Finding a New Route to the Moon using Paintings

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Abstract

A new theory of space travel using low energy chaotic trajectories was dramatically demonstrated in 1991 with the rescue of a Japanese lunar mission, getting its spacecraft, Hiten, to the Moon on a different type of route. The design of this route and the theory behind it is based on finding regions of instability about the Moon. This approach to space travel was inspired by a painting of the Earth-Moon system which revealed these regions and the new chaotic trajectories. The brush strokes in the painting revealed the dynamics of motion which are verified by the computer. The painting itself can be used as a way to uncover dynamics in the field of celestial mechanics that cannot be easily found my standard mathematical methods.

A New Approach to Space Travel

The classical route from the Earth to the Moon uses the Hohmann transfer, named after the German engineer Walter Hohmann [1]. Let's assume a spacecraft is to go from a circular orbit about the Earth to a circular orbit about the Moon. The Hohmann transfer is a nearly straight path, actually half of a highly eccentric ellipse, from the circular orbit about the Earth to the circular orbit about the Moon. To leave the orbit about the Earth, the spacecraft briefly fires its engines to gain the necessary velocity, then coasts to the Moon in three days. At the Moon, it needs to be captured into the lunar circular orbit. To do that it needs to slow down by about one kilometer per second by firing its engines again. This is called a capture maneuver. It is risky to do and also uses a lot of fuel, which is expensive. Is there a better way to do this?

It would be desirable to go into orbit about the Moon, automatically, without needing to slow down and firing the engines. This is called ballistic capture. Prior to 1986 it was thought to be impossible to do. If it could be done, however, then a spacecraft could go to the Moon and then into orbit with much less fuel and more safely. I got interested in this problem at that time when I was working at NASA's Jet Propulsion Laboratory. I knew that ballistic capture may be possible due to my training as a mathematician, from New York University's Courant Institute. My specialty was celestial mechanics and chaotic dynamics. I figured that there may be a way to utilize the gravitational forces between the Earth and Moon to achieve ballistic capture, but with a longer flight time. In early 1986, I was given three months to try and find a way to achieve ballistic capture for a robotic lunar mission study, called LGAS (Lunar Get Away Special). The ability of achieving ballistic capture would provide a new approach for how spacecraft could go orbit about the Moon with many exciting possibilities. Due to the time allotted, and the complexity of the problem, with nothing in the literature, I felt it was not going to be possible to figure out.

Dynamic Channels, Chaos, and Paintings

To gain an insight into the problem, I sought out help from my other profession as an artist doing paintings. The hunch I followed was something that is evident from looking at a Van Gogh painting, for example,

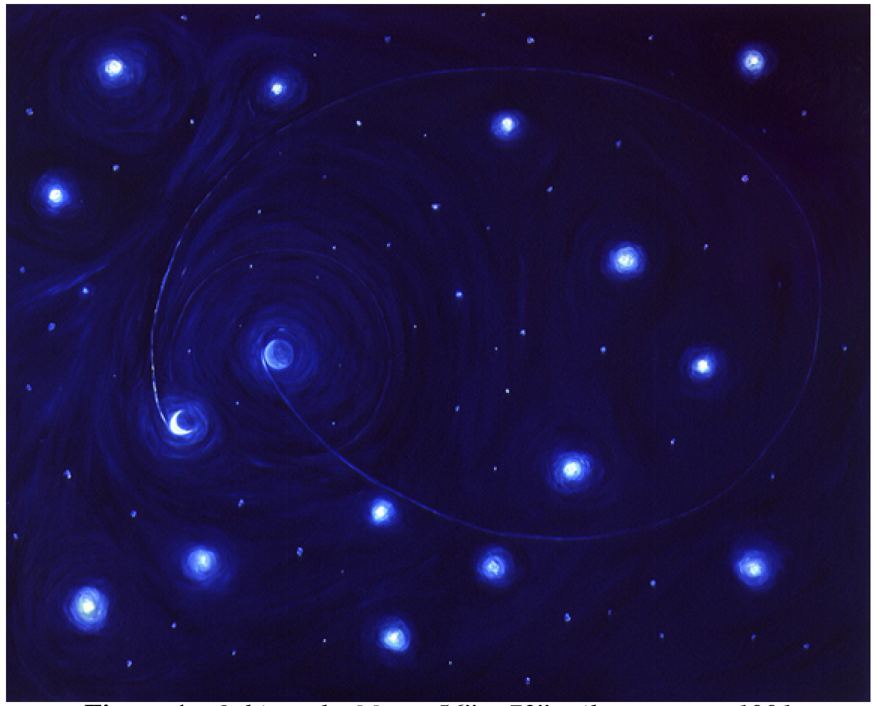

Figure 1 : *Orbit to the Moon,* 56" × 72"*, oil on canvas, 1991*

Starry Night. The brush strokes he used are applied very quickly, in a spontaneous manner, being guided by intuition. His paintings reveal a deeper aspect to reality. I felt that if I used his painting style, and painted the Earth-Moon system, the brush strokes may reveal patterns that would give insight into ballistic capture trajectories. The painting I did revealed a region about the Moon that seemed to lie at the boundary of the gravitational field of the Earth and Moon, allowing a trajectory to delicately be captured about the Moon ballistically, which appeared to be a chaotic, that is, sensitive, process, see [1, Figure 6.2]. When I went to the computer and simulated this, I found the ballistic capture transfer and the regions supporting it about the Moon, called weak stability boundaries [1,2]. From a mathematical perspective, these boundaries are associated to a complex network of surfaces called invariant manifolds which define dynamic channels where these chaotic trajectories can move [2,3].

However, a more useful and important ballistic capture transfer was found a few years later in 1990. It was found in order to resurrect a failed Japanese lunar mission and get its spacecraft, Hiten, to the Moon in 1991 [1]. This transfer utilizes the more complex four-body problem in celestial mechanics, where one has to take into account the gravitational interactions of four bodies: Earth, Moon, spacecraft and the Sun. The flight time is only four months making it far more useful. A painting of this transfer is shown in Figure 1. The trajectory starts near the Earth, travels out about 1.5 million kilometers from the Earth where it encounters the boundary of the gravitational fields between the Earth and Sun. In this region, the spacecraft is essentially balancing on the gravitational fields of these two bodies, like a surfer would balance on a wave. It then arcs back to go to ballistic capture about the Moon at an analogous boundary, due to the balancing of the Earth and Moon gravitational fields. As it falls towards the Moon, one can see the brush strokes defining the gravity fields.

These pathways and the underlying theory were inspired by brush strokes in a painting.

References

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