**OBSERVING THE IRREGULAR MOONS OF URANUS BY THE URANUS ORBITER PROBE MISSION, PART 2: OBSERVATION CAMPAIGNS.** T. Denk[1], A. J. Verbiscer[2], S. Mottola[1], S. B. Porter[3], [1]DLR (German Aerospace Center), Rutherfordstr. 2, 12489 Berlin, Germany, Tilmann.Denk@dlr.de, [2]Univ. of Virginia, Charlottesville, VA, [3]Southwest Research Institute, Boulder, CO.

**Introduction:** The companion by Verbiscer *et al.* (Part 1) [1] and this abstract (Part 2) present the benefits of observing the Irregular moons of giant planets from spacecraft (S/C) orbiting the host planet of the moons. Here, we describe the unique advantages in general, the observation campaign by Cassini at Saturn, and the envisioned campaigns by JUICE at Jupiter and by UOP (Uranus Orbiter Probe [2]) at Uranus.

**Observing Irregular Moons by Spacecraft:** Despite the strong potentials of ground-based data [1], much deeper insights are possible by observing Irregular moons with a S/C orbiting the host planet [3]. These include sidereal rotation periods at sub-second level accuracy, unambiguous pole-axis orientations, convex-shape models, object semi-axes sizes, and phase curves up to very high solar phase angles. (From Earth, only phase angles < 3° are accessible for Uranian satellites.) This information is obtained through lightcurves from imaging data of unresolved objects taken over many hours or even days.

Major advantages of S/C for this task are the proximity to the moons (which increases the apparent brightness tremendously, and also astrometric precision [4]), the wide range of solar phase angles (since the S/C is located inside the orbits of the Irregulars), the vanishing of the 180°-longitude ambiguity for the pole/shape solution [5] (since the S/C can hover far above or below the planet's orbit plane), and the potentially easier availability of an observing device (on-board telescope) compared to Earth-based campaigns where only giant telescopes (which are under giant competition) might be used for parts of this task [1].

**Cassini's campaign at Saturn:** The first systematic campaign to observe Irregular moons with a S/C has been performed with Cassini during its extended mission [3]. Almost all objects were unresolved, and almost all observations have taken place during the apoapsis parts of the S/C orbits. The campaign revealed 24 new rotation periods [3] plus >10 pole/shape solutions and phase curves [6]. The data support the hypothesis that the Irregulars are of low density and potentially cometary in nature. Binary or contact-binary configurations may well be possible [7]. The mission also included the first close flyby of an Irregular moon; Phoebe has been passed at ~2070 km altitude three weeks before Saturn orbit insertion [7].

**JUICE at Jupiter:** An observation campaign even more sophisticated than Cassini's is envisioned for the JANUS camera onboard the ESA JUICE mission. In principle, observations of >70 objects to find rotation periods are possible, and phase curves and pole/shape solutions for >30 Irregulars might be obtained. The small moons ($D \sim 1$ to 5 km) will usually be good targets for JANUS twice in the mission for a few weeks or months while at low phase and apparent magnitude ≲ 17. The longest synodic orbit periods of Jovian Irregulars are ~2.1 years and thus not much more than half as long as the JUICE orbit tour (~3.4 years).

**Irregular-moons with UOP:** We propose to implement an Irregular-moons observation campaign to UOP. For a mission duration of ~2000 d at Uranus between fall 2044 and Dec 2049, all nine known objects will be visible at least once at low phase angle < 30°. This will even be the case for objects Setebos and Ferdinand which require more time for one orbit [1] than the UOP mission duration.

A targeted flyby of an object should be considered high priority. However, since none of the Uranian Irregulars orbits near the ecliptic plane, this might be difficult to achieve w.r.t. timing.

**References:** [1] Verbiscer+ 2023, this conference; [2] Simon+ (2021) Planetary Mission Concept Study https://tinyurl.com/2p88fx4f; [3] Denk&Mottola 2019 *Icarus*; [4] Jacobson+ 2022 *AJ*; [5] Kaasalainen&Ďurech 2007 *IAU Symp.*; [6] Denk&Mottola, Mottola& Denk in prep.; [7] Denk+ 2018 chapter in *Enceladus book* (Schenk+, *eds.*, UofA press); [8] Farkas-Takács+ 2017 *AJ*; [9] Sheppard website https://sites.google.com/carnegiescience.edu/sheppard/moons/uranusmoons; [10] Maris+ (2007) *A&A*.

*Table:* Uranus's Irregular moons: Sizes, rotations.

| Satellite | JPL Code | *D* [km] | LC amp [mag] | *a/b* [] | $P_{rot}$ |
|---|---|---|---|---|---|
| Margaret | 723 | 20 | | | |
| Francisco | 722 | 22 | | | |
| Caliban | 716 | 42 | 0.16 | 1.15 | 9.9484 h ± 1 m |
| Stephano | 720 | 32 | ≳0.4 ? | | |
| Trinculo | 721 | 18 | ≳0.4 ? | | |
| Sycorax | 717 | 157 | 0.121 | 1.1 | 6.9162 h ± 5 s |
| Prospero | 718 | 50 | 0.41 | 1.4 | 14.290 h ± 11 m |
| Setebos | 719 | 47 | 0.27 | 1.25 | 8.510 h ± 2 m |
| Ferdinand | 724 | 21 | 0.54 | 1.6 | 23.68 h ± ½ h |

*Notes:* Sizes *D* of Caliban and Sycorax from [8], others from [9]. 'LC amp' (lightcurve amplitude) of Stephano and Trinculo from [10], all others from [8]. Minimum ratio of the equatorial prime axis of each object *(a/b)* is calculated from lightcurve amplitudes. $P_{rot}$ (rotation period) values calculated from [8] assuming double-peaked lightcurves for all objects.