Publ. Astron. Obs. Belgrade No. 65 (1999), 105 – 110

QSO ENVIRONMENT AND ASSOCIATED DAMPED LY$_\alpha$ GALAXIES

NATAŠA STANIĆ,[1] MILAN M. ĆIRKOVIĆ,[1] and SRDJAN SAMUROVIĆ[2]
[1] *Astronomical Observatory, Volgina 7, 11000 Belgrade, SERBIA*

[2] *Dipartimento di Astronomia, Università degli Studi di Trieste, Via Tiepolo 11,I-34131 Trieste, ITALY*

Abstract. The ionization state of matter in physical proximity to the QSO is considered in view of several recent developments. The best indicators of the physical conditions in the vicinity of powerful ionizing sources such as QSOs are the so-called associated damped Ly$_\alpha$ systems, many examples of which have been discovered during last ten years. We discuss various processes which could both increase and decrease the intensity of the observable emission and absorption spectrum, such as quasar winds, quasar-induced galactic winds and enhanced depths of the Strömgren layer of galactic disks. This is a part of ongoing project aimed at detailed modelling of the state of matter in unusual conditions expected in the QSO vicinity and in early epochs of cosmic time. Prospects for further work and finding "fossil" relicts of such conditions in the local universe are briefly discussed.

1. INTRODUCTION

Damped Lyman-alpha systems (DLAS) are mainly highly redshifted, high column density Ly$_\alpha$ absorbing systems containing a huge amount of gas and appear to be progenitors of present-day galaxies. From an observational point of view, we know about them from the QSO spectra (and, in several cases from their own emission [Gnedin 1987]). Their wide (hence the qualification "damped") absorption lines are unlike narrow lines in the Ly$_\alpha$ forest and are always associated with other (mainly metal) absorption lines, from which we learn much about the chemical and ionization structure of matter at high redshift. DLAS are optically thick to ionizing radioation above the Layman limit ($h\nu > 13.6eV$). Their number was much greater at early epoch of the universe when gas component was dominant (evolved little apart form forming stars), which is expressed in the empirical formula for redshift evolution of their number density [Storrie-Lombardi et al. 1996]:

$$\frac{dN}{dz} = 0.04^{+0.03}_{-0.02}(1+z)^{1.3\pm0.5} \qquad (1)$$

The lowest redshift DLAS was recently discovered at $z = 0.093$ [Turnshek 1997]. A subgroup of DLAS we are particularly interested in are **associated DLAS (ADLAS)**, which are those DLAS whose redshift are kinematically close to the emission redshift of QSO. In some cases, damped absorption redshift could be even higher than the emission redshift [e.g. Ref]. Whether an ADLAS is also physically associated with the QSO lying in its vicinity, and what are criterions for suvh physical association, remain some of the most intriguing mysteries in the absorption studies research. Some recently noted peculiarities (e.g. chemical abundance anomalies) have emerged as possibilities which will be considered in more detail in the course of this research.

The contribution of DLAS, as a population of high column density layers of neutral hydrogen ($N_{HI} \geq 10^{20} atoms \quad cm^{-2}$), to the comoving mass density of neutral gas ($\Omega_g(z) \approx 10\%$ of baryonic content of the universe at high redshift $z \approx 3.5$) is comparable to current visible matter [Ref] and decreases with time (because of gas consumption due to star formation since $z \approx 3.5$ to the present time). As we know till now, most of visible matter is in normal, luminous spirals, so at first sight we see a close connection between them and DLAS. From an intent study of kinematics of the low and high ionization gas phases (velocity broadening of absorption lines etc.) we got a direct evidence of their internal velocity dispersion. Such a velocity broadening could be due to the rotation (furthermore measured velocity is order of magnitude as in rotational disk, about $120 kms^{-1}$), random motions, infall effects or merging. In several cases, spectral signatures can be used to directly measure rotational velocity of the DLAS, and it is consistent with their interpretation of disks of normal, $L \sim L^*$ galaxies [Ćirković, this volume].

