

Degeneracy Breaking with CMB+LSS

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Cosmology with CMB-S4 / Future Cosmic Surveys

Chicago, IL

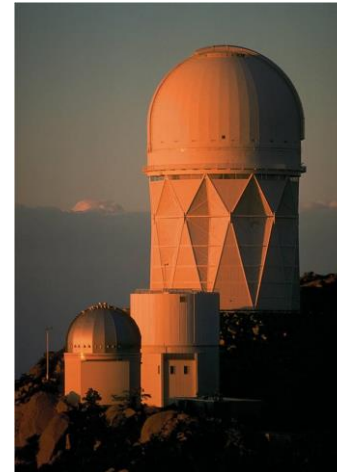
September 21, 2016

Forthcoming Data

CMB

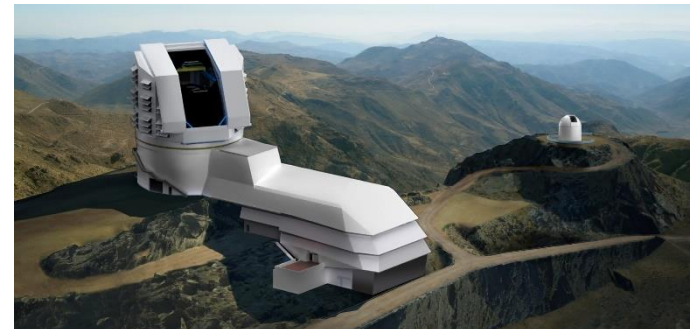


LSS

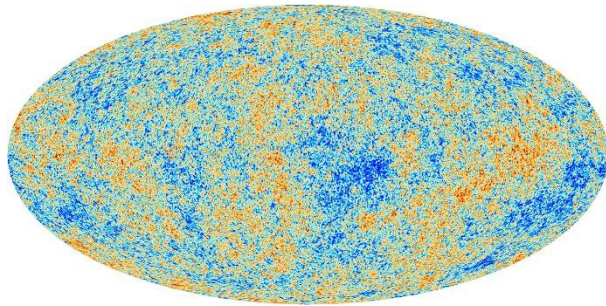


SIMONS OBSERVATORY

CMB-S4
Next Generation CMB Experiment

