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Quantized Redshifts: A Status Report

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Abstract. The current status of a continuing programme of tests for redshift periodicity or 'quantization' of nearby bright galaxies is described. So far the redshifts of over 250 galaxies with high-precision HI profiles have been used in the study. In consistently selected sub-samples of the datasets of sufficient precision examined so far, the redshift distribution has been found to be strongly quantized in the galactocentric frame of reference. The phenomenon is easily seen by eye and apparently cannot be ascribed to statistical artefacts, selection procedures or flawed reduction techniques. Two galactocentric periodicities have so far been detected, ~ 71·5km s^{-1} in the Virgo cluster, and ~37·5km s^{-1} for all other spiral galaxies within ~ 2600km s^{-1}. The formal confidence levels associated with these results are extremely high.

Key words. Galaxies: distances and redshifts, spiral, radio lines.

1. Introduction

A few years ago we embarked on an investigation (Napier *et al.* 1989) into the quantized redshift claims made by Tifft and his colleagues. We have made use of new, high-precision HI redshift data which have become available for large numbers of bright, nearby galaxies, arising out of extragalactic surveys which had been carried out using the major radio telescopes; and we have exploited the computing power now available which allows extensive Monte Carlo simulation and consequent stringent testing of the quantization hypothesis.

A limited trial on galaxies in the Virgo cluster (Guthrie & Napier 1990) revealed that, away from the dense central core, the redshifts were offset from each other preferentially in multiples of ~ 71 km s^{-1}, indistinguishable from the ~ 72 km s^{-1} which Tifft (1977) had claimed to be present in the galaxies of the Coma cluster. A second study on 40 high-precision redshifts scattered over the sky with galactocentric redshifts ≤ 1000km s^{-1} revealed a periodicity of 37·5km s^{-1} (Guthrie & Napier 1991), again indistinguishable within the errors from that of 36.2km s^{-1} claimed by Tifft & Cocke (1984) to exist globally. The confidence levels in these cases were respectively at the levels of ~ 10^{-3} and ~10^{-4}, which we regarded as sufficiently positive to justify embarking on a major analysis. This has now been carried out (Guthrie & Napier 1996), and we confirm the presence of a galactocentric redshift periodicity of ~ 37·5km s^{-1}, in Local Supercluster galaxies, at an extremely high confidence level. Statistical or observational artefacts, observational selection procedures and the like seem incapable of accounting for the phenomenon.

2. Some statistical considerations

The periodogram, in which a time series is converted to a frequency spectrum, is widely employed for periodicity-hunting and was used in the present analysis. Its statistic I is intrinsically noisy, the standard deviation being equal to the mean, and the I–distribution may be affected not only by periodicity in the data, but also by other factors such as edge effects, secular trends and so on. For such reasons several authors (Thompson 1990; Newman *et al.* 1989) consider that, in testing for periodicity, the unwindowed spectrogram is an unreliable estimator. In the absence of these effects $\bar{I} = 2$ for random data, with a distribution $\sim \exp(-I/2)$ for I not too high (the exact distribution for up to 100 data is tabulated by Webster 1995).

Various procedures are available for reducing the variance, but in the present study we have preferred to employ the simple, unwindowed periodogram, and to allow for all the above factors by making extensive use of synthetic datasets. The latter were constructed so as to be identical to the real datasets in every respect except the periodicity under test. By analyzing large numbers of synthetic datasets in identical fashion to the prescribed real one, a distribution (say) $n(I)$ is derived. By construction this distribution has, imbedded within it, the same bias, inconsistency etc. which are to be found in the spectrum of the real dataset, whence any significant offset between $n(I_{\text{synth}})$ and I_{real} can be ascribed only to the sole non-simulated property, namely periodicity.

A velocity component $V_\odot \cos \chi$ must be subtracted from each heliocentric redshift to arrive at the galactocentric one, before applying power spectrum analysis to the corrected redshift distribution. However an uncertainty of several km s^{-1} is associated with the velocity components of the Sun's motion around the Galaxy. There is therefore freedom to adjust velocities within this error box, and this could lead to an artificial boosting of a relatively insignificant signal. This was dealt with by using, not a single peak at some velocity, but the overall power in some region of $V_\odot$–space, since a peak occurring in one region of $V_\odot$–space may lead to peaks in other regions. This modified statistic (the sum of powers exceeding some limit) has the further advantage that conclusions do not depend on a single high peak, whence extreme value statistics are avoided.

