Tiltmeter for Europa Lander

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With contributions from
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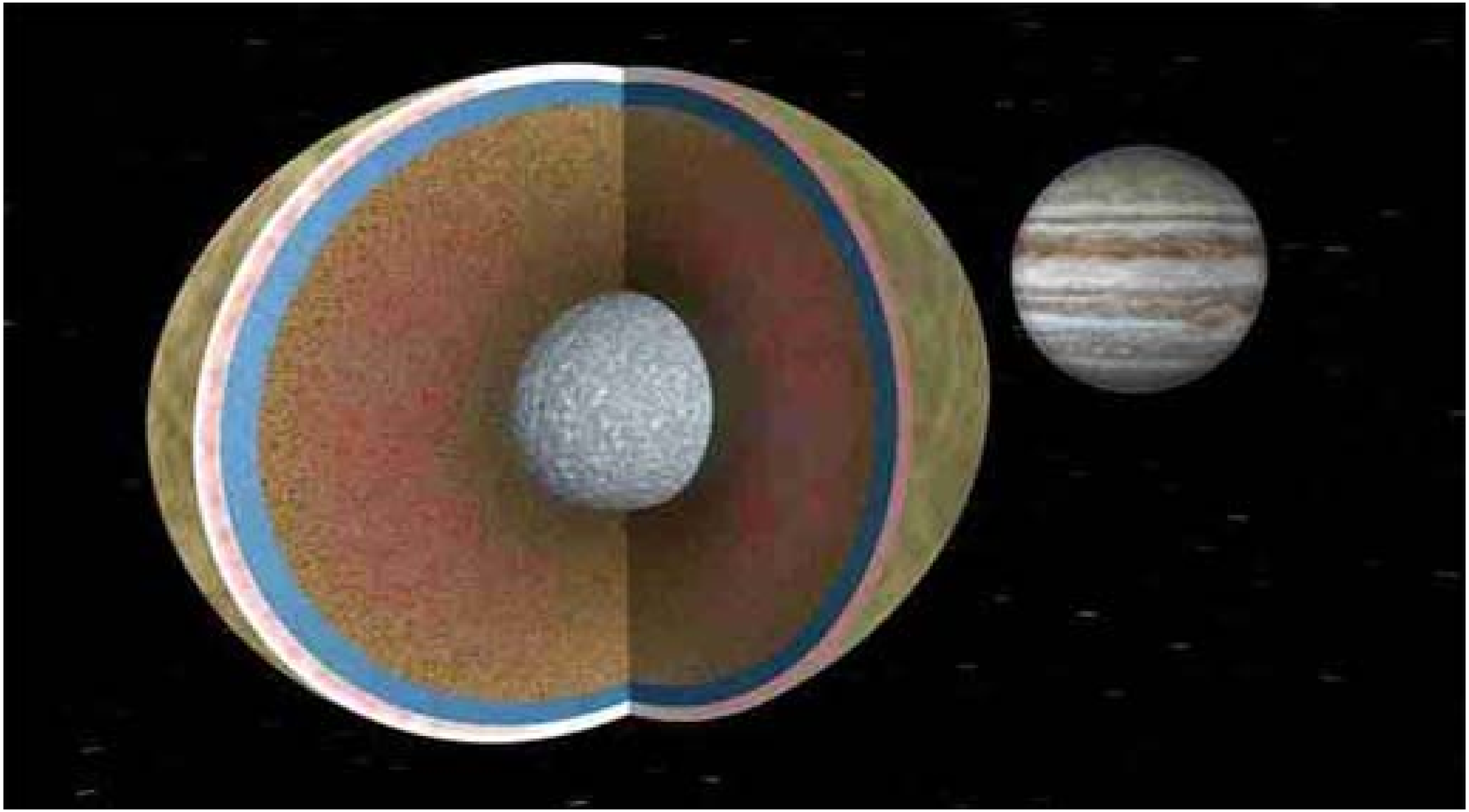
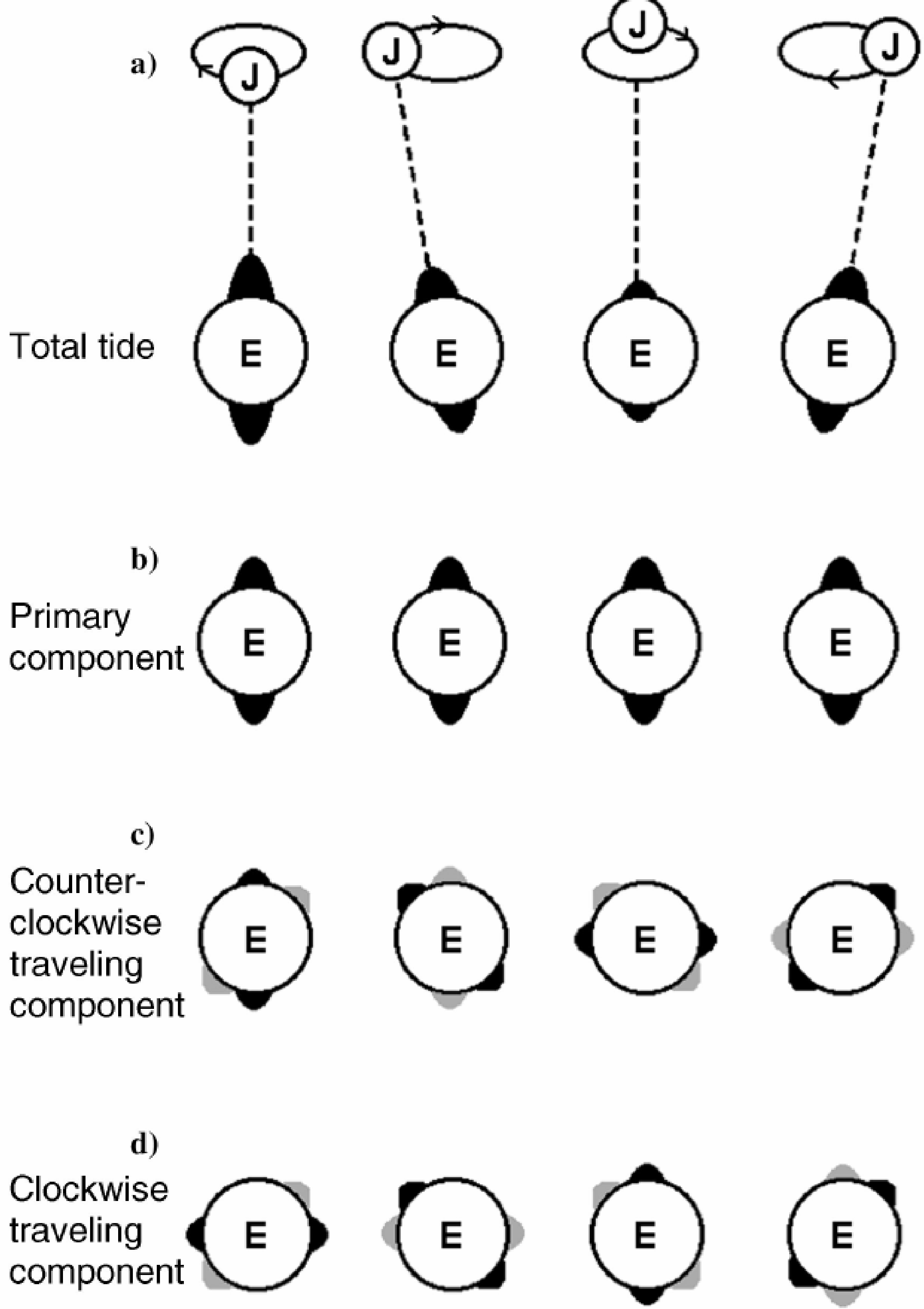
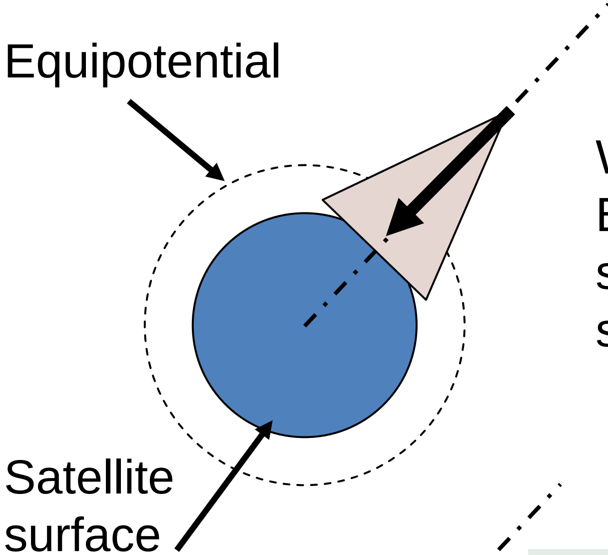


