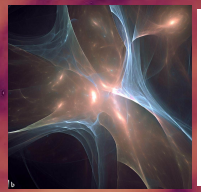
ARMONIA
Constraining Dark Matter and Dark Energy with Astrophysical probes

- Alejandro Benítez-Llambay -

- On behalf of ARMONIA -

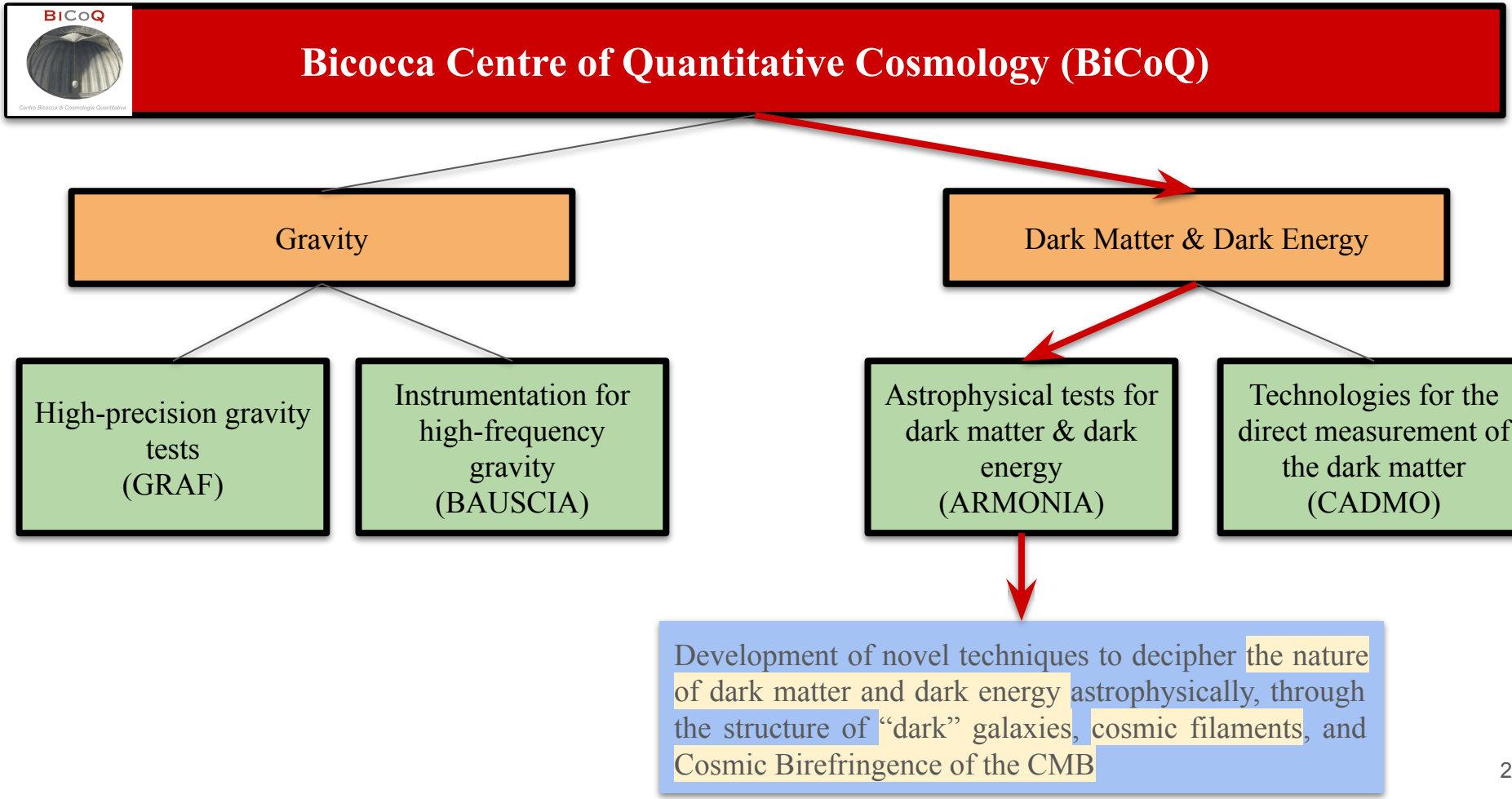


BICOCQ

Centro Bicocca di Cosmologia Quantitativa

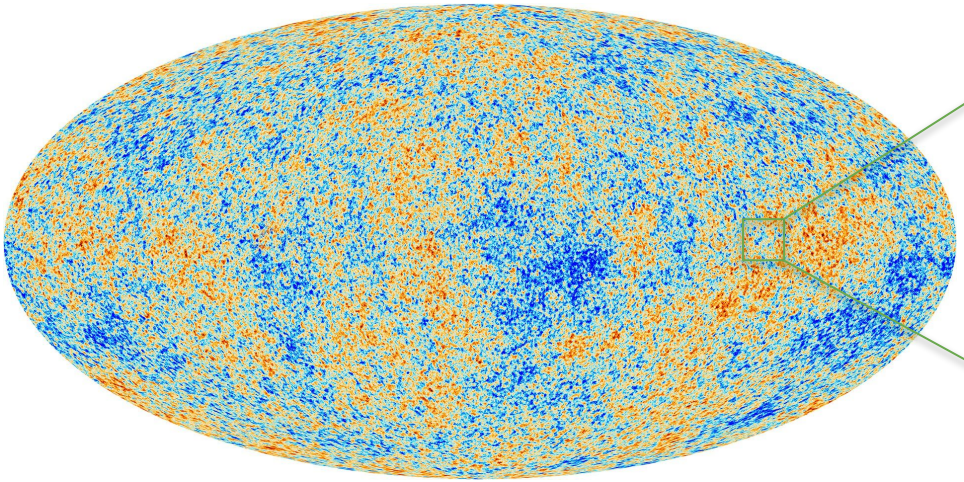
UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

Bicocca Centre of Quantitative Cosmology (BiCoQ)

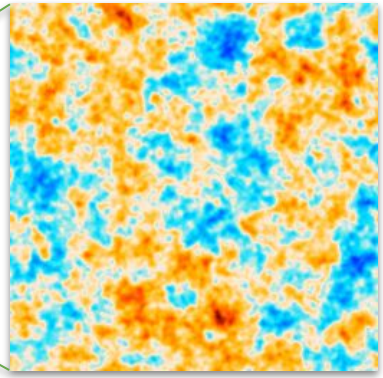


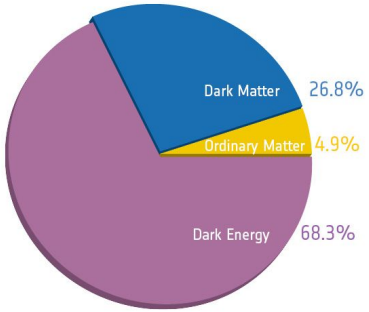
The Need for Dark Matter and Dark Energy

