מה יש ביקום על רגל אחת...

Powers of Ten

a nice remake (no text)

and with some imagination...

movie from the seventies and some remake, to put things in perspective

כדו״א

רדיוס כ-6400 ק״מ

הירח

מרחק 385000 ק”מ
רדיוס 1750 ק”מ

First picture where the whole earth and moon are seen (by voyager)

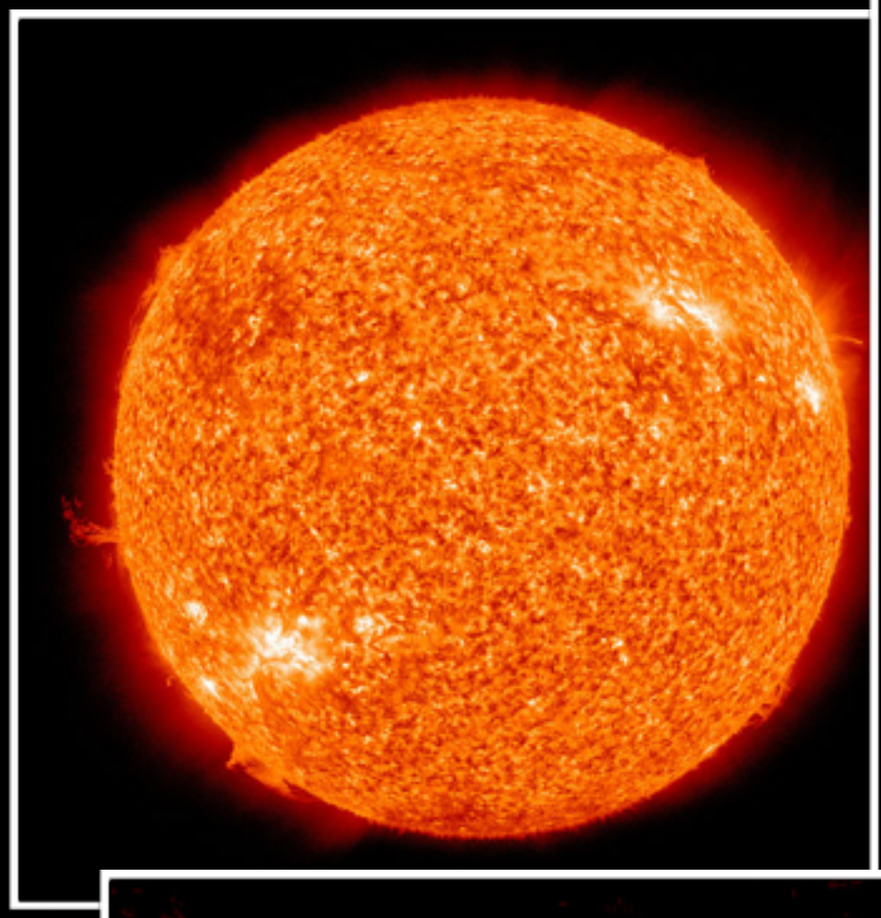
השמש

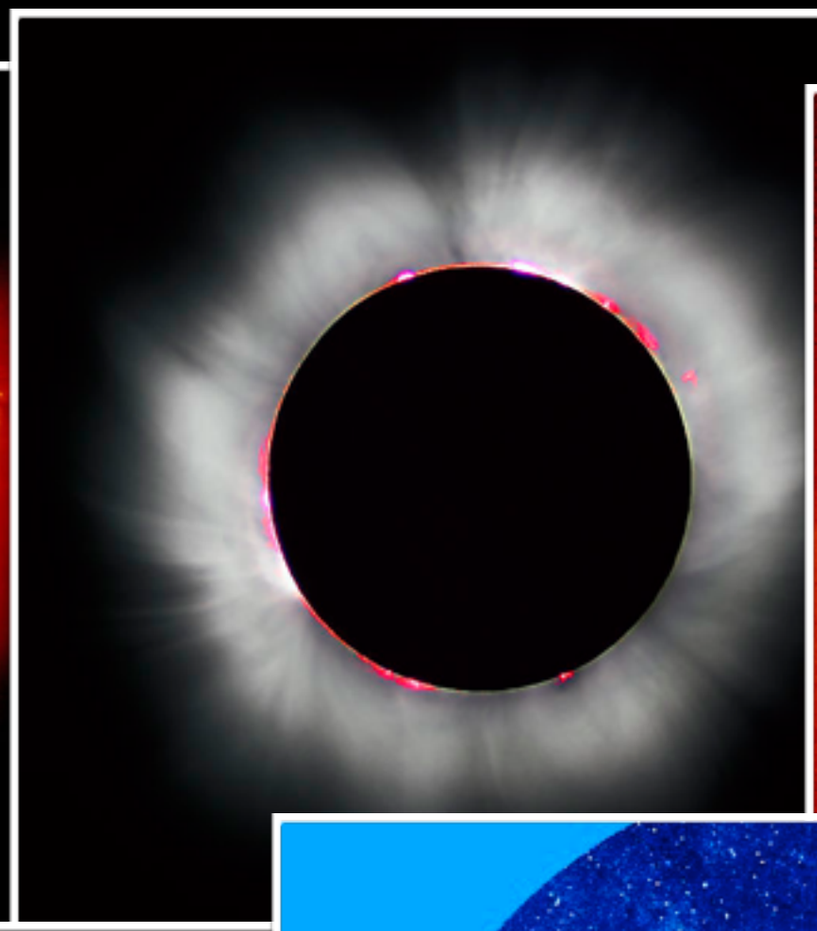
הכוכב הכי קרוב אלינו. כ-150 מליון ק"מ = 1AU

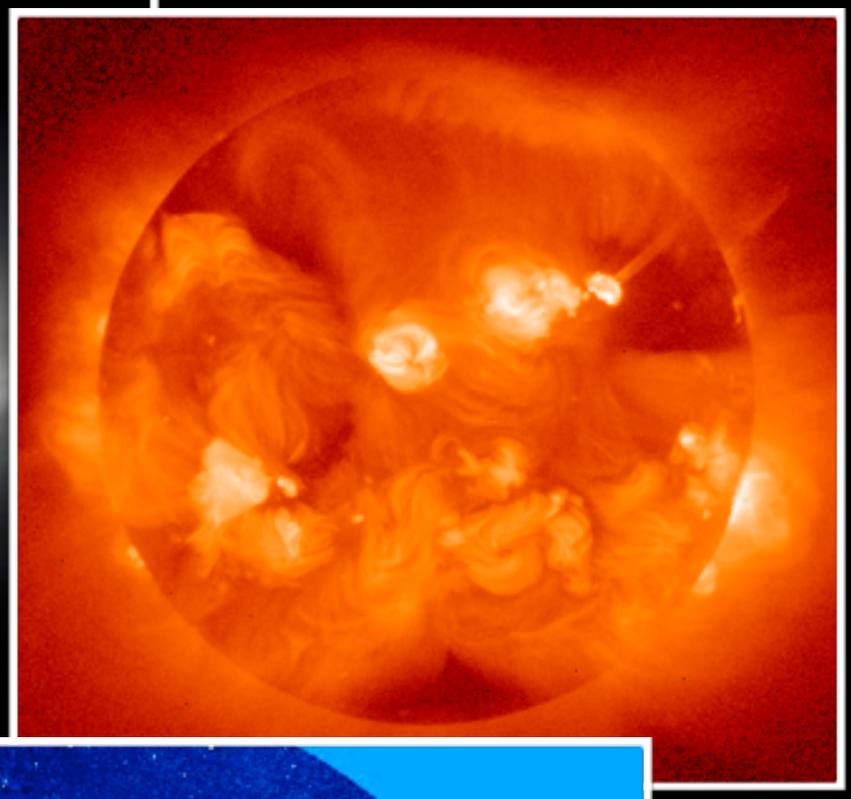
רדיוס 600000 ק"מ

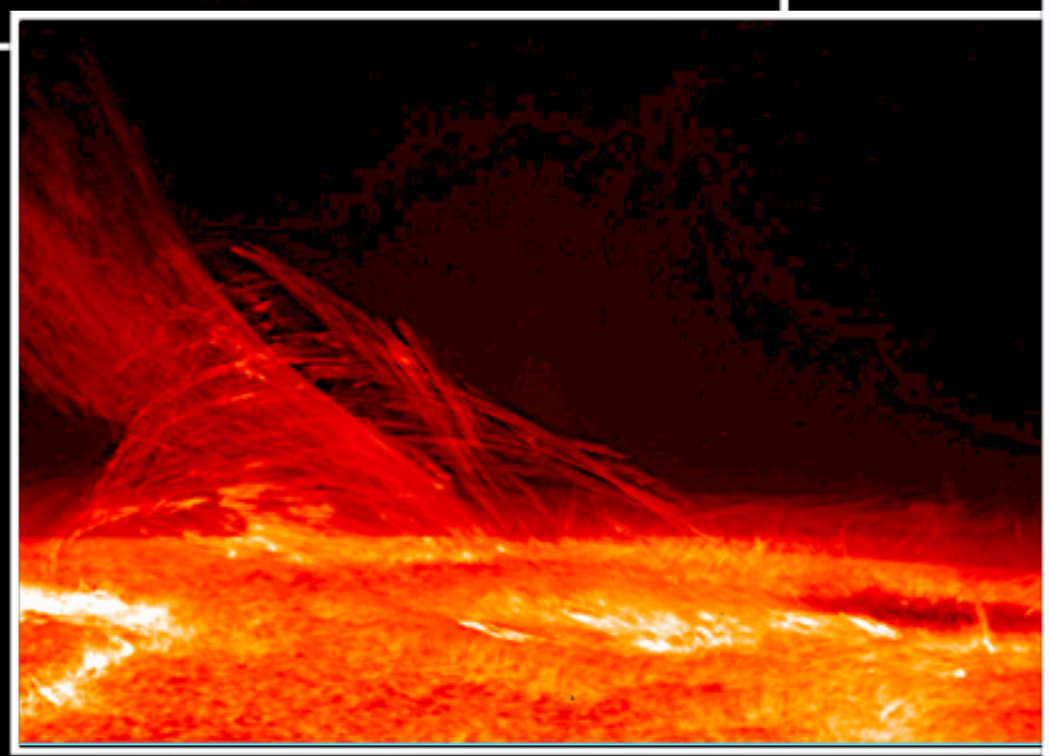
מסה כ- $2x10^{30}$ ק"ג

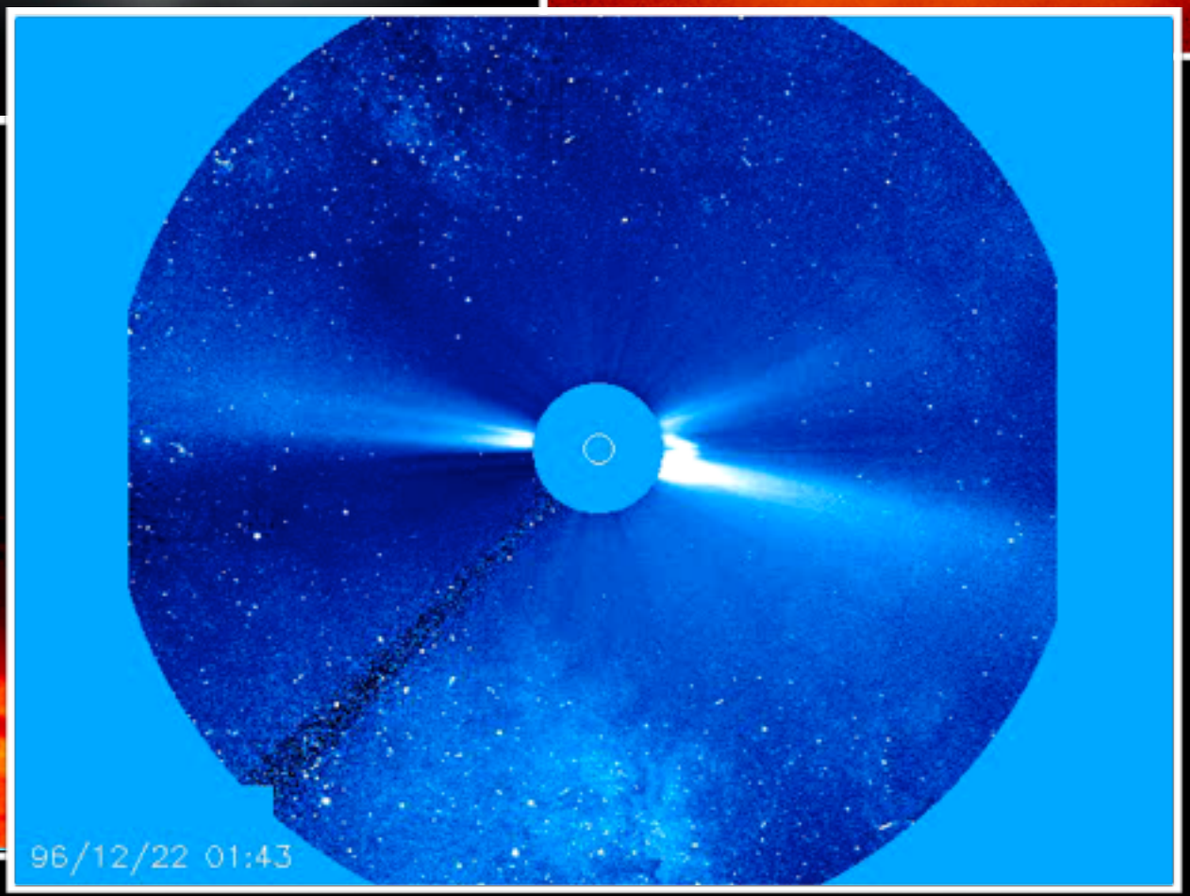
Sun in visible (in hebrew, Shemesh comes from shamash, Mesopotamian god of the sun)







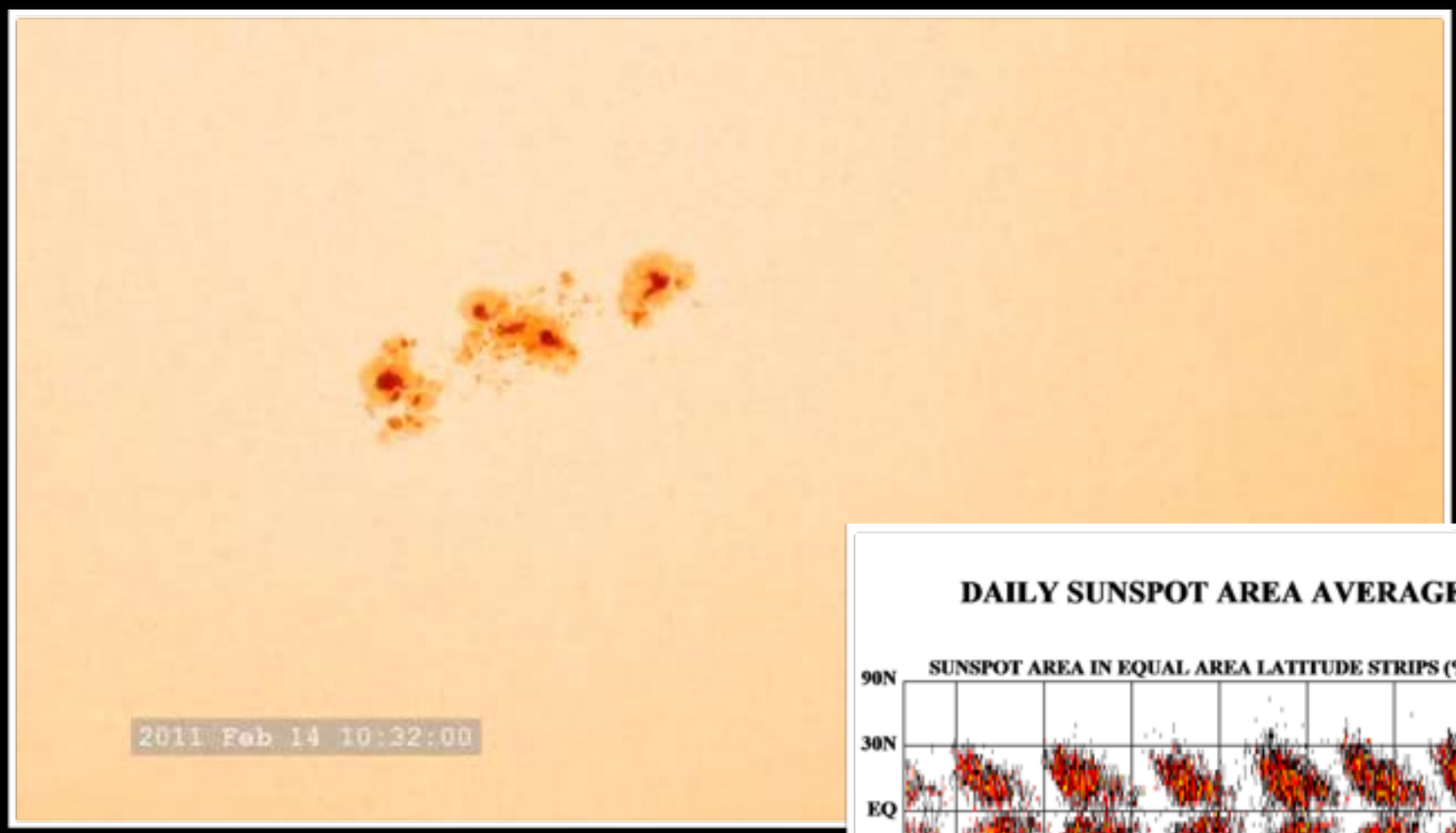


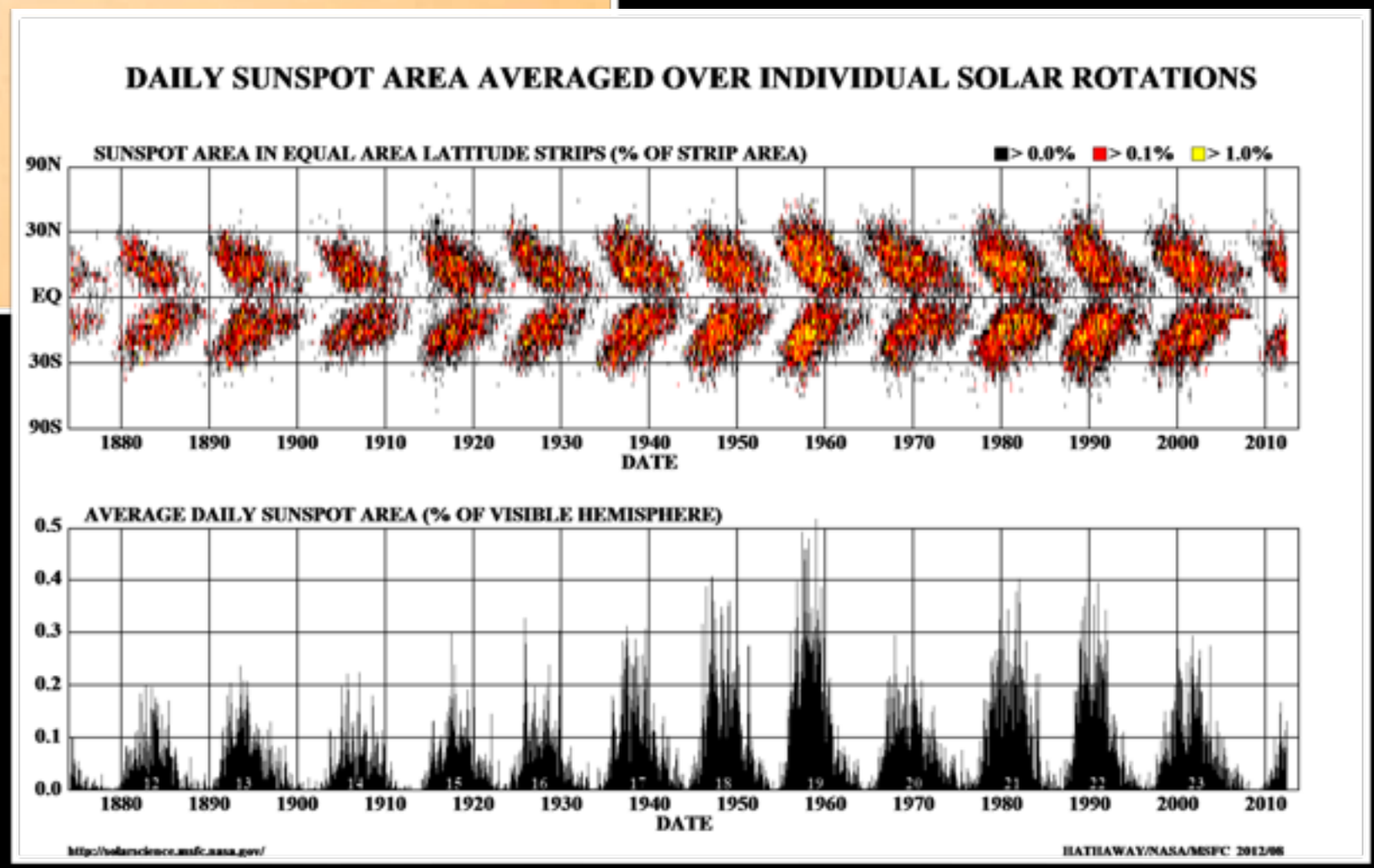


[התפרצות על השמש](#) [heliosiemology](#) [סרטים של soho](#)

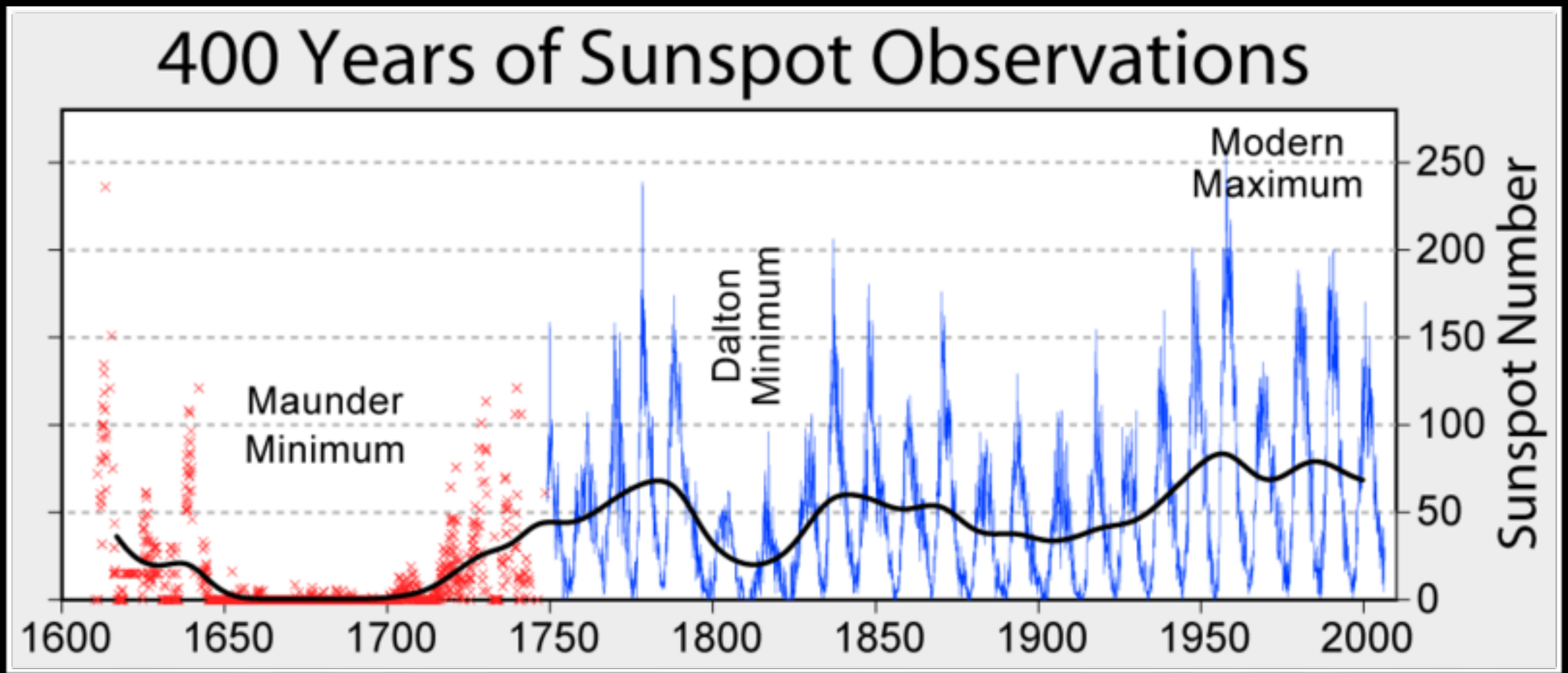
The sun in other frequencies shows it is variable (top left) – in UV, solar halo in an eclipse, x-rays, solar flare and a move showing that the sun has a wind. (and a comet that plunges into the sun)

כתמי שמש



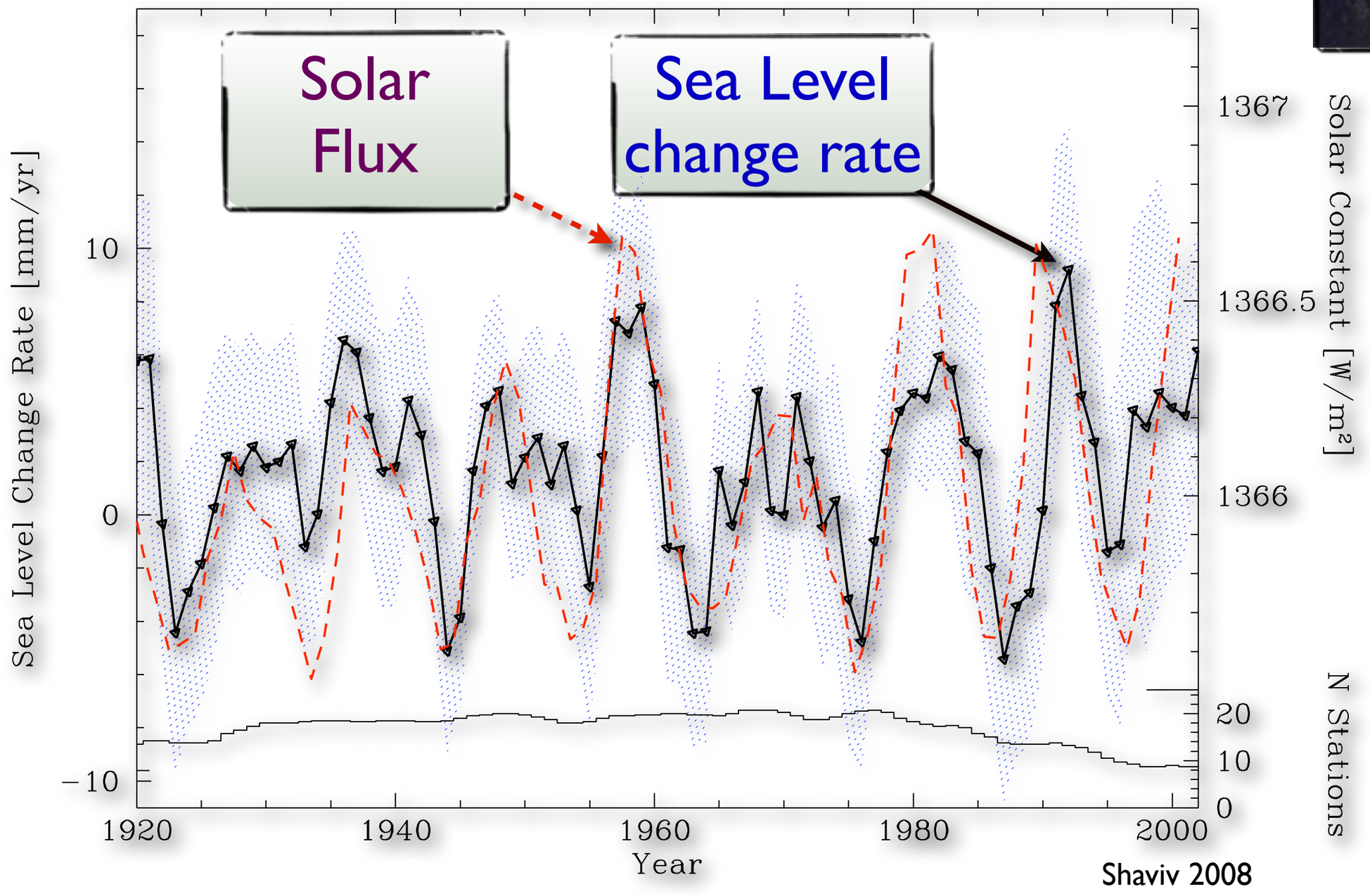


Sun spots are the footprints of magnetic field loops. They occur with an 11-year cycle (over which the large scale magnetic field flips polarity)



