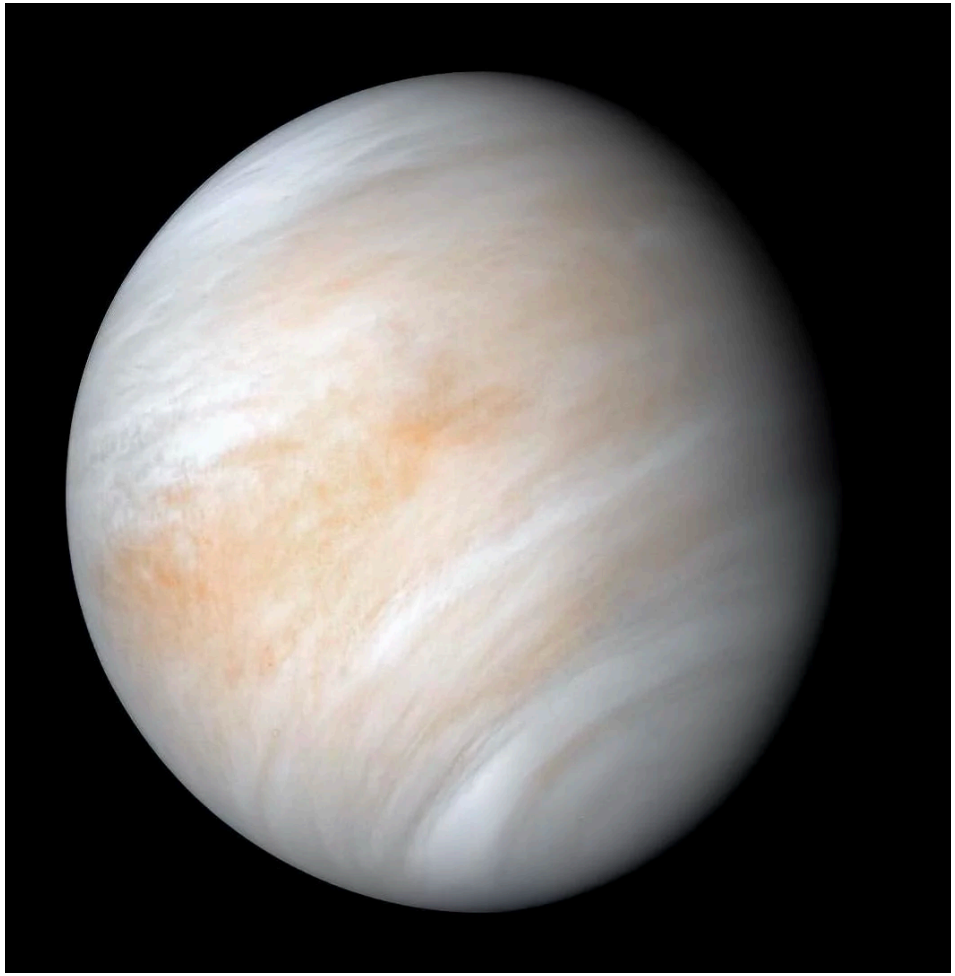
Solar System

Part 2: Venus, Jupiter, asteroids and comets.

What's New in Astronomy, June 17, 2021

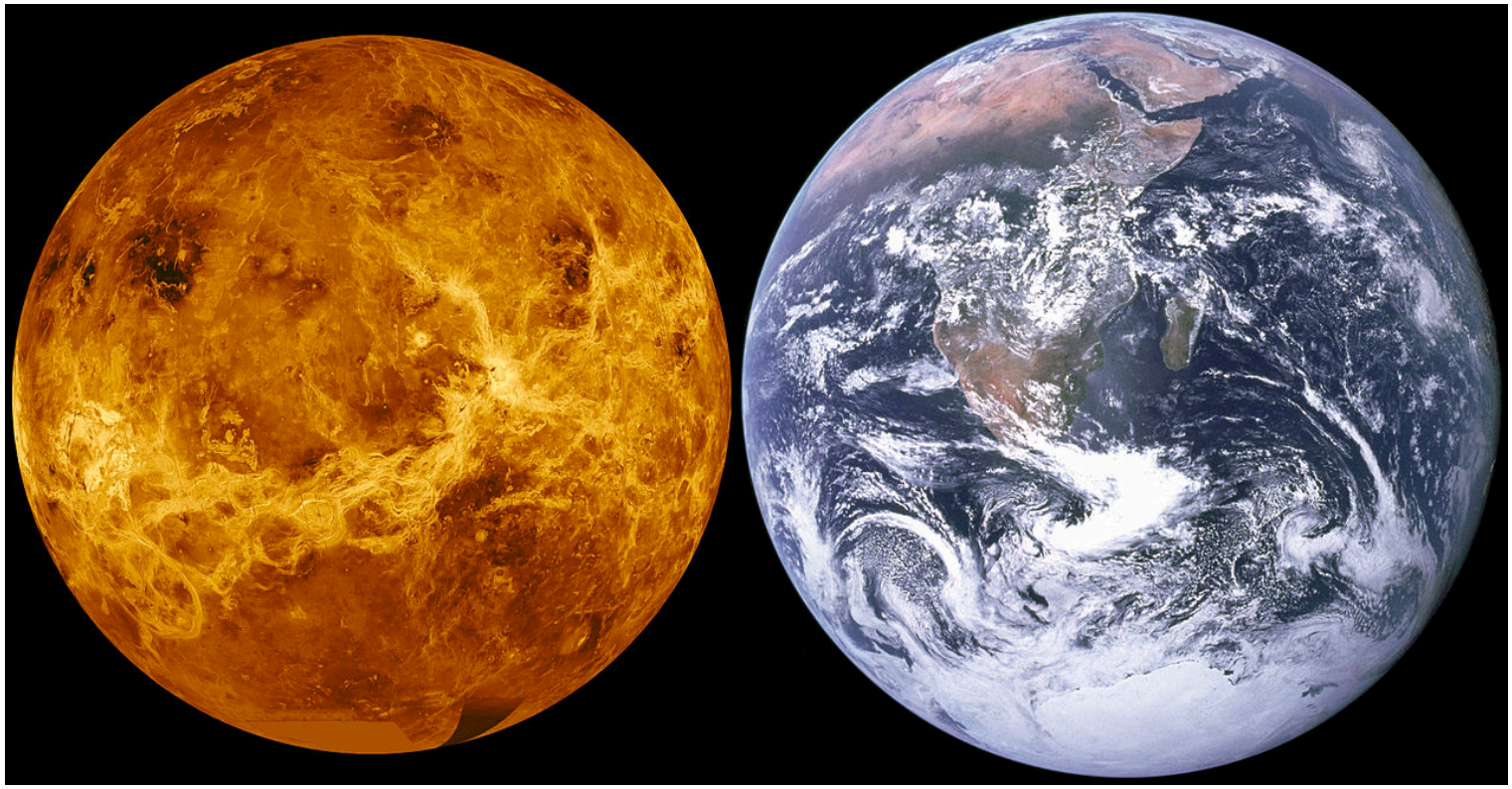
Venus

- Close to the same size & mass as the earth.
- 72% as far from the sun
- 90% more sunlight
- Thick atmosphere and clouds
- Rotates backwards, very slowly (~116 earth days)
- Image: Mariner 10, 1974 flyby

