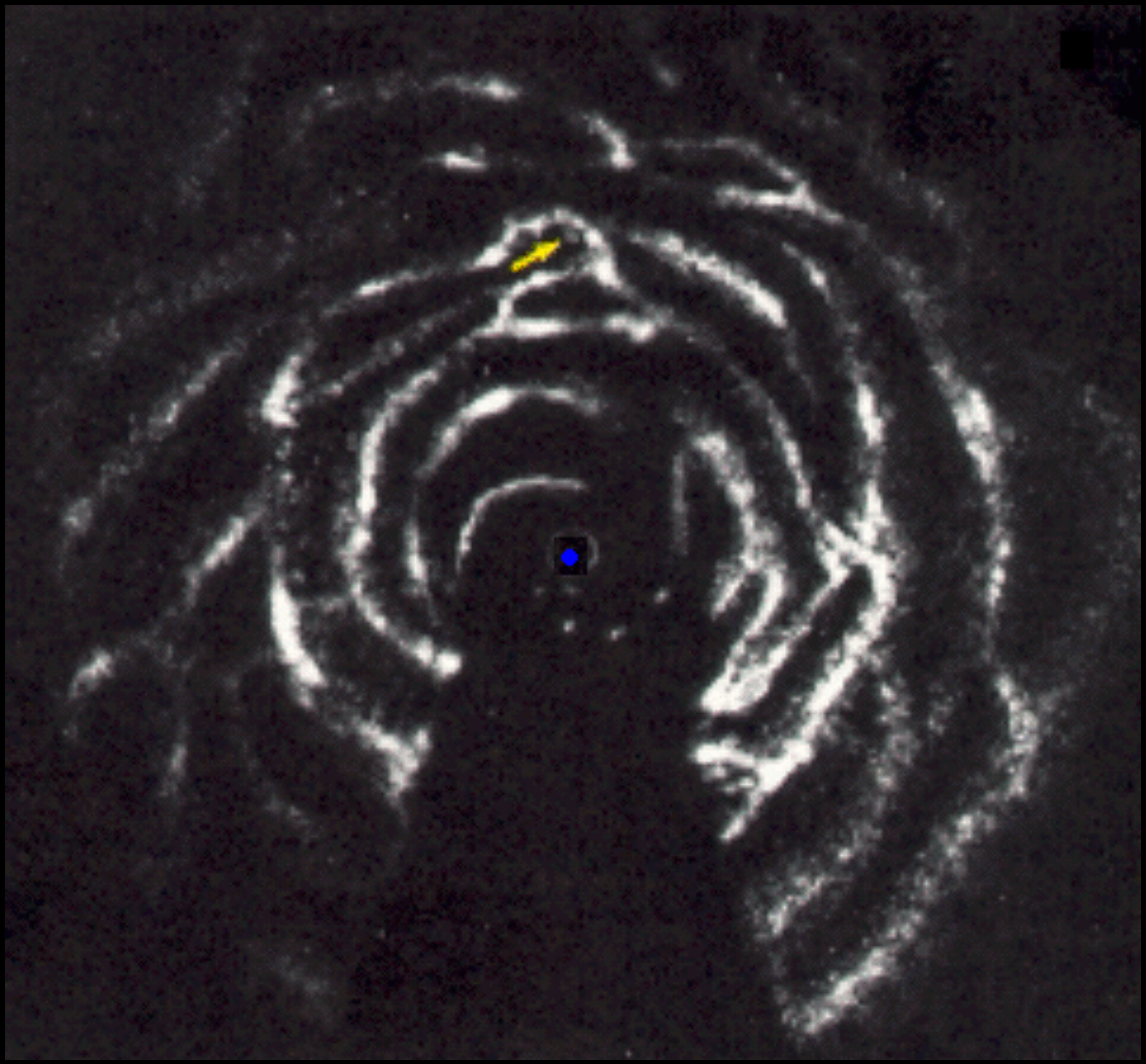
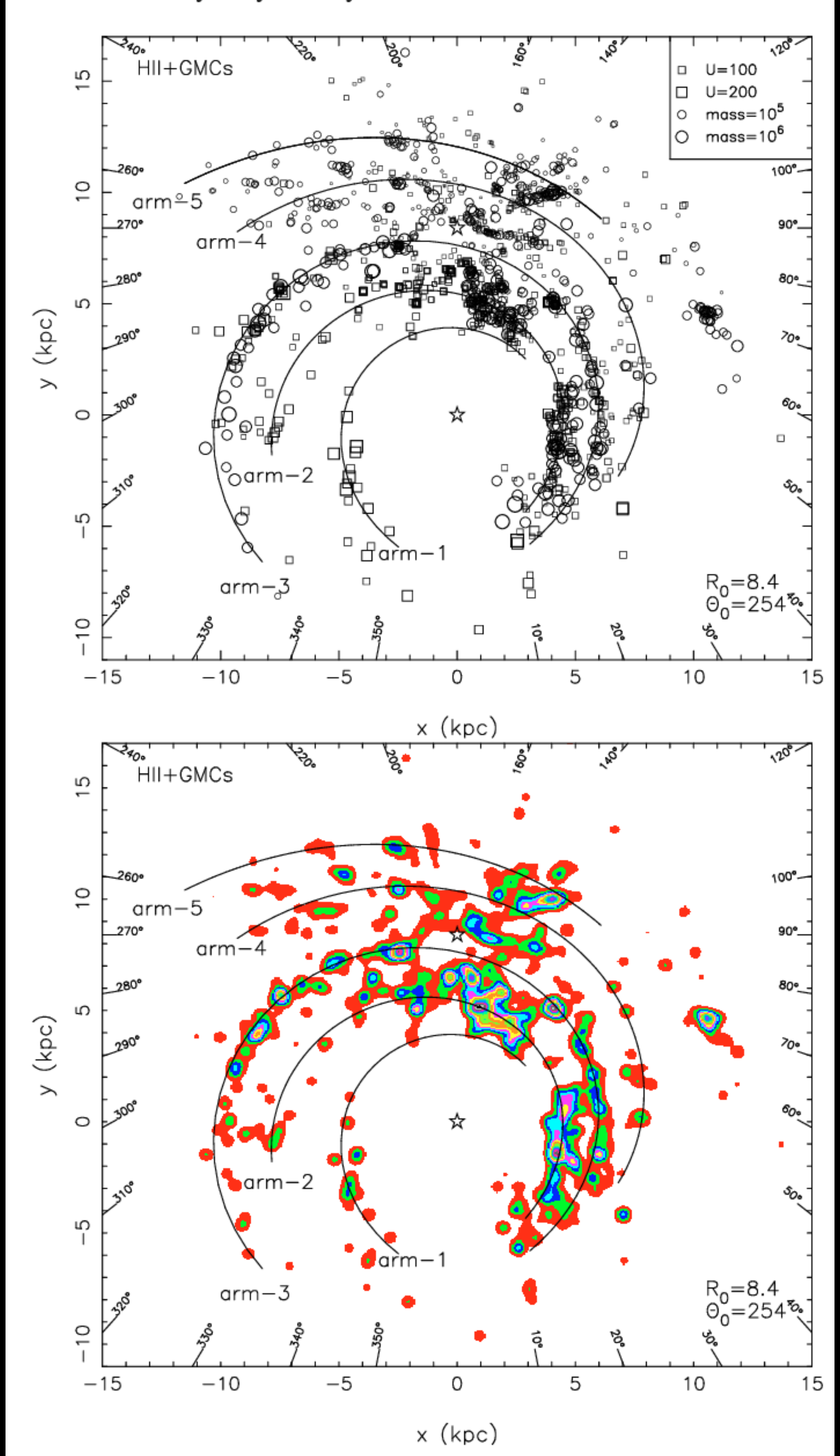
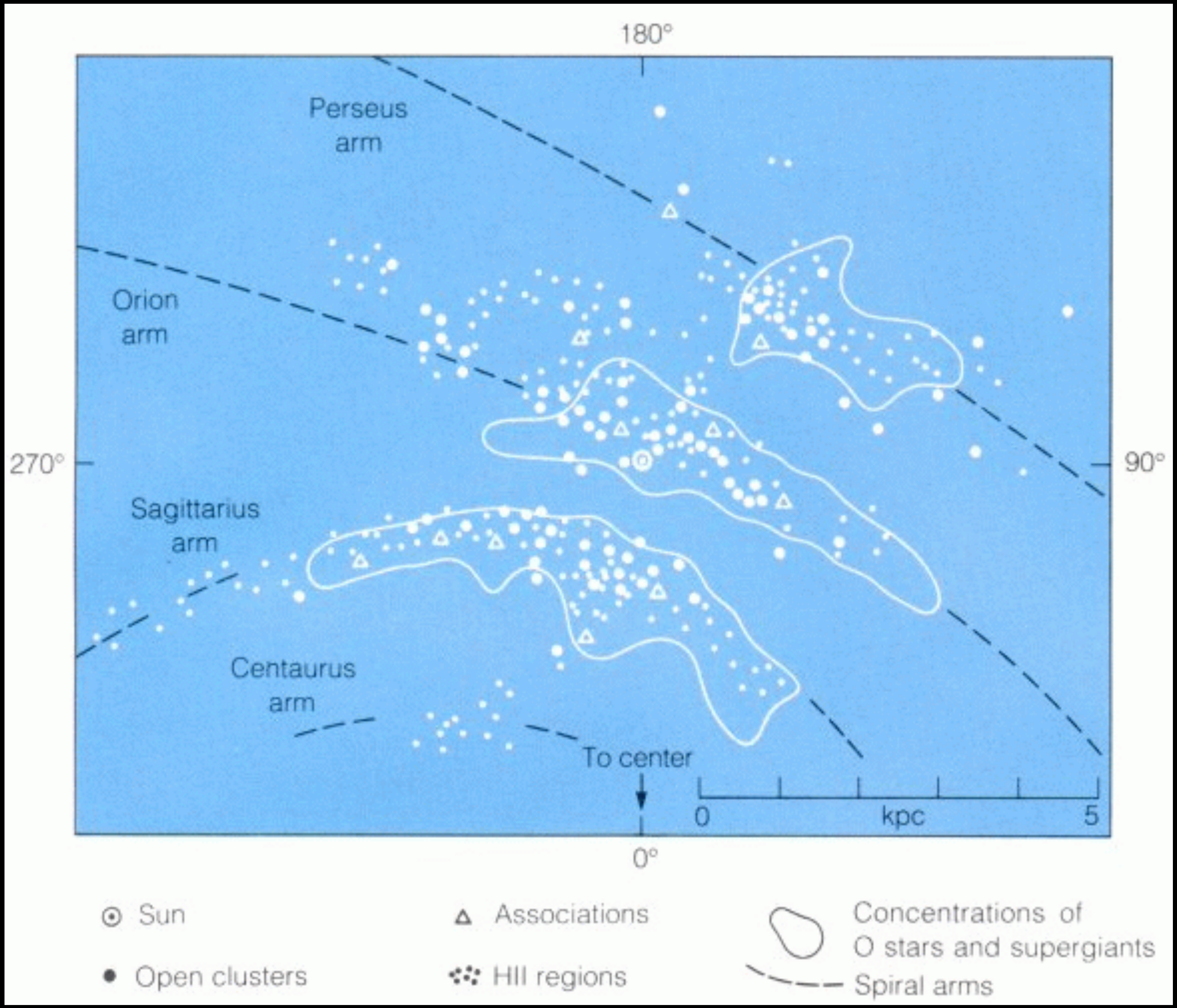


