Cross-Correlations of ATLAS Galaxies with the CMB
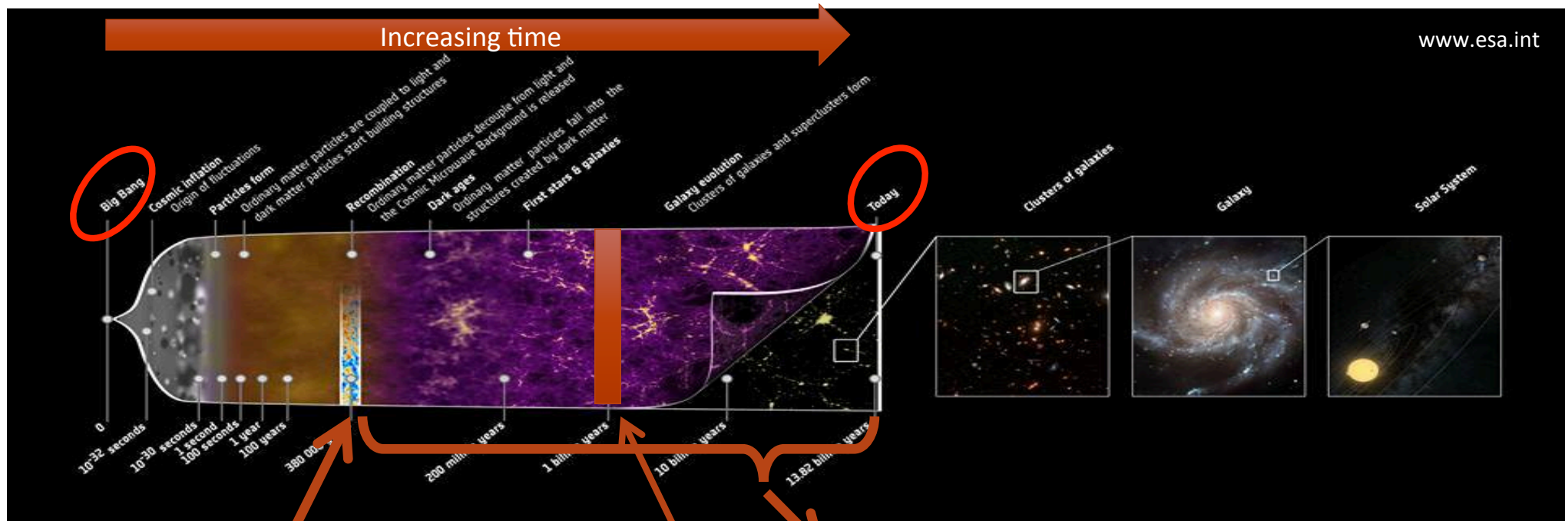
James G. Bartlett
Raphaël Kou

Astroparticule et Cosmologie - Université de Paris

The Cosmic Web

- Foundation: dark matter
- Baryons
  - Stellar mass: ~10-20%
  - Diffuse gas: ~80-90%

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Vista Point

Increasing time

www.esa.int

Recombination: "Emission" of cosmic
microwave background (CMB)

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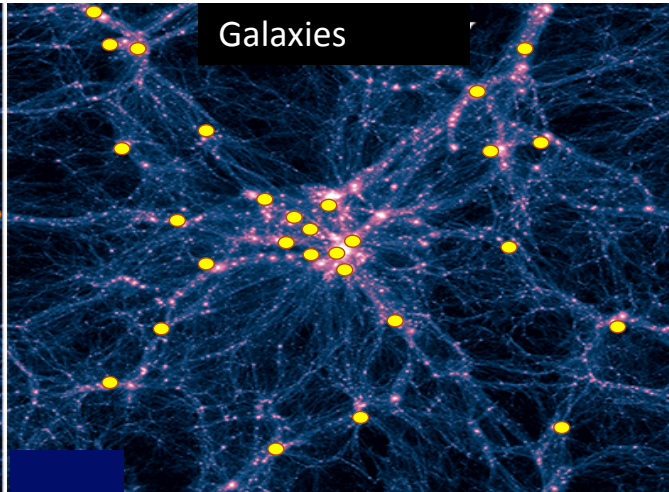Reionization

