Harmonizing Cosmic Distance Scales in a Post-Hipparcos Era
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Carl Wilhelm Wirtz – Pioneer in Cosmic Dimensions

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Abstract.
The Strasbourg Observatory initiated the first statistical project of celestial nebulae with the goal of deriving their nature. The compilation of this early data base became a link to modern observational cosmology, largely due to Carl Wirtz's early work on nebular proper motions, followed by his introduction of correlations between radial velocities and nebular distance indicators in his most productive period in the nineteen-twenties.

1. Early Nebular Statistics

In 1881, Winnecke, the director of the new observatory of Strasbourg University initiated an extensive observing program of nebular positions, the results to be used as a data base for nebular proper motions. The goal was to reveal 'the cosmic role of the nebulae'.

Carl Wirtz joined the Strasbourg Observatory in 1902. Among his early work were solar-system observations. His measurement of the diameter of Neptune in 1903 yielded the best value for decades. He also became a member of the nebular team. The project was terminated in 1910 and, subsequently, Wirtz reduced the 1 257 nebulae of the Strasbourg project. In the following years, he used the data with the goal of deriving the nature of the nebulae from their proper motions. His first short publication based on these data was published in 1912. Combining the nebular positions from the Strasbourg data with 500 earlier ones from Schulz, Uppsala, he thought to have obtained nebular proper motions, although with low accuracy. The note "An attempt concerning the cosmic role of the nebulae" was Wirtz's first step towards observational cosmology.

In 1916, Wirtz completed the Strasbourg Catalogue of Nebulae and published it in the 'Annalen der kaiserlichen Universitäts-Sternwarte Straßburg'. Based of these data, Wirtz wrote four papers on the solar apex and the secular parallax of nebulae in the 'Astronomische Nachrichten' from 1916 to 1918. Due to World War I, he was then already drafted into the German army and stationed in Berlin, never to return to Strasbourg.

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2. New Theories, New Observations and Applications to Nebulae

In early 1917, Einstein's General Relativity of 1915 was extended to Relativistic Cosmology including a Λ term. In the autumn of 1917, de Sitter introduced the 'massless' universe, with scarce 'nebulae' providing negligible mass to the universe while moving towards an outer cosmic singularity. The 'de Sitter universe' became a challenge for both theoreticians and observers, the former trying to explain the intricate geometry, the latter to use the model for understanding the nebular redshifts. Wirtz first adopted the de Sitter world in a paper of 1924.

In December 1917 and the third year of World War I, Wirtz in Berlin obtained an issue of the 'Publications of the Astronomical Society of the Pacific' with a list of nebular radial velocities, compiled by Paddock (1916). Immediately using the data to determine the solar apex and the nebular parallax both from proper motions and radial velocities, Wirtz wrote in 1918: "It is remarkable that our system of fixed stars should include such an incredibly large displacement of $820\,\mathrm{km\,s^{-1}}$ relative to the average of the spirals, and also incredible is the interpretation of the systematic constant $k = +656\,\mathrm{km\,s^{-1}}$. If one gives this value a literal interpretation, the system of spiral nebulae disperses with the velocity $656\,\mathrm{km\,s^{-1}}$ relative to the momentary position of the solar system as center."

3. The Radial Velocity – Magnitude Relation

Wirtz's tabular presentation of the velocity-magnitude relation of 1922 is shown as diagram in Fig. 1. It shows six normal points from 29 objects. Radial velocity data are plotted versus apparent magnitudes, a combination chosen by an observer. The correlation coefficient for the $v(m)$-relation is cc = 0.972. For the log $v(m)$-relation or the log $z(m)$-relation it would have been cc = 0.950. The better correlation might explain Wirtz's choice of the coordinates.

For a homogeneous expanding universe, the expected slope is $\log z(m) = 0.2$. The slope of Wirtz's data would have been 0.098, thus providing an early example of a magnitude-limited sample with significant losses of data near the nominal limit (later known as Malmquist effect). Hubble's linear diagram of 1929 shows radial velocity versus distance. The $\log z(m)$-diagram, now called the Hubble diagram, was introduced by de Sitter in 1930.

