Opportunities for Multimessenger Astronomy in the 2020s

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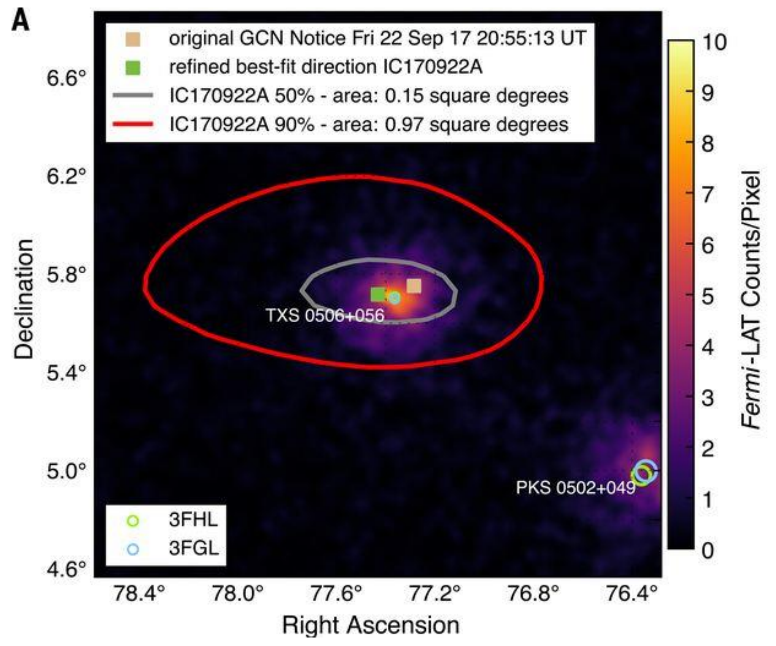
Opportunities for Multimessenger Astronomy in the 2020s
https://arxiv.org/abs/1903.04461

