Gas kinematics in the nucleus of the nearby galaxy M83

A Multi-Wavelength 3D Perspective of a single galaxy

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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 Hα with GHαFaS
- Published results
  - "Molecular gas in the galaxy M 83. II - Kinematics of the molecular gas", Lundgren et al. 2004, A&A, 422, 865
  - "Spiral Inflow Feeding the Nuclear Starburst in M83, Observed in Hα Emission with the GHαFaS Fabry-Perot Interferometer", Fathi et al. 2008, ApJ, 675L,17F
- CO(2-1) and Hα 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 resonanses?

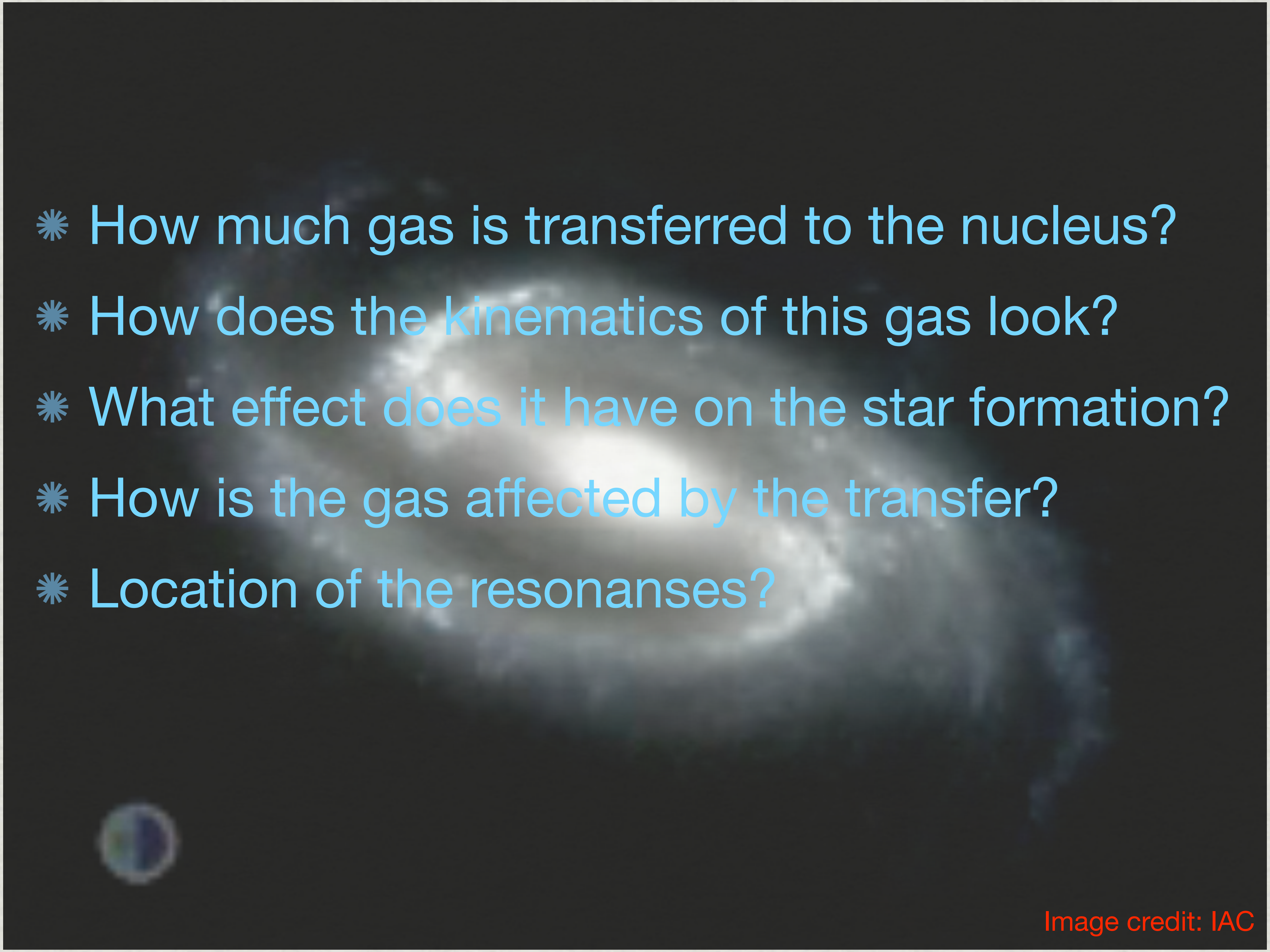

Image credit: IAC

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
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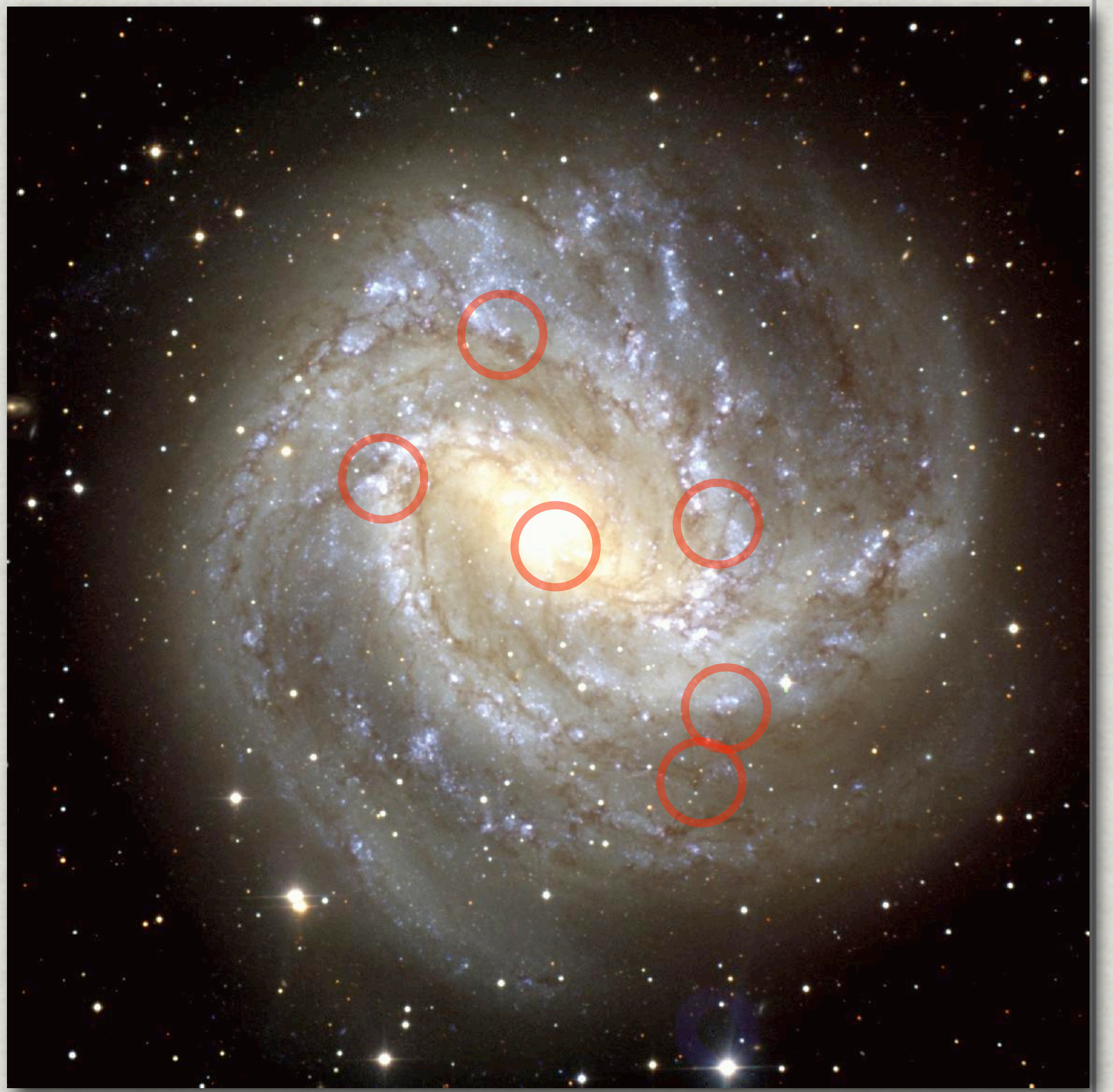
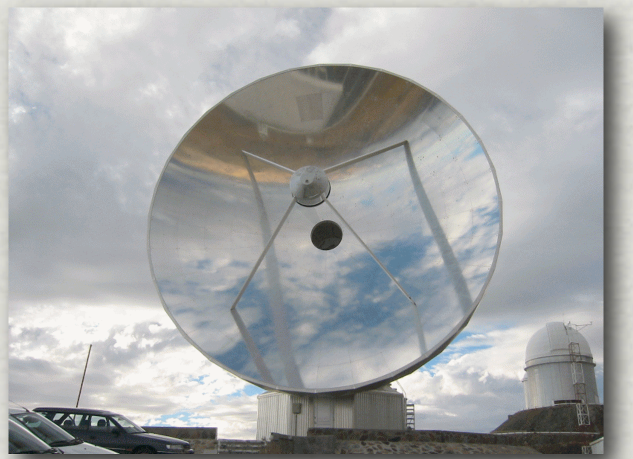


Observations - Radio



- 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

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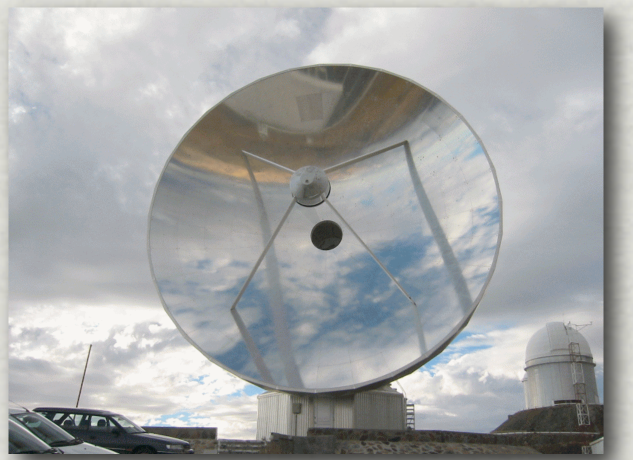

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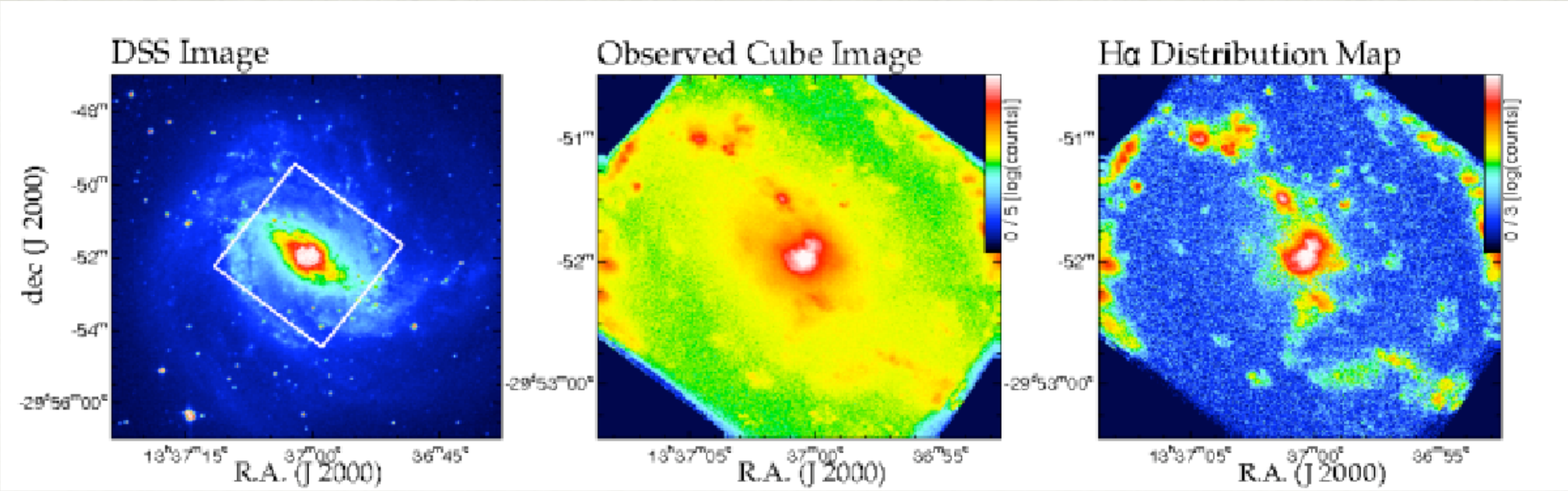


Results CO: iso-velocity curves

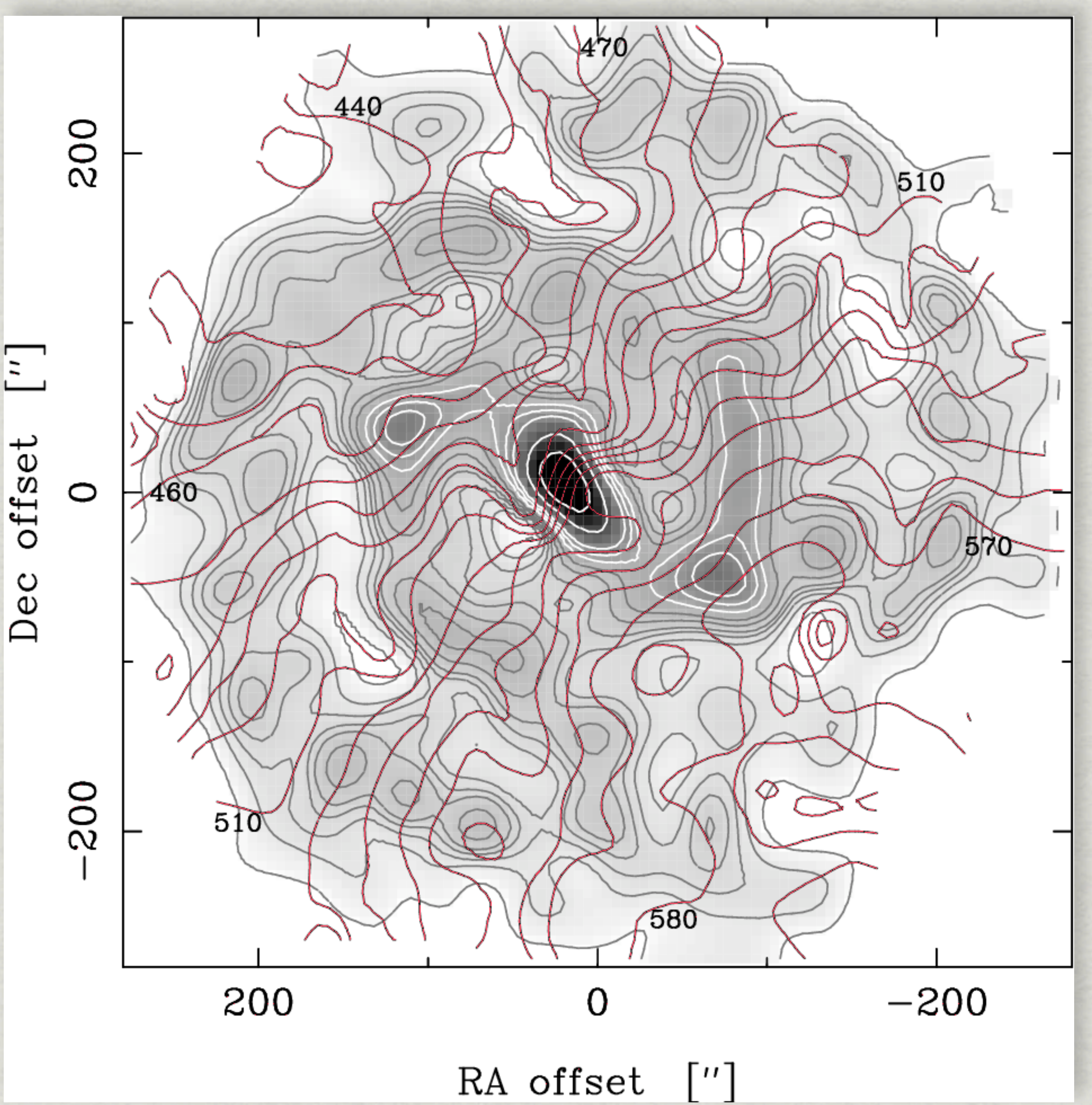
Iso-velocity curves CO(1-0)

Contour increment 10 km s^{-1}

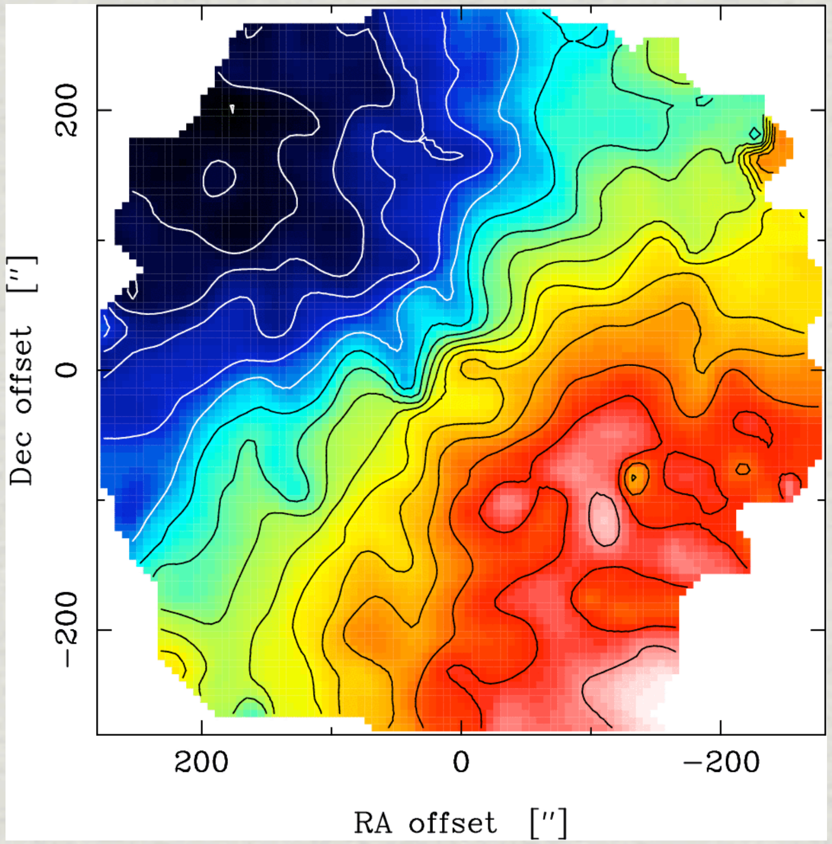
Pattern of rotating disk

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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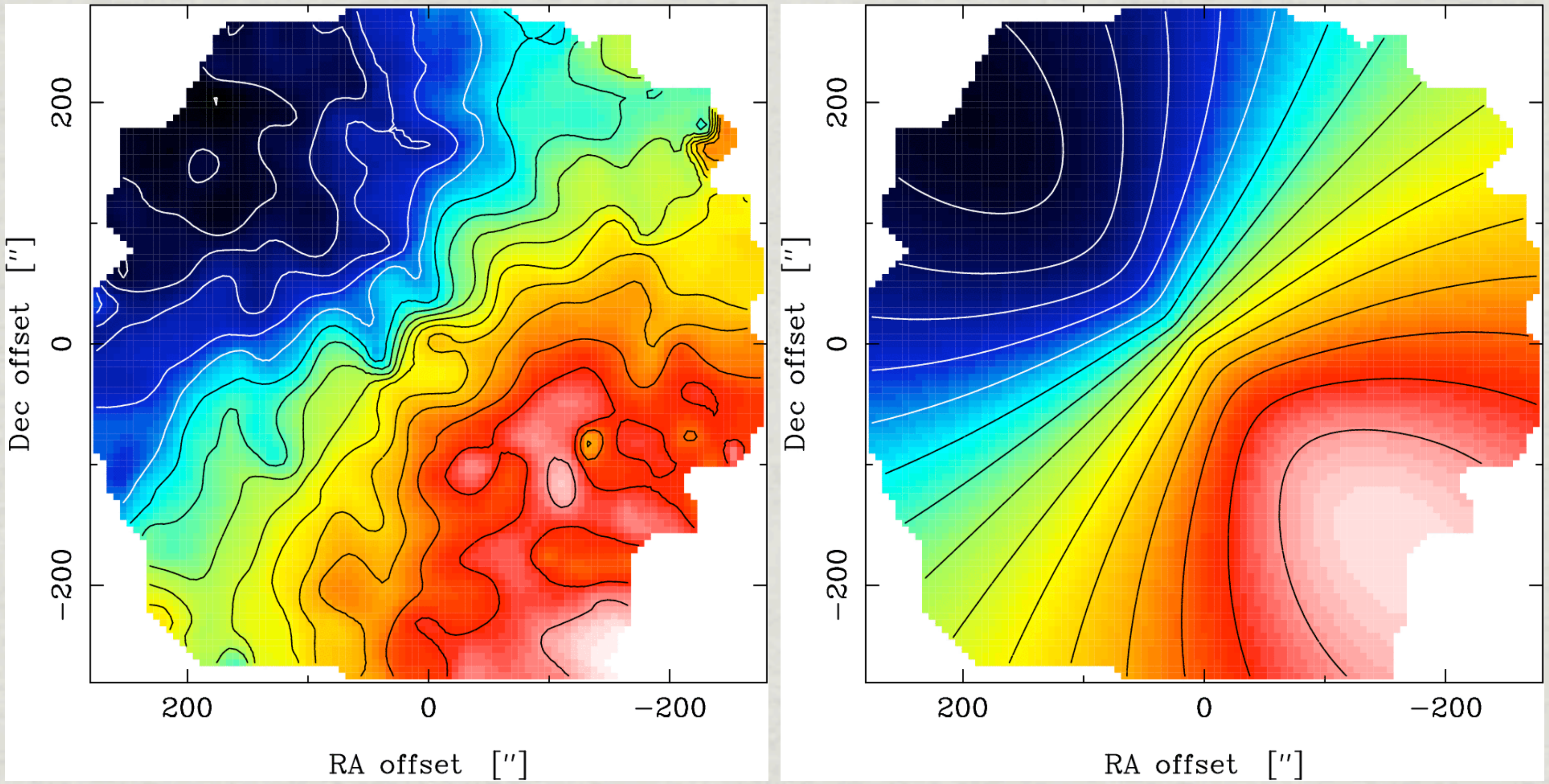

