Meeting PANTHEON
Report del gruppo di Napoli

Roma 4 ottobre 2024

Membri del nodo di Napoli

- Gianpiero Mangano (I fascia UNINA)
- Ofelia Pisanti (I fascia UNINA)
- Fabio Iocco (II fascia UNINA)
- Luigi Rosa (II fascia UNINA)
- Louis Hamaide (Assegnista INFN (NA)) 1 ottobre 2024
- Antonio Marinelli (RTDA UNINA)*
- Ninetta Saviano (INFN Napoli)*
- Mattia Cielo (dottorando UNINA)*
- Andrea Boccia (dottorando SSM)*
- Simone Sgarlatella (dottorando UNINA)*

Budget

Assegnazione

Corrente : 33400 Euro

Pluriennale: 2500 Euro

Disponibile

Corrente: 24484 Euro (73%)

Pluriennale: 1414 Euro (56%)

Attività di ricerca

- Cosmology:
  - il vacuum per le perturbazioni
  - non gaussianità
  - inflazione con assioni e campi di gauge
  - modello di Starobinsky
  - N_{eff}
  - BBN e low reheating
  - PBH e BBN
  - GW e leptogenesi
- Fisica degli aloni
- Archimedes e dark photons
- Sorgenti astrofisiche

Altre attività

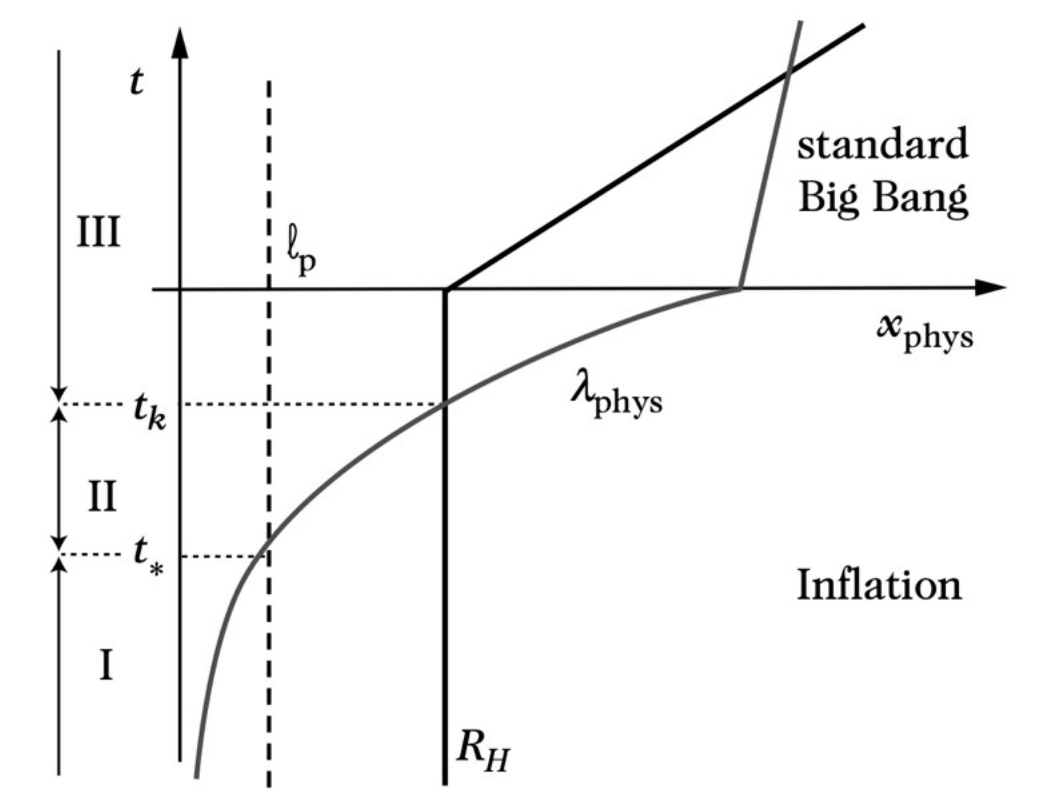
- tutoraggio tesi di dottorato (7)
- tesi magistrali (2)
- Attività seminariali e talks su invito

Choice of vacuum and transplanckian physics

$$\frac{k(t_i)_{phys}}{M} \approx 200\left(\frac{M}{10^{16}GeV}\right)\left(\frac{k}{1Mpc^{-1}}\right)e^{\Delta N-(\Delta N)_{min}}$$

$$M = \rho_{inflation}^{1/4}$$

Two issues for stage I:
can we trust classical GR?
can we trust linear approximation?



