The measurement of the Hubble Constant: beyond the cosmic ladder

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A precisely determined Hubble's constant H_0 would have an overarching effect on any feature of cosmological theory: the age of the Universe, the critical density of the Universe, or in the formation of cosmic structure. Producing a conclusive value for H_0 is difficult as absolute distances on the cosmic scale are difficult to measure. Inhomogeneous gravitational acceleration generates motion which does not follow the simple expansion as described by Hubble's Law $v = H_0 d$. An uncertainty arises due to the discrepancy between the methods to connect local distances to the smooth large-scale Hubble flow (Fukugita et al. 1993).

Several approaches for cosmic distance measurement should therefore be used to reduce systematic errors. These measurements can form the "rungs" of a *cosmic distance ladder*, where large extragalactic distances (> 1000 Mpc) are informed and calibrated by techniques which have smaller ranges (Carroll and Ostlie 2007). Astronomers may employ a variety of methods in tandem, therefore the ladder could instead be expressed as several pathways (Figure 1).

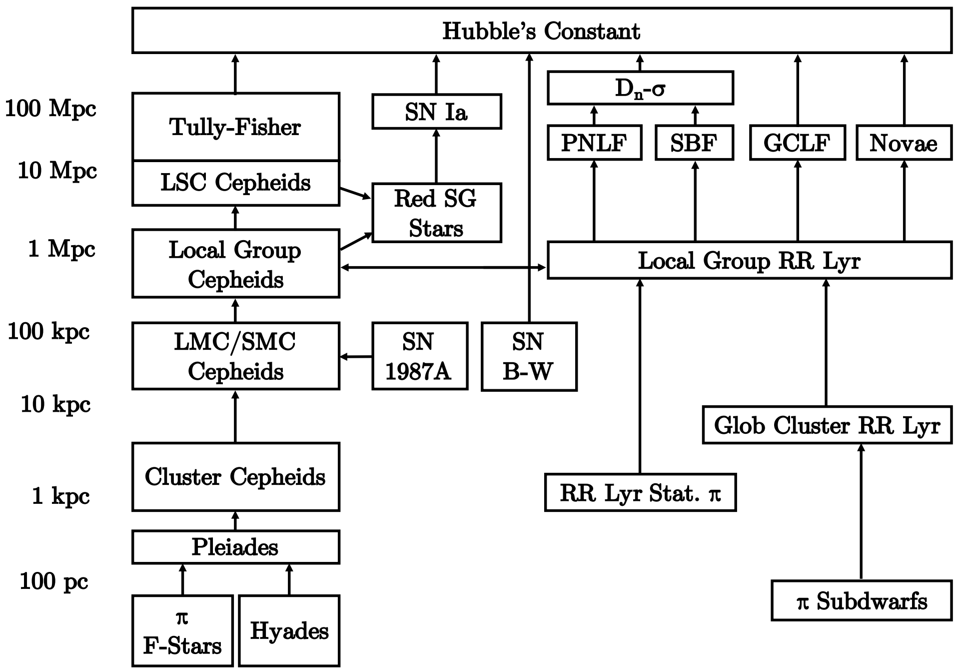

Figure 1: Adapted from Jacoby et al. (1992), this diagram illustrates the various approaches to calculate H_0, each technique is roughly placed at the approximate range it operates at. One can see that there is not one strict "cosmic ladder", rather multiple pathways. For reference, the acronyms used are: B-W - Baade-Wessenlink; GCLF - Globular-Cluster Luminosity Function; LSC - Local Super Cluster; PNLF - Planetary Nebula Luminosity Function; SBF - Surface-Brightness Fluctuations; SG - Super Giant; SN - Supernovae; π - parallax.

The Hubble Space Telescope (HST) H_0 Key Project was an effort in the early 2000s to determine H_0 by calculating distances to Cepheid variables in local galaxies ($\leq$ 20

Mpc) then applying them as a calibration to 5 secondary independent distance indicators. Described by Freedman et al. (2001), four of the methods (Type Ia supernovae, Tully-Fisher relation, surface-brightness fluctuations, and Type II supernovae) were able to produce $70 \leq H_0 \leq 72$ kms^{-1} Mpc^{-1} and the remaining technique (fundamental plane for elliptical galaxies) $H_0 \approx 82$ kms^{-1} Mpc^{-1}. Over the next decade, the methodology would be refined and the sample of Cepheids and Type Ia supernovae would increase leading to $H_0 = 73.8 \pm 2.4$ kms^{-1} Mpc^{-1} (Riess et al. 2011). These results set a standard benchmark for H_0, they were found by taking steps along the cosmic pathways and whilst they have high accuracy, it would be beneficial to directly calculate H_0 at large distances without the need to calibrate with Cepheids.

One of the key alternative methods is the usage of Cosmic Microwave Background (CMB) measurements.

References

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