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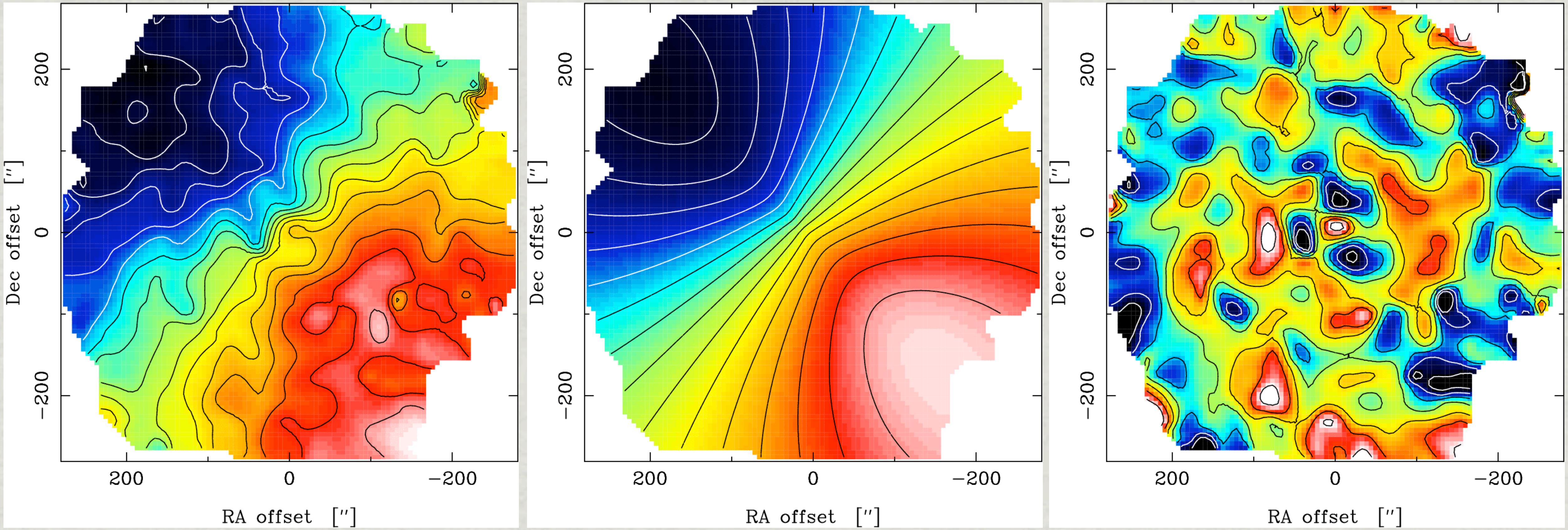

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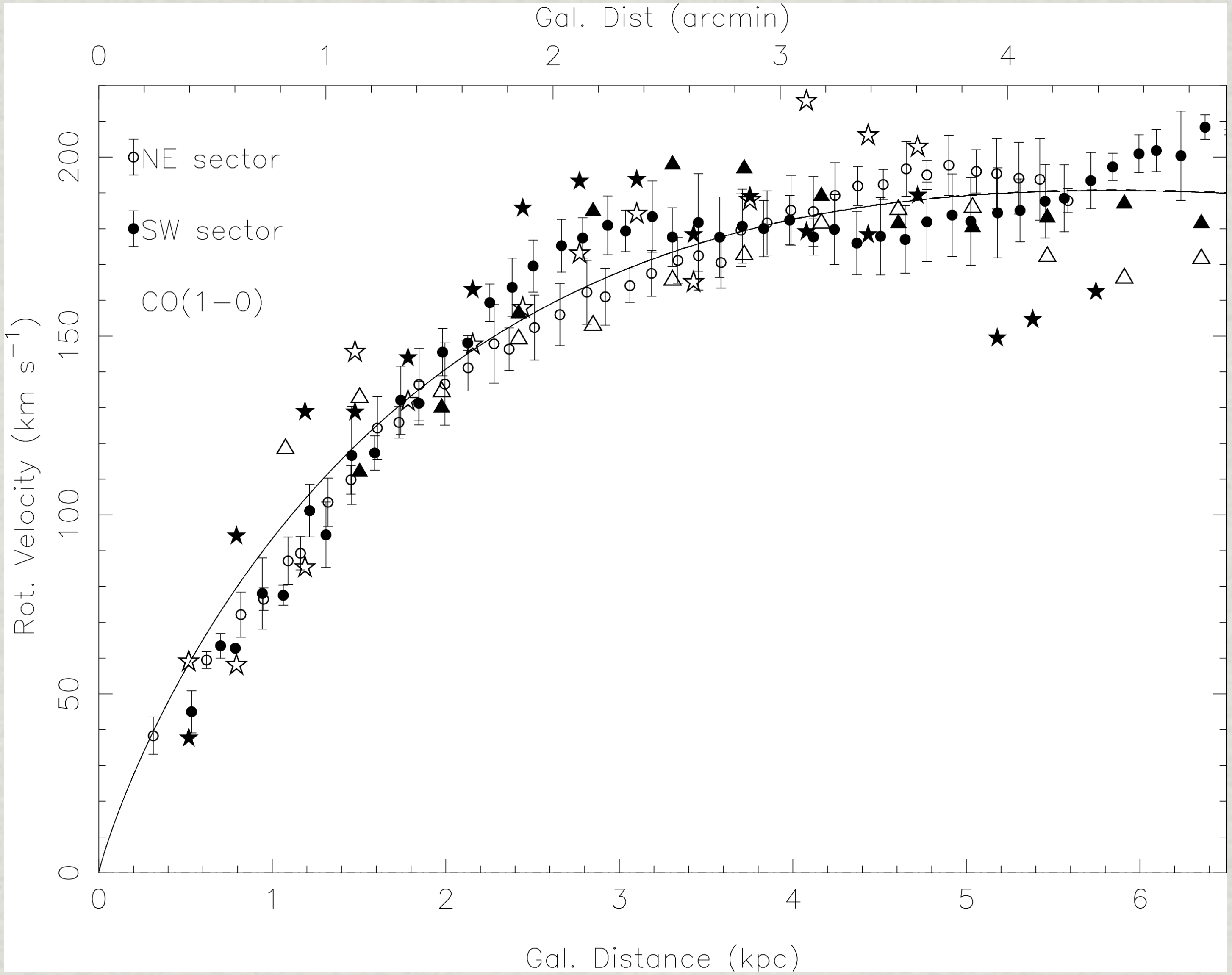

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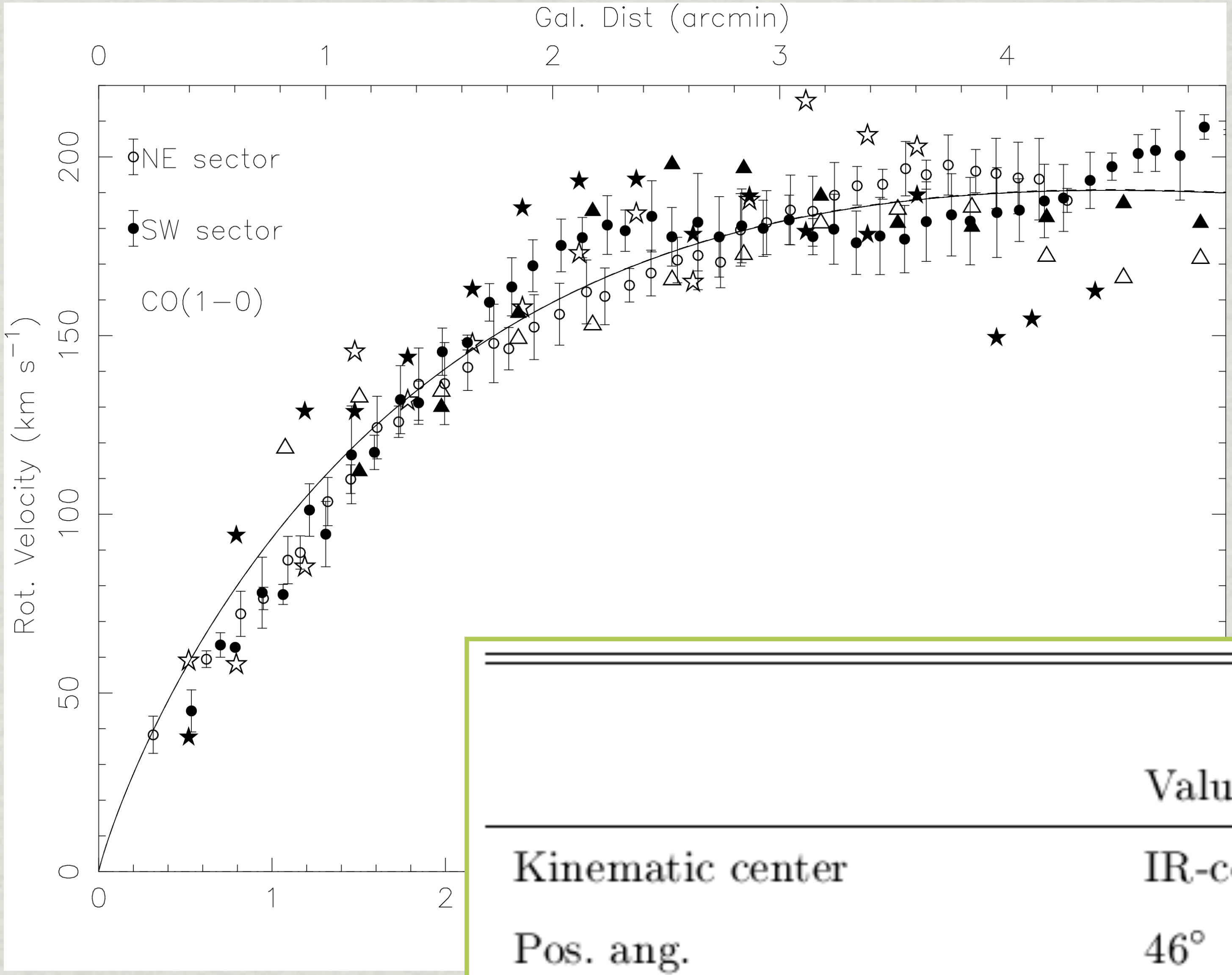

	CO(J=1-0)		CO(J=2-1)	
	Value	Error (1σ)	Value	Error (1σ)
Kinematic center	IR-center	fixed	IR-center	fixed
Pos. ang.	46°	5°	46°	5°
inclination	24°	fixed	24°	fixed
Systemic vel. (LSR) [km s^{-1}]	511.8	0.6	511.5	0.7
Disk Mass [10^9 $M_\odot$]	59	7	62	8
Disk scale length [kpc]	2.7	0.2	2.9	0.2

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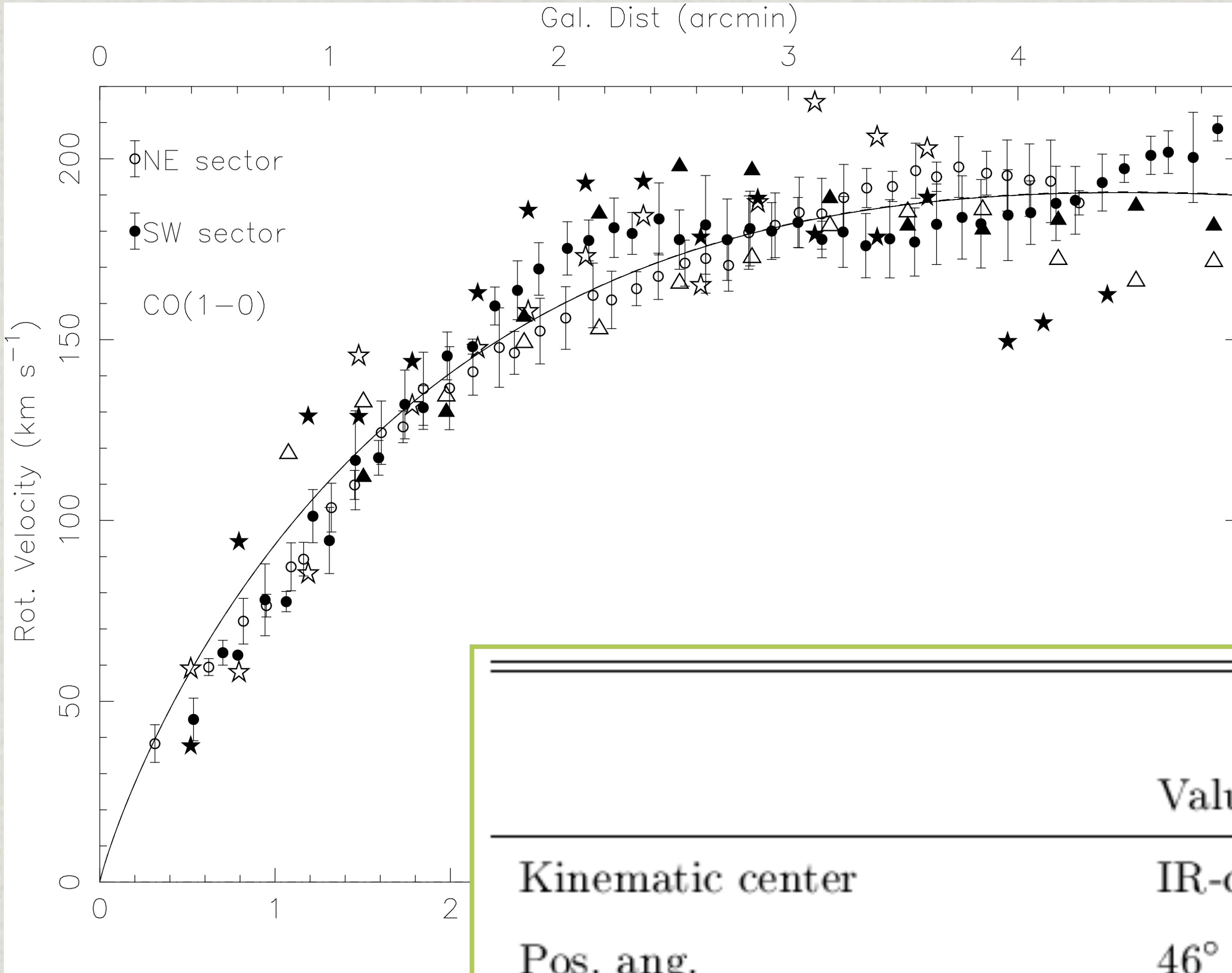

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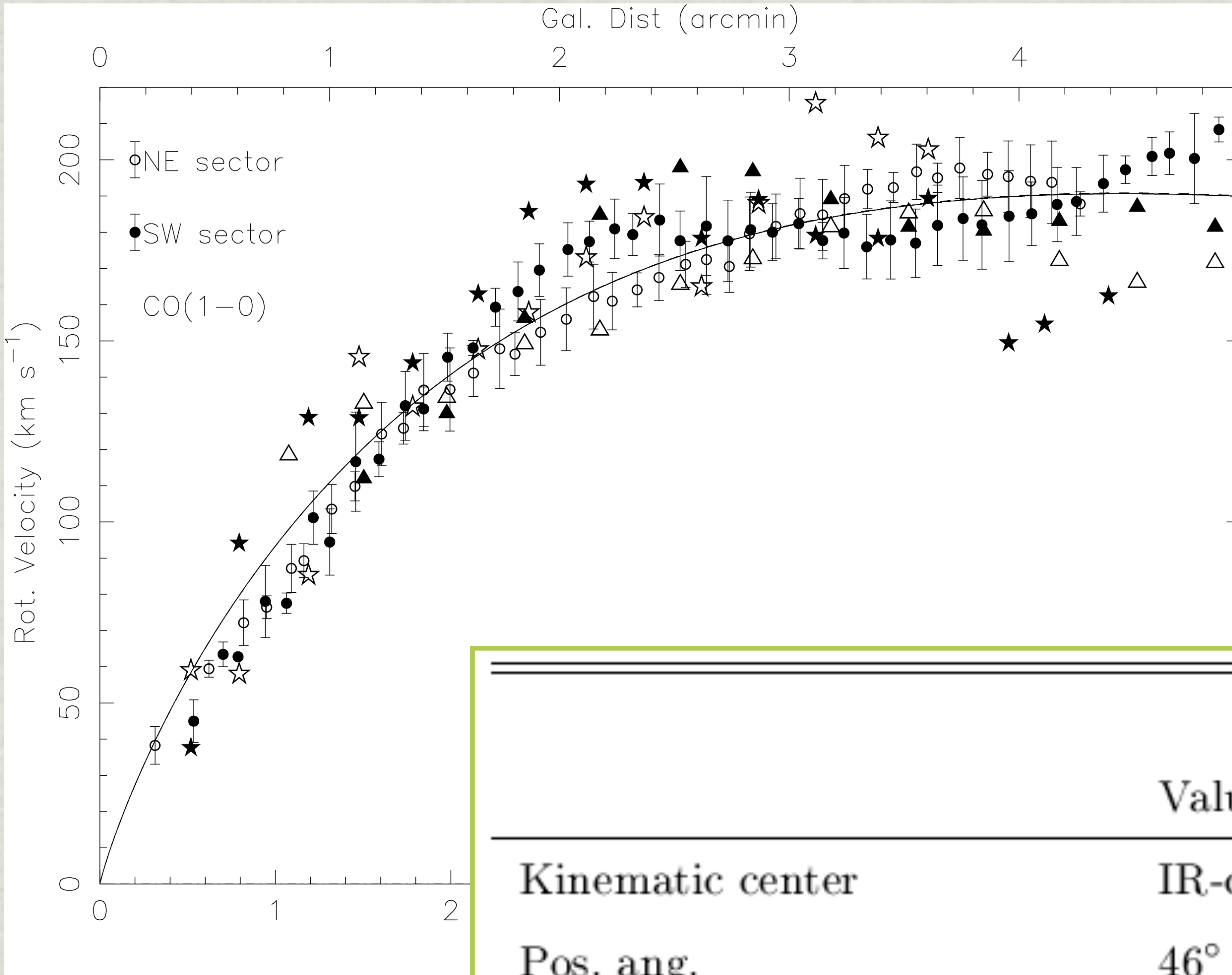

