CHEMICAL EVOLUTION OF LOW MASS GALAXIES

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Some points that a model must treat

- The gas in dwarf galaxies
- The SFR histories
- The possible existence of galactic winds
  - Selective metal loss by galactic winds
- The influence of the dark matter halo
- The mass-metallicity relation
- The relation of the metallicity Z with the fraction of gas μ
- The variation of N/O and C/O with O/H

INTRODUCCION

–The classical scenario:

- **low Z,**
- **blue galaxies, first episode of SF**
- **SFR in bursts**
- **Winds by SN´s explosions**
- **Mass loss and/or ejection of metals**

–The closed box model or simple model can not explain the relation Z-μ: Effects of inflows or outflows of gas, effective yield

–Chemical evolution models assuming a burst of SFR, and galactic winds which produce loss of metals and gas (Larson ,1974; Matteucci & Tosi, 1985; Carigi et al. 1995; Bramadante et al. 1999, Larsen et al. 2001; Rechi et al. 2001). Model constraints: gas fraction, abundance data, star formation histories

•New observations about SFR, gas, ...in these galaxies

•Multiphase chemical evolution models: summary description and results for low mass galaxies

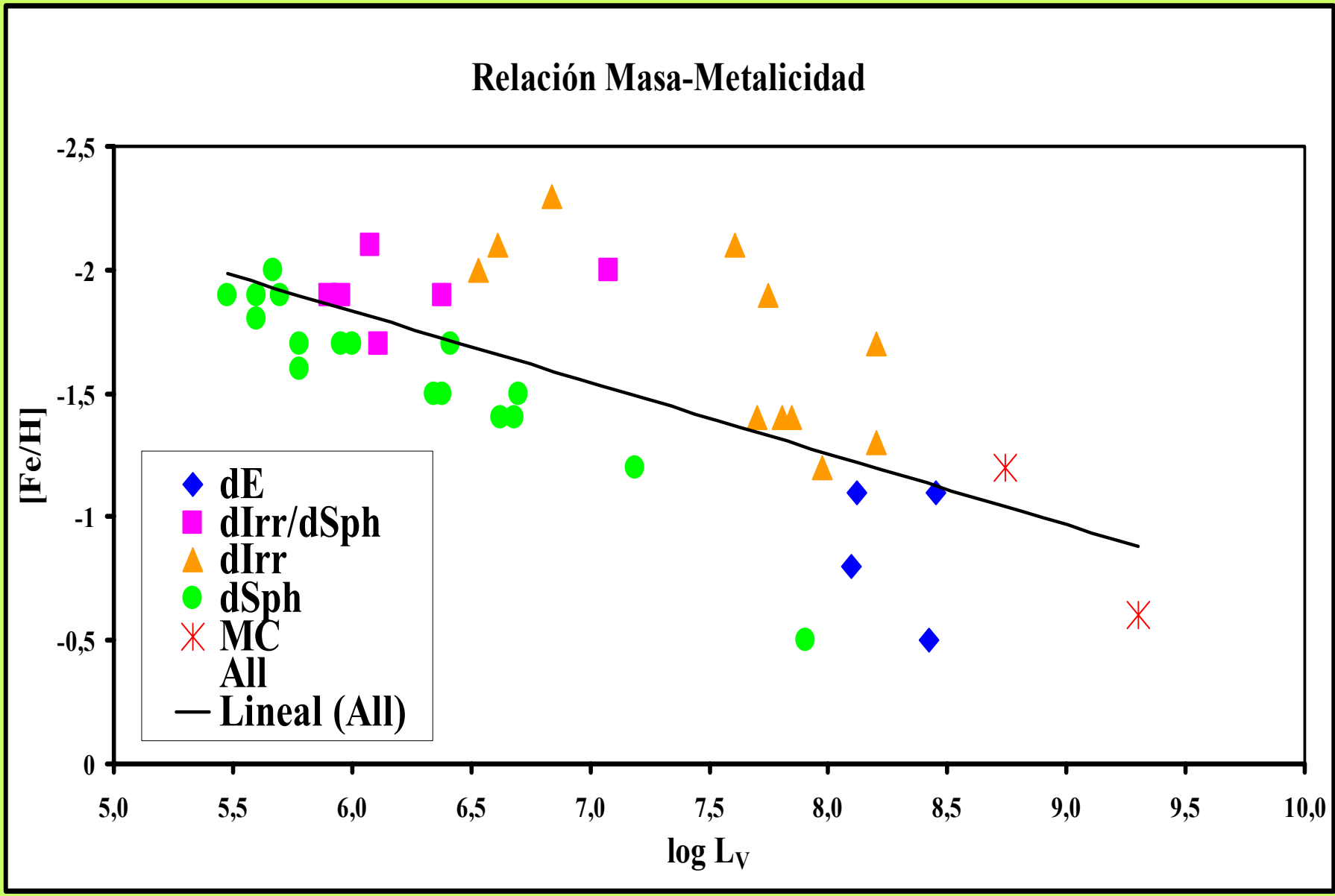
New observational facts

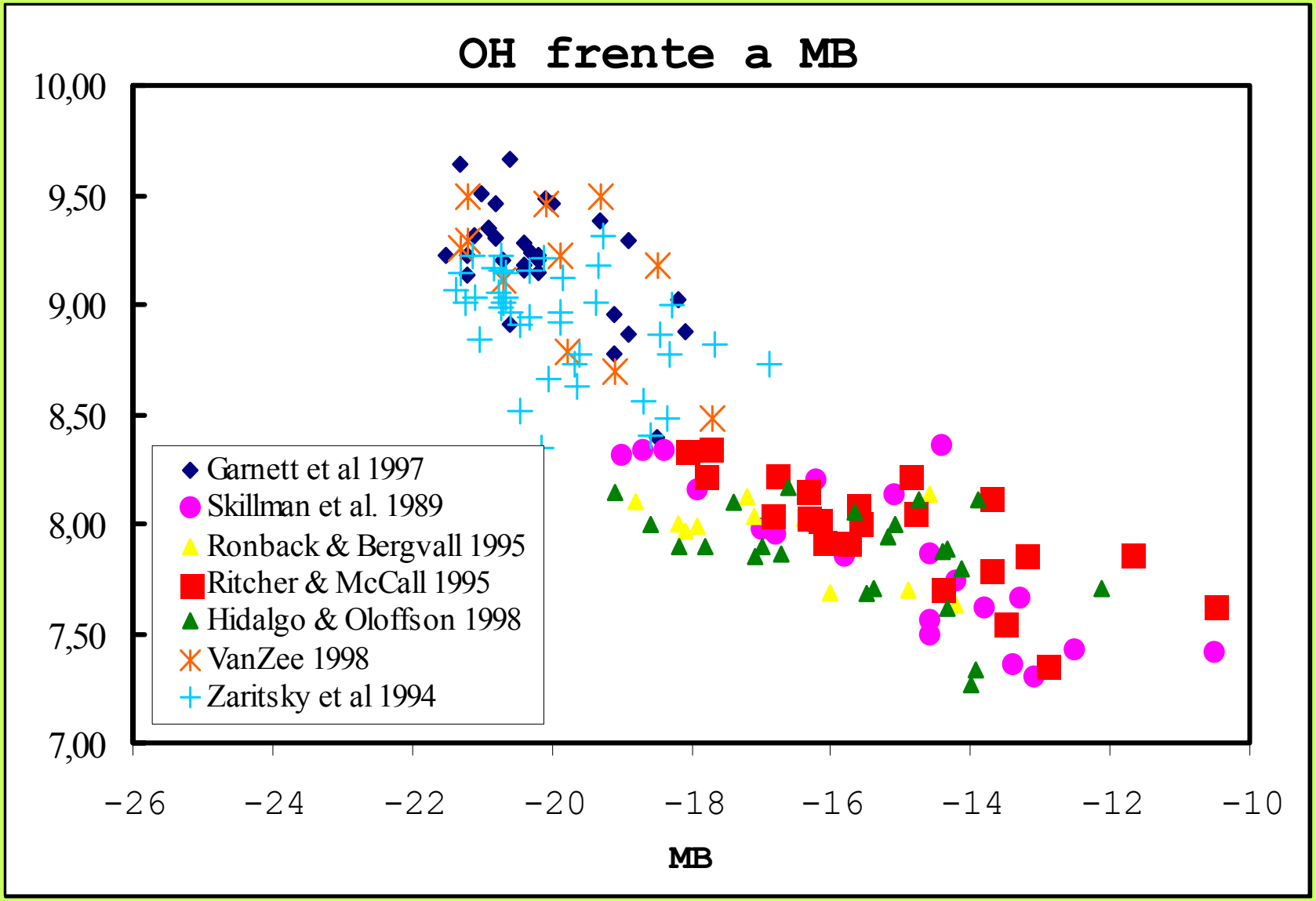
- **Mass of gas and radial distributions**
- **Colors: continuous SFR**
- **An old subjacent stellar population below the young component (Östlin 2000; Östlin & Kunth 2001; Kong, astro-ph 0210406; see Tosi, 2002): galaxies older than assumed**
- **Gas dominated by rotation (dE´s, Pedraz et al. astro-ph 0204173, Vrot=20 km s^{-1})**
- **Mass-Metallicity relation**
- **Radial distributions of brightness flattening in the inner**
- **The existence of several types of low mass galaxies**
- **BCG embedded in a large low surface brightness**
- **The flat radial gradients of abundances in low mass galaxies: uniformity in the abundances found within dwarf galaxies (González-Delgado et al. 1994; Kobulnicky et al. 1997; Hidalgo-Gámez et al. 2001)**

Moreover, from the linear fit between Z and ln(μ), Lequeux et al. (1979) obtained a derived yield for the oxygen which is in agreement with the current estimates from stellar evolution models

The mass-metallicity relation

- **The relation for dSph,dE and dIrr´s (Grebel et al. 2003)**
- **The metallicity-luminosity relation is essentially the same for all types of galaxies (Zaritsky et al. 1994; Vílchez 1995; Hunter & Hoffman 1999; Pilyugin 2000; Hidalgo-Gámez & Olofsson 1998)**
- **The slope of this relation: Does this change for the low-mass galaxies?**
- **From the chemical content no distinction is clear between the dwarf and the large massive galaxies**


Relación Masa-Metalicidad
-2,5
-2
-1,5
-1
-0,5
0
[Fe/H]
5,0
5,5
6,0
6,5
7,0
7,5
8,0
8,5
9,0
9,5
10,0
log L_V
dE
dIrr/dSph
dIrr
dSph
MC
All
Lineal (All)


OH frente a MB
10,00
9,50
9,00
8,50
8,00
7,50
7,00
-26
-24
-22
-20
-18
-16
-14
-12
-10
MB
Garnett et al 1997
Skillman et al. 1989
Ronback & Bergvall 1995
Ritcher & McCall 1995
Hidalgo & Oloffson 1998
VanZee 1998
Zaritsky et al 1994

THE GALACTIC WINDS

- **The galactic winds in the chemical evolution of low mass galaxies is not beyond question (see Skillman 1997 for arguments for and against)**
- **The deficiency of oxygen in low mass galaxies is an argument in favor of a mass exchange with the environment**
- **The effect of the dark halo must be taken into account:**
- **Recent calculations (Silich & Tenorio-Tagle, Mac Low & Ferrara 1999, D´ Ercole & Brighenti 1999) imply that the mass loss only will in some galaxies when the mass involved in the starburst is larger than a given value which depends on the ISM density and on the distribution of the mass**
- **Chemo-dynamical evolution models (Hensler et al.1999) support the idea that mixing effects by the evaporation of clouds by SN´s prevent selective depletion of elements, and therefore the dispersion of data in the N/O vs O/H graph is not explained by winds.**

The possible galaxies supporting galactic winds

- **These new results and the observations given an old age and a continous star formation history for low mass galaxies imply that other chemical evolution without ejection of metals is possible (Legrand, 1999; Legrand et al. 2001; Carigi et al. 2002): the halo is a barrier to retain metals, at least in some cases.**
- **It is necessary a strong burst of SFR to allow galactic winds ejecting metals out of the galaxy**
- **The BCD are the dwarf galaxies with highest Lum. Hα**
- **The BGD have metallicities well according their gas fractions**

When galactic winds are possible?

Which kind of galaxies or regions may suffer a mass loss by them?

Chemical evolution models

All dwarf galaxy types could plausibly come from the same type of progenitor, but because of differences in initial dark matter content or environment or chance encounters with other galaxies, they have followed different evolutionary paths which result in different present-day properties

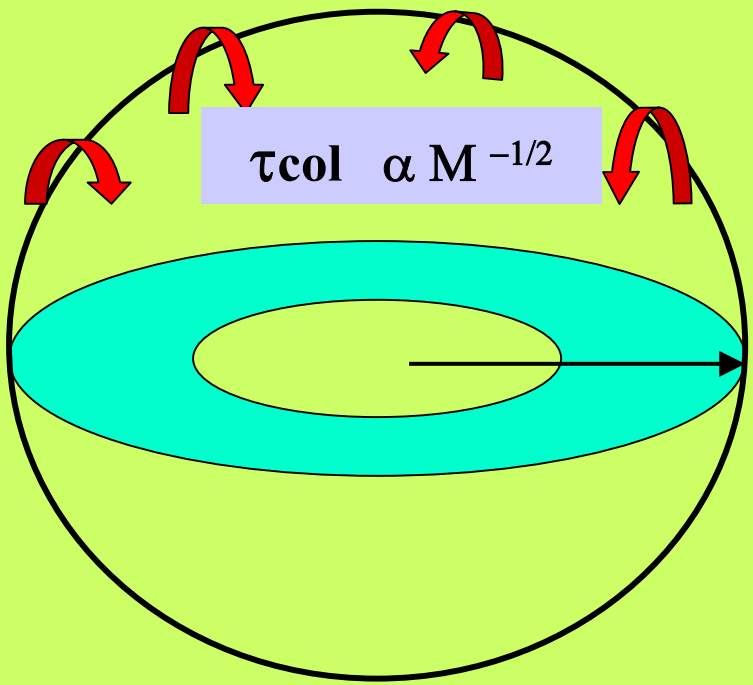
The total mass of a galaxy has a critical impact on the ability to form stars. It determines how effectively is compressed the gas to increase the efficiency of star formation.

