Voids may solve cosmology's biggest questions!

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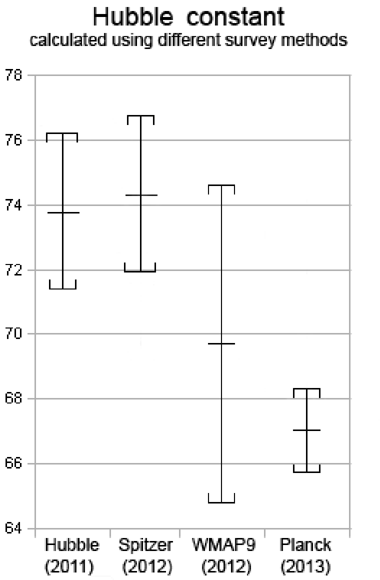
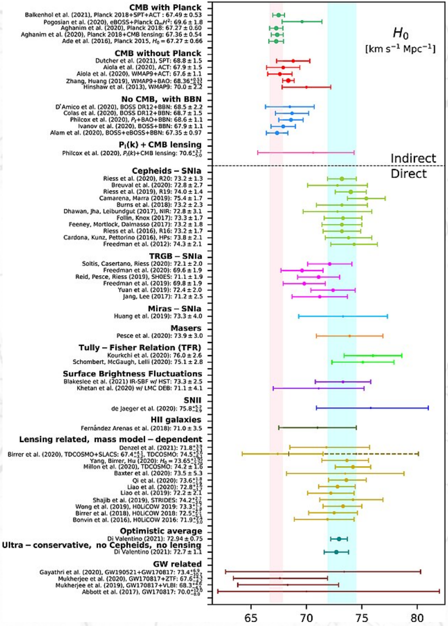
Cosmology and Astrophysics

- In part because they have some major puzzles to solve, researchers have been searching for new instruments.
- The first, and most confusing, is the Hubble constant, which measures how quickly the universe is expanding.
- Scientists have been unable to reconcile divergent estimations of this rate for over ten years; some have even dubbed the problem the biggest cosmological catastrophe.
- Furthermore, disparate measurements of the average density of massive structures, dark matter, galaxies, gas, and voids spread throughout the universe as a function of time, as well as the clumsiness of cosmic stuff, exist.



Hubble tension



Hubble tension

- Astronomers typically gauge those values using two complimentary methods.
- Strangely, these two approaches provide different values for the so-called matter clustering strength and the Hubble constant.

- Pisani and her colleagues have developed a unique method to determine both values: they employ cosmic voids.
- Additionally, their preliminary findings, which appear to align more closely with one of the conventional approaches than the other, are currently adding more complexity to an already contentious dispute.

- Inside a void "very little happens". As structures never originated and evolved inside voids, voids are considered to be "time capsules of the early universe." Put another way, the gaps might have maintained the physics of the early cosmos if it differed from the physics of the present.
- Voronoi diagram, a mathematical tool has been used for 6,000 voids from Baryon Oscillation Spectroscopic Survey (BOSS), which identifies the shapes that make up a 3D mosaic.

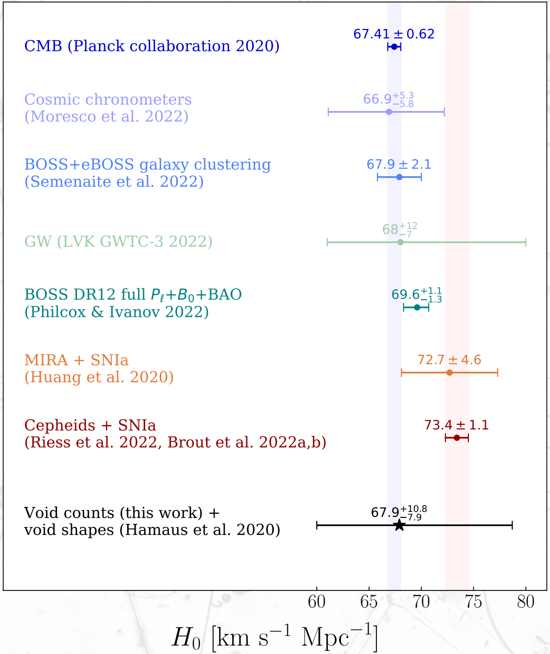
- A higher density of more compacted, smaller voids was created by a slower rate of expansion.
- On the other hand, they anticipated finding more big, smooth voids if growth had been rapid and matter had not clumped as easily.

- The Hubble constant found in the vacuum data differed from the CMB estimate by less than 1%.
- Clumsiness produced a more jumbled output, but it also matched the CMB more closely than Type Ia supernovas.
- Upcoming projects like SPHEREx Observatory and NASA's Nancy Grace Roman Space Telescope to gather sufficient void data to match the contradictory Type Ia supernova and CMB readings.

