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Time-dependent solution for reorientation of rotating tidally deformed visco-elastic bodies

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Many icy satellites or planets contain features which suggest a (past) reorientation of the body, such as the tiger stripes on Enceladus and the heart-shaped Sputnik Planum on Pluto. Most of these icy bodies are tidally locked and this creates a large tidal bulge which is about three times of its centrifugal (equatorial) bulge. To study the reorientation of such rotating tidally deformed body is complicated and most previous studies apply the so-called fluid limit method. The fluid limit approach ignores the viscous response of the body and assumes that it immediately reaches its fluid limit when simulating the reorientation due to a changing load. As a result, this method can only simulate cases when the change in the load is much slower than the dominant viscous modes of the body. For other kinds of load, for instance, a Heaviside load due to an impact which creates an instant relocation of mass, it does not give us a prediction of how the reorientation is accomplished (e.g. How fast? Along which path?). We establish a new method which can give an accurate time-dependent solution for reorientation of rotating tidally deformed bodies. Our method can be applied both semi-analytically or numerically (with finite element method) to include features such as lateral heterogeneity or non-linear material. We also present an extension of our method to simulate the effect of a fossil bulge. With our method, we show that reorientation of a tidally deformed body driven by a positive mass anomaly near the poles has a preference for rotating around the tidal axis instead of towards it, contrary to predictions in previous studies.

References

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