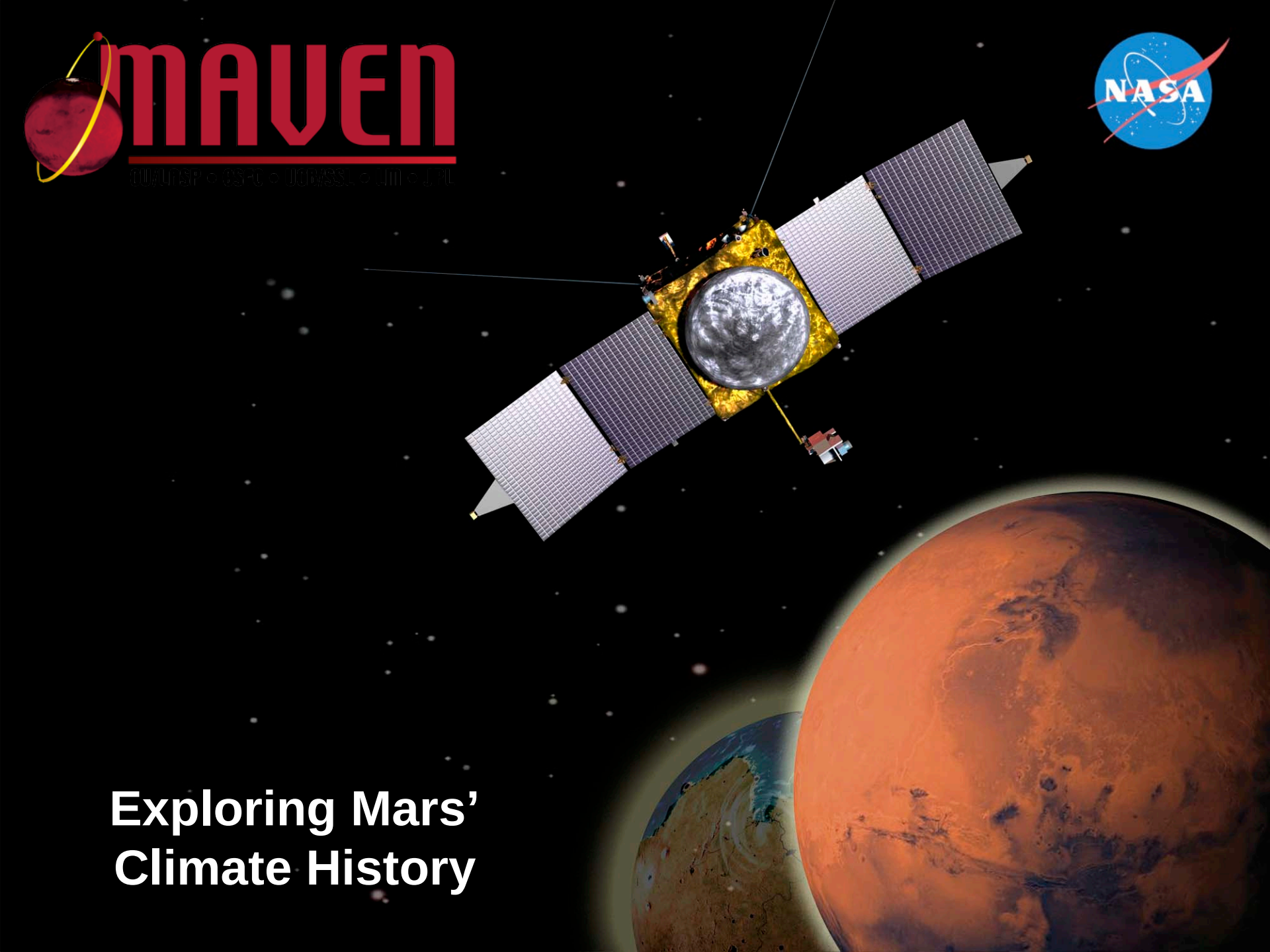
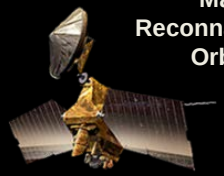

MAVEN
NASA
Exploring Mars'
Climate History

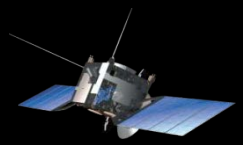
Current & Future Mars Missions

Operational
2001 - 2012

Mars Odyssey

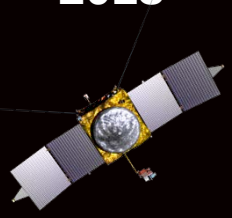


Mars Reconnaissance Orbiter



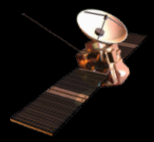
ESA Mars Express
(NASA: MARSIS)

2013



MAVEN Aeronomy Orbiter

2016



ESA Trace Gas Orbiter
(NASA: Electra)

2018

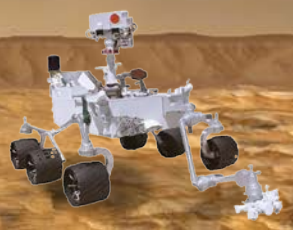
2020

2022

Follow the Water → *Habitable Environments* → *Seeking Signs of Life* → *Future*

Opportunity –
Mars Exploration Rover

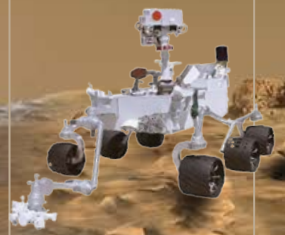
Curiosity –
Mars Science Laboratory



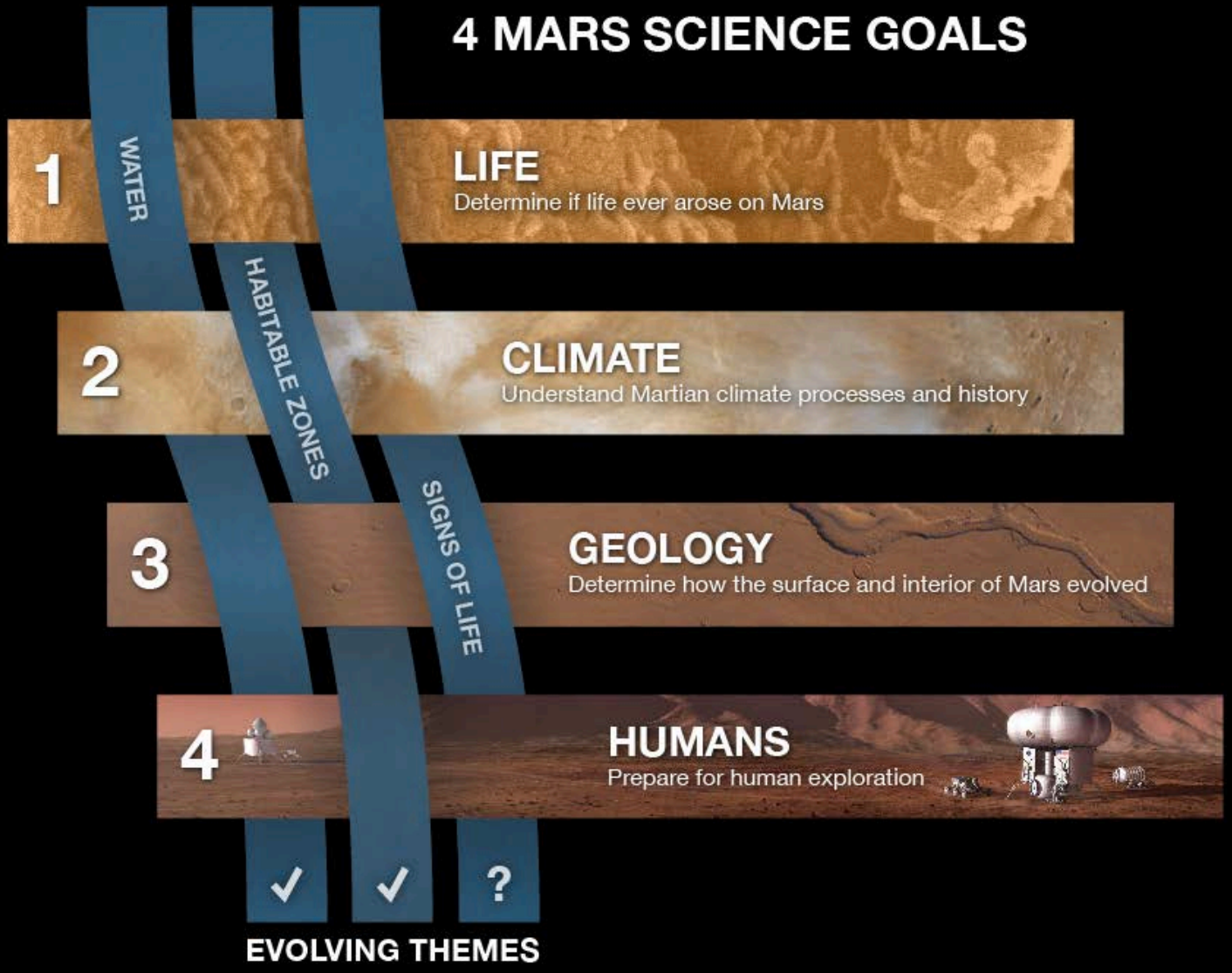
InSight

ESA ExoMars Rover
(NASA: MOMA)

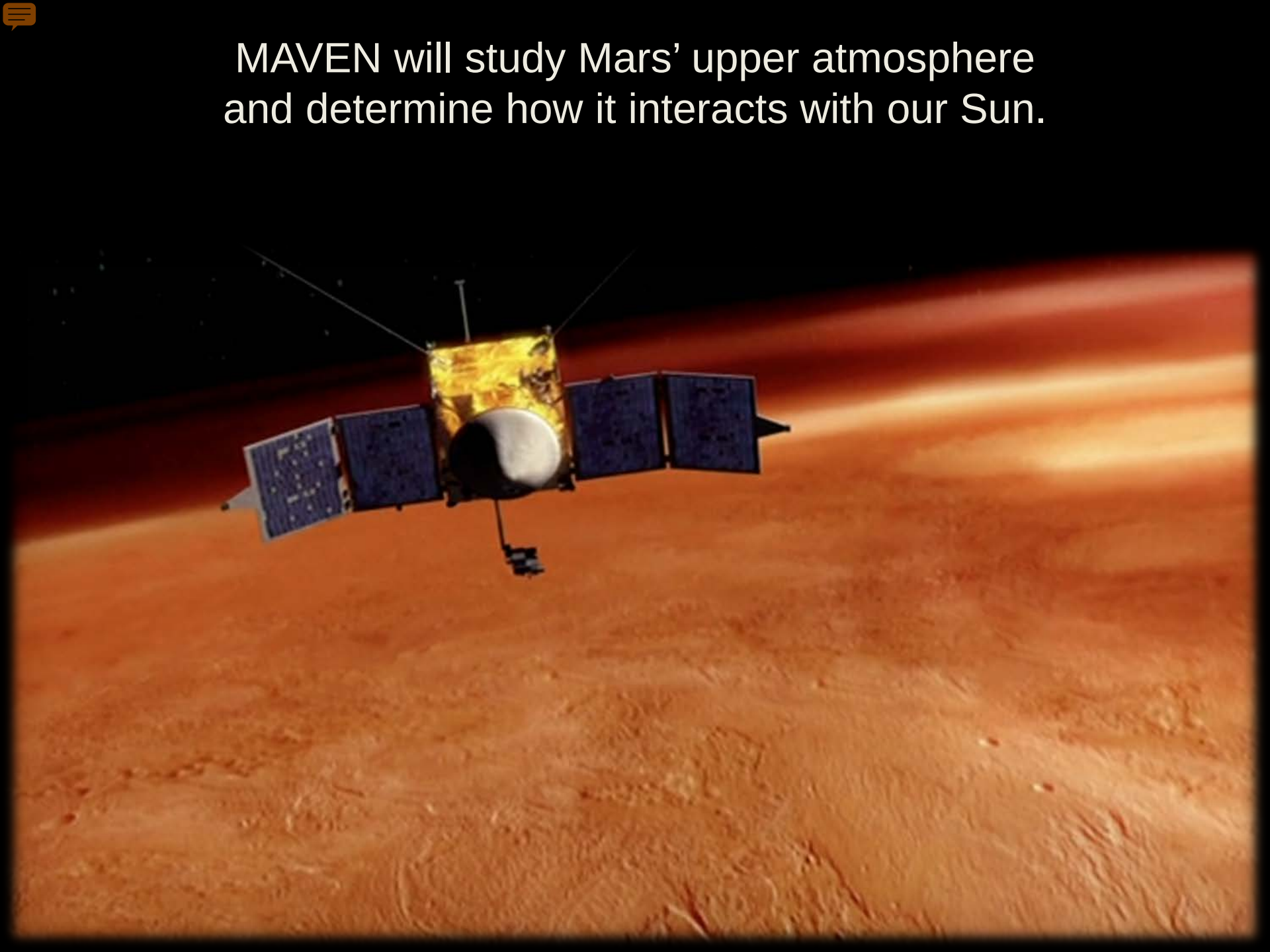
2020 Science Rover



Mars missions contribute to key science goals and themes.



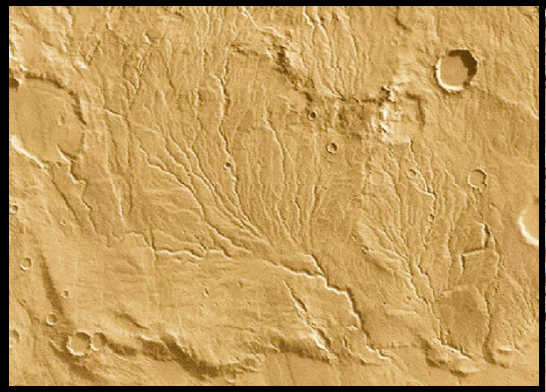
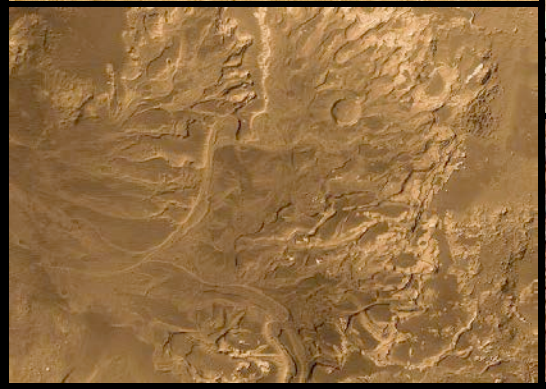
MAVEN will study Mars' upper atmosphere and determine how it interacts with our Sun.



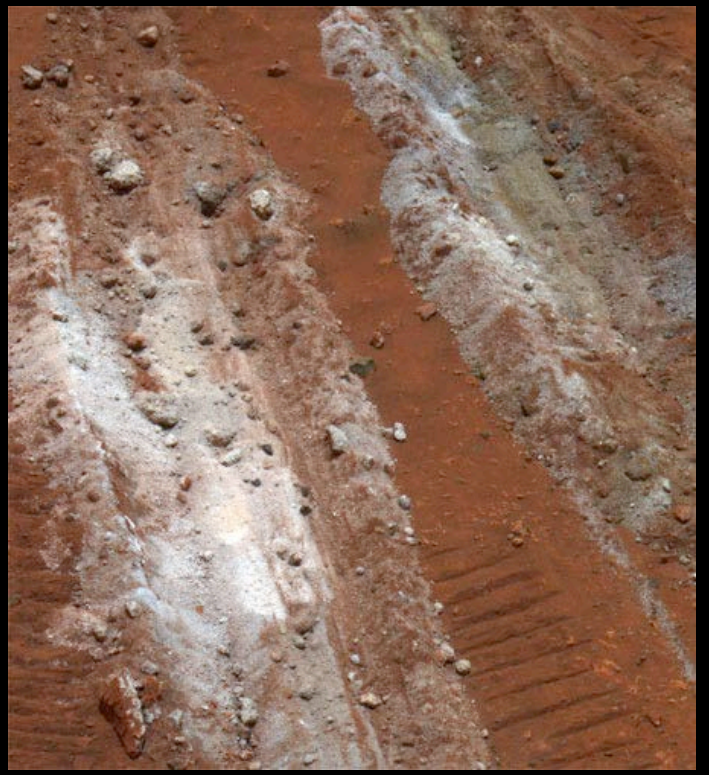
We will learn how Mars lost
most of its atmosphere and water to space,
making today's Martian climate challenging for life.


The Martian atmosphere today is very thin,
so surface pressure is very low (1% of Earth’s).
Long-lasting surface water is no longer possible.

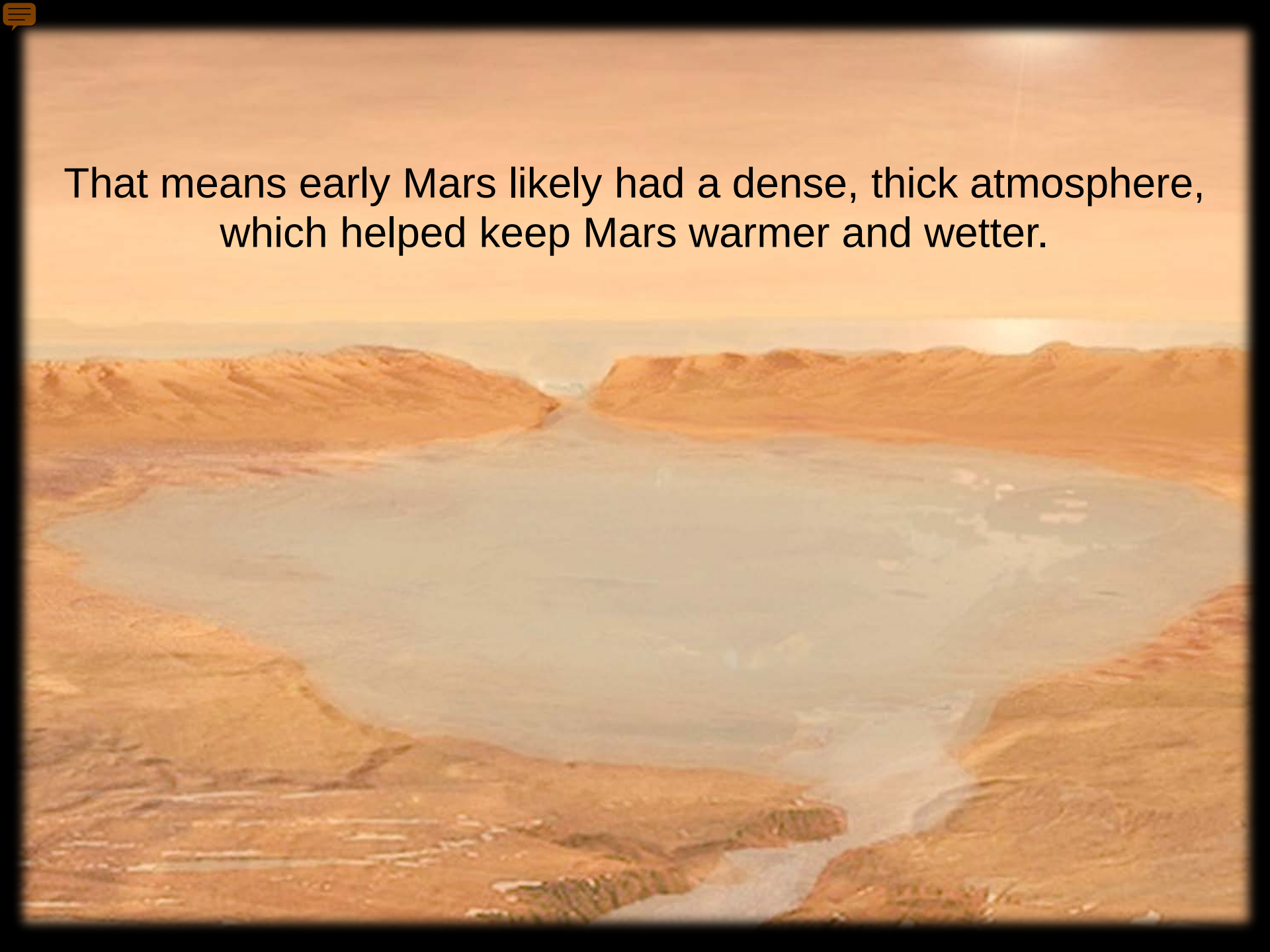
Yet, Mars has abundant evidence for ancient water!

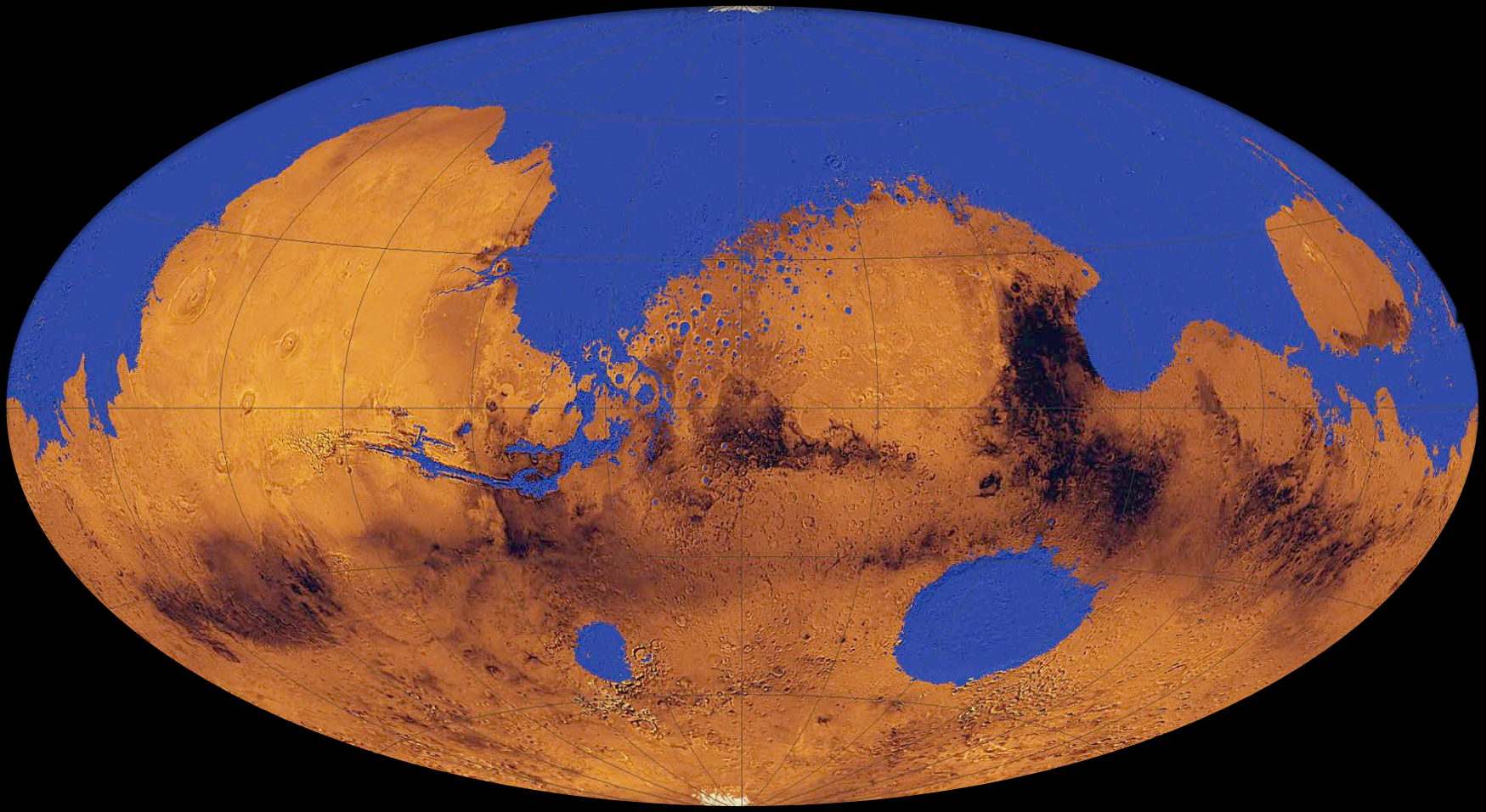




(outflow channels, deltas, sedimentary and conglomerate rocks, salts, minerals that form in water etc.)