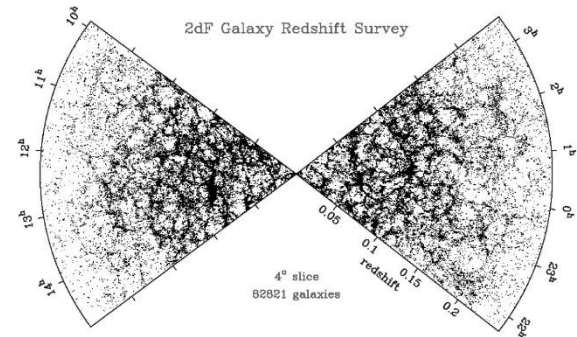


CMB and LSS Probe Different Physics



CMB

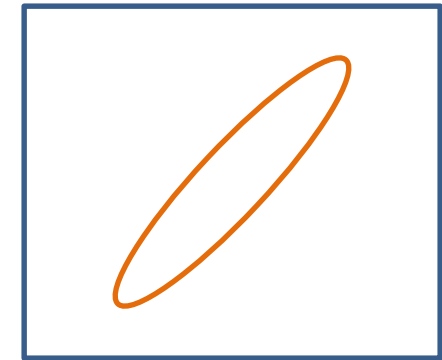
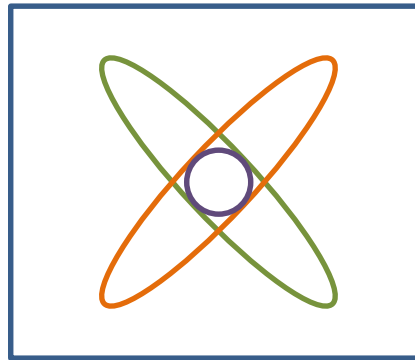
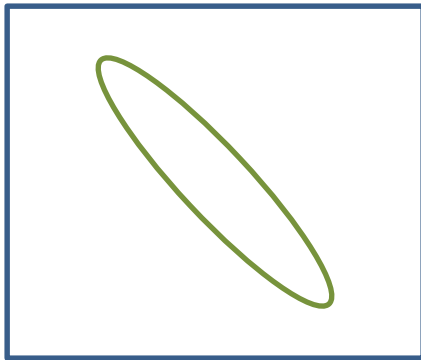
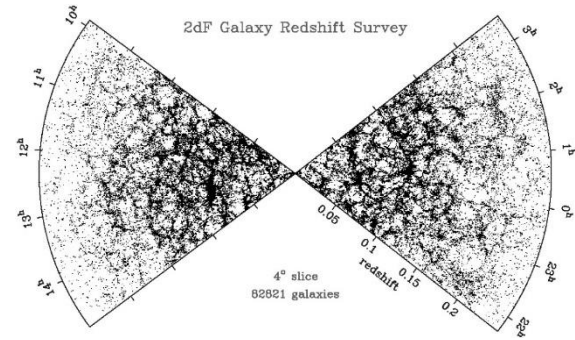
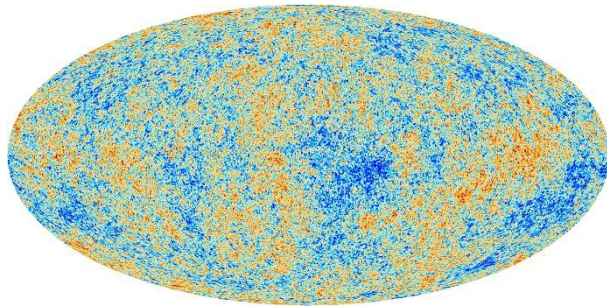
- 2d screen at $z=1100$
- Lensing at $z=2$
- Decoupling physics
- Probes larger scales



