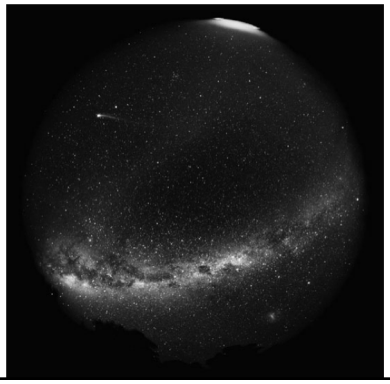
Chapter 19: Milky Way Galaxy



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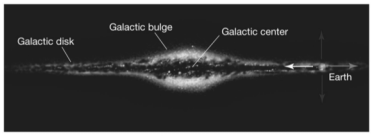
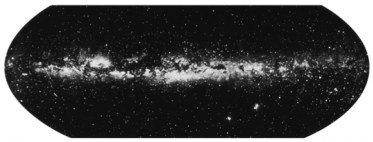
Our Parent Galaxy

From Earth, see few stars when looking out of galaxy (red arrows), many when looking in (blue arrows). Milky Way is how our Galaxy appears in the night sky.



(a) Artist's view of Milky Way from afar



(b) Real image of Milky Way from inside

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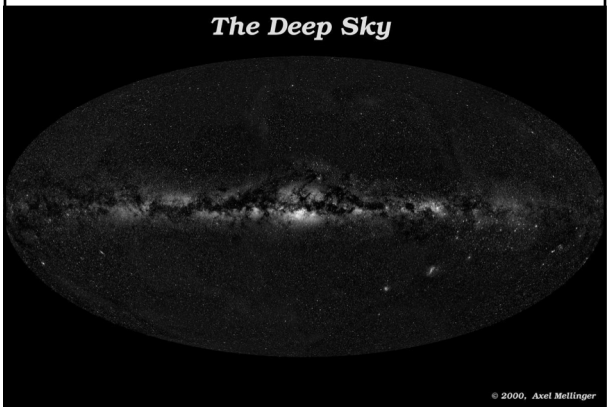
All sky view from Alex Mellinger http://www.milkywaysky.com



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A view from just above the plane (painting by Jon Lomberg)

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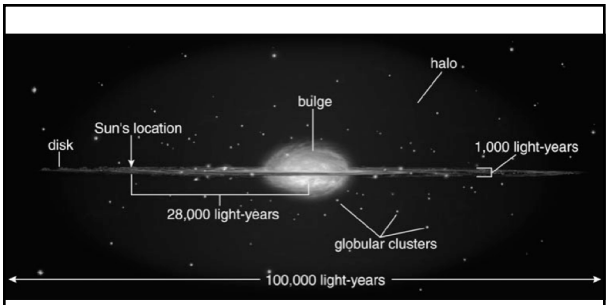

Primary features: disk, bulge, halo, globular clusters

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Components of the Galaxy

Disk – flattened distribution of mainly young stars and star formation regions – clouds of gas and dust, open clusters, and spiral arms (Sun resides in the disk)

Central Bulge – contains a mix of older and younger stars surrounding center

Halo – large spherical region containing some stars and globular clusters (very old stars; little gas or dust)

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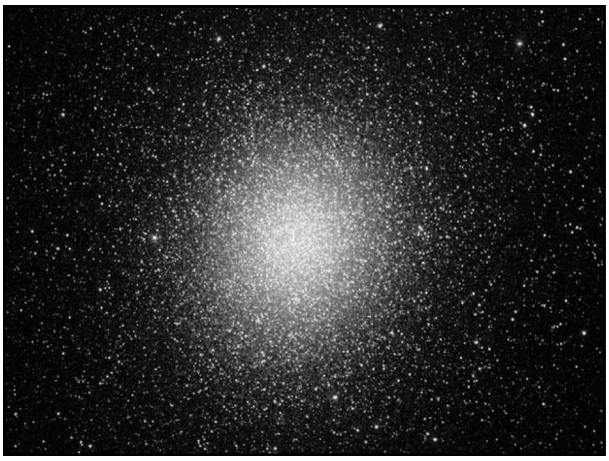

