

SYNERGIES OF LARGE SCALE STRUCTURE SURVEYS WITH CMB S₄

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Dongwon Han

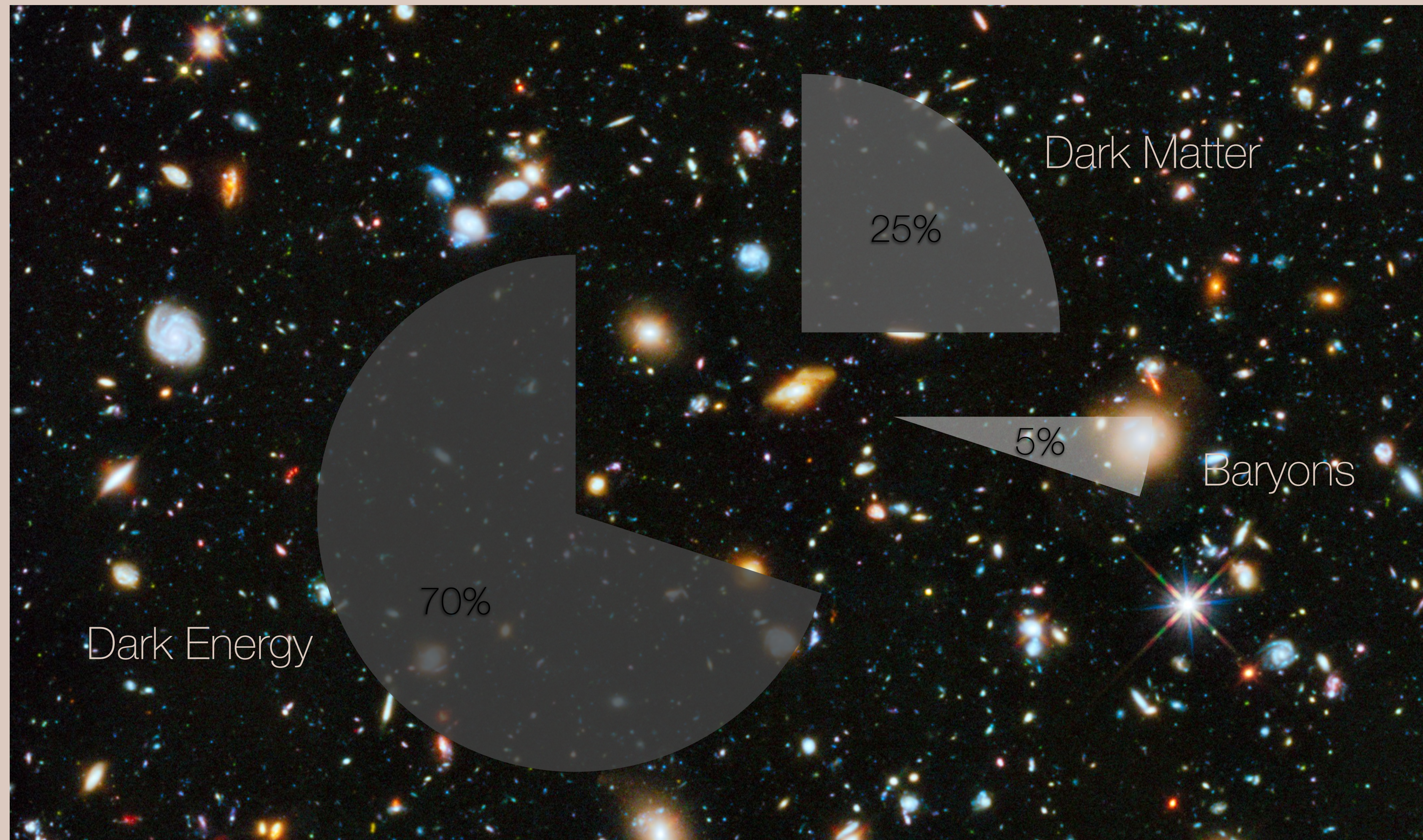
CMB S₄ Summer Collaboration Meeting, August 11th, 2021

THE PILLARS OF THE Λ CDM COSMOLOGICAL MODEL

Λ + DM + GR + INFLATION



OUR DARK UNIVERSE



*“I say, there is no darkness but ignorance.”
— William Shakespeare, Twelfth night (IV.II)*

COSMOLOGICAL PROBES

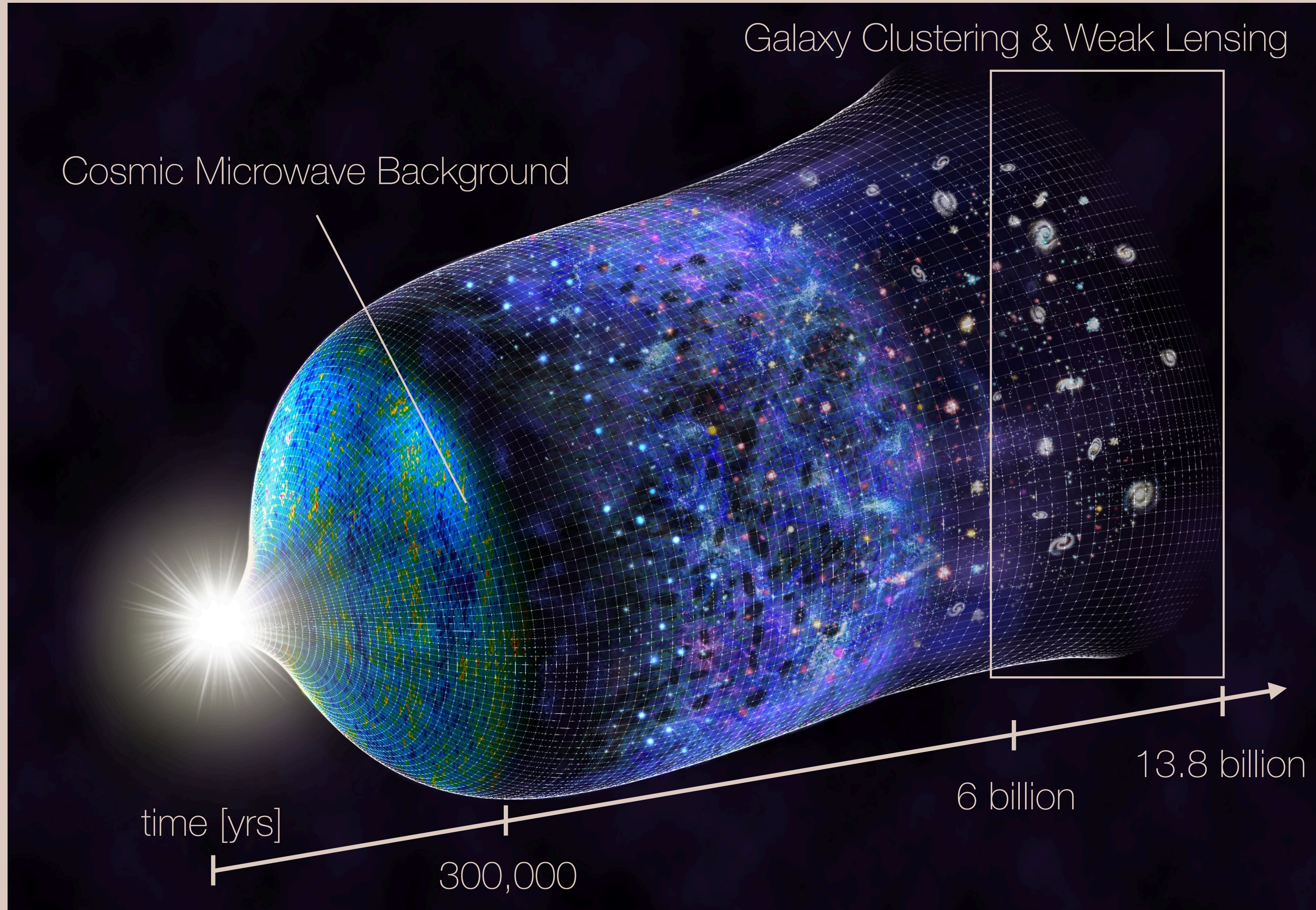
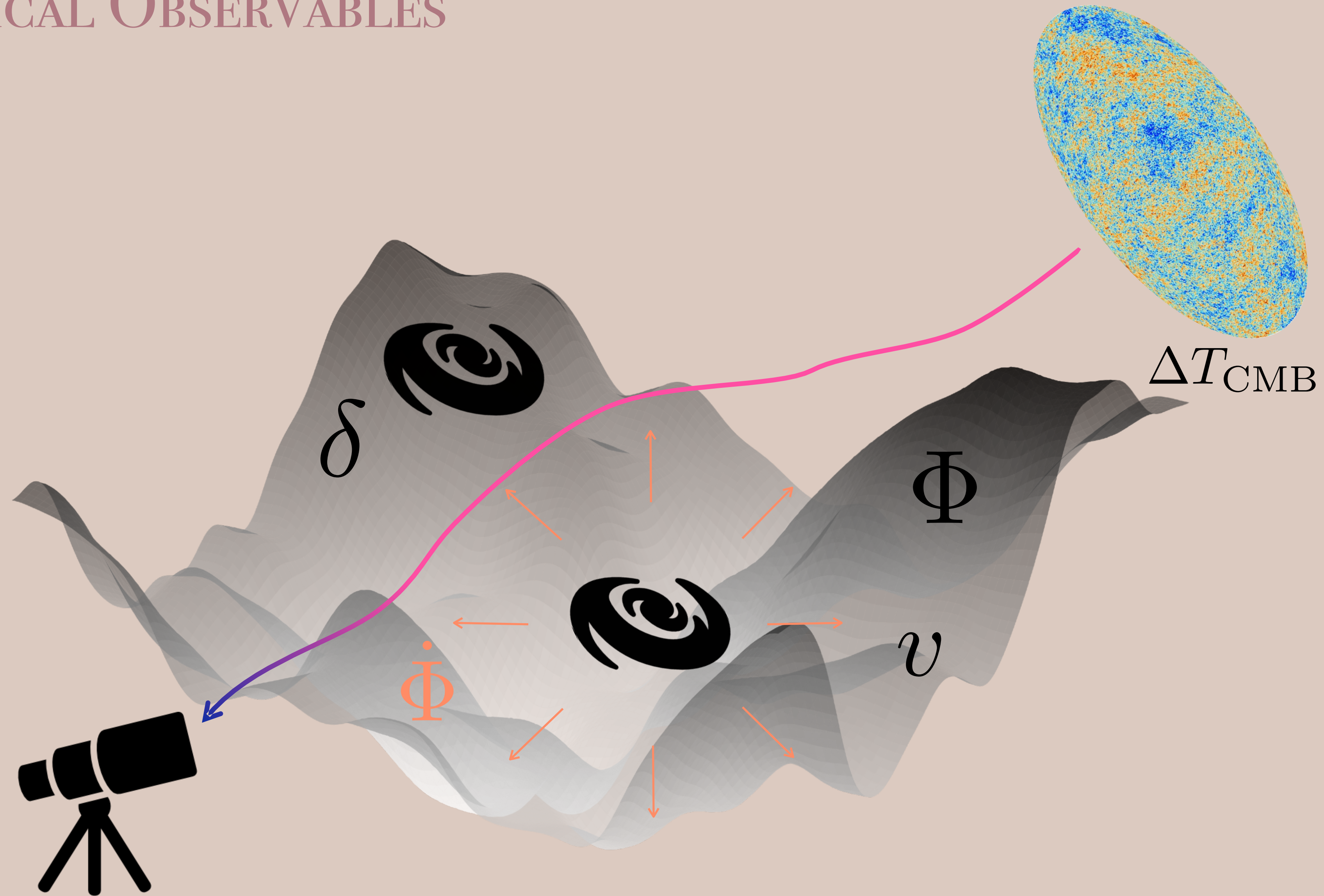


