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a gran escala



UNIVERSIDAD DE ANTIOQUIA
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Diego Restrepo

Junio 4, 2020 -

[PDF: <http://bit.ly/granuniverso>]

Instituto de Física
Universidad de Antioquia
Phenomenology Group
<http://gfif.udea.edu.co>

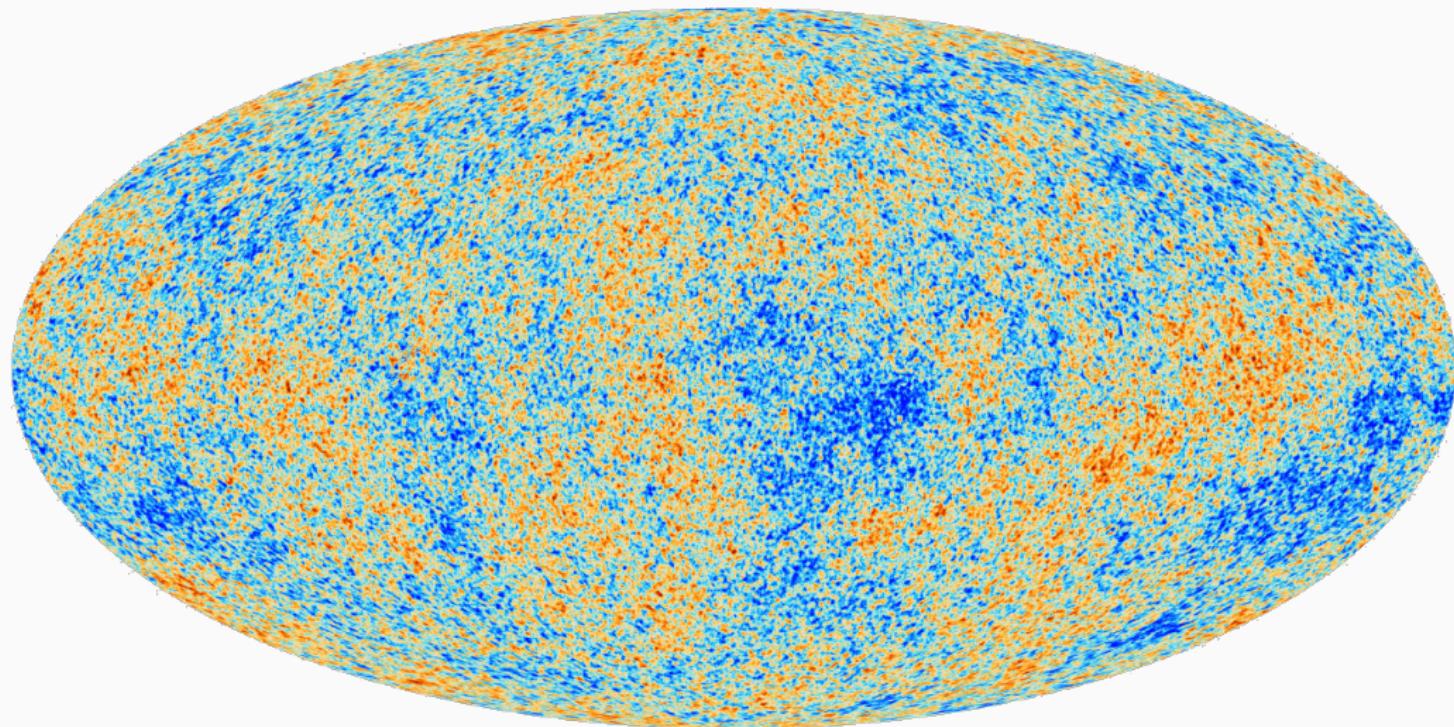
Focus on

In collaboration with

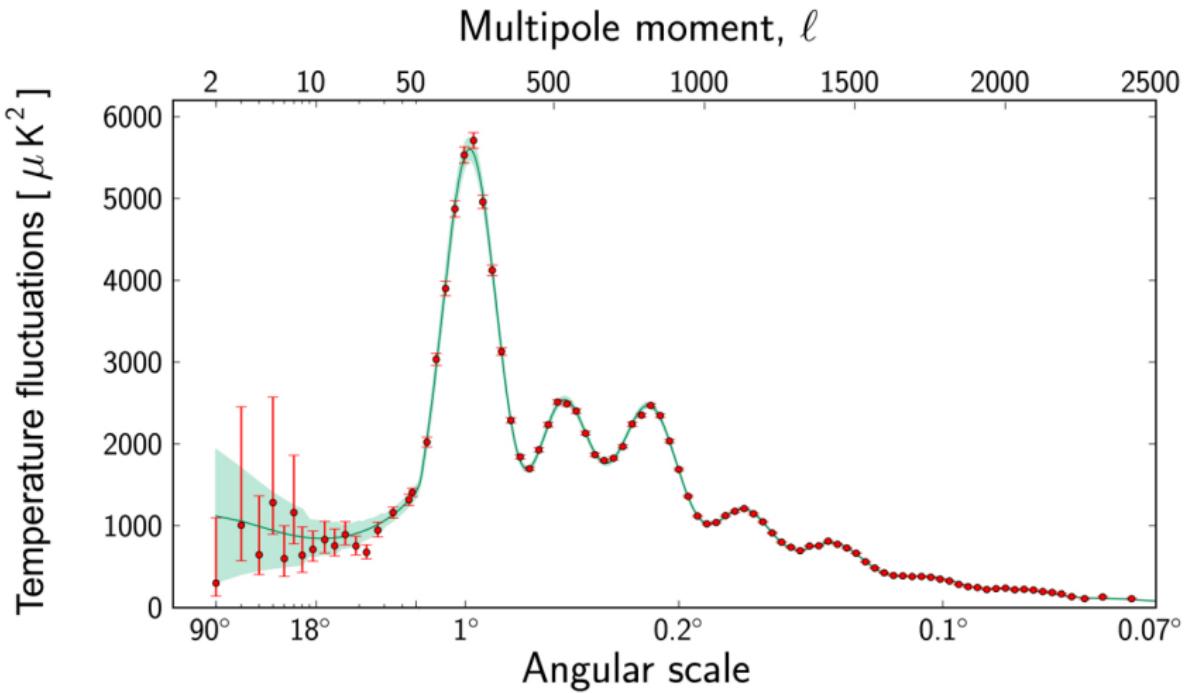


Λ CDM concordance model (with
baryonic effects)

Cosmic Microwave Background temperature: $T = 2.726 \text{ K}$ with $\Delta T/T \sim 10^{-6}$



The Cosmic Microwave Background - as seen by Planck. Credit: ESA and the Planck Collaboration