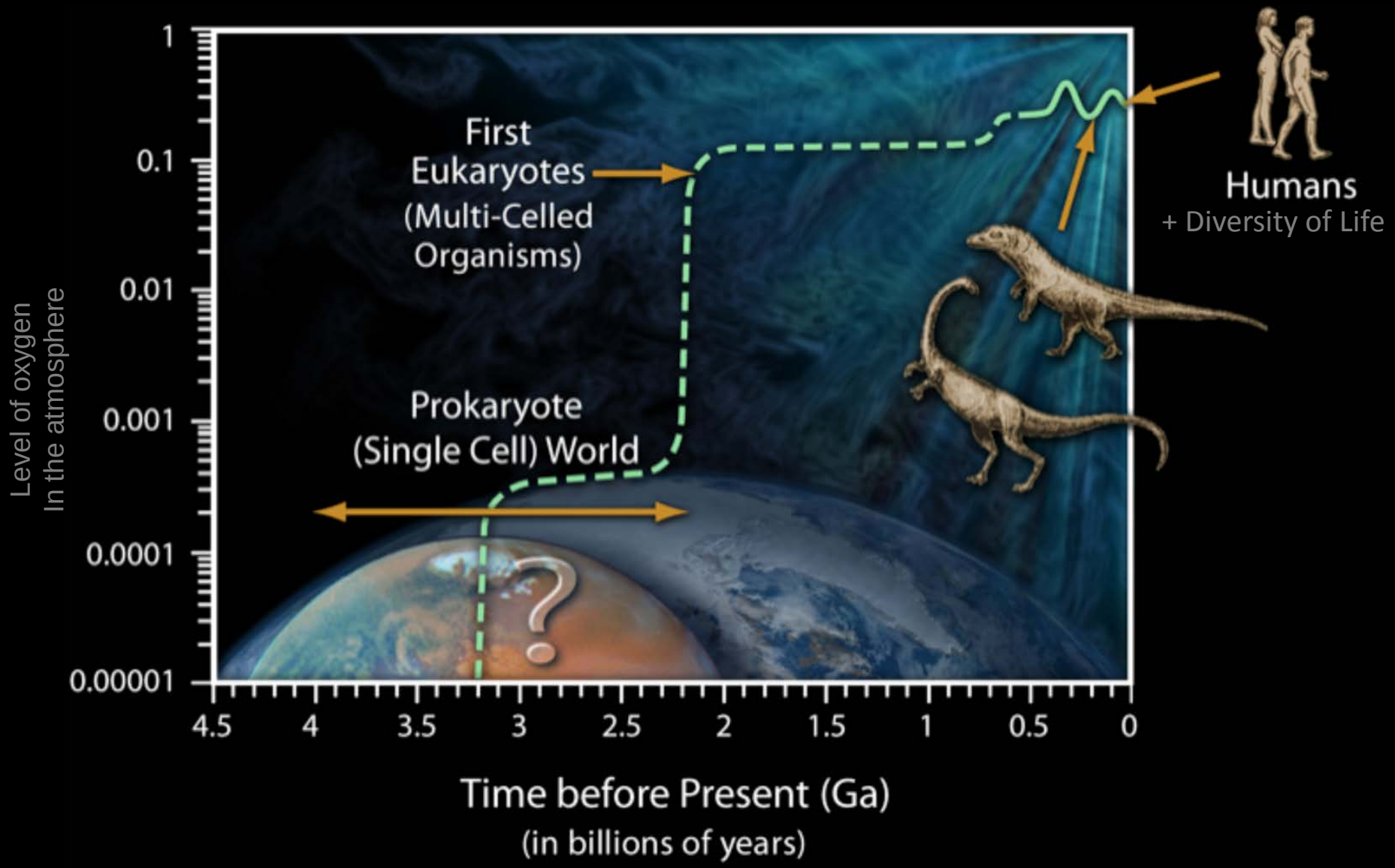

That means early Mars likely had a dense, thick atmosphere, which helped keep Mars warmer and wetter.

Early Mars may have even had a global ocean.



Water is necessary for life as we know it, along with carbon-based and other chemicals life needs to thrive.

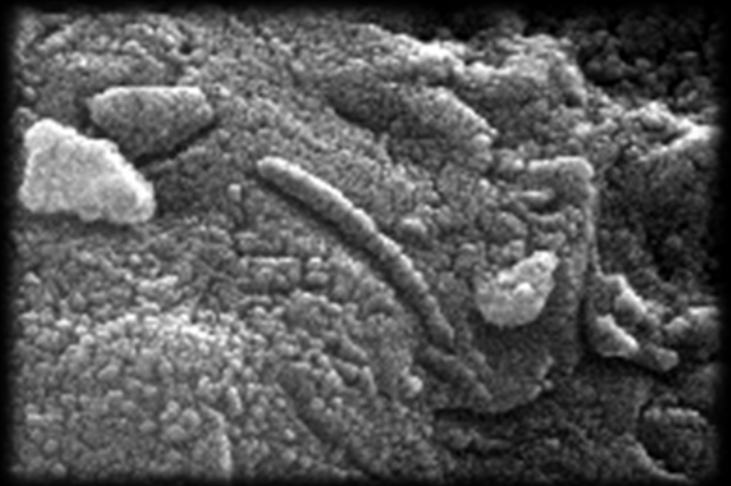
Over 3 billion years ago, simple, microbial life was on Earth. How about on Mars?



We don’t yet know if early Mars ever had microbial life.

METEORITE FROM MARS:

ALH84001

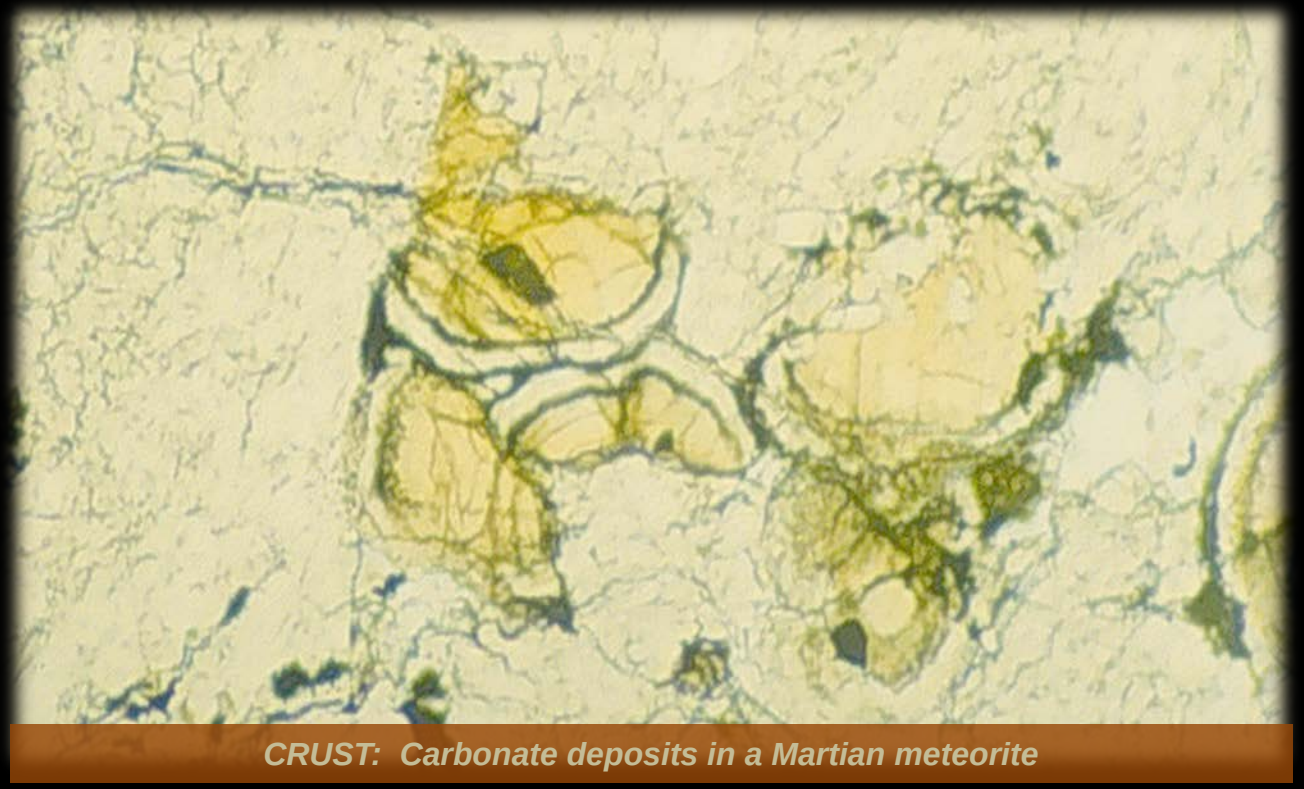


- BLASTED INTO SPACE BY A LARGE IMPACT
- TRAVELED TO EARTH & LANDED IN ANTARCTICA
- SIGNS OF LIFE?

We don’t know exactly how habitable conditions on Mars changed over time – or how long they lasted.

MAVEN's Mystery to Solve:
Where Did All of the Water & CO_2 Go?

SUBSURFACE: Water Ice



CRUST: Carbonate deposits in a Martian meteorite

OPTION 1: DOWN

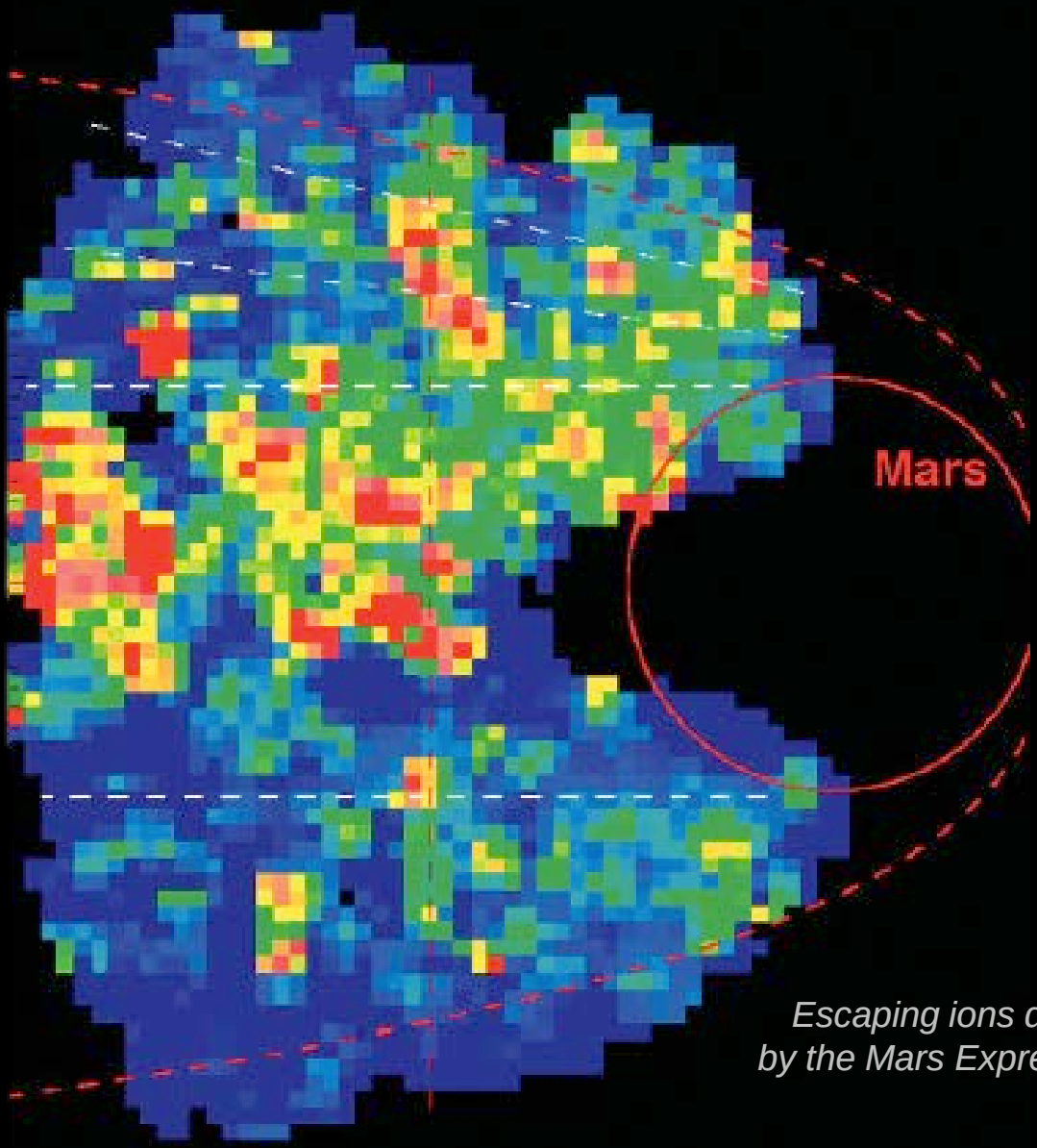
Underground or in the rock record?

Yes, but not enough to account for the loss.

MAVEN's Mystery to Solve:
Where Did All of the Water & CO_2 Go?