Therefore, investigation of DLAS allows us to probe the distant part of normal galaxies. For instance, their chemical abundances (gas plus dust) allow us to test our comprehension of galactic chemical evolution (from early nucleosynthesis till now). But we should be cautious about real chemical composition if part of elements is removed from the gas to the solid phase (dust grains) as we find to happen in interstellar medium of our galaxy. Some results [Vladilo 1997] rely on the assumption that dust in DLAS has the same chemical composition as a galactic interstellar dust. DLAS are especially interesting for us to obviously point out that they really are very young protogalactic disks as may contain even molecular hydrogen at high redshift. That statement was confirmed as two DLAS with molecular hydrogen (H_2) component are detected (ADLAS toward QSO PKS 0528-250 and DLAS toward QSO 0013-004, see [Ćirković 1999]).

It is also interesting that one of these is the example when redshift of ADLAS can be greater than emission redhift of the quasar (for PKS 0528-250 $z_{qso} \approx 2.779$ corresponding $z_{abs} \approx 2.8108$), that indicates closeness between them. In addition, this object has been one of the few DLAS observed in emission, and a low impact parameter inferred could help us in reconstructing the geometry of the system and examination of the influence of powerful ionizing sources (quasar, QSO) on various processes in nearby physical environment. Of course, there are no isolated ADLAS themselves - they are rather usually residing in regions of significant cosmological overdensity (e.g. galaxy clusters), containing Active Galactic Nuclei (AGN) [Djorgovski 1997]. Whether there is any connection with the known preference of radio-loud AGNs to reside in rich clusters, remains to be investigated.

2. THE SIMPLIFIED PICTURE OF ADLAS

We consider here the existence of two dominating ionizing sources: Ultraviolet Background ionization (**UV BG**) and nearby Quasi Stellar Object (**QSO**). Both of them have significant influence on ionization state of disk matter (from $\tau \ll 1$ to $\tau \gg 1$) - especially QSO considering its proximity to absorber (and low impact parameter mentioned above). In fact, we have neglected ionization arising in cosmic rays, thermal collisional ionizations, shock waves propagating through the disk gas and eventually corresponding halo continuum emission, in order to simplify our physical picture as well as emphasize QSO contribution (all of them we shall take into account, step by step, in our further work). Such simplified ionization rate can be written as

$$\Gamma = \sum_i \int_{\nu_0}^{\infty} \frac{4\pi J_\nu^i}{h\nu} a_\nu d\nu, \qquad (2)$$

where the index i takes two values, for the UV BG radiation and for the local QSO radiation field. **UV BG** radiation is supposed to be strictly isotropic. In contradistinction, the QSO ionizing flux is different for different position in absorbing disk (according to different distance as shown below, Fig. 1.). Therefore, a specific signature in the form of a "silhouette" of the higher neutral column density region should be detected, even in the "zeroth" approximation of homogeneous absorbing disk. In general, since $\Gamma \propto J_\nu^{QSO}(\vec{r})$, it will explicitly depend on position.

In Fig. 1. we have presented plane parallel geometry of the disk, since the thickness of absorbing disk (**D**)is three order of magnitude less than distance to the QSO ($L_{QSO} \sim 100kpc$ and $D \sim 100pc$ - these are not to be understood as exact values, only orders of magnitude). In this approximation we took the fictitious value of 30kpc for disk radius (R). Further, we state the plane passing trough QSO (as a distant point source) and a projection of straight line passing trough QSO and the center of the disk on the main disk plane. In our cylindrical system (with the center of absorbing disk as a center) we measure the angle ϕ from the projection of the QSO line of sight to the plane of the disk, **r** - distance from disk axes (varying from zero to R) and **z** - height under the main disk plane (varying from zero to d/2).

As we are dealing here with absorbers arising very close to quasar souorce of ionization, we expect to find ionization rate dependence on the position in absorbing disk. According to this, we shall have different radiation originated in process of recombination along **r** and ϕ coordinates.

First we considered the trivial case of pure hydrogen composition for $\tau \ll 1$. After integration of ionizing flux along cylindrical coordinates **r** and ϕ we assumed ionization equilibrium in the slab of the disk (we took the case of pure photoionization neglecting collision and other possible effects).

