Cosmology with stacked cluster weak lensing and cluster-galaxy cross-correlations

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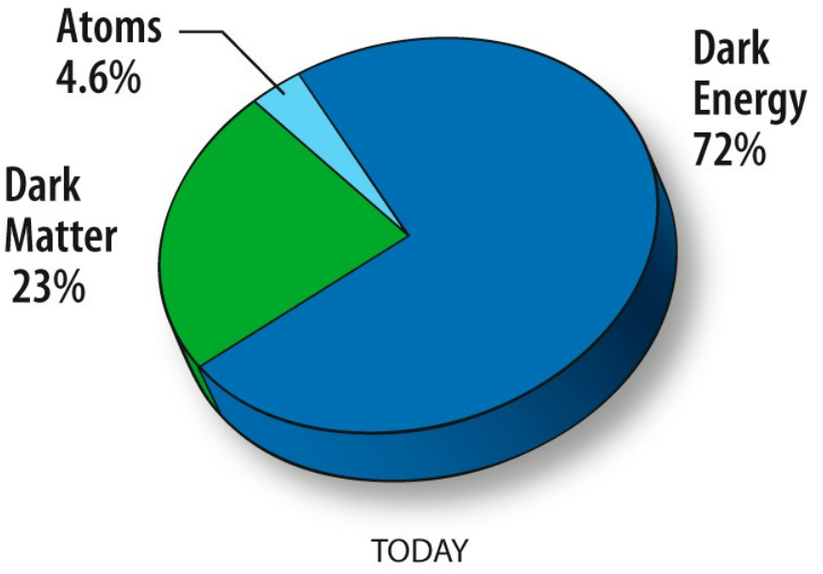
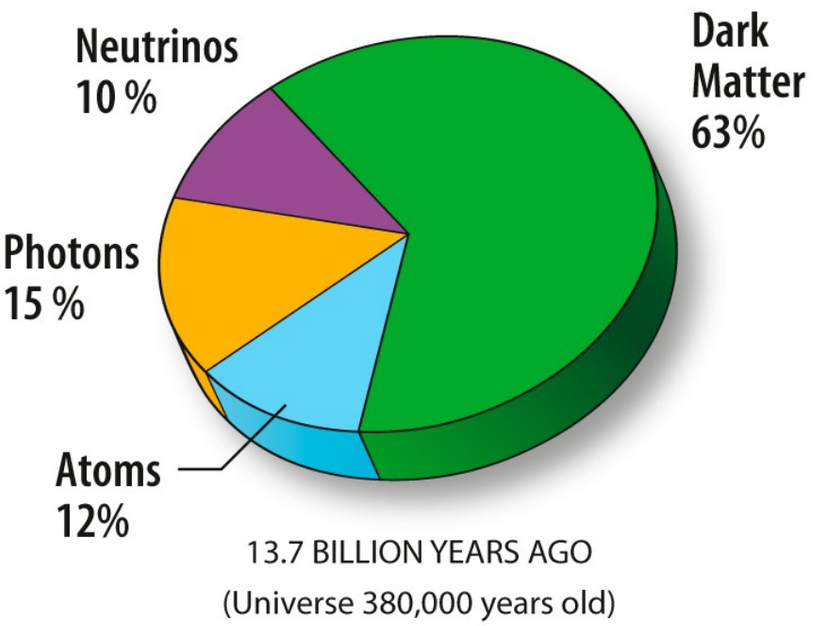
Physical cosmology

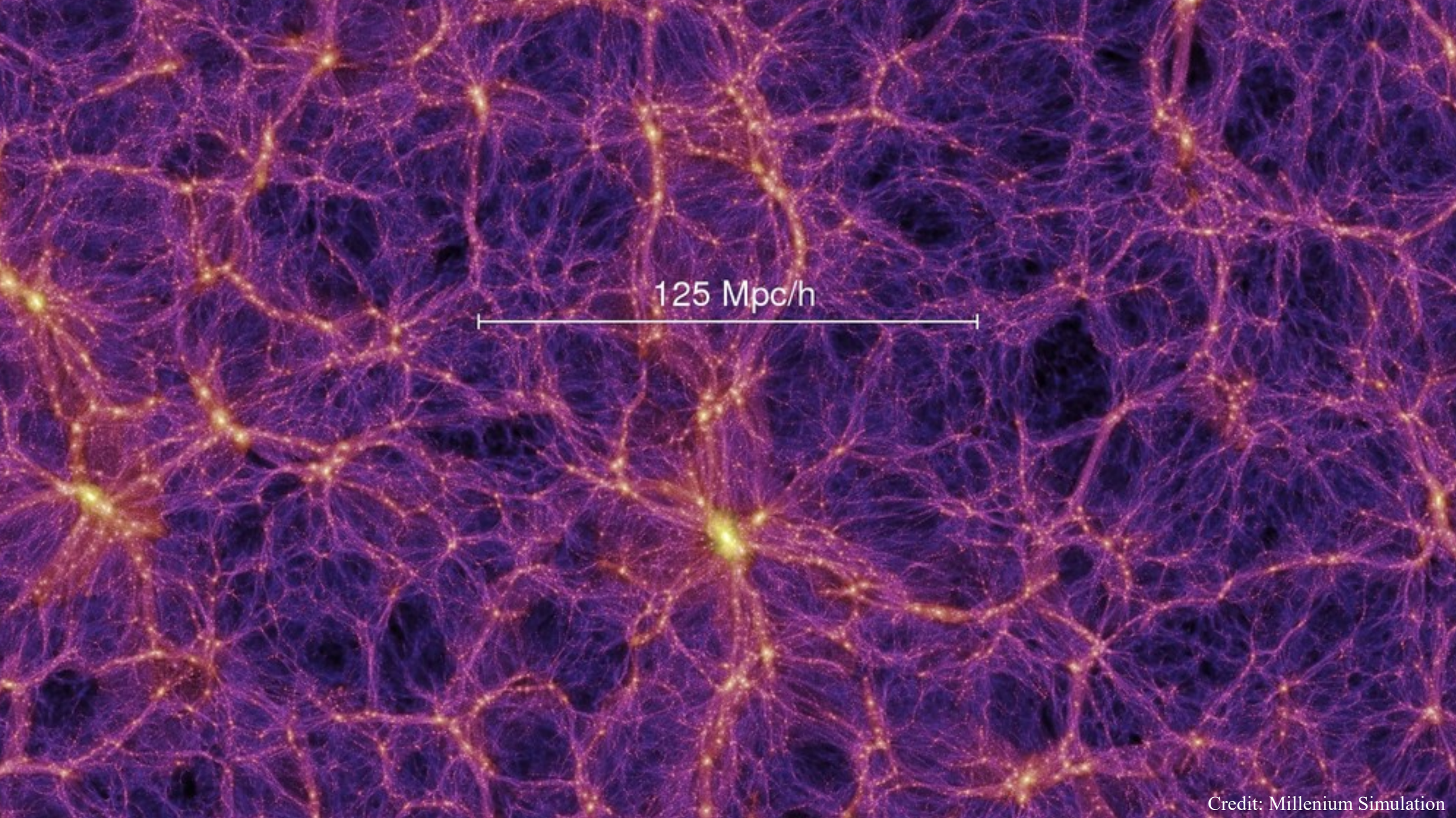
We live in a flat expanding universe with three major consituents:

1. **Baryonic matter**, what we are made of.
2. **Dark matter**, only interacts gravitationally.
3. **Dark energy**, an unknown form of energy that affects the expansion of the universe on large scales.





Credit: NASA/WMAP Science Team



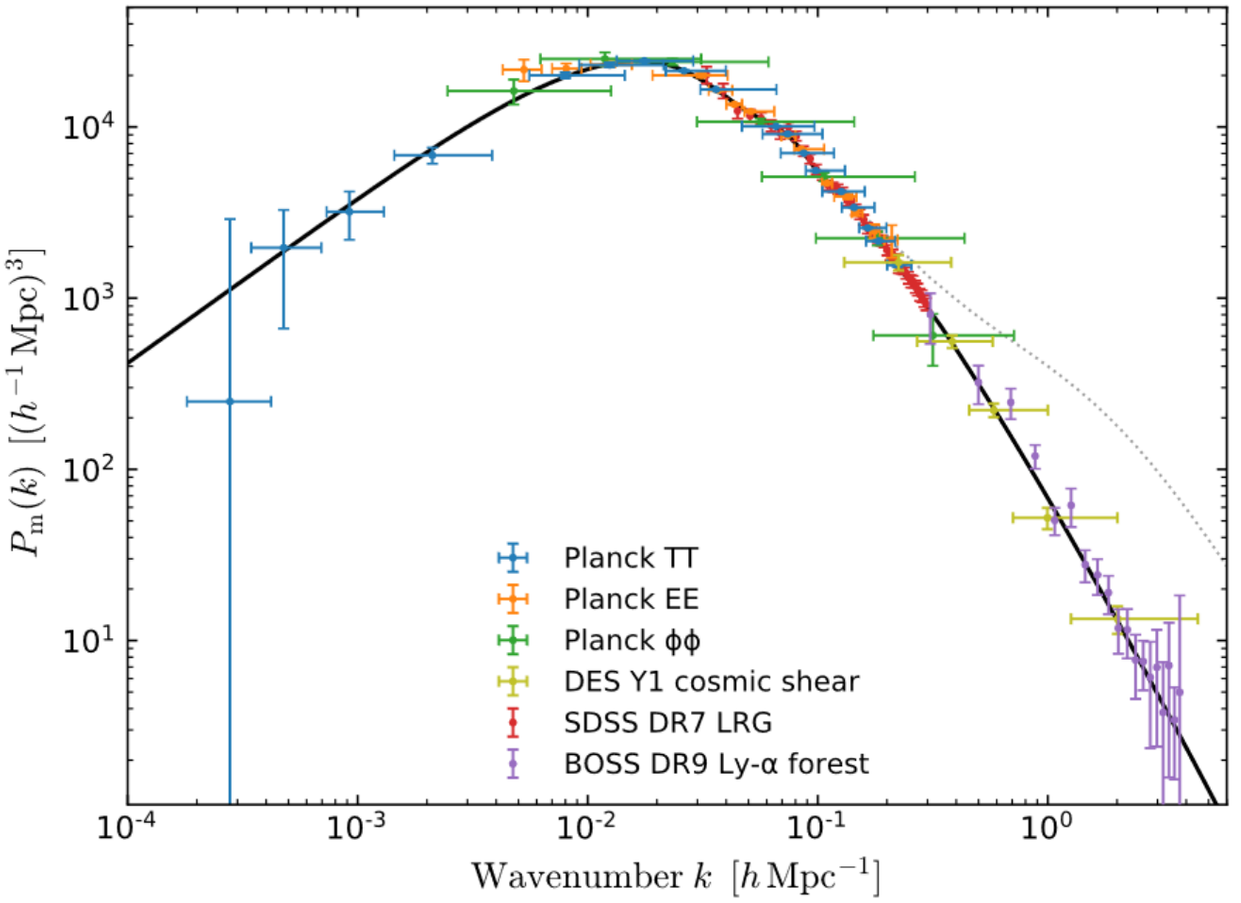
Credit: Millenium Simulation

Statistics of the cosmological density field

$$\Delta^2(k) = \frac{k^3 P(k)}{2\pi^2}$$