3. The Virgo cluster revisited

The data employed were two samples of galaxies within 10° of M87, which lies near the core of the Virgo cluster. The first sample comprised 112 HI redshifts of spiral galaxies with stated accuracies ≤ 10 km s^{-1}, and the second was 77 dwarf irregulars, chosen on the basis of HI flux/line width ratios and unconfused profiles. Originally (Guthrie & Napier 1990) quantization was tested assuming a range of possible values taking account of the large uncertainty in the infall velocity towards Virgo. A weak periodicity ~ 71 km s^{-1} was found to be present in the spirals, and this strengthened progressively as sub-samples in lower density regions of the cluster were examined. It

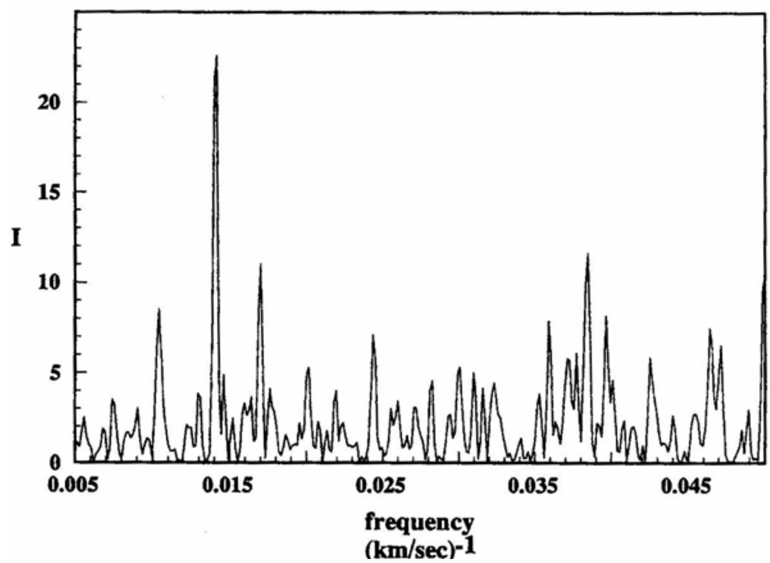

Figure 1. Power spectrum of 48 relatively isolated spirals in the Virgo cluster, in the Galactocentric frame of reference. The main peak is at ~ 71.1 km s^{-1}.

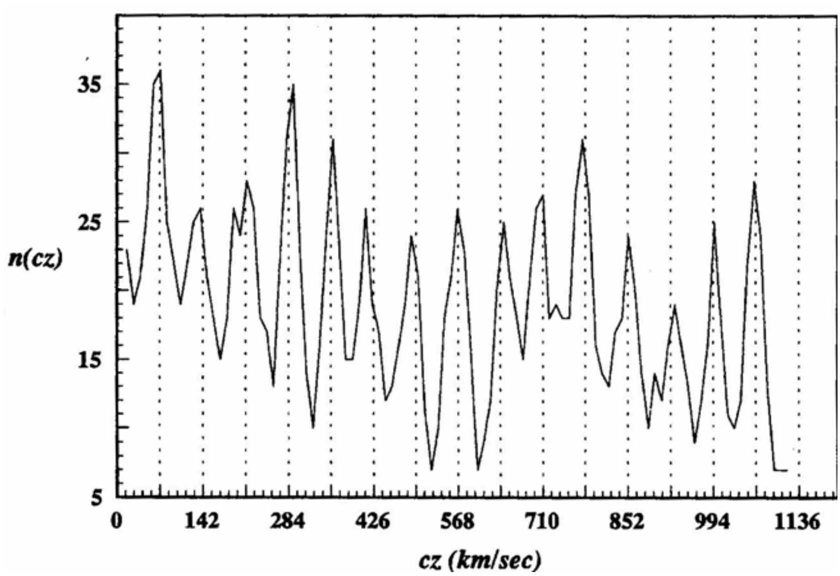

Figure 2. Galactocentric differential redshifts of the 48 Virgo spirals, in bins 11 km s^{-1} wide. No data smoothing has been applied. Dotted vertical lines represent a periodicity 71.1km s^{-1} and zero phase.

was found that, for 48 relatively isolated bright spirals, a strong peak (I ~ 20) was obtained at 71.1 km s^{-1}. This periodicity was judged to be significant at a confidence level $0.996 \lesssim C \lesssim 0.999$.

