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THE EVOLUTION OF N/O IN GALAXIES: THE ROLE PLAYED BY THE STAR FORMATION RATE

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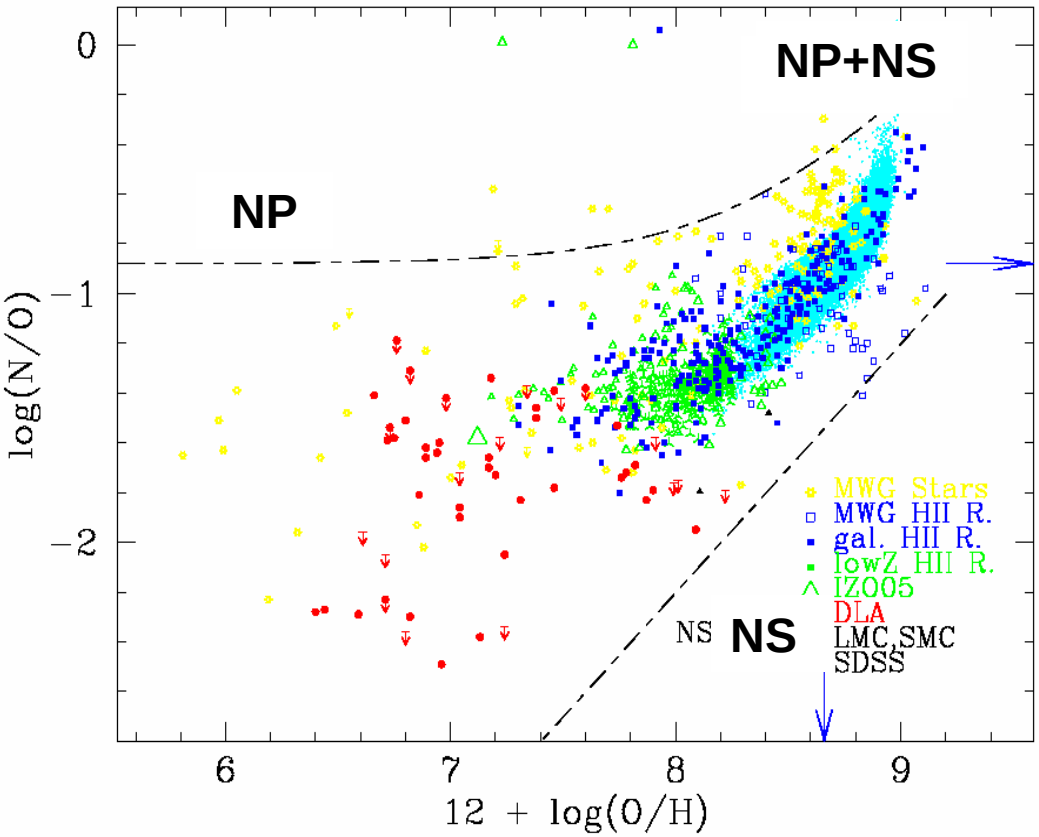
ABSTRACT

- Our objetive is to explore if different star formation efficiencies produce different tracks in the N/O-O/H plane and to check if the results show acceptable trends as compared with the data.

- In order to do that, we analyze the evolution of nitrogen resulting from a set of spiral and irregular galaxy models computed for a large number of input mass radial distributions and with various possible star formation efficiencies for each one of them (Mollá & Díaz, 2005).

- We use the same basic set of stellar yields: Woosley & Weaver (1995) for massive stars and Gavilán et al. (2005), which have a certain proportion of primary nitrogen, for low mass and intermediate stars.

THE PLANE N/O-O/H

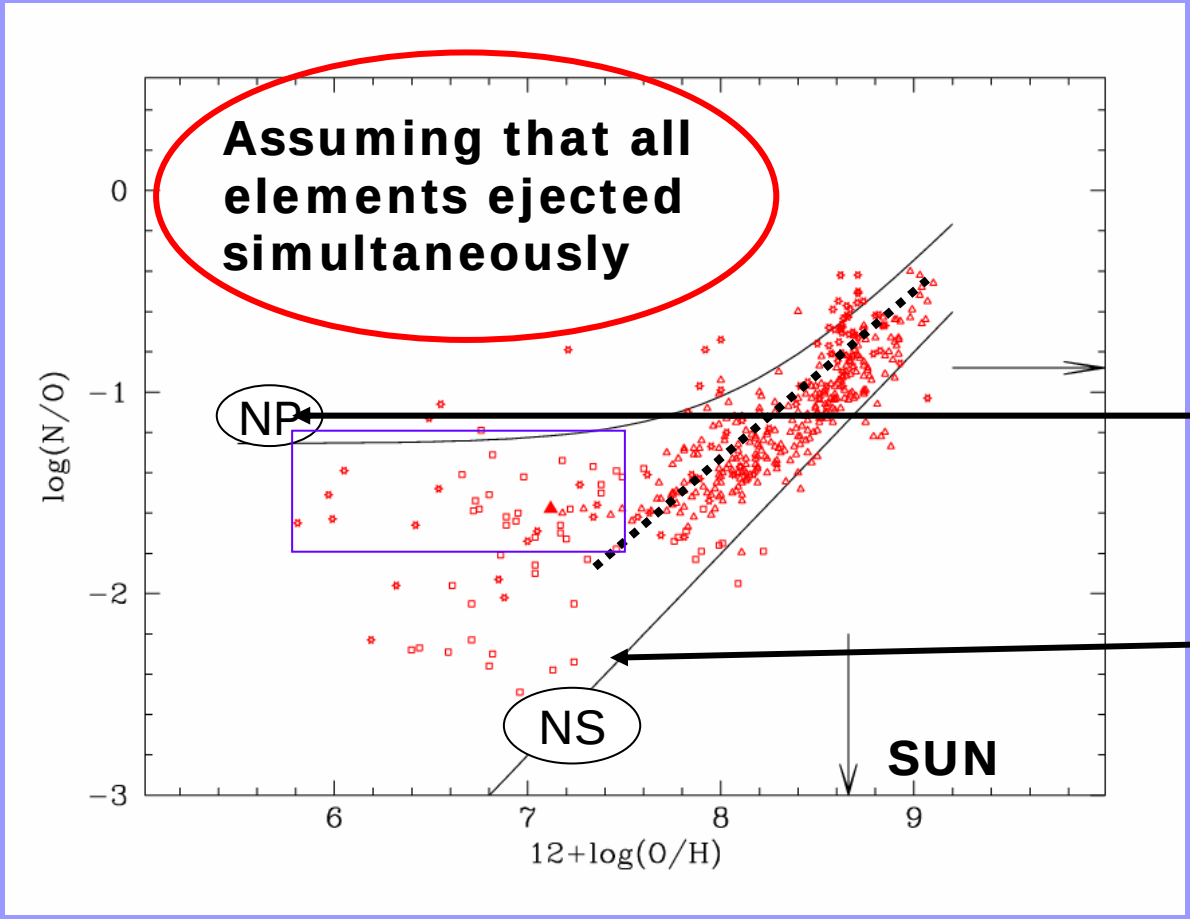


The whole set of data in the plane N/O-O/H is limited by three possible theoretical lines:
1) NS, when N needs a seed of O to be created.
2) NP when N is created directly from H or He for any oxygen abundance.
3) NS+NP when both contributions there exist.

It is evident from the data that a primary N contribution must be exist

If there exists a seed of C or O in the star, N forms as secondary

Otherwyse, N is created as primary



Closed Box Model

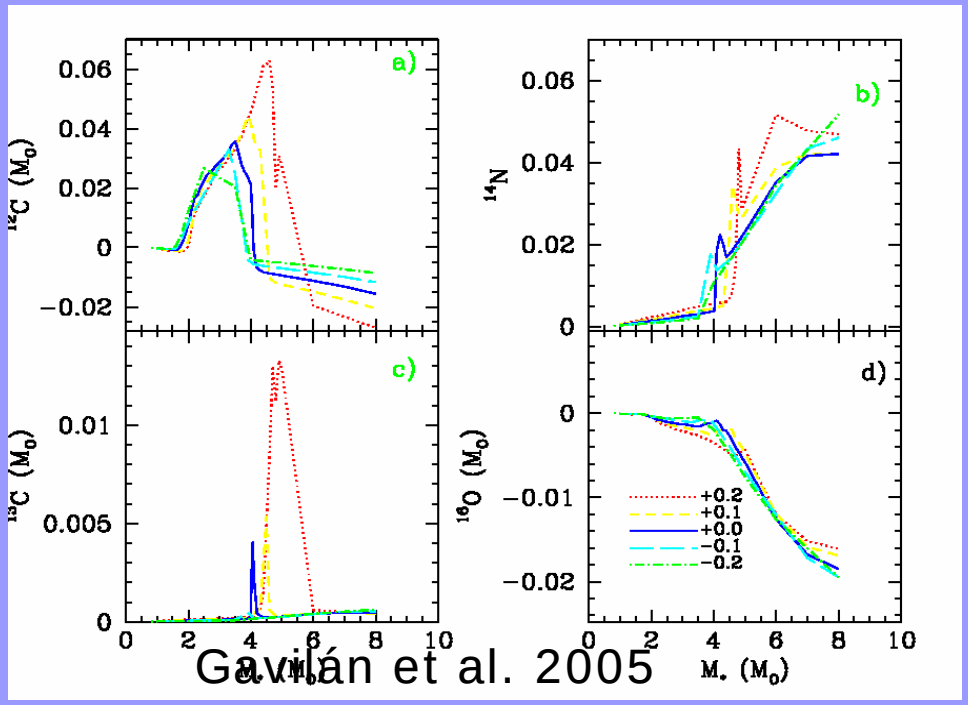
$$Z = p \ln \mu^{-1}$$

$$\frac{N}{O} = \frac{p_N}{p_O} = cte$$

$$\frac{N}{O} = \frac{p_N(O)}{p_O} \propto O$$

The need of a primary component appears soon when the low metallicity data are included in a plot N/O *vs* O/H

LIM STAR NEW YIELDS



Gavilán et al. 2005

- The evolution of a LIM star during the TP-AGB phase is dominated mainly by two processes: The third dredge up events and the Hot Bottom Burning (HBB).
- The first ones affect stars with masses between 2 Mo and 4 Mo, by increasing the abundance of carbon. In stars more massive than 4Mo, the HBB produces an abrupt increase of nitrogen (with a proportion of primary N) and a similar decrease of carbon.
- It is necessary to take into account the transformation from carbon in nitrogen during the HBB phase.

