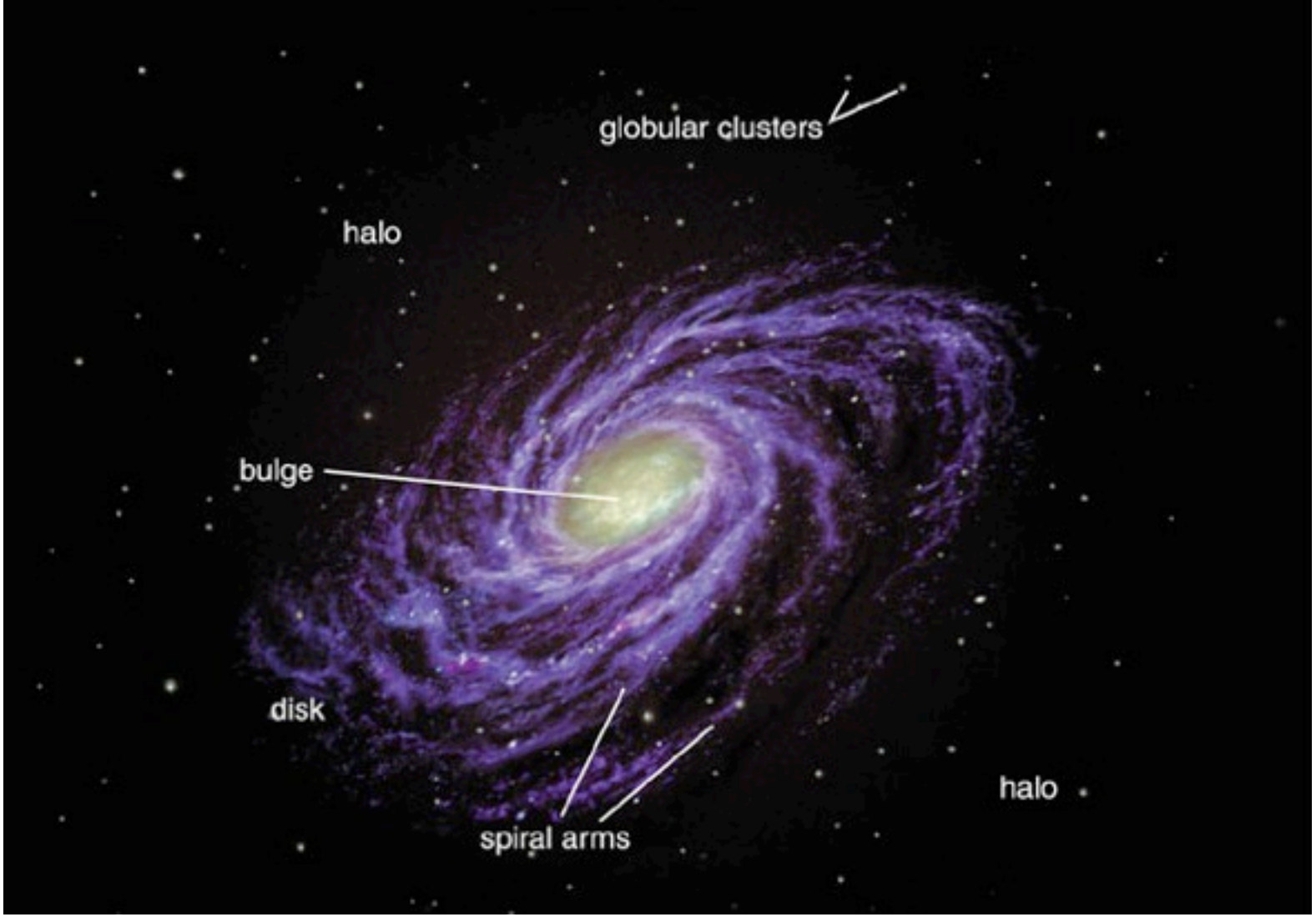
Today

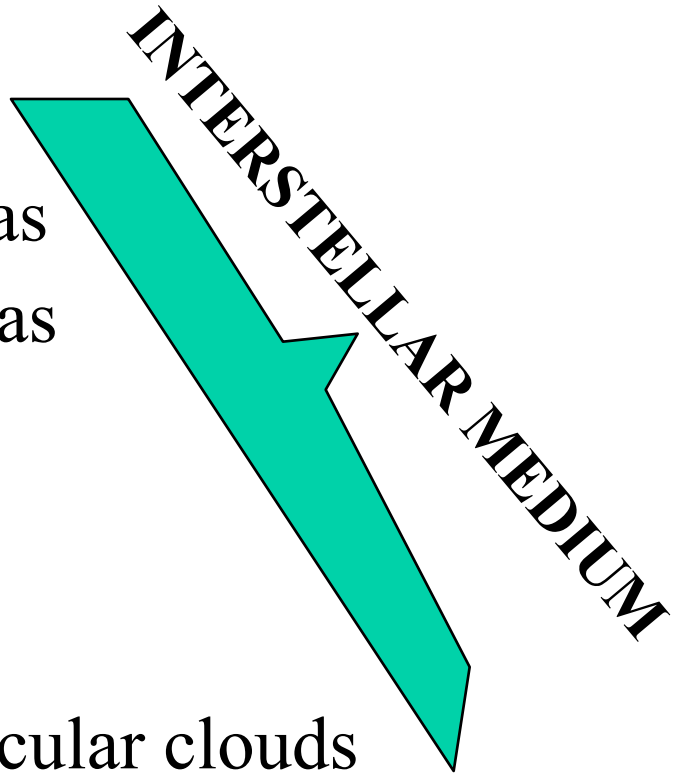
- The Milky Way
  - Galactic Structure
  - The Interstellar Medium
  - Star Formation
  - Stellar Populations



Our Milky Way: the view from above the disk

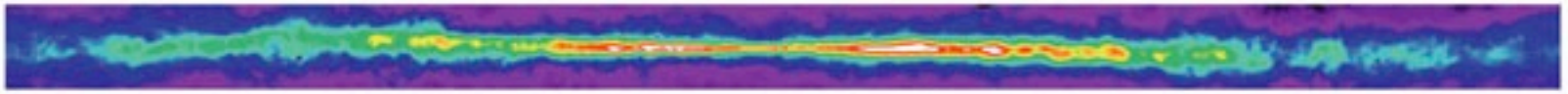
Galactic Structure

- Stars ~80% of mass
  - DISK ~80% of stars
  - BULGE ~20% of stars
- Gas ~20% of mass
  - atomic gas ("H I") ~2/3 of gas
  - molecular gas (H_2) ~1/3 of gas
  - hot, ionized gas ("H II")
- Dust
  - between stars
  - mostly in spiral arms & molecular clouds



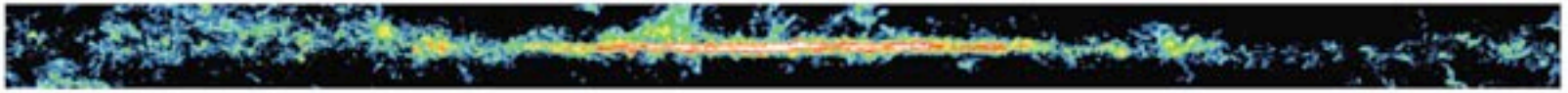
Multi-wavelength Milky Way

radio (21 cm)
HI gas



a 21-cm radio emission from atomic hydrogen gas.

radio (CO)
molecular gas



b Radio emission from carbon monoxide reveals molecular clouds.

far-IR
dust

c Infrared (60–100 μm) emission from interstellar dust.

near-IR
stars

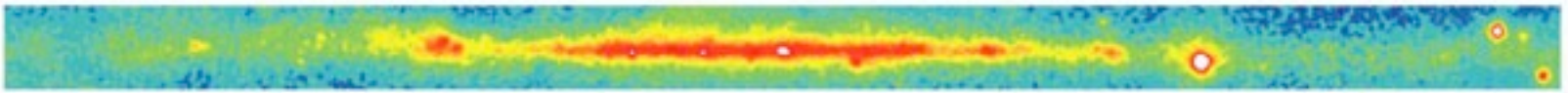
d Infrared (1–4 μm) emission from stars that penetrates most interstellar material.

Optical
stars & dust

e Visible light emitted by stars is scattered and absorbed by dust.

