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# The $H_0$ Key Project: Cepheids in NGC925, M101 and M100

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**Abstract.** As part of the Extragalactic Distance Scale Key Project, the *Hubble Space Telescope* has been used to identify Cepheids in M100, M101 and NGC925, and to measure distances derived from the Cepheid PL relation. For M100, the distance of 17.1 ± 1.8 Mpc has been used to infer a preliminary value for $H_0$ of $\sim$ 80 km/s/Mpc, which brings the age of the Universe derived from the standard model of the Big Bang into conflict with the ages of the oldest stars.

## 1. Introduction

To date the quest for $H_0$ has been plagued by systematic errors in at least some of the various methods for measuring distances to galaxies beyond Virgo (and hence to galaxies whose Hubble flow velocities are significantly greater than their peculiar velocities). The aim of the Key Project is to provide a sample of 18 galaxies with well-determined distances derived from Cepheids detected and measured with the *Hubble Space Telescope's* WFPC2, which can then be used to calibrate the secondary distance indicators: the IR Tully-Fisher relation (IRTF), Surface Brightness fluctuations, the luminosity functions of Planetary Nebulae and Globular Clusters, the Expanding Photospheres of Type II SNe (EPM), and Type Ia SNe. The ultimate goal of the Key Project is use these calibrations to measure $H_0$ to an (external) accuracy of 10%.

## 2. Cepheids in NGC 925

NGC925 is a member of the NGC1023 group, which contains galaxies suitable for PNLF, SBF and SNII calibrations. While analysis is still in progress, of 5540 stars, 80 seem to be Cepheids (Silberman et al. 1995).

## 3. Cepheids in M101

M101 was selected as a test for any metallicity effects in the Cepheid PL relation, as M101 has a very steep metallicity gradient. Two fields have been targeted in M101, at radii of 1.7 and 7.9 arcmin, with a metallicity difference of a factor $\sim$ 5 between them. The outer field was observed mainly with WFPC1, and these have now been reduced (Kelson et al. 1995), with 29 Cepheids being found from a total of more than 23,000 stars. Although the calibration of the photometry is still preliminary (based on a transformation from WFPC2 at −88° to WFPC2 at −76°), the current figures indicate a large extinction of $A_V = 0.45$ mag, and a reddening-free distance of $6.5 \pm 0.6$ Mpc. This compares to ground-based distances of 7.2 Mpc by Cook et al. (1986) derived from 2 Cepheids, and 7.6 Mpc by Cohen (1993) derived from a further 2 Cepheids. SN1970G gives an EPM distance of $7.4^{+1.0}_{-1.5}$ Mpc (Schmidt et al. 1994). The inner field is currently being calibrated (Stetson 1995), and will be very important to see if/how the Cepheid PL relation is affected by metallicity.

## 4. Cepheids in M100

The *HST* results for M100 were reported by Freedman et al. (1994), who detected more than 20 Cepheids out of 40,000 stars, and derived an extinction to M100 of $A_V = 0.15$ mag, and a reddening-free distance of $17.1 \pm 1.8$ Mpc. This compares to IRTF distances of $18.4 \pm 2.2$ Mpc (Pierce & Tully 1988) and $14.5 \pm 2.7$ Mpc (Pierce 1994), and an EPM distance to SN1979C of $15 \pm 4$ Mpc (Schmidt et al. 1994).

An estimate of $H_0$ is derived by assuming the M100 distance is representative of the distance to the Virgo cluster (a large uncertainty of 3.4 Mpc is added to account for the large extent of Virgo). The uncertainty in Virgo's Hubble flow velocity is avoided by using the well-measured distance between the Virgo and Coma clusters of $77.1 \pm 3.1$ Mpc, giving $H_0 = 77 \pm 16$ km/s/Mpc.

$H_0 \sim 80$ km/s/Mpc in the standard (Einstein-de Sitter) model ($\Omega = 1$), gives an age for the Universe of $T_0 = 2/(3H_0) = 8$ Gyr, *inconsistent with oldest star ages of* 14± *2 Gyr*. This conflict with stellar ages can only be resolved by either: (1) allowing a lower density of $0.1 < \Omega < 0.3$, which would then give an age $T_0 = 12$ Gyr ($\Lambda = 0$), consistent (barely) with stellar ages, (2) allowing $\Lambda > 0$, or (3) concluding that theories of stellar and galactic evolution are incorrect.

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