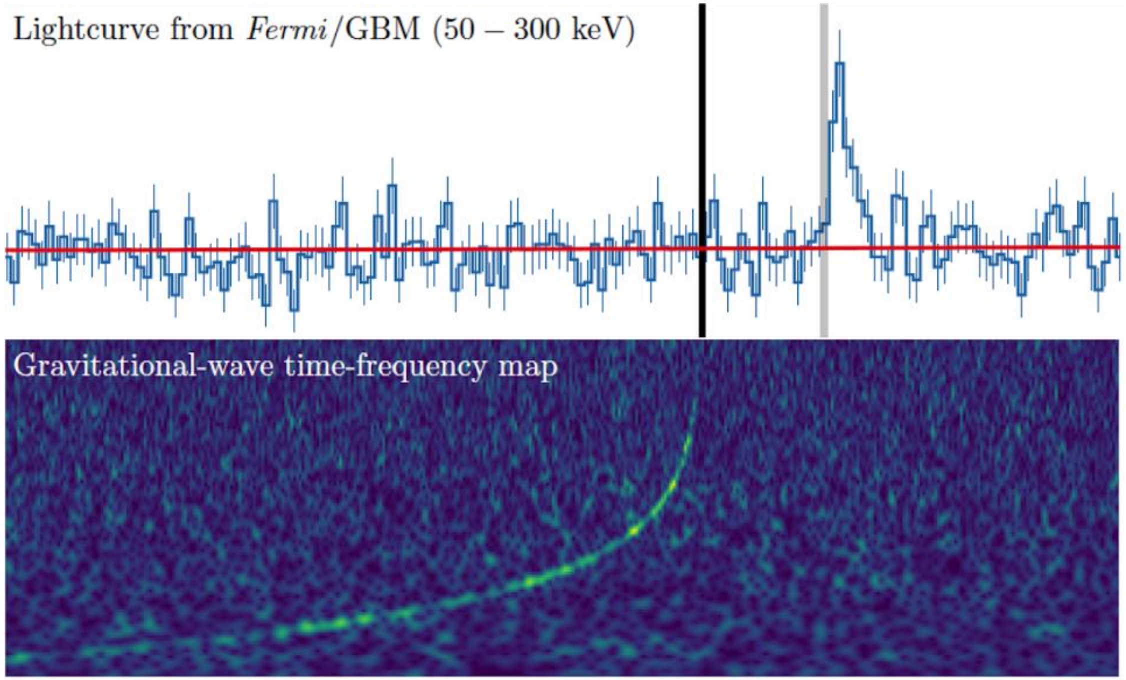
And also

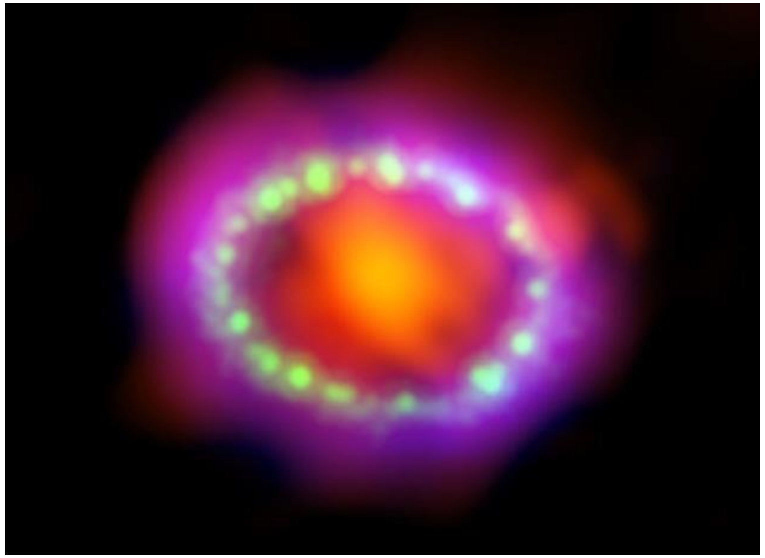
The full MMA SAG

The MMA SAG Final Report

Multimessenger Astronomy







(which is more than just transients)

Sections of the Final Report

1. Motivation and Goals – John Conklin (Previous Talk)
2. Summary of MMA Opportunities – Eric Burns (Current Talk)
3. Science Goals Enabled by Multimessenger Astrophysics
    1. *Multi-physics of AGN Jets*
    2. *High-Energy Neutrinos as probes of AGN physics*
    3. Intermediate and Supermassive Black Hole binaries – John Tomsick
    4. Neutron Star Mergers – Colleen Wilson-Hodge
    5. *Galactic Binaries*
    6. Core Collapse Supernova – Chris Fryer
    7. Stellar-Mass Binary Black Hole Mergers – John Tomsick
    8. Gravitational Waves as a Statistical Probe of AGN and other astrophysics – K. E. Saavik Ford
    9. Thermonuclear Supernova – Chris Fryer
    10. *Fast Radio Bursts*
    11. *Neutrinos and Cosmic Rays*
    12. Extreme Mass Ratio Inspirals – John Tomsick
4. Communication and Interactions across the MMA Observatories – Aaron Tohuvavohu
5. Conclusions – Eric Burns (Current Talk)

Messengers; **Astro2020 Thematic Areas** and Sub-Topics	NS Mergers	CCSN	AGN/Blazars	SMBHBs	IMBHs	Gal. Binaries	Pulsars	sBBH	SNRs	GMF
Thematic Area 2: Star and Planet Formation								x	x	x
Formation of Stars and Clusters								x	x	
Molecular Clouds and the Cold Interstellar Medium; Dust									x	x
Thematic Area 3: Stars and Stellar Evolution	x	x				x	x	x	x	
Stellar Astrophysics		x				x	x	x	x	
Structure and Evolution of Single and Multiple Stars	x	x				x	x	x	x	
Thematic Area 4: Formation and Evolution of Compact Objects	x	x			x	x	x	x	x	
Stellar-mass Black Holes	x	x				x		x	x	
Neutron Stars	x	x				x	x		x	
White Dwarfs						x			x	
Supernovae		x				x			x	
Mergers of Compact Objects	x				x			x	x	
Gamma-ray Bursts	x	x								
Accretion	x	x				x	x	x		
Production of Heavy Elements	x	x							x	
Extreme Physics on Stellar Scales	x	x				x	x	x	x	
Thematic Area 5: Resolved Stellar Populations/Environments					x	x	x	x	x	x
Structure and Properties of the Milky Way and Nearby Galaxies					x	x			x	x
Stellar Populations and Evolution						x	x	x	x	
Interstellar Medium and Star Clusters								x	x	x
Thematic Area 6: Galaxy Evolution			x	x	x			x	x	x
(Forma/Evolu)tion/Dynamics/Properties of SMBHs/Galaxies/Clusters			x	x	x			x		x
Active Galactic Nuclei and QSOs			x	x				x		
Mergers			x	x	x					
Star Formation Rates			x					x	x	
Gas Accretion; Circumgalactic and Intergalactic Media			x	x					x	x
Thematic Area 7: Cosmology and Fundamental Physics	x	x	x	x			x	x	x	x
Early Universe			x							
Cosmic Microwave Background			x							x
Determination of Cosmological Parameters	x		x	x				x		
Dark Matter and Dark Energy	x			x						
Astroparticle Physics	x	x	x	x			x		x	x
Tests of Gravity	x		x	x			x	x		
Astronomically Determined Physical Constants	x		x	x						
Thematic Area 8: Multi-Messenger Astronomy and Astrophysics	x	x	x	x	x	x	x	x	x	x
Identify Sources of GWs, Neutrinos, Cosmic Rays, and Gamma-rays	x	x	x	x	x	x	x	x	x	x
Coordinated Multimessenger and Multiwavelength Follow-ups	x	x	x	x	x	x	x	x	x	x

