MIRS - A Map of the Ice Regions in the Solar System

J. Agarwal[1], T. Albin[1], H. Böhnhardt[1], B. Dabrowski[1], M. Fränz[1], N. Kappelmann[3], H. Krüger[1], P. Lacerda[1], U. Mall[1], S. Mardaneh[2], N. Oklay[1], R. Orlik[1], E. Roussos[1], C. Snodgrass[1], R. Srama[2], C. Tubiana[1], J.-B. Vincent[1], K. Werner[3]

1) Max-Planck Institute for Solar System Research, Göttingen, Germany
2) Institut für Raumfahrtsysteme, University of Stuttgart, Stuttgart, Germany
3) Institute for Astronomy and Astrophysics, University of Tübingen, Tübingen, Germany

Proposal

We propose a low-cost mission that will allow mapping the distribution of icy objects in the Solar System in order to constrain solar system evolution models.

Scientific Rationale

Recent theoretical progress has led to the development of a scenario for the dynamical evolution of the Solar System, which explains essential features of the planetary system in which we live. The Nice model proposes the migration of the giant planets from an initial, more compact configuration into their present positions, long after the dissipation of the initial proto-planetary gas disk.

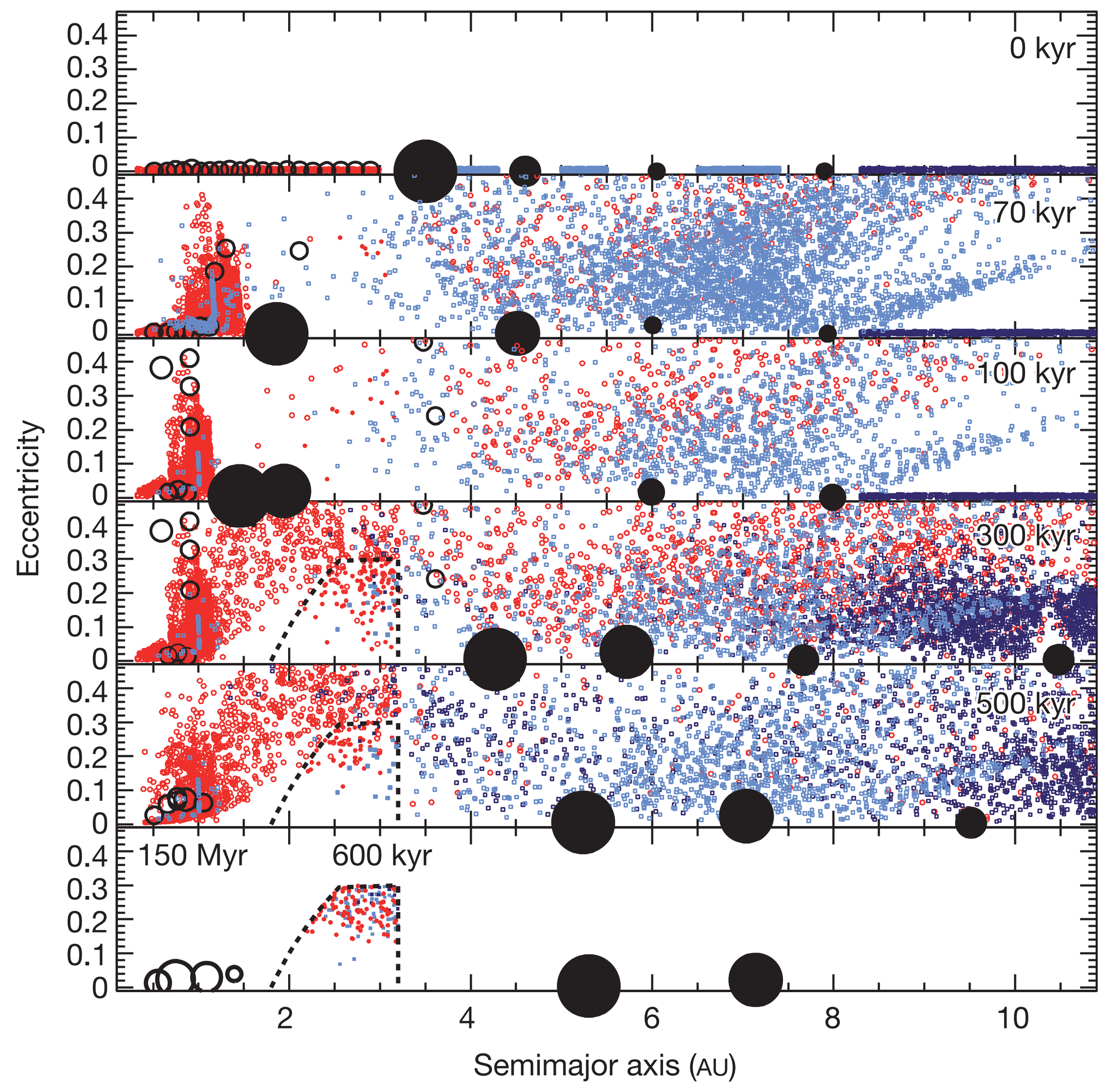

Figure: The evolution of the small-body populations during the growth and migration of the giant planets. Planets are represented by large black filled circles with evident inward-then-outward migration. S-type planetesimals are represented by red dots, initially located between 0.3 and 3.0 AU. Planetary embryos are represented by large open circles. Figure from Walsh et al.,

Despite reproducing several major events in the evolution of the Solar System (e.g. the Late Heavy Bombardment of the inner planets, and the formation of the Oort cloud) the Nice model remains unsatisfactory. Due to the model's many free parameters, a wide range of dynamical outcomes are feasible, thereby making testable predictions observationally difficult to constrain. Earlier, more static theoretical models of the evolution of the solar system relied on the concept of a snow line as a more or less fixed heliocentric distance in the solar nebula separating two physically distinct regions: a central region where the environment is too hot for light element (HCNO) compounds to condense and the solid phase consists mainly of rocky material, and a more distant one where solid ice grains can readily form. The idea of a snow line leads to clear predictions for where ice can be found in the solar system. Even though planetary migration induces significant mixing of the