Alignments of quasar axes with large-scale structures

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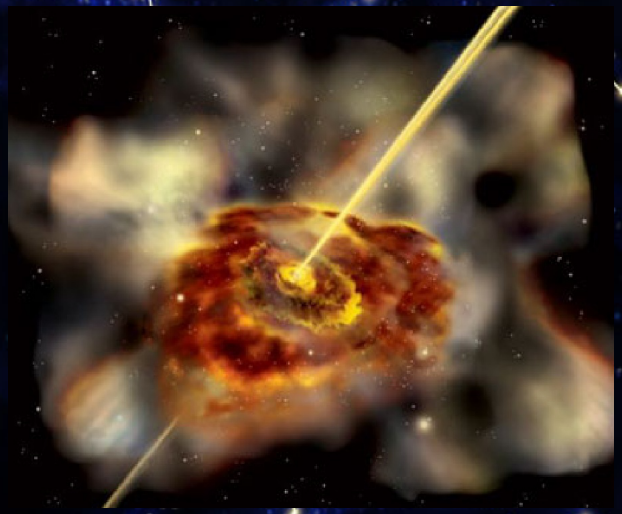


Drifting through the Cosmic Web: the Evolution of Galaxies within the Large Scale Structure
10th Marseille Cosmology Conference, 6-11 July 2015, Aix-en-Provence, France

Outline

➔ Optical linear polarization in quasars and its relation to the quasar morphological axis

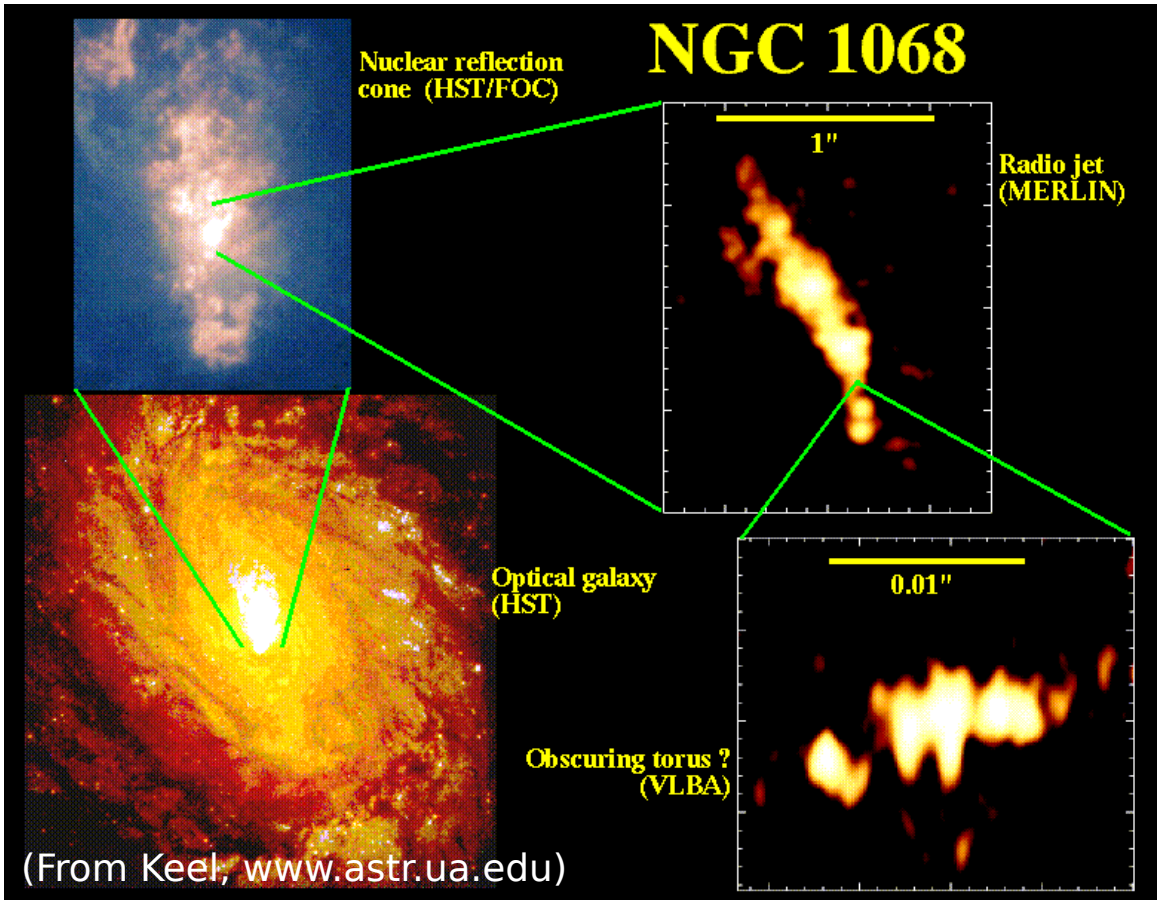
➔ Alignment of quasar optical polarizations measured in two Large Quasar Groups (LQGs)

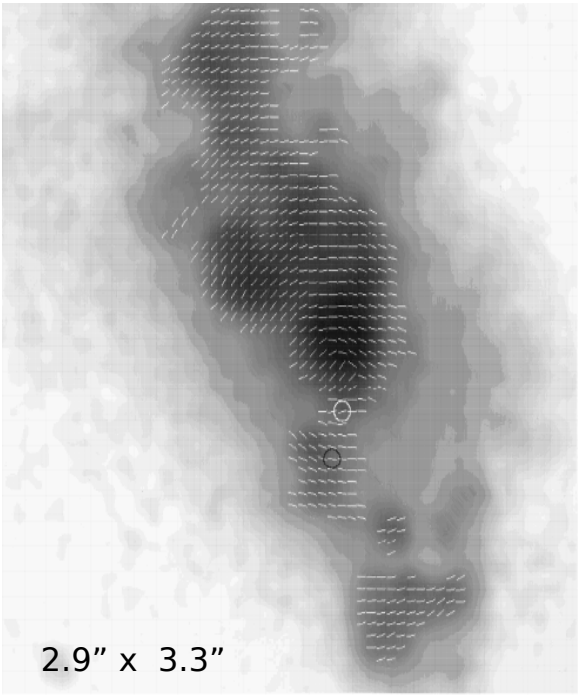
➔ NEW: alignment of radio polarizations with LQG axes for about 40 LQGs *(see Poster with Vincent Pelgrims)*

Based on:

- Hutsemékers, Braibant, Pelgrims, Sluse: 2014, A&A 572, A18
- Pelgrims, Hutsemékers: 2015, in preparation