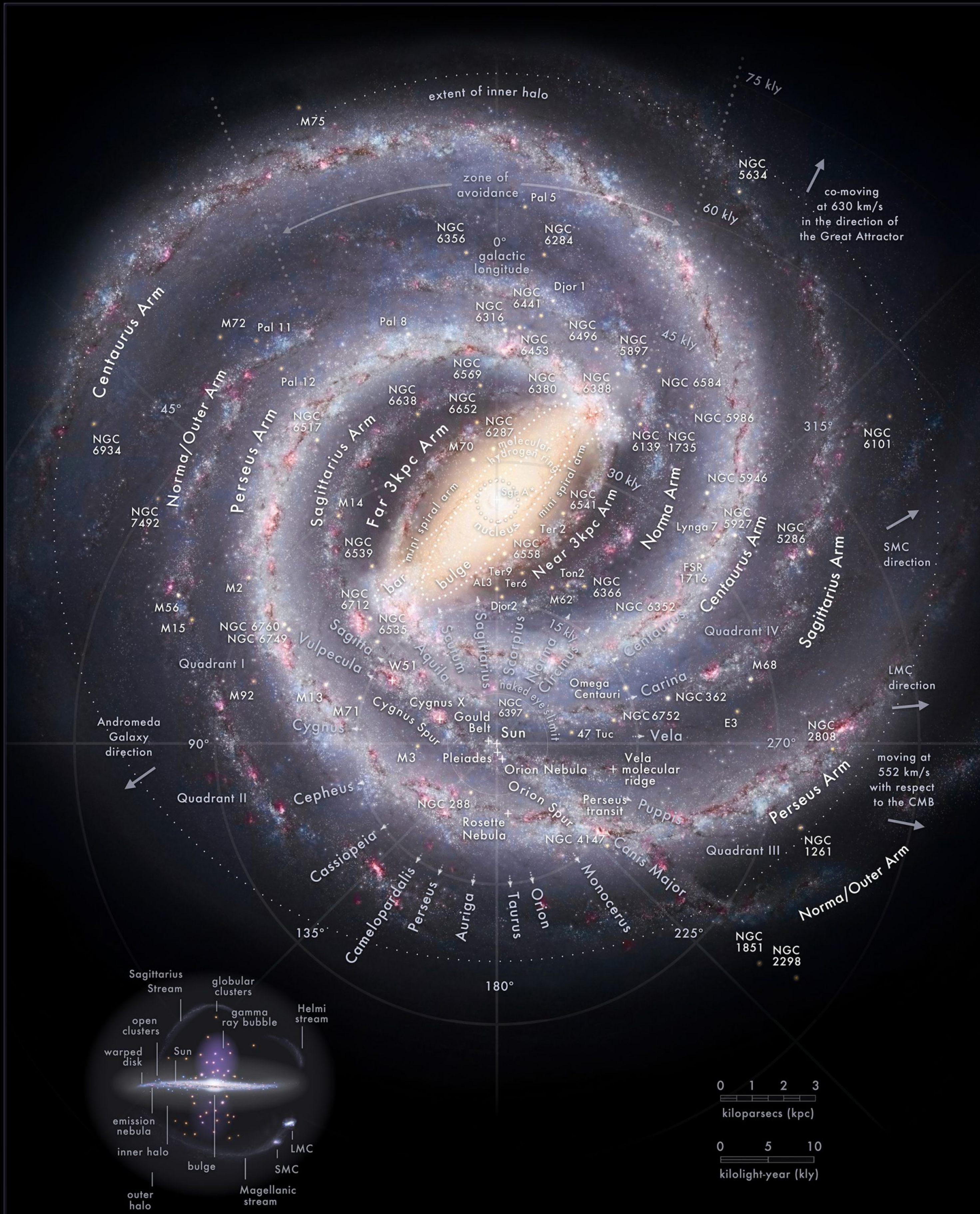
It is difficult to measure the structure of our Galaxy since we are inside it (trying to see the forest from the trees). One method is to plot the position of tracers, such as HI gas above (the yellow arrow is the position of the Sun, blue dot is the Galactic Center).

Other tracers are the position of nearby HII regions, young clusters of stars and giant molecular clouds. Since these are all young objects, then they will not have drifted far from their formation places.

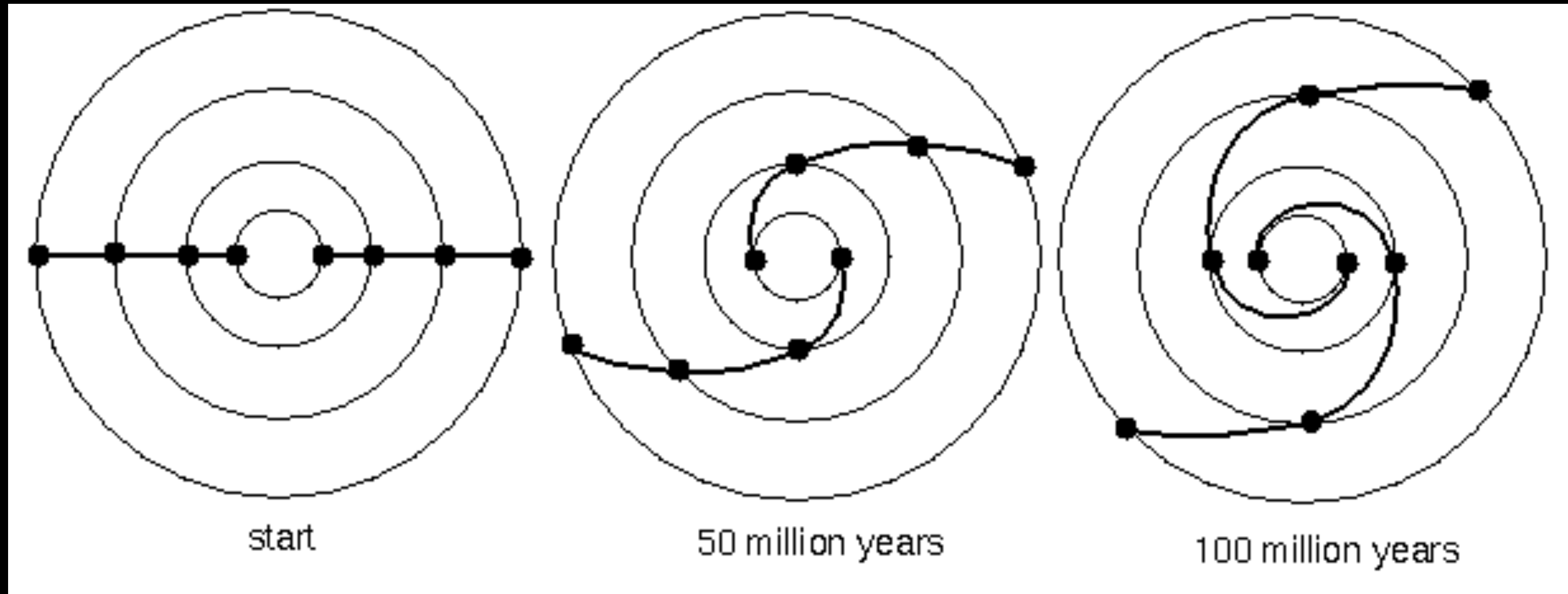




Interstellar extinction prevents a map much larger than the one above for optical tracers, but even this plot is enough to show that there are distinct arms of material in the Galaxy.

