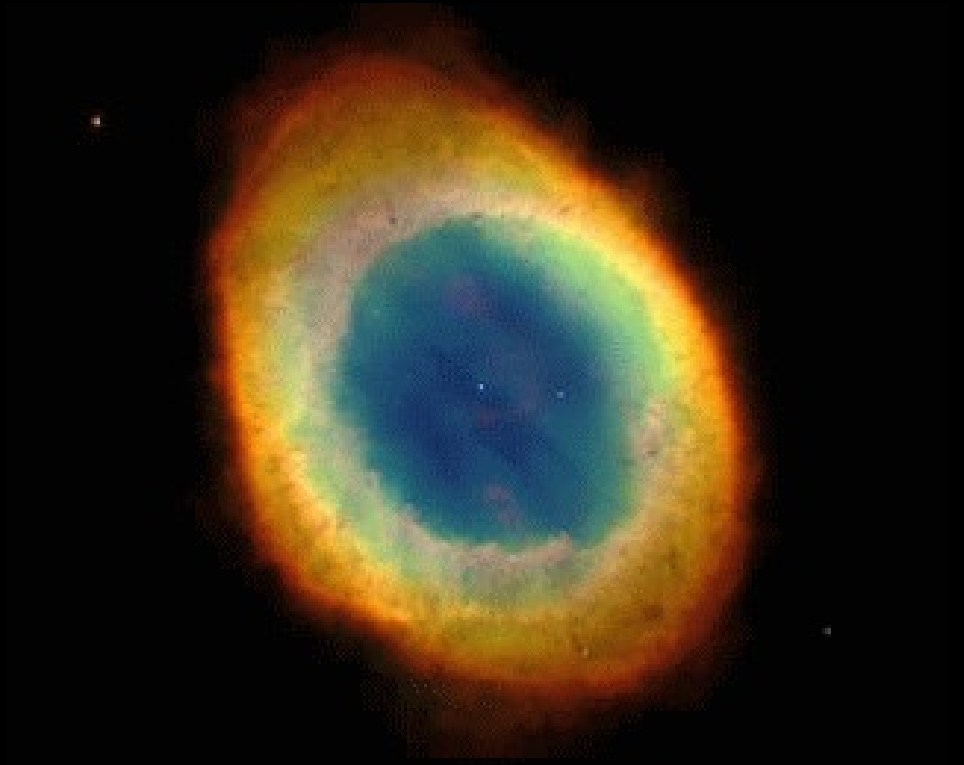


The Interstellar Medium

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What is the ISM?

- Interstellar gas.
 - Emission nebulae.



What is the ISM?

- Interstellar gas.
 - Emission nebulae.
- Interstellar dust.
 - Dark nebulae.



© David Malin

What is the ISM?

- Interstellar gas.
 - Emission nebulae.
- Interstellar dust.
 - Dark nebulae.
 - Reflection nebulae.