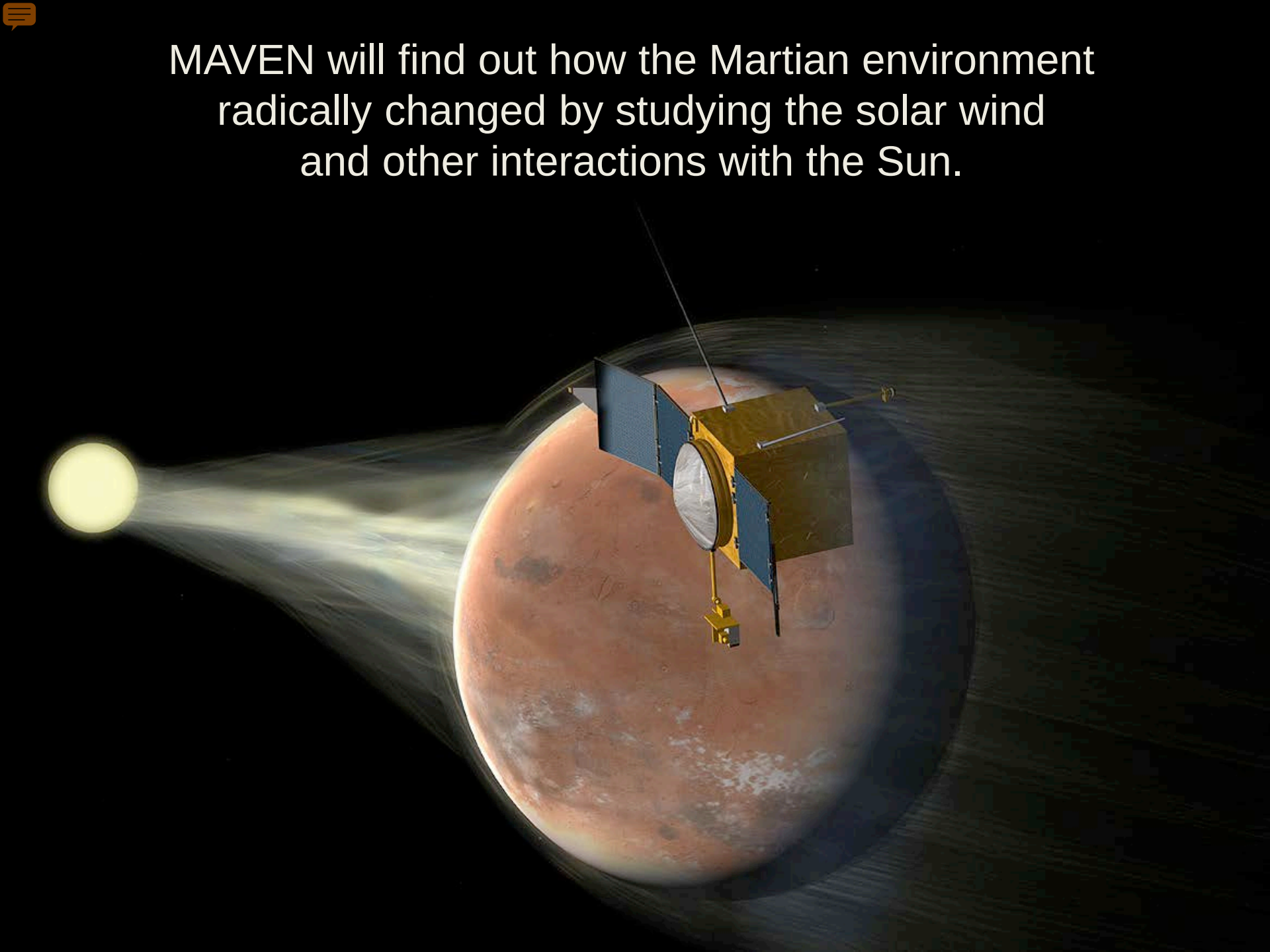
OPTION 2:
UP

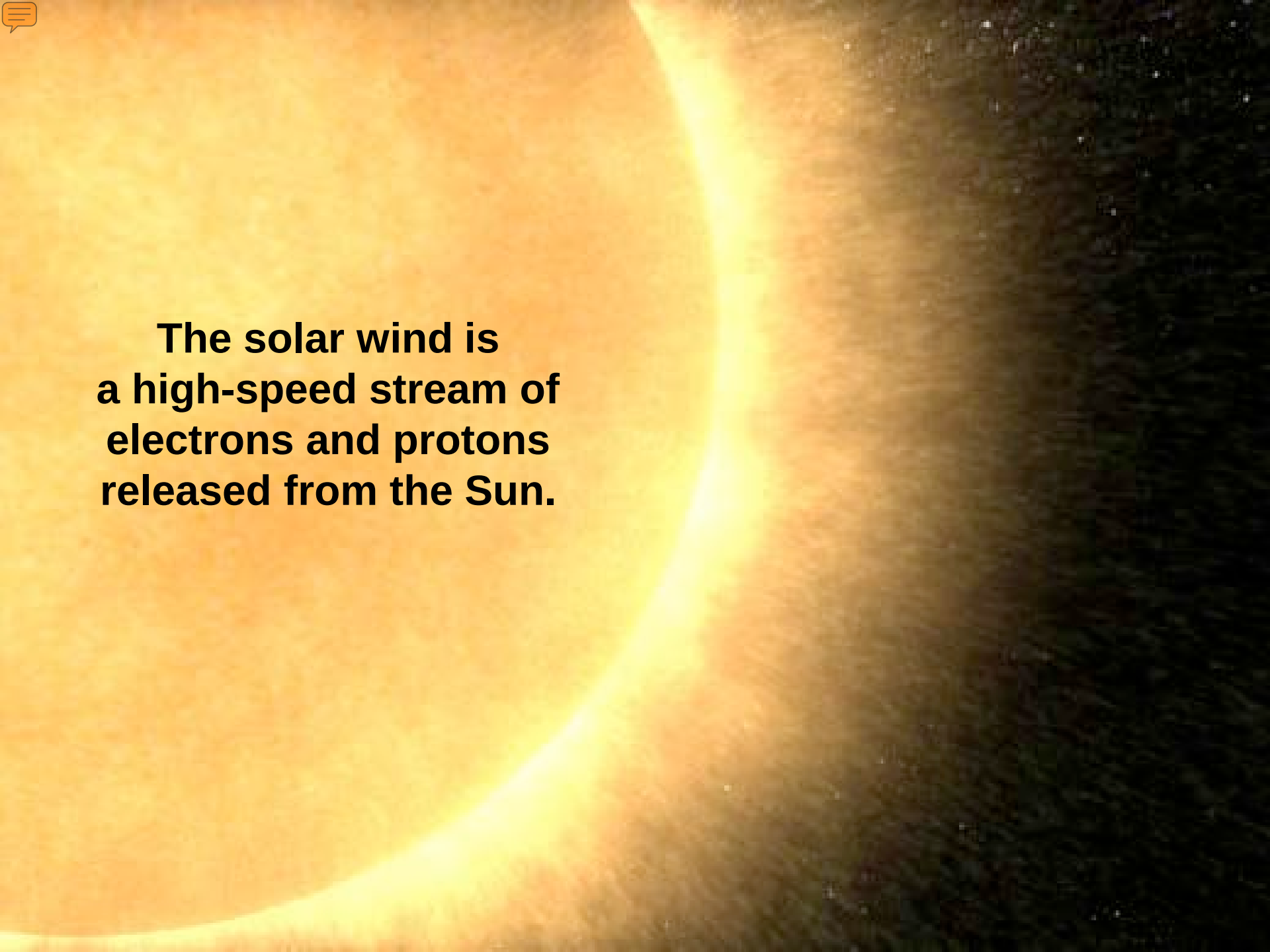
Lost to Space

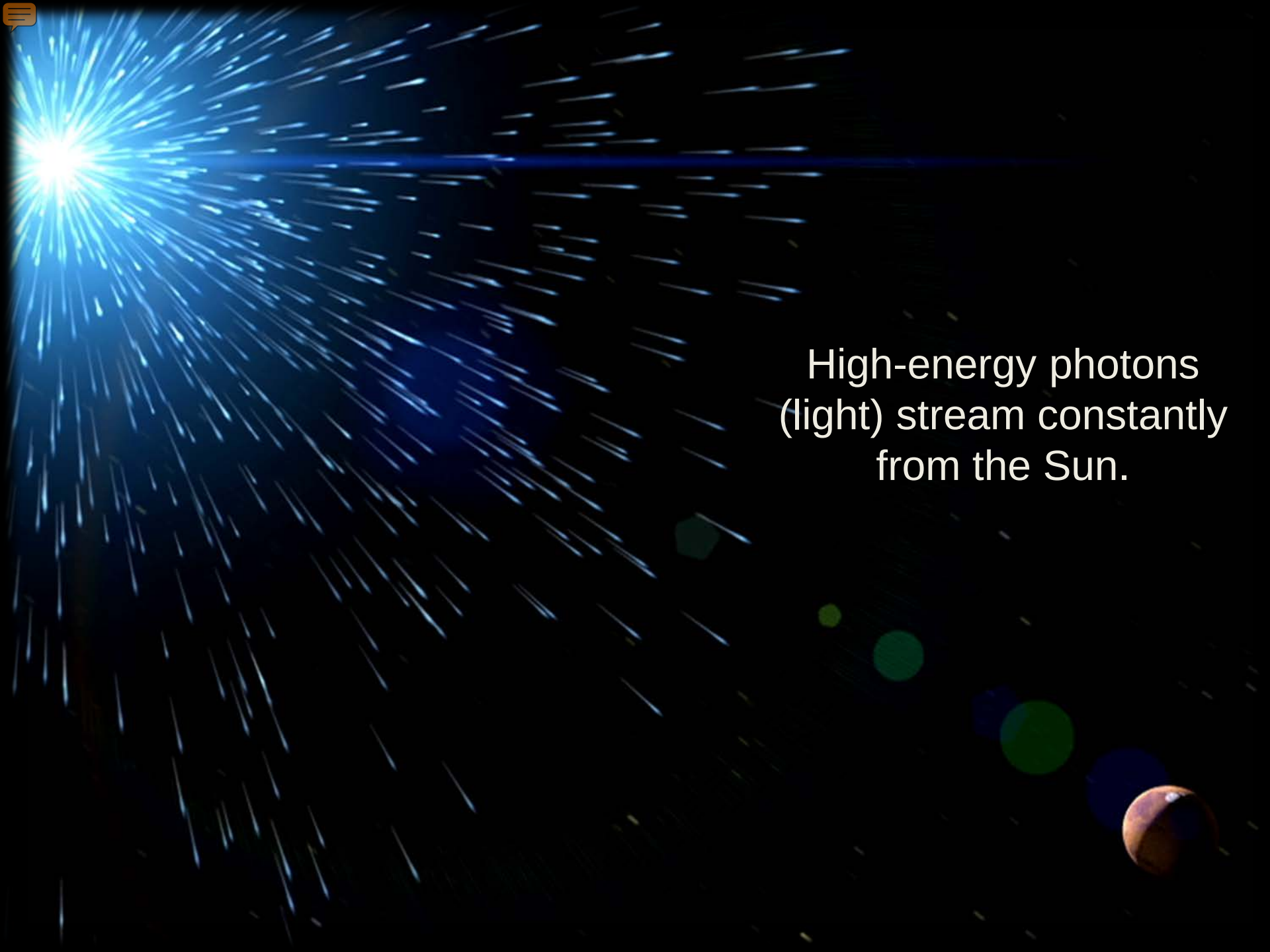


Escaping ions detected by the Mars Express orbiter

MAVEN will find out how the Martian environment radically changed by studying the solar wind and other interactions with the Sun.



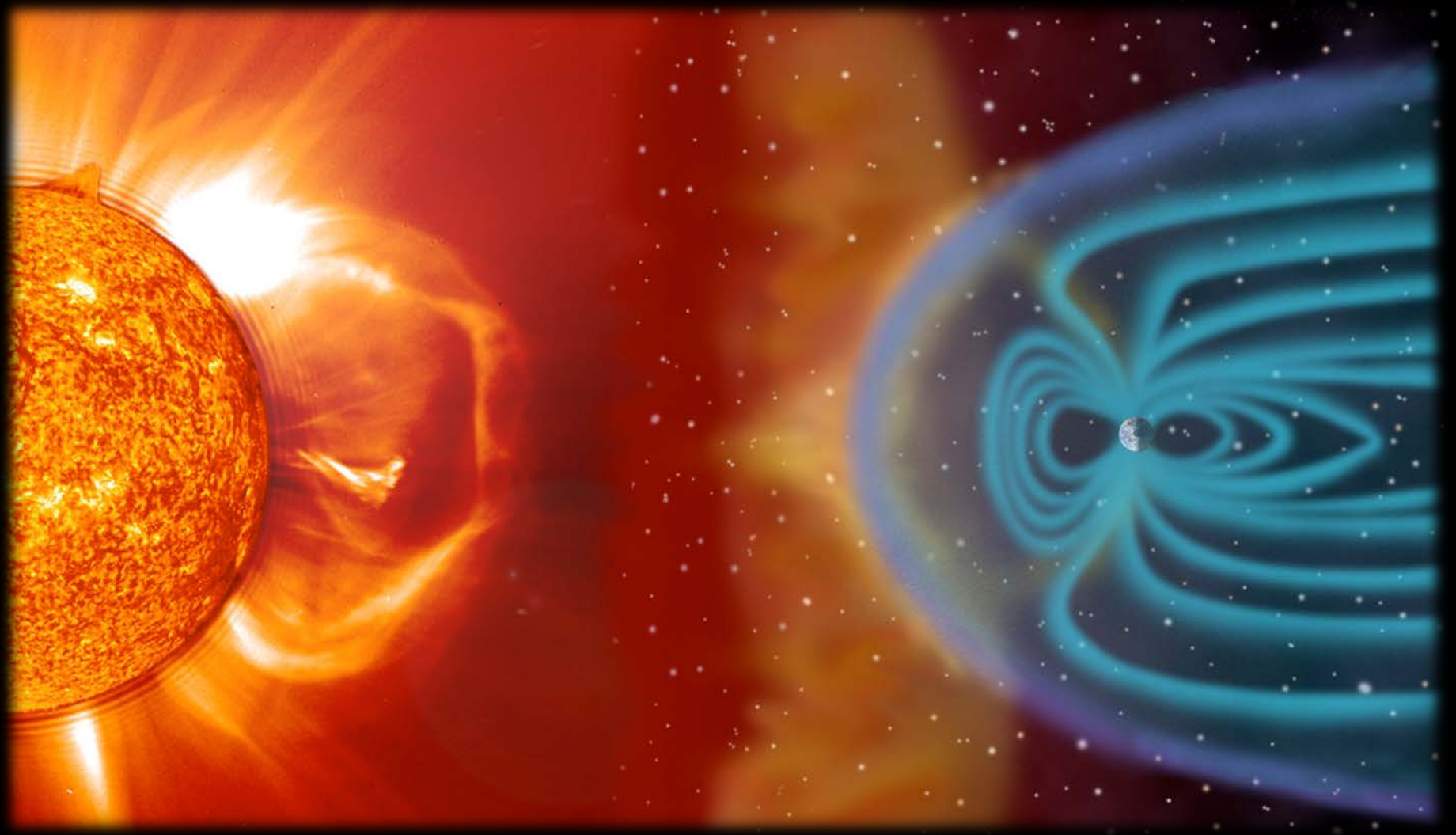

The solar wind is
a high-speed stream of
electrons and protons
released from the Sun.


High-energy photons (light) stream constantly from the Sun.

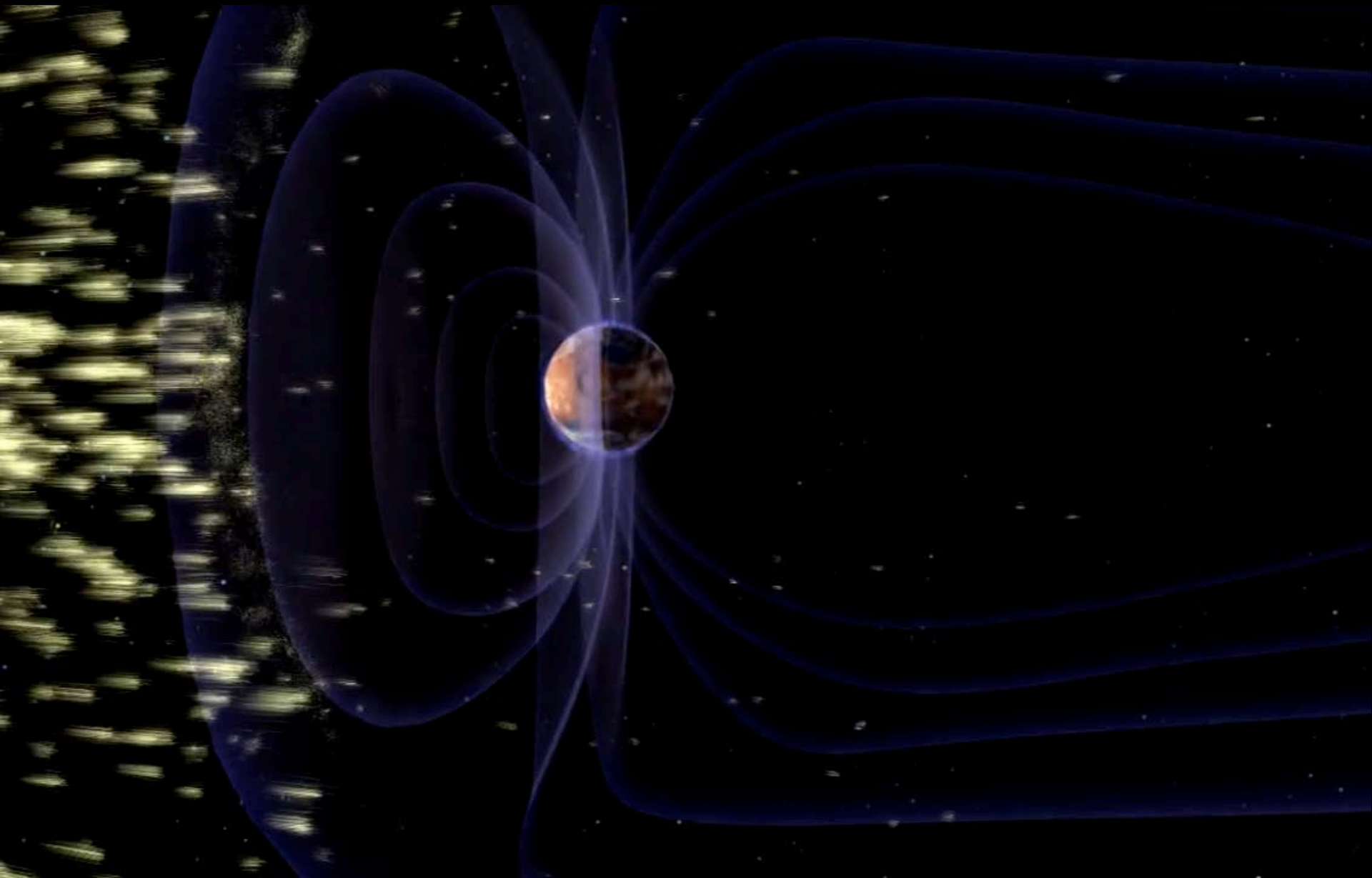

The Sun’s activity
has an impact
on planets.

On Earth, we see “northern and southern lights” when the solar wind’s charged particles collide with gases in our atmosphere.

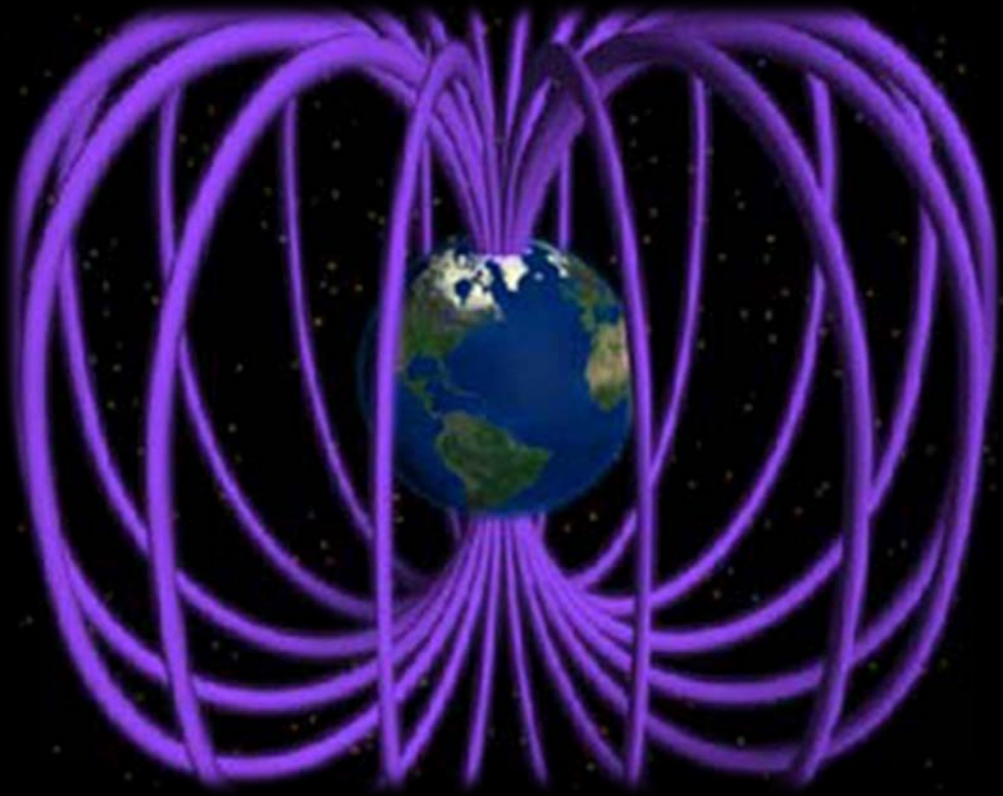
Earth’s strong magnetic field deflects many solar wind particles, preventing them from slamming into the upper atmosphere and stripping it away.

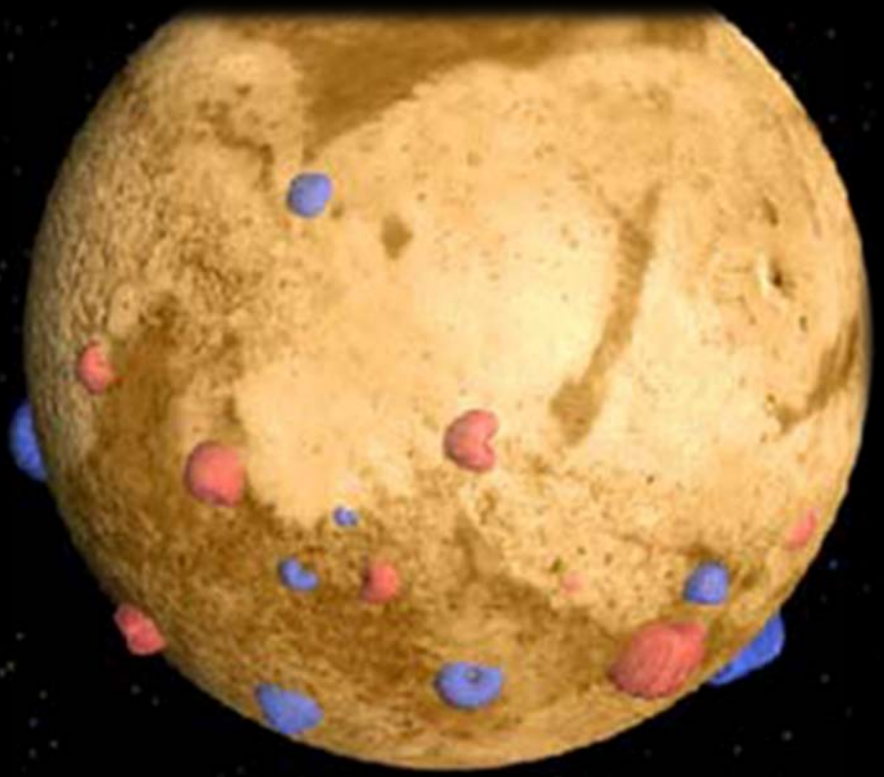


Early in its history, Mars had a strong magnetosphere that likely protected it more from solar wind.

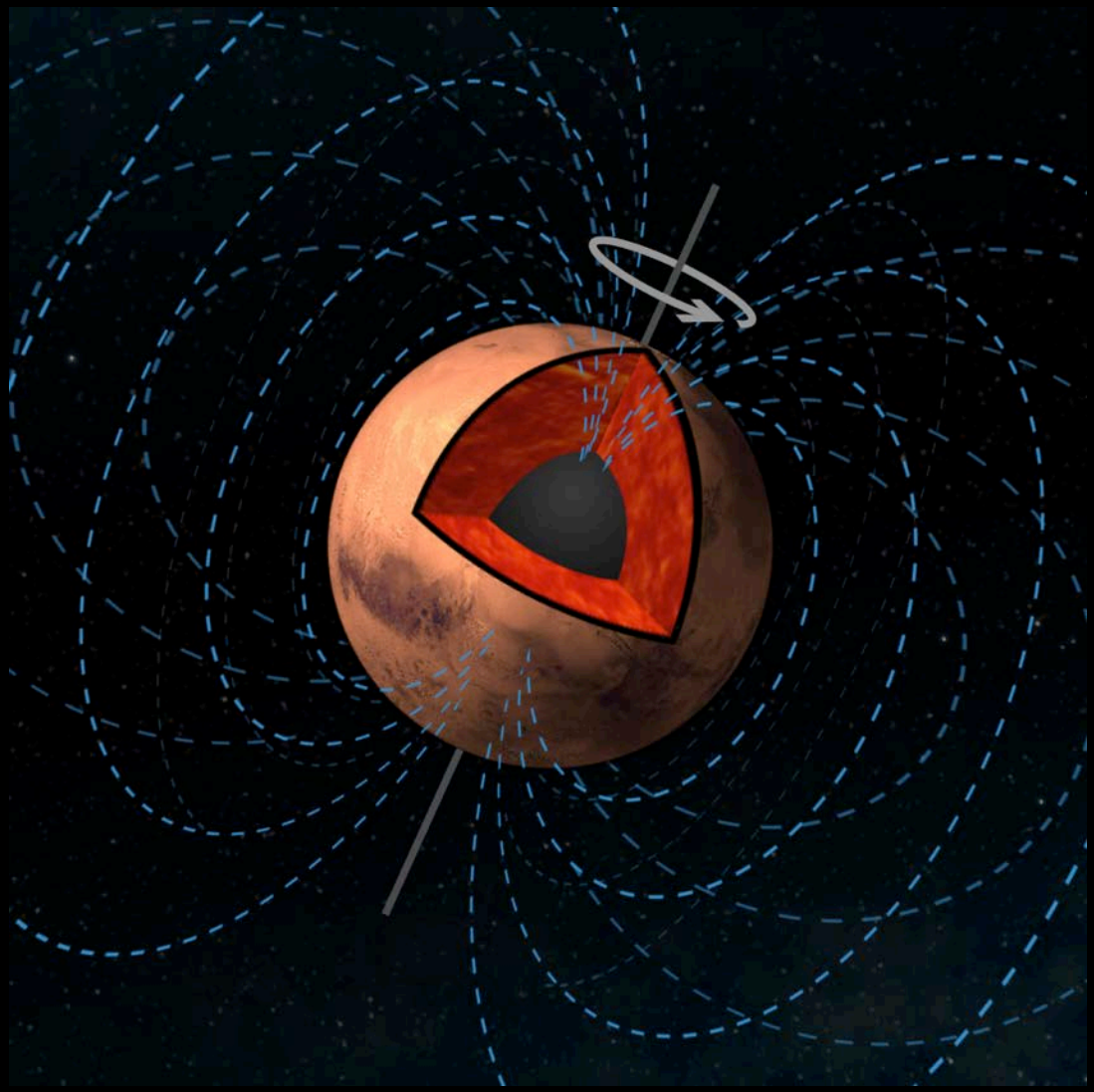


Today, Earth’s magnetic field is globally strong and more uniform, while Mars’ is localized and scattered.

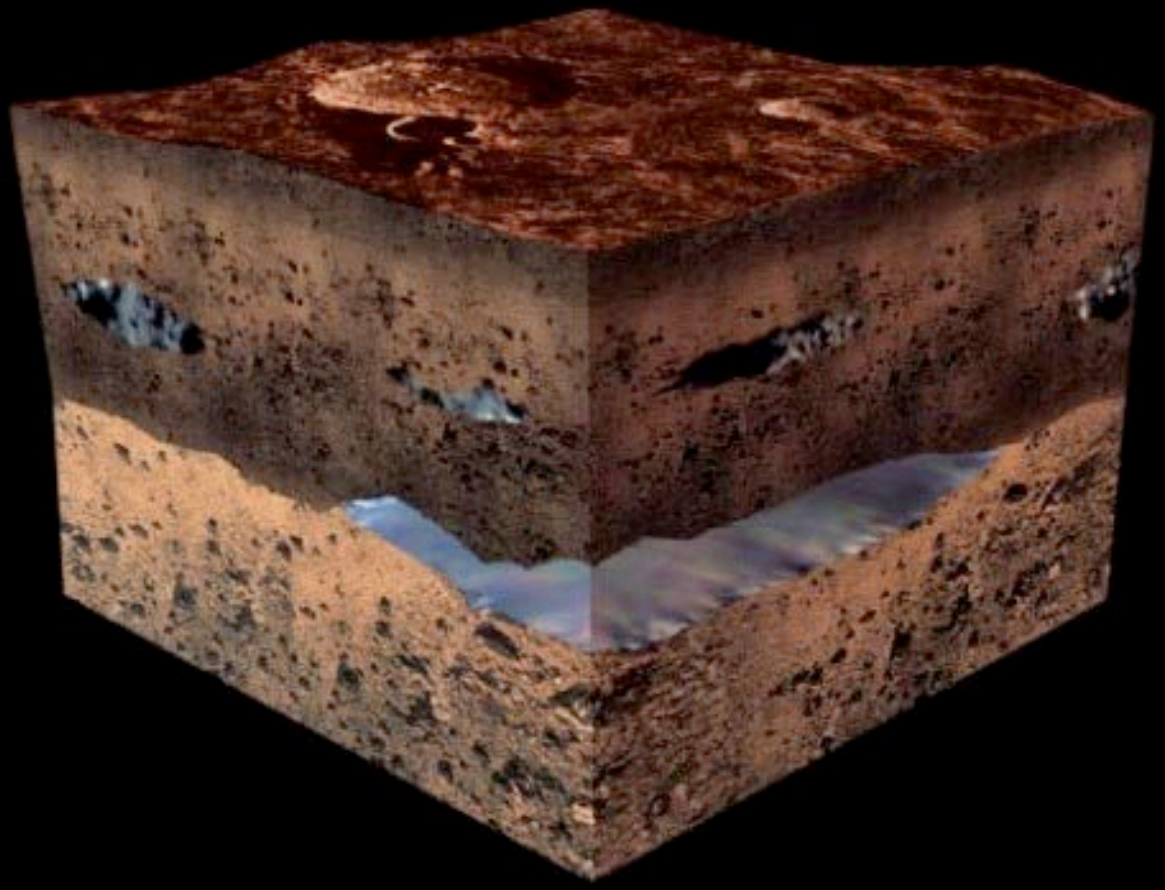




A magnetosphere emerges when electrically charged molten material within a planet churns in convection while the whole system rotates.

