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ORIGINAL ARTICLE

Spatial distribution of active galactic nuclei based on the 1995 CFA catalogue

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Abstract The spatial distribution for 37 Active Galactic Nuclei (AGN) included in the Harvard catalogue of red-shifts has been studied in terms of their distances and red-shifts. We investigated the completeness of the catalogue by using an intrinsic property of the AGN, their absolute luminosity. The absolute luminosity for the 37 AGNs was calculated and they were partitioned into classified into two categories, above and below $10^{11}L_{\odot}$. This study finds no observable differences between the two luminosity groups, so that the AGNs are distributed randomly and uniformly, implying the completeness of the catalogue.

1. Introduction

The term Active Galactic Nucleus (AGN) refers to the existence of energetic phenomena in the nuclei of galaxies, or in their central regions, which cannot be clearly attributed to stars (Shields, 1999). Many of these galaxies have the same morphology as normal galaxies, but they have much greater power output. They are very distant bodies, probably distributed randomly throughout the universe and less common than normal galaxies (Blandford, 1990). AGNs involve the most powerful, long-lived steady sources of luminosity in the Universe. They range from the nuclei of some nearby galaxies emitting about 10^{40} erg s^{-1} (1 erg = 0.1 μJ) to distant quasars emitting more than 10^{47} erg s^{-1} (Andrew, 1999). The emission is spread widely across the electromagnetic spectrum, often peaking in the UV, but with significant luminosity in the X-ray and infrared bands (Osterbrock and Mathews, 1987; Bregman, 1990; Netzer, 1990). The power output of AGN is often variable on time scales of years and sometimes on time scales of days, hours, or even minutes (Wallinder et al., 1992; Wagner and Witzel, 1995; Ulrich et al., 1997). This variability provides evidence of the very compact of the central engine. The best explanation of the energy generation in this size-constrained luminosity and high variability leads the scientists to believe that gravitational energy released by materials accreting onto

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Table 1 The AGNs Selected from the CFA Catalogue and their calculated properties.

Name	RA (h)	Dec (h)	Recession speed (km/s)	Distance (Mpc)	Red Shift (z) (Vh/c)	Bolometric magnitude (Bmag)	Apparent magnitude (Bmag*Vh^2)
8.08E+08	0	0	7.28E+04	1.01E+03	2.43E−01	4.37	2.32E+10
8.42E+08	0	12	4.26E+04	5.91E+02	1.42E−01	120.23	2.18E+11
8.42E+08	0	−2	7.17E+04	9.95E+02	2.39E−01	10.00	5.13E+10
8.25E+08	0	−1	9.74E+04	1.35E+03	3.25E−01	6.92	6.57E+10
8.08E+08	0	0	9.68E+04	1.34E+03	3.23E−01	3.63	3.40E+10
8.42E+08	2	2	4.65E+04	6.45E+02	1.55E−01	69.18	1.49E+11
9.26E+08	3	−77	6.69E+04	9.28E+02	2.23E−01	43.65	1.95E+11
9.43E+08	4	−8	1.15E+04	1.60E+02	3.84E−02	54.45	7.21E+09
8.09E+08	5	0	8.75E+04	1.22E+03	2.92E−01	31.33	2.40E+11
8.43E+08	7	39	2.87E+04	3.99E+02	9.58E−02	131.83	1.09E+11
8.09E+08	7	65	4.45E+04	6.18E+02	1.48E−01	158.49	3.14E+11
9.60E+08	10	29	9.87E+04	1.37E+03	3.29E−01	63.10	6.14E+11
9.09E+08	10	6	4.44E+04	6.16E+02	1.48E−01	20.32	4.00E+10
9.43E+08	10	−28	5.70E+04	7.92E+02	1.90E−01	39.81	1.29E+11
8.76E+08	10	4	6.90E+04	9.58E+02	2.30E−01	2.09	9.95E+09
8.09E+08	11	61	1.93E+04	2.69E+02	6.45E−02	3.98	1.49E+09
8.76E+08	11	−34	7.74E+04	1.07E+03	2.58E−01	10.00	5.98E+10
8.26E+08	12	2	4.75E+04	6.59E+02	1.58E−01	591.56	1.33E+12
9.26E+08	12	−7	8.00E+04	1.11E+03	2.67E−01	6.31	4.04E+10
9.26E+08	12	57	9.59E+04	1.33E+03	3.20E−01	6.92	6.37E+10
8.59E+08	12	−33	5.70E+04	7.91E+02	1.90E−01	3.63	1.18E+10
8.93E+08	13	5	6.15E+04	8.54E+02	2.05E−01	2.29	8.66E+09
8.59E+08	13	24	3.26E+04	4.53E+02	1.09E−01	91.20	9.68E+10
8.09E+08	13	0	9.77E+04	1.36E+03	3.26E−01	39.81	3.80E+11
8.76E+08	13	64	2.64E+04	3.66E+02	8.80E−02	120.23	8.37E+10
8.42E+08	13	18	4.56E+04	6.33E+02	1.52E−01	58.61	1.22E+11
8.59E+08	14	43	9.72E+04	1.35E+03	3.24E−01	25.12	2.37E+11
8.08E+08	14	20	3.93E+04	5.45E+02	1.31E−01	63.10	9.73E+10
8.26E+08	17	51	8.63E+04	1.20E+03	2.88E−01	67.30	5.01E+11
9.60E+08	18	69	1.50E+04	2.08E+02	5.00E−02	251.19	5.64E+10
8.76E+08	18	64	9.00E+04	1.25E+03	3.00E−01	229.09	1.86E+12
8.42E+08	19	72	9.09E+04	1.26E+03	3.03E−01	3.31	2.73E+10
8.42E+08	20	−42	6.63E+04	9.20E+02	2.21E−01	9.12	4.00E+10
9.26E+08	21	−17	3.33E+04	4.62E+02	1.11E−01	120.23	1.33E+11
8.76E+08	22	14	7.11E+04	9.87E+02	2.37E−01	15.85	8.00E+10
9.09E+08	23	16	8.39E+04	1.17E+03	2.80E−01	3.98	2.81E+10
9.43E+08	23	−8	6.33E+04	8.78E+02	2.11E−01	10.00	4.00E+10