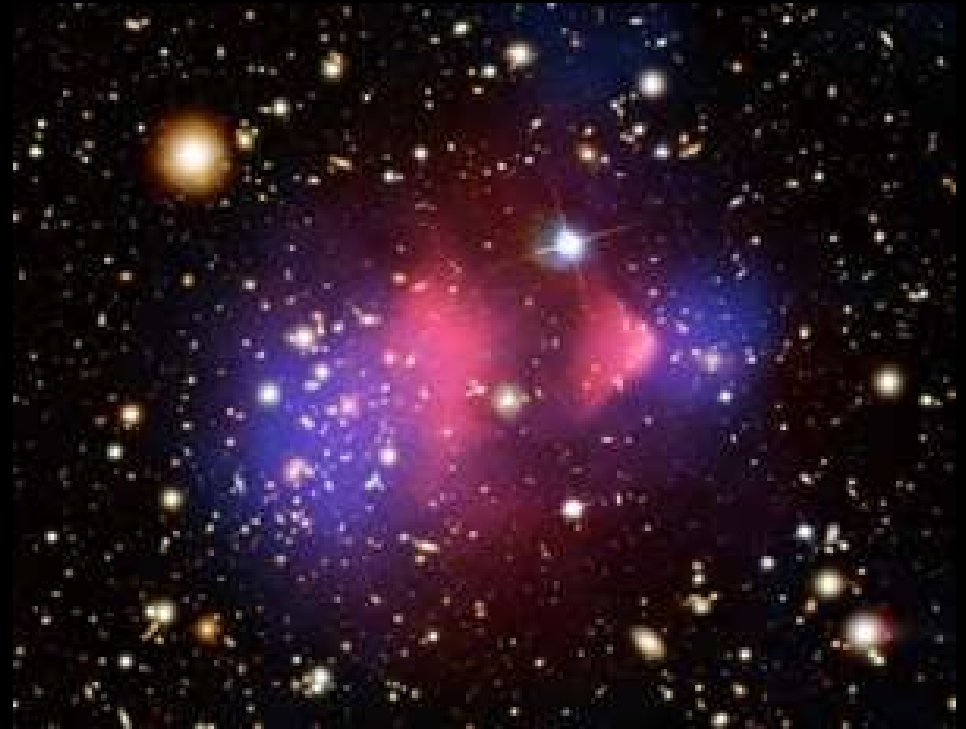
What is the ISM?

- Interstellar gas.
 - Emission nebulae.
- Interstellar dust.
 - Dark nebulae.
 - Reflection nebulae.
- Cosmic rays.
- Electromagnetic radiation.
- Magnetic fields.



What is the ISM

- Gravity.
- Dark matter.



Historical Context

Northern Milky Way



© Tommy Eliassen/Caters

Historical Context

Southern MW



© Alex Cherney/BNPS

Early Ideas

- Appears as a milky band arching over the sky.
 - Milky Way from Latin: *Via Lactea*.
 - Milk spilt when Hera was feeding Heracles.
 - Akash Ganga.
- Every star in the sky is part of the Milky Way.




Observational Details

- Surface brightness of 5.
 - Sagittarius.
 - More detail at a limiting magnitude of 6.
- Individual stars are not seen.



Siderius Nuncius



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EXHIBITIONS

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Society of America Conference

Sixteenth Biennial New
College Conference on
Medieval and Renaissance
Studies

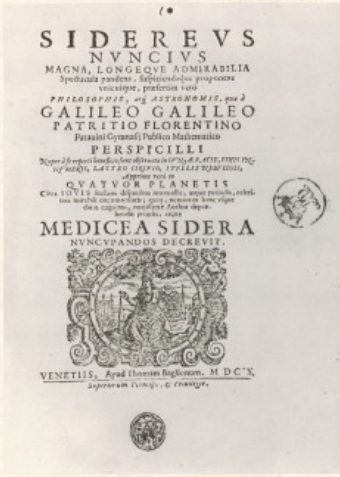
Artiste nell'Italia dell'età
moderna / Women Artists of
Early Modern Italy

"Una giornata a S. Maria
Maddalena a Caldine"

Medici Women as Cultural

Medici (1577-1713)

STARRY MESSENGER

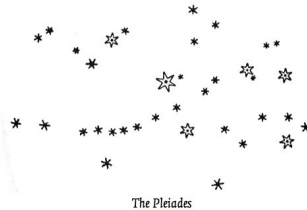


SIDEREAL MESSENGER
unfolding great and very wonderful sights
and displaying to the gaze of everyone,
but especially philosophers and astronomers,
the things that were observed by
GALILEO GALILEI
Florentine patrician
and public mathematician of the University of Padua,
with the help of a spyglass lately devised by him,
about the face of the Moon, countless fixed stars,
the Milky Way, nebulous stars,
but especially about four planets
flying around the star of Jupiter at unequal intervals
and periods with wonderful swiftness;
which, unknown by anyone until this day,
the first author detected recently
and decided to name
MEDICEAN STARS

translation: Albert van Helden

Sidereus Nuncius

In the second example I have depicted the six stars of Taurus known as the Pleiades (I say six, inasmuch as the seventh is hardly ever visible) which lie within very narrow limits in the sky. Near them are more than forty others, invisible, no one of which is much more than half a degree away from the original six. I have shown thirty six of these in the diagram; as in the case of Orion I have preserved their intervals and magnitudes, as well as the distinction between old stars and new.

