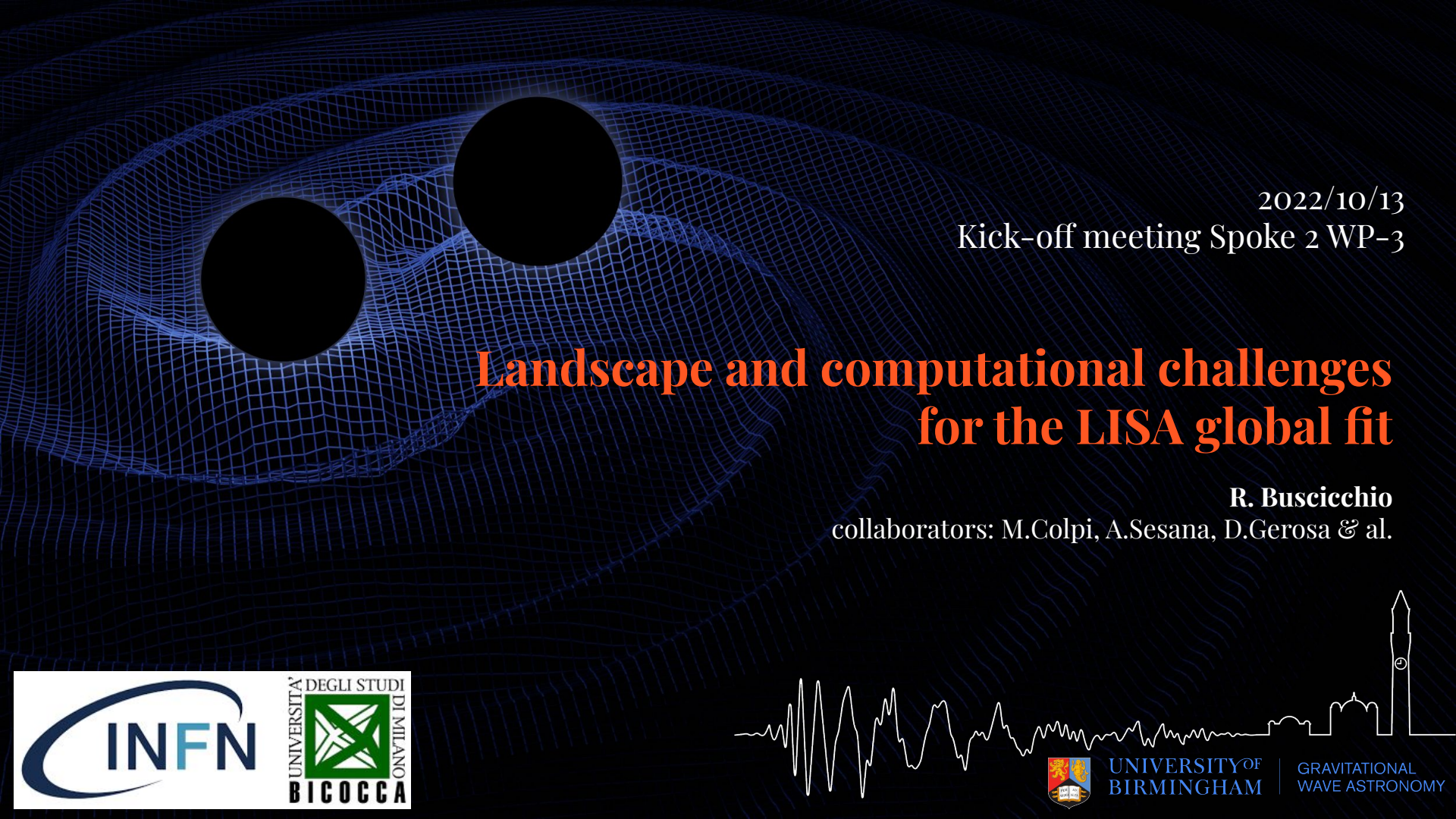


2022/10/13
Kick-off meeting Spoke 2 WP-3

Landscape and computational challenges for the LISA global fit

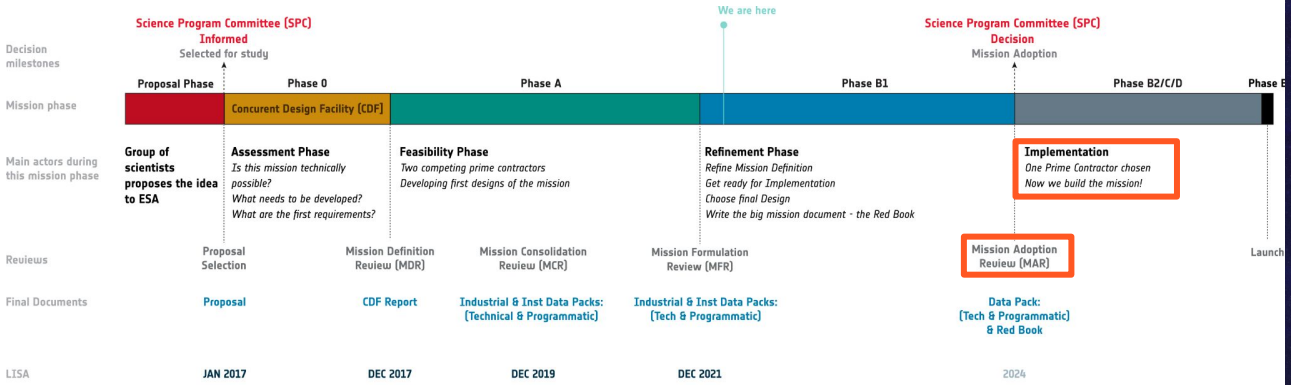
R. Buscicchio
collaborators: M.Colpi, A.Sesana, D.Gerosa & al.

INFN
UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA
UNIVERSITY OF BIRMINGHAM
GRAVITATIONAL WAVE ASTRONOMY

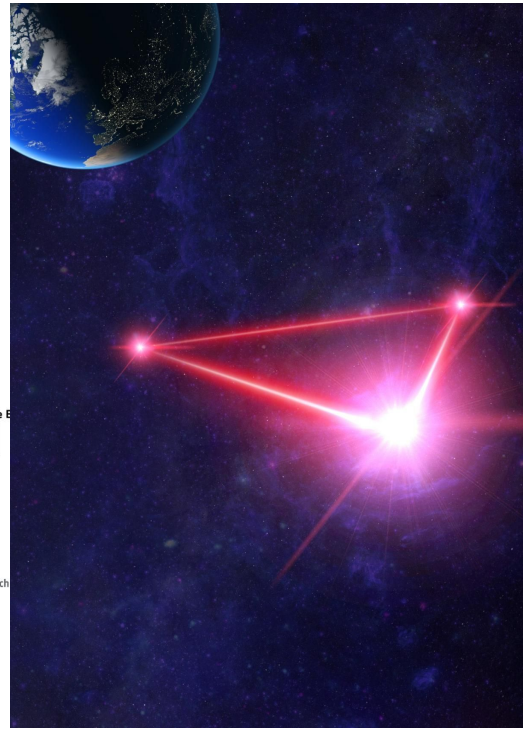
LISA

Outline and mission status

- Mission Formulation Review ✓
- Towards Mission Adoption:
  - Reshaping the collaboration:
    Performance Experts & Data Analysis Experts Groups
  - Red book
- Launch expected in 2034



Credits: ESA



Credits: NASA/JPL-Caltech/NASAEA/ESA/ CXC/STScI/GSFCSVS/S.Barke

Question: Are we ready to process LISA data?
Answer: Data Challenges

Summary

Computational challenges

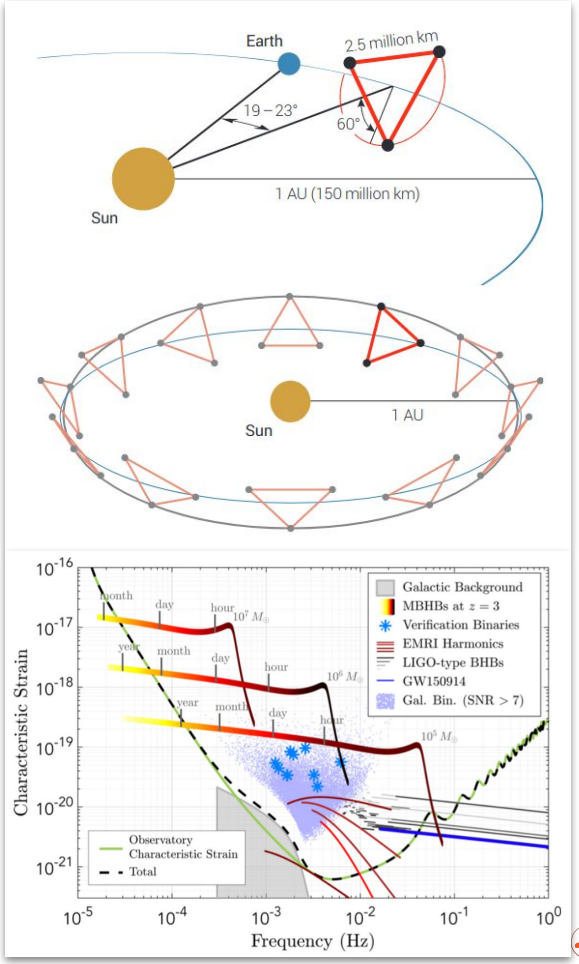
- Waveforms
- Instrument response
- Likelihoods
- Global fit
- Population inference
- Get in touch for references and discussion!