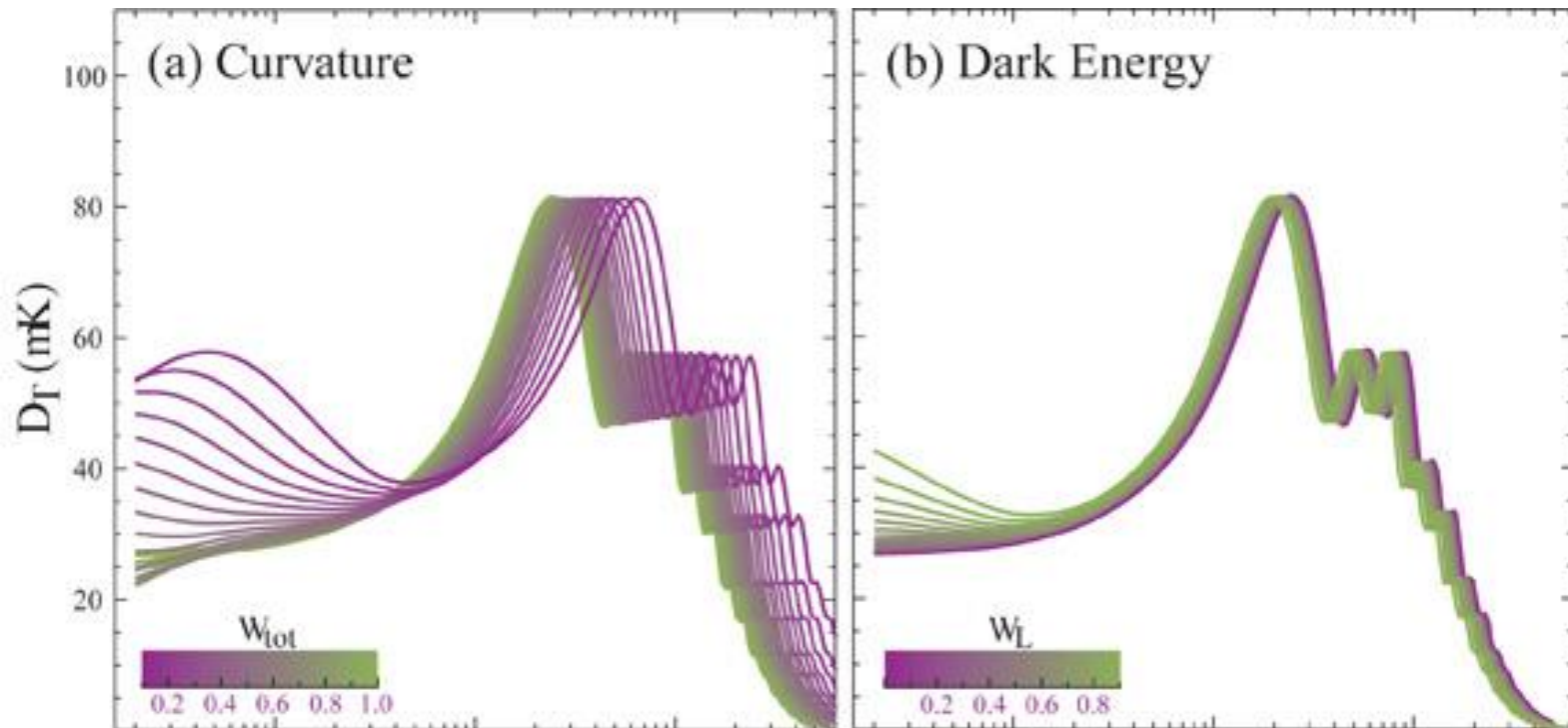
LSS

- 3d volume at low z
- Many redshift slices
- Traces matter
- Probes smaller scales

Degeneracy Breaking

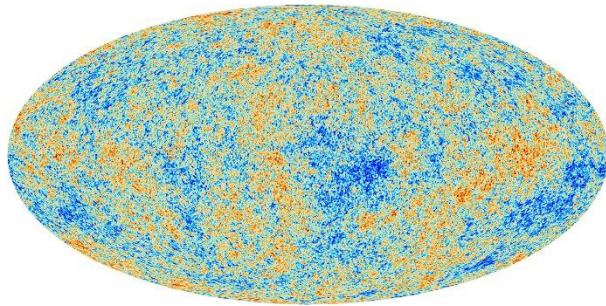


Past Example: Geometric Degeneracy



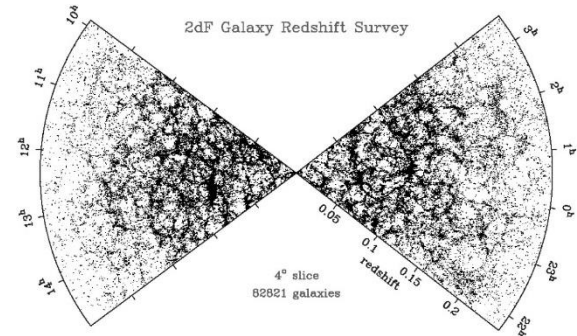
- There exists a well known degeneracy in the primary CMB between curvature and dark energy, since both parameters affect peak positions

