Spiral Structure of Galaxies

An Analytical Model

The Model

A double-arm Archimedean Spiral of order one, known as an Archimedes' Spiral.

Agenda

1. Describe the problem/conflict
2. Present evidence of the conflict
3. Mention some historical approaches
4. Determine the assumptions
5. Derive a mathematical solution
6. Verify the solution with direct observation

The Conflict

- If Galaxies are spirals, they contradict the rotation profile
- If the rotation profile is valid, galaxies cannot be spirals

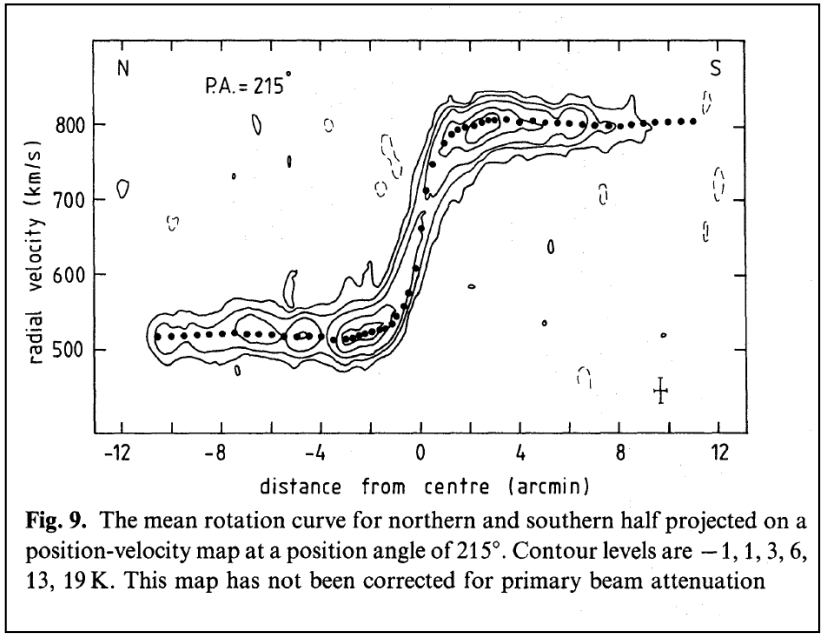


Fig. 9. The mean rotation curve for northern and southern half projected on a position-velocity map at a position angle of 215°. Contour levels are −1, 1, 3, 6, 13, 19 K. This map has not been corrected for primary beam attenuation

Flat Velocity Rotation Profile

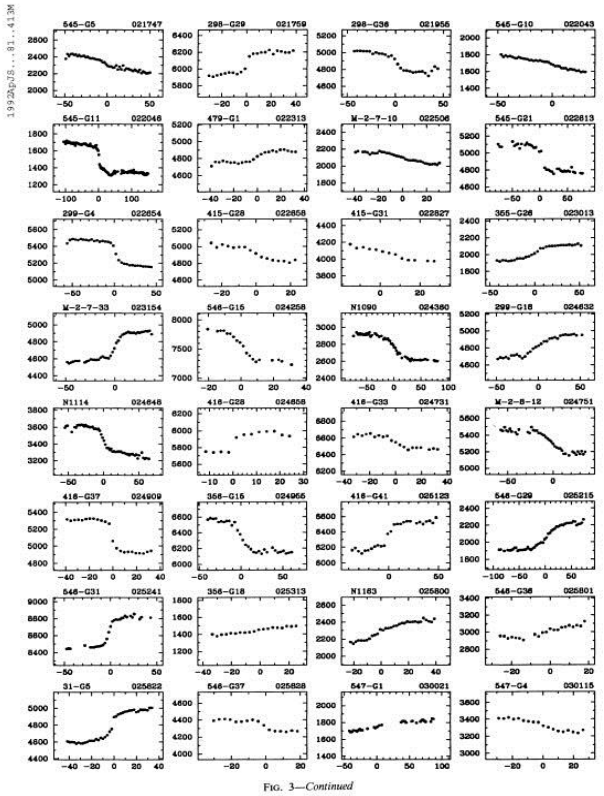
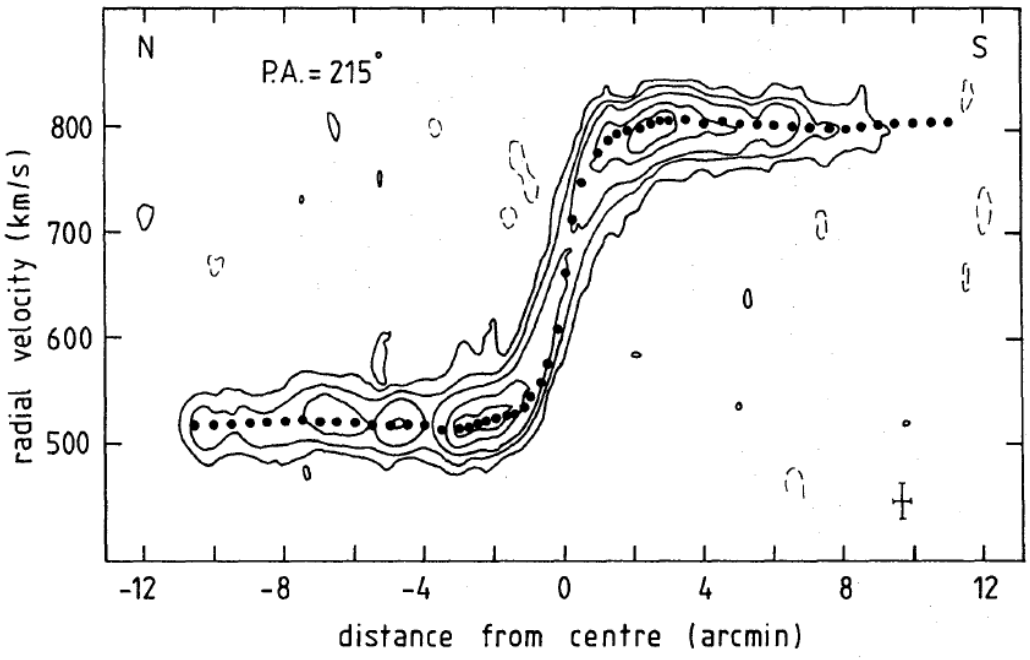


