The Milky Way

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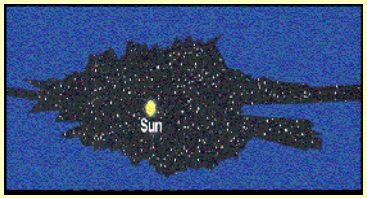
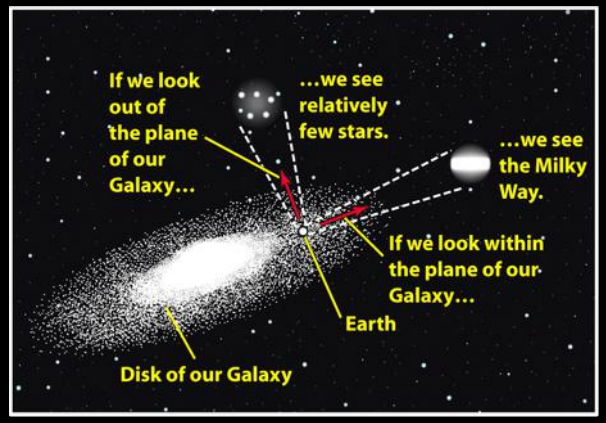
Q: *What is the Milky Way? Where are we located in it? What is its shape and size? How did it form?*

• ***Milky Way*** is a ***galaxy*** ("*galactos*" or *milk*) a collection of *gravitationally bound stars & gas*

• ***Herschel*** (1700's) counted stars in all directions *in the disk*

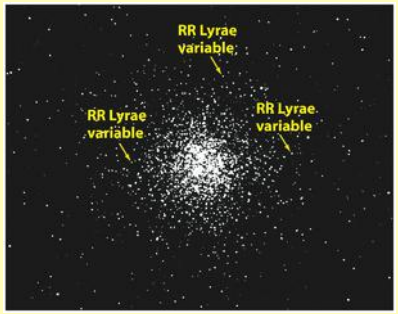


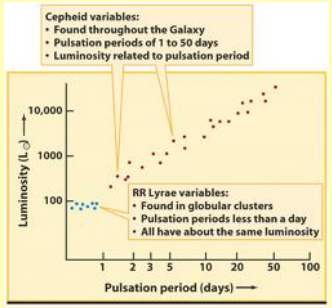
• ***density*** *seemed* uniform - ***Sun centered***?



• ***dust*** obscures views in the ***plane*** of the disk…

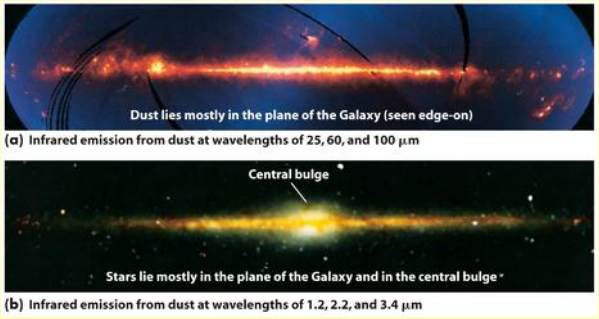
• ***globular clusters*** determined Sun's ***true*** location





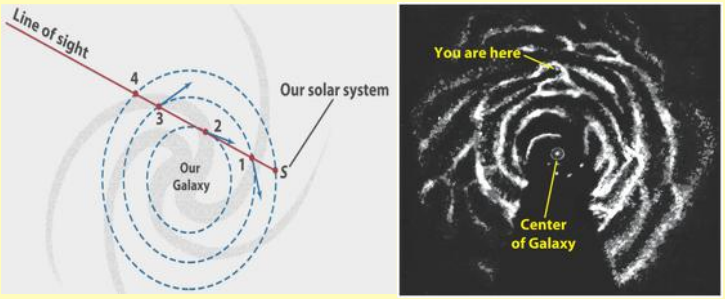
• *distribution* uniform about core of ***Milky Way***

• observations at ***nonvisible wavelengths*** yield the size & shape of ***Milky Way***



