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A minor mission to *Ice Giant* Neptune?

Juan R. Sanmartin and Jesús Peláez

ETSI Aeronáutica y del Espacio, Universidad Politécnica de Madrid

Abstract

Broad missions *Cassini* at *Saturn* and *Galileo*, and now *Juno*, at *Jupiter*, provided deep overall knowledge about the *Gas Giants*. For specific visits, electrodynamic tethers, which are thermodynamic in character and can provide free propulsion and power for capture by a planet, followed by free maneuvering for exploration, could make for more than 'orbiter' missions. The two *Ice Giants*, *Uranus* and *Neptune*, are being considered by NASA as *flagship* missions in the next decade. We show here how tethers could be used for a minor mission to *Neptune*, particularly effective because of its offset dipole magnetic field, while presenting the slower spin along with *Uranus*, and the highest density, among *Giants*. Preliminary estimations suggest a greater spacecraft-capture efficiency at Neptune as against Jupiter and Saturn.

1. Introduction

Missions *Cassini* at *Saturn* and Galileo, and now *Juno*, at *Jupiter*, provided overall knowledge about the *Gas Giants*. For missions involving specific visits, like exploring *Europa* at *Jupiter* [5] (or maybe *Enceladus* in the *Saturn* case [6]), electrodynamic tethers might be convenient. The two *Ice Giants*, *Uranus* and *Neptune*, are being considered by NASA as *flagship* missions in the next decade ('Ice Giants Pre-decadal Survey Mission Study', http://www.lpi.usra.edu/icegiants/mission_study/Full-Report.pdf). We discuss here whether tethers might be used for a minor mission to *Neptune*. As in the case of Saturn, tether operation could appear tough at Neptune because its magnetic field ***B*** is similarly small compared with Jupiter, the spacecraft-capture efficiency (*S/C-to-tether mass ratio*) going down as B^2 for weak fields.

It was shown, however, that efficiency for Jupiter is less than expected because of its very high *B* itself, which might result in strong tether heating and/or energetic attracted electrons crossing the tether tape and missing collection [5]. This requires design with limited tether length, to keep length-averaged current density well below its maximum, *short-circuit*, value, just proportional to *B*, thus limiting efficiency. Further, tethers were then shown as effective at Saturn as at Jupiter, weak-*B* operation avoiding the issues at [5], and allowing current-density reach near the particular short-circuit maximum [6].

2. The Neptune environment

Tether operation depends on both field *B* and electron density, data from the *Voyager* 2 1989-flyby not yielding definite models for the ambient magnetized plasma the tether would be operating in. Regarding *B* at distances of interest, *quadrupole*, even *octupole* terms of the magnetic moment might be comparable to the dipole term [3], which was dominant at Jupiter and Saturn. In this preliminary analysis of just S/C capture, we only use the dipole term, itself complex in both location and orientation. As regards plasma measurements, in-situ data from the *PLS* instrument [4] agree well with neither data from detected plasma (*whistler*) waves [1] nor *radio-occultation* data [2].

That may not be a problem, however, a reasonable range of density values leading to current-densities near the short-circuit maximum (for appropriate tether lengths), thus weakly dependent on actual electron density. The most relevant difference in planetary environment, (for which space telescopes and ground telescopes with adaptive optics made some contributions of interest), is the high *offset* of Neptune's dipole moment, shared by the other Ice Giant. That could make capture more efficient than at either Saturn or Jupiter, somehow midway between weak and strong magnetic cases.

3. Summary of Results

Tether drag in planetary S/C capture, from a slightly hyperbolic orbit to a barely elliptical one, is calculated for an equatorial orbit parabolic throughout, with periapsis very close to the planet, $r_p \approx R_N$, as for Jupiter and Saturn [5], [6]; the Lorentz drag, being quadratic in the planetary dipole field, has a limited radial reach. Because of the strong dipole offset, the S/C should best reach periapsis when crossing the meridian plane that contains the dipole center along with the Neptune rotation axis. This would result in the dipole optimally facing the S/C when at periapsis. That meridian plane has been reasonably well determined; also, when observed from away, Neptune keeps announcing its orientation with its stunning magnetic-structure rotation.

Actually, the above synchronism is not very requiring and is somewhat tempered by Neptune having the highest density and faster speed at periapsis among the *Giants* and the slowest spin along with Uranus. Preliminary estimates appear to support a higher tether-capture efficiency at Neptune as against Jupiter and Saturn.

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References

[1] Gurnett, D. A. and Kurth, W. S.: Plasma Waves and Related Phenomena in the Magnetosphere of Neptune'. In *Neptune and Triton,* ed. D. P. Cruikshank (Tucson: Univ. of Arizona Press), pp. 389-423, 1995.

[2] Lindal, G. F.: The Atmosphere of Neptune. 'An Analysis of Radio Occultation Data Acquired with Voyager 2'. *Astron*. *J*., Vol. 103, pp. 967-982, 1992.

[3] Ness, N. F., Acuña, M.H., and Connerney, J. E. P.: Neptune's Magnetic Field and Field-Geometric Properties'. In *Neptune and Triton*, pp. 141-168.

[4] Richardson, J. D., Belcher, J. W., and McNutt, R. L.: The Plasma Environment of Neptune. In *Neptune and Triton*, pp. 279-340.

[5] Sanmartin, J. R., Charro, M., Garrett, H. B., Sánchez-Arriaga, G., and Sánchez-Torres, A.: Analysis of tether mission concept for multiple flybys of moon Europa. *J. Prop. Power,* Vol. 33, pp. 338-342, 2017.

[6] Sanmartin, J. R., Peláez, J., and Carrera-Calvo, I.: Comparative *Saturn*-versus-*Jupiter* tether operation (submitted to *J. Geophys. Res.*: *Space Physics*).