Deconstructing M_ν Constraints from Galaxy Clustering and CMB Lensing

Aoife Boyle (IAP)

Collaborators: Eiichiro Komatsu, Fabian Schmidt (MPA)

arXiv: 1811.07636, 1712.01857

Motivation

- How do different cosmological probes contribute to constraints?
- What are the most significant cosmological degeneracies?
- How sensitive are constraints from different probes to the assumed cosmology?

BAOs, RSDs, the shape of $P(k)$, CMB lensing…

$\tau - M_\nu$ degeneracy

Varying Ω_k, w_0, w_a

Extending to NLO

Desjacques, Jeong & Schmidt, 2018
(1806.04015)

$$\delta_g(x,\tau) = \sum b_O(\tau) O(x,\tau) + \epsilon$$

Local bias expansion: $\boldsymbol{b_1}\delta + \frac{1}{2}\boldsymbol{b_2}\delta^2 + \ldots$

Higher derivative bias: $\boldsymbol{b_{\nabla^2\delta}}\nabla^2\delta$

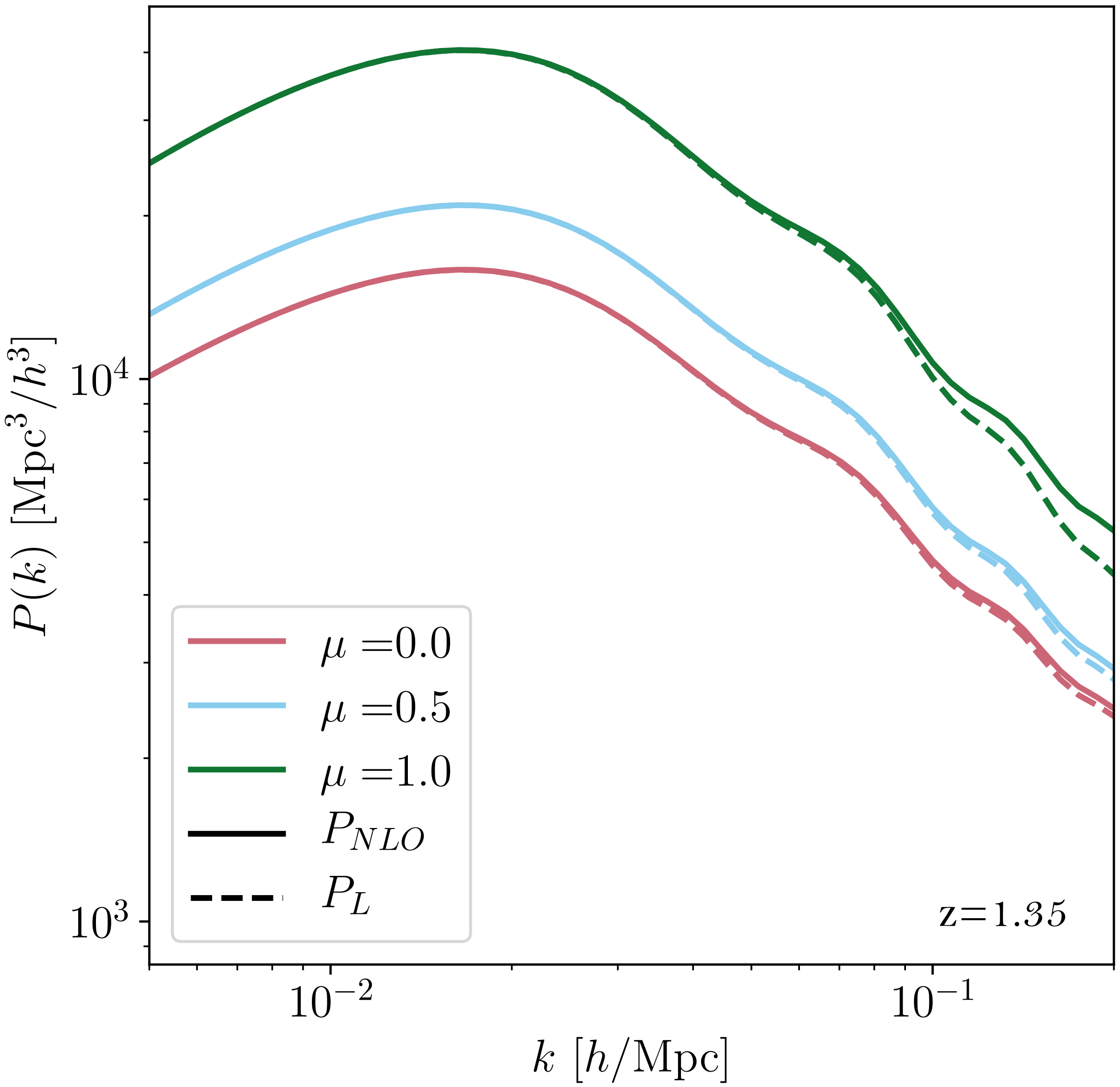
Tidal bias: $\boldsymbol{b_{K^2}}K^2 \rightarrow K^2 = K_{ij}K^{ij}$

$$\boldsymbol{b_{td}}O_{td} \rightarrow O_{td} = \frac{8}{21}K_{ij}D^{ij}\left(\delta_m^2 - \frac{3}{2}K^2\right)$$

Velocity bias: $\boldsymbol{b_{\nabla^2 v}}\nabla^2 v$

Stochastic parameters: $\boldsymbol{P_{\epsilon}^{\{0\}}}, \boldsymbol{P_{\epsilon}^{\{2\}}}, \boldsymbol{P_{\epsilon\varepsilon_\eta}^{\{2\}}}$

Many of these parameters change the galaxy power spectrum in a scale-dependent way.

