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REDSHIFT QUANTIZATION – A REVIEW

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Abstract. Redshift quantization has three main facets: 1) the internal organization of galaxies, 2) differential effects between galaxies in physical systems, 3) global effects linking all galaxies and cosmology. The subject originated as an outgrowth of redshift correlation studies including studies of internal kinematics of galaxies. While possibly central to understanding redshift quantization, this aspect is complex and largely undeveloped. The bulk of the evidence for redshift quantization comes from differential and global periodicity testing. More recently redshift variability has been associated with the phenomenon. Early work in theory led to a determination of q_0 close to 0.5. A new association between quantization and the Cosmic Background Radiation further links redshift quantization with basic cosmology.

Key words: Redshifts, Periodicities, Cosmic Background Radiation, Galaxies

1 Introduction

The redshift is normally assumed to be an extrinsic quantity, unrelated in most respects to intrinsic properties of individual galaxies. Within the standard framework the redshift can be decomposed into three parts, the Hubble flow due to expansion of the Universe, local peculiar motion governed by the mass distribution on various scales, and internal motions within galaxies. This viewpoint is the logical extension of theories of mechanics developed within a *very* tiny part of one galaxy, and while seeming to explain many aspects of the Universe it has created some well known problems. One problem which has attracted much attention is the 'missing mass' or 'dark matter' problem. When interpreted as standard Doppler shifts, redshift measurements imply the presence of far more mass than is obviously visible in ordinary barionic form. One of the more recent versions of this problem is the apparent requirement for large chaotic motions on very large scales. Our motion with respect to larger and larger reference frames of galaxies does not appear to be related to the cosmic background dipole anisotropy.

Few people have seriously questioned the basic assumptions which underlie the standard model of the Universe. Numerous tests are possible, however, and beginning in 1970 a series of experiments on the 'nature of the redshift' was initiated by the author at Steward Observatory. The work has developed within three broad categories, beginning with, (1), correlations between the redshift and intrinsic properties of galaxies. These studies quickly led to the discovery of apparent redshift quantization which provides the second type of test. (2) Is the redshift a discrete or continuous quantity? The need for high precision and a thorough understanding of uncertainties led more recently to

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the detection of apparent redshift variability which provides a third form of testing. (3) Is the redshift rapidly variable? Throughout the development of the program it has seemed increasingly clear that the redshift has properties inconsistent with a simple velocity and/or cosmic scale change interpretation. Various implications have been pointed out from time to time, but basically the work is observationally driven. It seems that the more we look, the less we can presume we know.

2 The Discovery of Redshift Quantization

Some of the original correlation studies are relevant here. For broader discussions see IAU Symposium 58 (Tifft 1974) and IAU Colloquium 37 (Tifft 1977c). Redshift was found to correlate in unexpected ways with galaxy luminosity (redshift-magnitude bands), morphology, and activity (radio, optical emission). The work suggested that at least part of the redshift was intrinsic to the galaxies or their constituent matter. All or part of the Hubble Law could be interpreted to show redshift/galaxy evolution displayed in lookback time. Redshift spread could arise from a dispersion in rates or stages of evolution applicable to all galaxies, not just certain types. It was in this correlation-induced galaxy-centered evolutionary atmosphere that redshift quantization was discovered as redshift precision was progressively improved. This work was done using clusters of galaxies. The Coma cluster provided the first calibration of the quantization interval.

The quantization concept was formally presented in a series of three Astrophysical Journal papers in 1976-77. The papers examined internal properties of individual galaxies (Tifft 1976), systems of galaxies (Tifft 1977a), and stars along with peculiar galaxies (Tifft 1977b). Two basic principles are introduced in the 1976 paper. the first states that "the redshift occurs in discrete steps with a step size near 70-75 km s^{-1} and/or multiples thereof". The second states that "all major galaxies (and presumably related objects) contain two states of redshift which appear on opposite sides ... of the nucleus. Lesser amounts of other states may be present." In later usage this second concept is more generally stated as "galaxies consist of a superimposition of specific redshift states". The correlation studies had already made it likely that galaxies (and redshifts) evolved from within. The quantization picture reinforced that idea and gave it structure.

Aside from the definition paper, and some commentary at the 1987 Venice Symposium (Tifft 1988), there has been little discussion of quantized structure for individual galaxies. A follow-up paper exists as Steward Observatory Preprint 513 but it did not survive the intense review process that attends radical new approaches. This is, nonetheless, where the quantization concept and the basic number 72 km s^{-1} were born. They originated there because good differential measurements in rotation curves showed character-