LISA landscape

Key computational features

- Long baseline: 2.5 Mkm
- Sensitivity bucket ~ mHz
- Data on a stick:
  4 to 10 years, 3 “science” channels = 15 GB
- Source-rich sky: persisting & overlapping sources
- Time dependent response: that’s new wrt ground-based detectors
- Noise/Signal distinction is blurry: “confusion” noise
- Dominating laser phase noise: synthetic interferometry

LISA Proposal L3 ESA mission



Waveform evaluations

Key computational features

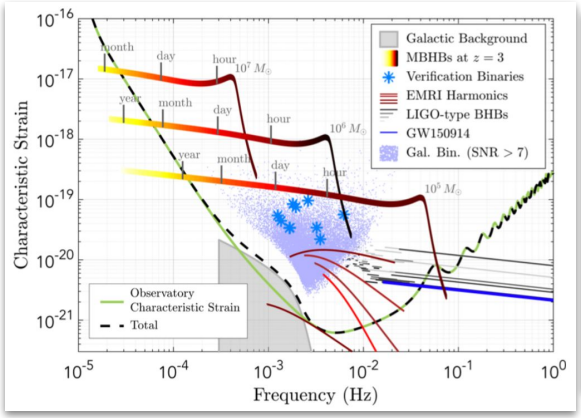
Bayesian parameter estimation:
~a few long-term, incremental, codebase developments worldwide
(including UniMiB)

(+noise)

(+noise)

- **Monochromatic (DWDs)**
- **Drifting sources (BBHs)**
- **Chirping sources (SMBBHs)**
- **Polichromatic (EMRIs)**
- **Many unresolved ones (SGWBs)**
- **Instrumental artifacts**
- **Multiband sources ↠**

  computationally challenging



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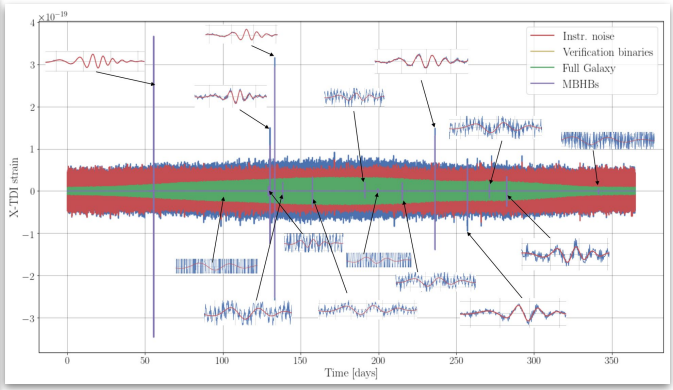

Question: Are we ready to search for all?
Answer: Yes for some sources, other under development

Waveform evaluations

Key computational features

Bayesian parameter estimation:
~a few long-term, incremental, code developments worldwide (including UniMiB)

(+noise)

(+noise)

- **Fast multi-sources waveforms»slow**
- **Slow single-source bright waveforms»slow**
- **Only heterogeneous modelling is possible**