However our later study of field galaxies and loose groups (section 4) reveals that the signal is strictly galactocentric. Thus the velocity $V_{\odot}$ to be subtracted from the

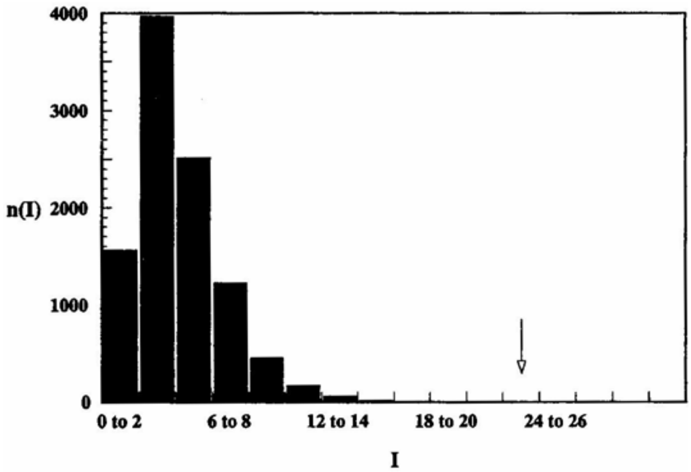

Figure 3. Power distribution of 10,000 random datasets identical to the real Virgo cluster dataset in all respects except for the application of random 'jitter' to the redshifts. None of these random trials reproduced the observed power (marked by arrow).

heliocentric redshifts is that of the Sun around the centre of the Galaxy (Merrifield 1992), presumably with a further adjustment to allow for the Sun's motion relative to the local standard of rest, but without correction for infall towards Virgo. The resultant vector $V_\odot$ is ($V_\odot$, $l_\odot$, $b_\odot$) = (213 km s^{-1}, 93°, 2°). Fig. 1 shows the power spectrum of the 48 redshifts obtained after subtraction of this $V_\odot$, while Fig. 2 is a plot of the redshift differences. A periodicity ~ 71 km s^{-1} is easily seen by eye; the power spectrum analysis yields 71.1 km s^{-1}. Its significance may be assessed by identical analysis of random datasets, suitably constructed: the distribution obtained from 10^4 Monte Carlo trials is shown in Fig. 3, from which it may be inferred that the chance probability p of obtaining a signal of the strength observed in this period range is ~ 10^{-5}. Allowance for the *a posteriori* choice involved in avoiding the core of the Virgo cluster reduces this figure by a factor of 5 or 10.

No significant periodicity was found for the sample of 77 irregular galaxies.

4. Galaxies within the Local Supercluster

A second pilot study (Guthrie & Napier 1991) made use of a catalogue of 6439 galaxies (Bottinelli *et al.* 1990). Forty bright, nearby spirals ($cz \leq 1000$ km s^{-1}) with accurately determined systemic redshifts (formal precision $\sigma \leq 3$ km s^{-1}), revealed a periodicity in the range 37.2-37.5 km s^{-1}. This is essentially that claimed by Cocke & Tifft (1984) for wide-line field galaxies, although this was an independent dataset. Once again, no evidence was found for any periodicity in a sample of nearby, irregular galaxies. A feature which emerged in this second pilot study was the presence of signals when correcting vectors $V_\odot$, which might be quite far from the galactocentric one, were applied to the data. These 'ghost peaks' make it difficult to determine the frame of reference within which the periodicity exists, if indeed there is a unique frame. Two vectors fairly close to the solar apex were conspicuous.

Table 1. Stability of main peaks with increasing sample size.

