Gravitational slingshot effect

Gravitational Slingshot is the use of the planet's gravitational field to accelerate the spacecraft, throwing it to the next target, that is, the planet as a "gravitational booster".

The use of gravitational slingshots enables us to explore all planets within Pluto. In space dynamics and space dynamics, the so-called gravitational boost (also known as gravitational slingshot effect or orbiting planets) uses the relative motion and gravity of planets or other celestial bodies to change the orbit and speed of spacecraft to save fuel, time and planning costs.

Gravitational boost can be used not only to accelerate the aircraft, but also to reduce the speed of the aircraft.

引力弹弓效应

引力弹弓就是利用行星的重力场来给太空探测船加速，将它甩向下一个目标，也就是把行星当作“引力助推器”。

利用引力弹弓使我们能探测冥王星以内的所有行星。在航天动力学和宇宙空间动力学中，所谓的引力助推（也被称为引力弹弓效应或绕行星变轨）是利用行星或其他天体的相对运动和引力改变飞行器的轨道和速度，以此来节省燃料、时间和计划成本。

引力助推既可用于加速飞行器，也能用于降低飞行器速度。

\_\_\_\_\_\_\_\_百度百科

行星的引力助推作用能够改变飞行器相对于太阳的速度，但由于必须遵守能量守恒定律，所以它和行星间的相对速度并没有改变。在飞行器第一次从远距离接近行星时，产生的运动效果就像该飞行器被行星反弹开了。科学家们称这种情况为弹性碰撞，不过两者之间并没有发生实体接触。

假设你是一个静止的观测者，那么你就会看到：行星以速度U向左运动，飞行器以速度v向右运动。由于两者的运动方向相反，所以当飞行器运行至行星右侧时，其轨道就会发生弯曲，进而以U+v的相对速度（相对于行星表面）运行。当飞行器脱离环行星轨道时，其相对于行星表面的速度仍然为U+v，但是此时的运动方向与原来相反——即向左运动。而由于行星本身正以速度U向左运动，所以在观测者看来，飞行器正以2U+v的速度向左运行——其速度提升幅度为2U，即行星运行速度的两倍。

由于未考虑轨道的各种细节，所以这是一个过于简单化的模型。但是事实证明如果飞行器沿双曲线轨道运行，则其无需启动引擎即可从相反方向离开行星，同时只要其脱离了该行星引力的控制，那么它就可以获得2U的速度增量。

\_\_\_\_\_\_\_\_百度百科

The gravitational boost of a planet can change the speed of an aircraft relative to the sun, but the relative speed between it and the planet remains unchanged because the law of conservation of energy must be observed. When an aircraft first approaches a planet from a long distance, it produces a motion effect similar to that of the aircraft bounced off by the planet. Scientists call this an elastic collision, but there is no physical contact between the two.

Assuming you are a stationary observer, you will see that the planet moves to the left at speed U and the aircraft moves to the right at speed v. Because the two are moving in opposite directions, when the vehicle moves to the right side of the planet, its orbit will bend and then move at the relative speed of U+v (relative to the planet surface). When the spacecraft is out of the orbit of the annular planet, its velocity relative to the surface of the planet is still U+v, but the direction of motion at this time is opposite to the original - that is, to the left. Since the planet itself is moving to the left at a speed of U, it seems to the observer that the spacecraft is moving to the left at a speed of 2U+v, with a speed increase of 2U, which is twice the speed of the planet.

This is an oversimplified model because the details of the orbits are not taken into account. However, it has been proved that if the vehicle travels in hyperbolic orbit, it can leave the planet in the opposite direction without starting the engine, and as long as it is out of the control of the planet's gravity, it can obtain a 2U speed increment.

The theory seems to violate the laws of conservation of energy and momentum, but this is because we neglect the influence of aircraft on planets. The linear momentum obtained by an aircraft is numerically equivalent to the linear momentum lost by a planet, but due to the huge mass of the planet, the effect of such loss on its velocity can be neglected.

The encounter between spacecraft and planets in real space actually has two dimensions. In the case provided by the above theory, vector gain is needed because of the need to improve the speed of the aircraft.

At the same time, gravitational boost can also be used to reduce the speed of aircraft. Sailor 10 in 1974 and Messenger in 1974 slowed down by gravitational boost, both of which were detectors heading for Mercury.

If the aircraft needs more acceleration, the most economical way is to ignite the rocket when it is near the arch of the planet. The acceleration provided by rocket boost is always the same, but the change of kinetic energy caused by rocket boost is proportional to the real-time velocity of the aircraft. So in order to get the maximum kinetic energy from the rocket boost, the rocket must ignite when the speed of the vehicle is the highest, that is, when it is near the arch point. This technique has been explained in detail in the Albert effect.

该理论看似违背了能量守恒和动量守恒定律，但这是由于我们忽略了飞行器对行星的影响。飞行器获得的线性动量在数值上等同于行星失去的线性动量，不过由于行星的巨大质量，使得这种损失对其速度的影响可以忽略不计。

在现实宇宙空间中飞行器与行星的相遇实际上会出现两个维度上的因素。在上述理论所提供的案例中，由于要求提高飞行器的速度，所以需要实现的是矢量增益。

同时，引力助推也能被用于降低飞行器的速度。1974年的水手10号以及后来的信使号即通过引力助推实现了减速，两者都是飞往水星的探测器。

如果飞行器需要获得更多的加速度，最经济的做法是当其位于行星近拱点时点燃火箭。火箭助推为飞行器提供的加速度总是相同的，但是它引起的动能变化则与飞行器的实时速度成正比。所以为了从火箭助推中获得最大动能，火箭必须在飞行器速度最大时——即处于近拱点时点火。在奥伯特效应中该技术得到了详细阐释。

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