a super massive black hole with masses about 10^6 to 10^{10} solar masses, is the source of powering the AGN (Begelman, 1985; Abramowicz et al., 1987; Kormendy and Richstone, 1995; and Richstone et al., 1998). Recent observational data from Hubble space telescope and ground-based radio interferometers have confirm this idea.

Because AGNs are so luminous and have distinctive properties, they can be discovered fairly easily. There are different classes according to their physical properties, morphological types, spectral lines and radio emissions. These classes include different objects such as Quasars, radio galaxies, BL-Lac objects and Seyfert galaxies. For instance, Quasars are AGNs but they differ from Seyfert galaxies in having greater luminosity. In the same way we can distinguish radio galaxies, blazars and so on as different categories of AGN, (Antonucci, 1993; Urry and Padovani, 1995; and Osterbrock and Shaw, 1988).

The present work aims to determine the spatial distribution of active galactic nuclei and thereby test the completeness of the 1995 CFA Harvard catalogue (which contains them). This is done by running through the catalogue and selects AGNs and analyse the data.

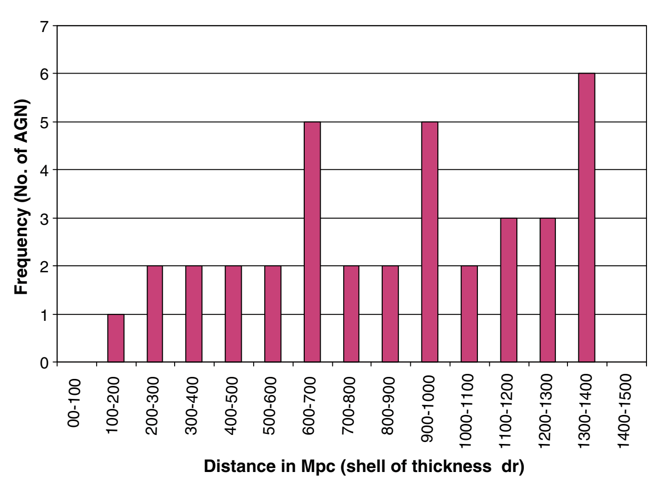

Figure 1 Spatial distribution of the selected AGN in terms of distance in a shell of thickness dr = 100 Mpc.

