Mergers involving black holes

John Tomsick

UC Berkeley/Space Sciences Lab

MMA SAG co-chair

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Decadal Science White Papers

Lead author(s)	Title	Primary Topic
Peter Shawhan	Multimessenger Astrophysics Opportunities with Stellar Mass Binary Black Hole Mergers	Stellar mass BBH (sBBHs)
K.E. Saavik Ford	AGN (and other) astrophysics with Gravitational Wave Events	sBBHs may probe gas disks around AGN
Michael Eracleous	An Arena for Multi-Messenger Astrophysics: Inspiral and Tidal Disruption of White Dwarfs by Massive Black holes	Extreme mass ratio inspirals (EMRIs): IMBHs and SMBHs
Jillian Bellovary	Where are the Intermediate Mass Black Holes?	IMBHs
Luke Kelley & Maria Charisi	Multi-Messenger Astrophysics with Pulsar Timing Arrays	SMBH binaries
Priyamavada Natarajan & Angelo Ricarte	Disentangling nature from nurture: tracing the origin of seed black holes	SMBH formation
Curt Cutler	What we can learn from multi-band observations of black hole binaries	Gravitational Waves from all BH categories

Landscape for GWs from BHs

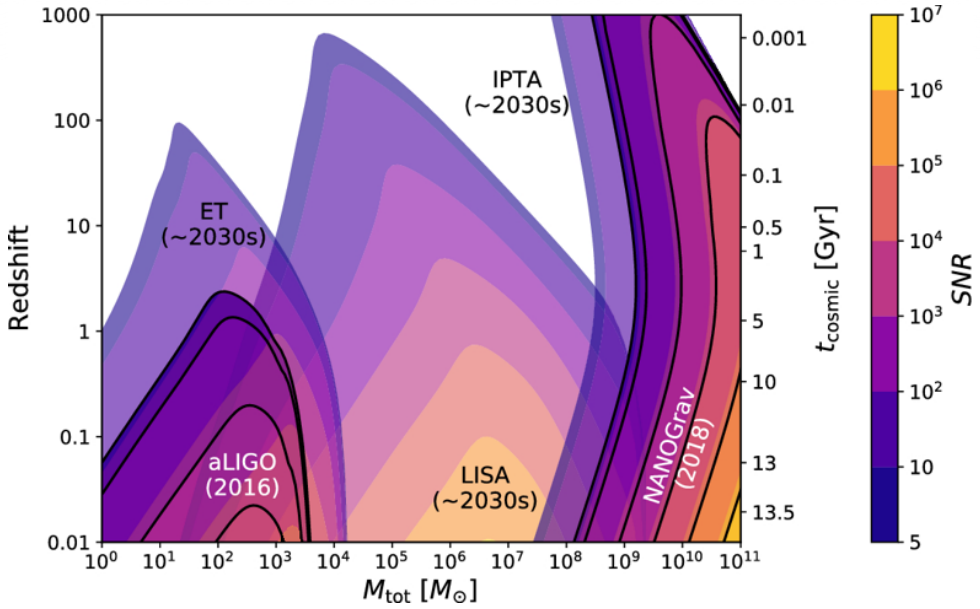
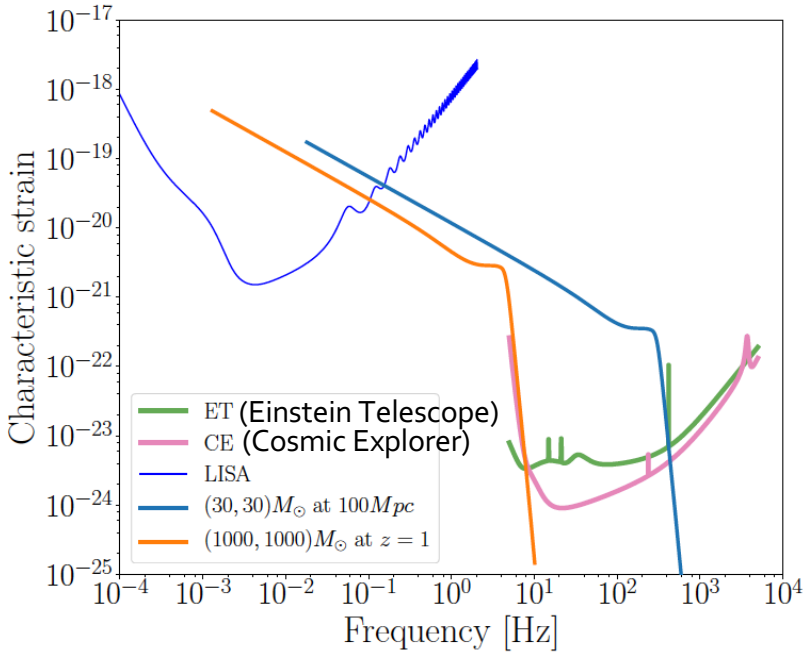


