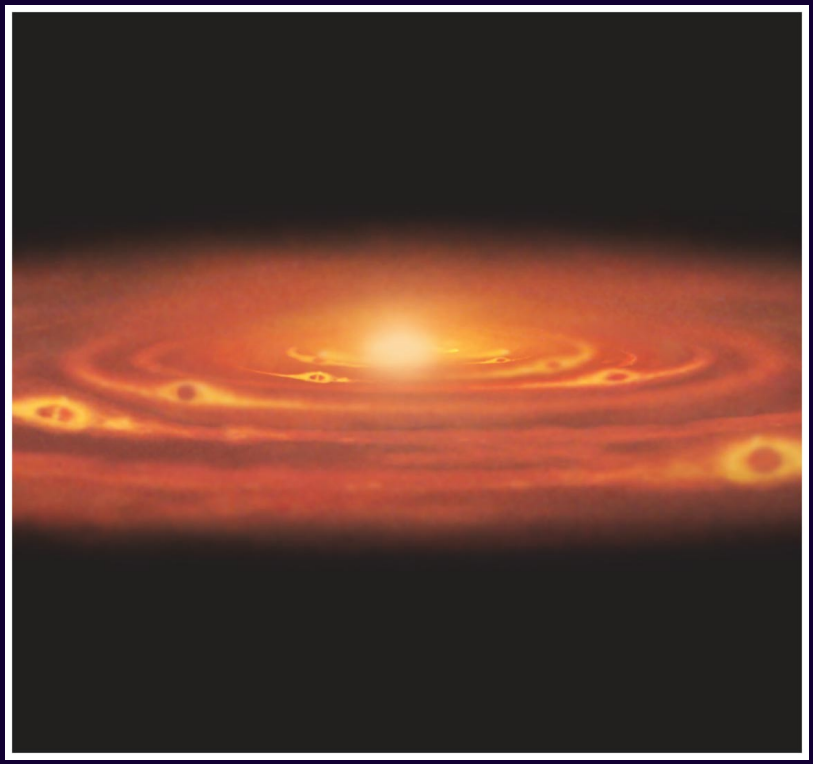
Planets and their atmospheres

Astronomy 101
Syracuse University, Fall 2022
Walter Freeman

17 ноября 2022 г.



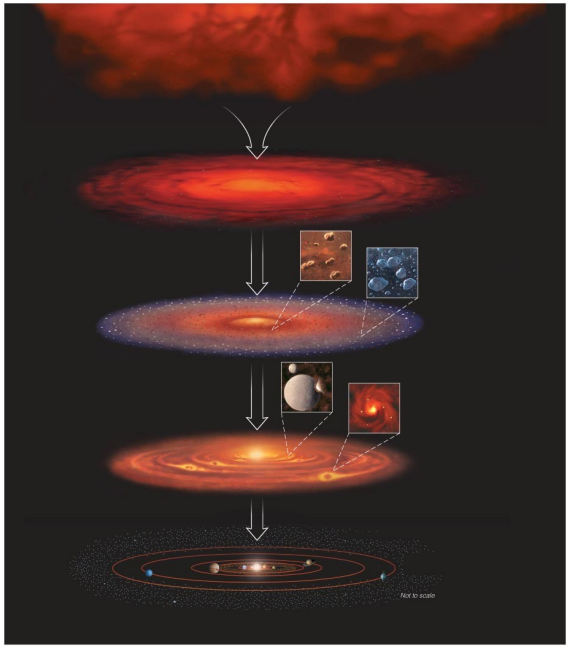
My life is forever connected with aviation. I cannot live without the sky. I dream that perhaps one day I will lift a peaceful aircraft into space.

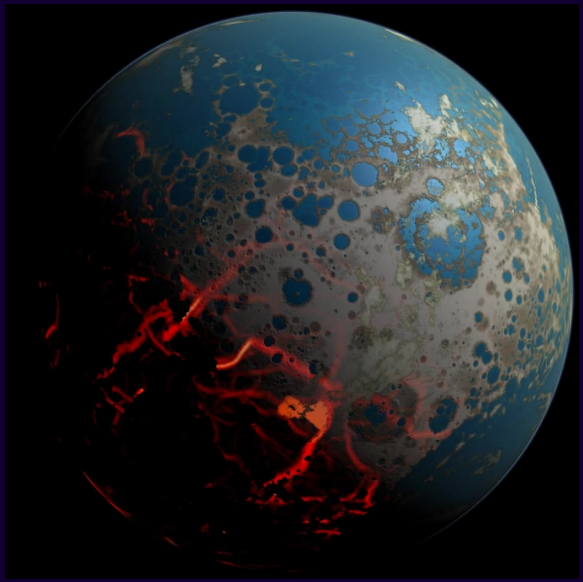
–Іван Кожедуб (Ivan Kozhedub), Ukrainian fighter pilot,
top-scoring fighter-pilot ace of World War 2, from his 1969 memoirs