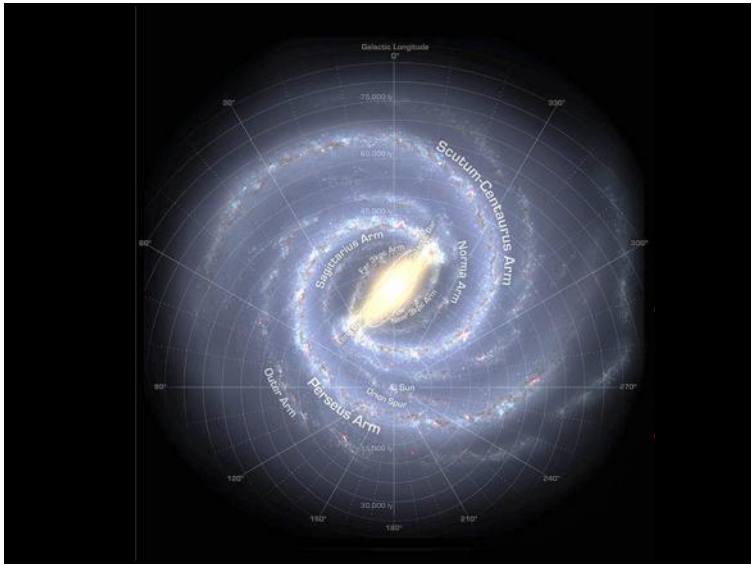
*(**eg**) in far infrared, **dust** emits most strongly; in near infrared, **cool stars** dominate emission*

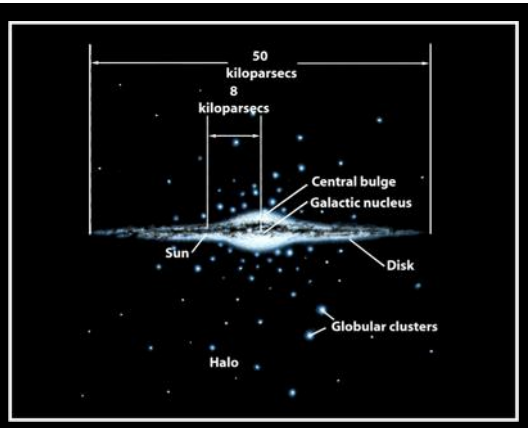
• collect *radio emissions* along "***line of sight***"



Q: *How do we sort out the mix of radio emissions?*

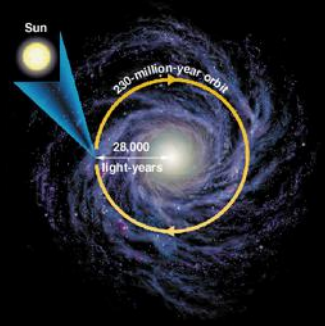
• ***source regions*** are moving relative to us
• ***doppler shift*** varies for ***source regions***
• separate (bin) by ***doppler shift*** *of* ***H*** *emission*





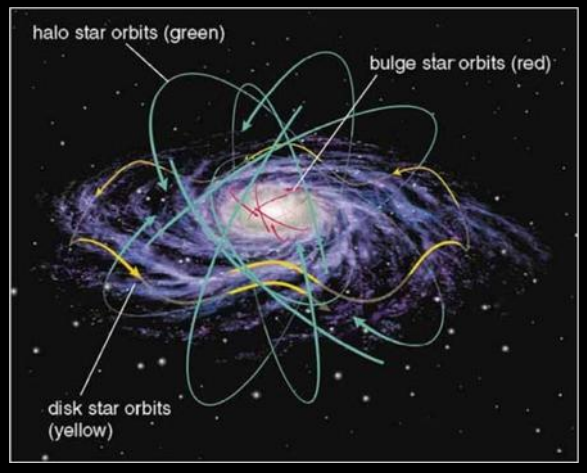
• ~150,000 ly across, 1000-5000 ly thick
• contains ~ ***100+ billion stars***

Motion of Sol within *Milky Way*



- ***Sun*** orbits core in ~ 230 My at ~ 200 km/s!
- orbital speed Earth around Sun ~30 km/s

General Stellar Motions



CLICKER: How are globular clusters distributed in the Milky Way?