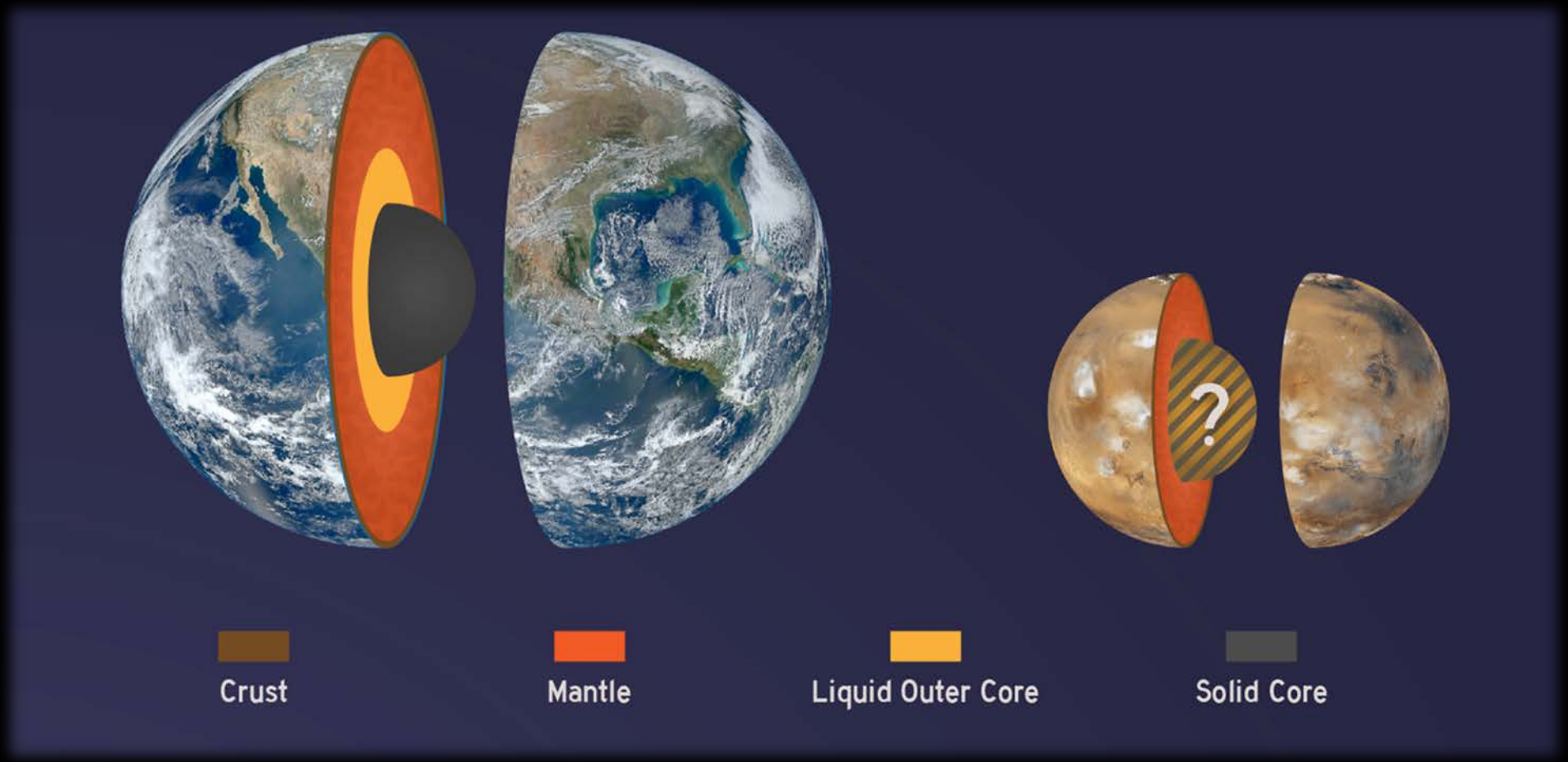


When Mars was only 500 million years old,
Mars cooled and lost its magnetic field,
radically changing the environment.

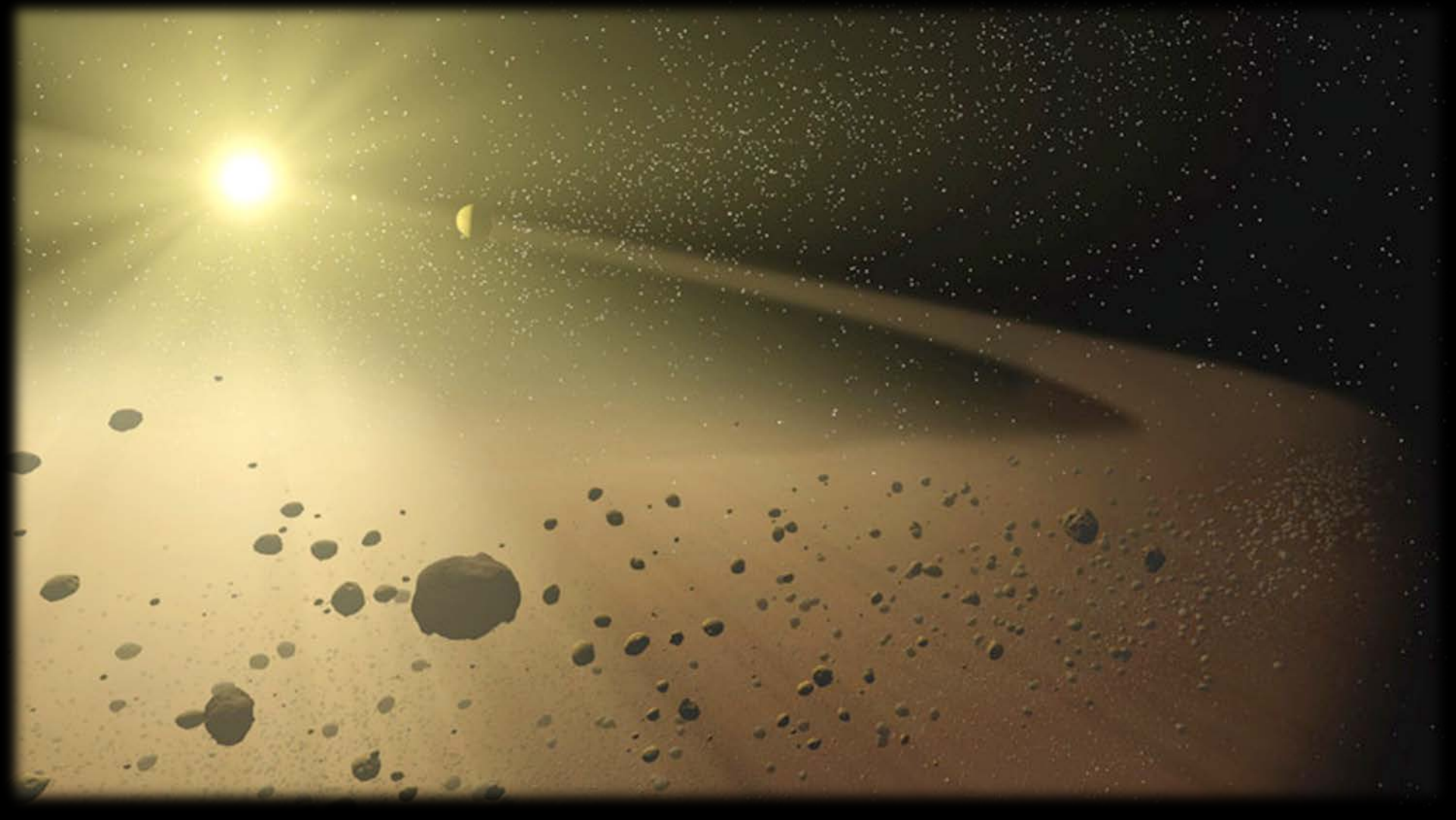


Any small life forms that may have emerged
likely died or moved underground.

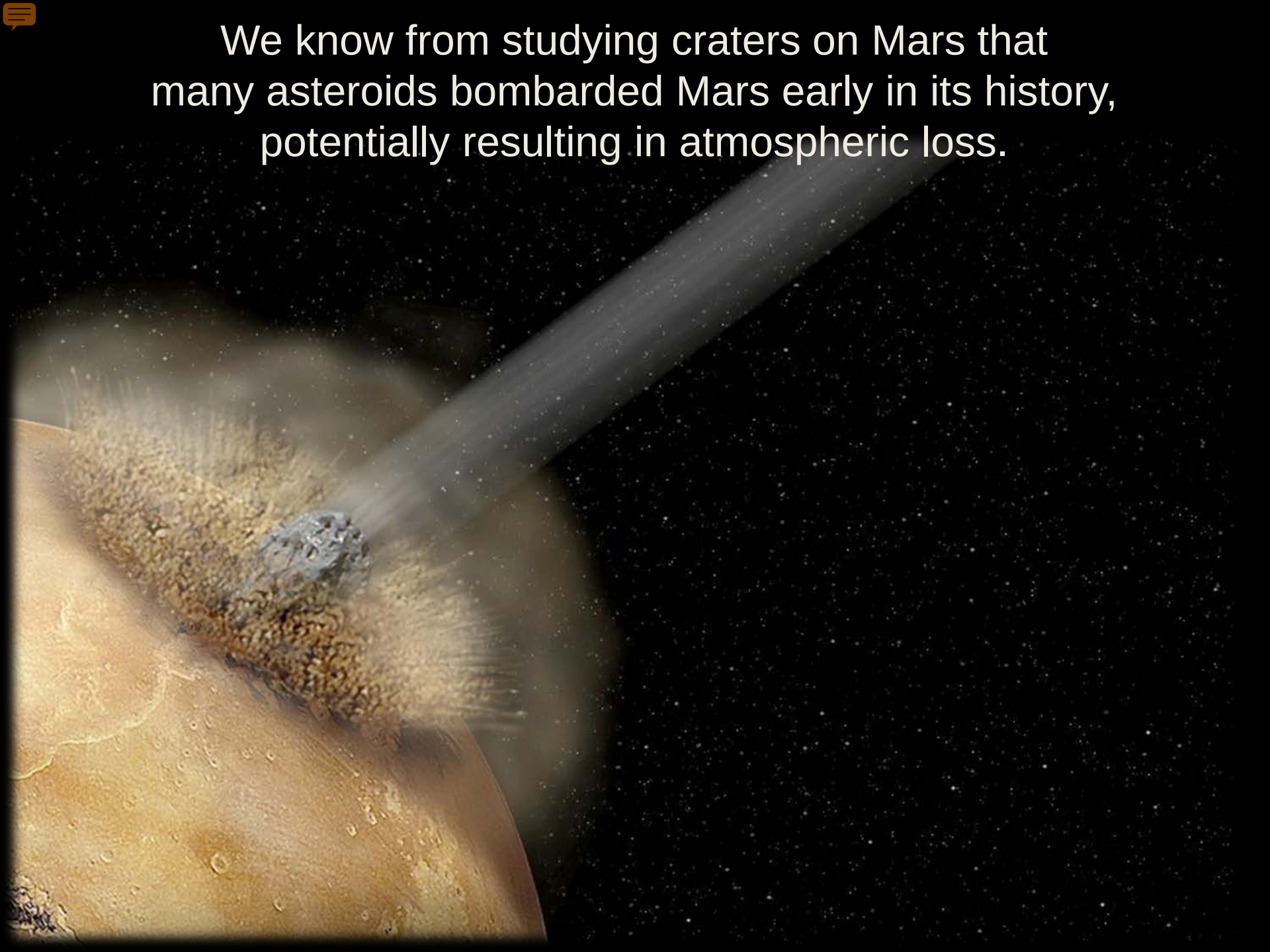
Maybe Mars simply cooled on its own due to its smaller size, turning off its internal convection cycle and magnetosphere.



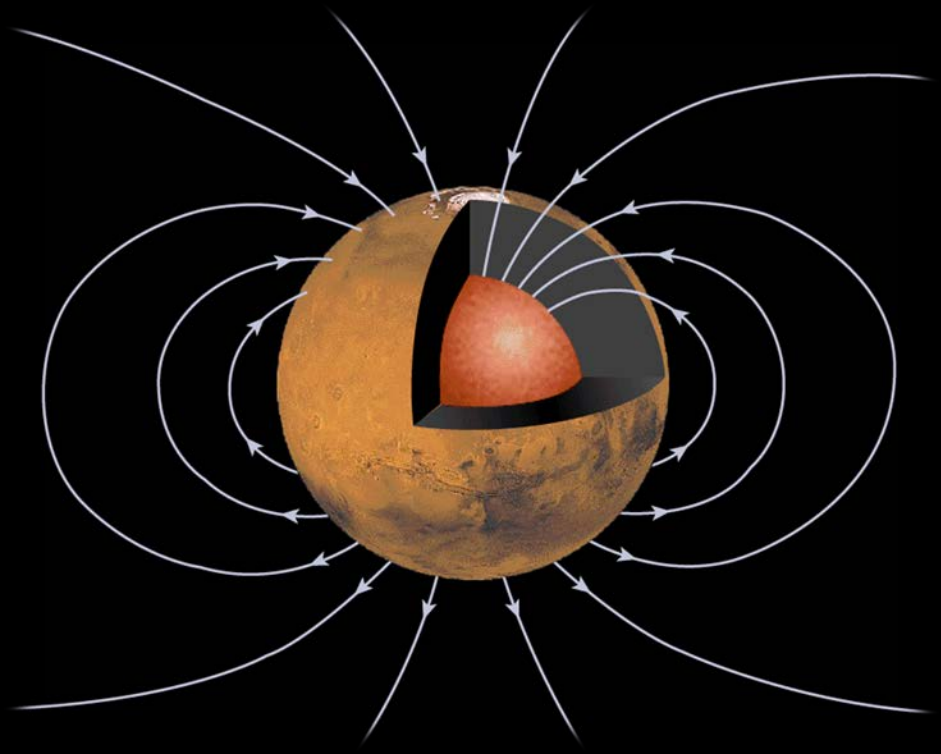
In addition to cooling, in its early days, Mars was still vulnerable to impacts from asteroids and other bodies.



We know from studying craters on Mars that many asteroids bombarded Mars early in its history, potentially resulting in atmospheric loss.

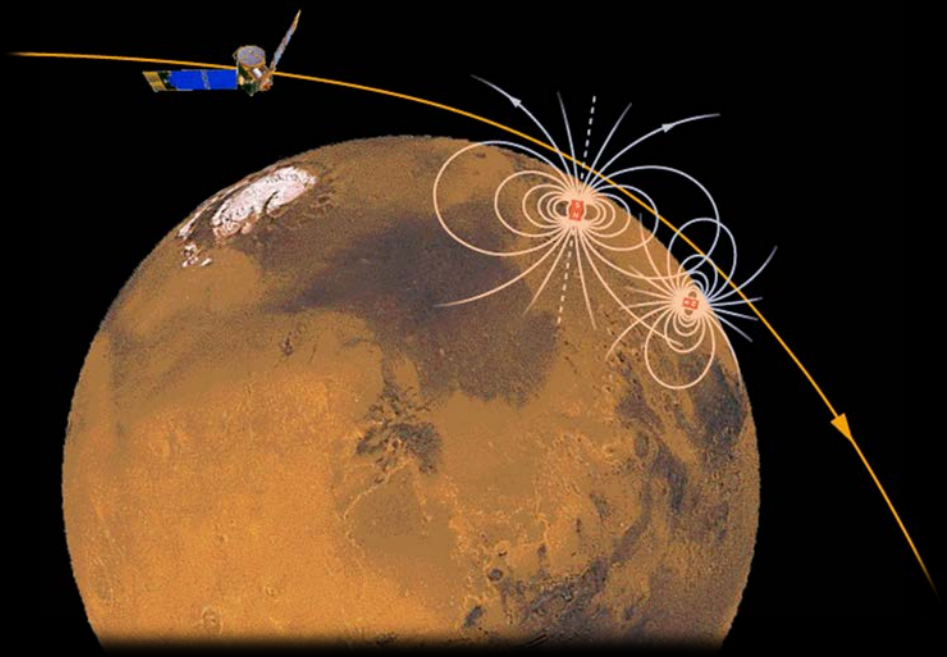


As the core and layers of Mars cooled, its magnetic field began to disappear.



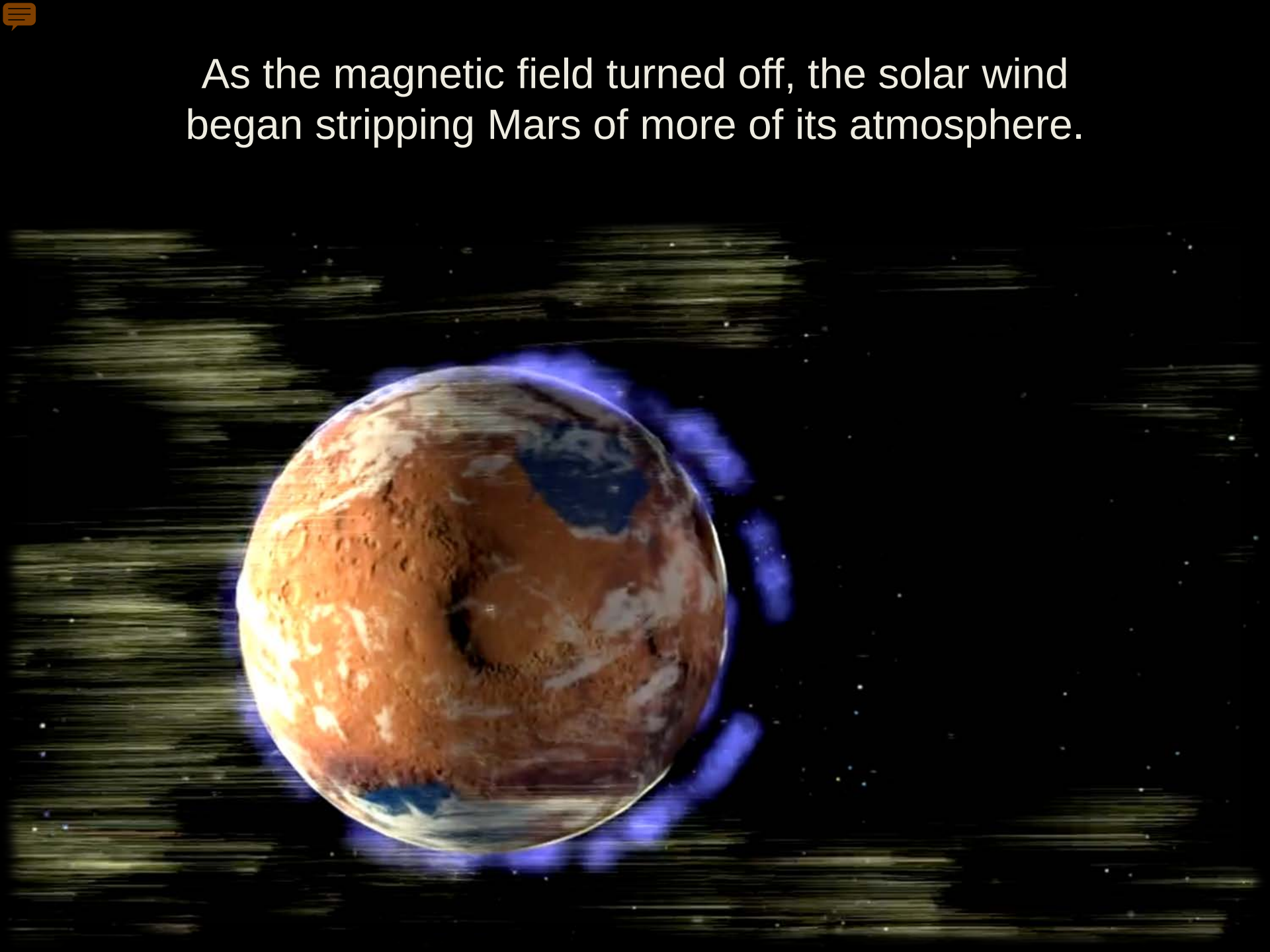
Ancient Global Magnetosphere

Today, only local magnetic fields remain.

