Laser-powered Electric Propulsion for Interstellar Precursor Missions

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Abstract

Voyager 1 is the fastest human-made object and the first to venture into interstellar space; it crossed the heliopause, the boundary separating solar and galactic plasmas, in August 2012 at 120 AU from the Sun, 35 years after the launch from Cape Canaveral. However, the minimum required distance to reach the unperturbed "virgin" interstellar medium is expected to be at least 200 AU. When Voyager 1 will cover that distance the on-board power will be too low to operate any scientific instrument.

In the last 30 years, the space community has proposed a few concepts for an Interstellar Heliopause Probe which could reach 200 AU within a scientist career lifetime (< 30 years), but no solution has been found that does not need extensive technology development.

If Planet Nine is confirmed to exist, it could be at 1000 AU from the Sun, too far for any realistic mission with current propulsion technology. The Thousand Astronomical Unit (TAU) mission was an interstellar precursor mission concept, studied by JPL scientists in the late 1980s, which could have reached 1000 AU within a 50-year trip time. The challenging ΔV needed (> 100 km/s) could be achieved with a nuclear electric propulsion system including a nuclear fission reactor in the 1-MWe class with a specific mass of 12.5 kg/kWe and advanced ion thrusters with a specific impulse of 12,500 s. While The NASA´s HiPEP ion thruster has demonstrated a specific impulse of ~ 10,000 s, the needed lightweight nuclear reactor still exists only on paper.

This paper proposes an advanced propulsion concept for challenging interstellar precursor missions, Laser-powered Electric Propulsion (LEP). A high-power laser beam is aimed at a lightweight photovoltaic (PV) collector on the target spacecraft, where it is converted to electric power for an ultra-high specific impulse EP system. The PV collector/converter on the spacecraft can be tuned to the laser wavelength, thus achieving high monochromatic conversion efficiencies, currently ~ 50% with the potential to reach 80% in the near future.

The TAU mission could greatly profit from the LEP concept. Instead of a heavyweight nuclear reactor we could have a monochromatic PV collector with 50% conversion efficiency and a specific mass of just 1 kg/kWe; such a lightweight power source could pave the way to challenging missions beyond the heliopause like Planet Nine and the exploration of the Oort Cloud, with travel times well within a scientist career lifetime.

This paper is submitted for the day <1>, session < Energetic Reaction Engines >.

Keywords: Interstellar Precursor Mission, Electric Propulsion, laser-powered, TAU

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