

Mercury, Venus, Earth, and Mars

Astronomy 101
Syracuse University, Fall 2020
Walter Freeman

November 5, 2020

Announcements

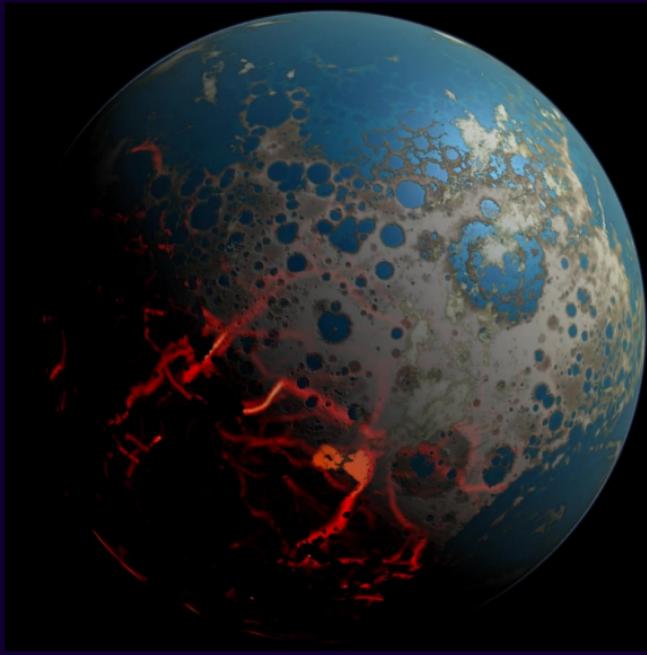
- Project 4 due Sunday
- There is a revised version of Lab 9 available online that has different reference spectra that might be easier to use
- In the printouts for Lab 9, one question asks “Which of these is an incandescent light and which is sunlight?”
 - How can you tell? (*Type in chat.*)

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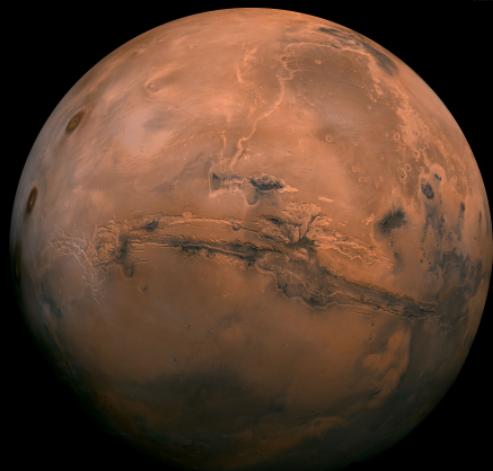
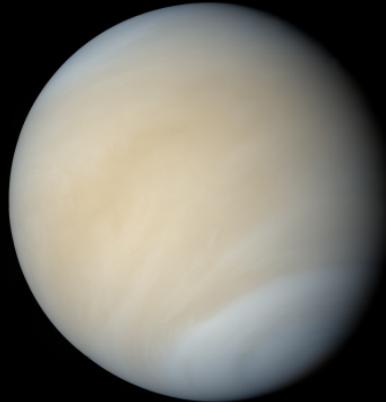
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How do we get from there to here?



A few things to keep in mind

- Asteroids: any unprotected object gets hit repeatedly (more in early solar system)
- Our atmosphere is thick enough to burn up many, but not all, asteroids
- Volcanism:
 - Hot rocks melt
 - Molten things flow
 - If the core of a planet is hot, it has volcanic activity
 - Radioactive decays of uranium sustain internal heat of planets over billions of years

	Orbit (AU)	Radius (km)	Temp (actual)	Temp (pred.)	Volcanism?
Mercury	0.39	2440	700 / 100 K	439 K	Long ago
Venus	0.72	6051	740 K	321 K	Yes
Earth	1	6378	290 K	273 K	Yes
Mars	1.52	3397	220 K	222 K	In the past

	Orbit (AU)	Δ Temp	Atmosphere	Atmospheric pressure
Mercury	0.39	small	None	None
Venus	0.72	+419 K	CO ₂	92 atm
Earth	1	+17 K	N ₂ ; O ₂ ; CO ₂ ; H ₂ O	1 atm
Mars	1.52	-2 K	CO ₂ ; N ₂ ; Ar	0.006 atm

Mercury, the fleet messenger god, whizzing around the Sun...



