

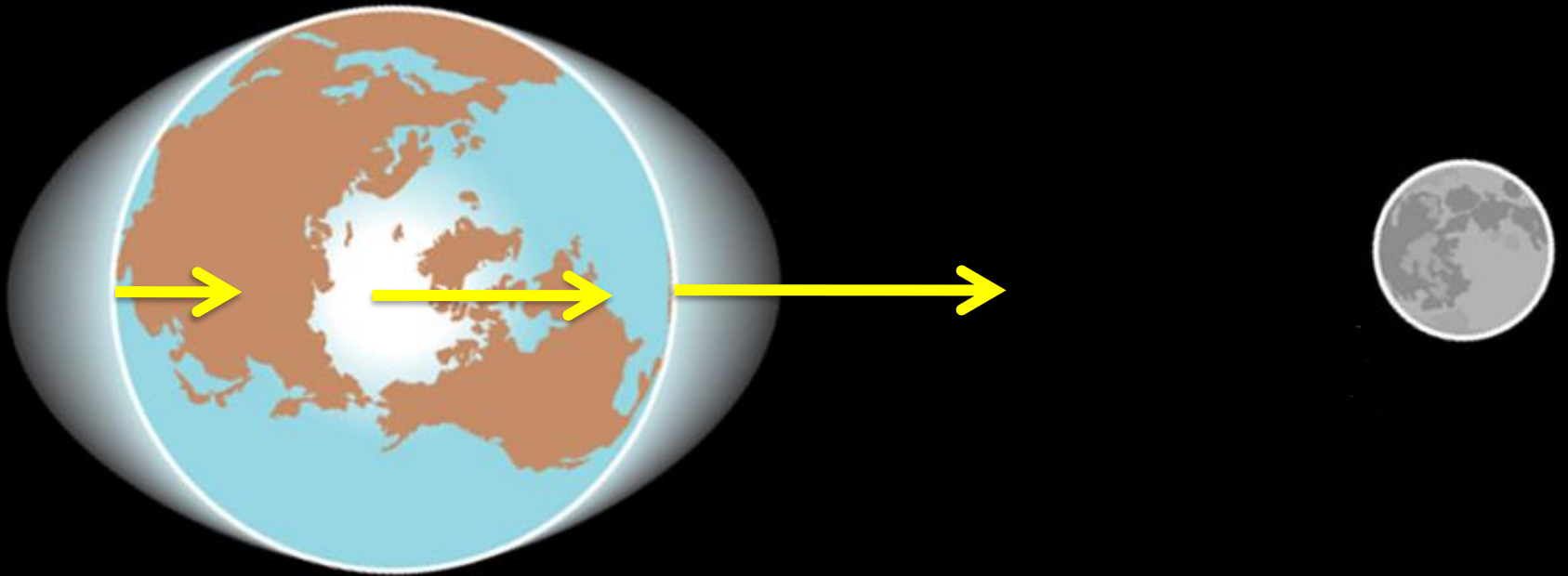
tide = distortion due to gravity

Physics of Tides: <https://youtu.be/3RdkXs8BibE>

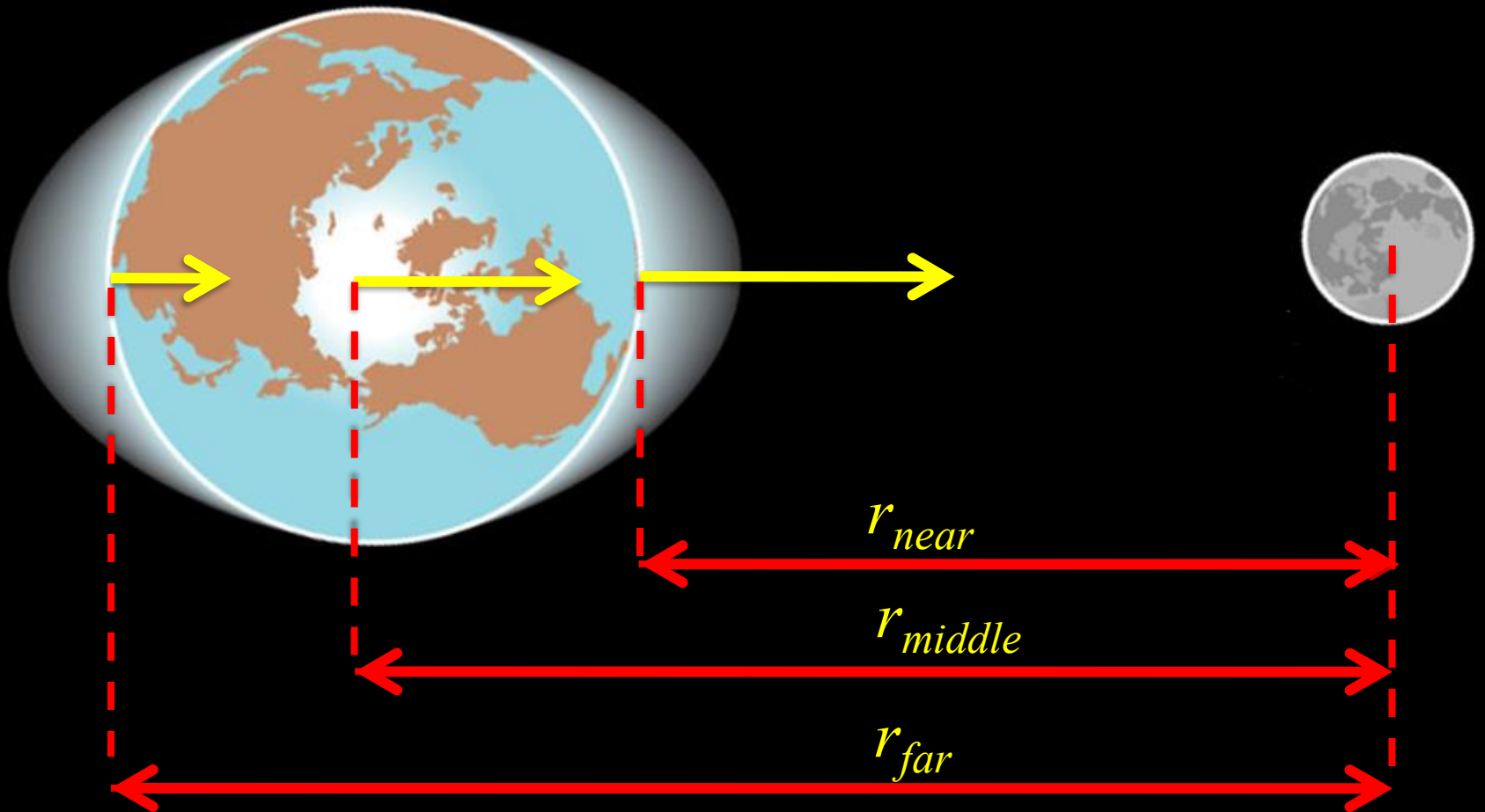


scale greatly exaggerated!

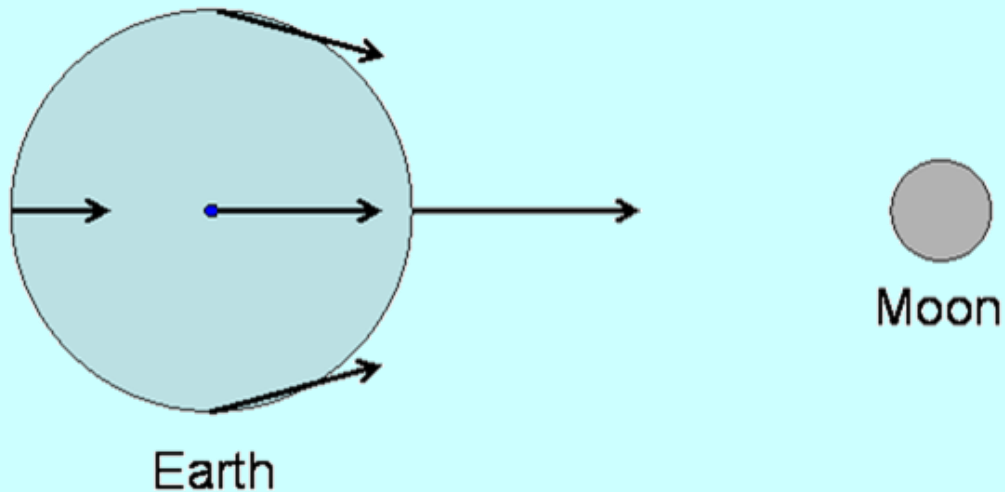
$$F = \frac{G M_{\text{moon}} M_{\text{earth}}}{r^2}$$



$$F = \frac{G M_{\text{moon}} M_{\text{earth}}}{r^2}$$

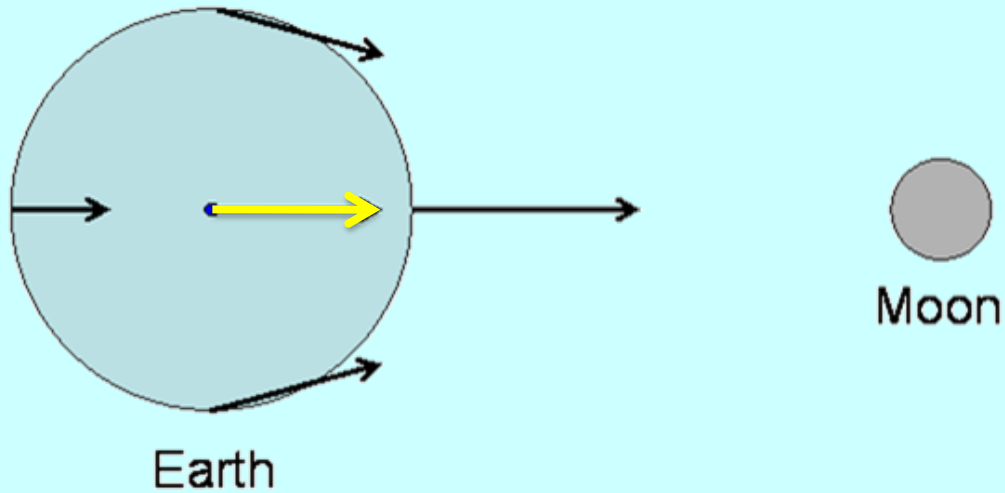


This bulging on both sides of the Earth can be shown mathematically by **VECTORS**

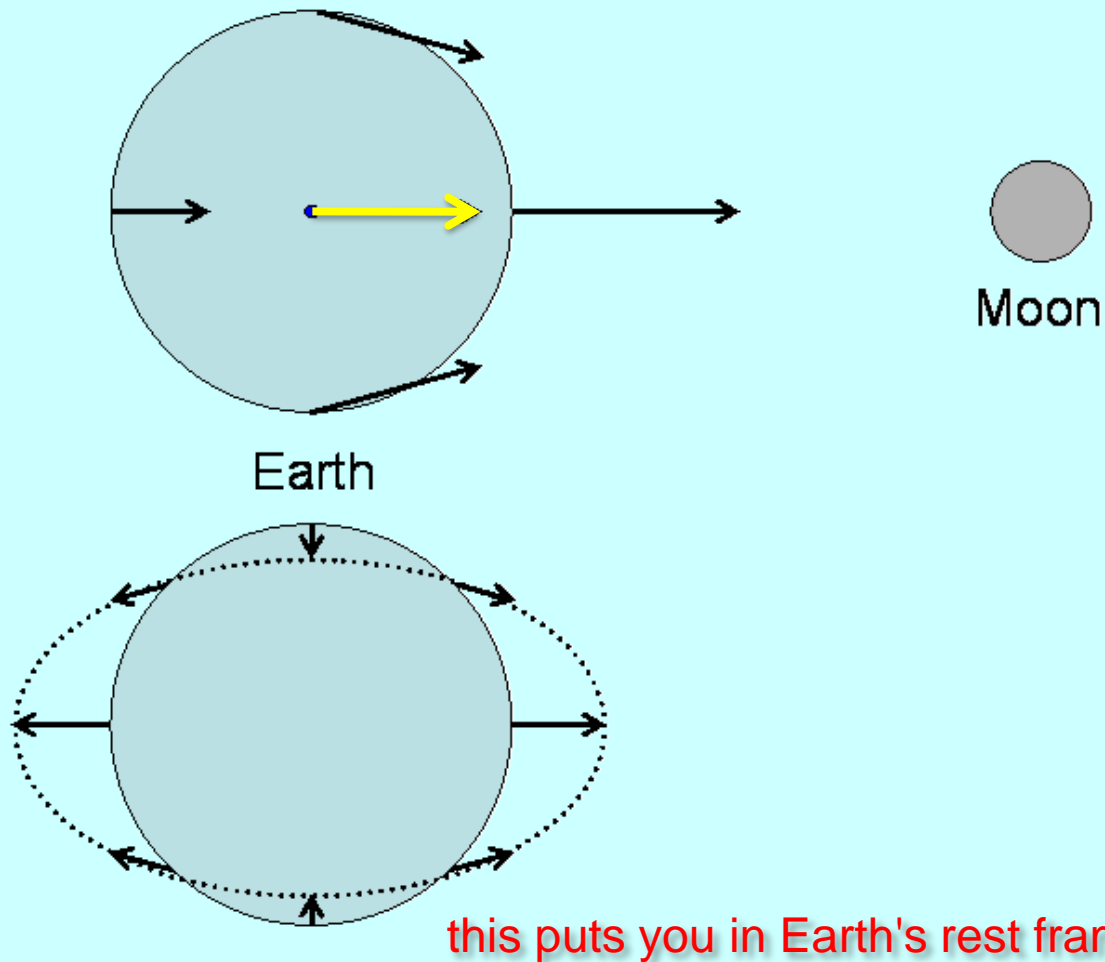


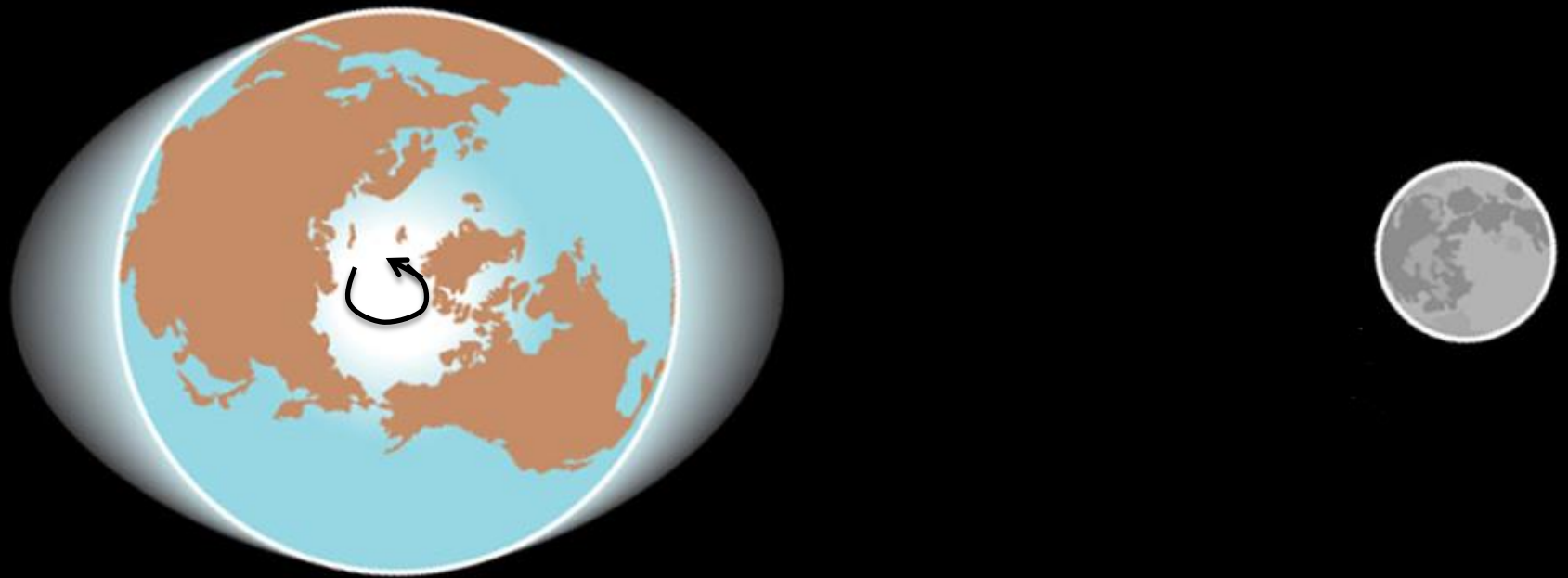
Consider the arrows which represent the force of the Moon on different parts of Earth. These are called vectors. Their length indicates gravitational strength. Their direction is toward the center of the Moon.

