Are we alone in the Universe?

Class 3.

Emrah Kalemci

ekalemci@sabanciuniv.edu

Office: FENS G018

Sabancı University, FENS

Sabancı Üniversitesi LİSE YAZ OKULU

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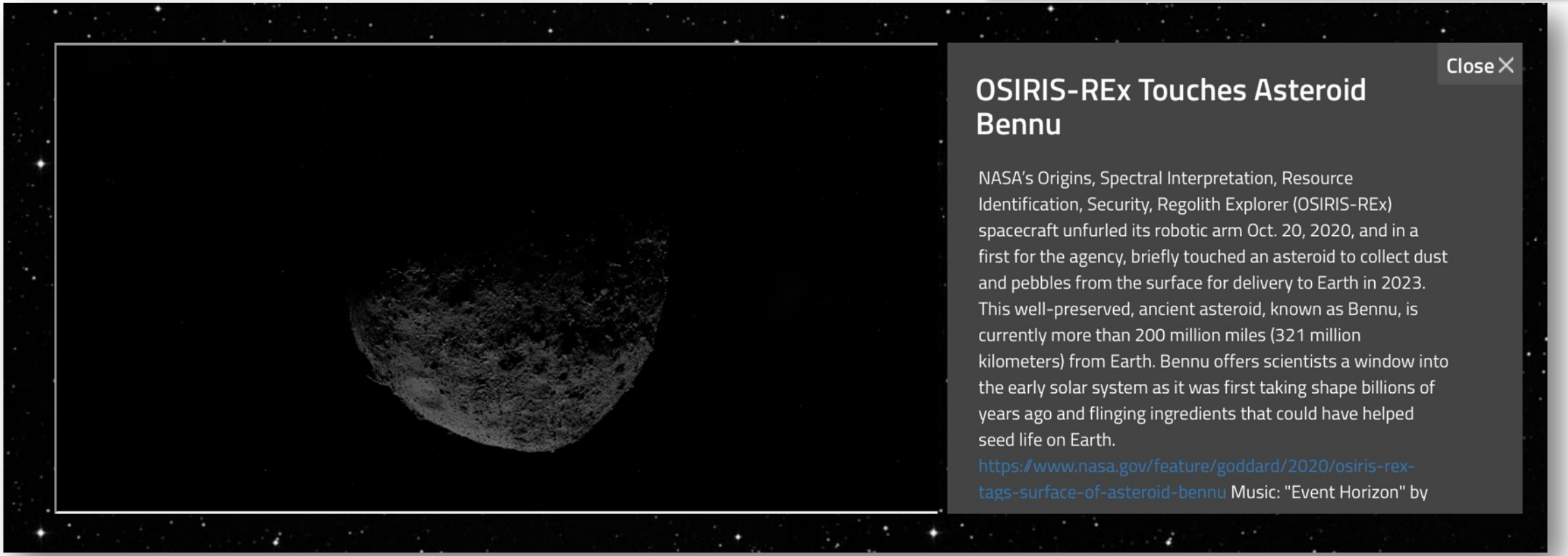
Learning from Asteroid *Bennu*

https://solarsystem.nasa.gov/news/517/why-bennu-10-reasons/

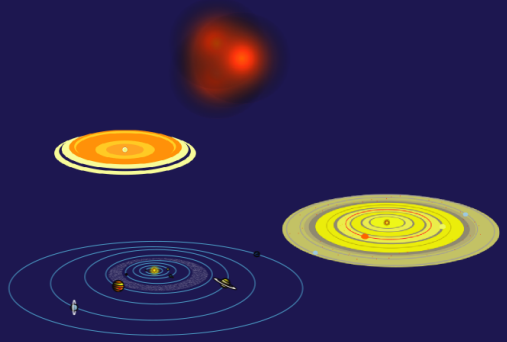


https://www.nasa.gov/content/osiris-rex-videos

Our Map:

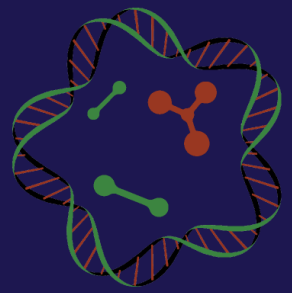
What are there in the Universe?
Scales involved in describing Universe

Our planet and Solar system



How did the Solar system form?
Is it unique?

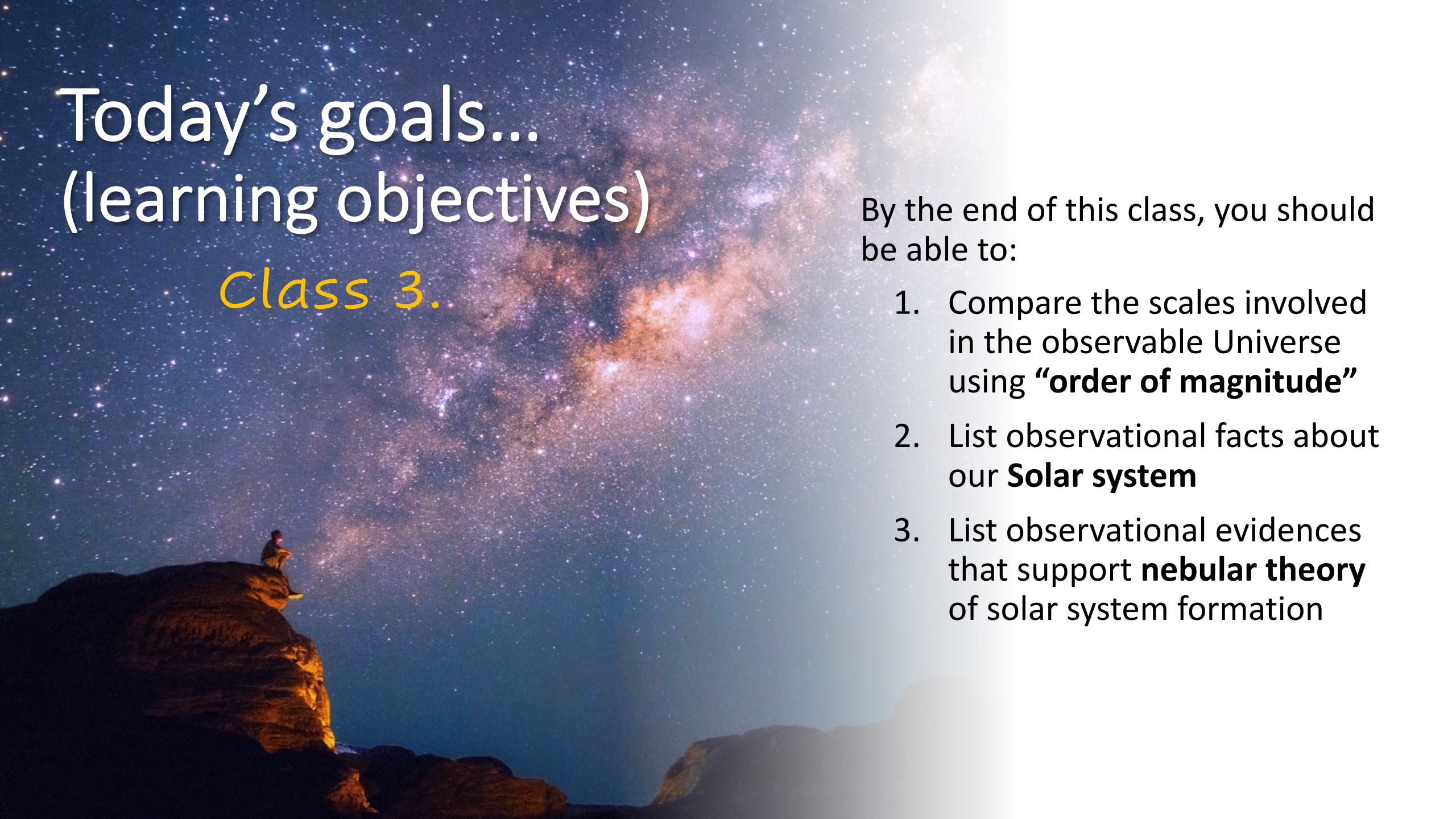
Are we alone in the universe?