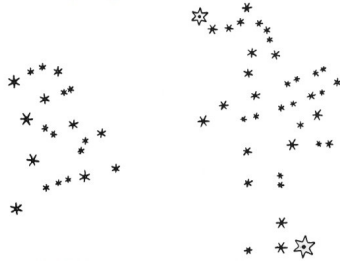


The Pleiades

Third, I have observed the nature and the material of the Milky Way. With the aid of the telescope this has been scrutinized so directly and with such ocular certainty that all the disputes which have vexed philosophers through so many ages have been resolved, and we are at last freed from wordy debates about it. The galaxy is, in fact, nothing but a congeries of innumerable stars grouped together in clusters. Upon whatever part of it the telescope is directed, a vast crowd of stars is immediately presented to view. Many of them are rather large and quite bright, while the number of smaller ones is quite beyond calculation.

But it is not only in the Milky Way that whitish clouds are seen; several patches of similar aspect shine with faint light here and there throughout the aether, and if the telescope is turned upon any of these it confronts us with a tight mass of stars. And what is even more remarkable, the stars which have been called "nebulous" by every astronomer up to this time turn out to be groups of very small stars arranged in a wonderful manner. Although each star separately escapes our sight on account of its smallness or the immense distance from us, the mingling of their rays gives rise to that gleam which was formerly believed to be some denser part of the aether that was capable of reflecting rays from stars or from the sun. I have observed some of these constellations and have decided to depict two of them.

In the first you have the nebula called the Head of Orion, in which I have counted twenty-one stars. The second contains the nebula called Praesepe,¹⁷ which is not a jingle star but a mass of more than forty starlets. Of these I have shown thirty-six, in addition to the Aselli, arranged in the order shown.