Planck Collaboration (2016)



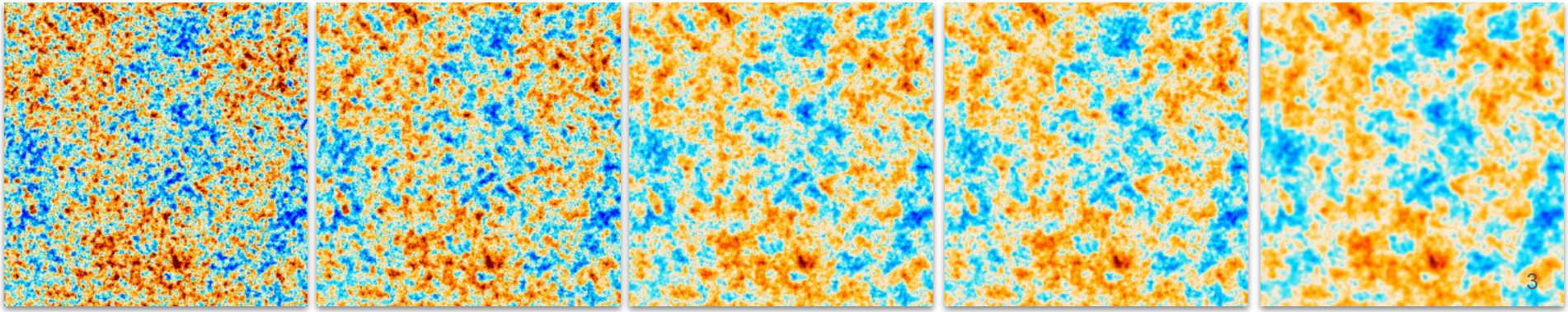
Our Universe





Baryonic matter

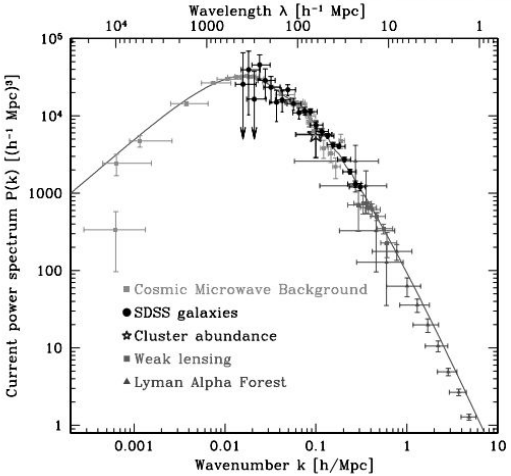
Increasing contribution of non-baryonic Dark Matter



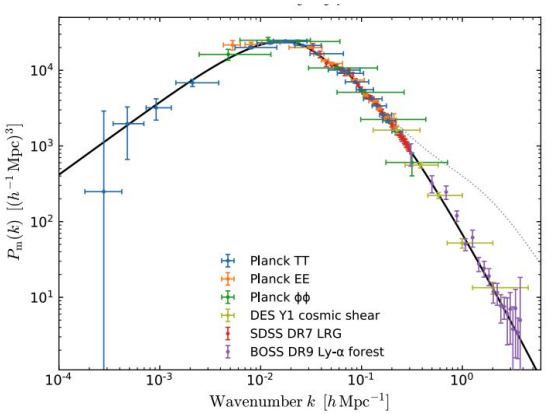
The Standard Model of Cosmology

The standard model of cosmology (ΛCDM) fits observational data over scales spanning several orders of magnitude.

Remarkably, observations taken at different times and over different scales, can be accurately described by a single curve: the ΛCDM power spectrum.



