On to Galaxies....

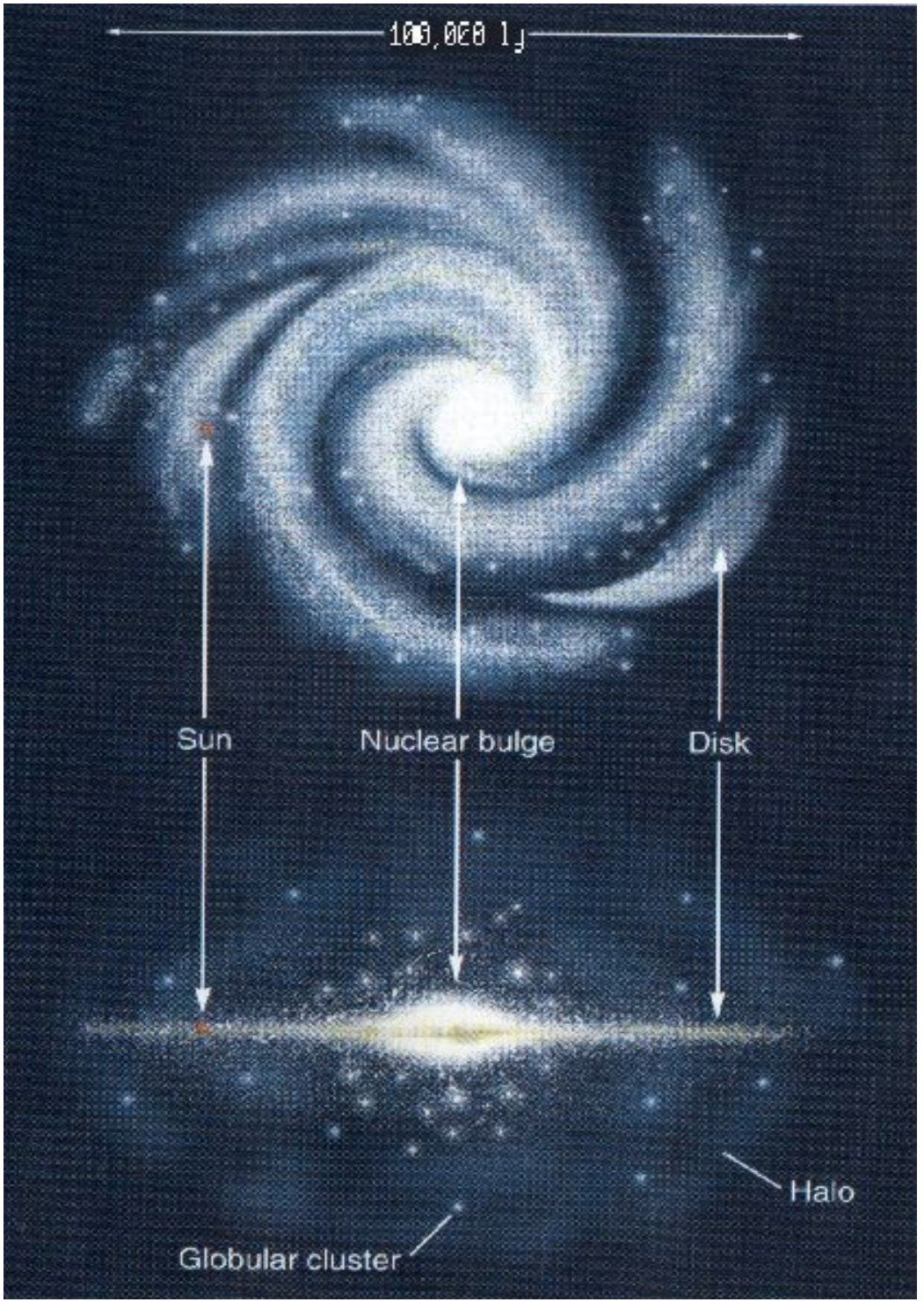
Galaxies

Galaxies are collections of stars and gas (and dust) that are gravitationally bound together.

Galaxies

We will start with the easiest galaxy to study: Our own Milky Way.

Our Milky Way galaxy contains over 200 billion stars (that's 2_x10^{11}!)

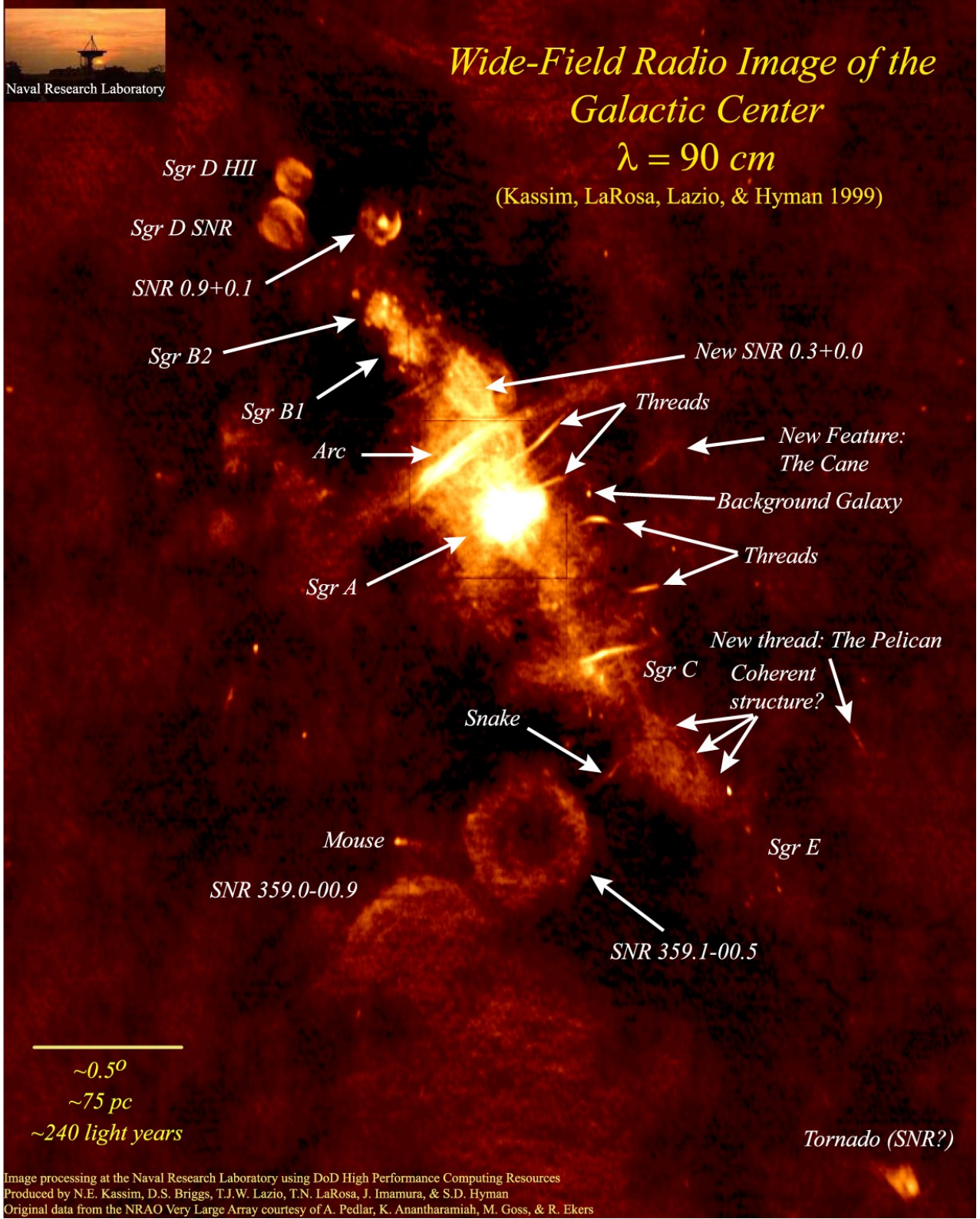


Our (spiral) Galaxy consists of 3 parts:

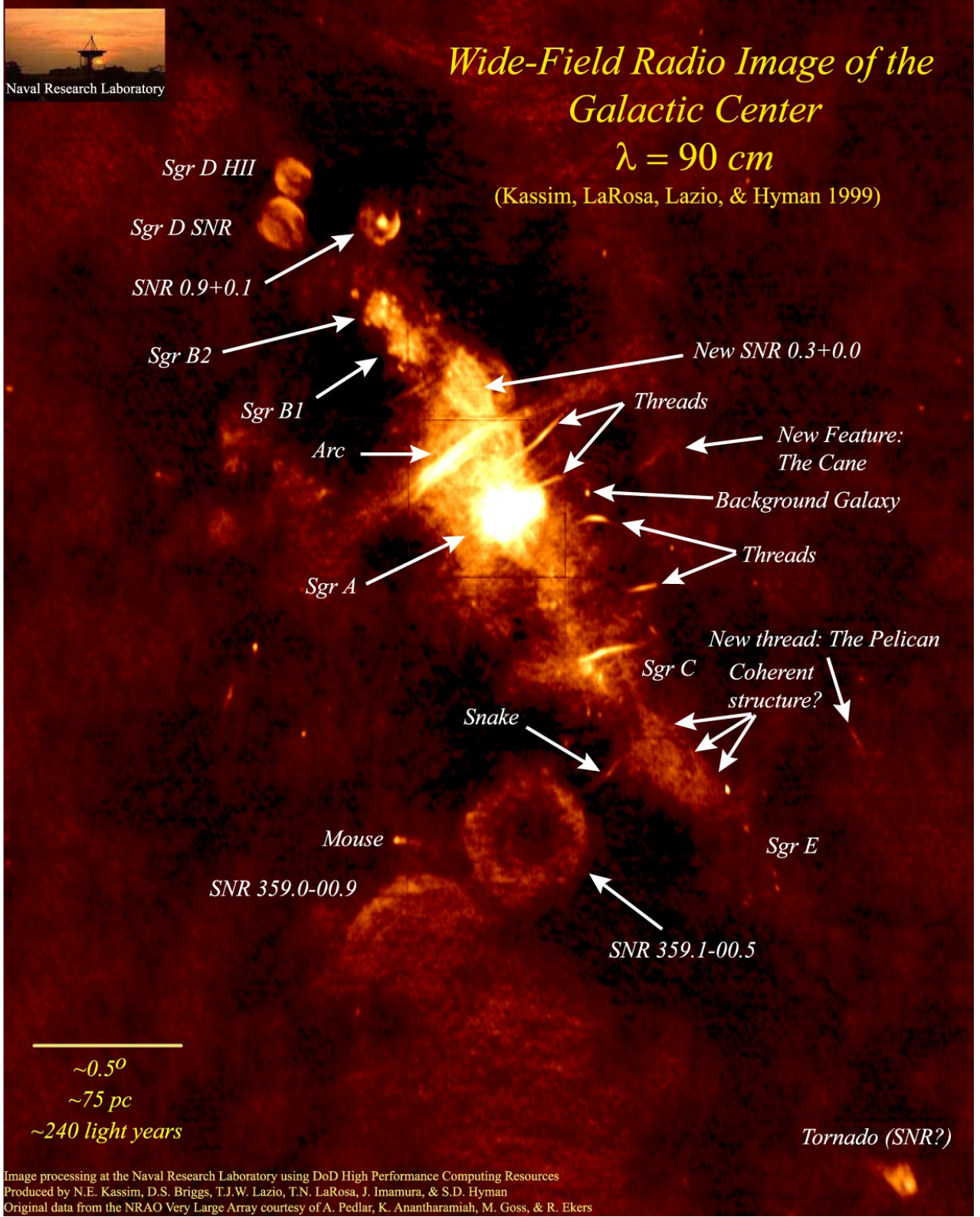
The Bulge (center)