FIG. 3—*Continued*



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Previous Explanations of Rotation Profile

- The observed velocity of matter around the galactic center is not Keplerian.
  - Significant amounts of non-luminous matter has been proposed for a Keplerian model to match observed orbital behaviour of galaxies. (Dark Matter)
    - Top-down tree search algorithm
    - Moving mesh algorithm
  - Some new hypothesis on the laws of gravitational dynamics exist in lieu of Kepler's laws. (MOND)
    - Small intrinsic acceleration

Galaxies are spirals

Discovered & classified by Hubble

- Large number of spiral galaxies
- Stable morphology
- Lin-Shu “winding problem”
  - Non-rotating galaxy
  - Gravitational resonance

Stable Galactic Structure

- The flat velocity rotation curve of galaxies indicates that nearly all the stars within a galaxy have the same tangential velocity.
- However, this would result in a quickly deteriorating galactic structure.
- The model presented here shows this is caused by a discrepancy between the measure of tangential velocity using shifting of spectral lines and the actual tangential velocity defined as the rate of arc length traversed using our clocks and rulers.

Statements

- Established scientific theories can explain the orbital behaviour of galaxies and their spiral morphology without requiring undiscovered gravitational principles.
- This is done by refuting that galaxies behave as though they consist of non-interacting orbiting particles of zero-viscosity;
- Rather that they consist of interacting orbiting bodies to which relativistic considerations must be applied.

Galaxies are Non-Keplerian

- To apply the laws dictated by Kepler 1619, the system must behave as a central massive region around which particles orbit without significantly interacting with each other such as in the solar system.
- If the distribution of matter in a galaxy were such that the gravitational viscosity was not negligible, then such a galaxy would no longer be comprised of a disc rotating with orbiting zero-viscosity matter.

Relativistic Effects

- Previous explanations of galactic morphology and parameters do not take into account the relativistic effects of accelerating reference frames.
  - The special relativistic effects of material in orbit about the center of a galaxy appear to be negligible since such stars to not appear to be moving at relativistic speeds.
- However, we show that the general relativistic effects as a result of rotational acceleration are significant.
  - Special Relativity: inertial reference frame, γ constant
  - General Relativity: accelerating reference frame, γ variable

Coordinate System Parameters

1. Since the stars comprising galaxies are in circular orbit, each star experiences centripetal acceleration.
2. The path of light which passes through the center of rotation is spiral-shaped as viewed within a rotating coordinate system.
3. The tangential velocity behaves peculiarly as a function of distance from the center.
4. The tangential speed must never reach the speed of light.

