Colloque de l'Union Astronomique Internationale
N° 37 – DECALAGES VERS LE ROUGE ET EXPANSION DE L'UNIVERS

DISTANCES DE GROUPES ET AMAS PROCHES ET LA VALEUR LOCALE DU RAPPORT DE HUBBLE

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Résumé

La méthode correcte pour construire l'échelle des distances extragalactiques nécessite l'emploi de tous les indicateurs primaires (novae, cephéides, variables RR Lyrae) et secondaires (étoiles les plus brillantes, amas globulaires, plus grandes régions H II annulaires) pour étalonner sans extrapolation arbitraire tous les meilleurs indicateurs tertiaires (magnitudes et diamètres des galaxies), précisément corrigés de tous les effets connus dépendant du type, de la classe de luminosité, de l'orientation, de l'extinction interne et galactique et du déplacement spectral. De telles données sont maintenant disponibles pour plus de 1000 galaxies du "Second Reference Catalogue".

Les distances révisées des membres du Groupe Local déduites des indicateurs primaires et des estimations nouvelles des distances des groupes les plus proches déduites des indicateurs primaires et secondaires sont utilisées pour étalonner les indicateurs tertiaires par l'intermédiaire d'un nouvel indice de luminosité composite.

Les distances déduites des amas globulaires de 3 amas de galaxies dominées par les elliptiques (Vir I, For I, Hya I) ayant des vitesses corrigées moyennes $1000 \leq V_o \leq 3650$ km s^{-1} donnent pour valeur moyenne du rapport de Hubble $\langle H \rangle = 88(1 \pm 0.15)$ km s^{-1} Mpc^{-1}.

Les distances déduites des indicateurs tertiaires de 19 spirales du champ et 28 groupes proches dominés par les spirales ayant des vitesses corrigées $V_o < 1800$ km s^{-1} donnent $\langle V \rangle = 82\ (1 \pm 0.15)$ km s^{-1} Mpc^{-1}.

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DISTANCES OF NEARBY GROUPS AND CLUSTERS, AND THE LOCAL VALUE OF THE HUBBLE RATIO.

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ABSTRACT

The correct approach to build up the extragalactic distance scale is to use all available primary (novae, cepheids, RR Lyrae) and secondary indicators (brightest stars, globular clusters, largest HII rings) to calibrate without arbitrary extrapolation all reliable tertiary indicators (magnitudes and diameters of galaxies), precisely corrected for all known effects of type, luminosity class, orientation, internal and galactic extinction and redshift. Such data are now available for over 1000 galaxies in the Second Reference Catalogue.

Revised distances to members of the Local Group from primary indicators and new estimates of distances to the nearest groups from primary and secondary indicators are used to calibrate the tertiary indicators via a new, composite luminosity index.

The distances derived from globular clusters for 3 galaxy clusters dominated by ellipticals (Vir I, For I, Hya I) with mean corrected velocities $1000 \leq V_o \leq 3650$ km s^{-1} give a mean Hubble ratio $\langle H \rangle = 88\ (1 \pm 0.15)$ km s^{-1} Mpc^{-1}. This value rests entirely on the calibration of the globular clusters luminosity function in the Galaxy as a gaussian of dispersion $\sigma = 1.1$ mag. and mean $\langle M_B \rangle (\oplus) = -6.55$, with $\langle (B-V)_o \rangle = 0.75$, based on the adopted RR Lyrae zero point $\langle M_V \rangle (RR) = +0.86 \pm 0.15$.

The distances derived from tertiary indicators to 19 field spirals and 28 nearby groups dominated by spirals with corrected velocities $V_o < 1800$ km s^{-1} give $\langle H \rangle = 82\ (1 \pm 0.15)$ km s^{-1} Mpc^{-1}. This value rests on the relations between luminosity index and fully corrected absolute magnitudes or linear