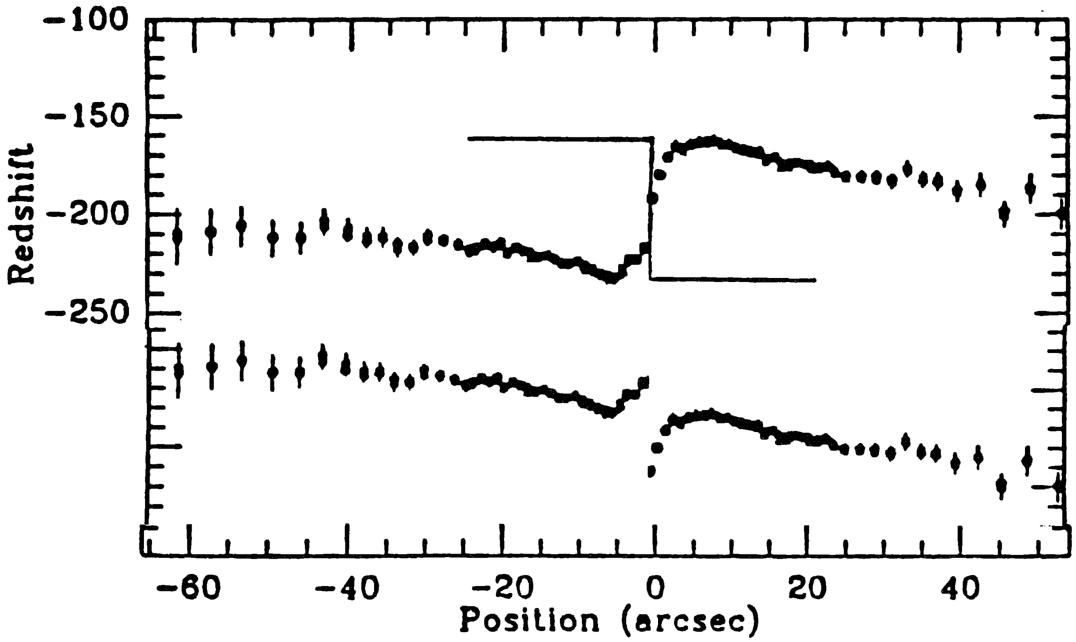

Fig. 1. The rotation curve for M32 from Tonry (1984). The upper curve shows rotation velocity as a function of angular distance from the nucleus. A step function of 72 km s^{-1} is shown for comparison. The lower curve removes a 72 km s^{-1} step from the rotation curve.

istic offsets in a regular pattern consistent with the presence of *two* velocity distributions differing by a constant. That constant was ≈ 72km s^{-1}. Most redshifts were then too uncertain to make many precise comparisons between galaxies.

Figure 1 shows a rotation curve for M32, from Tonry (1984), which provides an example of internal offsets. The original curve shows a sharp transition across the nucleus with peak rotation occurring close to the nucleus. The curve then drops back to essentially the nuclear value. The transition amplitude is indistinguishable from 72 km s^{-1} as shown with a step function. When the curve is cut and realigned shifted by 72 km s^{-1} the second curve is produced. A smooth rotation curve with 'flat' wings, well known in more rapidly rotating galaxies, results. Note that if the outer rotation curve drops back below the nuclear value a situation is produced where the nucleus and outer parts rotate in opposite directions. Such 'counter-rotation' is observed in the cores of several galaxies. A study of the frequency of offsets of specific sizes would be interesting.

The original explanation of offsets envisioned outflowing streams of intrinsically different material. The two 'streams' define a dipole or 'multiple state' structure of a galaxy. The third initial paper (Tifft 1977b) examined stars and interstellar material for evidence that the velocity pattern could be caused by a variation in electron massor some other process at the atomic physics level. Several velocity correspondences were found but there has been no follow-up work. Whatever the structure is, intrinsically different material, quantum-mechanically constrained velocity 'wave-functions', or something else, is not known. Nuclei do seem to be an origin point for the phenomenon. A multiple state structure does not deny effects of normal kinematics. States seem to be wound up and intermingled by ordinary motion; they are easily seen only in kinematically simple systems, like ellipticals, or in galaxies carefully modeled to remove rotation and/or radial flow. Galaxies need not be presumed to be static systems and could evolve by radial outflow. This is consistent with correlations which suggest that luminosity and/or morphological evolution could be occurring (Tifft 1979).

The second introductory paper (Tifft 1977a) extended quantization constraints to differentials between galaxies, at least physically associated ones. This constraint was already implied by earlier work suggesting that redshift-magnitude correlations could be linked together into some absolute global structure (Tifft 1973). Such a linkage is obviously at variance with conventional extrapolated gravitational theory. It either eliminates large scale motion or constrains it to quantized jumps. Quantization was apparently present, continuity was not. Quite explicit predictions could be made. The quantized redshift problem was defined.

3 Differential Redshift Testing

The second definition paper discussed expected patterns for redshift differentials in binary galaxies. Barring extreme biases or selection, conventional dynamics predicts a smooth monotonic distribution of differentials peaking at zero. The quantized redshift requires peaks near multiples of 72 km s^{-1} with clear gaps between. The first sample of pairs for which this test could be carried out became available when Peterson (1979) published 21 cm radio data for widely spaced pairs. The Peterson data were shown to conform closely to the quantization prediction (Tifft 1980). A revision of the original study gave the same result (Tifft 1982a). A program to measure accurate differentials for more than 200 close pairs using optical techniques further confirmed quantization (Tifft 1982b).