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Scale length of the kinematic fit similar to that of the CO distribution fit (2.3 kpc)

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Results CO: angular velocity

Corotation

$$\Omega = \Omega_p$$

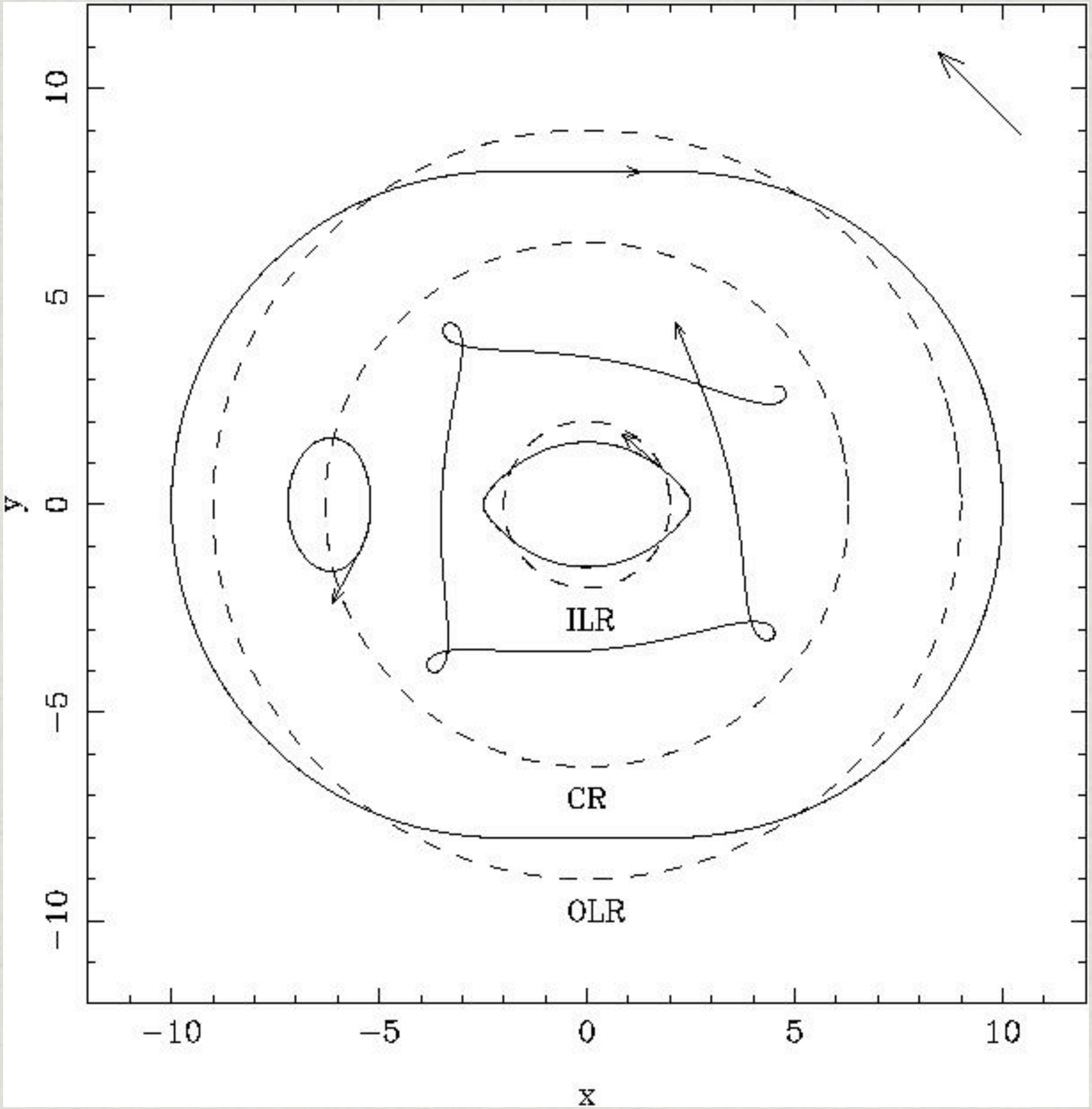
Resonances

$$nm(\Omega - \Omega_p) = \pm\kappa$$

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
<u>50±9 km s^{-1} kpc^{-1}</u>

(Zimmer et al. ApJ 607 2004)



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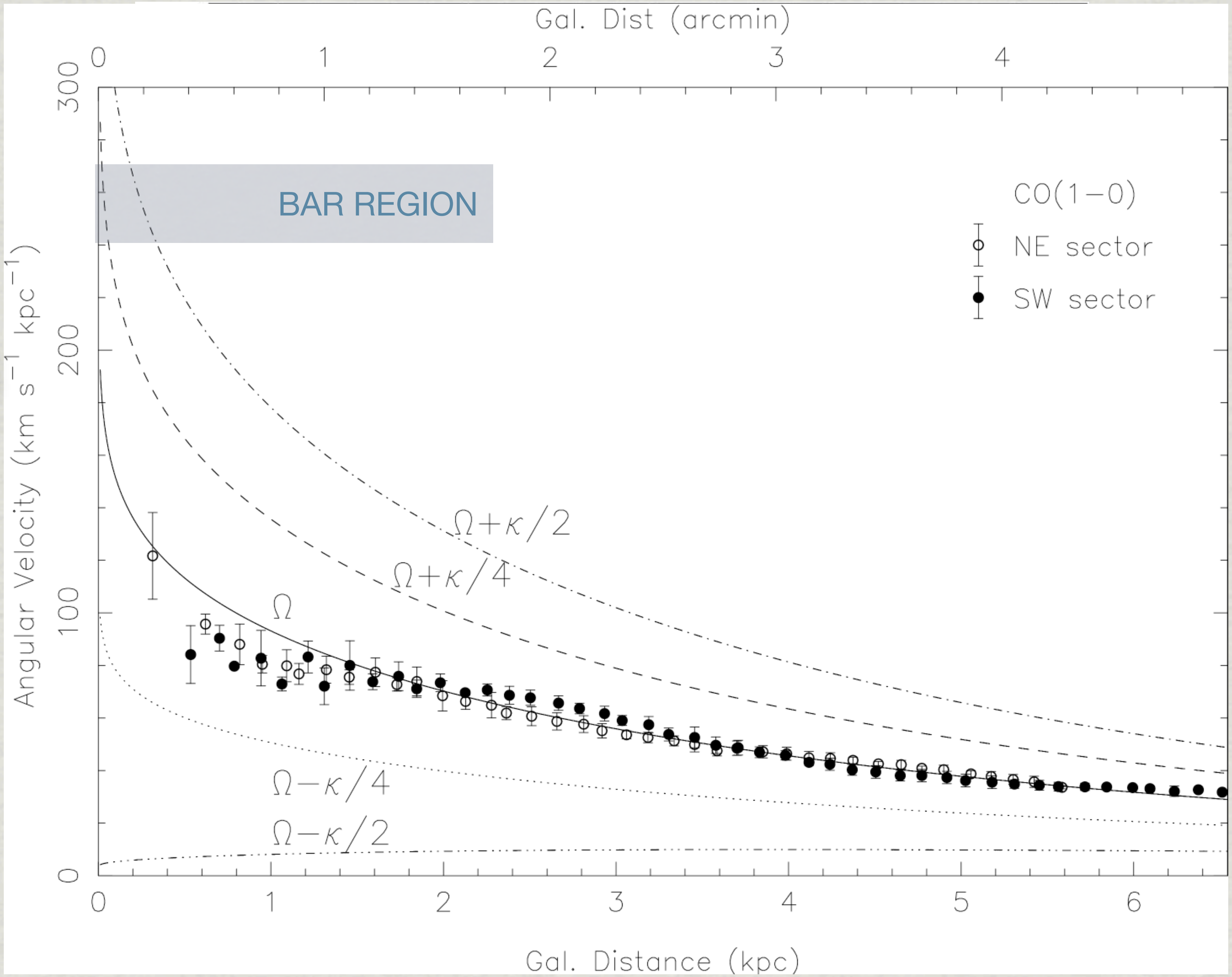

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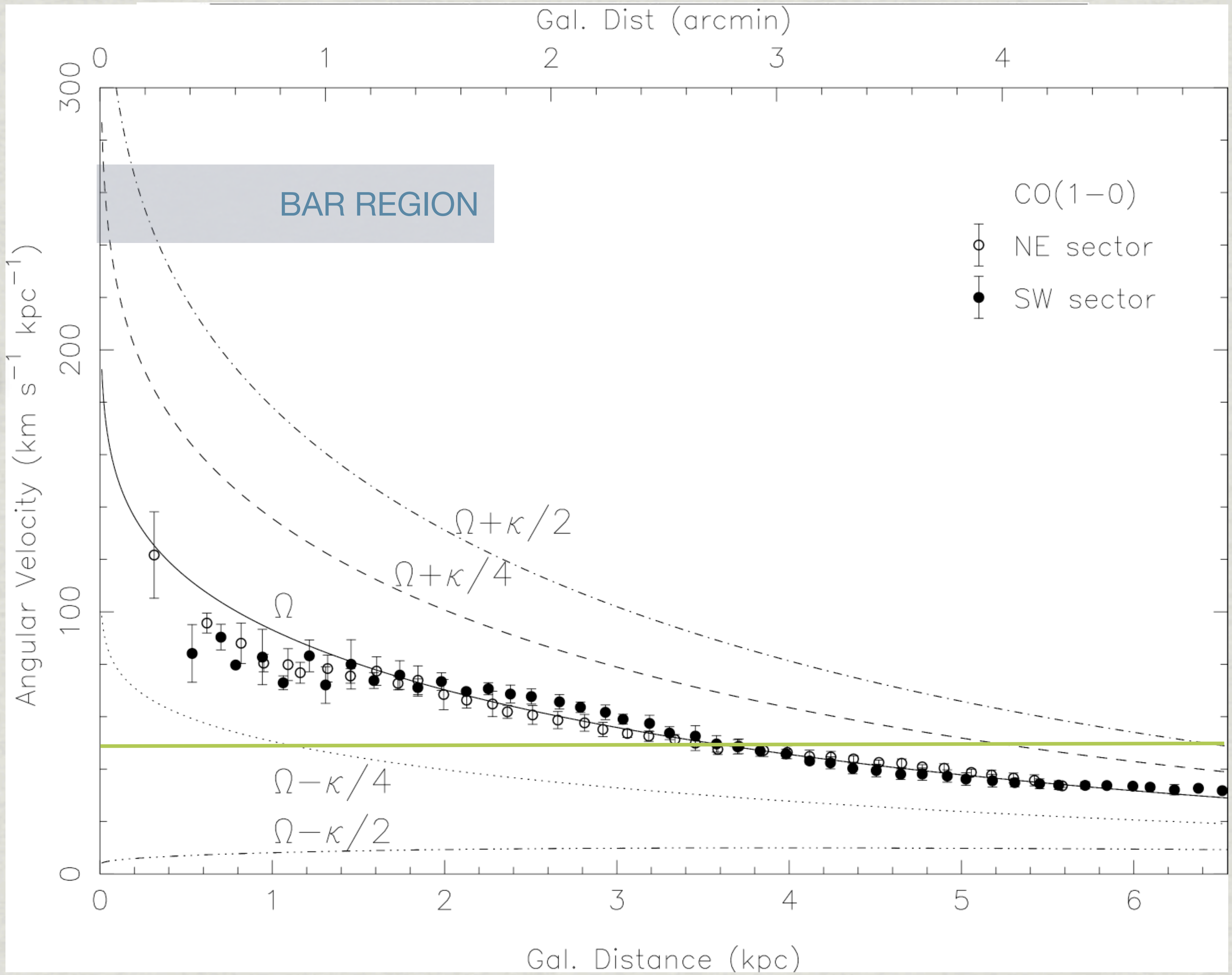

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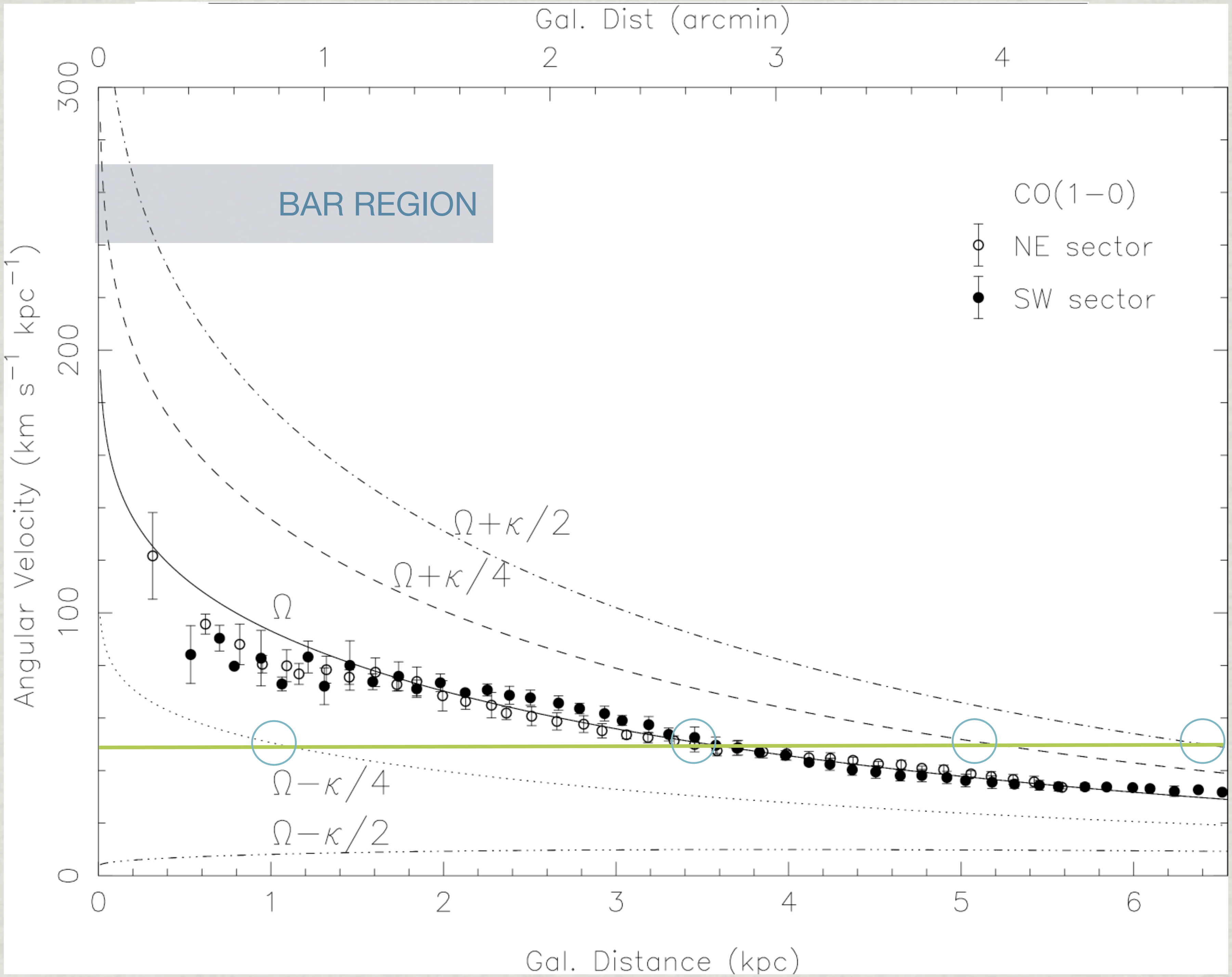

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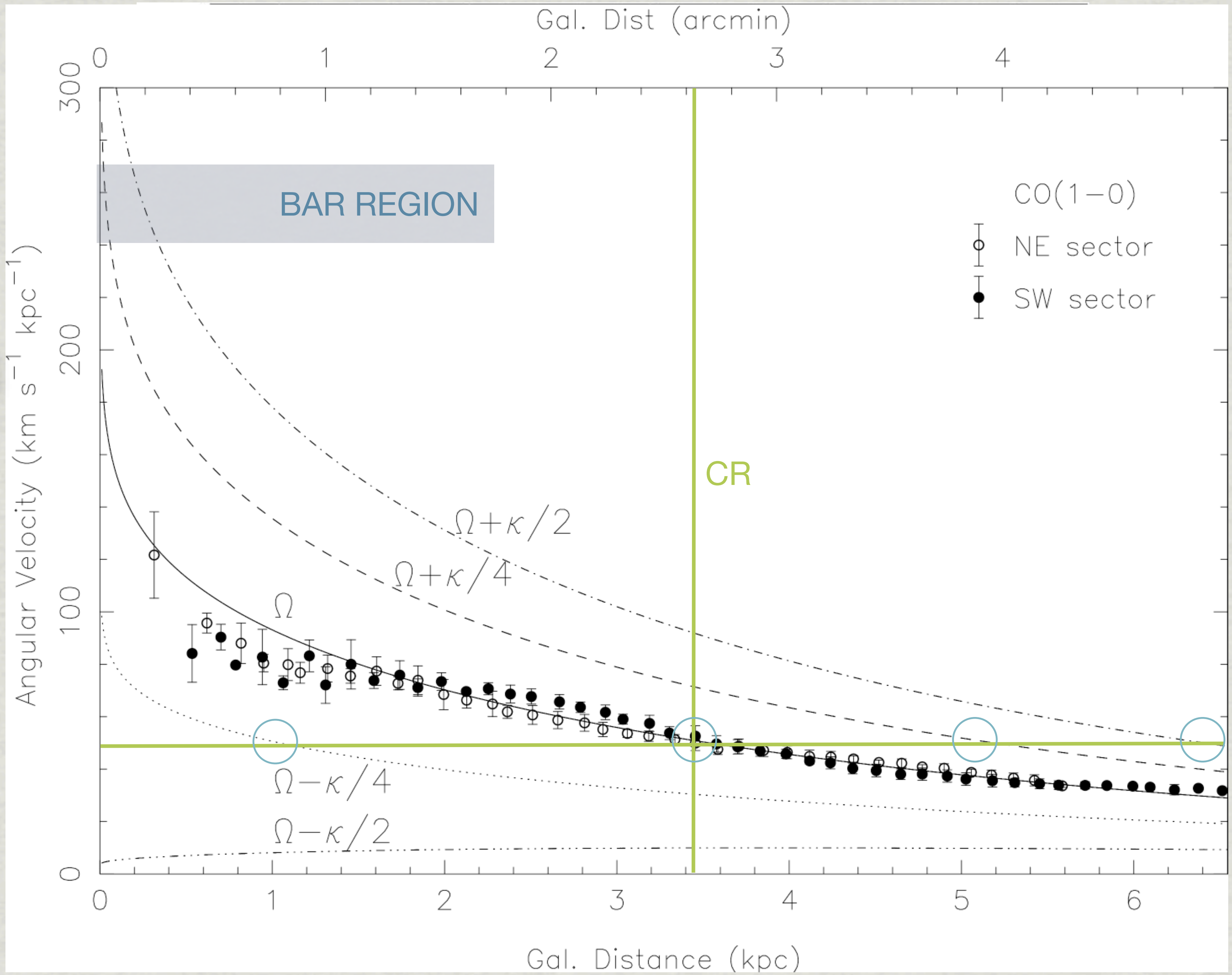