Rotating Polar Coordinates

- Consider two identical clocks
  - One revolving about an origin
  - Second not revolving
- Each clock will have two different measures of the period of rotation
  - $\tau(r)$ = period of rotation revolving clock
  - T_o = period of rotation non-revolving clock
  - $T_o / \tau(r) = \gamma(r)$ by definition
  - $\omega_o = 2\pi / T_o$

Metric in Rotating Polar Coordinates

$$ds^2 = \frac{c^2}{\gamma^2} dt^2 - dr^2 - \gamma^2 r^2 d\theta^2$$

$$g_{tt}^{-1} = g^{\theta\theta} = \left(1 + \frac{\omega_0^2 r^2}{c^2}\right)$$

$$\gamma = \sqrt{1 + \omega_0^2 r^2 / c^2}$$

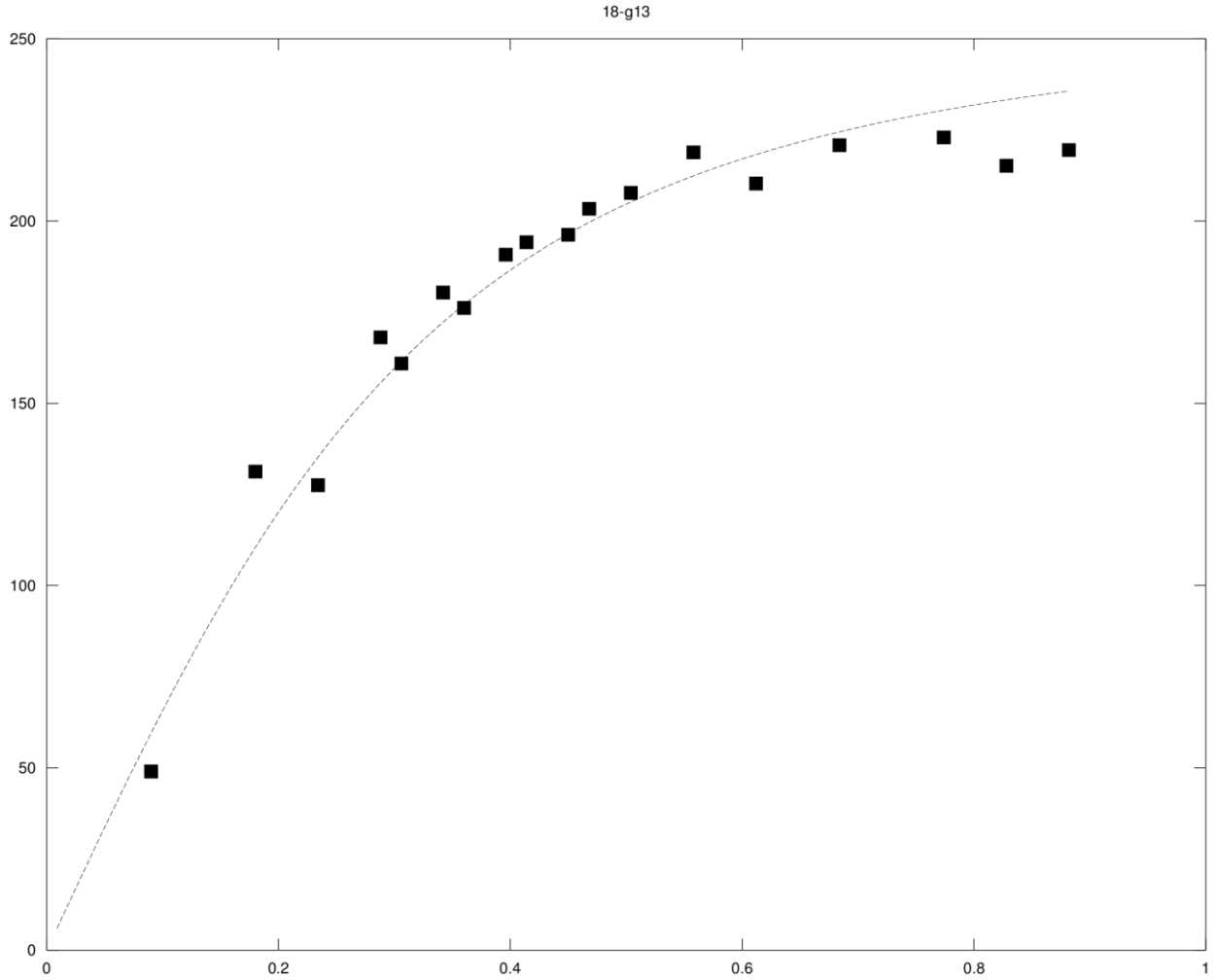
Resultant Equations

$$v_{max} / c = 2\pi\omega_0$$

$$R = \frac{2\pi}{v_{max} / c}\theta$$

$$v = v_{max} \frac{\omega_0 R}{\sqrt{1 + \omega_0^{\ 2} R^2}}$$

Flat Velocity Rotation Profile