If you subtract the center vector in the diagram from all the other vectors,

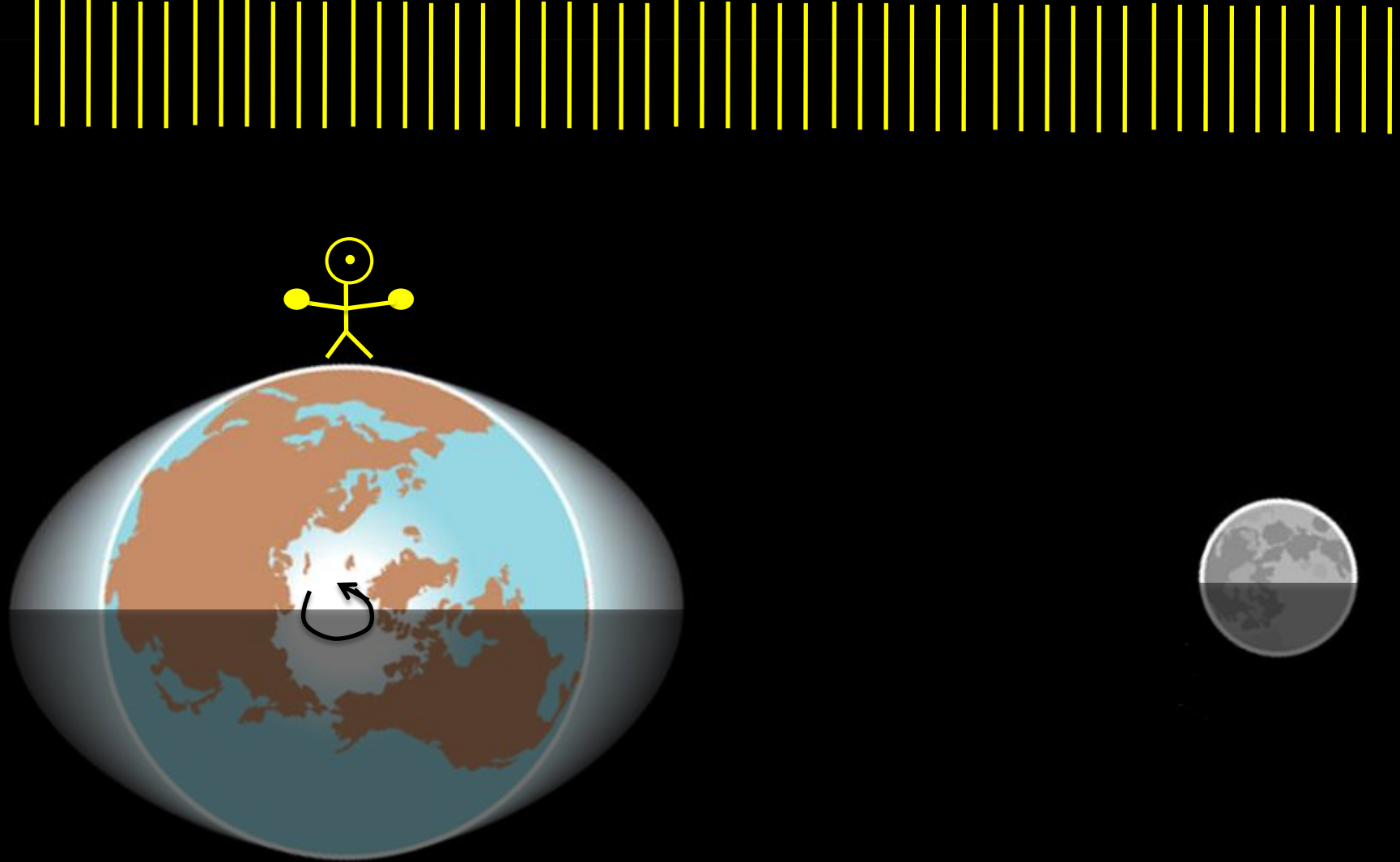


If you subtract the center vector in the top diagram from all the other vectors,

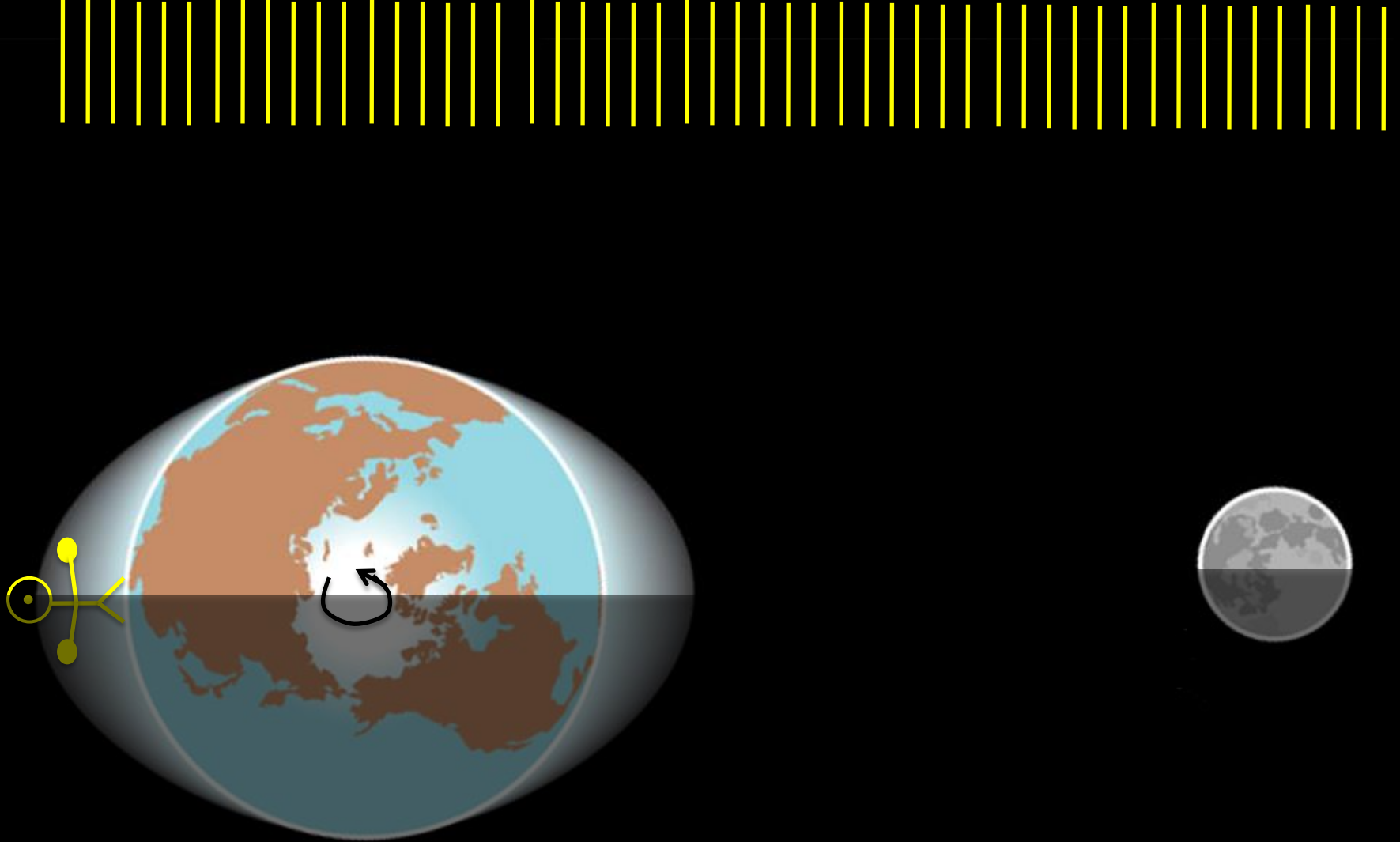




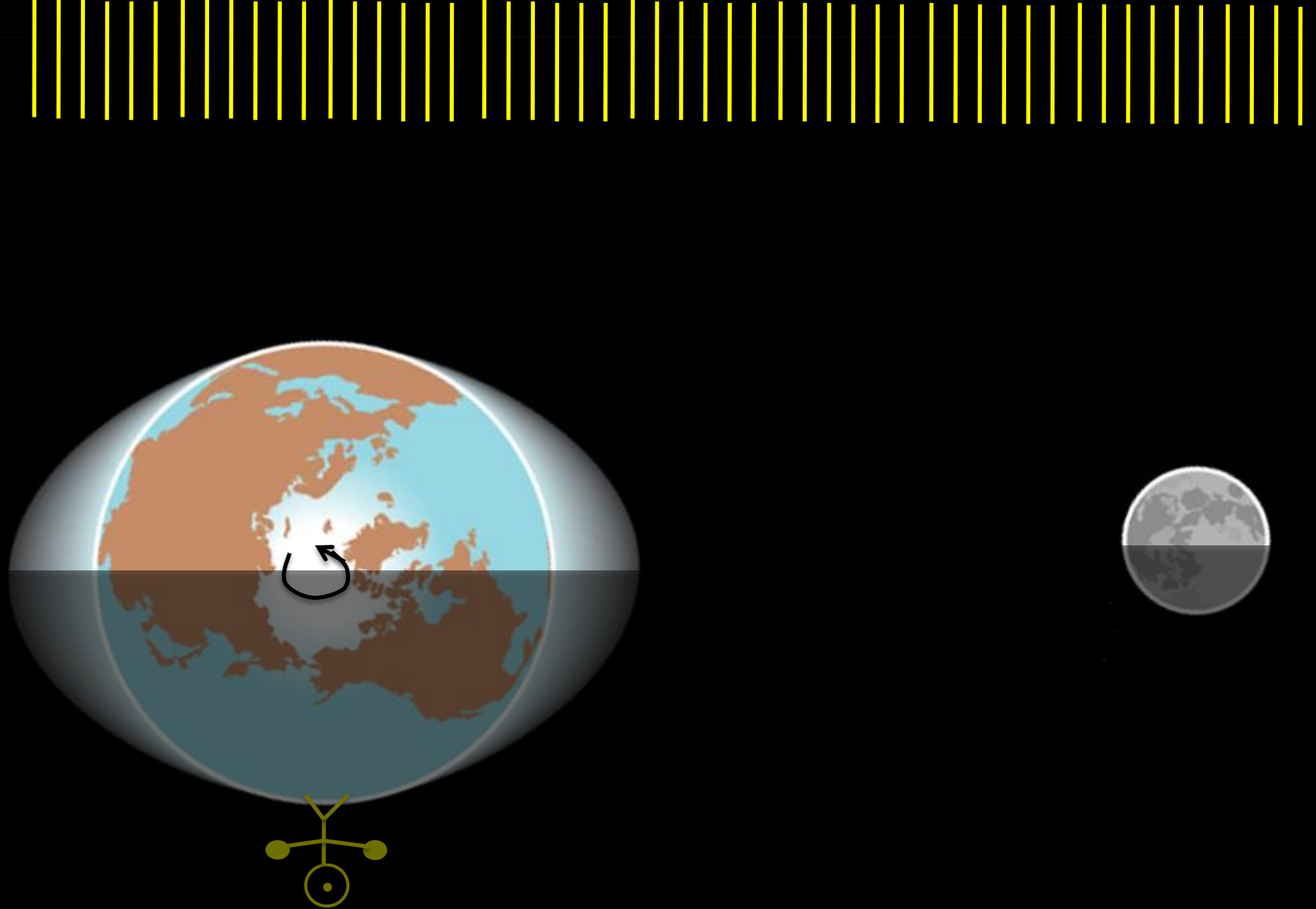
Earth spins but the bulge always points toward the Moon,
so we experience 2 low tides and 2 high tides in 24 hrs



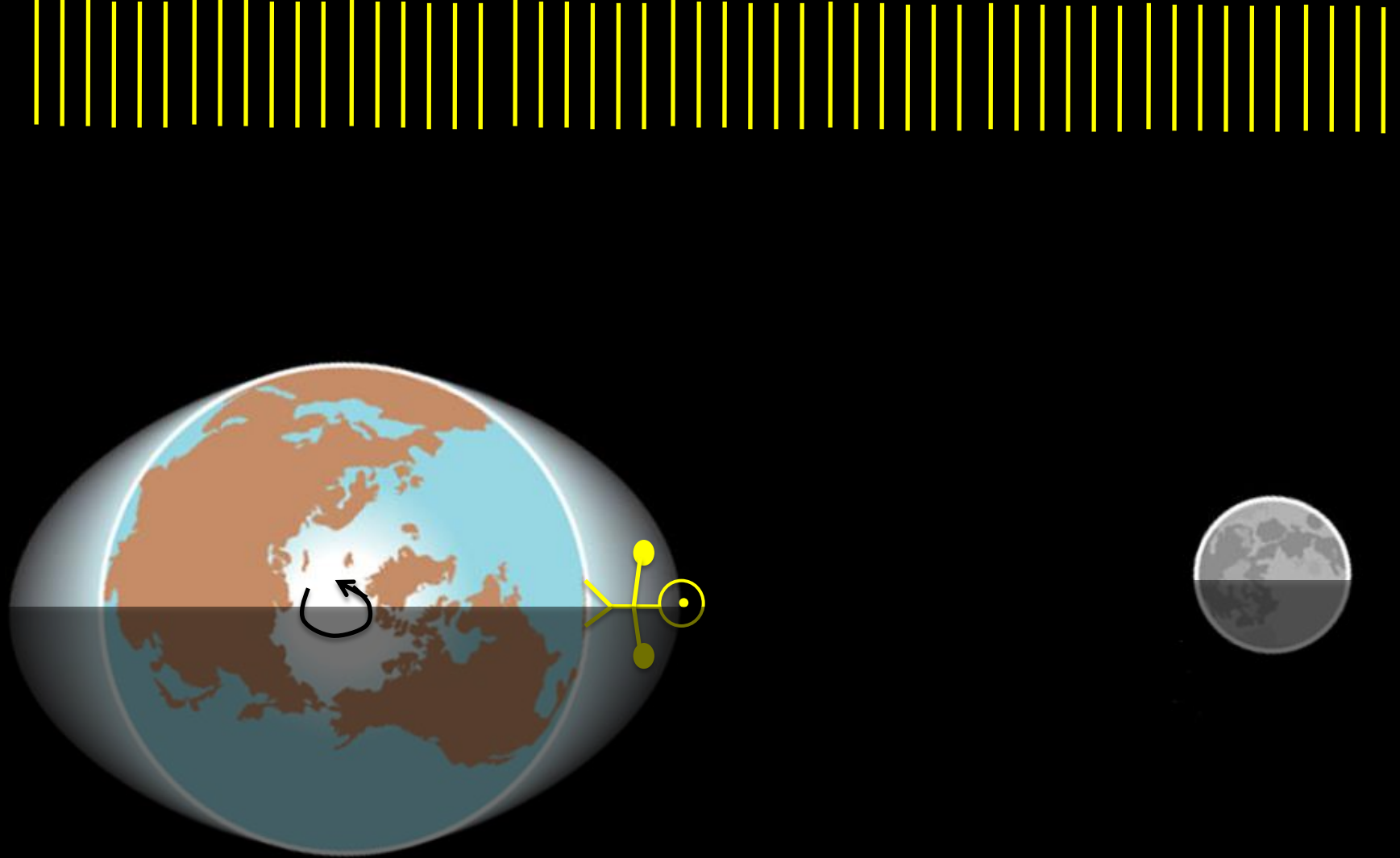
this person would experience a low tide



At sunset, this person would experience a high tide



At midnight, this person would experience a low tide



At sunrise, this person would experience a high tide

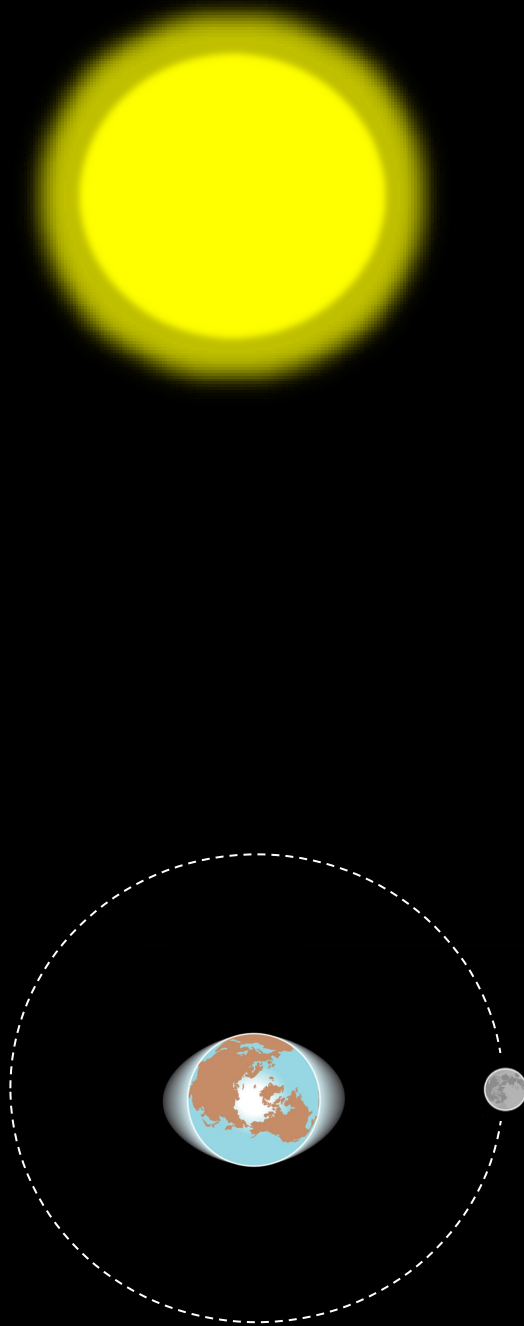


high tide

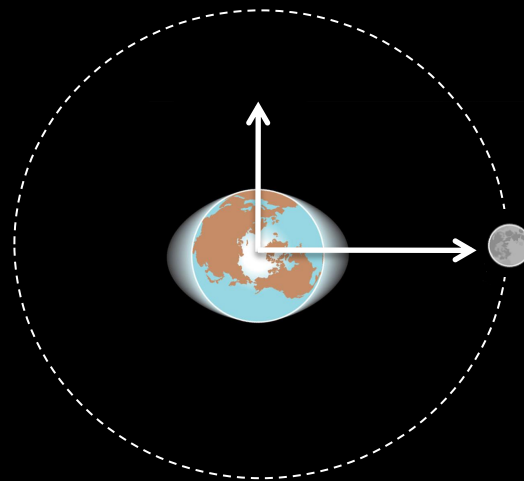


low tide

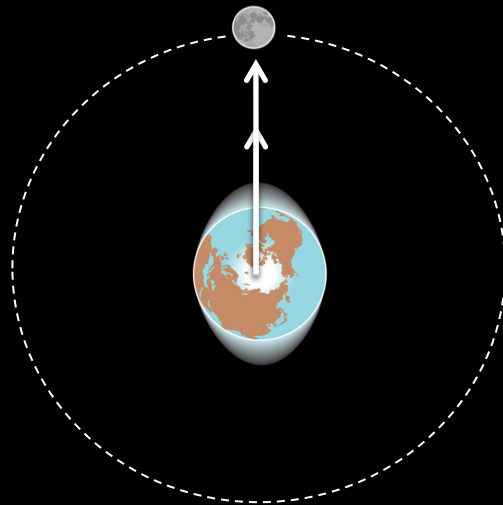
But the Sun plays a
role, too, in tides on
Earth, although only
about half as much as
the Moon



If Sun and Moon pull
in different directions
it affects the height
and depth of the tides
— the bulge must
face toward the Moon
at all times

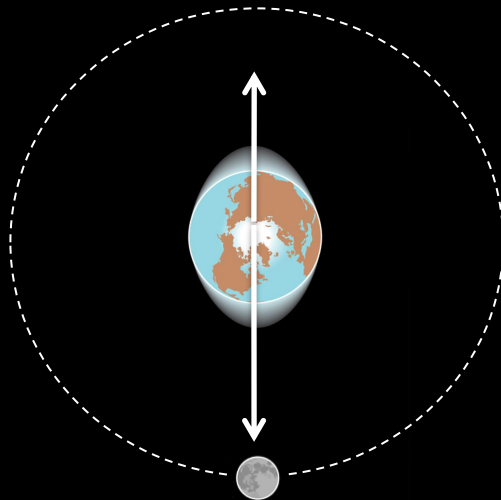


When Moon and Sun
are in a straight line
through Earth —
either at New Moon
or...

