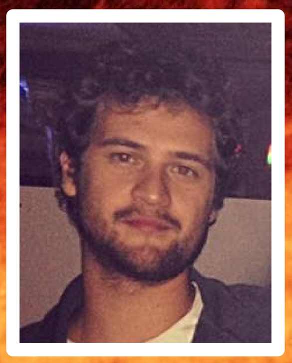

Dust in the ISM: evolution in DLA systems, irregular and spiral galaxies

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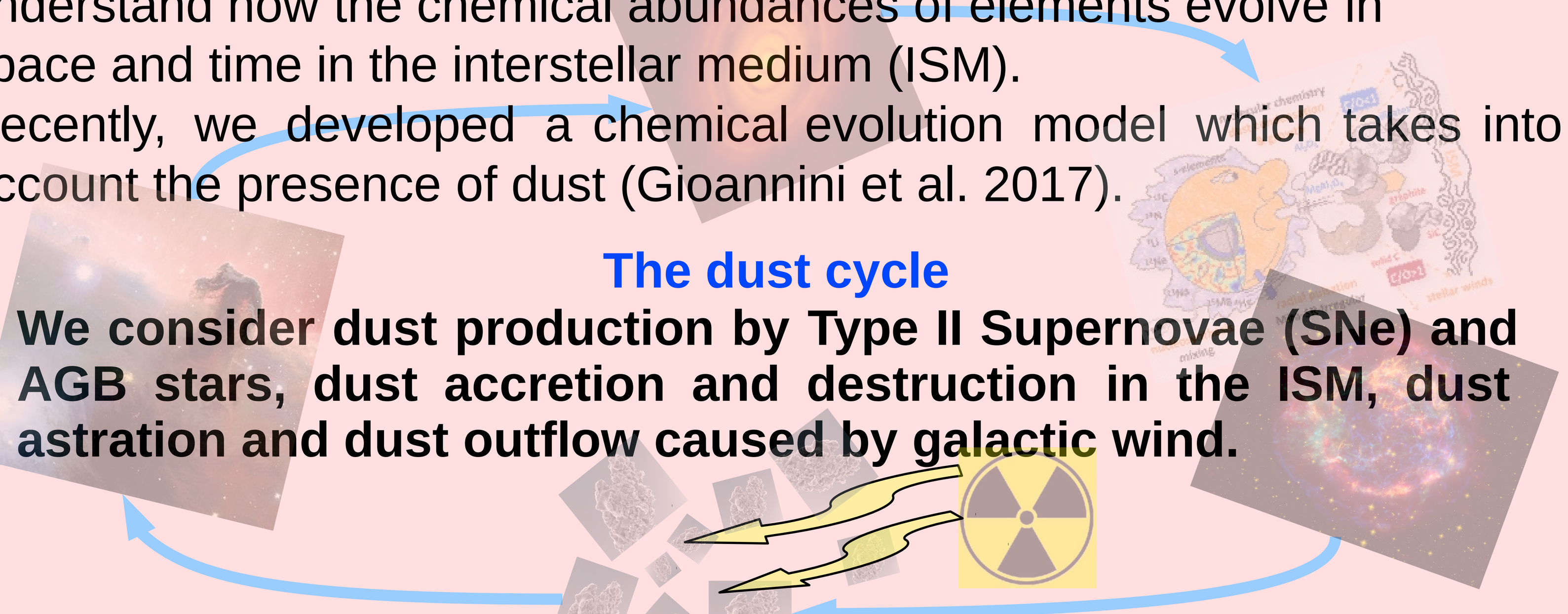
1. Introduction: a chemical evolution model with dust

The study of the chemical evolution of galaxies allows us to understand how the chemical abundances of elements evolve in space and time in the interstellar medium (ISM).
Recently, we developed a chemical evolution model which takes into account the presence of dust (Gioannini et al. 2017).



The dust cycle

We consider dust production by Type II Supernovae (SNe) and AGB stars, dust accretion and destruction in the ISM, dust astration and dust outflow caused by galactic wind.

Our model is very useful to study dust properties in the ISM of different environments. Here, we focus on:

1) Damped Lyman Alpha (DLA) systems.
2) Dust-to-gas (D/G) ratios in the ISM of irregular and spiral galaxies.
Star formation histories of our models are presented in Fig. 1.

