Corotation Resonance of Non-barred Spiral Galaxies

A
Research work

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Outline

- Motivation / Objective
- Introduction
  - Density wave theory
  - Corotation resonance
- Method
  - Multi-band Photometry method
- Results and Discussion
- Conclusion

Structure of a spiral galaxy

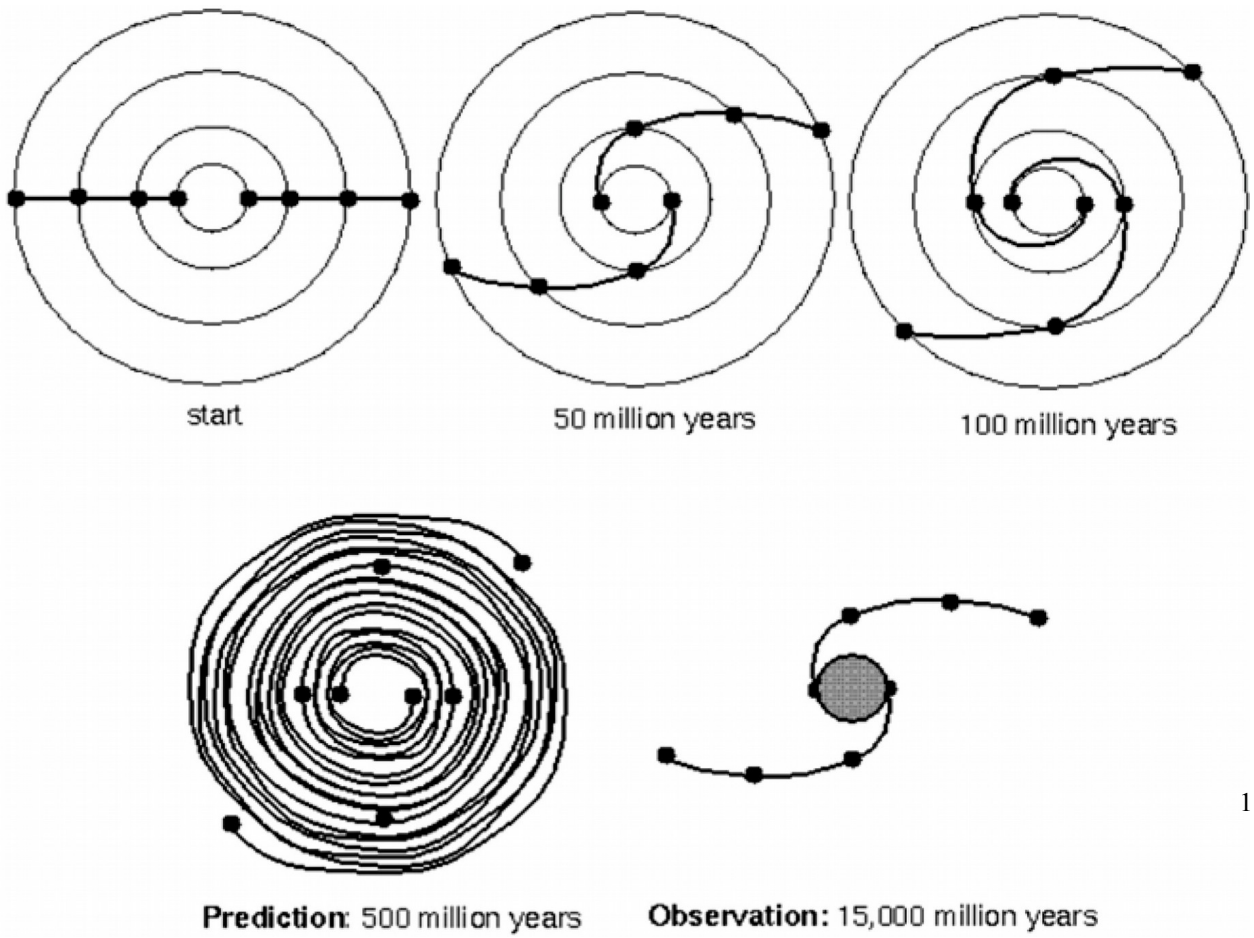
Image courtesy of ESA/NASA and Hubble

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.



Seigar, 2017

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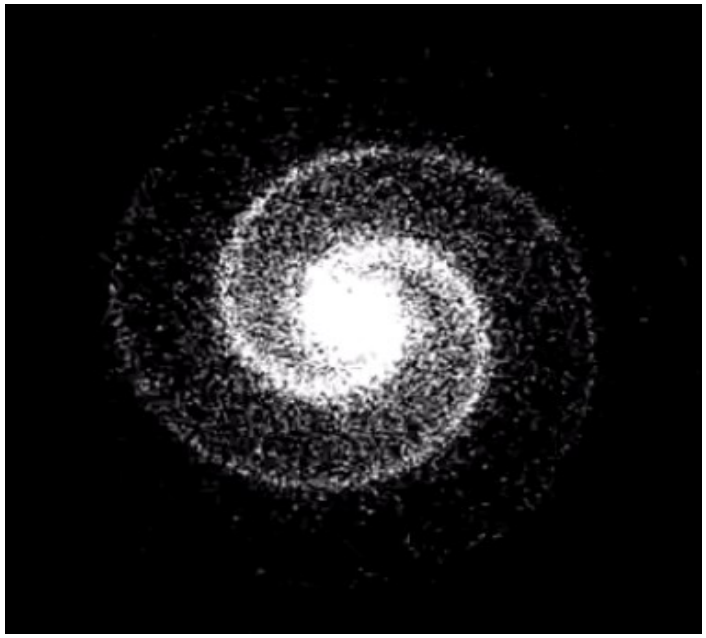
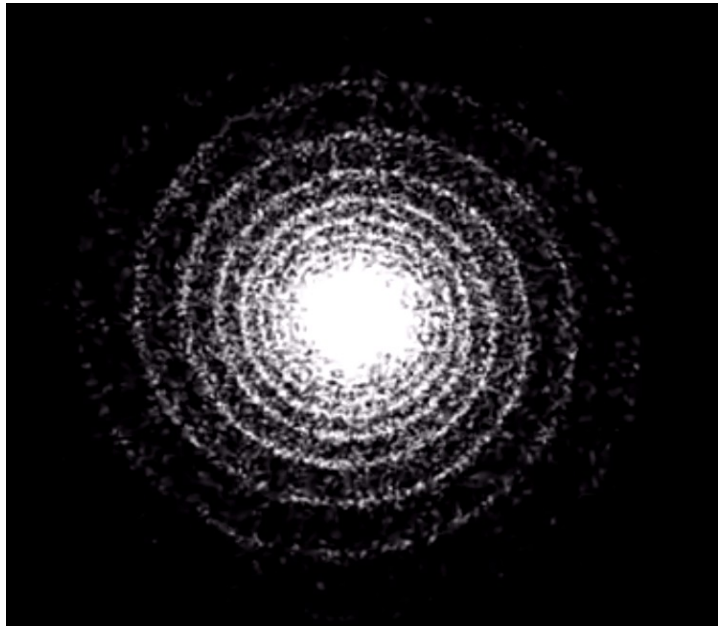