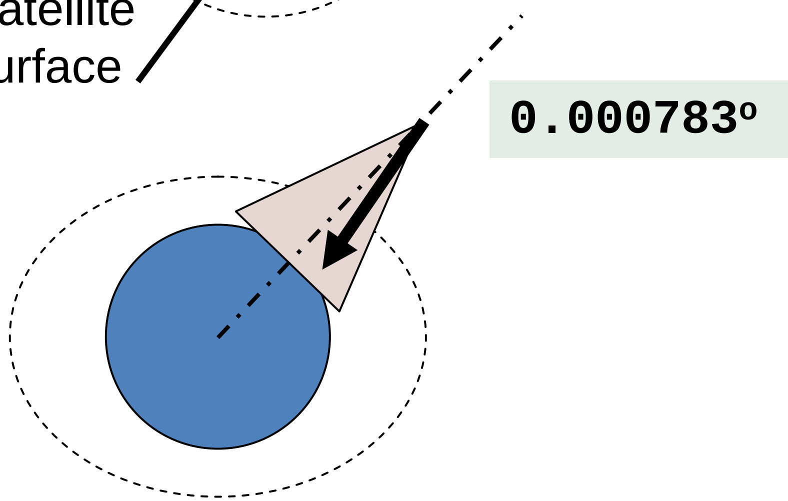


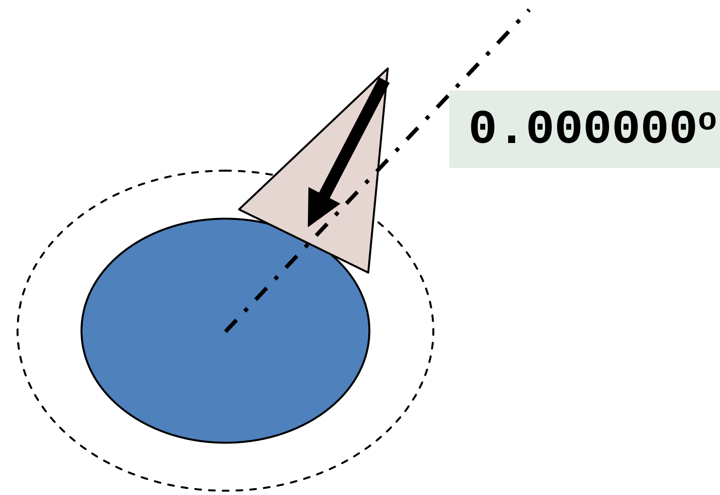
a)
J
J
J
J
Total tide
E
E
E
E
b)
Primary component
E
E
E
E
c)
Counter-clockwise traveling component
E
E
E
E
d)
Clockwise traveling component
E
E
E
E



0.000000°

With no tide present, tiltmeter measures zero. Both the gravitational equipotentials, and the surface onto which the tiltmeter is sitting, are spherical.





With strong tide, tiltmeter pendulum responds to horizontal acceleration. If satellite is rigid (low k2) surface remains spherical and thus tiltmeter reading is high

With strong tide on a deformable satellite, tiltmeter pendulum responds as before. However, the surface (and thus the tiltmeter housing) also tilt to follow the equipotential. The tilmeter output (difference between pendulum and housing) is therefore zero.

