The LIST list of theory/computation challenges associated with LISA

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(unprioritized)

1. Development of methods for separating thousands of simultaneous wavetrains of diverse sorts from a single time series. This includes both abstract statistical theory and concrete algorithms designed around particular families of waveforms of likely interest in the LISA band. It also includes techniques for estimating spectra of residual confusion backgrounds of unfitted sources, in the context of the specific LISA mission architecture.

2. Studying the formation and evolution of nuclear star clusters around supermassive black holes. This includes computations of the rates of capture of compact stars, and orbital parameters of the captured stars.

3. Prediction of waveforms from compact objects spiralling into supermassive black holes ($m/M < 10^{-4}$ limit). First approximate waveforms (1-2 yr timescale), then development of radiation reaction formalism to give exact waveforms (8 yr timescale).

4. Understanding the fate of merging supermassive black holes in galactic mergers. What are the formation and merger histories of galaxies and their massive nuclear holes? What happens (mechanisms of energy loss, changes in orbital parameters) between the radius where the black hole gravity strongly dominates ($r = 0.1GM/\sigma^2$, say, where σ^2 is the galaxy's central velocity dispersion) and the radius where gravitational radiation takes over? What are the statistical predictions (and prediction uncertainties) for the fates and the rates of successive mergers of binaries of various masses at various redshifts?

5. Computing the emission from the merging massive black holes. This would involve both development of post-Newtonian semianalytical approches for the early phases, full numerical relativity for the late stages, and perhaps other techniques for intermediate stages. The success of ground-based gravitational wave detectors requires solution of many of these problems on a much shorter timescale than is required for LISA, so NASA may rely on NSF support for this work in the near term. Note however that the much higher signal-to-noise ratio of LISA for black hole mergers makes detection easier, but also in the long run demands higher accuracy of numerical solutions for precision tests of strong-field, highly dynamical relativity.

6. Astrophysical studies of tides and mass transfer in very short-period white dwarfs (using non-gravitational $\dot{P}$'s for many white dwarf binaries in LISA band). Better statistical characterization of the binary source populations in the LISA band, based on astronomical data.

7. Theoretical prediction of stochastic primordial background spectra due to inflation, phase transitions, brane worlds, and other sources involving new physics.