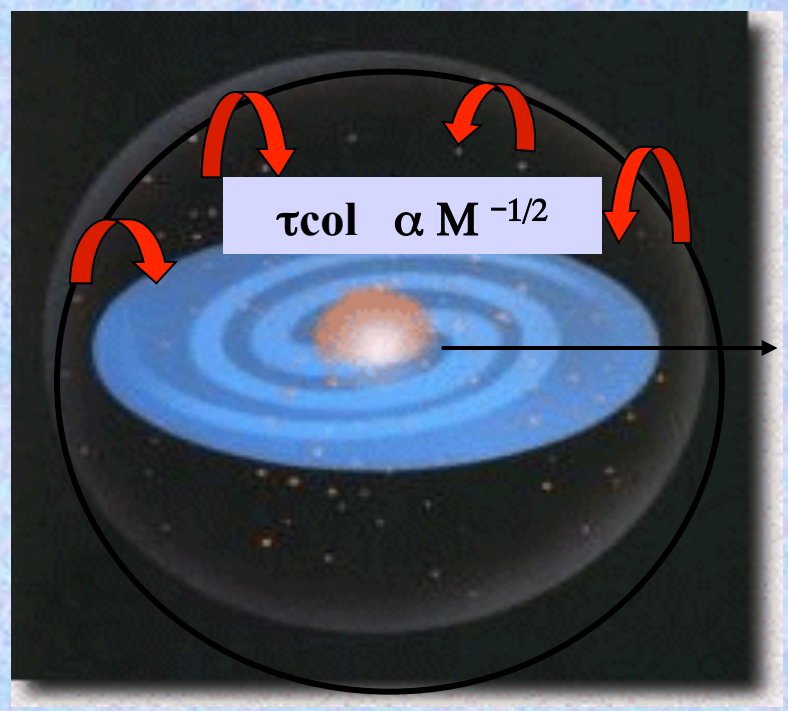
2D-Chemical evolution models: The spiral density wave role

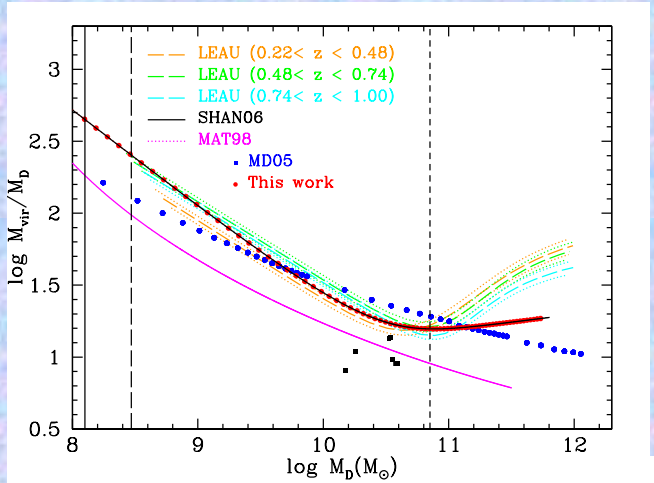
Mercedes Mollá
CIEMAT
S. Wekesa, O. Cavichia, A.I. Díaz, Y. Ascasibar, F. F. Rosales-Ortega, Wamalwa, B. Gibson, S.F. Sánchez

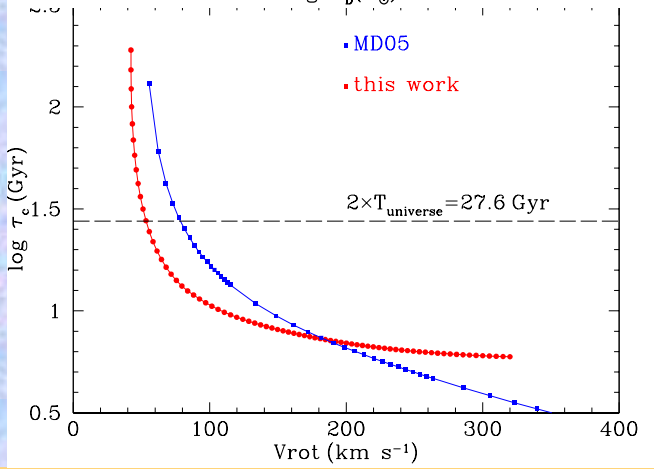
ABSTRACT

- We present the work which we are doing within a collaboration with the Univ. of Nairobi as part of the Ph.D. by Sheillah Wekesa.
- Chemical evolution models (CEM) are a powerful tool to interpret how the chemical elements are formed inside the stellar interiors and how these are redistributed into the ISM.
- CEMs commonly assume that abundances distributions are azimuthally symmetric
- A spiral disk requires a full 2D description so that arms, bars and other structures, may be also included.
- Our objective is to develop 2D chemical evolution models for spiral galaxies, to compare with observed abundance distributions using the IFS data.
- In the present work we start by including the spiral wave as a first step.
- The spiral wave produce an over-density in comparison with the average mass density on the disk (with its radial exponential decrease).
- We have modified our classical chemical evolution model in 1D by a 2D scheme
- We analyze the effects of the overdensity of a spiral wave on the resulting elemental abundances and star formation rate (SFR) 2D-distributions.