Image: Nicolle R. Fuller, National Science Foundation

COSMOLOGICAL OBSERVABLES



Images: Planck, Science, icons made by Freepik from www.flaticon.com

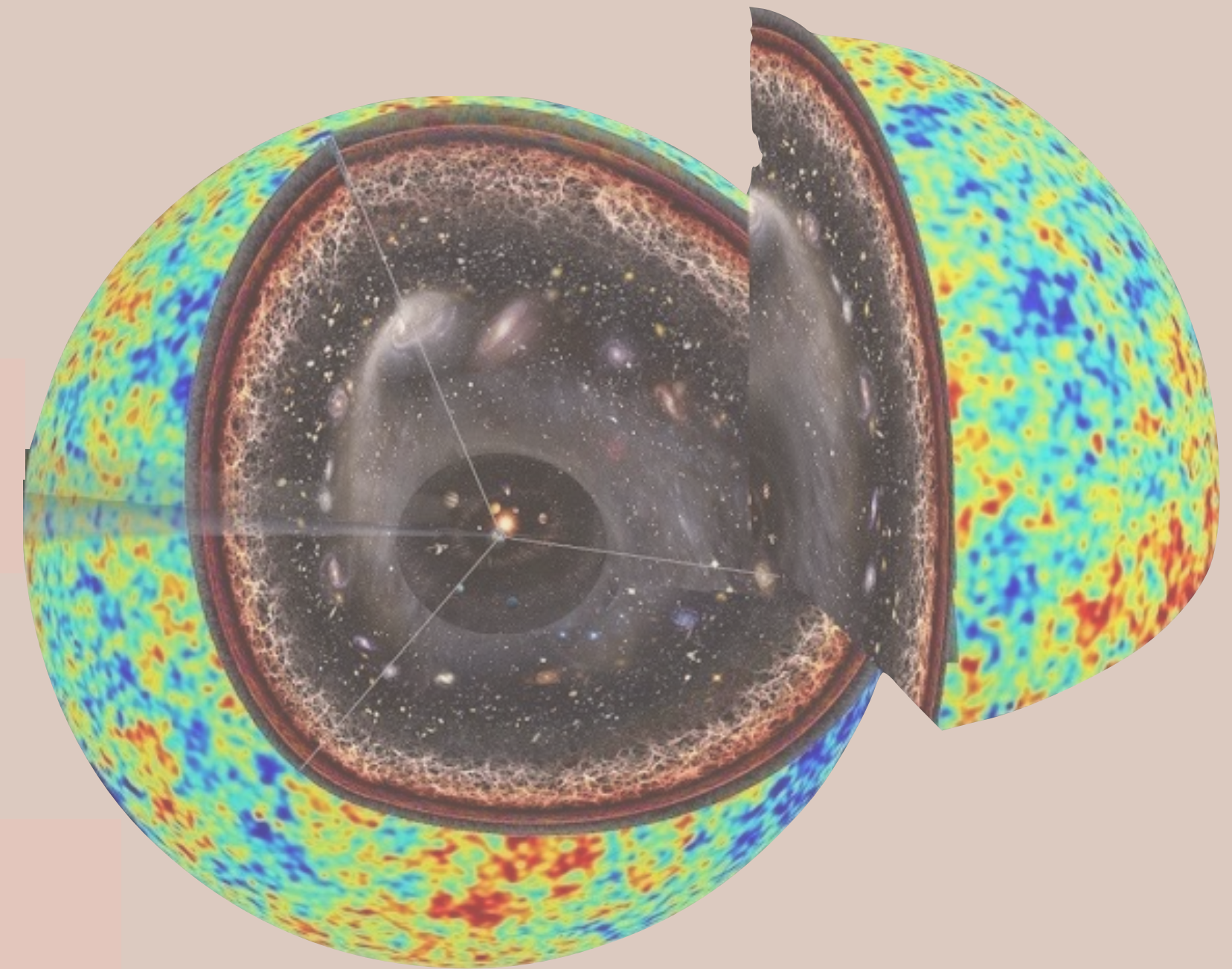
THE POTENTIAL OF JOINT CMBxLSS ANALYSES

Robust constraints on Λ CDM & extensions due to complementarity

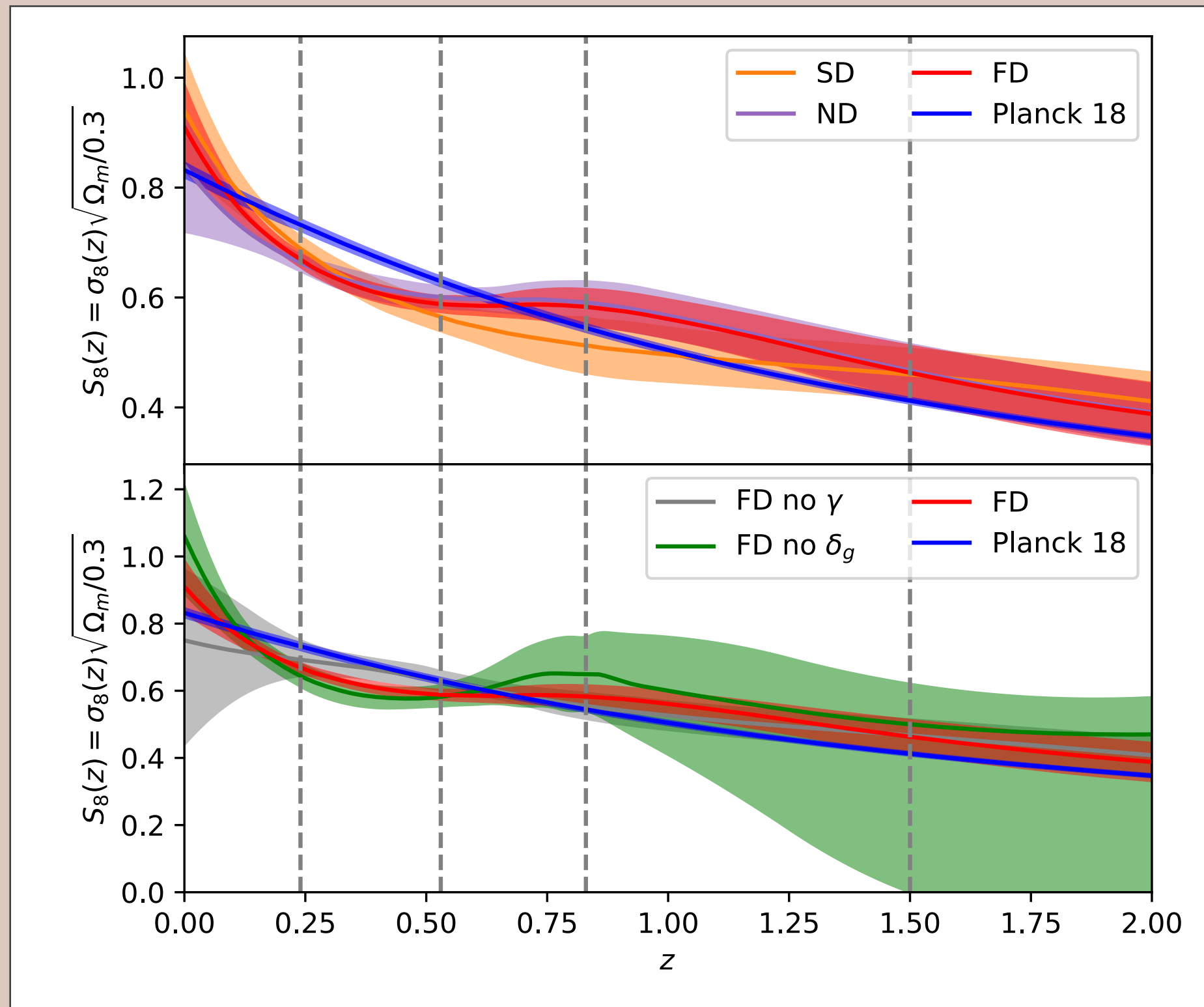
Consistency tests of cosmological model

Constraints on astrophysical systematics, e.g. baryon feedback

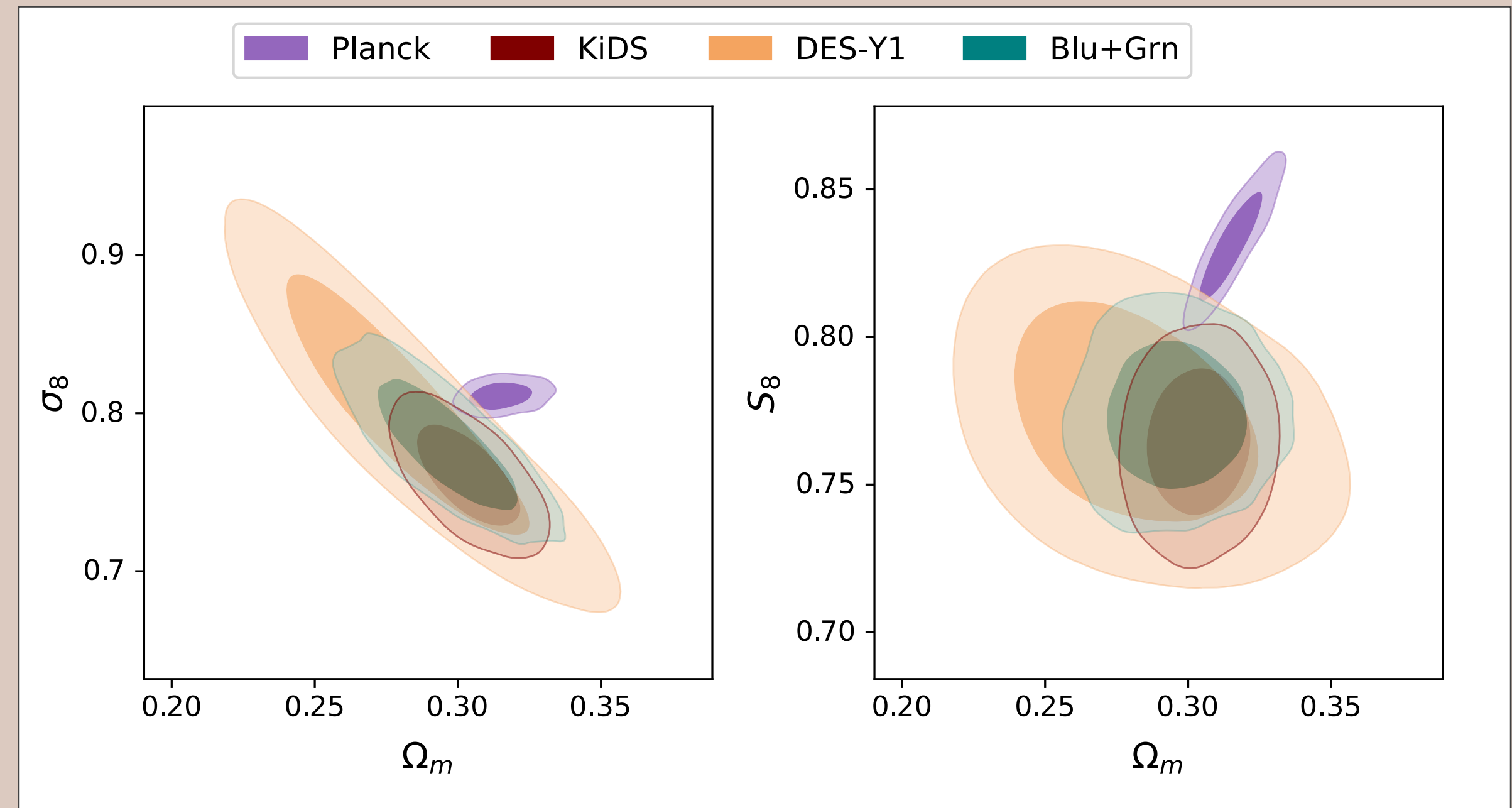
Systematics calibration & identification



