Hiding Neutrino Masses in Modified Gravity Cosmologies

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Introduction (I): Neutrinos

- Neutrino flavour conversion $\Rightarrow$ massive eigenstates.
- Cosmological effects in ΛCDM cosmology well understood:
  - change background history.
  - change growth of structure: $\Delta P/P_{m_\nu=0} \propto \Sigma m_\nu$ at $k \gtrsim k_{nr}$.
- Up-coming surveys: neutrino mass scale and effects, but...
  Probing new scales $\Rightarrow$ GR still valid?
- GR alternatives: ν effects may be hidden by gravity.

  Baldi *et al.*, arXiv:1311.2588

Introduction (II): Horndeski's models

- Horndeski's gravity: most general theory with one scalar dof that has 2^{nd} order EOM and satisfies WEP.

$$S = \int d^4x\sqrt{-g}\left[\sum_{i=2}^{5}\mathcal{L}_i(\phi, X) + \mathcal{L}_m[g_{\mu\nu}, \psi_m]\right]$$

- Freedom: four functions of ϕ and $X = -\phi^{;\mu}\phi_{;\mu}/2$

$$K(\phi, X),\ G_3(\phi, X),\ G_4(\phi, X),\ G_5(\phi, X)$$

- Can we directly constraint $\{K, G_3, G_4, G_5\}$ with observations?

Introduction (III): EFT-like approach for Horndeski's gravity

Cosmological information contained in $\begin{cases} 5 \text{ functions of time} \\ 1 \text{ constant} \end{cases}$

Bellini and Sawicki, arXiv:1404.3713

$w(t)$ equation of state of DE.

Ω_{m0} dark matter fraction today.

$\alpha_K(t)$ kineticity, kinetic energy of scalar perturbations.

$\alpha_B(t)$ braiding, mixing of scalar and metric kinetic term.

$\alpha_M(t)$ Planck mass run-rate, rate of evolution of Planck mass.

$\alpha_T(t)$ tensor speed excess, deviation of tensor speed from c.

New scale dependence

$$\textit{Braiding Scale}: \quad \frac{k_B^2}{a^2 H^2} = \frac{9}{2}\Omega_m + 2\left(\frac{3}{2} + \frac{\alpha_K}{\alpha_B^2}\right)(\alpha_M - \alpha_T)$$

Data

Likelihoods:

Audren *et al.*, arXiv:1210.2194

CMB CMB temperature, E-mode polarization and deflection angle power spectrum;

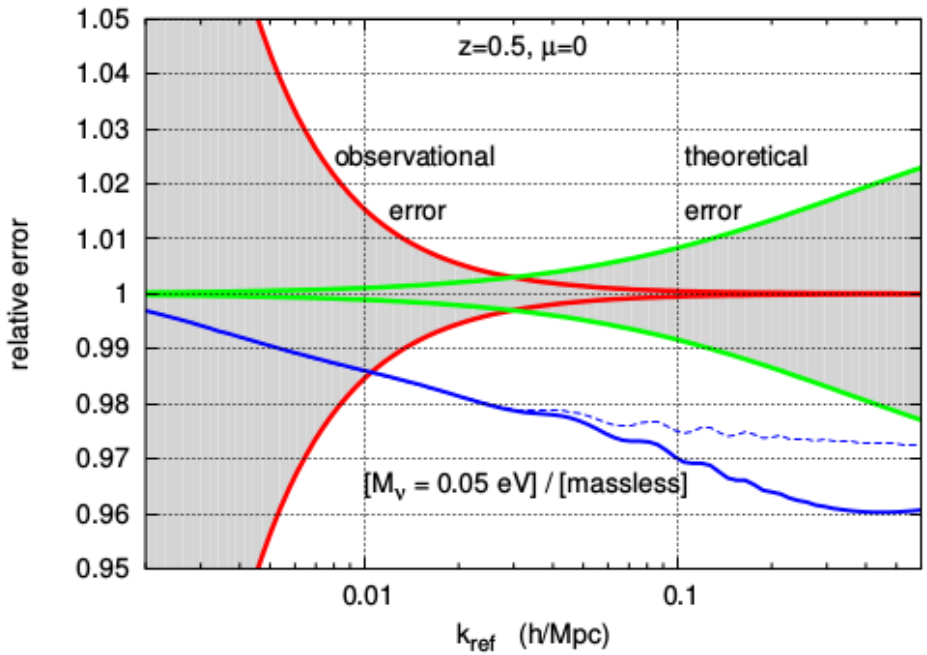
$P(k)$ galaxy power spectrum, including scale independent bias, Kaiser RSD, spectroscopic/photometric errors and FoG effects;

Full $P(K)$ $P(k)$ plus geometrical distortions (BAO and Alcock-Paczynski).

