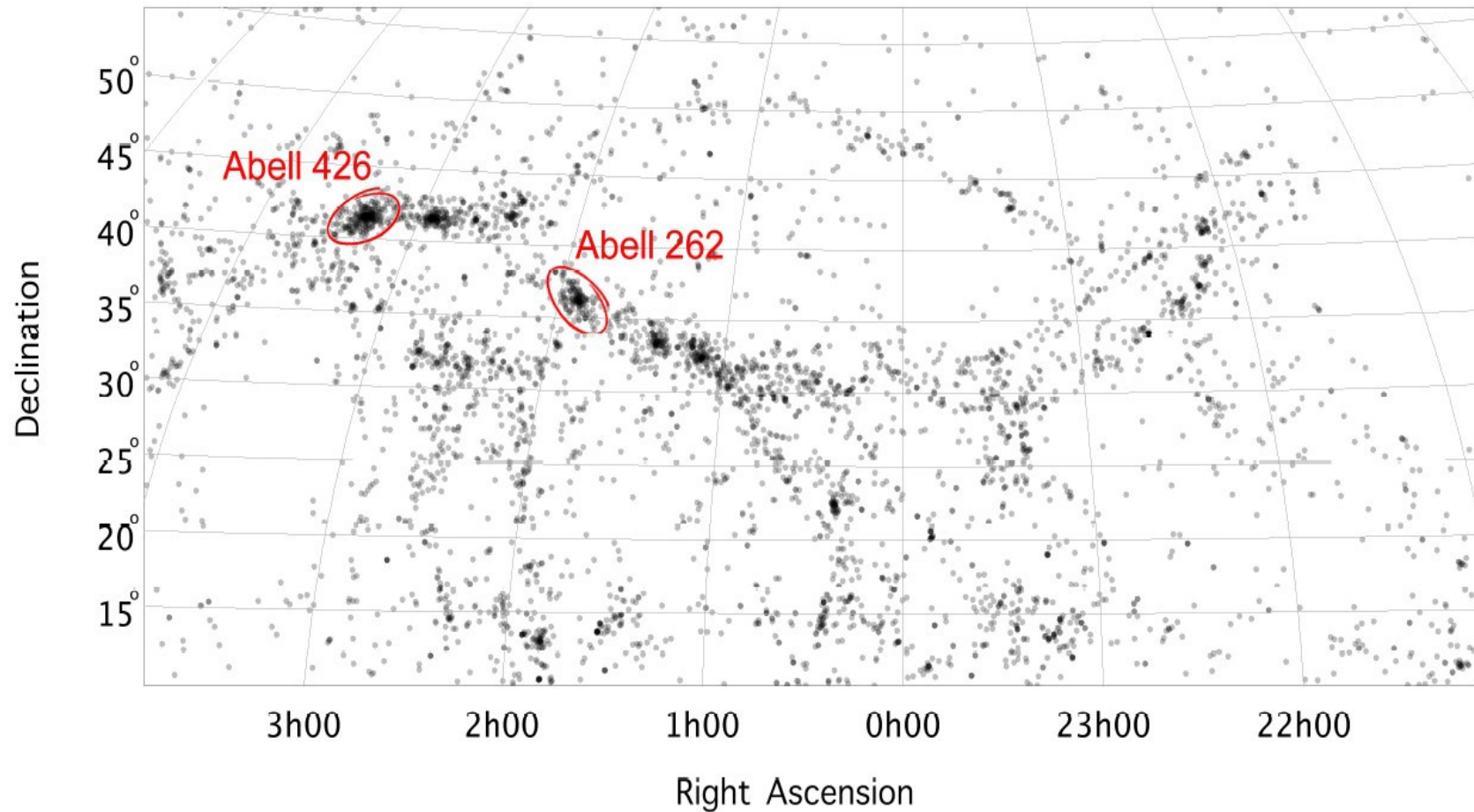


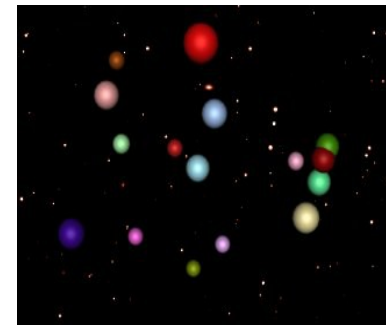
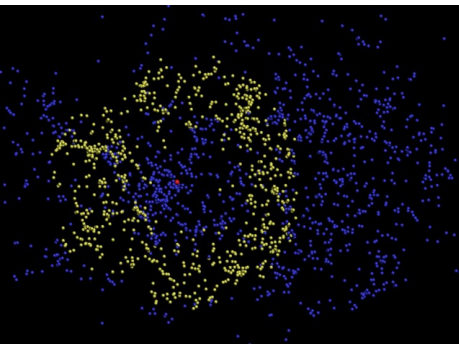
The challenge of the largest structures in the cosmic web



Maret Einasto

Tartu Observatory, Tartu University, Estonia

Norcic-Baltic Astronomy Days 2026



What are the largest structures in the cosmic web?

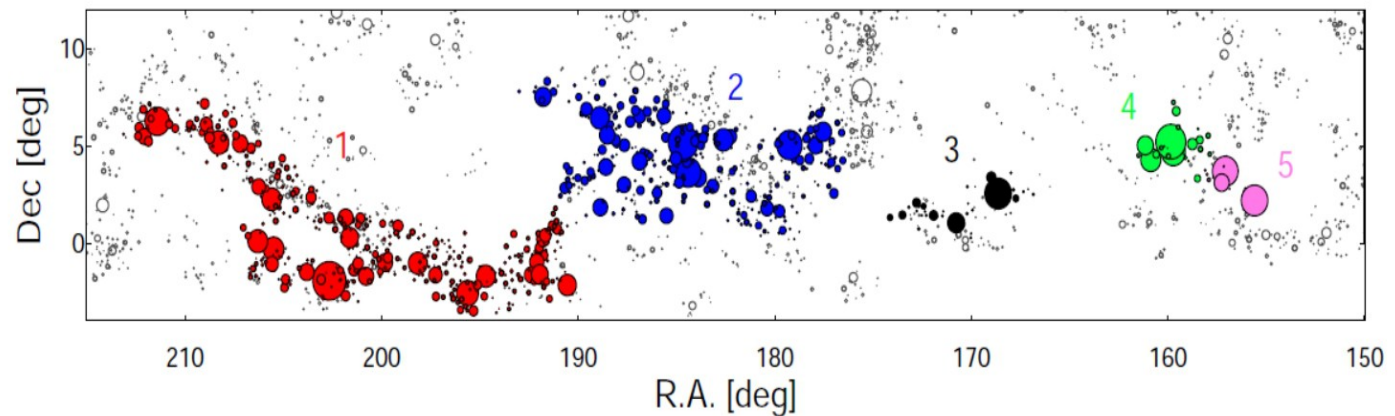
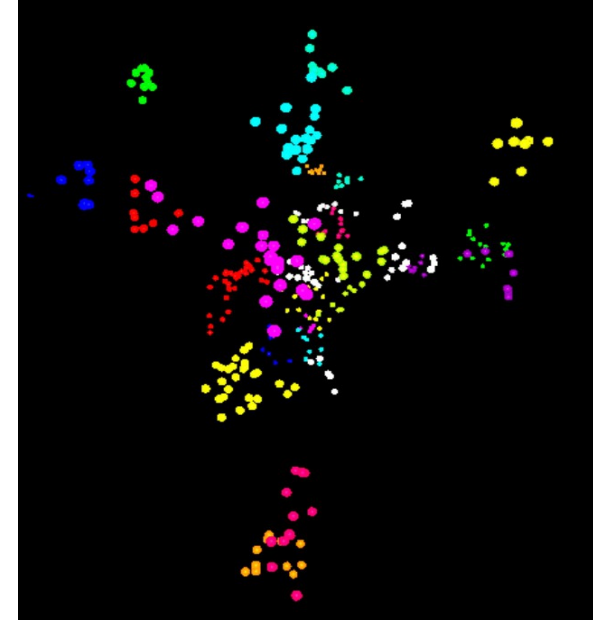
Superclusters and giant voids?