Breaking Geometric Degeneracy



CMB

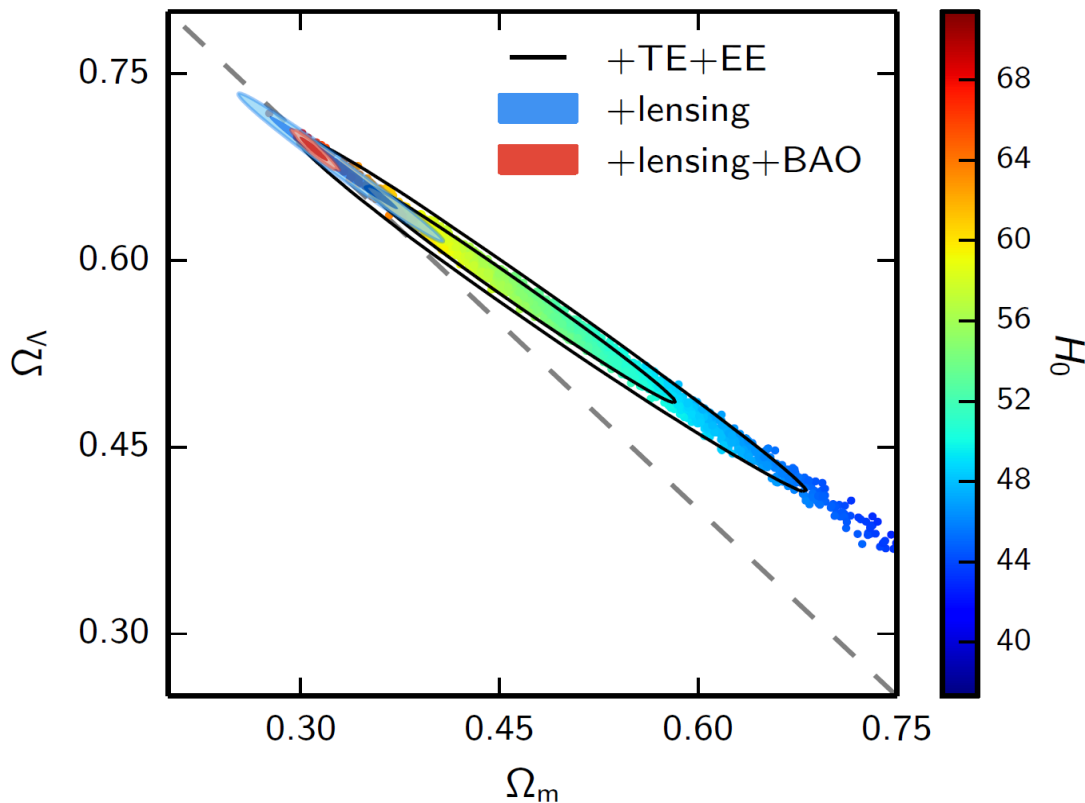
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Curvature and Dark Energy Constraints



- CMB lensing partially breaks the degeneracy since it probes low redshift matter density
- Adding expansion history information from structure measurements strongly breaks the geometric degeneracy

Current Example: Neutrino Mass

- Massive neutrinos are non-relativistic at late times and contribute to the matter power spectrum
- On small scales, neutrinos free stream out of potential wells and suppress the growth of structure
- Small scale matter power is affected by neutrino mass and total matter density