CROSS-CORRELATION RESULTS



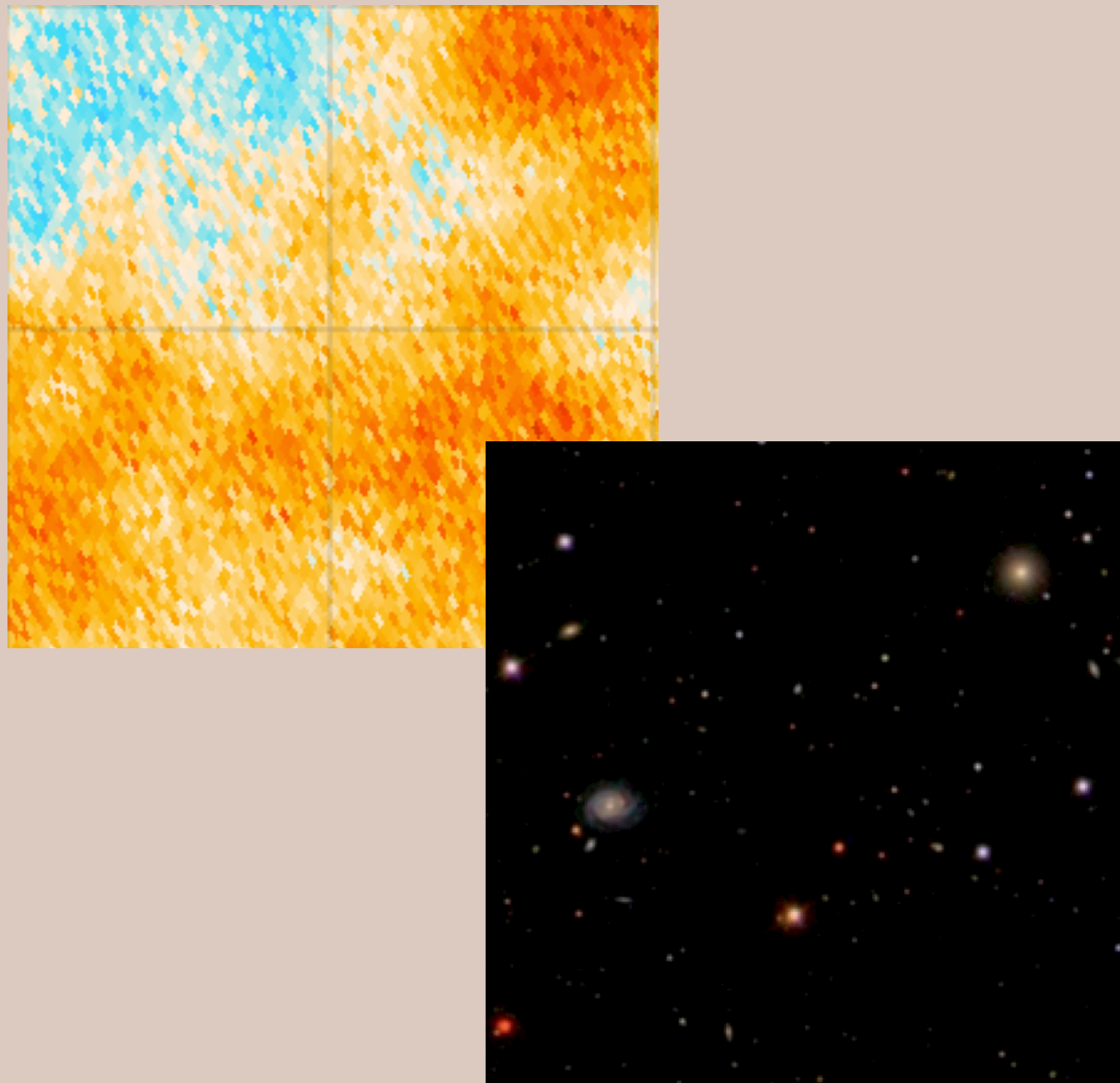
García-García et al., 2021



Krolewski et al., 2021

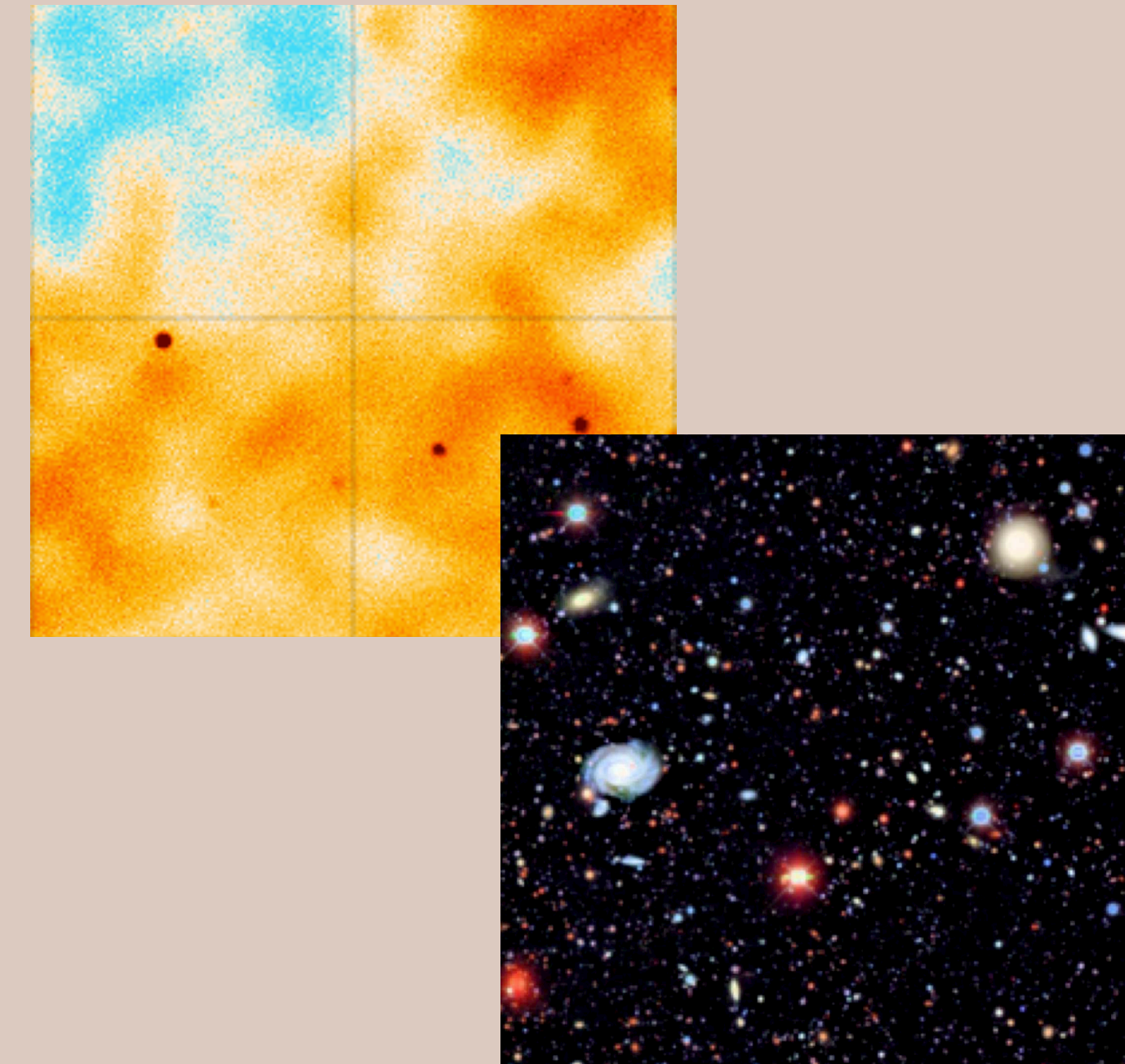
A NEW ERA FOR OBSERVATIONAL COSMOLOGY

PAST



e.g. SDSS, Planck

PRESENT & FUTURE



e.g. HSC, LSST/Rubin,
ACT/SPT, CMB S4

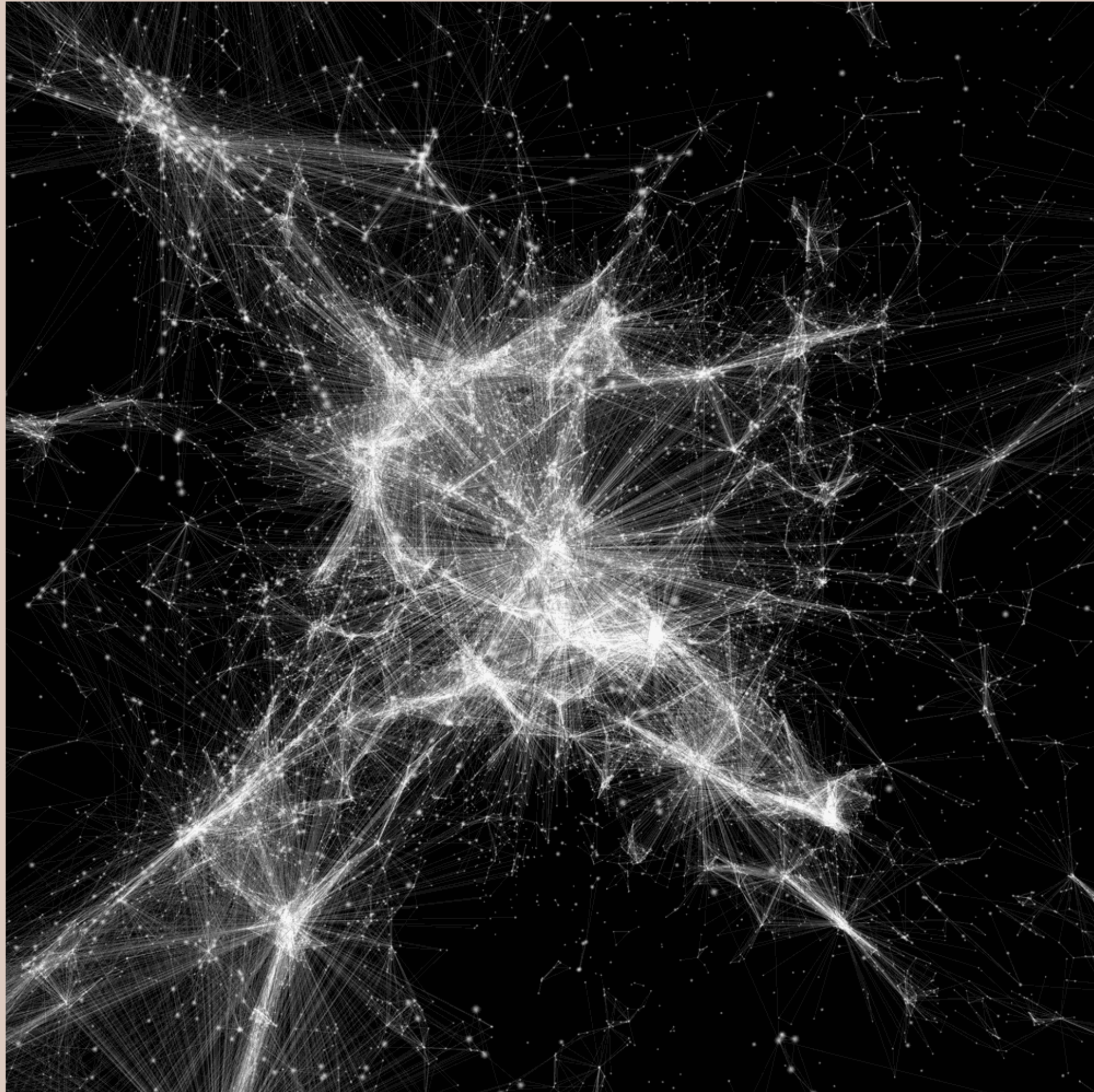
Images: ACT, Ivezić et al., 2008

THE COSMOLOGICAL DATA REVOLUTION