Are there even larger structures?

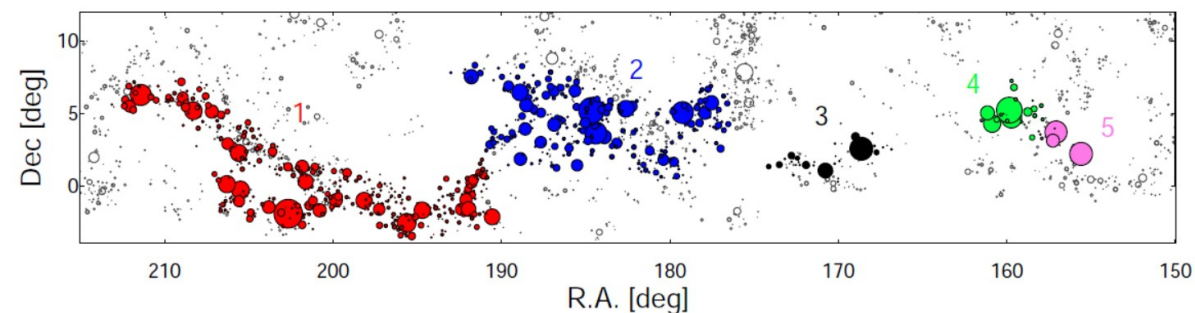
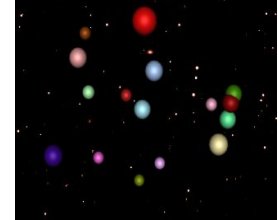
If yes, are these structures compatible with the Λ CDM model?

Supercluster complexes and planes

Regularity in the distribution of galaxy superclusters and quasar systems



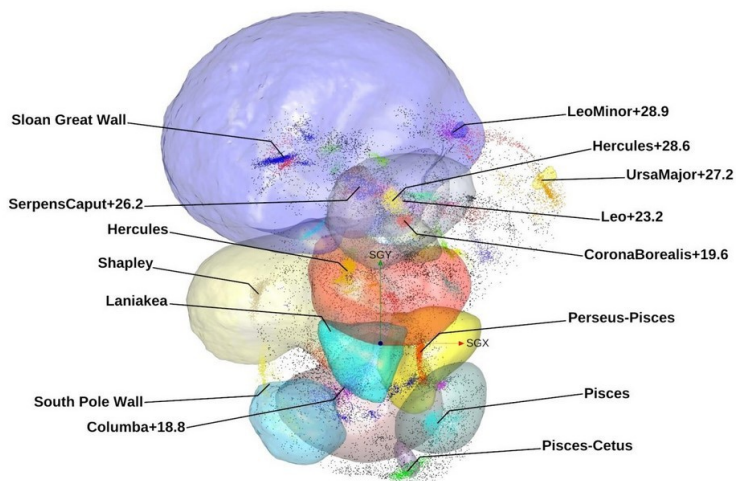
Complexes of rich superclusters



The Sloan Great Wall – five superclusters

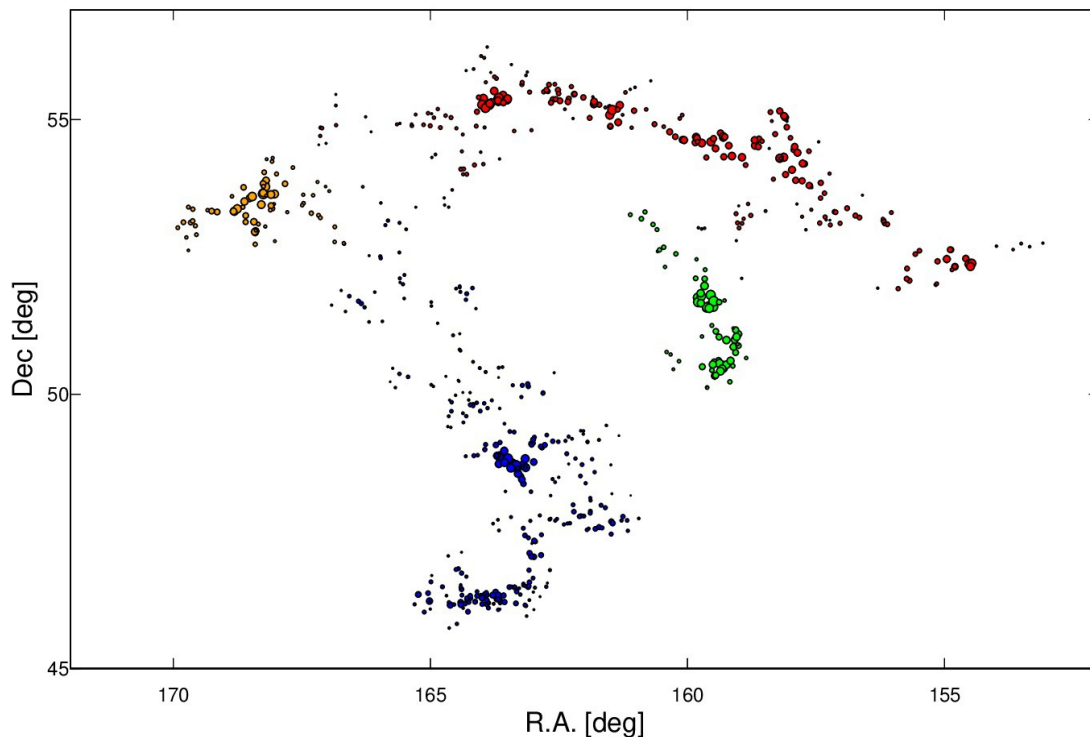
Length $\sim 220 h^{-1}$ Mpc, redshift ~ 0.08

