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DEPLOYMENT OF THE ASTROD-GW AND OTHER GRAVITATIONAL WAVE MISSION FORMATIONS

Abstract

Space Gravitational Wave (GW) mission proposals often use constellation or formation flying for the required interferometry implementation. The spacecraft of most of these mission proposals go to deep space and many have Earthlike orbits around the Sun. ASTROD-GW, Big Bang Observer and DECIGO have spacecraft distributed in Earthlike orbits in formation. The deployment of orbit formation is an important issue for these missions. ASTROD-GW (Astrodynamical Space Test of Relativity using Optical Devices optimized for Gravitation Wave detection) is to focus on the goal of detection of GWs. The mission orbits of the 3 spacecraft forming a nearly equilateral triangular array are chosen to be near the Sun-Earth Lagrange points L3, L4 and L5. The 3 spacecraft range interferometrically with one another with arm length about 260 million kilometers with the scientific goals including detection of GWs from Massive Black Holes (MBH), and Extreme-Mass-Ratio Black Hole Inspirals (EMRI), and using these observations to find the evolution of the equation of state of dark energy and to explore the co-evolution of massive black holes with galaxies.

In this paper, a 4th-order compact finite-difference method for the multi-body two-point boundary-value problem is proposed to design the transfer orbits. The results show that the optimal delta-Vs and propellant ratios are within 2.5 km/s and 0.55, respectively, for the transfer orbits of the ASTROD-GW spacecraft from the separations of the launch vehicles at low-Earth orbit (LEO) to the mission orbits with 1 to 3 inclination to the ecliptic plane. This method can also be applied to adjust the initial velocity of the mission orbits to conduct the geodetic measurement for 20 years within the specified ranges of the arm lengths and their differences. We also apply this numerical method to the deployment of other GW mission formations, and make comparisons in terms of total spacecraft weight and the measurement sensitivity of GW frequency band.