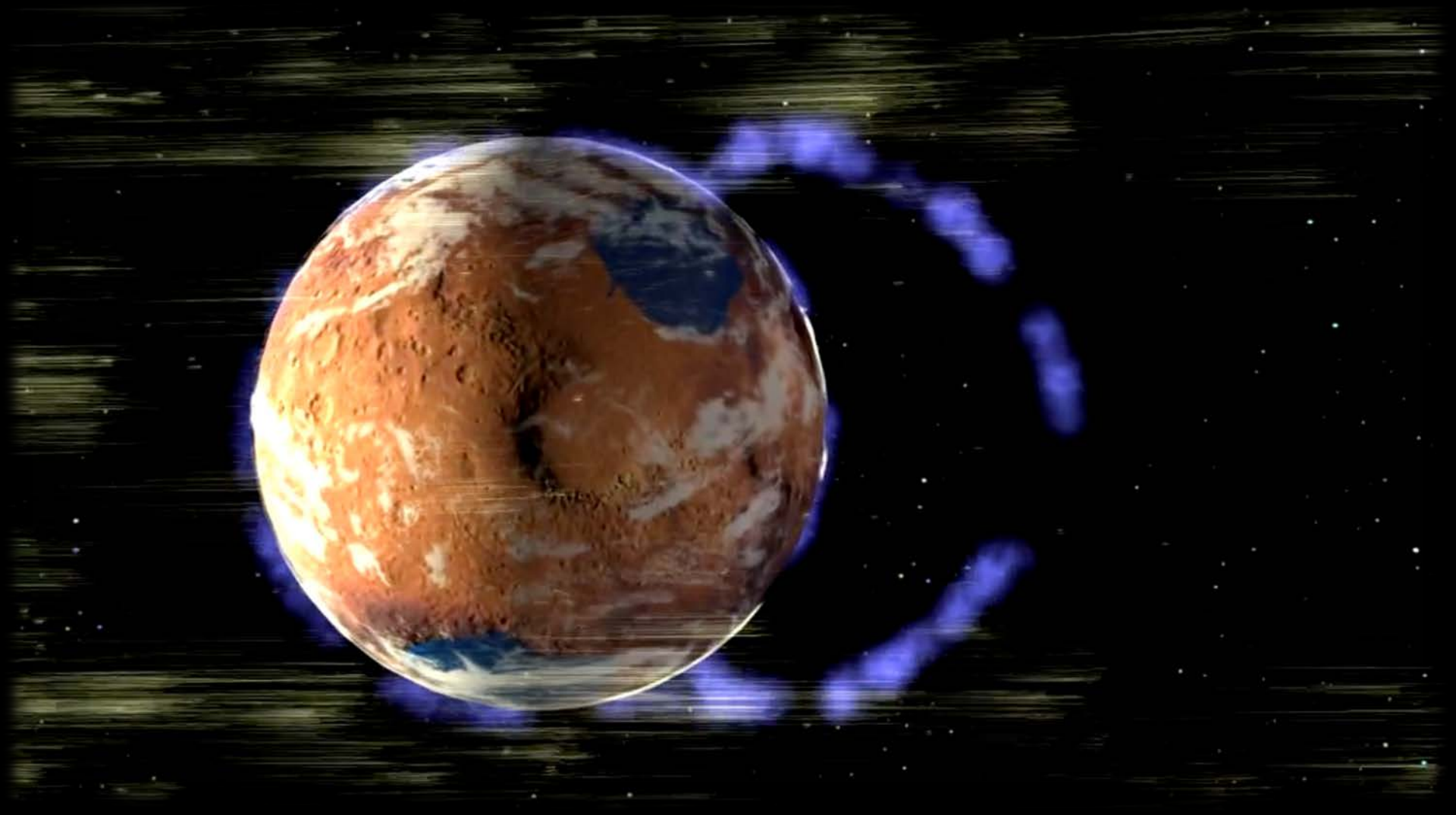


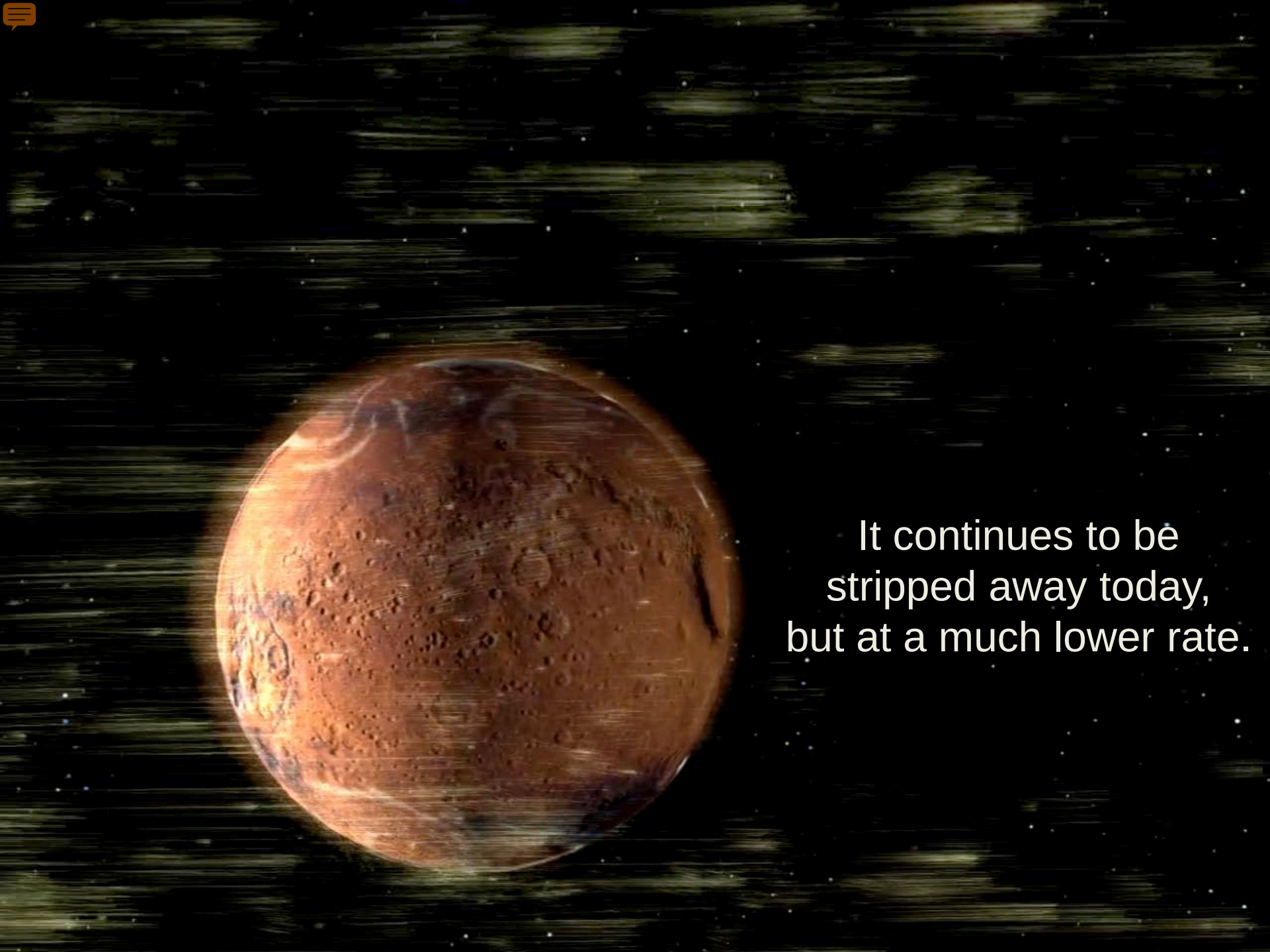
Local Remnants of a Magnetosphere

As the magnetic field turned off, the solar wind began stripping Mars of more of its atmosphere.



Over several hundred million years,
Mars has lost most of its atmosphere.



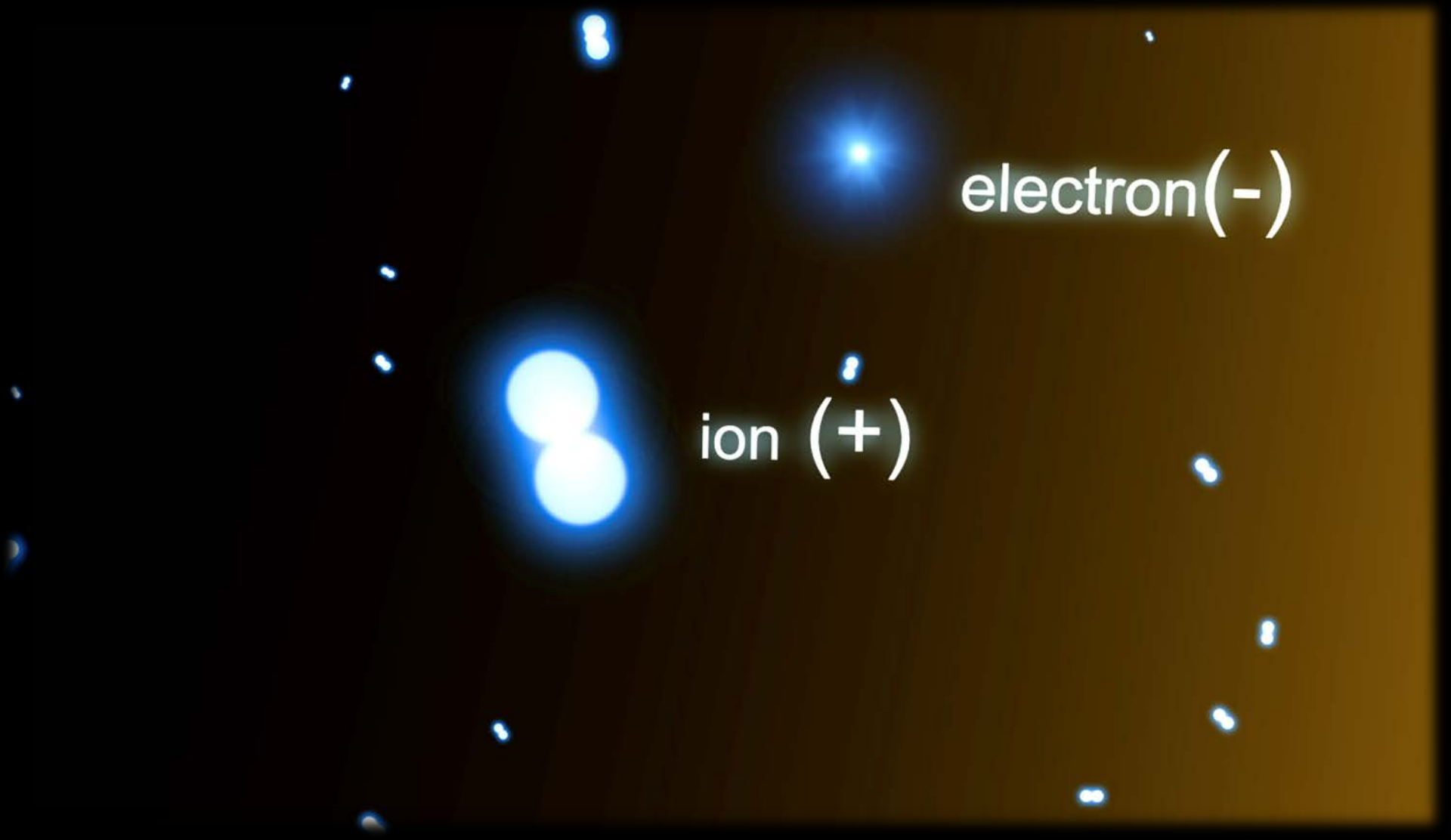

It continues to be
stripped away today,
but at a much lower rate.

Without a strong global magnetosphere,

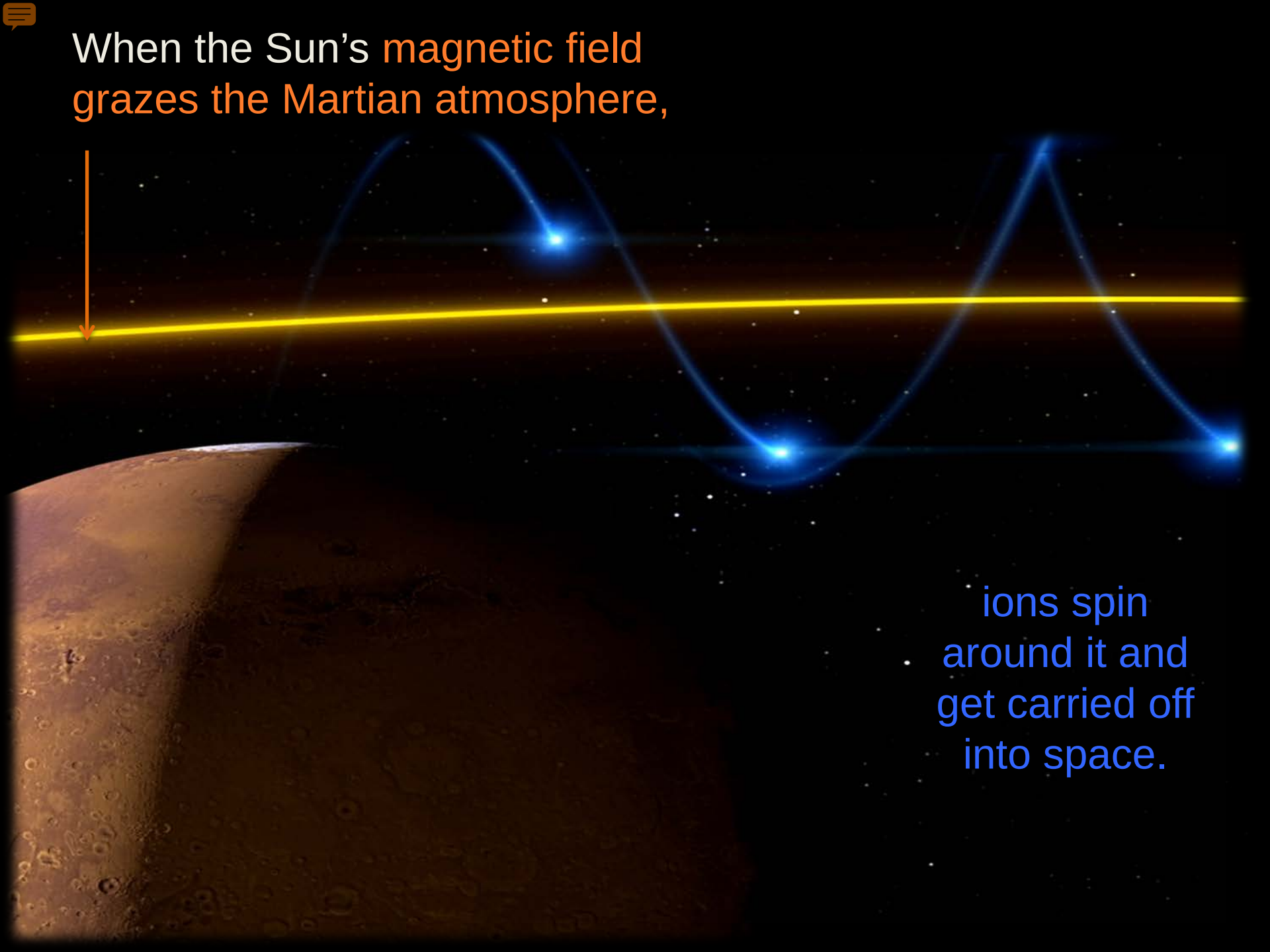
Mars is vulnerable.

When an ultraviolet photon from the Sun crashes into a molecule in the Martian atmosphere . . .

. . . it knocks away an electron,
turning the molecule into an ion.



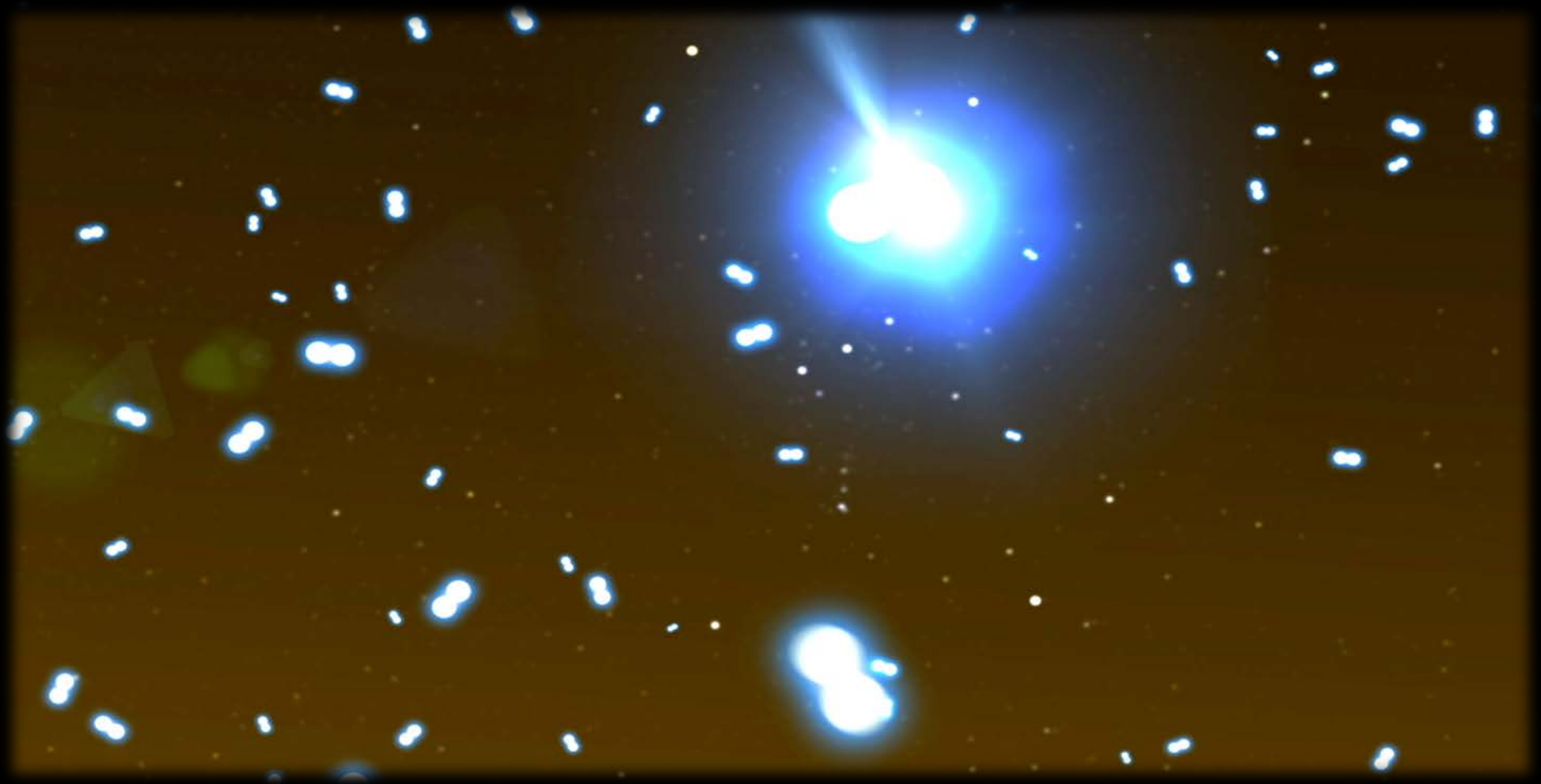
When the Sun's magnetic field grazes the Martian atmosphere,



ions spin around it and get carried off into space.


The Sun’s magnetic field also flings ions
right back into the Martian atmosphere.

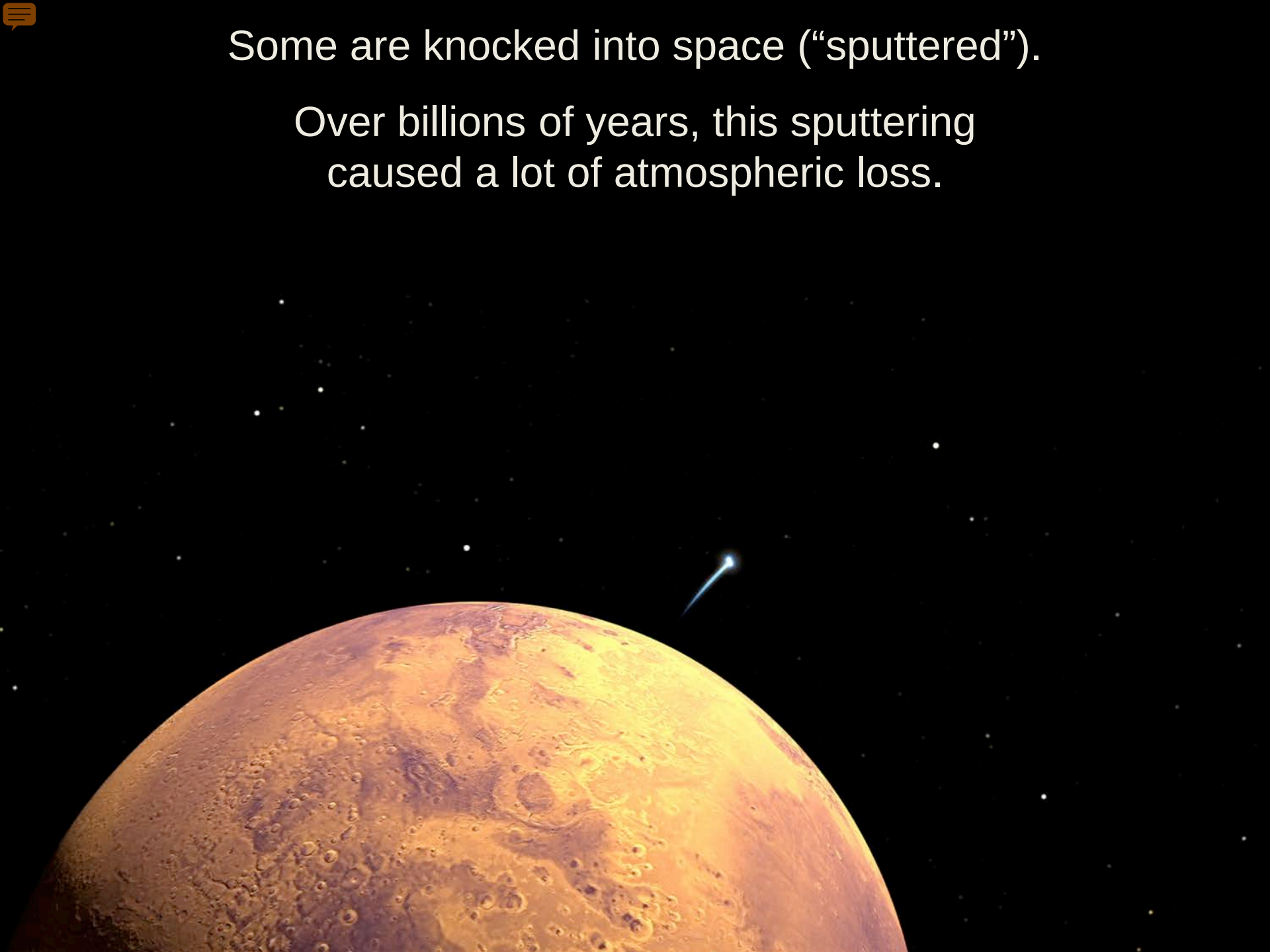
Those ions zoom back into the atmosphere
going over 2 million miles per hour!



