Propellant-less Space Travel with Tethers : Swimming in Space using an Asteroid's Gravity Gradient

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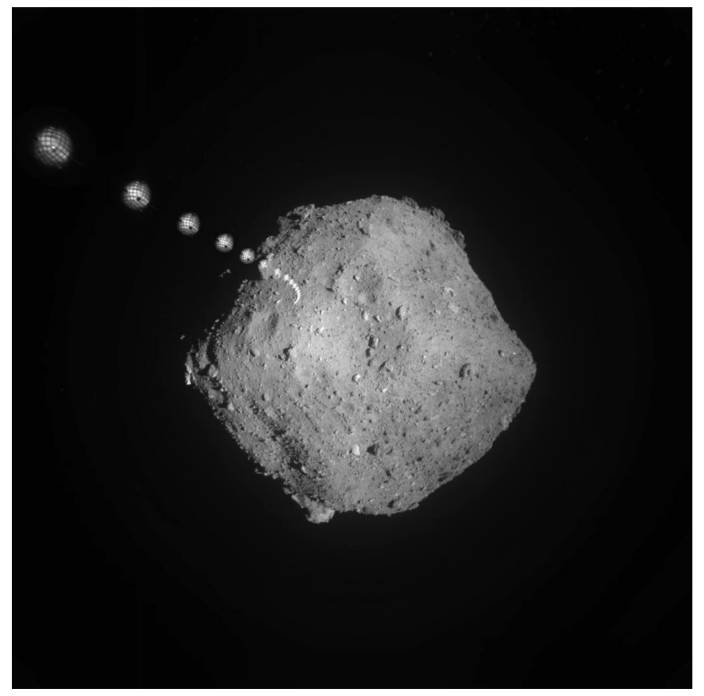
The thesis demonstrates the possibility of propellant-less space travel with a tether, two masses separated by a variable length. By computer simulations, we show how to lengthen and shorten the tether to swim in space using the gravity gradient of a nearby asteroid, moon, or planet.

JAXA Spacecraft Hayabusa at asteroid Ryugu. (2020)



Artist rendition of TiPS(Tether Physics and Survivability) Tethered spacecraft in Earth Orbit. (1990s)

$$T = \frac{1}{2} m_1 \dot{\vec{r}}_1 \cdot \dot{\vec{r}}_1 + \frac{1}{2} m_2 \dot{\vec{r}}_2 \cdot \dot{\vec{r}}_2$$

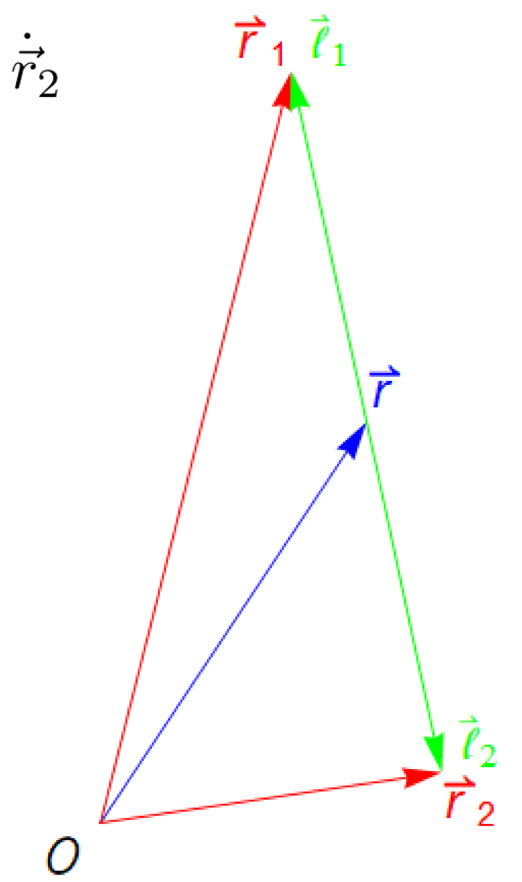
$$V = -GM \left(\frac{m_1}{r_1} + \frac{m_2}{r_2} \right)$$

$$\mathcal{L} = T - V$$

$$\frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{r}} = \frac{\partial \mathcal{L}}{\partial r}$$

$$\frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{\theta}} = \frac{\partial \mathcal{L}}{\partial \theta}$$

$$\frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{\phi}} = \frac{\partial \mathcal{L}}{\partial \phi}$$



