Corotation Resonance of Non-barred Spiral Galaxies

A Research work

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(Research advisor)
Outline

- Motivation / Objective
- Introduction
  - Density wave theory
  - Corotation resonance
- Method
  - Multi-band Photometry method
- Results and Discussion
- Conclusion
Structure of a spiral galaxy

Image courtesy of ESA/NASA and Hubble
Motivation

- To understand about Density wave theory
- To know about corotation resonance and its importance in the disk galaxies.
- To learn the method of determining the location of corotation resonance.
What is winding problem?

- Differential rotation of materials such as gas, dust, cloud etc in the galactic disk.
- Tightening of spiral arms due to decrease in the pitch angle of the spiral arms.
- Destruction of the spiral arm structure causing the galaxy to lose the shape of spiral arms.
Continued

After some rotations

Real images of some galaxies
Density Wave Theory

Introduction

- This theory was proposed by two astronomers, Lin and Shu in 1964.
- The theory introduced the concept of quasi-static density waves.

Assumptions

- Presence of long lived quasi-static density wave
- Constant pattern speed of spiral arm and differential rotation of material
Corotation resonance

Plot of angular speed as a function of radius

Angular velocity (km/s/kpc)

Radius (kpc)
Data sample: a short description

- Data sample were taken from the Carnegie-Irvine Galaxies Survey (CGS; Ho et al. 2011)

- Optical images were observed on the 2.5 m du Pont Telescope at the Las Campanas Observatory in Chile in between 2003 and 2007 with the Direct CCD Camera during dark time.

- The galaxy images were taken in four different bands.

  B  V  R  I
Method

- **Multiband photometry method**
  - Developed by Puerari and Dottori in 1997
  - Photometric analysis of existing images
  - Images are analyzed using different routines within PyRAF
  - Images are processed through **3 major steps**

They are:

1. Foreground star subtraction
2. Image deprojection
3. Fourier transformation
Foreground star subtraction

- PyRAF `daofind` task is used to determine the co-ordinates of all foreground stars present in the image.
- PyRAF `psf` task is run to select those stars which were needed to be removed from the image.
- PyRAF `substar` task is run to subtract those fitted stars from the image.
The galaxy image is rotated by an angle equal to PA using PyRAF `rotate` task.

PyRAF `ellipse` task is used to fit elliptical isophotes over the images.

The rotated image is magnified along x-axis by an amount equal to its axis ratio using PyRAF `magnify` task.
Fourier transformation

- Creating azimuthal and radial profiles

Each galaxy image is divided into 360 azimuthal sections, each of 1 degree wide and 120 radial sections, each 1 of pixel wide.

- Applying Fourier transformation

\[
F_2(r) = \int_{-\pi}^{\pi} I_r(\theta) e^{-2i\theta} d\theta
\]

The phase angle can be obtained as

\[
\theta(r) = \tan^{-1} \left( \frac{\text{Re} \left[ F_2(r) \right]}{\text{Im} \left[ F_2(r) \right]} \right)
\]

Here, Re and Im mean the real and imaginary parts of the complex Fourier coefficient.
Phase angle versus radius plot

Presence of azimuthal age gradient (color gradient)
Some examples

This galaxy has a single phase crossing which represents the location of corotation radius.
This galaxy has more than one phase crossing (within the range of 5 arc-seconds) which represents the location of corotation range / region.
## Data results

<table>
<thead>
<tr>
<th>Galaxy name</th>
<th>P.A (deg)</th>
<th>Axis ratio (a/b)</th>
<th>Ellipticity [1 - (b/a)]</th>
<th>Corotation radius (arcsec)</th>
<th>Corotation radius (pix)</th>
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<tbody>
<tr>
<td>IC 2627</td>
<td>20</td>
<td>1.3</td>
<td>0.22</td>
<td>12.28±0.04</td>
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<td>52.60±1.06</td>
<td>203.09±4.09</td>
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</table>
continue,

<table>
<thead>
<tr>
<th>Galaxy name</th>
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<th>Corotation radius (pix)</th>
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</table>
Conclusion

- We were successful to find the location of CR on those spiral galaxies.
- We used multi-band photometry method to determine the location of CR in a sample of 19 non-barred spiral galaxies.
- Out of 19 galaxies, 15 galaxies were found to have a single phase crossing while remaining 4 galaxies had more than one phase crossing.
- We were unable to compare the results with any other method’s results.