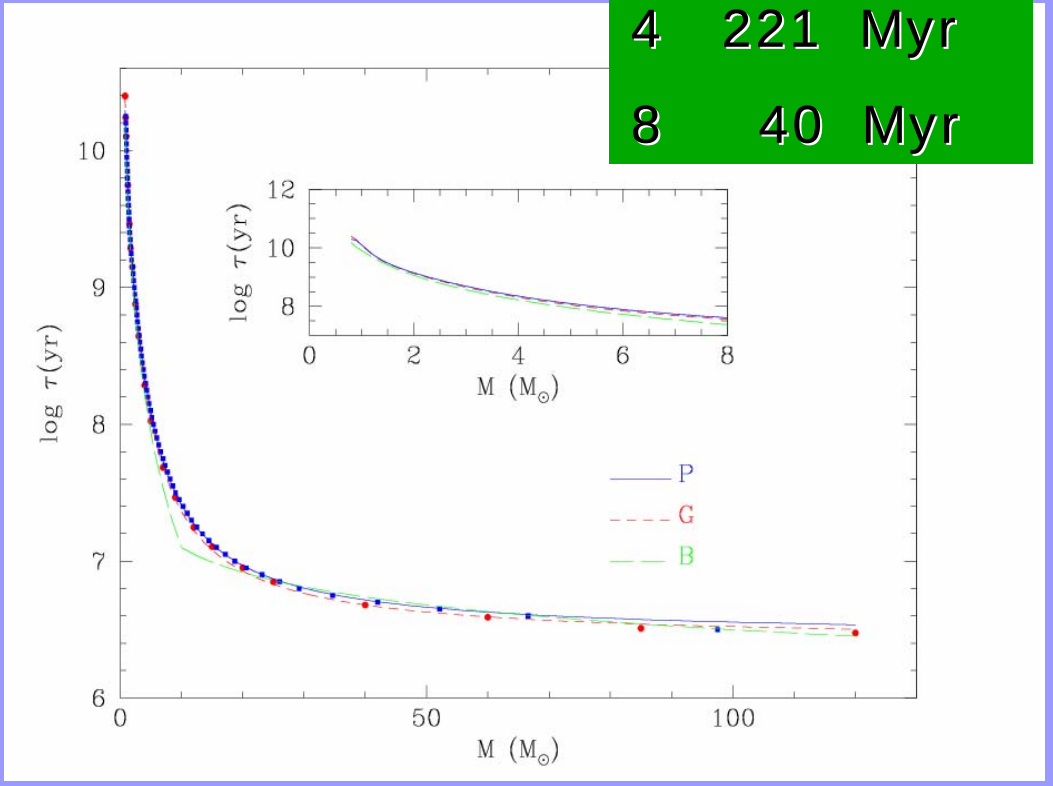
The mass loss depends on the metallicity because its rate depends on the stellar radius which decreases with metallicity decreasing: This affects the yields by increasing the time a star spends on the TP-AGB allowing for more dredge-up events to occur, increasing the amount of primary production of either carbon or nitrogen.

The HBB causes an increase of ^{14}N and a decrease of ^{12}C

The stellar meanlifetimes

- Massive stars (M > 8 Mo) produce O and secondary N, without delay
- Low and intermediate mass stars (4 < M < 8) create both, primary and secondary nitrogen
- They die a time τ after the oxygen appears in the ISM

2	1212 Myr
4	221 Myr
8	40 Myr



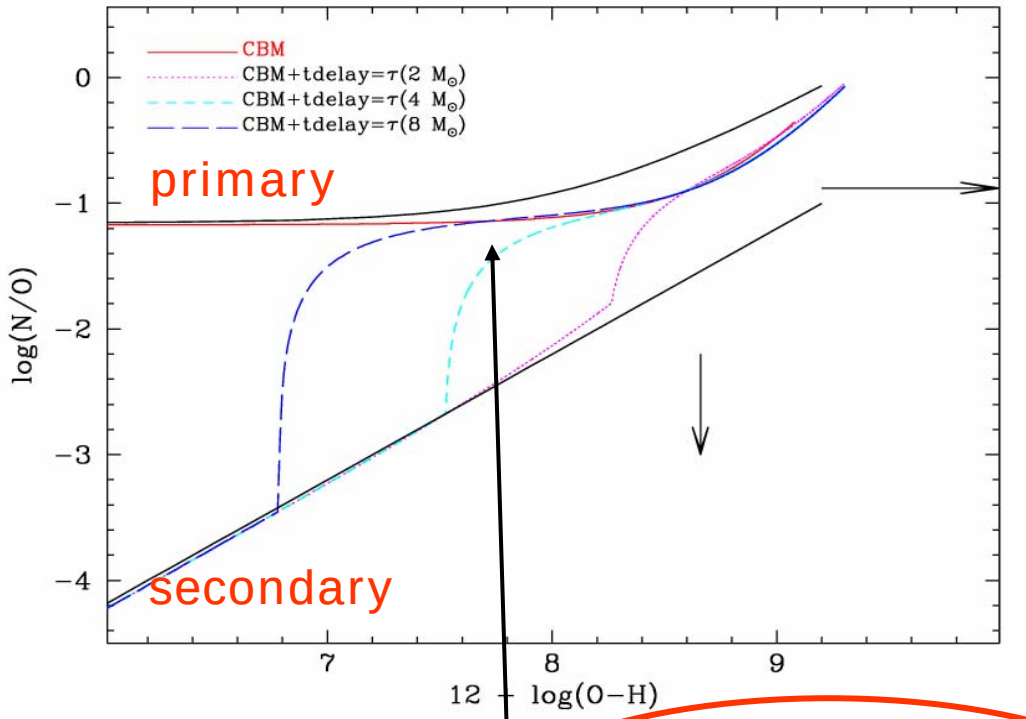
If the NP is ejected by low and intermediate mass stars, it will appear in the interstellar medium after a time delay, that is after O/H reaches a certain value (Henry et al. 2000)

The massive stars also produce secondary N

Two clear facts:

1) The N/O increases abruptely when the NP appears in the ISM (a change of regime)

2) The oxygen abundance at which the change occurs depends on the mass of the first stars that eject NP



(Henry et al. 2000)

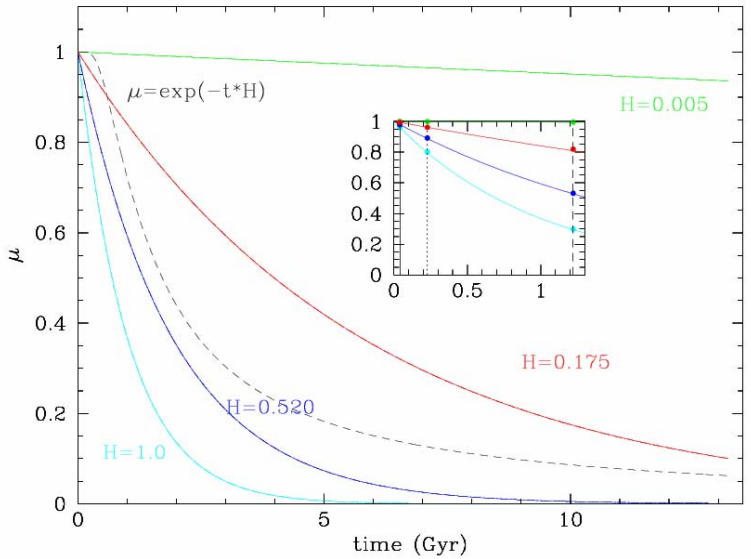
$$Z_N = \frac{p_{s,N}\,p_{p,C}}{2\,p_O^2}\,Z_O^2 + \frac{p_{s,N}\,p_{s,C}}{6\,p_O^2}\,Z_O^3 + \frac{p_{p,N}}{p_O}\,(Z_O - Z_\tau)\exp\frac{Z_\tau}{p_O}$$

