Who discovered Universe expansion?

Controversy persists over who first found that the Universe is expanding. Last year, Mario Livio quashed suggestions that Georges Lemaître's 1927 theoretical prediction of expansion was deliberately suppressed (*Nature* **479,** 171–173; 2011). Since then, another contender has emerged.

The joint NASA and Infrared Processing and Analysis Center Extragalactic Database of Galaxy Distances, in Pasadena, California, which I co-lead, has tabulated and made public the historical distance estimates published by Edwin Hubble and his contemporaries to prove expansion (see I. Steer *J. R. Astron. Soc. Can.* **105,** 18–20; 2011). These reveal that measurements by a Swedish astronomer, Knut Lundmark, were much more advanced than formerly appreciated.

Lundmark was the first person to find observational evidence for expansion, in 1924 — three years before Lemaître and five years before Hubble. Lundmark's extragalactic distance estimates were far more accurate than Hubble's, consistent with an expansion rate (Hubble constant) that was within 1% of the best measurements today.

However, Lundmark's research was not adopted because it relied on one unproven method (galaxy diameters), cross-checked with one unproven distance to the Andromeda galaxy, which was derived from a type Ia supernova observed in 1885 and mistaken for a normal nova (W. Huggins and W. F. Denning *Nature* **32,** 465–466; 1885).

Hubble's research in 1929 yielded a value for the Hubble constant that was inaccurate by almost an order of magnitude. It was adopted because it was derived from multiple methods — including one still in use (brightest stars) — and was cross-checked with multiple galaxies with distances based on proven Cepheid star variables.

Lundmark established observational evidence that the Universe is expanding. Lemaître established theoretical evidence. Hubble established observational proof.

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Further information will be presented in: Hubble's Law: Who Discovered What and When, at the American Astronomical Society meeting (AAS 221), in Long Beach, California, January 6-10, 2013, during the AAS Historical Astronomy Division (HAD) VI History of Astronomy session, Tuesday, January 8, 2013, 10:00 AM to 11:30 AM.

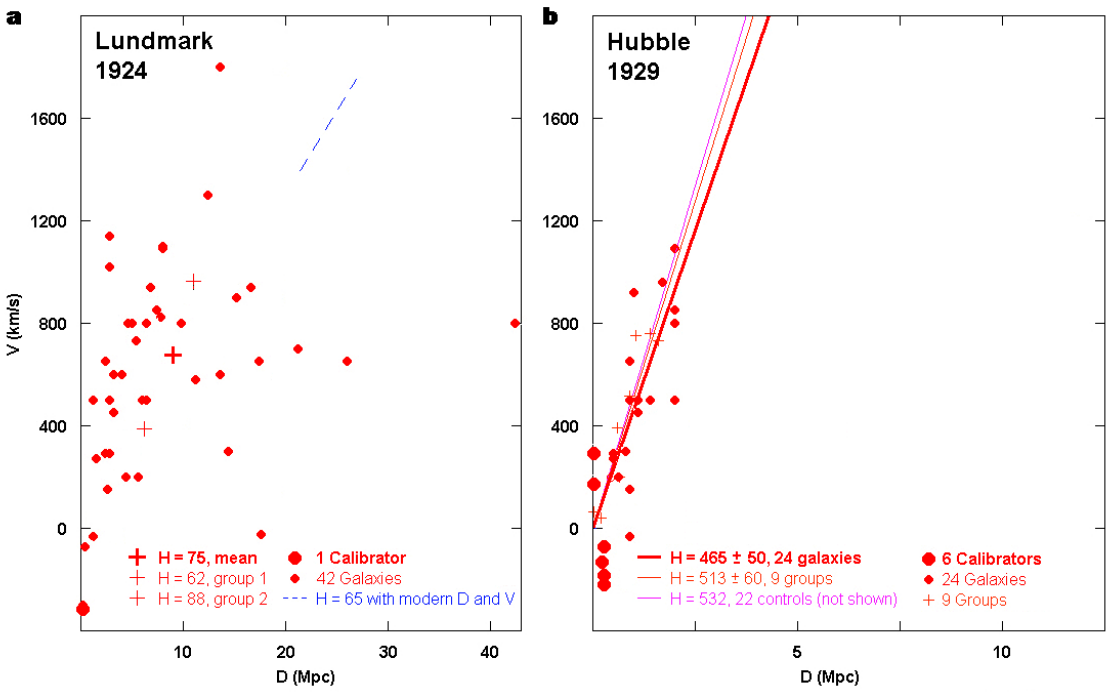

Figure 18 - Lundmark published distance estimates based on the apparent angular diameters of 42 galaxies with known recessional velocities. For twenty-three of these galaxies, with an average distance of 6.2 Mpc or 30.8 “Andromeda units”, he reported an average recessional velocity of 386 km/s. For eighteen galaxies at a greater average distance of 11 Mpc, he reported a significantly higher recessional velocity of 963 km/s. With 21st century hindsight, the resulting Hubble constant (H) or recessional velocity per unit of distance for the nearer group is H = 62 km/s/Mpc. For the farther group, H = 88 km/s/Mpc. Note the mean of these two values, H = 75 km/s/Mpc. That is only 4% higher than H = 72 +/- 8 km/s/Mpc established from NASA’s HST Key Project, which is considered precise to within 10% (Freedman et al. 2001). It is merely 3%, 2% and 1% larger respectively than three of the most precise estimates made to date, including H = 73 +/- 2(stat.) +/- 4(syst.) km/s/Mpc (Freedman & Madore 2010), H = 73.8 +/- 2.4 km/s/Mpc (Riess et al. 2011), and H = 74.2 +/- 3.6 km/s/Mpc (Riess et al. 2009). Lundmark, not Hubble, was first to discover observational evidence for the redshift-distance relation.

Figure 18a shows why Lundmark’s velocity-distance research was not widely adopted. There was no linear relation overplotted in Lundmark’s velocity-distance graph. Nor was there an arithmetic relation in his paper demonstrating the change in recessional velocity with distance. Lundmark himself was unconvinced, stating “there may be a relation between the two quantities [velocity and distance] although not a very definite one” (Lundmark 1924).

Figure 18b, shows why Hubble's research by comparison, was adopted, from his graph with the overplotted mean trend, to his written and arithmetic relation, to the observationally determined constant, H = 500 km/s/Mpc. That estimate was confirmed whether based on 24 galaxies with redshift-independent distances analyzed individually or in 9 separate groups, or based on 22 control galaxies with distances based on redshift alone. Multiple calibrators, multiple methods, and multiple lines of evidence convinced astronomers of the day. Although Lundmark had discovered observational evidence for the relation in 1924, and Lemaître had discovered theoretical evidence for it in 1927, it was Hubble alone among at least a dozen other researchers then actively pursuing the "de Sitter effect" who had discovered observational proof.

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