Overview of the MMA SAG

Multimessenger Astrophysics Science Analysis Group

https://pcos.gsfc.nasa.gov/sags/mmasag.php

John Tomsick

UC Berkeley/Space Sciences Lab

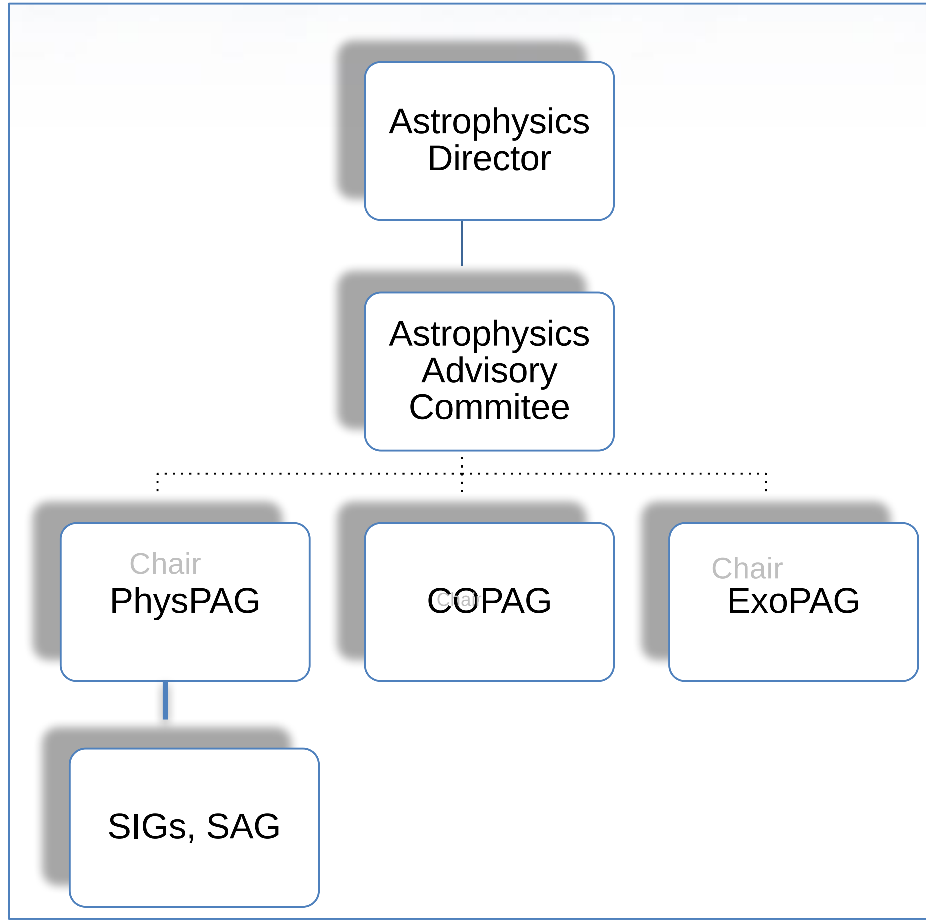
MMA SAG co-chair

HEAD Meeting – Tuesday, March 19, 2019

SSL
UC Berkeley

What is a Science Analysis Group (SAG)?

- Science Analysis Groups conduct specific analyses
  - Start and end dates
  - Report delivered at the end
- Science Interest Groups (SIGs) are for community discussion
  - X-ray SIG was at lunch today
  - GammaSIG is at lunch tomorrow