What is life?
How did life on Earth begin? Building blocks of life, first form of life on Earth.

How can we look for ET life?
Atom and EM spectrum.

What form of life would you look for and how? Possibility of life on other planets.



Today's goals… (learning objectives)

Class 3.

By the end of this class, you should be able to:

1. Compare the scales involved in the observable Universe using **"order of magnitude"**
2. List observational facts about our **Solar system**
3. List observational evidences that support **nebular theory** of solar system formation

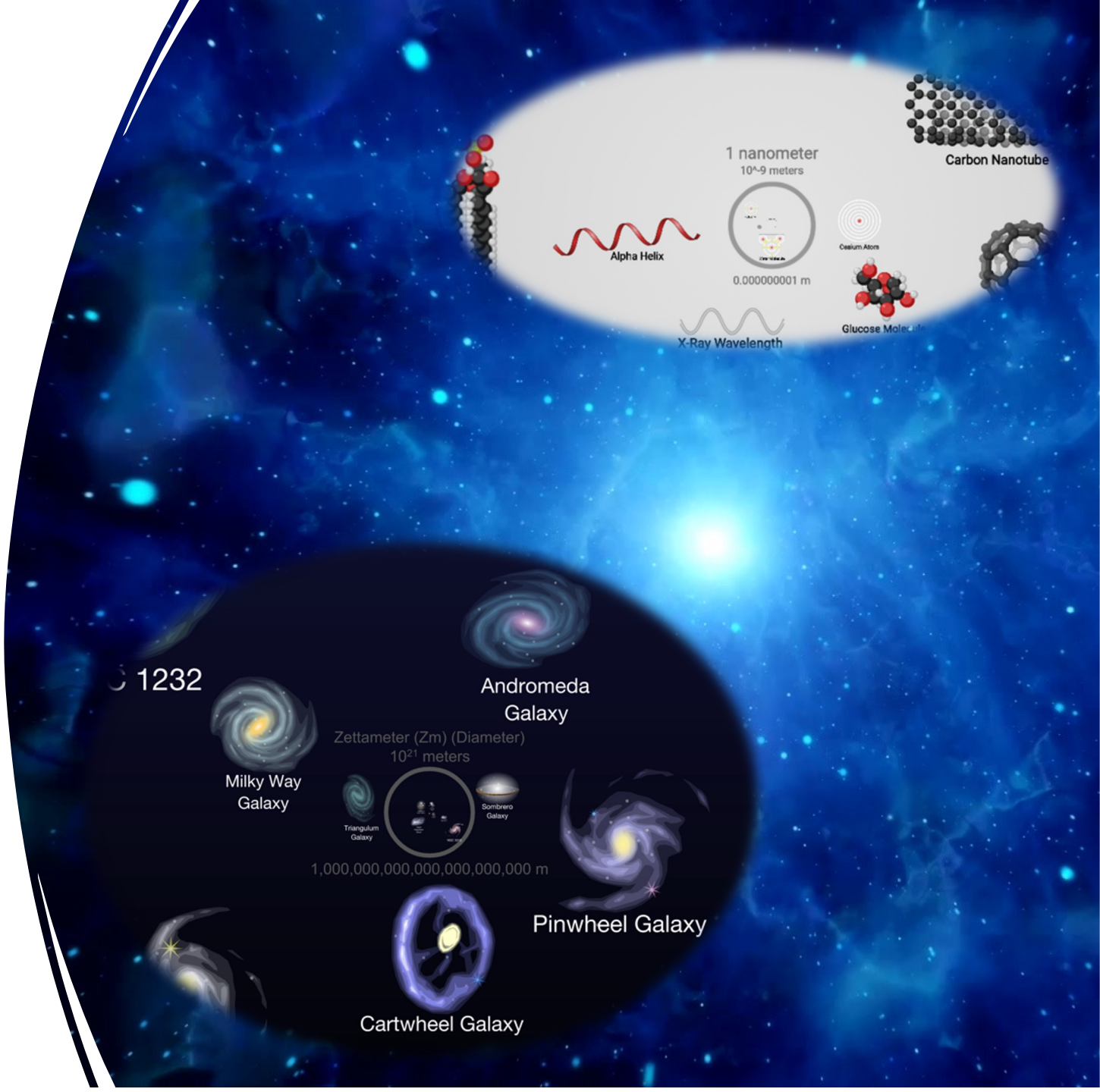
Scale of the Universe

Questions:

What are some of the

- SMALLEST observable objects?
- LARGEST observable objects

Go to: https://htwins.net/scale2/
Or Google “scale of the universe 2”



Scales, Units, Scientific Notation

Scientific notation Examples:

$1000 = 1 \times 10^3 = 1E3$	$5467 = 5.467 \times 10^3 = 5.467E3$
$1/1000 = 0.001 = 1 \times 10^{-3} = 1E{-}3$	$0.00064 = 6.4 \times 10^{-4} = 6.4E{-}4$

More Examples:

- Electron mass = $9.10938356 \times 10^{-31}$ kg ≈ 9.11E−31 kg
- Sun-Earth Distance = 149597870700 m = $1.496 \times \mathbf{10^{11}}$ m = 1.496E11 m
- The size of Solar system ~ $\mathbf{10^{14}}$ m = 1E14 m (Distance from Sedna to the Sun)
- The diameter of the Milky Way Galaxy ~ $\mathbf{10^{21}}$ m = 1E21

→ The difference in "**order of magnitude**" between the size of our Galaxy and the Solar system is 21 – 14 = 7. → the Galaxy is larger than the Solar system by a factor of 10^7!!