(Tolstoy 2002)

Multiphase chemical evolution model used for a wide mass range and star formation efficiencies without assuming galactic winds

The scenario

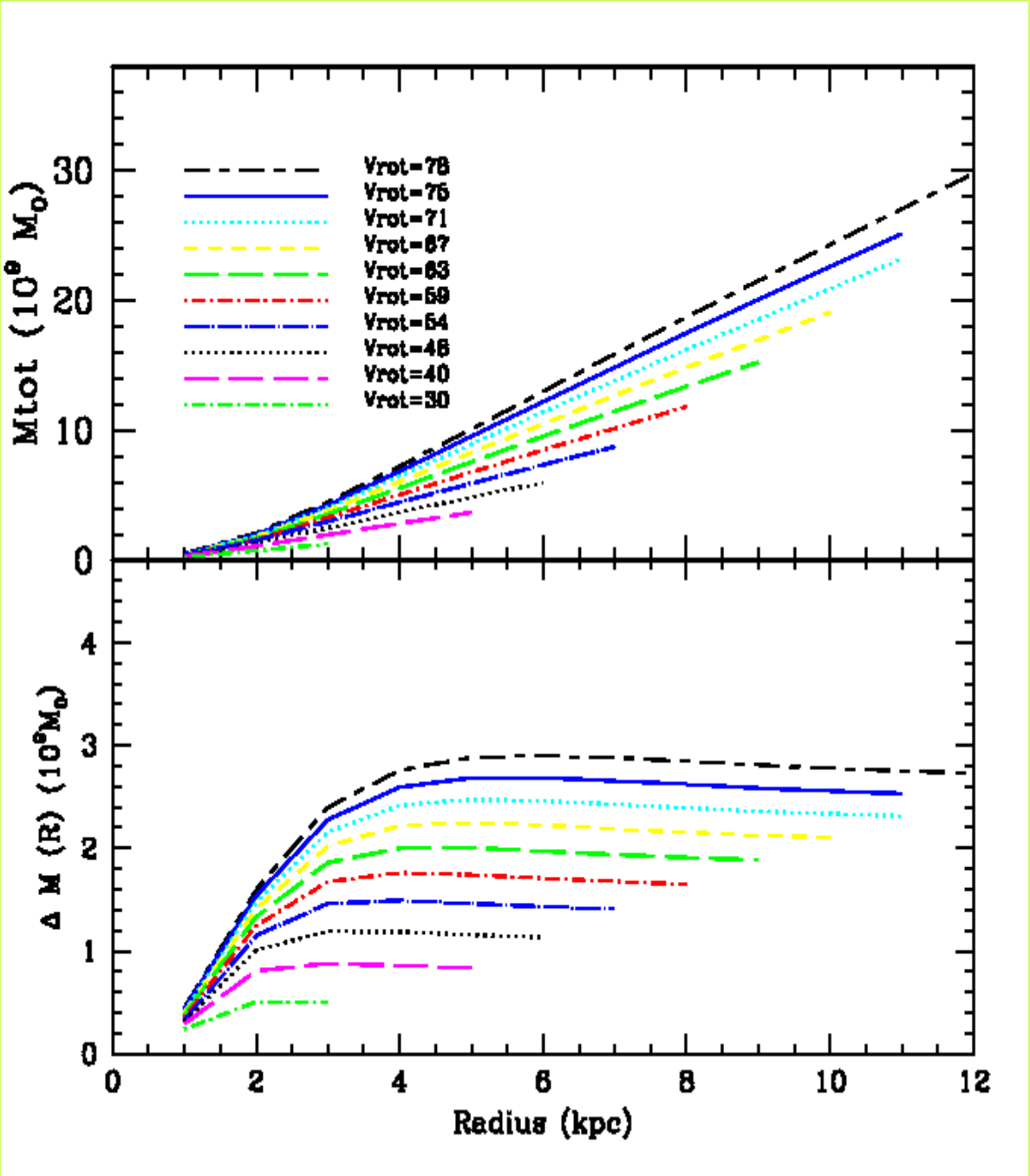
The gas of the protogalaxy has a mass M (R) computed from the rotation V(R)



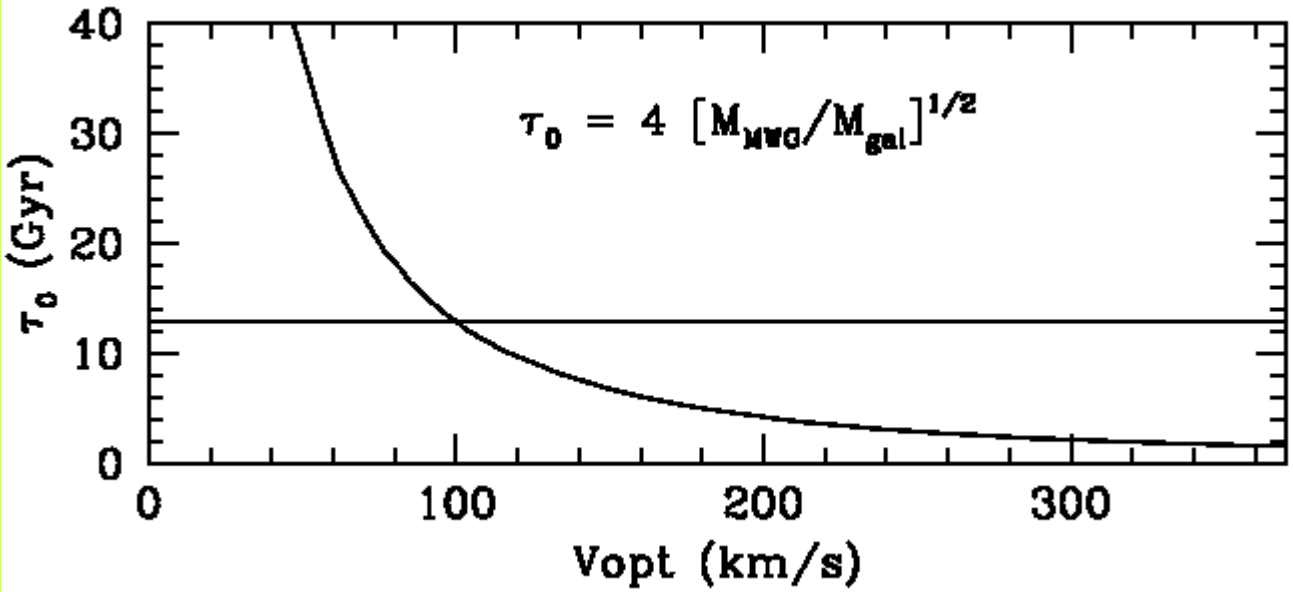
The gas collapses onto the equatorial plane and forms out the disc

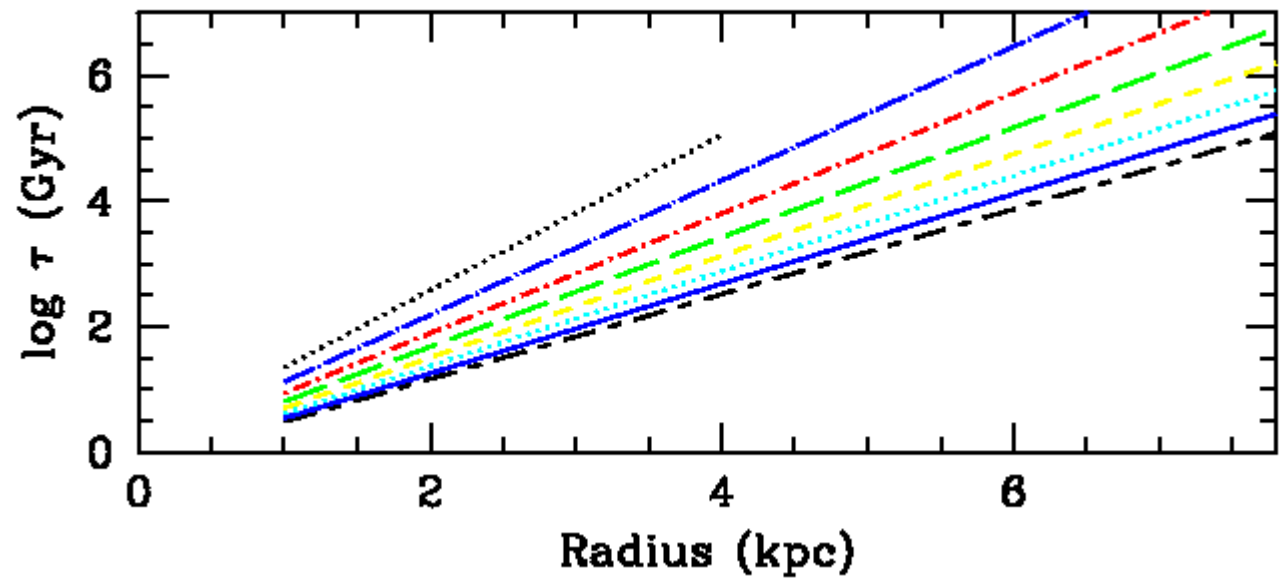
The infall rate is inversely proportional to a characteristic collapse time scale τcol

Since the mass density depends on galactocentric radius, the collapse time scale also changes along this radius



The rotation curve is obtained from the Universal Rotation Curve from Persic, Salucci & Steel (1996)





The collapse time scale is computed depending on total mass through the calibration with the MWG

The star formation law has 2 steps:

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

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

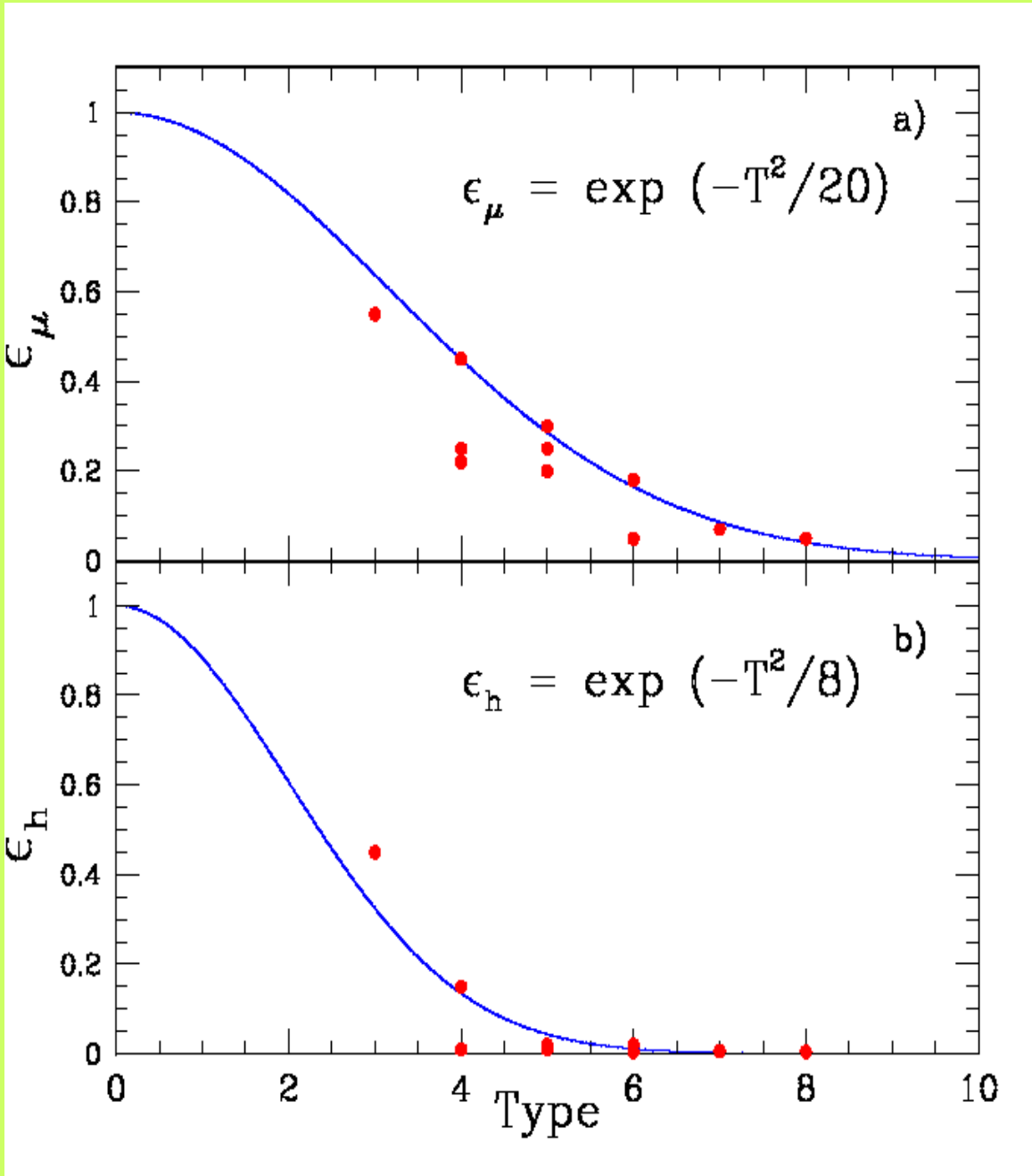
Stars form through cloud-cloud collisions: s α Hc ^{2}

In the disc molecular clouds are formed 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 $_2$

THE DEPENDENCE OF PARAMETERS

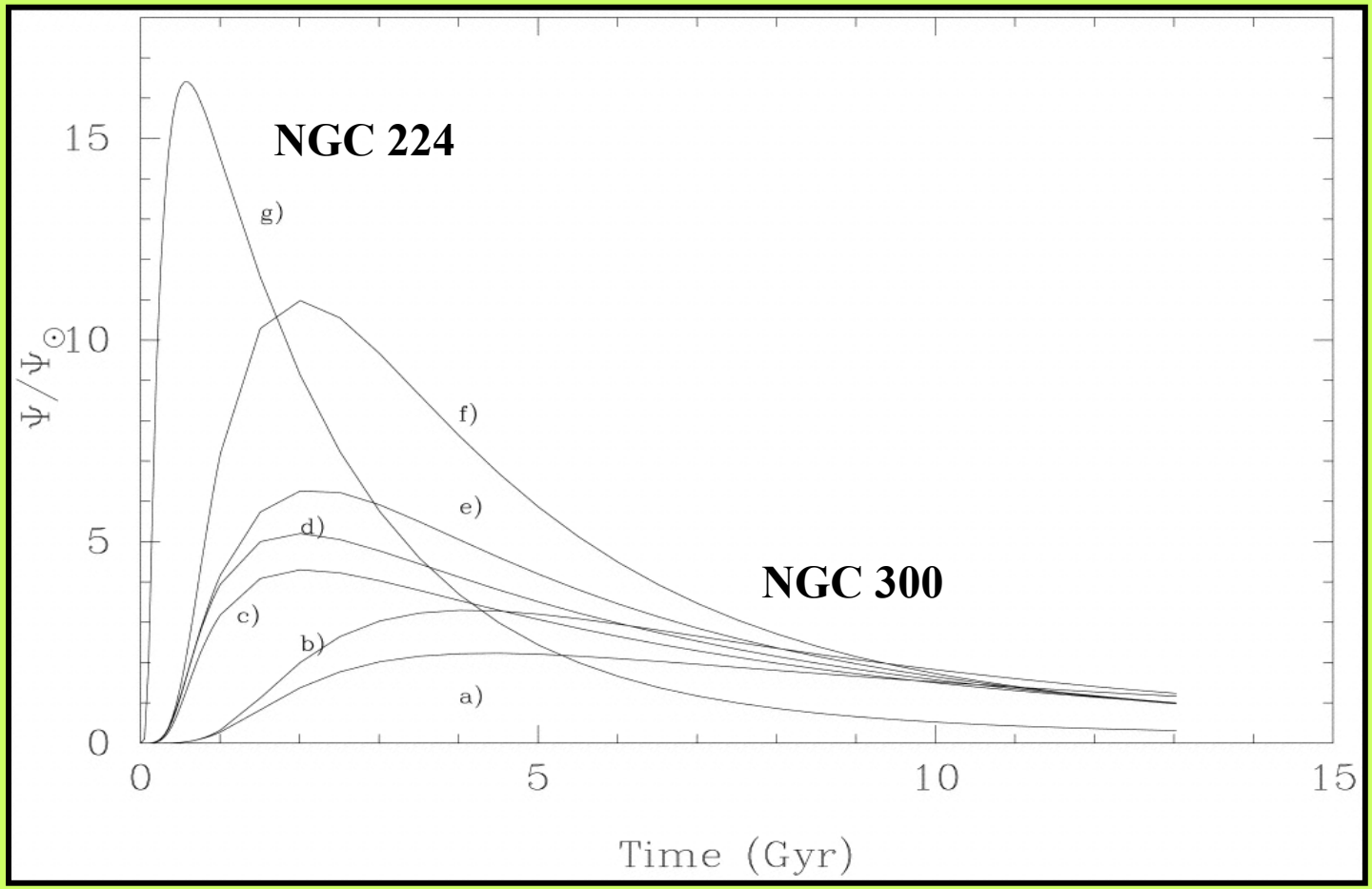
- Every parameter changes along the galactocentric radius through the volume of each region and the efficiency (probability) of each process:
  - $K = \varepsilon_K (G/V)^{1/2}$
  - $\mu = \varepsilon_\mu (G/Vd)^{1/2}$
  - $H = \varepsilon_H$ cte $/Vd$
  - $a = \varepsilon_a (G \rho_c)^{1/2} / \langle m_{s2} \rangle$
  - $\tau_{col} = \tau_{col,0} \exp(R/l)$
- The efficiency ε_a does not change with R and it is constant for all galaxies (local process)
- The efficiency ε_K is assumed as constant for all halos
- Efficiencies ε_μ y ε_H are variable for each galaxy
- The collapse time scale τ_{col} changes according to the total mass of the galaxy



