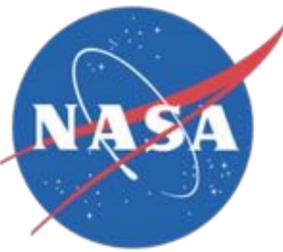


Data Science Challenges in Gravitational Wave Astronomy

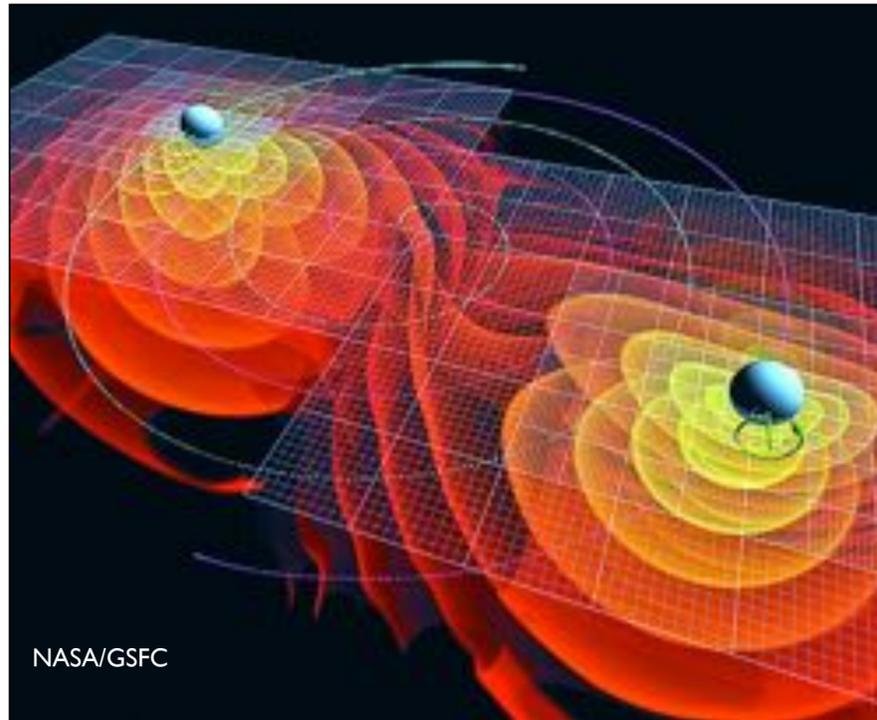
Tyson Littenberg (NASA/MSFC)