4. The Radial Velocity – log Diameter – Relation and Beyond

In 1924, Wirtz used galaxy diameters to test the de Sitter universe with 44 nebulae – following the 3 nebulae in de Sitter's seminal paper of 1917. Wirtz writes: "The dispersion of the linear dimensions of nebulae fills the triangular plane in such a way that among the nearby nebulae both absolutely small and large objects are visible, while in the depth of space only the absolutely largest are subject to observing their radial motions", as shown in Fig. 2. Wirtz's sample of nebulae is again magnitude-limited and affected by selection effects. This is illustrated in Fig. 3, which contrasts Wirtz's relation with the generally diameter-limited sample from the Uppsala Catalogue of Galaxies (Nilson 1973). Wirtz interpreted his data as follows: "For the largest nebulae one finds from the graphic presentation the formula $v = 2200 - 1200 \times \log D$ [v measured in

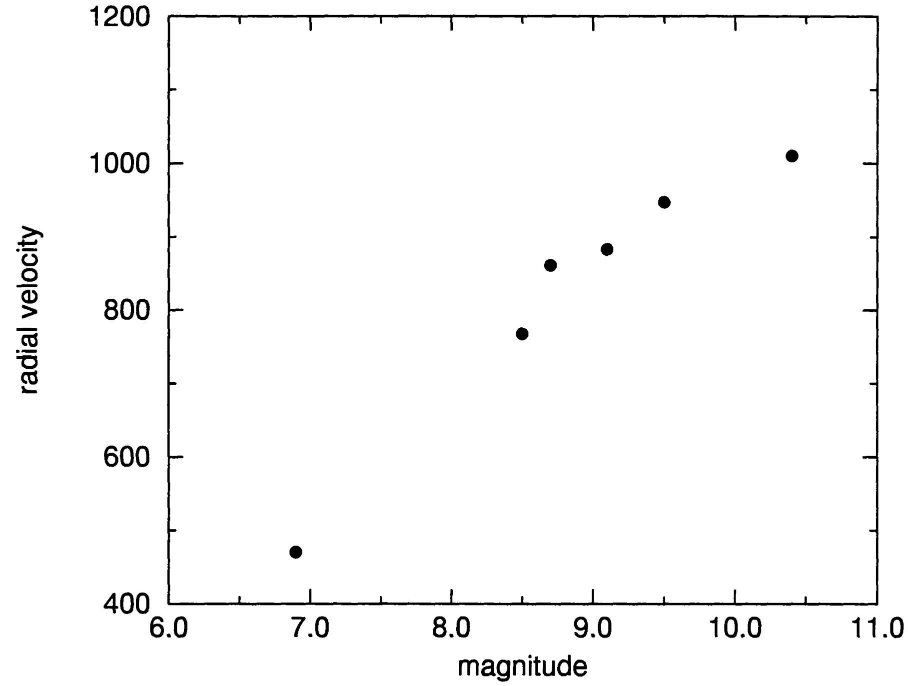

Figure 1. The radial velocity-magnitude relation from the tabular data by Wirtz (1922).

km $\sec^{-1}$ and D in arc min]. The coefficient 1200 indicates that with a tenfold increase of the distance, the redshift, assuming to be the pure Doppler effect, increases by 1200 km/s..., the velocity of light would be reached only at a distance 10^{200} parsec – a quantity which exceeds all estimates of the radius of curved space."

The shape of the radial velocity-distance relation in the de Sitter universe was a challenge for theoreticians. When Wirtz attempted to derive its shape from observations, no reliable theoretical redshift-distance relation was available. In 1923, Eddington derived the $v \sim d^2$ law, in 1924, Weyl the $v \sim \tan d$ law; also in 1924, two months before Wirtz, Silberstein derived the approximately linear redshift-distance relation $v \sim \pm d$ and applied it with limited success to stars, globular clusters and the Magellanic clouds – objects whose distances were available at that time. Also in 1924, and after Wirtz, Lundmark and Strömberg tested the de Sitter universe with galaxies. The former found a relation between radial velocity and distance, the latter did not.