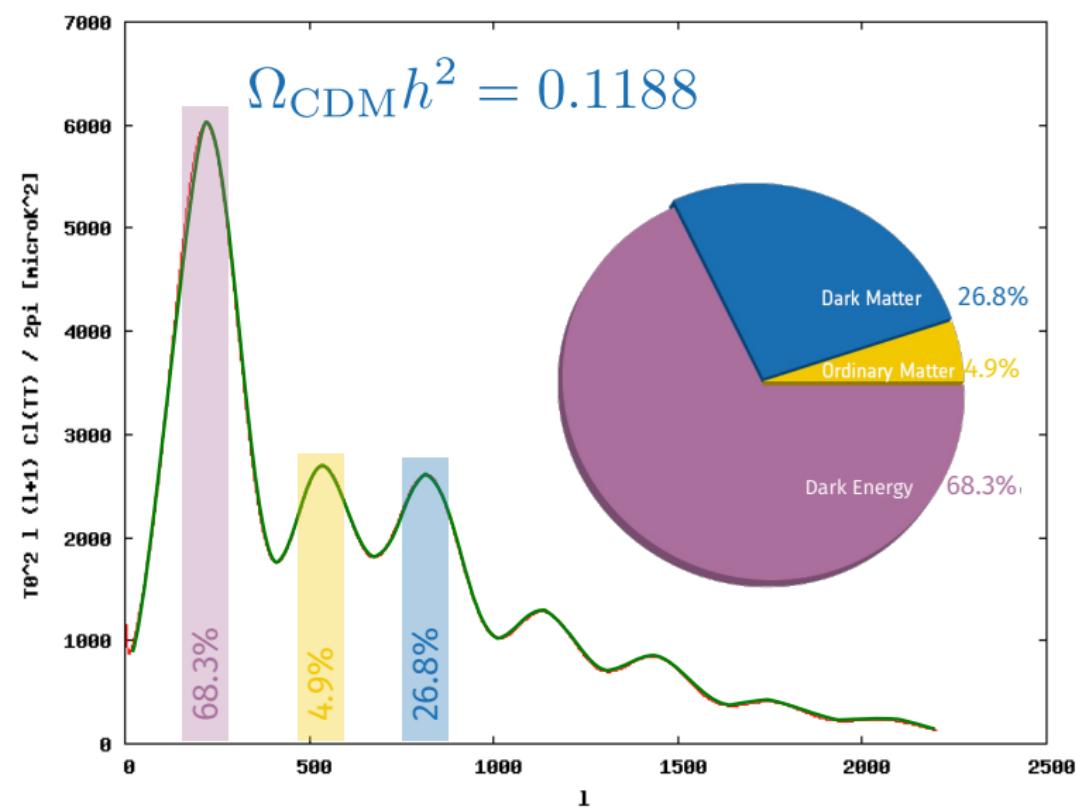


Planck's power spectrum of temperature fluctuations, ΔT , in the Cosmic Microwave Background. Credit: ESA and the Planck Collaboration

ΛCDM : $\Omega = 1$, $w = -1^\dagger$

Symbol	Value
$\Omega_b h^2$	0.02230(14)
$\Omega_{\text{CDM}} h^2$	0.1188(10)
t_0	$13.799(21) \times 10^9$ years
n_s	0.9667(40)
Δ_R^2	2.441×10^{-9}
τ	0.066(12)

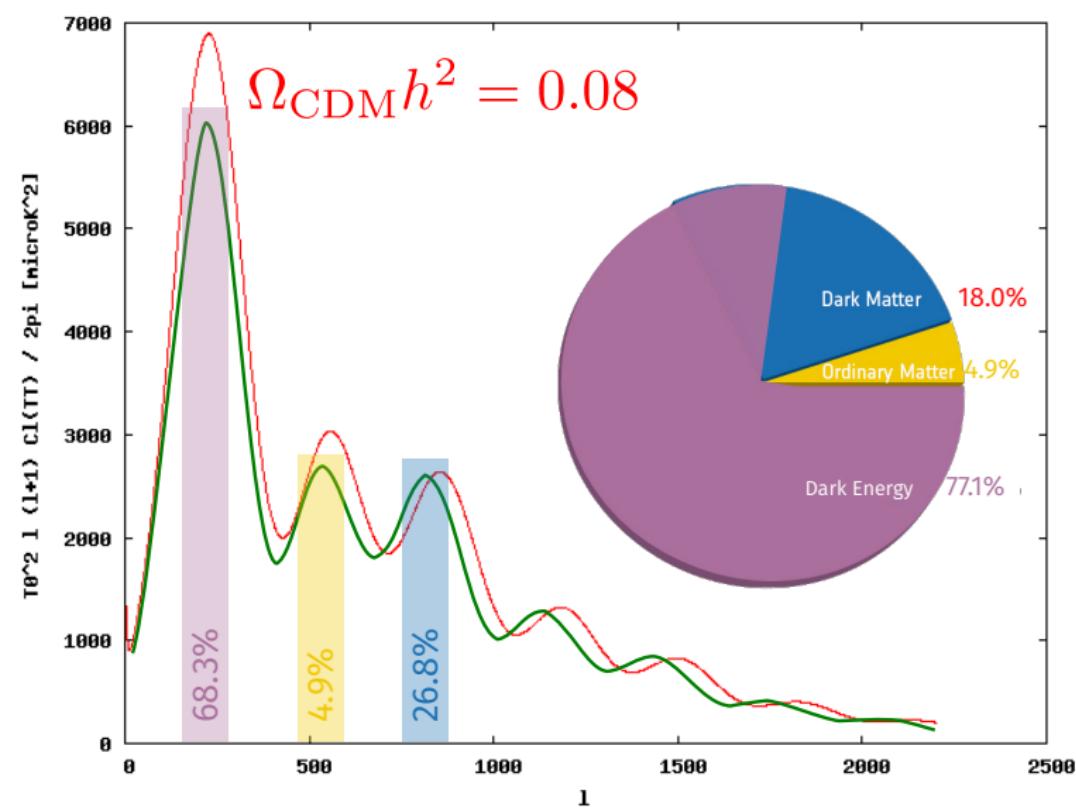
† Cosmological constant



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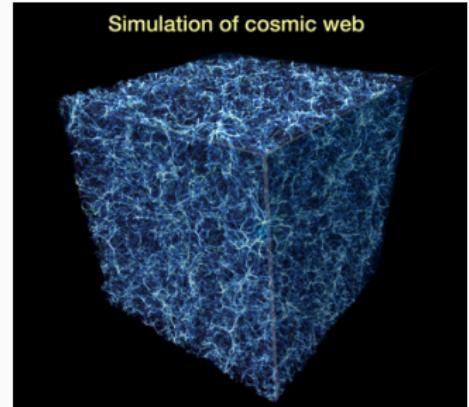
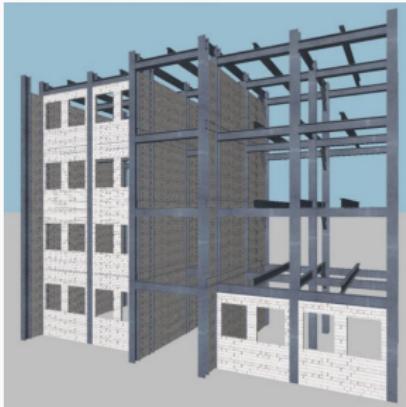
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Cosmic web

Dark matter connects clusters of galaxies with massive tendrils, forming a cosmic web that serves as an unseen skeleton for the universe.

