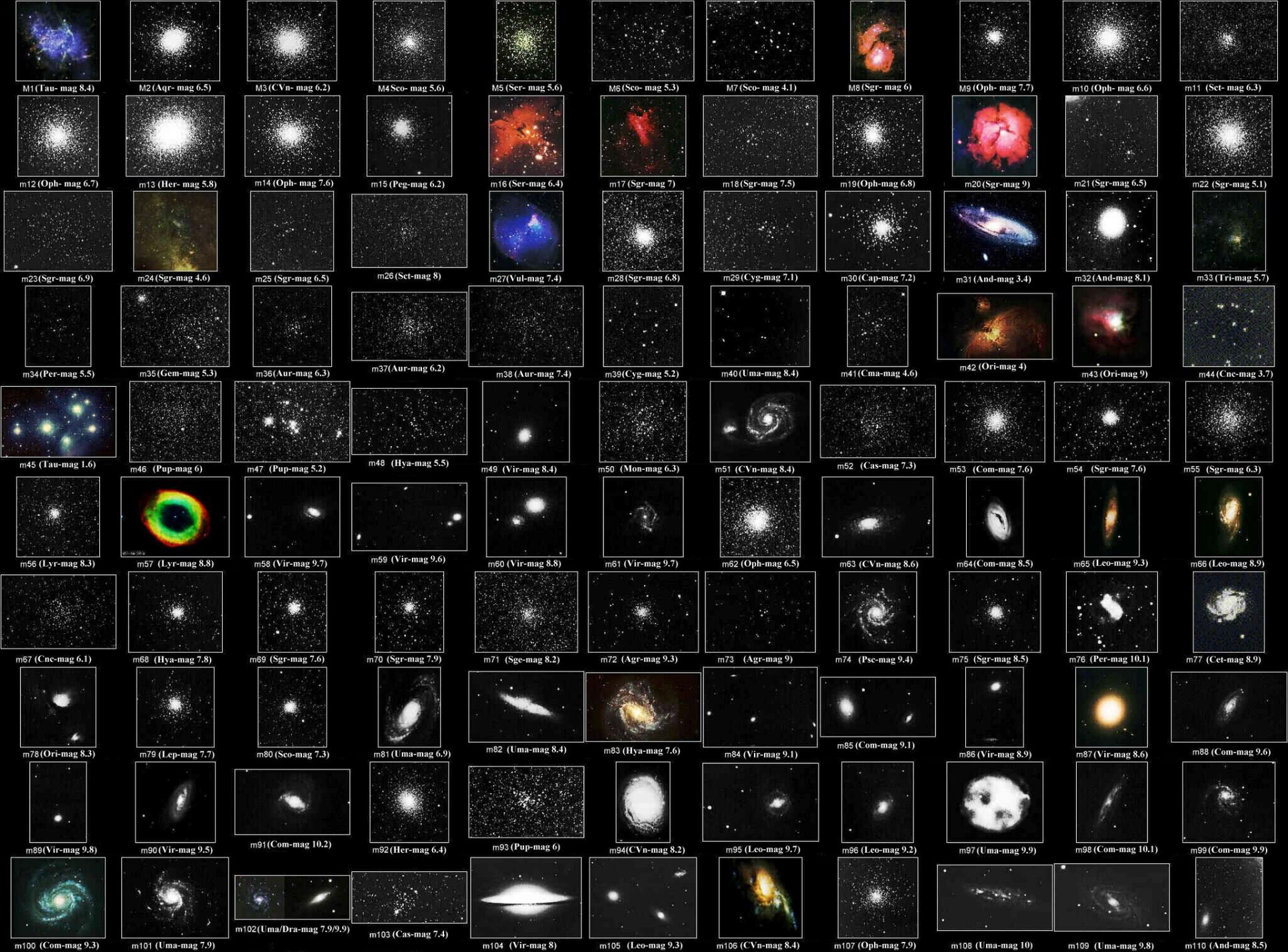


Our Home, The Milky Way



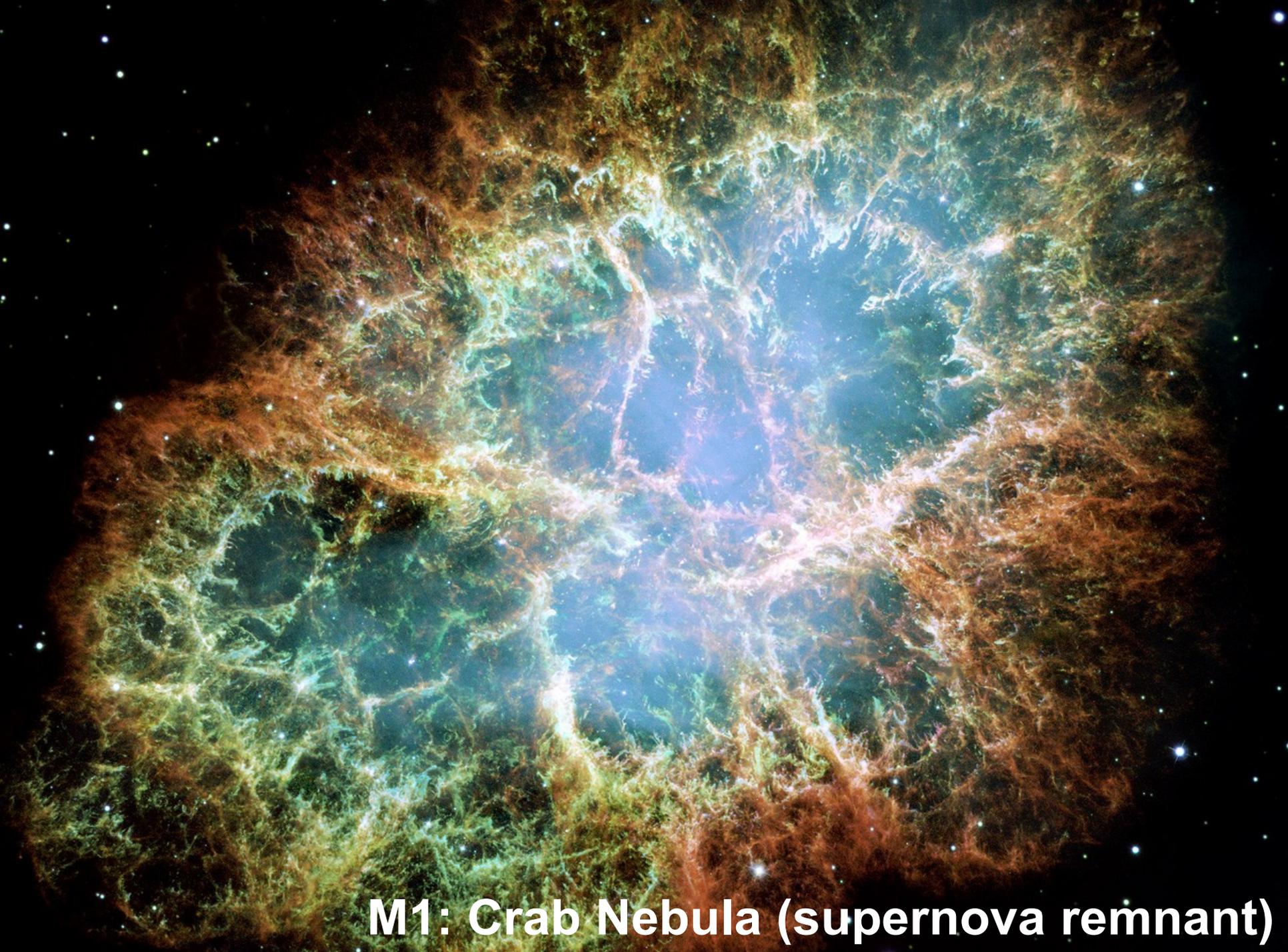
Charles Messier (1730-1817)

- He was a comet hunter, so he needed to know all non-stellar objects on the sky that were ***not*** comets.
- From 1774 to 1781, he published a list of such objects.
- We still label objects from his catalog as M1, M2, ..., M110.
- Messier catalog is a mixed-bag collection. It includes stellar clusters, gaseous nebulae, and external galaxies.





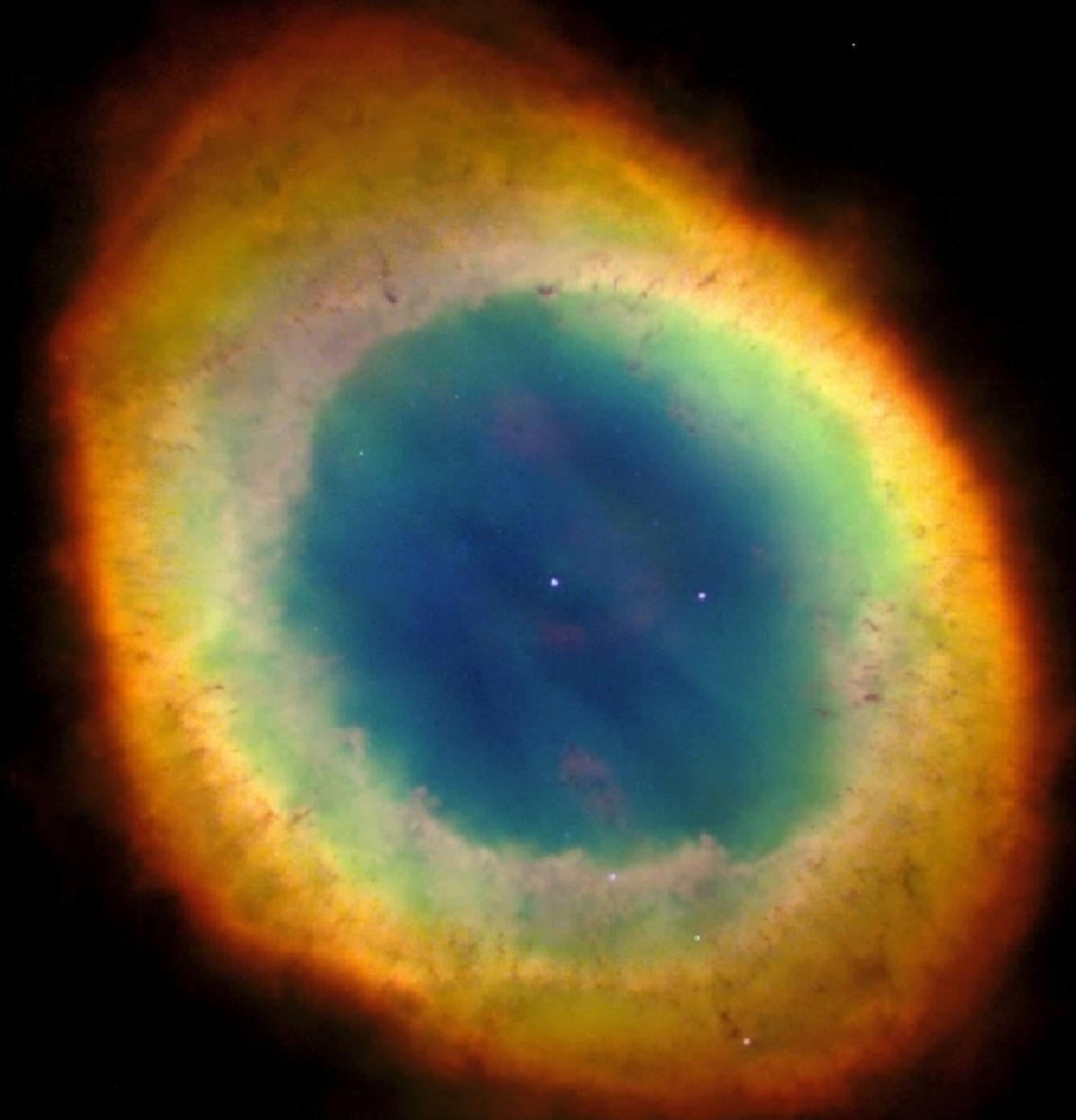
M13: Globular cluster (cluster of stars)