The Disk and

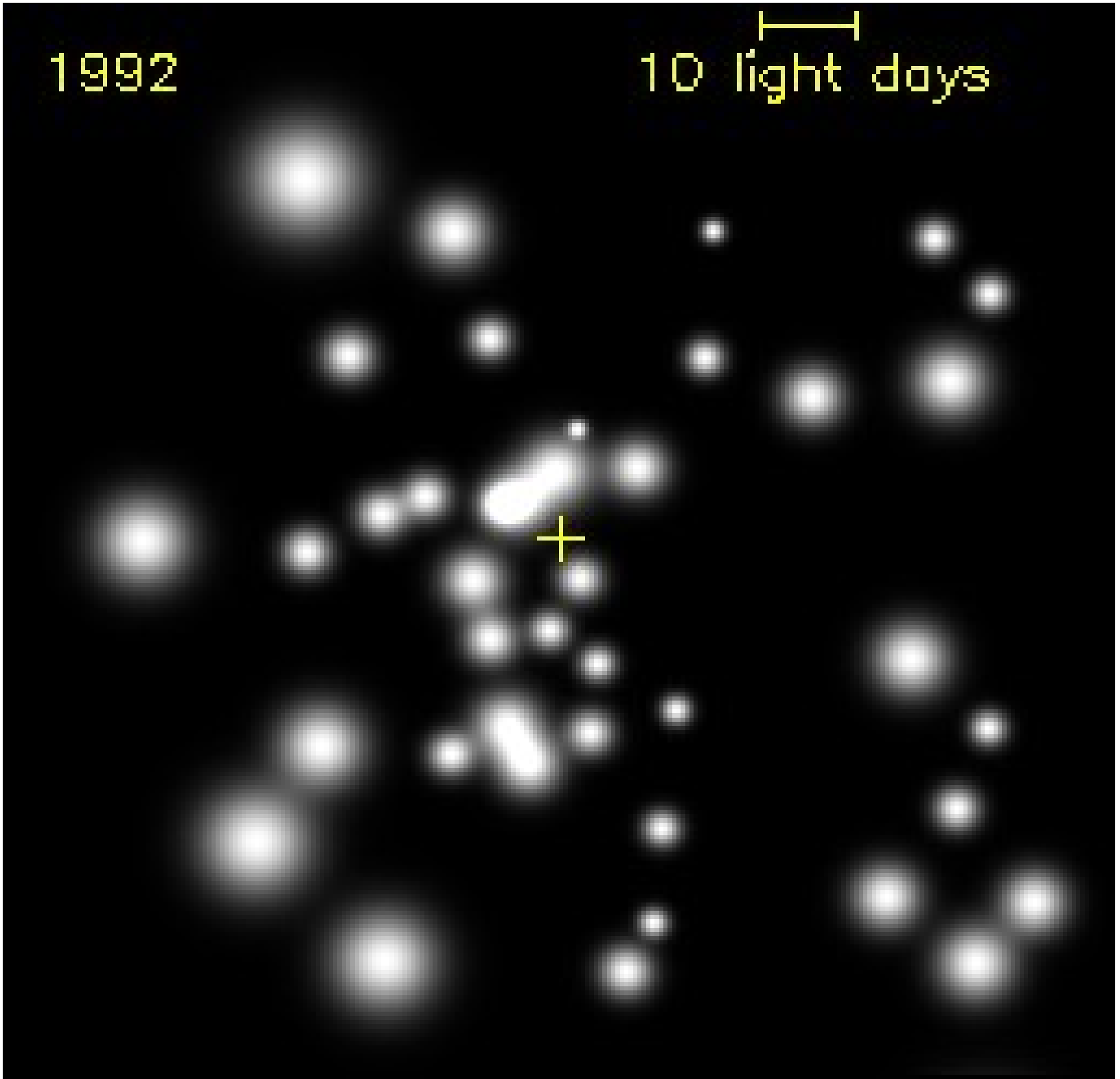
The Halo

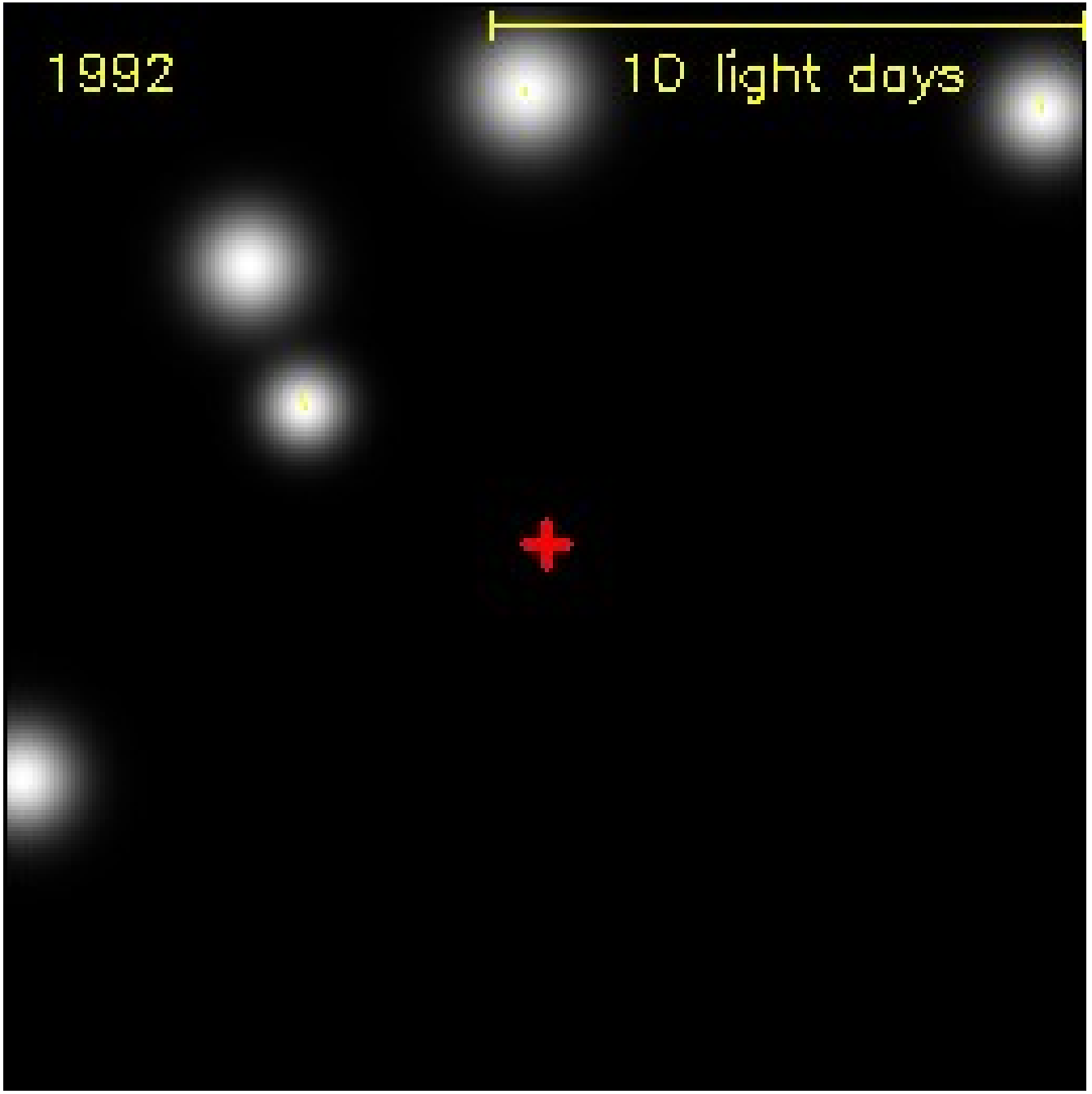


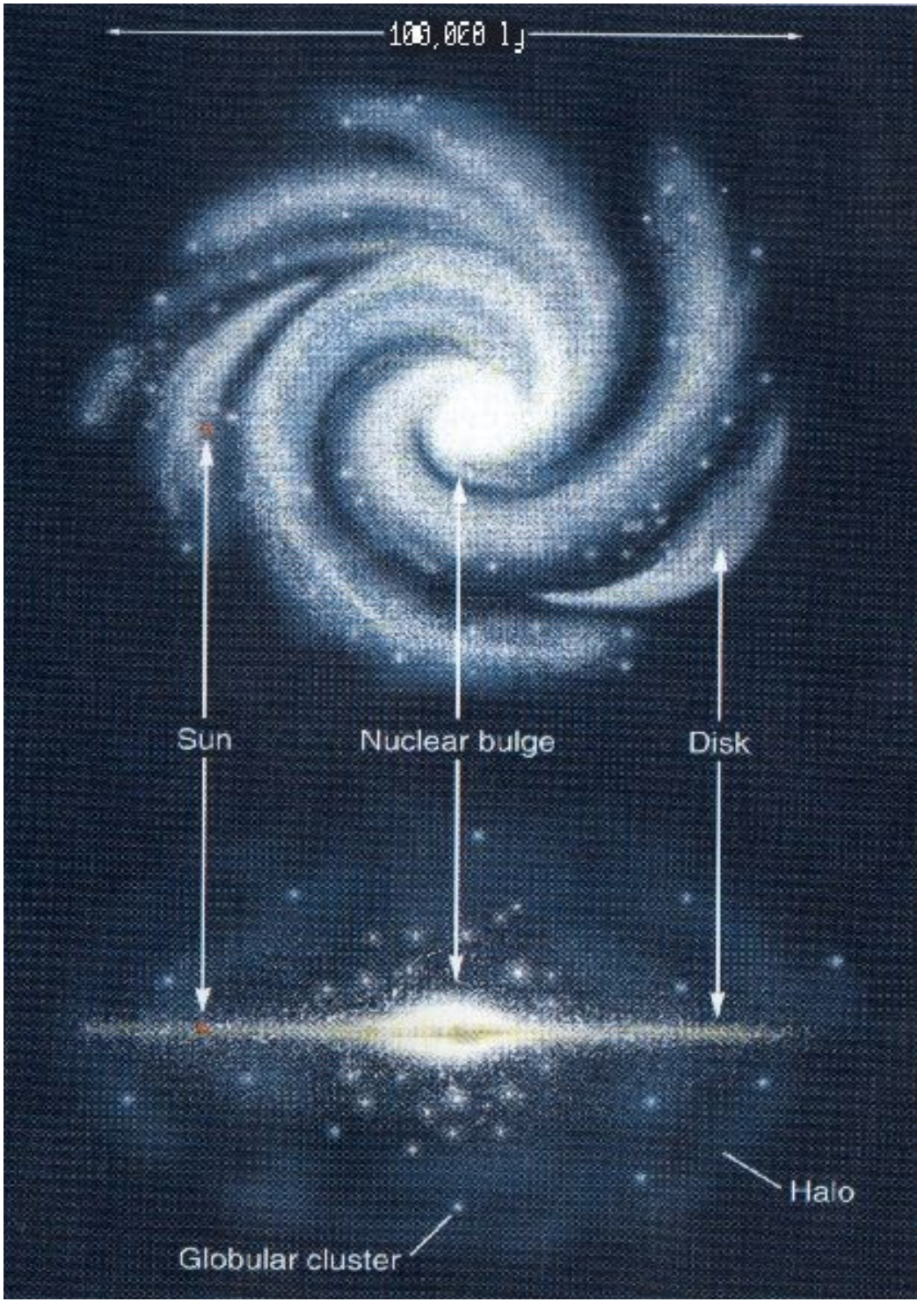
The bulge of our galaxy contains mostly old (Pop II), red stars (about 10 billion years old), which orbit in random directions.



The center of our galaxy has a black hole (as do nearly all bulges). Ours is about 5 million solar masses.


1992
10 light days


1992
10 light days



Our (spiral) Galaxy consists of 3 parts:

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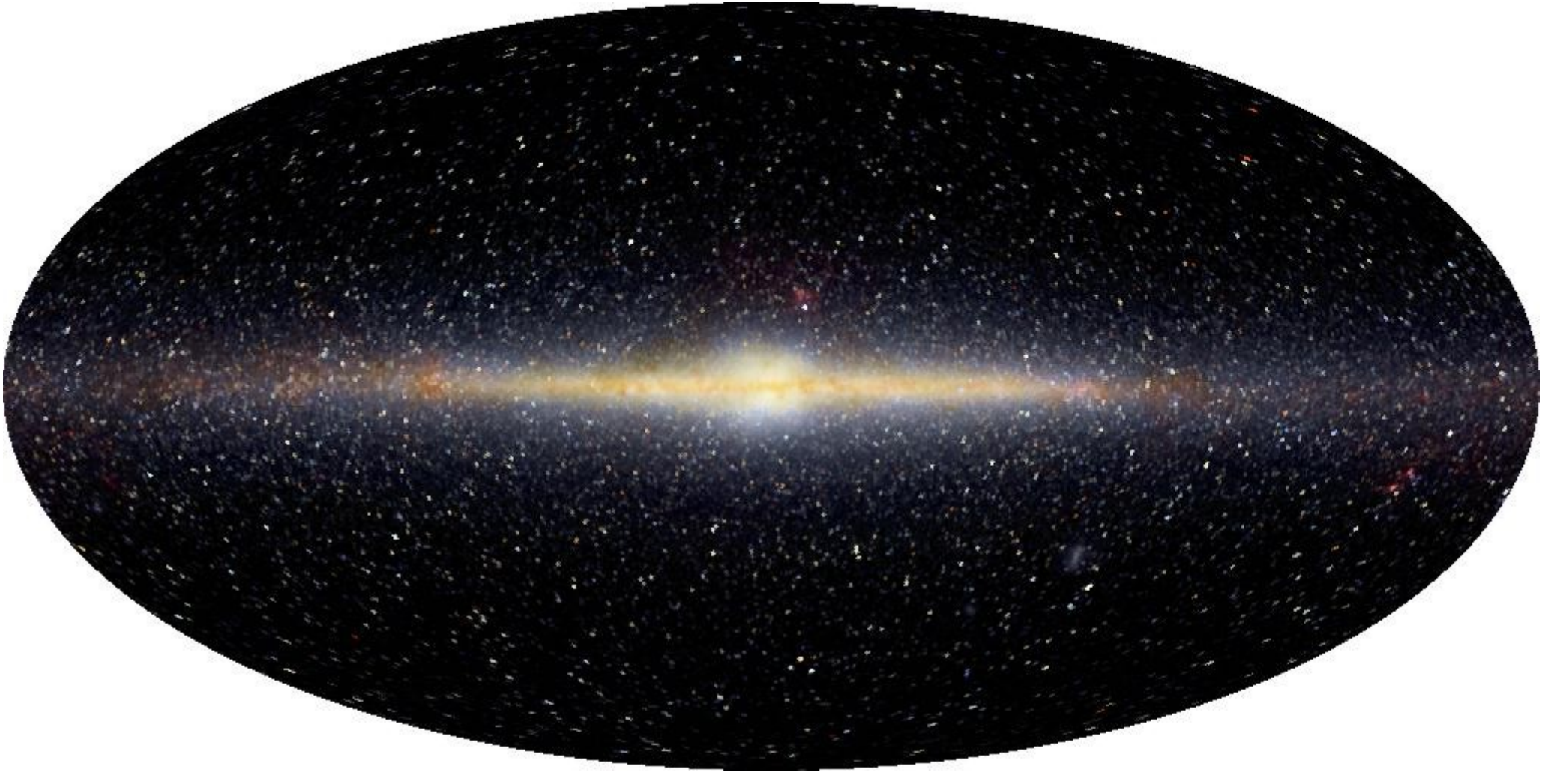
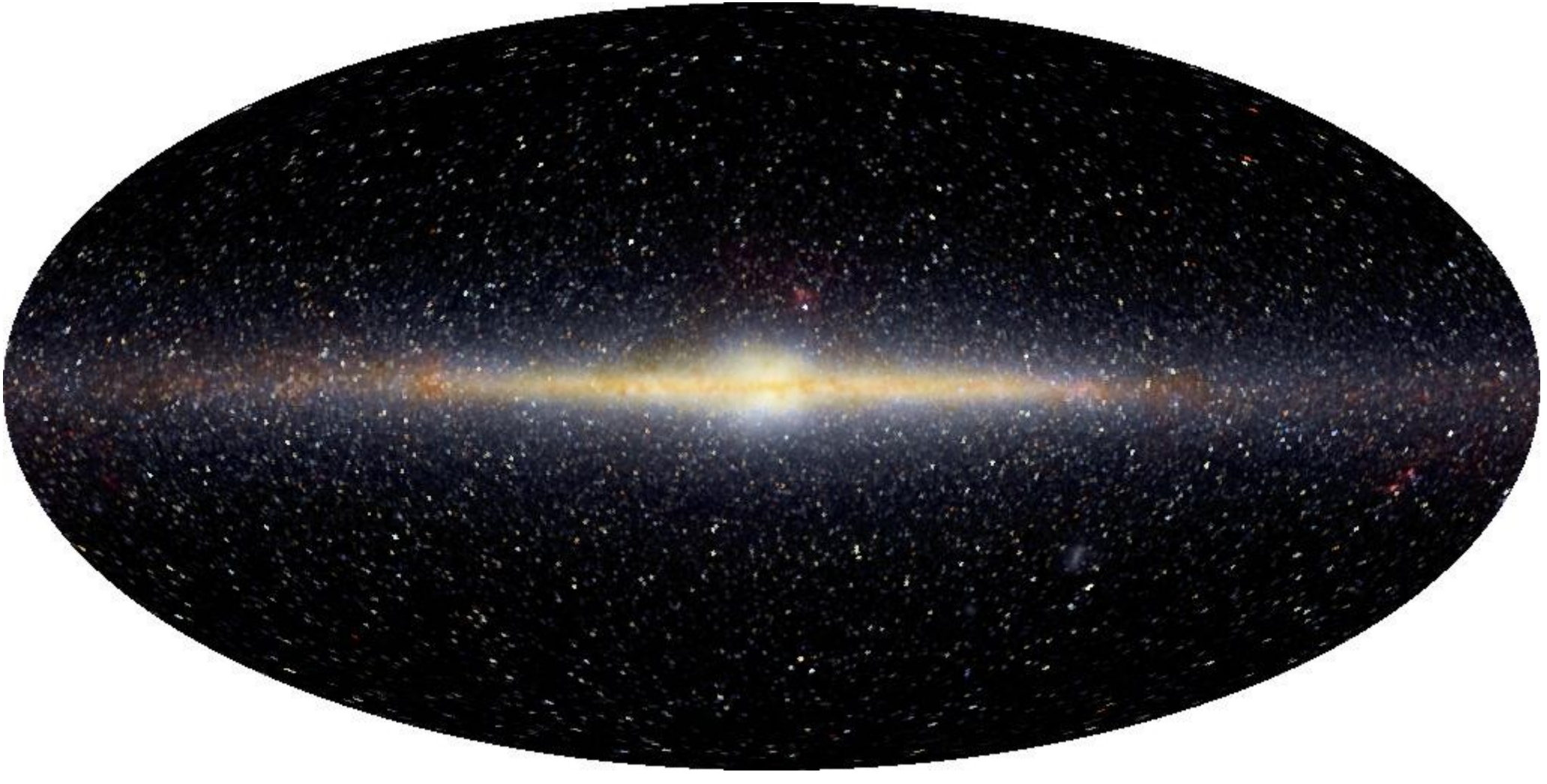
The Halo

The disk of the Milky Way is about 100,000 light years across (50,000 light years in radius) but only 900 light years (300 pc) thick.

The Sun is about 2/3 of the way out, at about 25,000 light years (8,000 pc).



Stars in the disk are younger and bluer (Pop I- 1 million to 10 billion years old). They orbit in the same direction. Nearly all the gas is in the disk.



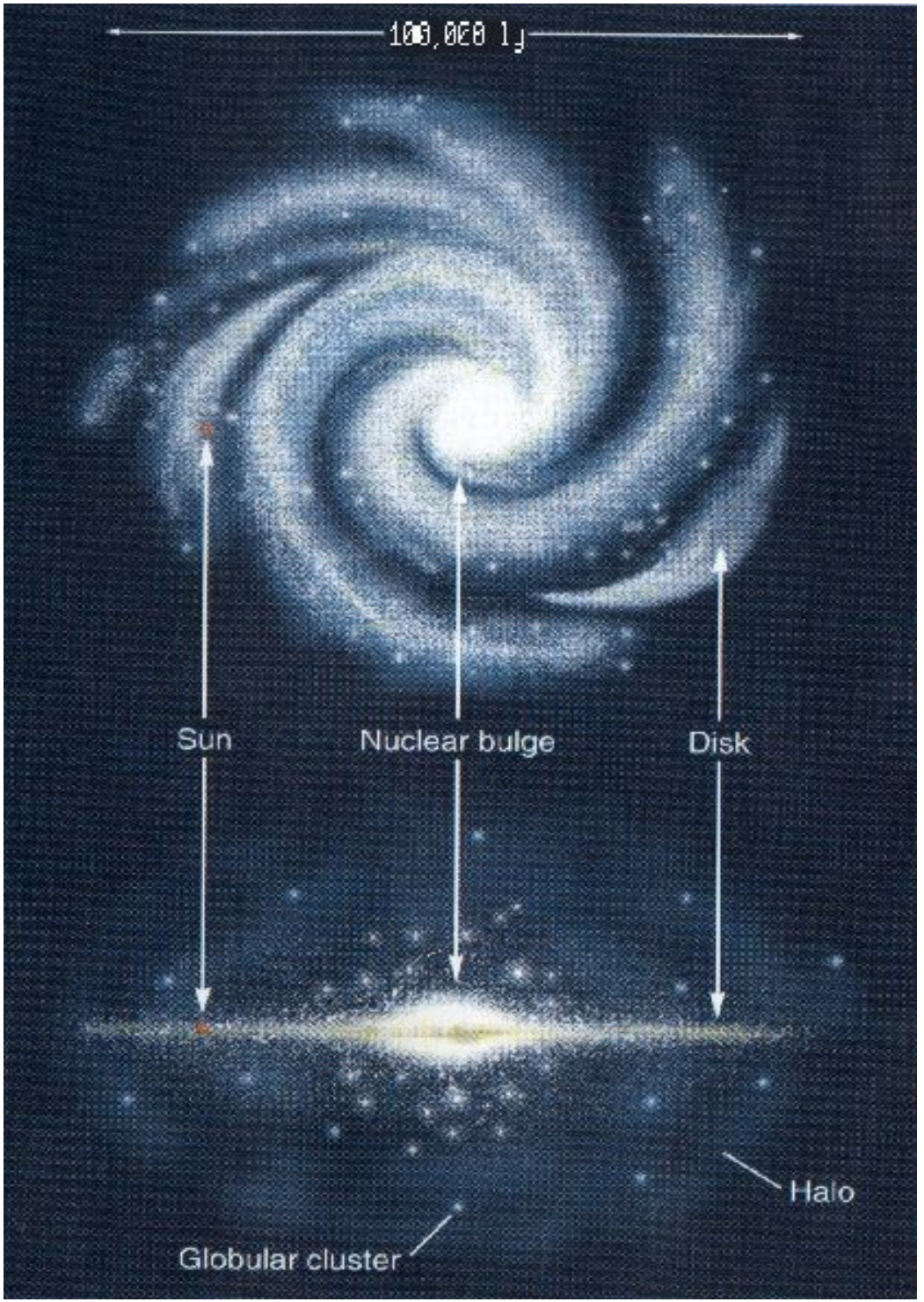
What makes the spiral arms?