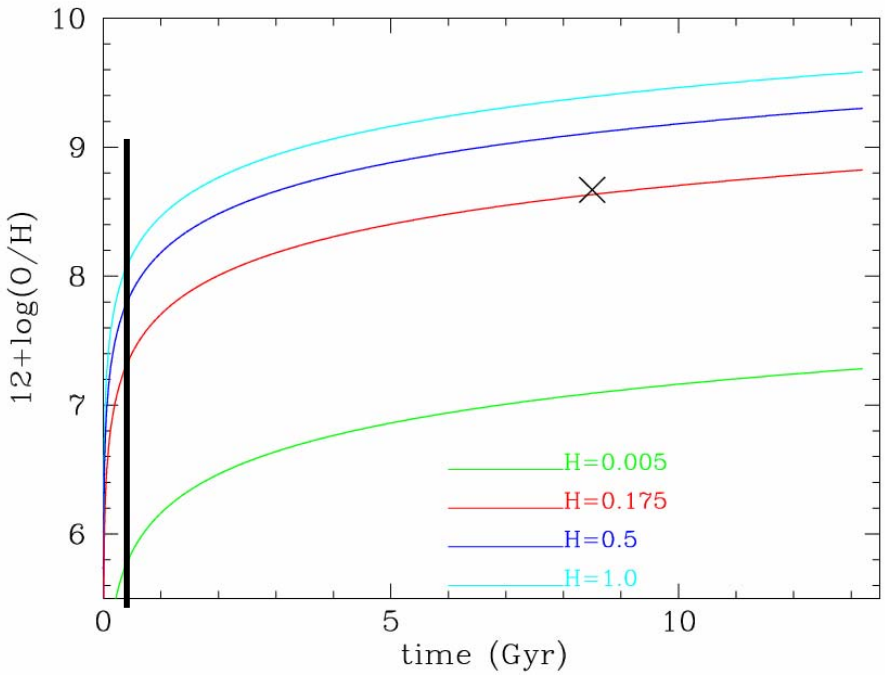
One must calculate $Z_\tau = Z_o(\text{delay})$

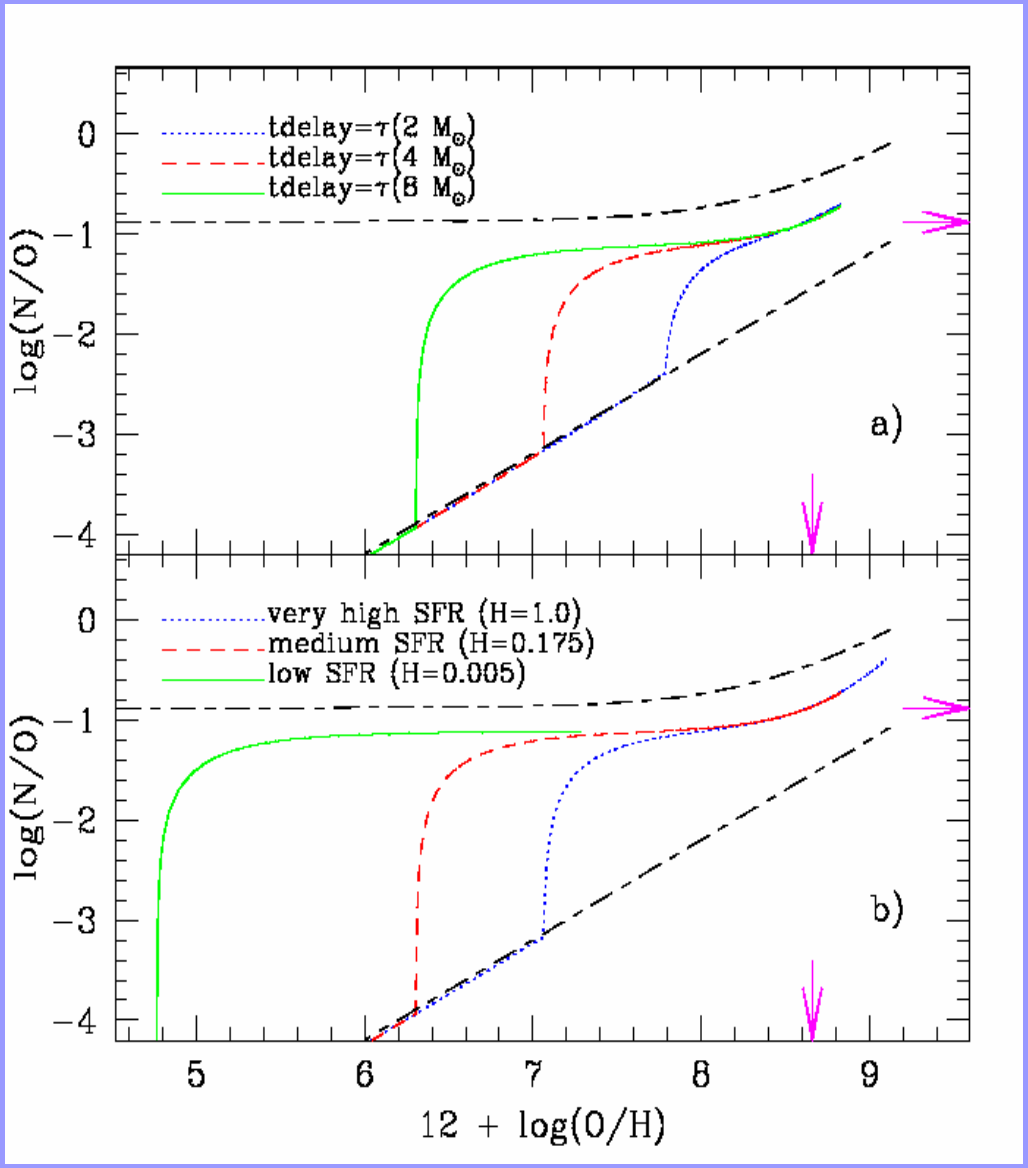
$$Z_O(\tau) = p_O \ln \mu^{-1}(\tau)$$

The star formation rate

$$\mu(t) = \exp(-t*H)$$



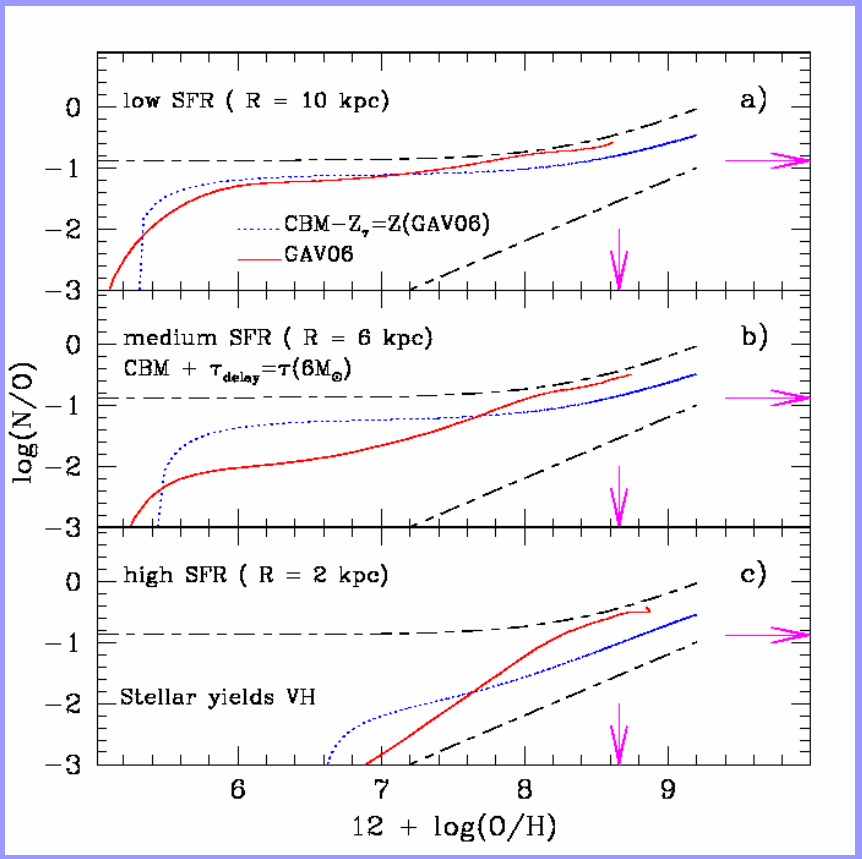


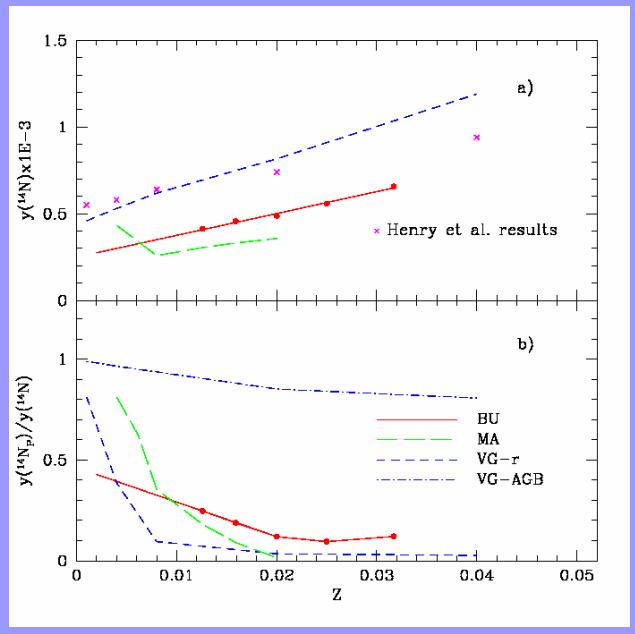


The resulting N/O depends on the meanlifetime of the star and on the efficiency to form stars