N	I	P km s^{-1}	V km s^{-1}	l (°)	b (°)
51	30	38.1	207	95	−7
97	37	37.8	209	94	−7
51	30	37.8	215	93	−13
97	38	37.5	217	95	−12

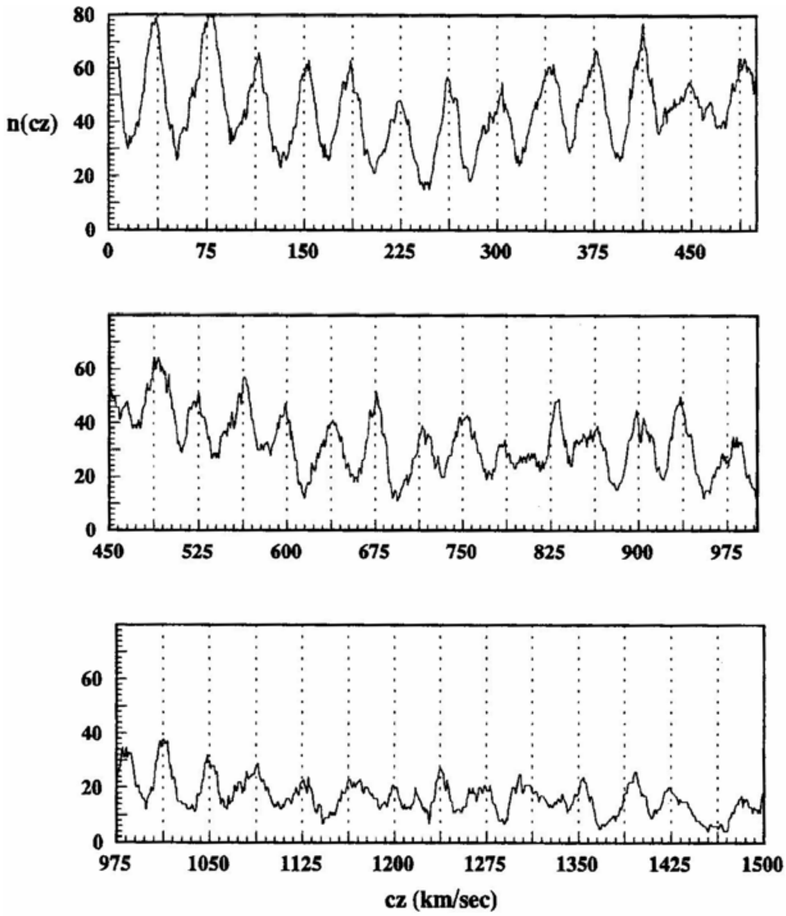

Figure 4. Galactocentric periodicity of ~ 37.5 km s^{-1} observed in the differential redshifts of 97 bright spiral galaxies scattered throughout the Local Supercluster.

The sample was then extended from 51 nearby spirals with $\sigma \lesssim 3$ km s^{-1} to 97 such galaxies (Guthrie &Napier 1996), going out to 2600 km s^{-1}, roughly the edge of the Local Supercluster. The two main peaks continued to increase in strength with increasing cz out to 2600 km s^{-1} (they would of course have gone into progressive decline had the earlier results been a statistical fluke), while the corresponding vectors continued to hold with remarkable stability, namely ±2 km s^{-1} in speed, ±1° in direction, and a fraction of a km s^{-1} in periodicity, the sample size increasing from 40 to 97 galaxies (Table 1). The differential redshifts for these data, corrected for the southernmost of these vectors, are plotted in Fig. 4: a periodicity $P \sim 37.5$ km s^{-1} is clearly seen by eye. Although the signal continues to strengthen in the extended sample, its rate of increase is less than would be expected by extrapolation from the smaller sample. This suggested that the phenomenon – whatever its nature – might gradually weaken with increasing separation between galaxies. Conversely, it might be stronger in galaxies belonging to groups and associations. This was indeed found to be the case: for 53 galaxies linked by group membership, the signal was almost as strong ($I \sim 42$) as for the entire sample of 97. However, in accordance with orthodox statistical procedure, this modification of the original hypothesis had to be tested against a fresh dataset. A further sample of LSC spirals was therefore taken from data obtained with the 300-foot Greenbank telescope by Tifft and Cocke over the period 1984–1988. A sample of 117 'new' spirals with signal to noise ratio > 10 was thereby obtained. These were significantly more distant than the sample of 97 ($\bar{cz}$ = 1511 km s^{-1} as against 997 km s^{-1}), and the periodic signal in this sample as a whole was indeed significantly weaker, consistently with the trend already discerned. However, some of the 'new' spirals in this group belonged to catalogued groups of galaxies (Fouque *et al.* 1992), and it was found that, if attention was paid simply to galaxies belonging to groups, the strength of the signal continued to increase with sample size. In conjunction with 50 galaxies so linked in the earlier sample, the signal strengths for the combined sample of 80 group-linked galaxies was 48.