Resultant Equations

$$\rho_l = \frac{v_{max}^2}{2G}$$

$$M_g = L\rho_l$$

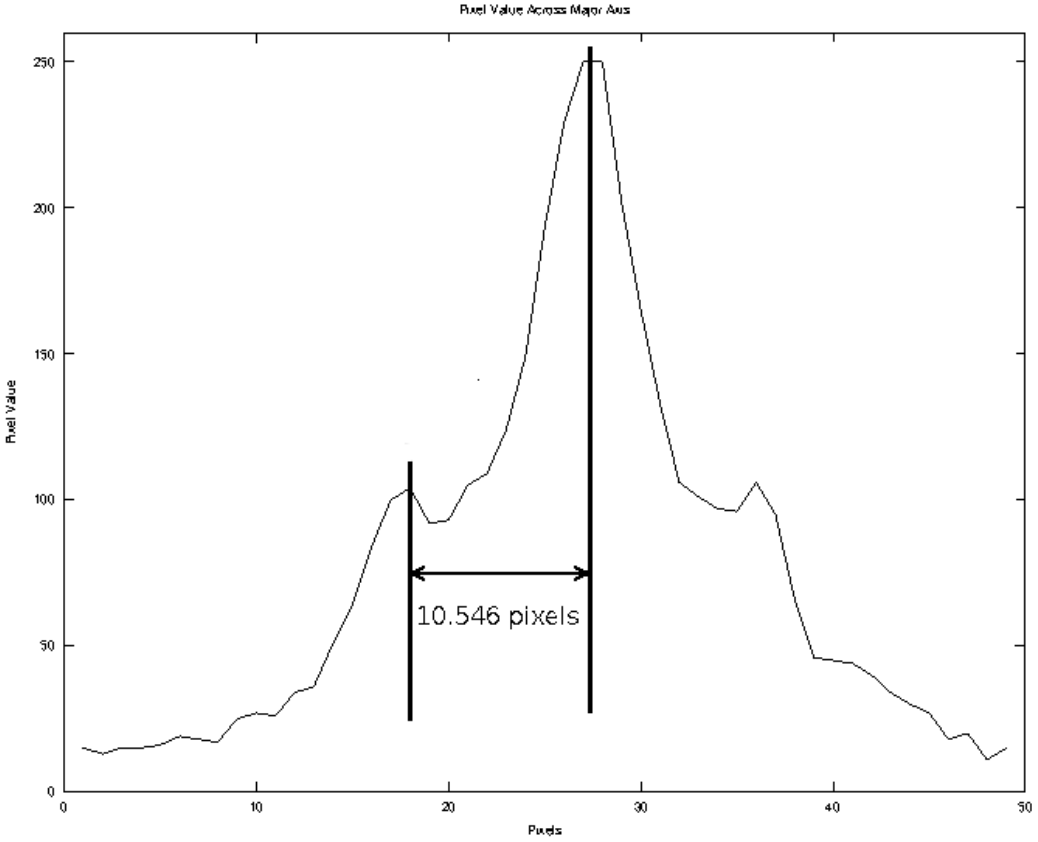
$$l = v_{max}\,\rho_l L^2$$

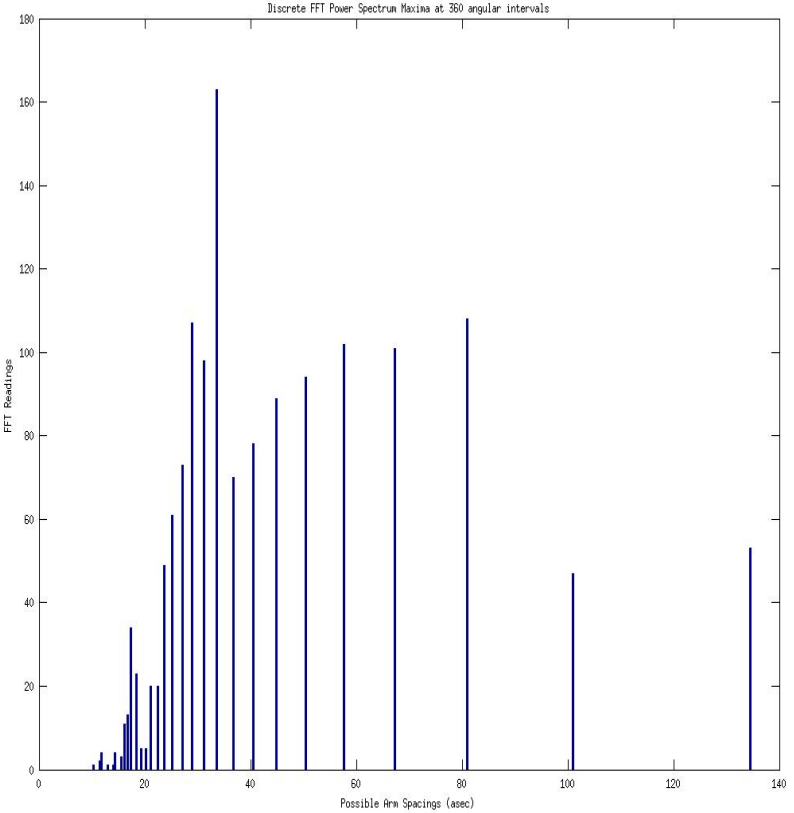
Distance Formula

$$d = \frac{2\pi^2 \times 360 \times 60}{\left(v_{max} / c\right) \times 4\pi\alpha_s}$$

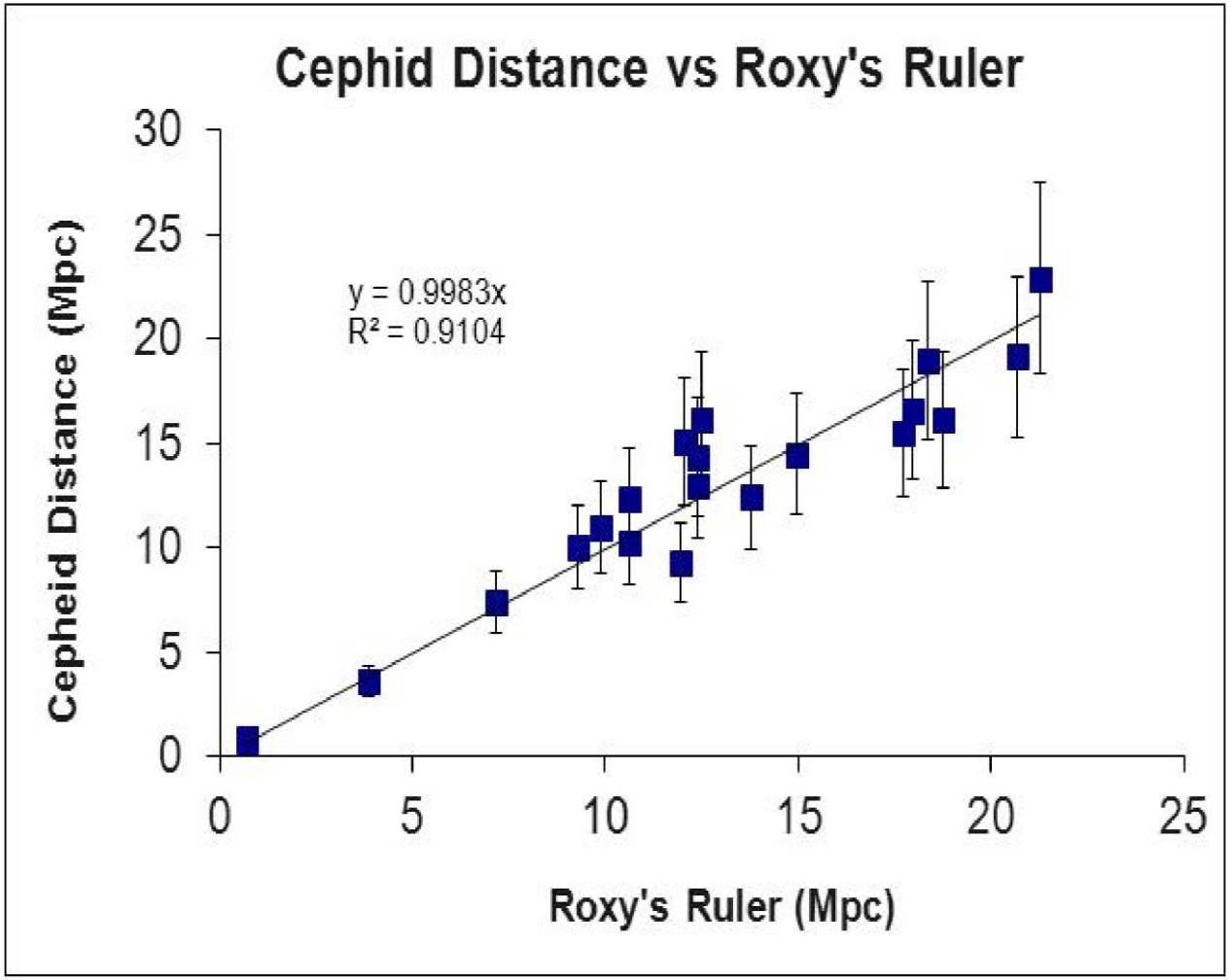
$$D = \frac{3.12 \times 10^9}{v_{max} \times \alpha_s}$$

