Gas kinematics in the nucleus of the nearby galaxy M83

A Multi-Wavelength 3D Perspective of a single galaxy

Andreas Lundgren
Atacama Pathfinder EXperiment, ESO, Chile
Talk at the workshop “Gas and Stars in Galaxies - A Multi-Wavelength 3D Perspective” in Garching on June 10th 2008
Introduction: Overview

• Observations
  • SEST CO(2-1) and WHT H\( \alpha \) with GH\( \alpha \)FaS

• Published results
  • “Spiral Inflow Feeding the Nuclear Starburst in M83, Observed in H\( \alpha \) Emission with the GH\( \alpha \)FaS Fabry-Perot Interferometer”, Fathi et al. 2008, ApJ, 675L,17F

• CO(2-1) and H\( \alpha \) spectra in the nucleus of M83 - a direct comparison
Introduction: Questions
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- How much gas is transferred to the nucleus?
- How does the kinematics of this gas look?
- What effect does it have on the star formation?
- How is the gas affected by the transfer?
- Location of the resonances?
Observations - Target

- **M83 (NGC5236)**
  - R.A. 13 37 01, Dec -29 51 56 (J2000)
  - Barred spiral galaxy
- Low inclination
- Fairly symmetrical
- Rich in blue young stars
  - 6 SN in during this century
- No nearby companions
- Distance 4.5 Mpc
  - 1” = 22pc
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Observations - Radio

- **APEX CO(J=4-3) data**
  - Receiver not commissioned

- **SEST - Complete coverage of the optical disk**

- **CO(J=1-0)**
  - Spectra in 1900 positions, 11” spacing, 45” spatial resolution, 1.8 km/s velocity resolution
  - Deconvolved, using a MEM-method, to 23” spatial resolution, 5 km/s velocity resolution

- **CO(J=2-1)**
  - 2574 positions, 7”+11” spacing, 23” spatial resolution, 0.9 km/s velocity resolution
  - Deconvolved to 13” spatial resolution, 5 km/s velocity resolution
  - Data corrected for the error beam
Observations - Radio

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Observations - Hα

- GHαFaS Fabry-Perot interferometer
  - Nasmyth focus of the 4.2m William Herschel Telescope (WHT), Tenerife, Spain
  - FOV 3.4’x3.4’, pixel size 0.4”
  - Channel width 8.2 km/s, 48 channels, spectral range 392 km/s
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Results CO: iso-velocity curves

Iso-velocity curves CO(1-0)
Contour increment 10 km s$^{-1}$
Pattern of rotating disk
Deviations - streaming motions

To obtain the rotation curve, the kinematic data has to be compensated for inclination, position angle, systemic velocity and kinematic-center offset.
Results CO: the model

- Residuals range from -20 km/s to +20 km/s
- The pattern seems to be spiral shaped, and seen in CO(1-0, 2-1) and HI data
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Results CO: rotation curve

\( M_{\text{gas}} (6.8 \times 10^9 \, M_\odot) \)
responsible for 11% of the dynamical mass

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Scale length of the kinematic fit similar to that of the CO distribution fit (2.3 kpc).

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Results CO: angular velocity

**Corotation**

\[ \Omega = \Omega_p \]

**Resonances**

\[ nm(\Omega - \Omega_p) = \pm \kappa \]

- m - number of arms
- n - integer number
- n=2 for Lindblad resonance
- n=4 for Ultraharmonic resonance

Our CO data has been used to calculate the pattern speed with the Tremaine-Weinberg method.

\[ 50 \pm 9 \text{ km s}^{-1} \text{ kpc}^{-1} \]

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Nuclear disk:
- Mass: $3\times10^8 M_\odot$
- Scale length 50pc
Results CO: Disk stability

A gaseous disk becomes unstable against axisymmetric perturbations when the mass surface density exceeds a critical value (Toomre ApJ 1964):

\[ \Sigma_{cr} = \alpha \frac{\sigma_{gas} \kappa}{\pi G} \]

Where the epicyclic frequency is given by

\[ \kappa^2 = \left( R \frac{d \Omega^2}{d R} + 4 \Omega^2 \right) \left[ \text{km s}^{-1} \text{kpc}^{-1} \right]^2 \]

Under gravitational instability mass concentrations will appear along the spiral arms (Elmegreen ApJ 1994). The separations between these agglomerations are:

\[ \lambda = 2.2 \left( \frac{\sigma_{gas}}{7 \text{ km s}^{-1}} \right)^2 \left( \frac{\Sigma_{gas}}{20 \text{ M}_\odot \text{ pc}^{-2}} \right)^{-1} \left[ \text{kpc} \right] \]
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Distance between the Galactic Molecular Associations (GMAs) can be used to independently derive the velocity dispersion of the interstellar gas

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\[ \sigma_{\text{gas}} = 7.8 \pm 0.9 \text{km s}^{-1} \]

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The derived velocity dispersion is consistent with the ones observed in H2 and HI

Fig. 10. Velocity dispersion in the CO\((J=1-0)\) and CO\((J=2-1)\) data sets, at a common spatial resolution of 49\(^9\), as a function of the galactocentric distance.
The ratio of the mass surface density of the gas divided by the critical critical value:

$$\Upsilon = \frac{\Sigma_{\text{gas}}}{\Sigma_{\text{cr}}}$$

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$$\Sigma_{\text{gas}} = \Sigma_{\text{H}_2} + \Sigma_{\text{HI}} + \Sigma_{\text{He}}$$
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Correlates with the location of the HII regions in M83
Results Hα: The model

- We derive kinematical properties that are consistent with the ones seen in the CO data
Removing the 2D velocity field from the data reveals a spiral residual pattern superimposed on the rapidly rotating inner component.

Harmonic decomposition gives a $v_{rad}$ of the order of 50 km/s.

Results Hα: Kinematics

- Hα Nuclear disk:
  - Mass: $5.5\pm0.9 \times 10^8 \, M_\odot$
  - Scale length: 60±20 pc

- CO Nuclear disk:
  - Mass: $3\times10^8 \, M_\odot$
  - Scale length: 50pc

- Dust ring seen in J-K
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Elmegreen et al., AJ, 116, 1998
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Elmegreen et al., AJ, 116, 1998
Comparison: Maps
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Comparison: Spectra
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Summary

- In the barred galaxy M83 we have been able to kinematically follow the gas falling in from 10 kpc to within 300 lightyears from the nucleus.

- The GHαFaS data give the first high-resolution view over 2 kpc radius of M83 and unveiled the inner disk with a mass corresponding to 5% of the total ISM mass of the galaxy, and 0.5% of the total dynamical mass.

- The infalling gas is driven by the bar and is responsible for forming the disk, as well as feeding the circumnuclear starburst in this galaxy.