Time-Delay Interferometry: Modeling and Simulating Laser Frequency Noise in LISA

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Abstract

The Laser Interferometer Space Antenna (LISA) space mission aims to measure gravitational waves in the millihertz range. The frequency instability of the on-board laser sources constitutes the dominant source of noise that enters the measurements, exceeding 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. In the continuity of TDI, extra combinations are proposed to reduce other instrumental noises, based on the correlation pattern with which they enter the measurements.

In this talk, I will show that simulations and analytic studies allow for a better understanding of the remaining instrumental noises after these algorithms have been applied, and provide insight on how to reduce them. I will first go over the different stages of the TDI algorithms, with a particular focus on the laser frequency noise and the computation of the residuals under realistic assumptions. I will show that an unexpected coupling between the time-varying armlengths and the on-board anti-aliasing filters arises, worryingly decreasing the performance of the laser noise reduction. However, this new noise depends strongly on the filter characteristics. I will propose a well-designed filter and a dedicated offline treatment that help reduce this new noise. In addition, I will show that simulations, using the prototype mission simulator `LISANode`, are able to validate these results. To conclude this talk, I will show that this recipe can be applied to other sources of noise, such as clock noise, in order to obtain insight on how to reduce residual instrumental noises.