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Jupiter, Saturn, Uranus and Neptune; gas giants one launch away

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Abstract

One way to test different solar system formation theories would be to measure the atmospheric composition of all gas giants. These measurements could give an indication on the composition of the original accretion disk that preceded the planets. Comparisons with the forecasted composition resulting by different models might then shed some light into how our solar system has evolved. As the interesting well-mixed region often lies deep within the target atmosphere, in-situ measurements up to depths of 10 – 50 bars of all the gas giants are needed ,and a case for such a mission has been raised by Atreya et al, 2006 [1]. We propose here a mission that could answer this call and name it tentatively as JUSAUNE (JUpiter, SAturn, Uranus and NEptune - sail).

Jupiter is the only one of the outer planets that has already been probed. This was done by the Galileo probe in 1995. With the novel Electric Solar Wind Sail (or E-sail) technology travel times to gas giants are reduced as are the launch masses since no propellant is needed [2]. This leads to reduced mission costs, which might enable building four similar probes simultaneously and sending them off in a common launch to reach all of the gas giants.

As an example, with a standard 1 N E-sail we could fly 500 kg of payload to Jupiter in a year, and 1000 kg in 1.5 years. The furthest giant, Neptune, could have 500 kg of payload delivered to its vicinity in less than five years. Delivering 1000 kg would take 8 years, but in addition no time would need to be wasted in waiting for a suitable window (see Sec 2.). Such a mission might include several entry probes, as envisioned already in 2003 by Solar System Exploration Survey [3]. Travel times are tabulated in following table for 500 and 1000 kg payloads:

Target planet	Payload weight	Travel time
Jupiter	500 kg	1.0 yr
	1000 kg	1.6 yr.
Saturn	500 kg	1.7 yr.
	1000 kg	2.8 yr.
Uranus	500 kg	3.1 yr.
	1000 kg	5.3 yr.
Neptune	500 kg	4.6 yr.
	1000 kg	8.0 yr.

1. Electric Solar Wind Sail

The Electric Solar Wind Sail (E-sail) is an invention that might change the way we do space travel. It was invented and patented in 2006 by a Finnish scientist Pekka Janhunen and is now developed further with EU funding (FP7 project ESAIL, **http://www.electric-sailing.fi/fp7**) [2,4,5]. Using solar wind protons as a driving force, it can move speedily and relatively freely within the solar system.

Coulomb interaction between the solar wind and positively charged (~20 kV), long and thin tethers gives a thrust of about 1 N at Earths vicinity for a 100 kg propulsion system weight. The E-sail can thus produce up to three orders of magnitude more impulse than chemical rockets or ion engines, if compared over a mission lifetime of ten years. However, the E-sail has to be launched into the solar wind by traditional means, as behind the magnetosphere's shielding ions do not carry enough momentum to be of a much practical use.

The E-sail is alluring for missions into the outer solar system, as the force produced scales as 1/r when pulling away from the Sun. For photonic solar sail, in comparison, the force diminishes as 1/r^2. The advantage is further increased by the easier upscalability of the E-sail technology: it is more arduous to increase the area of a photonic solar sail than it is to engineer more and longer tethers of the E-sail.

2. One design, one launch

Building several identical spacecraft reduces their design costs. So in order to gain the most science per cost, one could build four identical atmospheric probes, each with an E-sail carrier spacecraft, and send each of them to explore a different gas giant.

One of the greatest advantages of using propulsion systems that provide continuous, albeit relatively small, thrust is that the course of the spacecraft does not need to be determined at launch. Whereas traditional planetary missions need to select their launch dates with care within the launch window, the E-sail probe can be launched at any time as planetary fly-bys are not needed to gather the needed velocity.

Moreover, direction of the escape orbit is inconsequential as the propellantless E-sail takes care of the acceleration in the solar wind. At present, without E-sail, a launch which takes a probe towards e.g. Jupiter can not take any other piggybacks except those that are also destined to Jupiter (or to planned gravity assist planets), and typically there are not too many such. This, combined with the fact that small launchers typically do not go to escape orbit, at least not with well-proven upper stage hardware, has created the present 'vicious circle' situation, which effectively blocks us from having small planetary probes. The E-sail has a potential to change this trend and to enable low-cost small and moderate mass planetary probes that can be launched in arbitrary mixed combinations with any escape-capable launcher to any solar system targets. This makes it possible to build a fleet of JUSAUNE-sails ready to wait for available piggybacking options, further decreasing the manufacturing costs per spacecraft.

This independency on the escape trajectory characteristics also makes it possible to launch all the four probes on a same carrier. On Earth escape orbit the individual probes would separate from each other and start their own E-sail propelled journey towards their individual destinations. In this way we could reach all of the outer planets with a single dedicated launch taking four JUSAUNEs above the boundaries of the magnetosphere.

4. Summary and discussion

In-situ observations of gas giant planets atmospheres could shed some light into the history of our solar system. Here we have proposed the usage of the Electric Solar Wind Sail technology to reach Jupiter, Saturn, Uranus and Neptune in a cost-effective, fast and flexible manner.

The Electric Solar Wind Sail is a novel propulsion technology that provides constant propulsion without any propellant consumption. Moreover, the thrust of an E-sail scales as 1/r when moving to a distance r away from the Sun, making it attractive option for outer solar system exploration.

References

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