

Data Science Challenges in Gravitational Wave Astronomy

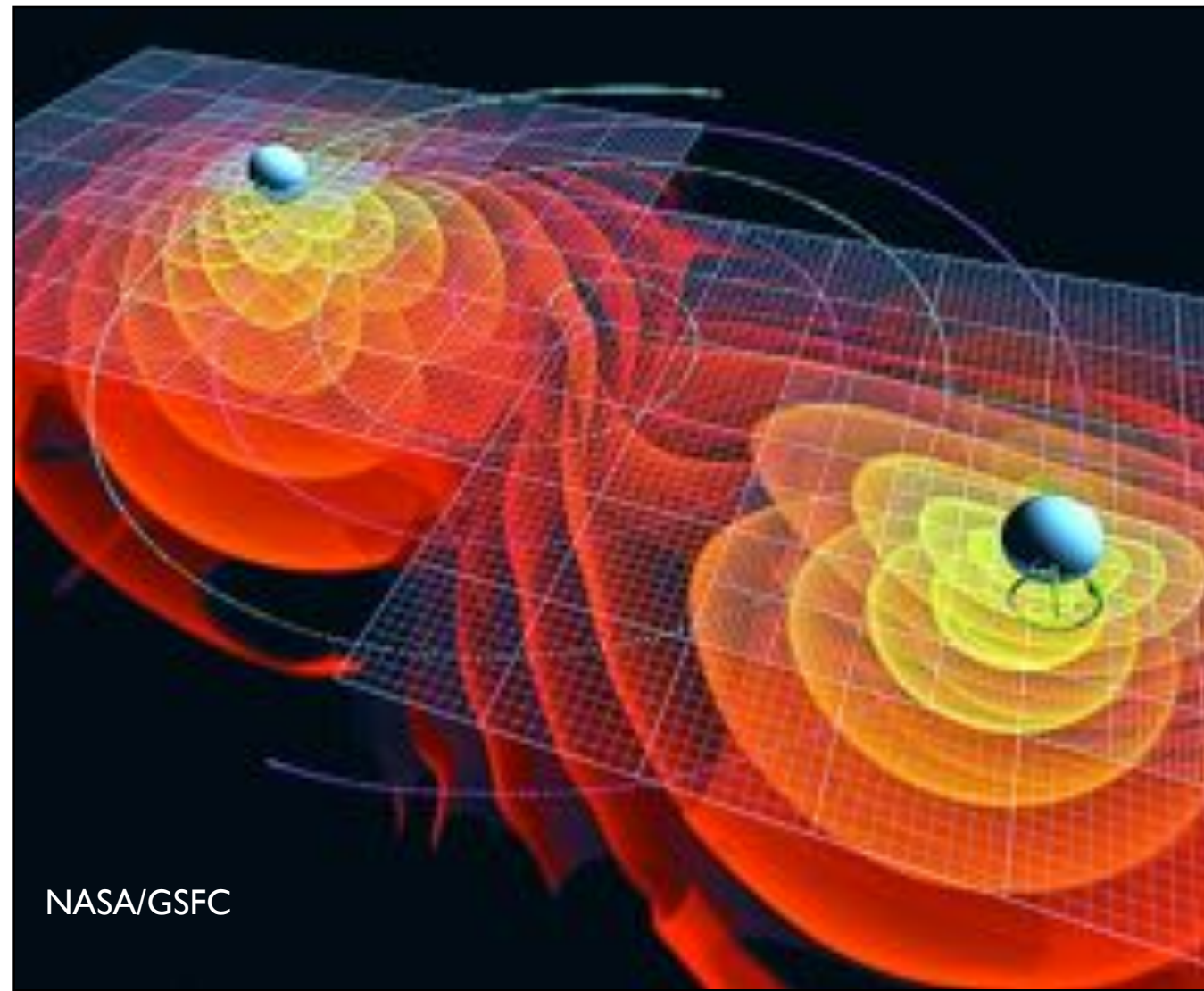
Tyson Littenberg (NASA/MSFC)