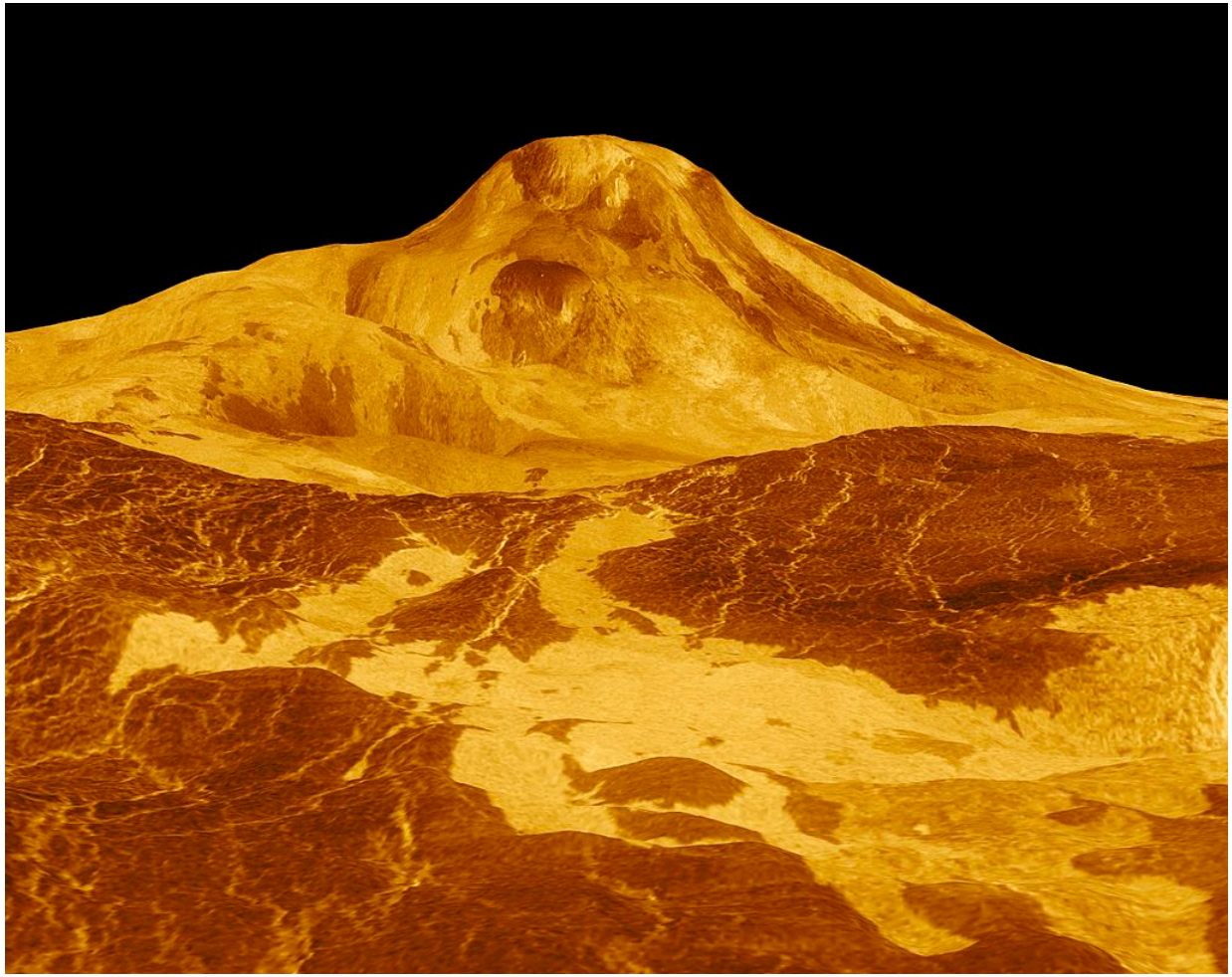


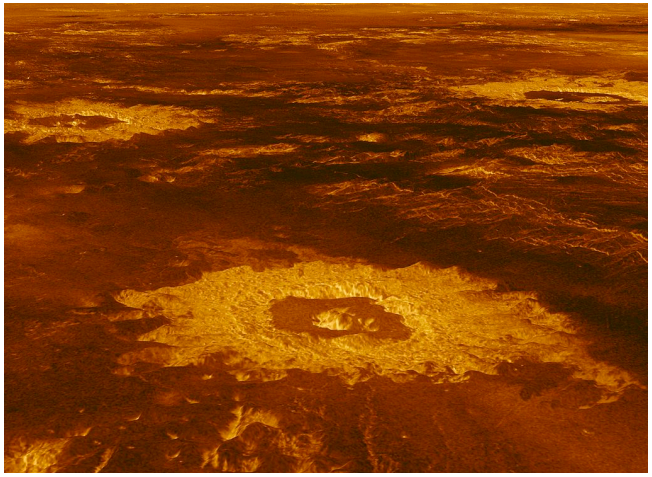
- Passes the earth in orbit every 589 (earth) days, which is almost exactly 5 rotation periods. We usually see the same side of Venus every closest approach.
- Atmosphere is about 90 x the pressure of earth's. 95% CO2, with thick clouds of sulfuric acid and other nasty things.
- Surface temperature averages 850 F or so, hot enough to melt lead.
- Carl Sagan's PhD thesis work showed a runaway greenhouse effect was responsible for the very high temperatures. Sunlight comes in as visible light, heats the surface, which radiates in the infrared where the atmosphere is very opaque, acting like a blanket.
- No global magnetic field

- Surface maps can be made with radar
- Magellan 1990-91
- USSR landed spacecraft 1970s and 80s



- Surface geology shows volcanos and some impact craters
- It's unclear if any volcanos are active, though SO_2 in atmosphere fluctuates.
- Apparently no plate tectonics





- Maat Mons (vertically exaggerated 20x)
- And a pair of impact craters.

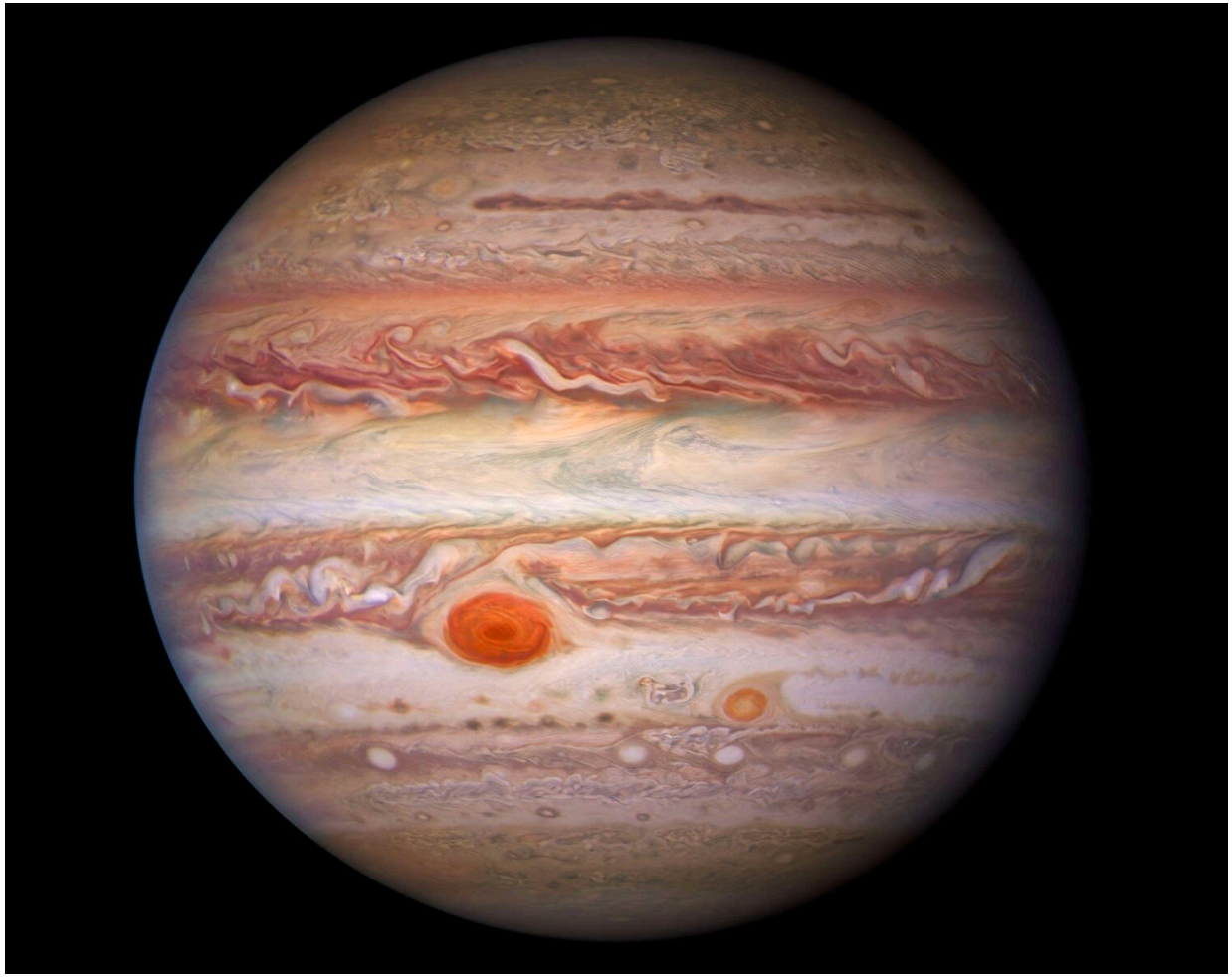
- Two new Venus missions were announced last week by NASA:
- DAVINCI+ will study the atmosphere with a spacecraft parachuting through it towards the surface. Was there water in the past? Perhaps noble gases left behind can tell us. Also, Phosphine?
- VERITAS will use radar to map the surface in greater detail. For example, if there's a San Andreas-scale fault, we wouldn't see it in the Magellan radar data. Recent volcanos?
- ESA is also sending a mission called EnVision with a suite of instruments to study the planet from orbit.

