

Possible local variation of the Hubble constant in van den Bergh's calibration of Sc-type galaxies

IN an important series of papers for the determination of the Hubble constant, Sandage and Tammann^{1–6} have concluded that the Universe is expanding in a remarkably uniform and isotropic way, with Hubble constant (H) $55 \pm 5 \text{ km s}^{-1} \text{ Mpc}^{-1}$. If true, this result is evidently crucial for all future cosmological models. As a consequence it should be tested and analysed in all possible ways. Their low H value is evidently based on their recalibration of the absolute magnitudes of the various luminosity classes of Sc-type galaxies based on two samples of nearby, and one sample of distant galaxies (Tables 3 and 4, ref. 5, and the Table, ref. 6).

Table 1 Recalibration of Sandage and Tammann's data on sources in local supergalaxy anticentre direction using van den Bergh's absolute magnitudes

| Sc classes | M_{ST} | M_{vdB} | $\alpha = H_{vdB}/H_{ST}$ |
|------------|----------|-----------|---------------------------|
| I | –21.25 | –20.0 | 1.778 |
| I–II | –20.74 | –19.7 | 1.614 |
| II | –20.23 | –19.4 | 1.466 |
| II–III | –19.72 | –18.9 | 1.459 |
| III | –19.21 | –18.3 | 1.521 |

Here we discuss some consequences of Sandage and Tammann's specific choice of absolute magnitudes, and to compare them with the calibration of van den Bergh⁷, which had been generally accepted in the literature.

Two preliminary remarks should be made here. First, starting from the data and calibration of Sandage and Tammann, de Vaucouleurs has analysed possible variations of the redshift distribution with supergalactic longitude and latitude, and discovered significant deviations from isotropy. Second, if one calculates H using only the Sc I galaxies, one does indeed

log $v \leq 3.3$. The same has been done for distant Sc I galaxies—we have restricted the calculation (as prescribed by Sandage and Tammann) to the 40 anticentre objects with log $v \leq 3.92$.

The results are summarised in Table 2. Column 1 shows the Sc classes analysed; columns 2 and 3, the corresponding H values obtained in calibrations by Sandage and Tammann and van den Bergh for the sample of 7 Sc I, 4 Sc I–II and 8 Sc II nearby unbiased anticentre galaxies. Columns 4 and 5 contain the respective H values for the unbiased sample of 40 distant anticentre Sc I galaxies.

We derive three conclusions from Table 2. The first is that Sandage and Tammann's calibration yields significant differences in the $\langle H \rangle$ values obtained with different types of nearby Sc galaxies—a fact difficult to reconcile with their own assumptions. The second is that van den Bergh's calibration, though possibly open to criticism, does not present this inconvenience, and yields a consistent $\langle H \rangle$ value for all classes of nearby Sc galaxies: $\langle H \rangle = 111.2 \pm 6.3 \text{ km s}^{-1} \text{ Mpc}^{-1}$, for 19 objects. The third is that this latter value differs significantly from the distant Sc $\langle H \rangle$ value (that is, $\langle H \rangle = 92 \pm 5 \text{ km s}^{-1} \text{ Mpc}^{-1}$) since we have $\Delta H = 19.2 \pm 8.1 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

If one accepts van den Bergh's calibration, this evidently yields a statistically significant decrease of H with distance, since for the hypothesis $H(\text{nearby}) = H(\text{distant})$, $t = 2.38$ ($P < 0.05$). Finally it should be noted that the existence of such a variation of H is independently supported by very recent determinations of the distance D of 29 Sc-type galaxies (12 of which belong to the preceding Sandage–Tammann sample) made on the 21-cm line at the Nançay Radiotelescope by Durand⁸ and Bottinelli *et al.* (unpublished). Indeed, if one divides Durand's result into two groups: the first with 15 objects at $D \leq 30 \text{ Mpc}$ and the second with 14 objects at $D > 30 \text{ Mpc}$, one obtains $\langle H \rangle_1 = 95.2 \pm 11.0$ and $\langle H \rangle_2 = 63.5 \pm 5.4 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