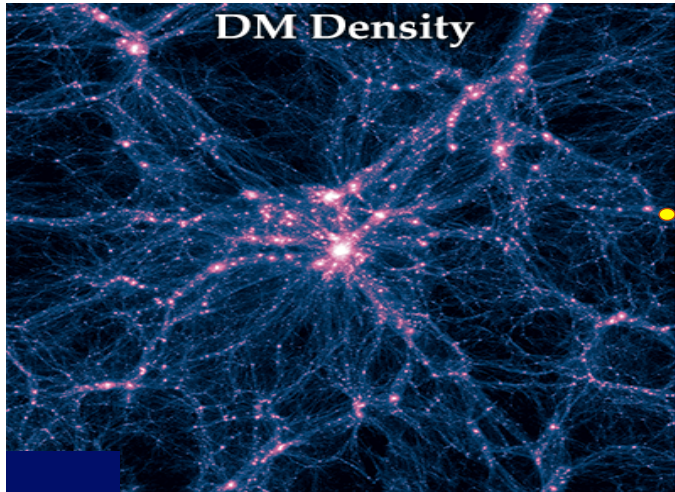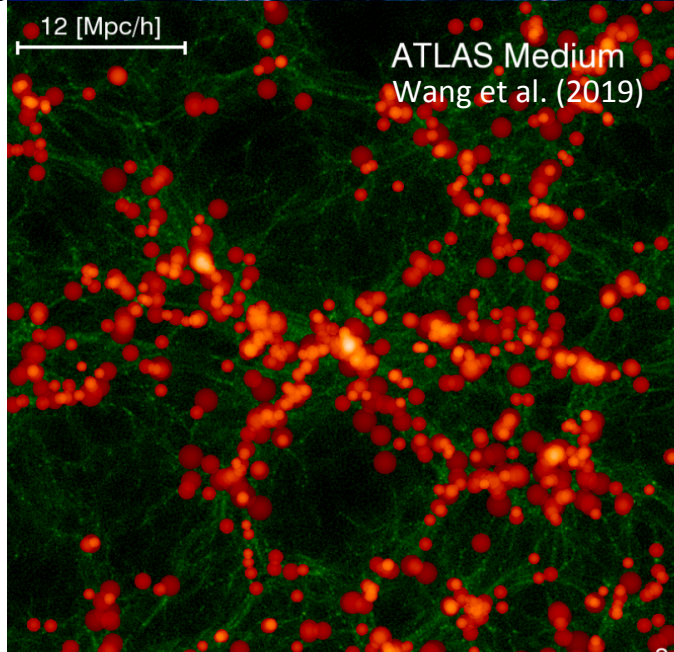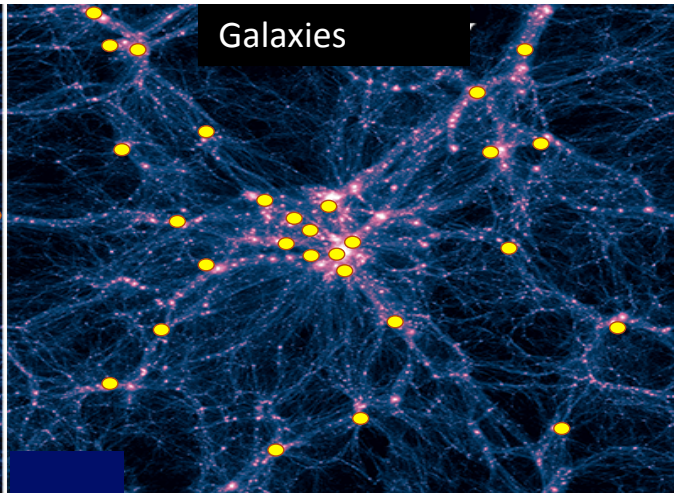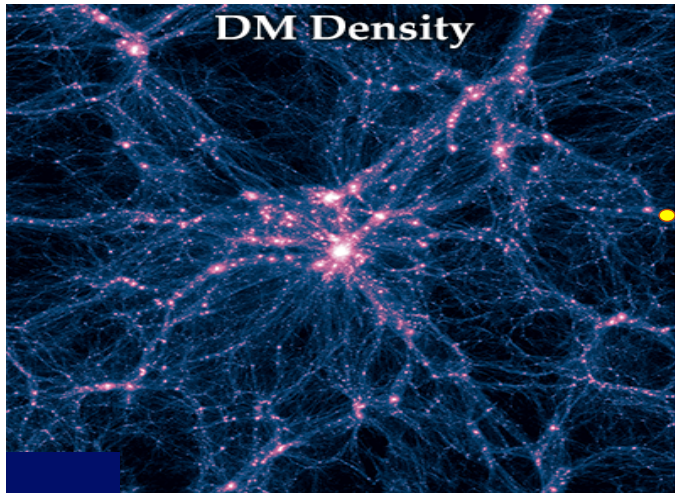Large-scale structure (LSS):
the cosmic web

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DM Density

100 Mpc

Galaxy cluster

The cosmic web of LSS:
Illustris Simulations
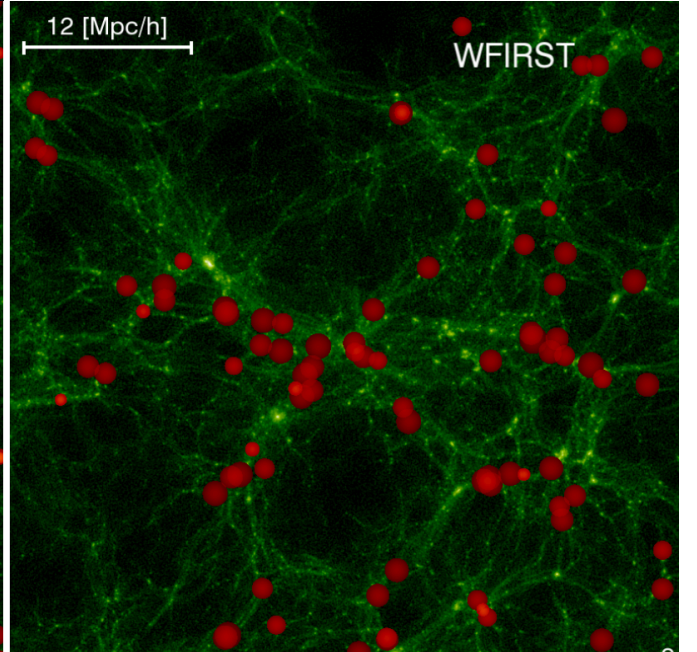(http://www.illustris-project.org)