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

Agile, lively Mercury...

Mercury's surface is pockmarked with craters. This tells us:

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- It didn't have an atmosphere when this happened
- No weathering, geologic activity, or the like has taken place since

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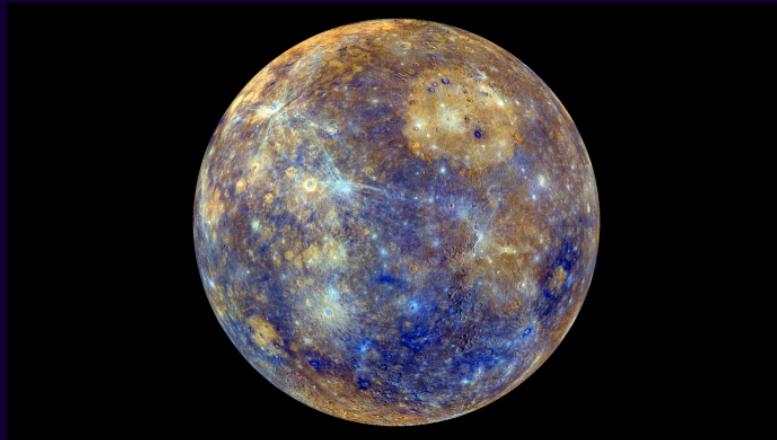
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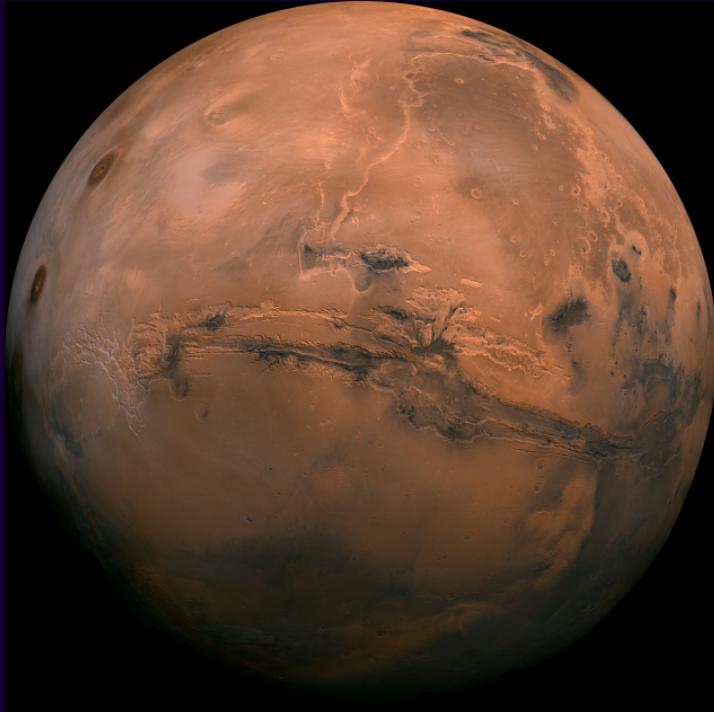
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Mars, the cruel god of war...



<https://www.youtube.com/watch?v=cX0anvv4plU>

Bloodthirsty, violent Mars...

We've sent robots to Mars that have explored it some detail. We find:

- Rocks with rust in them, making it red
- Only a thin atmosphere, mostly CO₂
- Large volcanoes, none active
- Evidence of interior heat, but not like Earth and Venus
- Evidence that liquid water once ran on its surface
- Evidence that it once had an atmosphere of water and CO₂
- Evidence that was once much warmer than it is today

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- Evidence that was once much warmer than it is today
- ... what happened?

Rusty, peaceful Mars...