Announcements

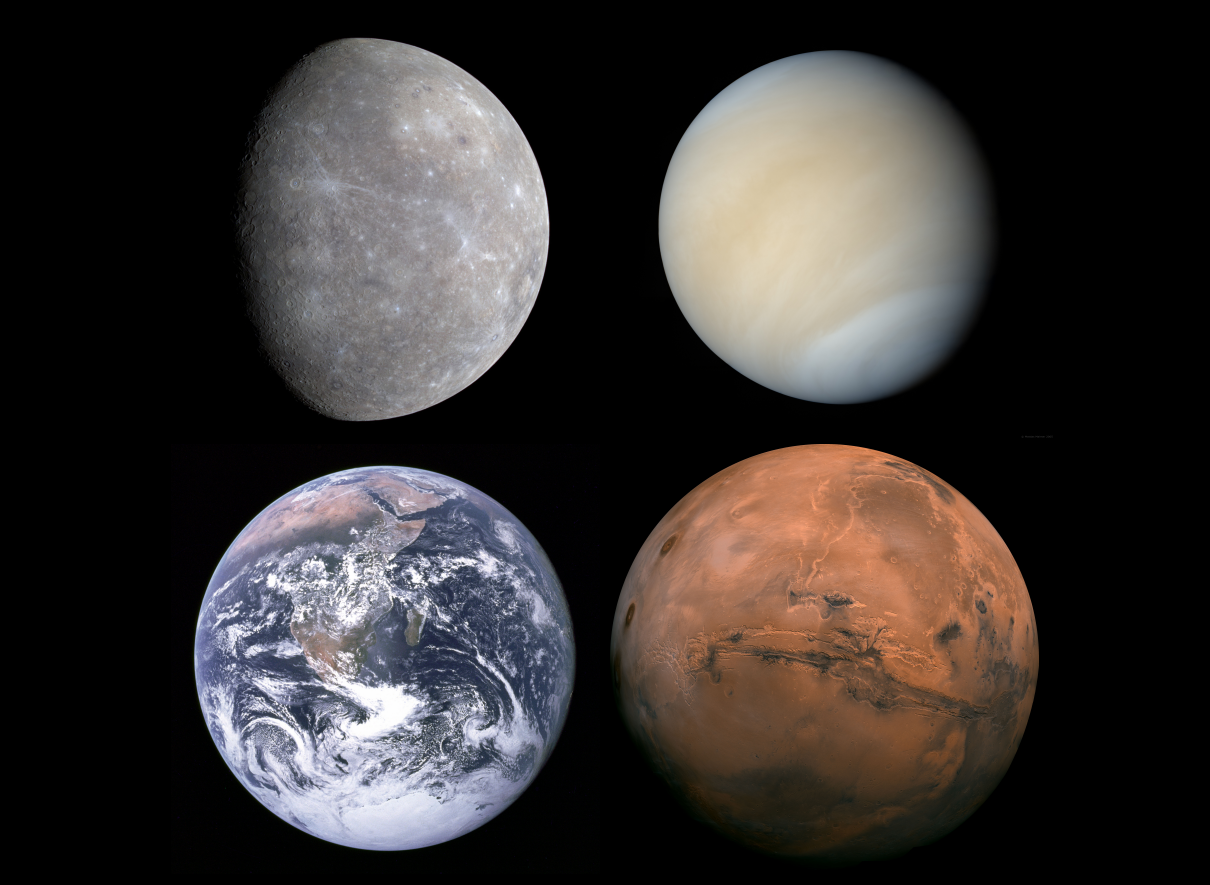
- No prelab next week (we don't want you to have to do one over Thanksgiving)
- Office hours/help session tomorrow, 12-2pm
- Please continue to send me project ideas!