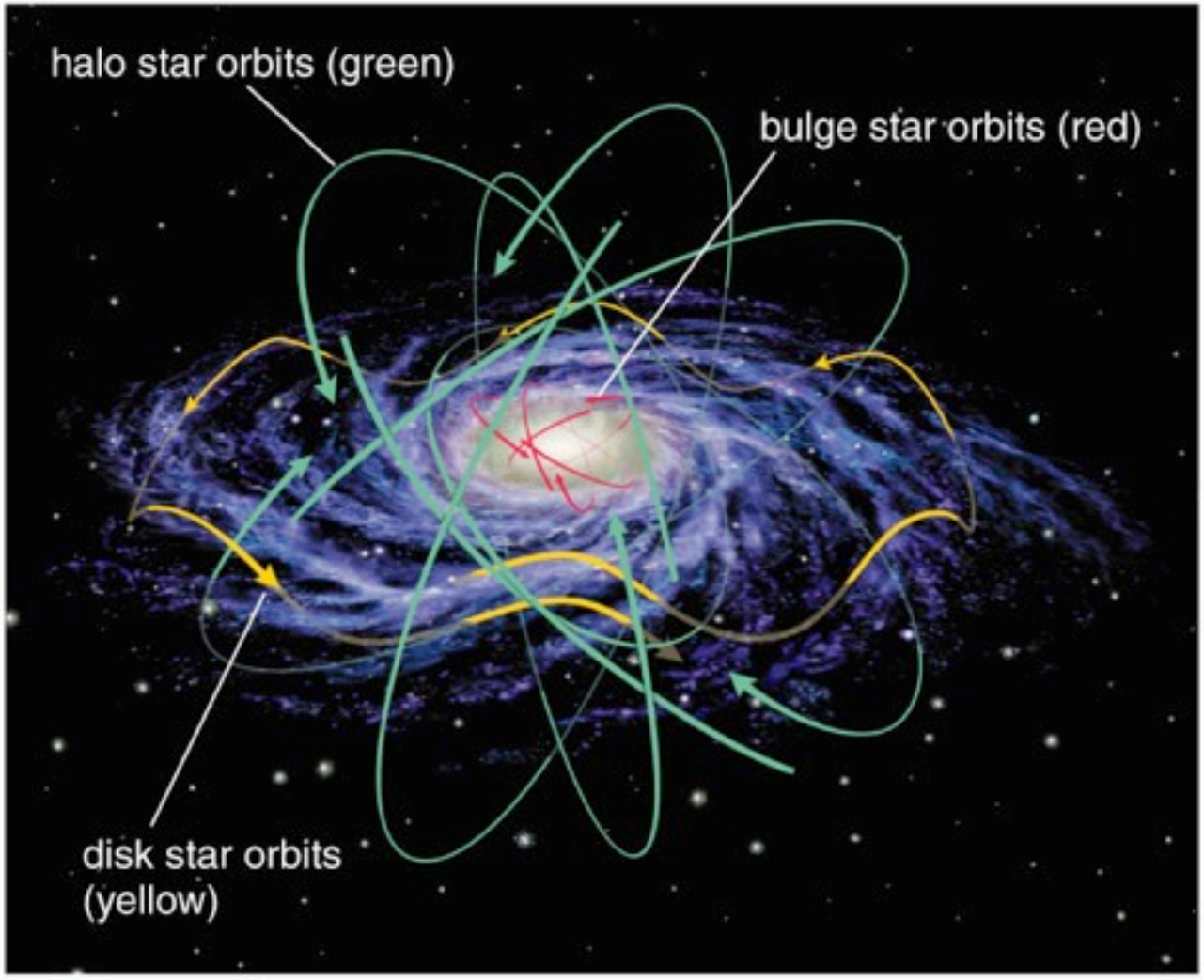
X-ray
hot gas

f X-ray emission from hot gas bubbles (diffuse blobs) and X-ray binaries (pointlike sources).



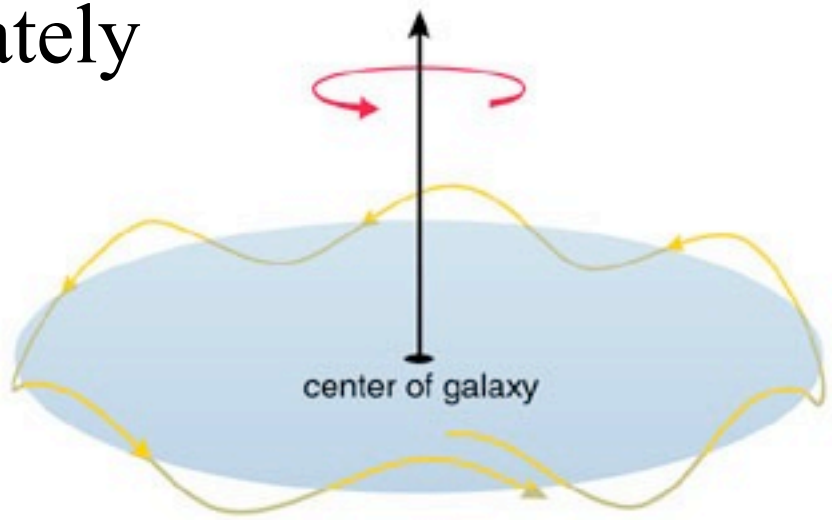
g Gamma-ray emission from collisions of cosmic rays with atomic nuclei in interstellar clouds.