The oxygen abundance is not a time scale

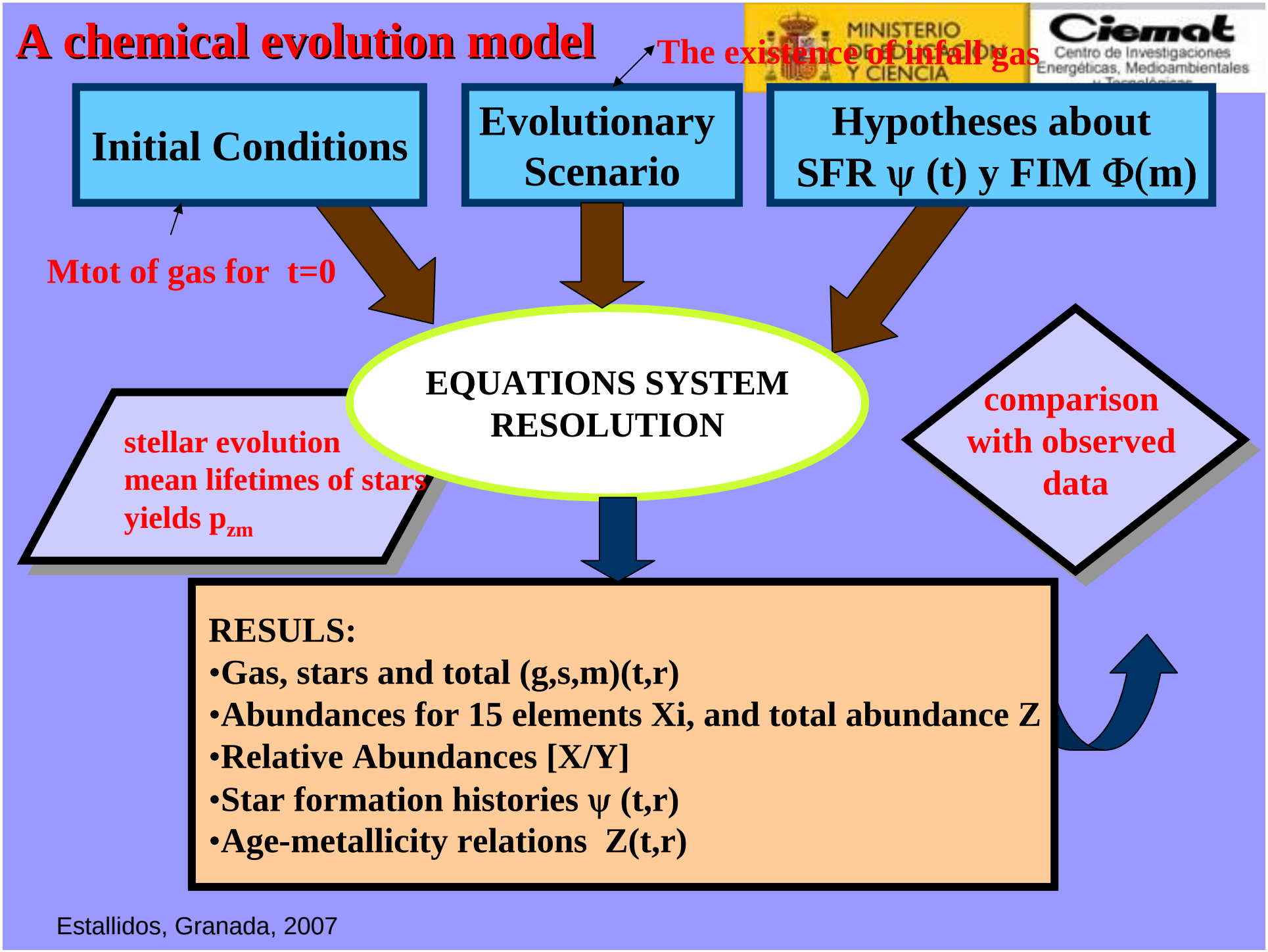
The effect of metallicity dependent yields



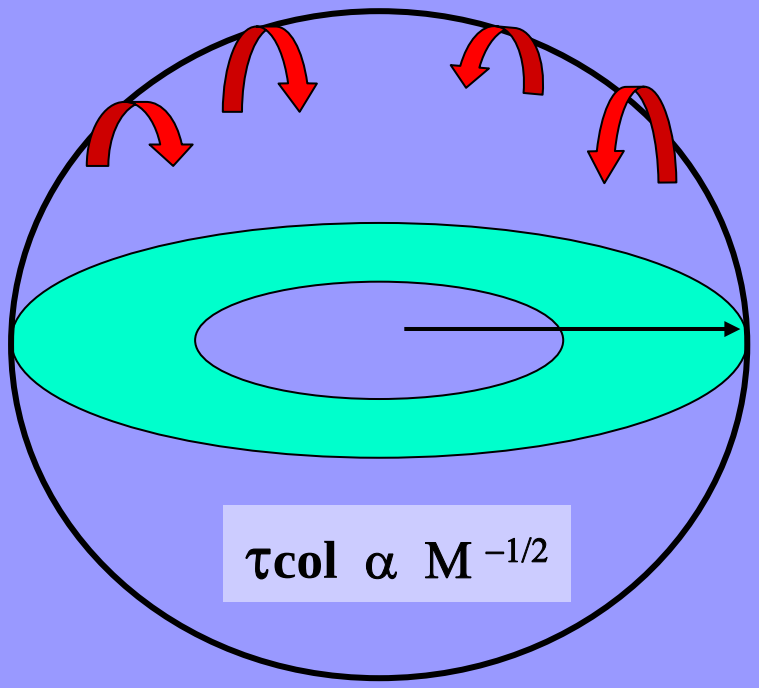


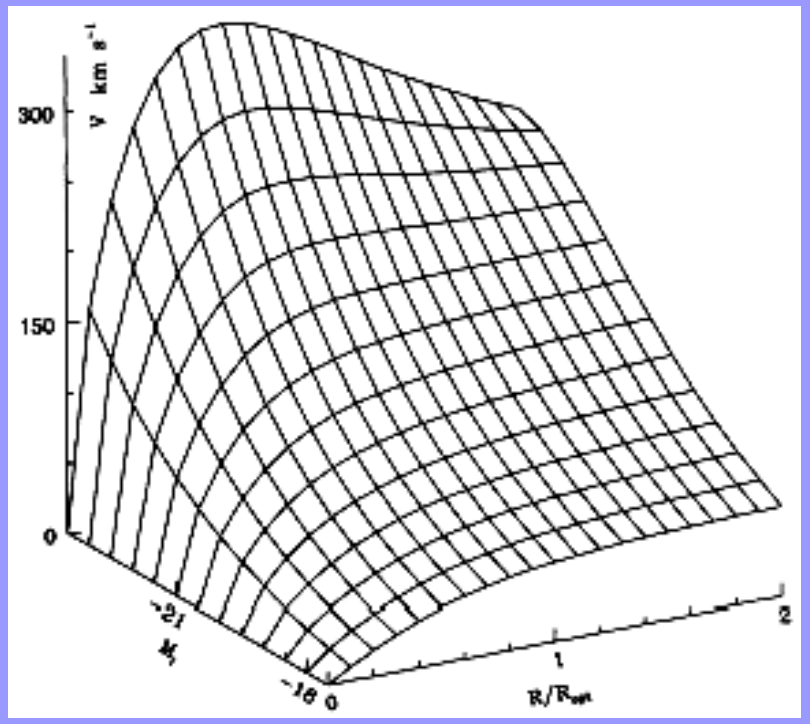
The effect of using metallicity dependent yields: the tracks in the plane N/O--O/H are diagonally elongated.
This occurs for the simple model and for more sophisticated numerical models.
The NP is larger when Z is low and NS increases when Z is high