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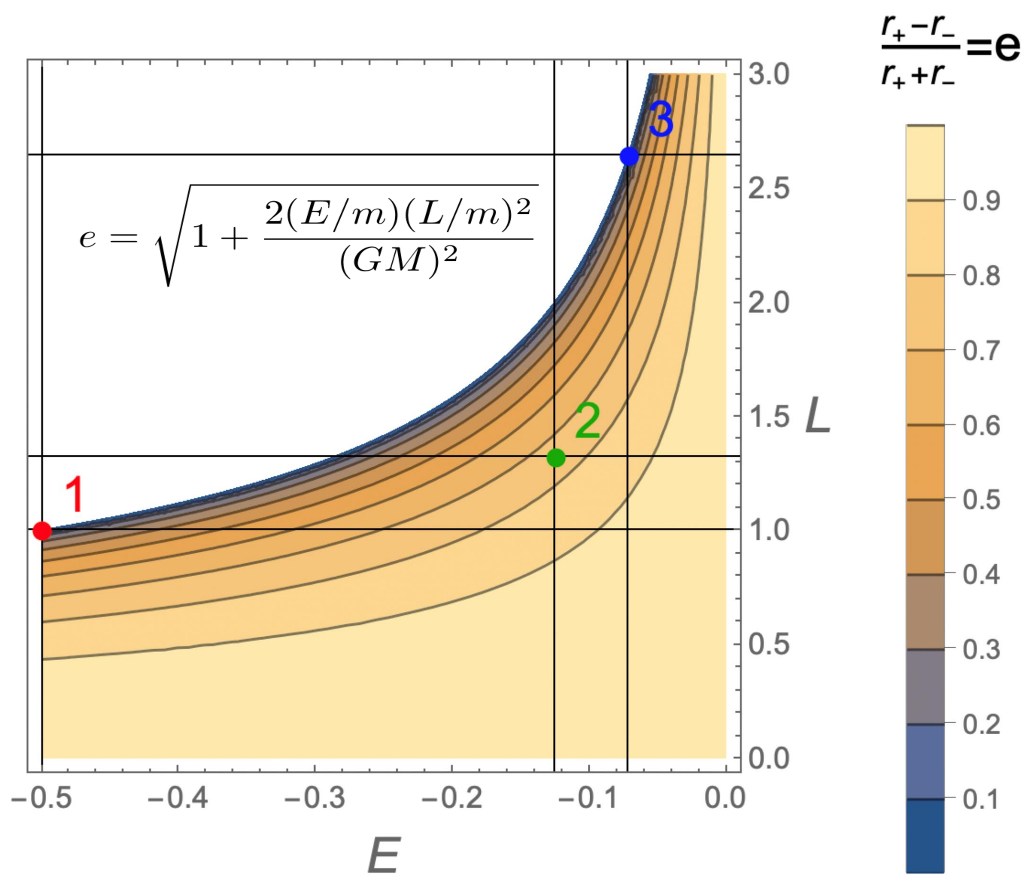
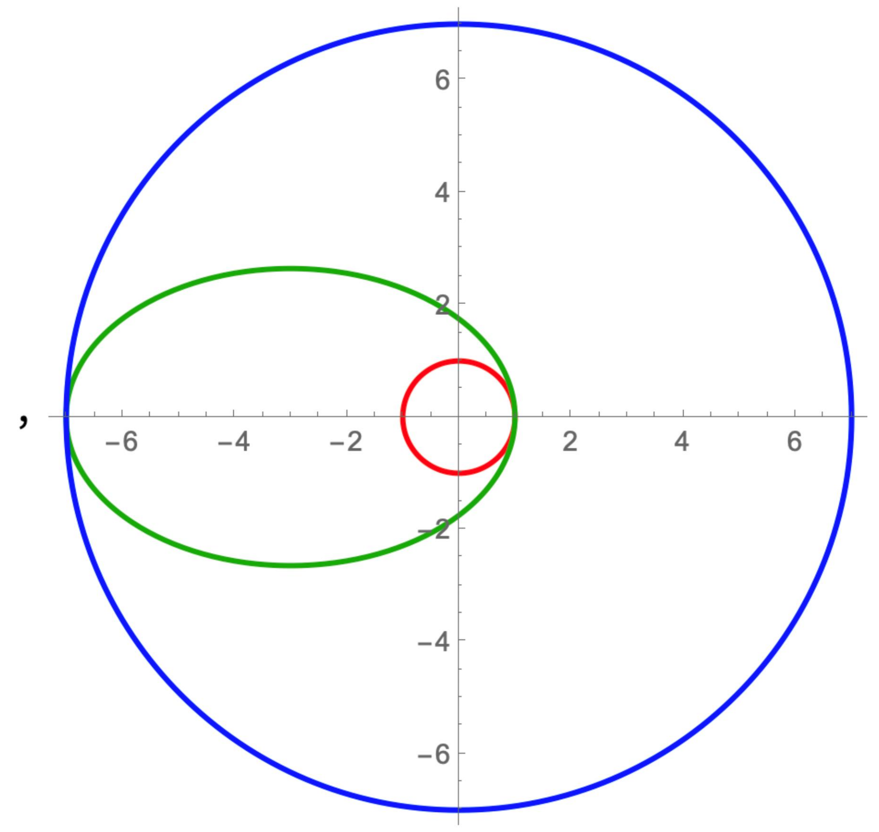