various planetesimal populations formed at different temperature, the ice content of an object is a strong indicator of its formation location, and is largely preserved over the history of our Solar System. This fact offers a way to use the current surviving and observable planetesimals as tracers for the evolutionary processes in which they were involved. In this context, it is inherently clear that the strongest tracer of the origin and history of a body in the Solar System is its water-ice content.

Key Goals

We propose here a low cost mission to place a dedicated platform into a fast reachable orbit (e.g. inclined orbit, or Lagrangian point) which can operate for a long duration period with the goal to:

- identify signatures of water and volatiles in main-belt asteroids, Near-Earth Objects (NEOs) and distant objects (Centaurs, Kuiper belt objects and the moons of giant planets) with the goal of mapping the distribution of water in the solar system;
- identify and characterise Main Belt Comets (MBCs) and bodies like Themis, Ceres and others - the most likely candidates to hold water ice among the asteroids;
- observations of UV emission of the exospheres of the terrestrial planets, observations of aurorae of outer planets;
- extend our picture of the NEO population and identify potential hazards.

Identification Technique

While near-infrared (NIR) spectroscopy is a well developed and proven method to identify ices (of water, methane or other volatile species) on the surfaces of our targets, it is applicable only to the brightest bodies (even when using the largest modern telescopes from Earth) and is not suitable to identify water released at lower rate (< 1E26 molecules/s) from asteroids in its gas phase. Since water in asteroids must be buried below the surface to have survived to the present day, NIR spectroscopy is of limited use for constraining the presence of water, even ignoring the sensitivity limits of current technology. Therefore, water must be detected via emission lines from the gas phase, following its sublimation from the subsurface of the small body. As water can be best detected via its daughter molecules, primarily the OH radical, one can identify its existence via photometry and/or spectroscopy covering the UV range around the 308nm OH emission line. This line is the strongest seen in comet spectra, but is challenging to observe from the ground due to UV absorption by ozone in the terrestrial atmosphere and has only been observed from the ground in bright, highly active comets.