$$\sigma^2(R) = \int_0^\infty \Delta^2(k) |W_{\rm TH}(k,R)|^2 d\ln k$$

$$\sigma_8 \equiv \sigma(R = 8\ h^{-1}\ {\rm Mpc}, z = 0)$$



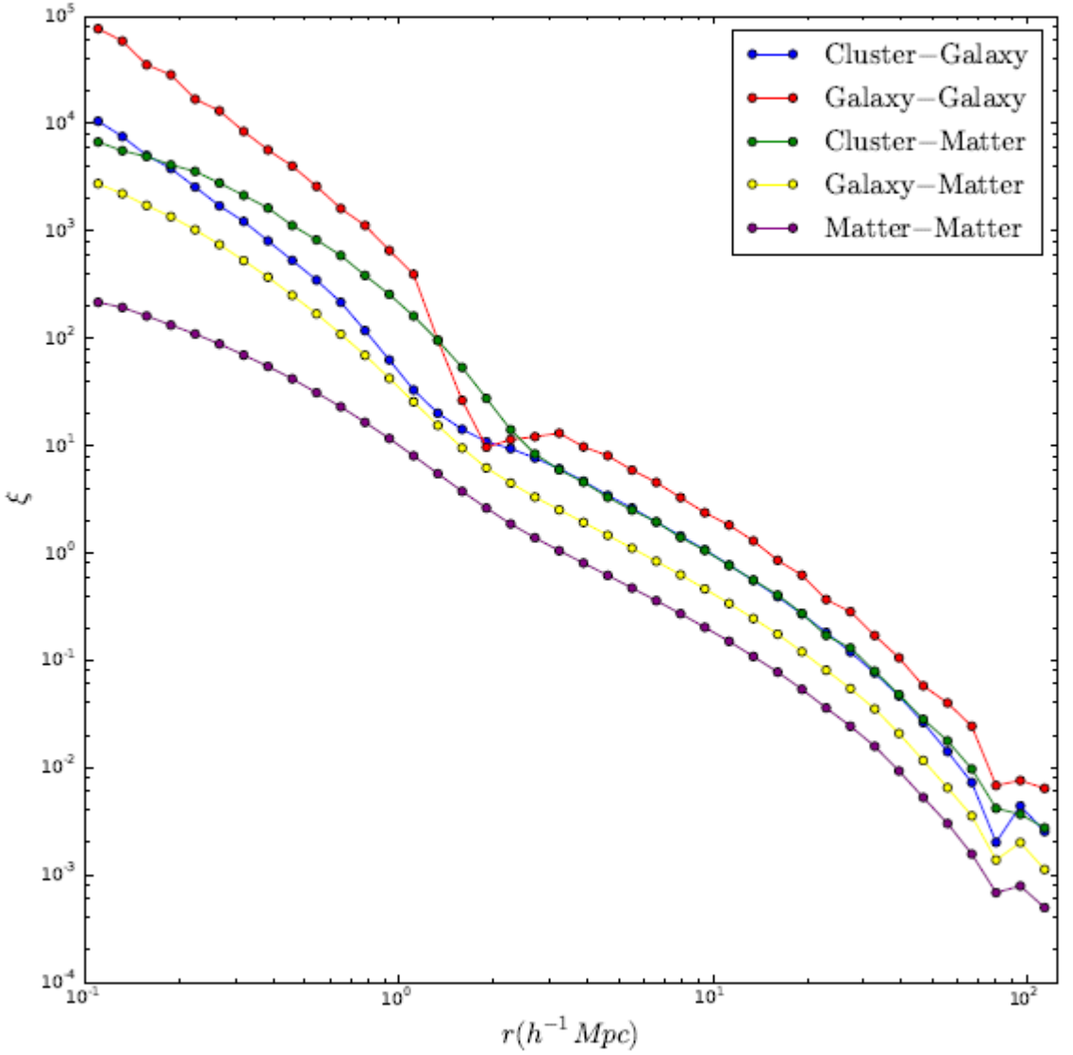
Credit: Planck 2018 Results

Statistics of the cosmological density field

$$\xi(r) = \frac{1}{2\pi^2} \int k^2 P(k) \frac{\sin(kr)}{kr} dk$$

$$\xi_{mm}(r) \propto \sigma_8^2$$

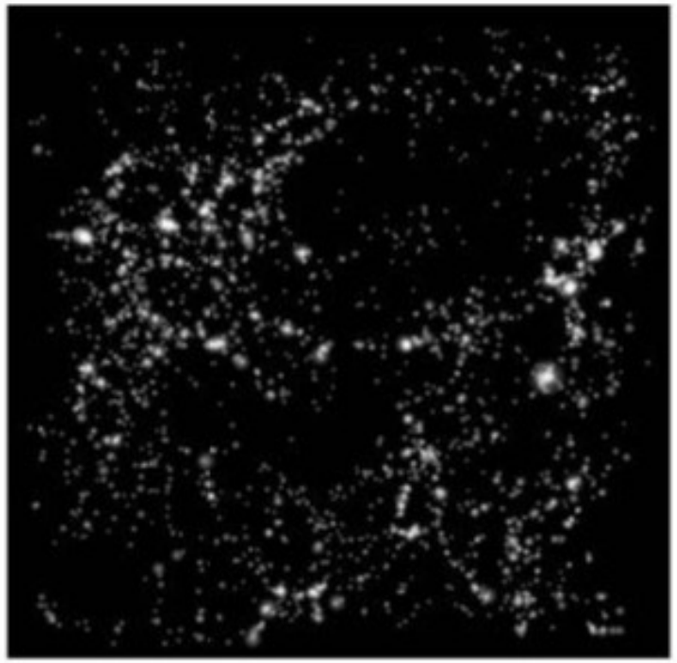
$$\xi_{AB}(r) = b_A(r) b_B(r) \xi_{mm}(r)$$



