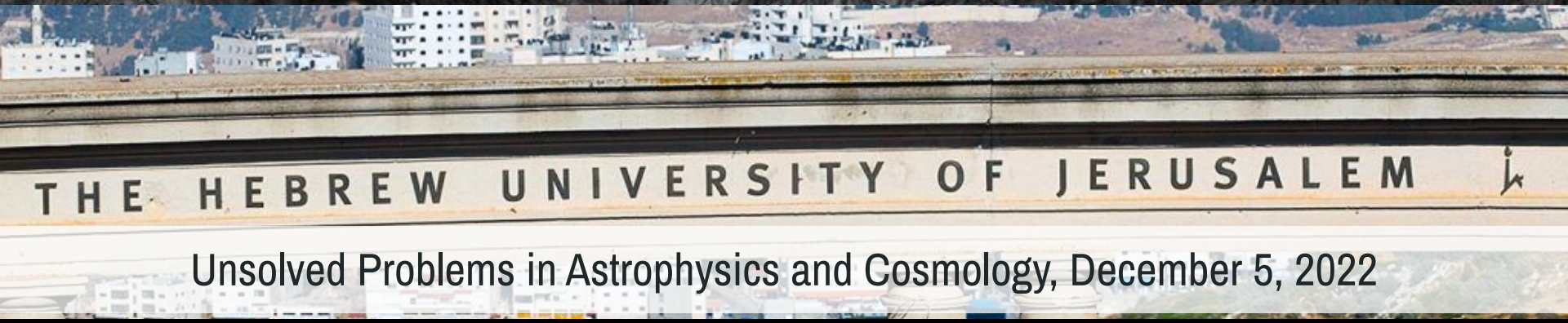
NEUTRINO MASS FROM COSMOLOGY



Unsolved Problems in Astrophysics and Cosmology, December 5, 2022

Jia Liu

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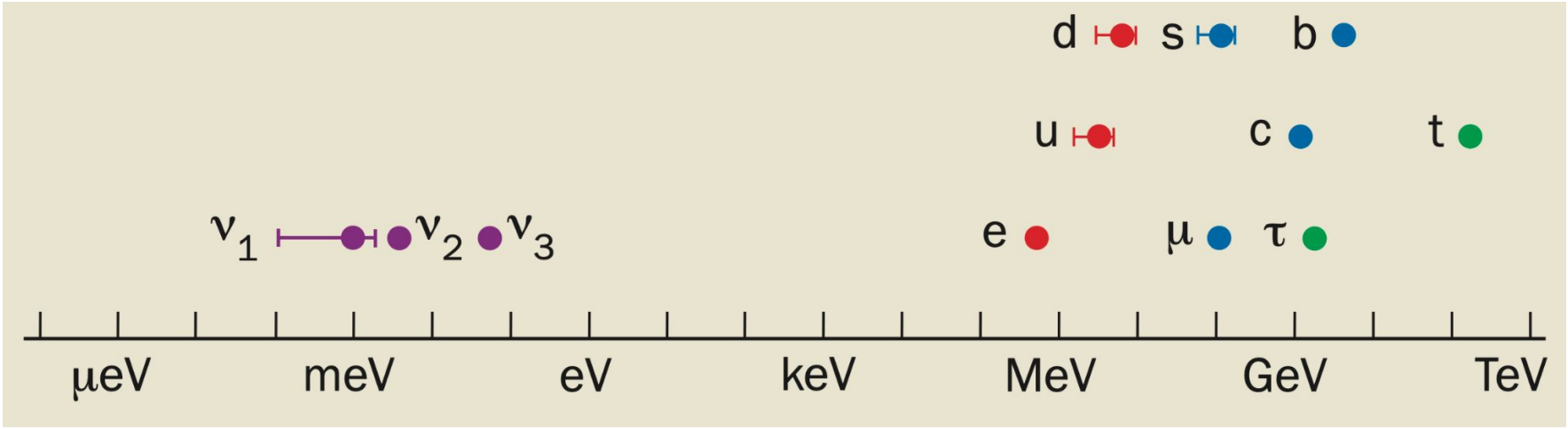
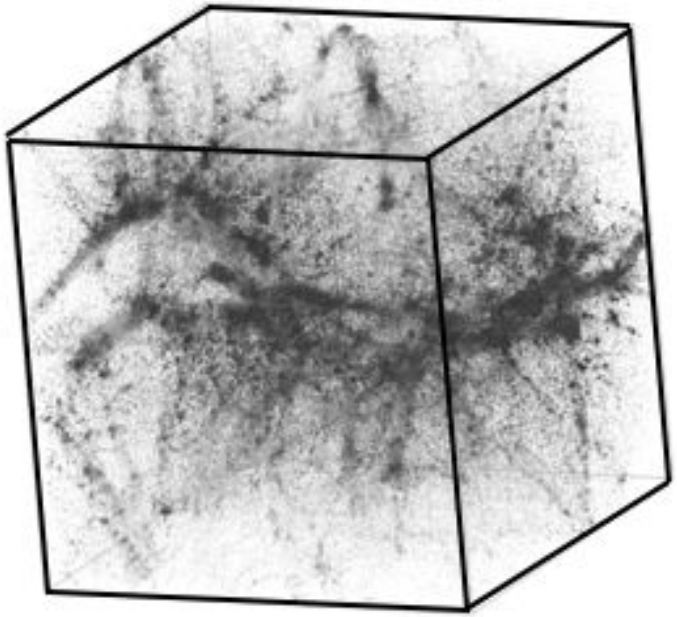
Fermion masses