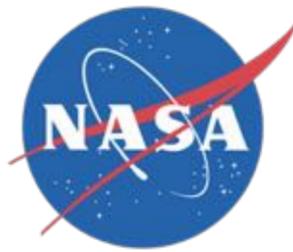
Gravitational Wave Sources



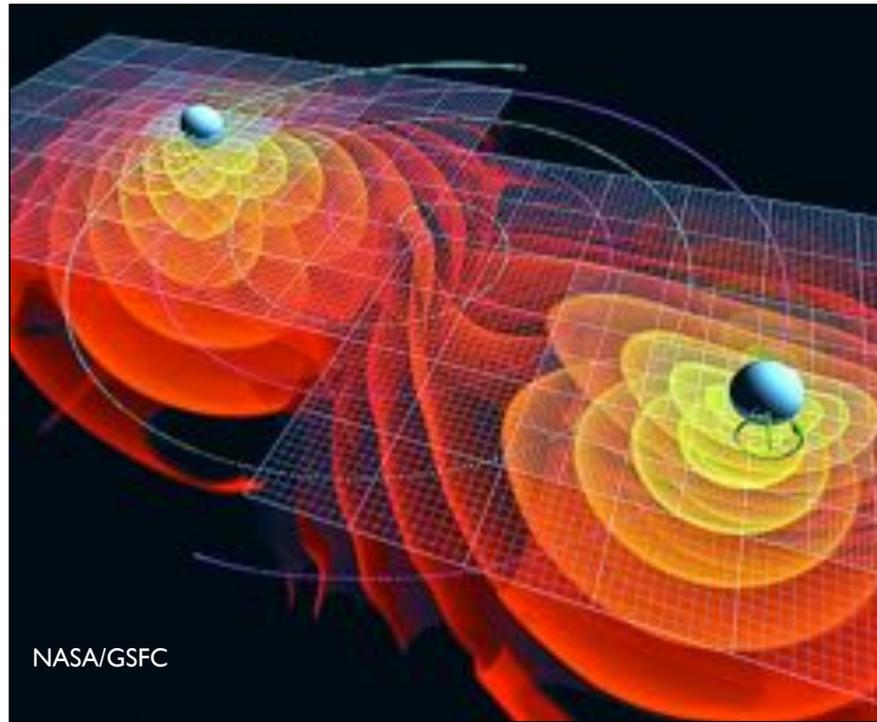
Modeled Transient Sources



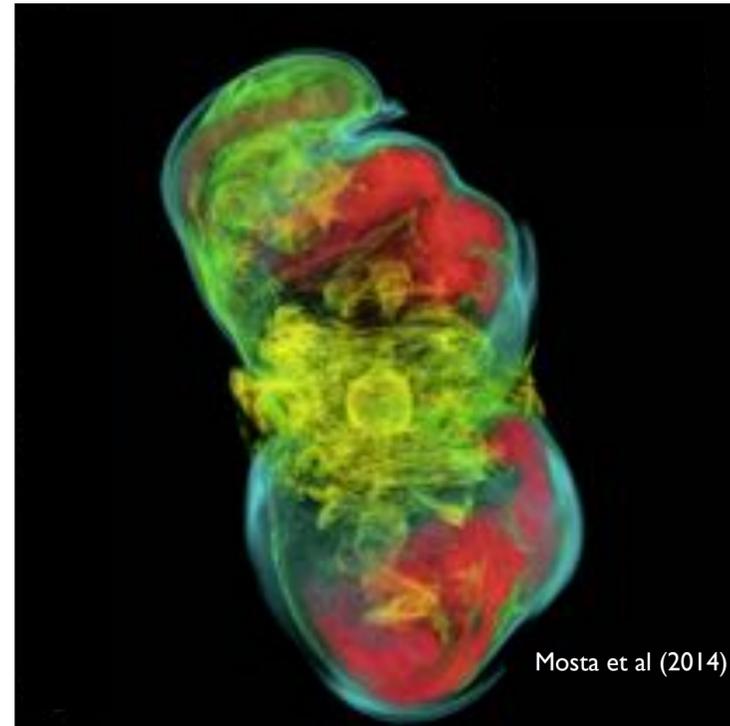
Gravitational Wave Sources



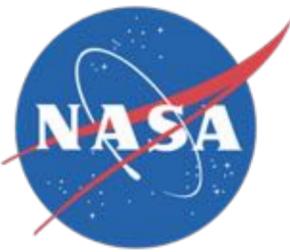
Modeled Transient Sources



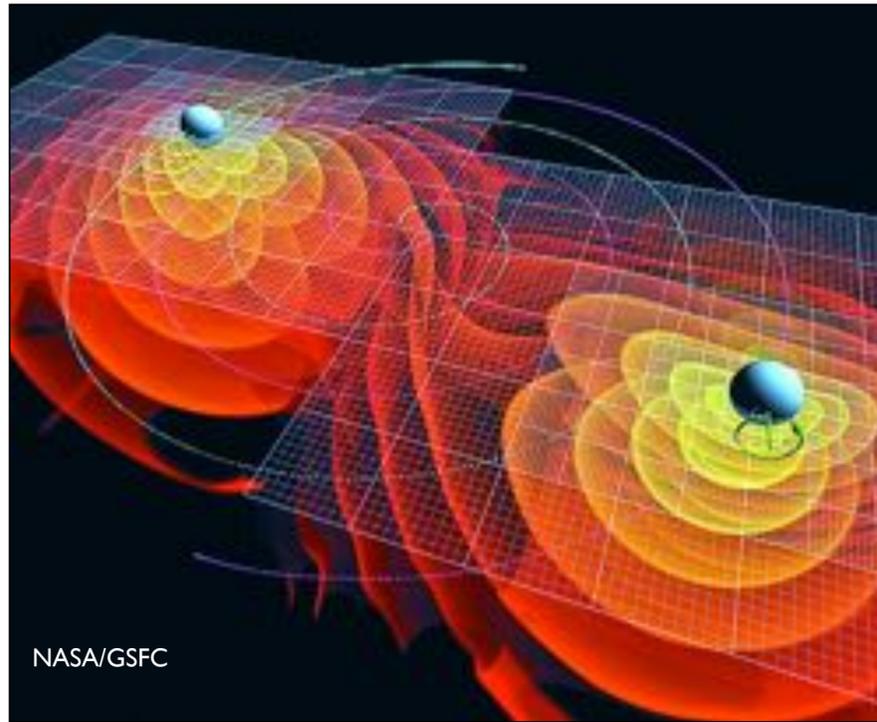
Un-modeled Transient Sources



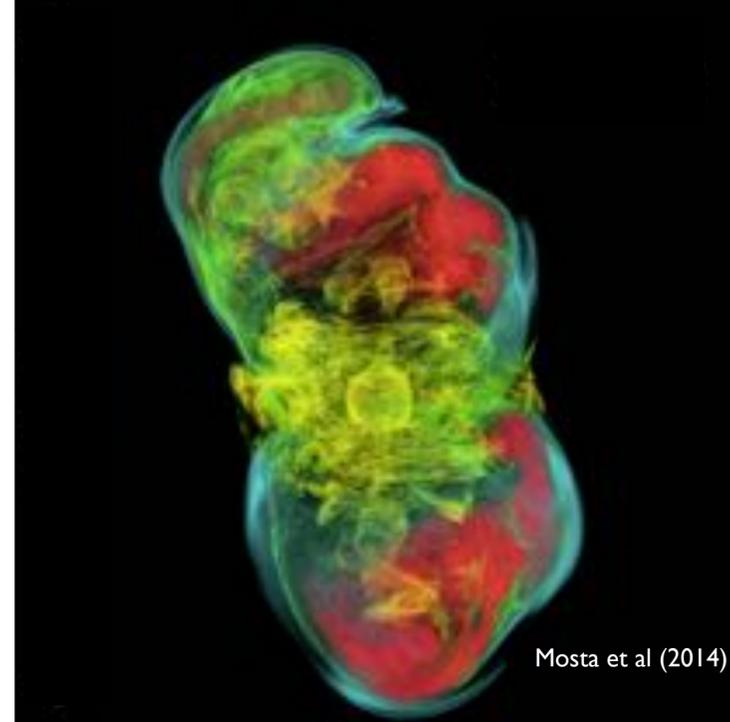
Gravitational Wave Sources



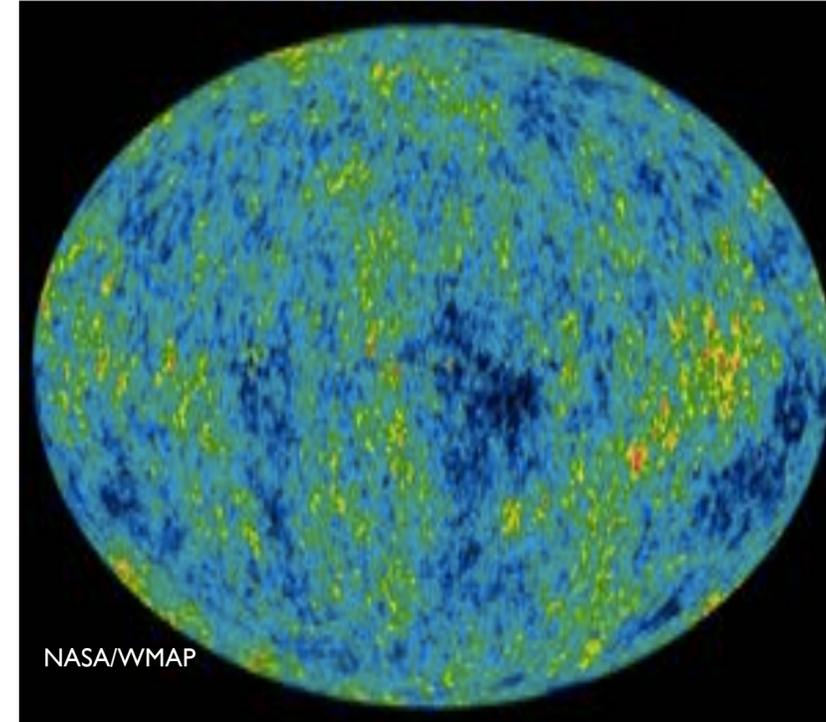
Modeled Transient Sources



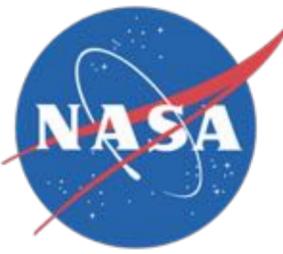
Un-modeled Transient Sources



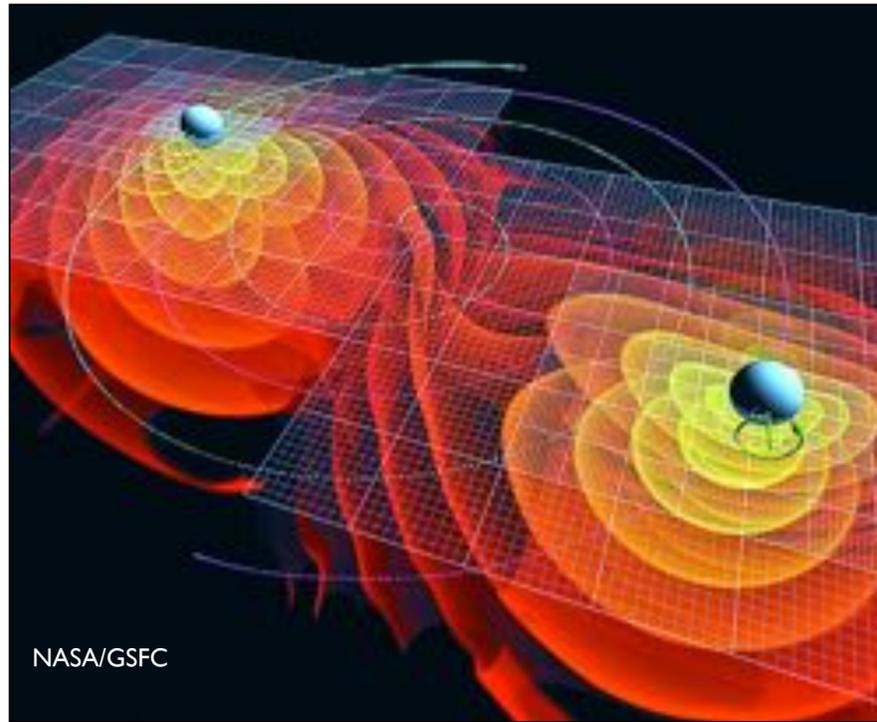
Stochastic Backgrounds



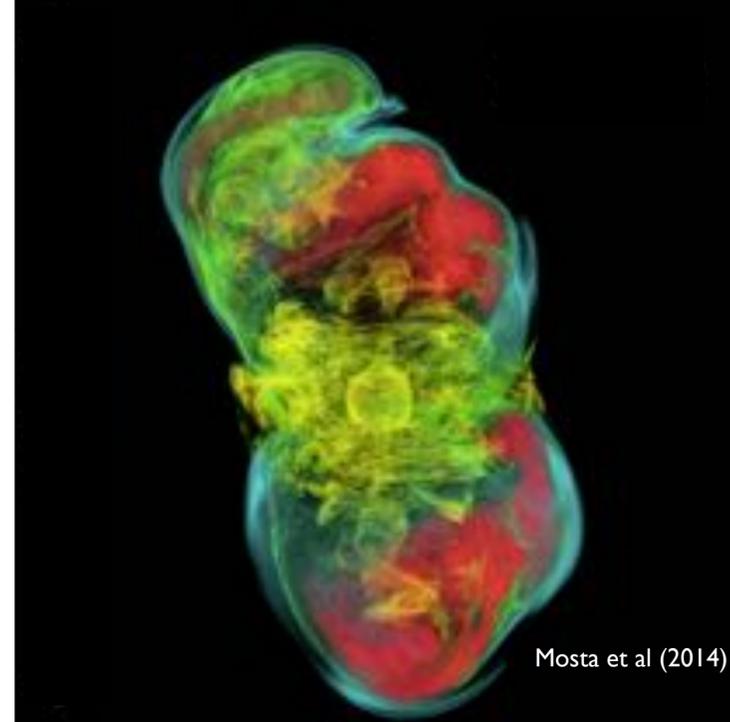
Gravitational Wave Sources