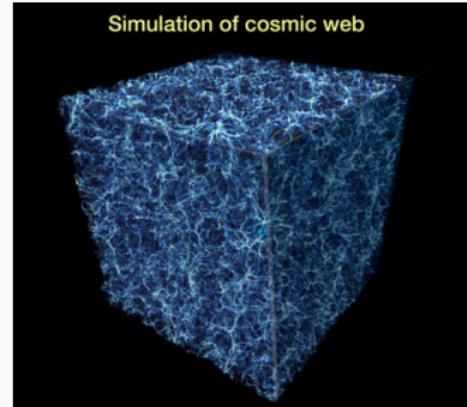
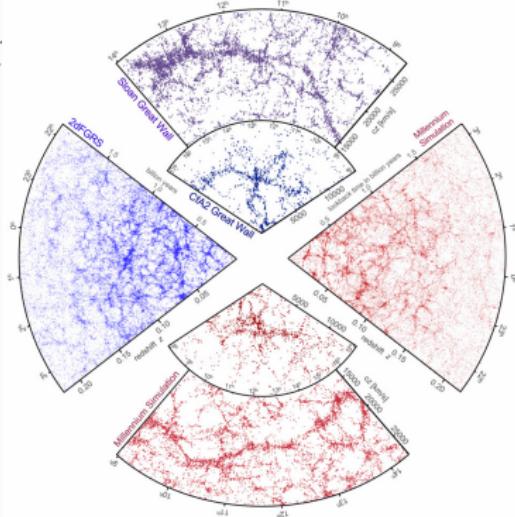
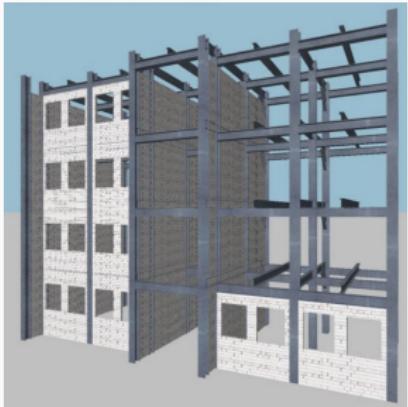
<https://phys.org/news/2018-06-years-scientists-account-universe.html>



Cosmic web

Dark matter connects clusters of galaxies with massive tendrils, forming a cosmic web that serve.

<https://phys.org/news/2018-06->

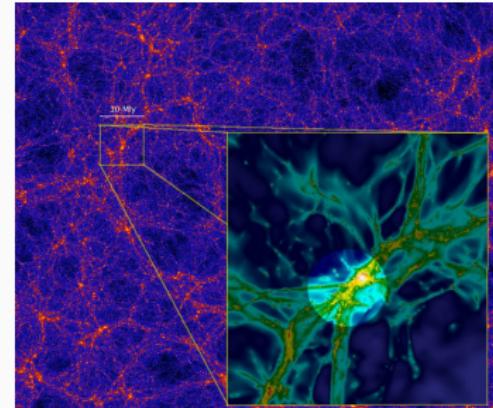
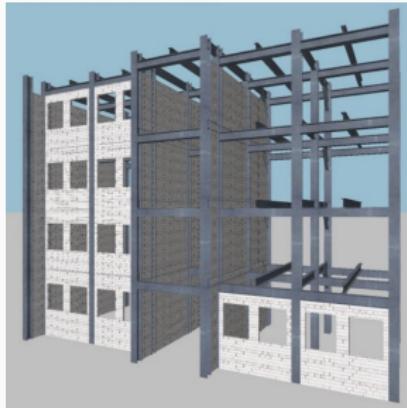


Galaxy redshift surveys vs large scale structure formation simulations: V. Springel, et al [astro-ph/0604561](#) [Nature]

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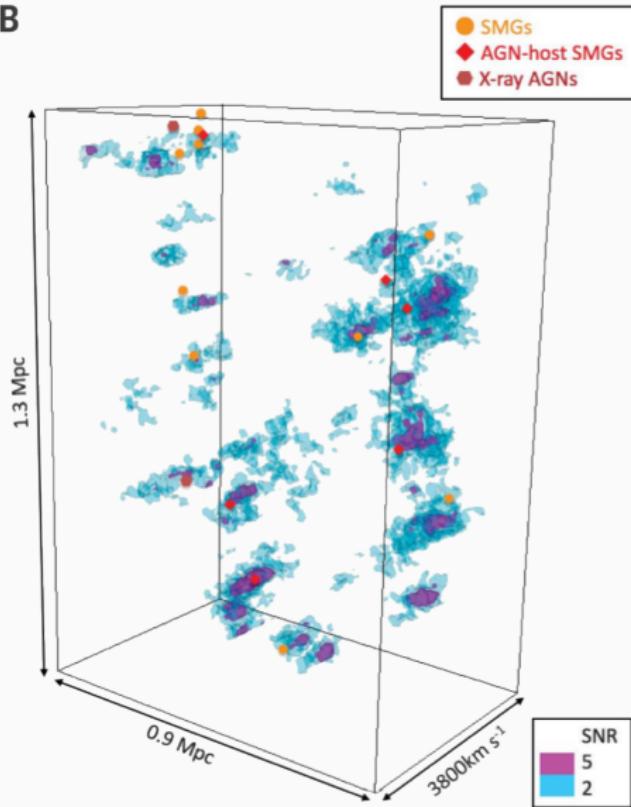
An excess of a gas (20σ) is observed between Milky Way and Andromeda (M31): arXiv:1403.7528 [MNRAS]¹

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¹ See also: arXiv:1603.05400 [A&A]

Three-dimensional pictures of Ly α filaments

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The 3D distribution of Ly α filaments shown with

signal-to-noise ratio (SNR) > 5

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H. Umehata *et al*, Science 366, 97, 4 Oct 2019