2. Motivations and models

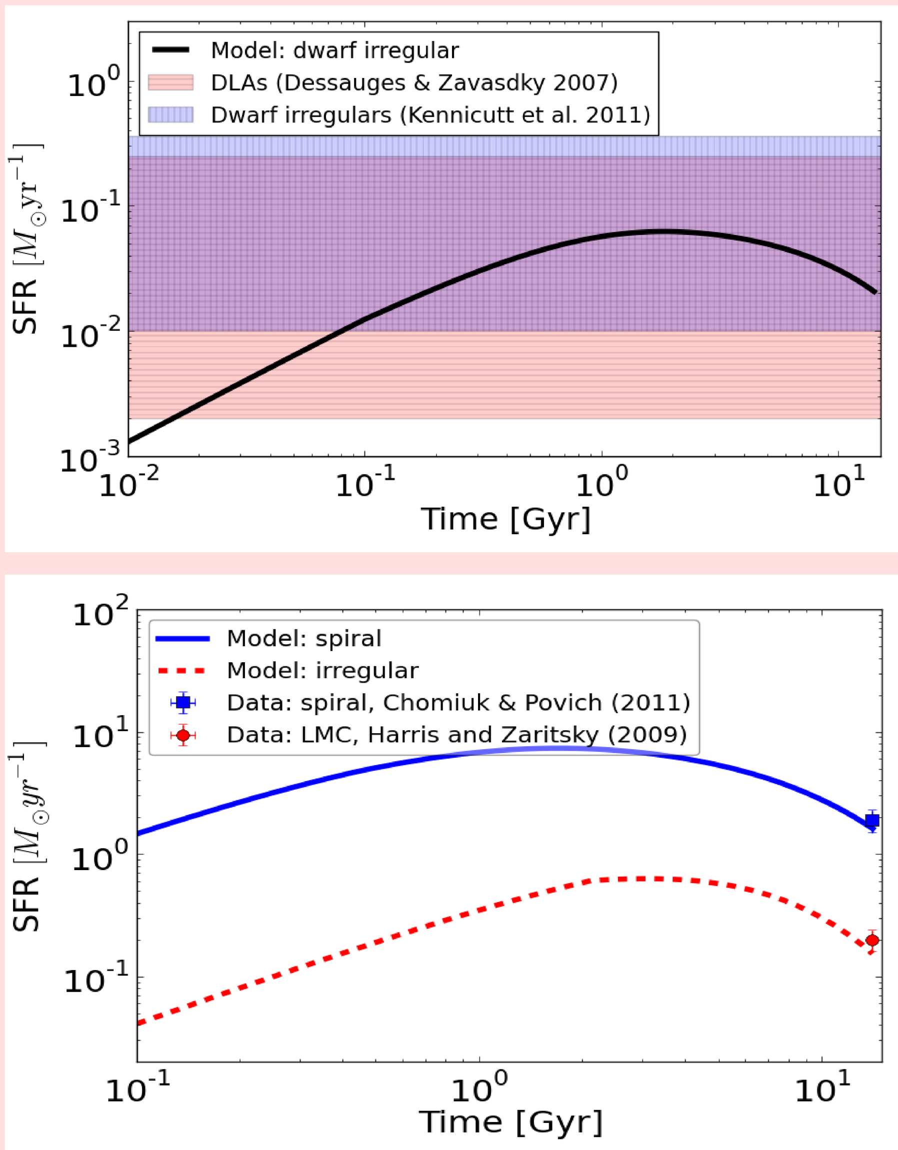


Fig. 1. Star formation histories of our reference models of a typical dwarf irregular (top panel), Magellanic irregular and spiral galaxy (bottom panel). Our models are in agreement with star formation rates measured in each galaxy type.

