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LISA data analysis : an inverse problem method For Galactic binaries parameters estimation

ABSTRACT

The design, the construction, and the development of large interferometers such as LIGO and VIRGO (which occurs approximatively since the begining of the 2000s), for **gravitational wave detection**, makes it today a major issue for fields of interrests like astrophysics, cosmology, and fundamental physics. In addition to confirming Einstein's general relativity theorie, it will make possible to characterize some particular celestial bodies such as black holes binaries, neutrons stars binaries, or white dwarves binaries. It will enable to map galactic and extragalactic backgrounds, providing then a new comprehension of our universe and of the nature of its stars population.

For this purpose, **LISA** is an challenging project of a **giant space interferometer detector** which main interest, compare to existing ground interferometers, consists in its low frequency sensitivity thanks to its isolation from Earth seismic noises.

The LISA mission is an equilateral triangle of satellites constellation in heliocentric orbit linked together with 6 infrared lasers. During the year 2011 this design is called into question, for budgetary issues, but whatever its future results, LISA will provide us some key information to improve theorie with experience.

Knowing that all LISA usable information comes from its data streams at the output of its phasemeters, the correct analysis of these data is crucial. Among all the others steps of the mission indeed, and like others (micro-thrusters design for instance), the criticality degre is function of the difficulty.

In this context, this thesis subject is the galactic binaries parameters estimation with LISA. The interest of this type of waveforms is that are the best compromise between a general gravitational waveform including the main angular parameters, having in the same time a -relatively- simple model/template (less parameters than other waveforms). This double property allowed us to develop an original and robust data analysis method for parameters estimation of the wave. This method follows the comprehension of the wave template, LISA geometry, and research in the parameter space. In this way it is different from the statistics and probability based methods, exploring the parameter space with random guided by the maximum likelihood.

the philosophy of our research work was to develop a general and adaptable enough method, in order to be able to apply it later to more complex waveforms. This is the reason why it includes more advanced techniques than this waveform a priori requires. The method we have

developped take the form of a modular code written in Matlab langage, and in which each module corresponds to one among the six main steps of the hierarchichal parameters search :

1. **Low frequency heterodyn detection** of the signal fundamental frequency,
2. **Extraction of the signal envelope** after low-pass filtering,
3. Scan of the least mean squares space with dynamic triangular mesh,
4. Correction of LISA main ambiguity / symetry using its Doppler effect,
5. Optimisation / convergence step using BFGS algorithm and after local concavity condition check,
6. Amplitude estimation.

This research takes place starting from the more visible parameters (which are also the more important ones), and ending with the more implicit : ν (frequency), θ (ecliptic latitude), φ (ecliptic longitude), ψ (polarisation), ι (orbital inclination), h (amplitude) in this order.

The statistical studies we lead are mainly from two different natures : those aiming for testing our the noiseproof of our method on parameters estimation, and those striving for mesuring the precision reached on the angular location parameters. This last one also allowed us to check some symetries of the system and to quantify correlation between some parameters.

In the context of LISA-France data analysis researchs, and in the more gobal LSA data analysis context, it is possible to extend this method to other gravitational known waveforms.