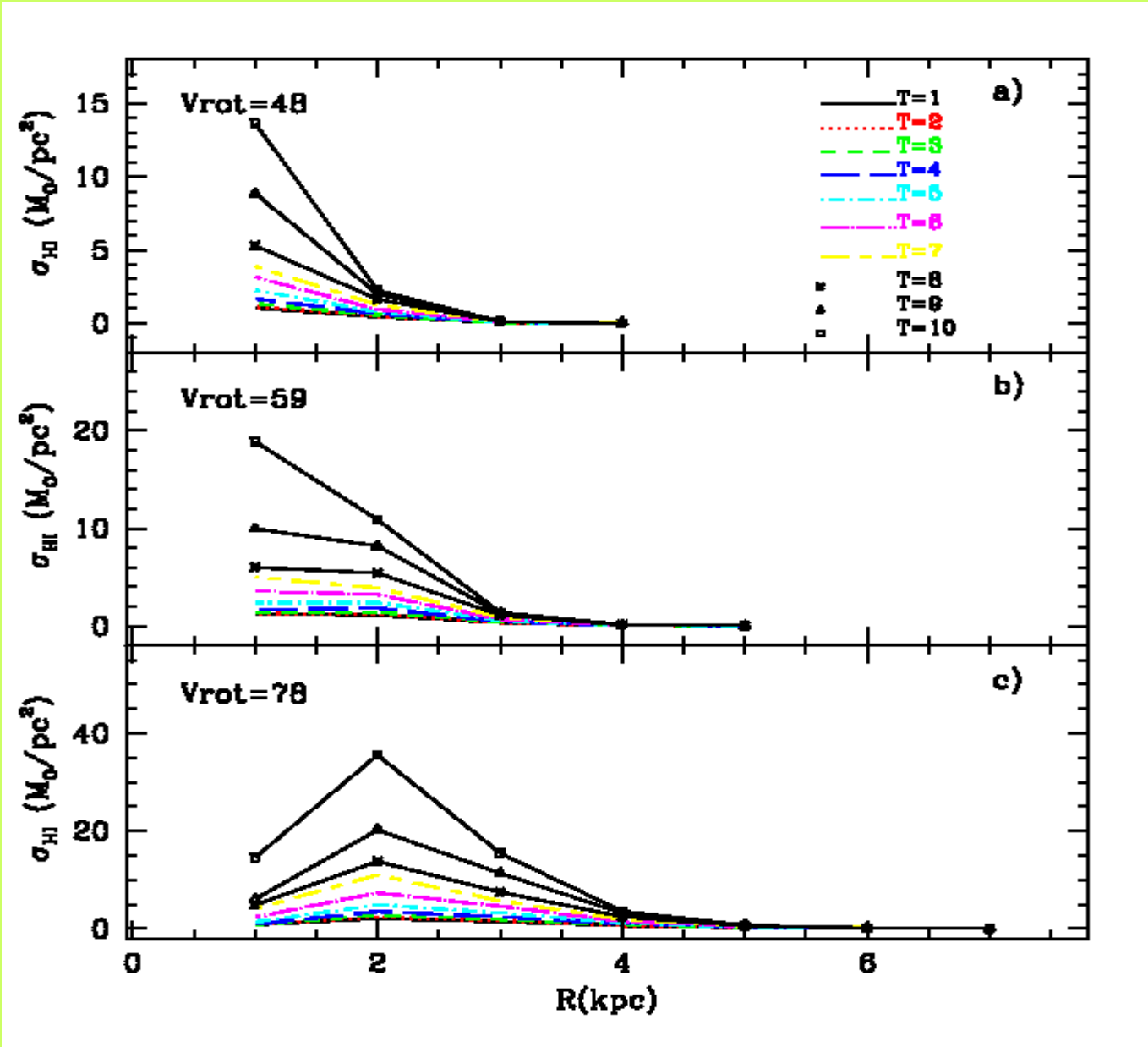
Eficiencies for particular galaxies were chosen following the arguments from Ferrini & Galli (1988,1989) and estimations from observations

RESULTADOS GENERALES:

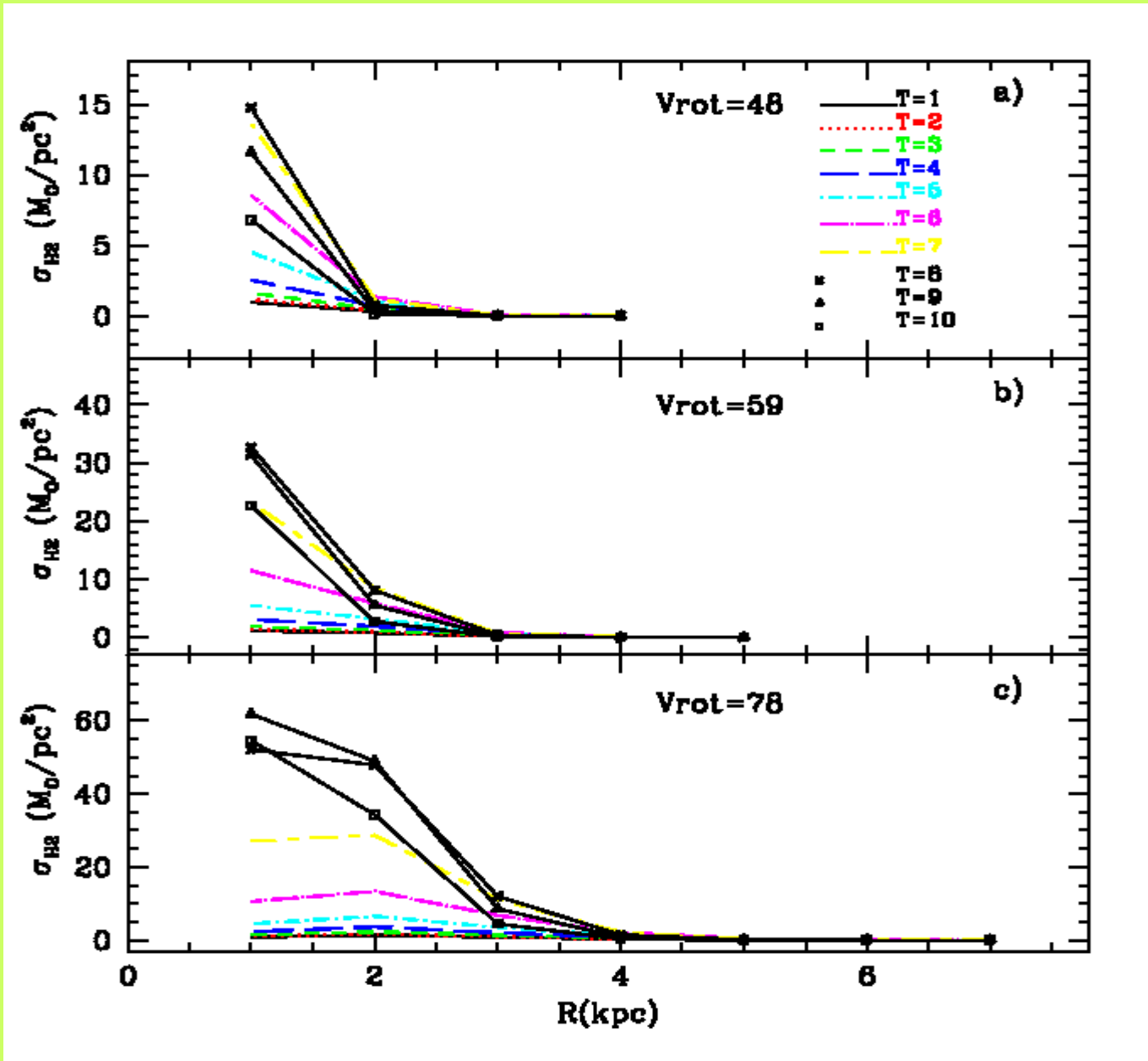
La formación estelar es más fuerte y ocurre antes en las galaxias masivas de tipo temprano que en las galaxias tardías menos masivas