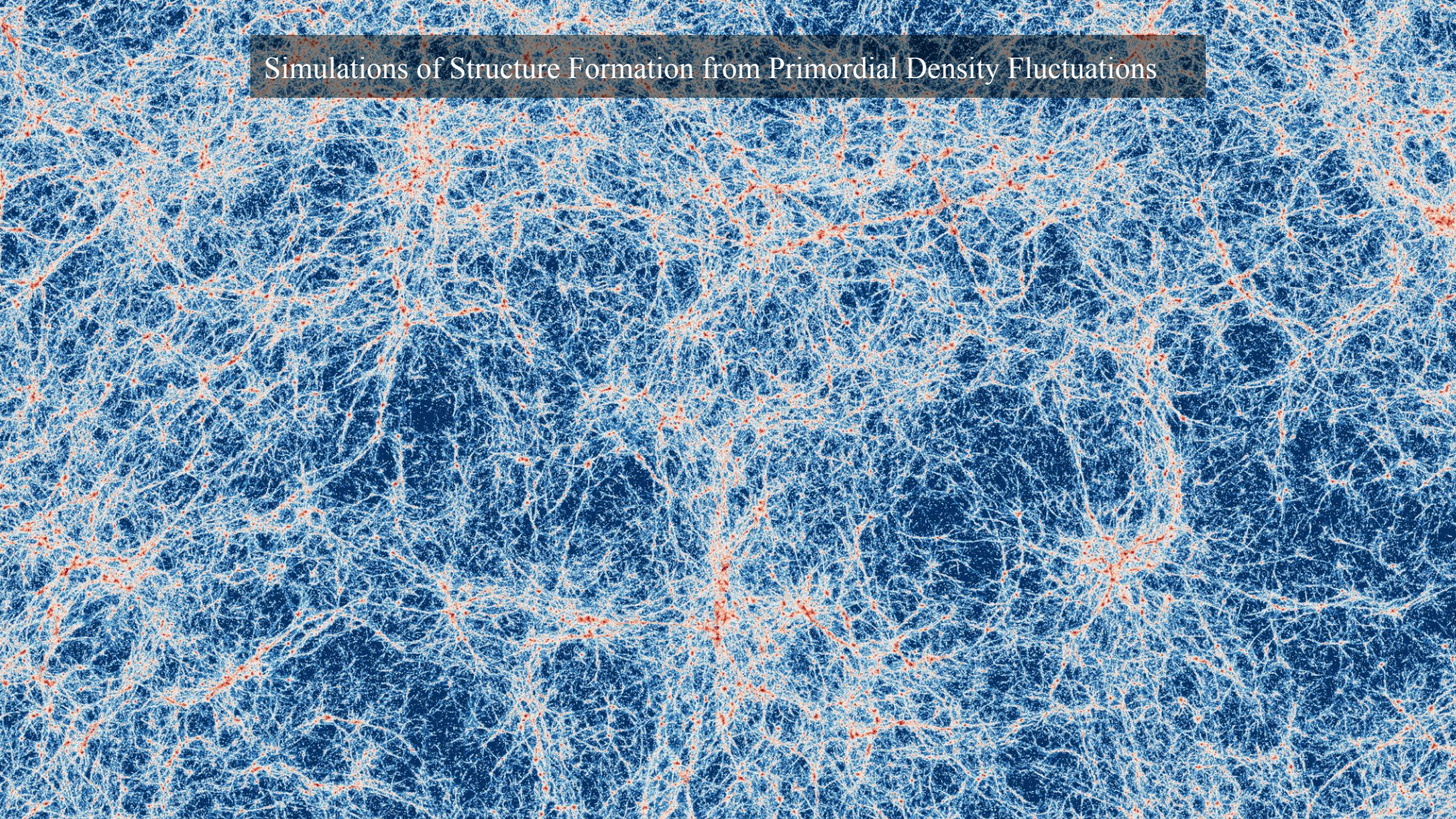
Tegmark 2004



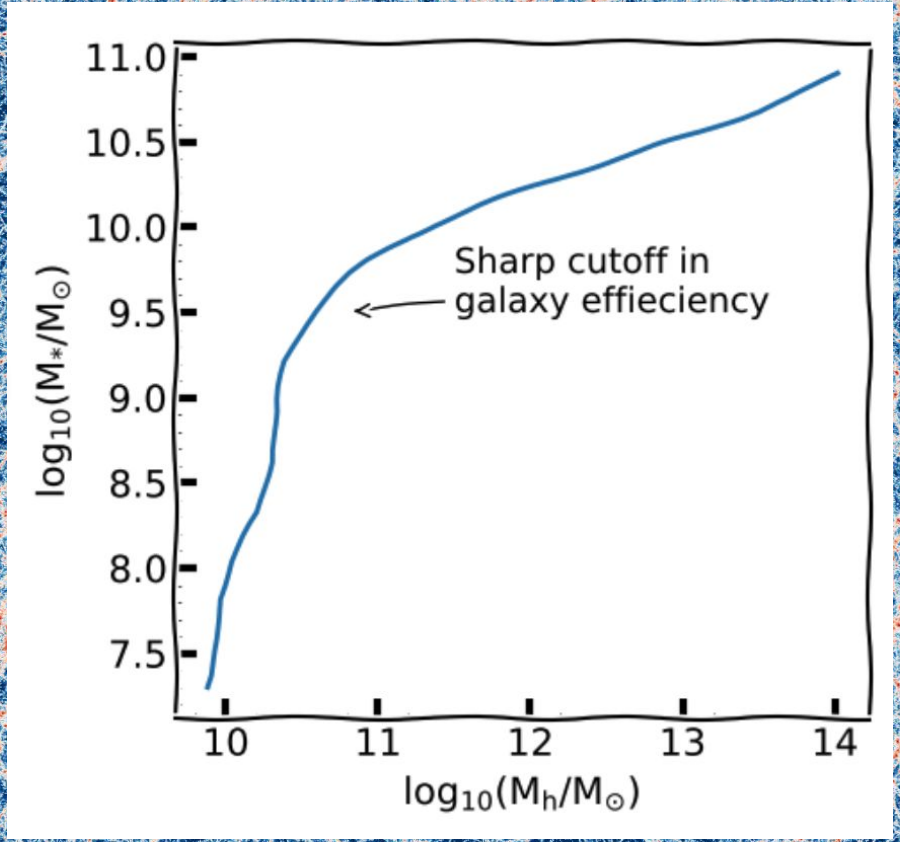
Planck collaboration (2019)

Agreement between CMB data at z~1000 and galaxy clustering at z~0 validates the paradigm of structure formation triggered by the gravitational instability of small density fluctuations.

Any hope to rule out ΛCDM from astrophysical observations lies to the right of these plots, where we do yet not have observations!


Simulations of Structure Formation from Primordial Density Fluctuations

Simulations of Structure Formation from Primordial Density Fluctuations

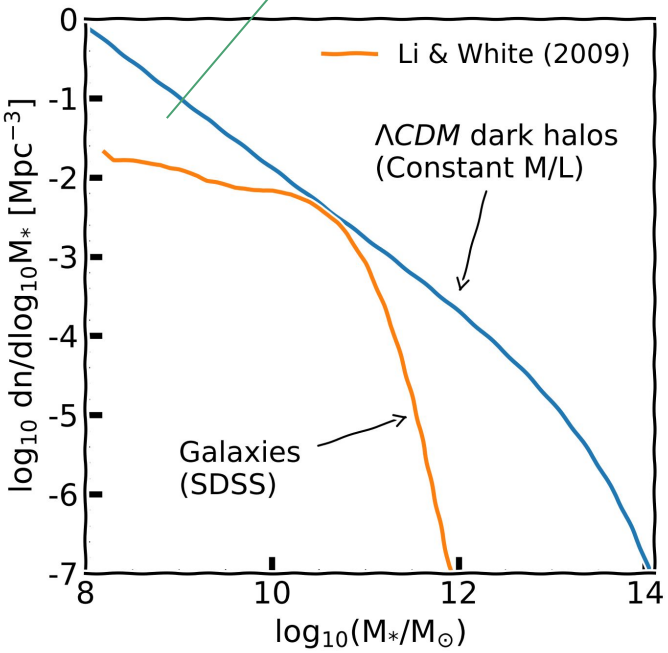


State-of-the-art numerical simulations of galaxy formation indicate that below a characteristic halo mass, galaxies becomes increasingly less massive, and eventually stop forming altogether.