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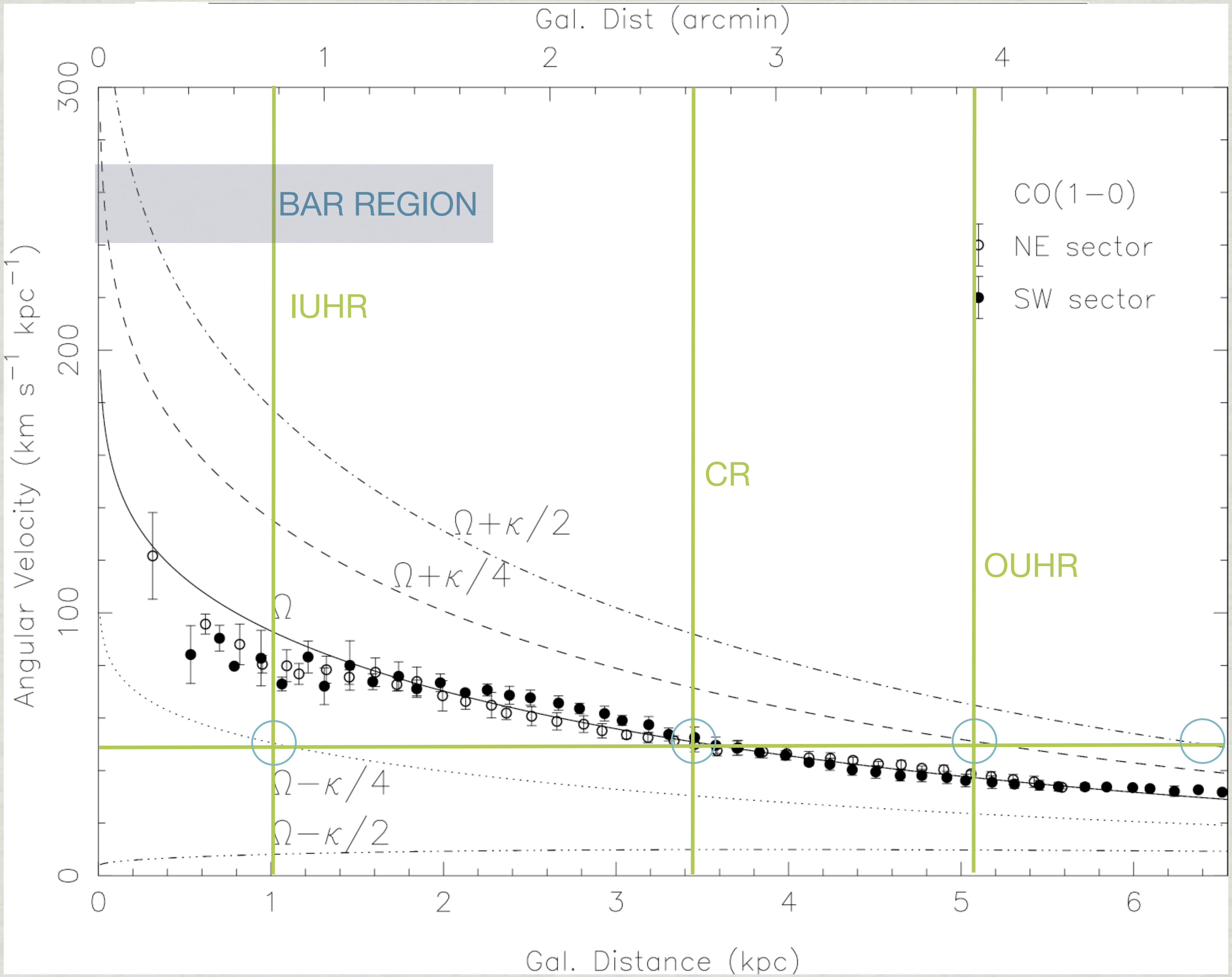

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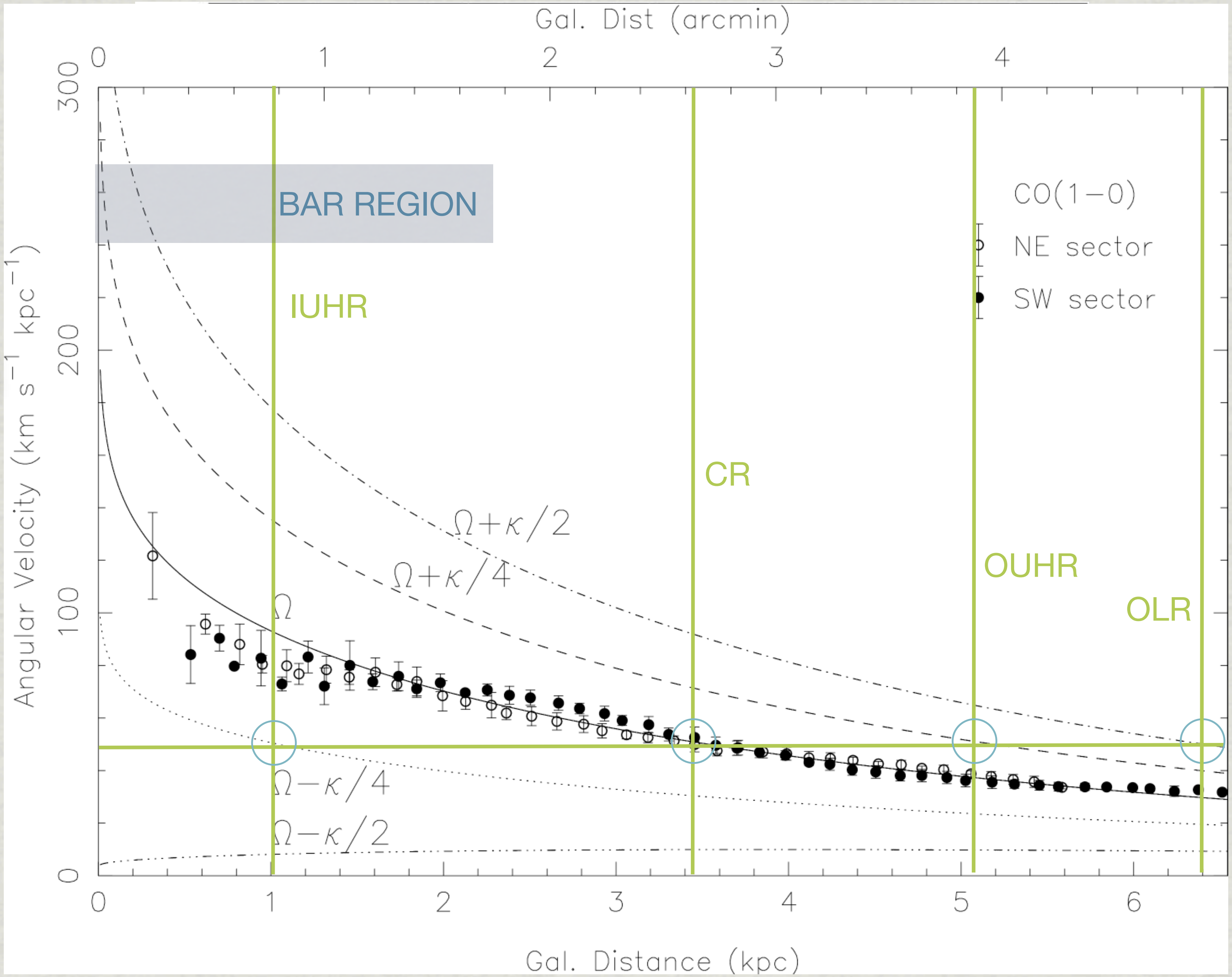

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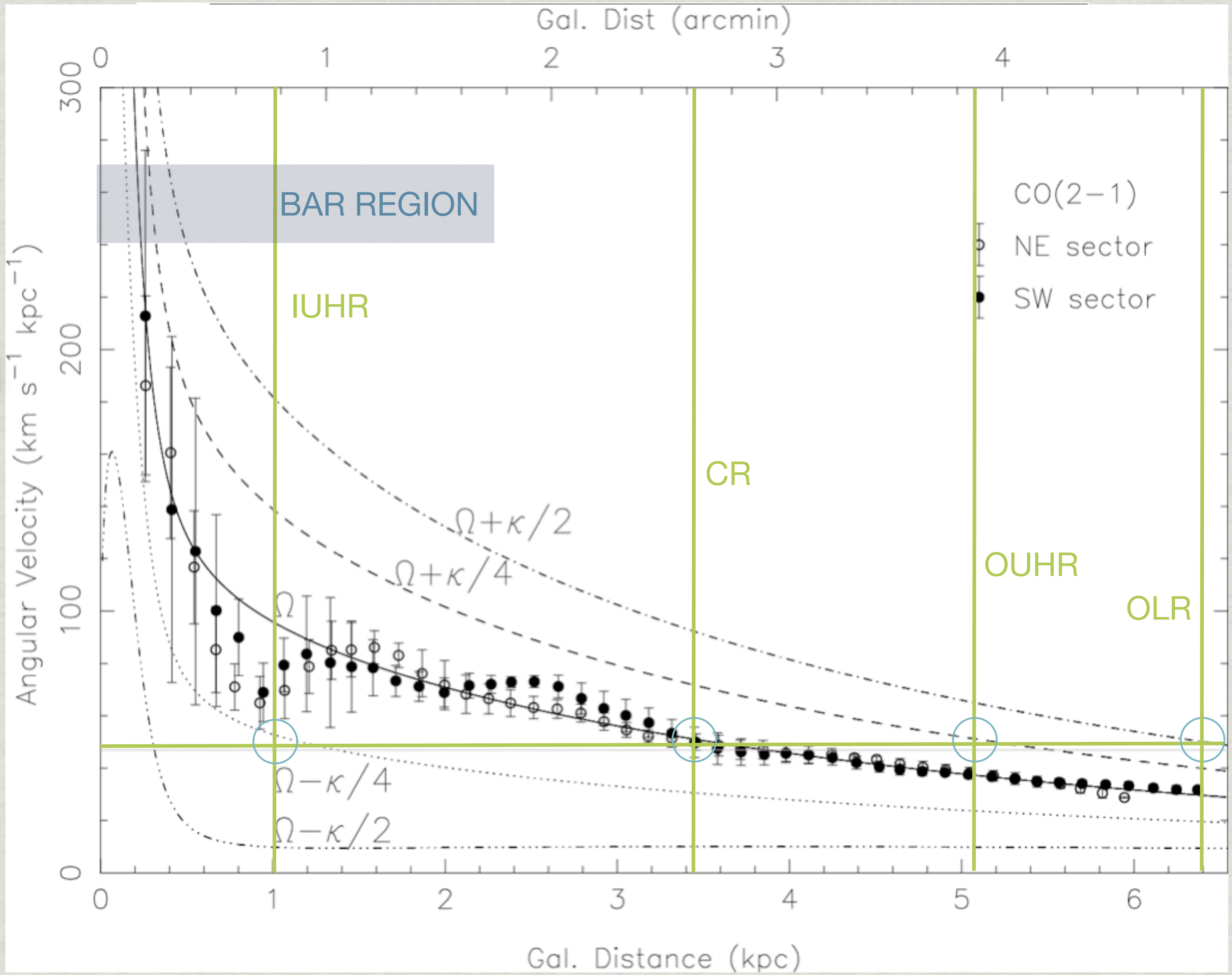

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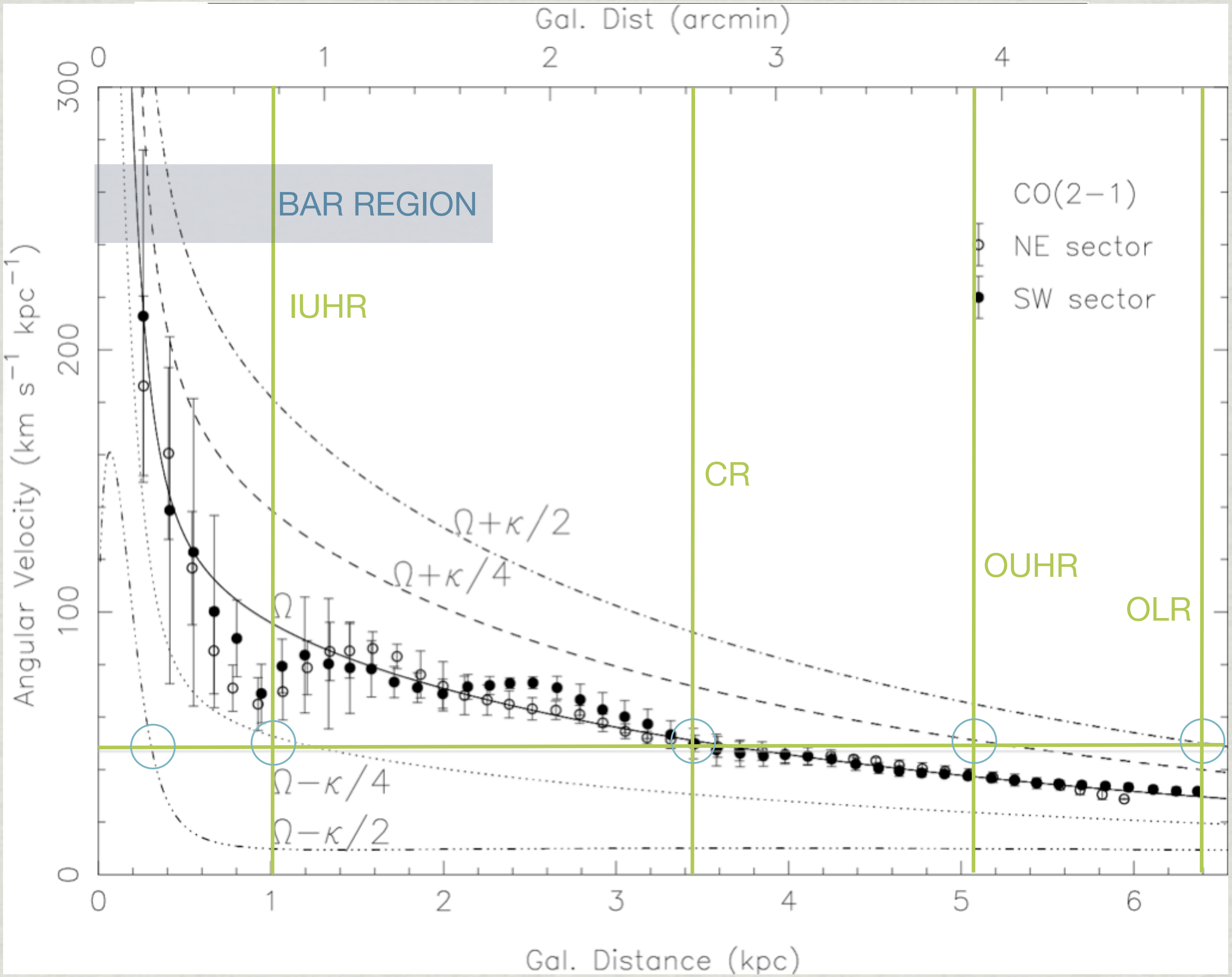

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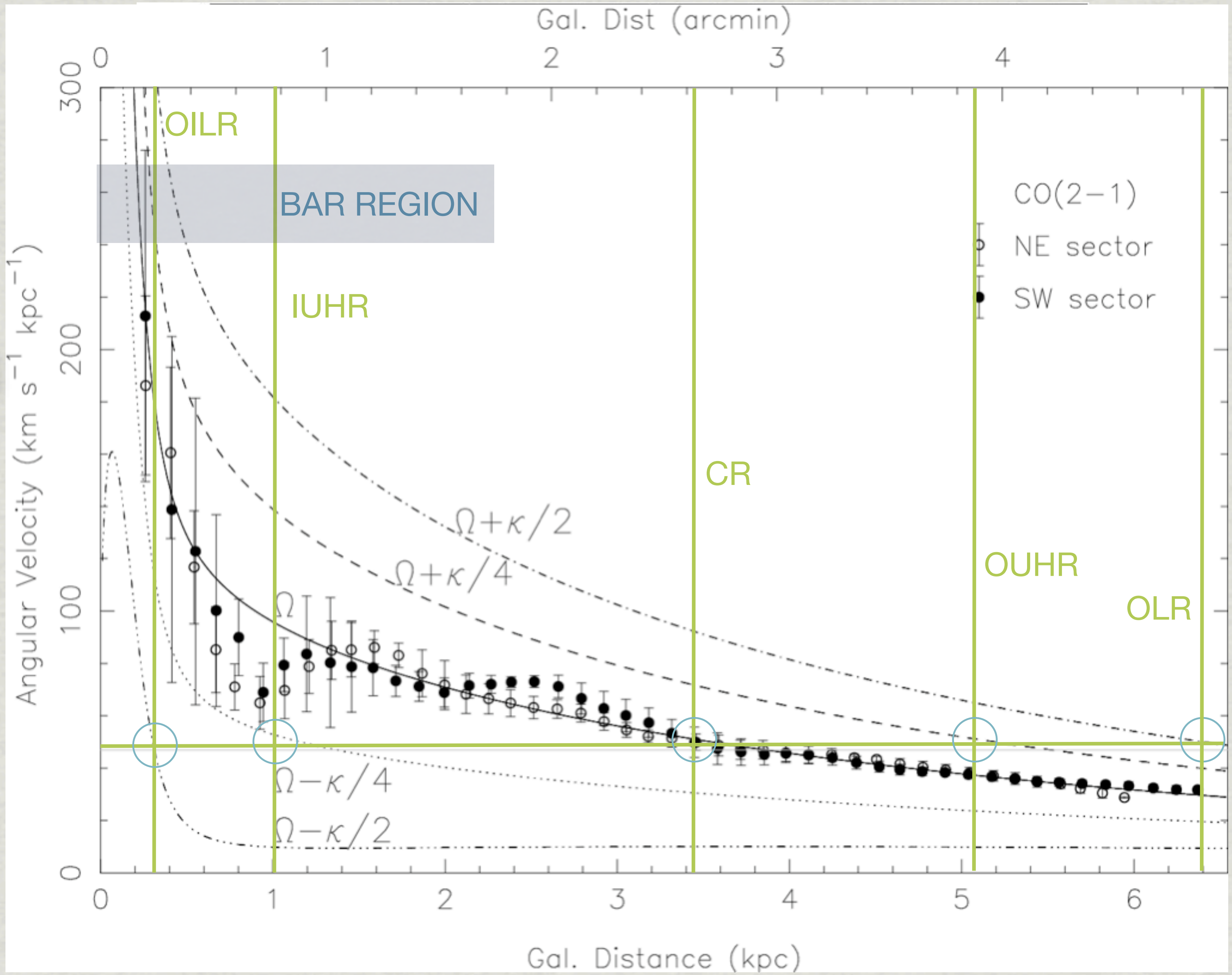