After some rotations



Real images of some galaxies

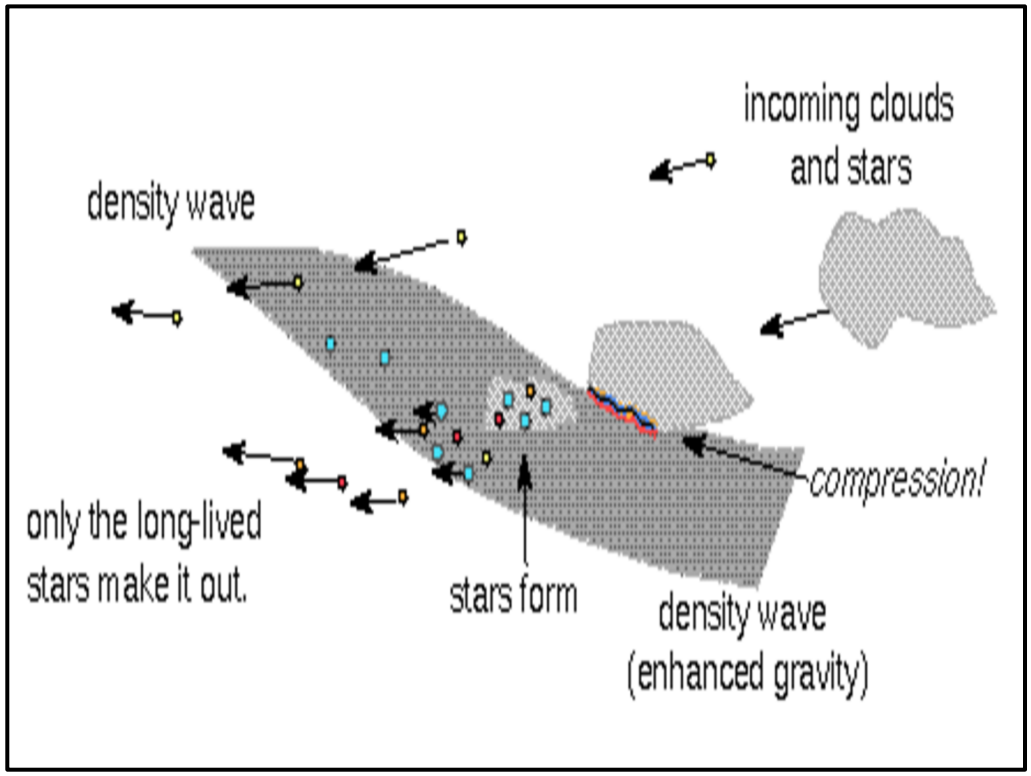
Density Wave Theory

Introduction

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

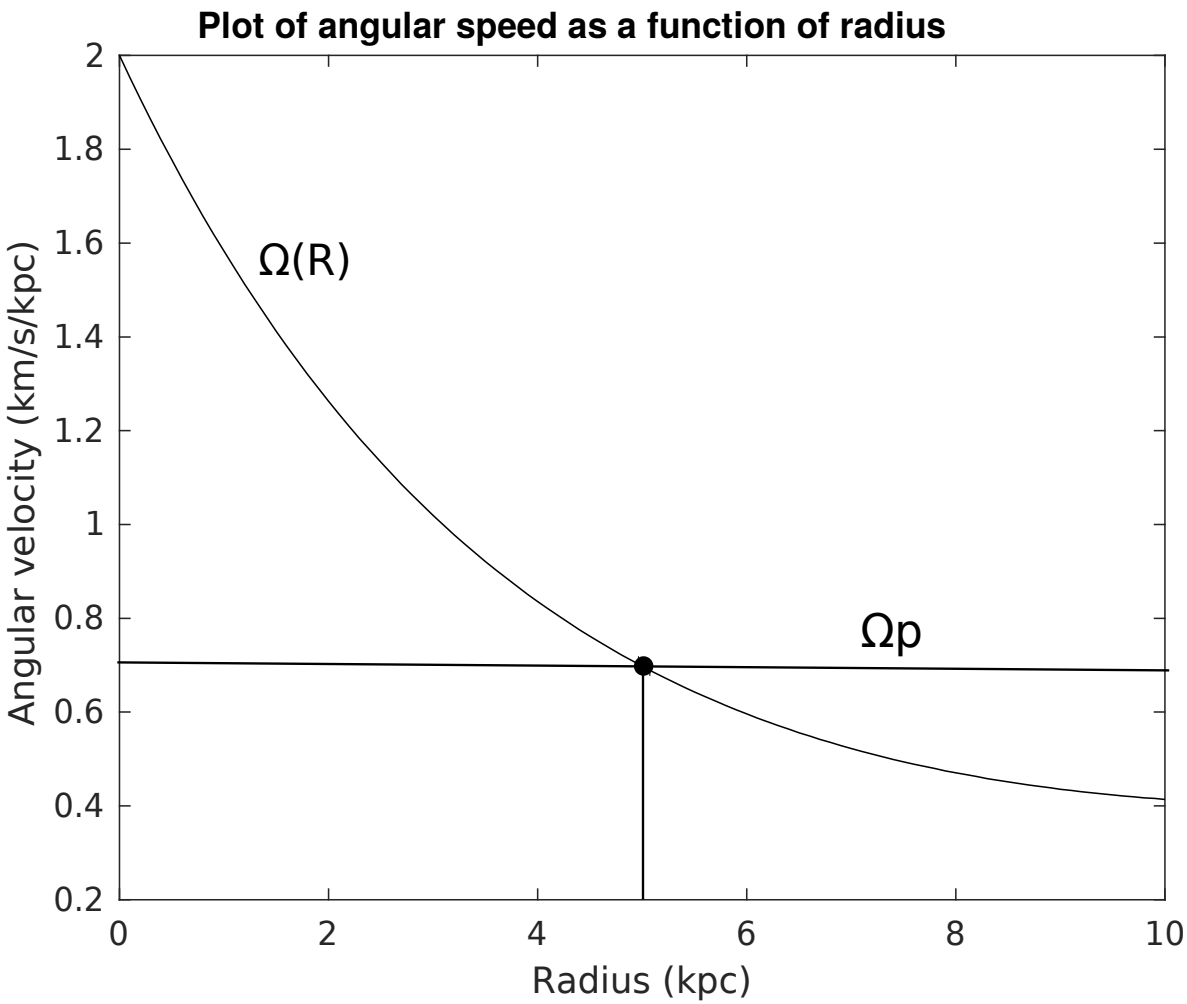
Assumptions

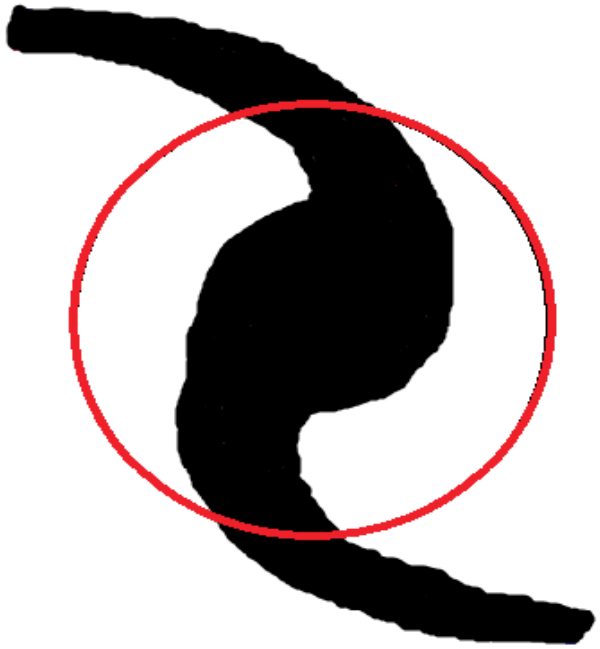
- Presence of long lived quasi-static density wave