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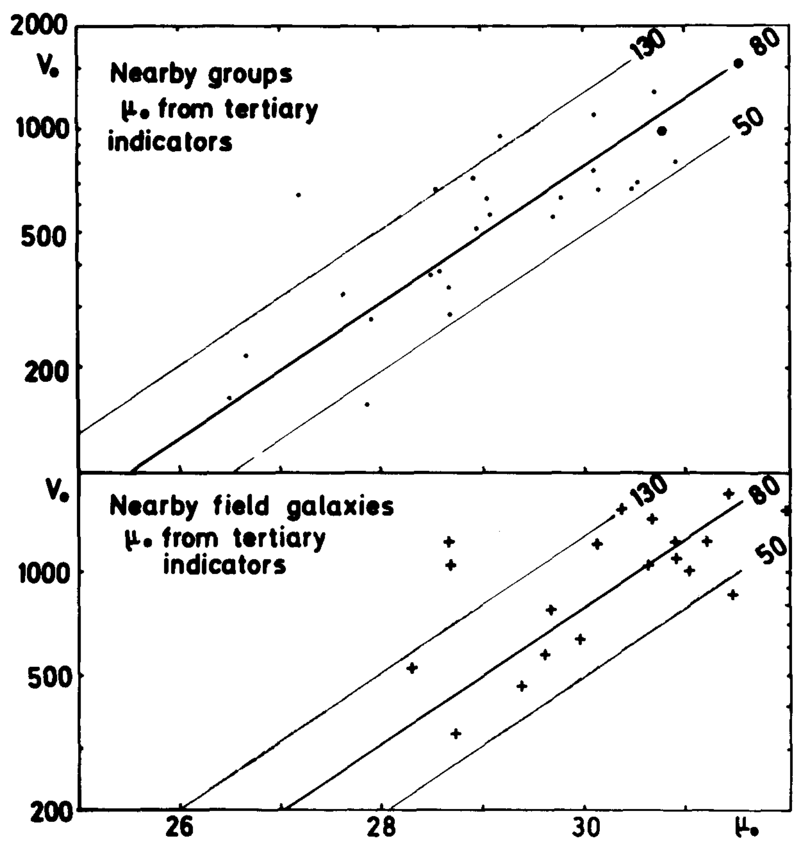
diameters of galaxies derived without extrapolation and calibrated in ~20 nearby galaxies by seven secondary indicators. The zero points were derived from the 3 primary indicators, including 15 galactic novae with $\langle M_{15} \rangle = -5.5 \pm 0.15$, and 13 cepheids in 8 galactic clusters with $\langle M_B \rangle (\log P_o = 0.8) = -2.92 \pm 0.15$ (for an adopted Hyades modulus of 3.16 ± 0.05).

The low values of $H_o \simeq 50$ to 55 can be explained by an accumulation of complex systematic errors arising from a multiplicity of sources. These errors, all but one acting in the same sense, have been identified and evaluated; a full report will appear elsewhere.



Velocity-distance modulus relation for field spirals and nearby groups derived from tertiary indicators.

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DISCUSSION

W.T. SULLIVAN,III: a) In your composite luminosity index, is it correct that two types of galaxies, e.g. an Sb II and an Sc I, are equivalent in terms of your calibration of distance indicators? b) If so, is there any physical basis as to why this should be so?

G. DE VAUCOULEURS: a) Yes, b) No, not yet; but, then, when the P-L relation was discovered, there was no known physical basis for it.

L. GOUGUENHEIM: Do the dwarf galaxies fit this scheme? (Do they enter the Λ = T + L classification) Fisher and Tully have found that they cover a very large luminosity range though having about the same type.

G. DE VAUCOULEURS: Yes, but the magnitude discrimination near Λ = 1.8 and 1.9 is poor because the DDO scheme apparently fails to discriminate between normal distant and dwarf nearby Sm-Im types, as shown by Fisher and Tully. However, this is not important for the distance scale problem because we use mainly the brightest or largest members of distant groups to estimate distances, not their (generally uncatalogued) dwarfs.

M. ROWAN-ROBINSON: I would like to ask a question that I put to Tammann at the Local Group conference last summer: what is the range outside which you could not imagine the Hubble constant lying? (I think Tammann's answer was $H_o \ngtr 100, \nless 30$).

G. DE VAUCOULEURS: This is the kind of question that is impossible to answer, because there is no known upper limit to the blunders of mankind - of which physicists and astronomers are unfortunately a subset. All I can say within the framework of conventional wisdom is that to the best of my current knowledge of the basic calibrators, systematic corrections, etc. and for Δ < 40 Mpc, $< \log H_o > = 1.93 \pm 0.05$ where the error is an estimate of the standard deviation from all known sources of errors. - No one can predict the possible size of as yet unknown systematic errors, perhaps due to our use of the wrong theoretical framework (suppose some of the current "heretics" are right after all?).

I.E. SEGAL: In order to make a model-independent statement, it would seem desirable to associate estimates of the Hubble parameter with specific distances; or alternatively, to associate specific distances

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with given redshifts. May I ask, therefore, what distances you would consider your respective estimates primarily to refer to?