M1: Crab Nebula (supernova remnant)



M42: Orion Nebula (star-forming region)



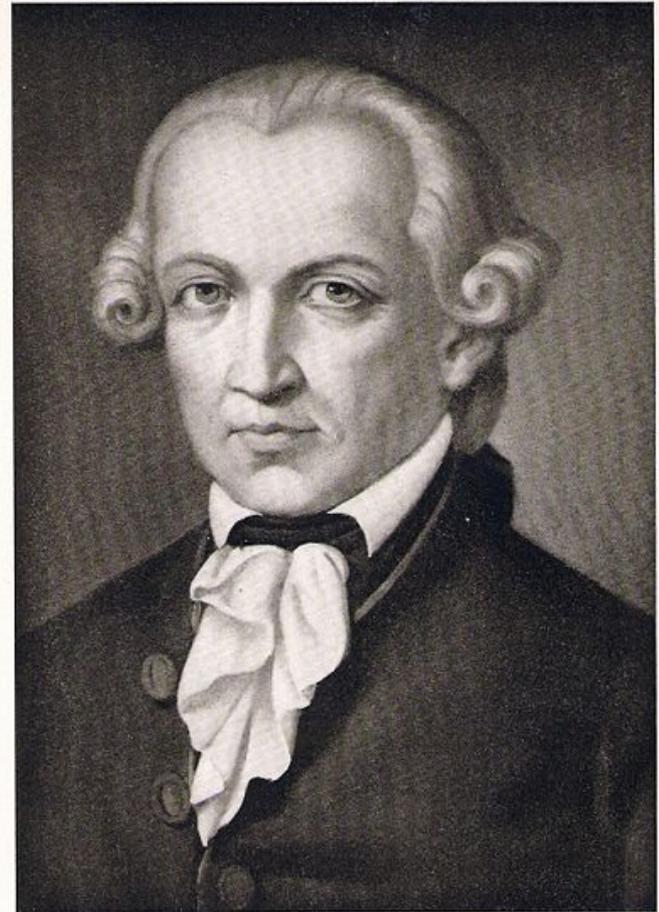
M57: Ring Nebula (planetary nebula)



M51: Whirlpool Galaxy (spiral galaxy)

Immanuel Kant (1724-1804)

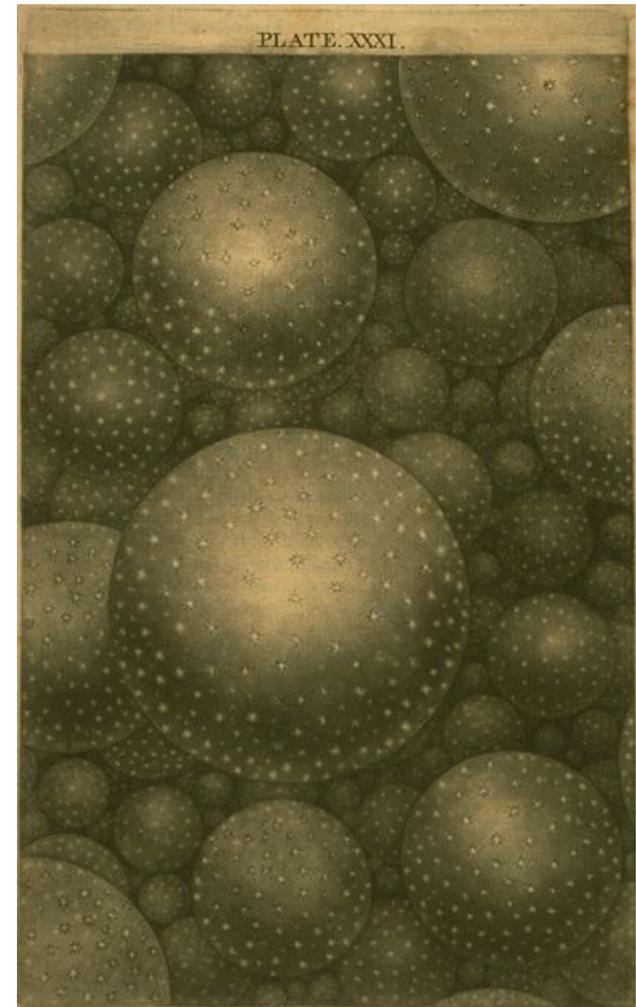
- He was first and foremost a philosopher, but he also proposed interesting astronomical ideas.
- In 1755, extending ideas of Emanuel Swedenborg, he proposed that Solar System formed from a rotating nebula (cloud) of gas and dust, which collapsed under the force of gravity, flattening on the way.



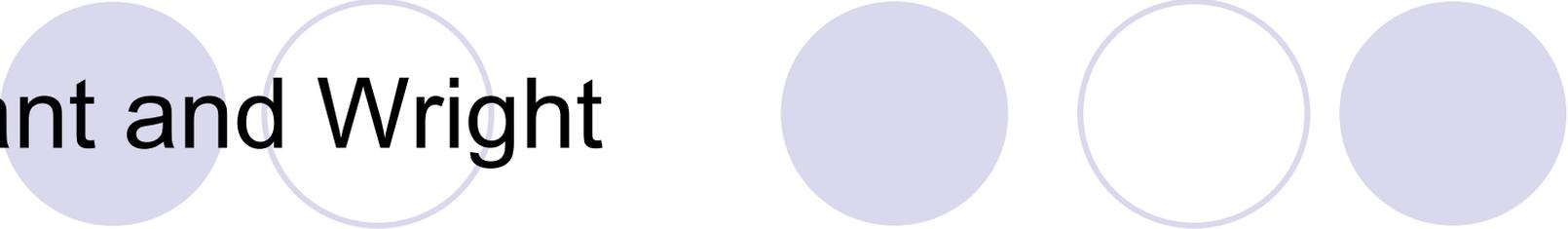
IMMANUEL KANT
From a painting

Kant and Wright

- In 1750 an English astronomer, Thomas Wright, published "*An Original Theory of the Universe*", in which he explains the Milky Way as a spherical shell of stars, with Sun being just one star in it.
- He created many other models of the universe.
- He also considered the Earth to be a living organism.



Kant and Wright



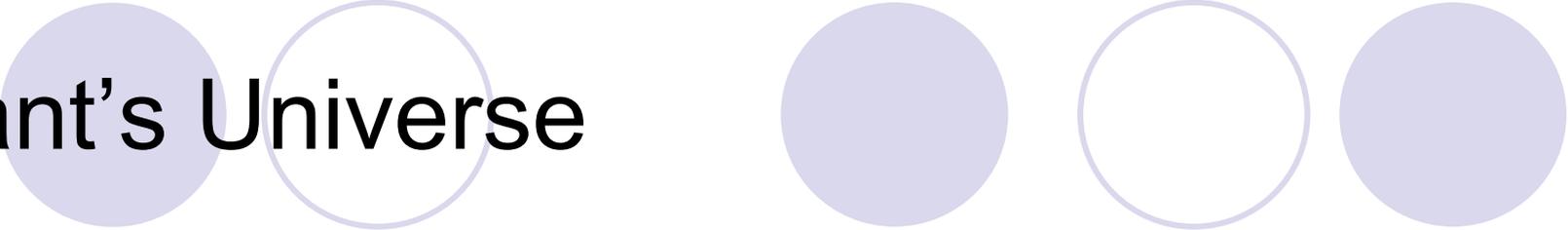
- Kant read a (highly) distorted review of Wright's book in a newspaper. It looked remarkably similar to his ideas about the formation of the Solar system.
- He proposed that:
 - Stars are mostly located in a plane, just like planets in the Solar system.
 - Stars go around a common center far away; they move so slow that their apparent motion on the sky has not been detected yet (actually, it was, by Edmund Halley in 1718).