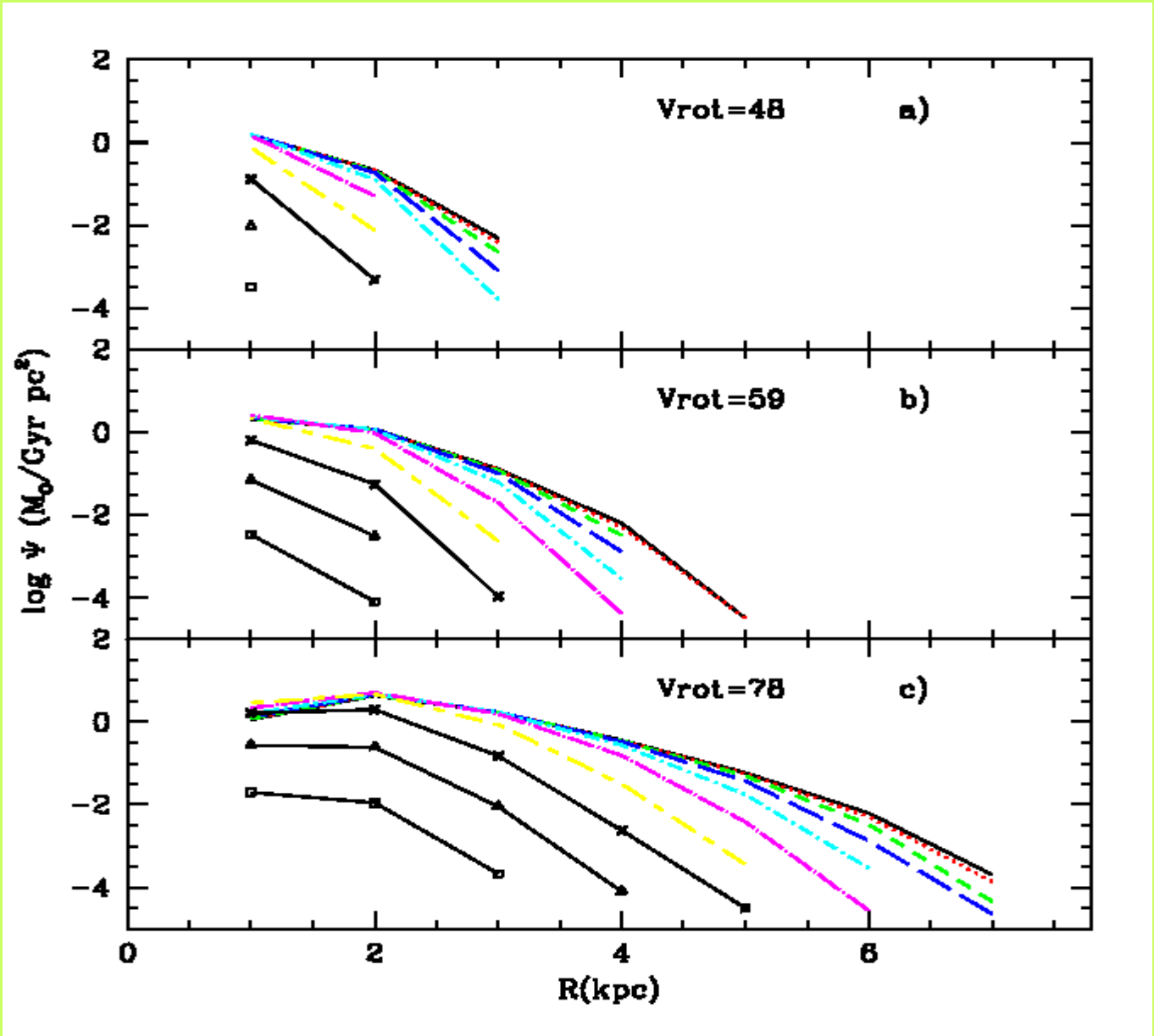
RADIAL DISTRIBUTIONS OF DIFFUSE GAS



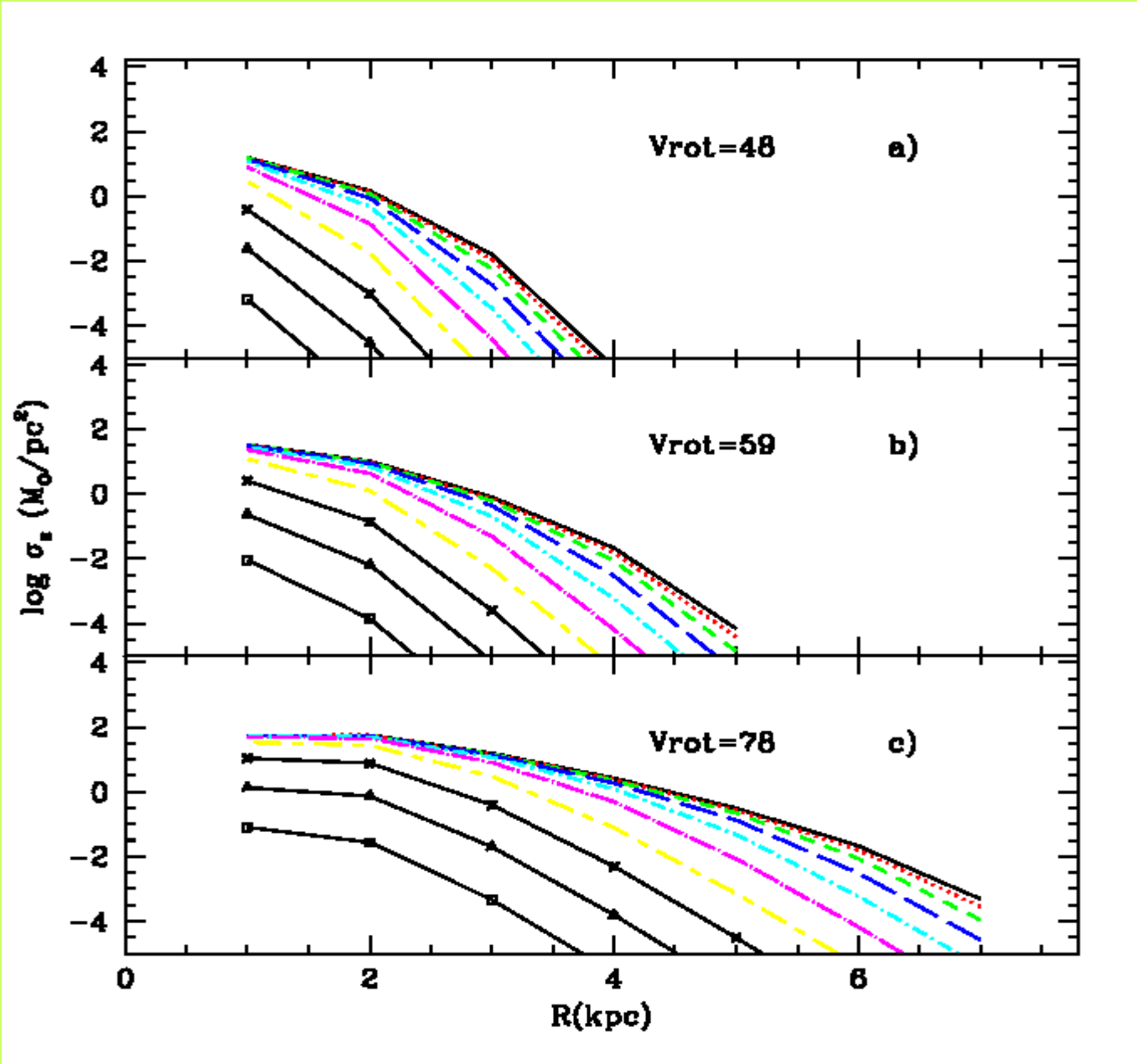
RADIAL DISTRIBUTIONS OF MOLECULAR GAS



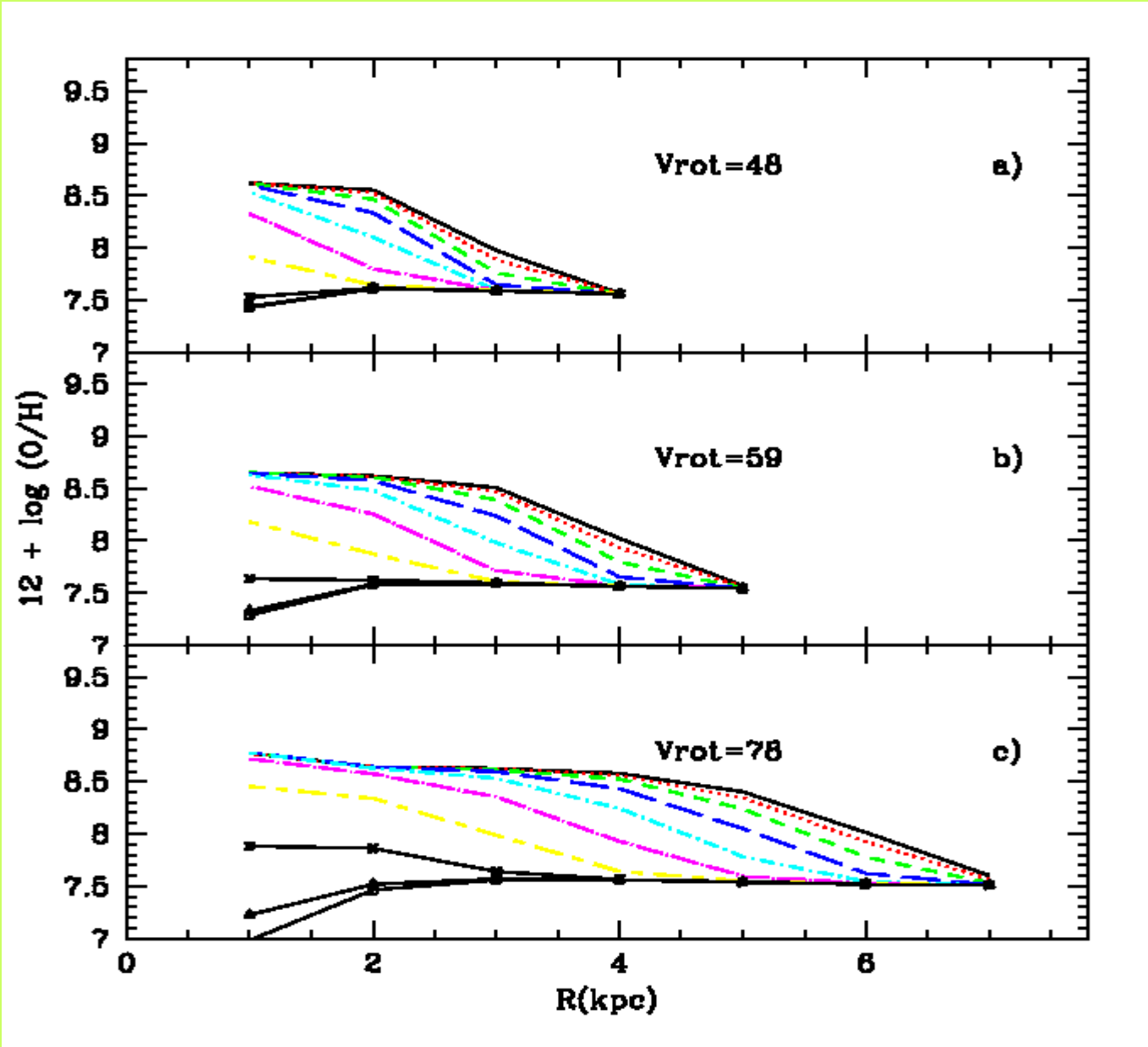
RADIAL DISTRIBUTIONS OF SFR



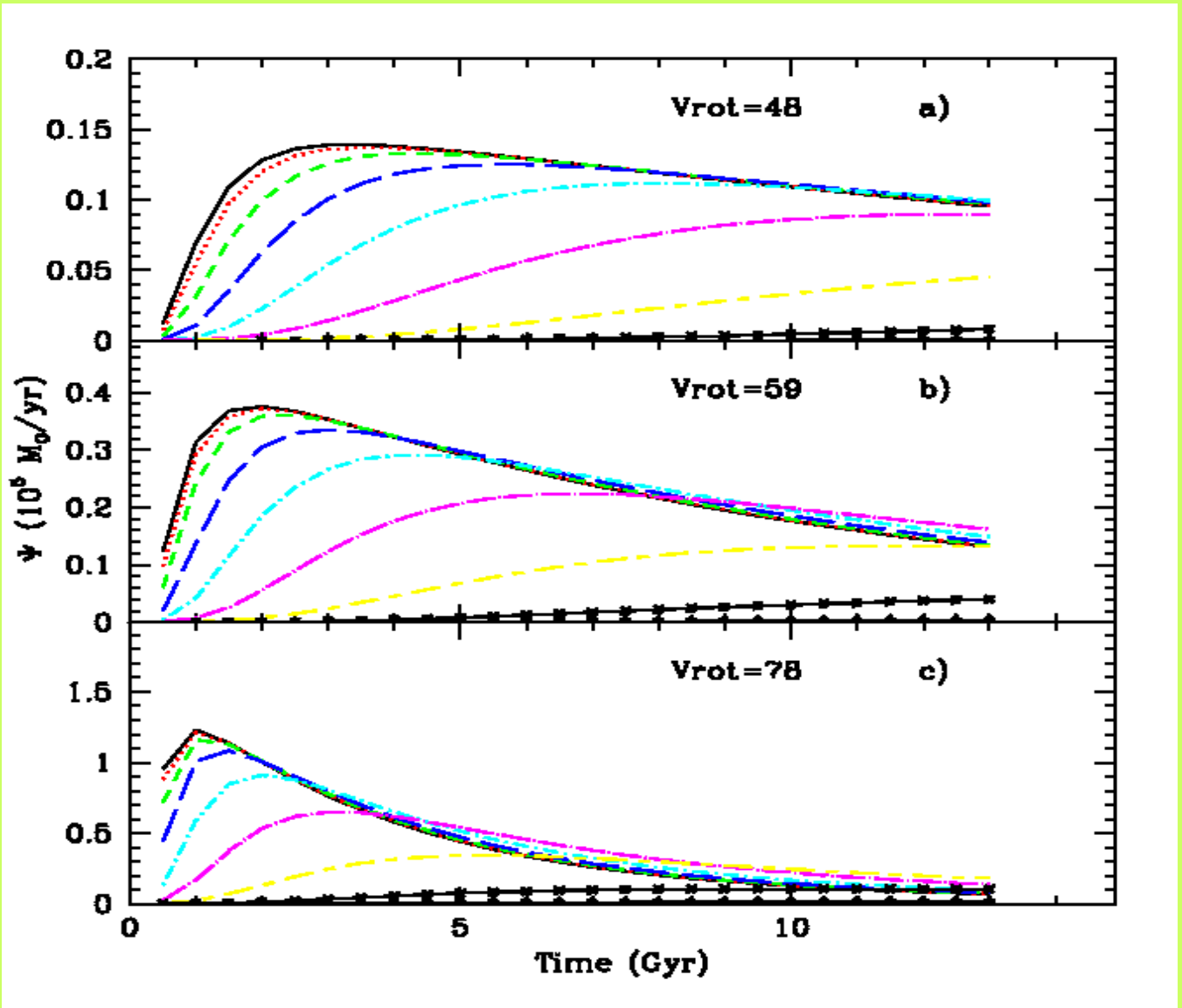
RADIAL DISTRIBUTIONS OF STELLAR MASS



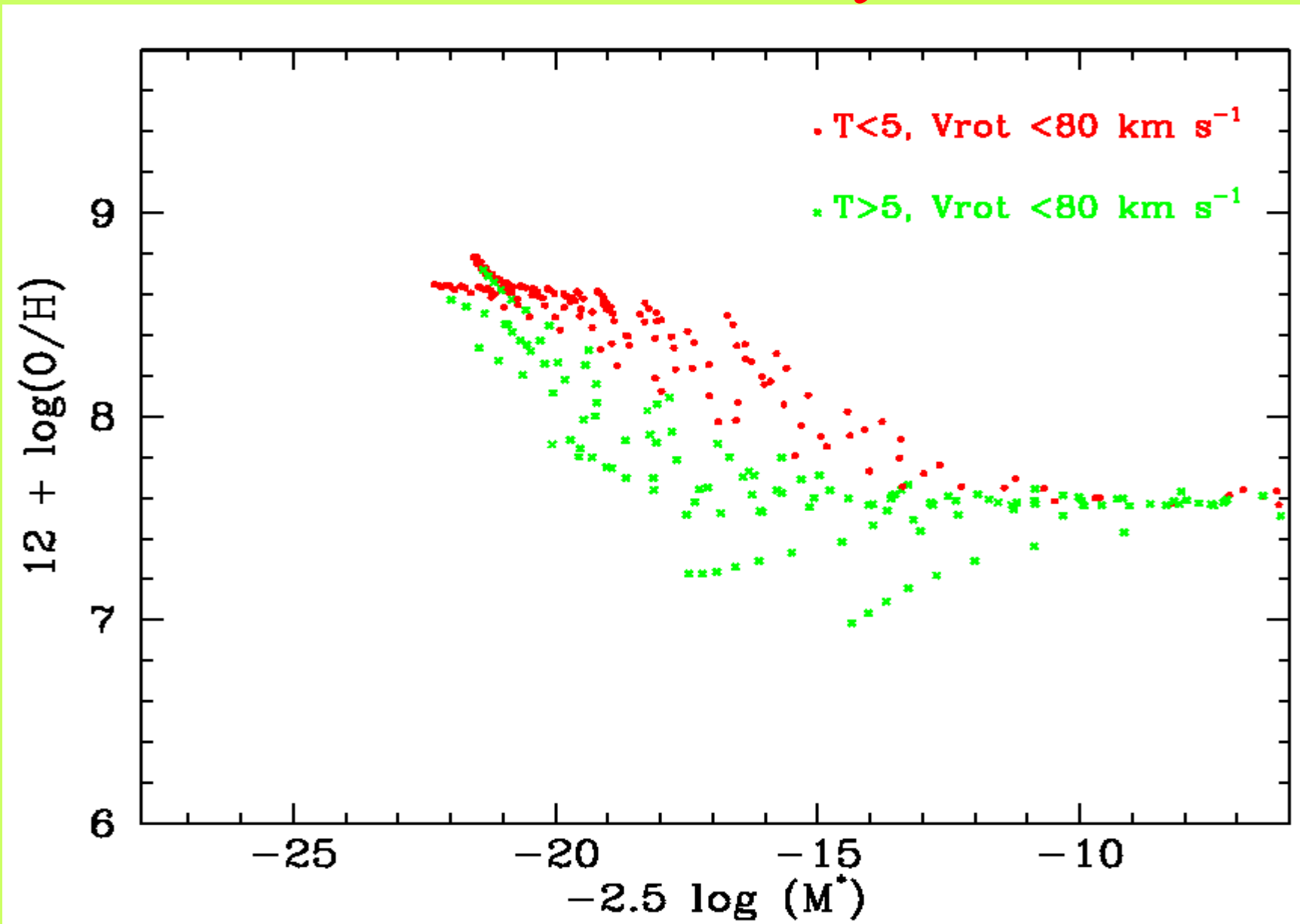
RADIAL DISTRIBUTIONS OF OXYGEN



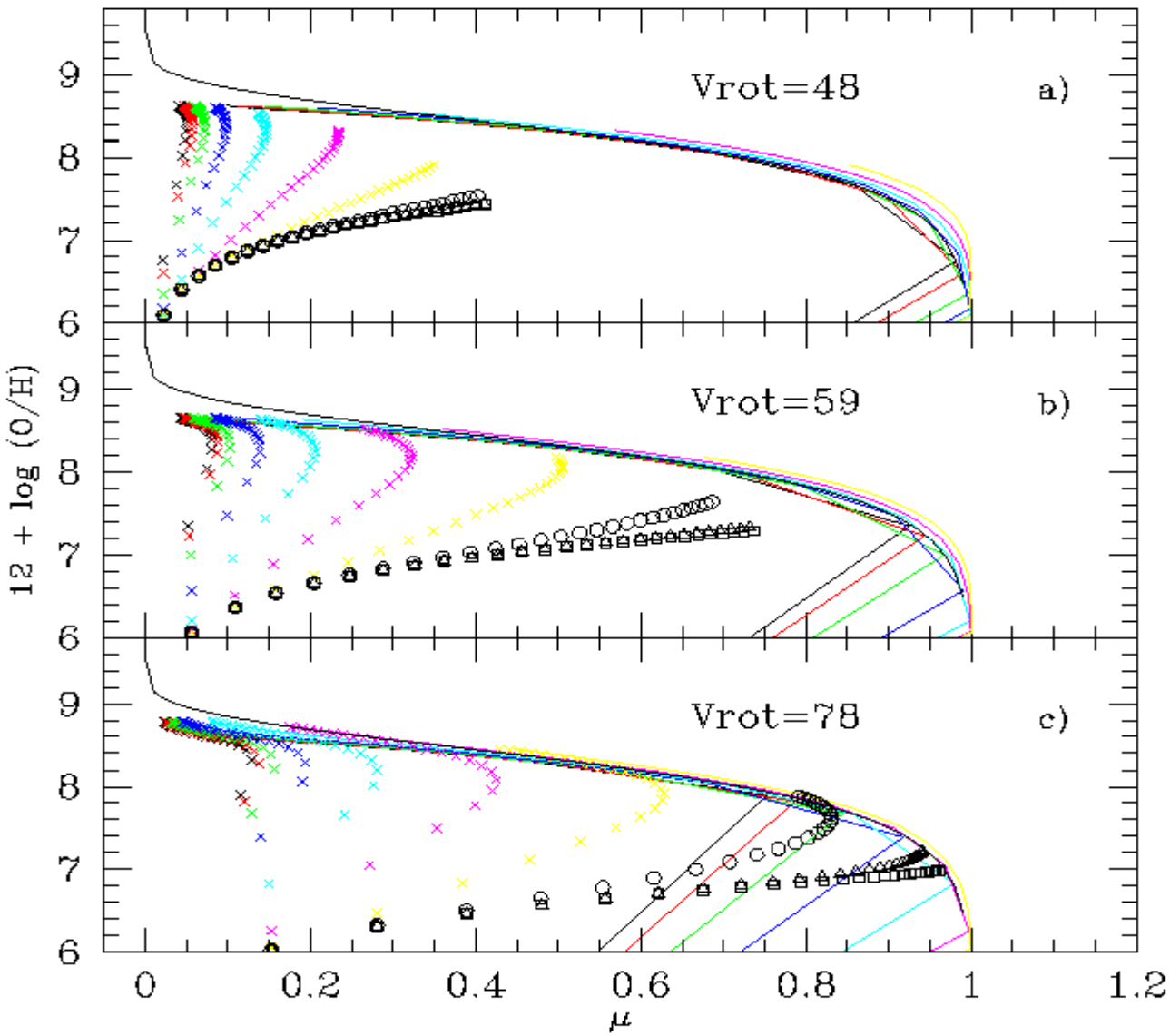
STAR FORMATION HISTORIES



