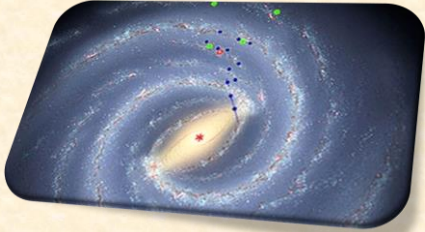


ASTR 1020: Stars & Galaxies

October 30, 2013

- Reading: Chapter 20, sections 20.1 – 20.2.
- *MasteringAstronomy* Homework on **The Milky Way**, due on Nov. 1.



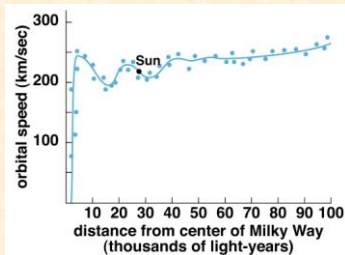
Astronomy Picture of the Day



Beautiful emission nebula NGC 6164 was created by a rare, hot, luminous O-type star, some 40 times as massive as the Sun. Seen at the center of the cosmic cloud, the star is a mere 3 to 4 million years old. In another three to four million years the massive star will end its life in a supernova explosion. Spanning around 4 light-years, the nebula itself has a bipolar symmetry.

Reality for the Milky Way

- Rotation curve is flat or even rising!
- Most of the mass of the galaxy is outside the solar circle!
- But few stars, little gas there...
- DARK MATTER?!



(c)

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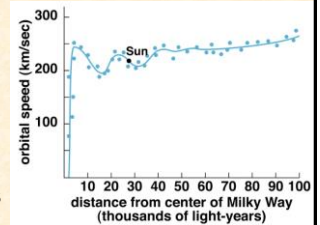
$$\text{Mass} = R \times V^2 / G$$

R = radius; V = orbital velocity

Very little gas or stars at large radii → not much to measure

Still don't know the extent of the dark matter

Possibly outweigh stars by factor of 10!



Today's Class

Chapter 19:
Spiral arms
The Galactic Center

Reading Clicker Question: The famous 21-cm spectral feature is created by what kind of gas?

- A) hydrogen
- B) carbon monoxide
- C) interstellar dust
- D) water vapor

Reading Clicker Question: The famous 21-cm spectral feature is created by what kind of gas?

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Spiral patterns in galaxies are very common



Why don't they wind up?"

Spiral Arms– why?

"Density waves"– stars move in and out of denser regions

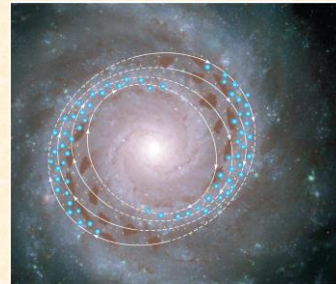
More like ripples in a pond than arms of a pinwheel

In dense regions, star formation is more intense, so "arms" are brighter



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.



How did it get started?

- Possibly a bump/pull from the gravity of another galaxy



The Galactic Center

- Constellation Sagittarius

Nothing very interesting there?



Clicker Question: What is the mass of the object at the center of the Milky Way?

- A. 40,000 solar masses
- B. 300,000 solar masses
- C. 4 million solar masses
- D. 40 million solar masses
- E. 300 million solar masses

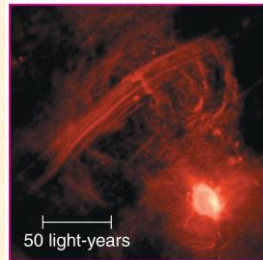
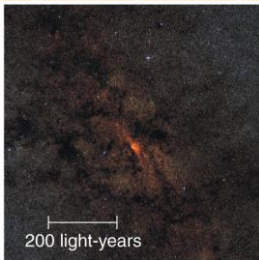
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Use Longer Wavelength Observations in the IR and Radio to Probe the Galactic Center

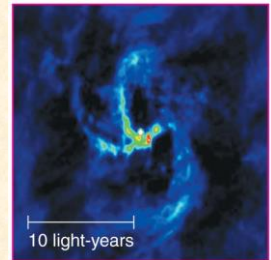
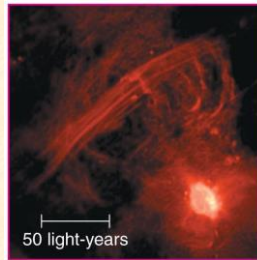
Infrared light from center

Radio emission from center



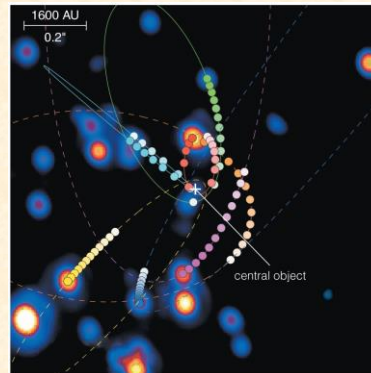
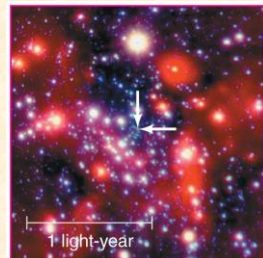
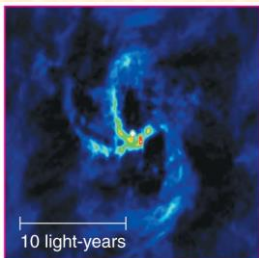
Radio emission from center

Swirling gas near center



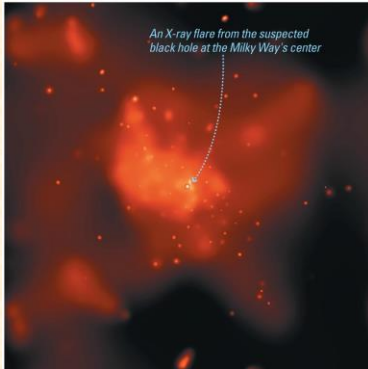
Swirling gas near center

Orbiting stars near center



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

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



An X-ray flare from the suspected black hole at the Milky Way's center

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

Clicker Question: A 4 million solar mass black hole represents:

- a) 99.9% of the mass of the Milky Way
- b) 1% of the mass of the Milky Way
- c) less than 1/1000th the mass of Milky Way

Hint:

- How many stars are in the Milky Way (check last class' notes)
- Dark matter outweighs this by about a factor of 10...

• **(C) Less than 1/1000th**

Number of stars = 100 billion $\sim 10^{11}$
Total mass = $10 \times 10^{11} = 10^{12}$ (a trillion)

4 million solar masses / 10^{12} solar masses $\sim 10^{-5}$,
or 1/100,000

Tiny fraction of the galaxy– but still remarkable because it's in such a tiny space!