The significance of the original double galaxy quantization tests has been actively debated. Sharp (1984,1990) concluded that the periodicity was present but dismissed its significance from a dynamical viewpoint. Despite the fact that quite precise predictions preceded the testing, Newman et al (1989) argued that this did not matter and that the findings were not significant. Cocke & Tifft (1991) reaffirmed that proper statistical procedures were followed and that the significance was quite high. Disagreement remains concerning the accuracy of some optical differentials; compare Sharp (1990) with the Appendix in Tifft & Cocke (1989).

Periodicity analysis was quickly extended beyond simple pairs although isolated pairs retain a special significance. W. J. Cocke joined with Tifft in an analysis of compact groups (Cocke & Tifft 1983) which again confirmed the presence of specific multiples of 72 km s^{-1}. Efforts were also begun to formulate a quantum mechanical basis for redshift periodicities where redshift retains a velocity interpretation subject to quantum constraints (Cocke 1983, 1985). Observations of companion galaxies by Arp (1982, 1986), Arp & Sulentic (1985) and Sulentic (1984) also verified quantization effects in the early 1980 period. Many of the companion studies refer to groups, and include data from varied sources, which complicates comparisons with isolated pairs. Redshift accuracy and sample homogeneity is of paramount importance in discussing quantization (Tifft 1982b).

Emission activity in the large study of close isolated pairs (Tifft 1982b) has been discussed (Tifft 1985). Activity increases as differential redshift decreases, but does not seem to associate with a specific quantum level as Arp & Sulentic (1985) have suggested. The morphology of an interacting pair is generally related to emission activity, but all clearly interacting pairs show quantization independent of interaction morphology or the intensity of emission (Tifft 1982b).

The next stage of differential redshift studies was marked by the introduction of several new samples or sample upgrades. Schneider et al (1986) compiled a large sample of 21 cm data, Schweizer (1987) provided an accurate optical sample of Southern Hemisphere pairs, and Tifft & Cocke (1988) provided improved 21 cm redshifts for a large number of galaxies, including many in pairs and groups. Schneider et. al. found the sharp drop in frequency of differentials below 72 km s^{-1} predicted by the quantization model, but argued against the presence of larger preferred intervals. This group has gone on to propose a dynamical explanation based upon radial infall and strong selection biases in defining pairs (Schneider & Salpeter 1992). Models show that a small peak can be produced; however, the dip inside 72 km s^{-1} is shallow and no additional peaks exist at larger differentials. The Schneider pairs were selected using a very weak isolation criterion; when more stringent criteria are applied the distribution is consistent with the multiple peaks seen previously. Cocke (1992) finds, by both likelihood and Baysian analysis, that a quantized distribution is by far the best fit to existing samples.

The precision 21 cm redshift survey by Tifft & Cocke (1988) removed most doubts about the accuracy of 21 cm data being used. It also indicated that the 'zero' differential redshift peak is displaced from zero and centered near 24 km s^{-1}, 1/3 of the basic 72 km s^{-1}. Identical redshifts do not seem to occur in close proximity to one another. This suggested that some type of exclusion principle could be operating. Tifft & Cocke (1989) introduced the zero deviation and applied a revised model to the new Schweizer (1987) sample, finding excellent agreement. Figure 2 shows differentials for isolated pairs. The first panel shows 21 cm data. The initial sample and later additions are distinguished. The other panels add the Schweizer pairs and the

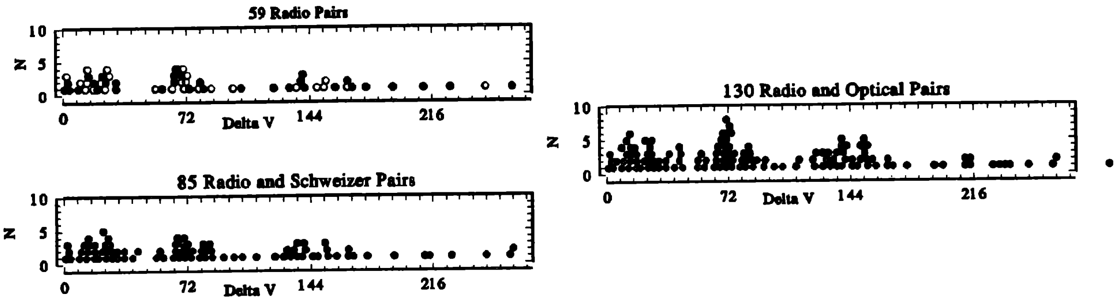

Fig. 2. The upper left panel shows differential redshifts for galaxy pairs measured at 21 cm. Filled circles refer to pairs from Tifft (1982a); open circles refer to additional 21 cm pairs from Schneider et. al. (1986) which meet the same standards. The lower left panel adds pairs measured optically by Schweizer (1987), as described in Tifft and Cocke (1989). The right panel adds the most accurate subset of close pairs measured optically by Tifft (1982b).

best data on close optical pairs from Tifft (1982b).