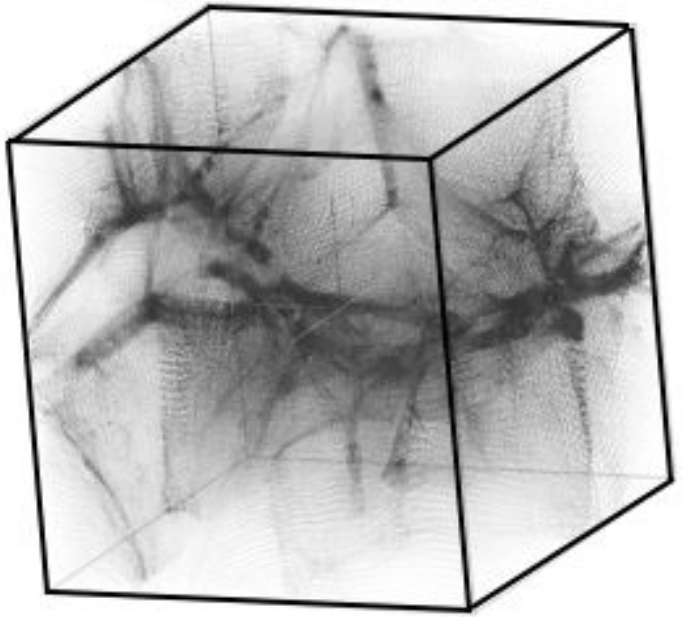


Hitoshi Murayama

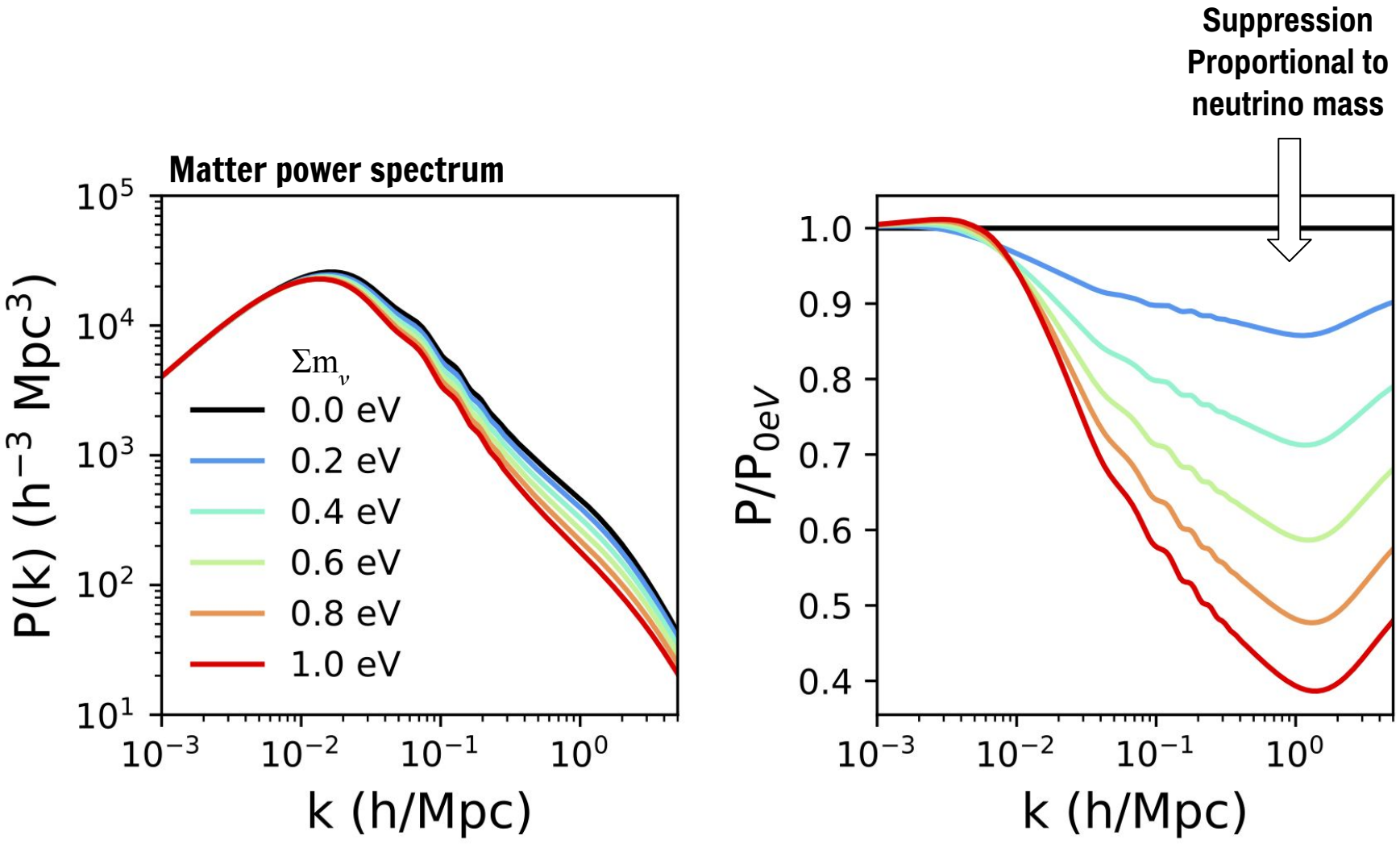
Massless Neutrino



Massive Neutrinos



Katrin Heitmann

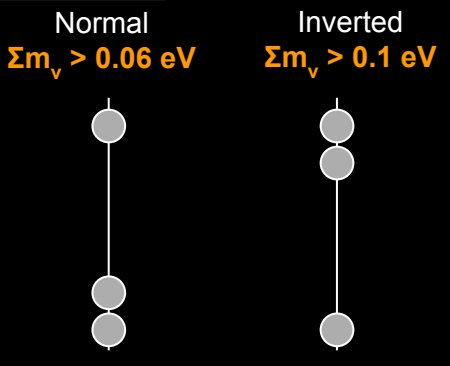

Matter power spectrum
P(k) (h^{-3} Mpc^3)
10^5
10^4
10^3
10^2
10^1
Σm_ν
0.0 eV
0.2 eV
0.4 eV
0.6 eV
0.8 eV
1.0 eV
10^{-3}
10^{-2}
10^{-1}
10^0
k (h/Mpc)
Suppression
Proportional to
neutrino mass
P/P$_{0eV}$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
10^{-3}
10^{-2}
10^{-1}
10^0
k (h/Mpc)

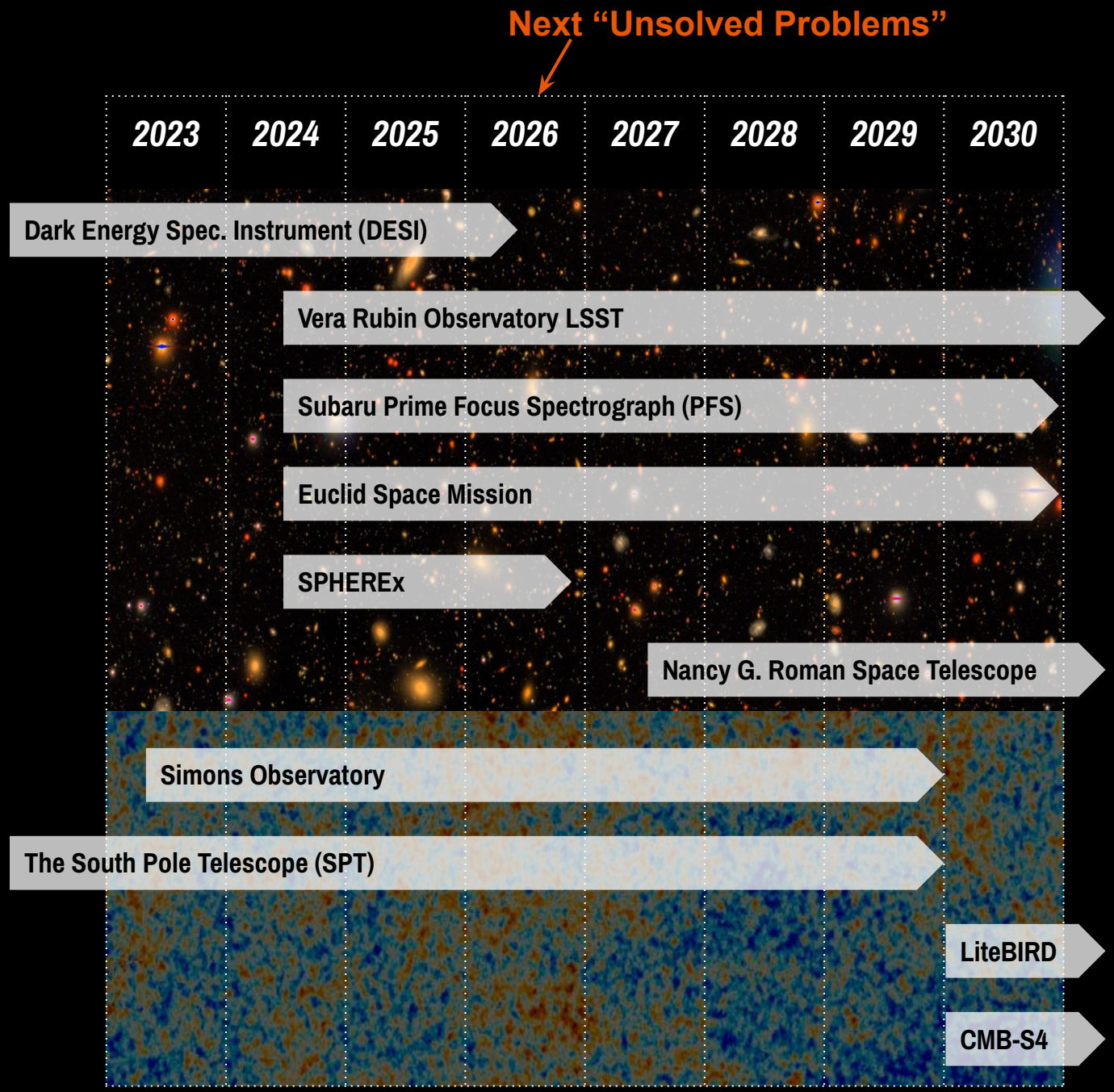
	PARTICLE EXPERIMENT	COSMOLOGY
Present Upper Limit	**0.8 eV** KATRIN (2022, 90% CL)	**0.13 eV** Planck + BAO (2018, 95% CL)
Future Sensitivity	**~ 0.2 eV** KATRIN 2023	**~ 0.02 eV** LSST, Euclid, PFS, DESI, SO, CMB-S4, LiteBIRD