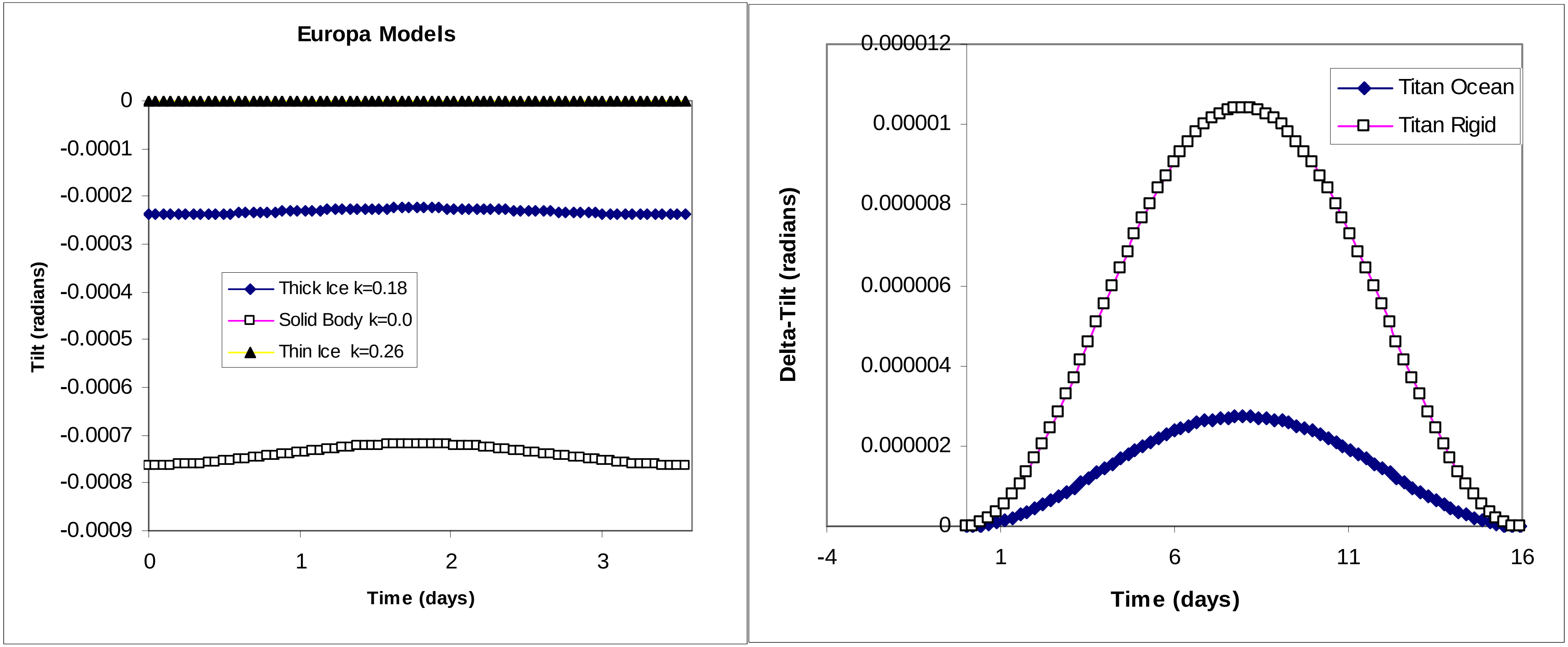


Figure 2. Absolute tilts relative to a sphere (left) on Europa for thin ice (1 or 10km look the same on this plot), thick ice (100km) or a rigid body. The steady-state values here cannot be measured by a tiltmeter without astronomical references, but the changing component (shown again on an expanded scale in Figure 3) is easily measured without additional data. Plot on right shows the changing part only of the tilt for Titan.