M. Cielo, G. M. and O. Pisanti, PRD 108 (2023)
M. Cielo, M. Fasiello, G. M. and O. Pisanti, JCAP (2024)
M. Cielo, G. M., O. Pisanti and D. Wands, in preparation
M.Cielo, L. Cirillo, G.M. and O. Pisanti, in preparation

$$h_k'' + 2\mathscr{H} h_k' + k^2 h_k = 16\pi G \Pi_k \qquad \tau \leq \bar{\tau}(k)$$

$$h_k'' + 2\mathscr{H} h_k' + k^2 h_k = 0 \qquad \tau > \bar{\tau}(k)$$

$$\bar{\tau}(k) = -\frac{\Lambda}{kH}$$

$$\hat{\Pi}_k^r(\tau) = \Pi_k(\tau)\hat{a}_k^r + \Pi_k^*(\tau)\hat{a}_{-k}^{r\dagger}$$

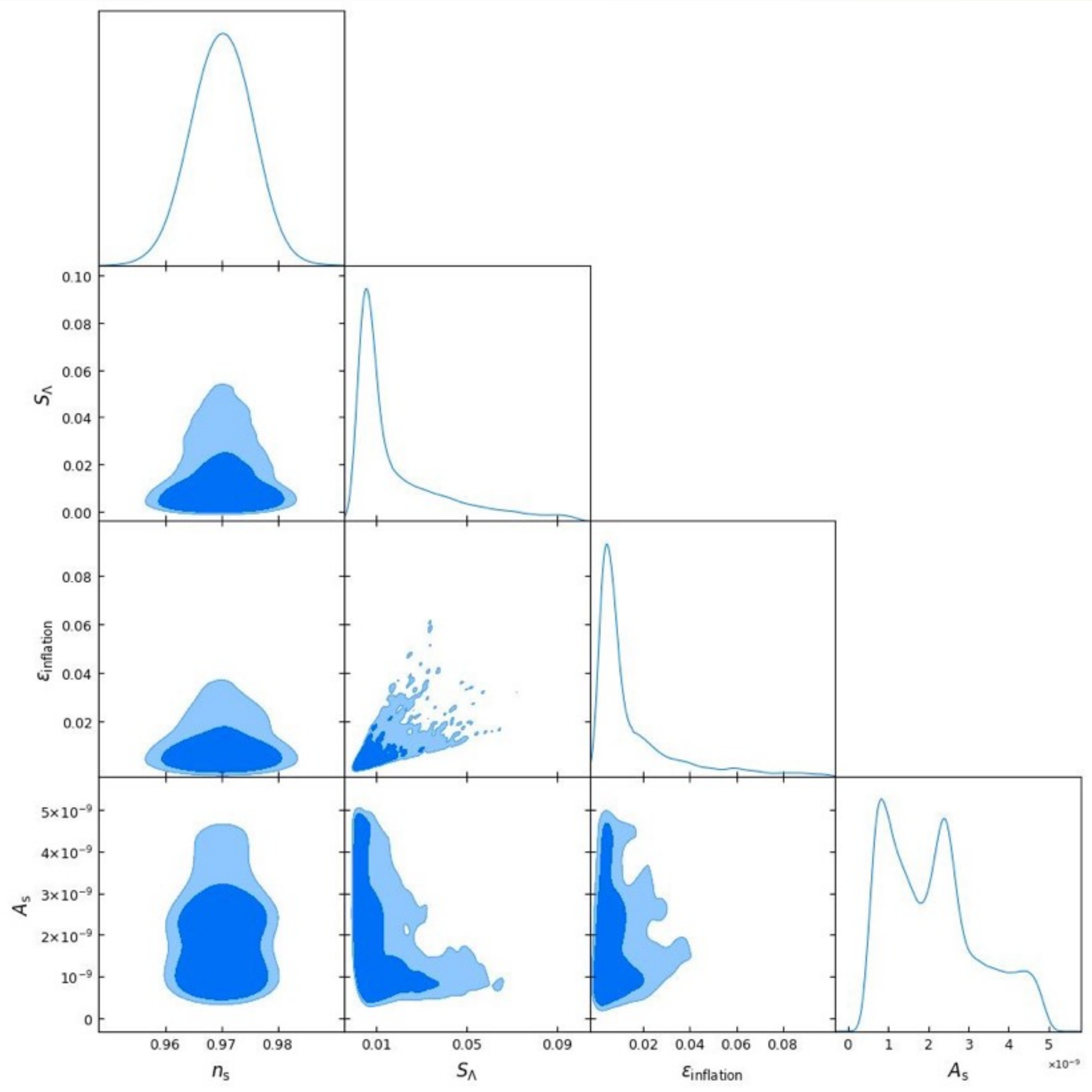
$$\langle \Pi_k(\tau) \rangle = 0$$

$$\langle \Pi_k(\tau)\Pi_k^*(\tau') \rangle = \mathscr{N}\delta(\tau - \tau')F(k)$$

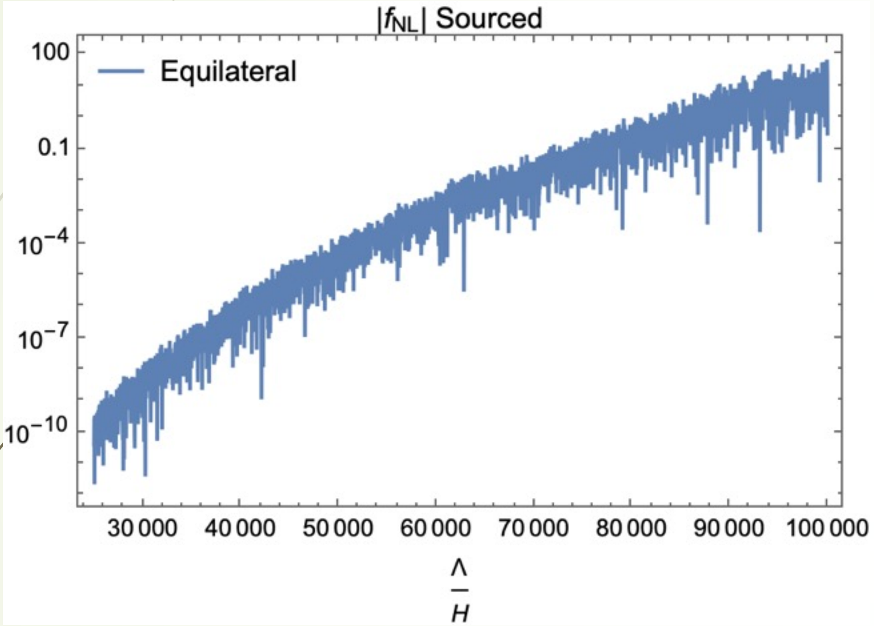
$$F(k) = \int_0^\infty \underbrace{\xi(M)dM}\, \underbrace{e^{-\frac{k_{phys}}{T_H}}}$$