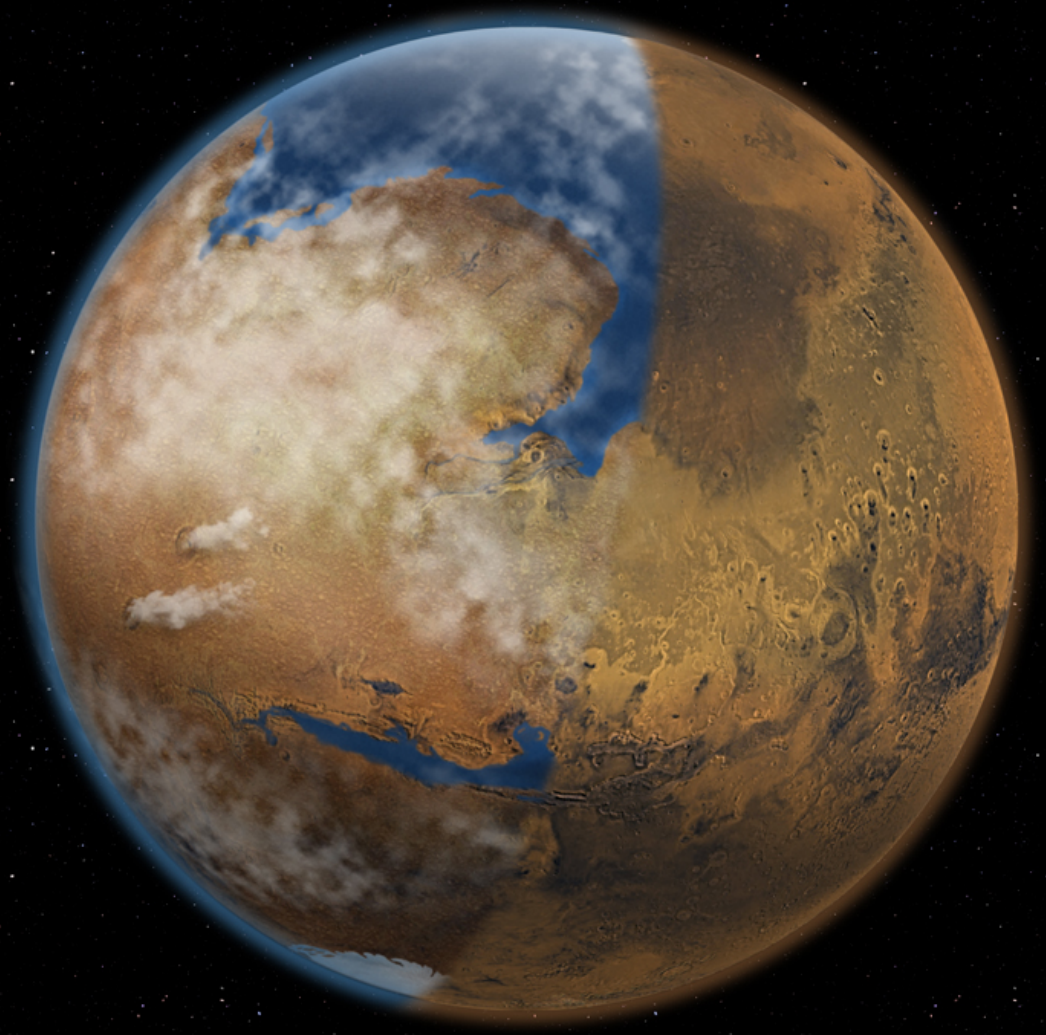
Like hitting balls in a game of pool, they slam into
one atom after another, flinging atoms everywhere.

Some are knocked into space (“sputtered”).

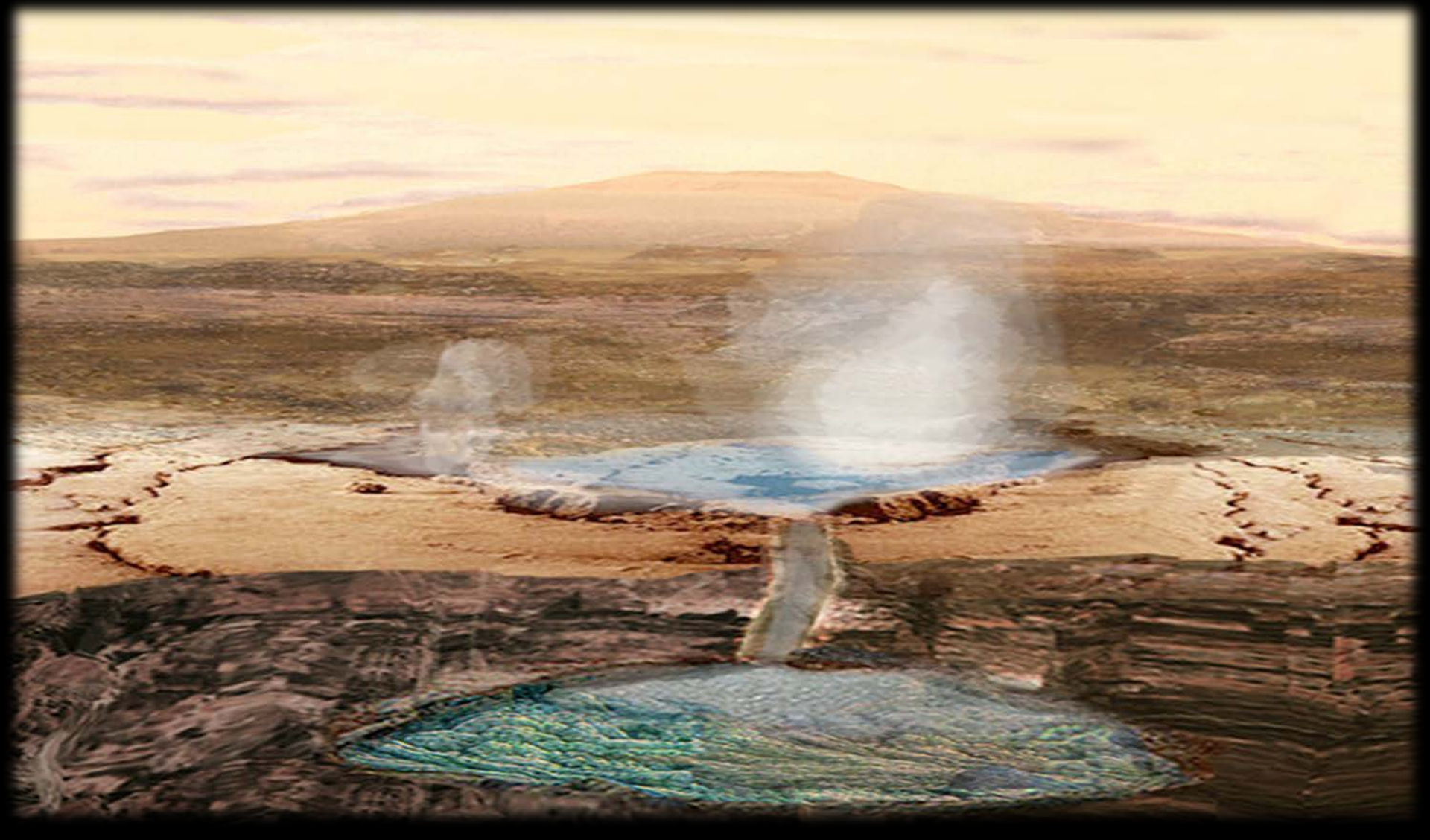
Over billions of years, this sputtering caused a lot of atmospheric loss.



By measuring the rate of escape to space today, scientists can infer how Mars' environment changed through its ~4.5 billion year history.



What we learn from MAVEN may help us understand early conditions favorable to life and how long they lasted.

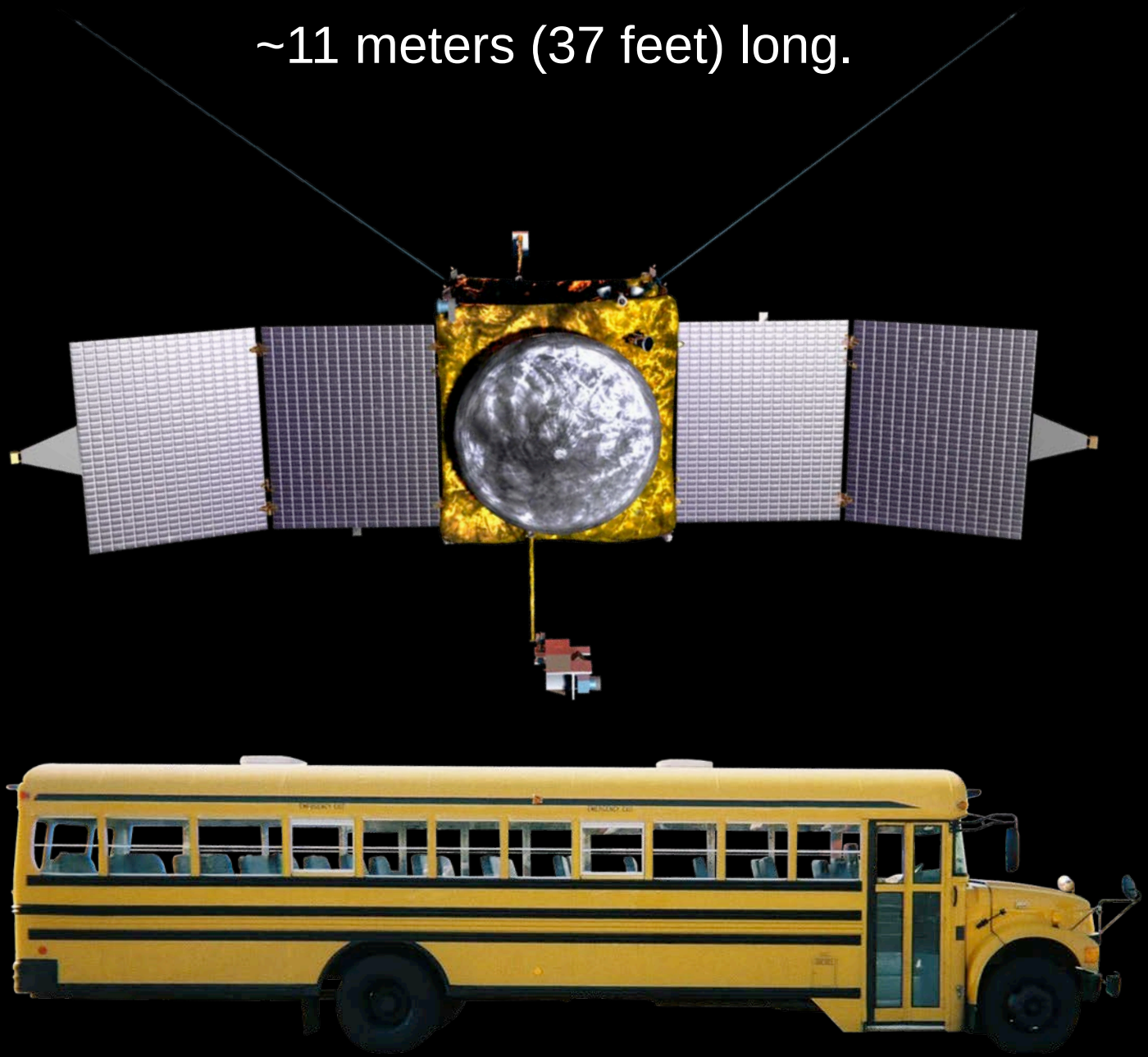


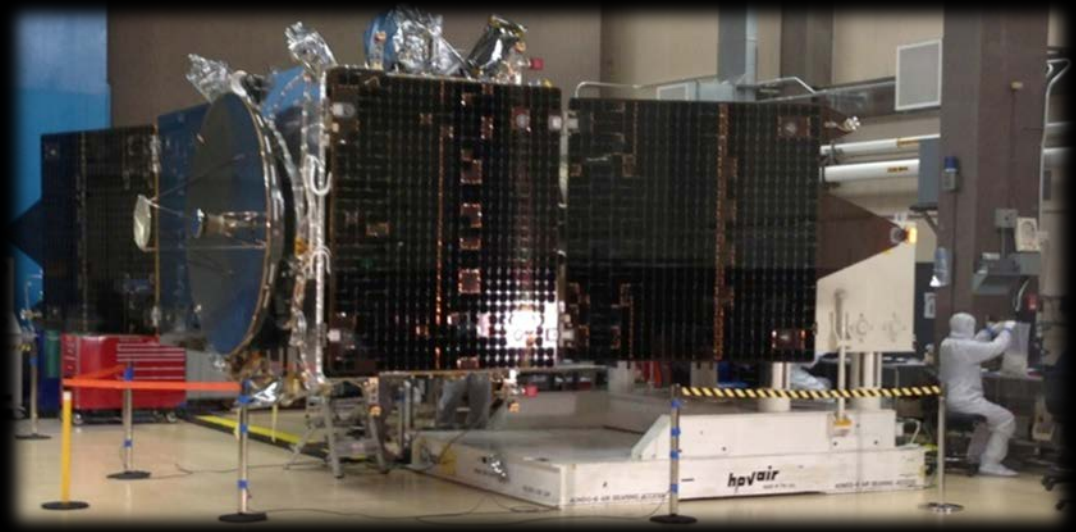
MAVEN launches on an Atlas V 401 rocket
from Cape Canaveral Air Force Station, Florida,
between November 18 & December 7, 2013.

MAVEN carries with it the names of ~100,000 people, artwork from children all over the world, and haiku poetry submitted in an online contest.

MAVEN is the length of a school bus:

~11 meters (37 feet) long.





The orbiter weighs
as much as
an SUV loaded
with a family:

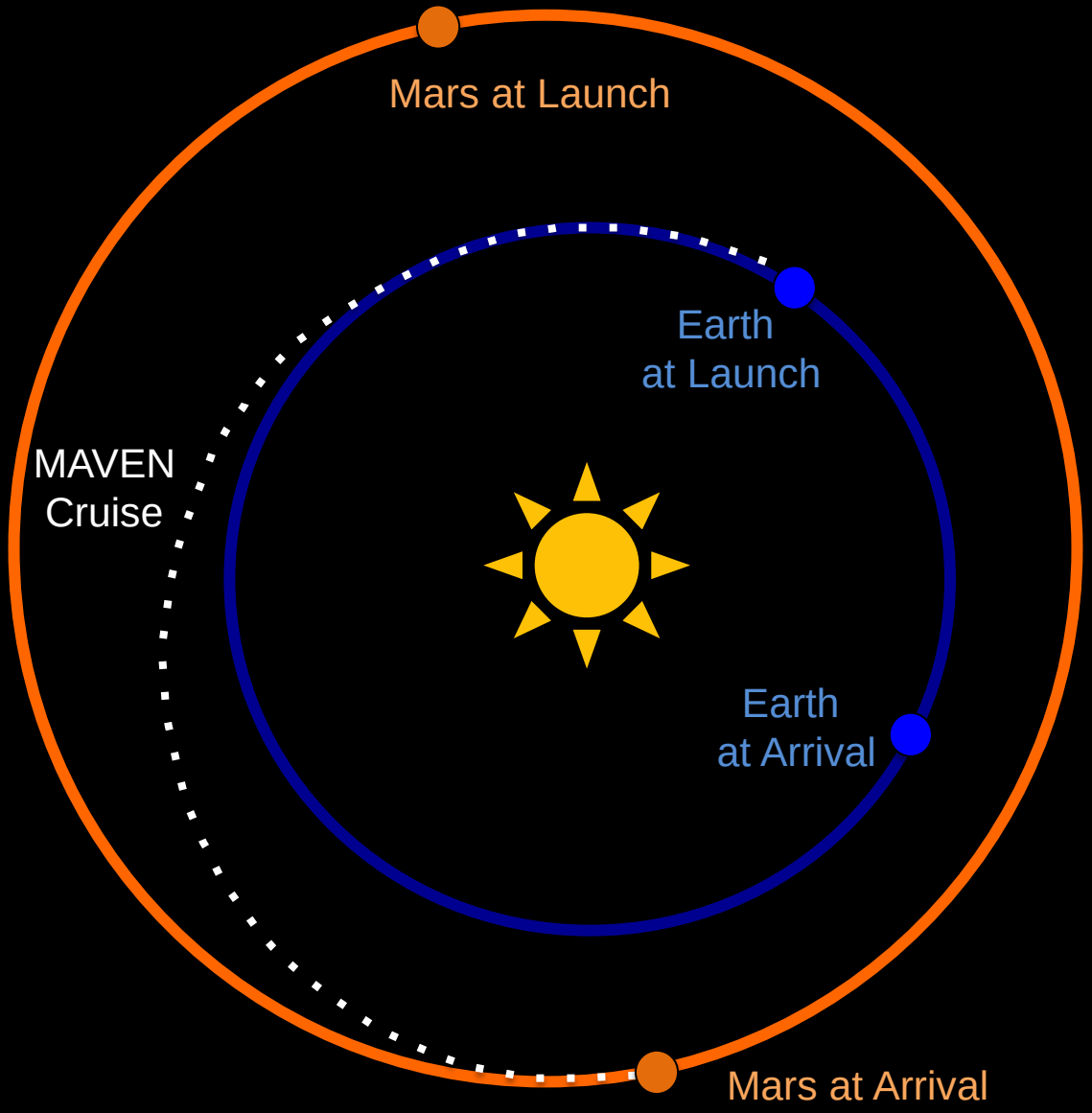
2,550 kg

(~5,622 lb)

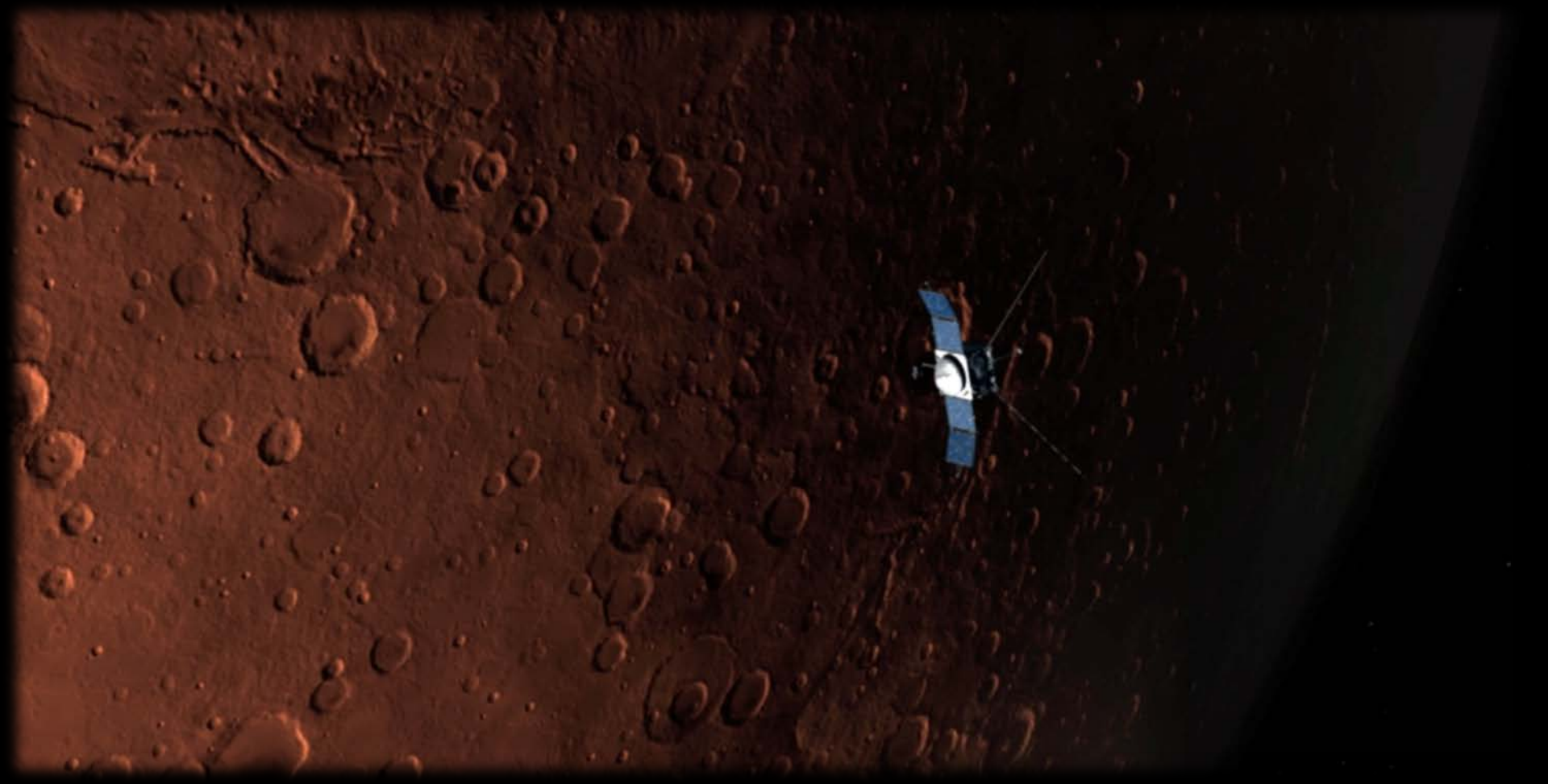
During launch, MAVEN
Is protected in the rocket's
"nose cone" (its fairing).

Shortly after launch,
the fairing drops away,
making way for MAVEN to
be released on its journey
through space to Mars.

For about 10 months after launch,
MAVEN will cruise from Earth to Mars.