What makes the spiral arms? Density waves.
What makes the density waves? We are less certain

Our Sun orbits

Our Sun is 8,000pc from the center of the galaxy. Our Sun orbits at a velocity of 250 km/s. (That's over half a million miles per hour!)

Our Sun has gone around the bulge 18 times in its 4.6 billion year history.



Our (spiral) Galaxy consists of 3 parts:

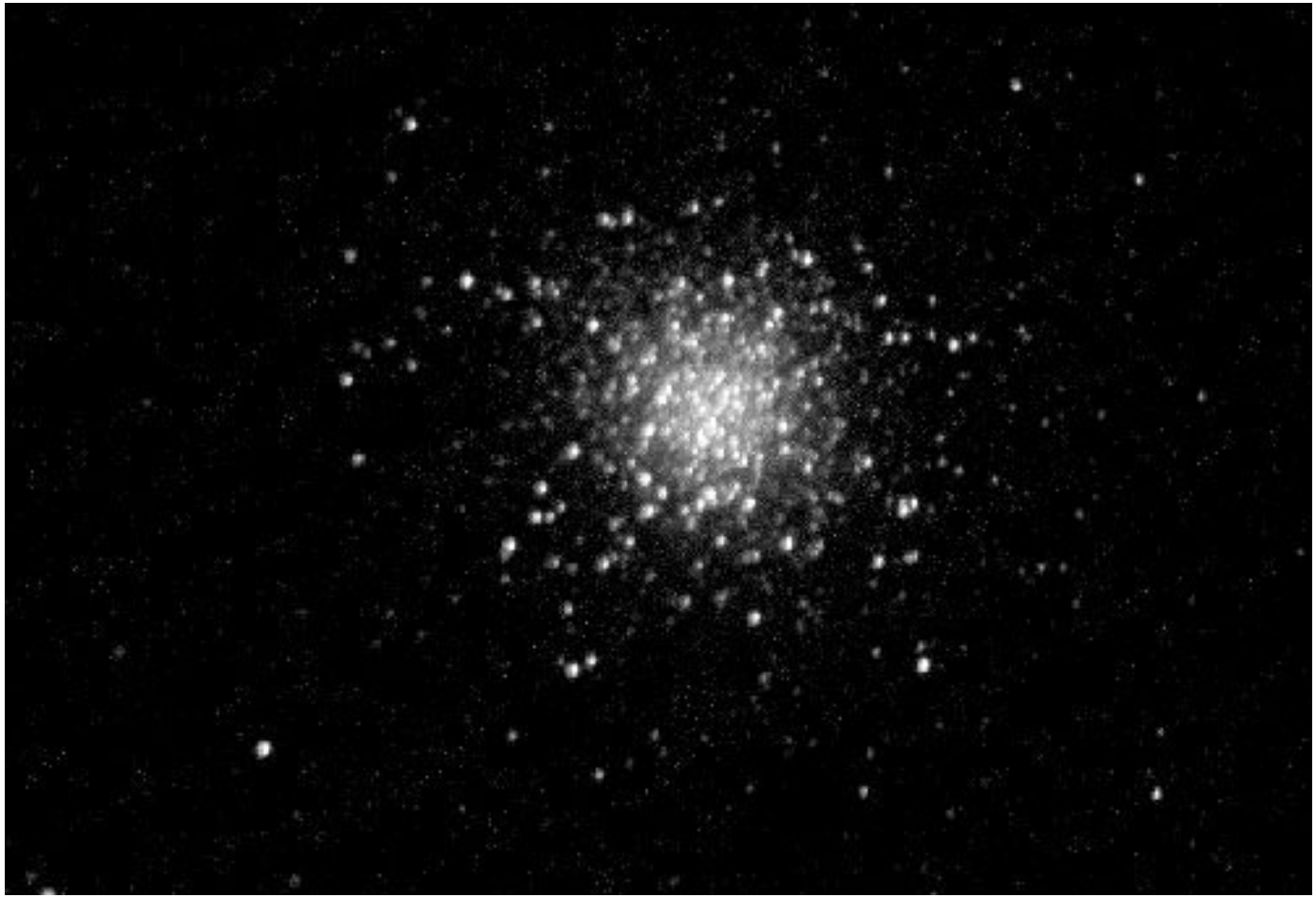
The Bulge (center)

