DISCOVER THE UNIVERSE

À LA DÉCOUVERTE DE L'UNIVERS

UNDERSTANDING GRAVITY

Welcome! We will get started in a few minutes.

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Astronomy training program for teachers and informal educators

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UPCOMING ACTIVITIES

Webinar: Junior Astronauts, presented by the Canadian Space Agency – December 11, 2019

And a lot more in the new year : new format, more content…

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UNDERSTANDING GRAVITY

WHAT IS GRAVITY?

It's a fundamental force which affects everything that has a mass.

The force of gravity between two objects depends on:

- the mass of the objects;
- the distance between them.

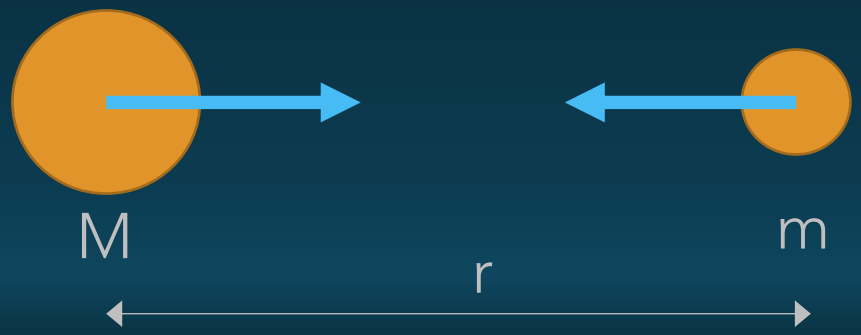
GRAVITATIONAL FORCE

The same force applies on both objects, but the effect will be different (e.g. me and the Earth).

$$F = G\frac{Mm}{r^2}$$

What increases the force of gravity:

- large mass
- small distance between objects



EARTH'S GRAVITY

If we calculate the force of gravity for an object (mass m) at the surface of the Earth:

$$F = G\frac{Mm}{r^2}$$

with:

G = 6.67 x 10^{-11} Nm^2/kg

M_{Earth} = 5.97 x 10^{24} kg

r_{Earth} = 6 370 000 m

$$F = mg$$

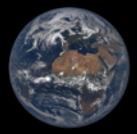
g= 9,8 m/s^2

What happens if we increase the mass of the object AND its size?

Does the gravitational force increase or decrease at the surface?

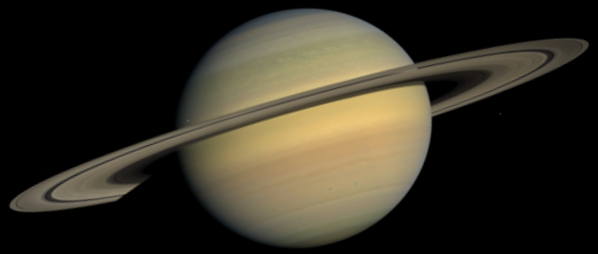
1 g

(9.8 m/s^2)



2.5 g

1.1 g



Planets not to scale

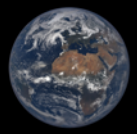
Earth: NASA - https://epic.gsfc.nasa.gov/
Jupiter: NASA/ESA - https://www.nasa.gov/feature/goddard/2019/hubble-new-portrait-of-jupiter
Saturn: NASA/JPL/Space Science Institute - https://photojournal.jpl.nasa.gov/catalog/PIA11141

What happens if we increase the mass of the object but decrease its size?

Does the gravitational force increase or decrease at the surface?

1 g

(9.8 m/s^2)



1,000,000 g

white dwarf

100,000,000,000,000,000,000,000,000 g

neutron star

Not to scale

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Earth: NASA - https://epic.gsfc.nasa.gov/
White dwarf: NASA - https://en.wikipedia.org/wiki/White_dwarf
Neutron star: https://en.wikipedia.org/wiki/File:Neutron_Star_gravitational_lensing.png

What is a black hole?