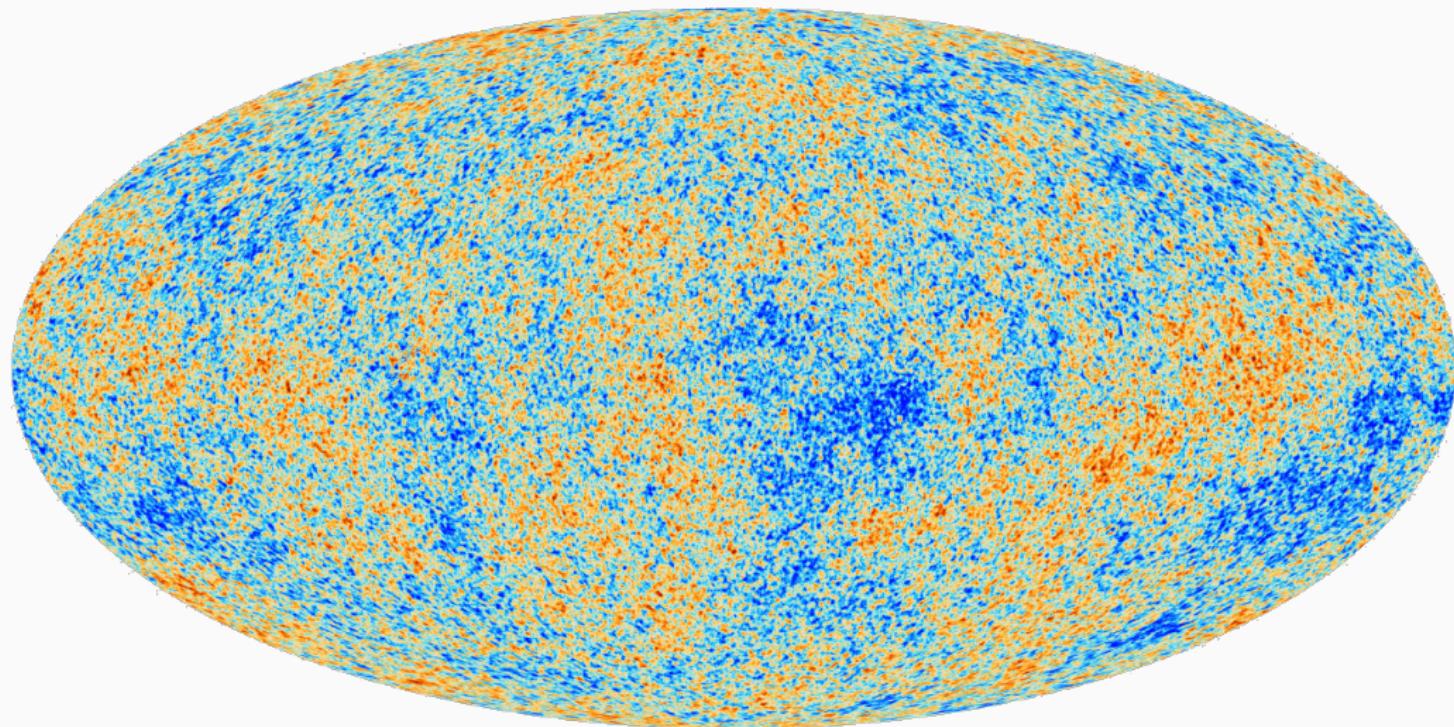
Dark matter properties

Apart from its manifold gravitational influences, (particle) dark matter has so far eluded detection, prompting model builders to think more broadly about what dark matter can be and in the process consider other and more subtle ways to search for it.

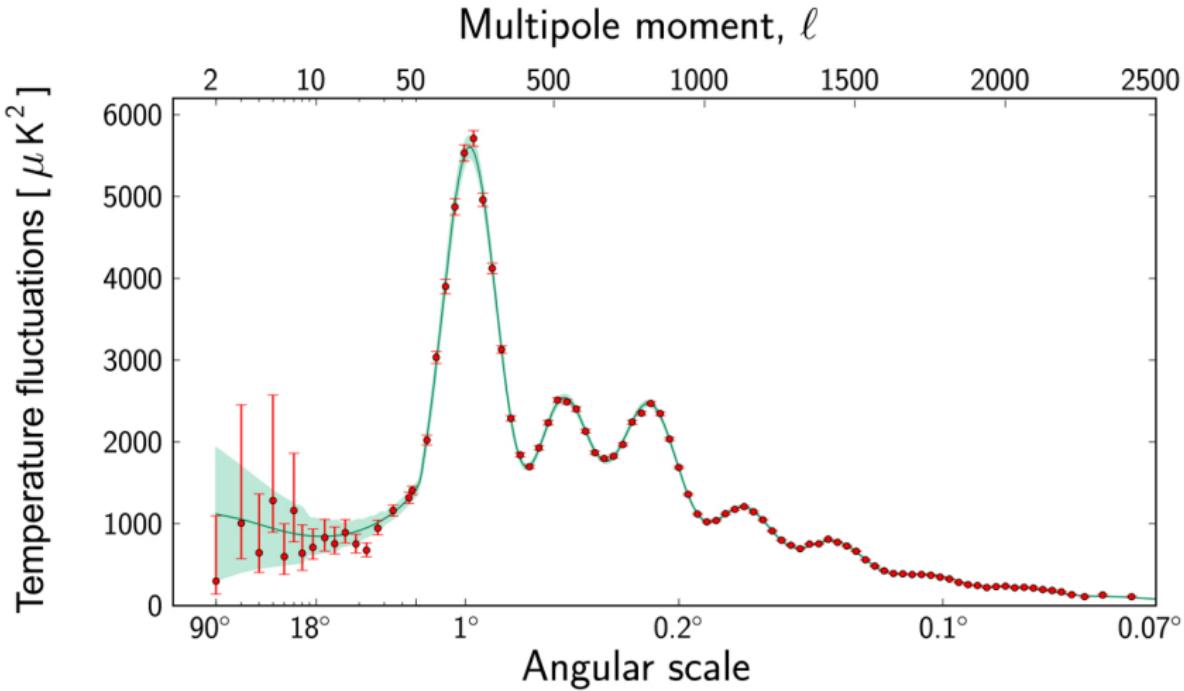
Agrawal, et al, arXiv:1610.04611 [JCAP]

Λ CDM paradigm (with baryonic effects)

Cosmic Microwave Background temperature: $T = 2.726 \text{ K}$ with $\Delta T/T \sim 10^{-6}$



The Cosmic Microwave Background - as seen by Planck. Credit: ESA and the Planck Collaboration