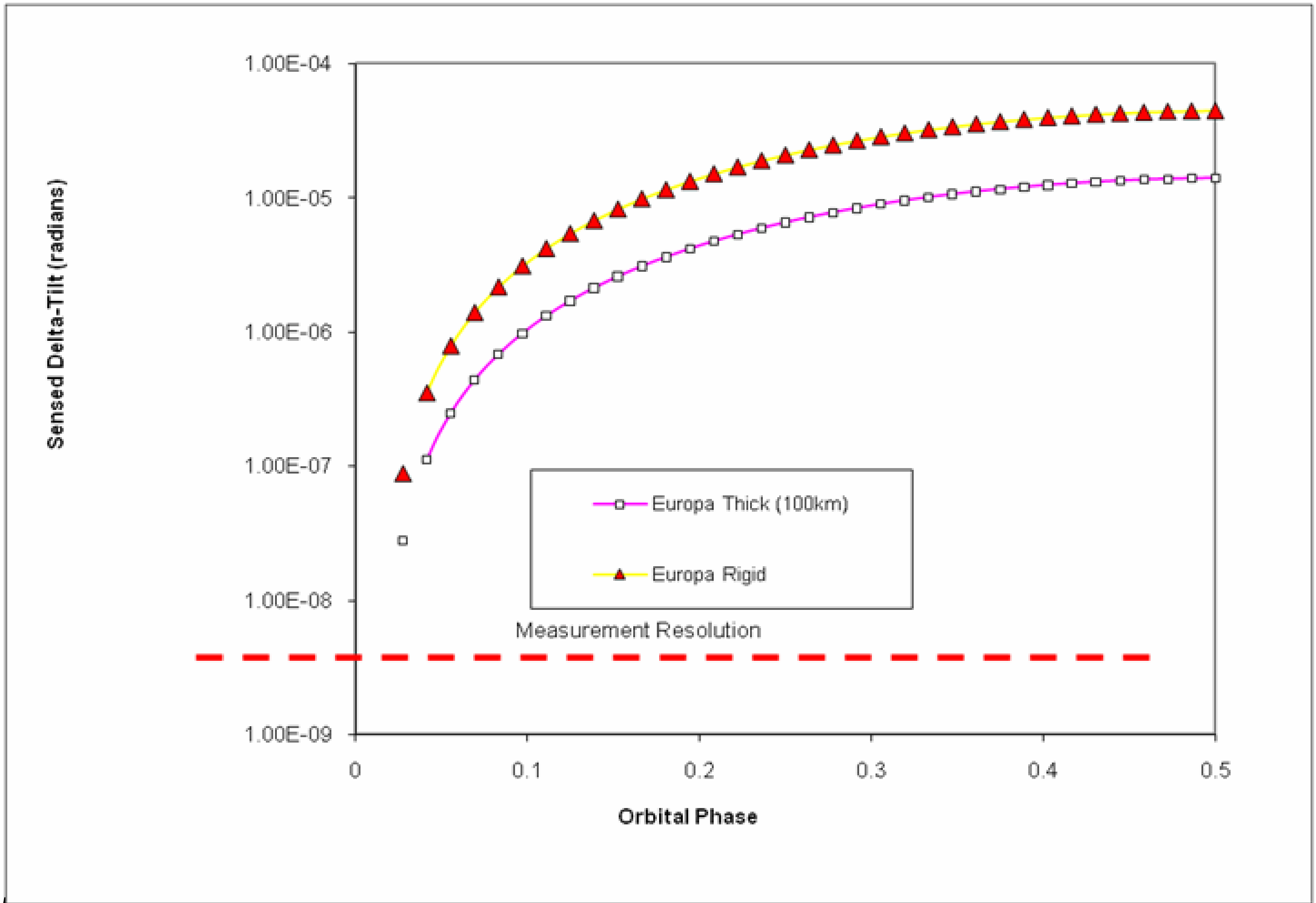
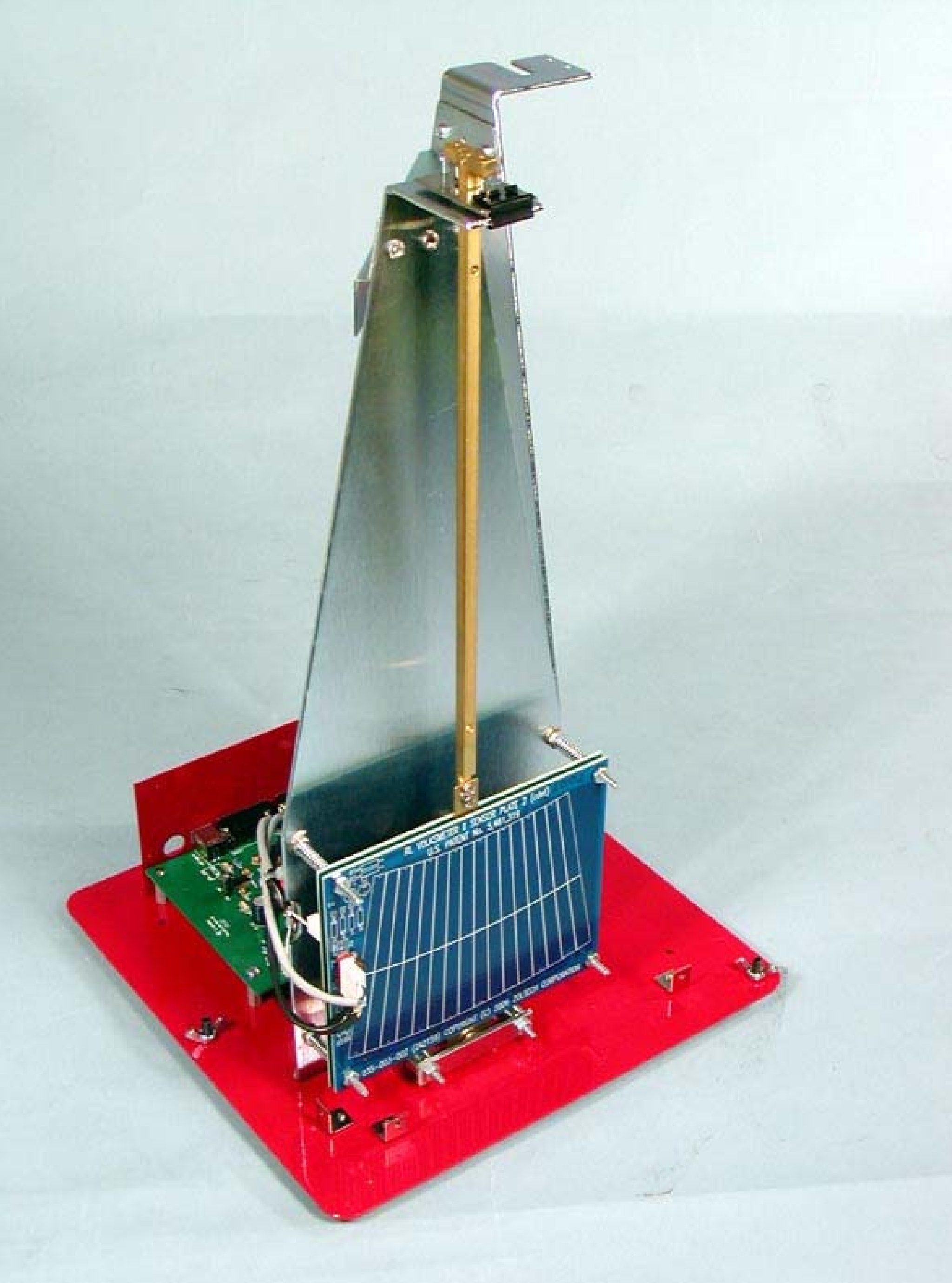