A small detour…

- Since 1995 astronomers have detected about 4400 planets orbiting other stars. These are called “Exoplanets”
- If an exoplanet passes between us and its star as it orbits, it obscures a small amount of the star’s light.
- If it has an atmosphere, we can see a tiny bit of starlight through the planet’s atmosphere, which gives us a chance to study its composition.
- To interpret the data, people who model atmospheres have done a wide variety of calculations, so we know what to expect, and what might be going on based on what we see.
- “Biosignatures” are things we might see in planetary atmospheres that might be signs of life.

- Example: The oxygen in the earth's atmosphere is biogenic. Photosynthesis takes CO_2, water, and sunlight and makes sugars and oxygen.
- It's also possible to generate atmospheric oxygen on an ocean world, by evaporating the water, using sunlight to split it into H_2 and O_2, and then letting the H_2 escape to space. So simply observing oxygen in the atmosphere of a planet doesn't imply life.
- On earth, methane (CH_4) is biogenic. It's not on Jupiter.
- Phosphine, PH_3, was detected in the atmosphere of Venus in fall 2020. Or… maybe not?
- The quantities indicated were far more than could be explained with volcanos (we think… see above under new space missions to check).
- Stay tuned on this one… it's a developing story.

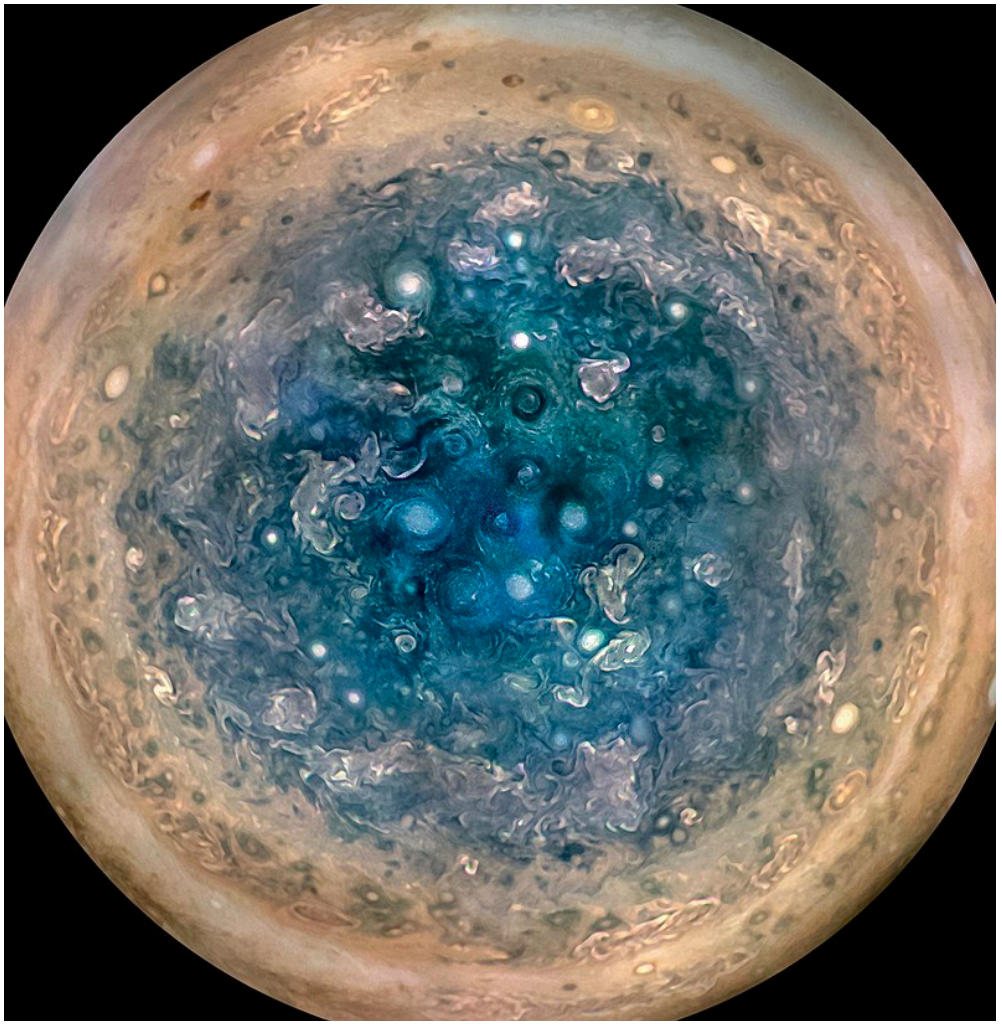
- The notion of life on Venus is not completely nuts.
- If Venus had an ocean in its first billion years, life might have developed. Microbes are great at finding ways to adapt and survive.
- There are remarkably earth-like conditions (temperature, pressure, possibly water-based clouds) high in Venus' atmosphere (near the cloud tops).
- Anywhere within a few miles of earth's surface (or ocean) where there's a living to be made doing chemistry, there are microbes there doing it. From the pores of rocks miles deep, mid-ocean ridges, geysers, to high in the air (e.g. nucleating snowflakes).
- Carl Sagan was fond of saying "Extraordinary claims require extraordinary proof." This is merely suggestive.

