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QSO/AGN environments at different redshifts

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ABSTRACT

With the availability of large data sets like the Sloan Digital Sky Survey (SDSS) is it now possible to study a huge amount of galaxy spectra in a statistical manner. The spectroscopical data set of the seventh SDSS data release covers 9380 deg^2 (≈23% of the whole sky). We selected nearly 100000 objects from this SDSS data release 7 that were *spectroscopically classified* as quasars to investigate their environment. We developed a dedicated software-pipeline to process this enormous amount of data. We classified all galaxies within the Quasar/AGN-neighbourhood of 1 Mpc according to Kauffmann (2003) and Kewley et al. (2006) *by mean of* a diagnostic BPT diagram. For doing this we had to measure the narrow Balmer-line components manually. Furthermore, we studied the distribution of these objects in the QSO/AGN environment as well as their spectroscopical properties *and the absolute magnitudes*.

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1. Introduction

The existence of nuclear activity in many galaxies requires transport of mass into the nuclear region for maintaining the activity over long periods of time. Gravitational distortion caused by nearby galaxies might result in nuclear gas transport in the host galaxies of AGN. Therefore we are investigating the galaxy environment of a large number of AGNs. We examine not only the galaxy density of the AGN environment but also the spectroscopic properties of the neighbouring galaxies. In an early study based on the environment of 122 AGN only, we could show that the activity degree of the neighbouring galaxies depends on the distance to the AGN (Kollatschny and Fricke, 1989). With the advent of the Sloan Digital Sky Survey (SDSS) we can bring these investigations on a large statistical basis. The Seventh Data Release of the SDSS, which was released in 2008, contains now an area of 9380 deg^2 of spectroscopy (Abazajian, 2009). Based on these data we are investigating the following question: Is there a connection between a Quasar/AGN and the type or distribution of galaxies in the neighbourhood of the quasar? To do this, we first have to define the size and shape of the neighbourhood. The typical relative velocity of a galaxy is approx. 200 km s^{-1} perpendicular to the line of sight, and the adopted average duration of an activity phase is 10^7 yr. Galaxies can travel over a distance of 2 Mpc with these values. Parallel to the line of sight (in redshift direction) we have to consider the internal cluster group velocities of approx. ±800 km s^{-1}. With a Hubble constant H_0 of 71 km s^{-1} Mpc^{-1} we get a distance of ±11.2 Mpc in this direction. This result is illustrated in Fig. 1.

After defining the neighbourhood we have to find a way of measuring the distance of the central quasars to the objects in their environments. To do this we need the formula for the metric of a three-dimensional space with constant curvature in polar coordinates (Robertson–Walker metric) and the Friedman equation:

$$ds^2 = c^2dt^2 - R^2\left[d\omega^2 + S_k^2(\omega)(d\theta^2 + \sin^2(\theta)d\phi)\right] \tag{1}$$

$$H^2 = \left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi G}{3}\varrho - \frac{kc^2}{R^2} + \frac{\Lambda}{3} \tag{2}$$

From these two equations we can derive the redshift distance relation (see Fig. 2):

$$D_0 = \frac{c}{H_0}\int_0^z dz' \frac{1}{\sqrt{\Omega_M(1+z')^3 + \Omega_K(1+z')^2 + \Omega_\Lambda}}$$
$$D = \frac{D_0}{1+z} \tag{3}$$

where D is the distance at the time when the light of the object was emitted and D_0, the distance at present time. Ω_M is the cosmological mass density, Ω_K is the so called "spatial curvature density", a value for the curvature of space. Ω_Λ is the vacuum density, H_0 the Hubble constant and c the speed of light. Throughout this work we will use: $\Omega_M = 0.27, \Omega_K = 0, \Omega_\Lambda = 0.73, H_0 = 71$ km s^{-1} Mpc^{-1} and $c = 299792$ km s^{-1}.

With formula (3) we can calculate $D(z_{center})$ – the distance to the central quasar and $D(z_{neighbour})$ – the distance to the objects in the neighbourhood. Using these two values and the observational angle α between the objects we can compute d_z and d_{proj} as shown in Fig. 1 wherein d_z has to be less than 11.2 Mpc and d_{proj} less than 1 Mpc.

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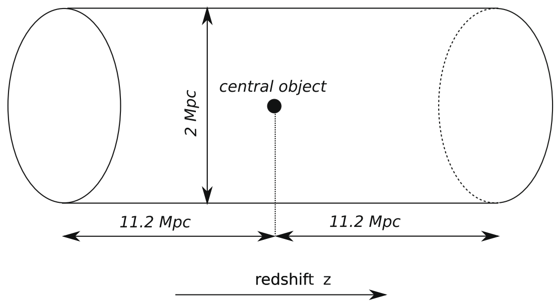

Fig. 1. Size and shape of the neighbourhood to investigate.

