NASA GW-EM Task Force Summary

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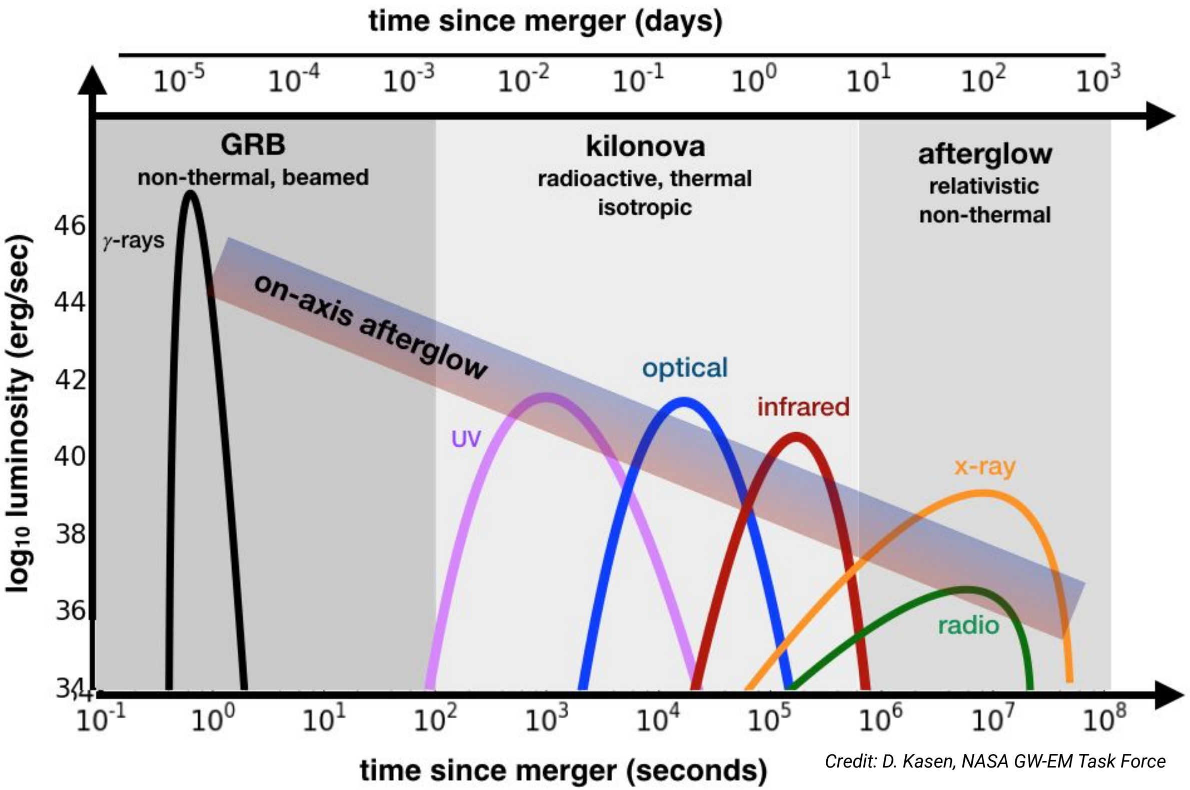
GW-EM Task Force Goals and Implementation

- Charge
  - How can current and upcoming NASA missions optimize observations, operations, R&A, etc?
  - How can NASA resources adapt to increased rates of sources in A+?
  - How can NASA improve coordination/communication?
  - What capabilities are needed for future missions?
  - Focus on neutron star mergers from by ground-based high-frequency GW detectors
- Implementation
  - NASA Mission Questionnaire & Follow-up Discussions
  - GW-EM Community Survey
  - Future Mission Capabilities: Source Rates and Detectability Analysis
- Topics
  - Observation Strategy, Mission Resources, Use of NASA facilities, Multiwavelength Coordination, Observing Plan Coordination, Data Analysis and Theory Proposals, Joint observing programs, Transient Communication Systems, Proprietary Periods, Archives, Diversity
- Full final report was released in early 2020:
  - https://pcos.gsfc.nasa.gov/gw-em-taskforce/GW-EM_Report_Final.pdf

