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ORIGINAL ARTICLE

A large anisotropy in the sky distribution of 3CRR quasars and other radio galaxies

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Abstract We report the presence of large anisotropies in the sky distributions of powerful extended quasars as well as some other sub-classes of radio galaxies in the 3CRR survey, the most reliable and most intensively studied complete sample of strong steep-spectrum radio sources. The anisotropies lie about a plane passing through the equinoxes and the north celestial pole. Out of a total of 48 quasars in the sample, 33 of them lie in one half of the observed sky and the remaining 15 in the other half. The probability that in a random distribution of 3CRR quasars in the sky, statistical fluctuations could give rise to an asymmetry in observed numbers up to this level is only ~ 1 %. Also only about 1/4th of Fanaroff-Riley 1 (FR1) type of radio galaxies lie in the first half of the observed sky and the remainder in the second half. If we include all the observed asymmetries in the sky distributions of quasars and radio galaxies in the 3CRR sample, the probability of their occurrence by a chance combination reduces to $\sim 2 \times 10^{-5}$. Two pertinent but disturbing questions that could be raised here are—firstly why should there be such large anisotropies present in the sky distribution of some of the strongest and most distant discrete sources, implying inhomogeneities in the universe at very large scales (covering a fraction of the universe)? Secondly why should such anisotropies lie about a great circle decided purely by the orientation of earth's rotation axis and/or the axis of its revolution around the sun? It seems yet more curious when we consider the other anisotropies, e.g., an alignment of the four normals to the quadrupole and octopole planes in the CMBR with the cosmological dipole and the equinoxes. Then there is the other recently reported large dipole anisotropy in the NVSS radio source distribution differing in magnitude from the CMBR dipole by a factor of four, and therefore not explained as due to the peculiar motion of the Solar system, yet aligned with the CMBR dipole which itself lies close to the line joining the equinoxes. Are these alignments a mere coincidence or do they imply that these axes have a preferential placement in the larger scheme of things, implying an apparent breakdown of the Copernican principle or its more generalization, cosmological principle, upon which the standard cosmological model is based upon?

Keywords Galaxies: active · Quasars: general · Galaxies: nuclei · Cosmic background radiation · Large-scale structure of universe

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1 Introduction

Copernican principle states that earth does not have any eminent or privileged position in the universe and therefore an observer's choice of origin and/or orientation of his/her coordinate system should have no bearing on the appearance of the distant universe. Its natural generalization is the cosmological principle which states that the universe on a sufficiently large scale should appear homogeneous and isotropic, with no preferred directions, to all observers. However to us on earth the universe does show heterogeneous structures up to the scale of superclusters of galaxies and even somewhat beyond, but the conventional wisdom is that it would all appear homogeneous and isotropic when observed on still larger scales, perhaps beyond a couple of hundreds of megaparsecs. Radio galaxies and quasars, the most distant discrete objects (at distances of gigaparsecs and farther) seen in the universe, should trace the distribution of matter in the universe at that large scale and should therefore appear isotropically distributed from any vantage point in the universe, including that on earth.

On the other hand Cosmic Microwave Background Radiation (CMBR) observations from the WMAP satellite have in recent years been reported to show some unexpected anisotropies, which surprisingly seem to be aligned with the ecliptic (Tegmark et al. 2003; de Oliveira-Costa et al. 2004; Ralston and Jain 2004; Schwarz et al. 2004; Land and Magueijo 2005). The alignment of the four normals to the quadrupole and octopole planes in the CMBR with the cosmological dipole and the equinoxes (Copi et al. 2010) could undermine our ideas about the standard cosmological model with very damaging implications. The latest data from the Planck satellite have confirmed the presence of these anisotropies (Ade et al. 2014). Also using a large sample of radio sources from the NRAO VLA Sky Survey (NVSS, Condon et al. 1998), which covers whole sky north of declination $-40°$ and contains 1.8 million sources with a flux-density limit $S > 3$ mJy at 1.4 GHz, Singal (2011) showed in this faint radio source distribution the presence of a dipole anisotropy which is about 4 times larger than the CMBR dipole (Lineweaver et al. 1996; Hinshaw et al. 2009), presumably of a kinetic origin due to the solar motion with respect to the otherwise isotropic CMBR. These unexpected findings have recently been corroborated by two independent groups (Rubart and Schwarz 2013; Tiwari et al. 2015; also see Singal 2014a for a clarification on some misgivings in the literature about the formulation used in these analyses). The fact that the direction of the two independently derived dipoles, viz. from NVSS and CMBR, coincide implies that there is certainly some peculiarity along this direction in sky which incidentally lies close to the line joining the equinoxes. But the large difference in the inferred motion (as much as a factor of ~ 4) cannot be easily explained. A genuine discrepancy in the dipoles inferred with respect to two different cosmic reference frames would imply a relative motion between these frames, not in accordance with our present ideas of cosmology.