Why you should care about multimessenger astronomy in the form of the Astro2020 thematic areas

Messengers; **Astro2020 Thematic Areas** and Sub-Topics	NS Mergers	CCSN	AGN/Blazars	SMBHBs	IMBHs	Gal. Binaries	Pulsars	sBBH	SNRs	GMF
GWs - kHz	x	?					x	x		
GWs - mHz			?	x	x	x	?	x		
GWs - nHz			?	x						
Neutrinos - TeV-EeV	x	x	x					?	x	
Neutrinos - MeV-GeV	x	x							x	
Cosmic Rays - Ultra High Energy	x	x	x							x
Cosmic Rays - High Energy	x	x	x	x					x	x
Gamma-rays - keV-TeV	x	x	x	?	?	x	x	?	x	x
X-rays	x	x	x	x	x	x	x	x	x	
UV	x	x	x	x	x	x	x	x	x	
Optical	x	x	x		x	x	x	x	x	x
IR	x	x	x		x	x	x	x	x	x
Radio	x	x	x	x	x	x	x	x	x	x

White Paper Recommendations:

(i) sensitive coverage of the non-electromagnetic messengers,

(ii) full coverage of the electromagnetic spectrum, with either fast-response observations or broad and deep high-cadence surveys,

(iii) improved collaboration, communication, and notification platforms.

(for iii see Aaron's talk)

Final Report Recommendations: NASA Wavelength Coverage and Capabilities

1) It is clear that to maximize multimessenger science, a wide EM and GW wavelength coverage is needed as well as neutrino detectors. While this may seem like an overly broad need, there are a few measurements in particular that are either currently lacking or exist now but will go offline in the near future. **One critical tool is an observatory with a fast response that has a focus on time-domain astronomy.** The Neil Gehrels Swift Observatory is a good example of this type of observatory, but Swift is now quite old (launched in 2004), and a replacement would needed to continues these types of observations. Also, the Fermi Gamma-ray Space Telescope provides vital MMA measurements, including with its GRB monitor. Launched in 2008, the end-of-life of this observatory is not too far on the horizon. **A replacement wide field GRB monitor should be considered in the near term. Both of these observations, along with X-Ray, UV and low-frequency gravitational waves can only be made from space. They therefore should remain a priority of NASA's Astrophysics Division**

Final Report Recommendations: NASA and NSF Need to Work Together

2) **Multimessenger astrophysics requires NASA and NSF to work more collaboratively then ever, since both ground- and space-based measurements are often needed.** Proposing for time on both ground and space observatories can be a challenge. **There are a number of reasons for this.** Mismatching time frames of relevant NASA and NSF solicitations can be a roadblock for making simultaneous space and ground observations. More joint time proposal opportunities would be very beneficial, since many proposals to one of the agencies that includes observations from the other are considered 2nd or 3rd tier science goals because they require multiple instruments. The separation of NSF and NASA solicitations for observing time can also lead to a bifurcation of the astrophysics community. This has a detrimental effect, since it hinders interactions between certain sub-communities. It is also important that disparate catalogs and database systems (e.g. GCN) can work together to facilitate analyses requiring multiple observations. Finally, there is MMA science that can be performed using archived data. They do not require observing time, but personnel and computing time instead. More opportunities for support of these resources without the need of observing time are desirable as well.

Final Report Recommendations: Improved Comms Capabilities

3) Many of the multi-messenger science cases in space require not only instruments sensitive in particular wavelengths and with sufficient sensitivities, but also operational capabilities such as extremely rapid commanding to enable ultra rapid re-pointing and enhanced data taking modes. Such capabilties require both communications and commanding infrastructure, as well as flexible scheduling of the ground segment, to enable them. **It is important that enhancement be made to the autonomous and real-time capabilities of the TDRSS network, and adequate attention be paid to the development of flexible and autonomous observation scheduling software for mission ground segments, to be able to maximally utilize next generation space based observatories.**

Final Report Recommendations:
True Interdisciplinary Work

4) Multi-messenger astronomy is now reaching a fidelity where astrophysicists increasingly need to leverage the progress in computer science and a wide range of physics. These capabilities include fluid dynamics and turbulence, plasma physics, atomic physics, numerical general relativity, nuclear and particle physics. **To maximize the science learned from multi-messenger astronomy, it is important for these different disciplines to work together, sharing expertise.**