$M \sim 10^{17} h^{-1} M_{\odot}$



SGW is surrounded by very big voids

E+2011, Liivamägi+2012,
Park+ 2012, Valade+2024

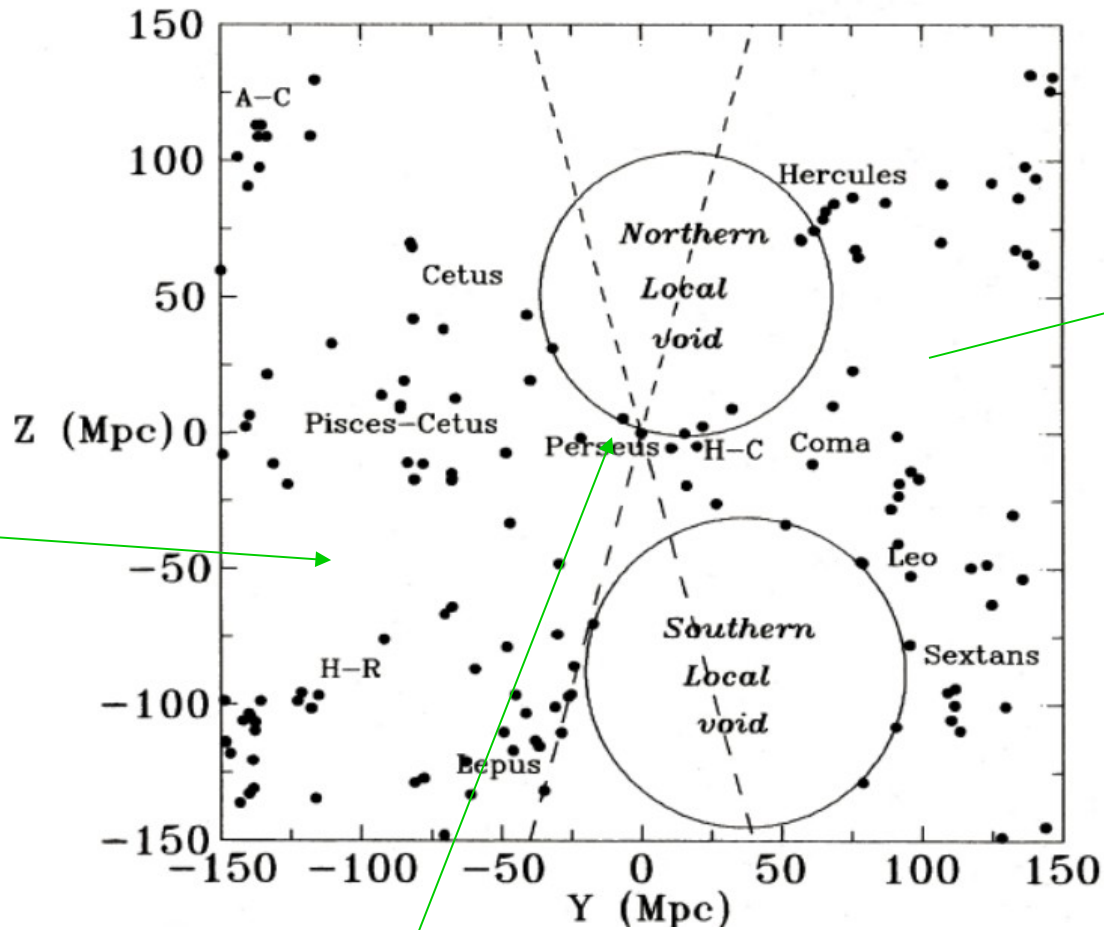


BOSS Great Wall: four superclusters

Lietzen+2016

Length $250 h^{-1}$ Mpc, redshift ~ 0.46

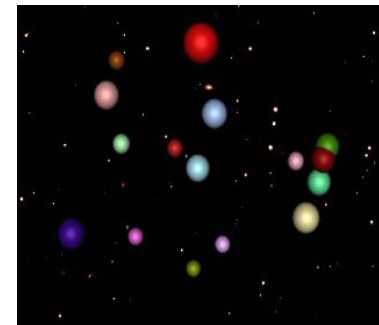
Supercluster planes



Eridanus
supervoid

Towards
Sloan Great Wall

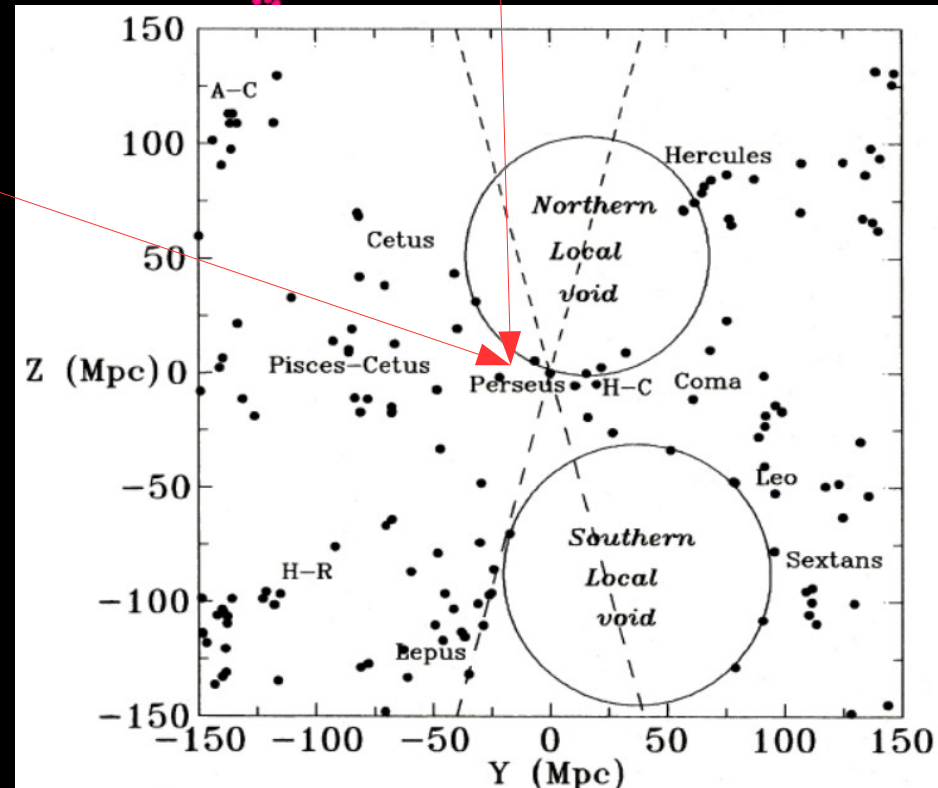
Local Supercluster Plane, thin plane with length ~ 400 Mpc
optical and X-ray clusters, superclusters, and radio galaxies
(Einasto+ 1983, 1994, Chon+ 2021, J. Peebles 2021, 2023, 2026)