Object with an extreme gravity close to its « surface »

(large masse as a function of its radius)

Credit: ESO/Jordy Davelaar et al./Radboud University/BlackHoleCam
https://www.eso.org/public/images/eso1907g/

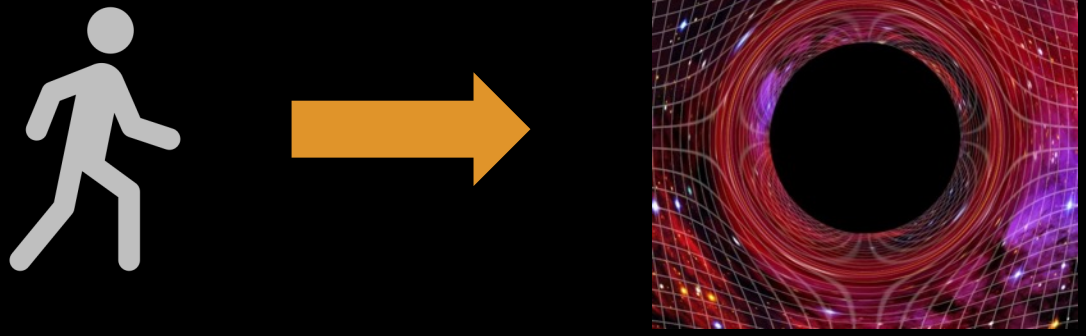
Do all black holes have extremely large mass?

Not necessarily!

Stellar black holes have masses of a few suns, while supermassive black holes at the centre of galaxies have masses of millions/billions suns. Mini black holes could also exist…

Credit: Event Horizon Telescope
https://www.eso.org/public/france/news/eso1907/?lang

We can even calculate the size of a black hole created by compressing a human!



Credit: Pocket Black Hole

What would happen if the Sun turned into a black hole?

(it won't happen)

The Earth would continue on the same orbit without any change because it's located far enough from the black hole and the mass of the Sun/black hole would remain the same.

The gravity of a black hole is only extreme when very close to it.

(Sun into a black hole: radius of 3 km; our distance to the Sun: 150 million km)

What would happen if we fell into a black hole?

Spaghettification!

Close to the black hole, the difference in the gravitational pull on your feet and on your head would be large enough to stretch you!

This is an extreme tidal effect.

HOW ARE TIDES CREATED?

Tides are caused by differences in the gravitational pull from the Moon on different parts of the Earth.

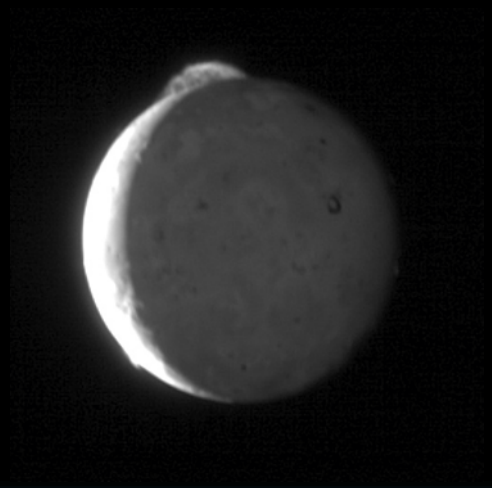
This difference stretches the Earth, and this motion is more noticeable with water.

Not to scale

Credit: Crash Course Astronomy #8 – Tides
https://youtu.be/KlWpFLfLFBI

The tidal effect (stretching) is also responsible for:

- the volcanoes on Io, moon of Jupiter (rock tides!);
- the disintegration of comet Shoemaker-Levy 9 before it hit Jupiter in 1994;
- and many other phenomena…