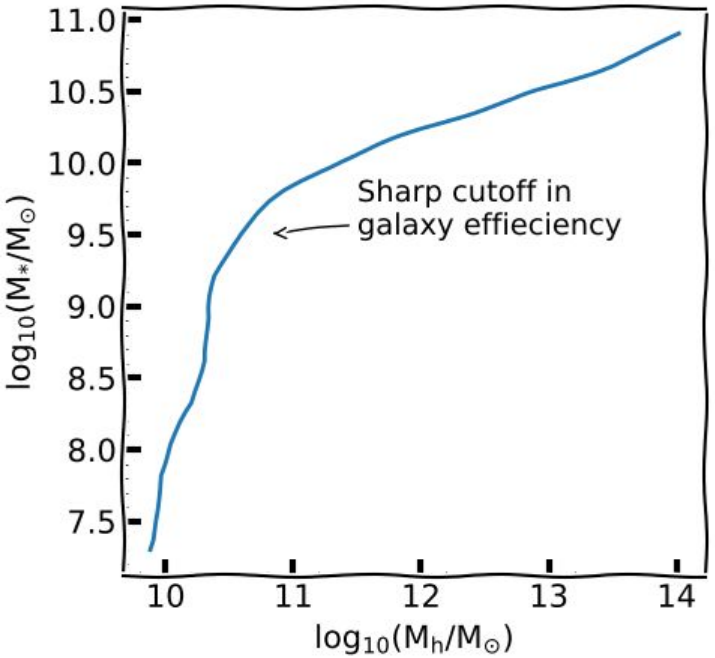
The low-mass end of the galaxy-halo connection

Discrepancy largely due to reionization

Increasingly large number of starless haloes below 10^{10} $M_\odot$



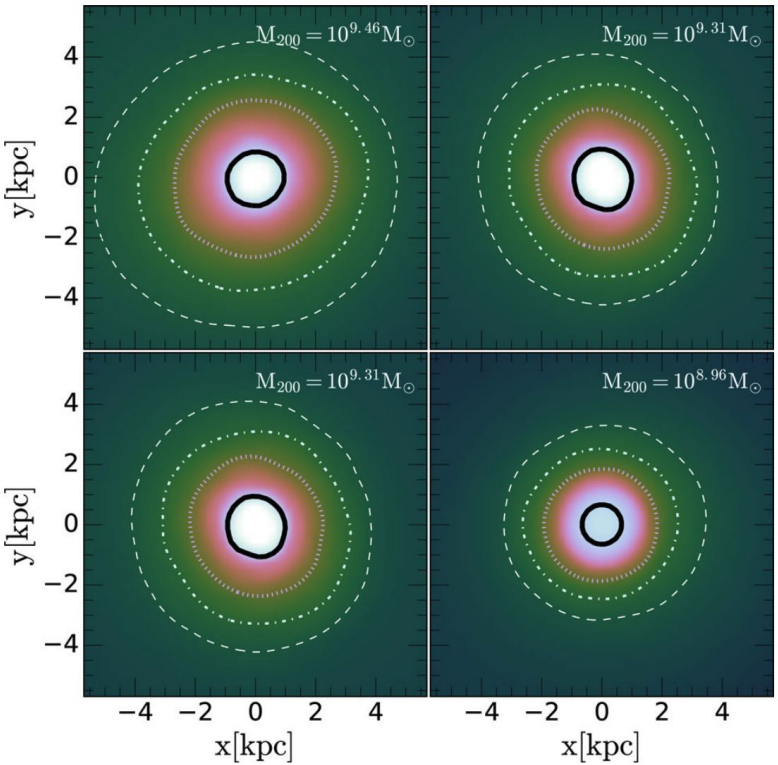
$$n(> M_{halo}) = n(> M_*)$$



Matching halos and galaxies by abundance
(e.g. Behroozi et al. 2013)

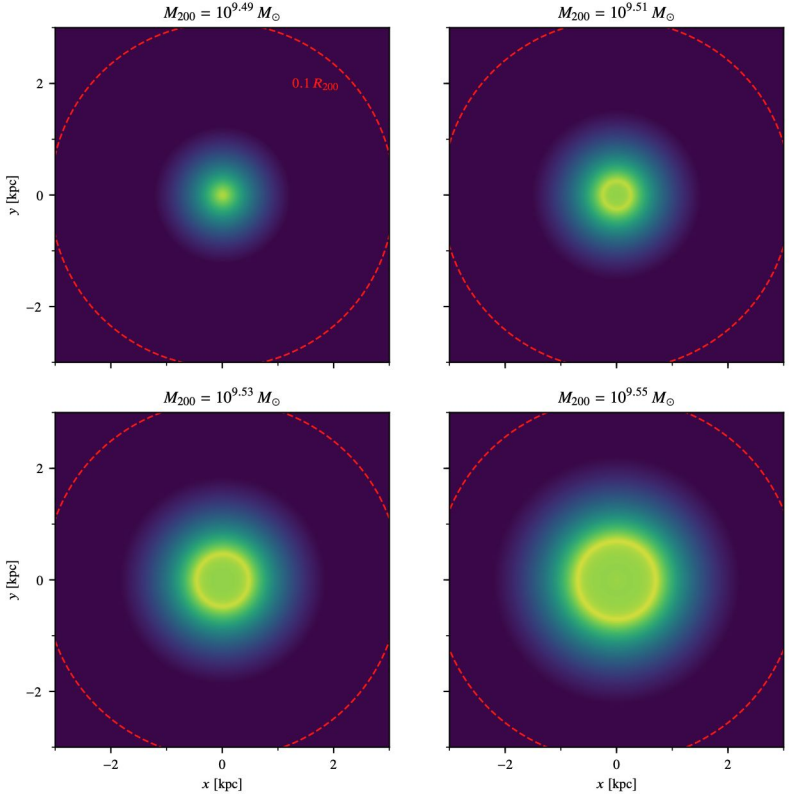
RELHIC: Reionization-limited-HI-Cloud

Emission in 21 cm



(ABL et al. 2017)

Emission in Hα



(Sykes, Fumagalli, ABL 2019)

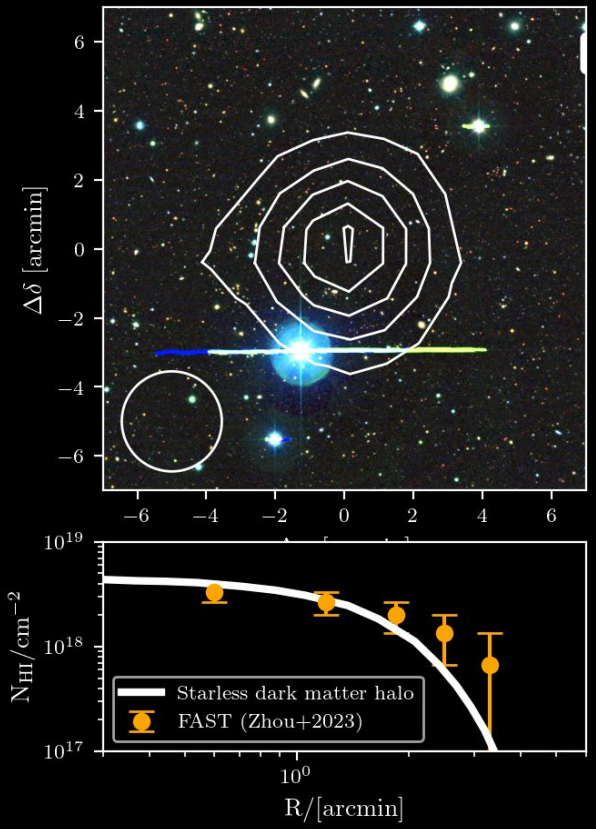
The First RELHIC detected with FAST?

