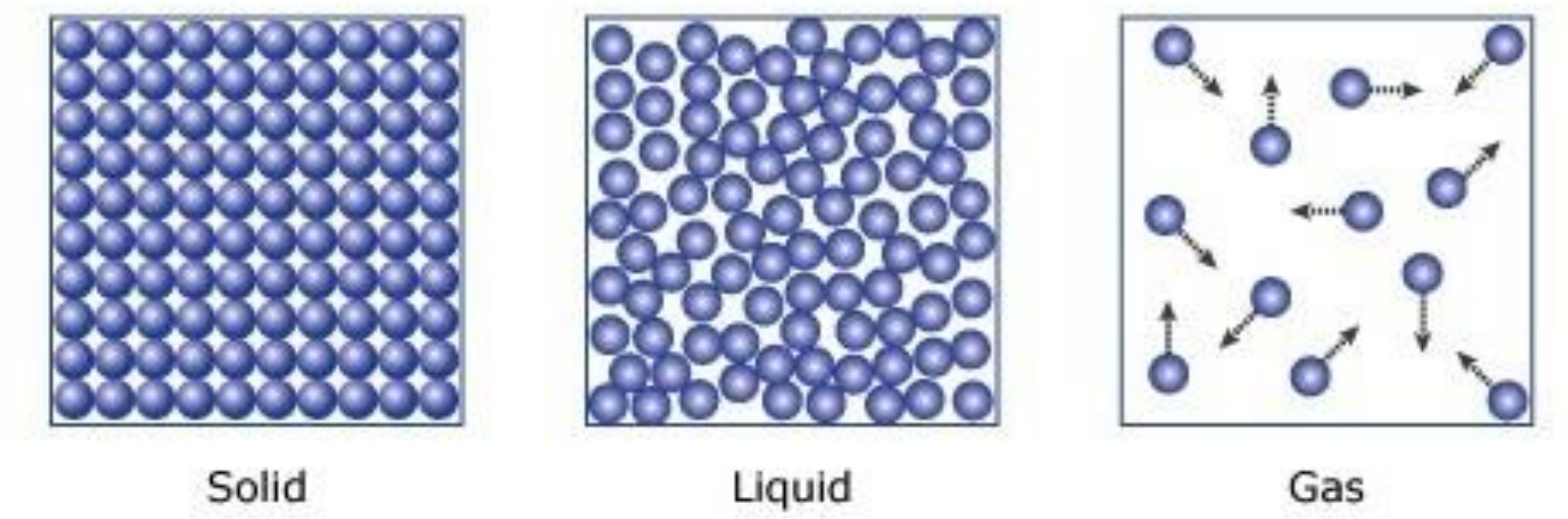
Unit 4
Gravity, Forces, and Motions

GRAVITY

What is Gravity?

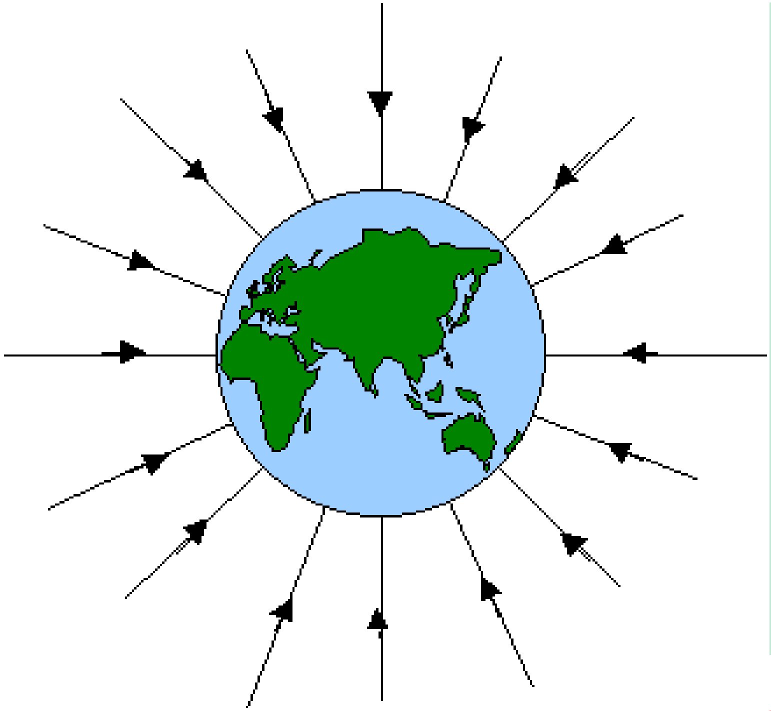
Gravity is the mutual attraction force between all forms of matter in our universe.

- Pull force.
- Action-at-a-distance force—objects do not need to be touching in order for them to pull on each other.
- All matter in the universe attracts all other matter in our universe.



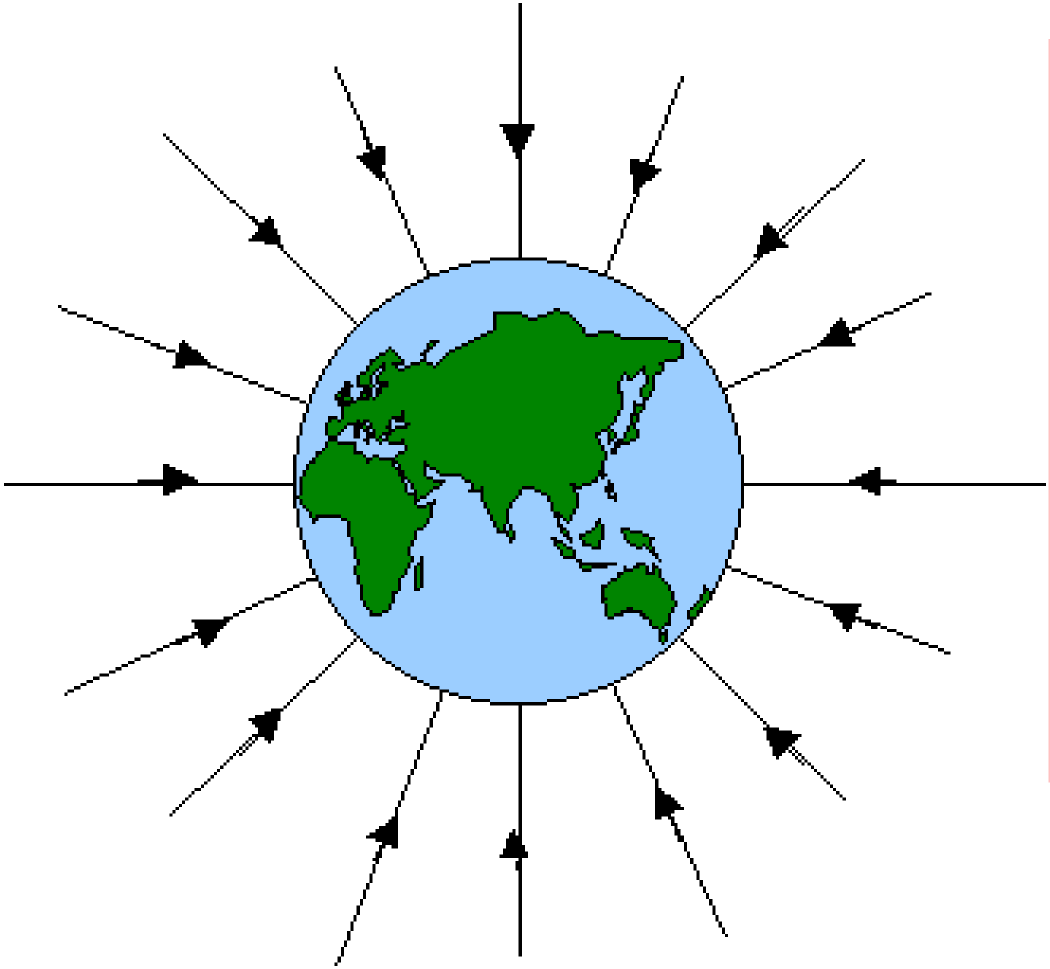
Gravity is a fundamental force.