DM Density

Galaxies

DM Density

Galaxies

12 [Mpc/h]

ATLAS Medium
Wang et al. (2019)

DM Density

Galaxies

12 [Mpc/h]

ATLAS Medium
Wang et al. (2019)

12 [Mpc/h]

WFIRST

DM Density

Galaxies

Gas Density

12 [Mpc/h]

ATLAS Medium
Wang et al. (2019)

DM Density

Galaxies

Gas Density

12 [Mpc/h]

ATLAS Medium
Wang et al. (2019)
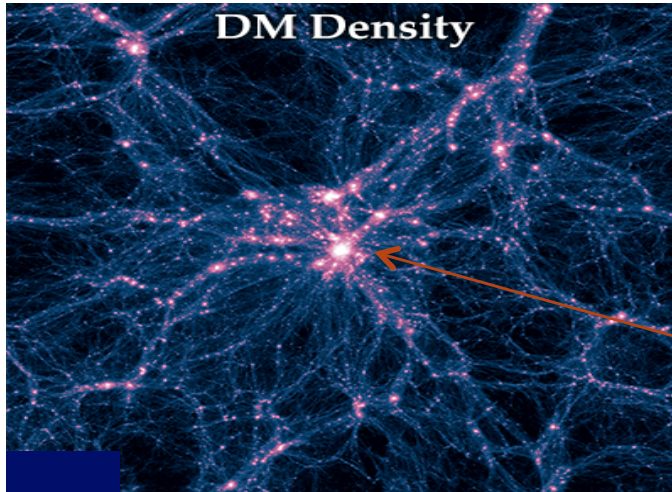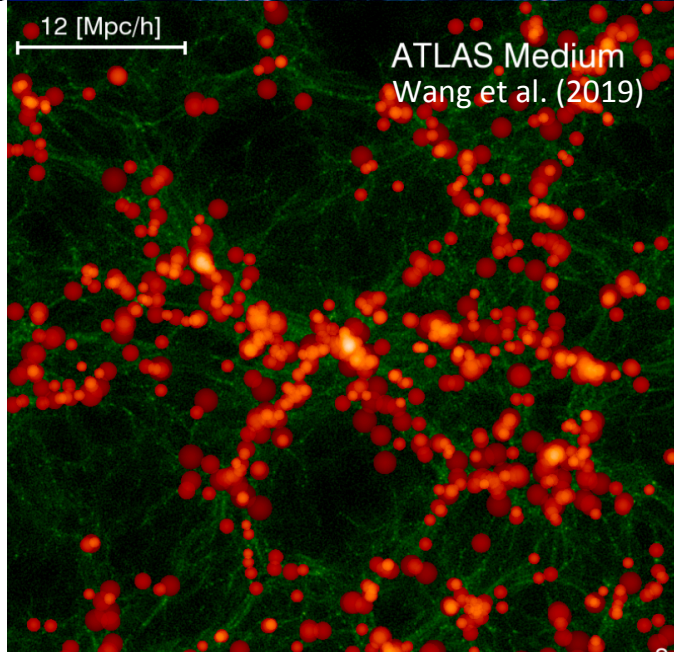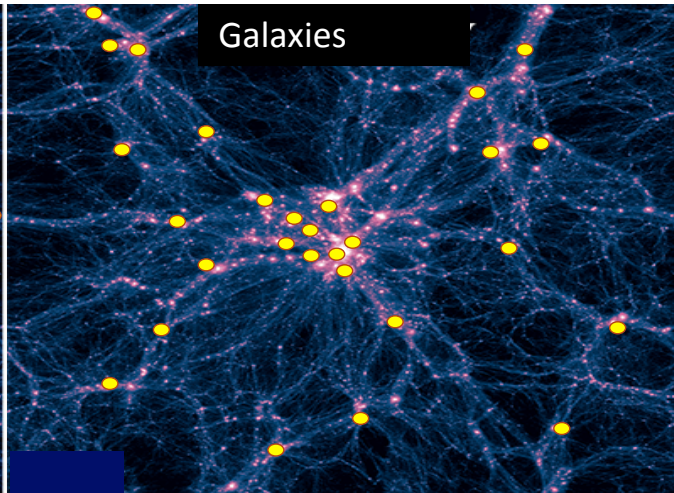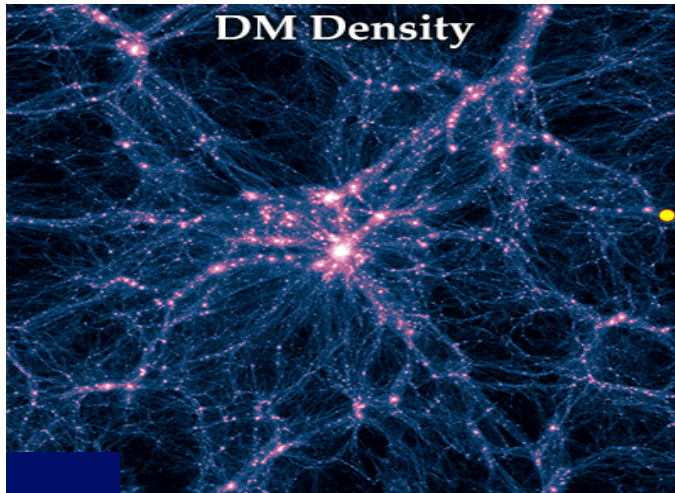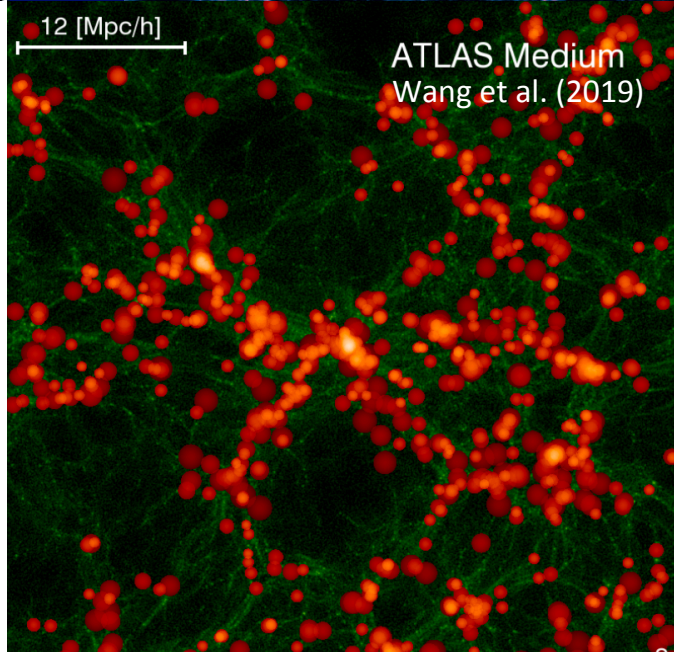