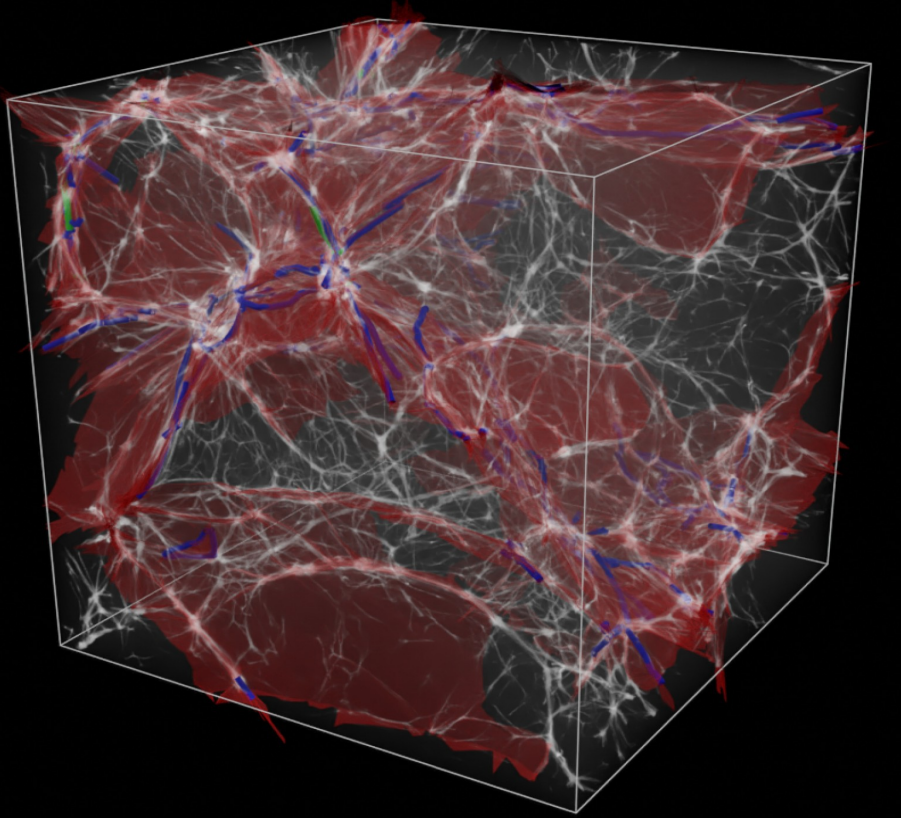
Supercluster planes: Dominant supercluster plane perpendicular to the Local supercluster plane

Superclusters planes - walls in the cosmic web?