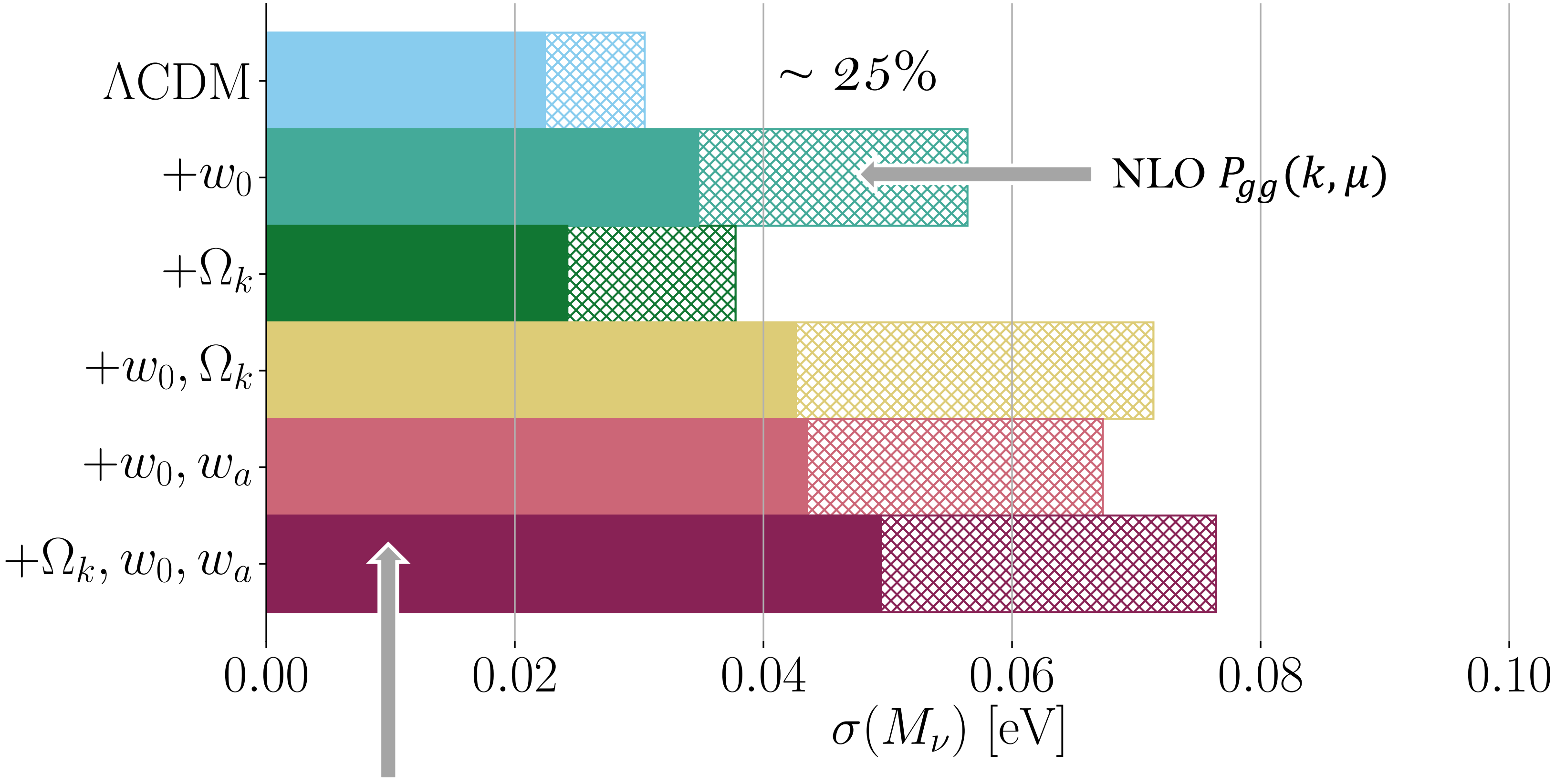


Calculation Details

- Fisher matrix with $k_{\mathrm{max}} = 0.2$ h/Mpc.
- Forecasts for Euclid spectroscopic survey and Simons Observatory.
- Start with Planck TT, Simons Observatory EE/TE, $\sigma(\tau)$=0.008.
- Free parameters:
  - $\omega_b, \omega_c, A_s, n_s, \theta_s, \tau$
  - M_ν, N_{eff}
  - $(+\Omega_k, w_0, w_a)$

Full Power Spectrum Constraints

Planck TT, Simons Observatory EE/TE, $\sigma(\tau) = 0.008$, Euclid $P_{gg}(k,\mu) \rightarrow 0.2\ h/\mathrm{Mpc}$.