- Constant pattern speed of spiral arm and differential rotation of material



https://www.astronomynotes.com/ismnotes/s8.htm
http://ircamera.as.arizona.edu/NatSci102/NatSci/lectures/spiralarms.htm

Corotation resonance

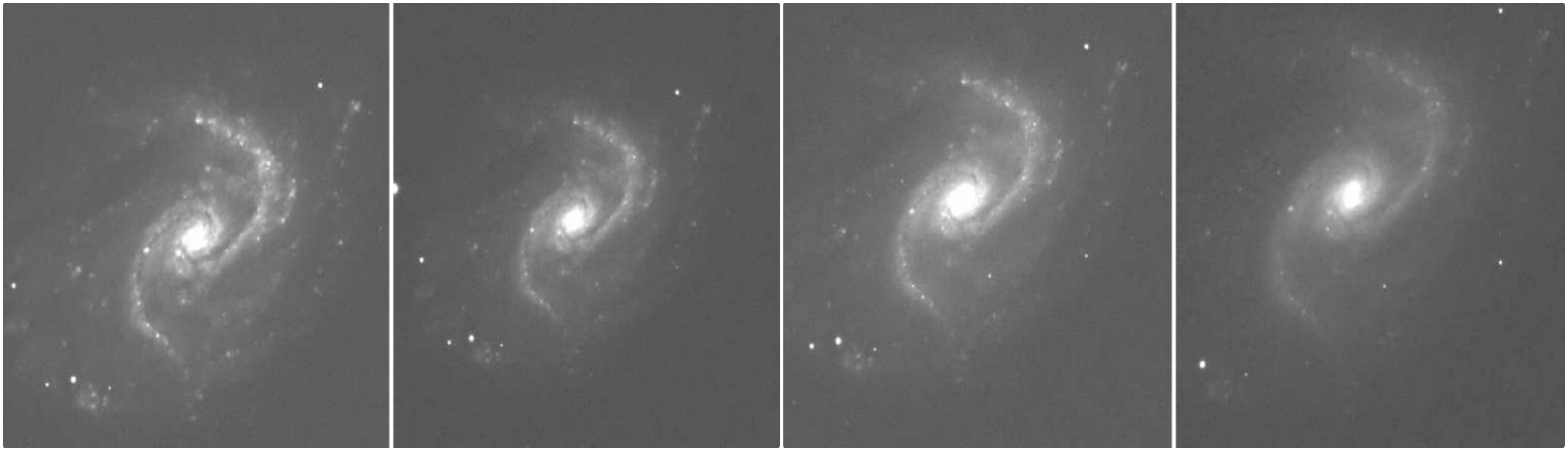




Data sample: a short description

- 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.