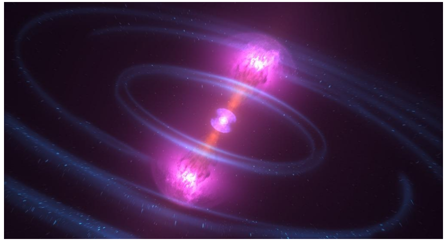
GW-EM Task Force Executive Summary

- **NASA missions played a critical role** in the discovery and characterization of the first binary neutron star merger (GW170817)
- In the near future, the **balanced mission portfolio is well-positioned** to continue to make major contributions to EM followup of gravitational-wave sources.
- **Enhanced target-of-opportunity capabilities, improved communication and coordination, and improvements to Guest Investigator/Observer and Research and Analysis programs**, could further augment the science return.
- **By the mid-2020's, NASA runs a serious risk of lacking critical observational capabilities for supporting gravitational-wave science goals**. Current workhorse facilities (*Fermi, Swift, Chandra, HST*) are well past design lifetimes and lack suitable replacements. In addition, **new capabilities (wide-field UV imaging, improved sensitivity at high energies)** are needed to realize the full scientific potential of gravitational-wave detectors.

Electromagnetic (EM) Counterparts Overview



Credit: D. Kasen, NASA GW-EM Task Force



- Gamma-ray burst (GRB) and On-Axis Afterglow: Relativistic jet viewed within cone
- Kilonova: Radioactive glow from heavy elements, isotropic
- Off-Axis Afterglow: Relativistic jet viewed after lateral spreading
- **Panchromatic phenomenon with a variety of time scales**

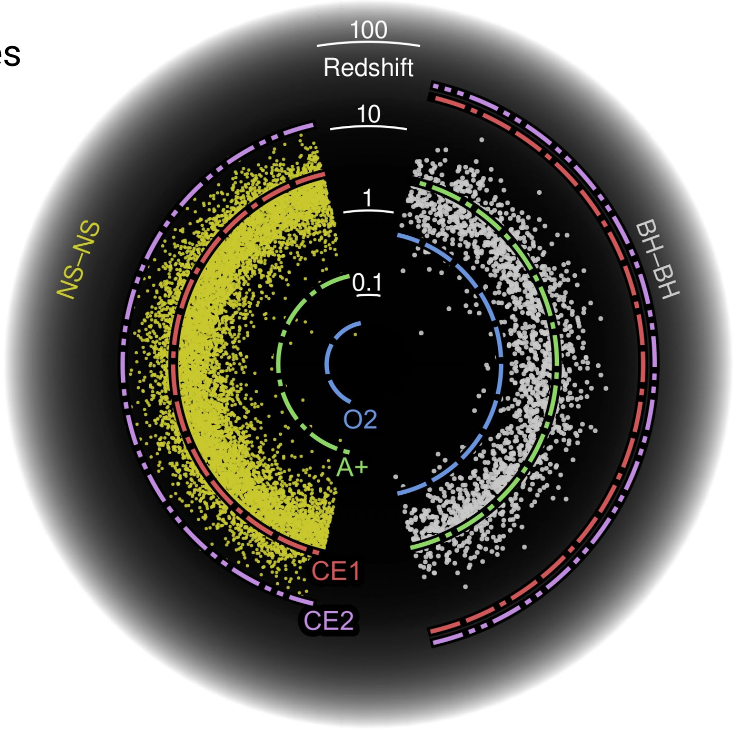
GW Network Landscape

Anticipated improvements:

More GW detectors
Increased GW sensitivity
➡
Improved GW localizations
Increased GW detection rates
Increased distance horizon

Observing Run	**Timescale**	**BNS Rate (yr^{-1})**	**BNS Range (Mpc)**	**Redshift**
O1: LIGO	2015-2016	0.05-1	80	0.02
O2: LIGO/Virgo	2017-2018	0.2-4.5	100 / 30	0.02
O3: LIGO/Virgo	2019-2020	0-13	110-130 / 50 / 8-25	0.03
O4: LIGO/ Virgo/KAGRA	2021-2023	0.6-62	160-190 / 90-120	0.04
O5 (A+): LIGO/ Virgo/KAGRA/India	**late-2024+**	**10-200 / >30**	**330 / 150-260 / 130+**	**0.07**
Voyager	~2030?	>daily	1000	0.4
Cosmic Explorer 1	2035-2040	>hourly	>10,000	1.4
Cosmic Explorer 2	~2045	>hourly	All	10

