令和4年度

京都大学大学院理学研究科

Ｄ３発表会アブストラクト

（2022年7月28日）

物　理　学　第　二　分　野

D3 発 表 会

日時　　　令和4年7月28日（木）13時30分～
場所　　　理学研究科5号館　525号室+オンライン
発表時間　15分＋5分（質問）

《目　次》

Transient resonances in extreme-mass-ratio inspirals

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Abstract We study the impact of tidal resonances on extreme-mass-ratio inspirals due to a nearby tertiary. These resonances contain information about the next closest BH(s) or stars to EMRI systems and may hold important clues about the formation of galaxies. The work outlined in thesis shows in-depth studies of tidal resonances and creating resonant waveform models, which is crucial in enabling the LISA mission to achieve its targeted science goals.

We witnessed the first direct detection of gravitational waves (GW) in 2015 by LIGO interferometers. The space-based interferometers like LISA will explore the sources emitting GWs in the mHz frequency range. Extreme-mass-ratio inspirals (EMRIs) are one of the most exciting and promising target sources for space-based interferometers. Observing their emitted GWs will offer stringent tests on the general theory of relativity, and provide a wealth of information about the dense environment in galactic centers. To unlock such potential, it is necessary to correctly characterize EMRI signals. The current models are focused on isolated EMRI systems. However, EMRIs may exist within noisy environments (presence of accretion disks or nearby stars/black holes), and their evolution can therefore deviate from the pure vacuum predictions of general relativity. If not accounted for, environmental effects will introduce parameter estimation bias, spoiling precision GW astrophysics. In a recent work [1], tidal resonances in binary orbital evolution induced by the tidal field of nearby stars or black holes have been identified as being potentially significant in the context of EMRIs. These resonances occur when the three orbital frequencies describing the orbit are commensurate. During the resonance, the orbital parameters of the small body experience a "jump" leading to a shift in the phase of the gravitational waveform. In our work [2,3], we treat the tidal perturber as stationary and present a first study of how common and essential such resonances are over the entire orbital parameter space. We find that a large proportion of inspirals encounter a low-order resonance in the observationally important regime. While the "instantaneous" effect of a tidal resonance is small, its impact on the accumulated phase of the gravitational waveform of an EMRI system can be significant due to its many cycles in the band; we estimate that the effect is detectable for a significant fraction of sources. We also provide fitting formulas for the induced change in the constants of motion of the orbit due to the tidal resonance for several low-order resonances. Dephasing implies that resonances can impact parameter inference, and therefore the scientific outcome, if not properly modeled. To analyze the resonant signals, accurate templates that correctly incorporate the effects of the tidal field are required. Therefore, we explore how to model resonances and develop an efficient implementation. The evolution through resonances is obtained using a step function, whose amplitude is calculated using an analytic interpolation of the resonance jumps. We benchmark this procedure by comparing our approximate method to a numerical evolution. We find that there is no significant error caused by this simplified prescription, as far as the astronomically reasonable range in the parameter space is concerned. Further, we use Fisher matrices to study both the measurement precision of parameters and the systematic bias due to inaccurate modeling. Modeling of self-force resonances can also be carried out using the implementation presented in our study, which will be crucial for EMRI waveform modeling.

References

[1] B. Bonga, H. Yang, and S. A. Hughes, Phys. Rev. Lett.123, 101103 (2019).
[2] P. Gupta, B. Bonga, A. J. K. Chua, and T. Tanaka, Phys. Rev. D 104, 044056 (2021).
[3] P. Gupta, L.Speri, B. Bonga, A. J. K. Chua, and T. Tanaka, e-Print: 2205.04808 [gr-qc].