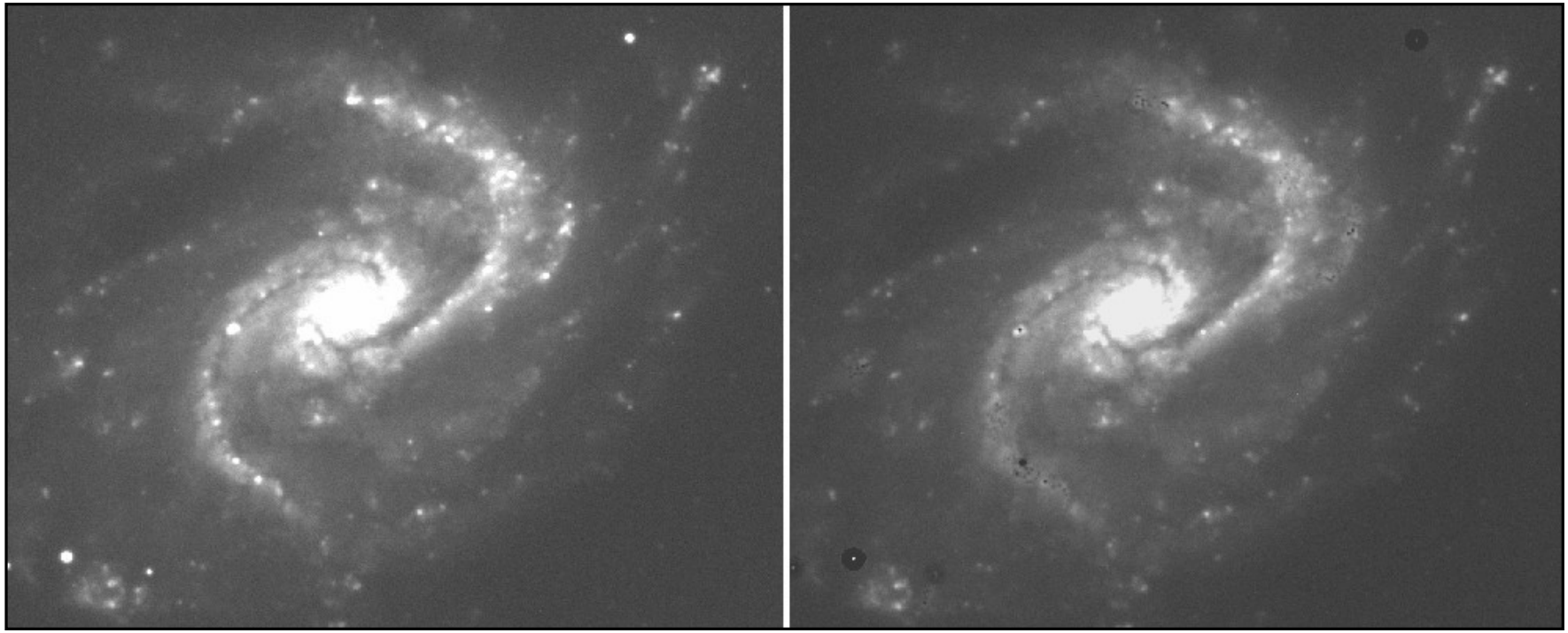
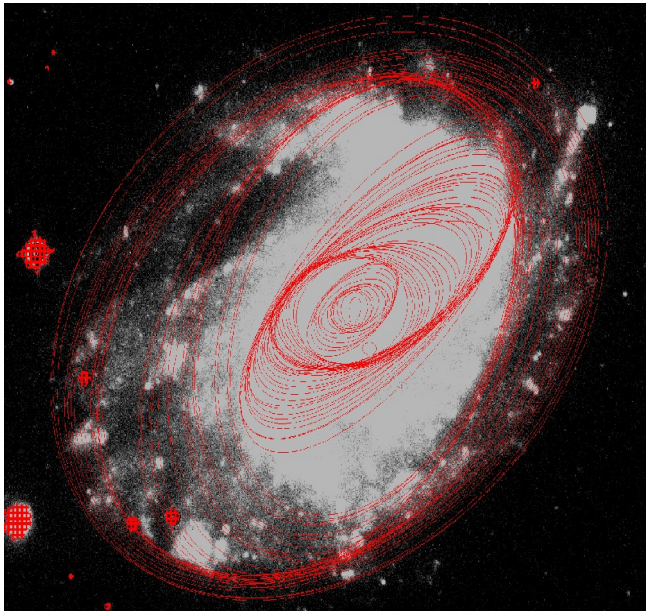


