Using Elastic Torque to Predict Libration on Icy Satellites

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Why we are interested:
- Motions of bodies can reveal internal structure
- Attractive Targets for Space Missions
- Origin of observed surface deformation are yet unexplained

What we are doing:
- Using Elastic Restoring to examine the motions of bodies with a surface shell decoupled from the interior by a fluid layer
- Analyzing the effects of viscous dissipation in the shells

What we are learning:
- Elastic Libration predicts a range of amplitudes
- Viscous layers reduce these motions
- Might build significant stresses

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Viscoelastic Layering:

With this EET, we can then use the elastic energy calculation of Goldreich and Mitchell (2010)[1] for a thin elastic shell.

\[
\kappa = \frac{32\pi}{5} \left(1 + \nu\right) (1 - k_{\text{ice}})^2 \left(\frac{nR}{GM}\right)^2 \left(R^3 - (R - EET)^3\right)
\]

We write the moment of inertia, \(C\), as

\[
C = \frac{8}{15} \pi \rho \left(R^3 - (R - h)^3\right)
\]

It follows that

\[
\omega_0^2 = \frac{k}{C} \propto \frac{EET}{h}
\]

Elastic Libration is a competition between elastic energy storage and the energy required to move the whole shell.

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Implications:

With this model, measurements of rotation rate variation can constrain rheological profiles for ice shells.

Dissipation of energy by viscous layers can tell us about the quantity of energy which goes into tidal heating on bodies.

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References:


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Other Bodies:
- Ganymede
- Enceladus
- Mercury
- Titan

Future Work:

- How can we quantify viscous dissipation?
  \[ Q = 2\pi \frac{E}{\Delta E} \]

Layer Coupling:
How will individual layers couple to each other [4]?
- Gravity
- Pressure

Surface Stress:
If the shell rotates at a different rate then the rest, reorientation stresses should act through the shell.
- Magnitudes
- Patterns

How does this process relate to the often invoked “Non-Synchronous Rotation”?