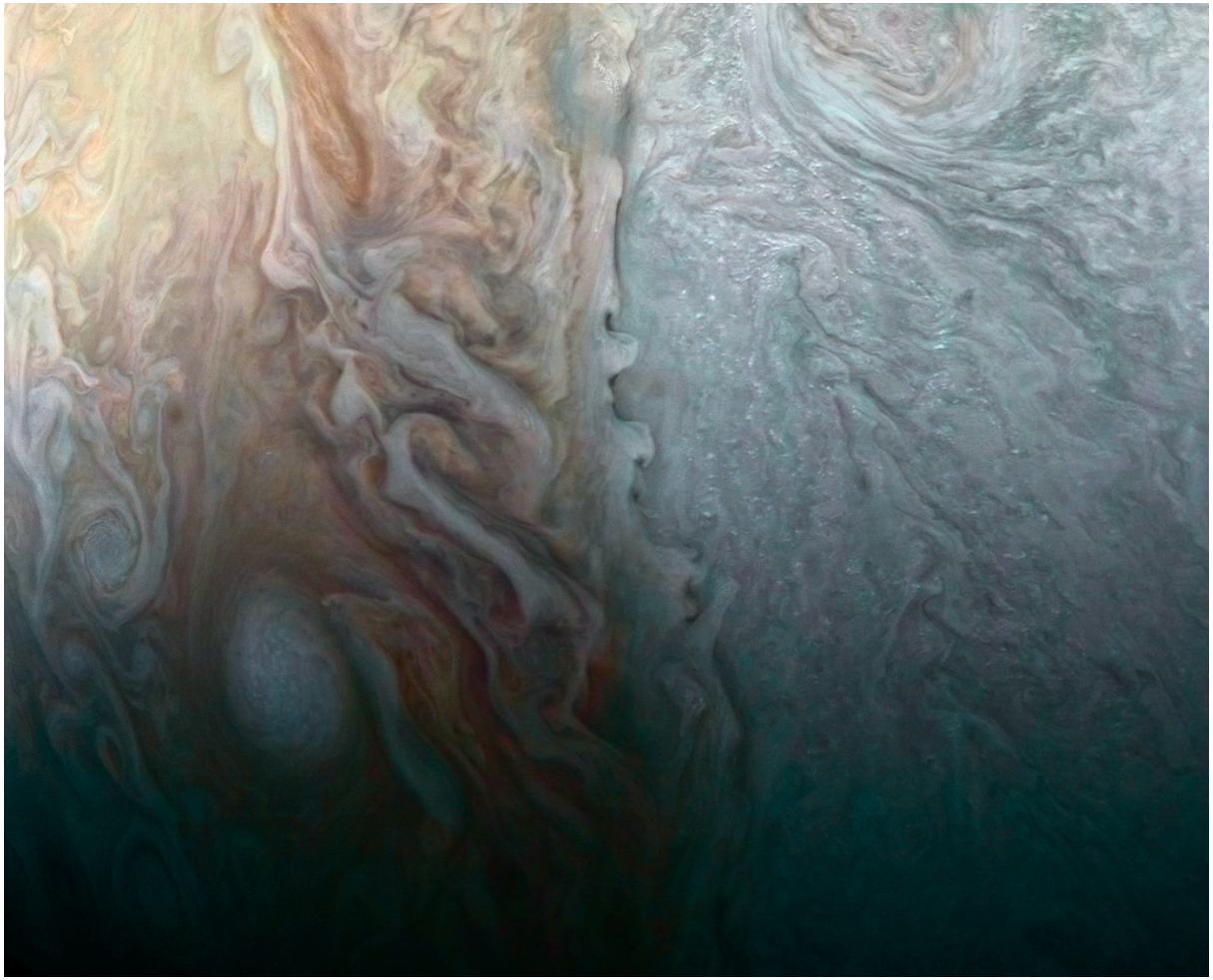


- Jupiter
- Juno spacecraft currently in orbit
- Stunning cloud pictures

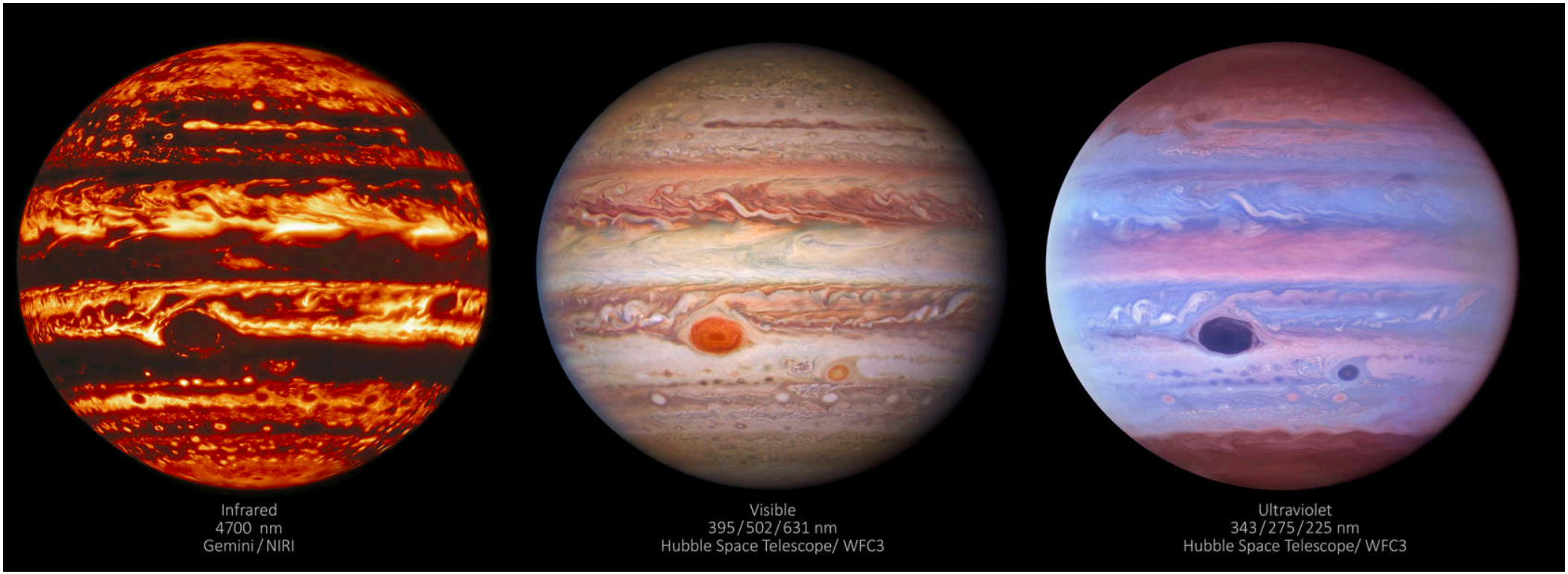
- 300x earth mass
- 5 AU from the sun, so 4% of earth's sunlight
- 1/1000 of sun's mass.
- Probably gaseous throughout, possibly with condensed core.
- Complex magnetic field (at least 3 poles…)
- Has 4 big satellites and dozens of little ones, plus a faint ring.

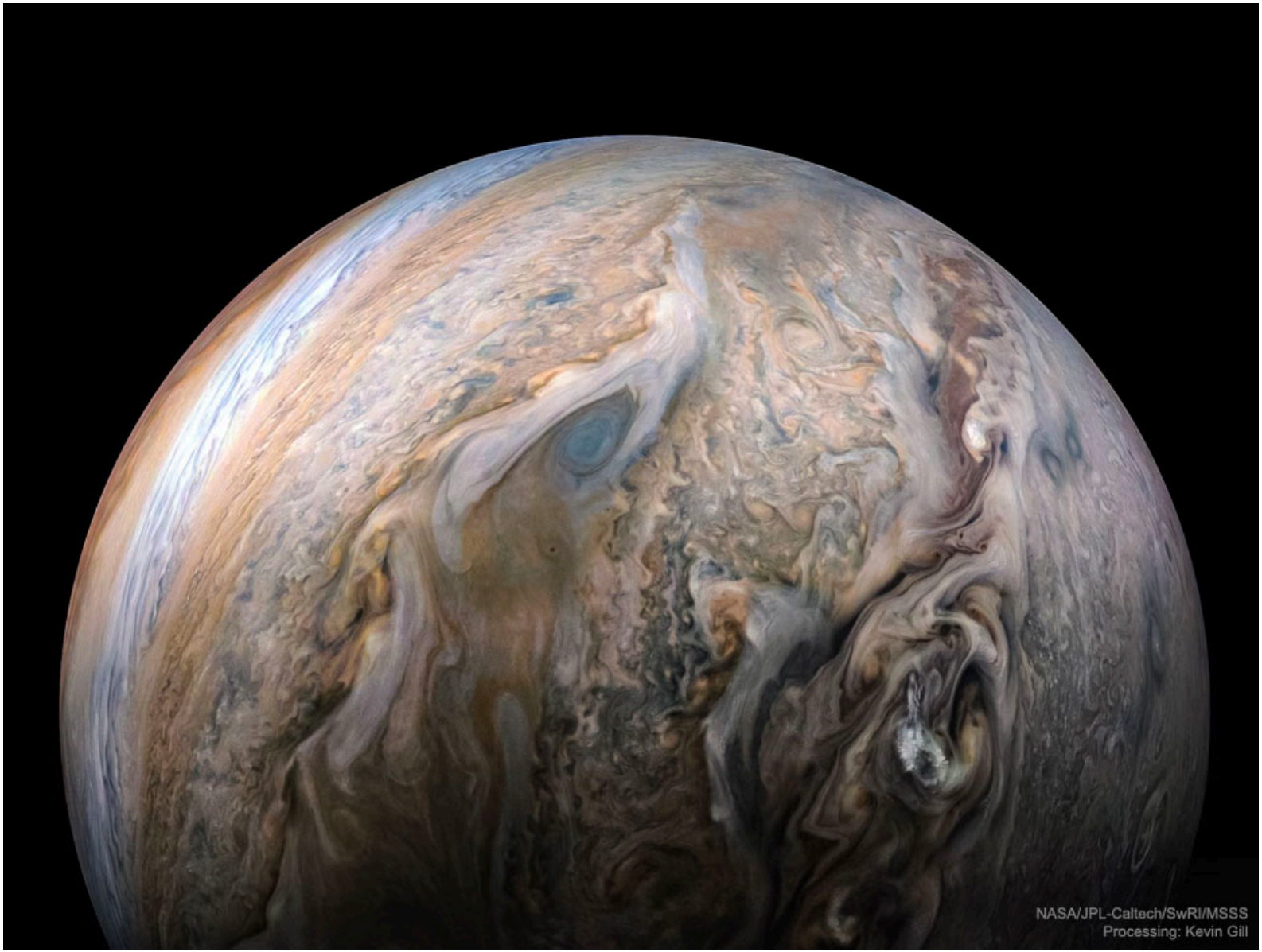
- Juno's mission is to study the interior, but they also had a camera…
- Polar orbit shows views not possible from near-earth observatories (e.g. Hubble)
- These are storms near Jupiter's south pole.