So here we are...





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

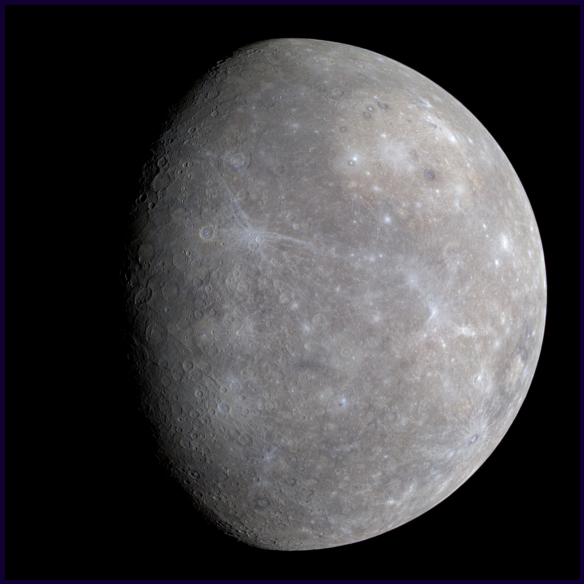
	Orbit (AU)	Radius (km)	Temp (actual)	Temp (pred.)	Volcanism?
Mercury	0.39	2440	700 / 100 K	439 K	Long ago
Venus	0.72	6051	740 K	321 K	Yes
Earth	1	6378	290 K	273 K	Yes
Mars	1.52	3397	220 K	222 K	In the past

	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	$N_2; O_2; CO_2; H_2O$	1 atm
Mars	1.52	-2 K	$CO_2; N_2;$ Ar	0.006 atm

"Temp (pred)" is the temperature you predicted in Lab 10 – what you get if the planet is just a rock in space.

Δ Temp is the difference between the actual temperature of the planet and the temperature that your calculation in Lab 10 predicted.

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:

- It clearly has been hit by asteroids.
- It didn't have an atmosphere when this happened
- No weathering, geologic activity, or the like has taken place since

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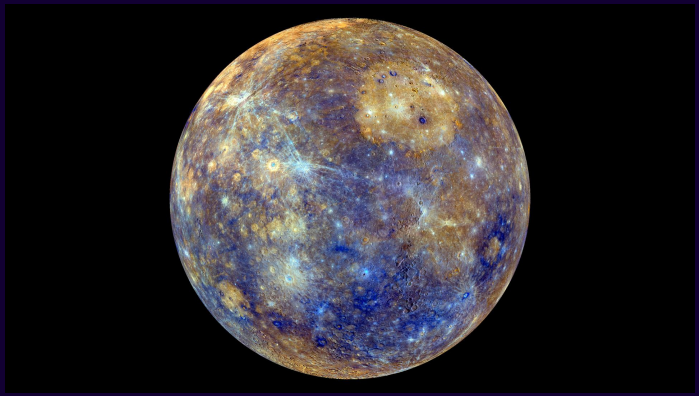
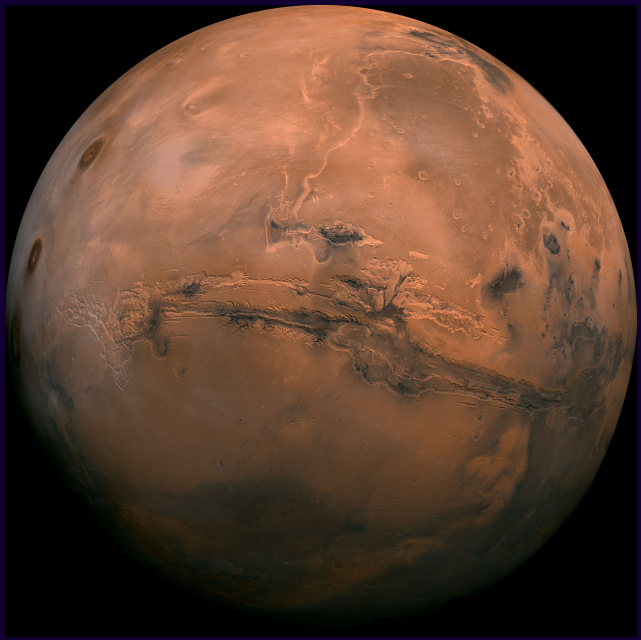