» Towards the global fit «

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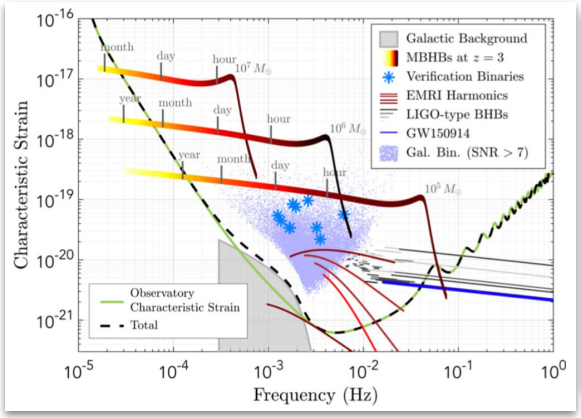
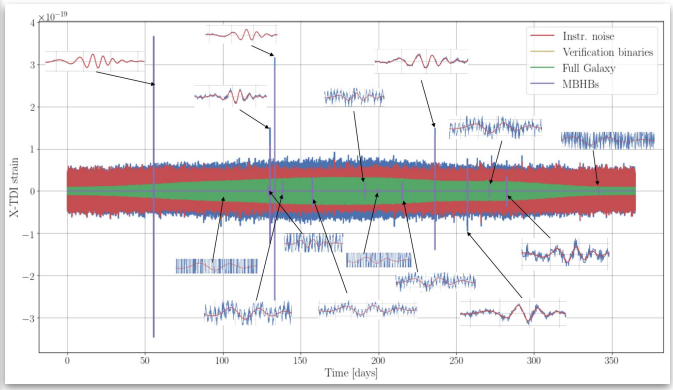




Question: Are we ready to search for all?
Answer: Yes for some sources, other under development

Computational challenges

Waveforms

- Some source classes are GPU accelerated.
- Some other are going to be
  - Chirping signals are inherited from ground-based detectors (+eccentricity)
  - Drifting signals are slowly inspiralling. Must track ~10^{5-6} signal cycles
- Surrogates
  - Leverage exact solutions from numerical relativity. Useful for massive sources. Require massive simulations to “train”
  - Reduced order models trained on neural networks: suitable for gradient based inferences

Computational challenges

Likelihoods

- highly multimodal (multiple source inference):
  - issues are solvable on a statistical basis (label switching problem)
  - other just require massive computation
- highly curved likelihood surfaces
- a zoo of stochastic samplers:
  - Nested sampling
  - Markov-Chain Montecarlo
  - Hamiltonian samplers
  - multithreading is mostly out-of-the-box
- Sometimes enhanced with
  - normalizing flows
  - genetic programming (not algorithms)
- gaussian process augmentation
- neural amortized proposals
- particle swarm optimizers

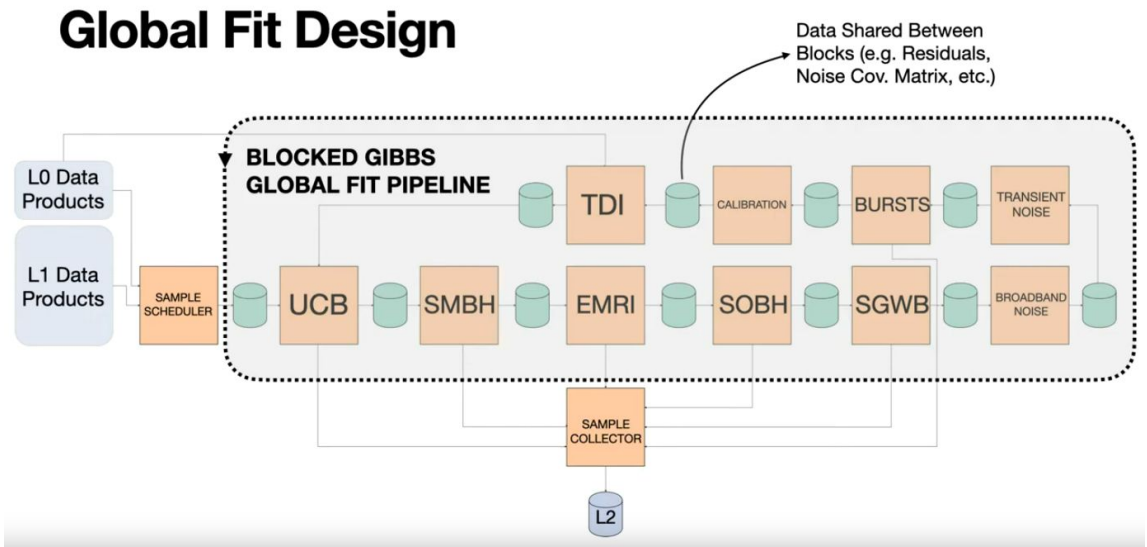
To sample parameters

To decorrelate parameters

To increase proposal acceptance rate

Computational challenges

Global fit: the elephant in the room

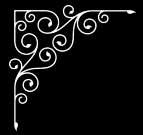
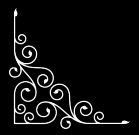


Designing a Global Fit Analysis for LISA (T. Lyttenberg Talk)

It's a logistic problem: heavily parallelizable

Population inference:

Given the number of sources, established hierarchical likelihoods might be too slow. Not covered in this talk.

The end

Questions?