

Tides of the Earth/Moon



Earth

What causes it? **Luni-Solar**

How is it? **Time varying**

How much does it vary? (peak-to-peak)

Gravity tide ~ 0.24 mgal

Deflection of the vertical $\sim 0.05''$

Most important frequency? $\sim 1/2$ day

How to measure? Gravity, Tide Gauge,
Extensometer, Tiltmeter

Moon

What causes it? **Geo-Solar**

How is it? **Constant** + Time varying

How much does it vary?

Gravity tide ~ 1 mgal

Deflection of the vertical $\sim 1.0''$

Most important frequency? ~ 1 month

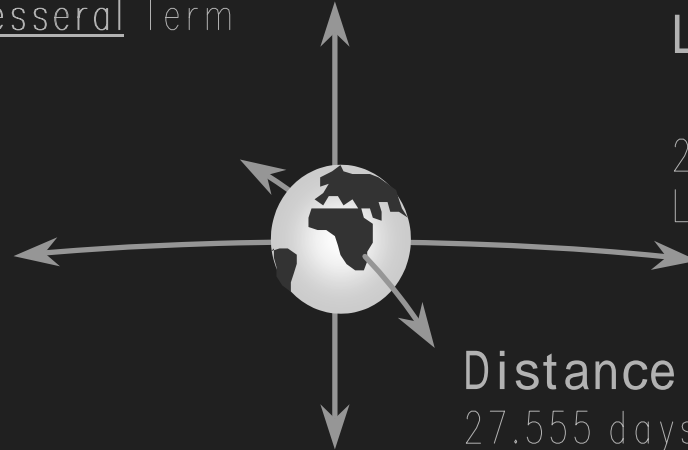
How to measure? LLR, Satellite orbit,
Deflection of vertical (ILOM)

Libration in latitude

$\pm 6.68^\circ$

27.212 days (draconitic month)

Lunar Tide: Tesseral Term



Libration in longitude

$\sim \pm 8^\circ$

27.555 days (anomalistic month)

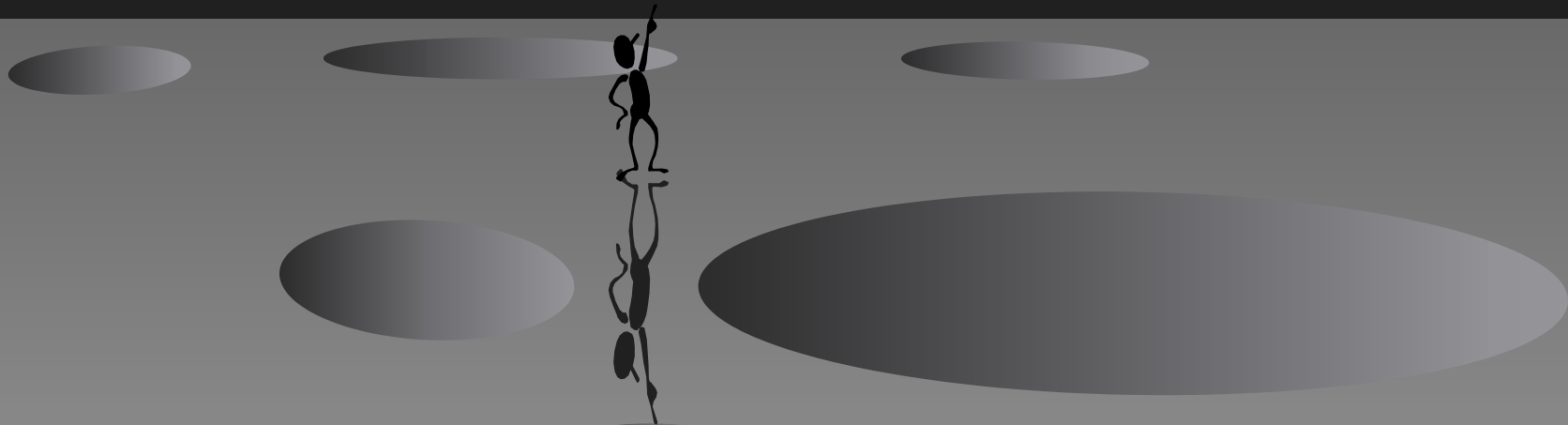
Lunar Tide: Sectorial Term

Distance change

27.555 days (anomalistic month)