Experimental proof of the de Sitter universe was thought to be in Hubble's (1929) observational paper "A relation between distance and velocity among extra-galactic nebulae" while the non-linear effects, predicted by Tolman (1929), were not present.

Friedmann's 1922 model of a universe with a changing scale factor was long ignored by theorists and observers. It was reborn in Lemaître's paper of 1927, which included the pressure term for the first time. Lemaître derived the Hubble law as an approximation from his complete relativistic cosmology and illustrated it with observations. His work became generally known in 1930 and accepted

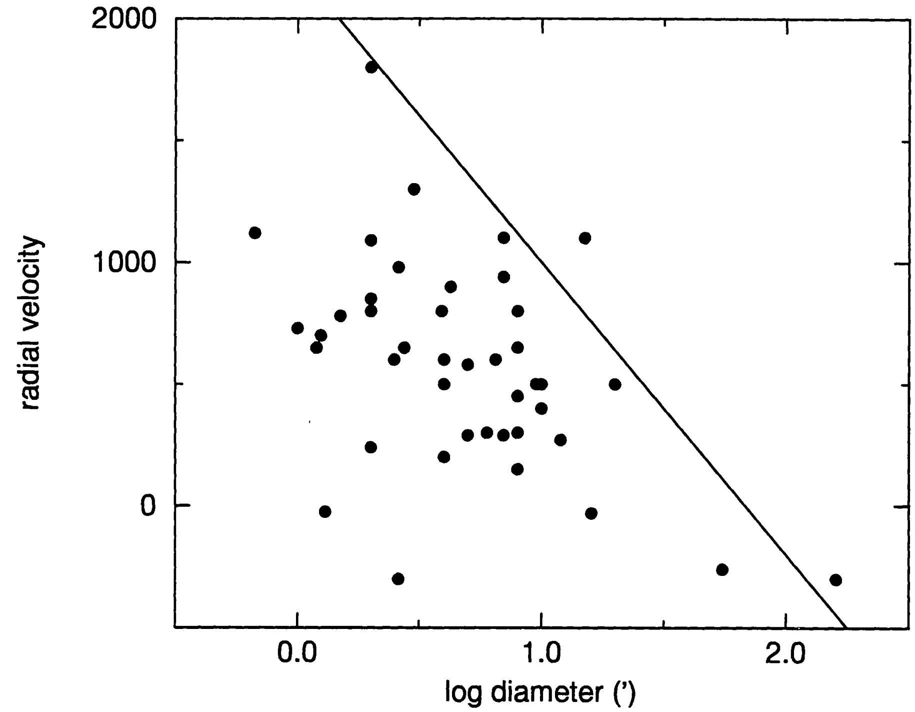

Figure 2. Wirtz's radial velocity – log diameter relation of 1924.

