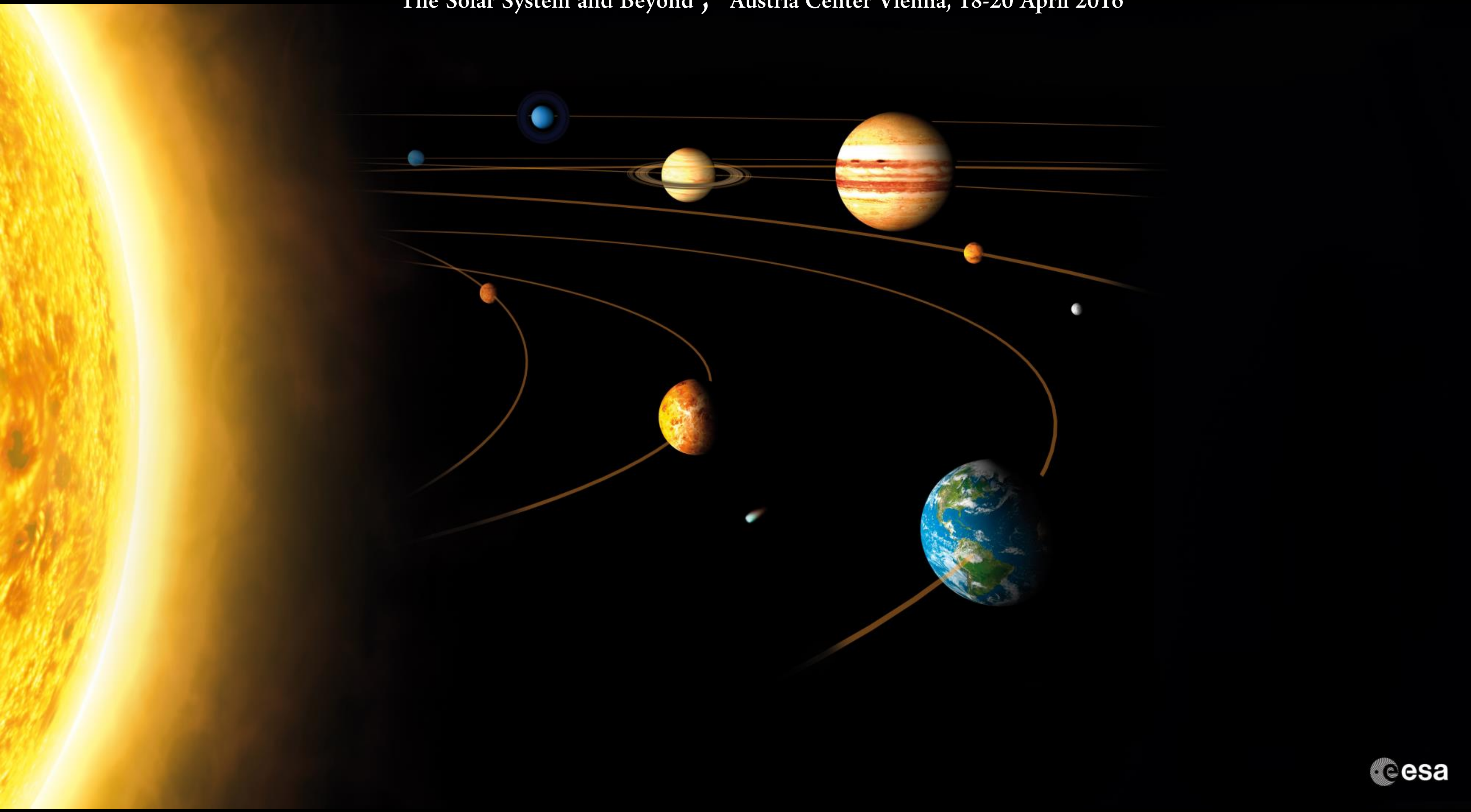
European Geosciences Union – General Assembly

GEOSCIENCE INFORMATION FOR TEACHERS (GIFT) WORKSHOP

'The Solar System and Beyond', Austria Center Vienna, 18-20 April 2016

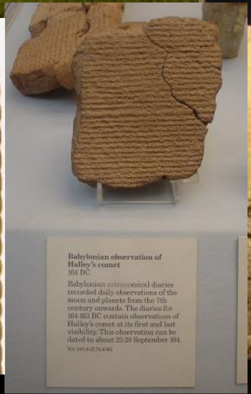
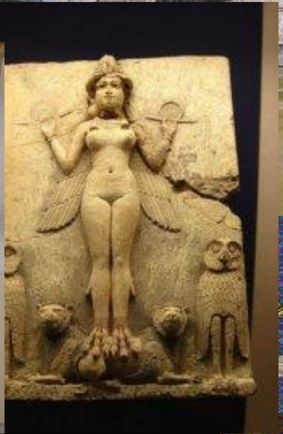


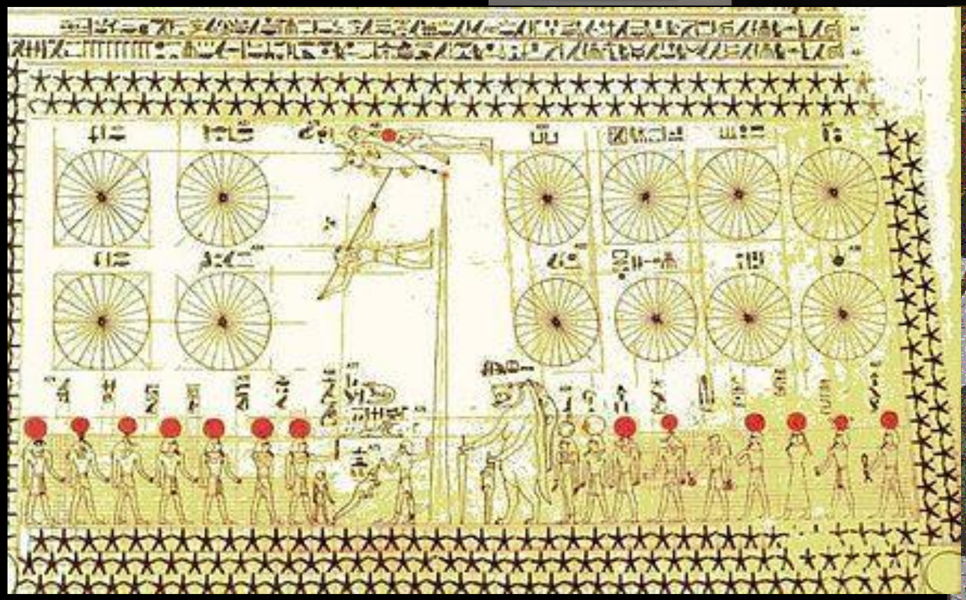
INTRODUCTION TO THE SOLAR SYSTEM

Dr. Özgür Karatekin, Royal Observatory of Belgium






Babylonian observation of Halley's comet


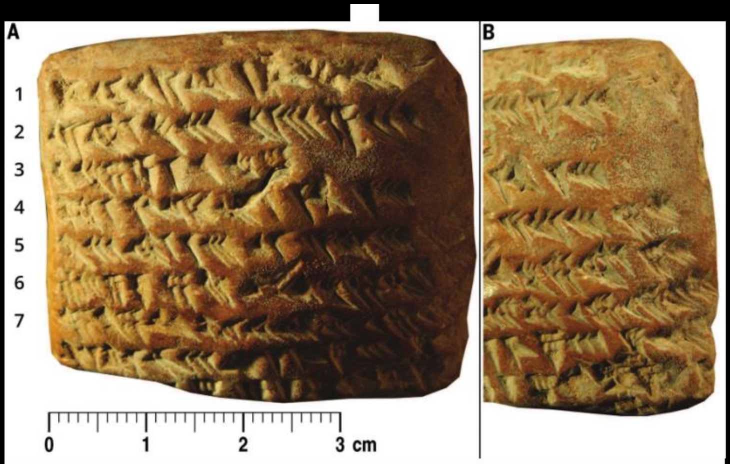
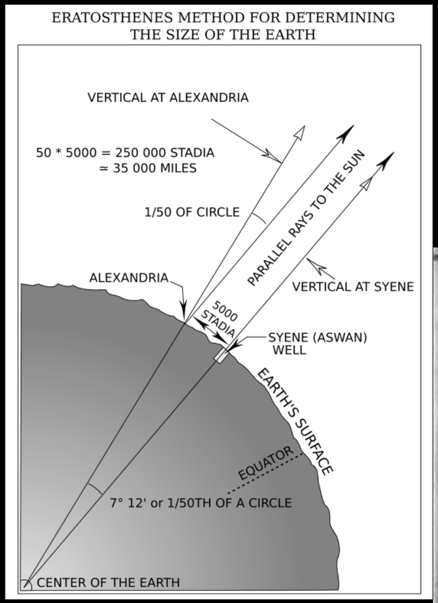
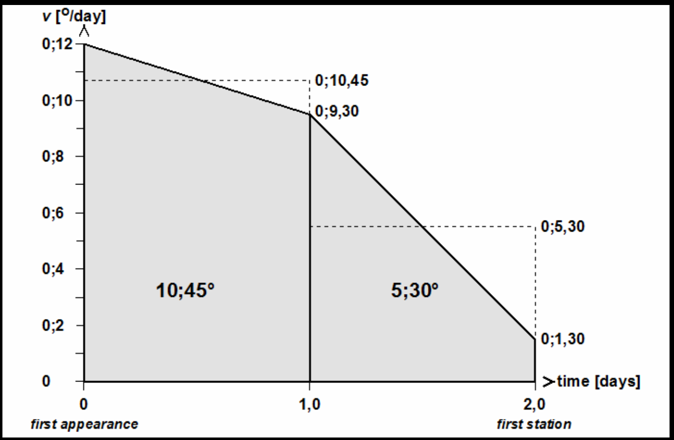
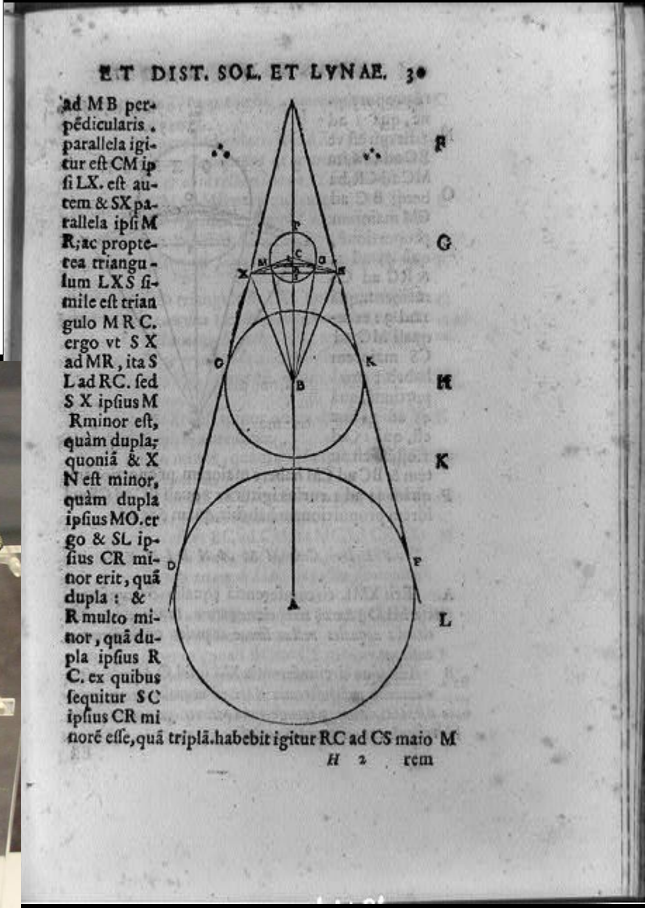



Fig. 1. Photograph of text A (lines 1to 7). (A) Full image. (B) Partial image of the right side taken under different lighting conditions.



Angle of sunbeam and the gnomons (vertical sticks) at Syene and Alexandria allowed Eratosthene to' estimate radius and circumference of Earth.




ET DIST. SOL. ET LVNAE. 30

ad MB per-
pẽdicularis,
parallela igi-
tur eſt CM ip
ſi LX. eſt au-
tem & SX pa-
rallela ipſi M
R; ac propte-
rea triangu-
lum LXS ſi-
mile eſt trian
gulo MRC.
ergo vt SX
ad MR, ita S
L ad RC. ſed
SX ipſius M
R minor eſt,
quàm dupla;
quoniã & X
N eſt minor,
quàm dupla
ipſius MO. er
go & SL ip-
ſius CR mi-
nor erit, quã
dupla: &
R multo mi-
nor, quã du-
pla ipſius R
C. ex quibus
ſequitur SC
ipſius CR mi
norẽ eſſe, quã triplã. habebit igitur RC ad CS maio
H 2 rem

Ancient Babylonians Used Geometry to Track the Planets. in four ancient Babylonian cuneiform tablets, Jupiter's displacement along the ecliptic is computed as the area of a trapezoidal figure obtained by drawing its daily displacement against time (Ossendrijver 2016)

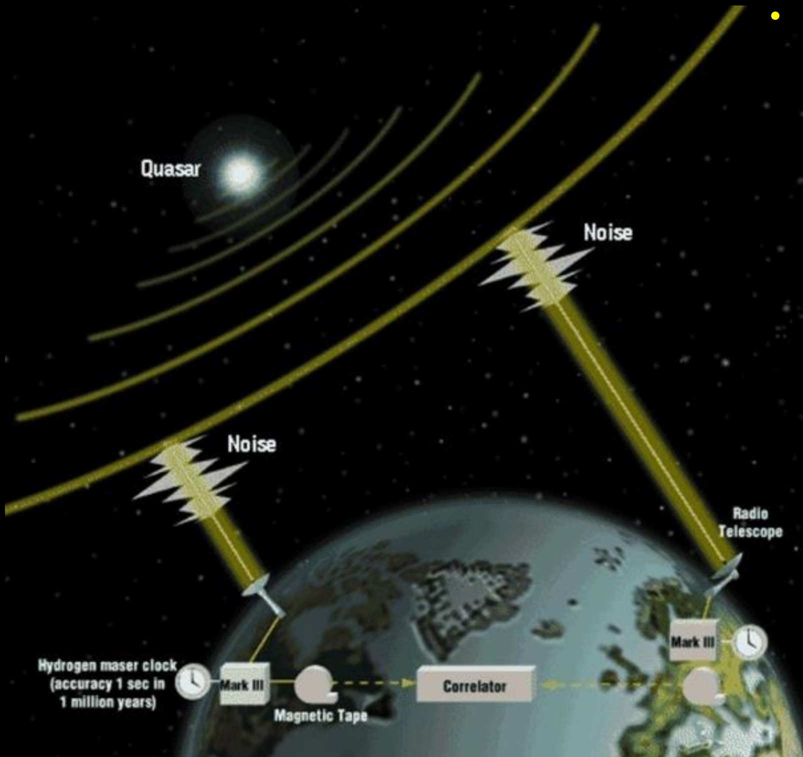
The Antikythera mechanism is an ancient analog computer[designed to predict astronomical positions and eclipses for calendrical and astrological purposes,

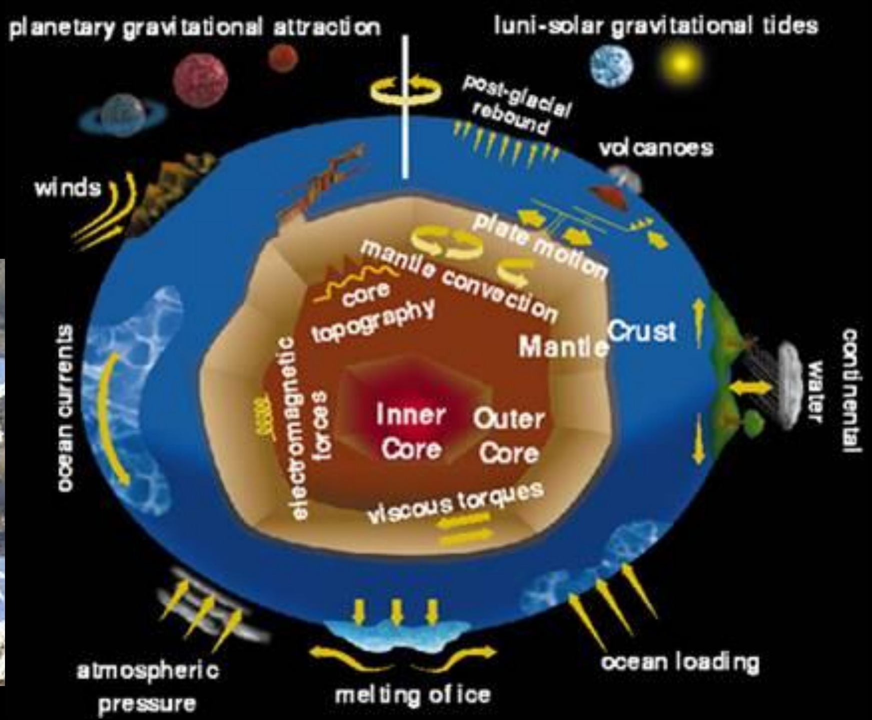
This illustration from a translation of Aristarchus work shows how he approached measuring the size of the Earth based the size of the Earth's shadow on the moon during a Lunar eclipse

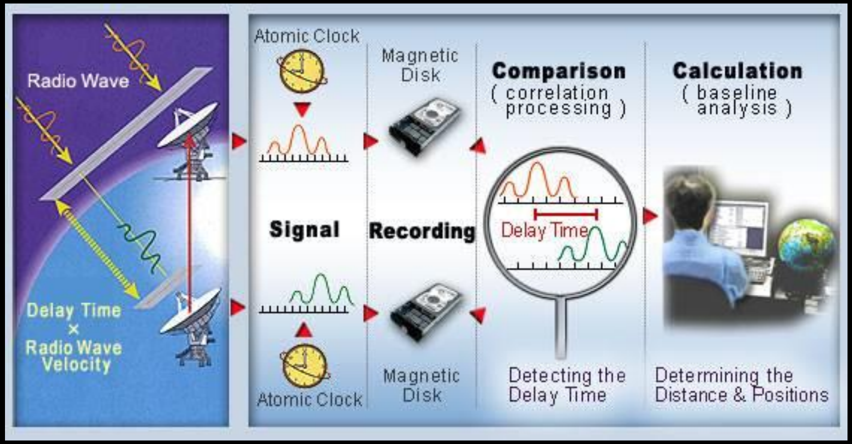
Observation of night sky has been a driver for natural sciences and has allowed a better understanding of our planet!

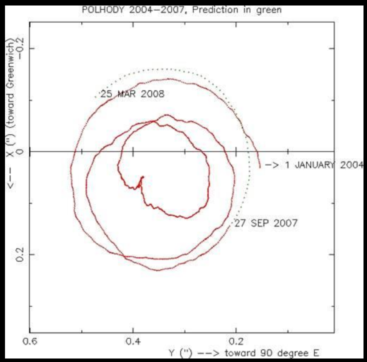
Geodetic VLBI allows for accurate measurement of :

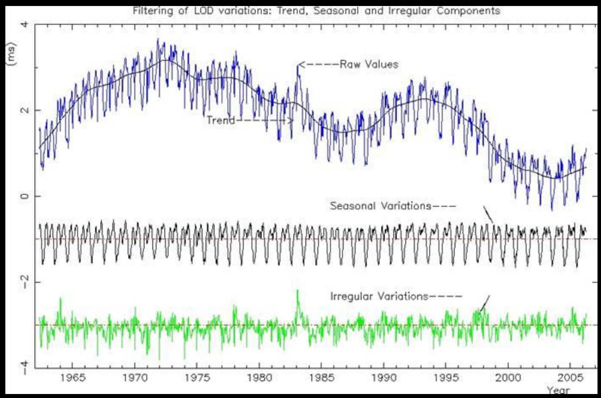
- Earth Orientation Parameters (EOP) – UT1, polar motion, nutation, precession
- Positions and velocities of sites occupied by VLBI antennas
- Troposphericparameters – total and wet zenith path delays, meteorological data for stations











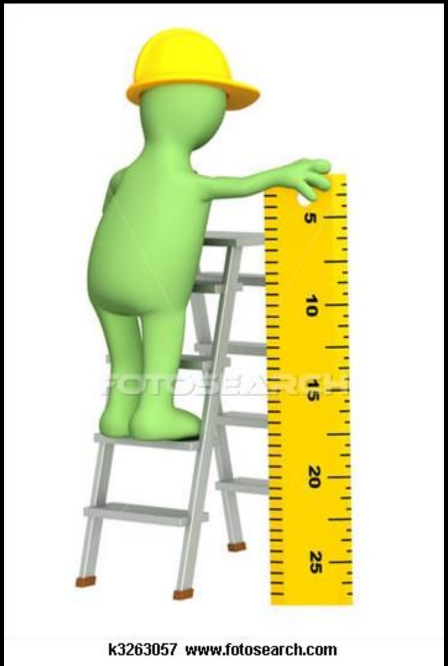
http://geodesy.hartrao.ac.za/site/en/geodesy-equipment/radio-telescope-vlbi.html

Credit: P. Laudet

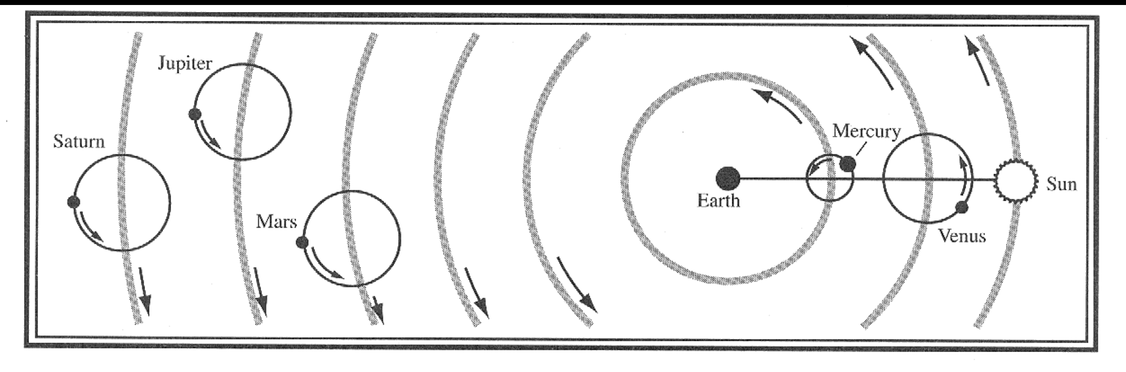
Scientific Reasoning

1
Observe
…and question

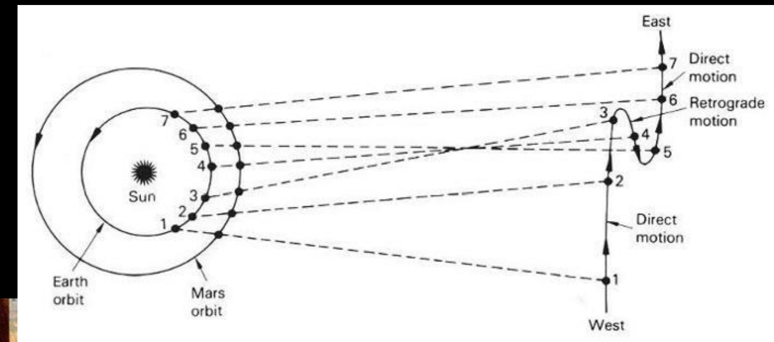
2
Think..
…and may be understand

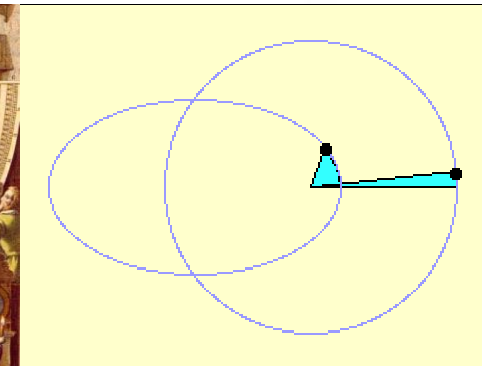


3
Verify
…that the thought was correct



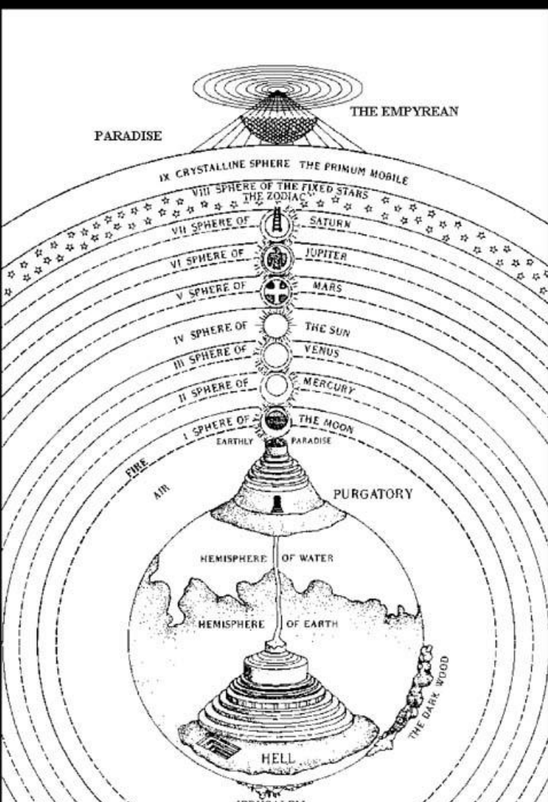
Ptolemy's model for planetary motion, with deferents (big spheres) and epicycles (small spheres).





