Kinematics modelling of molecular gas in NGC 3100

F. Fragnito[2], R. Paladino[1,2], I. Prandoni[2], I. Ruffa[1,2] et al.

[1] University of Bologna; [2] INAF – Istituto di Radioastronomia

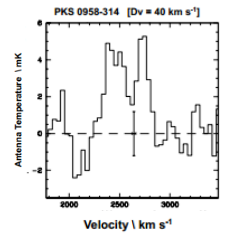
Abstract

A kinematics modelling of molecular gas in the centre of NGC 3100, a FRI radio galaxy hosted by a S0 galaxy at redshift z = 0.0088. The inner region of NGC 3100 has been observed with ALMA at Band 6 during Cycle 3. The CO(2-1) 230-GHz line (restfrequency) was clearly detected. The analysis of the line through the integrated intensity map (moment 0) and the integrated velocity map (moment 1) revealed a ring-like rotating structure. A tilted-ring model was built through the software 3D-Barolo to better understand the complex kinematics of the gas. The modelling allowed us to explore purely rotational velocity fields as well as fields including non-circular motions.

Introduction

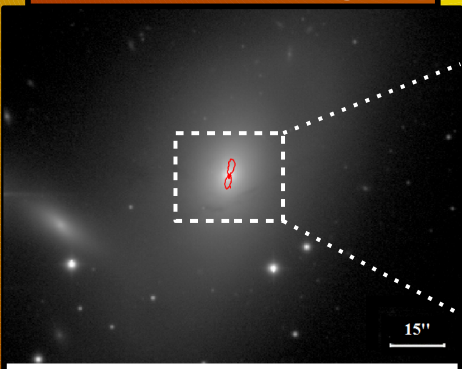
This work is part of a project aimed at providing a comprehensive study of different galaxy components (stars, warm, cold gas) in the core of radio-loud early-type galaxies, and look for kinematical signatures of feeding/feedback loops that can be causally related to the presence of radio jets. For this purpose a complete, volume limited (z < 0.03) sample of eleven radio galaxies in the Southern sky was selected from the Parkes 2.7-GHz survey. This sample is the target of VLT/VIMOS integral-field-unit optical spectroscopy (warm gas and stellar components) and ALMA CO line imaging (molecular gas).

APEX 230-GHz observations



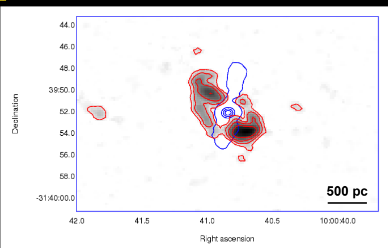
t_{ON} min	T_{sys} K	Δv_{res} km s^{-1}	$T^*_{A,rms}$ mK	$T^*_{A,peak}$ mK	S/N	Δv_{FWHM} km s^{-1}	$\Sigma T^*_A dv$ K km s^{-1}	R kpc	K	$\log(M_{H_2})$ $M_\odot$
62	191	40	1.2	5.3	4.4	446	1.68	4.9	1.06	8.17±0.03

NGC 3100 inner region



NGC 3100 in Band R with red contours for the jets detected by VLA at 5 GHz

ALMA moment 0 map and radio jets

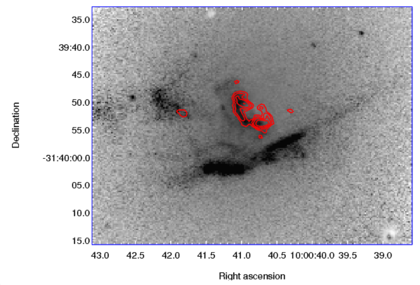


The CO(2-1) integrated intensity image clearly shows a **ring-like structure.**

The **ring appears inhomogeneous** and even disrupted along the minor axis.

The **radio jets (in blue)** from the central AGN could be **responsible for the partial disruption** that affects the CO ring.

Dust and CO(2-1) overlap

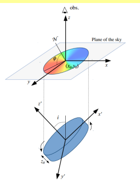


The CO nicely overlaps the inner semi-circular dust feature, suggesting both trace the same rotating structure. This allows us to identify the side of the CO disk, which is closer to the observer.

NGC 3100 kinematics modelling

The tilted-ring model (TRM)

The TRM describes the **kinematics of rotating disks** as observed in spectral line experiments, constructing a **velocity field** (2D-TRM) or **parametrized model data cubes** (3D-TRM).



3D-TRM principal **parameters**

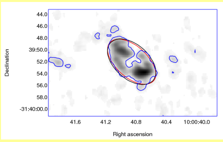
- **inclination angle** i ;
- **position angle** Φ ;
- **rotational/circular velocity** Vrot;
- **radial velocity** Vrad (non-circular motions)

Input and first guess **parameters**

- i = 60°
- Φ = 225°
- Vrot = 100 km/s
- Vrad (if present) = 50 km/s

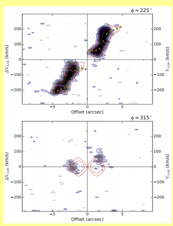
The **software** used

3D-Barolo (3D-Based Analysis of Rotating Object via Line Observations) (Di Teodoro, Fraternali 2015).

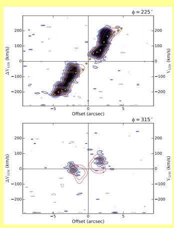


Position-Velocity (PV) diagrams

Rotational Model



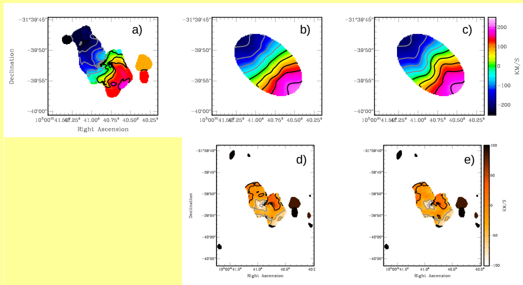
Non-circular Model



Position-velocity diagrams along major (top) and minor (bottom) axes for the rotational and non-circular models. Data are shown in grey-scale with blue contours, models in red, rotation curves as yellow dots. The non-circular model provides a better result in surface brightness distribution along the minor axis.

Velocity Fields

Data | Rotational | Non-circular



The panels in the top row show (a) the observed velocity field, (b) the rotational and (c) the non-circular models. The velocity fields are plotted on the same color scale, shown in km/s to the right of the top row. The panels in the bottom row show residual maps (Data - Model) for (d) the rotational and (e) the non-circular models, with the color scale in km/s for both shown to the right of that row. Black contours are for positive velocities, grey contours are for negative velocities with respect to the V_{sys} = 2592 km/s

Results and Conclusions

The gas was modelled as rotating disk. Different fixed position angles and inclinations were tested The position angle that best reproduces the whole structure is 225°. The best-fit inclination resulted in 60°. The purely rotational model produced a disk with rotational velocity in a range of ~ ± 250 km/s, consistent with the data. However, the residual image of the purely rotational model suggest the presence of radial flows along the minor axis (Panel d), that seem to be at least partially accounted for when including non-circular motions (Panel e). The non-circular model also better reproduces the tilts in the moment 1 and PV diagrams (see above). The fact that the blue/red-shifted flows are seen in correspondence to the near/far side of the CO disk, it may suggest that we are seeing a jet-driven outflow.

francesco.fragnito@studio.unibo.it