DISCRETE STATES OF REDSHIFT AND
GALAXY DYNAMICS I,
INTERNAL MOTIONS IN SINGLE GALAXIES

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Received 1975 June 20
Revised 1975 October 15

May 15 A.J.T

INTRODUCTION

In a series of papers (Tifft 1974 and references therein) evidence for a totally intrinsic redshift has been developed. The concepts are founded on the existence of correlations with the redshift of "normal" galaxies which are at variance with conventional gravitational dynamics. The tentative explanation is that multiple substates of matter exist and that matter in galaxies forms a time evolving progression of discrete states which we see displayed serially in lookback time. At a given cosmic time only a limited range (or ranges) of states is present. Our immediate solar neighborhood is representative of one specific state.

Up to the present time, the greater part of the concept rests upon studies in clusters of galaxies, notably the Coma cluster. If the idea is general, however, it must be consistent with observations at all cosmic scales. In this series of papers, we show that the concept is consistent with phenomena observed in single and multiple galaxies, including our own galaxy. This approach also permits considerable refinement of the concept.

Two new observationally derived concepts will be introduced in this paper. Because of their unusual nature they will be stated in advance and should be considered as hypotheses to be tested against observations. Within observational limitations they are consistent with all new and published data known to the author. Critical examples will be used in the text to develop the ideas: first, the redshift

occurs in discrete steps with a step size near $70\text{-}75 \text{ km sec}^{-1}$ and/or multiples thereof; second, all major galaxies (and presumably related objects) contain two states of redshift which appear on opposite sides or "poles" of the nucleus. Lesser amounts of other states may be present.

In this paper we will consider the internal motions within single galaxies. Several phenomena are observed which complicate the model of a simple rotating galaxy. These include the general class of so-called "non-circular motions" as well as specific high velocity clouds, warping of discs, multiple peaks in rotation curves, and an apparent lack of Keplerian wings at large radius. It is the contention of this paper that most or all of such deviations from a simple single-peaked symmetrical rotation curve and simple radial motion are non-Doppler in origin.

Observations for investigation of internal motions exist for many galaxies. However, for the majority of the systems limited spatial or spectral resolution makes it extremely difficult to determine if effects of the type proposed in this paper are present. $70\text{-}75 \text{ km sec}^{-1}$ is usually beyond the resolution ability of the spectrographs and dispersions employed on galaxies. At H and K 75 km sec^{-1} corresponds to a $1\text{\AA}$ shift and at H α to a $1.7\text{\AA}$. Where there is mixing or blurring of states, as is inevitable due to seeing, guiding, or boundary region geometry, the spectrograph will record a single line, the position of which will depend upon the relative strengths of the states. A boundary cannot, therefore, always be sharp. Furthermore, the differential away from boundary regions will be clear only if spatial resolution is great enough to clearly separate regions. With sufficient spectral resolution a transition region could show doubling and will at least show broadened lines if the internal real

Doppler broadening is not too large. In addition to spatial and spectral resolution limitations, zero point differences between the redshifts given in various studies must be kept in mind when intercomparisons are made.

On the basis of the spectral and spatial resolution arguments given above, the galaxies critical to the arguments in this paper are the largest and best studied. In particular M31 and our own Galaxy are primary and are discussed in detail. Because the concepts employed are new and complex, several other galaxies are used to introduce the ideas and develop the methodology of treating M31. M51, for example, is one of the preliminary examples considered since it presents one of the clearest cases of well defined spiral arms and has been extensively studied. A much more extensive analysis of galaxies for which lower resolution data are available is in progress and will be presented subsequently. These data appear completely consistent within the limitations of the data.

A number of basic statistical tests are employed in this study to evaluate the reality of the phenomena proposed. Since a periodic effect is involved, power spectrum analysis is the natural means of testing. The significance of peaks at various power levels in power spectra is an important statistical tool. This is especially so if the periodicity is predicted in advance. The procedure used is therefore to analyse a series of successive independent samples of data using predictions from previous samples. This is an inescapably powerful statistical approach and is at the very heart of the scientific method. Despite the success of the statistical treatment the author is very much aware that because the result deviates from the "conventional" view that the typical response

is likely to be "I am unconvinced." The history of science carries many examples, however, where the "conventional" view was indeed ultimately shown to be wrong. The author happens to believe that conventional theory is seriously incomplete and as further data is amassed, the discrepancies with conventional dynamics strengthen. The problem will not vanish by being ignored.

In various figures in this paper lines have been drawn through data points to indicate the various redshift states. The lines have been consistently drawn at the spacing indicated by the numerous impartial power spectral analyses carried out and are not the capricious choice of the author. In most cases the "lines" are obviously in agreement with the data and in all cases they are at least consistent within the resolution limits of the data. A standard spacing is used throughout.

PRESENTATION OF CONCEPTS

We will begin with an example from NGC 2903 which is an Sc spiral showing marked "non-circular motion." We choose this galaxy simply as a convenient introductory example for which two independent investigations are available. NGC 2903 has been studied by Burbidge, Burbidge and Prendergast (1960) and by Simkin (1975). Figure 1 reproduces, with no interpretive lines, the Burbidge et al (1960) rotation curve from position angle 24° and the Simkin (1975) H β rotation curve from position angle 29° . The irregularities in the curve are apparent. Note that Simkin places the nucleus at $+45''$ rather than at zero. Her values also differ rather seriously in zero point from Burbidge et al (1960) as discussed in her paper. A point not mentioned in her paper is that the scale along the slit appears to differ between the two studies by a factor close to 1.2,

suggesting that one observer used an incorrect conversion. This explains why the two curves have different slopes and systematic shifts in the positions of irregularities. None of these uncertainties will change the internal differential redshift of primary concern here. It does, however, prevent derivation of accurate absolute redshifts which would be highly desirable.

Figure 2 is the same as Figure 1 with interpretive lines. Two smooth parallel rotation curves spaced a "standard" $70\text{--}75 \text{ km sec}^{-1}$ are shown. The galaxy follows first one and then the other progressing outward from a discontinuity at the nucleus. What it is contended is being witnessed are two streams of material, arising on opposite sides of the nucleus and winding outward in interleaved spirals. The spiral arising on the southwest has a systematically positive redshift and reappears at progressively greater distances on alternate sides with at least four appearances in all. The spiral stream arising on the northeast follows a similar pattern at a lower redshift and is somewhat weaker. The Simkin (1975) observations at higher spectral resolution show, in addition to the alternating pattern, what we shall tentatively interpret as higher and lower "states" which tend to occur at the nuclear discontinuity and other boundary regions. The outer region at $+120''$ in Simkin's data, where the peculiar deviation is strong, corresponds to one end of a bar-like structure in the disc of NGC 2903.

