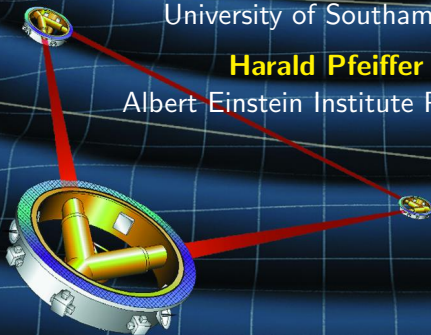# Introduction to LSG Work Package 1 and the Waveform Working Group

Leor Barack
University of Southampton

Harald Pfeiffer
Albert Einstein Institute Potsdam

Plan

- **Organization:**
  LSG, WPs, WGs and all that. Roles, responsibilities, interrelations.
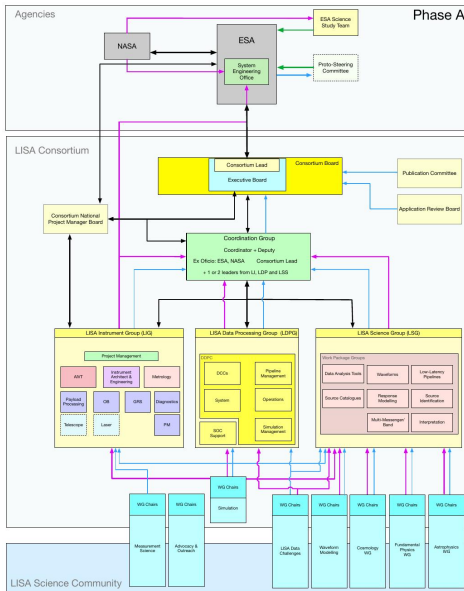
- **Communication:**
  Finding information, online tools, mailing lists

- **Some thoughts**
  on the challenge of waveform modelling for LISA
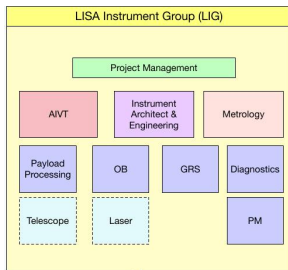
Management structure of LISA project

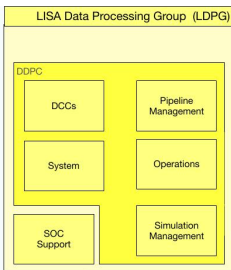← Agencies: ESA & Nasa

← LISA Consortium

← LISA Science Community

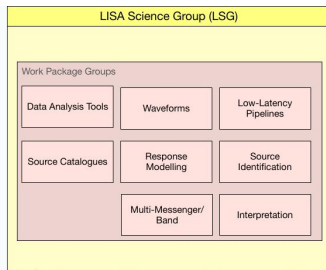# Consortium's operative bodies: LIG, LDPG & LSG

LISA Instrument Group **(LIG)**
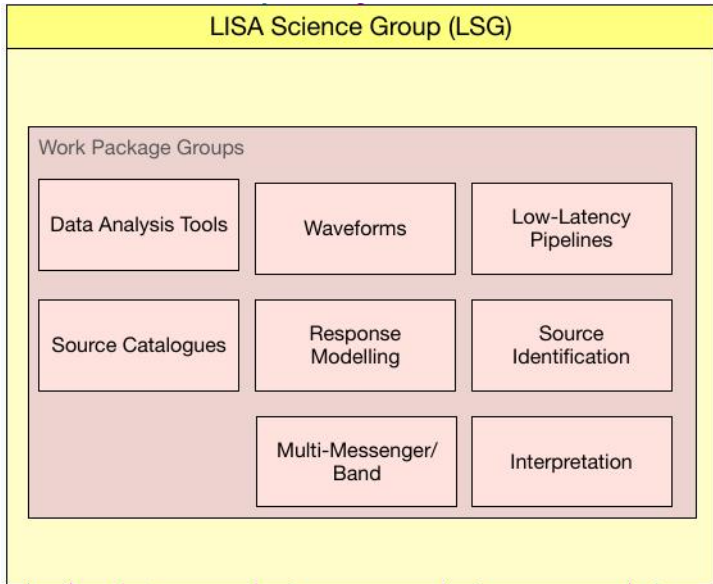
LISA Data Processing Group **(LDPG)**

LISA Science Group **(LSG)**

Responsibility for defining <u>work packages</u>*, organizing work, monitoring progress.