Ingredients : The infall rate

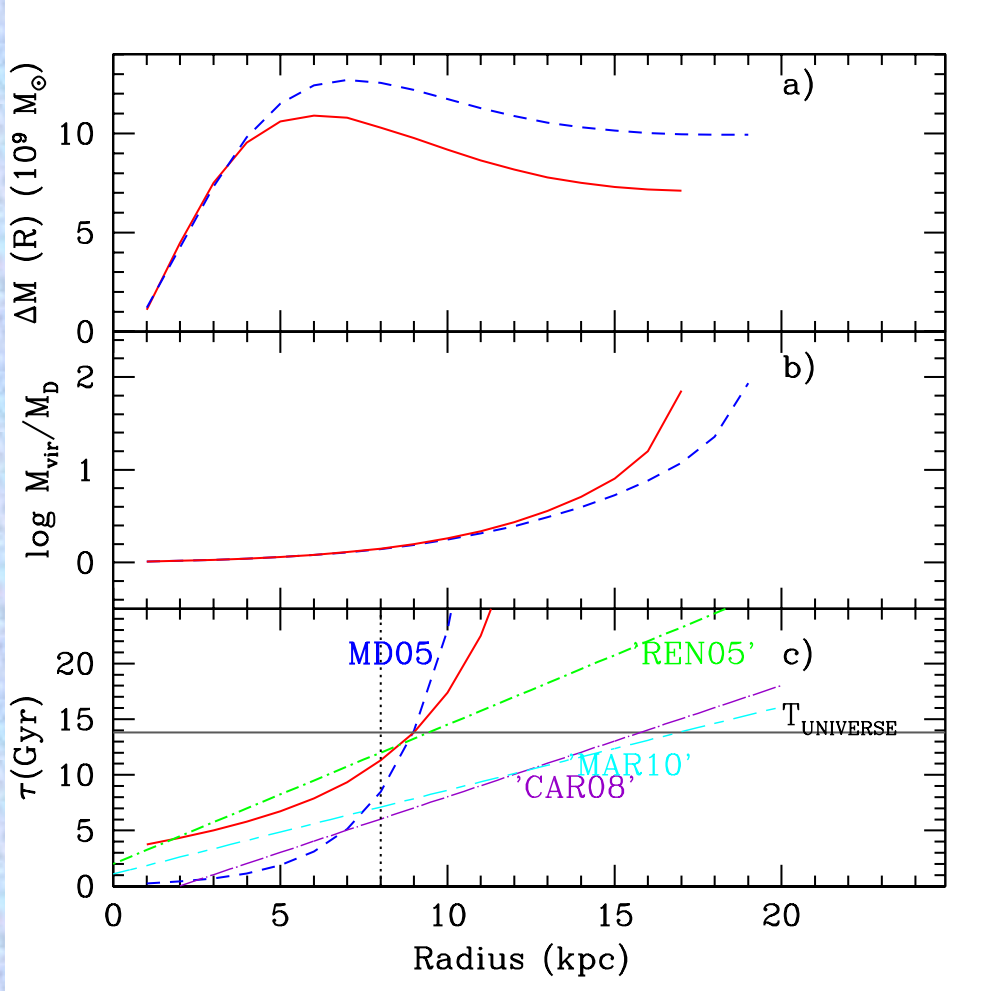






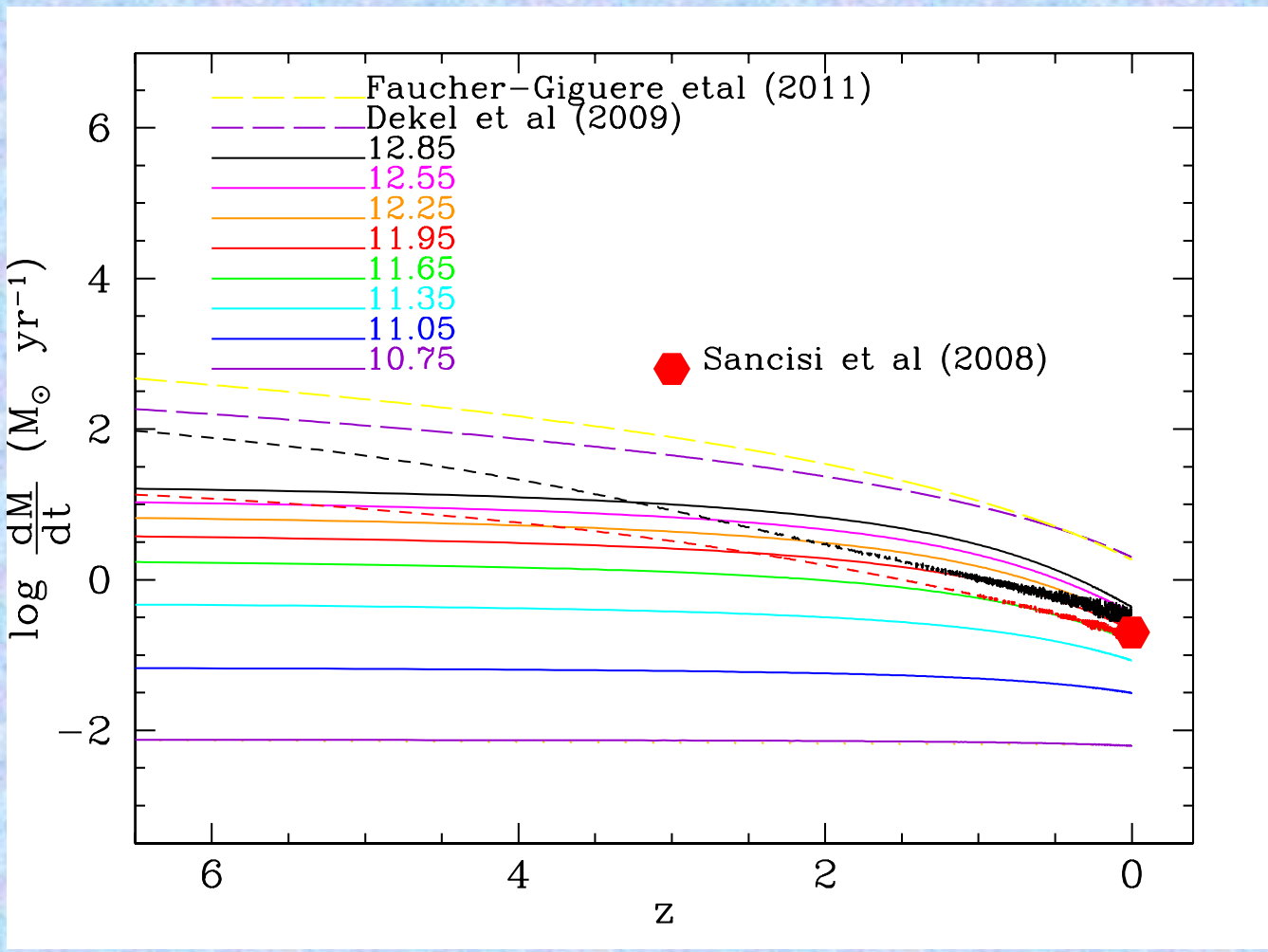
- The gas collapses onto the equatorial plane and forms out the disc
- Infall rate $\alpha\ 1/\tau_{col}$
- τ_{col} = f(Mgal) ...calibration with the MWG
- Since σmass =f(R), τ=τ(R), following Shankar et al.

Ingredients of the multiphase chemical evolution model: the scenario



The total mass M of each modeled galaxy and its radial distribution M(R) have been computed from Salucci (2007)

THE INFALL RATE HISTORY IN MOLLA + 2016



Inputs of the multiphase chemical evolution model:

The star formation law

$$\Psi_D(t) = (H_1 + H_2)c_D{}^2(t) + (a_1 + a_2)S_{2,D}(t)c_D(t)$$

Star formation in the halo: SFR α K g $^{1.5}$

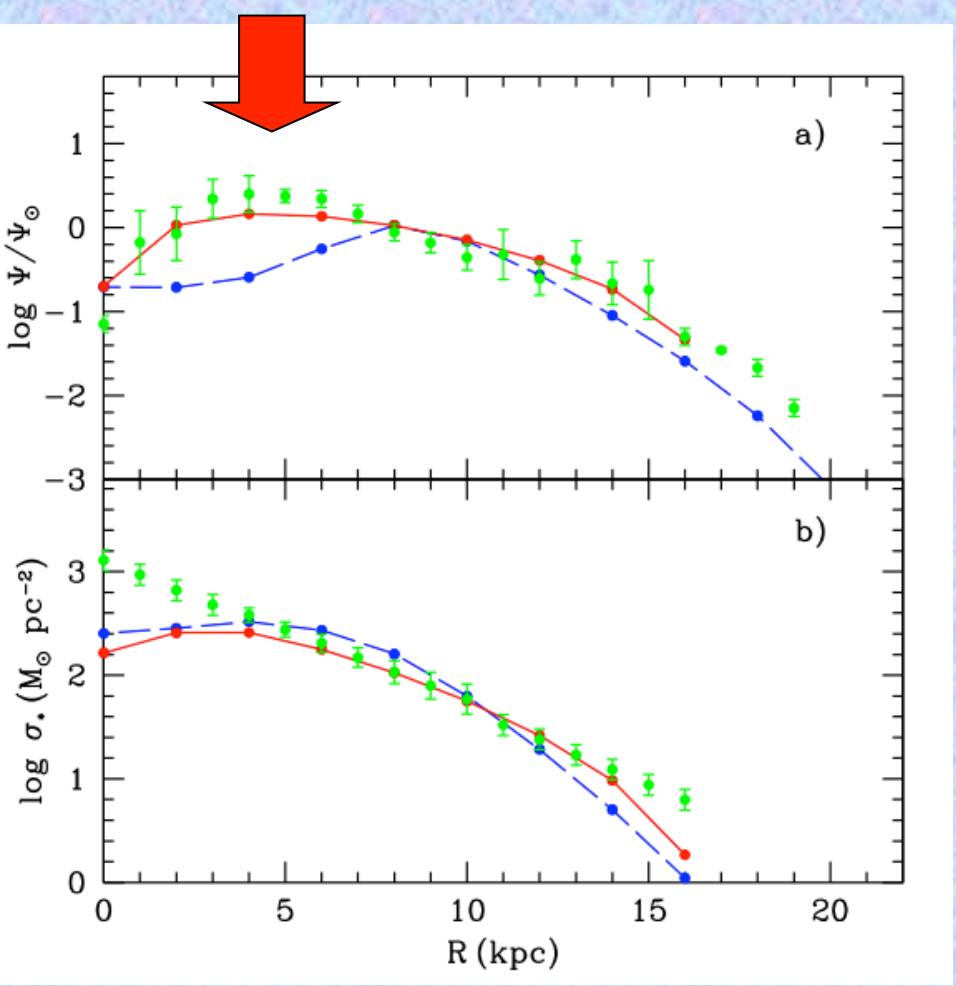
Stars form through cloud-cloud collisions: s α Hc ^{2}

