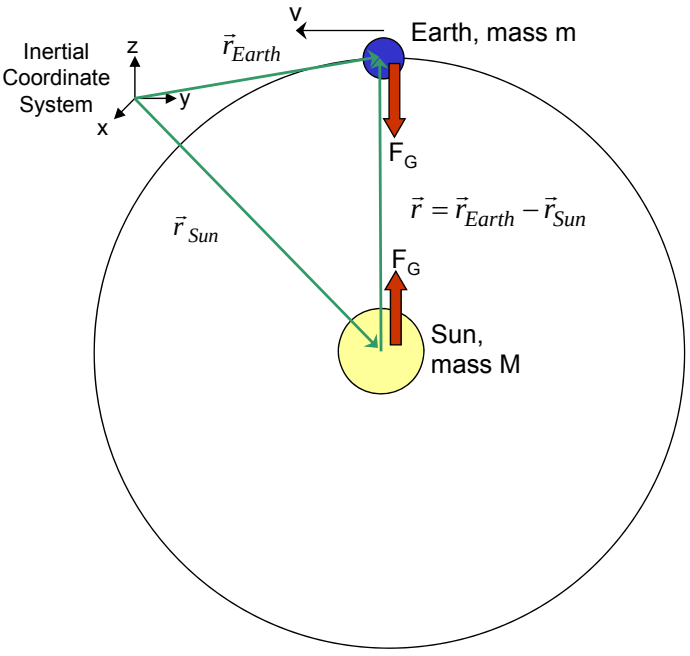
Lesson Objectives:
Answers to Typical Fundamental Questions…

- Why does a satellite stay in orbit???
- Is an astronaut weightless???
- Which orbit types can be realized???
- Which velocities do we need???
- **Do we "feel" on Earth the gravitational pull of the Sun??? (mostly as "task of the week"…)**

The 2-Body-Problem for the Sun-Earth-System



- Gravitational pull on Earth is compensated by a continuous „free-fall" towards Sun.
- Acceleration occurs (almost) perpendicularly to Earth's own velocity, changing continuously the direction of the velocity vector.
- Acceleration is thereby so that the amount of Earth's velocity remains (almost) unchanged.

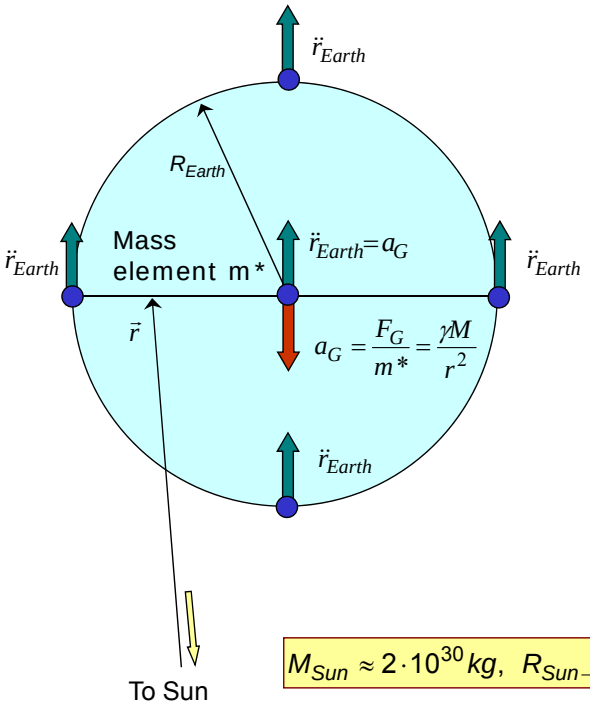
⇒ ***The entire Earth is in a continuous free-fall around the Sun!***

Assumption here: Point mass!!!