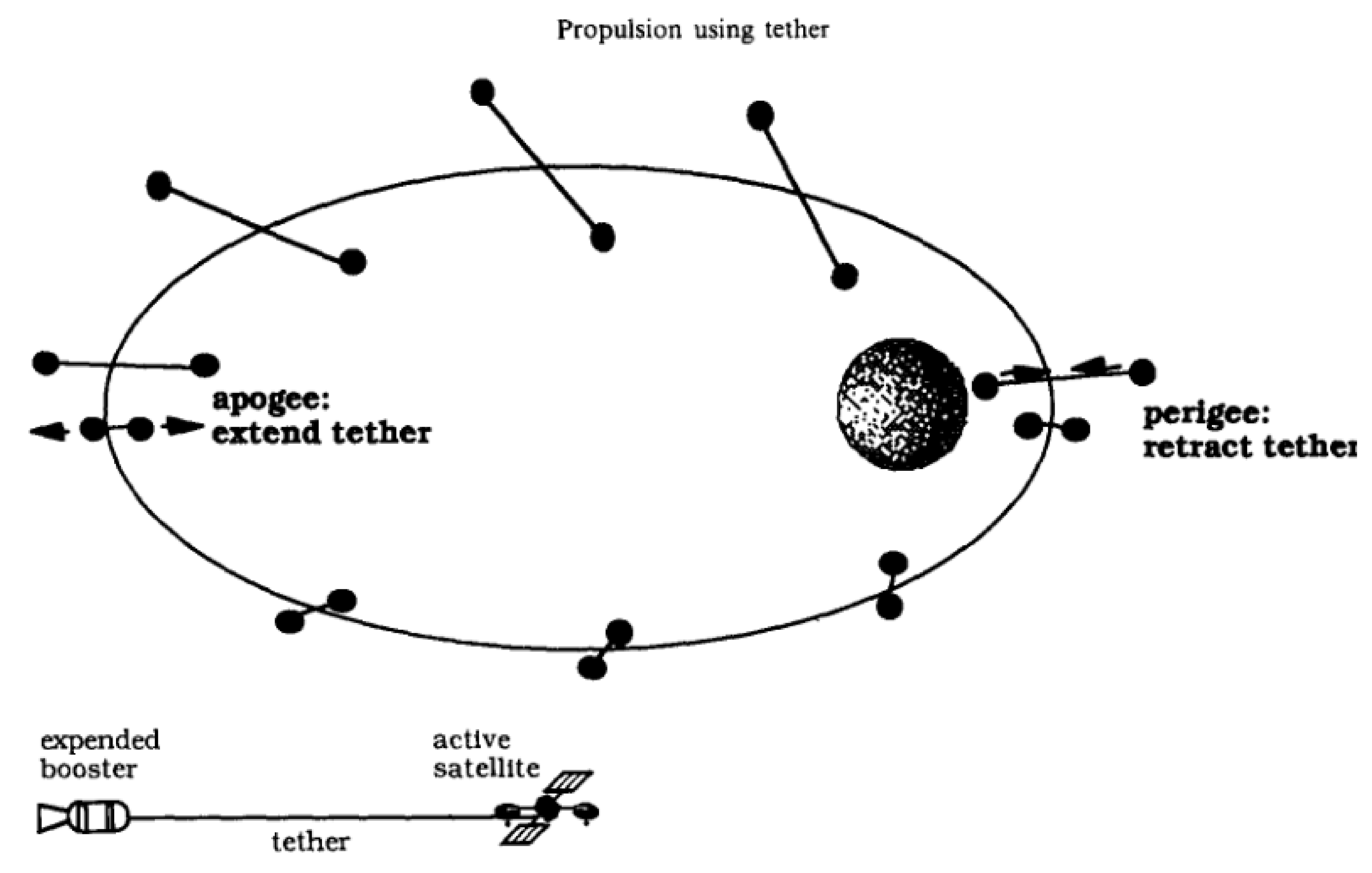
The traditional way of changing orbits with traditional chemical rockets.