Principal areas of disagreement between workers concern the definition of isolation and the use of wide pairs. In discussing 21 cm data Tifft & Cocke require more stringent isolation than Schneider et al. The widest pairs were also excluded from the Schweizer sample in order to generate a sample comparable to close optical pairs known to be well isolated. The importance of such restrictions was demonstrated by Tifft & Cocke (1989) by means of a 'triplets' test. The test shows that potential pairs, which have a third galaxy closer to one of the objects than the purported companion, show systematic offsets from the standard pattern of differentials. The combination rules are presumably more complex for complex systems; homogeneous samples are essential for testing. To cite an example, Schneider et. al. consider UGC12808 to be a pair with UGC12815 which is 5.4 arc minutes away. UGC12815, however, has a companion, UGC12813, only 1.4 magnitudes fainter and 1.1 arc minutes distant, with which it shows direct signs of interaction. While the wide 'pair' may be suitable for some dynamical modeling it is not acceptable in a quantization test of isolated pairs.

The risk of contamination increases and the strength of interaction drops with separation. Large differentials can be expected only in relatively close pairs. Tifft (1988) has suggested that the range over which a given differential can be traced corresponds to the range over which the standard gravitational potential could generate the motion conventionally. Large differentials at larger separations could involve a group potential rather than the pair potential. Group members provide the primary source of contamination in studies of pairs. It is well known that galaxies occur in groups and rarely in isolation. Crossing times in groups are significantly less than a Hubble time, hence it is unlikely that many unperturbed very wide pairs exist. The effective testing ground for quantization in pairs is necessarily concentrated in the close pairs. Resolution limits at 21 cm and lack of neutral hydrogen in many galaxies place most such work in the optical domain.

One test involving very wide pairings is of interest. If the range of a quantization level is set by the potential field, and if an exclusion condition prevents identical redshifts, then the range over which a zero differential does not occur is a measure of the potential range. Tifft (1988) and Tifft & Cocke (1989) found that the zero deficiency extends out to roughly a Megaparsec. One possible consequence of an exclusion condition is that at high galaxy density galaxies could be forced into higher and higher levels. Large 'velocity' dispersions could be a consequence of degeneracy, not large masses. This suggests that the degree of ordered periodicity on the large scale could relate to galaxy density. Tifft (1988) has found that high density regions around the Coma cluster are strongly periodic in redshift. At low density the periodicity fades. When the distribution of galaxies is examined as a function of phase (fractional position in a periodic cycle, V/P, P = period, V = redshift) structural elements associated with superclusters are suggested. This study is at variance, however, with work by Guthrie & Napier (1990) who found quantization in the lower density parts of the Virgo cluster.

4 Global Redshift Testing

Studies in the early 1970s suggested a globally linked pattern in redshift correlations (Tifft 1973). Quantization definition studies (Tifft 1977a) reached the same conclusion. Associations on progressively larger scales implied that an absolute frame of reference of quantum levels existed. Quantization is a property of galaxies; galaxy redshifts are presumed to be means over specific states. If the pattern of states is linked into a global hierarchy one must be in the quantum frame to see global effects. Specifically one must remove 'ordinary' solar motion with respect to the frame. Differential redshifts for closely spaced centers are insensitive to global corrections, hence quantization is seen locally without global reference. To go further 'solar motion' corrections were required. Presumably galactocentric redshifts, not heliocentric ones, should reflect global quantization.

Tifft (1977a) demonstrated that Local Group galaxies were periodically distributed in redshift at 72 km s^{-1} when galactocentric corrections were applied. Arp (1986) confirmed and extended the work using an independent solar motion determination. Napier *et al.* (1988) further verified the periodicity. Since the Local Group is a physical group, quantization at this level is a three-dimensional generalization of the differential work in pairs and groups. The analysis shows the significance of the transformation to the galactic center. To extend the quantization linkage between groups, Tifft (1977a) went on to show that the redshift pattern in the external M101 group was apparently in phase with the Local Group. The intergroup phasing was then extended out to the Coma cluster to provide an accurate estimate of the periodicity, (72.46 ± 0.5 km s^{-1}), assuming a global scale for linked redshift states. General studies followed.