⇒ ***What happens if we consider a three-dimensional Earth??***

⇒ ***"task of the week"…***

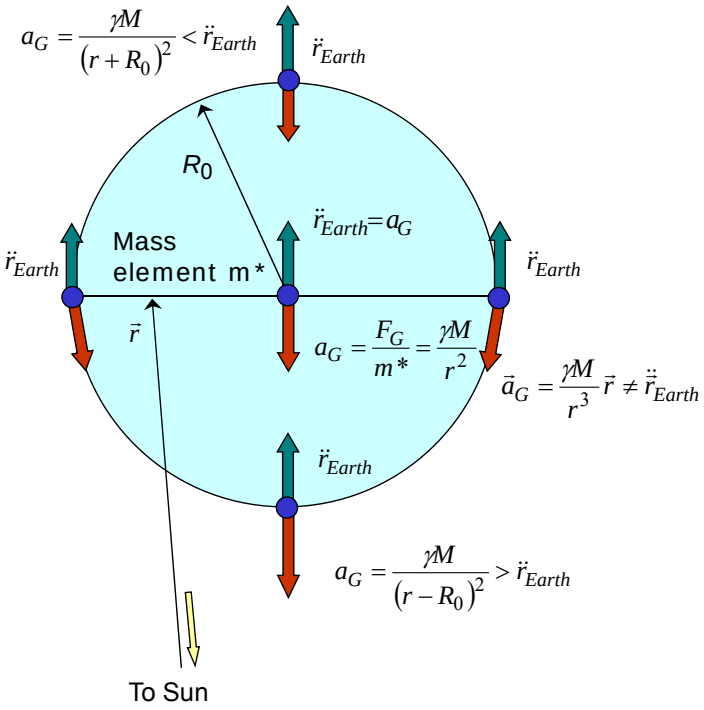
Task of the Week - Introduction
Do we “feel” on Earth the gravitational pull of the Sun???



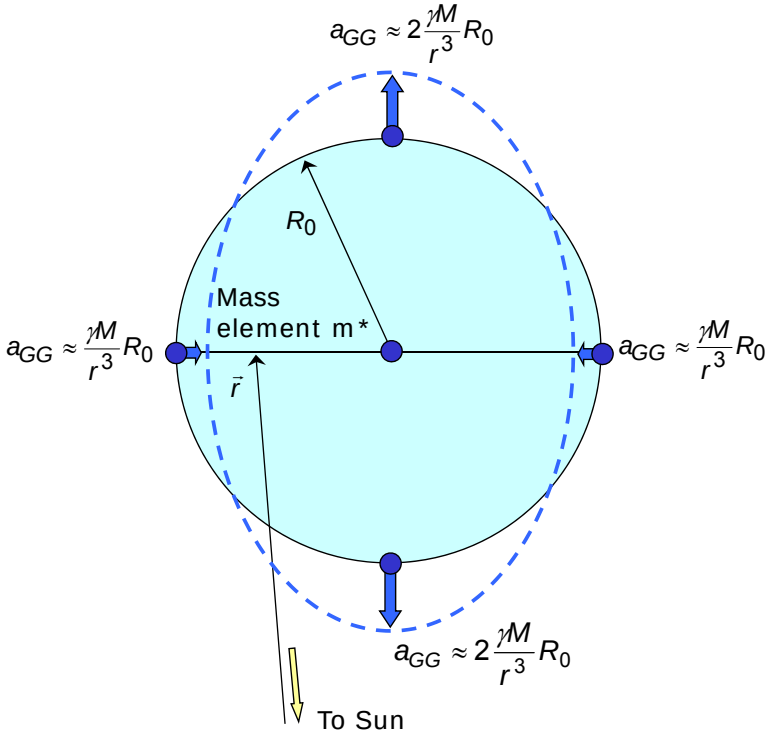
$M_{Sun} \approx 2 \cdot 10^{30}\, kg, \quad R_{Sun \rightarrow Earth} = r \approx 150 \cdot 10^{9}\, m$

$M_{Earth} \approx 6 \cdot 10^{24}\, kg, \quad R_{Earth} \approx 6378\, km$

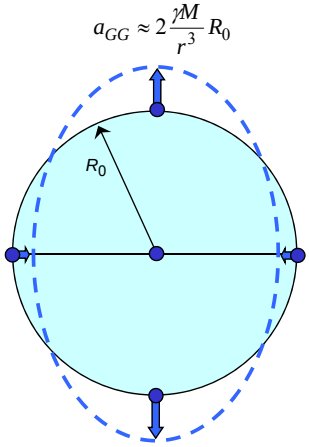
Task of the Week – Solution
The Gravity Gradient



Task of the Week – Solution
The Gravity Gradient



Task of the Week – Solution
The Gravity Gradient – Some Numbers

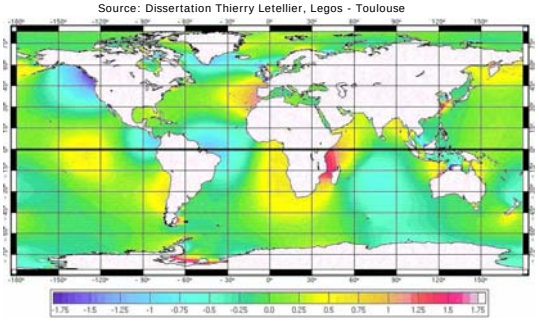


- Earth gravitation on surface: g_0 = 9.81 m/s²
  - For spherical Earth (R_0=6378 km) everywhere equal.
- For comparison, in low Earth orbit (R=6678 km): g = 8.94 m/s²
- Earth rotation: 0.0339 m/s²
  - Value at the equator, decreasing with increasing latitude, vanishes at the poles.
- Sun's gravity gradient on Earth's surface (max.): 0.000 000 5 m/s²
  - Relative to g_0 ca. 0.05 ppm…
  - Because Earth's gravitation varies also with the distance to its centre, this value corresponds to an altitude change on Earth's surface of about 0.15 m…
- Gravity gradient of Moon (max.): 0.000 001 1 m/s²
  - Relative to g_0 ca. 0.11 ppm…

