Observing the Dark Side of the Universe with LISA

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For the LISA International Science Team

Abstract

LISA is a joint NASA/ESA space mission designed to measure gravitational waves in the band from 0.3 mHz to 0.1 Hz, a band that is richly populated by strong sources of gravitational waves. Signals will come from a wider range of sources: massive black holes merging in galaxies at all distances; stellar-mass compact objects captured by massive black holes; ultra-compact Galactic binaries; and possibly other sources including relics of the Big Bang. These sources convey detailed information addressing a wide range of physics and astrophysics: the history of galaxies and black holes in the universe; general relativity and the behavior of space-time; precision measurements of luminosity distances, the physics of dense matter and stellar remnants; and possibly new physics associated with events in the very early universe. We will survey the science goals of LISA and discuss their impact on physics and astrophysics.

The Science

LISA signals record a richly populated universe of strong sources

- Gravity Waves (GW) are not attenuated
- GW sources are "standard sirens" - Luminosity distance measurements with 1% accuracy - Black holes have mass and spin & radiate coherently - GW sources are strong - High signal-to-noise allows precision measurements

High SNR waveforms carry precision information about the emitting systems

- Merger signals have high SNR even in a single wave cycle
- Absolute, physical calibration using gravitational wave background

Data Analysis

Mock LISA Data Challenge

- Friendly competition to develop tools and methods for LISA data analysis and demonstrate capabilities
- Used a sophisticated simulation of LISA data stream including realistic instrument response, realistic spacecraft orbits, Time-Delay Interferometry (TDI), and signals from millions of individual gravitational wave sources
- Demonstrated conclusively that tens of thousands of sources can be individually identified and characterized in the LISA data stream
- Started in 2005. Currently in round 3
- More than 23 groups participating from 9 different countries

Histograms of WD binary SNRs + parameter estimation errors for 19,324 resolved sources

Electromagnetic Counterparts

- Not guaranteed, but if detected yields exciting scientific return
- Host galaxy identification provides unique information on galaxy-BH co-evolution
- Host galaxy identification allows precise determination of distance-redshift relation
- LISA will provide few-degree error boxes and time of merger weeks-months before event
- Error boxes shrink to degree or sub-degree size as signal-to-noise increases and merger approaches

LISA Mission Quick Facts

- Frequency Range: 0.1 mHz - 0.1 Hz
- Mission Scopes: Laser metrology between six fiducial masses on three spacecraft

For more information see: http://www.srl.caltech.edu/lisa/mission_documents.html

Science Questions

- Is there a large population of ultra-compact binaries in the Galaxy?
- How did compact binaries form and what is the outcome of the common-envelope phase?
- What is the nature of the fundamental physical interactions in compact binaries?
- How are compact binaries distributed in the Galaxy and what does that tell us about the formation and evolution of the Galaxy?