Observations by Zhou et al. (2023)

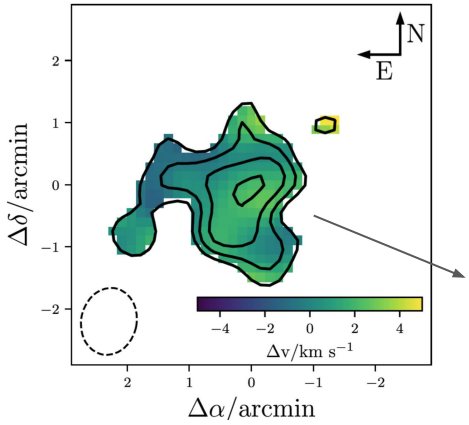
Video by ABL

The First RELHIC detected with FAST?

Benítez-Llambay & Navarro (2023)

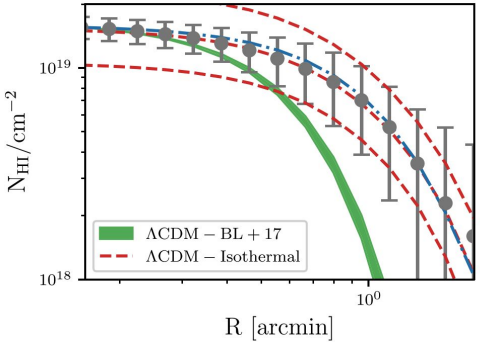


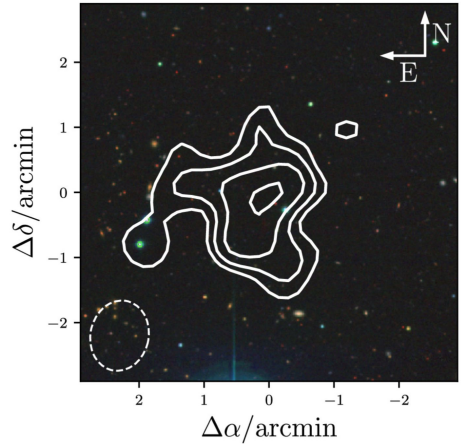
Very Large Array Observations of Cloud-9

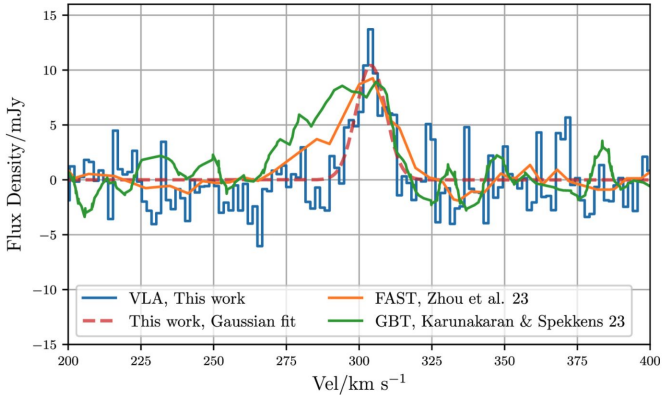


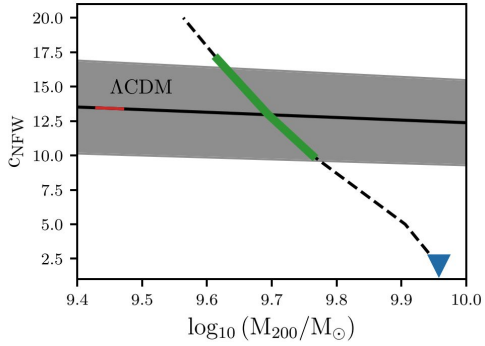
Observed with VLA, the system displays features consistent with being subject to ram pressure stripping.

The central gas distribution is still consistent with a gaseous system in hydrostatic equilibrium with a large amount of dark matter.