Biased tracers of an underlying distribution

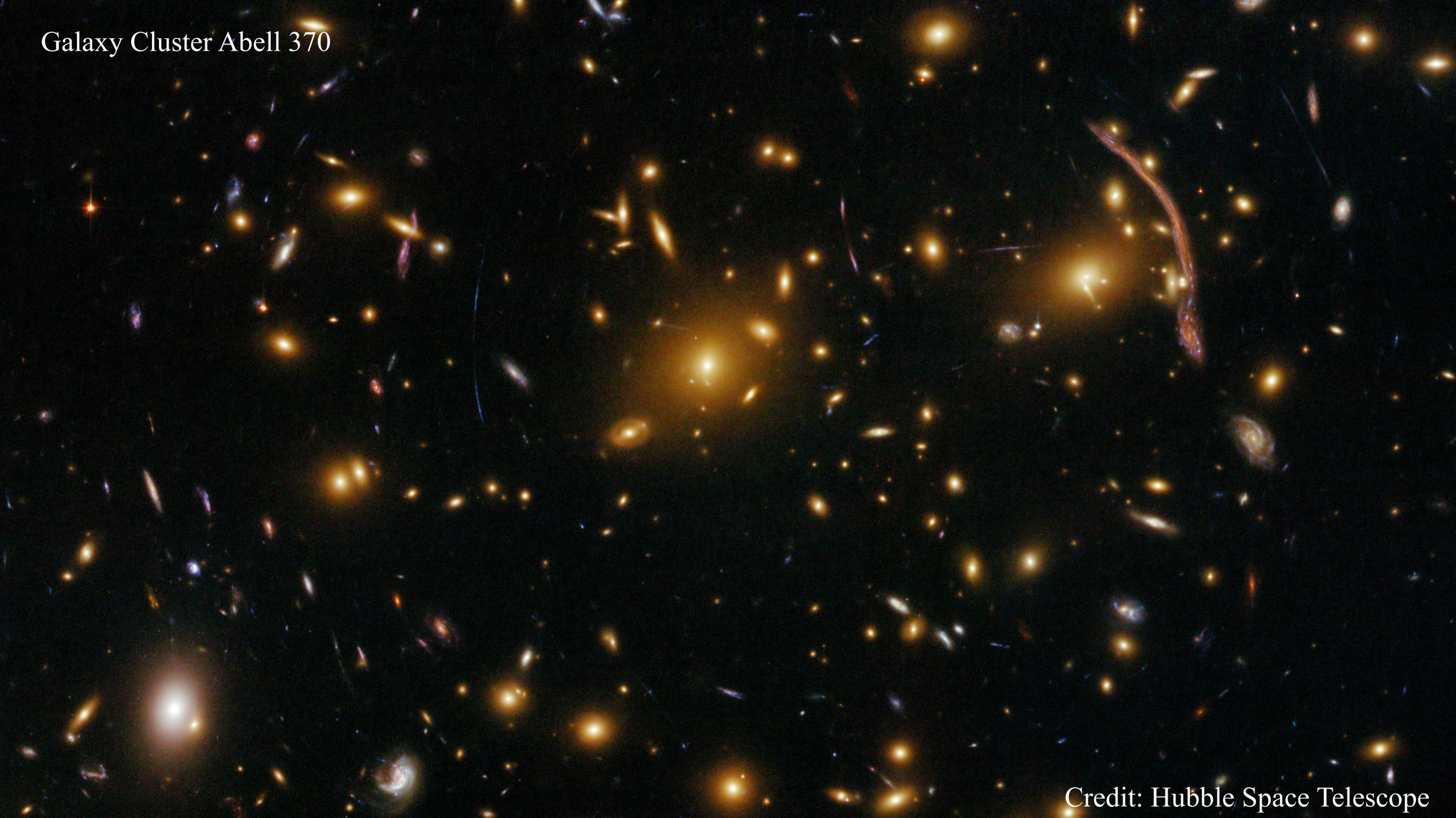
Dark Matter

Galaxies

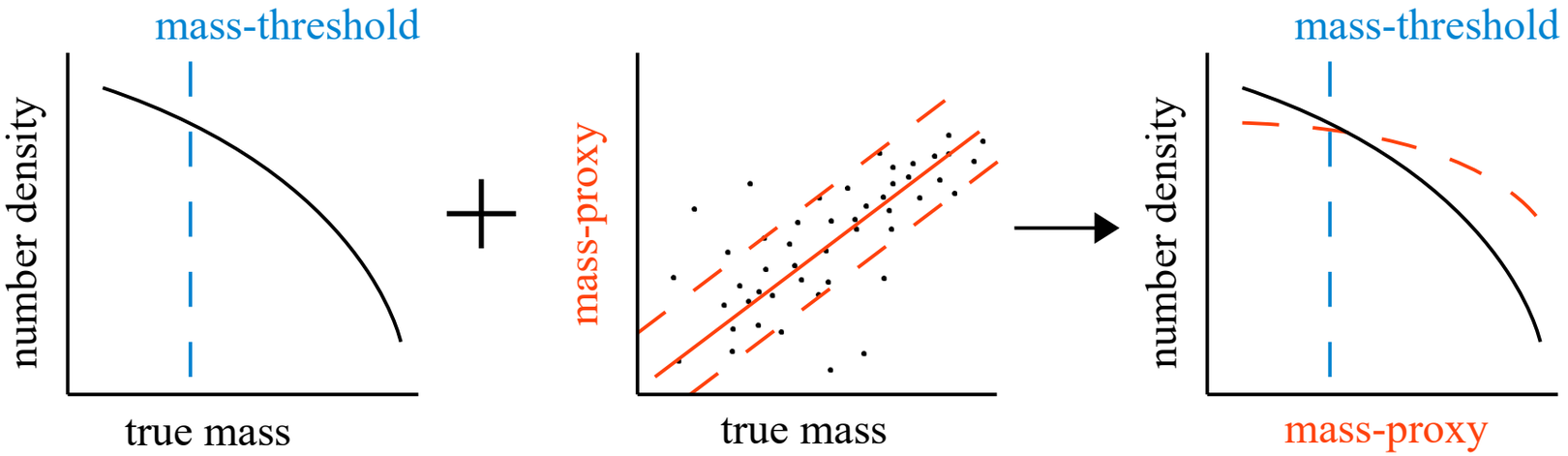


Visible galaxies trace the underlying distribution of invisible dark matter.