A nearby Seyfert 2 : NGC 1068

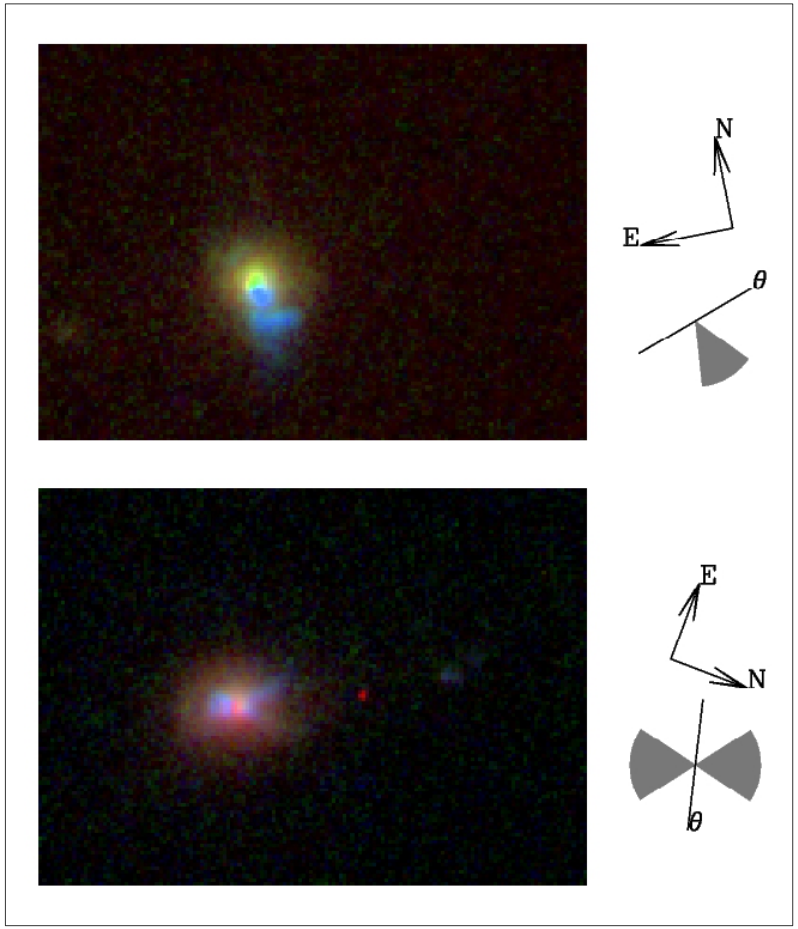




Centrosymmetric polarization
due to dust scattering
(HST UV observations, Capetti et al. 1995)

- polarization due to scattering of nuclear light
- electrons inside the NLR and dust in external regions
- polarization vectors perpendicular to the radio jet / ionization cones

Polarization and morphology : quasars at z ~ 0.5

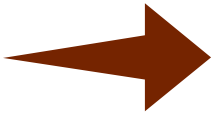


Three-band HST color-composite images of Type 2 quasars. The irregularly shaped blue spot is identified as a one-sided scattering region (top) or as a fairly symmetric bi-conical region (bottom). (From Zakamska et al. 2005)

- The polarization of Type 2 quasars is perpendicular to the extended UV continuum (Zakamska et al. 2005)
- After image deconvolution, the polarization of Type 1 quasars appears mostly parallel to the extended UV continuum (Borguet et al. 2008)
- The polarization is misaligned with the host galaxy imaged in the near-IR (Borguet et al. 2008)

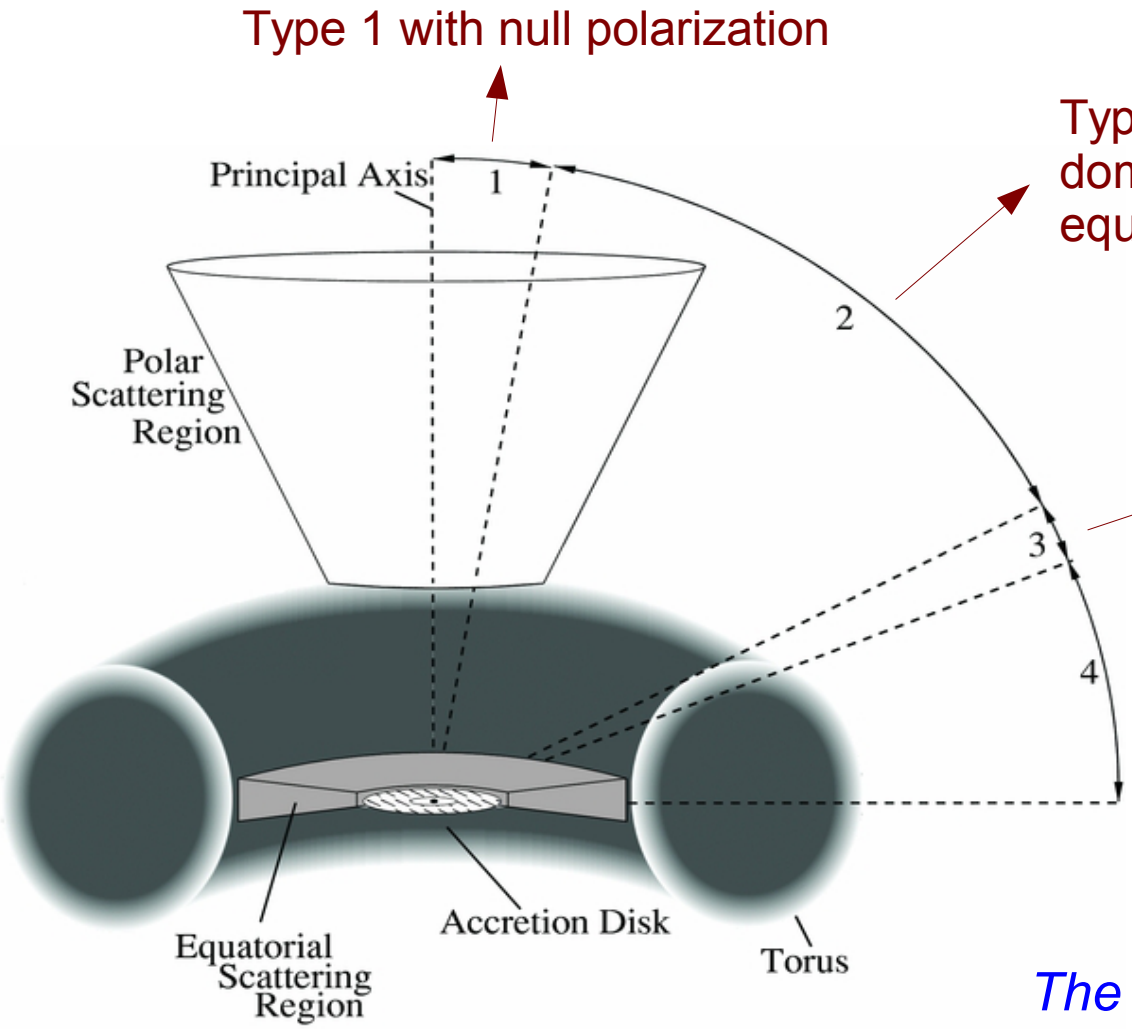
Polarization in quasars

- Electron scattering close to the accretion disk is likely the main polarization mechanism. Dust in the torus and the NLR can also contribute
- Type 2 AGN show high optical polarization > 3%. The polarization is perpendicular to the radio axis and/or to the ionization cones (e.g., Zakamska et al. 2003, 2005). This suggests polar scattering.
- Type 1 AGN have low optical polarization ~ 0.6%, a minority (~ 1/100) showing p > 3%. The polarization of is most often parallel to the radio axis / ionization cones but perpendicular polarization is also observed (Stockman et al. 1979, Rusk and Seaquist 1985, Berriman et al. 1990, Kishimoto et al. 2004). This suggests equatorial and polar scattering.