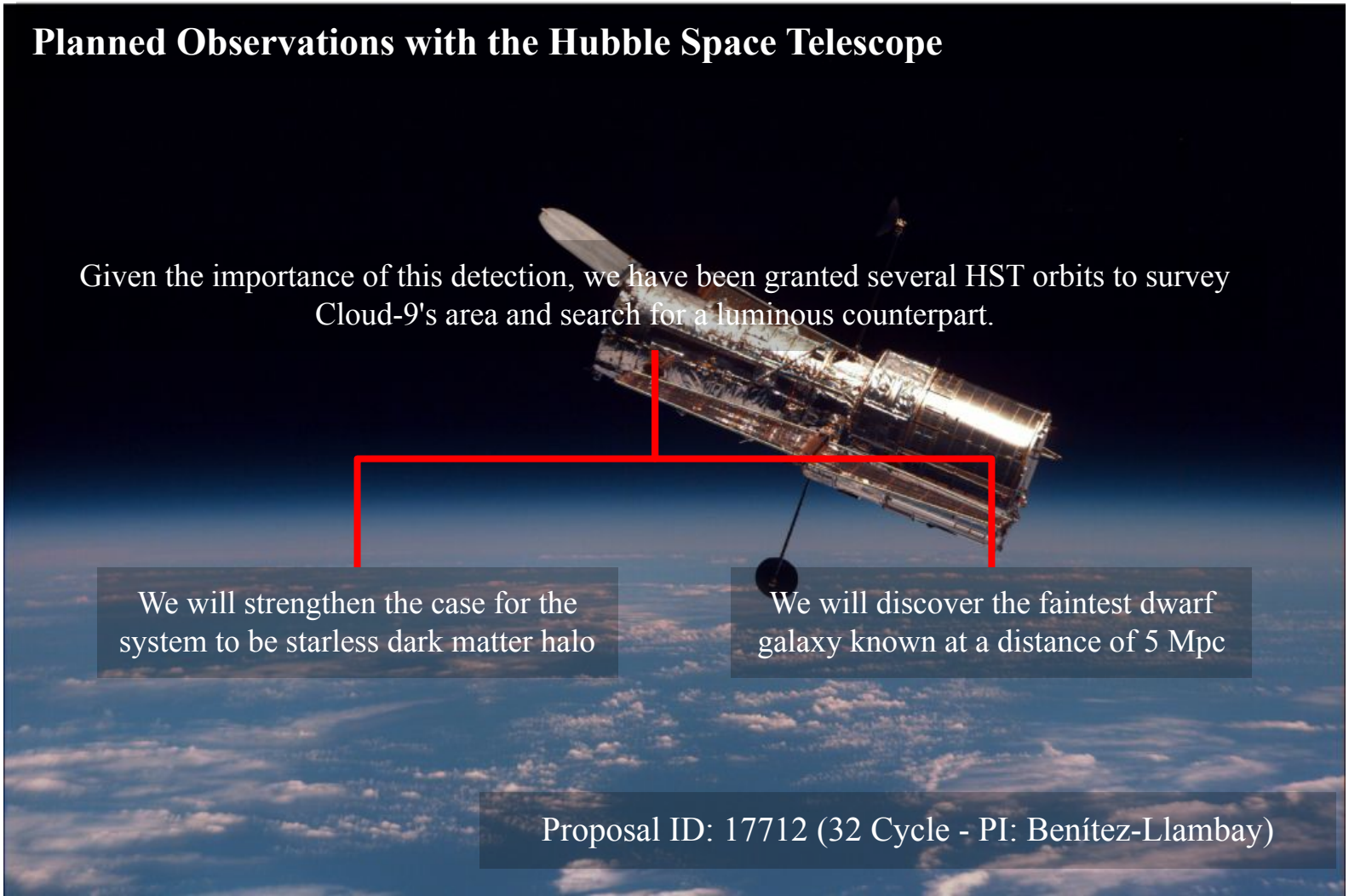






Benítez-Llambay et al. (2024)

Planned Observations with the Hubble Space Telescope



Given the importance of this detection, we have been granted several HST orbits to survey Cloud-9's area and search for a luminous counterpart.

We will strengthen the case for the system to be starless dark matter halo

We will discover the faintest dwarf galaxy known at a distance of 5 Mpc

Proposal ID: 17712 (32 Cycle - PI: Benítez-Llambay)

Involvement with SKA

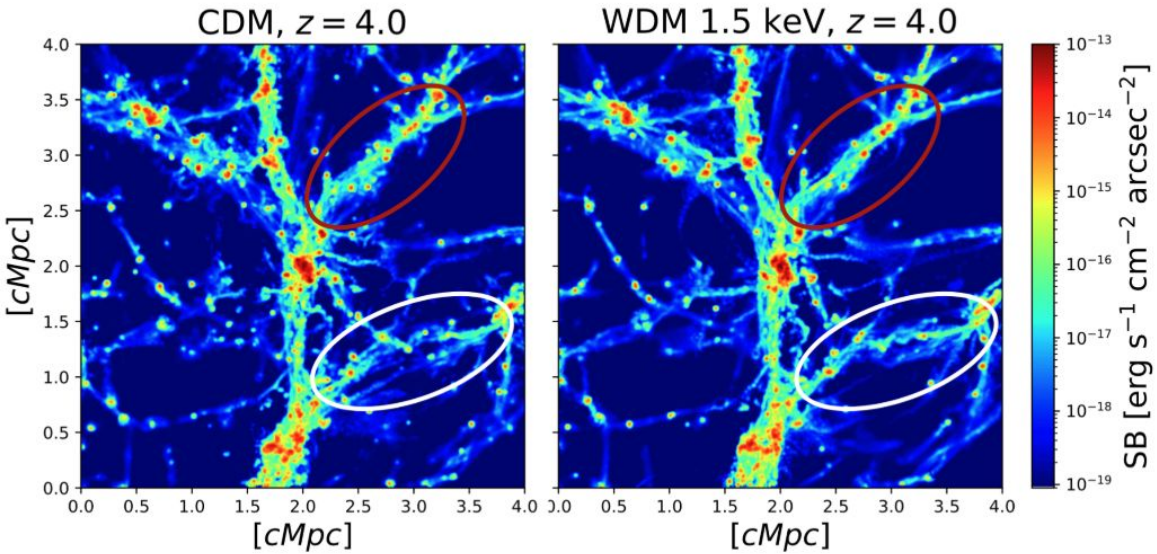
We have joined the SKA collaboration and are currently designing observational approaches to survey for these objects more systematically.

Constraining dark matter from Lyα emitting filaments

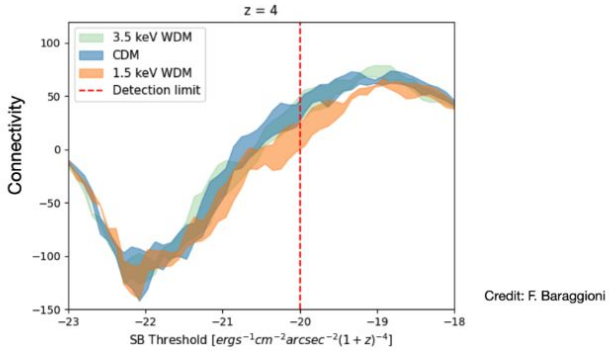
- Develop tools to analyse these maps and constrain dark matter
  Example: topological analysis with "Minkowski functionals"
  connectivity = # islands above a threshold - # holes

- From simulations output, we create mock surface brightness maps

$$SB_{Ly\alpha} \propto \frac{\text{resolution}}{(1+z)^4} h\nu_{Ly\alpha} T_{gas} n_H^2$$



Visible difference between Lyα SB maps in two dark matter scenarios!



First evidence of the impact of the nature of dark matter on the Lyα emission from the intergalactic medium!

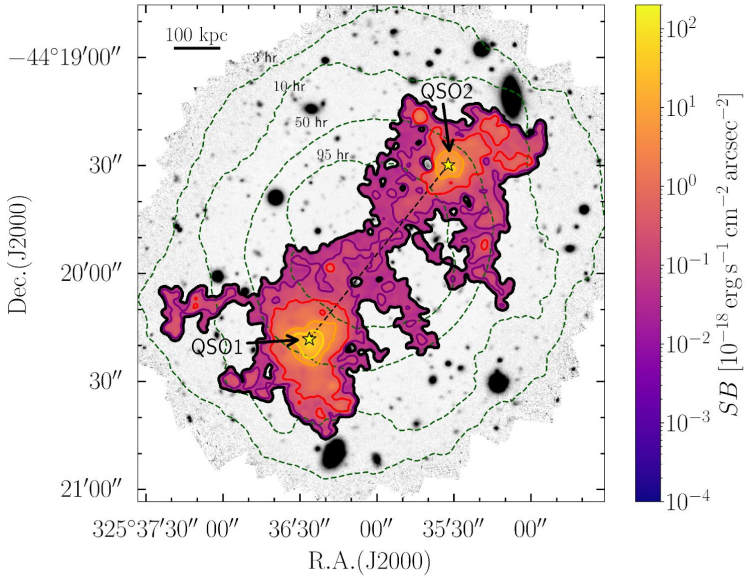
With a new calibrated hydrodynamical model, there are noticeable differences between the connectivity of filaments in Ly-α surface brightness maps in Cold vs Warm Dark Matter models.