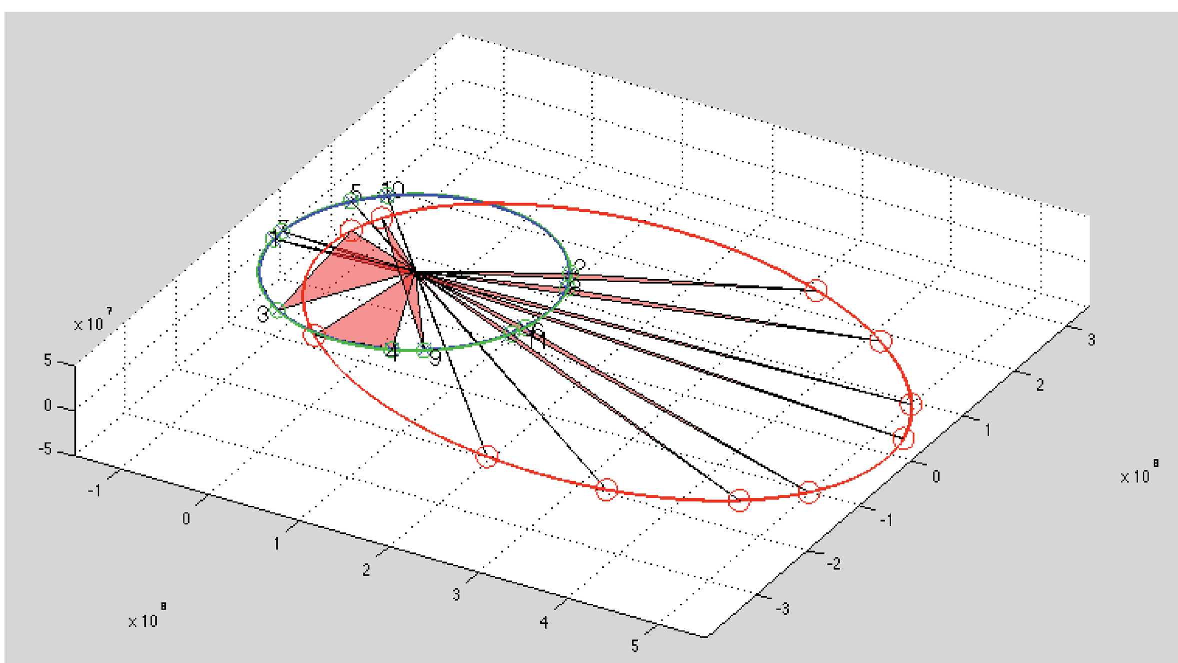

Figure: Orbit of asteroid Oljato exemplifying how the JPL small body data base was used to find suitable asteroids which could be tracked with a 30 cm telescope from L2 during a mission flown between 2014 and 2020. The visibility of the asteroid is show in the next figure.

The detection of very weak activity, as is expected for MBCs and other weakly active objects, requires an unrealistic amount of ground-based observing time, even on the largest telescopes, or observations from outside the Earth's atmosphere. The latter approach has many advantages, and a dedicated search needs only a small telescope (30-50cm aperture) with fast optics and a narrowband filter to image at 308nm to perform a high efficiency survey. A survey using photometric detection of OH (rather than high resolution spectroscopy, as can be done with the Hubble Space Telescope, for example) has the advantage of much greater sensitivity. The out-