Obviously, this possible variation of H with distance can be correlated with the angular anisotropy of H observed by

Table 2 Comparison of values of H obtained for the new calibration, for the two samples described in the text

| Sc-type | H_{ST} $\text{km s}^{-1} \text{ Mpc}^{-1}$ | H_{vdB} $\text{km s}^{-1} \text{ Mpc}^{-1}$ | H_{ST} $\text{km s}^{-1} \text{ Mpc}^{-1}$ | H_{vdB} $\text{km s}^{-1} \text{ Mpc}^{-1}$ |
|---------|-------------------------------------------------|--------------------------------------------------|-------------------------------------------------|--------------------------------------------------|
| Sc I | 61.40 ± 6.84 | 109.16 ± 12.16 | 51.73 ± 2.72 | 91.98 ± 4.83 |
| Sc I–II | 67.83 ± 9.59 | 109.48 ± 15.5 | | |
| Sc II | 77.61 ± 5.99 | 113.70 ± 8.82 | | |

find the same H at all distances, although Sandage and Tammann's unbiased data for Sc II anticentre galaxies (Tables 3 and 4, ref. 5), yield $\langle H \rangle = 77.6 \pm 6.0 \text{ km s}^{-1} \text{ Mpc}^{-1}$, which differs significantly from the result for Sc I anticentre galaxies (Table 2) $\langle H \rangle = 61.4 \pm 6.8 \text{ km s}^{-1} \text{ Mpc}^{-1}$ so that $\Delta H = 19.2 \pm 8.1 \text{ km s}^{-1} \text{ Mpc}^{-1}$ (Student's $t = 2.53$).

If, then, one accepts de Vaucouleurs' result (unpublished), that the overall motion of the local supergalaxy contributes significantly to the redshift distribution, one should concentrate discussion of the possible consequences for H determination of a recalibration of Sandage and Tammann's samples with van den Bergh's absolute magnitudes, on sources located in the anticentre of the local supergalaxy direction.

We do this in Table 1. Column 1 shows the Sc classes used in Sandage and Tammann's determination of H ; columns 2 and 3, the values of the corresponding absolute magnitudes used by them and by van den Bergh, column 4, the numerical factors by which the $H = v/r$ values of Sandage and Tammann should be multiplied, to pass to the corresponding values in van den Bergh's calibration, that is α in $H_{vdB} = \alpha H_{ST}$.

The calculations have been performed on all the unbiased anticentre galaxies in refs 5 and 6. For nearby galaxies we have used exactly the limit proposed by Sandage and Tammann to eliminate a possible bias, that is, for those with values of

Rubin, Ford and Rubin⁹, which has been confirmed on various types of source¹⁰. Independently of any specific interpretation (such as a variation of the redshift of photons passing through the radiation field of distant galactic clusters¹⁰, this conflict between the results of calibrations on the same sample by Sandage and Tammann and van den Bergh shows that further observational work needs to be done on this calibration problem.

We thank Drs L. Bottinelli, N. Durand, L. Gougenheim, J. Heidmann, G. Paturel, and Professor G. de Vaucouleurs for helpful discussions and advanced communication of their results.

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Received June 30; accepted September 23, 1975.

- Sandage, A., and Tammann, G. A., *Astrophys. J.*, **190**, 525 (1974).
- Sandage, A., and Tammann, G. A., *ibid.*, **191**, 603 (1974).
- Sandage, A., and Tammann, G. A., *ibid.*, **194**, 223 (1974).
- Sandage, A., and Tammann, G. A., *ibid.*, **194**, 559 (1974).
- Sandage, A., and Tammann, G. A., *ibid.*, **196**, 313 (1975).
- Sandage, A., and Tammann, G. A., *ibid.*, **197**, 265 (1975).
- van den Bergh, S., *Pub. David Dunlap Obs.*, **2**, (1960).
- Durand, N., thesis, Univ. Paris (1975).
- Rubin, V. A., Ford, K., and Rubin, J., *Astrophys. J. Lett.*, **183**, L111 (1973).
- Jaakkola, T., Karoji, H., Moles, M., and Vigier, J. P., *Nature*, **256**, 24 (1975).