INTERNSHIP REPORT

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Supervised by:

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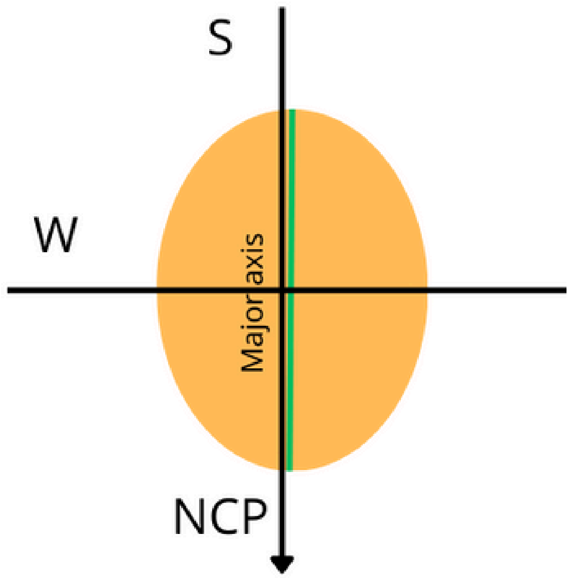
Observatory of Strasbourg| 2024

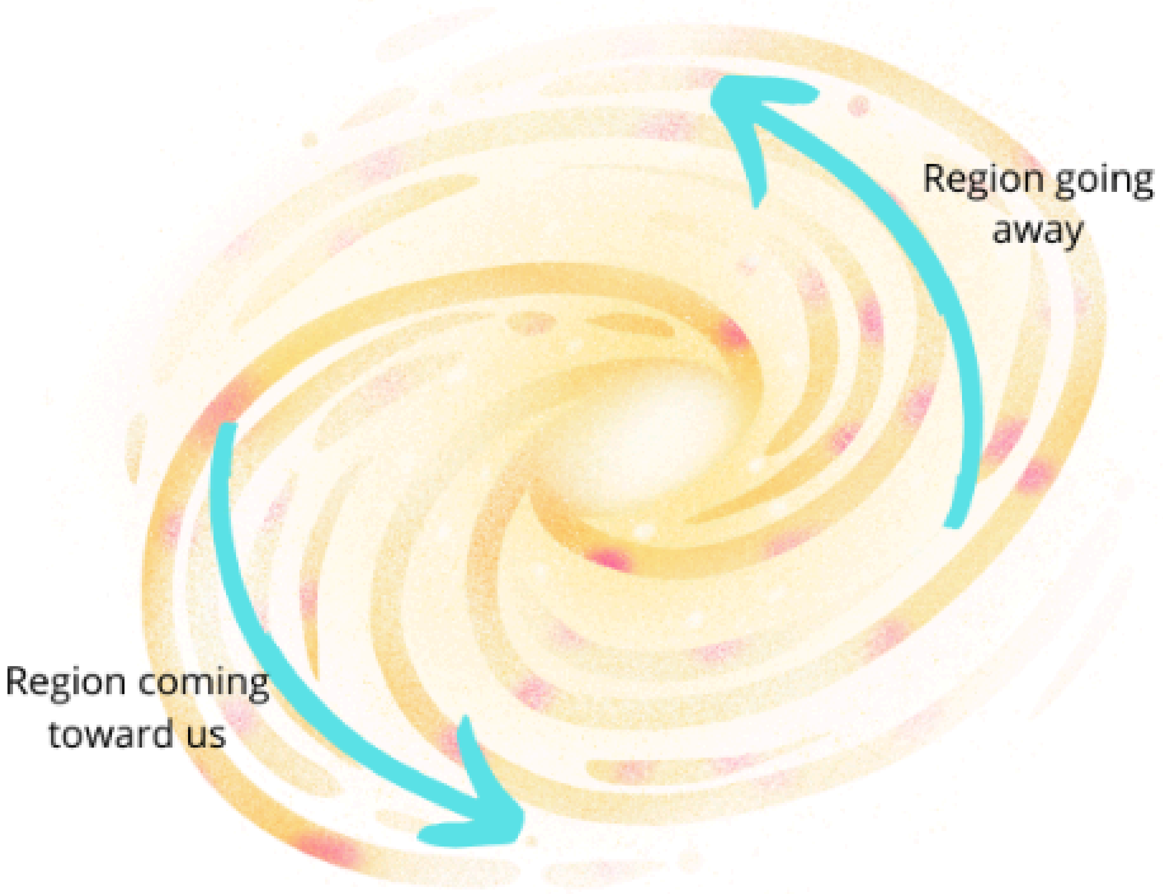
INTRODUCTION

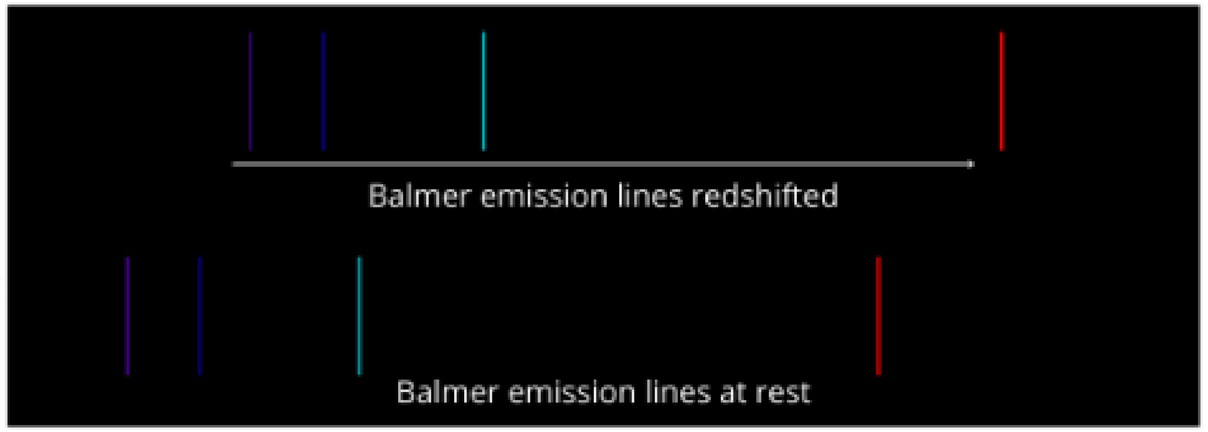
The objective is to determine the dark matter fraction of galaxies at low and high redshift (different epochs), with two different methods: position-velocity diagram along the major axis and 3D BBarolo.