- Hubble IR, Visible, UV images
- UV/Vis show reflected sunlight; IR shows heat from the interior
- Check out https://noirlab.edu/public/news/noirlab2116/ for slider views

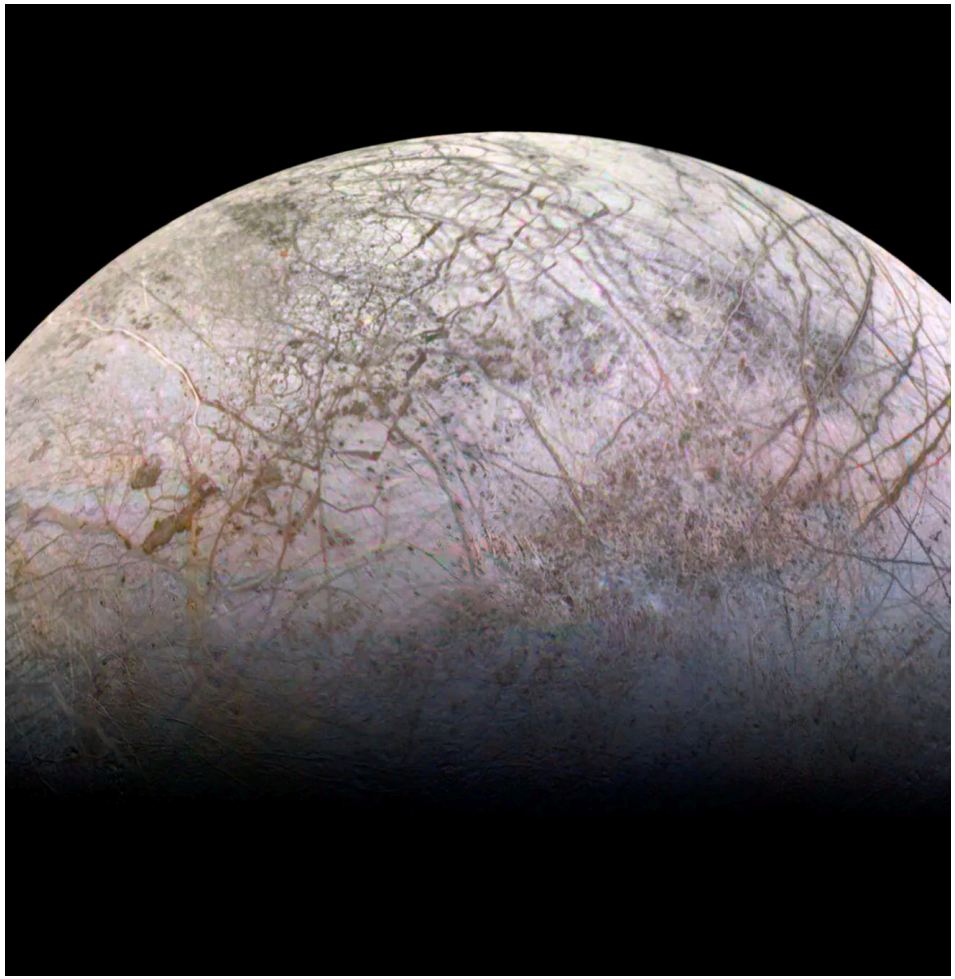



NASA/JPL-Caltech/SwRI/MSSS
Processing: Kevin Gill

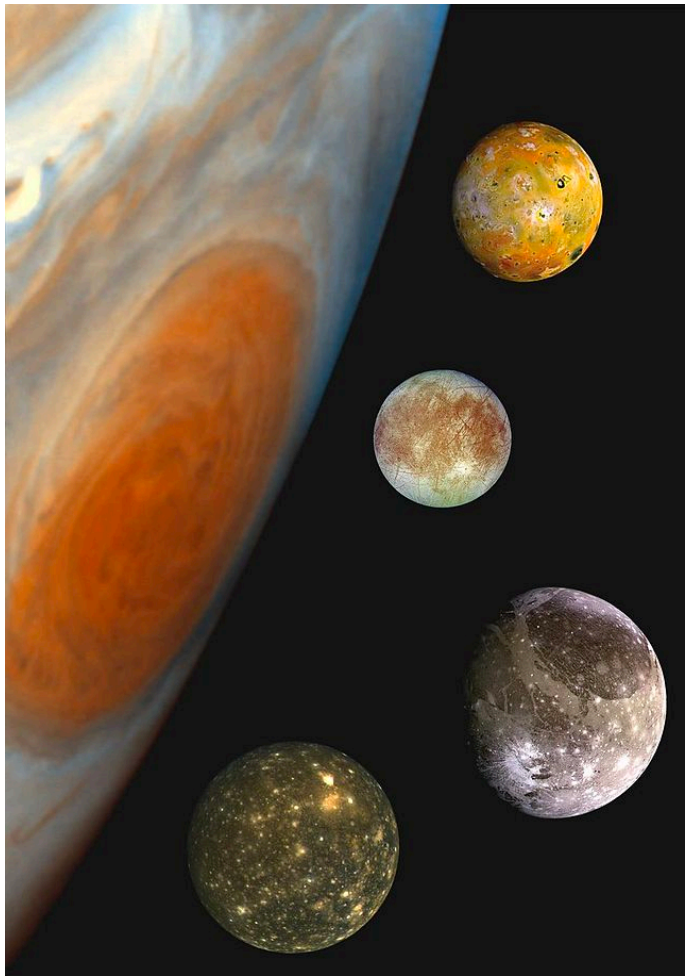
Juno mission extended

- Flybys and slingshots around the Galilean moons can adjust the orbit
- Juno flew by Ganymede, largest moon in our solar system, last week.
- Ice world, possibly with a subsurface ocean.
- Europa and Io are also in the queue.