amplitude changes in the 206 days period

Lunar Tide: Zonal Term



Optical Libration of the Moon

Diminishing factors in tidal measurement



Tide gauge

$$D = 1 + k_2 - h_2$$

k_2, h_2 : Love numbers



Gravimeter

$$G = 1 - 3/2 k_2 + h_2$$



Tiltmeter

(tilt of surface
w.r.t. equipotential)

Same as tide gauge



Telescope

(tilt of surface
w.r.t. celestial reference)

$$L = h_2 - l_2$$

l_2 : Shida number

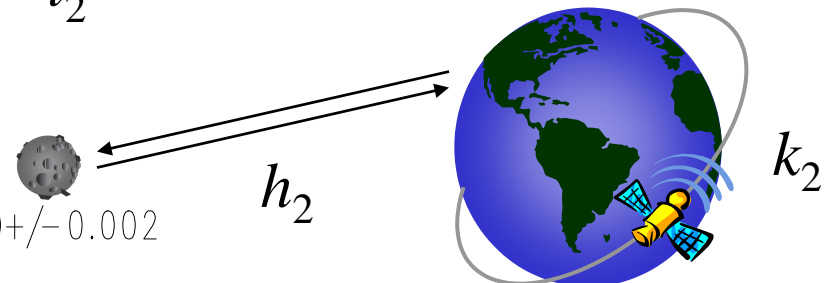


Photo Zenith Tube

(tilt of equipotential
w.r.t. celestial reference)

$$L = 1 + k_2 - l_2$$

Lunar k_2 : 0.030 +/- 0.002



Measurement of Gravity Field

Method

In-situ

Absolute (pendulum, free fall)
Relative (cryogenic, spring, etc.)

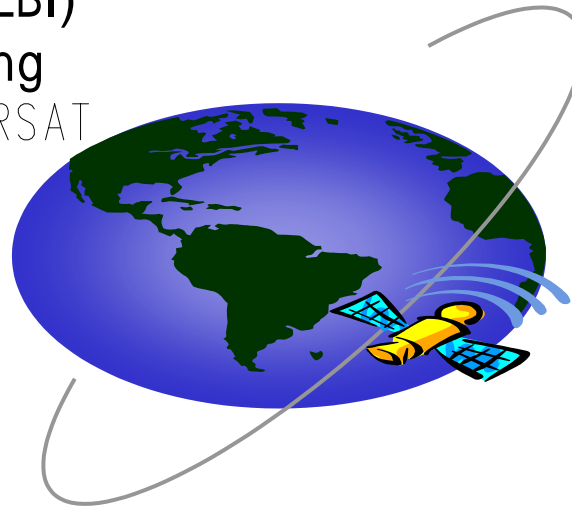
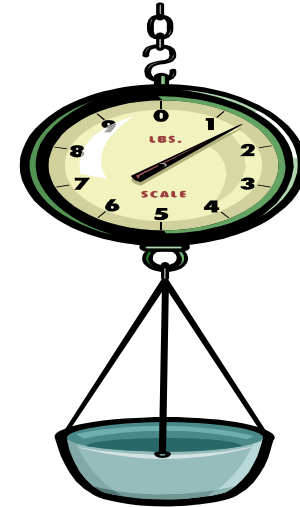
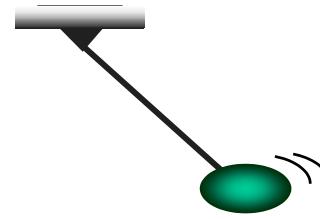
Satellite

Direct tracking (Doppler, VLBI)

