Large-scale polarization alignments of quasars in the JVAS/CLASS 8.4-GHz surveys

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We analyzed the large sample of polarization measurements of the flat-spectrum radio sources of the JVAS/CLASS 8.4-GHz surveys compiled by Jackson et al. (2007). We tested the uniformity of the polarization position angles for a wide range of angular (2D) and comoving (3D) separations and studied several subsamples, dividing the main sample of 4155 sources regarding their object type (QSO, galaxies, radio sources,...). We found regions of the sky of ~20° radius in which quasars have correlated polarization position angles.

– Motivations –

Very large-scale correlations of quasar polarization position angles (PPA) have been discovered at optical wavelengths (Hutsemékers 1998). These – still unexplained – Gpc-scale correlations have been subject to confirmations both at the observational and at the data analysis levels (Hutsemékers et al. 2001, 2005; Jain et al. 2004; Shurtleff 2013; Pelgrims & Cudell 2014). These correlations have the characteristics to be redshift dependent (at least in the North Galactic cap) and to be mainly due to sources located in two well-defined regions, the so-called A1 and A3 regions.
Based on the JVAS/CLASS 8.4-GHz surveys, Joshi et al. (2007) searched for systematic alignments of radio polarization vectors of the type reported at optical wavelengths. They did not reveal such large-scale alignments. However, using the same sample, Tiwari & Jain (2013) reported PPA correlations for small angular separations (<2°) but not at large-scale. Beside, Shurtleff (2014) found little (but not significant) indications of PPA correlations for sources grouped in circular regions of 24° radius.
Despite these analyses, the status of the PPA distributions at radio wavelengths remained obscure and an analysis taking the redshift of the sources into account was missing.

– Method –

We applied a few dedicated statistical tests to the entire sample of 4155 flat-spectrum radio sources (FSRS) and to the different subsamples showed in Table 1. These tests are the Hawley-Peebles Fourier method (Hawley & Peebles 1975), the density test of Pelgrims & Cudell (2014) and the so-called S and Z tests introduced by Hutsemékers (1998) and modified by Jain et al. (2004) which are well-suited at assigning the probability that the PPA distributions in spatially defined groups of objects are due to statistical fluctuations within the sample (see Pelgrims & Hutsemékers 2014 for a review of these tests). These tests are applied in 2 dimensions taking only the angular separation of the sources into account or in 3 dimension taking also the distance (redshift) of the sources into account. An example of the application of the test S of Jain et al. (2004) in 2 dimensions to the sample of the 1450 QSOs is shown in Fig. 1.

– Results –

- Despite the poor overlap between the optical and the radio catalogues, we unveiled an alignment of the polarization vectors of FSRSs falling inside the A3 region defined from studies at optical wavelengths (320°<RA<360° ; DEC<50° ; 0.7<z<1.5).
  The probability of uniformity is found to be < 1%.

- The 2-dimensional analyses with the S and Z tests reveal significant correlations (S.L. ~ 1%) for the sample made of QSO only and for sources grouped in circular regions of angular radius in the range 10 – 25° (see Fig. 2). The 3-dimensional analysis reveals a weak correlation for QSO having redshift > 1, but only with the Z test (see Pelgrims & Hutsemékers 2014).

- Within the sample of QSO, the groups that show significant correlation of their PPA are found to cluster in 3 distinct regions. Interestingly, the regions of the sky where the polarization vectors of quasars are seen to align at radio wavelengths coincide pretty-well with the regions of alignment at optical wavelengths. This coincidence is shown in Fig. 3 where the grey lines represent the boundaries in the northern hemisphere (equatorial) of the A1 and A3 regions.

– Discussion and interpretations –

The large-scale polarization alignments found at radio wavelengths in the JVAS/CLASS catalogues are reminiscent of those discovered at optical wavelengths by Hutsemékers in 1998.
However, radio alignments prove to be difficult to interpret either as resulting of biases in the dataset or as being the signature of a physical effect. One can find arguments for and against each scenario.
Among them, the fact that the alignments are more pronounced in 2D than in 3D and that the mean position angles of the aligned regions are close to multiple of 45° would suggest a biased dataset.
On the other hand, the detection of alignments for one class of object but not for the other ones and the clustering of aligned sources in a few regions of the sky consistent with those found at optical wavelengths might be seen as the signature of a physical effect.