Stellar orbits

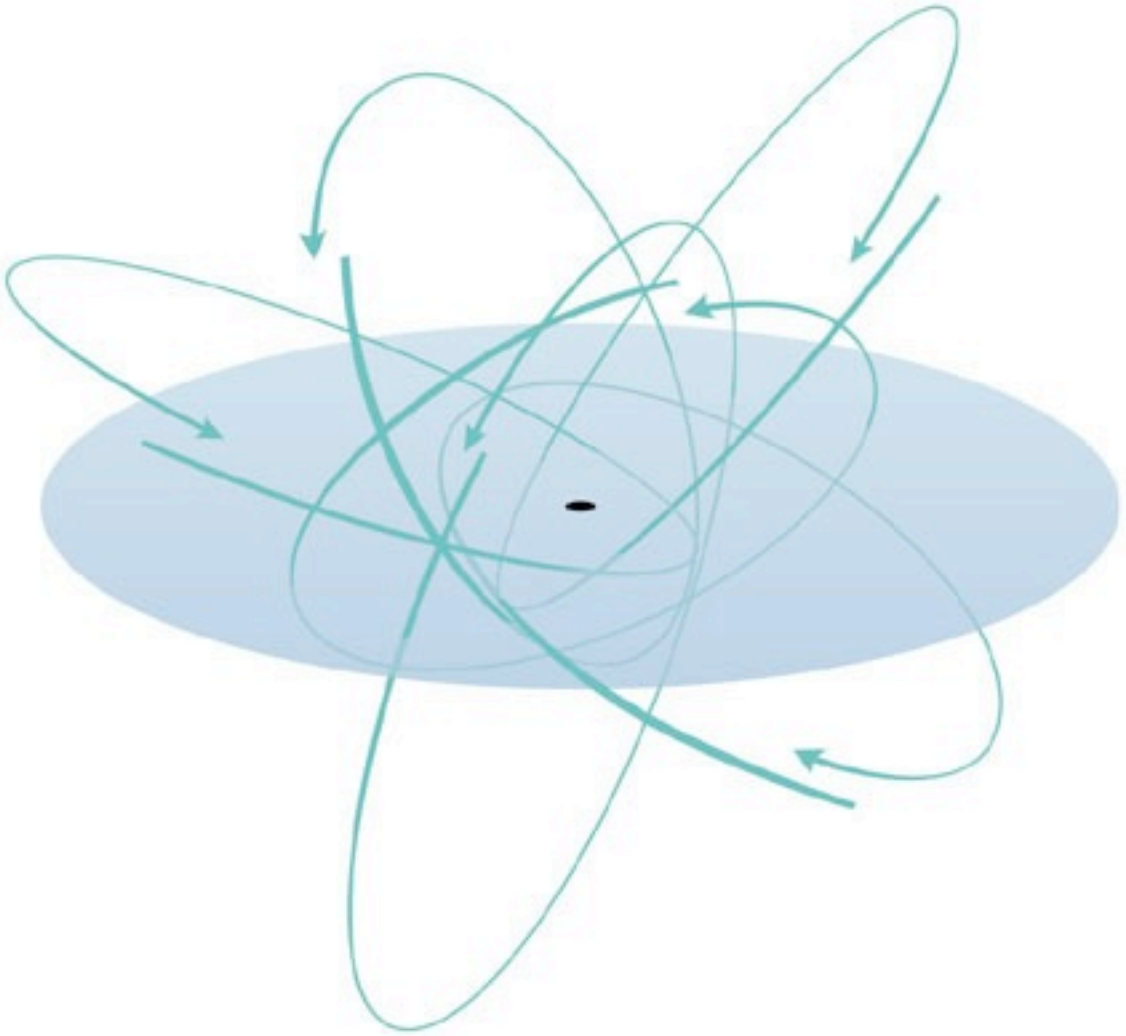


Disk

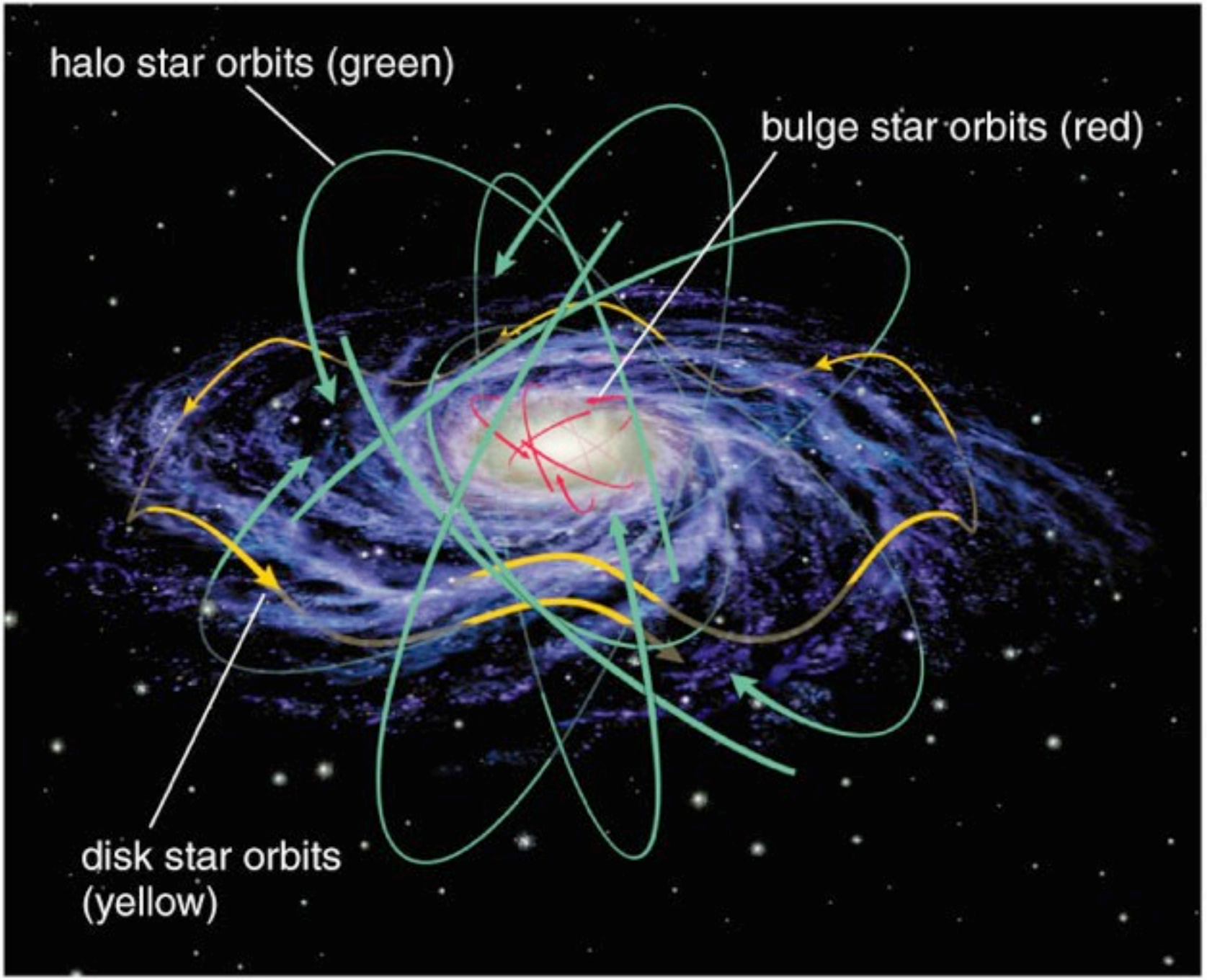
- Most stars are in the disk (2D)
- Disk stars have approximately circular orbits
- Disk stars orbit in same direction
- Individual stars oscillate slightly in the vertical direction (perpendicular to the disk), giving the disk a finite thickness

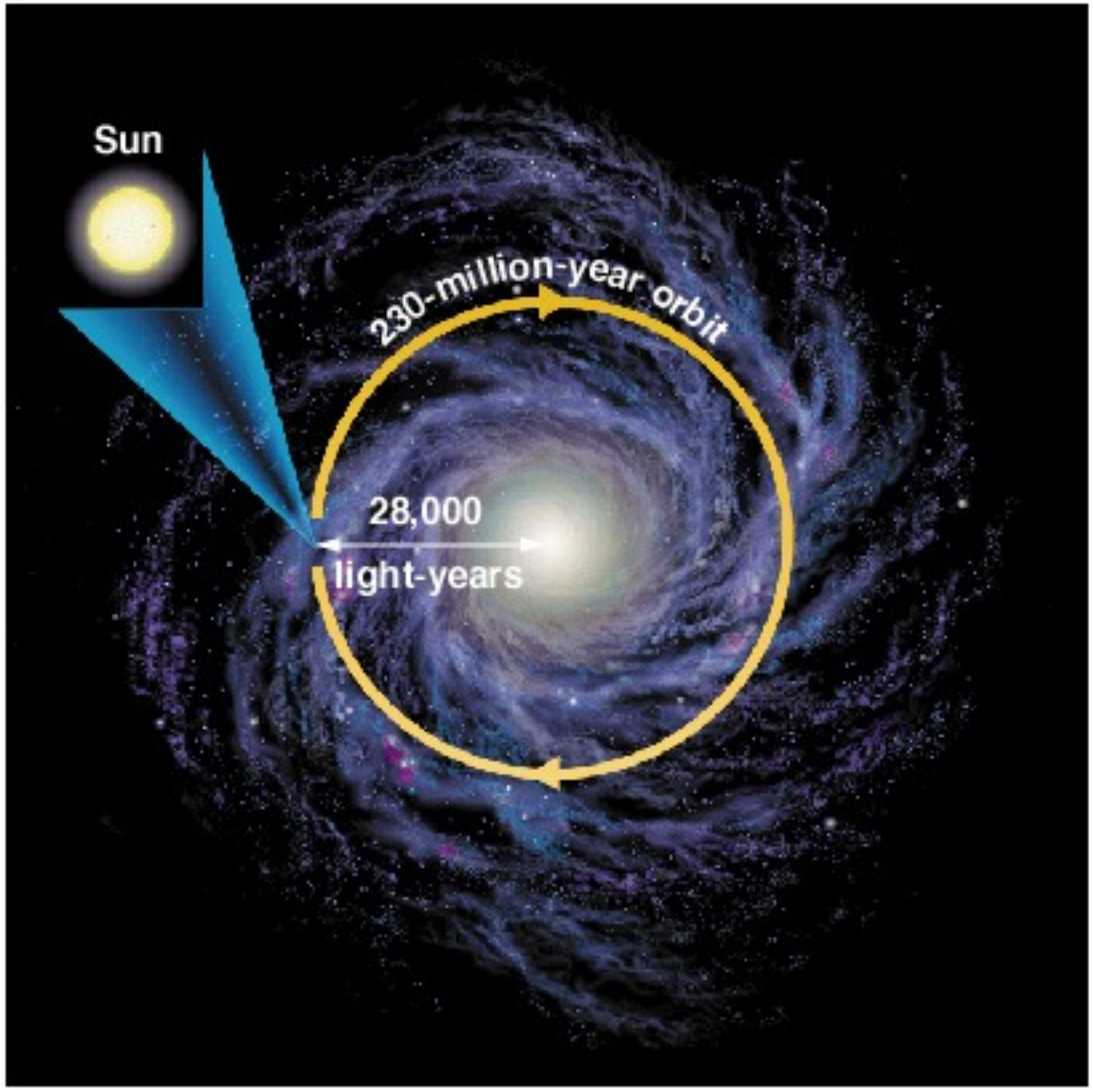


Bulge & Halo



- Bulge mass < 20% of disk
- Halo fraction small ~1%
- Bulge & halo stars have elliptical orbits
- Bulge & halo stars orbit with random orientations; fill out 3D structure





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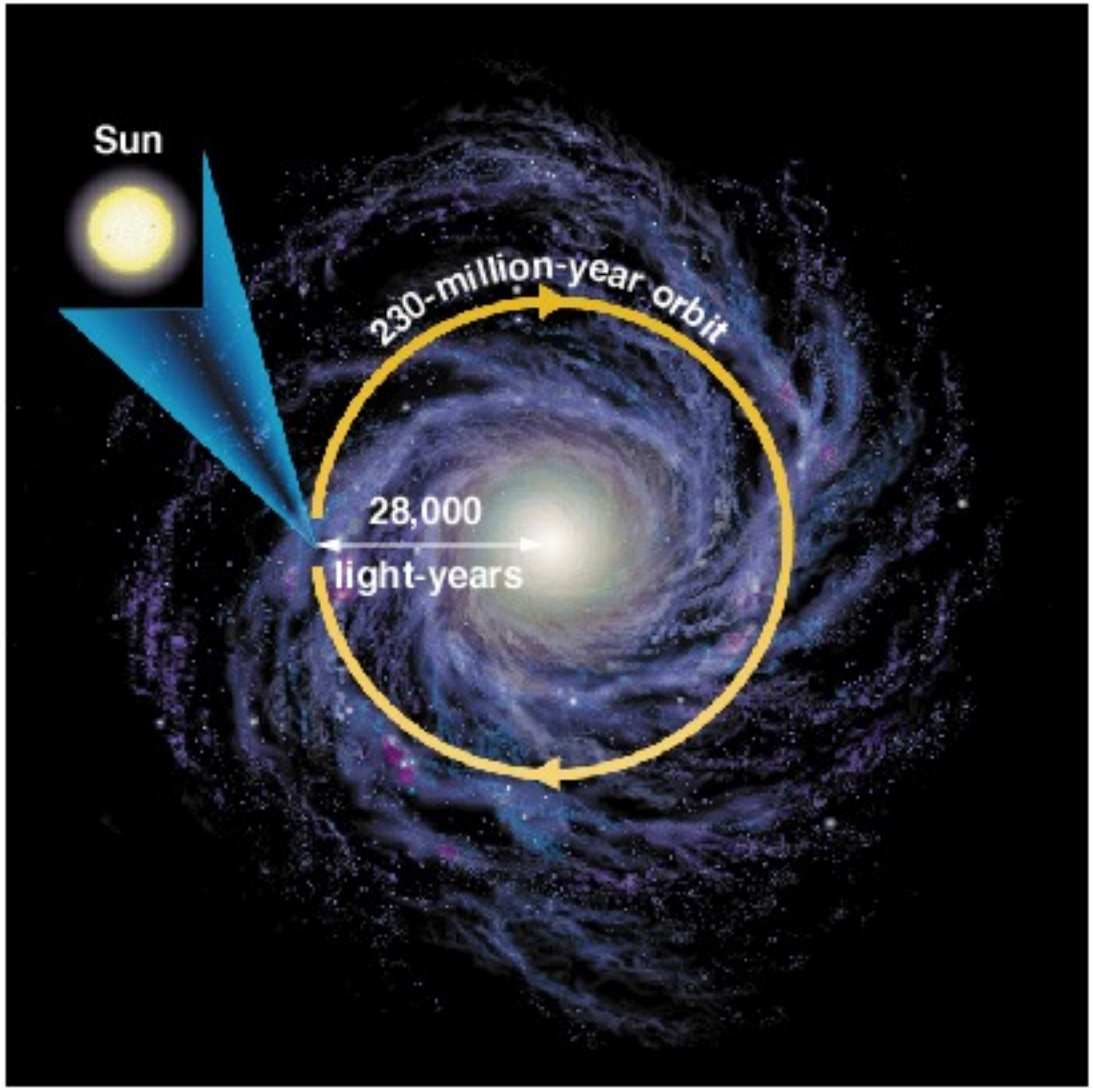
Sun's orbital period is about 230 million years.

