CENTRIPETAL FORCE & GRAVITY

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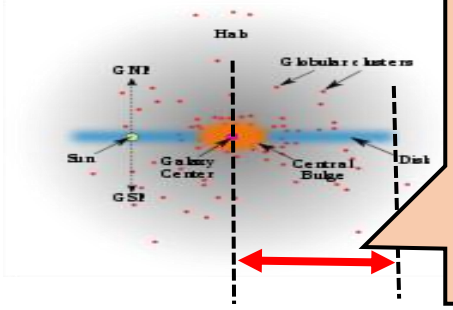
Vera Rubin, 88, Dies; Opened Doors in Astronomy, and for Women

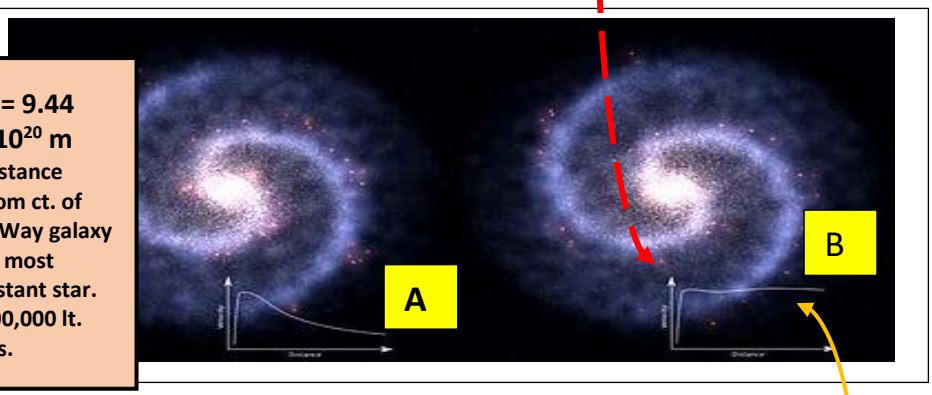
When Dr. Rubin went about plotting the velocity of stars in the galaxy vs. their radial distance, she found something **really surprising: stars farther away from the center of the galaxy didn't move much faster than stars near the center.** Graphically, this is the so-called "flat rotation curve" (B in the picture below). Now, this is really weird, and definitely doesn't match the curve you'd expect from simple Newtonian gravity given the mass we can observe in the galaxy (e.g curve A). This implies one of two things:

We gravely misunderstand something about gravity.
There's more mass out there - *we just can't see it.*
The former has led to attempts at modifications of Newtonian gravity (see: Modified Newtonian dynamics - Wikipedia) to resolve the discrepancy between theoretical expectation and observation. It's worth noting here that Newtonian gravity works really really really really REALLY well. And we're pretty sure we understand it. For this reason, most scientists today favour option 2……..called Dark matter.

Vera Rubin in the 1970s, when she mapped the distribution of mass in spiral galaxies by measuring how fa**st they rotated.** Credit Carnegie Institution of Washington.



R = 9.44 X10^{20} m Distance from ct. of MWay galaxy to most distant star. 100,000 lt. yrs.



Her work helped usher in a Copernican-scale change in cosmic consciousness, namely the realization that what astronomers always saw and thought was the universe is just the visible tip of a lumbering iceberg of mystery.

Scientists now know we are not the center of the universe, nor are we even made of the same stuff as most of creation. Cosmologists have now concluded **that there is five or 10 times as much dark matter in the universe as there is ordinary atomic matter — the stuff of stars, planets and people.**

INTRODUCTION: The goal with this application is to show (using visible mass of milky way galaxy 1.86 x 10^{41} kg.) the speed of rotation (linear speed) of most distant star of the Milky way galaxy is less than measured ~220 km./s.

HINTS: From Newton's gravitational law providing the centripetal force: $G\,Mm/R^2 = m\,V^2/R$, Thus, $(GM/R)^{1/2} = V$, where G = gravitational constant = 6.67 X 10^{-11} $Nm^2/kg.^2$, M_{MW}(visible mass of Milky Way) = 1.86 X 10^{41} kg , visible from earth) , R = distance from center of milky way to most distant star is 100,000 light years or 9.44 X 10^{20} m.

QUESTION: (a) Find linear speed of rotation of most distant star of the Milky way galaxy? (b) How does the computed speed , using visible mass of the galaxy, compare with the experimental rotational speed of 220 km./s.? (c) What could be the reason for experimental higher rotational speed?

ANSWERS: (a) ~115 km./s., (b) Computed speed is almost ½ the actual speed, (c) 5 – 10 times more mass exists (called dark matter) which we can not see. NASA states mass of Milky way galaxy is 16 – 30 X 10^{41} kg.