NLO $P_{gg}(k,\mu)$

Linear $P_{gg}(k,\mu)$

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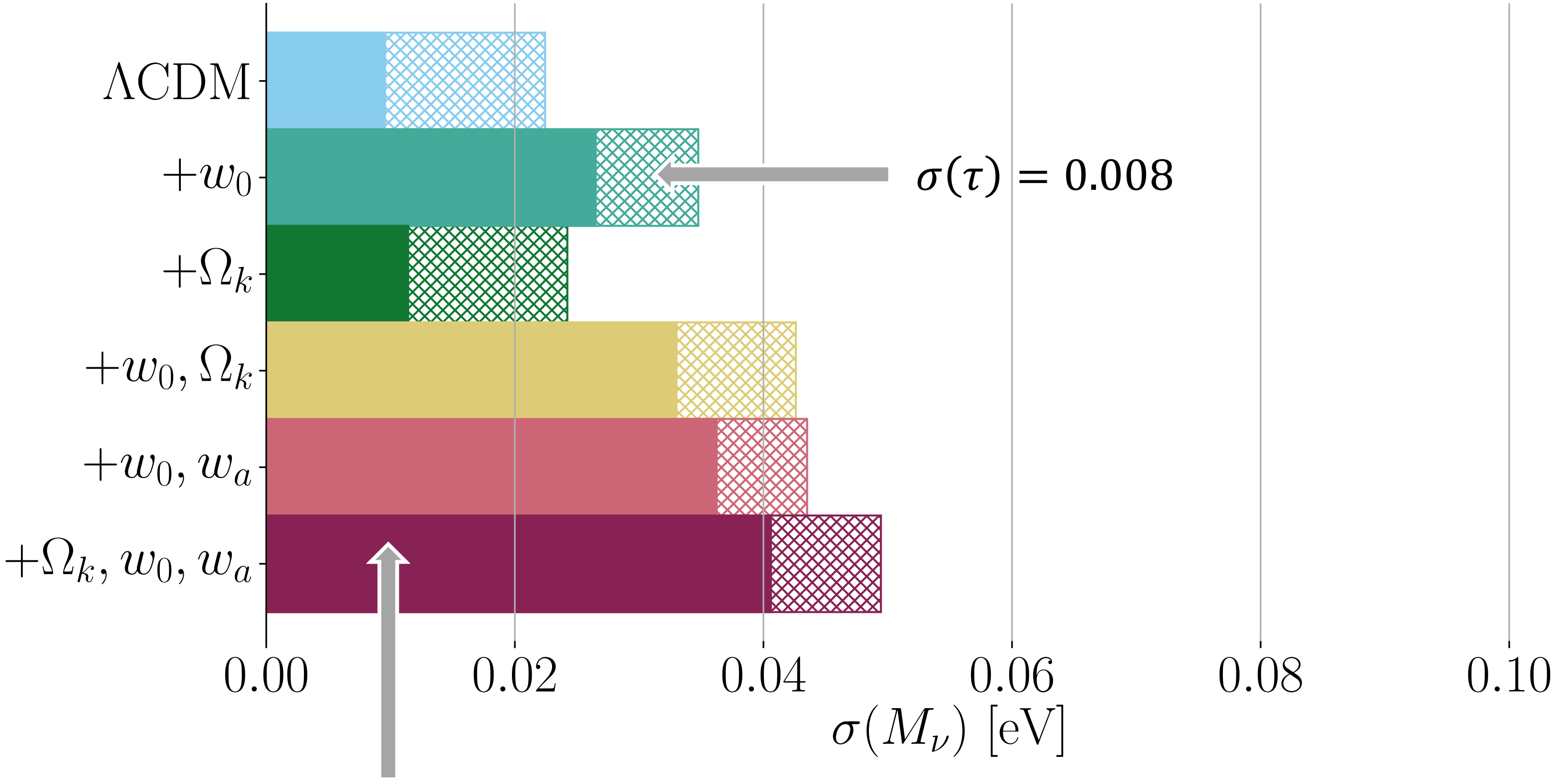
$M_\nu - \tau$ Degeneracy (Linear Case)

Planck TT, Simons Observatory EE/TE, $\sigma(\tau) = 0.008$/Fixed, Euclid $P_{gg}(k, \mu) \rightarrow 0.2\ h$/Mpc.