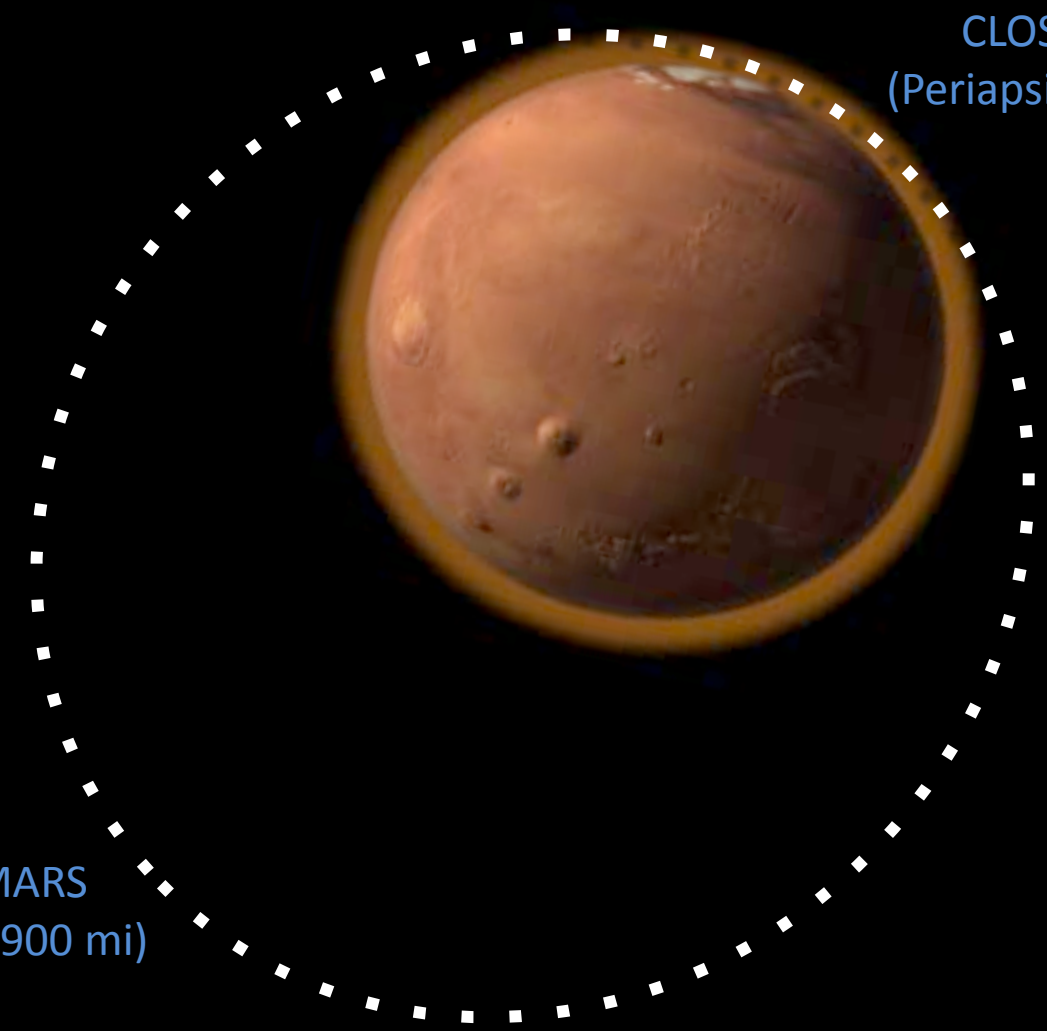


Mars Orbit Insertion on ~September 22, 2014
captures MAVEN into orbit around Mars.



Then, it takes about a month to go from capture to final orbit,
deploy the booms, and test instruments and the spacecraft’s alignment.

MAVEN will fly in an elliptical orbit above Mars, measuring all relevant parts of Mars' upper atmosphere.

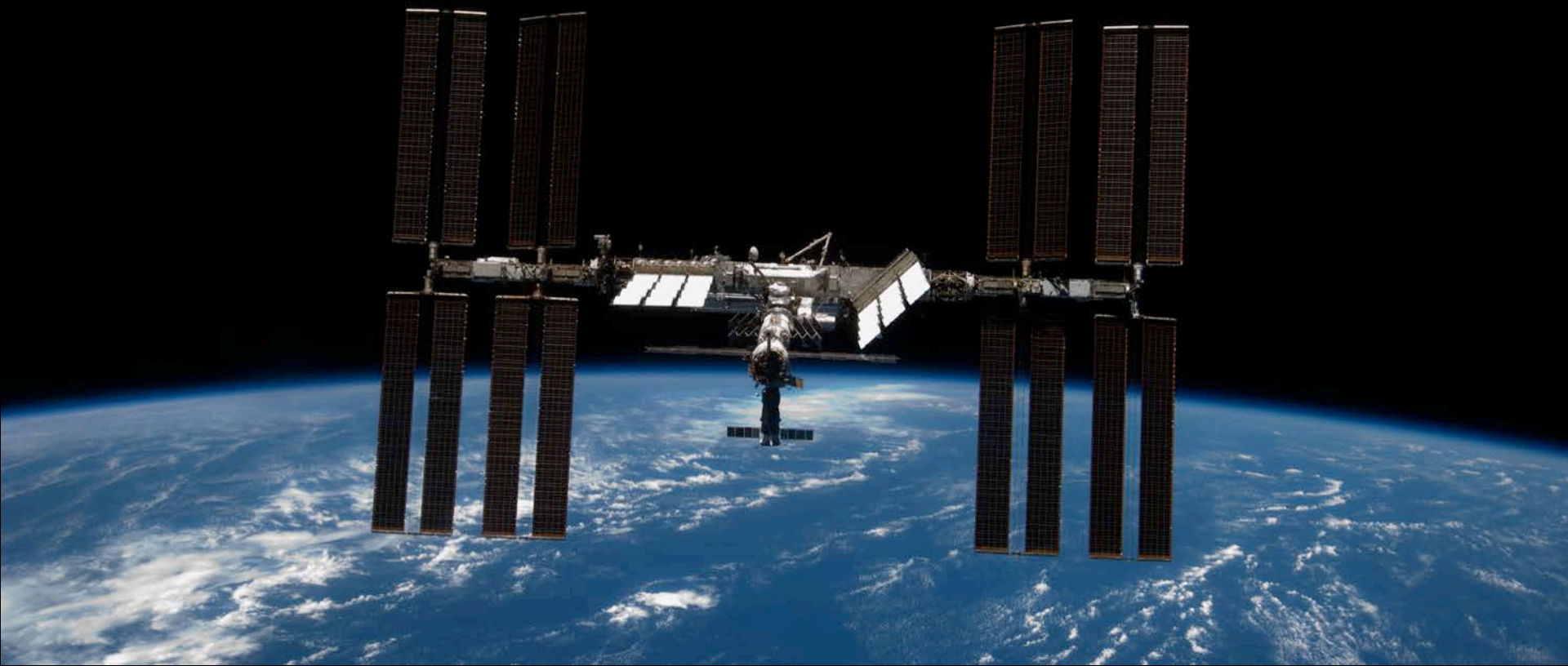


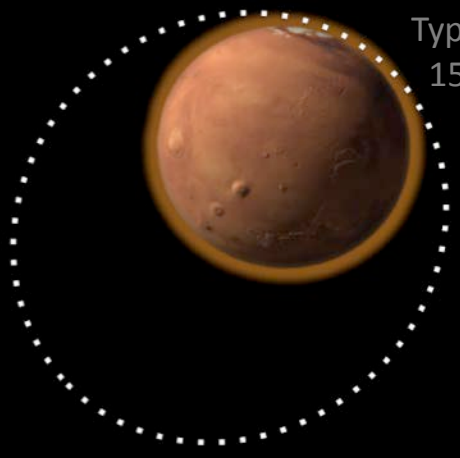
CLOSEST TO MARS
(Periapsis: 150 km/93 mi)

FARTHEST FROM MARS
(Apoapsis: 6200 km/3900 mi)

CLOSEST TO MARS
(Typical Periapsis: 150 km/93 mi)

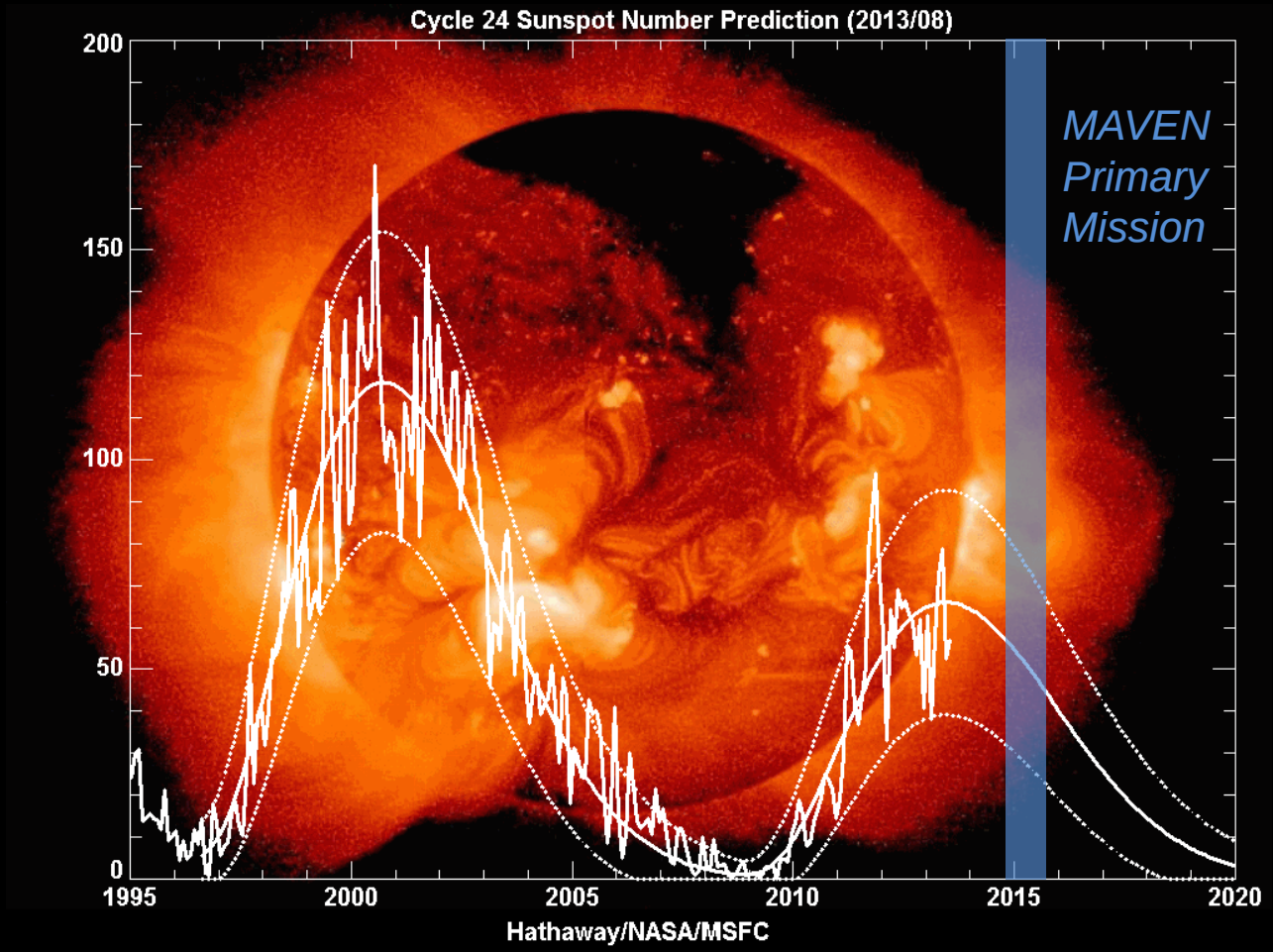
At MAVEN's closest approach,
it is 3 times closer to Mars than the
International Space Station is to Earth.





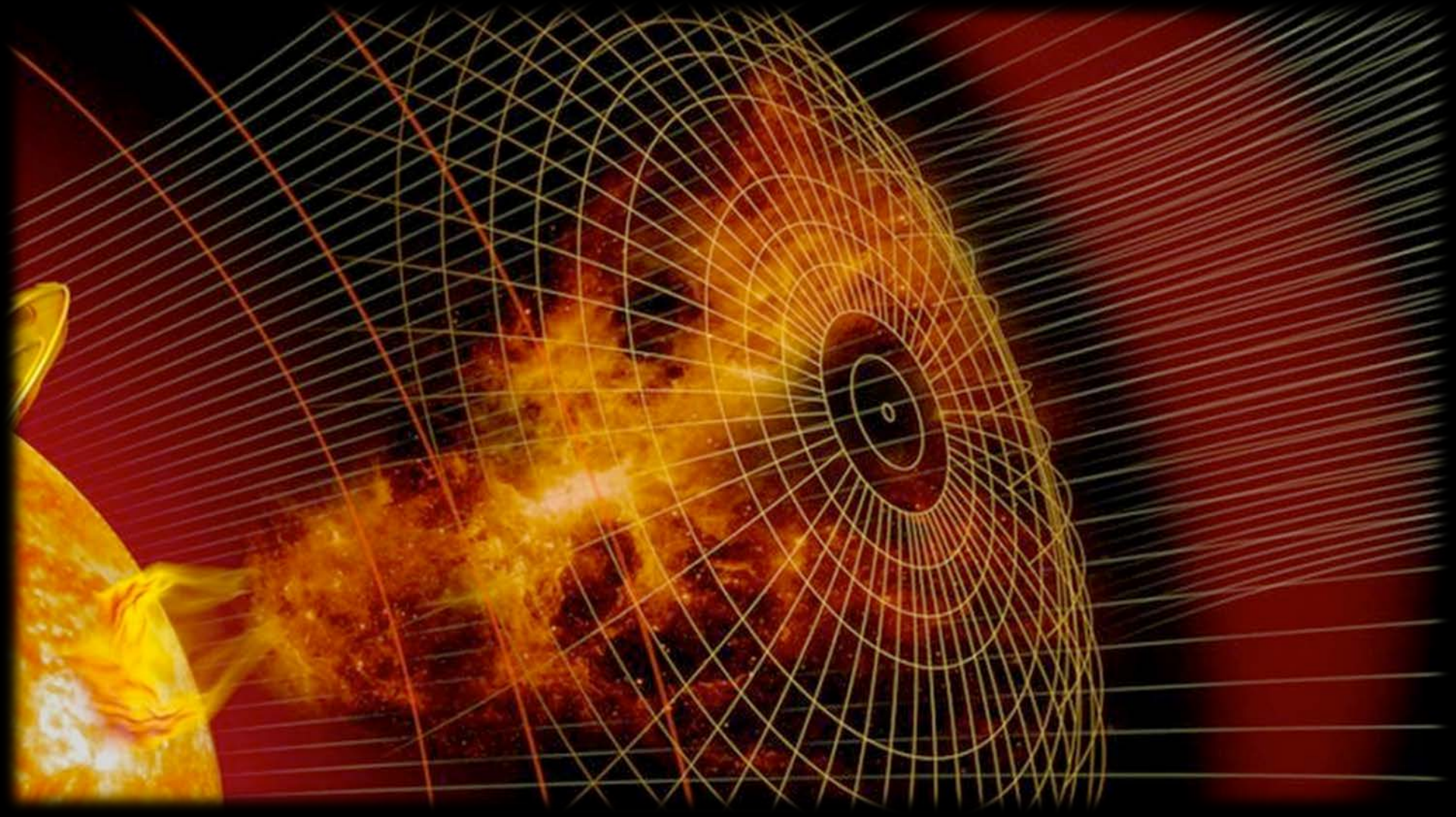
Five times on its closest approach,
MAVEN will perform “deep dips”
into the Martian atmosphere,
coming as close as
125 km (78 mi).

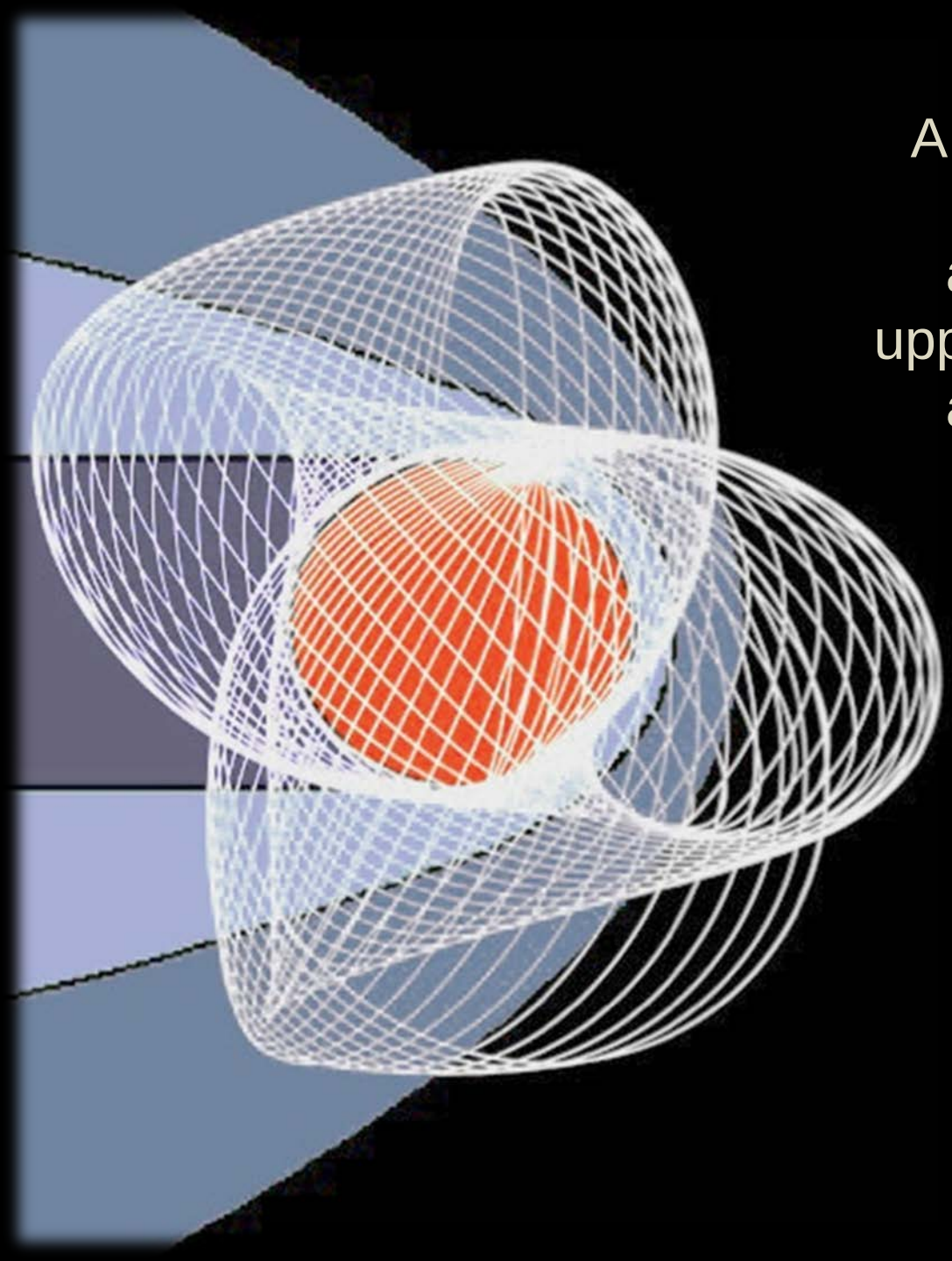
MAVEN will study the atmosphere just after "solar maximum," a time when the sun is most active.



During this time, the Sun's activity reveals processes like those billions of years ago when our star was young.

In addition to understanding atmospheric changes and loss in general, MAVEN will also take measurements when events such as solar flares occur.





A year of MAVEN orbits will provide data on all key regions of the upper Martian atmosphere and magnetosphere.

Mars

MAVEN Orbits

Solar Wind

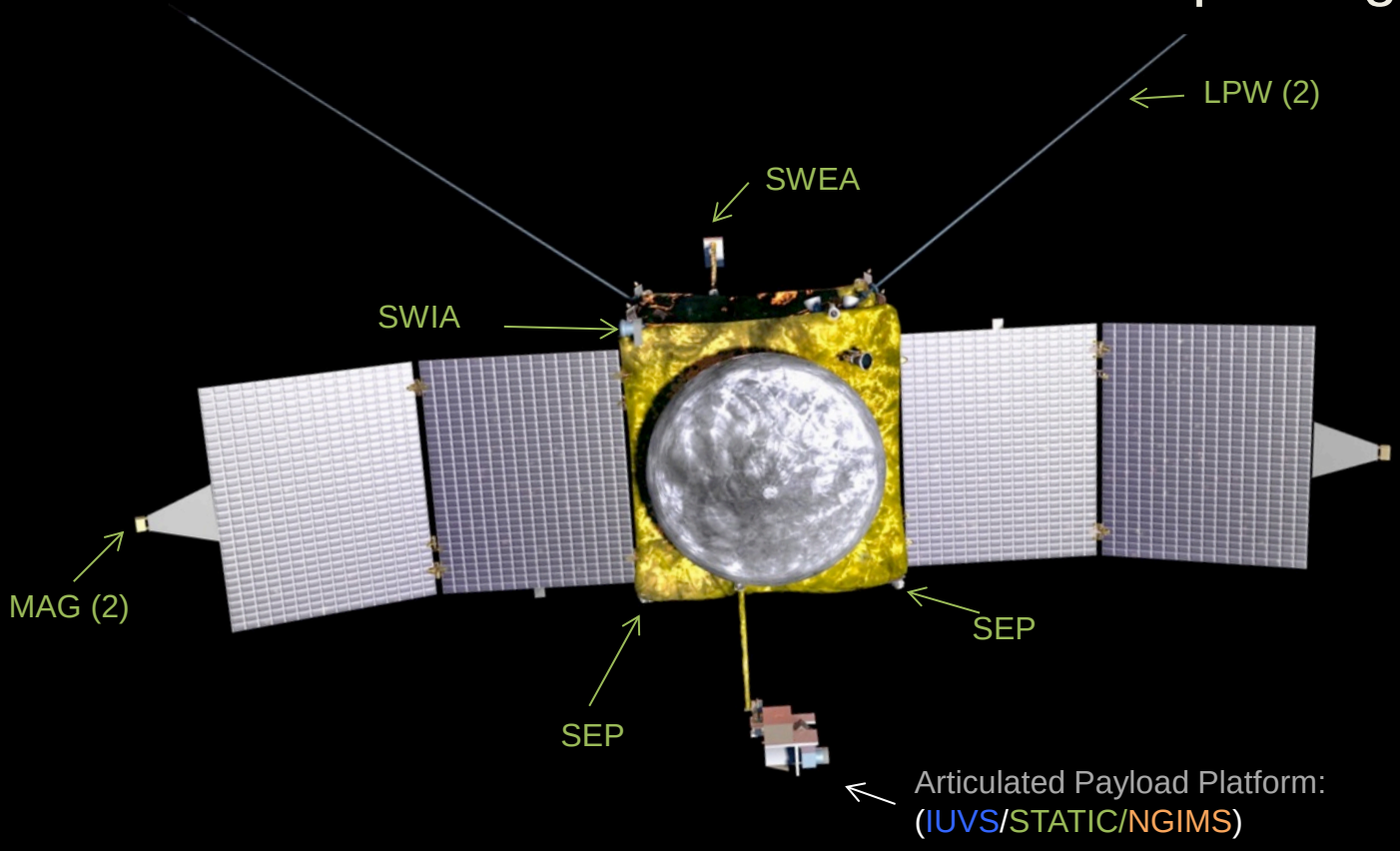
REGIONS OF THE MAGNETOSPHERE

Magnetosheath

Magnetic Pile-up Region

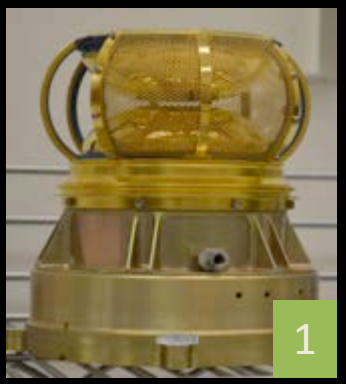
Wake

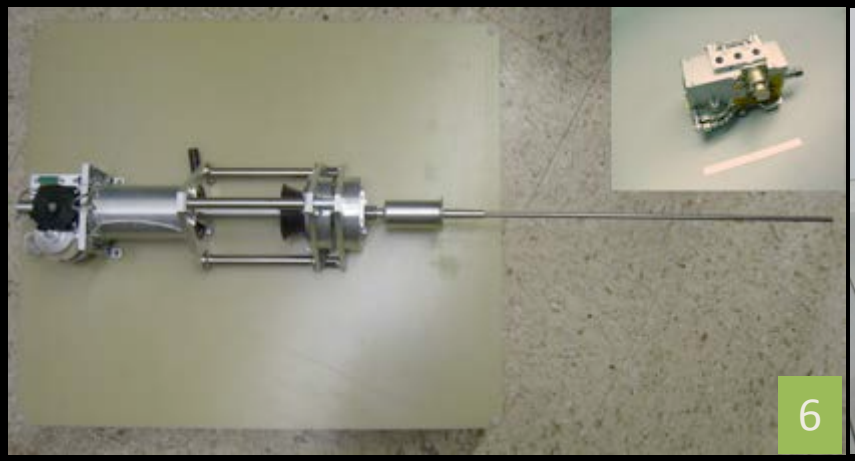
For making discoveries, MAVEN science instruments come in 3 packages.