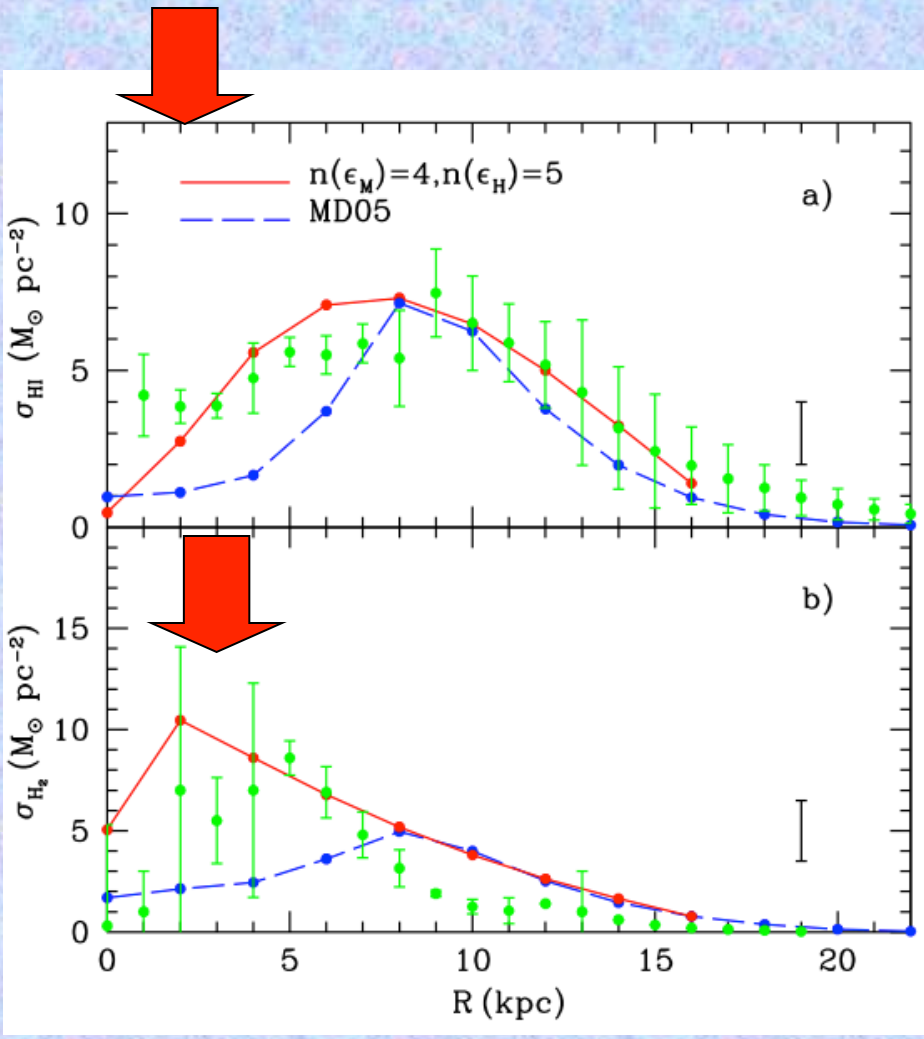
In the disc molecular clouds form from the diffuse gas c α μg $^{1.5}$

Stars also form from the interaction between massive stars and molecular clouds: s α *a* c s $_2$

- Every parameter changes along the galactocentric radius:
  - $K = \varepsilon_K (G/V)^{1/2}$
  - $\mu = \varepsilon_\mu (G/Vd)^{1/2}$
  - $H = \varepsilon_H$ cte /Vd
  - $a = \varepsilon_a (G \rho_c)^{1/2} / \langle m_{s2} \rangle$
- The efficiency ε_a is a local parameter
- The efficiency ε_K is assumed as constant for all halos
- Efficiencies ε_μ y ε_H are variable for each galaxy

