Dynamics and Stability of Tethered Satellites at Lagrangian Points

Executive Summary

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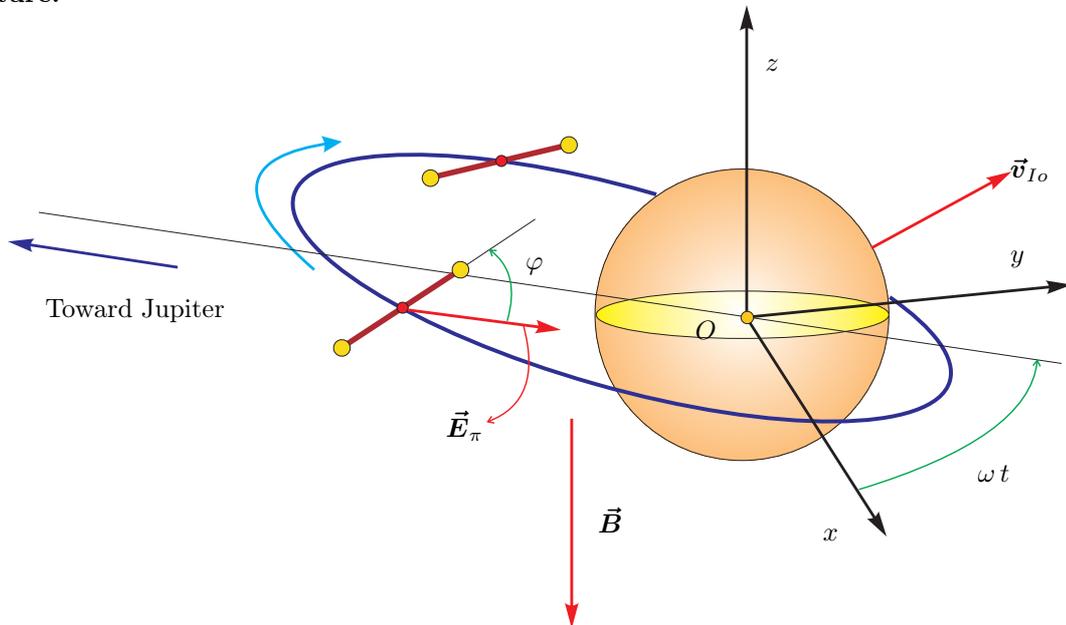University of Padova, CISAS
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Duration of the study: 6 months

Picture:

Rotating EDT in retrograde equatorial orbit around Io

Methodology:
The topic of the research stems from two unique properties of tethered satellites interacting with a planetary system. First, as observed in ref. [18-20], a tethered satellite controlled in length and placed at a Lagrangian point can be used to enhance stability, improve the characteristics of a given orbit or, in some cases, to stabilise an unstable orbit. All of it without expending fuel. Second, the propellantless Lorentz force available to electrodynamic tethers can be exploited for improving the stability of an orbit and also to extract continuous power from a rotating plasmasphere or from the orbital energy of natural satellites as observed in [8,9]. The present report investigates these topics with a systematic approach. A variable length inert or electrodynamic tether (EDT) either graviy-gradient- or spin-stabilised in a three body system is considered . General equations of motions are derived to investigate : stabilisation of the collinear lagrangian points with variable length inert or rotating tethers, stabilisation of halo orbits with constant length fast-rotating tethers, continuous power generation with EDT in a three body system both at the collinear and triangular Lagrangian points.

Results:
1) Asymptotic stability was achieved for the control of variable-length rotating tethers in the neighbourhood of the collinear lagrangian points without the tether losing tension.

2) Stable Eight-shaped orbits where obtained with constant length fast-rotating inert tethers. Stability was also found for some normally unstable halo orbits.

3) Continuous power generation of EDT in circular retrograde orbit around Io was achieved without compromising the orbit stability. A simple control scheme was also implemented allowing to quickly reach escape velocity from a low altitude ionian orbit only using the electrodynamic force.

4) For the case of EDT at the triangular lagrangian points, new equilibrium positions emerge when the electrodynamic force is activated, showing the possibility to maintain a tethered S/C fixed in the co-rotating frame and at the same time to extract kilo-Watts of electrical power (useful on-board of the S/C) from the super-rotating Jovian plasma sphere. Non-linear dynamics around new equilibrium positions has been used to explore and scan the Jovian Plasma Torus by means of a rotating EDT of moderate length.

Publications:

• *Dynamics of tethered libration-points satellites*, by

Manuel Sanjurjo Rivo, Fernando R. Lucas & Jesús Peláez,

XI Jornadas de Trabajo en Mecánica Celeste, 25—27 June 2008, Albergue de la Real Fábrica, Ezcaray, La Rioja, Spain

• *Dynamic behavior of a fast-rotating tethered satellite*, by

M. Lara & Jesús Peláez,

XI Jornadas de Trabajo en Mecánica Celeste, 25—27 June 2008, Albergue de la Real Fábrica, Ezcaray, La Rioja, Spain

• *On the dynamics of a tethered system near the colineal libration points*, by

M. Sanjurjo-Rivo, F. R. Lucas, J. Peláez, C. Bombardelli, E. C. Lorenzini, D. Curreli, D. J. Scheeres & M. Lara,

AIAA paper 2008-7380, The **2008 AAS/AIAA Astrodynamics Specialist Conference and Exhibit**, 18—21 Agosto 2008 Hawaii Convention Center and Hilton Hawaiian Village, Honolulu, Hawaii, USA

• *Io exploration with electrodynamic tethers*, by

C. Bombardelli, E. C. Lorenzini, D. Curreli, M. Sanjurjo-Rivo, F. R. Lucas, J. Peláez, D. J. Scheeres & M. Lara,

AIAA paper 2008-7384, The **2008 AAS/AIAA Astrodynamics Specialist Conference and Exhibit**, 18—21 Agosto 2008 Hawaii Convention Center and Hilton Hawaiian Village, Honolulu, Hawaii, USA

• *Dynamics and Stability of Tethered Satellites at Lagrangian Points*, by

J. Peláez,

Workshop on Stability and Instability in Mechanical Systems: Applications and Numerical Tools, 1—5 December 2008 Institute of Mathematics of the University of Barcelona, Barcelona, Spain

Abstracts sent:

• *Plasma torus exploration with electrodynamic tethers*, by

E. C. Lorenzini, D. Curreli, C. Bombardelli, M. Sanjurjo-Rivo, F. R. Lucas, J. Peláez, D. J. Scheeres & M. Lara,

19th AAS/AIAA Space Flight Mechanics Meeting, February 8—12, 2009, Savannah, Georgia, USA

Highlights:

Placing an inert or electrodynamic tether in a 3-body gravitational environment modifies the structure of the dynamics in such a way to allow passive or active stabilisation of the tether motion in the vicinity of the lagrangian points or orbiting around them. In addition, continuous power generation without compromising orbit stability is possible in some cases using electrodynamic tethers. The Jupiter-Io system appears particularly effective both in terms of power generation (at the expense of plasmasphere energy) and in terms of orbit control.