Gravitational Wave Sources



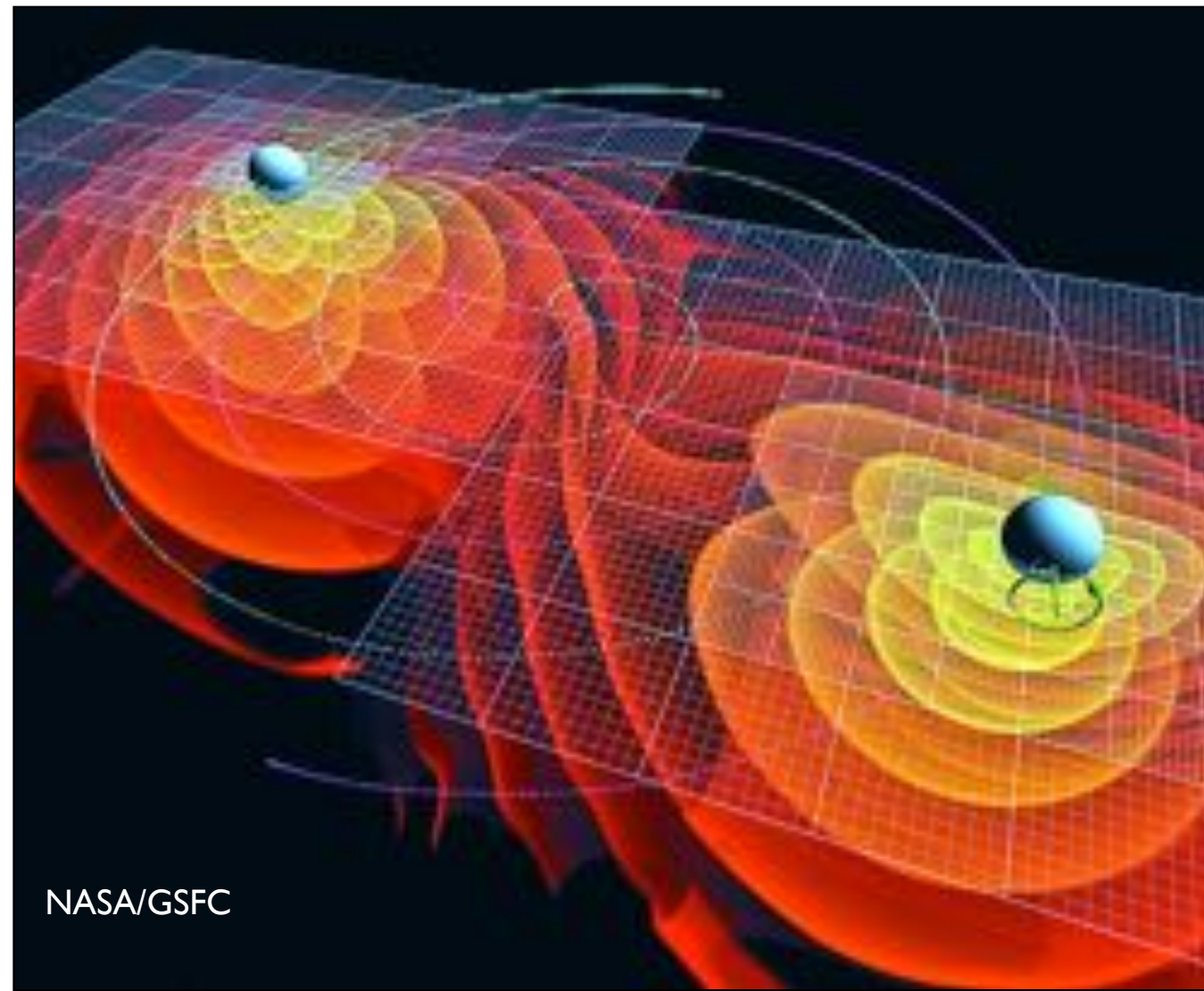
Modeled Transient Sources



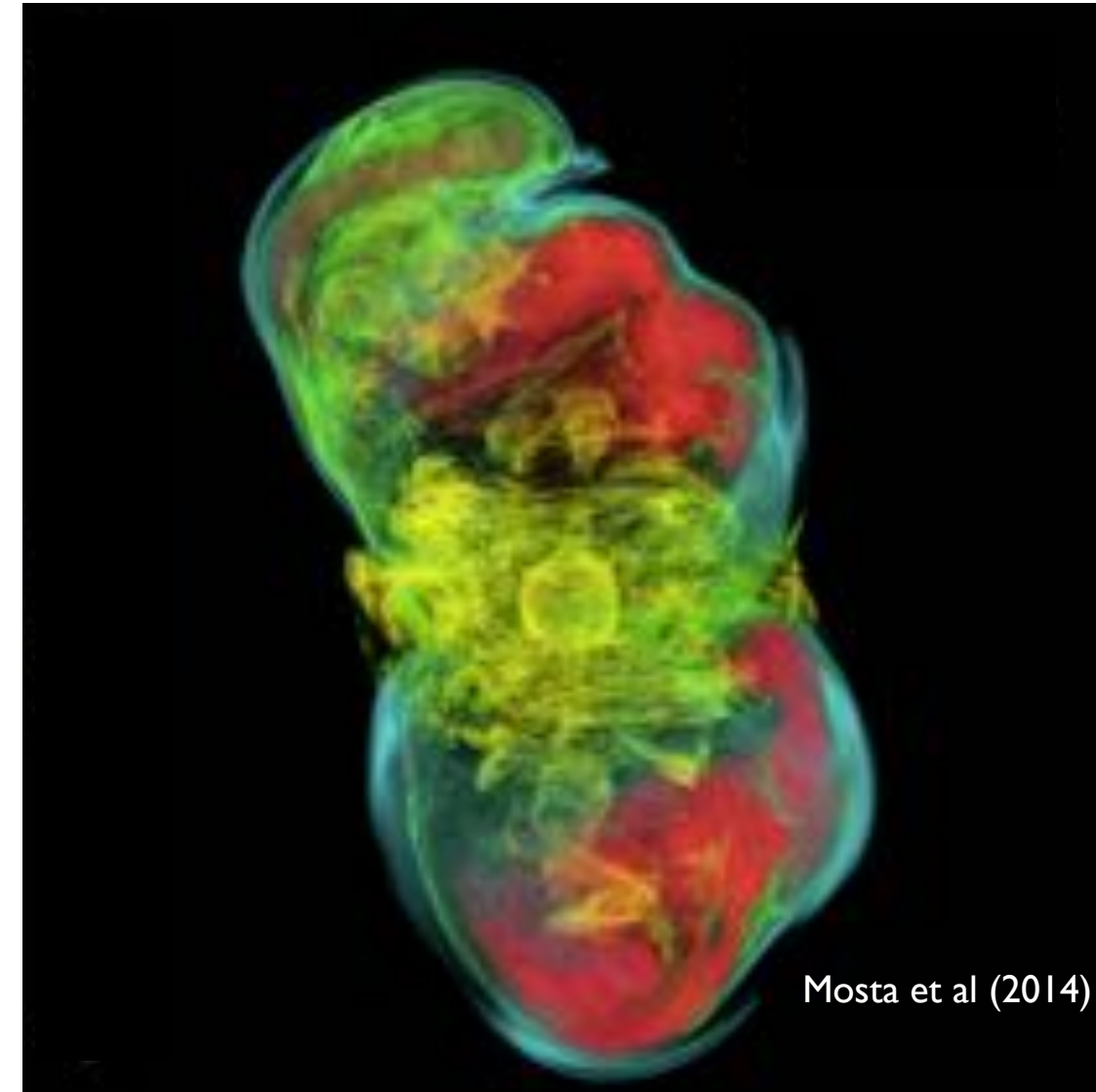
Gravitational Wave Sources



Modeled Transient Sources



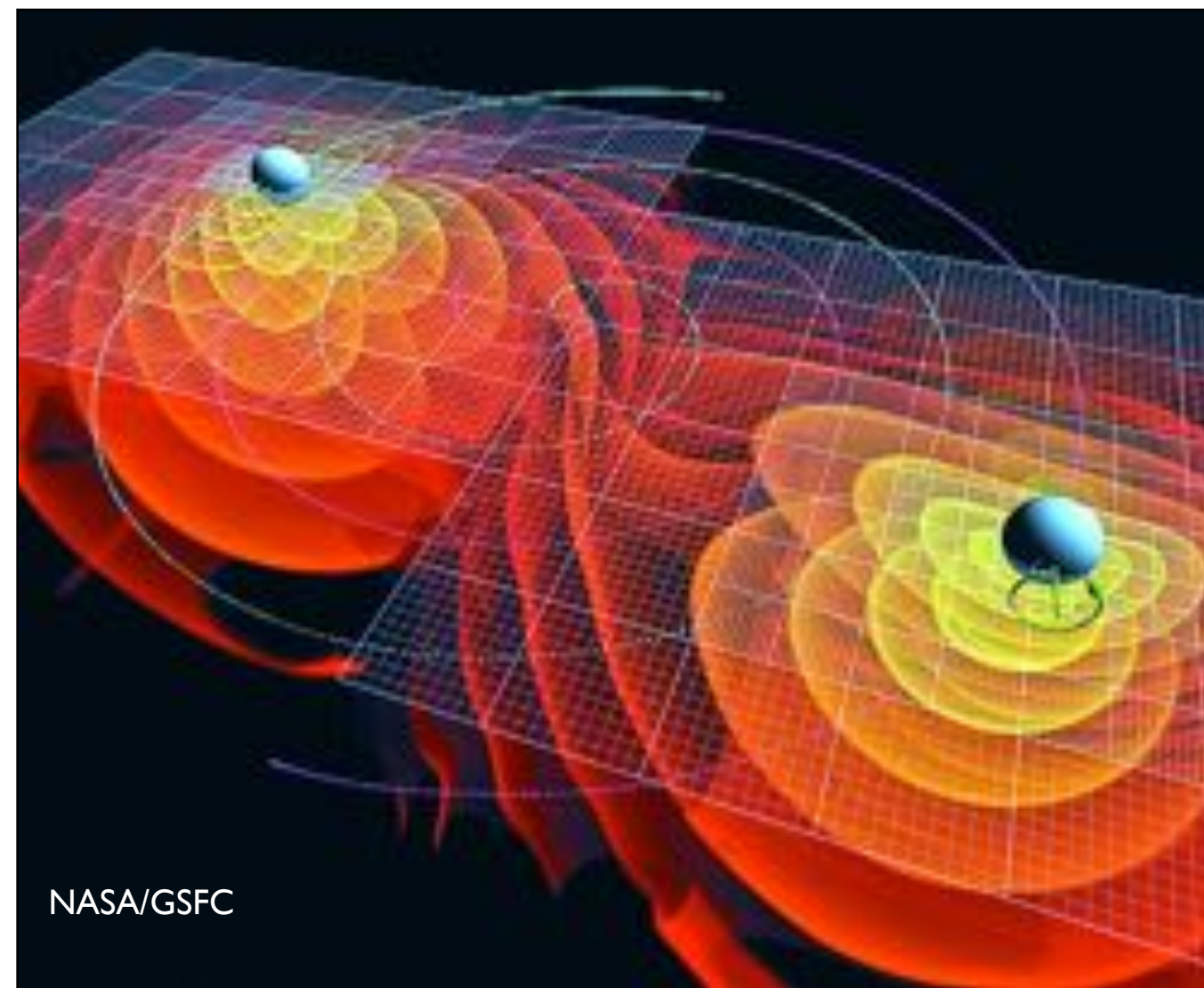
Un-modeled Transient Sources



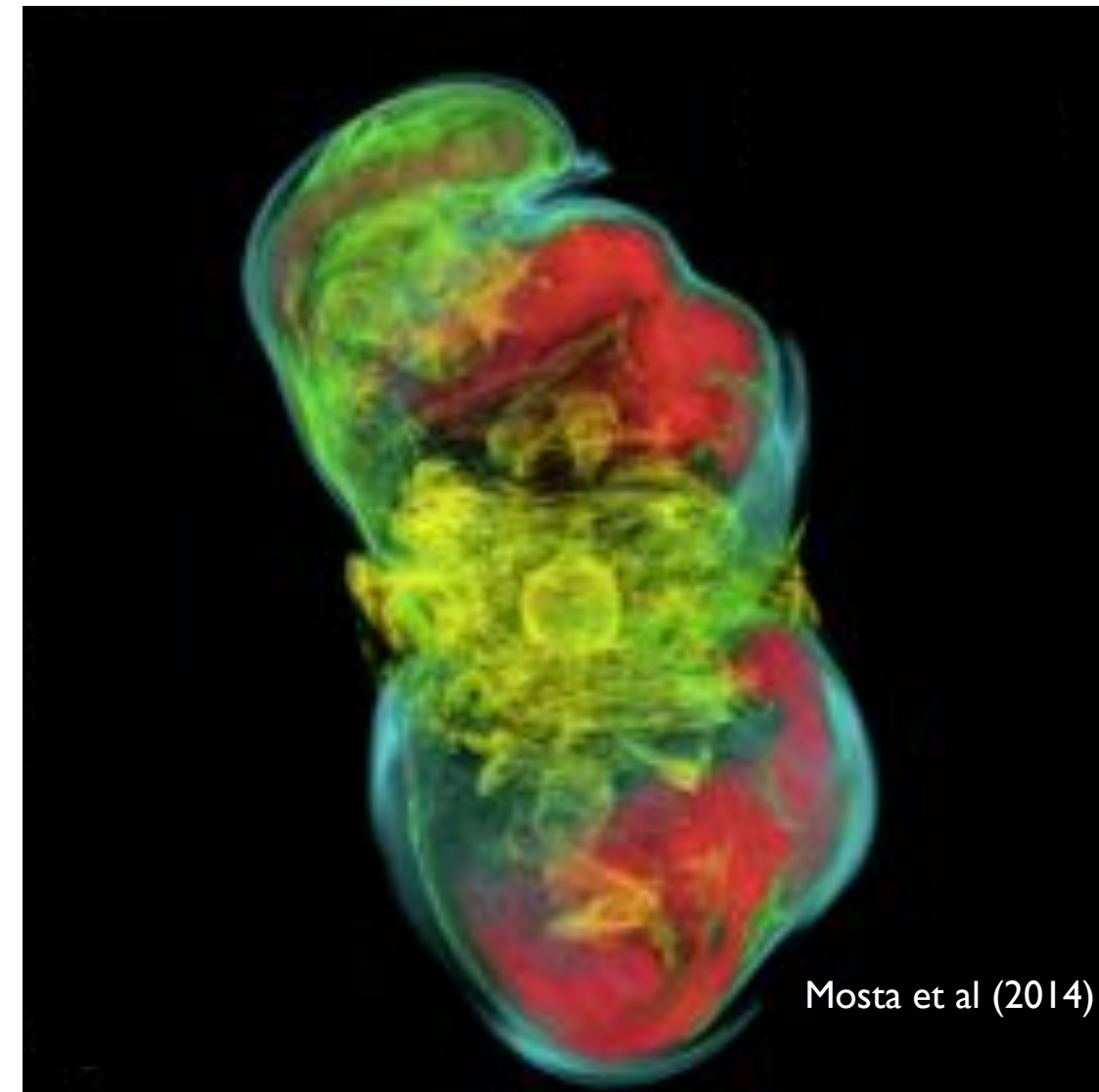
Gravitational Wave Sources



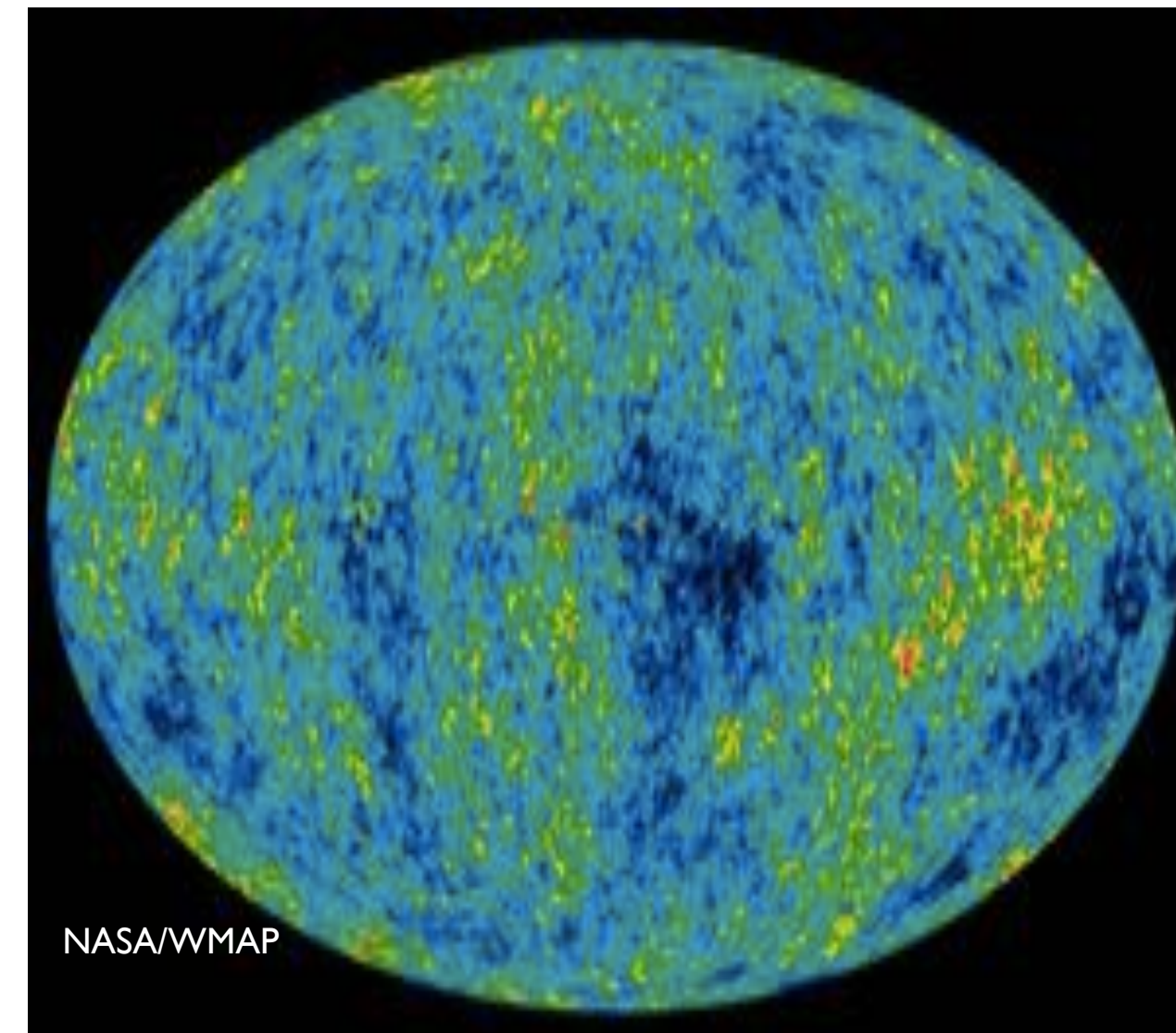
Modeled Transient Sources



Un-modeled Transient Sources



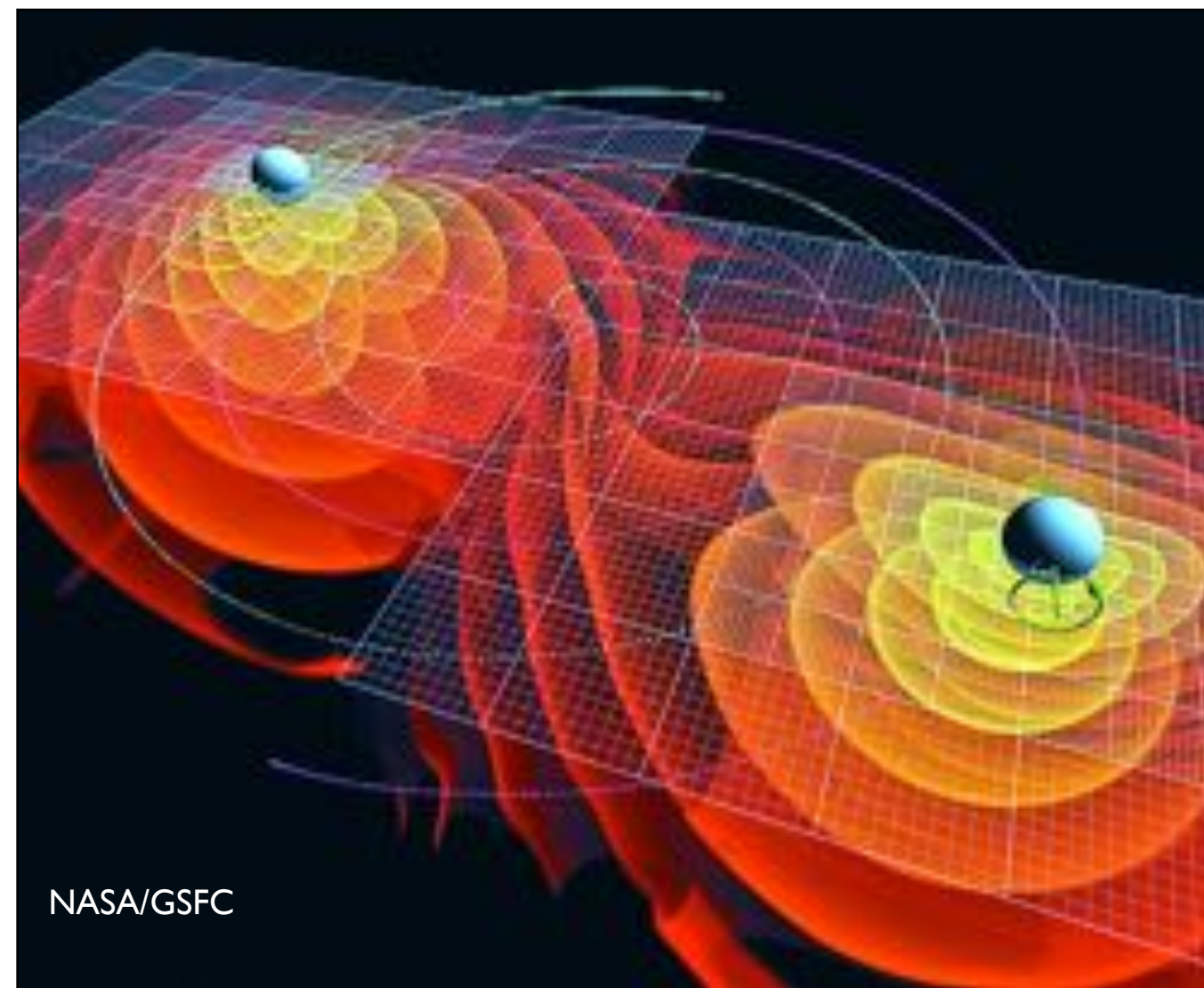
Stochastic Backgrounds



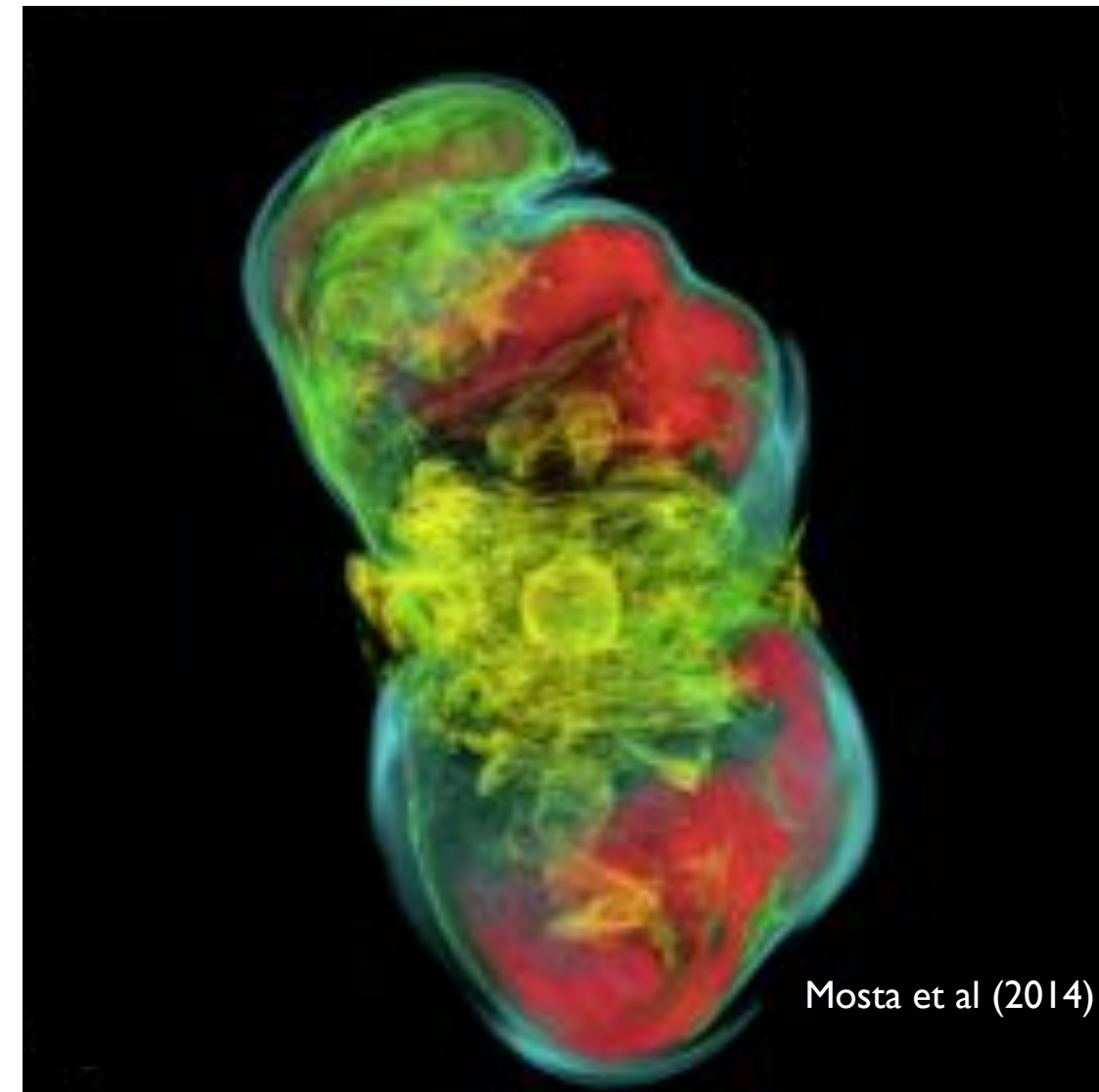
Gravitational Wave Sources