A chemical evolution model



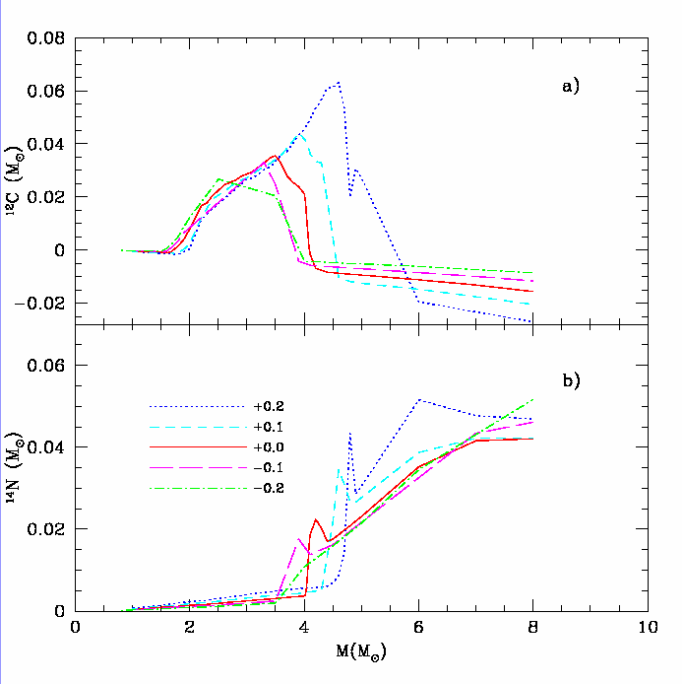
El escenario del modelo multifase



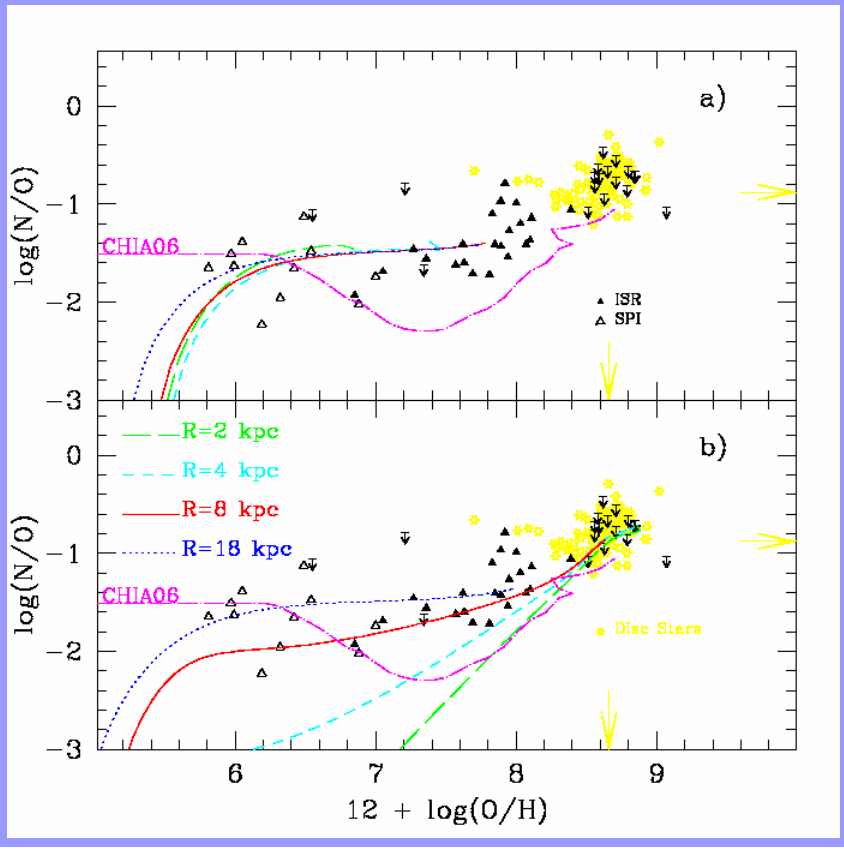


El gas de la protogalaxia tiene una masa M (R) calculada con la curva de rotación V(R) de Steel et al. (1995)

The Galactic multiphase model

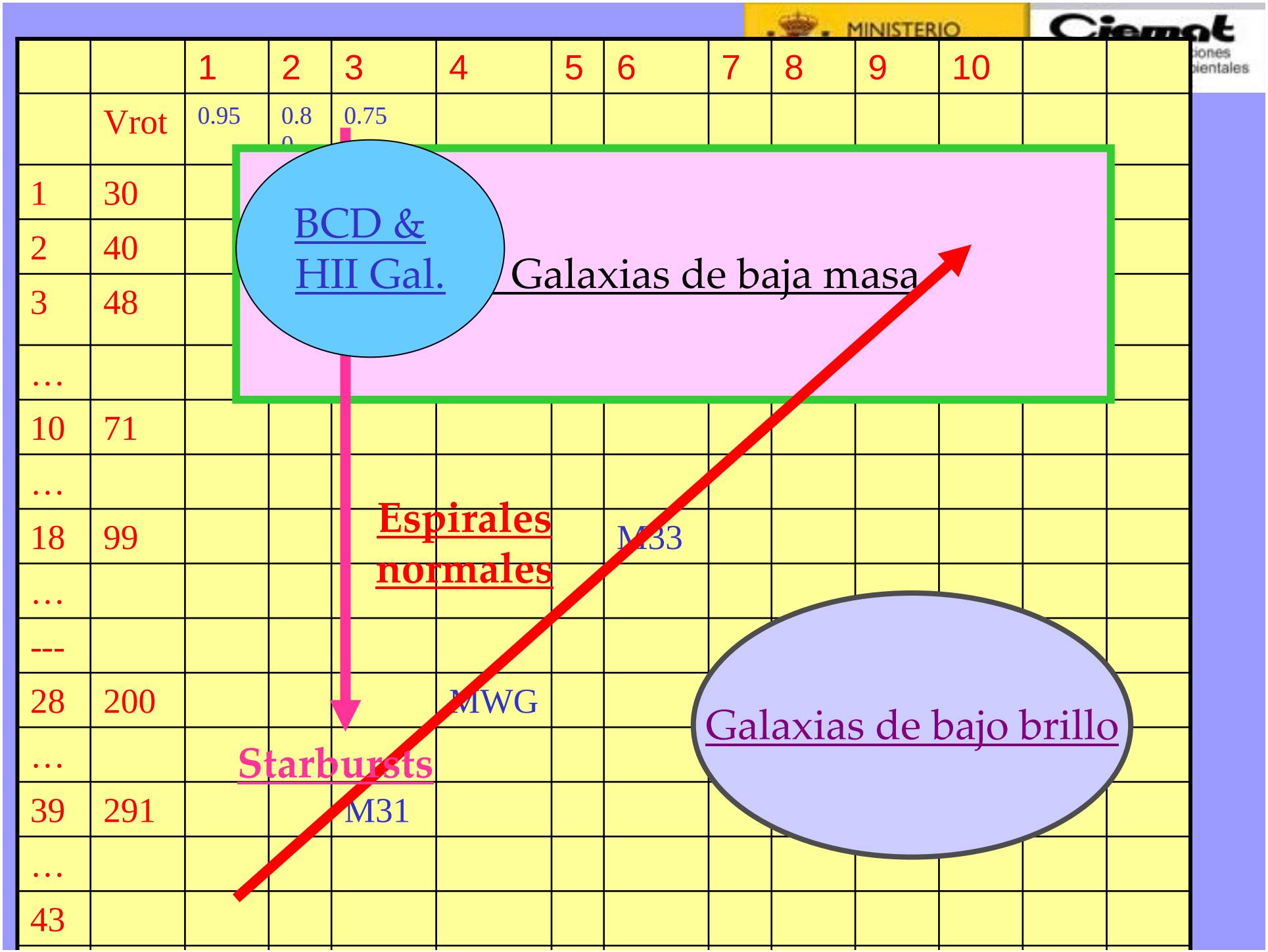


Using massive star yields from Woosley & Weaver (1995) and low and intermediate star yields from Gavilán et al. (2005), with a certain proportion of primary N, a Galactic chemical evolution model has been calculated (Gavilán et al. 2006)



Results are in agreement with the observational trends in MWG, in particular those of the halo stars from Israelian et al. (2004) and from Spite et al. (2005)

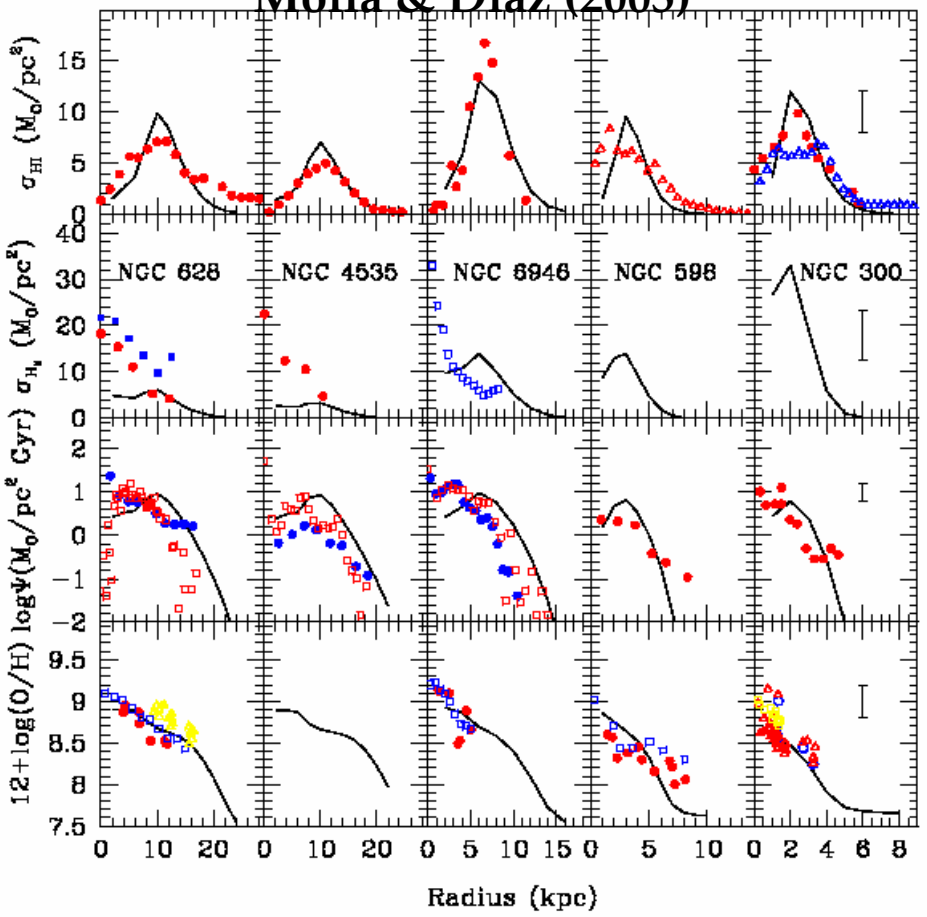
The Galactic model from Chiappini et al. (2006) where NP proceeds from low Z massive stars rotating at very high velocity is drawn as the magenta line.