Funded, Not yet Funded



Reitze et al., arXiv: 1903.04615

Data:
LIGO, Virgo, and Kagra Collaborations et al. arXiv:1304.0670 (updated 9/2019)
Burns 2019, arXiv:1909.06085
Leo Singer, private communication, updated version of Observing Scenarios, LVC, in-prep

Enhance ToO capabilities of current and planned missions

Given growing community need, increased number of events, and technical limitations to decrease fastest response times, (a) ***increasing number of fast ToOs*** *and (b)* ***ensuring ToO capability in planned*** *missions should be top priorities.*

Mission	Current or planned ToO capability?	Fastest Response	Number of fastest response ToOs in latest cycle	Limitations to increasing number of fast-response ToOs
HST	Y	<36 hr	1-2	Technical feasibility, 24/7 on-call staff for responding to ToOs
Chandra	Y	<5 days	8 GO + 4 DDT	Technical limitations leading to difficult scheduling
Swift	Y	<1 hr	Not Limited	Ground station contacts
NuSTAR	Y	<48 hr	500 ksec	Operations funding (lack of 24/7 on-call staff)
NICER	Y	<1 hr	Not Limited	Tools such as web visibility calculator
JWST	Y	<48 hr	8	Scheduling, technical
WFIRST	N	< 2 weeks	N/A	Funding

GW-EM Science Benefits from Joint Observing Opportunities

Joint observing opportunities (using most recent calls for proposals as of November 2019):

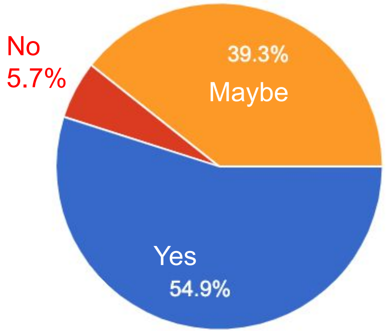
	Primary Program							
Joint Facility	***HST***	***Chandra***	***XMM***	***Swift***	***NuSTAR***	***Fermi***	***TESS***	***NICER***
HST		✓	✓					
Chandra	✓		✓					
XMM	✓	✓			✓			
Swift		✓	✓		✓		✓	
NuSTAR		✓	✓	✓				✓
Fermi								
TESS	✓							
NICER					✓			
NOAO	✓	✓				✓		
NRAO	✓	✓	✓	✓		✓		
INTEGRAL			✓			✓		
VLT			✓					
VERITAS						✓		
MAGIC			✓					
H.E.S.S.			✓					

- Maintaining a public updated list of **joint observing opportunities**
- NASA pursuing **additional joint programs** where scientifically relevant
- In addition to single agency calls, a **joint funding program** with the NSF (LIGO, LSST, etc.) would open new opportunities for novel multi-messenger programs.

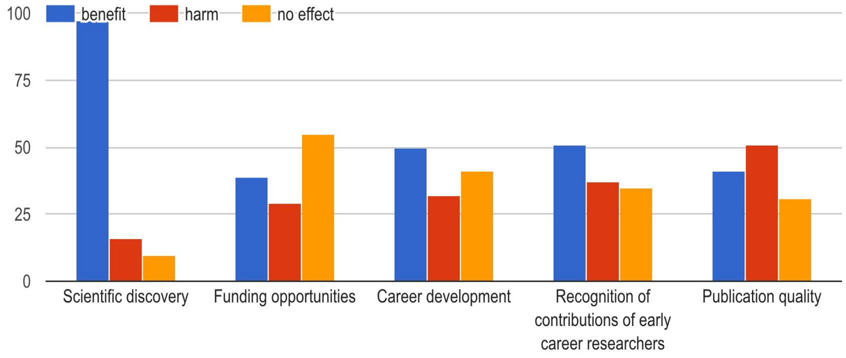
Proposals and Proprietary Periods

- Community survey respondents **were positive about allowing multiple co-PIs**, which could help early career scientists get recognition as PIs and facilitate collaboration among groups.
- Most community survey respondents **favored shorter (< 1 month) proprietary periods**, believing this would enhance science discovery and benefit early career scientists

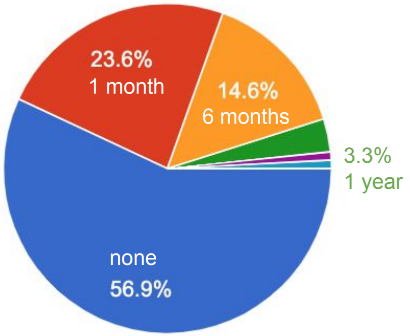
Community Survey: *Will allowing multiple co-PI's benefit early career researchers?*