In summary, in NGC 2903 the new concepts set forth in the introduction are illustrated and may be usefully expanded slightly for further reference.

- a) The basic nuclear redshift discontinuity is the origin of two streams showing different redshifts. The streams

are interleaved and wound up by the rotation of the galaxy.

- b) The two streams may not be equal in the strength of optical markers.
- c) Additional states beyond the basic pair may occur near the nuclear discontinuity and other boundaries.
- d) The states are spaced by close to 70 km sec^{-1} .
- e) The effects of different spectral resolution are easily seen by comparison of the two studies.

From the simple case of NGC 2903, intended only to introduce the concepts, we will now move to a more complex object, M51=NGC 5194. Two investigations of this galaxy will be utilized: Tully (1974a) for the outer portions and Burbidge and Burbidge (1964) for the nuclear region. M51 is the well known Whirlpool Nebula which is nearly face-on ($i \approx 20^\circ$) and shows strong, well defined spiral arms with a companion, NGC 5195, at the end of one arm. The study by Burbidge and Burbidge (1964) showed strong "non-circular motions" in the nuclear region which on a conventional picture represents large motion perpendicular to the plane of the galaxy.

When the extensive Fabry-Perot HII measures of Tully (1974a) are plotted in various position angles the strong spiral features are clearly recognizable. Figure 3 presents the material out to $200''$ for position angle $45^\circ/225^\circ \pm 15^\circ$ where the separation of the arms is especially clear so minimum blending occurs. This position angle is intermediate between the major and minor axes. The two crossings of each major arm are indicated and the arms designated A and B. The dashed lines show a suggested linear rotation curve with a nuclear discontinuity of $70\text{-}75 \text{ km sec}^{-1}$. The A arm is at the more positive redshift. Note that there is no indication in the data that the rotation curve is continuous across the nucleus.

This is also true for the much more extensive major axis diagram given by Tully (1974b, Fig. 3). Note that the data slope within each arm in Fig. 3, especially the well defined northeast A arm, matches the slope of the suggested dual valued rotation curve. This effect in Tully's major axis diagram causes very striking deviations from his single valued rotation curve. The data is strung out into elongated features which point at each other across the nucleus and cross the "smooth" rotation curve at steep angles. It should be noted that Tully corrected his figure for tilt hence the apparent separation of the two redshifts is much larger than the 70-75 indicated here. A real intrinsic redshift is, of course, independent of tilt.

The intercomparison of the model based upon Tully's (1975) outer data and the Burbidges' (1964) inner region analysis permit an interesting test to be formulated. If the dual redshift model suggested in Figure 3 is correct, the inner data from the Burbidges should show the same major features at the same slope and spacing given by the outer data in the same position angle intervals. If, on the other hand, the peculiarities in the nuclear redshift pattern are random non-circular velocities there should be little relationship with the dual rotation curves derived from the outer data.

The Burbidge and Burbidge (1964) data on M51 from all but two isolated position angles is shown in Figure 4. The upper left panel shows the observations in the position angle interval 38° - 62° , close to the position angle of Tully's data in Figure 3. A small systematic difference of 20 km sec^{-1} is allowed for between the two sets of observations.

The following points can be drawn from Figure 4a: first, the A and B features are present at the same slope and spacing seen in Figure 3;

second, the A feature is present to some extent on both sides and is a good fit to the dual redshift model. The northeast extension is, however, in distinct disagreement with the conventional rotation curve. The points group well at $70\text{--}75 \text{ km sec}^{-1}$ intervals and the expected slope. Material at $+75$ with respect to the A arm is also present in the nuclear region and also fits the same basic slope.

The upper right panel of Figure 4 includes observations in the position angle interval 71° to 89° which falls near the minor axis. This diagram shows the same features as Figure 4a with both principal states extending through the nucleus. The points concentrate well to the two major states. The lower left panel of Figure 4 shows data near the major axis which again fits the pattern of $70\text{--}75 \text{ km sec}^{-1}$ spaced states. Figure 4d contains little data but demonstrates that absorption line redshifts are in agreement with the emission and appear to show the same effects. In general, the multiple intrinsic redshift concepts set forth in the introduction of this paper are consistent with the redshift pattern observed in M51. A conventional dynamical model requires major deviations from simple motion.

At this point we introduce a method of viewing and testing the multiple redshift concept. Figure 5a is a histogram of the redshift values for the 104 nuclear points in M51 with $R < 75''$ in Figures 4a-c with rotation removed. Note that the rotation values may be taken independently from Tully; the values used were 40, 0, and 50 km sec^{-1} per arc minute for the three orientations.

Two peaks in Figure 5a are apparent, corresponding to the A and B arm populations. The tail produced by the additional high redshift material is also visible. Figure 5b contains the power spectrum of

Figure 5a. The high power and obvious dual peak in the redshift distribution could be used alone to argue that the nucleus of M51 can be represented as having two redshifts, especially since the parameters entering into the test were independently derived. Figure 5 clearly illustrates how the supposedly complex M51 "velocity" field may be given a simple dual redshift representation. There is no observational basis for a continuous rotation curve or even multiple cloud ejections seen in various orientation.

We now return to the Tully (1974a) observations of the outer arms, where, using his complete sample, we tabulate the apparent redshift of the A and B arms separately in various position angle intervals. This is then compared with a simple rotation model allowing the arms to be systematically redshifted from one another. Figure 6 presents the data. The open circles are the mean redshifts at 30° intervals of position angle. The points are well represented by the solid lines which converge to two nuclear redshifts 430 and 500. The dashed line illustrates the form of a simple rotation curve with line of nodes in position angle $335^\circ/155^\circ$ which seems to be the best representation and is in reasonable agreement with Tully (1974b) and most other investigations which indicate values near 0° .

The deviations between the solid and dashed curves demonstrate that rotation alone will not represent the data. Addition of expansion will, however, shift the expected curve in the direction shown by the arrows and can remove the difference. Since a more comprehensive discussion of expansion appears later in conjunction with M31 and our galaxy, the point will not be pursued further here beyond introducing the concept

and indicating that M51 shows expansion on this model.

Before leaving M51, a comment with respect to the companion NGC 5195 is in order. Burbidge and Burbidge (1964) note that there is a redshift difference of 60 km sec^{-1} across the nucleus of the companion at a mean $V_0=606$. This difference is consistent with the dual redshift concept considering the expected uncertainty in the difference and some allowance for real rotation. The Burbidge and Burbidge data (1964) will therefore give a set of redshifts for the M51 system of about 410 (75) 485 (91) 576 (60) 636 where the figures in parentheses are the differences between adjacent values. Within observational uncertainty the four values form a regular progression with a mean difference close to 75 km sec^{-1} . This is, therefore, a useful point to introduce the concept that the redshift differences between galaxies (at least in associated groups) as well as within single galaxies seem to occur primarily in multiples of a number close to 70-75.