Nebula of Orion

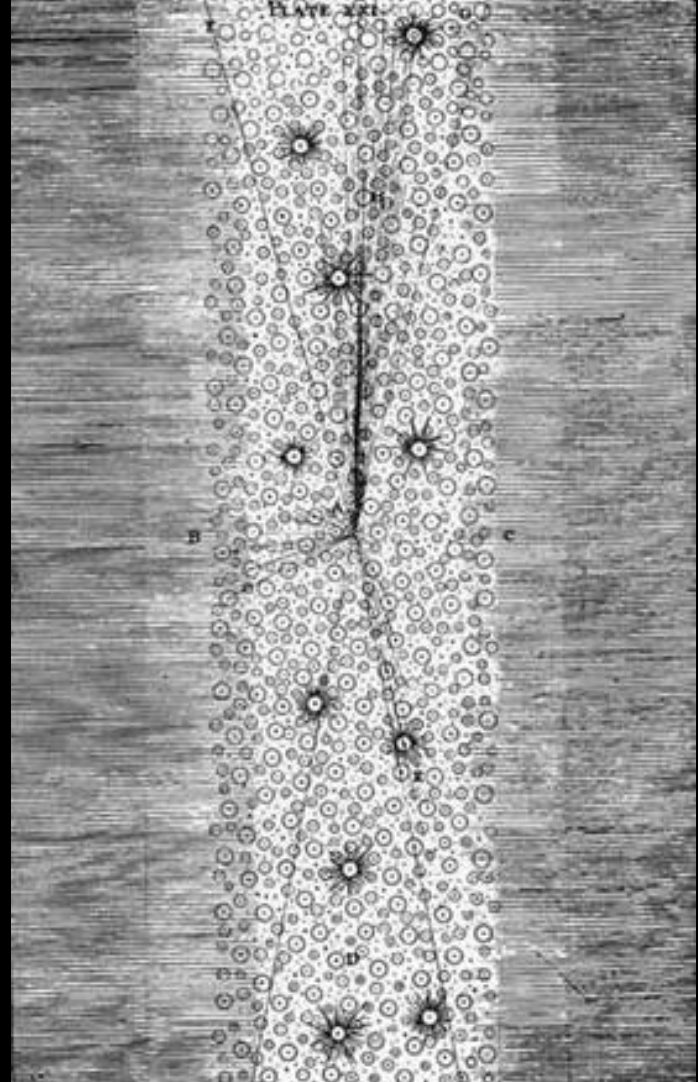
Nebula of Praesepe

¹⁷ Praesepe, "the Manger," is a small whitish cluster of stars lying between the two Aselli (ass-colls) which are imagined as feeding from it. It lies in the constellation Cancer.

- Galileo saw many more stars with telescope than with naked eye.
- Found that nebulae and Milky Way were comprised of stars.
- For the Galaxy is nothing else than a congeries of innumerable stars distributed in clusters.*

Evolution of Galactic Models

- Thomas Wright (1750).
 - *An original theory or new hypothesis of the Universe.*
 - The Sun is at the centre of an infinite plate of stars.
 - Bright stars are nearby.

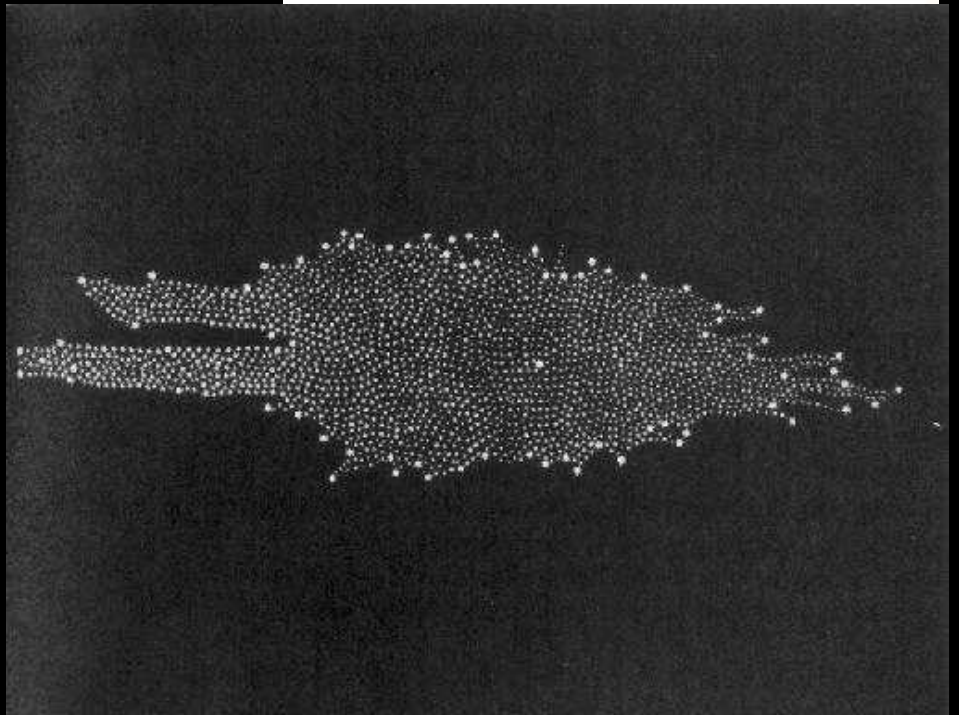


Immanuel Kant

- *Universal Natural History and Theory of the Heavens or An Essay on the Constitution and the Mechanical Origin of the Entire Structure of the Universe Based on Newtonian Principles (1755)*
- *<http://records.viu.ca/~johnstoi/kant/kant2e.htm>*
- *Outline of a general systematic arrangement among the fixed stars, derived from the phenomenon of the Milky Way. Similarity of this system of fixed stars to the planetary system. Discovery of many such systems, showing up in the expanse of the heavens in the form of elliptical shapes. New idea about the systematic arrangement of the entire creation*
- *Suggested that each nebula is an Island Universe.*

