Carnegie Observatories Astrophysics Series, Vol. 4:
Origin and Evolution of the Elements, 2004
ed. A. McWilliam and M. Rauch (Pasadena: Carnegie Observatories,
http://www.ociw.edu/ociw/symposia/series/symposium4/proceedings.html)

Chemical Abundances in Nearby Disk Galaxies and Distant DLAs

S. BOISSIER
The Observatories of the Carnegie Institution of Washington

Abstract

Chemical abundances measured in distant DLAs (Damped Lyman Alpha systems) are often used to probe the chemical evolution "of the universe" on cosmic timescales. This contribution summarizes several works * recently accomplished in the context of relatively simple models of the evolution of nearby galaxies, and its application to the study of DLAs. The importance of models reproducing the properties of nearby galaxies, the likely existence of biases affecting the observations of DLAs, and the possible contribution of disk-galaxies to the population of DLAs are the main topics of the text.

1.1 Introduction

Most of the knowledge of chemical abundances at high redshift comes from observations of DLAs (Damped Lyman Alpha systems). They are frequently used as tracers of the "cosmic evolution", despite the unanswered question of their nature.

Prochaska and Wolfe (1999) suggested that DLAs could be the precursor of present day spiral galaxies, while observational studies indicate a probable 'mixed bag' of morphologies for the DLA galaxies (e.g. Le Brun et al., 1997).

In the "backward" approach adopted here, models of the chemical and spectro-photometric evolution of galaxies are carefully calibrated in the nearby universe in order to match the properties of the present day galaxies. The "backward" approach is opposed to the forward approach in which the history of galaxies is derived from high redshift initial conditions and first principles. At the present time, semi-analytical (forward) models fail to reproduce the trends in the colors of disk galaxies (e.g. Bell et al., 2003).

In section 1.2, a family of recent "backward" models of the evolution of the Milky Way and spiral galaxies is presented. The latest computations concerning Low Surface Brightness galaxies are discussed in section 1.2.3. Once established that *these models are realistic for the nearby disk galaxies*, the chemical evolution of DLAs (Sec. 1.3.1) and their nature (Sec. 1.3.2) are explored within their framework.

* These studies involved the following collaborators: Chantal Balkowski, Alessandro Boselli, Giuseppe Gavazzi, Jinliang Hou, Delphine Monnier Ragaigne, Karen O'Neil, Céline Péroux, Max Pettini, Nikos Prantzos and Wim van Driel

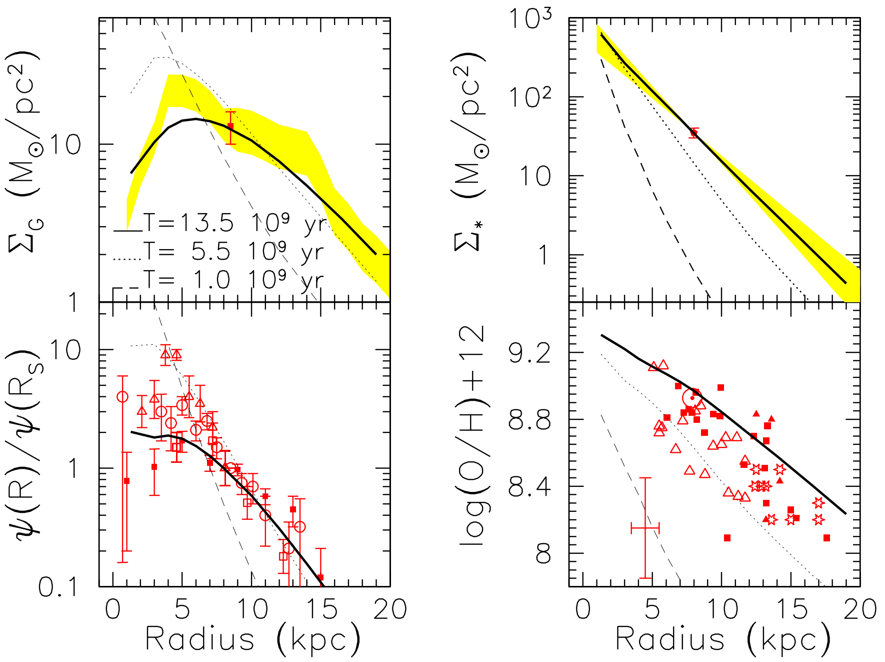

Fig. 1.1. Model of the chemical evolution of the Milky Way at various ages (lines), and comparison with the observations (for the gas, stellar, star formation rate ψ and oxygen abundance profiles) in our Galaxy (details in Boissier & Prantzos, 1999).