*All things that need be done for LISA to deliver all the science we think it can deliver

LISA Science Group (LSG) (Chairs: J. Gair, E. Rossi, M. Vallisneri)

Waveforms Work Package (WP1) (L. Barack, H. Pfeiffer)

Overall responsibility:

- To provide "sufficiently accurate" waveforms needed for source identification and interpretation:

    – EMRIs (extreme mass-ratio inspirals)
    – IMRIs (intermediate mass-ratio inspirals)
    – MBHBs (high-mass BBH, inspiral+merger in LISA band)
    – GBs (galactic WD binaries, far from merger)
    – SOBHBs (steller-origin black-hole binaries, low mass, LISA→LIGO)
    – Jokers (non-GR, cosmic strings, primordial)

Aim: To ensure quality of LISA science is limited by experimental precision, not by our (in)ability to accurately solve Einstein's equations!

Waveforms Work Package (WP1) (L. Barack, H. Pfeiffer)

To achieve this:

- Define subpackages and assign priorities

- Identify and allocate personnel to work on specific tasks

- Define and routinely review accuracy requirements

- Monitor availability, efficacy, speed of existing waveform models and identify areas where more work needed

- Form interface and pursue exchange with WGs (especially WavWG & LDC but also Astrophysics, Cosmology, fund. physics) and LDPG

- Understand "user" needs (speed, waveform formats, etc)

Waveforms Work Package (WP1): substructure

WP1.1 Assess LISA waveform modelling requirements (priority 1 -- End 2019)

- Overall lead Ed Porter
- 1.1.1 IMRI/EMRI Requirements - Maarten van de Meent
- 1.1.2 SMBH/SOBH Requirements - Richard O'Shaughnessy

WP1.2 Provide EMRI waveforms (priority 2 -- 5 years)

- Overall lead - Leor Barack
- 1.2.1 Theory of self-force in GR - Adam Pound
  - Proposed projects: https://tinyurl.com/ybsul6vs
- 1.2.2 Implementation/numerics/waveforms - Niels Warburton
  - Proposed projects: https://tinyurl.com/y9qt4jjh
  - How the 1.2.1 and 1.2.2 projects interact: https://tinyurl.com/y84qxw6f
- 1.2.3 non-GR signatures in EMRIs - Richard Brito
  - Proposed projects: https://tinyurl.com/y283dnma

WP1.3 Provide MBHB waveforms (priority 2 -- 5 years)

- 1.3.1 NR in GR - Deirdre Shoemaker
- 1.3.2 Analytical modelling - Tanja Hinderer
- 1.3.3 beyond-GR effects on MBHB - Paolo Pani

WP1.4 Provide GB waveforms (priority 2 -- 5 years)
Lead Guillaume Faye

WP1.5 Provide IMRI waveforms (priority 3 -- 10 years)
Lead - Eliu Huerta

WP1.6 Provide SOBHB waveforms (priority 2 -- 5 years)

- 1.6.1 PN modelling - Sylvain Marsat
- 1.6.2 NR modelling - Carlos Lousto

WP1.7 Provide waveforms for cosmic strings and other modelled transient events (10 years)
Lead Barry Wardell

WP1.8 Waveform interface and tools (priority 1 -- end of 2019)

- 1.8.1: Tools for generating ROM - tbd
- 1.8.2: Efficient MBHB models - Sascha Husa
  - Living document: https://tinyurl.com/LISAWP-efficient-MBHB-models
- 1.8.3: Efficient EMRI models - Alvin Chua
  - Proposed projects: https://tinyurl.com/emri-templates

EMRI Modelling Roadmap

Adam Pound and Niels Warburton

3 December 2018

Model Development	Implementation

< 2 years

- Generic adiabatic inspirals and waveforms in Kerr → LDC
- Osculating-geodesic evolution using full first-order GSF with NIT (near-identity transform) in Kerr

- Two-timescale framework for generic non-resonant orbits in Kerr (w/out finite-size effects)
- Complete development of all tools needed for quasicircular orbits in Schwarzschild at second order in Lorenz gauge

- Two-timescale evolutions (combined with NIT) for generic orbits in Schwarzschild
- Post-adiabatic quasicircular inspirals in Schwarzschild
  - Open up second-order computational tools to community

Initial work at sub-package level (example)

Finite-size effects (spin and higher moments)

Active   *derivation of equation of motion from matched expansions*
-- Adam Pound, Sam Upton (PhD project)

estimates of impact on GW phasing, possibility and impact of chaos, inclusion in orbital evolution
-- Georgios Loukes-Gerakopoulos, Vojtech Witzany