M31

With the exception of our own galaxy, which is complex because of our position within it, M31 has probably had more internal dynamical material collected than any other galaxy. No model will have much chance of acceptance if M31 is not represented. In fact, no simple single model for M31 exists and studies from nuclear to large scale each call upon separate dynamical subsystems and even within these subsystems serious deviations exist. Using the concepts introduced via NGC 2903 and M51 we shall now turn attention to a multiple redshift model of M31. We shall draw upon several basic studies including

Walker (1974) and Morton and Thuan (1973) for the nuclear region, Rubin and Ford (1971) and Babcock (1939) for the inner disc, deHarveng and Pellet (1975) for extended HII, Rubin and Ford (1970) for outlying HII regions, and Roberts (1966) for HI. Several studies are omitted because the data is shown only as a figure and is not tabulated. This is also true for Babcock (1939), however the special importance of that data warrants including it here. Most of the other data has been supplanted by later papers.

The high resolution studies of the M31 nucleus by Light et al (1974) have shown that the major axis of the nuclear region of M31 lies in position angle 63° . For studies of the nucleus and inner disc this value is assumed. For the outer regions the usual value of 38° is adopted. An inclination angle of 77° will be used where appropriate.

Figure 7 contains the nuclear region stellar absorption line redshifts in M31, primarily the data from Walker (1974). The raw data is shown containing no projection effects. In his paper, Walker presented the data folded with respect to the center and discussed the data in terms of a dynamically distinct rotating nucleus. Walker noted the presence of deviations from simple rotation and also that the devious points did not correspond to photometric anomalies which might represent superimposed clouds. The most deviant points are the negative values to the northeast of the nucleus which Walker omitted in his figure. Another striking aspect of the data is a tendency for segments of the data to show preferred slopes of about 30 km sec^{-1} over about $10''$ intervals. The lines drawn in Figure 7 show that the segments of related points and the "deviant" points are in close accord with the dual redshift model and a nuclear discontinuity. There is no indication of redshift continuity across the nucleus in Walker's data. The much more limited data of

Morton and Thuan (1973) is also shown in Figure 7 and is also in general accord with the dual redshift model, especially in the southwest where points deviating markedly from Walker are present. Note that neither Walker nor Morton and Thuan give absolute redshift, simply differentials from the nucleus. Thus there is some uncertainty as to how to combine the data. Finally, before leaving the nuclear region, the presence of more extreme redshift states at the nuclear discontinuity is indicated by the outermost lines drawn at the standard $70\text{--}75 \text{ km sec}^{-1}$ spacing. The limited resolution near the M31 nucleus will in general blur these states with the more dominant ones so the lines can represent only the extreme points rather than the mean.

The nuclear region absorption line studies just discussed extend out about $20''$. From $20''$ to $100''$ the best data on M31 comes from Rubin and Ford (1971) using diffuse emission lines in the disc. Figure 8 is a composite of the Rubin and Ford data for five position angles within 35° of the 63° inner major axis orientation. Hatched regions in the center show the Walker (1974) data. The smooth continuation of the multiple redshift pattern found in the nucleus is shown with light dashed lines. The two sets of data are internally consistent and consistent with the multiple redshift pattern. Note the point spacings where multiple values occur at the same radius and how well the points of inflection in the data fit on the various parallel rotation curves. Five stages of redshift are seen, the main pair connected by the solid line marking the nuclear discontinuity, and two more positive and one more negative.

A normal dynamical model of the inner part of M31 could represent the northeast data with a 200 km sec^{-1} peak on the rotation curve near

60" followed by a return to close to zero. This is, however, an exceedingly poor representation of the data to the southwest. There is scarcely any symmetry at all about the nuclear $V_{0\sim 300}$. The deviations from ordinary dynamics are obviously extreme. The only deviations from a multiple redshift model occur as a "bridging" between states which should occur when adjacent states blend together at boundary regions. The spectral resolution in the work by Rubin and Ford (1971) is close to 70 km sec^{-1} but is not quite sufficient to separate lines of $70\text{-}75 \text{ km sec}^{-1}$ spacing even assuming that separate lines are sharp enough to resolve. The following is taken verbatim from their paper (*italics are mine*).

---"the knots we observe on the emission lines occur always when the spectrograph slit is crossing a dust patch. Here *the lines generally thicken, and there is often a velocity discontinuity*, light from the background integrated starlight is absorbed producing a horizontal absorption line on the spectra. (---) On the spectrum there is a *pronounced discontinuity* in the emission line, and a very positive velocity is measured".

This statement contains much information. The line thickening is what would be expected at the boundary of two states as would a "velocity" discontinuity. The other interesting point is that dust regions mark the boundaries of adjacent states. The generally narrow widths argue against local violent activity which might provide a mechanism to produce the peculiarities by normal dynamics.

It would be possible to project the data in Figure 8 along the rotation curve(s) and demonstrate periodicity in the data.

Since the rotation curve can be considered somewhat arbitrarily, however, this test will instead be made on independent data taken from the minor axis direction where rotation does not enter. Figure 9 illustrates the Rubin and Ford data taken in position angles within 35° of the inner region minor axis. This represents all the remaining Rubin and Ford data for spectrograms passing through the nucleus. The open circles mark the central redshifts indicated by the major axis data. The arrows indicate data which either clumps at or points toward the predicted values. A composite diagram is shown at the lower right. Three basic features of these diagrams stand out. First, the periodicity appears well confirmed; secondly, the ridge lines fall at the redshifts predicted from the major axis; and thirdly, there is a decided tilt to the ridges in the diagram. This tilt is readily explained in terms of radial motion and corresponds to a radial motion rate of 35 km sec^{-1} per arc minute. Figure 10a is the histogram of the data in Figure 9d projected to the nuclear position along the 35 km sec^{-1} slope. Figure 10b is the power spectrum of the distribution. A peak power of 18 is observed at a periodicity of 75 km sec^{-1} . Considering that most of the properties of the minor axis distribution were predicted, the significance of the peak can scarcely be ignored.

The least well defined redshift state on the northeast side of the major axis is the state with $V_{02} \sim 290$ at the nucleus. Rubin and Ford (1970) included a spectrogram taken $60''$ out on the northeast major axis with alignment perpendicular to the major axis. The information from this spectrogram is displayed in Figure 11. The open circles are the nuclear redshift values displaced by 105 km sec^{-1} for the rotation at $60''$. The strong low redshift (-220) state on the major axis at $+60''$ is seen to

be an "island" on the next (-290) state. The radial motion tilt parallel to the minor axis is easily seen but is less than the nuclear value as it must be from the less favorable projection factor in this position. It is apparent that a multiple redshift pattern with a periodicity of 70-75 coupled with a simple smooth rotation law and radial flow can fit the nuclear region of M31 virtually perfectly.