Satellite-to-satellite tracking

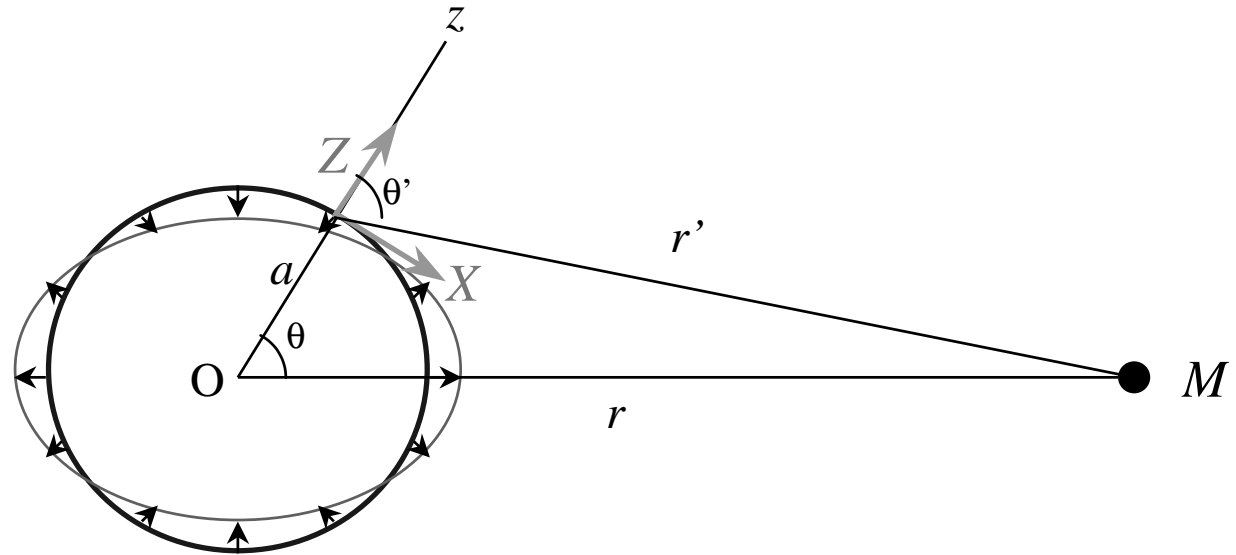
(high-low : CHAMP, SELENE/RSAT
low-low : GRACE, MORO)

Gradiometry (GOCE),



Interest

TIDE



if $r \gg a$

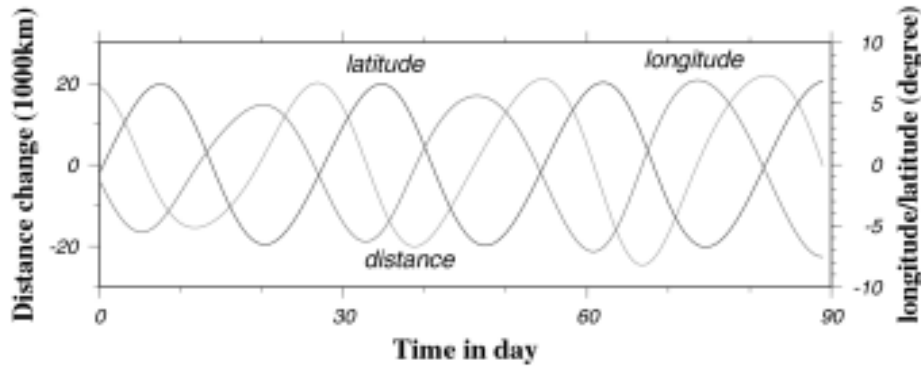
$$X = \frac{3}{2} \frac{GaM}{r^3} \sin 2\theta \quad Z = \frac{GaM}{r^3} (3 \cos^2 \theta - 1) \quad W_2 = \frac{GaM}{r^3} P_2(\cos \theta)$$

$$\frac{\partial X}{\partial \theta} = \frac{3GaM}{r^3} \cos 2\theta \quad \frac{\partial Z}{\partial \theta} = -\frac{3GaM}{r^3} \sin 2\theta$$

Factors

$$D = 1 + k - h \quad G = 1 - 3/2 k + h \quad L = 1 + k - l$$

Terrestrial Tides



Solar Tides