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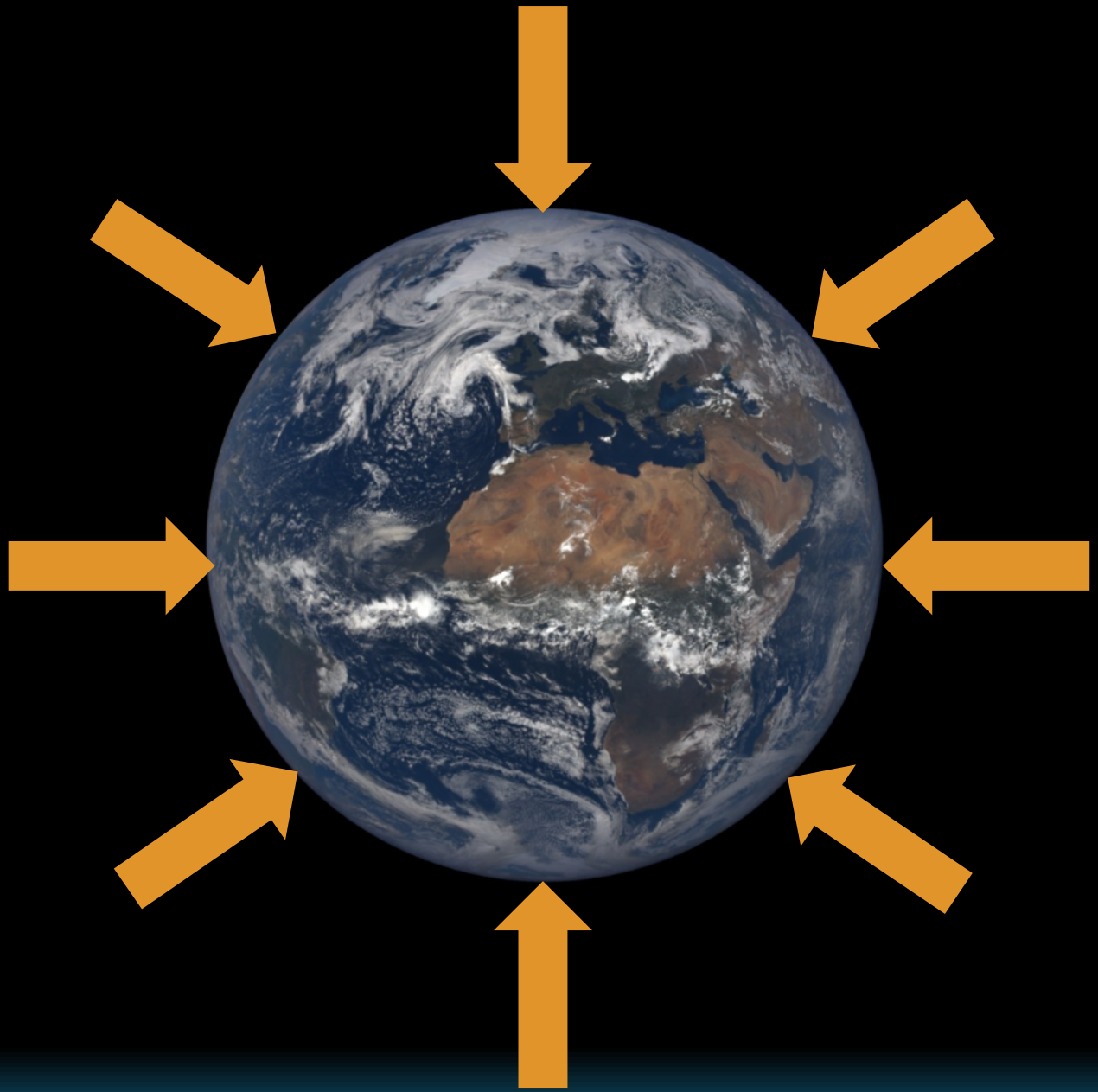
Io: NASA - https://www.nasa.gov/topics/solarsystem/features/io-volcanoes-displaced.html
Comet Shoemaker-Levy 9: NASA/ESA - https://hubblesite.org/contents/media/images/1994/26/167-Image.html

LET'S LOOK AT SOME MISCONCEPTIONS ABOUT GRAVITY...

GRAVITY PULLS US DOWN

To be exact we should say:

Gravity pulls us towards the centre of the Earth.



