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Tides are a means of probing the internal structure of Europa and establishing the existence or absense of a liquid water ocean at depth (1-4). An ocean may lie beneath Europa's outer icy shell which may have a depth ranging from a few to 100km. It is also possible that the observed icy crust is frozen all the way to the rocky surface of the mantle. The rocky mantle could be solid down to a liquid iron *core*. Another alternative is that the lower mantle is soften by tidal heating, perhaps even partially melted at depth as was originally proposed for Io(3). One can discriminate between these three extremes by measuring the 3.60d$=2\pi/n$ surface tide (or the h_2 Love number) and the corresponding change in external gravity (or the k_2 Love number). An alternative to the ocean is a plastic ice layer at depth. An examination of Love numbers for a range of models for Europa illustrates the extent that measurement of these parameters can distinguish between these models. The nominal model includes a water layer of 105km thickness, a lunar-like rocky mantle and a liquid iron core of radius 600km and density 5gm/cc. The table below divides the water layer into a rigid outer shell with S-wave velocity vs ranging from 1 to 2km/s arid which covers a 'soft.' layer with much lower v_S.

	outer icy shell thickness	soft. icy layer velocity v_s (km/s)	h2	k2	h2/k2
1	105	2.0	0.039	0.021	1.86
2	25	0.30	0.0'1"1	0.030	2.58
3	25	0.05	0.12.2	0.039	3.30
4	25	0.01	0.732	0.165	4.44
5	25	0.001	1.288	0.282	4.57
6	65	0.01	0.219	0.060	3.67
7	65	0.0005	1.204	0.275	4.38
8	25	0.01	1.084	0.458	2.37
9	25	0.01	1.2.53	0.587	2.13

Column 1 corresponds to the solid shell case and the surface radial tide amplitude is $d \approx 3eR(M_J/M)(R/a)^3 \approx 24h_2 m \approx 1m$. Columns 2-5 progressively decrease v_S in the soft layer (of thickness 80km) until it. reaches a 'fluid' layer limit for which $k_2 \cong 0.29$. We find that both Love numbers increase, as does the ratio h_2/k_2. Columns 8 and 9 includes a soft lower mantle layer below radius 1400km with S-wave velocity $\approx$0.5km/s and 0.0km/s, respectively. The addition of a softened lower mantle t-o a model with a nearly decoupled icy shell tends to increase Love numbers further while reducing the ratio h_2/k_2 toward a limiting value near 2. If the icy shell is completely decoupled, then for $k_2 > 0.3$ there must be a contribution from a softened mantle. The ratio h_2/k_2 also helps discriminate between these extremes. A ratio near 2 implies that the mantle contributes significantly to the tide while a ratio greater than 3 implies that the icy shell/ocean layer is the main source of the tide.

These two parameters are not enough to completely constrain all possibilities, especially if the 'soft' ice layer as in col. (2-4,6) inhibit shell deformation. Measurement, of the phase lag or dissipation Q for this tide might help since one might expect a thick mushy layer Of ice to be highly dissipative while a deep ocean layer would not.. Tidal friction in Europa results in a heat.ir]g rate of 5.4X10^{21} k_2/Q ergs/s (2) or a surface heat flow of $1.7\times10^4 k_2/Q$ erg/s/cm^2 . Radiogenic heating might contribute 10ergs/s/cm^2 to surface heat. flow and therefore tides are an important heat_ source for $Q/k_2 < 1.7\times10^3$. ']'he contribution from solid friction within the mantle with 0.020 and $Q=25$ **is** 14ergs/s/cm^2, but this rate could be increased by a factor of 10 or more for mantle models with a softened lower mantle as in col. 8. Ojakangas and Stevenson(4) obtain $k_2/Q \approx 0.0004$ for an equilibrium shell model coated with 'soft.' , plastic ice at its base. increasing this rate requires mechanisms other than conduction through the solid icy layer to remove heat, such as open cracks or resurfacing. High dissipation might also be achieved with a thin ocean 1 ayer . Ocean currents cause skin friction at the interfaces and dissipate tidal energy. As with Earth, ocean currents are a very efficient energy loss mechanism since here the mean depth can adjust to match heat flow. The rheology of ice is not relevant except as it effects heat flow.

Covariance analysis of an orbiting spacecraft about. Europa has been performed to determine its sensitivity to the k_2 Love number. 'l'he tidal flexing period is an anomalistic; orbit and differs for the rotation period by the apsidal 1yr period. We expected that aliasing of the 3.6d tide with odd harmonics in the permanent gravity field might dilute the ability to detect this parameter for short duration missions, but this suspicion happens to be unfounded. Two factors which improve tide resolution include spacecraft- altitude which allows it to partially sense gravity on the backside of Europa. Also, for polar orbits, contributions from the fixed field which might alias with the tidal signature are small . Continuous Doppler tracking for 5d (at X-band) of a polar orbiting spacecraft. at an al ti tude of 1 00-200km and nearly edge-cJ1l to Earth can resolve k_2 (and also k_2/Q) to about ±0.001 (1 standard deviation) . Realistic errors are expected to be no worse than 2-5 times larger(5) . A laser altimeter aboardsucha spacecraft and with $\approx\pm5m$ range accuracy should be sensitive to h2 to±0.1 or better. Therefore, an orbiter should be able to discriminate between models with and without liquid oceans or a softened lower mantle and determine whether tidal friction is a significant source of heating compared to internal sources. These and other issues such as detection of polar moment of inertia from spin pole orientation shall be discussed.

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