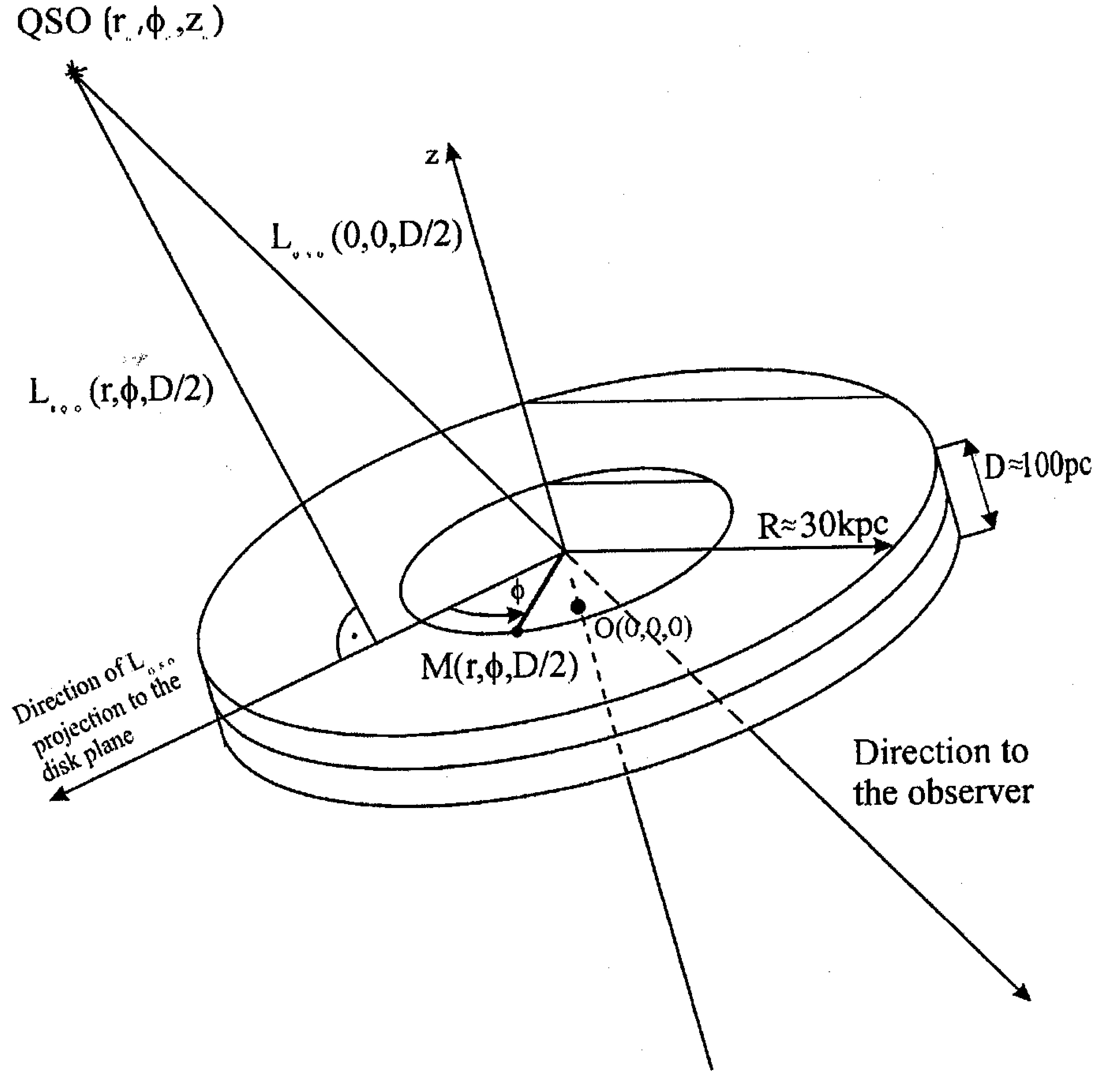

Fig. 1. The simplified picture of the absorbing disk

This consideration is important from the observational point of view. According to Gnedin (1987), several quasars with very close companion are investigated (impact parameter is less than $4h^{-1}kpc$). These companions are significant since their H_α, OII and OIII emission lines (with full width $W_\lambda \geq 20\AA$) are measured. That may suggests many conclusions: **a)** quasar radiation is isotropic, **b)** companion galaxies contain measurable amount of gas that could be assessed using photoionization model and **c)** host galaxies (if present) have been depleted of gas or do not interact with the companions. Recent detection of extraplanar gas in recombination H_α emission at large galactocentric distance in the local universe [ii] stimulate us to examine the possibility of such situation in galaxies i.e. ADLAS at all epoch. In short, we have laid grounds for the theoretical program of interaction of matter and ionizing fields throughout the history of the universe which could offer information on both galactic and cosmological structures.