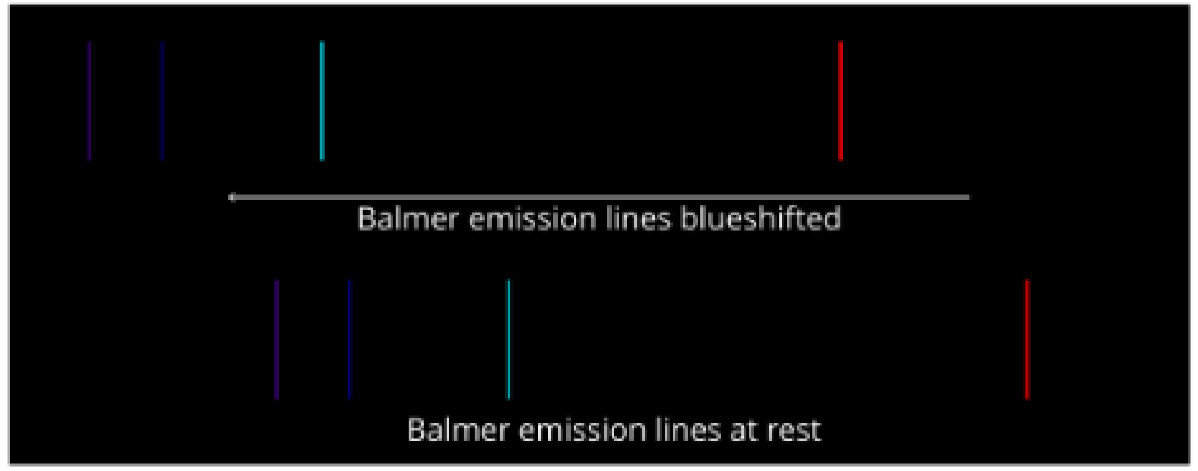
SUMMARY

Circular galaxy







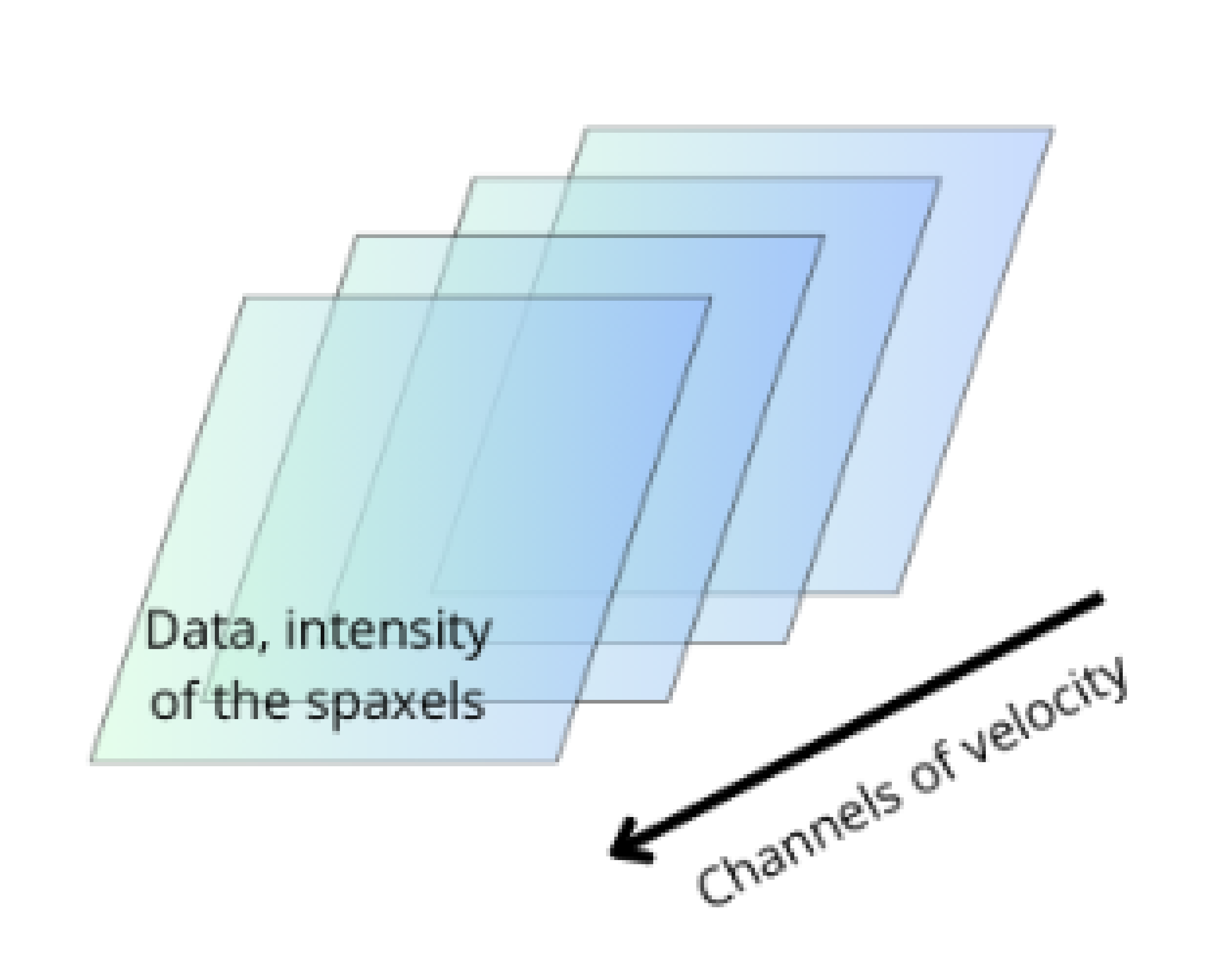


Par Merikanto — Created using the Balmer formula:Whereis the wavelength.B is a constant with the value of 3.6456×10-7 m or 364.56 nm.n is equal to 2m is an integer such that m > n.The lines are plotted horizontally and coloured to match their respective wavelengths., Domaine public, https://commons.wikimedia.org/w/index.php?curid=760401

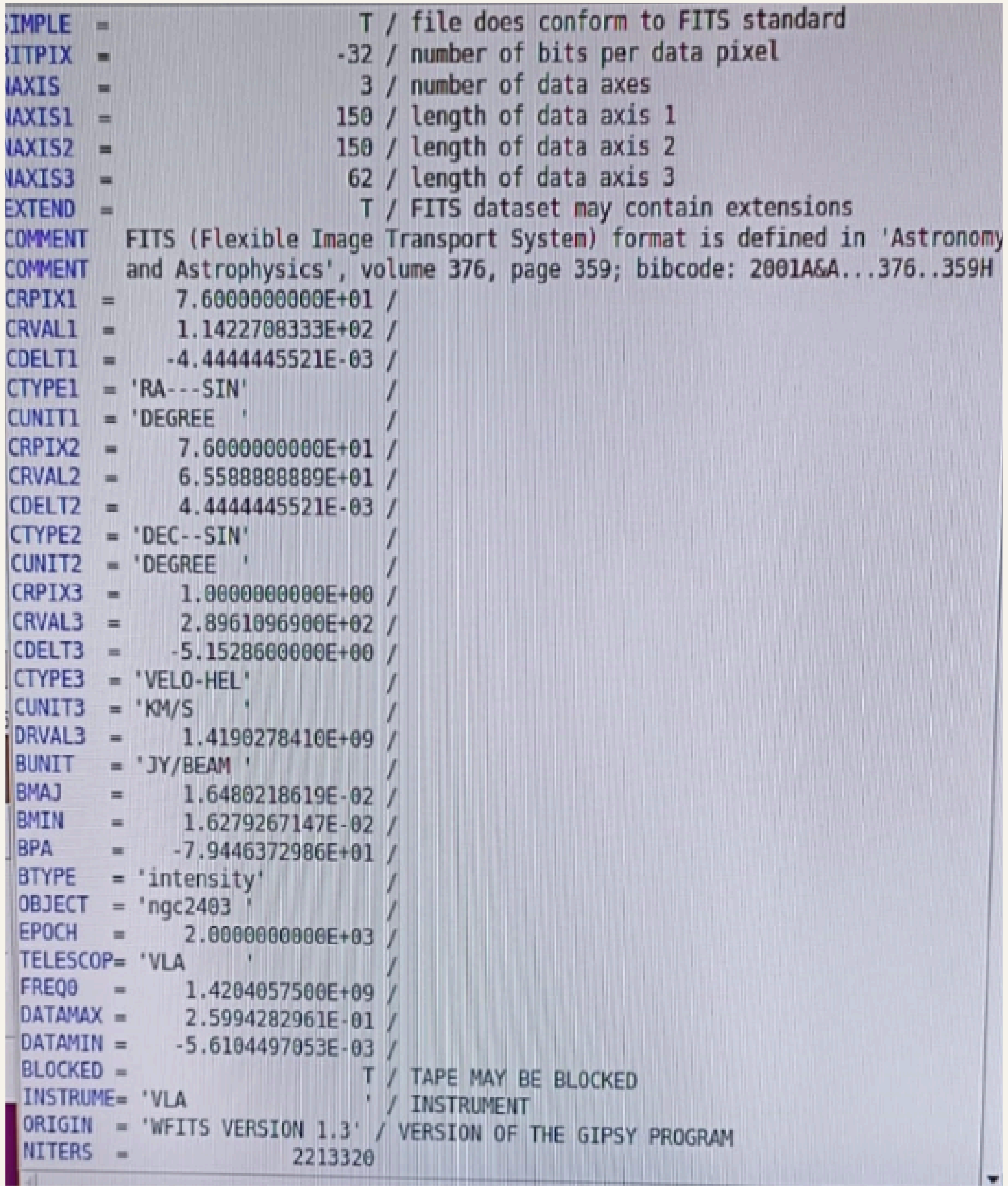
The redshift of Halpha (high z galaxies) or 21cm HI (low z galaxies) emission lines allows us to determine the velocity of a given part of a galaxy.

I) METHODOLOGY WITH VELOCITY PROFILE

- Galfit
- Total rotation curves
- Results



a) Galfit



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NAXIS1  =                  150 / length of data axis 1
NAXIS2  =                  150 / length of data axis 2
NAXIS3  =                   62 / length of data axis 3
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
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CRVAL1  =     1.1422708333E+02 /
CDELT1  =    -4.4444445521E-03 /
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CUNIT1  = 'DEGREE  '           /
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DATAMIN =    -5.6104497053E-03 /
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ORIGIN  = 'WFITS VERSION 1.3'  / VERSION OF THE GIPSY PROGRAM
NITERS  =              2213320
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Header:
Gives many informations about the observations

Sersic

$$F_{\mathrm{Tot}} = 2\pi R_e^2 \Sigma_e \exp(\kappa) n \kappa^{-2n} \Gamma$$

F_{Tot} total luminosity.

R_e effective radius.

t_{exp} exposure time.

Σ_e surface brightness.