- We did not find any convincing sources of contaminations that could explain the PPA correlations.
- If the polarization alignments are real and as polarization is usually correlated to the morphological axis of the object (e.g., Saikia & Salter 1988), our study would suggest a common explanation for the large-scale correlations of PPAs at radio and at optical wavelengths possibly by spin-axis alignments of quasars with their host large-scale structure (Hutsemékers et al. 2014). We are currently investigating this hypothesis in details.

For all details: **Have a look at arXiv:1503.03482**

Object Type	n
All	3858
QSOs	1450
Radio Sources	1379
Galaxies	381
Other Objects	648

Table 1. Number (n) of the different source species for the objects retrieved in the NED database among the sample of 4155 sources with reliable PPA measurements (here without redshift information). The category named Other Objects contains various species with small membership.

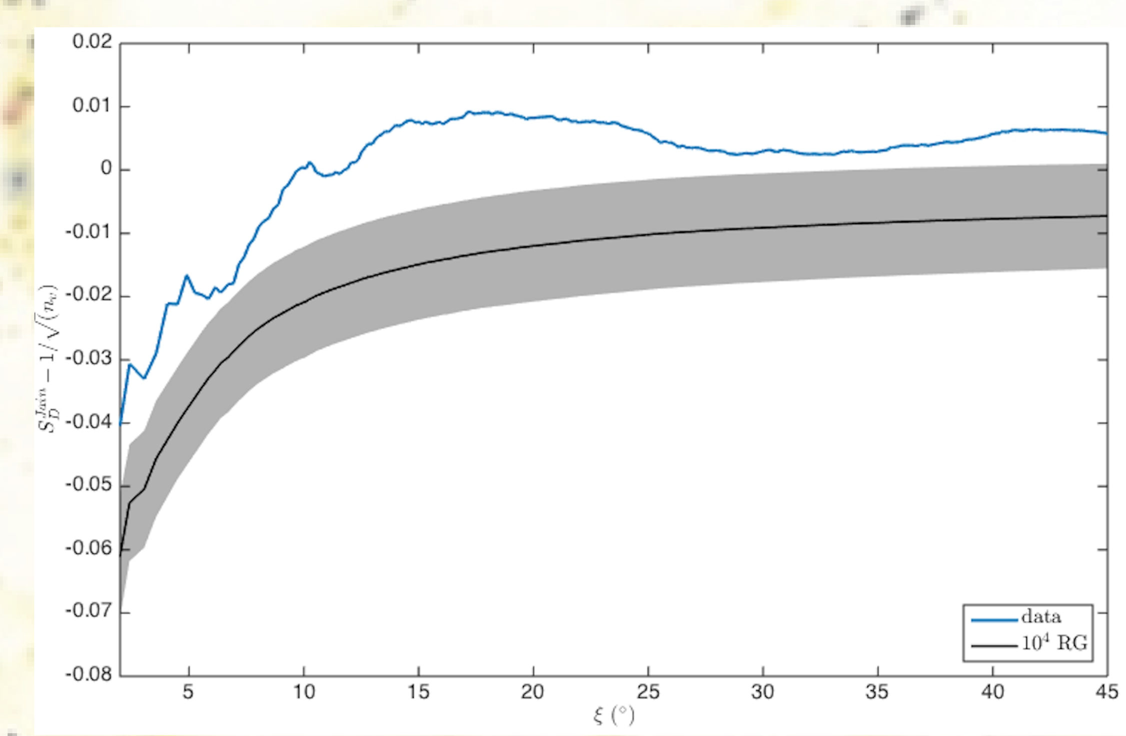

Fig. 1. Statistics of the S test of Jain et al. (2004) applied to the sample of QSOs in 2 dimensions versus the typical angular separation defining groups of neighbors. The blue line refers to the real data. The grey shaded area and black line correspond to the 1σ dispersion and the mean statistics for 10.000 random simulations by shuffling of the PPAs. A clear excess is apparent for the range ξ ~ 10 – 25°.