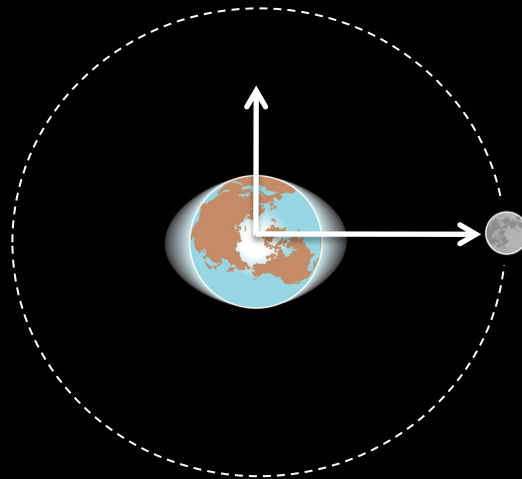


... at Full Moon the
highs will be extreme
and the lows will be
extreme —

Spring Tides

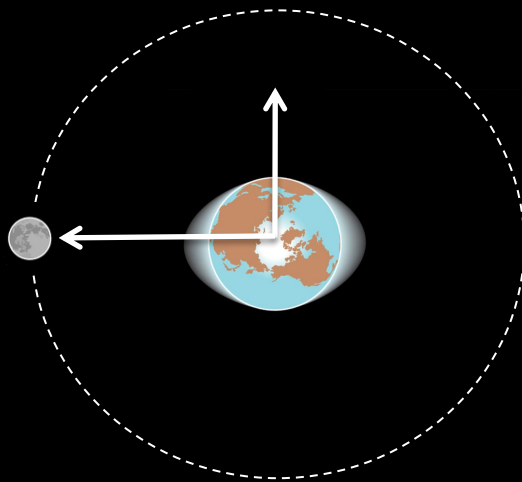


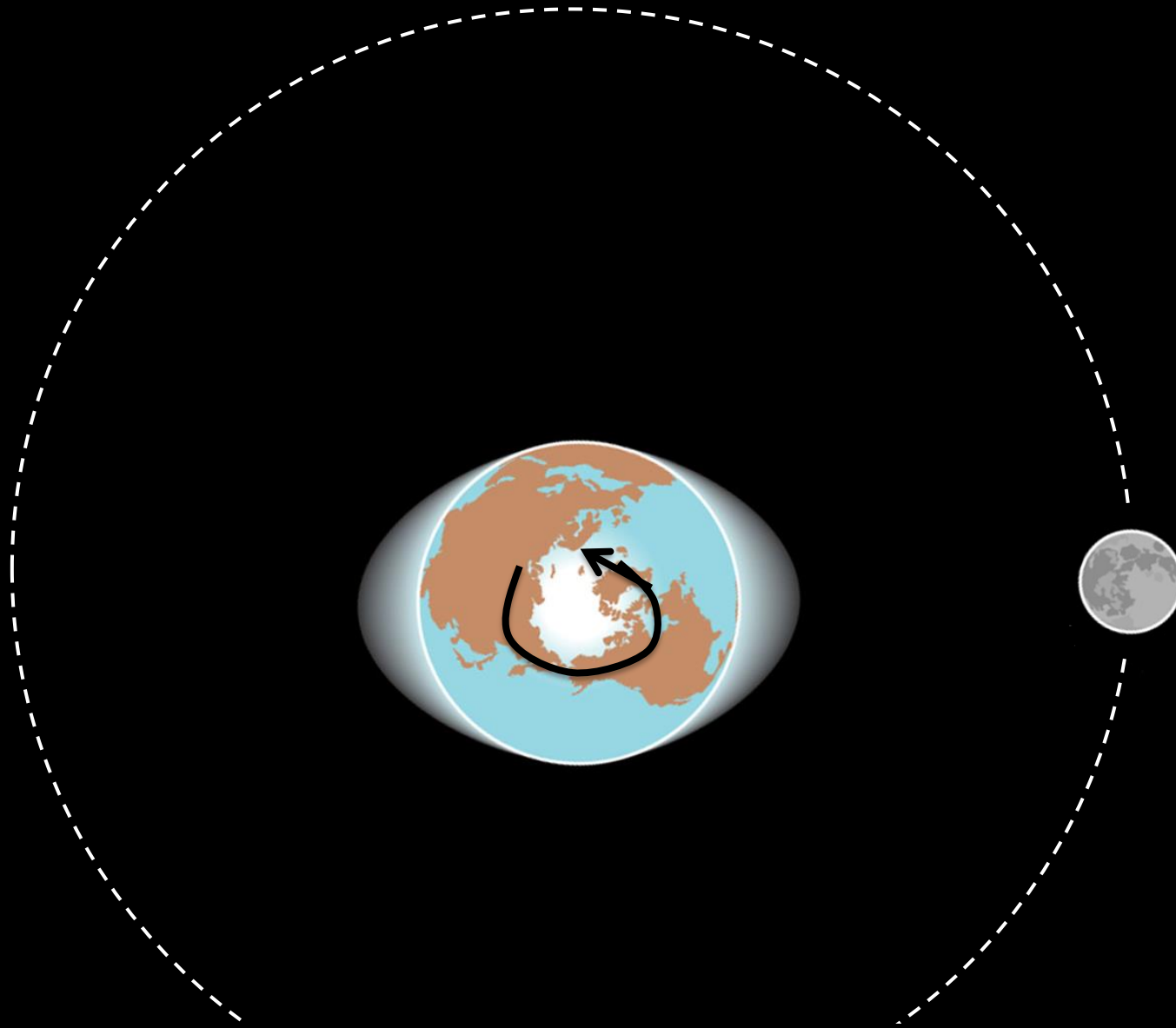
When Moon and Sun
are at 90 degrees
relative to Earth —
either at 3rd Quarter
or...



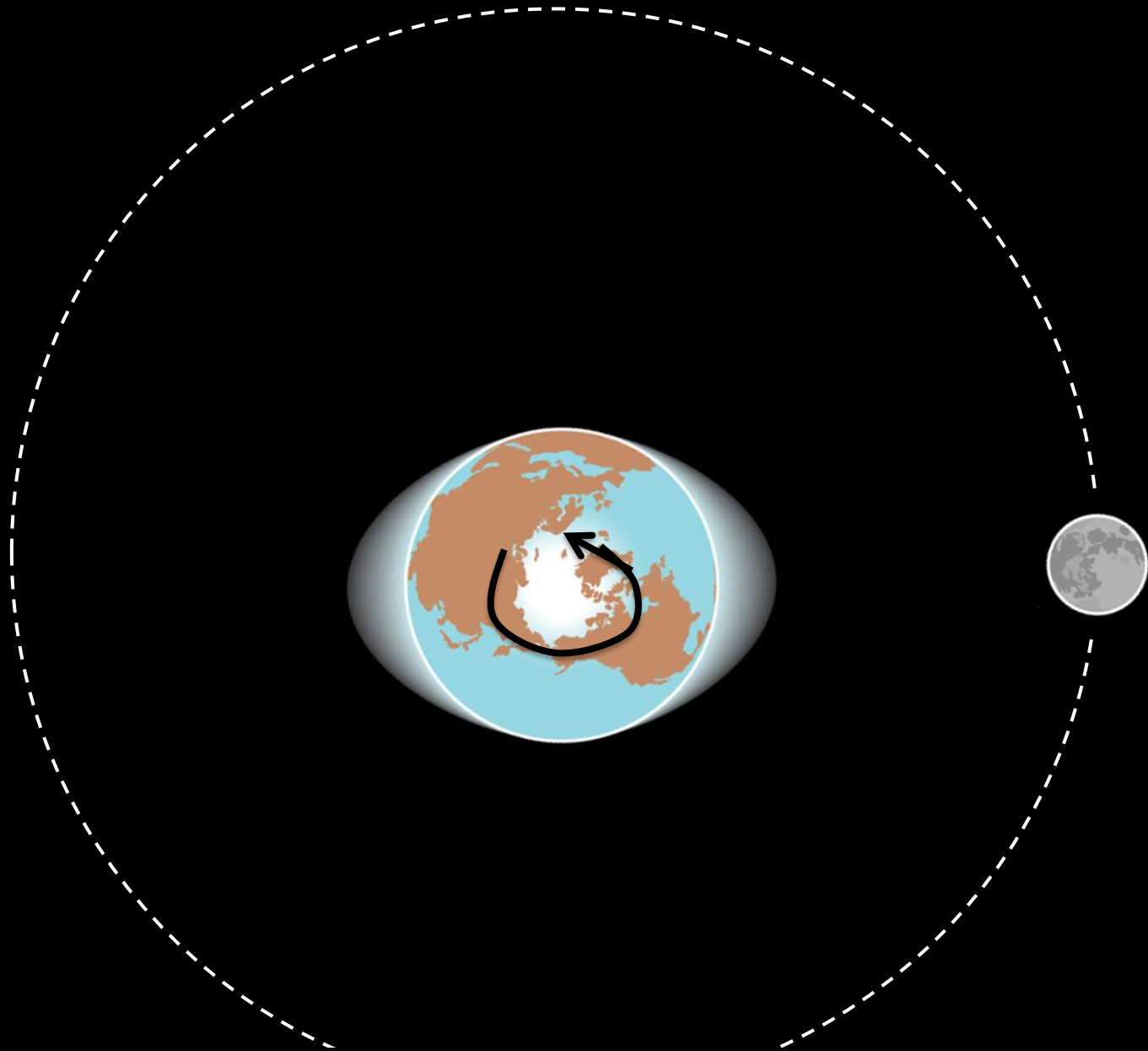
At 1st Quarter the
highs are weak and
the lows are weak

Neap Tides

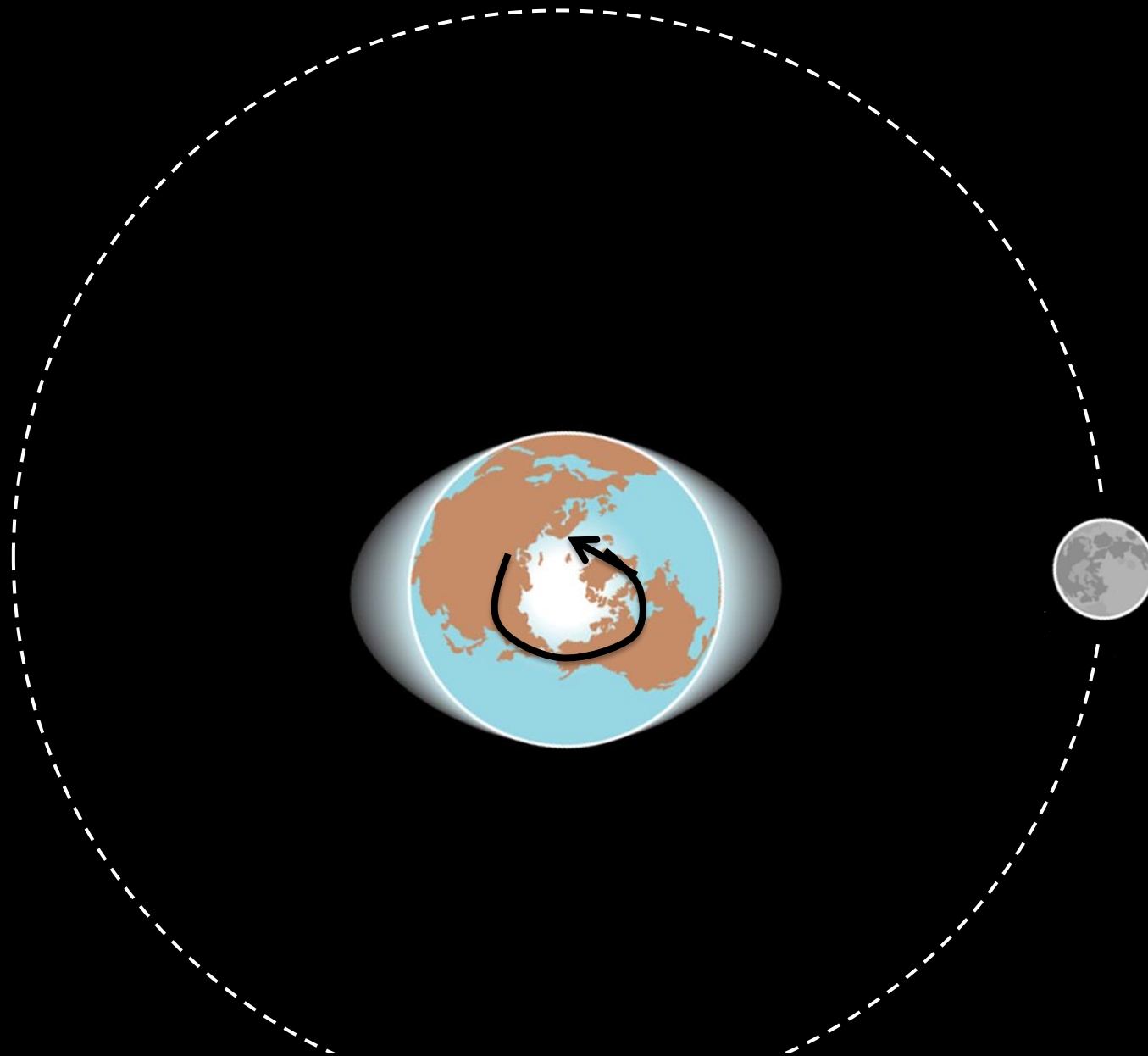




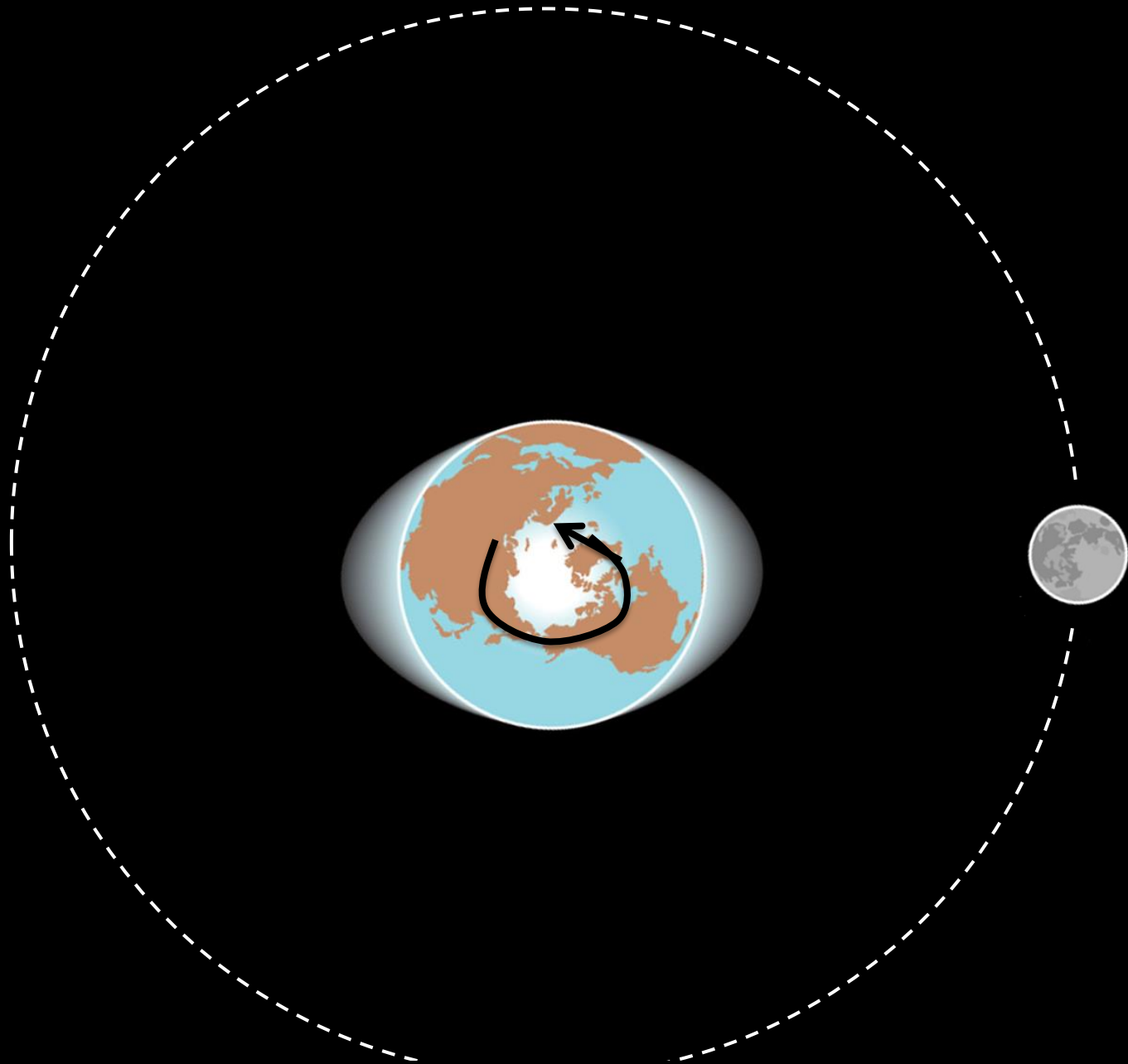
Earth spins 29 times for each time the Moon goes around once, yet Earth's bulge faces toward the Moon at all times



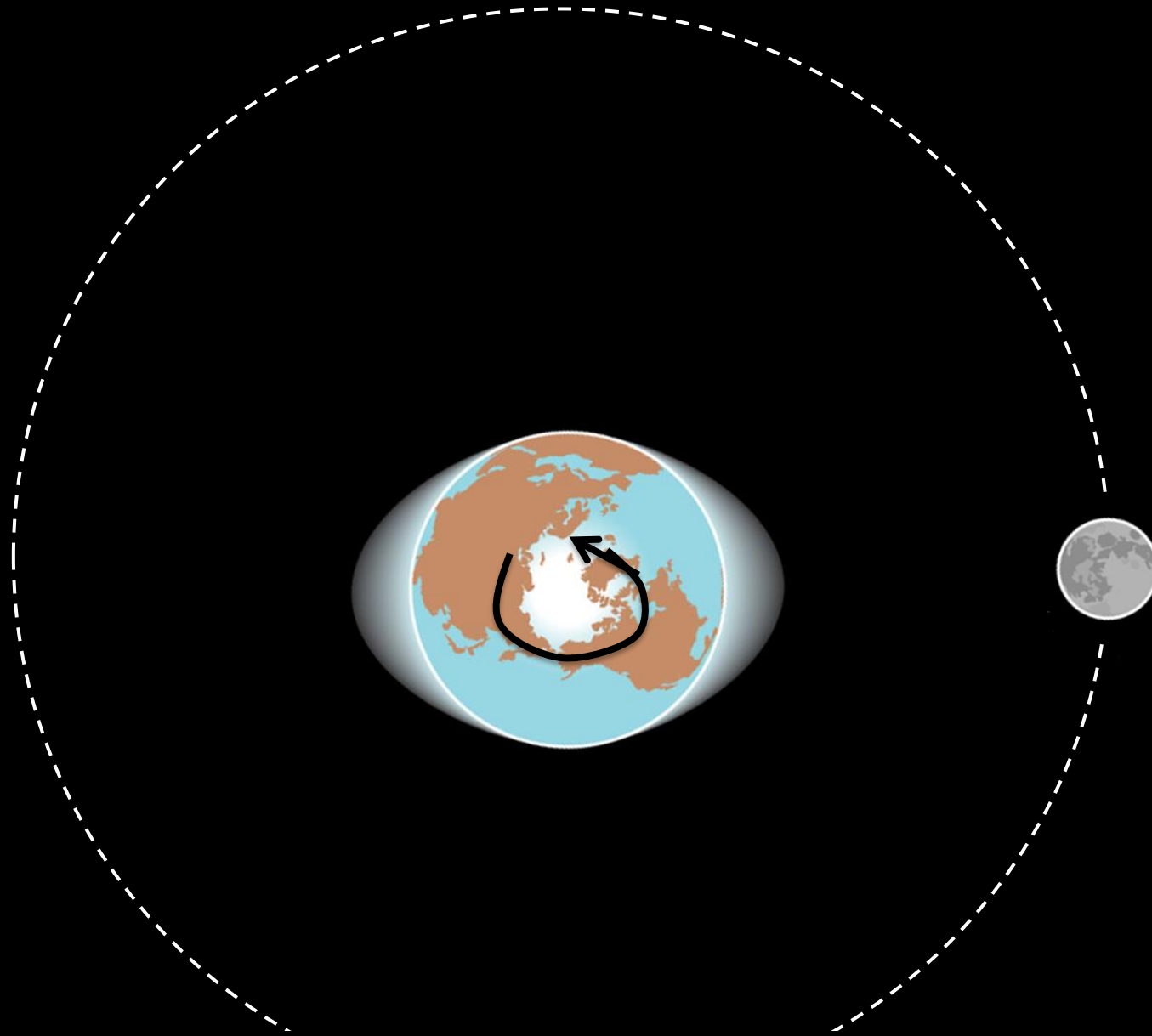
This causes FRICTION and the Earth is slowing its rotation



