Cosmological constraints on neutrino properties with *Euclid* in beyond ΛCDM models

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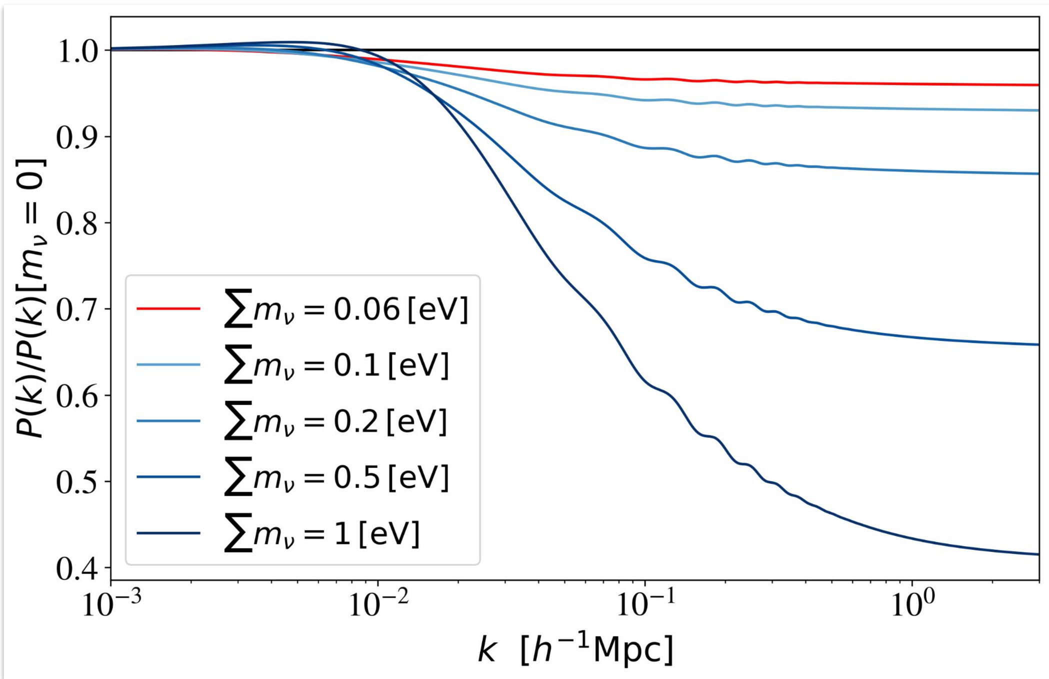
Neutrinos in Cosmology

- Neutrinos influence a wide variety of phenomena from the early stages of the Universe to recent epochs: they affect the expansion rate of the Universe and shape the large-scale structure (LSS).
- Suppression of the matter power spectrum on small scales due to neutrino masses in the standard ΛCDM cosmological model.