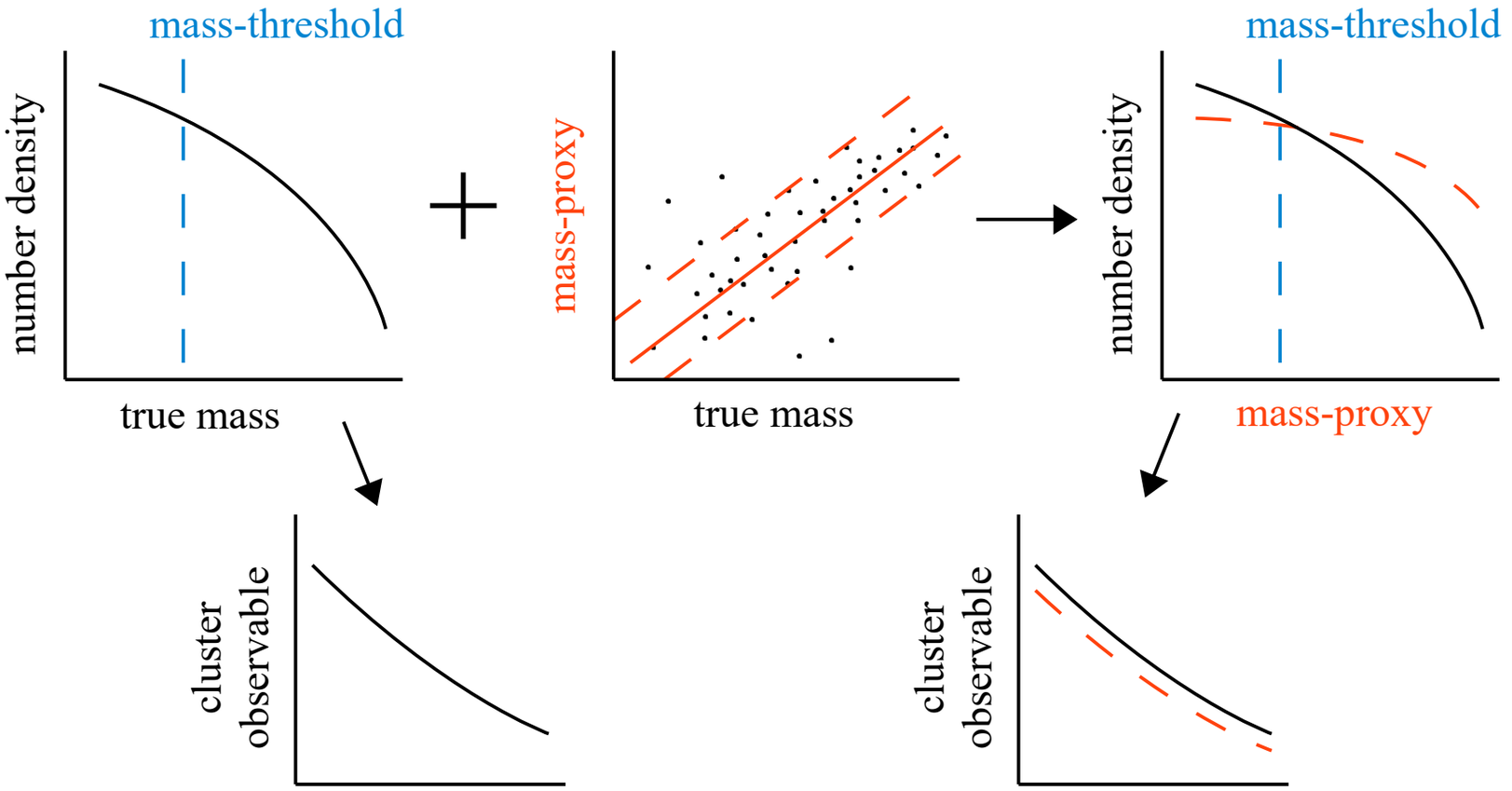
Credit: https://ned.ipac.caltech.edu/level5/March18/Wechsler/Wechsler2.html#Figure%201


