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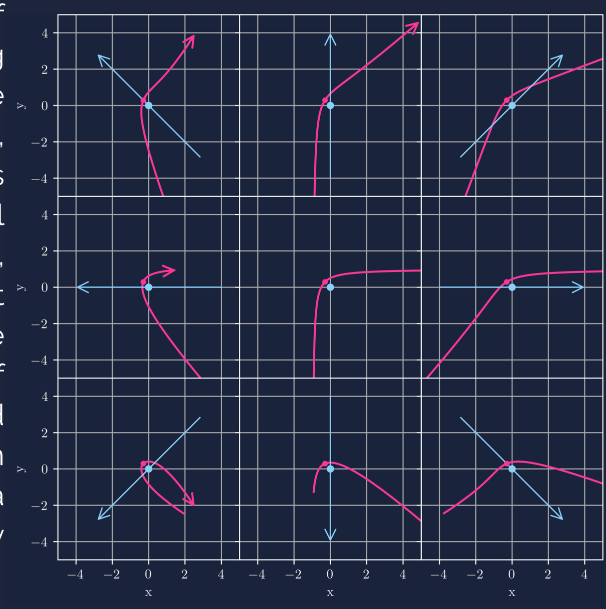
EXPLORING INTERPLANETARY TRAVEL

PLANNING AND OPTIMISING A MISSION FROM EARTH TO SATURN'S MOON ENCELADUS

INTRODUCTION & GRAVITY ASSIST MANEUVERS

Reaching distant destinations like Enceladus, a moon of Saturn that may host life, requires careful mission planning to minimise fuel consumption. One of the most effective techniques for achieving this are **gravity assist maneuvers**, which use a planet's gravity to modify a spacecraft's trajectory and velocity without needing additional propellant. By strategically **flying past planets** like Venus, Mars, or Jupiter, a spacecraft can gain or lose speed, adjust its direction, and ultimately reach Enceladus more efficiently than with direct propulsion alone. Examples of such maneuvers, with different spacecraft velocities and directions relative to the planet, are shown in the graph on the right. This study aims at designing and optimising a trajectory using Python. The ultimate goal is to use gravity assists to **reduce** the **total fuel required** for the mission.



DESIGNING A NEW MISSION

In order to create a new mission, we first analyse and recreate the **Cassini-Huygens** mission (1997), which used gravity assists from Venus, Earth, and Jupiter to reach Saturn efficiently. Since its flyby sequence and timing are well-documented, reconstructing the trajectory is straight-forward. Using Python, we calculate each transfer orbit between gravity assists using **Lambert's problem**. Then, we compute the total fuel requirement and plot the spacecraft trajectory, as shown on the right. Fortunately, our calculated trajectory strongly resembles the real one, suggesting that our reconstruction is accurate. Unlike the reconstruction of the Cassini mission, here we have no predetermined trajectory. Thus, we must determine the optimal flybys, maneuvers, and timing to minimise fuel consumption. However, this problem is highly **non-linear** and exhibits **chaotic** behavior. Small changes in flyby timing drastically alter the entire mission plan, making optimization **non-trivial**. To address this, we use a combination of two powerful algorithms to search for an optimal trajectory: **COBYLA,** a local optimization algorithm, and **MBH,** a global optimization method to escape local minima. This approach resulted in a fuel-efficient trajectory to Enceladus (plotted on the left), bringing us closer to uncovering the secrets of our Solar System.