$\sigma(\tau) = 0.008$

τ fixed

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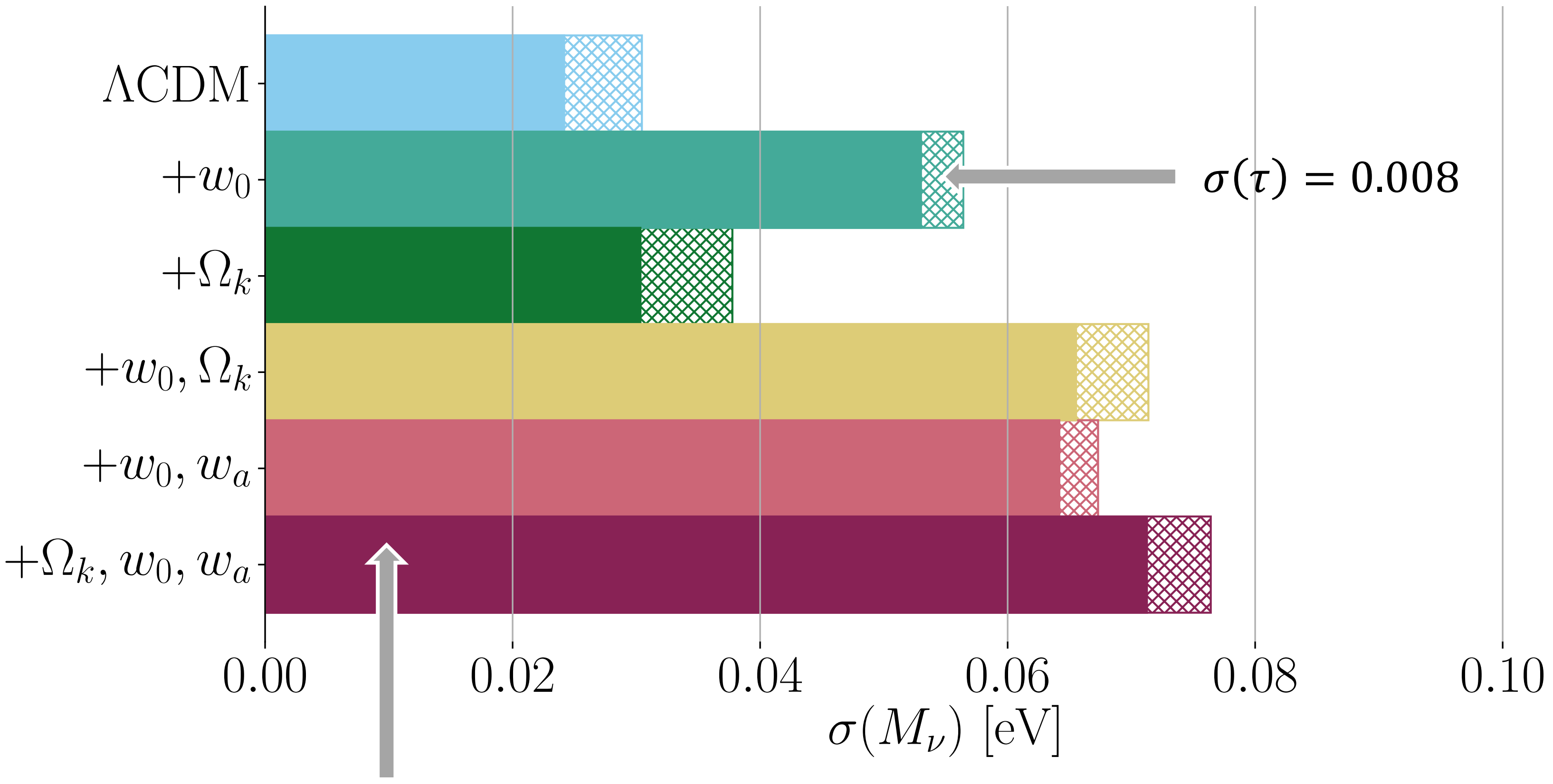
$M_\nu - \tau$ Degeneracy (NLO Case)

Planck TT, Simons Observatory EE/TE, $\sigma(\tau) = 0.008$/Fixed, Euclid $P_{gg}(k, \mu) \rightarrow 0.2\ h$/Mpc.



$\sigma(\tau) = 0.008$

τ fixed

Degeneracies with New Parameters

- The bias and stochastic parameters are primarily *all somewhat degenerate with each other*.
- Adding priors on any particular one does not significantly improve constraints on the neutrino mass.