Layover: Stellar Proper Motion

- Barnard's star
(Edward Barnard, 1857 – 1923, UofC astronomer)
- 1.8 pc (6 lyr) distant, faint red dwarf star
- Moves 10.3 arcsec per year (90 km/s) > ½ Moon diameter in 100 years



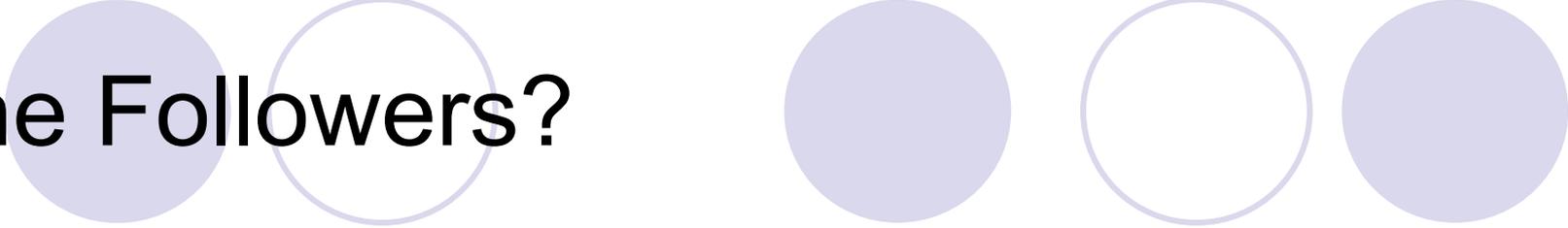
Kant's Universe



- He realized that disky-shaped round galaxies would appear as faint elliptical blobs of light, if observed from very far way.
- He proposed that numerous elliptical nebulae seen in the sky are other Milky Ways.

“The fixed stars, as we know, are all connected to a common plane and thus create a coordinated totality, a world of worlds. We see that in the immeasurable distances there are more such star systems and that creation in the entirety of its infinite extent is everywhere systematic and interconnected.”

The Followers?

The title is positioned to the left of a row of five circles. The first circle is solid light purple. The second circle is a light purple outline. The third circle is solid light purple. The fourth circle is a light purple outline. The fifth circle is solid light purple.

- Almost the whole print of Kant's book was seized for publisher's debts.
- Kant (briefly) mentioned these ideas in his later works.
- Several other people published books with similar ideas, including Lambert and Laplace. They could have been aware of Kant's work, so it is not clear how independent their ideas were.

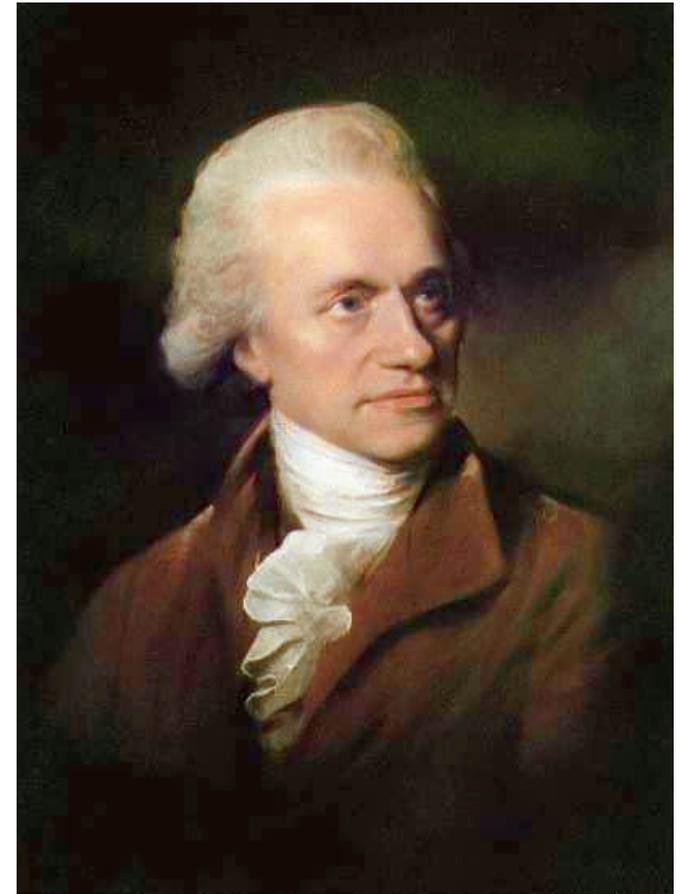
Pierre-Simon Laplace (1749 – 1827)

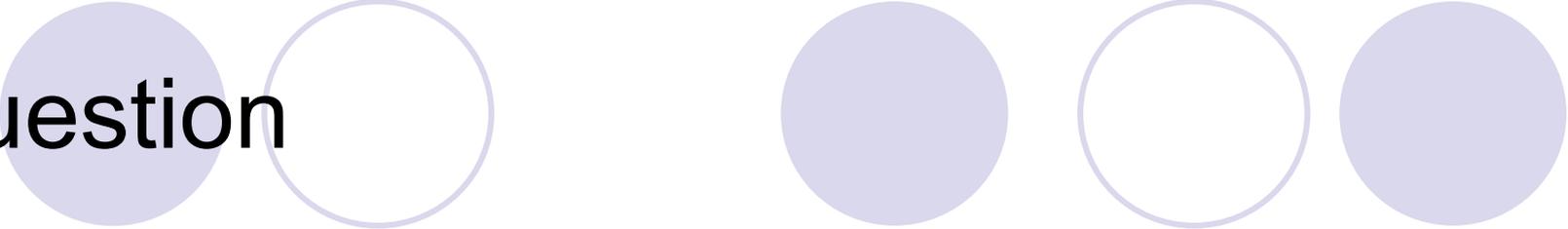
- He was first and foremost a mathematician, but many of his math works related to the celestial mechanics.
- He proved that the Solar system was stable.
- He was the first to propose an existence of “dark stars” (which we now call ***black holes***).
- He introduced a concept of ***Laplace's demon***.



William Herschel (1738 – 1832)

- German immigrant to England, he began his career as an organist in a chapel, but got bored really soon.
- Founded Royal Astronomical Society.
- Got himself into building telescopes (could not get a good enough one at Target).
- His work spelled death for large refracting telescopes.





Question

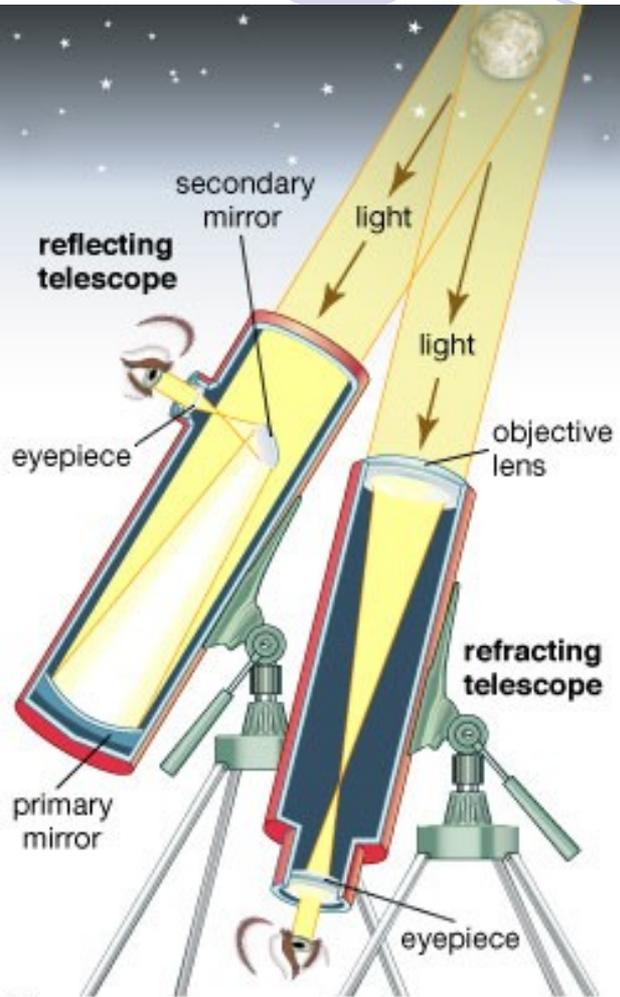
- What do telescopes do?
 - **A** They move distant objects closer.
 - **B** They magnify views of celestial objects.
 - **C** They gather more light from celestial objects.

Layover: Telescopes

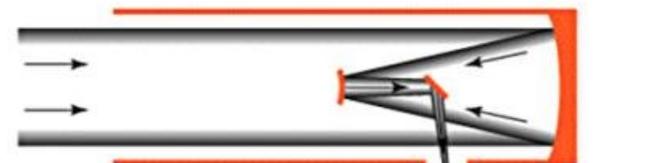
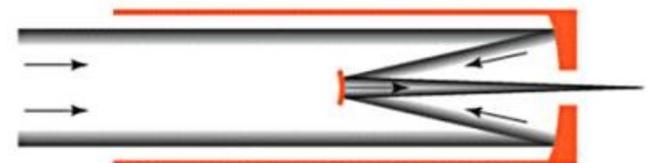
- Telescopes magnify **and** collect more light from very distant sources of light.
- Magnification = **angular resolution**
 - Human eye: 1 arcmin (1 cm @ 10 m)
 - Hubble (HST): 0.05 arcsec (1 cm @ 12 km)
- Amount of light = **aperture** x **QE** x **exposure**
 - Human eye: 5 mag (3mm, 3%, 0.1 sec)
 - Hubble (HST): 35 mag (2.5m, 90%, 11 days)
 - Keck or LBT: 34 mag (8m, 90%, 8 hours)

