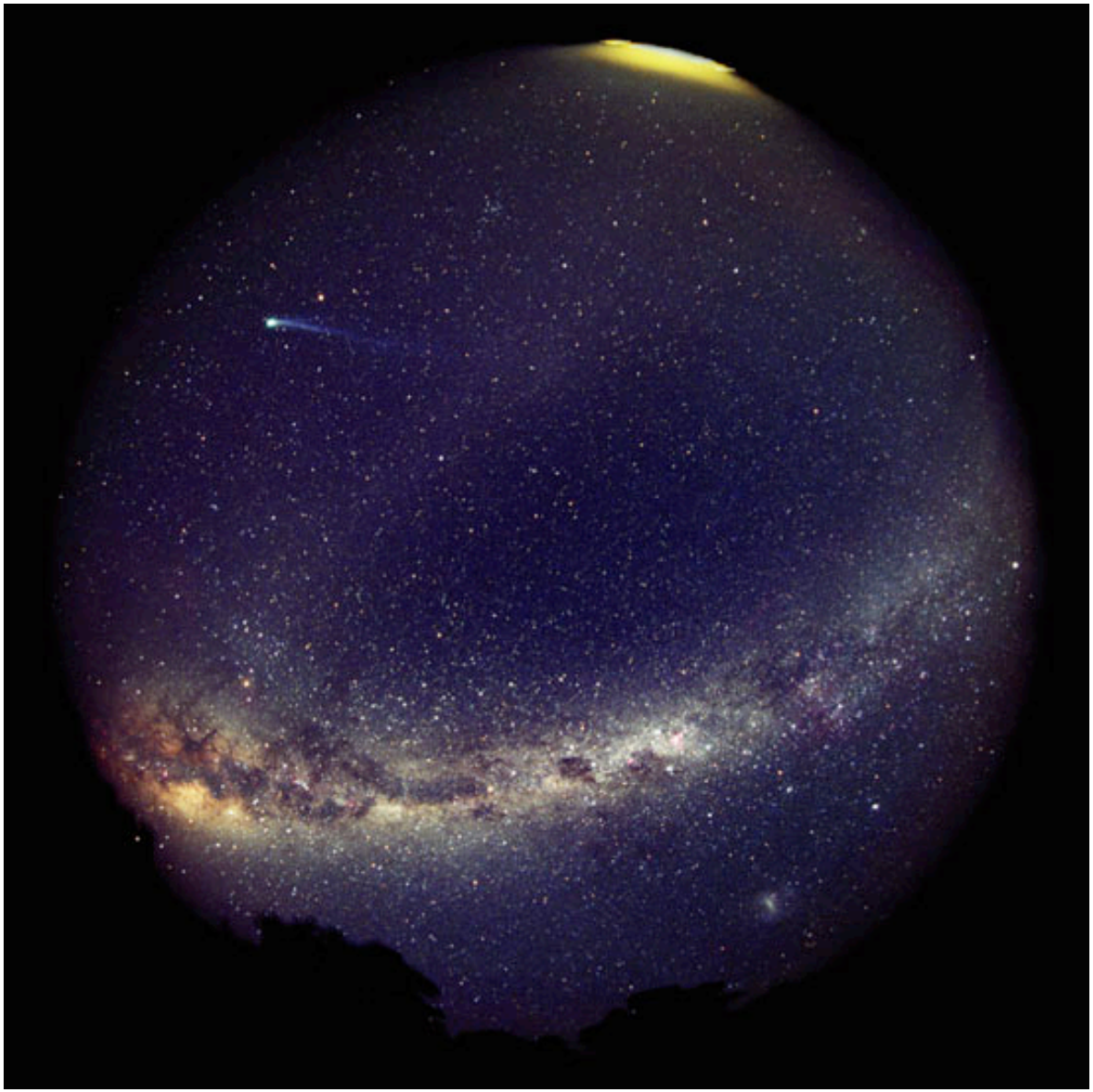
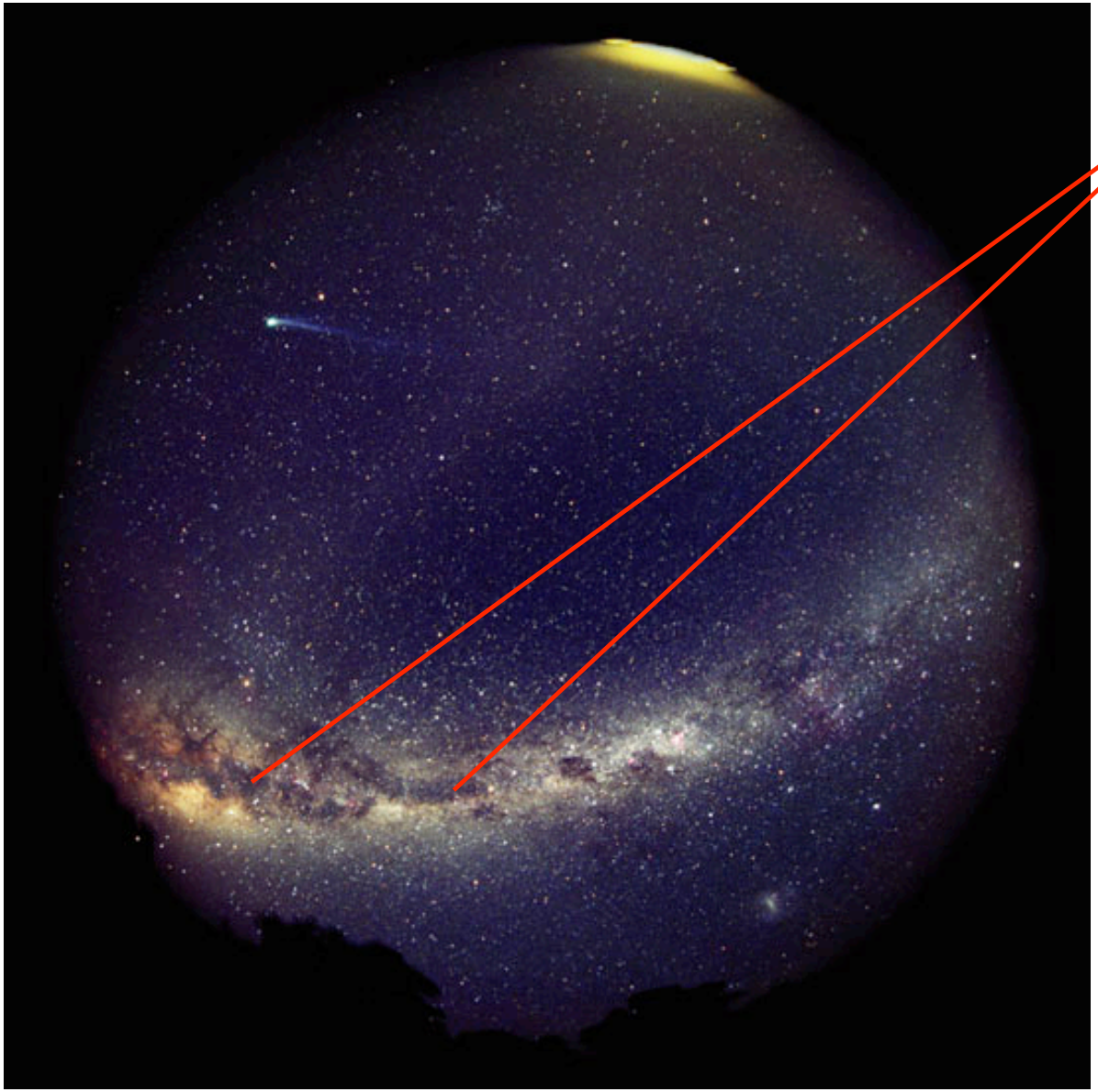
Chapter 19
Our Galaxy

What does our galaxy look like?



The Milky Way galaxy appears in our sky as a faint band of light



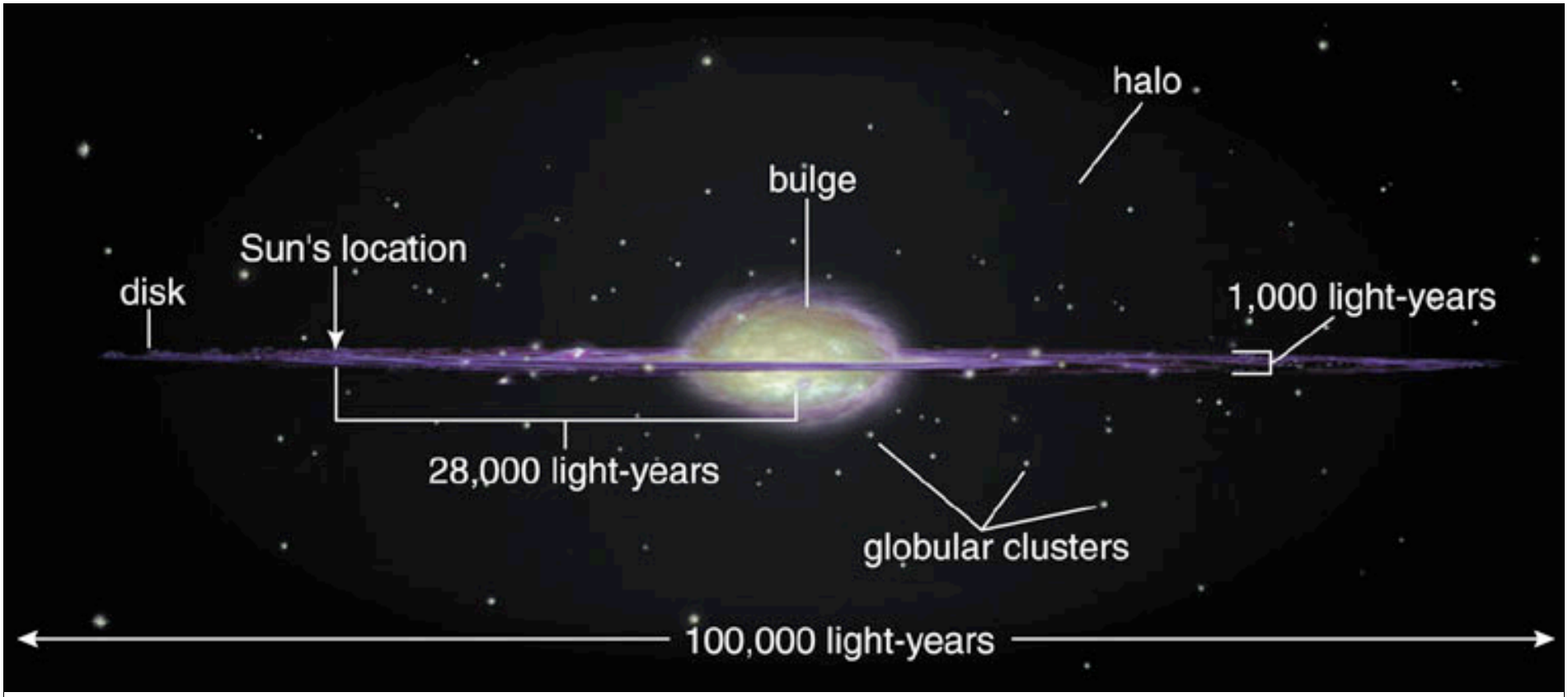
Dusty gas clouds obscure our view because they absorb visible light