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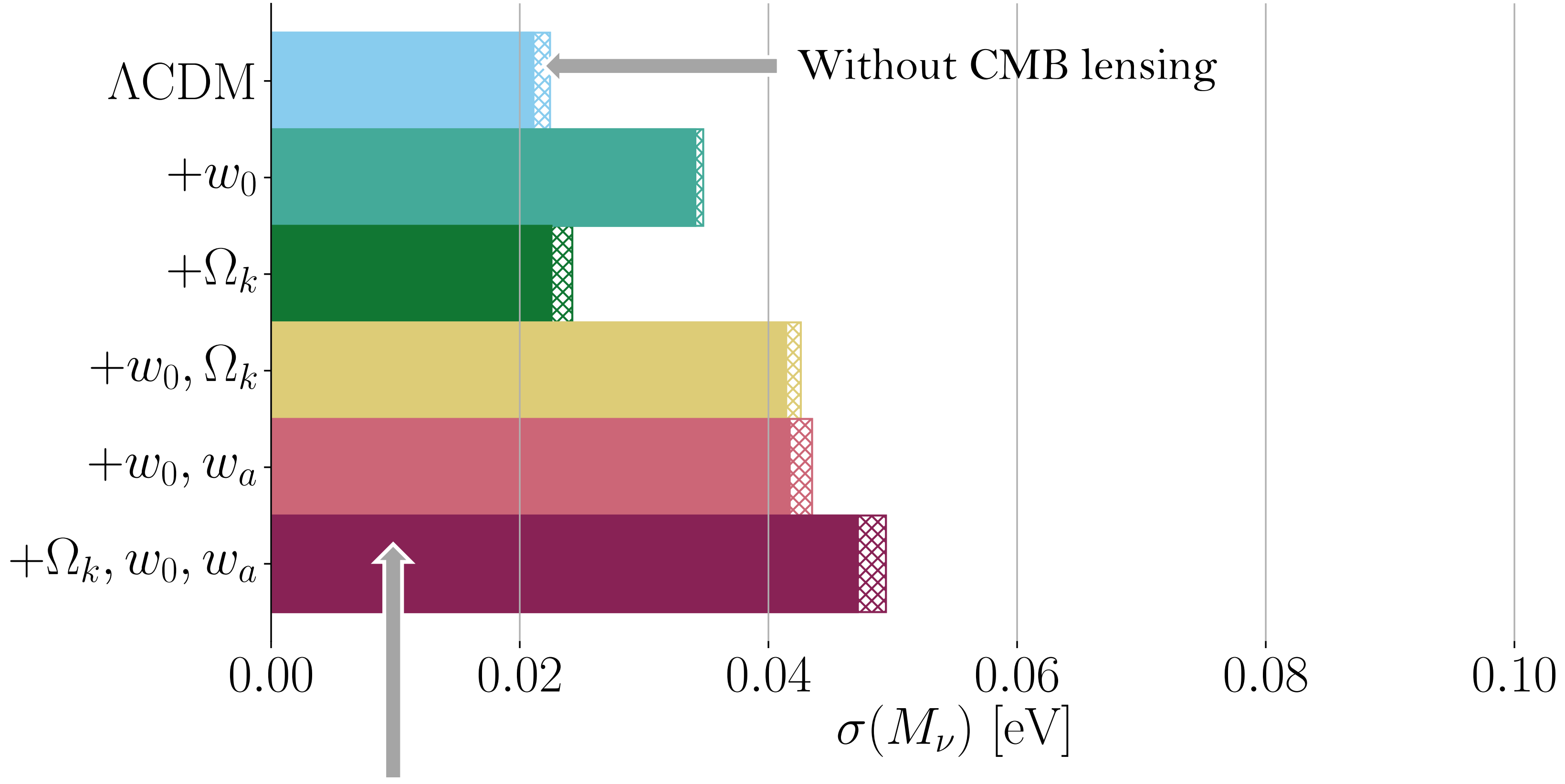
CMB Lensing (Linear Case)

Planck TT, Simons Observatory EE/TE, $\sigma(\tau) = 0.008$, Euclid $P_{gg}(k, \mu) \rightarrow 0.2\ h/\mathrm{Mpc}$, Simons Observatory CMB Lensing