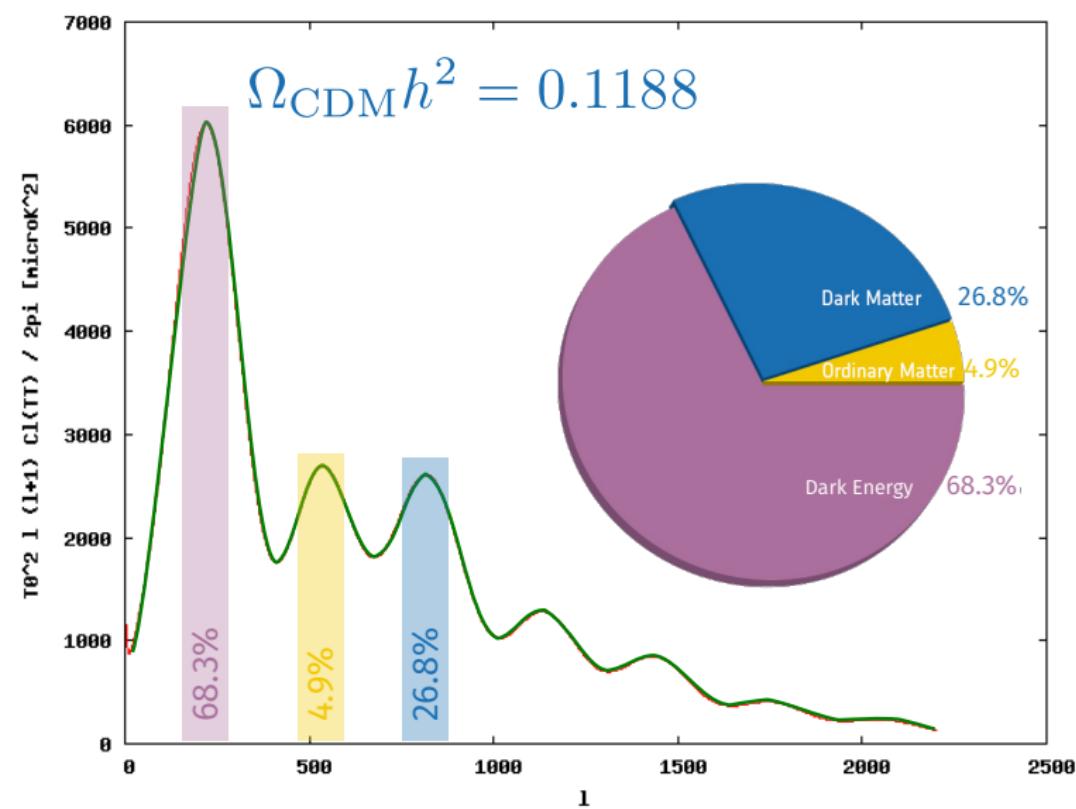


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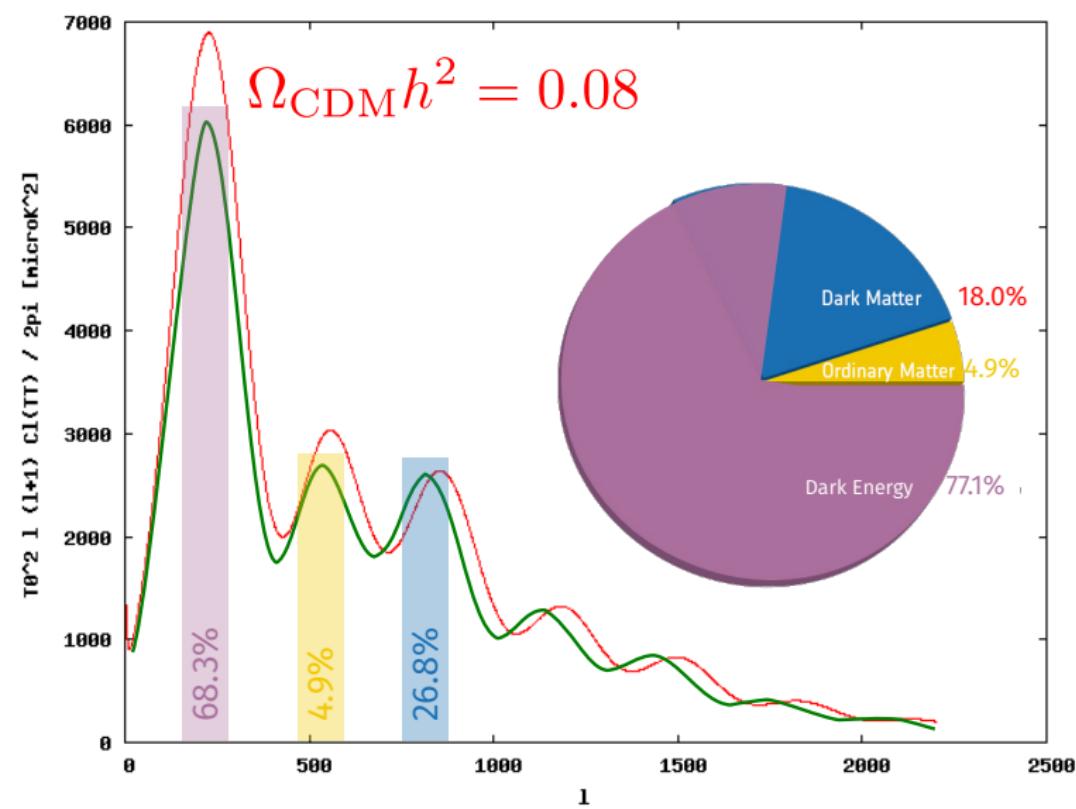
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Cosmic Miso Soup

- When matter and radiation were hotter than 3000 K, matter was completely ionised. The Universe was filled with plasma, which behaves just like a soup
- Think about a Miso soup (if you know what it is). Imagine throwing Tofus into a Miso soup, while changing the density of Miso
- And imagine watching how ripples are created and propagate throughout the soup



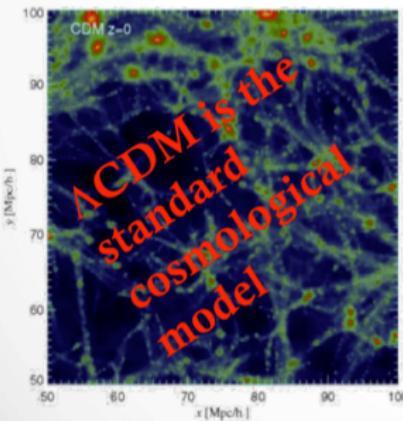
Nobu São Paulo version

Large scale structure simulations: Gas of not hot and almost collisionless dark matter particles

Cold Dark Matter
(Slow moving)

$m \sim \text{GeV-TeV}$

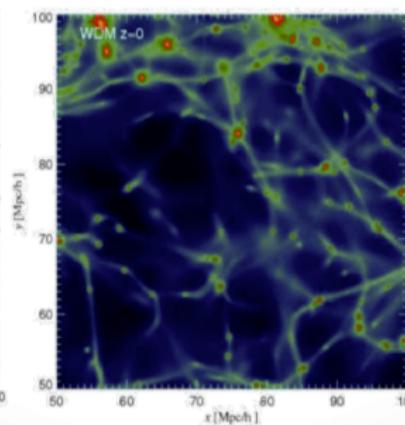
Small structures form
first, then merge



Warm Dark Matter
(Fast moving)