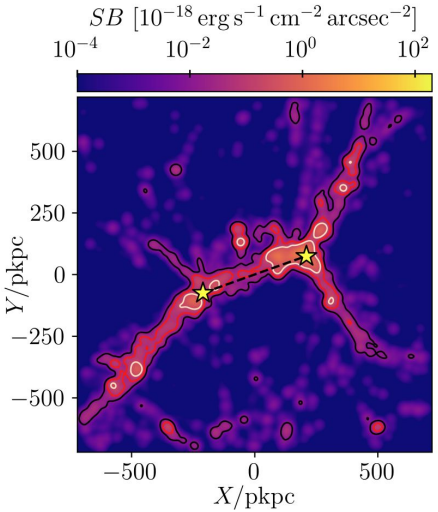
Novel avenue to further explore with future observations.

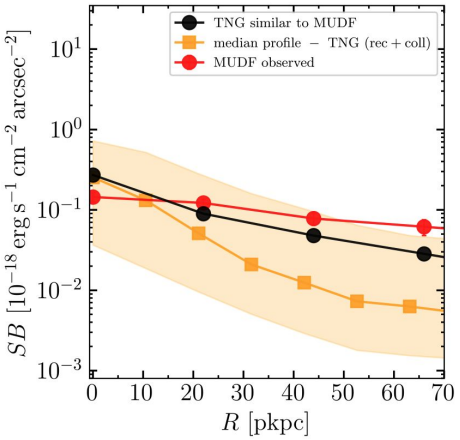
Courtesy of Titouan Lazeyras

High-definition imaging of an extended filament connecting active quasars at cosmic noon

In-house observations in a new ultra deep field using the MUSE instrument (the MUDF), collecting over 150 hours on-source in a single sky region. **To date this is one of the two ultradeep fields available in the community.**







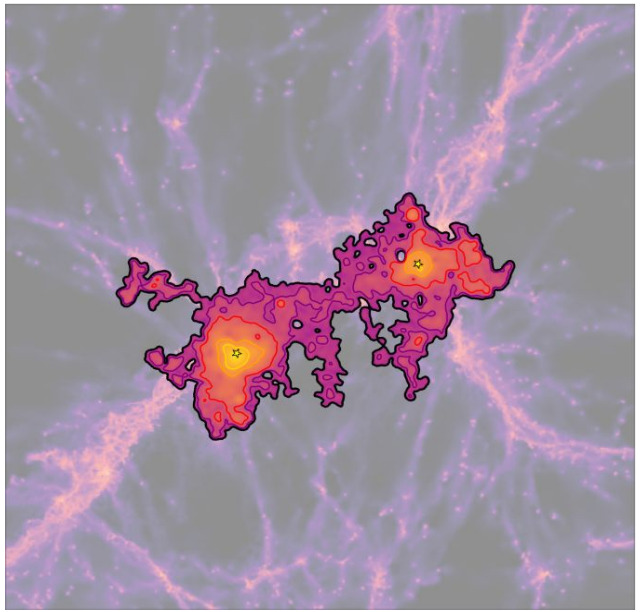
These types of observations enable complementary validation of the paradigm of gravitational instability in a Universe with predominantly cold dark matter

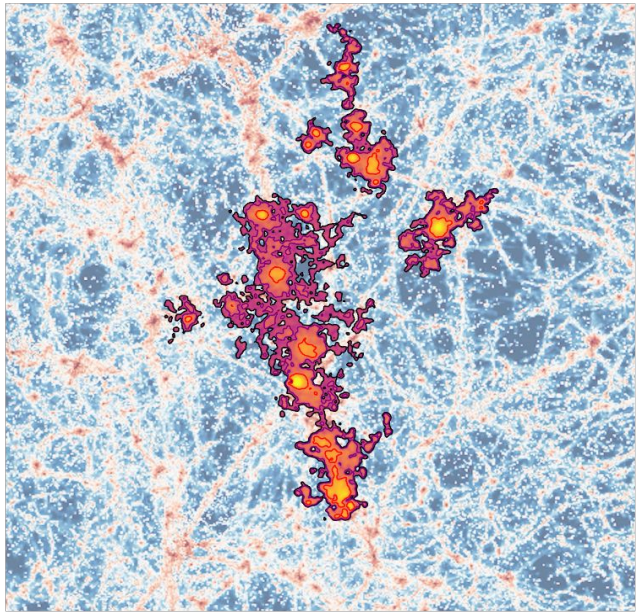
Work by Davide Tornotti et al. (2024)

nature astronomy

High-definition imaging of an extended filament connecting active quasars at cosmic noon

Additional filaments identified, including a big stretch of gas at z ~ 4. These observations will open up a new era of characterization of the Cosmic Web in emission and provide complementary probes to the paradigm of structure formation in a dark matter-dominated Universe.