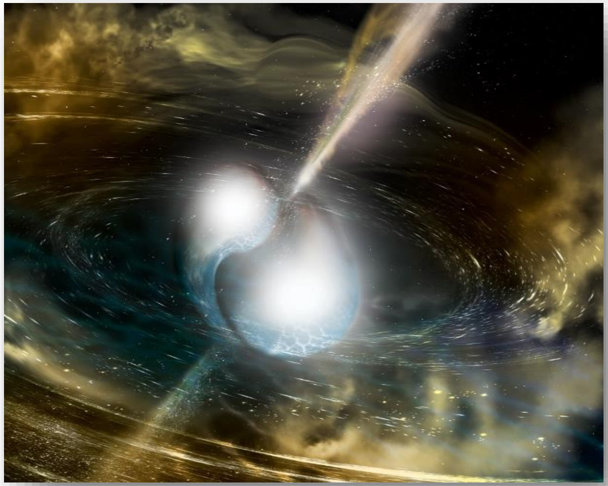


Lines of communication from the community to NASA leadership

What is the MMA SAG?

- Charge is to analyze the potential scientific benefits of multimessenger observations made possible by NASA observatories working with each other and with other ground and space-based instruments
- Multimessenger currently includes photons, GWs, neutrinos, and cosmic rays
- Leadership
  - Chair, John W. Conklin, University of Florida
  - Co-chair, Suvi Gezari, Univ. of Maryland (from Cosmic Origins Program Analysis Group, COPAG)
  - Co-chair, John Tomsick, UC Berkeley (from PhysPAG)

Goals of the MMA SAG



1. Identify **science** achievable by combining different messengers
2. Identify **measurements** that can be made by existing, currently approved, and planned ground or space-based observatories in the 2020s or early 2030s
3. Determine how these enhanced or new science goals align with **NASA Astrophysics Division's scientific priorities**
4. Identify the key **technical drivers** that are needed to achieve these science goals (e.g., wavelength, sensitivity, sky localization, latency, …)

MMA SAG Source Teams

- Organized around astrophysical sources (not wavelength)
  - Goal: form teams with people interested in the same sources but observing via different messengers
- Source Teams
  1. AGN, SMBH binaries, EMRIs
     - Sarah Burke-Spolaor & Bindu Rani, co-leads
  2. NS+NS, NS+BH, WD-WD binaries, GRBs
     - Eric Burns, Colleen Wilson-Hodge, co-leads
  3. Stellar mass BH-BH binaries
     - Peter Shawhan, Saavik Ford, co-leads
  4. FRBs, SNe Ia, SN remnants
     - Geoff Clayton, lead

Approach to Preparing the Report

- We organized the astrophysics community to prepare Astro2020 science white papers
- Community volunteers organized around each source discussed and then prepared WPs
- These (in some form) will become part of the final report, or they will be referenced in the final report

Submitted Decadal White Papers (I)

Overview		
Authors	**Title**	**Primary Topic**
Eric Burns +24 co-authors	Opportunities for Multimessenger Astronomy in the 2020s	Intended to give the broader perspective

Team 1: AGN, SMBH binaries, EMRIs		
Authors	**Title**	**Primary Topic**
Bindu Rani +M. Petropoulou, H. Zhang, F. D'Ammando, J. Finke+18 co-authors	Multi-Physics of AGN Jets in the Multi-Messenger Era	AGN
Marcos Santander +S. Buson, K. Fang, A. Keivani, T. Maccarone, K. Murase, M. Petropoulou, I. Taboada, N. Whitehorn +many endorsers	A Unique Messenger to Probe AGN: High-Energy Neutrinos	AGN
Luke Kelley & Maria Charisi+28 co-authors	Multi-Messenger Astrophysics with Pulsar Timing Arrays	SMBH binaries

Submitted Decadal White Papers (II)

Team 2: NS+NS, NS+BH, Galactic binaries, CCSNe		
Authors	**Title**	**Primary Topic**
Eric Burns +19 co-authors	A Summary of Multimessenger Science with Neutron Star Mergers	NS+NS
Thomas Kupfer +5 co-authors	A Summary of Multimessenger Science with Galactic Binaries	Galactic binaries (continuous GW sources)
Chris Fryer +7 co-authors	Core Collapse Supernovae and Multimessenger Astronomy	CCSNe