= Powers of 10

Assignment

What is the order of magnitude difference between:

1. the size of the Earth and the size of the Sun?
2. the size of an electron and a proton?

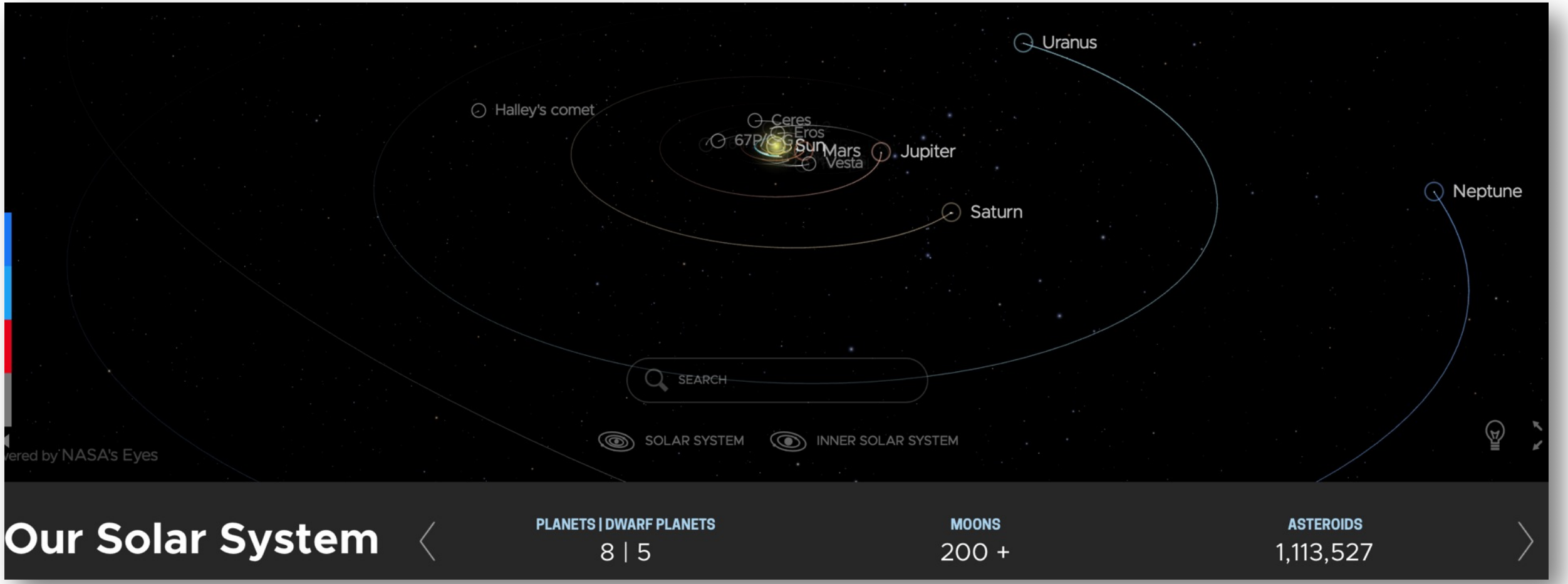
Use the Scale of the Universe app to answer the above questions.

When you click on an object in the app, you can see more information about the object.

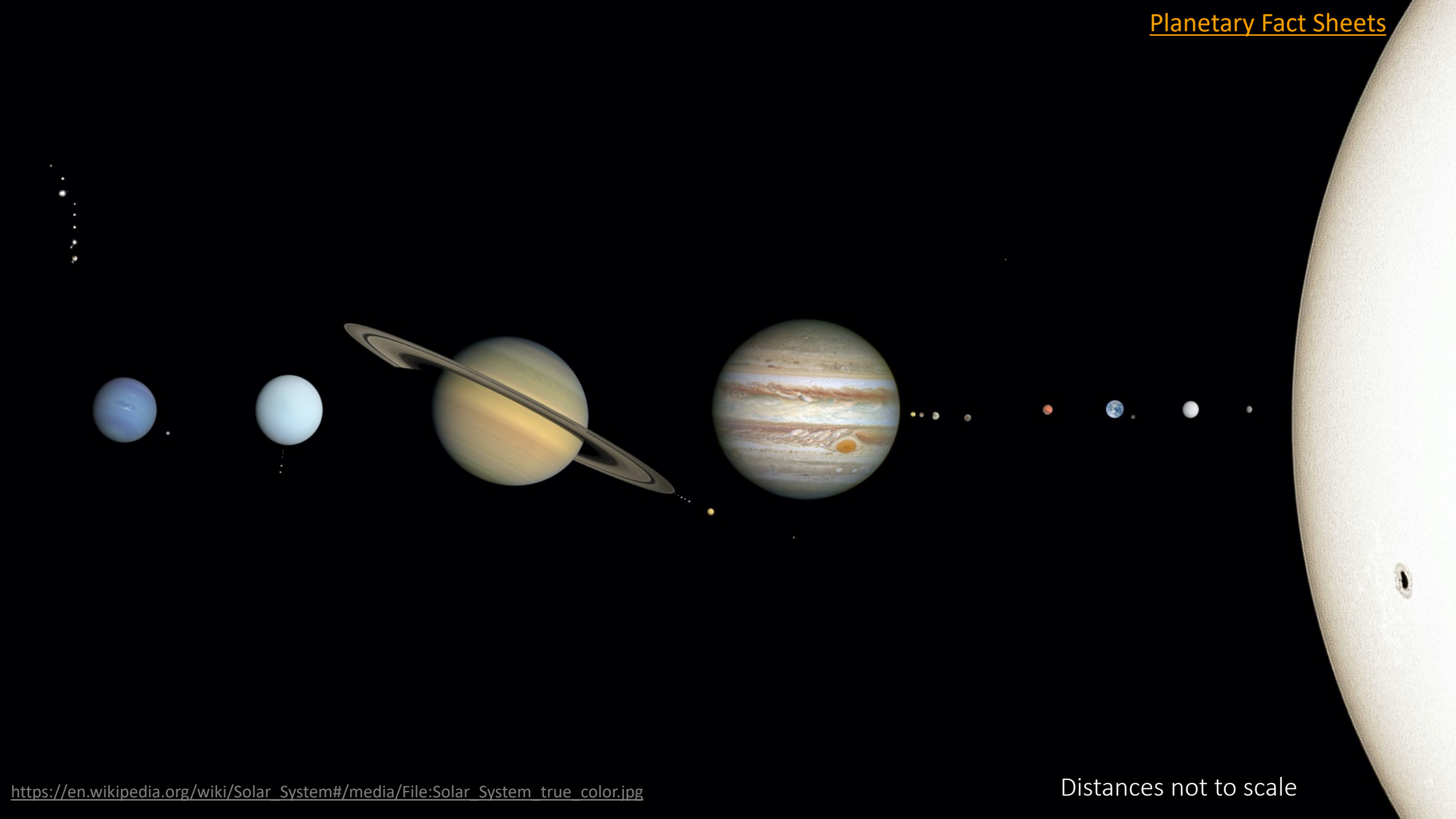
All assignments are in the web page:
http://myweb.sabanciuniv.edu/ekalemci/arewealone/