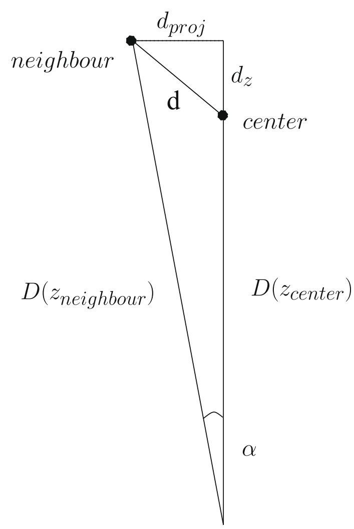

Fig. 2. Measurement of the distance.

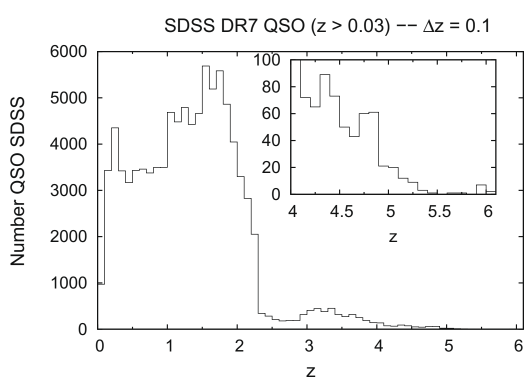

Fig. 3. Redshift distribution of the selected QSO.

2. Technical realization

We run the quasar query on the Seventh Data Release of the Sloan Digital Sky Survey (SDSS (Abazajian, 2009)) with the *sdssQA* tool provided by the SDSS web site http://www.sdss.org. We got a sample of approx. 95 000 QSO spectra for the redshift range from $z = 0.03$ to $z = 6.003$. We have chosen this lower limit in order to exclude nearby objects.

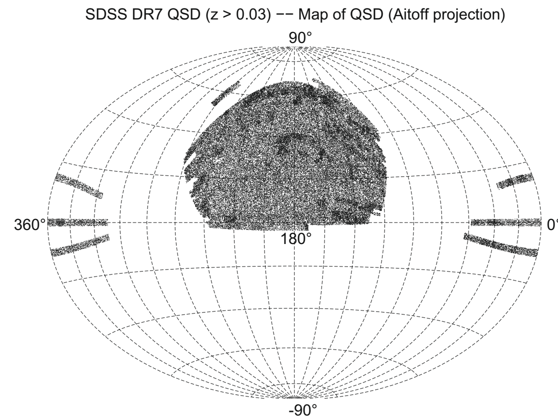

Fig. 4. Spatial distribution of the selected QSO.

Fig. 3 shows the number count over the redshift range and Fig. 4 the *spatial* distribution of our QSO sample. Afterwards we made the environment query for all 94 787 quasars as described in Fig. 1 with a program, that processes all quasars in the following steps.

- We did an SQL query according to the "neighbourhood tube" using the SQL-function "dbo.fGetNearbyObjEq" in a given angle around the quasar.
- We computed d_z an d_{proj} for every object in the queried "cone".
- We only selected the QSO neighbours that meet the limits of d_z and d_{proj}.

Fig. 5 shows the number of neighbours within $r = 1000$ kpc for all our quasars. For 2700 QSOs we only detected neighbours in the SDSS according to our definition. The number of QSO neighbours decreases as a function of redshift as can be seen in Fig. 5. Therefore, the fact that we only detect very few neighbours for distance QSOs is mainly a selection effect based on the absolute luminosity of the neighbours.

According to Eq. (3) the redshift distance relation has the following form: *with* growing redshift the distance of an object increases up to a *definite* redshift value which depends on the value of Ω_M. For $\Omega_M = 0.23$ this redshift value is $z = 1.643$ and the distance is 1766 Mpc. Beyond this redshift value the distance of an object is decreasing with growing redshift. Due to this fact it might happen that an object fits in the neighbourhood of a central object described in Fig. 1 but does not fit in look-back time by several gigayears. To avoid this, we not only have to check the distance but also the difference in look-back time. We decided to allow only objects with a difference of less than 10^7 yr in look-back time to be part of the neighbourhood.

Since the spectroscopic data of the SDSS DR7 do not cover the whole sky, it can happen that a quasar is located near the edge of an observed range and its neighbourhood cannot be studied completely. We inspected all neighbourhoods and had to exclude 8 cases only. Fig. 6 shows the spectroscopic sky coverage of the SDSS DR7. Every open circle in this figure represents a spectroscopic plate with diameter of 3°.

We also inquired all line fluxes from SDSS, especially those from the Hα, Hβ, [O III] λ5007 and [N II] λ6583 lines to classify the spectra accordingly to the BPT diagram by Baldwin et al. (1981). Our investigation showed that the published SDSS-line fits are single-line fits only. These single-line fits are not correct if the Balmer lines consist of narrow and broad components. For the BPT diagram we have to use the narrow components only. Therefore, we had to measure the narrow Balmer-line components of Hα and Hβ by hand.

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