Neutrinos and Gravity

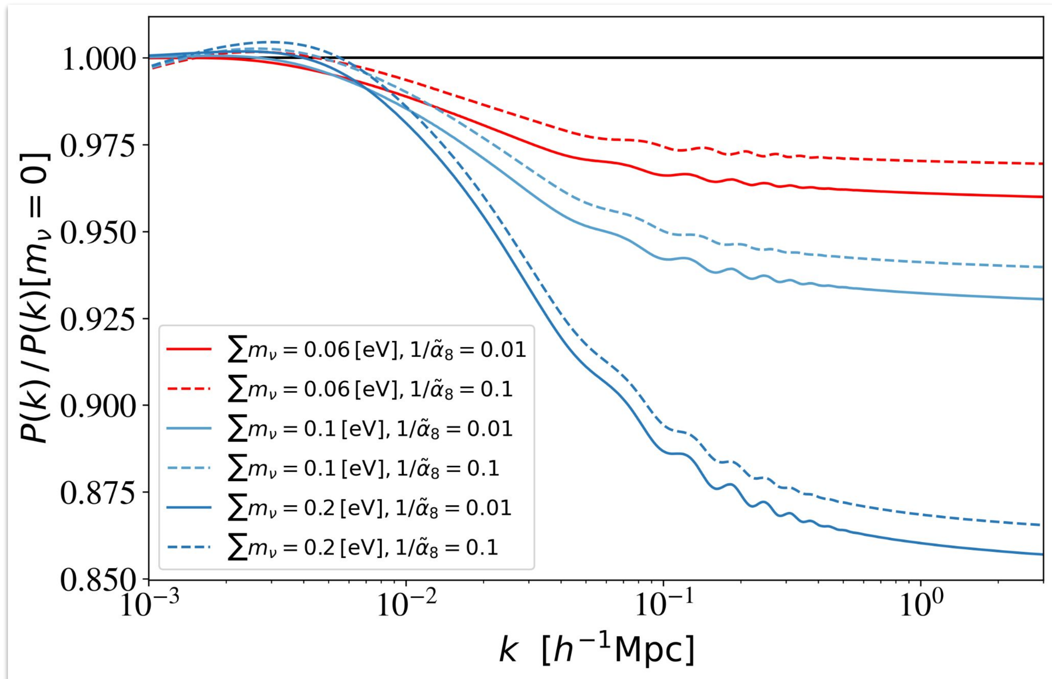
Cosmology can constrain neutrino mass

BUT…

It is sensitive to neutrinos mostly through **gravity**: assuming a different theory of gravity changes the constraints with respect to using General Relativity.

Change in the suppression of power spectrum due to Σm_ν in a modified gravity model studied in [1].

$1/\alpha 8$: modified gravity extra parameter.

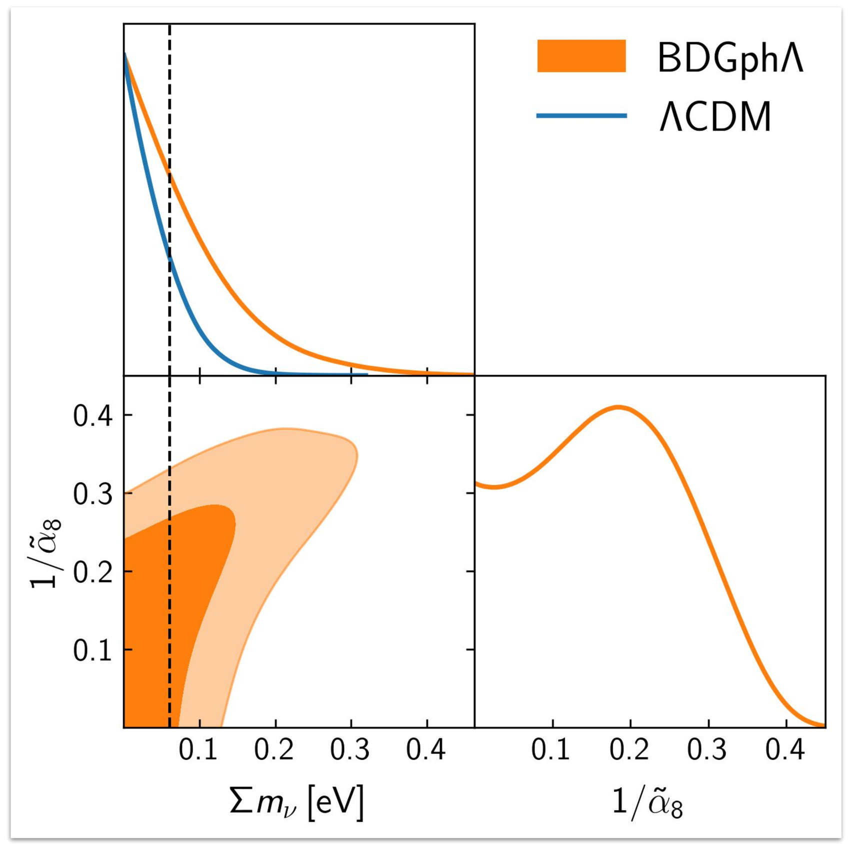


Constraints on neutrino mass in modified gravity models

Constraints on the sum of neutrino masses in the standard ΛCDM model and in the Brans-Dicke Galileon [1]: **parameters are degenerate and the bound depends on the theory of gravity**