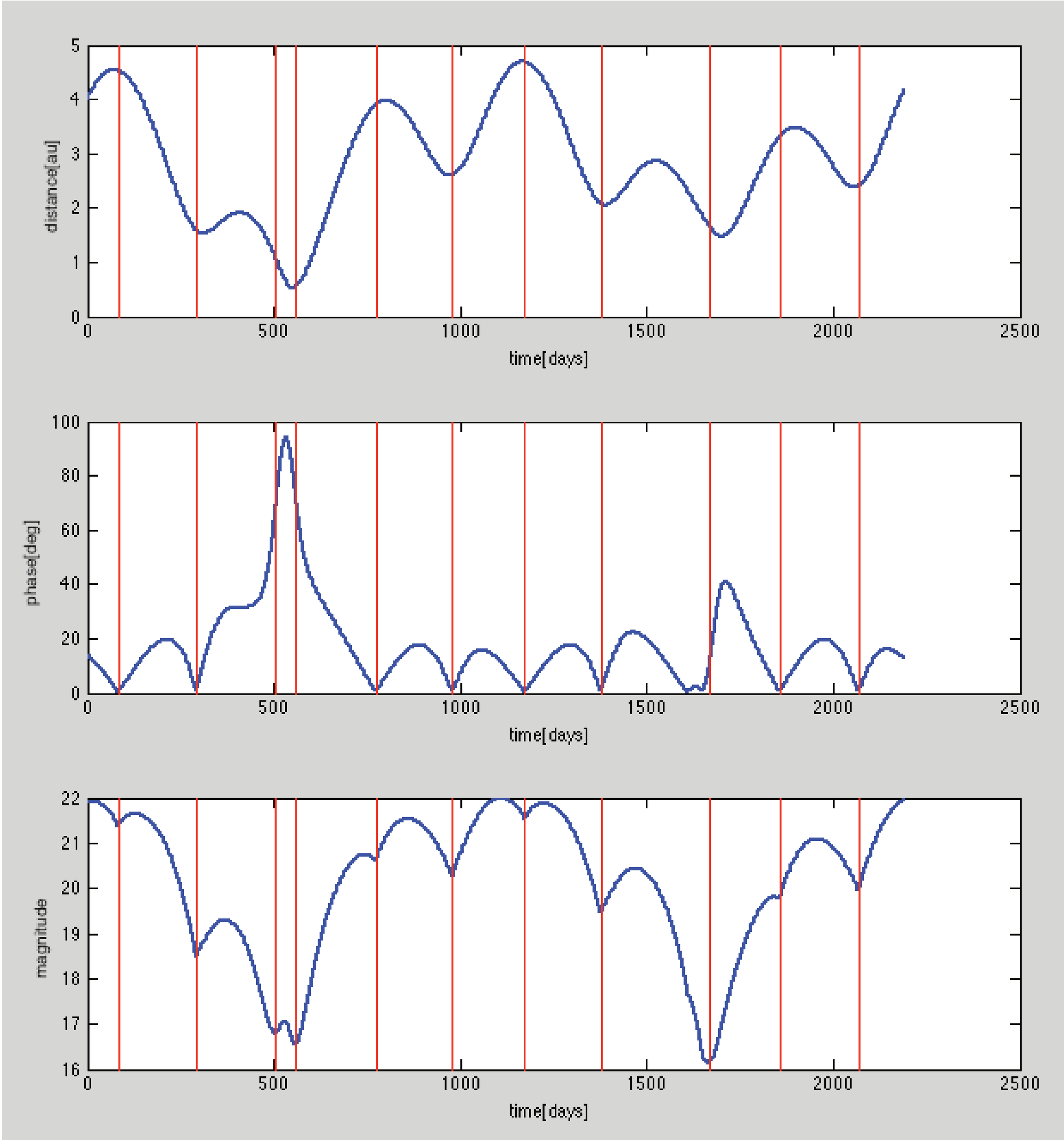

Figure: Visibility of sample asteroid Oljato as seen from L2 during time frame 2014-2020.

gassing rates of MBCs and other water bearing asteroids are very low, but a dedicated imaging system allows integration across the whole OH band and the whole area of the diffuse OH coma, and integrations on each target over many hours and days. In such a way a small, cheap mission can achieve greater sensitivity than is possible using more expensive but a general-purpose space observatory, and achieve a very significant result: A map of the location of present-day water ice in our solar system.