1) **DLA systems:**

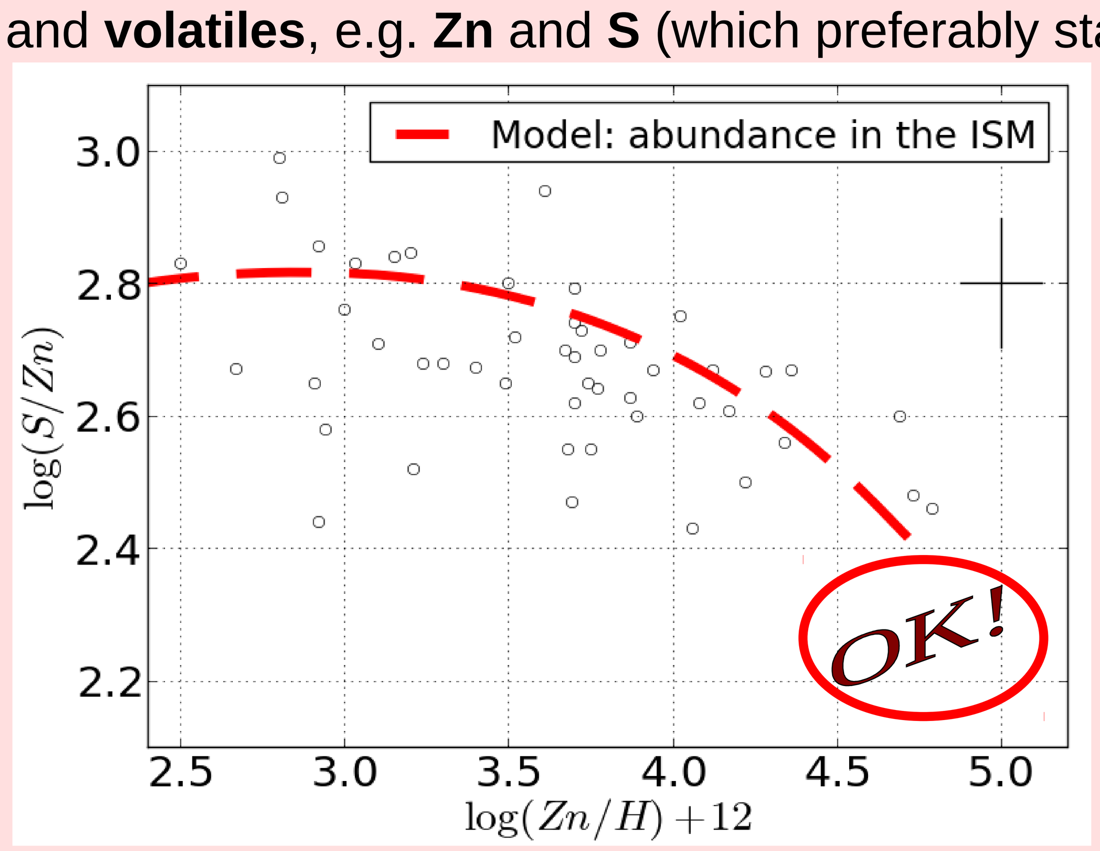
- Quasar-absorbers with $N_{HI}>10^{20}cm^{-2}$
- Redshift range [1<z<5].
- Associated to dwarf irregular galaxies.
- Directly reflect the chemical composition of the gas phase of the ISM.
- Comparison with models to constrain dust chemical composition.

2) **Dust-to-gas ratio and metallicity:**

- The D/G links the metal mass restored in the dust phase of the ISM to the total metal abundance.
- The metallicity is a key parameter in the study of galaxy evolution.
- The relation between D/G and metallicity is an important diagnostic tool to understand the dust evolution in galaxies.
- Study of the origin of the observed spread in irregular and spiral galaxies.

3. Results: dust chemical abundances in DLAs

For our purpose, we compare the abundance of different elements: **refractories**, e.g. **Si** and **Fe** (which tend to be incorporated into dust grains), and **volatiles**, e.g. **Zn** and **S** (which preferably stay in the gas phase).



The abundances of volatiles represent those of the ISM and can be used to constrain our models (Fig. 2).
The agreement between our model and data, **confirms the tight connection between DLAs and dwarf irregulars**.

Fig. 2. Volatile S/Zn abundance ratios versus Zn/H in DLA systems. Data: collection of Vladilo et al. (2011) and Gioannini et al. (2017).

Here we compare refractory elements with volatiles. In the case of silicon (Fig. 3, left panel) our "dust-corrected" model agrees with data. On the contrary, the depletion pattern of iron (right panel) is well reproduced by our model only if we consider an **additional source of iron dust** (from Type Ia SNe or more efficient dust accretion).