1 2 3 4 5 6 7 8 9 10
Vrot
0.95
0.75
1 30
2 40
3 48
…
10 71
…
18 99
…
---
28 200
…
39 291
…
43
BCD &
HII Gal.
Galaxias de baja masa
Espirales
normales
M33
MWG
Starbursts
M31
Galaxias de bajo brillo

Resultados:

1. **Distribuciones radiales de cada galaxia para cada paso de tiempo calculado**
2. Evolución temporal de cada una de las cantidades calculadas para cada región de la galaxia
   a) Historia de la formación estelar de cada región
   b) Relación edad-metalicidad

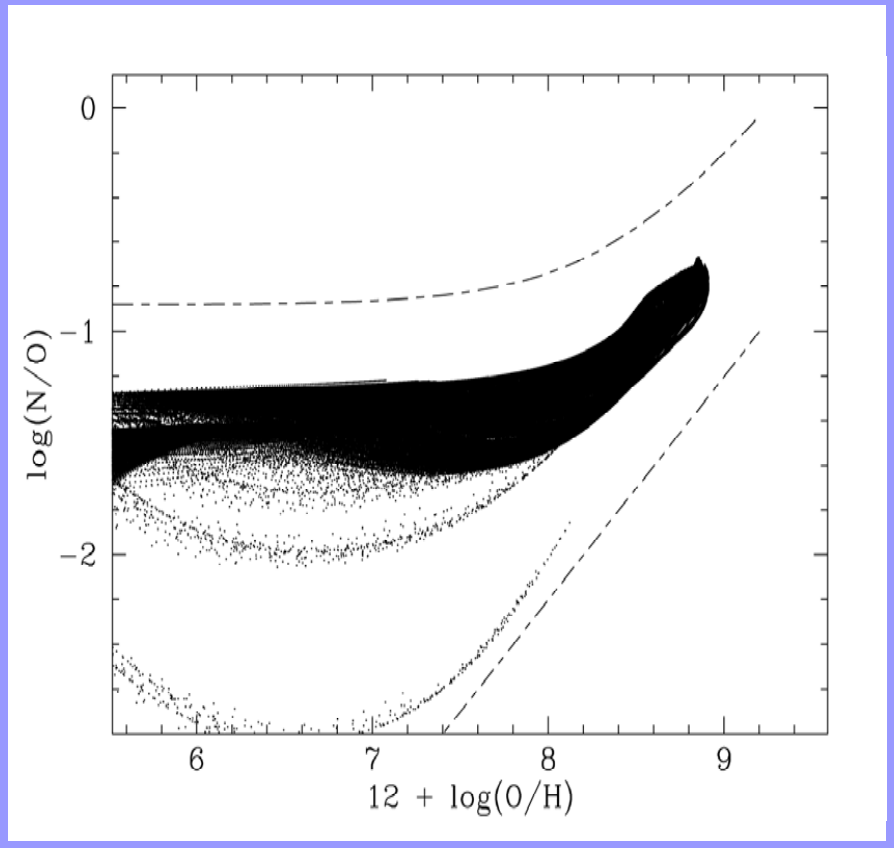
Mollá & Díaz (2005)

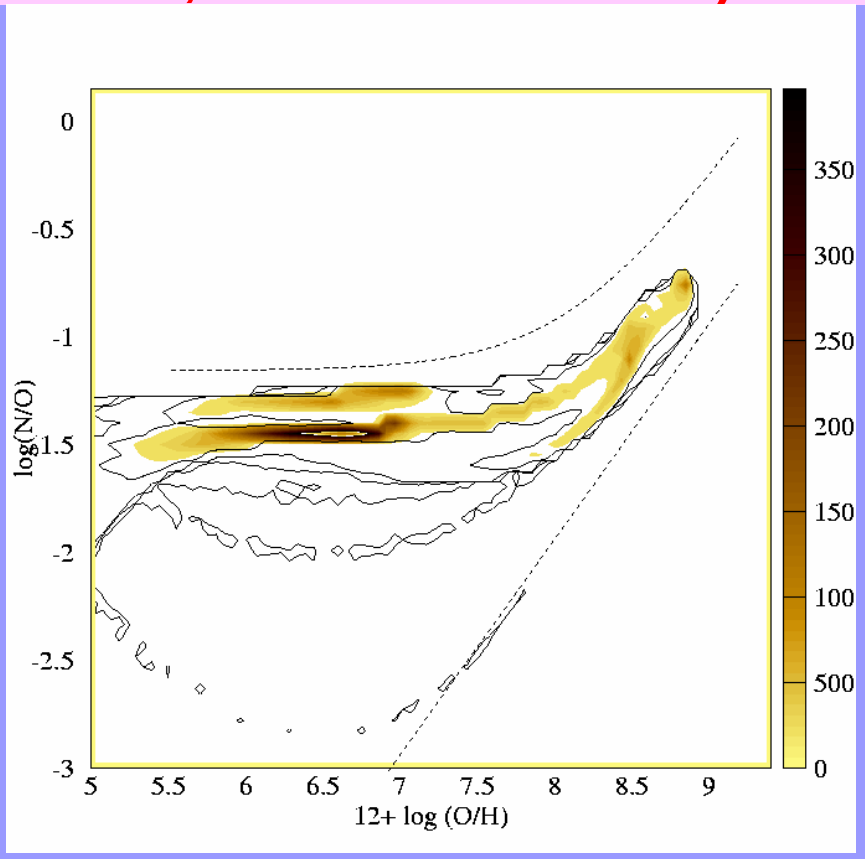


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We apply the same basic model to a wide grid of theoretical galaxies (Mollá & Díaz 2005) with 44 possible total mass radial distributions. Using 10 different star formation rate efficiencies, we have obtained these results in the plane N/O vs O/H for the whole set of models and all computed time steps (Mollá, Vílchez, Gavilán & Díaz 2006).