>10¹² times fainter

Layover: Telescopes II

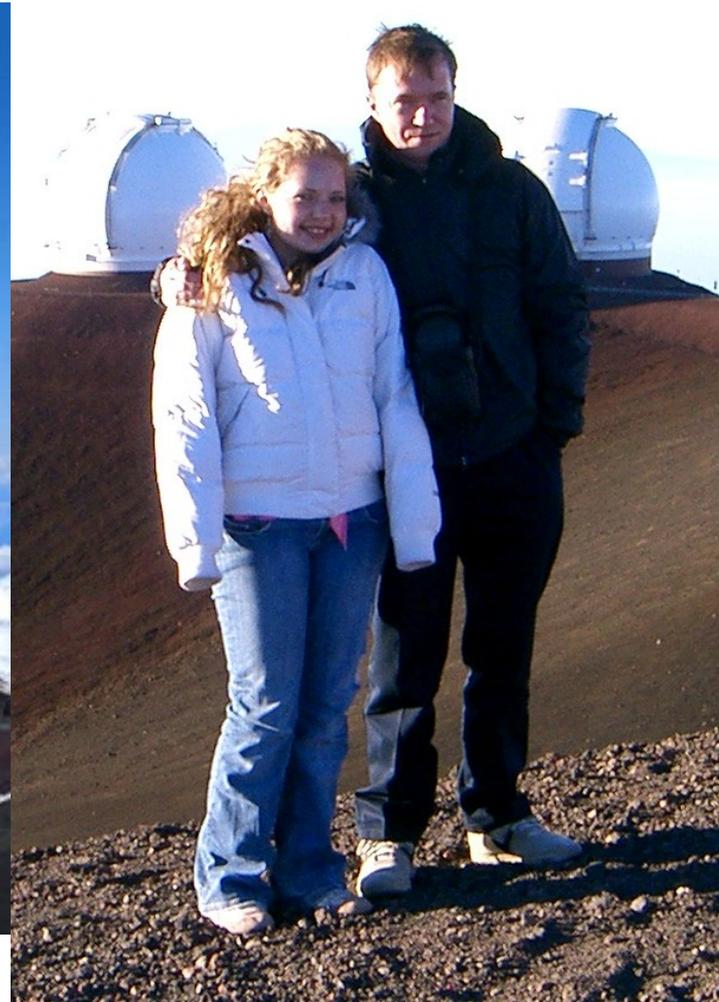


- Refractor: uses lenses to focus light
- Reflector: uses mirrors to focus light



Biggest World Telescopes

- Keck (Mouna Kea, Hawaii), 2 x 8m



Biggest World Telescopes

- Very Large Telescope (ESO, Chile), 4 x 8m

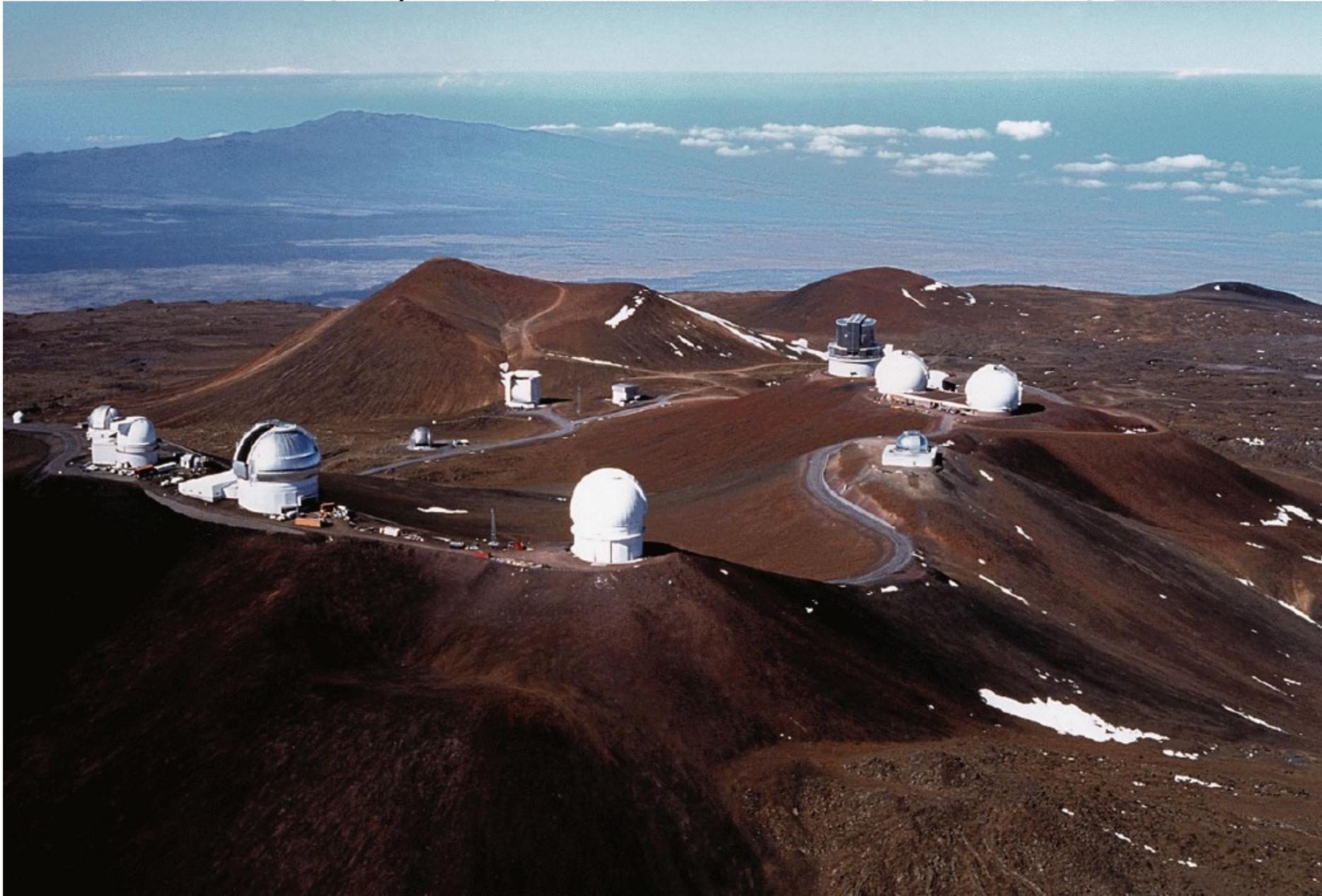


Biggest World Telescopes

- Subaru (Mouna Kea, Hawaii), 8m
- Gemini (Hawaii & Chile), 2 x 8m

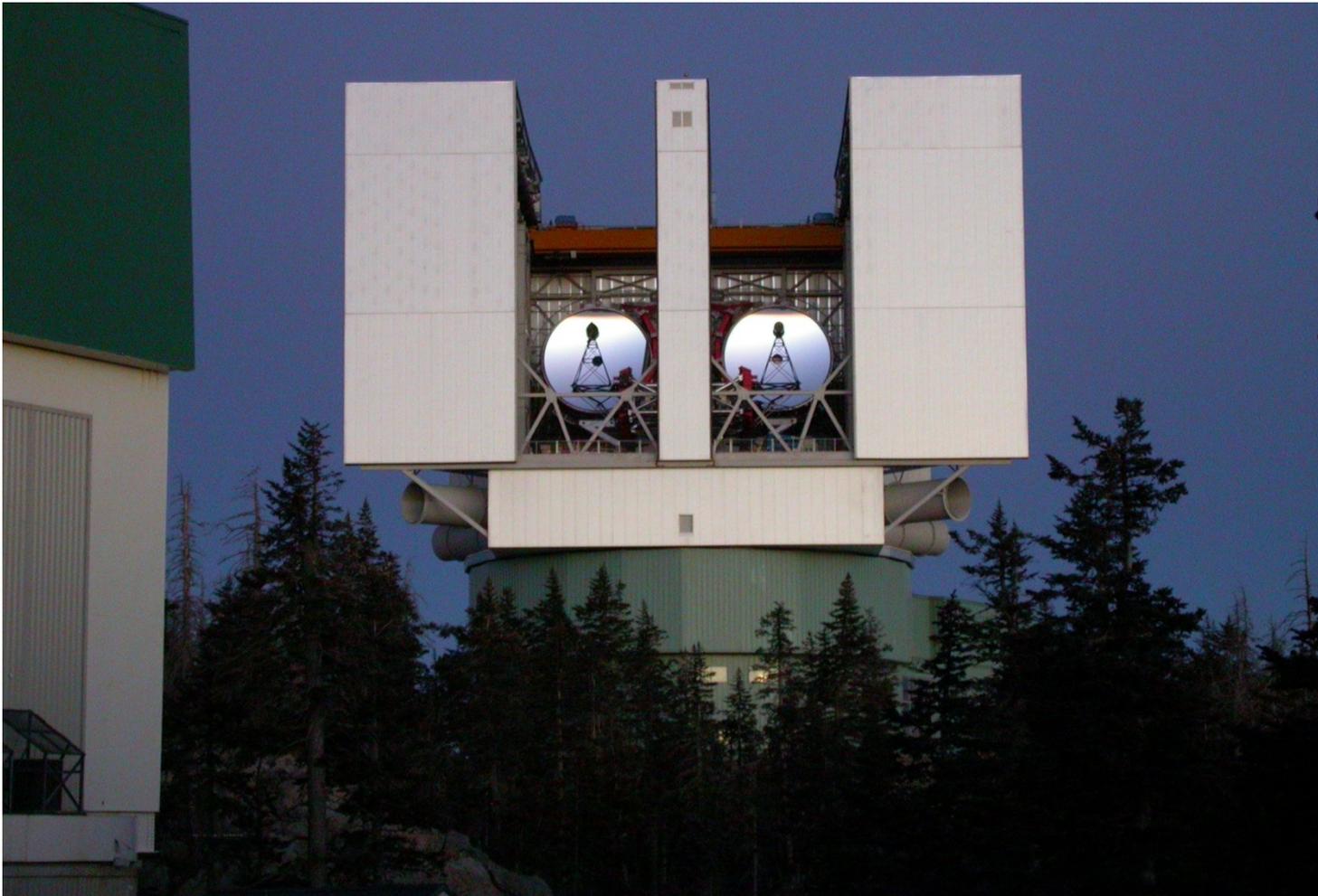


Mauna Kea, Hawaii



Biggest World Telescopes

- Large Binocular Telescope (Mt. Graham, AZ), 2x8m



Radio Telescopes

- Green Bank Telescope (Green Bank, WV), 100m



Radio Telescopes

- Arecibo (Arecibo, Puerto Rico), 300m

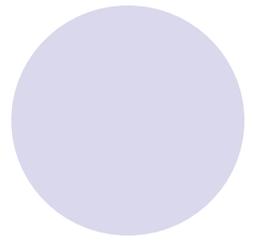
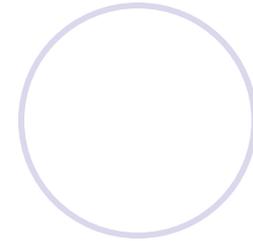
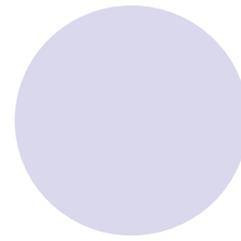