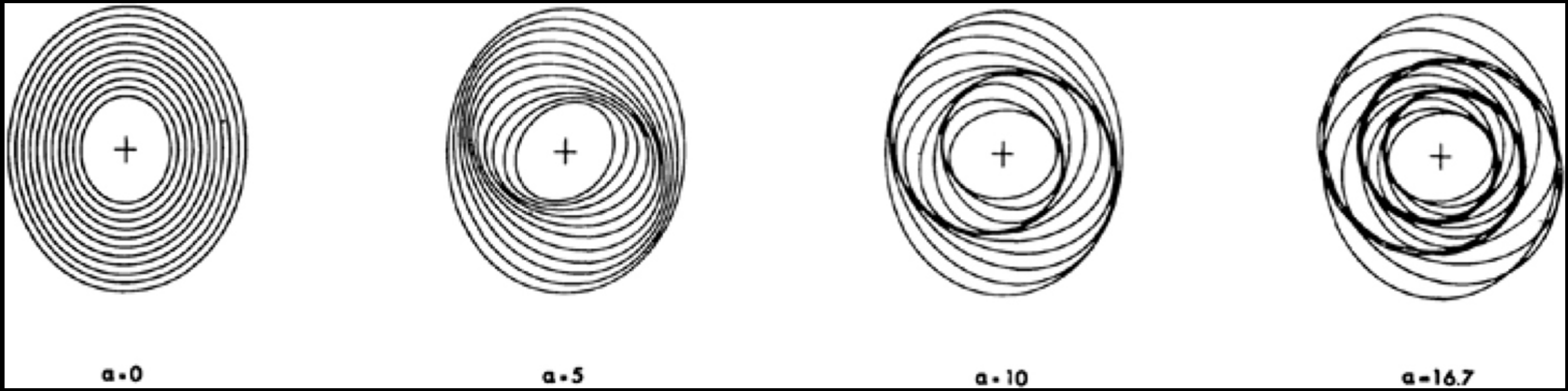


MILKY WAY GALAXY



Differential rotation: stars near the center take less time to orbit the center than those farther from the center. Differential rotation can create a spiral pattern in the disk in a short time.

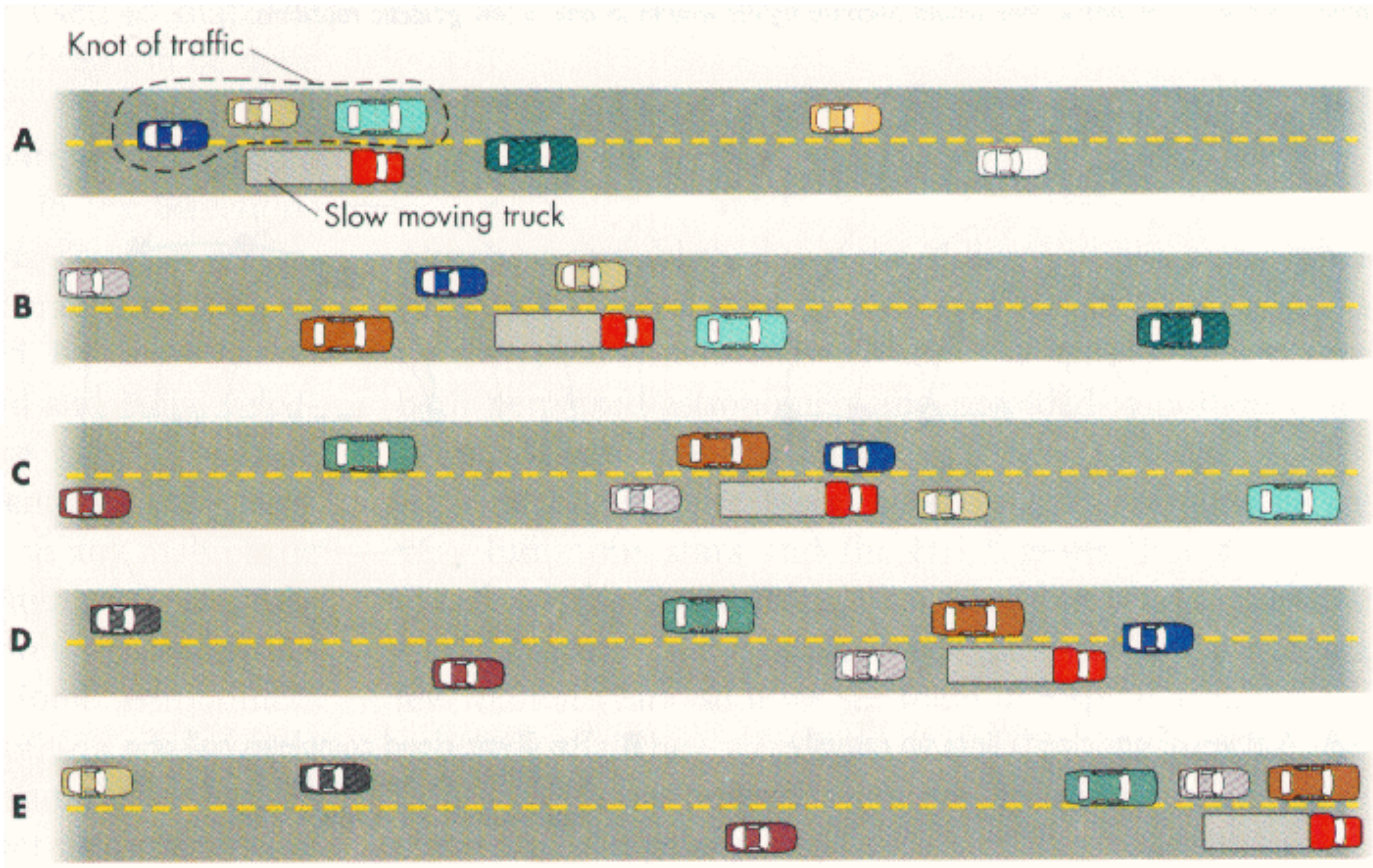
It is somewhat surprising that we even see a spiral pattern since the Galaxy does not rotate as a solid body. After a few rotations, the spiral pattern would be wound up very tight, as shown in the diagram below. This is known as the winding dilemma.