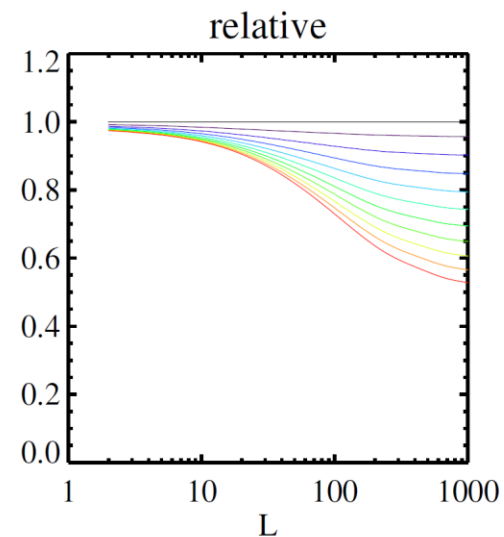
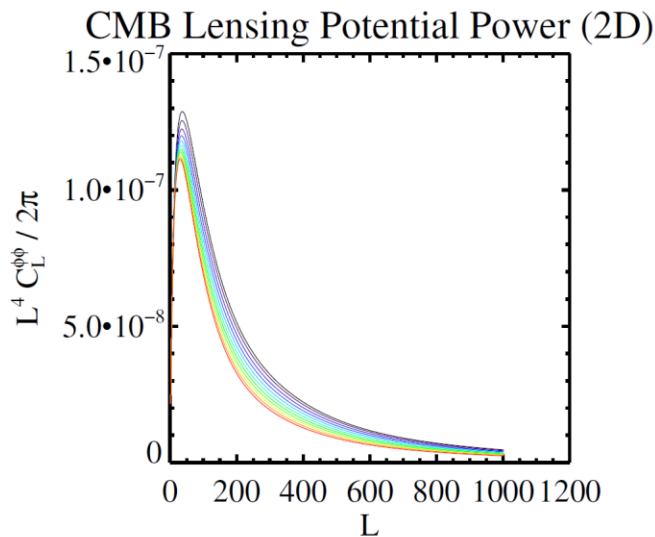
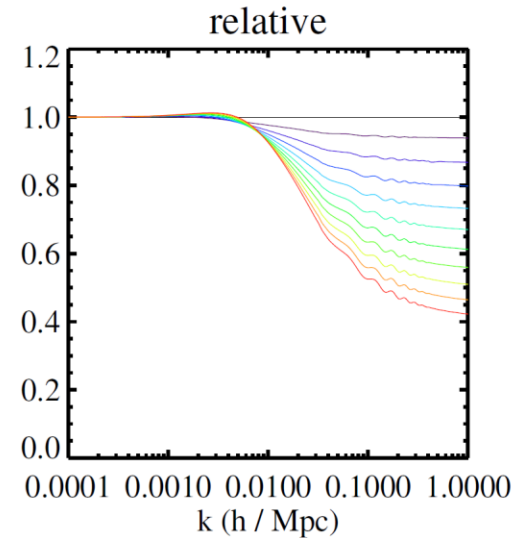
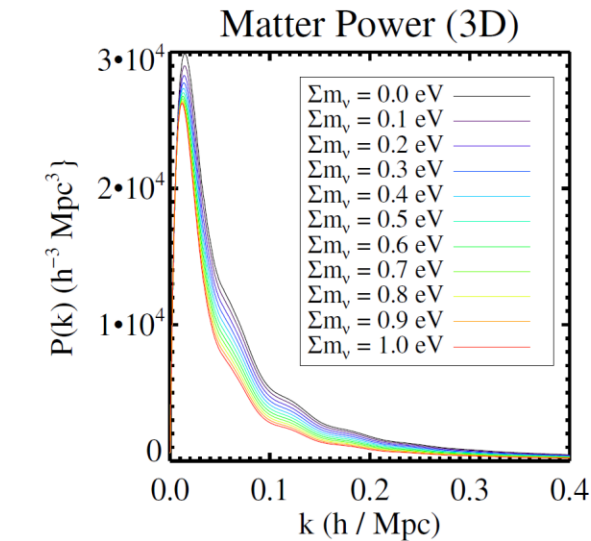
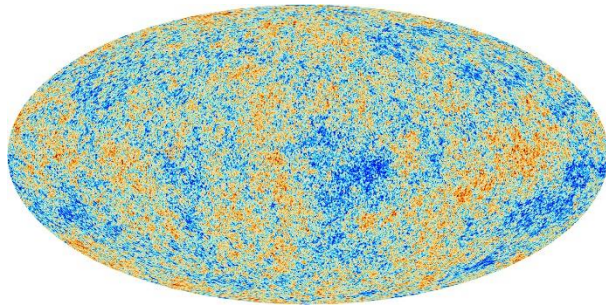