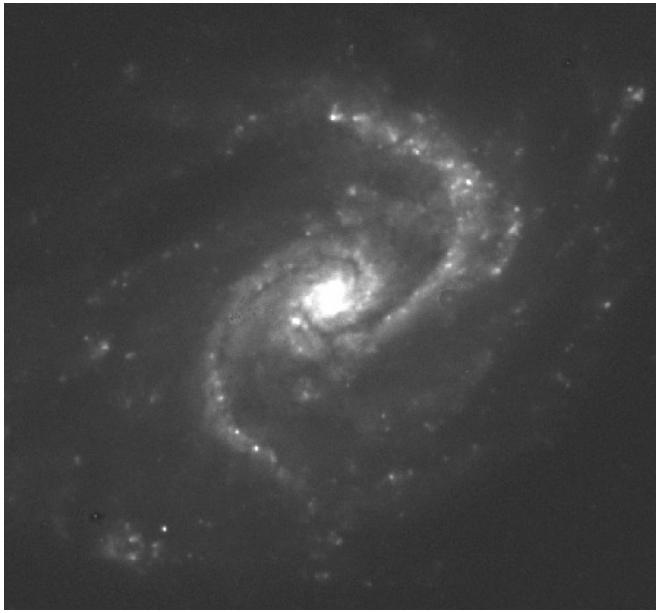
Image deprojection

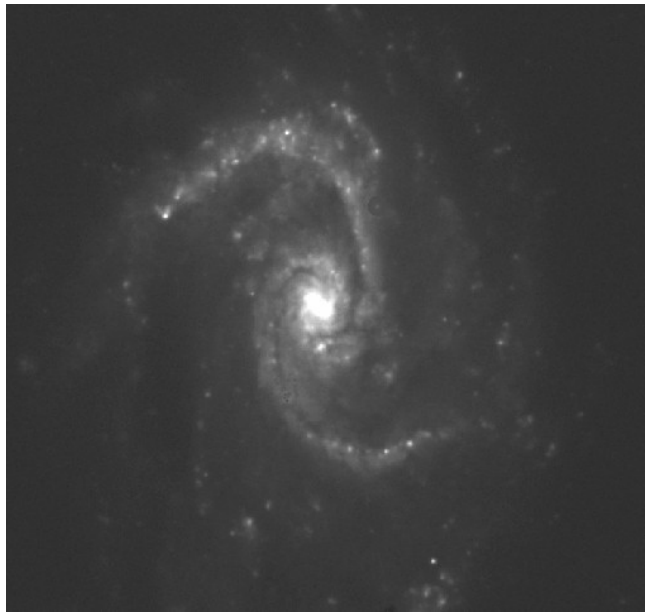


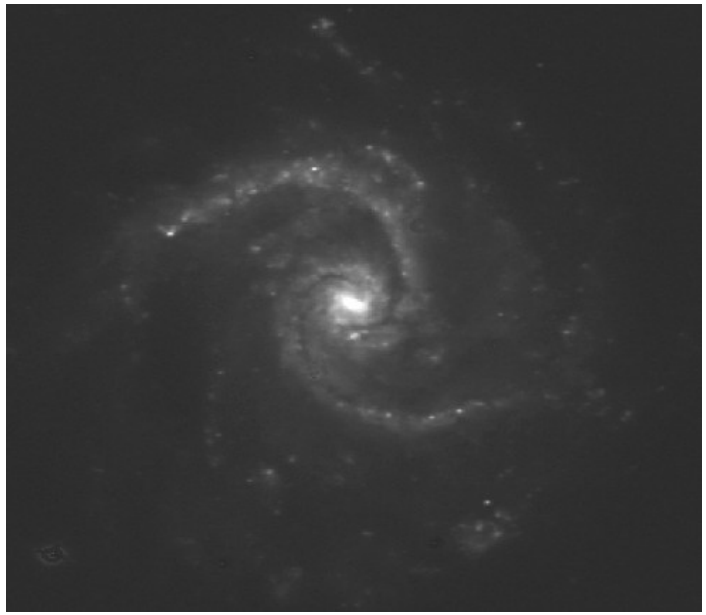
PyRAF ellipse task is used to fit elliptical isophotes over the images.

The galaxy image is rotated by an angle equal to PA using PyRAF rotate task.

