Candidate galaxy clusters in z~1 Large Quasar Groups

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LQG's International Team

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Outline

- Working definition of Large Quasar Groups (LQG's)
- What is the relation of quasars to LSSs of galaxies for both quasars in general and for quasars in LQG's?
- Are LQG's possible progenitors of present day superclusters?
- Studies of LQG's Clowes- Campusano at z=1.3, and another at z=0.8.
- What LQG's can contribute to the study of the star formation history of galaxies?

Working definition of LQG's

Since 1982 there have been many reports of large-scale structures (LSSs) in the distribution of quasars, which are now generally known as Large Quasar Groups. They are the largest structures so far seen in the early universe (z~0.4-2.0), with sizes in the range 70-250 Mpc, and membership >=5. Recently, the difficulties with quasar data has been lessened by the the SDSS and the 2dF QSO Redshift Survey.

Are LQG's precursors of superclusters?

Miller et al. (2004) and Pilipenko (2007) have investigated LSS in the 2QZ quasars, with Miller et al. finding ~200 Mpc structures in a statistical sense, and Pilipenko more specifically given properties of the discovered LQGs. The LQG space density is 7 Gpc^{-3} at $0.3<z<1.9$ (Pilipenko) , or 3-4x below galaxy supercluster values at $z<0.1$ (~25 Gpc^{-3} Swinbank et al. 2007), implying LQG's as larger perturbations.

LQG's properties (Pilipenko 2007)

They form two classes, ~70% with 6-8 members, average sizes of 90 Mpc, and overdensities of ~10, and 30% with 15-19 members, average scale of 200 Mpc and overdensities of ~4. He found six such mega-structures in the 2QZ survey (750 deg2), implying 500-1000 "jumbo" LQGs in the sky.

LQG's as unique structure markers

There is evidence that quasars are triggered by mergers in moderately high density environments, and are part of the evolutionary process of most galaxies (e.g. Hopkins et al. 2007). Therefore, regions with high quasar space density should help to constrain the various physical mechanisms (feedbacks, mergers, etc) which produce them.

LQG's as a lab for galaxy formation and evolution

If LQGs can be shown to trace galaxy clustering, they they would be efficient probes of mass overdensities in the early Universe. In addition, LQGs would provide a very efficient mean to study at given redshifts, both quasars and galaxies in a wide variety of environments, from low to high densities.

Formation of quasars at z~0.4

In an effect similar to star formation quenching, quasars at z~0.4 form preferentially in cluster outskirts; also, they delineate the underlying galaxy LSS. Although LQGs are too large to be virialized, they are still highly biased tracers of what may be the largest scale density perturbations.

The Clowes-Campusano LQG at z~1.3

The CCLQG is the largest known LQG (Clowes& Campusano 1991) and has the most members. It contains at least 18 bright quasars at 1.2<z<1.5 and a spatial overdensity of 3 for BJ<=20.0 mag. It covers ~2.5x5 deg2 (~120x240 Mpc2) and is 590 Mpc deep. It has an associated factor 3 overdensity of MgII absorbers at 1.2<z<1.5 (Williger et al. 2002).