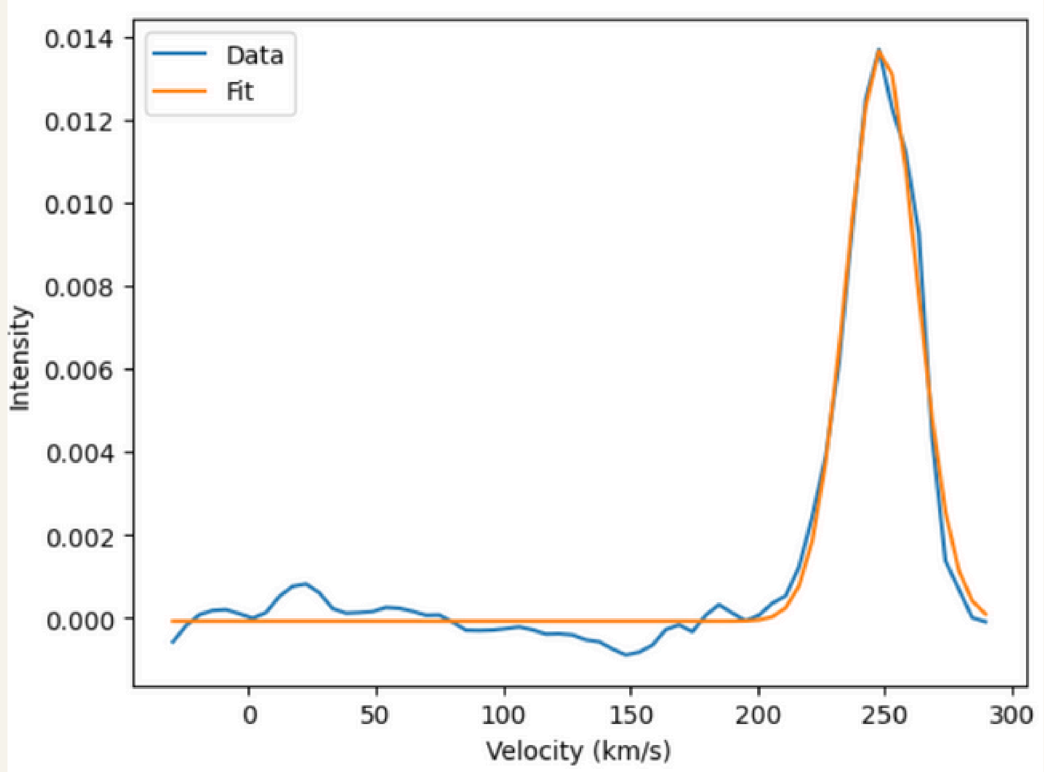
q minor axis on major axis ratio.

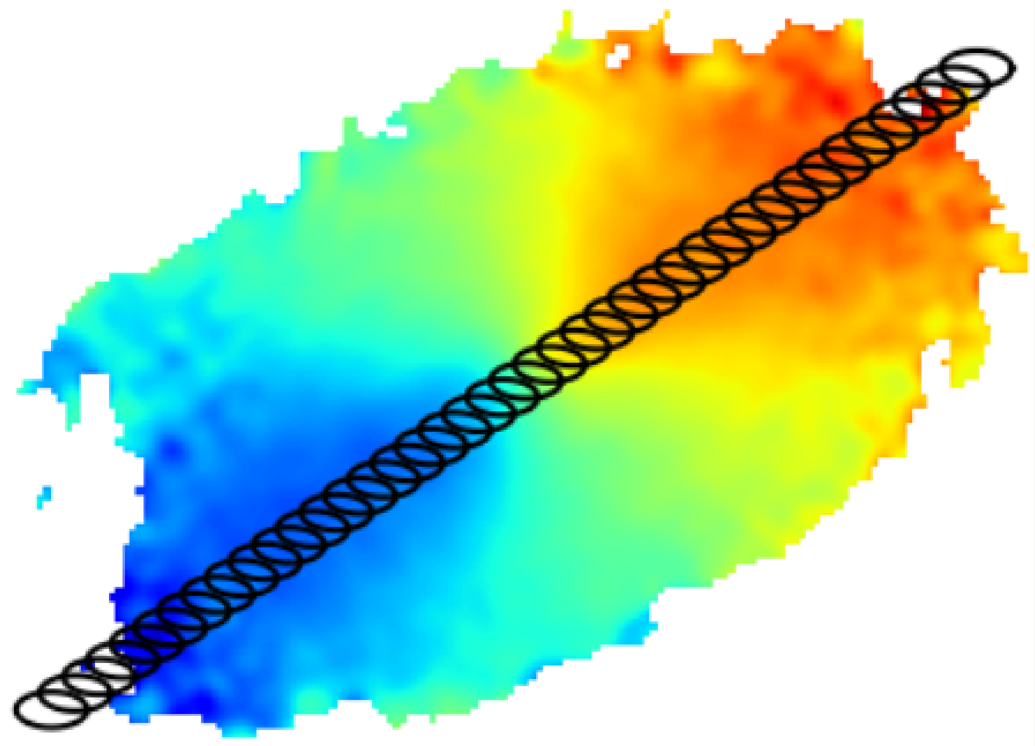
b) Determination of the rotational curve

1 **1st step**
Define ellipses along the major axis.

2 **2nd step**
Define the velocity of each spaxels inside the ellipse.

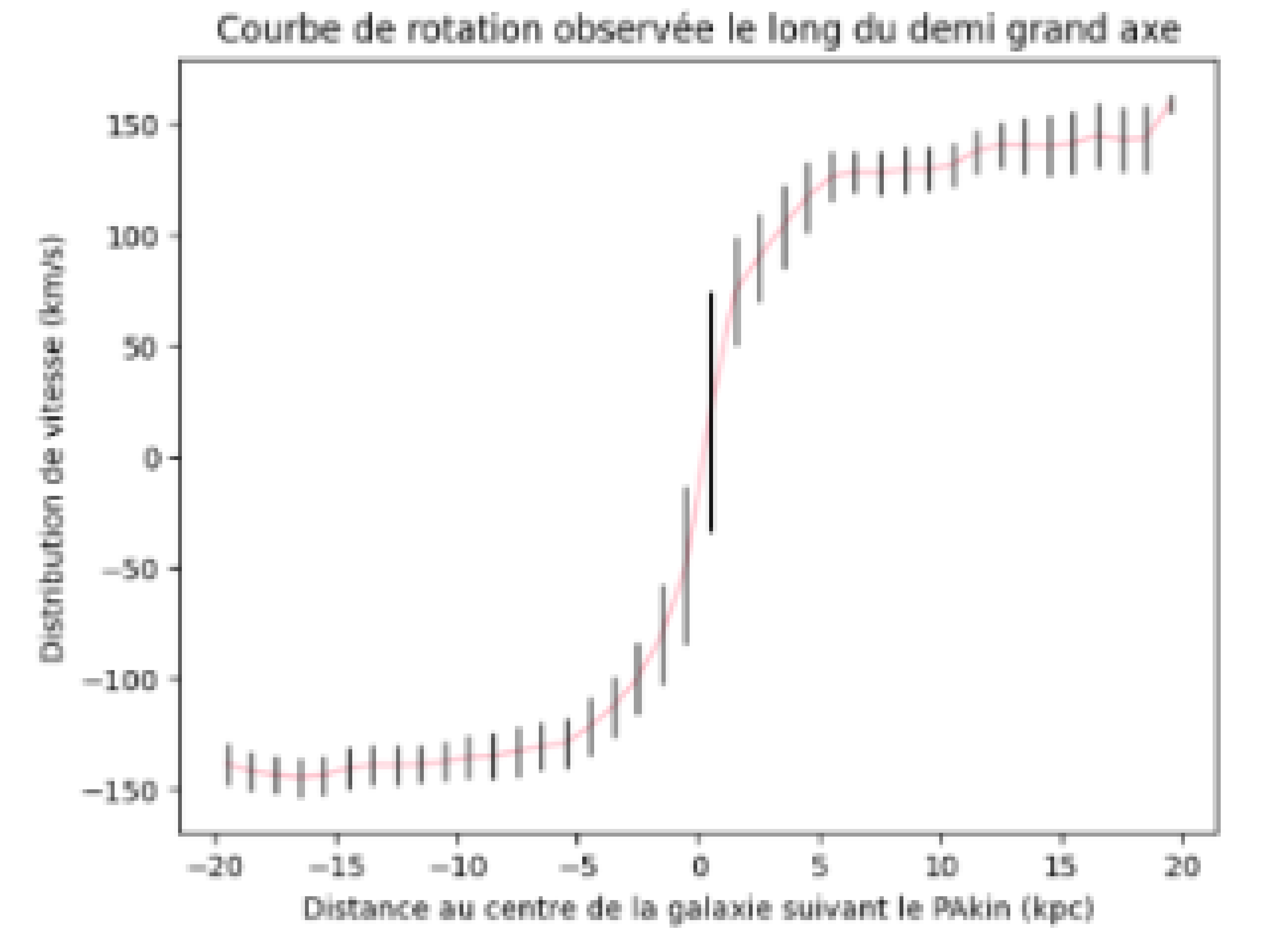
3 **3rd step**
Do the mean velocity inside each ellipses.





