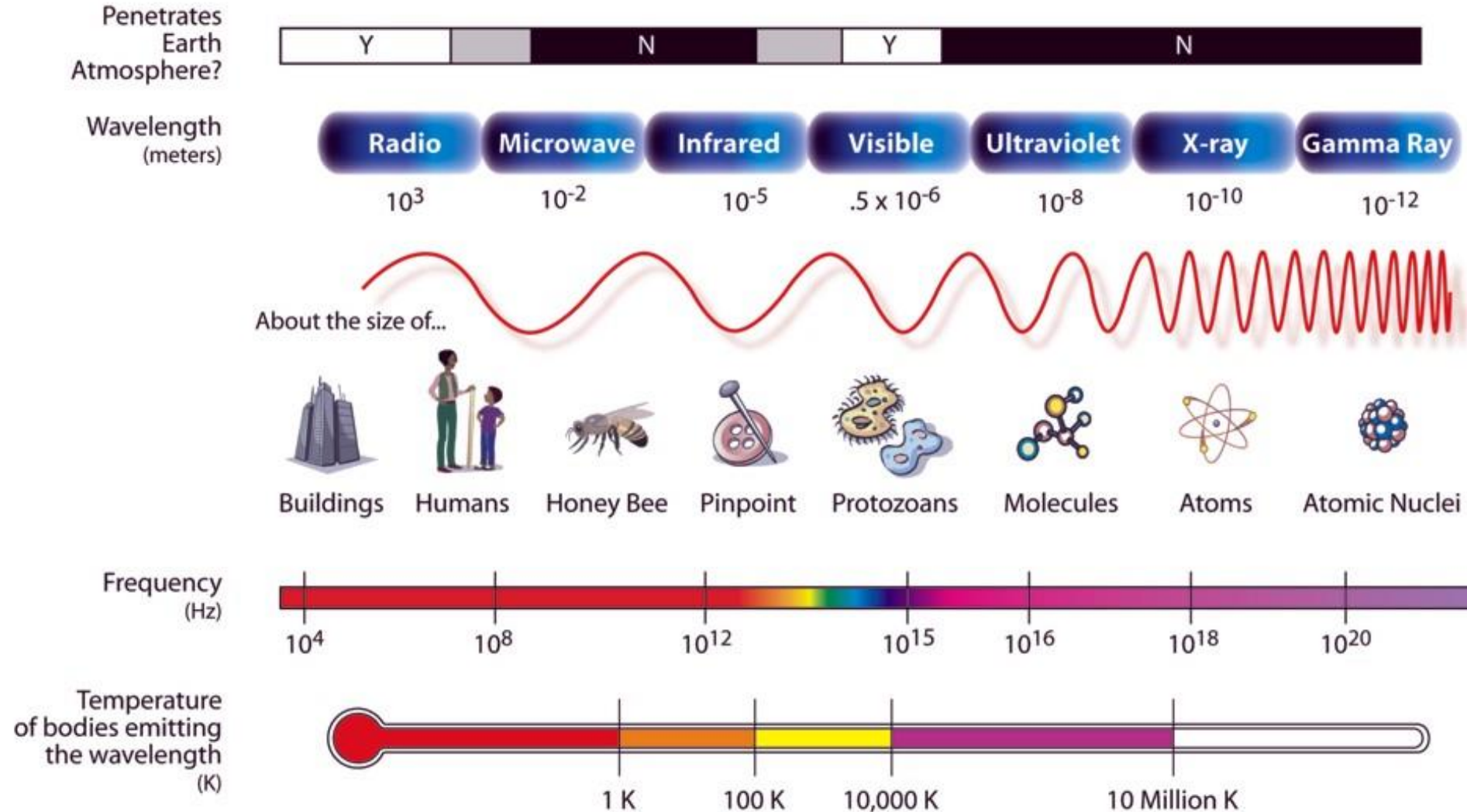
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	Relativistic jets	Supermassive black holes	Cosmic explosions	Element formation & CR outflows	Fundamental physics

Filled boxes indicate primary science applications discussed in the community survey inputs.