Calibration of the MWG

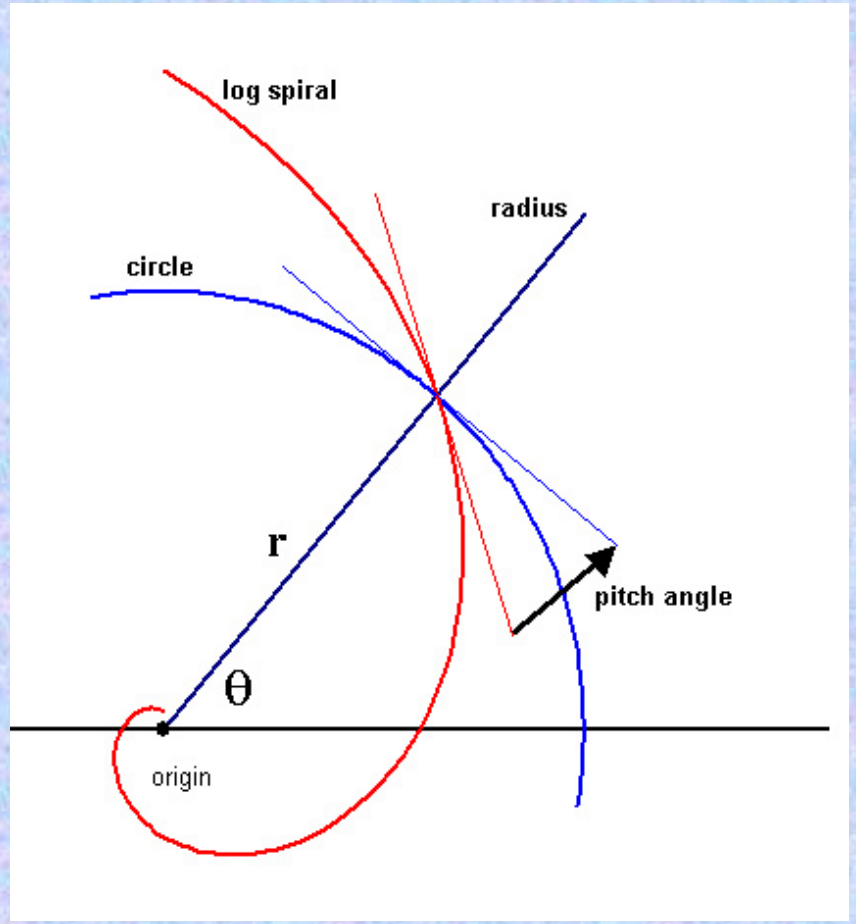




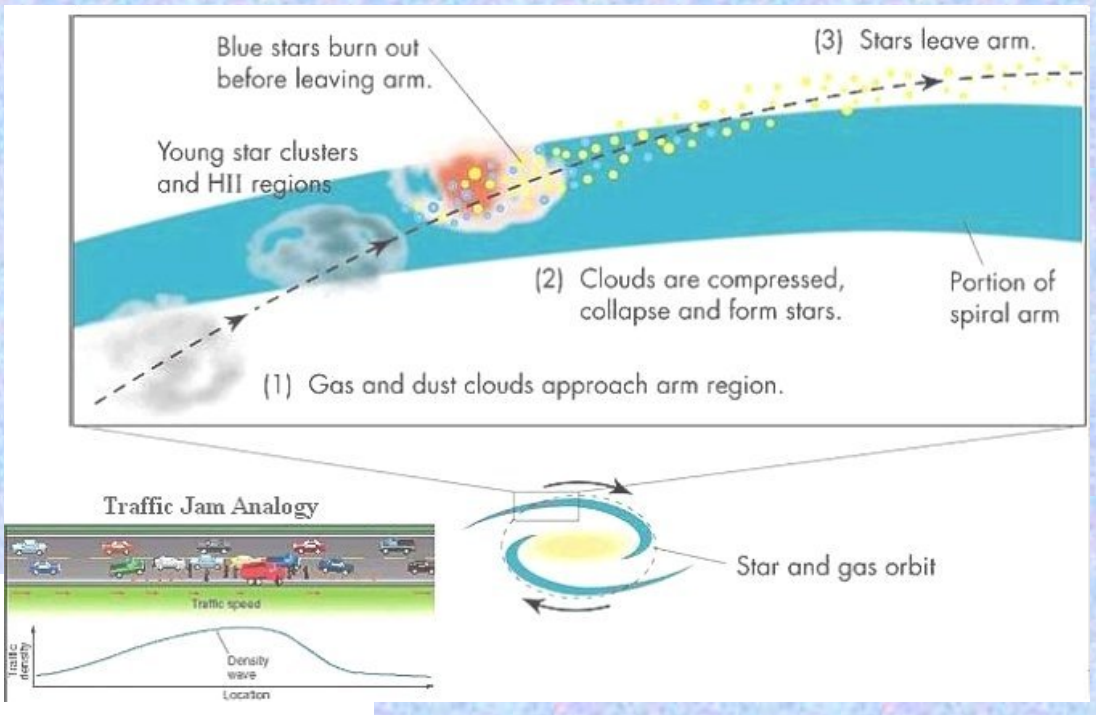
The MWG model:

- Ndis=68, Mdyn=10^{12} M_0 Mdisk=6.5$10^{10}$ M_0 Ropt=12 kpc
- N(ε_M)=4, N(ε_H)=5




log spiral
radius
circle
r
pitch angle
θ
origin

-Prescriptions from Junqueira et al. for the overdensity due to the arms



$$\Sigma_{sw}(R,\theta) = \Sigma_{so} e^{-\frac{R^2}{\sigma^2}[1-\cos(m\theta - f_m(R))]}$$

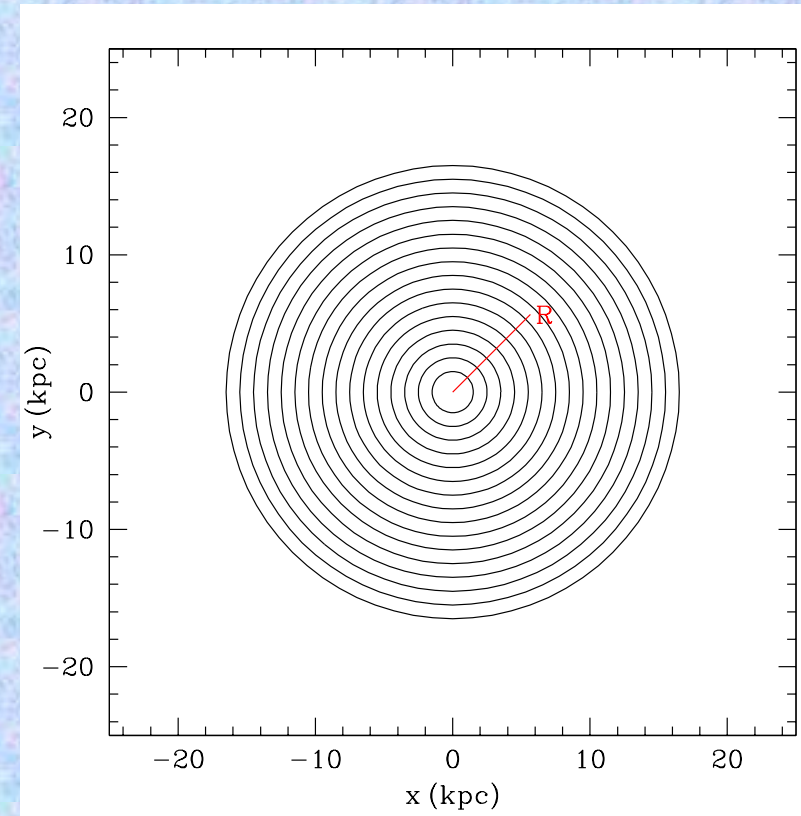
where

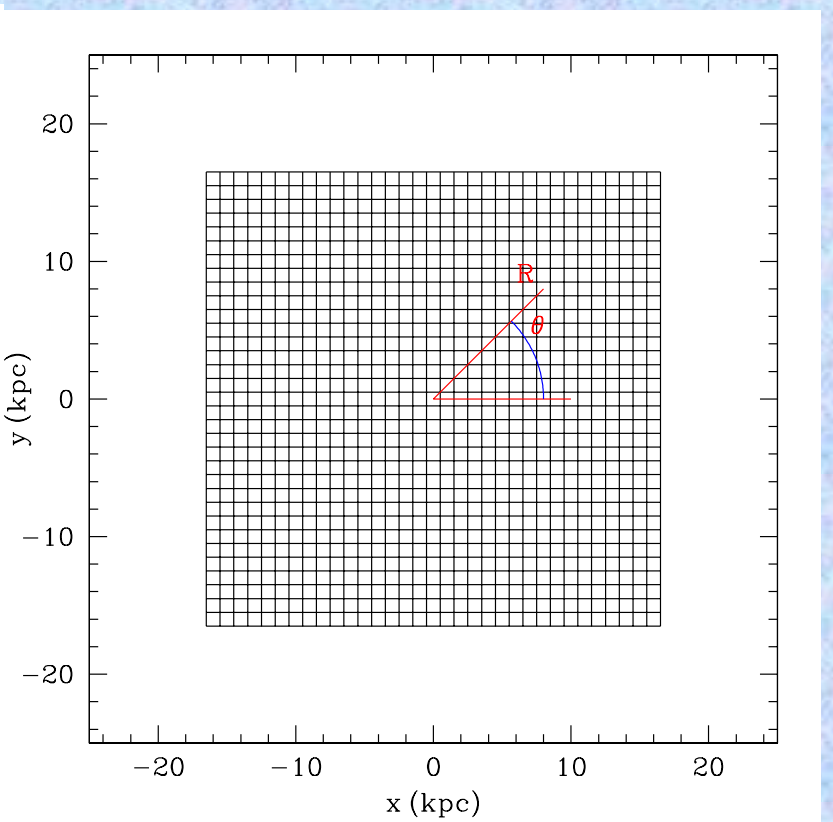
$$\Sigma_{so}(R,\theta) = \frac{\zeta_0 m}{2\pi G} \frac{R^2}{\sigma^2 \mid \tan i \mid} e^{-\varepsilon_s R}$$

with $f_m(R)$ being the shape function given by:

$$f_m(R) = \frac{m}{\tan(i)} \ln(R/R_i) + \gamma$$

The scheme of work

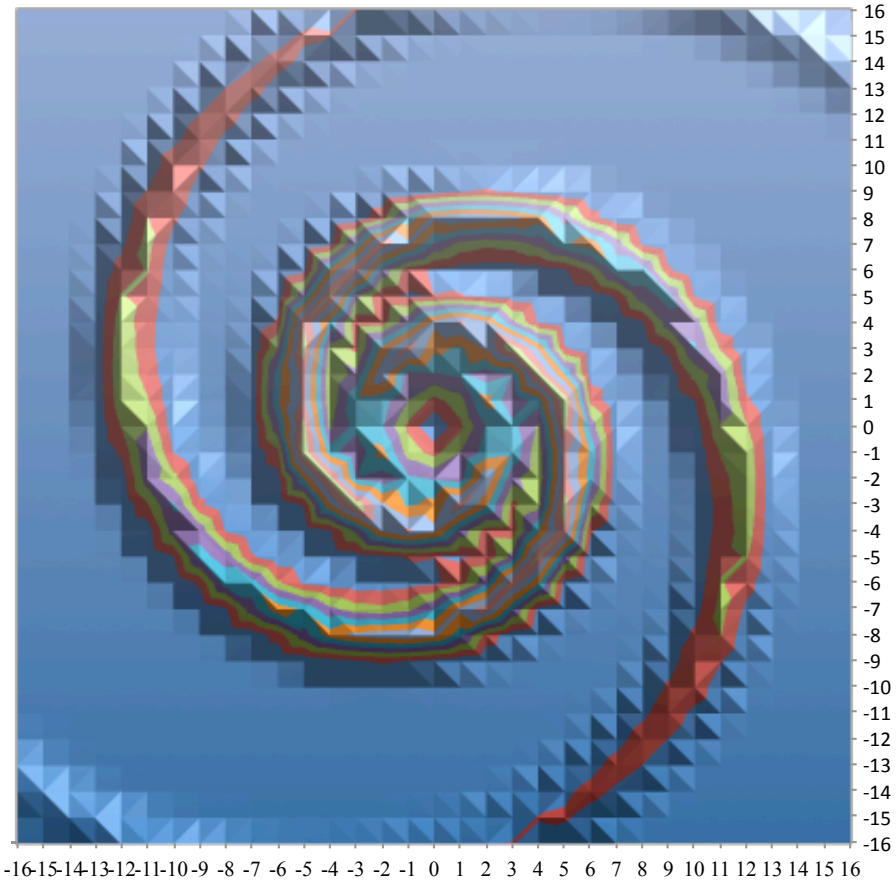




We change our scenario with asy-simetrical simetry (R) with concentric radial regions, in other with small regions 1kpcx1kpc area defined by

(R,ϑ) or (x,y)

The spiral density wave



We calculated the Spiral density wave with Equations by Junqueira et al. (2013)

$$\Sigma_{sw}(R,\theta) = \Sigma_{so} e^{-\frac{R^2}{\sigma^2}[1-cos(m\theta - f_m(R))]}$$

where

$$\Sigma_{so}(R,\theta) = \frac{\zeta_0 m}{2\pi G} \frac{R^2}{\sigma^2 \mid \tan i \mid} e^{-\varepsilon_s R}$$

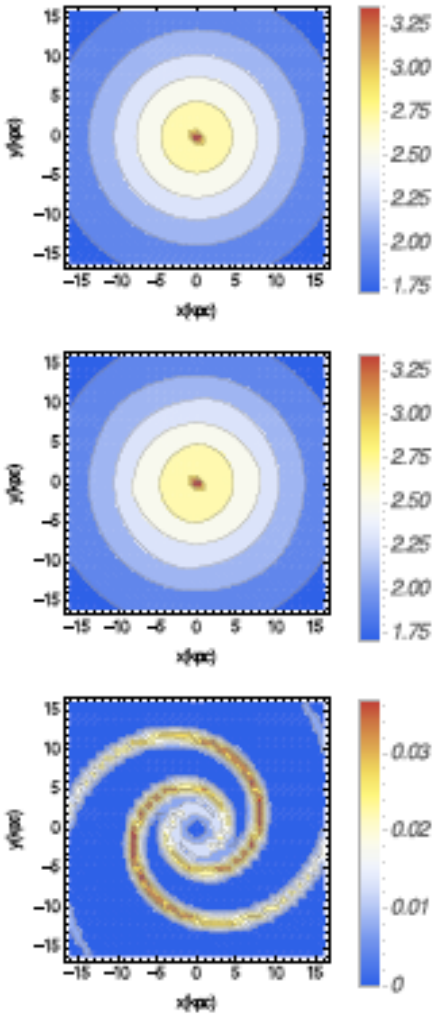
with $f_m(R)$ being the shape function given by:

$$f_m(R) = \frac{m}{\tan(i)} ln(R/R_i) + \gamma$$

$\Sigma_d(R,\vartheta)$

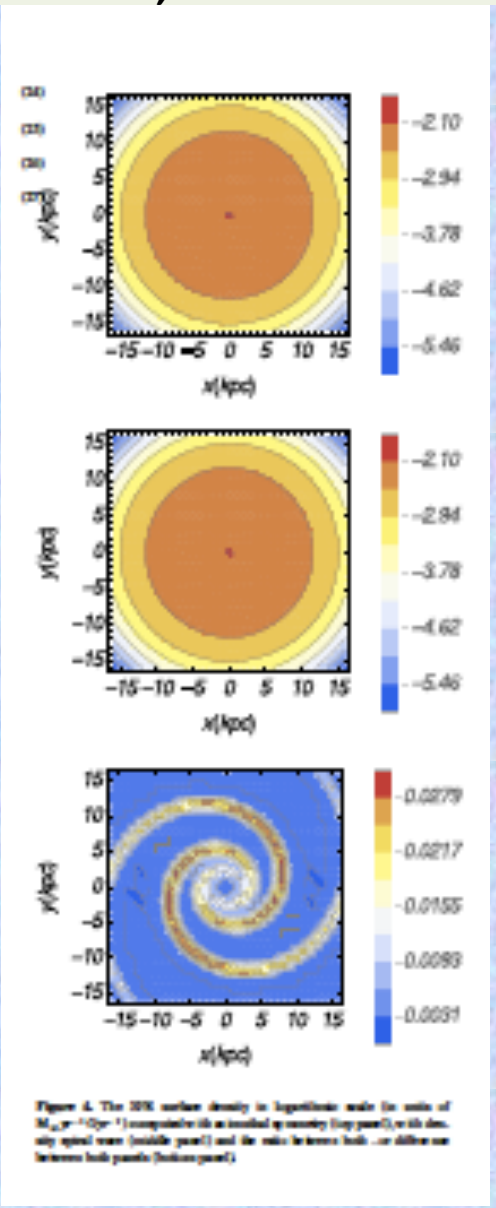
Table 2. Properties of spiral arms

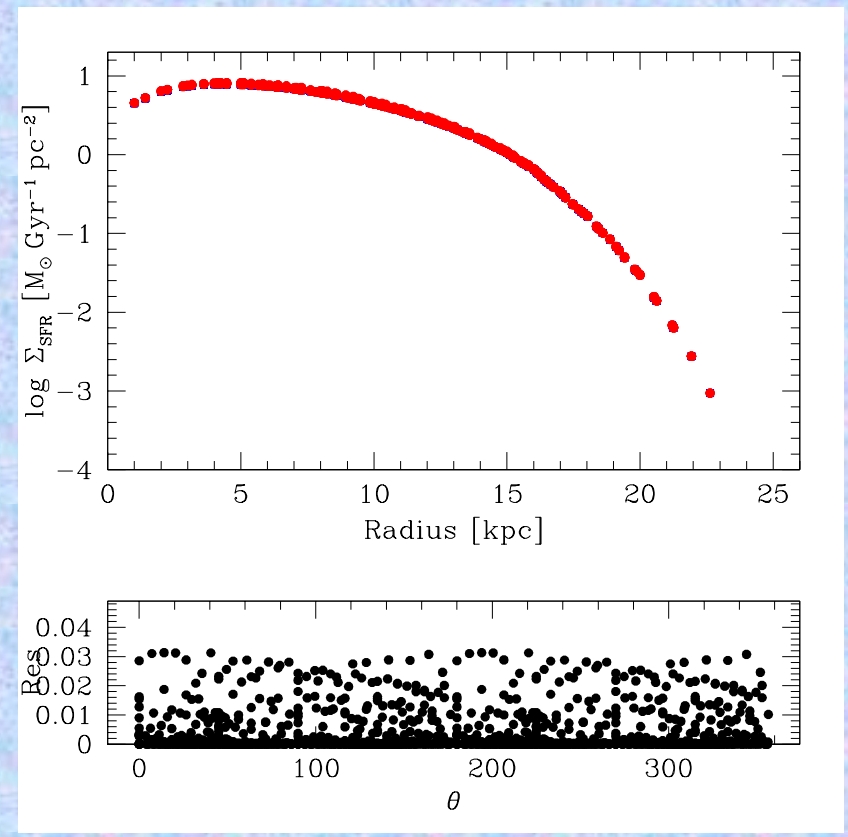
Property	symbol	value	unit
Number of arms	m	2	-
Pitch angle	i	14	-
Half width	σ	4.7	kpc
Perturbation amplitude	ζ_0	600	$km^2\ s^{-2}\ kpc^{-1}$
Scale length	ε_s^{-1}	2.5	kpc
Spiral Wave crossing distance	R_i	1.618	kpc