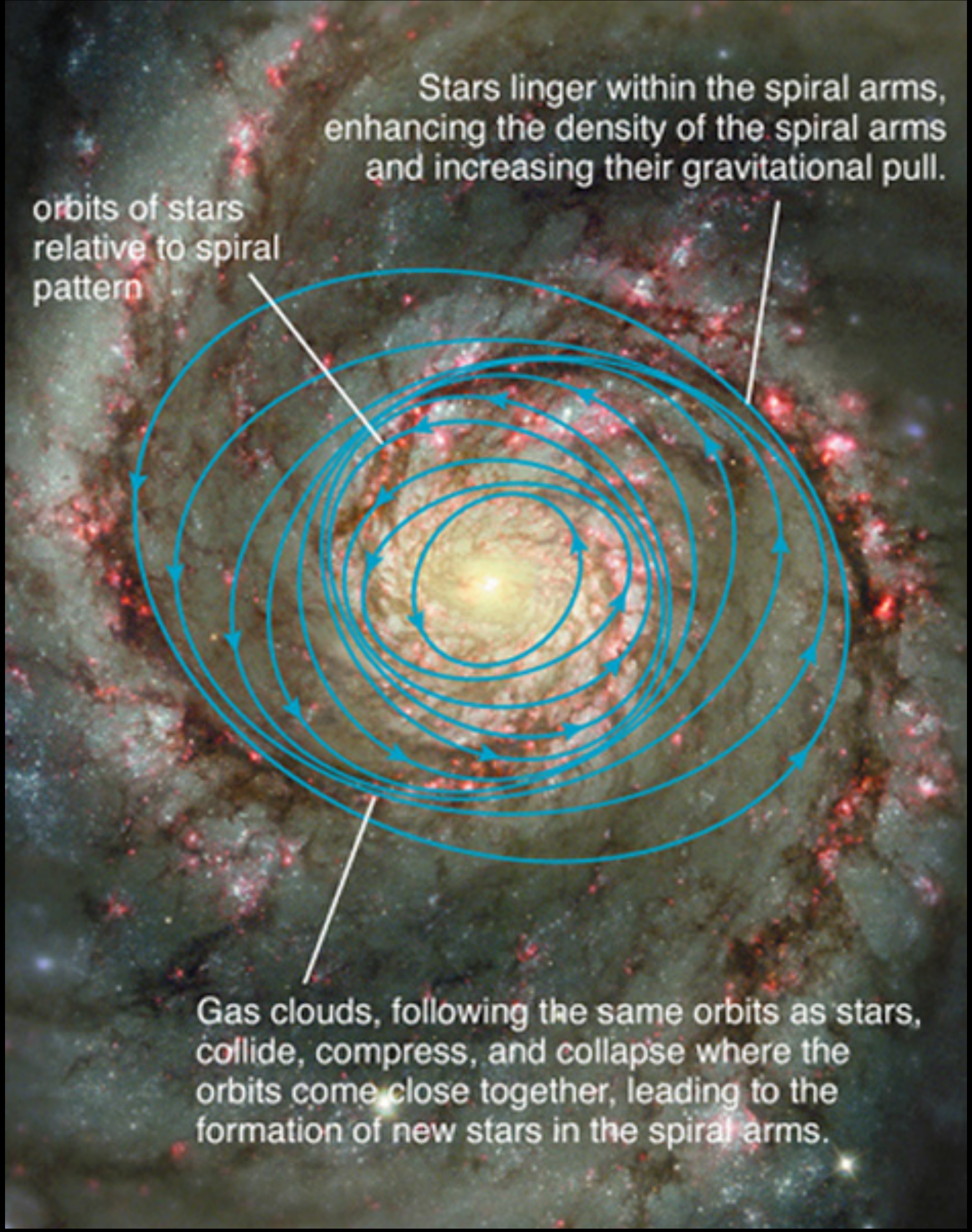


One explanation for the winding dilemma is to use density waves. Imagine a scenario such as shown below.

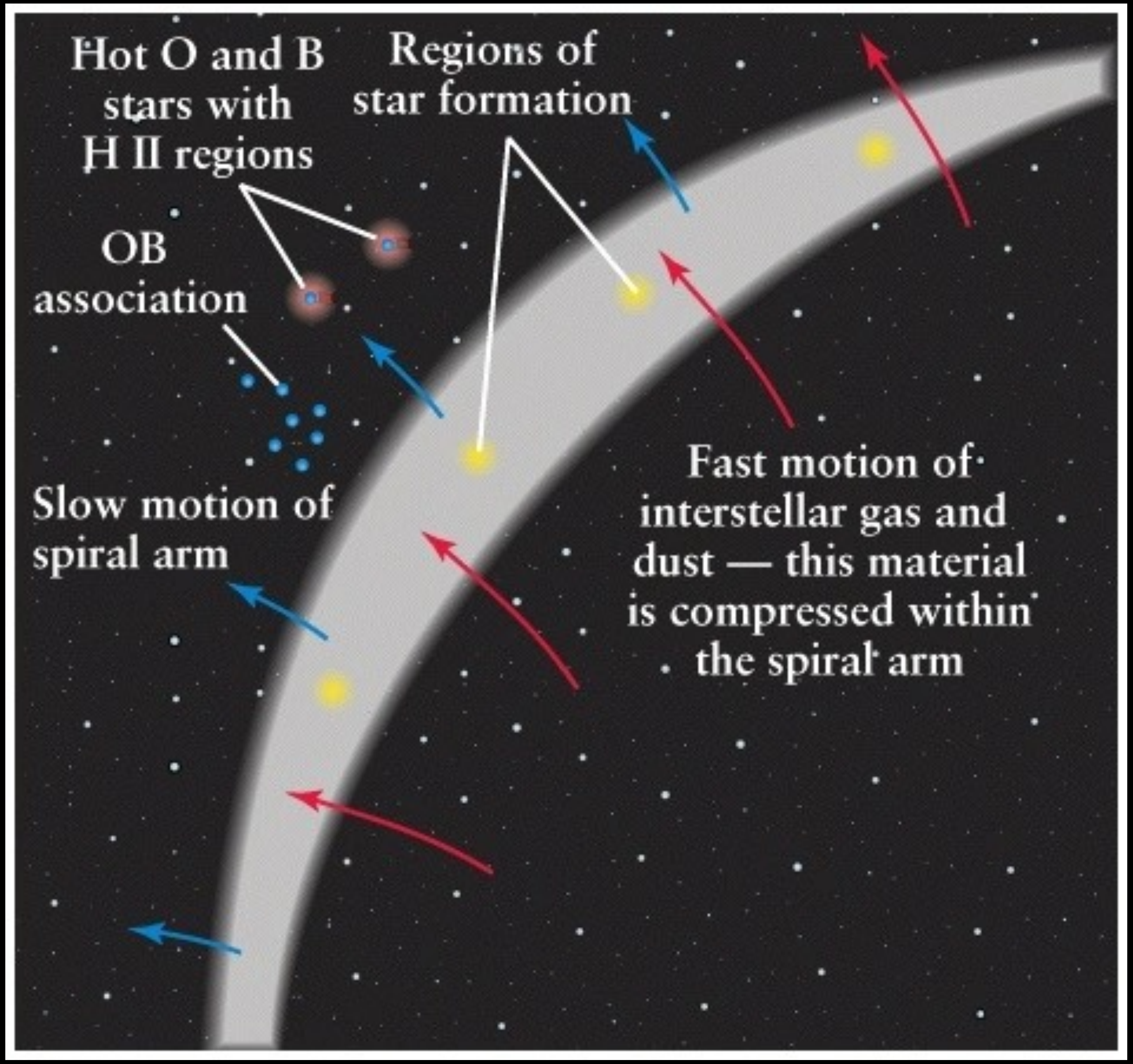
Density Wave

A slow moving truck causes a knot of traffic that moves along the highway at the speed of the truck. Individual cars approach the traffic know, slow down as they move carefully through the knot, and then resume speed as they leave the knot. As a result, the traffic knot consists of different cars at different times.