A large-scale bulk flow has also been inferred from peculiar velocities of clusters of galaxies (Kashlinsky et al. 2009), though the genuineness of these results has been severely criticized in the literature (Keisler 2009; Osborne et al. 2011). There are reports of the presence of other large-scale alignments in radio and optical polarizations data (Jain and Ralston 1999; Hutsemekers et al. 2005). It seems the universe might not be all isotropic and homogeneous, as assumed in the cosmological principle. Here we report even larger anisotropies which are seen in the sky distributions of powerful extended quasars and some other sub-classes of radio galaxies.

2 The sample

One of the earliest and best studied source of radio galaxies and quasars is the third Cambridge twice revised (3CRR) catalogue (Laing et al. 1983), which is radio complete in the sense that all radio sources brighter than the sensitivity limit ($S_{178} = 10.9$ Jy) of the survey are included (and certainly with no spurious entries as each and every source in the sample has been studied in detail). It covers the sky north of declination, $\delta = 10°$, except for a zone of avoidance, a band of $\pm 10°$ about the galactic plane ($b = 0°$). Also it has a 100 % optical identification content with detailed optical spectra to classify radio sources into radio galaxies and quasars. The catalogue with the latest updates is downloadable from http://astroherzberg.org/people/chris-willott/research/3crr/.

The steep spectrum radio sources (radio spectral index $\alpha > 0.5$ with $S \propto \nu^{-\alpha}$) in the 3CRR catalogue are divided broadly into two classes, radio galaxies and quasars, the former further sub-divided into two types, Fanaroff-Riley 1 and 2 (FR1 and FR2), based on their radio morphologies (Fanaroff and Riley 1974) with the quasars almost always resembling the radio morphology of FR2 types. When compared to FR1s, the FR2 types are almost always found amongst the more powerful radio galaxies, overlapping the radio luminosities of quasars. However FR2 radio galaxies in general show only narrow emission lines in their optical spectra, while quasars always show broad emission lines in addition to the narrow emission lines. Included among quasars is a small number of what are termed as broad line radio galaxies (BLRGs) or weak quasars (WQ), the latter with broad emission lines seen in polarized optical emission, or/and compact optical nuclei detected in infrared or X-rays. FR2 radio galaxies are further sub-divided by their optical spectra into low excitation galaxies (LEGs) and high excitation galaxies (HEGs). One object (3C386) shows an overlap of LEG and WQ properties (see Grimes et al. 2004), which we have therefore dropped from our sample. Also excluded are a small number of compact steep spectrum sources (CSSS, with angular size $\lesssim 2$ arcsec) which seem to be a different class (Kapahi et al. 1995). Then we have 23 FR1s, 17 LEGs, 65 HEGs and 48 quasars, making a total of 153 radio sources in our sample.

The conventional wisdom (Laing et al. 1994; Grimes et al. 2004) is that steep spectrum ($\alpha > 0.5$) HEGs and quasars belong to the same parent population, and that it is the orientation of the source in the sky that decides whether it will appear as an HEG or a quasar, the latter when the major radio-axis happens to be within a certain critical angle (ξ_c) around the observer's line of sight. HEGs and quasars, in all other respects, are considered to be intrinsically the same. In this orientation-based unified scheme (OUS), because of the smaller inclinations of the radio axes of the quasars with respect to the observer's line of sight, the observed radio sizes of the quasars will be foreshortened due to the geometry and should appear systematically smaller than those of the HEGs. It is a popular notion that $\xi_c \sim 45°$ and that in the 3CRR catalogue the observed sizes of quasars are accordingly about a factor of two smaller as compared to those of radio galaxies (Barthel 1989; Urry and Padovani 1995; Peterson 1997).