5. The galactocentric vector

For differential redshifts within groups spanning at most a few degrees over the sky, the solar motion correction is differential and of second order. This suggests that varying $V_\odot$ in speed and direction might yield less ambiguity from 'ghost peaks' and so yield a unique solar vector. This turns out to be the case: Fig. 5 shows that the signal optimizes for a correcting vector indistinguishable, within the errors, from the solar motion as determined from Galactic HI observations and stellar kinematics.

The nature of the signal being so optimized can be seen by simply plotting the data corrected for this galactocentric vector (Fig. 6). It is clear that these new, high-precision data confirm the hypothesis under test. A similar exercise for the 48 Virgo cluster spirals does not yield a definite Galactic latitude, but the derived solar speed and longitude are, within their uncertainties, the same.

6. Discussion and conclusions

The positional coincidences illustrated in Fig. 5 have probability $\lesssim 10^{-4}$. The probability that the observed (and, within the errors, predicted) 37.5 km s^{-1} periodicity (Figs. 4 and 6) would arise by chance is $\lesssim 10^{-5}$. The corresponding figures for the Virgo cluster are $\sim 10^{-2}$ for the positional coincidence, and $\lesssim 10^{-4}$ for the predicted $\sim$ 71 km s^{-1} periodicity. It is inconceivable that chance could yield these confirmations, in independent, precise datasets, at such confidence levels. It remains to be asked whether statistical artefact, observational selection procedures or telescope/ reduction anomalies might yield these results.