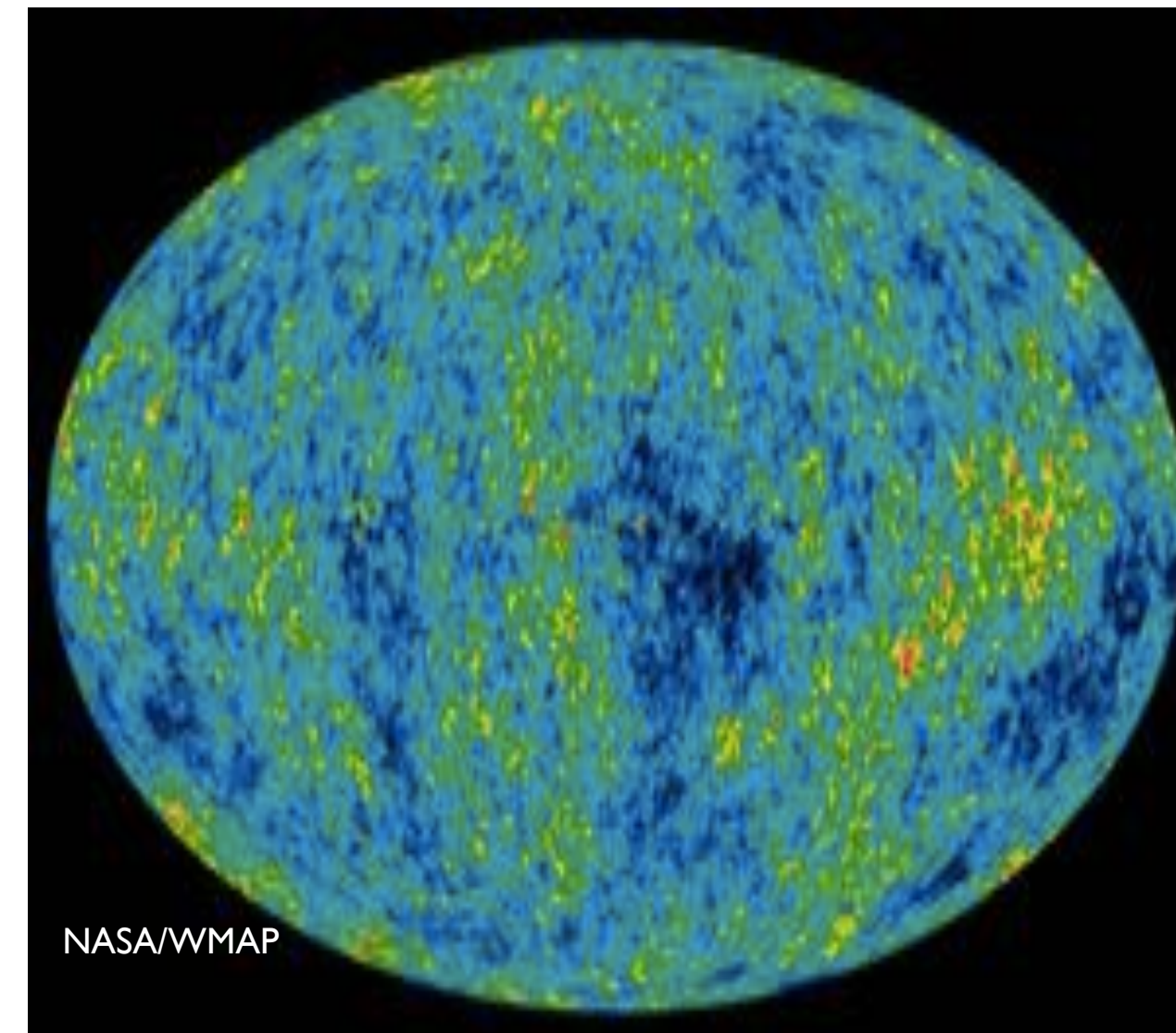
Modeled Transient Sources



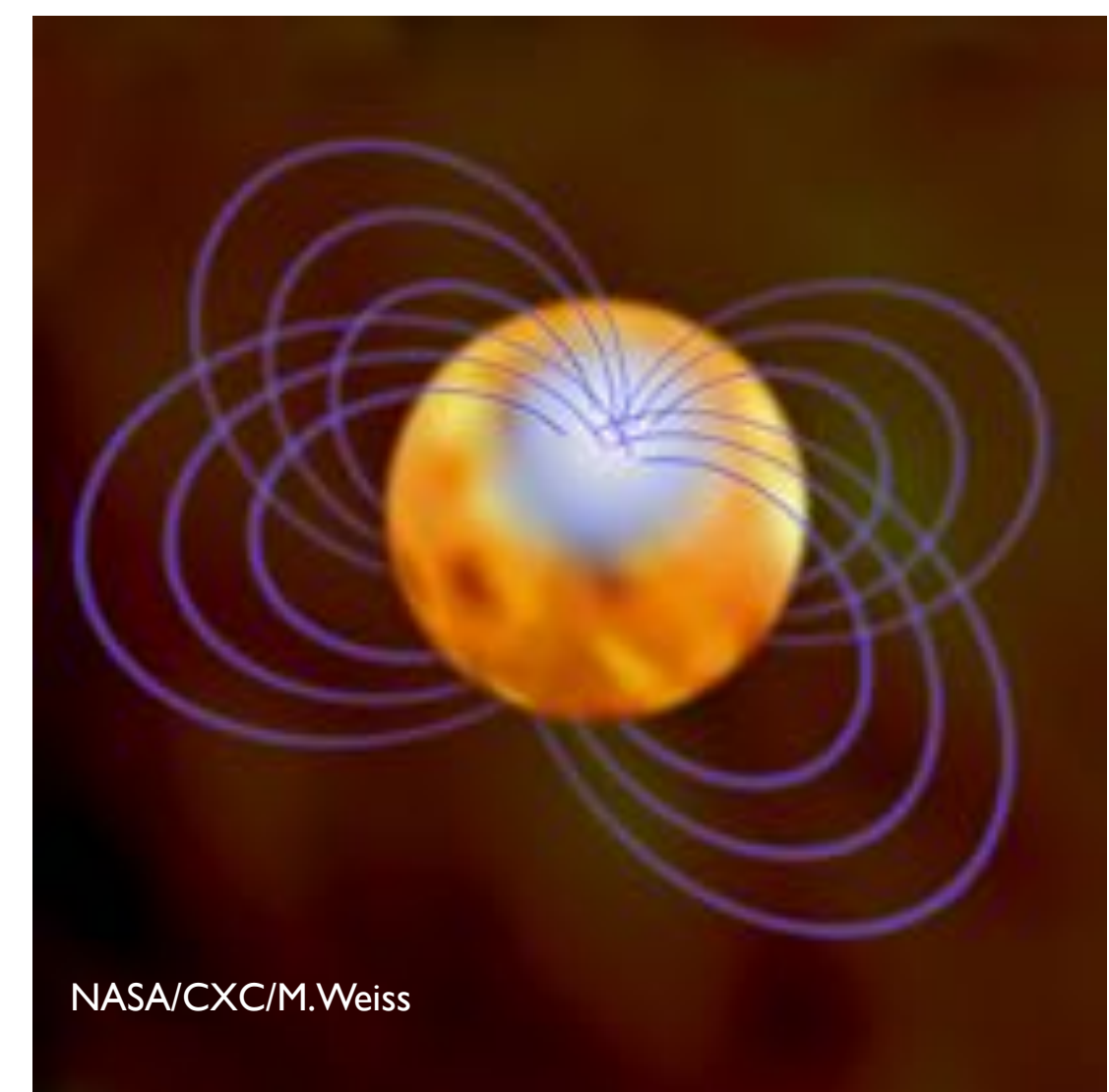
Un-modeled Transient Sources



Stochastic Backgrounds



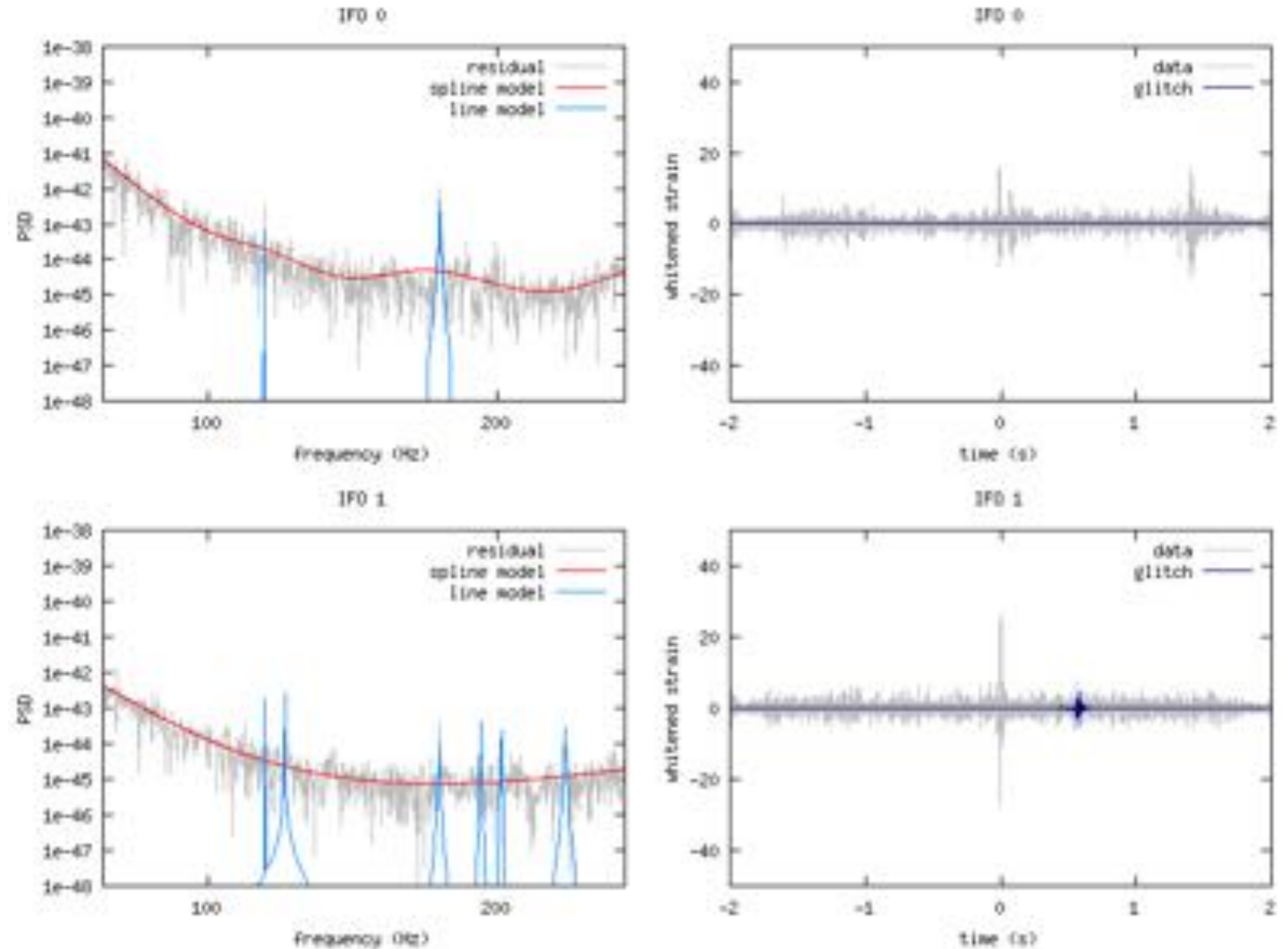
Continuous Sources



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

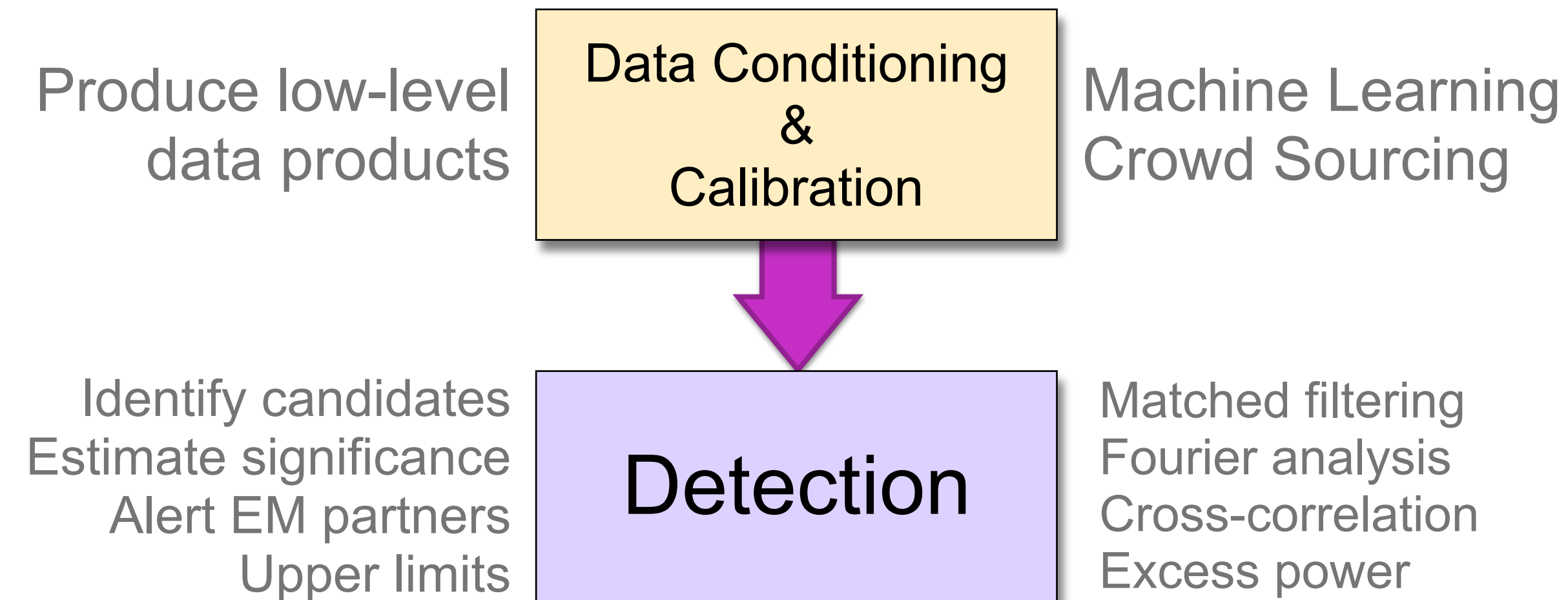


Produce low-level
data products

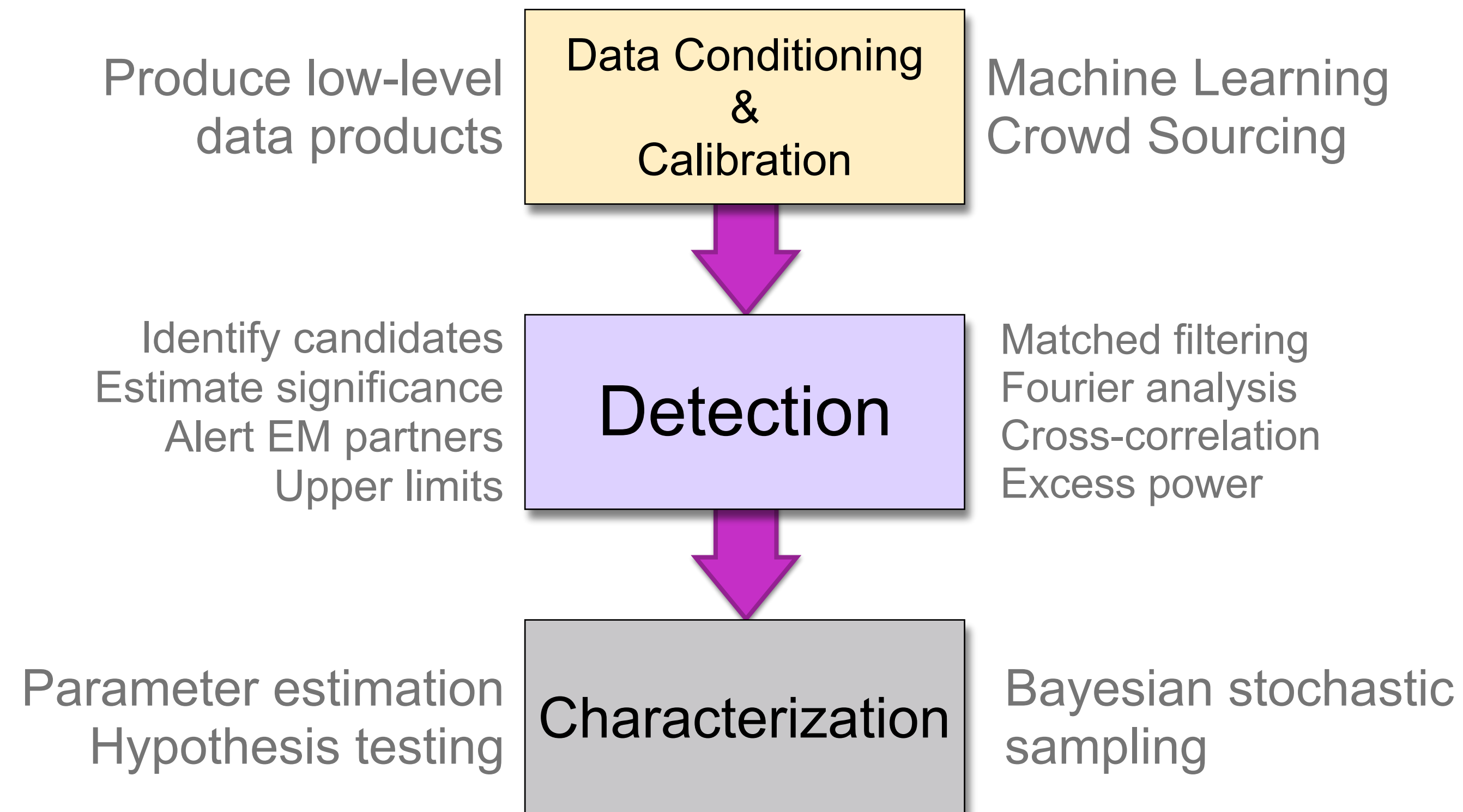
Data Conditioning
&
Calibration

Machine Learning
Crowd Sourcing

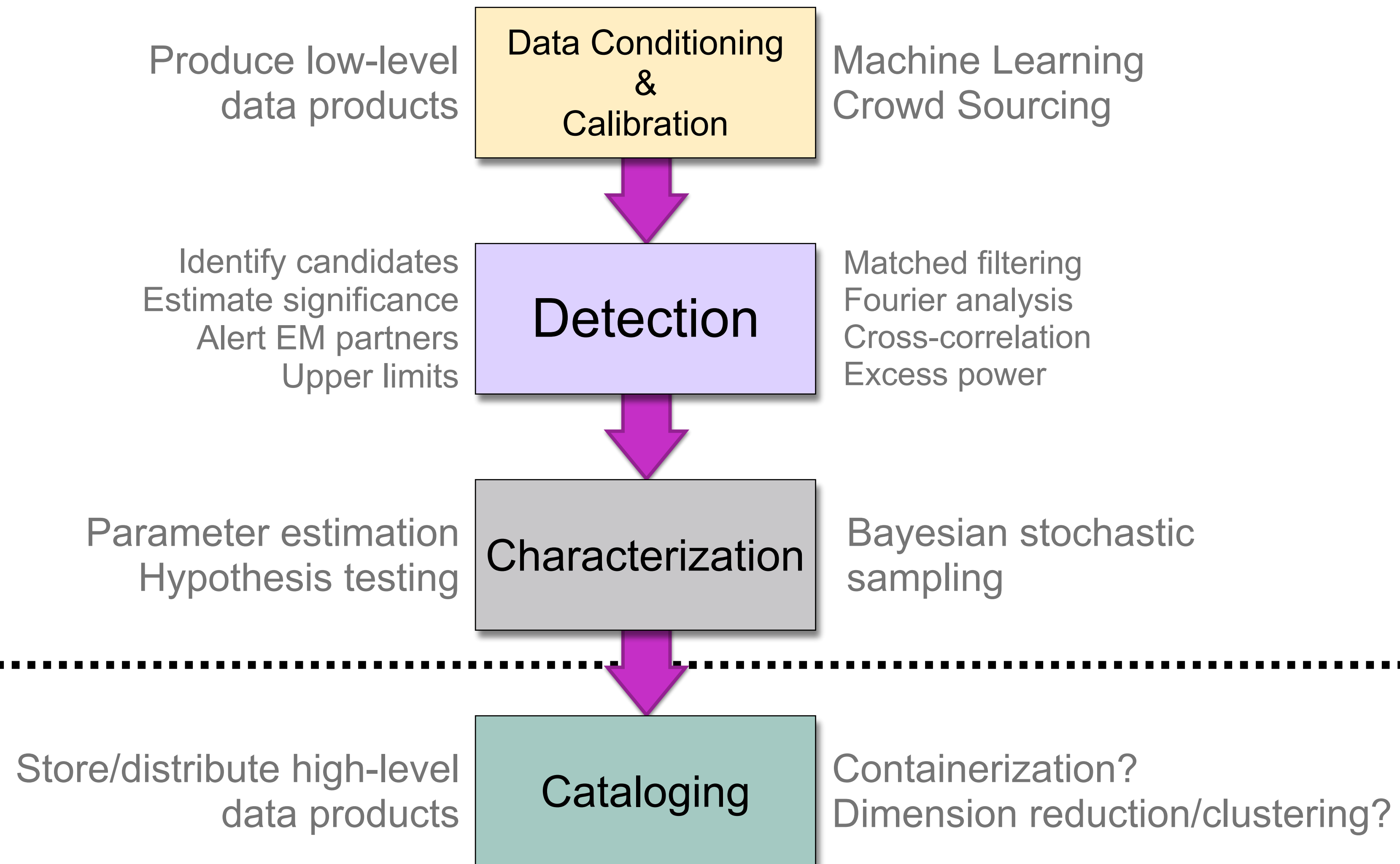
Gravitational Wave Data Analysis in a Nutshell



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