Solar System

https://solarsystem.nasa.gov/solar-system/our-solar-system/overview/



Planetary Fact Sheets



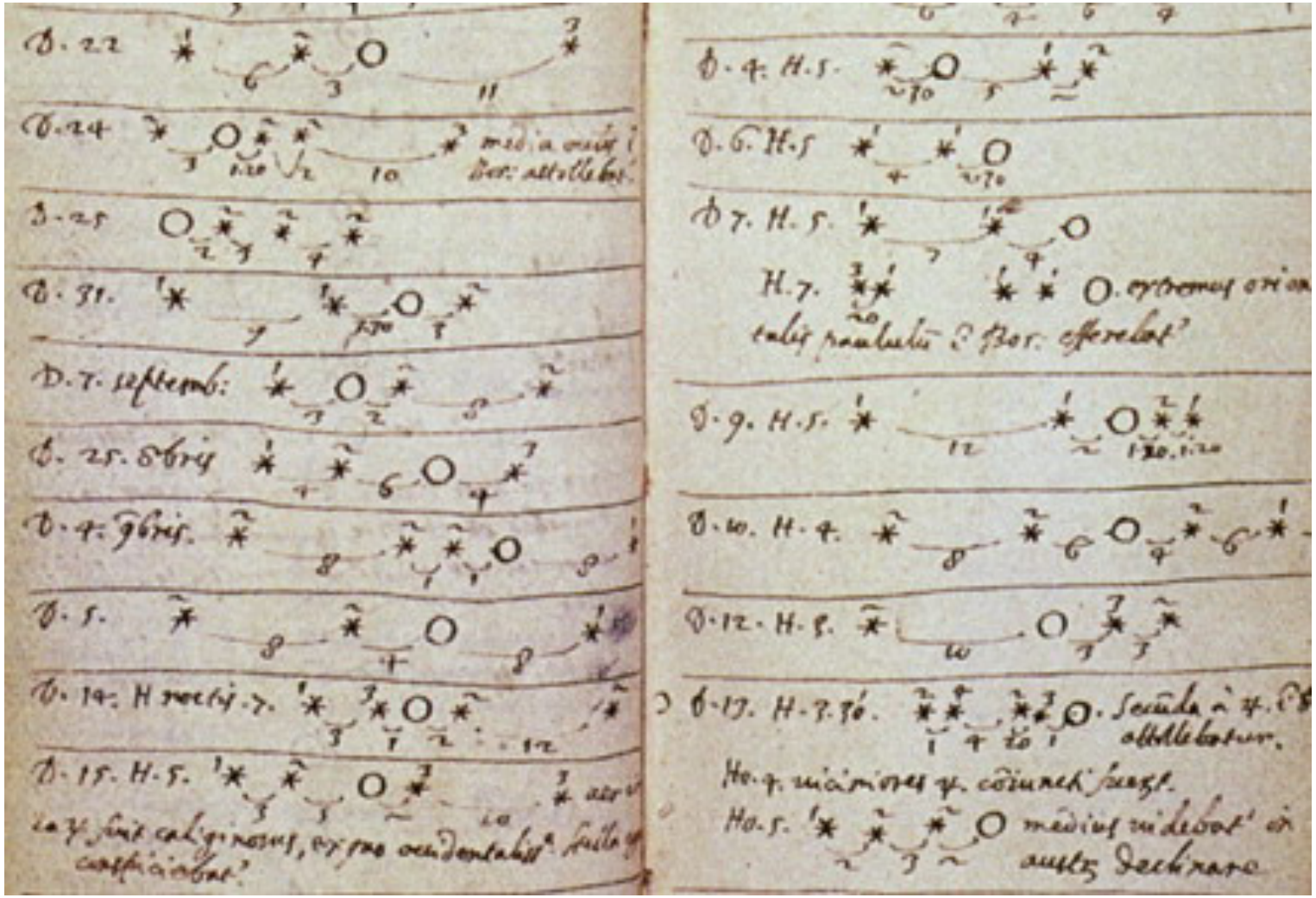
https://en.wikipedia.org/wiki/Solar_System#/media/File:Solar_System_true_color.jpg