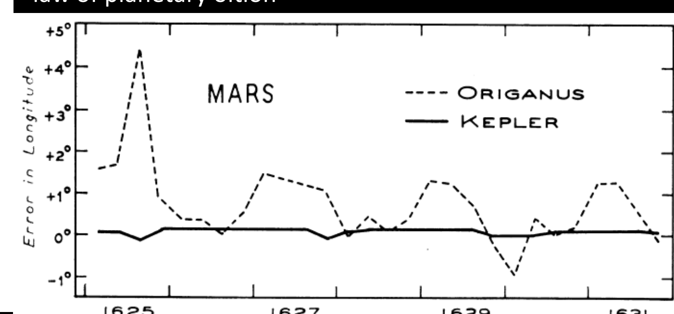
Planet	Radius of orbit (R) in A.U.	Cube of radius, R^3	Time to go around orbit (Period, P) in yrs.	P^2	P^2/R^3
Mercury	0.387	.0580	.241	.0581	1
Venus	0.723	.378	.615	.378	1
Earth	1.00	1.00	1.00	1.00	1
Mars	1.524	3.54	1.881	3.538	1

Using precise astronomical data, Kepler's proposed a theory for the orbital motions of the solar system bodies: Kepler's law of planetary oition

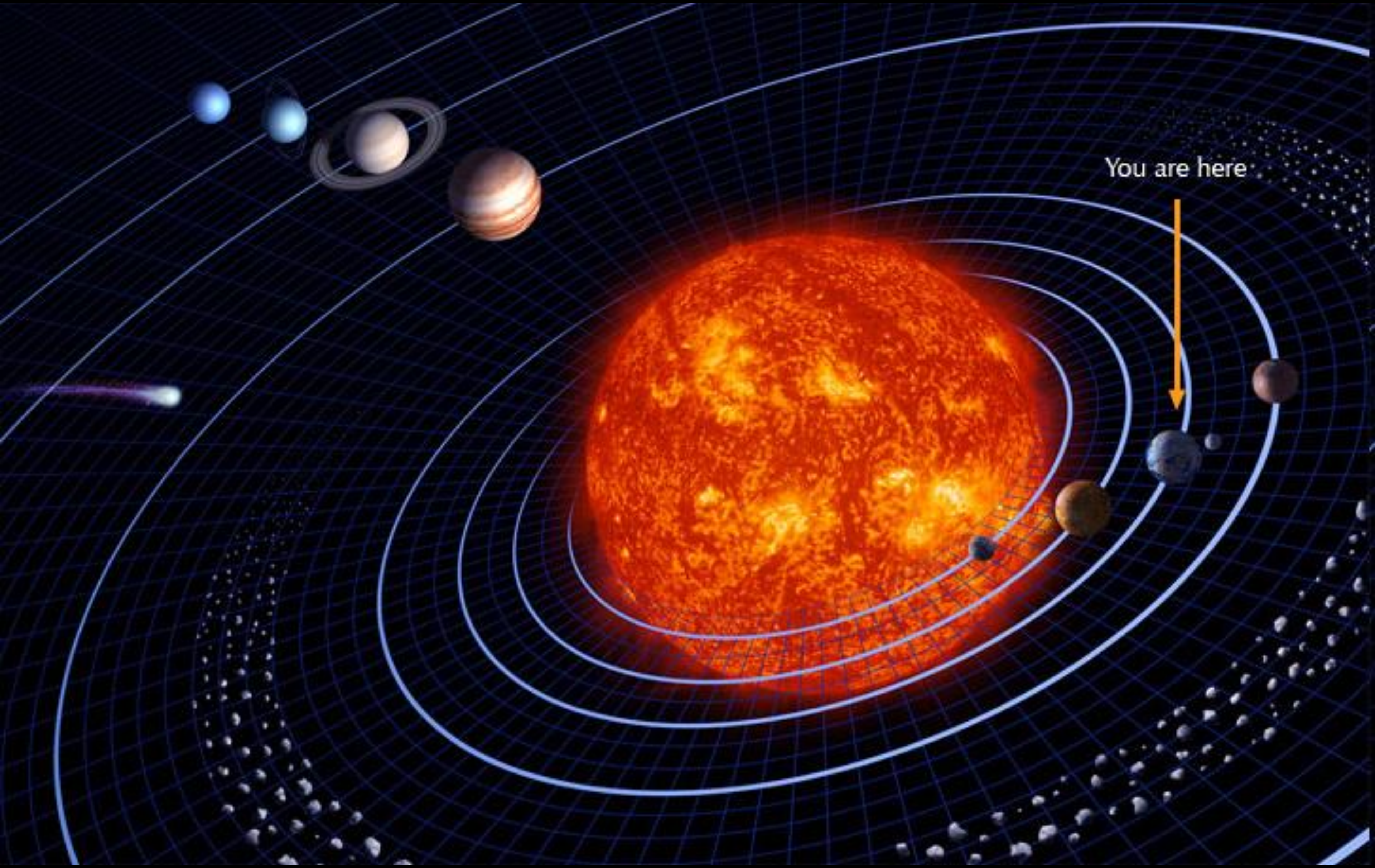


From Dante's (1265-1321) "The Divine Comedy

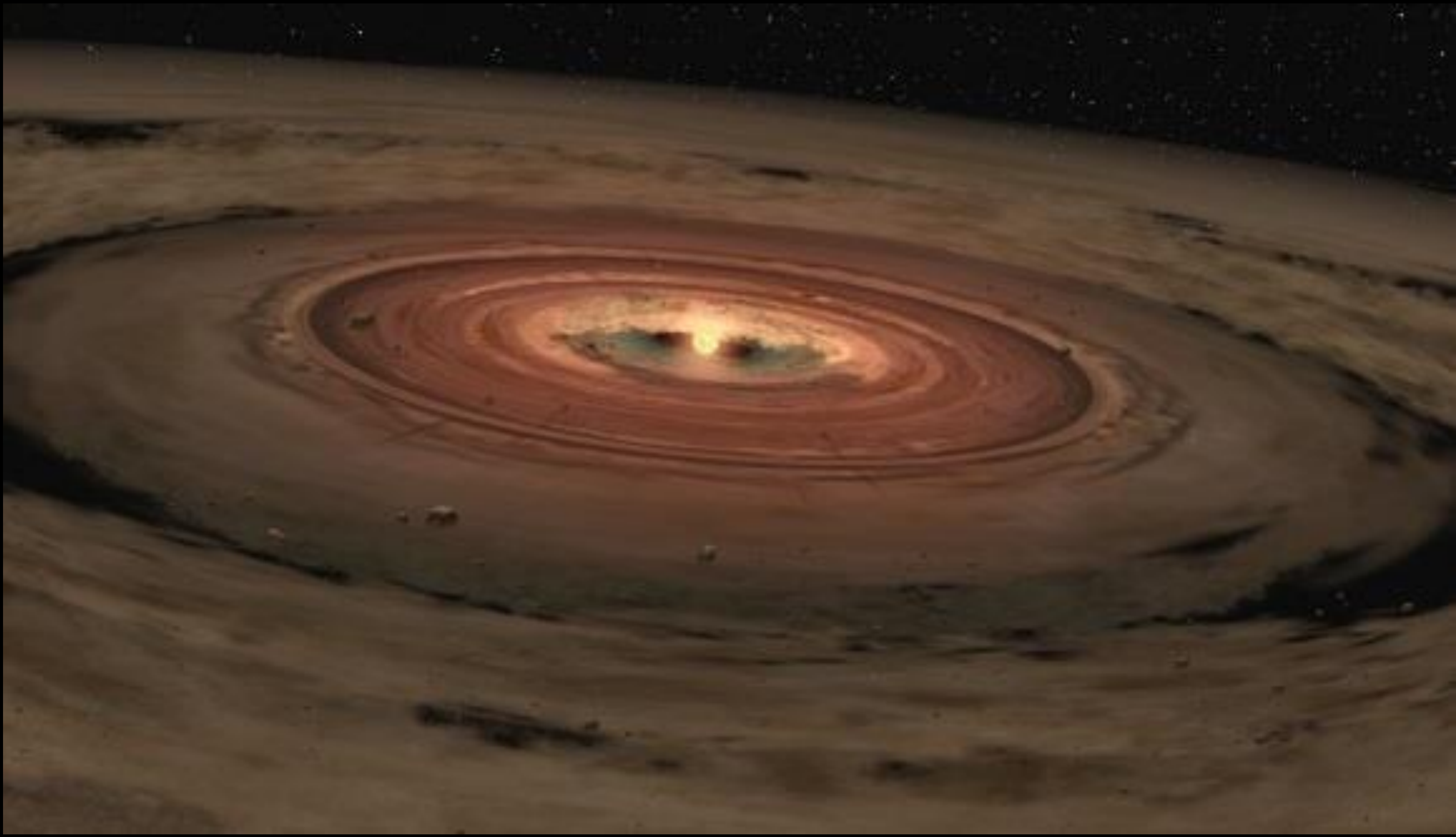
Copernicus' drawing of his system. He notes that Mars is far from its predicted position.



Comparison of the calculated position of Mars with the Ptolemy/Copernicus systems, as carried out by Origanus, and its true position, as calculated by Kepler.(O. Gingerich, 1971)

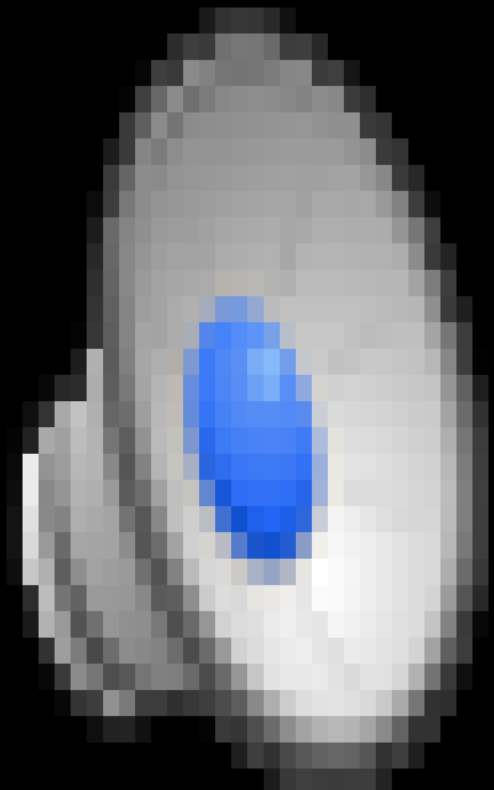

You are here

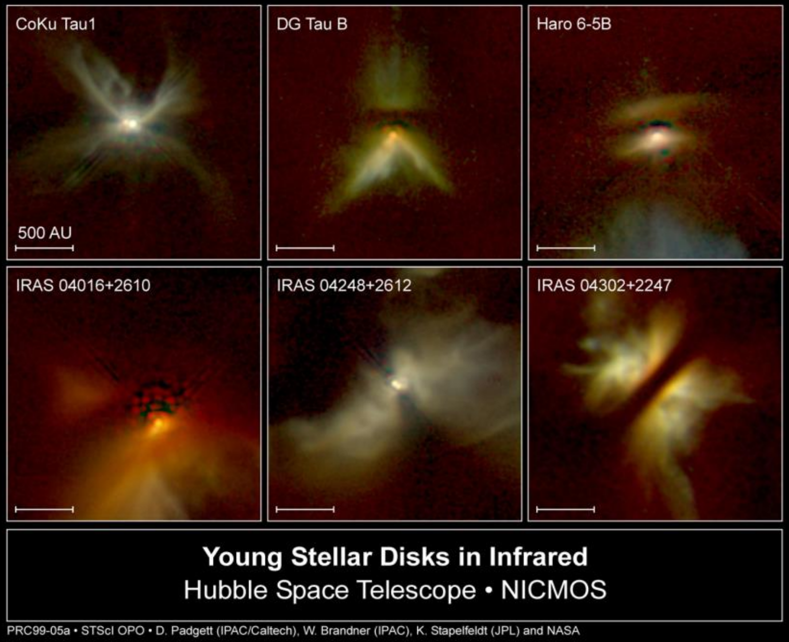
Origins…




‘Our origins’… ‘The Pilars of creation’
Eagle Nebula, M 16, Messier 16
Milky Way ~ 7000 light years
Constellation: Serpens Cauda

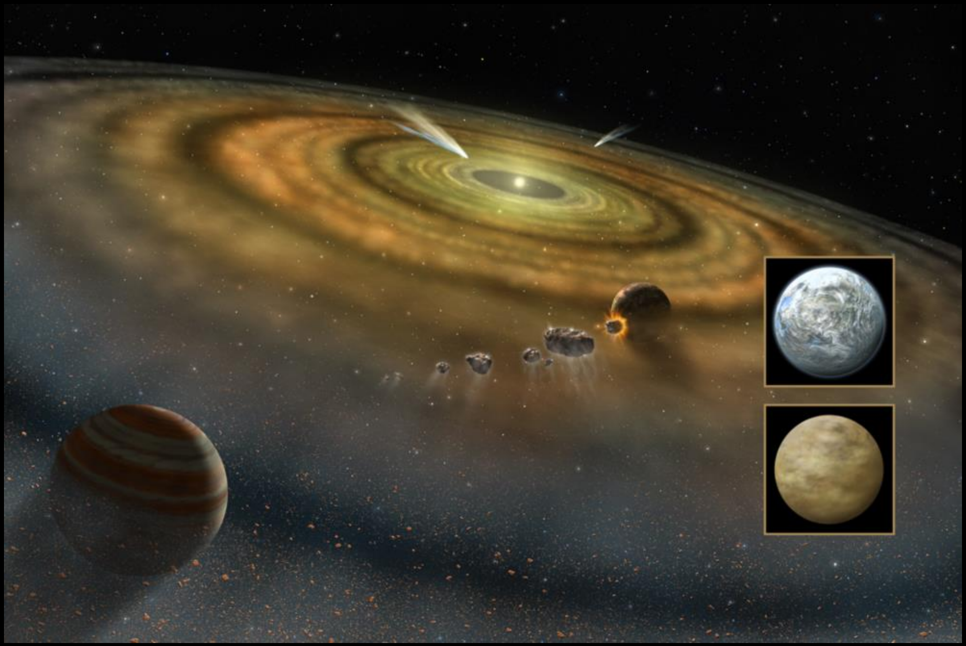
‘Our origins’… *‘The Pilars of creation’*

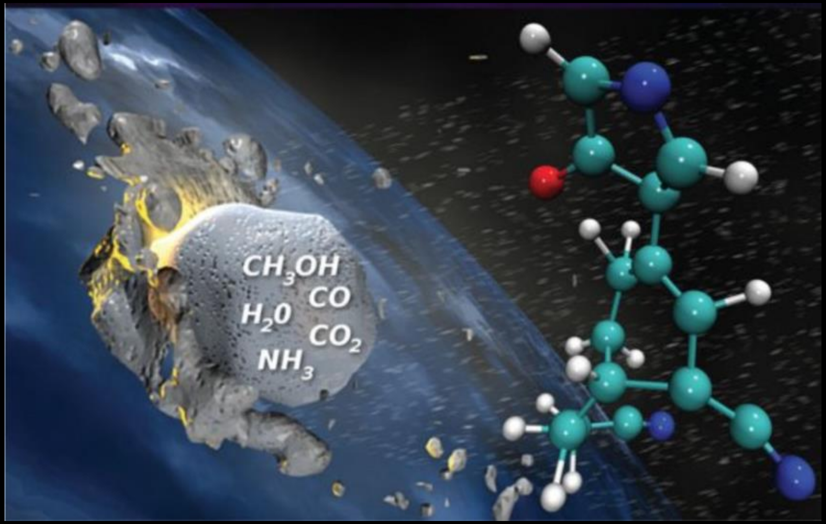


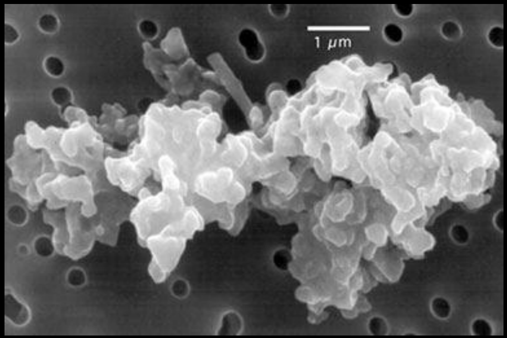


Source: ESA/ATG Medialab

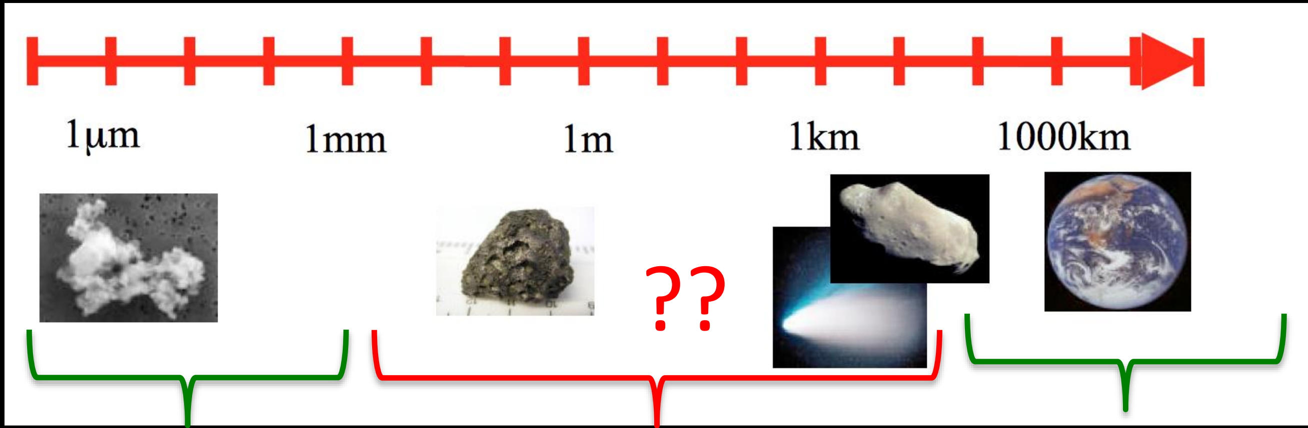
…Some outstanding issues in Solar System formation…



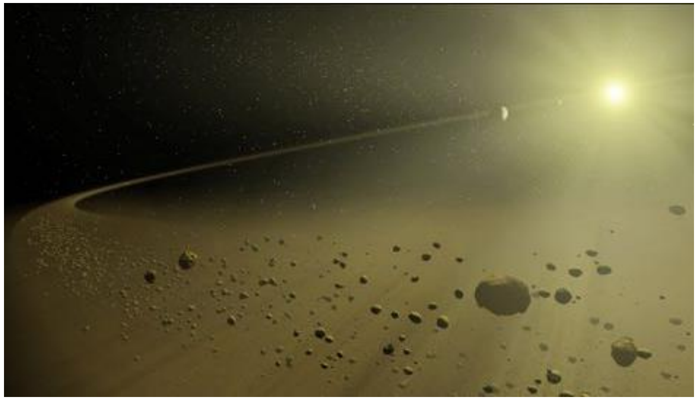




N. Altobelli



… Role of collisions in the Solar System….