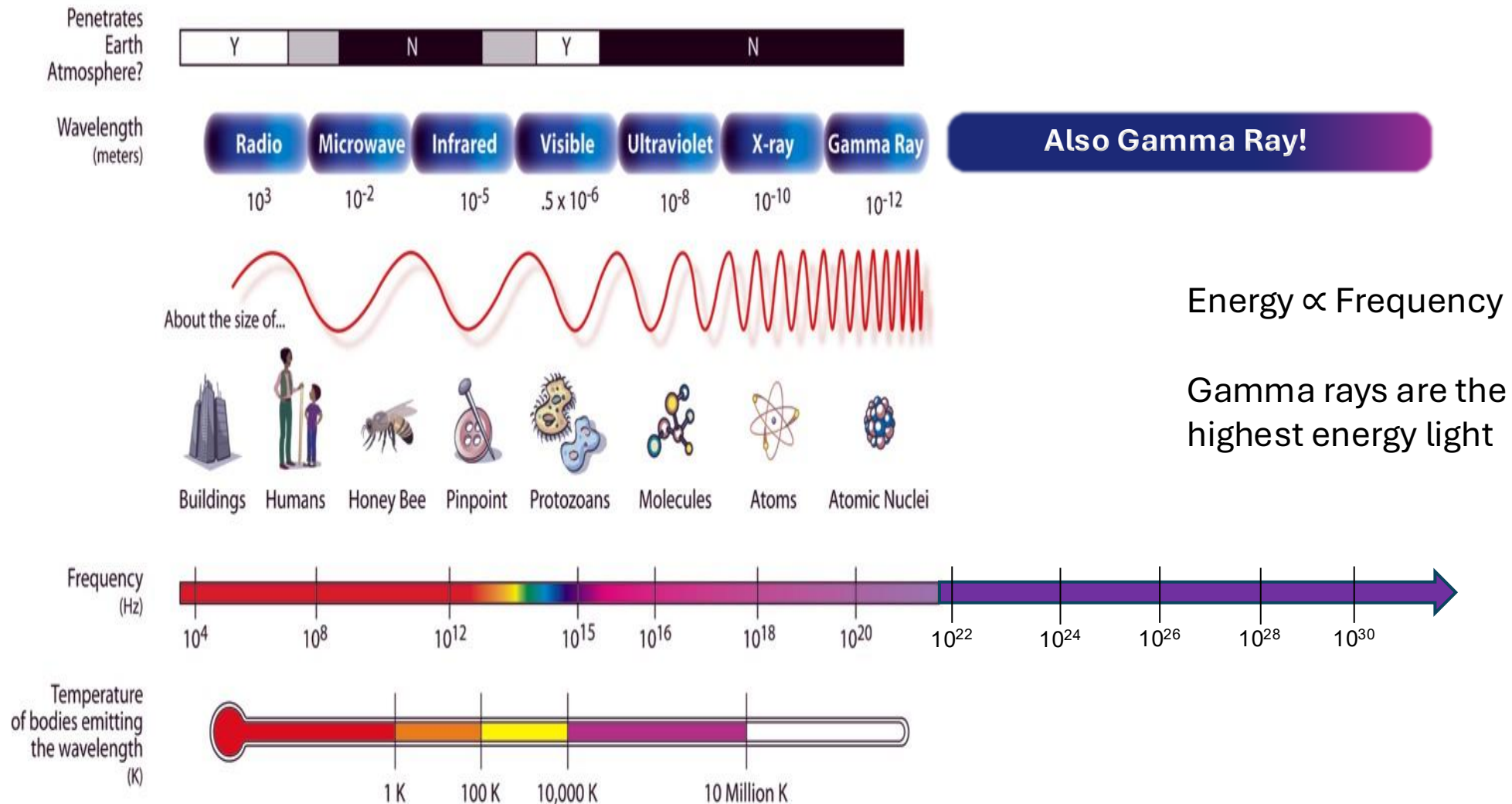
Take-Away Messages

- FLAG SAG Activities
 - Community survey synthesis underway. Thank you to submitters for providing fantastic ideas and materials.
 - Report draft in preparation now. Goal for final report in December.
 - Next FLAG SAG meeting at the end of September.
- Gamma-ray instrument development in the 2020s has been successful in expanding capabilities for future large gamma-ray telescopes.
- Capability options for performance optimization include
 - Transient coverage and localization.
 - Improved sensitivity, acceptance and angular resolution (most notably in MeV band) coupled with optimizations for wide and narrow field approaches.
 - Exploration of broad and narrow-line spectroscopy in addition to continuum.
 - Pathfinders for polarization measurements.
 - Feasibility studies for focusing telescopes.
 - New architectures and orbits.

THE ELECTROMAGNETIC SPECTRUM



THE ELECTROMAGNETIC SPECTRUM



Astrophysics Driven by Gamma-ray Observations

- Gamma rays identify sources of nonthermal emission
 - Processes that produce gamma rays are the same or closely related to those producing cosmic rays and neutrinos – approaches are inherently multimessenger.
- Populations capture the activity of black holes and other compact objects over a range of scales and distances
 - Distant sources involve relativistic plasma jets; the beaming provides a sample of distant/older populations
- Measurements are sensitive to nuclear processes, magnetism and models for particles and gravity
- In some classes of explosive events, hard x-rays/gamma rays are the earliest electromagnetic signals. Role as a first indicator guiding multiwavelength and multimessenger campaigns.
 - Emergence of gamma rays provide a critical probe of explosions and in some cases carry.

Broad Instrument Capability Groupings

- Wide field gamma-ray missions (> 0.5 MeV) optimized for continuum, transients and polarization
 - AMEGO-X / AMEGO (Si pixel tracker and CsI calorimeter)
 - APT / ADAPT (scintillating fibers and CsI, L2 orbit)
 - e-ASTROGAM class Si tracker telescope (ESA heritage)
 - TANGO (BGO spectrometers in lunar orbit)
 - Electron tracking gas TPC (ETCC and pair camera)
 - LEAP, GRAPE, ASCOT (scintillator polarimeters, Compton telescope)
 - Large grasp pair conversion telescope for the gamma-ray PTA (GeV optimized, high-precision timing)
 - Thin Si tracker for pair polarimetry
- Wide field gamma-ray missions (> 0.5 MeV) with high resolution line spectroscopy
 - ARCTIS (Ge pixel Compton telescope, cislunar orbit)
 - GammaTPC (liquid argon TPC)
 - GRAMS (liquid argon TPC)
 - Large volume CZT Compton imagers (TERI heritage)
- Wide field hard X-ray imagers (coded masks, lobster optics) with rapid follow-up
 - GECCO / GALE (CZT and deployable coded mask)
 - TERI (CZT, coded mask and Compton modes)
 - Gamow / THESEUS / SVOM type burst mission with IR telescope
 - SmallSat and CubeSat fleets, hosted burst monitors (IPN)
- Pointed hard X-ray and gamma-ray telescopes (focusing optics, formation flying)
 - Soft gamma-ray focusing imager (multilayer optics to 1 MeV)
 - Hyperspectral microcalorimeter telescope (TES, 50 keV to 2 MeV)
 - ^{44}Ti / ^{56}Ni TES spectrometer (60 to 165 keV)
 - 511 keV line telescope (Laue lens or channeling optics)