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



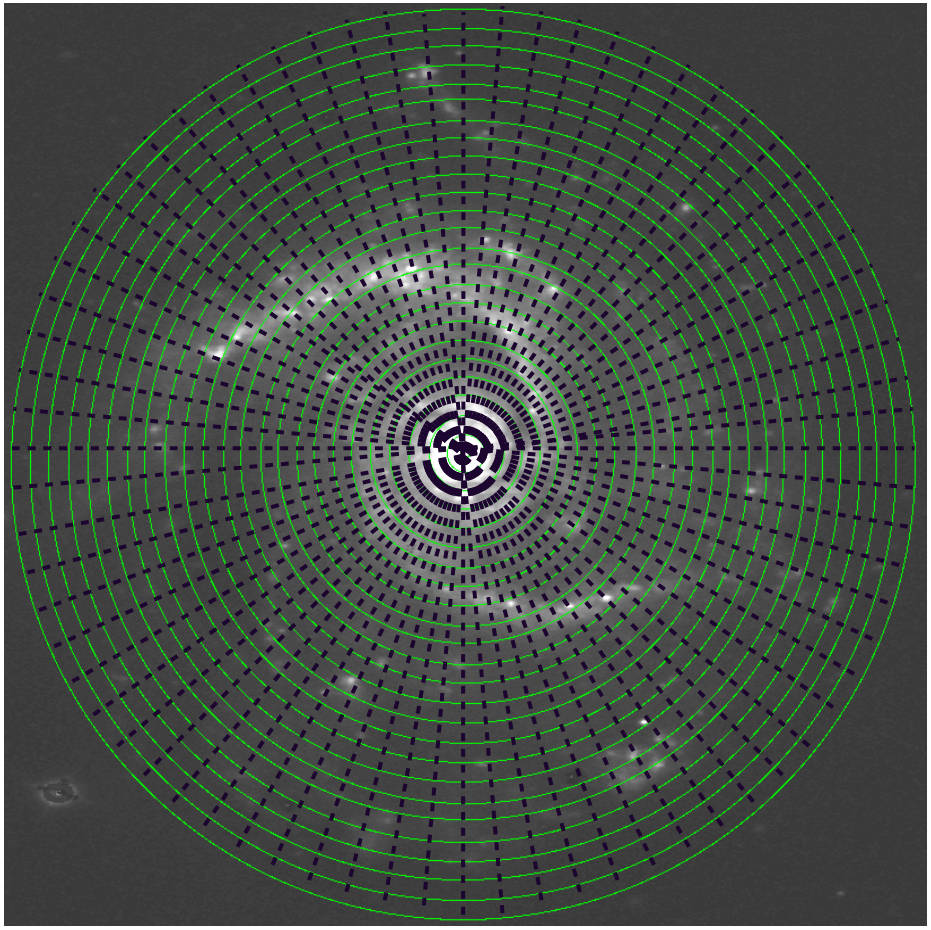




Fourier transformation

- 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

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

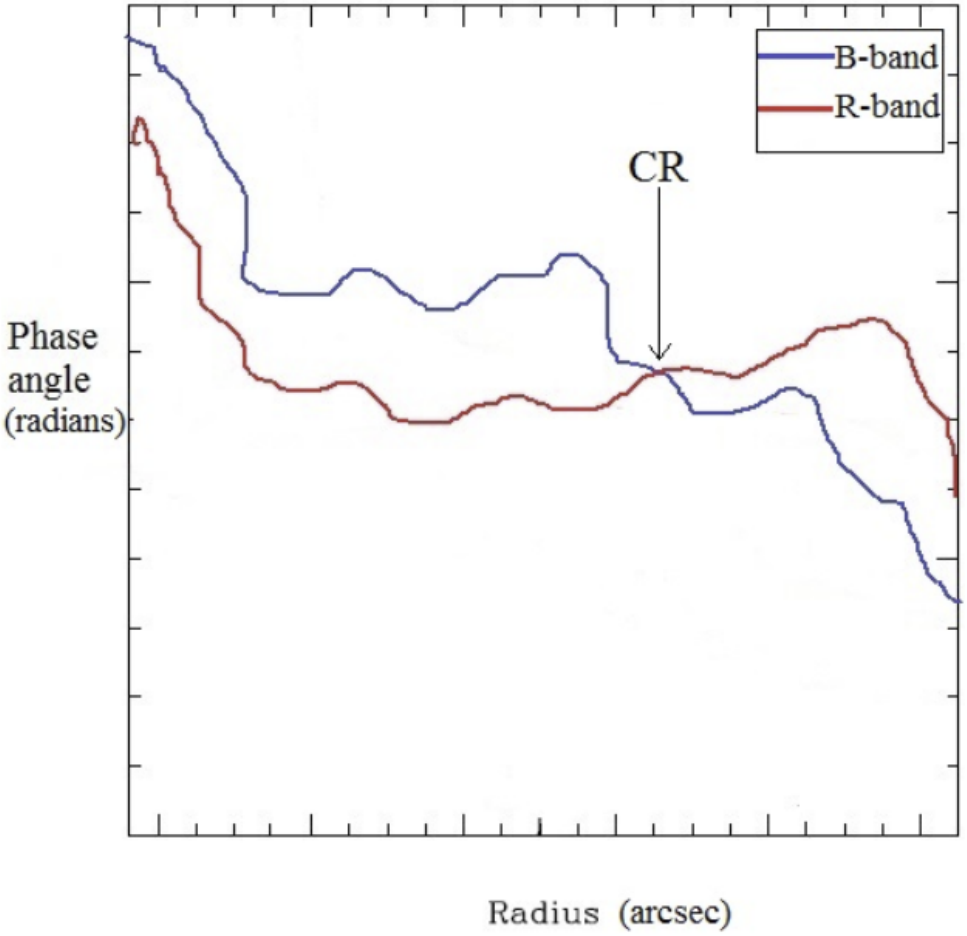
The phase angle can be obtained as

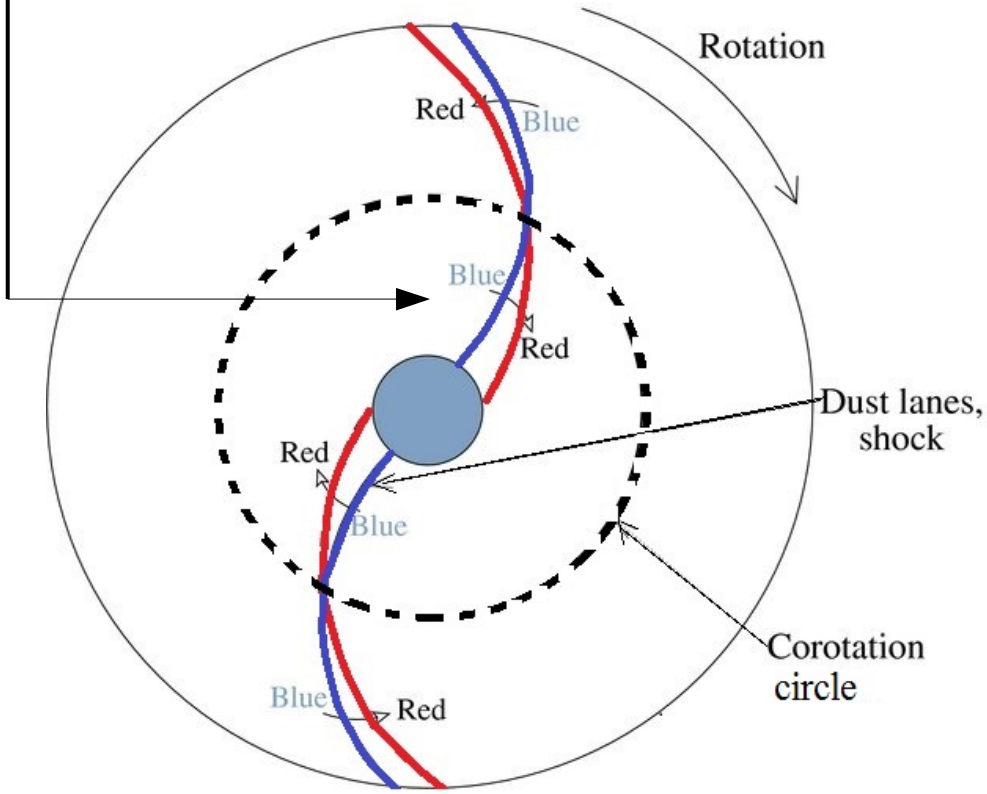
$$\theta(r) = \tan^{-1} \frac{Re\left[F_2(r)\right]}{Im\left[F_2(r)\right]}$$

Here, Re and Im mean the real and imaginary parts of the complex Fourier coefficient.