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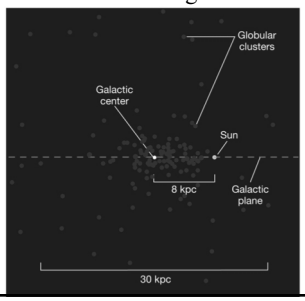
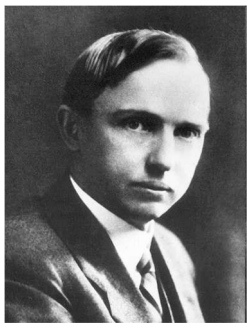
Our Position: Harlow Shapley 1920

- Found the globular clusters form a nearly spherical distribution around a point in the direction of Sagittarius.





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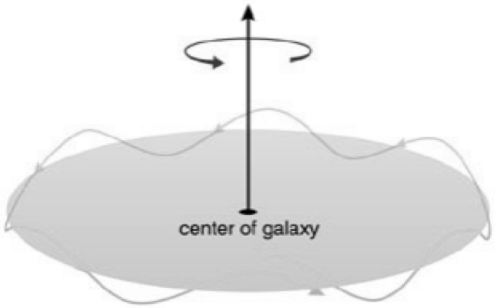
Stellar orbits in our galaxy



Stars in the disk all orbit in the same direction with a little up-and-down motion

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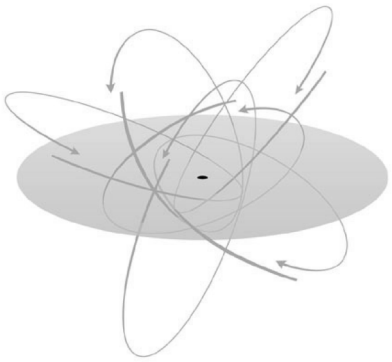

Orbits of stars in the bulge and halo have random orientations

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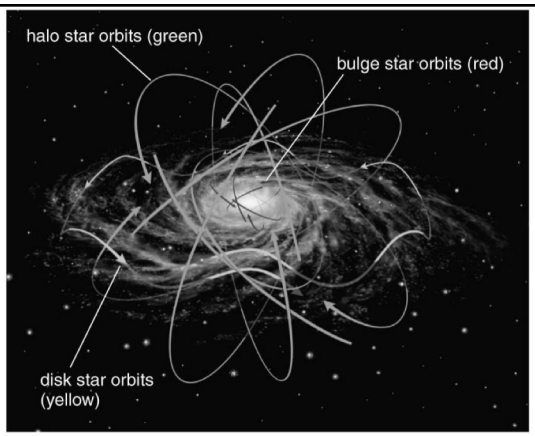

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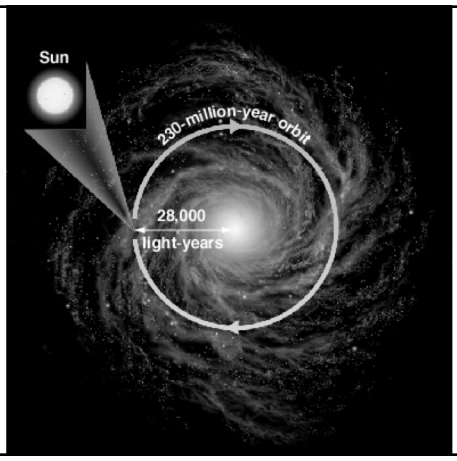

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The Mass of the Milky Way Galaxy

Use Kepler's Third Law: $(M + m)\,P^2 = a^3$

M = mass interior to Sun (solar masses)
m = mass of Sun (solar masses) ($1 \ll M$)
P = orbital period (years) = 230×10^6 years
a = distance to Galactic center (AU)
= 8600 pc x 206265 AU/pc = 1.8×10^9 AU

$M = a^3 / P^2 = 1.1 \times 10^{11}$ solar masses
(110 billion Suns!)