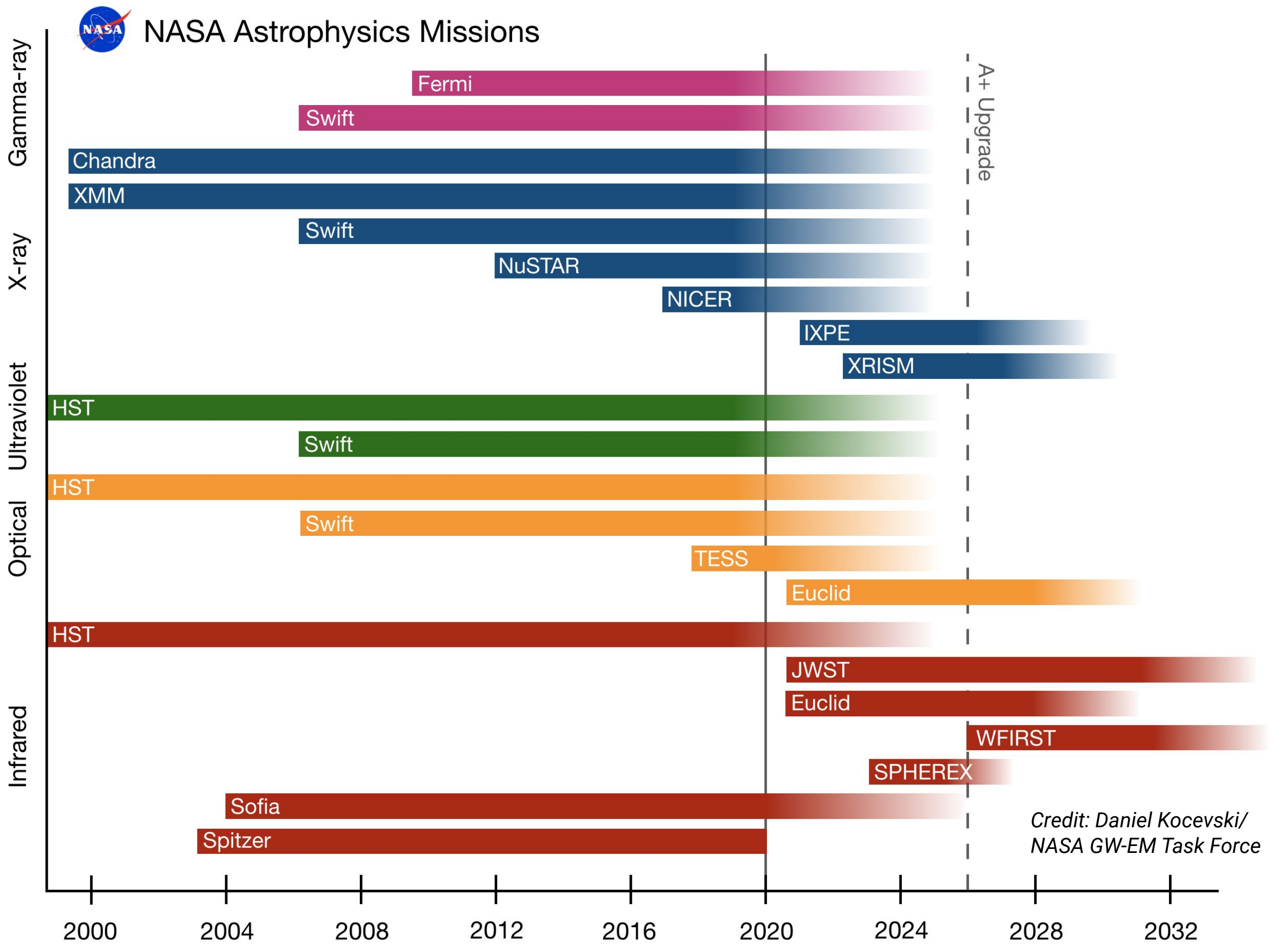


Community Survey: *How would zero proprietary periods affect the following?*



Community Survey: *What proprietary period for NASA missions would be most appropriate for GW-EM observations?*