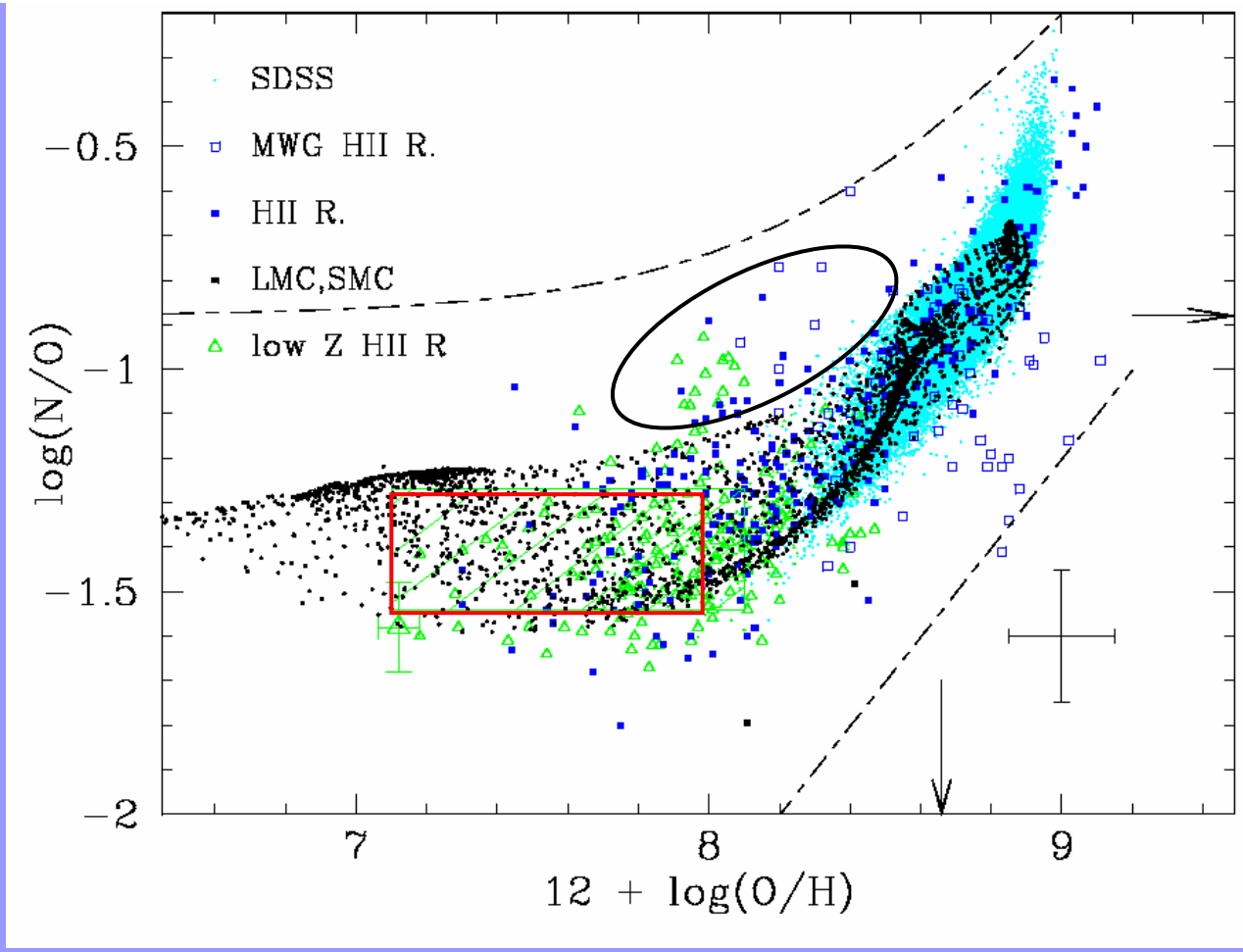




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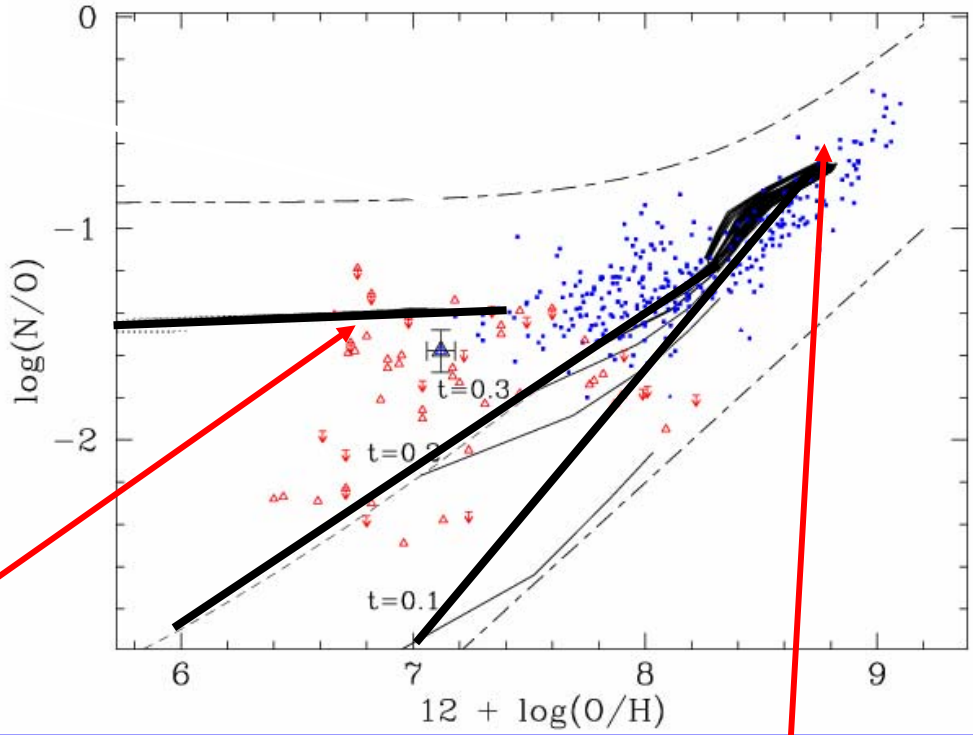
The present day abundances distribution in the plane N/O vs O/H compared with data from Galactic and extragalactic HII regions



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Time evolution of a region

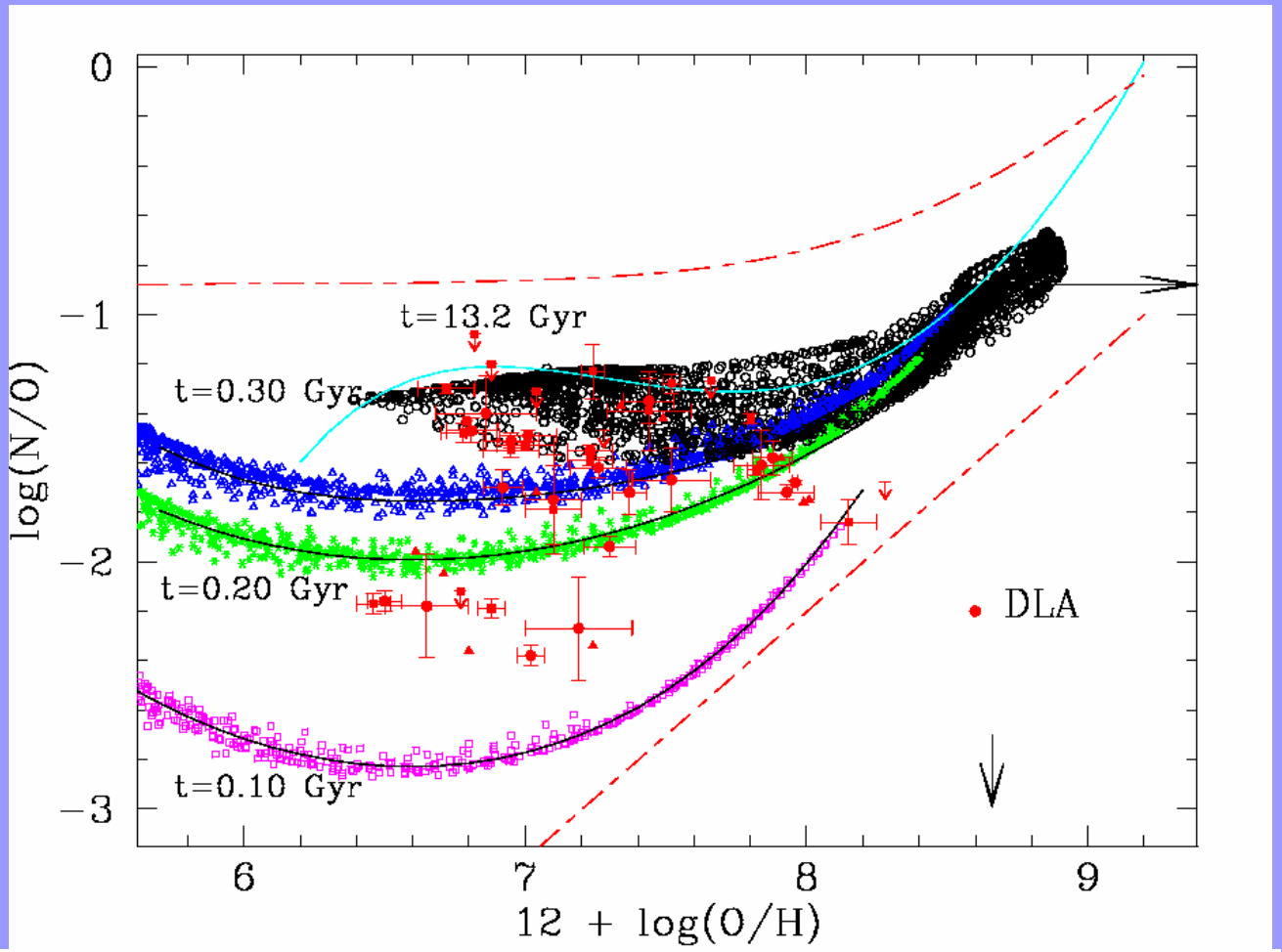


Tracks of the lowest mass galaxy with the smallest star formation efficiency.

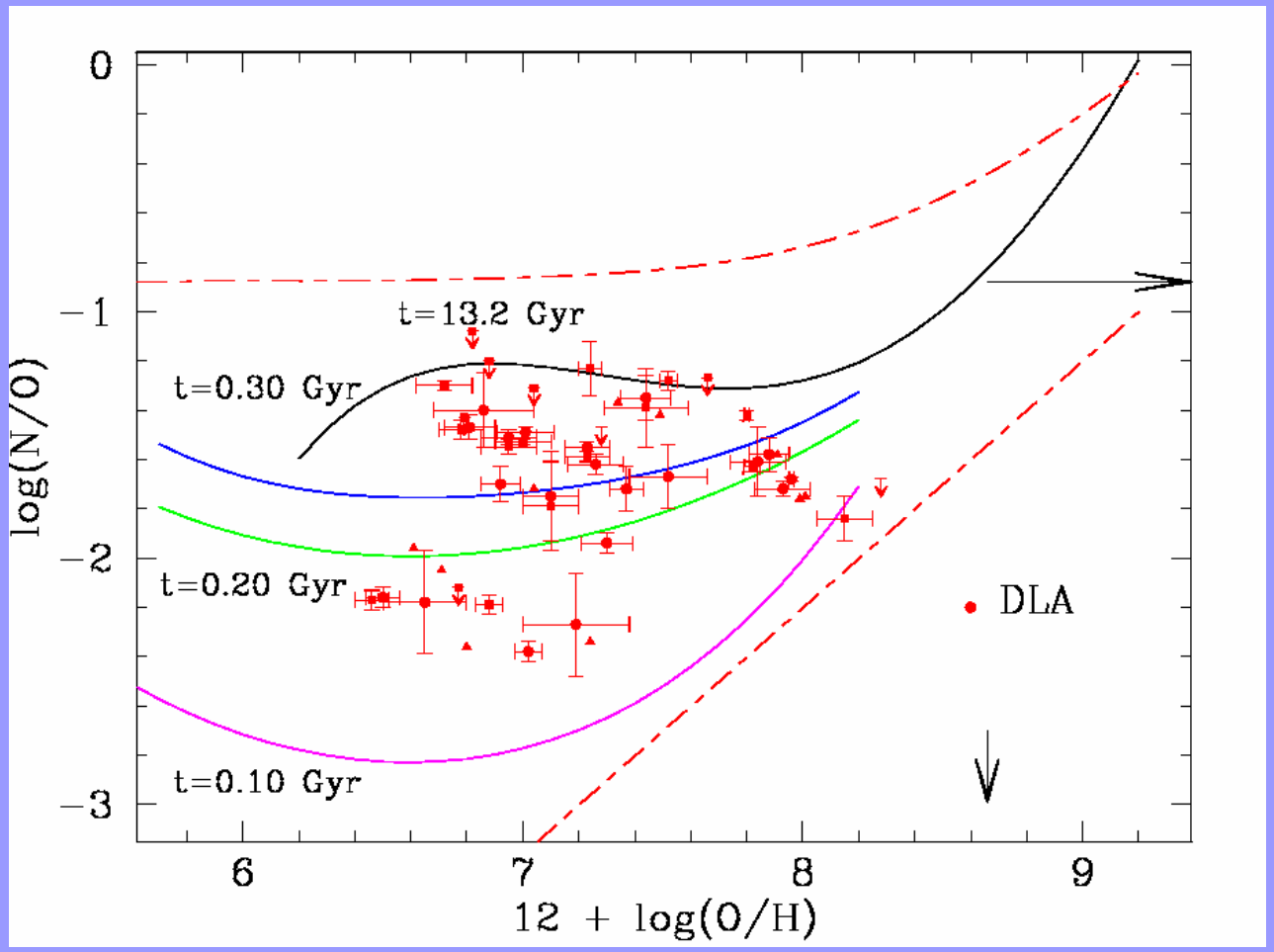
Tracks of the most massive galaxy and the highest star formation rate.