Global quantization studies are much more complex than differential work. First, the redshifts must be accurate; only 21 cm data easily meet this condition. Second, one should work with homogeneous classes of objects. If galaxies are superimpositions of states one should compare similar combinations to minimize phase or period differences. Sorting by the width of the 21 cm profile is one way this is done. Third, the solar motion is not accurately known. A global quantization study is, in effect, a solar motion study; can one find a reasonable solar motion which reveals quantization? A sizeable amount of accurate homogeneous data is required. The first global solution (Tifft 1978a,b) used the original Fisher-Tully (1975) 21 cm study of dwarf galaxies. In retrospect, the sample was too small for the task but it verified a galactocentric reference and indicated a dependence upon profile width and perhaps shape. Periods were simple fractions of 72 km s^{-1}. Narrow profile galaxies (the simplest galaxies?) were clearly distinguished. The transition from dwarf irregulars (with narrow single peaked 21 cm profiles) to rotating disk systems (with double horned profiles) occurs for profile widths just sufficient to accommodate a 72 km s^{-1} interval along with a minimum natural width. An effort was made to construct galaxies from simple combinations of states. Various combinations are required to match different types of galaxies. Wide and narrow profile galaxies must be distinguished in most work.

Tifft & Cocke (1984) used the extended Fisher-Tully (1981) 21 cm study of more than 1000 galaxies to show that narrow 21 cm profile galaxies were strongly periodic in redshift at $72.45/3 = 24.15$ km s^{-1} for a well defined solar motion vector $(\theta, \pi, z) = (231 \pm 2, -35 \pm 3, 1 \pm 2)$ km s^{-1}. θ, π, and z are the tangential, radial, and perpendicular components of galactic rotation, positive in the direction of rotation, inward, and toward the north galactic pole. The significance of the narrow profile finding is clouded by the number of parameters fit; however, for the same motion vector the widest profile galaxies were shown to be strongly periodic at $72.45/2 = 36.2$ km s^{-1}. The agreement of the solar motion with standard values (see Arp (1986) for a discussion), and the fitting of galaxies at both extremes of profile width with 72 km s^{-1} related periods, is very unlikely if accidental. Redshifts appear to be globally periodic. At intermediate profile widths it is complex; at the extremes it seems to be simpler.

Several independent investigations followed. M. Croasdale (1989) examined 21 cm data for wide profile galaxies in Arecibo data. Although most of the Arecibo data is in the unexplored domain of higher redshifts, he generally confirmed the presence of a 36 km s^{-1} periodicity. Guthrie & Napier (1991) examined a sample of very nearby galaxies and found a strong periodicity at 37.1 km s^{-1}. This study, and a newer version extending the redshift range (Napier & Guthrie 1993), have recently heightened interest in the quantization phenomenon. Guthrie & Napier do not restrict the type of galaxy studied. Their sample is dominated by bright galaxies in nearby groups with profiles between 100 and 300 km s^{-1} wide. The result is not readily connected to less luminous galaxies with similar profiles in the Fisher-Tully data. The quantization phenomenon depends upon properties of galaxies. There seem to be various ways to find compatible samples, but much work remains to understand the factors involved.

If the redshift is a velocity, regardless of how it is constrained, it should show relativistic and/or cosmological effects. The global quantization study by Tifft & Cocke (1984) included a correction in the form $V_{corr} = c\ln(1 + V/c)$. As attempts to find a theoretical approach to quantization developed (see Cocke & Tifft (1989) for details), various models suggested that the quantization interval should scale as the square root of the Hubble constant. Within a standard Friedman cosmology $H(t)$ can be expressed as a function of H_0 and q_0, hence the quantum interval can be written as a function of z and q_0. Including a transformation to the external rest frame observed intervals should scale as

$$\Delta V = (1 + \bar{z})^{-3/2}(2q_0\bar{z} + 1)^{-1/4}\delta V_{obs}.$$

This relationship was used to explore quantization in the Lyman alpha forest of quasars. On the hypothesis that Lyman alpha clouds could be associated with dwarf galaxies or protogalaxies, Cocke & Tifft (1989) predicted that the 24 km s^{-1} global periodicity associated with dwarf galaxies could be reflected in the spacings of Lyman alpha lines. They found that a strong periodicity did occur for q_0 close to 1/2, the value associated with inflationary cosmologies. For q_0 of exactly 1/2, observed and corrected redshifts can be directly related. For small deviations of q_0 from 1/2 the expression for ΔV can be integrated in a Taylor expansion to give redshift corrections (Tifft 1991b). This correction is included in recent work, but is of little consequence locally. It seems that quantization observations have the potential to precisely determine q_0. The association of predicted periods with a unique value of q_0 would be a remarkable accident if quantization had no cosmological significance. New work, discussed in Section 6, has now associated quantization with the 3 degree Cosmic Background radiation rest frame, further strengthening a cosmological connection.