3 Results

Recently it was shown that the relative size distributions of quasar and HEGs do not always show the projection effects, predicted by the OUS, when we compare the sources within different redshift bins (Singal 2014b). But what about when the size distributions are compared for different directions in the sky? To test this we divided the sample, starting from the first source in it, into two equal right ascension (RA) regions, region I from RA 0 to 12 and region II from 12 to 24 hours. While in region II the two size distributions differed by a factor of two or so, with quasar sizes being statistically smaller as one would expect due to the foreshortening in the OUS, in region I the sizes appeared statistically indistinguishable, contrary to the predictions of the OUS. This unexpected result prompted us to check their numbers as well in these two sky regions, since to be consistent with the OUS predictions, not only their relative sizes but their relative numbers should also differ by a factor of about two for a 'canonical' value of $\xi_c \sim 45°$. And again we found that while in region II the number of quasars was indeed about half that of HEGs, but in region I there were as many quasars as the HEGs, contrary to what expected according to the OUS. Figure 1 shows normalized cumulative plots of the linear size distributions of HEGs and quasars in the two regions. In region II we do notice the quasar sizes (as well as numbers) to be smaller than those of the HEGs by a factor of about two. However in region I, the differences, if any, in radio sizes or numbers are hardly seen and a Kolmogorov-Smirnov test shows that the two distributions are statistically almost indistinguishable, thereby punching a hole in the unification scheme. Not only does this seem to be a very strong evidence against the OUS (after all the OUS could not hold good in just one half of the sky), but it seems that there could be much more at stake here than just the validity of the OUS.

In the OUS, the ratios in the sizes and numbers of HEGs and quasars could change with redshift depending upon details of the model used as, for example, in the receding-torus-type scheme (Lawrence 1991; Hill et al. 1996) where the critical angle (ξ_c) may be evolving with redshift or luminosity. But in any case the ratio should not vary with the direction in sky. Therefore while any variations in numbers or sizes with redshift one could try to put down to some sort of cosmological evolution of their properties, irrespective of whether or not unified scheme holds good, but the same type

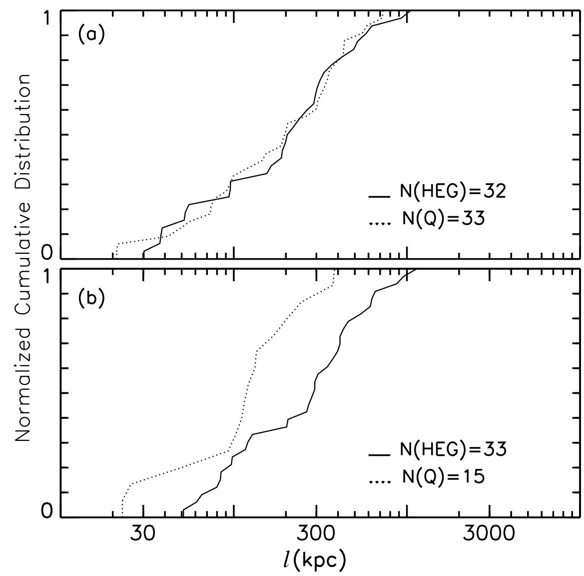

Fig. 1 Normalized cumulative distributions of the linear size (l) of HEGs (*continuous curves*) and quasars (*broken curves*) for the 3CRR sample (**a**) for region I (**b**) for region II. N(HEG) and N(Q) give the number of High Excitation galaxies and quasars respectively, in each case

of escape route cannot be available for a variation (over and above what might be due to statistical fluctuations) in the sky distribution. Further, any effects of zone of avoidance ($\pm 10°$ around the galactic plane, $b = 0$) should proportionally be the same for both HEGs and quasars, without affecting their number ratios.