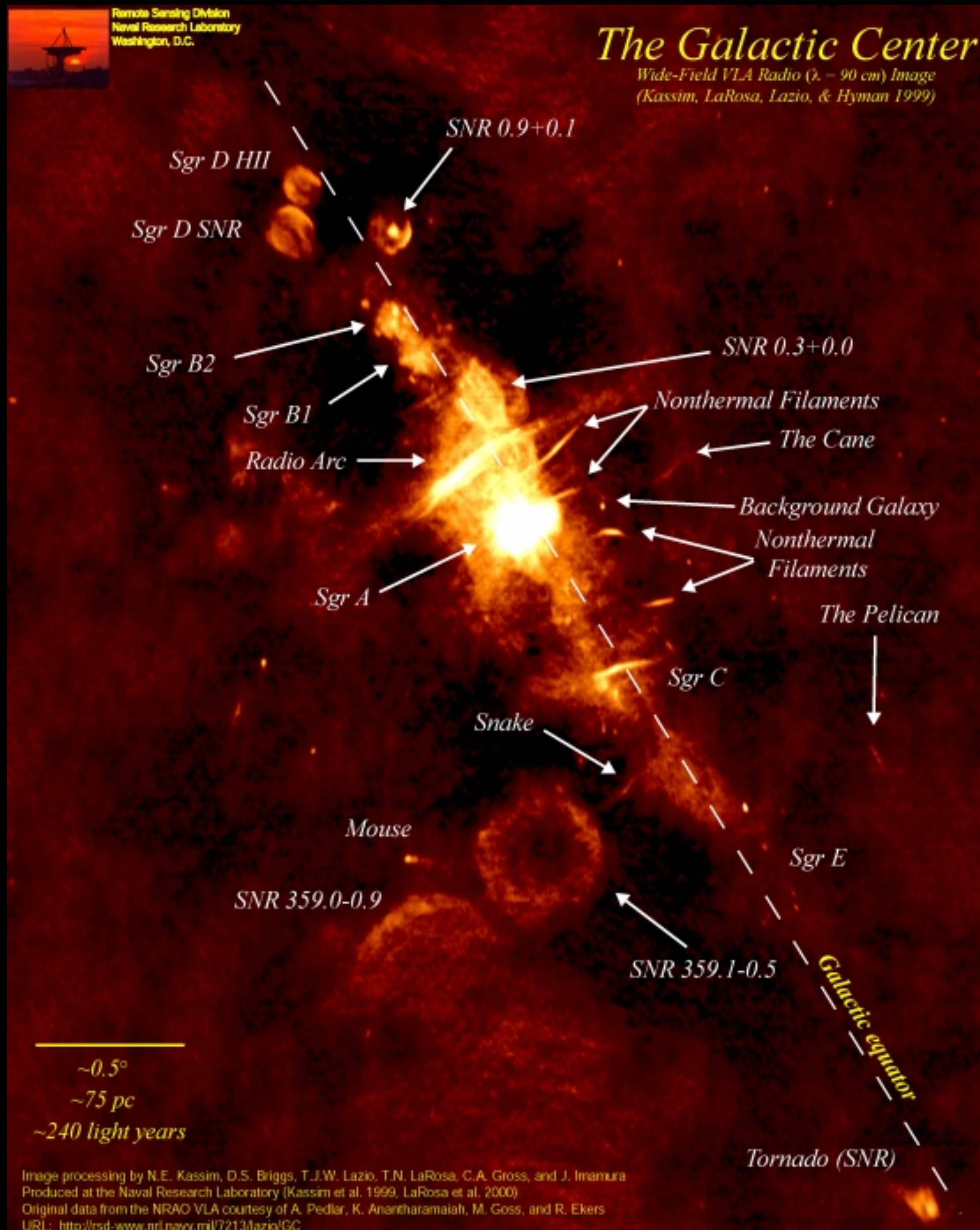


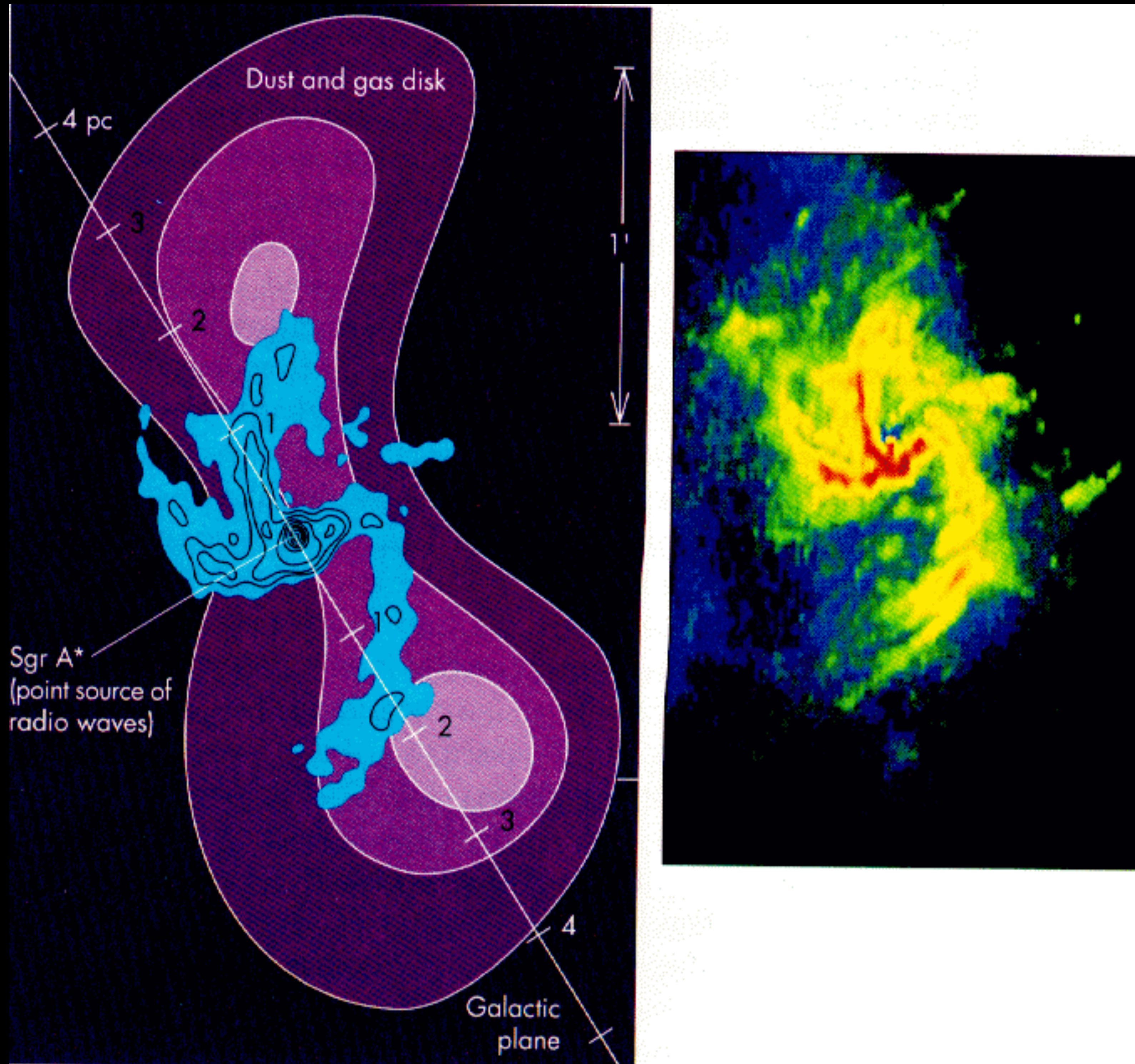
A similar explanation is proposed for spiral arms in our Galaxy, they exist because they exert a gravitational influence on stars and gas that orbit the Galaxy. In particular, gas clouds will orbit slower in the arms and, thus, the density goes up in this region. The spiral arms don't wind up because they are not made of material arms, but rather density patterns that shift like cars in traffic.



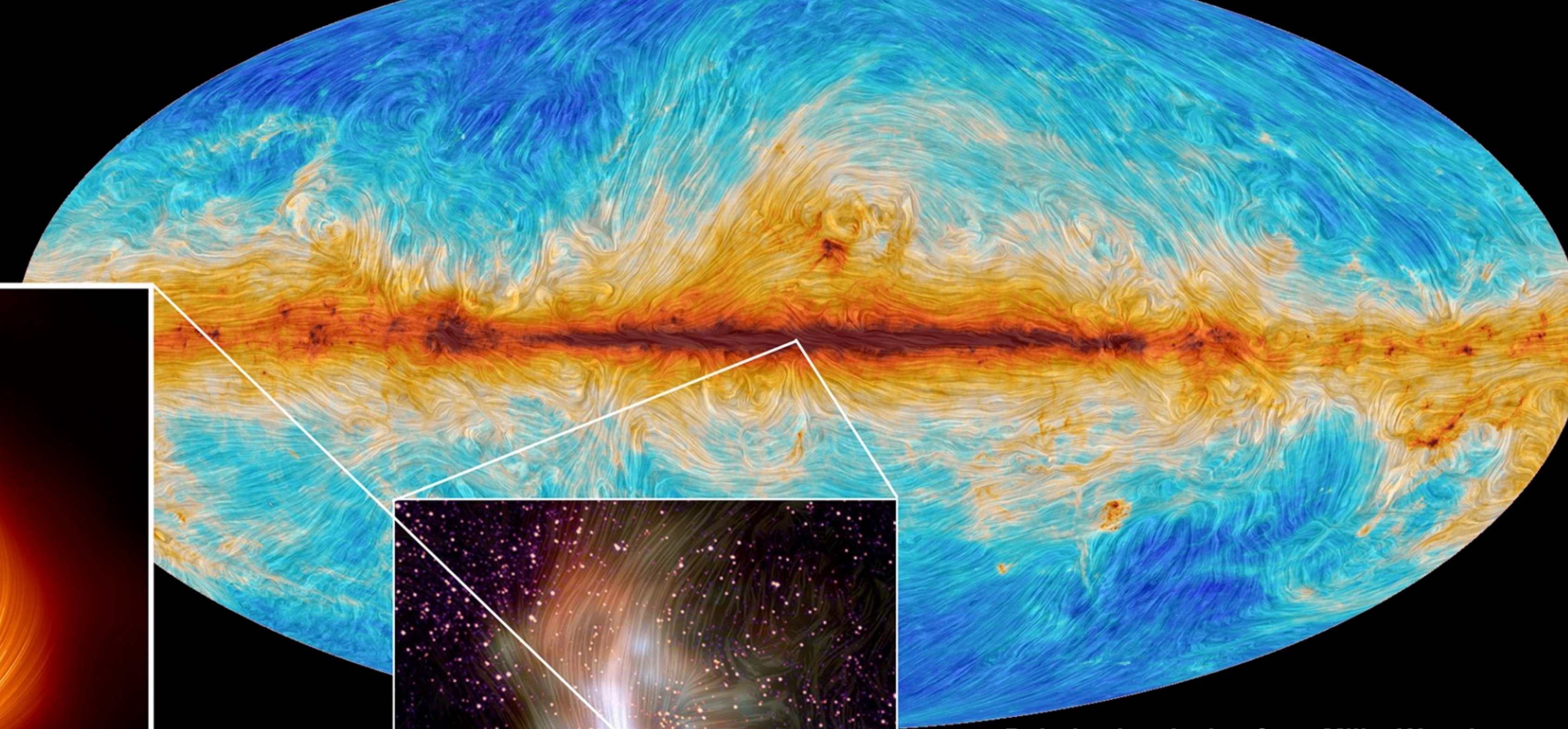
The concentration of gas in the spiral arms explains why neutral hydrogen maps trace spiral structure, but why do young stars occur in spiral arms. Higher density of gas means more gas clouds and cloud collisions. This sparks star formation, which leads to HII regions and young clusters. As the young stars age, they drift out of the spiral pattern.