A foreground LQG to the CCLQG

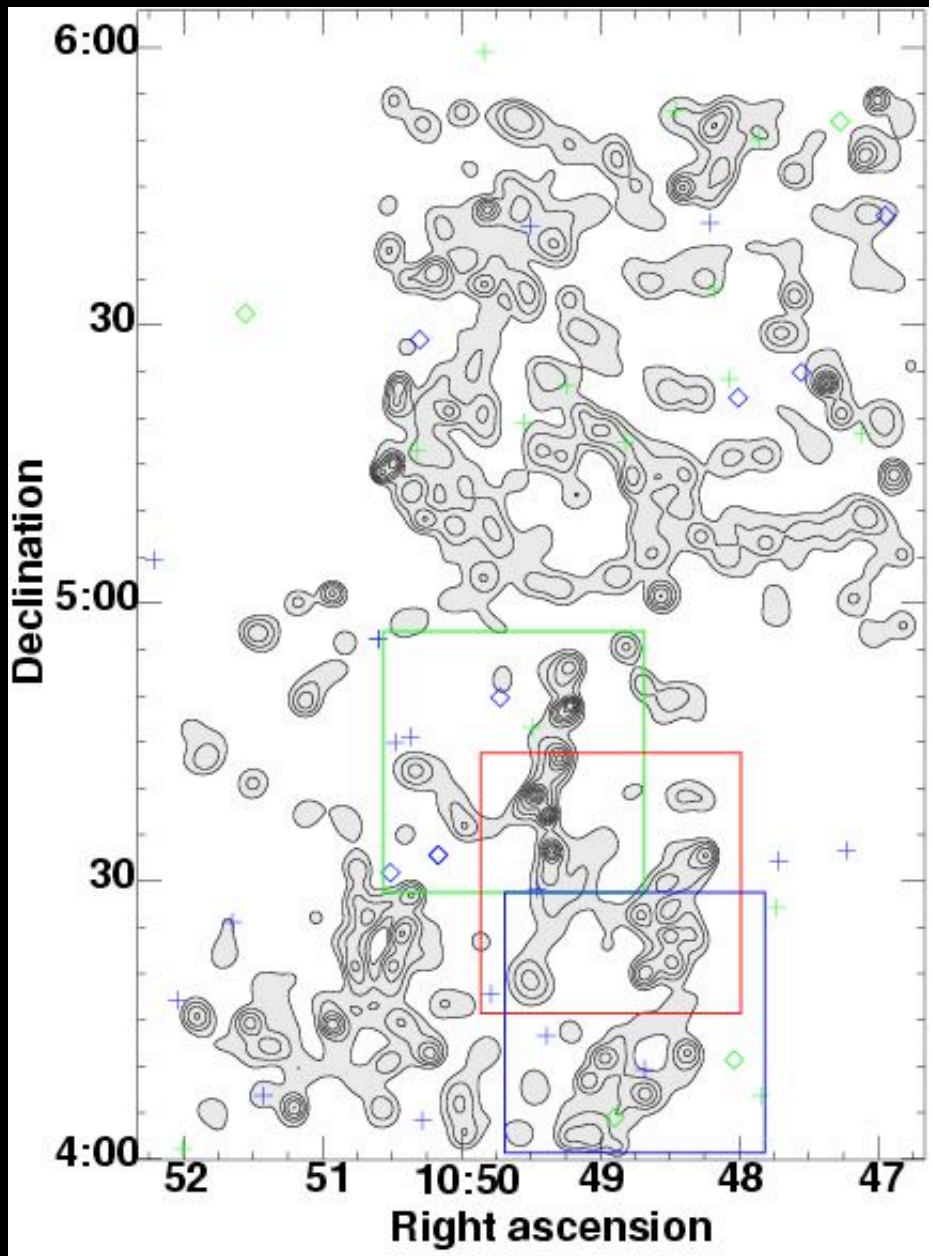
A foreground z~0.8 LQG contains >=14 quasars and spans 3.5x3 deg2 on the sky. Studies of the 2 overlapping LQGs showed 30% overdensities of red galaxies (I-K>3.4) at z-0.8 and z=1.2 (Haines et al. 2001, 2004). Deep V,I imaging over ~40'x34' reveals galaxies with colors consistent with an evolved population, and seem to be part of sheets.

Candidate cluster-chain in the z~0.8 LQG

We have detected a red selected candidate cluster-chain consistent with z~0.8, reminiscent of the ~40' cluster-chain found associated with a z~1.1 LQG (Tanaka et al. 2001). This candidate filament and more general overdensities at z~0.8 in the LQF field, offers a unique opportunity to relate quasars, galaxies and cluster gas, in evolution as mass tracers.