- All matter has gravity because matter has mass.
- From the tiniest molecules and atoms to the largest galaxies, all matter (regardless of size) has gravity.
- All states of matter have gravity.



Gravity field is the 3-dimensional region that extends into space from a massive object in which the force of gravitational attraction by that object is strong enough to cause acceleration of another object.

The **gravity field** of the planet attempts to accelerate objects toward the planet's center of mass. (the solid surface stops objects from moving downward)

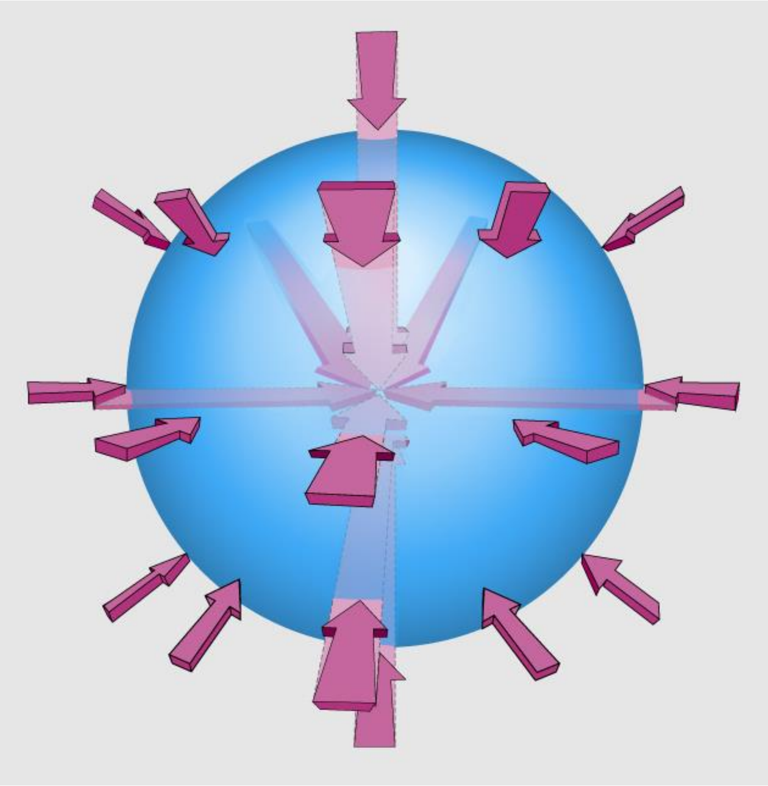


Gravity fields become progressively stronger closer to the planet.

Gravity fields become progressively weaker with increasing distance away from the object.

Gravity is an action-at-a-distance force. Earth’s gravity (for example) has influence through space. Earth’s gravity can weakly affect objects millions of km away from Earth.

Gravity force pulls matter inward from all directions towards a common **center of mass** or **center of gravity**. Gravity makes large, fluid objects pull inward to form spherical shapes.   Planets and stars are **spherical** because as they form and accumulate matter, the growing planet or star’s mass is pulled inward towards the center of mass.



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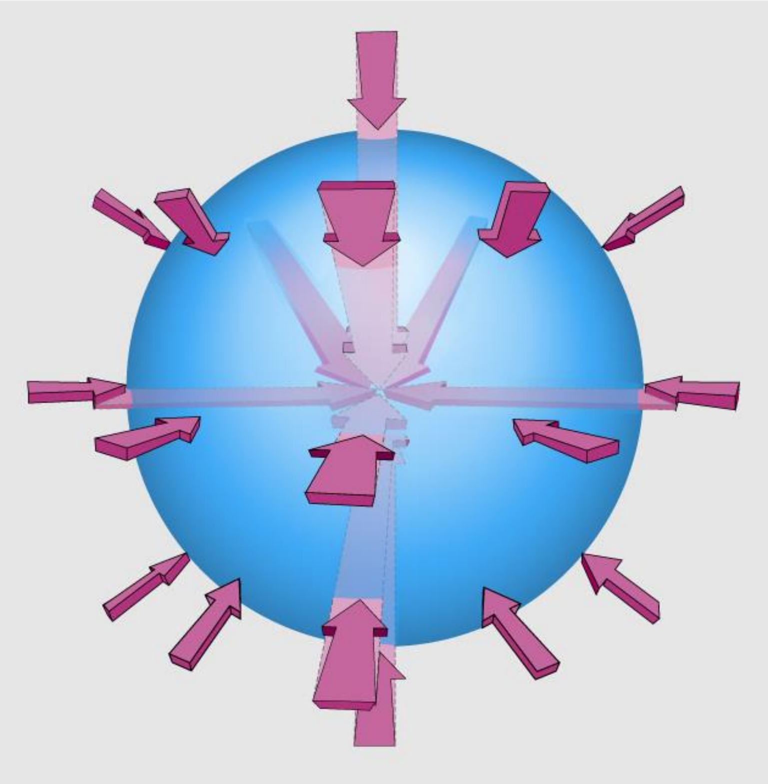


Newton's Law of Universal Gravitation (natural law)