Expressions of interest   Maarten van de Meent

Perturbative frameworks

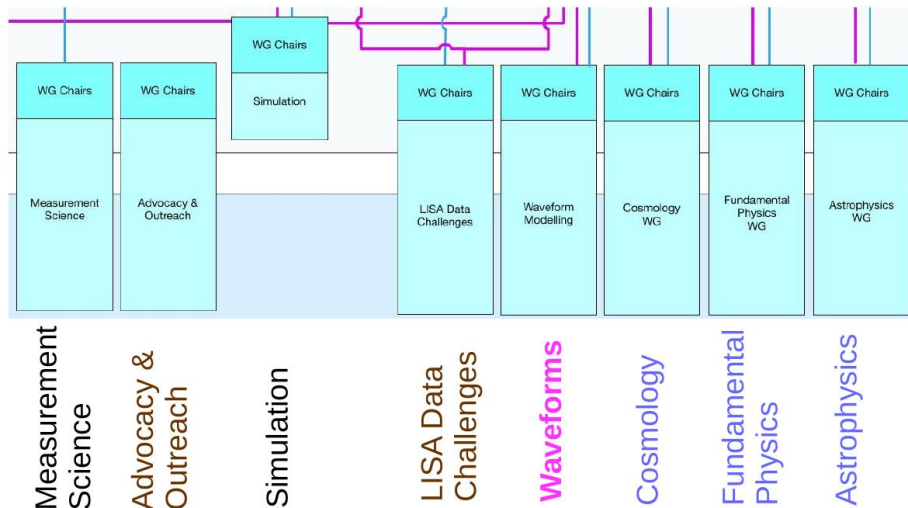- **Two-timescale approximation**

  Active   *general formulation, boundary conditions at infinity, finite-size effects*
  -- Eanna Flanagan, Tanja Hinderer, Jeremy Miller, Jordan Moxon, Adam Pound

  boundary conditions at horizon
  -- Soichiro Isoyama, Adam Pound, Takahiro Tanaka, Kei Yamada

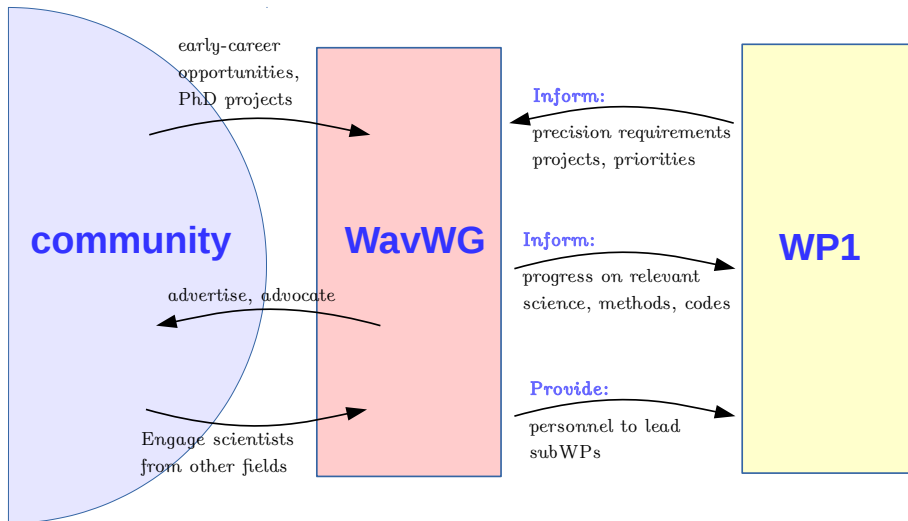# Working Groups of the LISA Consortium

Mission of Waveform Working Group (WavWG)