Images: DESI, Euclid, SO, Rubin/LSST, Roman, CMB S4, MSE, MegaMapper

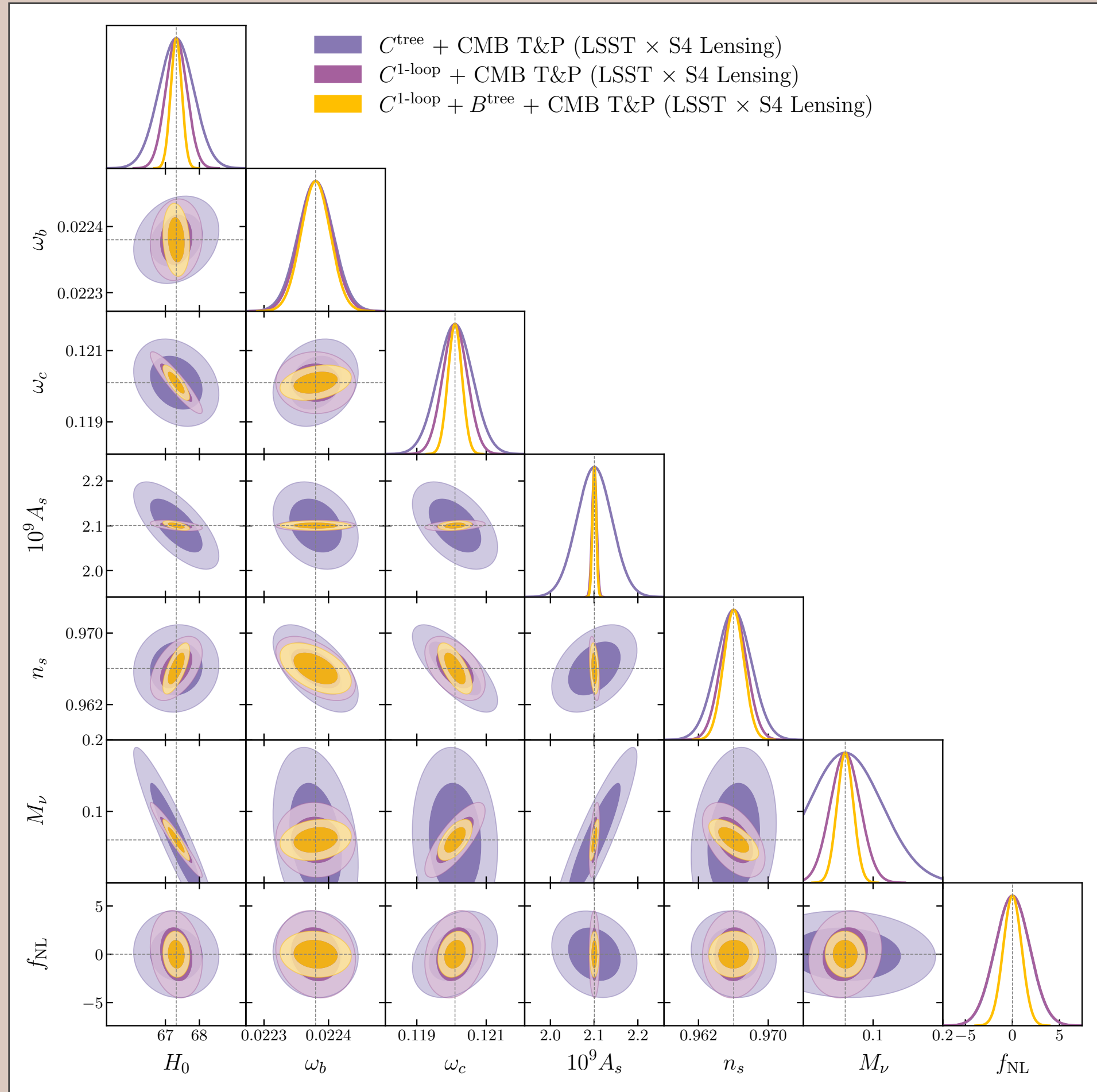
OUR NON-LINEAR UNIVERSE



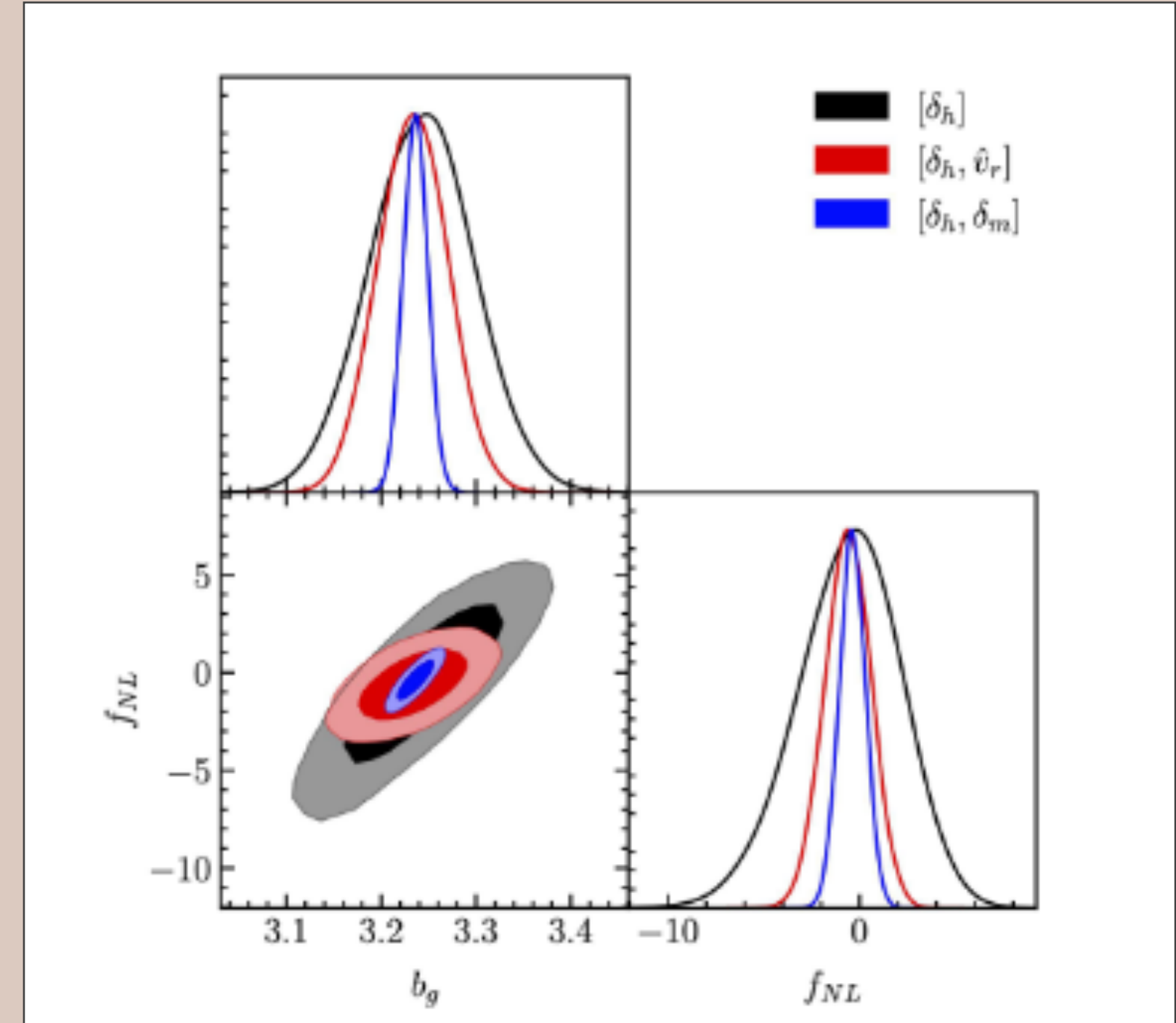
Additional information contained in:
Cosmological fields at small spacial scales
Non-Gaussian features

Image: Illustris Collaboration / Illustris Simulation

HIGHER-ORDER STATISTICS



Chen et al., 2021



Giri et al., in prep.