The mass-metallicity relation



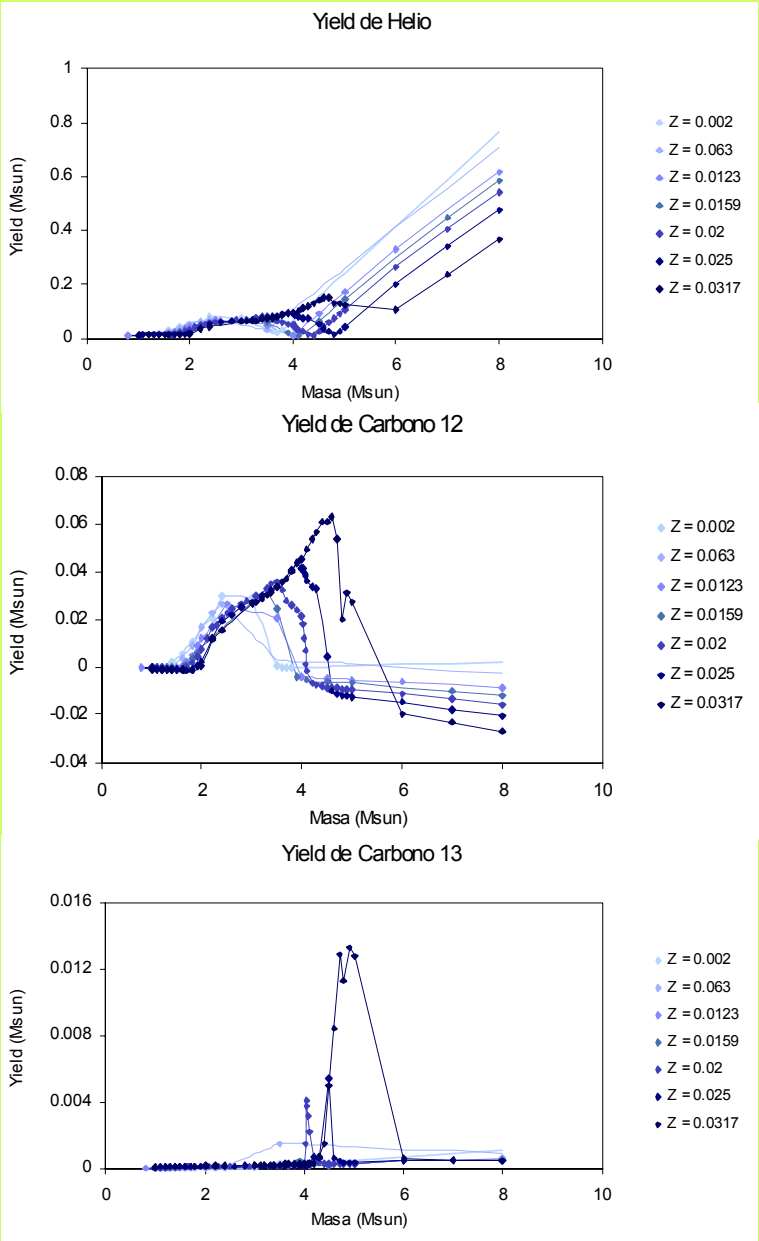
Z-μ RELATION

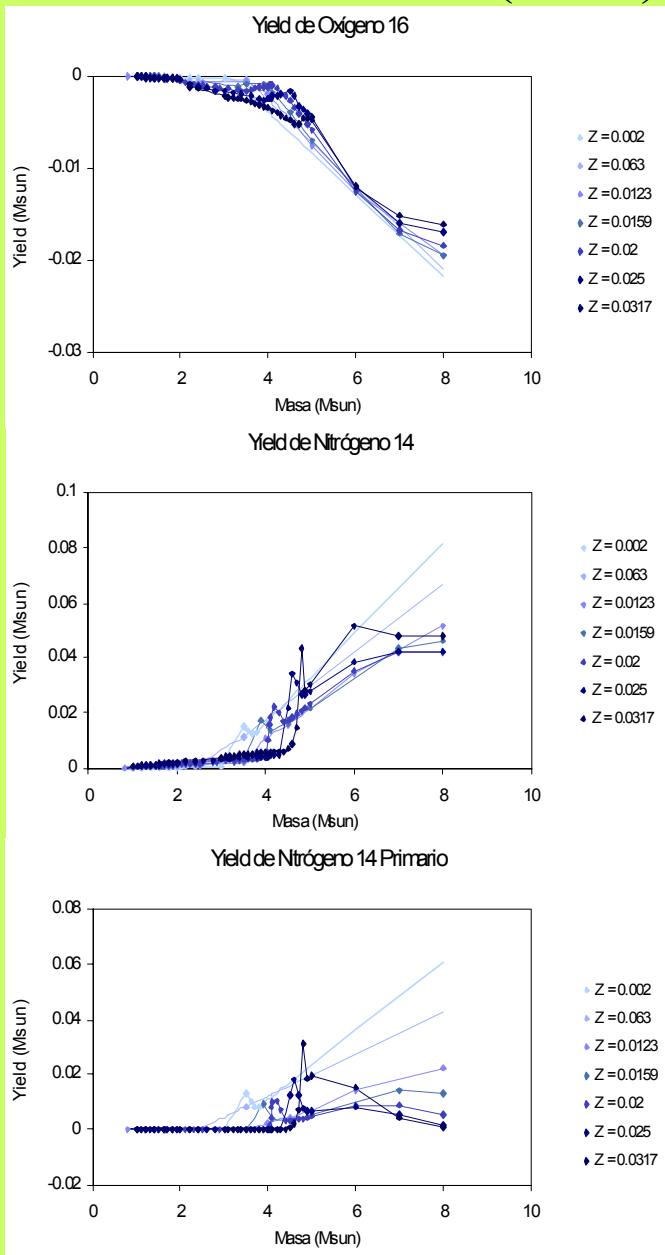


The variation of N/O and C/O with O/H

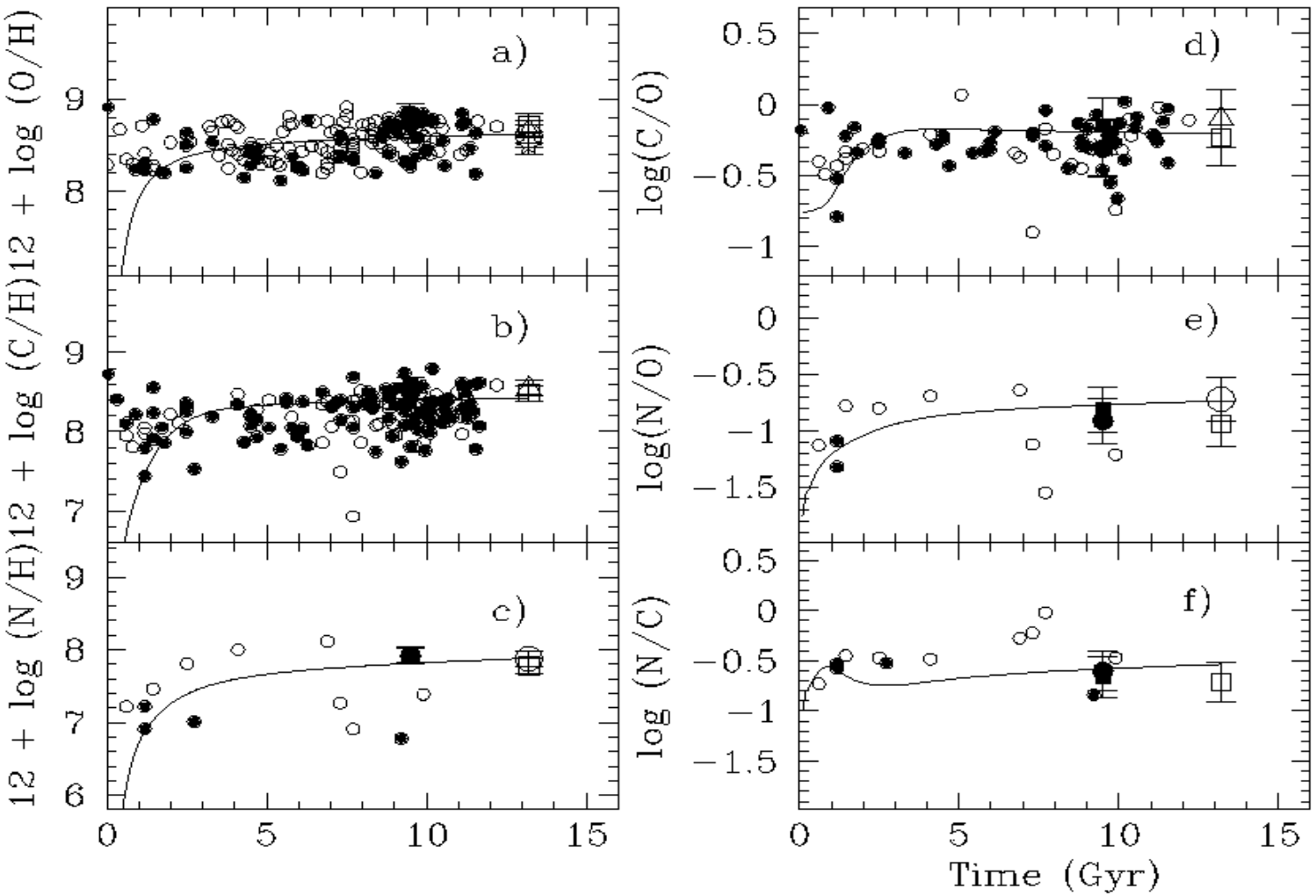
- Diagram with an initial $\log(N/O) \approx -1.7$ due to primary nitrogen and a secondary nitrogen component.
- Large scatter
- The age of the stellar populations and the star formation rate
- The different types of dwarf galaxies: BCDG and dIG.

