Tracing high redshift cosmic web with quasar systems

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To understand how the cosmic web formed and evolved we need to describe it at low and high redshifts.

We use data about quasars to get information about the cosmic structures at redshifts $1.0 < z < 1.8$.

Quasars have low space density and short lifetime – rare events in group size haloes with masses $\approx 10^{12} \, M_\odot$. What information we obtain about the cosmic web from their distribution?
We study clustering properties of quasars and random samples with Friend-of-Friend (FoF) method

In FoF systems each object has at least one neighbour at a distance smaller or equal than the linking length l.

- determine systems of quasars at a series of linking lengths

- analyse quasar system properties and their large-scale distribution

- present quasar system catalogues.

Our sample: SDSS DR7 QSO catalogue (Schneider et al., 2010)
redshift interval $1.0 < z < 1.8$,
i - magnitude limit $i \leq 19.1$,
sky coordinates: $-55 < \lambda < 55$, $-33 < \eta < 35$,
$N = 22381$
Random samples: the same sample limits and number of points
FoF results

The number of systems.

FoF: differences between quasar and random systems at the linking lengths $l \leq 30$ Mpc and $l \geq 80$ Mpc (percolation of quasar systems).

Multiplicity functions.
N of quasar and random systems of different diameter, \( l = 30 \) and \( 70 \) Mpc/h.

The number of quasar systems with diameters < 30 Mpc is larger than the number of random systems at all linking lengths.

Large systems at \( l = 70 \) Mpc/h with sizes of 500 – 700 Mpc/h can be found also in the random catalogues.
Number of quasars in systems $N_{QSO}$ vs. system diameters.

At $l = 20 - 50$ Mpc the sizes and space density of quasar systems, $\approx 10^{-7} (h^{-1} \text{Mpc})^{-3}$, comparable to the sizes and density of local galaxy superclusters.

At $l = 70$ Mpc - sizes as the sizes of local rich superclusters and supercluster complexes (like SGW)

The largest quasar systems the same as LQGs by Clowes et al. 2012, 2013
Cosmic web at redshifts $1 \leq z \leq 1.8$

Red circles: $l = 70 \text{ Mpc/h}, N_{\text{QSO}} > 50$, black crosses: $l = 20 \text{ Mpc/h}, N_{\text{QSO}} = 3$. 
Quasar systems as markers of galaxy superclusters

AGNs in poor groups and outskirts of clusters in the supercluster Cl 1604 at $z \approx 0.9$ (Kocevski et al. 2009)
Polarization vectors of quasars indicate that quasar spin axes are parallel to their host large-scale structures (Hutsemékers et al. 2014).

Quasar systems as markers of galaxy superclusters
QSO systems (Park et al. 2014)

LRG superclusters

SGW
Summary

Quasar systems as markers of galaxy superclusters and supercluster complexes give us a snapshot of the high-redshift cosmic web.

Quasar system catalogues: database to search for high-redshift superclusters of galaxies and to trace the cosmic web at high redshifts.

www.aai.ee/~maret/QSOsystems.html
Einasto et al. 2014, AA, 568, A46
Thank you!