$m \sim \text{keV}$

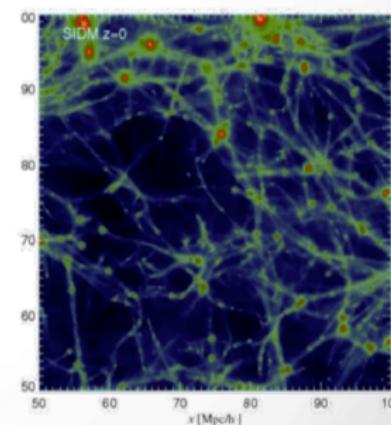
Small structures are
erased



Self-Interacting Dark Matter
Strongly interact with itself

Large scale similar to CDM,

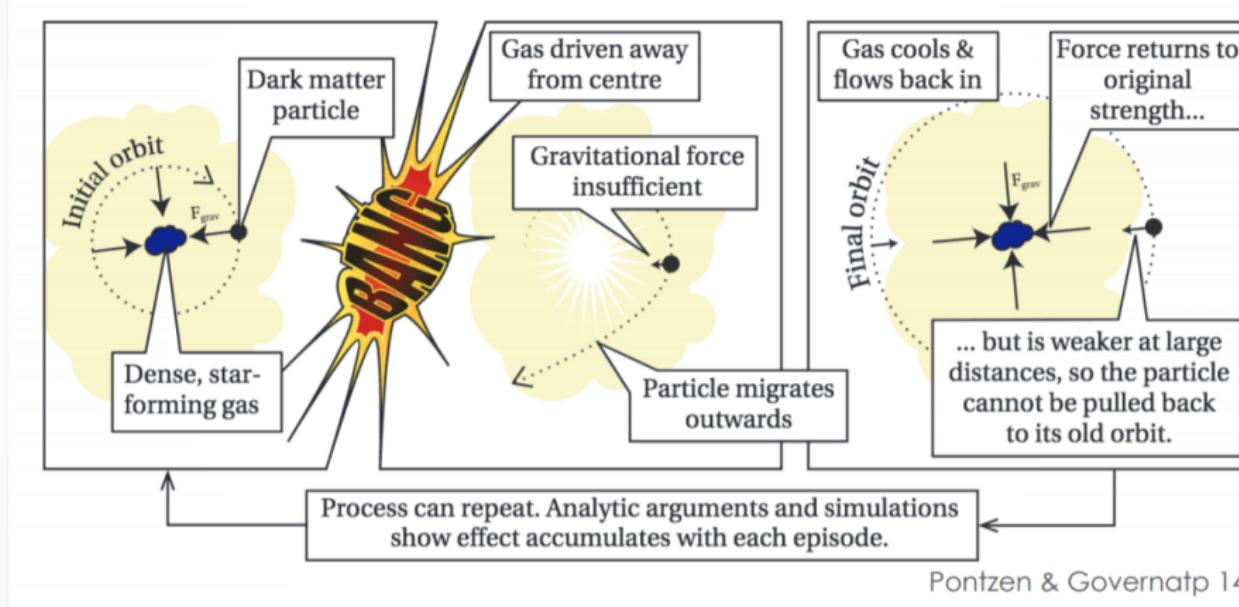
Small galaxies are different



Credit: Arianna Di Cintio (Conference on Shedding Light on the Dark Universe with Extremely Large Telescopes, ICTP - 2018)

Particle: from elementary sub-eV to Primordial Black Hole of several solar masses

Baryonic effects



Once the effect of baryonic physics is included, it is **hard to distinguish between WDM/SIDM/CDM**

- For a review see: Gravitational probes of dark matter physics, M.R. Buckley, *et al*, arXiv:1712.06615 [PR]
- Distinguish WDM/CDM with subhaloes detection: See arXiv:1910.06617

Cosmic web

Dark matter in the universe evolves through gravity to form a complex network of halos, filaments, sheets and voids, that is known as the cosmic web

A.C Rodriguez *et al* arXiv:1801.09070 [CAC]

Cosmological simulations of structure formation predict that the majority of gas in the intergalactic medium (IGM) is distributed in a cosmic web of sheets and filaments as a consequence of gravitational collapse. The intersections of these structures become the locations at which galaxies and their supermassive black holes (SMBHs) form and evolve.

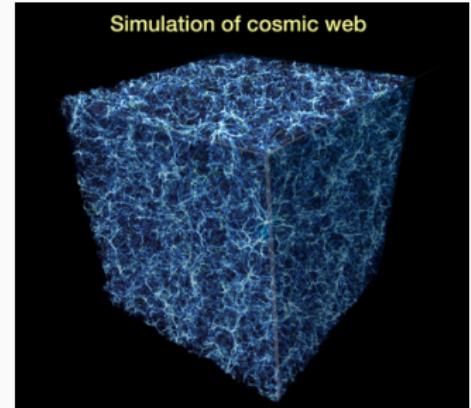
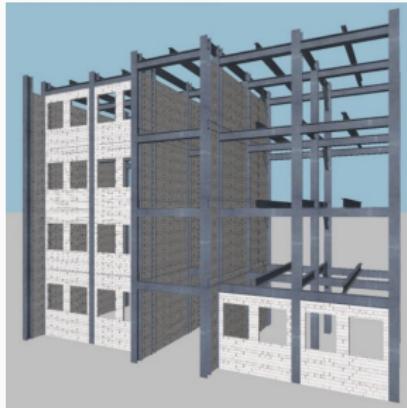
[...] 60% of all gas in the Universe resides in filaments

H. Umehata *et al*, Science 366, 97, 4 Oct 2019

Cooking the soup: Cosmic web

Dark matter connects clusters of galaxies with massive tendrils, forming a cosmic web that serves as an unseen skeleton for the universe.