(a) about the center, within the disk
(b) spherically about the core, in the galactic halo
(c) only in the spiral arms
(d) only in the core/nucleus

"Weighing" the Galaxy

- ***Newton's** form of **Kepler's 3rd Law** ($p^2=a^3$):*

$$p^2 = 4\pi^2 r^3/GM_r$$

$$\Rightarrow M_r = v^2 \times r/G$$

- M_r mass *within* orbit of *radius r, kg*
- v orbital speed, *m/s*
- r orbital radius, *m*
- G *gravitational constant, 6.67×10^{-11} Nm^2/kg^2*

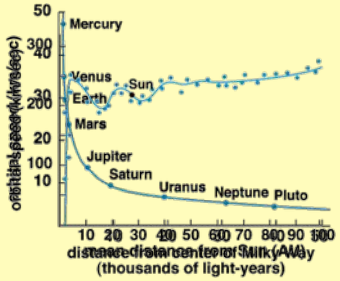
- *r, v $\Rightarrow$ mass M contained within an object's orbit*

Rotation Curve

• plot ***orbital speed*** as function of *radius*

• *speed* from nearby *stars* and *radio doppler shifts* of gas in spiral arms

• *amazingly, the speed stays ~* ***constant past the visible edge of the galaxy***



Q: *What does this tell us?* $\Rightarrow M_r = v^2 \times r/G$

• from rotation speeds, $M_{galaxy} \sim 10^{12}\ M_\odot$

• only enough *luminous material* to yield *~10%* of this - *so what is the rest of the mass?*

• *90%* of galaxy is made of "***dark matter***"
• does ***not*** show up in *EM spectrum*
• detectable via *gravitational effects*

• ***dark matter*** is distributed ~ *spherically* about ***core***

• ***MACHOs, neutrinos, WIMPs?***

CLICKER: The main observable effect of dark matter on galaxies is:

(a) stars near the edges move faster than expected
(b) central supermassive black holes are larger
(c) galactic disks are thicker
(d) much higher rate of star formation in spiral arms

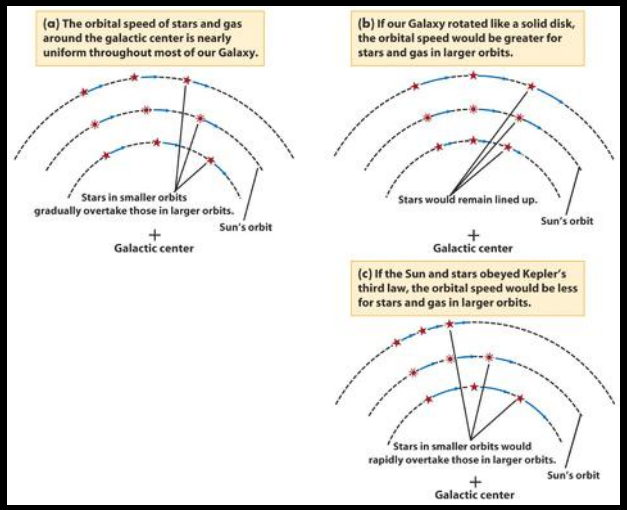
Spiral Structure

• our galaxy has ***spiral arms***, like ***M51*** and others

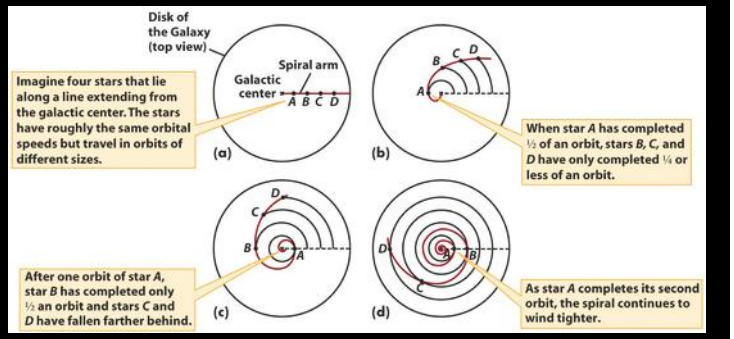
• ***spiral arms bluer*** (*why?*)