It should be noted that even within the unification scheme, HEGs and quasars observationally are not identical and each class has distinct properties and they are identifiable or distinguishable as separate type of objects observationally and each of them should have their own isotropic distribution and there should be no sky-position dependent effect between the two. In fact with or without the unified schemes, from the isotropy expected from the cosmological principle, the number of any type of distant extragalactic objects should not vary with direction in sky, apart from the statistical fluctuations. A close investigation showed that while the HEGs, which are the largest number of the 3CRR constituents, are quite uniformly distributed over the observed sky, the quasars are quite unevenly distributed. While about two thirds (33 out of a total of 48) quasars in the sample lie in region I, the remainder one third (15 out of 48) appear in region II. In a priori chosen division of the sky in two adjacent and contiguous regions, for a random distribution of the sources one expects to get a binomial distribution. The probability of such a deviation in a binomial distribution to occur at $(33 - 15)/\sqrt{48} \sim 2.6\sigma$ level due to statistical fluctuations is only ~ 0.01 (Bevington and Robinson 2003).

Could the anisotropy in the distribution of quasars have any local Supercluster or some other local origin? Such a

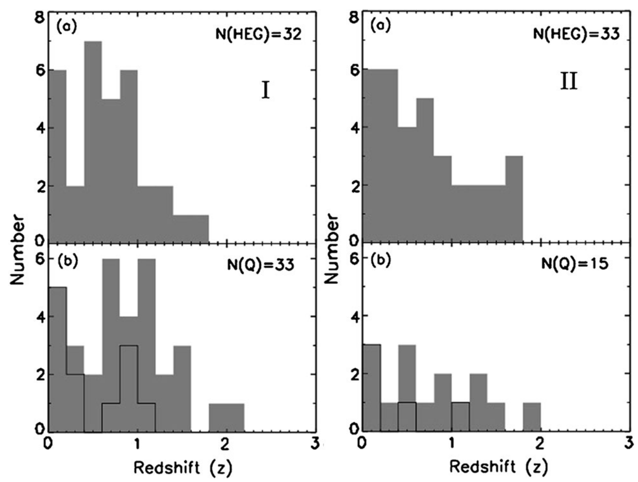

Fig. 2 Histograms of the redshift distributions of the 3CRR sample in regions I and II of the sky (**a**) for HEGs (**b**) for quasars. In the *lower panels*, the regions under the overlaid *darker lines* represent WQs or BLRGs. N(HEG) and N(Q) give the number of high excitation galaxies and quasars respectively, in each region

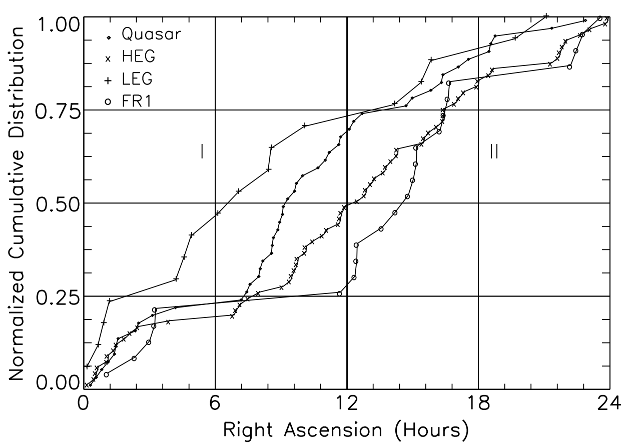

Fig. 3 Normalized cumulative sky distributions of various objects in the 3CRR sample plotted against RA

thing, if any, should show up as a difference in the redshift distributions in the two regions. Figure 2 shows the redshift distributions of HEGs and quasars. Apart from the total number of quasars being less in region II, there does not appear to be any gross changes with redshift in the distribution of quasars and as well of HEGs in the two regions. This almost rules out the possibility that the quasar anisotropy has any local origin. Even the weak quasars (WQs), which like the other quasars are also proportionally less in region II, have redshift distributions which are very similar in the two regions, so any anomaly in quasar distribution is certainly not due to the presence of a differential number of WQs.