Stacked ISW / CMB lensing around superstructures - Hang, Cai et al., 2021

MOVING BEYOND TRADITIONAL METHODS

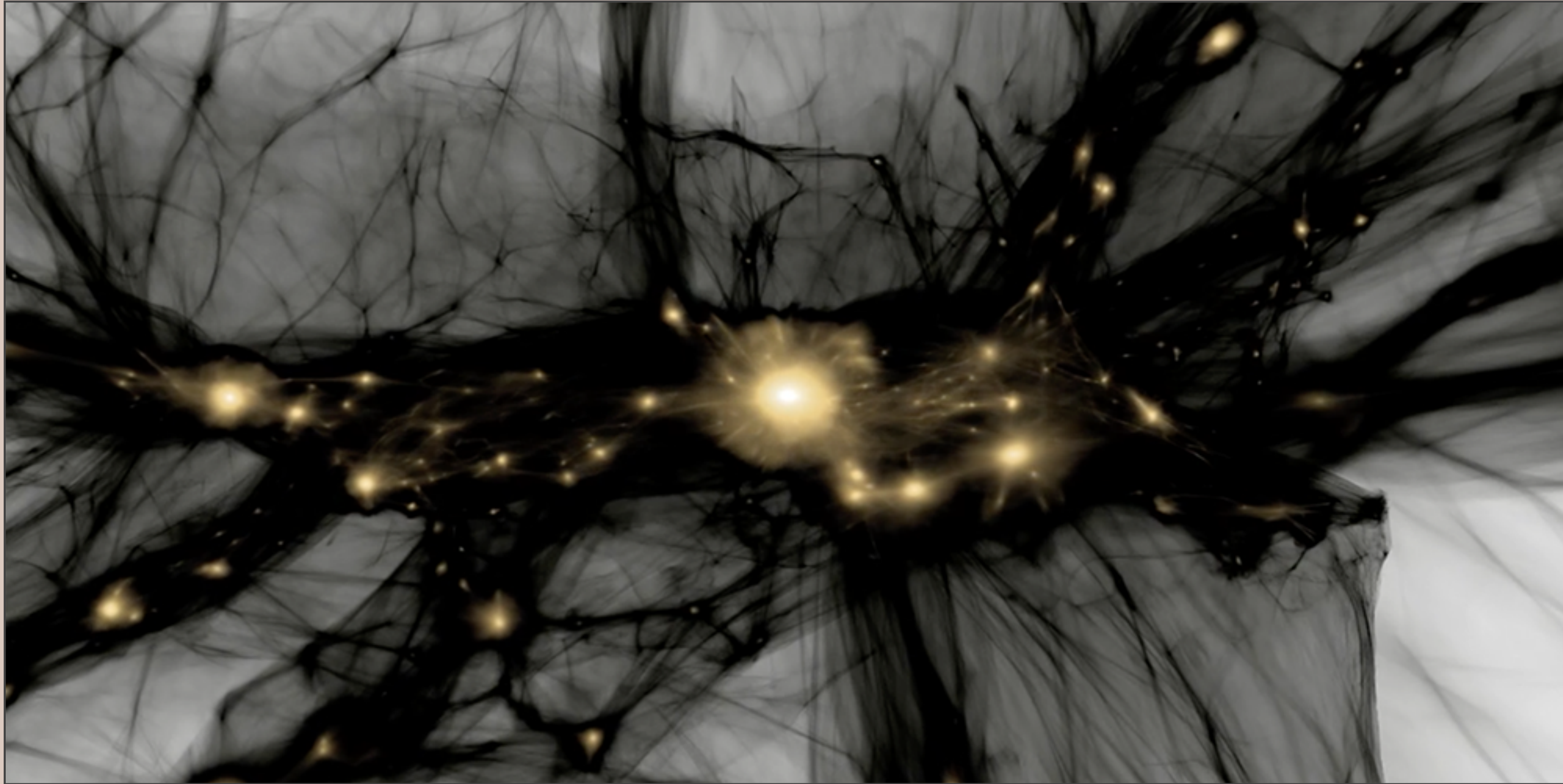


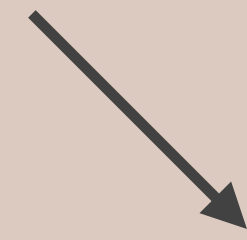
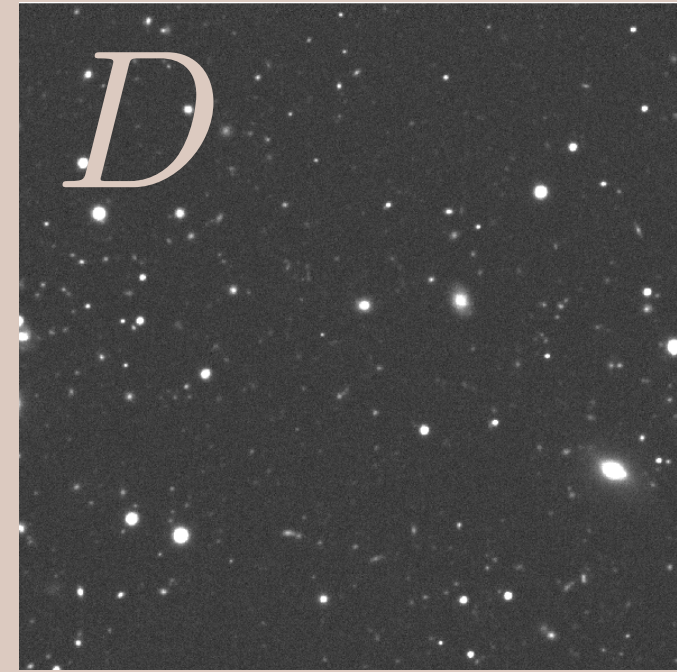
Image: S. Skillman, Y-Y. Mao, KIPAC/SLAC National Accelerator Laboratory

SIMULATION-BASED INFERENCE

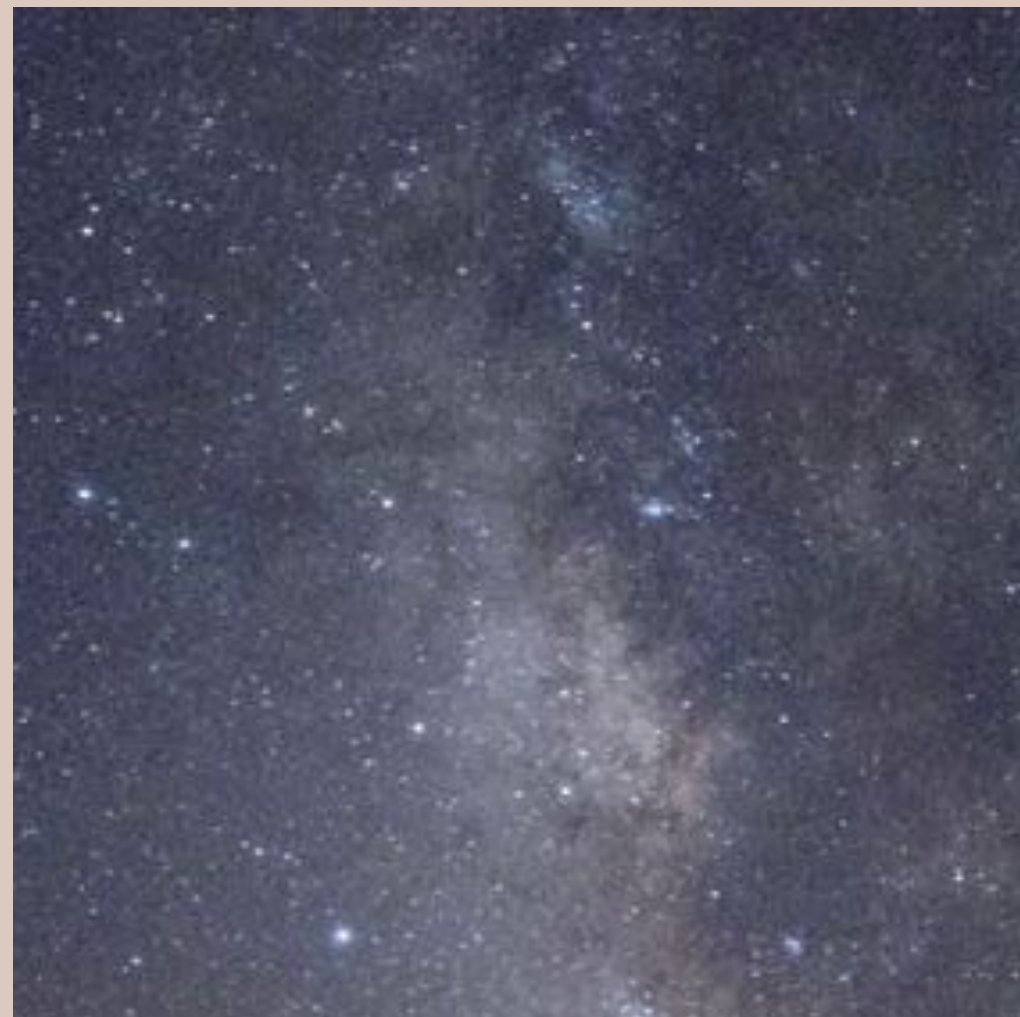
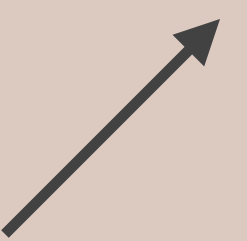
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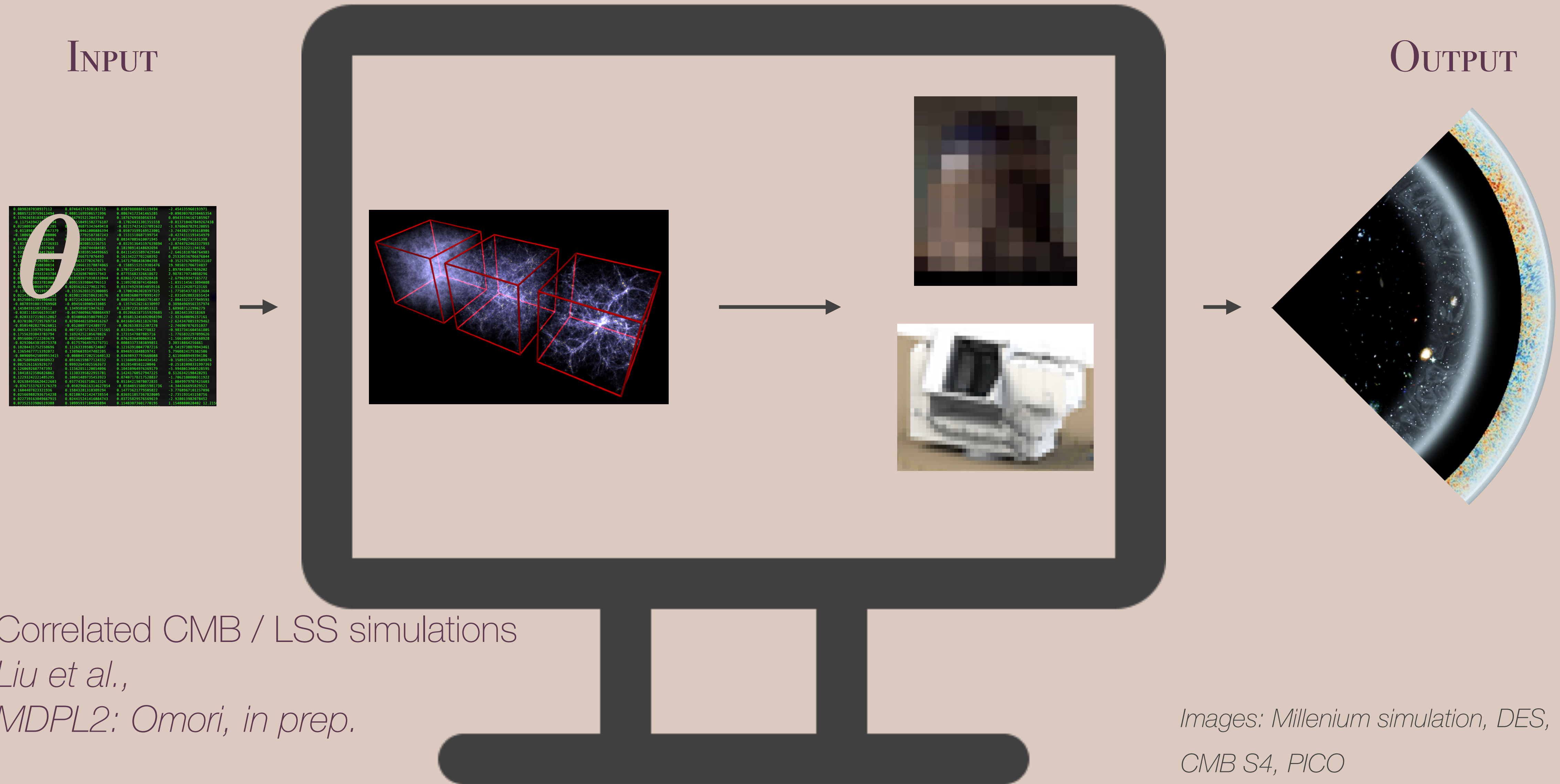