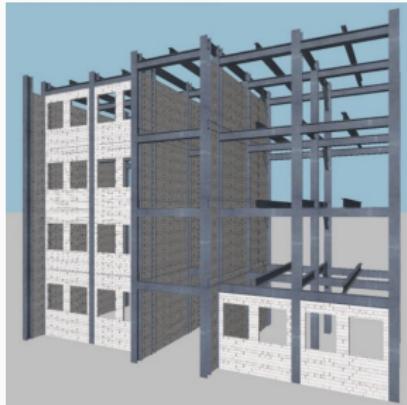
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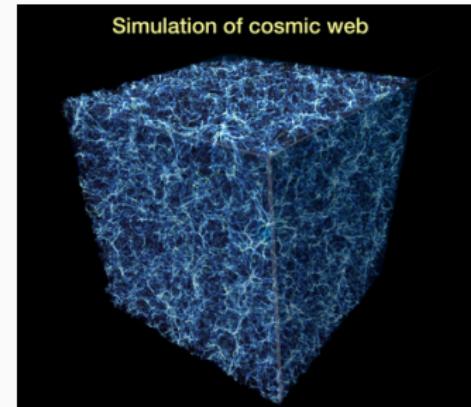
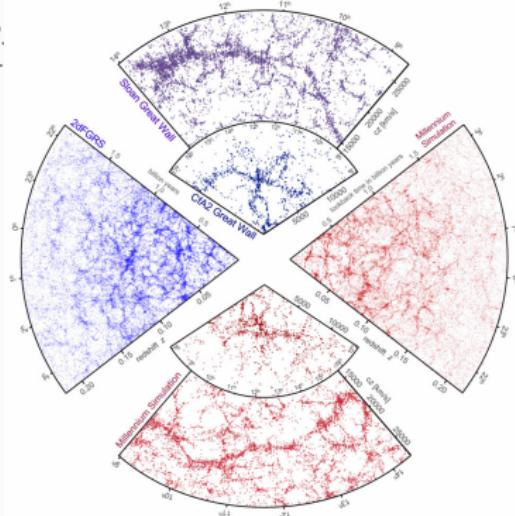
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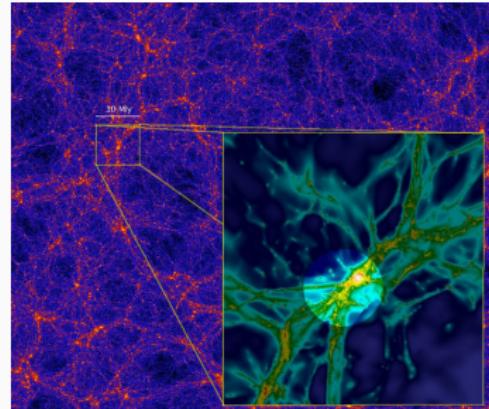
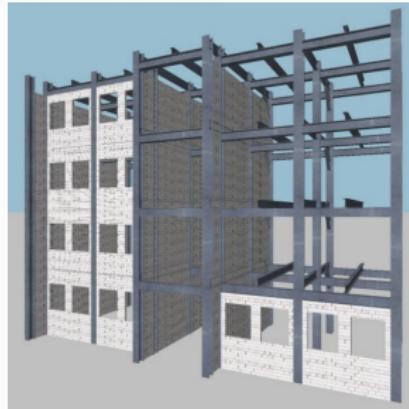
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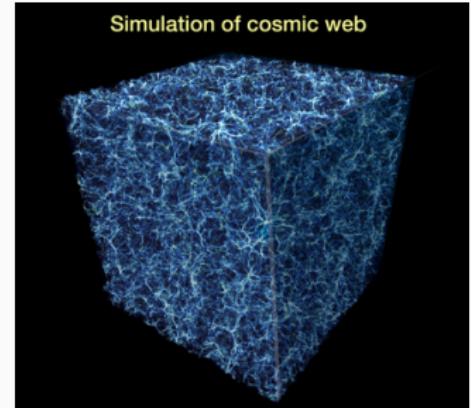
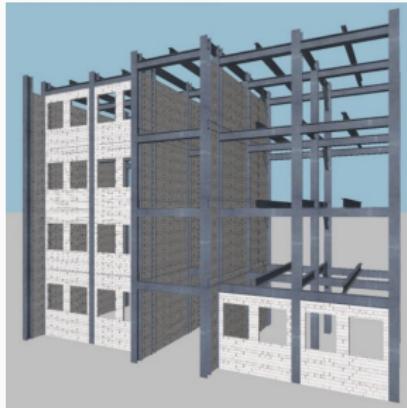
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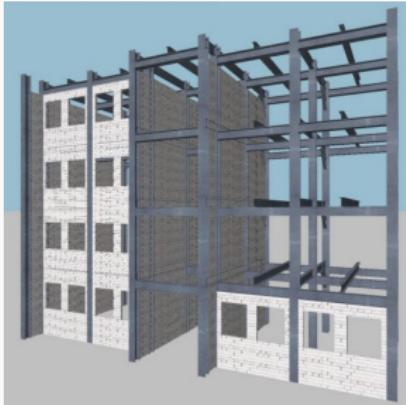
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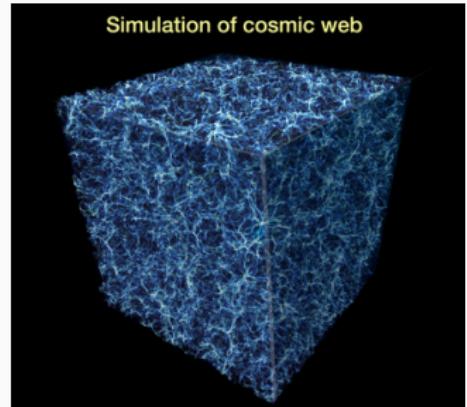
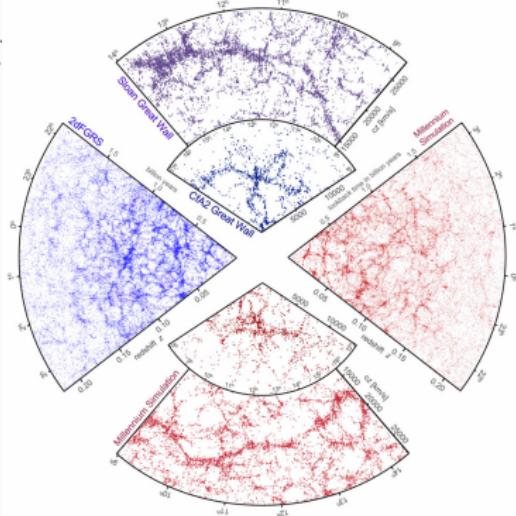
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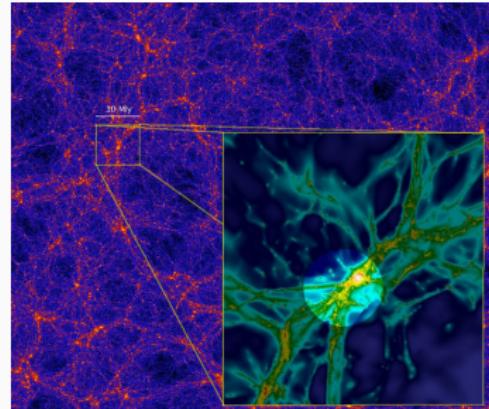
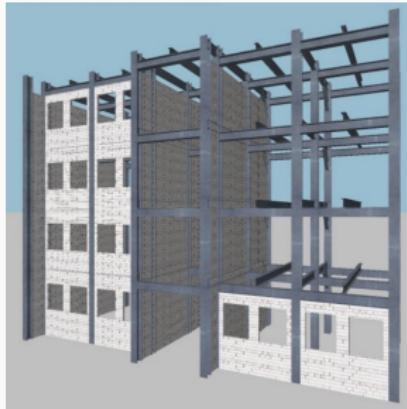
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Cosmic Anatomy