Figure 3 in report (Burke-Spolaor et al., 2019, A&A Reviews, 27, 5)



From Cutler et al. white paper

- When LISA is added, the entire BH mass range will be covered
- LISA will detect impending mergers well in advance
  - The tracks in the figure start *4 years* before merger

GW+EM observations

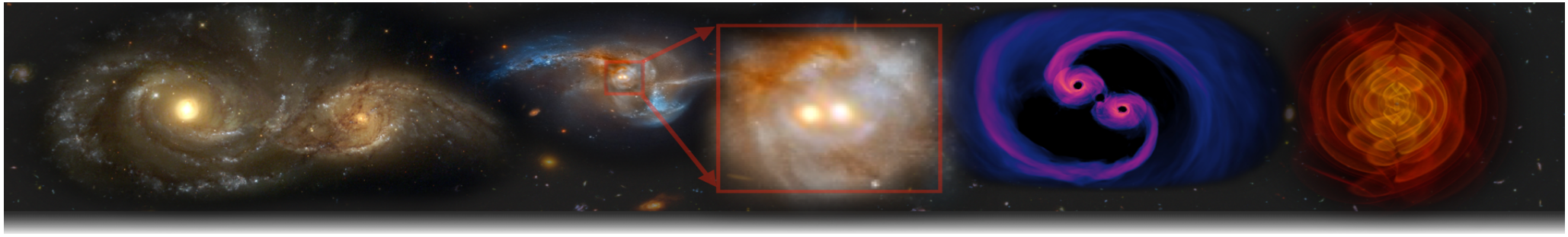
- GW observations provide information about the merging BHs themselves
- EM observations provide:
  - Counterpart identification and localization
    - Host galaxy identification (and redshift)
    - Location within the host galaxy
  - Information about the environment around the BHs

See, e.g., Kelly, B. et al. (2017, Phys Rev D, 96, 123003)

Science sections covered

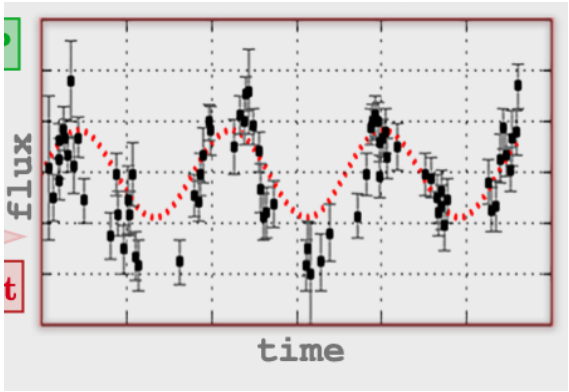
- 3.3 Intermediate and super-massive black holes
- 3.7 Stellar-mass binary black hole mergers
  - Based on the Shawhan et al. WP
- 3.12 Extreme Mass Ratio Inspirals (EMRIs)
  - Based on the Eracleous et al. WP