The smooth fit of the nuclear absorption line pattern with the inner disc emission line pattern implies that all material partakes of the same redshift pattern, rotation, and radial motion. As further confirmation, the inner disc absorption line measures by Babcock (1939) are shown in Figure 12. Since the Babcock data is not tabulated but simply given in a figure, the figure has been carefully transcribed and the lines from the rotation curves in Figure 8 superimposed and extended smoothly out to about 20'. One additional redshift state has been added. There is no doubt that the data is well represented. Thus, the complete inner stellar disc as well as the gaseous component of M31 is apparently in smooth rotation and radial motion and presents six distinct redshifts. Figure 12 also illustrates the alternating nature of the redshift pattern as predicted from the two spiral stream model. The major axis crossings of the streams match closely the M31 spiral arms of Baade (1948).

To complete the analysis of M31 to large radius we now consider the extensive Fabry Perot HII data from deHarving and Pellet (1975). The data consist of nearly 1400 "velocities" at discrete points distributed over the galaxy. Since the number of points is extremely large and the distribution rather uneven, we will consider the data in three samples. The reference system usually employed for M31 denotes each location with an X, Y coordinate in minutes of arc. X is measured along the major

axis, positive toward the northeast, and Y is measured along the minor axis positive toward the southeast. The first sample from the deHarving and Pellet study will be all points with $X < 0$ and $X > 30$. This sample of just under 500 points represents the greater part of M31 without weighting any region unduly. The remaining points tabulated by deHarving and Pellet are heavily concentrated in the strong northeast arm. The second sample we will utilize has $0 < X < 20$ and contains over 450 points, most, but not all, of which fall in the northeast arm region of M31. The final sample has $20 < X < 30$. This sample of about 430 points represents almost exclusively the dominant northeast arm. The question we ask here is simply how well can the HII data be represented by the multiple redshift model with state spacing of $70\text{--}75 \text{ km sec}^{-1}$ and a single symmetrical rotation curve and radial expansion curve in a flat disc.

Adopting a rotation and expansion curve the velocity of each point having an HII observation was calculated and a residual formed. If a perfect fit were found, the residuals would all be zero or multiples of $70\text{--}75$ and should group into the alternating spiral stream model. The inner part of the rotation and expansion curve is already specified but the outer part must be derived from the HII pattern itself. Little freedom is actually introduced since perfect symmetry is still assumed and the complete two dimensional surface must be represented. A minor zero point difference of 10 km sec^{-1} between Rubin and Ford (1971) and deHarving and Pellet (1975) was assumed. The final residual diagrams are shown in Figure 13.

Figure 13a is the histogram of HII residuals from the first sample representing the greater part of M31. The power spectrum of the distribution is given by the solid line below the histogram. A peak power of

35 occurs at a periodicity of 70 km sec^{-1} . Figures 13b and 13c illustrate the residual histograms for the other two samples of HII data. In both cases the two main redshift peaks are clearly present but the overwhelming population of points from the dominant northeast arm makes the histogram very uneven. The power spectrum of such uneven distributions is accordingly considerably distorted. The dashed line in the power spectrum diagram in Figure 13 is the power spectrum of the second sample. It possesses a distinct shoulder at the 70 km sec^{-1} periodicity. There appears to be no question that the multiple redshift model with $70\text{--}75 \text{ km sec}^{-1}$ state spacing can represent the M31 HII data virtually perfectly with a single symmetrical rotation and expansion curve.

To complete the analysis of M31, we now consider the HI data from Roberts (1966). The data consists of about 300 "velocities" at discrete points observed along constant declination scans and covering the galaxy from approximately 1° north to 1° south of the center. Interpreted with a conventional dynamical model, several major peculiarities appear. The rotation curve is not symmetrical along the major axis and two opposite quadrants show deviations which have been interpreted as warping of the HI plane.

A resolution problem arises when attempting to represent the HI observations. The radio beam width in the survey by Roberts (1966) is $10'$, hence the spatial resolution is very poor. Towards the center of M31, as a general rule, parts of both main streams in the two stream model will be simultaneously present in the beam. A second effect arises from the distribution of HI. Rapid variation in HI density is likely to mean that the beam center is not representative of the position from which the signal is arising. The dynamical parameters assigned to any

given HI point refer to the beam center position hence may not represent the hydrogen responsible for the signal. This is especially true toward the center where the dynamical properties vary rapidly with position. The net result is that the HI redshift pattern near the center of M31 will be considerably distorted and a broadened distribution peaking between the two main state redshifts can be expected. Away from the center, however, the dynamical parameters vary slowly and the streams are large enough that spatial overlap is minimal. Under these conditions, the excellent spectral resolution of the radio data should emerge and the two main peaks should appear sharp and distinct. We thus will treat the HI data in two samples: the inner $1\frac{1}{2}$ beam widths, and the points beginning $16''$ from the nucleus. We will also exclude the outermost points since they lie well outside the region modeled by HII.

The dynamical model to be applied to the HI data is completely specified by the HII analysis. Thus HI provides an independent test of the model. The data are treated the same as the HII by calculating a residual for each observed point. No detectable zero point difference was found between the HII and HI data. Figure 14a is the histogram of HI residuals for 220 outer points. Sharp, well defined peaks appear at the predicted redshift differentials of 0 and -70 and there is also evidence for points at +70. The sharpness of the peaks is consistent with the good spectral resolution in HI. Figure 14b shows the residual diagram for the 53 points nearest the nucleus. The single broad peak predicted from resolution considerations is present. The power spectrum of the outer sample gives a broad peak with power near 15 in the 70-75 km sec⁻¹ range. The HI data in general is therefore consistent with the multiple redshift model and also graphically illustrates the effects of both spectral

and spatial resolution.

Table 1 contains the adopted curves for rotation and expansion in M31. No effort was made to find the best possible fit and further optimization is no doubt possible. Several interesting points can be seen from inspection of the table. The rotation curve rises rapidly to about $5'$ then more slowly to a peak near 320 km sec^{-1} at $100'$ which is as far as the HII data extend. More outlying HI points are consistent with a smooth extrapolation but are too limited to reliably extend the model. The rotation period of the nucleus itself is about 20 times the value given by Walker (1974) or about 7×10^6 years. The expansion curve rises quickly to a peak near 60 km sec^{-1} (actual radial disc motion) at $12'-15'$ (in face-on projection), then declines quite rapidly and then slowly. It definitely does not retain the large value indicated near the nucleus, neither does it appear to go to zero in the interval modeled.