A two-component polar + equatorial scattering model can explain most observations

Polarization in AGN : the unified view



Type 1 with polarization dominated by equatorial scattering

Type 1 with polarization dominated by polar scattering

Type 2 with polarization from polar scattering

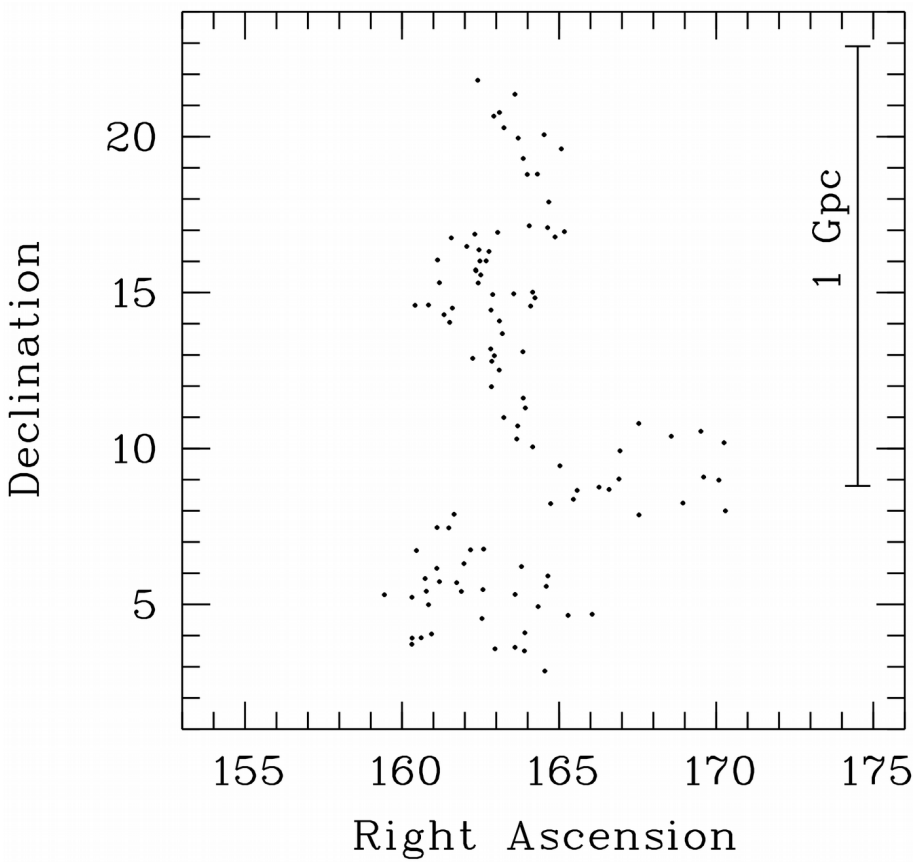
The relative importance of extended polar scattering and compact equatorial scattering is determined by inclination

(Smith et al. 2004, Batcheldor et al. 2011)

Do quasars align with large-scale structures ?

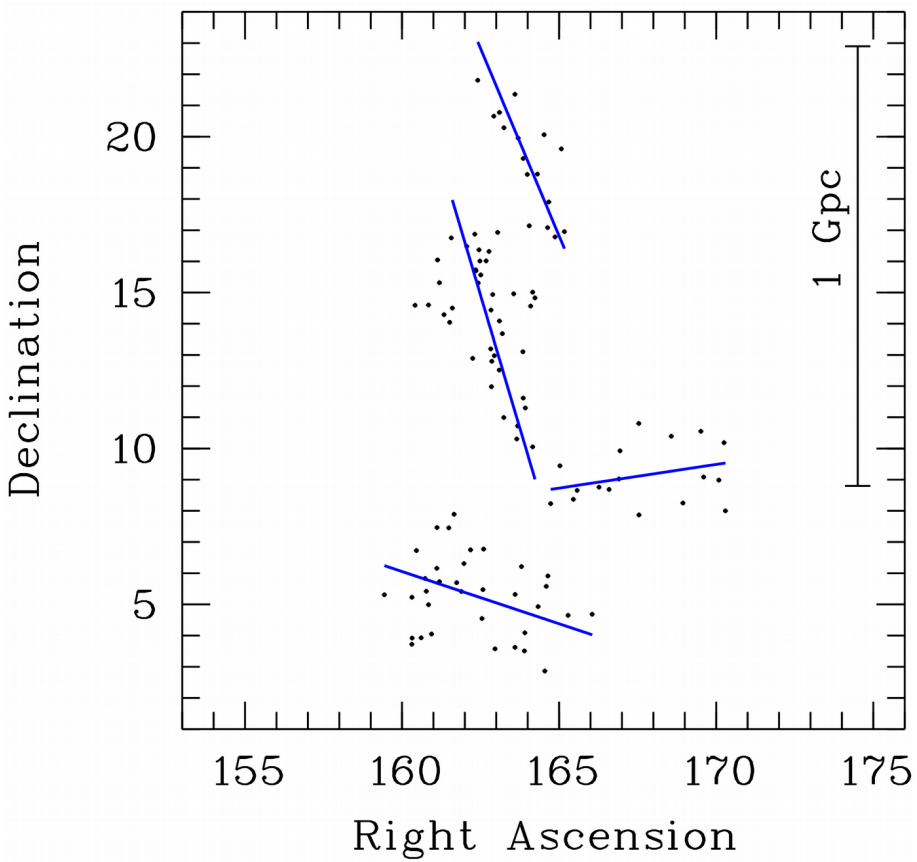
- Since quasar linear polarization is related to the morphological axis (thought to be the SMBH spin axis), it allows us to test alignments with large-scale structures at moderate to high redshifts
- We have measured the polarization of quasars belonging to Large Quasar Groups at redshift z ~ 1.3. Such groups are thought to be the precursors of local superclusters
- We considered the Huge-LQG and the CC-LQG (Clowes et al. 2013). The Huge-LQG is associated to MgII absorbers and extends over more than 500 Mpc
- 93 quasars (Type 1) have been observed. 19 of them are significantly polarized ($p > 0.6\%$)