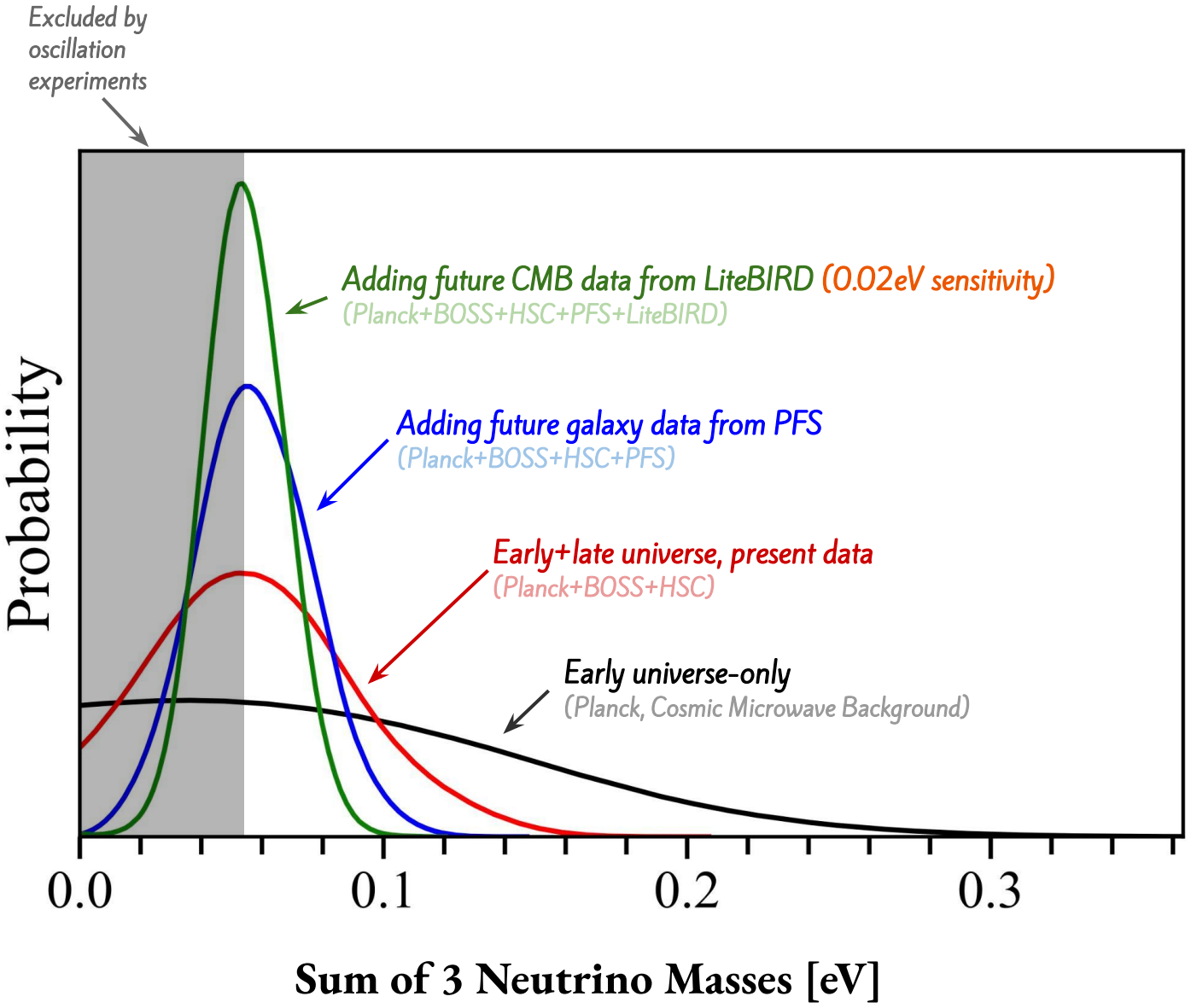
2018: 2 eV
(Troitsk)

2018: 0.23 eV
(Planck15+BAO)

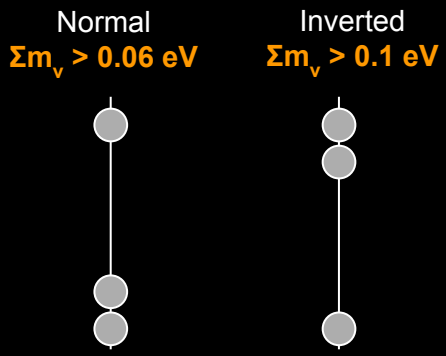
	PARTICLE EXPERIMENT	COSMOLOGY
Present Upper Limit	**0.8 eV** KATRIN (2022, 90% CL)	**0.13 eV** Planck + BAO (2018, 95% CL)
Future Sensitivity	**~ 0.2 eV** KATRIN 2023	**~ 0.02 eV** LSST, Euclid, PFS, DESI, SO, CMB-S4, LiteBIRD




Next “Unsolved Problems”
2023
2024
2025
2026
2027
2028
2029
2030
Dark Energy Spec. Instrument (DESI)
Vera Rubin Observatory LSST
Subaru Prime Focus Spectrograph (PFS)
Euclid Space Mission
SPHEREx
Nancy G. Roman Space Telescope
Simons Observatory
The South Pole Telescope (SPT)
LiteBIRD
CMB-S4