The center of the Galaxy is obscured from us by thick interstellar clouds of gas and dust. We can observe the Galactic bulge as an ellipse of stars above and below the Galactic plane. In the solar neighborhood, the stellar density is about one star per cubic parsec (one parsec is 3.26 light-years). At the Galactic core, around 100 parsecs from the Galactic center, the stellar density has risen to 100 per cubic parsec, crowded together because of gravity.


Remote Sensing Division
Naval Research Laboratory
Washington, D.C.
The Galactic Center
Wide-Field VLA Radio (λ ~ 90 cm) Image
(Kassim, LaRosa, Lazio, & Hyman 1999)
SNR 0.9+0.1
Sgr D HII
Sgr D SNR
Sgr B2
SNR 0.3+0.0
Sgr B1
Nonthermal Filaments
The Cane
Radio Arc
Background Galaxy
Nonthermal
Filaments
Sgr A
The Pelican
Sgr C
Snake
Mouse
Sgr E
SNR 359.0-0.9
SNR 359.1-0.5
Galactic equator
~0.5°
~75 pc
~240 light years
Tornado (SNR)
Image processing by N.E. Kassim, D.S. Briggs, T.J.W. Lazio, T.N. LaRosa, C.A. Gross, and J. Imamura
Produced at the Naval Research Laboratory (Kassim et al. 1999, LaRosa et al. 2000)
Original data from the NRAO VLA courtesy of A. Pedlar, K. Anantharamaiah, M. Goss, and R. Ekers
URL: http://rsd-www.nrl.navy.mil/7213/lazio/GC

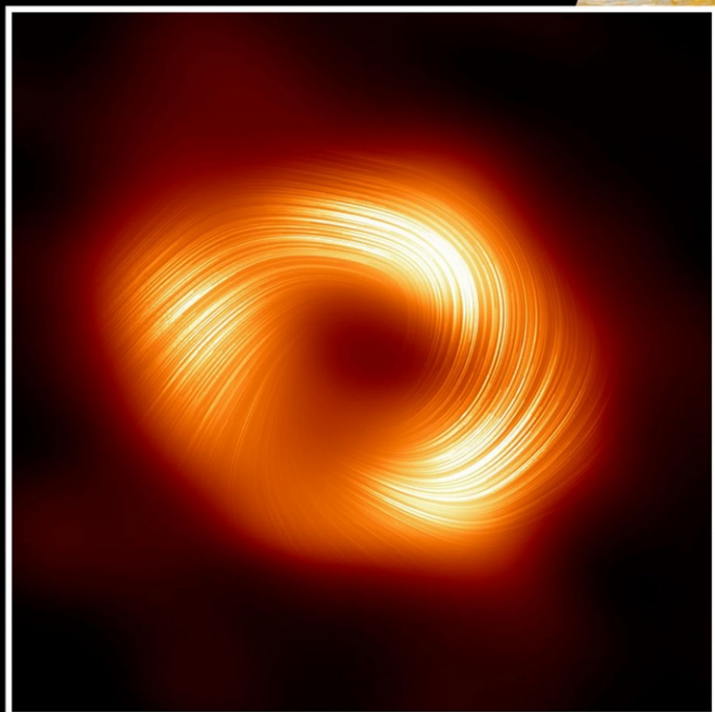


As one approaches the Galactic center, not only does the number of stars increase, but a thin ring of gas and dust forms visible by its radio radiation. Streamers of gas are visible in the image below, suggesting an accretion disk over 10 parsecs in size.



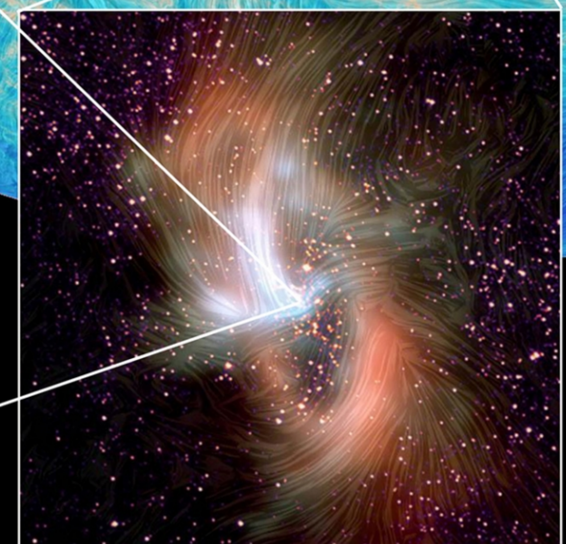
Polarized emission from Milky Way dust

Cr. ESA and the Planck Collaboration



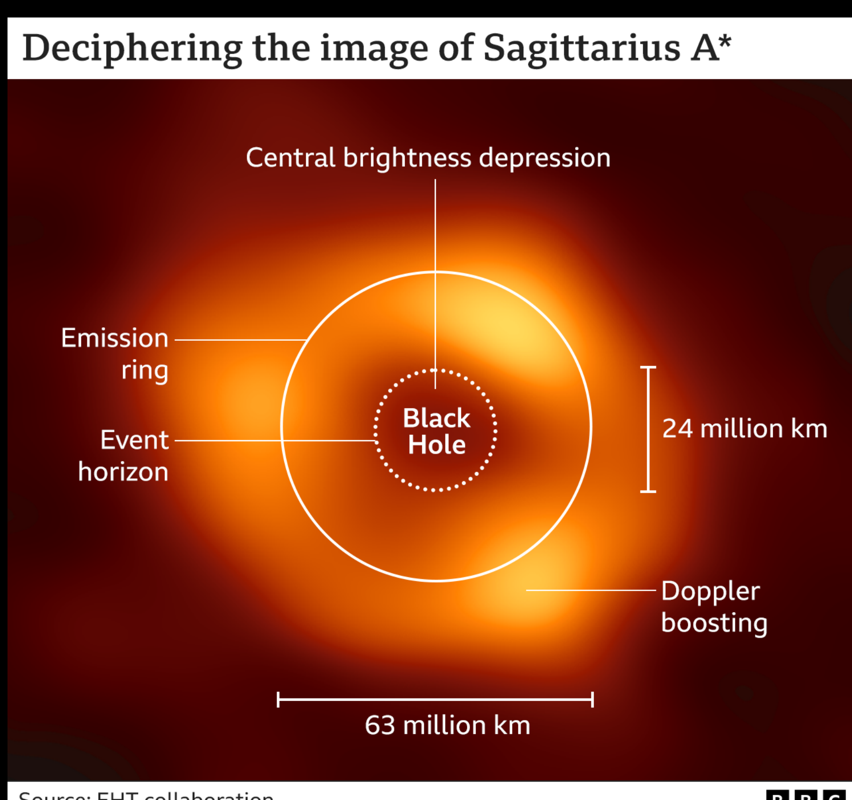
Polarized emission from plasma around our Milky Way supermassive black hole Sagittarius A*