Figure 3 shows a normalized cumulative plot of HEG and quasar distributions in RA in sky. The sky distributions of HEGs and quasars appear very different, with slightly more than two thirds of all quasars lying in region I, while HEGs

Table 1 Counts of radio sources in two regions of the sky

Sky region	N(HEG)	N(Q)	N(LEG)	N(FR1)
I + II	65	48	17	23
I	32	33	12	6
II	33	15	5	17

are distributed quite evenly over the sky. Also plotted in the figure are distributions of LEGs and FR1s. These too show very uneven distributions, with about 70 % of LEGs lying in regions I and only about 1/4th of FR1s in that region. Overall the percentage of FR1s varies substantially between the two regions, while in region 1 there are only 7 % of the total sources as FR1s, in region II the percentage is as much as 24 %. Table 1 gives the number counts of different type of sources in the two regions of the sky. The probabilities of such a deviation to occur in a binomial distribution at $11/\sqrt{23} \sim 2.3\sigma$ level due to statistical fluctuations is ~ 0.02 for FR1s. Further, as asymmetries of quasars and FR1s would have independent binomial probabilities, if these were due to random statistical fluctuations, then their combined probability of occurrence due to being simply a statistical fluctuation is only about $0.01 \times 0.02 \sim 2 \times 10^{-4}$, i.e., a 4σ result.[1]

Similarly LEGs also show an asymmetric distribution though at somewhat lower level (Table 1); while in region I there are 12 LEGs, in region II there are only 5 LEGs, implying a $7/\sqrt{17} \sim 1.7\sigma$ deviation. If we include their probability of occurrence at ~ 0.09 as well, then the total combined probability becomes $\sim 2 \times 10^{-5}$. It should be noted that LEGs and FR1s, which may have overlap in some of their properties, are otherwise different type of objects classified by their distinct radio properties, e.g., their different radio morphologies. Moreover LEGs are of higher radio luminosities than the FR1s and are seen at relatively much higher redshifts. Therefore their uneven distributions are not a result of a mix-up in their classifications. Quasars of course stand apart, being the most energetic and most distant of these objects.

To ensure that there is nothing amiss in our probability calculations, we also did Monte Carlo simulations by throwing quasars, LEGS and FR1s randomly in the sky covered by the 3CRR. Starting with a different seed for a random number generator, 100000 different random throws of 48 quasars, 17 LEGs and 23 FR1s were done every time, counting the number of "successful" times (that is when we got a distribution like that in Table 1) in each simulation of 100000 trials. These counts over a total of 1000 independent simulations gave an average of value of ~ 1.9. To be exact,

[1] It may be noted that the referee was not fully convinced of these combined probability calculations.

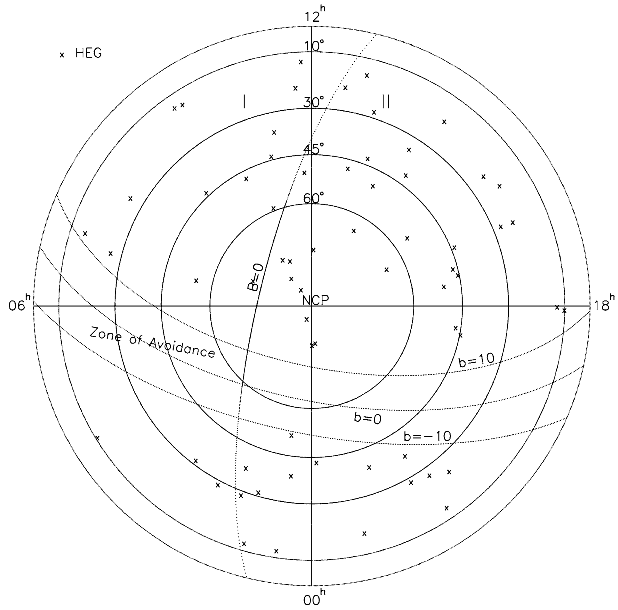

Fig. 4 Sky distribution of HEGs from the 3CRR sample shown in an equal-area projection of the Northern hemisphere, centered on the North Celestial Pole. Region I extends in right ascension from 0 to 12 hour and lies to the *left* of the *vertical line* passing through the NCP while region II lies to the right of it. The zone of avoidance is shown by a band of $\pm 10°$ about the galactic plane ($b = 0°$). Also shown is the Super-galactic plane ($B = 0°$)