Ryu Makiya, Masahiro Takada

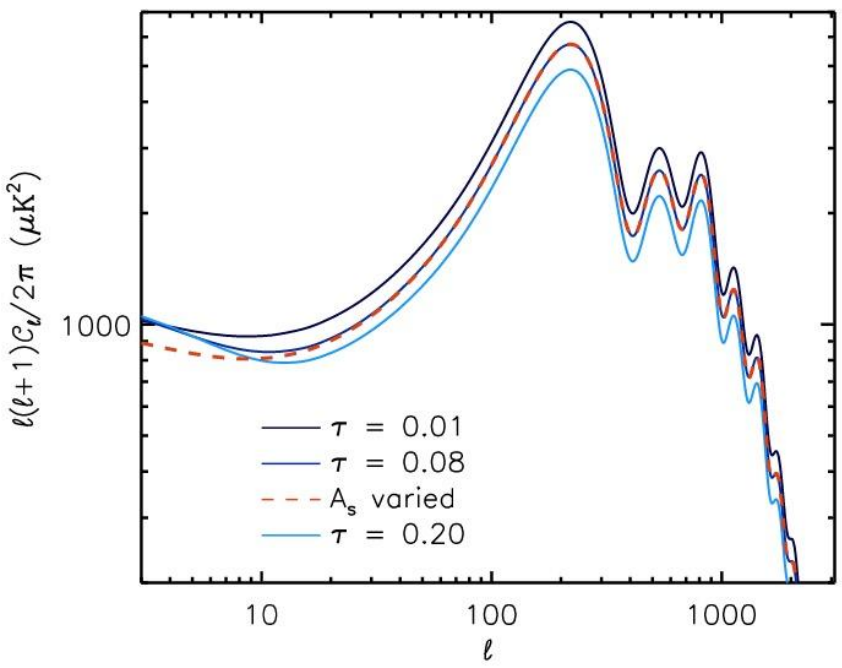


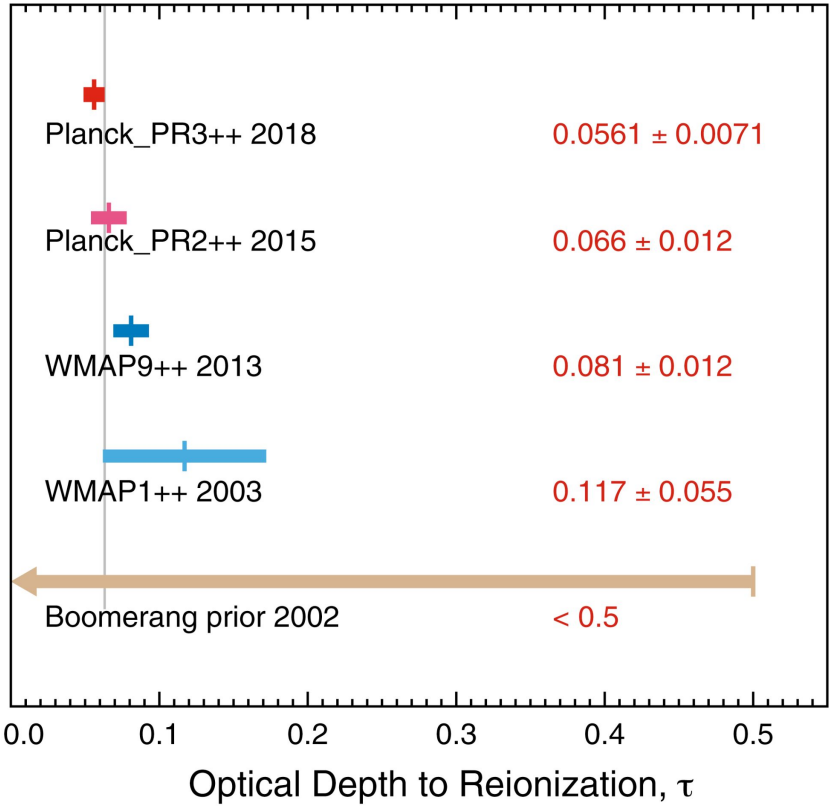
0.02 eV sensitivity = Discovery

	Neutrino Mass	Mass Hierarchy
$\Sigma m_\nu > 0.1$eV	Discovery	No
$\Sigma m_\nu < 0.1$eV	Maybe	Discovery

Challenge 1: Optical Depth to Reionization τ_{reio}

Currently limited by Planck's τ_{reio}

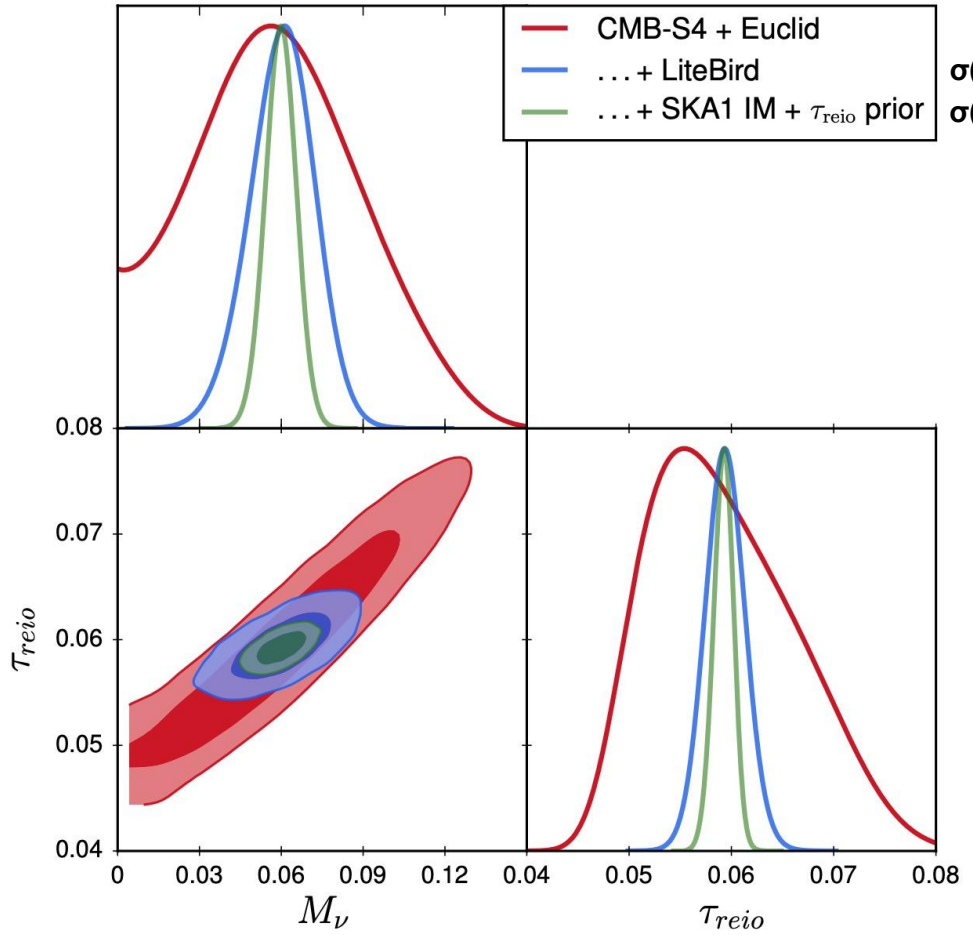


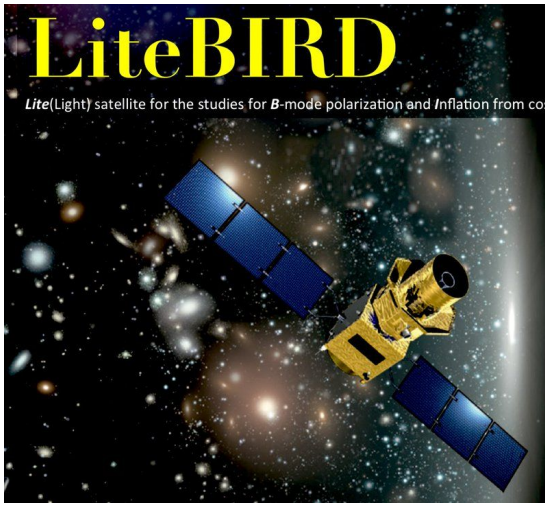


Christian Reichardt

LAMBDA - September 2018

Better τ_{reio} from LiteBIRD (in 10 years)