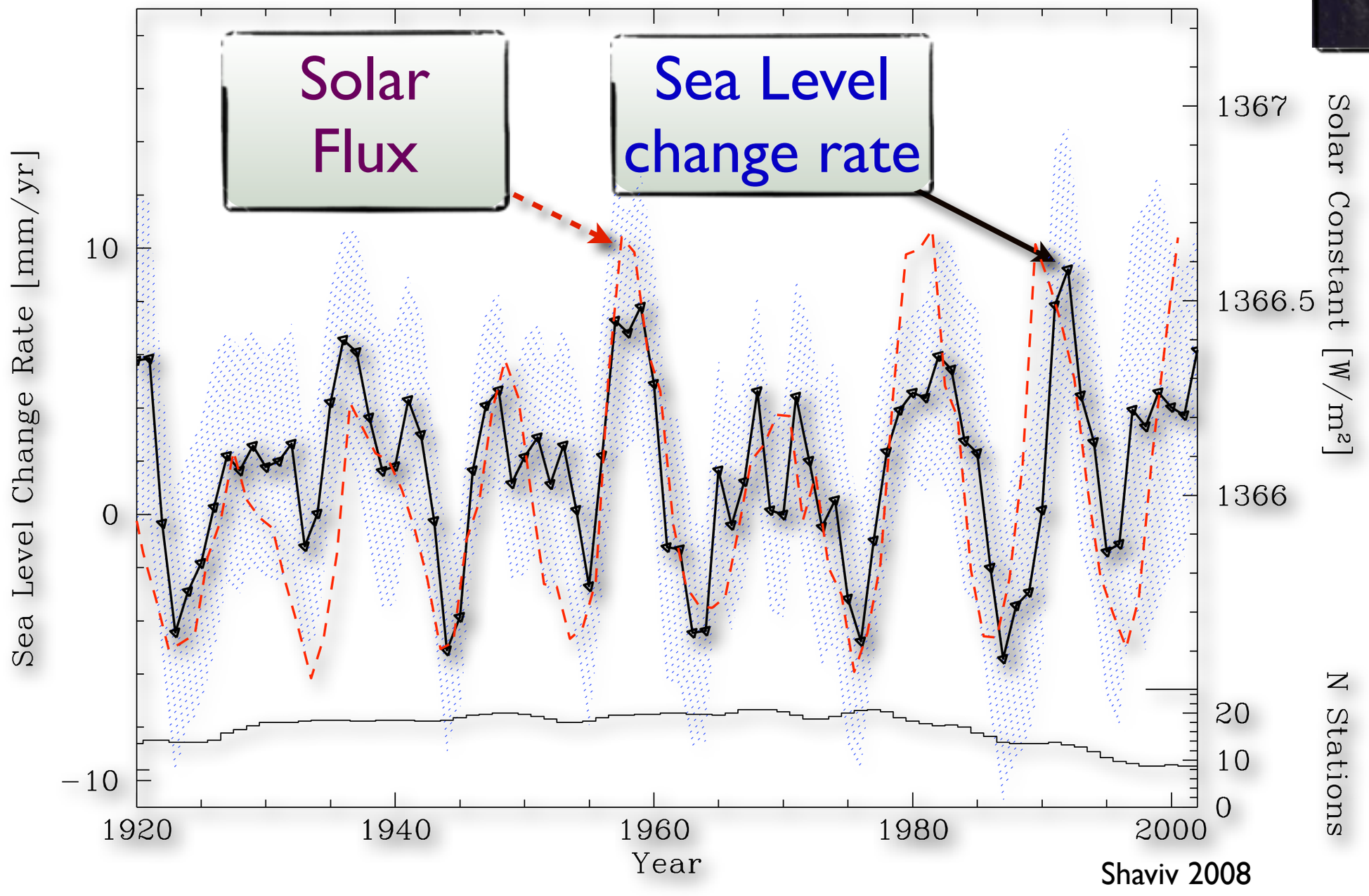
There are also long term variations in the solar activity (modulating the solar cycle). It turns out that climate on earth is influence by these variations (more active sun = warmer)

שינוי גובה פני הים



This can be seen in this figure, where the oceans thermally expand during the solar maxima

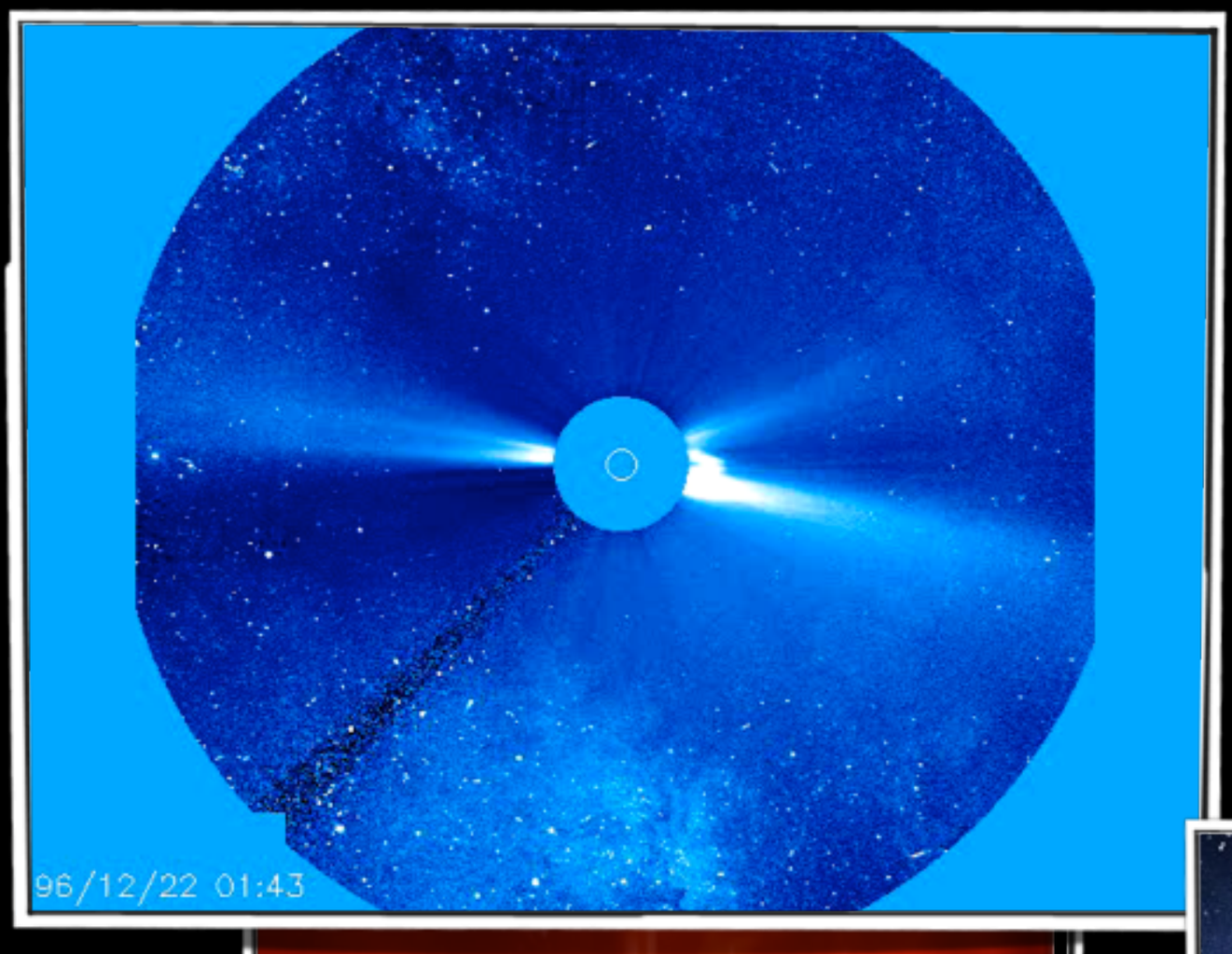
שינוי גובה פני הים

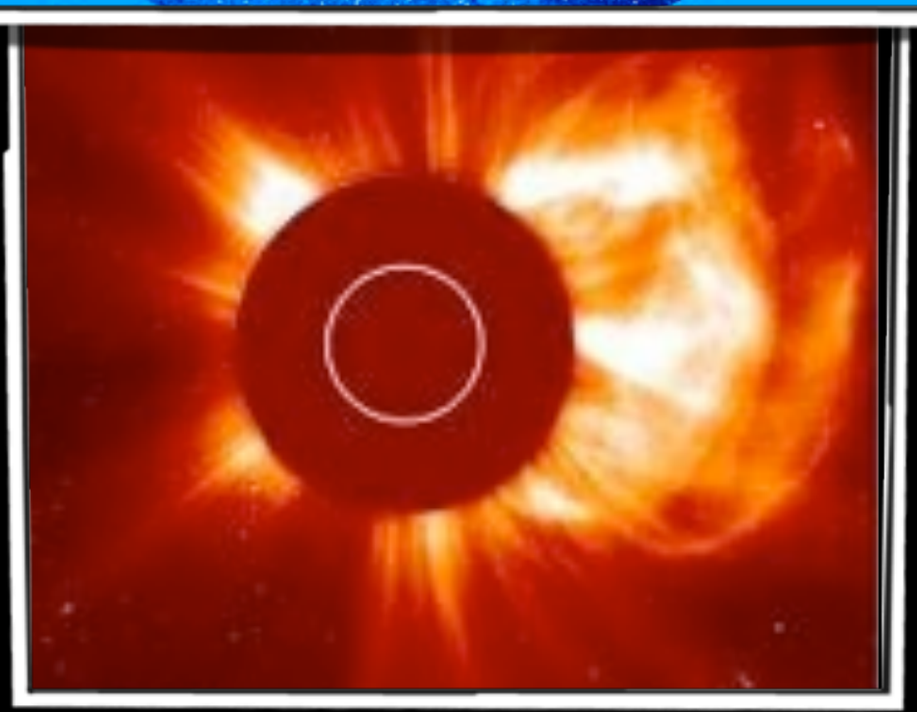


Oceans = Largest Calorimeter in the World!!!

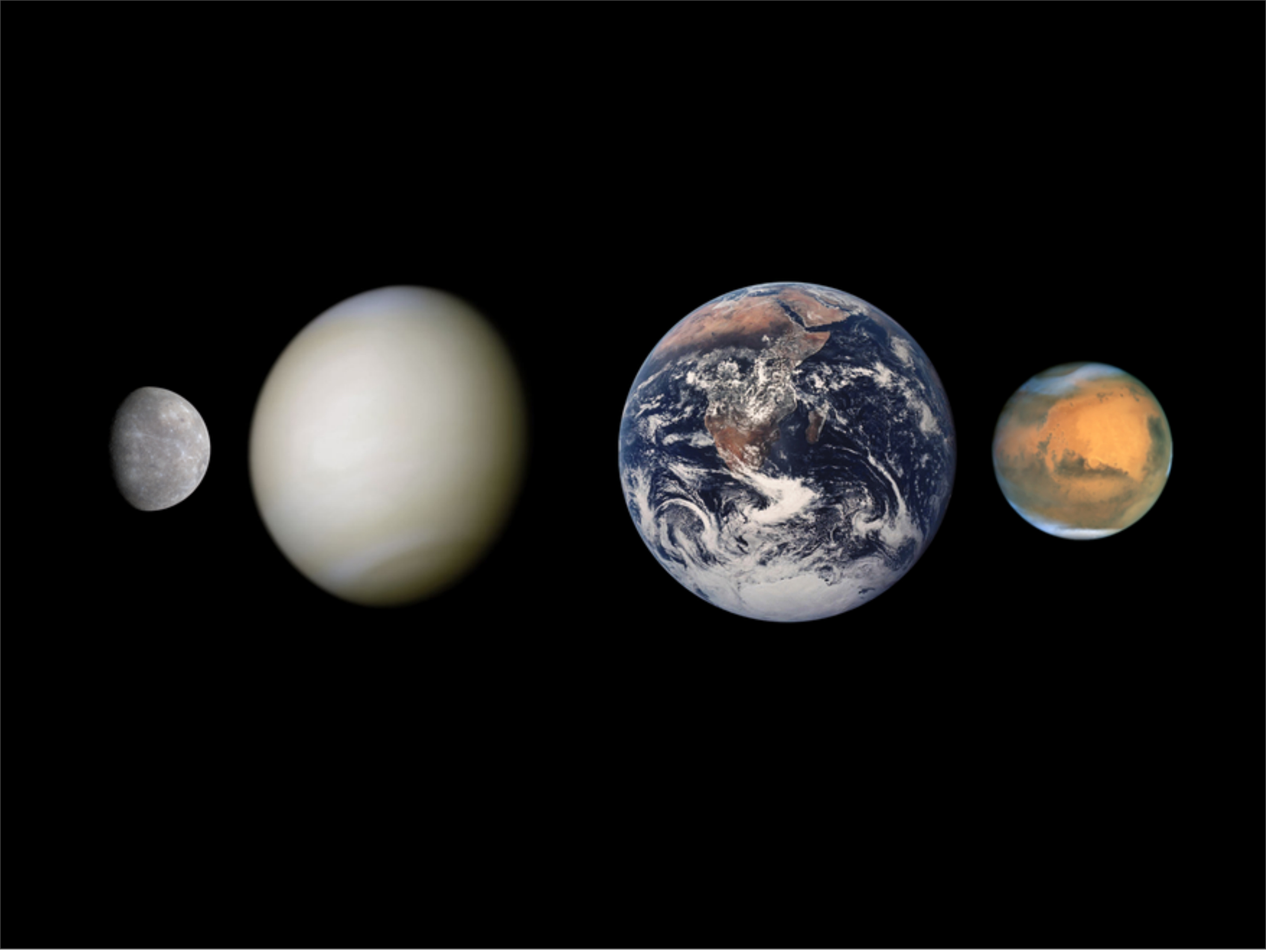
This can be seen in this figure, where the oceans thermally expand during the solar maxima

רוח השמש

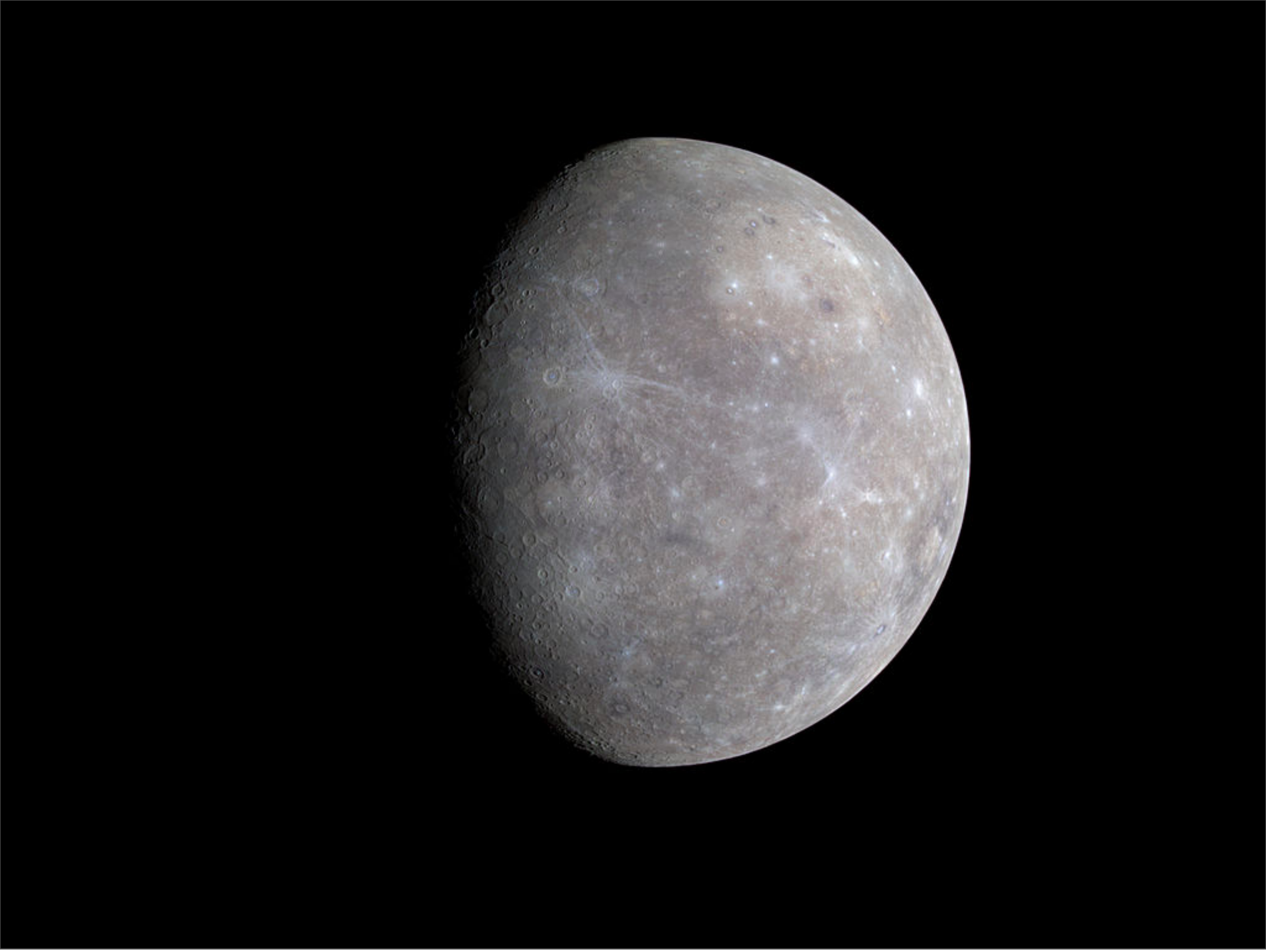




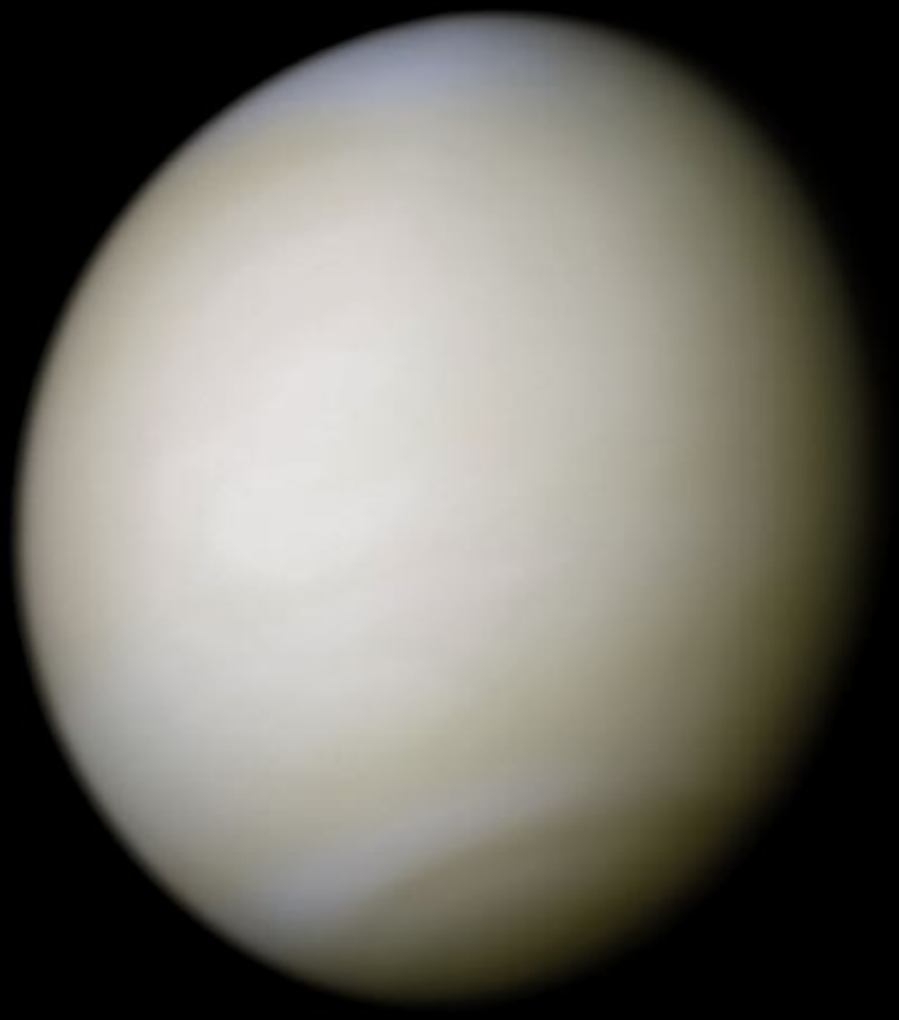
The sun has a solar wind. When the particle reach earth, they follow a helix path towards the magnetic poles, reach the atmosphere and give rise to aurorae (ionization and subsequent recombination). They are also responsible for the tails of comets.

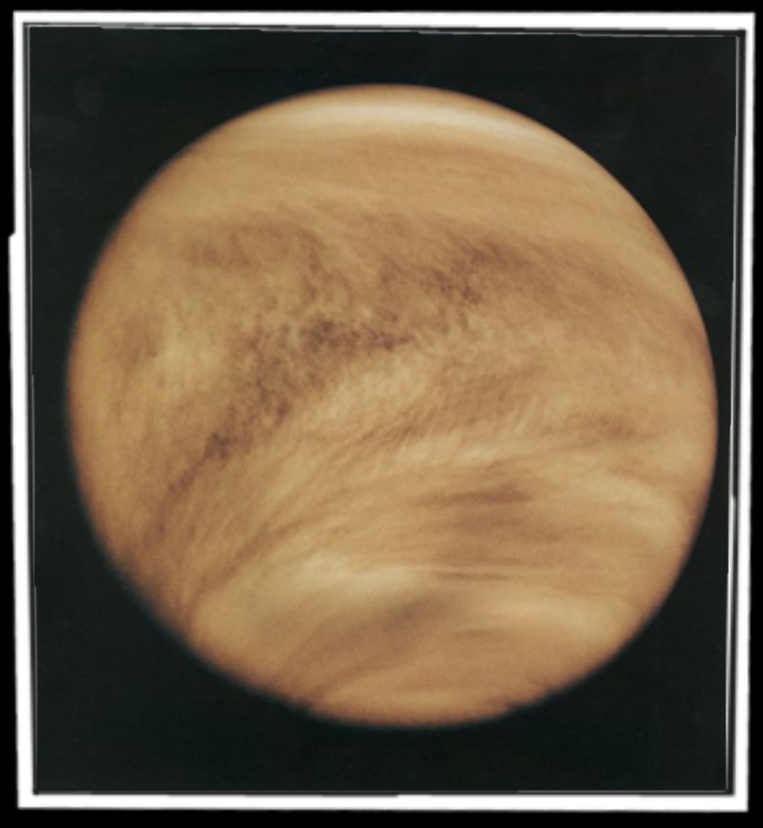


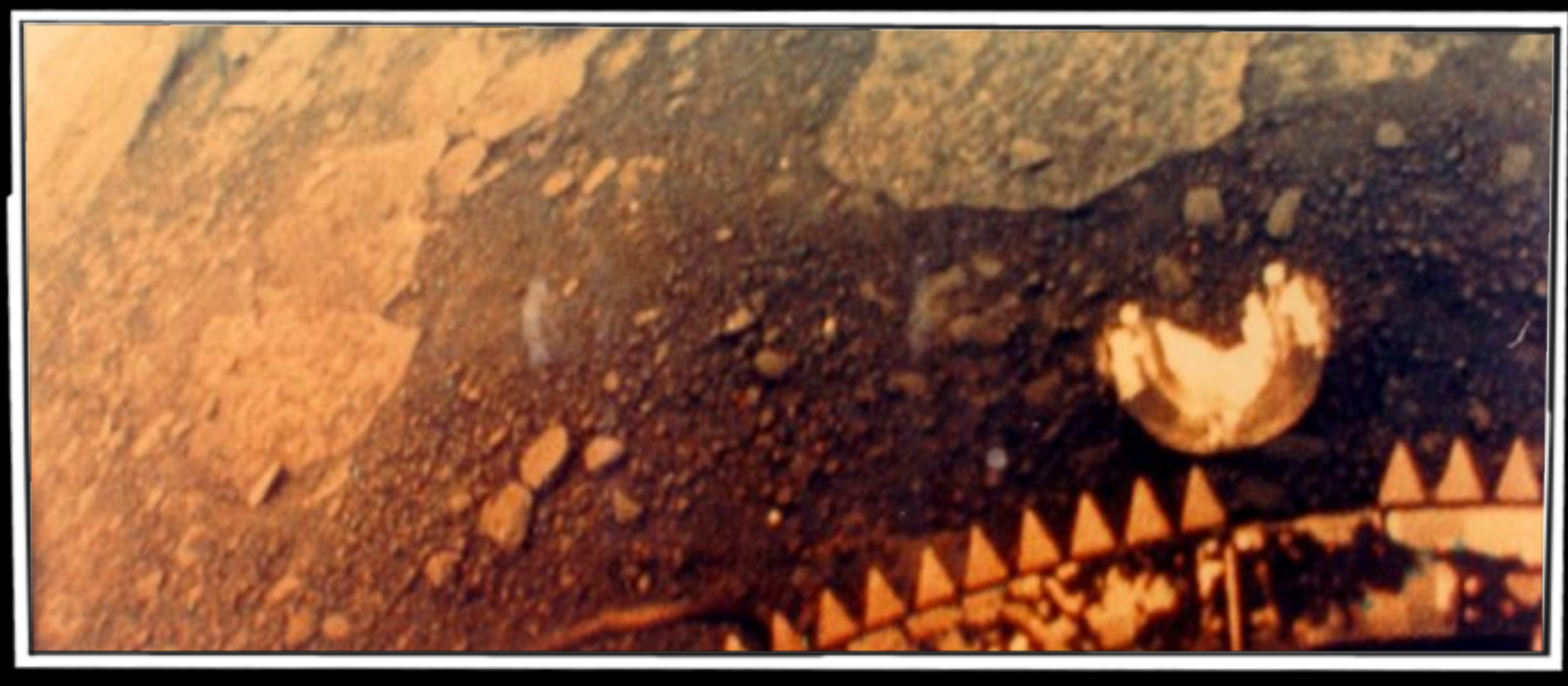
The four inner planets on earth are the “terrestrial planets”. Mostly solid (or liquid) + a thin atmosphere.