Quasar polarization in LQGs



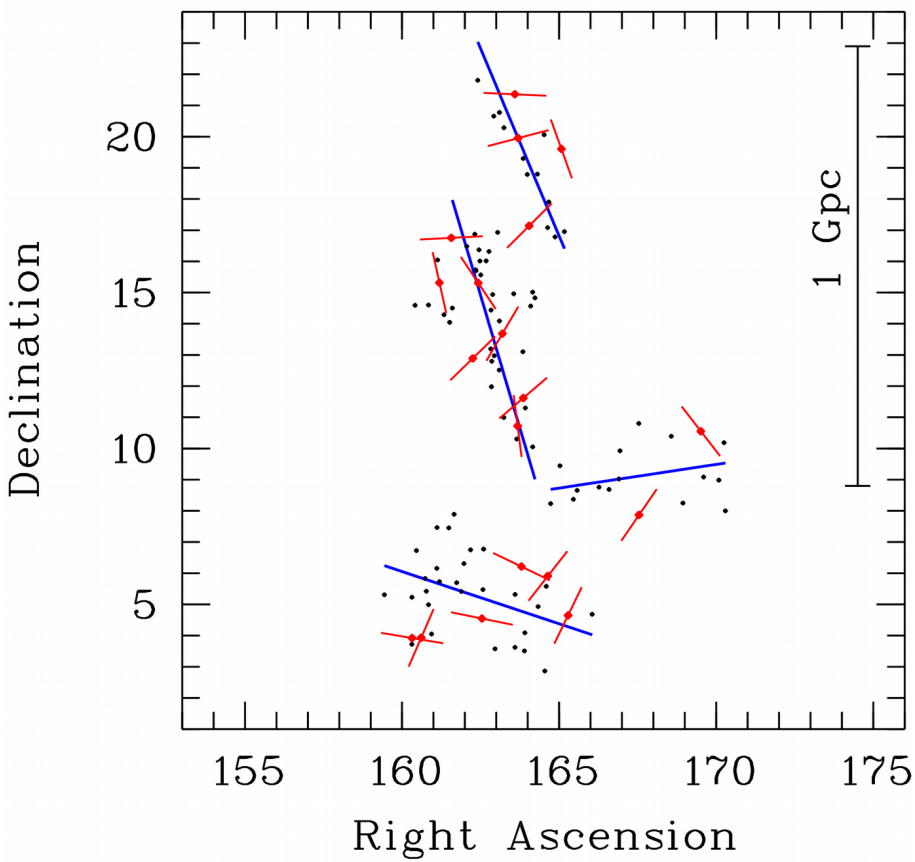
The Huge- and CC- LQGs

Quasar polarization in LQGs



The LQGs and the orientations of sub-structures

Quasar polarization in LQGs



The LQGs and the orientations of sub-structures
In these groups 19 quasars were found to be significantly polarized (p > 0.6%)

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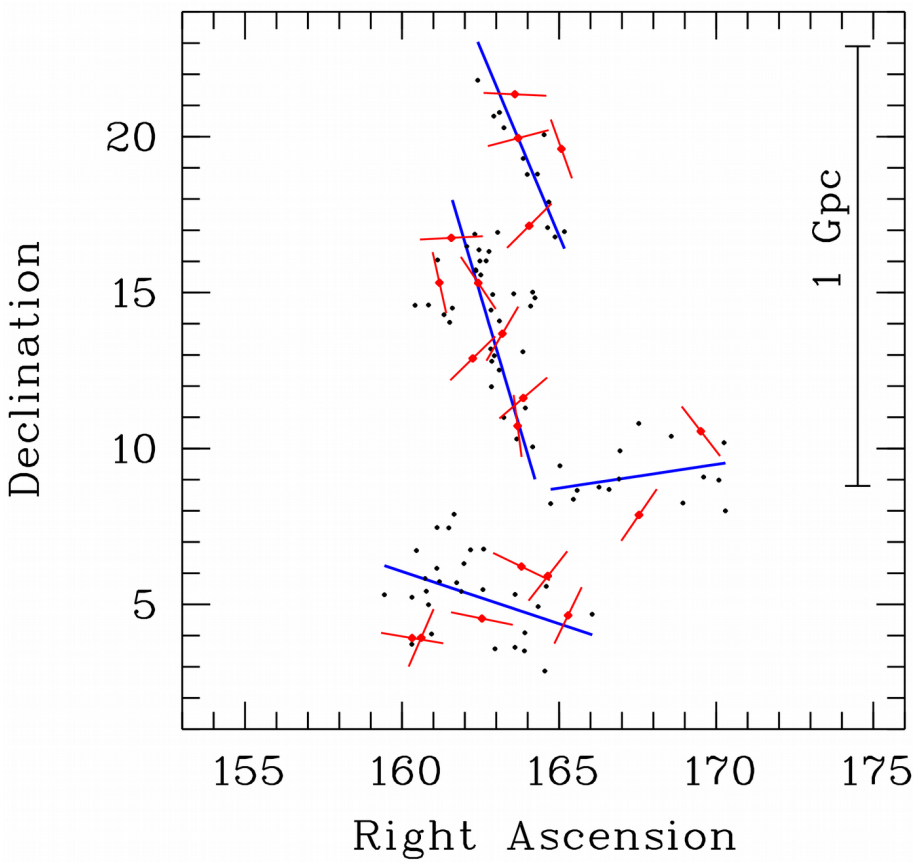

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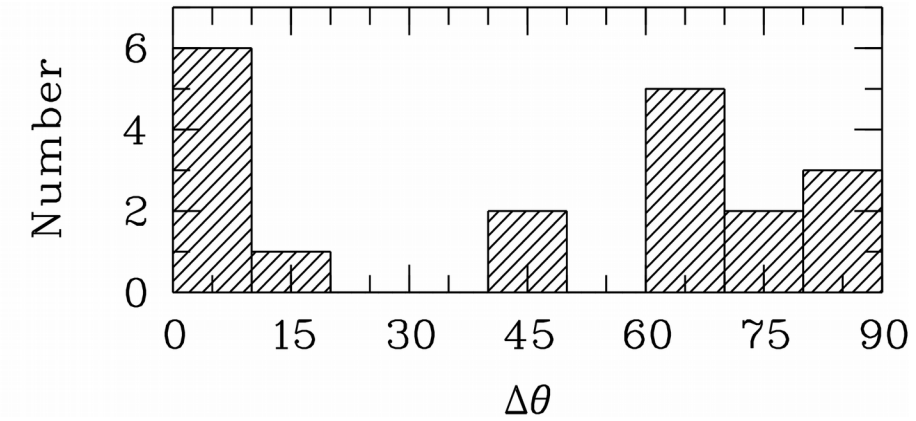
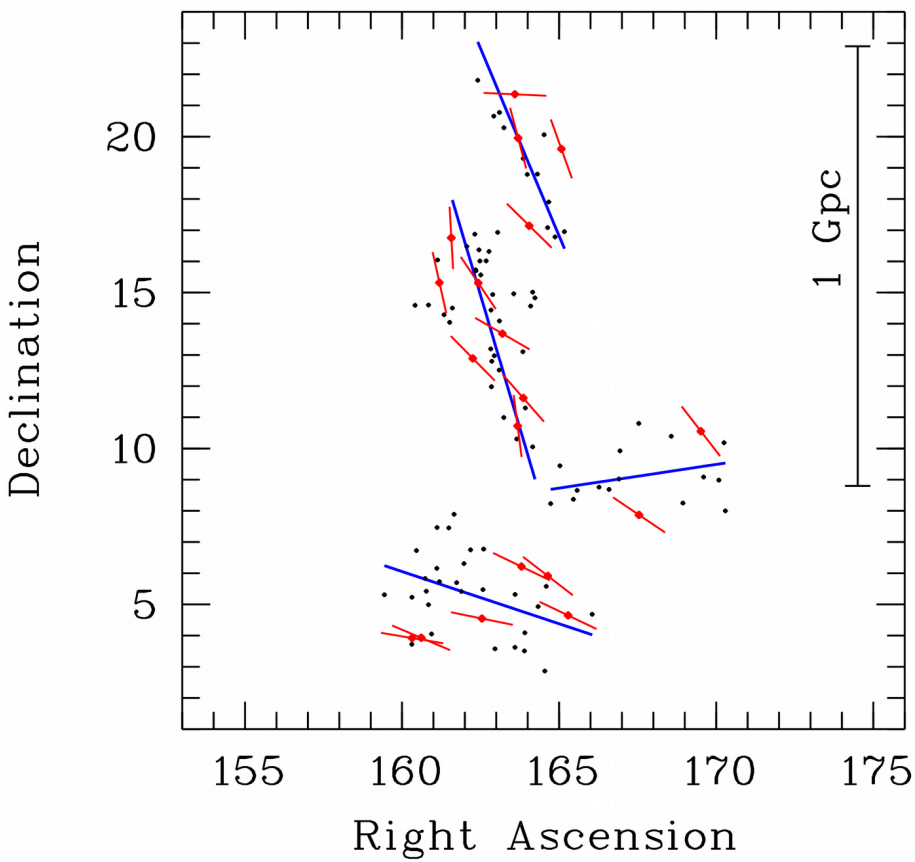