Radio Telescopes

- Very Large Array (Socorro, NM), 27x25m



Space Telescopes



- Hubble (visible), 2.5m

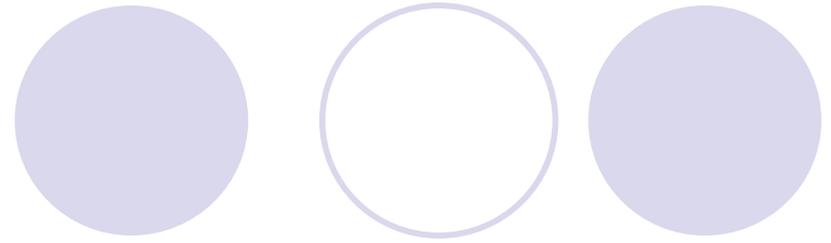


Space Telescopes

- Chandra (X-ray), 33cm



Space Telescopes

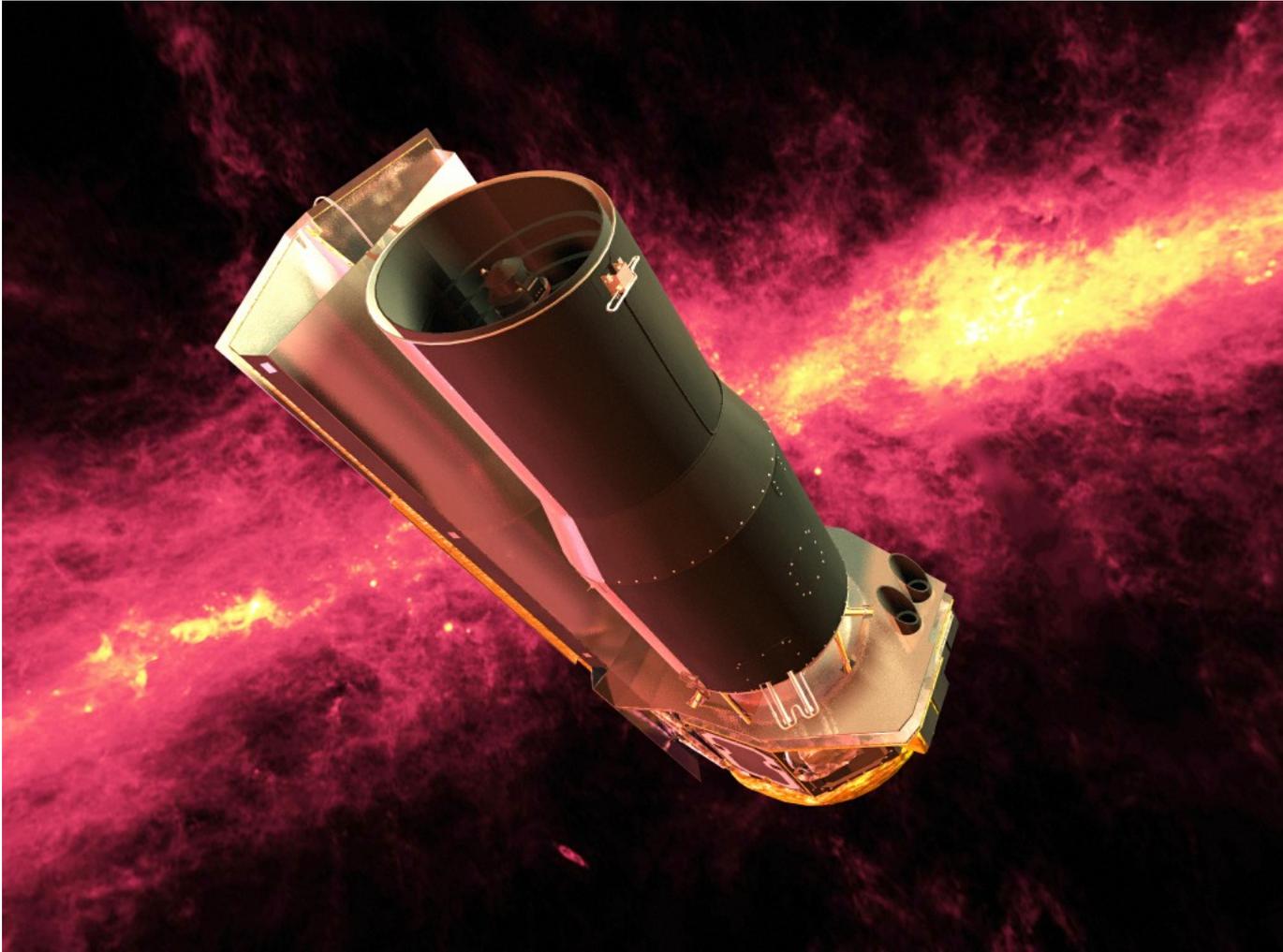


- Fermi (gamma-rays), 90cm



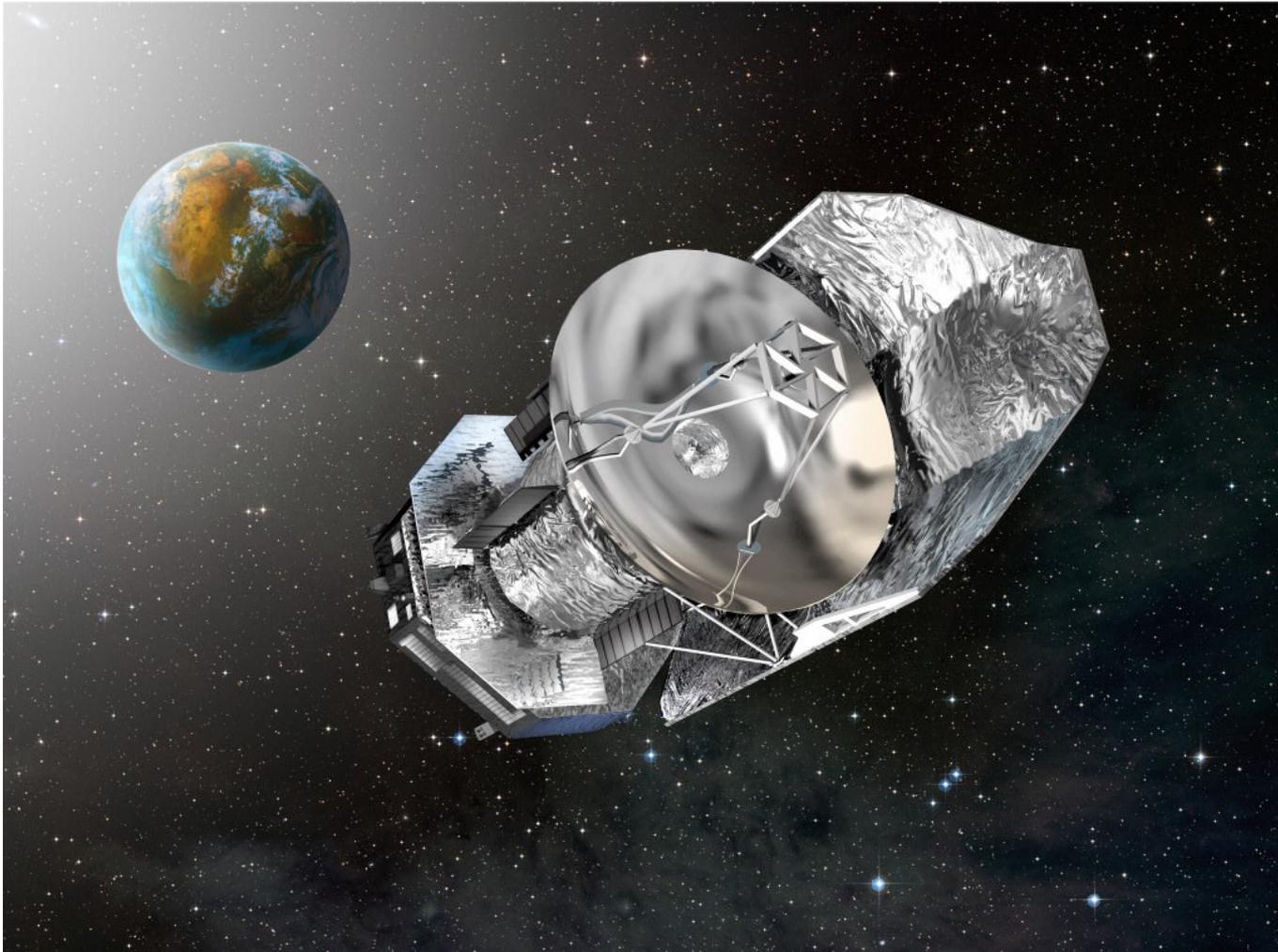
Space Telescopes

- Spitzer (near infrared), 85cm



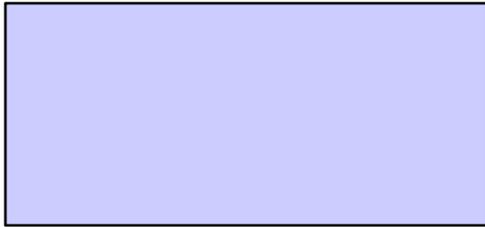
Space Telescopes

- Herschel (far infrared), 3.5m

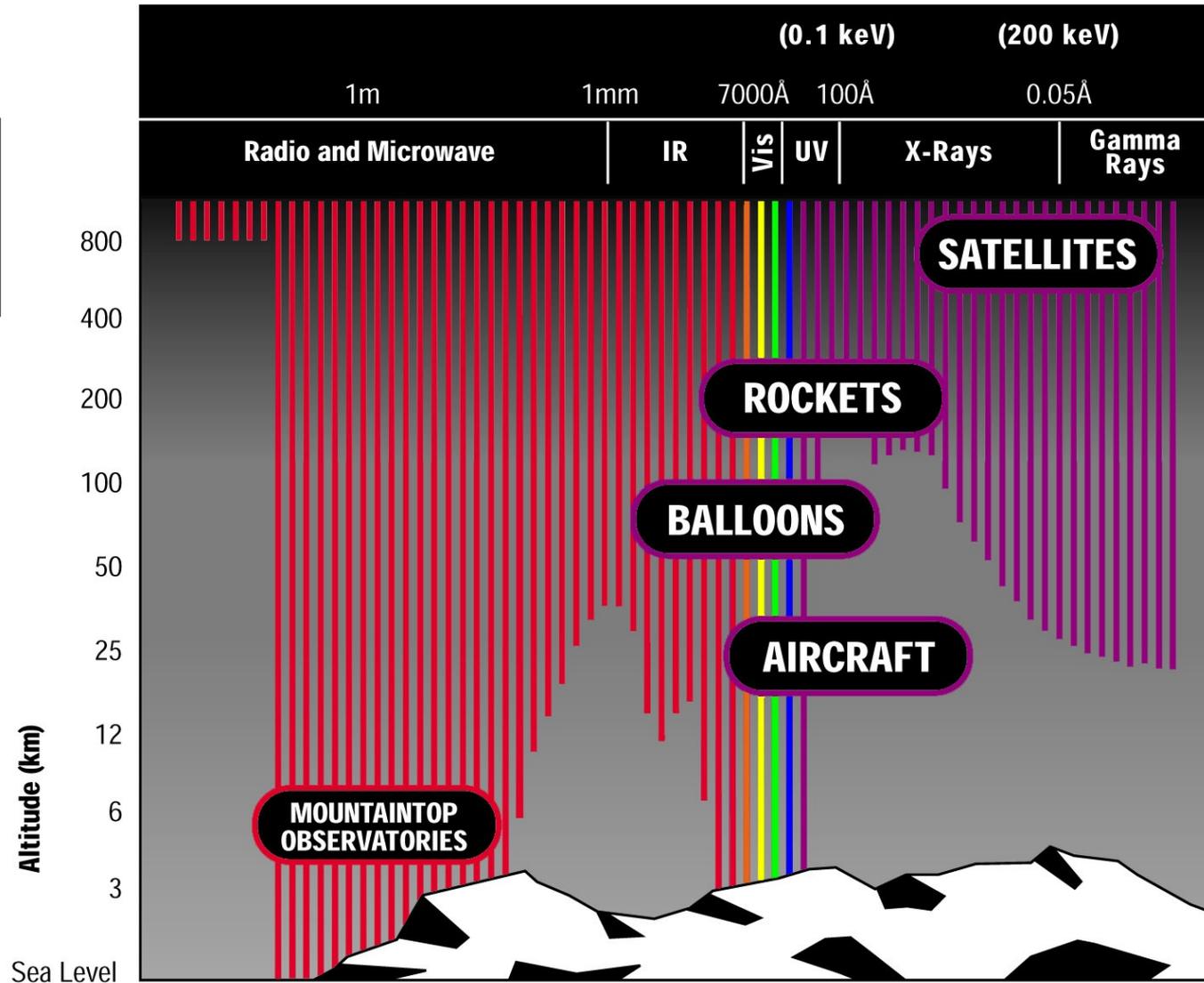


Absorption in the Atmosphere

● Depth:

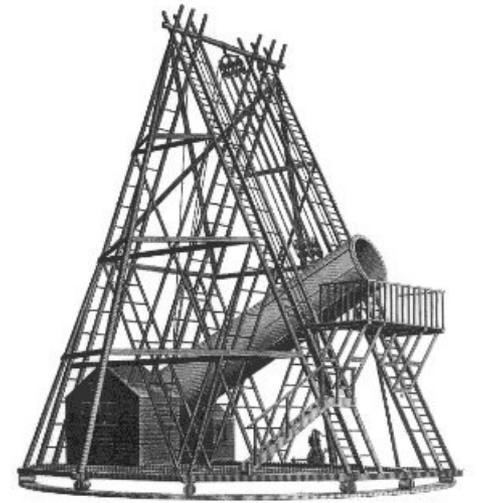


- X-rays: ionization
- UV: ozone
- IR: water



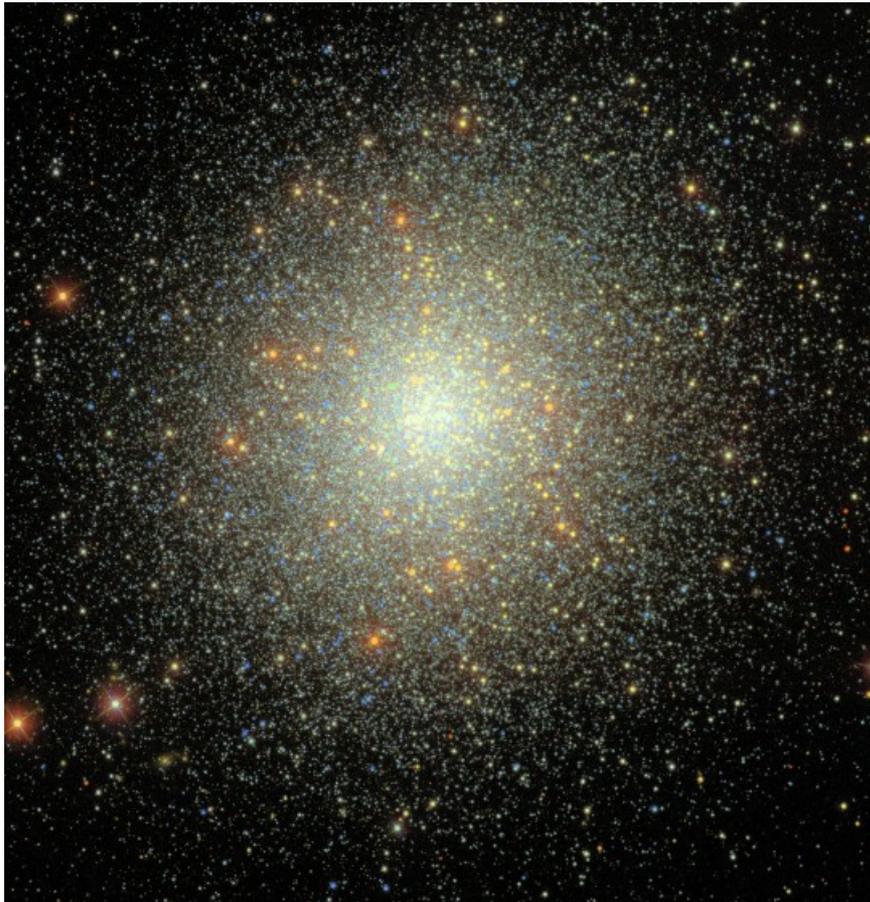
Herschel's Astronomy

- Thanks to the money he got from king George III for naming Uranus after him, Herschel built the world's largest telescope – 1.2m (48").