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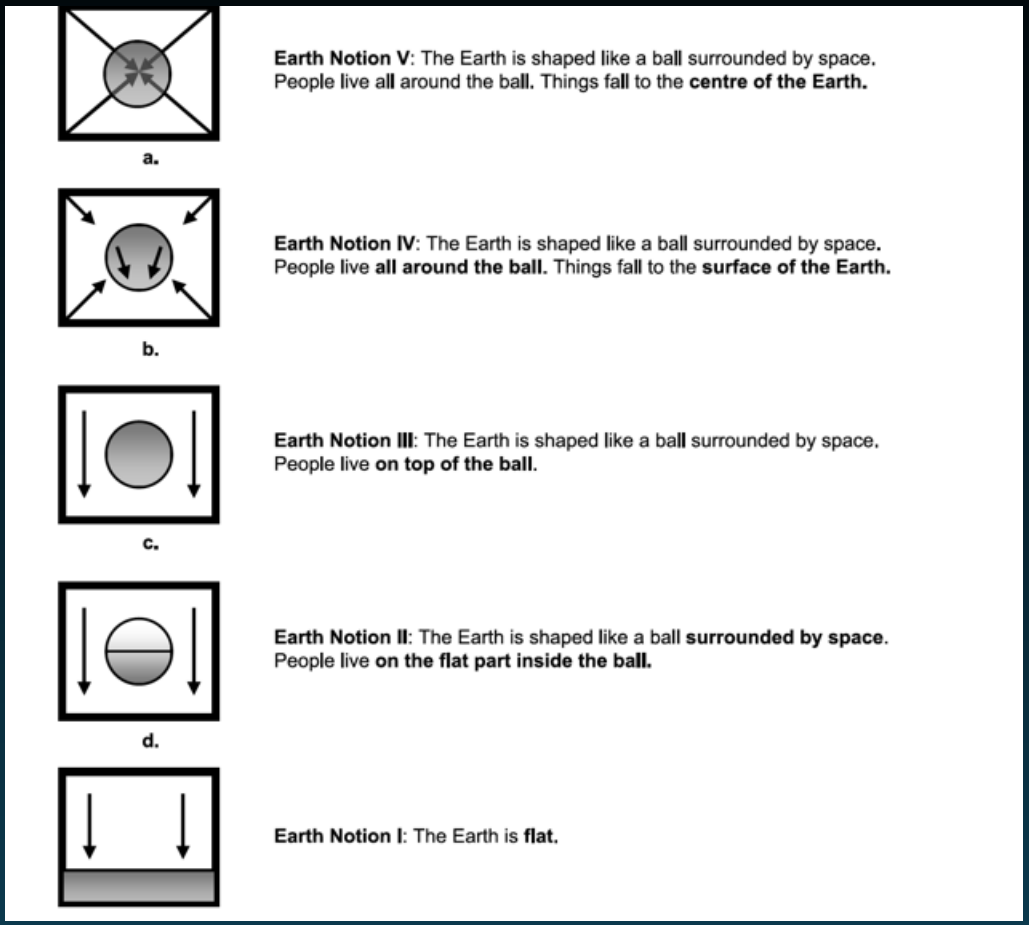
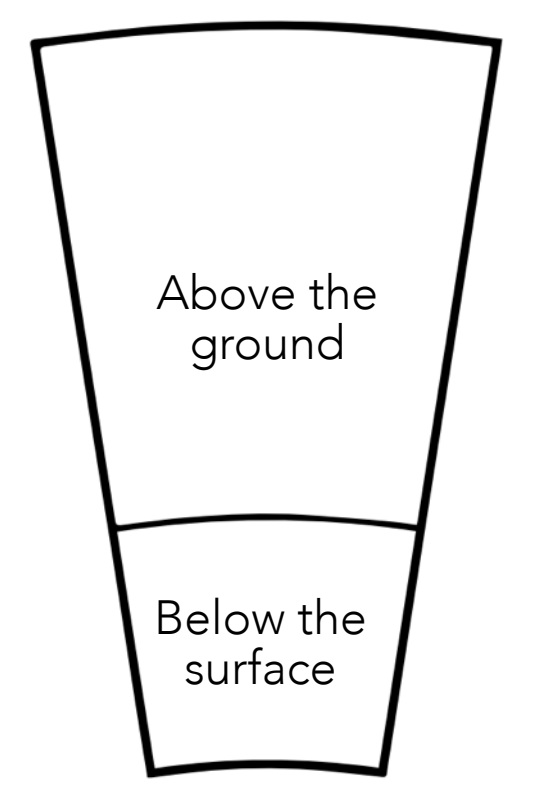
Credit: NASA
https://epic.gsfc.nasa.gov/



Lelliott and Rollnick, 2009

It's very hard for young children to understand that down means the direction of the gravitational pull.

Activity: Up or Down



https://www.unawe.org/static/archives/education/pdf/Universe_in_Box_activitybook.pdf p. 47

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The object's self-gravity pulls on all its parts towards the centre of mass. This smoothens the Earth and gives it its spherical shape.

gravity > rock strength

Credit: NASA
https://epic.gsfc.nasa.gov/

Smaller objects, such as asteroids and comets, do not have a large enough mass to change their shapes.