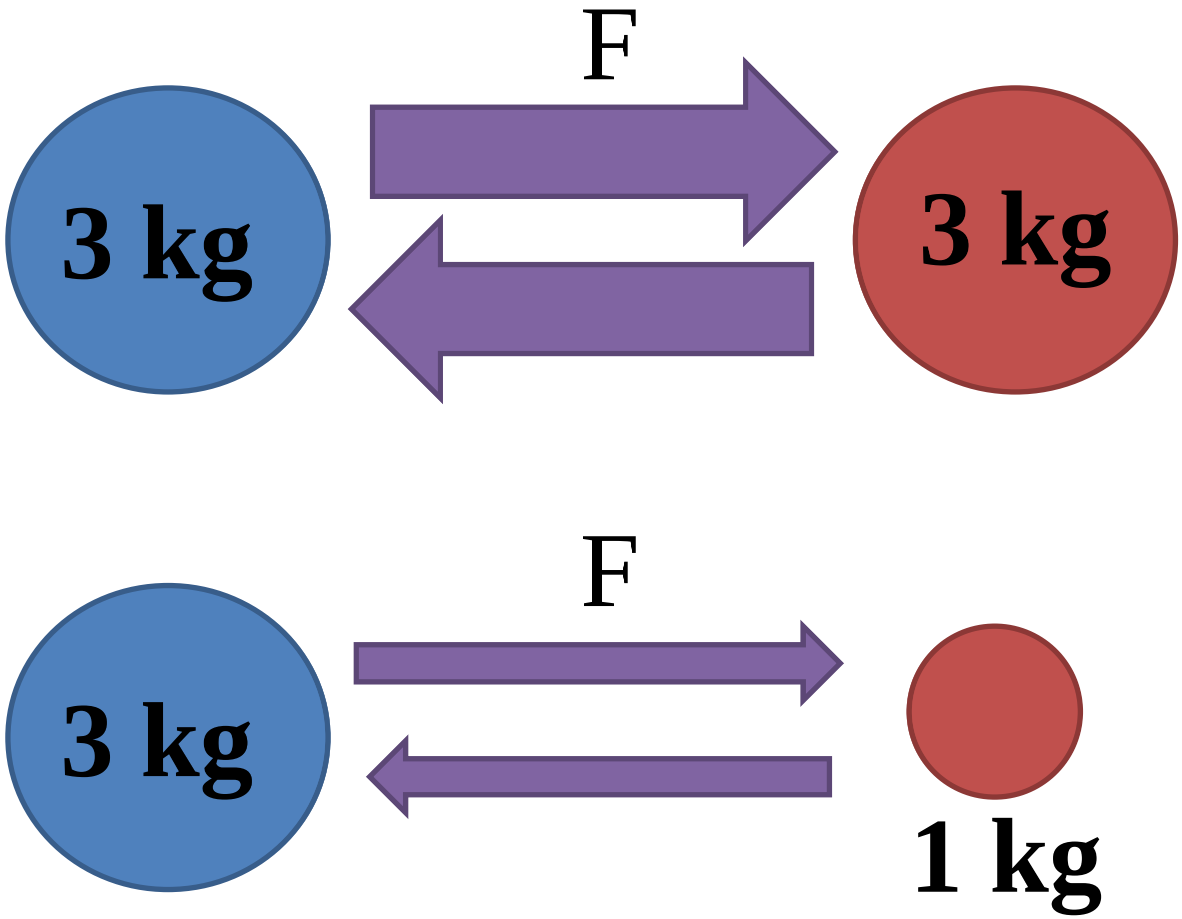
The attractive force due to gravity is proportional to the product of the masses of the attracting objects and inversely proportional to the distance squared between the objects.

m_1 = mass of object 1 (kg)
m_2 = mass of object 2 (kg)
d = distance between objects (m)
G = Universal gravity constant

$$F_g = G \cdot \frac{m_1 \cdot m_2}{d^2}$$

$$G = 6.67 \times 10^{-11} N \frac{m^2}{kg^2}$$

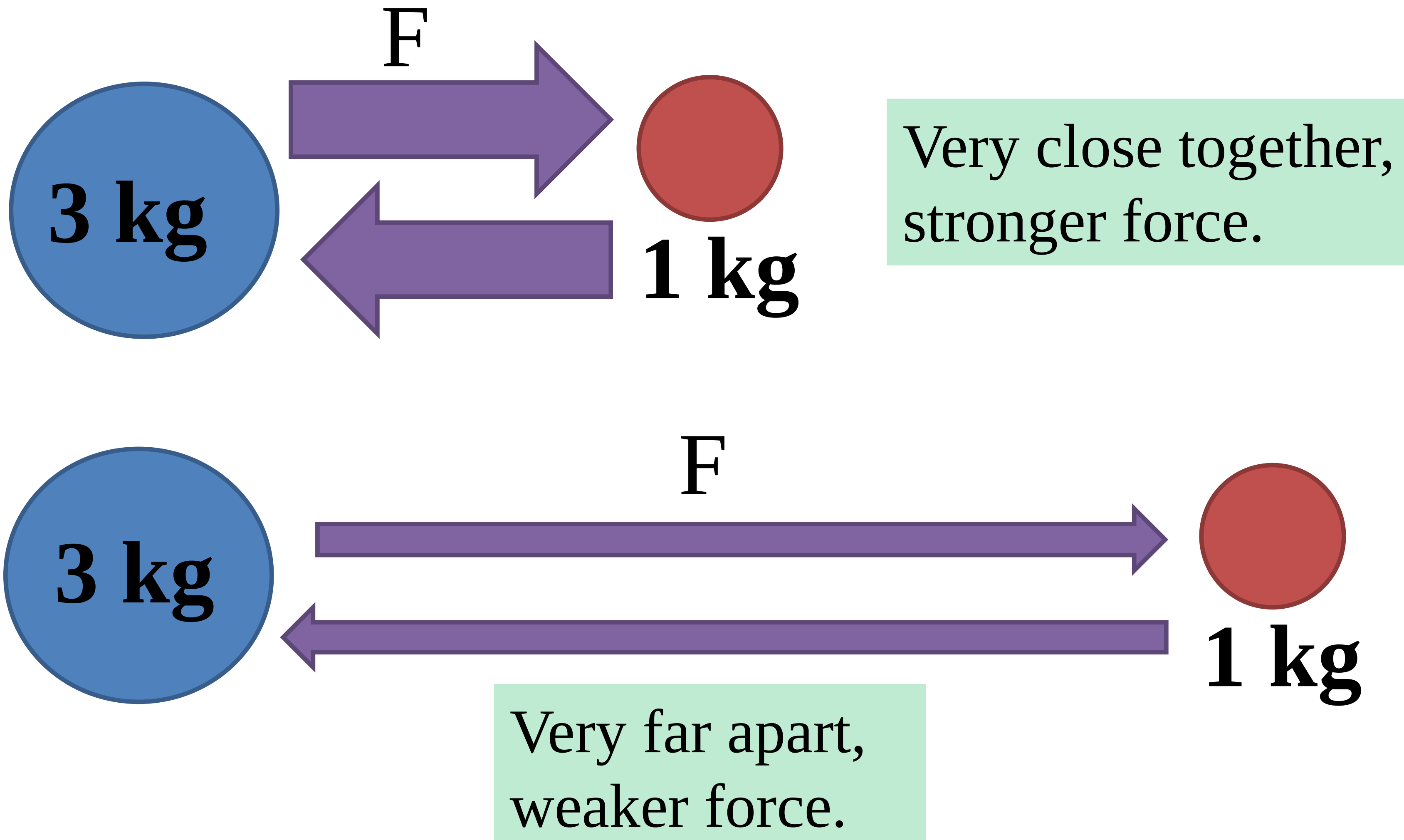
- Greater the masses, stronger the attraction force
- Lesser the masses, weaker the attraction force