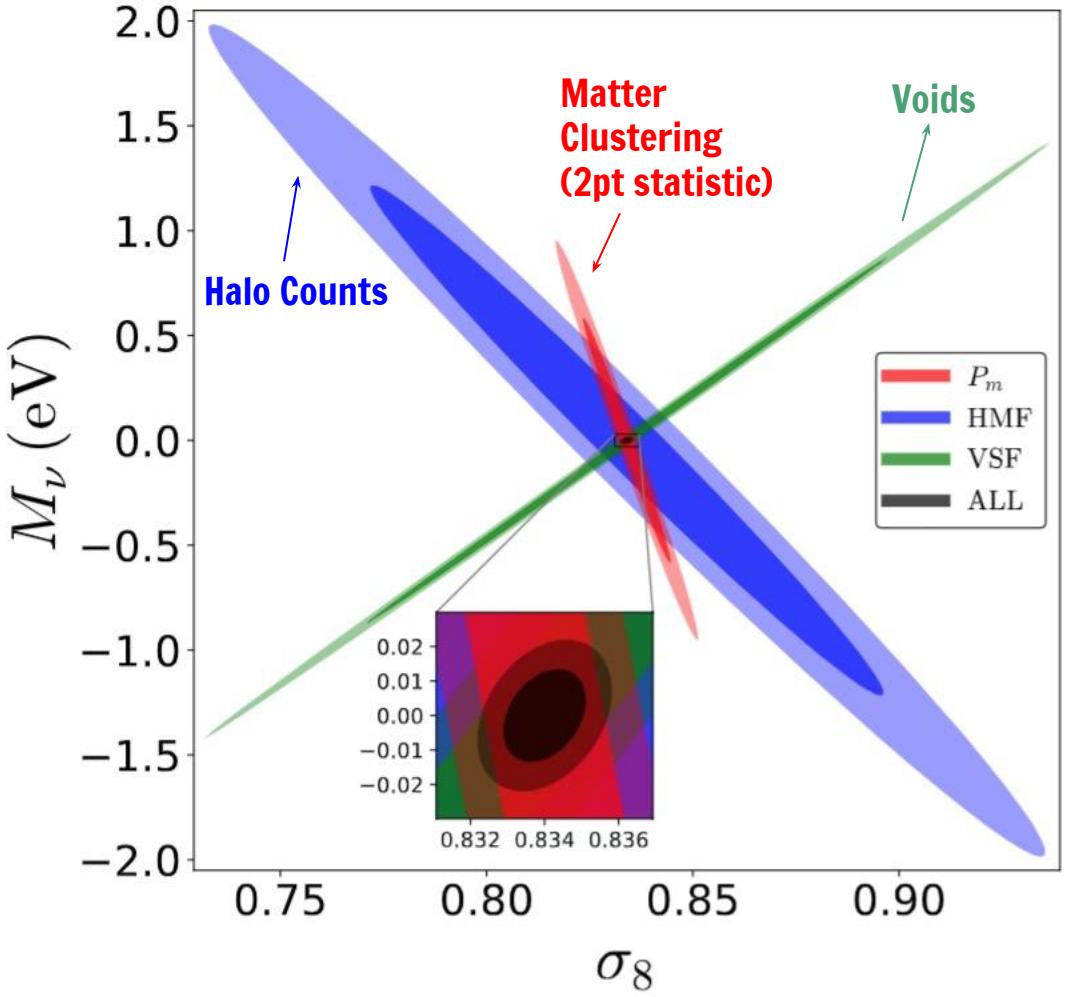




Brinckmann+2019

** assumes minimal 7 parameter LCDM+M_ν model*

Before LiteBIRD: Potential in Beyond-2pt Statistics

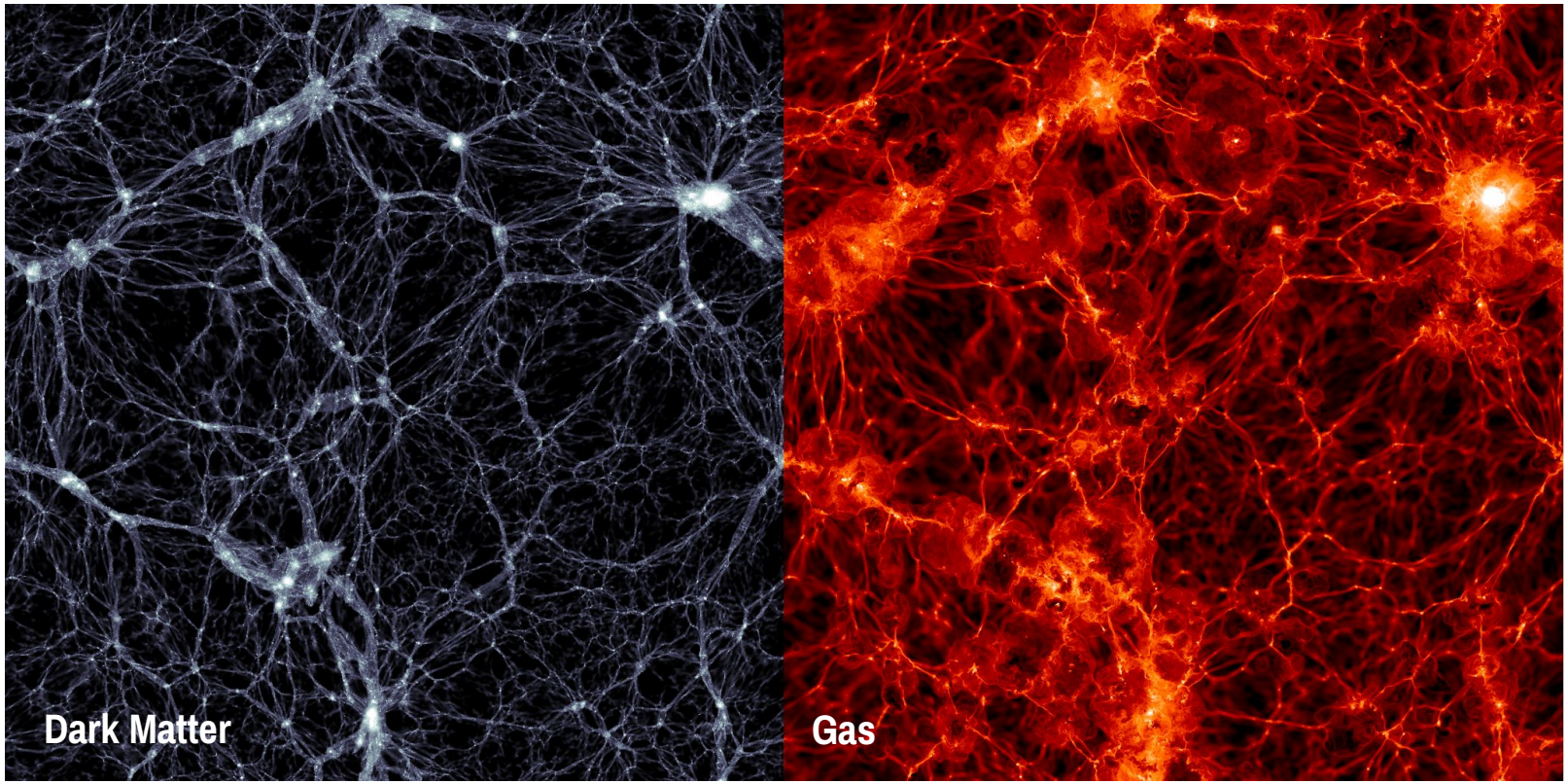


Requires significant improvement in theoretical modeling of nonlinear structure growth with numerical simulations.