• ***spiral arms*** are ***not*** fixed groups of stars revolving about ***core***, ***eg.*** *fan blades*

Q: *How do we know spiral arms do* ***not*** *act this way?*



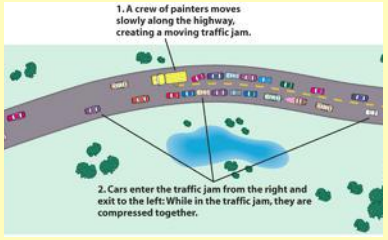
Spiral Arm Structure



- we do ***not*** see such tightly wound spiral arms!

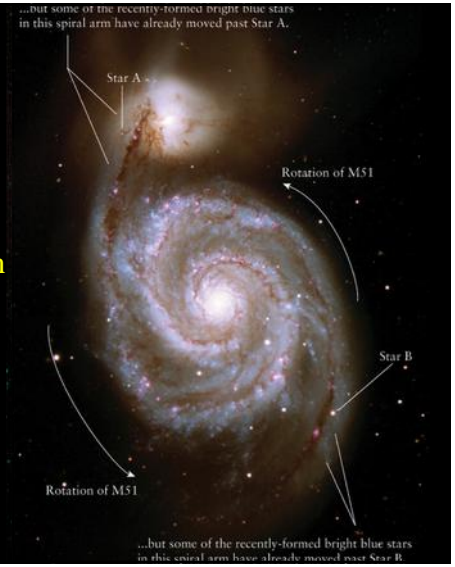
- ***spiral arms*** likely ***propagating density waves***

- like *waves on a pond* from a dropped stone
- *slower moving* than ***stars*** or ***interstellar matter***



- as material passes through ***density wave***, *it is slowed & compressed by increased gravity/density*

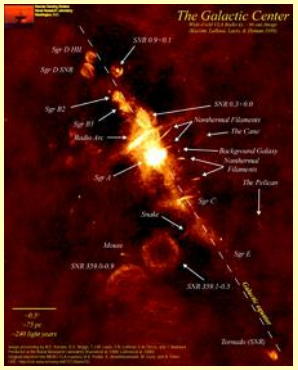
- ***big blue stars*** do ***not*** live long enough to move away much from ***spiral arms***

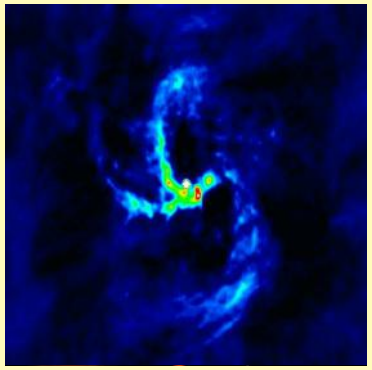


CLICKER: If the spiral arms were "solid", like rotating blades of a fan, then

(a) orbital speeds of all stars would be the same
(b) stars closer to edge would move slower
(c) stars closer to the edge would move faster
(d) spiral arms would become "tighter" over time

The Galactic Core



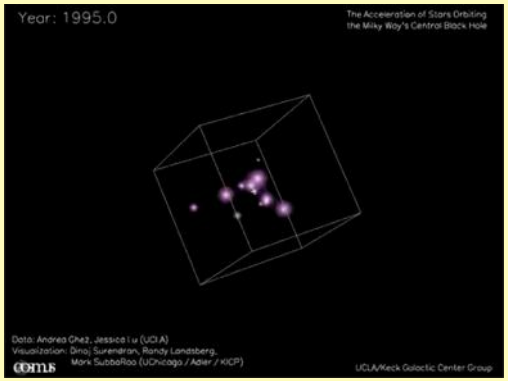


• "invisible", strong ***radio/X-ray source Sgr A****

• track ***orbits*** *within 120 AU* of ***Sgr A**** in ***infrared***

• orbital speeds of *1000's km/s (~1% c)*

• ***Kepler's Third Law***: $M_{SgrA*} \sim 4$ *million* $M_\odot$



• what else besides a ***(supermassive) black hole*** could put ***so much mass into such a small region?***