- The monster was so unwieldy, Herschel soon returned to using smaller telescopes.
- Herschel found that most of Messier objects resolve into stars; he concluded that **all** nebulae were star clusters (like globular clusters).



M13: Globular cluster (cluster of stars)

HST Picture



Picture with Hershel's telescope

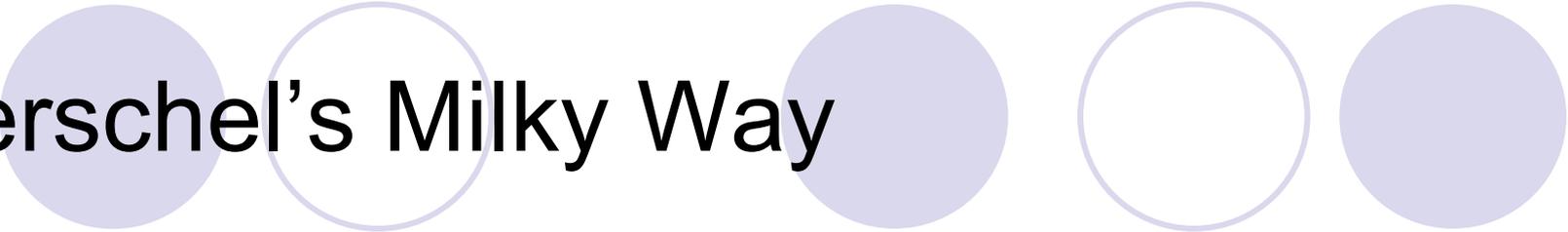


Herschel's Astronomy

- But in 1790, he observed a central star in a planetary nebula, and concluded that some nebulae must be made of “shining fluid”.
- He called the Orion nebula “material of future suns” (which is what it is).
- He also unexpectedly discovered infrared radiation.
- He believed that every planet was inhabited, even the Sun – every one has its whims...