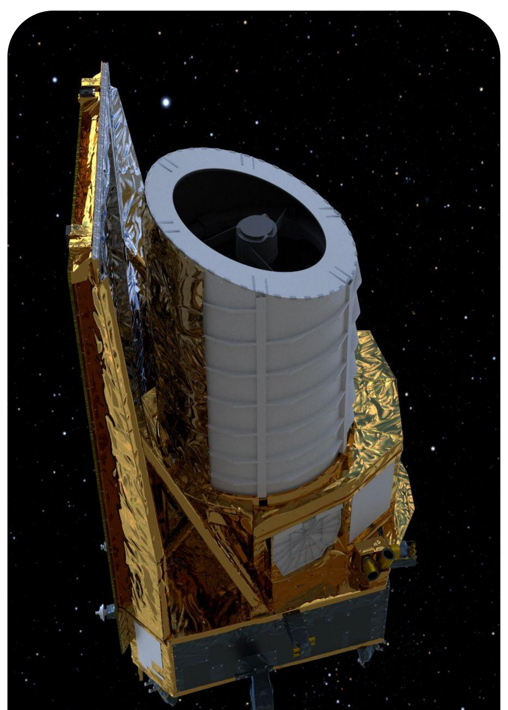
__Datasets__: Planck TTTEEE + Lensing & BAO measurements from SDSS

Plot from Ferrari et al. 2024, in preparation.



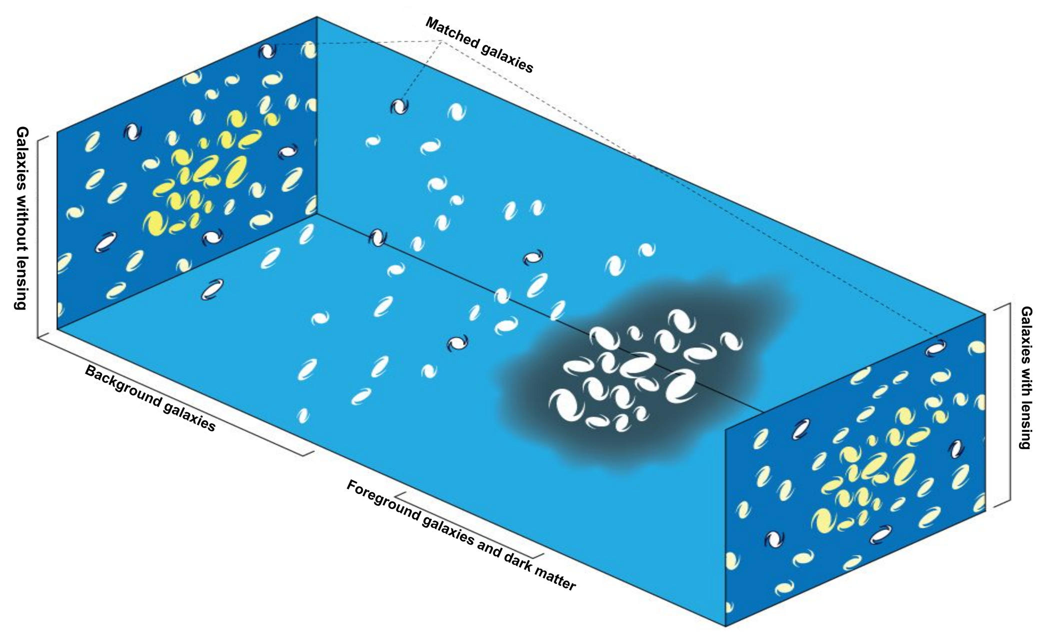
The *Euclid* mission

The *Euclid* mission probes the LSS of the Universe by observing the **weak gravitational lensing (WL)** of galaxies and **galaxy clustering (GC)**.



Euclid will build the largest galaxy survey to date observing **1.5 billion galaxy shapes** and **photometric** redshifts, and over **35 million spectroscopic** redshifts (3D galaxy positions).