Figure 15 illustrates the northern and southern ends of M31; both HI and HII data are shown. In addition to the deHarving and Pellet (1975) observations, HII regions from Rubin and Ford (1970) are plotted using the same model with a 10 km sec^{-1} zero point shift. Points within $\pm 20 \text{ km sec}^{-1}$ of the state values are shown for HI (large circles) and for the deHarving and Pellet HII (small circles). The less accurate Rubin and Ford HII data (squares) are shown for points within $\pm 25 \text{ km sec}^{-1}$ of the state values. Filled symbols refer to points near the -70 km sec^{-1} state and open symbols to the 0 km sec^{-1} state. Plus and minus symbols refer to more extreme states near -140 or $+70 \text{ km sec}^{-1}$. The north and south ends of M31 are illustrated here since the resolution is a maximum and the results are almost unaffected by the radial motion assumptions. The two primary arms in each region are apparent. Furthermore, the alter-

nating nature of the arms is readily seen; N5 and S4 are dominantly -70 material while N4 and S5 are 0 material. It is possible to extend the maps through the central regions and unambiguously trace the two main spiral streams. Since this is somewhat off the main theme a more comprehensive discussion of the M31 spiral pattern will be published separately.

The large number of accurate data points permits a critical examination of various details of the streams. Although each stream is clearly dominated by one state certain clumps within a stream contain a mixture. The best examples are marked with small arrows in Figure 15. In each of these regions intermediate redshift values are also seen. This is a natural consequence of limited spectral resolution blending the states together. Thus even the high spatial resolution HII studies in the outer regions show some blending. In the case of HI with a 10' beam the blending is obviously more severe and adjacent streams may not be separated. This is why the central region was distinguished in the HI analysis. The two regions which appear most complex and near the HI resolution limit occur between 20' and 25' north and south on the east and west sides respectively. These are the regions which led to the suggestion of warping in the M31 disc. These regions, which we shall refer to as the complex regions, represent about the closest spacing of strong HI features in adjacent states. At smaller radii the HI weakens to produce the central "hole" in the HI "ring". Figure 16 illustrates the southwest complex region. Although the spatial resolution is poor the excellent spectral resolution is able to distinguish the states. The observations clearly fit the multiple redshift pattern. The innermost state is at -75 and the outermost at 0 as required by Figure 15.

One of the concepts in the discrete redshift hypothesis is that material in nuclei of galaxies will at times undergo transitions between states. These transitions occur in a time systematic sense with more negative redshift states coming later in time. The material so far presented has indicated that opposed streams of outflowing material are present in galaxies. If a state transition were to occur in the nucleus of a galaxy, a discontinuity in redshift would occur within each stream and would flow outward with the stream. Segments of more positive redshift material from a former state might then be expected to occur in the outer parts of galaxies. The S6 arm in M31 may present such a situation. The concentrations of material near $X=-75$, $Y=-13$, and $X=-96$, $Y=0$ are distinctly $+70 \text{ km sec}^{-1}$ material. To change the redshift residual appreciably would be inconsistent with the simple rotation curve employed for the remainder of the galaxy. We therefore conclude that the S6 arm may consist of residual material from a former state of the galaxy.

THE GALAXY

Before passing on to a discussion of our own galaxy, a brief consideration of its companions, the Magellanic Clouds, is of interest. The dynamics of the LMC in particular is rather complex on a conventional picture. The rotational center lies well north of the principal optical bar and the line of nodes lies nearly perpendicular to the bar. The bar thus lies more or less along the minor axis of the conventional rotation ellipse and should show little rotation effect. Major non-circular motion deviations are present throughout the LMC, especially near 30 Doradus.

No attempt to analyze the LMC completely on a dual redshift model has been made, however a brief examination was carried out to verify

that the basic manifestations are present. Figure 17 is an HI V- α diagram adapted from one constant declination scan of the LMC by McGee and Milton (1966). This scan falls north of the bar, near the supposed dynamical center, and makes a small angle with the bar. The HI pattern has a distinct Z-shape with the two arms spaced by close to $70\text{--}75 \text{ km sec}^{-1}$ as indicated. This general pattern persists throughout the LMC with an additional redshift discontinuity at 30 Doradus. The basic elements of the dual redshift model are therefore present and suggest a rotation with line of nodes generally E-W or along the bar and a primary redshift discontinuity near $\alpha=5^{\text{h}}17^{\text{m}}$. Most of the major "non-circular" motions appear to fit the pattern.

There is reasonable agreement on a conventional dynamical model for the SMC. The elongated optical structure marks a steeply inclined structure and shows a marked rotational gradient. The dynamical center, as in the LMC, does not correspond with the principal concentration of stars. The HI redshift pattern along the principal axis is shown in Figure 17 as adapted from Hindman (1967). HII redshifts from Smith and Weedman (1973) are shown on the same diagram. The HI points represent the actual redshift peaks in the observations. Hindman converted this diagram into a rotation curve by taking the mean or median redshift at a given position and interpreting the splitting as expanding clouds or giant shells. It is obviously possible to represent the data with two parallel rotation curves spaced by about $70\text{--}75 \text{ km sec}^{-1}$ and a principal discontinuity about 2° southwest of Hindman's center. A second weaker discontinuity may be present slightly north of center. The principal discontinuity lies slightly off the southwest end of the main optical structure of the SMC. Thus, as with all the galaxies so far examined, most of the

peculiarities requiring unique or individual dynamics can be represented by one simple dynamical pattern and the multiple redshift concept with basic spacing of $70\text{--}75 \text{ km sec}^{-1}$ between states.

The Magellanic Clouds are particularly interesting in that they have no visible nuclei yet they show the same redshift discontinuities. Whatever gives rise to the opposed redshift streams need not, therefore, be a visible object although in most galaxies it clearly resides in the optical nucleus. The SMC is also an extreme example of the lack of optical symmetry in the principal streams.

At this point, having discussed a series of galaxies of progressively closer distance, we will consider the Galaxy itself. No attempt can possibly be made here for anything resembling a complete description of the Galaxy, however several specific aspects will be treated in turn, beginning with the nuclear region as seen in neutral hydrogen. For the nucleus two major investigations have been utilized: Burton (1970) and Kerr (1969). The former is limited to the galactic plane and extends only to longitude -6° . The survey by Kerr extends over a wide range of longitudes on either side of the nucleus and a $\pm 2^\circ$ latitude interval.