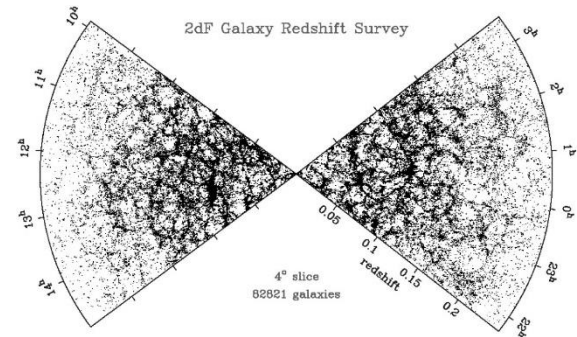
Figure Credit: Alex van Engelen

Breaking Neutrino Mass Degeneracy



CMB

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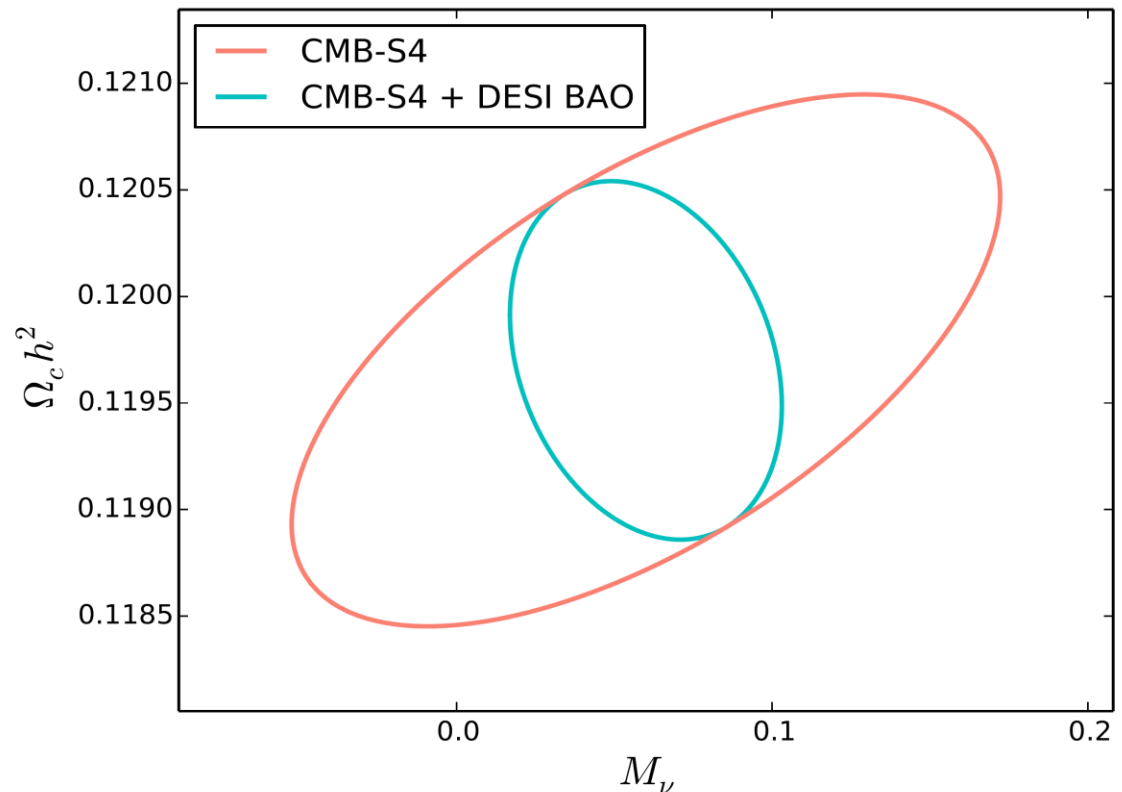