$$p(D_* | \theta)$$



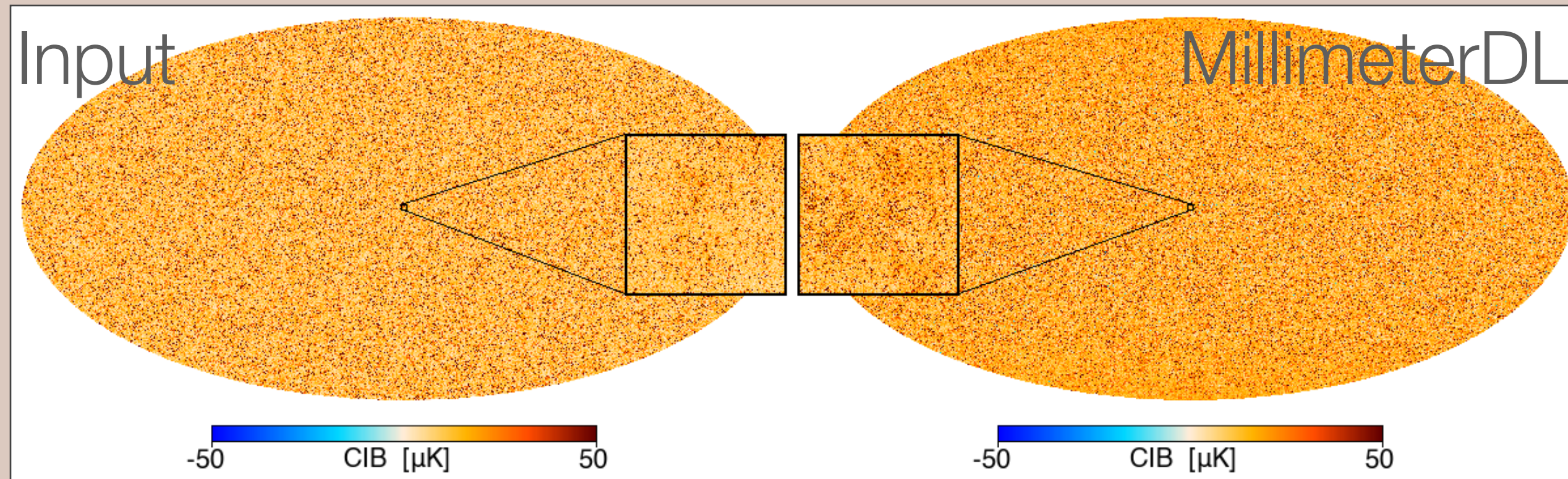
Alsing et al., 2019, Tejero-Cantero et al., 2020