Greater product of mass, stronger attraction

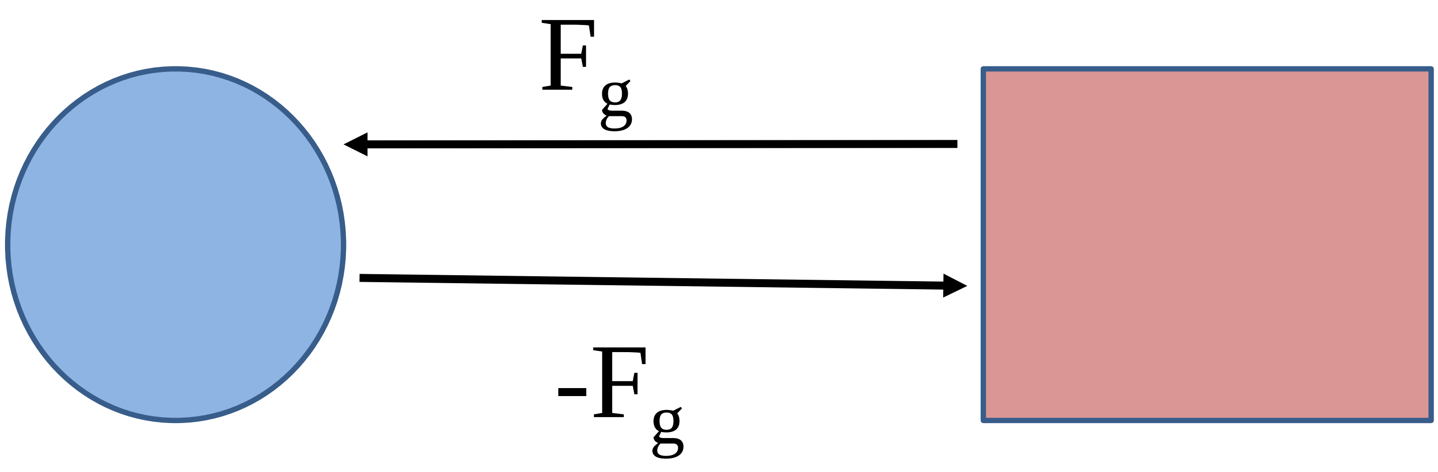
Smaller product of mass, weaker force.

- Shorter the distance, stronger the attraction force
- Greater the distance, weaker the attraction force



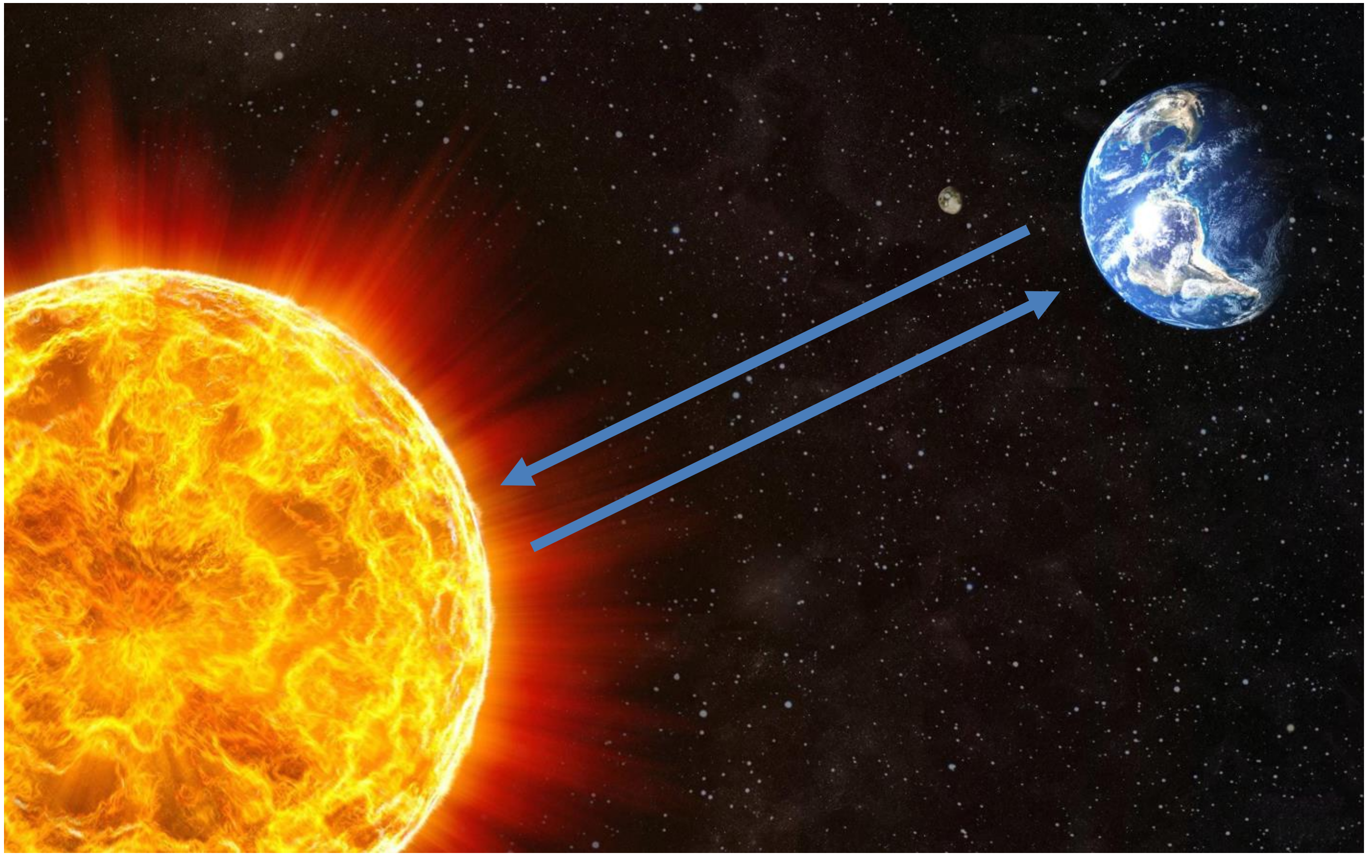
Gravitational attraction is a mutual force

- Obeys Newton's 3rd Law (equal and opposite)
- The force of one object attracting is the other is equal in magnitude and opposite in direction to the force of the other.



Force of blue circle pulling on red square is equal in magnitude and opposite in direction to the red square pulling on blue circle.