This is the ***interstellar medium*** that makes new star systems:

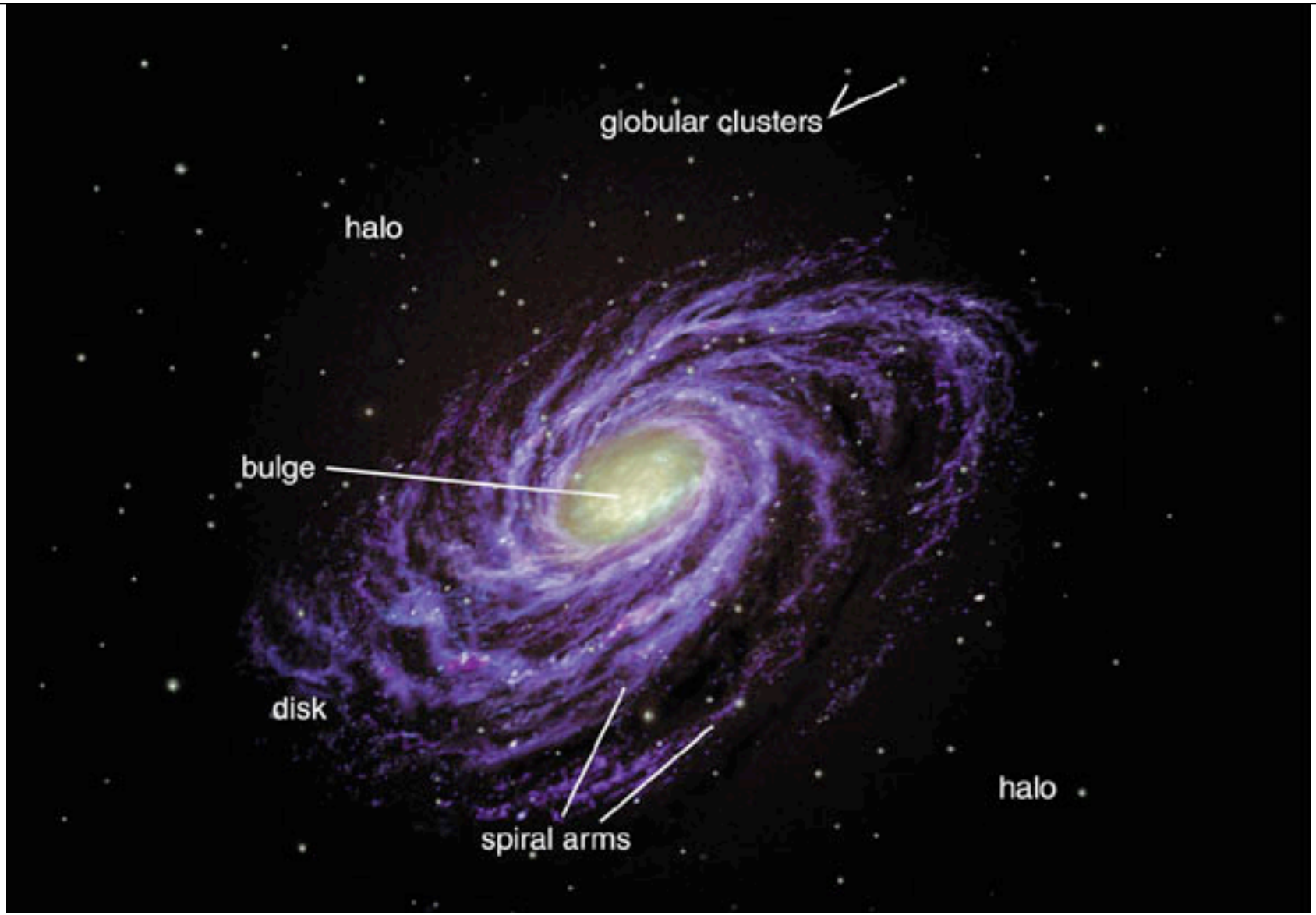
Friday's lecture

All-Sky View

We see our galaxy edge-on

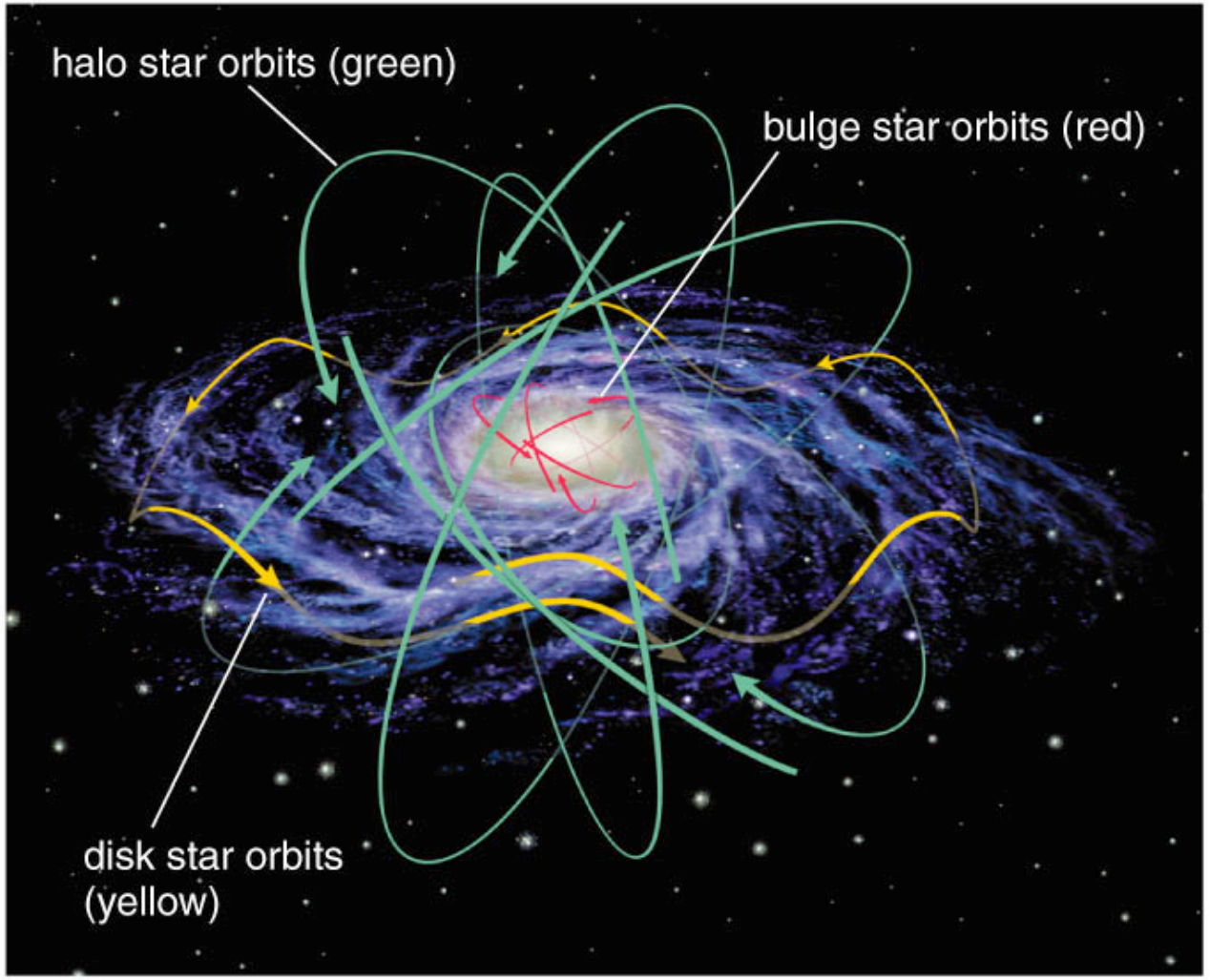


Primary features:
- disk - majority of stars, gas, and dust
  - has star formation
- bulge - older stars, little gas and dust
- halo - spherical distribution of oldest stars
  - does not have star formation
- globular clusters - in the halo