gravity < rock strength

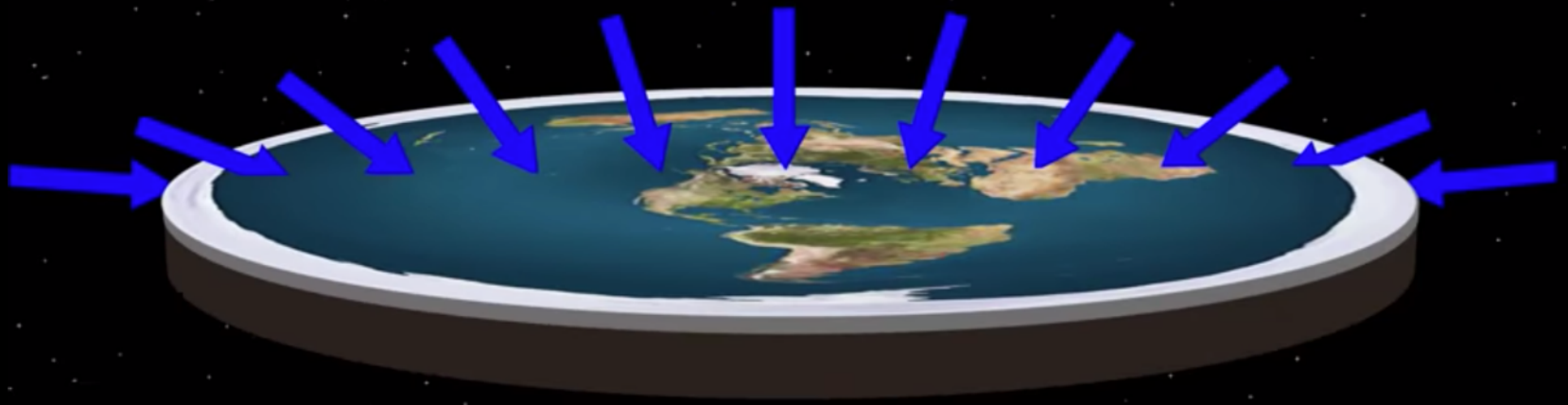
Credit: ESA/Rosetta/NAVCAM
http://www.esa.int/spaceinimages/Images/2014/09/Comet_on_19_September_2014_NavCam

Could the Earth be flat?

No!

An object with the mass of the Earth could not stay flat due to its own gravity.

Also, the gravity felt on a flat Earth would be pretty strange…



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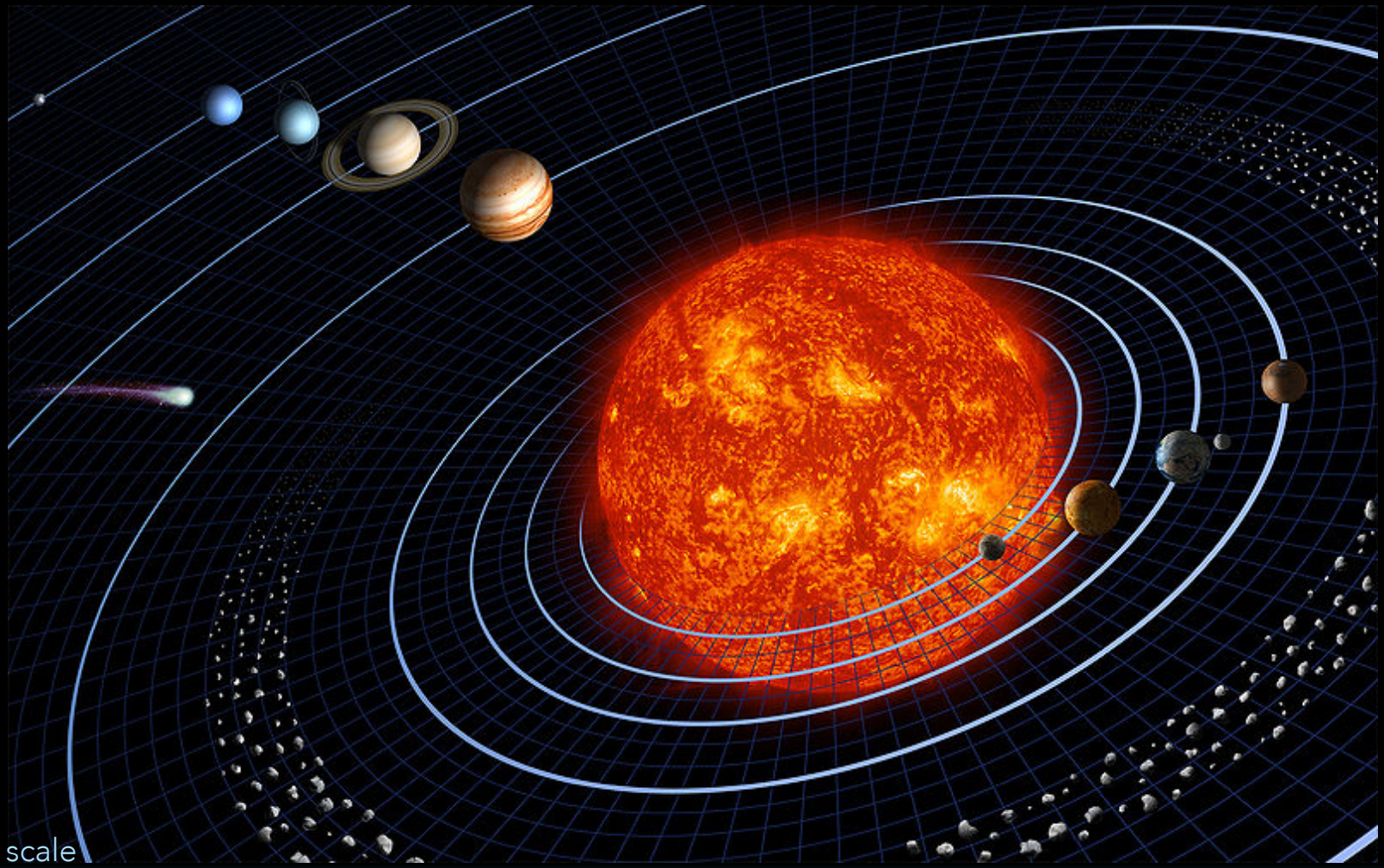
Credit: Tech Insider
https://youtu.be/1xwmqEUMWRI