FFT measure of α_s



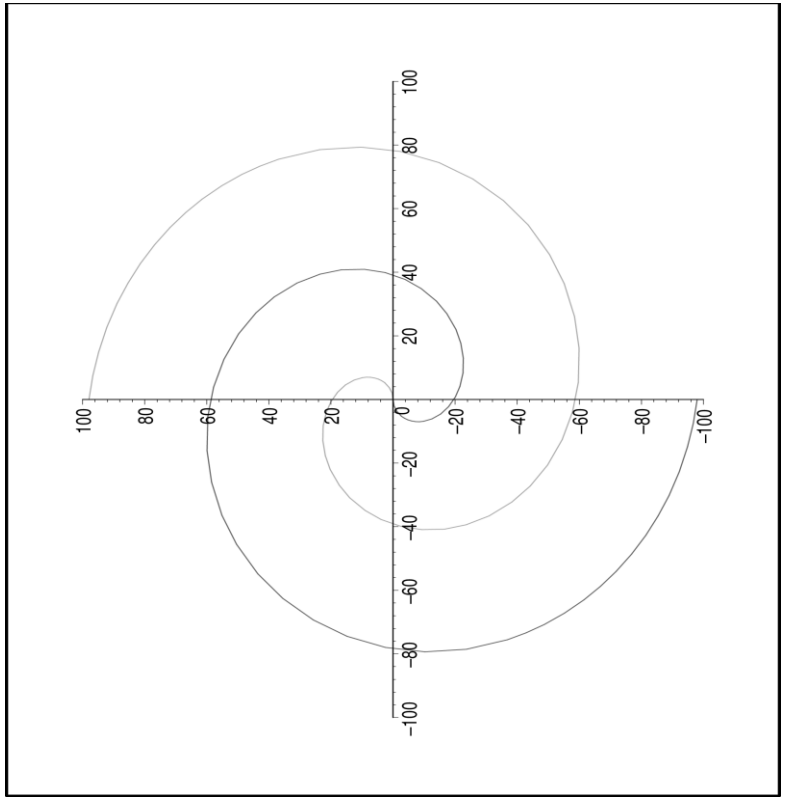


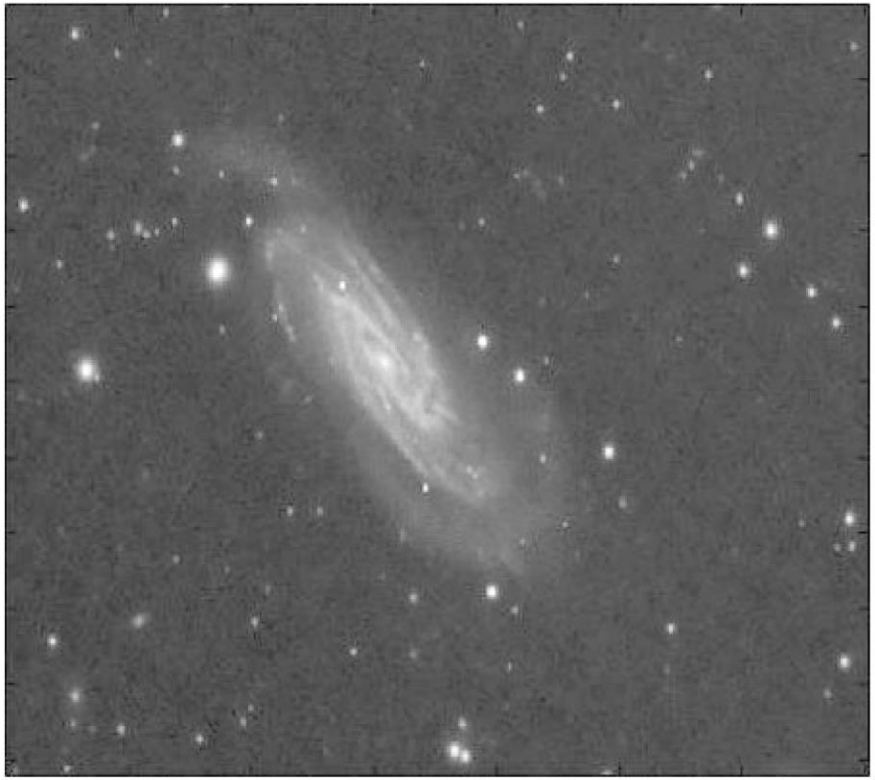
Compare to Cepheid Variables



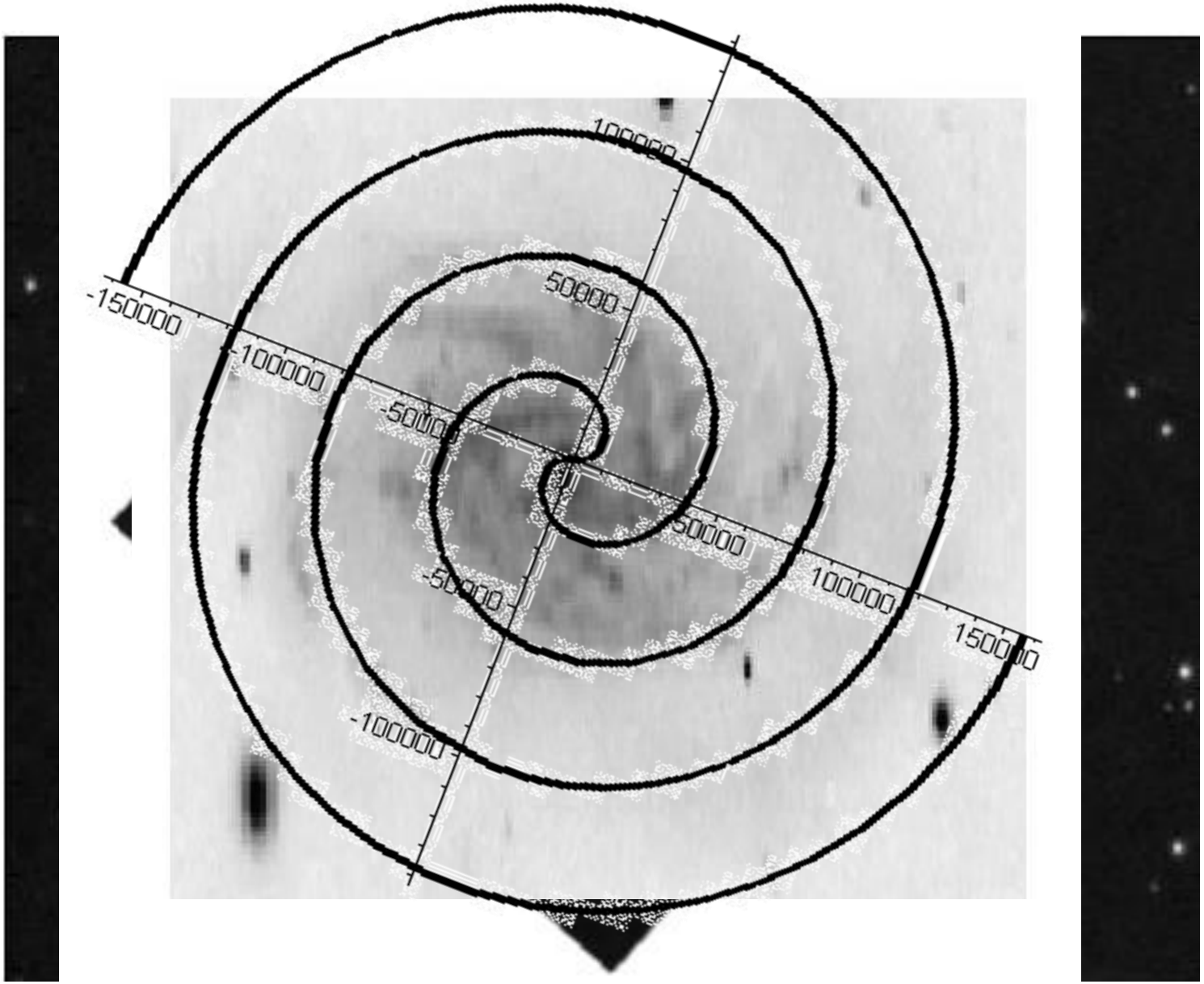
R^2 = .91
Slope = 0.998

Spiral Morphology