The distribution of the acute angle Δθ between quasar polarizations and the orientation of their host large-scale structure. The bimodal distribution shows that quasar polarization vectors are either parallel or perpendicular to the large-scale structure to which they belong (probability ~ 99%)

Quasar polarization in LQGs



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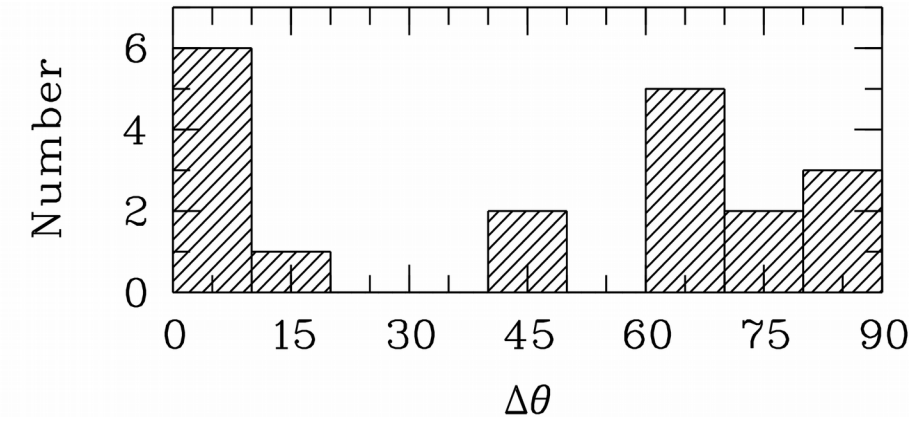

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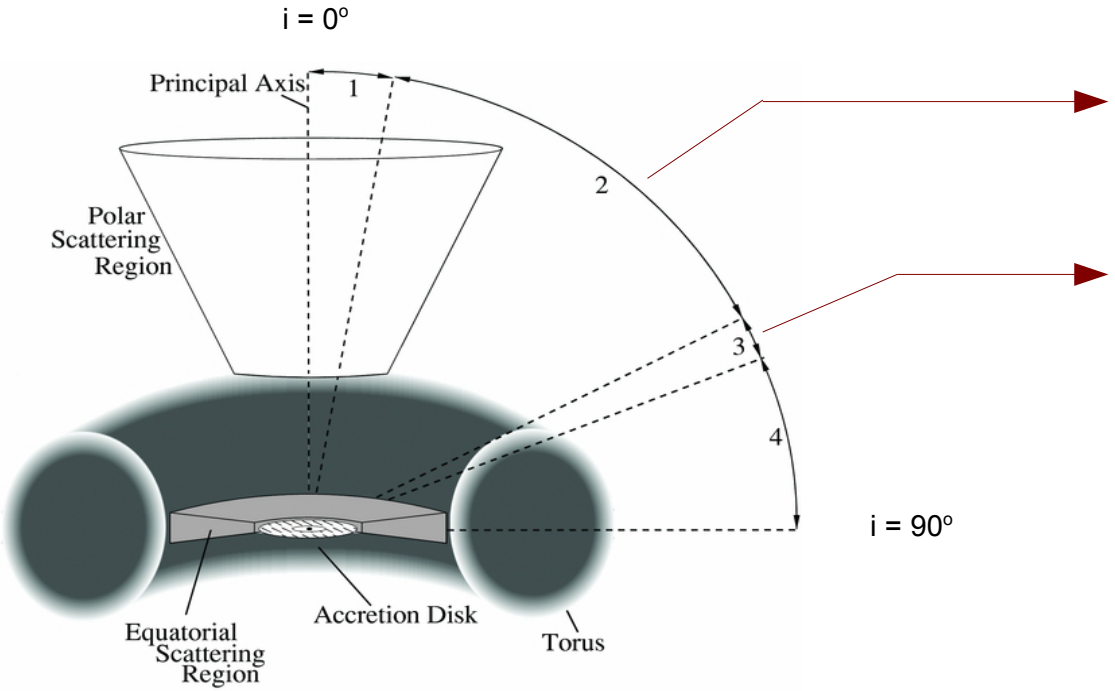
$$\theta' = 90^o + mod(\theta, 90^o)$$

Quasar polarization in LQGs

- Statistical tests indicate that the probability that polarization vectors are randomly oriented is of the order of 1% (distribution of Δθ, correlation of polarization orientations between nearest neighbors)
- If Type 1 quasar morphological axes are aligned with their host structure we indeed expect their polarization to be either parallel or perpendicular to the structure axis depending on their inclination