Galaxy Cluster Abell 370
Credit: Hubble Space Telescope

Cluster mass-observable relation



Cluster mass-observable relation



Cluster and cosmological parameters of interest

σ_8 : amount of dark matter structure

Ω_m : density of the universe

$\sigma_{\ln M_c}$:log-normal scatter between cluster mass and observable

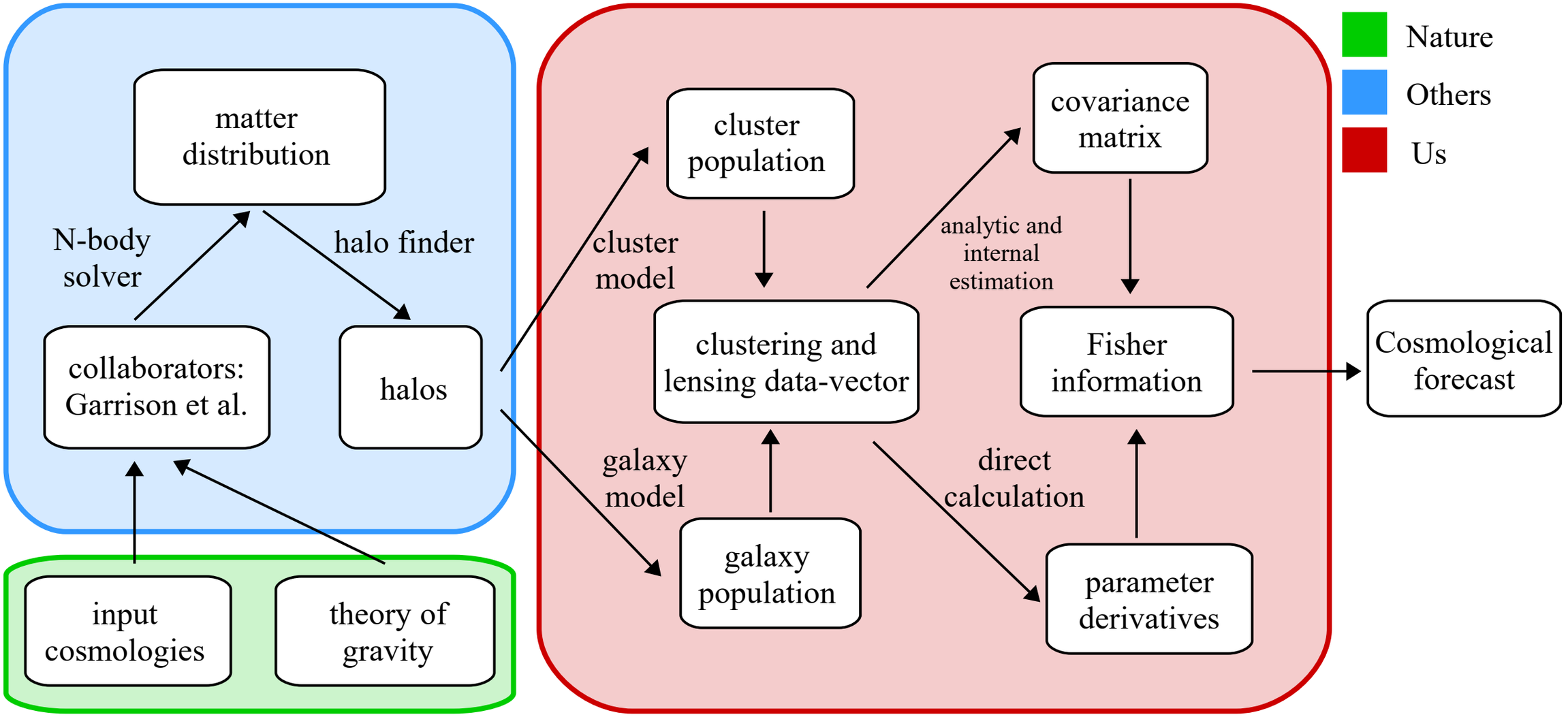
Three unknowns, three observables

Cluster weak lensing $\Delta\Sigma \propto \xi_{cm} \propto b_c \sigma_8^2,$

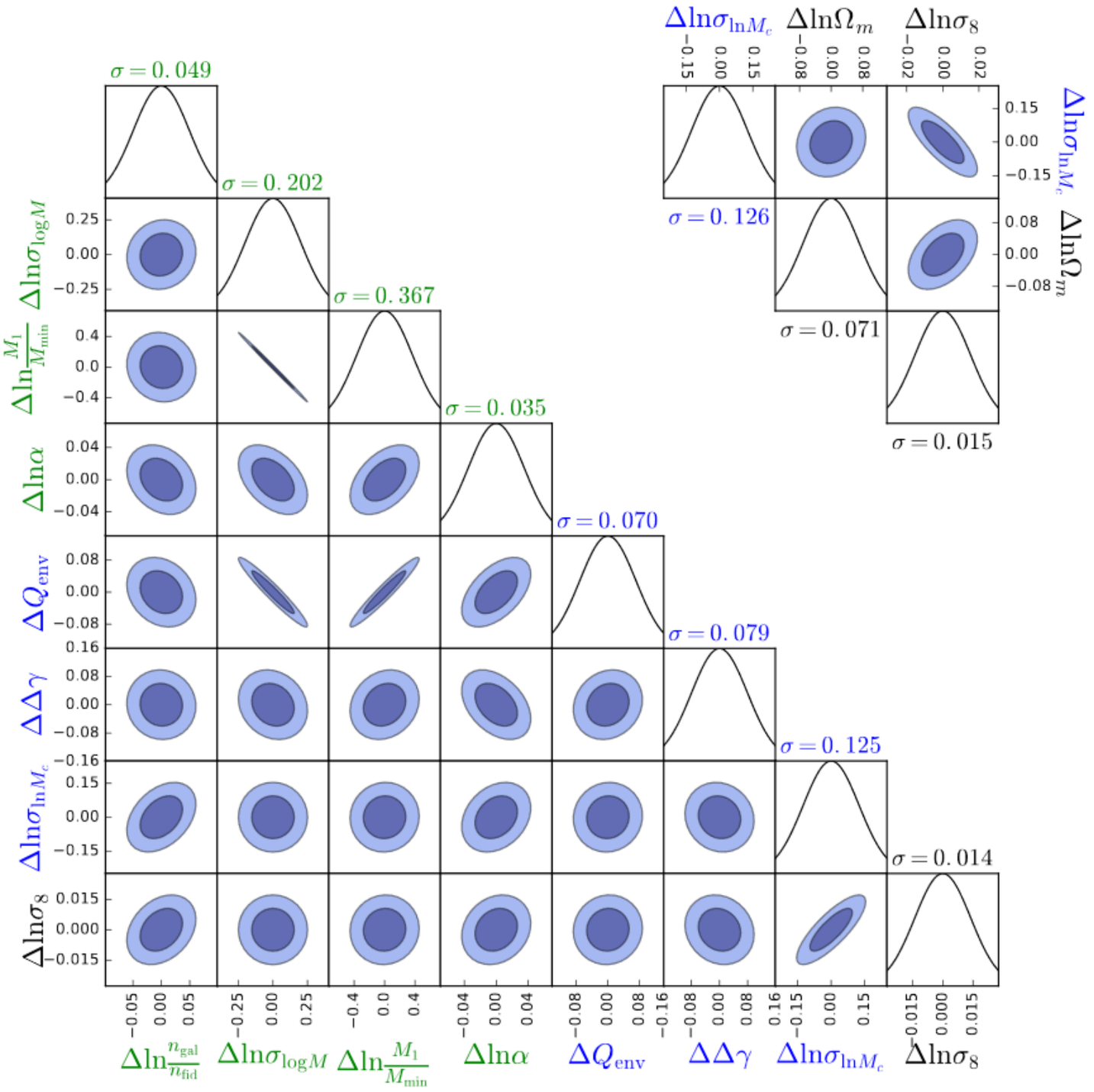
Cluster-galaxy cross-correlation $w_{p,cg} \propto \xi_{cg} \propto b_c b_g \sigma_8^2,$