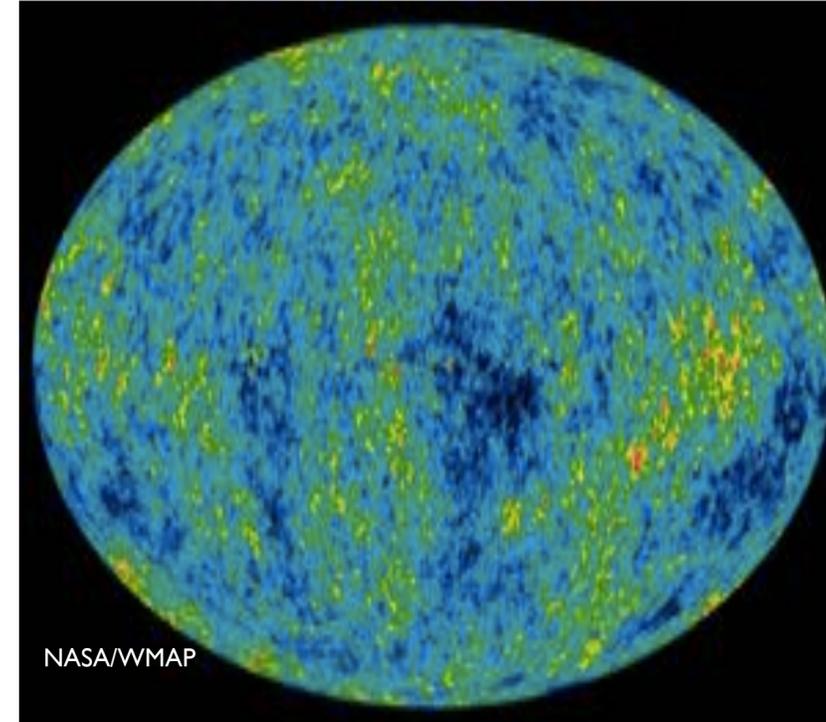
Modeled Transient Sources



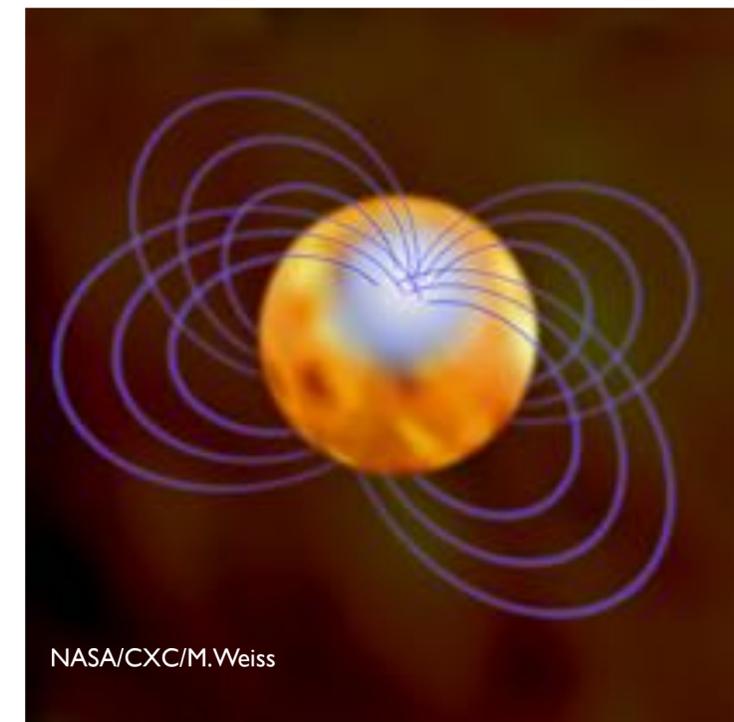
Un-modeled Transient Sources



Stochastic Backgrounds



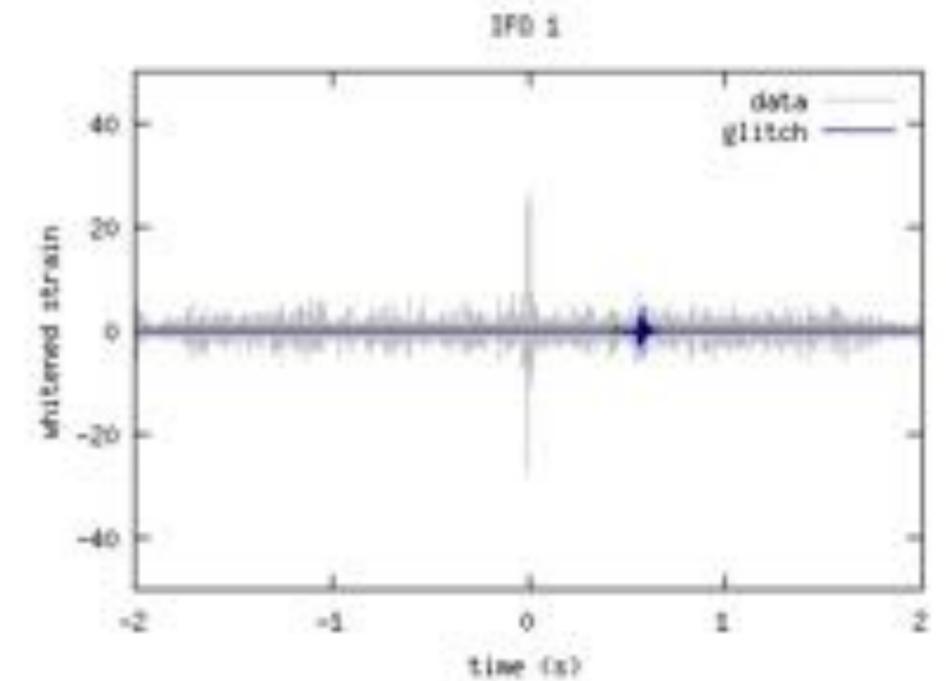
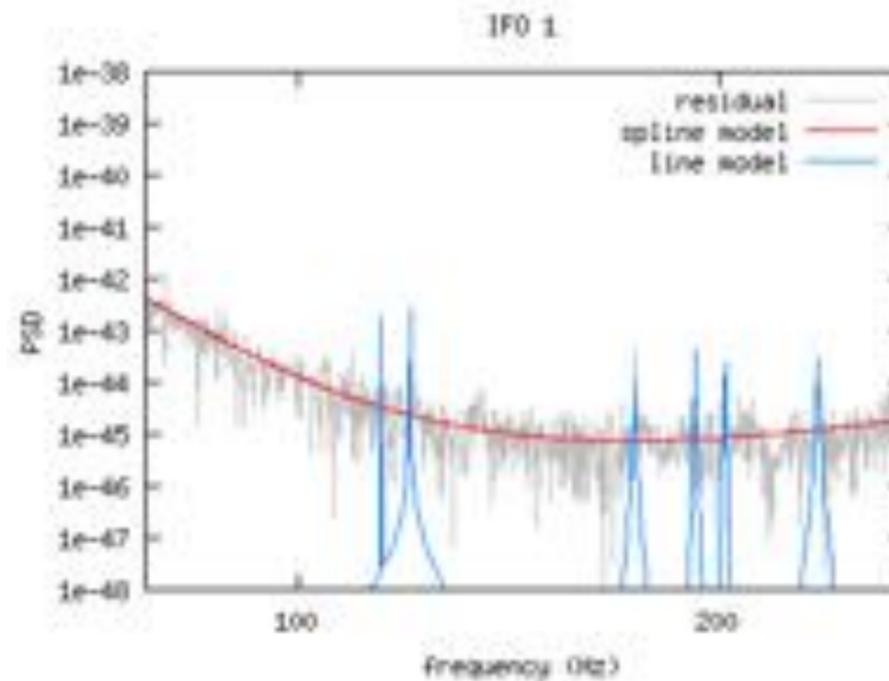
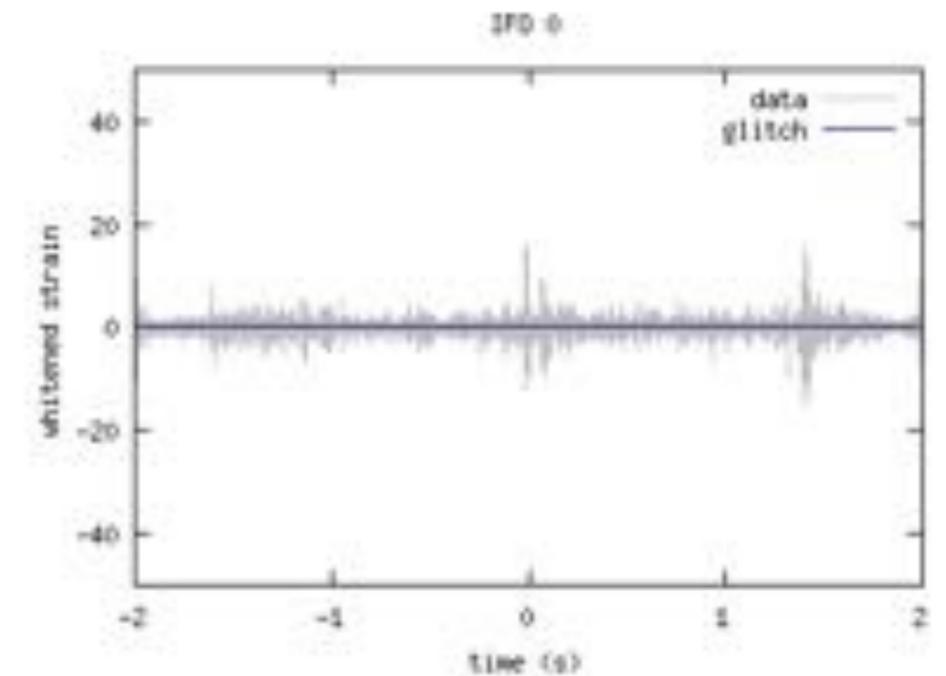
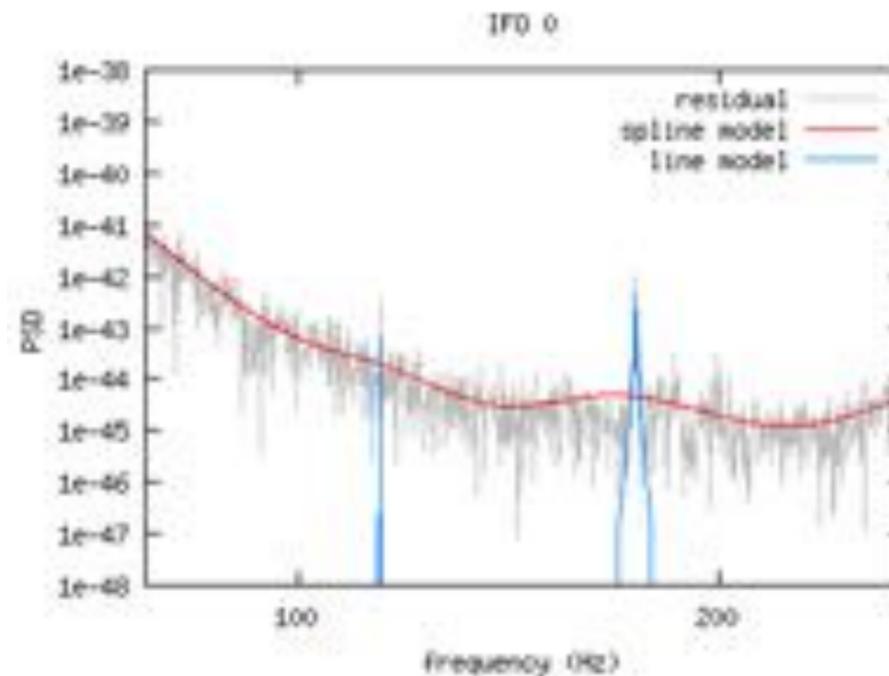
Continuous Sources



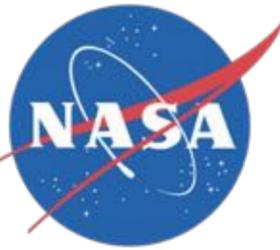
GW Instrument Noise Modeling



- GW data is typically noise-dominated
- Noise characterization as important as signal characterization
- Noise statistics are tricky—time varying, occasional transients
- Mitigate for covariances with astrophysical sources, or false alarm detections.



