First Stop on the Interstellar Journey: The Solar Gravity Lens Focus

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Abstract

Whether or not *Starshot* [1] proves practical, it has focused attention on the technologies required for practical interstellar flight. They are: external energy (not in-space propulsion), sails (to be propelled by the external energy) and ultra-light spacecraft (so that the propulsion energy provides the largest possible increase in velocity). Much development is required in all three of these areas. The spacecraft technologies, nanospacecraft and sails, can be developed through increasingly capable spacecraft that will be able of going further and faster through the interstellar medium. The external energy source (laser power in the *Starshot* concept) necessary for any flight beyond the solar system (>~100,000 AU) will be developed independently of the spacecraft.

The solar gravity lens focus is a line beginning at approximately 547 AU from the Sun along the line defined by the identified exo-planet and the Sun [2]. An image of the exo-planet requires a coronagraph and telescope on the spacecraft, and an ability for the spacecraft to move around the focal line as it flies along it. The image is created in the "Einstein Ring" and extends several kilometers around the focal line – the spacecraft will have to collect pixels by maneuvering in the image [3]. This can be done over many years as the spacecraft flies along the focal line. The magnification by the solar gravity lens is a factor of 100 billion, permitting kilometer scale resolution of an exo-planet that might be even tens of light-years distant. The value of such an image would be enormous. A mission to 500-1000 AU is a small fraction of interstellar flight, approximately 0.3%. Yet, its requirements are beyond current spacecraft state-of-the-art. A 10 kg spacecraft with a solar sail of 115x115 meters, capable of flying to 0.1 AU perihelion distance can reach 600 AU in 20 years and 1000 AU in about 32 years [4]. Achieving this is a tall order: we do not have sails of this size, we do not have materials for this close a flyby of the Sun, and we do not have working spacecraft for a 20-40 year journey that weigh on the order of 10 kg. But meeting these requirements are necessary if we are going to create even lighter spacecraft to capture the external energy which can enable interstellar flight. If heavier spacecraft are required, the sail area will have to be correspondingly larger in order to maintain the same area/mass ration, which determines the spacecraft velocity. If the sail material permits closer distances to the Sun than 0.1 AU that will also permit faster velocity and shorter trip times. Other types of sails besides solar sails may also be considered – for example, e-sails, drawing power from the interaction of the solar and interstellar wind with charged wires on the spacecraft. Hybrid propulsion with sails and nuclear electric propulsion are also to be considered since the spacecraft will likely require a small nuclear power source for operating hundreds of AU from the Sun.

The solar gravity lens focus is the only destination in the interstellar medium (except for possible unknown rogue planets) that can serve as a milestone for interstellar flight. Beyond the heliopause (~120 AU) there are no natural objects which have compelling science and mission goals. If we can operate a spacecraft on the focal line created by the solar gravity lens we can in principle provide high resolution images of an identified interesting exo-planet, one that might itself be itself a fundamental interstellar goal. Because the spacecraft technologies necessary to operate such a mission are those which must be developed for interstellar flight it also serves as a technology driver. These include laser communications, deep-space/long-lived power, autonomy and reliability over long flight times, precise attitude control and stability and the materials and thermal technologies for very close flyby of the Sun. Thus a putative solar gravity lens focus mission is both a scientific interstellar precursor (imaging the identified potentially habitable exo-planet) and a technology precursor for interstellar flight. No other such precursor has been identified.

Keywords: Interstellar Precursor, Solar Gravity Lens, Solar Sails

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