Bayer+(JL) 2021

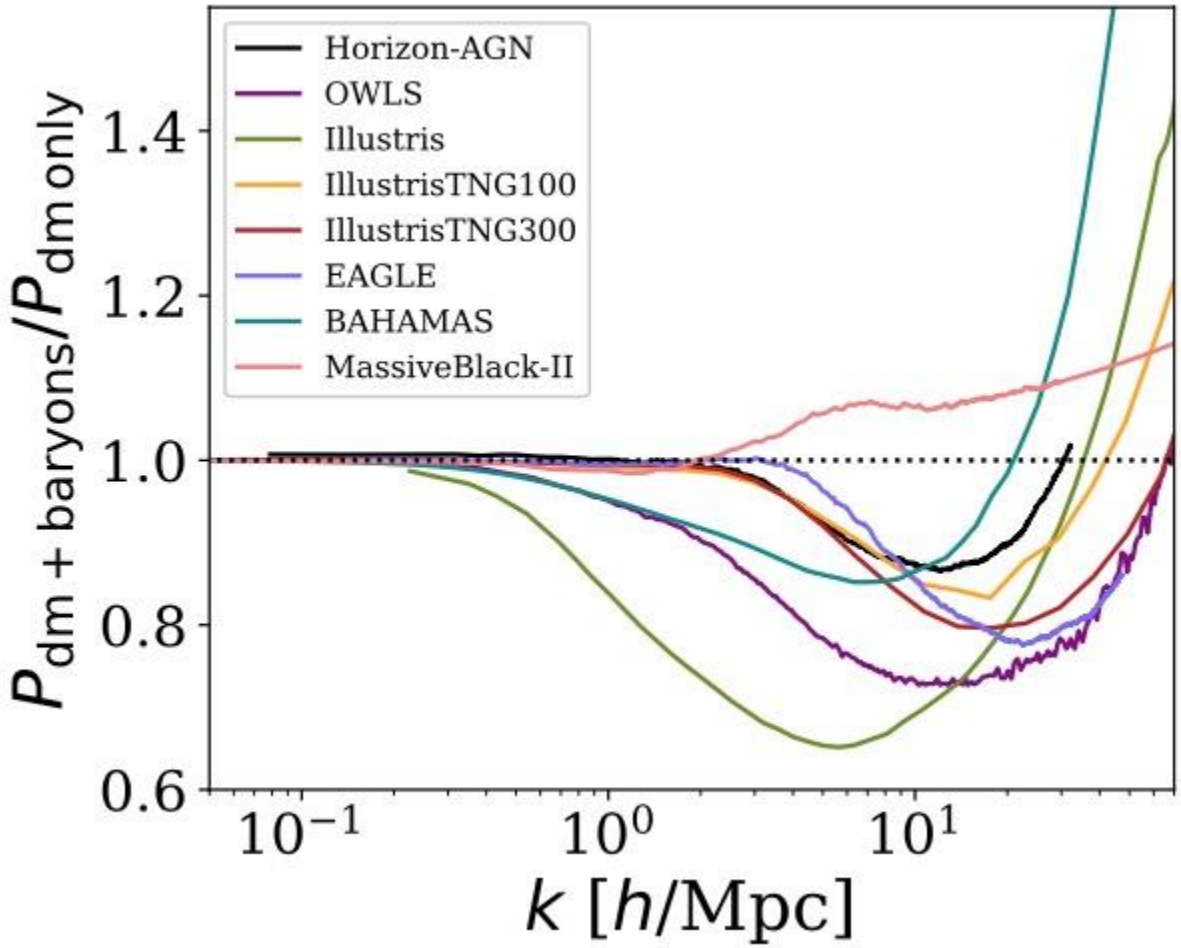
Challenge 2: Baryons

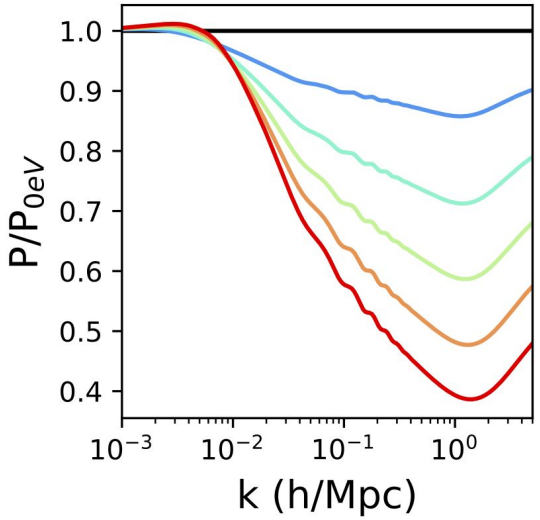
Baryonic Feedback



Illustris Simulation

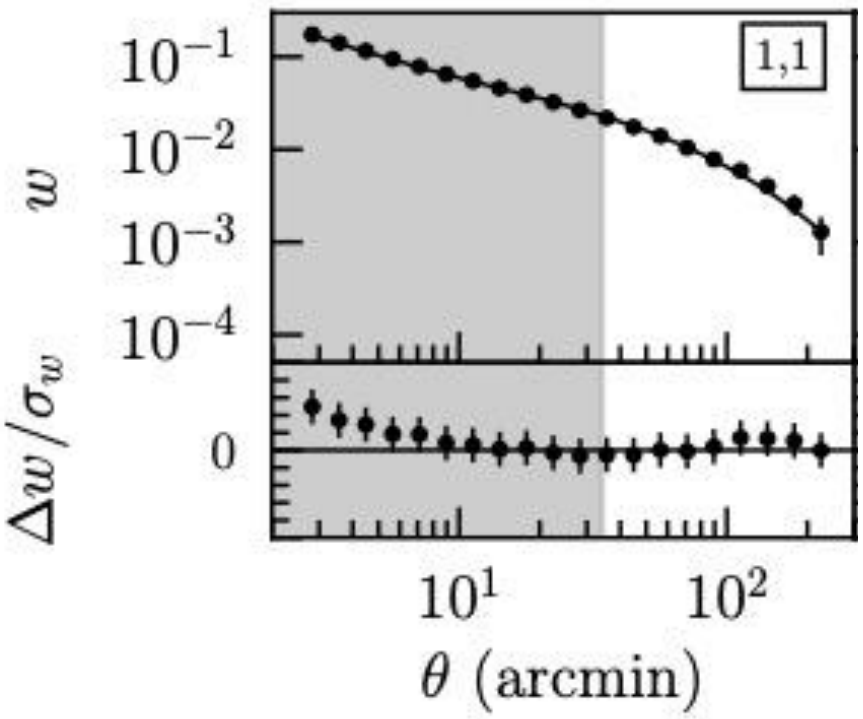
Like neutrinos, baryons also suppress the matter clustering