Gravitational Wave Data Analysis in a Nutshell

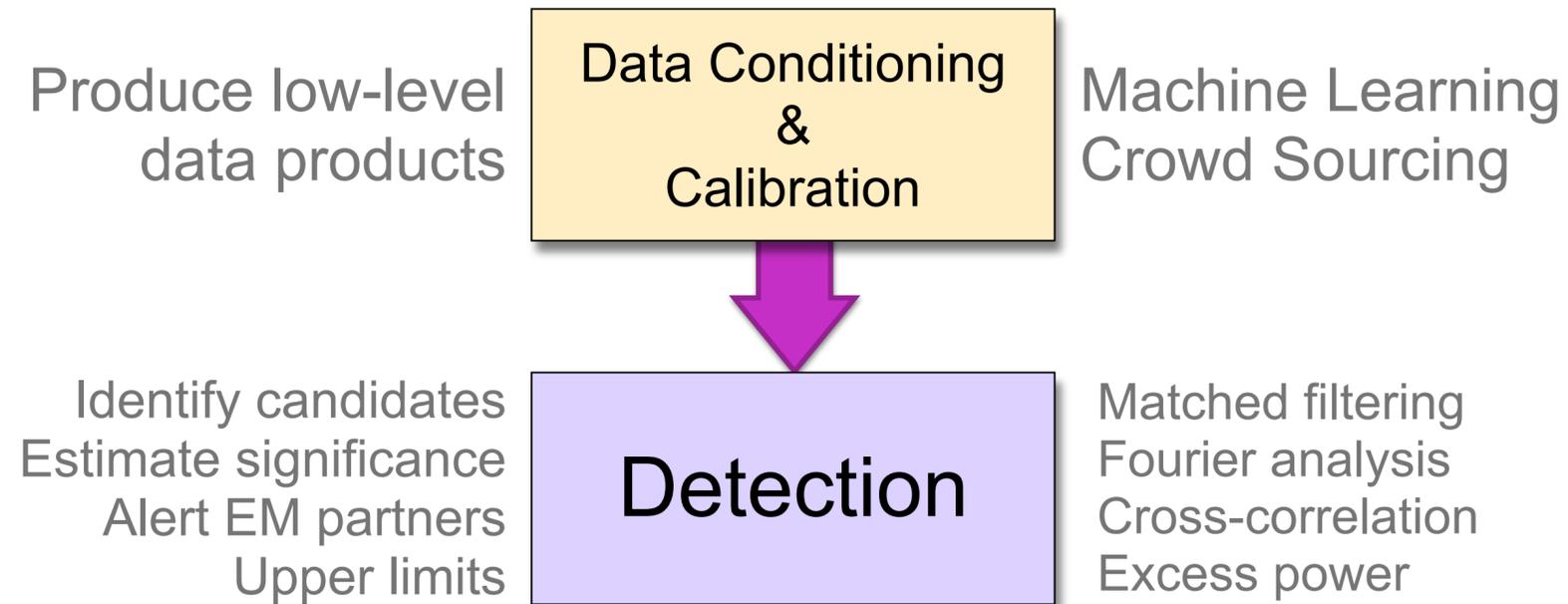


Produce low-level
data products

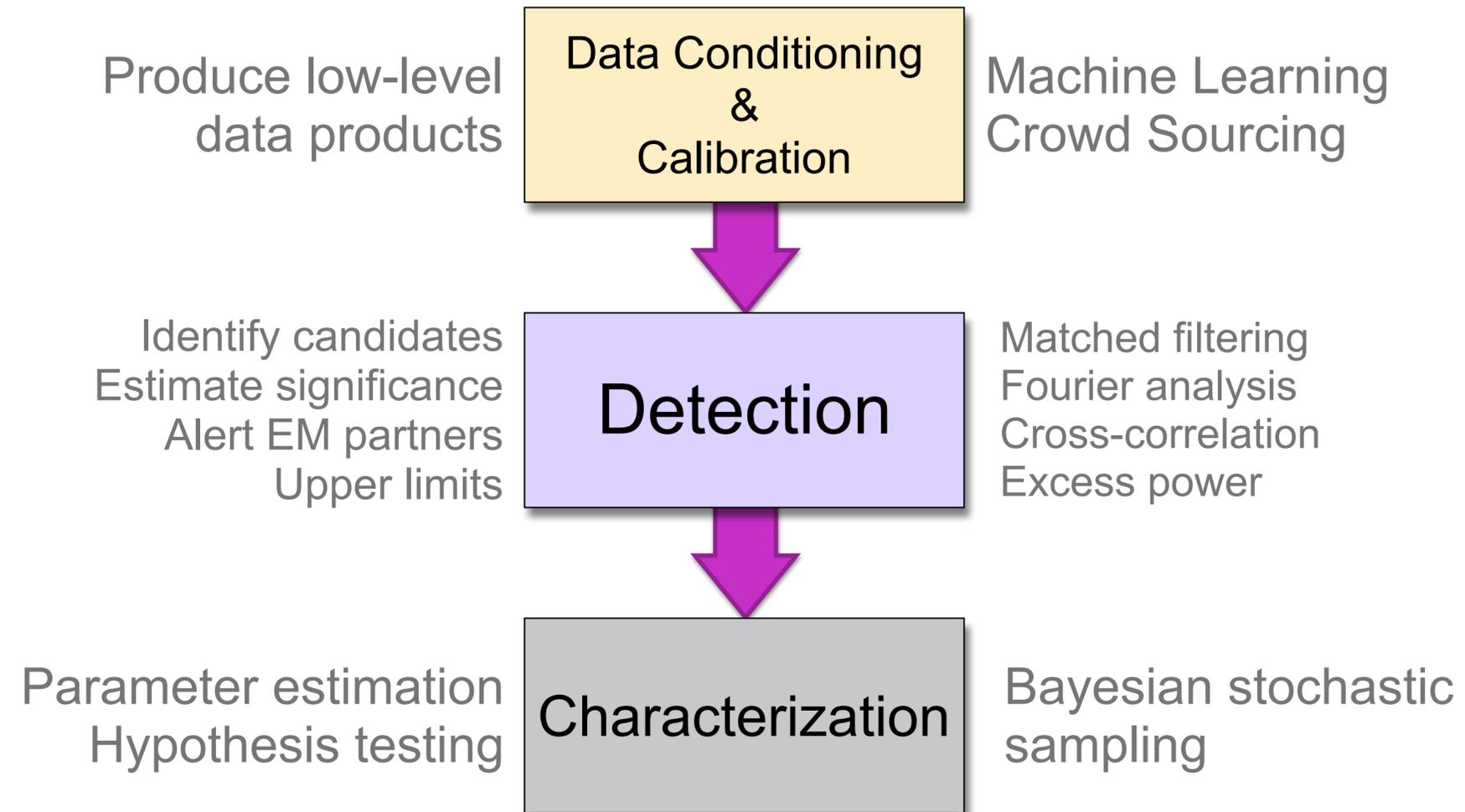
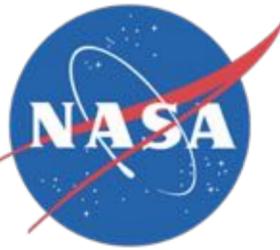
Data Conditioning
&
Calibration

Machine Learning
Crowd Sourcing

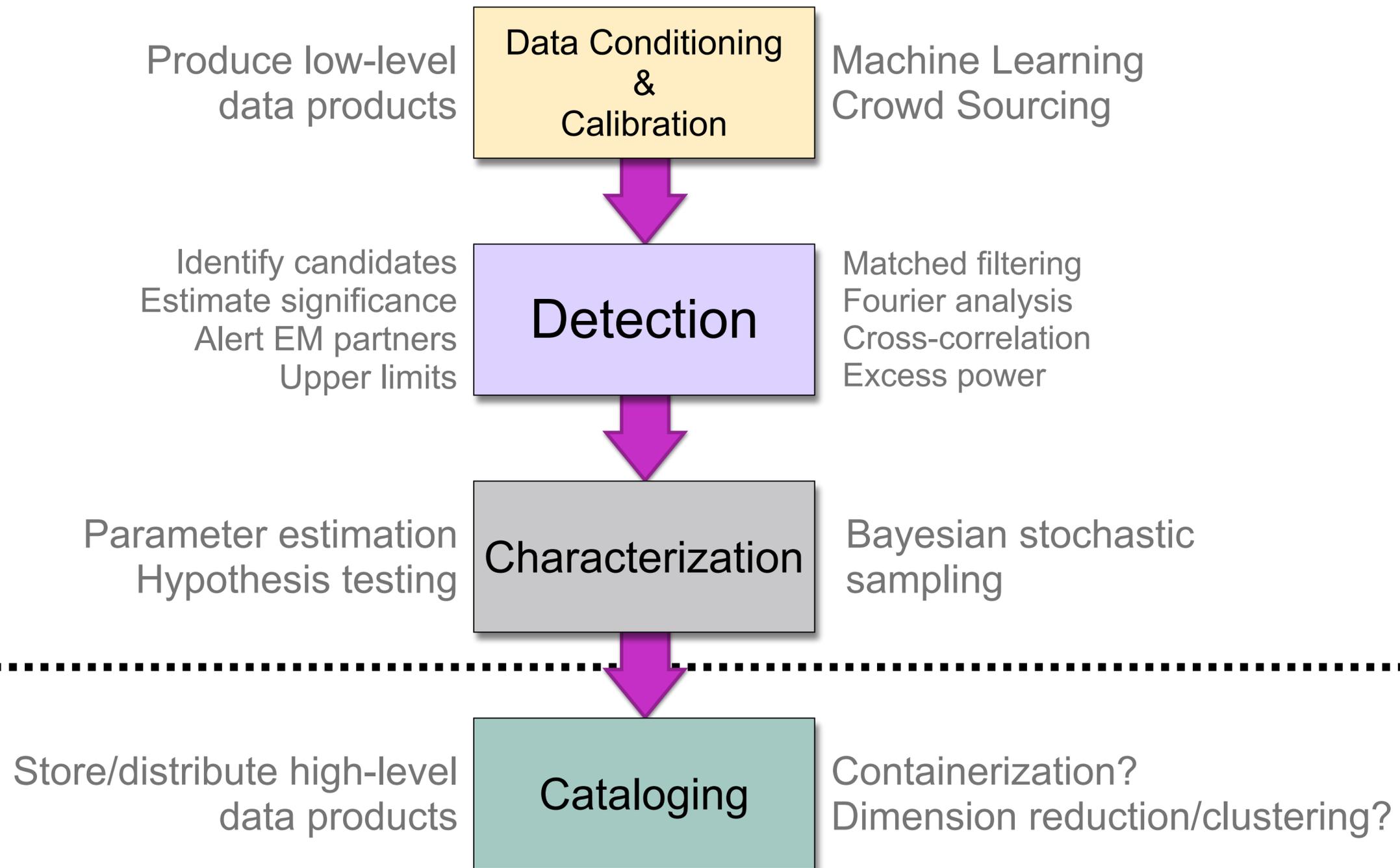
Gravitational Wave Data Analysis in a Nutshell