Work by Davide Tornotti et al. in prep

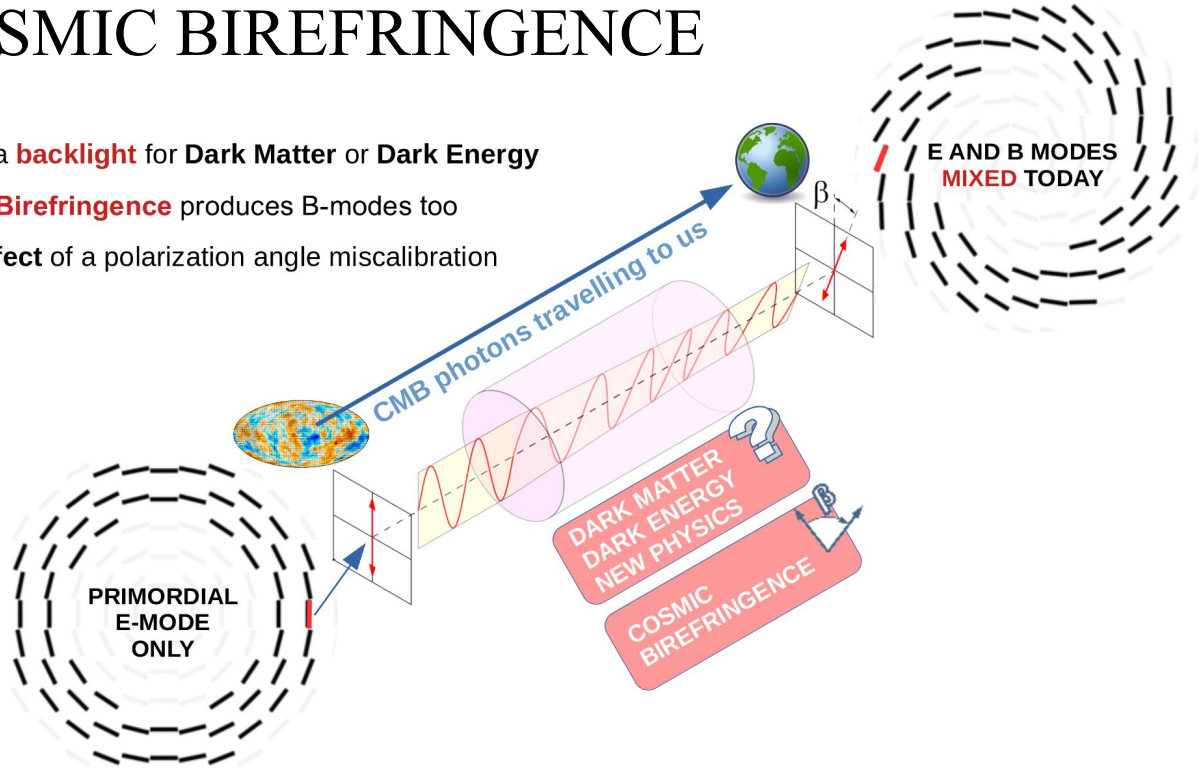
COSMIC BIREFRINGENCE

Mario Zannoni
Federico Nati
Gabriele Coppi

CMB as a **backlight** for **Dark Matter** or **Dark Energy**

Cosmic Birefringence produces B-modes too

Same effect of a polarization angle miscalibration



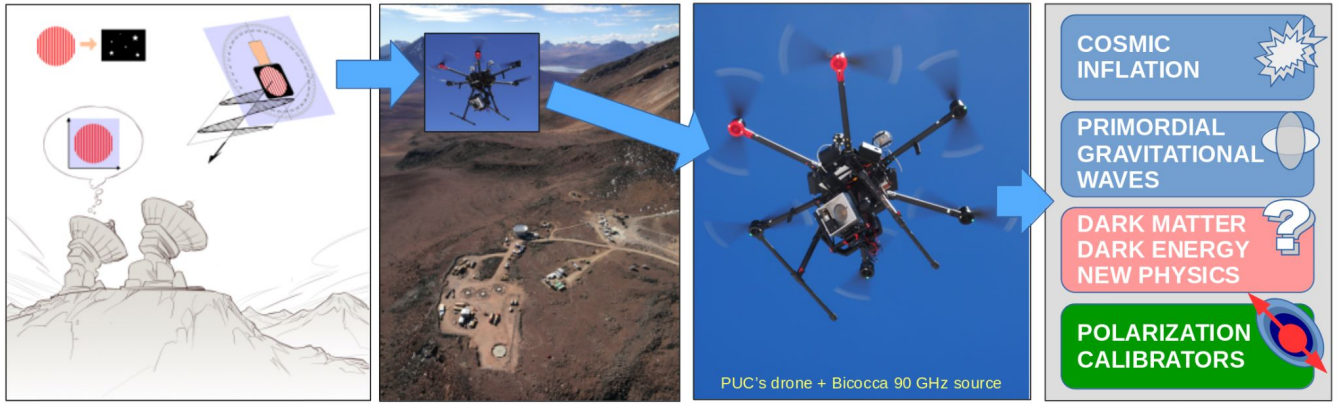
+ ERC-funded Postdocs and PhDs
+ Master's students

WE CANNOT MEASURE COSMIC BIREFRINGENCE WITHOUT ANGLE CALIBRATORS

OUR SOURCES HAVE ABSOLUTE ANGLE SENSORS TO PROVIDE CELESTIAL COORDINATES

Courtesy of Federico Nati

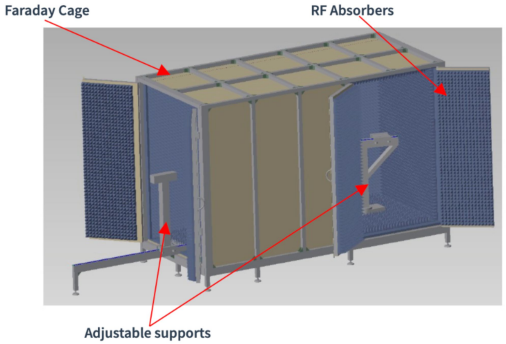
Need of accurate polarization angle calibrators



Anechoic Chamber

Sources and Horn Antennas Characterization

Upgrade of lab facilities at Bicocca



Images from Federico Nati, Mario Zannoni, Lorenzo Scalcinati, Gabriele Coppi

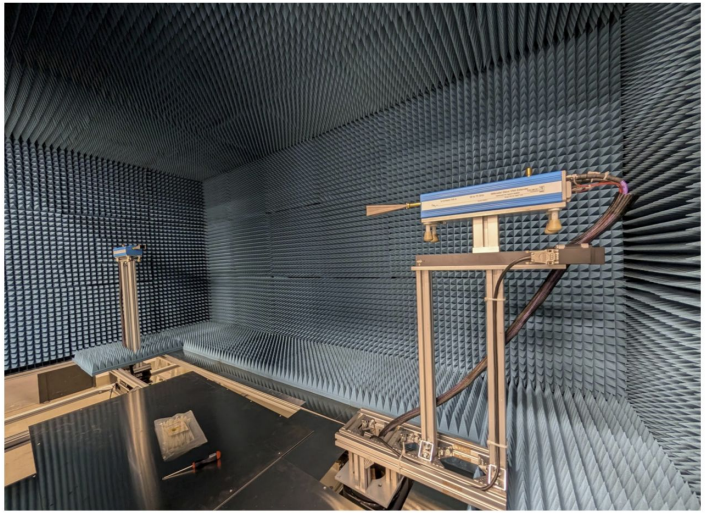
Design realized by E. Pagana & G. Gotti

Courtesy of Federico Nati

Drones already flying on site and New Anechoic chamber

Drone being tested on site at 5000 m in Chile

New Anechoic chamber at Milano-Bicocca



Courtesy of Federico Nati