Dark Matter

Worksheet 3

Dark Matter within a Galaxy

Astronomers have analysed the stars in the galaxy UGC 11748. They found that most of the stars lie within a radius $r = 1.64 \times 10^{20}$ m and that the total mass within this radius is 1.54×10^{41} kg, or 77.4 billion times the mass of the Sun.

It is expected that the stars that lie outside this radius will orbit in the same way that planets orbit the Sun. In this activity you will analyse the motion of stars located in the outer regions of UGC 11748.

#1 #2 #4 #5.

Orbital radius of star ($x10^{20}$m)	Measured Speed ($x 10^5$ m/s)	Calculated speed ($x 10^5$ m/s)	Gravitational Mass ($x 10^{41}$ kg)	Missing Mass (%)
1.85	2.47	2.36	1.69	8.99
2.75	2.40	1.93	2.37	35
3.18	2.37	1.80	2.68	42
4.26	2.25	1.55	3.23	52
6.48	2.47	1.26	5.93	74

1. Use the values from the table above to plot measured speed against orbital radius on the graph provided. Label this line "measured".

#2. $M = 1.54 \times 10^{41}$ kg $V = \sqrt{\frac{GM}{r}}$

2. a) For each orbital radius, calculate the speed expected if the only mass is the luminous mass of 1.54×10^{41} kg. Record your answers in the "Calculated speed" column (show a sample calculation).
   b) Plot calculated speed against orbital radius on the graph provided. Label the line "calculated".

3. Compare the "measured" and "calculated" plots.

Calculated is always lower.

4. a) Use the measured speeds to calculate the mass of the galaxy contained within each orbital radius. Record your answers in the "Gravitational mass" column (show a sample calculation).

$M = \frac{v^2 r}{G}$

5. For each orbital radius, calculate the difference between the gravitational mass within this radius and the total mass of the stars (1.54×10^{41} kg). Represent this difference as a percentage of the gravitational mass within the orbital radius. Record your answers in the "Missing Mass" column. $\frac{\#4 - 1.54}{\#4}$

6. Do your results support the following statement?
   "It is reasonable to expect that stars orbit around the gravitational mass contained within the radius of their orbit in the same way that planets orbit around the Sun."
   Discuss.

Yes it is reasonable but the data does not support this.