FORWARD MODELING



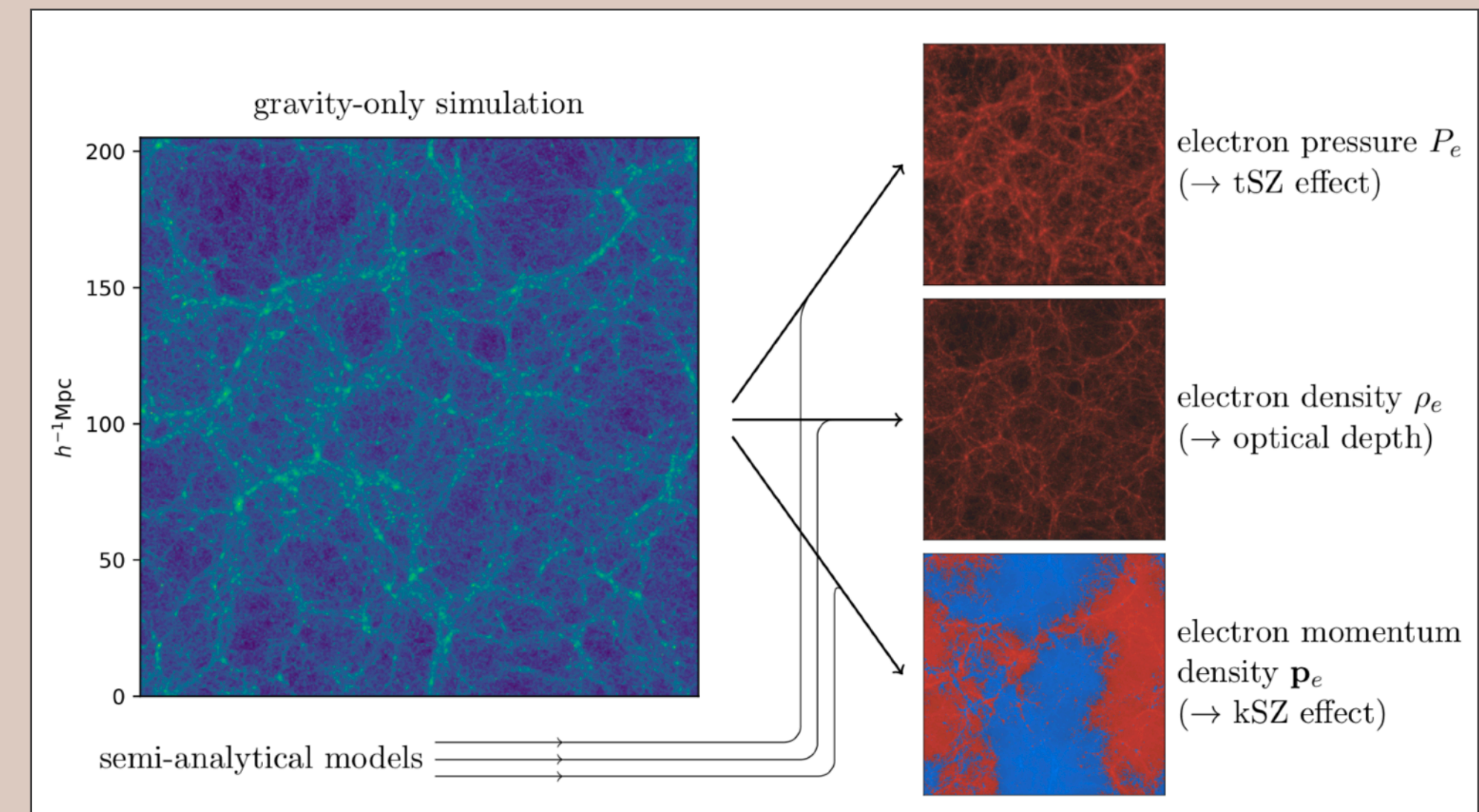
ML-ASSISTED JOINT FORWARD MODELS

CMB & FOREGROUNDS



Han et al., 2021

SECONDARY ANISOTROPIES



Thiele et al., 2020

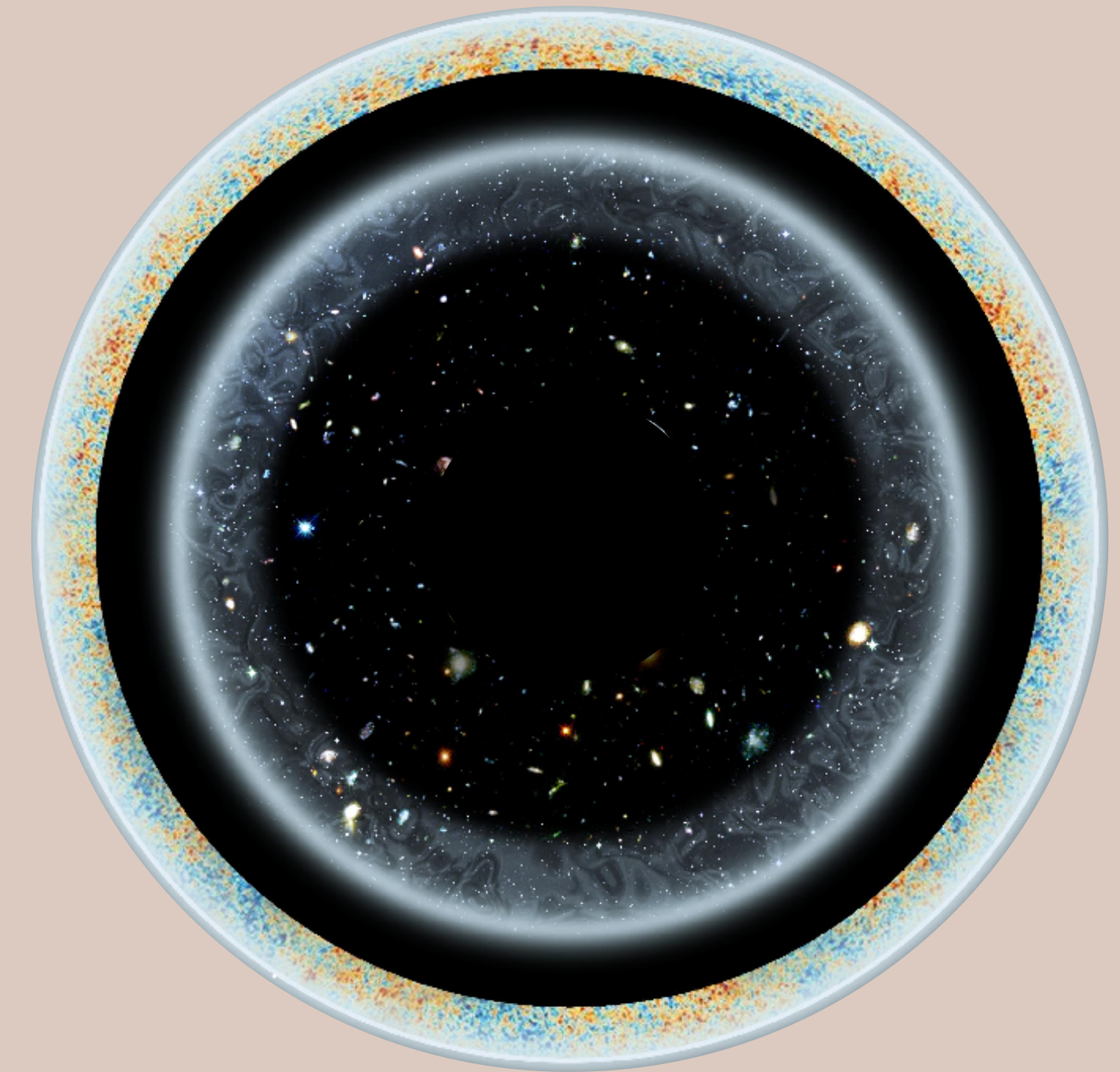
CROSS-SURVEY COORDINATION

Joint CMB and LSS analyses require

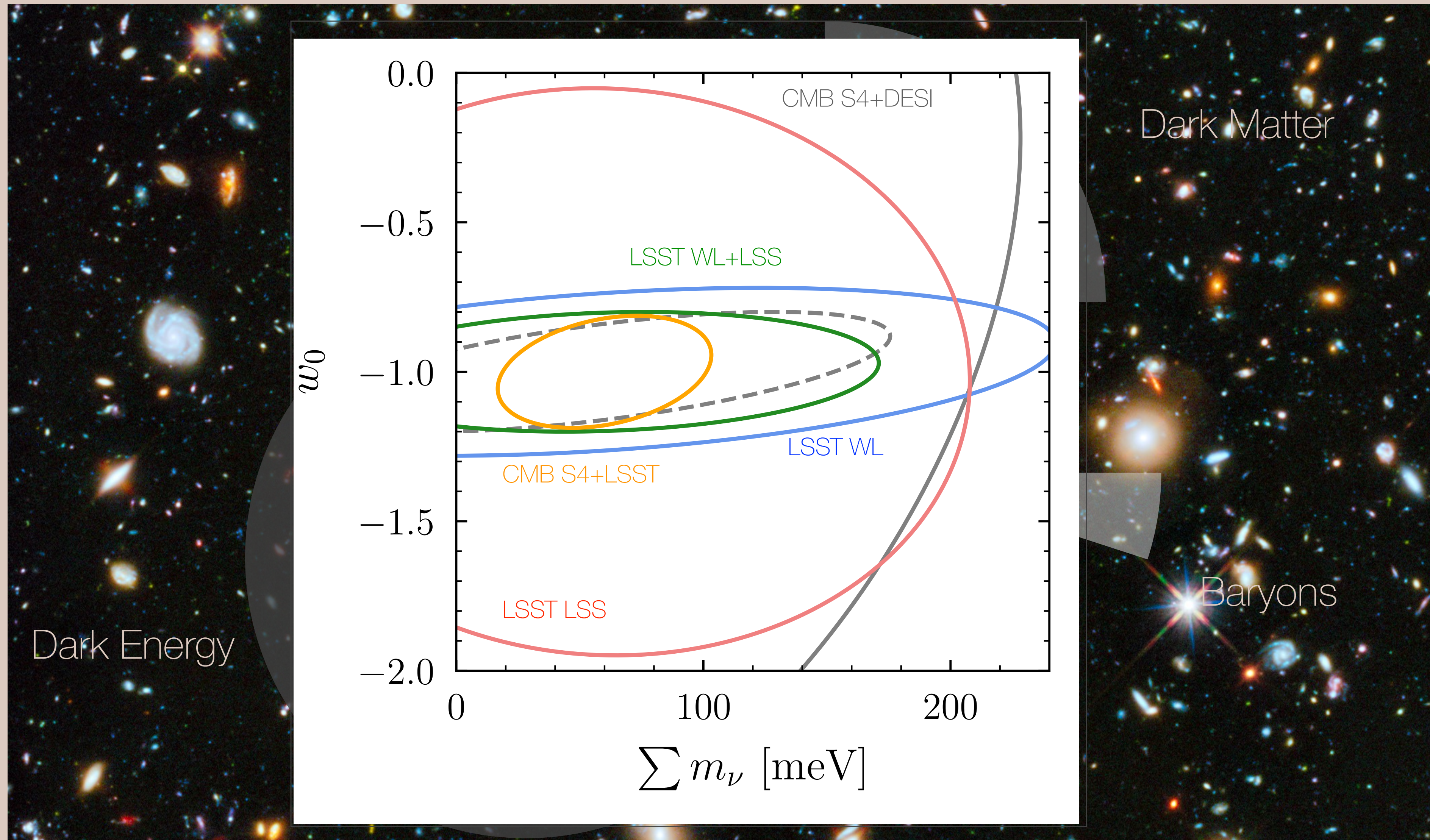
- Joint simulations / forward-models
- Homogeneous analysis tools
- Analyses of precursor data to learn about systematics

Coordination

- Consistent theory predictions (FREECODES)
- Correlated simulations (*Liu et al., Omori*)
- Precursor data analyses performed across collaborations?



TESTING PILLARS OF Λ CDM WITH FUTURE SURVEYS



Mishra-Sharma et al, 2018

SUMMARY

Combining CMB & LSS is essential to constrain cosmology

Tight constraints on extended models & astrophysics (*e.g. Krolewski et al., 2021, Giri et al.*)