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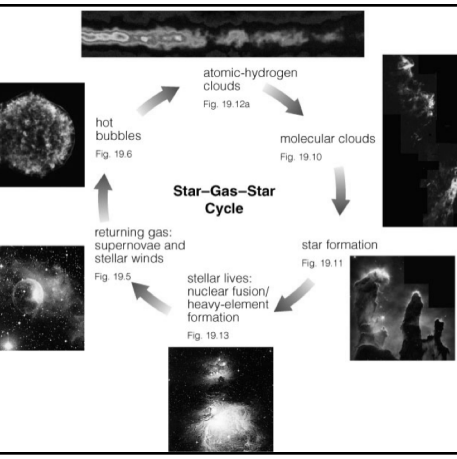

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Galactic Recycling

Gas Cools

- Stars make new elements by fusion
- Dying stars expel gas and new elements, producing hot bubbles (~10^6 K) and cosmic rays (energetic electrons, protons and atomic nuclei)
- Hot gas cools, allowing atomic hydrogen clouds to form (~100-10,000 K)
- Further cooling permits molecules to form, making molecular clouds (~30 K)
- Gravity forms new stars (and planets) in molecular clouds

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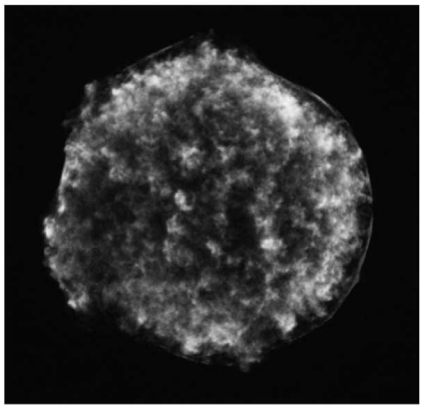

X-rays from hot gas in supernova remnants

New elements made by supernova mix into interstellar medium: gas *enriched* with heavy elements

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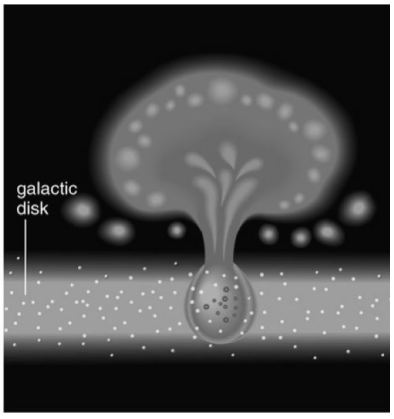

Multiple supernovae create huge hot bubbles that can blow out of disk

Gas clouds cooling in the halo can rain back down on disk

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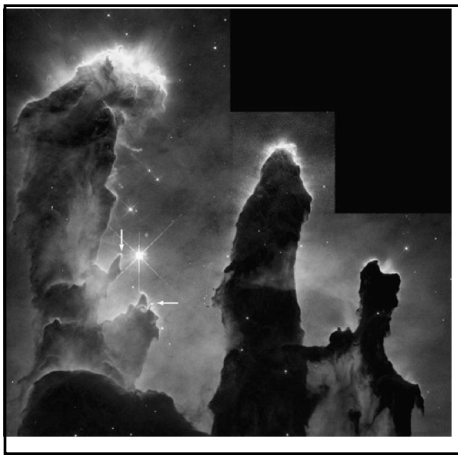

Gravity forms stars out of the gas in molecular clouds, completing the star-gas-star cycle

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Thought Question

Where will the gas be in 1 trillion years?