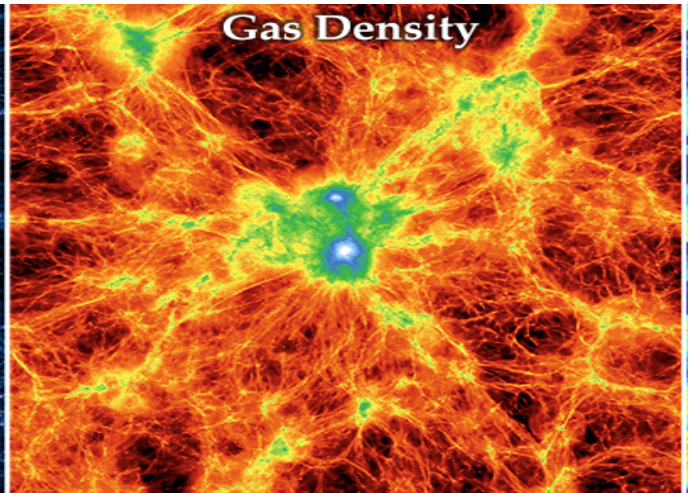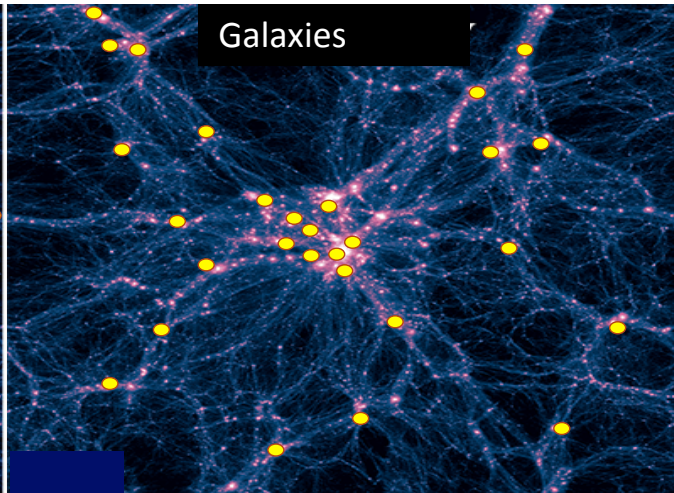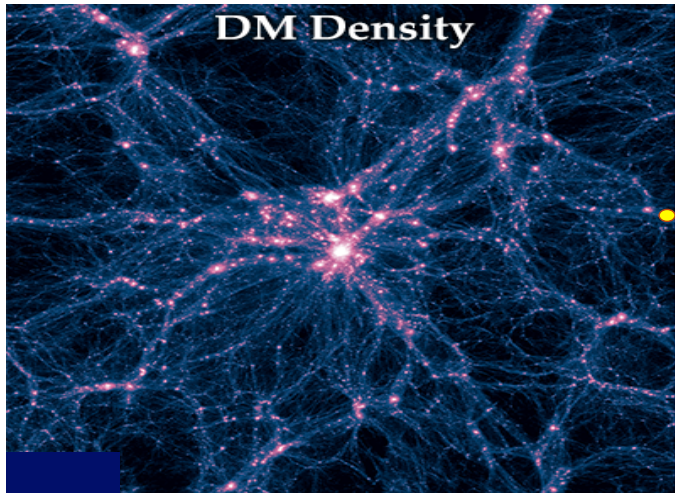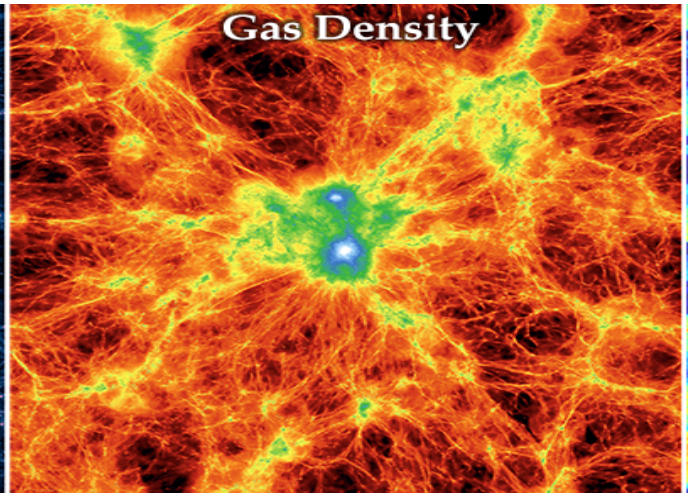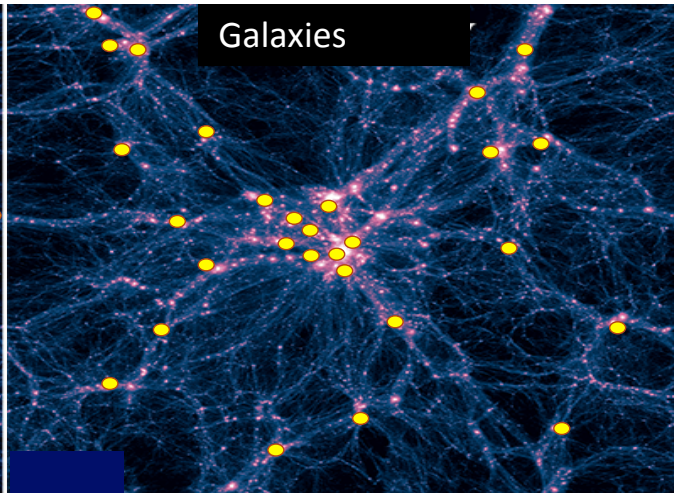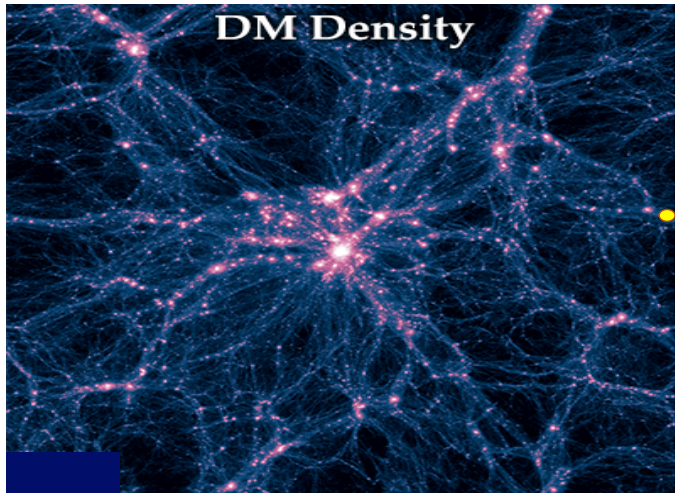
CMB
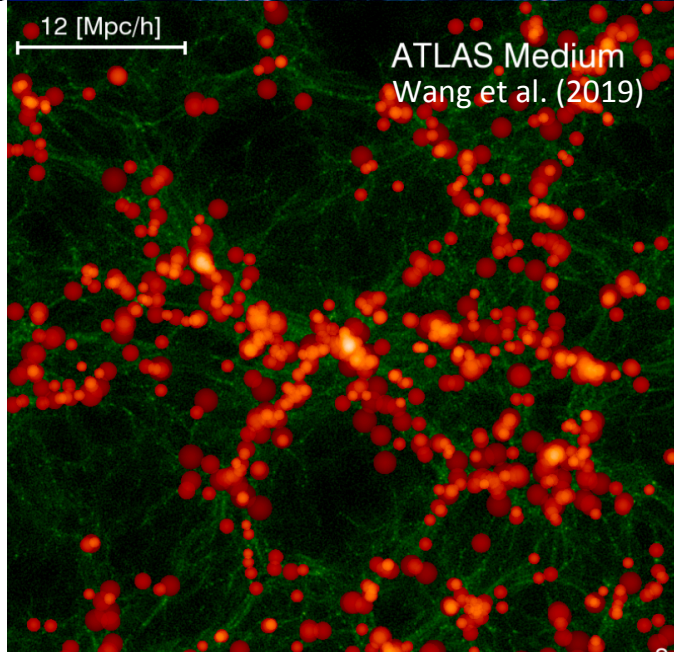
Lensing