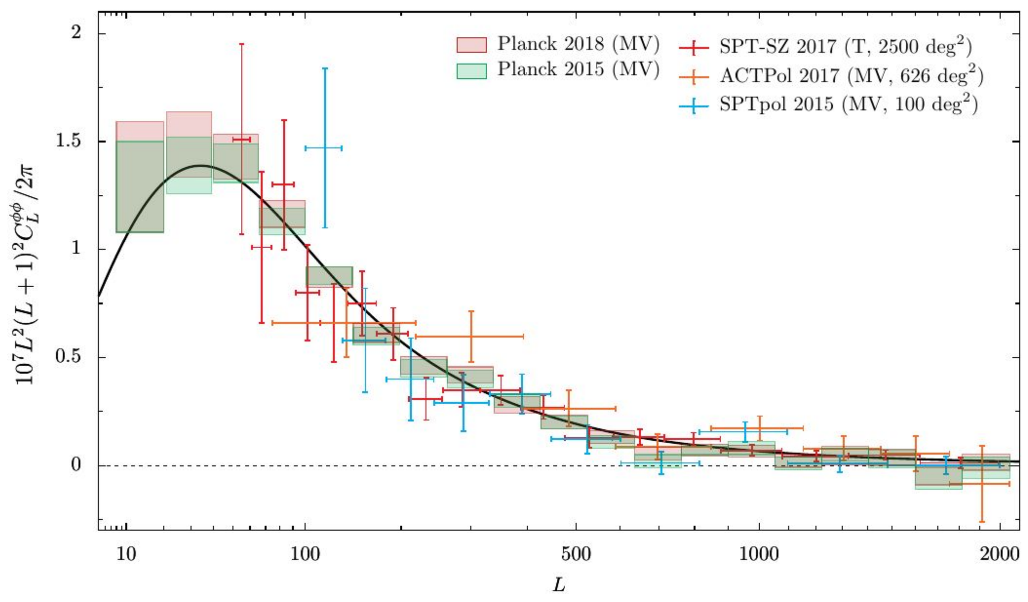
- **WL**: shapes distorsion of galaxies due to intervening matter along line of sight.



- **GC**: distribution of the galaxies in the Universe. Spectroscopic measurements (**GCs**) are more precise on redshift estimation ($\sigma_z \lesssim 0.001(1+z)$) but target less objects. Photometric measurements (**GCp**) less precise ($\sigma_z \lesssim 0.05(1+z)$) but with a much higher statistics.

For a full exploitation of all these observables WL, GCp and GCs, it is crucial to extract the most from the *Euclid* photometric survey (WL, GCp and their cross correlation).

Complementary data: CMB Lensing



- CMB lensing is the same effect of WL on the CMB.
- Sensitive to LSS.
- Measured by several collaborations (*Planck*, ACT, etc..) and to be improved by the Simons Observatory (SO).

Core idea: Combine *Euclid* photometric survey with CMB lensing and its cross-correlations (XCMB) with Euclid probes to tighten constraints and keep systematics under control.