- Europa Clipper will launch in 2024.
- Europa has geysers, jetting water from a subsurface ocean into space.
- Possible habitat for microbial life??
- This is a Voyager 2 picture (1979)

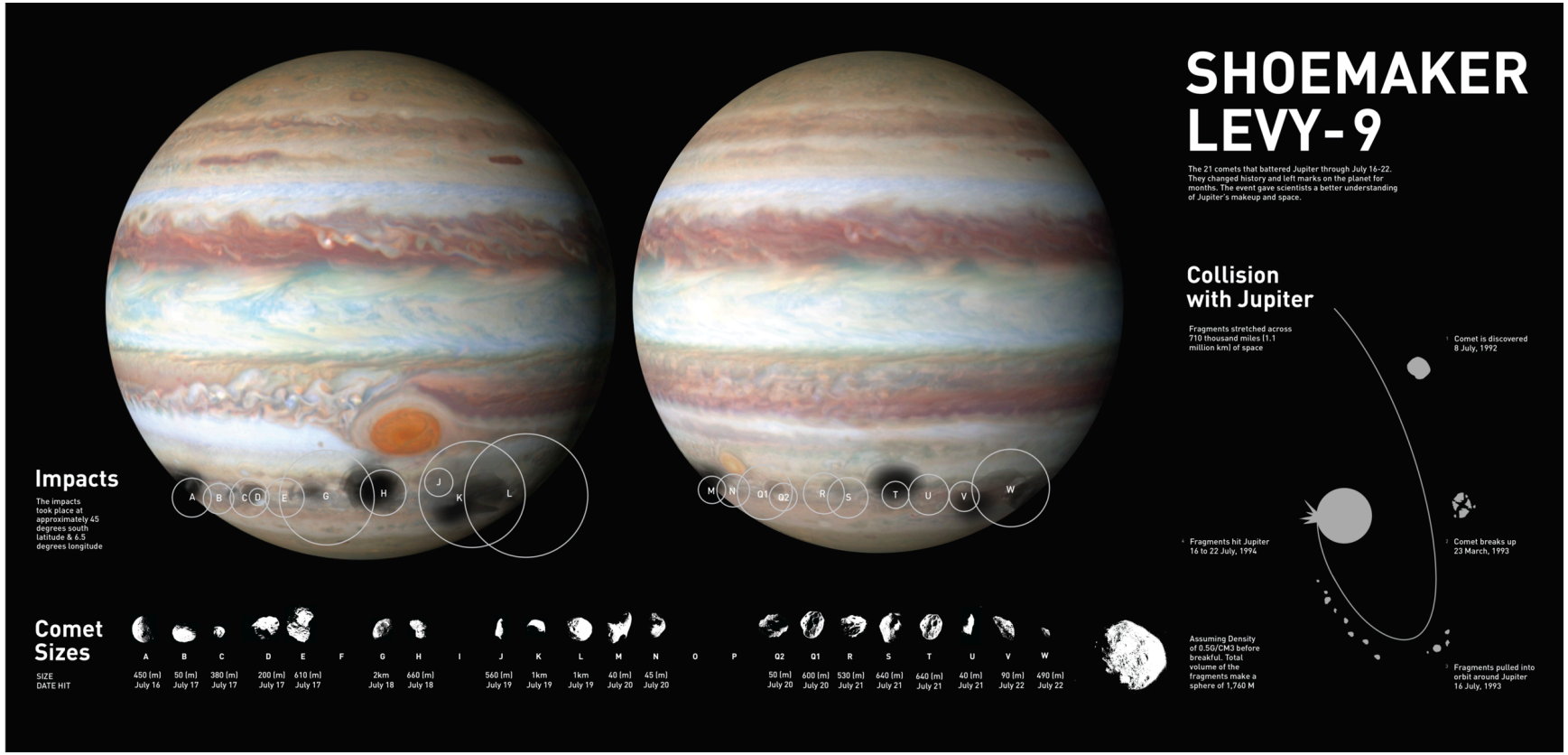


- Major moons of Jupiter
- Io: very active volcanically due to tidal flexing. Contributes most of the radiation Jupiter's magnetosphere
- Europa: Ice world, with geysers
- Ganymede: Ice world with its own magnetic field. Larger than Mercury.
- Callisto: icy world with older surface
- Inner 3 in a 1:2:4 orbital resonance

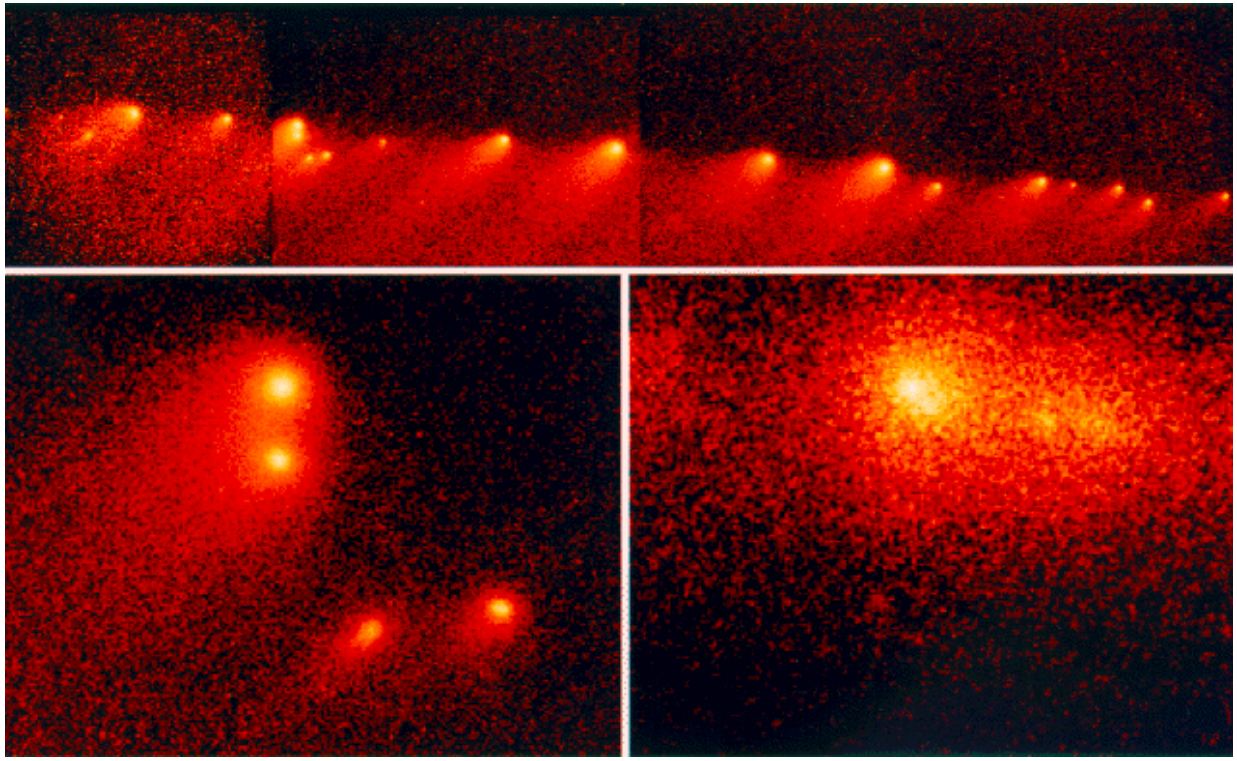


- In Dec 2020, Jupiter and Saturn were close together on the sky as seen from earth.
- Saturn is upper left
- Jupiter is lower right, with at least 3 of the major moons visible (above/left of Jupiter, and one very close below/right).
- Dec 2020

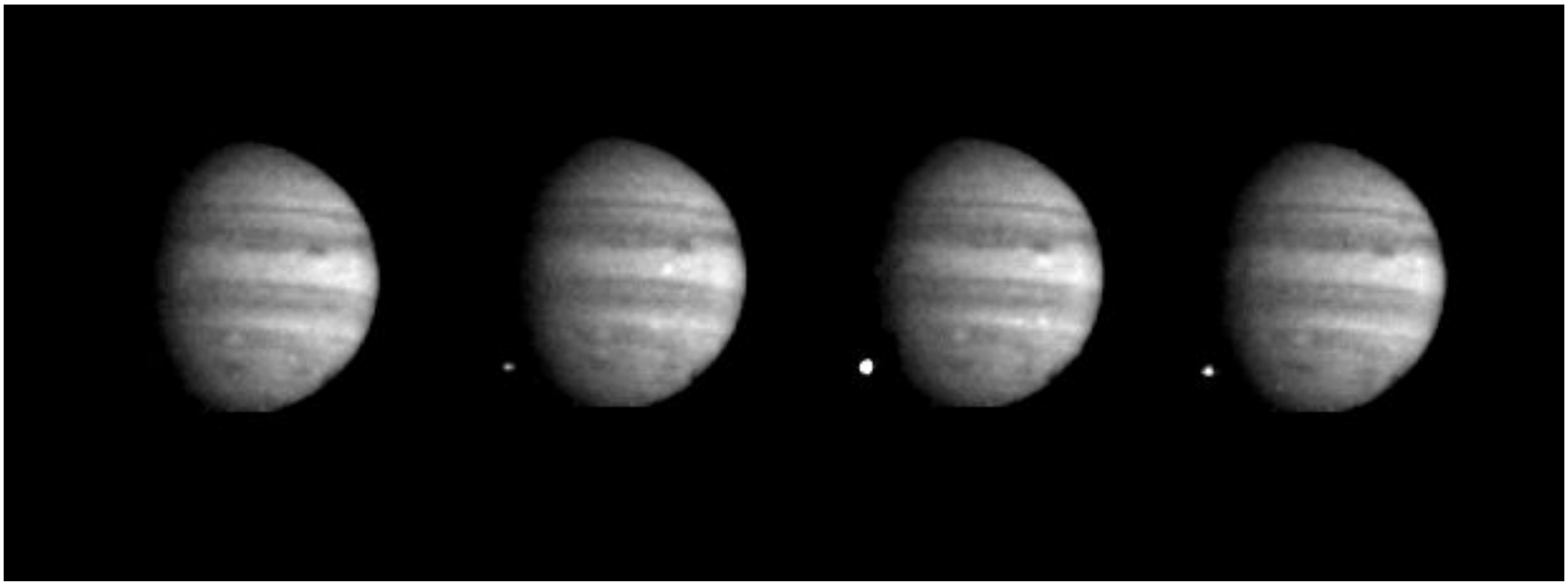
- In 1992 Comet Shoemaker-Levy 9 collided with Jupiter.
- The black scars in the clouds are larger than the earth (!!)