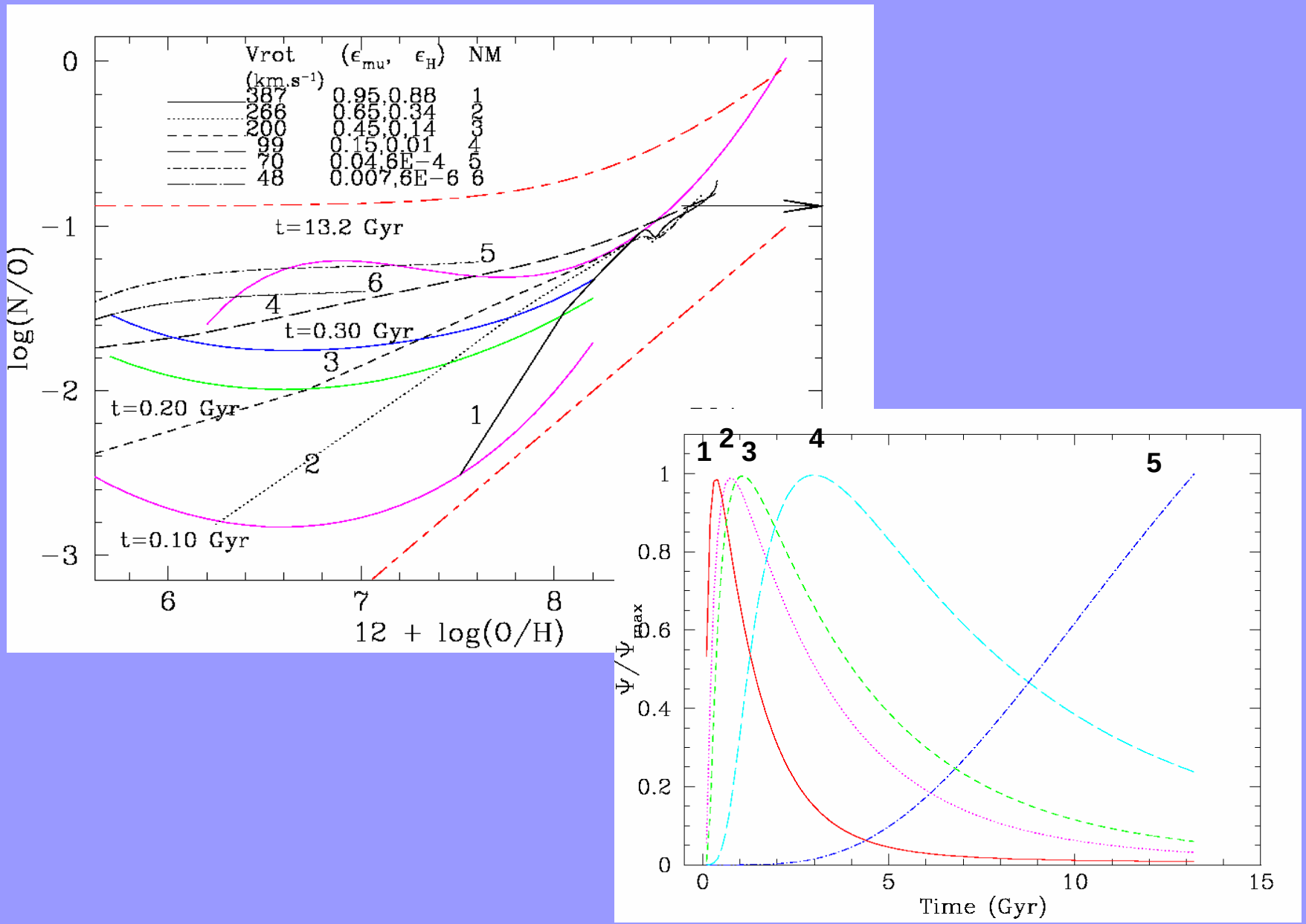
Each line joins the different radial region results for a same time step

Different time steps results



Something as a plateau appears in the results for high redshifts

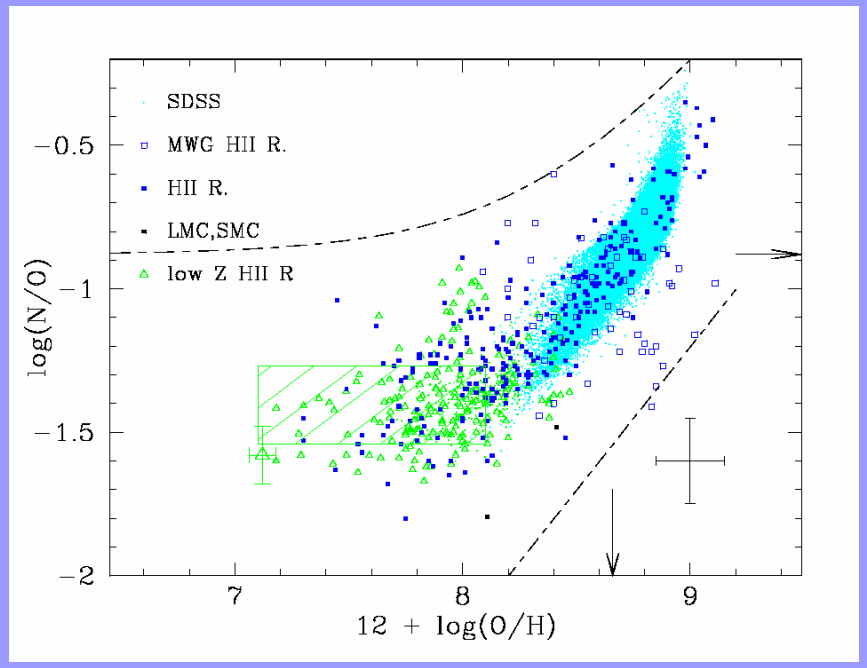

0
−1
−2
−3
log(N/O)
t=13.2 Gyr
t=0.30 Gyr
t=0.20 Gyr
t=0.10 Gyr
DLA
6
7
8
9
12 + log(O/H)

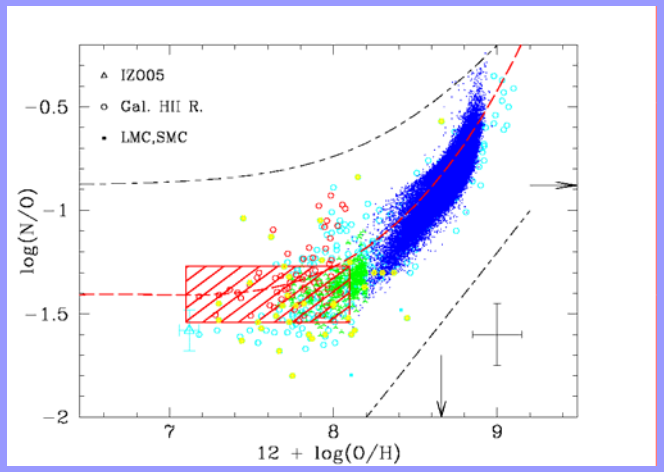

Vrot (km.s⁻¹)
(ε_mu, ε_H)
NM
387 0.95,0.88 1
266 0.65,0.34 2
200 0.45,0.14 3
99 0.15,0.01 4
70 0.04,6E−4 5
48 0.007,6E−6 6
t=13.2 Gyr
t=0.30 Gyr
t=0.20 Gyr
t=0.10 Gyr
log(N/O)
12 + log(O/H)
Ψ/Ψmax
Time (Gyr)

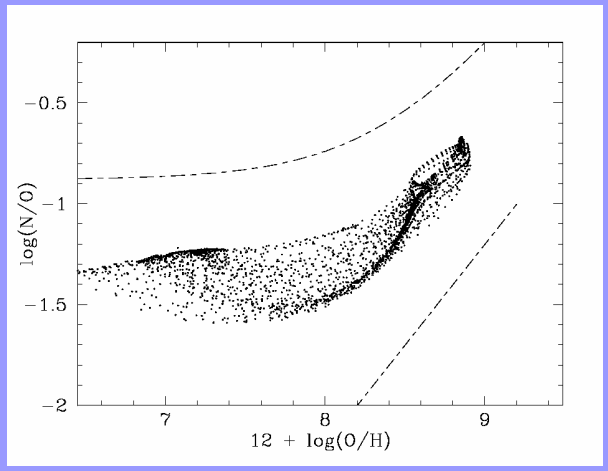
CONCLUSIONS

- **The differences in the star formation history of the regions and galaxies modeled result essential to reproduce the observational data in the N/O-O/H plane.**
- **The resulting generic trends and the obtained dispersion in the N/O-O/H plane are in good agreement with the observational data when using LIM star yields ejecting primary N and different star formation histories.**
- **Low N/O values, as those estimated for high-redshift objects such as the Damped Lyman Alpha (DLA) galaxies, may be obtained simultaneously to other higher (and constant) values of N/O as those observed for irregular and dwarf galaxies or for halo stars, at the same low oxygen abundances (12+log(O/H) ~7) .**

The present day abundances distribution in the plane N/O vs O/H compared with data from Galactic and extragalactic HII regions







We apply the same basic model to a wide grid of theoretical galaxies with different total mass. Using different star formation rate efficiencies, we obtain these results for the whole set of models and all computed time steps.