1.2 Models of the Evolution of Disk Galaxies

1.2.1 The Milky Way

In the Galaxy, many data are available (stellar abundances, gaseous profiles, present day mass function, age-metallicity relationship ...) which makes it possible to constrain the parameters (SFR, IMF, infall) of a model of its chemical and spectro-photometric evolution (e.g. Boissier & Prantzos, 1999).

Fig. 1.1 shows that the Milky Way model of Boissier & Prantzos (1999) is in agreement with the observed profiles of gas, stars, star formation rate and oxygen abundances. For the abundance gradients of other elements, see Hou et al. (2000). *Note that it is crucial that the models produce relatively realistic gas and metallicity profiles in order to compare them to Damped Lyman Alpha observations since the absorption can occur at any radius.*

1.2.2 Generalization : The Spiral Galaxies

Models of all kind of disk galaxies are obtained by *generalizing the Milky Way model*, assuming *i)* the same star formation rate prescription (a local Schmidt law modified by the the dynamical factor V(R)/R), *ii)* the same dependence of infall-timescales (accretion of primordial gas) on surface density, *iii)* the scaling relationships of Mo, Mao & White (1998), suggested in CDM scenarios. The size and total baryonic mass of the galaxy depend on the spin parameter λ (measuring angular momentum) and the rotational velocity V_C (measuring the mass of the dark halo), *iv)* a dependence of the infall time-scales on the mass

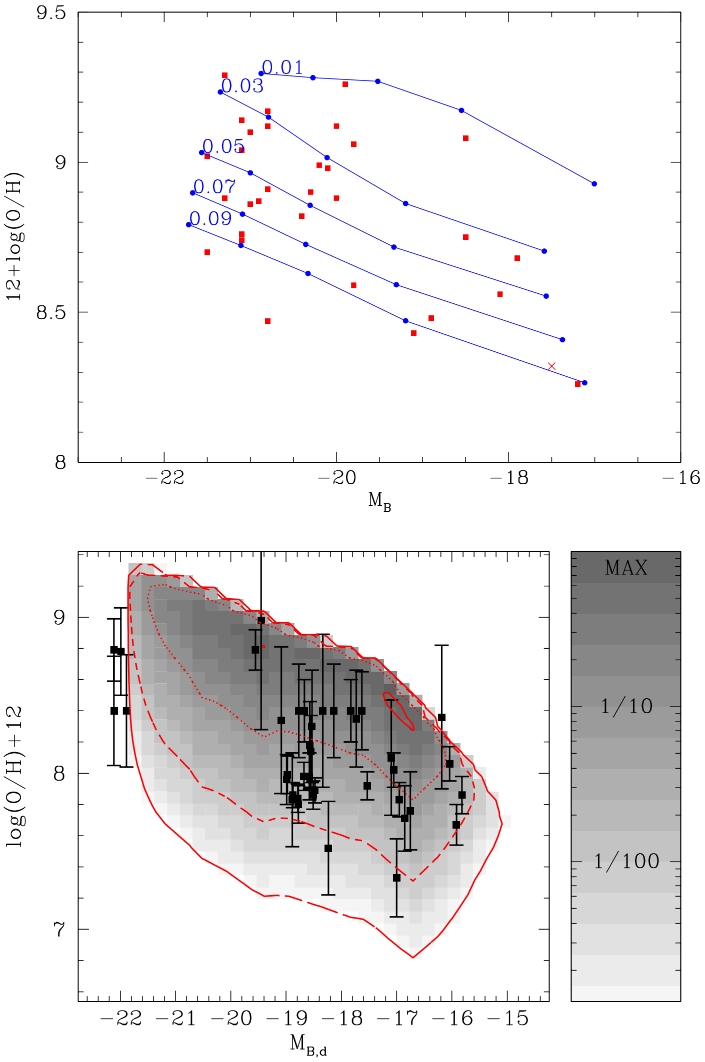

Fig. 1.2. Mass metallicity relationship for spirals (left) and LSB galaxies (right). For spirals, the data are from Garnett (2002) and O/H is determined at the effective radius of the galaxy. The lines are the models. For LSB galaxies, the data are from McGaugh (1994), obtained in HII regions at any radius in the galaxy. The expectations of the models are the contours and the gray scale.

of the galaxy: *more massive galaxies are "formed" earlier. This is a necessary assumption to reproduce several trends in the properties of present-day spirals* (Boissier et al. 2001).