Planetesimal formation

Collisional accretion

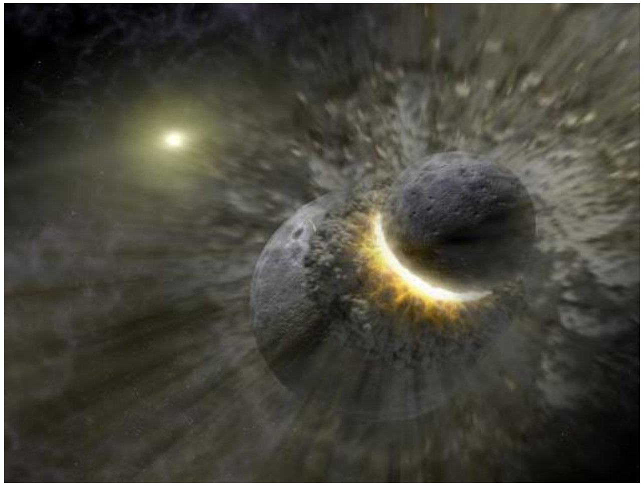
Early phases

Planet formation

Asteroid disruption

Collisional disruption

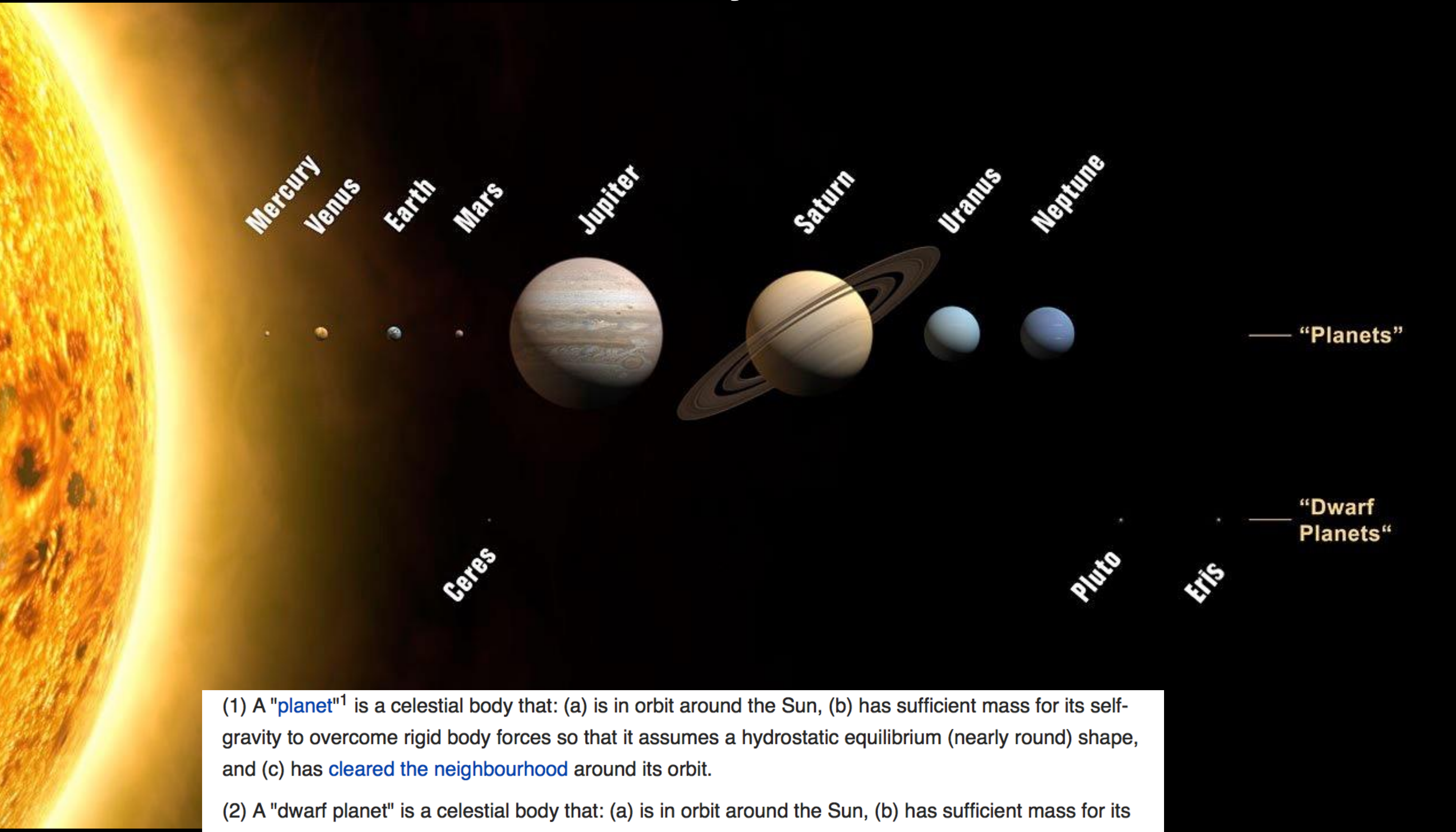
Late phases



European Space Agency

Giant impacts

Solar System

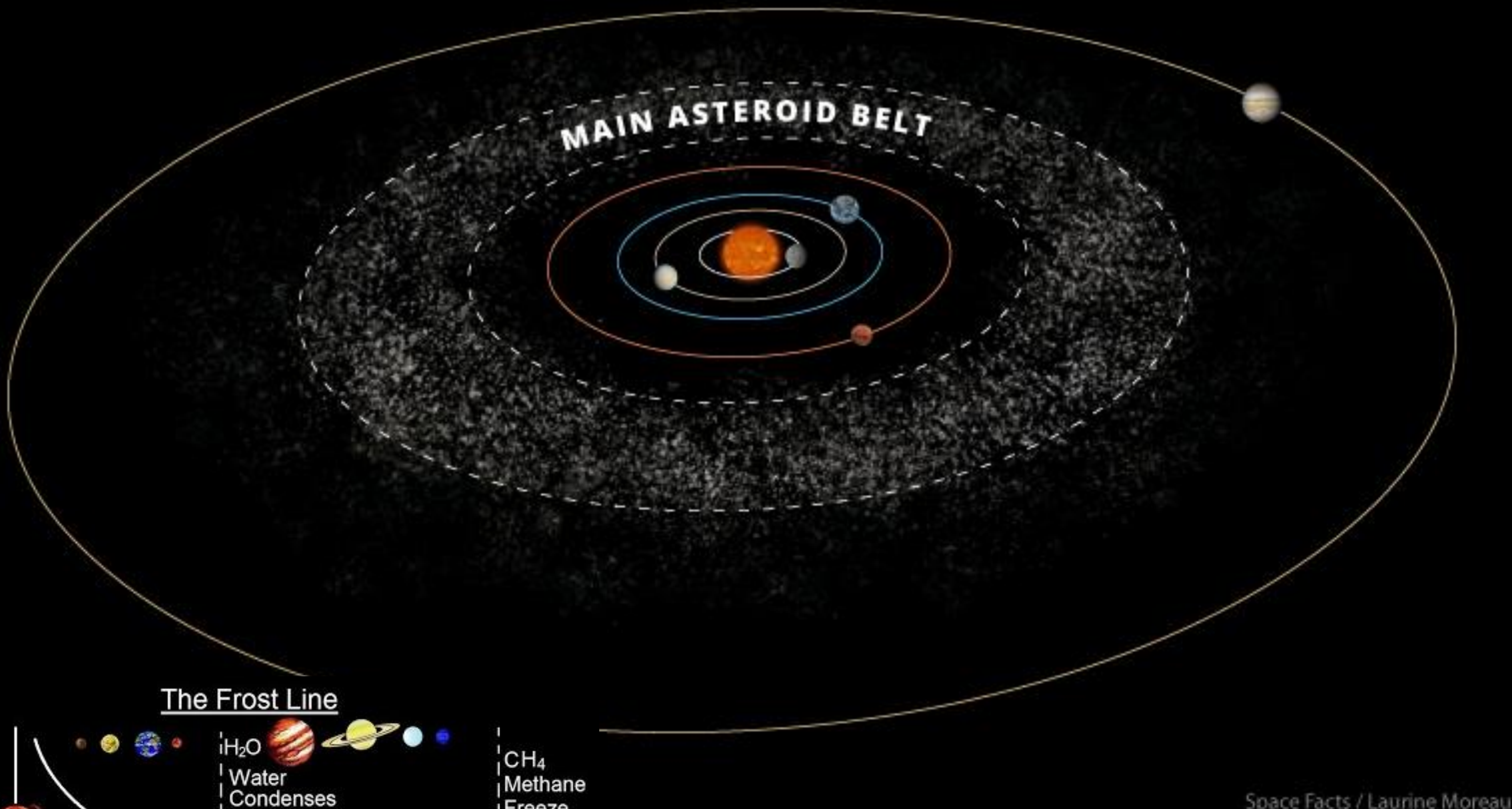


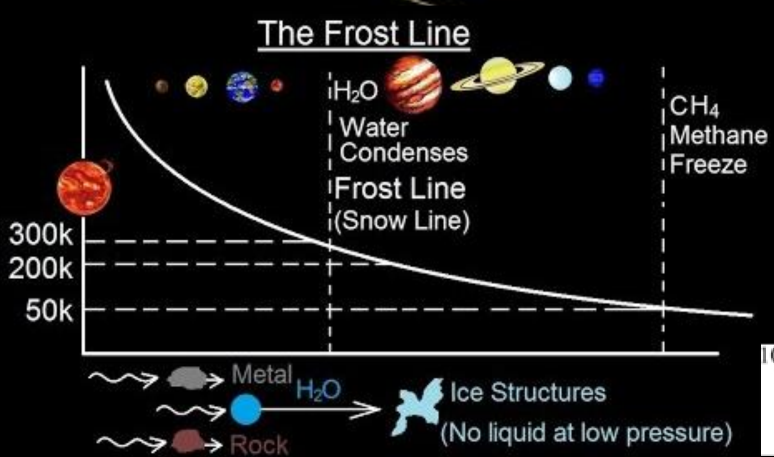
(1) A "planet"[1] is a celestial body that: (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighbourhood around its orbit.

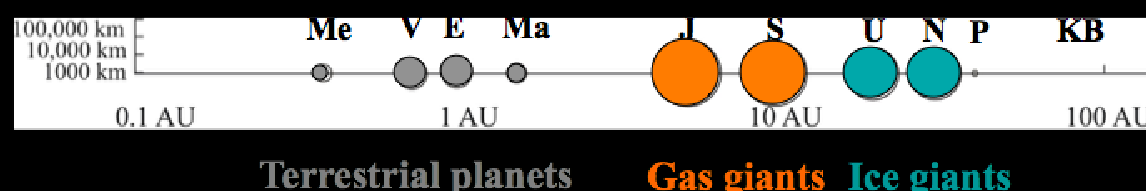
(2) A "dwarf planet" is a celestial body that: (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape[2], (c) has not cleared the neighbourhood around its orbit, and (d) is not a satellite.

(3) All other objects[3], except satellites, orbiting the Sun shall be referred to collectively as "Small Solar System Bodies".

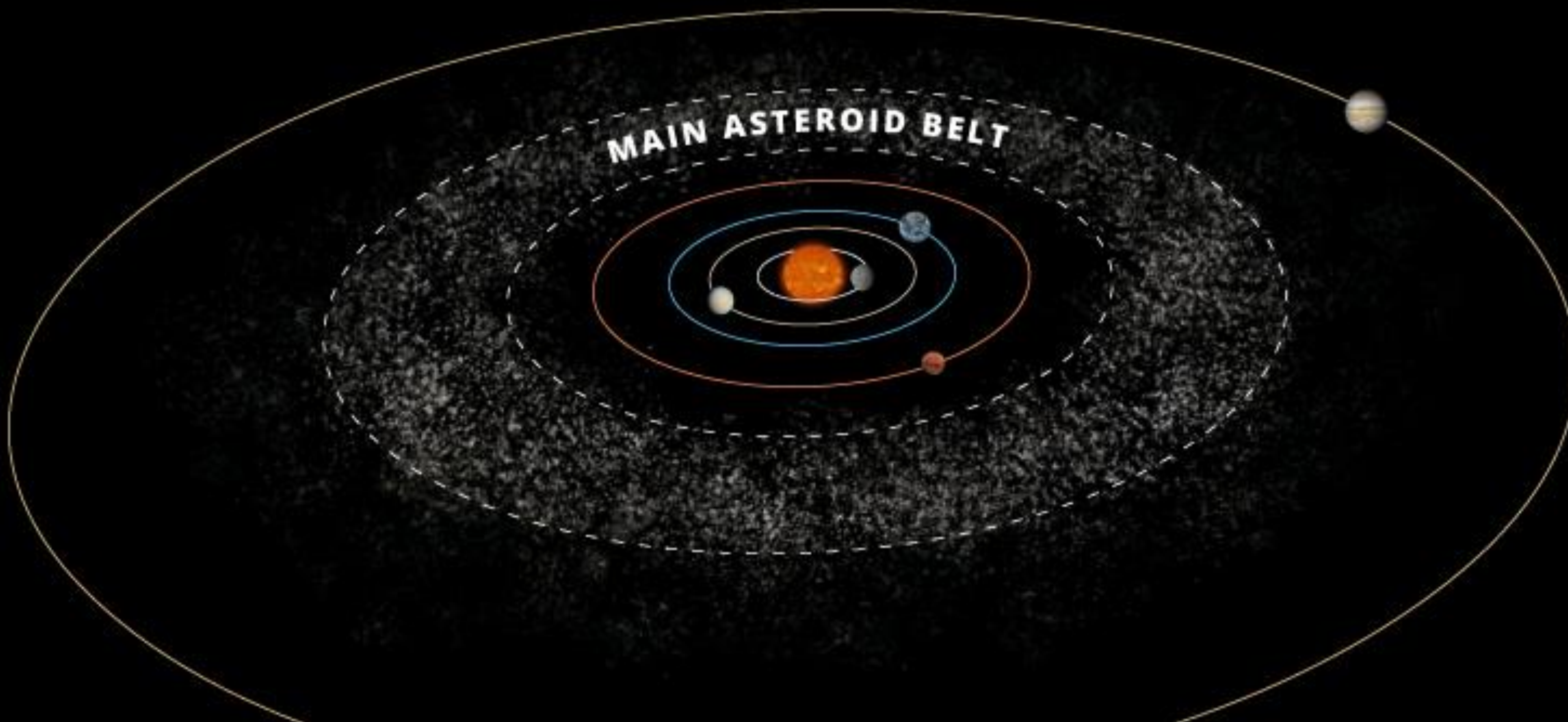
..Stable and Orderly System….

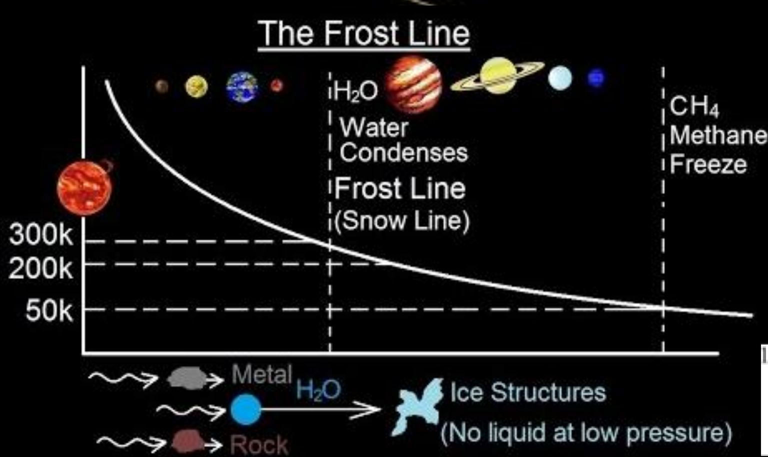






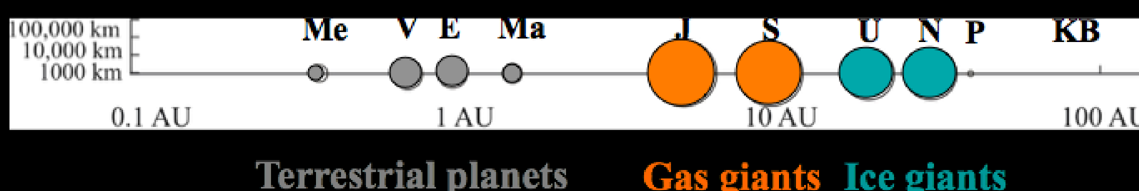
..Stable and Orderly System….or not ?



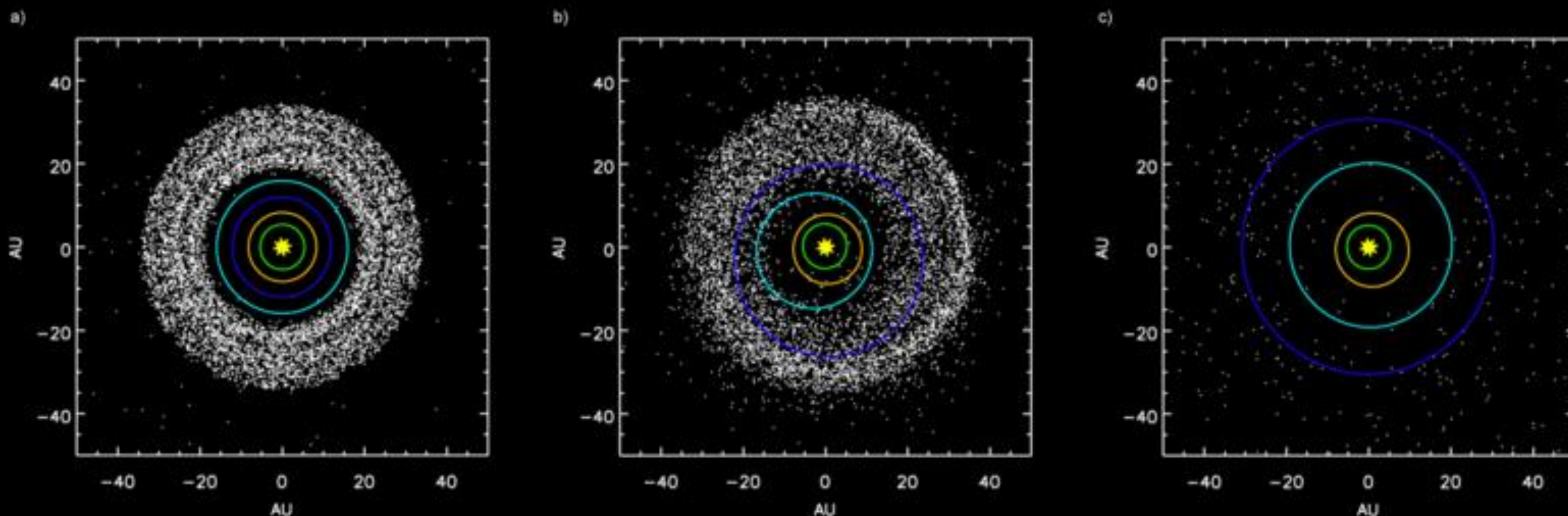


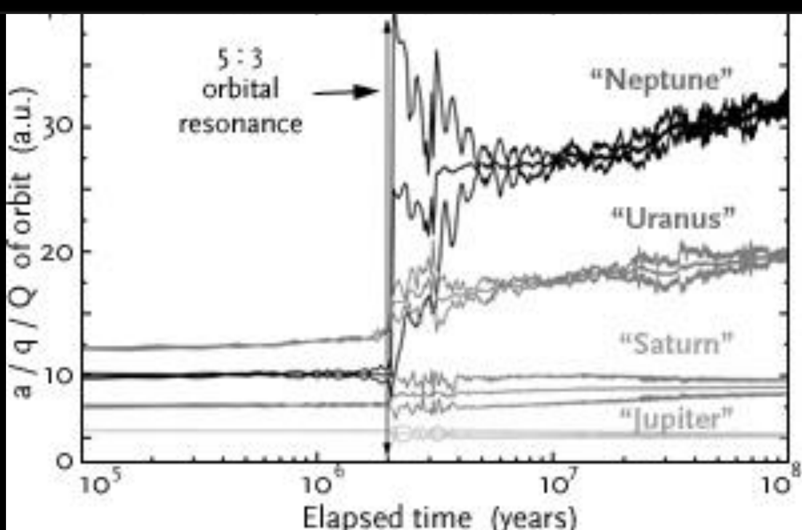
If planets are formed where they are now:

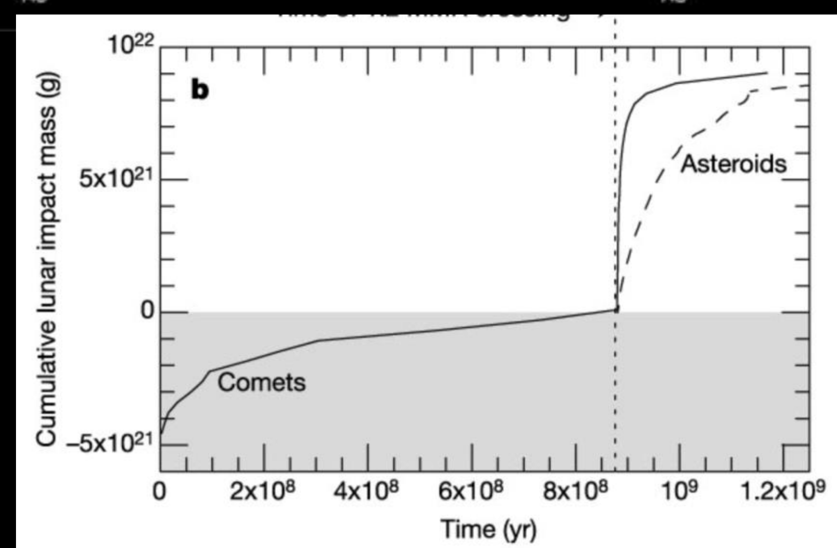
- Uranus and Neptune should have ended up much smaller and less massive.
- Conversely, Mars formed in the fat of the disk and should have ended up at least 10 times more massive than it is today.
- No good explanation of s the asteroid belt's existence — particularly why it's crudely divided into rocky bodies (called S types) nearer the Sun and dark, carbon-dominated hunks (C types) farther out.