Cr. Event Horizon Telescope Collaboration

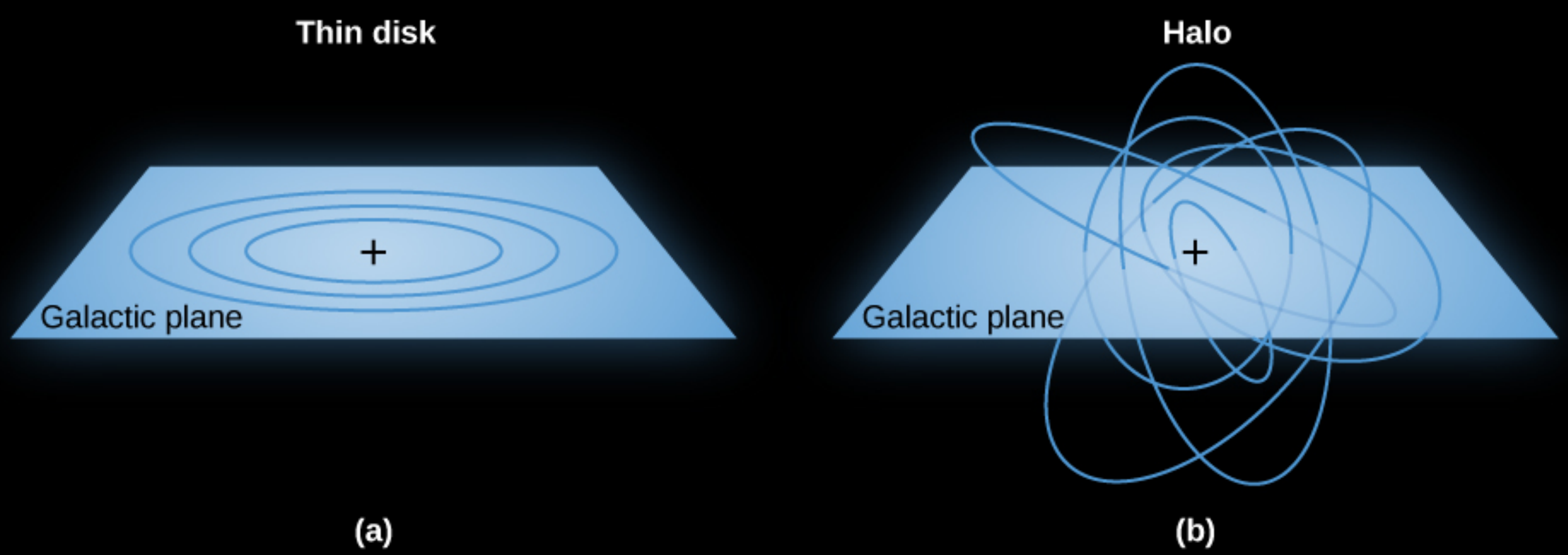


Polarized emission from dust at the center of our Milky Way

Cr. NASA/SOFIA, NASA/Hubble Space Telescope/NICMOS.



The rotation speeds of this inner gas ring indicates that the object located at Sgr A is less than 13 A.U.s in size and masses over 1 million solar masses. Only a black hole of massive proportions would satisfy these requirements.

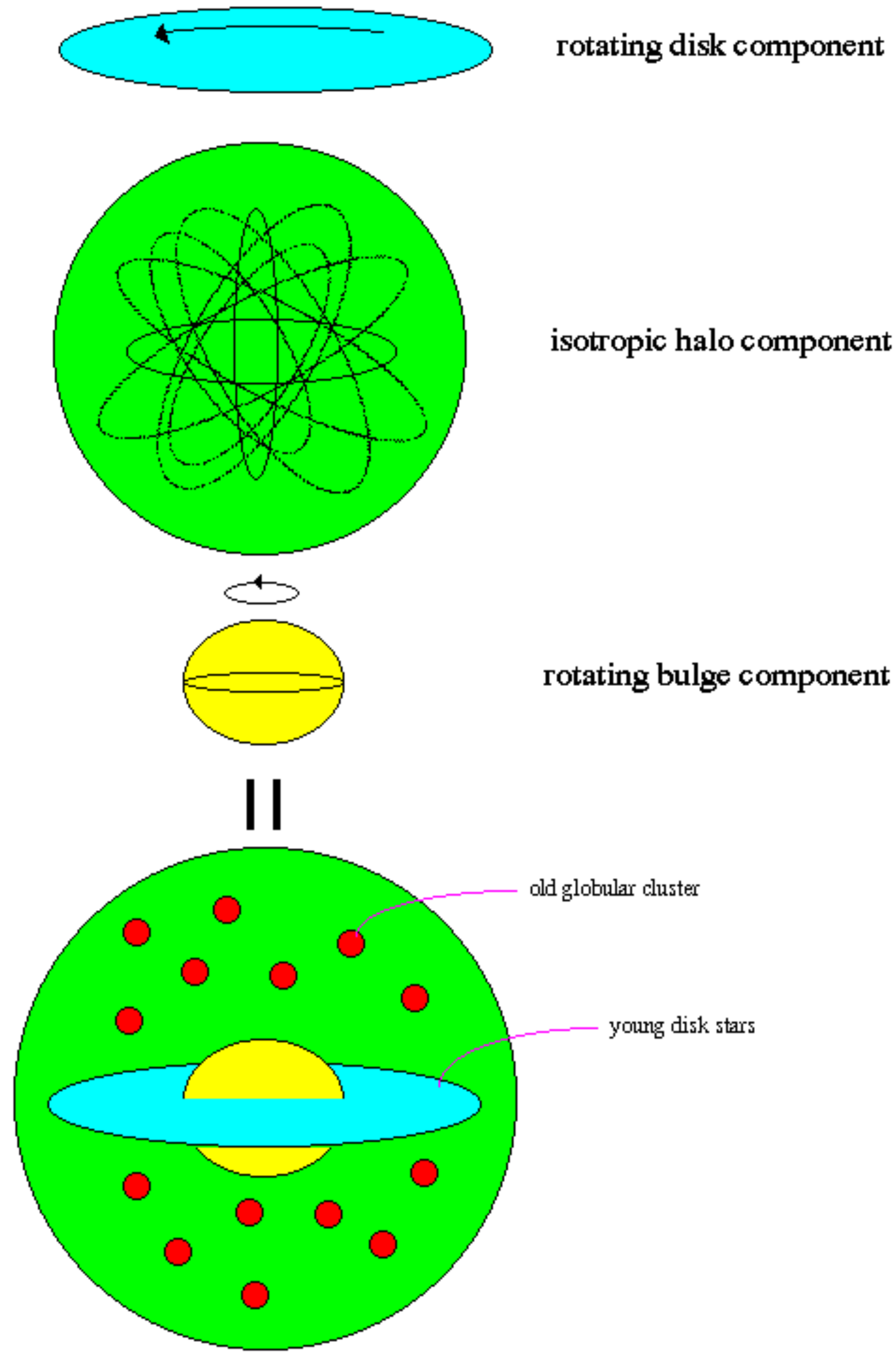


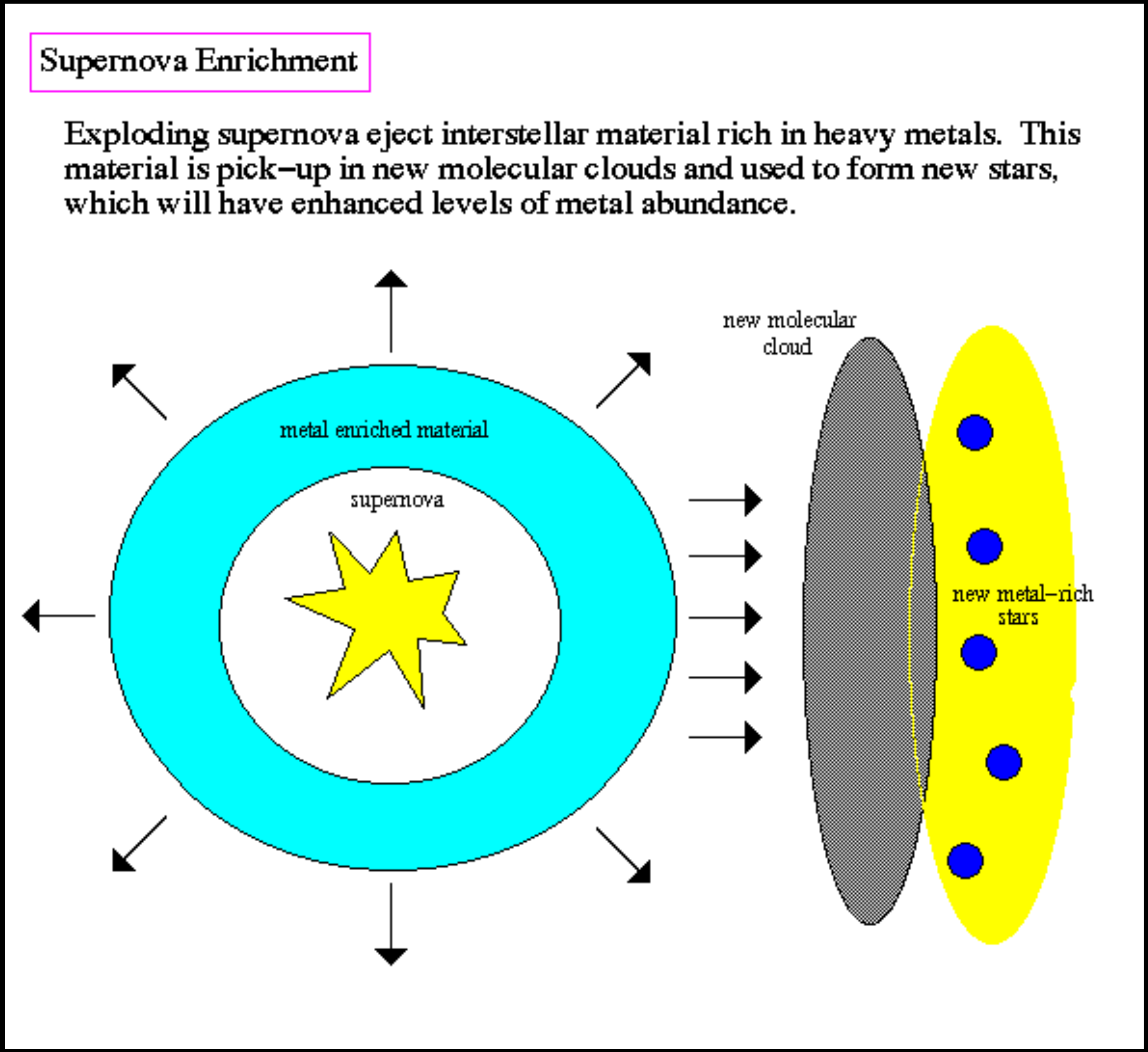
A group of stars within the Galaxy that resemble each other in spatial distribution, chemical composition or age are called a stellar population. Stellar populations are not discrete in their properties, but rather have a continuum of characteristics that reflect the changes in star formation with time. Stellar populations are tracers of events in our Galaxy's past and formation.