In 4.5 billion years, it has completed over 19 orbits.



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Sun's orbital motion (radius and velocity) tells us mass within Sun's orbit:

$$1.0 \times 10^{11}\, M_{\text{Sun}}$$

Orbital Velocity Law

$$V^2 = \frac{GM}{R}$$ measure circular velocity and radius

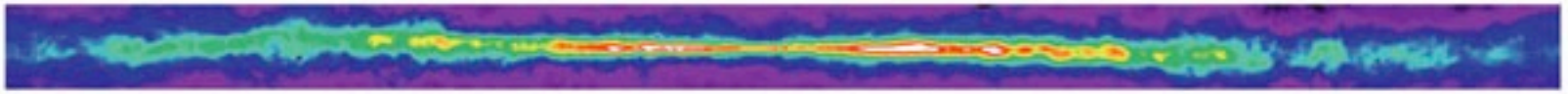
solve for mass: $$M = \frac{V^2 R}{G}$$

- The orbital speed (*V*) and radius (*R*) of an object on a circular orbit around the galaxy tell us the mass (*M*) enclosed within that orbit.

stars and gas: $$M \approx 6 \times 10^{10}\ M_{sun}$$

Relation of Milky Way components

radio (21 cm)
HI gas



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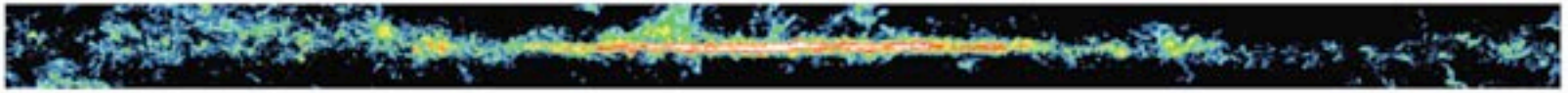

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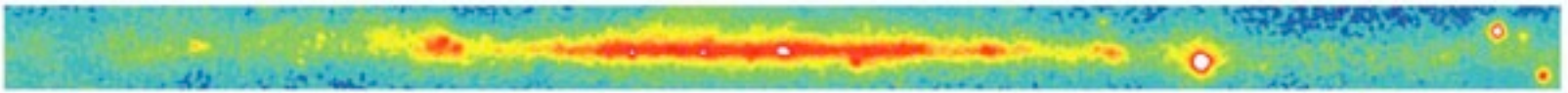

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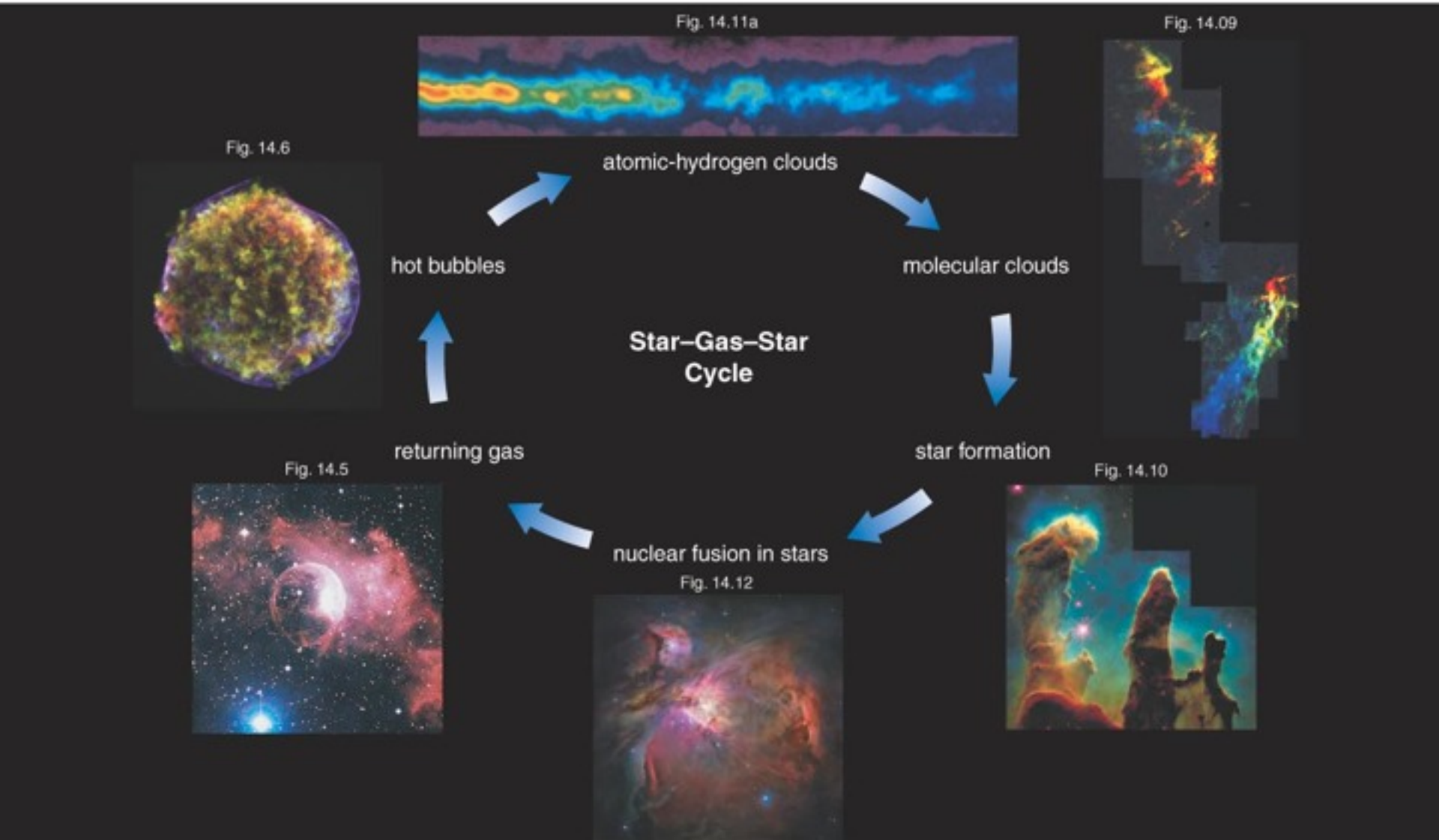
Gas recycling in our galaxy

