THE MOTION OF THE LOCAL GROUP OF GALAXIES WITH RESPECT TO THE BACKGROUND OF GALAXIES

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A measurement of the motion of the Local Group of galaxies through the Universe provides an indication of their peculiar motion relative to the Hubble flow consequent upon the gravitational influence of the local large scale mass inhomogeneities. This motion can be measured either relative to the cosmic microwave background at $z \sim 1000$ or relative to the background or nearby ($z \sim 0.01$) galaxies. The interpretation of published measurements is subject to some uncertainty. As an example, the Local Group motion derived from optical studies of nearby galaxies (Rubin et al. 1976) differs from that derived from radio frequency measurements of the dipole anisotropy in the microwave background. (Boughn et al. 1981, Gorenstein & Smoot 1981).

At Jodrell Bank, Hart & Davies (1982) have made a new determination of the Local Group motion relative to the background of galaxies which obviates many of the difficulties inherent in previous optical determinations. The 21 cm neutral hydrogen flux density integral of each galaxy, an indicator of the HI mass, is used as a standard candle. No correction is required to this integral for inclination or galactic absorption. The velocity width of the neutral hydrogen profile is used as a third parameter to indicate whether the galaxy is a giant or a dwarf; this is similar to the Tully-Fisher approach for optical or infrared distance determination.

The basic data set used in our determination is the HI survey of Sbc (T=4 in the de Vaucouleurs morphological classification) galaxies by Davies & Johnson (1983). These galaxies were chosen so as to give a good sky coverage down to Dec = -30°; they were supplemented by southern galaxies in the HI survey by van Woerden et al. The velocity range covered was 1000 to 5500 km s^{-1}. An independent data set was taken from the HI observations of Sc galaxies published by Rubin et al.

In the analysis we take the observed velocity of the galaxy, V_c, corrected to the centre of the Local Group, to be composed of the following components

$$V_c = V_H + \Delta V_G + V_{pec}$$

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where V_H is the velocity it would have in the Universal Hubble flow, ΔV_G is the component of the Local Group motion in the direction of the galaxy and V_{pec} is the random velocity of the galaxy. We determine from a series of expressions of this form, the vector V_G giving the velocity of the Local Group relative to the backdrop of galaxies. An estimate of the true distance of each galaxy, and hence V_H, is provided by its HI flux density with a correction for its profile width.

Table I Observations of the motion of the Local Group of galaxies

Method	V_{LG} (km/s)	ℓ (o)	b (o)	L (o)	B (o)
HI fluxes: 78 Sbc galaxies	436±55	264±18	45±12	119±14	-29±12
HI fluxes: 53 Sc galaxies	580±62	245±18	35±9	111±13	-45±9
CMB: Boughn et al.	653±33	273±6	27±5	140±6	-35±5
CMB: Gorenstein & Smoot	567±60	256±9	41±7	117±8	-36±7
Average of above	546±70	261±9	39±7	122±9	-35±7

Table 1 gives the motion of the Local Group of galaxies derived from the HI and cosmic microwave background (CMB) measurements in galactic (ℓ,b) and supergalactic (L,B) coordinates. There is evident agreement between the CMB and galaxy backdrop results; the average gives the present best estimate of the Local Group motion. The disagreement with the Rubin et al. results is emphasized.

We draw the following conclusions from the data presented above.

1. The close agreement between the HI and the CMB results implies that the two types of measurement are the result of a common cause - the local group motion.
2. The CMB dipole anisotropy is mainly extrinsic, $\lesssim 1$ mK out of the observed 3.5 mK is likely to be intrinsic. We would expect the intrinsic quadrupole anisotropy to be <<1 mK.
3. The Local Group is moving within $\sim 30^o$ of the direction of the centre of the Virgo cluster of galaxies; the component of infall is 450 ± 50 km s^{-1}.
4. If this infall were due to the gravitational influence of the Virgo cluster acting over the lifetime of the Universe, the local density relative to the closure density is Ω = 0.15 to 0.50.

REFERENCES

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Discussion

B. Jones: What is the selection criterion for your samples and what causes the difference between your results and the old result of Rubin and collaborators?

Davies: Our set of Sbc galaxies is composed essentially of the brightest objects in the Second Reference Catalogue. The majority are of luminosity classes L = 1 to 4.

The reason for the difference between our HI result and the earlier Rubin et al. result is not entirely clear. It is most likely a large-scale effect over the celestial sphere, for example, a variation of Zwicky magnitudes around the sky and/or an incorrect galactic absorption correction.

Hanes: Could you remind us of the agreement between your study and that of de Vaucouleurs? Do these studies, which both pertain to moderately remote galaxies, agree on the existence of a (small) discrepancy between the inferred motions and the cosmic microwave background? If so, what is the significance?

Davies: The de Vaucouleurs et al. sample contains galaxies which are on average closer by ∿ 30% than those we have used. Thirty percent of the de Vaucouleurs galaxies have a velocity less than 1000 km s^{-1} and ten percent are Virgo cluster members; all these galaxies will be influenced by the Virgo-centric flow. Even so, the de Vaucouleurs local group motion is in a similar direction to our solution, although significantly smaller in magnitude.

The difference between our result and the CBR result could be due to a small (∿ 1 mK) intrinsic component of the CBR or due to a motion of our volume of space (out to a redshift of 5000 km s^{-1}) relative to the comoving frame.

Segal: We have used a nonparametric and statistically optimal technique to estimate the motion of the Local Group from optical magnitudes and redshifts in the large Visvanathan E + SO sample, from the distortion such a motion would produce in the observed magnitude-redshift relation. Our cutoff-bias-removed least-squares estimate is largely independent of whether the Hubble or Lundmark law is used to supply the requisite magnitude-redshift regression, and is about 450 km s^{-1} in the direction L = 220 to 230; B = 10 to 20. An independent estimate using the same sample but based on the maximization of spatial homogeneity as measured by a V/V_m test with redshifts conservatively limited to 2250 km s^{-1} (and greater than 500 km s^{-1}), still inclusive of ∿ 200 galaxies brighter than the limiting magnitude of 12.4, also gives an estimated motion of similar magnitude almost in the galactic plane but slightly below it. Are these estimates at least marginally consistent with yours? If not, do you have a suggestion regarding the discrepancy? If they are, can you give any physical explanation for the apparent motion to be largely in the galactic plane? It seems interesting that if the component of this apparent motion in the plane is removed, the remaining motion is of the order of magnitude ($\lesssim$ 100 km s^{-1}) of the apparent peculiar velocities typical of other galaxies.

Davies: Your derivation of the Local Group velocity appears to be in the same general direction as our measurement. I believe that our results, based on samples extending to greater redshifts than your sample, show that the motion is directed significantly out of the galactic plane. This is also true of the microwave background dipole asymmetry.

Miller: The difference between your solution and the CBR solution (which presumably gives our velocity relative to comoving coordinates) could be interpreted as motion of the Virgo-centric group relative to comoving coordinates. Do you think this is reasonable?

Davies: Our solution for the Local Group motion is referred to a sphere of galaxies extending to a radius of 5000 km s^{-1} ($\sim$ 75 Mpc) around us. The difference of $\sim$ 100 km s^{-1} between our solution and the CBR solution might indicate the motion of this whole volume towards some nearby supercluster, if sufficiently massive.