A. Blown out of galaxy
B. Still recycling just like now
C. Locked into white dwarfs and low-mass stars

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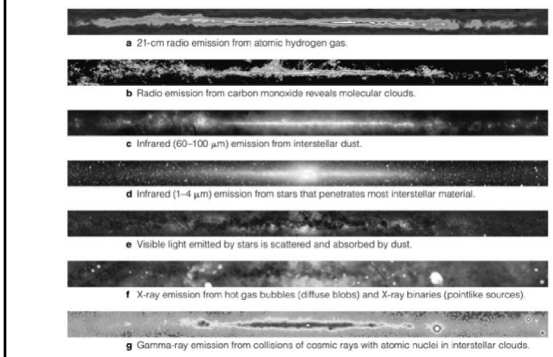

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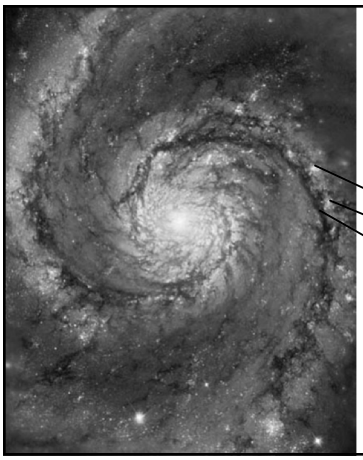

Much of star formation in disk happens in spiral arms

Ionization Nebulae
Blue Stars
Gas and Dust Clouds

Whirlpool Galaxy

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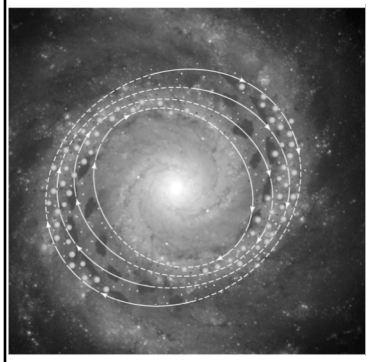

Spiral arms are waves of star formation

1. Gas clouds get squeezed as they move into spiral arms
2. Squeezing of clouds triggers star formation
3. Young stars flow out of spiral arms

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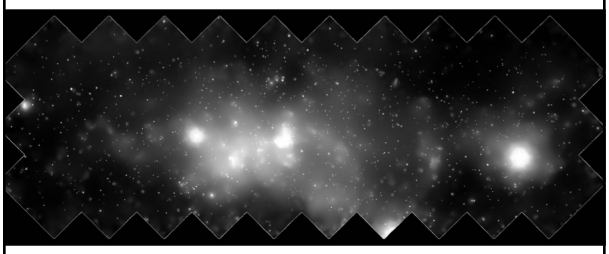
Zooming into Center of the Galaxy
https://www.eso.org/public/usa/videos/eso1835c/



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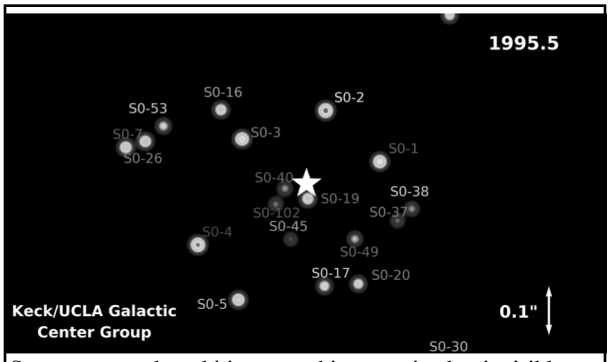

Stars appear to be orbiting something massive but invisible …
black hole: Orbits of stars indicate a mass of 4 million M_{Sun}

http://www.astro.ucla.edu/~ghezgroup/gc/animations.html

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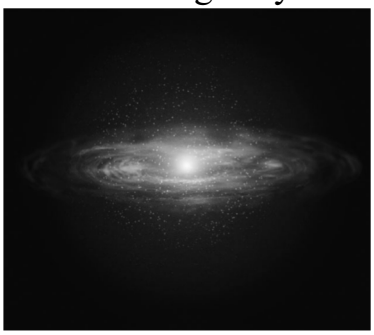
How did our galaxy form?