G. DE VAUCOULEURS: I specified $1000 < V_o < 3650$ kms^{-1} for the 3 clusters of ellipticals, (i.e. $12 < \Delta < 40$ Mpc) and $200 < V_o < 1800$ kms^{-1} ($2 < \Delta < 22$ Mpc) for the groups of spirals used to estimate the mean local value of H.

P. BIERMANN: Could Dr. Tammann answer the question of Dr. Rowan-Robinson so that we have the comparison of your range and the range mentioned by Dr. de Vaucouleurs?

G.A. TAMMANN: I cannot imagine the Hubble-constant to be above 70 km/sec/Mpc and I cannot quote a lower limit - except for $H_o < 30$ our Galaxy is suspiciously dwarfed in comparison with field galaxies.

J.C. PECKER: I would hate to reply to Dr. Rowan-Robinson's question. To me, $< H >$, as determined by either of the two groups of authors, is an <u>average</u> or a <u>sample</u> concerning a certain <u>local</u> past of the universe. Anisotropy, inhomogeneities cannot be ruled out; hence I would consider that the question is meaningless!

J.M. BARNOTHY: In the FIB cosmology, where the Hubble constant H is equal to the square root of the cosmological constant, Λ, the value of H can be computed from fundamental physical constants. The FIB cosmology belongs to the class of cosmologies in which some fundamental physical units change with time. It differs, however, from the other cosmologies of this class (Haas, Dirac, Brans-Dicke, Hoyle-Narlikar) in that respect that time, length and mass units change at the same rate; the parameter of the change being $\Lambda^{\frac{1}{2}}$. It is a non-expanding Friedmann universe of projective geometry, in which $\Lambda^{\frac{1}{2}} = \Pi c^3/4GM$, where M is the mass of the universe. Adopting Eddington's theory that the number of stable elementary particles of one kind in the universe is equal to the number of independent wave functions we obtain $M = 1.03 \times 10^{56}$g. In a pressureless universe the value of the Hubble constant becomes $H = \Lambda^{\frac{1}{2}} = 95$ km/s/Mpc. The value could be lower if a significant radiation pressure were present in the form of a neutrino sea.

J.J. WITTELS: Can either Dr. de Vaucouleurs or Dr. Tammann or both explain in a few sentences what is the basis of the disagreement over

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the value of H_o since both of you use basically the same distance indicators? Does it lie in a difference in emphasis on one indicator versus another, or in the presence or absence of additional corrections to specific indicators; or elsewhere?

G. DE VAUCOULEURS: There is no single main reason for the low value of H_o, but an accumulation of systematic errors, most working in the same sense (overestimating distances), and due to incorrect allowance for galactic extinction, faulty extrapolations and unreliable indicators. I have already listed the 6 main classes of errors in session 1. The cumulative errors add up to about 0.4 mag. in the Local Group, 0.4 to 0.8 mag. in the nearer groups and 1.0 mag. at the Virgo cluster. - A detailed technical analysis will appear elsewhere.

G.A. TAMMANN: About ten years ago most astronomers would have agreed that $H_o \sim 75$-100. Then a new effect was found: several fundamental distance indicators change their properties with the size of the parent galaxy. For instance brightest stars or brightest globular clusters and largest H II regions are brighter and larger in giant spirals than in dwarf systems. This is now well established and can be demonstrated without adopting any distance scale, e.g. in the M 101 group. The effect can be understood as a statistical consequence of different sample sizes in the presence of a natural dispersion. The effect seems to introduce only a scatter into the distance determinations. However, the available calibrators in the Local Group are <u>dwarf systems</u> (SMC, NGC 6822, IC 1613) or of quite moderate size (LMC, M33). At larger distances one works necessarily with large or giant systems, hence one compares distance indicators in dwarf systems with those in giant systems, committing in this way a <u>systematic</u> error in the sense of too low distances and too high a value for H_o .

S. VAN DEN BERGH: At this point some of you are no doubt quite confused about the conflicting results on the value of H_o that you have heard so far.

Two major problems face us in attempting to determine the scale-size of the Universe:

1. Present observational techniques have to be pushed to their

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limits to observe Cepheids etc. in distant galaxies.

2. The Local Group, in which our calibrators are located, is a very small cluster. As a result there is a major statistical uncertainty in the calibration of such parameters as the magnitude of the brightest stars or the diameters of the largest H II regions.

The basic reason why each investigator is so optimistic about the mean error of his own particular value of H is that he pre-selects those distance calibration criteria that show a small scatter within the limited Local Group sample.

In view of the present state of the art I feel that it is probably not wise to include the numerical value of H among ones strongest astronomical prejudices.

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