Instrumentation and Mission Design

First photometric calculations indicate that a telecope with a 30 cm mirror and a mass <20 kg could be sufficient to detect potential water gas phases around asteroids using simple nonimaging spectrometers.

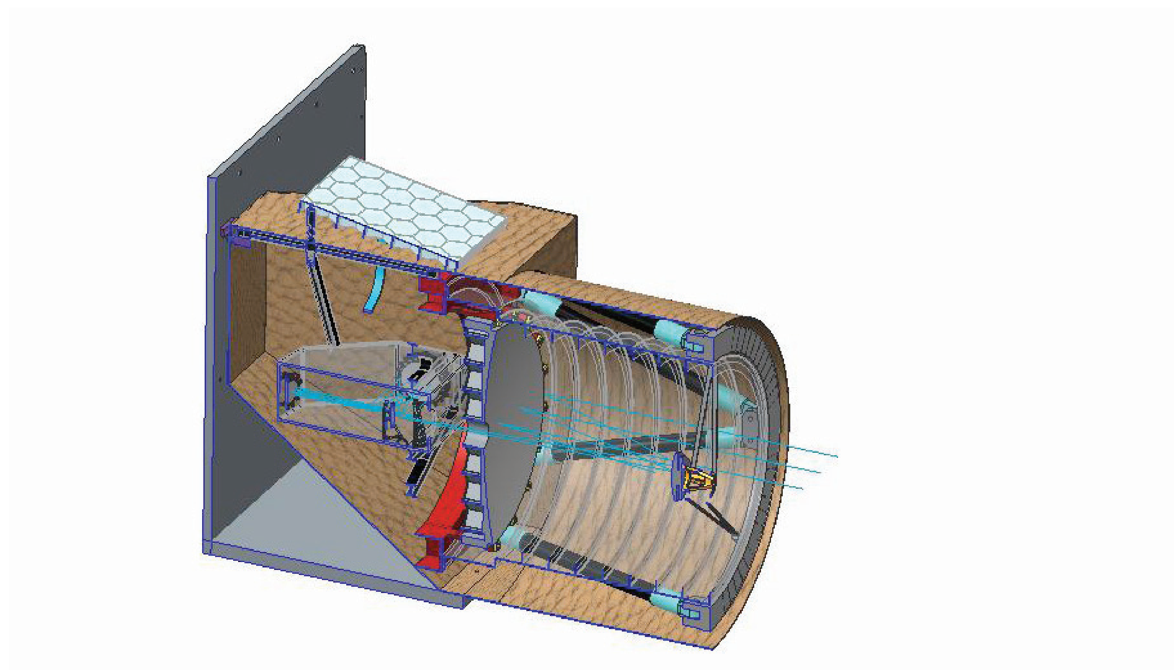

Figure: Telescope design used to study the feasibility of the mass payload assumptions.

For an envioned payload which could carry additional instruments beyond the telescope, three types of launcher are feasible: Long March (CZ2), Soyuz/Fregat and Vega. The Long March launcher could transport a mass of up to 1400 kg to GTO.

Reference: Walsh, K., Morbidelli1, A., Raymond, S.N., O'Brien, D. & Mandell, A., A low mass for Mars from Jupiter's early gas-driven migration, NATURE, Vol. 475, 206-209, 2011.

Interested parties please contact:
Urs Mall (email: mall@mps.mpg.de)
Max-Planck Institute for Solar System Research
Göttingen, Germany