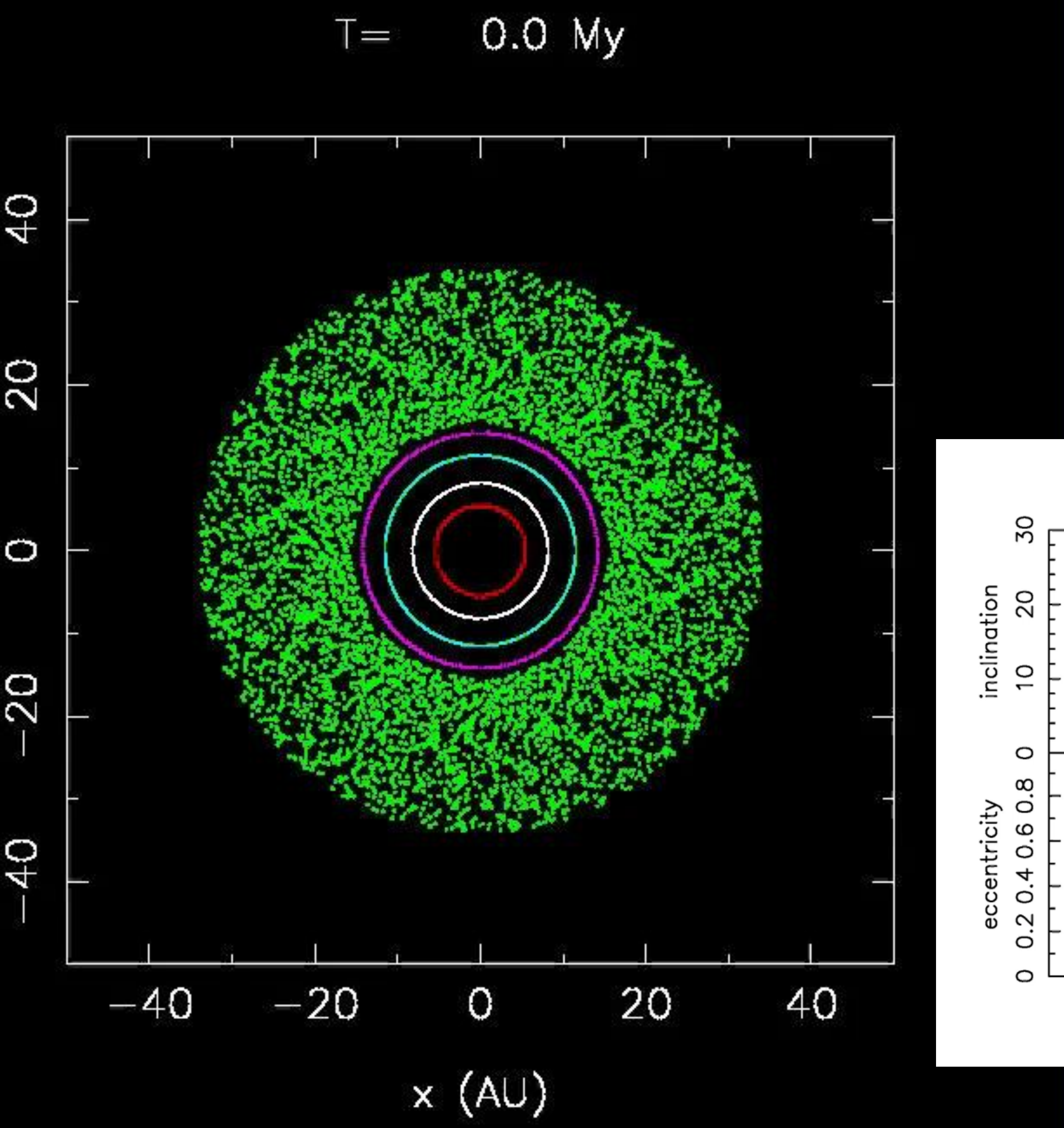


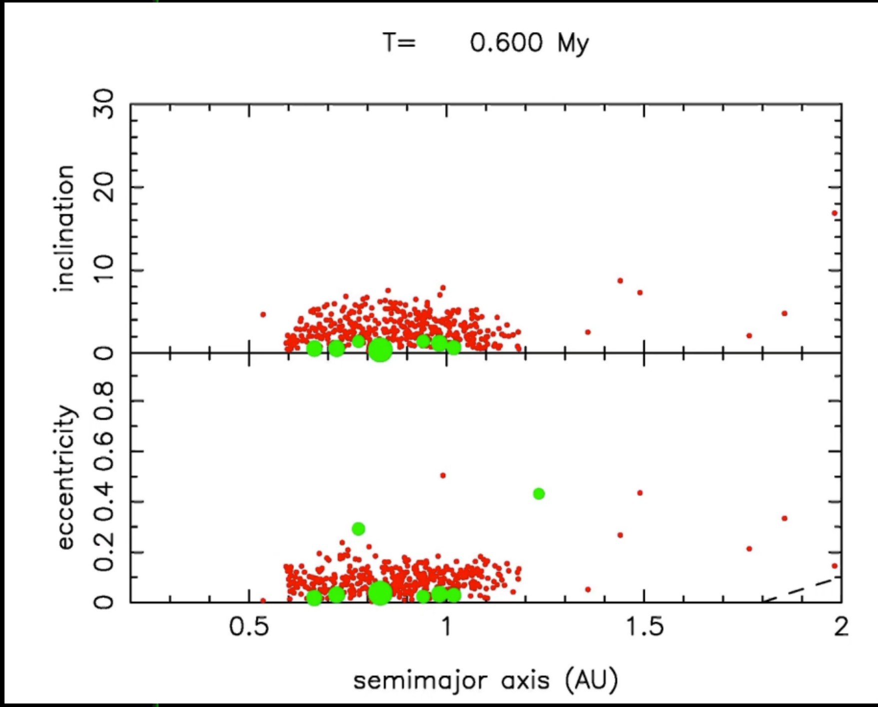
…Migration of Gas Giants & Orbital resonnances…NICE MODEL (Gomez et a. 2005)





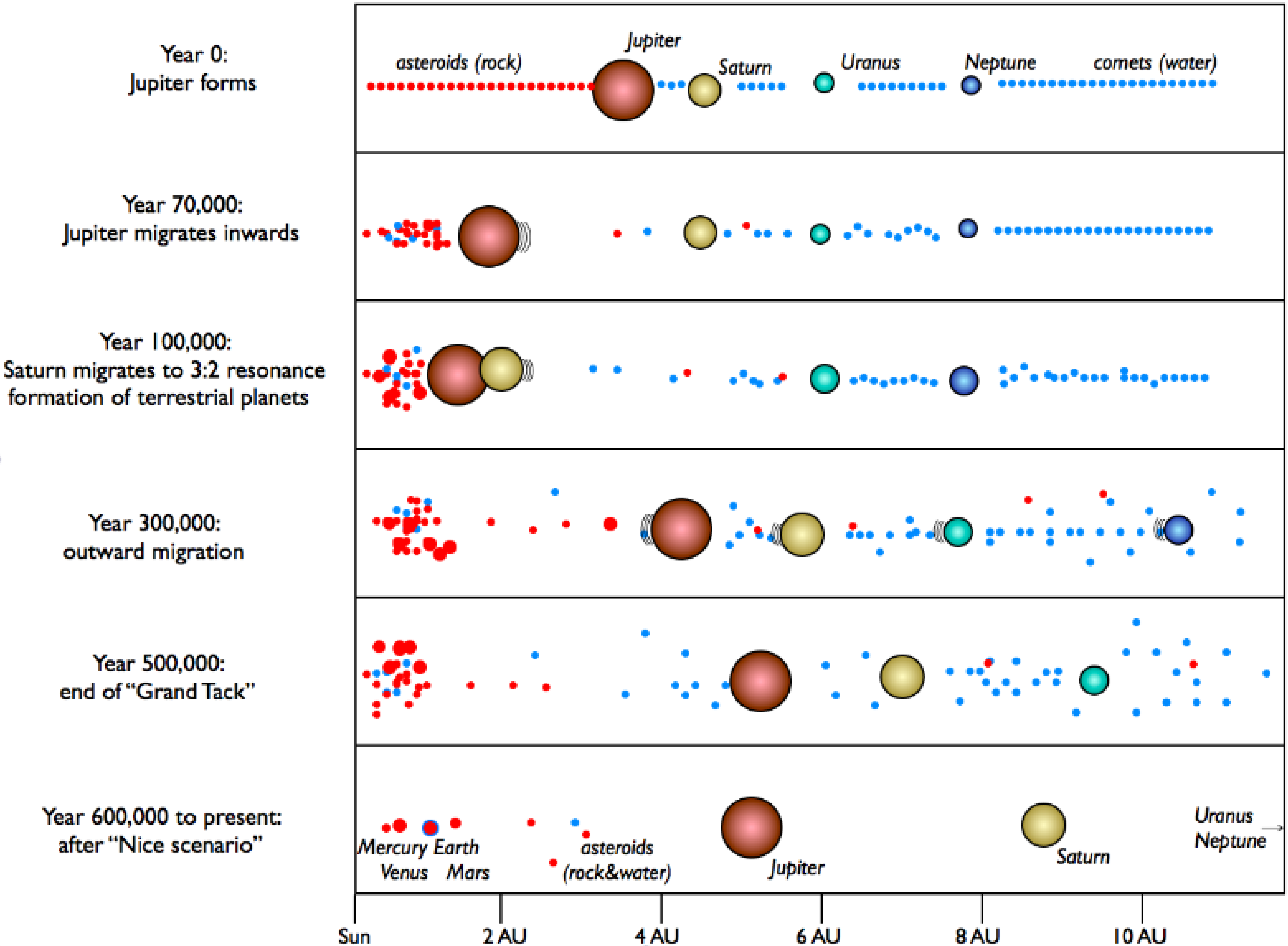




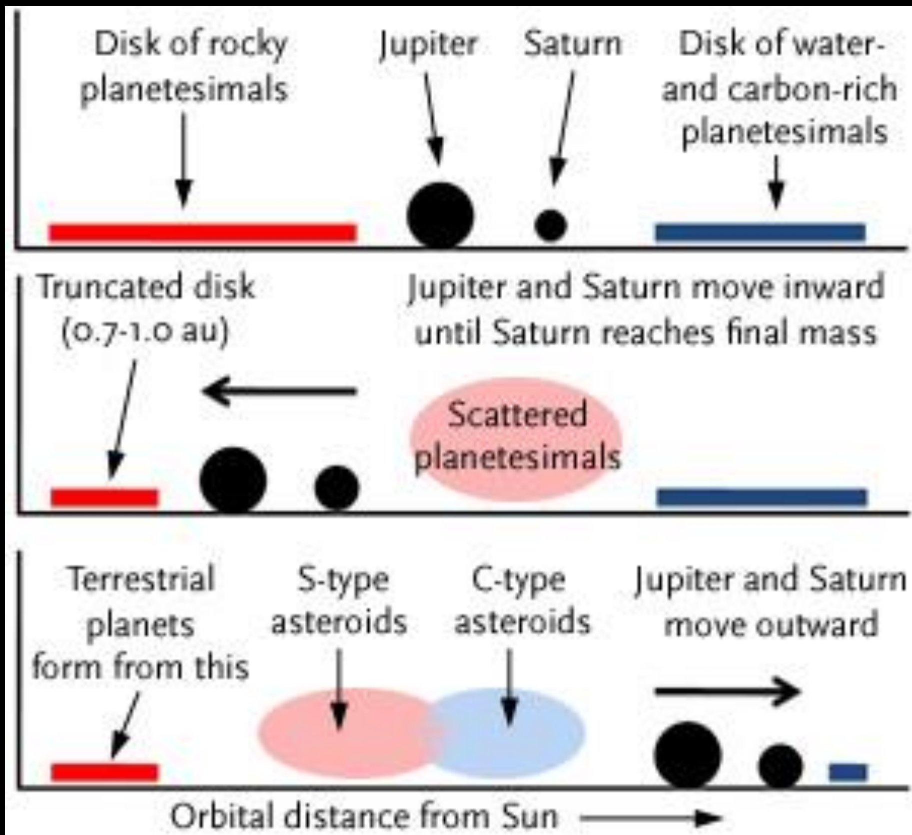


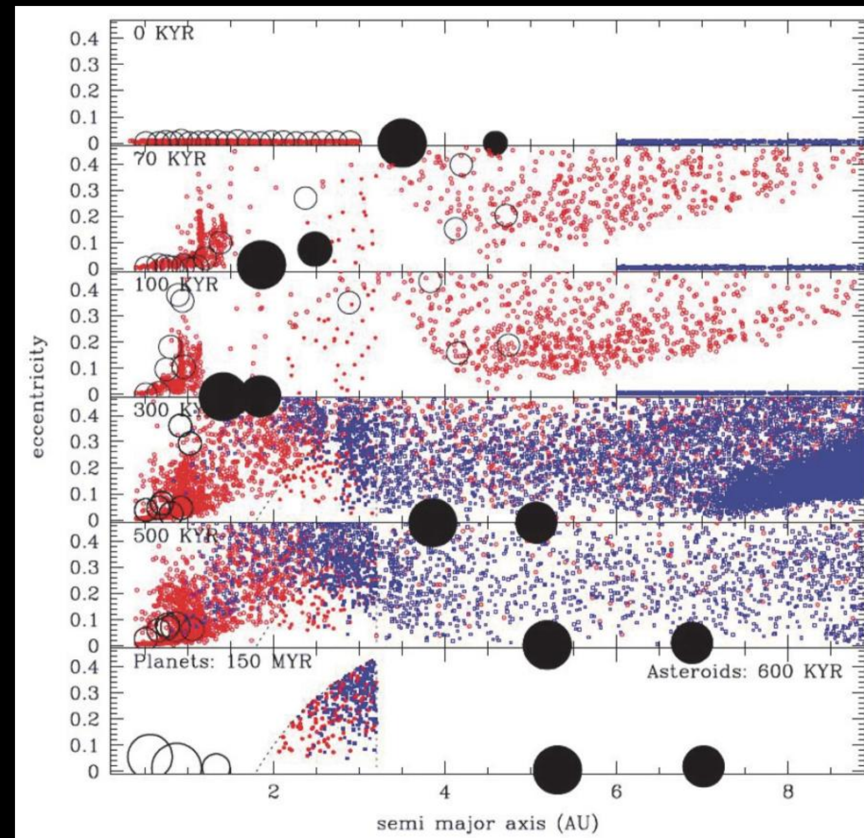
Nice Model: Morbidelli et al..

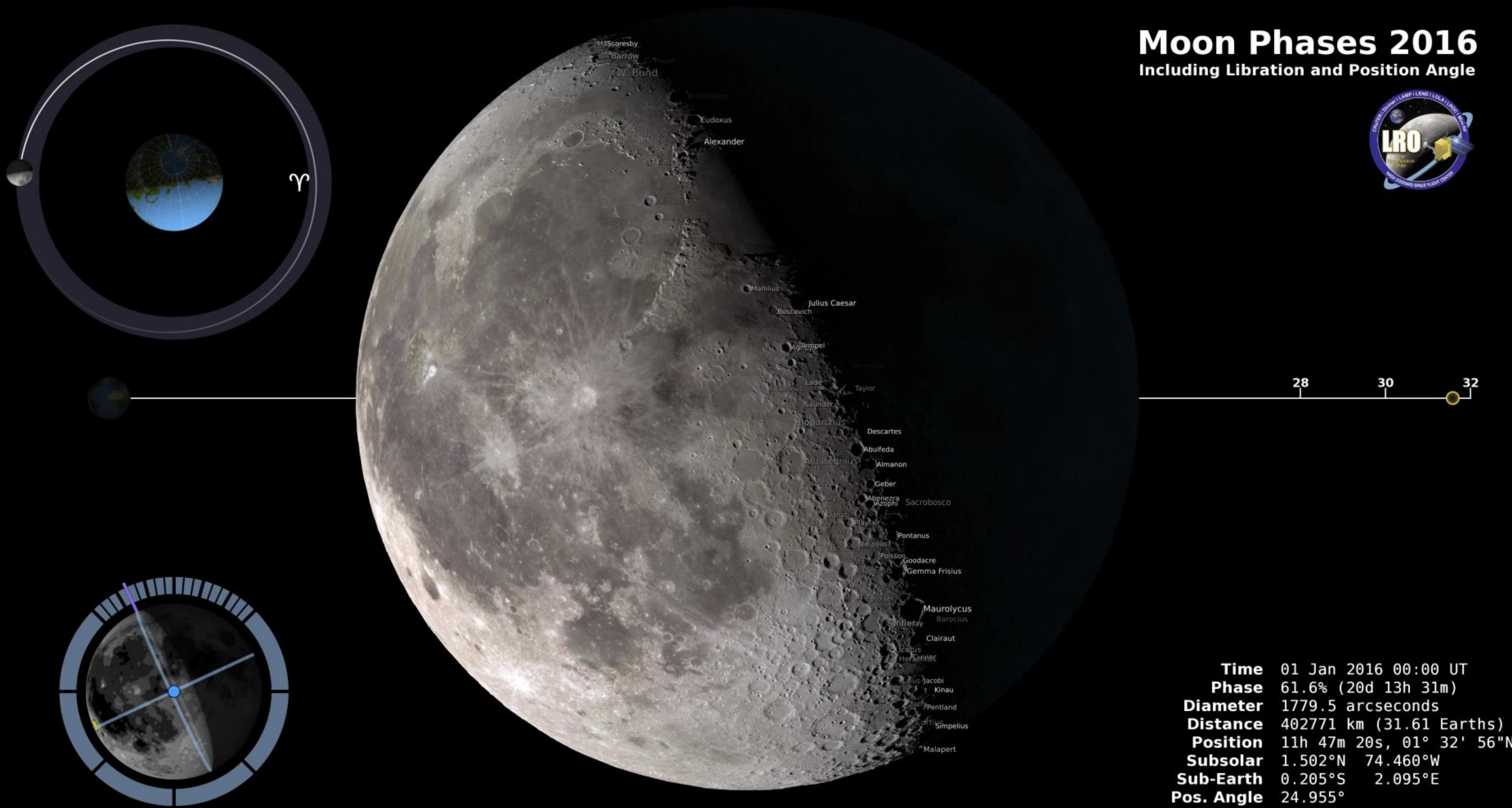
Grand Track Scenario (Walsh et al.)



…Migration of Gas Giants & Orbital resonnances Grand Track Scenario …



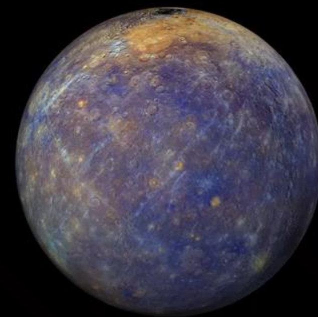



Moon Phases 2016
Including Libration and Position Angle
LRO
Scoresby
Barrow
W. Bond
Eudoxus
Alexander
Manilius
Julius Caesar
Boscovich
Tempel
Lade
Taylor
Saunder
Hipparchus
Descartes
Abulfeda
Almanon
Albategnius
Geber
Abenezra
Azophi
Sacrobosco
Playfair
Pontanus
Poisson
Goodacre
Gemma Frisius
Maurolycus
Barocius
Clairaut
Jacobi
Kinau
Pentland
Simpelius
Malapert
28
30
32
Time 01 Jan 2016 00:00 UT
Phase 61.6% (20d 13h 31m)
Diameter 1779.5 arcseconds
Distance 402771 km (31.61 Earths)
Position 11h 47m 20s, 01° 32' 56"N
Subsolar 1.502°N 74.460°W
Sub-Earth 0.205°S 2.095°E
Pos. Angle 24.955°

...LUNAR EVOLUTION ...

The Sun
Solar Dynamics
Observatory
2011

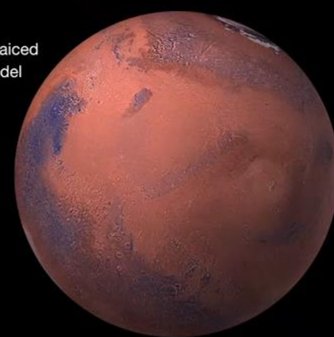
Mercury
Messenger
2011



Venus
Magellan
1990-1992

Earth
MODIS
2001

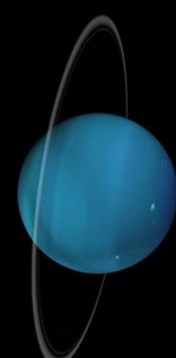
Mars
Viking/Mars Mosaiced
Digital Image Model
(MDIM)
1975/2015



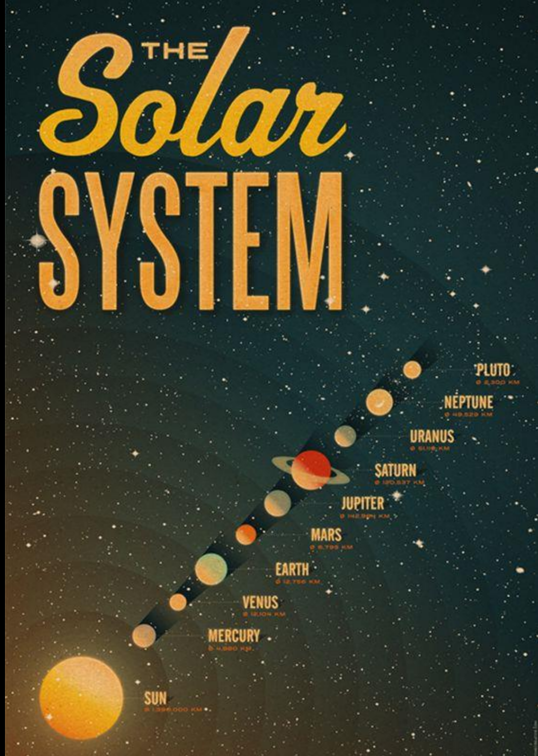
Jupiter
Hubble Space
Telescope
2015

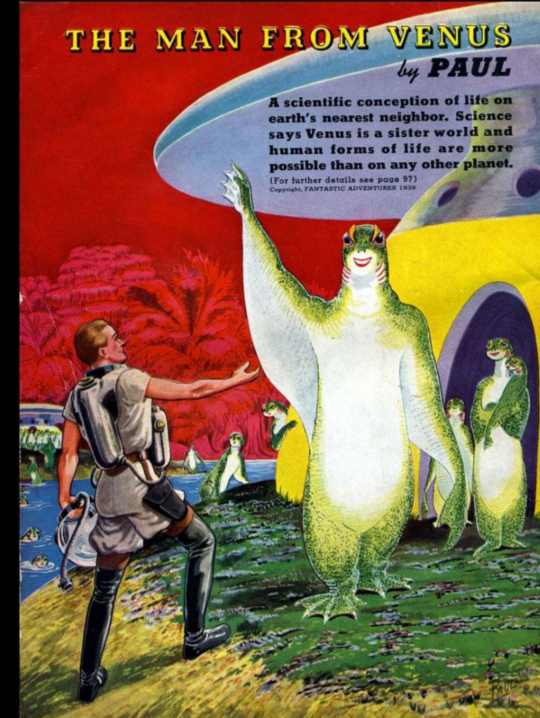
Saturn
Voyager/Cassini-Huygen
1980-'81/2008