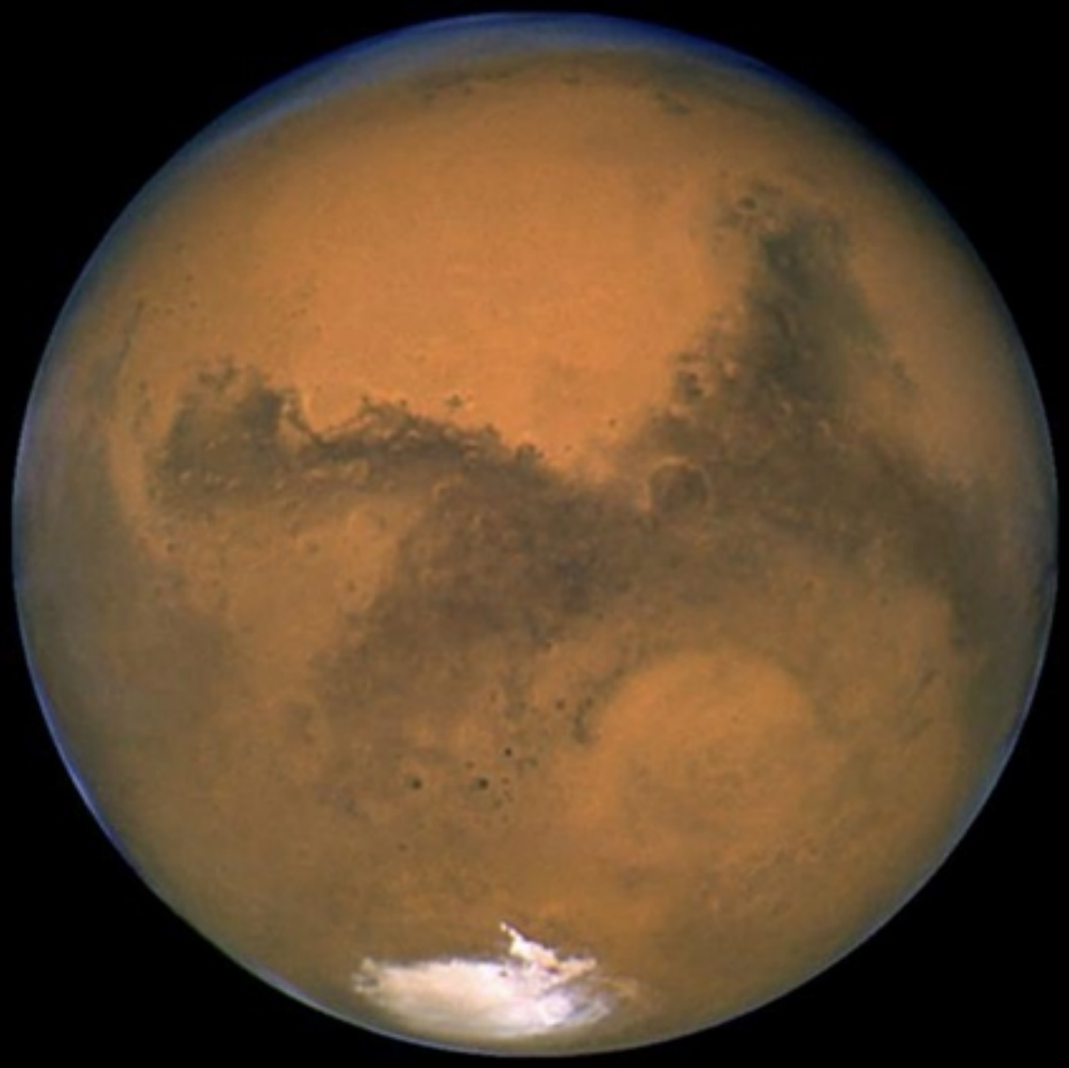
Mercury is too small and hot to have an atmosphere.

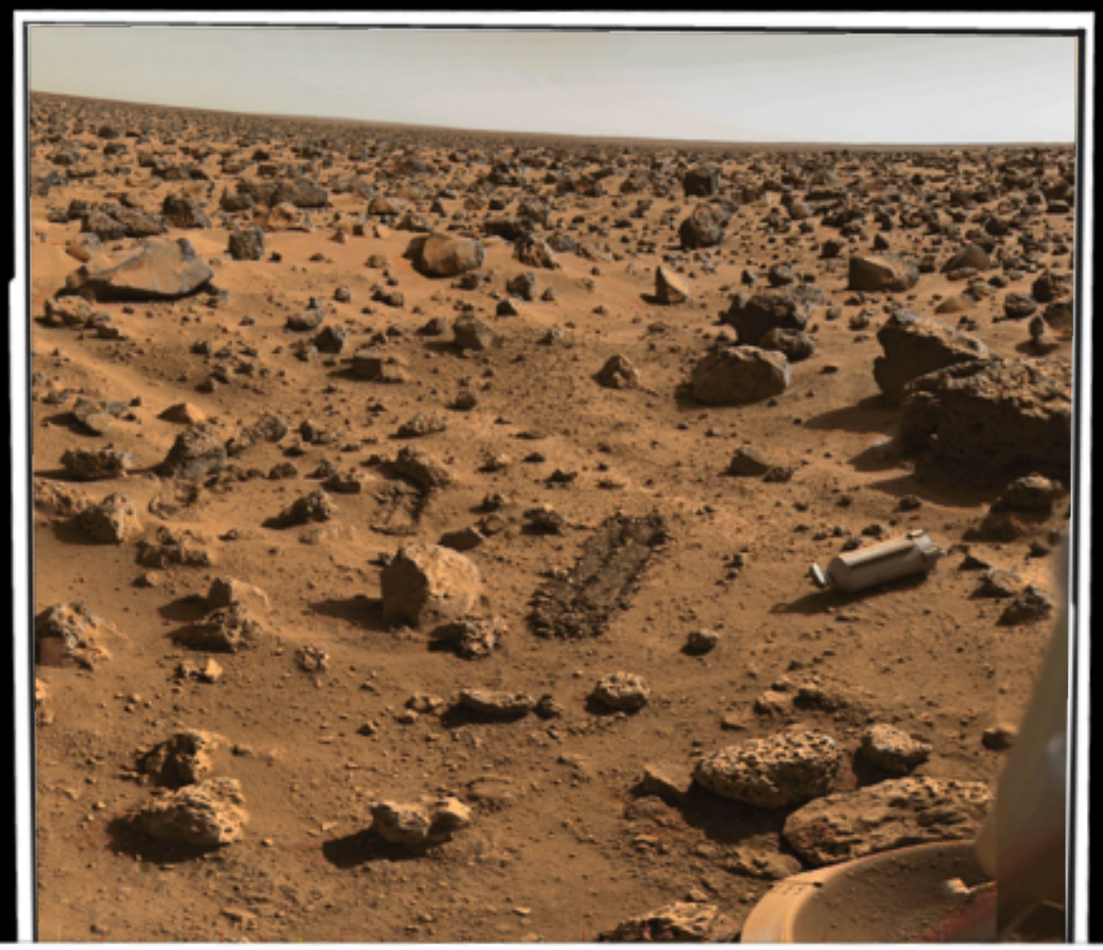


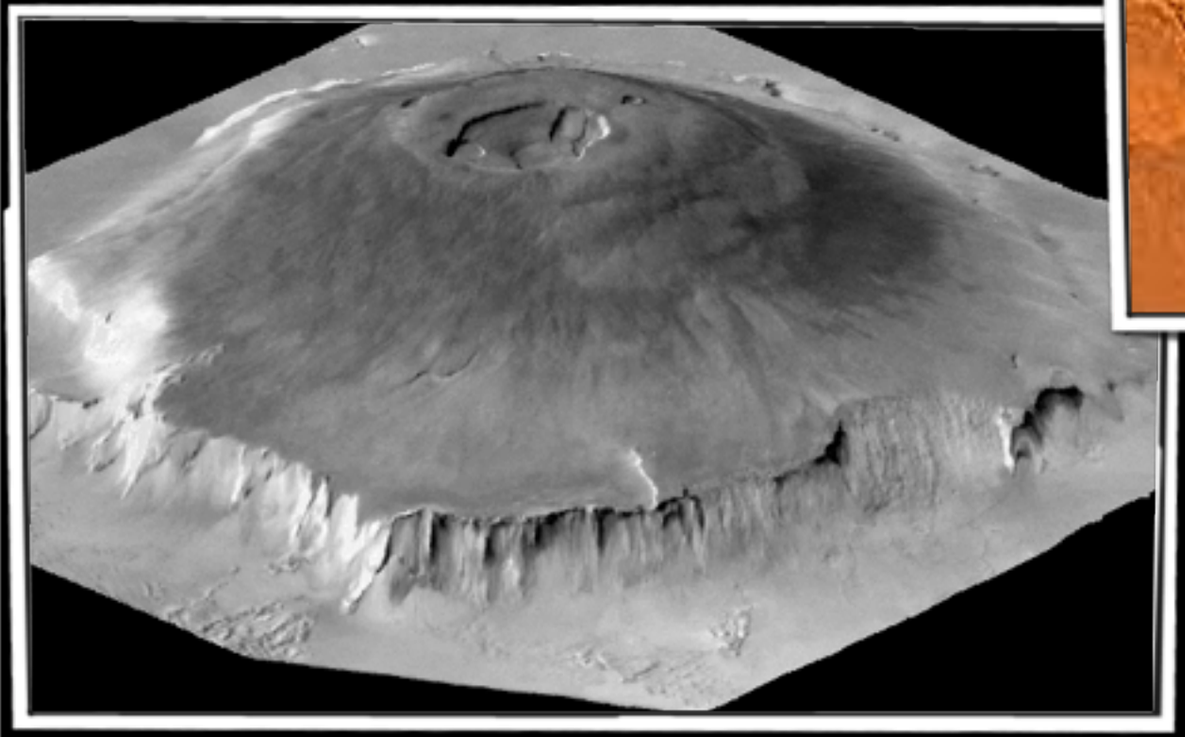


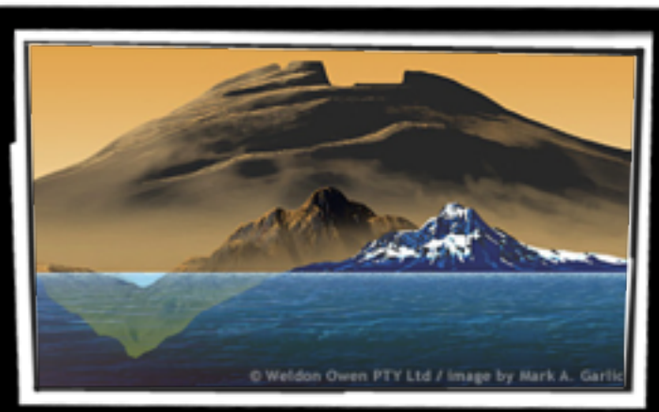


venus has a very thick atmosphere. The temperature is roughly 700K (from the greenhouse effect of CO2) and the surface pressure around 90 atmospheres.

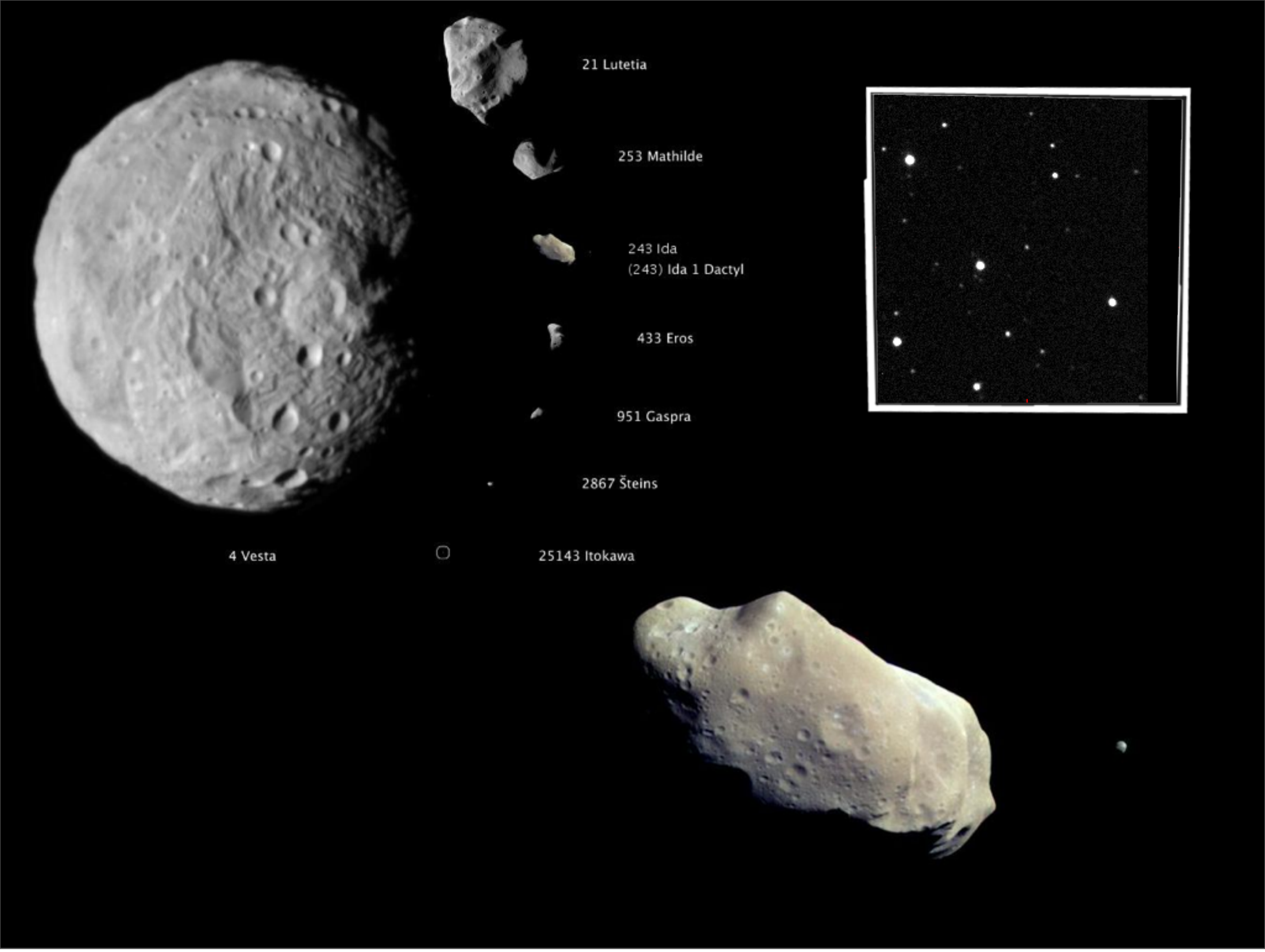




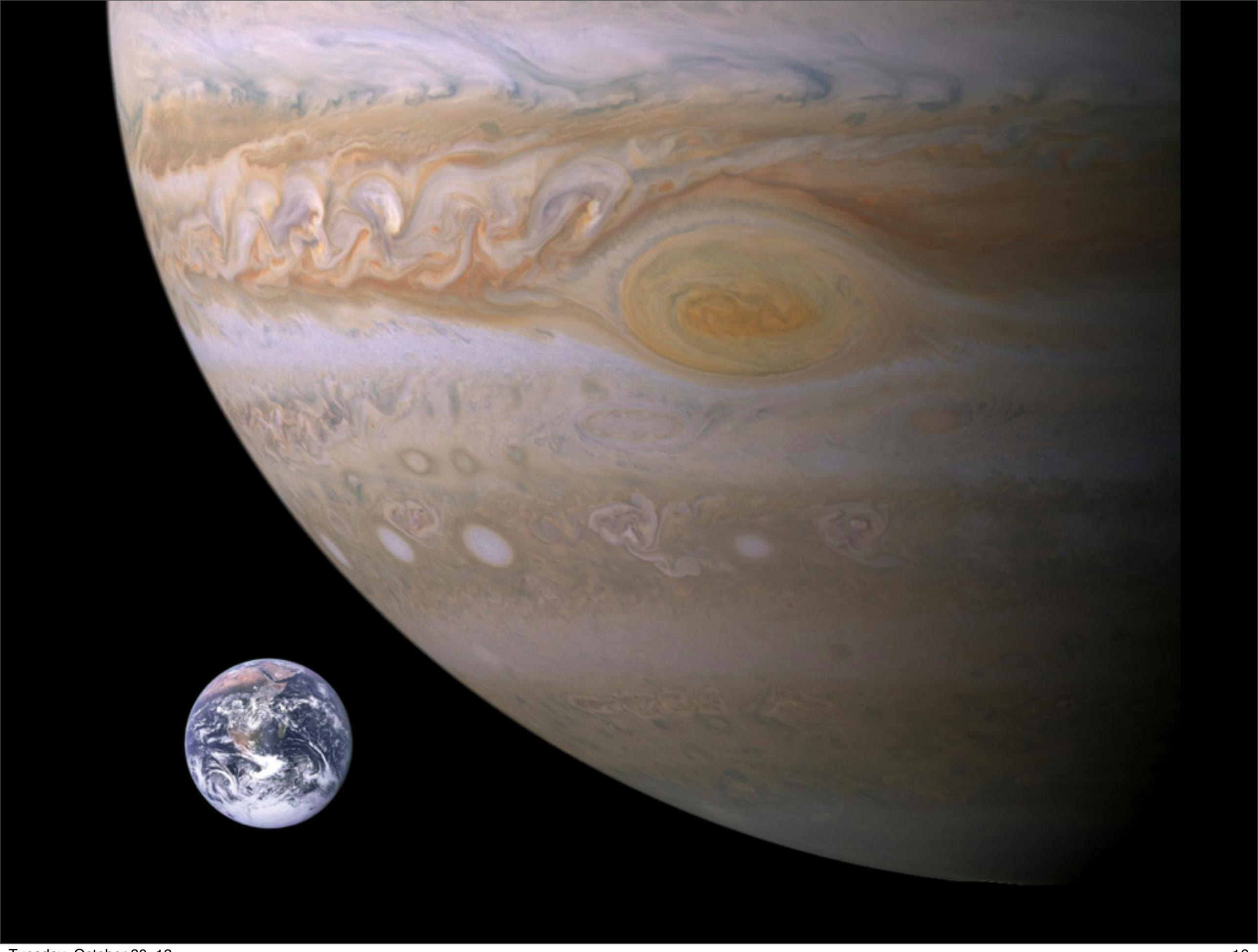




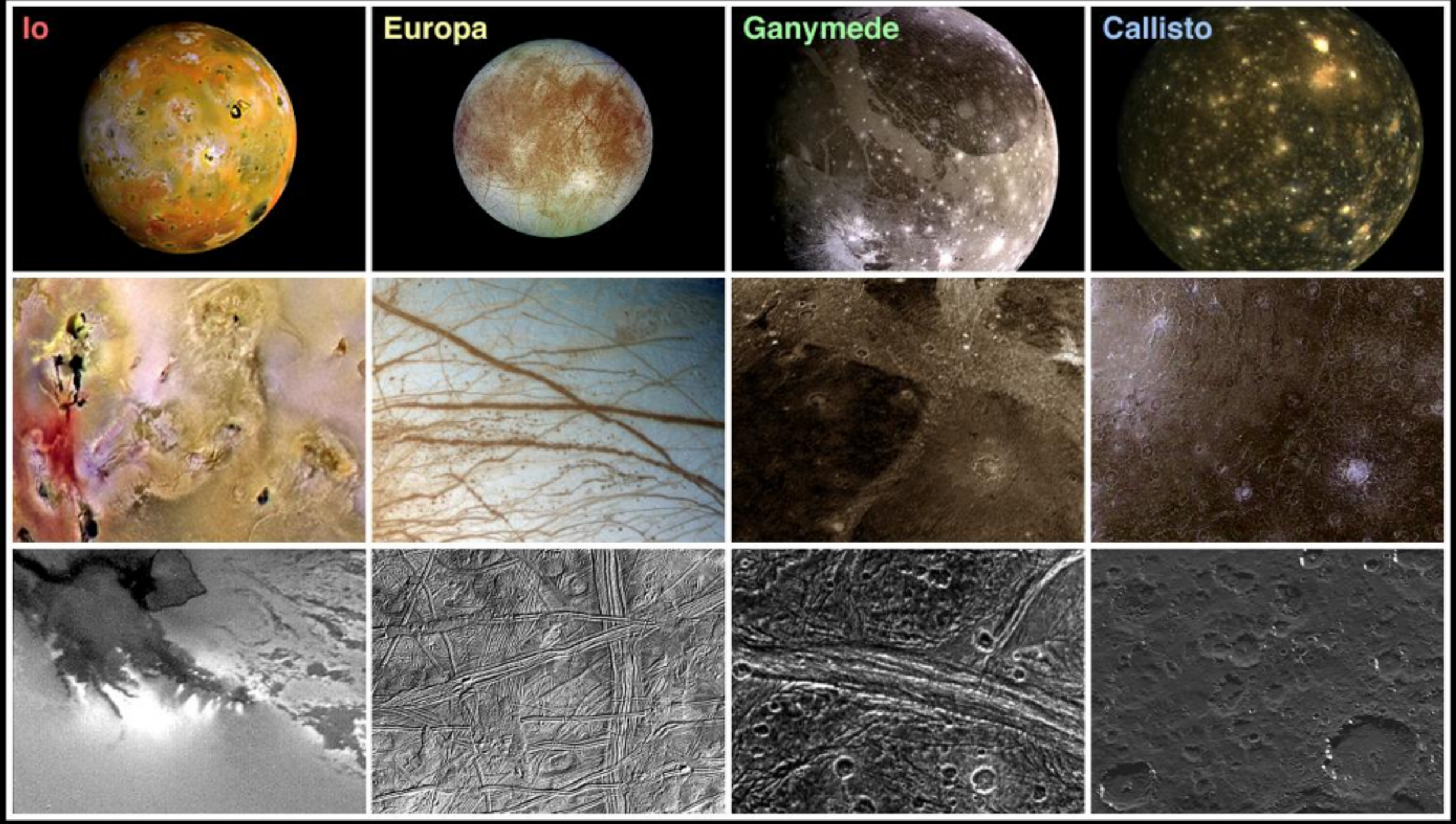
mars has a very thin atmosphere. Because it is smaller, its gravity is smaller too, and this allows for much larger volcanoes.



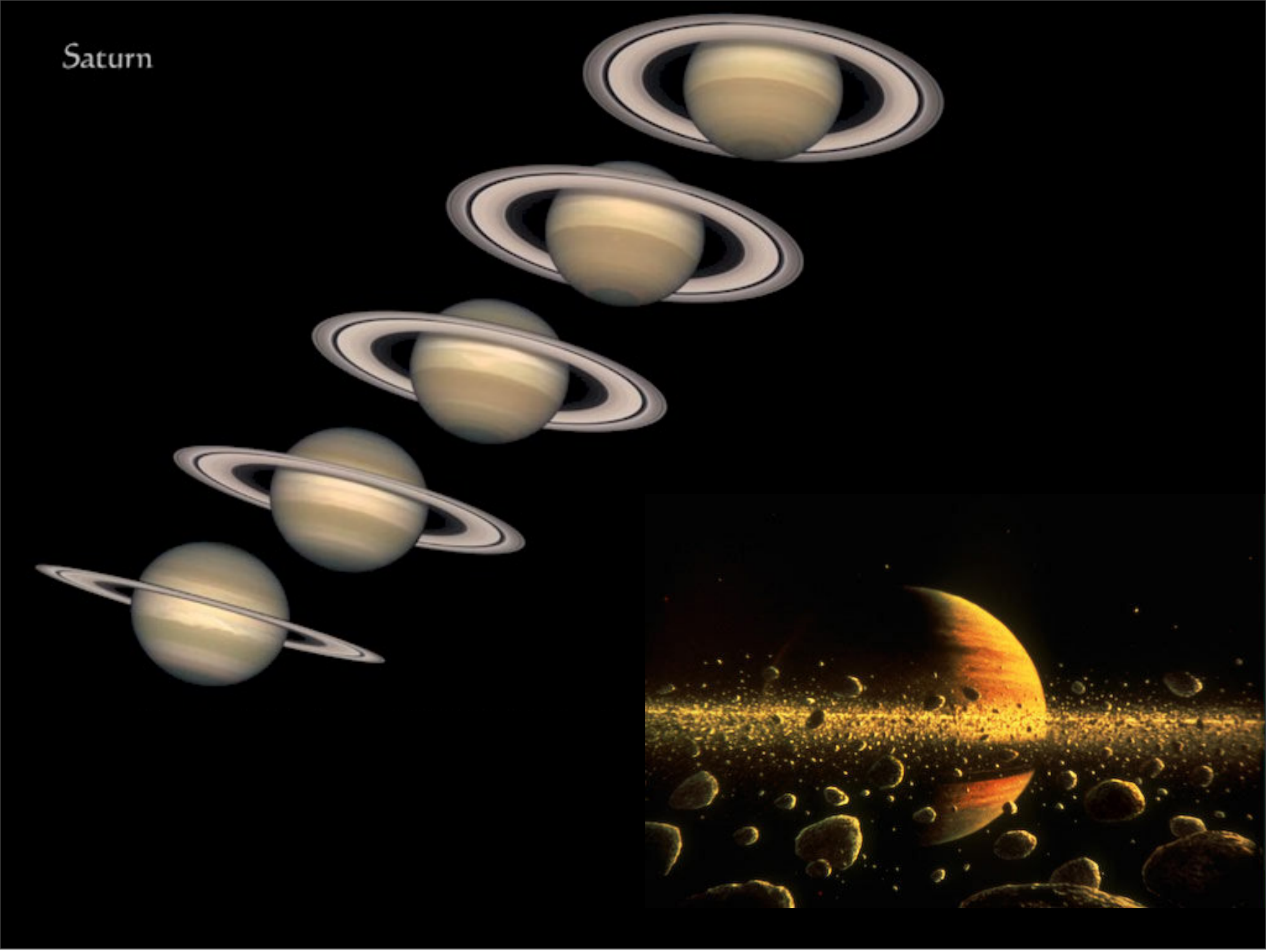
between mars and jupiter is the asteroid belt. the largest asteroids are roundish because of their self gravity. Smaller asteroids don't have a large enough gravity. However, they may have moons like small ida and its tiny rock circling it. Ida is 53.6 km on the long axis. Its moon is 1.5 km in diameter, orbiting at a radius of roughly 100 km and period of 20 hours.



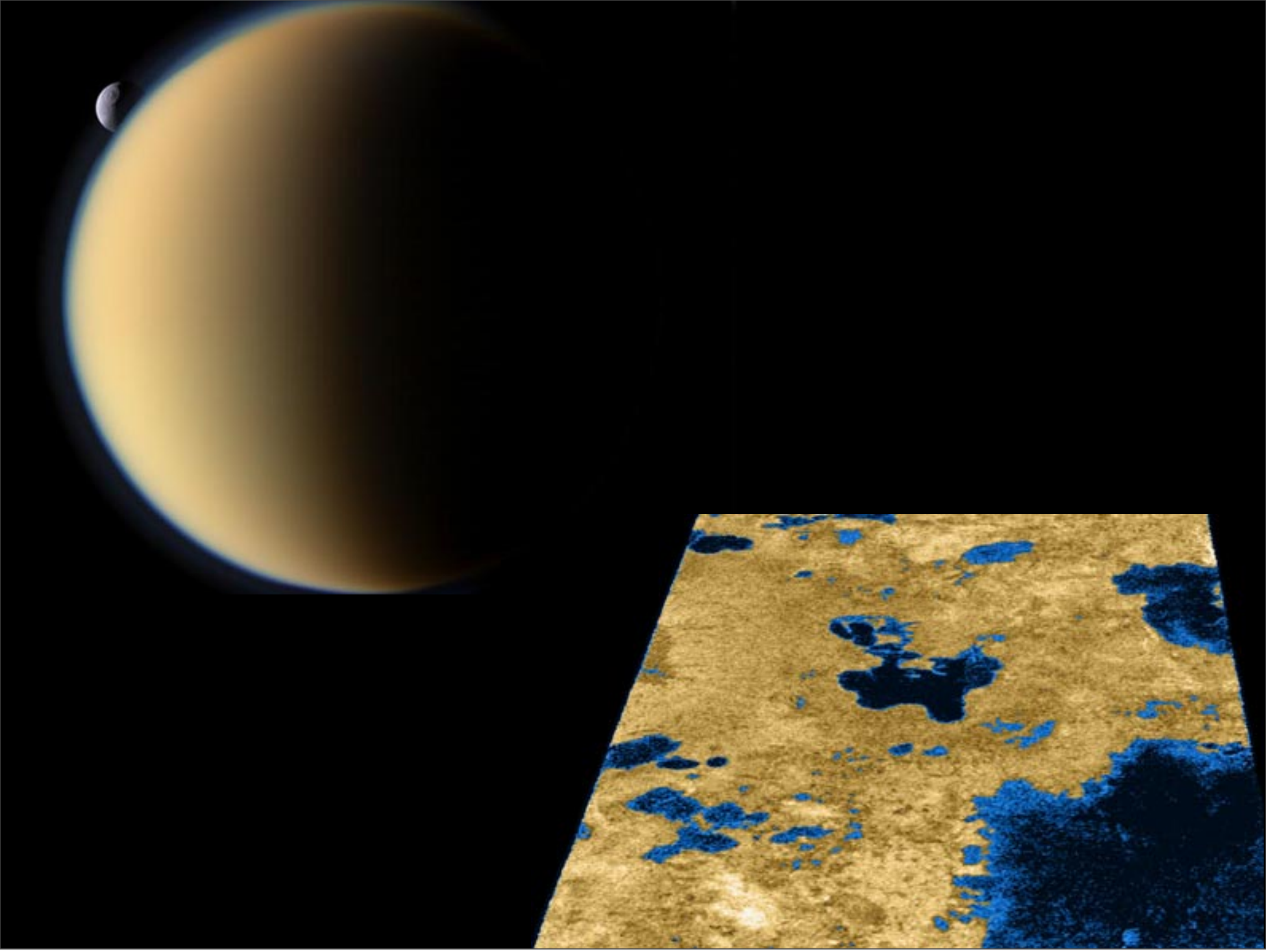
Jupiter is the largest planet. the orbital angular momentum is most of the angular momentum in the solar system. Like the other giant planets, it consists of mostly gas.