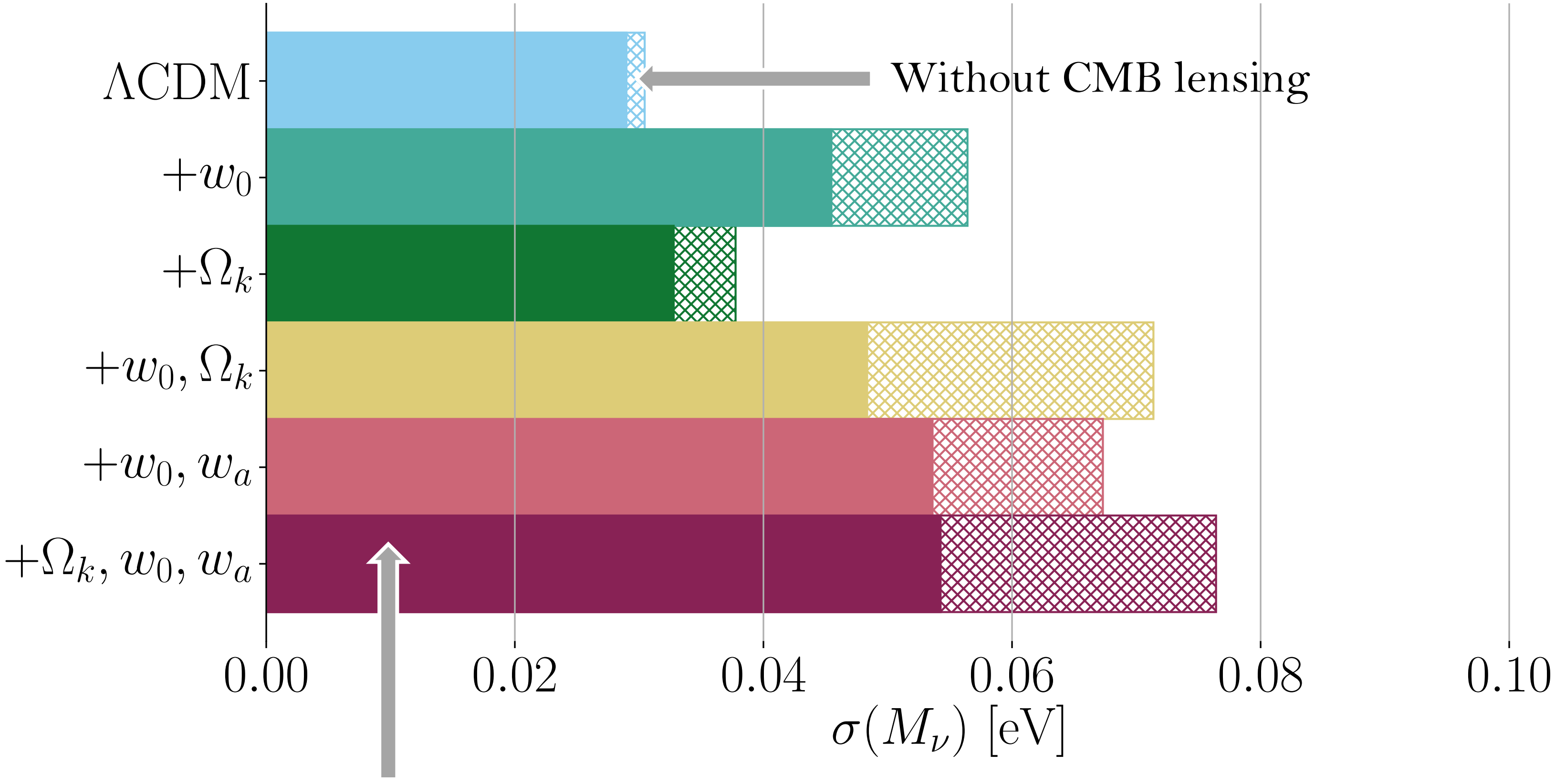


Without CMB lensing

With CMB Lensing

CMB Lensing (NLO Case)

Planck TT, Simons Observatory EE/TE, $\sigma(\tau) = 0.008$, Euclid $P_{gg}(k,\mu) \rightarrow 0.2\ h/\mathrm{Mpc}$, Simons Observatory CMB Lensing