NGC 3198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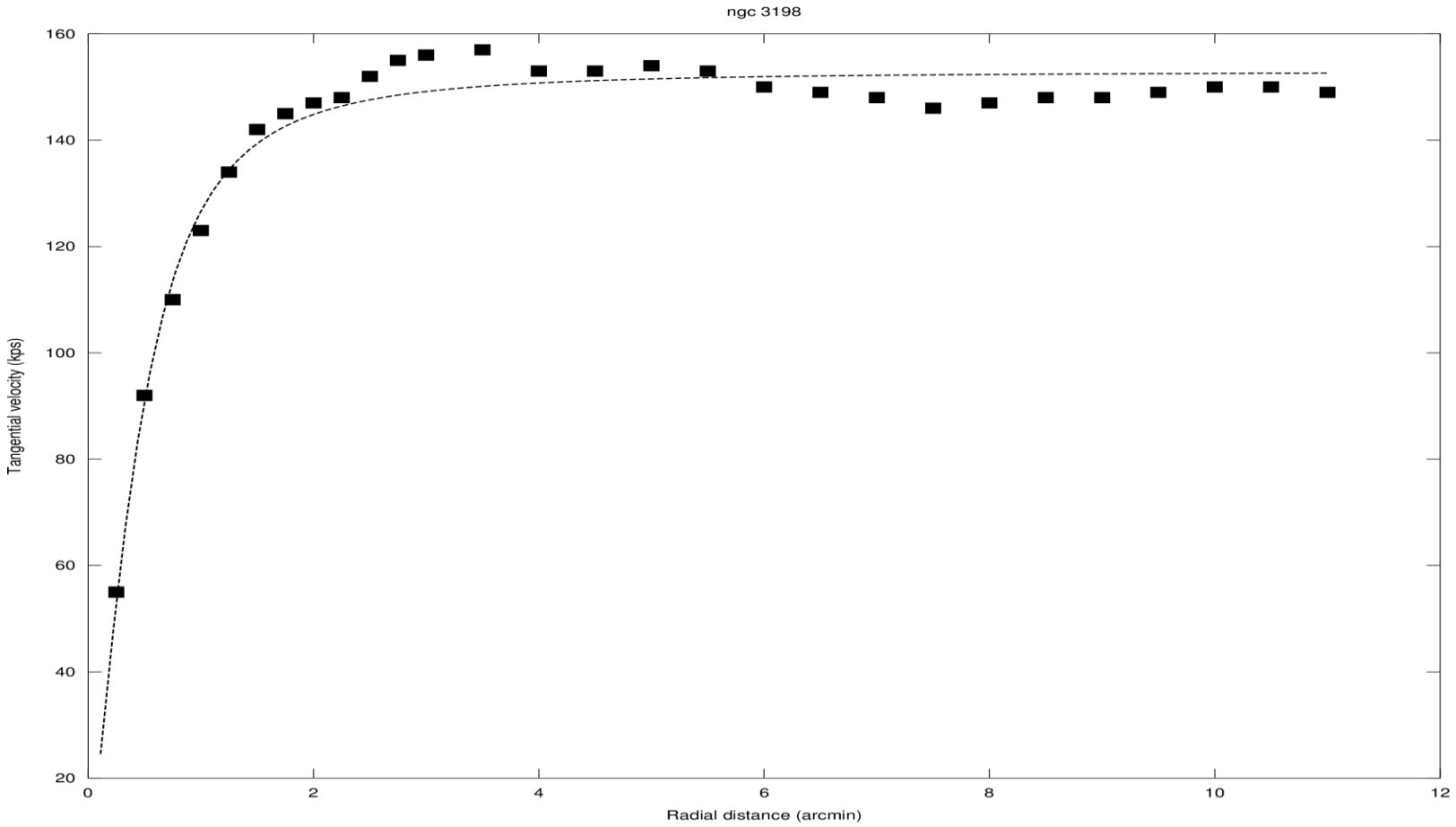

Conclusions

- Relativistic effects of centripetal acceleration results in an analytic double armed spiral model of spiral galaxies which:

1. This model determines the flat velocity rotational velocity profile of spiral galaxies
2. This model yields a distance measure as well as predictions of mass, angular momentum and mass/luminosity distribution of spiral galaxies

Thank you