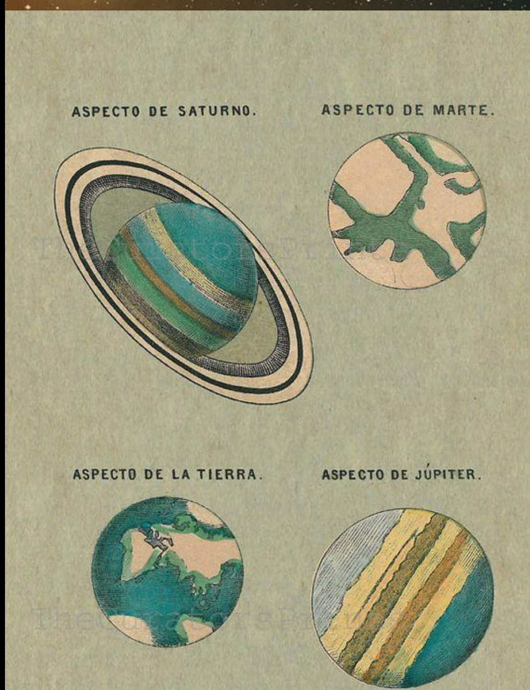
Uranus
W.M. Keck Observatory
2004



Neptune
Voyager
1989







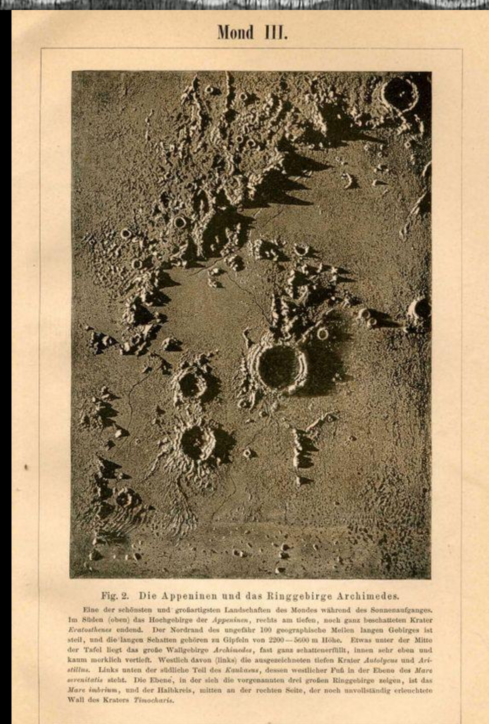
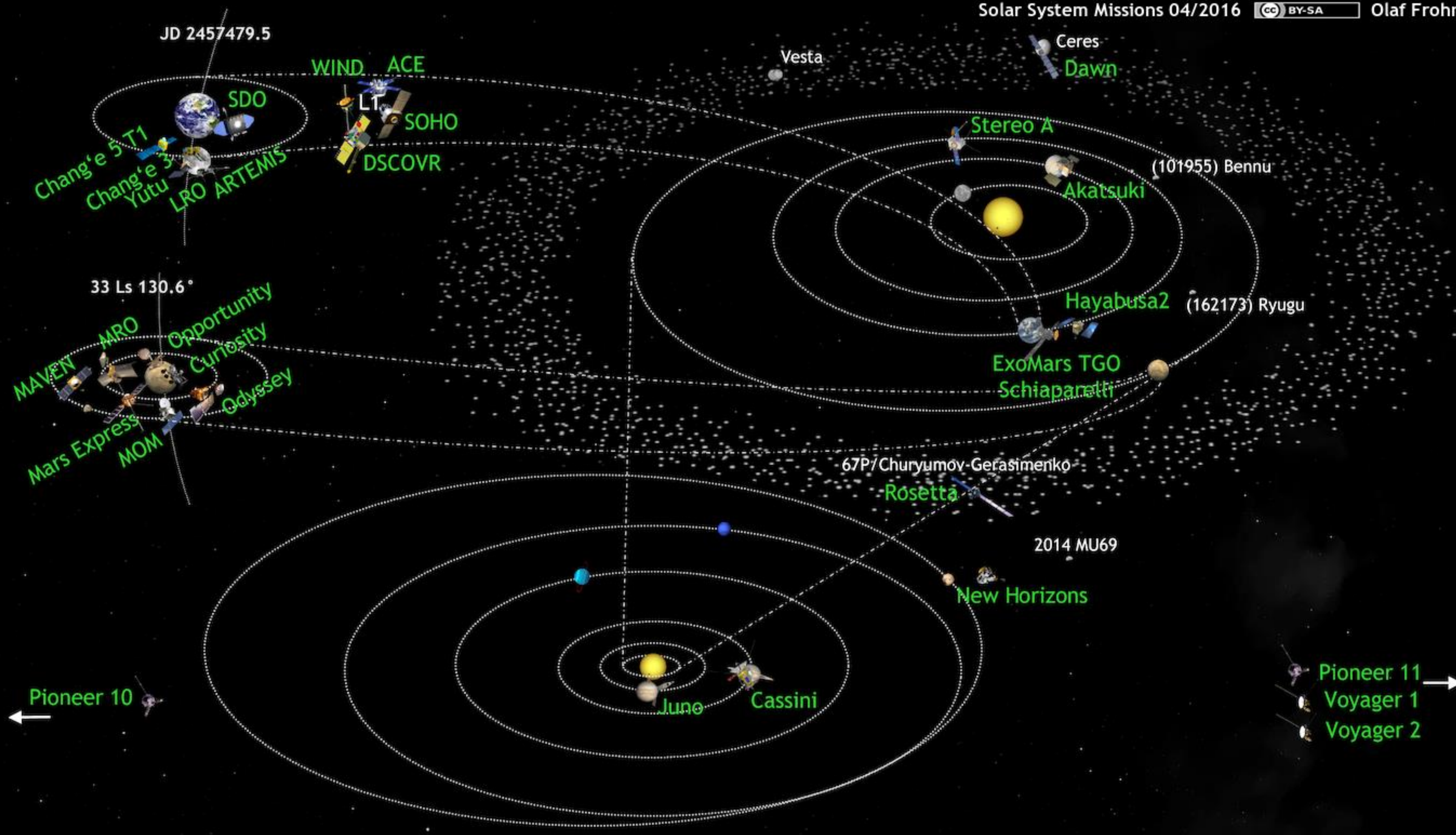

Mond III.

Fig. 2. Die Appeninen und das Ringgebirge Archimedes.

Eine der schönsten und großartigsten Landschaften des Mondes während des Sonnenaufganges. Im Süden (oben) das Hochgebirge der *Appeninen*, rechts am tiefen, noch ganz beschatteten Krater *Eratosthenes* endend. Der Nordrand des ungefähr 100 geographische Meilen langen Gebirges ist steil, und die langen Schatten gehören zu Gipfeln von 2200—5600 m Höhe. Etwas unter der Mitte der Tafel liegt das große Wallgebirge *Archimedes*, fast ganz schattenerfüllt, innen sehr eben und kaum merklich vertieft. Westlich davon (links) die ausgezeichneten tiefen Krater *Autolycus* und *Aristillus*. Links unten der südliche Teil des *Kaukasus*, dessen westlicher Fuß in der Ebene des *Mare serenitatis* steht. Die Ebene, in der sich die vorgenannten drei großen Ringgebirge zeigen, ist das *Mare imbrium*, und der Halbkreis, mitten an der rechten Seite, der noch unvollständig erleuchtete Wall des Kraters *Timocharis*.



Upcoming Events

2016

Jul: Juno OI Jupiter
Sep: OSIRIS-REx Launch
Sep: Rosetta EOM/SL 67P/Chury
Sep: Lightsail 2 Launch
Oct: ExoMars TGO OI Mars
Oct: ExoMars/Schiaparelli EDL Mars
Oct: Juno Science Orbit Jupiter

FB: Flyby; OI: Orbit Insertion; App: Approach; Dep: Departure; Imp: Impact
EDL: Entry, Descent and Landing; SL: Soft Landing; EOM: End of Mission

2017

Jan: Bepi-Colombo Launch to Merc.
Sep: Cassini EOM
Chang'e 5 Launch/SL Moon
Chandrayaan 2 Launch/SL Moon
Solar Orbiter Launch

2018

Mar: Juno EOM
May: ExoMars Rover Launch
May: InSIGHT Launch to Mars
May: MarCO Launch to Mars
Jun: Chang'e 4 Relay Launch/OI Moon
Sep: OSIRIS-REx App Bennu
Chang'e 4 Launch/SL Moon
Hayabusa2 App/SL Ryugu
DSO Launch to Earth/Sun L1
Orion EM-1 Launch/FB Moon
+10 EM-1 Cubesats Launch/OI/FB Moon/Heliocentric Orbit
Solar Probe Plus Launch

2019

Jan: ExoMars Rover EDL Mars
Oct: OSIRIS-REx Sample Acq. Bennu
New Horizons FB 2014 MU69
Hayabusa2 Sample acq. Ryugu
Luna 25 Lander Launch

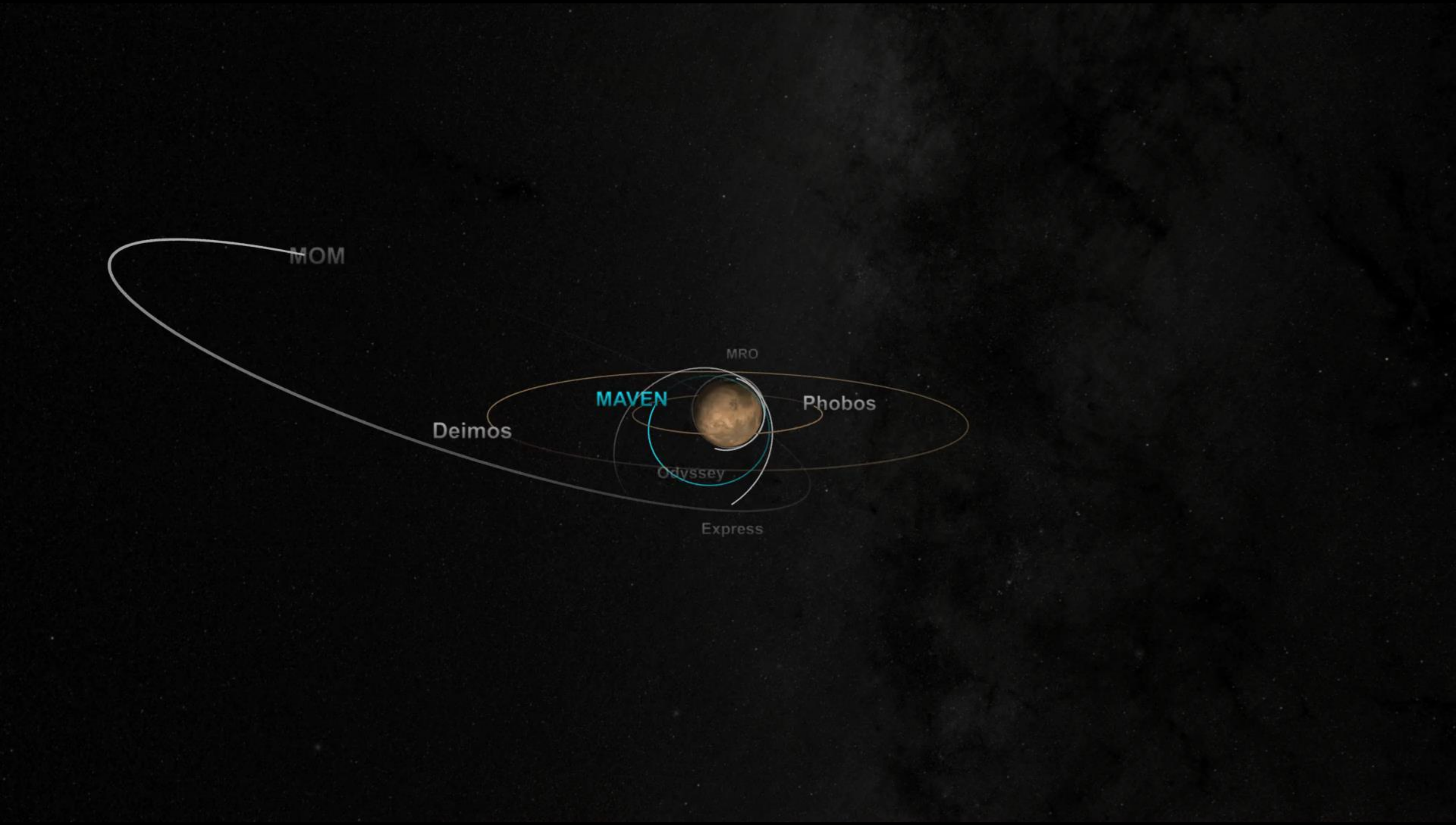
2020

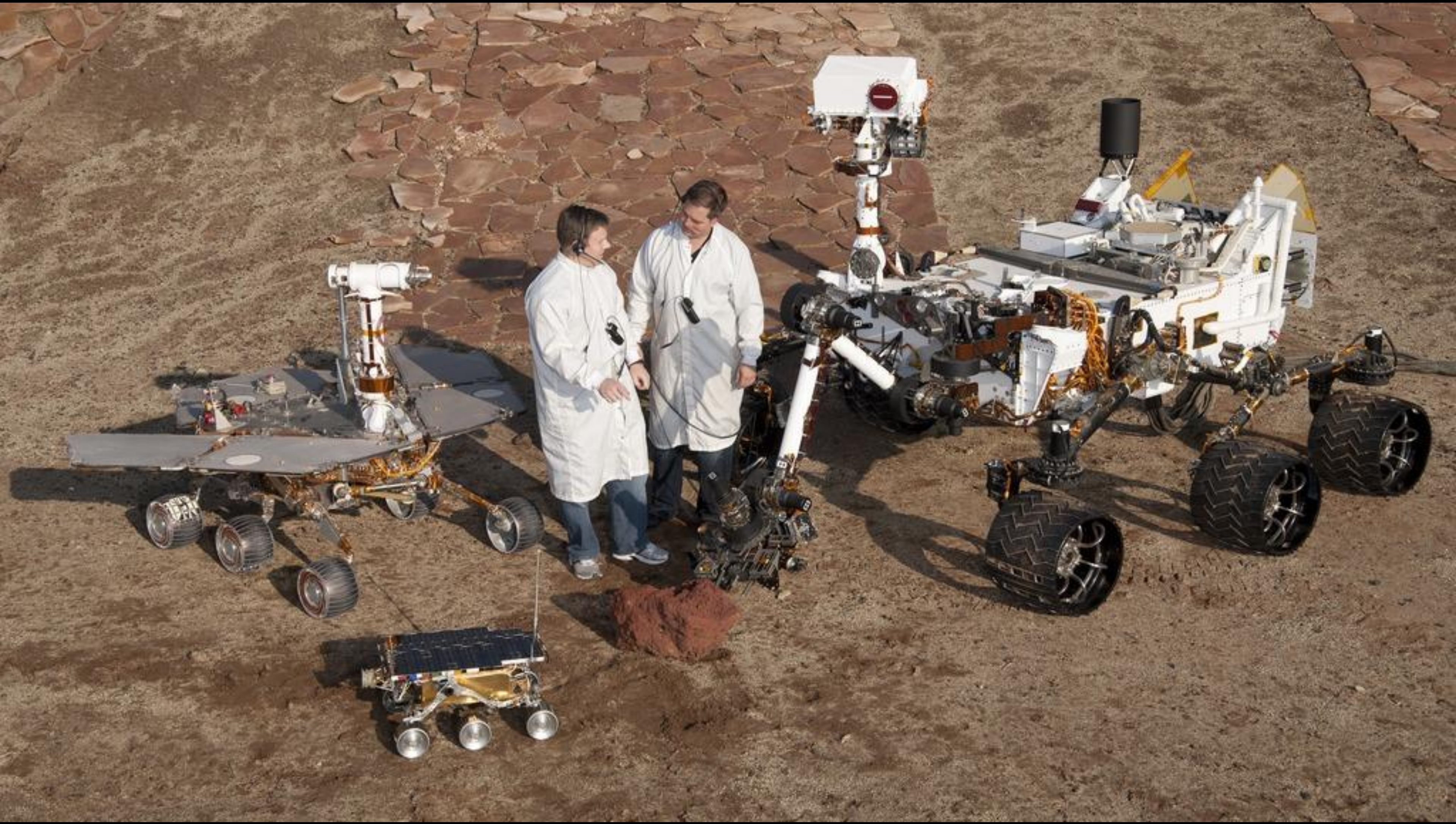
2020 Mars Rover Launch
Chang'e 6 Launch/SL Moon
Hayabusa 2 EDL Earth
Mars Hope Launch to Mars
MGRSO Launch to Mars

2021+

Mar: OSIRIS-REx Dep Bennu
Luna 26 Orbiter Launch
[Chinese Asteroid FB] Launch (2022)
EMFM Launch to Jupiter (2022?)
EM-2 Launch to Cislunar Space (2022)
JUICE Launch to Jupiter (2022)
OSIRIS-REx EDL Earth (2023)
Luna 27 Lander Launch (2023)
Bepi-Colombo OI Mercury (2024)

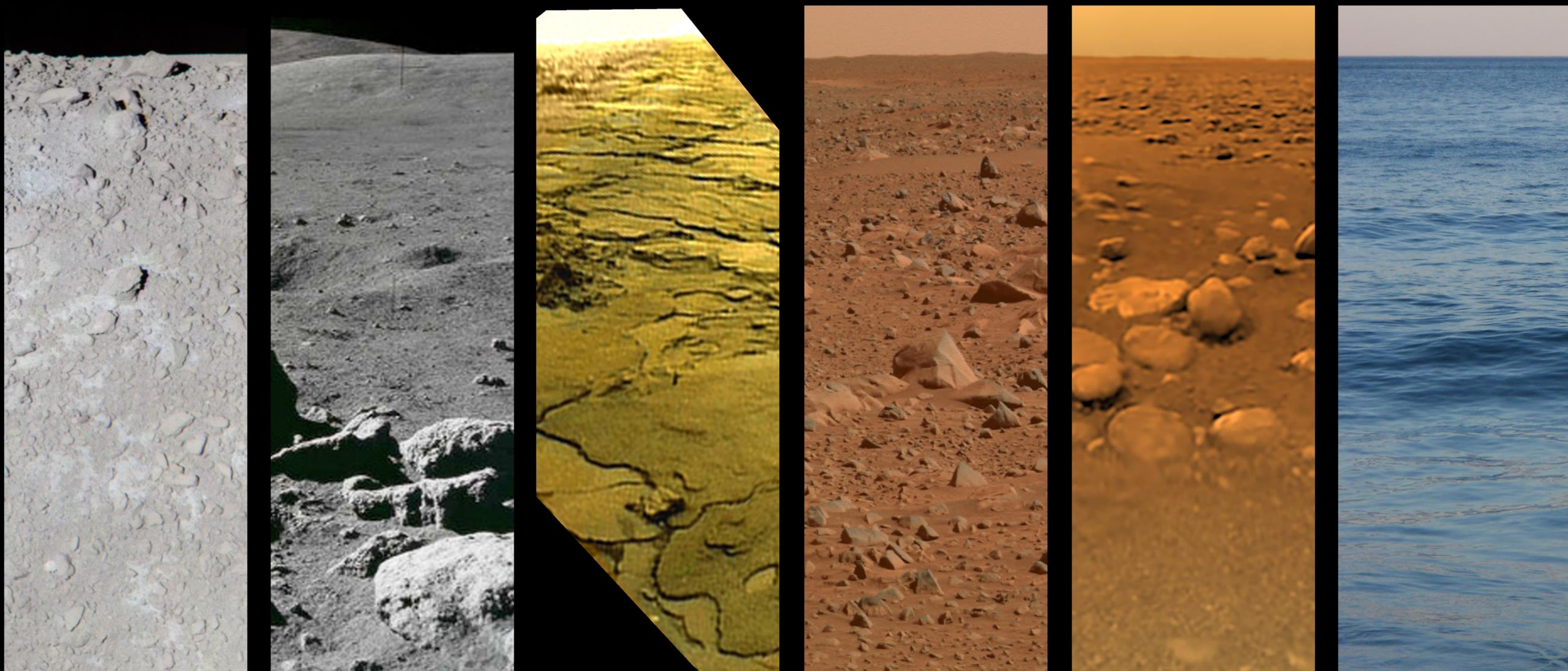
Mars Fleet





Opportunity's climb out of Victoria crater.

The images used to create this animation were taken on the three days Opportunity spent driving out of the crater on Aug. 24, 26 and 28, 2008 (Sols 1630, 1632 and 1634)



Distant Horizons - Different Surfaces

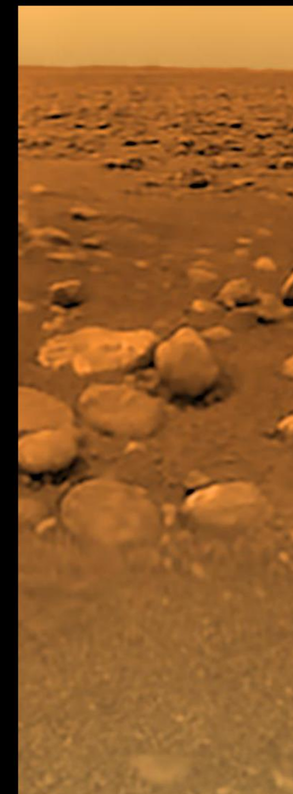
Asteroid Itokawa

Moon

Venus

Mars

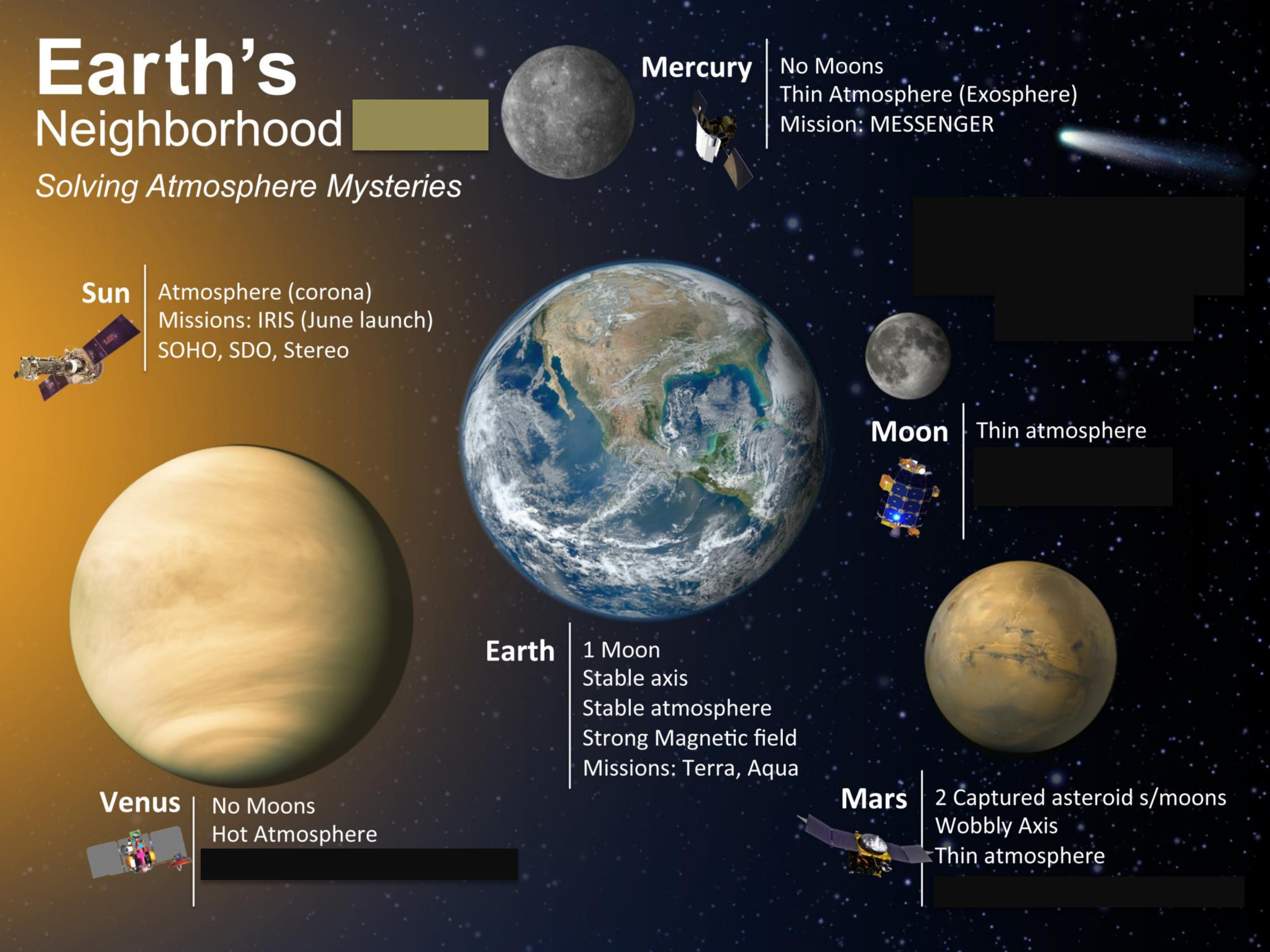
Titan



Earth

Image Credits:
Asteroid Itokawa [Hayabusa]: ISAS / JAXA / Gordan Ugarkovic
Moon [Apollo 17]: NASA
Venus [Venera 14]: IKI / Don Mitchell / Ted Stryk / Mike Malaska
Mars [Mars Exploration Rover Spirit]: NASA / JPL / Cornell / Mike Malaska
Titan [Cassini Huygens]: ESA / NASA / JPL / University of Arizona
Earth: Mike Malaska

Composition by Mike Malaska


Earth's
Neighborhood
Solving Atmosphere Mysteries
Mercury
No Moons
Thin Atmosphere (Exosphere)
Mission: MESSENGER
[redacted]
Sun
Atmosphere (corona)
Missions: IRIS (June launch)
SOHO, SDO, Stereo
Moon
Thin atmosphere
[redacted]
Earth
1 Moon
Stable axis
Stable atmosphere
Strong Magnetic field
Missions: Terra, Aqua
Venus
No Moons
Hot Atmosphere
[redacted]
Mars
2 Captured asteroid s/moons
Wobbly Axis
Thin atmosphere
[redacted]

EARTH & MARS

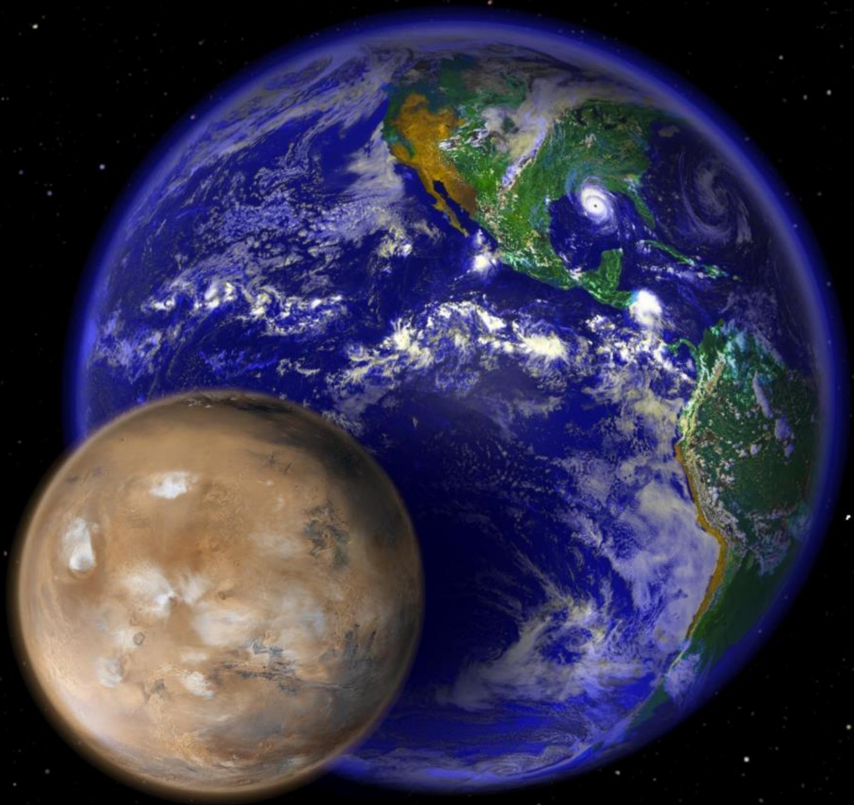
AS DIFFERENT AS THEY ARE ALIKE

Both Earth and Mars have canyons, valleys, craters, volcanoes, ice caps, storms, and seasons.