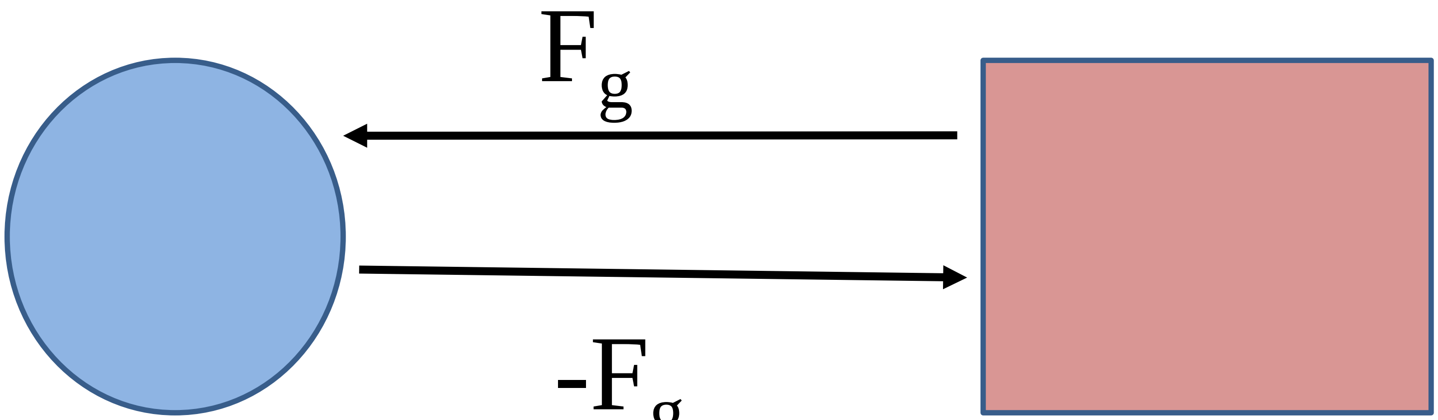
Force of sun pulling on Earth is equal in magnitude and opposite in direction to Earth pulling on the Sun.

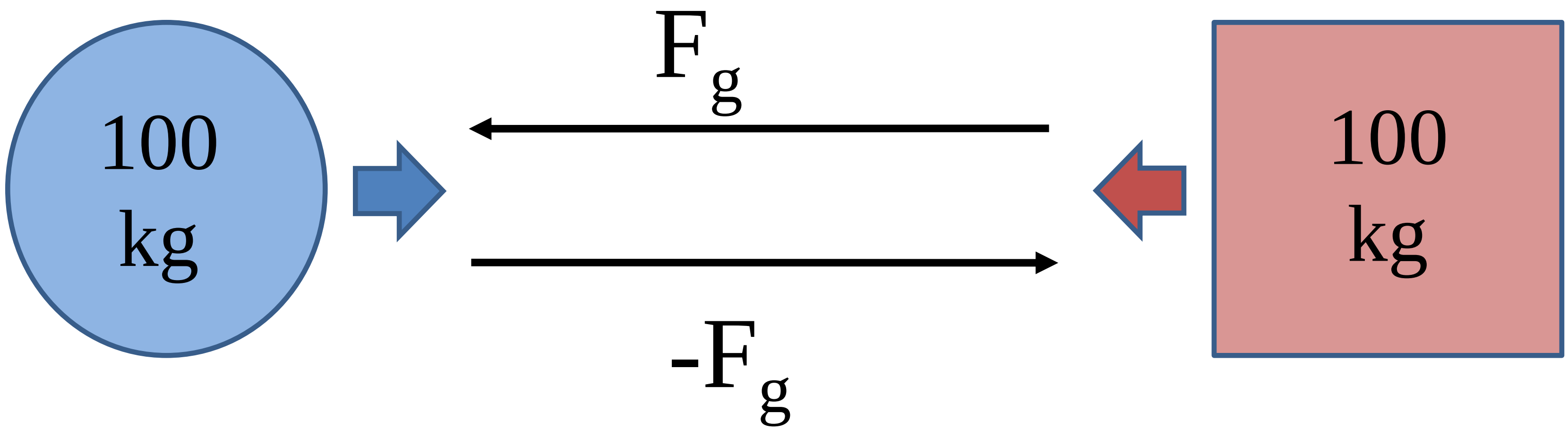


The attraction force is equal and opposite despite the size difference.

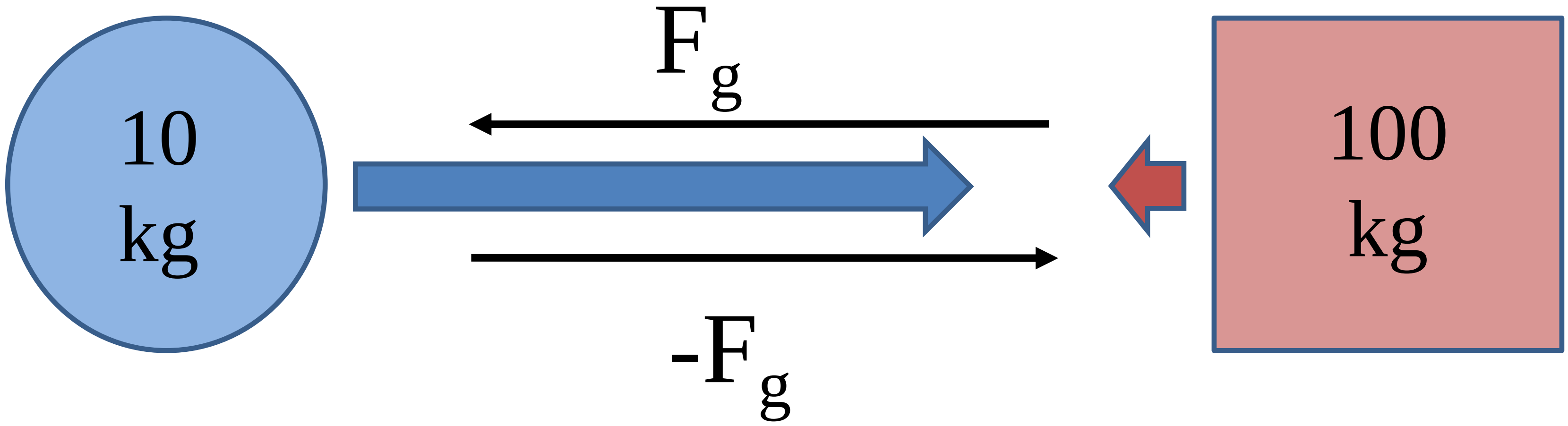
Gravitational attraction is a mutual force that obeys *Newton's 3rd law of motion*. Objects are pulling with forces equal in magnitude and opposite in direction.

Acceleration of the objects because of gravity force obey *Newton's 2nd law of motion*.