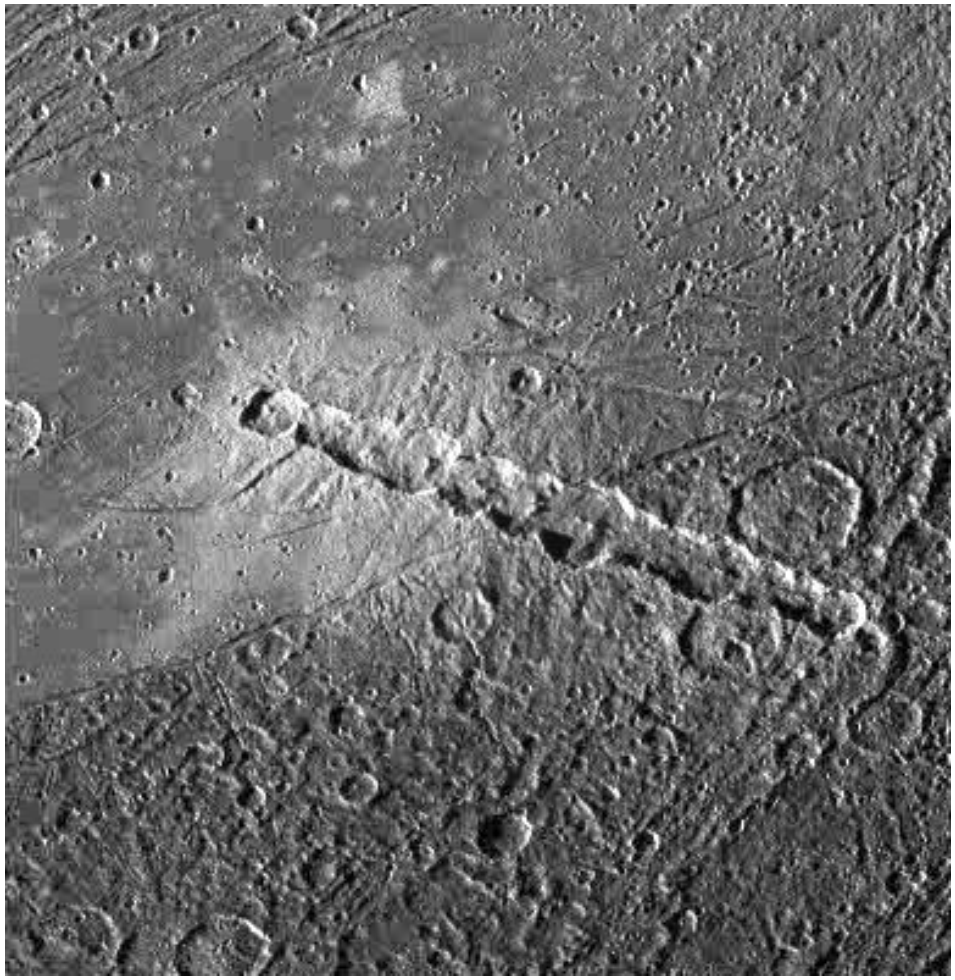
- After being captured into orbit around Jupiter, tidal forces broke the comet in pieces, which spread out along the orbit.
- They impacted just over the edge of Jupiter as seen from earth, one after another after another.



- Series of images from Galileo, in orbit around Jupiter.
- Impact is the bright spot just over into the night side of the planet.



- This is a chain of impacts on the surface of Ganymede.
- Presumably they were all made close together in time, by a disrupted object like Shoemaker Levy 9 (though presumably much smaller than the comet).



- Asteroids & comets hit the earth sometimes.
- 1908 at Tunguska in Siberia
- Investigation interrupted by the Russian Revolution
- Significant damage to forest, no obvious crater.
- Possibly an airburst explosion of a comet?
- 50 to 80 meter size object

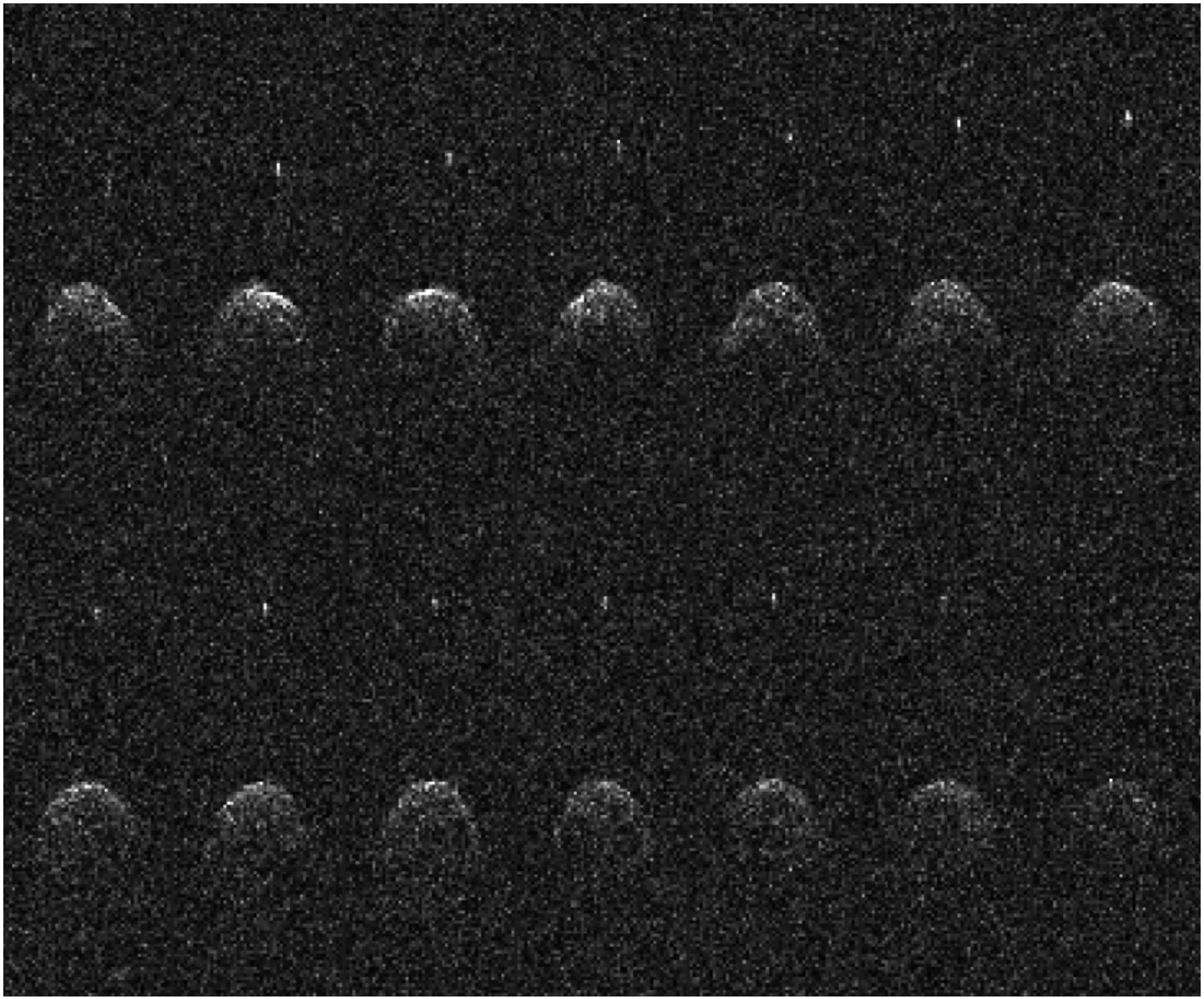
- Chelyabinsk, Russia in Feb 2013. A large number of fragments were recovered.
- Lots of dashboard camera footage. ~ 20 meter rock