A screenshot of the Einstein@Home website. The header features the Einstein@Home logo and navigation links: HOME, NEWS, SCIENCE, COMMUNITY, HELP, LOGIN, and SEARCH. The main content area includes a large section titled "What is Einstein@Home?" with a description of the program and a "JOIN NOW" button. To the right, there's a "Einstein@Home Progress" section with a line graph showing a sharp spike. Below that is a news article titled "Einstein@Home Discovers First Millisecond Pulsar Visible Only in Gamma Rays" dated February 28, 2018. At the bottom, there's a "Project Downtime 2018-01-30" announcement dated January 23, 2018. The footer area includes a "User of the day" section with a profile picture and a list of users, and a section stating "Over 500,000 volunteers and counting." with icons for Windows, Mac, and Linux.

einstein home

HOME NEWS SCIENCE COMMUNITY HELP LOGIN SEARCH

What is Einstein@Home?

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. [Learn more](#)

JOIN NOW

Einstein@Home Progress
(Credits per day)

Einstein@Home Discovers First Millisecond Pulsar Visible Only in Gamma Rays
February 28, 2018

Einstein@Home has found two previously unknown rapidly rotating neutron stars in data from the Fermi gamma-ray space telescope. While all other such...

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Project Downtime 2018-01-30
January 23, 2018

Update: due to an unrelated hardware problem at our Milwaukee site we need to extend this brief downtime to the entire project, not just the website. The...

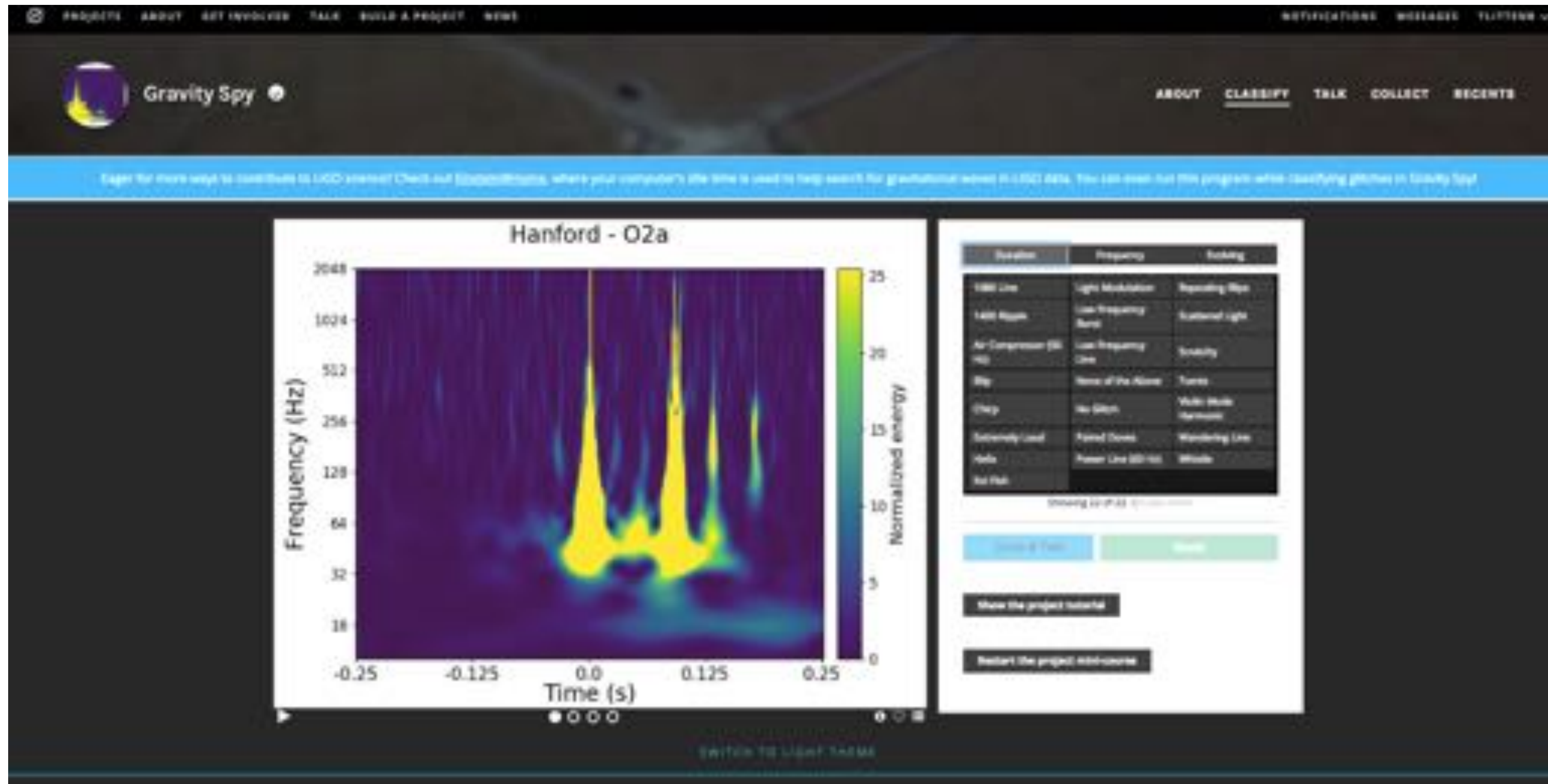
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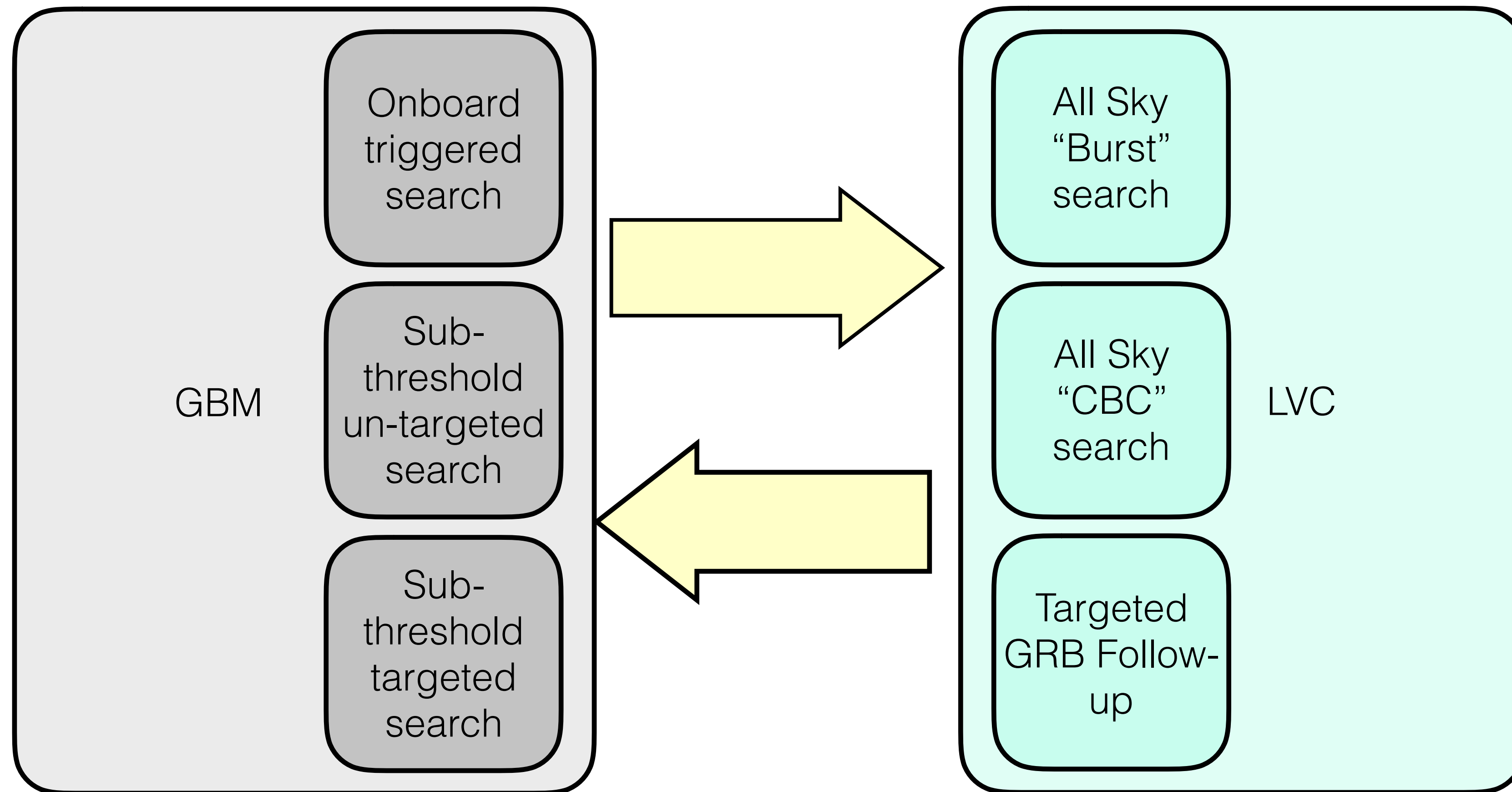
User of the day
[AF>FRANCE>T
DM>PICARDE>
OISE]
BDEMIC92