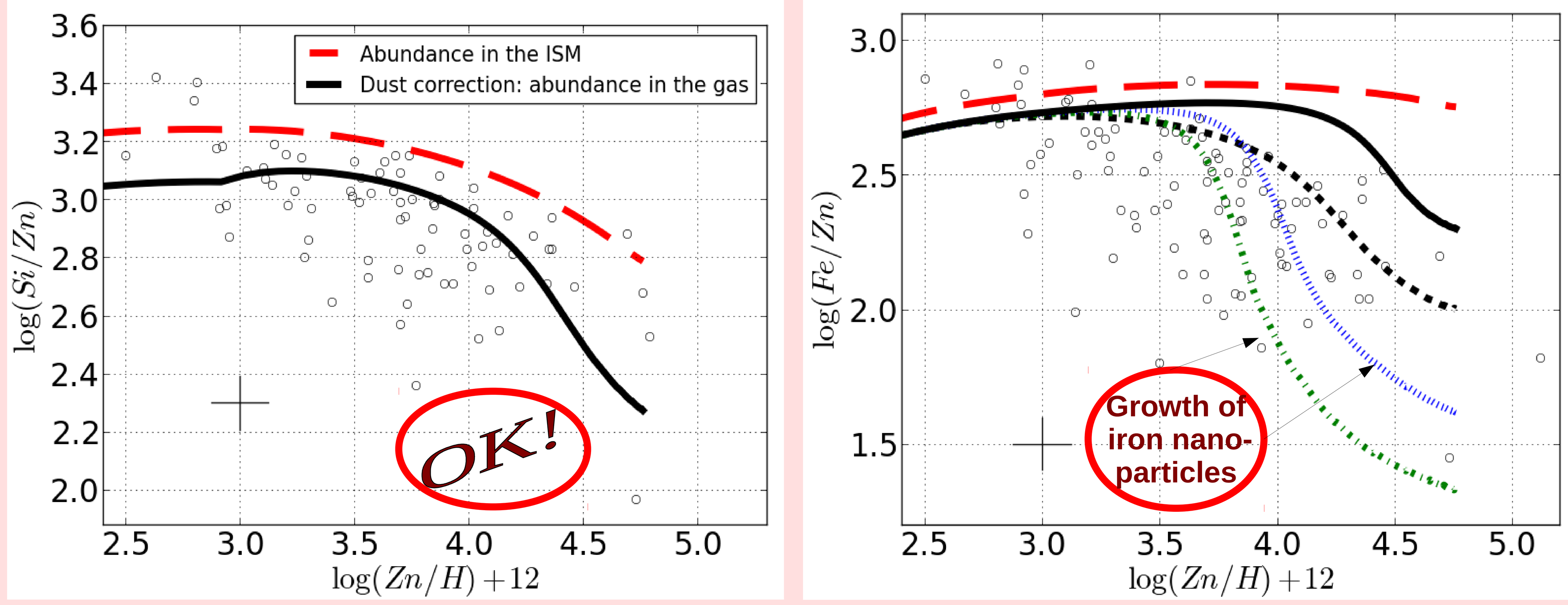


Fig. 3. Abundance ratios of refractory (Si,Fe) over volatile (Zn) versus log(Zn/H)+12 in right and left panel, respectively. Different lines: model with dust contribution from Type Ia SNe (black-dashed), model with more efficient iron-growth (Blue and green).

4. Results: dust-to-gas ratio in irregulars and spirals

D/G spread in galaxies of different morphological Type (Fig. 4, right panel):

- **Irregulars show a large spread at low metallicities**. This is explained by different contributions of Type II SNe and can be connected to the ISM density.
- **Spirals have a narrower dispersion at higher metallicity**;
This is mainly due to variations of star formation efficiency and it is independent from the efficiency of dust formation in stars.
- Our reference models agree with the median values of the measured dust-to-gas ratios (Fig.4, left panel).