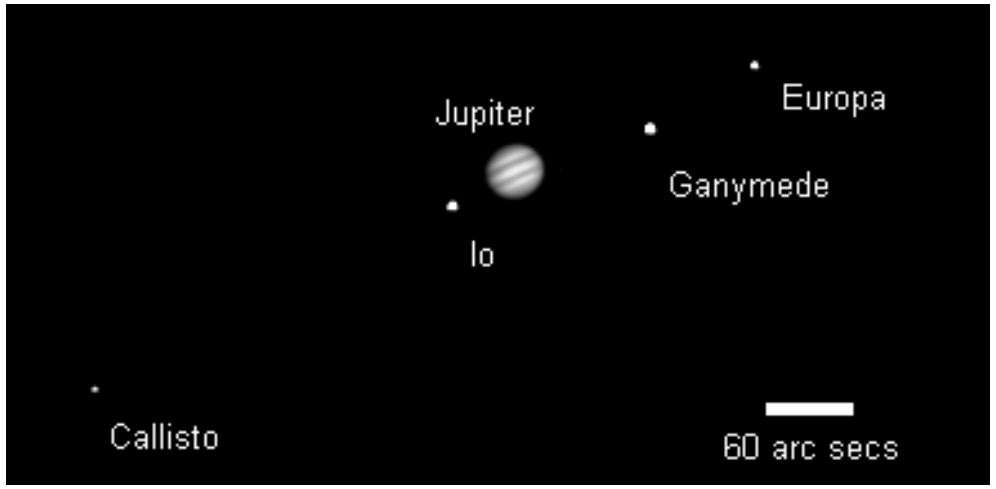
Distances not to scale

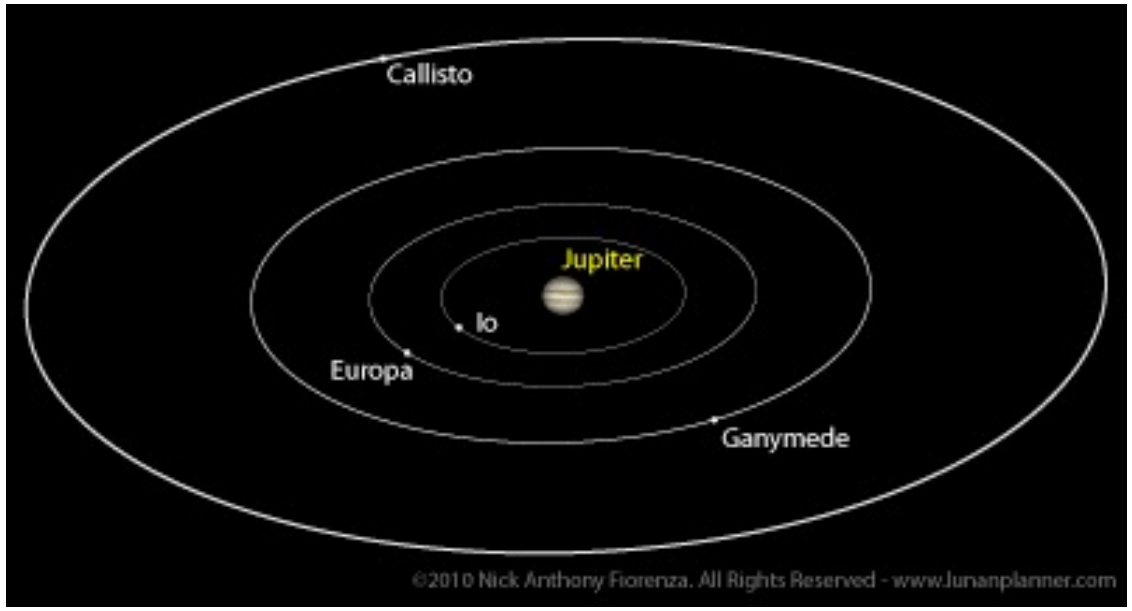
How would you describe the motions?

Observations: What do we see?

Galileo's observation notes




Jupiter
Europa
Ganymede
Io
Callisto
60 arc secs


Callisto
Jupiter
Io
Europa
Ganymede
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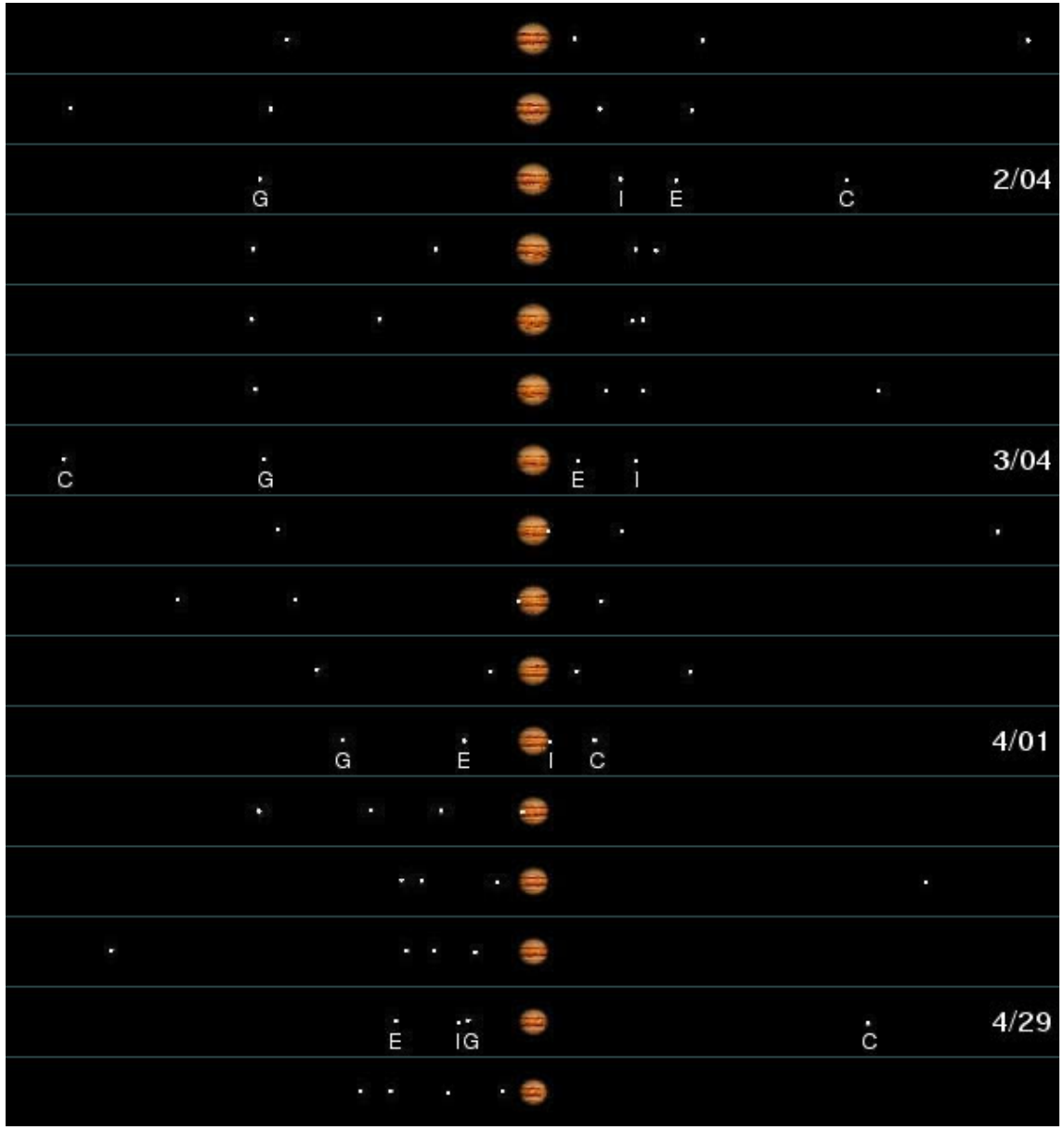
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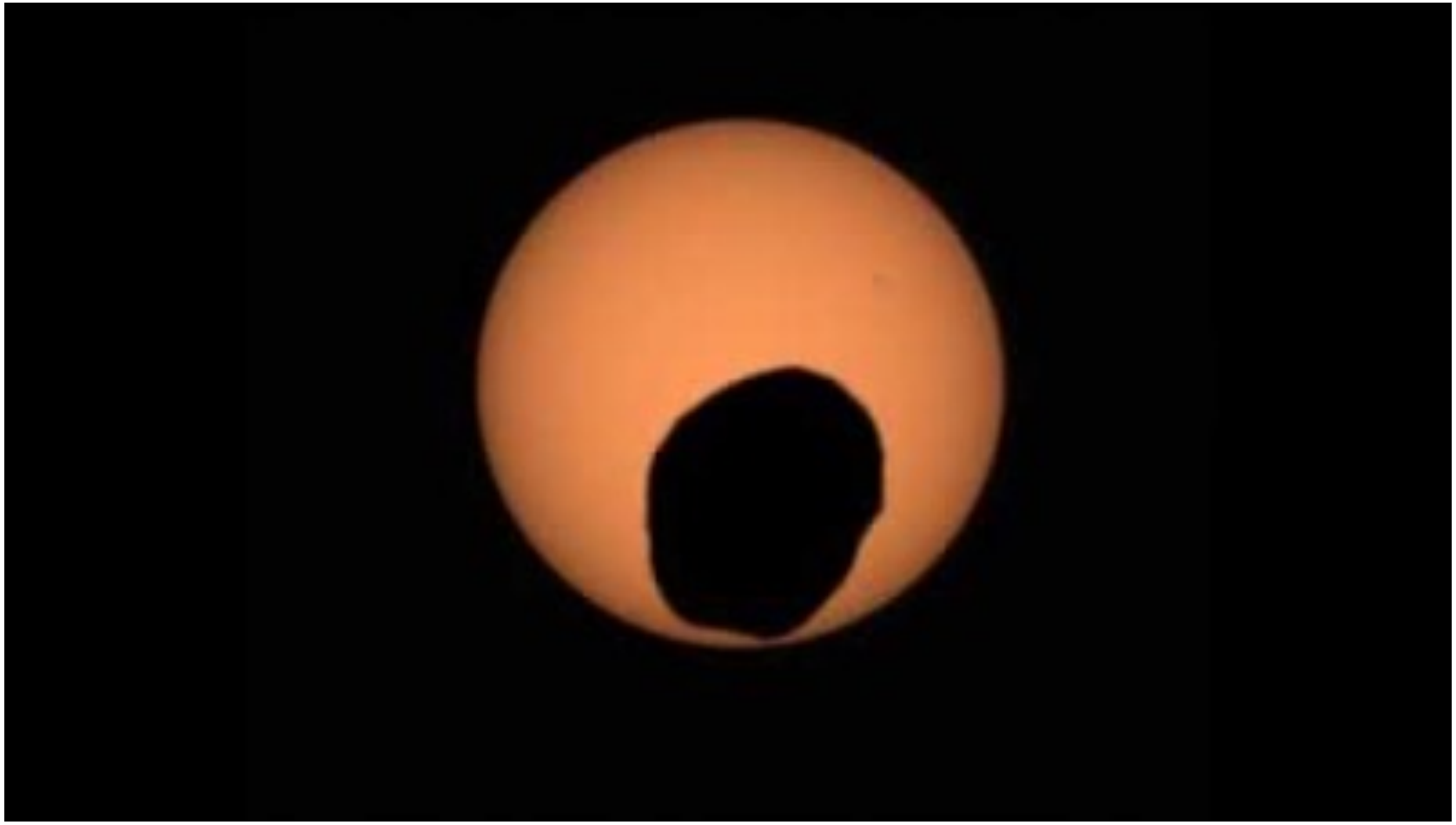
Solar eclipse on Mars