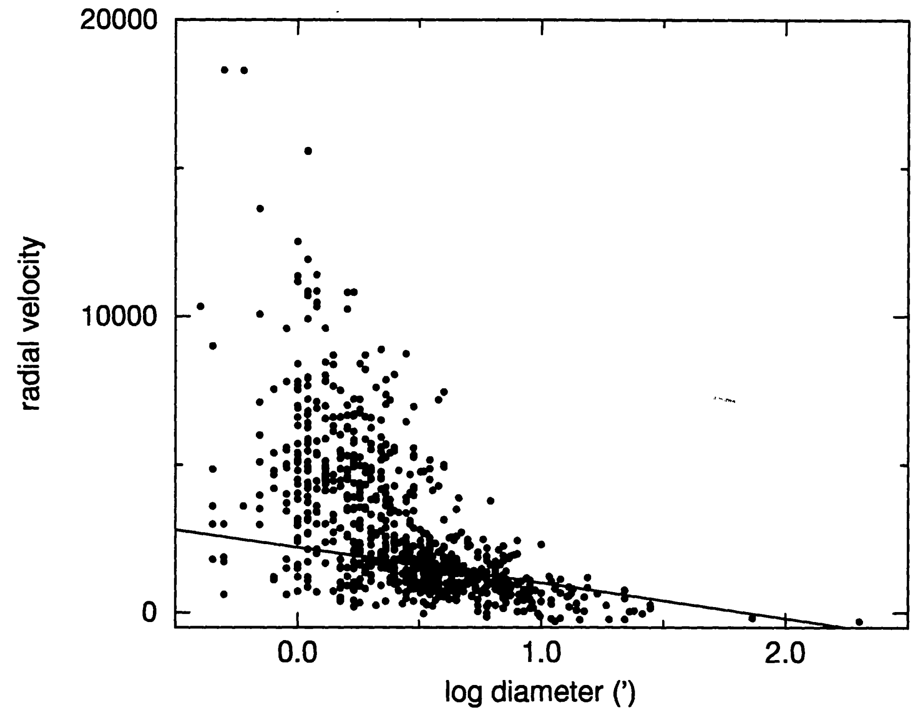

Figure 3. The radial velocity – log diameter relation for UGC objects with known radial velocities. Wirtz's boundary curve is marked.

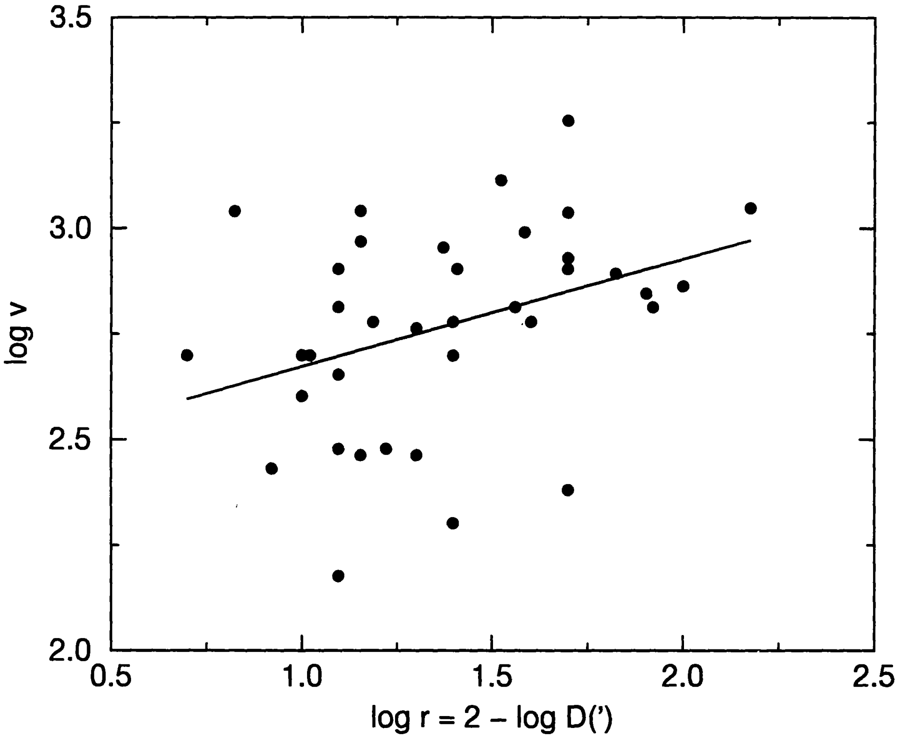

Figure 4. The log velocity – log distance relation, derived from Wirtz's data of 1924.