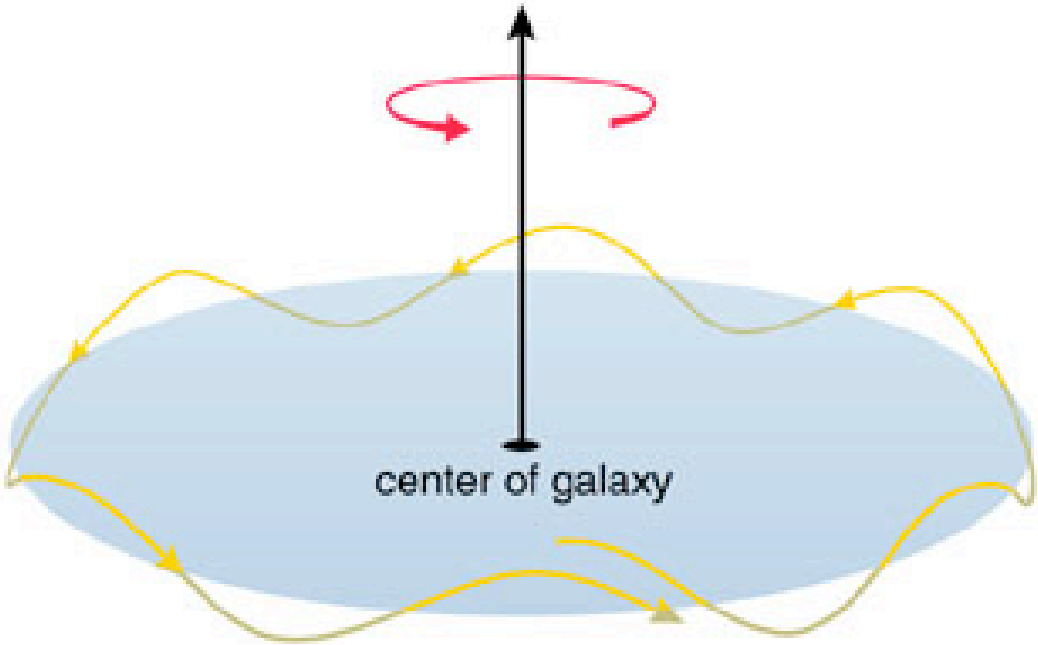


If we could view the Milky Way from above the disk, we would see its spiral arms

How do stars orbit in our galaxy?

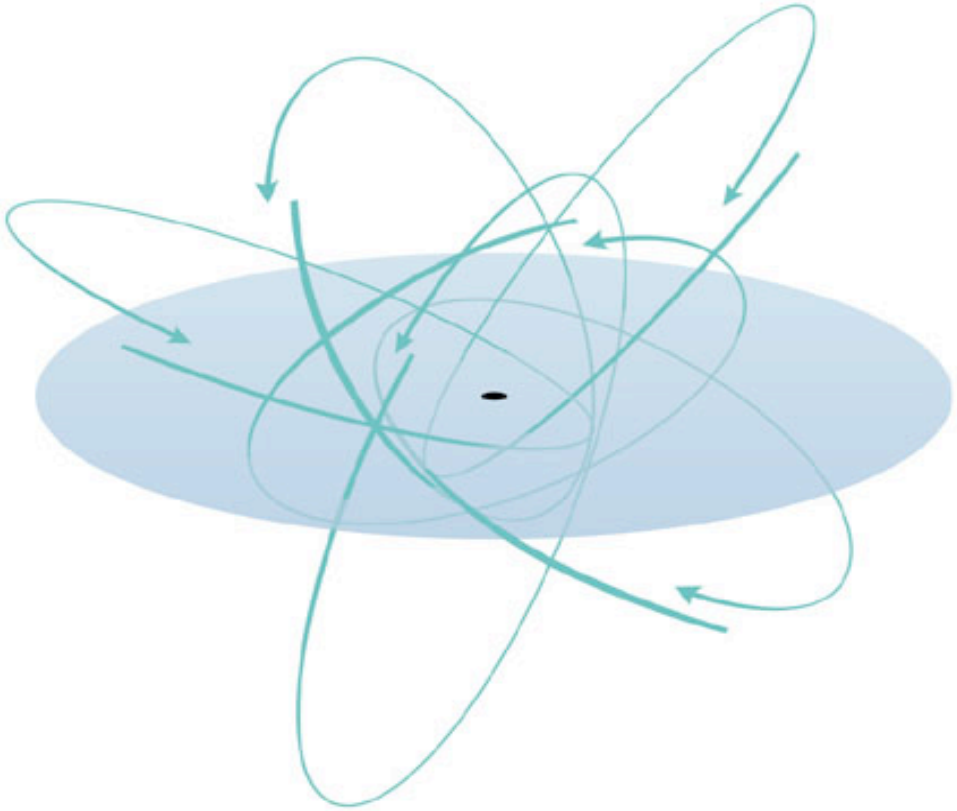


Disk Stars:



- Stars in the disk all orbit in the same direction with a little up-and-down motion
- Sun's orbital time is 230 million years
  - gravitational pull towards galactic center
- Sun's up-and-down motion 65 million year period
  - localized pull of gravity within the disk itself

Bulge and Halo Stars:



Orbits of stars in the bulge and halo have random orientations

Thought Question

What do we call the bright, sphere-shaped region of stars that lie within a few thousand light-years of the center of the Milky Way Galaxy?

1. the galaxy's halo
2. the galaxy's bulge
3. the galaxy's disk
4. the globular clusters

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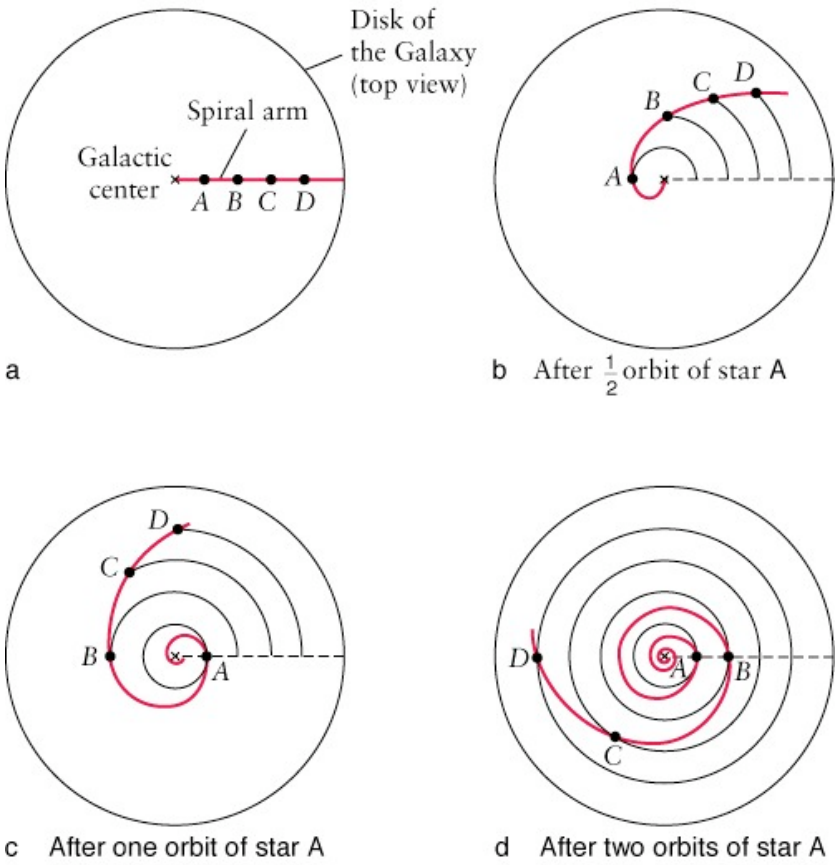
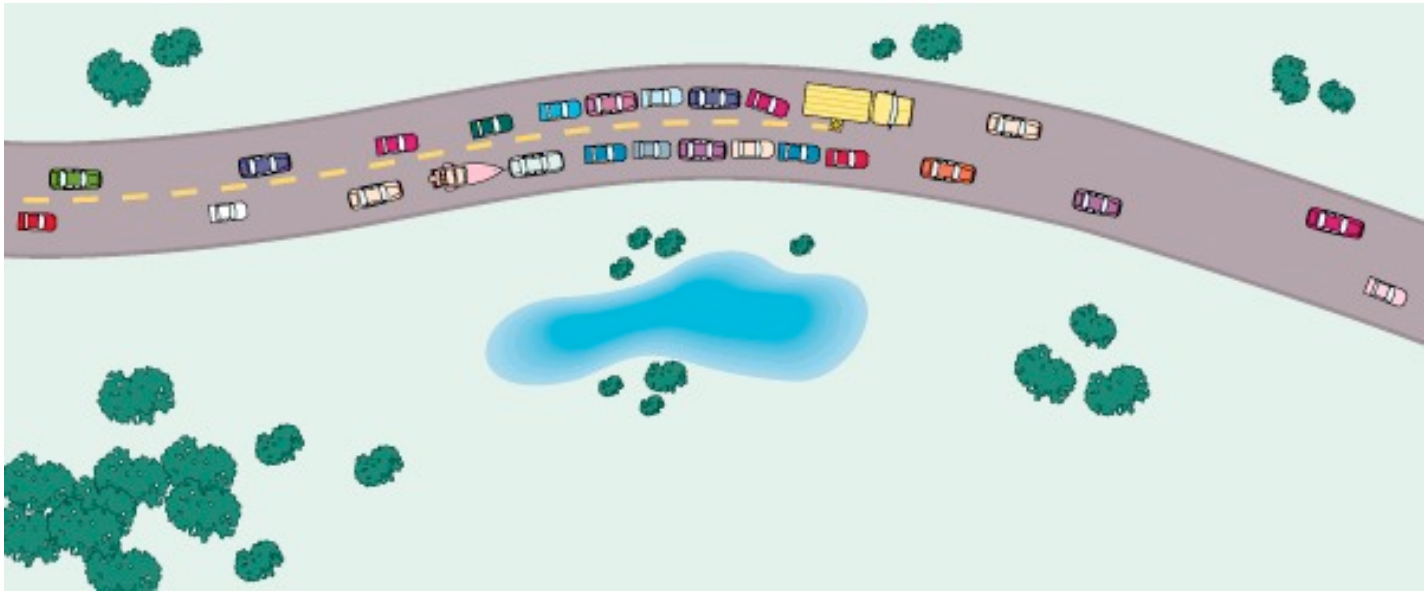
Why do galaxies have spiral arms?



