On a possible solution to the Hubble tension

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Annual seminar of Department of Fundamental Research
December 5, 2024

Hubble constant

- Hubble law:

$$v = H_0 \cdot d$$

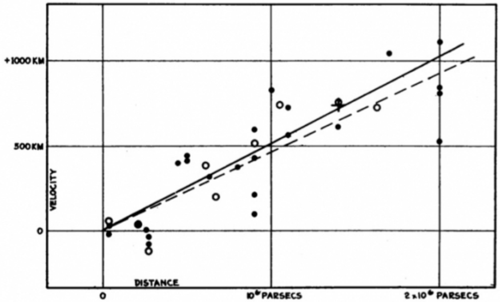


FIGURE 1
Velocity-Distance Relation among Extra-Galactic Nebulae.

Edwin Hubble, Proceedings of the National Academy of Sciences, 1929

Hubble constant

- Hubble law:

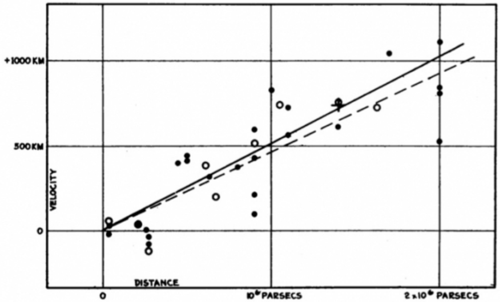
$$v = H_0 \cdot d$$

- cosmological Hubble law ($\Omega_k = 0$):

$$(1+z)\cdot\int_0^z \frac{\mathrm{d}z}{E(z)} = H_0\cdot d_L \ ,$$

where:

$$E(z) = \left(\Omega_m(1+z)^3 + \Omega_\Lambda\right)^{1/2}$$



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Velocity-Distance Relation among Extra-Galactic Nebulae.

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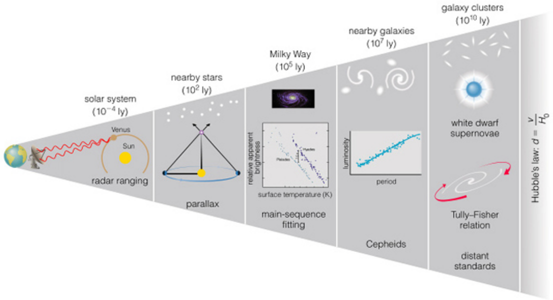
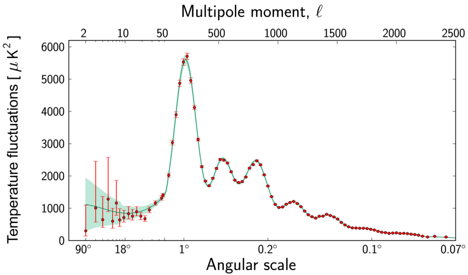
Hubble constant measurements