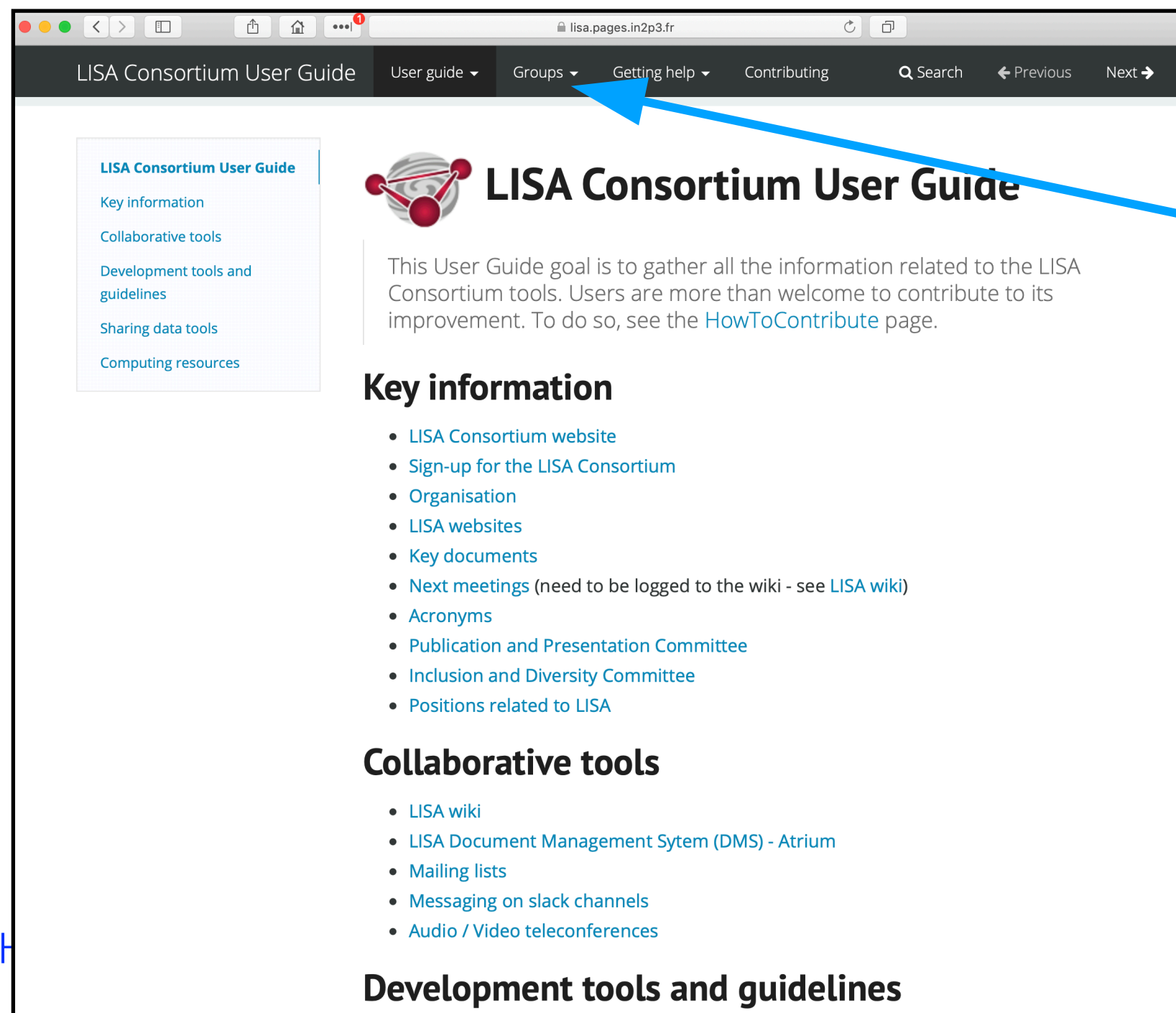**(Chairs: M. van de Meent, Deirdre Shoemaker, Niels Warburton, Helvi Witek)**

- Provide platform and organizational tools to facilitate interaction between all scientists working on modelling of LISA-relevant sources. Serve a *community-building* instrument.

- Inform WP1 work & priorities through identification of pertinent science developments

- Supply personnel to lead/take part in WP1 activities

- Attract early-career scientists to LISA community (PhD projects, etc.)

- Attract and capitalize on interest from adjacent fields (e.g.: modelling methods inspired from QCD or from quantum fields in curved space)

Interaction between WP1 and WavWG

community

WavWG

WP1

early-career opportunities, PhD projects

advertise, advocate

Engage scientists from other fields

Inform: precision requirements projects, priorities

Inform: progress on relevant science, methods, codes

Provide: personnel to lead subWPs

Finding information

- Starting point — **LISA Consortium User Guide**
 https://lisa.pages.in2p3.fr/consortium-userguide/

Pull-down menus with more info

Info+Tools reachable from User Guide

- Key LISA documents, incl. organisation, work-packages, code of conduct

- LISA Consortium Sign-up

- LISA Wiki. Specifically
  - https://wiki-lisa.in2p3.fr/LSG/WP1
    Top-level entry-page into WP1
    WP sub-package coordinators, link your info on that page!
  - https://wiki-lisa.in2p3.fr/WorkingGroups/WFWG   ***Waveform Working Group***

- Teleconference tools — ***Teamspeak***

- GitLab server — https://gitlab.in2p3.fr
  - repository+wiki+issue tracking for your (sub-)package

- Document Management System — ***Atrium*** (~ LIGO DCC)

- Mailing lists

- LISA Data Challenge

Back to Science

- Waveform modeling for LISA is harder than for current ground-based interferometers. That's why we're here!!