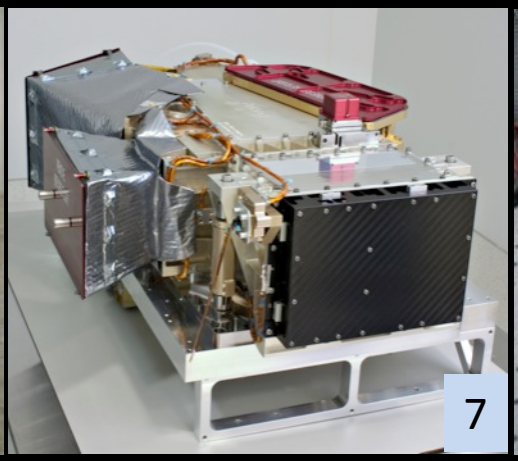


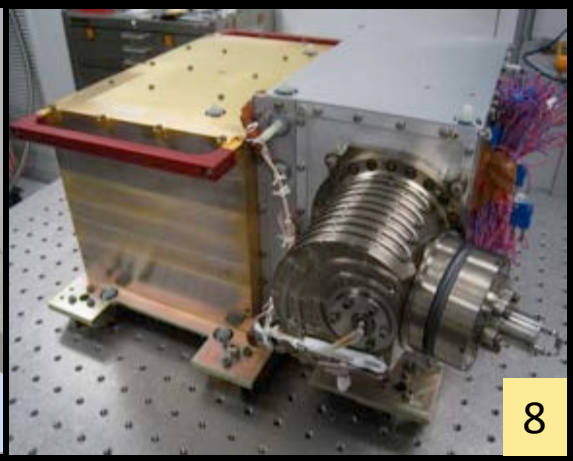
Particles and Fields	Remote Sensing	Neutral Gas & Ion Mass Spectrometer
6 instruments characterize the Sun and solar wind.	1 instrument studies global characteristics of the upper atmosphere & ionosphere.	1 instrument measures the composition & isotopes of neutral gases and ions.

MAVEN Instrument “Glamour Shots”









Particles and Fields

1. Solar Wind Electron Analyzer (SWEA)
2. Solar Wind Ion Analyzer (SWIA)
3. SupraThermal And Thermal Ion Composition (STATIC)
4. Solar Energetic Particle (SEP)
5. Magnetometer (MAG)
6. Langmuir Probe and Waves (LPW)

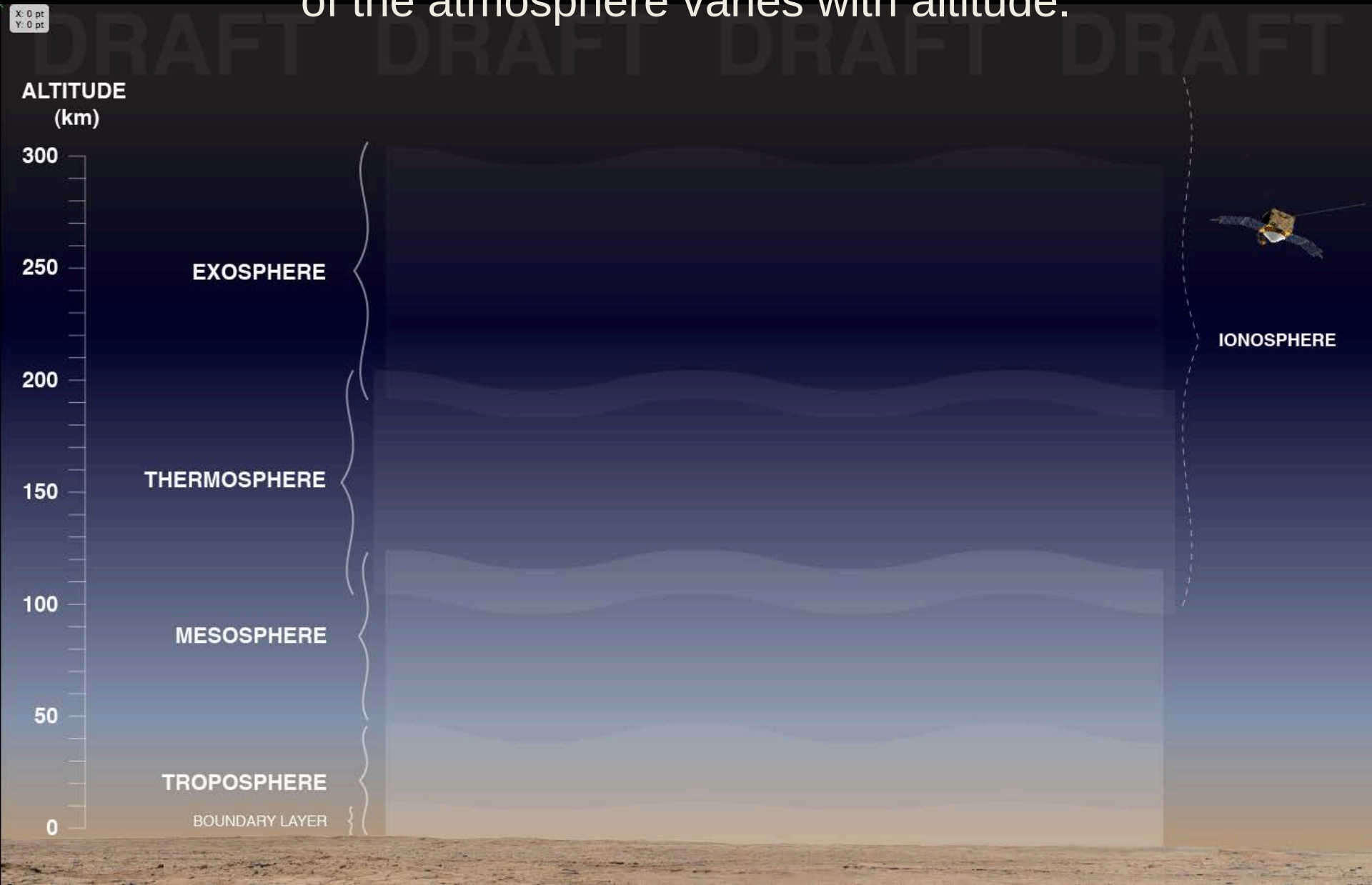
Remote Sensing

7. Imaging Ultraviolet Spectrometer (IUVS)

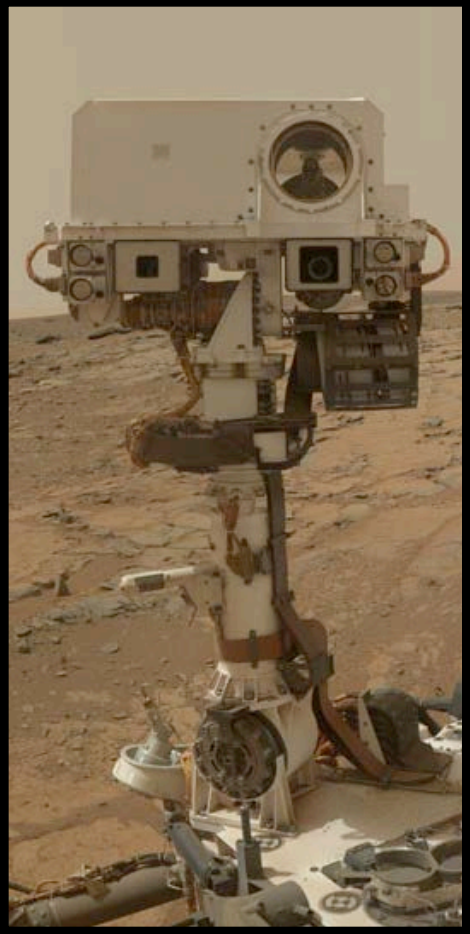
Spectrometer

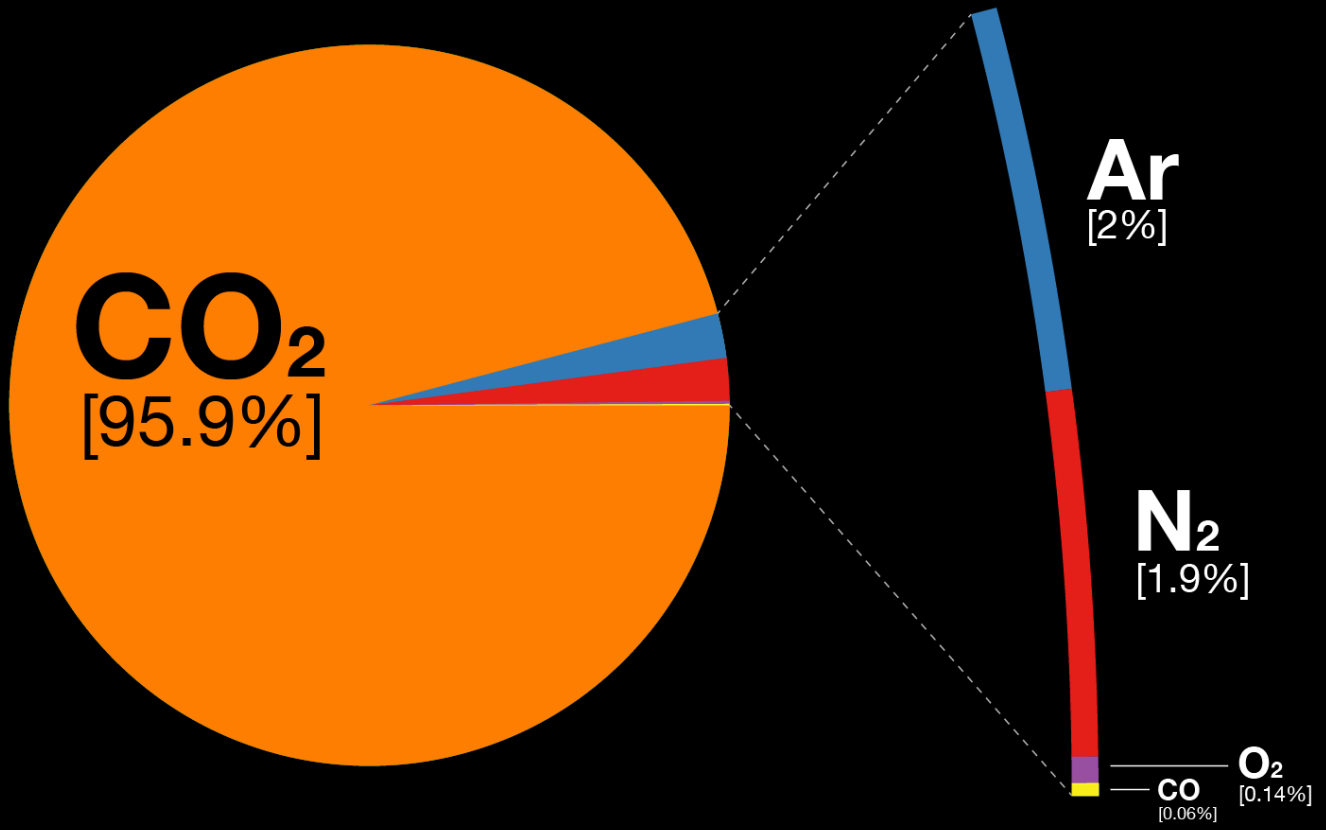
8. Neutral Gas and Ion Mass Spectrometer (NGIMS)

By scanning low and high in the upper atmosphere, MAVEN instruments will measure how the composition of the atmosphere varies with altitude.

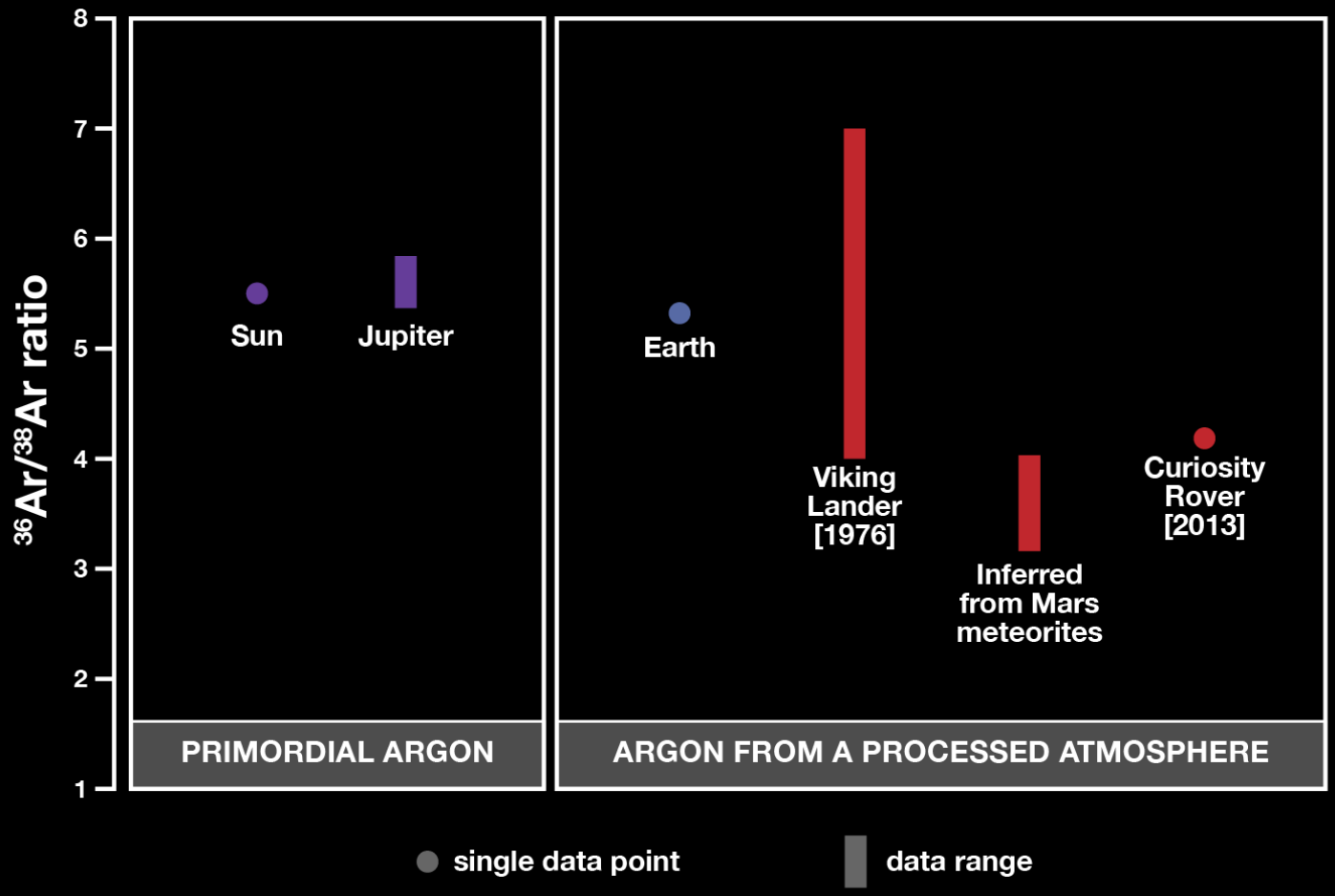


MAVEN will compare its measurements with data collected by the Curiosity rover on the lower atmosphere.



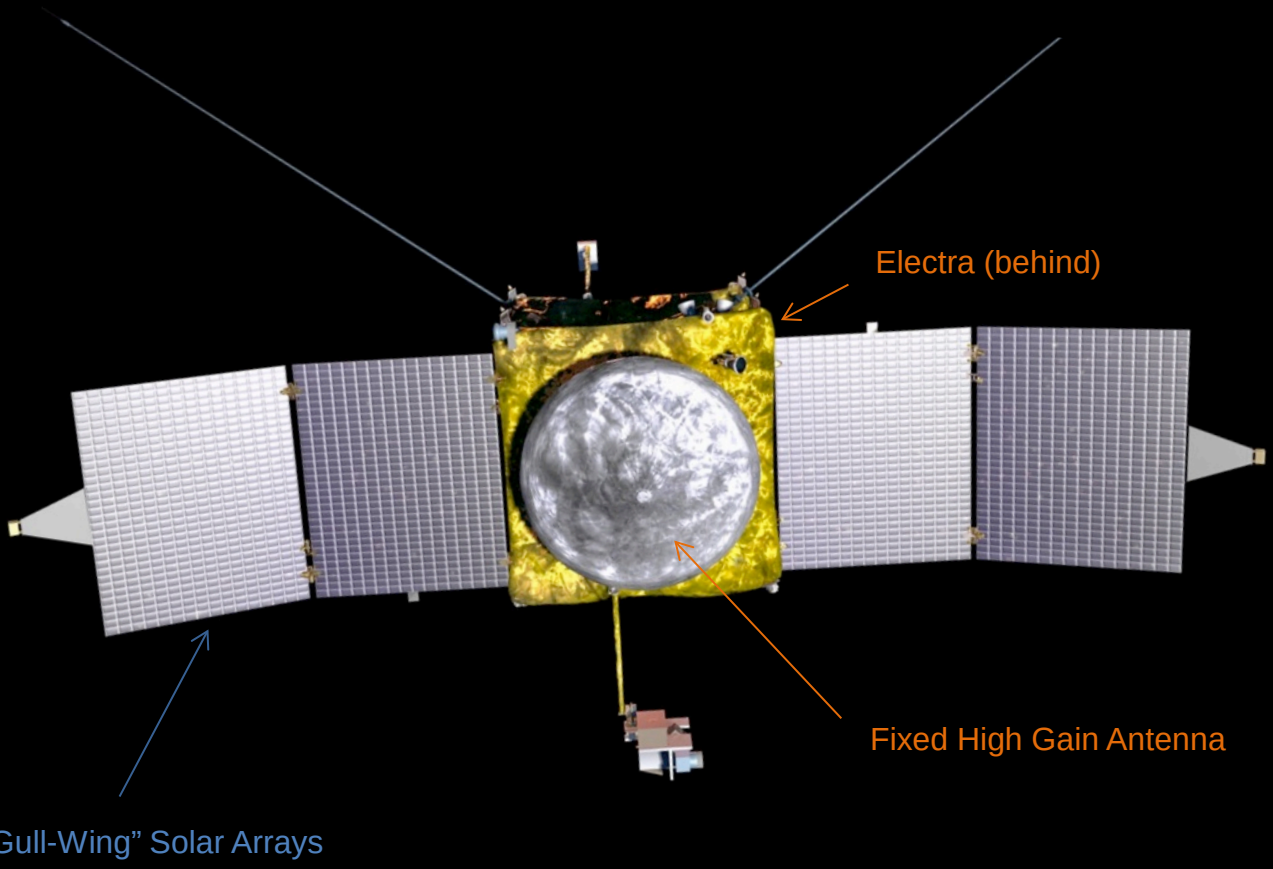


MAVEN and Curiosity measure the amounts of different kinds of atoms, ions, and isotopes to calculate escape rates.

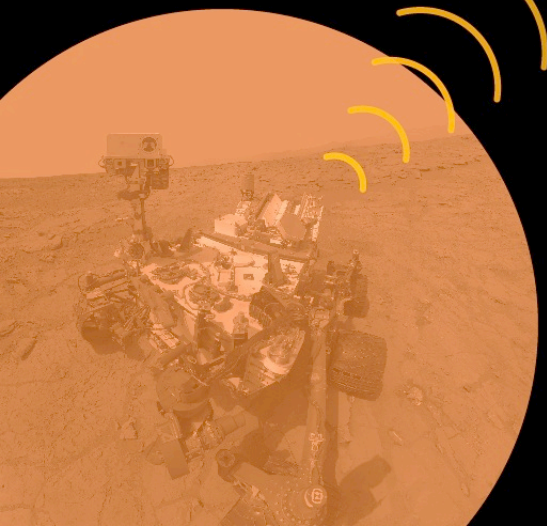


Hotter, lighter particles escape much faster.
Argon especially helps determine atmospheric loss.

MAVEN communications and power assets are also key components of the orbiter.



After its primary science mission, MAVEN can also support current and future Mars landers and rovers by relaying data back to Earth.



Mission Success:
It takes a team of talented people!

lasp.colorado.edu/maven

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QUESTIONS ABOUT MAVEN?