Asteroids & comets

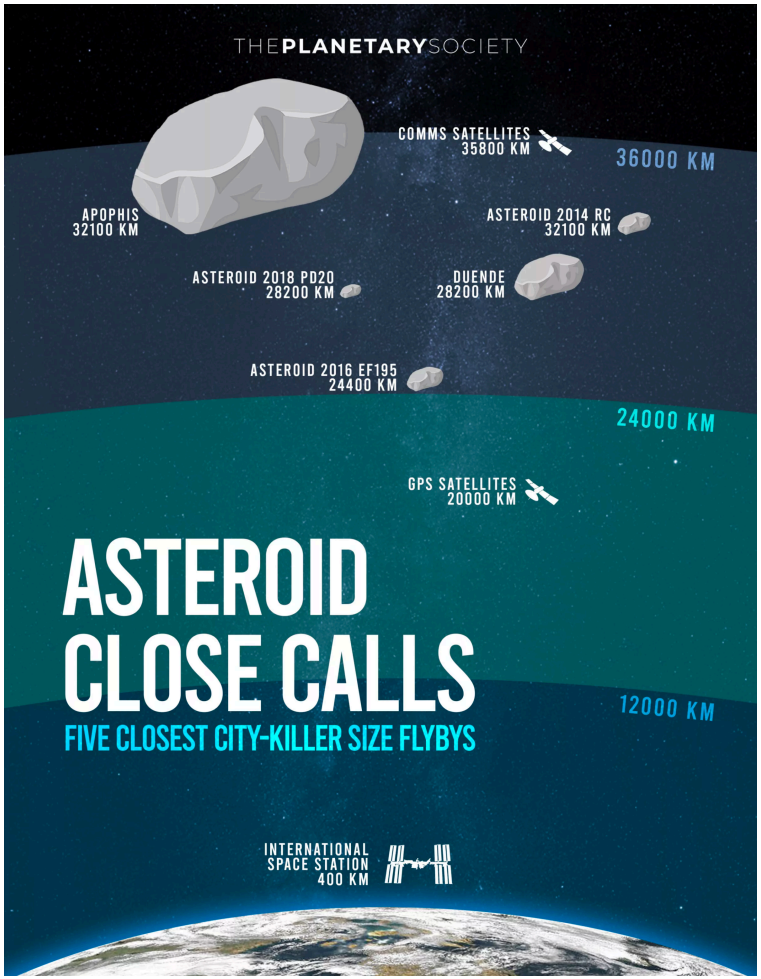
- Small objects left from the formation of the solar system
- Comets come from beyond Neptune's orbit, and are dirty snowballs: rock, water ice, other frozen volatiles.
- Asteroids are mostly rock (either one solid piece, or a loose stack of rocks and gravel very loosely bound by gravity).
- Most orbit between Mars and Jupiter.
- Some cross the earth's orbit: Near-Earth Objects
- Minor Planet Center in Cambridge, MA maintains a database of all known minor planets.

- Some earth-crossing asteroids are “Potentially Hazardous Objects,” where orbit calculations can’t rule out impact with the earth. Further observations almost always rule out impacts.
- Smaller objects are often detected days to hours before closest approach.
- After the Shoemaker-Levy 9 impact on Jupiter, the possibility of a catastrophic impact on earth was taken more seriously.
- WISE, the Wide-field Infrared Survey Explorer, was repurposed to search for NEOs… NEOWISE. IR is nice because asteroids are warmer than the background deep space.
- About 40% of NEOs bigger than 140 meters have been discovered.
- If we know years to decades ahead, we might be able to divert an asteroid on a collision course with earth.

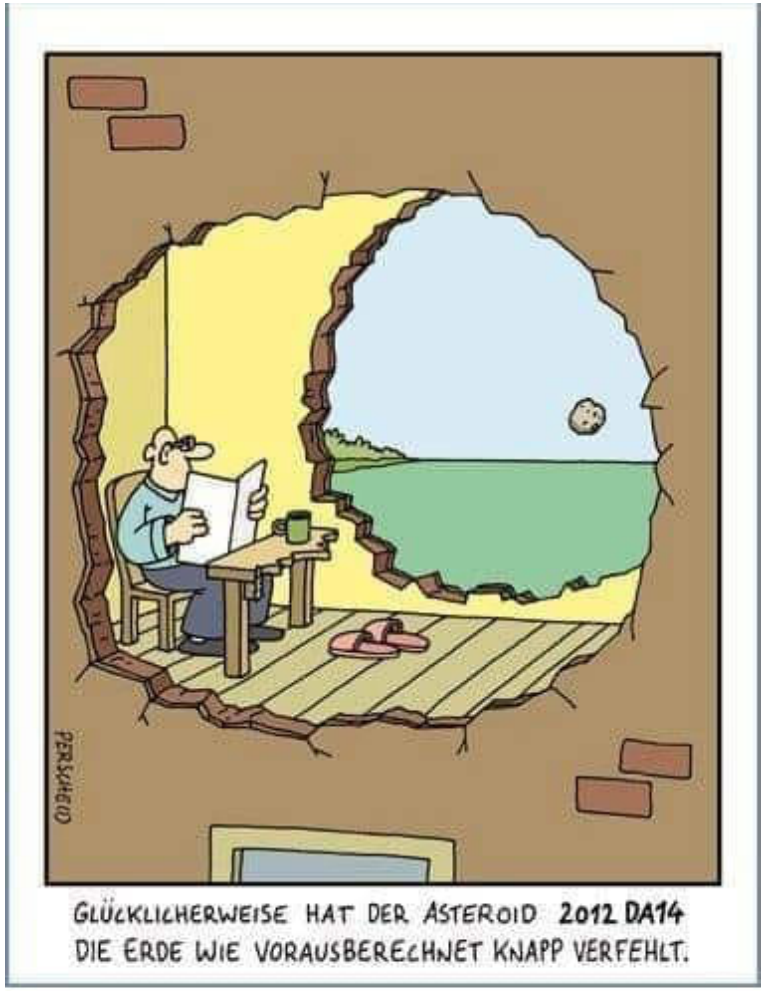
- Various proposals have been suggested. A NASA mission called DART will impact on asteroid DART (Double Asteroid Redirection Test) will attempt to nudge the tiny (160 m) companion of asteroid 65803 Didymos (780 m).
- The DART spacecraft will impact on the moonlet and alter its orbit around Didymos slightly.
- ESA is sending another spacecraft to survey the results.
- Next slide shows radar imagery of the double asteroid, from the Aricebo radio telescope (which recently collapsed).
- Note that the center of mass of the asteroid and any impactor continues in orbit, whether it's fragmented or not. There's a risk of turning one impact into a series of impacts.



- Here are a few recent close calls
- Some of these asteroids flew by the earth closer than communications satellites
- Apopphis is on the PHO list
- Some others were discovered hours or days before closest approach



- Next time:
  - The Sun, and what it does for and to us on the earth
  - Other stars
  - Planets around other stars
  - Where stars come from
  - What stars do when they get old and run out of fuel
  - Stars as citizens of the Galaxy



"Fortunately, the asteroid 2012 DA 14 just missed the earth as predicted"