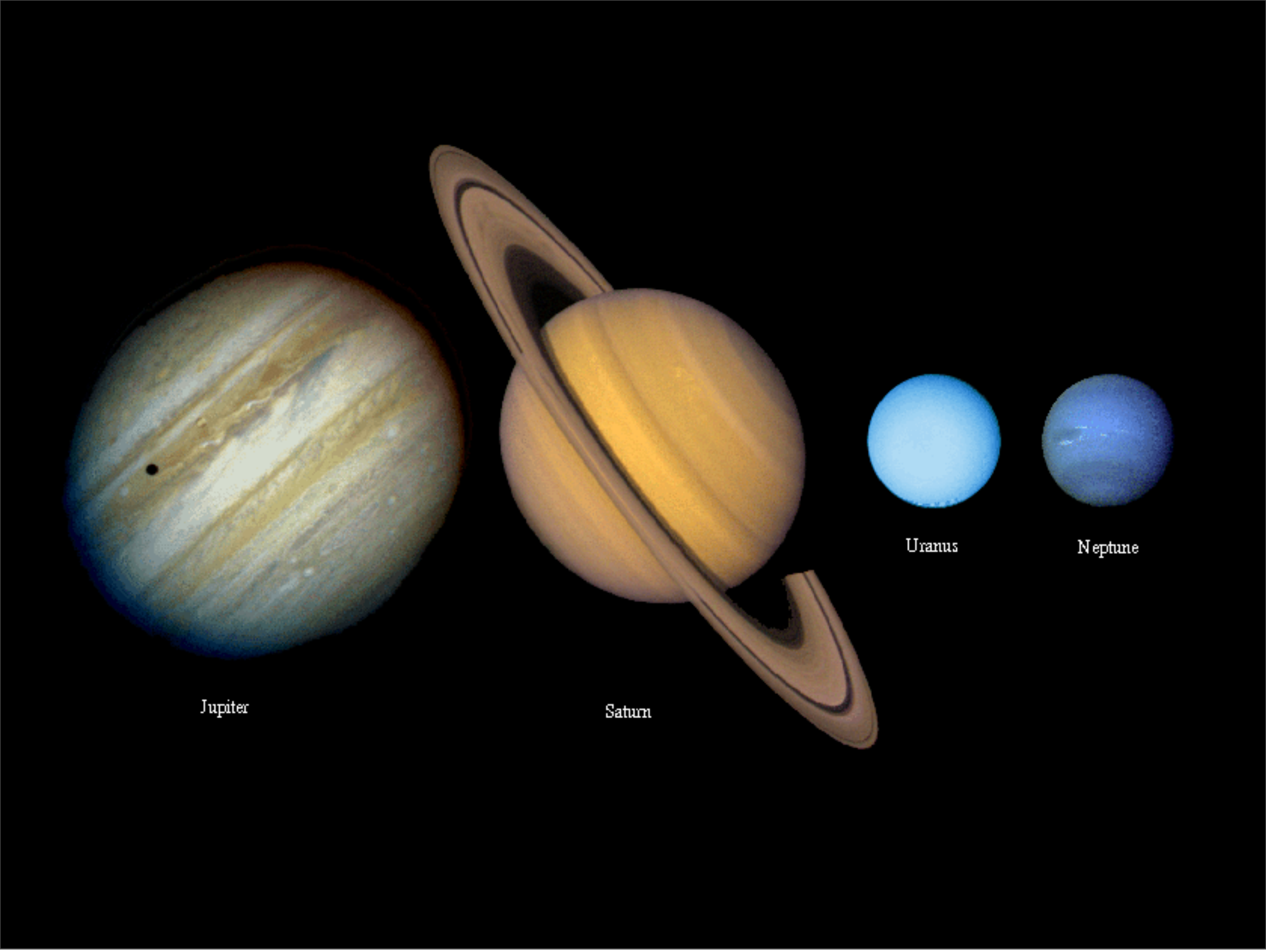
Jupiter has many moons. The 4 largest are like Earth's moon in size, but each one is different. Io is kept warm because of tidal interaction with Jupiter. It therefore has volcanic activity. Europa probably has a large ocean underneath the crust.



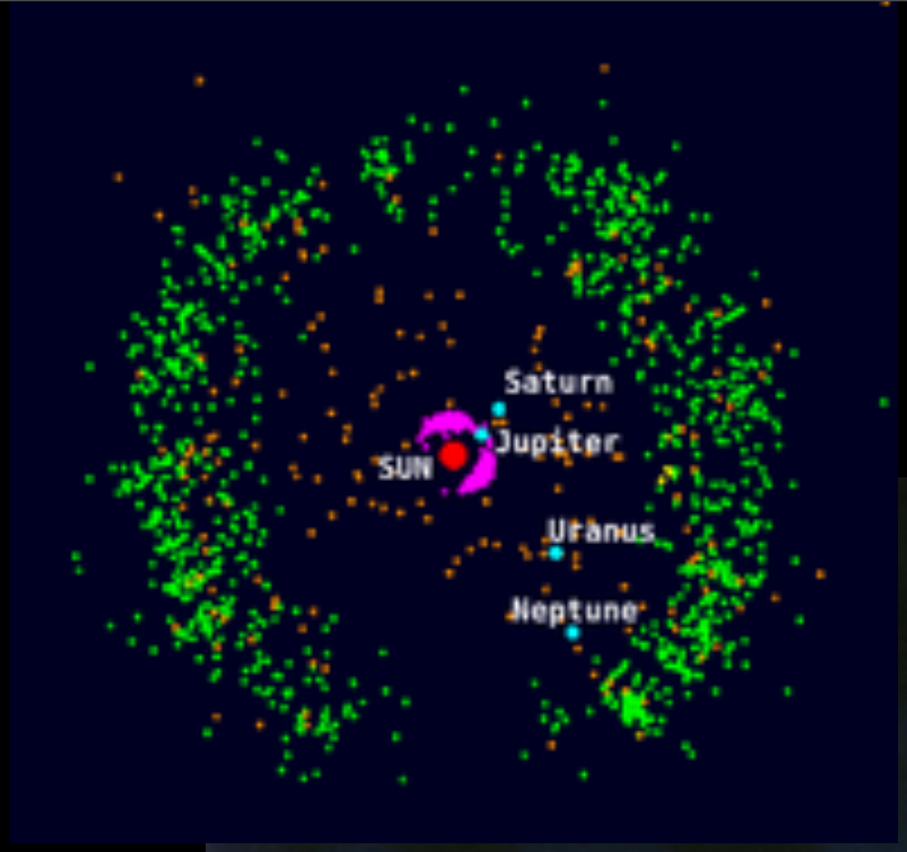
Saturn has many moons, but also prominent rings (jupiter and the other planets have minor rings). The rings are kept in place by shepherd moons.

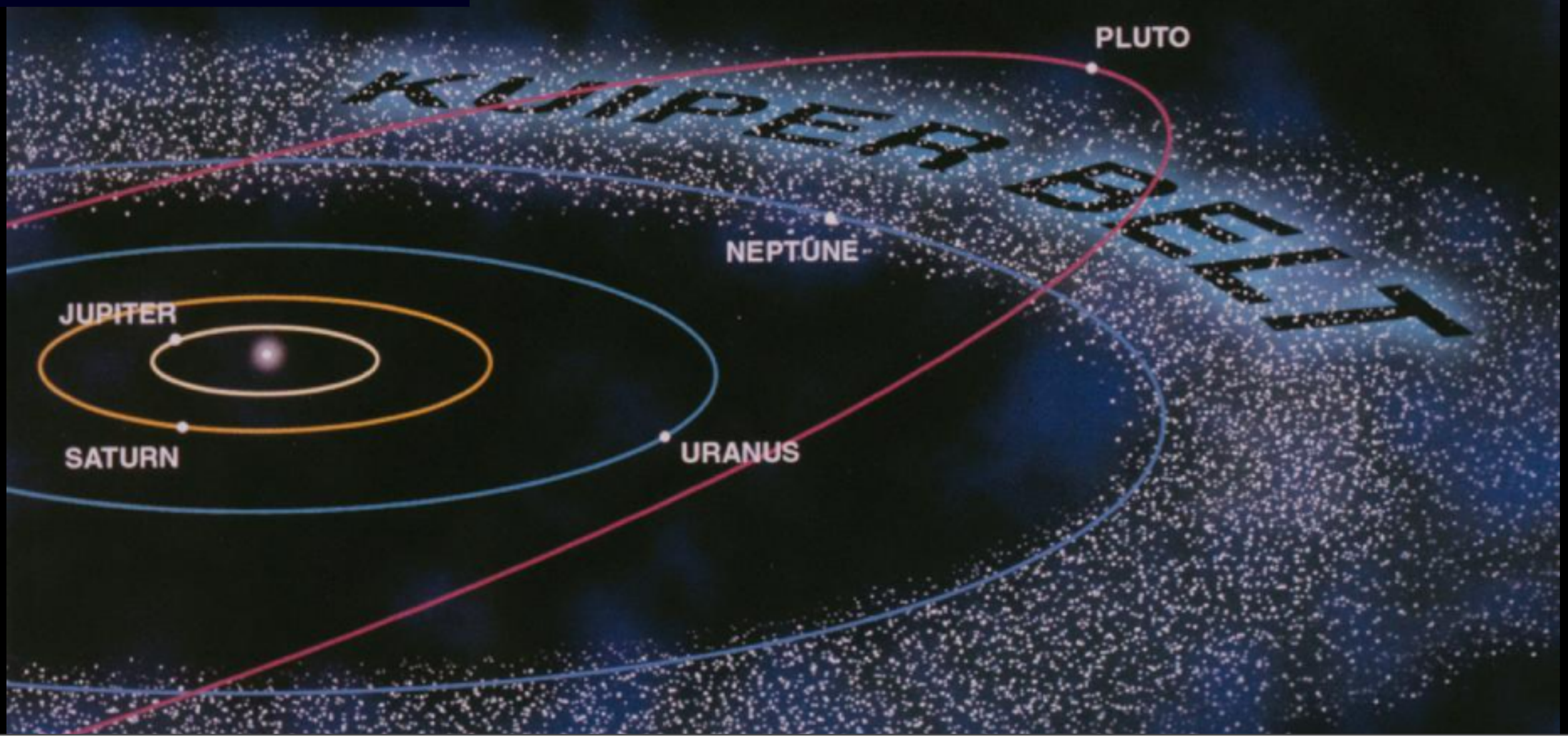


Titan is the largest moon in the solar system. It has an atmosphere (1.6 atm). It methane and ethane cycles similar to the water cycle on earth (here is evidence for methane or ethane lakes).

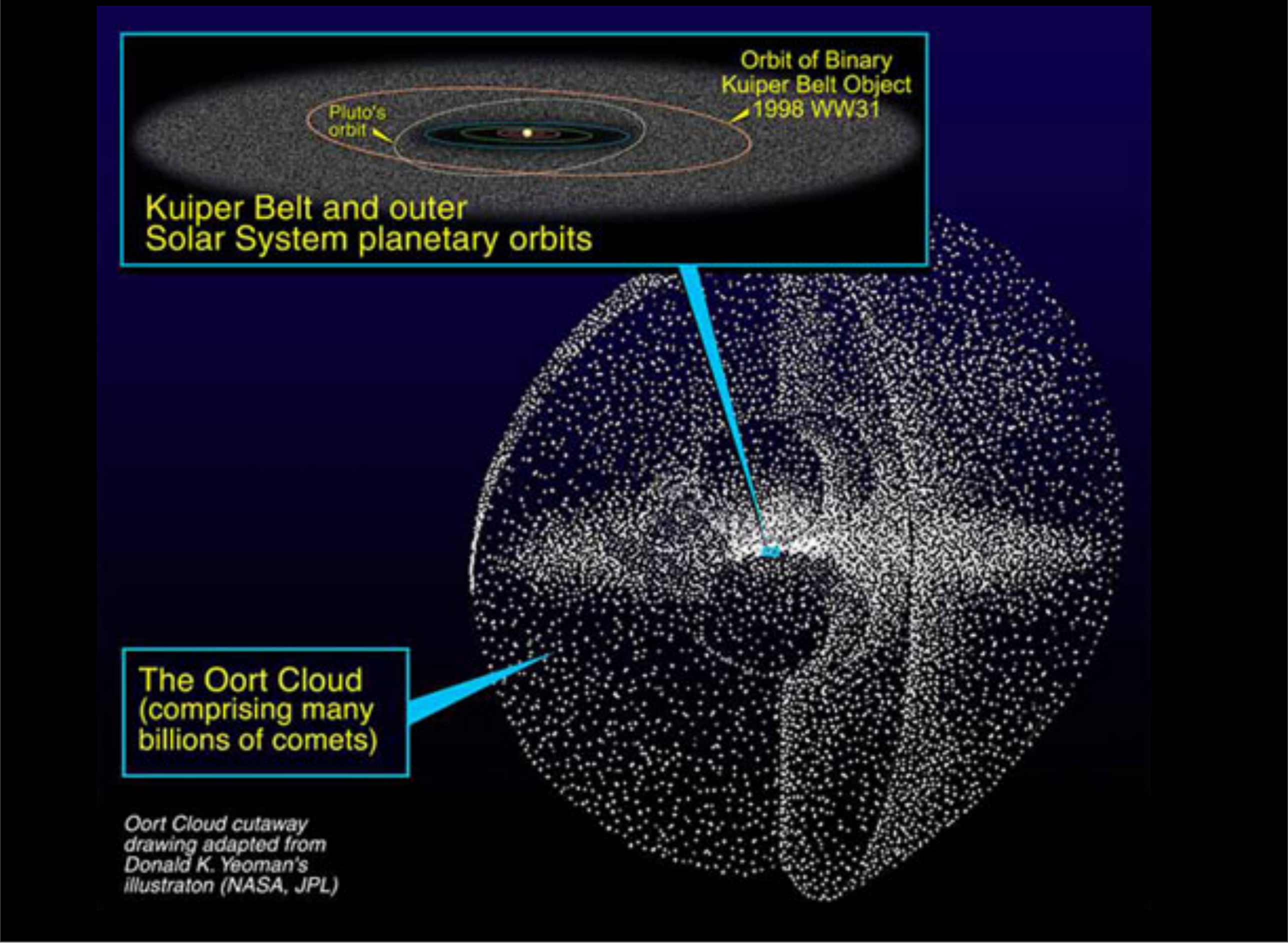


The four giant planets.

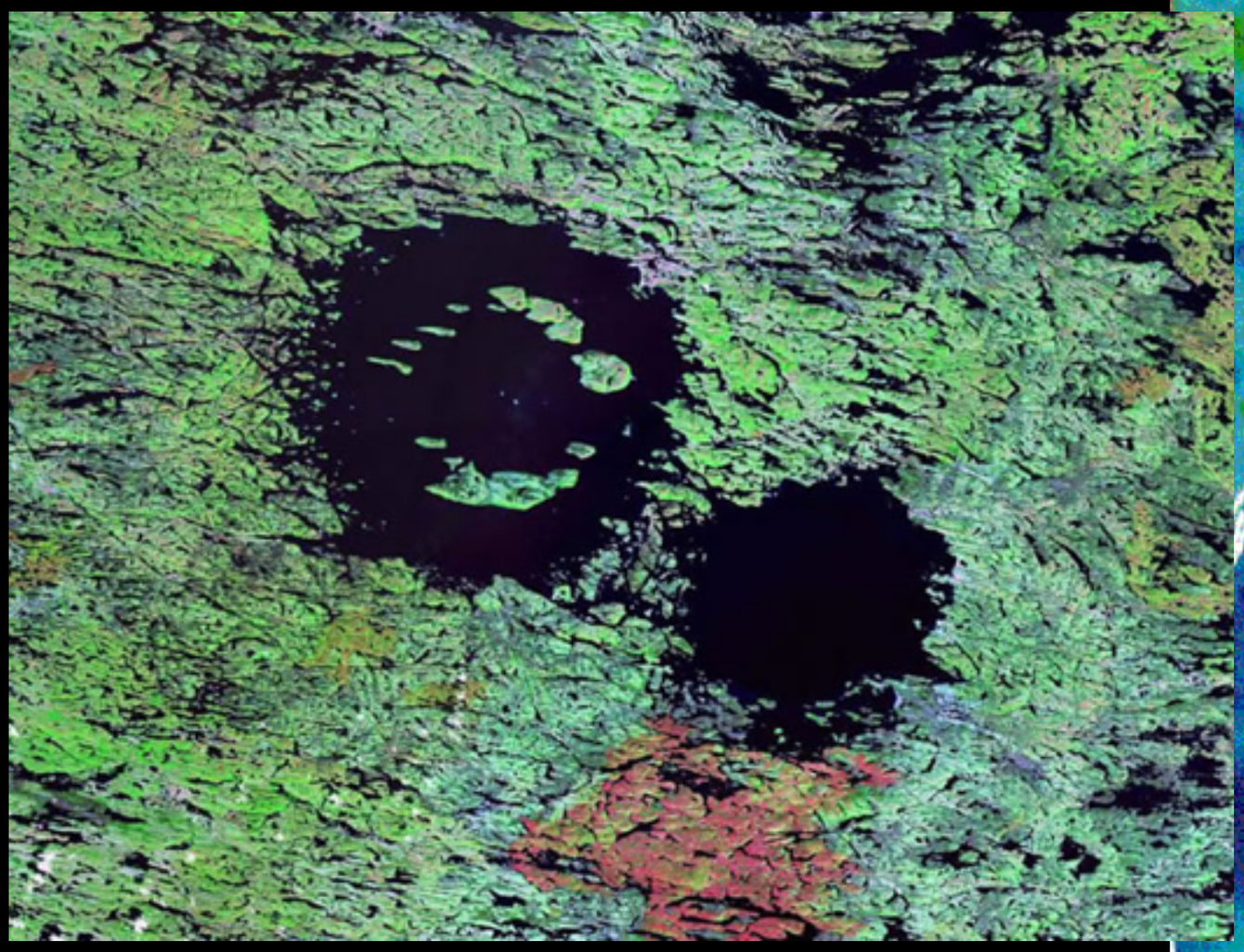


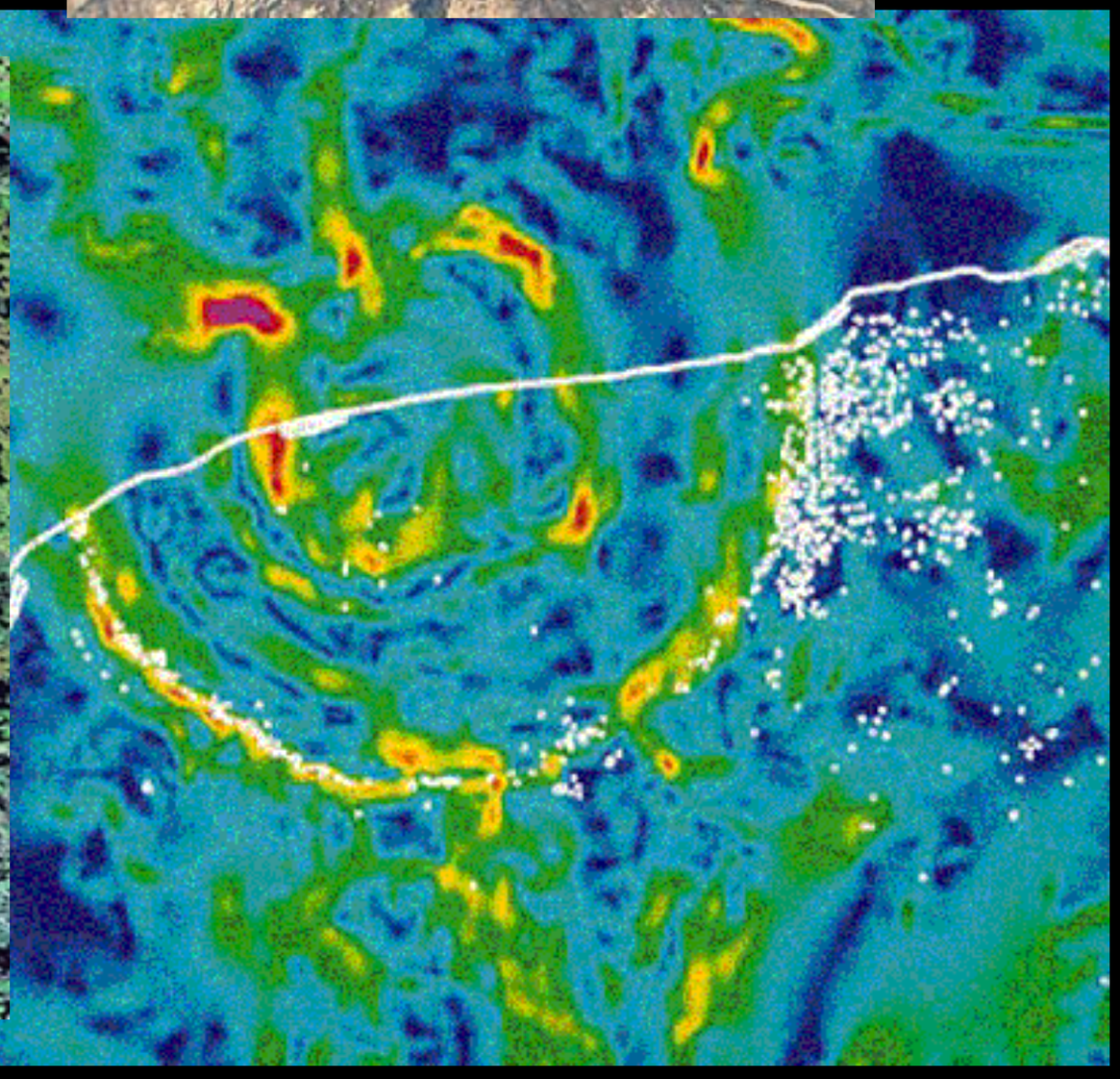


Beyond is the kuiper belt. Pluto is the largest Kuiper belt object

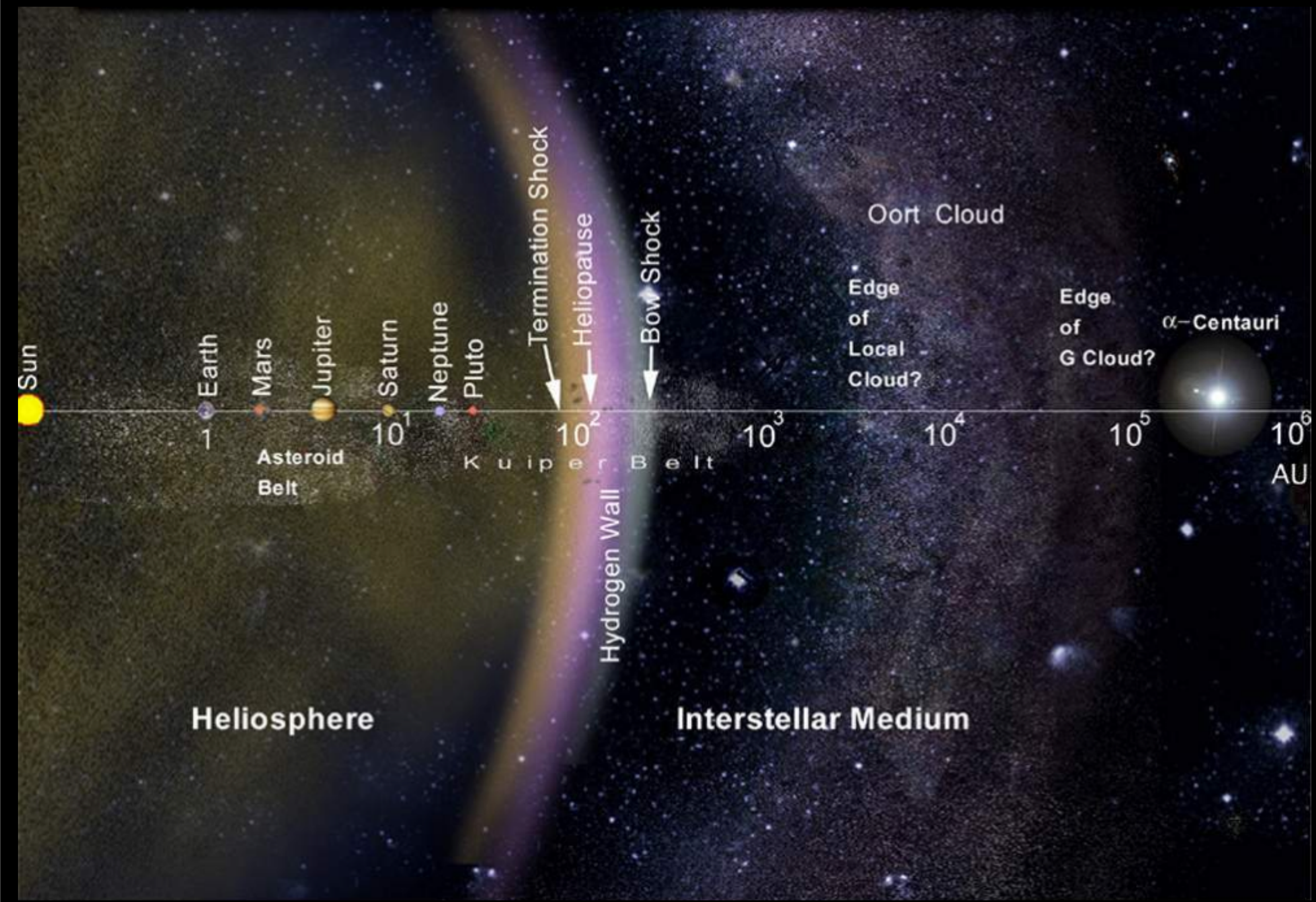


At the outskirts of the solar system is the Oort cloud which is the source of comets.