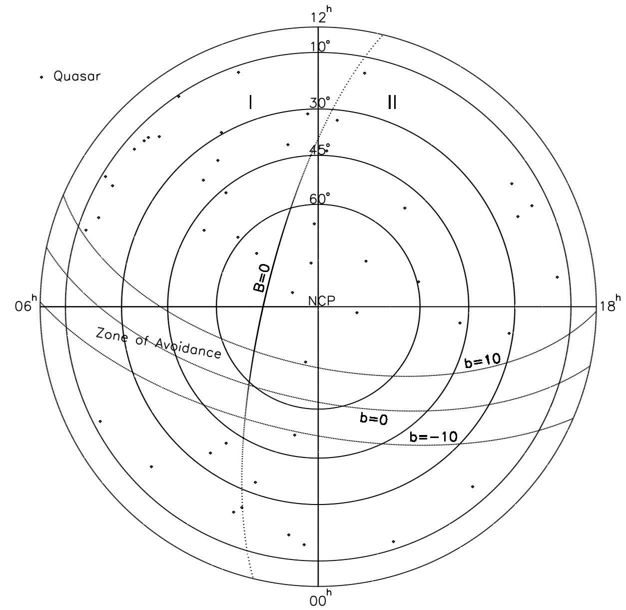

Fig. 5 Sky distribution of quasars from the 3CRR sample shown in an equal-area projection of the Northern hemisphere, centered on the North Celestial Pole. Region I extends in right ascension from 0 to 12 hour and lies to the *left* of the *vertical line* passing through the NCP while region II lies to the right of it. The zone of avoidance is shown by a band of $\pm 10°$ about the galactic plane ($b = 0°$). Also shown is the Super-galactic plane ($B = 0°$)

out of a total a 100 million independent trials (1000 times 100000 throws), 1856 cases were found to have deviations equal to those in Table 1, implying a probability consistent with our calculations of $\sim 2 \times 10^{-5}$.

Figure 4 shows a Lambert azimuthal equal-area projection, mapping the Northern hemisphere onto a circular disc centered on NCP and accurately representing areas in all regions of the hemisphere. All points on a circle at a declination δ in sky are represented by a circle of radius $\propto \sqrt{1 - \sin\delta}$ on the disc. The figure shows plot of HEGs from the 3CRR catalogue; the distribution seems to be fairly uniform on the sky.

Figure 5 shows plot of quasars from the 3CRR catalogue on the sky. To a first order, this division of sky in regions I and II happens to yield almost the maximum asymmetry visible in the quasar distribution, and it amounts to passing a great circle between the equinoxes (intersection points of the equatorial plane and the ecliptic) and the north celestial pole (NCP). First thing we want to be sure is that the observed number of quasars in region I being double or so of that in region II is not due to any instrumental/observational selection effects in these two regions in the 3CRR catalogue. This is guaranteed by the fact that virtually no difference is seen between the numbers of HEGs from these two regions in the same catalogue (Fig. 4), which could not have happened if there were any such selection effects. It confirms that the quasar anomaly is not due to any observational selection effects, as any selection effects would not treat HEGs and quasars differentially, which were first radio selected and only later categorized as HEGs or quasars from their optical/infrared properties. The same argument can also be applied for the absence of any influence of our Galaxy on various distributions, as the Galaxy could not have affected distribution of different type of objects differently. Even otherwise the quasar asymmetry in Fig. 5 seems to have no correlation with the galactic plane.

Comparing the regions between RA 06 to 12 hours and 12 to 18 hours in top half of Fig. 5, we notice that there are 22 quasars between RA 06 to 12 hours while there are only 10 between 12 to 18 hours, giving a ratio of 2.2 in quasar numbers between these two regions. Actually with about 10 % of the region from 06 to 12 hours overlapping the zone of avoidance, one would rather expect a proportionally smaller number of quasars in that region as compared to that in RA 12 to 18 hours, contrary to what actually seen. The total number of sources in the bottom half of the figure is less as compared to that in the top half, mainly because of a large fraction of area in the bottom half overlapping with the zone of avoidance. But even there as well a ratio of 2.2 is found between the region 0 to 6 hour (11 quasars) and that between 18 to 24 hour (5 quasars). From this it is clear that the asymmetry in quasar distribution is not due to a local excess (i.e., any local clustering) in neighborhood of some point in sky and that this excess in RA range 0 to