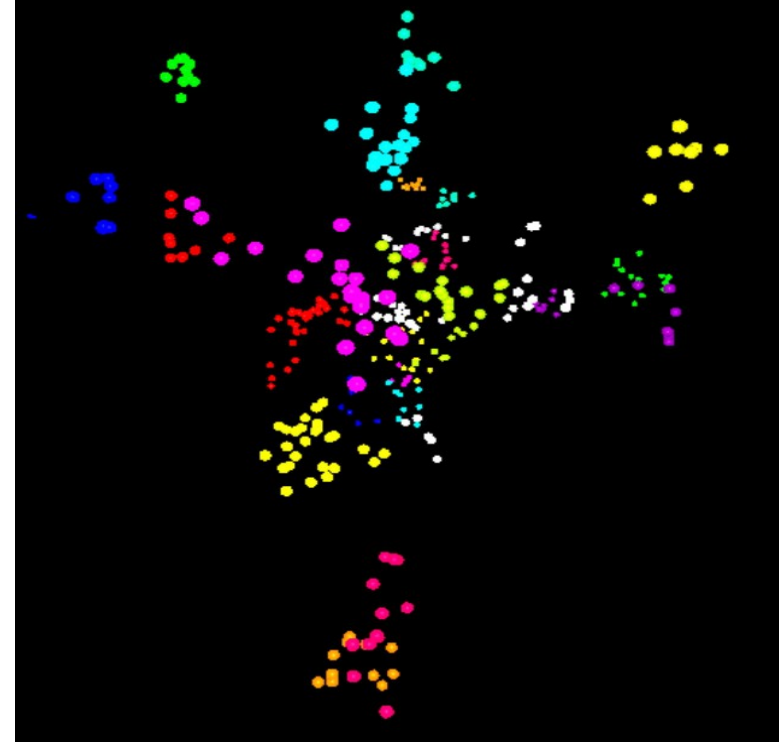
E+1997



Supercluster planes



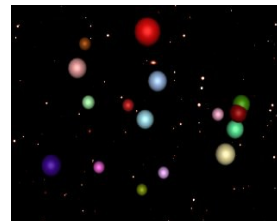
Cosmic web:
nodes
filaments
walls
voids



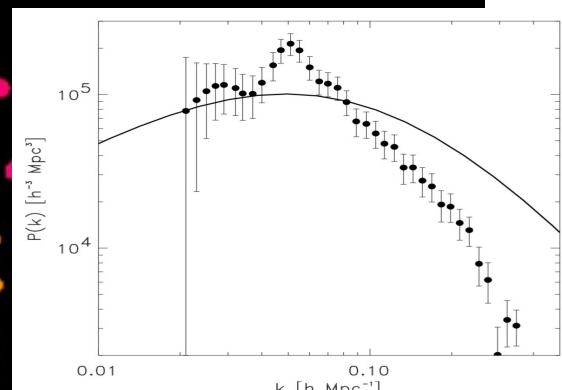
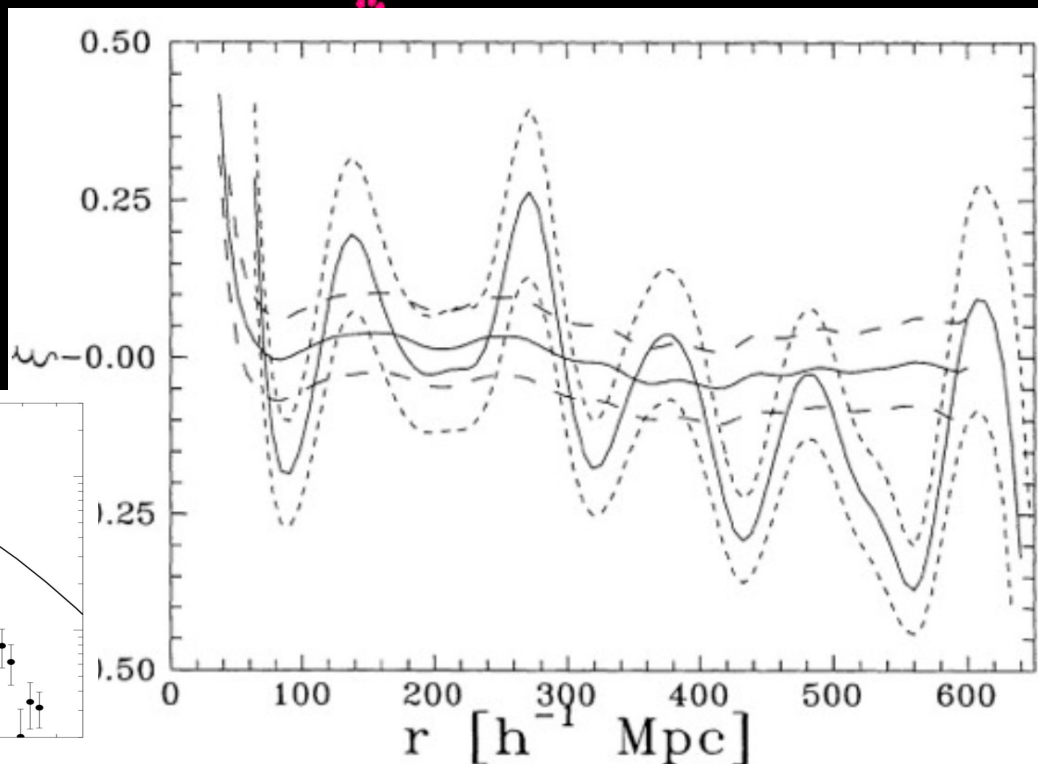
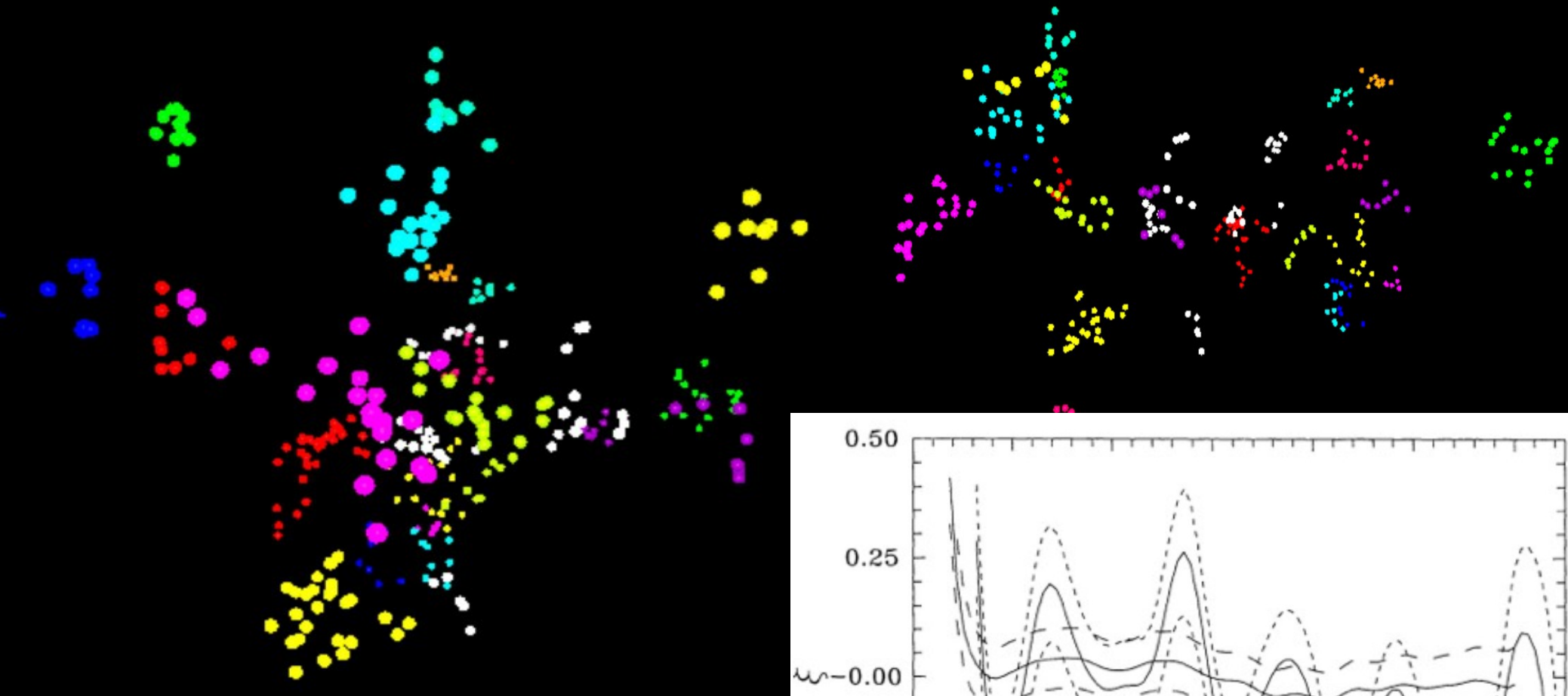
Walls in Illustris simulation
(Hertzsch+ 2026)

Can walls be very thin, flat, perpendicular?

Dolag+2023, A&A 677, 169: constrained simulations: ~ 100 Mpc plane
Saar+ 2002, Peebles (2024) – evidence of long strings?