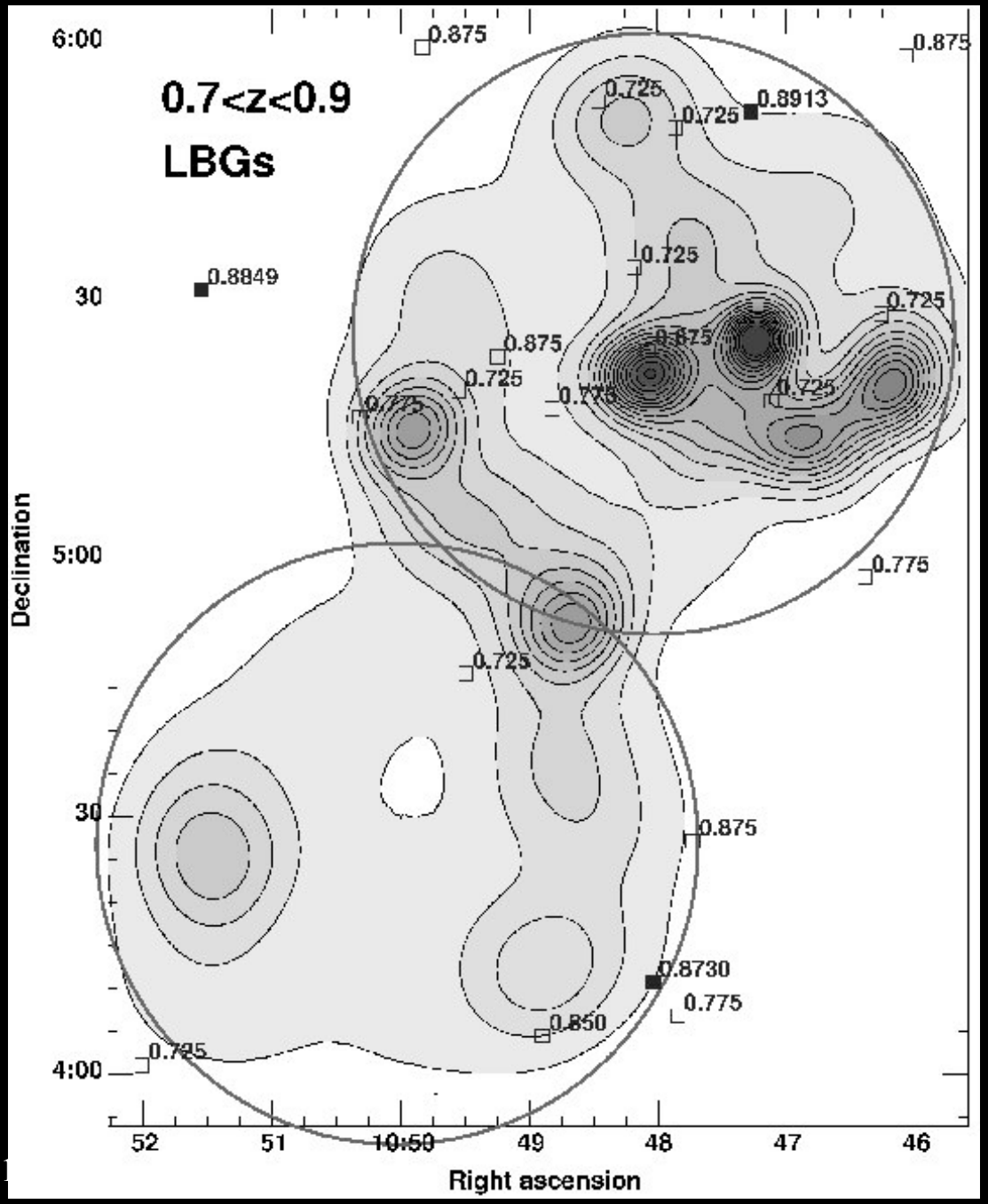
Clustering revealed by imaging

CFHT r,z imaging. In Fig red selected galaxies with z_phot>=0.6 . Quasars from 0.7<z<0.9 (green) and 1.2<z<1.4 (blue) LQG's . Contours spaced log with every second contour indicating a factor 2 change in density and the lowest contour with 1 gal/arcmin^2



Lyman break galaxy overdensities associated with z=0.8 and 1.3 LQGs?

Haberzettl et al. (2009) have detected overdensities of LBGs at z~0.8 and z~1.3, suggesting association with the respective LQGs. The analysis of these sheet-like structures was done using two contiguous GALEX fields (FUV and NUV) cross-correlated with optical data from the SDSS.