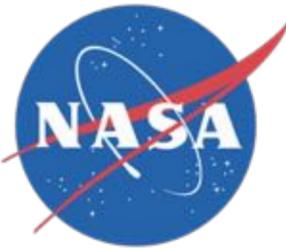
Gravitational Wave Data Analysis in a Nutshell



Gravitational Wave Data Analysis in a Nutshell



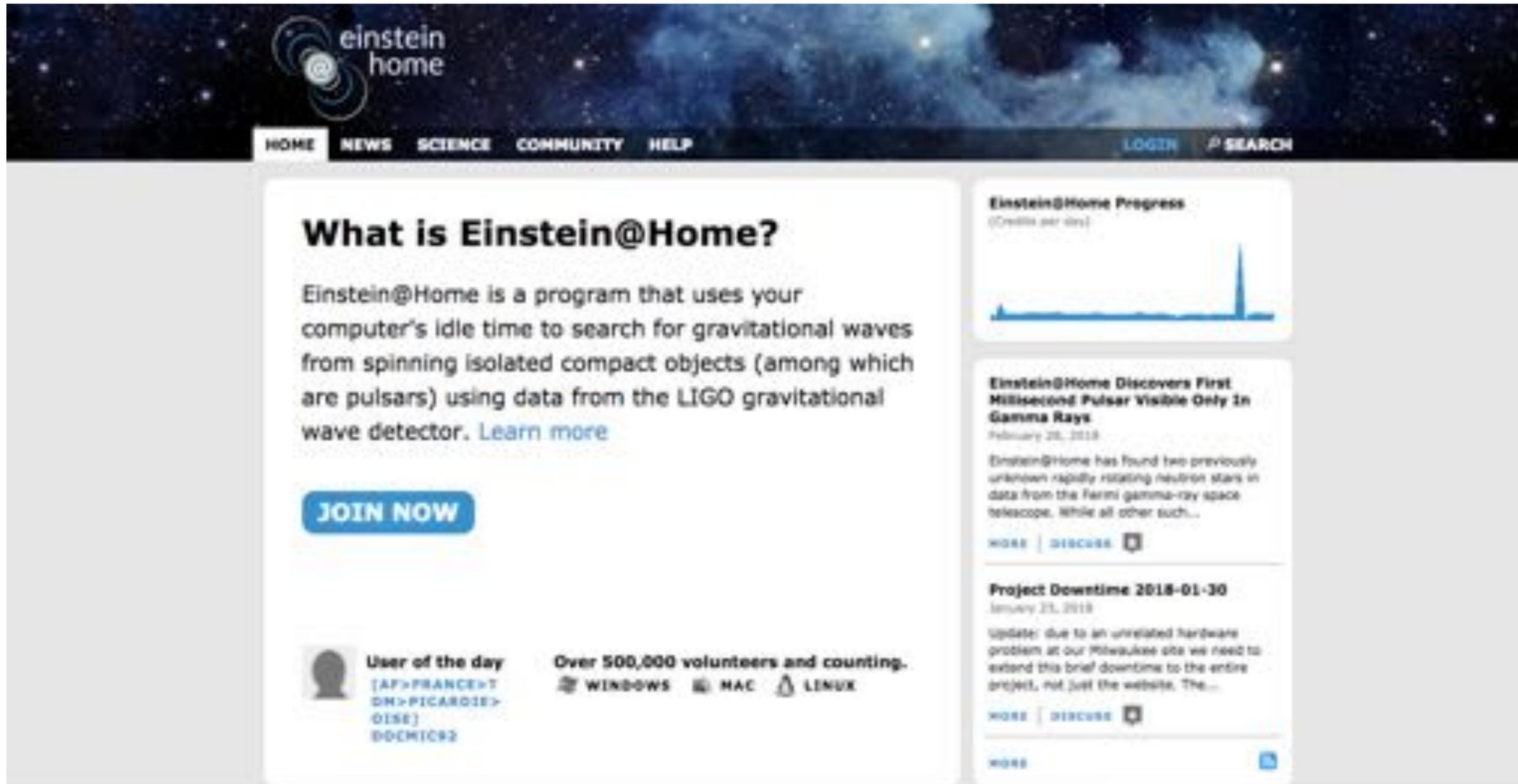
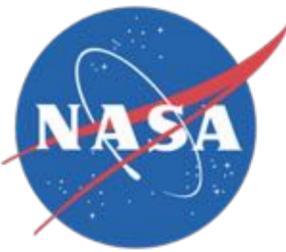
LIGO



- NSF-funded project
- Both LSU and MSFC are members of the LIGO Scientific Collaboration
- NASA involvement primarily through multi messenger follow-up (c.f. Fermi-GBM)
- Active areas of cross-cutting data science include:
 - Joint multi-messenger analyses (MSFC-led)
 - improving latency and communication w/ observing partners (GSFC-led)



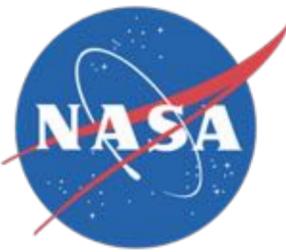
Einstein@Home



The screenshot shows the Einstein@Home website homepage. At the top, there is a navigation bar with links for HOME, NEWS, SCIENCE, COMMUNITY, and HELP, along with LOGIN and SEARCH options. The main content area is divided into several sections:

- What is Einstein@Home?**: A section explaining the program's purpose: "Einstein@Home is a program that uses your computer's idle time to search for gravitational waves from spinning isolated compact objects (among which are pulsars) using data from the LIGO gravitational wave detector." It includes a "JOIN NOW" button and a "Learn more" link.
- Einstein@Home Progress**: A section with a line graph showing "Credits per day" over time.
- Einstein@Home Discovers First Millisecond Pulsar Visible Only in Gamma Rays**: A news article dated February 28, 2018, mentioning the discovery of two previously unknown rapidly rotating neutron stars.
- Project Downtime 2018-01-30**: A notice dated January 23, 2018, regarding a hardware problem at the Milwaukee site that caused a project-wide downtime.
- User of the day**: A section highlighting a user named [AF>FRANCE>T DM>PICARDE>OISE] BOCHIC92.
- Over 500,000 volunteers and counting.**: A section with icons for operating systems: WINDOWS, MAC, and LINUX.

Gravity Spy



PROJECTS ABOUT GET INVOLVED TALK BUILD A PROJECT NEWS NOTIFICATIONS WELCOME TUTORIAL

Gravity Spy

ABOUT CLASSIFY TALK COLLECT RECENTS

Sign up for more ways to contribute to LIGO science! Check out [@gravityspy](#), where your computer's idle time is used to help search for gravitational waves in LIGO data. You can even join this program while classifying glitches in Gravity Spy!

Hanford - O2a

Frequency (Hz)

Time (s)

Normalized energy

Location	Frequency	Looking
1000 Line	Light Modulation	Repeating Ring
1400 Room	Low Frequency Bump	Scattered Light
Air Compressor (AC)	Low Frequency Cline	Scintillation
Big	None of the Above	Ticks
Chop	No Glitch	Video Work Harmonic
Extremely Loud	Power Down	Wandering Line
Halls	Power Line 60 Hz	Whistle
No Data		