The principal features of the nuclear region are well known and are conveniently summarized by Burton (1974). The data is interpreted to show a rapidly rotating disc within 2° of the nucleus which produces a ridge of intensity extending from -210 km sec^{-1} at -1.5° to equivalent positive "velocities" at $+1.5^\circ$. Outside of this a still higher "velocity" rotating "ring" occurs at about $\pm 4^\circ$ longitude. The other striking feature of the central region is the expanding 3-kpc arm characterized by an absorption at $l=0 \text{ } V=-53 \text{ km sec}^{-1}$ and a ridge of HI at progressively more negative "velocity" extending toward southern longitudes. The

feature extends into positive longitudes to $+4^{\circ}$ and disappears into the main mass of hydrogen emission at $+6^{\circ}$. An absorption trough is observed at slight positive "velocity" extending to both positive and negative longitudes. At positive longitudes and low negative to high positive "velocities" the HI emission pattern is very complex.

Figure 18 is a redshift-longitude diagram of the galactic nucleus. Regions with redshifts ≤ -180 and intensities of ≥ 4 (Kerr's units) from Kerr (1969) are shown by open circles. The "expanding arm" according to Kerr (1969) is shown by crosses. Vertical lines mark regions where isolated negative redshift material appears in the HI profiles by Burton (1970). The positive redshift region at positive longitudes is omitted because of confusion as described further below. A solid line has been drawn through the "expanding arm" points and is reflected across the nucleus with a discontinuity. The curves are repeated at intervals of 70 km sec^{-1} . Little hydrogen is observed between the two main features at negative redshift, however many features appear on the positive side of the "expanding arm." The only relatively clean part of the redshift-longitude diagram is the portion shown. The fit of the multiple redshift concept to the data is good and requires no special dynamical units in the nucleus. The -210 material is one of the expected higher redshift states at the nuclear discontinuity. The "expanding arm" is interpreted as a negative redshift stream arising directly from the nucleus. At zero radius in the nucleus the observed redshift is the intrinsic component plus any solar reflex velocity. The opposing stream is not actually observed because of confusion, however, for the standard discontinuity it must lie at slightly positive redshift. If we associate the sun with the material in the stream close to zero redshift, the small positive

residual is consistent with a slow expansion of the Galaxy at the sun. Thus the galactic center has the same basic properties seen in the M31 model and has one of the same two basic redshifts.

Having generally accounted for some of the principal features in the galactic nuclear region the next basic question is can the nuclear model be extended outward to fit the general HI pattern at all longitudes? More simply put, does the dual redshift model predict observable features in agreement or disagreement with general HI surveys? For this investigation the comprehensive survey by Weaver (1970) was utilized. A specific fit to the "expanding arm" region utilized data from Kerr (1969). No attempt was made to make a specific fit to Weaver's (1970) data; comparisons were simply made qualitatively with general diagrams presented by Weaver (1970).

In order to calculate a predicted longitude redshift diagram, radial rotation and expansion functions are required. Given trial functions a grid of predicted redshifts was calculated and a spiral pattern drawn to fit the "expanding arm" to Kerr (1969) specifically, and the rest to Weaver (1970) in general. Two or three iterations provided a reasonable fit. The outer part of the curves were found to be relatively insensitive and no effort was made to particularly optimize them. The expansion rate at the sun was taken close to 18 as derived from the nuclear region discontinuity fit previously discussed. Table 2 gives the adopted galactic rotation and expansion parameters. Linear interpolation was used between the tabulated points. The solar radius vector was taken as 10 units. The expansion curve is remarkably similar to M31 although derived independently. The rotation curve rises much more slowly than in M31, however it has not been determined how critical the form of the inner rotation curve is for the fitting.

Figure 19 is a schematic plan view of the Galaxy. The sun is indicated with the usual symbol and galactic longitude increases counterclockwise about the solar location. The two separate streams or arms are drawn with different weight lines, the solar stream being drawn heavier. The lighter weight stream has the more negative redshift of the pair at the nuclear discontinuity. Various points along the arms are numbered or lettered for reference. The figure turns out to be almost identical to Figures 5 and 6 of Weaver (1970) although derived independently. In the actual final model developed the central region was somewhat expanded with respect to the outer spirals so the pattern rather resembles an SBB spiral.

Figure 20a is the longitude-redshift diagram for the accepted model assuming that the dual redshift pattern extends uniformly throughout and each arm contains only material with a single redshift. The result can be changed slightly by adjusting the radius at which the spiral pattern is drawn or by varying the expansion or rotation functions. The basic character of the diagram, however, remains largely unchanged for small adjustments. Aside from the redshift offset on the negative arm, Figure 20a is very similar to Figure 2 of Weaver (1970). The numbers and letters from Figure 19 are copied onto Figure 20a to facilitate identifying sections of the pattern. Heavy and light lines are used to distinguish the two streams as previously. Zero redshift local hydrogen has been indicated and vertical lines are placed where we look more or less along the local arm.

Several features are worthy of note in comparing Figure 20a with Weaver's (1970) general HI redshift-longitude diagram in his Figure 4. The "expanding arm" feature which appears as a loop entirely at negative

redshifts is well fit. The general fit of the model to Weaver's diagram is fair but there is difference in detail. There are important observed features that are not represented in the model. Most of the predicted features are present in the observations. One exception is the weakness or absence of the negative arm where it should be distinct at longitudes $>10^\circ$. The negative stream, which provides such an excellent fit to the "expanding arm" does not appear to continue in any strength beyond point 3.

In M31 two effects were seen or suggested which have not been considered in the Galaxy model. First, each arm while dominantly in one state contained some amounts of the other. Thus a spiral arm seen from within the plane of a galaxy can appear twice in a "velocity"-longitude diagram. Secondly, evidence was given that redshift discontinuities could appear along an arm with more negative redshifts occurring in the inner part. There is evidence that the nucleus of our galaxy may be active and could have recently been involved in such a state transition or fluctuation. One possible location for a transition point which could explain the weakness of the outer part of the negative arm is shown by a double line in Figure 18. By symmetry such a break presumably occurs on the Solar arm as well.

Figure 20b is a longitude-redshift diagram allowing for mixtures of states as suggested in the previous paragraph. Each stream is now plotted twice over much of its length. A solid line is used to represent the part of each stream most likely to be dominant in accord with possible changes at the break points. A dashed line is used for parts less likely to be dominant and also for the most outlying portions of the streams. The diagram is now in remarkably close agreement with all major

features in Weaver's (1970) HI diagram. No important predicted features are absent in the observations and no important observed features are not predicted. The multiple redshift hypothesis can therefore successfully represent the galactic HI pattern. It is also now apparent in Figure 20b why the positive redshift region at small positive longitudes is so complex and was omitted in the nuclear region discussion.

One further line of evidence remains to be explored. It was previously noted that at active regions or discontinuities there appeared to be a tendency for other associated redshift states to appear. Is there any indication that such an effect is present in the Galaxy? Small amounts of such material might not be too easy to detect in the galactic plane, but away from it they might be more readily seen. Figure 20b identifies the longitudes where most positive and negative high and intermediate "velocity" clouds are seen according to Verschuur (1973). Positive high "velocity" clouds up to $+290 \text{ km sec}^{-1}$ are apparently observed near longitude 280° and latitudes up to about 25° . This is close to the longitude for the possible transition in the solar stream. It is also the general direction along the solar arm, hence the direction any clouds drifting laterally away from the arm could be seen. Little detail about these southern clouds seems to be yet available.

