Dark Matter in NGC3762—11 Nov

- Use rotation curves & Kepler's Law
  Mass = R v^2
  to find mass of NGC3762 and where the mass is
- Where is the mass?
  - Answer: Mass is not where the stars are.
- Galaxies are made mostly of what we cannot see.

1. What in the spectrum along the major axis shows different parts of the galaxy are moving at different speeds?
2. Why is the same motion not seen in the spectrum along the minor axis?

NGC 3672, Vera Rubin, Norbert Thonnard, & Kent Ford, jr., 1977, Astrophys. Journal 217, L1.

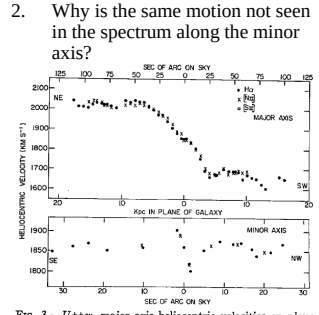
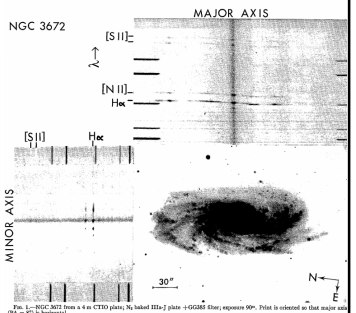
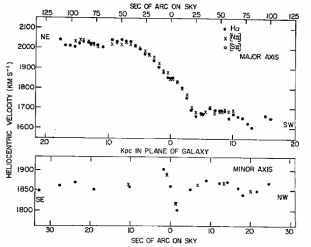


FIG. 3.—*Upper*, major axis heliocentric velocities on plane of sky, as a function of distance from the nucleus. *Lower*, minor axis velocities as a function of distance from the nucleus; note change in scale from upper plot. The steep velocity gradient in nuclear region along minor axis is prominent.



1. How fast is the galaxy moving from us? Why is the galaxy moving from us? If the mass of the galaxy were greater, would this speed be different?
2. What is the rotation speed of gas that is 16 kpc from the center? If the mass of the galaxy were greater, would this speed be different?



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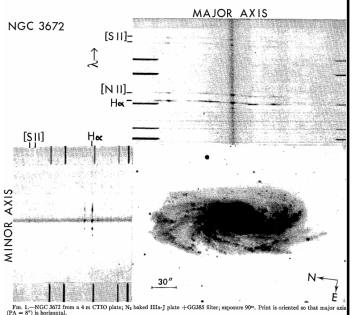
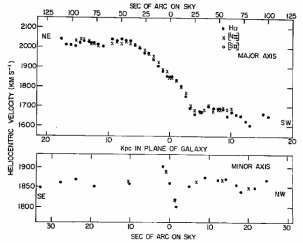


Calculating mass

- Astronomer's gravitational constant for use in M=1/G r v^2
  - 1/G=232 M_{sun}/parsec/(km/s)^2.
- If a test object orbits a big mass at a radius of 1 parsec with a speed of 1km/s, then the big mass has the same mass as 232 suns.
- The earth orbits the sun at a radius 1/200000pc with a speed 30km/s. The mass inside the orbit of the earth is
  - 232M_{sun}/parsec/(km/s)^2.(pc/200000)(30km/s)^2 = 1 M_{sun}.

Mass within 16 kpc

- Gas at R=16 kpc orbits the galaxy at 180 km/s.
- Find mass with K's 3rd
  M= 232 M_{sun}/parsec/(km/s)^2 r v^2
- Ignore mass outside orbit of gas when applying K's 3rd law.
  - If galaxy is spherical,
    - Mass inside 16 kpc pulls on gas
    - Pull of mass outside 16 kpc cancels.
  - Approximately true if galaxy is not spherical.
- Within a radius of 16 kpc, the mass is
  232 M_{sun}/pc/(km/s)^2*16,000pc *(180km/s)^2
  = 120Billion M_{sun}.
- Where is the mass? Is the mass all in the center of the galaxy?
  - Examine the rotation curve.



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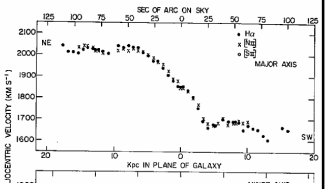
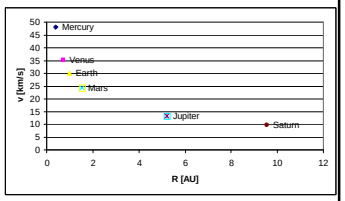
Where is the mass?

- Gas at R=16 kpc orbits the galaxy at 180 km/s.
- Where is the mass? Is the mass all in the center of the galaxy?
  - Examine the rotation curve.

3. Which part of the galaxy is rotating the fastest? NE edge, center, or SW edge?
4. Sketch the "rotation curve," which is a plot of distance from center *vs*. rotation speed.

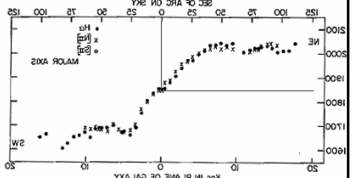


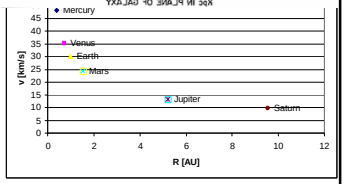


Where is the mass?

- Gas at R=16 kpc orbits the galaxy at 180 km/s.
- Where is the mass? Is the mass all in the center of the galaxy?

5. In what way is the rotation curve different from that of the solar system?
- M(R) ∝ v^2 R





Where is the mass?

- Where is the mass? Is the mass all in the center of the galaxy?

5. In what way is the rotation curve different from that of the solar system?
   - Rot speed in center is low
   - Rot speed rises between 0 & 8 kpc
   - Rot speed is constant beyond 8 kpc.
- Hypothesis: Mass is all at center. Compare with speed @ 16kpc. M(R) ∝ v^2 R

6. Is actual speed at 2kpc & mass within 2kpc higher or lower than that of hypothesis?