The Disk and

The Halo

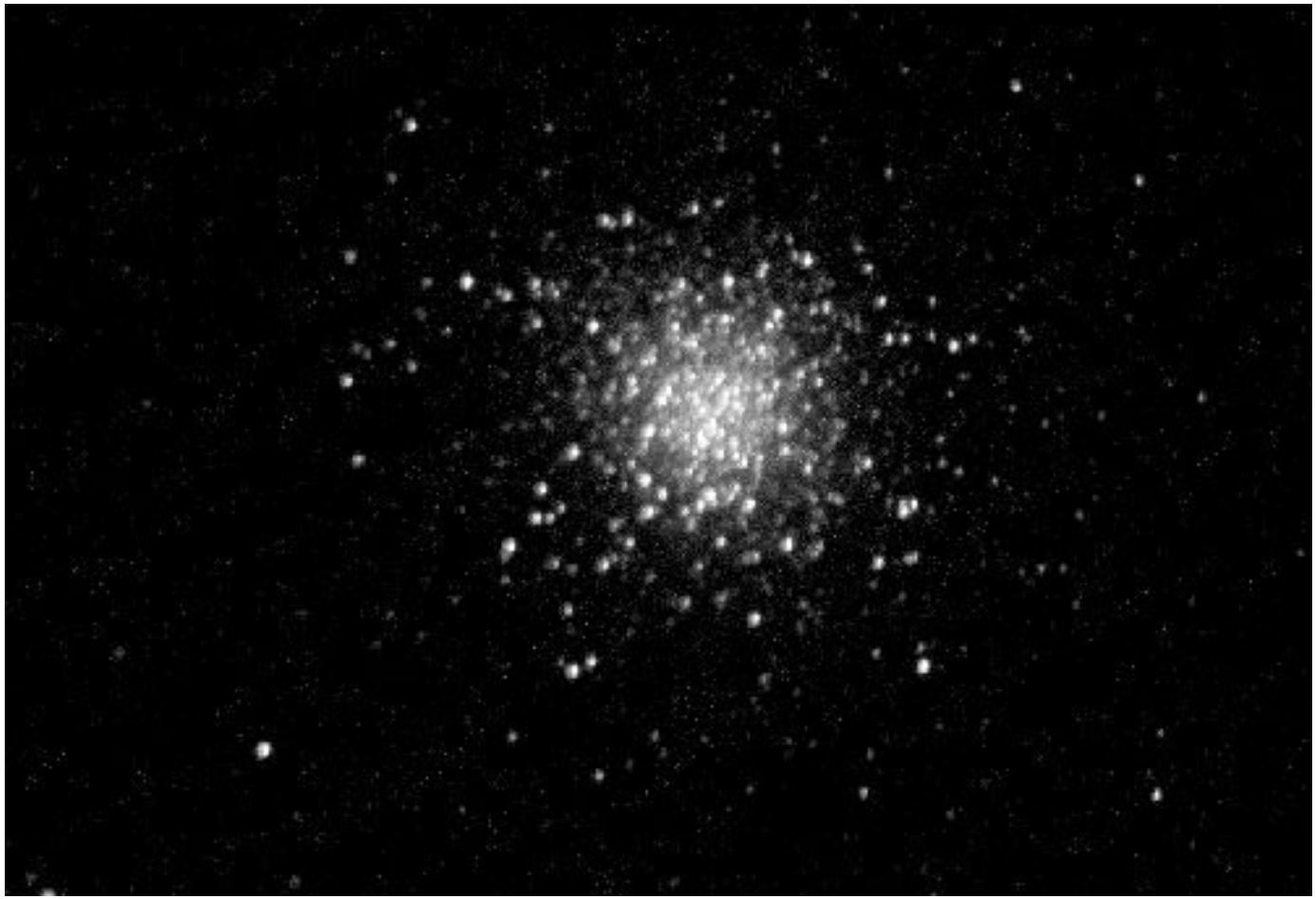
The Halo

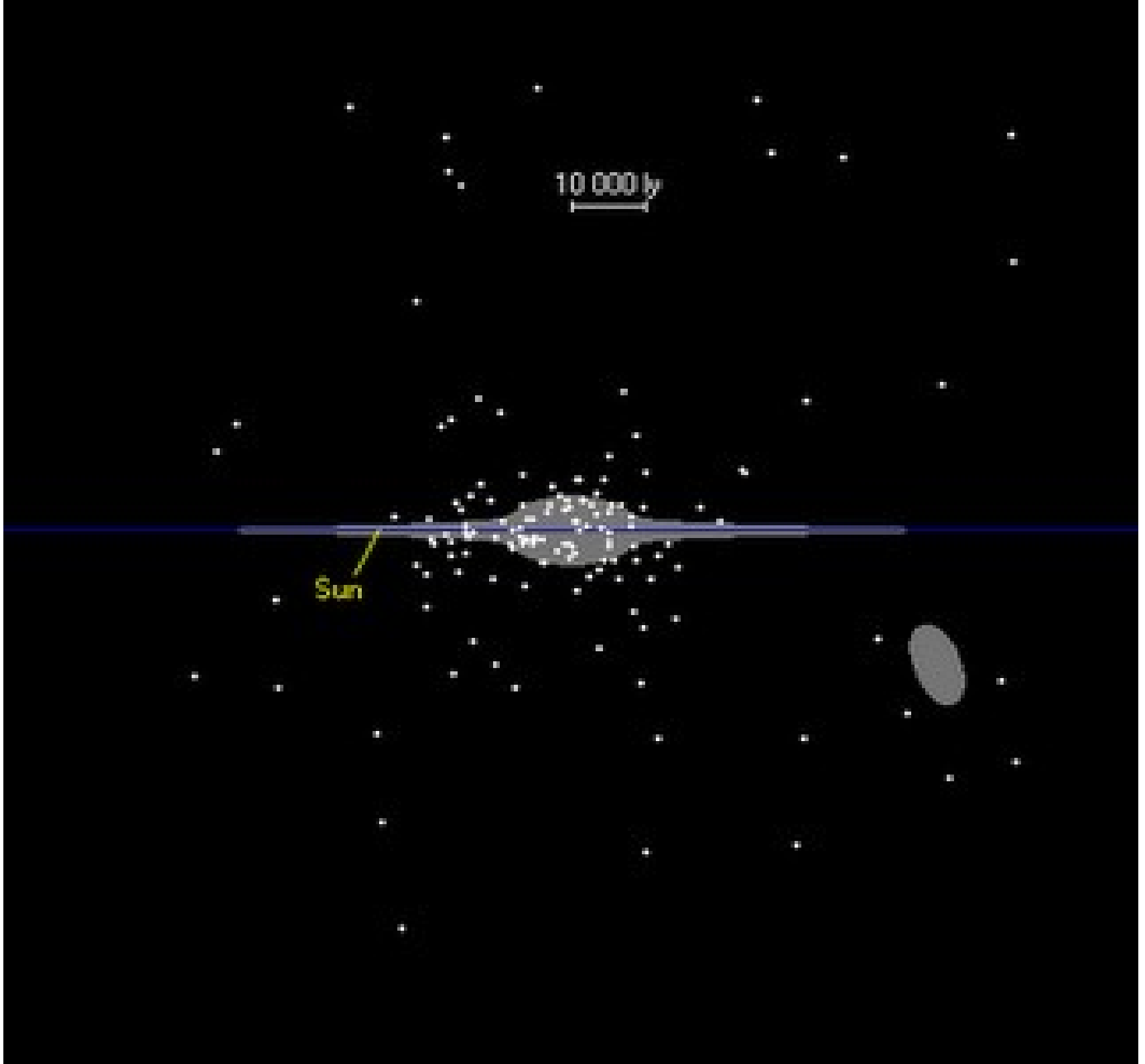
The visible portion of our halo is made mostly of globular clusters. Globular clusters are groups of 10,000 to 1 million stars. There are about 300 known globular clusters.

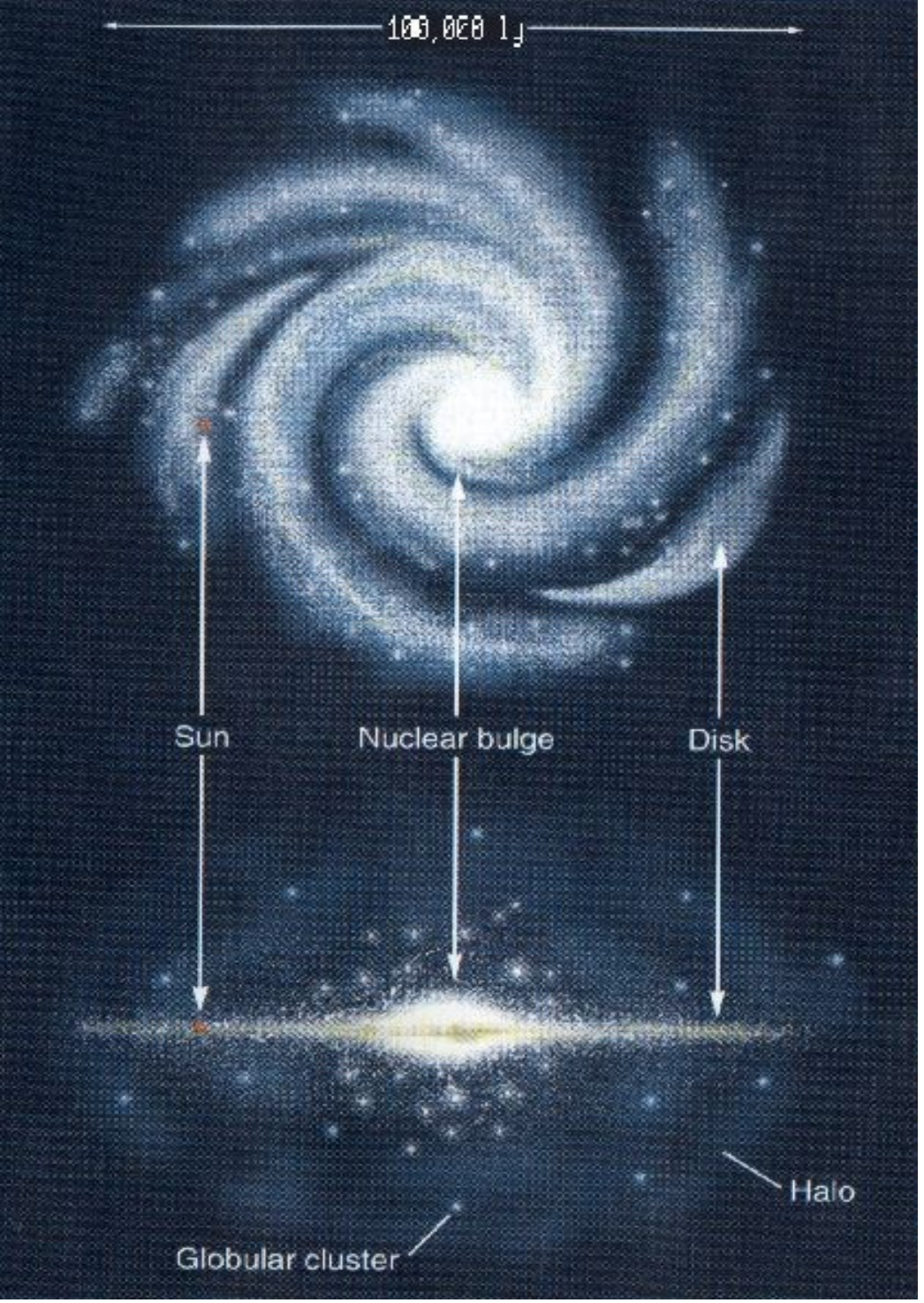


The Halo

Globular clusters have elliptical orbits that go around the bulge in any direction. They very seldom are in the disk of the galaxy. This means that they formed before the disk of our galaxy: Pop II stars- before the gas in our galaxy flattened to its pancake shape. This makes globular clusters the oldest component of our galaxy.