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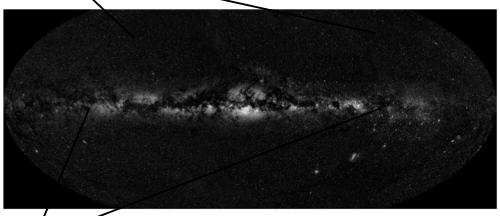
Halo Stars:
0.02-0.2% heavy elements (O, Fe, …),
only old stars

Halo stars formed first, then stopped



Disk Stars:
2% heavy elements,
stars of all ages

Disk stars formed later, kept forming

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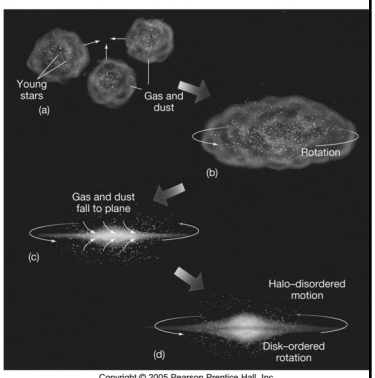
Protogalaxy formed first condensations some 14 billion years ago:
- initial collapse forms halo stars
- remaining gas rains in, forms disk
- inner part has highest heavy atom content from early, intense star formation



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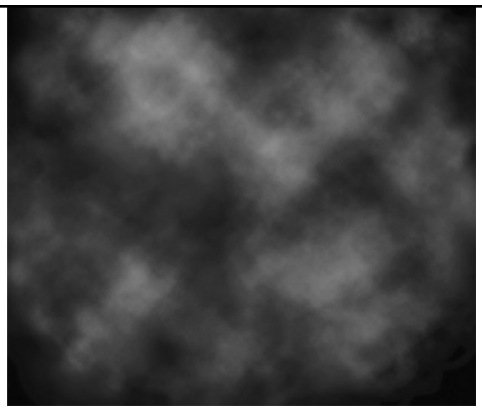

Our galaxy probably formed from a giant gas cloud

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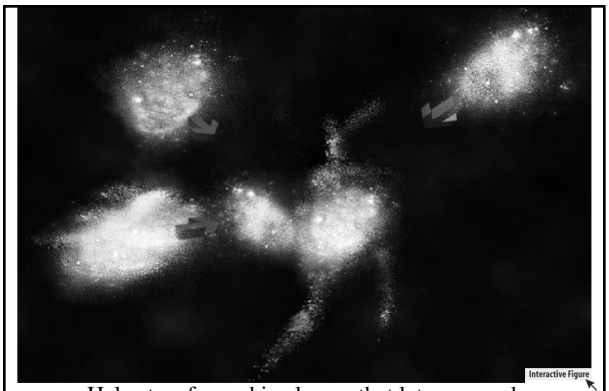

Halo stars formed in clumps that later merged

https://www.youtube.com/watch?v=OltYfc38bn0

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Remaining gas settled into spinning disk

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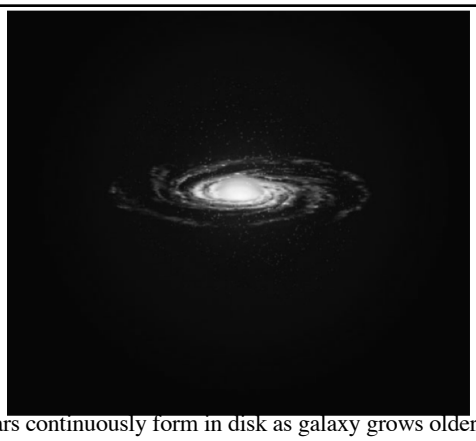

Stars continuously form in disk as galaxy grows older

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