LSS

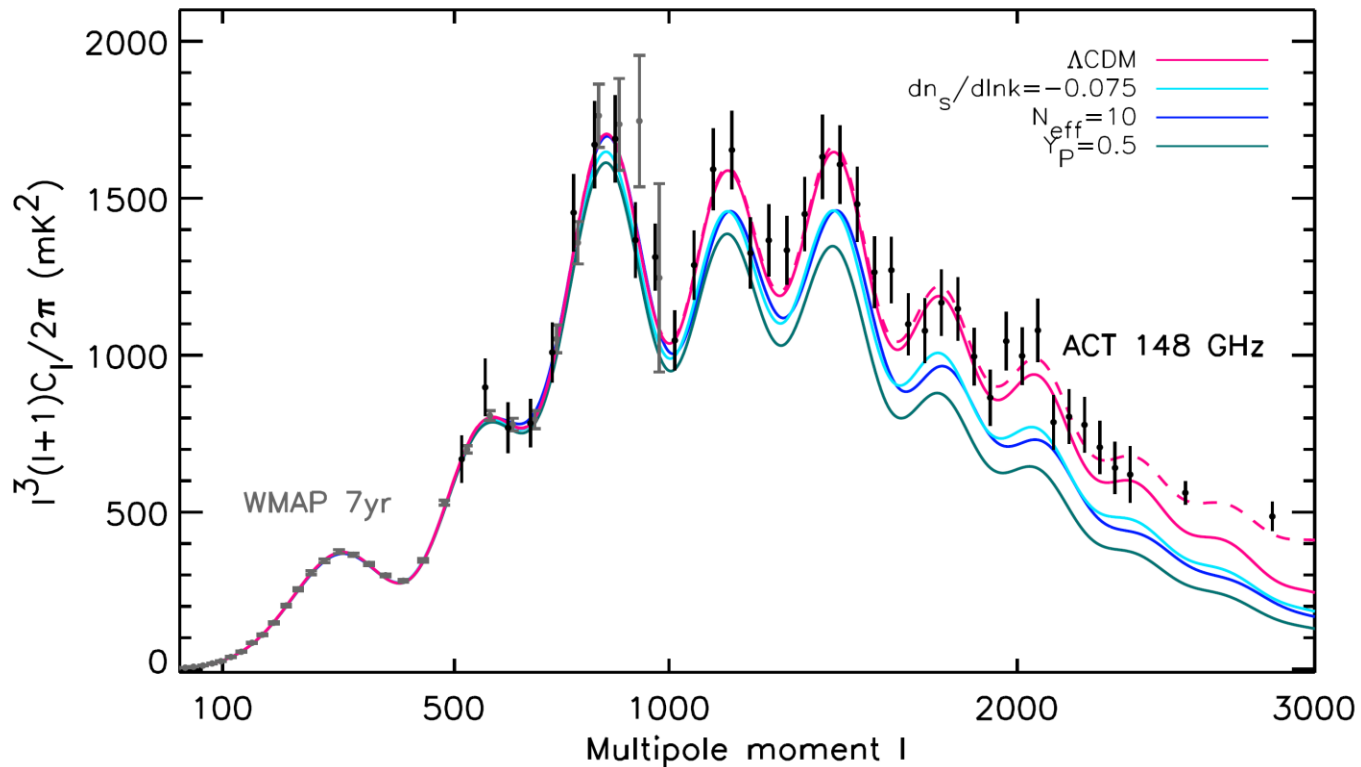
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Neutrino Mass and Expansion History

- Expansion history information precisely determines the total matter density, which impacts the amplitude of the matter power spectrum
- CMB measurements determine the amplitude of fluctuations on large scales (especially if τ is accurately measured)