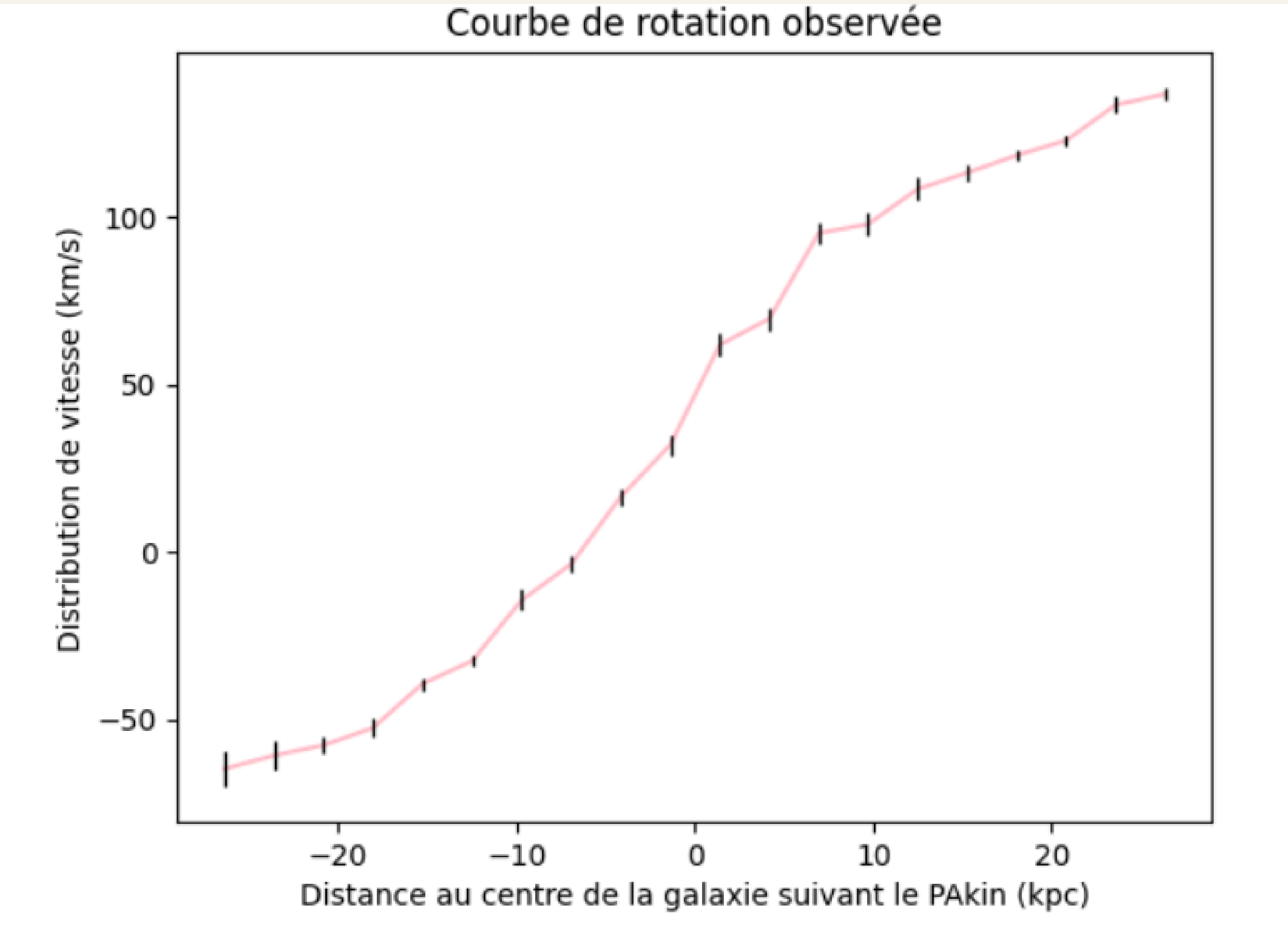
c) Resulting rotation curves

NGC_2403



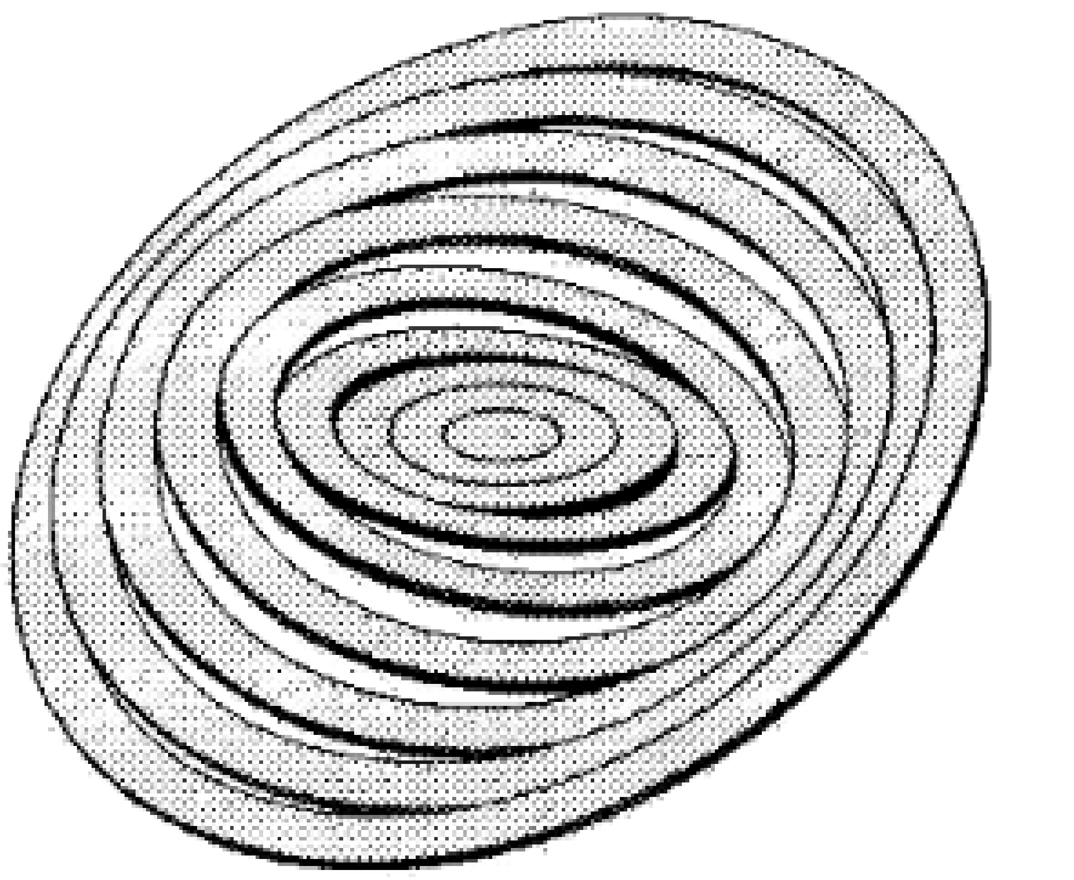
Redshift: z = 0

U3_25160



Redshift: z = 0.897

II) 3D BAROLO'S METHOD



Tilted-ring model of M83 by Rogstad et al. (1974)