Forecast for *Euclid* photometric survey combined with CMB lensing

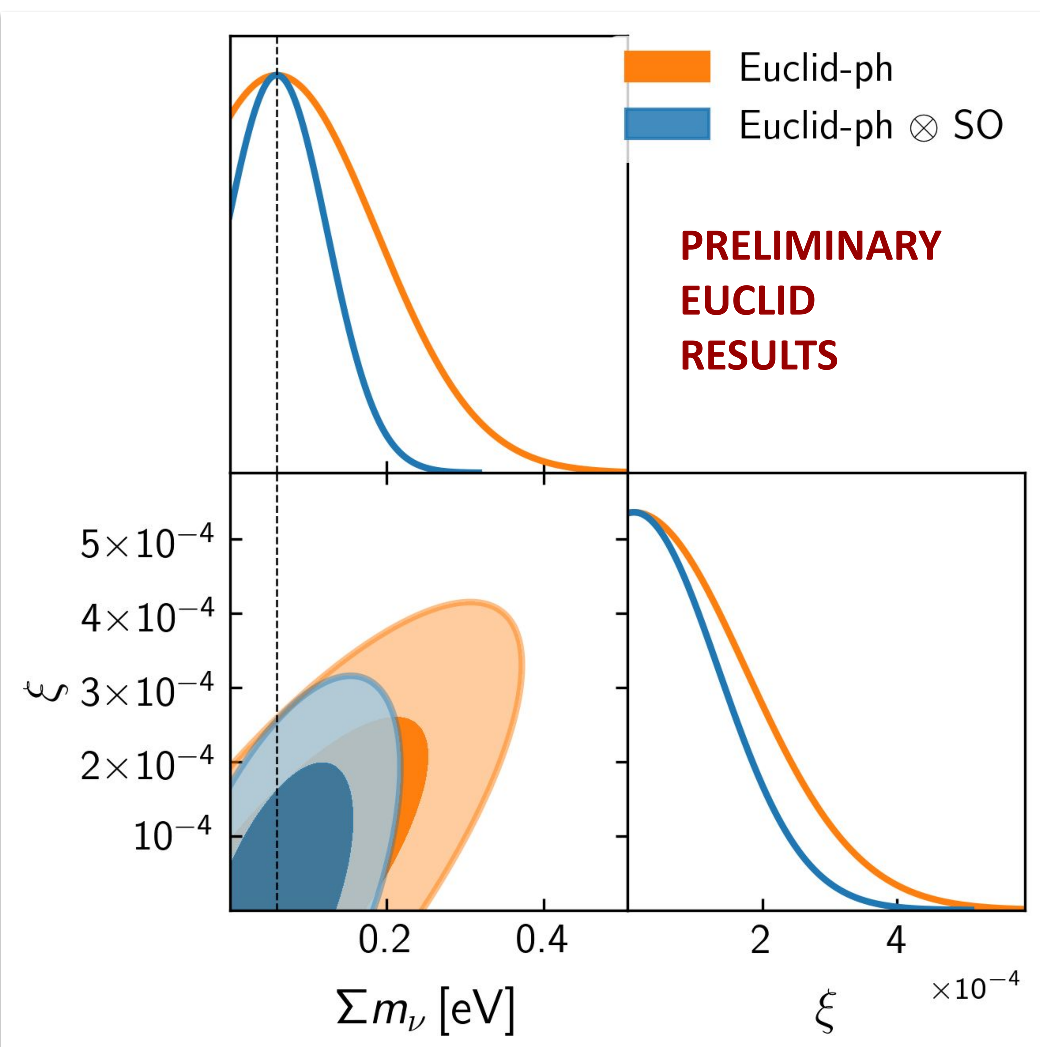
Joint analysis with CMB lensing (SO-like) in modified gravity (IG):

- **50% improvement on neutrino mass constraint** with respect to the *Euclid* photometric survey alone:
  - ➢ Euclid-ph: $\Sigma m_\nu < 0.26$ eV (95% CL)
  - ➢ Euclid-ph ⊗ SO: $\Sigma m_\nu < 0.13$ eV (95% CL)
- Not gauging full constraining power but relative improvement and relevance of XCMB for the photometric survey.
- Constraints including all *Euclid* probes and CMB could provide a **5σ detection of neutrino mass in ΛCDM** [2]. (Planck collab. reports $\Sigma m_\nu < 0.13$ eV at 95% CL from CMB + BAO).
- **Euclid-photo and CMB joint analysis necessary to achieve this target.**

INDUCED GRAVITY (IG)

$$\mathcal{L}^{\rm IG}_{\rm grav} = \frac{1}{2}\xi\sigma^2 R - \frac{1}{2}\nabla_\mu\sigma\nabla^\mu\sigma - V(\sigma)$$

ξ modulates the strength of the coupling with the Ricci scalar



Conclusions

- Model-dependent inference of neutrino mass from cosmology
- ***Euclid*: 5σ detection possible in ΛCDM, bounds relax in beyond ΛCDM models**. (Planck collab. reports $\Sigma m_\nu < 0.13$ eV at 95% CL from CMB + BAO)
- **CMB lensing cross-correlation** complements the *Euclid* photometric survey: **50% improvement on the determination of neutrino mass**.
- CMB lensing cross-correlation allows to calibrate some systematics of the photometric survey (shear multiplicative bias): **more robust results**.

References

[1] A. G. Ferrari et al. - *Cosmological effects of the Galileon term in Scalar-Tensor Theories.* Phys. Rev. D 108, 063520 (2023)

[2] M. Archidiacono et al. - *Euclid preparation. Sensitivity to neutrino parameters*. arXiv:2405.06047