THERE'S NO GRAVITY IN SPACE

False!

Credit: David Saint-Jacques / Twitter
https://twitter.com/Astro_DavidS/status/1142078004518105090

Gravity is what keeps the objects in orbit around the Sun…



Not to scale

Credit: NASA
https://en.wikipedia.org/wiki/File:Solar_sys8.jpg

…and what causes collisions of galaxies. It's the only fundamental force that still has an impact on that scale…

Credit: NASA
https://svs.gsfc.nasa.gov/10687

Galaxies colliding, over 100 million light-years away.

Credit: Canada-France-Hawaii Telescope
http://www.cfht.hawaii.edu/HawaiianStarlight/HawaiianStarlight-AIOM.html

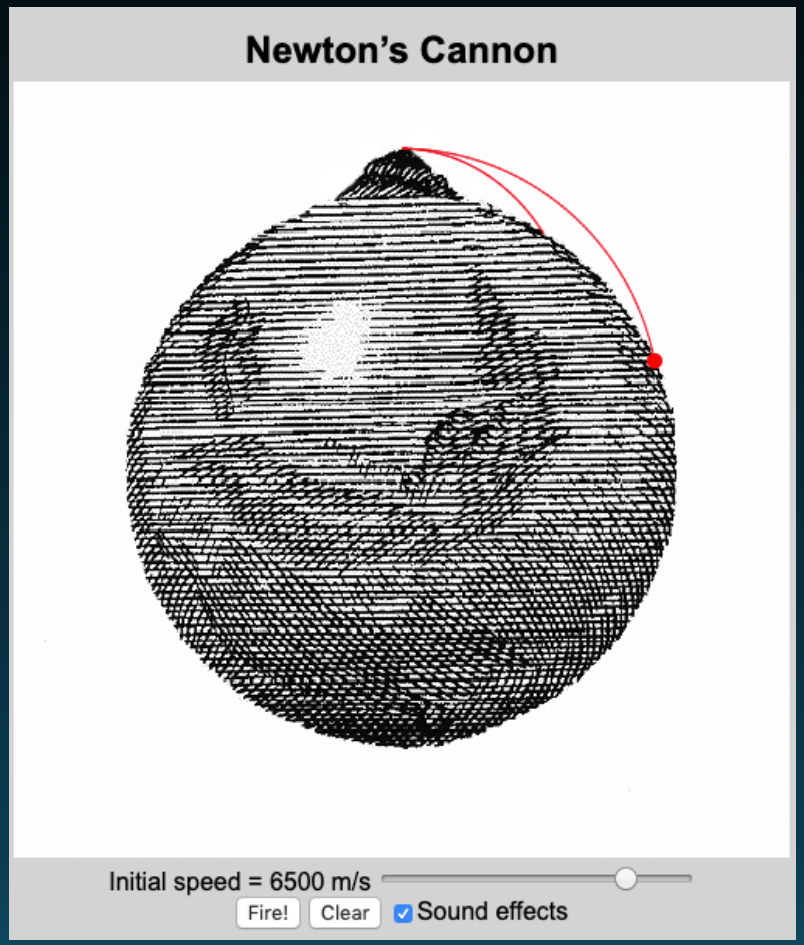
So yes, there is gravity in space!