Mars is half the diameter of Earth, but both planets have the same amount of dry land.

Earth's atmosphere is 77% nitrogen and 21% oxygen. Mars' atmosphere is 95% carbon dioxide.

Mars has four seasons, just like Earth, but each one lasts twice as long.

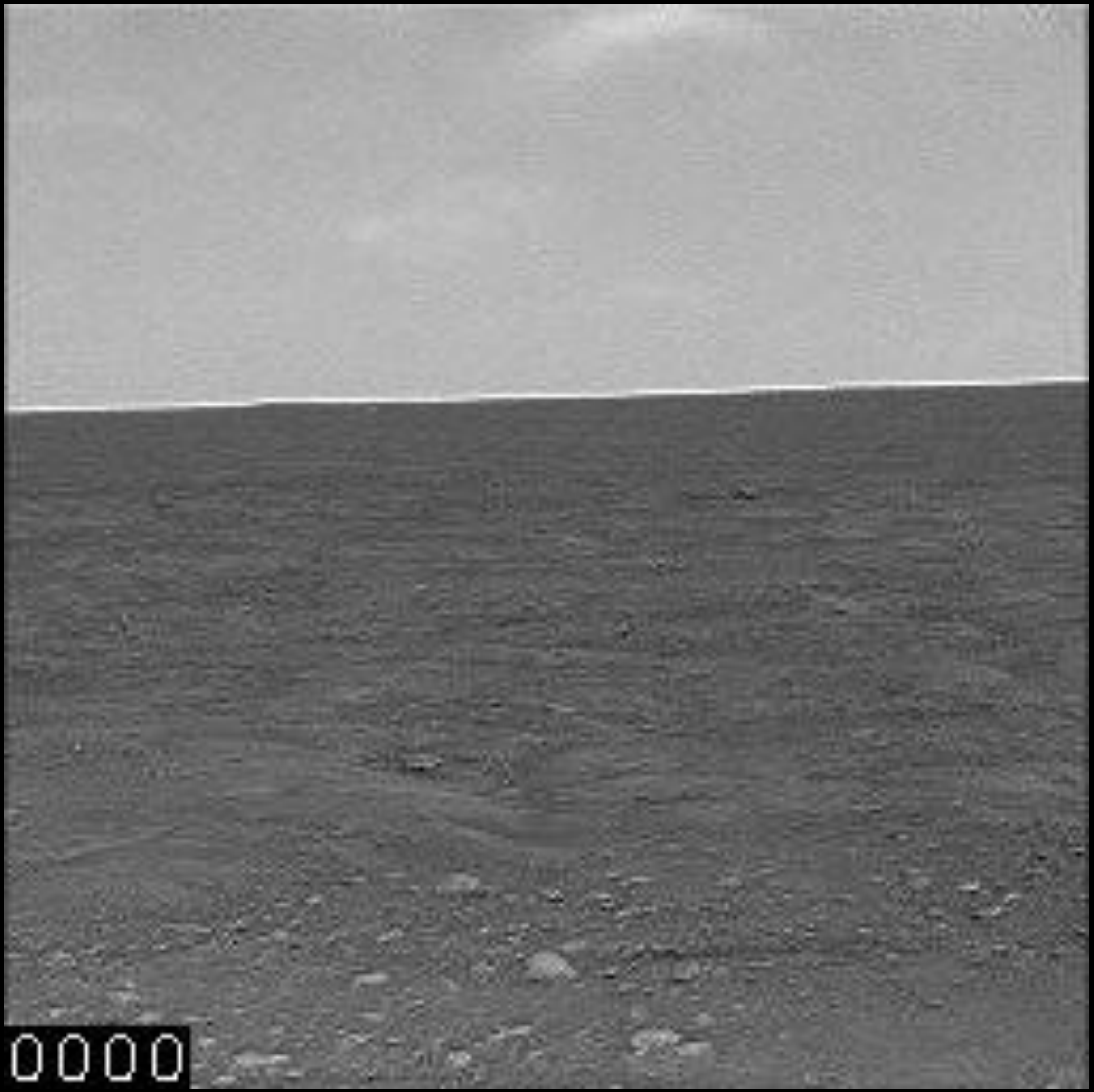


Explore Mars

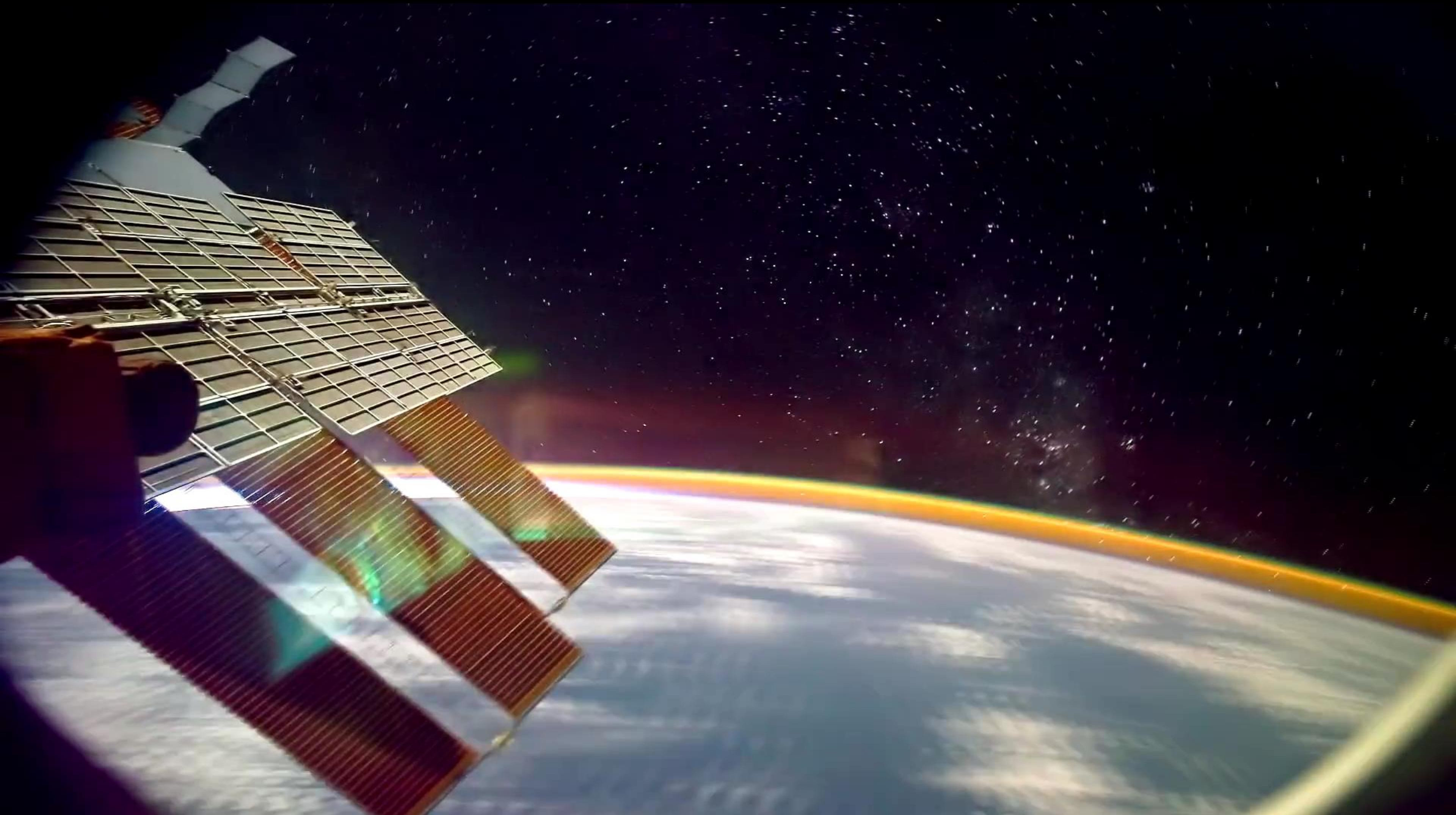
http:/ / mars.jpl.nasa.gov

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

JPL 400-935 3/01/01
EW-2001-02-009-JPL

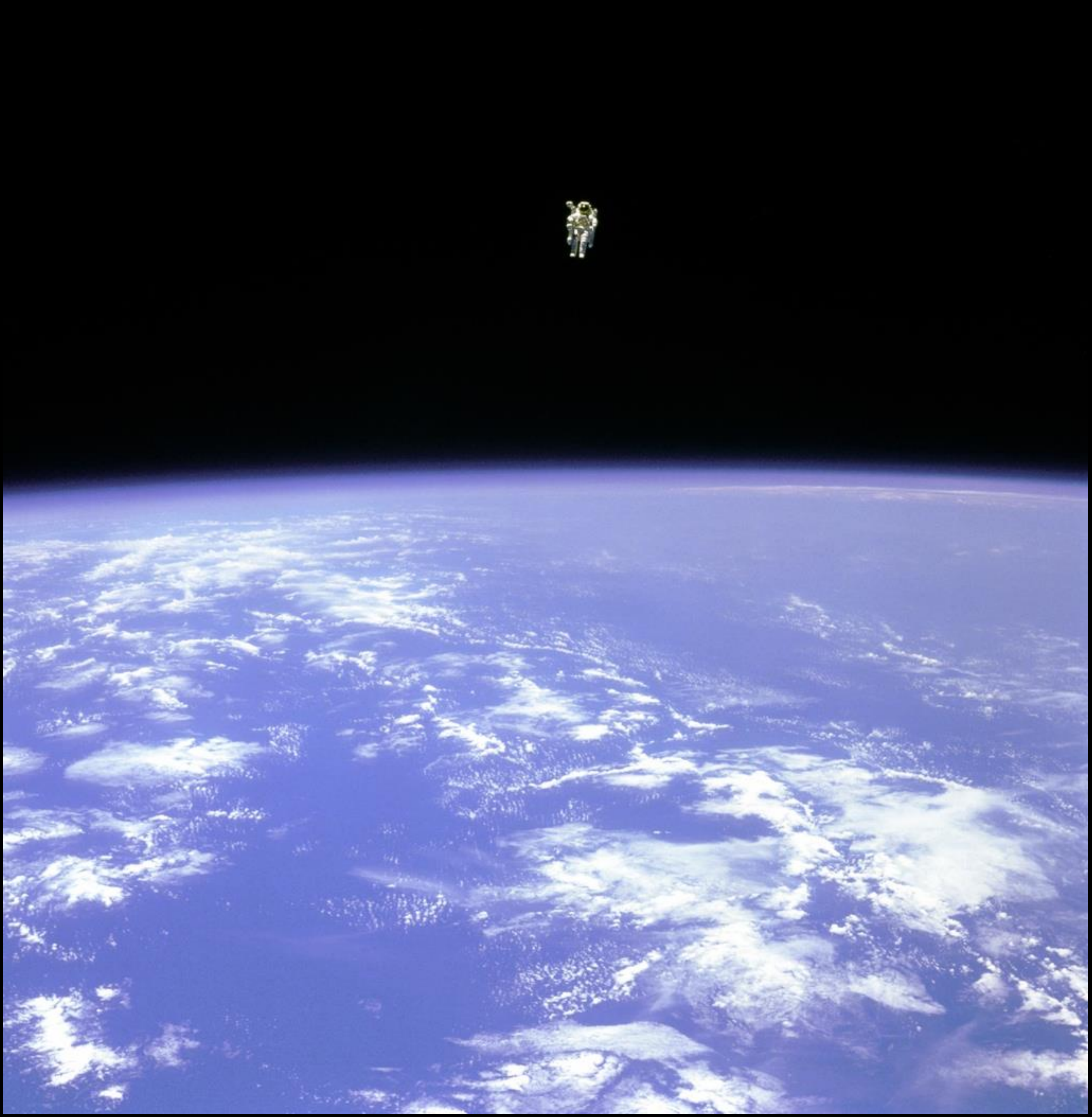


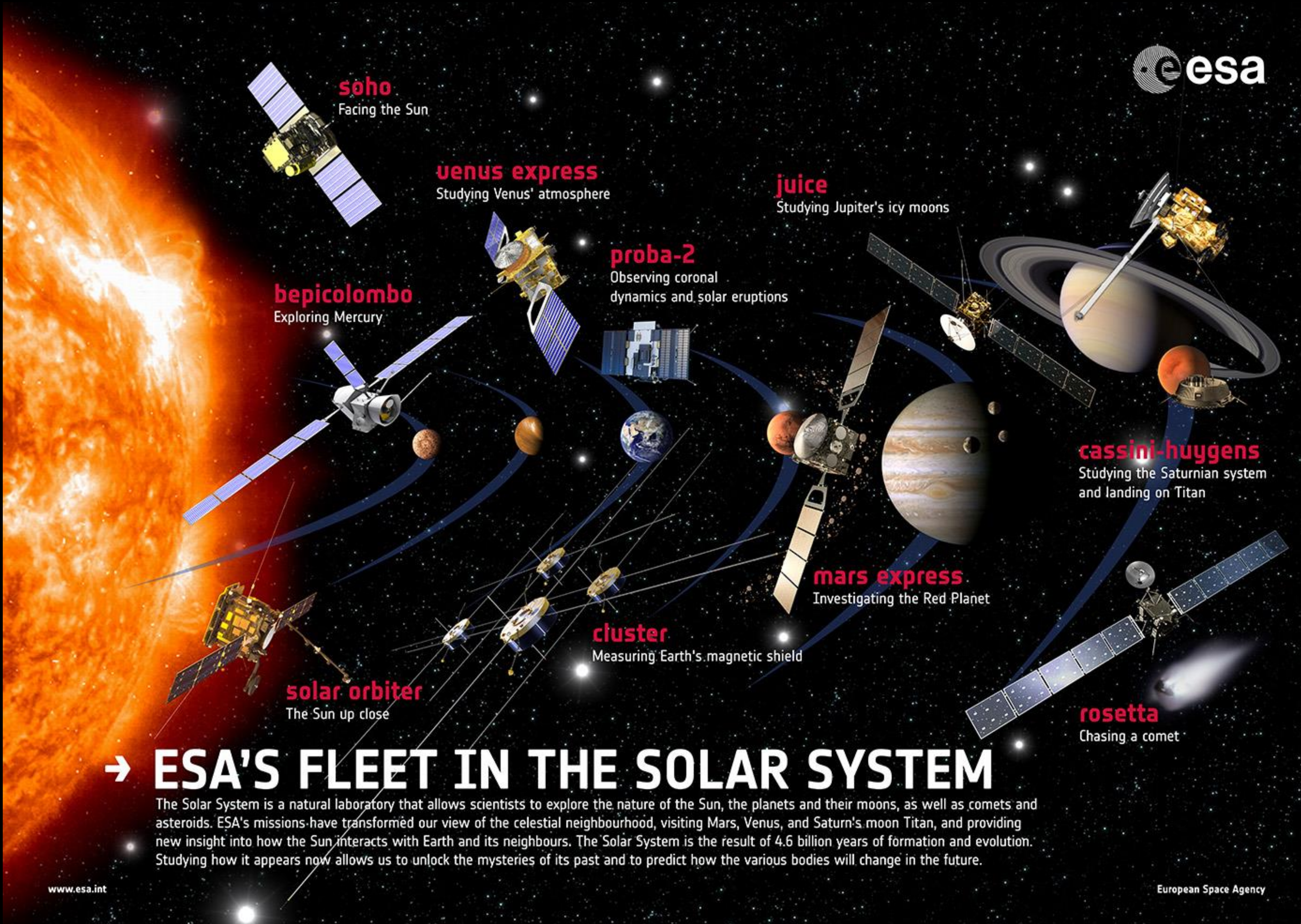
This sequence combines 32 images of clouds moving eastward across a Martian horizon. The Surface Stereo Imager on NASA's Phoenix Mars Lander took this set of images on Sept. 18, 2008, during early afternoon hours of the 113th Martian day of the mission.




You are here

Even higher in the Martian sky, the Earth and Moon hang in space, as seen from Mars. The HiRISE camera onboard the Mars Reconnaissance Orbiter acquired this image at 5:20 a.m. MST on October 3rd, 2007, at a range of 142 million kilometers, while orbiting Mars.




esa
soho
Facing the Sun
venus express
Studying Venus' atmosphere
juice
Studying Jupiter's icy moons
proba-2
Observing coronal
dynamics and solar eruptions
bepicolombo
Exploring Mercury
cassini-huygens
Studying the Saturnian system
and landing on Titan
mars express
Investigating the Red Planet
cluster
Measuring Earth's magnetic shield
solar orbiter
The Sun up close
rosetta
Chasing a comet
→ ESA'S FLEET IN THE SOLAR SYSTEM
The Solar System is a natural laboratory that allows scientists to explore the nature of the Sun, the planets and their moons, as well as comets and asteroids. ESA's missions have transformed our view of the celestial neighbourhood, visiting Mars, Venus, and Saturn's moon Titan, and providing new insight into how the Sun interacts with Earth and its neighbours. The Solar System is the result of 4.6 billion years of formation and evolution. Studying how it appears now allows us to unlock the mysteries of its past and to predict how the various bodies will change in the future.
www.esa.int
European Space Agency


esa


E X O M A R S

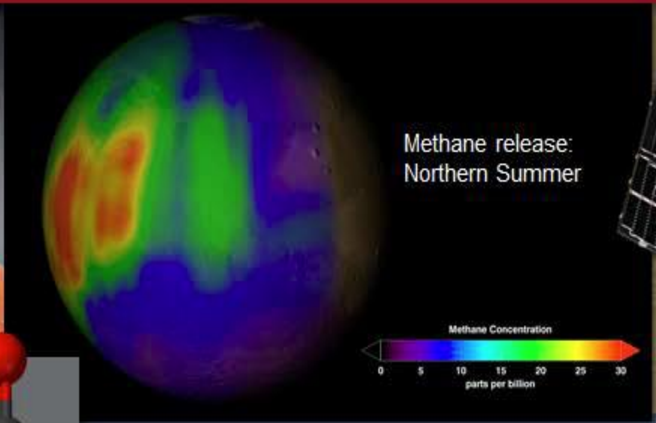
2016

TECHNOLOGY OBJECTIVE

- Entry, Descent, and Landing (EDL) of a payload on the surface of Mars.

