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Science Goals and Drivers for Future Exoplanet, Space Astronomy, Physics, and Outer Solar System Science Missions (2)

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MISSION CONCEPTS FOR EXPLORATION OF THE KUIPER BELT, THE INTERSTELLAR MEDIUM AND TO THE SOLAR GRAVITY LENS

Abstract

Recent data from Voyager, Kepler, Siptzer and New Horizons spacecraft have resulted in breathtaking discoveries that have excited the public and invigorated the space community. From Voyager, we have learned that the Interstellar Medium (ISM) is much more complicated and interesting than ever thought. New Horizons gave us our first look at Pluto radically changing our understanding of Kuiper Belt Objects. Furthermore, ground and near Earth space based telescopes have discovered many Earth-like exoplanets, including the recent discovery of Earth-like planets in the TRAPPIST-1 system. While delivering exciting science, future near-Earth telescopes, including JWST, will be limited to only single-pixel imaging of exoplanets.

Fortunately, nature presents us with a powerful instrument that we can use for multi-pixel imaging of distant exoplanets. This instrument is the Solar Gravitational Lens (SGL), a location distant from our Sun that takes advantage of the ability of the Sun's gravity field to focus light from faint, distant targets. In this paper, we propose the following mission goals, to be achieved using near-term technology coupled with innovative mission design concepts:

- Reach the SGL in $\leq$ 40 years for exoplanet imaging.
- Reach the local ISM ($\sim$100 AU) in $\leq$ 10 years, compared to Voyager's 120 AU in 40 years.
- Perform Heliophysics, Astrophysics, ISM, KBO fly-by investigations on the way to SGL.

Given the long travel times, a new kind of mission design is needed to make the SGL mission possible. A recent Keck Institute study (by authors of this paper) has shown that achieving distances beyond 500 AU with less than 40-year flight time requires a low-perihelion Oberth escape maneuver. In this paper, we do a comprehensive trade study looking at augmenting the low-perihelion Oberth maneuver with electric

propulsion or solar/electric sail. We also look at alternate mission design options utilizing only a Jupiter flyby with other propulsion technologies, expanding the work done by original Keck Study. A notional instrument design and data acquisition concept using a 1 m telescope will also be addressed. The notional SGL instrument will implement a miniature diffraction-limited high-resolution spectrograph, enabling Doppler imaging techniques, taking full advantage of the SGL amplification and differential motions (e.g. exo-Earth rotation). The resulting high performing mission concepts are then optimized with a tailored spacecraft design. The final list of mission concepts analyzed and compared for cost feasibility, science return. Near-term technologies required to enable these mission concepts is also identified.