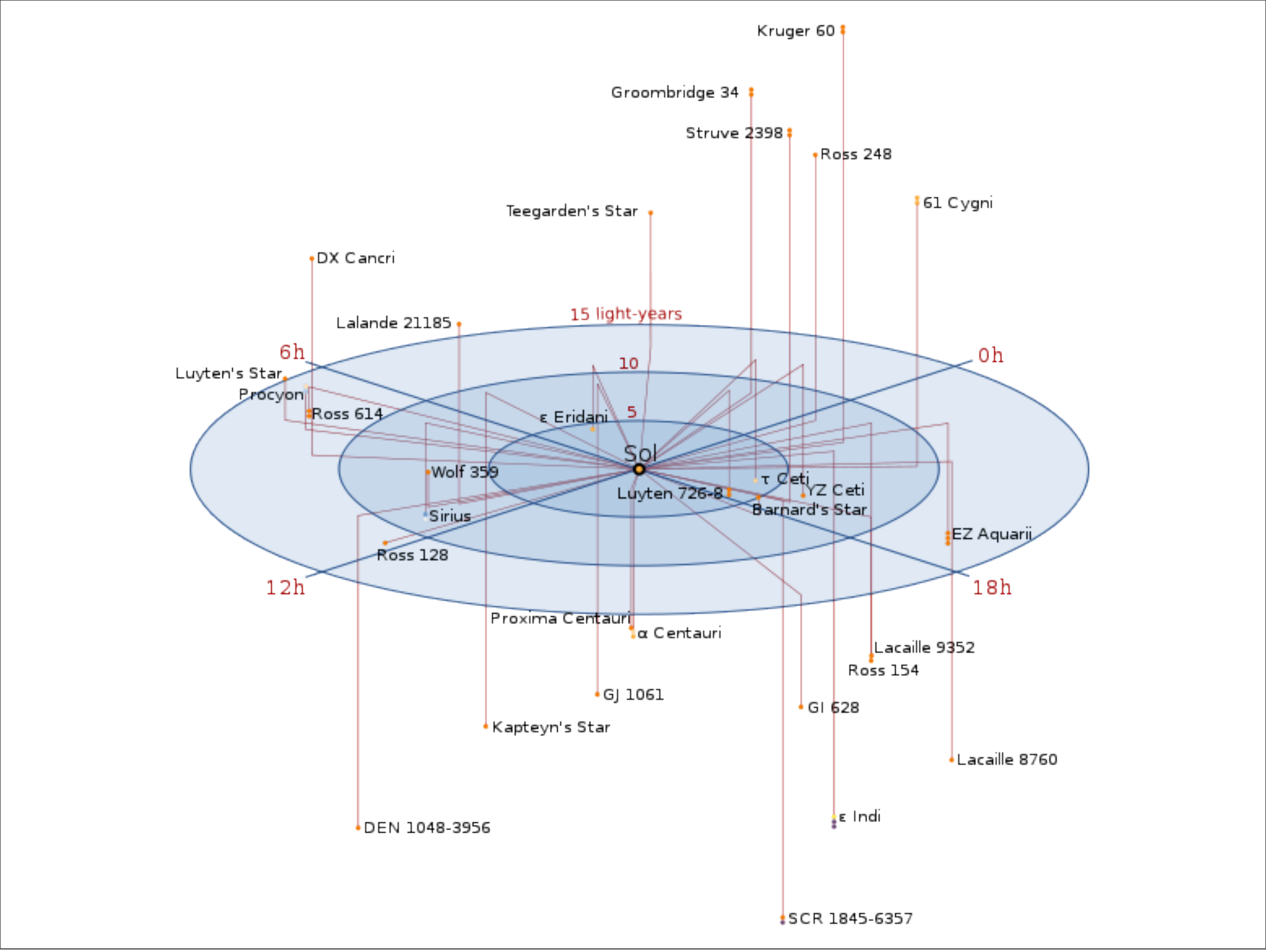




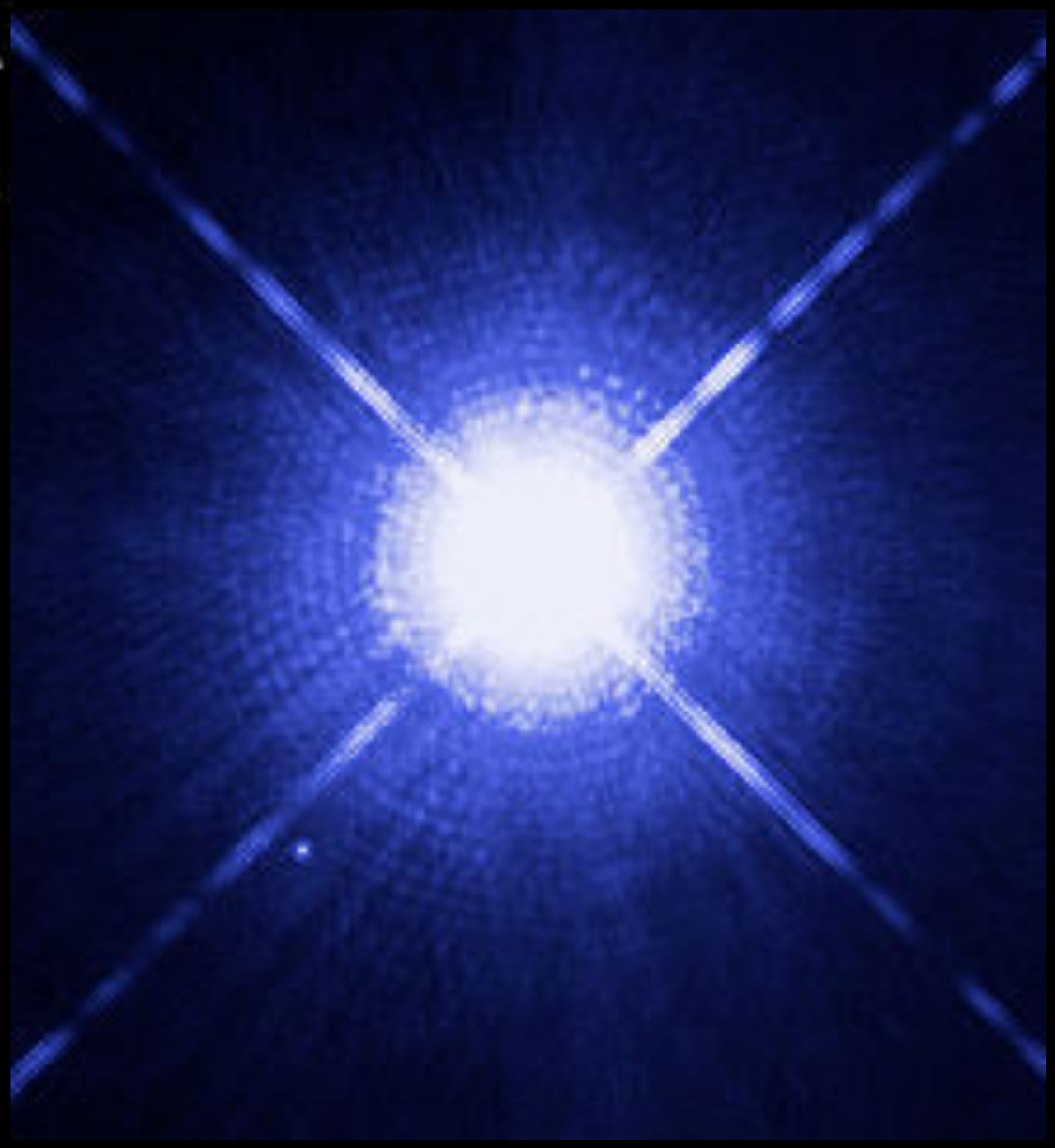
Occasionally, comets or asteroids can reach earth and form craters. (top left: meteor crater, two impacts in quebec, one is of an object that split into two before reaching Earth). The last crater is the one left by the dinosaur killer (it is filled with sediments, and can be detected by small changes in g).



The nearest star is several 100,000 of AU.



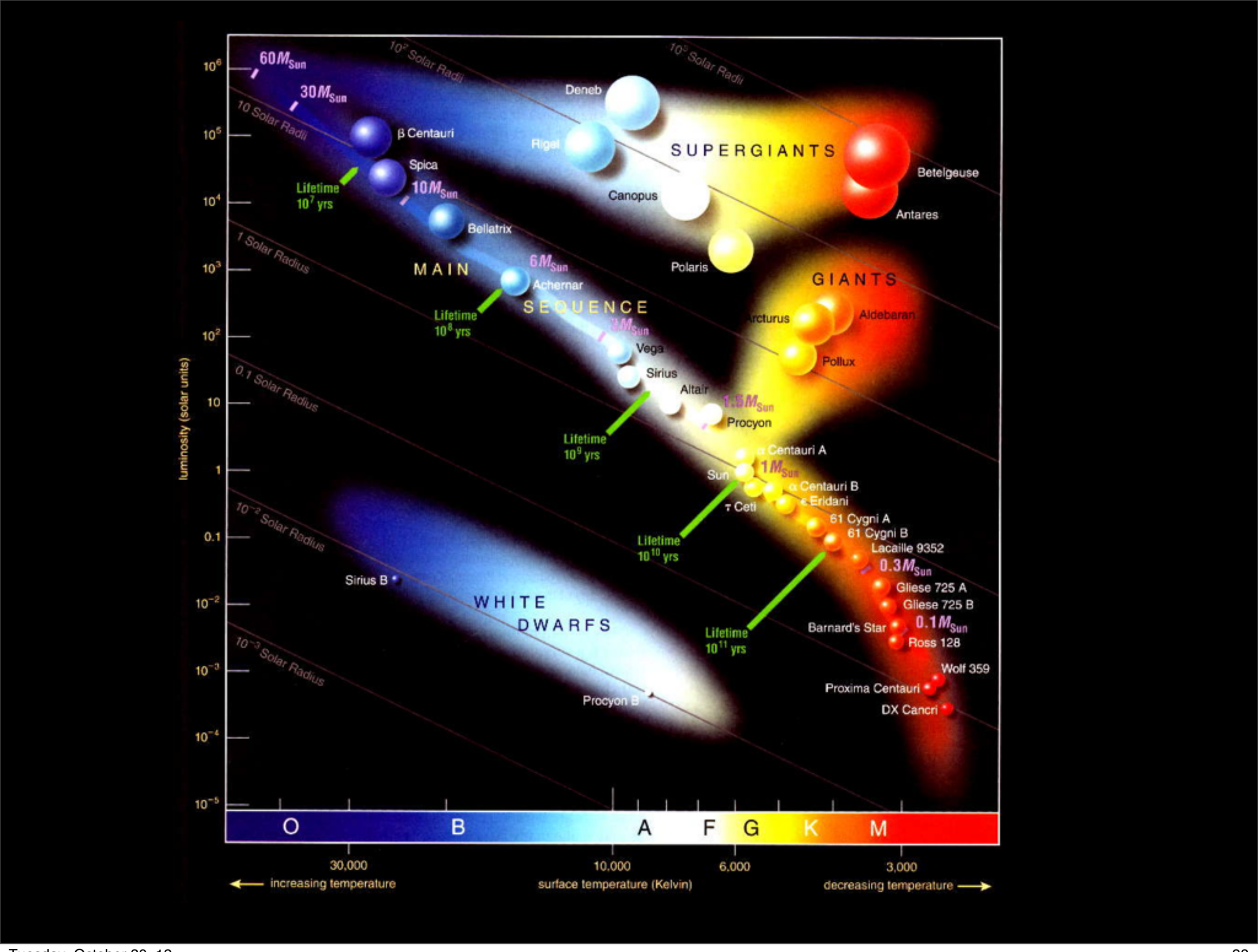
nearest stars to the solar system



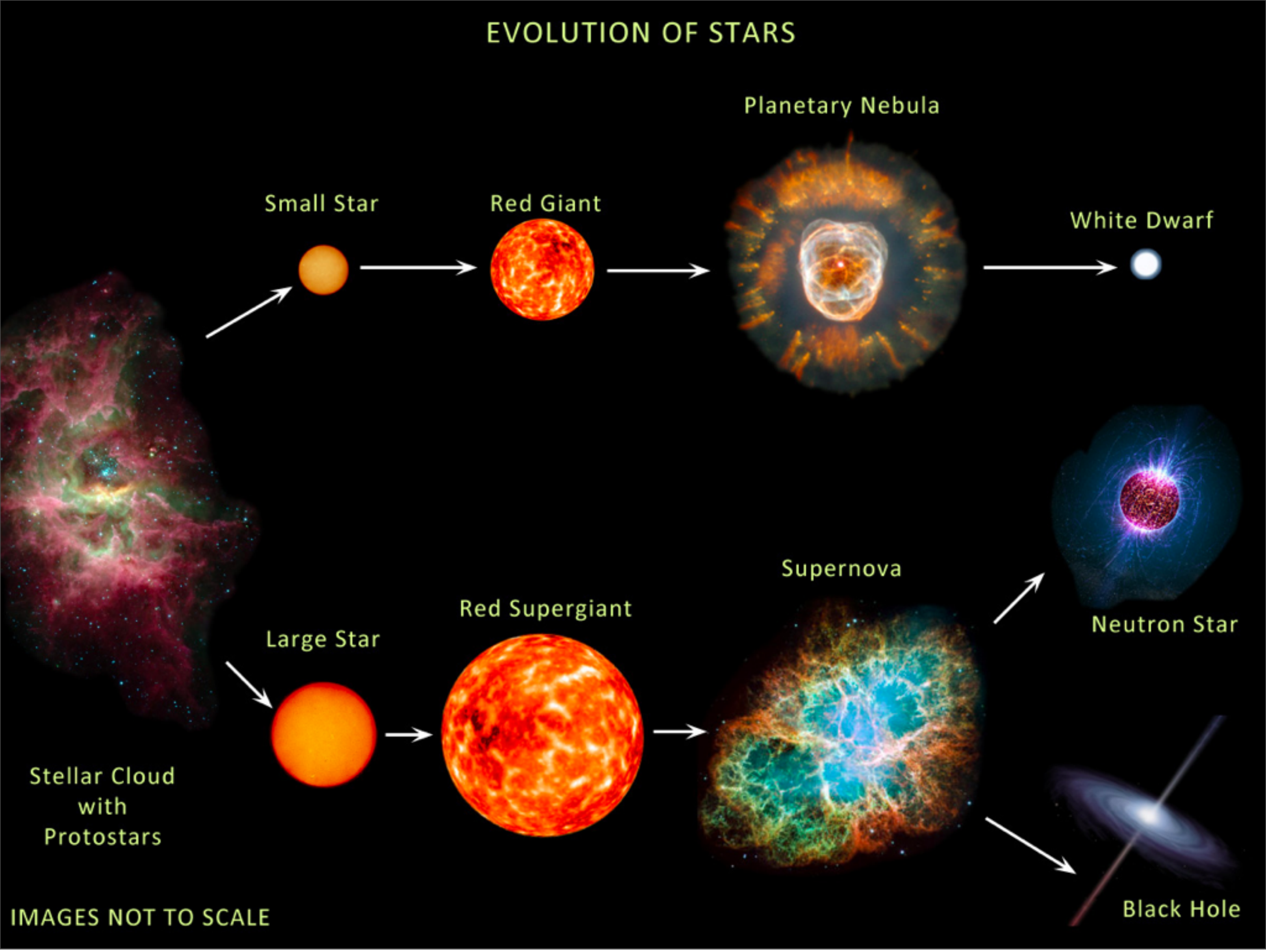
One of the nearest stars is Sirius (the brightest star after the sun). It is a double star. Sirius B is a white dwarf star.

מהם כוכבים?

כדורים של גז

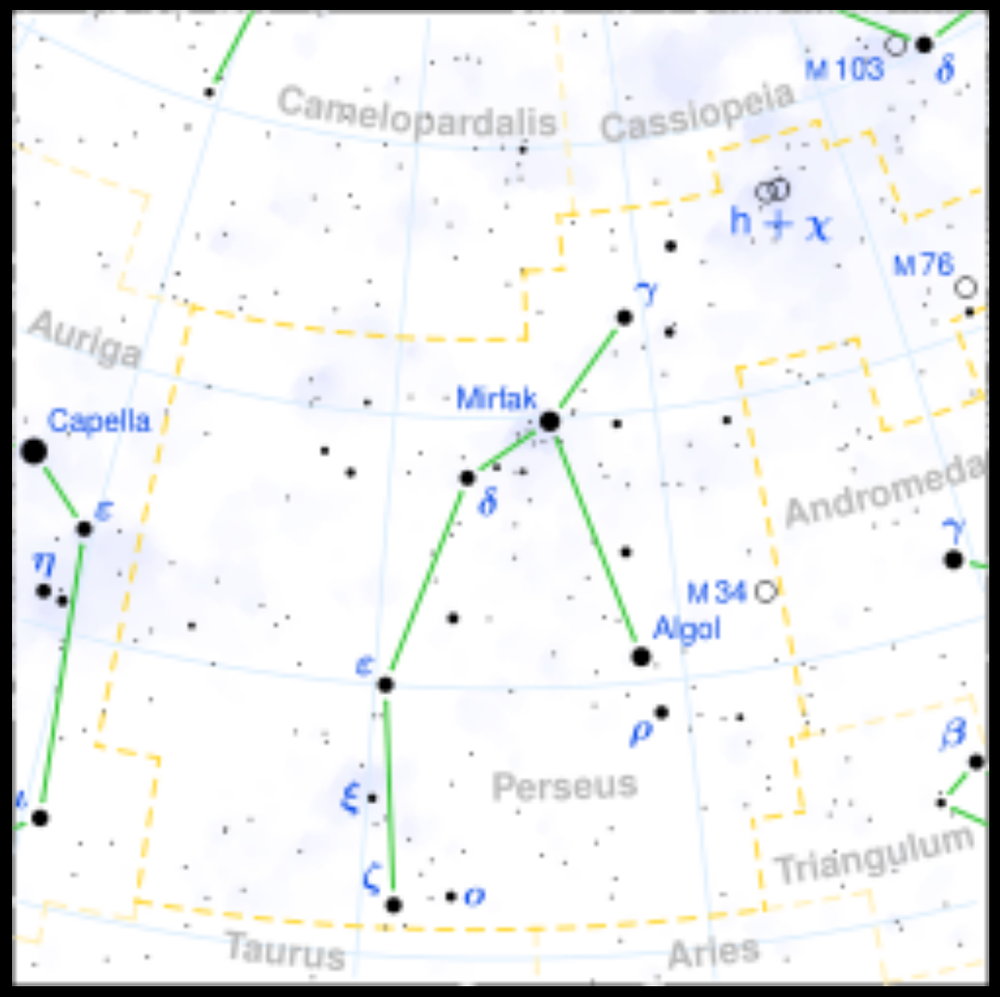


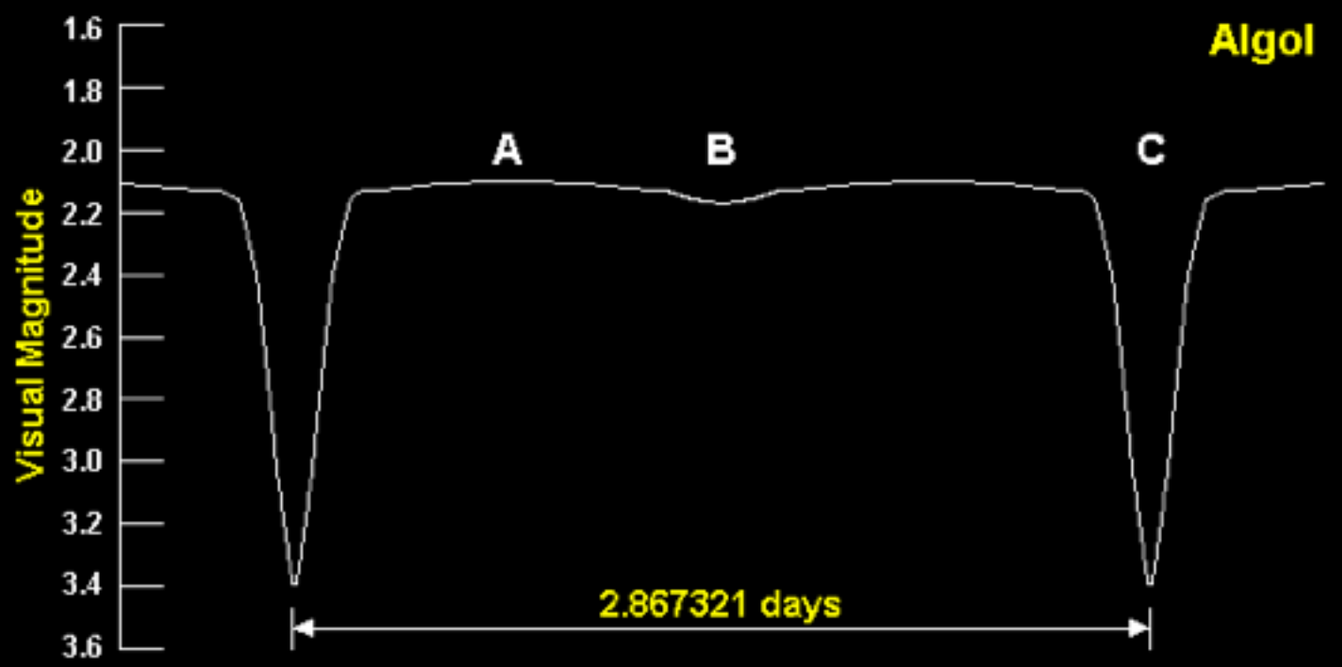
This is the hertzsprung-russell (HR) diagram showing different types of single stars (we will understand this diagram later). Plotted is the luminosity of the star vs. the temperature (note the opposite scale, hot is on the left!)

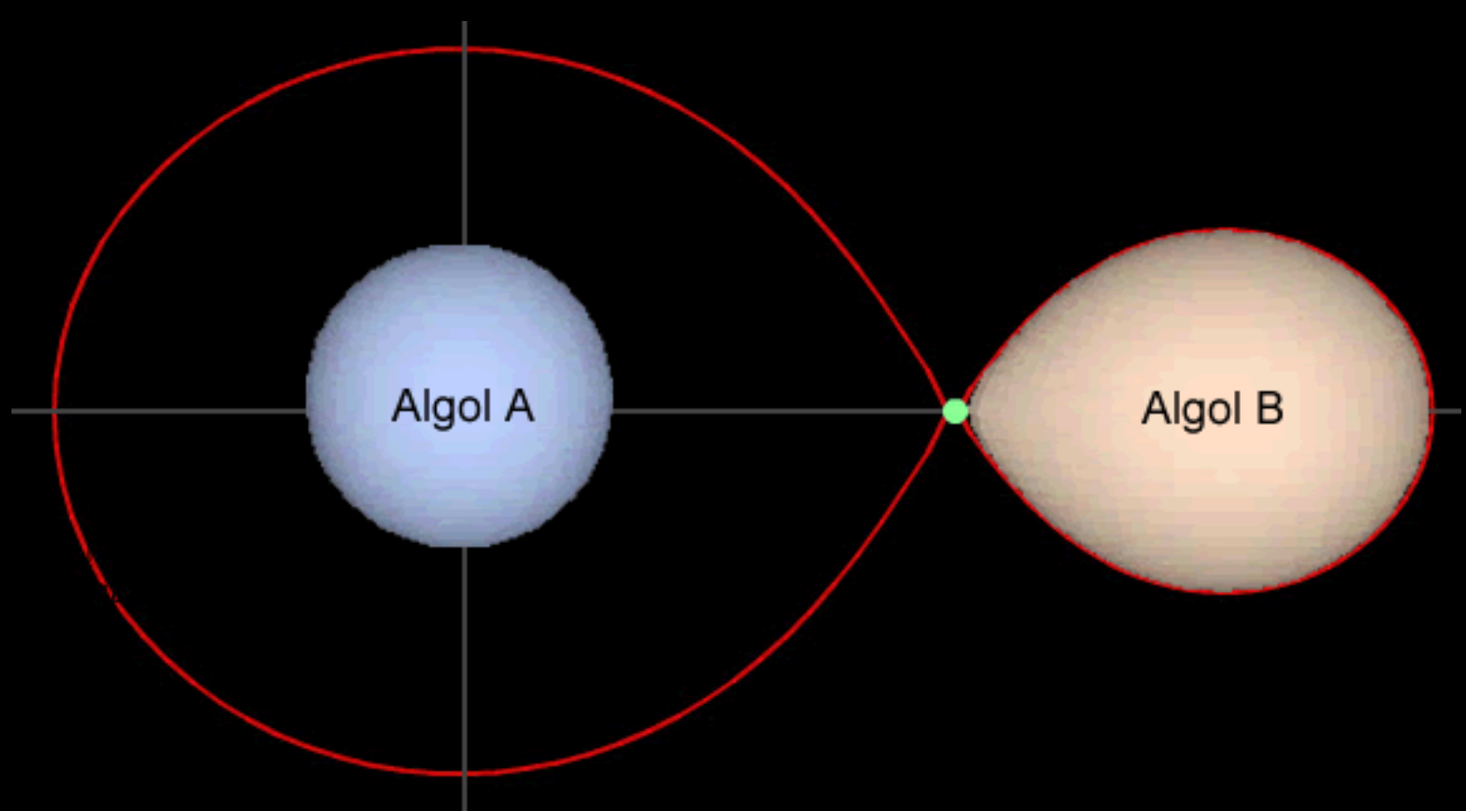


Very short summery of the evolution of stars. Small masses (below about 8 solar masses) end with a planetary nebula and a white dwarf (WD). Higher masses have a supernova explosion and either a neutron star (NS), or if massive enough, a black hole (BH).

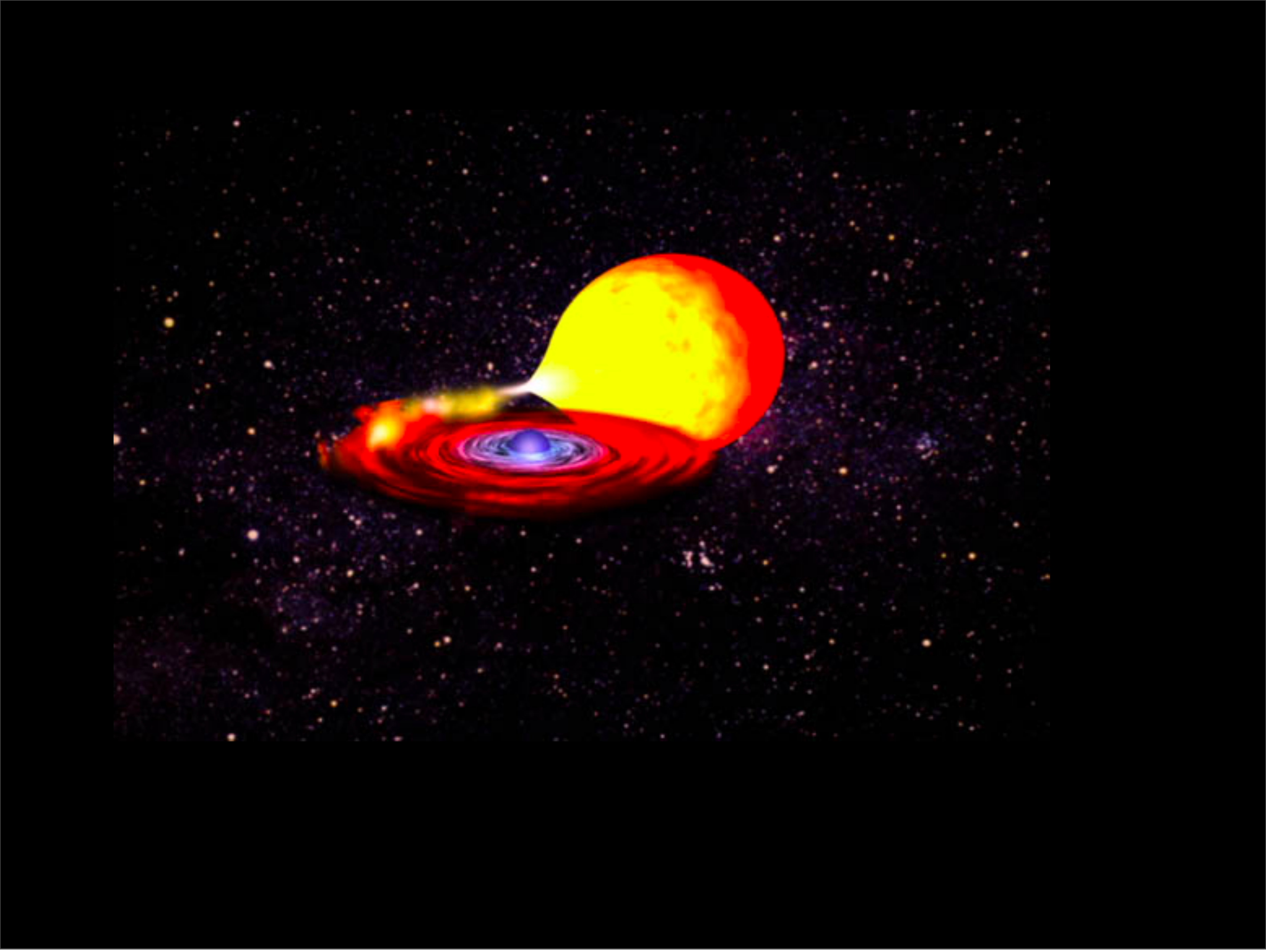
size of stars







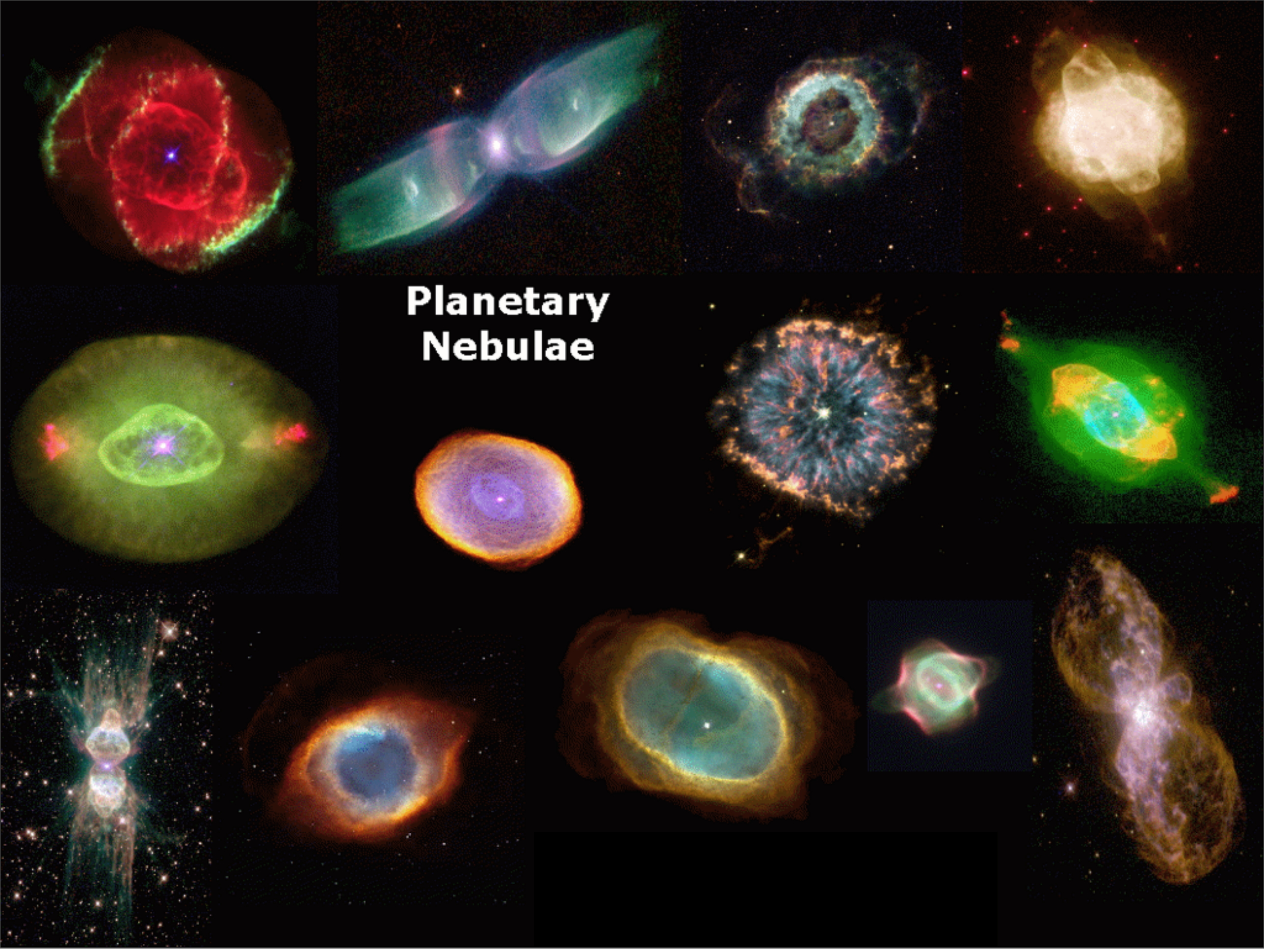
The majority of stars are actually binaries. A famous one is Algol. It is eclipsing. One is filling its Roche lobe.