Over 500,000 volunteers and counting.
 WINDOWS MAC LINUX

Gravity Spy



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

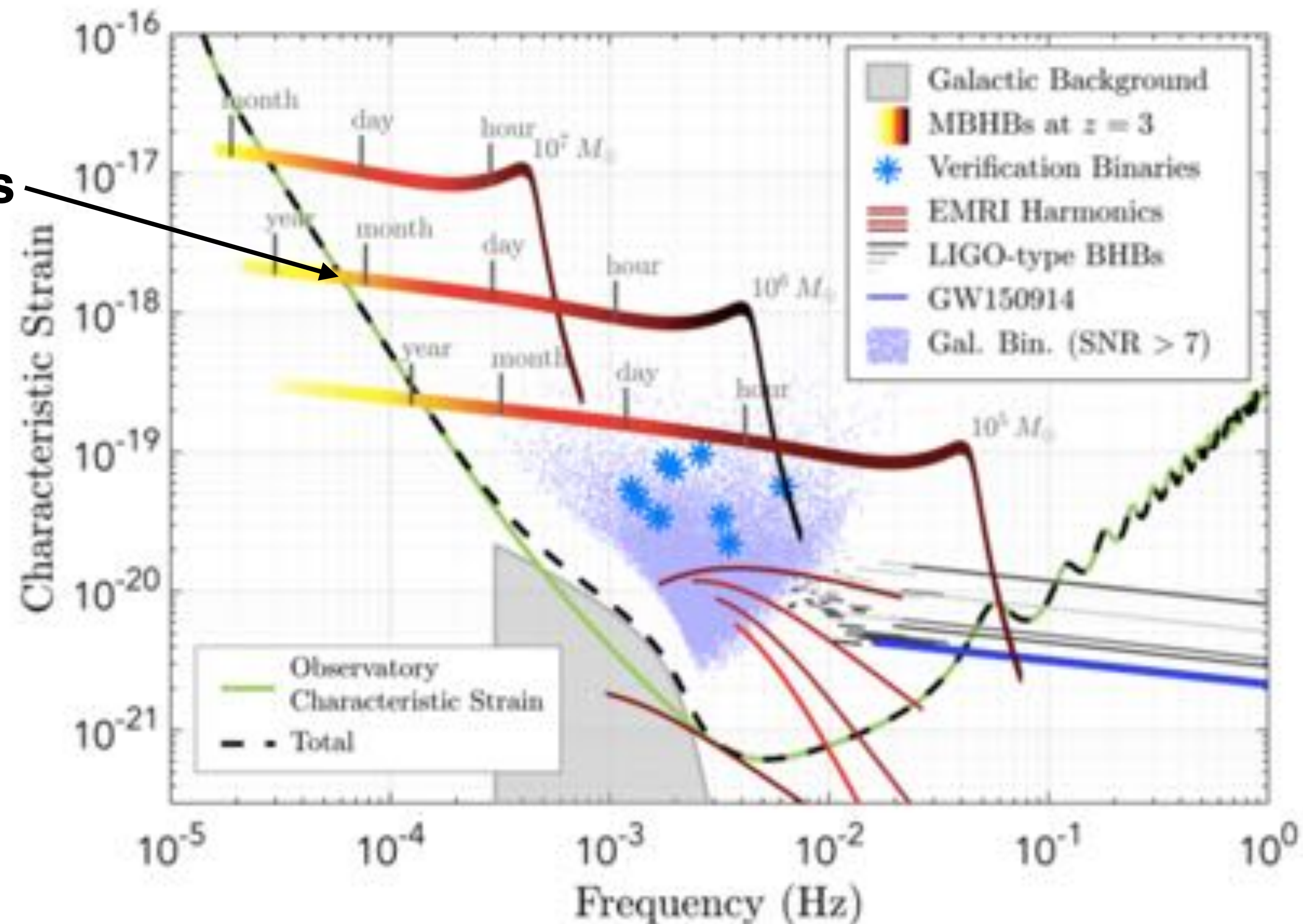


LISA Sources



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.

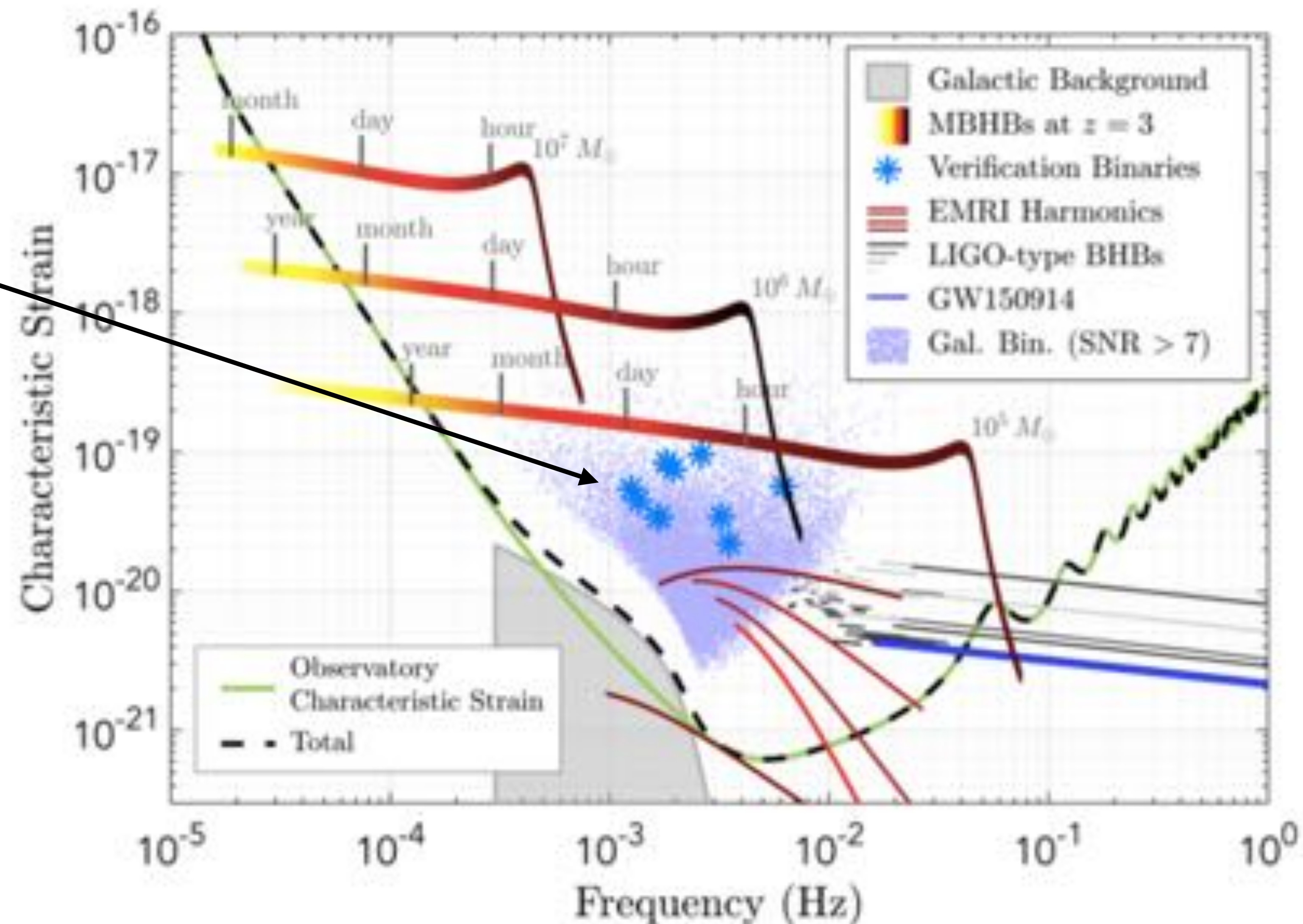


LISA Sources



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!