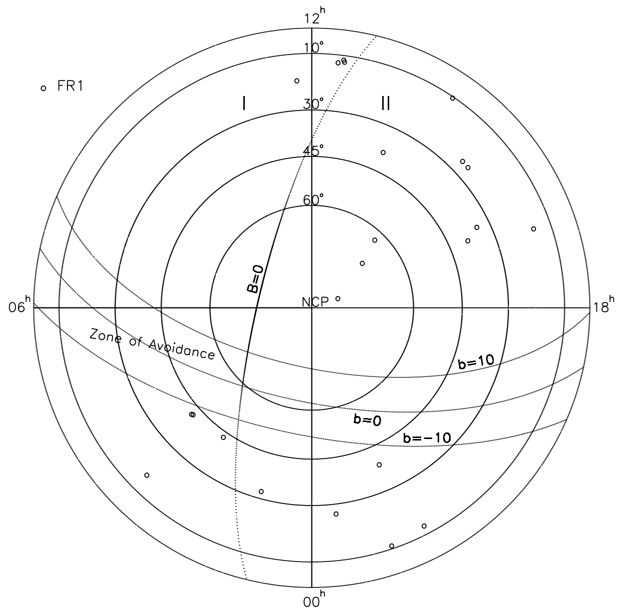

Fig. 6 Sky distribution of FR1 type of objects from the 3CRR sample shown in an equal-area projection of the Northern hemisphere, centered on the North Celestial Pole. Region I extends in right ascension from 0 to 12 hour and lies to the *left* of the *vertical line* passing through the NCP while region II lies to the right of it. The zone of avoidance is shown by a band of $\pm 10^\circ$ about the galactic plane ($b = 0^\circ$). Also shown is the Super-galactic plane ($B = 0^\circ$)

12 hour as compared to 12 to 24 hour is fairly widely distributed. Also there seems to be no effect of the Galactic latitude on the quasar distribution outside the zone of avoidance. The Super-galactic plane ($B = 0$) too does not seem to have any relation with the distribution of quasars on sky. This of course is expected as quasars are at much higher redshifts as compared to that of the local Virgo supercluster. Therefore being two to three orders of magnitude more distant than the Virgo Supercluster, quasars can in no way be physically related to it or some other local objects.

Figure 6 shows the distribution of FR1 types of radio galaxies in the sky. It is clear that FR1 radio galaxies also have a highly asymmetric number distribution between the two regions, though in opposite sense to that of quasars. The distribution is particularly asymmetric about the line joining the Autumn equinox (RA = 12 hour) to the NCP. While there are 13 FR1s between RA = 12 to 18 hour, there is only 1 FR1 radio galaxy between RA range from 6 to 12 hour, and that too lies close to the boundary at 12 hour. The area covered by galactic plane in the region RA 06 to 12 hours is only ~ 10 %, so that does not resolve the asymmetry. Nor is this order of magnitude difference explained even if we exclude a couple of FR1s (M84; M87 or Virgo A) which lie close to the Super-galactic plane ($B = 0$). If we drop the two FR1s close to the Super-galactic plane and adjust for the 10 % galactic plane coverage, then we have approximately 10 versus 1 FR1s in the two regions which may imply a $9/\sqrt{11} \sim 2.7\sigma$ fluctuation, with a ~ 0.007 chance probability.

4 Discussion and conclusions

It is interesting that while relatively low redshift (up to $z \sim 0.2$) FR1s have excess between 12 to 18 hr RA, high redshifted quasars (up to $z \sim 2$) have an excess in the RA range from 6 to 12 hour, in direction where FR1s are almost non-existent. This shows not only an anisotropic universe but also a direct evidence of the presence of large scale inhomogeneities. It should be noted that the scale spanned by FR1s in the universe (up to $\sim$ a gigaparsec) is almost an order of magnitude larger than the scale at which inhomogeneities (Super-clusters, Great-Wall, Voids etc.) have till now been seen through optical observations. And of course quasars further cover a scale an order of magnitude larger than FR1s. This in fact is the largest scale in which discrete objects have been seen in the universe and any anisotropy or inhomogeneity on that scale is certainly a cause of worry as it will negate the cosmological principle.

These results are robust. There is little likelihood that these anomalies could be due to some missing or even spurious sources in the 3CRR catalogue, a radio complete sample of sources, in the sense that all source above the sensitivity limit of the catalogue have been detected and listed.