Figure 3 shows the changing part of the tidal tilt signals expected (at a point at 45 deg latitude on the prime meridian of Europa where the tilt is maximum). Notice that all are 2-3 orders of magnitude greater than the resolution of a commercial tiltmeter and thus can be well-characterized by a spacecraft instrument. A thin-ice Europa will lie somewhere between the thick-ice case and zero. Nondetection of a cyclical tilt implies a strengthless crust.



Commercial unit (~$1000)

Simple pendulum with capacitive position sensing - notionally ~ 1 nanoradian accuracy.

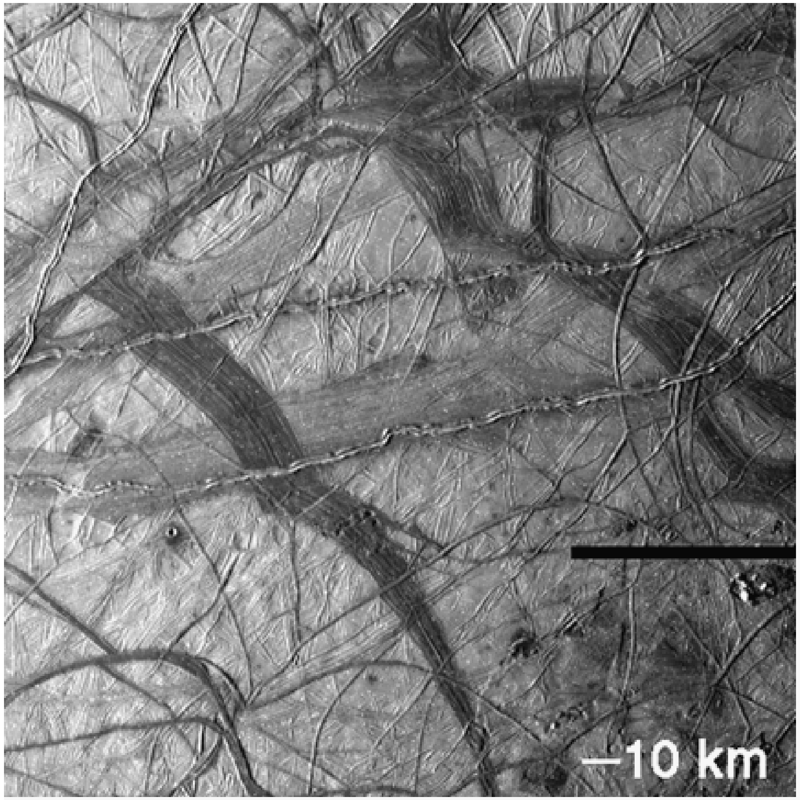
(Pendulum mass in this instance only ~150g)

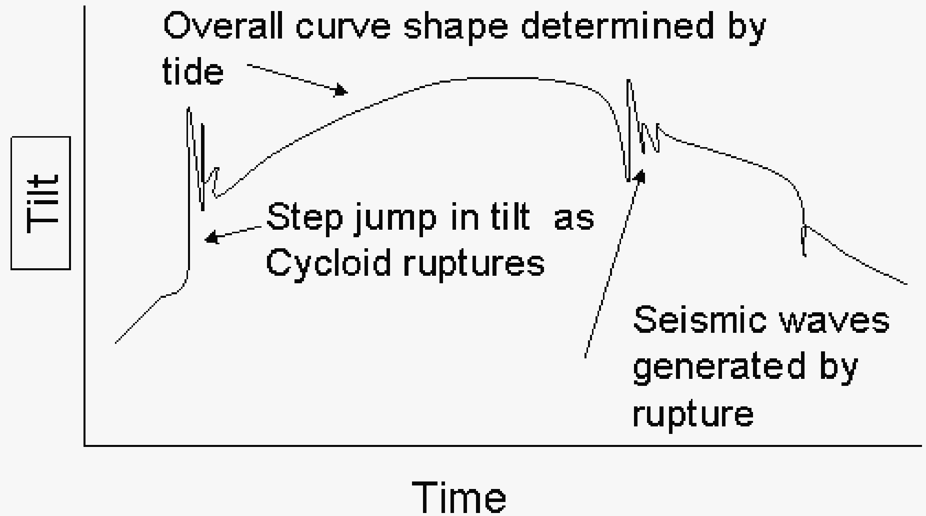
Can be sampled (capacitance sensor is limiting factor) at ~10 Hz.