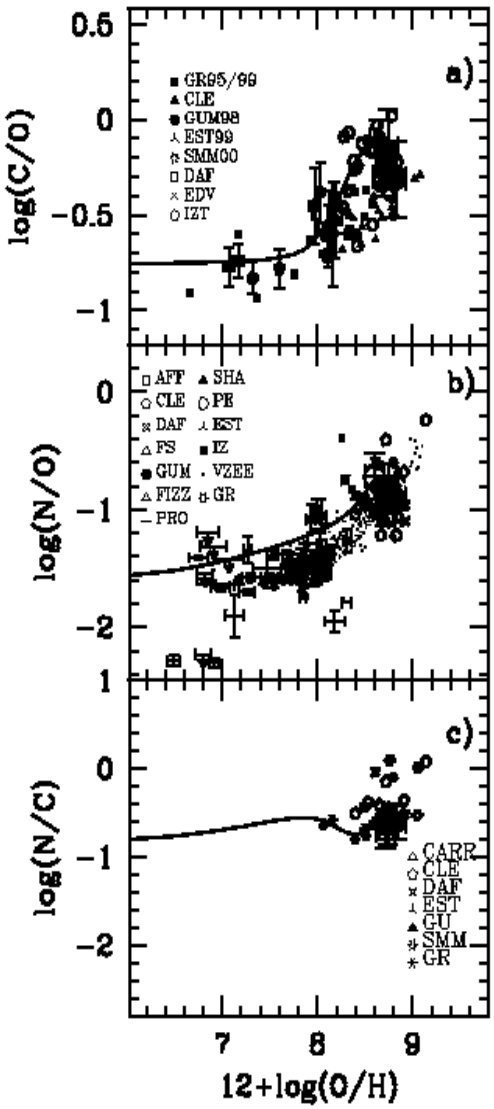
Yields for low and intermediate stars from Buell (1997)





THE SOLAR NEIGHBORHOOD

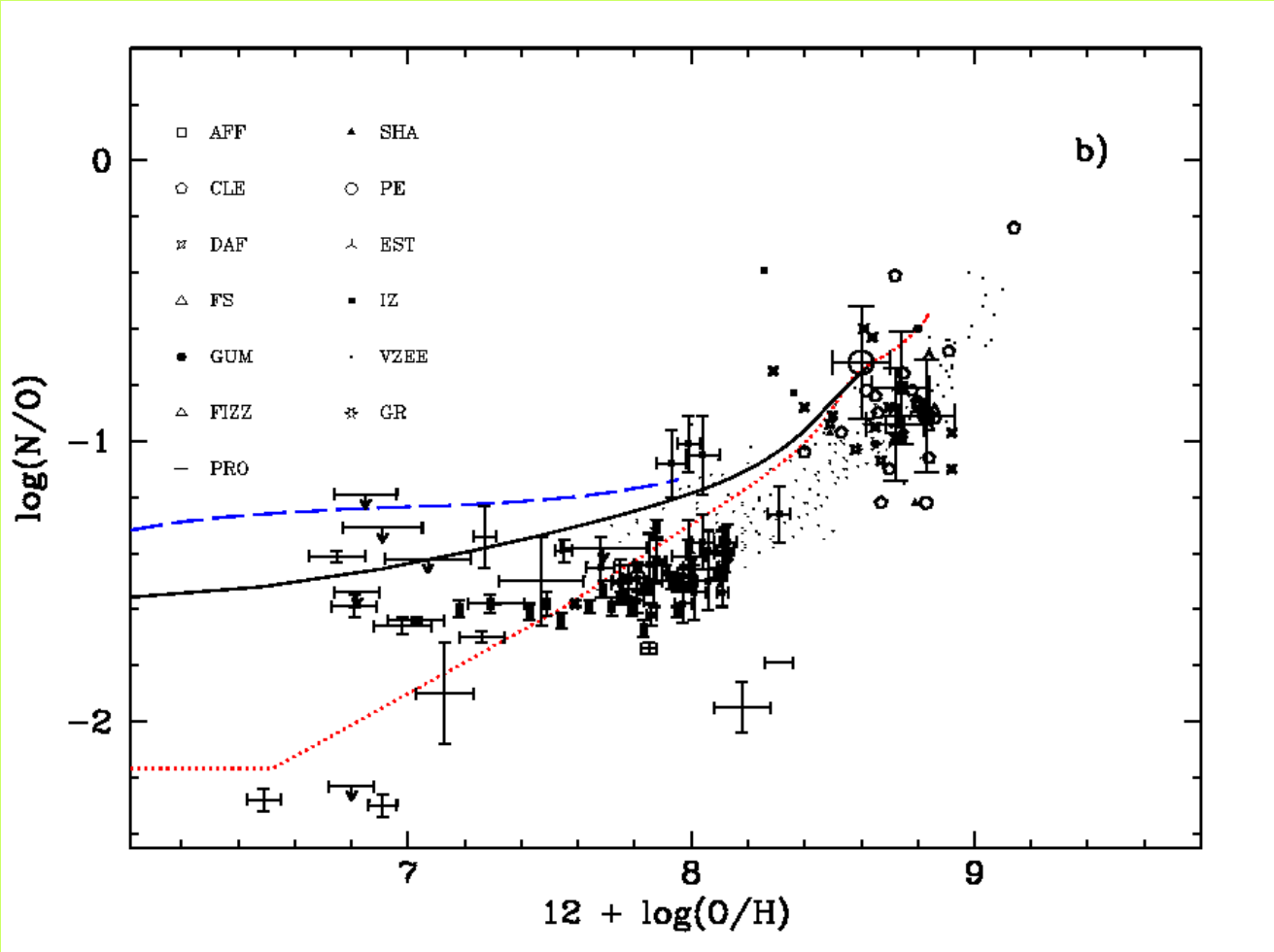




THE CNO ABUNDANCES

- The massive star yields are from Woosley & Weaver (1995)
- The Carbon is eyected mostly by massive stars
- The Nitrogen has a primary component from LIM stars

Using the yields from Buell (1997) for low and intermediate stars:



The most evolved regions (red line) has a track different than the outer less evolved disk regions (blue line)

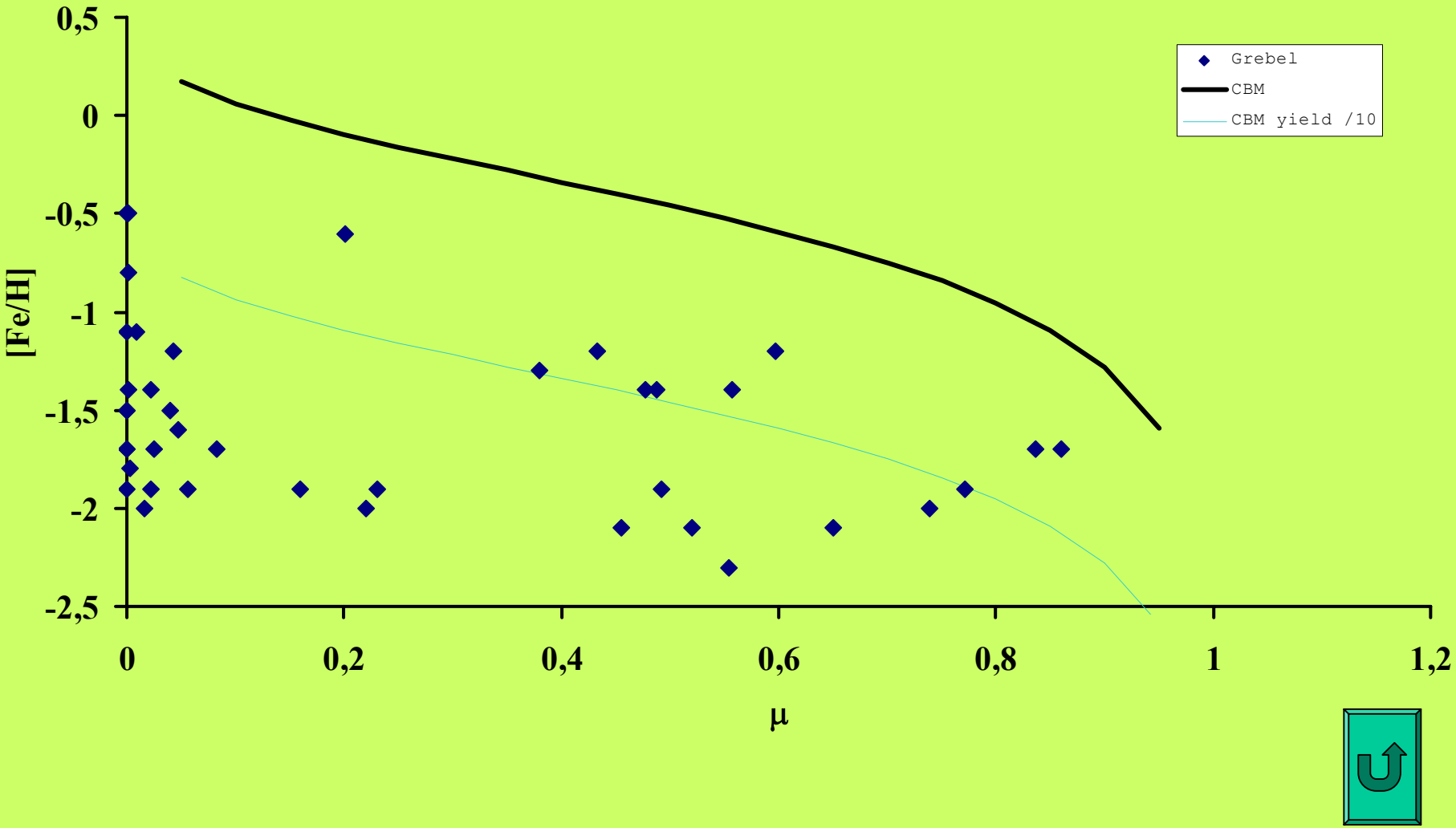
A dispersion will appear with different SFR efficiencies

This is in agreement with the behaviour found by Pilyugin, Vílchez & Thuan (2002)

SUMMARY

- The galactic winds may show a low rate of occurrence
- The low metallicity of regions with low fraction of gas may be explained if the protogalaxy gas falls more rapidly than stars form.
- The dispersion of relative abundance as N/O for low mass galaxies might be explained with new yields for LIM stars
- We need to compute more multiphase chemical evolution models for low mass galaxies using the new LIM yields and, also, including possible galactic winds.

The relation of metallicity with the gas fraction



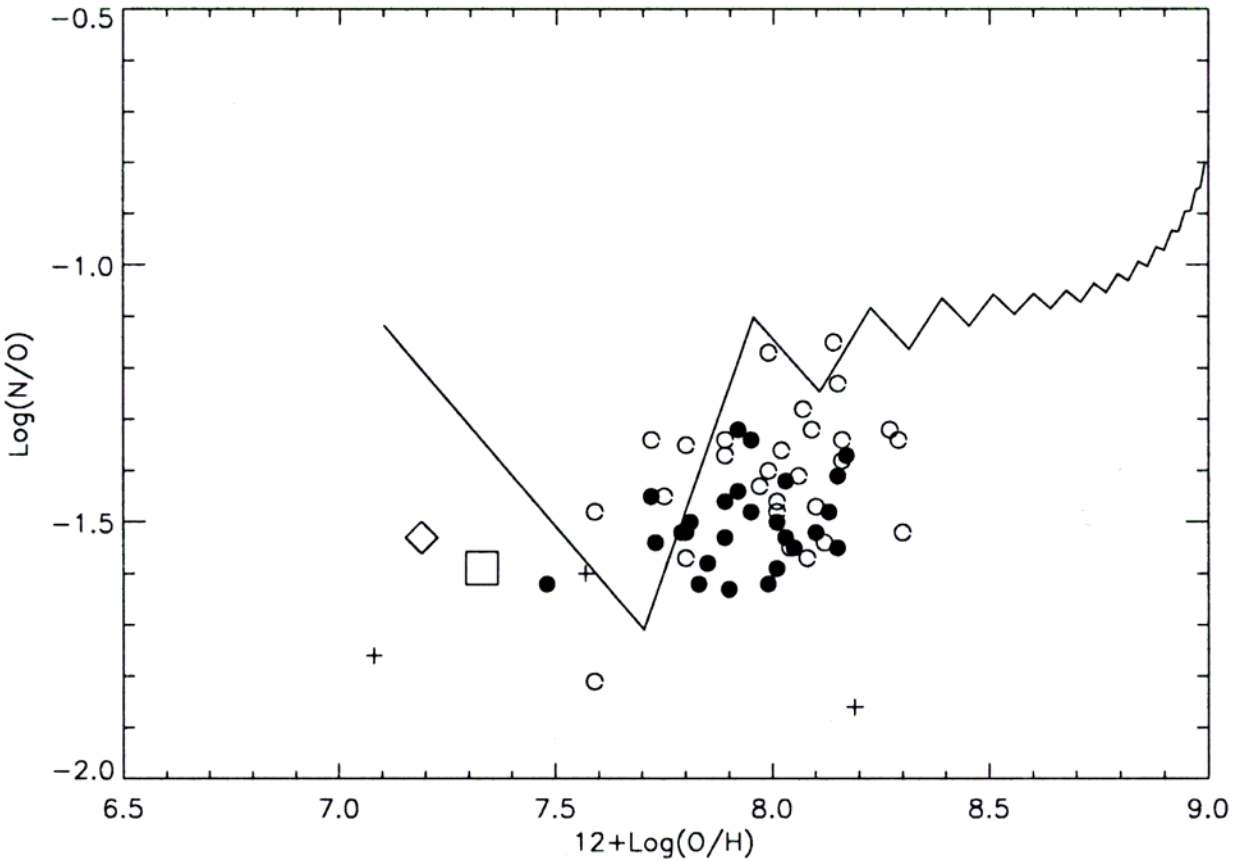
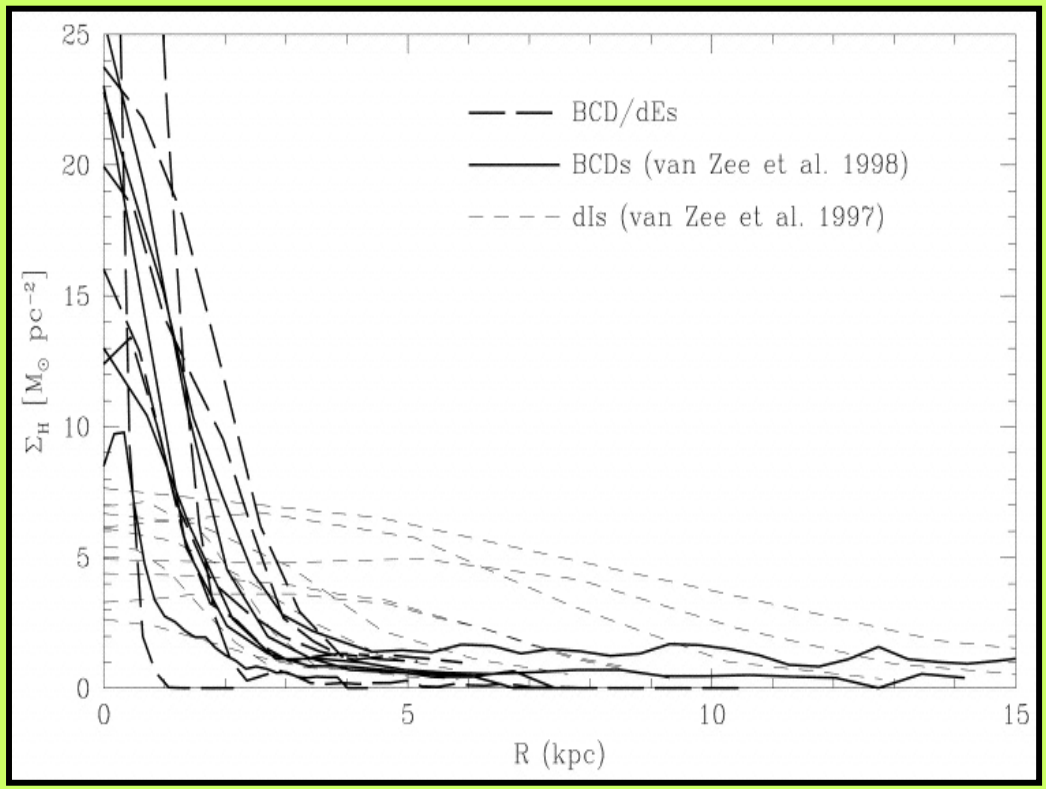


Figure 5. Results for a closed model using yield set no. 1 and $m_L = 0.1\,M_\odot$. The following parameters were adopted. The period between pairs of bursts is 1 Gyr and the short interburst periods are 30 Myr. The mass of the first burst is $1 \times 10^6\,M_\odot$ and those of the succeeding bursts are $3 \times 10^6\,M_\odot$. The observations shown are the same as in Fig. 1.