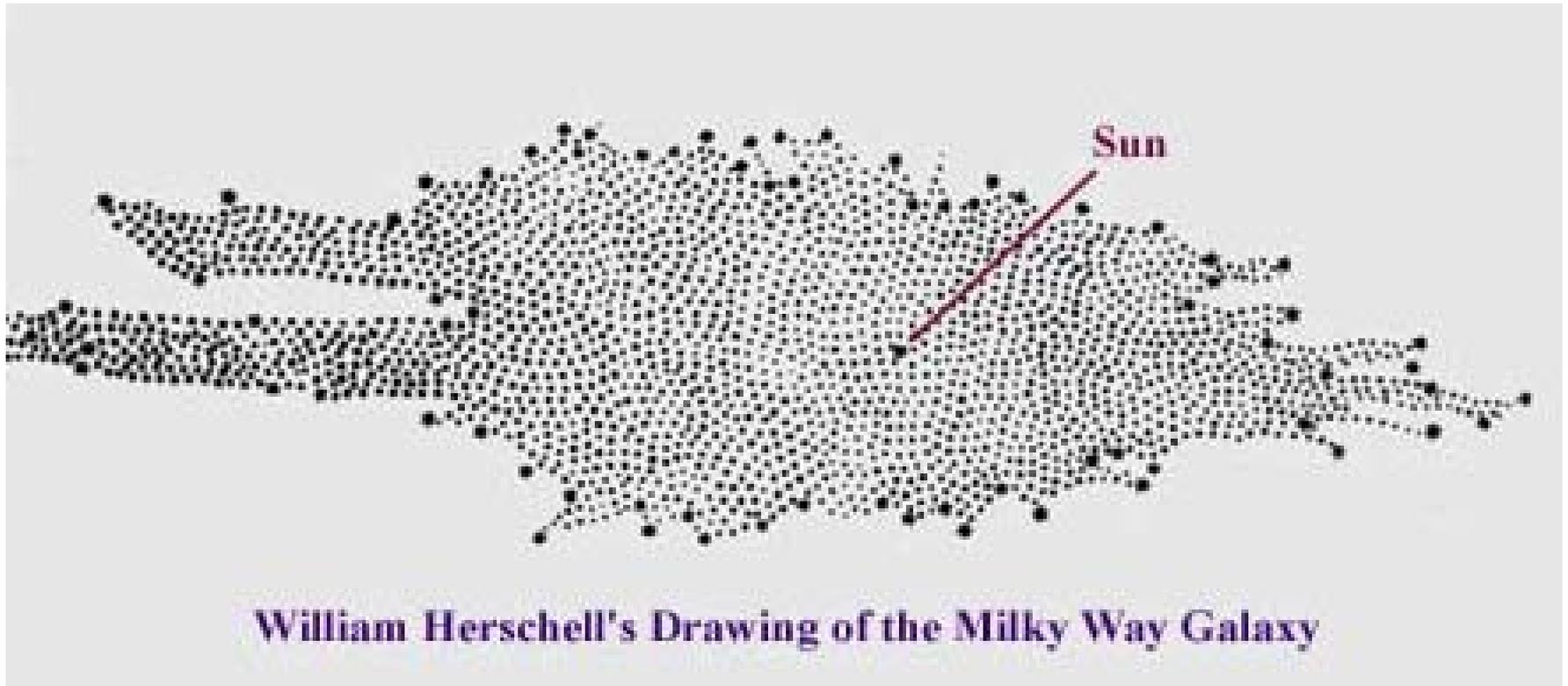
Herschel's Milky Way



- One of his many undertakings was to map the Milky Way.
- He assumed that
 - Stars are all more-or-less equally bright (i.e. they have the same **luminosity**).
 - Then the apparent magnitude of a star (its **brightness**) can be used to estimate the distance to a star.
- He found that the Milky Way was rather small (according to modern standards), with the Sun close to its center.

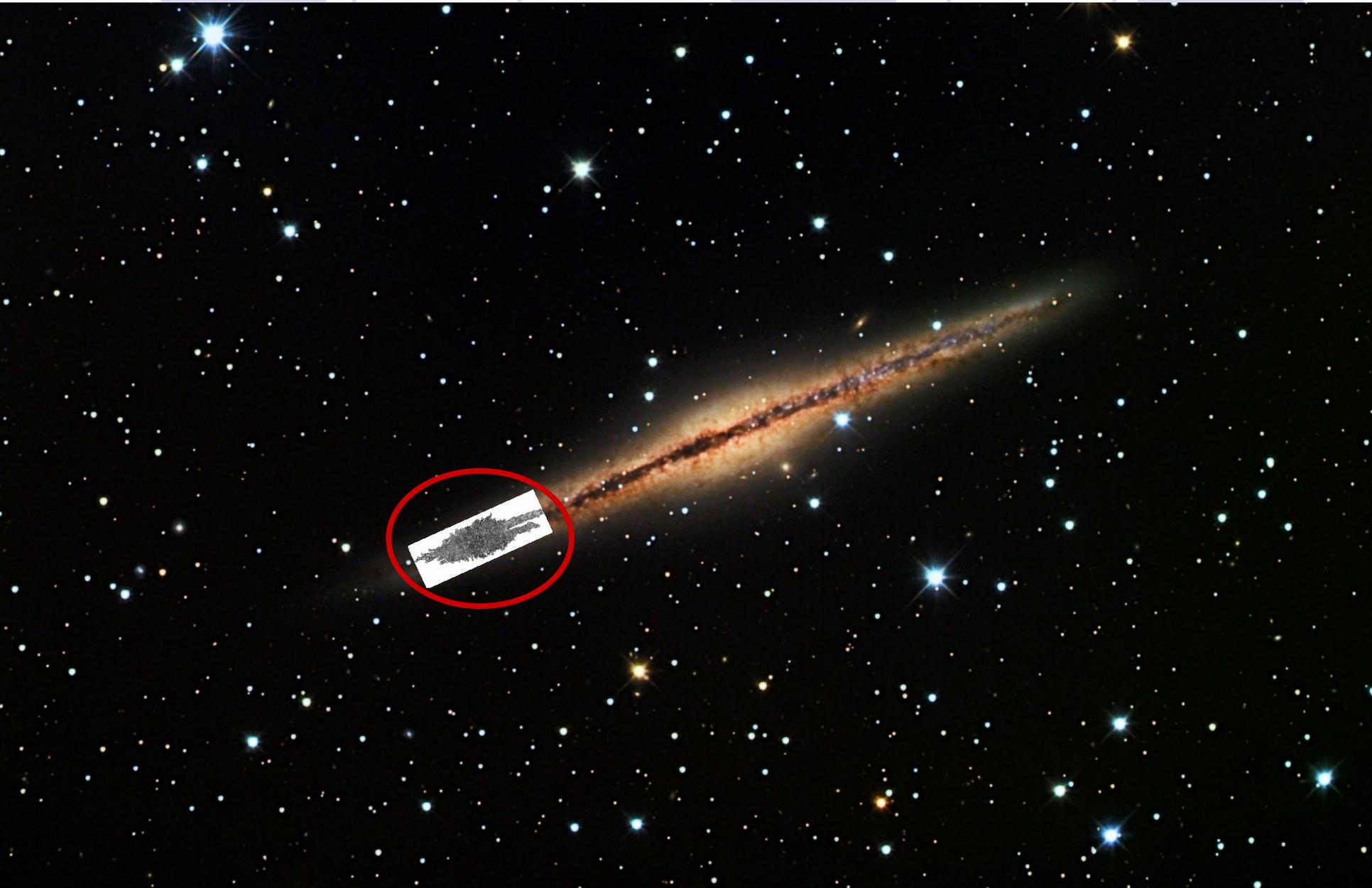
Herschel's Milky Way

- Later, Dutch astronomer Jacobus Kapteyn (1851 – 1922) followed up on Herschel's work.
- He confirmed his map.



William Herschel's Drawing of the Milky Way Galaxy

Herschel's & Kapteyn's Milky Way



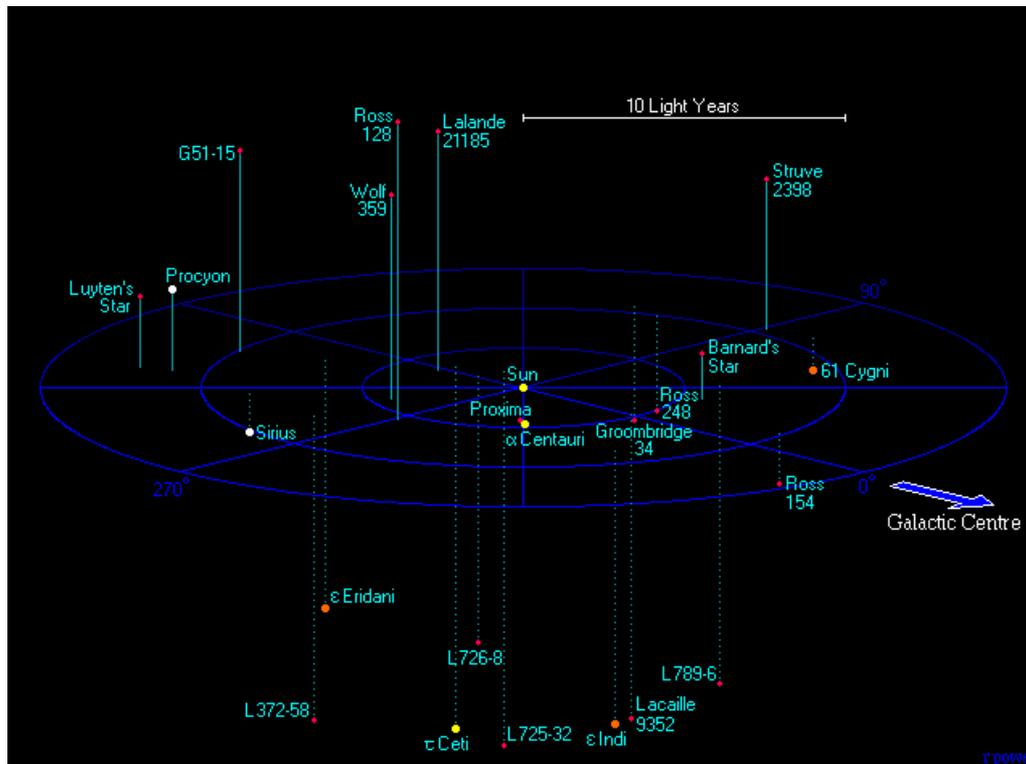
Herschel's & Kapteyn's Milky Way

- They both misestimated the size of the Milky Way by a factor of 10.
- They both got it wrong, because
 - Stars do not all have the same luminosity.
 - Space between stars (*interstellar medium*) is not empty.
 - Dark interstellar clouds block most of the visible view of our galaxy.