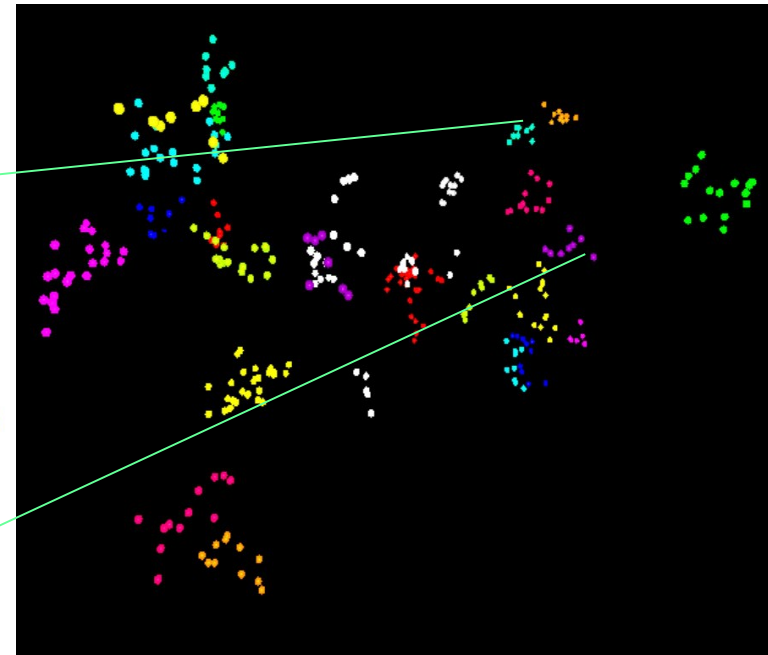
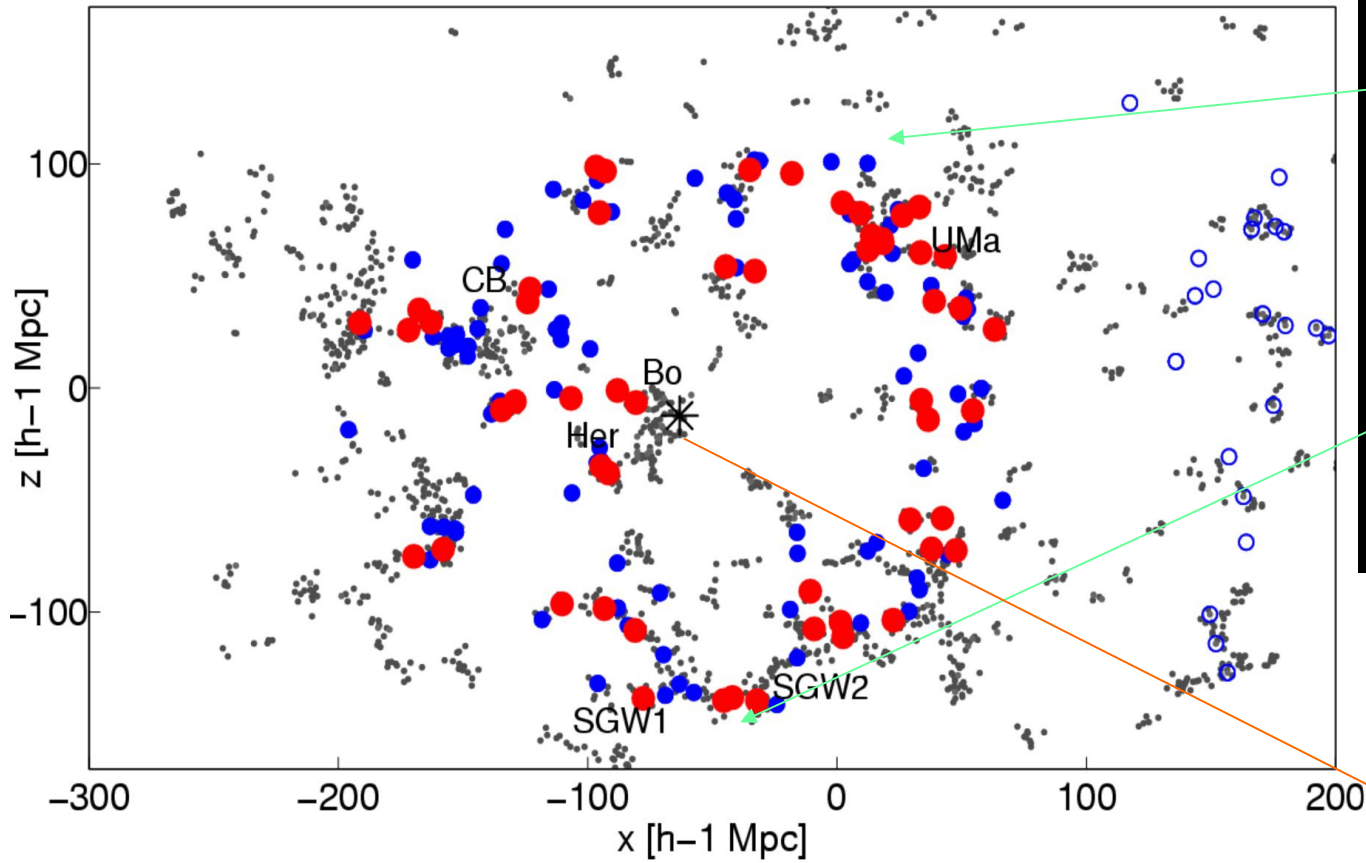


Regularity in the cluster distribution: ~130 Mpc scale, correlation function and power spectrum



E+ 1994,
E+ 1997
MNRAS 289, 801,
Nature 385, 139
Saar+ 2002, A&A393, 1
(periodogram)

Superclusters: quasiregular pattern and “shells”



$$M_{\text{shell}} \sim 2.5 \times 10^{17} M_{\odot}$$

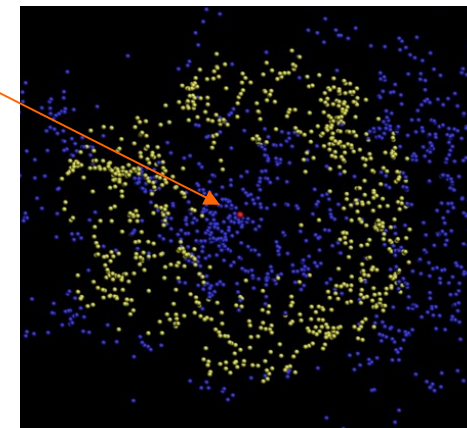
$$M_{A1795} \sim 10^{14} - 10^{15} M_{\odot}$$

Structures of rich superclusters with 130 h-1Mpc scale
as a part of the regular pattern of superclusters (6 “shells”)