3. FURTHER IMPROVEMENTS

Further improvements are necessary for many reasons, both theoretical and observational. From theoretical point of view we need to include the influence of ionization due to halo processes, quasar winds and quasar induced galactic winds. There is a significant distribution of hot gas (at large distances from protogalactic center) with strong X and UV emission in the early epoch of galaxy evolution (t¡1 Gyr). Since the supernovae heated gas (at early epoch SFR should be very high), produced winds carried it for a short time (less than 1Gyr) so its mass can reach star mass component in galaxy. Galactic winds become very metal-rich, so halo metallicities increase with time (rapidly attaining values $Z \approx 0.1 - 0.3Z_\odot$ as well as halo mass. That is in agreement with the values derived from observations. However, it remain to be seen whether high chemical abundances inferred for some ADLAS and the central regions of AGN host galaxies themselves could be accomodated in any picture with normal star formation mechanisms, or some completely novel approach is required [Artymovicz 1993].

As we suppose that the absorption is mainly due to disk processes, we should undertake detailed examination in the case of enhanced optical depth ($\tau \gg 1$). In particular, if we are gradually going deeper and deeper into Strömgren layer of disk, physical picture is essentialy changed: number density of neutral atoms (H and He, as we assumed for chemical abundance 90 % H and 10 % He) increase, ionization rate decreases and for $\tau \gg 1$ we can even find a layer of cold molecular hydrogen in disk. It is exactly in this region where the dynamic processes due to massive star formation are taking place. If ionizing O and B stars suddenly "switched on" in the disk plane, we would not easy recognize the origin of ionization in the choosen layer - to what extent it originates in nearby quasar and to what extent in the stars.

So, the layer we consider has not only a character of absorption as we assumed in our simple picture, but instead has more complicated, topologically non- trivial "Swiss-cheese" structure, recently inferred for the Milky Way ISM also. These complication remains to be dealt with in the course of the future work.

References

Artymowicz, P.: 1993, *PASP* **105**, 1032.

Ćirković, M. M. and Samurović, S.: 1998, *Astrophysics and Space Science* **257**, 95-106.

Ćirković, M. M., Bland-Hawthorn, J. and Samurović, S.: 1998, *MNRAS* **306**, L15.

Djorgovski, S. G.: 1997, 13^{th} *IAP Astrophysics Colloquium* edited by Petitjean, P. and Charlot, S., 303.

Gnedin, O. Y.: 1987, *Astropys. J.* **319**, 632.

Kippenhahn, R.: 1977, *Astron. Astrophys.* **55**, 125-133.

Ledoux, C., Petitjean, P. and Bergeron, J.: 1997, 13^{th} *IAP Astrophysics Colloquium* edited by Petitjean, P. and Charlot, S., 422.
Lu, L., Sargent, W. L. W. and Barlow, T.: 1997, 13^{th} *IAP Astrophysics Colloquium* edited by Petitjean, P. and Charlot, S., 251.
Salati, P., Chardonnet, P., Luo, X., Silk, J. and Taillet R.: 1996, *Astron. Astrophys.* **313**, 1-7.
Silk, J.: 1971, *Astron. Astrophys.* **12**, 421-427.
Storrie-Lombardi L. J., Irwin M. J. and Mc Mahon R. G.: 1996, *MNRAS* **282**, 1330.
Turnshek, D. A.: 1997, 13^{th} *IAP Astrophysics Colloquium* edited by Petitjean, P. and Charlot, S., 263.
Vladilo, G.: 1998, *Astrophys. J.* **493**, 583-594.