5 Redshift Time Dependence

Commentary on the accuracy of 21 cm redshifts is useful here. Tifft & Cocke (1988) reobserved many galaxies with older 21 cm redshifts to determine

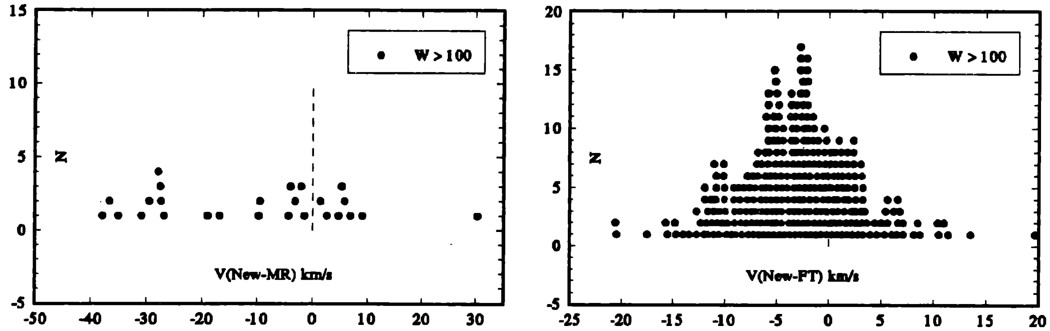

Fig. 3. Deviations between new and old redshifts. Data from Roberts (1968) are shown at the left. The Fisher-Tully (1981) comparison is shown at the right. The dashed line marks zero deviation. There appear to be multiple components and, on average, a significant negative displacement.

uncertainties and get accurate values. Tifft (1990) and Tifft & Huchtmeier (1990) made multi-telescope comparisons and established redshift standards. 21 cm redshifts involve precise frequency measurements.

After eliminating a few system or software errors, systematic error in 21 cm data was found to be vanishingly small. Beam size differences can produce systematic effects in resolved disk galaxies; inner regions seem to show a slight blueshift not seen in non-rotating dwarf galaxies (Tifft, 1991a). Precision comparisons require data sets from the same telescope. Pointing ultimately limits precision at high signal-to-noise levels. With consistent pointing random error is related to the signal-to-noise ratio. The most common method of redshift measurement uses the mean of two frequencies measured at specific levels on each wing of the profile. Observers differ in how the points are defined, but at high S/N the accuracy of each measure depends only on the bandwidth employed. The repeatability of high S/N data (S/N $>$ 10) varies with the square root of the bandwidth used and is basically independent of profile width. Single observations made with a 5 MHz bandwidth can repeat within about 0.8 km s^{-1}.

The interpretation of a redshift is different problem. From a conventional viewpoint random fluctuations in cloud motions or hydrogen distribution limit the degree to which a redshift measure, no matter how precise, can represent the center-of-mass motion of a galaxy. This limit is assumed to increase with profile width. If, however, galaxies are quantized structures it is not obvious that this uncertainty applies. The ultimate test of what level of regularity can be seen in redshifts has to be determined empirically, it cannot be determined from preconceived concepts of dynamics which may not apply. Random fluctuations cannot consistently produce predicted periodicities. Sizeable systematic errors in 21 cm data are difficult to generate, or when present, difficult to casually dismiss.

It was therefore interesting to find that comparisons of new and old 21 cm data contained *periodic systematic deviations.* It had been known previously (Rood 1982), that Fisher-Tully redshifts were, on average, slightly too large. Tifft (1991b) demonstrated this offset conclusively (9 sigma), and showed that other studies from the same era also deviated. Still older data from the 1960s by Roberts (1968) contain larger displacements, some exceeding 30 km s^{-1}. Figure 3 shows the comparison with Roberts (left) and Fisher-Tully (right). Despite the regular trend, one would be hesitant to suggest real changes based purely on systematic deviations in older data. However, the deviations correlate with global redshift phase. There is a direct connection with quantization, very unlikely if accidental. The effect was first reported at the Venice Symposium (Tifft 1988), where new redshifts were compared with Fisher-Tully values. Deviations were subsequently confirmed (Tifft & Cocke 1990) using entirely new redshifts spaced 2-3 years apart. The initial work is summarized in Tifft (1991b) where the temporal variation concept was formally developed. The 1991 temporal variation paper also examined the effect of rapid variation on the determinations of the period and solar motion. Slightly modified values were derived by optimizing periodicities in a two dimensional phase-deviation diagram. Figure 4 illustrates phase-deviation diagrams comparing new observations with Fisher-Tully data for galaxies with narrow 21 cm profiles. The upper left ordinate is phase at the recent epoch, the lower left panel shows phase at the initial epoch. The amount of 'drift', down and to the left or straight to the left, depending upon phase epoch, is a function of phase. The upper right panel contains a schematic six-level phase-deviation diagram showing how redshift might cascade between narrowly spaced levels to produce the observed correlations. A level-and-transition model was proposed which views the redshift as occurring in specific relatively stable levels. During brief periods, perhaps several years apart, transitions bridging levels must occur. The population within levels may be modulated over a range of levels to give rise to longer periodicities. The frequency and/or times of transition must differ between levels. The dominant change is down in redshift. Surrealistic though this model sounds, continuing monitoring of standards supports the concept. The lower right panel in the figure shows an enlarged, less homogeneous sample; the phase dependent drift pattern is consistent.