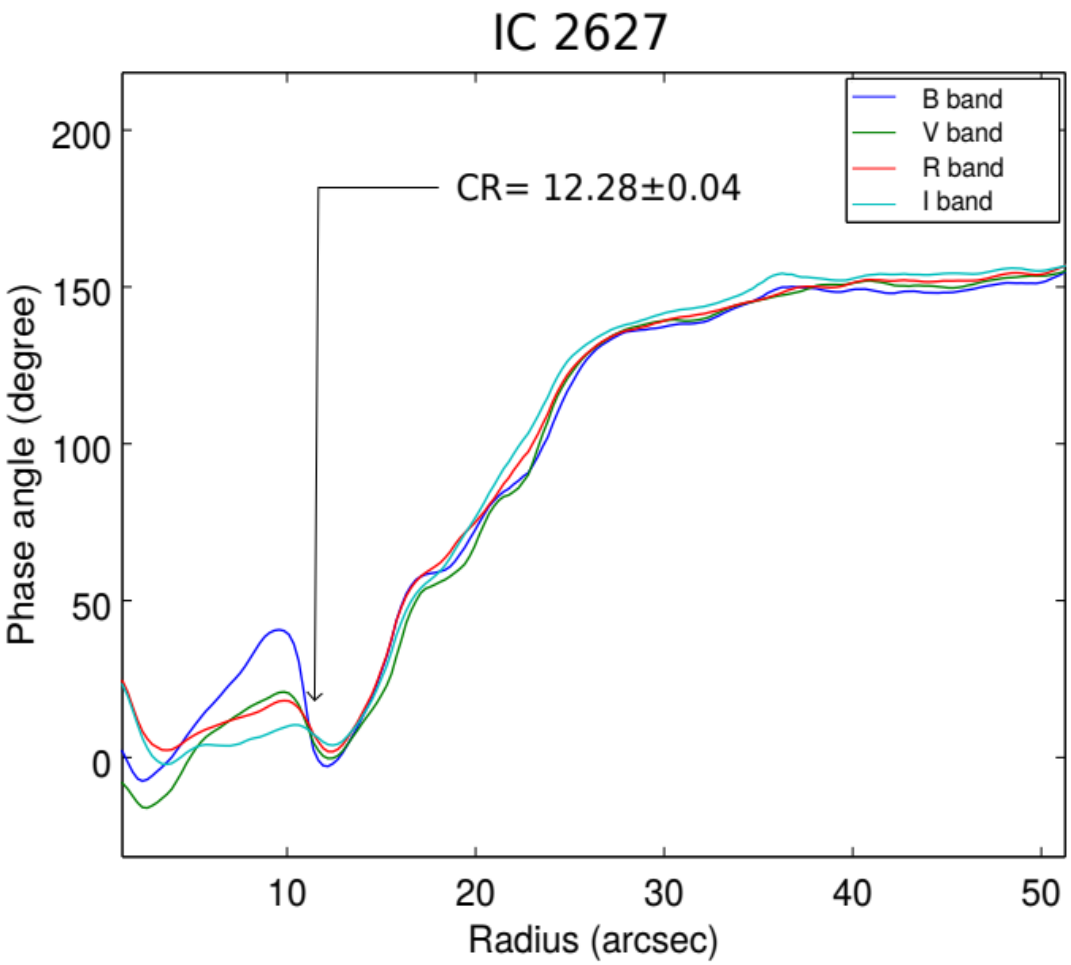
Phase angle versus radius plot

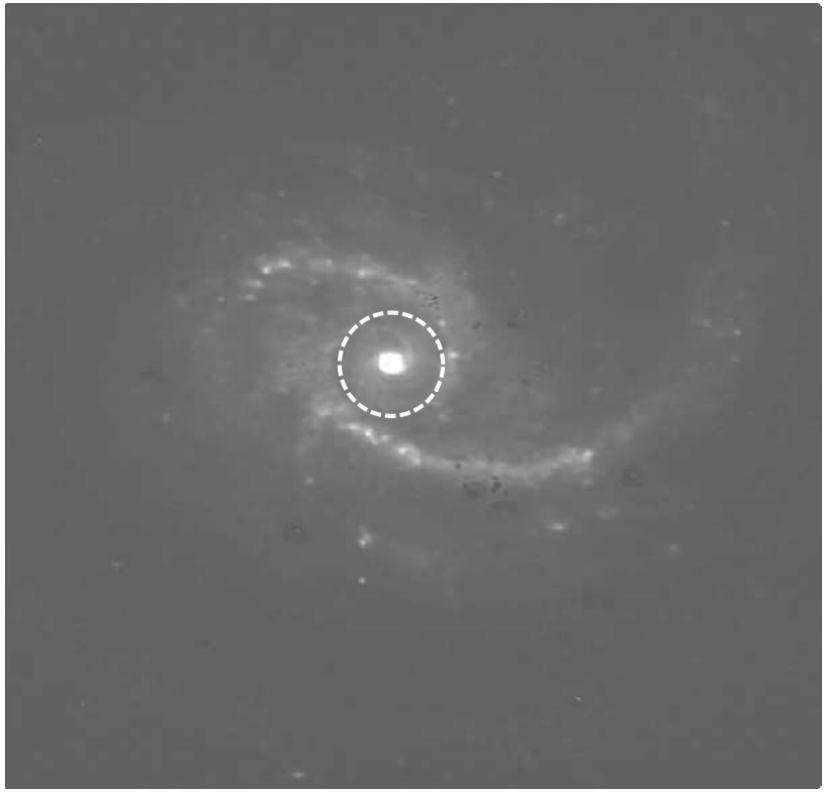
Presence of azimuthal age gradient (color gradient)





Some examples





This galaxy has a single phase crossing which represents the location of corotation radius.