- parallel polarization

- perpendicular polarization

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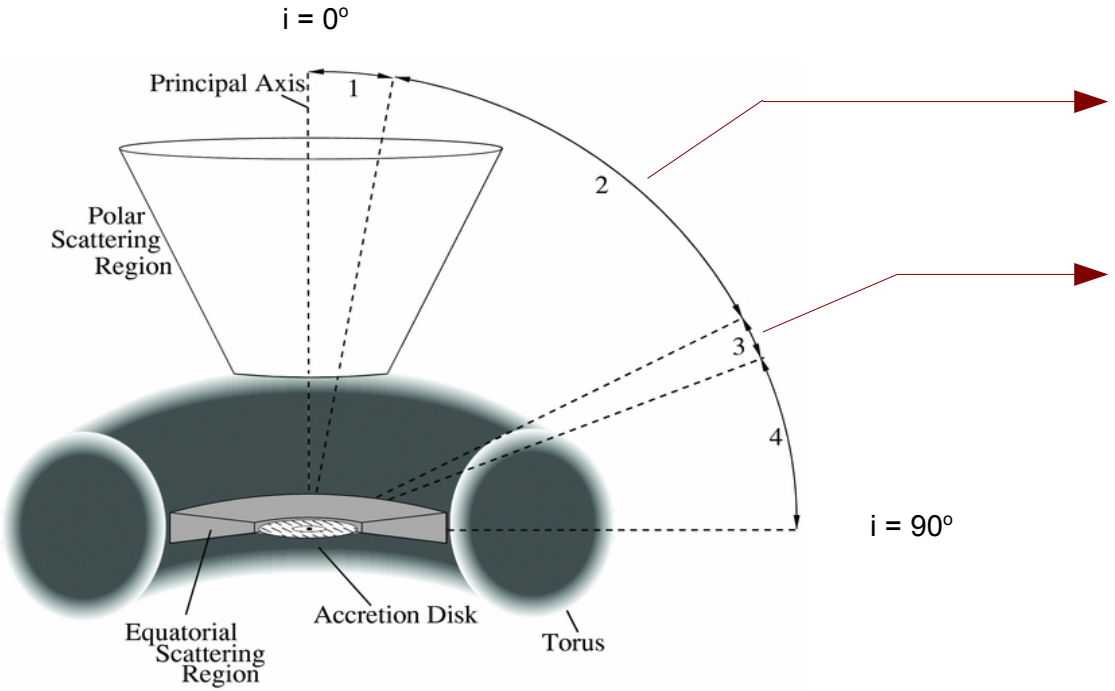
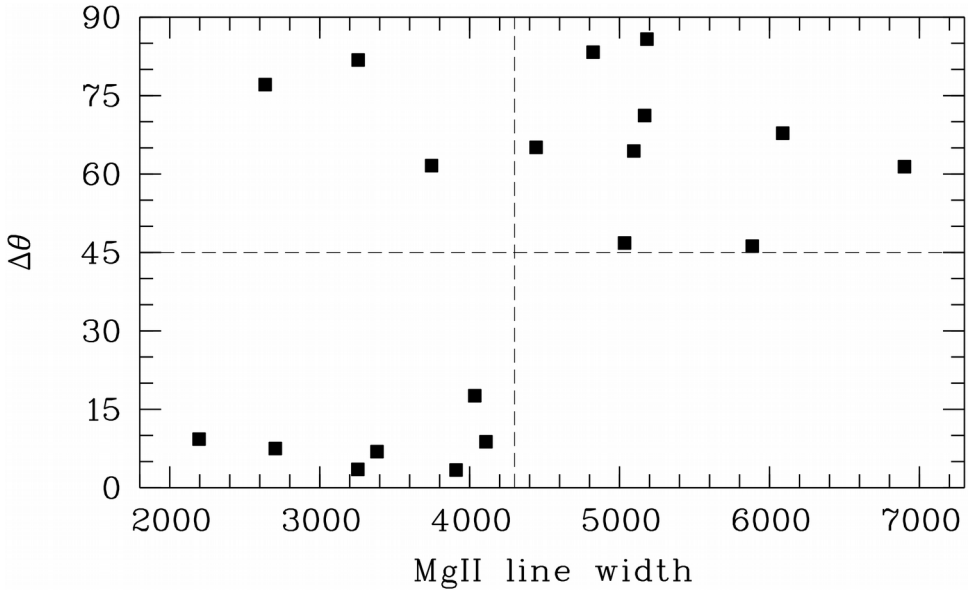


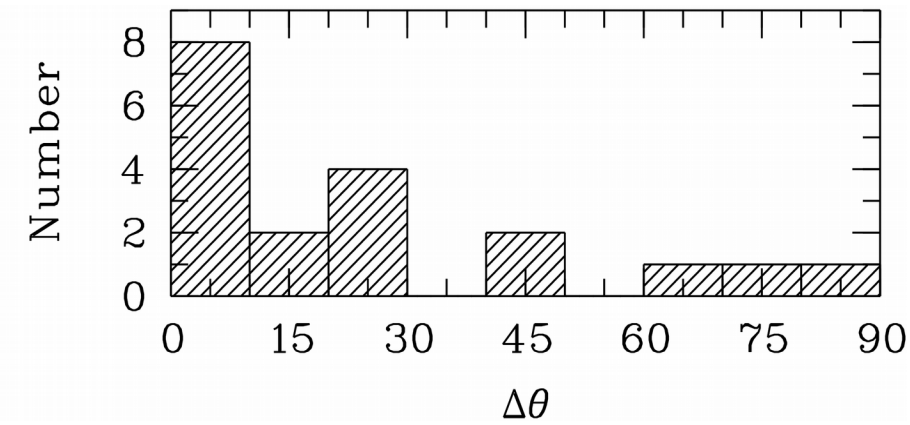
- parallel polarization
- lower BEL FWHM

- perpendicular polarization
- higher BEL FWHM

If the low-ionization broad emission lines are formed in a rotating disk

Quasar axes in LQGs





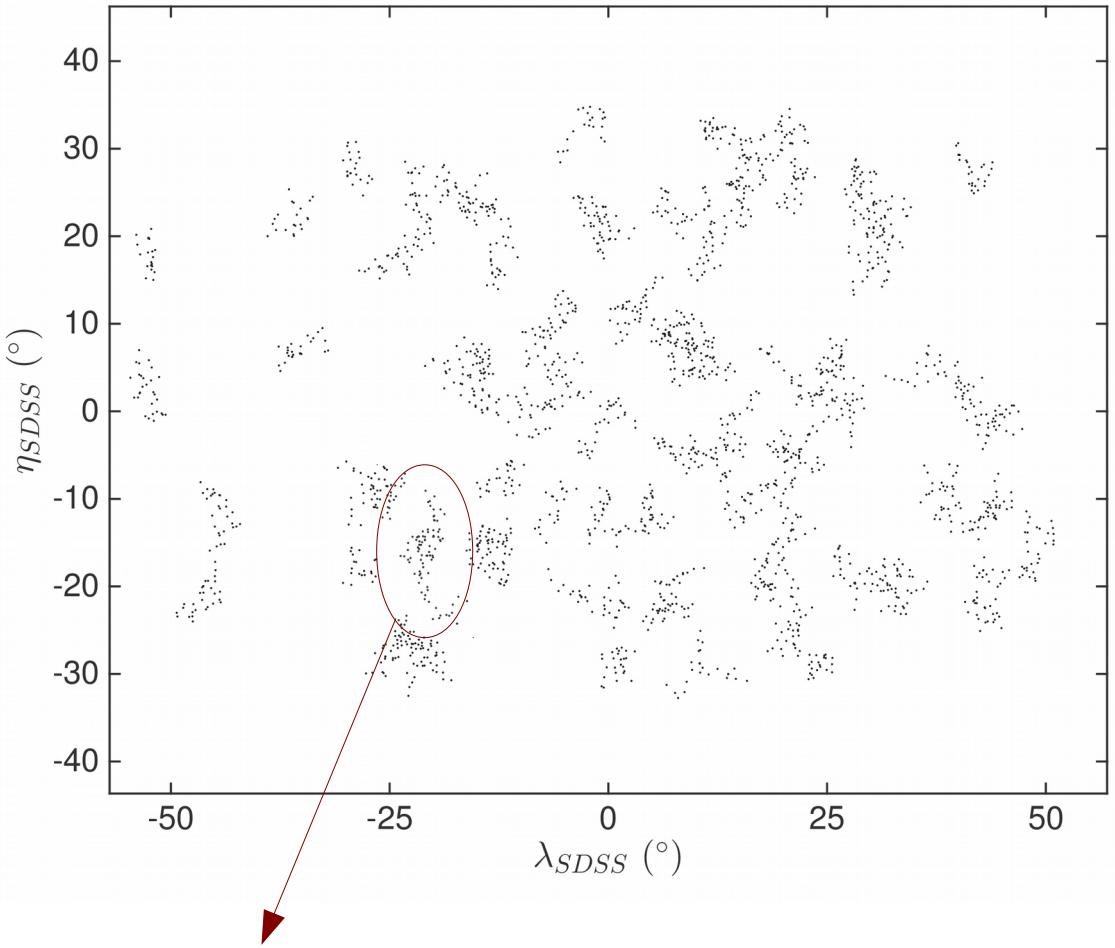
Distribution of the angle Δθ after rotating by 90° the polarization angles of objects with very large MgII emission line widths