Without CMB lensing

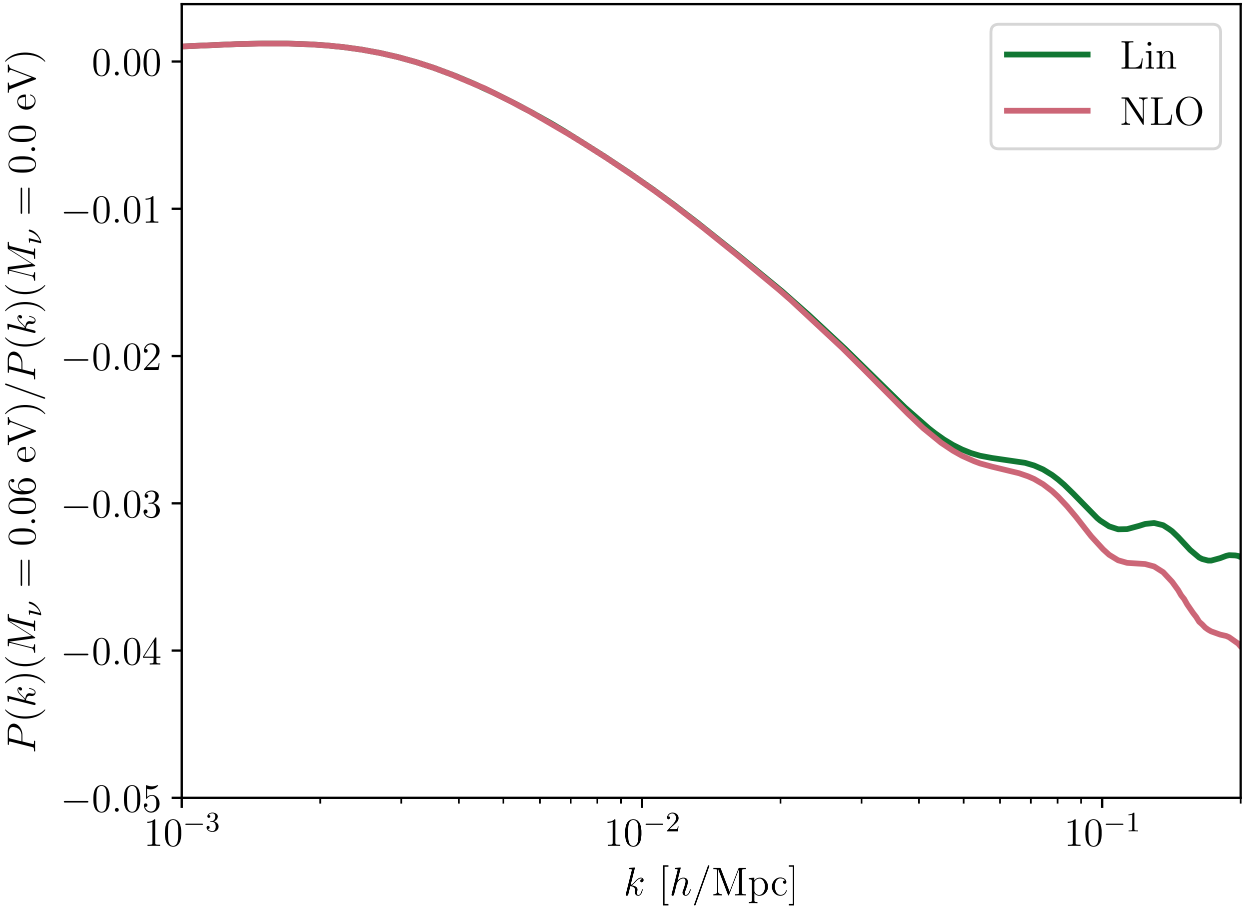
With CMB Lensing

Cosmology-Independent Constraints

- Isolating the relative suppression in the power spectrum caused by massive neutrinos provides a cosmology-independent measurement of M_ν.
- This suppression is actually enhanced in the NLO case.

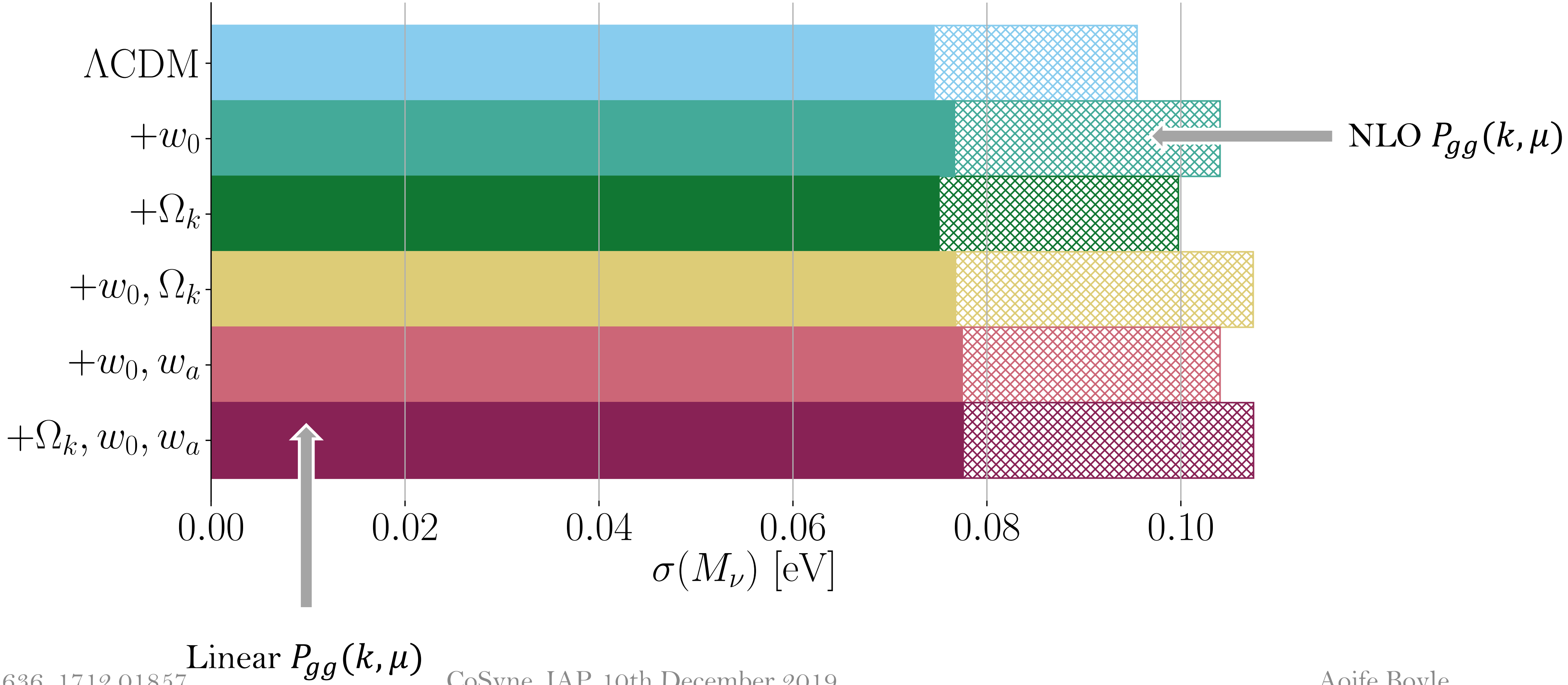
Method:

  - $P_m(k) = P_1.P_2(k)$
  - Calculate $\partial P_{gg}(k,\mu)/\partial\theta$ holding P_1 fixed and varying only $P_2(k)$.
  - Smooth out BAO wiggles.
  - Marginalise over P_1.



