STUDY OF THE GRAVITATIONAL CAPTURE AT MERCURY IN THE ELLIPTIC RESTRICTED THREE-BODY PROBLEM

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ABSTRACT

Gravitational capture is an important characteristic of N-body ($N \geq 3$) dynamical systems. It occurs when the eccentricity of the osculating ellipse around one celestial body is altered from greater than 1 to less than 1 without use of any propulsive system. The gravitational capture is a temporary capture, but it costs less fuel consumption to accomplish the permanent capture comparing with traditional Hohmann transfer[1-3]. Therefore it is a useful phenomenon interplanetary low energy transfer (LET).

In this paper, we study the gravitational capture at Mercury in the elliptic restricted three-body problem (ERTBP), due to the high eccentricity of Mercury's orbit.

Firstly, using the analysis about the mechanical characters in the space near Mercury, the corrected ratio of the radial force, *k*, is proposed. It describes the proportion of the radial force in two-body model to that in the ERTBP, which can help us construct the relationship between the capture eccentricity in the ERTBP, e^*, and that in two-body model, e. The relationship between them is as follows.

$$e^* + 1 = k(e+1) \quad (1)$$

The parametric analysis reveals the effect of Mercury true anomaly on *k*.

Considering the restriction of the time-of-flight, we propose the minimum capture eccentricity $e_{\min}$ of the capture point (200km periherm altitude). As we know, the capture eccentricity is significant for capture. Small capture eccentricity represents a higher capture quality, because it implies small capture velocity and osculating orbit closer to circle. Therefore the capture eccentricity can be used as an effective index to evaluate the quality of the gravitational capture points. Inverse time integration displays the special regions on the sphere of capture to possess the global minimum $e_{\min}$, which denote the optimal regions of the gravitational capture (see Fig. 1).

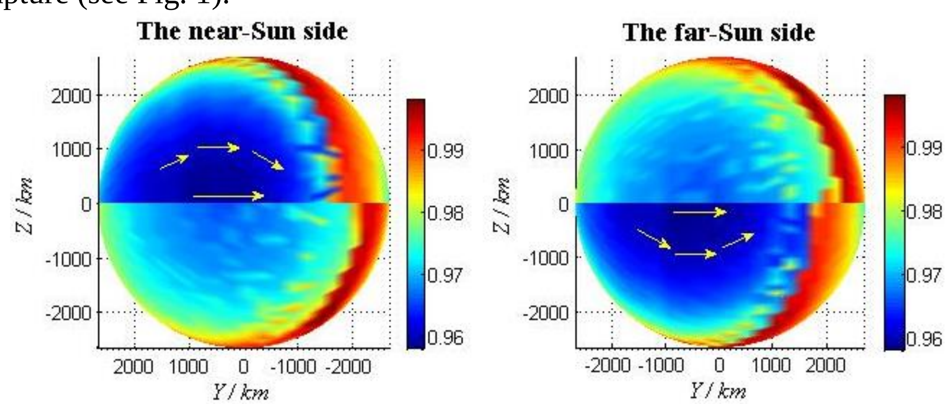

Fig. 1 The special regions on the near-Sun side and the far-Sun side of the sphere of capture

We use the longitude of ascending node Ω, the orbit inclination i and the argument of perilune ω to describe the sphere of capture. Fig.1 is the scenario where Ω=90°. The left figure is viewed from the Sun and the right one is viewed from the far side of Mercury. The dark blue regions represent the global minimum $e_{\min}$, and the yellow arrows indicate the velocity direction of capture points. Limited by space, we only demonstrate this scenario, but from the figures, we can find the special regions distribute on the near-Sun side and the far-Sun side of the sphere of capture, and only the direct orbit in these region corresponds to the global minimum $e_{\min}$.The distribution of k on the sphere of capture can explain this phenomenon. In addition, numerical result also reveals, if Mercury is at the vicinity of perihelion, lower values of the global minimum $e_{\min}$ occur in the special regions (see Fig. 2).

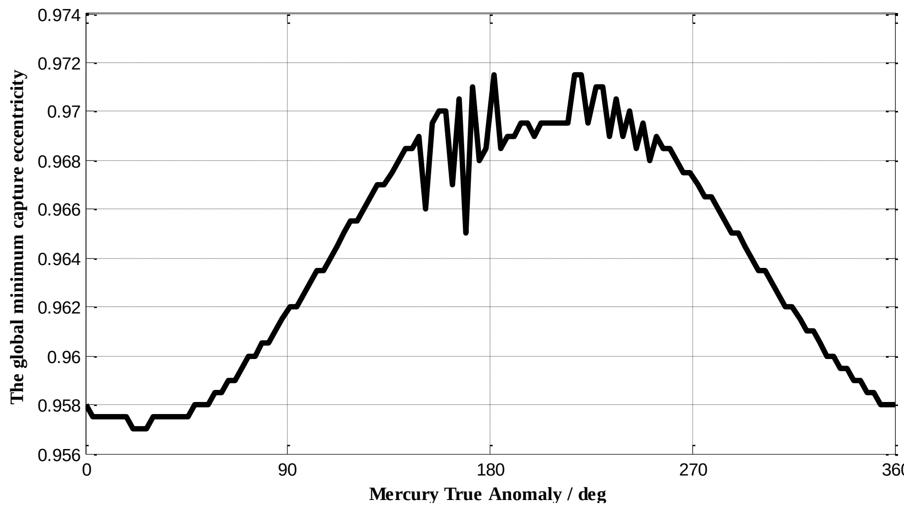

Fig. 2 The global minimum $e_{\min}$ with different Mercury true anomaly

Therefore perihelion is optimal epoch of the gravitational capture. Using Eq. (1), the corrected minimum capture eccentricity $e^*_{\min}$ is also proposed, which integrates the mechanical characters of the capture point into $e_{\min}$. Numerical methodology will as well illustrate the distribution of the special regions for the global minimum $e^*_{\min}$.

At last, we apply our results to the design of interplanetary LETs and give some constructive suggestions.

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