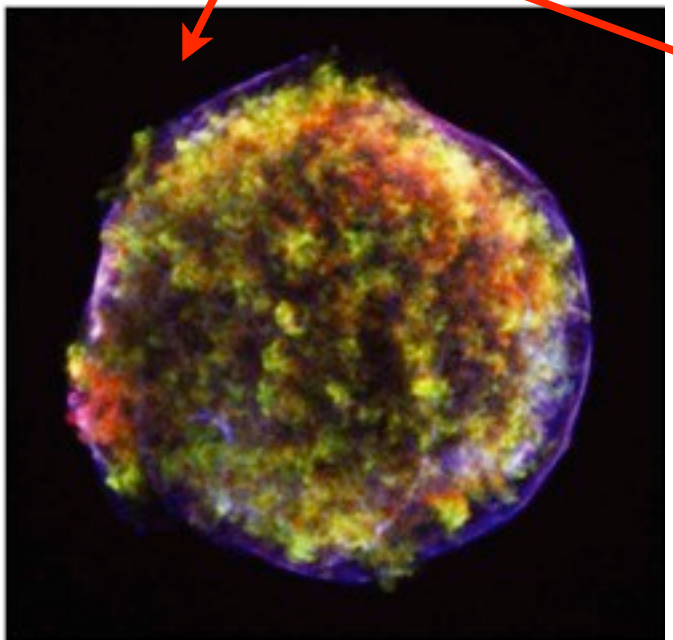


Gas recycling

- Stars form in cold molecular gas clouds

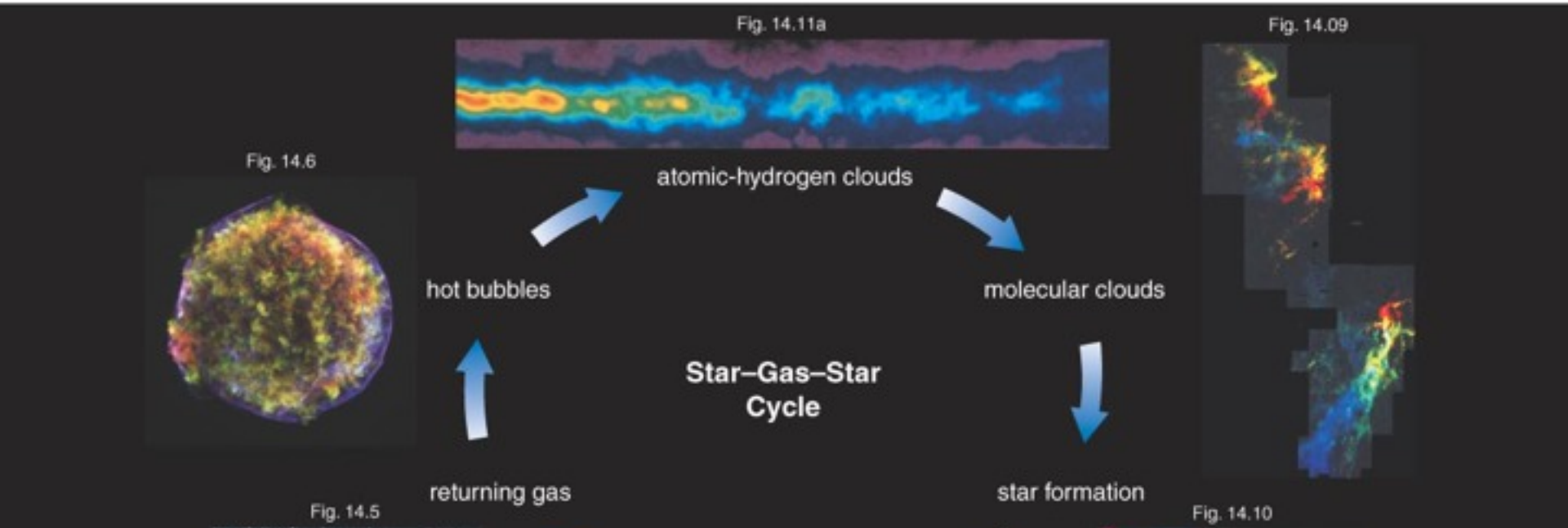
Gas recycling

- Stars form in cold molecular gas clouds
- High mass stars explode
  - return processed gas to interstellar medium
  - heat surrounding gas
    - Supernova bubbles
    - Ionized gas (H II regions) [hot stars emit UV radiation]



Gas recycling

- Stars form in cold molecular gas clouds
- High mass stars explode
- Hot gas cools
  - First into "warm" atomic gas (H I), then
  - into "cold" molecular gas (H_2) in dusty places (~30 K)



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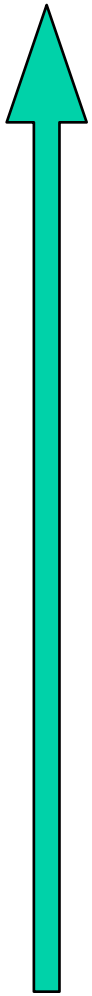

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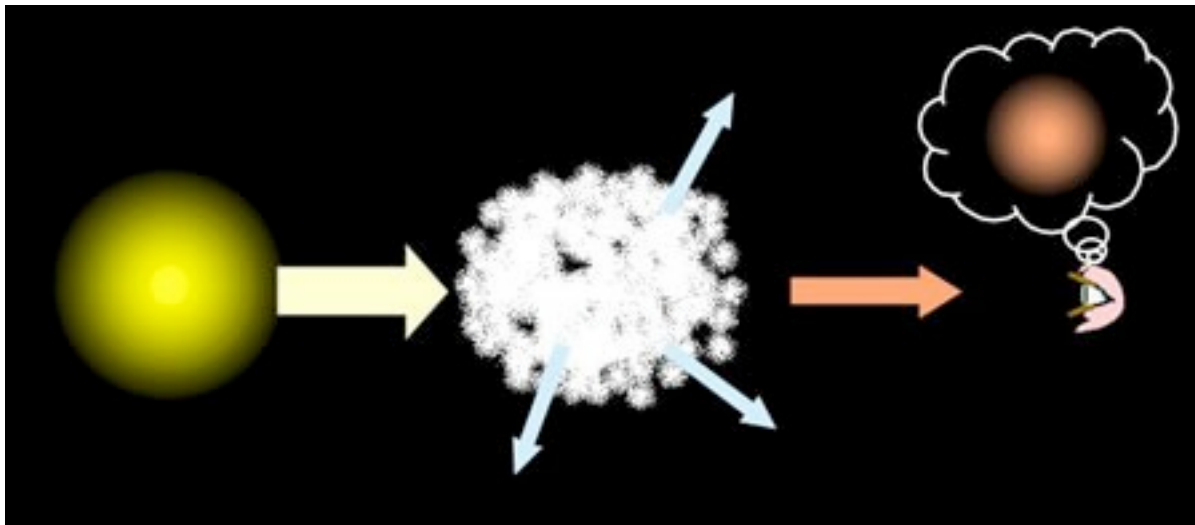
- Hot gas cools
  - First into "warm" atomic gas (H I), then
  - into "cold" molecular gas (H_2) in dusty places
- Stars form in cold molecular gas clouds

Note: recycling is inefficient. Some mass locked up in remnants.

The Effects of Dust

- Interstellar dust
  - small grains in space
  - scatters star light passing through it
- Dims light

- Reddens it



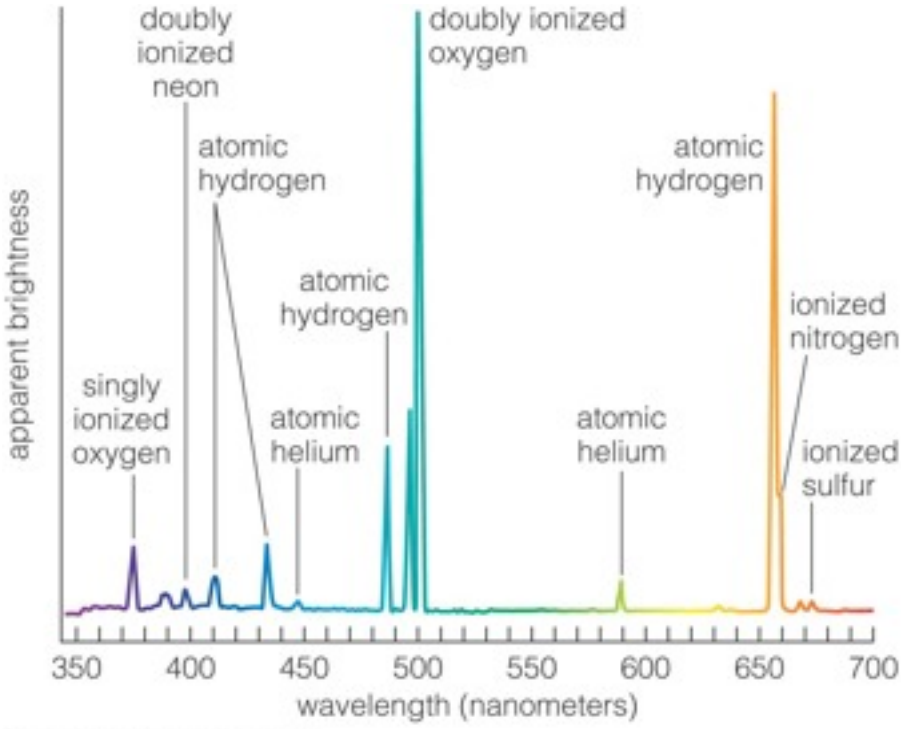
The Effects of Dust

- Interstellar dust
  - small grains in space
  - scatters star light passing through it
- Dims light
  - blocks some light
  - stars appear fainter than they otherwise would
- Reddens
  - preferentially scatters blue light
  - light that gets through is redder than it started

Various Nebulae

H II Regions

Ionization nebulae are found around short-lived high-mass stars, signifying active star formation.



Reflection nebulae scatter the light from stars.

Why do reflection nebulae look bluer than the nearby stars?

Reflection nebulae scatter the light from stars.