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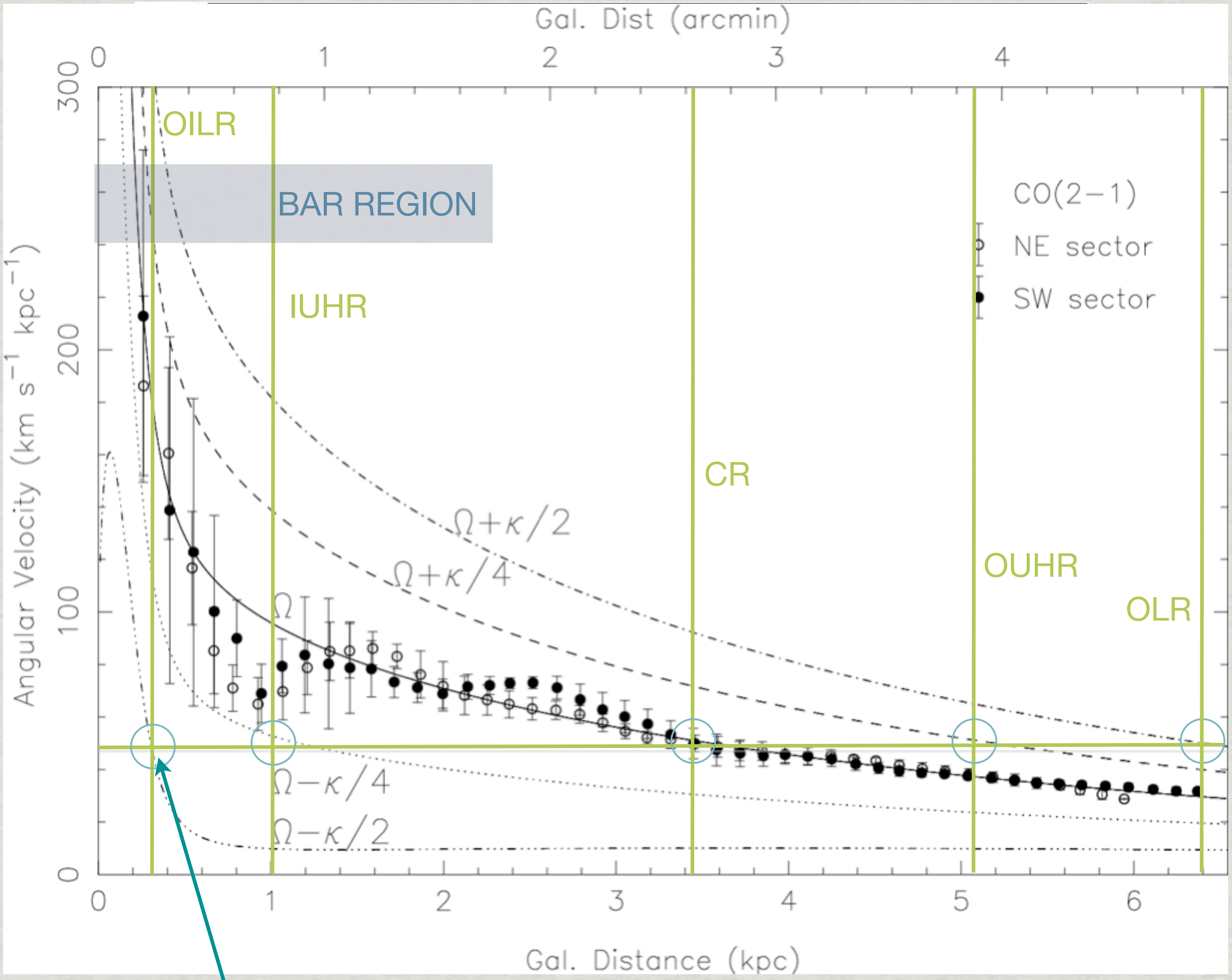

Nuclear disk:
- Mass: 3x10[8] $M_\odot$
- Scale length 50pc

Results CO: Disk stability

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

$$\Sigma_{\rm cr} = \alpha \frac{\sigma_{\rm gas}\kappa}{\pi G}$$

Where the epicyclic frequency is given by

$$\kappa^2 = \left(R\frac{d\Omega^2}{dR} + 4\Omega^2\right)_{R_{\rm g}} \ [{\rm km\,s^{-1}\,kpc^{-1}}]^2$$

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

$$\lambda = 2.2\left(\frac{\sigma_{\rm gas}}{7\ {\rm km\ s^{-1}}}\right)^2\left(\frac{\Sigma_{\rm gas}}{20\ {\rm M_\odot\ pc^{-2}}}\right)^{-1} \ [{\rm kpc}]$$

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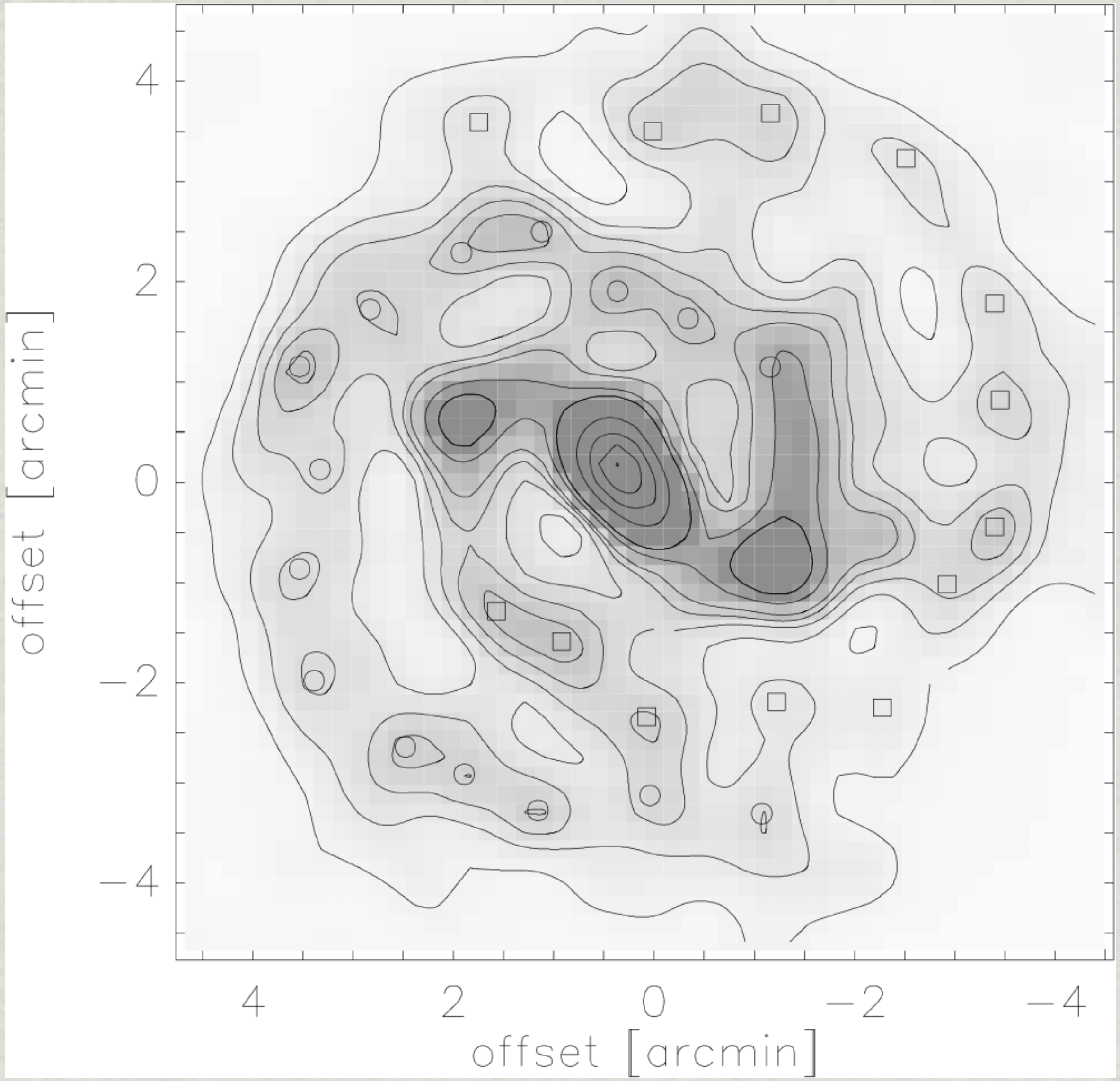

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Distance between the Galactic Molecular Associations (GMAs) can be used to independently derive the velocity dispersion of the interstellar gas

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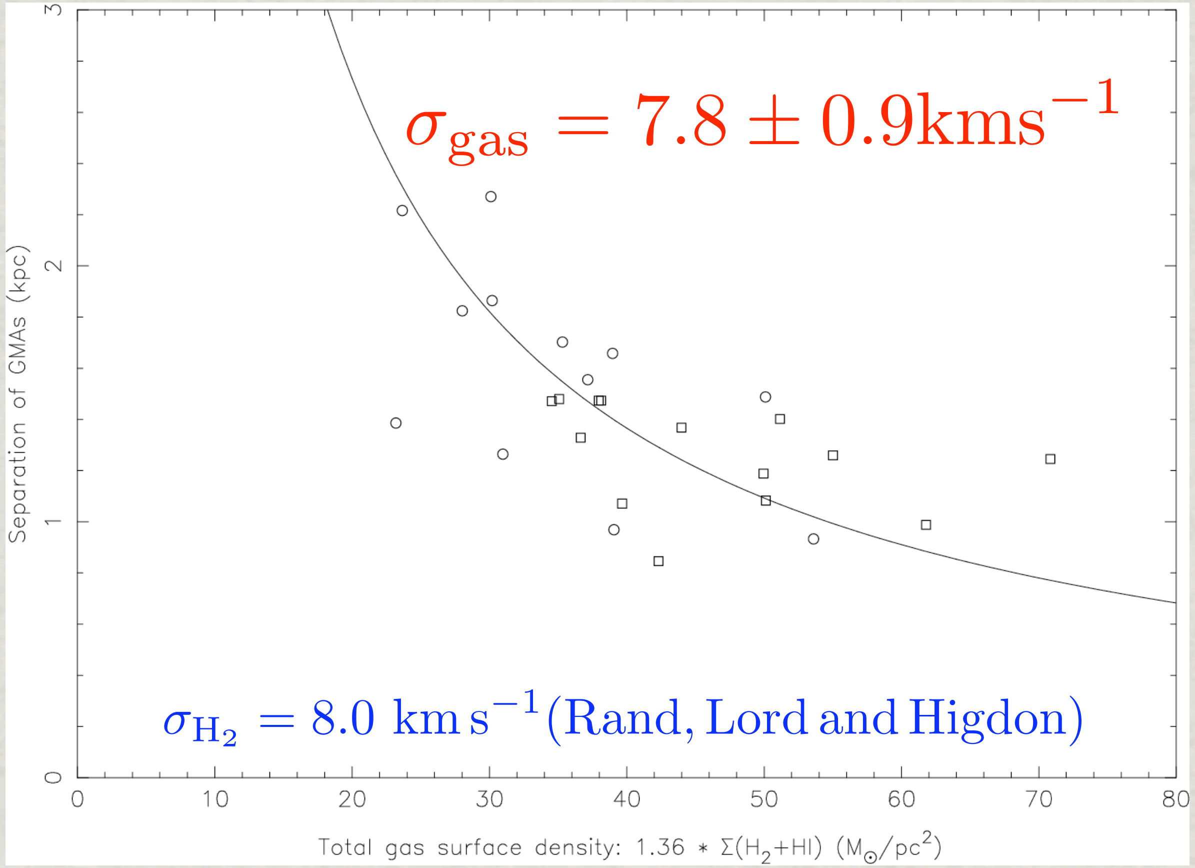

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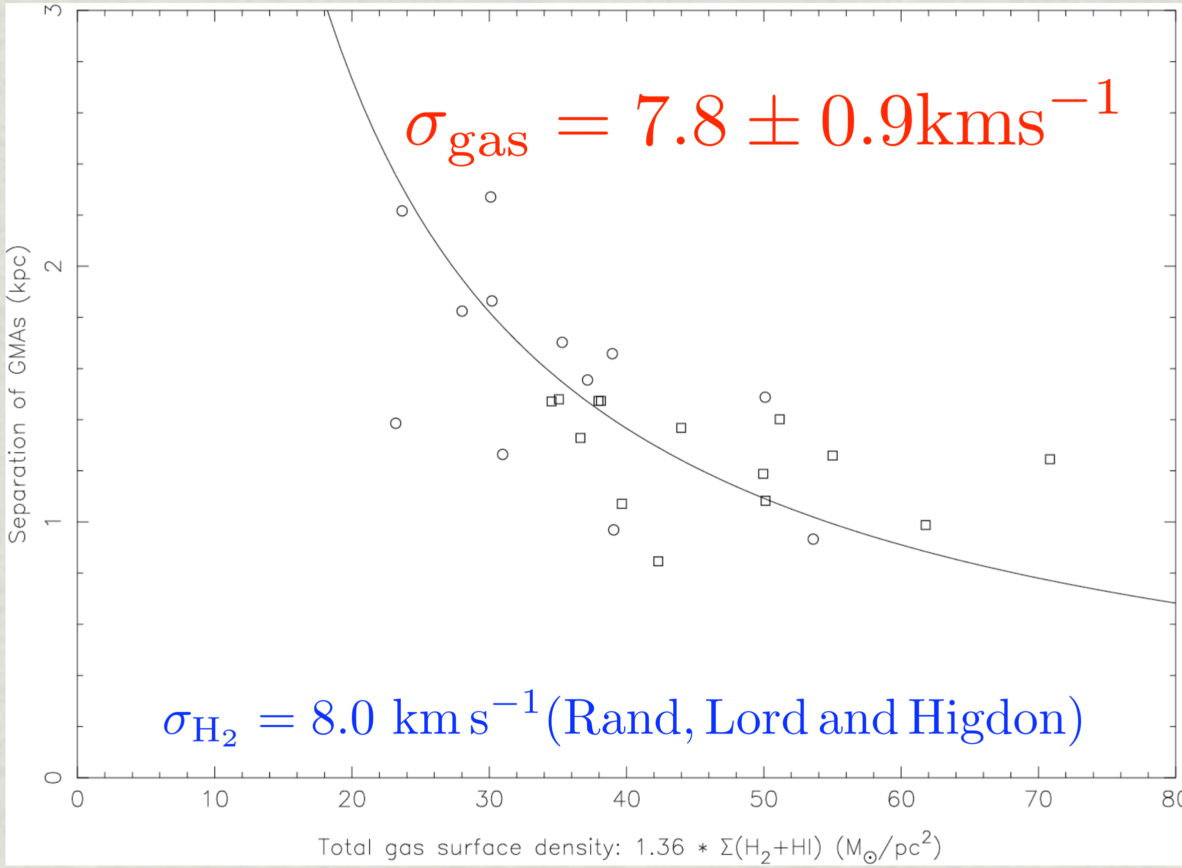

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The derived velocity dispersion is consistent with the ones observed in H2 and HI

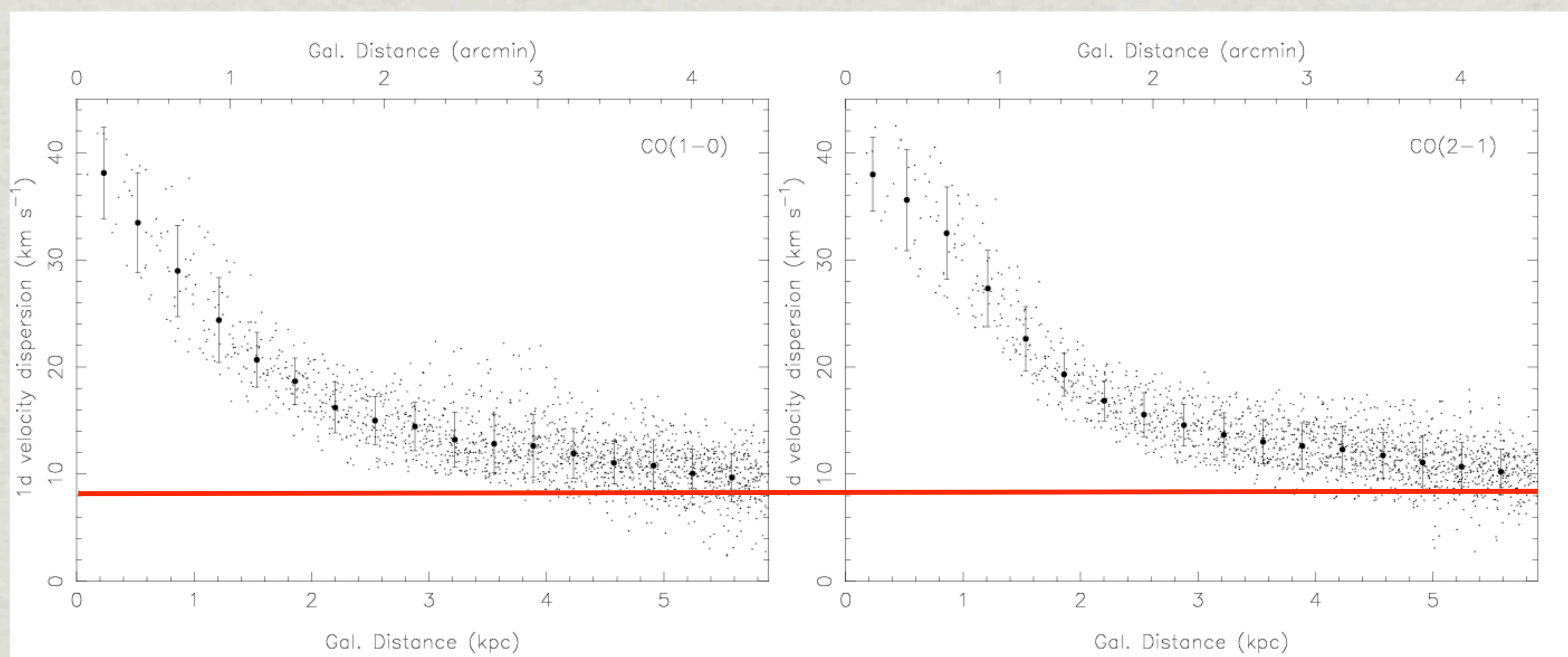


Fig. 10. Velocity dispersion in the CO(J=1–0) and CO(J=2–1) data sets, at a common spatial resolution of 49″, as a function of the galactocentric distance.