Spiral pattern **not** due to "differential" movement of stars, otherwise the spiral pattern wraps up on itself in only a couple rotation periods.

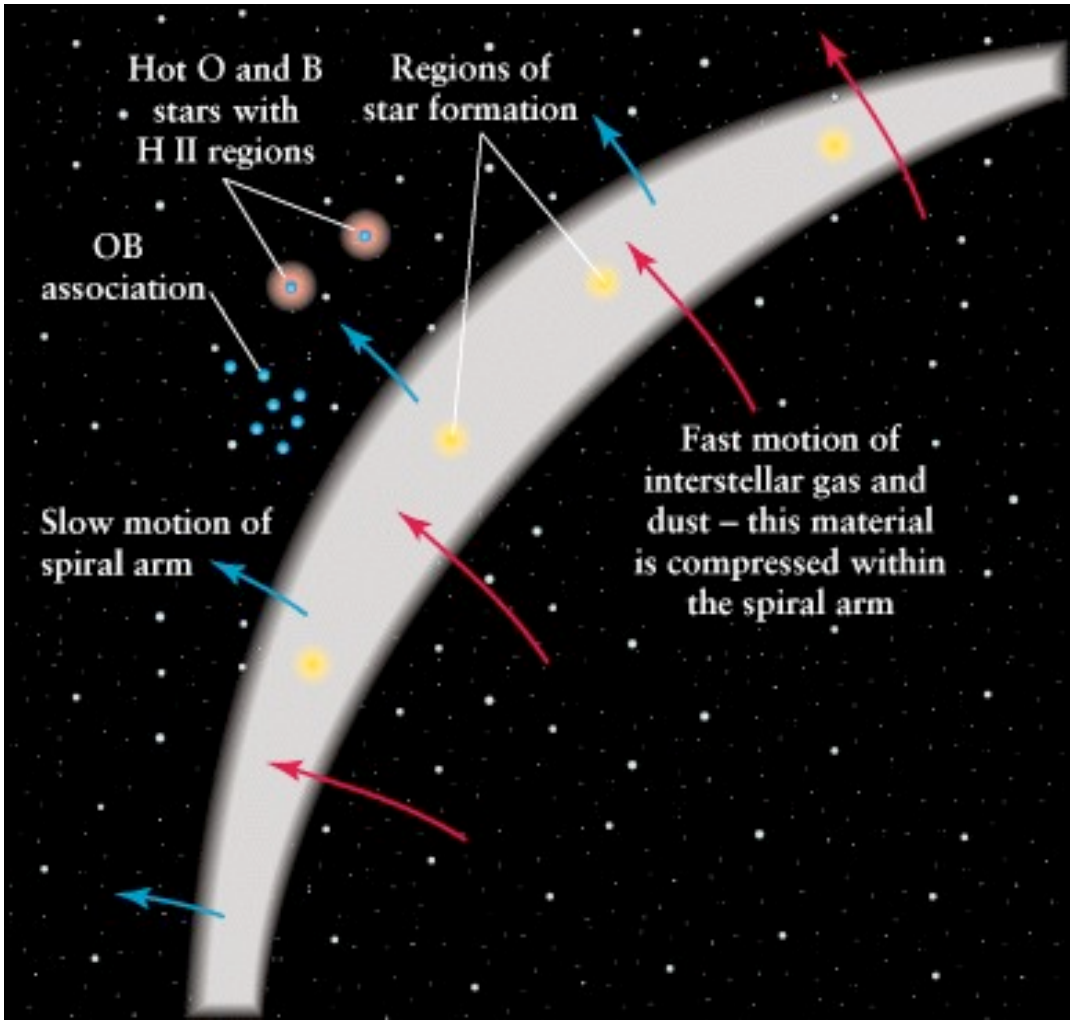
Spiral Density Waves



Traffic Jam example:

- Jam occurs due to slow tractor in left lane
- Cars slowly work their way out of it, and accelerate
- Jam moves along highway at slower speed
    - speed of jam is not the same as the material

