Internship in ESA’s Advanced Concepts Team

on

Consequences of the maximum principle in General Relativity

Topic description

General relativity is a most accurate description of gravitation and modifies the classical laws of mechanical motion discovered by Newton. This is especially true around strong gravitating objects such as neutron stars or black holes [2]. What's more, it is even possible in some circumstances for an external system to harvest the energy stored in the black hole (Penrose process) [3]. Imagining that we could reach such astrophysical systems, what kind of optimal trajectories should a rocket follow in such spacetimes? Can it harvest the energy of the black hole to its advantage?

The goal of this project is to use Pontryagin's maximum principle [1] to explore those questions by analyzing the optimal motion of a rocket in different black hole spacetimes and see if the optimal control point of view offers a new way to look at the geometry of spacetime in General Relativity.

Candidate's tasks

- Properly formulate the optimal control problem in General Relativity, using Pontryagin's maximum principle.
- Explore, solving the related two-point boundary value prioblem (TPBVP), the optimal trajectory of rocket in a black hole spacetime.

The ideal candidate

Mandatory:

- Background in General relativity and Optimization techniques.
- Programming skills in python.

References

[1] Pontryagin, Lev Semenovich. Mathematical theory of optimal processes. Routledge, 2018.

[2] Weinberg, S. (1973). Gravitation and cosmology: principles and applications of the general theory of relativity. New York: Wiley.

[3] Lasota, J. P., Gourgoulhon, E., Abramowicz, M., Tchekhovskoy, A., & Narayan, R. (2014). Extracting black-hole rotational energy: The generalized Penrose process. Physical Review D, 89(2), 024041.