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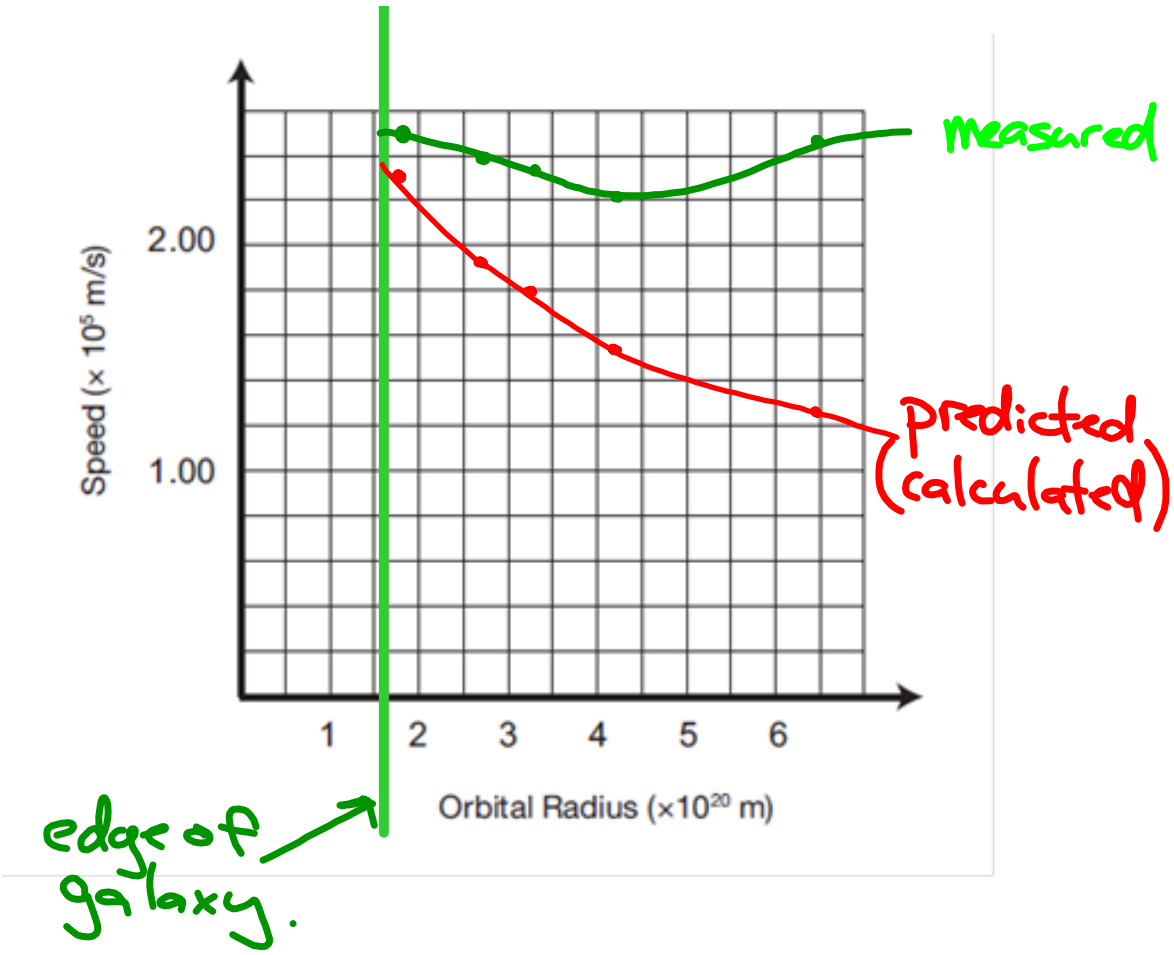
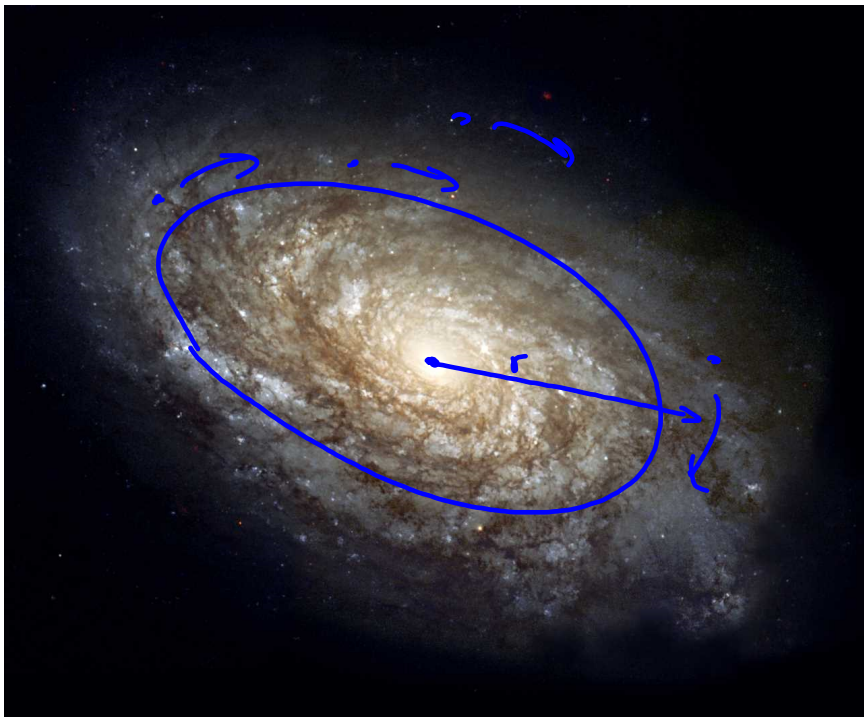

Speed (× 10⁵ m/s)
2.00
1.00
1
2
3
4
5
6
Orbital Radius (×10²⁰ m)
measured
predicted
(calculated)
edge of
galaxy.


r

Dark Matter

Observational Evidence

1. Galaxy Rotation Curves
   → stars at edge of galaxy are moving too quickly.
2. Gravitational Lensing.

3. galaxies are moving to fast.
4. patterns in CMB (Cosmic Microwave Background) do not align with today's galaxy structure without considering (adding) dark matter
5. Bullet Cluster

Dark Matter

Possible Explanations of Observational Evidence

1. Dark Matter (matter we cannot see)
   - → invisible
     - → has no charge
     - → has mass
   - → makes up 85% of matter in universe
   - → not uniformly distributed in universe.
2. Observational Error

   $F_g = \frac{G m_1 m_2}{r^2}$

   - → missing normal matter
   - → r may be measured wrong
3. G → may be wrong
   - change with time & or distance.
4. our theory of gravity may be wrong.

   MOG → modified gravity
   MOND → modified Newtonian dynamics

Properties of Dark Matter

5% - normal matter
68% - dark energy.

- predicted to make up about 27% of the mass/energy content of the universe
- invisible (doesn't absorb or reflect light) - a better term would be invisible matter
- not uniformly distributed throughout the universe - tends to clump up around galaxy clusters
- as of today - Dark Matter has never been actually detected - scientists have only surmised it's existence based on observational data.