A primary objection to the level-and-transition model is that the finer levels are spaced only a few km s^{-1} apart. While compatible with measurement error the visibility of this fine structure requires models for galaxies at variance with popular opinion. Newer work permits demonstration of changes at longer periods although finer levels remain. Monitoring is continuing.

The problem, of course, is the rate of change. Even if the Hubble Law was entirely due to a lookback effect in redshift evolution, changes should be unobservable if transit times across galaxies or intergalactic distances are considered. If the variation is real, the cause must be very local or a

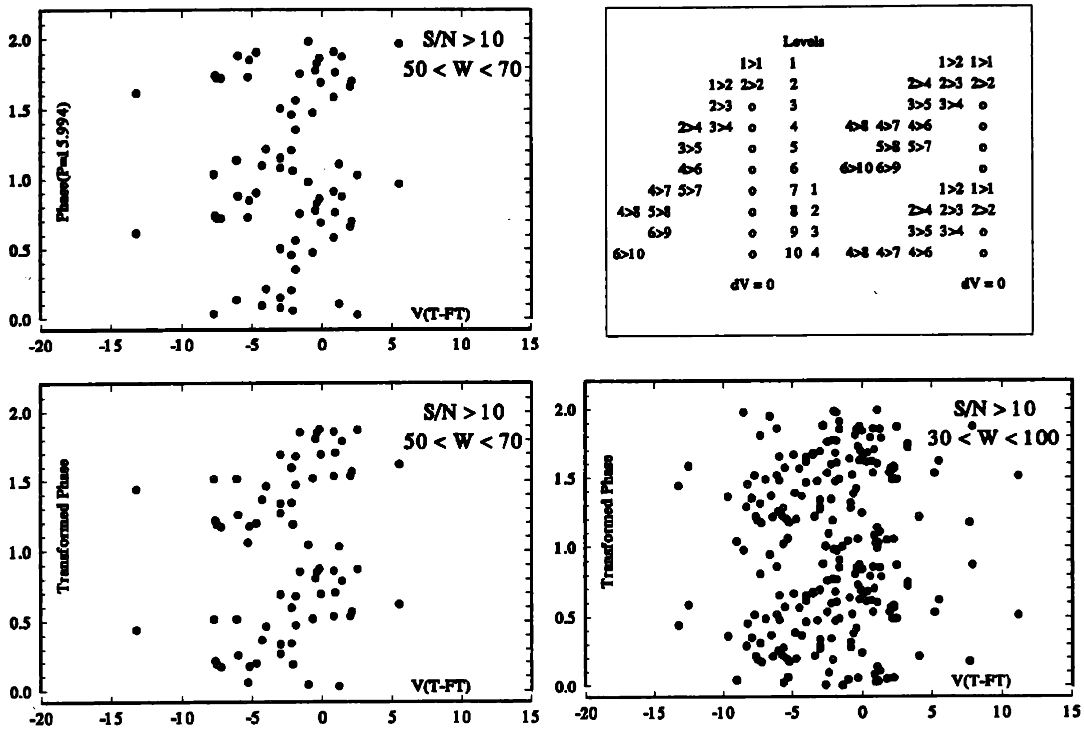

Fig. 4. Phase-deviation diagrams comparing recent observations with Fisher-Tully redshifts for galaxies with narrow 21 cm profiles. The ordinate is redshift phase, plotted as a double cycle to illustrate periodicity. The abscissa is redshift difference (new−old) in km s^{-1}. At upper left, phase is calculated at the new epoch; the figure at lower left shows the same data with phase figured at the older epoch. The diagram at upper right indicates how jumps between levels in a multi-level phase diagram can produce the observed drift patterns. Numbers refer to phase levels, arrows indicate transitions taking place between the two epochs. This example contains six levels drifting at different rates. Points are displaced diagonally or horizontally depending on the epoch used to determine phase. Some duplicate points are omitted for clarity. At lower right an extended sample shows the general nature of the effect.

completely different view of galaxies is required. If galaxies are described by a purely quantum mechanical analog with particle physics then there may be a mechanism which could produce rapid oscillations. Time scale estimates for an analog of the Zitterbewegung or 'jitter' phenomenon in relativistic quantum mechanics indicate changes might occur over a few years (Tifft & Cocke 1990).