CMB

Thermal and kinetic
Sunyaev-Zeldovich
(tSZ and kSZ) effects

CMB Lensing

Photons deflected by gravitational potential ψ along the line-of-sight to last scattering surface at comoving distance χ_*

$$\vec{\alpha} = \nabla\phi \qquad \text{Deflection angle}$$

$$\phi(\hat{n}) = -2 \int_0^{\chi_*} d\chi\, W(\chi)\psi[\chi\hat{n}, z(\chi)]$$

CMB z=1000

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CMB Lensing

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www.sci.esa.int

Planck 2018

Lensing deflection angle [rad]

-0.0016   0.0016

ATLAS 2021

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www.sci.esa.int
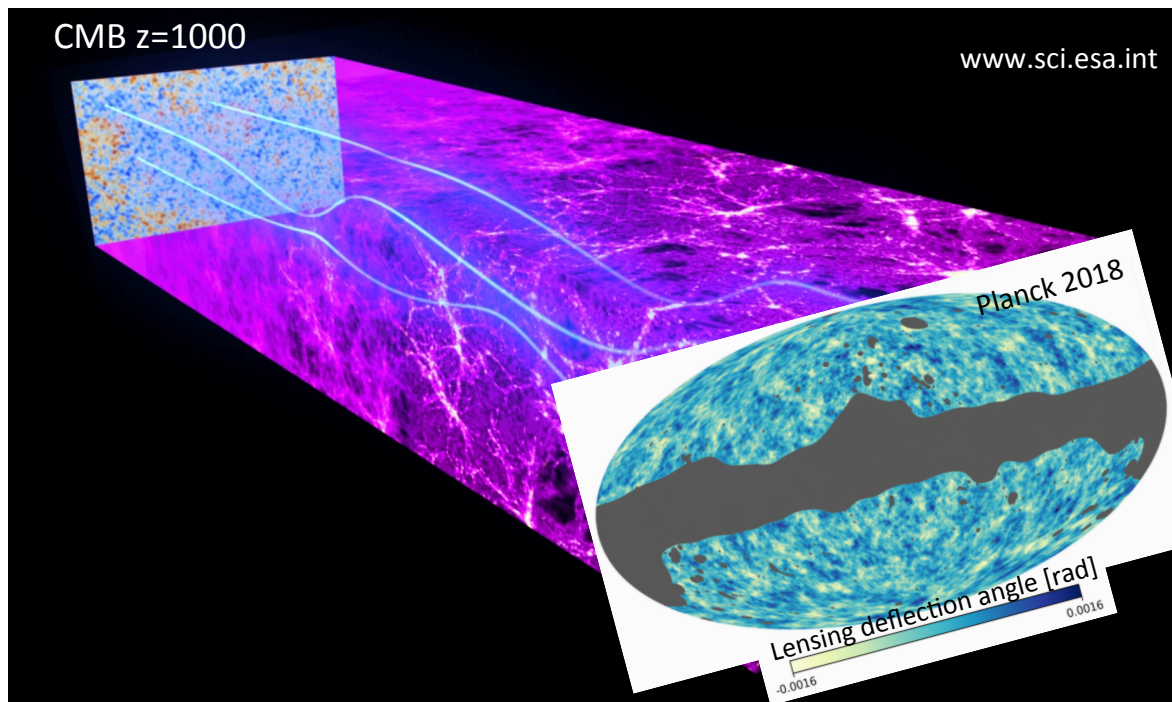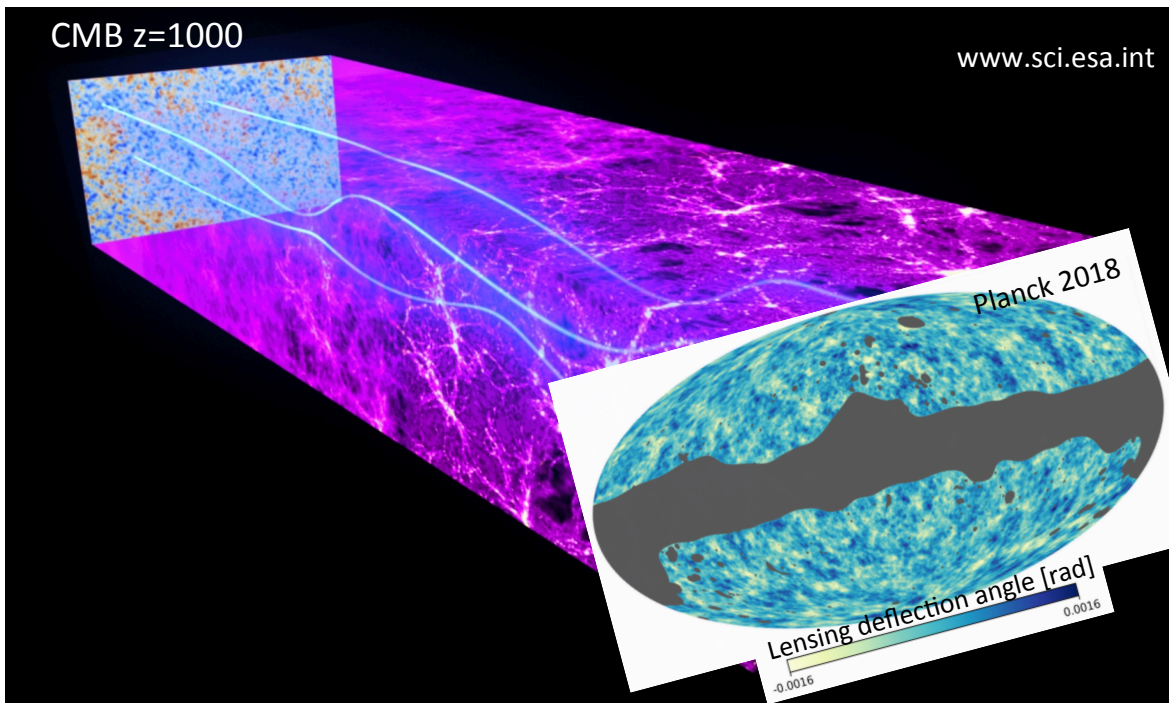
Planck 2018