Chisari+2019

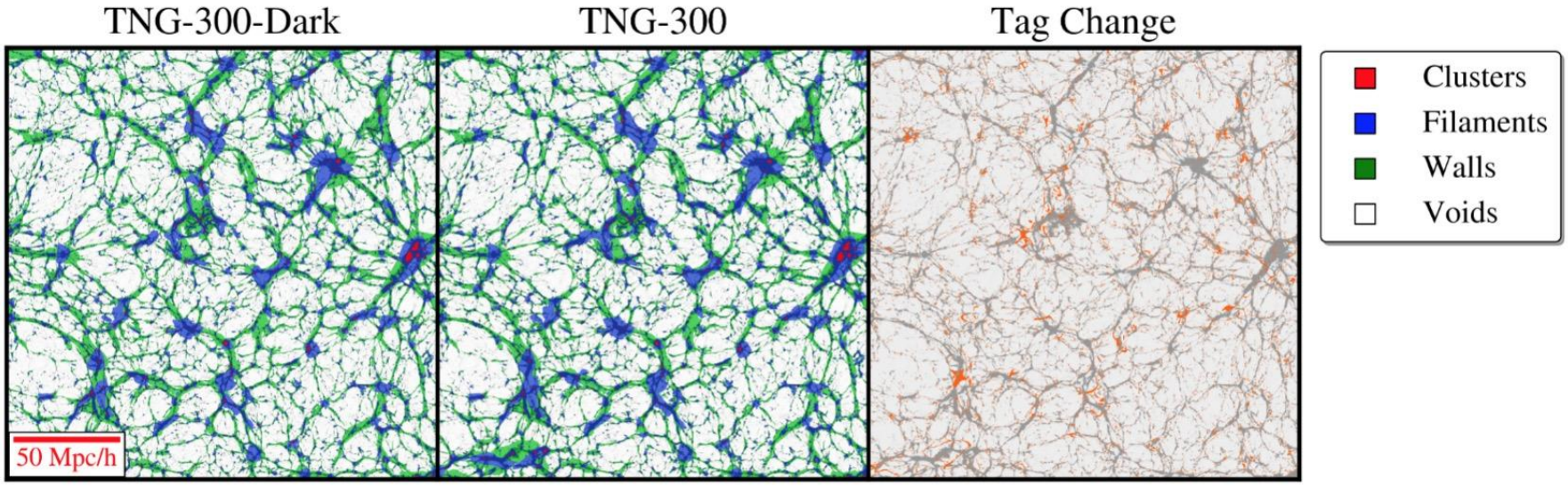
Already, we are limited by baryon models



*The shaded regions indicate scales **not used** in the fiducial analysis, primarily due to uncertainties in the impact of **baryonic effects**.*

Dark Energy Survey Y3 Results (2021)

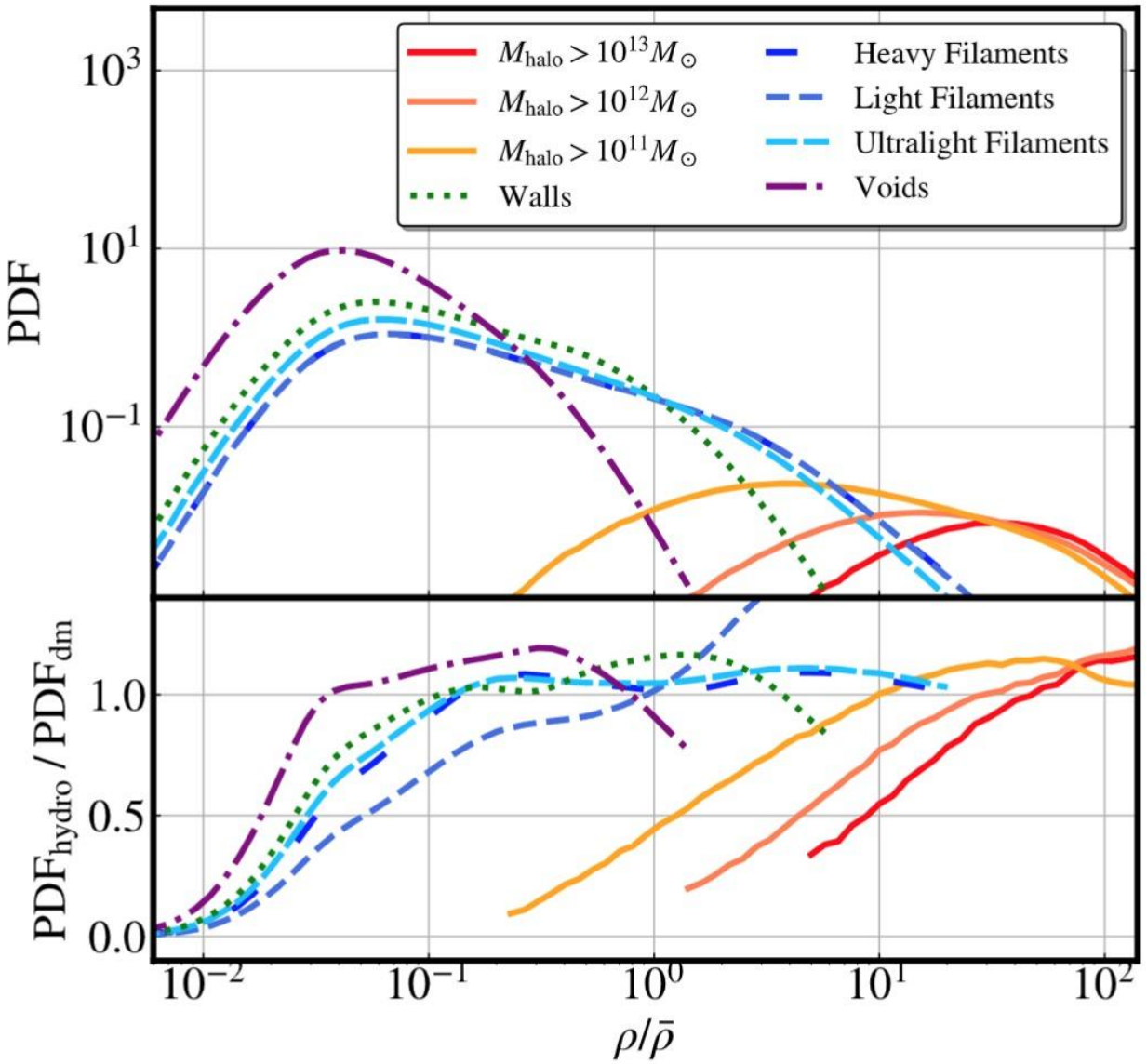
**Angular correlation function of MagLim galaxies*



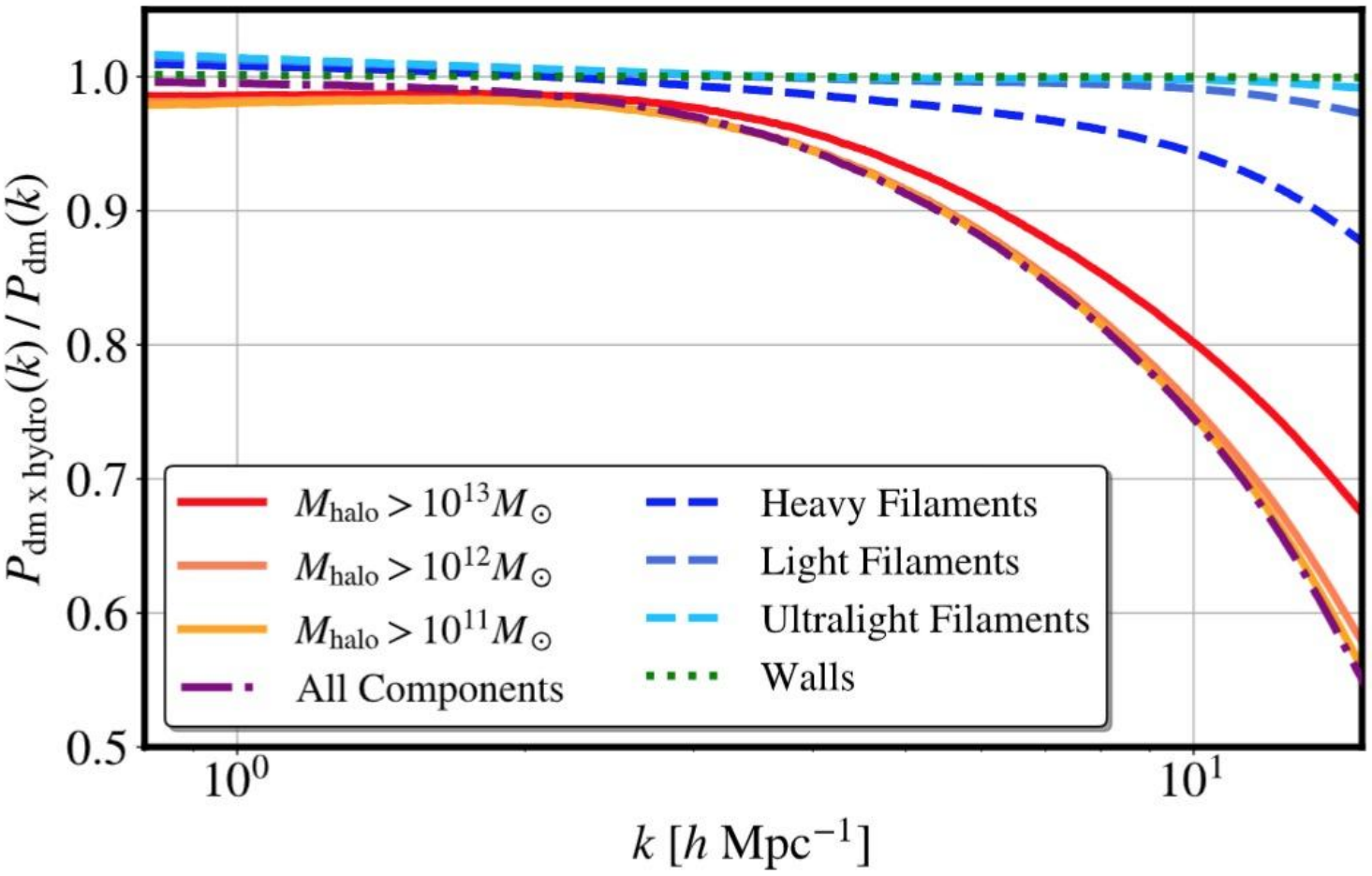
*Current baryon models focus mainly on halos. Here we examine the effect on **filaments, walls, and voids**.*