If the star fills its Roche lobe, and expanding, mass will be transferred to the companion. If the companion is compact (WD, NS or a BH), an accretion disk will form (where angular momentum is transferred out). Accretion disks are very prominent objects.

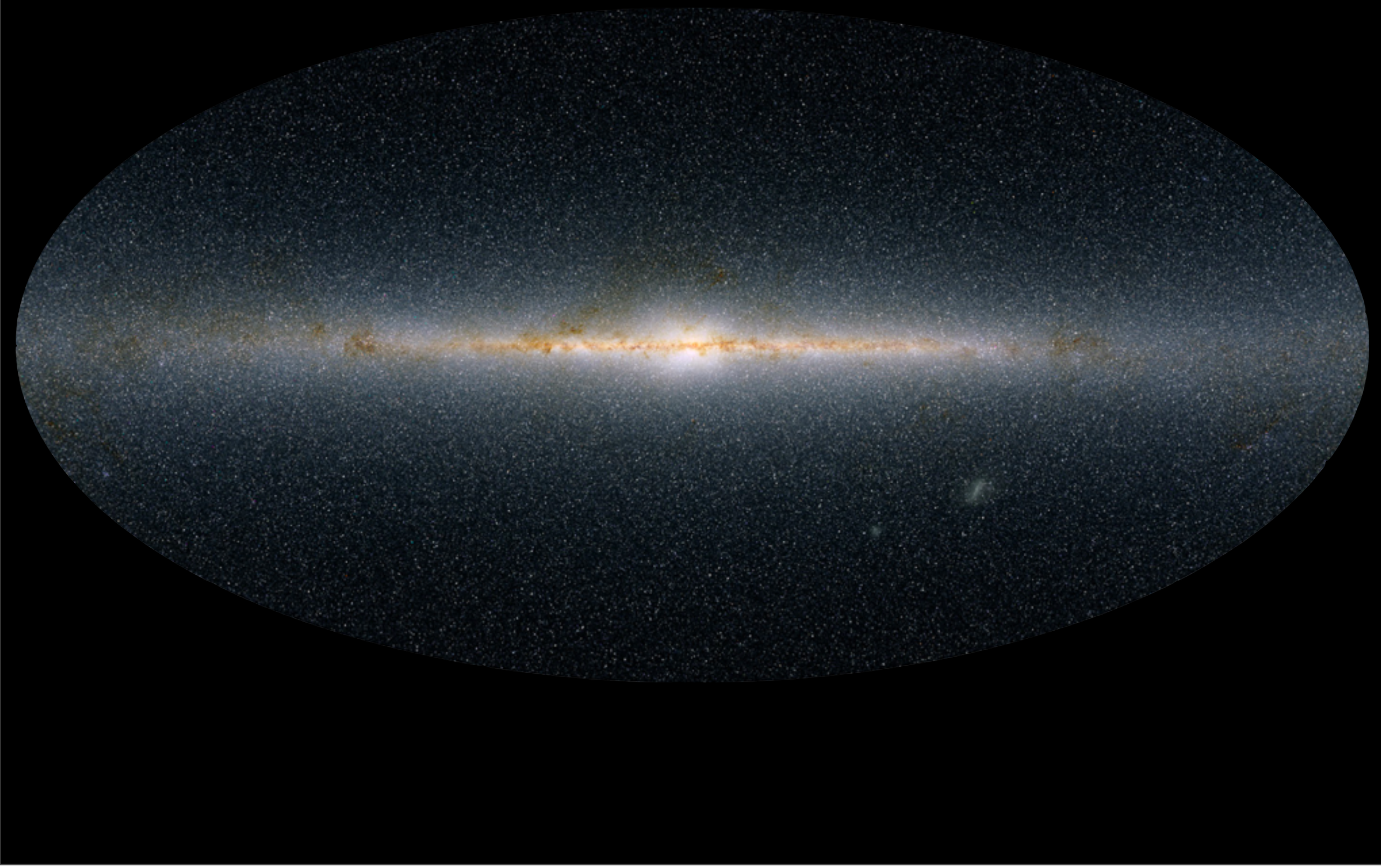
These are interstellar clouds which form new stars. (orion nebula, horsehead nebula, eagle nebula)

Stars are formed in such nebulae. They then evaporate the gas, and we are left with an open cluster, like the Pleiades (Subaru in japanese, Kima in hebrew). The cluster on the right is a globular cluster. These clusters include up to about a million stars. They are very old and they formed together with the galaxy (or even earlier).

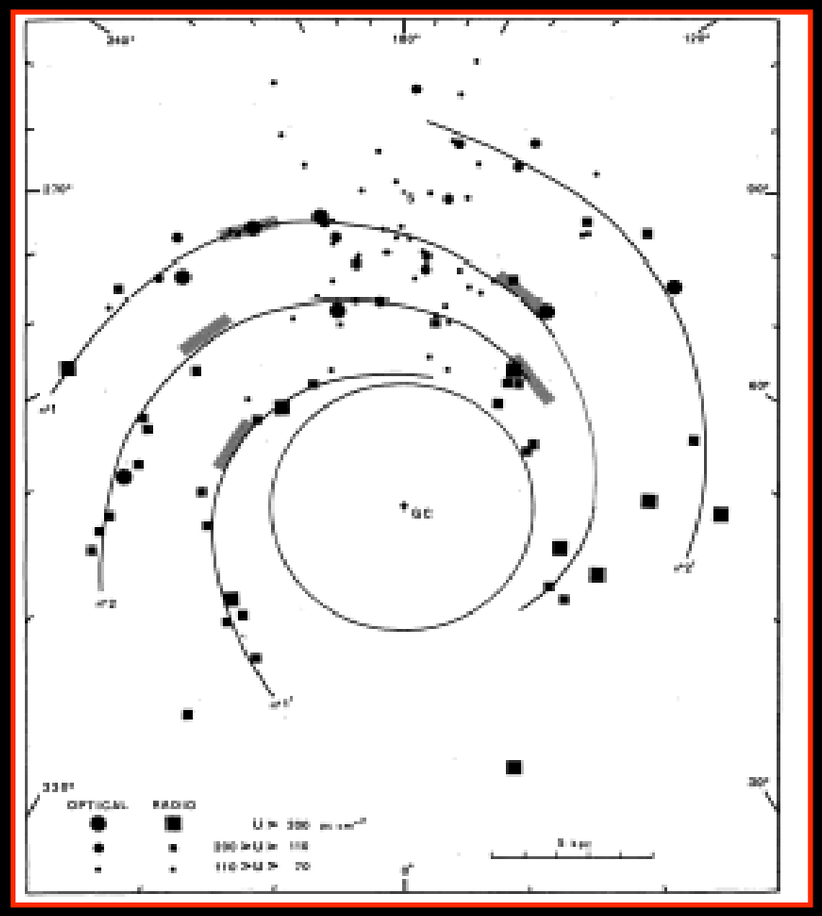


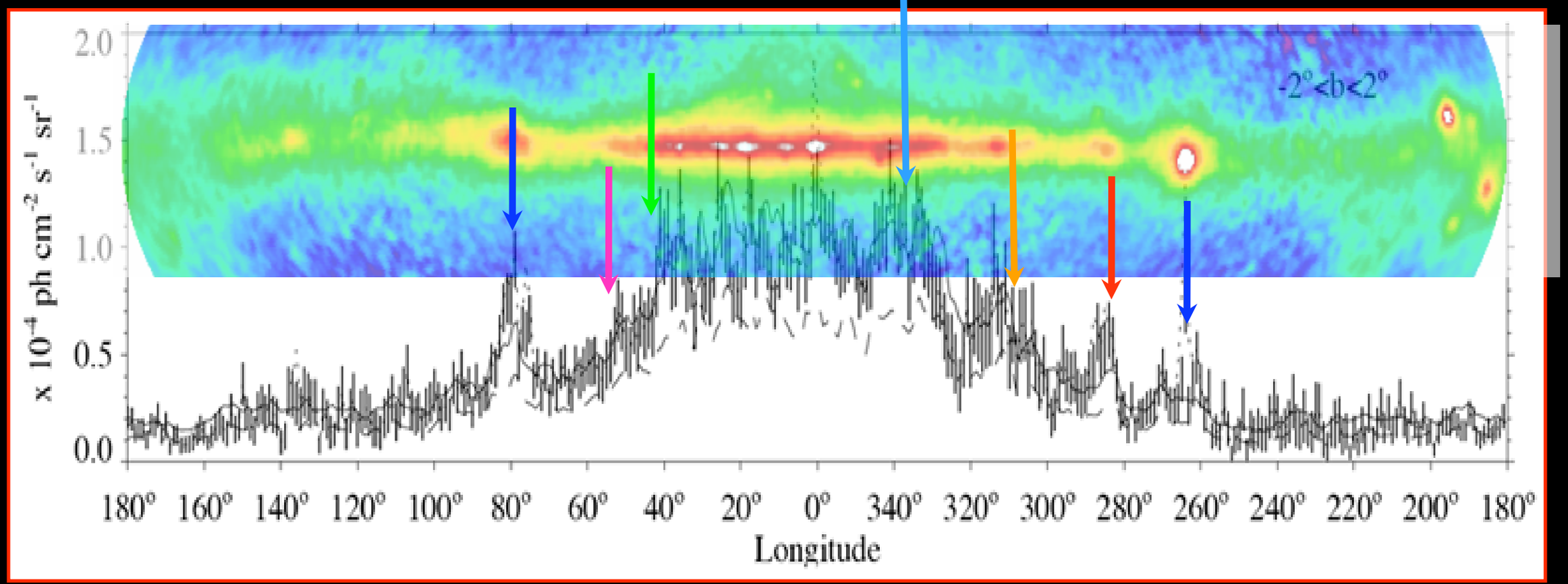
Planetary nebulae are the envelope of low mass stars (shedding the envelope and leaving a WD)

The milky way is our galaxy. It includes 10^11 stars. We are in the disk and therefore cannot see the structure properly.



In the infrared, we can penetrate deeper, but still , hard to see. We do see that there are many stars concentrated towards the disk, that we are not at the center of the galaxy (more on one side) and that there is also a lot of dusty gas in the disk (seen here as brown silhouettes)





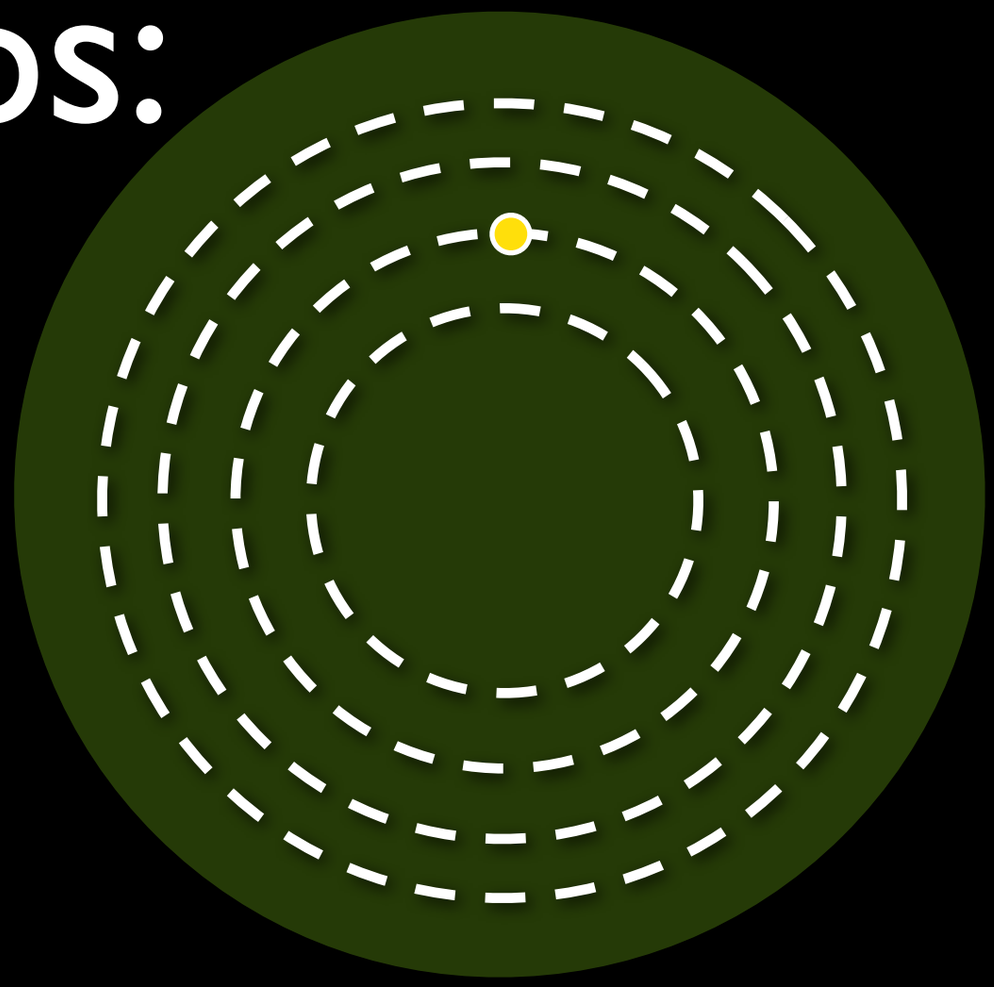
If we look at gamma rays, we can see cusps in certain directions which originate from spiral arms.

v-l maps:

- v-l maps translate (longitude, doppler)

  ↓

  (longitude, distance)



We can map the arms using the fact that different radii are circling the galaxy at a different speed. Therefore, the doppler shift of an element can tell us where this element resides. This is similar to Synthetic Aperture Radar.

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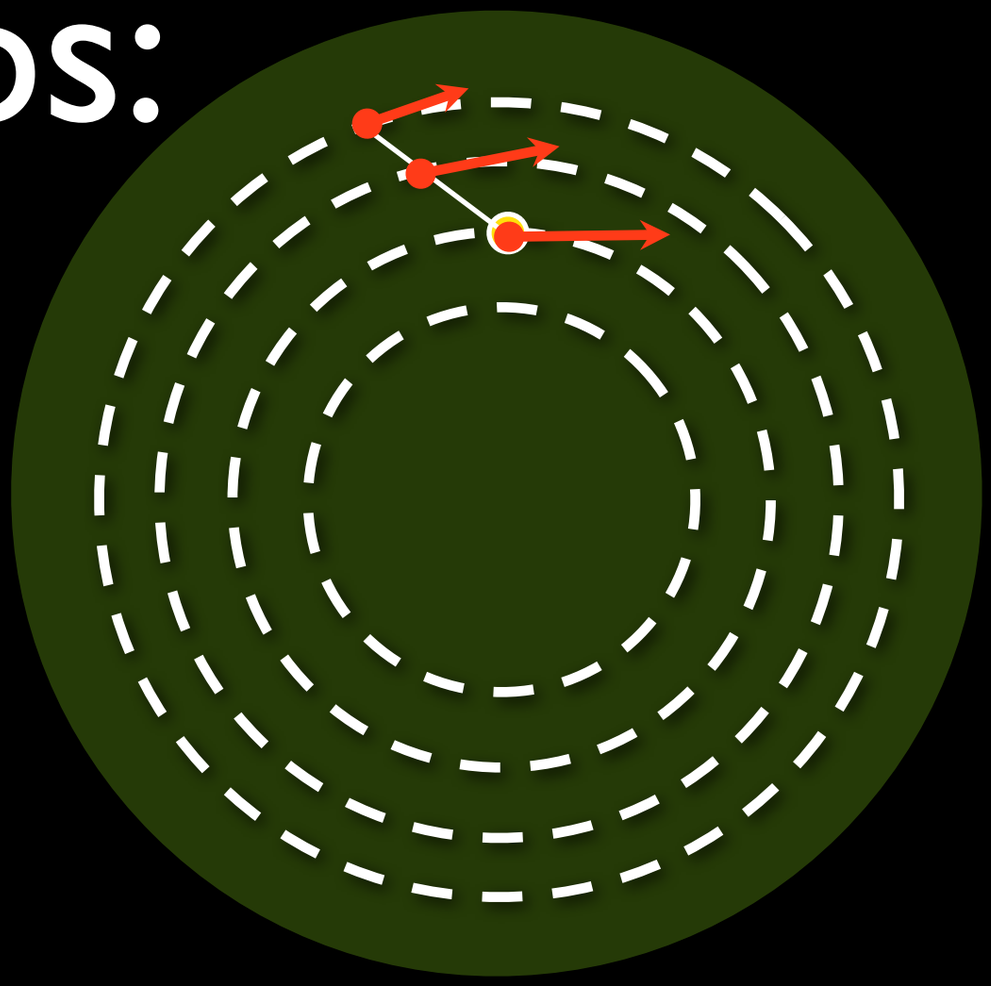
  ↓

  (longitude, distance)



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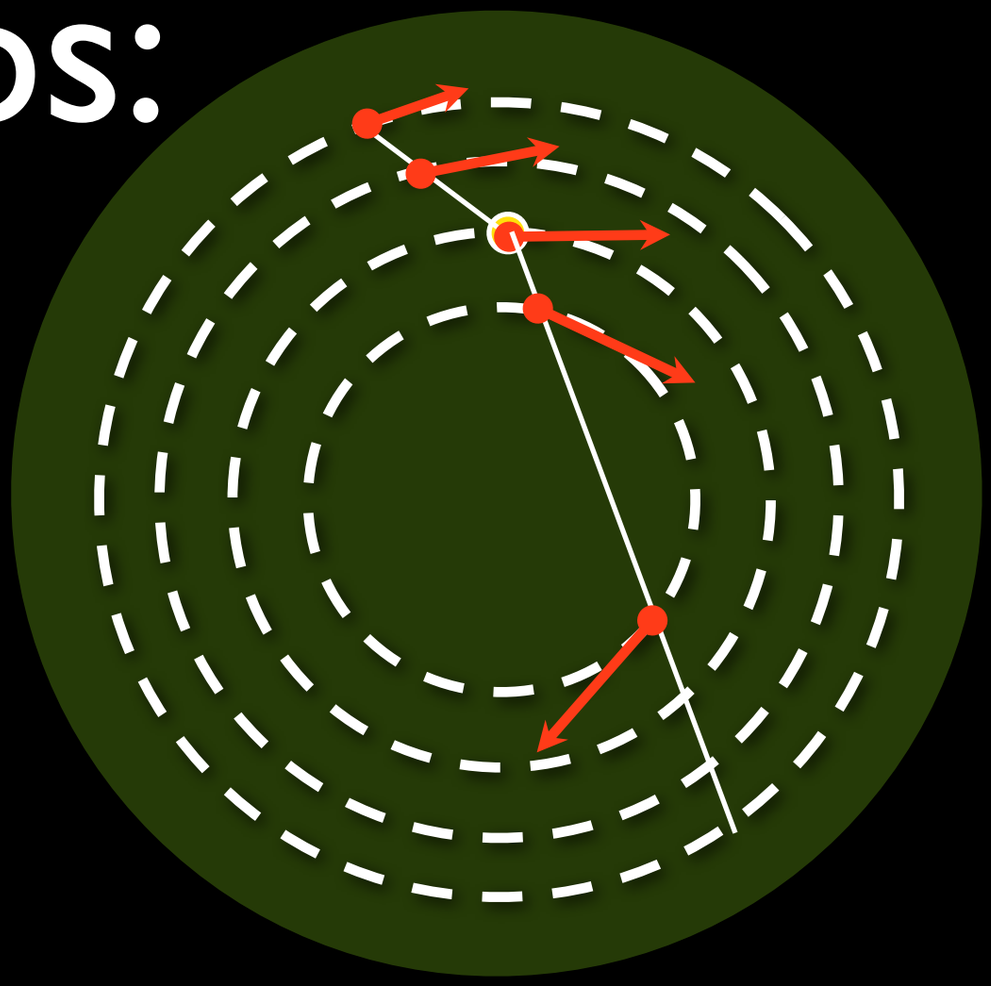

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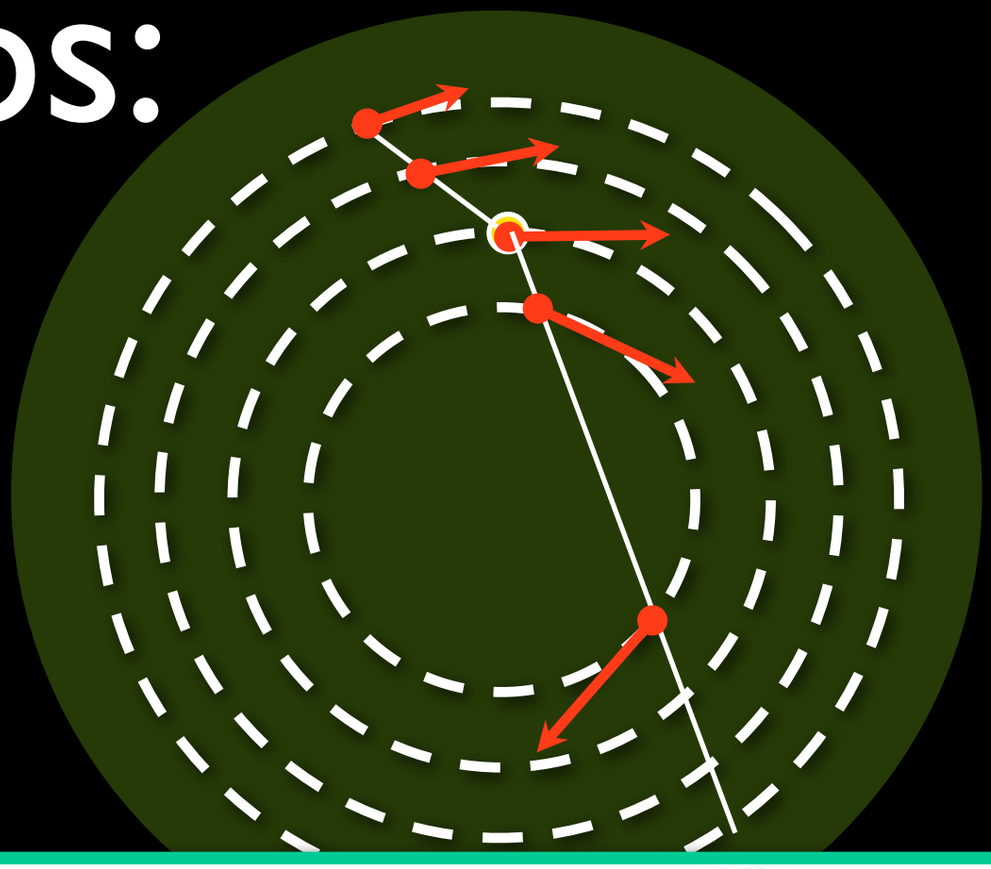
v-l maps:



- v-l maps translate (longitude, doppler)

