LISA International Science Team Working Group 1

http://www.tapir.caltech.edu/listwg1

Sources & data analysis working group

Chairs: Sterl Phinney & Bernard Schutz

Loosely organized "Task Groups" that study issues relevant to LISA, webpage used to centralize & share results or discussion.

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This page centralizes the various task groups WG1 puts together to address issues related to LISA sources and data analysis.

Task groups on specific topics are being set up by members of the LIST participating in WG1. Interested persons may sign up for task groups on the topics listed below. To do so, submit a short CV and list of relevant publications, and a statement of committment to do relevant work to Scott Hughes. WG1 will call upon these task groups for help addressing issues brought to it by the LIST or the LISA project, and would then sponsor telecons and request white papers. Task group participants can of course also work independently as desired, and can submit results (or links thereto) to the WG1 website.

As interested persons sign up for tasks, a separate page will be created for it, password protected (if desired) for task group participants to report results and white papers. Active and complete task force activities are listed in the side bar.

Source astrophysics (models of rates, relevant physics and astronomy)

- Galactic (including globular cluster, LMC, SMC etc) binaries
- Supermassive black holes in merging galaxies and protogalaxies
- Compact objects in star clusters around supermassive black holes
- Intermediate mass black holes
- Cosmological backgrounds (inflation, EW phase transition, etc)
- Other (e.g. cosmic strings, VMOs, etc)

Source waveforms and data analysis issues

- Galactic binaries
- Black holes of mass ratio 1/1 to 1/100
- Compact objects captured by black holes (mass ratio <1/100).
  - See "Extreme mass ratio inspiral" link on side bar.
- Other (including cosmic strings, cosmological backgrounds, etc)

Data pipeline

- Detailed simulation of LISA data stream from sources

Scott A. Hughes, Coordinating Scientific Secretary of WG1
Last modified: 17 November 2001

Issues in extreme mass ratio inspiral (compact bodies spiralling into galactic mass black holes)

This page centralizes the various activities currently planned or underway geared towards understanding extreme mass ratio inspiral.

If you have information you would like linked onto this page, please send it to Scott Hughes. At the moment, the various active task items are grouped in the left bar, along with links and downloadable items that may be of interest.

Waveform modeling

- Kludged inspiral waveforms
- Teukolsky formalism waveforms: frequency domain
- Teukolsky formalism waveforms: time domain
- Self force calculations

Applications of waveforms

- Counting templates; template metric evaluation
- Dealing with a background of inspirals

Other items of interest

- Hughes geodesic integrator
- Mail archive

Scott A. Hughes, Coordinating Scientific Secretary of WG1
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Kludged inspiral

Our goal is to produce crude waveforms for compact bodies spiraling into massive Kerr black holes as a first foundation for understanding data analysis. Scott Hughes, Teviet Creighton, Daniel Kennefick, and Kostas Glampedakis are looking at this issue in depth.

Our current approach assumes that the inspiral will be adiabatic so that the orbital constants change "slowly". Operationally, this means that we regard the small body as following a Kerr geodesic orbit, but we allow the constants that specify the geodesic to slowly evolve due to gravitational-wave emission. Because we do not yet have a strong field description of radiation reaction for orbits that are inclined and eccentric, we use weak field formulae derived by Fintan Ryan to evolve the orbits' energy and angular momentum. We assume that orbits spiral in at constant inclination to get the change in the orbits' Carter constants. (The constant inclination assumption is very good for most central black hole spins according to work by Hughes on inspiral of orbits with zero eccentricity.)

Generating a waveform proceeds in three parts:

1. Compute the inspiral trajectory in "configuration space". This tells us how the "constants" of an orbit evolve due to gravitational-wave emission [ie, it tells us $E(t)$, $L_z(t)$, $Q(t)$ for a particular initial condition E_0, $L_{z,0}$, Q_0].

2. Compute the inspiral in physical space. One uses the configuration space trajectory to specify how the constants evolve in the geodesic equations. This then gives the actual inspiral trajectory in Boyer-Lindquist coordinates, *r(t), theta(t), phi(t)*.

3. Finite difference the physical space trajectory to make a waveform using a crude implementation of the quadrupole formulae. We consider this crude because we build the source's quadrupole moment by pretending that the Boyer-Lindquist coordinates are spherical and then convert to Cartesian; then, $I_{xx} = (\text{mass})(x^2 - 1/3\, r^2)$, etc.

STATUS:

Glampedakis and Hughes have written code to perform the first step; Hughes has written code for the second step; and Creighton has written code for the third step. Presently, Hughes, Glampedakis and Kennefick are bringing their codes into a state where they agree with one another, and are mapping out the limitations of this approach.

Progress reports:

21 Nov 2001: (Hughes and Creighton only.) The configuration space trajectories were behaving rather bizarrely (eg, an "inspiral" might eventually turn into an "outspiral" if we wait long enough). This turned out to be because of higher post-Newtonian terms included in Fintan Ryan's formulae. In retrospect, this is not surprising: pushing post-Newtonian formulae into the strong-field is generically a Bad Idea. One typically sees the post-Newtonian "corrections" grow bigger than the leading order piece; of course, the next highest correction compensates for that, but if you don't have that correction, you have problems. The solution I have implemented is to eliminate the higher pN contributions. This means that the *dE/dt*

Science Impact of the Low Frequency Performance of LISA

E.S. Phinney for the LIST WG1 LFP task force *

3rd DRAFT: 4 November, 2001

Abstract

The LIST has been asked to comment on the impact on LISA science of the low-frequency noise performance of LISA. In particular, the LISA pre-Phase A design assumes white acceleration noise at least for $3 \times 10^{-3} > f > 10^{-4}$Hz. Yet the current baseline for the SMART-2/LISA Test Package tests of the gravitational reference sensor set a requirement on the accleration noise level only for frequencies $f > 10^{-3}$Hz. If the observed noise in the test rises sharply below 10^{-3}Hz, predictions of LISA's actual performance at lower frequencies would be based largely on extrapolation, and unexpected noise sources at lower frequencies might substantially degrade its performance. Consequently we have examined the impact on science of dramatic increases in LISA's noise (a 'noise wall') at frequencies $f < f_w$, with f_w in the range $3 \times 10^{-5} < f_w < 10^{-3}$ Hz. What constitutes a 'noise wall' depends on the individual sources considered. For Galactic binaries and extragalactic backgrounds, it would be an acceleration noise (per proof mass) more than 10 times LISA's nominal 3×10^{-15}m s^{-2}Hz$^{-1/2}$. For merging supermassive black holes, it would be 30-100 times LISA's nominal acceleration noise.

Our overall conclusion is that even with a noise wall at 10^{-3}Hz, the LISA mission would be worth flying. But science would be substantially impacted. Therefore there is strong motivation to ensure

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More people needed!

Contact Scott Hughes if you want to join or start a task, or if you have work you want us to know about.