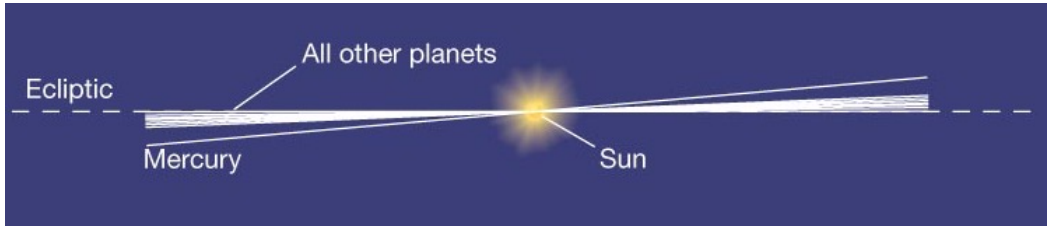
April 22, 2022

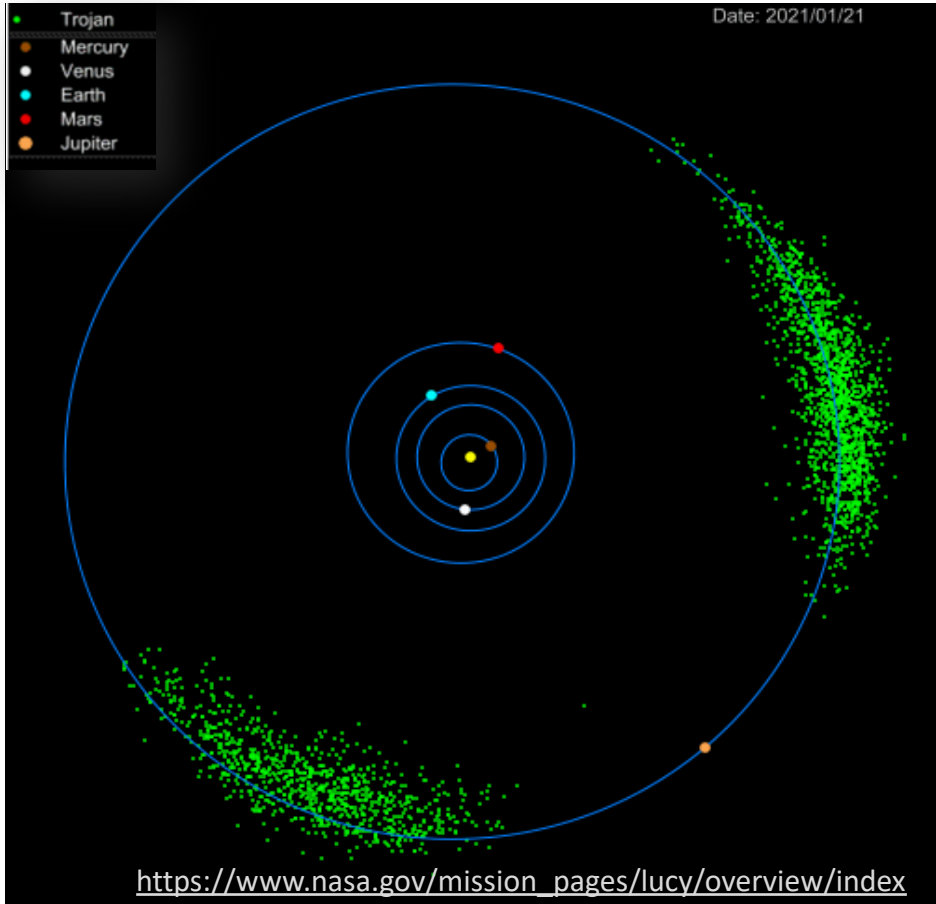


https://mars.nasa.gov/mars2020/multimedia/videos/?v=509

Observations: what we see in our Solar system

1. The Sun and all planets lie along in the disk
   (See https://solarsystem.nasa.gov)
2. All planets orbit in the same direction as the rotation direction of the Sun at the center
3. Most planets and even their moons also spinning in the same direction as the Sun.
4. Most planet orbits being close to circles
5. There are two types of planets:
   - small, rocky **terrestrial planets inside**
   - large, hydrogen-rich **gaseous planets outside**
6. Icy comets exist outside





https://www.nasa.gov/mission_pages/lucy/overview/index

Lucy mission: http://lucy.swri.edu/mission/Overview.html

Nebular theory of Solar system formation

How did our solar system come to be?