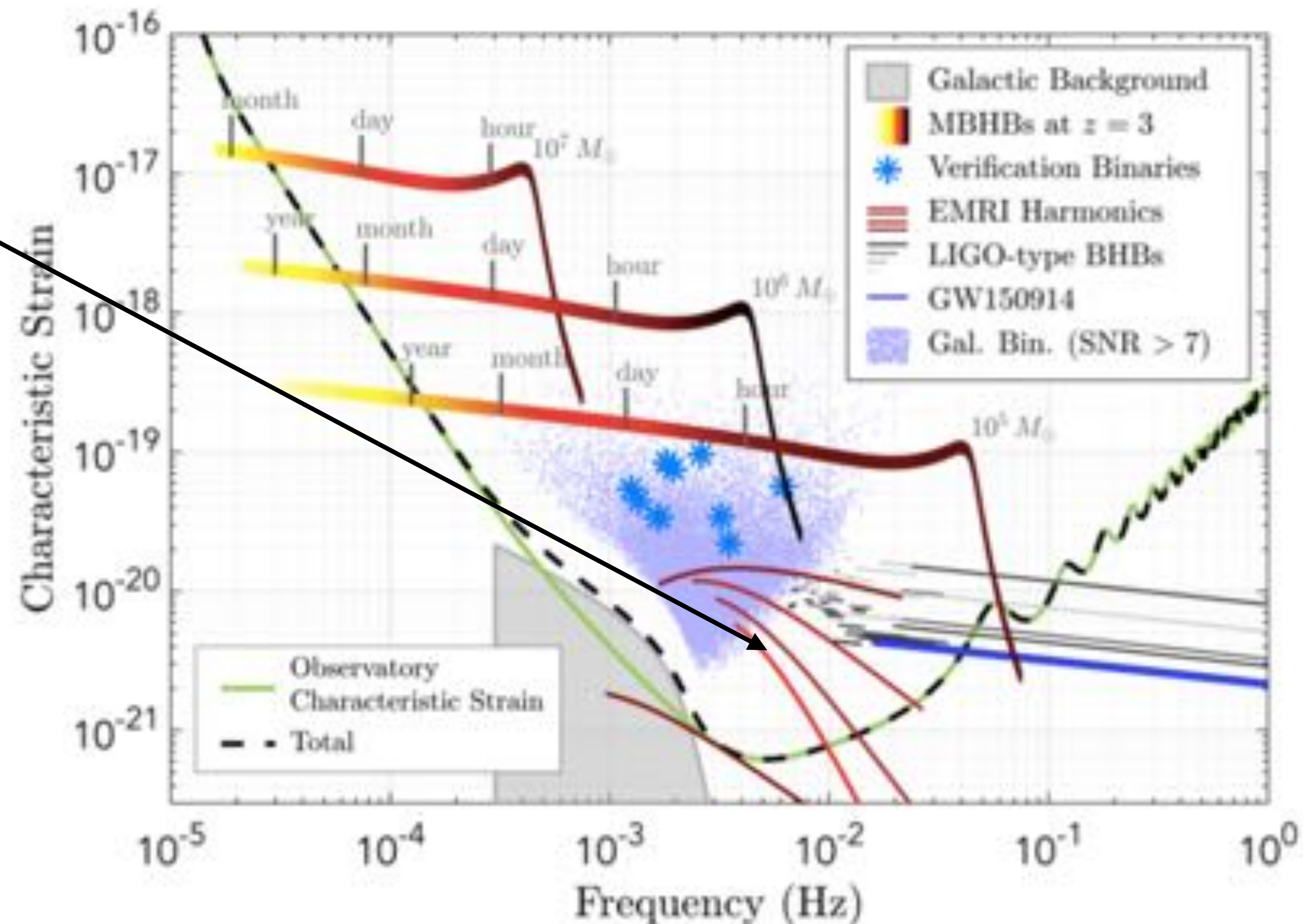


LISA Sources



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

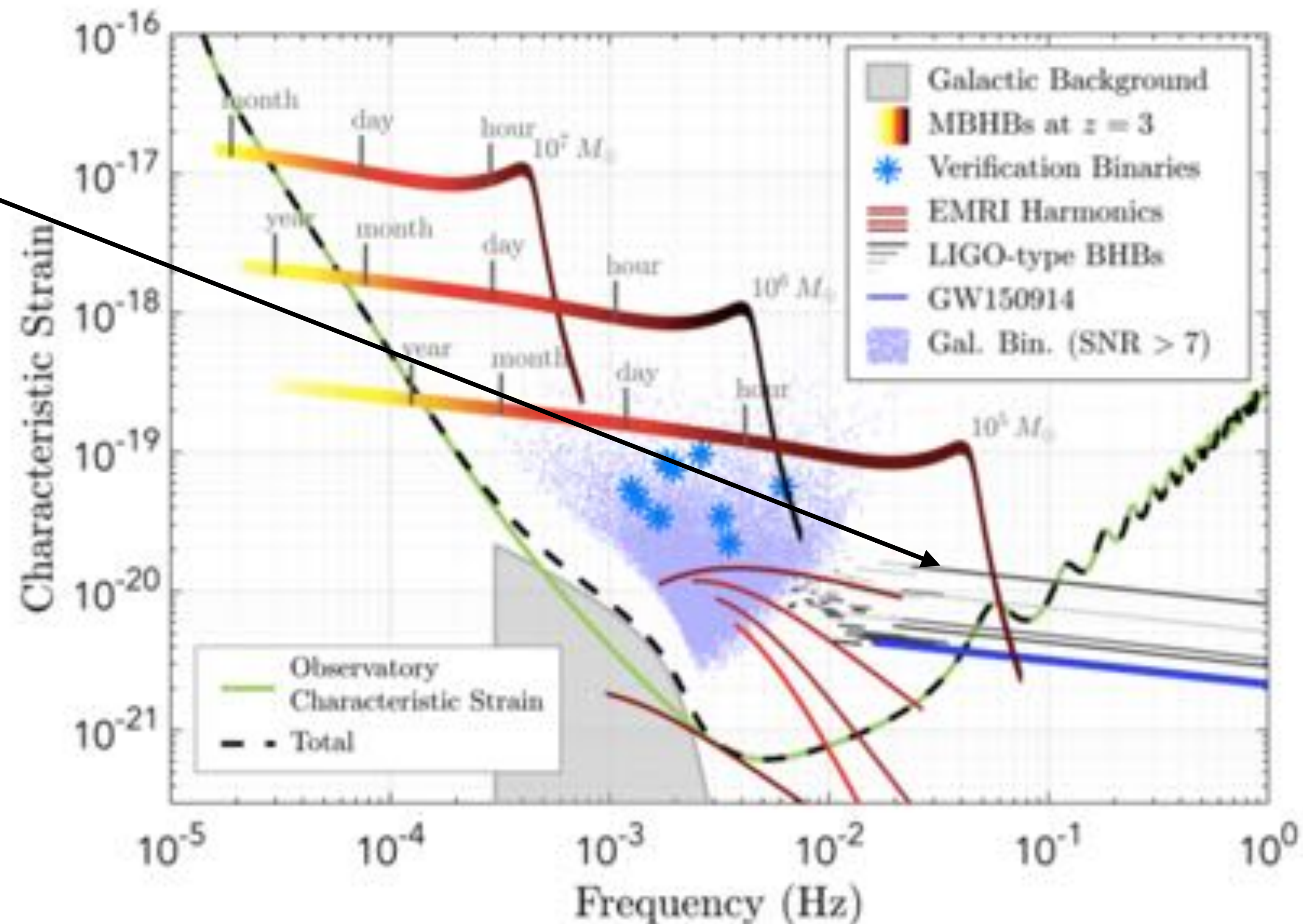


LISA Sources



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

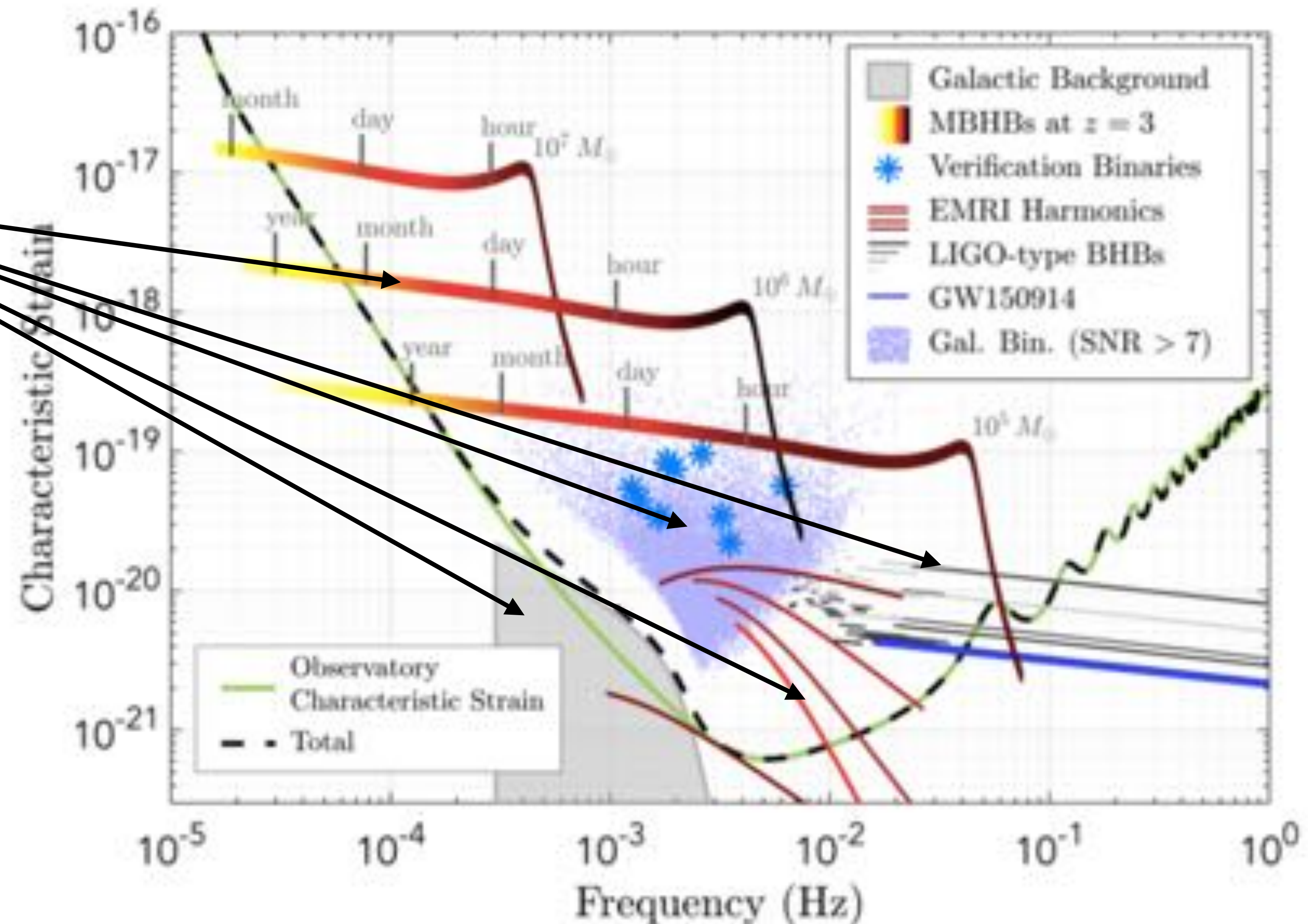


LISA Sources



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: LISA-LCST-SCS-WPD-001	
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		Date: 2018/01/18	Page: 1 / 1

LISA Data Analysis Work Packages

N/Ref:	LISA-LCST-SCS-WPD-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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