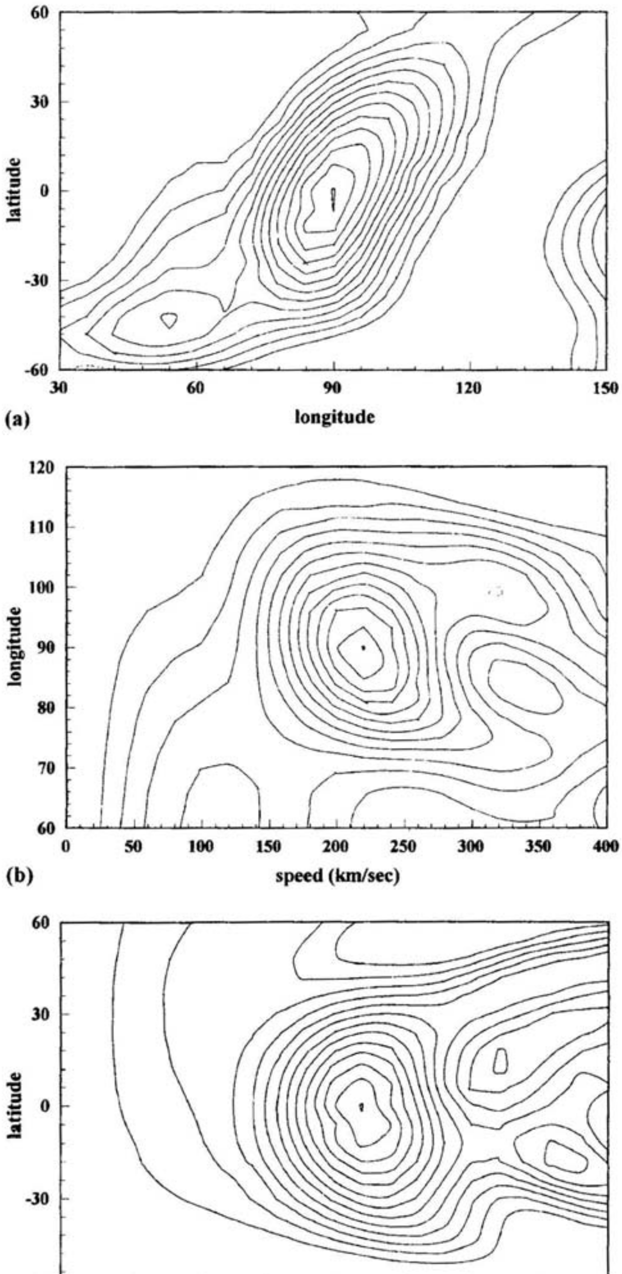

Figure 5. Periodicity strength in differential redshifts of 28 groups (comprising 80 galaxies) as a function of correcting vector. The peak contour is I = 30 and ΔI = 2. The peak is within the error box of the solar motion:

$$V_\odot = (213 \pm 10 \text{ km s}^{-1}\ 93° \pm 3°, 2° \pm 5°).$$

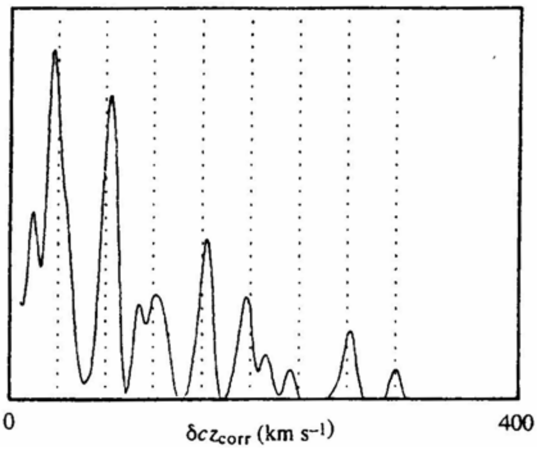

Figure 6. Differential redshift distribution for galaxies within groups throughout the Local Supercluster, corrected for the 'best estimate' Galactocentric vector (c.f. Fig. 5). A smoothing window has been applied. The vertical dots mark a periodicity $P = 38$ km s^{-1}, $\phi_0 = 0°$.

In general, for the quoted redshift precisions and periodicities under test, a periodicity should begin to be evident when more than about 15 or 20 redshifts are examined. The datasets employed are thus numerically more than adequate. The selection criteria have been extremely simple throughout (accurate, pristine redshifts). There have been few branch points in the logic which would allow artificially high confidence levels to appear. Two such are the 'hunches' that the signal would concentrate in galaxies away from the core of the Virgo cluster, and that it would concentrate in loose groups and associations: these were *a posteriori* adjustments of the hypothesis under test. The first of these was allowed for by reducing the calculated confidence level, and the second was tested (and confirmed) on fresh data in accordance with orthodox procedure.

The statistical procedures have in fact been standard throughout, and extensive use has been made of Monte Carlo simulations to control the well-known effects of bias and inconsistency of the power *I*. The statistics are in fact largely superfluous: the periodicity is simply an observed result. It has appeared consistently in every dataset so far examined with the precision to reveal it.

It remains to ask whether this observed effect is due to a diseased radio telescope. However, first, the phenomenon is seen independently in data from Arecibo, Effelsberg, Green Bank 140 ft and 300 ft, Jodrell Bank, Owens Valley and Westerbork (Guthrie & Napier 1996). Second, the periodicity is precisely galactocentric (e.g. Fig. 5), although no information about the centre of the Galaxy is fed into the analysis (indeed most of the extragalactic data employed pre-date the Merrifield (1992) HI solution by some years). A third problem with an artefact theory is that the original claim of a 72 km s^{-1} periodicity was made by Tifft (1977), for the Coma cluster, employing optical data: it is not easy to conceive of an artefact which spans such different telescopes and wavelengths.

Still untested are the more recent claims of Tifft and colleagues that there exists a spectrum of periodicities, some as short as 2·67 km s^{-1}, in the rest frame of the microwave background. To date, our conclusion is that extragalactic redshifts are quantized along the lines originally suggested by Tifft and coworkers, with galactocentric periodicities of 37.5 km s^{-1} in field galaxies and loose groupings, and 71.1 km s^{-1} in the environment of dense clusters.

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