All covered in the following presentations

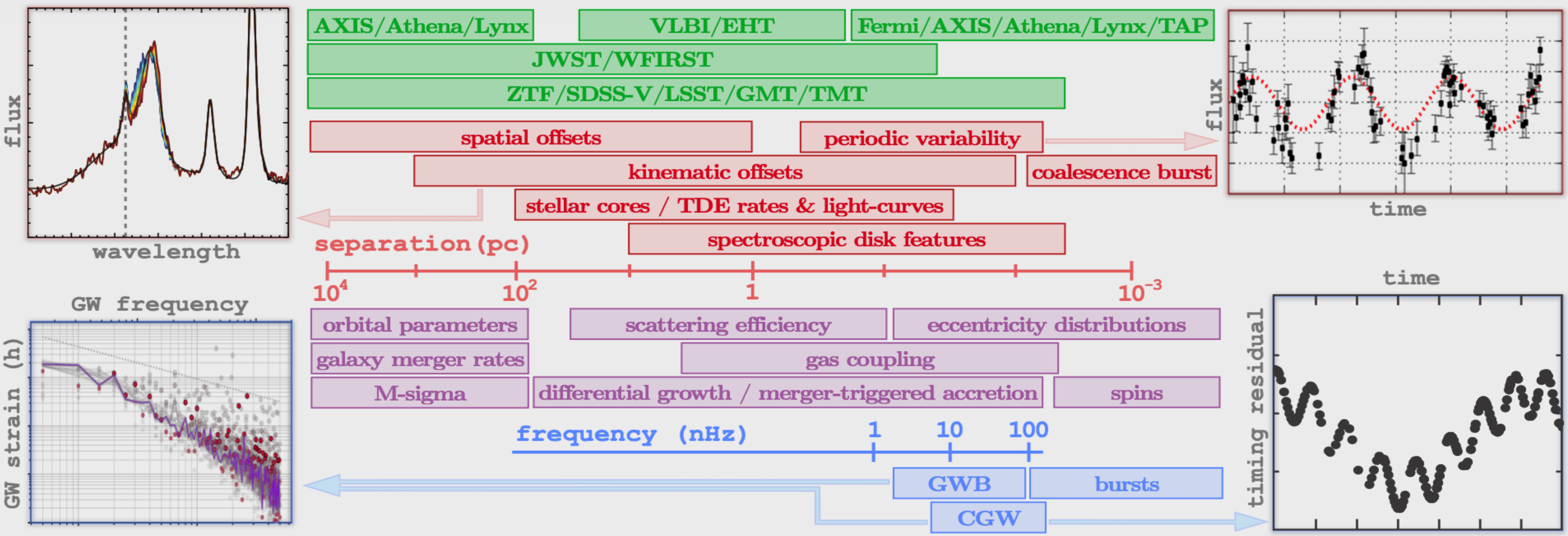
Submitted Decadal White Papers (III)

Team 3: Stellar mass BH+BH binaries		
Authors	**Title**	**Primary Topic**
Peter Shawhan +7 co-authors +5 endorsers	Multimessenger Astrophysics Opportunities with Stellar Mass Binary Black Hole Mergers	sBBH
K.E. Saavik Ford +17 co-authors +10 endorsers	AGN (and other) astrophysics with Gravitational Wave Events	sBBHs may probe gas disks around AGN

Team 4: FRBs, SNe Ia, SN remnants		
Authors	**Title**	**Primary Topic**
Mike Zingale +7 co-authors	Thermonuclear Supernovae	SNe Ia and SNRs

Multi-Messenger Astrophysics With Pulsar Timing Arrays

Luke Zoltan Kelley (LZKelley@northwestern.edu), Maria Charisi (MCharisi@caltech.edu),
Joseph Simon, Sarah Burke-Spolaor, NANOGrav collaboration, et al.