Showing 10 of 141

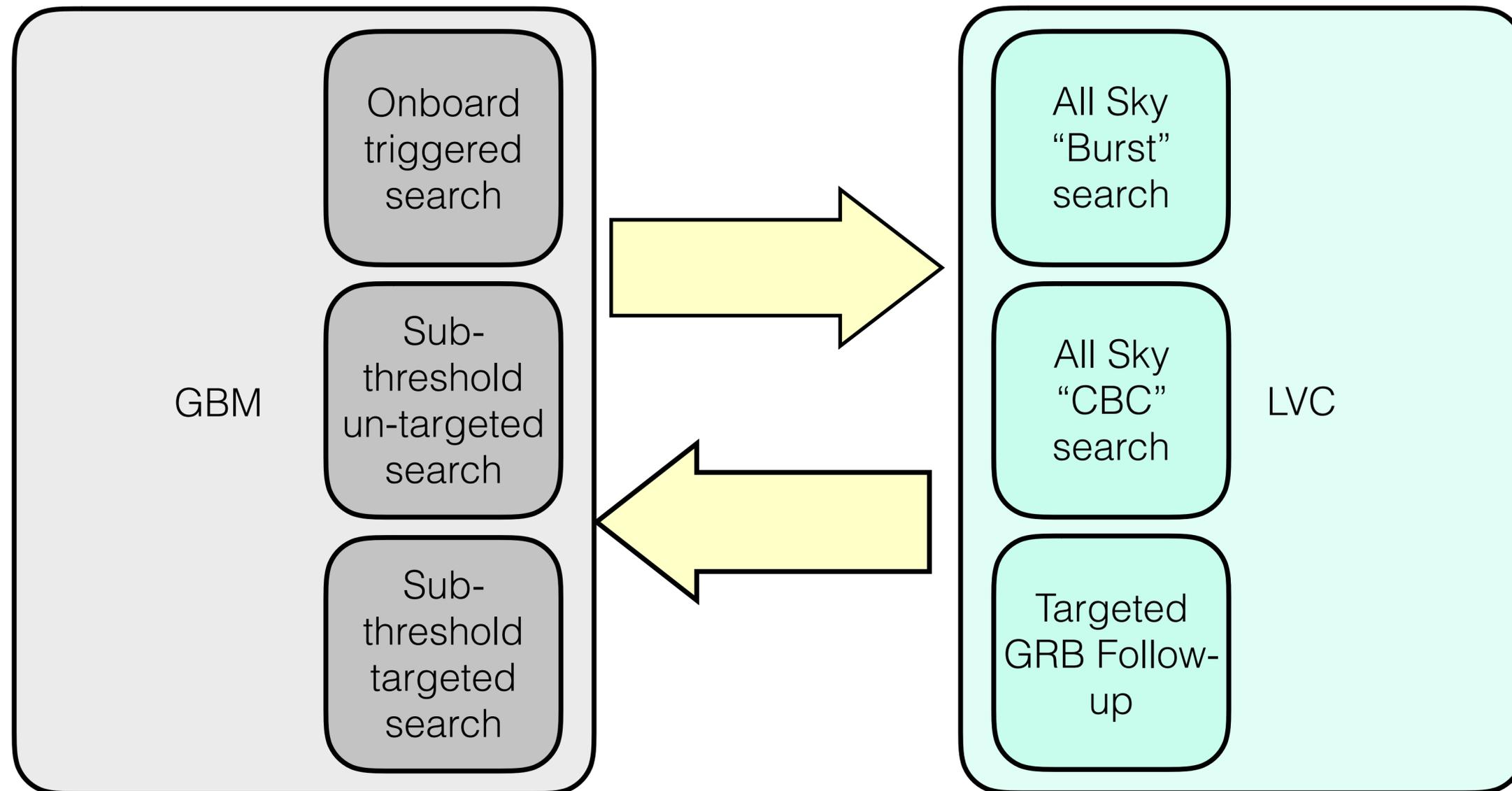
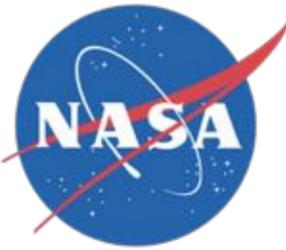
Classify This Glitch

Show the project tutorial

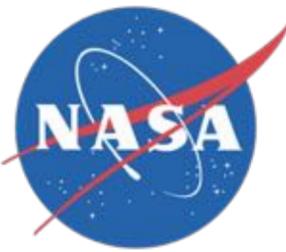
Restart the project introduction

SWITCH TO LIGHT THEME

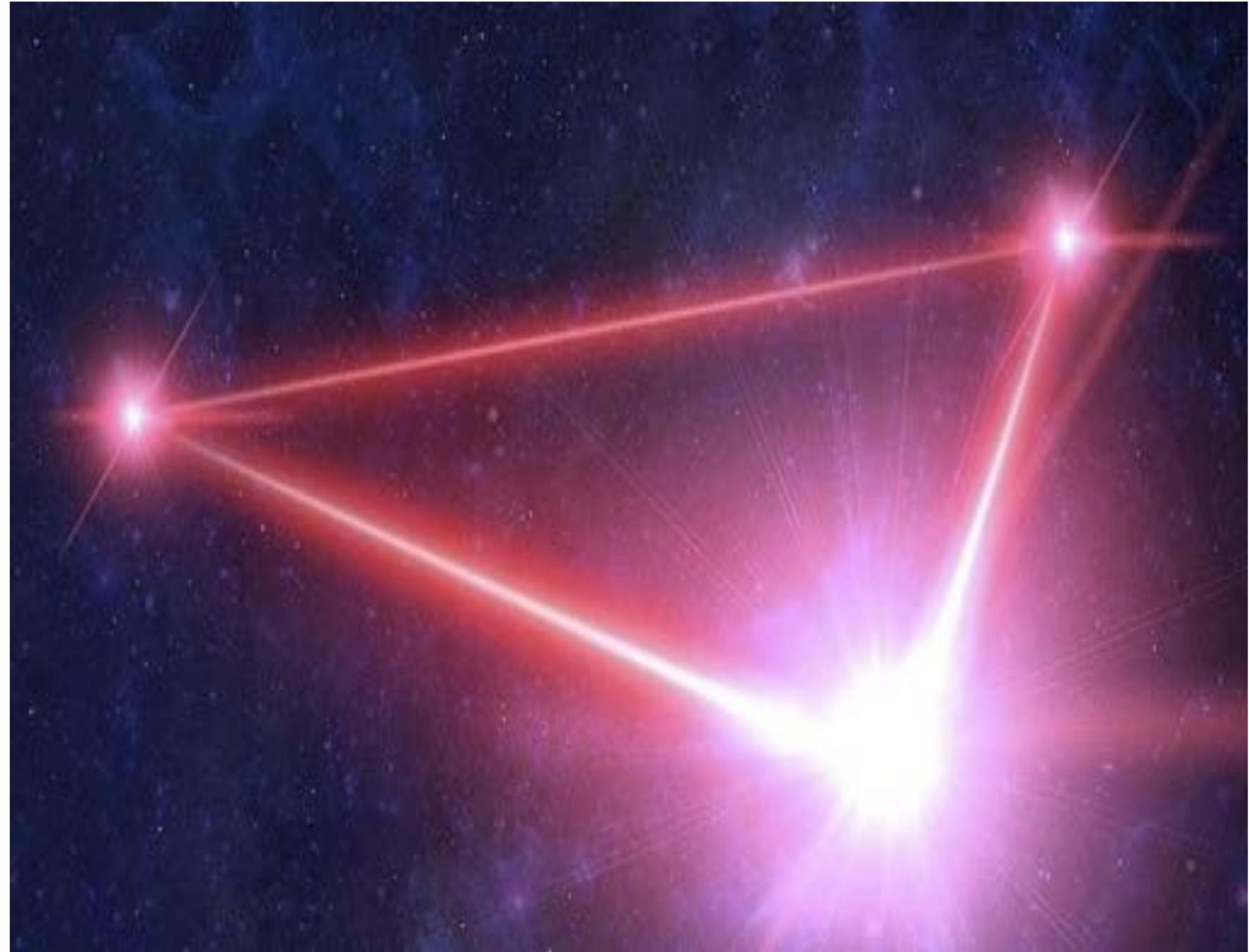
Joint GW+Gamma-ray Analyses



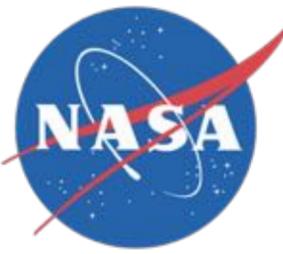
LISA



- ESA-led mission selected for launch in early 2030s, Entering Phase-A in Europe this spring.
- NASA contribution under study lead by GSFC, supported by MSFC and others
- Data Science among technology contributions from NASA being studied

