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SYSTEMATIC ERRORS IN GALAXY REDSHIFTS

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Environ 410 galaxies possèdent une estimation de leur vitesse de récession déduite à la fois des spectres optiques et des observations de la raie 21cm. La comparaison de ces observations est un moyen sensible de détecter les erreurs systématiques. A partir de l'énorme quantité de données expérimentales dont on dispose à ce jour, ce papier a pour but de vérifier le travail antérieur de Roberts, sur l'effet de décalage vers le rouge, et de tester les erreurs d'échelle et les erreurs corrélées au type, à la couleur, à l'inclinaison ou au degré de concentration central.

Lewis (1975) summarizes most earlier data and work on systematic errors in the systemic velocities of galaxies. The more recent observations of Gallagher et.al. (1975), Huchtmeier et.al. (1976), and Shostak (1975) have been used to correct and place realistic error-estimates on some of the 21 cm observations. Most of the newer data are from Rubin et.al. (1976), Roberts and Shostak (1975), Peterson and Shostak (1974), Huchtmeier and Bohnenstengel (1975), Rood and Dickel (1976), Dean and Davies (1975) and from Bottinelli and Gouguenheim (1976). Comparisons between the 21 cm data treated as a single set V_{21} and the various sources of optical data largely reproduce the results obtained by Lewis with smaller samples.

The most significant result of the increase in data size, is the improved delineation of the Roberts' redshift effect. Roberts (1972) noticed that velocities obtained from the blue spectral region were over-estimated by 100 km s^{-1} in the range 1200 to 2400 km s^{-1}. Most of the effect was found by Lewis (1974) to be due to the Lick (L) velocities of Humason, Mayall and Sandage (1956) and of Mayall and de Vaucouleurs (1962).

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Figure 1 shows these differences. A systematic effect is evident from about 1600 to 2800 km s^{-1}. It begins in the region from 1400 to 1600 km s^{-1} for which $\bar{\Delta}_{21-L}$ = -75±34 (σ=111) km s^{-1}. After adjusting for this scale error, the 150 Lick Observations L' give $\bar{\Delta}_{21-L'}$ = -4.8±6.9 (σ=85) km s^{-1}. The adjusted observations are used in all later comparisons.

The differences Δ_{21-W} between V_{21} and the low dispersion Mt. Wilson velocities of Humason et.al. are plotted in Figure 2. Suggestions of scale errors between +200 and +800 km s^{-1} and between 1600 and 2800 km s^{-1} exist, but are partly masked by the greater dispersion of this source. Over the latter range, the trend followed by the Mt. Wilson data is parallel to that of the Lick data. Direct comparison of the two optical sources in this range gives $\bar{\Delta}_{Wa-L}$ = -47±16 (σ=88) km s^{-1} from 33 pairs, whilst the mean over all velocities is $\bar{\Delta}_{21-W}$ = -0.4±9.8 (σ=105) km s^{-1} from 116 pairs. No adjustment of the Mt. Wilson data is worthwhile.

While the origin of the Roberts' effect is uncertain, it may be encountered to some degree, in any source of observations that are made in the blue spectral region. Thus comparison of V_{21} with the data of de Vaucouleurs and de Vaucouleurs (1967) results in only four differences in the range of interest. Three of these are large, and all are primarily derived from measurements on emission-lines. From the extent data, the Roberts effect seems to perturb both absorption and emission-line observations from the blue spectral region; it does not affect observations of emission-lines in the red spectral region (cf Lewis, 1975). Accuracy is greatly improved when observations depend primarily on emission lines. Experience also shows that the variance is halved by working in the red spectral region (cf Rubin et.al. 1976).

Rubin et.al. (1976) obtain from their own observations of 120 Sc galaxies $\bar{\Delta}_{21-Opt}$ = +3±5 (σ=50) km s^{-1}. Their earlier independent data for Sc galaxies gives $\bar{\Delta}_{21-Opt}$ = +27±11 km s^{-1}. When three double systems are excluded (with Δ of 48, 48, 85), the mean drops to +13±11 km s^{-1}. These data are therefore unbiased. Comparison of V_{21} with the velocities determined by the Burbidges gives $\bar{\Delta}_{21-B}$ = -18±7 km s^{-1} from 37 pairs. But the mean for types Sb to Sm is a significant, -30.8±5.3 (σ=25) km s^{-1} from 23 pairs. After this correction is applied, these sources give no scale errors and can be combined with the adjusted Lick and all other sources to provide an adopted optical velocity (A) for comparison with V_{21}.