- Something happened around three billion years ago
- Mars lost its atmosphere
 - Decline in interior heat → less volcanism?
 - Solar wind stripping the atmosphere away?
 - Still an area of active research
- This caused it to cool (no more greenhouse effect!)

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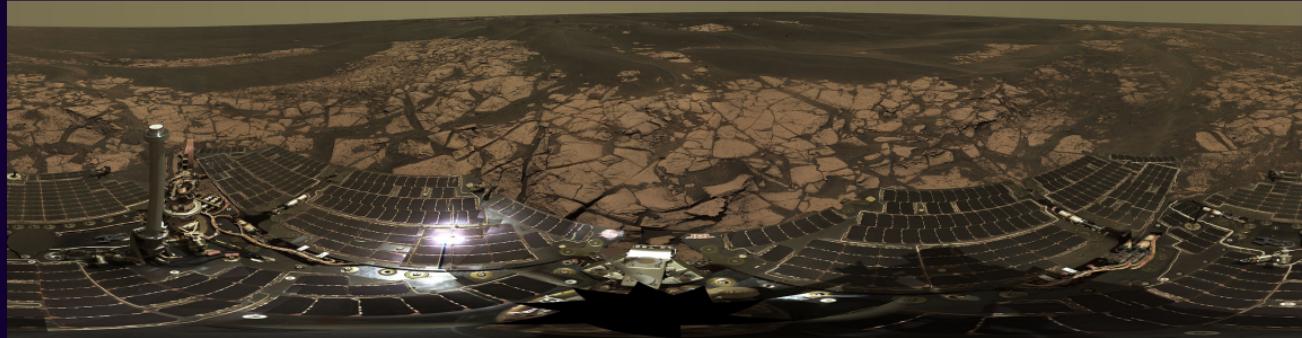
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- ... and robots!

Mars, the robots' domain...

NASA sent two small rovers to Mars that landed in 2004.

- These two little robots, named *Spirit* and *Opportunity*, were supposed to last 90 sols...
- *Spirit*: stuck after 2274 Martian days (6.4 years).
<https://xkcd.com/695/>
- *Opportunity*: unresponsive after a dust storm after 5,250 Martian days (14.7 years)



Venus, the goddess of love and beauty...



<https://www.youtube.com/watch?v=PyBkzZoMYN4>

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- It rains sulfuric acid
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- ... if there is a Hell in our solar system, it is Venus. What in Hell – literally – happened?

Horrifying, poisonous Venus...

- Visible light doesn't go through this atmosphere well
- ... radar does!
- We've used radar to map the Venusian surface
- It has some interesting geology
- You can read about it in your book



Earth, cradle of life...



<https://www.youtube.com/watch?v=MbHQ6eWANIo> (not by Holst!)

Earth, our home...

- Active volcanism throughout its history
- Large amounts of liquid water on surface
- Stable climate: most of surface between 273 K and 373 K (freezing/boiling) for a long time
- Atmosphere with significant oxygen, nitrogen, some CO₂

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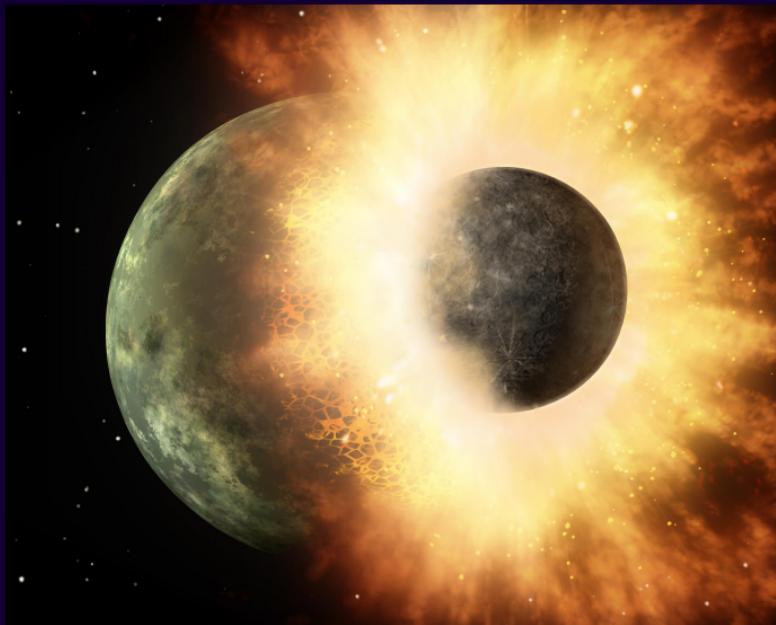
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- Stable climate: most of surface between 273 K and 373 K (freezing/boiling) for a long time
- Atmosphere with significant oxygen, nitrogen, some CO₂
- Surface covered by self-replicating, reactive, diverse, beautiful, *aware* machines, made of carbon compounds: *life!*
- Atmospheric oxygen from the byproducts of plant metabolism
- Hot core generates a magnetic field that shields atmosphere from solar wind