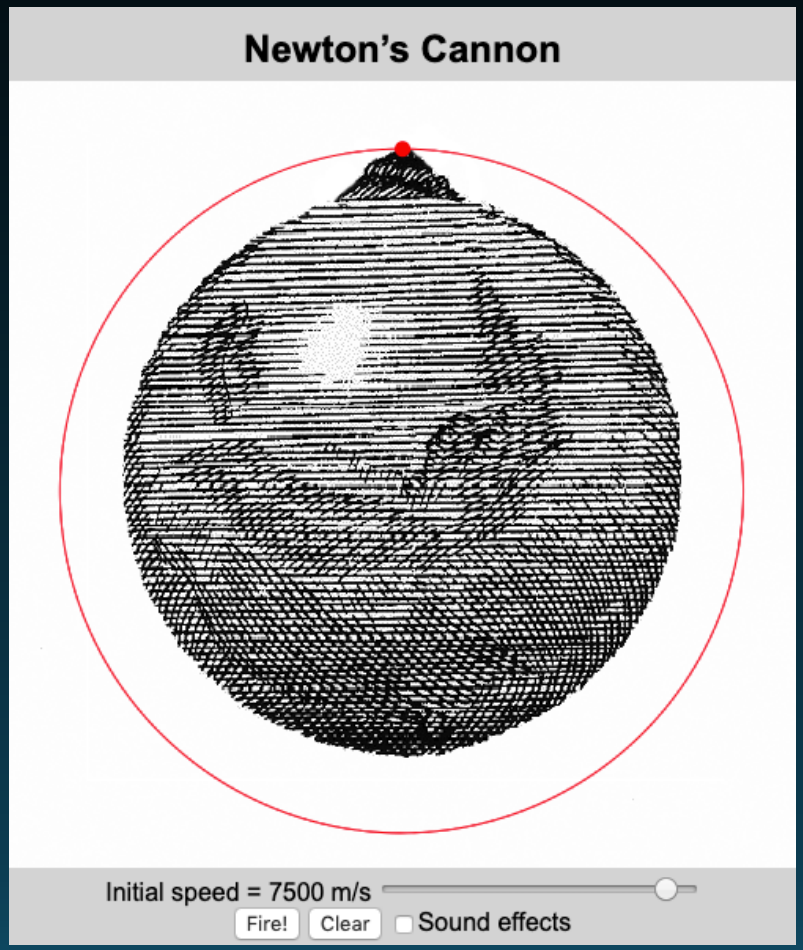
Then why do astronauts float, especially since they are close enough to the Earth to « feel » about 90% of their weight (8.69 m/s^2)?

Because they are in orbit!

They are constantly falling (and therefore floating) but they have enough speed not to crash down.

What would happen if we threw a cannon ball faster and faster?





Simulator:
https://physics.weber.edu/schroeder/software/NewtonsCannon.html

Imagine that instead of a javelin, Obelix throws a mini-rocket with mini-astronauts inside it.

They would be in orbit and would float in the rocket, even at 1m above the surface of the Earth.

The reason astronauts float is not because there's no gravity, it's because they are in freefall.

(We neglect any air resistance and varied terrain of the Earth…)

THERE'S NO GRAVITY ON THE MOON BECAUSE THERE'S NO ATMOSPHERE

False!

Gravity and atmosphere pressure are two separate things.

But it's true that the gravity on the Moon is much less than on Earth (1/6 g)…

Credit: NASA

QUESTIONS?

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Question I asked my physics teacher in college:

If someone comes out of an airplane, they fall.

But if someone comes out of the Space station, they float.

At what altitude does the transition happen?

What would you have told me?