Lensing deflection angle [rad]

-0.0016   0.0016

Normalized CMB Lensing Kernel

ATLAS Wide

Redshift

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CMB Lensing Tomography

CMB z=1000

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Z₁

Z₂

Cross correlation with galaxies of know redshift

3D reconstruction of total matter distribution in cosmic web

CMB lensing tomography
Cross correlation gives mass associated with galaxies at chosen redshift

ATLAS: precise redshifts at peak of CMB lensing kernel and slit spectra with galaxy properties.

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tSZ and kSZ Effects

CMB z=1000

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For ionized gas, the tSZ and kSZ effects measure projected along the line-of-sight:

- Thermal energy (tSZ)

$$y(\hat{n}) = \int d\ell \, \frac{kT_{\mathrm{e}}}{m_{\mathrm{e}}c^2} n_{\mathrm{e}} \sigma_{\mathrm{T}}$$

- Free electron density (kSZ)

$$\frac{dT}{T}(\hat{n}) = \int d\ell \, \frac{v_{\mathrm{e}}}{c} n_{\mathrm{e}} \sigma_{\mathrm{T}}$$
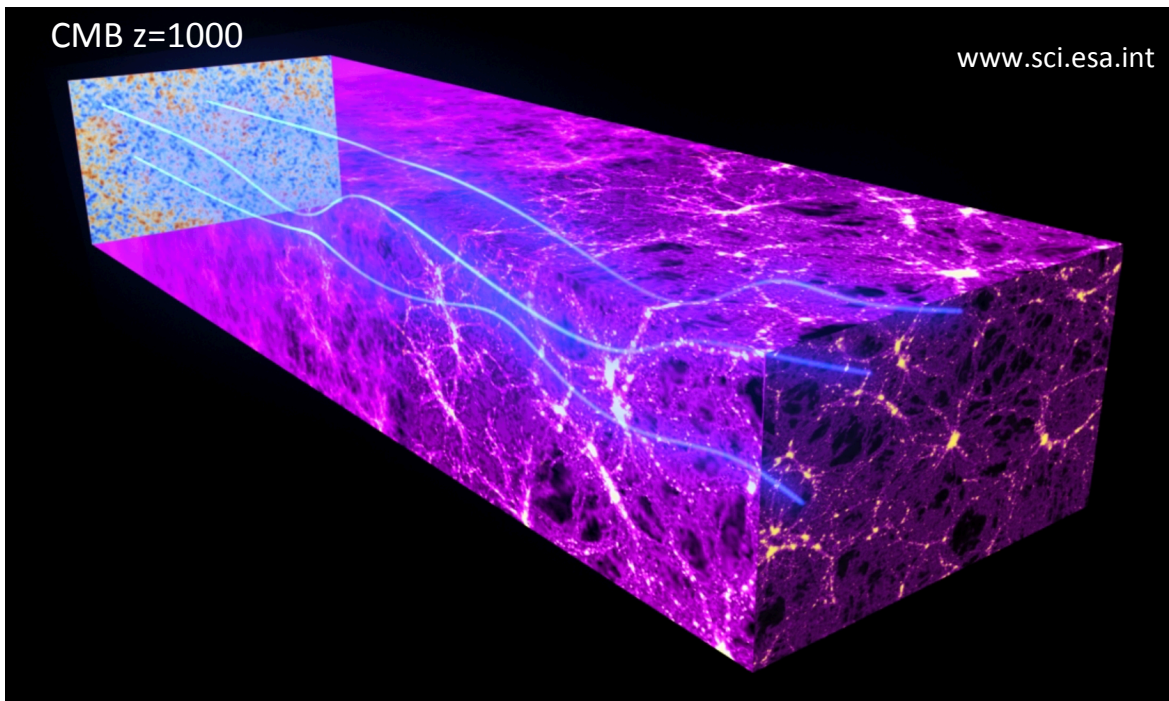
Cross correlating these maps with ATLAS galaxies will tell us about the gas distribution at the peak galaxy formation epoch z=2