6 New Directions

A question often asked when quantized redshifts are discussed is 'is there any connection with the Cosmic Background Radiation?' The answer to this is now yes. When redshifts are transformed to the CBR rest frame using the COBE cosmic dipole velocity and apex, widespread quantization is seen at the original 72 km s^{-1} period. Optimum tuning occurs at or within the error box for the COBE vector. The original demonstration (Tifft & Cocke

1993, Cocke & Tifft 1993), utilizes three independent data samples, each of which shows the CBR association with likelihoods of accidental coincidence at or below the 0.001 level. Periodic clumping of redshifts is consistently enhanced when viewed from the CBR rest frame. A large velocity space search around the CBR coincidence finds only chance fluctuations which do not reinforce from sample to sample. Figure 5 shows the velocity space correspondence with the COBE dipole vertex. The upper left panel is a phase-deviation diagram showing the phase concentration which occurs when redshifts are referred to the CBR rest frame. The lower left panel shows how solar motion choices which produce strong periodicities cluster at the COBE dipole vertex. The diagrams show the $\theta - \pi$ velocity plane for z velocities near 275 km s^{-1}. A Fisher-Tully galaxy sample was used in the left figures; Arecibo data on Perseus supercluster galaxies was used in the right panel. The CBR solar motion vector is $(-242, -31, +275)$ km s^{-1}, which compares with $(-245, -23, +275)$ km s^{-1} for COBE. Uncertainties are in the 5-10 km s^{-1} range.

A direct link between global and differential quantization seems apparent. Differential quantization has consistently shown 72 km s^{-1} intervals. Since redshift differentials are largely unaffected by any reasonable rest frame transformation, they might be expected to resemble the view from any fundamental frame which existed. This is what occurs in the CBR rest frame. Quantization has apparently achieved the CBR link which conventional large scale motion studies find very elusive. On the other hand the connection poses some interesting problems. There are now *two* frames which produce quantization, both involving apparent velocity transformations. There are indications that the CBR reference is widely applicable. The galactic reference may be more local.

In addition to the recognition of a possible fundamental rest frame recent work gives new insight into the hierarchy of periods present. Since this work is in development it is not discussed here. It appears possible to demonstrate variability using periods which are large compared with uncertainties, and some insight into what could cause changes now exists. We do not know what galaxies or systems of galaxies are, but it seems unlikely that conventional dynamics with or without dark matter will be sufficient to explain them.

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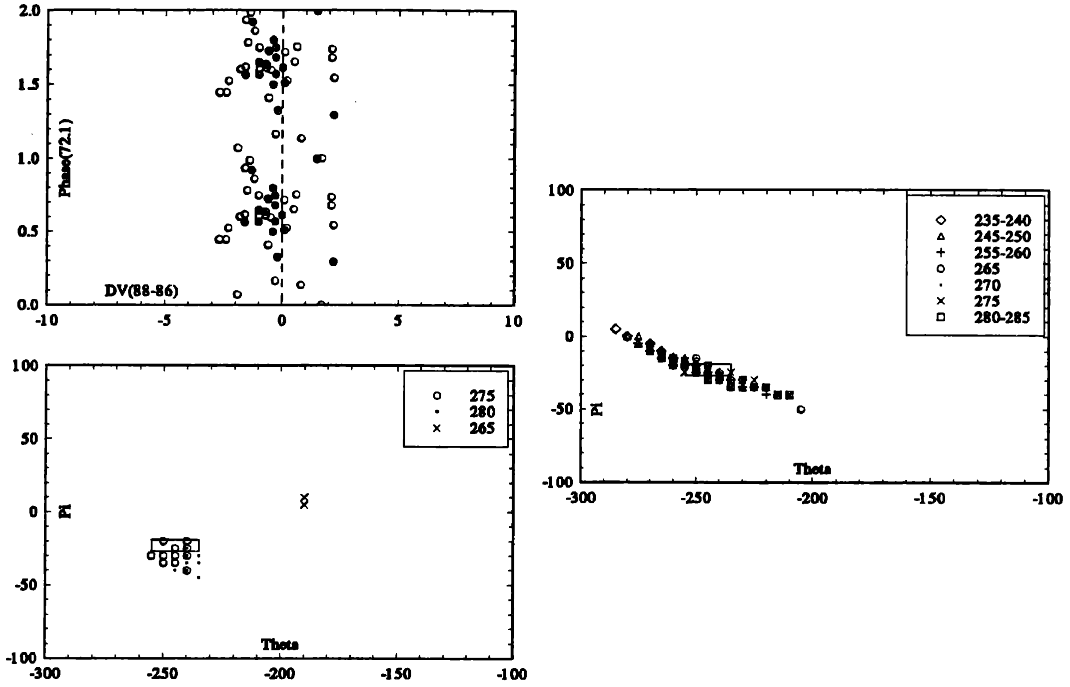

Fig. 5. Diagrams showing the association of redshift quantization with the Cosmic Background Radiation dipole vector. The upper left panel is a phase-deviation diagram for one sample. Filled circles show points with the highest signal-to-noise. The ordinate is a double phase cycle for a period of 72.1 km s^{-1} after referral of redshifts to the CBR rest frame. The abscissa is the redshift difference between 1986 and 1988. The dashed line denotes zero deviation. The other panels show the $\theta - \pi$ velocity plane for a range of z velocities. The small rectangle is the error box for the vertex of the CBR dipole moment centered at $z = 275$. The points mark the velocity coordinates of maximum phasing of redshifts. The sample at lower left is based upon Fisher-Tully galaxies; the right panel contains Arecibo data.

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