10 000 ly
Sun

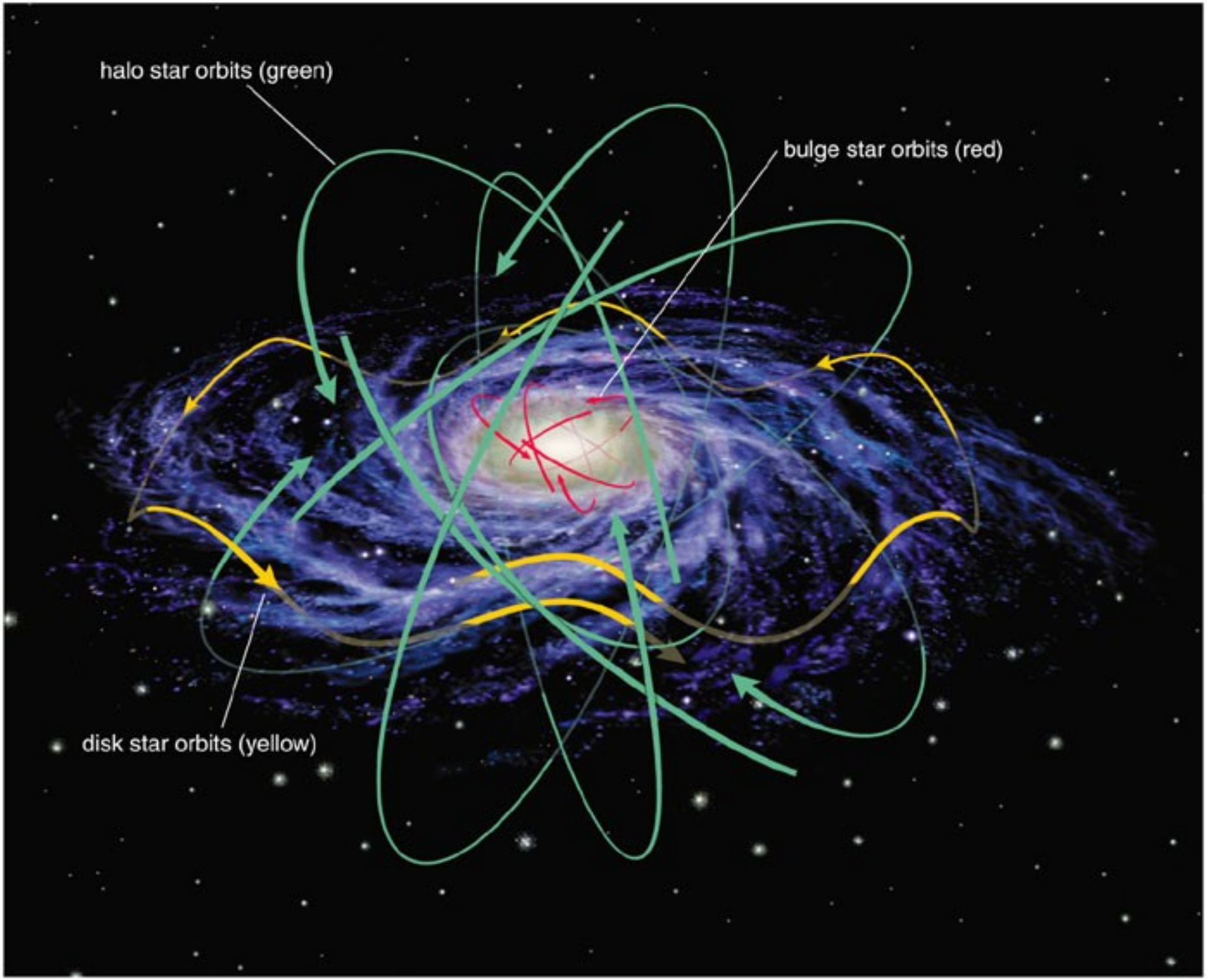


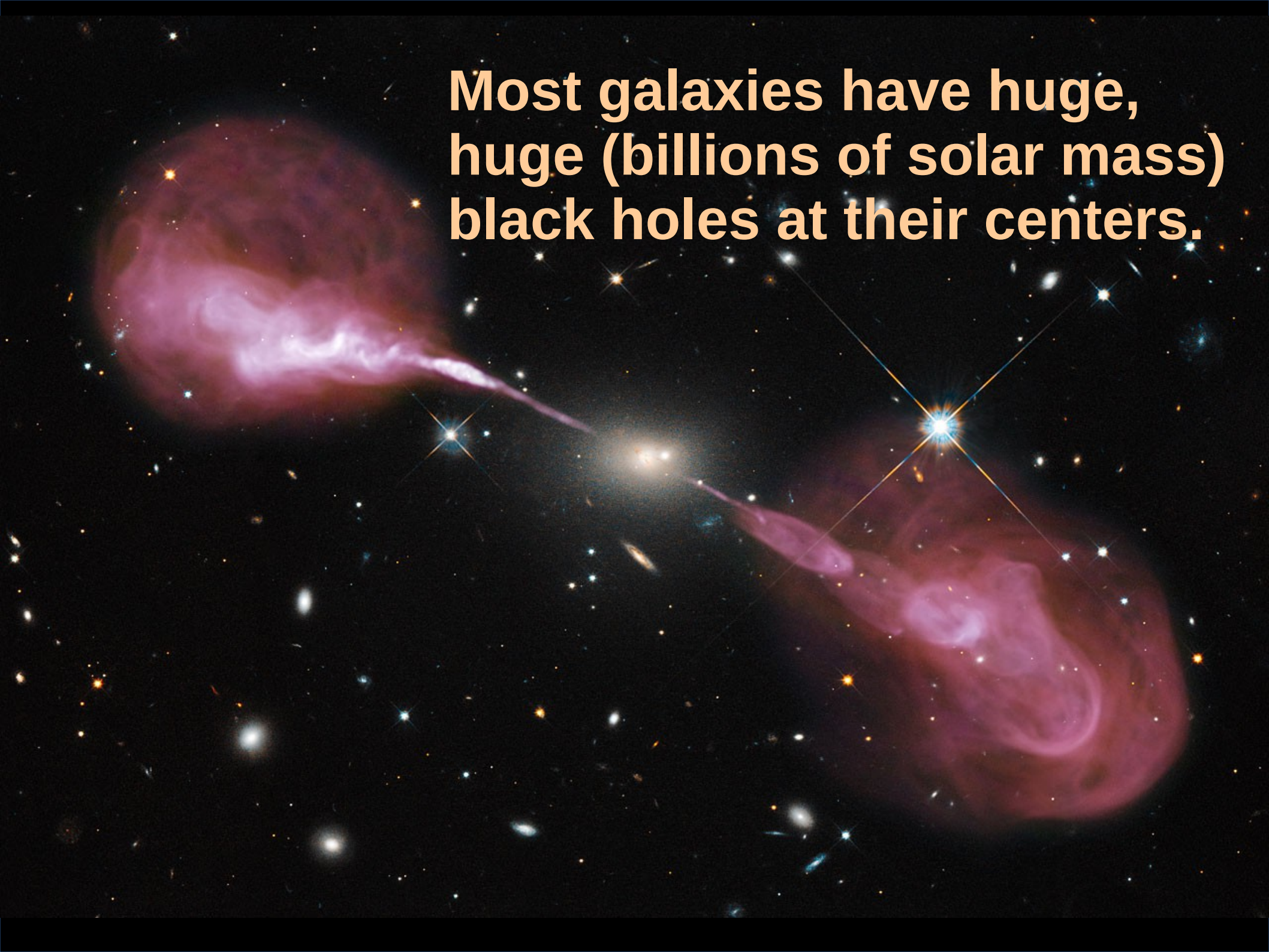
Spiral galaxies have 3 parts:

The Bulge (center): Old, Pop II stars which orbit randomly.

The Disk: Young, blue, Pop I stars which orbit uniformly. Gas/dust are here too.

The Halo: Globular clusters: orbit randomly, old Pop II stars.




Most galaxies have huge,
huge (billions of solar mass)
black holes at their centers.

We are inside of the Milky Way, so how do we know what the galaxy is made of? How do we measure things?

How would you determine how many trees are in a forest?

Mass of the Milky Way

Method 1: Look at representative regions of the galaxy, count up the mass in stars, gas, and dust. Then extrapolate those regions to the rest of the galaxy.


"Computers" in the 1890s
β AURIGÆ Dec 1889

Mass of the Milky Way

Method 2: Use stars at the edge of the galaxy to measure the mass of the galaxy.