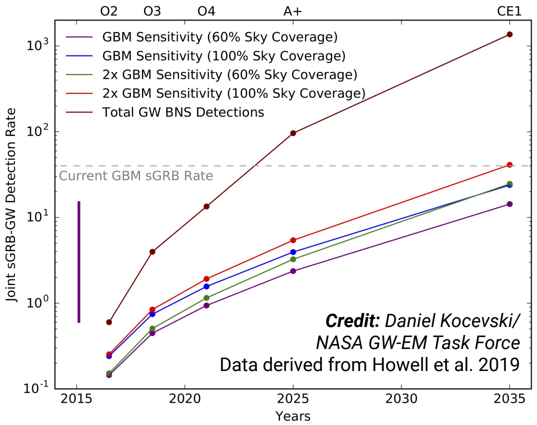


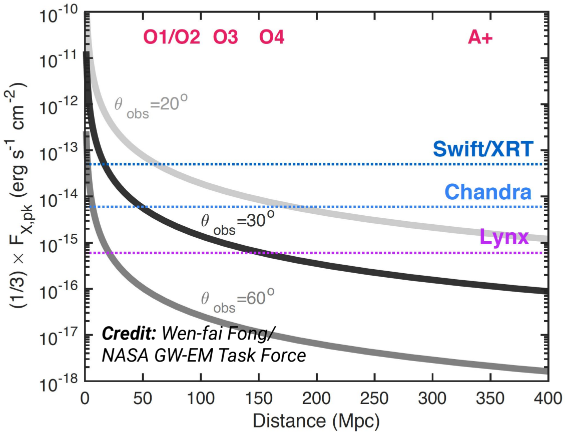
Credit: Daniel Kocevski/ NASA GW-EM Task Force

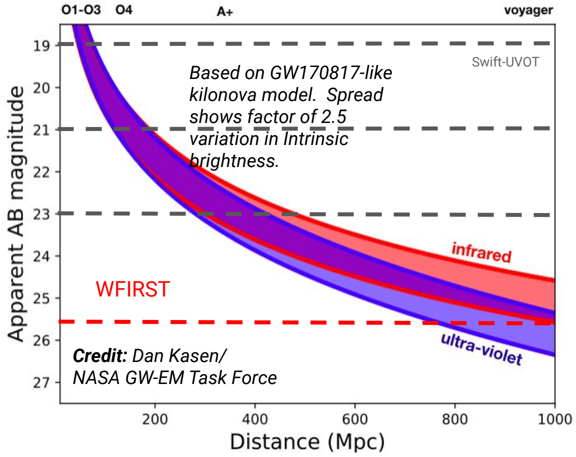
- Many current missions are well **past design lifetimes**
- Downside of a balanced mission portfolio is **little/no redundancy** in critical capabilities
- **No replacements** planned for multiple "workhorse" GW-EM facilities
- Future mission portfolio leaves **significant gaps** in capabilities (e.g. gamma-ray, UV)
- **Gaps** could **coincide** with dramatic increase with GW detector sensitivity
- CubeSats/SmallSats/MOOs are complementary, but do not replace capabilities of large missions

GW-EM Task Force Final Report

- Report is now public:
  - https://pcos.gsfc.nasa.gov/gw-em-taskforce/GW-EM_Report_Final.pdf
- Includes many other topics
  - Mission specific findings
  - Coordination/Communication
  - R&A program and joint observing programs
  - Analysis of GRB, kilonova, and afterglow source rates with GW network improvements







Archives and Tools for the A+ Era

- All NASA missions should ensure that both data and data products are stored in **common archives, with modern Application Programming Interfaces** (APIs) and (where possible) abiding by common standards.
- **Improved advertisement of existing capabilities and development of new resources for cross-mission archival searches** (both within NASA and between NASA missions and ground-based facilities) is a high priority for the community.
- **A funding mechanism to support community efforts to improve upon existing tools** (e.g., GCN, TACH) and **develop new resources/tools** (e.g., Treasure Map, NED Gravitational-Wave Follow-Up service) to better coordinate community follow-up and sub-threshold coincidence searches (e.g. Fermi-GBM, Swift-BAT) would result in exciting new scientific opportunities.
- Where possible, **prioritizing the processing and dissemination of GW-EM observations** would enable more efficient and effective follow-up by the community.
- To facilitate communication between missions and the broader astronomical community, all NASA missions should implement **common standards** for reporting on **planned and executed observations**, and the **detection of transient sources**. These standards should be identical to those adopted by **NSF-funded** (e.g., LSST) and **internationally funded** (e.g., SKA) facilities.