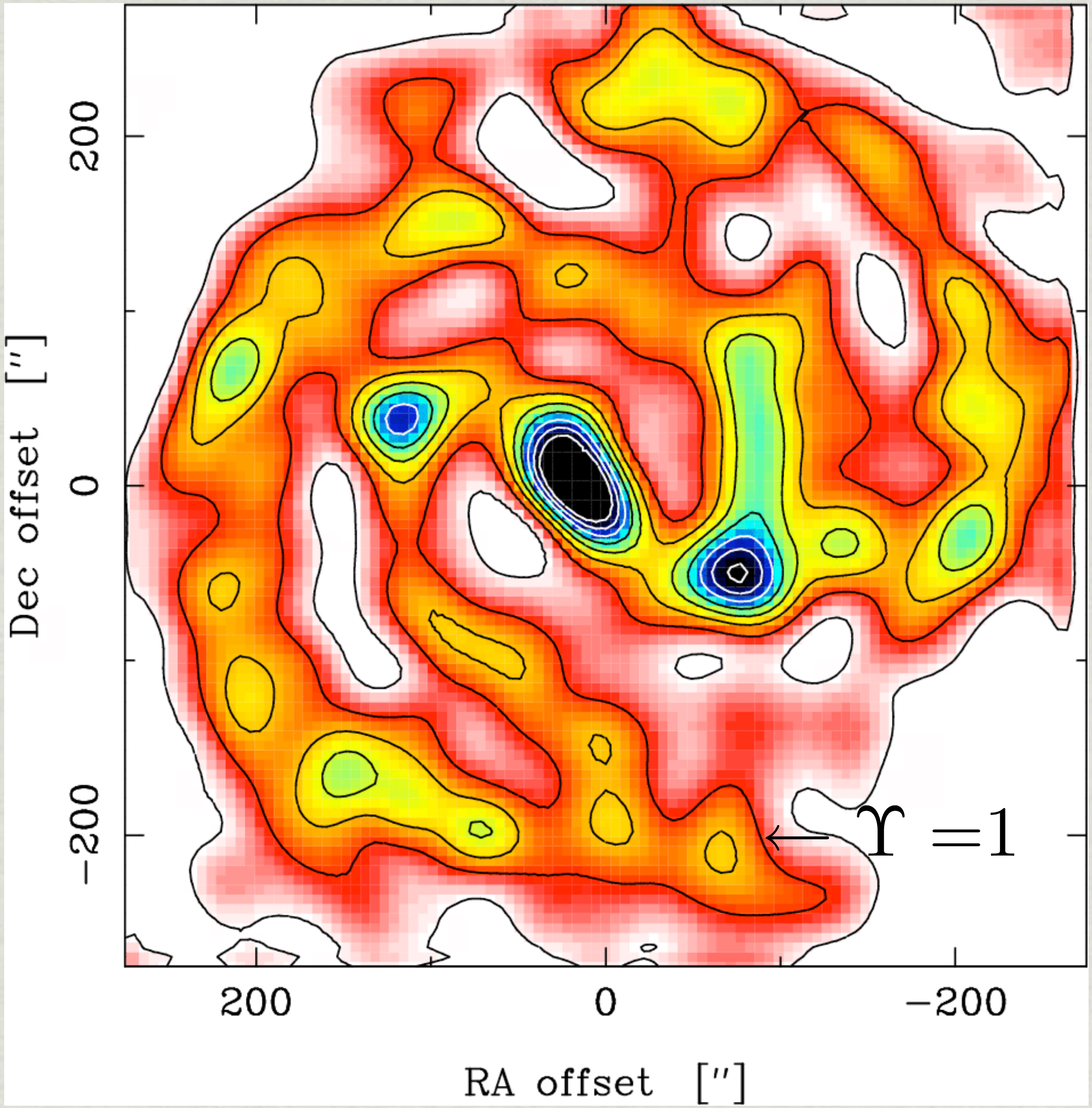
Results CO: Disk stability

The ratio of the mass surface density of the gas divided by the critical critical value:

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

$$\Sigma_{\rm cr} = \alpha \frac{\sigma_{\rm gas}\kappa}{\pi G}$$

$$\Sigma_{\rm gas} = \Sigma_{\rm H_2} + \Sigma_{\rm HI} + \Sigma_{\rm He}$$



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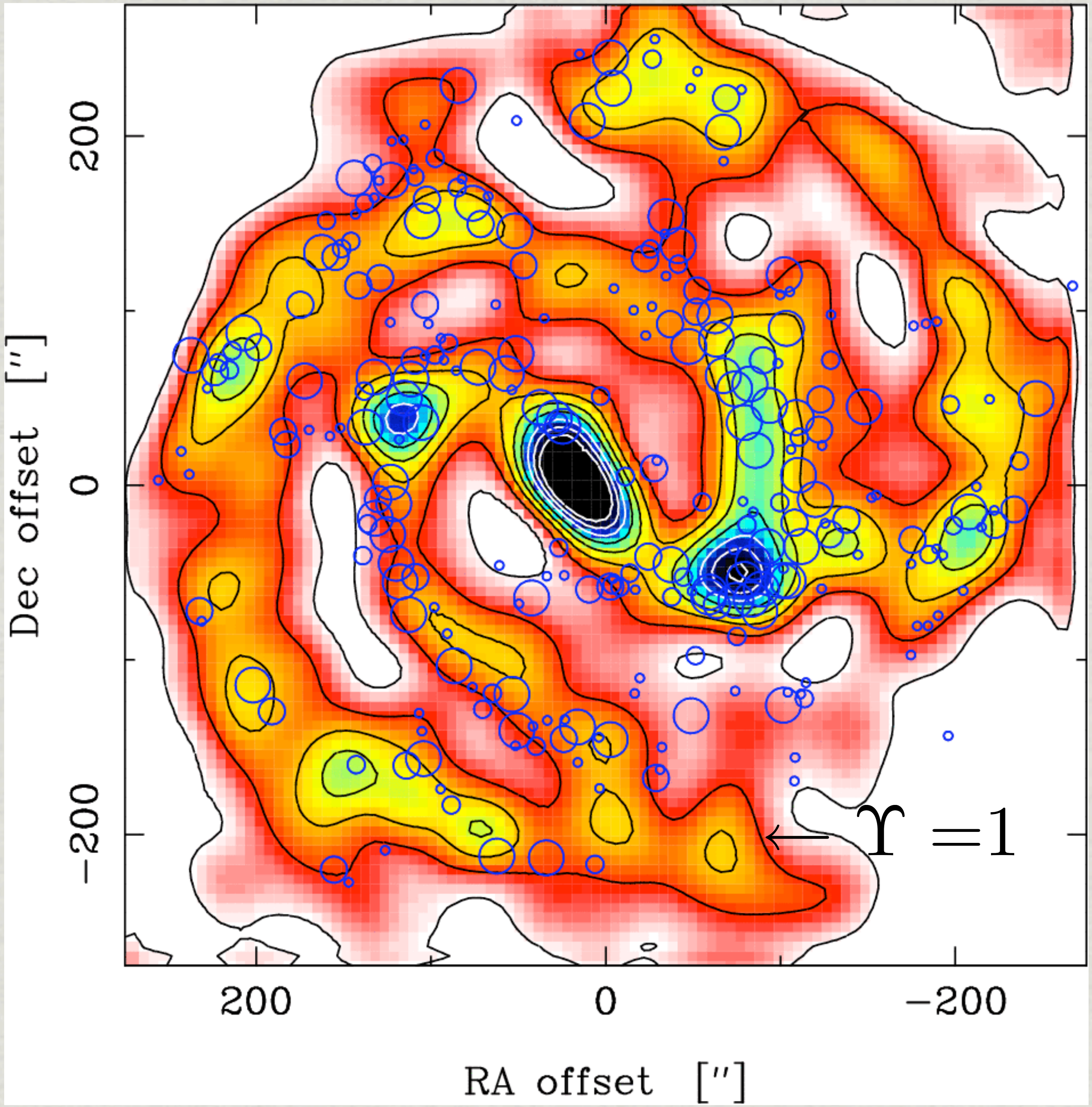
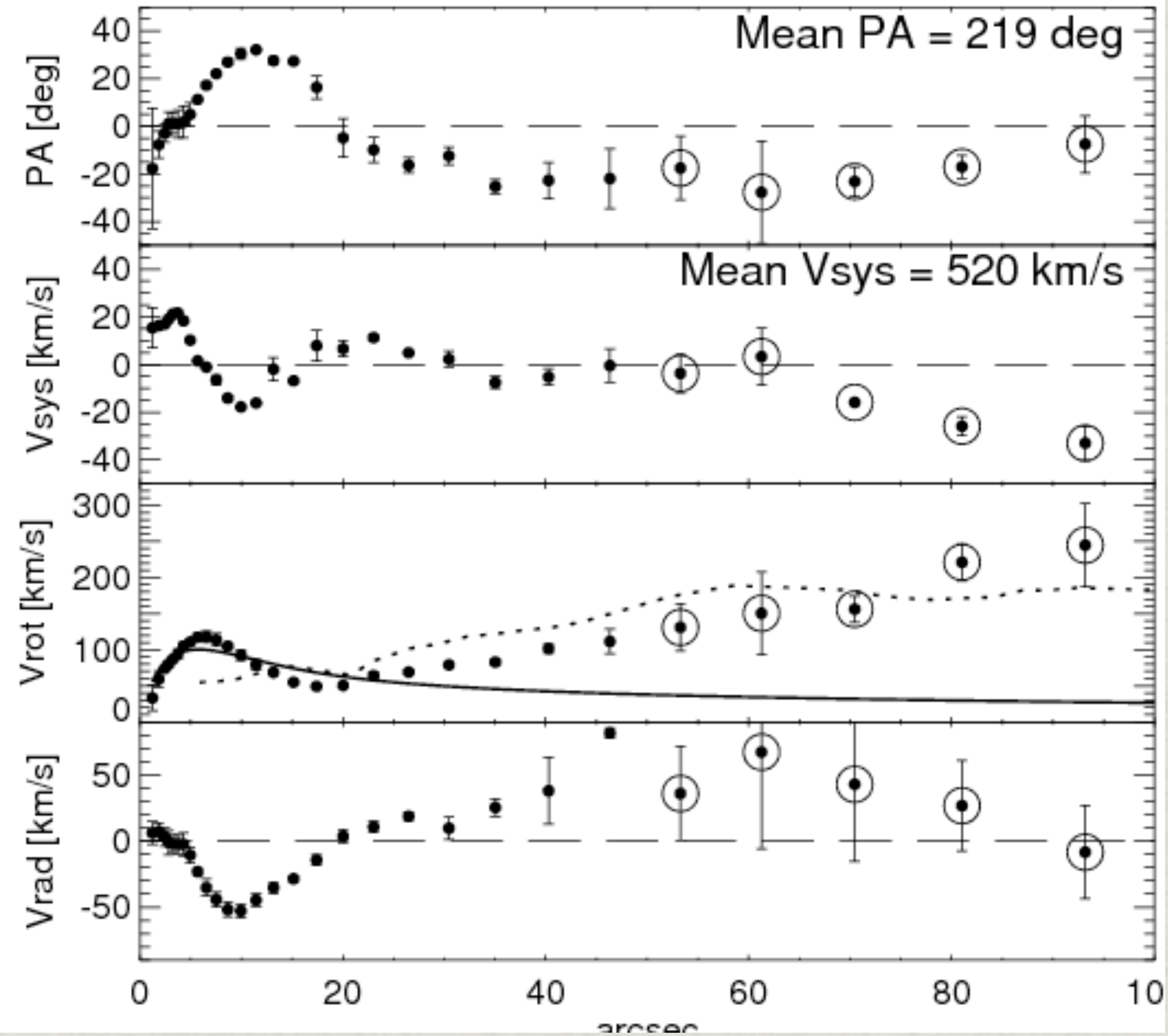


Correlates with the location of the HII regions in M83

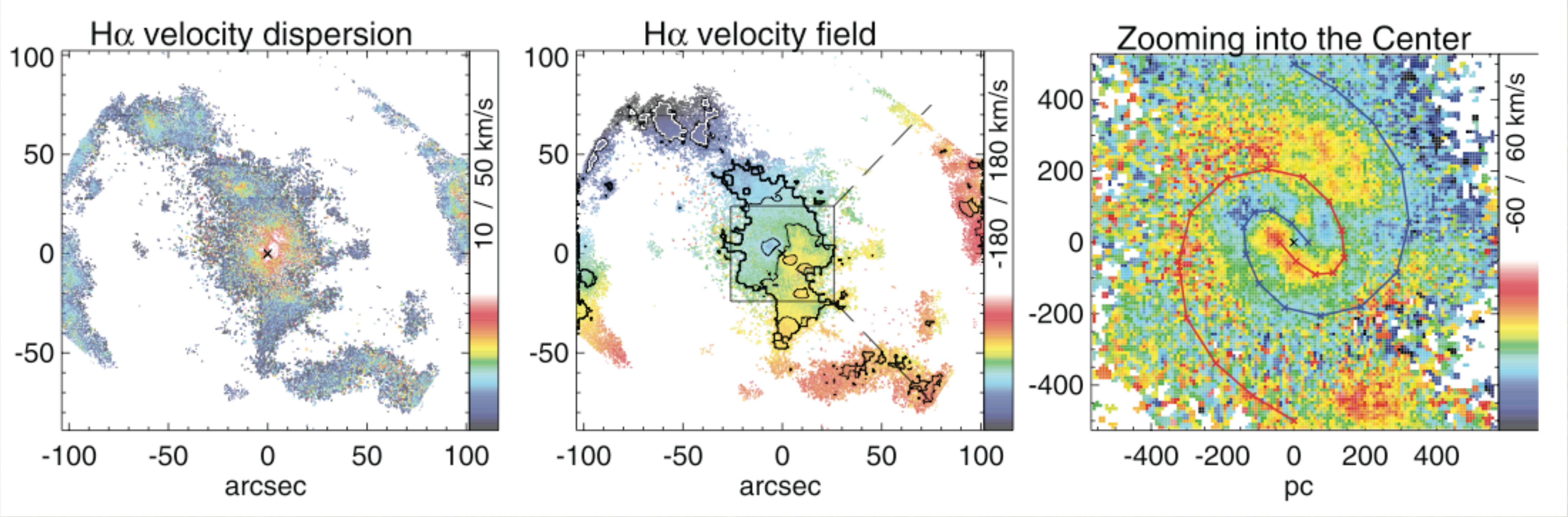
(HII region data from Rumstay & Kaufmann ApJ 1983)

Results Hα: The model

- Tilted ring decomposition combined with harmonic decomposition formalism (Shoenmakers et al. 1997, Fathi et al. 2005, Krajnovic et al. 2006)
- We derive kinematical properties that are consistent with the the ones seen in the CO data



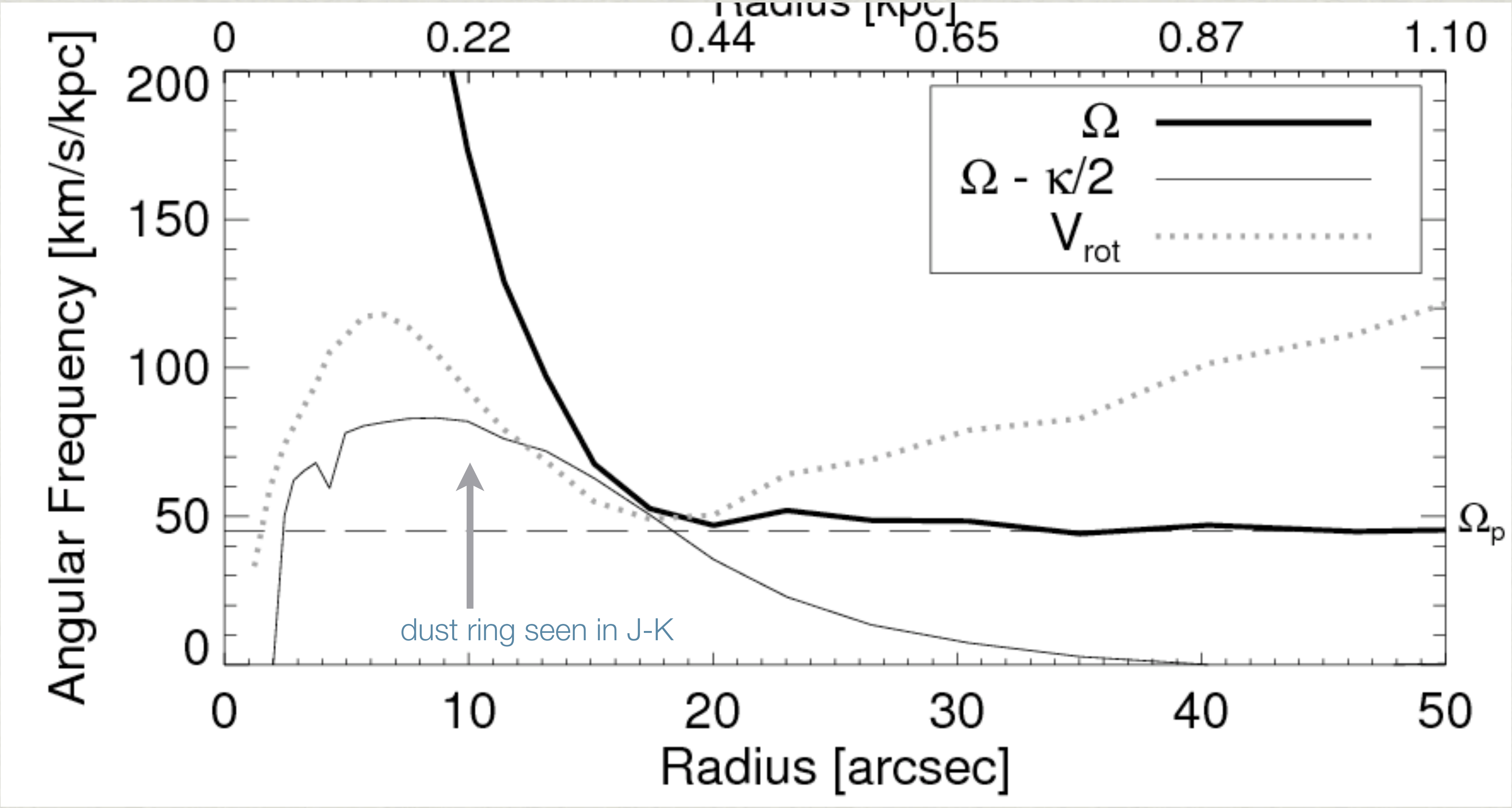
Results Hα: Kinematics



Fathi et al. 2008, ApJ, 675L

- Removing the 2D velocity field from the data reveals a spiral residual pattern superimposed no the rapidly rotating inner component
- Harmonic decomposition gives a v_{rad} of the order of 50 km/s

Results Hα: Kinematics



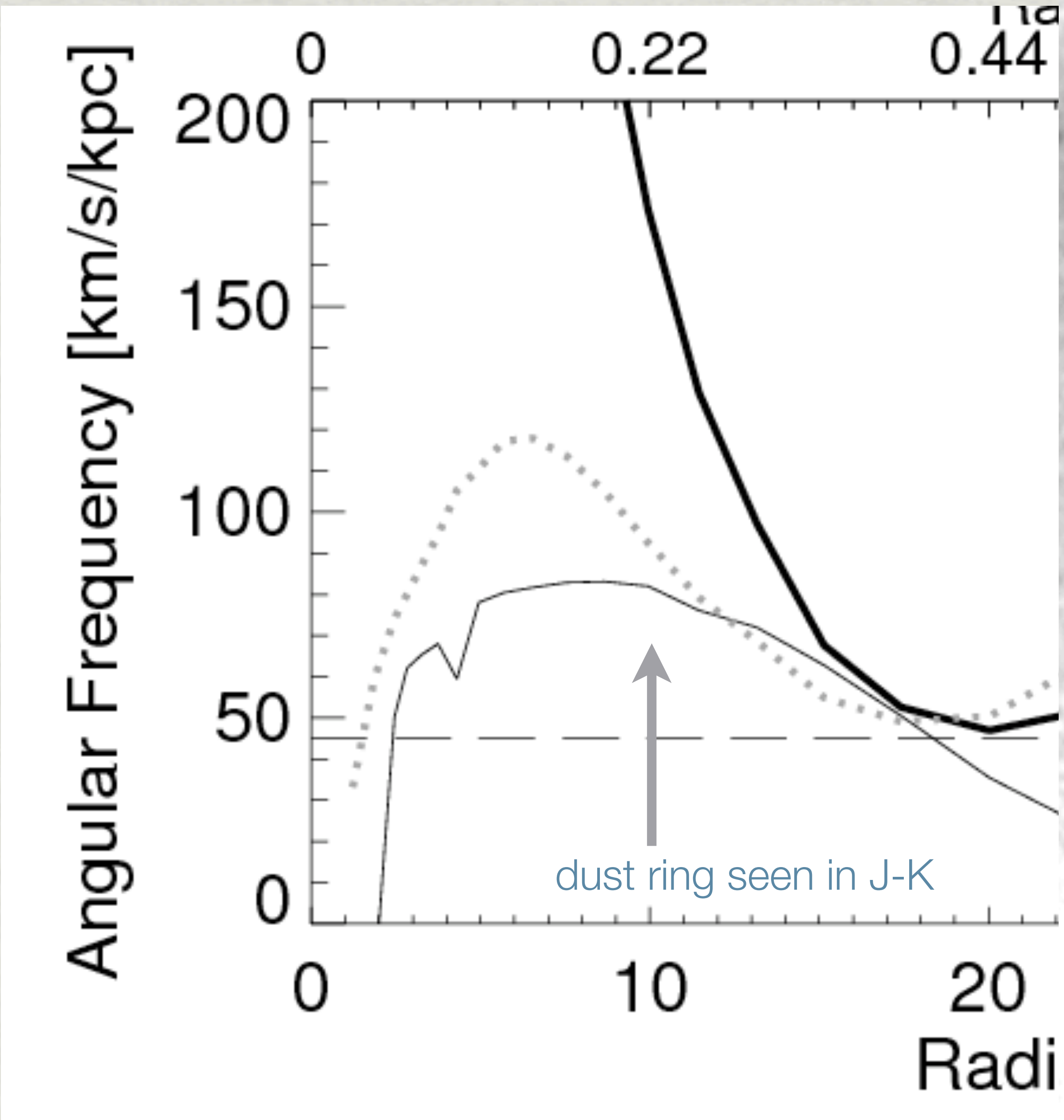
Hα Nuclear disk:

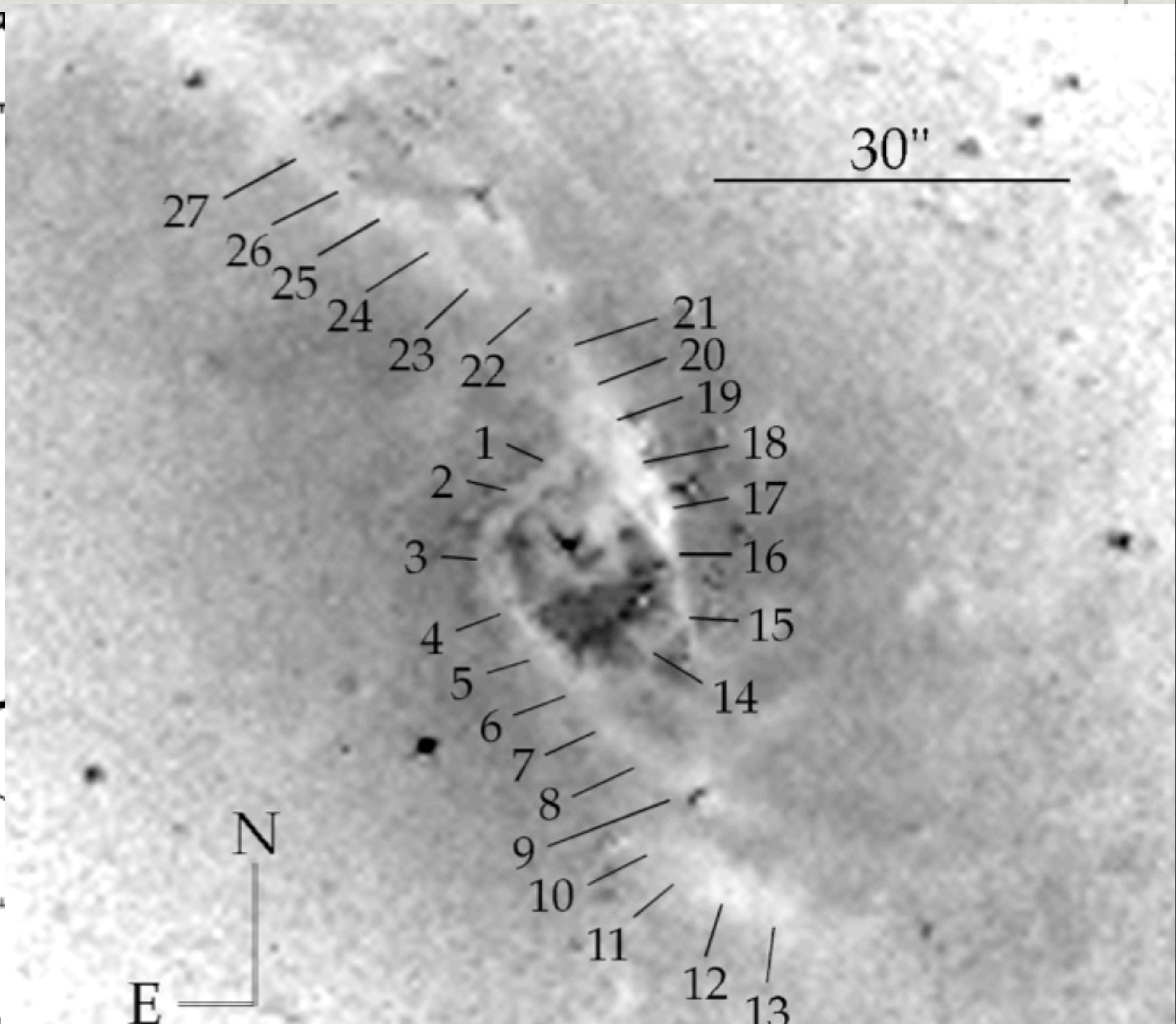
- Mass: 5.5±0.9 x 10^8 $M_\odot$
- Scale length 60±20 pc

CO Nuclear disk:

- Mass: 3x10^8 $M_\odot$
- Scale length 50pc

Results Hα: Kinematics





Elmegreen et al., AJ, 116, 1998

Hα Nuclear disk:

- Mass: 5.5±0.9 x 10^8 $M_\odot$
- Scale length 60±20 pc

CO Nuclear disk:

- Mass: 3x10^8 $M_\odot$
- Scale length 50pc

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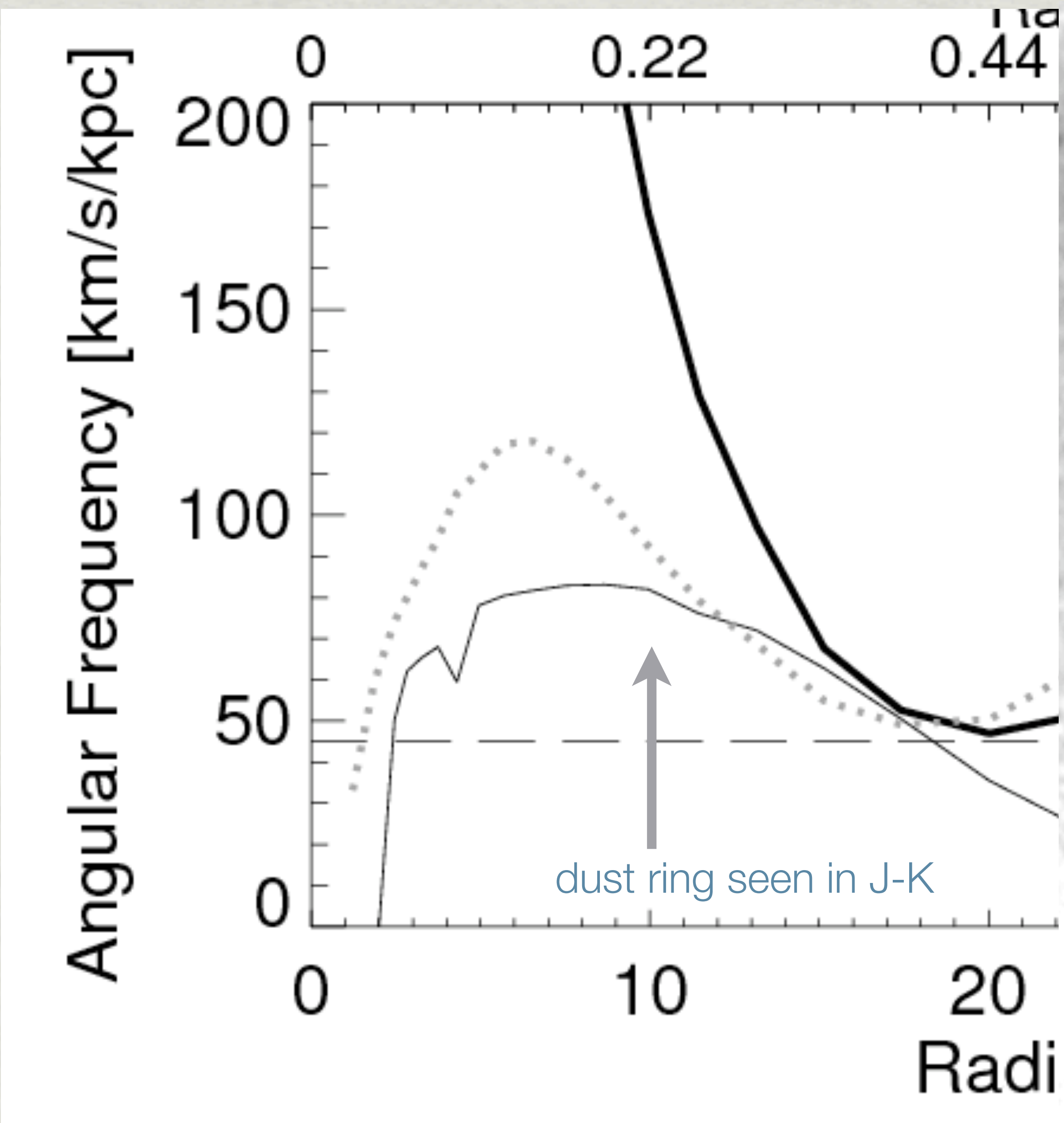

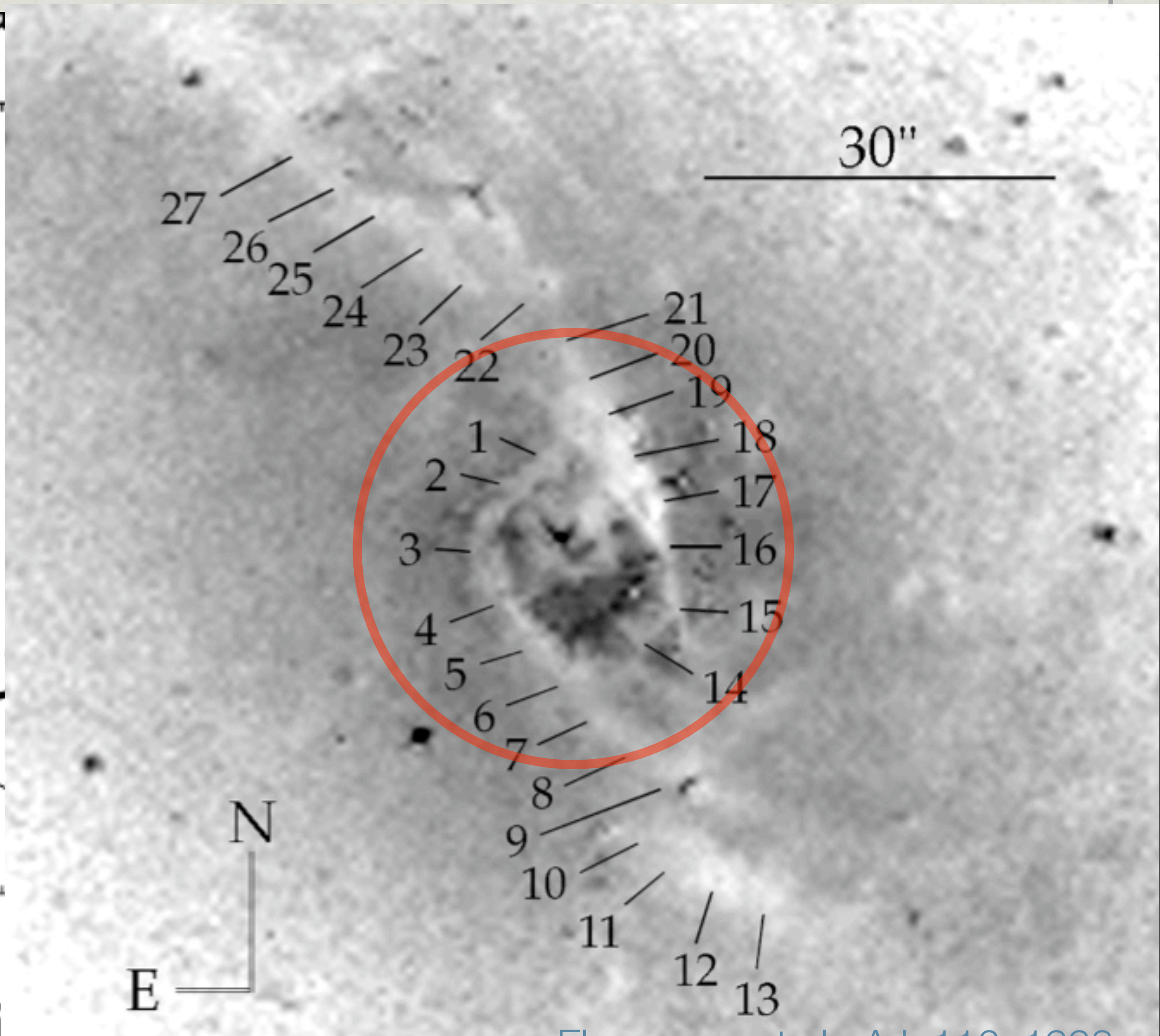

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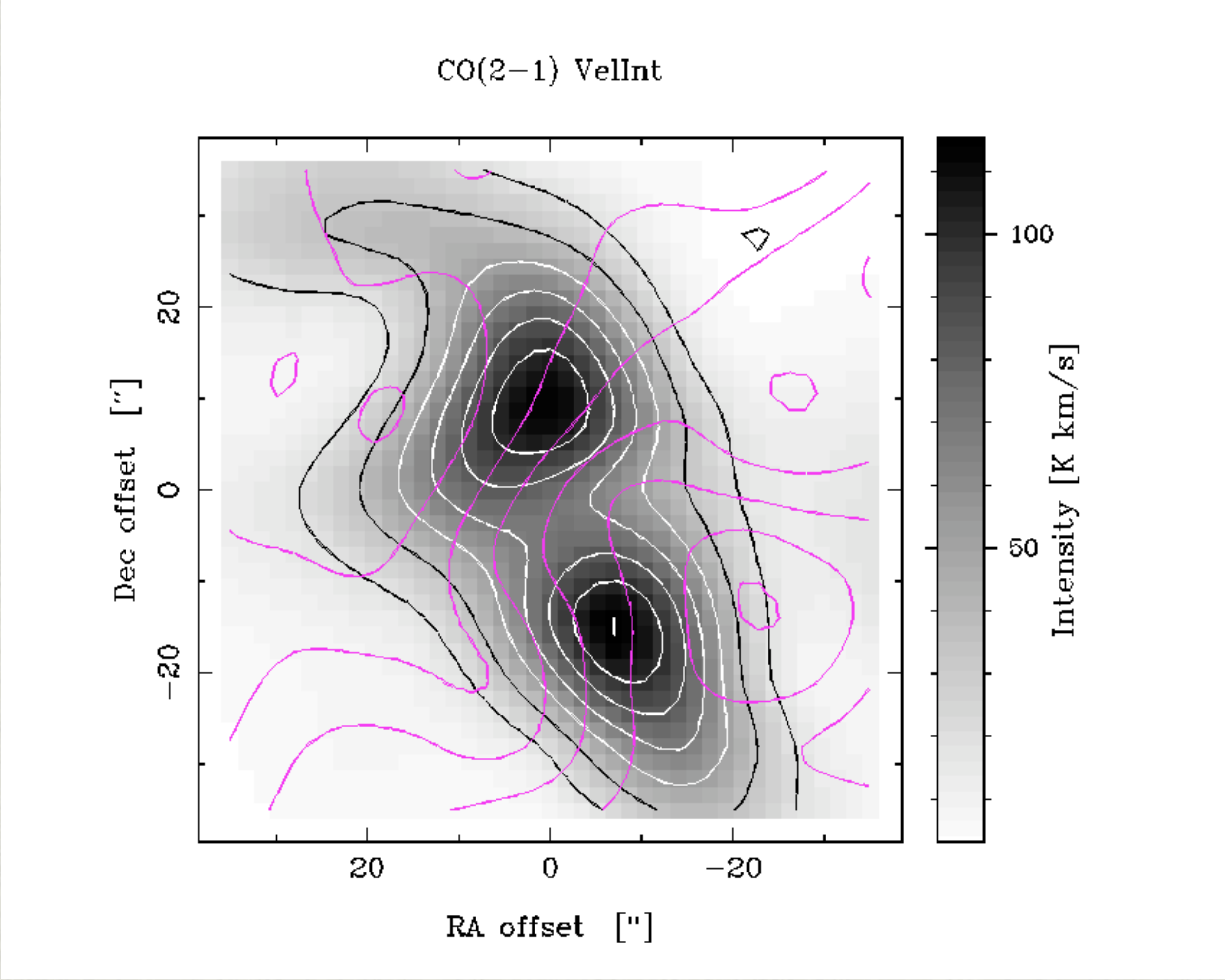
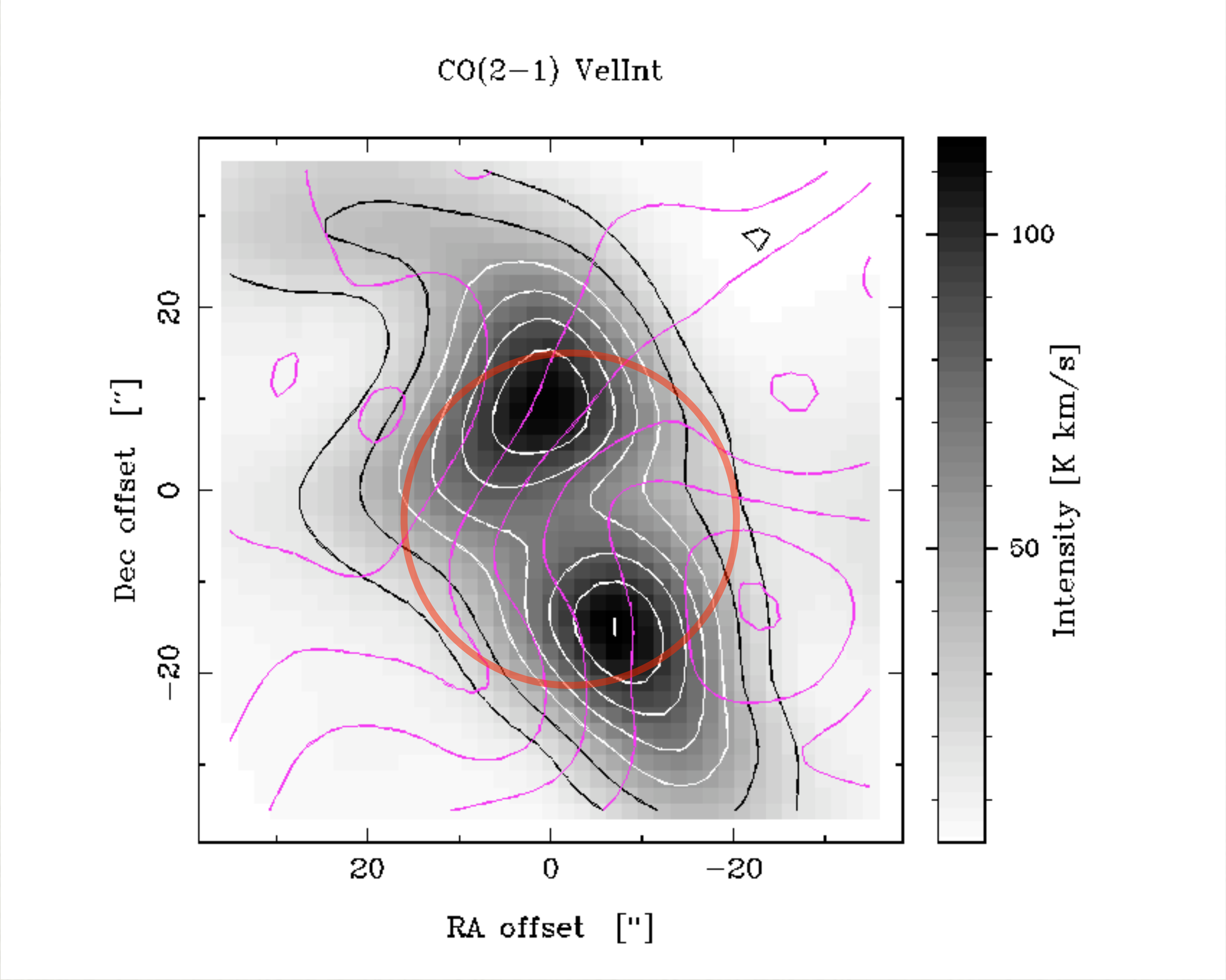
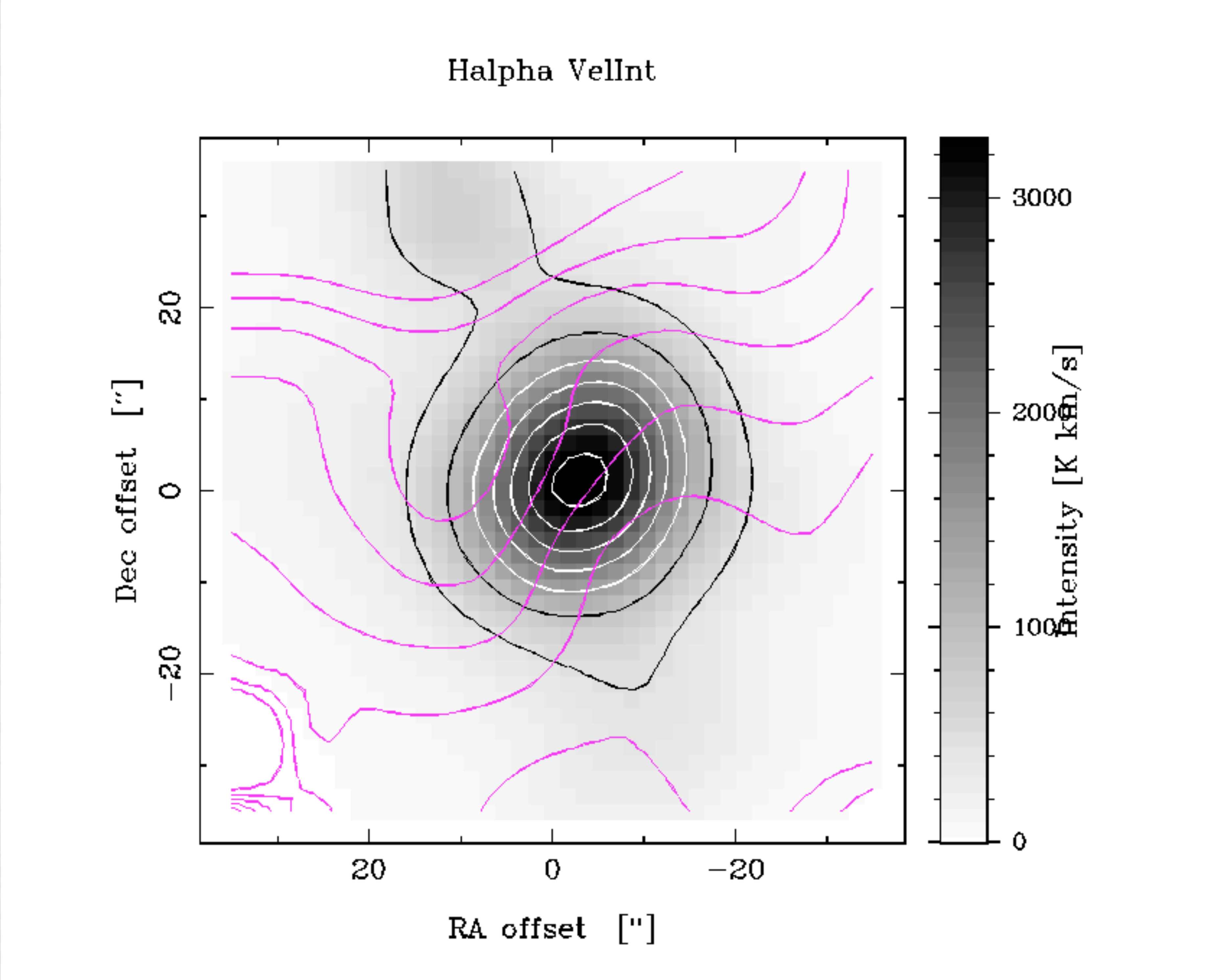
Comparison: Maps