Sunseri, Li, JL (in prep)
Using the IllustrisTNG simulations

Baryons affects the cosmic web beyond halos



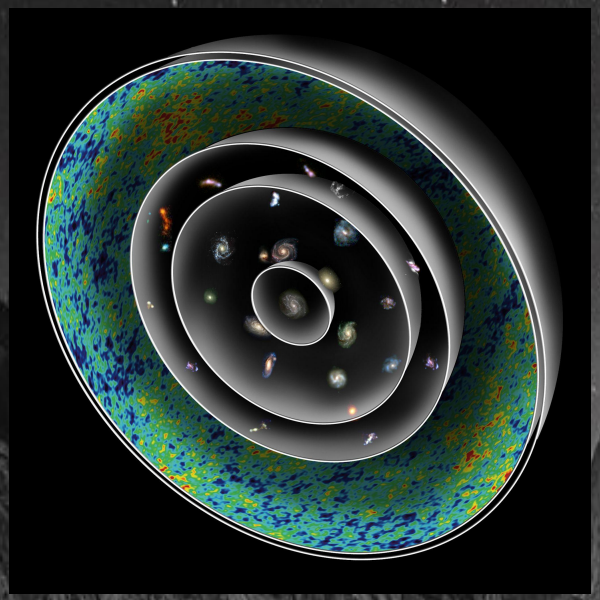
Sunseri, Li, JL (in prep)



Sunseri, Li, JL (in prep)

Challenge 3: Correlated CMB x LSS simulations

The Half Dome Simulation



Quick overview:

f_{sky}	full
M_{min}	10^{12} M_{sun}
Box	5Gpc/h
$N_{Particle}$	8192^3
Release	~mid 2023

Healpix maps of:
tSZ, kSZ,CIB, radio, CMB lensing, shear, galaxies, clusters

N-body
linecones, particles, velocities, halos, lensing

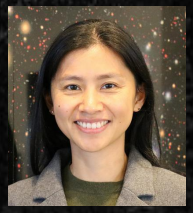
LSS
Shear, clusters, HOD…

CMB
tSZ, kSZ, CIB, Radio…


Yici Zhong


Adrian Bayer


Yu Feng


Jia Liu


Joe DeRose


Zack Li


Giuseppe Puglisi


Mat Madhavacheril


Marcelo Alvarez

Correlated Simulation Challenges

Assuming 1000 simulations*

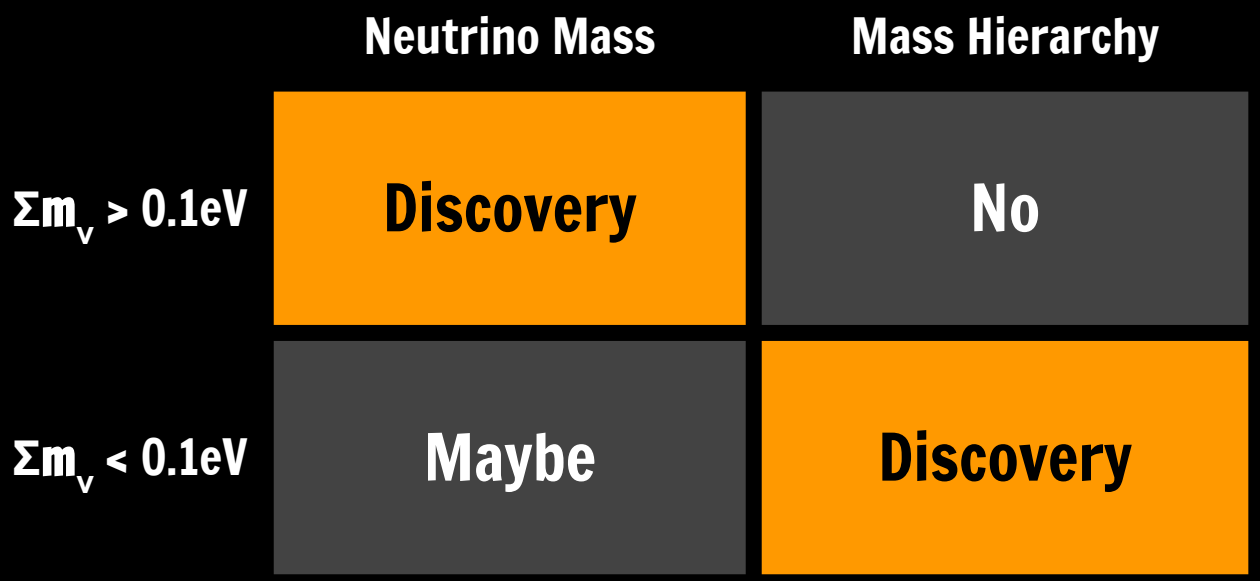
1. **Optical-CMB connections**
   AGN-Radio galaxies; SFR-CIB
   Adding other observables (21cm, LIM, x-ray)?

2. **Computing time: ~half billion CPU hours**
   Large memory need: quarter million cores simultaneously

3. **Storage: ~10-100s PB**
   Raw: 500TB/run; aggressive downsampling needed->100TB per run

4. **Cross-collaboration collaboration**
   Currently operate as a lose collaboration between people who are deeply embeded in DESI/LSST/SO/S4
   Future access to multiple surveys' internal pipelines & proprietary data for future upgrades: N^2 MOUs??
   Training and acknowledging simulation scientists

* A very conservative assumption..
Also see "Report from the Tri-Agency Cosmological Simulation Task Force" by Battaglia+2020



[SUMMARY]

(Almost guaranteed) discovery of neutrino mass or hierarchy in 10 years

- New potential in the nonlinear regime, before LiteBIRD's tau (10 yrs)
- Baryon models need to be improved beyond halos and 2pt
- Correlated simulations face computational challenges (also opportunities!)