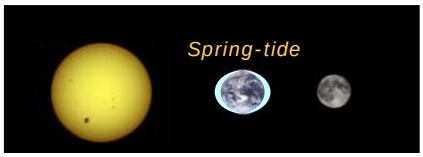
The Gravity Gradient – Some Consequences

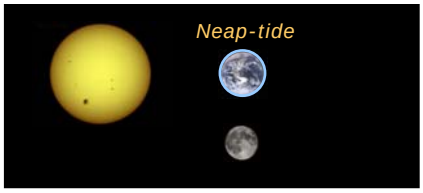
- On Earth: Reason for tides
  ⇒ Additional fluid flows due to pressure differences
  ⇒ Superimposition with Earth‘s rotation and existing „barriers“ (land areas)

Source: Dissertation Thierry Letellier, Legos - Toulouse



- For multiple bodies:
  Amplification / reduction of effects





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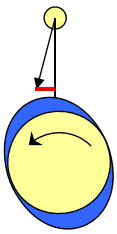
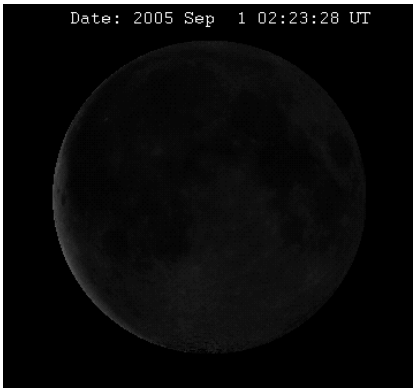
The Gravity Gradient – Some Consequences

- Earth rotates faster than Moon revolves
  ⇒ Moon obtains acceleration component in orbit direction
  ⇒ Increase of Moon‘s orbit at the expense of Earth‘s rotational energy



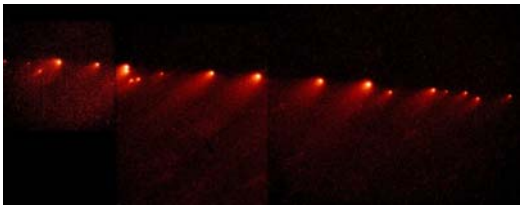
- Gravity gradient affects also Moon
  ⇒ Because Moon is the smaller body, faster reduction of own rotation until synchronous rotation



- Additional complexity due to
  - Tilt of Earth‘s rotation axis relative to ecliptic plane
  - Inclination of Moon‘s orbit relative to Earth‘s equator
  - Elliptical orbits
  - Etc.

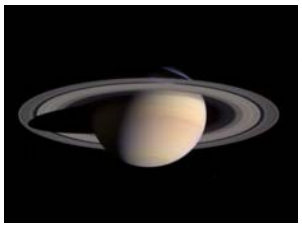
The Gravity Gradient – Some Consequences

- Comet Shoemaker-Levy
  - Passed Jupiter in July 1992 and burst in 21 „pieces“
  - Between16-22 July 1994: Fragments struck Jupiter‘s surface



Shoemaker-Levy, Hubble 18 May 1994

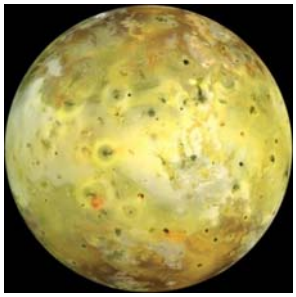
- Saturn‘s rings were believed to be within „Roche-limit“, where effect of gravity gradient is higher than a potential gravitational force of a (smaller) body (note: other explanation nowadays...)

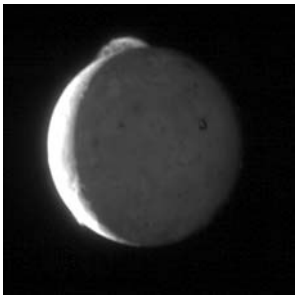


Saturn,
„Cassini“
27 Mar 2004

- Volcanic activity of Io caused by Jupiter‘s gravity gradient (because of elliptical orbit, although synchronous rotation!)

Jovian Moon Io,
„Galileo“ 3 Jul 1999





330 km tall eruption on Io,
„New Horizons“
28 Feb 2007

All Images: NASA