EM Observations
variability studies & EM-candidate followup

- Surveys, cadence/duration: $\sim 0.1 - 10\text{s yr}$
  IR/Opt/X-Ray/Gamma-Ray

- *Targeted followup, resolution:* $\lesssim \text{arcsec}$
  VLBI/IR/Opt/X-Ray

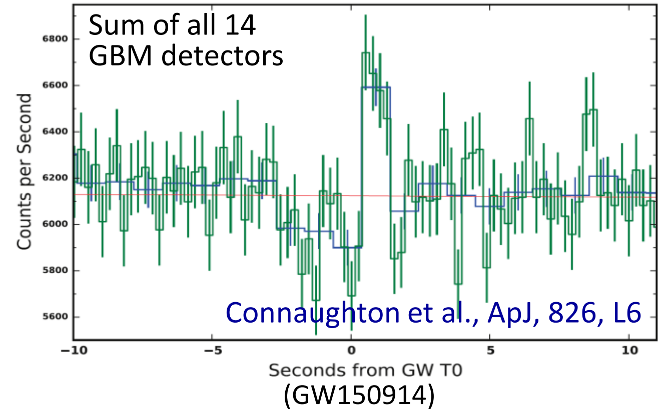
Theory & Computation
emission & dynamical interactions

- Binary AGN emission & variability
- Circumbinary disk sims w/ radiation & feedback
- Coupling simulations from cosmological to disk scales

GW Observations:
continued timing & new pulsars

- Radio: $100\text{s MHz} - \text{GHz}$
- Effective diameters: $\gtrsim 100\text{m}$
- Time: $\sim 1000\text{s hr/yr}$

The Potential of sBBH Mergers for MMA



- Recall that Fermi-GBM recorded a weak transient signal <1 second after GW150914
  - Intriguing but inconclusive
- Unclear if stellar-mass BBH mergers are MMA sources – but there *are* models!
  - Accretion of material from the surroundings of the BBH, producing a jet ➔ GRB
    - Circumbinary disk of outflow material from BH progenitor star
    - Leftover stellar material from recently triggered formation of second BH
    - Mass transfer from a star in a hierarchical triple with the BBH
    - Material from an AGN's accretion disk, in which the sBBH may be embedded
  - Also more speculative models
    - Black holes with non-negligible charge inherited from progenitor neutron stars
    - Magnetic or exotic field interactions

Science

- Stellar evolution and compact binary formation
  - Placing sBBH system in a particular galaxy tells about age and formation conditions
  - Timing, spectrum, strength of EM emissions tell about source of mass for accretion
- Cosmological measurements
- Tests of GR and fundamental physics

A cartoon AGN

- AGN have embedded stars & sBH
- Gas accelerates mergers
- LIGO rates already constrain
  - H/r, AGN lifetime
- Statistical correlations can further constrain AGN disks
- See Ford, Bartos, McKernan++ white paper