- GW sources
  - Sometimes loud: SNR > 1000
  - More diverse

    $q = 1 \ldots 10^6$

    $e = 0 \ldots 1$
  - New types

    galactic WD-binaries, SOBH, WD+NS?

- More/different physics
  - resonances, environmental effects, cosmology, precision-science

- Also very different data-analysis
  - much longer waveforms, overlapping sources, time-varying antenna-response functions
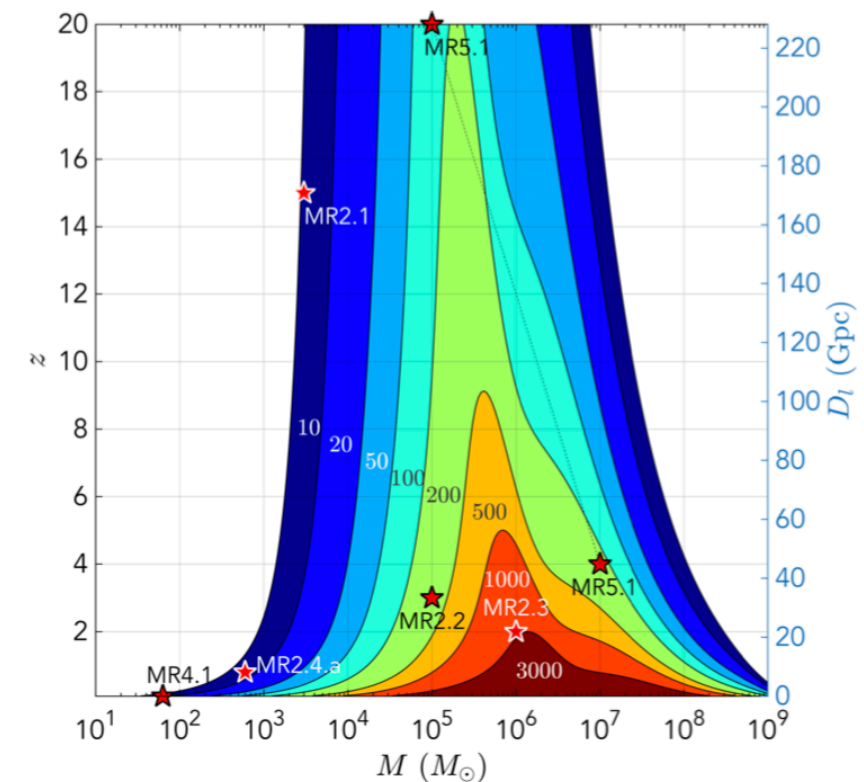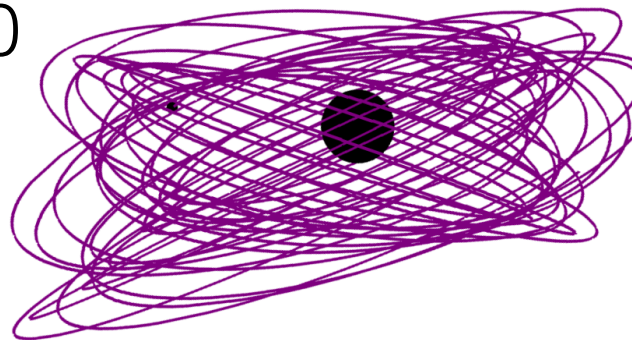
Some thoughts

- highly technical sub-fields
    - self-force, post-Newtonian, post-Minkowskian, effective-one-body, numerical relativity, …

- turn into waveform models
    - combine, calibrate, accelerate, automate, harden, interface …

- possibly develop entirely new techniques

- be mindful of needs: what accuracy is needed
  for which sources and for what application?
    - Astrophysics: Emphasize what's expected
    - Data-analysis: Improve where it impact measurements
    - Trade-offs: What science is lost with imperfect waveforms?
        If perfection is impractical and loss minor, perhaps move on (but LISA = multi billion!)
        Conversely, we **must** identify areas of unacceptable science-loss

- look also beyond the highlight sources
    - Galactic Binaries, cosmic strings, non-GR, NS+WD, …

Some thoughts

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