  ↓

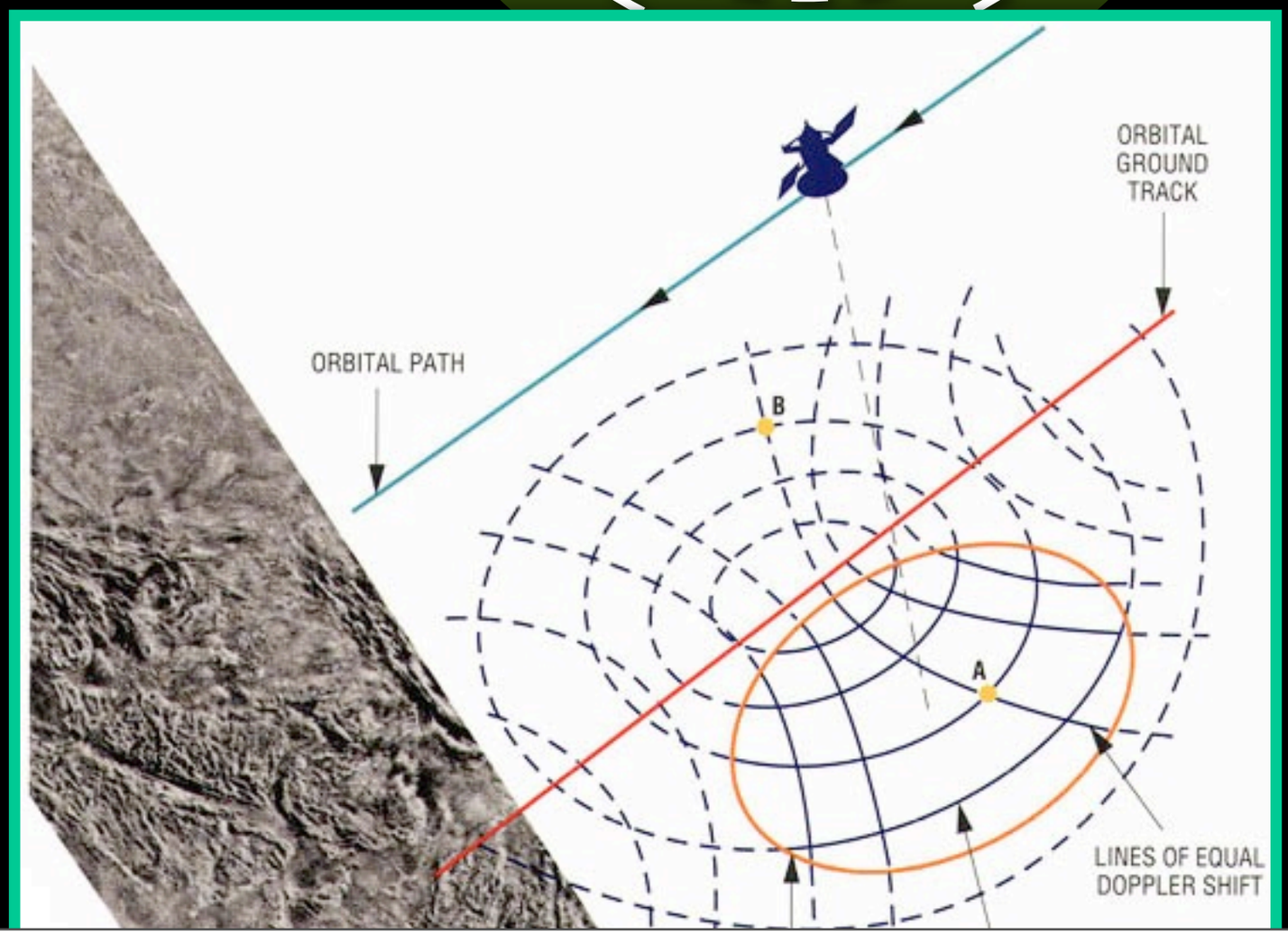
  (longitude, distance)

- Similar to SAR (Synthetic Aperture Radar)

  (distance, doppler)

  ↓

  (longitude, distance)



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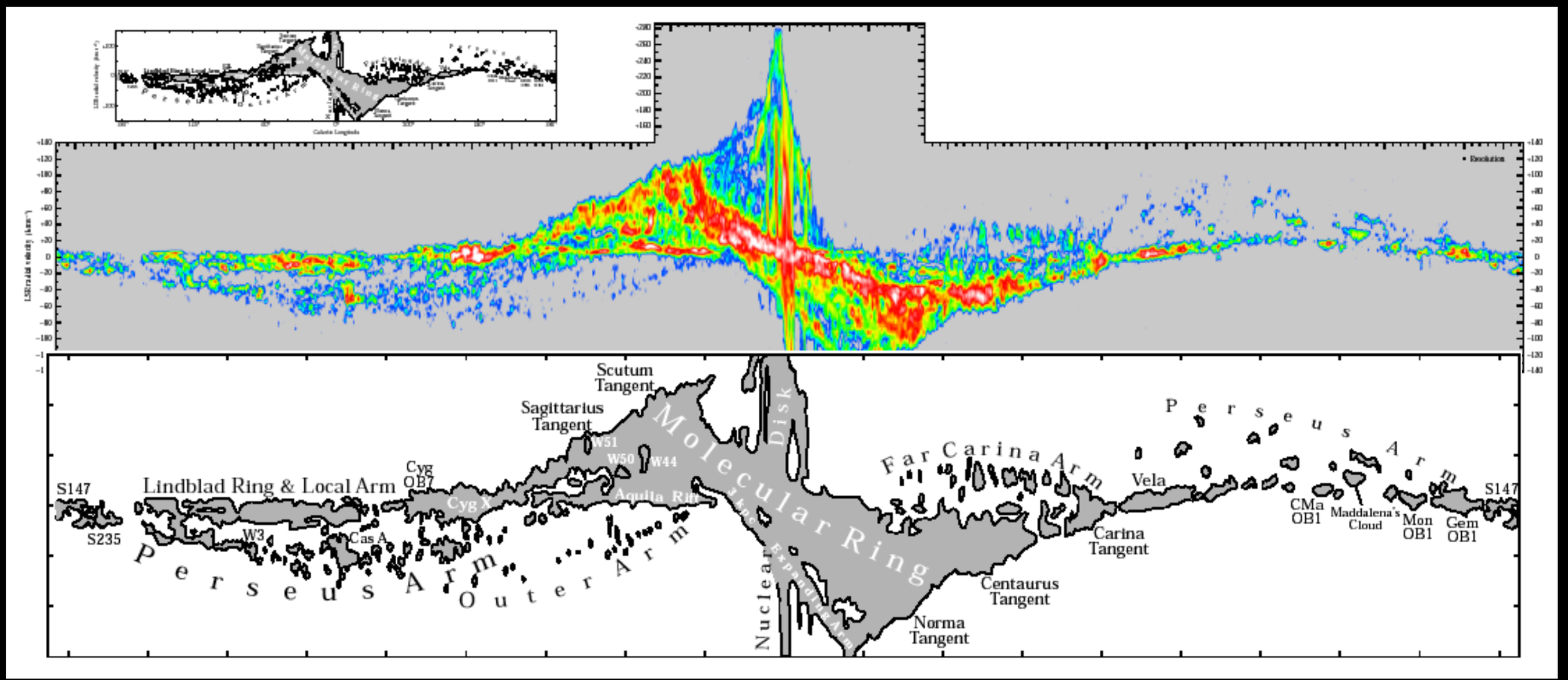
The Real Milky Way

- Arms cannot be seen directly (we're in the plane!)
- 4 spiral arms Extend out to $r \sim 2\ R_{sun}$

Dame et al., 2000



Velocity - Longiture maps reveal the spiral structure of the milky way

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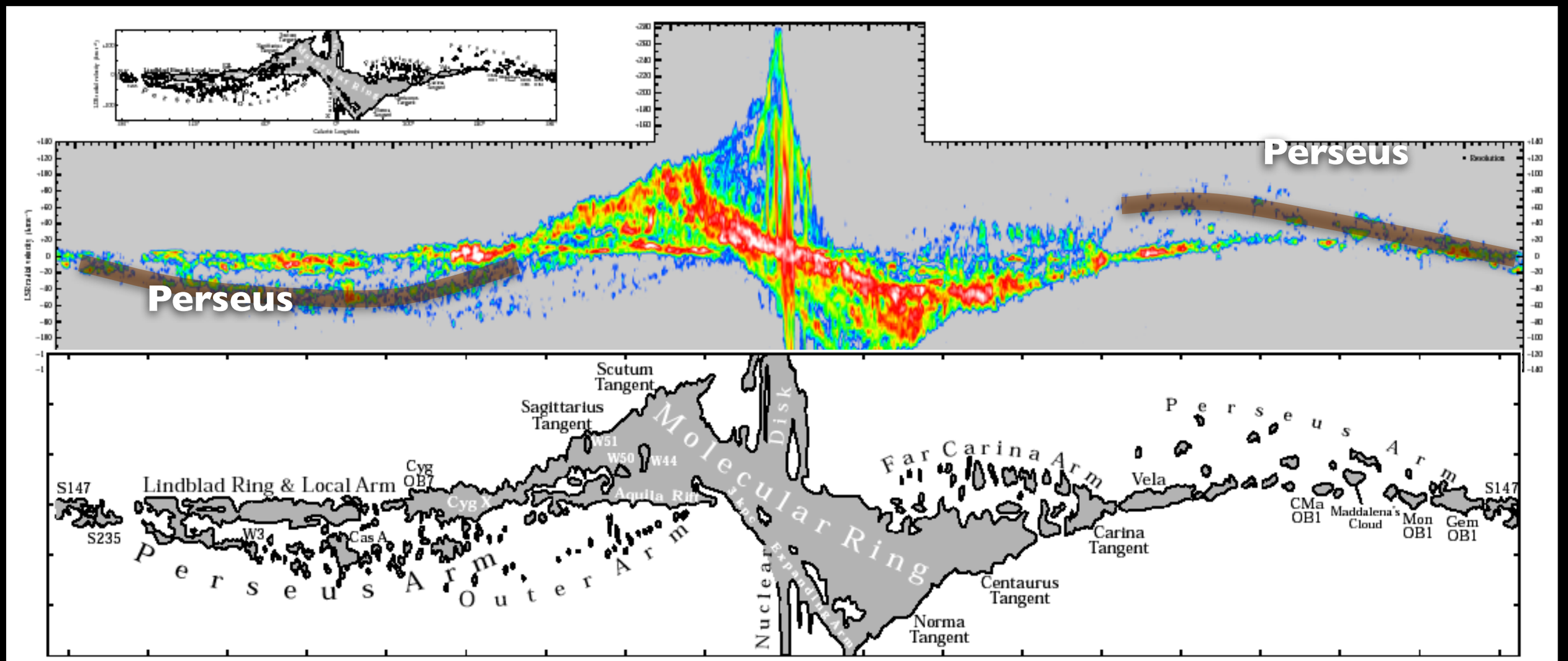

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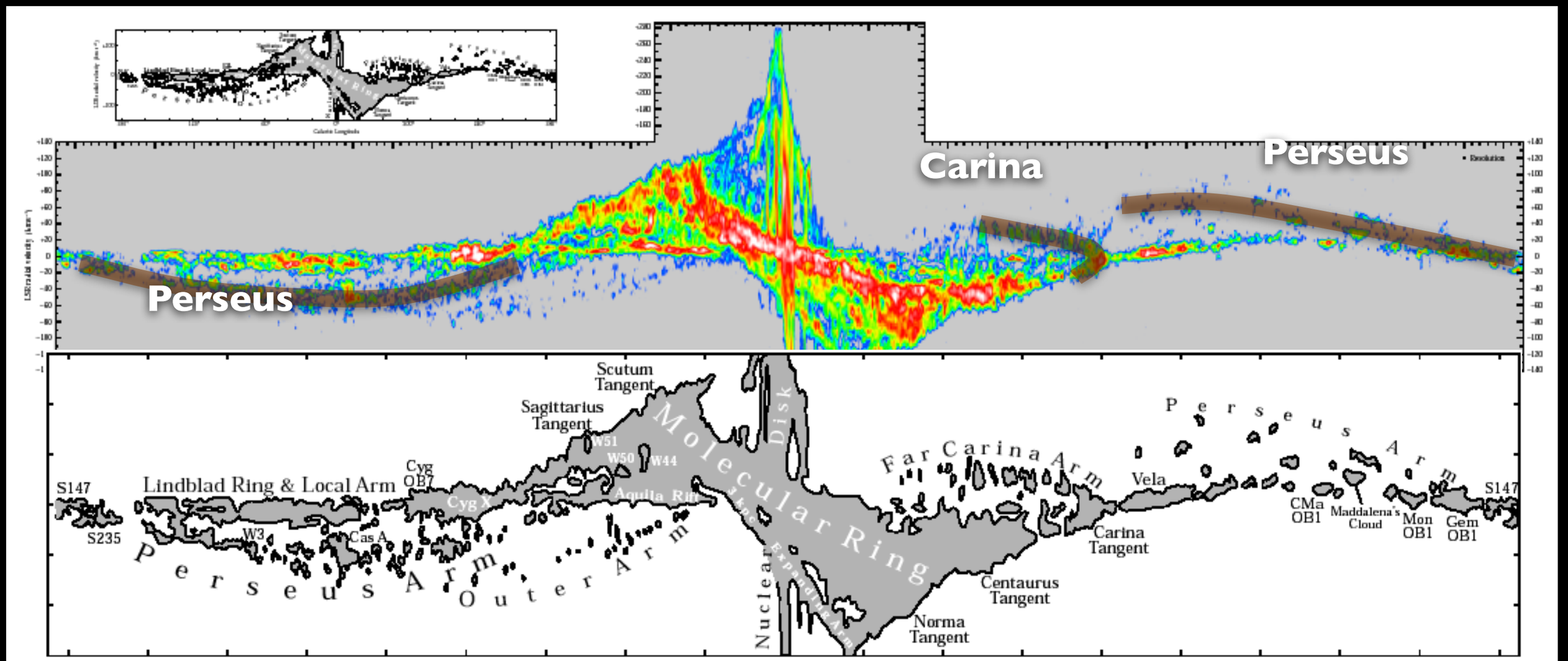

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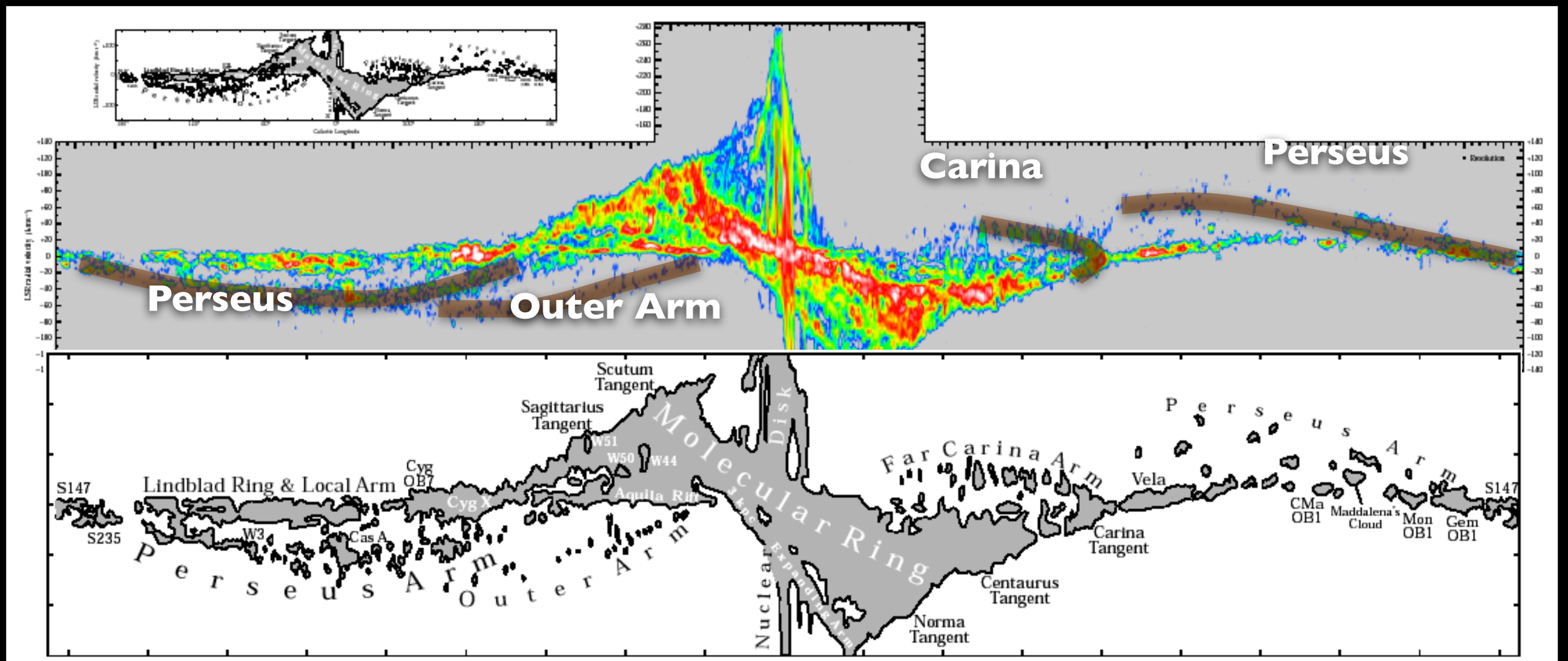

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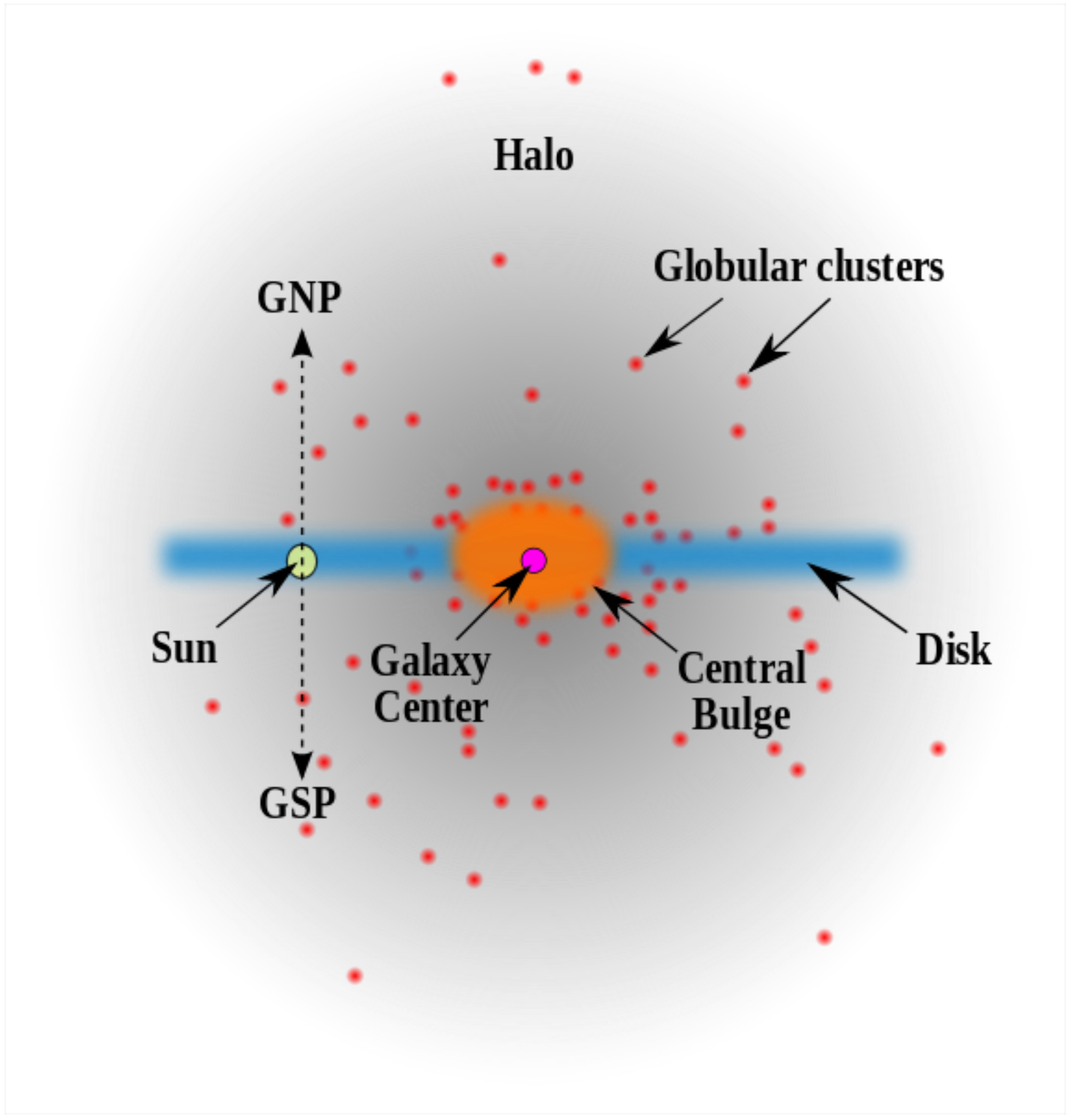
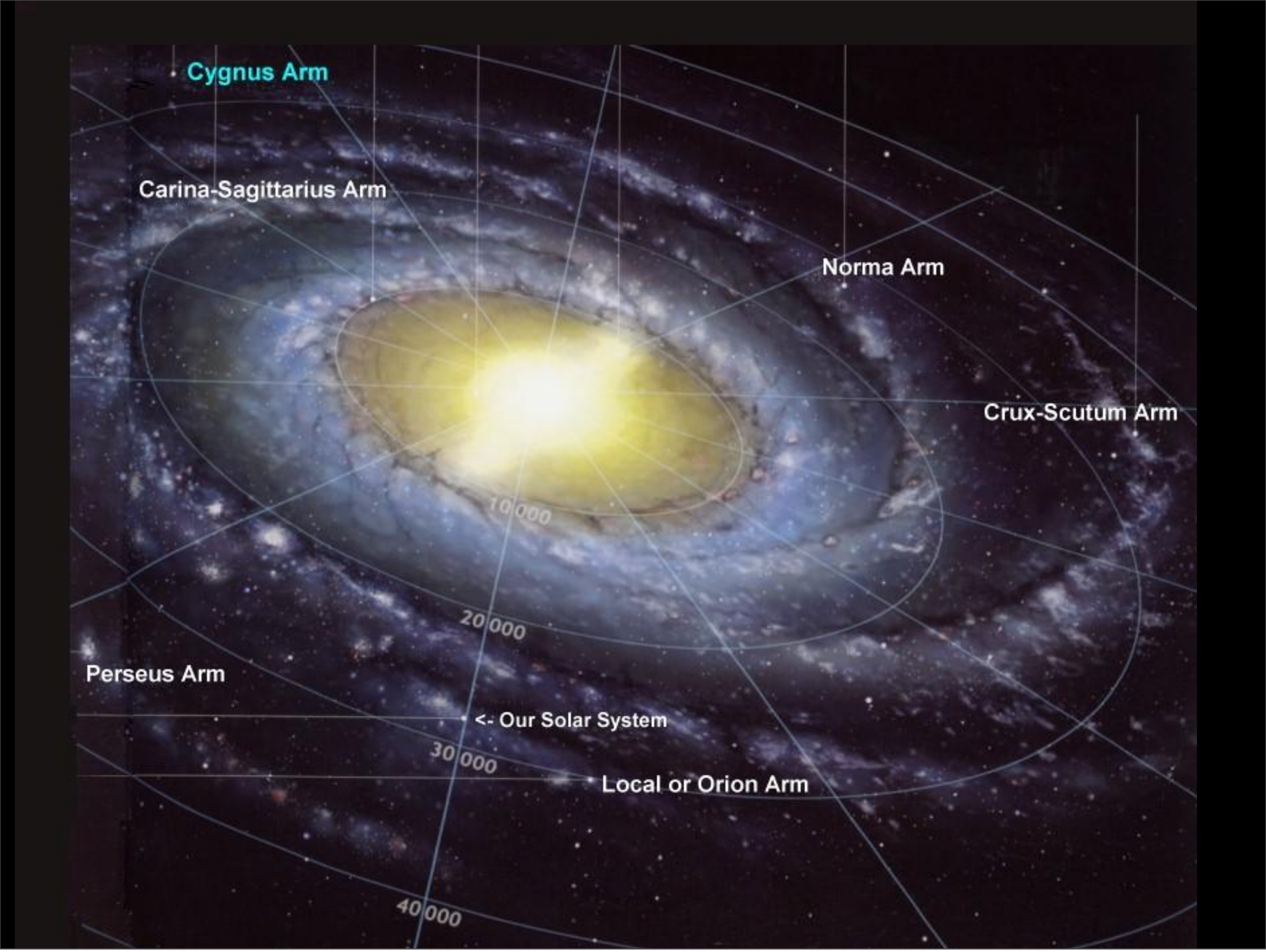
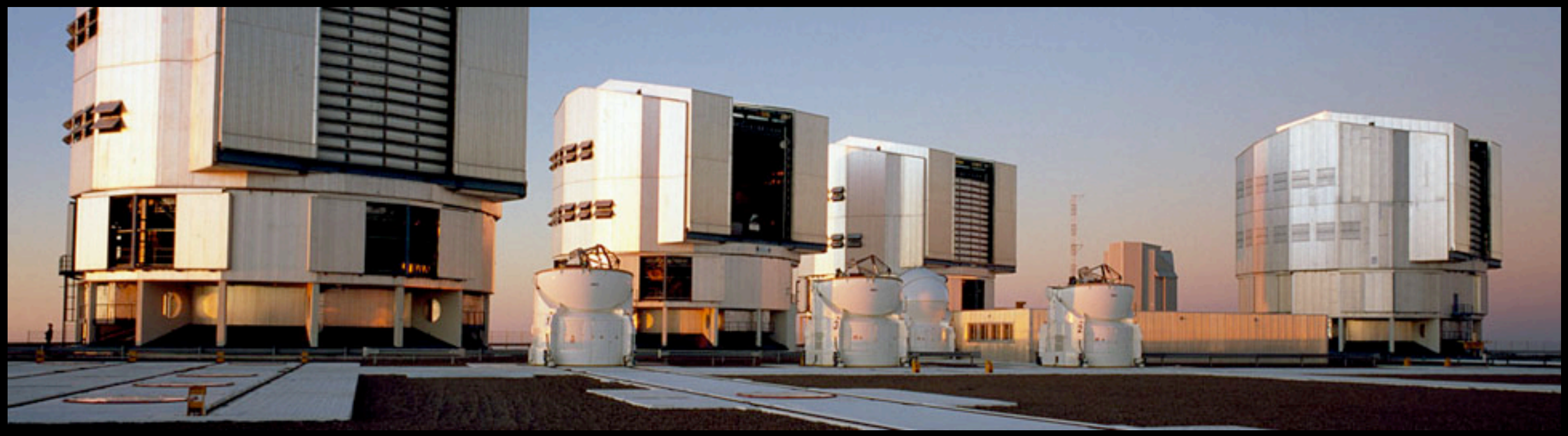


