ICE GIANT MISSIONS AS GRAVITATIONAL WAVE DETECTORS. Deniz Soyuer[1], Lorenz Zwick[1], Daniel D'Orazio[2] and Prasenjit Saha[3], [1]Institute for Computational Science, University of Zurich (soyuerd@ics.uzh.ch, zwicklo@ics.uzh.ch), [2]Niels Bohr International Academy, Niels Bohr Institute, [3]Physik-Institut, University of Zurich.

Introduction: Past years have seen numerous papers underlining the importance of a space mission to the ice giants in the upcoming decade. Proposed missions to Uranus and Neptune usually involve a ~10 year cruise time to the ice giants. Considering that they will spend most of their time in interplanetary space (rather than orbiting the planets they are destined for), the science potential of such mission configurations is limited to a fraction of their lifetime. This cruise time can be utilized to search for low-frequency gravitational waves (GWs) by observing the Doppler shift caused by them in the Earth-spacecraft radio link [1,2].

Aims: (i) Calculating the sensitivity of prospective ice giant missions to GWs, (ii) modelling a black hole binary population to derive a conservative estimate for the detection rate binary mergers, (iii) estimating the improvement on Laser Interferometer Space Antenna's (LISA) source localization by simultaneous detections.

Methods: GWs passing through between the transponder and the transmitter/receiver at Earth cause variations in the light travel time, corresponding to a Doppler shift in the signal. Analysis of the resulting shift allows to reconstruct the GW strain, making the Earth–satellite system an arm of a GW observatory.

Sensitivity of Doppler tracking to GWs is dependent on the radio link noise. A benchmark measure for space missions is to achieve an Allan deviation (a measure of frequency averaged stability of the Doppler link) of $\sigma_A \leq 3 \times 10^{-15}$ comparable with Cassini. Top panel shows the sensitivity of various experiments along with that of future ice giant missions with improvements of 3 (orange), 30 (blue), 100 (pink) times Cassini values [3] and examples of GW sources.

Results: For a total of ten 40-day observations during the cruise of a single spacecraft, $\mathcal{O}(f_{\text{bin}}) \sim 0.5$ detections of SMBH mergers are likely, if Allan deviation of Cassini-era noise is improved by ~100 in the $10^{-5} - 10^{-3}$ Hz range. For EMRIs the number of detections lies between $\mathcal{O}(0.1)$ and $\mathcal{O}(100)$. Bottom panel shows the number of detectable supermassive black hole binaries (SBHB) per log mass, redshift, and observed GW frequency. Ice giant missions combined with LISA would improve the source localization by an order of magnitude compared to LISA by itself. With a significant improvement in the total Allan deviation, a Doppler tracking experiment might become as capable as LISA at such low frequencies, and help bridge the gap between mHz detectors and Pulsar Timing Arrays. Ice giant missions could play a critical role in expanding the horizon of GW searches and may even be the first to detect the first SBHB merger.

References: [1] D. Soyuer et al. (2021) *MNRAS 503,* L73–L79. [2] J. W. Armstrong (2006) *Living Rev. Relativity, 9*, 1. [3] B. Bertotti et al. (1991) *Phys. Rev. D, 59*, 082001.