National Aeronautics and Space Administration

It all began about 4.6 billion years ago in a wispy cloud of gas and dust.

At some point, part of the cloud collapsed in on itself—possibly because the shockwave of a nearby supernova explosion caused it to compress.

The result: a flat spinning disk of dust and gas.

4.6 Billion Years Ago

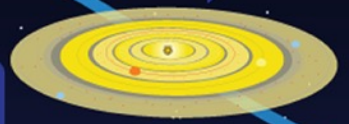
When enough material collected at this disk's center, nuclear fusion began. Our sun was born. It gobbled up 99.8% of all the material.

These clumps became planets, dwarf planets, asteroids, comets, and moons.

This cloud was a small part of a much bigger cloud.

Nuclear fusion occurs when hydrogen atoms fuse into helium.

The material left behind by the sun clumped together into bigger and bigger pieces.



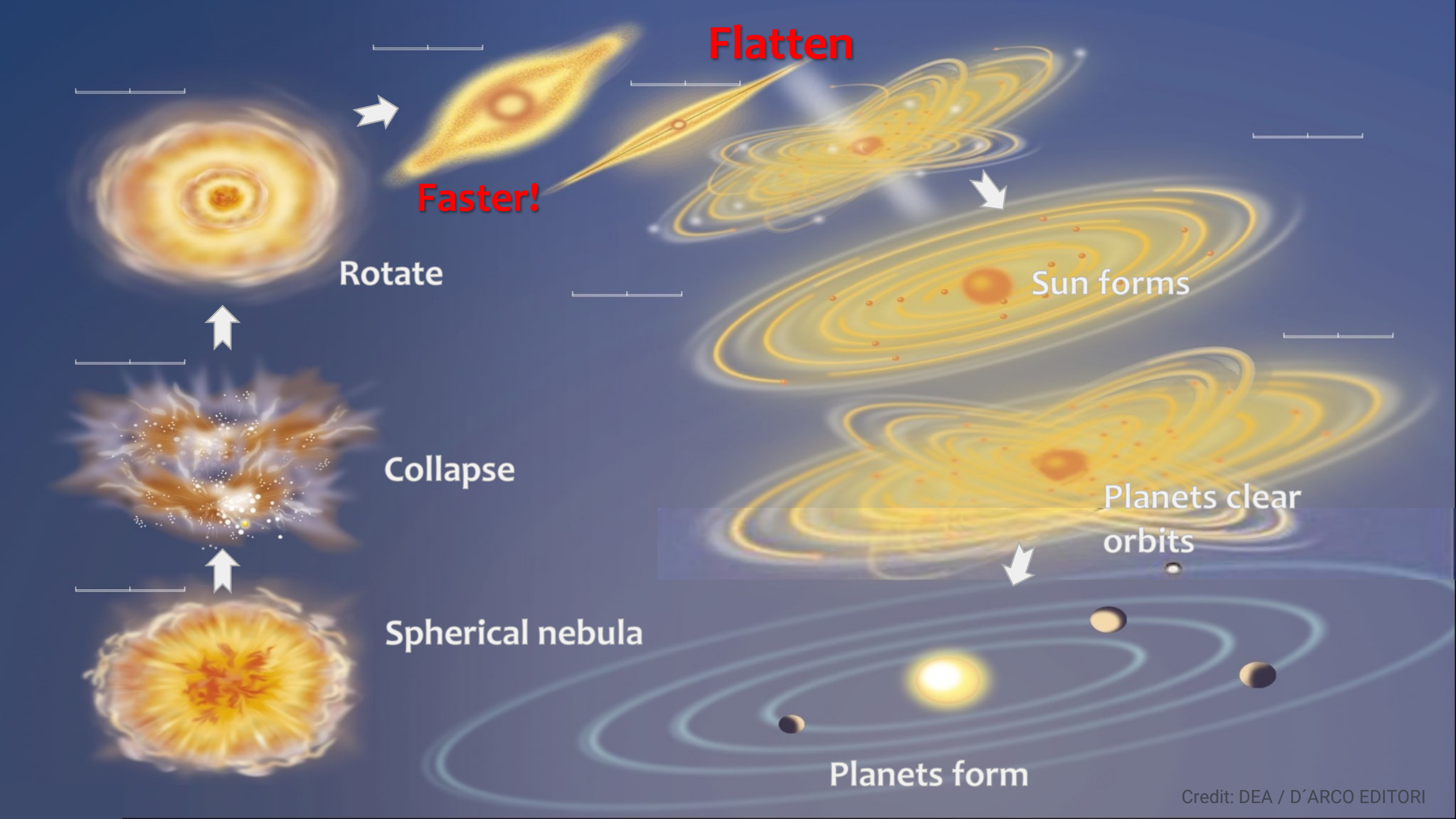
Present

Only rocky things could survive close to the sun, so gaseous and icy material collected further away. That's how our solar system came to be the place it is today!