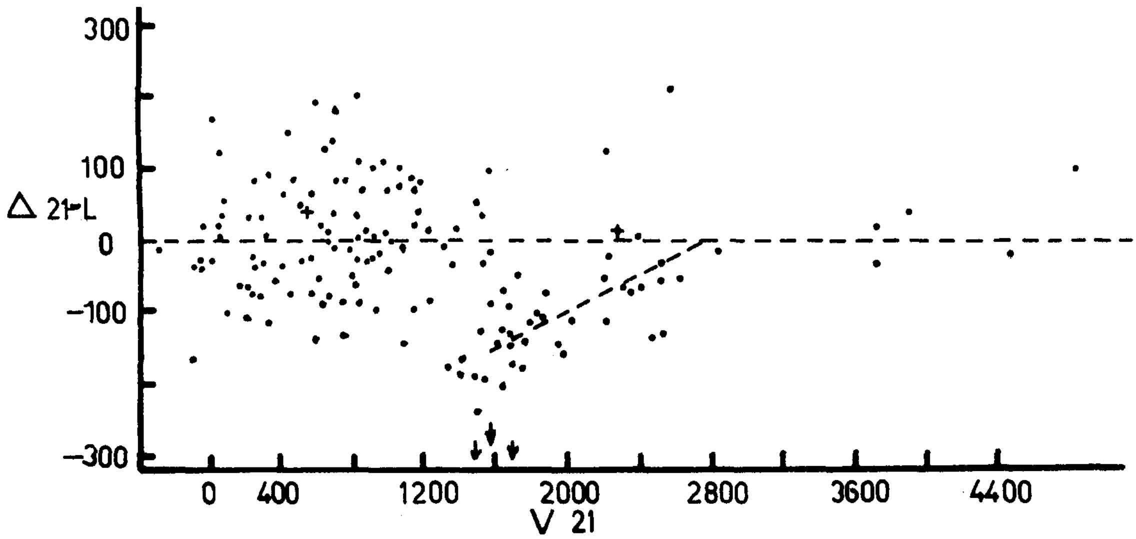

Fig. 1: Distribution of the differences (V_{21}-V_{Lick}) as a function of 21-cm velocity V_{21}.

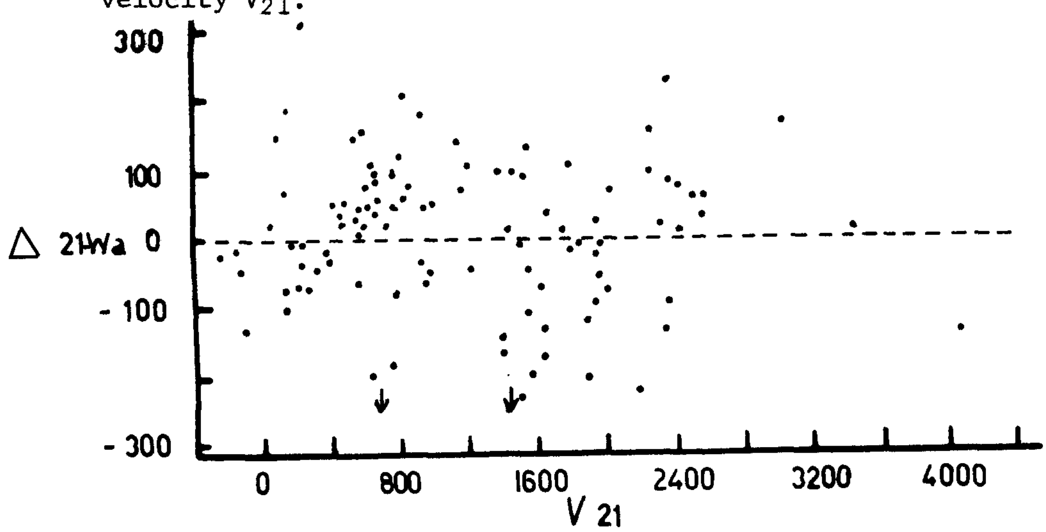

Fig.2: Distribution of the differences (V_{21}-$V_{Mt.\ Wilson}$) as a function of 21-cm velocity V_{21}.