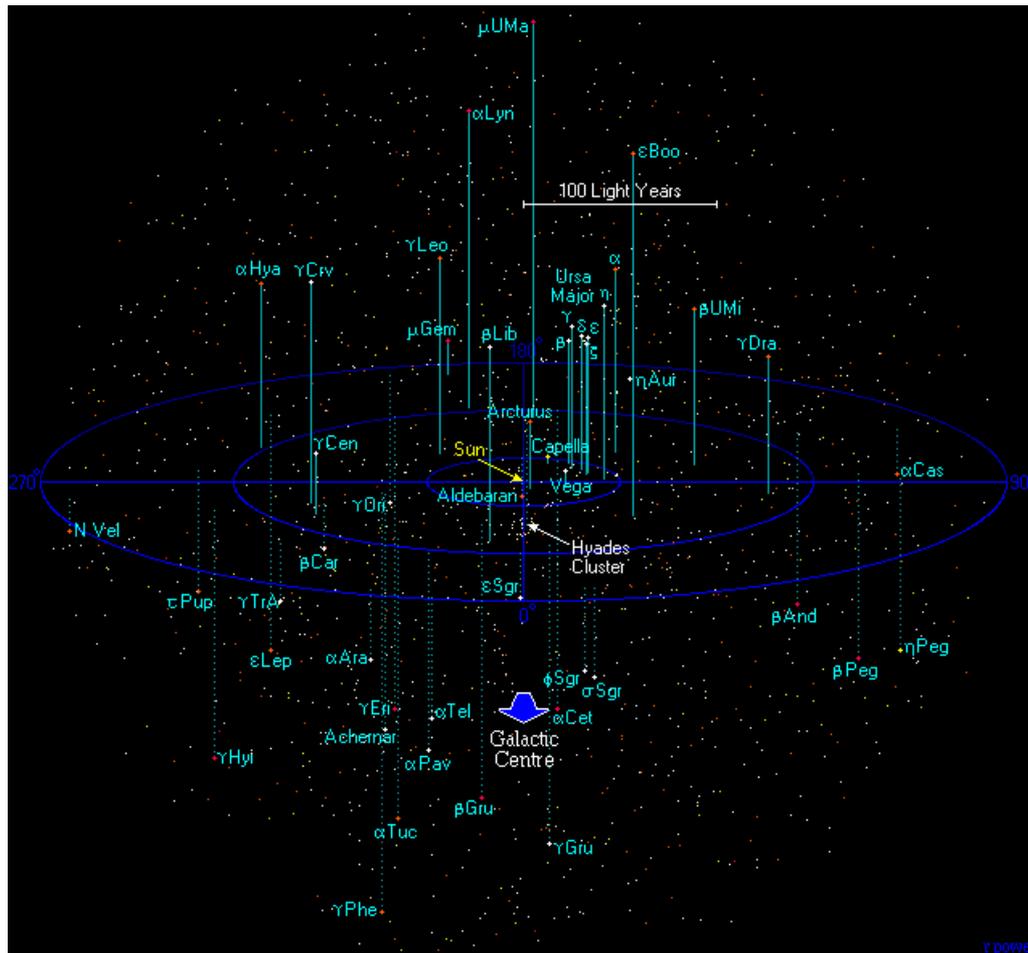
“Galaxigraphy” – Solar neighborhood

- 3 pc (10 lyr) scale



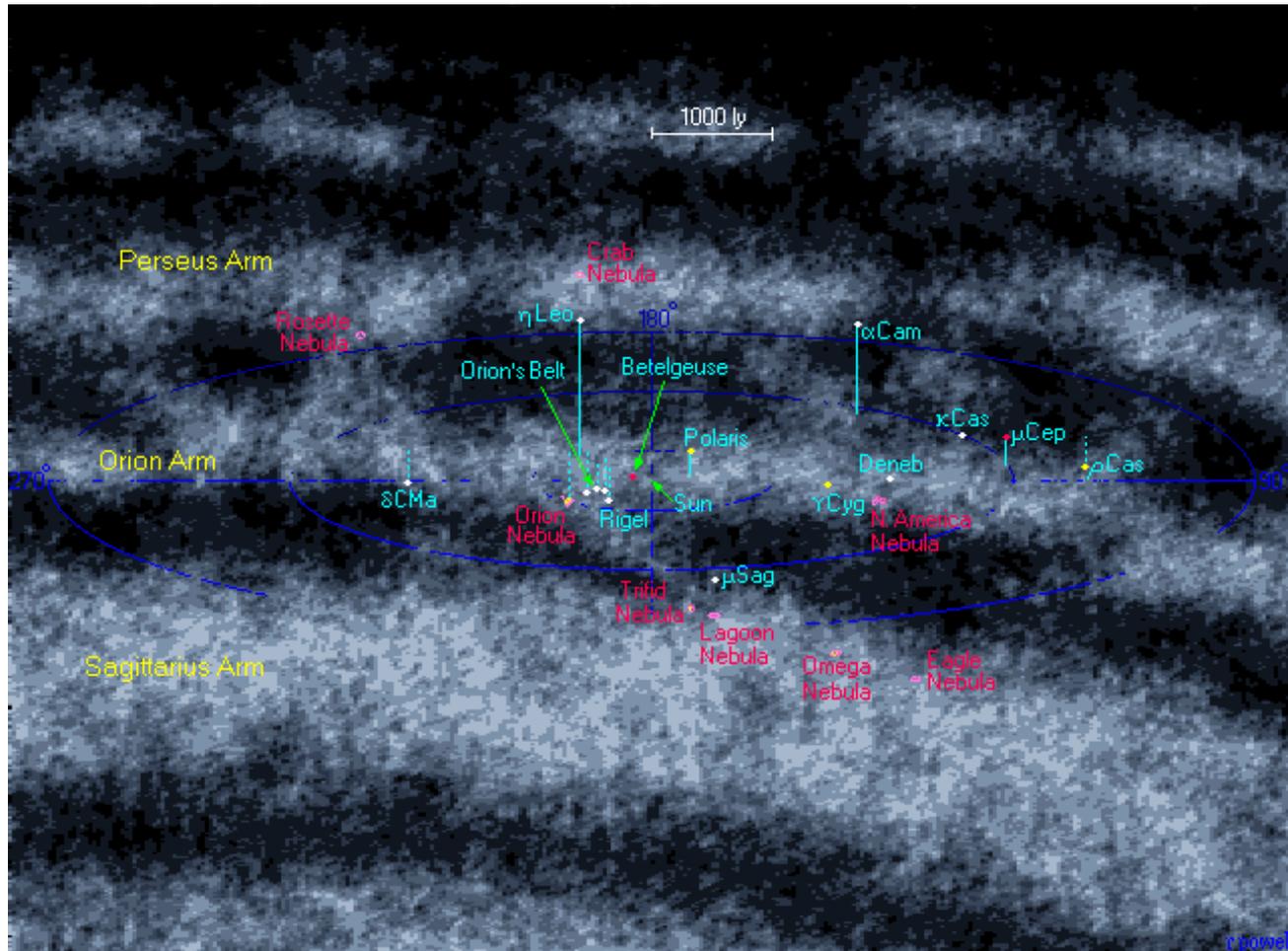
“Galaxigraphy” – Solar neighborhood

- 60 pc (200 lyr) scale



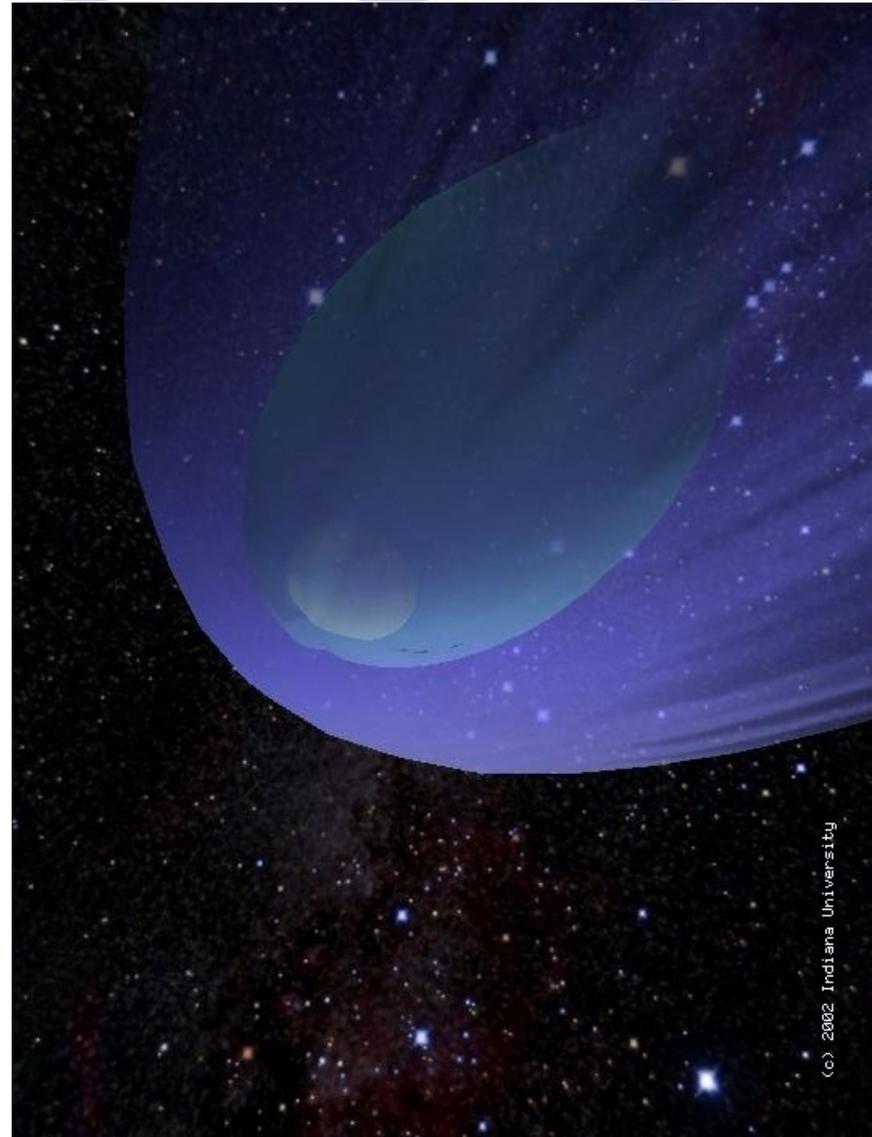
“Galaxigraphy” – Solar neighborhood

- 6kpc (20,000 lyr) scale



“Galaxigraphy” – Heliosphere

- Termination shock: 75 - 90 AU
- Heliopause: 110 AU
- Bow shock: 230 AU



“Galaxigraphy” – Local ISM

- Sun will exit Local Interstellar Cloud in about 10,000 years.
- LIC is located inside a Local Bubble – a very rarefied part of the ISM.
- There are a number of ***Molecular Clouds*** around, including the Orion region.