Mars, the cruel god of war...



https://www.youtube.com/watch?v=cXOanvv4plU

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 CO_2
- 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 CO_2
- 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 $\rightarrow$ 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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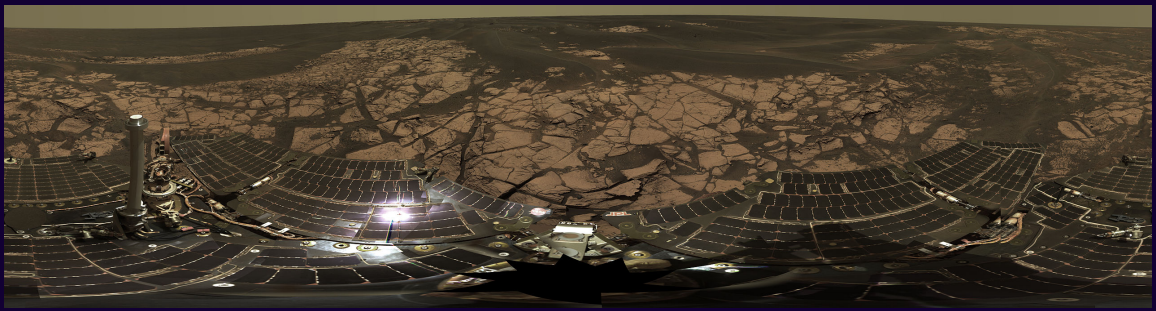
- Now Mars' surface mostly contains memories...
- ... and robots!

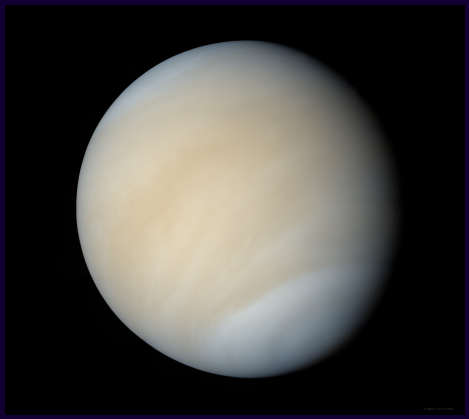
Mars, the robots' domain...

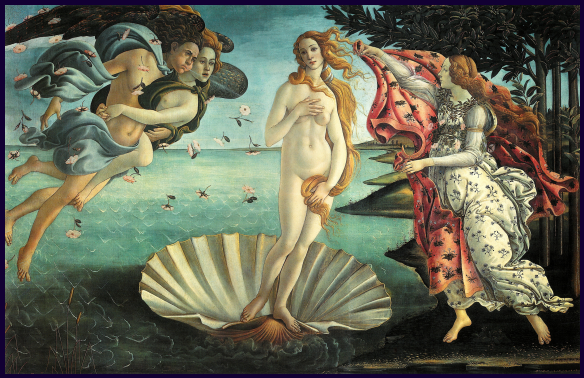
NASA sent two small rovers to Mars that landed in 2004.

- 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

Beautiful, lovely Venus...

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Beautiful, lovely Venus...

- The surface temperature is hot enough to melt lead
- It rains sulfuric acid
- The atmospheric pressure is high enough to crush bone
- ... 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 CO_2

Earth, our home...

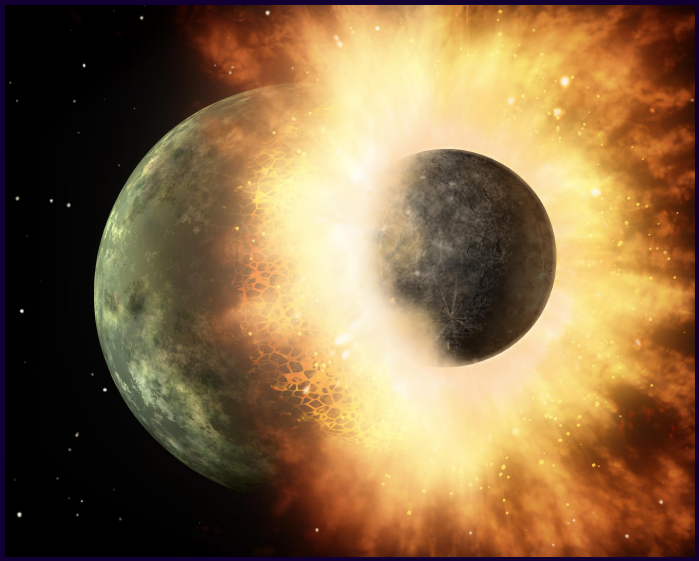
- Active volcanism throughout its history
- Large amounts of liquid water on surface
- Stable climate: most of surface between 273 K and 373 K (freezing/boiling) for a long time
- Atmosphere with significant oxygen, nitrogen, some CO_2
- Surface covered by self-replicating, reactive, diverse, beautiful, *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