Our 24 hr day is getting longer by 0.0017 sec per century



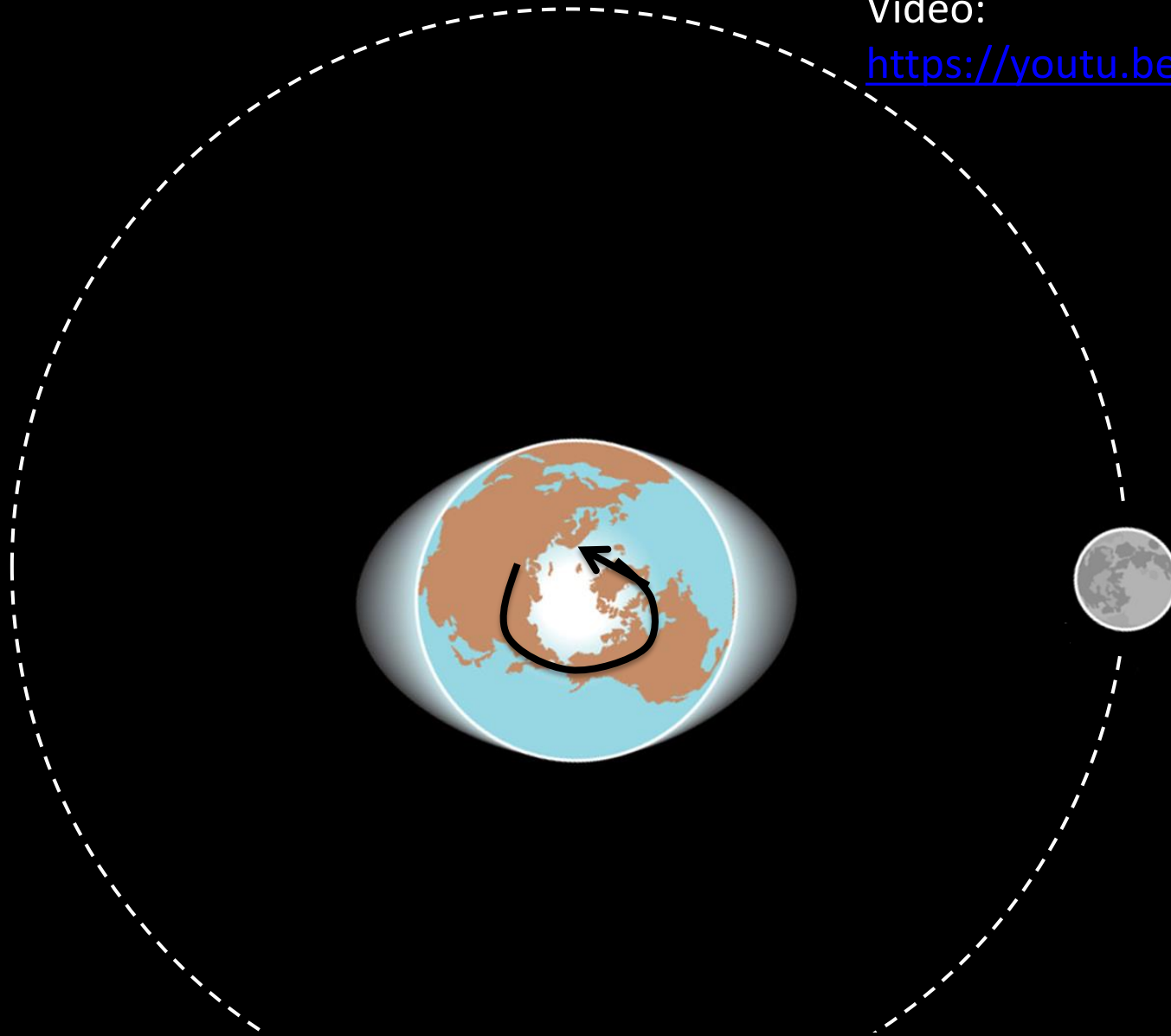
Fossil evidence shows that about 400 million yrs ago, one day was 22 hrs!



The Moon's spin slowed fast a long time ago — the result is that now the
Moon's rotation rate = orbital period

Video:

<https://youtu.be/6jUpX7J7ySo>



This is why the **SAME** side of the Moon always faces **EARTH**
— we call this phenomenon **TIDAL LOCK**

What is Energy?



**It's a way to do bookkeeping
for the Universe!**



Energy can be thought of as the **POTENTIAL** to put a force on something else.



For example, MONEY has the POTENTIAL to buy things



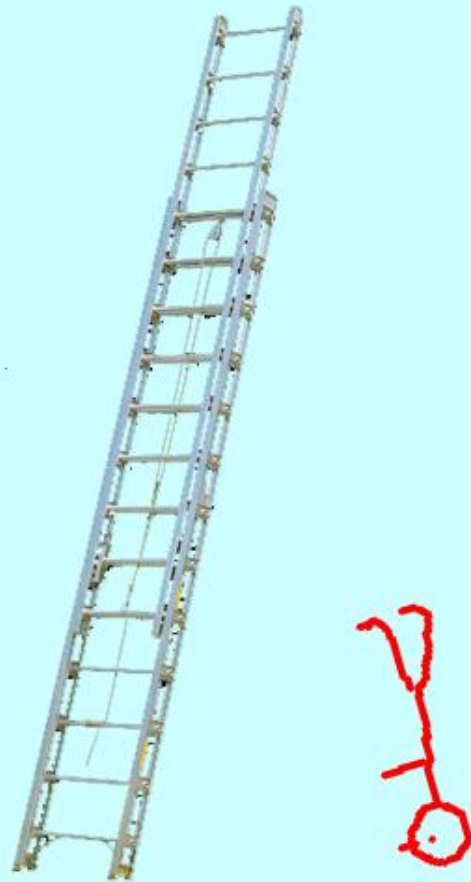
For example, the higher you climb...



... the greater **Gravitational Potential Energy** you have.



And the faster you'll be going when you hit the ground.
The bookkeeper takes back the energy you borrowed.



The potential energy turned into **Kinetic Energy** on the way down.



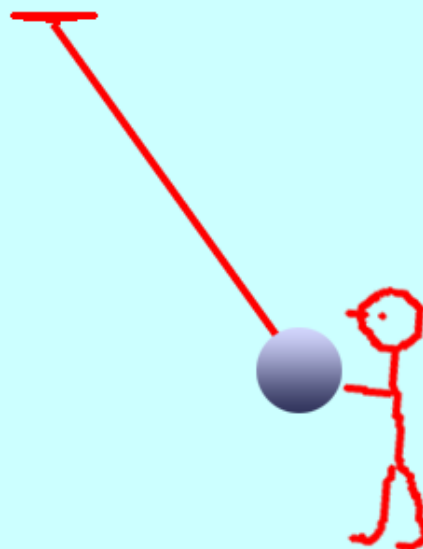
$$K_{energy} = \frac{1}{2}mv^2$$



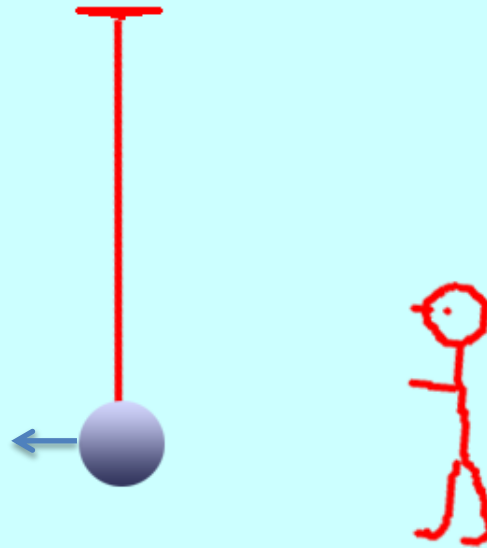
It's easy to see with a pendulum. Here it has no potential or kinetic energy.



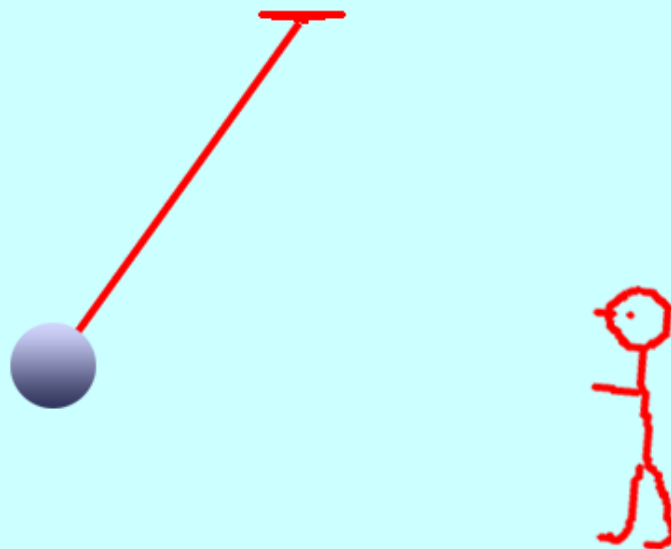
Here it has gravitational potential energy
but no kinetic energy.



Now it
has all kinetic energy.



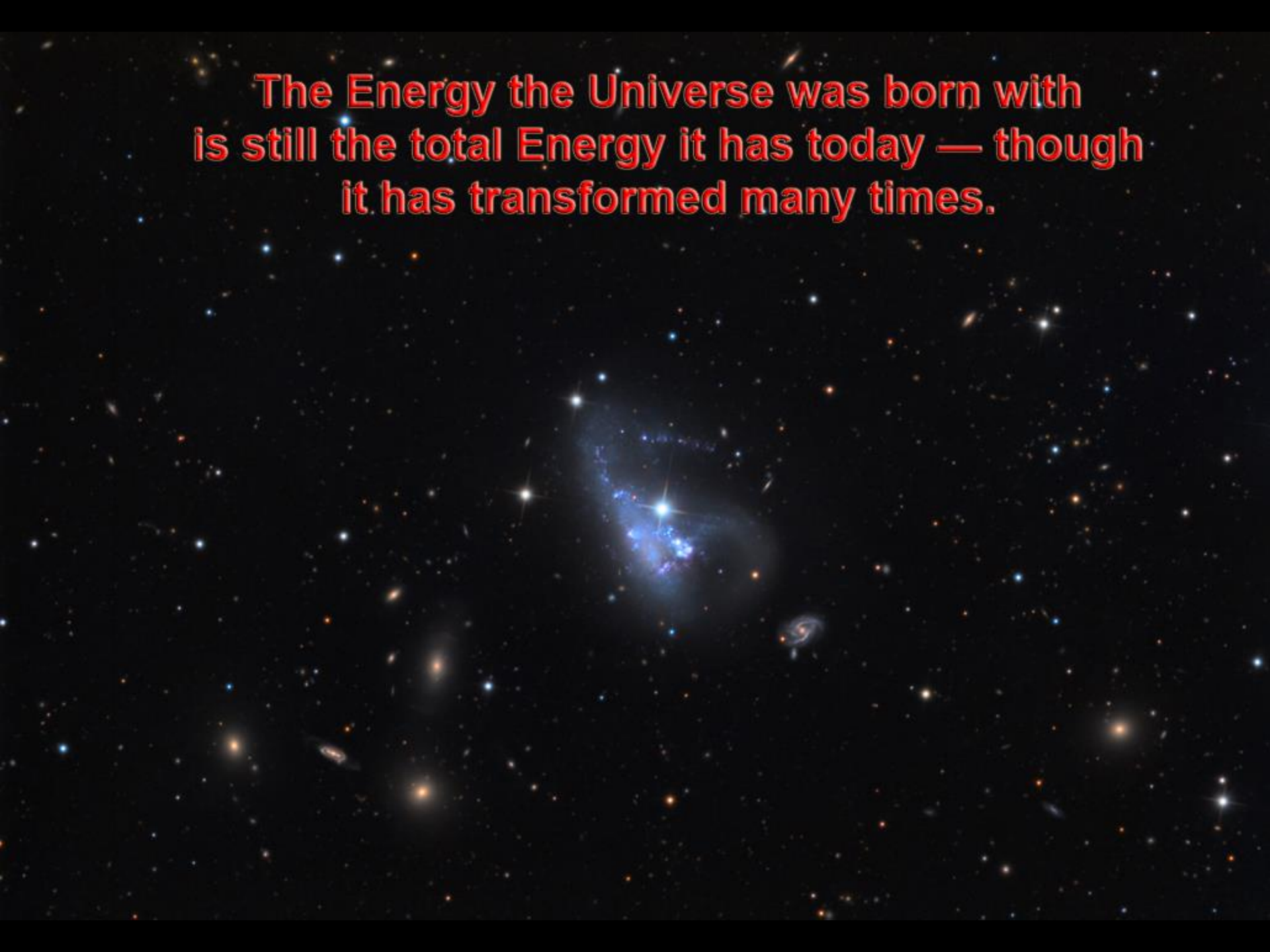
Now it
has all potential energy again.



Energy is conserved. It can be transformed, but it cannot be created or destroyed.



**The Energy the Universe was born with
is still the total Energy it has today — though
it has transformed many times.**



to make the stars and Earth and you and me!



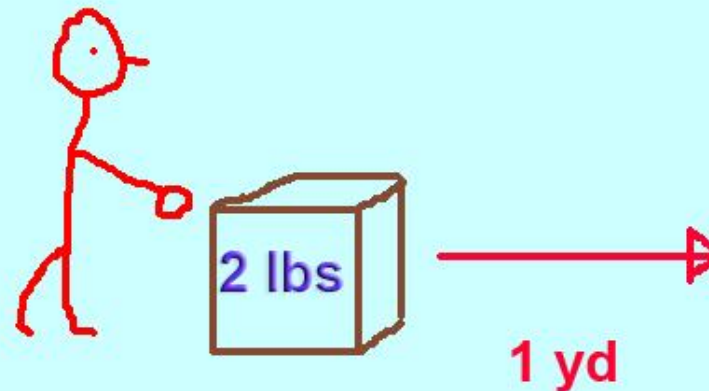


Energy in all its forms has a unit. A **Joule.**



One Joule is the energy needed to
move about 2 lbs one yard

or in metric units,
the energy to move 1 N one meter.



Light has Energy.



A savanna landscape with a rainbow in the sky and a herd of zebras in the foreground. The sky is filled with a vibrant rainbow, and the ground is covered in green grass and yellowish-brown shrubs. A herd of zebras is grazing in the foreground.

Each color (wavelength) of light
has a tiny amount of energy.

Visible light carries only 4×10^{-19} J in
each photon.

But there is so much light, it is easier
to talk about how much Energy
you receive per second.

Energy per second is called **POWER**



**A 100 Watt lightbulb USES 100 J of energy
per second to radiate light.**



The sun puts out 4×10^{26} W



The sun puts out 4×10^{26} W
That's 4×10^{26} Joules per second!



The sun puts out 4×10^{26} W

in astronomy, light power is called

LUMINOSITY



Mass has energy, too. Einstein
calculated how much by

$$E = mc^2$$



That's 4×10^{14} Joules — enough for all the energy needs of the US for one year!



That's 4×10^{14} Joules — enough for all the energy needs of the US for one year!

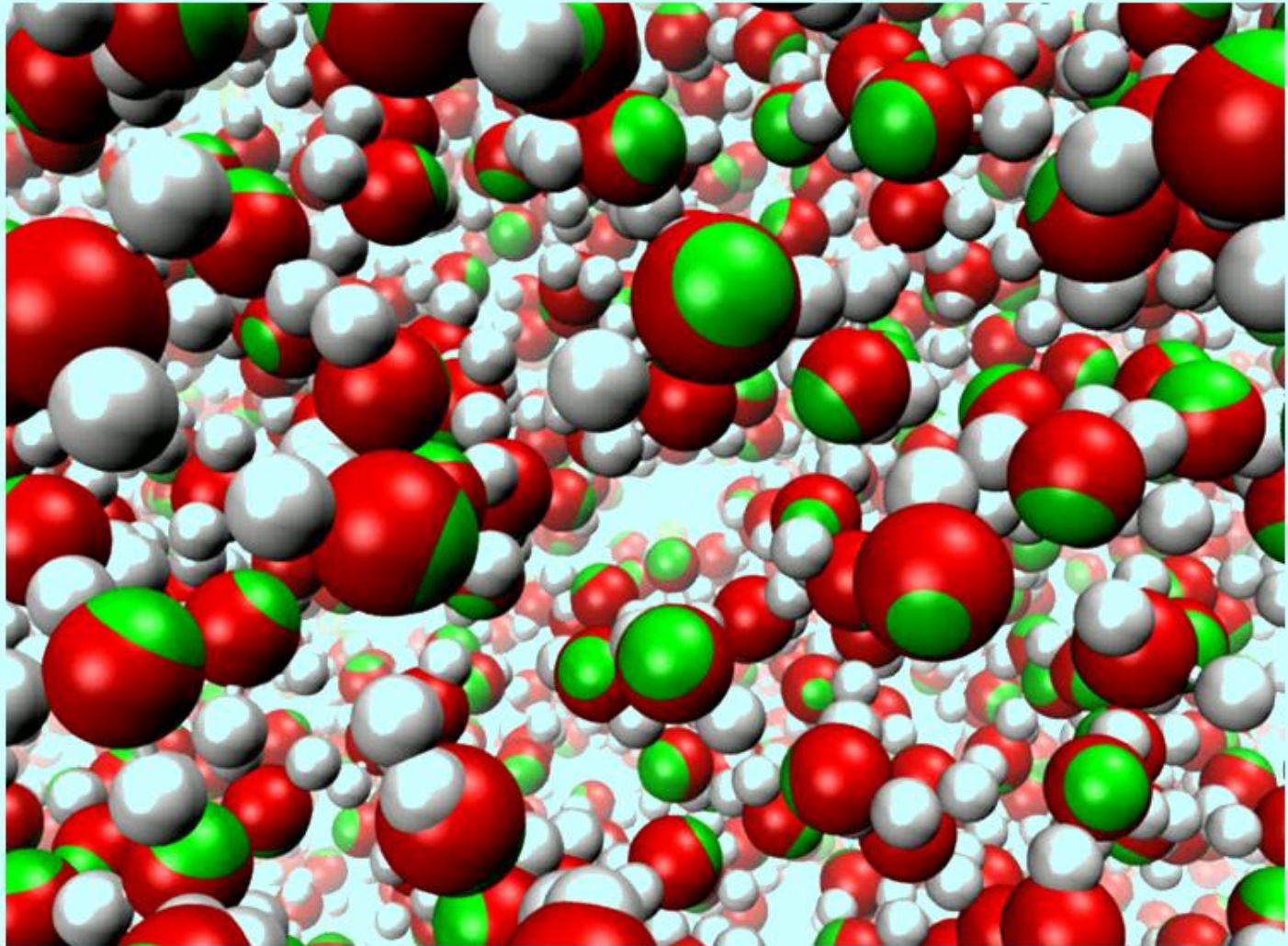


\$ 40×10^{12} → 40 trillion dollars!!