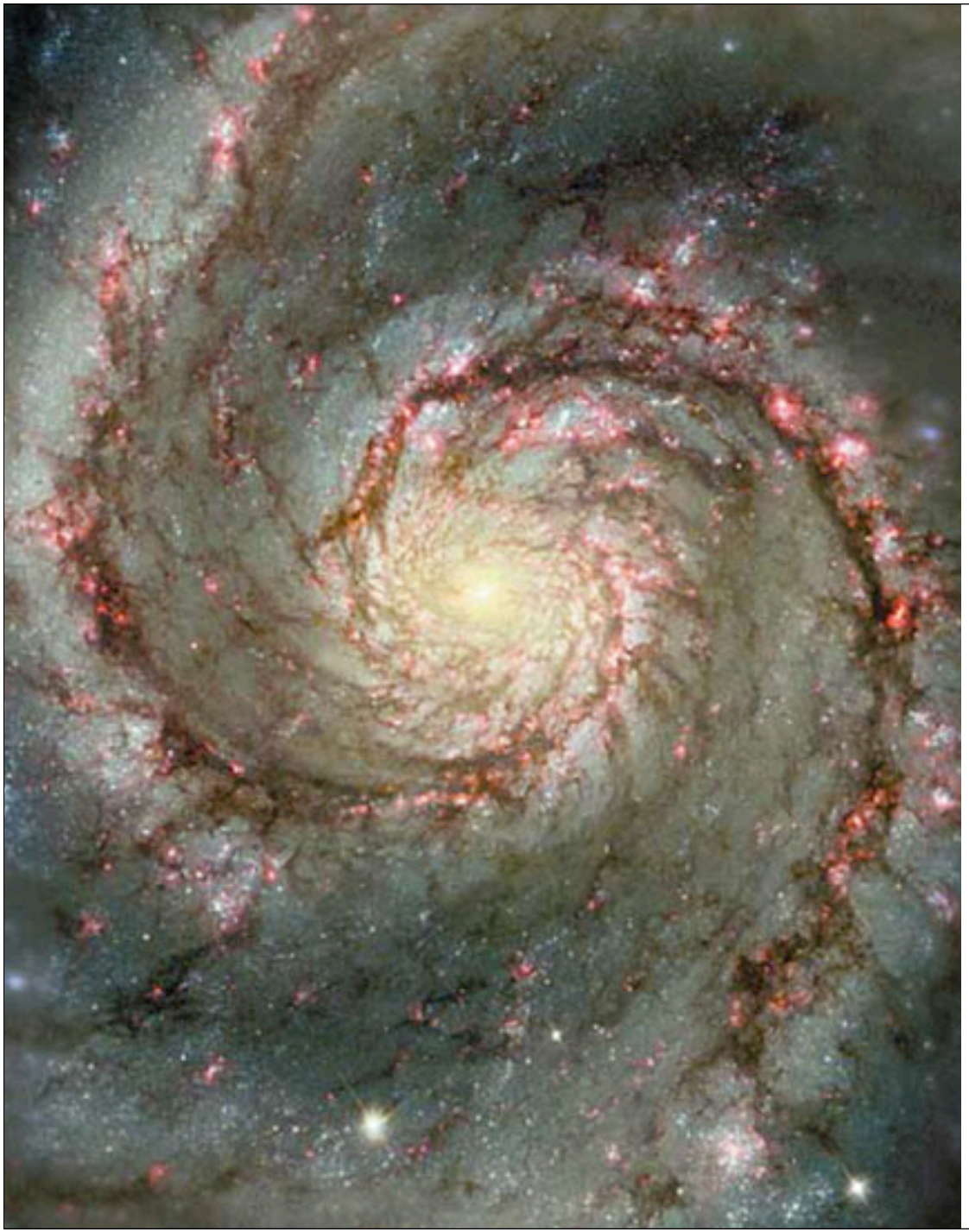
Spiral arms are waves of star formation



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

2. Squeezing of clouds triggers star formation

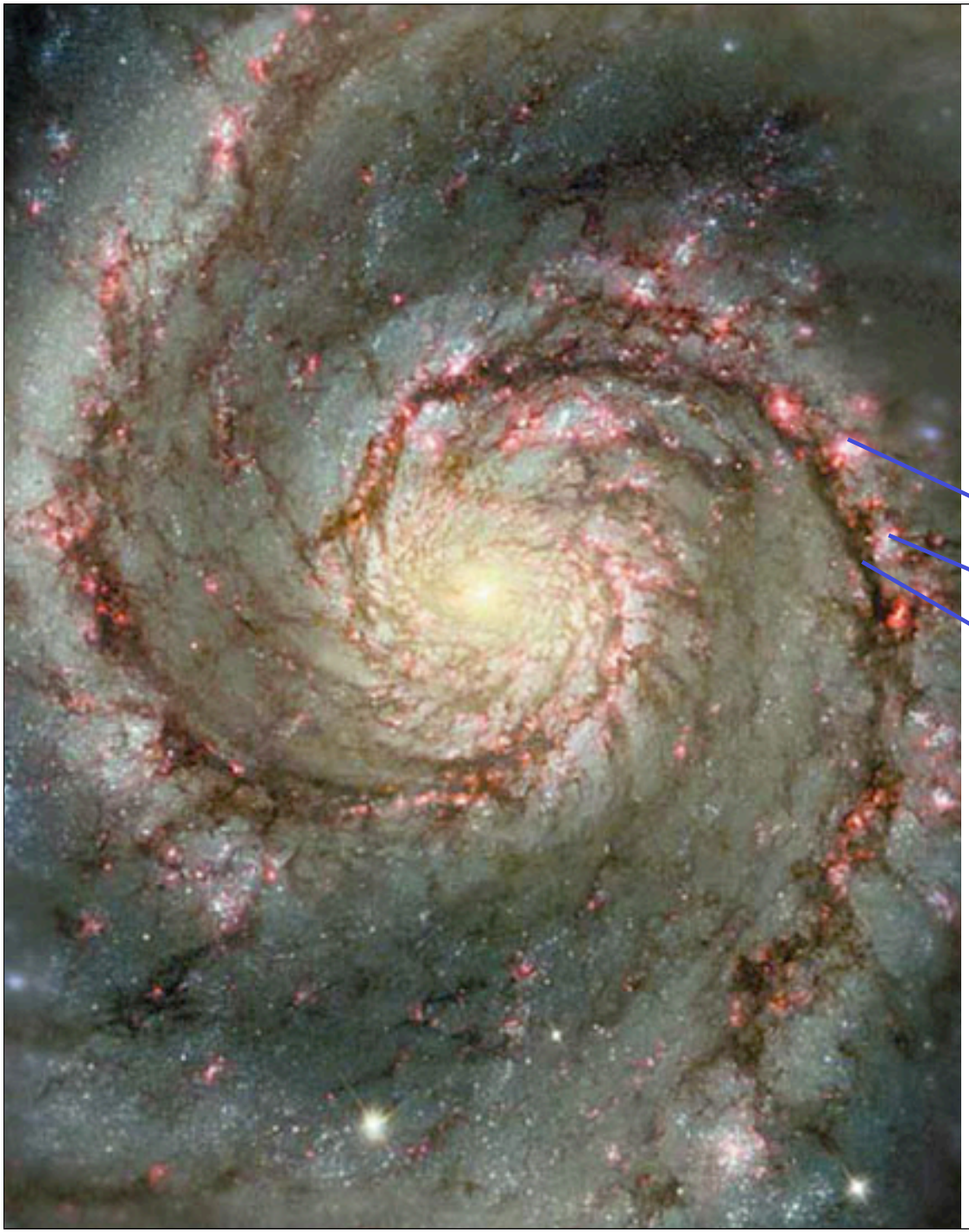
3. Young stars flow out of spiral arms



Example of real galaxy:

Whirlpool Galaxy

Much of star formation in disk happens in spiral arms



Much of star formation in disk happens in spiral arms

Ionization Nebulae
Blue Stars
Gas Clouds

These will be explained in Friday's lecture.

Whirlpool Galaxy


Ionization Nebulae
Blue Stars
Gas Clouds

What clues to our galaxy's history do halo stars hold?

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

Disk Stars (population I stars):
2% heavy elements,
stars of all ages

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

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

If we could watch spiral arms (imagine a telescope situated above the Milky Way) over 500 million years, what would we see happen?

1. The spiral arms will eventually unwind, as centripetal forces send the stars flying outwards into intergalactic space.

2. The spiral arms will eventually dissipate and fade away, since they are a temporary phenomenon that should only last for a million years or so.

3. The spiral arms will seem to "wind up", to wrap more and more tightly around the center of the Galaxy.

4. Stars will move through the spiral arms, bunching up closer as they pass through. Young hot stars will form and die within the arms before having a chance to move out.

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How would we know if there is a supermassive black hole at the center of the Milky way?

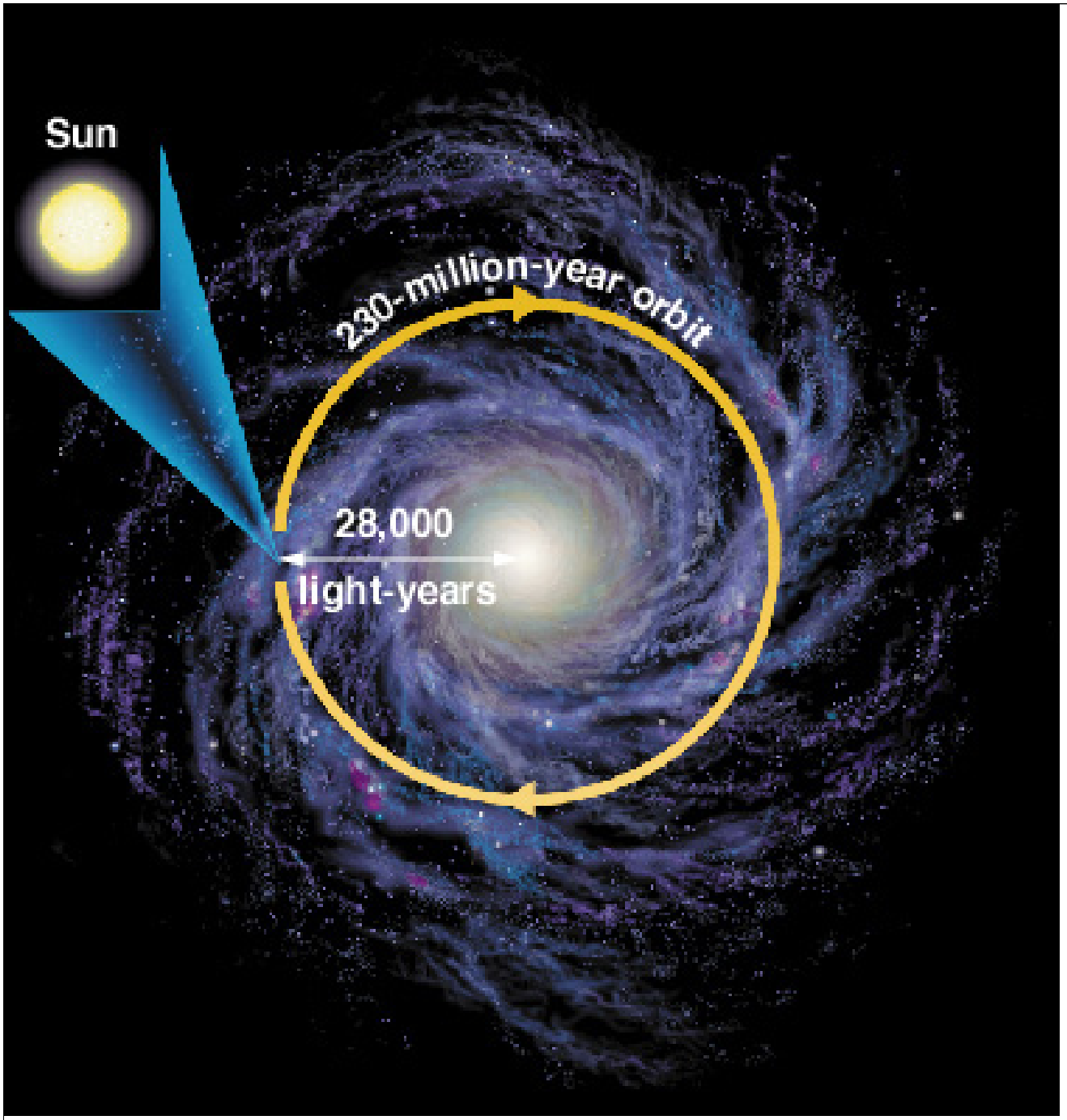
We have to measure the mass and volume of the center of our galaxy. How do we do this?

How do we measure the mass of our galaxy?

Orbital Velocity Law

$$M_r = \frac{r \times v^2}{G}$$

- The orbital speed (v) and radius (r) of an object on a circular orbit around the galaxy tells us the mass (M_r) within that orbit
- This comes from Newton's version of Kepler's third law and that the velocity of an orbiting star goes as 2*pi*radius/period.

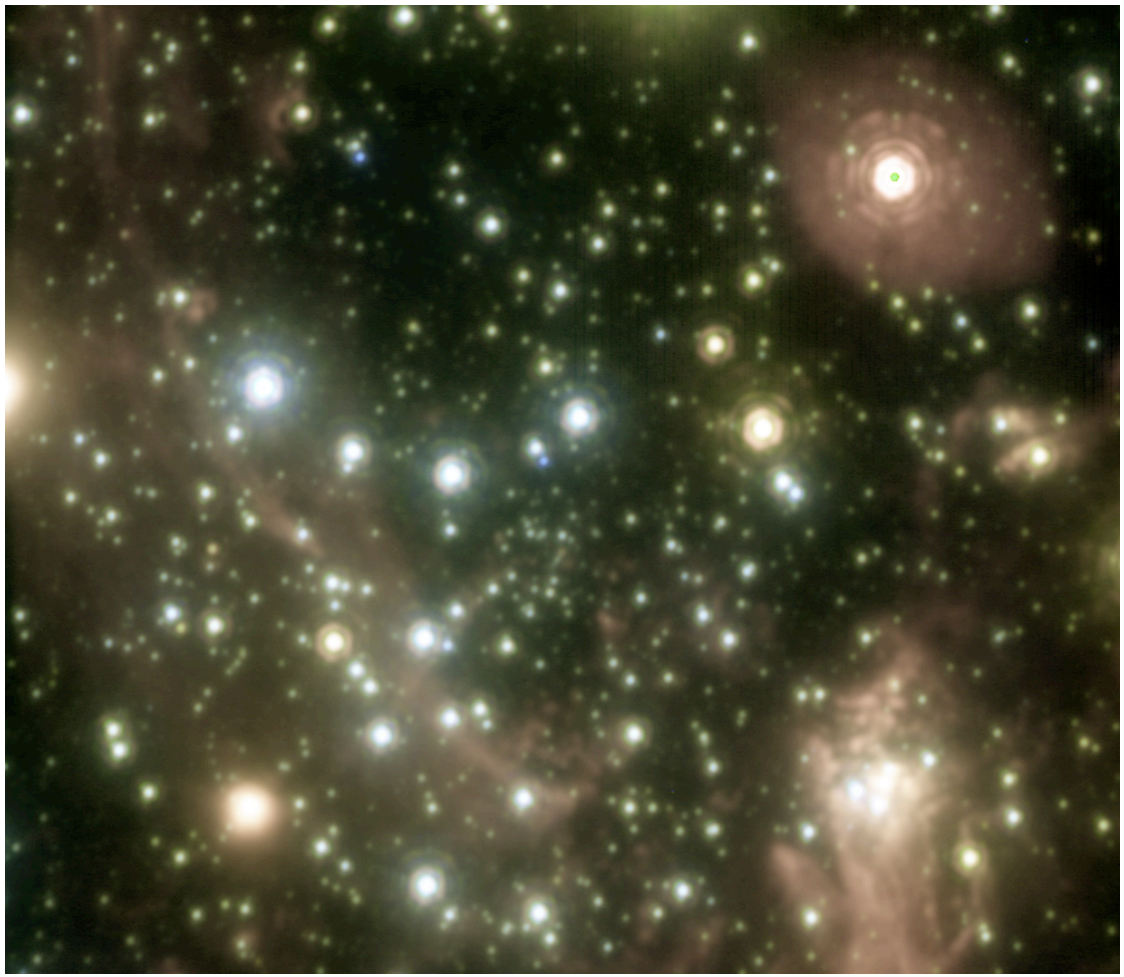


Sun's orbital motion (radius and velocity) tells us mass within Sun's orbit:

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

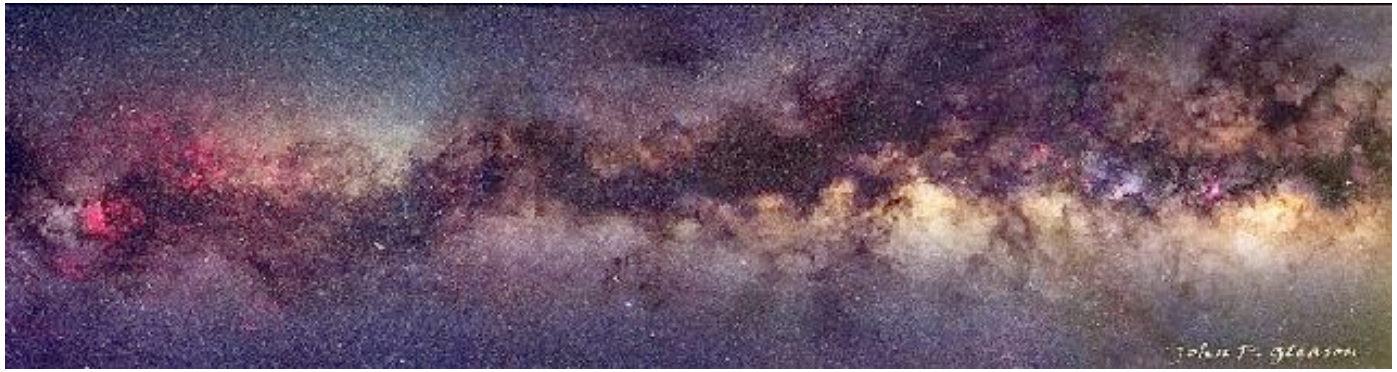
$$M_r = \frac{r \times v^2}{G}$$

What lies in the center of our galaxy?



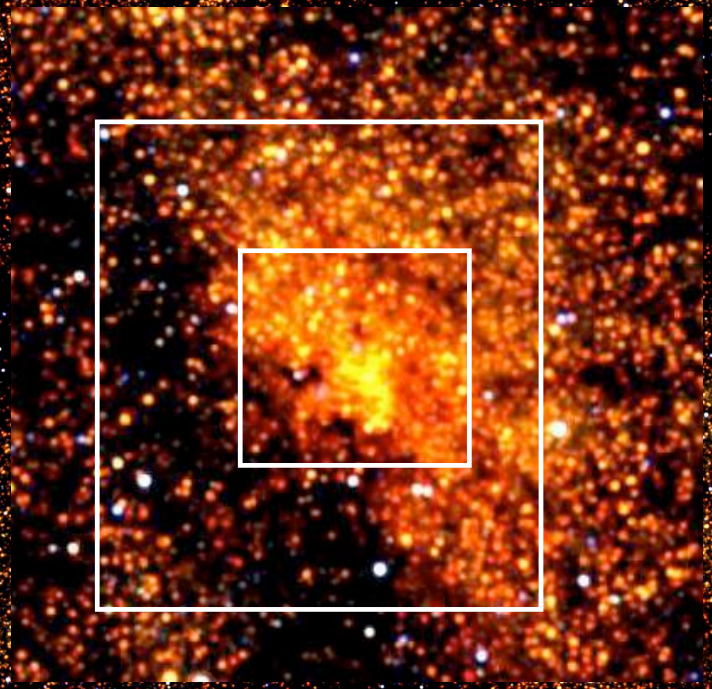
How can we see stars at the center of the galaxy if the dust blocks our view?

Optical light: 1 out of every 10 billion photons makes it to us (invisible)