Direct: distance ladder



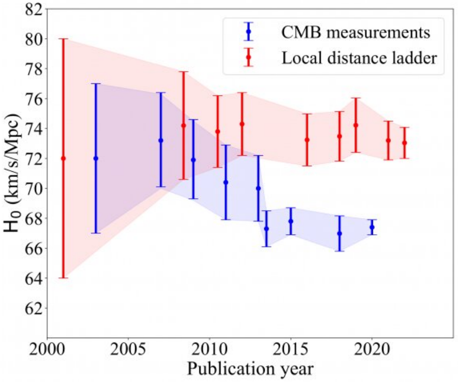
Indirect: Cosmic Microwave Radiation



ESA and the Planck Collaboration

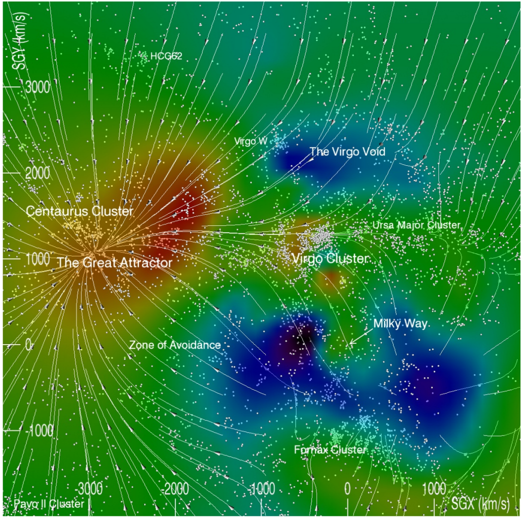
Hubble tension

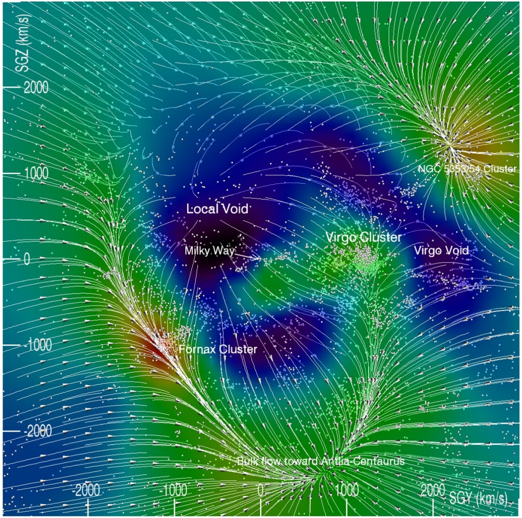
- the CMB-inferred Hubble constant is (Planck Collaboration 2020 *Astron. Astrophys*) $\mathbf{H_0 \approx 67.4 km/s/Mpc}$
- local distance ladder measurements give (Riess et al 2022 *Astrophys. J. Lett.*) $\mathbf{H_0 \approx 73 km/s/Mpc}$
- in the ΛCDM universe these values should be exactly the same



Perivolaropoulos, Skara, New Astronomy Review, 2022

Local universe (Cosmicflows-4, Tully et al 2022, *ApJ*)





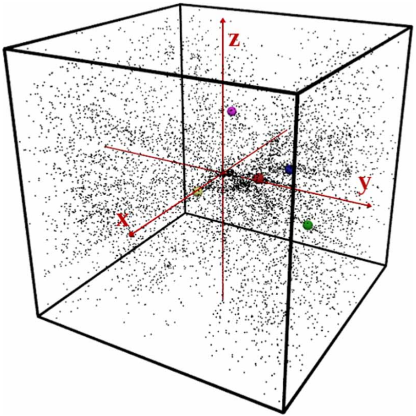
Geometry of the local universe

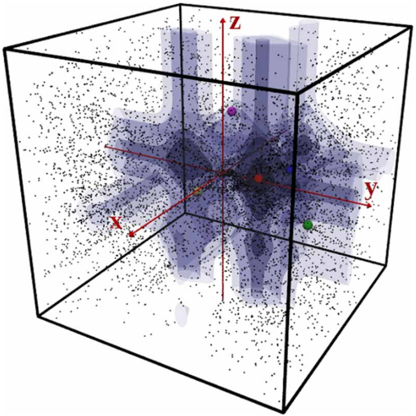
Name	N	X_i	Y_i	Z_i
Virgo Cluster	164	-3.60	15.75	-0.65
Hydra Cluster	67	-32.62	27.95	-33.13
Fornax Cluster	51	-1.86	-14.49	-13.09
Centaurus Cluster	49	-36.11	15.83	-8.08
Pavo Cluster	18	-49.79	-23.49	10.83

- 2nd order perturbed metric of the local universe

$$\mathrm{d}s^2 = -\mathrm{d}t^2 + a(t)^2 \sum_{l=0}^{2} \sum_{m=0}^{l} c_{ij}^{(l-m,m)}(x^\mu)\, \lambda^{l-m}\, k^m\, \mathrm{d}x^i\, \mathrm{d}x^j\, .$$