SCIENTIFIC OBJECTIVES

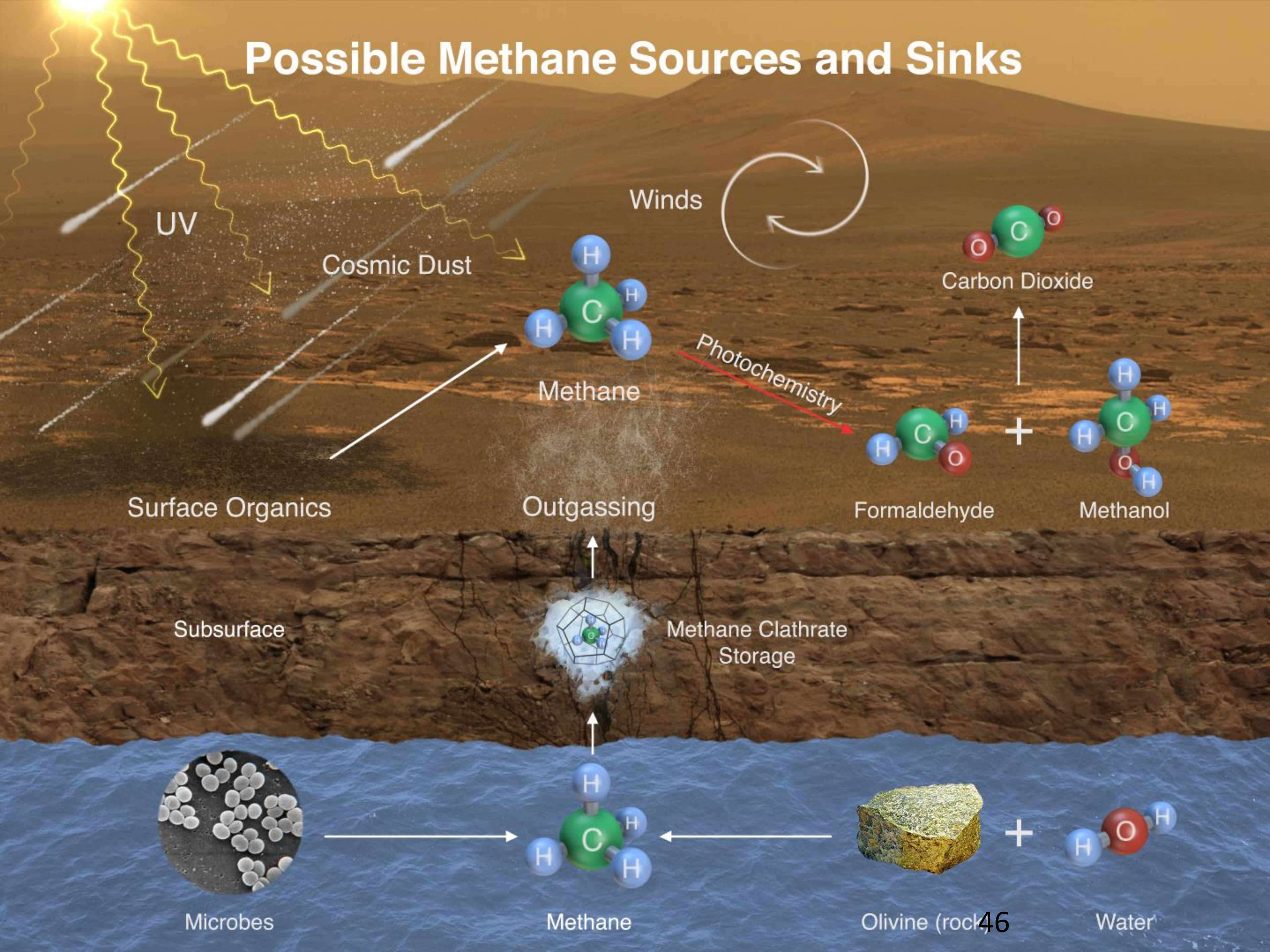
- To study Martian atmospheric trace gases and their sources;
- To conduct surface environment measurements.



- Data relay services for landed missions until 2022.

Courtesy: H. Svedhem (ESA)

Credit: Mamers Valles, MEX/HRSC


Possible Methane Sources and Sinks
UV
Cosmic Dust
Winds
Carbon Dioxide
Methane
Photochemistry
Surface Organics
Outgassing
Formaldehyde
Methanol
Subsurface
Methane Clathrate
Storage
Microbes
Methane
Olivine (rock)
Water

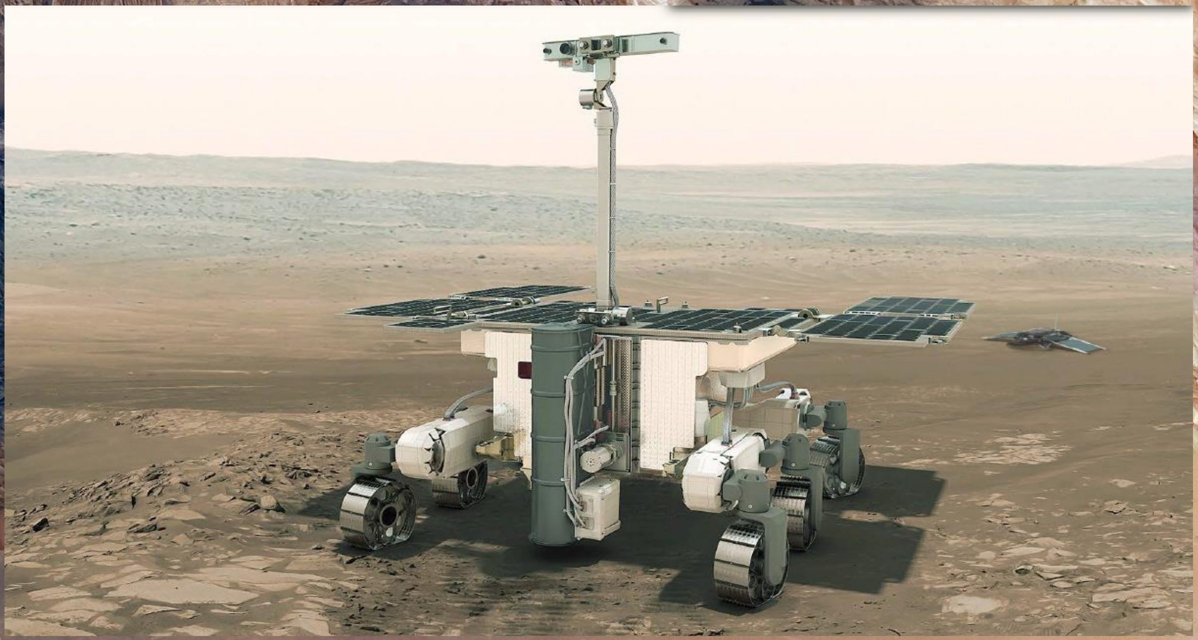
TECHNOLOGY OBJECTIVES

- Surface mobility with a rover (having several kilometers range);
- Access to the subsurface to acquire samples (with a drill, down to 2-m depth);
- Sample acquisition, preparation, distribution, and analysis.

2018

SCIENTIFIC OBJECTIVES

- To search for signs of past and present life on Mars;
- To characterize the water/subsurface environment as a function of depth in the shallow subsurface:
- To characterize the surface environment

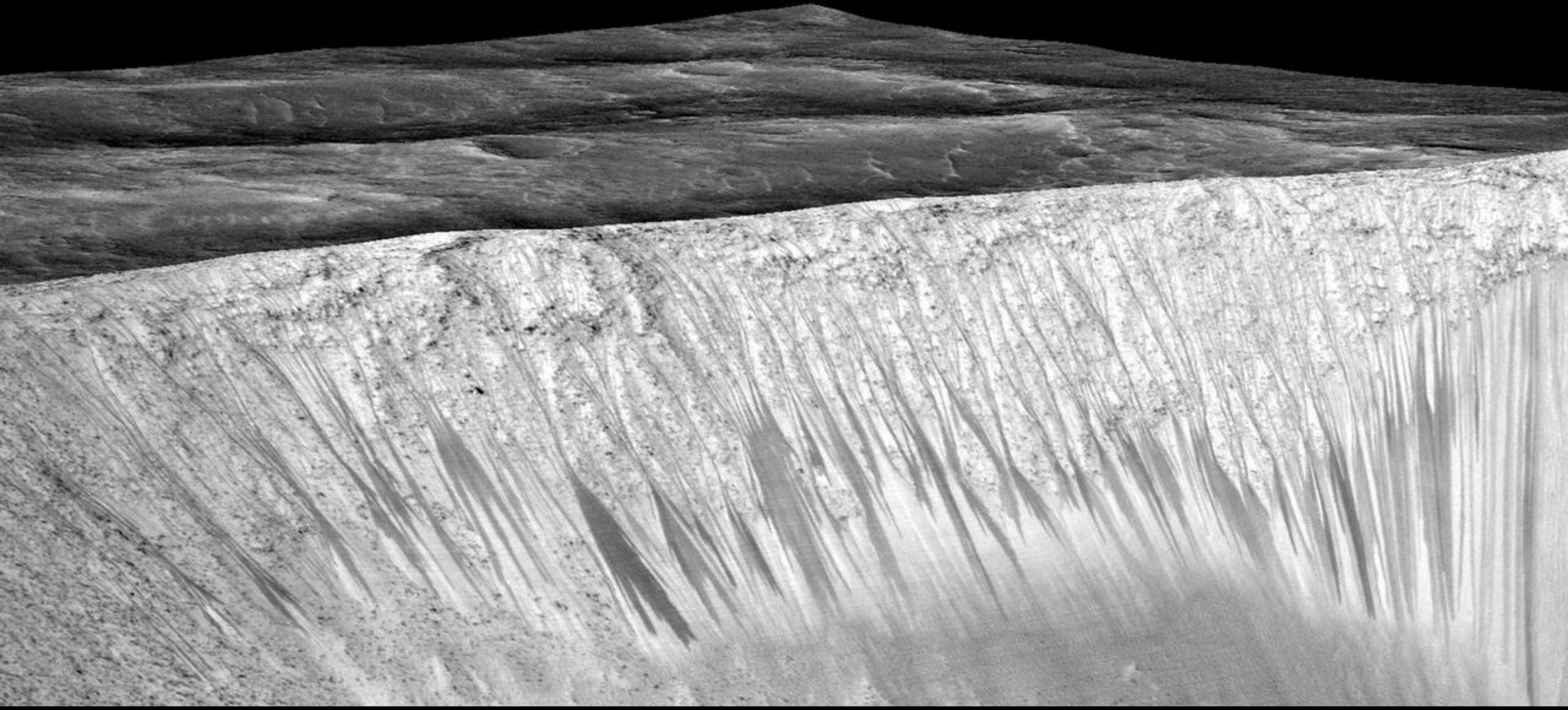


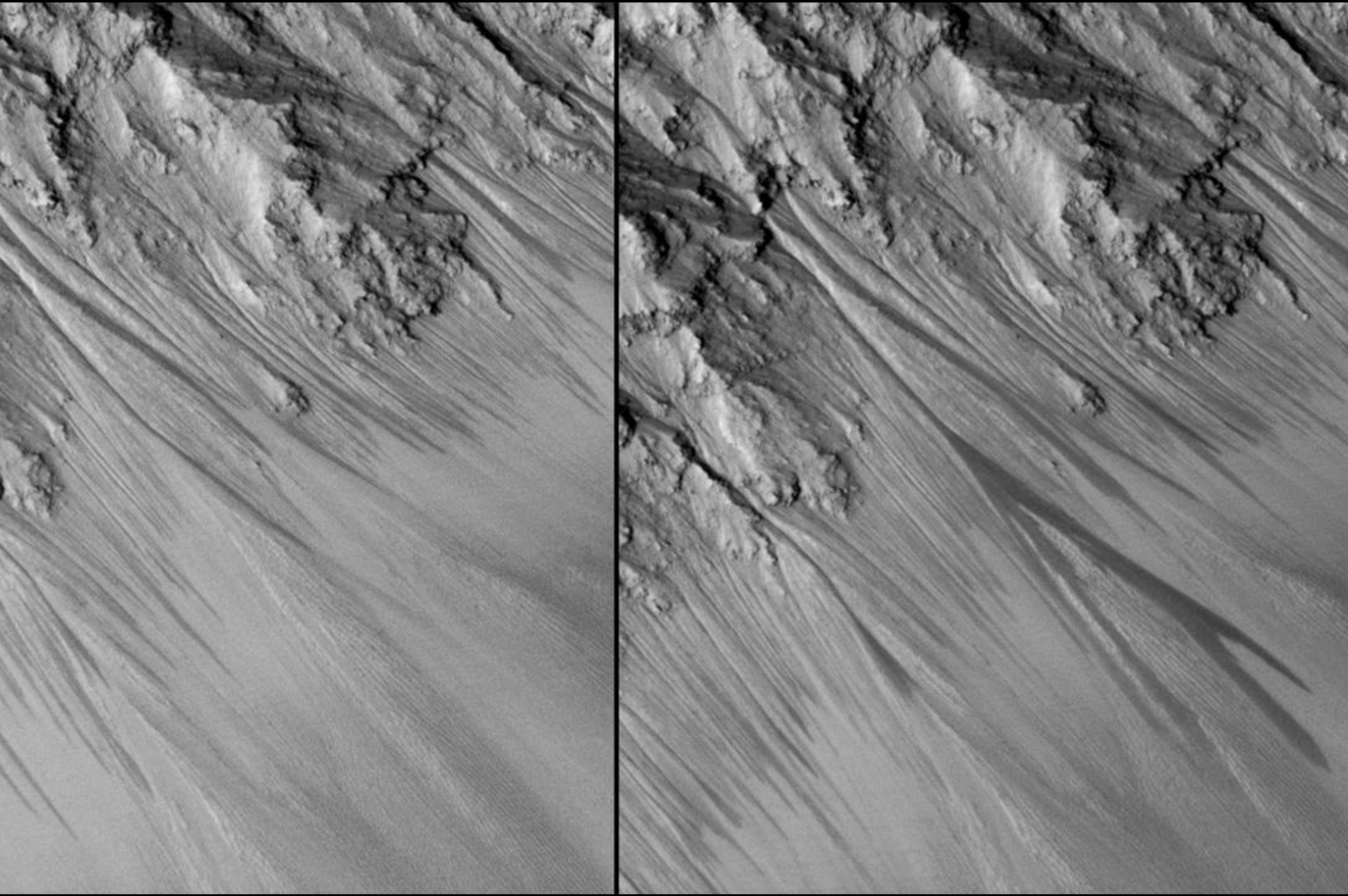
Credit: Hebes Chasma, MEX/HRSC

West Rim of Endeavour Crater on Mars

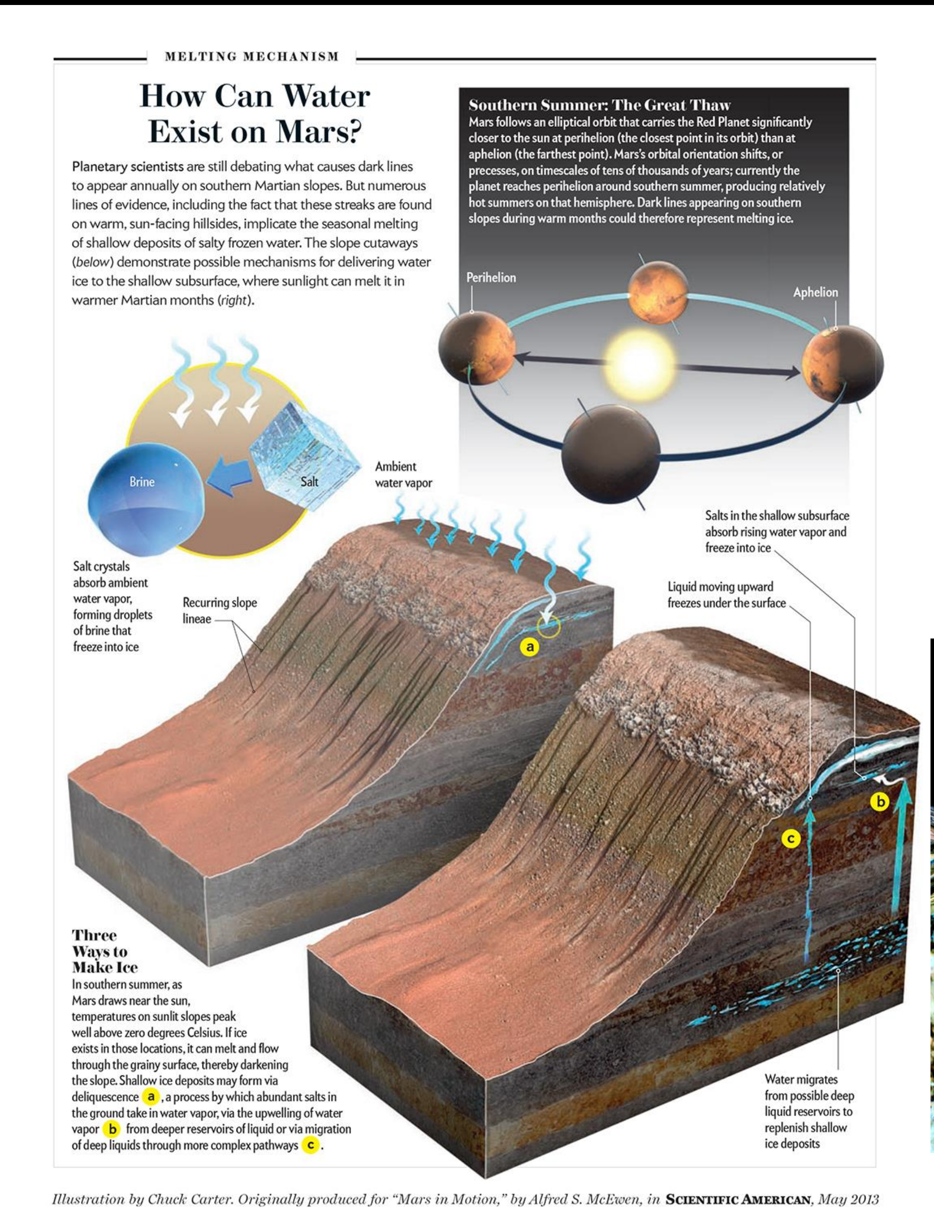
A dust devil on Mars photographed by the Spirit rover on Sol 486 (the 486th day of the Martian year). Credit: NASA

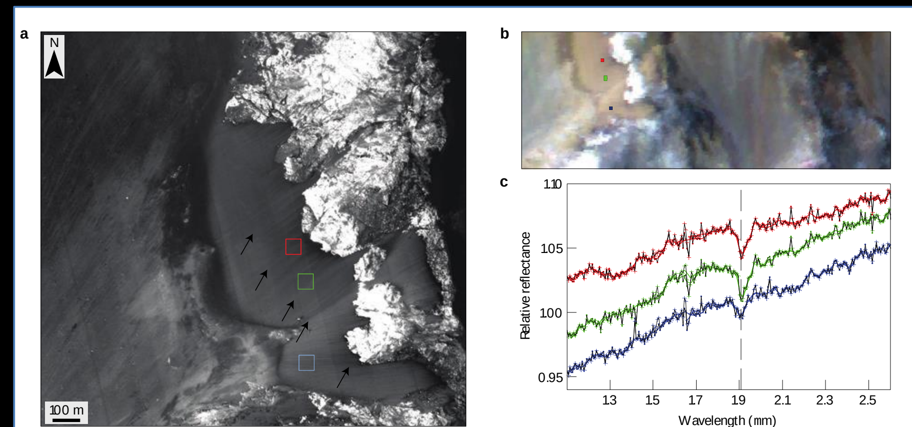
a large dust devil across the Arizona desert

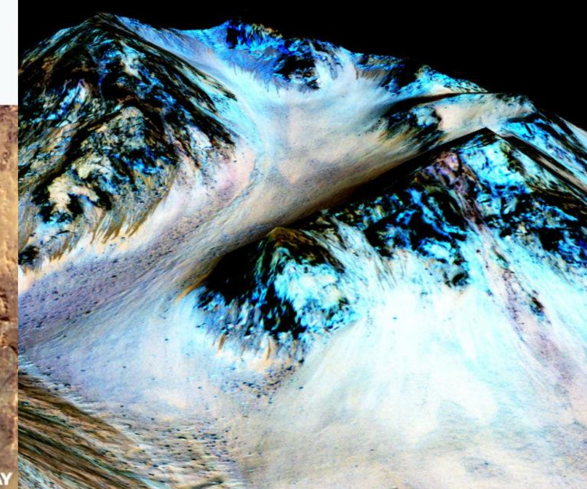


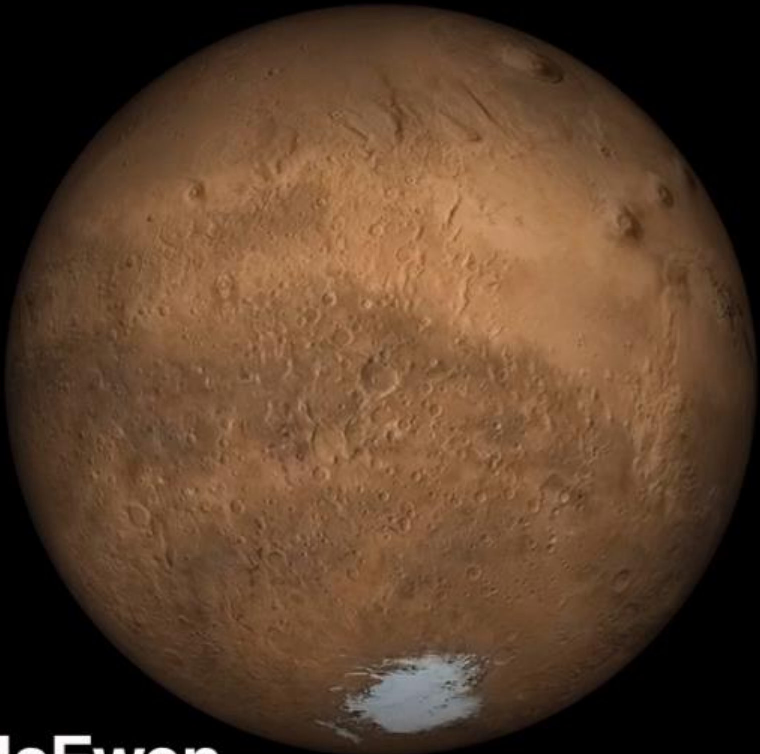


Liquid Water : Seasonal flows on warm Martian slopes, Recurring Slope Lineae (RSL)