TABLE I: Comparison V_{21} minus V_A with type*

Type (τ)	τ≤2	3	4	5	6	7,8	9	I9
$<V_{21}-V_A>$	+4	+11	+8	+5.2	+8	+4	-18	-40
$\sigma N^{-\frac{1}{2}}$	12	12	10	4.3	9	13	15	8
σ	87	71	59	57	55	52	61	31
N	49	34	35	172	35	17	16	14

* units km s^{-1}; $|\Delta| < 3\sigma$

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Tables I and II summarize the results of comparing the differences Δ_{21-A} with morphological type (τ) and colour. The tendency for Sb to Sd spirals to have a net positive mean in comparison with other types is weaker in the present data, and enables the mean $\bar{\Delta}_{21-A}$ = +6.1±3.4 (σ=63) km s^{-1} to represent all types earlier than Sm. The irregular magellanic (I9) class retains a significantly negative mean.

TABLE II: Comparison V_{21} minus V_A with (B-V)(0)*

Range (B-V)(0)	≲0.4	0.5	0.6	0.7	0.8	0.9	>	All
$<V_{21}-V_A>$	-52	-17	+4	+11	+11	+18	+1	+5.4
$\sigma N^{-\frac{1}{2}}$	23	11	10	8	8	13	16	4.4
σ	61	52	67	57	61	84	53	69
N	7	22	48	49	60	39	11	236

* units km s^{-1}; $|\Delta| < 3\sigma$

A least squares fit to the velocities, allowing for errors in both gives

$$V_{opt} = (0.99889 \pm 0.00092)\ V_{21} + (0.8 \pm 3.8)$$

These differences showed no significant dependence on the inclination of the observed galaxy, unless the nucleus was star-like and had a Byurakan classification of 4 or 5 (cf Lewis, 1975a). For those with inclinations $i < 53^{o}$ and a stellar nucleus, $\bar{\Delta}_{21-A}$ = +26.4±7.7 km s^{-1}, the rest have a mean of +6.2±4.4 km s^{-1}. This result is only half the size of that reported previously.

CONCLUSION: The doubling of the sample of data has generally weakened all of the reported systematic errors that appeared to depend on type, colour and inclination. It has allowed the scope of the "Roberts' effect" to be delineated. Some sources of optical velocities require a small systematic correction to bring them into agreement with the 21 cm-line velocities. A residual difference of ~ 5 km s^{-1} remains between the optical and 21 cm velocities overall, when the outliers are discarded.

I thank Dr. M.S. Roberts, V.L. Rubin and H.J. Rood for sending me data in advance of publication.

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DISCUSSION

G. DE VAUCOULEURS: I should like to call your attention to the reduction of optical and radio redshifts to uniform "error free" systems described by our group in the introduction to the "Second Reference Catalogue of Bright Galaxies".

B.M. LEWIS: In general I agree almost entirely with the statistical results you have found in the Second Reference Catalogue. I find the optical and 21-cm estimates to be in agreement to about 5 km s^{-1}. The main difference is in the different treatment of the corrections required for the "Roberts Redshift Effect".

M.S. ROBERTS: Some of the difference in optical *vs* 21 -cm redshift analyses as discussed by Lewis and by de Vaucouleurs may well lie in how the average "optical" redshifts are formed. As an example the systematic difference between 21-cm and blue optical determinations in the radial velocity range ~ 1400-2600 km s^{-1} is clearly evident in an optical *vs* optical comparison, specifically blue *vs* red.

B.M. LEWIS: Comparison of optical velocities from the red end of the spectrum (Hα, λ 6548, 6583 and SII lines etc.) show no scale distortions when compared with 21-cm velocities.

L. GOUGUENHEIM: Have you any comment concerning the quoted errors for both optical and 21 -cm line velocities? This point is important in connection with the problem of the stability of groups of galaxies.

B.M. LEWIS: For 21-cm velocities alone, an accuracy of about ± 10 km/s is realistic in most cases, as differences of technique and departure from symmetry can affect the results.

For recent optical velocities such as those of Rubin et. al., the quoted errors are realistic.

For older series (Lick and Mt. Wilson), the error estimates from internal consistency and from comparison with other optical series of velocities require to be increased by about 50 %.

Overall the 21-cm velocities are generally of much better quality than optical values.

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