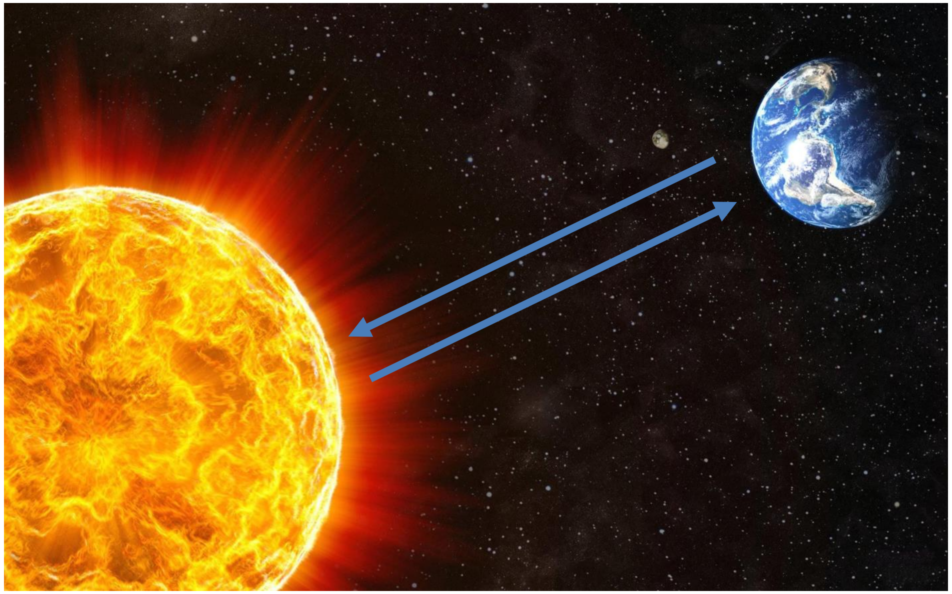


If two objects of **equal mass were in space**, away from all other influences and forces, the two objects would over time pull each other closer together. The acceleration at which they move together would be equal in magnitude (solid arrows). They have equal masses, therefore, they have equal inertia.



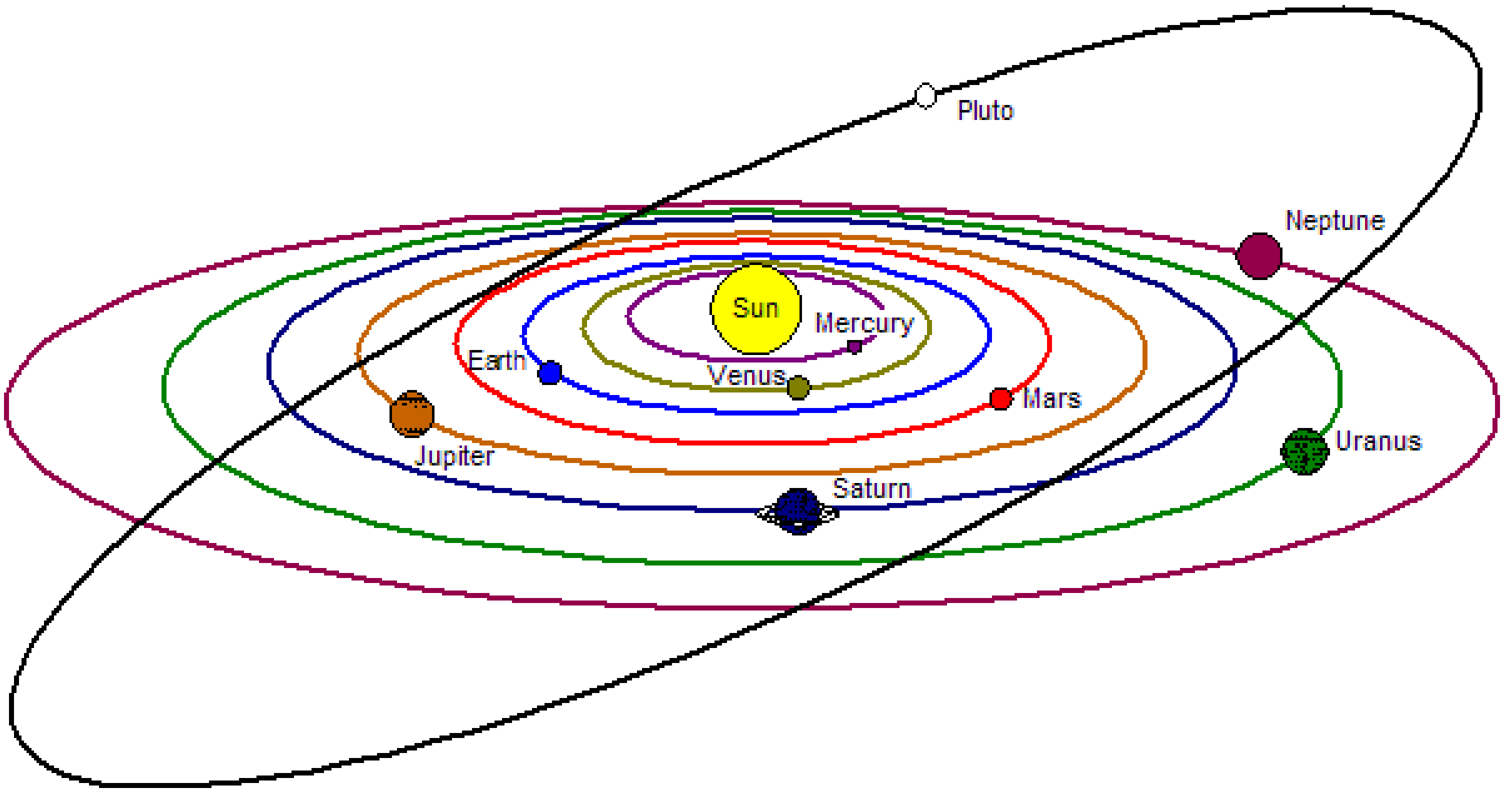
If two objects of **unequal mass were in space**, away from all other influences and forces, the two objects would over time pull each other closer together. The acceleration at which they move together would be unequal (solid arrows). The object with the lesser mass (10 kg) would accelerate faster towards the object with the greater mass (100 kg). The object with the lesser mass has lesser inertia and lesser resistance to the gravity force.

The force of sun pulling on Earth is equal in magnitude and opposite in direction to Earth pulling on the Sun. The attraction force is equal and opposite despite the size difference.