Stellar Populations

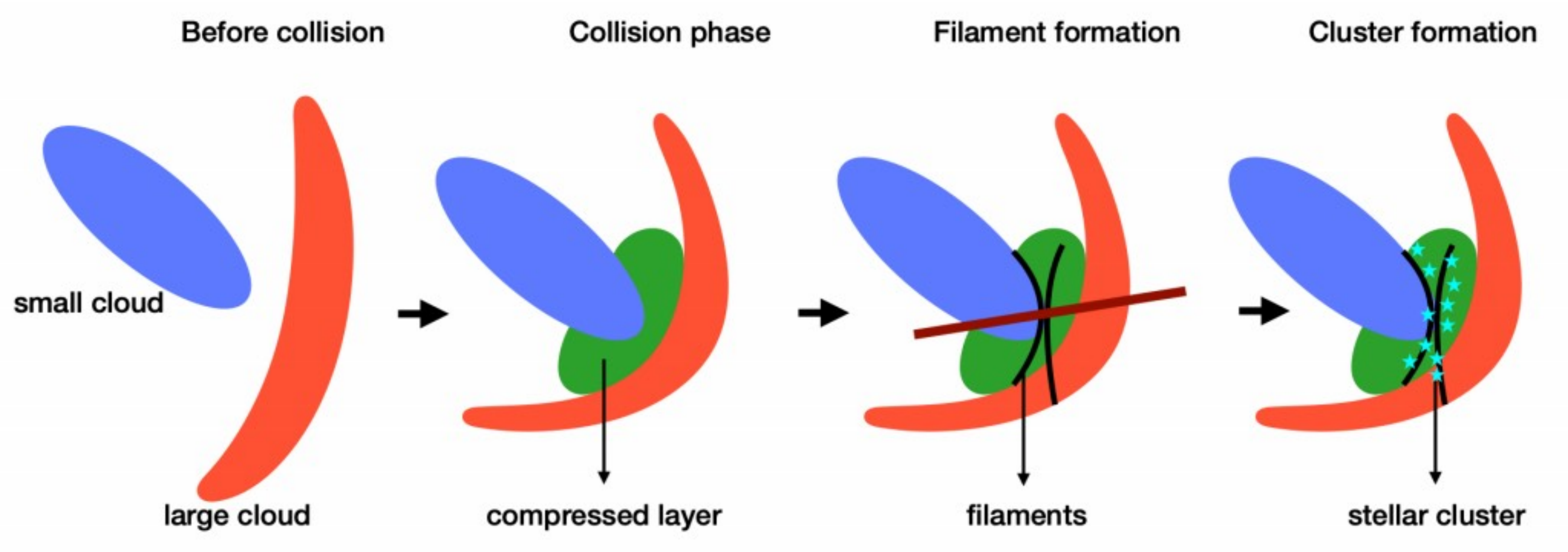
- Population I
  - Younger stars, found in disk of galaxy
  - 1 to 3% of star atoms are "metals"
    - Metal = element with more than 2 protons, not H, He
  - Orbits are in the plane of galaxy
- Population II
  - Older stars, found in halo, < 0.1 % metals
  - Orbits are inclined to plane of galaxy

There are basically three stellar populations in our Galaxy, corresponding to the three distinct dynamical components to the Galaxy; the disk population, the bulge population and the halo population. The disk population inhabits the rotating, flattened region of our Galaxy. The bulge population is restricted to the rounded, central region of the Galaxy, also rotating. And the halo population inhabits the far outer regions of the Galaxy, on long ellipisodal orbits that takes it into the disk and bulge.

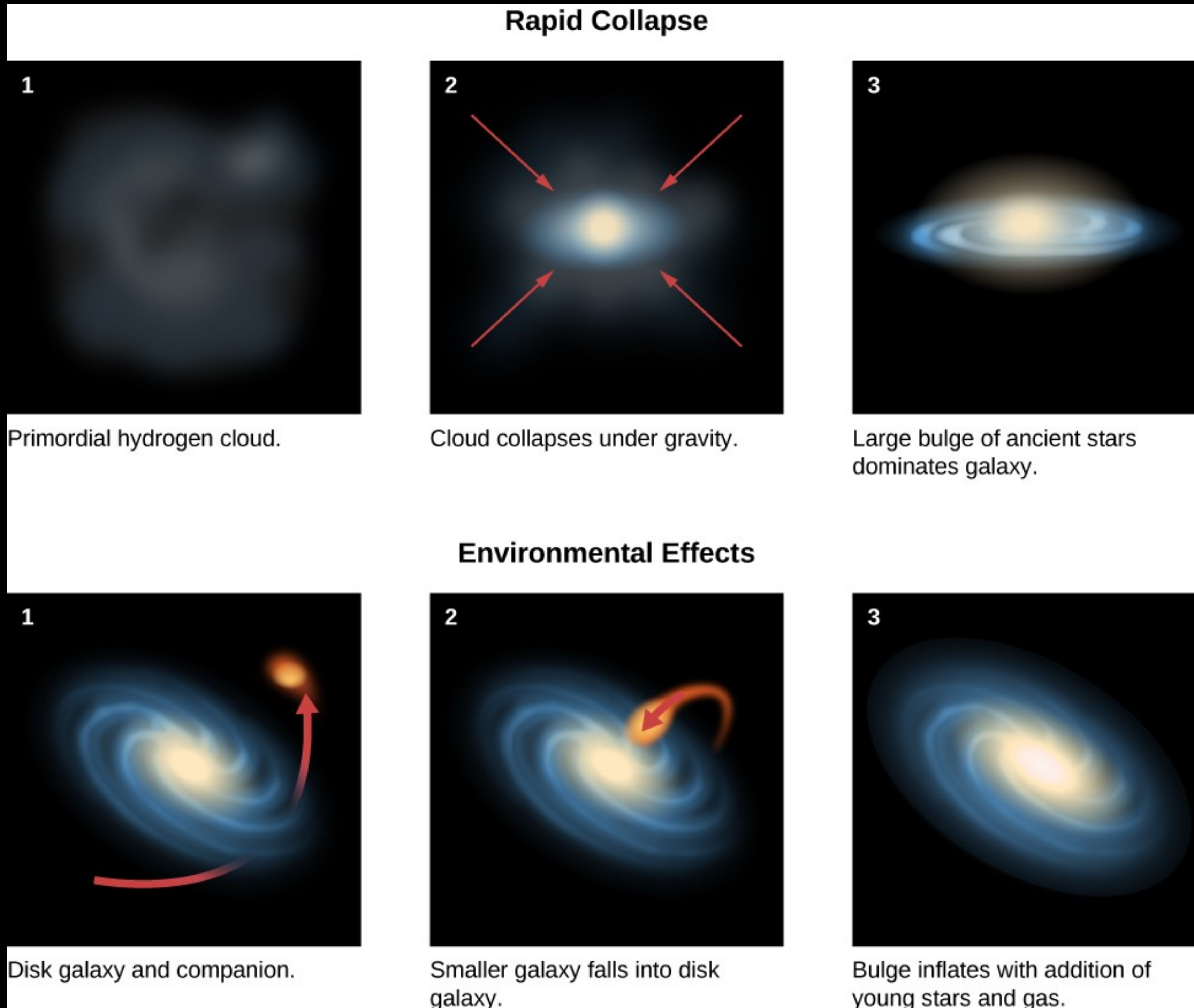

rotating disk component
isotropic halo component
rotating bulge component
old globular cluster
young disk stars



Changes in the chemical composition of a star are due to the initial chemical composition of the gas cloud that it was born from. This heavy elements are mostly produced by supernova explosions, gas clouds become enriched by the ejecta of supernova. The larger the number of supernova near a cloud, the richer in heavy elements it will become.



The key to understand how our Galaxy formed is the location, ages and chemical composition of the various stellar populations. The oldest stars are in the halo and bulge. The most metal rich stars are in the disk and bulge. From this we deduce that the halo formed first, followed by the bulge then disk. All the gas is located in the disk (which is rotating) because gas clouds can undergo inelastic collisions.



Even the above facts, the formation and evolution of our Galaxy must have taken place through a series of continuous stages. First, the Galaxy began as a large single gas cloud a few hundred of thousand light-years across. Passage near other proto-galaxies caused this large cloud to spin. This rotation was far from organized as currents and smaller clouds formed within the proto-Galaxy.