EUROPA’S GLOBAL SHAPE AND TIDAL DEFORMATION: STELLAR OCCULTATION ASTROMETRY AS A COMPLEMENT TO RADAR ALTIMETRY ON EUROPA CLIPPER

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Summary: The global shape of Europa, obtained from Galileo limb profiles, is only poorly constrained [1]. Obtaining more precise global and regional topography is important to determine Europa’s internal structure and the compensation state of the ice shell, and is an objective of the Europa Clipper mission [2]. The primary instrument for determining Europas global shape is the REASON radar system [3]. The main limitation in fitting global shape and tidal deformation with radar altimetry is the fact that the radar tracks do not have global coverage. Precisely timed stellar occultations can supplement the radar data with shape measurements that fill the gaps around 90° and 270° longitude, as shown in figure 1. By simultaneously fitting both radar measurements and occultation chords, Europa’s global shape can be fit significantly better than with either dataset alone.

Introduction: Europa Clipper’s UV Spectrograph [4] will observe stars as they pass behind Europa in order to study potential plumes or an atmosphere. However, the instrument’s maximum temporal resolution of ~1 ms is high enough that the duration of the occultation is a measurement of a chord across the planet with an uncertainty of ~meters.

Method: Broadly, we are using a least squares fit to find the set of spherical harmonics that best fit our (currently synthetic) data, in a similar fashion to [5].

Synthetic data: In the absence of real Europa Clipper measurements, our current work uses synthetically generated data. We use an assumed shape model, either the known shape of Earth’s moon or randomly generated spherical harmonics with a power spectrum which, based on limb profile data [1], is likely to approximate Europa. From these shape data we generate the measurements that Europa Clipper would see, both with and without finite measurement precision. Then we fit spherical harmonics to the measurements and compare them to the known harmonics that generated the measurements.

Fitting: For our initial work we just use a least squares fit, weighting the radar and occultation points such that both data sets contribute equally to our fits. By generating many randomly generated data sets, we can figure out the uncertainties involved in our fits, what the

Figure 1: Map of radar altimetry profiles (densely spaced black dots) and occultation measurements (green for ingress and red for egress, individual chords connected by a blue line) for one proposed trajectory (15F10). Notably, the radar measurements are concentrated around the subjovian and antijovian points. This results in global shape fits with large misfits at wavelengths smaller than the size of the gaps. The occultation measurements are able to fill in some of these gaps, significantly improving global coverage. Although this is just one proposed trajectory, the general trend of altimetry profiles around 0°/180° and occultations offset by 90° comes from orbital constraints. This is for a set of 109 total occultations. Background map created by Björn Jónsson.
main weaknesses are, and how we might improve our use of the data. Chords are broadly similar to point measurements, but are limited by the fact that they are only a difference between two locations rather than absolute altitudes.

**Preliminary Results:** Adding occultations to radar data does improve our ability to fit our synthetic data. Figure 2 shows an example of this, showing the misfit in map view for separate and combined data, and figure 3 shows how the misfit depends on the degree we try to fit. Notably, the locations with the worst fits are where the data are most sparse, and the combined data fill those gaps fairly well. A particularly valuable result of the combined fit is that the fit can be carried out to higher harmonic degree. A surprising observation is that the misfit comes pretty much entirely from the sparseness of the measurements and not from the uncertainty of the measurements themselves.

![Figure 2](image)

**Figure 2:** Fits up to degree and order 7. The first map is fitting only radar data (for the radar tracks in figure 1) the second map is fitting only occultation data, and the third map is fitting both datasets, showing a much better global fit.

**Upcoming Work** A primary goal of this work will be to establish whether occultations can be used to measure Europa’s tidal deformation, that is, the time-dependent topography as well as the static topography. Measuring Europa’s tidal deformation is an important aspect of the Clipper mission [3] because it helps constrain the ice shell properties [6]. In addition, several features of this method need to be fleshed out further. Most importantly, the uncertainty of the fit needs to be quantified. This can be accomplished by generating a wide range of possible “Europa’s” and quantifying the range of misfits. In addition, in the example above, the two datasets are weighted by the inverse of the number of points, but the optimal weighting between and within the datasets is likely more complicated and can be quantified. The sparseness in time coverage for the radar dataset is tied to the 40 flyby closest approaches.

The distributed timing of 100 occultations is largely within the similar +/- 12 hour encounter period but also includes several events closer to orbital apoapsis, more fully sampling Europas 3.55 day orbital period. Occultations therefore offer a powerful constraint to the tidal frequency analysis. Certain trajectory options have identified roughly double the number of occultation events considered in this initial analysis, and we will investigate the potential benefits of adding even more frequent (including dimmer / lower data quality) UV stellar occultation measurements.

**Conclusions:** Occultation chords are a valuable complement to radar altimetry for studying Europa’s long wavelength shape. They can increase the accuracy of the shape fit, increase the maximum harmonic that can be fit, and potentially increase precision enough to measure tides.