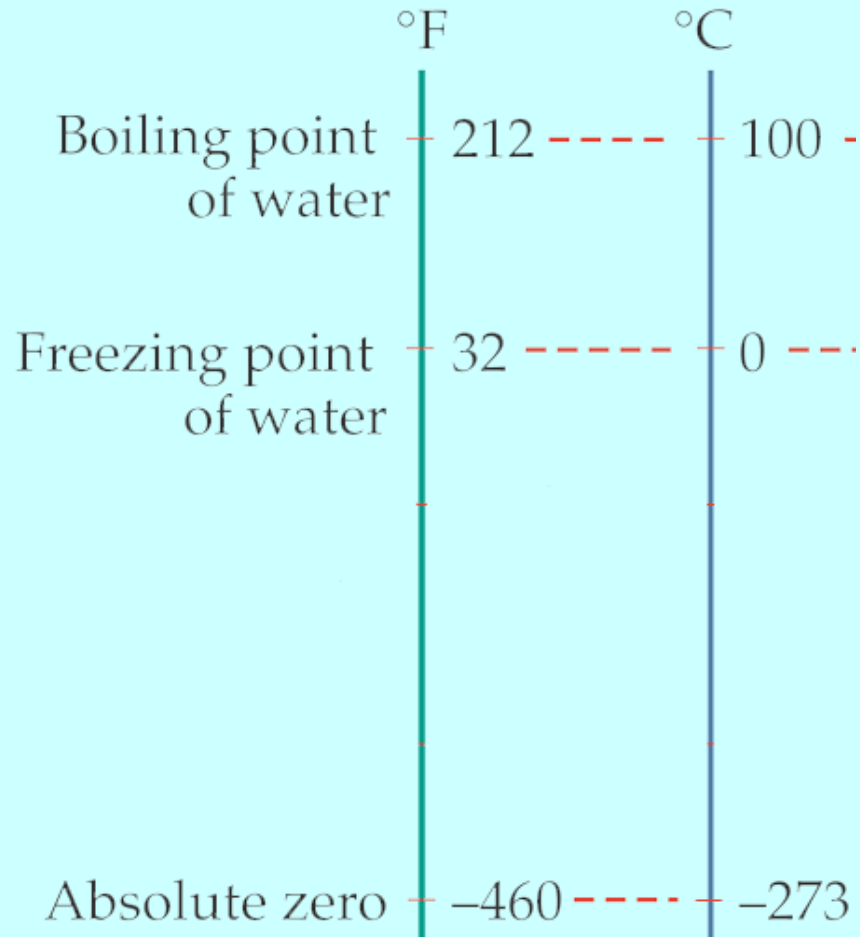
**What is the difference between TEMPERATURE
and HEAT?**

TEMPERATURE

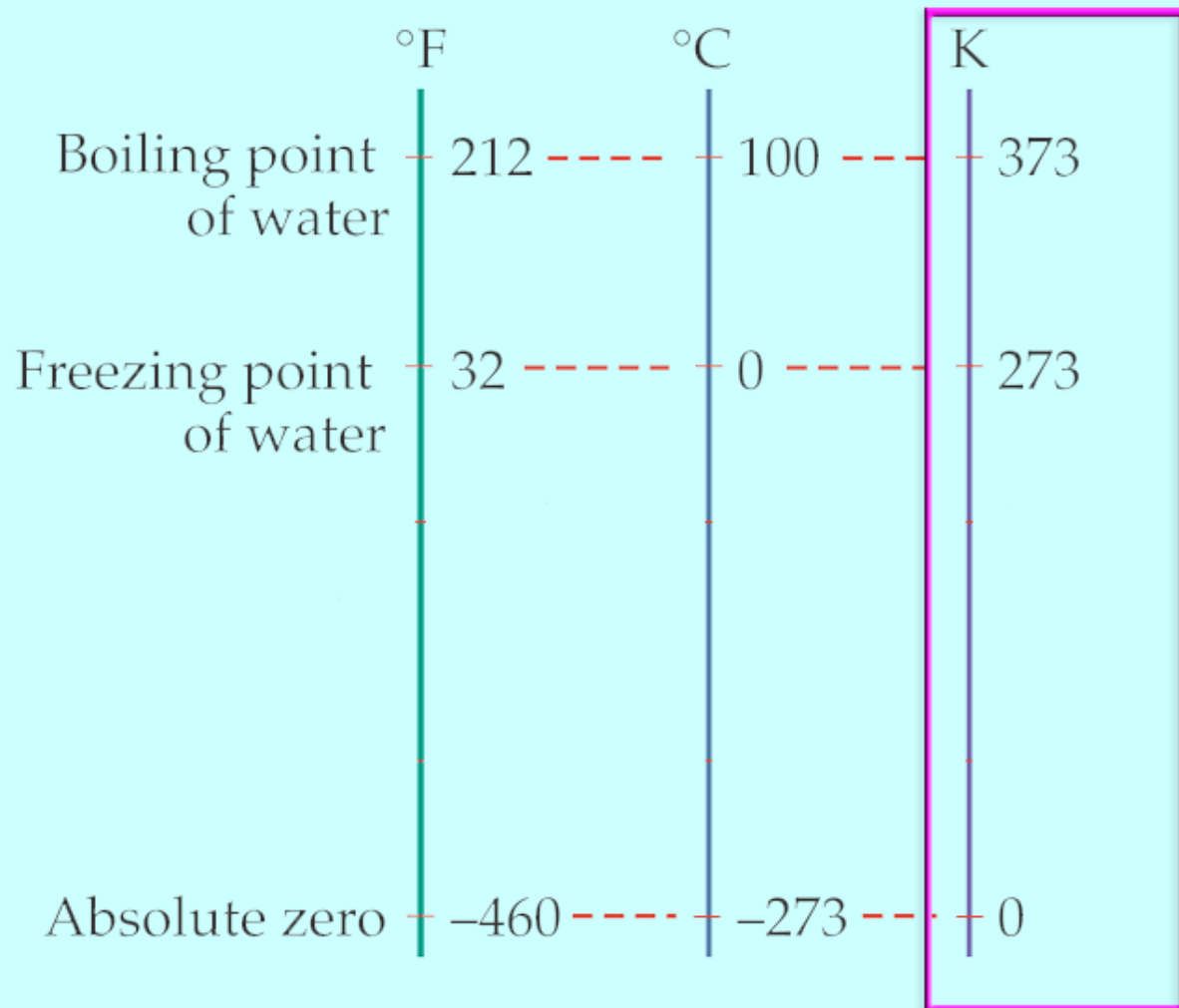
is a measure of the average speed of atoms



TEMPERATURE Scales



TEMPERATURE Scales



Heat is the energy transferred by collisions. For ex., by the atmosphere to you on a hot day.



HEAT

For ex., this wool and hunk of iron are at the same room temperature. Which would FEEL warmer to your hand?

wool



iron



HEAT

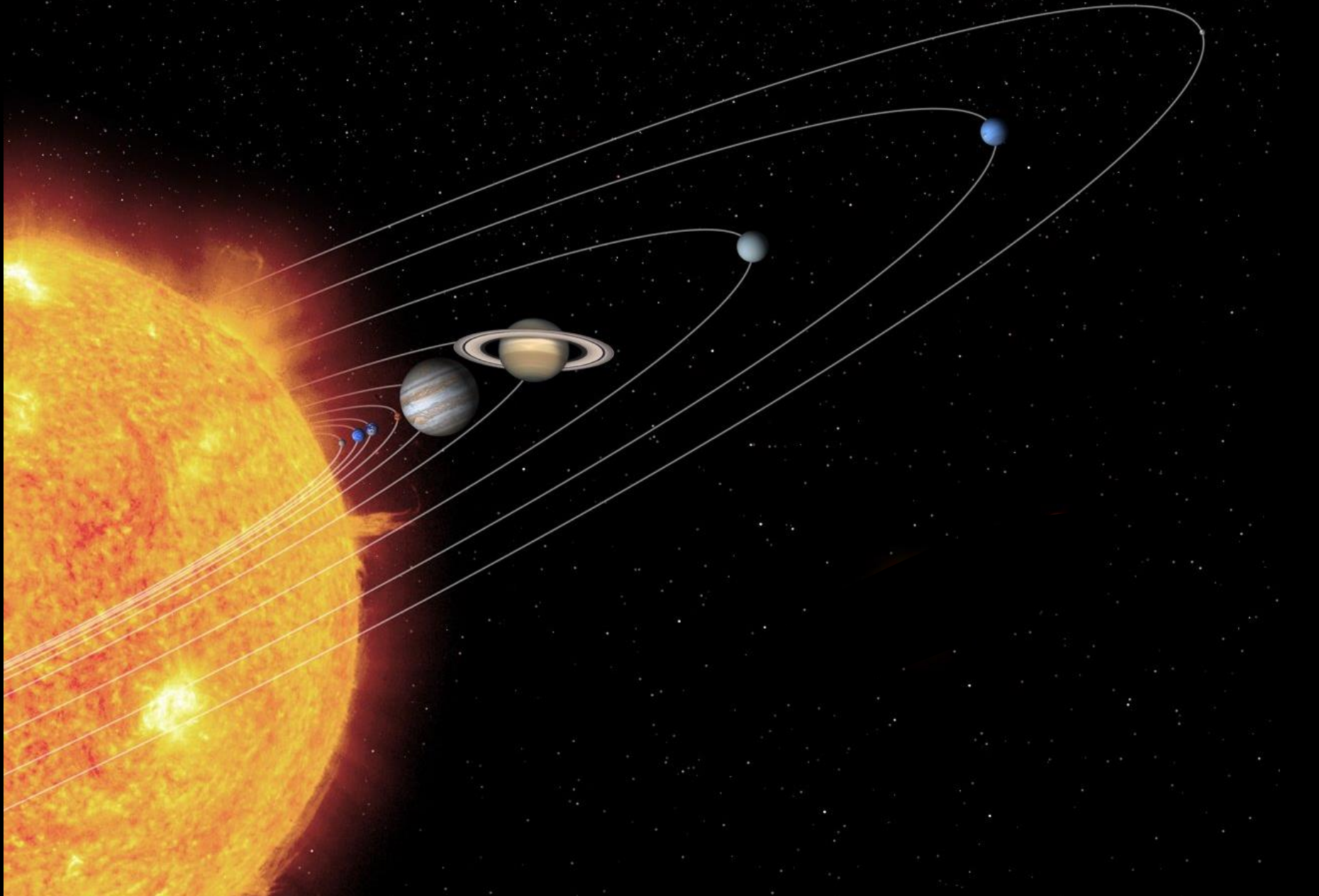
For ex., the TEMPERATURE of the Sun's Corona is 100 million degrees, but your hand would freeze solid in this gas!



It all comes down to ENERGY — bookkeeping the universe



Solar Nebula Theory



Observations of Today's Solar System

1. Sun and gas giants 74% H, 25% He 1% everything else.
Not rocky planets
2. All planets orbit in same plane: the ecliptic

Observations of Today's Solar System

1. Sun and gas giants 74% H, 25% He 1% everything else.
Not rocky planets
2. All planets orbit in same plane: the ecliptic
3. All planets orbit sun in same direction and Sun rotates in that direction, too

Observations of Today's Solar System

1. Sun and gas giants 74% H, 25% He 1% everything else.
Not rocky planets
2. All planets orbit in same plane: the ecliptic
3. All planets orbit sun in same direction and Sun rotates in that direction, too
4. Rocky planets are close in; gas giants far out

Observations of Today's Solar System

1. Sun and gas giants 74% H, 25% He 1% everything else.
Not rocky planets
2. All planets orbit in same plane: the ecliptic
3. All planets orbit sun in same direction and Sun rotates in that direction, too
4. Rocky planets are close in; gas giants far out
5. Debris throughout the ecliptic plane

Observations of Today's Solar System

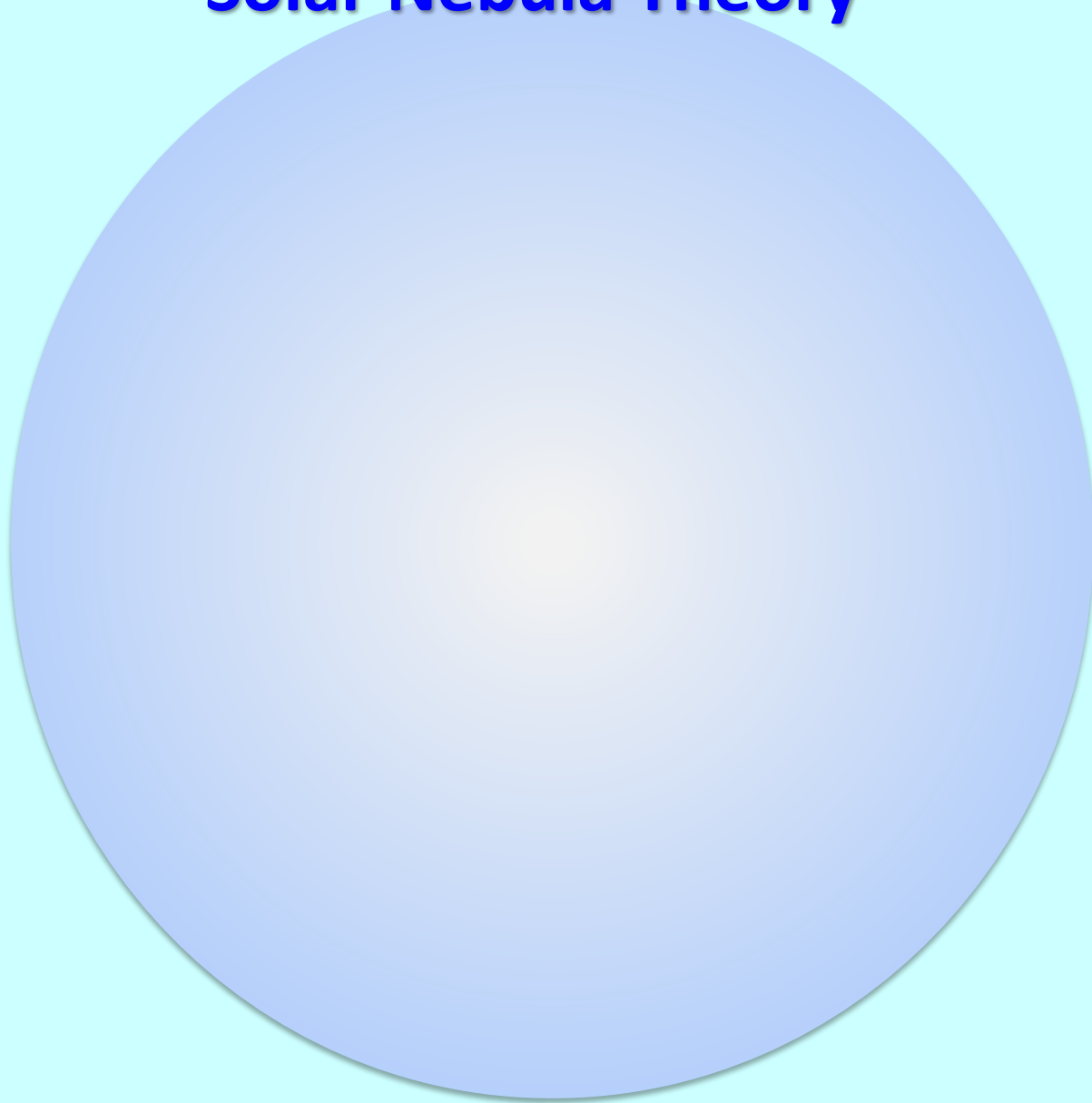
1. Sun and gas giants 74% H, 25% He 1% everything else.
Not rocky planets
2. All planets orbit in same plane: the ecliptic
3. All planets orbit sun in same direction and Sun rotates in that direction, too
4. Rocky planets are close in; gas giants far out
5. Debris throughout the ecliptic plane
6. Craters everywhere

Observations of Today's Solar System

1. Sun and gas giants 74% H, 25% He 1% everything else.
Not rocky planets
2. All planets orbit in same plane: the ecliptic
3. All planets orbit sun in same direction and Sun rotates in that direction, too
4. Rocky planets are close in; gas giants far out
5. Debris throughout the ecliptic plane
6. Craters everywhere
7. Oort Cloud