We add this spiral density wave as an overdensity in each region (x,y)

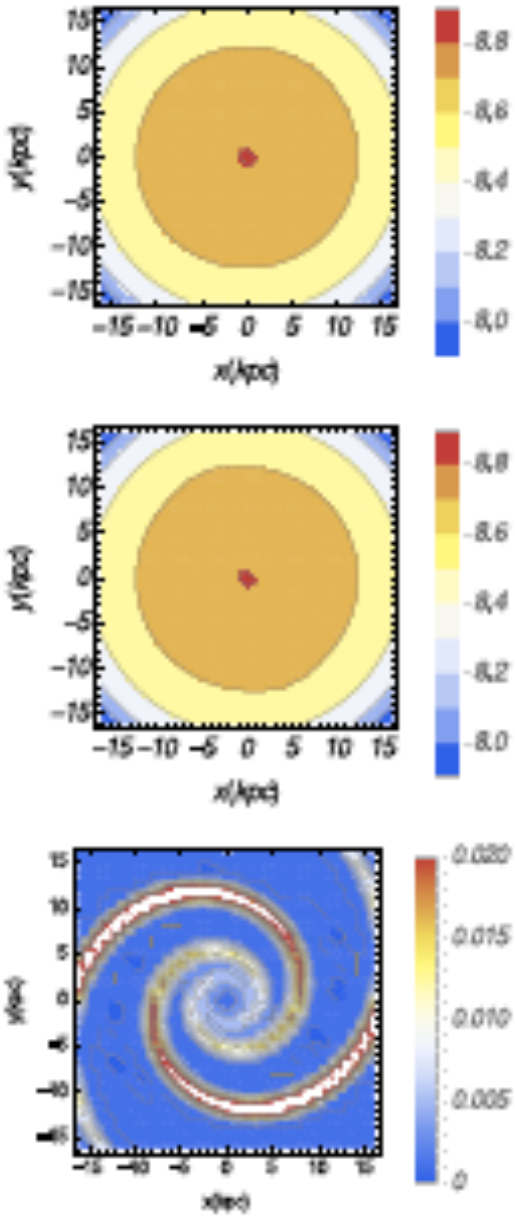
$\Sigma_{d,SFR}(R,\vartheta)$





The star formation rate surface density show maxima differences $\log(\Sigma_{sw}/\Sigma_{az})$~ 0.03 dex

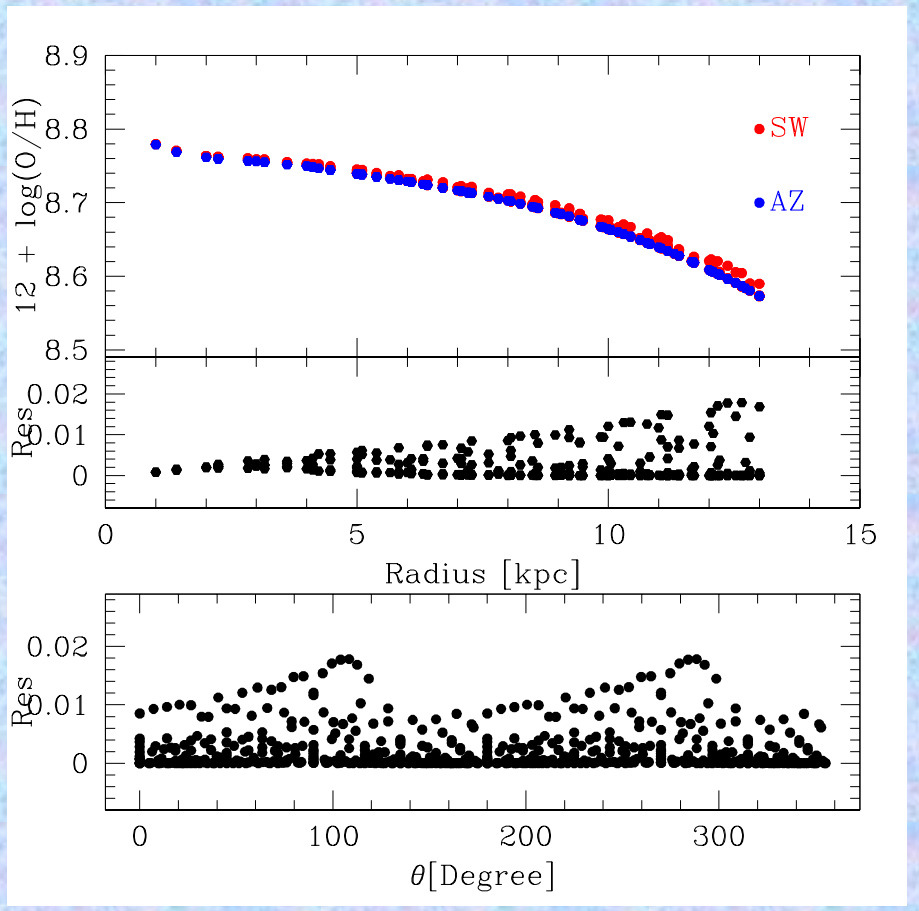
O abundances



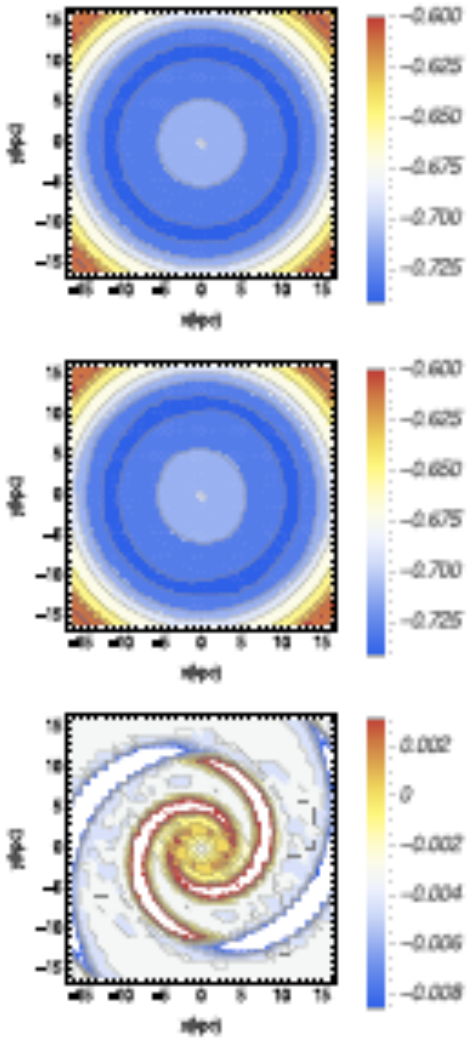
- **Differences in the Oxygen abundances are smaller than in SFR: $\log(O_{sw}/O_{az}) < 0.02$ dex**