Local density field





Hubble constant: inhomogeneous model

Standard ΛCDM approach

Inhomogeneous model

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Standard ΛCDM approach

- collecting data e.g. type Ia supernovae light curves

Inhomogeneous model

- mapping the local geometry and creating the mock catalog

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Hubble constant: inhomogeneous model

Standard ΛCDM approach

- collecting data e.g. type Ia supernovae light curves
- converting data to the $d_L - z$ relation
- fitting the low-redshift formula

$$d_L = \frac{cz}{H_0}\left(1 + A\,z + B\,z^2 + O(z^3)\right)$$

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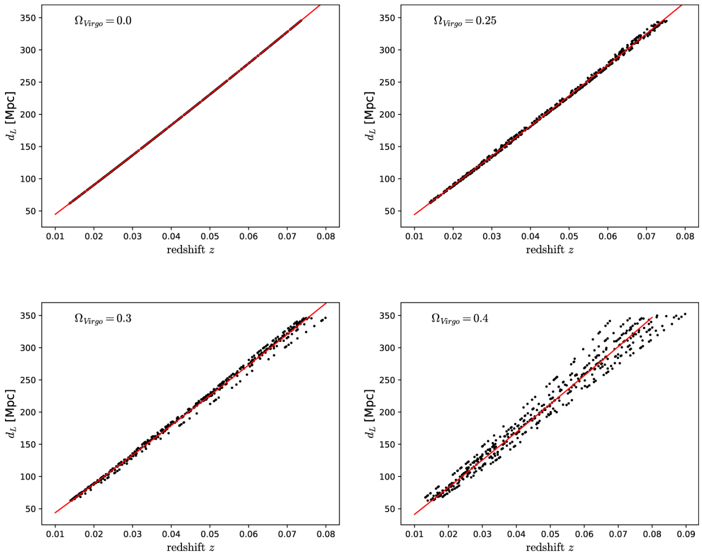
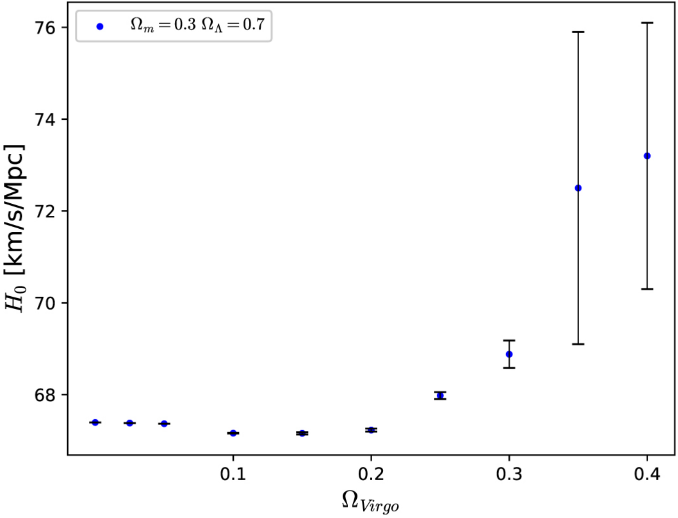
Mock data



$\Omega_{Virgo} = 0.0$
$\Omega_{Virgo} = 0.25$
$\Omega_{Virgo} = 0.3$
$\Omega_{Virgo} = 0.4$
d_L [Mpc]
redshift z

Hubble parameter in the 2nd order CPT



Summary

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Ω_{Vir}	**0.0**	0.1	0.15	0.2	0.25	0.3	0.35	**0.4**
H_0	**67.39**	67.1610	67.16	67.23	67.980	68.88	72.5	**73.2**
ΔH_0	**1.7e-06**	0.00015	0.025	0.032	0.076	0.30	3.4	**2.9**

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- more details can be found in: Sikora, Ostrowski 2024, *Classical and Quantum Gravity*