2. The catalogue

We use a zcat file (CFA red shift catalogue) produced by the Harvard Smithsonian Center for Astrophysics in 1995. The first CfA Redshift survey was completed in 1982. It includes measurement of radial velocities for all galaxies brighter than 14.5 and at high galactic latitude in the merged catalogues of Zwicky et al. (1968). The second CfA survey (CfA2), which we used in the present study, was started in 1984 and completed in 1995.

This catalogue incorporates much of the latest velocity data from the Whipple observatory and other sources, as well as velocities from earlier compilations such as the second reference catalogue of de Vaucouleurs and de Vaucouleurs (1964), de Vaucouleurs et al. (1976, 1991) and Gisler and Friel (1979) and the catalogue of radial velocities of galaxies by Palumbo et al. (1983). Some of the red shift observations were obtained from the literature, and others have been measured. The observations were made at the F.L. Whipple observatory with the photo-counting Reticon system on the Tillinghast reflector (1.5 m) or in the Multiple Mirror telescope. Reductions to the recession speeds were done using the RVSAO package developed for this project (Huchra and Geller, 1995).

This catalogue contains about 57536 celestial objects, together with their astronomical properties. The catalogue has been arranged so as to identify the objects selected by their morphological type, name, and position (e.g. Right Ascension and declination), recession speed (Vh = zc) and other properties. All related descriptions and an updated cfa catalogues have been described in Huchra et al. (1983), Huchra and Burg (1992), Huchra and Geller (1995), and homepage of the catalogue[1].

3. Data analysis

3.1. The first AGN distribution

The AGNs were first selected according to their morphological type, which was −9 in the catalogue categories, by using our code. By taking the Hubble constant equal to 72 kms^{-1} Mpc^{-1}, and the speed of light equal to (c = 299792.5 km/s), the distance and the red-shifts for these objects have been identified in term of their recessions speed Vh. Table 1 summarizes the general properties of the selected 32 AGNs. Since we do not know how AGNs are distributed throughout the volume, we were interested to find the distribution over shells of thickness (δr), which has been chosen to be 100 Mega-Parsec Mpc.

The spatial distribution for the selected AGNs in the shell in terms of distances is shown in Fig. 1, and in terms of the red-shifts in Fig. 2.

To find the spatial distribution in a unit of volume we divided the number of AGNs by $4\pi r^2 \delta r$, where r is the radius of the sphere. This has been taken as an average distance to the number of the AGN located in the same distance shell. The number of AGNs per cubic Mega-parsec is summarized in Table 2. We see from Table 2 that the density of recorded AGNs decreases with distance.

[1] <www.cfa.harvard.edu/˜huchra/zcat>.

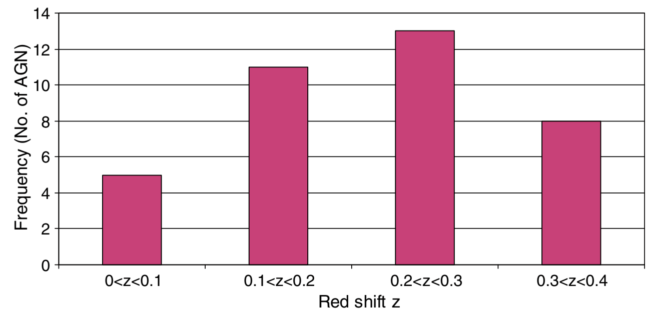

Figure 2 Spatial distribution of selected AGN in terms of redshifts.

Table 2 Number and density of recorded AGN in a given distance.