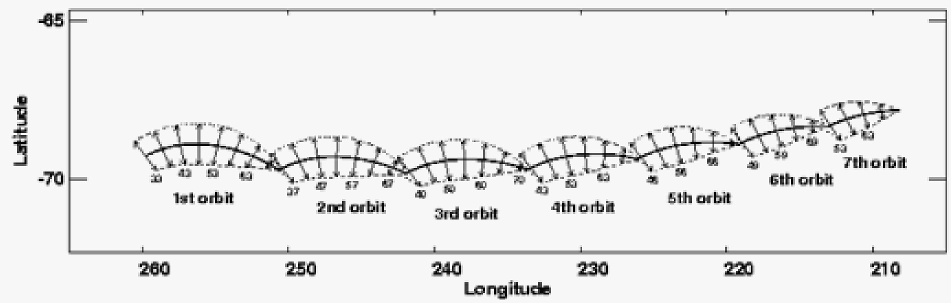
Alternative sensing technology - fluid vial with liquid position sensed electrolytically.

Sensors of this type were flown on Huygens probe to Titan to measure surface attitude and wave motion, as well as parachute dynamics (Lorenz et al., 2006)

Geophysical instruments (e.g. Applied Geomechanics Inc) can attain few nanoradian accuracy.







Tiltmeter signal contains several types of data diagnostic of habitable ocean, overlying ice crust and possible processes by which water can reach surface, e.g. through cracks such as the cycloidal ridges formed by tidal stress

Likely real tilt history on Europa will be more complex - discontinuous jumps as crust slides along cracks (e.g. cycloids). These jumps will also cause seismic waves to radiate through the crust and ocean which can also be detected