Measure how fast those stars are orbiting, and it gives us the mass of the galaxy.

Mass of the Milky Way

Using gravity, the total mass is 5×10^{11} solar masses (using the orbit of stars).

If you account for all the mass in stars and gas, you only get 5×10^{10} solar masses.

Why are these numbers different? If we can measure this mass via orbits of stars, why can't we see it?

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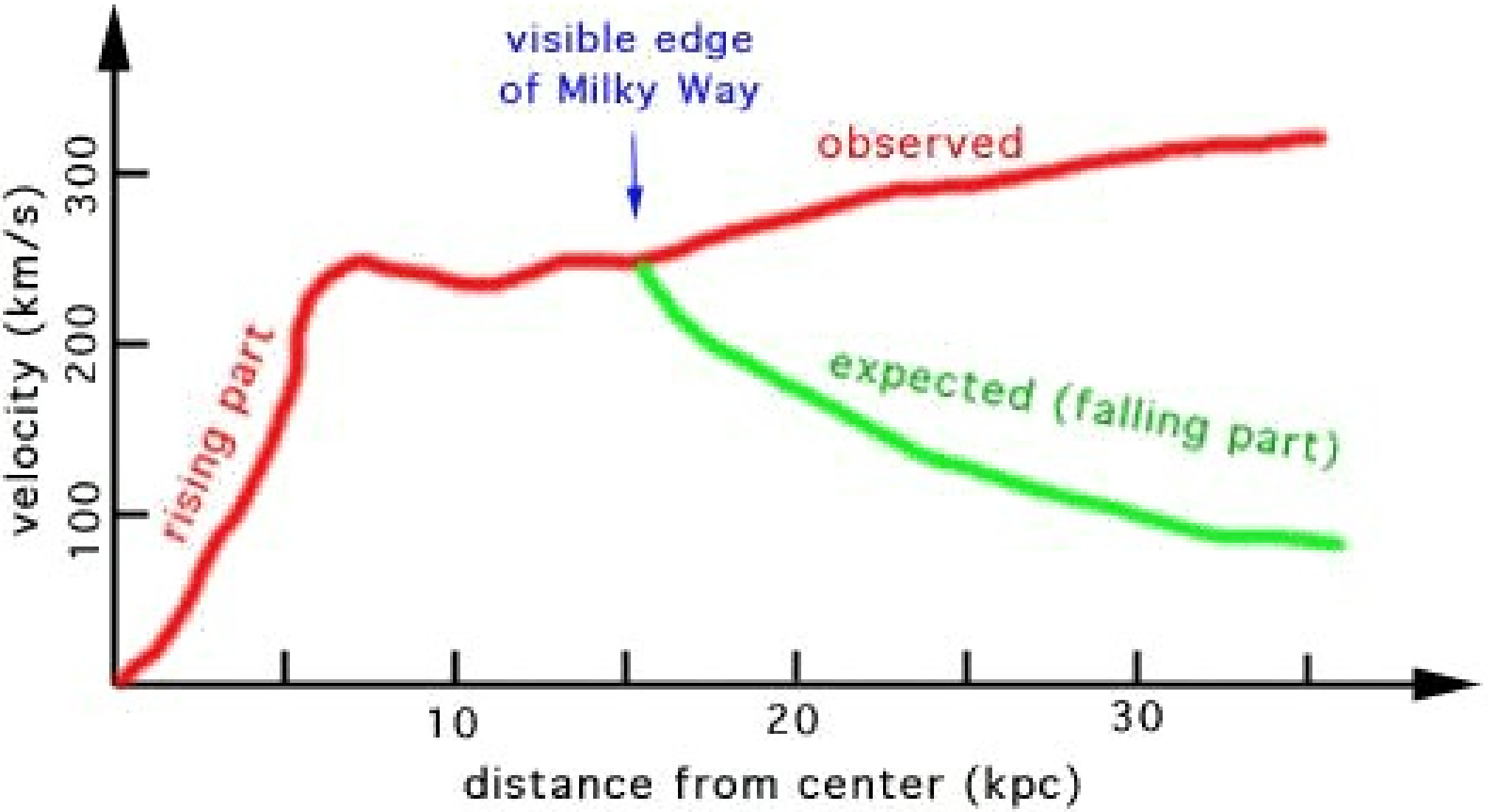
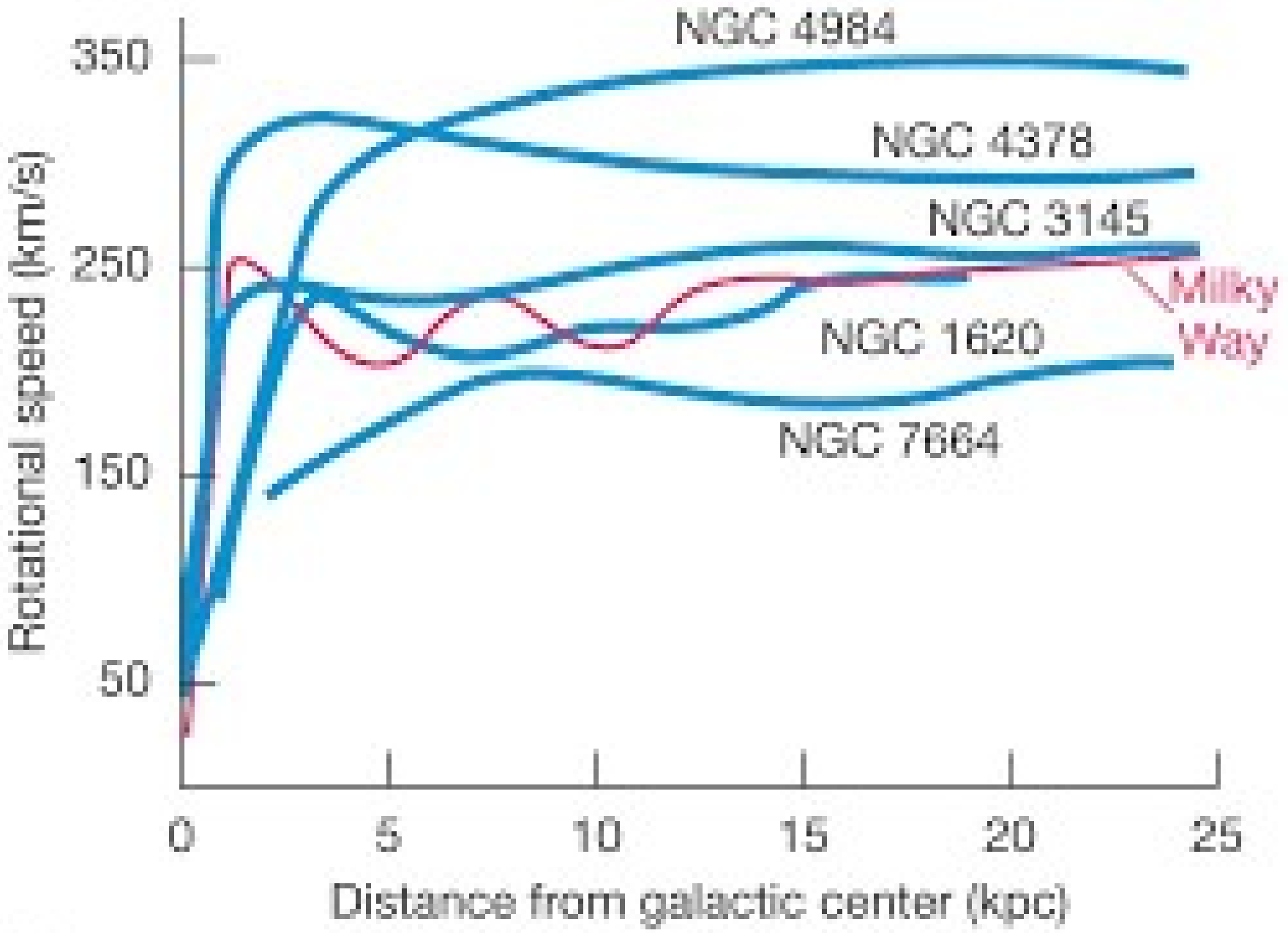
Dark Matter

How do we know we're missing mass?
Maybe we made a mistake somewhere

We can create a graph of the velocity with distance from the center of our galaxy.


visible edge
of Milky Way
observed
expected (falling part)
rising part
velocity (km/s)
100
200
300
10
20
30
distance from center (kpc)

We see this same thing in every galaxy.



As astronomers measure the rotation rate of galaxies (not just our own), and velocities of groups of galaxies, they realize that 90% of the Universe is Dark Matter.