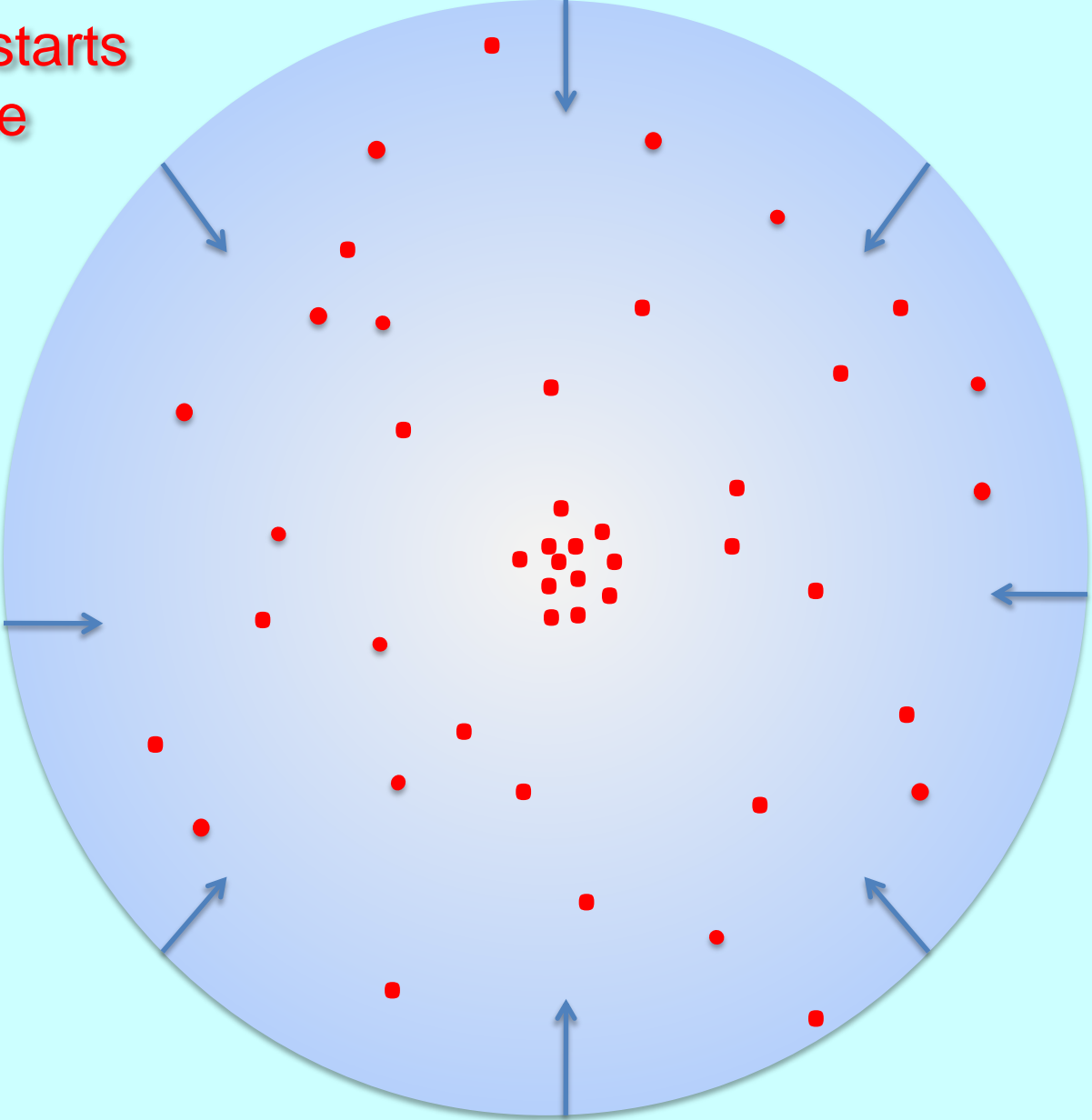
Solar Nebula Theory

Gas Ball

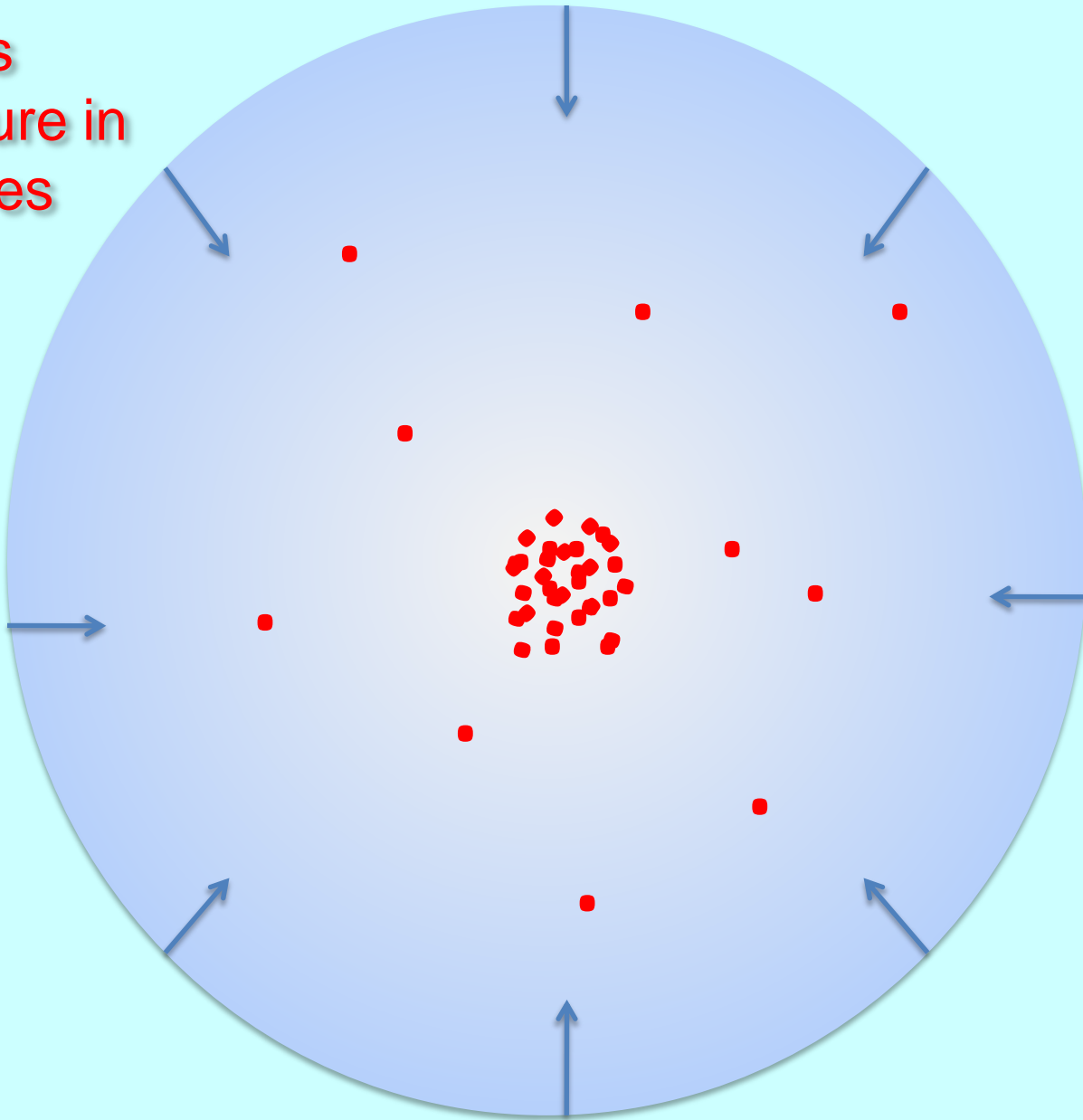


50,000 AU

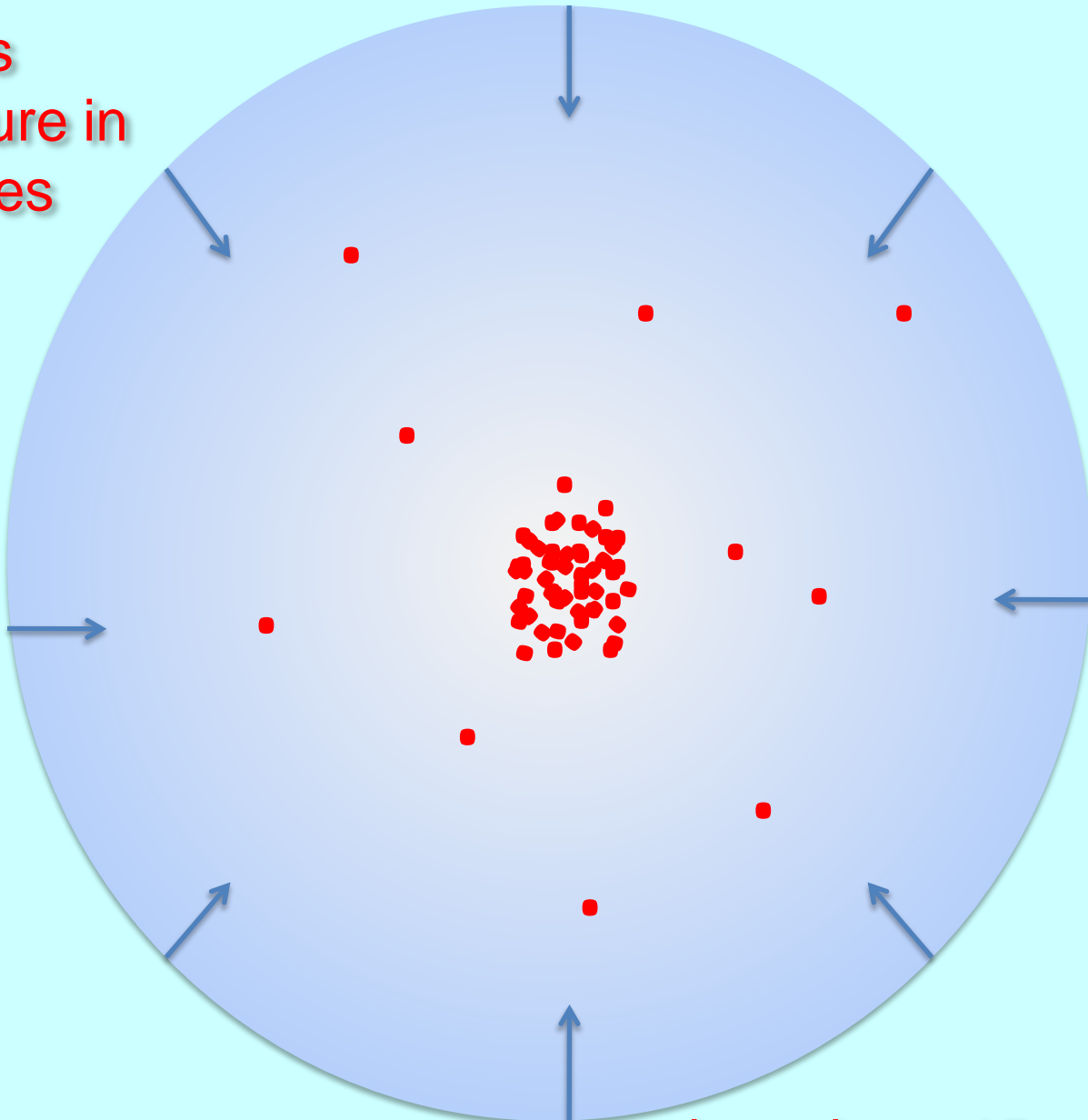
Gas Ball starts to collapse



Gas Ball's
temperature in
center rises

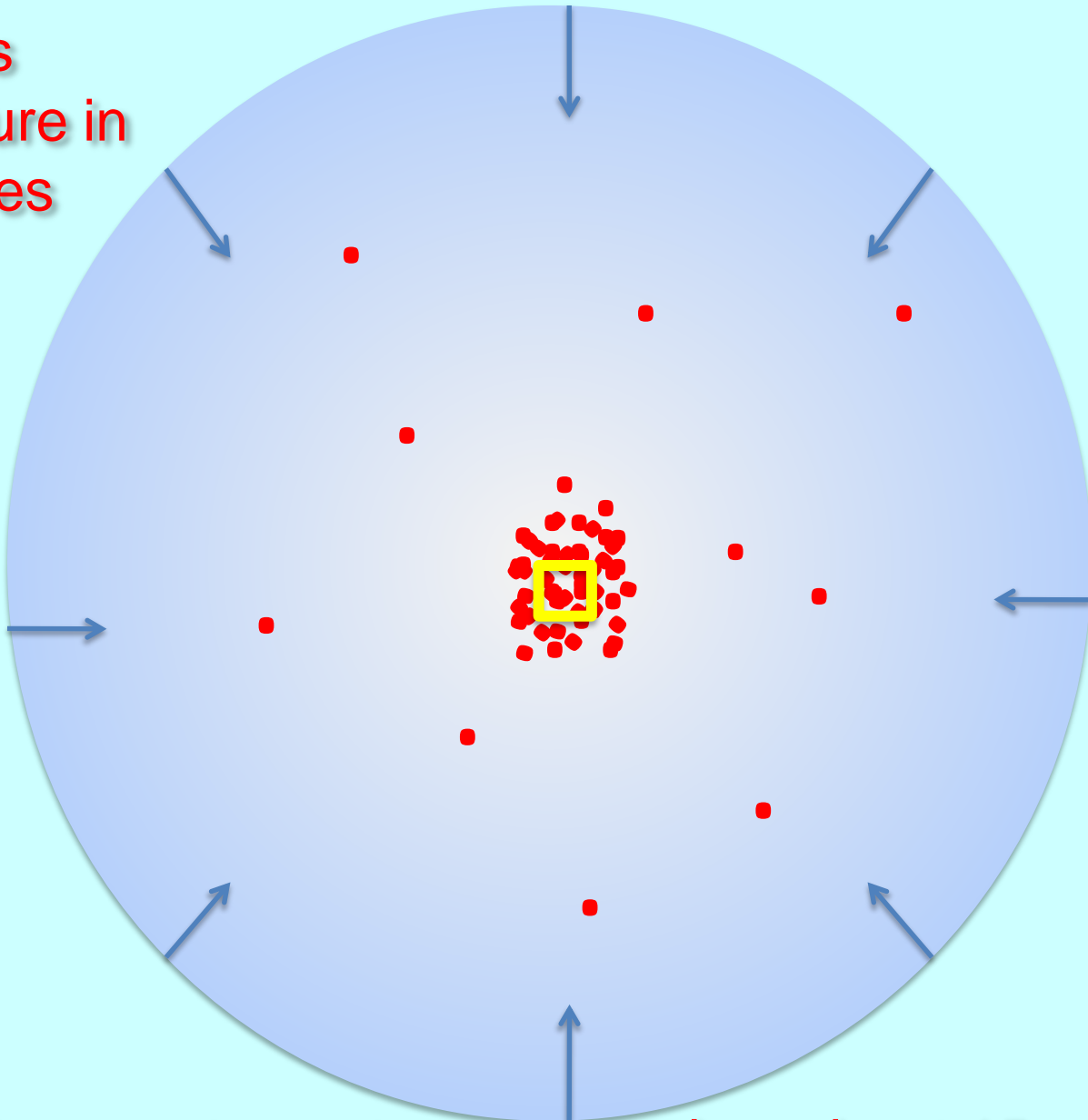


Gas Ball's
temperature in
center rises

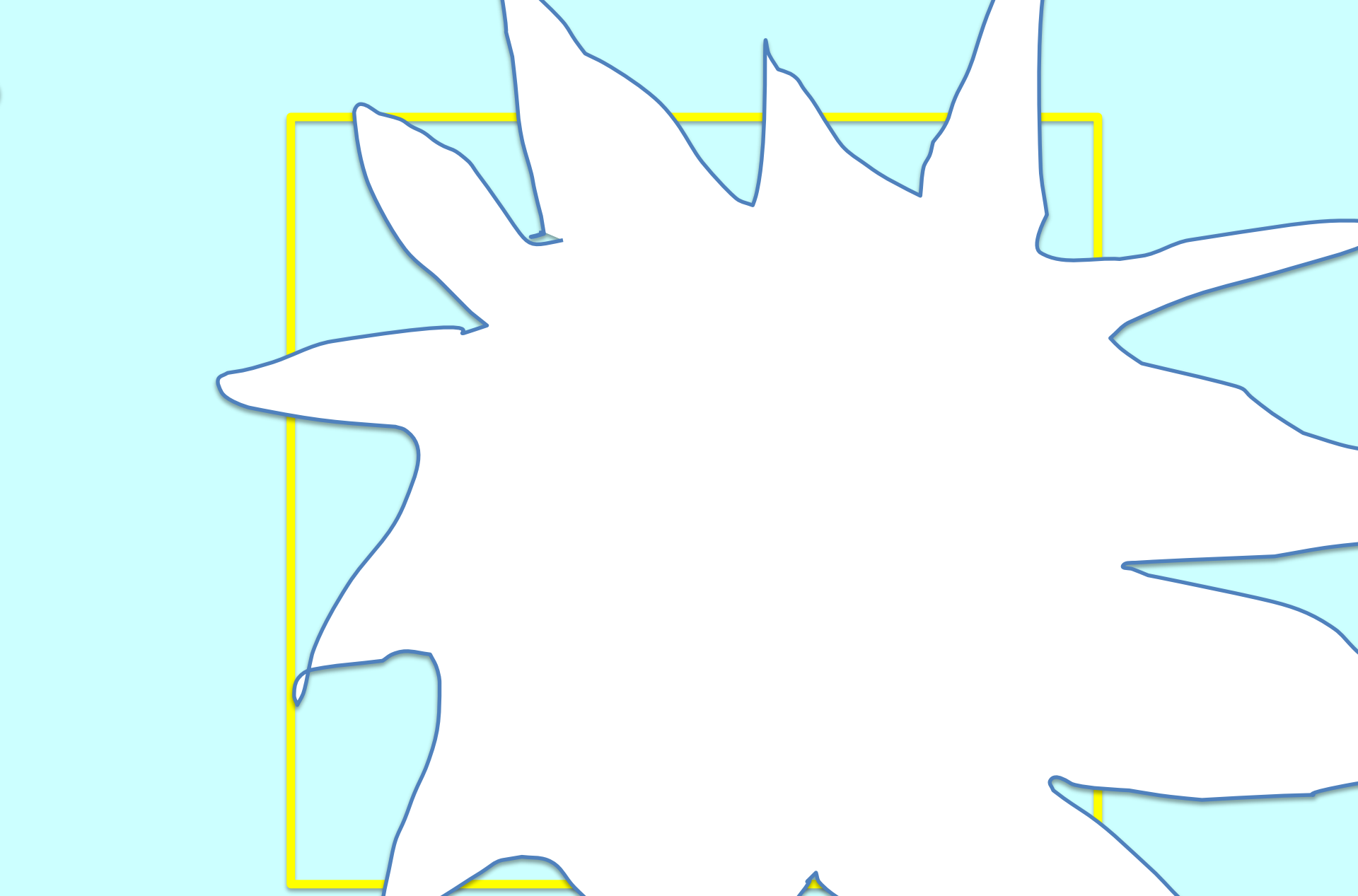


When temperature at center reaches about 15×10^6 K,
FUSION of H to He happens and A STAR IS BORN

Gas Ball's
temperature in
center rises

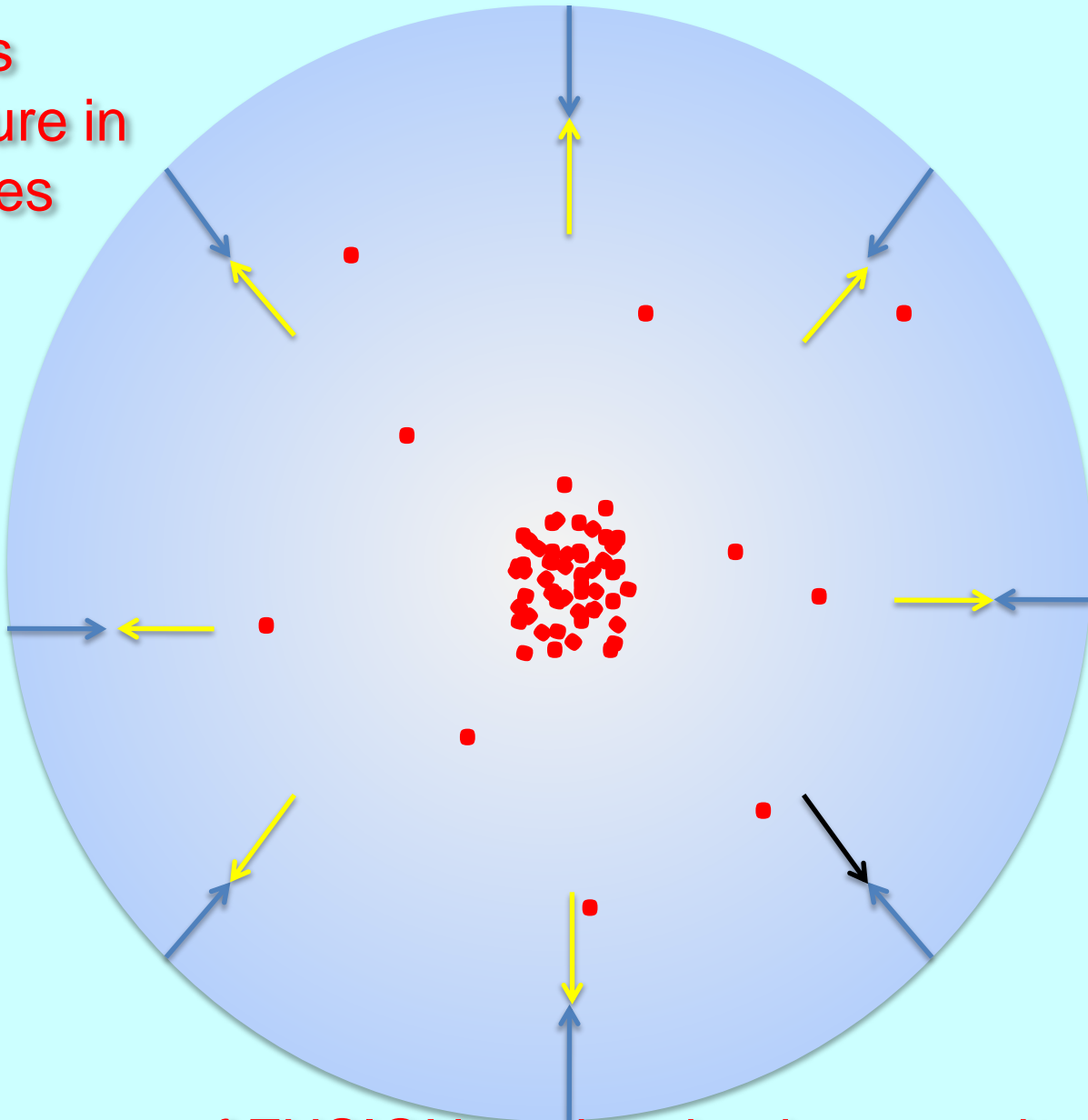


When temperature at center reaches about 15×10^6 K,
FUSION of H to He happens and A STAR IS BORN