Our large Moon...

- The Moon appears to have similar composition to Earth
- ... but it lacks active geology or an atmosphere

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- ... but it lacks active geology or an atmosphere
- Shortly after the formation of Earth, something the size of Mars hit us
- Some of the resulting fragments broke off and orbited the Earth
- They coalesced into the Moon



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What controls the temperature of a planet?

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Is there something adding energy to the Earth?

Is there a way for the Earth to give away energy?

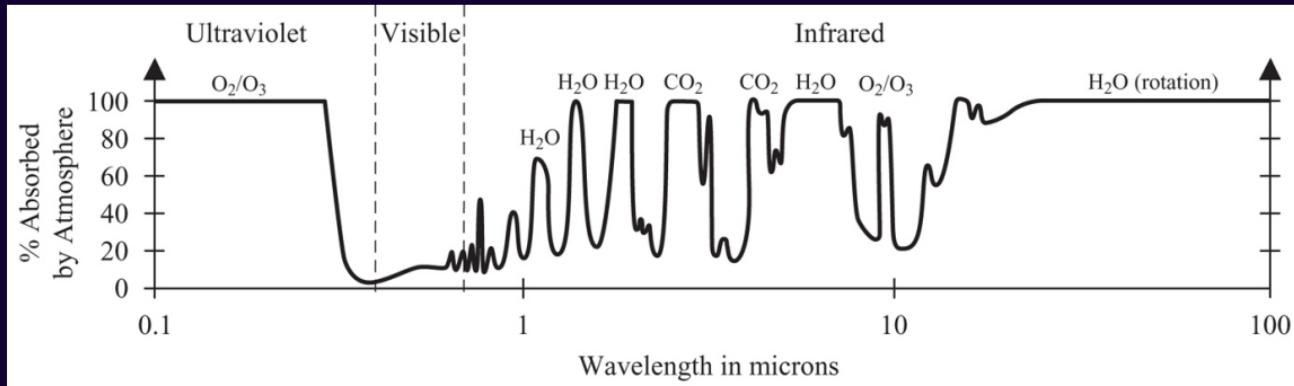
A planet will settle on a temperature where:

Incoming sunlight = Outgoing thermal radiation

Thermal radiation from 5700 K star = Thermal radiation from 300 K planet

Incoming (mostly) visible light = Outgoing far infrared

The greenhouse effect



- So planets' temperature set by radiation balance:
 - Incoming thermal radiation from Sun – visible
 - Outgoing thermal radiation from planet – infrared
- What happens if you have an atmosphere that reflects IR, but not visible light?
- The outgoing thermal radiation is greatly reduced!

This is called the *greenhouse effect*.

The greenhouse effect

Venus has a *tremendously thick* atmosphere and a powerful greenhouse effect.

- Its atmosphere contains a great deal of CO₂, which reflects IR strongly
- The thermal radiation that would carry heat away from Venus can't get out
- It is over 400 K hotter than was predicted by the calculation you are doing this week

Earth has a *thinner* atmosphere.

- Nitrogen doesn't absorb strongly at any relevant wavelengths
- H₂O and CO₂ are strong greenhouse gases, but they are only a bit of the atmosphere
- We are about 20 K warmer than predicted by that crude math
- These gases are very important for determining Earth's temperature!