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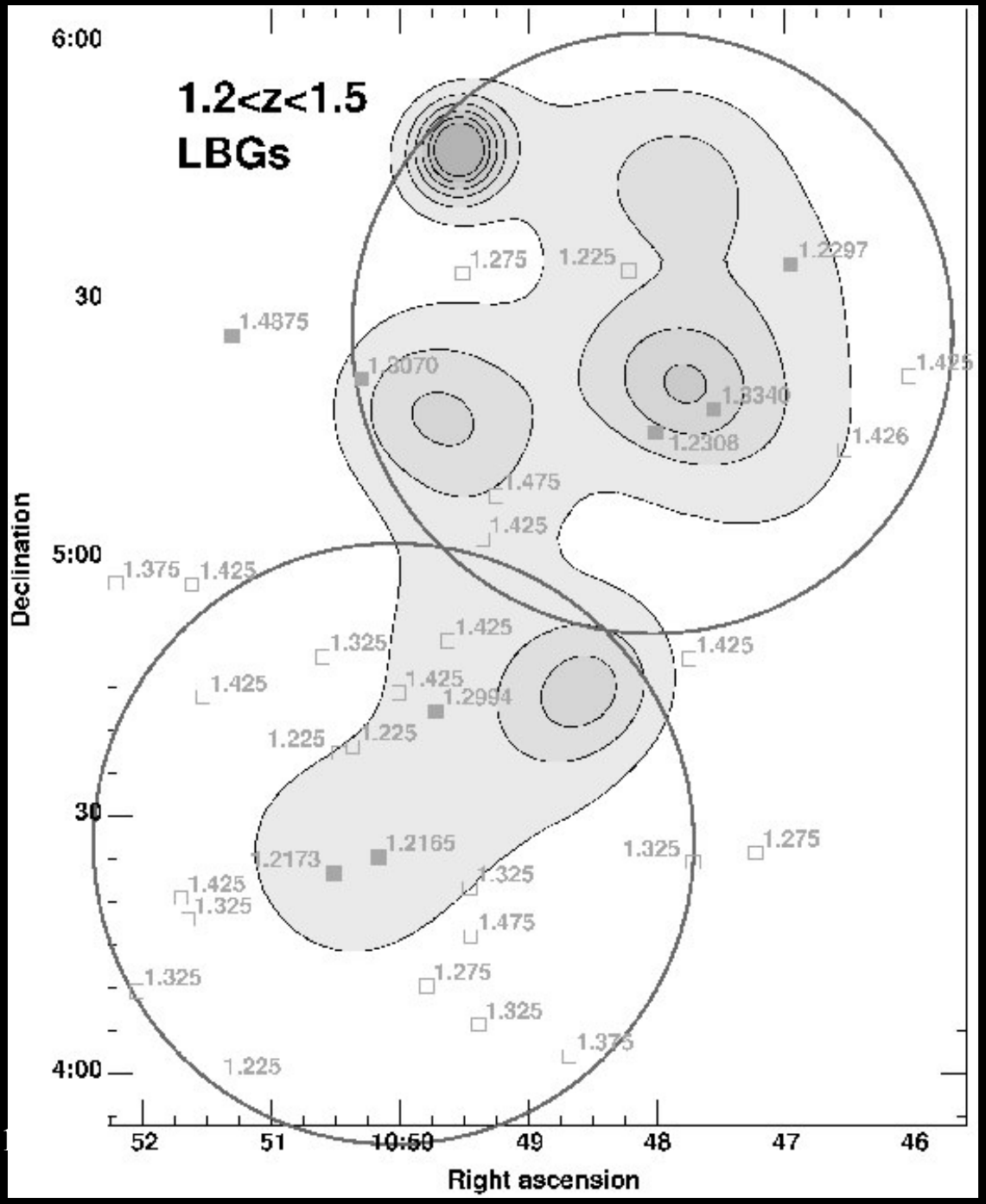

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Conclusions

LQG's are the largest coherent structures, signalled by quasars, present in the early universe (z~0.4-2.0) on 100-200 Mpc scales.

Quasars signal gas rich environments and are short lived. At least to z~0.4 they are related to clusters of galaxies.

For the CCLQG at z~1.3, evidence for associated enhancements of red galaxies, MgII absorbers, and LBG's has already been found.

Conclusions (cont)

In another LQG, a red selected candidate galaxy cluster-chain consistent with z~0.8 has been identified.

The candidate cluster-chain should be confirmed with spectroscopic redshifts. A related search for X-ray emission has been proposed for Chandra/XMM observations.

The End