Consistency checks of cosmological model (*e.g. García-García et al., 2021*)

Identification, understanding and calibration of systematics

Substantial synergies between CMB S4 and future LSS surveys (*e.g. Slosar et al.*)

Future surveys will deliver high-precision data

Significant information in small-scales, non-Gaussian features (*e.g. Chen et al., 2021, Cai et al., 2021*)

Limited by systematics

Need novel analysis methods

Joint forward-modeling and SBI / Bayesian pipelines (*e.g. Liu et al.*)

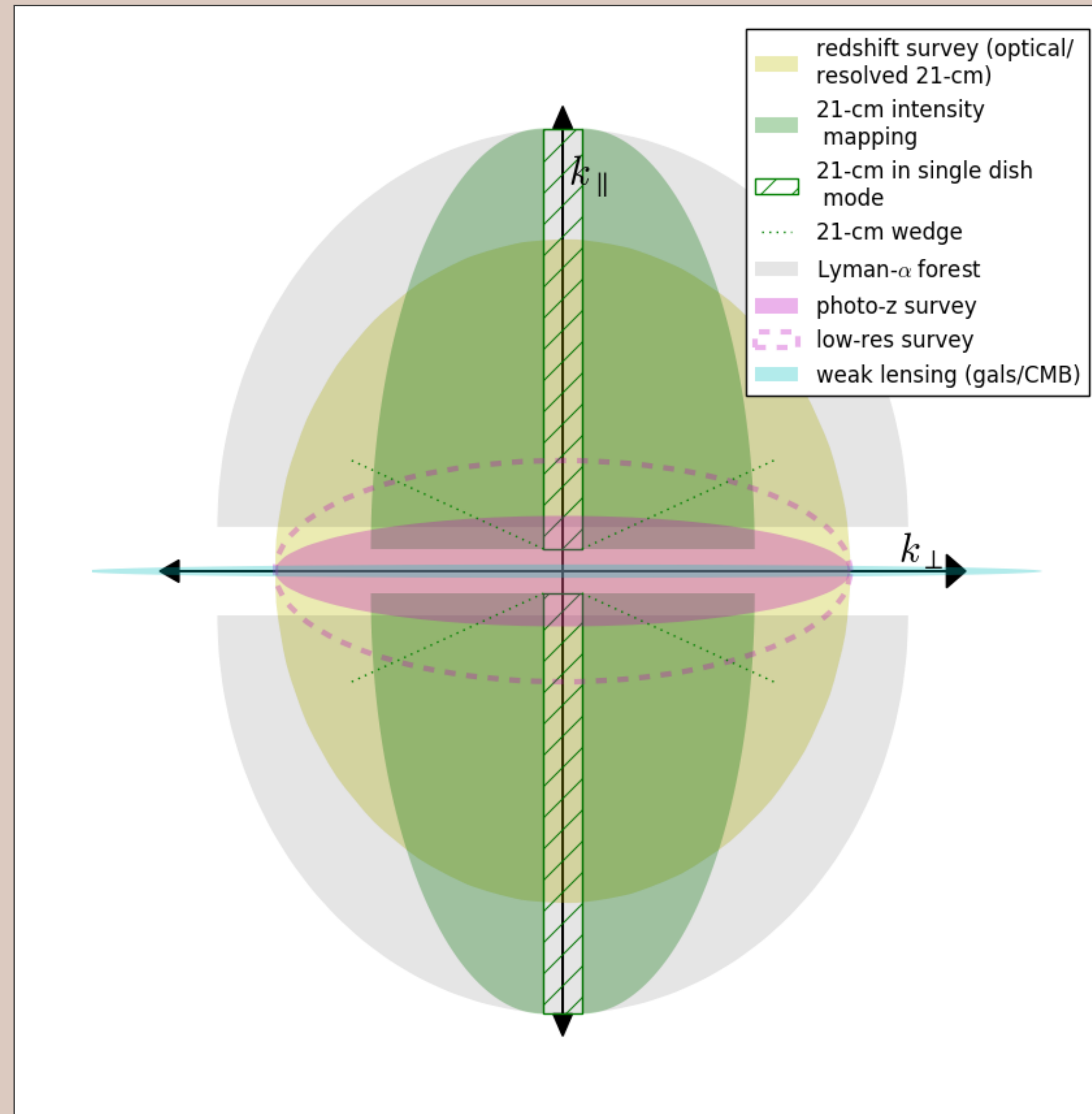
ML methods essential (*e.g. Han et al., 2021, Thiele et al., 2020*)

Early coordination and collaboration between surveys

Thank you!

and all the session contributors!

SYNERGIES OF CMB AND LSS IN K-SPACE



Slosar et al.