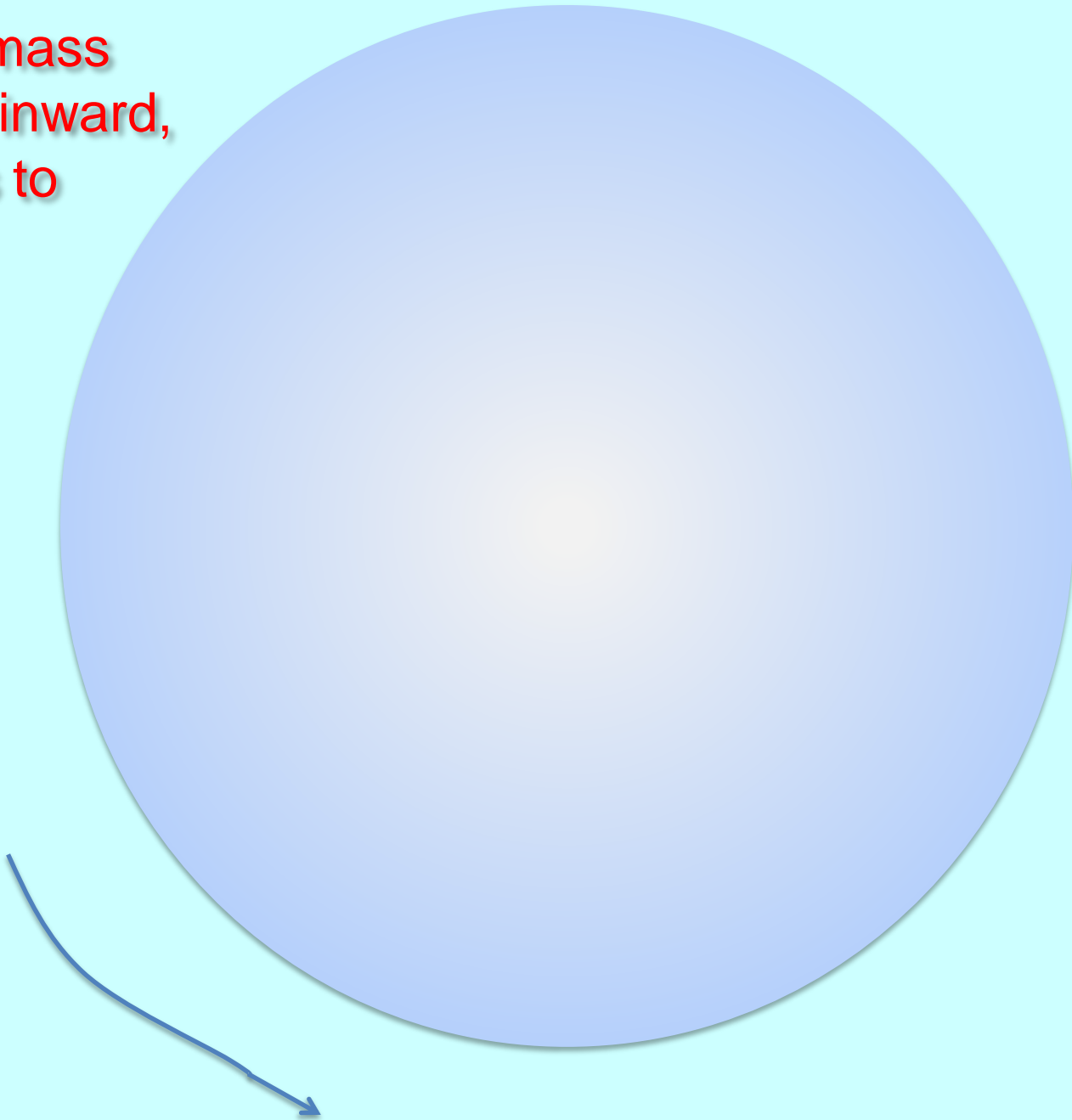
When temperature at center reaches 10^8 K,
FUSION of H to He happens and A STAR IS BORN

Gas Ball's
temperature in
center rises

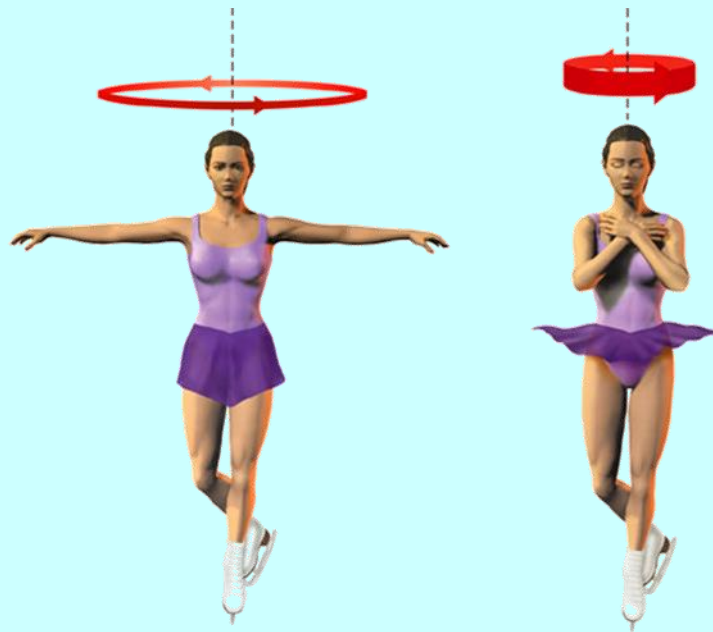


The energy of FUSION pushes back on gravity and the
collapse is stopped.

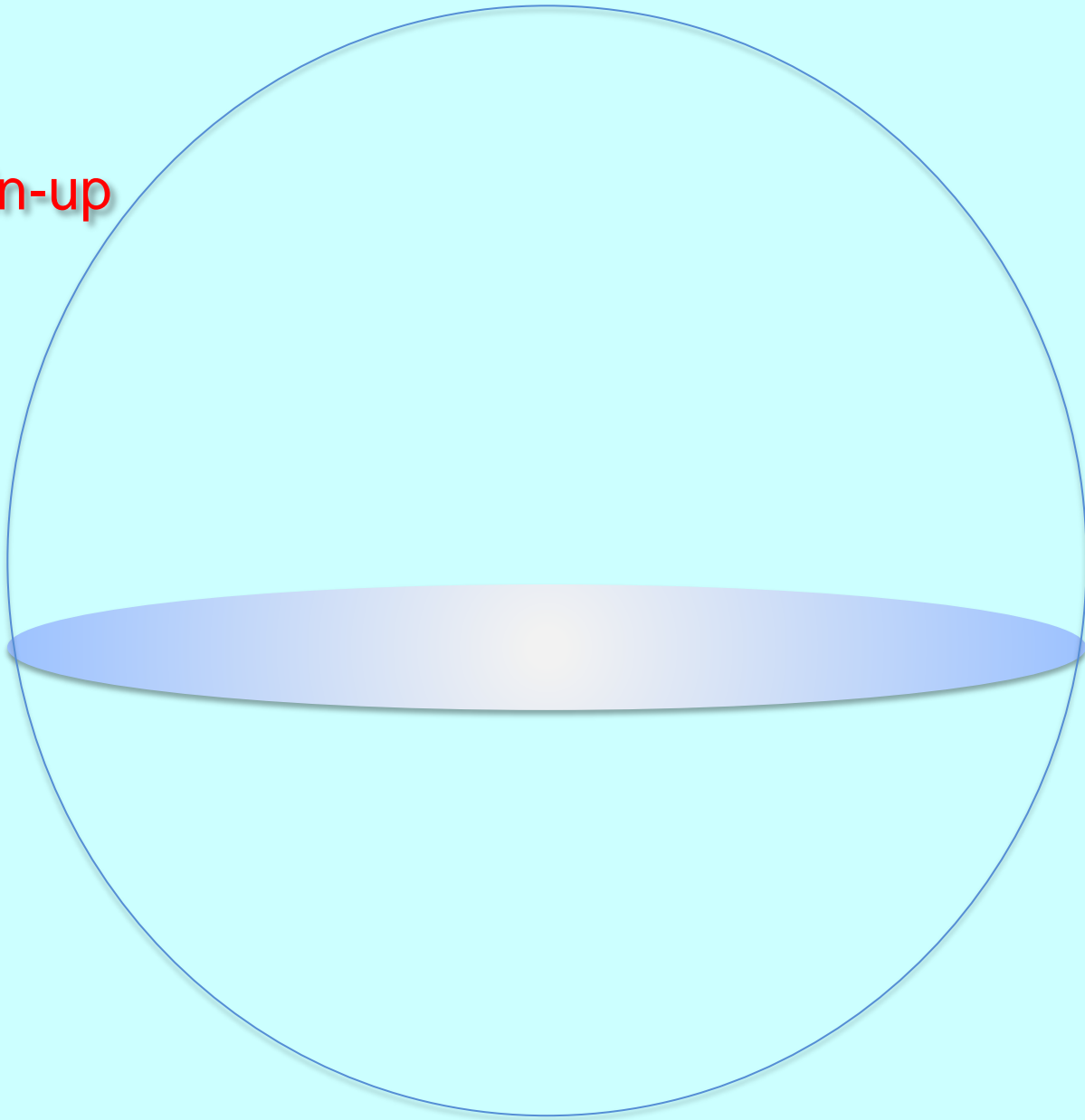
When mass
moves inward,
it starts to
rotate.



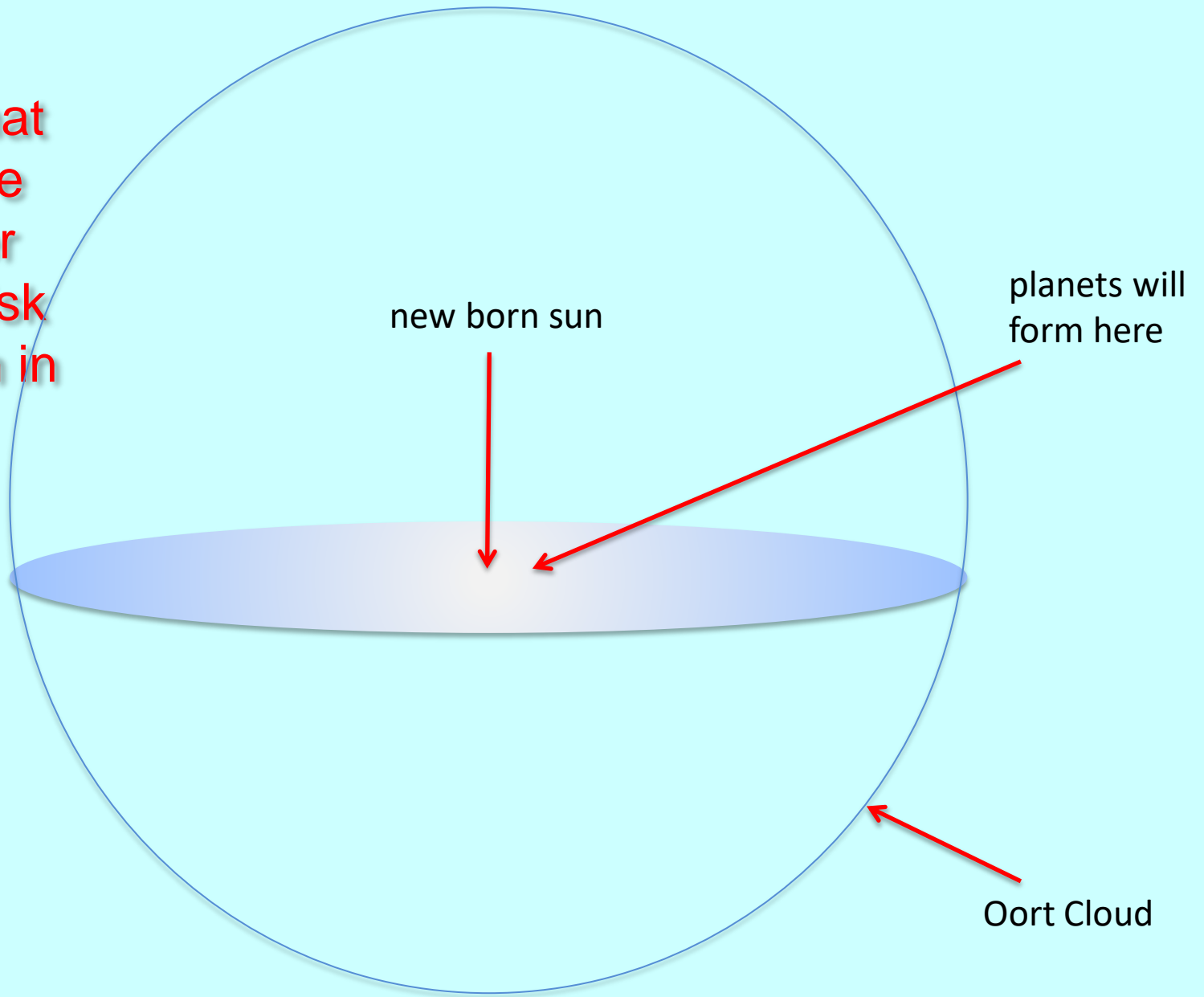
When a spinning object moves mass centrally, the object spins faster



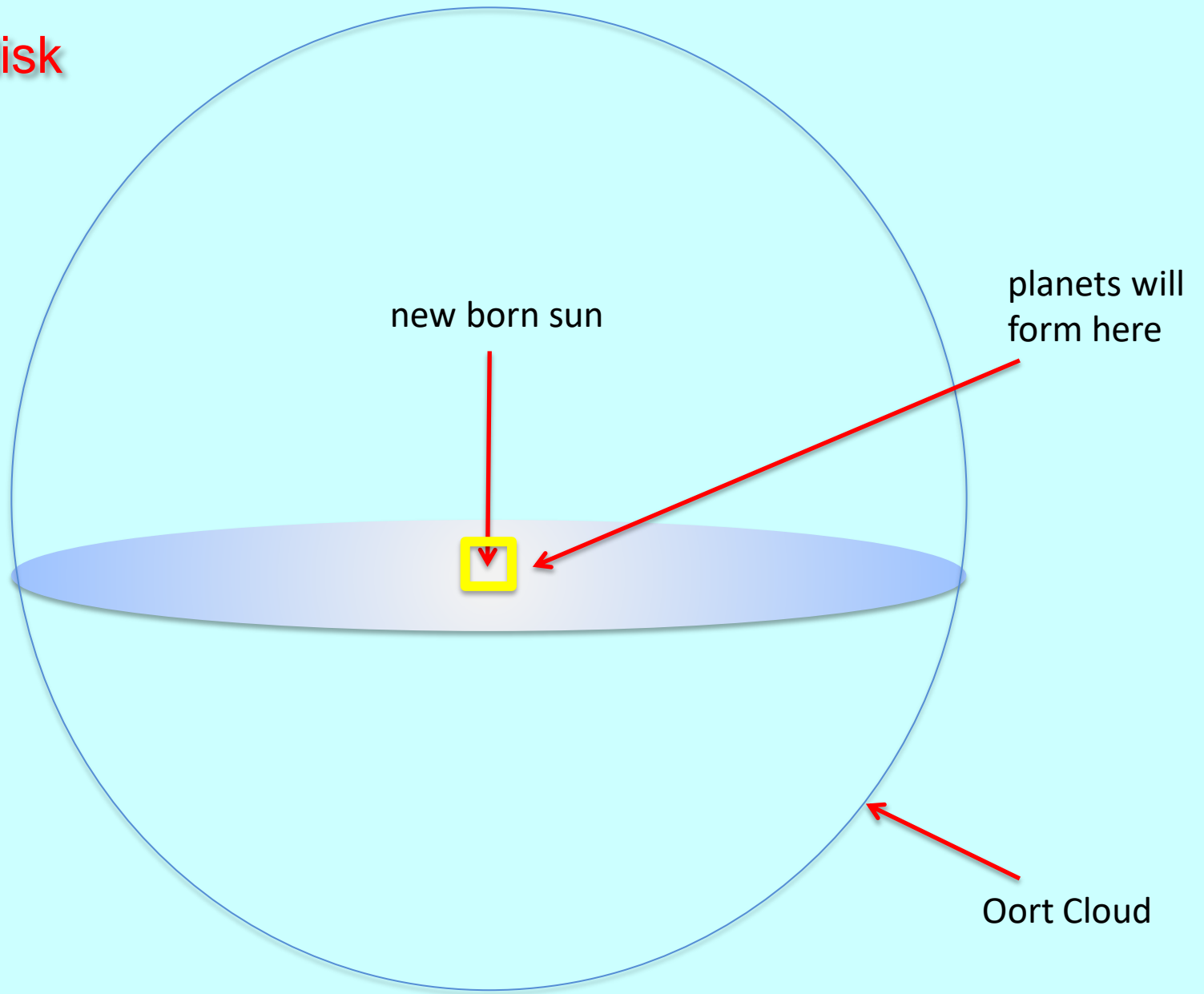
And like
making a
pizza, spin-up
flattens.

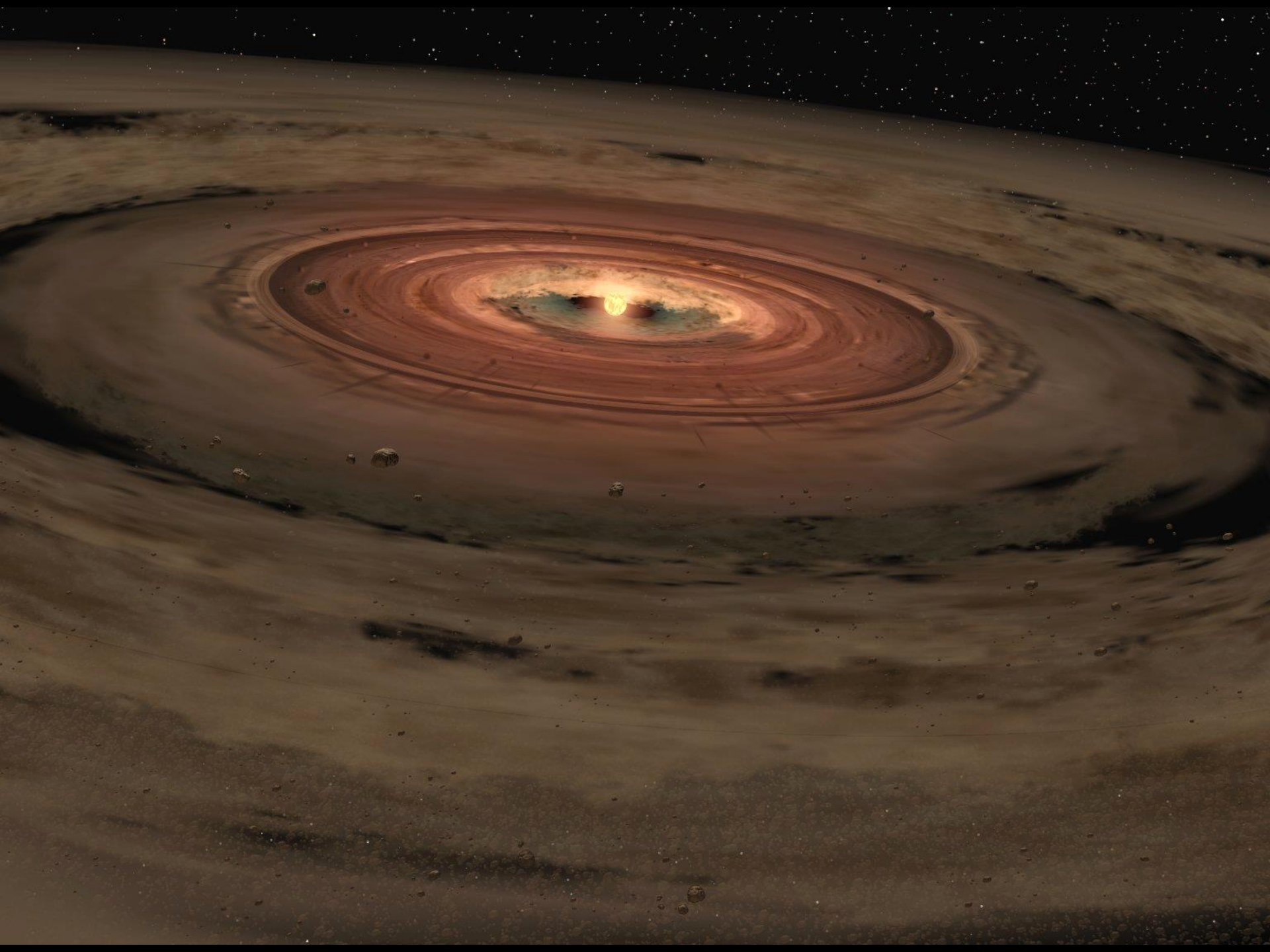


We are left with the remnants that did not move to the center and a flat disk with the sun in the middle.