- Initial parameters
- Explication of different graphs
- Result

a) Initial parameters

Fixed parameters

Initial position
Systematic velocity
Number of radii

Free parameters

Rotational velocity
Dispersion velocity
Angular position

```
FITSFILE    ngc2403.fits
THREADS     4

////////// 3DFIT parameters ////////////
3DFIT       true
// Input rings
NRADII      30
RADSEP      43.61762361
VSYS        132.8
XPOS        77
YPOS        77
VROT        120
VDISP       8
INC         60
PA          123.7
Z0          10
// Free parameters
FREE        VROT VDISP PA
// Normalization type
NORM        LOCAL
// Mask
MASK        SEARCH
// Other options
LTYPE       2
FTYPE       2
DISTANCE    3.2
BWEIGHT     1
WFUNC       2
TWOSTAGE    true
ADRIFT      true
FLAGERRORS  true
//////////////////////////////////////////
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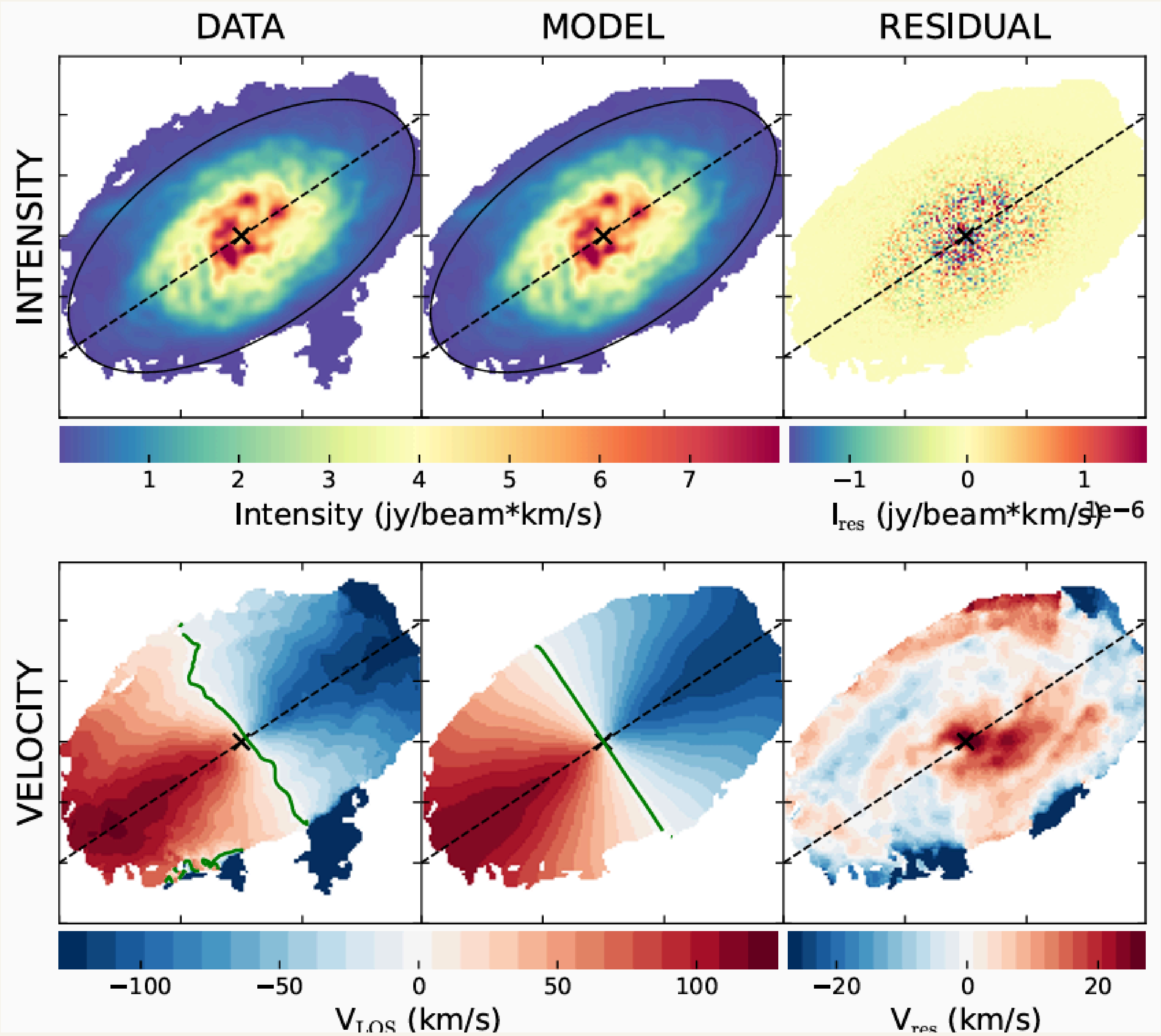
b) Graphs

Intensity and velocity maps

NGC_2403



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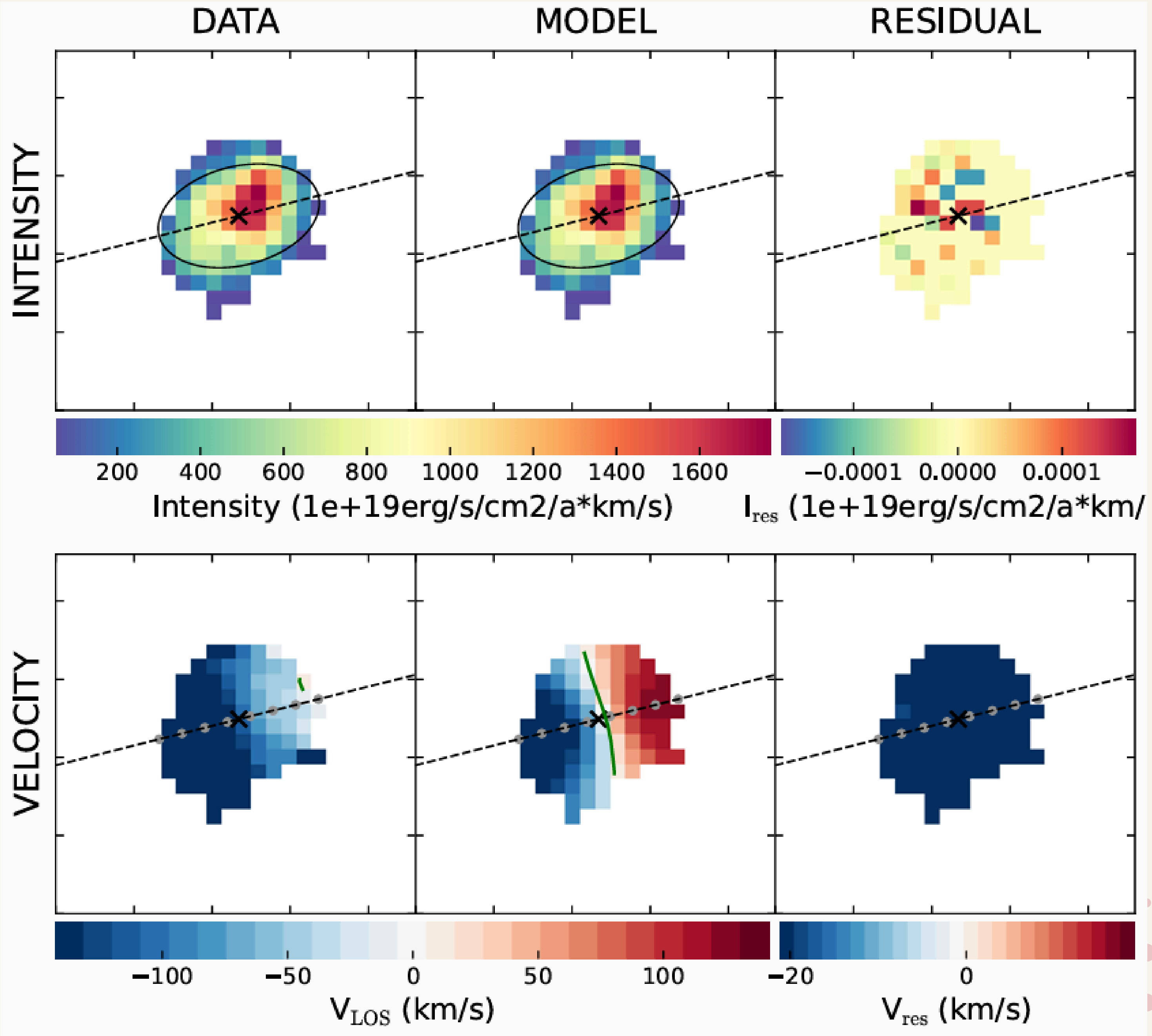