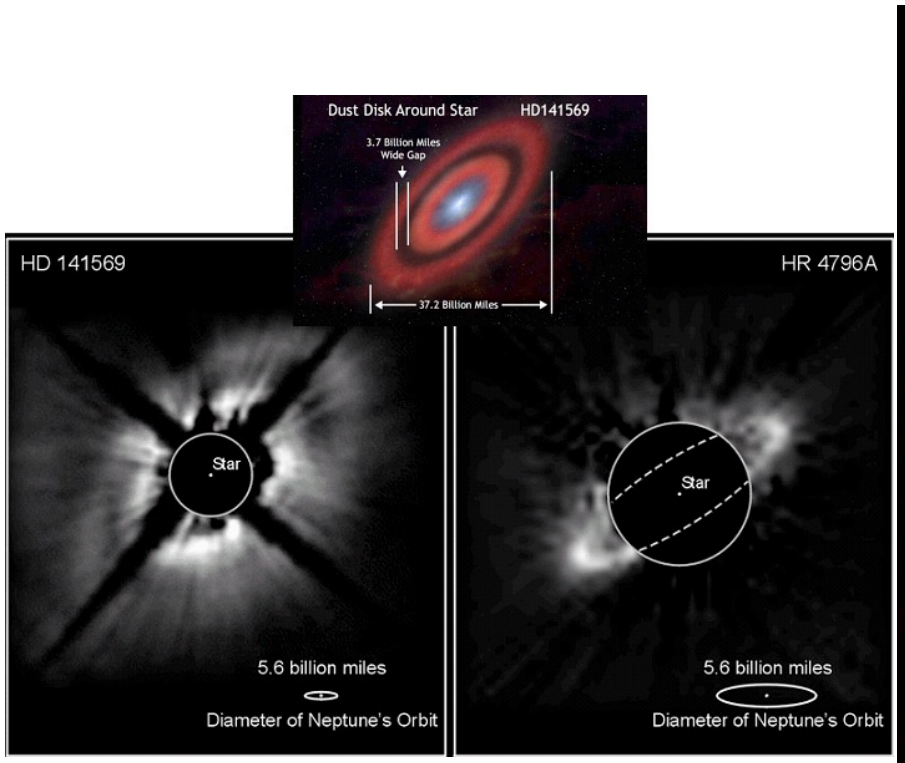
Comets and asteroids are the left over remains of the solar system's formation.

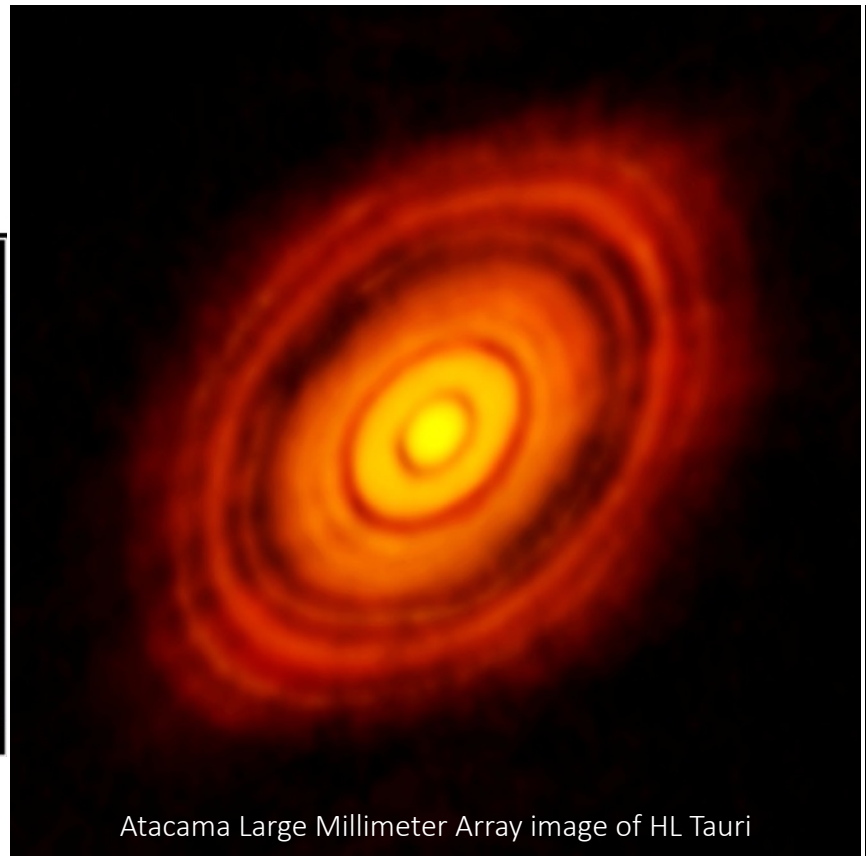
https://www.pbslearningmedia.org/resource/buac18-912-sci-ess-solarsystemformation/solar-system-formation/#.XaG74S2B3OQ

Not to Scale

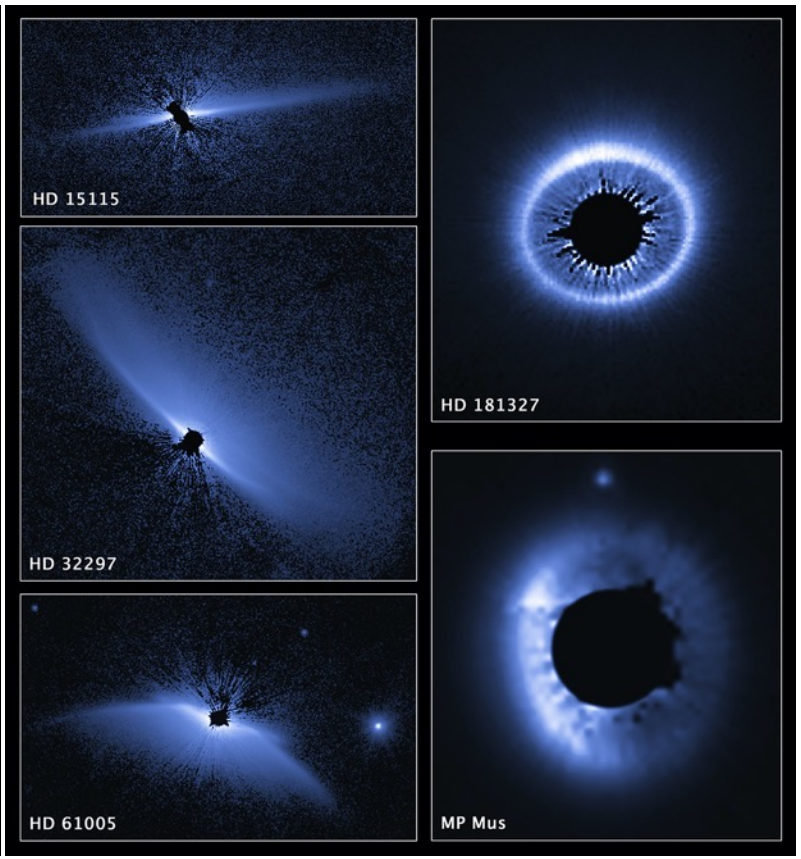

Flatten
Faster!
Rotate
Sun forms
Collapse
Planets clear orbits
Spherical nebula
Planets form
Credit: DEA / D´ARCO EDITORI

Disks around stars (Observations)





Atacama Large Millimeter Array image of HL Tauri



https://www.eso.org/public/archives/images/large/eso1436a.jpg

Solar system formation (VL)

- **Hypothesis**: Our Solar system formed out of a nebula which collapsed under its own gravity (This is the basis of nebular theory of star formation)

- **Supporting Observation 1:** Newly forming stellar systems are observed to be inside dense interstellar gas clouds.

Nebula: a large cloud in space consisting of gas and dust

Trifid nebula

Orion nebula

Eagle nebula