Look at the
very inner disk





Planets build up by accretion:

colliding dust and gas stick together.





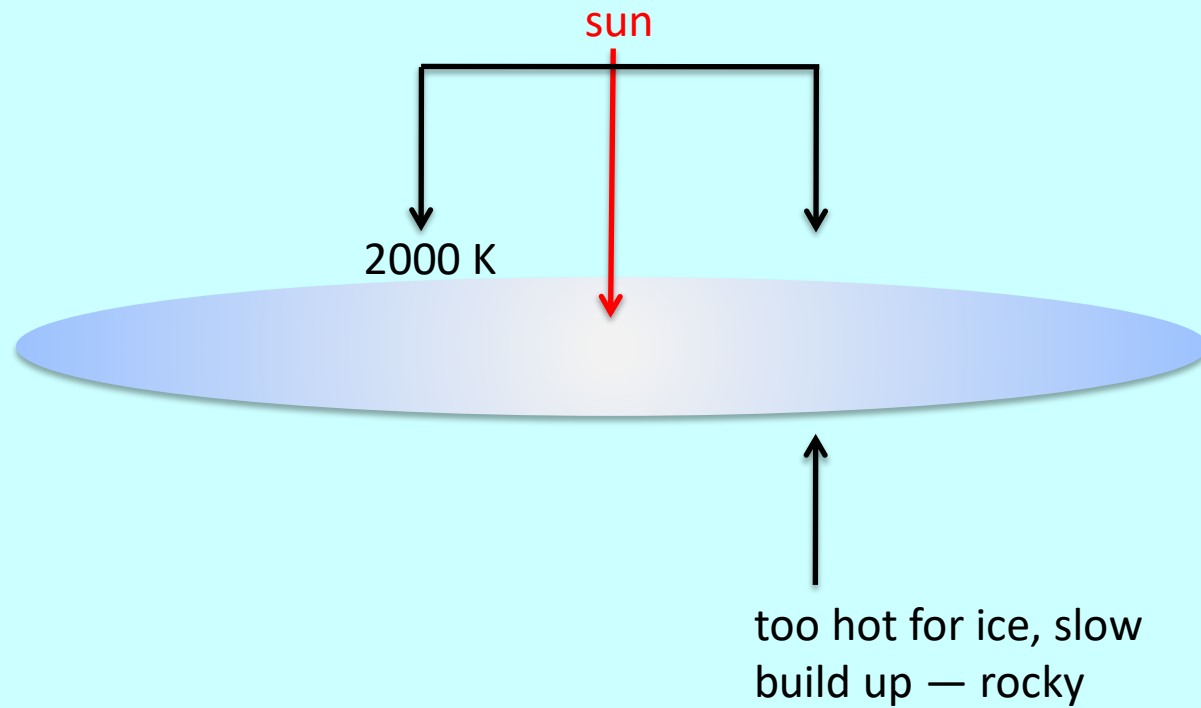
Illustration: NASA/JPL-Caltech

Computer models show that there were from 150 to 200 planets formed early on

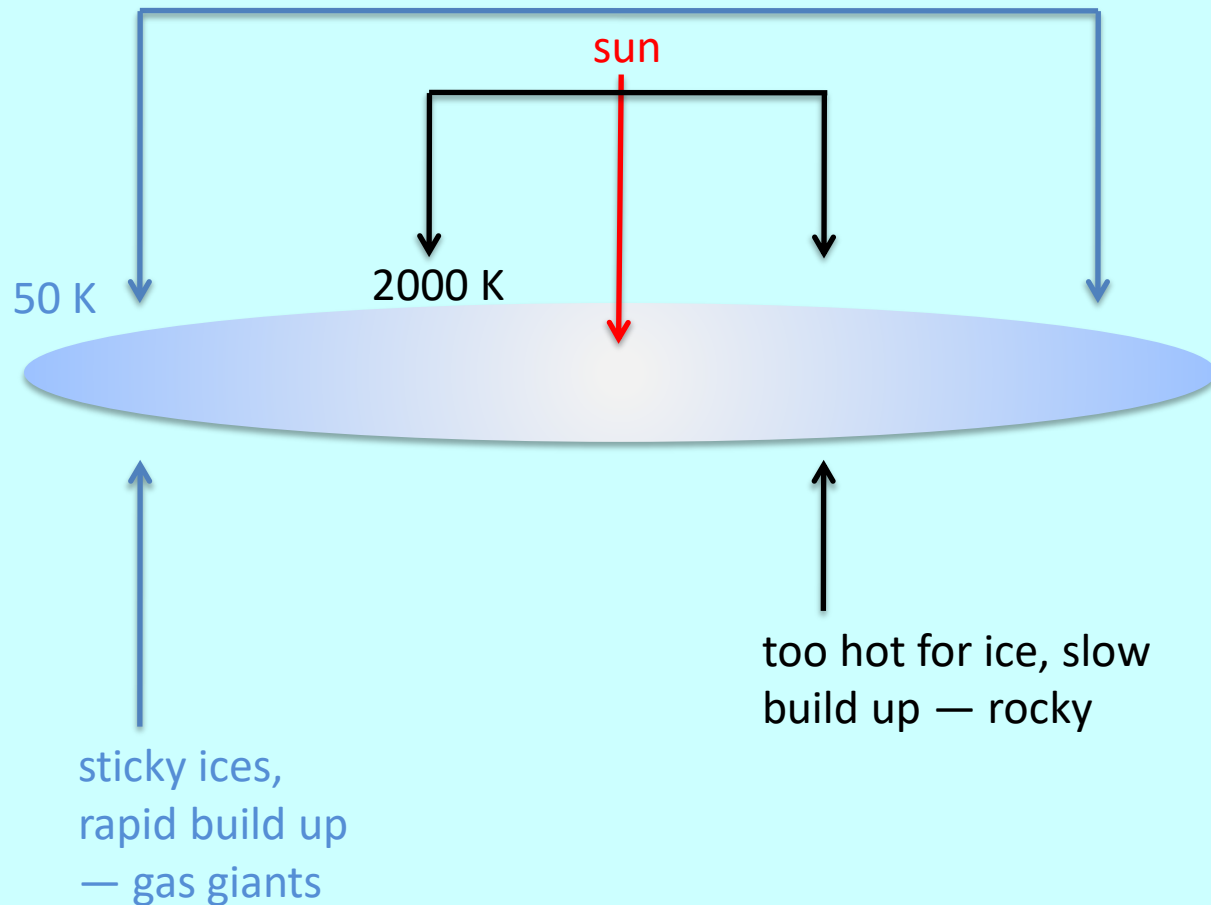


Once planets built up there were
one billion years of the Era of Bombardment

The rocky planets built up slowly in the inner region



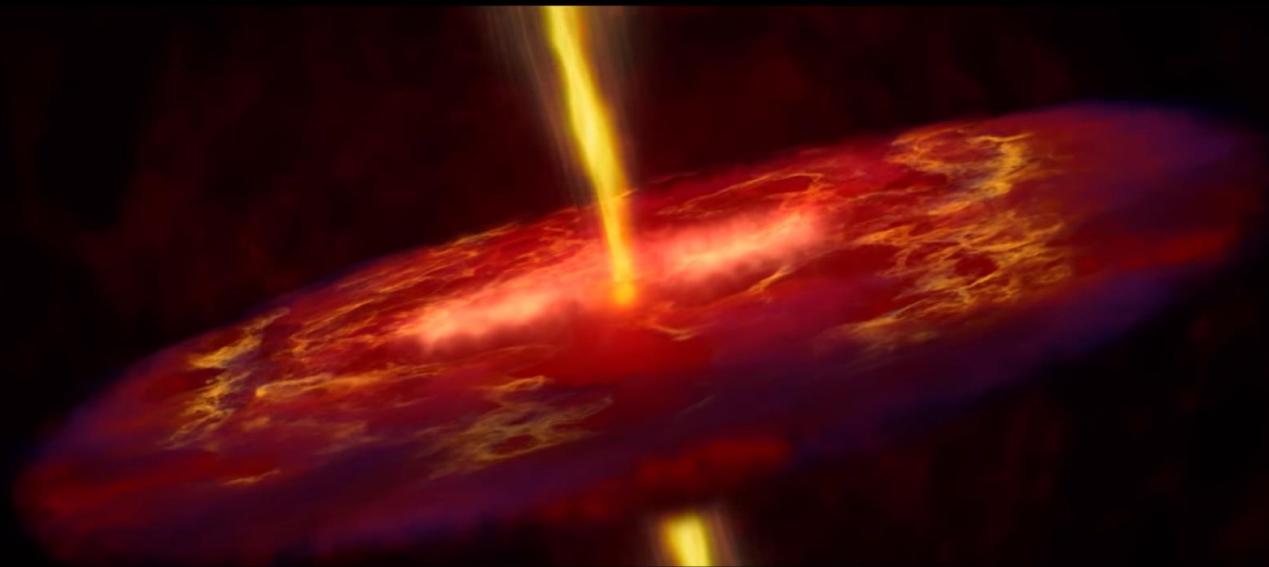
The rocky planets built up slowly in the inner region and large gas giants in the outer region



VIDEO: The Formation of the Solar System

<https://www.youtube.com/watch?v=x1QTc5YeO6w>

The Formation of the Solar System in 4K (Ultra HD)



In the geologic blink of an eye, 100,000 years,
gravity and angular momentum flatten the cloud

▶ ▶▶ 🔊 1:46 / 6:16

CC HD 🗉

TDC

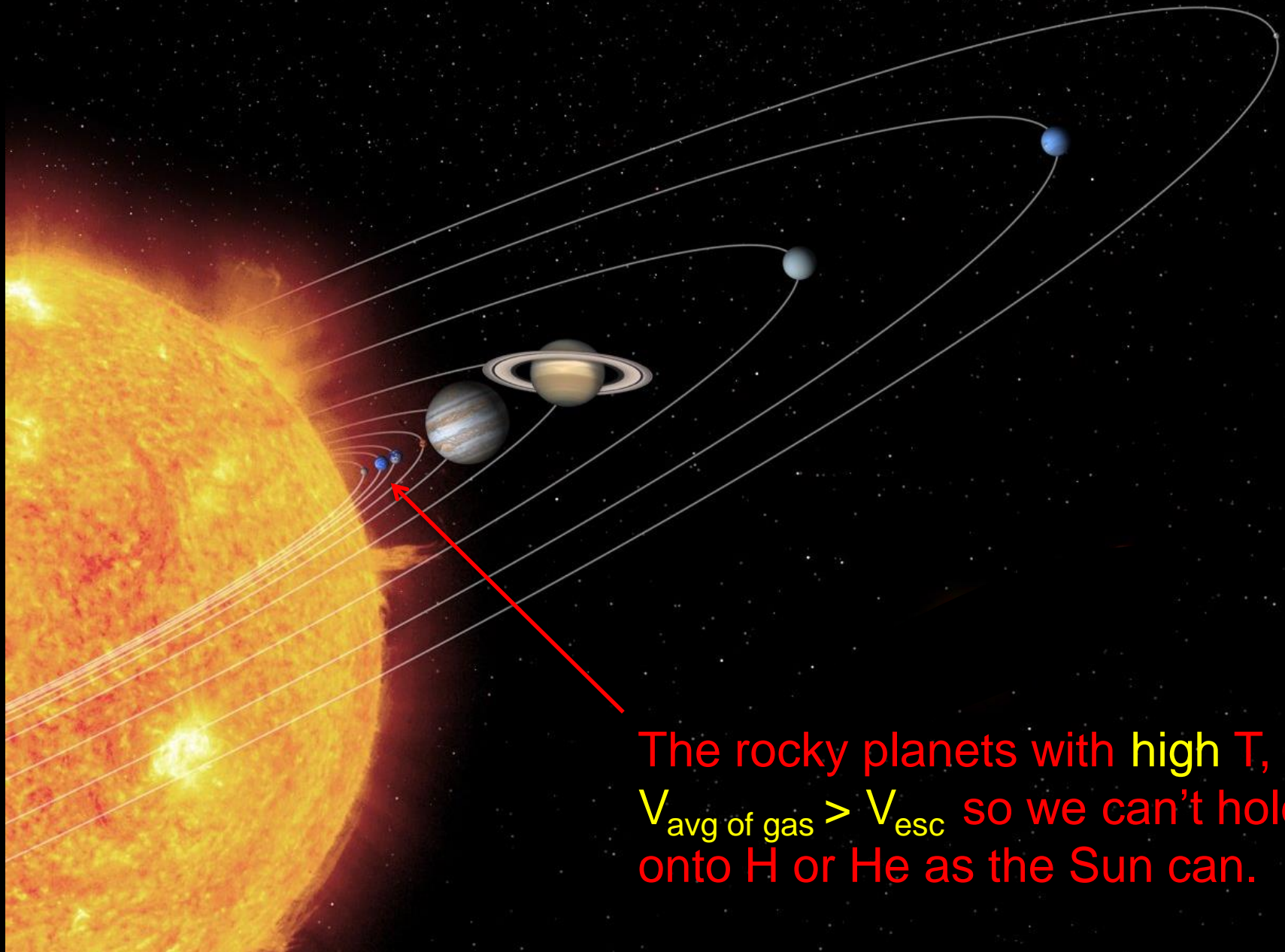
Why isn't the Earth made of mostly H gas?

Compare: V_{avg} with V_{esc}

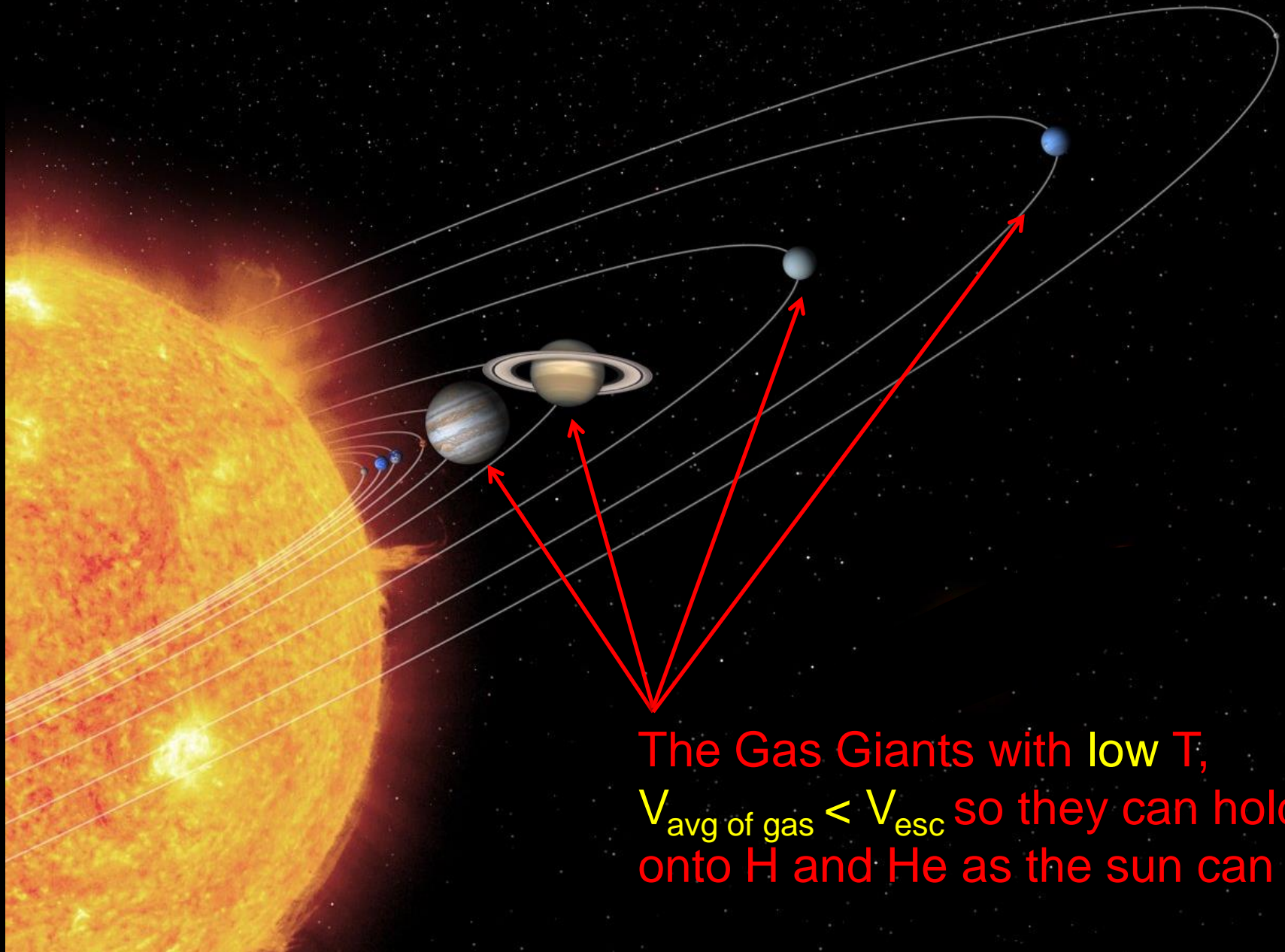
Why isn't the Earth made of mostly H gas?

Compare: V_{avg} with V_{esc}

$$V_{\text{avg H on Earth}} > V_{\text{esc Earth}}$$



The rocky planets with high T ,
 $V_{\text{avg of gas}} > V_{\text{esc}}$ so we can't hold
onto H or He as the Sun can.



The Gas Giants with low T,
 $V_{\text{avg of gas}} < V_{\text{esc}}$ so they can hold
onto H and He as the sun can