It is to be noted that a large scale dipole anisotropy in radio source distribution at much fainter levels was seen earlier, and was interpreted due to motion of the solar system with respect to an average universe. The derived direction of motion matched with that inferred from the CMBR, though the magnitude was found to be about a factor of four larger (Singal 2011) than for CMBR (Lineweaver et al. 1996; Hinshaw et al. 2009). These apparently anomalous results have recently been vindicated by the findings of two independent groups (Rubart and Schwarz 2013; Tiwari et al. 2015).

However the anisotropies pointed out here in the 3CRR sample could not be caused by a motion of the solar system as it could not give rise to different anisotropies for different kind of objects. We have seen that while powerful HEGs numbers are evenly distributed, quasars and LEGs have more numbers in region I, but the less luminous FR1's are found to be more in region II. It is as if different regions of the sky were more amenable to one kind of source types than the other. Nor could these be attributed to some effect of our Galaxy or some effect of local Supercluster. Any such things would have affected all type of different objects in roughly the same way, but as we have seen the HEGs, LEGs, quasars and FR1s have very different asymmetries in their distributions.

There is certainly something intriguing. Is there a breakdown of the Copernican principle as things seen in two regions of sky, divided purely by a coordinate system based on earth's orientation in space, show very large anisotropies in extragalactic source distributions? Why should the equinox points should have any bearing on the large scale distribution of matter in the universe? The only way to still retain the cosmological principle will be to doubt the reliability of the 3CRR survey, which will come very much of a surprise to almost all radio astronomers who take the 3CRR sample to be a true representation of strong radio source population. It should be noted that in the last three decades, since the 3CRR sample was formed (Laing et al. 1983), there have been a few, if any, changes due to addition of missing sources or deletions of spurious sources, and it is unlikely that the problem would get resolved that way. Many more deeper surveys covering all sky are certainly required in order to resolve this enigma, but even if deeper or more complete southern surveys show the absence of these anisotropies in the sky distribution of quasars and/or other radio galaxies, it will still remain to be explained why these anomalies are present in the strong 3CRR sample in the Northern hemisphere. After all many important studies like the number counts, luminosity function and/or cosmological evolution of other properties of radio population have been made using the 3CRR source distributions as an important ingredient, where an implicit assumption was an isotropic distribution of radio sources in the 3CRR sample (or at least presence of no such large anomalies), whether for quasars or for other radio objects. Even if in future it does turn out that one could explain away these anomalies due to some ill-understood subtle local effect, it might still require at least a rethinking on some of these earlier results. The OUS at least seems to be ousted as it cannot be valid only in one half of the sky as implied by the number and size ratios. A further confirmation of the asymmetries will of course be much vicissitudinous for all astronomers and cosmologists as well, since cosmological principle is the basis on which almost all modern cosmological theories depend upon as a starting point.

For the fore-mentioned apparent alignment in the CMBR in one particular direction through space, it has to be kept in mind that all such observations are obscured by the disc of the Milky Way galaxy, and one has to be extra careful while interpreting the data. Even there have been speculations whether solar system dust could give rise to sizable level of microwave emission or absorption, leading to a correlation with the ecliptic (Dikarev et al. 2009). But no such effect will be expected in the number distributions of discrete sources. The normals to the four quadrupole and octopole planes are aligned with the direction of the equinoxes and so does the dipole direction representing the overall motion of the solar system in the universe (Schwarz et al. 2004; Copi et al. 2010). Also our plane dividing the two regions of asymmetries for quasars or certain type of radio galaxies passes through the same two equinox points. This is in particular astounding as an alignment of the asymmetries with the equinoxes would imply a special time too because of the precession. However, it is not clear whether the asymmetries seen by us are related to that in the CMBR, and it is not presently possible to see if the anomalous distribution of radio sources is actually related to ecliptic coordinates as the region covered by the 3CRR, unlike equatorial coordinates, is not divided equally in two ecliptic hemispheres. Perhaps an all-sky complete catalogue in future will help resolve this issue. But irrespective of that there is no denying that from the large anisotropies present in the radio sky, independently seen both in the discrete source distributions and in the diffuse CMBR, the Copernican principle seems to be in jeopardy.

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