Comparison: Maps



Comparison: Maps



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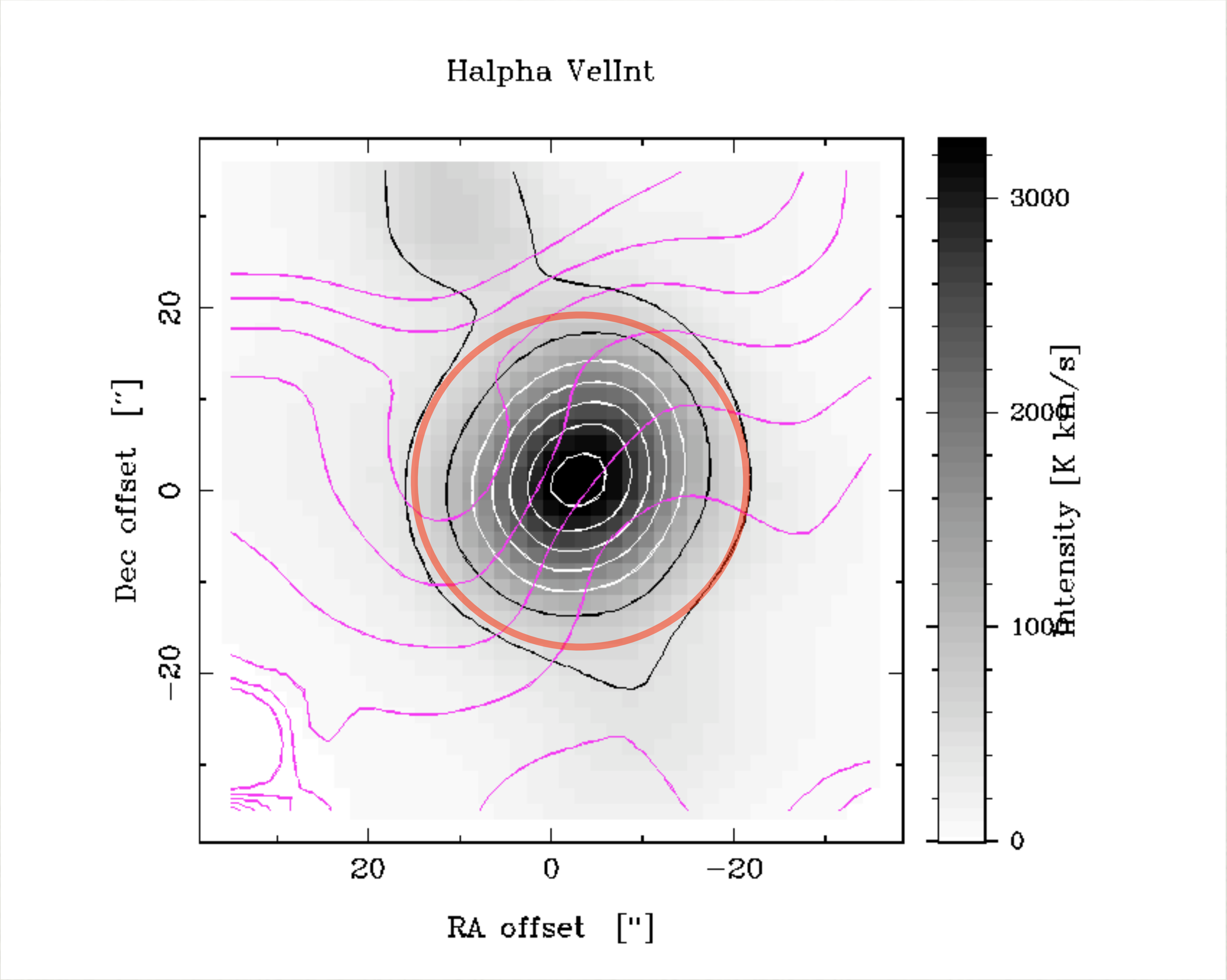
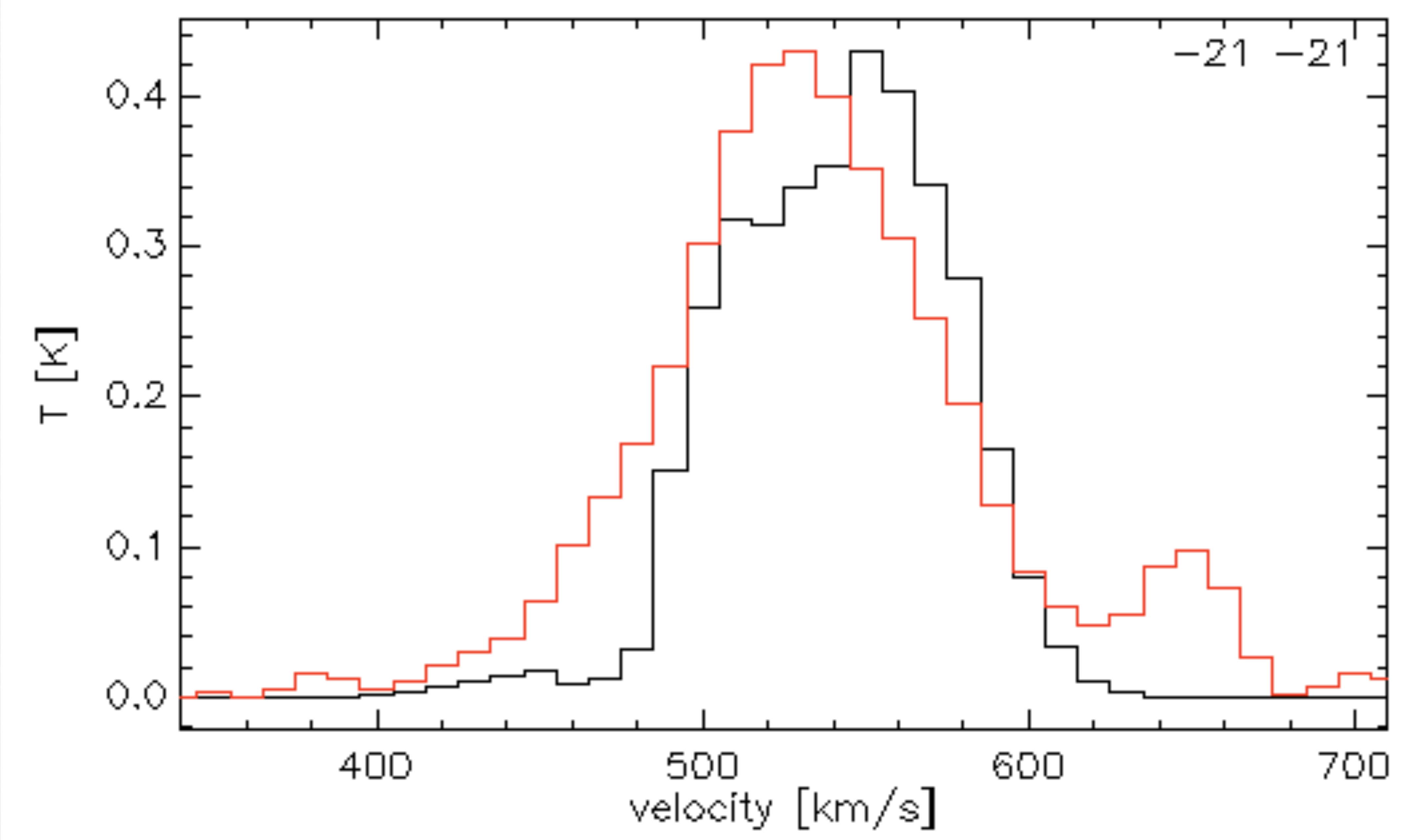
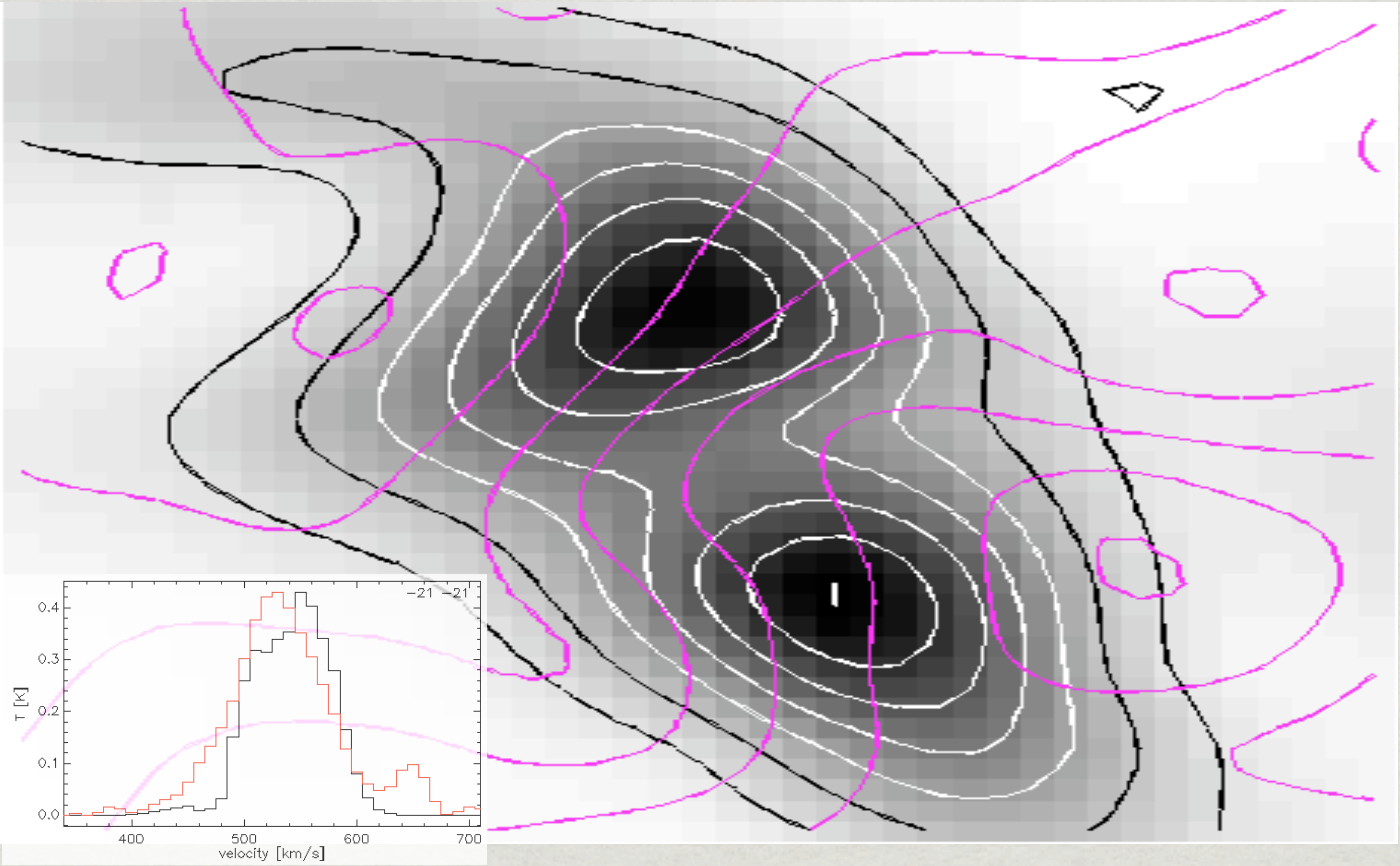


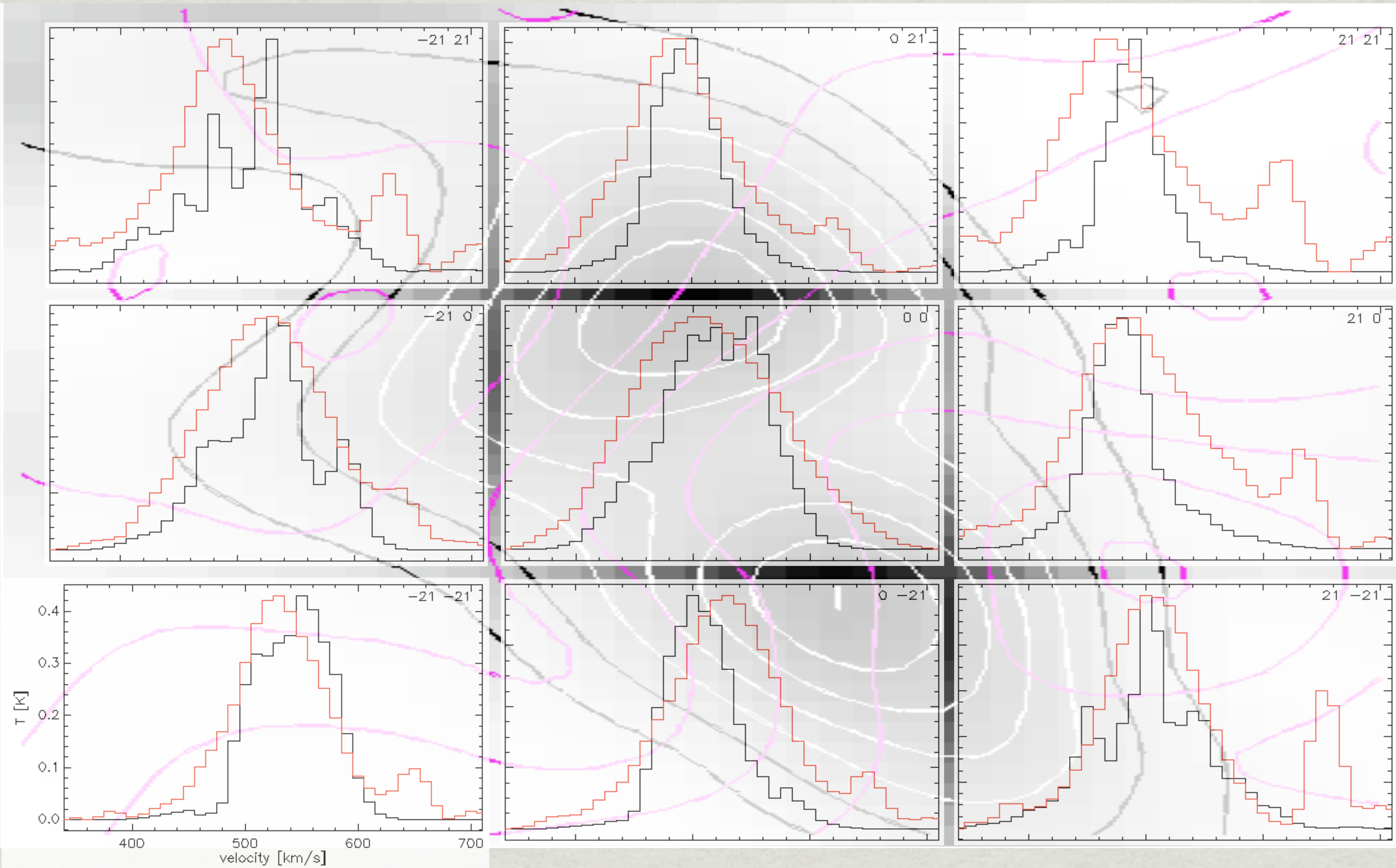
Comparison: Spectra



Comparison: Spectra



Comparison: Spectra



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.