Baryons

Missing Baryons

Dark Matter



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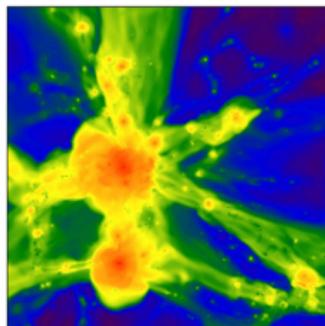
The muscles



Direct observations of filaments

Where are the Baryons? (Cen, Ostriker, astro-ph/9806281 [AJ])

Thus, not only is the universe dominated by dark matter, but more than one half of the normal matter is yet to be detected. (the muscles)



Warm-hot intergalactic medium (WHIM)
Density-weighted temperature projection of a portion of the refinement box of the C run of size $(18 h^{-1}\text{Mpc})^3$.
Low temperature WHIM confirmed by O VI line that peak at $T \sim 3 \times 10^5$ K

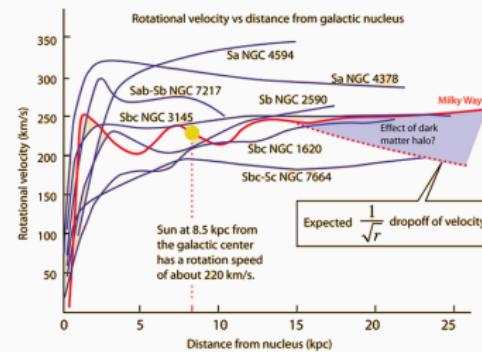
Credit: Cen, arXiv:1112.4527 [AJ]



Hotter phases of the WHIM: Observations of the missing baryons in the warm-hot intergalactic medium (Nicastro, et al. arXiv:1806.08395 [Nature]).

Evidences at all redshifts.

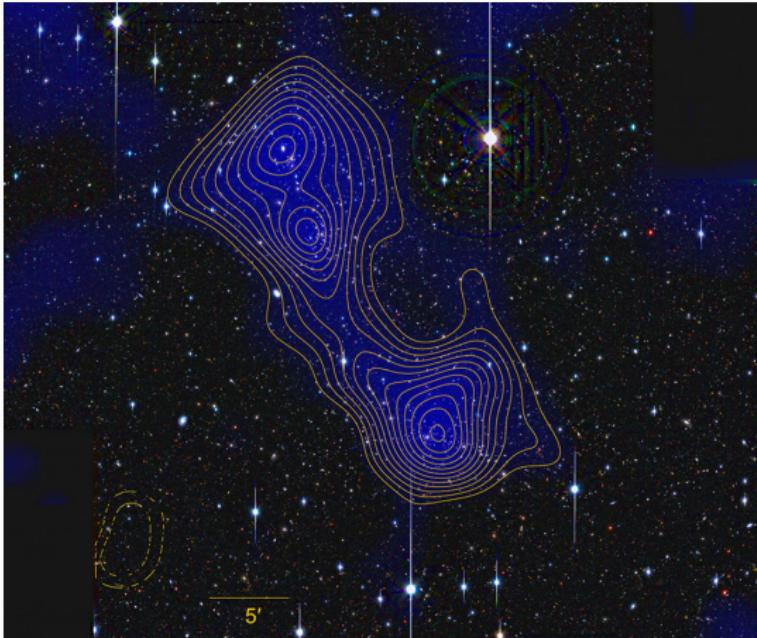
- For cluster of Galaxies
- For stars inside Galaxies
- Inside our Galaxy
- Senatore reconstruction
- En las simulaciones se parte de la CMB



Inner Milky Way

<https://www.nature.com/articles/nphys3237>

A filament of dark matter between two clusters of galaxies



Supercluster system of three galaxy clusters

- Abell 222 (south) detected at $\sim 8\sigma$
- Abell 223 (north) double galaxy cluster seen at $\sim 7\sigma$

reconstructed surface mass density (blue)

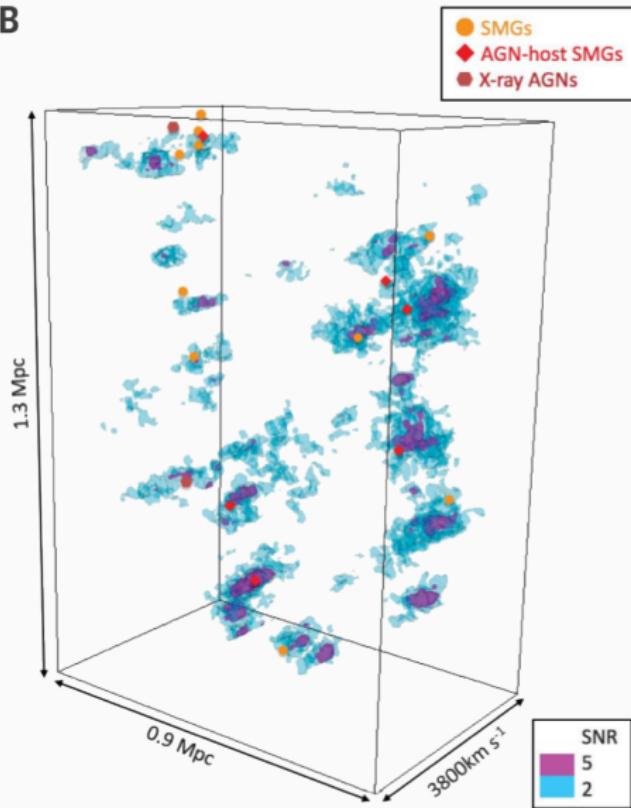
significance contours from 0.5σ to 2.5σ

J.P. Dietrich *et al*, arXiv:1207.0809 [Nature]

For a recent review see: arXiv:1905.08991

Three-dimensional pictures of Ly α filaments

B



The 3D distribution of Ly α filaments shown with

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H. Umehata *et al.*, Science 366, 97, 4 Oct 2019

Conclusions

In addition to accommodate usual simplified dark matter models, Left-right symmetric standard models have additional DM portals:

New Δ_R portal for direct detection of left-singlet right-triplet mixed dark matter, in companion with left-singlets charged and doubly charged fermions.

Next: Search for them in compressed spectra scenarios at the LHC

Thanks!