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Laser Interferometric Gravitational Wave Detection in Space and Structure Formation in the Early Universe† ⋆

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Abstract The laser interferometric gravitational wave detection in space is an important and realistic approach to studying some key problems of astronomy and cosmology, such as the stellar evolution and galactic formation in the early universe, the co-evolution of black holes and galaxies, etc. After performing two stages of the Advance Research Project of Space Science commissioned by the Chinese Academy of Sciences, and by weighing the feasibility of technology and the foresight of science, we have selected the gravitational wave sources including the high-redshift intermediate-and-large mass binary black hole mergers, and the intermediate-mass black holes in clusters and other dense dynamic environments, as the main scientific objectives, and given a preliminary design for the project of Chinese space gravitational wave detection in the frequency range from millihertz to hertz. Based on this, here we introduce briefly the science of the space gravitational wave detection, as a new measure of astronomical observations, as well as the scientific objectives and potential detectivity of the design for the Chinese space gravitational wave detection mission.

Key words gravitational wave—ΛCDM hierarchical structure formation picture—intermediate mass black hole—binary black hole coalescence

1. INTRODUCTION

Along with the continuous development of observational measures of astronomy in different electromagnetic wavebands, the modern astronomy and cosmology have gradually brought the human sense of touch to the early universe, while the observational and theoretical studies of astrophysics have reached a unprecedented level. Thus, how to understand the origin of the rich structures in the present universe becomes the predominant direction for developing astrophysics and cosmology in decades to come[1], including the formation and evolution of the 1st-generation stars, the formation of early galaxies, the co-evolution history of black holes and galaxies in the cosmological scale, the essence of dark matter and dark energy, and their roles played in the cosmic evolution, etc., which are the main scientific objectives and motives of the various ground-based and space telescopes of the world in operation or in development (TMT, GMT, JWST, EUCLID, ALMA, SKA, FAST, LSST, and 21cm astronomy antenna array, etc.).

Observations indicate that the supermassive black holes exist in the centers of both normal and active galaxies, and that the velocity dispersion of stars in the galactic bulge is closely correlated with the mass of the supermassive black hole in the galactic center, i.e, the $M-\sigma$ relation, which is one of the most important discoveries from the end of the 20th century to the 21th century[2−4]. This $M-\sigma$ relation reveals that a co-evolution history exists between the galaxy and its central black hole. The observations on the quasars at the