Since polarization is either parallel or perpendicular to the quasar axis depending on inclination and since quasars seen at high inclinations usually show broader emission lines (Wills & Brown 1986), ***quasar spin axes are preferentially parallel to the axis of the host large-scale structure***

Quasar radio polarization in LQGs

- Instead of measuring the polarization of quasars in a couple of LQGs, we can consider a large sample of LQGs and search for members with available polarizations
- We consider the sample of LQGs found in the SDSS DR7 quasar catalog by a friends-of-friends algorithm with a linking length of 70 h^{-1} Mpc and a richness larger than 10 members (Einasto et al. 2014)
- Optical polarization measurements are too scarce for those quasars
- We found 41 radio polarization measurements from the JVAS/CLASS survey at 8.4 GHz. This sample is basically free from biases and Faraday rotation uncertainties (Jackson et al. 2007)
- Radio (synchrotron) polarization is preferentially perpendicular to the quasar axis / radio jet (Joshi et al. 2007)

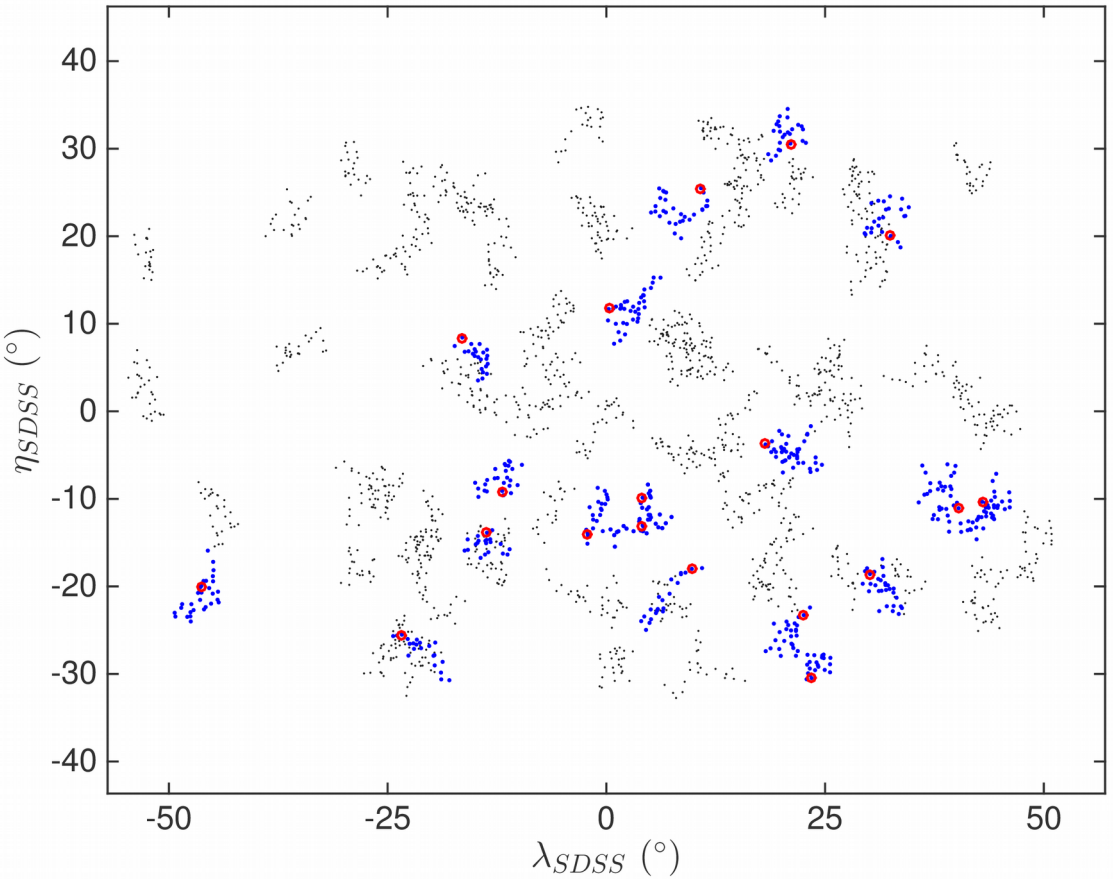
Quasar radio polarizations in LQGs



The Huge- and CC- LQGs

Quasars in LQGs
Linking-length = 70 h^{-1}Mpc
Richness m > 20 (for clarity)
Redshift 1.0 < z < 1.8
(Einasto et al. 2014)

Quasar radio polarizations in LQGs



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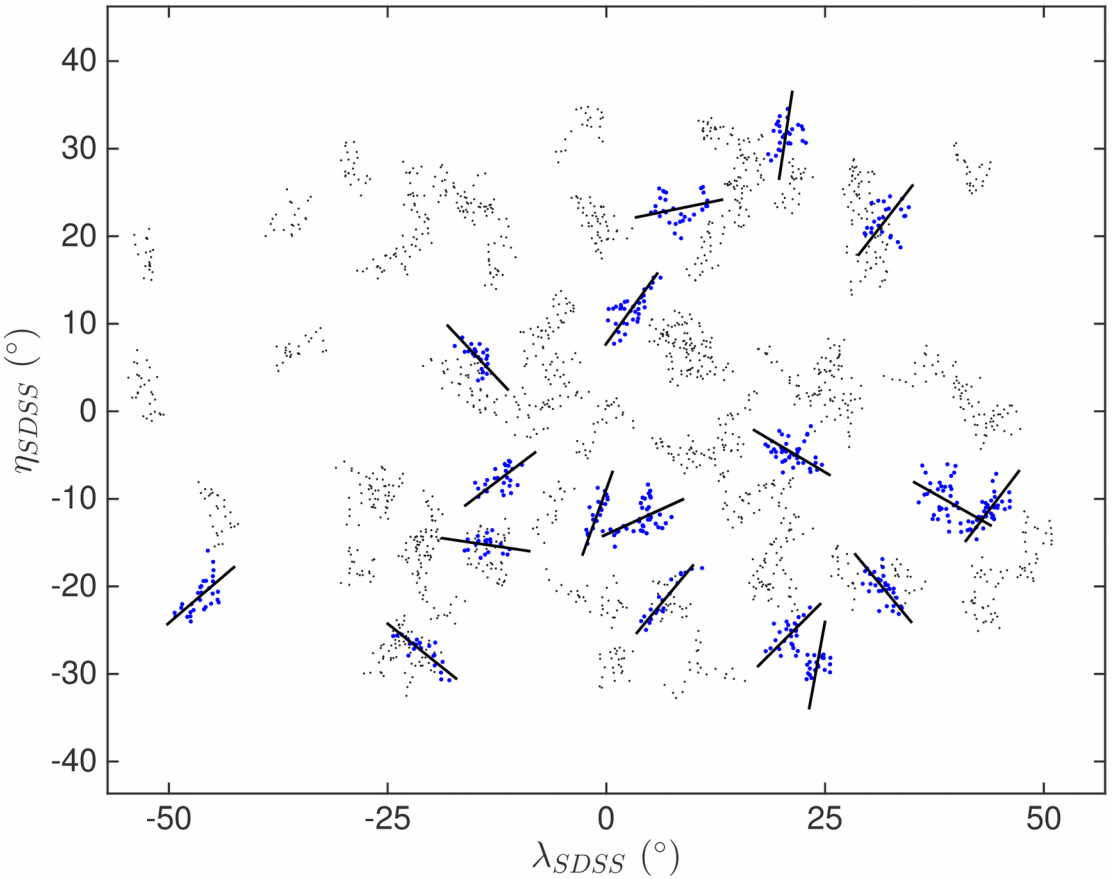
LQGs with at least one polarized quasar