Larger for outer regions

Two maxima in the spiral wave locus



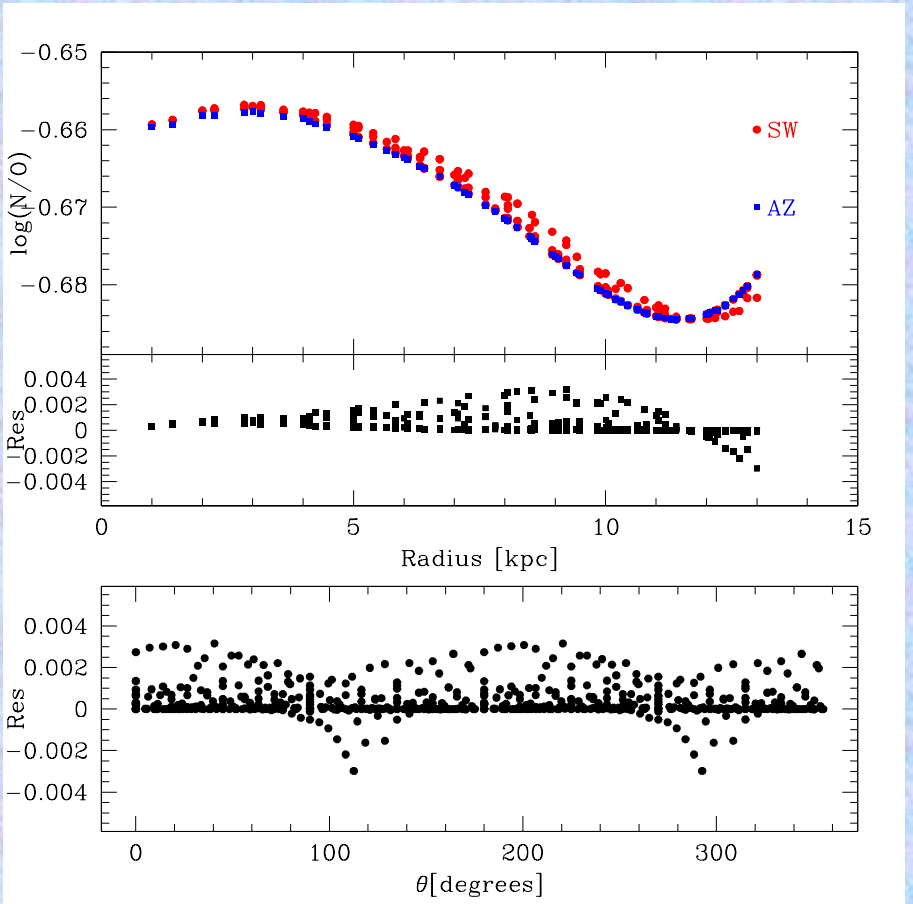
N/O abundances



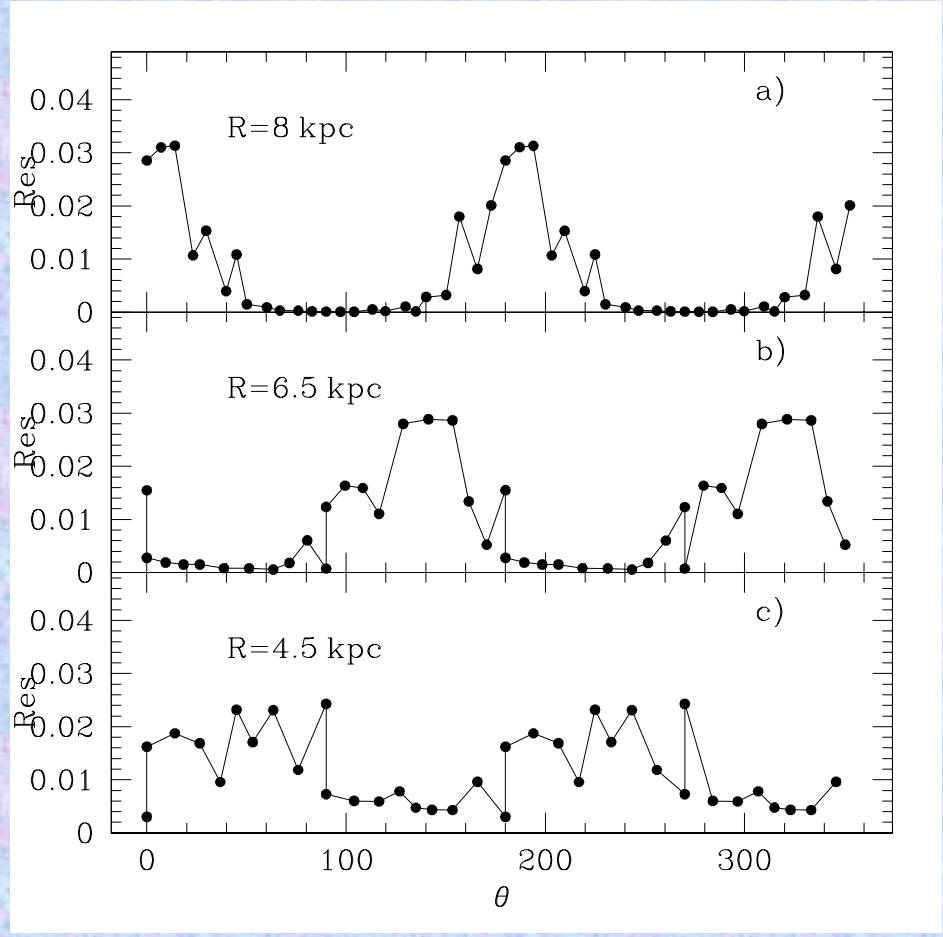
- **Differences in the N/O abundances are even smaller than in O:**
  $\log(N/O)_{sw}/(N/O)_{az}) < 0.002$ dex