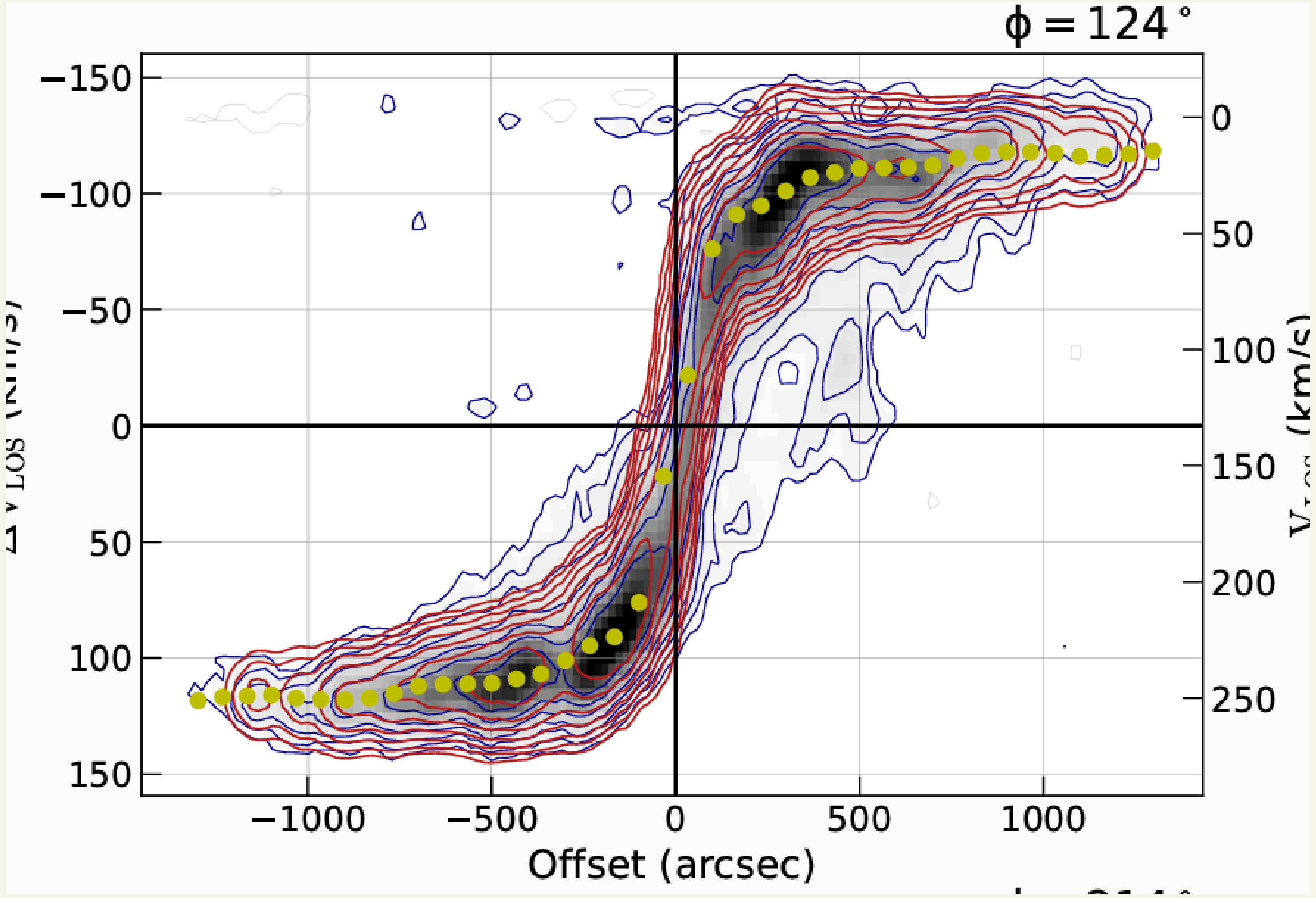


c) Resulting rotation curves

NGC_2403



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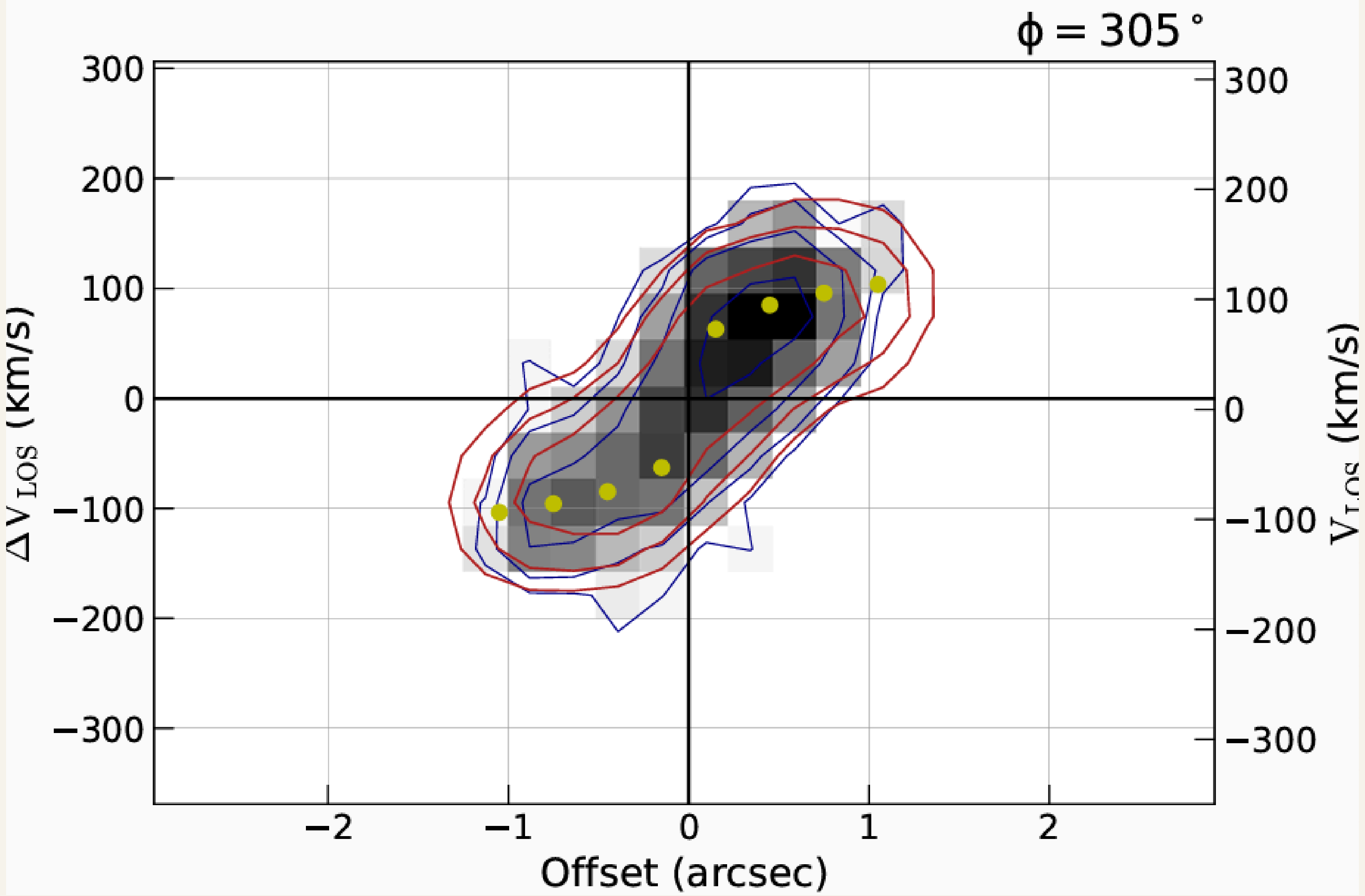


III) DETERMINATION OF THE MASS OF DARK MATTER

The total velocity should be :

$$V_{\text{Tot}} = \sqrt{V_{\text{disk}}^2 + V_{\text{gas}}^2 + V_{\text{DM}}^2}$$

Fraction of dark matter inside a radius r :

$$f_{\text{DM}}(r) = \frac{M_{\text{DM}}(r)}{M_{\text{disk}}(r) + M_{\text{gaz}}(r) + M_{\text{DM}}(r)}$$

For the velocity of the dark matter halo, we assume an NFW model (Navarro et al., 1996) :

$$\rho(r) = \frac{\rho_0}{\frac{r}{R_s}(1 + \frac{r}{R_s})^2}$$

$$M(r) = 4\pi \int_0^r \rho(r')r'^2 \text{d}r'$$

$$V_{\text{DM}} = \sqrt{\frac{GM_{\text{DM}(r)}}{r}}$$

IV) DISCUSSION

a) Correction of pressure

$$\mathrm{V}_{\mathrm{real}}^2 = V_{\mathrm{obs}}^2 - \alpha\sigma^2$$

(Genzel et al., 2017):

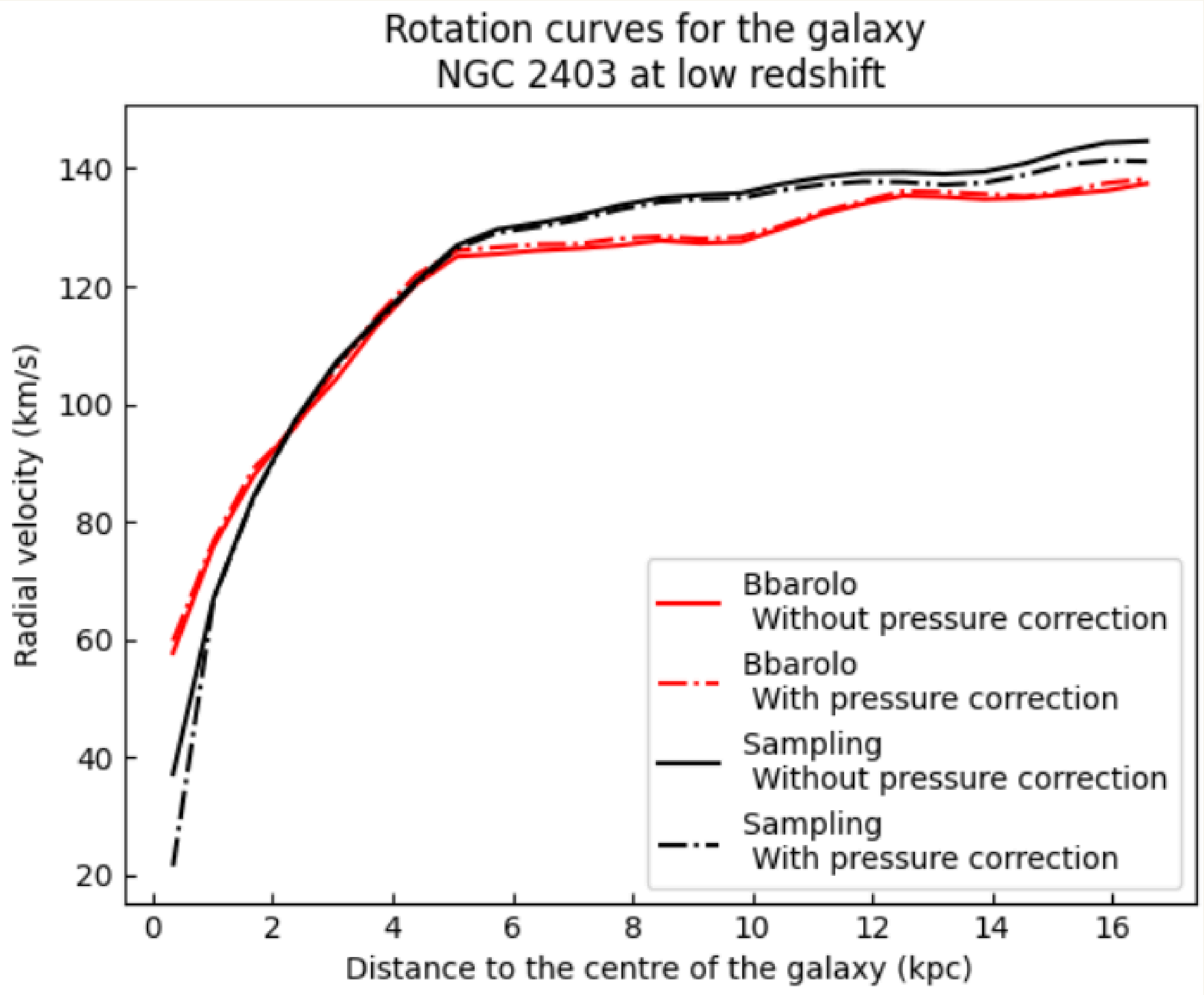
$$\alpha = \frac{r}{\frac{R_{\mathrm{eff}}}{1.68}}$$

(Sharma et al., 2021):