3.3 IMBHs and SMBH

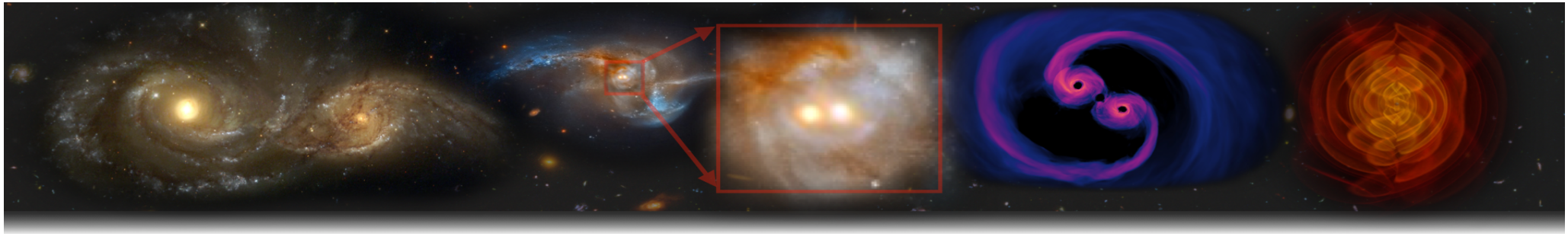


Kelley, L.Z., Charisi, Simon, Burke-Spolaor, et al. white paper

- EM observations for counterpart identification
  - Time-domain astronomy to find the periodic X-ray/UV/optical source in GW error regions
- Galaxy redshifts and cosmology



3.3 IMBHs and SMBH



Kelley, L.Z., Charisi, Simon, Burke-Spolaor, et al. white paper

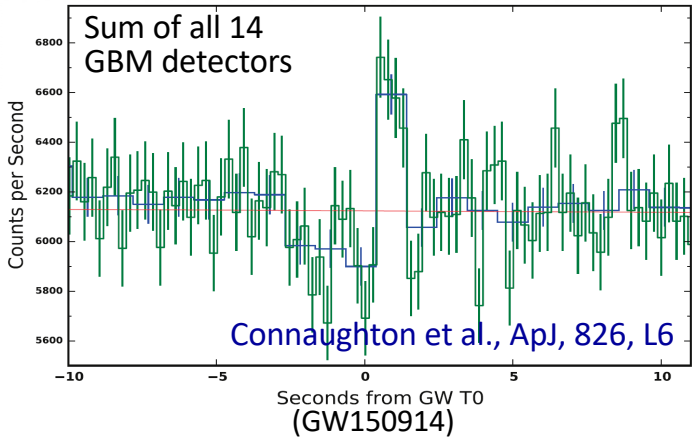
- EM observations combined with theory & numerical simulations
  - Accretion physics and galaxy evolution (next slide)

Accretion physics and galaxy evolution

- Leading up to merger
  - Dynamics of circumbinary disks
  - Co-evolution of SMBHs with host galaxies
  - Dynamical interactions between binaries and their galactic environments
  - Fundamental physics of accretion
- At merger
  - How much material survives the inspiral phase?

Stellar-mass BBH mergers and MMA (3.7)

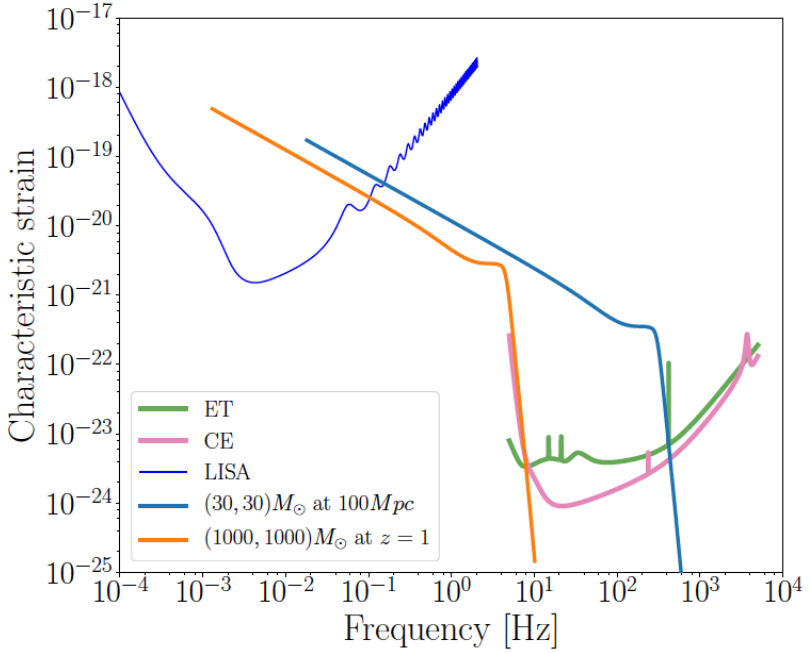
- Recall that Fermi-GBM recorded a weak transient signal <1 second after GW150914
  - Intriguing but inconclusive
  - To my knowledge, only candidate in 37 sBBH mergers in O1, O2, and O3



