Data Science Challenges in Gravitational Wave Astronomy

Tyson Littenberg (NASA/MSFC)



Modeled Transient Sources





Modeled Transient Sources



Un-modeled Transient Sources





Modeled Transient Sources



Un-modeled Transient Sources









Modeled Transient Sources



Un-modeled Transient Sources









Continous 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.



1e-38

1e-39

1e-40

1e-41

10-42

1e-44

16-45

1e-46

1e-47

1e-40

£ 1e-43





Data Conditioning & Calibration

Produce low-level data products



Machine Learning **Crowd Sourcing**

Produce low-level data products

Identify candidates Estimate significance Alert EM partners Upper limits





Machine Learning Crowd Sourcing

Matched filtering Fourier analysis **Cross-correlation** Excess power

Produce low-level data products

Identify candidates Estimate significance Alert EM partners Upper limits

Parameter estimation Hypothesis testing





Produce low-level data products

Identify candidates Estimate significance Alert EM partners Upper limits

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Parameter estimation Hypothesis testing



Store/distribute high-level data products



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



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





User of the day [AF>PRANCE>T DH>PICARDIE> 015E] DDEMICE2





Gravity Spy





Joint GW+Gamma-ray Analyses

	Onboard triggered search
GBM	Sub- threshold un-targeted search
	Sub- threshold targeted search





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





10-16

Supermassive black-hole mergers ~	10 ⁻¹⁷
 long-lived transient sources 	10 ⁻¹⁸
 need real-time updates of source properties to coordinate multi messenger observing 	10 ⁻¹⁹
 very strong signals—important to control systematic errors from data 	10 ⁻²⁰
models.	10 ⁻²¹





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10-17 White-dwarf binaries • continuous, slowly evolving signals Characteristic • 10s of millions(!) in band, 10s of 10-19 thousands resolvable, 10s of known sources from EM observations 10-20 • very complicated catalog!

10-21





10-16

10-17 Extreme mass ratio in-spirals • Long-lived transients õ Characteristic 10-50 • Small black hole falling into big black hole 10-19 Challenging to model. • Narrow, multimodal, likelihood surfaces. 10-21 • 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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Characteristic 10-10





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The Global Fit Problem

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

10-21

Characterist





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





Abstract	LISA DPC Definition and main contributions

	Name	Date	Signature
Prepared by	LISA WP mitting team	2018/00/18	
Checked by			
Checked by (QA)			
Appened by			

The statement is the property of the 1984 Homeson show moved by superstant is investigated without as superstand