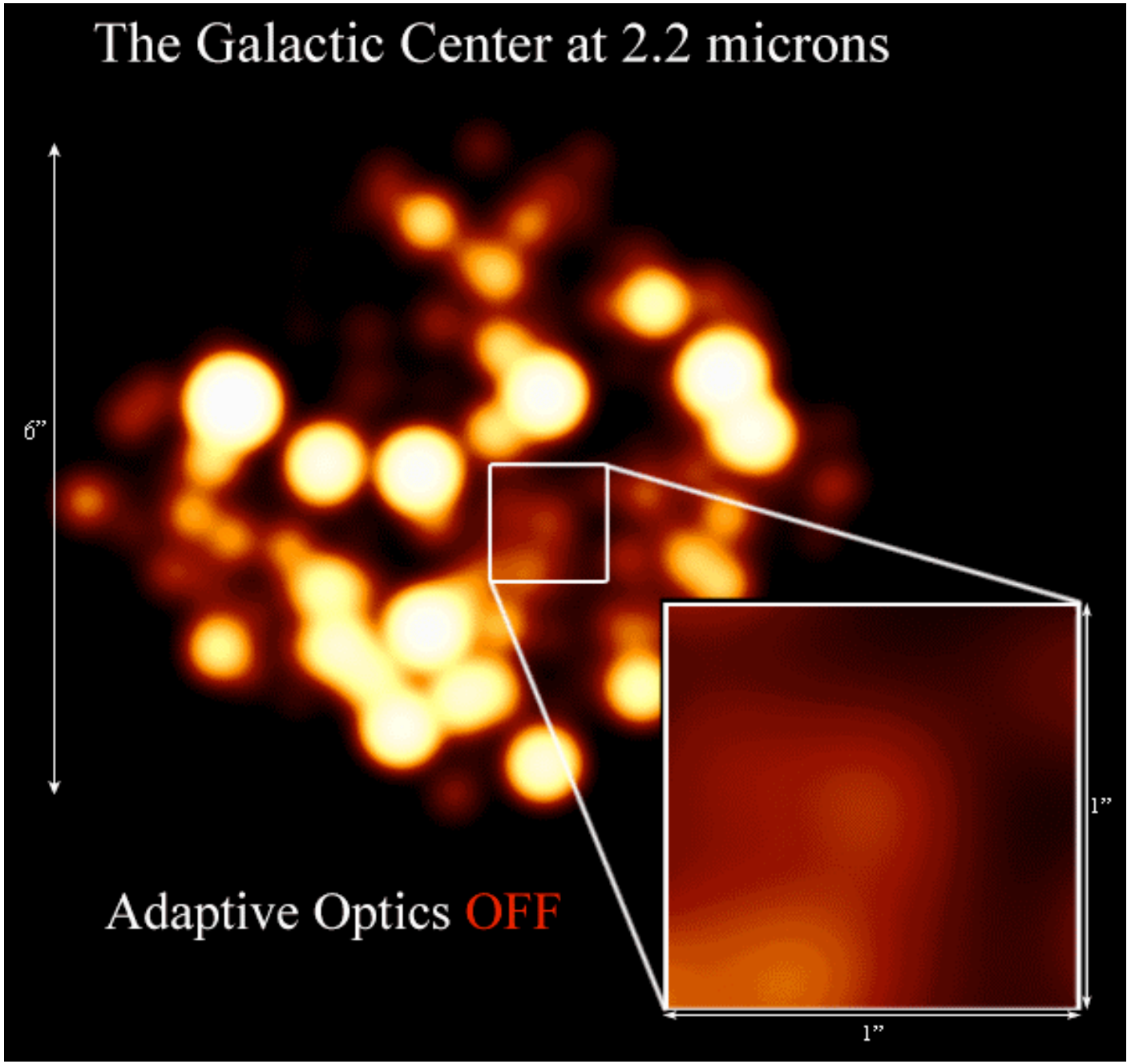


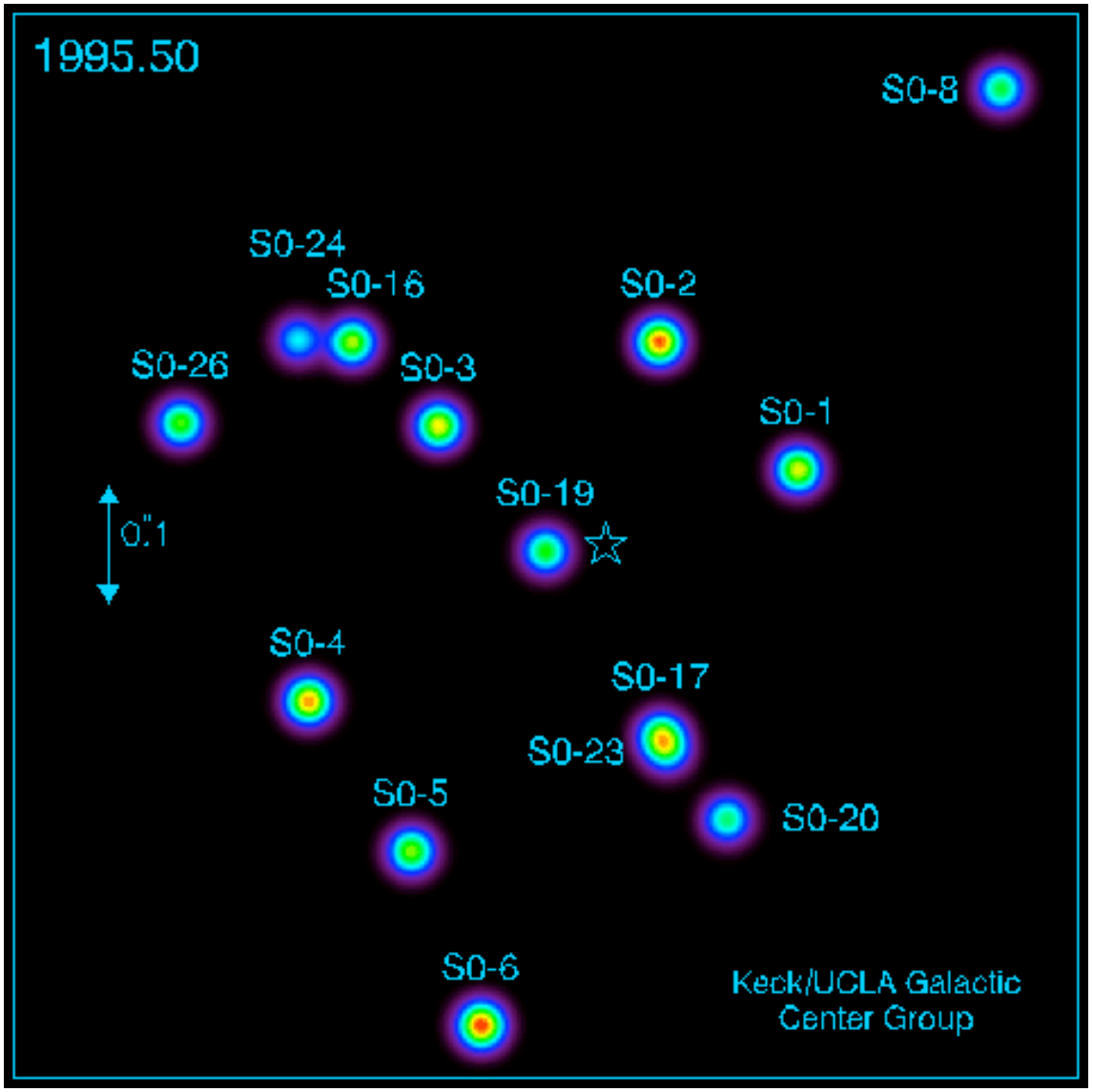
Infrared light: 1 out of every 10 photons makes it to us (visible)

Need higher resolution!



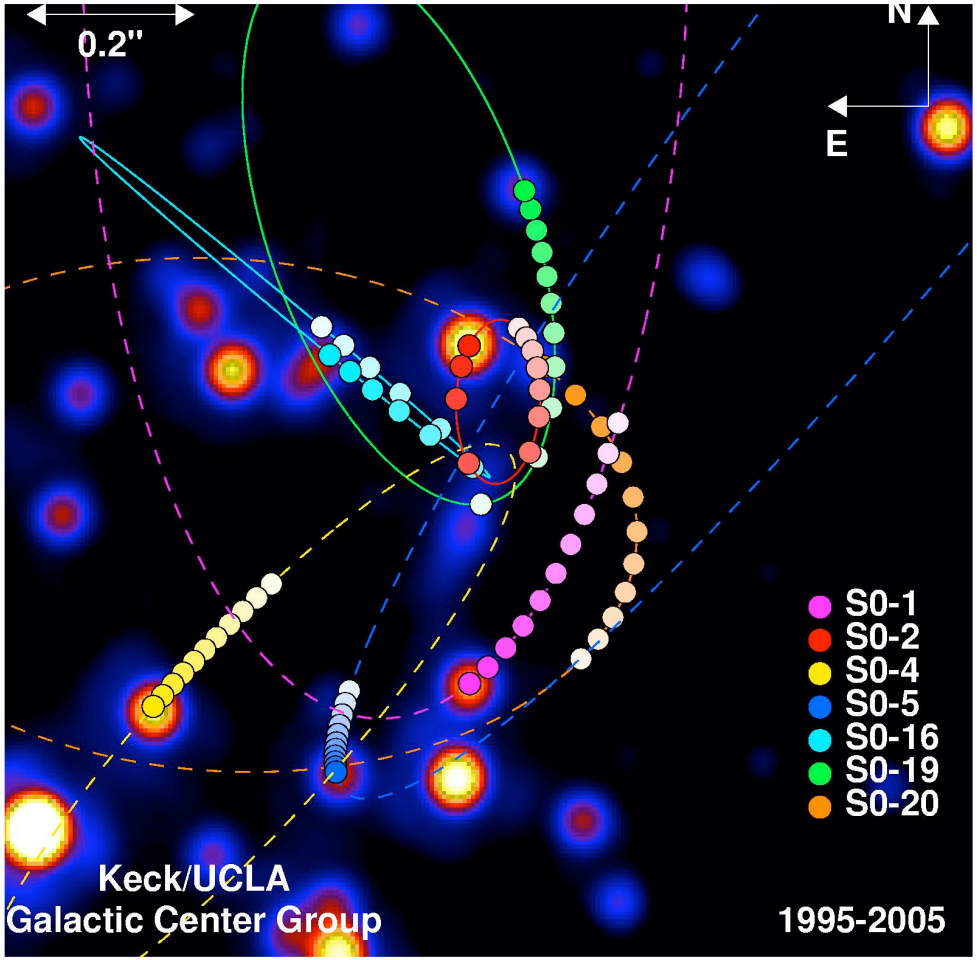
2MASS
2 MICRON ALL SKY SURVEY


The Galactic Center at 2.2 microns
6”
1”
1”
Adaptive Optics OFF



Stars appear to be orbiting something massive but invisible … ***a black hole?***

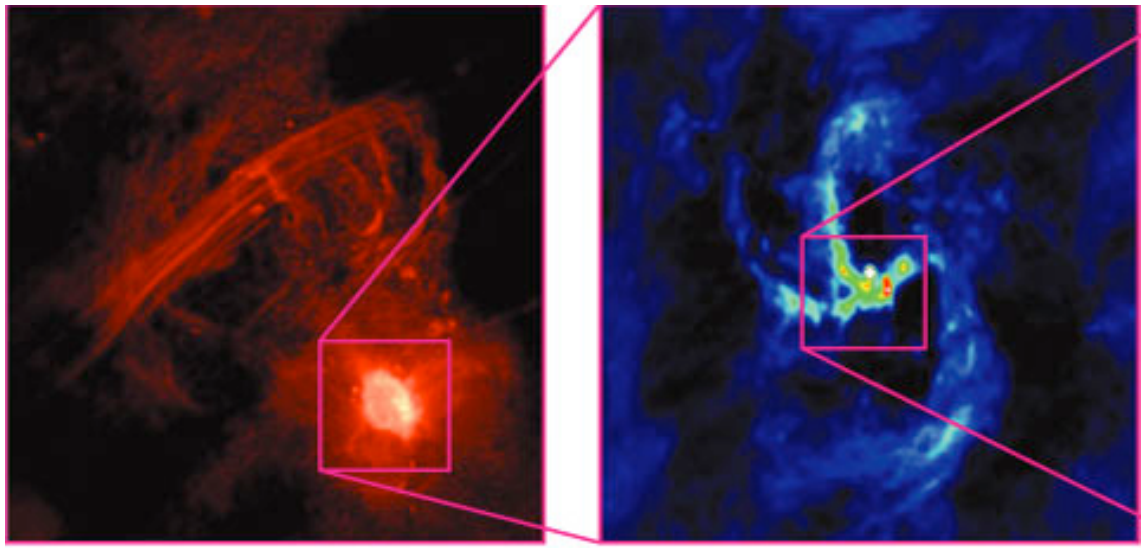
Orbits of stars indicate a mass of about 3-4 million M_{Sun}



- S0-16 comes within 45 AU (Sun-Pluto distance)
- S0-16 moves at 12,000 km/s
- Put 4 million solar masses into volume of our solar system