- Unclear if sBBH mergers are MMA sources, but continued EM coverage is still important
  - Beaming in relativistic jets could cause them to be seen in only a small fraction of cases
  - Other models for EM emission (e.g., BH charge)
  - *Even without detections, EM limits will constrain models*

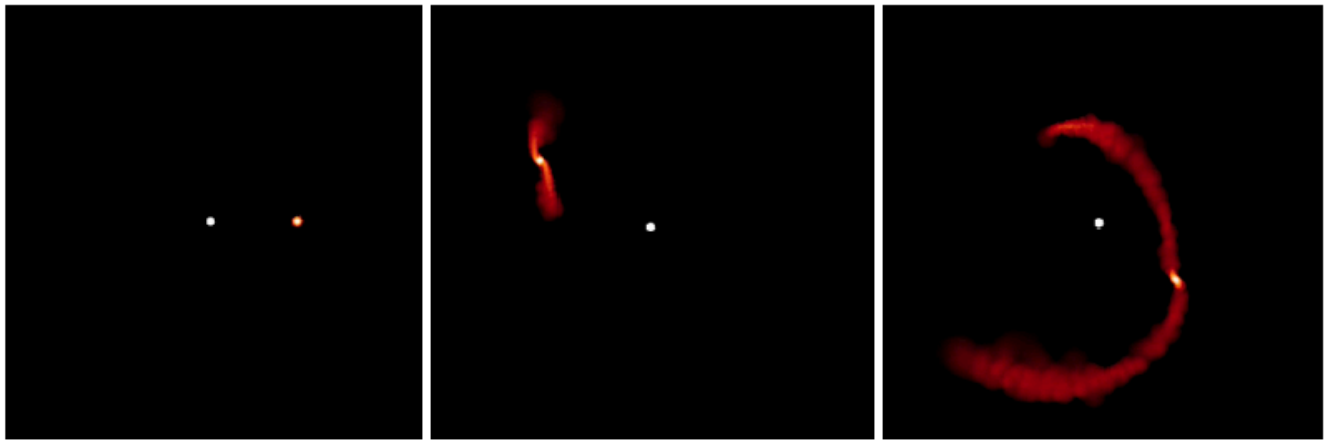
EM observations for sBBHs (3.7)

- Now: All-sky monitoring for gamma-ray or X-ray transients and X-ray afterglows
- Future: With LISA, it may be possible to identify the EM counterpart in advance
  - And then obtain very sensitive X-ray observations at the time of the merger



From Cutler et al. white paper

3.12 EMRIs



- Disruption of a 0.6 M_{sun} white dwarf around a 10^4 M_{sun} BH (Eracleous et al. white paper; simulation by D. Clausen)
- P_{orb}=16s
- Image size = $34R_g$

- If white dwarfs or M-stars are tidally disrupted outside of a massive BHs ISCO, it should be a strong MMA event
  - GWs would be detected by LISA for *about a dozen per year* (if all dwarf galaxies have massive BHs)
  - EM would be detected (may look similar to current TDEs)

Connections to report conclusions

- Related to conclusion #1 (GW and EM coverage)
  - *Time-domain astronomy for identifying and localizing EM counterparts of GW sources (also related to conclusion #2: NSF+NASA)*
  - *Large FOV (e.g., all-sky) EM missions to have coverage of the final merger*
- Related to conclusion #3 (real-time capabilities)
  - *In some cases, the GW detections will be close to the merger times*
  - *EMRI events happen quickly*
- Related to conclusion #4 (numerical simulations)
  - *To learn about accretion physics and galaxy evolution*
  - *EMRIs: accretion events following the tidal disruption*