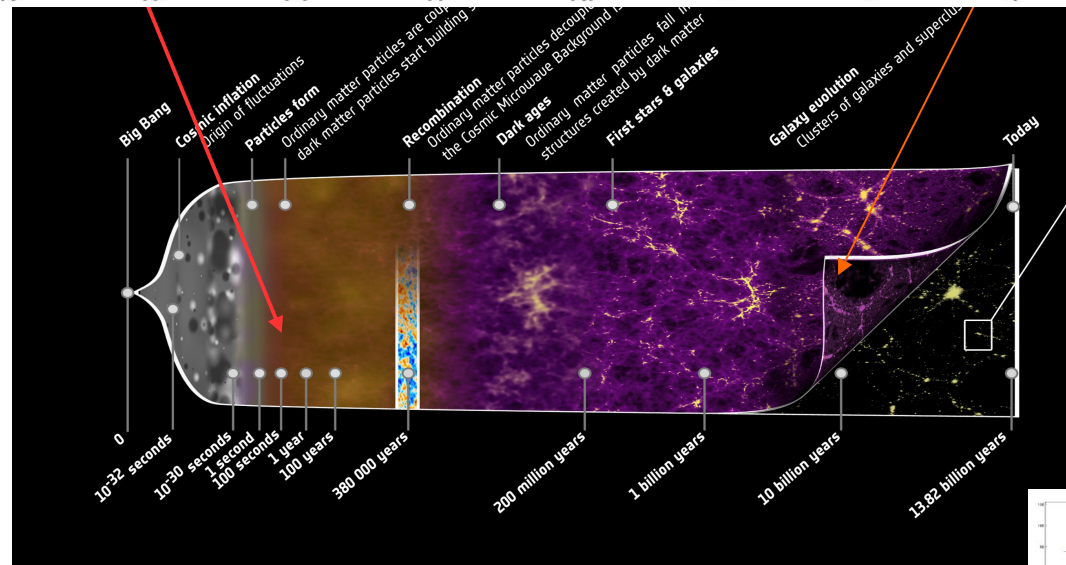
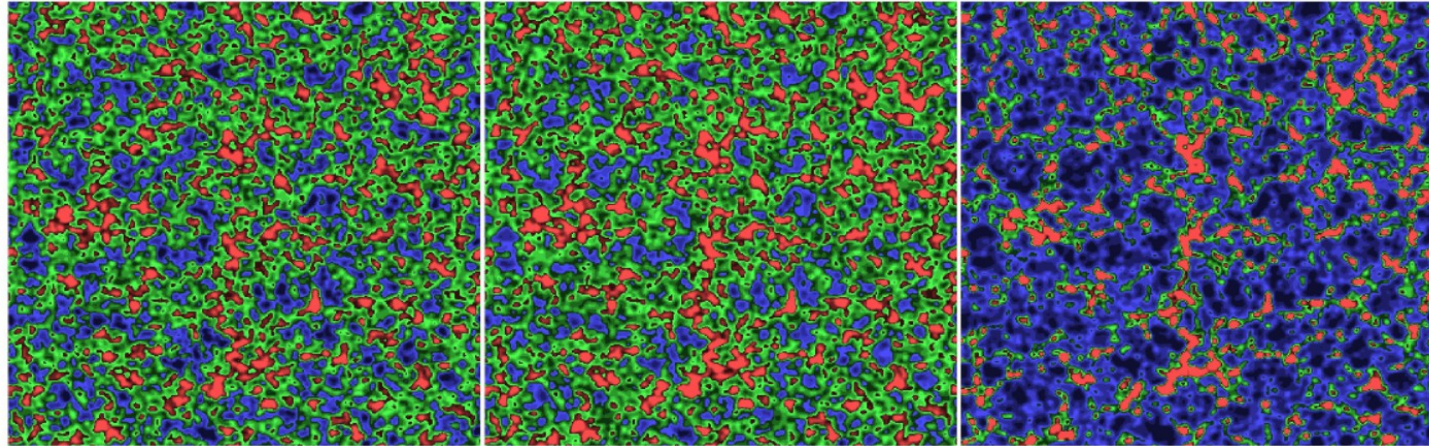
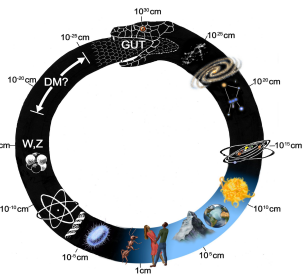
BAO shells? Dark matter oscillations?

Einasto+ 1994, 2011, 2016, Tully+ 2023 (BAO)

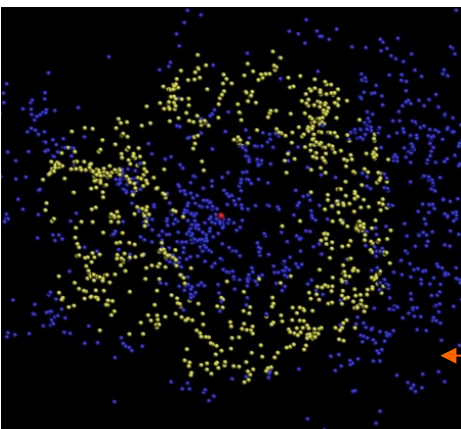
if BAO, then BAO was detected in E+1994 ☺



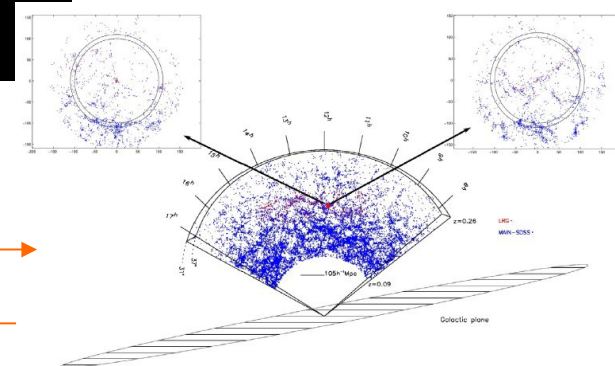
Superclusters: formation and evolution, dark and visible matter



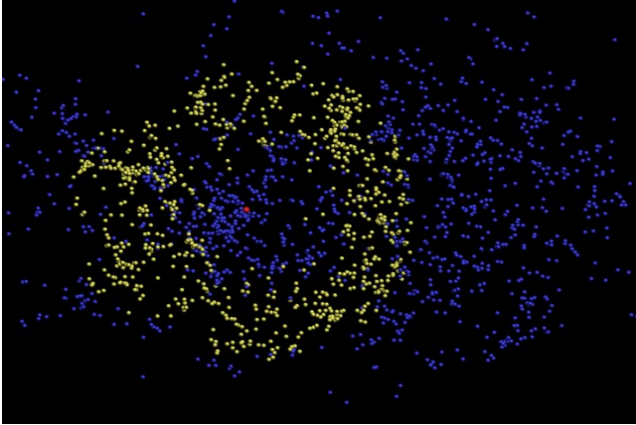
Einasto+ 2019



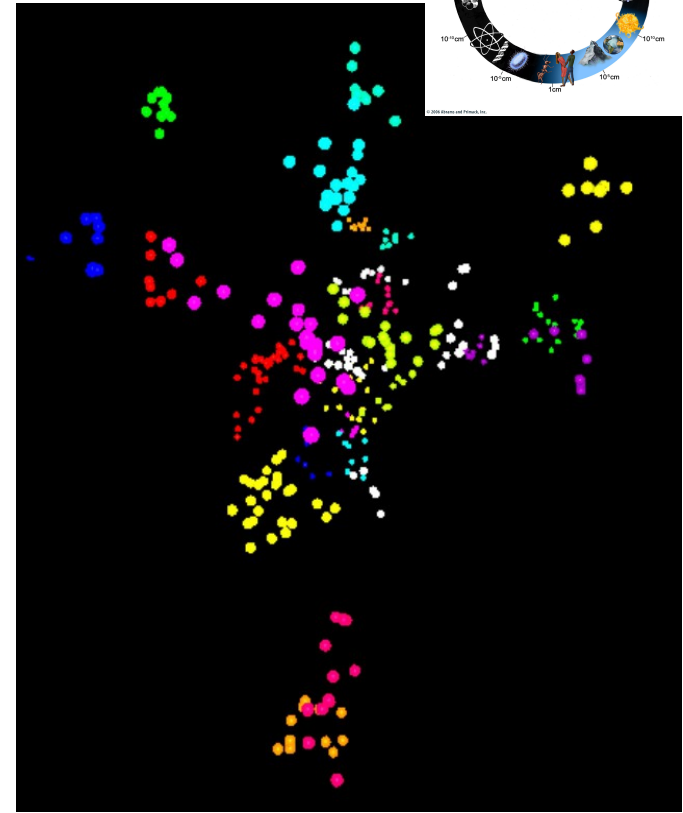
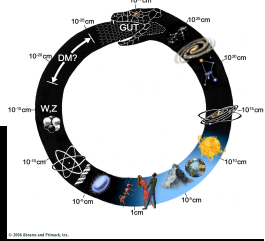
(BAO)enhanced galaxy formation on the top of (dark matter dominated) superclusters?