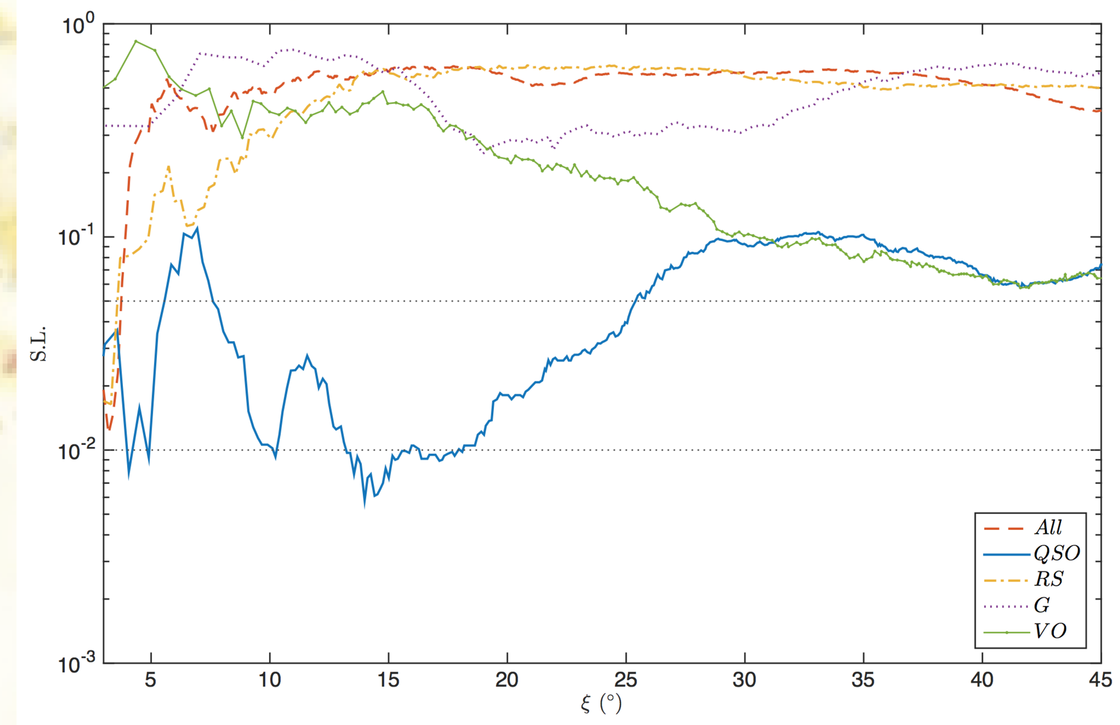

Fig. 2. The significance levels (S.L.) obtained with the S test of Jain et al. (2004) in 2 dimensions for the subsamples of *Table 1* versus the typical angular size of neighboring groups. The S.L. is defined as the percentage of random simulations that show a statistics S_D higher than that of the data. The subsample of QSOs exhibits a clear signal of correlated PPAs.