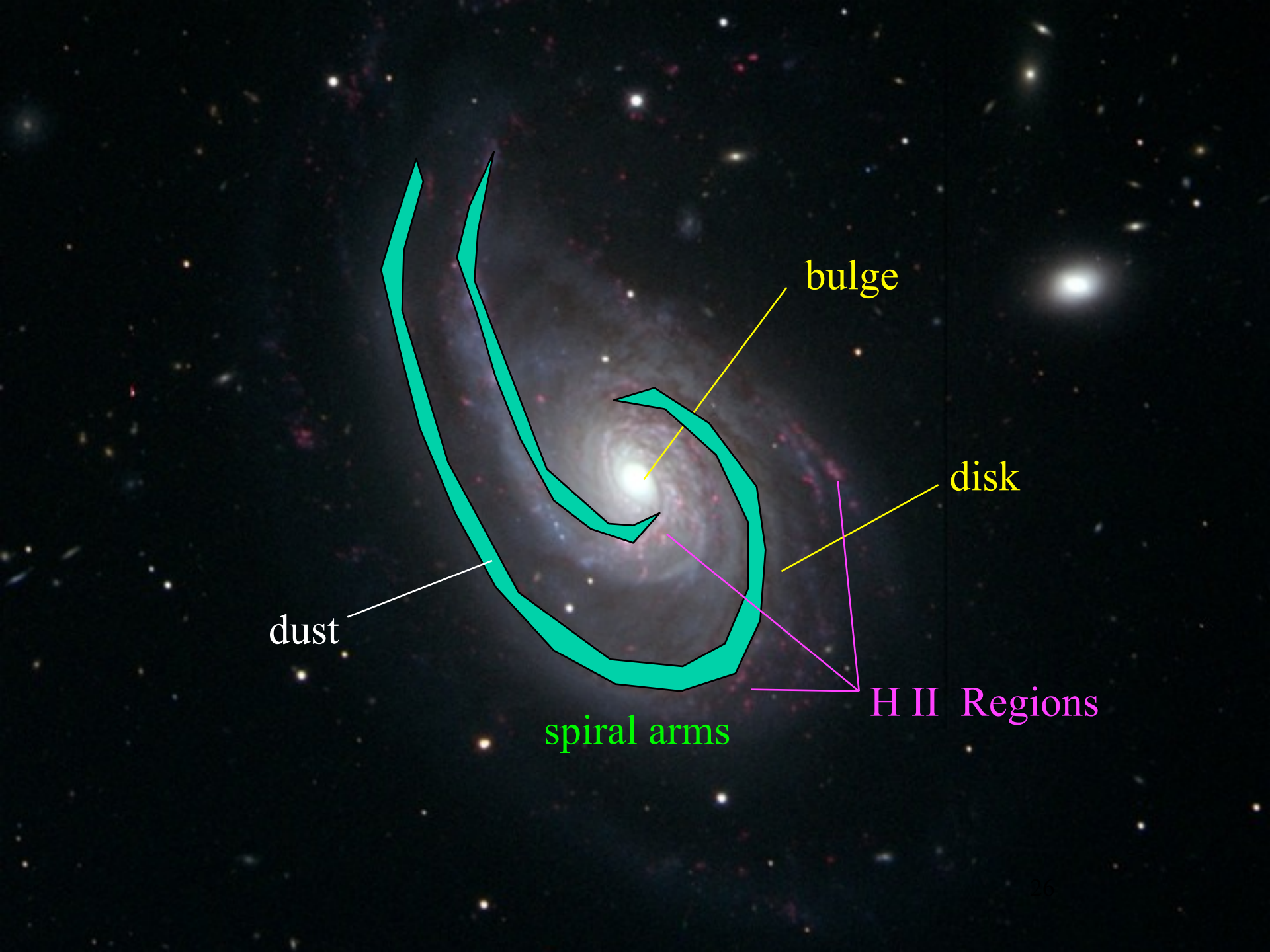
Why do reflection nebulae look bluer than the nearby stars?

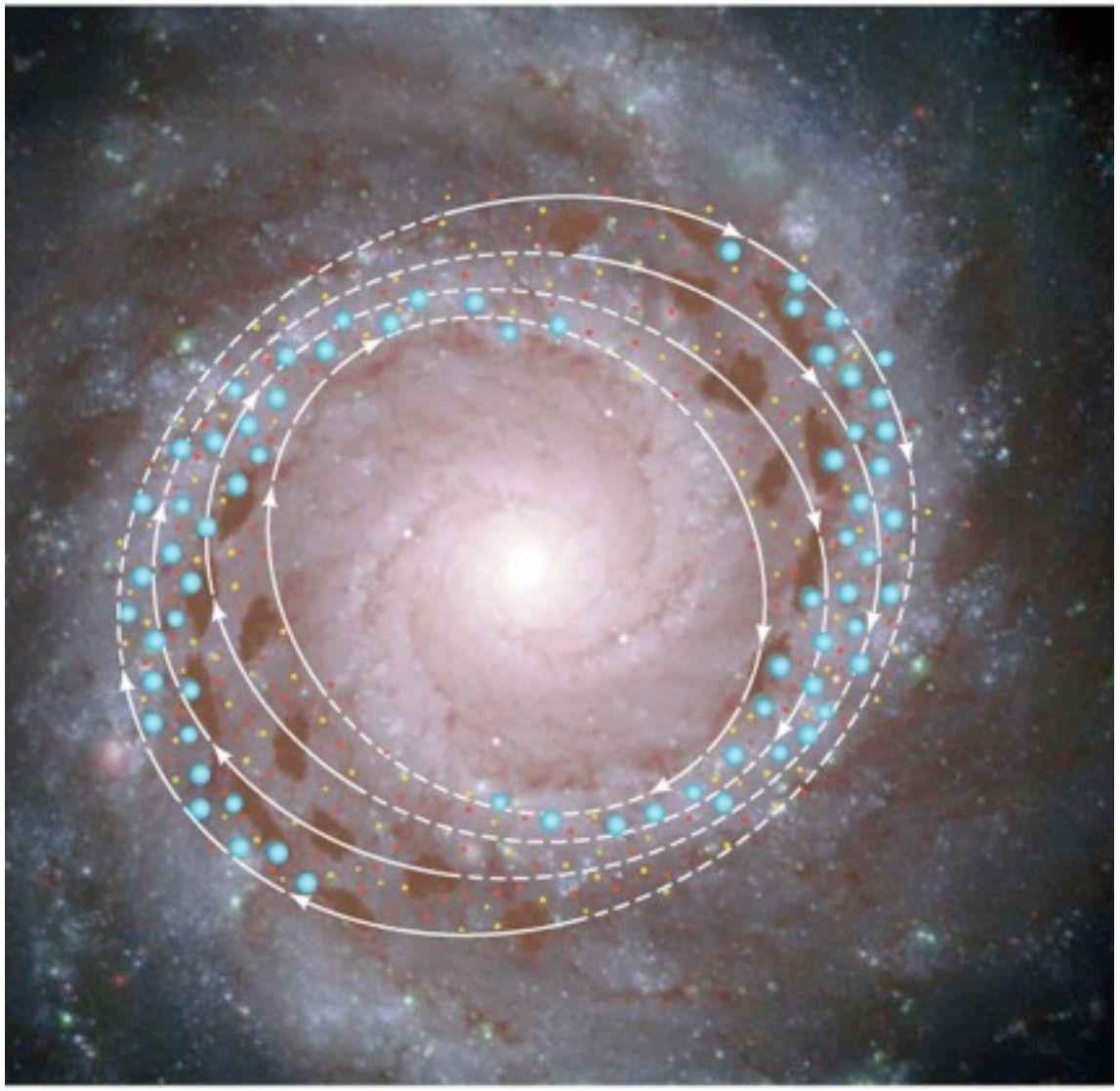
For the same reason that our sky is blue!

What kinds of nebulae do you see?

Star formation

- Stars form in molecular clouds
- Molecular clouds contain a lot of dust
- Most star formation occurs in spiral arms


bulge
disk
dust
H II Regions
spiral arms



Spiral arms are waves of star formation:

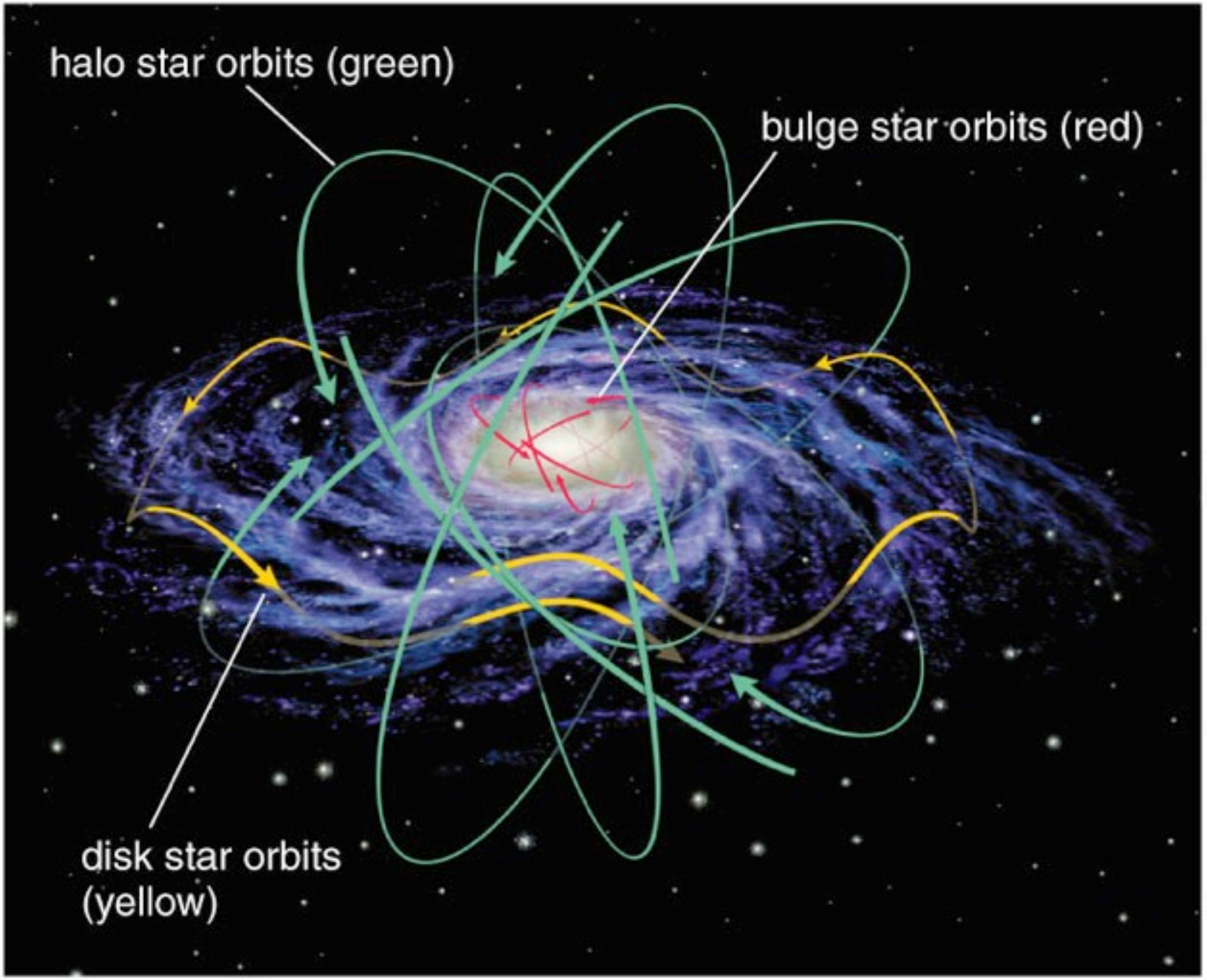
1. Gas clouds get squeezed as they move into spiral arms.

2. The squeezing of clouds triggers star formation.

3. Young stars flow out of spiral arms.

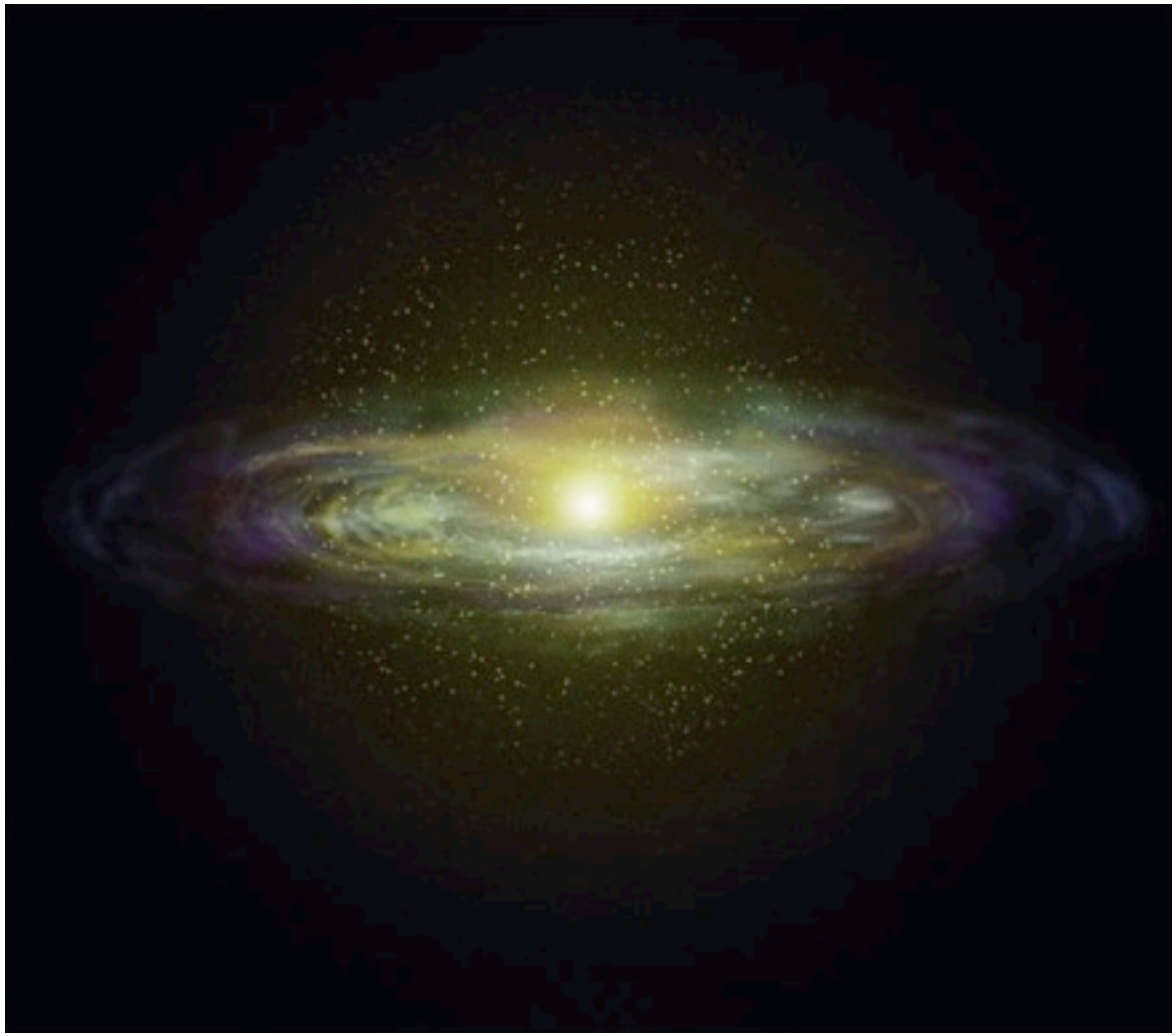
Stellar Populations

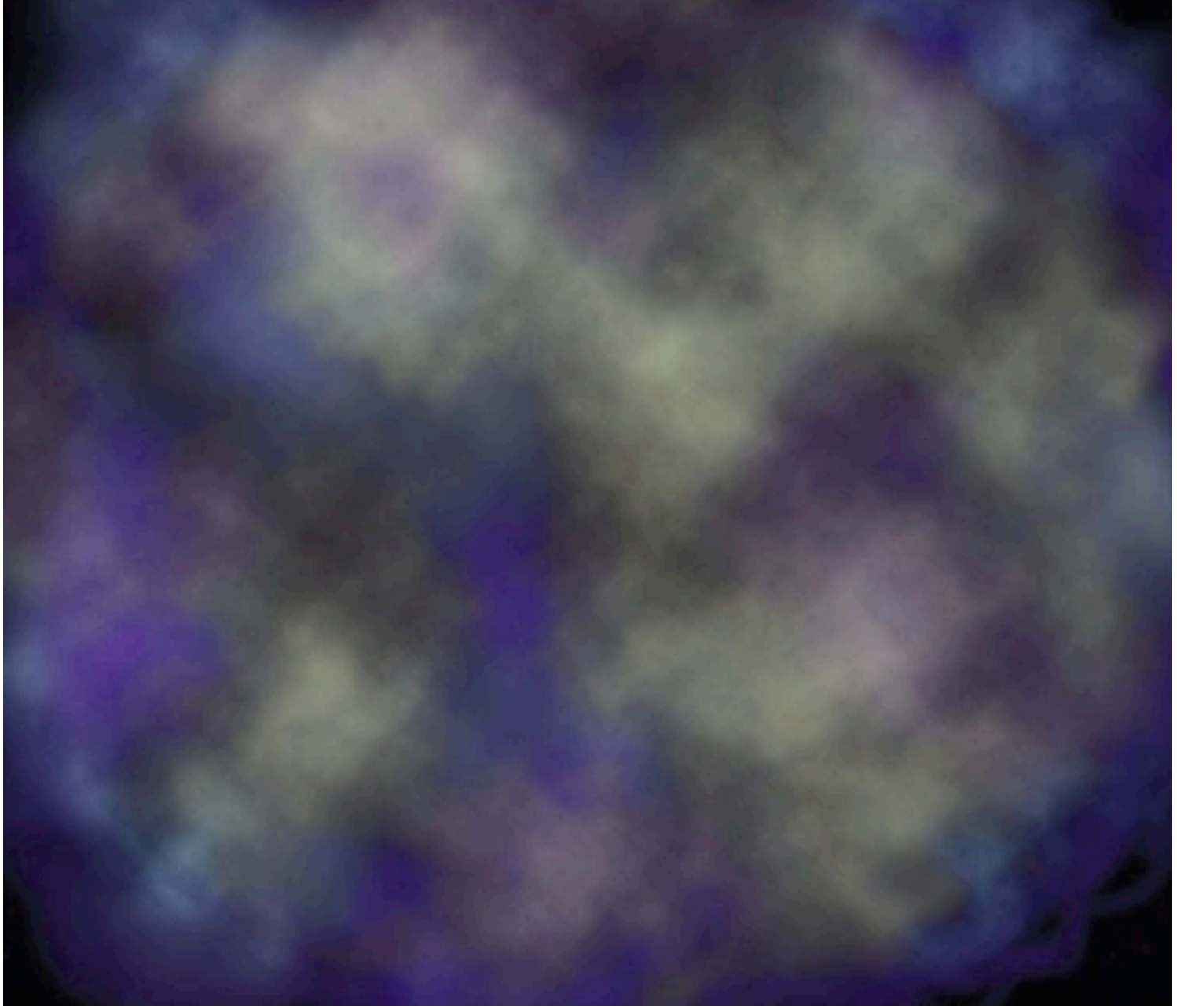
- **Population I**
  - circular orbits in plane of disk
  - mix of ages
    - young, newly formed OB stars
    - old stars (& everything in between)
  - metal rich, like sun (~2% mass in "metals")
- **Population II**
  - elliptical orbits of all orientations
  - old stars only
  - metal poor in halo (~0.2% metals)
    - but metal rich in bulge



