Galaxy Distances & Peculiar Velocities

Cosmicflows-3
18,000 galaxies

$H_0 = 75$
Cosmic Flows Program

- Measure distances: $d$
- Peculiar velocities: $V_{pec} = V_{obs} - H_0d$
  where $H_0 = \langle V_{obs}/d \rangle$
- Infer 3D velocities and density field

\[ \delta(r) = -\nabla \cdot \mathbf{v}/H_0f \]

Linear theory

Growth factor set by cosmological model
Measuring Distances !!

TRGB: Tip of the Red Giant Branch
RR Lyr, Horiz Br, Eclip Bin, Maser
Cepheid Period–Luminosity
SBF: Surface Brightness Fluctuation
SNIa: Type Ia Supernova
FP: Fundamental Plane
TF: Luminosity–Linewidth

18,000 distance measures within 30,000 km/s
mostly TF

TRGB

6dF
FP
δ < 0

SNIIa
Anand, Dolphin, Jacobs, Makarov, Rizzi, Wu

**TRGB distances**

Holmberg I
d = 4.0 Mpc

UGC 3974
d = 8.2 Mpc

UGC 7356
d = 7.3 Mpc

Nearly 500 measures
5% distances to most galaxies $M_B < -12$
within 10 Mpc!
Luminosity-Linewidth Distances

Hydrogen line profile
Arecibo,
Green Bank,
Parkes

Photometry:
SDSS u,g,r,i,z
(covers most of Arecibo sky)
WISE W1,W2 (3.4 & 4.6 µm)
(full sky)

NGC 925
Luminosity-Linewidth Distances

591 galaxies in 20 clusters

73 ZP galaxies with TRGB or Cepheid distances

DRAMATIC IMPROVEMENT IN NUMBERS AND QUALITY OF PARAMETERS

rms scatter at I band ~0.32 mag (16% in distance); at W1 band ~0.36 mag (18% in distance)

(PRELIMINARY)
Tension in the Value of $H_0$

$67.27 \pm 0.66$ km/s/Mpc (Planck Collab. 2015) assuming $\Lambda$CDM, 3 neutrino species, Planck CMB data

$73.02 \pm 1.79$ km/s/Mpc (Riess et al. 2016) Cepheid – SN Ia distance ladder

$74.03 \pm 1.43$ 2019
SNIa zero point and $H_0$

$H_0 = 75.5 \pm 3.4$ rms $\pm 2.7$ sys

At least 3 other Cepheids alone => 73

Riess+ 2016 + SN in groups

SNIa zero point set here gives $H_0$ here

Cepheids alone => 73
minimizing the monopole

\( H_0 = 75 \pm 2 \) if \( \text{out/in} < \pm 100 \, \text{km/s} \)

If \( H_0 = 67 \) => 800 km/s outflow at 0.05c !!

\[ V_{\text{pec}} = V_{\text{obs}} - H_0 d \]

increase \( H_0 \) 1 unit => -100 km/s infall at 16,500 km/s

decrease \( H_0 \) 1 unit => +100 km/s outflow at 16,500 km/s
Cosmicflows-3 Models

Bayesian MCMC LCDM linear theory

Hoffman et al. unpublished
Wiener filter/constrained realizations

Numerical Action Methods
Local Sheet

5% distances to most galaxies
nearest 10 Mpc
nearest 10 Mpc
Cosmicflows-3: COSMOGRAPHY OF THE LOCAL VOID

by

R. Brent Tully, Daniel Pomarède, Romain Graziani, Yehuda Hoffman, Hélène M. Courtois and Edward J. Shaya
Sketchfab models

Romain Graziani’s reconstruction of overdensities with CF3 in Sketchfab:

https://sketchfab.com/models/914b839927af403080b14eb75c1eff7e

CF3 Local Void + NAM (Shaya et al. 2017) in Sketchfab:

https://sketchfab.com/models/f0a44df256aa4faf93391887d66010e2