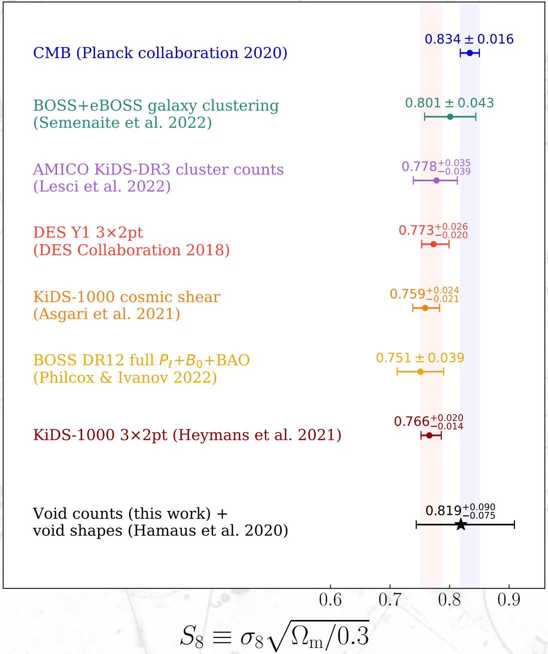
- We could be witnessing something different due to new physics, since the CMB and supernova groups are making quite different measurements.

Something is created out of nothing

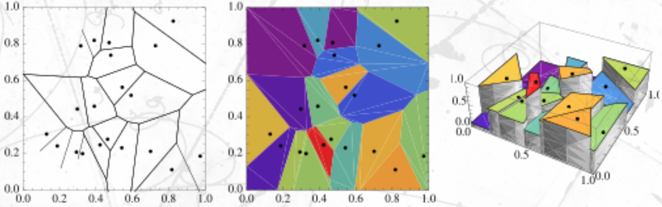
- Every cosmic emptiness serves as a window into a major cosmic struggle.
- The enigmatic factor responsible for the rapid expansion of our universe, known as dark energy, is present on one side.
- Dark energy rules the physics of the emptiness since it exists even there.
- Gravity, on the opposing side of the fight, aims to bring the emptiness together.
- The clumpiness of matter then gives the voids wrinkles.



CMB (Planck collaboration 2020)
67.41 ± 0.62
Cosmic chronometers
(Moresco et al. 2022)
66.9+5.3 −5.8
BOSS+eBOSS galaxy clustering
(Semenaite et al. 2022)
67.9 ± 2.1
GW (LVK GWTC-3 2022)
68+12 −7
BOSS DR12 full Pℓ+B0+BAO
(Philcox & Ivanov 2022)
69.6+1.1 −1.3
MIRA + SNIa
(Huang et al. 2020)
72.7 ± 4.6
Cepheids + SNIa
(Riess et al. 2022, Brout et al. 2022a,b)
73.4 ± 1.1
Void counts (this work) +
void shapes (Hamaus et al. 2020)
67.9+10.8 −7.9
60
65
70
75
80
H0 [km s−1 Mpc−1]

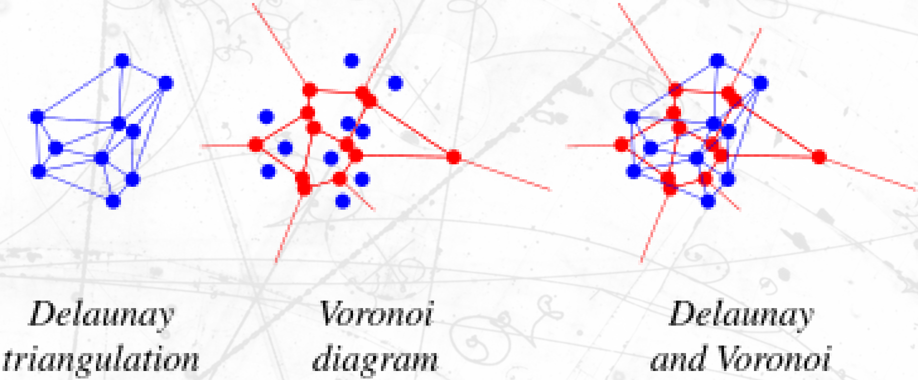


CMB (Planck collaboration 2020)
0.834 ± 0.016
BOSS+eBOSS galaxy clustering (Semenaite et al. 2022)
0.801 ± 0.043
AMICO KiDS-DR3 cluster counts (Lesci et al. 2022)
$0.778^{+0.035}_{-0.039}$
DES Y1 3×2pt (DES Collaboration 2018)
$0.773^{+0.026}_{-0.020}$
KiDS-1000 cosmic shear (Asgari et al. 2021)
$0.759^{+0.024}_{-0.021}$
BOSS DR12 full P_ℓ+B_0+BAO (Philcox & Ivanov 2022)
0.751 ± 0.039
KiDS-1000 3×2pt (Heymans et al. 2021)
$0.766^{+0.020}_{-0.014}$
Void counts (this work) + void shapes (Hamaus et al. 2020)
$0.819^{+0.090}_{-0.075}$
0.6
0.7
0.8
0.9
$S_8 \equiv \sigma_8\sqrt{\Omega_\mathrm{m}/0.3}$



Voronoi diagram

Future



The Delaunay triangulation and Voronoi diagram in $\mathcal{R}^2$ are dual to each other in the graph theoretical sense.