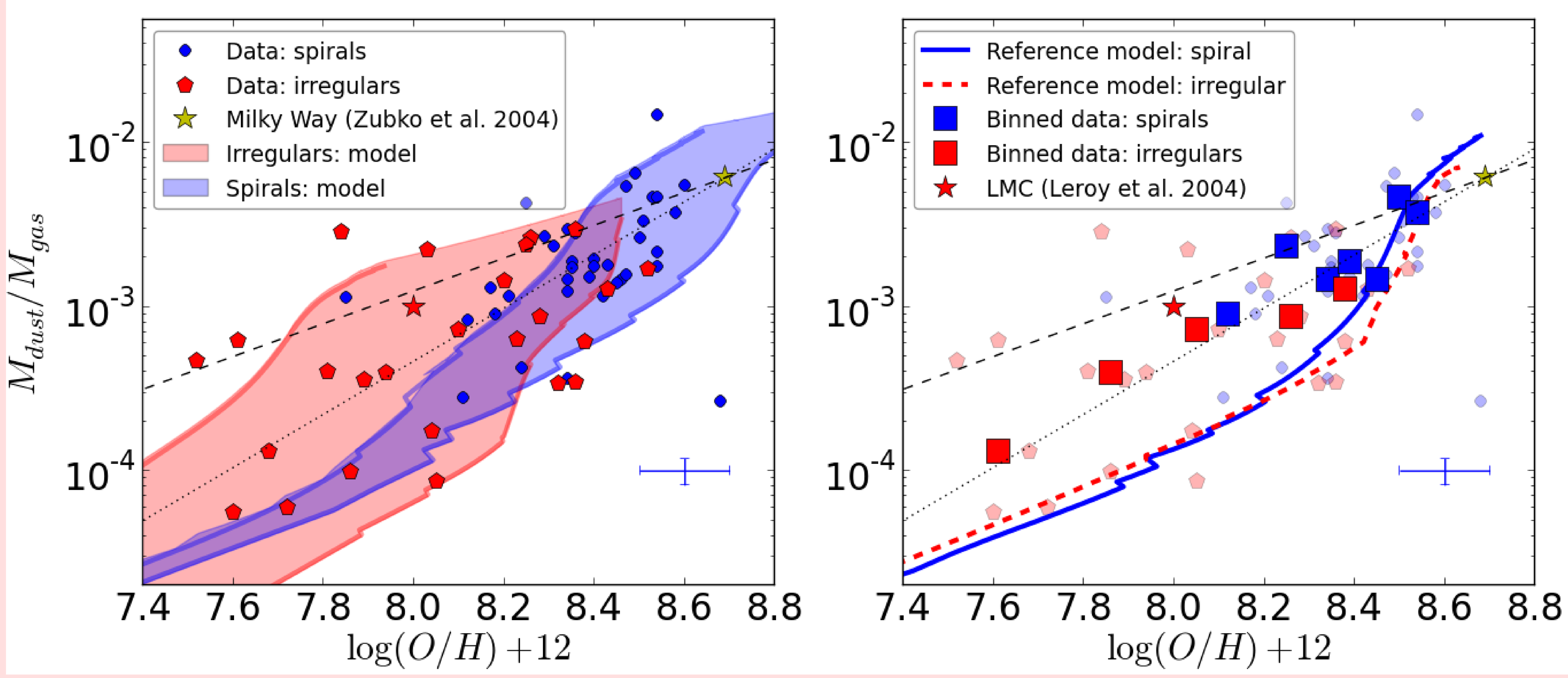


Fig. 4. Dust-to-gas ratio in irregulars and spirals versus metallicity. Left panel: filled areas represent regions occupied by models at varying the parameters. Right: blue and red lines represent our reference models for a typical irregular and spiral, respectively. Data from Rémy-Ruyer et al. (2014).

5. Conclusions and future work

- The depletion pattern of refractories, compared with the dust-corrected model, suggests that **Si and Fe undergo a different history of dust formation and evolution.**
- Iron in dust: model and data are in agreement if we assume a more efficient dust accretion, which is consistent with the **presence of iron nano-particles in the ISM**.
- The study of the D/G ratio in irregulars and spirals is fundamental to constrain the parameters of our models.
- Dust contribution from Type II SNe has a stronger impact on irregulars: this can be related to a lower density of the ISM with respect to spirals.

In the future, we will study elliptical galaxies, to understand the origin of dust in high redshift objects. Consequently, we will study the evolution of the dust mass during the cosmic time, i.e. **the cosmic dust rate**.

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