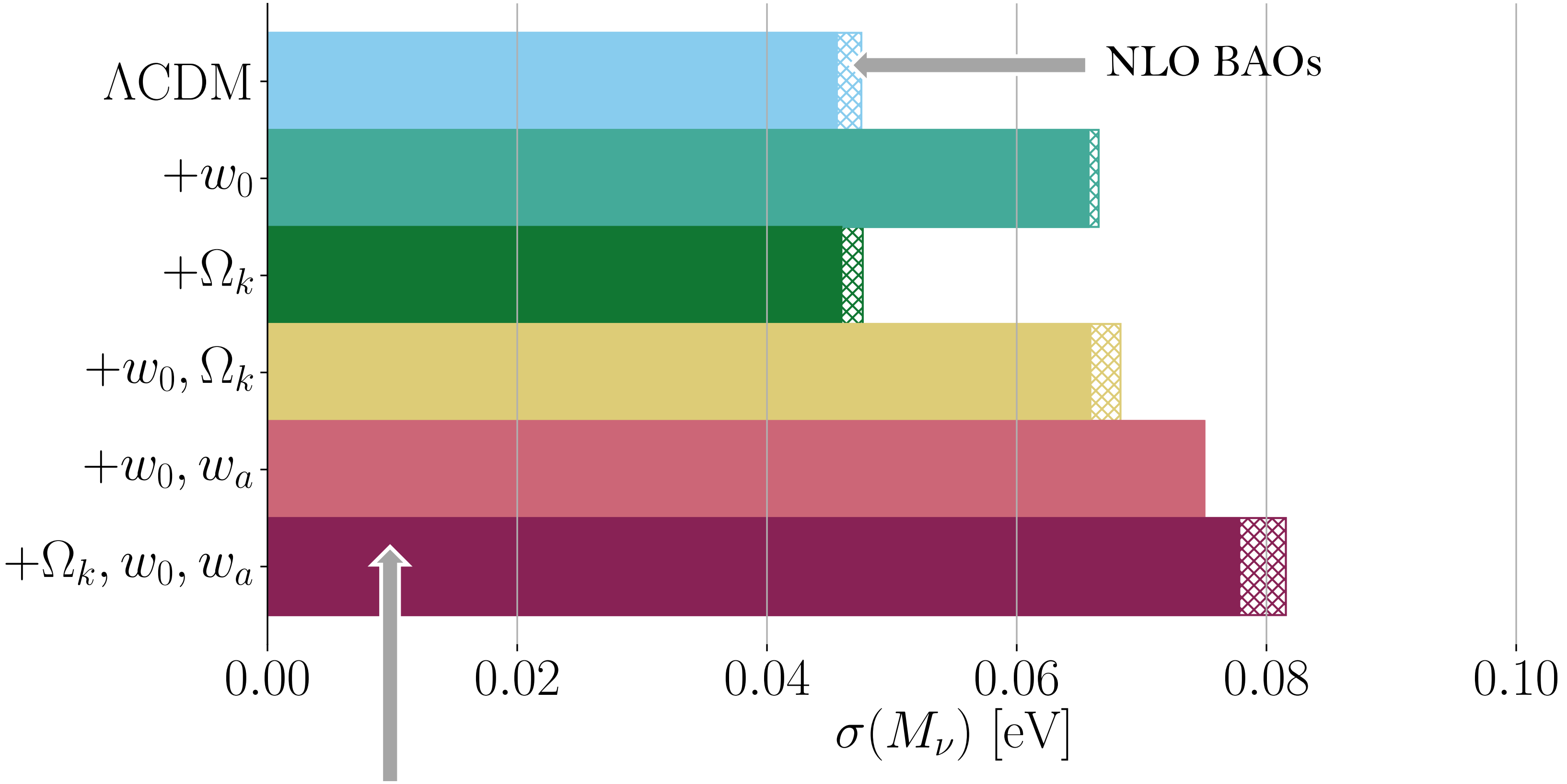
Cosmology-Independent Constraints

Planck TT, Simons Observatory EE/TE, $\sigma(\tau) = 0.008$, Euclid P_{gg} (shape only) → 0.2 h/Mpc, Simons Observatory CMB Lensing (shape only)



BAO-Only Constraints

Planck TT, Simons Observatory EE/TE, $\sigma(\tau) = 0.008$, Euclid BAOs → 0.2 h/Mpc, Simons Observatory CMB Lensing



Linear BAOs

Conclusions

Considering the 1-loop power spectrum has a significant qualitative and quantitative impact on neutrino mass constraints.

- 7 new free parameters → full combined constraints degrade by 25 – 40 %, cosmology-independent free-streaming constraints degrade by 20 %, BAO-only constraints barely change. **Realistic constraints, even up to k=0.2 h/Mpc, should include these parameters.**
- τ is less important than previously thought.
- CMB lensing becomes less irrelevant.
- Free-streaming constraints remain cosmology-independent, though weaker.

Neutrino mass constraints (apart from the free-streaming only constraints we developed) are strongly cosmology dependent.