Polar Ring Galaxies

Finding the Dark Halo Shape
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Papers

• (1) Polar ring galaxies and the Tully-Fisher relation: Implications for the dark halo shape
  ○ Iodice, E.; Arnaboldi, M.; Bournaud, F.; Combes, F.; Sparke, L. S.; van Driel, W.; Capaccioli, M.

• (2) Evidence for axisymmetric halos: The case of IC 2006
  ○ Franx, Marijn; van Gorkom, J. H.; de Zeeuw, Tim
Outline

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Introduction

Polar ring galaxies (PRGs):
- Central gas-poor spheroidal component, the host galaxy. Resembles So or E, but usually bluer and younger than typical.
- Outer ring of gas, stars and dust which rotates over the poles of the host galaxy; contains a lot of HI.
- Many similarities with spiral galaxies.

(Baryonic) Tully-Fisher relation:
- Relation between luminosity $L$ and HI line width $\Delta V$
- Probes a close connection between:
  - the dark halo (responsible for $\Delta V$ and flat rotation curve)
  - the total amount of baryons in the luminous component
Studied Topics

- (1): To look at the position of PRGs in the logΔV–L plane compared to the TF relation for standard spirals and find out how the dark halo shape can influence this position.

- (2): To derive the shape of the galaxy potential and the total mass inside the ring for IC 2006.
  - By first analyzing in detail the effects of triaxial potentials on the observed velocity field.
Purpose

- To find out if ellipticals (and S0s) have dark haloes like those found for spirals

- The dark halo shape is important:
  - to constrain dark matter models
  - to give hints on the nature of dark matter
  - because the dark halo properties of PRGs can give important constraints on their formation scenarios
Methodology - Data

• Data for (1):
  - 6 PRGs with K and B magnitudes (mostly from the host) and $\Delta V_{20}$ (from the polar ring; line width at 20% of the peak line flux density)
  - + 10 PRGs with only B magnitudes and $\Delta V_{20}$
    - in most PRGs both components are seen nearly edge-on
  - very large sample of spiral galaxies to derive the TF relation for normal disk galaxies

• Data for (2):
  - HI channel maps for IC 2006, an early type galaxy with a gas-filled polar ring
They first compare the position of PRGs in the \( \log \Delta V - M_{K/B} \) plane to the TF relation for standard spirals.

They then develop a model in which they can set the dark halo and host potential, which define the eccentricity of the ring.

They compute these models for massless and massive rings to consider the effect of the ring’s self-gravity.
Methodology \( (2) \)

- They work out a new method to derive the elongation of the potential in the plane of a gas ring (or disk) from its velocity field.
  - The velocity field is expanded into harmonics. These harmonic terms are then related to the intrinsic parameters of the PRG.
  - Both the velocity field and the geometry of the ring are needed to give complete information on the elongation of the potential.

- This method is applied to the ring in IC 2006.

- They also construct a mass model to compare to the data in order to get an idea of the amount of dark matter.
IC 2006 has a significant dark matter component within the radius of the ring and there is a radial gradient in the M/L ratio.

The velocity field of IC 2006 is very regular.

The potential in the plane of the ring is nearly circular ($\varepsilon_{\text{pot}} = 0.012 \pm 0.026$, not significant) so the halo must be close to perfectly axisymmetric.

- They find this surprising, as dissipationless simulations of halo formation produce triaxial haloes.
- Though this discrepancy may be caused by the infall of baryonic matter into the halo: this might make haloes more nearly oblate axisymmetric.
The majority of PRGs show larger HI rotation velocities than standard spirals at a given K- or B-band luminosity.
• If there was no dark matter or a spherical dark halo, the potential would be oblate in the same sense as the flattened host

⇒ the polar ring would be eccentric
⇒ measured velocities would be smaller than for a circular ring (depend on both the mean velocity and ring eccentricity)
⇒ expect PRGs to have LOWER velocities than standard spirals!
Oblate dark halo & flattened toward the host galaxy (massless ring)
  ➞ observed velocities would again be smaller
  ➞ not ok

Oblate dark halo & flattened toward the host galaxy or spherical halo (massive ring)
  ➞ the ring’s self-gravity makes the ring more circular
  ➞ but still cannot reproduce the large observed velocities
  ➞ not ok

Oblate dark halo & flattened toward the polar ring
  ➞ self-gravity not very important (potential already makes rings more circular)
  ➞ now possible to reproduce large observed velocities
  ➞ ok!
Discussion (1)
Alternative explanations for the observed velocities are discussed in the paper, but most of them discarded again.

Other halo shape arguments:
- A non-polar halo can explain the observed velocities if it is very massive; but they say this is unrealistic when compared to dark matter content in spirals.
- A prolate halo with a polar major axis could also explain the observed velocities.
In (2), they found a halo that is close to perfectly axisymmetric in the plane of the ring of IC 2006.

In (1), they found that the majority of PRGs show larger rotation velocities at a given luminosity than spirals, and comparison with N-body simulations led to the conclusion that this can be explained by a halo that is flattened towards the plane of the ring.

These findings seem to agree with each other.