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Author: Prof. Jianhua Zheng
1: National Space Science Center, Chinese Academy of Sciences;2: University of Chinese Academy of Sciences, China

Mr. Youliang Wang
1: National Space Science Center, Chinese Academy of Sciences;2: University of Chinese Academy of Sciences, China
Dr. Mingtao Li
1: National Space Science Center, Chinese Academy of Sciences; 2:University of Chinese Academy of Sciences, China

ORBITAL AND FORMATION OPTIMIZATION FOR SPACE GRAVITATIONAL WAVES OBSERVATORY MISSION

Abstract

Gravitational Waves (GW) is one of the major predications in the Einstein's General Theory of Relativity, which are the ripples in the curvature of spacetime. As the brand new window to understand the universe, the observation and direct measurements GW will lead to the great revolution of Astronomy and physics. **Spacecraft formation flying with laser interferometry technique** is an enabling and promising research to detect low-frequency gravitational waves, and several space-based interferometers are being developed, including LISA mission by European Space Agency (ESA), "Tianqin" plan by Sun Yat-sen University (SYSU), "Taiji" project by Chinese Academy of Sciences (CAS), and DECIGO by Japan. One of the key technologies is to design an extremely high stability **equilateral triangle formation** in a long operational phase duration.

In this paper, the orbital design and optimization for space gravitational waves detection is studied. Firstly, various perturbations are analyzed, and the perturbed orbital dynamics model considering the **third-body perturbations** from Earth, Venus and Jupiter is established. Then, an optimization model with twelve variables is derived with the relative motion and formation design method based on the orbital element, while a number of **mission requirements** are considered in the objective function, such as the arm length rate, breathing angle, and maximum distance from Earth center to formation center. Afterwards, a hybrid approach of **Differential Evolution** (DE) algorithm and **Sequence Quadratic Programming** (SQP) is proposed to optimize the objective function, which is fast in the convergence and robust in the best value.

Finally, compared with the LISA designing result, the simulation results show that the hybrid approach is effective, and can obtain the feasible solution efficiently. Besides, the influence of injecting time, operational phase durationarm length and initial trailing angle on the stability of equilateral triangle is analyzed, which will have some reference value in the future mission.