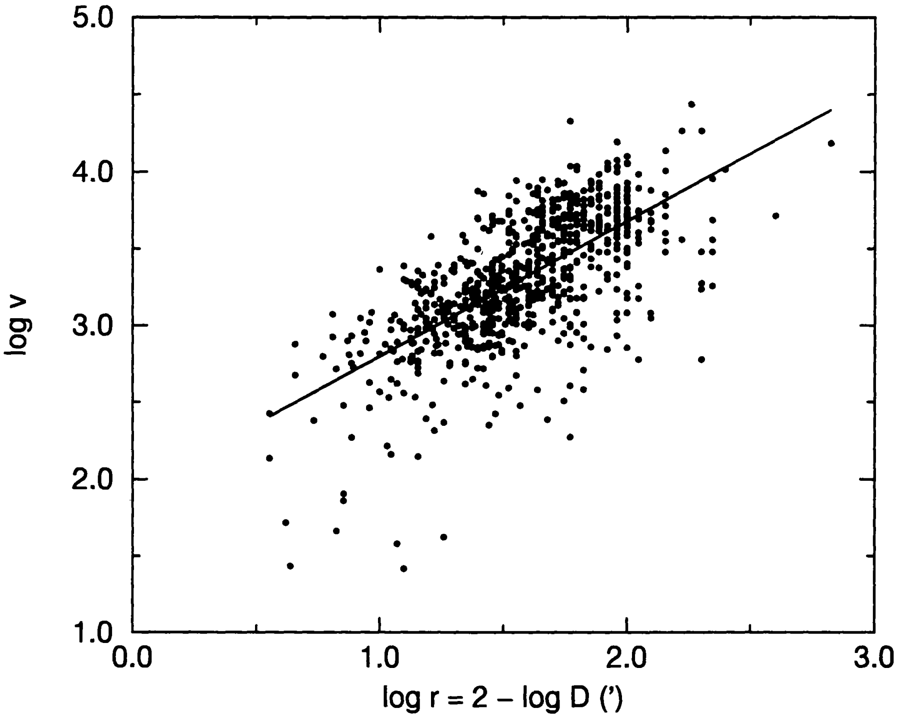

Figure 5. The log velocity – log distance relation, derived from the diameters from the UCG data of 1973.

in subsequent years. Applying the non-static solutions of the field equations found by Friedmann and Lemaître, de Sitter (1930) introduced the log radial velocity-log distance diagram (the 'Hubble diagram') to determine the expansion parameter.

Wirtz was first to use galaxy diameters as distance indicators. This approach can be evaluated by a log radial velocity-log distance relation, using diameters as standard rods. The sparse data of Wirtz (Fig. 4) barely suggest a correlation. It yields the slope 0.26, which points at a strong bias in the sample. The slope deduced from the UGC data is 0.88, which differs only slightly from the value 1.0 of the Hubble flow (Fig. 5).

5. Astrophysics of the Nebulae and Atmospheric Physics

Wirtz's methods to investigate extragalactic relations are fundamental, unfortunately, they suffer from sparse data and selection effects. His sound approach becomes apparent when Wirtz's relations are applied to the UGC data: from these a modern cosmological picture emerges.

From 1923 to 1927, Wirtz's papers included surface photometry of nebulae, the luminosity segregation in clusters of nebulae, intergalactic absorption and the luminosity function of galaxies (Wirtz 1927; an illustration is shown in Seitter & Duerbeck 1990). Subsequently, the luminosity function was derived by Hubble & Humason (1931) and Holmberg (1950). In his later years, Wirtz had neither scientific nor financial support for galactic and extragalactic projects. At the IAU General Assembly in 1935, 20 years after his first attempt, he suggested a network of galaxy positions in order to provide a reference frame for stellar proper motions. Lick Observatory carried out a similar project between 1947 and 1987.

In the 1930s, Carl Wirtz continued to publish copiously in meteorology and planetary science. He died in 1939.

References

de Sitter, W. 1930, Bull. Astr. Inst. Neth. 5, 157

Holmberg, E., 1950, Lund Obs. Publ. Ser. II, Nr. 128

Hubble, E. 1929, Proc. Nat. Acad. Sci. Washington 15, 168

Hubble, E., Humason, M.L. 1931, ApJ, 74, 43

Nilson, P. 1973, Uppsala Astr. Obs. Annaler, Vol. 6 (UGC)

Paddock, G.F. 1916, PASP, 28, 109

Seitter, W.C. & Duerbeck, H.W. 1990, in Modern Cosmology in Retrospect, eds. B. Bertotti et al., Cambridge University Press, p. 365

Tolman, R.C. 1929, ApJ, 64, 245

Wirtz, C. 1918, Astron. Nachr., 206, 109

Wirtz, C. 1922, Astron. Nachr., 216, 451

Wirtz, C. 1924, Astron. Nachr., 222, 21

Wirtz, C. 1927, Publ. Sternwarte Kiel, 15, 35