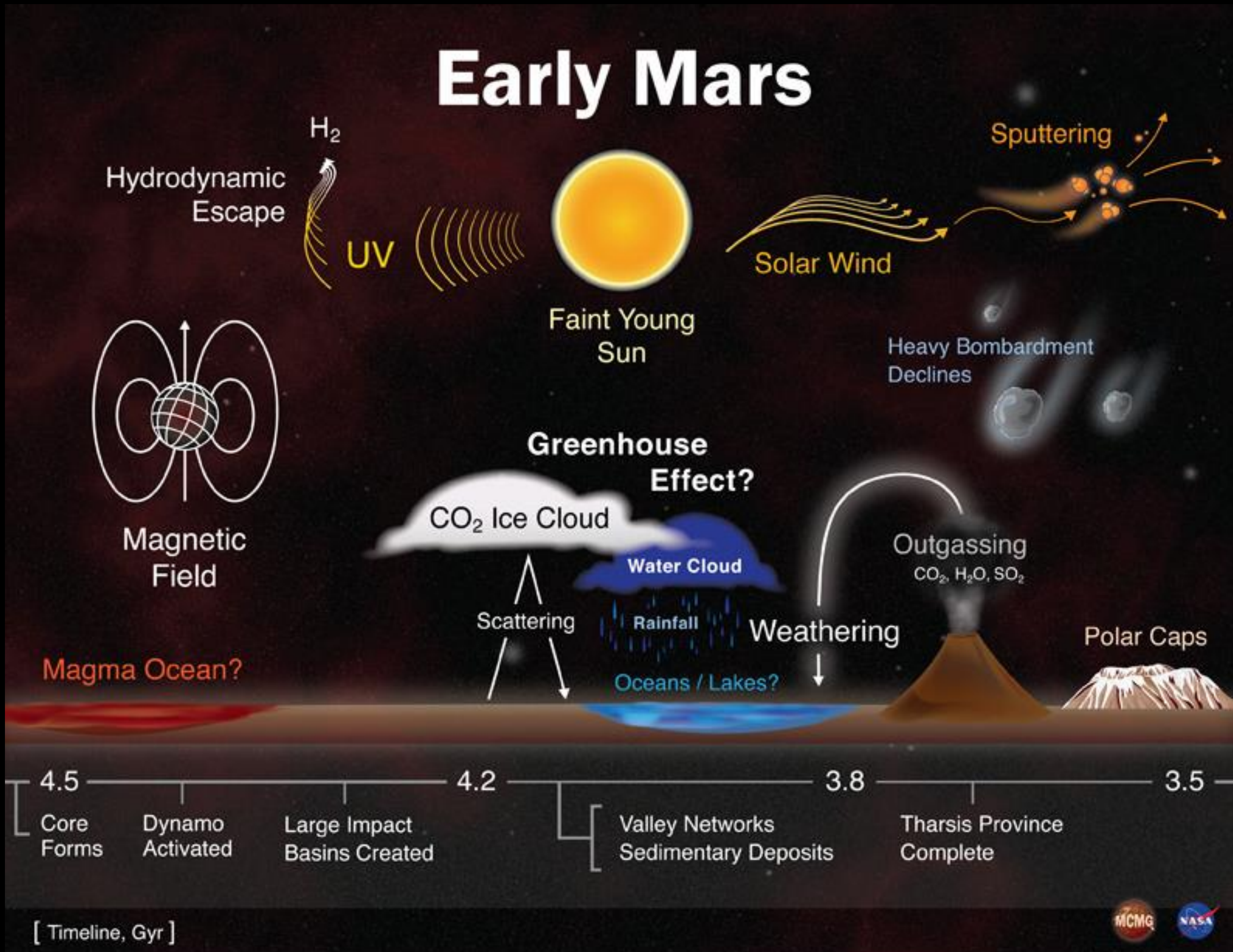




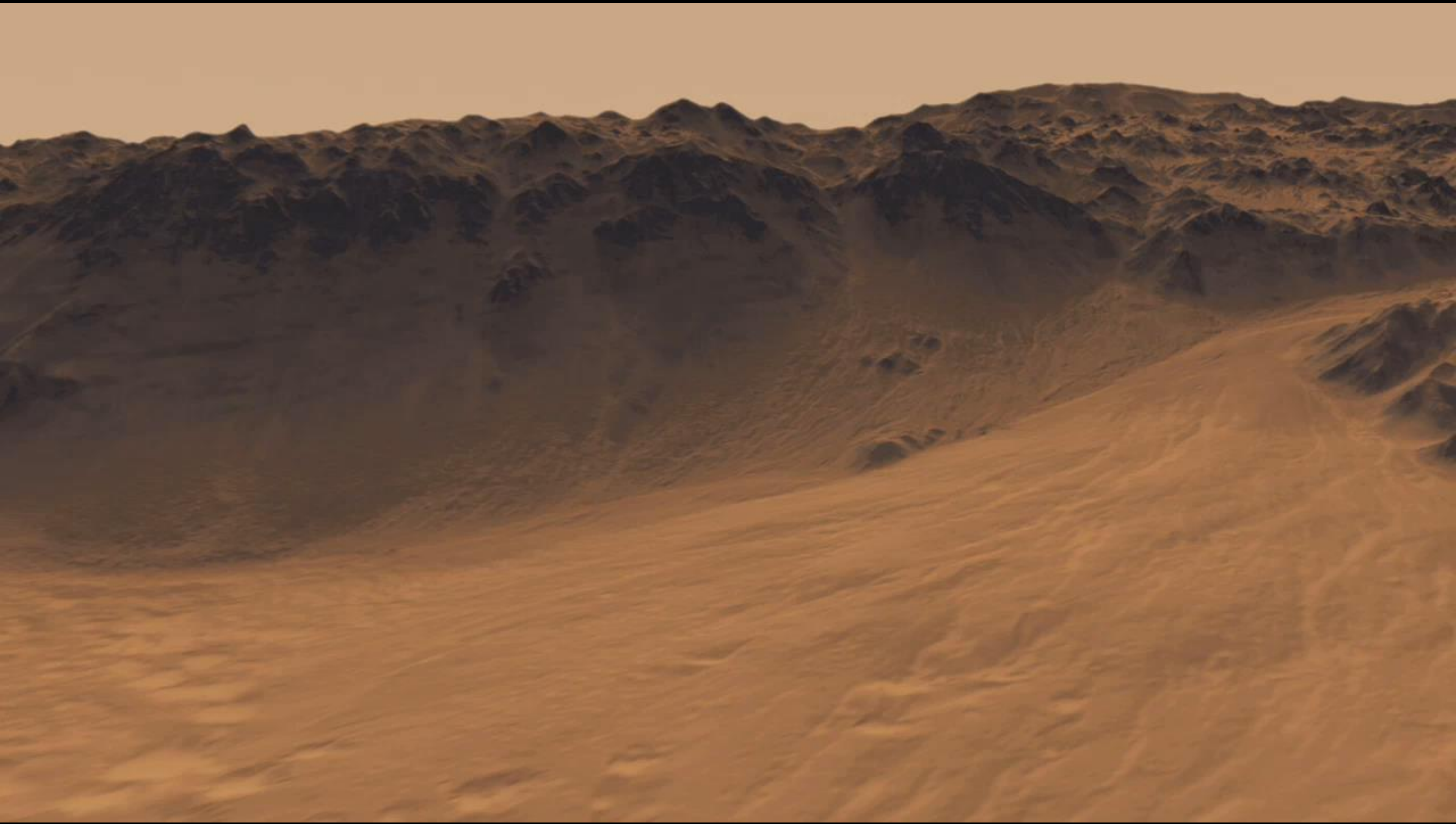


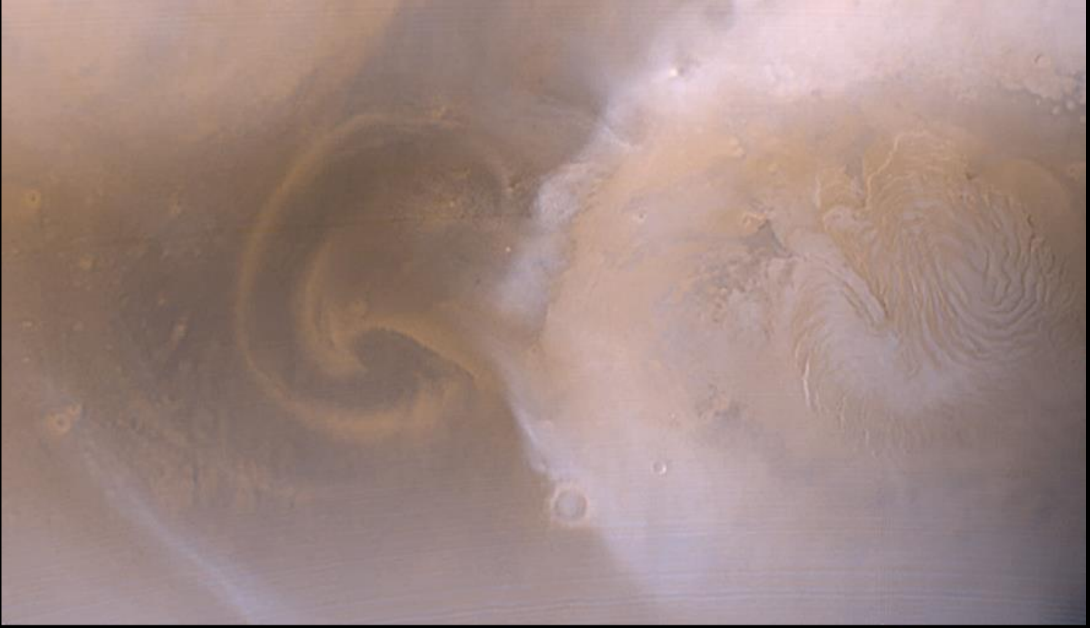


Alfred McEwen
HiRISE instrument Principal Investigator,
University of Arizona, Tucson

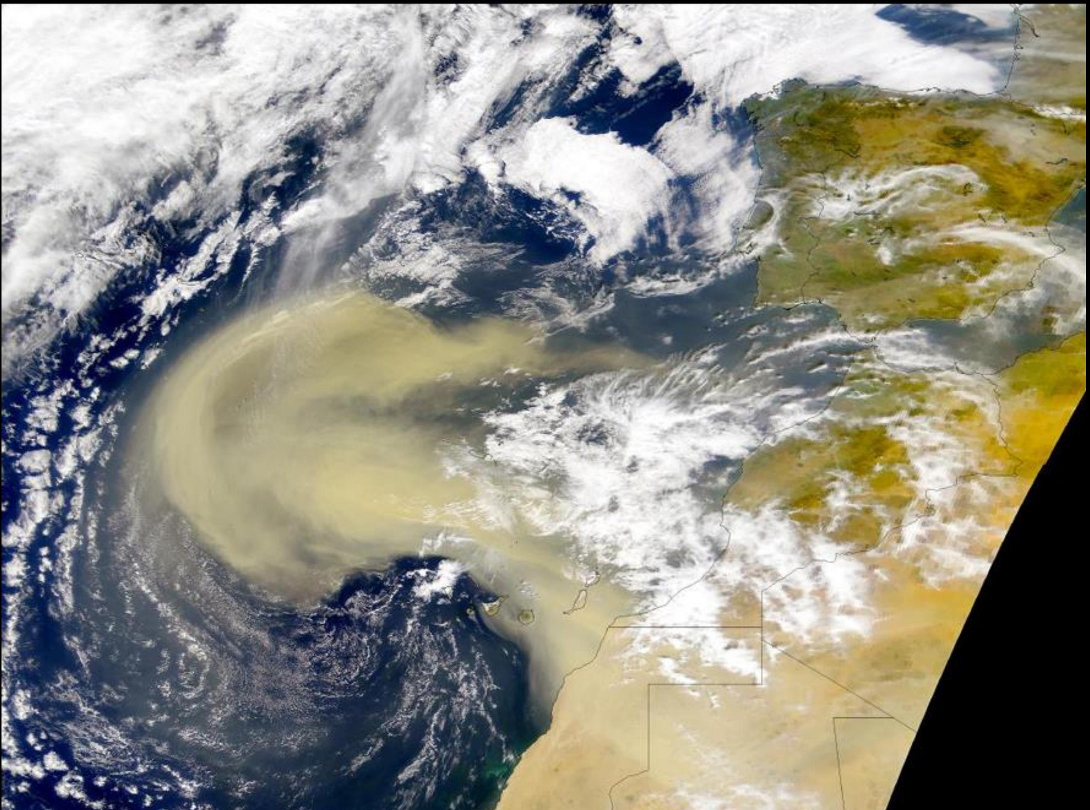


Early Mars
H_2
Hydrodynamic Escape
UV
Faint Young Sun
Solar Wind
Sputtering
Heavy Bombardment Declines
Magnetic Field
Greenhouse Effect?
CO_2 Ice Cloud
Water Cloud
Scattering
Rainfall
Weathering
Outgassing
CO_2, H_2O, SO_2
Polar Caps
Magma Ocean?
Oceans / Lakes?
4.5
4.2
3.8
3.5
Core Forms
Dynamo Activated
Large Impact Basins Created
Valley Networks
Sedimentary Deposits
Tharsis Province Complete
[Timeline, Gyr]
MCMG
NASA





Dust storm in the Sahara Desert on Earth, photographed by NASA's SeaWiFS project.

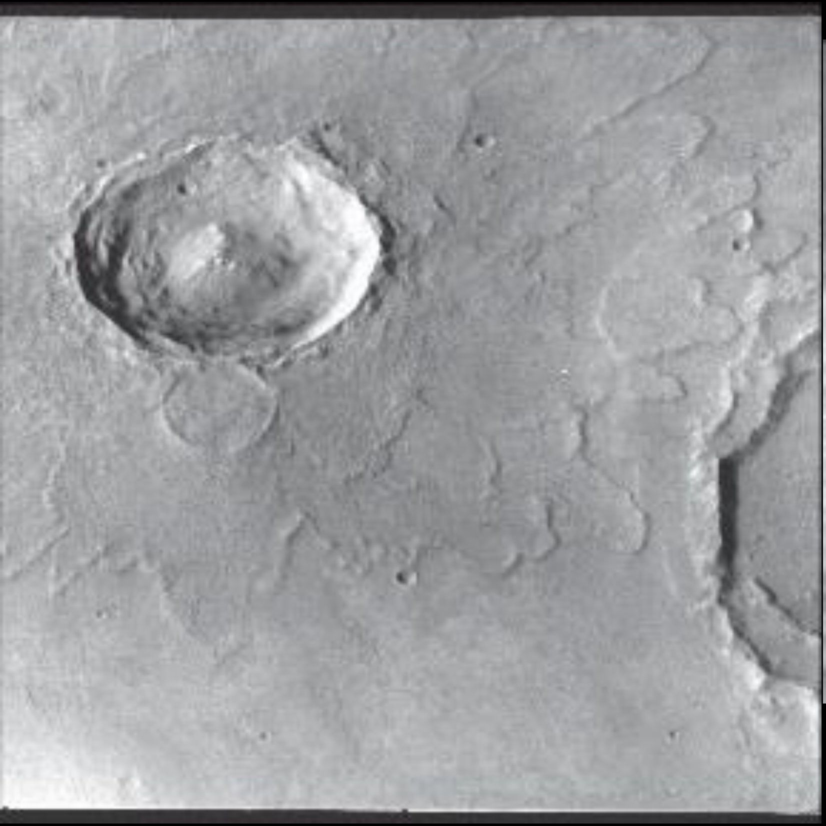


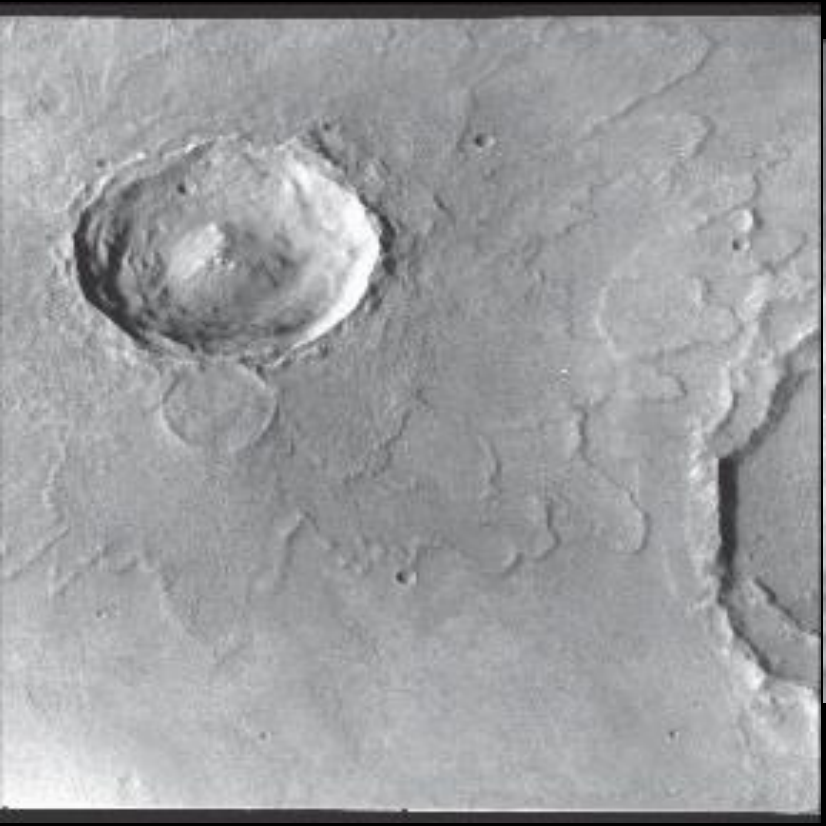
Dust storm near the northern polar cap of Mars, photographed by the Mars Global Surveyor spacecraft on August 29, 2000, the beginning of Martian summer.
The white material is frozen carbon dioxide. Although the winds reach speeds of up to 60 miles per hour, they are less destructive than storms on Earth, since the Martian atmosphere is thin.
From
http://antwrp.gsfc.nasa.gov/apod/ap0

Arres Valles “Twin Peaks,” Mars

Lavic Lake Desert, Earth

Wind erosion (aeolian processes) are important in arid (dry) environments. There is little vegetation to hold material down, so wind action causes most erosion.

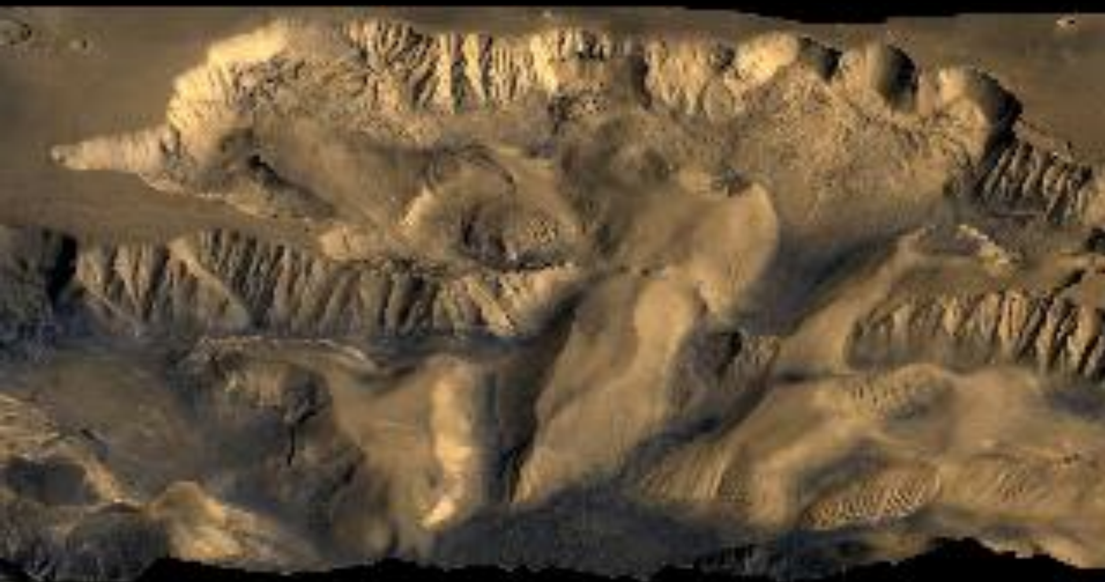


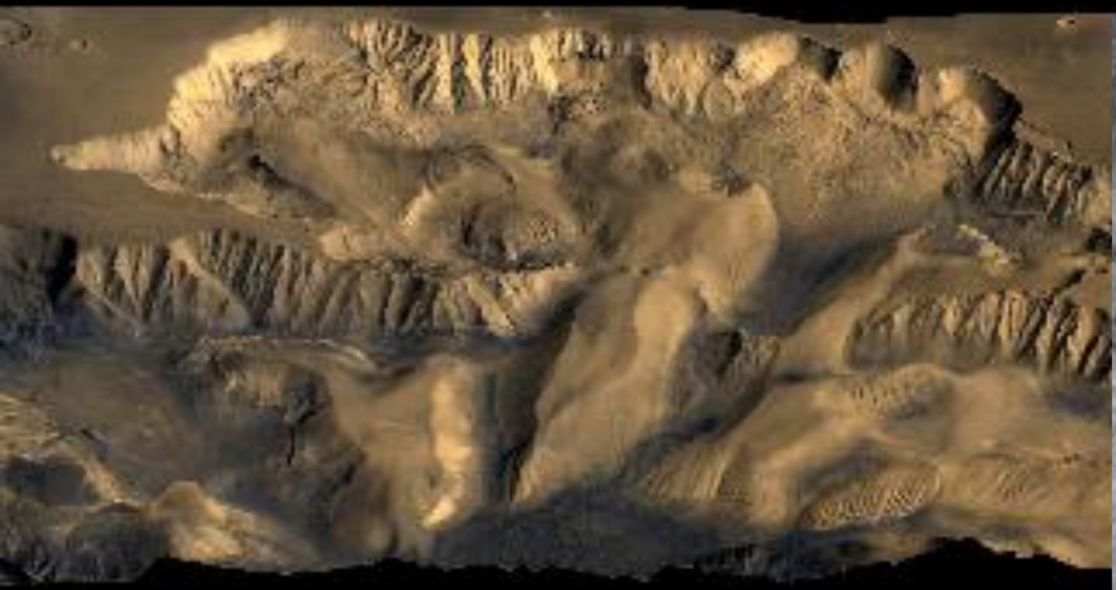


Yuty Crater, Mars

Meteor Crater, Earth

Meteor impacts produce unique landforms on both Earth and Mars. Vegetation obscures some craters on Earth.

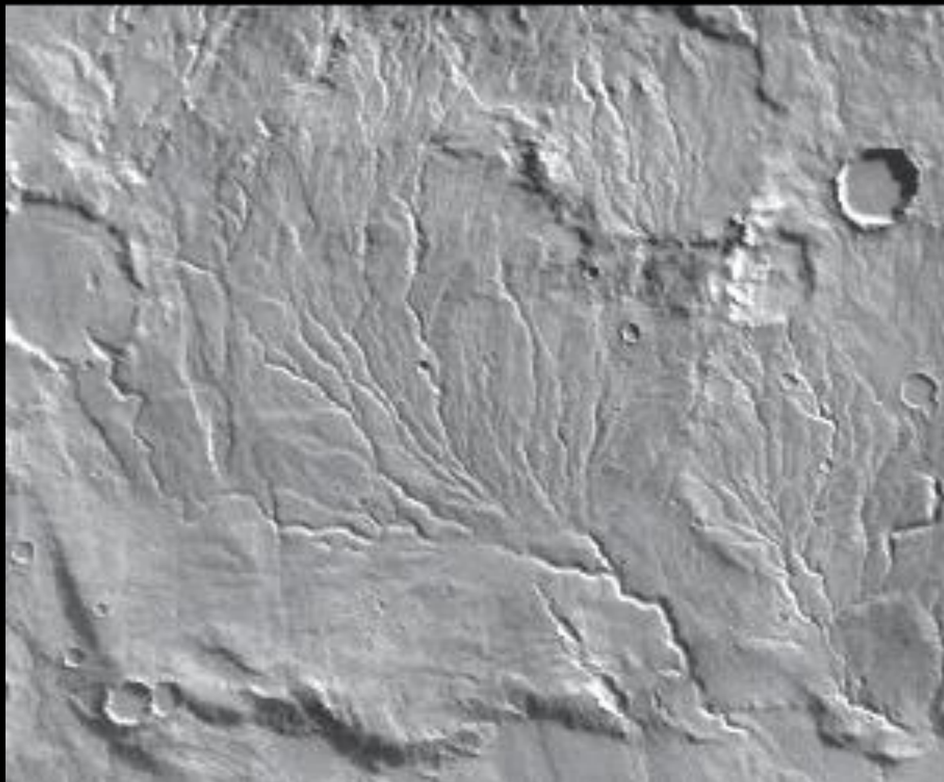


South Candor Chasma, Mars

Grand Canyon, Earth

Running water can be powerful enough to create canyons, in a process known as canyon incision. The processes illustrated in these images though producing the same result, may not be the same. The Grand Canyon was formed by a combination of two processes: uplifting and downcutting.



Warrego Valles, Mars

Yemen, Earth

Running water (fluvial processes) produces the distinctive branching pattern of streams evident in both images. Yemen, like Mars, was once a much wetter environment than it is today. Both images show “relic” landscapes, evidence of climate change.