Probing Galaxies through Quasar Absorption Lines
Proceedings IAU Colloquium No. 199, 2005
P. R. Williams, C. Shu, and B. Ménard, eds.

doi:10.1017/S1743921305002954

Self-consistent modelling of the dust evolution in damped Ly-alpha systems

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Abstract. We present a model which allows for a self-consistent calculation of spectrophotometric, chemical, and dust evolution of spiral and irregular galaxies. Dust evolution is treated without the Instantaneous Recycling Approximation on the basis of the Dwek (1998) model, where up-to-date dust yields for SNe and intermediate mass stars on their AGB phase are taken into account. Confronting model results with the chemical abundances observed in DLA systems, we conclude that spiral and irregular galaxies are good candidates for DLAs.

1. Introduction

Damped Lyα systems are a class of QSO absorbers with N(HI)$> 2 \times 10^{20}$ cm^{-2}. Due to high hydrogen column densities, they were traditionally assumed to be the progenitors of present day galaxies observed at early stages of their evolution. Several identifications of DLA systems at low redshifts and chemical evolution models developed by several groups have confirmed this idea (Ferrini *et al.* 1997; Lindner *et al.* 1999; Pilyugin 1999; Hou *et al.* 2001). Damped Lyα systems are famous for the strong influence of dust on their chemical pattern, which has been found from the difference in gas-phase abundances of heavy depleted and undepleted elements (Pettini *et al.* 1997). In the above-cited models, though, chemical evolution of DLA systems was described without distinguishing between the heavy element fraction in gaseous and dust phases. Only recently (Vladilo 2002a; Calura *et al.* 2003; Lanfranchi & Friaca 2003) has this issue been addressed on the basis of analytical dust corrections (Vladilo 2002b).

2. Dust evolution modelling

Chemical evolution models for gas-rich galaxies usually do not make the distinction between the heavy element abundances in gaseous and dust phases. When the correction for dust is needed, the dust-to-gas ratio is assumed to be equal to the value for the Milky Way or for one of the Magellanic Clouds. In this way self-consistency in dust evolution is broken, since the dust-to-gas ratios are taken as fixed values.

Usually, only optical properties of dust grains are taken into account properly (radiative transfer modelling, correction of galactic SEDs, and colours on internal and external extinction etc.). But during recent years a lot of new observational data and theoretical results concerning dust evolution have become available. Both dust sources and dust evolution processes have been studied in detail by many groups. And new possibilities are open now for self-consistent calculation of dust chemistry as well. Although such modelling is rather complicated, it is possible.

An alternative self-consistent description of chemical and dust evolution of the interstellar medium of gas-rich galaxies, based on numerical simulations of the dust formation and destruction processes, was first suggested by Dwek (1998). In this way the evolution of the dust fraction for each depleted heavy element in the galactic ISM may be calculated according the chemical evolution of this element in the interstellar medium. By summing up the dust fractions of all depleted elements, the total dust-to-gas ratio may be derived self-consistently at any stage of galactic evolution.

In our approach to dust evolution in damped Ly-alpha systems we follow Dwek's recipe. Here we present a description of our numerical model, which allows the simultaneous calculation of the spectrophotometric, chemical, and dust evolution of gas-rich galaxies. The model was developed on the basis of the spectrophotometric evolutionary synthesis code $PEGASE.2$ (Fioc & Rocca-Volmerange 1997). The original code has been modified and now incorporates all necessary ingredients for the calculation of the chemical and dust evolution, as well as tools to estimate the corresponding influence of dust on heavy element abundances in their gaseous phase. Together with the original $PEGASE.2$ outputs (SEDs, colours, ISM metallicity, etc.) the chemical abundances of several chemical elements in the gaseous and dust phases also become available.

The gas in the ISM is treated as a two phase system (dust and gas). The fraction of a depleted element X which is locked up in the solid state depends on the details of the dust evolution. The main dust evolution processes are taken into account: dust condensation during the SNe ejecta and during mass loss of low and intermediate mass stars in their AGB phase; dust grain growth by accretion onto pre-existing dust grains in dense molecular clouds; and dust destruction by interstellar shock waves (see Dwek 1998 for details). The evolution of the dust phase of the ISM is involved self-consistently and is calculated simultaneously with the spectrophotometric and chemical evolution. The model may be considered as self-consistent as far as integrated SEDs and colours are corrected for the interstellar extinction, the chemical enrichment of ISM is due to accounting for the increasing metallicity of new stellar generations, and the Instantaneous Recycling Approximation is not used in dust evolution calculations.

Our model for spiral galaxies matches several observational constraints, such as integrated colours, nearby template spectra, the SNe rates, oxygen gas-phase abundances in ISM, the gas content, and the dust depletion pattern in local ISM. We use the IMF in the form given by Kroupa (2001) and assume a Schmidt-type star formation law. Stellar yields for low and intermediate mass stars are taken from (Marigo 2001), for massive stars evolving as SN type II from (Portinari *et al.* 1998), and for SN type Ia from (Iwamoto *et al.* 1999) respectively. A more detailed description of the model and the first preliminary results may be found in (Kasimova & Shchekinov 2004; Kasimova 2004). An updated version of the model with recent stellar and dust yields will be published soon.

It should be noted that a dust evolution model based on Dwek's prescription allows numerous modifications:

i) The parameters describing the dust grain growth by accretion onto preexisting dust grains, and dust destruction processes caused by the interstellar shocks may be calculated separately for each depleted element. In this way the dust evolution of different elements may be considered with the purpose of reproducing the observed dust depletion pattern in the ISM;

ii) Dust yields from SNe and intermediate mass stars on their AGB stage may be restricted on the basis of recent theoretical calculations (Todini & Ferrara 2001; Gail & Ferrarotti 2005);

iii) Many possibilities exist within the framework of an open galactic evolution model. Selective gas and dust ejection caused by radiation pressure (Shustov & Vibe 1995) and by galactic winds (Martin 2004) may be useful in interpretation of high redshift objects.

3. Chemical abundances of DLA systems

DLA systems exhibit a wide scatter in their chemical abundances. Various types of gas-rich galaxies with different histories of star formation and, thus, different histories of chemical enrichment possibly may explain this observational fact, but dust corrections are essential in all interpretations.

We have developed a self-consistent spectrophotometric, chemical, and dust evolution model for gas-rich galaxies on the basis of the $PEGASE$.2 code and the Dwek (1998) model. Comparing abundances observed in DLA systems over the available redshift range with our simple one-zone model calculations for spiral (from early to late types) and irregular galaxies, we have concluded that these gas-rich galaxies fit the DLA's chemical pattern reasonably well, and may be considered as DLA absorbers (Kasimova & Shchekinov 2004; Kasimova 2004).

More complicated galactic evolution models with up-to-date chemical and dust yields for SNe stars and intermediate mass stars on their AGB phase (Todini & Ferrara 2001; Gail & Ferrarotti 2005) nevertheless are necessary and this work is under way.

Acknowledgements

E. Kasimova has the pleasure of thanking the IAU and RFBR 04-02-27168-z for travel grants and for the unique opportunity to visit Shanghai, and the organisers for their hospitality and a very stimulating conference.

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