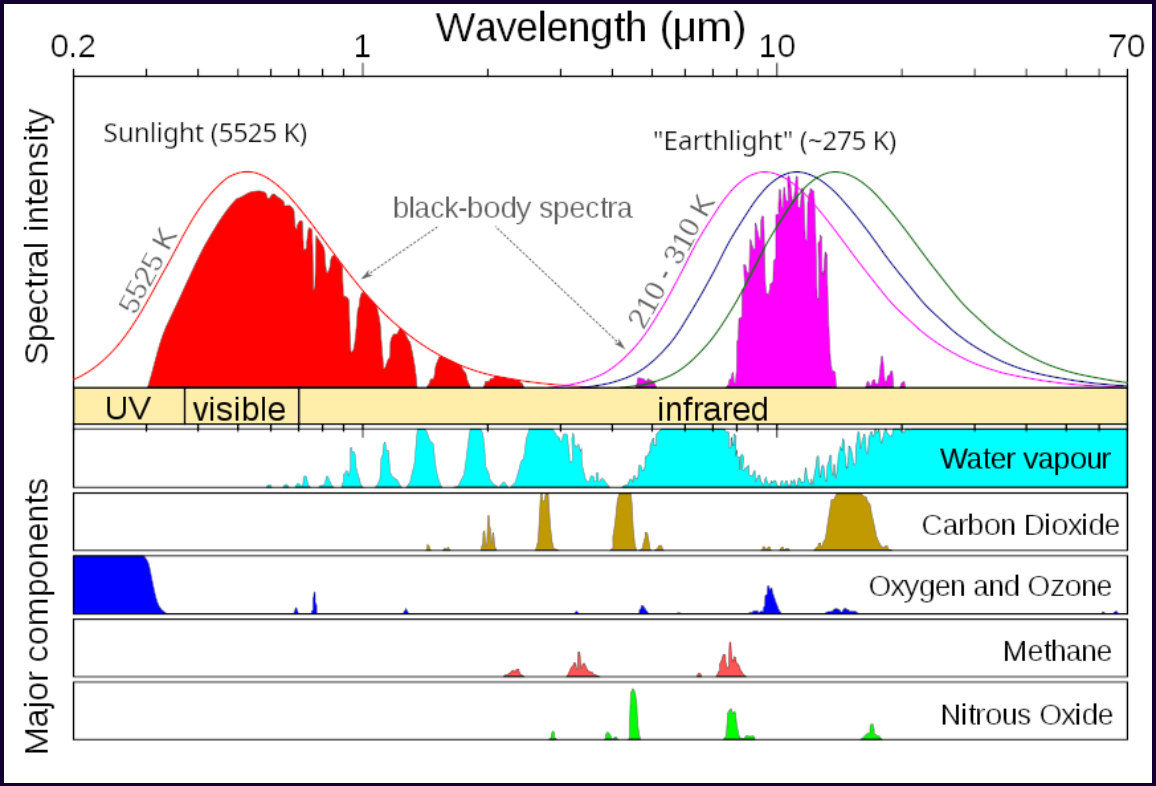
Our large Moon...

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

Our large Moon...

- The Moon appears to have similar composition to Earth
- ... 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




Wavelength (μm)
0.2
1
10
70
Spectral intensity
Sunlight (5525 K)
"Earthlight" (~275 K)
black-body spectra
5525 K
210 - 310 K
UV
visible
infrared
Major components
Water vapour
Carbon Dioxide
Oxygen and Ozone
Methane
Nitrous Oxide

The greenhouse effect

- As you saw in lab: planets' temperature set by radiation balance:
  - Incoming sunlight – visible
  - Outgoing "earthlight" – 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 CO_2, 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
- H_2O and CO_2 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!