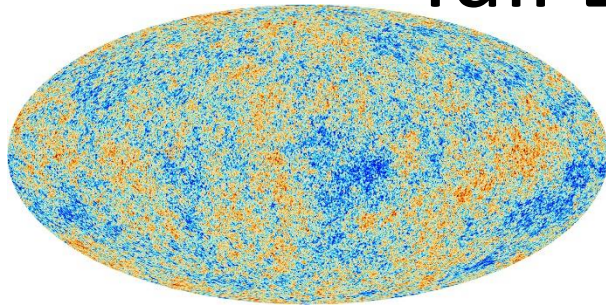


Future Example: Damping Tail and Scale Dependence



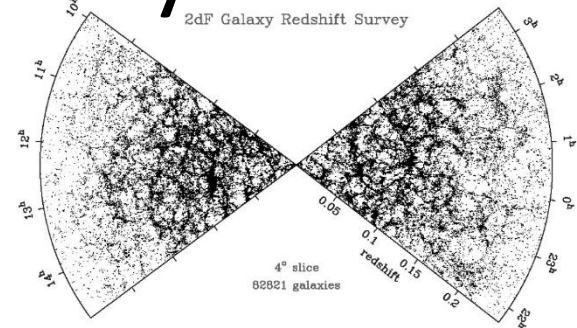
- Changes to the shape of the primordial power spectrum and to quantities which affect the damping tail have similar effects on the primary CMB

Breaking Scale Dependence/Damping Tail Degeneracy



CMB

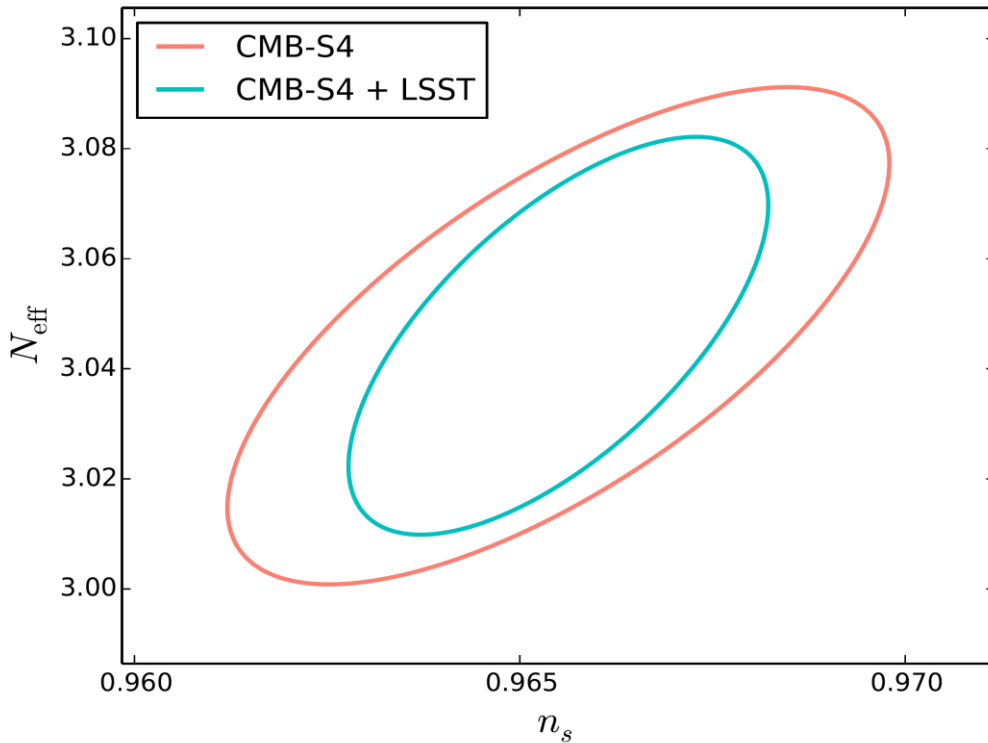
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N_{eff} and n_s Constraints



- Combining CMB and LSS extends the lever arm and better constrains the primordial power spectrum
- Damping tail physics affects the CMB but not LSS, and can therefore be distinguished

Conclusions

- A wealth of CMB and LSS data is forthcoming
- These probes are sensitive to different physics, which can be leveraged to break degeneracies that exist for either in isolation
- New and interesting parameters which are degeneracy-limited in CMB or LSS alone may not be so when datasets are combined
- Creative exploration of parameter space may yield surprisingly good constraints in combined datasets