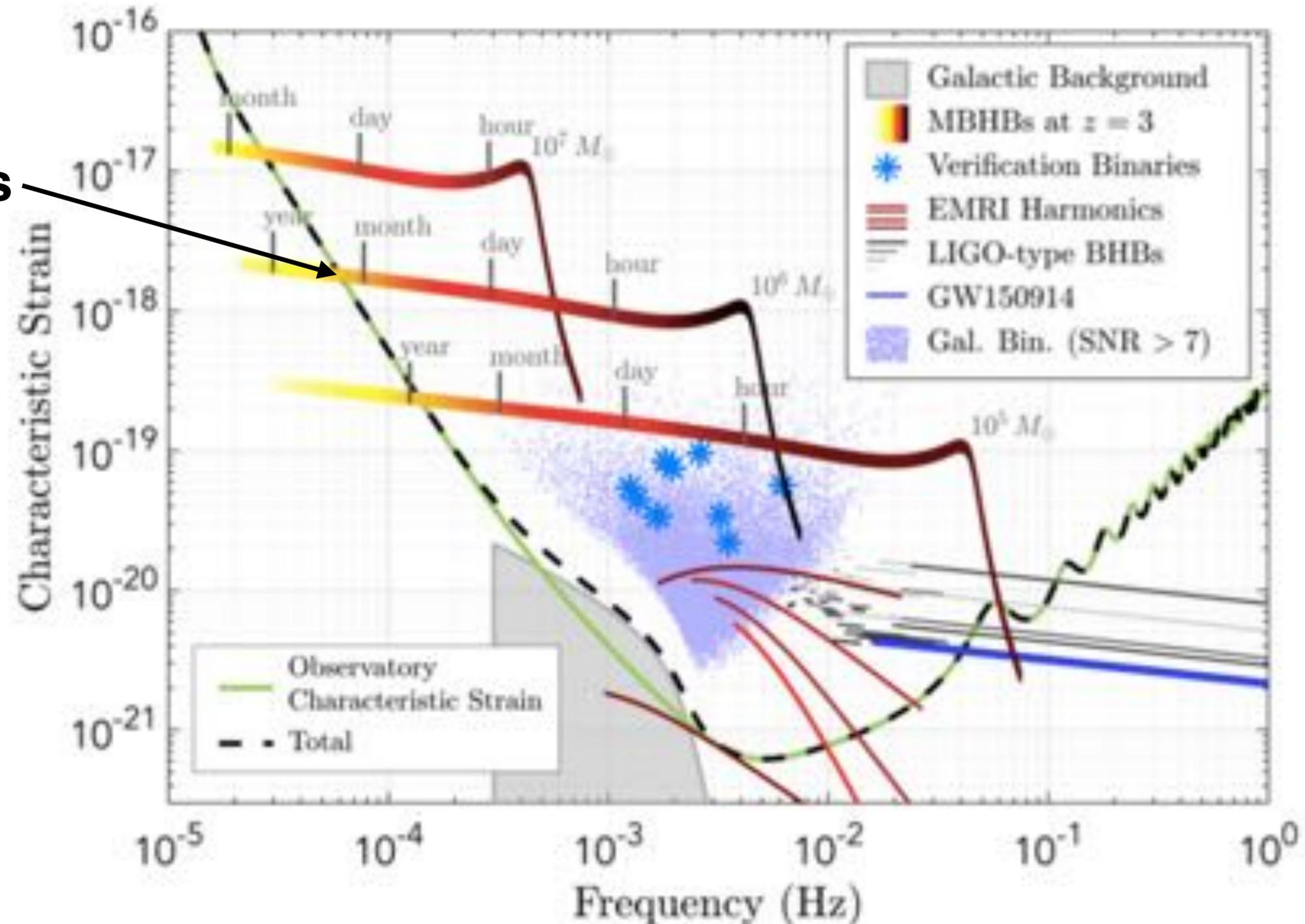


LISA Sources

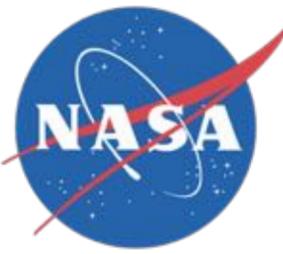


Supermassive black-hole mergers

- long-lived transient sources
- need real-time updates of source properties to coordinate multi messenger observing
- very strong signals—important to control systematic errors from data models.

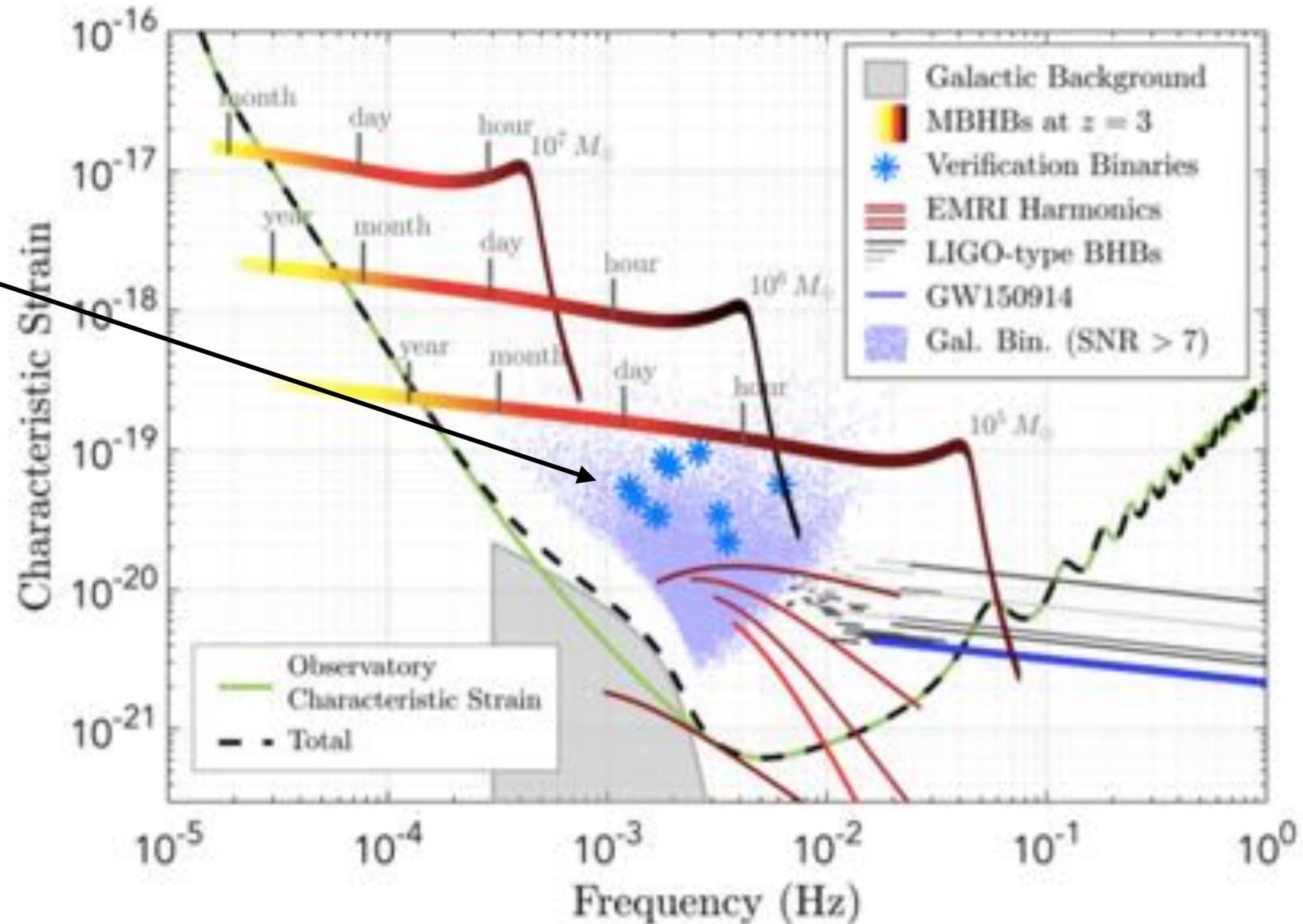


LISA Sources

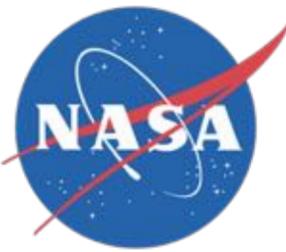


White-dwarf binaries

- continuous, slowly evolving signals
- 10s of millions(!) in band, 10s of thousands resolvable, 10s of known sources from EM observations
- very complicated catalog!

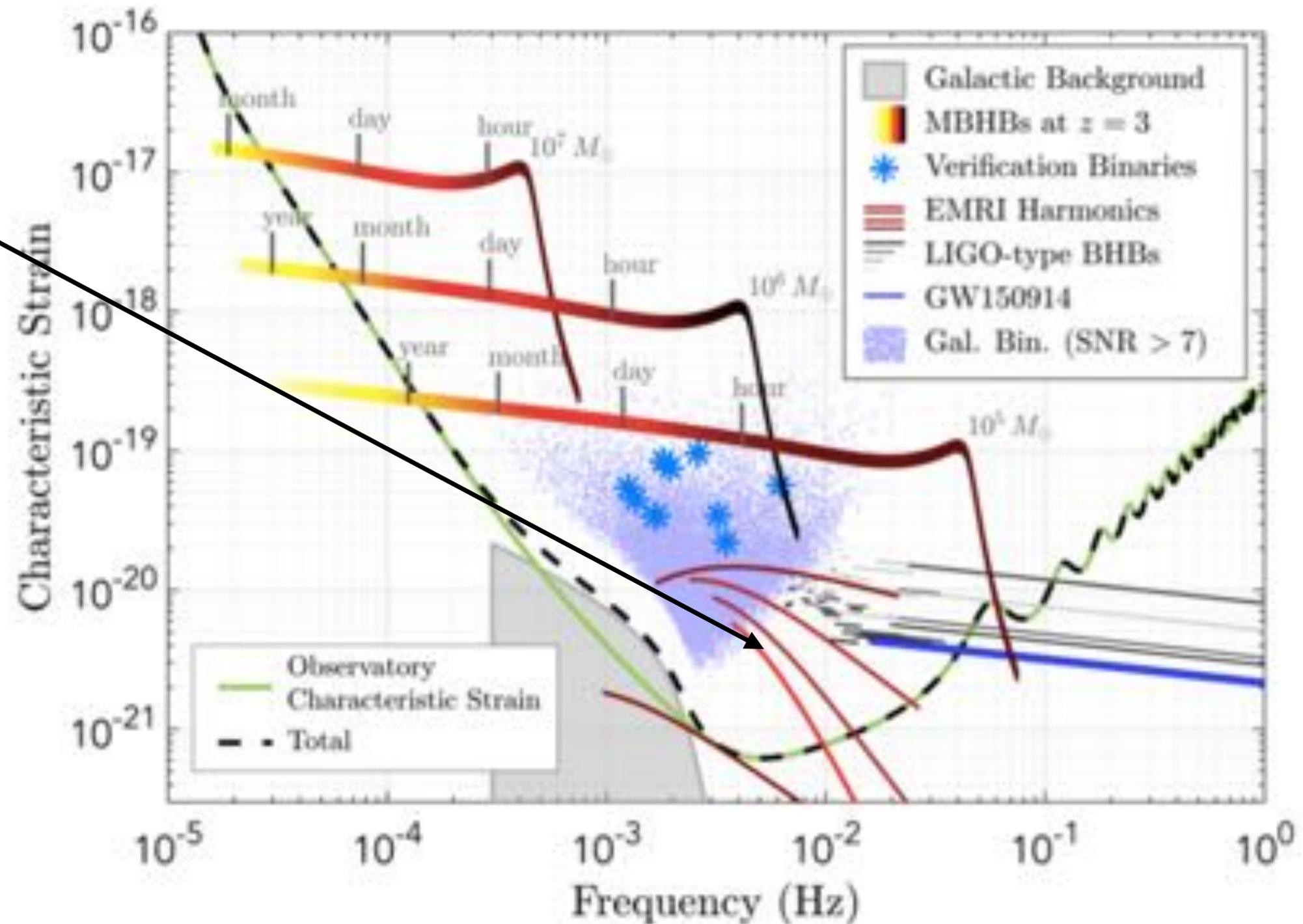


LISA Sources

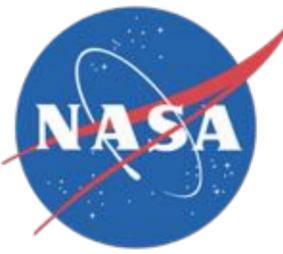


Extreme mass ratio in-spirals

- Long-lived transients
- Small black hole falling into big black hole
- Challenging to model.
- Narrow, multimodal, likelihood surfaces.
- Exquisite tests of relativity