Positive and negative values

Differences not located in the arms



SFR



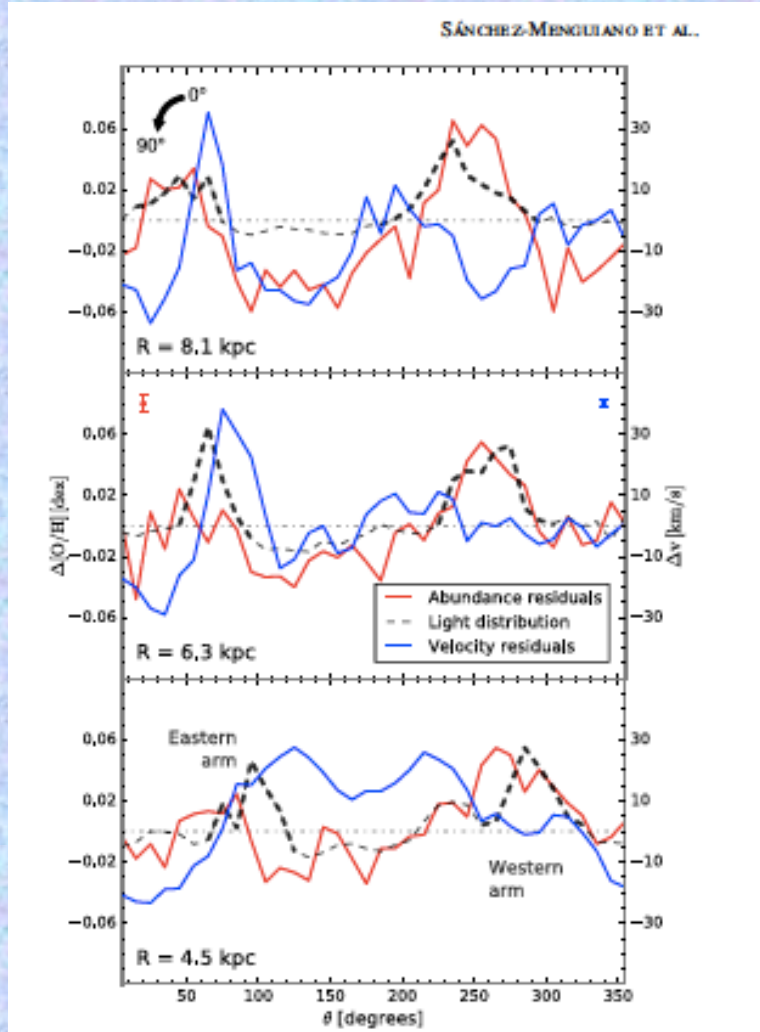
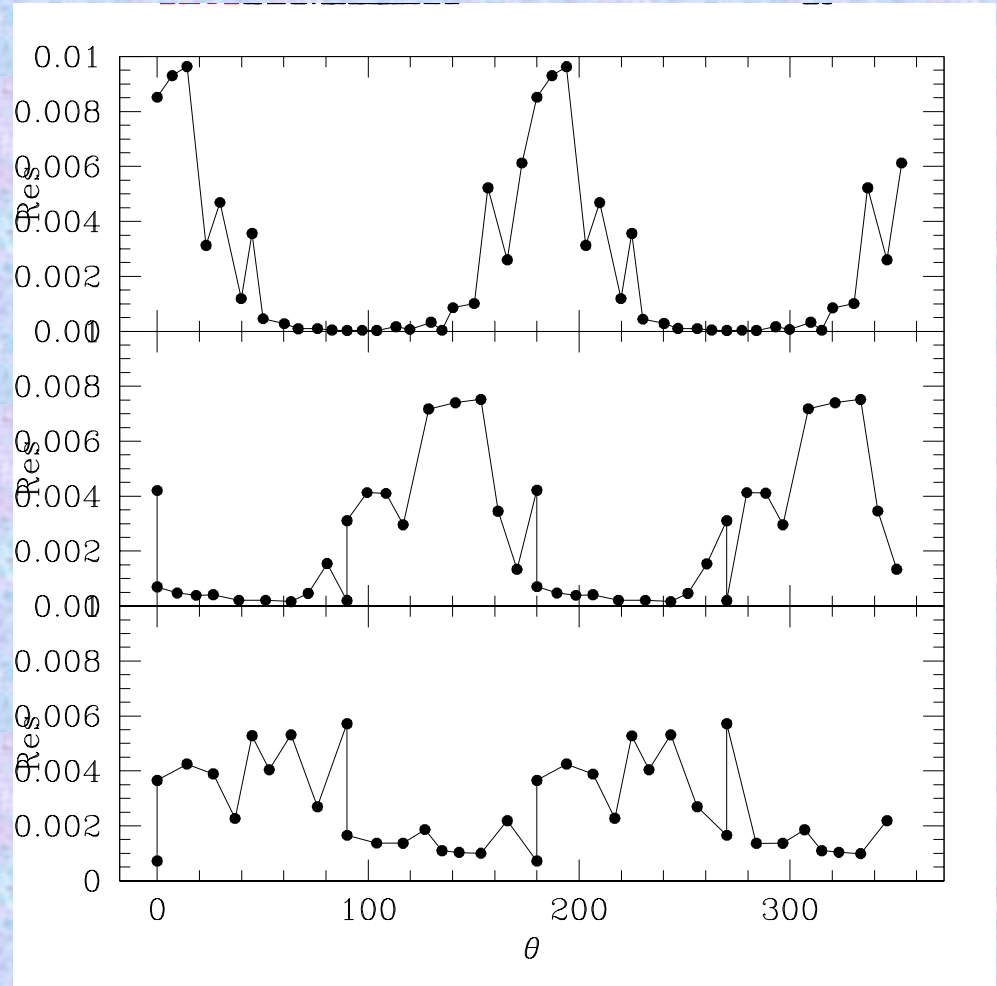


Figure 2. Azimuthal profiles of the light (black dashed), oxygen abundance residuals (blue, left-hand *y*-axis), and Hα LOS velocity residuals (red, right-hand *y*-axis) at three different radii (shown in Figure 1). The position of the spiral arms is marked with the bold dashed line. Mean errors in the azimuthal profiles are denoted by the vertical lines in the middle panel. The angles are measured counterclockwise from the positive *X*-axis in Figure 1.

Diferences az/sw for 3 galactocentric radii

O/H



Diferences az/sw for 3 galactocentric radii

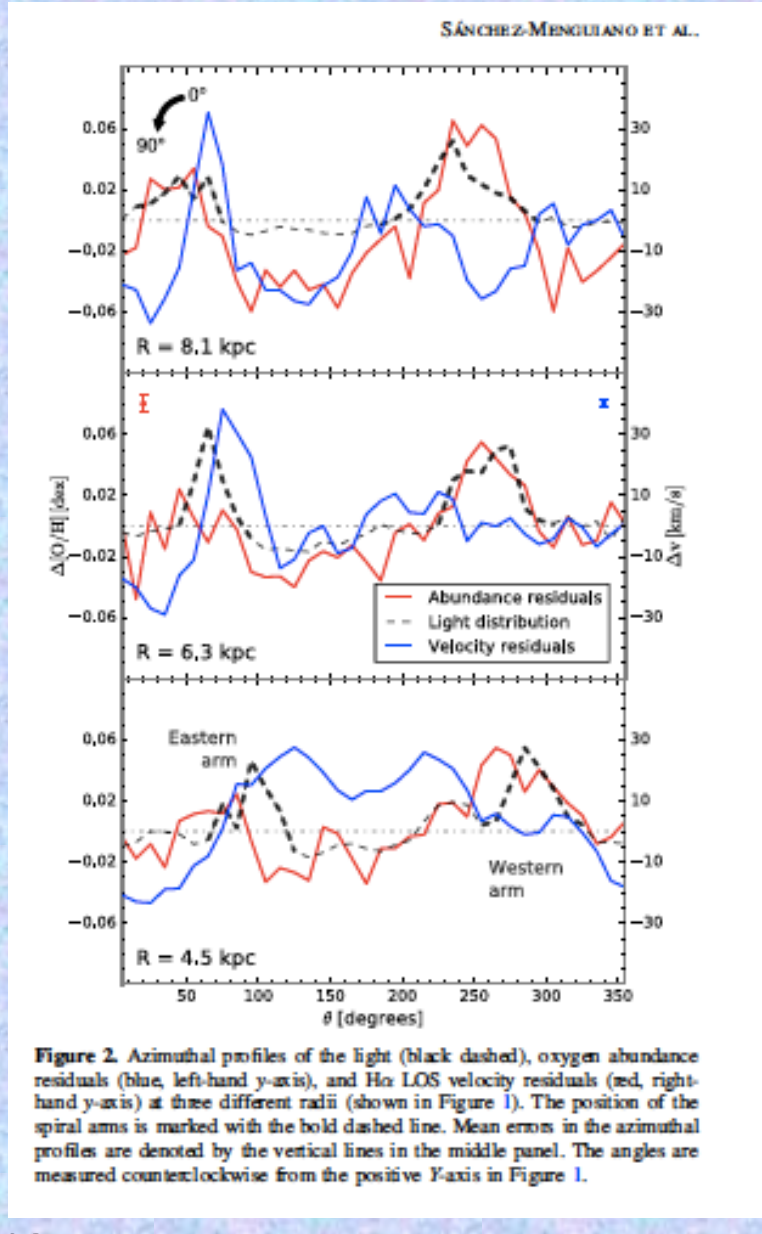


Figure 2. Azimuthal profiles of the light (black dashed), oxygen abundance residuals (blue, left-hand *y*-axis), and Hα LOS velocity residuals (red, right-hand *y*-axis) at three different radii (shown in Figure 1). The position of the spiral arms is marked with the bold dashed line. Mean errors in the azimuthal profiles are denoted by the vertical lines in the middle panel. The angles are measured counterclockwise from the positive *X*-axis in Figure 1.

Summary

- Differences are smaller tha erro bar in O/H and N/O if the contrast parameter is < 15%
- Check the time in which the spiral density wave may be included
- Check the influence of other parameters over the contrast and over the abundances (observational point of view)
- Next step: a spiral density wave variable on time