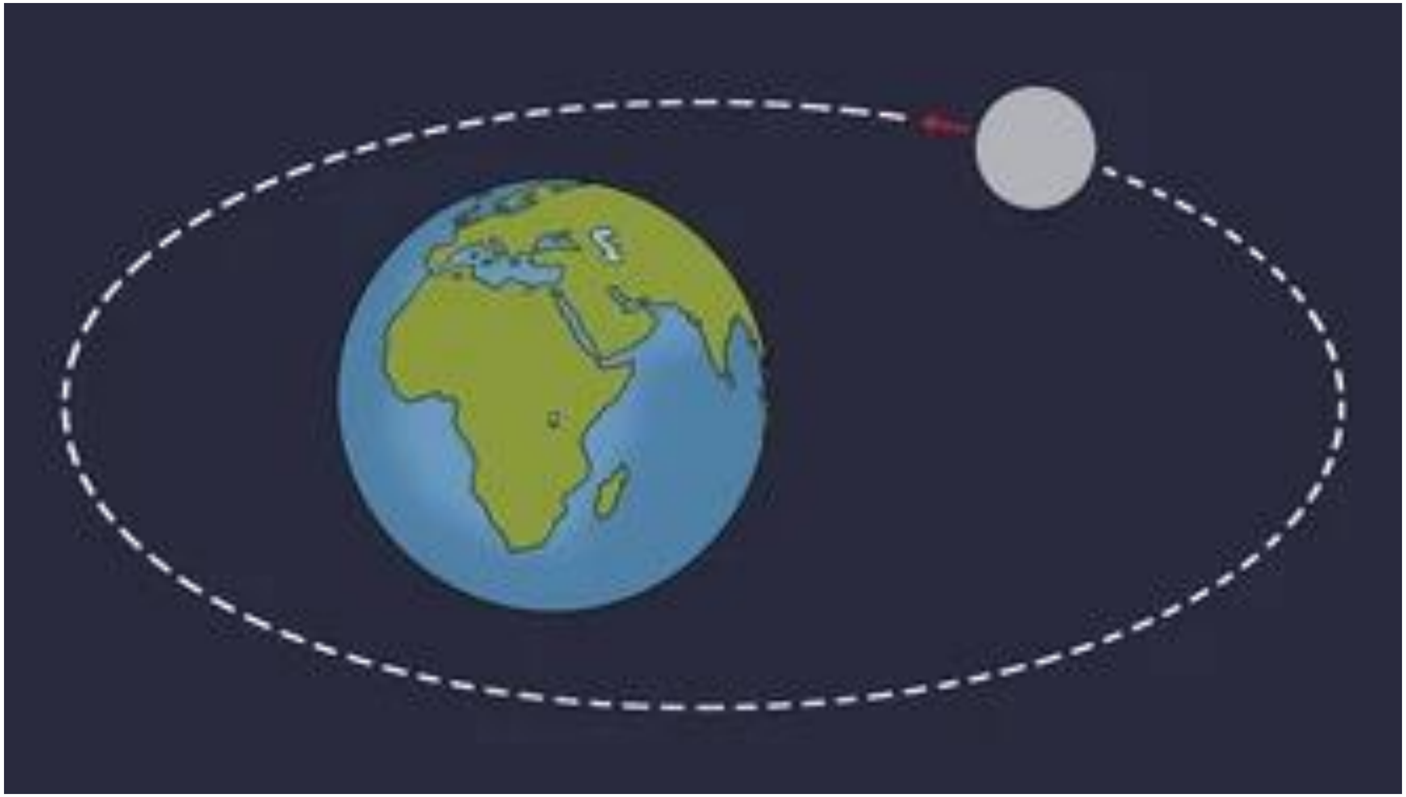


The sun’s astronomical mass gives it billions of times more inertia than the Earth. The Earth accelerates relative to the very large stationary sun.

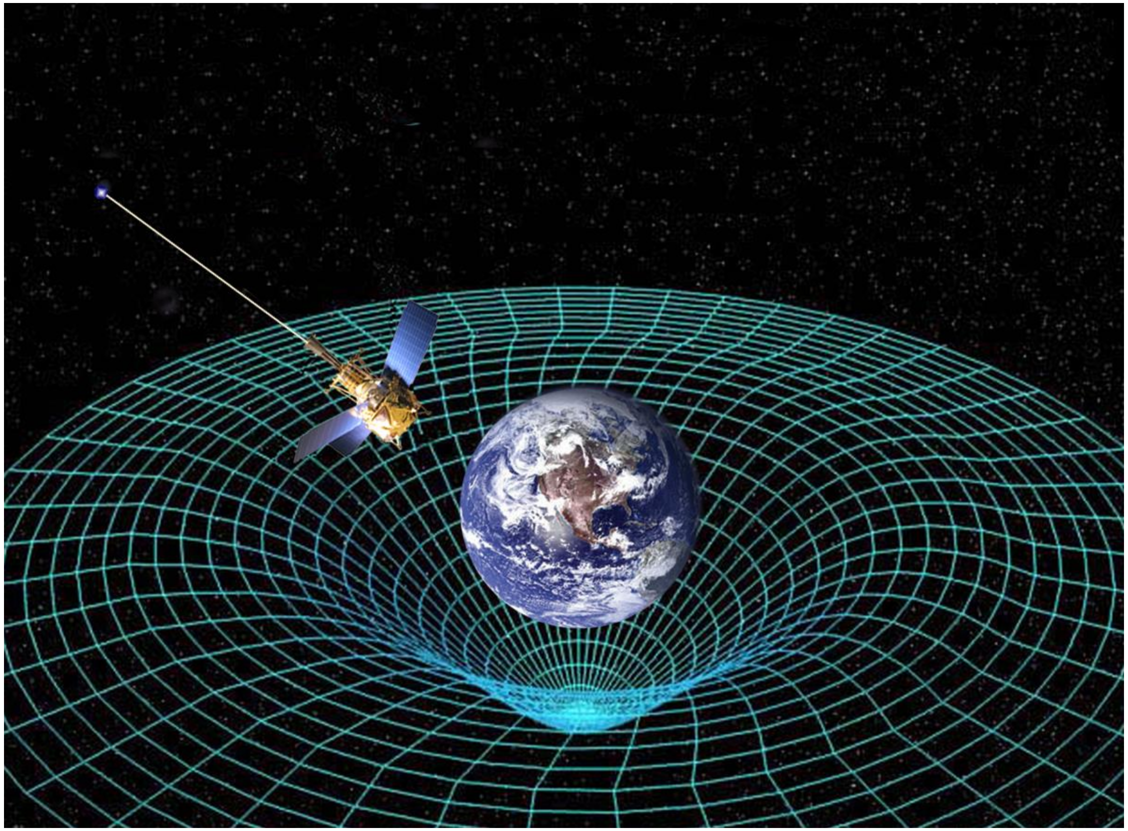
All of the planets in the solar system orbit the Sun. The Sun does not orbit the planets. The Sun's inertia is astronomical, it keeps a relatively fixed position. All other bodies are miniscule by comparison—their inertias are very, very small. They accelerate whereas the Sun does not.



Likewise the moon orbits the Earth, the Earth does not orbit the moon. The moon, having the smaller mass and smaller inertia accelerates more—it does the moving relative to the Earth. The Earth, having the greater mass and greater inertia, moves only a very little.

