NASA at the Dawn of Multimessenger Astrophysics

Abstract for the NASA Astrophysics Subcommittee Roadmap Task Force

We stand at the dawn of multimessenger astrophysics: Ambitious observatories first imagined a generation ago are now being realized, including the Advanced LIGO, VIRGO, and KAGRA gravitational-wave detectors, the ANTARES and IceCube high-energy neutrino observatories, and the Pierre Auger Cosmic Ray Observatory. Complemented by high-energy electromagnetic observatories and the infrastructure of global astronomy, these multimessenger facilities promise the first detections of gravitational waves and high-energy cosmic neutrinos, the resolution of the mystery surrounding the origins of ultrahigh-energy cosmic rays, and a new window into the formation and evolution of black holes – four of the most profound questions we can now ask about the high-energy cosmos. It is likely that most, if not all, of these questions will be resolved within the next 30 years. The promise and goals of multimessenger astrophysics thus offer highly relevant guideposts for NASA's 2013 Astrophysics Roadmap.

With appropriate planning and support, NASA facilities will be well-positioned to play a decisive role in these discoveries. We highlight two key primary capabilities here: wide-field monitoring of the high-energy sky for purposes of discovery, and fast-response high-energy observations for purposes of counterpart identification and characterization. We also note the critical secondary capability of enabling communications infrastructure.

Wide-field monitoring of the high-energy sky from space offers the best means to discover the highest-energy cosmic explosions as they occur. Known cataclysms including the various flavors of gamma-ray burst, supernovae, and tidal disruption events near nuclear black holes, and possible new event types such as black hole mergers, emit prompt high-luminosity pulses of high-energy photons. They are thus readily observed against the backdrop of the relatively dark high-energy sky with modest-sized wide-field space-based detectors. In contrast, the optical sky is populated by a virtual menagerie of moving and variable sources, and the brightest optical and radio emissions of high-energy transients often unfold over the course of days or weeks rather than seconds.

Prompt knowledge of the times and positions of the brightest cosmic explosions dramatically improves the effective sensitivity of multimessenger facilities. Although realized improvements are population- and model-dependent, they can easily be an order of magnitude or more (Smith et al. 2013, arXiv:1211.5602). Even when a multimessenger signal is significant on its own terms, high-energy observations offer the prospect of a much-improved localization for characterization and follow-on studies. The most interesting events for current multimessenger facilities are the rarest and brightest such transients; hence, a synergistic monitoring capability would emphasize field of view and duty cycle over sensitivity per se.

Subsequent to discovery of these events, having space-based resources capable of searching for and characterizing their longer-lived high-energy emissions will also be valuable, as has been proven time and again by follow-up programs of the Chandra, XMM-Newton, and Swift satellites.

Finally, realizing the promise of these primary capabilities naturally requires an active networking and planning infrastructure for rapid communication of alerts and repointing of space-based resources to observe targets of opportunity.

We have focused on the multimessenger motivation for these NASA capabilities. With time-domain astronomy called out as one of five key science frontiers by the "New Worlds, New Horizons" Decadal Survey, and given the time-domain science goals of forthcoming optical (Pan-STARRS, LSST) and radio (LOFAR, MWA, SKA) facilities, it is clear that maintaining NASA's ability to identify high-energy transients in progress and characterize the high-energy properties of new and interesting sources will be crucial to a broad array of astrophysical science investigations throughout the next 30 years.