The northern negative high "velocity" clouds range much more widely over the sky and are especially prominent in high and intermediate northern galactic latitudes. They are almost certainly to be associated with the local arm. Regardless of what the negative high "velocity" clouds are specifically associated with, their redshift distribution can be examined for the characteristic state spacing. Figure 21 is a histogram of the redshifts of all the individual negative high "velocity" clouds

listed by Verschuur (1973). The data were compiled directly from his Figures 1 and 2 since no simple compilation exists. Although the selection methods may not be ideal, there is little question that the basic periodicity in redshift is present and the high "velocity" clouds are consistent with the non Doppler multiple redshift concept.

SUMMARY

In final summary, the concept of multiple redshifts within single galaxies has been developed. The approach has been mostly empirical and intended to define the visible properties of the different redshift states and their interrelation to one another. Much more, obviously, needs to be done on the internal "dynamics" of galaxies, however, the present results may be summarized fairly well as follows: Material appears to flow outward in galaxies in two opposed streams which have a systematic intrinsic difference in redshift of $70\text{--}75 \text{ km sec}^{-1}$. These streams are the basis of observed spiral structure as they become wound by the rotation of the galaxy. Additional intrinsic redshift states are seen, particularly at boundaries between states and especially near the nuclear discontinuity. Redshift discontinuities may occur within a stream which suggests that at earlier times material of a more positive redshift was present at the nucleus. There is no evidence that violent motion occurs; essentially all observations are consistent with smooth rotation, expansion, and the multiple redshift concept.

Regardless of the interpretations which underlie the above paragraph, the statement is an empirical description of a natural relationship. Much of what is stated seems beyond reasonable doubt in view of its success in describing the best studied galaxies in a unified manner, something conventional dynamics is hard pressed to accomplish.

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TABLE 1

Rotation and Expansion Model for M31

R_{kpc}	R'	$V_R (\text{km sec}^{-1})$	$V_E (\text{km sec}^{-1})$
0	0	0	0
0.2	1	105	8
0.6	3	155	24
1.0	4	175	39
1.6	8	188	53
2.0	10	195	57
2.4	12	200	60
3	15	207	60
4	20	218	50
5	25	228	40
6	30	236	30
8	40	250	20
10	50	265	19
12	60	278	18
14	70	290	17
16	80	302	16
18	90	311	15
20	100	316	15

TABLE 2

Rotation and Expansion for the Galaxy

R	$V_R (\text{km sec}^{-1})$	$V_E (\text{km sec}^{-1})$
0.0	0	0
4.5	-	70
7.5	300	-
$R_0=10$	283	17.6
30	150	0

FIGURE CAPTIONS

- Figure 1 Major axis rotation curves for NGC 2903 from Burbidge et al (1960) and Simkin (1975). There are scale differences between the two curves, as discussed in the text, and Simkin places the nucleus near $+45''$ rather than zero on the major axis scale. Note the many deviations from a simple smooth symmetrical rotation curve.
- Figure 2 This figure is identical to Figure 1 excepting that a dual rotation curve model is drawn in. Two opposed streams differing in redshift by $70\text{--}75 \text{ km sec}^{-1}$ arise at the nucleus and wind outward. Additional peculiarities are seen at the nucleus and certain boundary regions.
- Figure 3 The rotation curve for M51 in position angle $45^\circ/225^\circ \pm 15^\circ$ from Tully (1974a). The four crossings of the major arms are easily seen, and the two arms are designated A and B. Dashed lines show the dual redshift model suggested with the A arm $70\text{--}75 \text{ km sec}^{-1}$ higher than arm B.
- Figure 4 The inner region of M51 is shown in various position angles from Burbidge and Burbidge (1964). The A and B arms identified in Figure 3 are marked. Open circles refer to absorption line measures and filled circles to emission. The diagrams illustrate that the extensive "non-circular motions" in M51 are consistent with a simple multiplicity in the redshift pattern.

Figure 5 The left (a) diagram is a histogram of the redshift data for M51 shown in Figures 4a-c after correction for rotation. The two well defined peaks demonstrate that the data contain two well defined redshifts. The right (b) diagram is the power spectrum of the redshift distribution in Figure 5a.

Figure 6 Redshift as a function of position angle for the two main arms in M51. The open circles are the mean redshift of each arm derived from Tully (1974a) and are represented by the solid curves which smoothly approach the two different nuclear redshifts shown. The dashed line illustrates a simple rotation curve as it should appear with line of nodes near position angle $335^{\circ}/155^{\circ}$. The deviations between the observed and predicted rotation curves can be interpreted as indicating expansion in the disc which will distort the dashed curve in the direction of the vectors shown.

Figure 7 The major axis absorption line differential redshift pattern in the nucleus of M31 from Walker (1974), filled circles, and Morton and Thuan (1973), open circles. The fit of the pattern to the multiple redshift model is shown with the standard $70\text{-}75 \text{ km sec}^{-1}$ spacing. Note especially how the deviant points at $+6''$ and $-4''$ fit the multiple redshift pattern, and how individual segments of the data fit the suggested rotation slope. Uncorrected data are shown in all cases since intrinsic redshifts are not altered by projection.

Figure 8 The major axis emission line rotation curve for the inner disc of M31 from Rubin and Ford (1971). Data in position angles $63^{\circ}/243^{\circ} \pm 35^{\circ}$ is shown and the inner absorption line data from Figure 7 is shown with shaded regions in the center. Five uniformly spaced rotation curves are shown which match the slope of the inner data and rise smoothly outward. Note how the data points clump, populate several levels simultaneously, and show inflections at the permitted redshift levels and how individual scattered points are accounted for. A solid line connects the two redshift states that are considered primary. Note that the data show almost no real symmetry when interpreted as a conventional rotation curve about a central $V_0 \approx -300$ km sec $^{-1}$.

Figure 9 The emission line redshift patterns for position angles near the M31 minor axis and out to $90''$ as given by Rubin and Ford (1971). The open circles mark central redshifts indicated by the major axis multiple rotation curves. Note how the individual segments of data, marked by vectors, form clumps or ridges directly in line with predicted redshifts. Figure 9c illustrates an interesting effect, occasionally seen, where different ionic species appear in different states. H α and [NII] indicate different levels. An understanding of this effect may give insight into understanding H α /[NII] ratio variations. The composite pattern in Figure 9d shows a well defined periodic pattern tilted by radial motion.