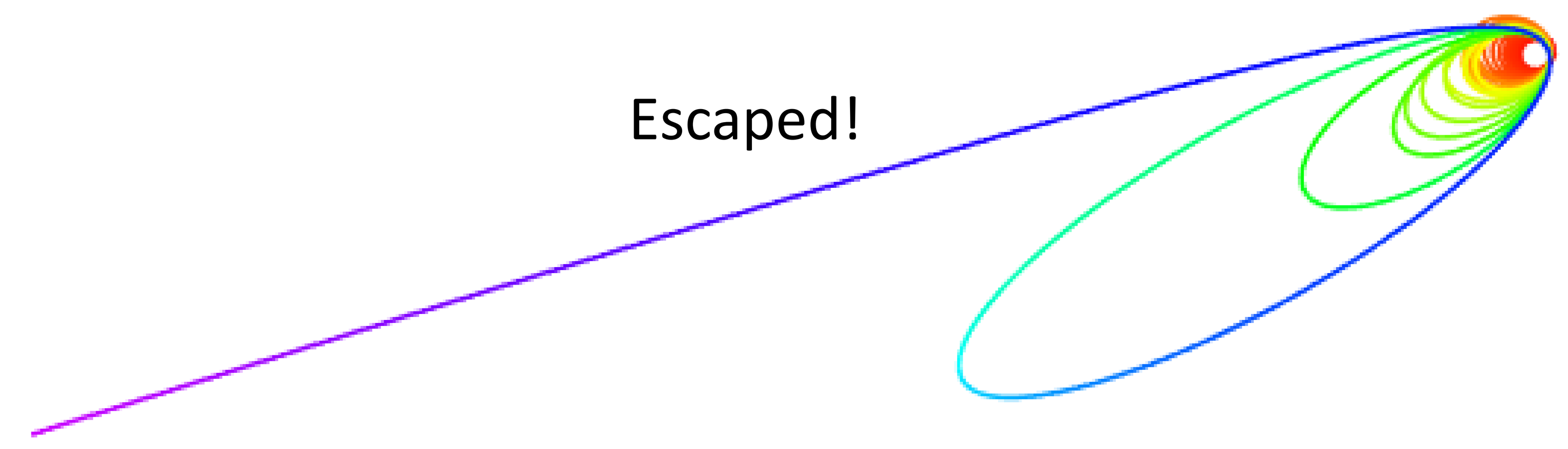




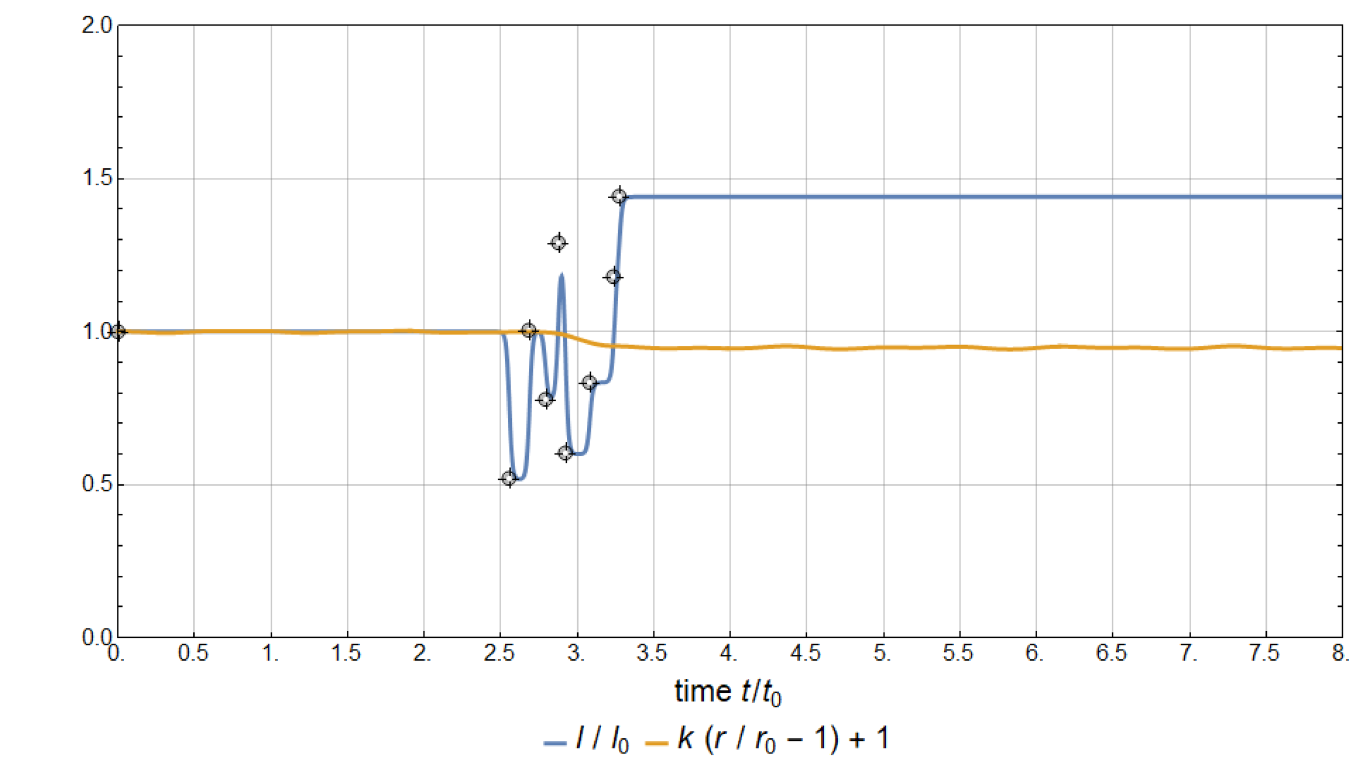
Symbol	Parameter
e	eccentricity
E	Energy
L	Angular Momentum
G	Gravitational Constant
M	Planet Mass
m	Spacecraft Mass