BAO signature in E+1994?



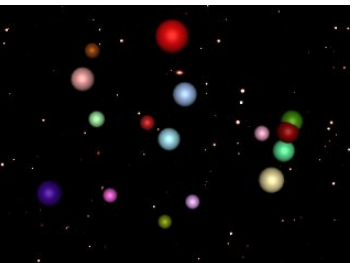
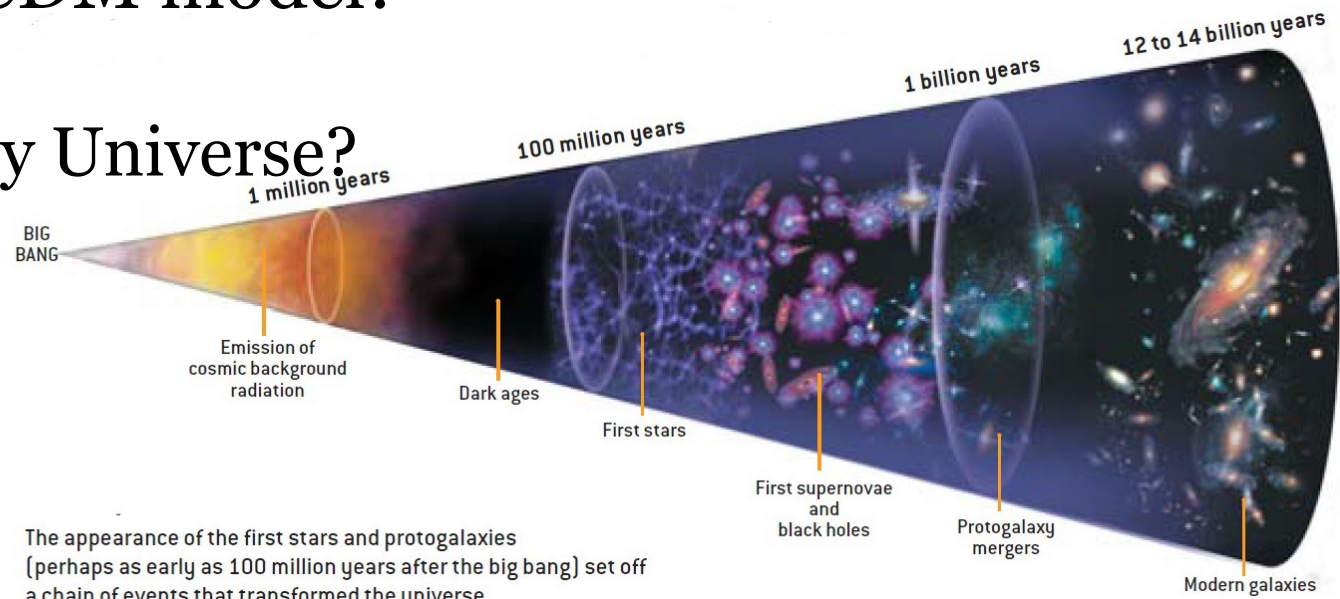
Summary

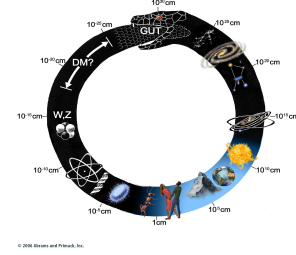


Rich superclusters form complexes and huge planes
 Regularity in the distribution of superclusters

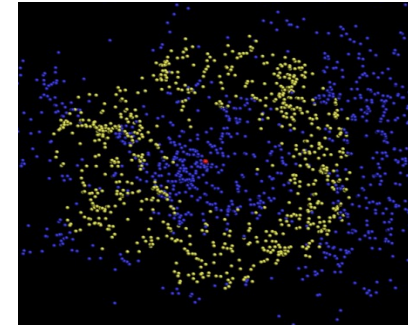
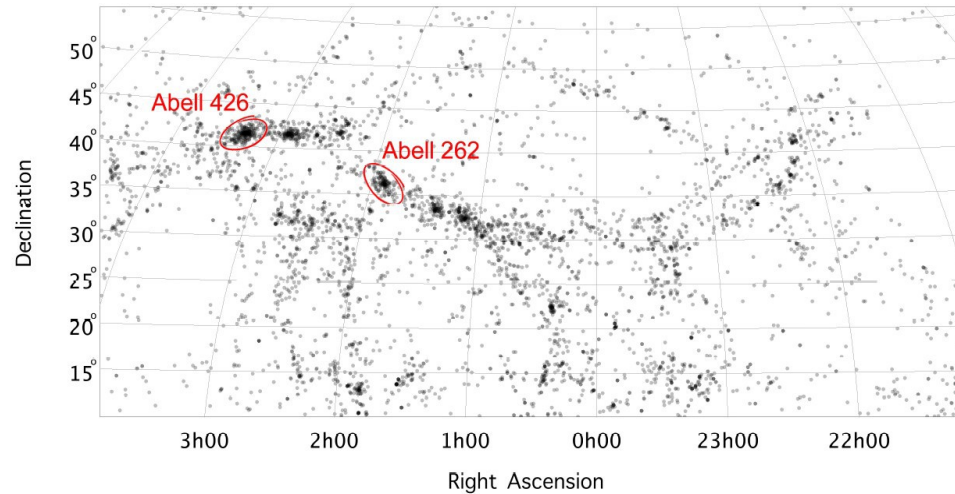
A challenge for the Λ CDM model?

Echo from the very early Universe?





Thank you!



Jaan Einasto, Gert Hütsi, Istvan Szapudi, Peeter Tenjes,
“Spinning the cosmic web”, World Scientific 2026

ME, “Galaxy superclusters and their complexes in the
cosmic web”, Universe, 11, 167, 2025

Di Valentino+ 2025, CosmoVerse White Paper