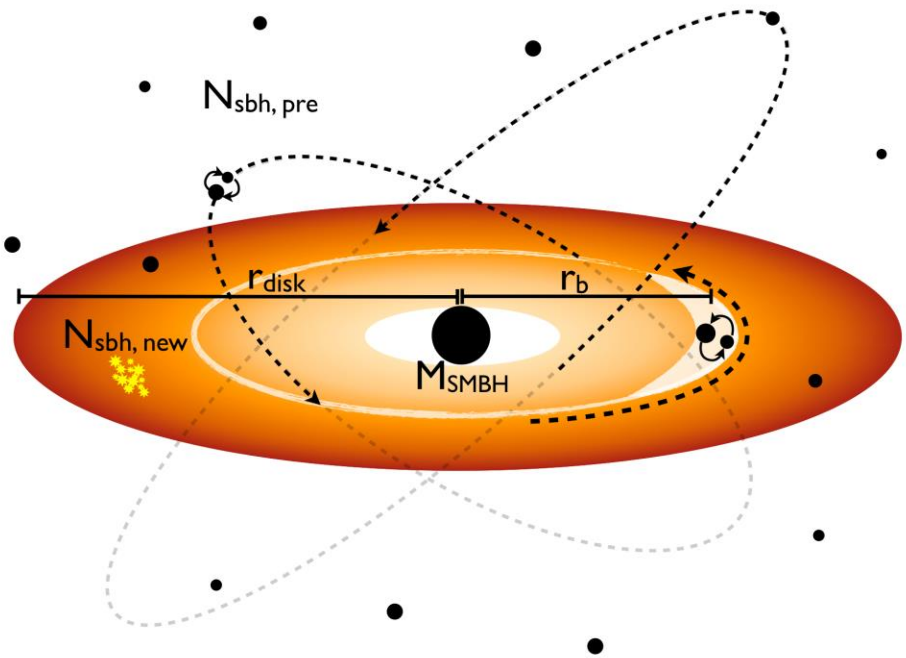


Image credit: Matthew O'Dowd

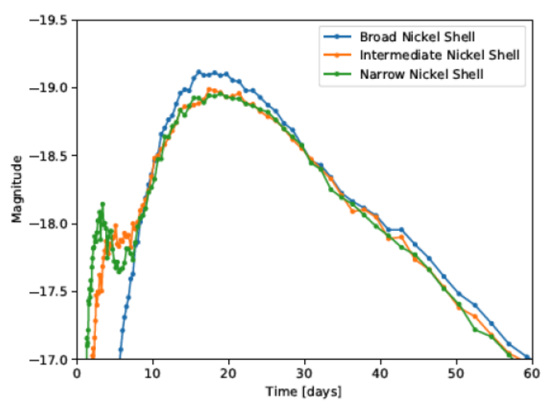
Thermonuclear Supernovae

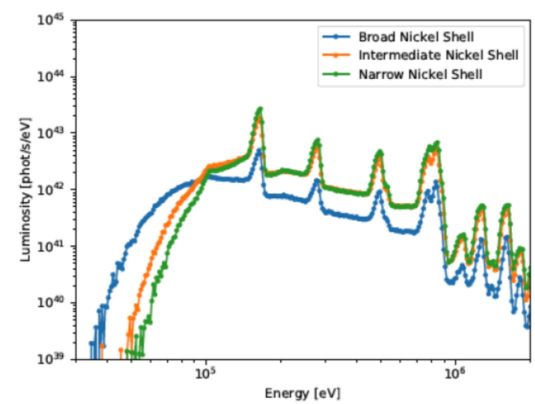
M. Zingale, C. L. Fryer, A. Hungerford, S. Safi-Harb, R. Trappitsch, R. Fisher, A. Calder, K. J. Shen

- Type Ia supernovae are important for:
  - Nucleosynthesis
  - Cosmological distance indicators
- Explosion mechanism / progenitor not known
  - Single massive WD in binary?
    - Chandra explosion model?
  - Double WD system?
    - collisions / mergers?
    - double detonations?

- Light curves + spectra in IR to UV
  - Illuminate early rise: can probe shock interactions
  - Early spectra allow detailed comparison to models
- Gamma-rays
  - Directly emitted from decay of ^{56}Ni
  - Different progenitors predict different ^{56}Ni distributions
- Gravitational waves
  - Probably only important for mergers
  - Detection can rule out single degenerates?

- Computational modeling and multi-messenger observations go hand-in-hand
  - Investments needed in both observational capability and software support and development





Path Forward on the Report

- There are a couple topics on our original list that did not get covered in the WPs
  - Extreme Mass Ratio Inspirals (EMRIs)…definitely need to be included
  - Fast Radio Bursts (FRBs)…very interesting, but are these radio only?
- The WPs all have recommendations, but these need to be discussed by the MMA SAG and a comprehensive summary needs to be written
- We plan to submit the report to the Astrophysics Advisory Committee (APAC) in mid-2019