Errors in galaxy power spectrum likelihood:

σ_{obs} shot noise and cosmic variance

σ_{the} effects not contained in the likelihood.



Hiding Neutrino Masses

In this work:
$$\begin{cases} w(t) = -1 \\ \alpha_K = c_K, \ \alpha_{B,M,T} = c_{B,M,T} \dfrac{1 + \tanh\left(\frac{z_{th}-z}{\Delta z}\right)}{1 + \tanh\left(\frac{z_{th}}{\Delta z}\right)} \end{cases}$$

MCMC

Fixed parameters	Varying parameters
$\Sigma m_\nu = 500\ meV$	$\omega_b, \omega_{cdm}, h, A_s, n_s, z_{reio}$
$c_K = 10, z_{th} = 100, \Delta z = 20$	c_B, c_M, c_T

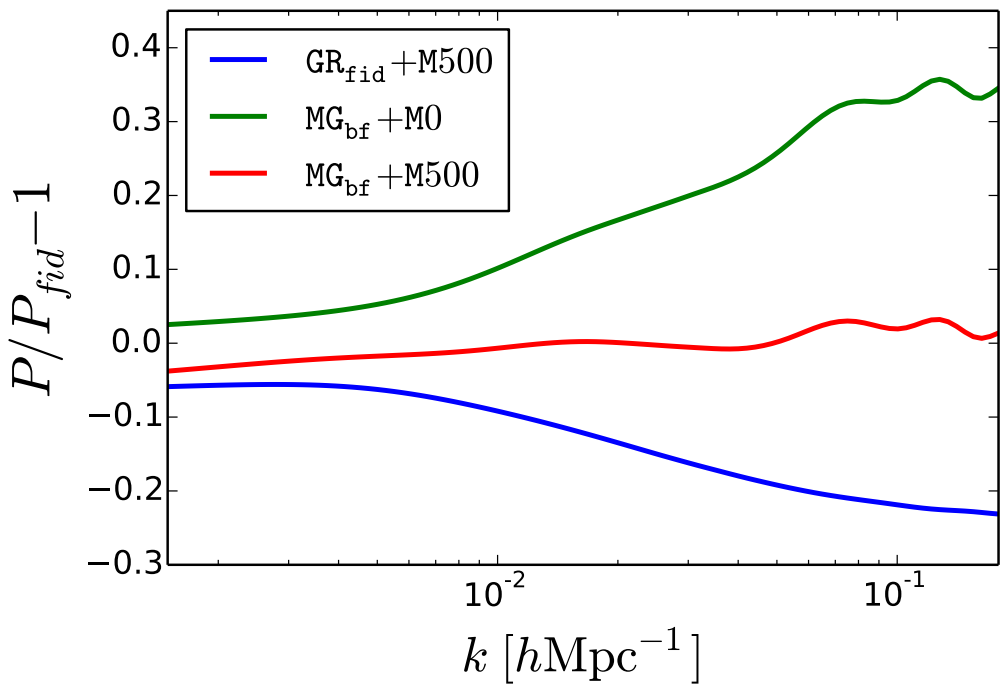
MG parameters effects:

$(z_{th}, \Delta z)$ change allowed c_B, c_M, c_T regions.

c_B enhance $P(k)$ at $k \gtrsim k_B$, fixed by Σm_ν.

c_K determines $k_B^2 \propto \frac{\alpha_K}{\alpha_B^2}$.

DETECTABLE EFFECT!