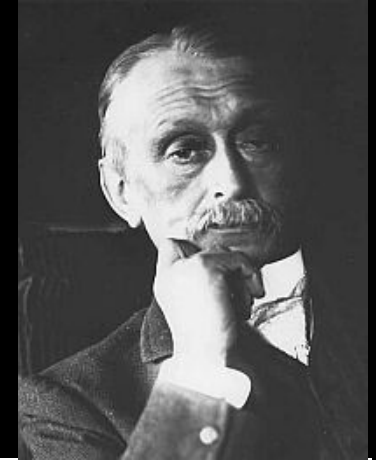
Herschel's Universe

- William and Caroline Herschel counted stars in fields (1785).
- Found that Sun was in the centre of the Galaxy.

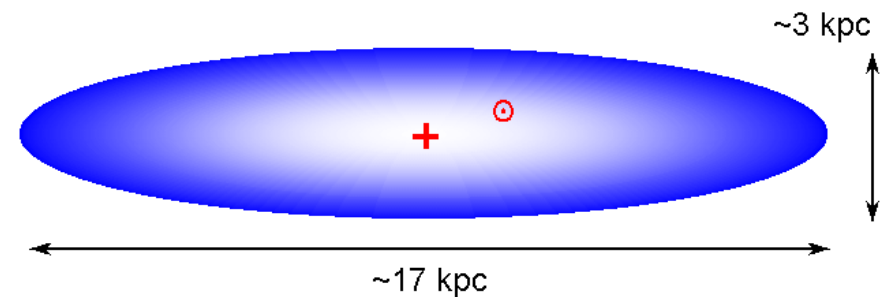


Kapteyn Universe

- Jacobus Kapetyn (1922)
- Cape Photographic Durchmusterung survey of 4,84,575 stars in the Southern Hemisphere.
- Found two streams of stellar proper motions.
- Galactic model from detailed study of Kapteyn's Special Areas.



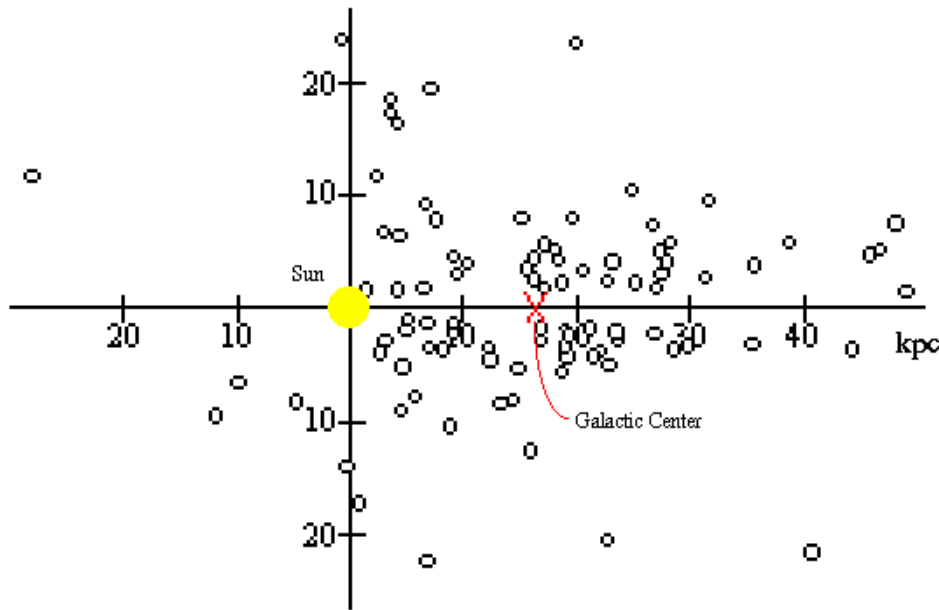
Kapteyn Model (1922)



kpc = kiloparsec = 1000 pc

Harlow Shapley

- Systematically measured the distances to globular clusters using Cepheid variables.



