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Kinematics modelling of molecular gas in NGC 3100

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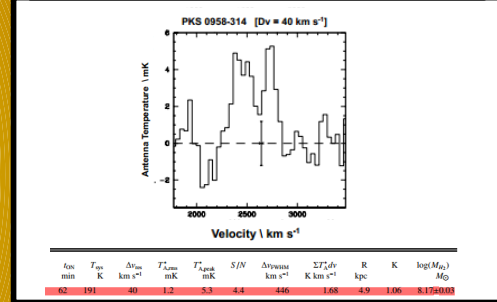
Abstract

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.

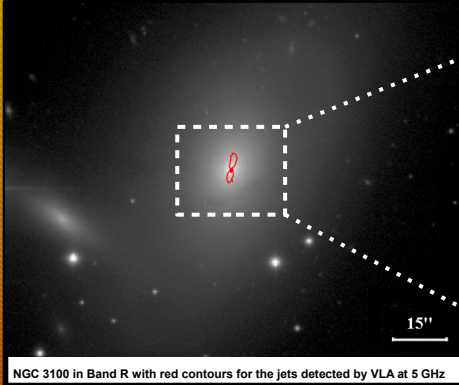
Introduction

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).

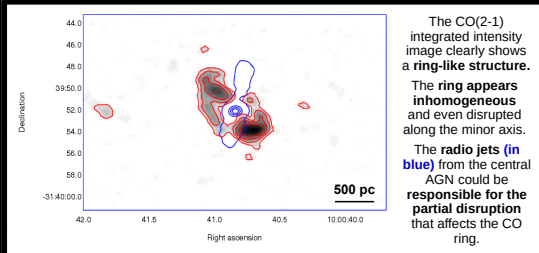
APEX 230-GHz observations



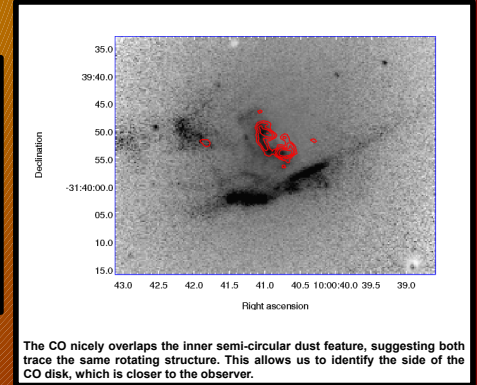
NGC 3100 inner region



ALMA moment 0 map and radio jets



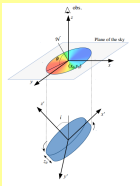
Dust and CO(2-1) overlap



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).



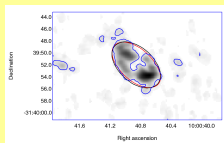
3D-TRM principal parameters

- inclination angle i ;
- position angle Φ ;
- rotational/circular velocity V_{rot} ;
- radial velocity V_{rad} (non-circular motions)

Input and first guess parameters

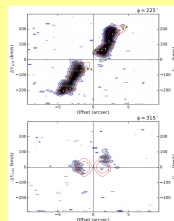
- $i = 60^\circ$
- $\Phi = 225^\circ$
- $V_{\text{rot}} = 100$ km/s
- V_{rad} (if present) = 50 km/s

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

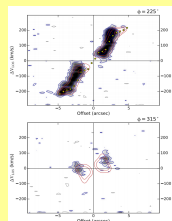


Position-Velocity (PV) diagrams

Rotational Model



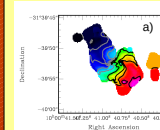
Non-circular Model



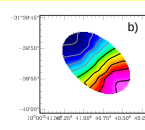
Position-velocity diagrams along major (top) and minor (bottom) axes for the rotational and non-circular models. Data are shown in grey-scale with blue contours, models in red, rotation curves as yellow dots. The non-circular model provides a better result in surface brightness distribution along the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

Velocity Fields

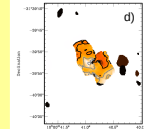
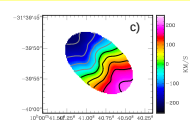
Data



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 $V_{\text{sys}} = 2592$ 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 $\sim \pm 250$ 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.