- Figure 10 The upper (a) diagram is a histogram of the redshift data for M31 shown in Figures 9a-c after correction for radial motion. The well defined peaks show how effectively the multiple redshift concept will fit the data. The lower (b) diagram is the power spectrum of the redshift distribution of the 129 points in Figure 10a. The chance of finding such a power peak by accident is vanishingly small.
- Figure 11 The redshift pattern in M31 parallel to the minor axis and displaced 60" to the northeast along the major axis. Data are from Rubin and Ford (1971). The central redshifts are shown shifted for 105 km sec^{-1} rotation at this point. The high redshift cloud of material is seen to be an "island" situated on the next lower state which is one of the two primary states. The minor axis expansion effect is seen as a tilt in the diagram.
- Figure 12 The absorption line redshift pattern for the diffuse stellar disc of M31 adapted from Babcock (1939). The two symbols represent the two instrumental systems used by Babcock. The inner major axis emission line data from Figure 8 are shown with shaded regions in the center. The rotational component of the inner data has been scaled down by a factor of 0.9 to account for the 25° difference in position angle of the major axis since Babcock assumed a conventional value near 39° . Segments of six parallel rotation curves are shown as smooth extensions of the inner data and represent the Babcock observations very well. At the lower edge of the figure,

(Fig. 12) the larger scale alternating dual stream pattern in M31 is indicated and shown to associate with the locations of the primary spiral arms according to Baade (1948).

Figure 13 Residual diagrams for HII observations from deHarving and Pellet (1975) in M31 when the observations are corrected for a simple smooth symmetrical rotation and expansion model. Three separate samples are shown, in the X intervals indicated, to isolate the overpowering effect of the large number of data points in one region. The power spectrum of the first sample is given with the solid line in the lower part of the first panel. The power spectrum of the second sample is shown dashed.

Figure 14 The upper (a) panel is the residual diagram for HI observations in the outer parts of M31 from Roberts (1966). The identical model used to fit the HII pattern was used to form the HI residuals. Away from the nuclear region the 10' beam resolution of the HI survey is sufficient to separate the two streams. The good spectral resolution in HI produces peaks distinctly sharper than the HII data in Figure 13. The lower (b) panel shows the HI residuals in the inner part of M31 where the spatial resolution is insufficient to separate the streams and a general blur bridging the two main states occurs. The importance of both high spectral and spatial resolution is well illustrated in this figure and Figure 13.

Figure 15 The northern and southern ends of M31. Points within ± 20 km sec⁻¹ of the state values are shown for HI (large circles) and for the deHarving and Pellet (1975) HII (small circles). Rubin and Ford (1970) HII data (squares) are shown for points within ± 25 km sec⁻¹ of the state values. Filled symbols refer to points near the -70 km sec⁻¹ state and open symbols to the 0 km sec⁻¹ state. Plus and minus symbols refer to more extreme states near -140 or $+70$ km sec⁻¹. Some points are omitted in crowded locations. In particular about 80 $+70$ points are located in the small box at $X=-75$. The two primary arms in each region are marked and identified by the Baade (1948) designations. The alternating nature of the arms is readily apparent. Small arrows indicate clumps of material where a mixture of states occurs within a single arm, thus although an arm contains a dominant state lesser amounts of the alternate state can appear. The S6 arm, represented by the points near $X=-75$, appears to be $+70$ material and may represent residual material from an earlier state of M31.

Figure 16 HI residuals from the southwest complex region of M31. Redshift residual is plotted against Y coordinate for the declination scans passing 20° (filled circles) and 25° (open circles) south of the M31 nucleus (X in the range -30 to -40). This is one of the regions responsible for the concept of warping in the M31 disc. The physical spacing of the streams is such that they are barely resolved as can be seen from Figure 15. Note that the Y values of the -70 and 0 states

(Fig. 16) match smoothly the corresponding arm extensions in Figure 15. Note also the presence of small amounts of the +70 state intermixed with the principal states. The data fit the multiple redshift concept very well but convey little impression of a smooth continuous warping.

Figure 17 The upper (a) diagram is an HI redshift-right ascension countour diagram for a constant declination scan near the center of the LMC adapted from McGee and Milton (1966). The two straight lines drawn at a 75 km sec^{-1} separation represent the main HI concentrations well and are consistent with the dual redshift concept. The lower (b) diagram is adapted from Hindman (1967) and shows the redshift of the peaks in the HI distribution as a function of distance along the major axis of the SMC. HII data from Smith and Weedman (1973) on the same coordinate system is shown by crosses. Again the two lines drawn at 75 km sec^{-1} spacing represent the bulk of the data.

Figure 18 Redshift-longitude diagram for the nucleus of the Galaxy. Redshifts of the prominent 3 kpc "expanding arm" are plotted as crosses and have been read from Kerr (1969). Redshifts of individual maxima in the HI distribution with $V < -180 \text{ km sec}^{-1}$ are also from Kerr (1969) and shown with open circles. Vertical lines with $V < -180 \text{ km sec}^{-1}$ indicate the location of HI clouds according to Burton (1970). Solid lines have been drawn through the two sets of data points at a spacing of 140 km sec^{-1} and dashed lines at other spacings near 70 km sec^{-1} .

(Fig. 18) The nuclear redshift discontinuity suggested for the Galaxy is shown shaded. The multiple redshift model is in good accord with the negative redshift material. The positive offset of the zero redshift material at the nuclear discontinuity would be expected if there is an expansion present in the Galaxy at the sun.

Figure 19 Schematic plan view derived in modeling of the Galaxy. The sun is shown with usual symbol and longitude increases counterclockwise about the sun. The two spiral arms are shown with different weight lines and reference points are identified. The general longitudes at which "high velocity" HI clouds concentrate are shown.

Figure 20 The upper (a) diagram is the redshift-longitude diagram for the Galaxy that would arise from the schematic model in Figure 19 assuming that the solar arm (heavy line) consists entirely of normal material and the counter arm (lighter line) consists entirely of material with a -70 km sec^{-1} intrinsic redshift component. Rotation and expansion functions from Table 2 were utilized. The lower (b) diagram is the same as the upper excepting that each stream is allowed to contain a second intrinsic component. The redshift which most likely dominates is shown solid, the secondary value dashed. Comparison of Figure 20b with comprehensive HI maps such as given by Weaver (1970) shows good overall agreement. The longitude locations of high and intermediate velocity HI clouds are also shown. Circled N and S symbols indicated the preference of high velocity clouds of one sign to fall

(Fig. 20) in the northern or southern hemisphere and suggest a lateral displacement of the indicated streams.

Figure 21 The redshift distribution of negative redshift "high velocity" and "intermediate velocity" HI clouds using data from Verschuur (1973). The distribution shows peaks with a spacing consistent with the multiple redshift concept.