One of the important properties of the present day disk galaxies that the models reproduce is the mass-metallicity relationship. This is illustrated on figure 1.2 with the data of Garnett (2002). The models also reproduce other properties of nearby spirals like colors, star formation efficiency, gas fraction (Boissier et al., 2001). Once again, it would be vain to compare

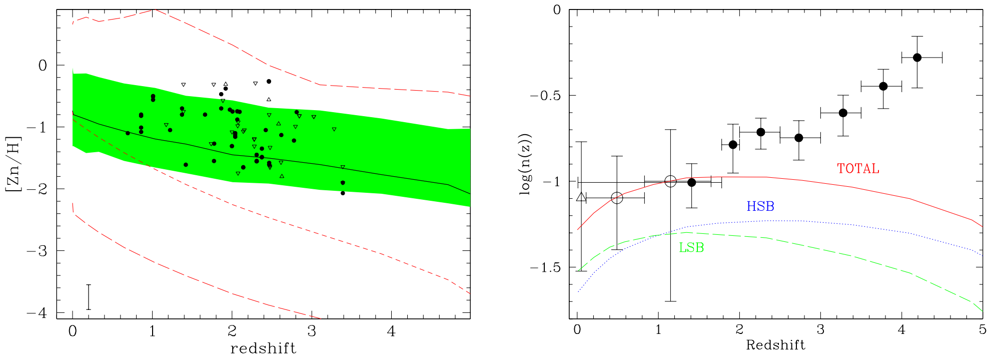

Fig. 1.3. LEFT: Evolution of the Zn abundance in DLAs (dots). The red lines show the minimum, maximum and average abundances found in models of spirals, when no bias is taken into account. When the biases (see text) are taken into account, the abundances obtained are within the green area. RIGHT: Evolution of the number of DLAs by unit redshift (dots) and predictions of the model for all disks, LSBs, and spirals (HSBs)

the models properties with high redshift DLAs if they were not matching local observations concerning the gas and the abundances ! The abundance gradients are also compatible with the observations in nearby disks (Prantzos and Boissier, 2000).

1.2.3 Low Surface Brightness Galaxies

In the framework of the models presented before, the galaxies with large spin parameters are Low Surface Brightness galaxies (LSBs). They represent a significant number of the total number of galaxies (35 % if adopting a limit of 22 mag arcsec^{-2}).

The properties of the large spin models and the observed LSB disk galaxies are presented in Boissier et al. (2003a). Here, is reproduced only the distribution of abundances (as measured in HII regions) expected from the models, and the few measurements available so far (figure 1.2). The range of abundances are compatible.

The weakness of the model for LSB galaxies is the fact that they do not produce the large range of colors observed in LSBs. However, this is likely to be due to small bursts and truncations of the star formation history, affecting mainly the colors but not the main properties (scale-length, abundances, HI) of the galaxies (see Boissier et al 2003a).

1.3 Damped Lyman Alpha Systems

1.3.1 Chemical Evolution

The abundance of Zn observed in DLAs (Fig. 1.3) present a very small evolution. this is contrary to the predictions of simple galactic models (red lines). However, *when detection limits and selection effects are taken into account, as well as the effect of the extinction, the evolution predicted for spiral galaxies is in good agreement with the observed evolution of [Zn/H] in DLAs* (see details in Hou et al., 2001, as well as similar results for other elements).

Dust effects may also be seen in relative abundances: the ratio of refractory elements to Zn (suffering little depletion) seems to depend on the quantity F=log(NH)+[Zn/H] (measuring probably the quantity of dust along the line of sight). Hou et al. (2001) suggest then than systems with very high value of F are not observed because of the large amounts of dust they contain, and the effects of dust become less and less large when F becomes lower.

1.3.2 Nature of the Absorbers

The previous section shows that the metallicity evolution of DLAs may be biased and thus a poor indication of the cosmic evolution. For this reason, we have to understand which objects dominate the population of DLAs, and how this evolves with redshift.

In Boissier, Péroux and Pettini (2003b), the number of DLA by unit redshift (Fig. 1.3), the distribution of HI column densities, the total gas densities predicted by models of spiral galaxies and LSB are compared with DLAs data.

It is concluded that *at low and intermediate redshift (below 2), most of the DLAs could indeed be spirals and LSB galaxies, each of them in similar amount*. At higher redshift, however, the precursors of today's disks are not in large enough number to explain the observed DLAs. DLAs at high redshift have typically smaller column densities and may be dwarf galaxies that will merge later to form more massive galaxies.

