Estimation of the interior density of a small body given its gravity field

Abstract

We present here a method for the retrieval of the **internal density distribution** of a small body, via a **least-squares inversion** of its gravity field.

Multiple solutions are **averaged** in order to limit the effect of the a priori density distribution. **Simulations** show successful density map estimations even with little to no initial information on the interior structure of the body.

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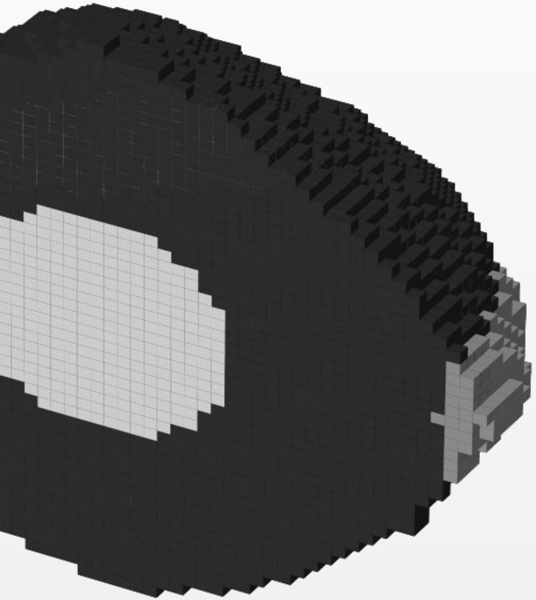
Gravity inversion



Gravitational potential

⇕ Spherical harmonics expansion

Interior structure → [1,2] → **Stokes coefficients** C_{nm}, S_{nm}

← ?

Measured e.g. via spacecraft **radio-tracking**

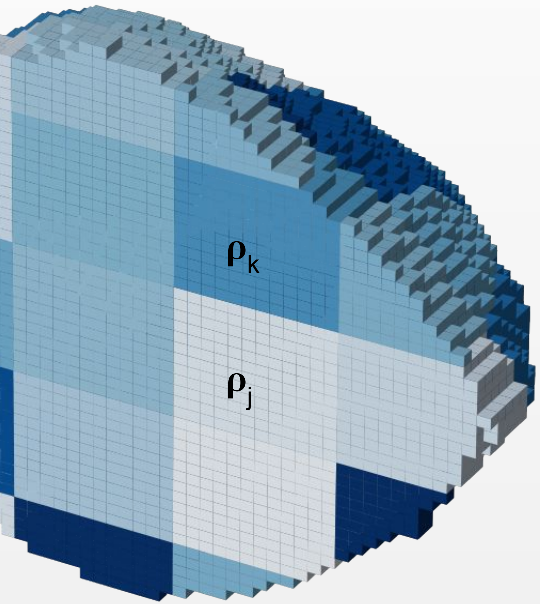
The body is **discretized** as a collection of cubes

↓ [2]

Gravitational potential as sum of contributions from each cube

Methodology

Density (ρ) estimated for homogeneous **zones**, so as to have an overdetermined system [3,4]:

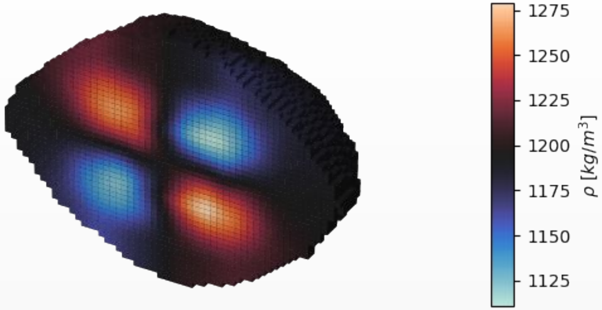


$$\begin{bmatrix} C_{nm} \\ S_{nm} \end{bmatrix} \xrightarrow{\text{Least-squares inversion}} [\rho_i]_{i \in zones}$$

Solution depends on the initial zones subdivision (**density map**). Hence:

1. Solution from different maps are **averaged** together [5]
2. An edge-detection algorithm (**Laplacian of Gaussian**) is employed to generate a new map from the averaged solution
3. The **inversion** is performed on the new density map

Retrieval simulation



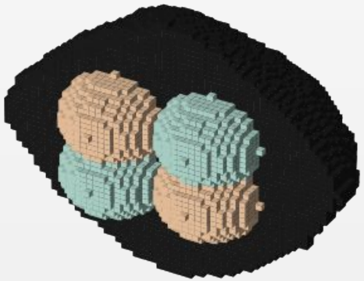
Inaccurate density values in the averaged solution

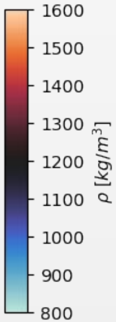
Least-squares inversion
With a range of initial density maps

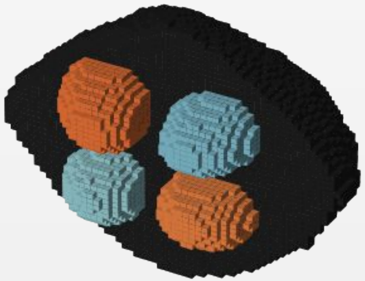
Anomaly detection
By averaging solutions for different initial maps

Laplacian of Gaussian, providing shape and location of anomalies

Reference density
Used to simulate a gravity field







Estimated density
Using the derived map for the inversion

Conclusions

Solution appraisal

- Successful detection of the **density anomalies**
- Small inaccuracies in the anomaly **size and shape determination**, which in turn affect the estimated density value
- **Non-unique solution** [6]: in a real scenario, it has to be confirmed by theoretical models or independent investigations

Future work

- Find a better agreement between the retrieved and the nominal models:
  - Improvement of the shape detection algorithm
  - Larger variability in the initial density maps
- Test on real data

Acknowledgements

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References

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