Neutral gas in BCD galaxies



The galaxies have :

- smooth symmetric isophotes and they appear to be rotationally supported
- stepper rotation curves than similar luminosity low surface brightness dwarf galaxies
- centrally concentrated mass distributions

The relation with SFR

- The star formation was assumed as bursts due to the low metallicity estimated in low-mass galaxies.
- Recent star formation histories, obtained from CMD of HST (Tolstoy) for local group dwarf galaxies, and colors UBV and Hα for a sample of isolated dwarf irregular galaxies (Van Zee 2001), imply that a large number of them has old stellar populations: the star formation has taken place in a quasi-continuous manner in dIrr´s. Only the BCG show bursting SFR concentrated in the center and steep radial color gradients.

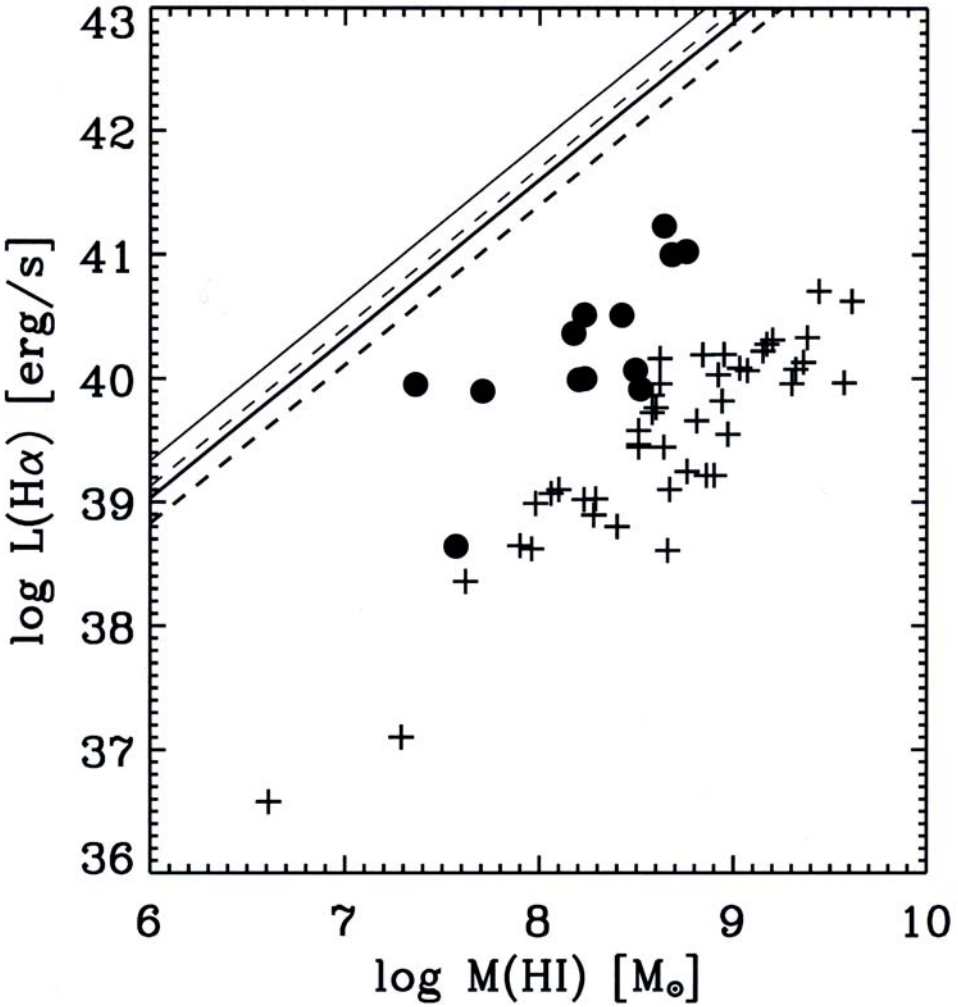
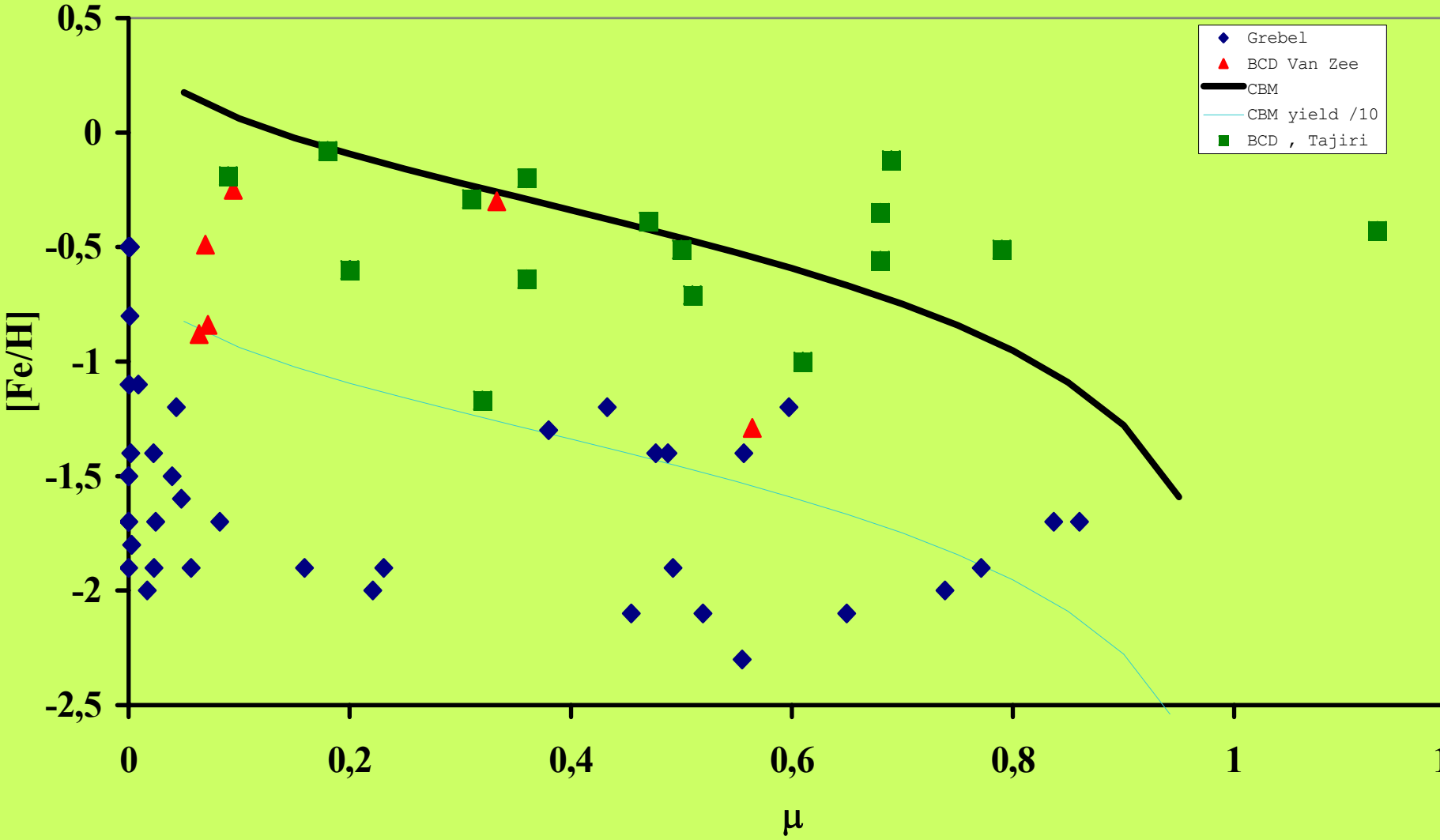


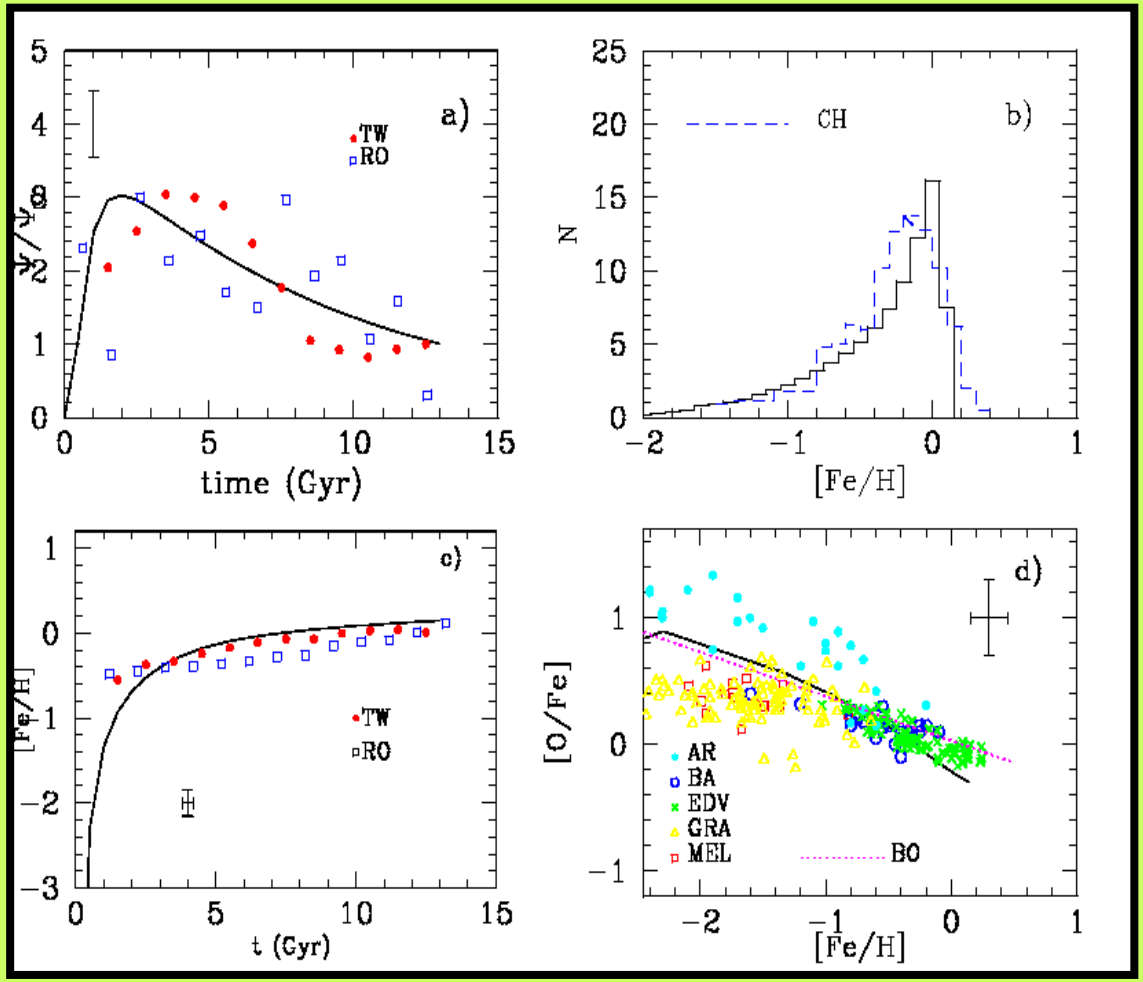
Fig. 1. The luminosity of Hα and the mass of HI gas instead of $M_{\rm gas}$. The filled circles are BCDs and the pluses are dIr The solid lines are from Eq. (6) and the dashed lines are from Eq. (6) with average internal extinction in dwarf galax: $(E(B-V)=0.2)$. The thick and thin lines are from Eq. (6) at $A_{\rm halo}=0$ and $A_{\rm halo}=1$, respectively.