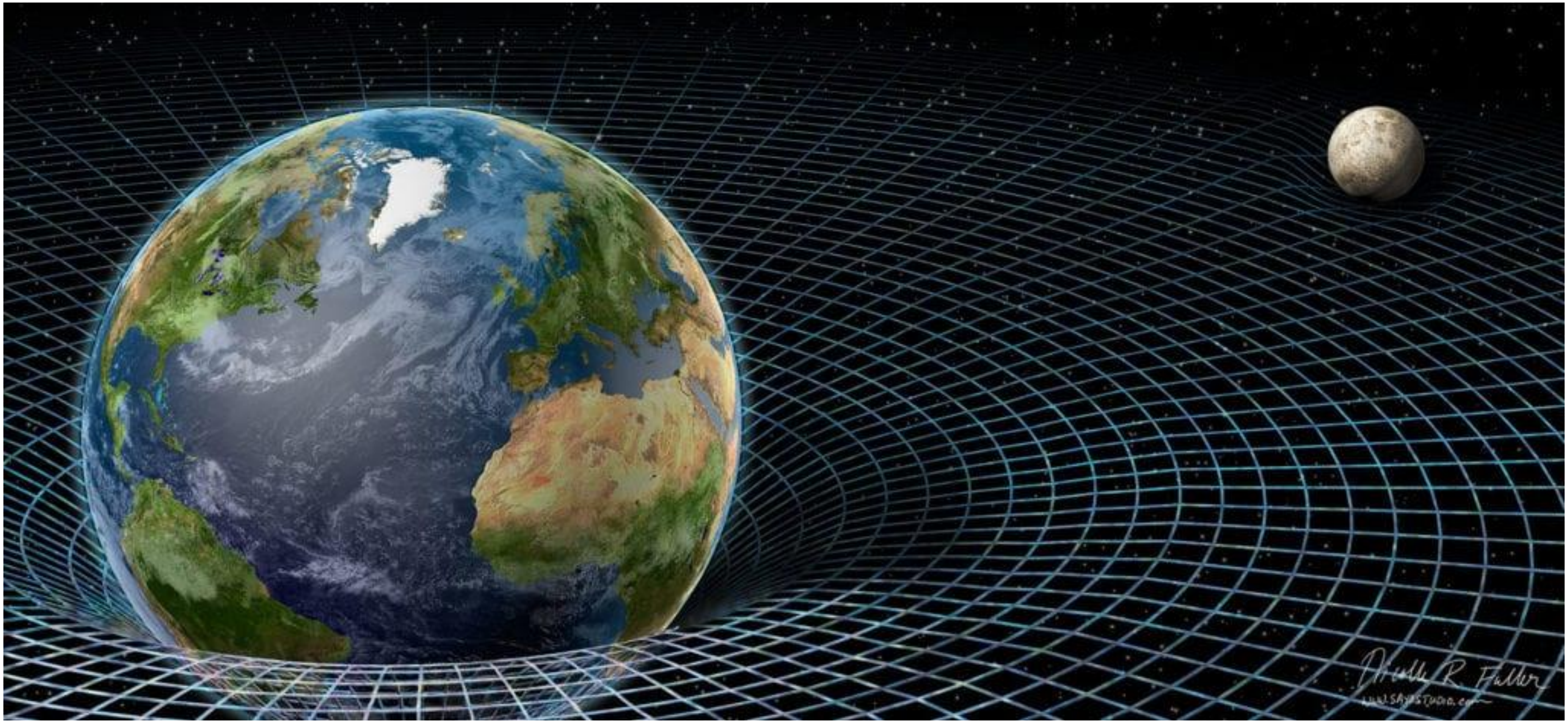


The modern view of gravity, per Einstein. The diagram shows the theoretical 3-dimensional warping of time-space because of gravity. Gravity is strongest closest to the Earth, it becomes weaker with increasing distance.

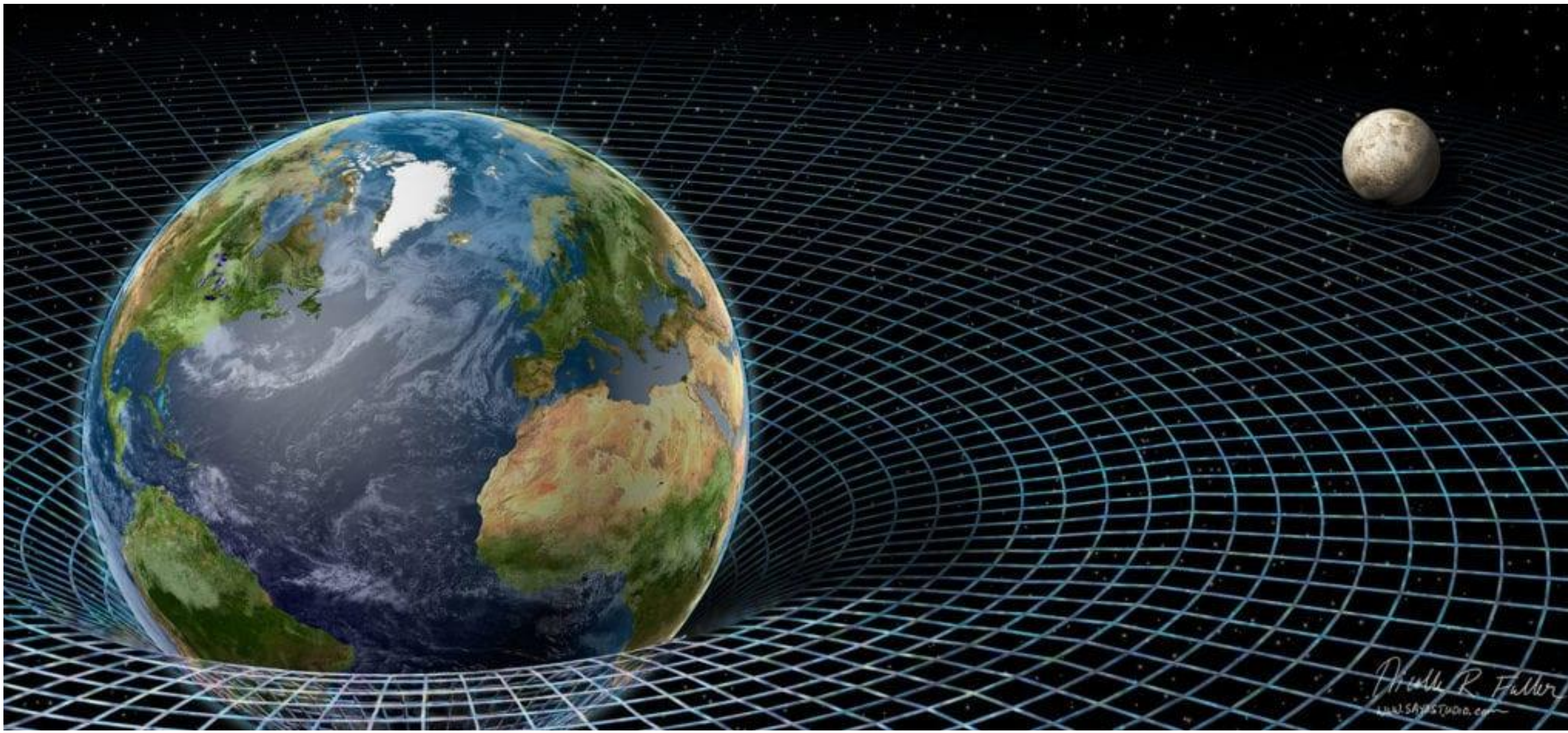


The greater the object's mass, the stronger the object's gravity field, the greater the warping of space-time by gravity.

The orbits of smaller objects around more massive objects happens when the moving smaller objects follow the curvature of space-time caused by the more massive object.



The moon moves in its orbit around the Earth by following the curvature of the Earth's deeper gravity well that curves space time around the Earth.



The Earth moves in its orbit around the Sun by following the curvature of the Sun’s deeper gravity well that curves space time around the Sun.