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Example: ACT + CMASS

Combined ACT tSZ and kSZ stacks of CMASS galaxies

Amodeo et al. 2021
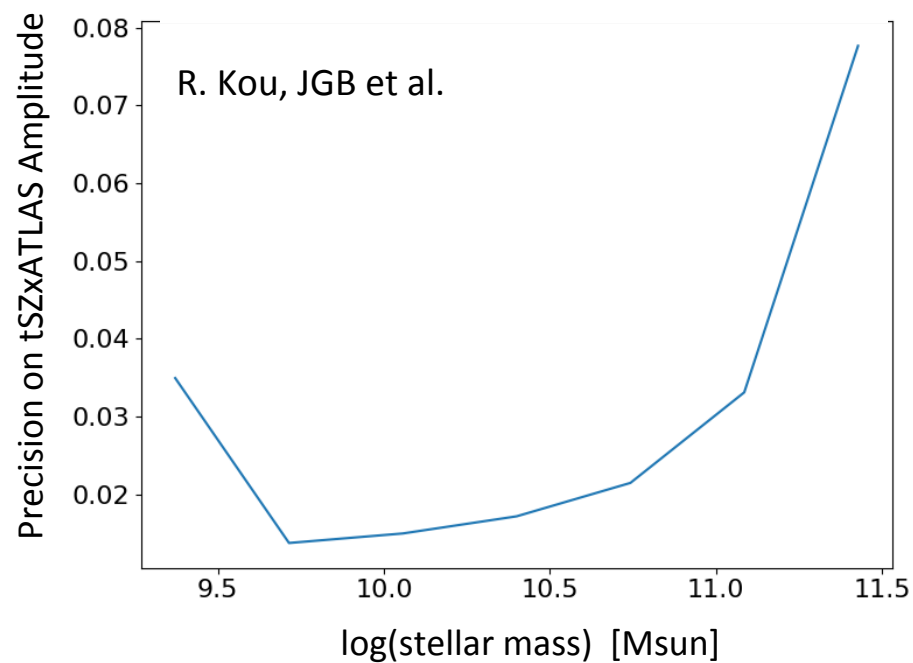

$\langle z \rangle = 0.55$
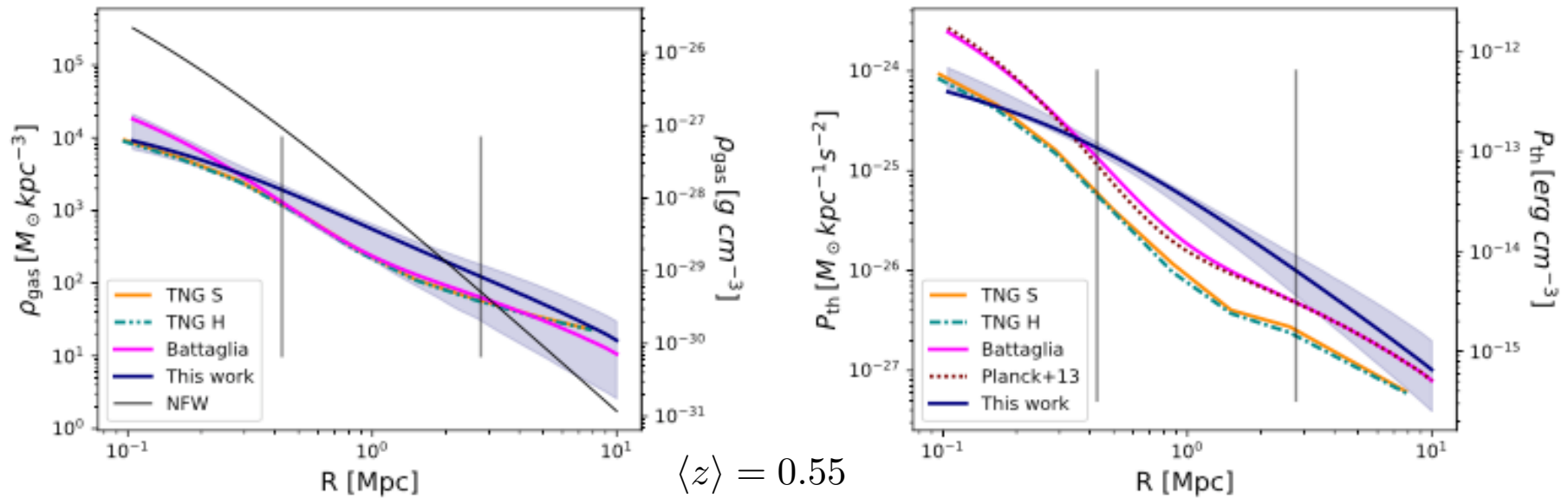
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ATLAS Predictions

Preliminary studies of cross-correlations with ATLAS in progress.

Example: *Planck* tSZ x ATLAS galaxies as a function of stellar mass

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Closing Remarks

- ATLAS will give us an SDSS-like picture of the universe around the peak of galaxy formation, i.e., "high-noon" at z=2, with
  - Precise spectroscopic redshifts
  - Detailed information on galaxy properties

- Cross-correlation studies of ATLAS galaxies with CMB lensing, tSZ and kSZ will give us a representative and comprehensive view of the cosmic web: co-evolution of matter, galaxies and gas at this critical epoch.

- At the time of the ATLAS survey, we will benefit from the high-quality CMB data from CMB-S4 for these studies: 70% of sky in the South to 1.5 arcmin angular resolution and sensitivity of 1microK-arcmin (https://cmb-s4.org)

- We're in the process of making ATLAS-CMB-S4 predictions.

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