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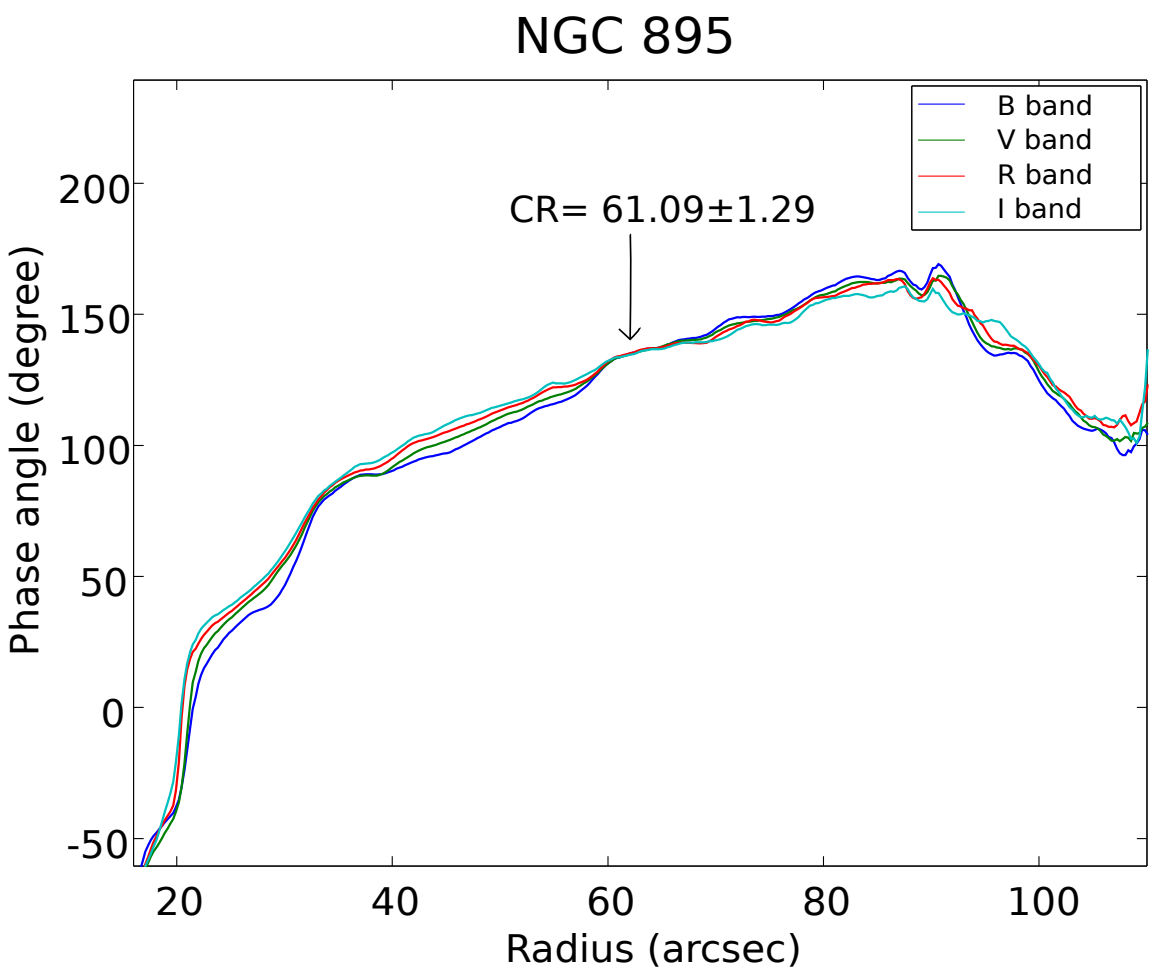

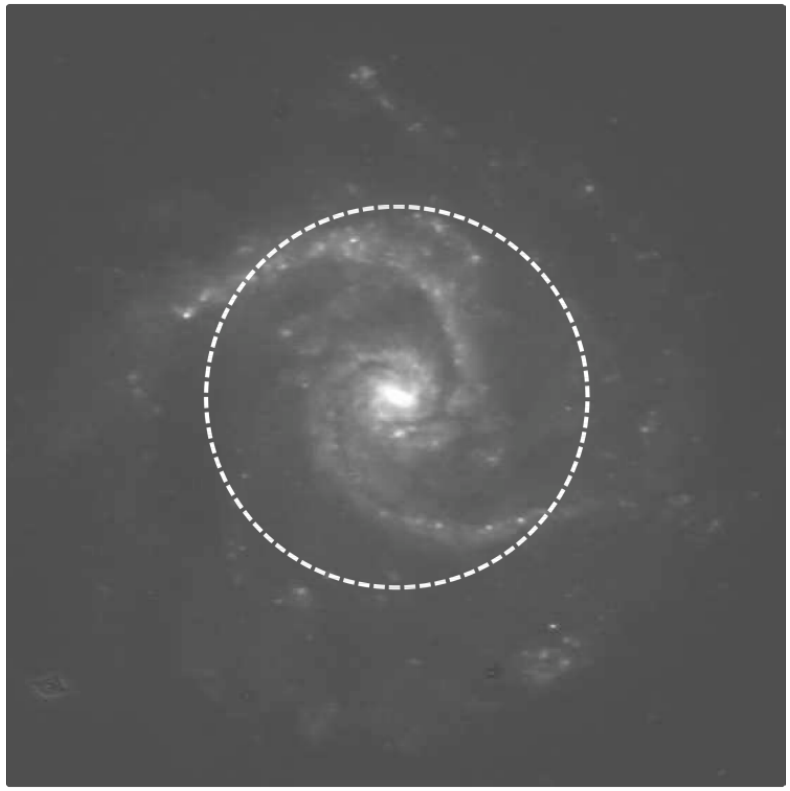

This galaxy has more than one phase crossing (within the range of 5 arc-seconds) which represents the location of corotation range / region.

Data results

Galaxy name	P.A (deg)	Axis ratio (a/b)	Ellipticity [1 - (b/a)]	Corotation radius (arcsec)	(pix)
IC 2627	20	1.3	0.22	12.28±0.04	47.30±0.15
IC 5332	17	1.2	0.17	49.65±1.27	191.70±4.90
NGC 895	-60	1.6	0.34	61.09±1.29	235.877±4.98
NGC 908	76	2.2	0.55	38.12±0.65	147.18±2.51
NGC 2280	163	2.2	0.55	32.90±0.82	127.03±3.17
NGC 2417	81	1.4	0.28	52.60±1.06	203.09±4.09
NGC 3223	135	1.8	0.45	56.26±0.38	217.22±1.47
NGC 3672	11	2.9	0.66	55.12±1.55	212.82±5.98
NGC 4030	41	1.5	0.33	72.57±0.75	280.19±2.90
NGC 4939	10	1.8	0.45	32.14±1.56	124.09±6.02

continue,

Galaxy name	P.A (deg)	Axis ratio (a/b)	Ellipticity [1 - (b/a)]	Corotation radius (arcsec)	(pix)
NGC 5054	-20	1.5	0.33	60.65±0.97	234.17±3.75
NGC 5247	20	1.1	0.09	18.02±0.82	69.58±3.17
NGC 5254	-55	2.3	0.57	47.79±0.51	184.52±1.97
NGC 5324	60	1.2	0.17	32.74±1.17	126.41±4.52
NGC 5483	-45	1.1	0.09	31.87±1.96	123.05±7.57
NGC 6118	55	2.6	0.62	77.59±1.15	299.58±4.44
NGC 6753	40	1.3	0.23	32.84±0.26	126.80±1.00
NGC 7083	5	1.5	0.33	62.55±0.96	241.51±3.71
NGC 7606	-36	2.2	0.55	58.66±2.03	226.49±7.84

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.