Time-Delay Interferometry: Challenges to Modeling and Simulating Instrumental Imperfections for LISA

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Abstract

The Laser Interferometer Space Antenna (LISA) space mission aims to measure gravitational waves in the millihertz range. In two decades, three spacecraft, forming an almost equilateral constellation, will trail the Earth on its orbit around the Sun and exchange laser beams. These beams will be reflected upon free-falling test-massed hosted in each spacecraft, and then made to interfere. Unfortunately, the frequency instability of the on-board laser sources constitutes the dominant source of noise that enters the measurements. This laser frequency noise exceeds the expected gravitational signals by several orders of magnitude.

Time-Delay Interferometry (TDI) is a technique designed to reduce the laser frequency noise, by combining all interferometric signals in a precise way, in order to synthesize a virtual equal-arm interferometer. Extended algorithms are proposed to reduce other similar instrumental noises, which enter the measurements with a given correlation pattern. Simulations and analytic studies allow for a better understanding of the remaining instrumental artifacts after TDI has been applied, and provide insight on how to reduce those.

In this talk, I will present the various challenges to modeling and simulating the remaining instrumental noises. I will go over the different stages of the TDI algorithms, and focus on the unexpected effect of time-varying armlengths and on-board anti-aliasing filters on the residual laser frequency noise. I will show that a constrained design of the filters and a dedicated offline treatment can help reduce this coupling noise. I will show that simulations using the prototype mission simulator LISANode validate these results. To conclude this talk, I will show that this recipe can be applied to other sources of noise, in order to obtain insight on how to reduce residual noises.