Heber Curtis



PASP 26, 206 (1917)

1988PASP...100....6C

ASTRONOMICAL SOCIETY OF THE PACIFIC 207

arithmetical mean of the maximum observed magnitudes of the 27 novae is 5.3. Some of the observed maximum magnitudes were visual and some were photographic, but the spectra of novae are rich in blue and violet light, and their color equation is therefore small. In several novae the maximum brightness occurred before their discovery, and we shall not be far wrong to assume that the average (arithmetical) maximum brightness of our galactic novae is 5. Presumably the novae already discovered in spiral nebulae are the brighter ones of their class; and there seems to be safety in setting 15 as the average maximum. There is thus an average difference of 10 magnitudes between galactic novae and spiral novae. Now all the evidence available assigns a great distance to the galactic novae. If we assume equality of absolute magnitude for galactic and spiral novae, then the latter, being apparently 10 magnitudes the fainter, are of the order of 100 times as far away as the former. That is, the spirals containing the novae are far outside our stellar system; and these particular spirals are undoubtedly, judging from their comparatively great angular diameters, the nearer spirals. Of course the effect of any existing absorbing materials in the spirals upon the novae is to reduce their apparent brightness and thus to make them seem farther from our system than they really are.

HEBER D. CURTIS.

Curtis-Shapley Debate

- PASP 107, 1133 Virginia Trimble (1995)
- http://apod.nasa.gov/diamond_jubilee/1920/cs_real.html
- http://apod.nasa.gov/diamond_jubilee/1920/cs_lplan.html
- First idea was to have a debate on relativity:
 - As to relativity, I must confess that I would rather have a subject in which there would be a half dozen members of the Academy competent enough to understand at least a few words of what the speakers were saying if we had a symposium upon it. I pray to God that the progress of science will send relativity to some region of space beyond the fourth dimension, from whence it may never return to plague us.
 - Am wiring Heber Curtis suggesting Debate him and Shapley on subject scale of universe for Academy meeting forty five minutes each suggest communicate Shapley and Curtis and wire if favorably arranged.

- Is the Sun at the center of the Galaxy?
 - Star counts indicate yes.
 - No interstellar dust.
 - Globular clusters say no.
 - Curtis distrusted cepheids.
- Are there other *island universes*?
 - Distances from novae say yes.
 - Van Maanen measured internal rotations so no.

points and the evidence are summarised below:

	Shapley	Curtis
Main point	The Milky Way is large and the 'spiral nebulae' are part of it.	The Milky Way is small and there may be other galaxies like it.
Evidence	Milky Way is so large that if the spiral nebulae have the same size, they are at inconceivably large distances from us.	The large range in angular sizes of the spiral nebulae indicates that there is a huge range in distances to them. They cannot all be in our small Milky Way.
	The surface brightness of the Milky Way is lower than that of the spiral nebulae. So they cannot be similar things. <i>We now know that this observation is caused by dust absorption.</i>	(Super-)Novae observed in the Andromeda nebula are much fainter than those in the Milky Way. This implies large distances. <i>In fact, Curtis even underestimated the distance to Andromeda as he looked at supernovae, not novae, without knowing.</i>
	Observations show that some spirals revolve once in about 10^5 years. If they are bigger than 5kpc, their outer regions travel at more than the speed of light. <i>It later turned out that these observations were simply wrong...</i>	Emission lines from the spiral nebulae are similar to those you would get if you summed up the spectra of stars in the solar neighbourhood. Their Doppler shifts are huge and so they travel at much larger speeds than stars. Therefore they cannot be part of the Milky Way.

- The question was resolved by Hubble in 1923 when he observed Cepheid variable stars in the Andromeda nebula. He estimated a distance of 300kpc (modern calibration of the Cepheid calibration gives 740kpc.)

Discovery of Interstellar Matter

- Otto Wilhelm von Struve.
 - Decline in number of stars with distance.
- E. E. Barnard (1919)
 - Observed dark nebulae.
- Robert Trumpler (1930)
 - Interstellar extinction in observations of clusters.
- Johannes Hartmann (1904)
 - Absorption lines in spectrum of binary star δ Orionis.