--> must be a supermassive black hole

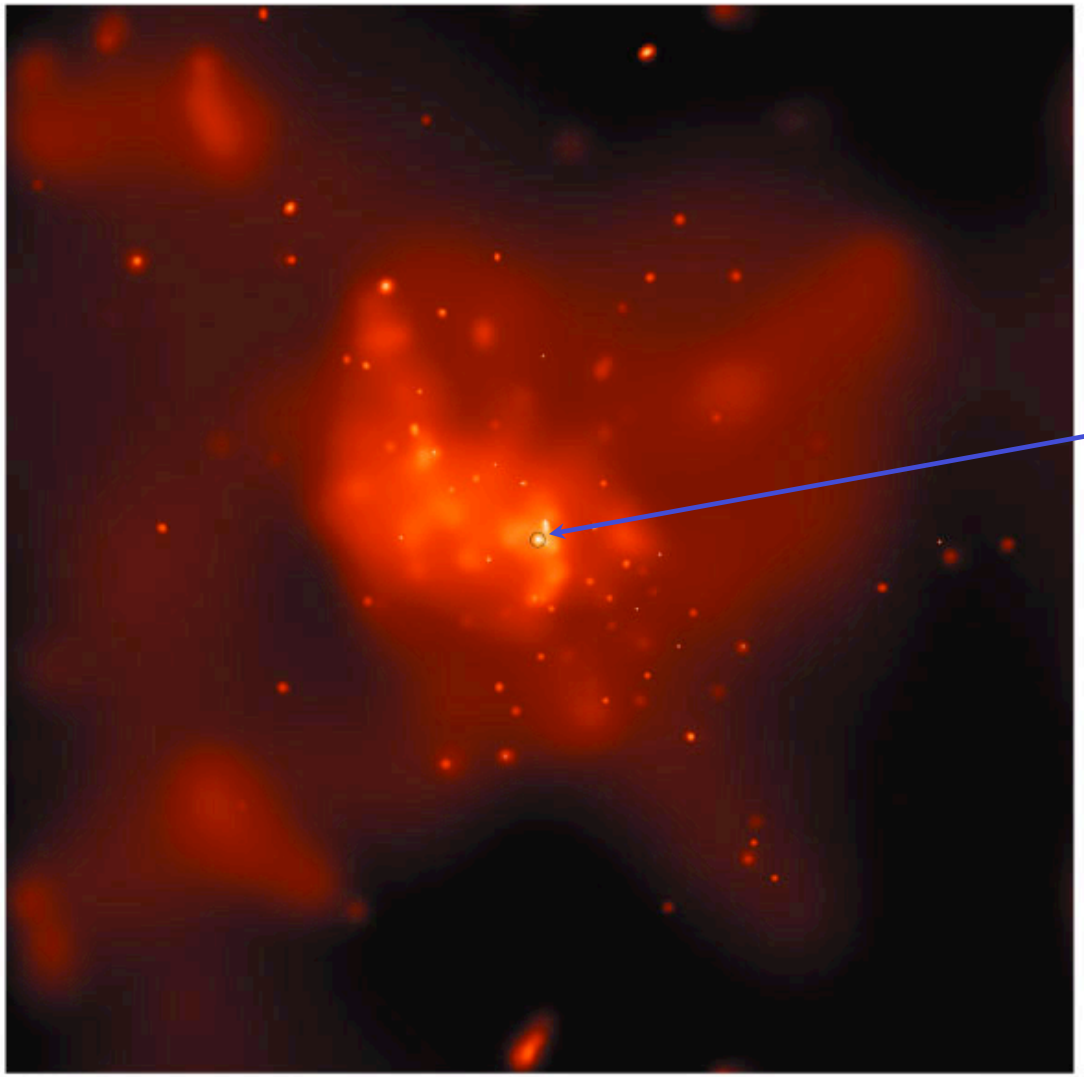
The Galactic center at radio wavelengths



Emission tracing magnetic field lines

Gas swirling around the center of galaxy

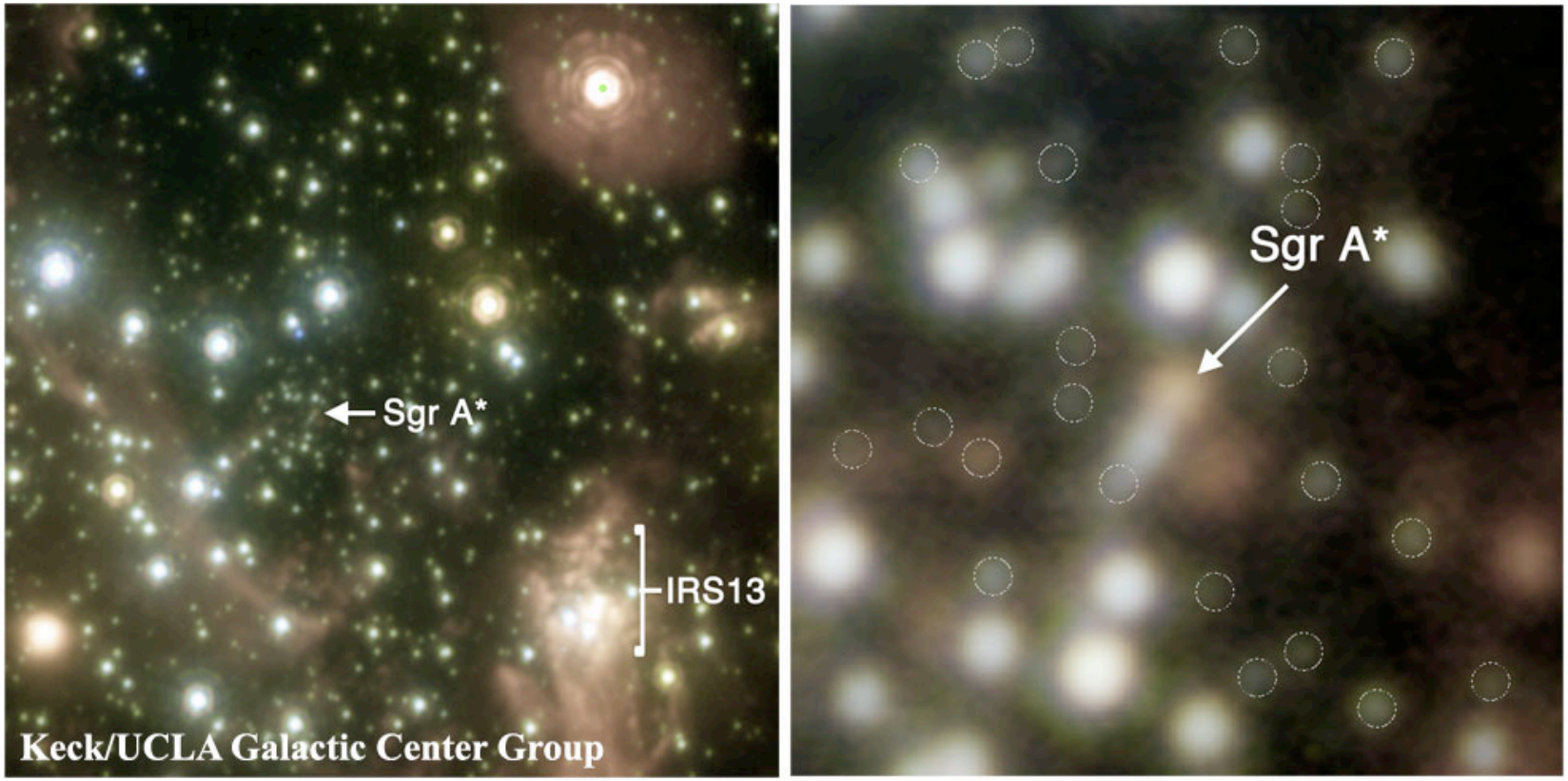
The Galactic center at X-ray wavelengths

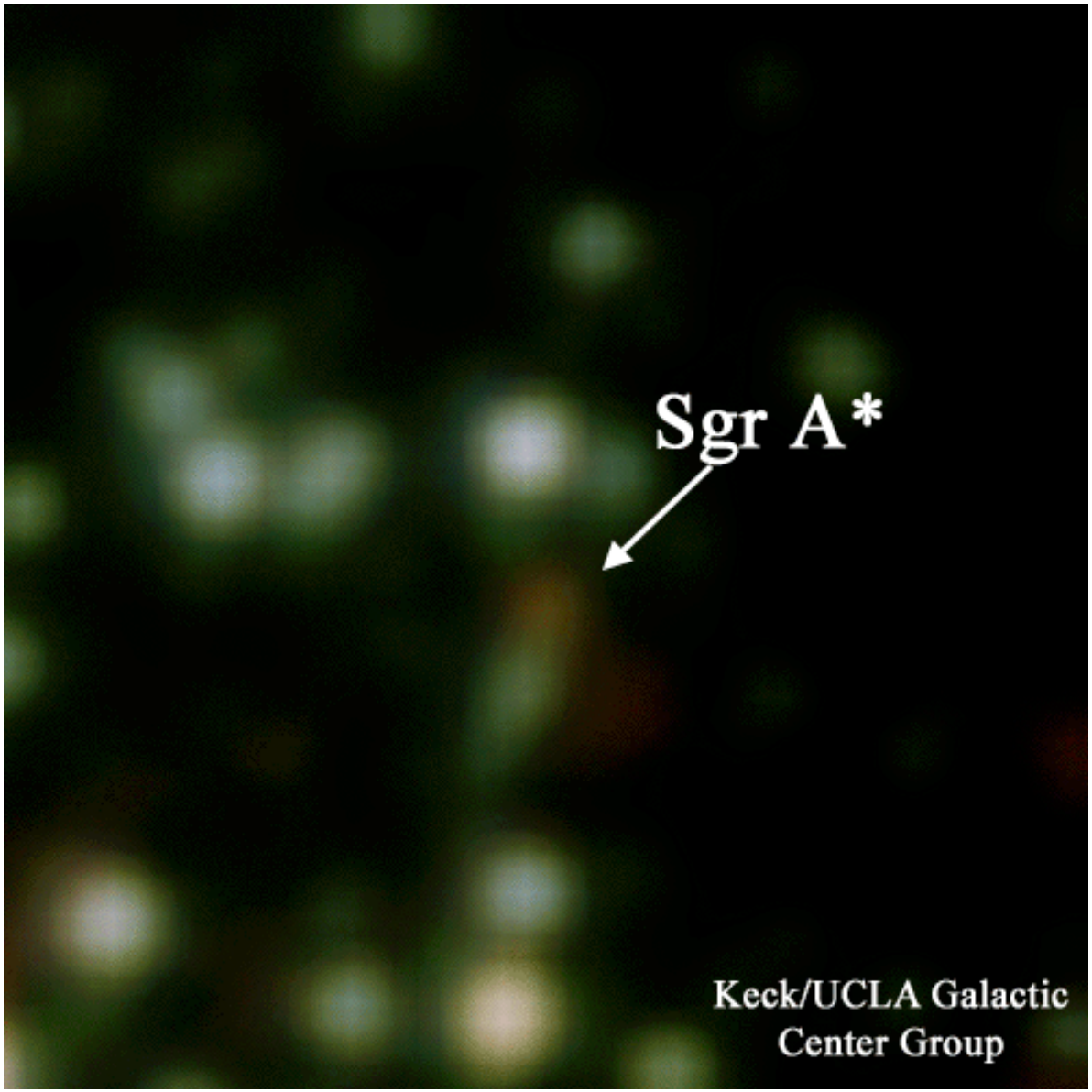


X-ray emission fainter than expected

X-ray flares from galactic center suggest that tidal forces of suspected black hole occasionally tear apart chunks of matter about to fall in

Can we see the black hole in the near infrared??





You can now also see Sgr A* flare in the infrared as well!!!!!!