No. of AGNs at given distance	Distance in Mpc	No. of AGN/Mpc^3
1	1.60E+02	3.11E−08
2	2.38E+02	1.41E−08
2	3.83E+02	5.43E−09
2	4.57E+02	3.81E−09
2	5.68E+02	2.47E−09
5	6.34E+02	1.98E−09
2	7.92E+02	1.27E−09
2	8.66E+02	1.06E−09
5	9.58E+02	8.68E−10
2	1.04E+03	7.32E−10
3	1.16E+03	5.94E−10
3	1.24E+03	5.15E−10
6	1.35E+03	4.36E−10

3.2. Luminosity distribution

Since AGNs are highly luminous, this property will now be used to find their spatial distribution. Although the catalogue does not give absolute luminosity, we inferred it from the information given in the catalogue. We multiplied the stated bolometric magnitude by the *square* of the recession speed, to compensate for the inverse square reduction of intensity

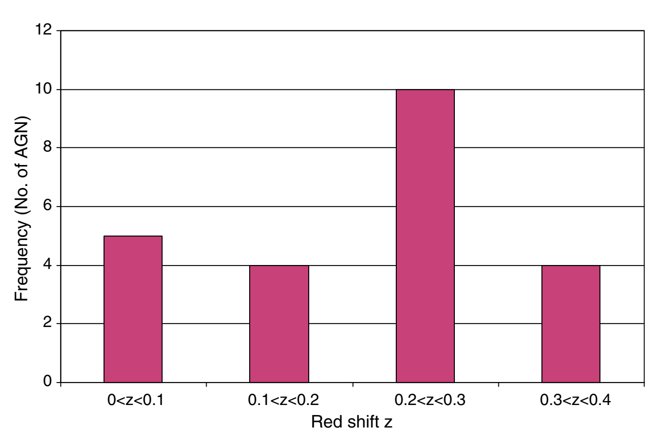

Figure 3 Spatial distribution of AGNs with absolute Luminosity < 10^{11}.

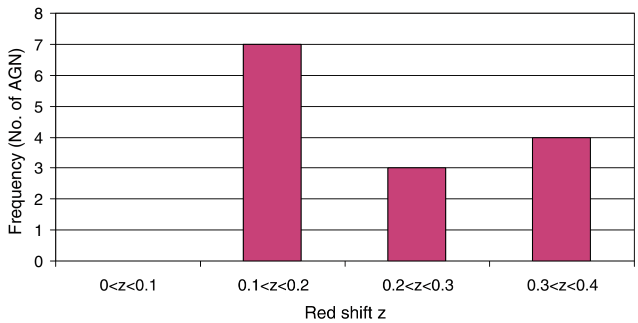

Figure 4 Spatial distribution of AGNs with absolute luminosity > 10^{11}.

with distance. Accordingly, the absolute luminosity was calculated and is given in the last column of Table 1. This parameter is crucial in finding the distribution of AGNs and in testing the completeness of the catalogue.

Two proposals have been made: either

1. We are failing to pick up some AGNs at large distances, or
2. There are fewer AGNs than expected at large distances.

To distinguish between these hypotheses we may partition the AGNs into two categories, fainter and brighter, according to their absolute luminosity. A threshold was chosen at an absolute luminosity of $10^{11}L_{\odot}$, with 23 galaxies showed values less than $10^{11}L_{\odot}$ and 14 galaxies showed values greater than $10^{11}L_{\odot}$. Separate histograms were then made of the number of AGNs at each redshift for these two categories of AGNs and the results are presented in Figs. 3 and 4, respectively.

If the first suggestion is true then the fainter AGNs should more affected and fewer should be observed; see Fig. 3.

There is no observable difference, so that the catalogue is probably complete, including low luminous AGNs and, in view of Fig. 4, high-luminosity AGNs. The spatial distribution of low and high-luminosity AGNs has therefore been found to be random and uniform.

4. Conclusions

The spatial distribution for 37 AGNs in the Harvard red shift catalogue (zcat of cfa) has been found and plotted in terms of their distances and red-shifts. The catalogue was then tested for completeness by finding the distribution for those AGNs with "absolute luminosity" less than 10^{11} and, separately, for those with luminosity greater than 10^{11}. The spatial distribution of AGNs was found to be random and uniform.

There are nevertheless small defects in the catalogue. One defect is that the catalogue does not specify the exact class of object, quasar or Seyfert or any other class of AGN. Also, some quasars, which are a category of AGNs, have large red-shift. However, the catalogue contains only relatively small red-shift objects.

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