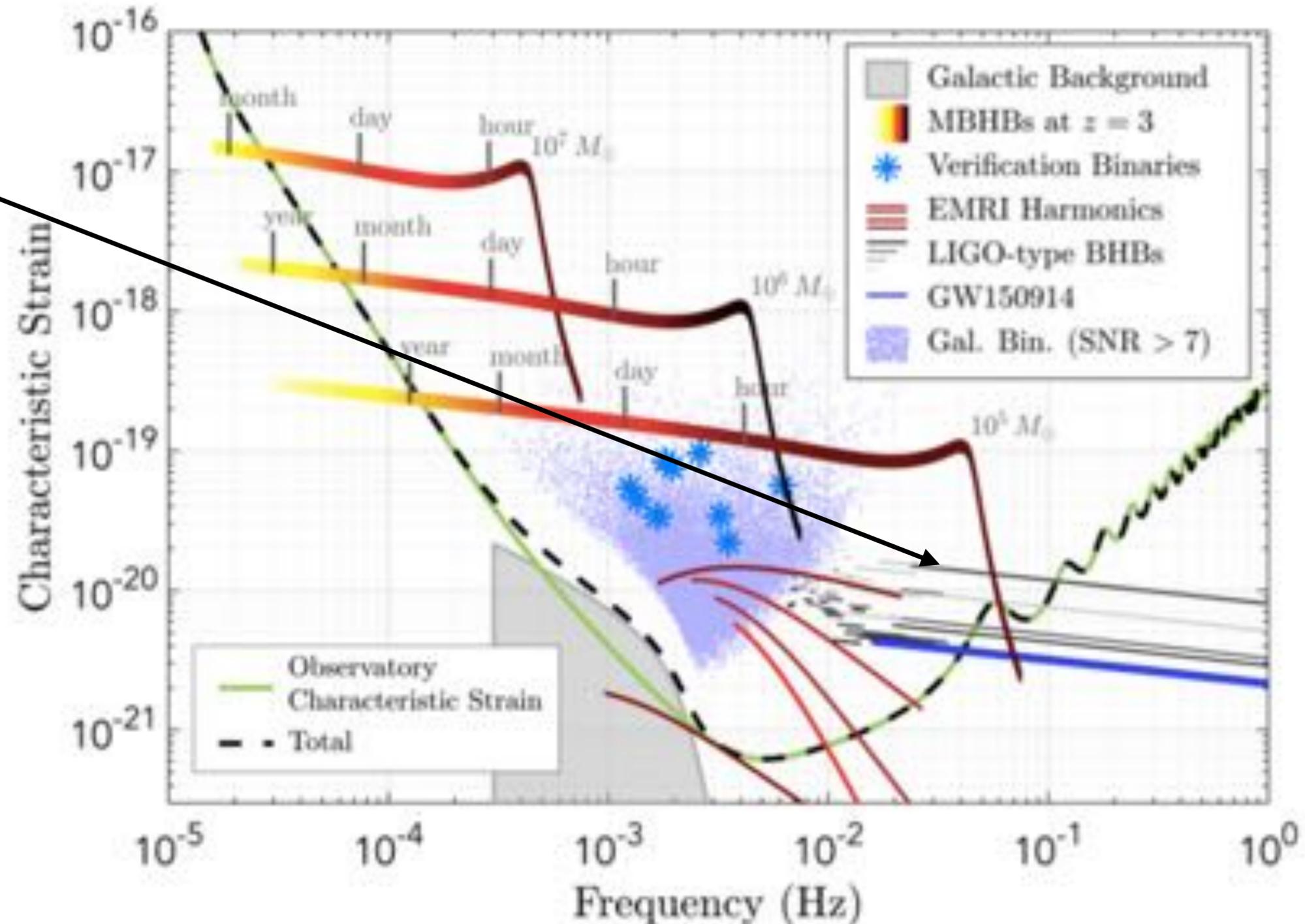


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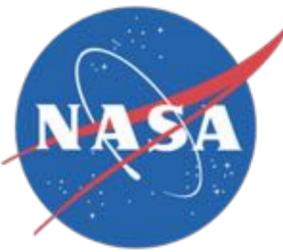


Stellar-origin binary black holes

- Continuous or long-lived transients
- New astrophysical sources, discovered by LIGO
- Possible for multi-band observations with ground-based GW observatories

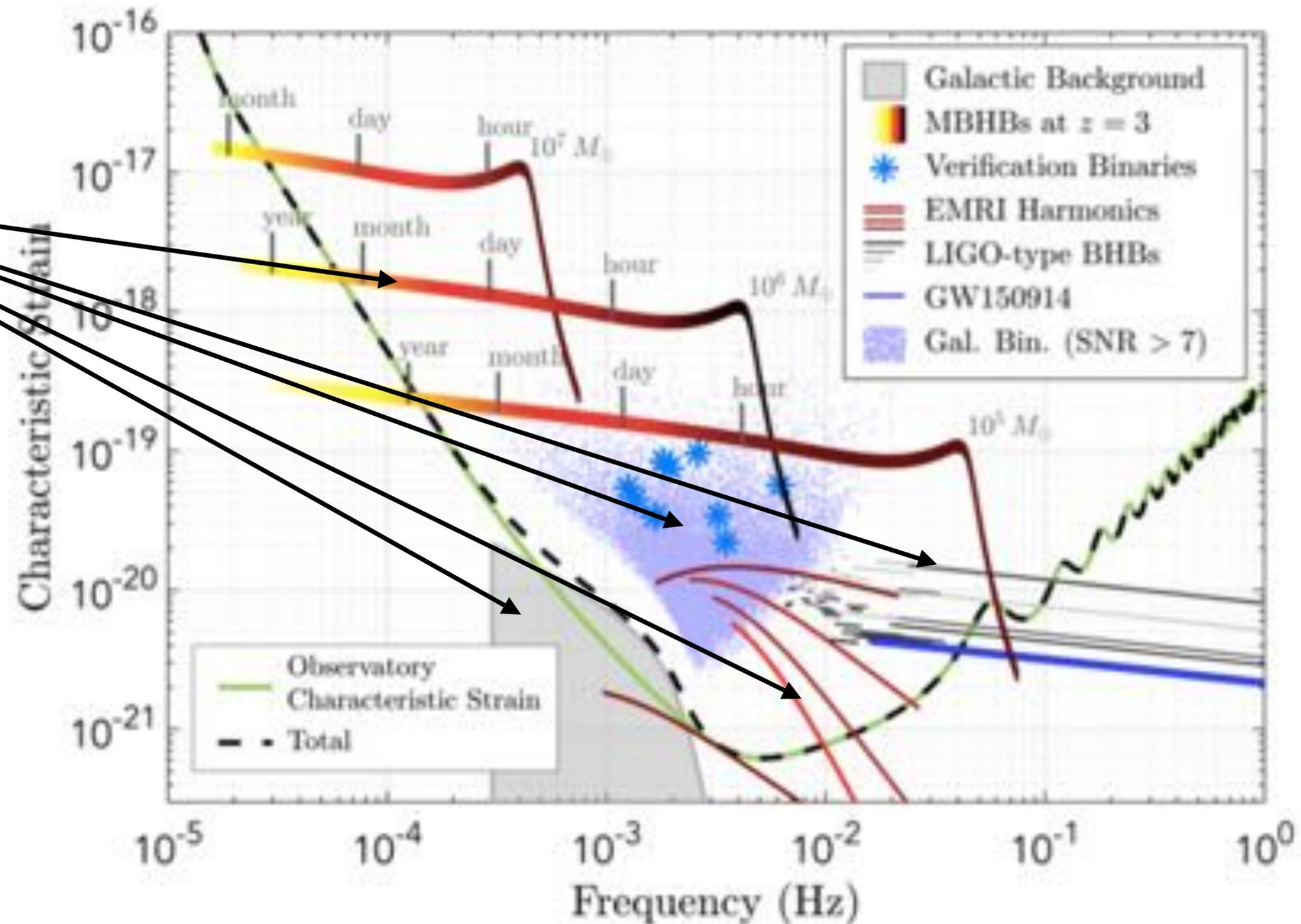


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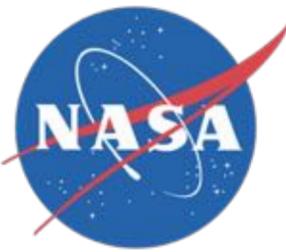


The Global Fit Problem

- 100,000+ parameter model with non-trivial covariances
- High-performance & high-throughput computing
- Challenge to take output of global fit and synthesize high-level data products for Astro community



LISA Science & Analysis Activities



- Waveform modeling
- Data analysis tools
- Instrument response modeling
- Low-latency pipelines*
- Individual & global source identification
- Source catalogs
- Multi-messenger analysis and operations strategies
- Astrophysical interpretation

Laser Interferometer Space Antenna		REF ID: A15151605-WP0-001	
Page: 1	Revision: 1	Date: 2018/01/18	Page: 1 / 17

LISA Data Analysis Work Packages

N/Ref:	LISA-LCST-SCS-WP0-001
Title:	LISA Data Analysis Work Packages
Abstract:	LISA DPC Definition and main contributions

	Name	Date	Signature
Prepared by:	LISA WP writing team	2018/01/18	
Checked by:			
Checked by (QA):			
Approved by:			

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