Galaxy auto-correlation $w_{p,gg} \propto \xi_{gg} \propto b_g^2 \sigma_8^2$

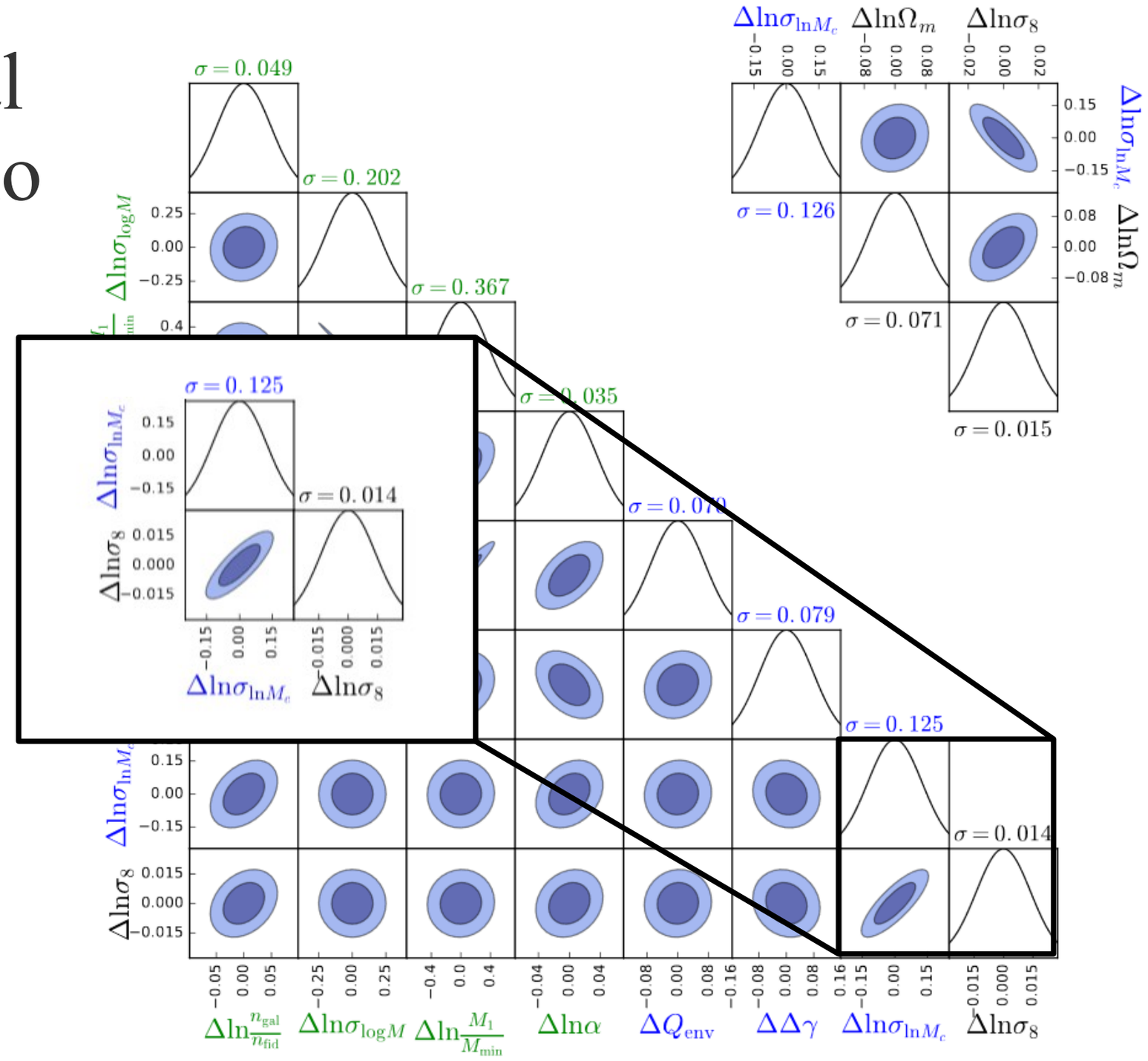
Analysis Overview



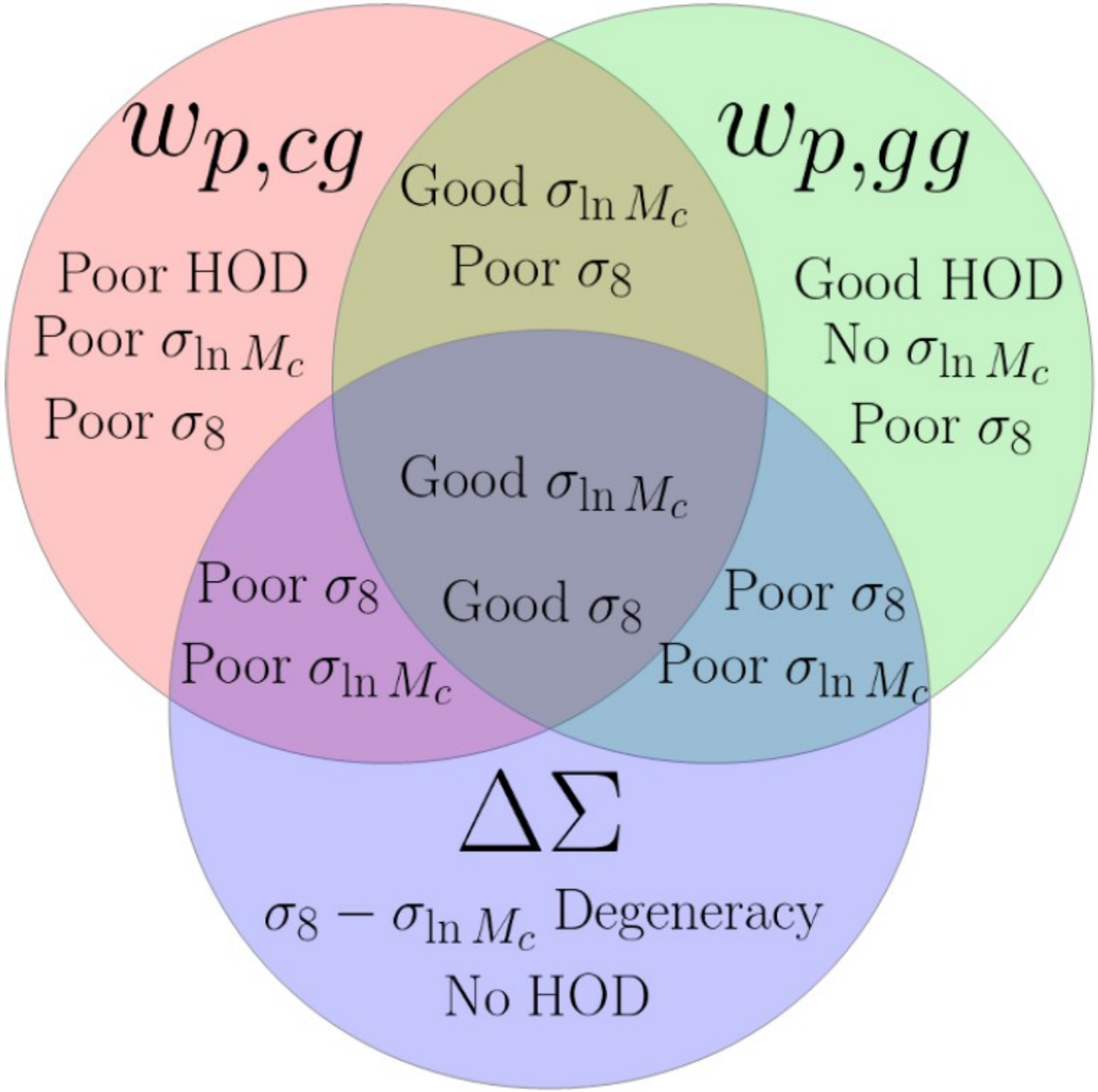