$$\alpha = \left[\frac{\partial \ln(\Sigma)}{\partial \ln(r)} + \frac{\partial \ln(\sigma^2)}{\partial \ln(r)} + \frac{1}{2}\left(1 - \frac{\partial \ln(V_{\mathrm{obs}})}{\partial \ln(r)}\right)\right]$$

b) Comparison

NGC_2403



	$M_{200}(M_{sun})$	c
Velocity profile without correction	$5.74 \cdot 10^{11}{}^{+1.40}_{-1.31}$	$9.77^{+1.18}_{-1.22}$
Velocity profile with correction	$5.30 \cdot 10^{11}{}^{+1.38}_{-1.30}$	$9.98^{+1.18}_{-1.22}$
BBarolo without correction	$3.56 \cdot 10^{11}{}^{+1.17}_{-1.12}$	$11.30^{+1.14}_{-1.16}$
BBarolo with correction	$3.53 \cdot 10^{11}{}^{+1.17}_{-1.17}$	$11.40^{+1.14}_{-1.17}$

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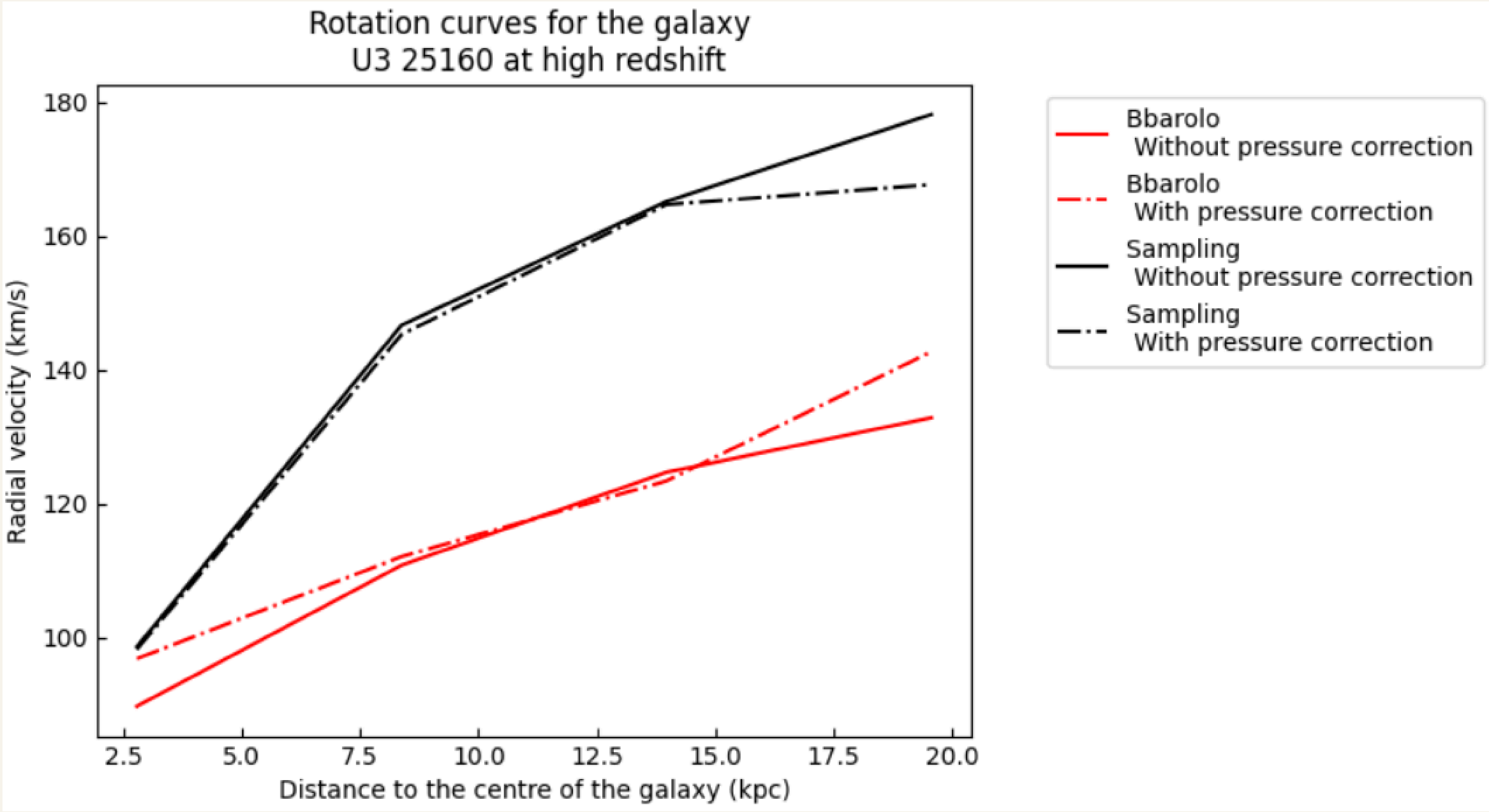
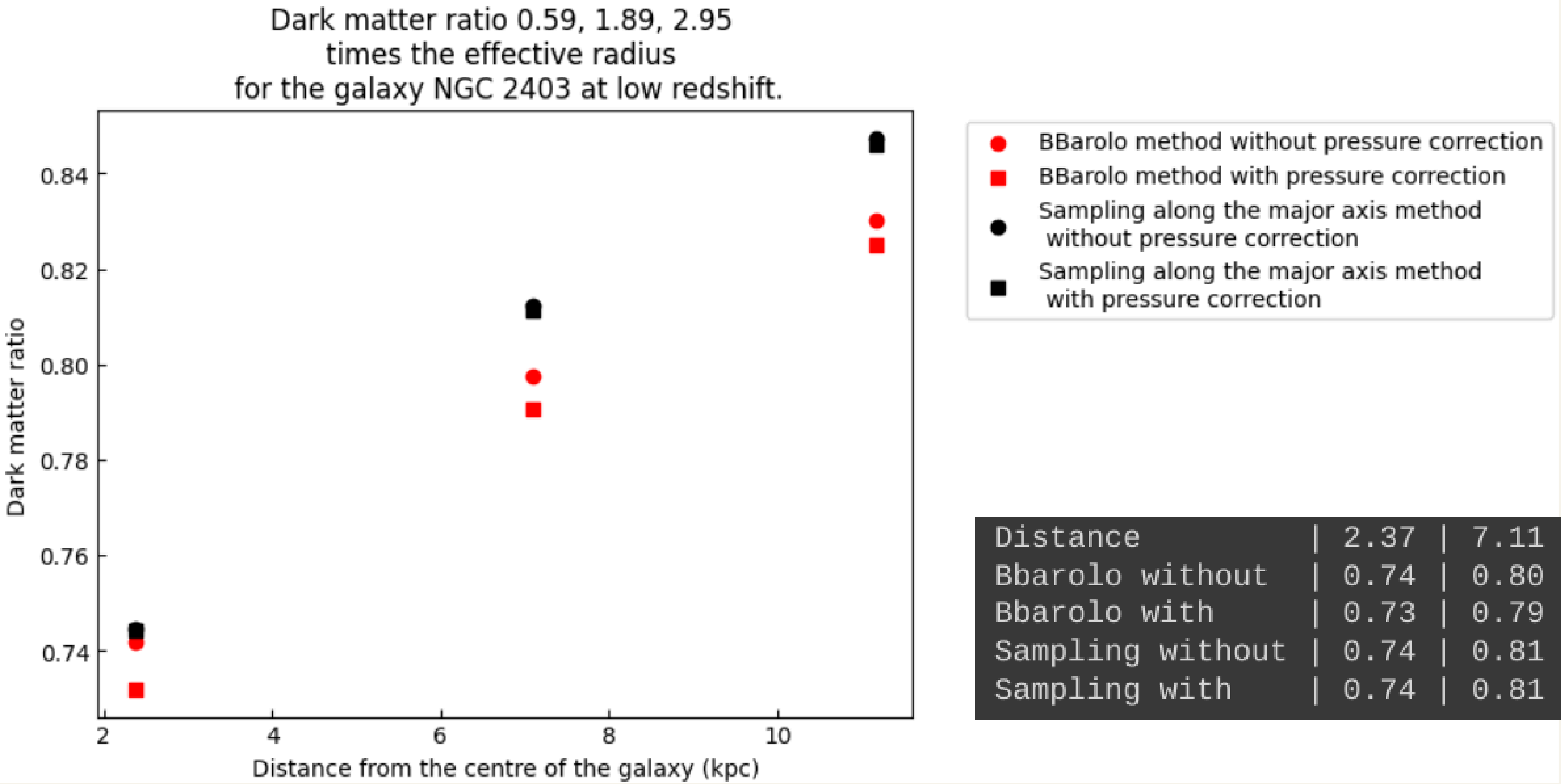


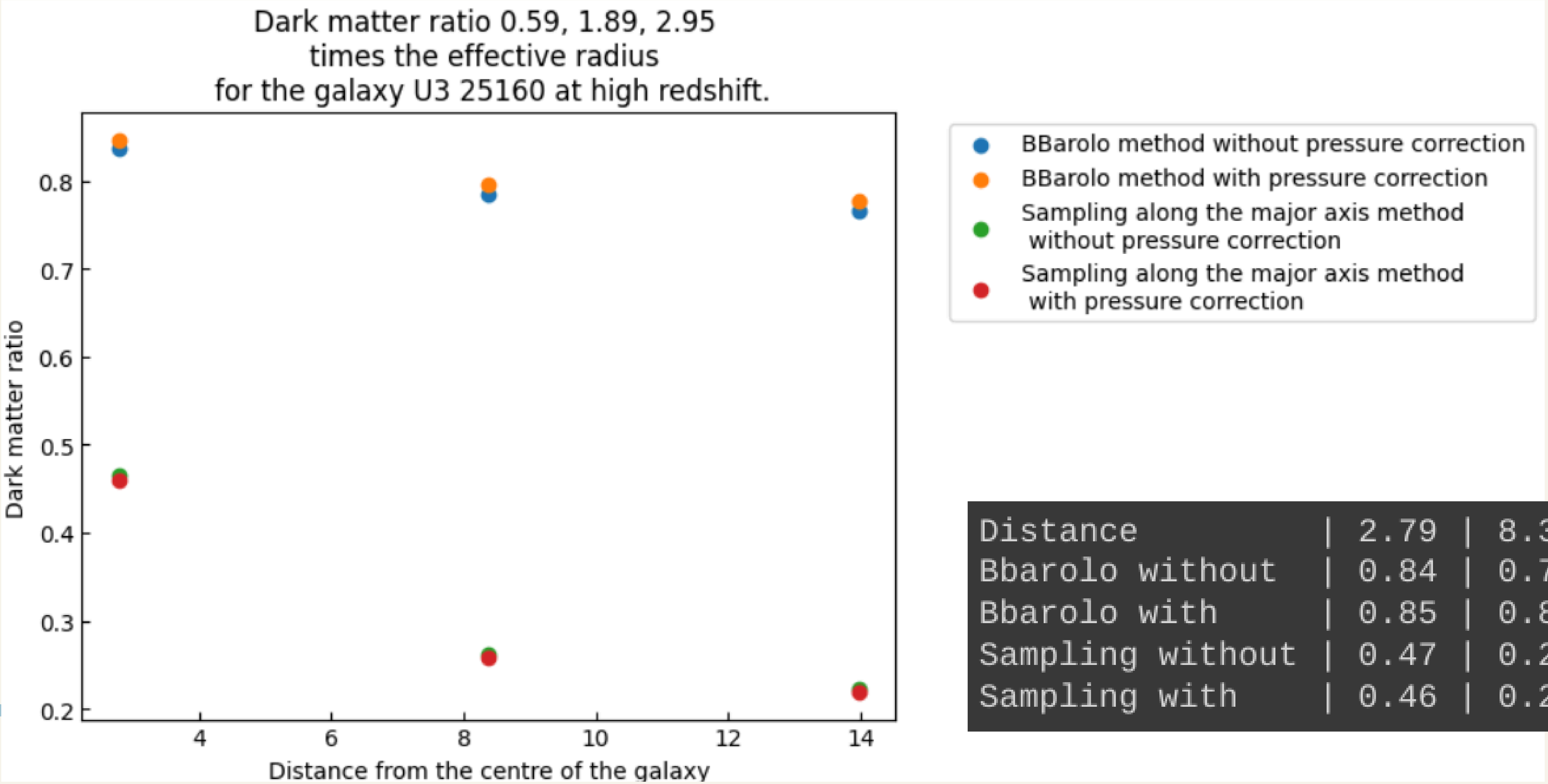
BBarolo without correction	$2.11 \cdot 10^{11}$	9.15
BBarolo with correction	$2.24 \cdot 10^{11}$	9.35

c) Dark matter fractions



Distance	2.37	7.11	11.17
Bbarolo without	0.74	0.80	0.83
Bbarolo with	0.73	0.79	0.82
Sampling without	0.74	0.81	0.85
Sampling with	0.74	0.81	0.85