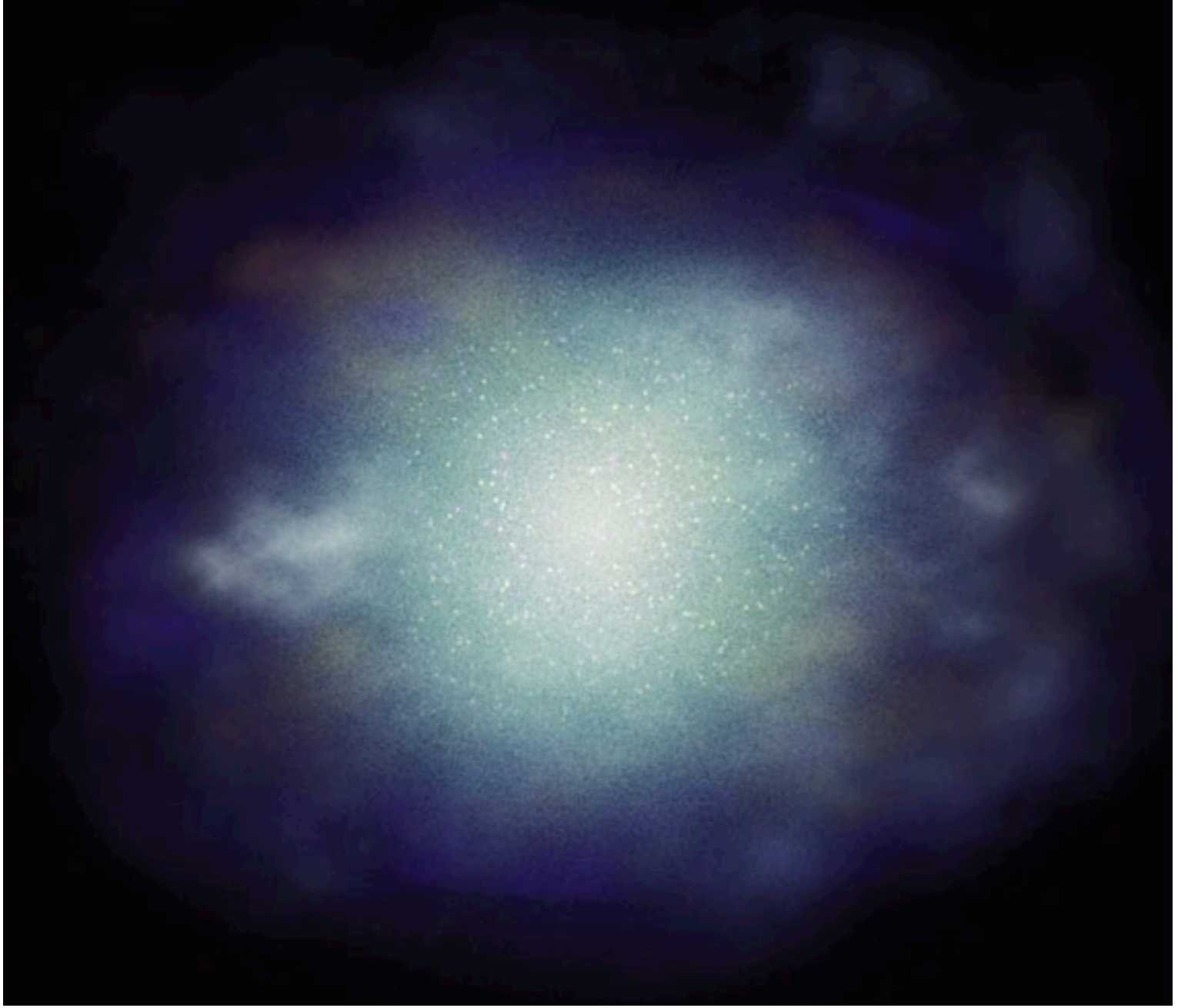

bulge (**Pop II**)
disk (**Pop I**)

How did our galaxy form?

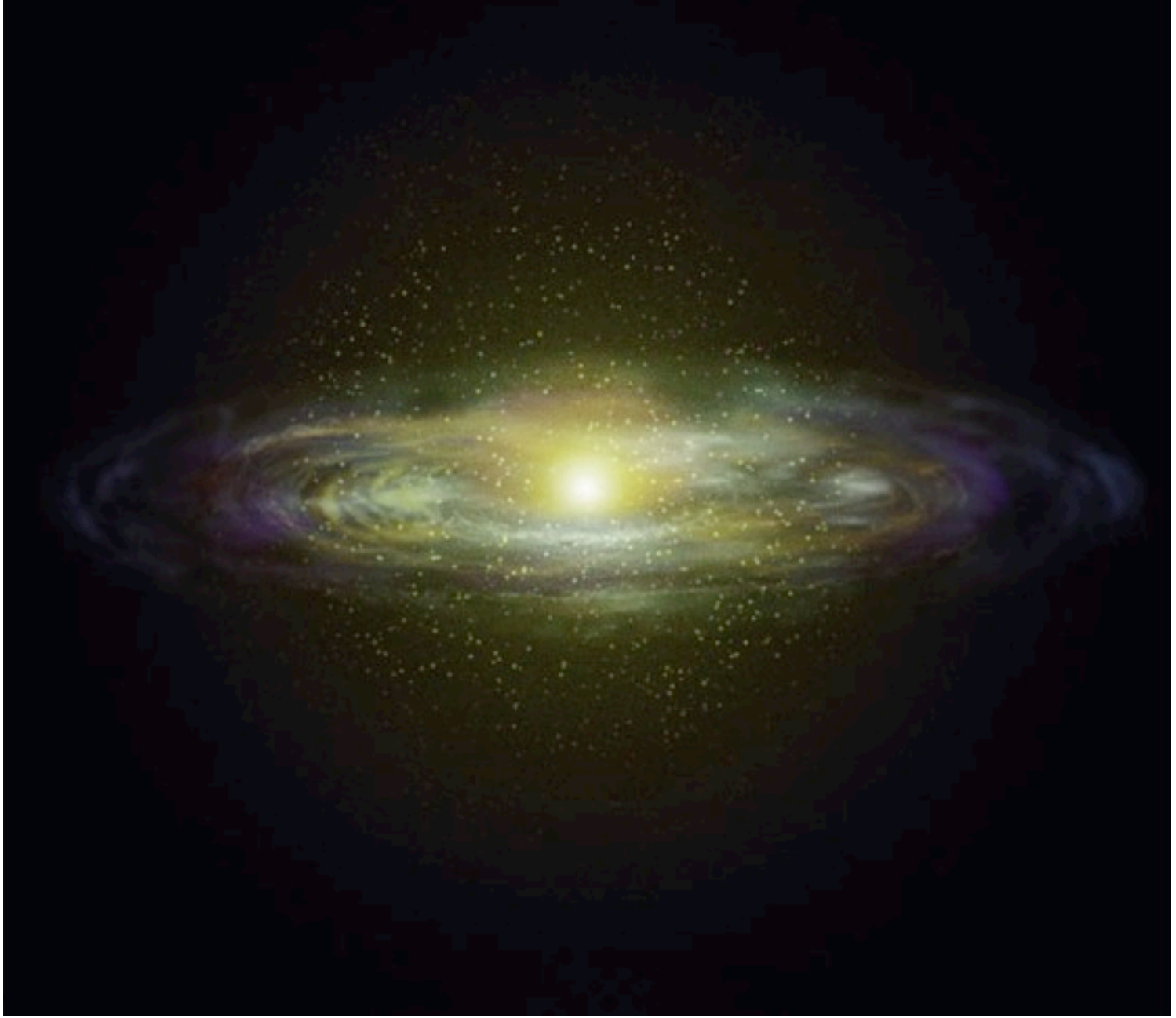




Our galaxy probably formed from a giant gas cloud.



Halo stars formed first as gravity caused the cloud to contract.



The remaining gas settled into a spinning disk.

Stars continuously form in the disk as the galaxy grows older.

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