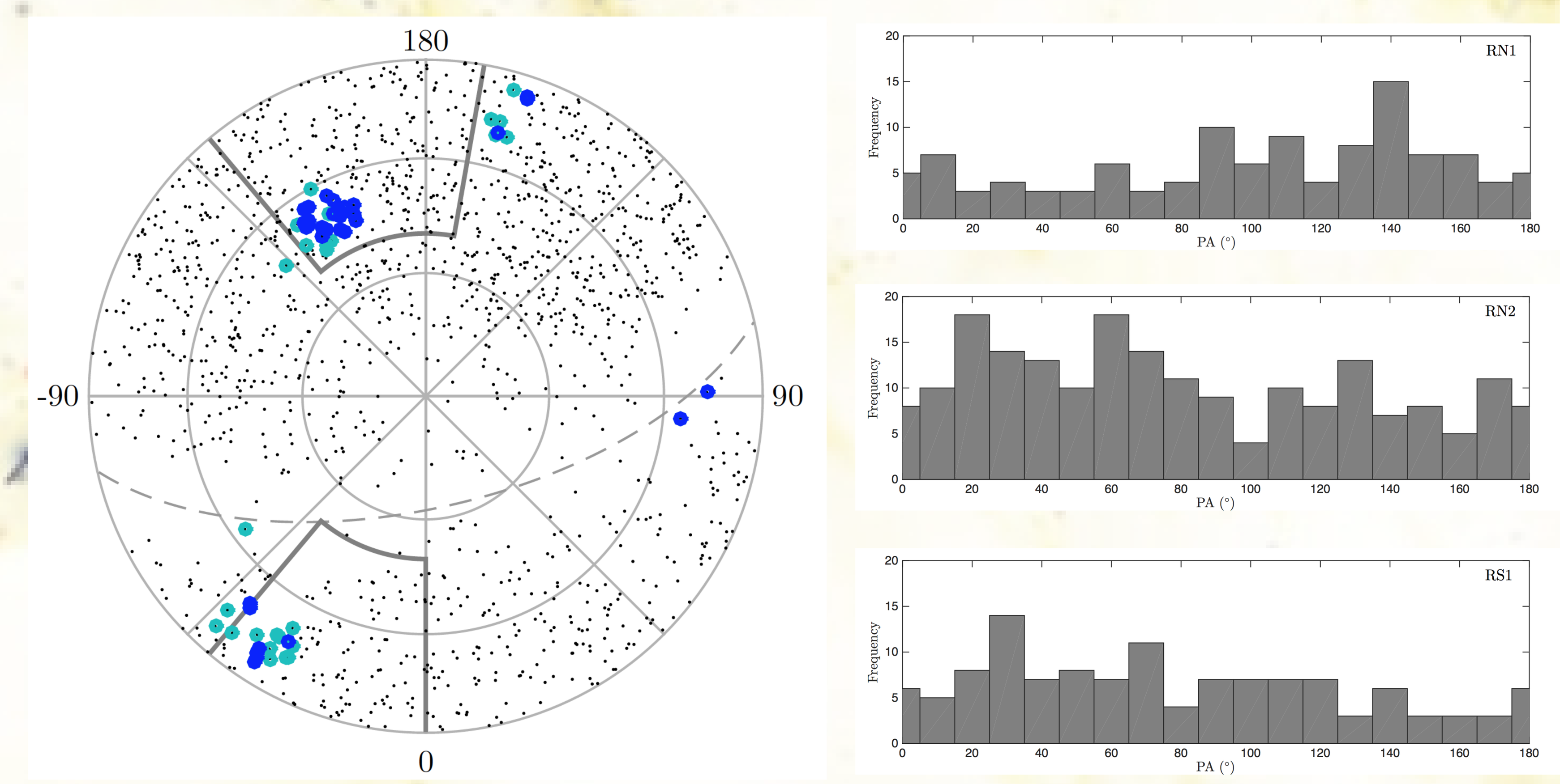

Fig. 3. left: Equal area Schmidt projection of the northern hemisphere of the sky of QSOs (small black dots). The highlighted dots show the locations of the central sources of groups in which the PPAs are significantly correlated. The significance of correlations are higher for blue dots than for cyan ones. Grey lines are northern boundaries of the A1 and A3 regions of optical polarization alignments. Based on this map, our identification procedure shows that the groups of neighbors having correlated PPAs are found to cluster in 3 regions of the sky. These coincide with the regions defined from alignment at optical wavelengths.
right: The figures are PPA histograms of the three regions of alignment, where departure from uniformity is observed. After inclusion of all the neighboring sources contributing to the correlations, these three principal regions of alignment labelled RN1, RN2 and RS1, have mean location (RA, DEC) at (163, 12)°, (206, 38)° and (-20, 18)°, respectively.

– References –

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The 2nd COST workshop on Polarization and Active Galactic Nuclei – Strasbourg (France) – May 11 & 12 2015

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