The overall structure of the Milky Way

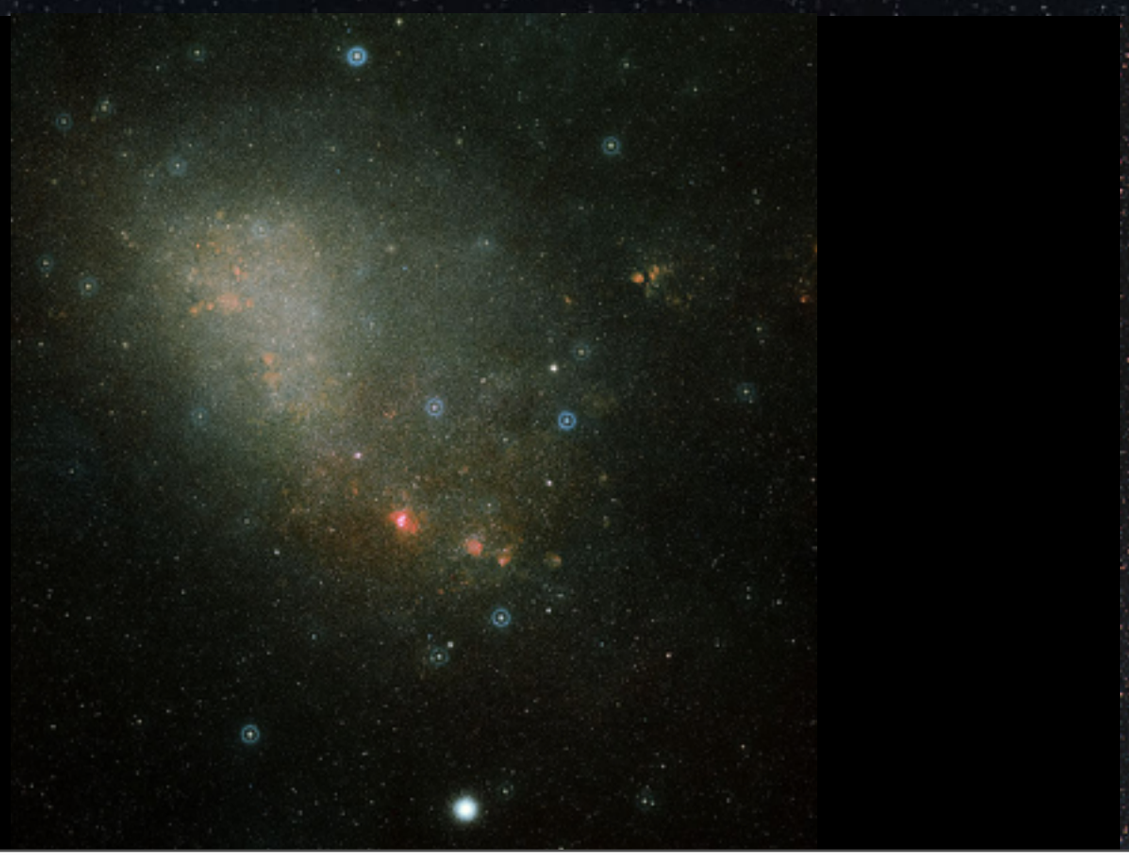


And an artist conception

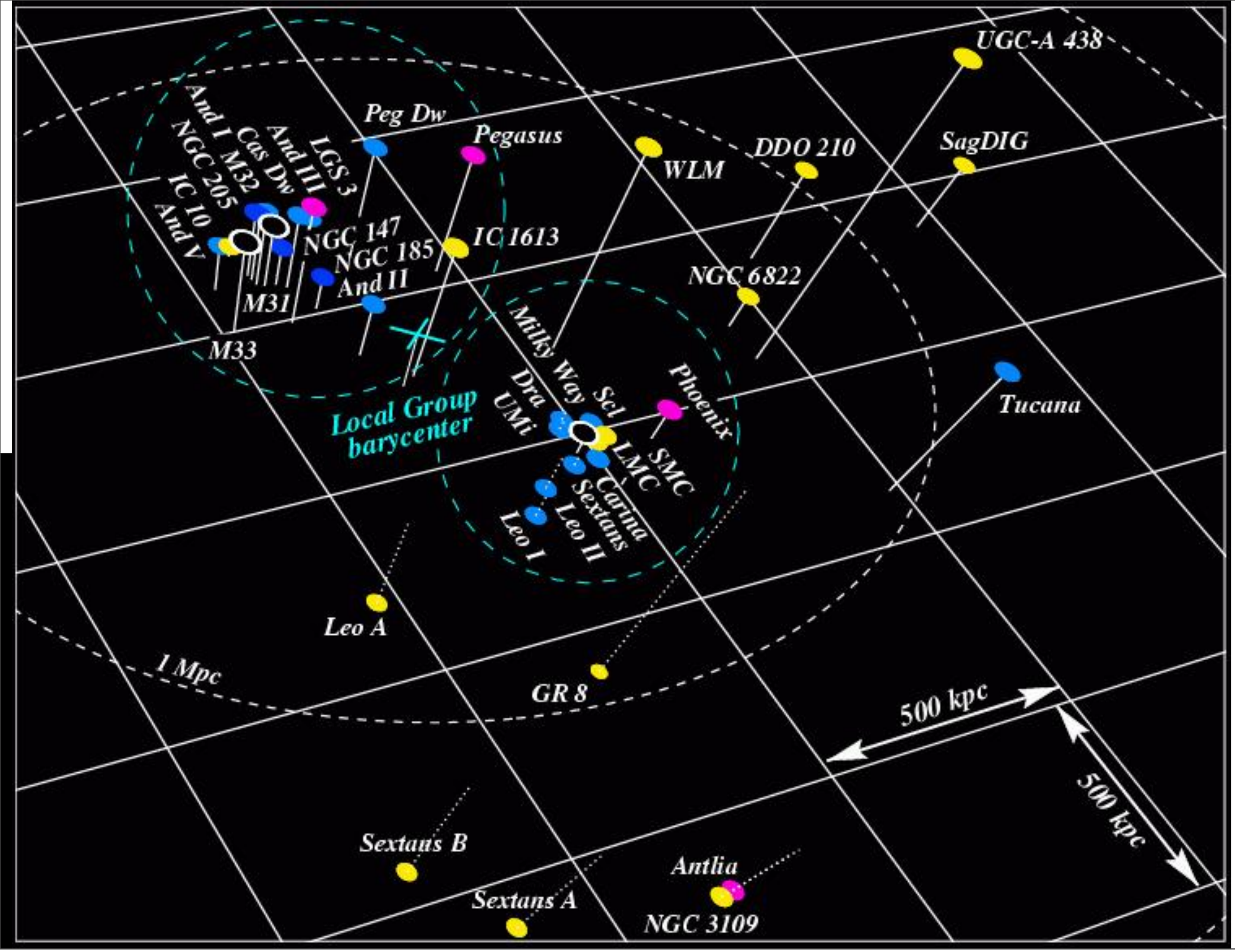


The Black Hole at the Center of the Milky Way

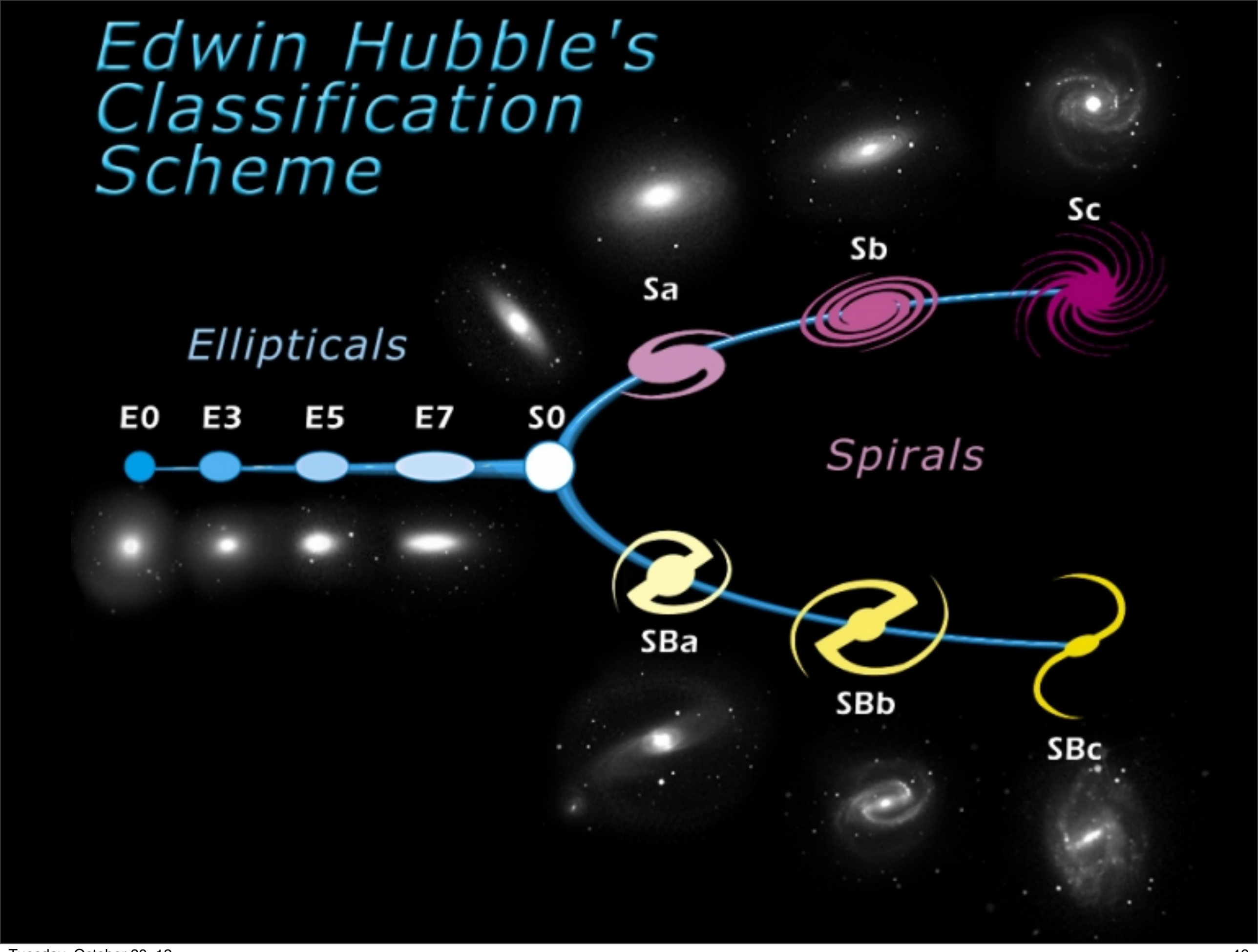
The galaxy has a black hole at the center.



The most prominent galaxies in the local group (andromeda, m33, small and large Magellanic clouds)



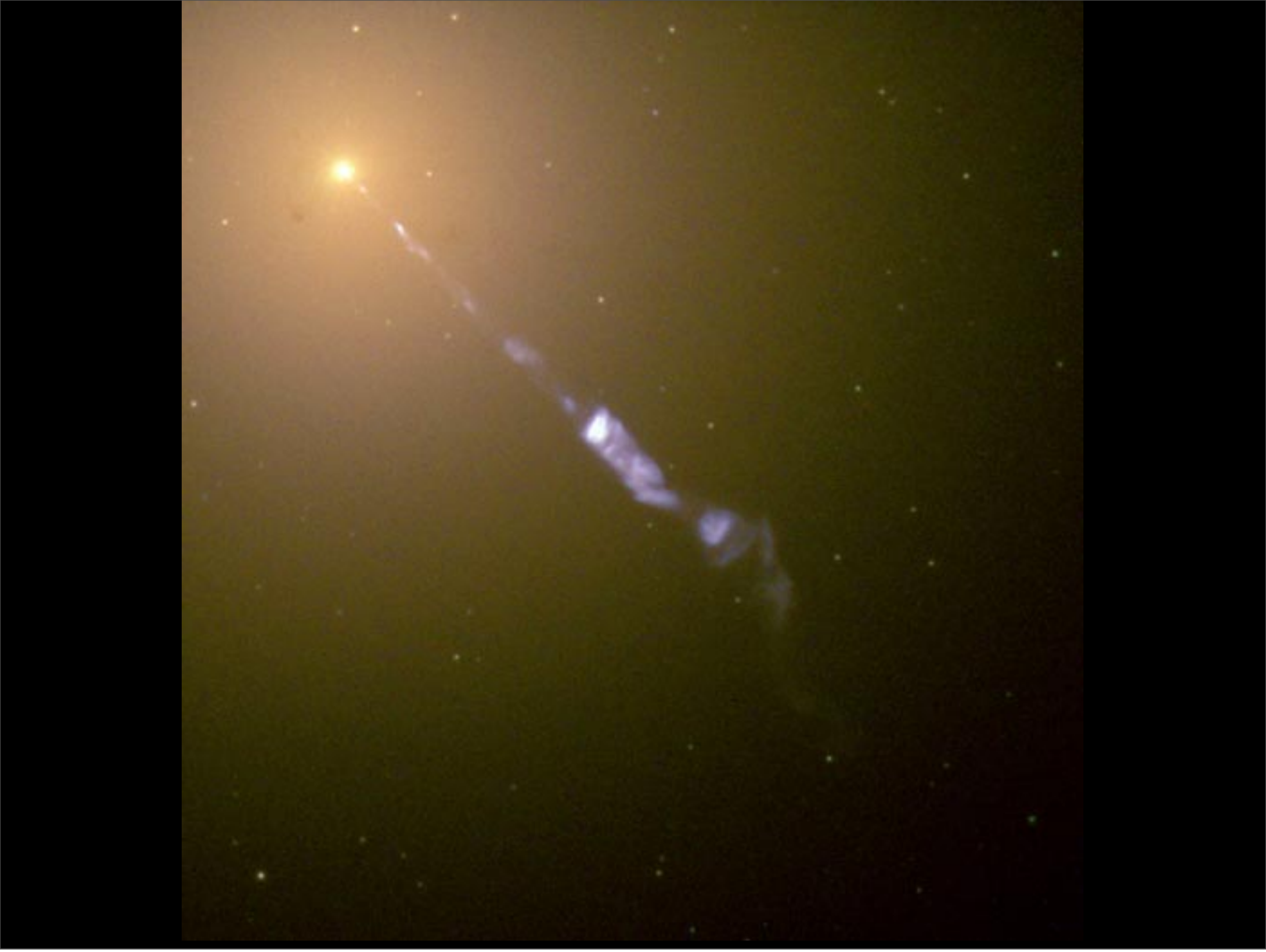
This is our galactic neighborhood.



Large galaxies (today!) come in various standard shapes, from elliptical to spiral armed (with or without a bar). Smaller galaxies are often irregular (as are many larger galaxies in the past)

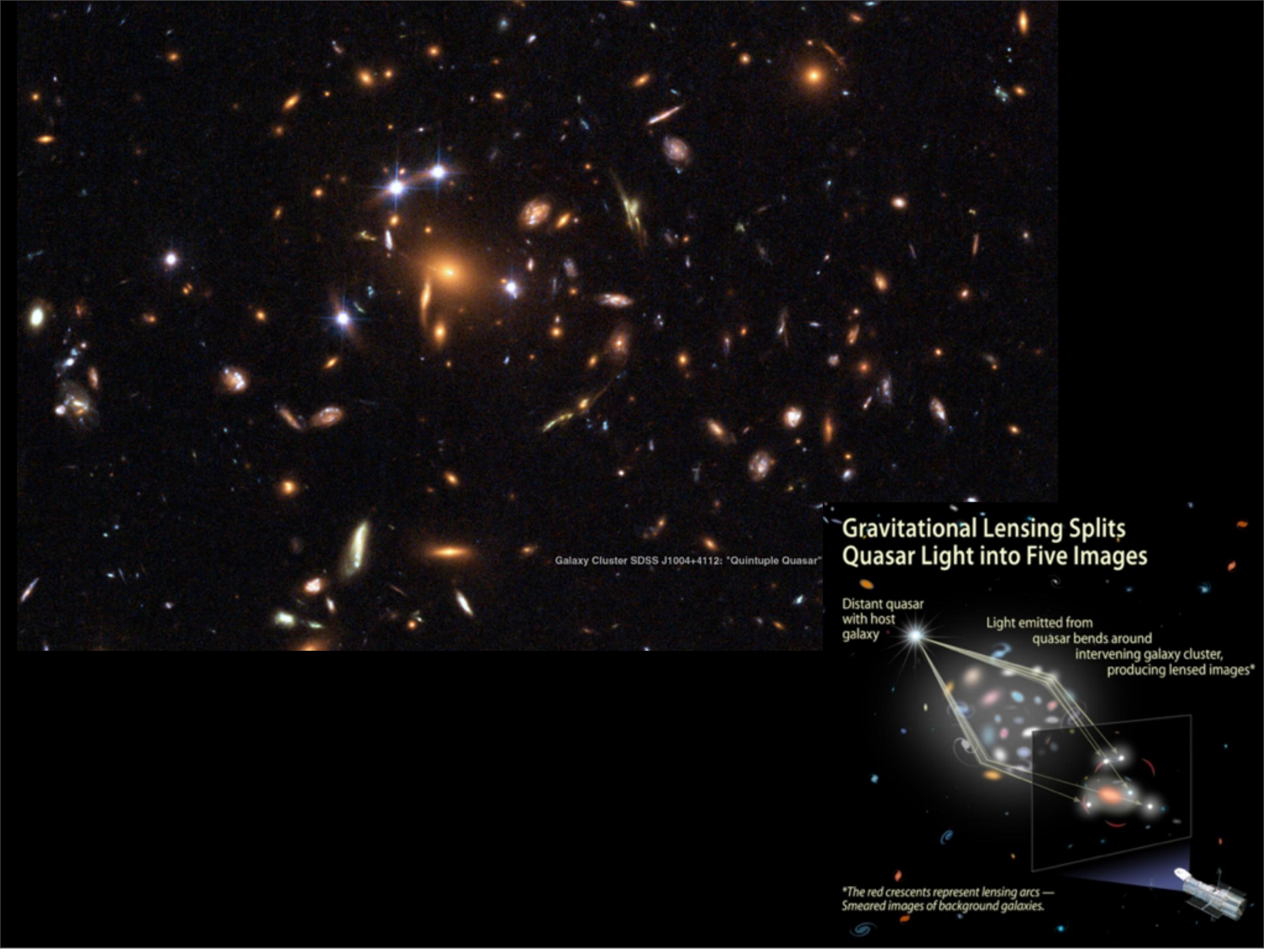
colliding galaxies are irregular and don’t fall on the previous scheme (because they haven’t reached a steady state)

Galaxies also come in groups or clusters (which are in dynamic equilibrium). Large clusters have a cD (giant elliptical) galaxy in the middle (e.g., M87 in Virgo has a mass 10^14 Msun, compared with 10^12 of the Milky Way).

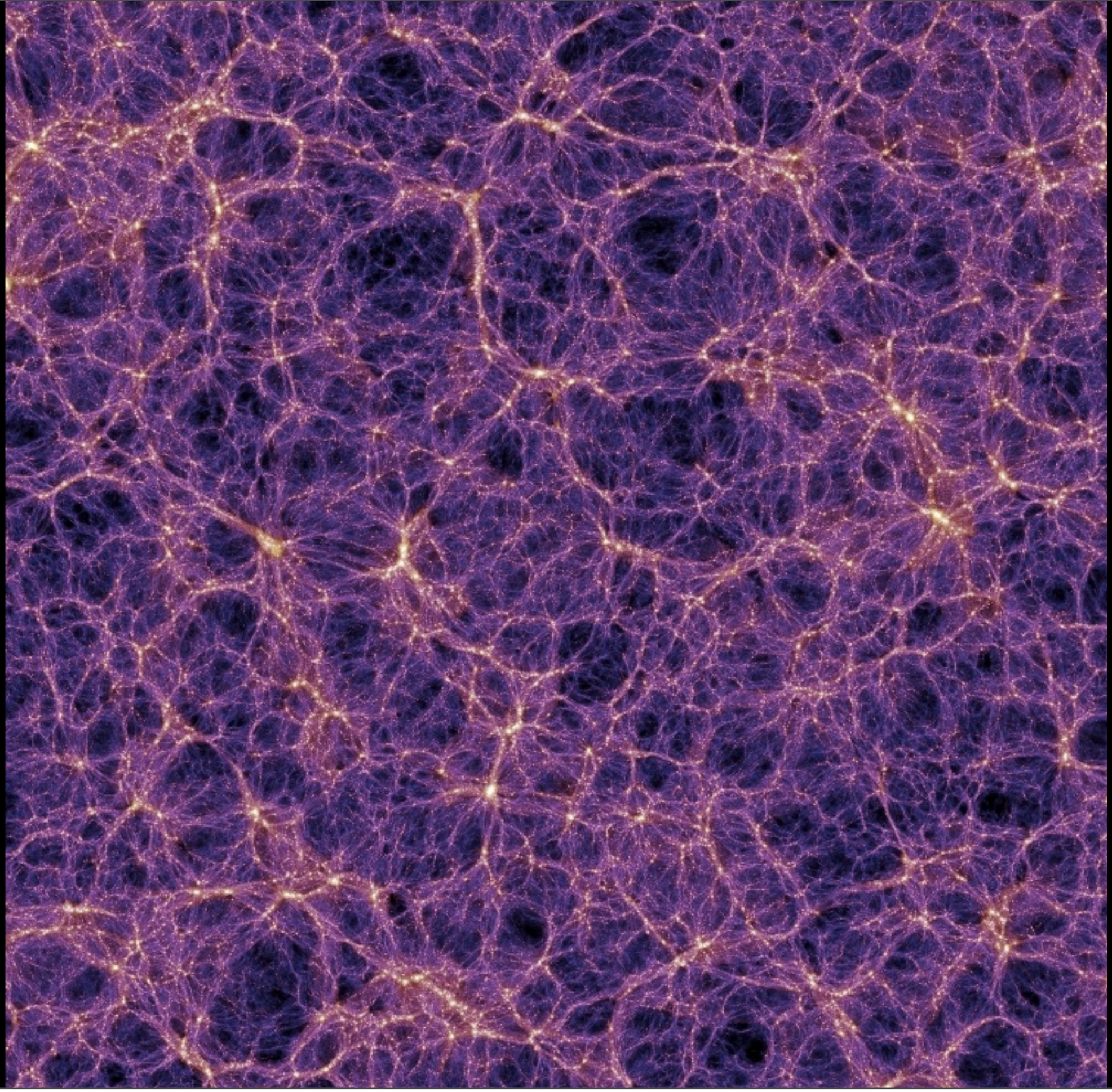


It has a giant black hole (~ 10^9 Msun) and it accelerate huge relativistic jets (because of relativistic effects, only the jet pointing towards us can be seen).

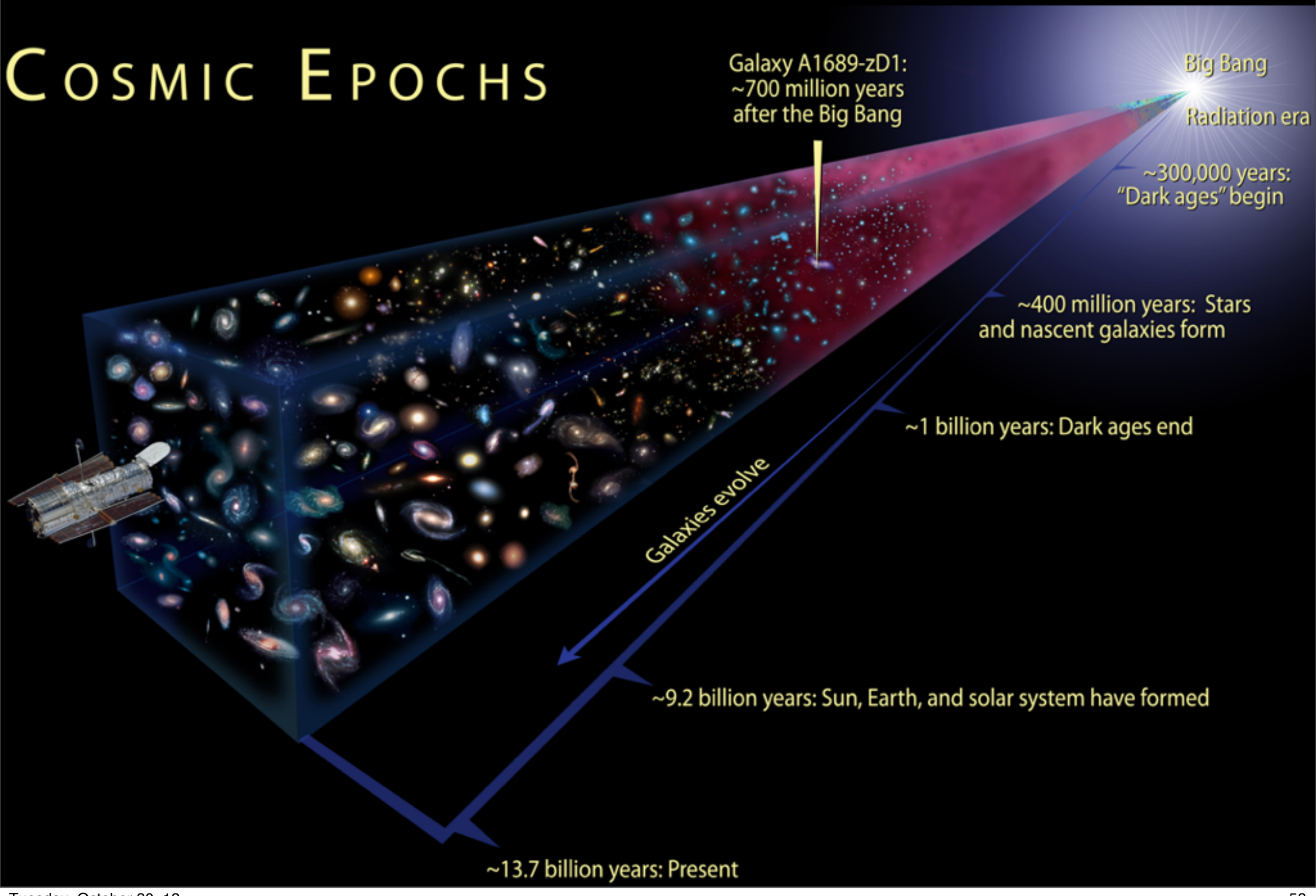
Artist conception... black hole accretes gas and stars (or just stars) from its vicinity. Active BHs appear as quasars



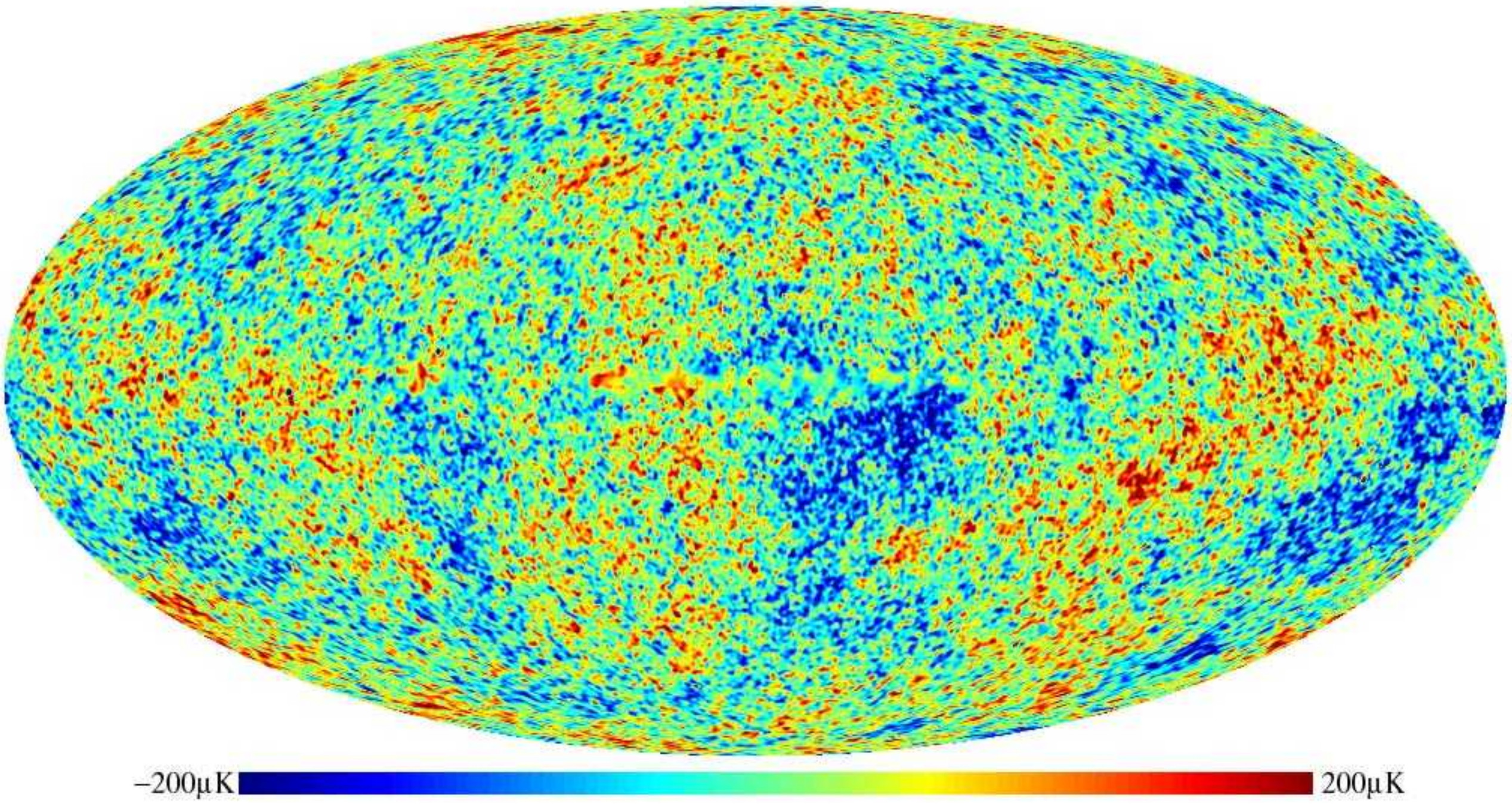
Large clusters can gravitationally deflect light and form gravitational lenses.



The gas collapsed to form a “cosmic web”. Filaments with clusters along them, and giant clusters on the Filament nodes.



On very large scales, we are also looking at the past.
There was a period between 300,000 years and 1 billion years when the universe was dark (until the first stars and galaxies formed). Before 300,000 years, the universe was dense enough and hot enough to have have been ionized and therefore optically thick.



When the universe was 300,000 years old (redshift of about 1200), the universe became transparent, and we can see the photons emitted at that time, as the cosmic microwave background radiation.

The Beginning