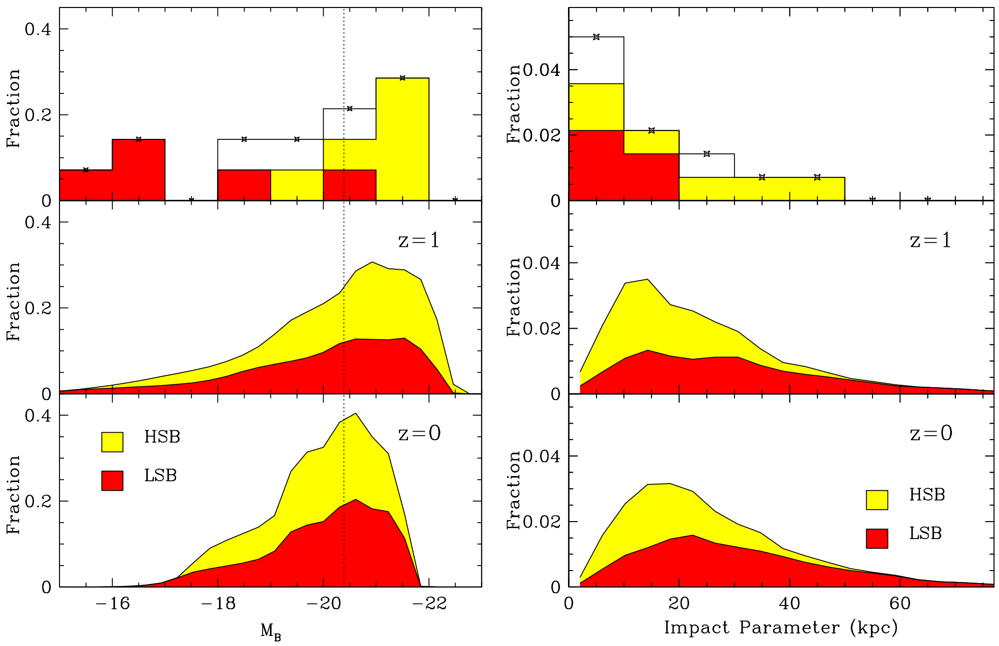

Fig. 1.4. Distribution of magnitude (left) and impact parameter (right) in DLA-galaxies identified at redshifts lower than 1 (histogram) and predictions of the models for redshift 1 and 0.

Imaging of nearby DLAs (redshift lower than 1) can help to understand the nature of DLAs. However, at the present time, identifications of DLAs with galaxies concern a small number of objects, with very few confirmations. Despite the fact that this sample is highly biased, the distribution of some properties (magnitude, impact parameter: see figure 1.4) of the DLA-galaxies have been computed and compared with models (see Boissier et al.

2003b). It is probably too early to derive conclusions from these distributions, but future observations and confirmations of DLA-galaxies will provide data to build more robust distributions.

1.4 Conclusion

It would be vain to compare DLAs with a model unable to reproduce the properties of nearby galaxies. The "backward" models presented in this contribution were carefully calibrated to reproduce the properties of the Milky Way, local spirals and Low Surface Brightness galaxies. The comparison of their evolution with DLAs observations indicates that the metallicity evolution of DLAs is in good agreement with the evolution of spirals once taken into account the role of dust and observational biases. The precursors of present-day LSB and spirals can well explain the number of observed DLAs at redshift lower of $\sim$ 2, spirals and LSBs contributing by a similar amount. At higher redshift, there are signs that DLAs may be smaller galactic units destined to merge on more massive systems. Finally, the properties of galaxies actually identified with DLAs are still too scarce to derive strong conclusions. However, the future confirmations and identifications of DLA-galaxies will bring more insight on the nature of DLAs.

References

Bell, E., Baugh, C., Cole, S., Frenk, C. & Lacey C., 2003, MNRAS, 343, 267
Boissier, S. & Prantzos, N., 1999, MNRAS, 307, 857
Boissier, S., Boselli, A., Prantzos, N. & Gavazzi, G., 2001, MNRAS, 321, 273
Boissier, S., Monnier Ragaigne, D., Prantzos, N., Balkwoski, C. & van Driel, W., 2003a, accepted in MNRAS.
Boissier, S., Péroux, C. & Pettini, M., 2003b, MNRAS, 338, 131
Garnett, 2002, ApJ, 581, 1019
Hou, J.L., Prantzos, N. & Boissier, S., 2000, A&A, 362, 921
Hou, J.L., Boissier, S. & Prantzos, N., 2001, A&A, 370, 23
McGaugh, S.S., 1994, ApJ, 426, 135
Mo, H. J., Mao, S.& White, S.D.M., 1998, MNRAS, 295, 319
Le Brun, V., Bergeron, J., Boisse, P., & Deharveng, J. M. 1997, A&A, 321, 733L
Prantzos, N. & Boissier, S., 2000, MNRAS, 313, 338
Prochaska, J. X. & Wolfe, A. M. 1999, ApJS, 121, 369