Quasar radio polarizations in LQGs



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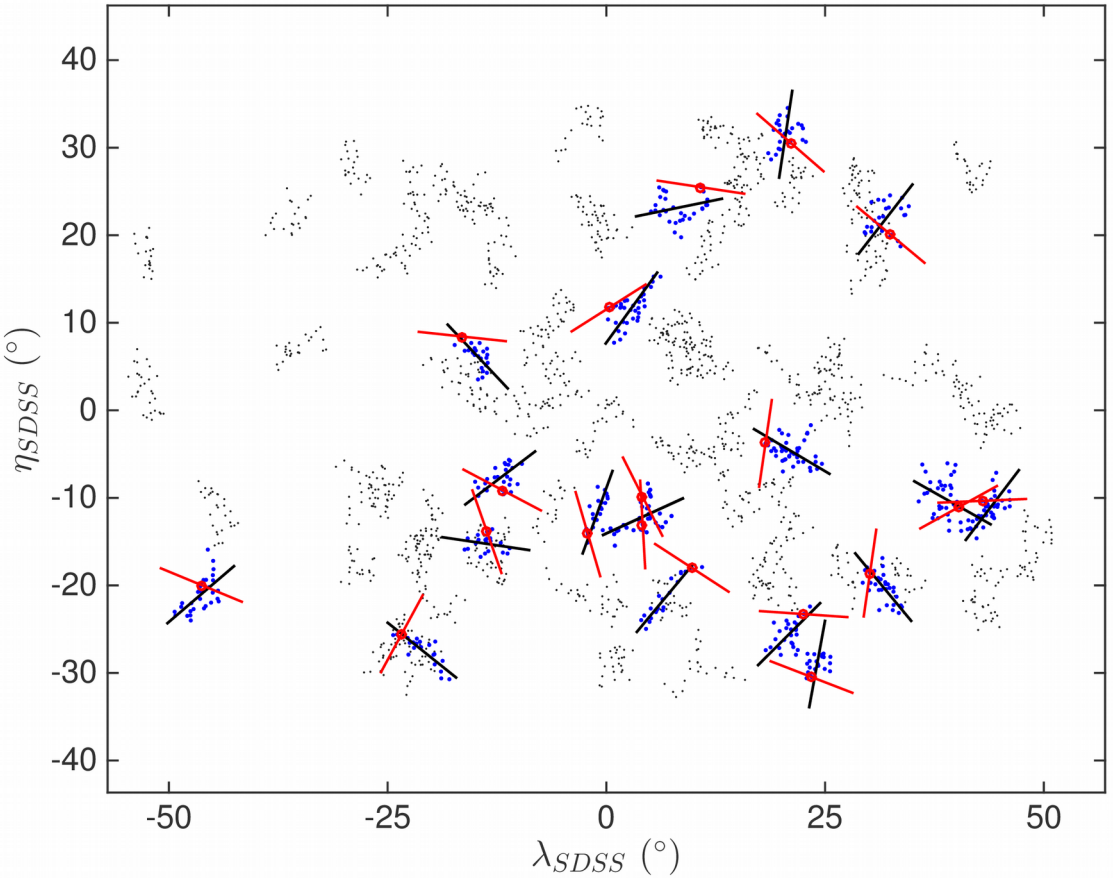
LQGs with at least one polarized quasar

Major axes of LQGs from inertia tensors

Quasar radio polarizations in LQGs



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LQGs with at least one polarized quasar

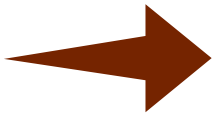
Major axes of LQGs from inertia tensors

Quasar polarization vectors

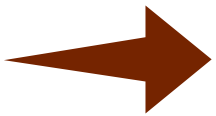
Quasar radio polarizations in LQGs

Main results (see our poster for details)

- The radio polarization vectors and thus the quasar spin axis orientations are correlated to the LQG major axes (probability higher than 99%)
- This confirms and extends our previous study based on optical polarizations
- The effect depends on the LQG richness



Polarization of quasars in rich groups at z ~ 1.5 reveals alignments of SMBH spin axes with the structures in which they are embedded

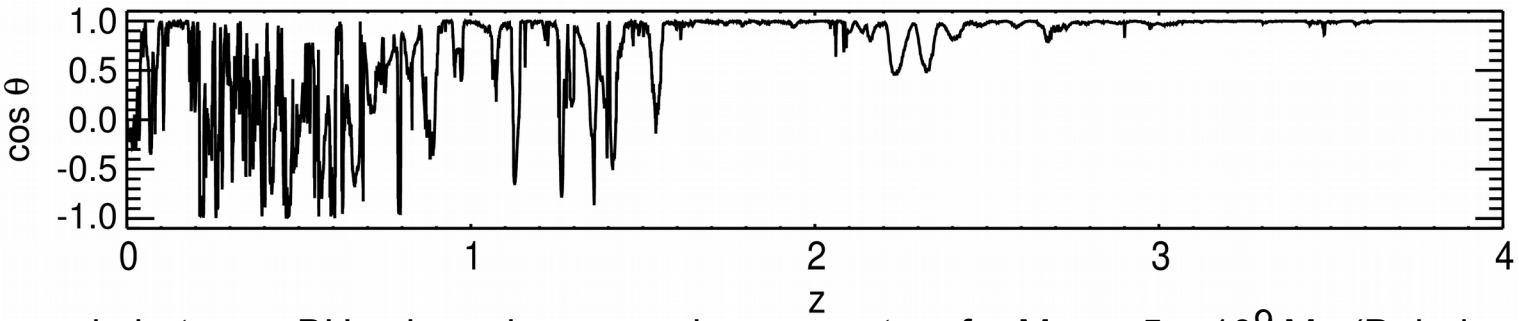


These alignments could be the high redshift counterparts of the galaxy – cluster – supercluster alignments known in the local Universe (Einasto et al. 1980, Binggeli 1982, West 1999, Paz et al. 2011)

Constraining current models ?

Models of coevolution of AGN, galaxies and large-scale structures : the scales investigated are one order of magnitude smaller

- Alignments SMBH / accretion disk / host galaxy / halo spin axes : depend on redshift.



The angle between BH spin and gas angular momentum for $M_{BH} = 5 \times 10^9 M_\odot$ (Dubois et al. 2014)

- Alignments with LSS depend on the halo mass (Aragon-Calvo et al. 2007). Accurate AGN M_{BH} and M_{Halo} are needed.

A better understanding of the relation between polarization and morphological structures (SMBH spin, radio jet, accretion disk) is needed, as well a better characterization of the LQGs as parts of the large-scale structure


Thank you