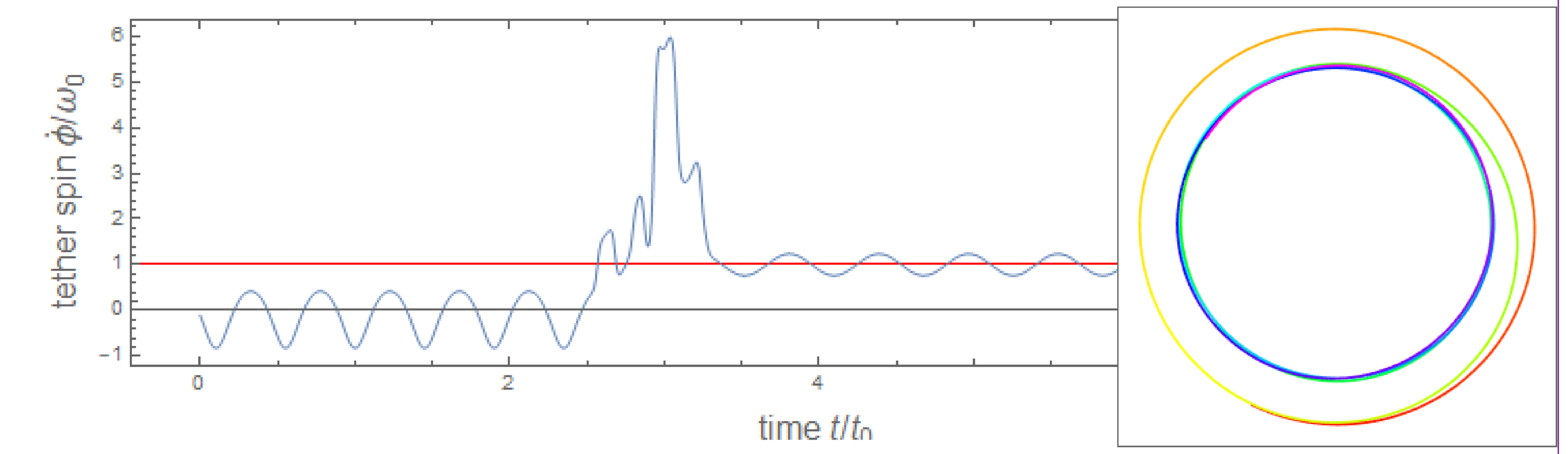
Pumping eccentricity with a radial tether





Orbit Transfer with Spinning Tether





By changing the tether every 90⁰ spin, slowly spiral inward/outward.