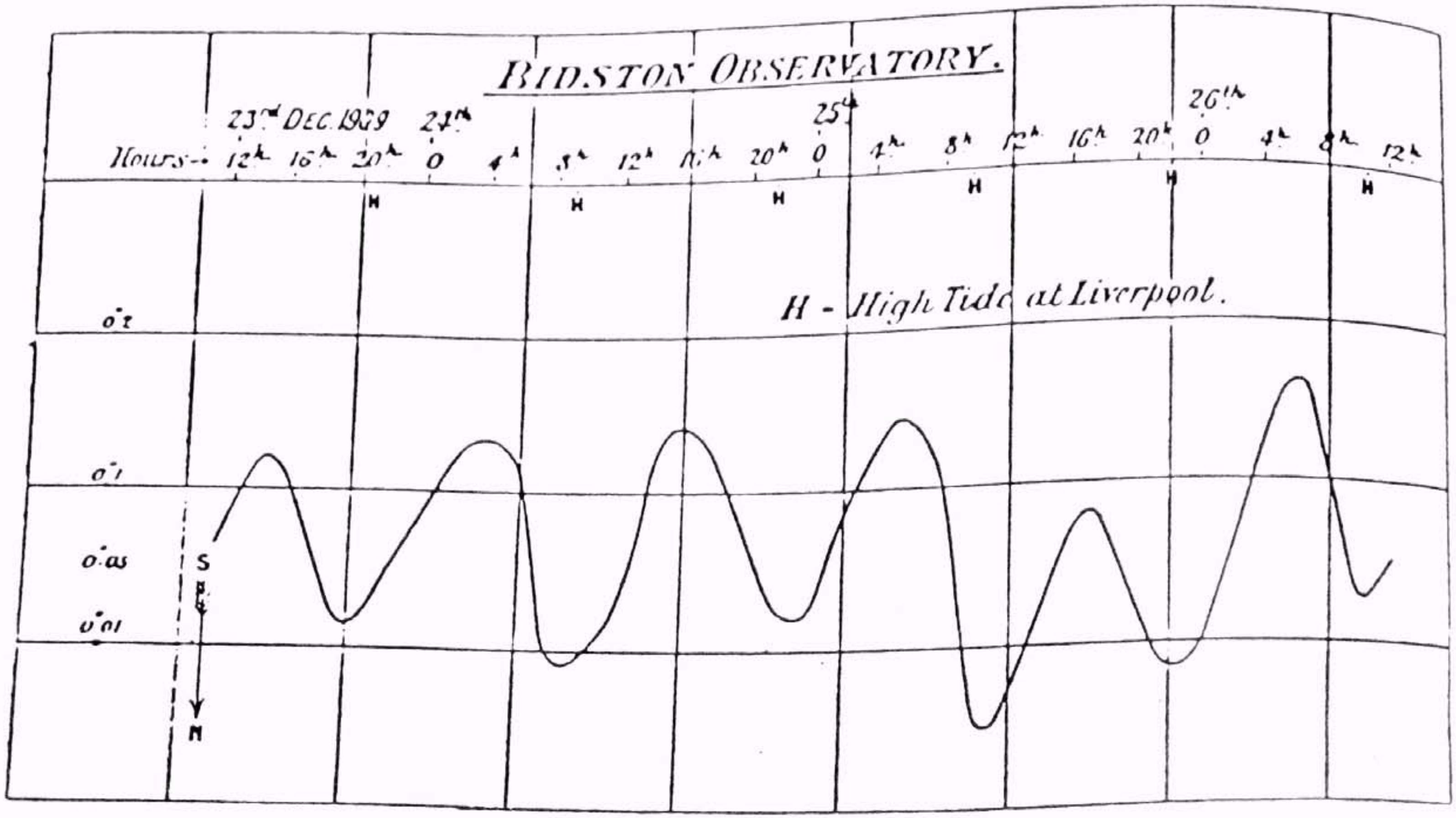


Figure 10.4. North (downward) – South (upward) tilt of the vertical between 23 and 26 December 1909, recorded by J. Milne in a vault below Bidston Observatory near Liverpool Bay. Times of HWT in the local sea are shown by letters H, where the tilt is obviously northward, that is, toward the sea. The vertical scale is graduated in 0.1 arc seconds. (From *Nature*, 82, 427, 1910.)

Notable measurements with a horizontal pendulum were made by Otto Hecker between 1902 and 1909. Darwin comments on them in his 3rd Edition supple

Challenges for Europa Lander application

Isolate pure tidal tilt from once-per-orbit thermal changes (tide and thermal distortion have same period.) Isolate instrument from direct sunlight with insulation blankets ; array of heaters to actively balance solar input.

Local thermal deformation of crust unavoidable. Star camera mechanically coupled to pendulum or pendulum mounting might augment accuracy.

Accommodate uncertain landing attitude (leveling mechanism)

Tolerate landing loads (need caging mechanism for pendulum type; liquid vial type likely g-tolerant)

Radiation effects on parts.

Measurement introduces a weak constraint on landing location - must be away from subJovian/Antijovian points, and from a great circle through poles at 90 and 270 degrees longitude.

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Satellite collision creates copious space junk

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Two space satellites smashed into each other on Tuesday in an unprecedented orbital accident. Government agencies are still assessing the aftermath, but early radar measurements have detected hundreds of pieces of debris that could pose a risk to other spacecraft.

As first reported by CBS News, a defunct Russian Cosmos satellite and a communication satellite owned by the US firm Iridium collided some 790 kilometres above northern Siberia on Tuesday.

"This is the first time that two intact spacecraft have accidentally run into each other," says Nicholas Johnson, chief scientist of NASA's Orbital Debris Program Office in Houston, Texas.

Danger to satellites

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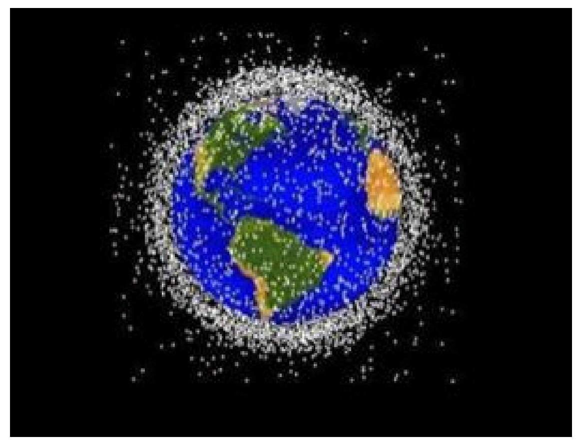

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