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Sparse source configurations for asteroid tomography

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Abstract

The objective of our recent research has been to develop non-invasive imaging techniques for future planetary research and mining activities involving a challenging *in situ* environment and tight payload limits [1]. This presentation will deal in particular with an approach in which the internal relative permittivity ε_r or the refractive index $n = \sqrt{\varepsilon_r}$ of an asteroid is to be recovered based on radio signal transmitted by a sparse set [2] of fixed or movable landers.

To address important aspects of mission planning, we have analyzed different signal source configurations to find the minimal number of source positions needed for robust localization of anomalies, such as internal voids. Characteristic to this inverse problem are the large relative changes in signal speed caused by the high permittivity of typical asteroid minerals (e.g. basalt), leading to strong refractions and reflections of the signal. Finding an appropriate problem-specific signaling arrangement is an important pre-mission goal for successful *in situ* measurements.

This presentation will include inversion results obtained with laboratory-recorded travel time data $\mathbf{y}$ of the form

$$y_i = \int_{\mathcal{C}_i} n_\delta \, ds + (y_{bg})_i + g_i, \quad \text{for} \quad i = 1, 2, \ldots, N$$

in which n_δ denotes a perturbation of a refractive index $n = n_\delta + n_{bg}$; g_i estimates the total noise due to different error sources; $(y_{bg})_i = \int_{\mathcal{C}_i} n_{bg} \, ds$ is an entry of noiseless background data $\mathbf{y}_{bg}$; and $\mathcal{C}_i$ is a signal path. Also simulated time-evolution data will be covered with respect to potential u satisfying the wave equation $\varepsilon_r \partial^2 u / \partial t^2 + \sigma \partial u / \partial t - \Delta_{\vec{x}} u = f$, where σ is a (latent) conductivity distribution and f is a source term. Special interest will be paid to inversion robustness regarding changes of the prior model and source positioning. Among other things, our analysis suggests that strongly refractive anomalies can be detected with three or four sources independently of their positioning.

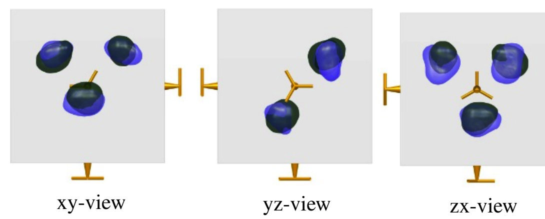

Figure 1: A comparison between exact (light blue) and recovered (dark green) anomalies recovered based on travel time data corresponding to three sources (yellow antenna symbols).

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