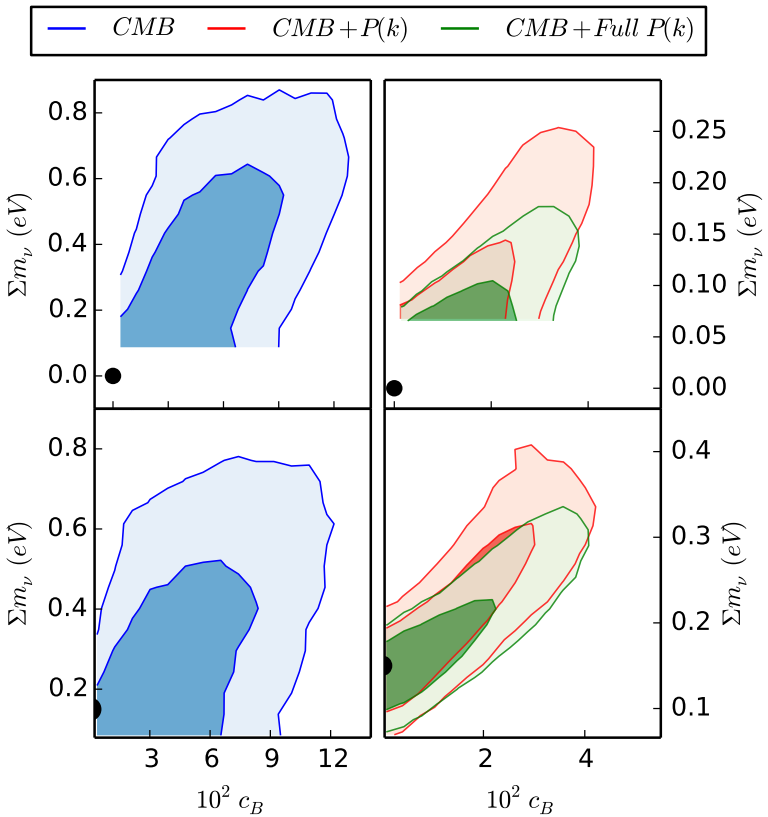


Fiducial: GR+$\Sigma m_\nu = 0.0\ meV$

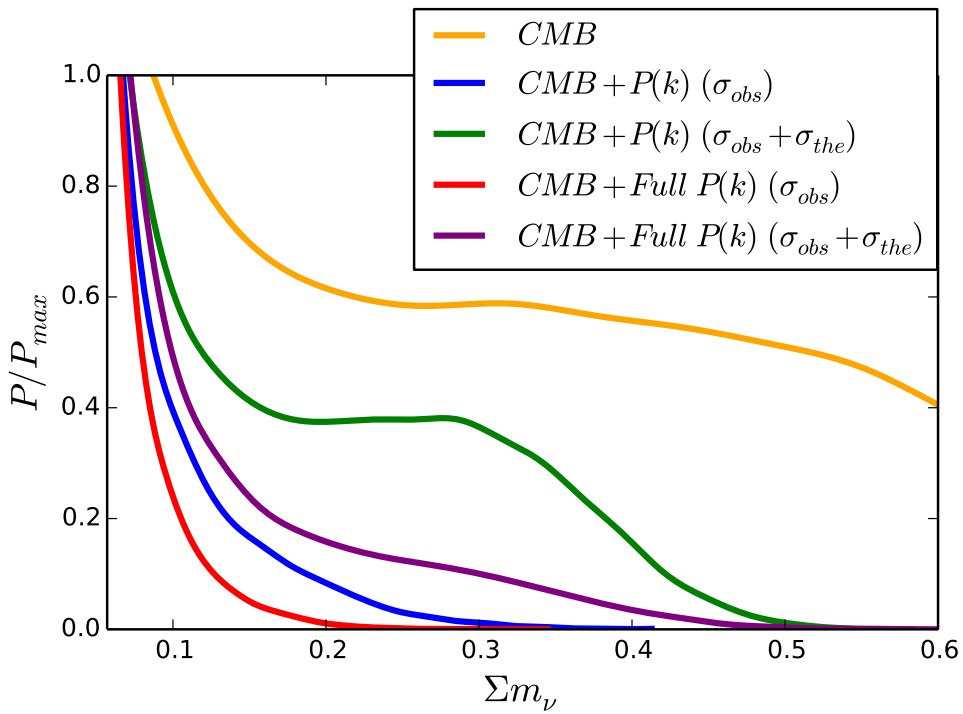
Modified Gravity - Neutrinos Degeneracies

MCMC

Fixed parameters	Varying parameters
$c_K = 10, c_T = 0$	$\omega_b, \omega_{cdm}, h, A_s, n_s, z_{reio}$
$z_{th} = 100, \Delta z = 50$	$\Sigma m_\nu, c_B, c_M$



●: Fiducial model
Fiducial upper panels: GR+$\Sigma m_\nu = 0.0$ *meV*
Fiducial lower panels: GR+$\Sigma m_\nu = 150.0$ *meV*



Fiducial: GR+$\Sigma m_\nu = 0.0$ *meV*

Conclusions

- Different gravity models can hide neutrino signature:
  - $\Rightarrow$ this work: change at perturbation level (ΛCDM background).
  - $\Rightarrow$ change only at background level. Upadhye, arXiv:1707.09354
- Limit of use of Quasi-Static approximation:
  - $\Rightarrow$ safe if $c_s > c_{s,min} = 0.1$ Bellini and Sawicki, arXiv:1503.06831
- Other cosmological observables (as weak lensing) and neutrino experiments can lift degeneracies.

Thanks for your attention!