c) Dark matter fractions



Distance	2.79	8.38	13.97
Bbarolo without	0.84	0.78	0.77
Bbarolo with	0.85	0.80	0.78
Sampling without	0.47	0.26	0.22
Sampling with	0.46	0.26	0.22

CONCLUSION

criticism and limits of the methods

● Velocity profile method

Assumption: flat disk

● 3D Barolo method

Assumption: disk made of concentric rings mutually inclined

Caveats:

- A lot of assumptions (galaxies at equilibrium, circular disk,...)
- PSF of the instrument not taken into account
- Several models for dark matter

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THANK YOU

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ROTATION CURVES OF STELLAR DISK AND GAS

1. Ist step
   Surface brightness

2. 2nd step
   Luminosity

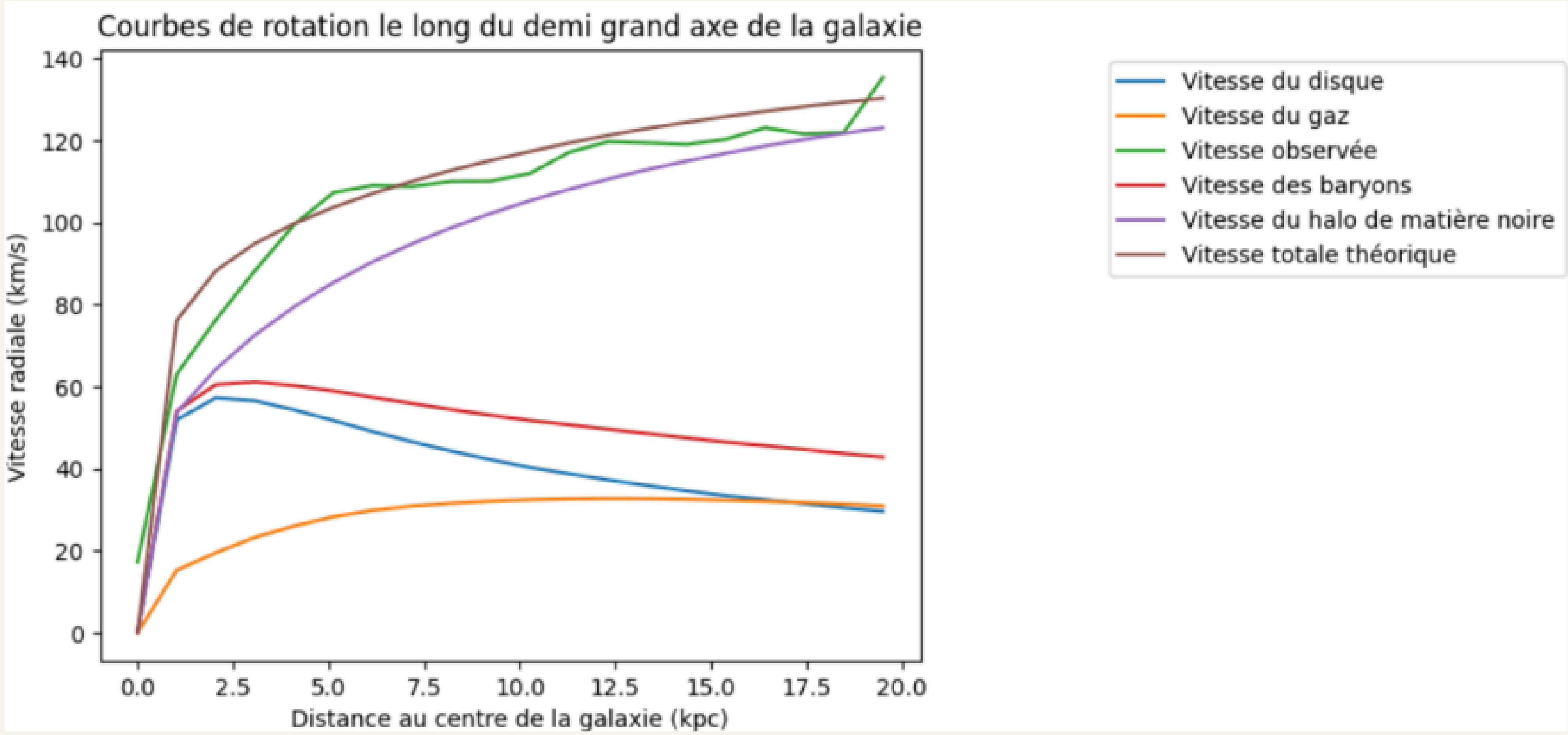
3. 3rd step
   Rotation curve

$$\mathrm{L(r)} = 2\,\pi \int_0^r \Sigma(r')\mathrm{d}r'$$

$$V(r) = \sqrt{\frac{GM(r)}{r}} = \sqrt{\frac{G\frac{M_{\mathrm{Tot}}}{L_{\mathrm{Tot}}}L(r)}{r}}$$

Complete rotation curves

NGC_2403



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