Fiducial Scenario



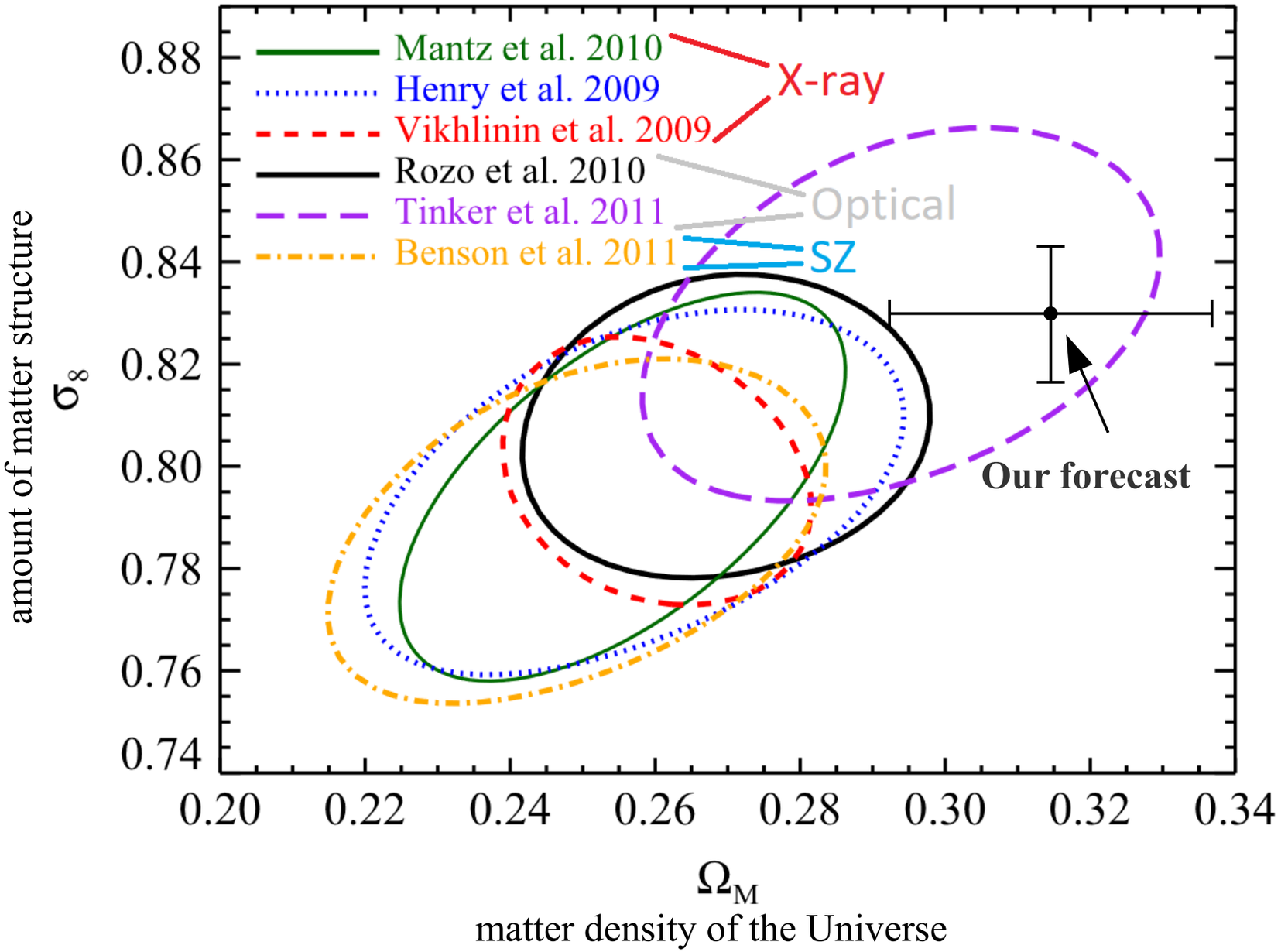
Fiducial Scenario



Where does the constraint come from?



Comparison with previous work



Acknowledgements and Questions