Characterising the Binary Confusion Signal

(i.e., characterising GW noise)

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Outline

- Motivation
- Definition
- Requirements of an analysis method for GW noise
- Existing methods
- Demonstration problems

Motivation

- Galactic binaries are a guaranteed signal for LISA
- Only ~10,000 out of ~30,000,000 are resolvable
- One man's confusion "noise" is another man's signal (spatial distribution, constituents, dN/df(?), binary evolution(?))
- Detection of primordial GW noise provides info about early universe and possibly exotic physics

Definition of GW noise

- Superposition of weak, independent, unresolved GW signals from many sources
- Characterised statistically (spectrum and spatial distribution)
- Astrophysical or cosmological (e.g., galactic binaries or inflationary GWs, ...)
- For galactic binaries, it what’s leftover when you “subtract out” the resolvable signals

Questions

1. How many signals can we resolve?
2. Where does confusion set in (at what freq and SNR)?
3. How does this change with observation time T?
4. How does the quality of the "subtraction" change with T?
5. How much spurious noise is introduced by the "subtraction"?
6. How does unresolvable GW noise change with T? (Gaussianity, spectrum, spatial distribution, ...)

Requirements of an analysis method

1. Distinguish GW noise from instrumental noise
2. Distinguish different types of GW noise from one another

How to do this?

1. Need a GW signal-only or instr noise-only measurement (e.g., cross-correlation for multiple detectors, symmetrised Sagnac for LISA)
2. Differentiate GW noise by their spatial distributions (e.g., anisotropy) and spectra

Existing methods (that I know of)

- Symmetrised Sagnac as noise calibrator:
  - Tinto et al., Hogan & Bender
- Modulation of anisotropic GW signal:
  - Allen & Ottewill, Ungarelli & Vecchio, Cornish
  - A, E, T correlations: Seto, Kudoh, Taruya ...
  - Cyclo-stationarity: Edlund, Tinto, et al.
  - Radon transform: Mohanty & Nayak, Hayama
- Spectral estimation methods: None(?) for LISA

Demonstration problems

1. Determine effectiveness of symmetrised Sagnac as instrumental noise calibrator
2. Determine effectiveness of an analysis method for determining the anisotropy of GW noise
3. Determine effectiveness of an analysis method for determining the spectrum of GW noise

1. Symmetrised Sagnac

- Implement Hogan & Bender prescription at low freq assuming known relation between instr noises in symmetrised Sagnac and Michelson
- Extend to the case where the relation between the instr noises is not known a priori
- Extend to high freqs where symmetrised Sagnac has GW contributions

[Start with white, isotropic GW noise, then make it colored and anistropic (problems 2 and 3). Evaluate effectiveness as function of SNR.]

2. Anisotropies

- Use correlation method of Seto et al. (or some other method) to analyse data corresponding to some simple anistropic GW noise distributions
- Determine the effectiveness of this method for extracting the distribution as a function of SNR
- Repeat for a more realistic anisotropic distribution produced by the galactic binaries. (Do the resolvable binaries need to be subtracted first?)
- Add isotropic GW noise and repeat. (Can the method discriminate between anisotropic and isotropic GW noise?)

3. Different spectra

- Determine optimal combination of TDI variables to estimate the amplitude and spectral index of a power-law spectrum for isotropic GW noise
- Extend to the case of a power-law spectrum for anisotropic GW noise
- Superpose two distributions with different power-law spectra. (Can the method discriminate between the two?)
- Extend to more complicated (realistic(?)) spectra

Current TRL levels

1. Symmetrised Sagnac:

   Level 0.5-1 (Ungarelli & Vecchio)

2. Anisotropies:

   Level 2 (Taruya et al.)

3. Different spectra:

   Level 0 (Nobody that I know of)

Final remark

- Characterising GW noise is not as hard (or sexy(?)) as resolving ~10,000 overlapping galactic binaries or doing matched filtering for EMRIs
- But still some non-trivial problems that need to be addressed