The relation of metallicity with the gas fraction

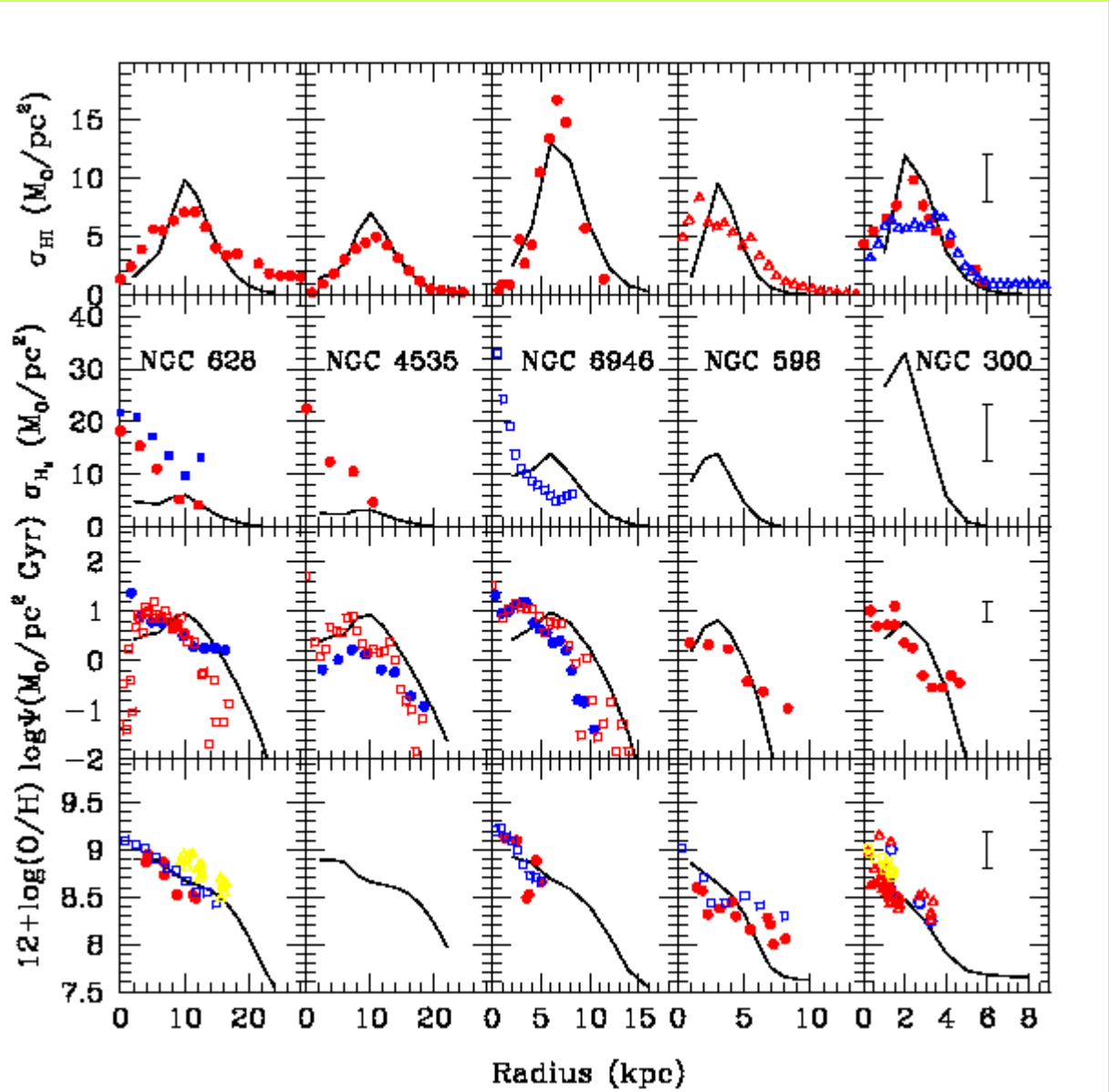


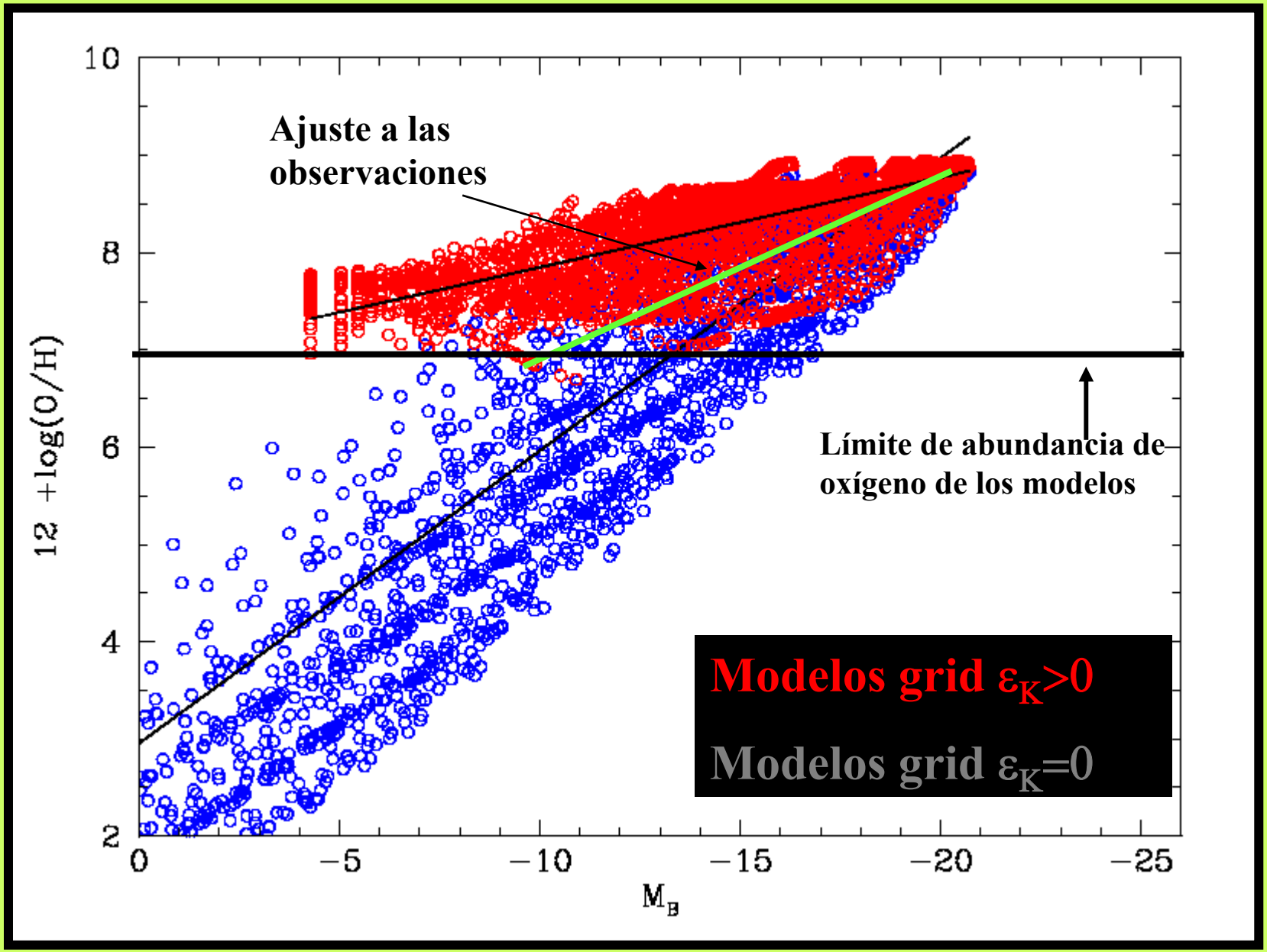
Resultados: La Vecindad Solar (calibración 1: Vrot=200 km/s y T=4)

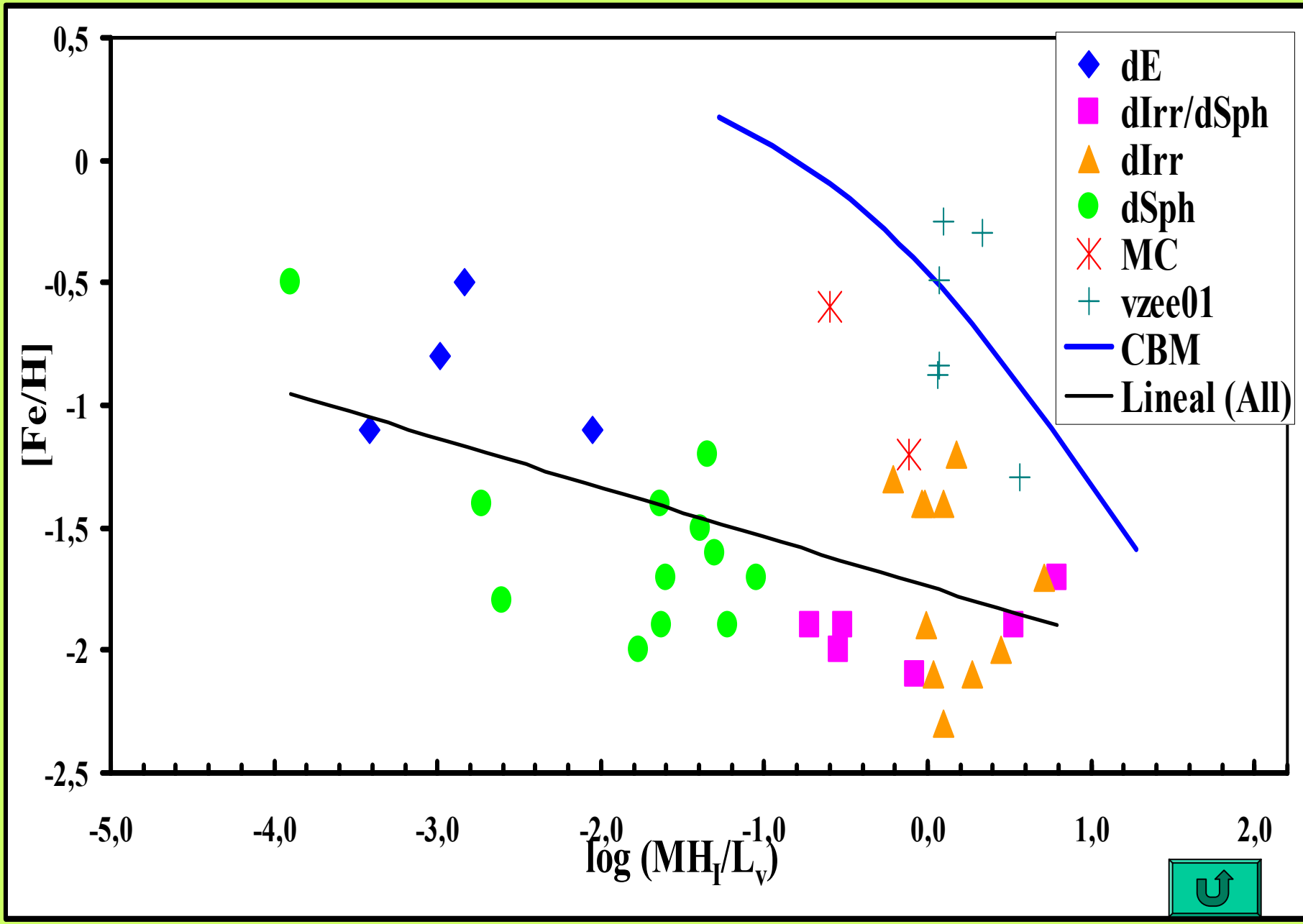
- **Tanto la relación edad-metalicidad como la historia de la formación estelar son adecuadamente reproducidas**
- **La distribución de metalicidad no tiene el problema de las G-dwarfs: la contribución del halo es esencial**
- **La abundancia relativa de los elementos α es +0.7 dex en [Fe/H]=-2, es decir, la contribución de SN-I y SN-II está bien calibrada**

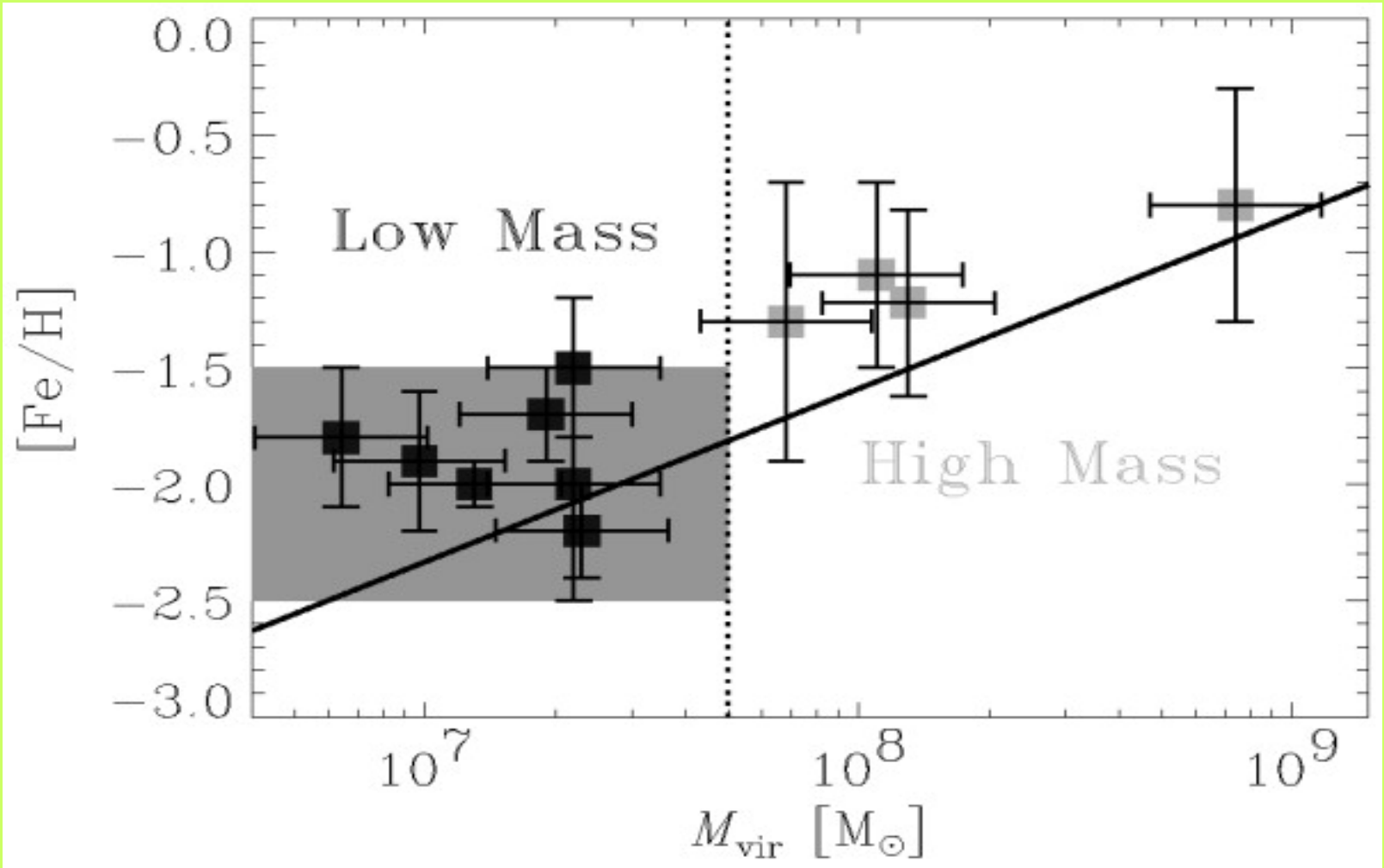


Resultados: Otras galaxias (calibración 3)




Ajuste a las observaciones
Límite de abundancia de oxígeno de los modelos
Modelos grid ε_K>0
Modelos grid ε_K=0
12 +log(O/H)
M_B
10
8
6
4
2
0
−5
−10
−15
−20
−25


0,5
0
-0,5
-1
-1,5
-2
-2,5
[Fe/H]
-5,0
-4,0
-3,0
-2,0
-1,0
0,0
1,0
2,0
log (MH_I/L_v)
dE
dIrr/dSph
dIrr
dSph
MC
vzee01
CBM
Lineal (All)


Low Mass
High Mass
[Fe/H]
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
10^7
10^8
10^9
$M_{\rm vir}$ [$M_\odot$]

Classification

Dwarf low mass galaxies are those with $M_B > -18$

Some types of these galaxies: dE´s,dSph´s, BCDG, dIrr´s

- dE´s without gas and elliptical shapes dominated by old stellar populations
- dSph´s least massive and luminous galaxies, low surface brighness, smooth distributions of stars, probably rotationally supported, complex star formation histories, poor-gas objects
- dIrr´s more gas-rich and less metallicity, without struture, gas dominated by random motions (Vrot in [5,60]km s^{-1})
- Transition objects dIrr/dSph combine features of both
- BCD rich gas systems dominated by a central region of active star formation. They may be embedded in a larger low surface brightness galaxies

- Both dSph´s and dIrr´s show similar exponential radial brightness profiles

A chemical evolution model

The existence of infall gas

Initial Conditions

Mtot of gas for t=0

Evolutionary Scenario

Hypotheses about SFR ψ (t) y FIM Φ(m)

EQUATIONS SYSTEM RESOLUTION

stellar evolution
mean lifetimes of stars
yields p_{zm}

comparison with observed data

RESULS:

- Gas, stars and total (g,s,m)(t,r)
- Abundances for 15 elements Xi, and total abundance Z
- Relative Abundances [X/Y]
- Star formation histories ψ (t,r)
- Age-metallicity relations Z(t,r)

Ingredients of the multiphase chemical evolution model

Nucleosynthesis prescriptions

1)Woosley & Weaver (1995) for M> 8

2)Renzini & Voli (1981) for stars 0.8 Mo < m < 8 Mo

3)Nomoto, Thielemann & Yokoi (1984) for SN-I

There exist different phases of matter in each radial cylinder

1.Diffuse gas

2.Molecular clouds

3.Massive stars

4.Low and intermediate mass stars

5.Remnants

The initial mass function was determined from the fragmentation of molecular clouds

$$\Phi(m) = 2.01 m^{-0.52} 10^{\left[2.07 (\log m)^2 + 1.92 \log m + 0.73\right]^{1/2}}$$