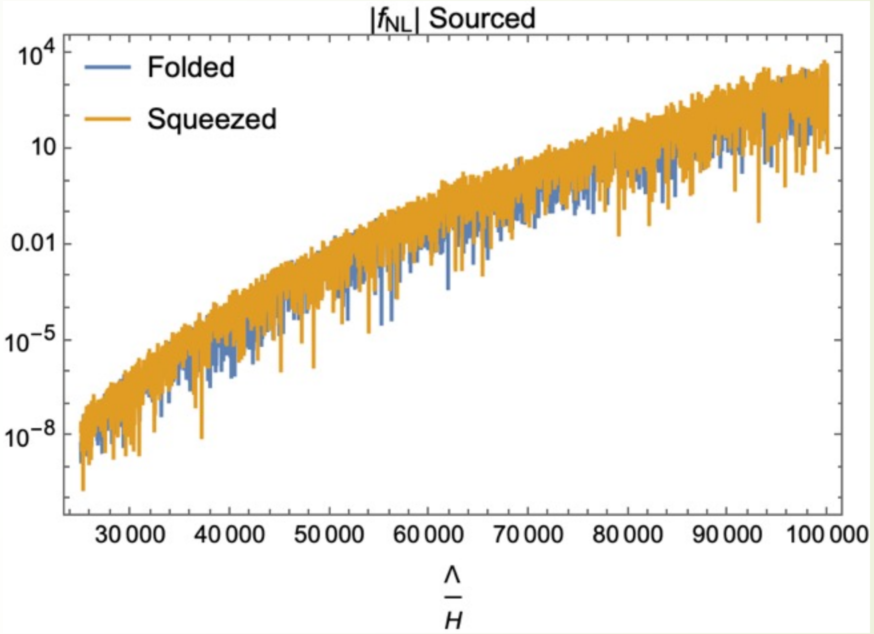
Black hole gas model

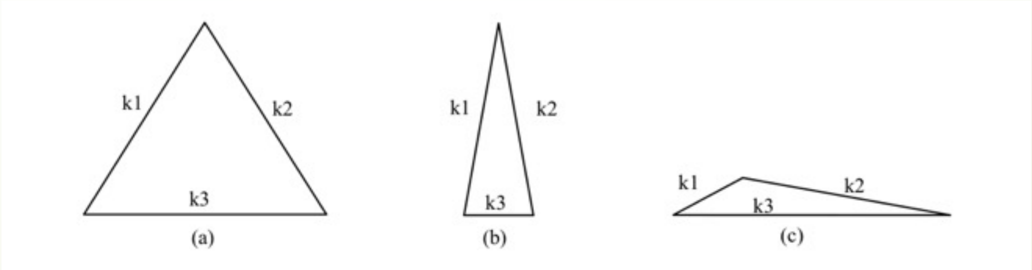
Tesi magistrale di L. Cirillo
Paper in progress



Non gaussianities

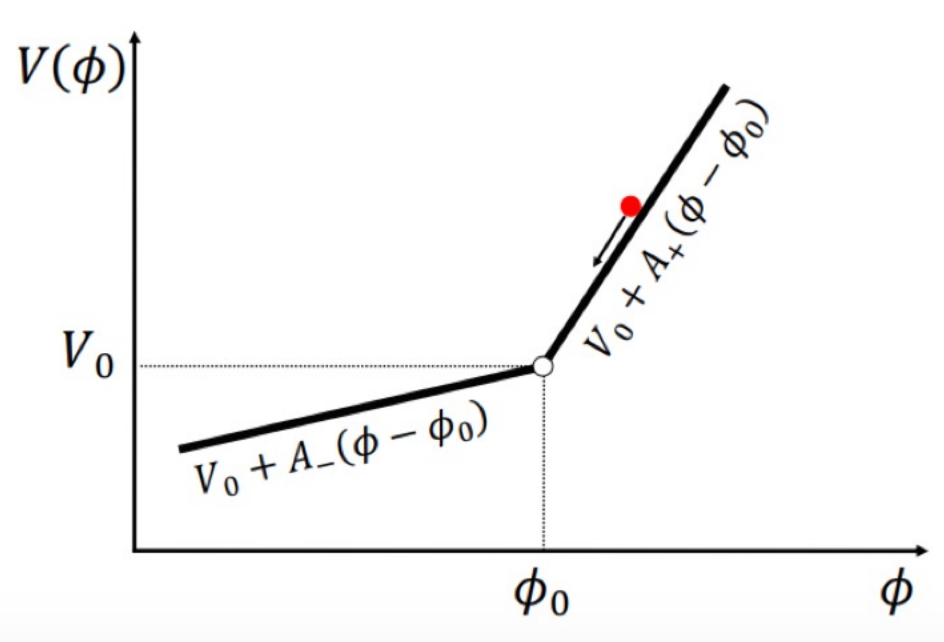






The Starobinsky model

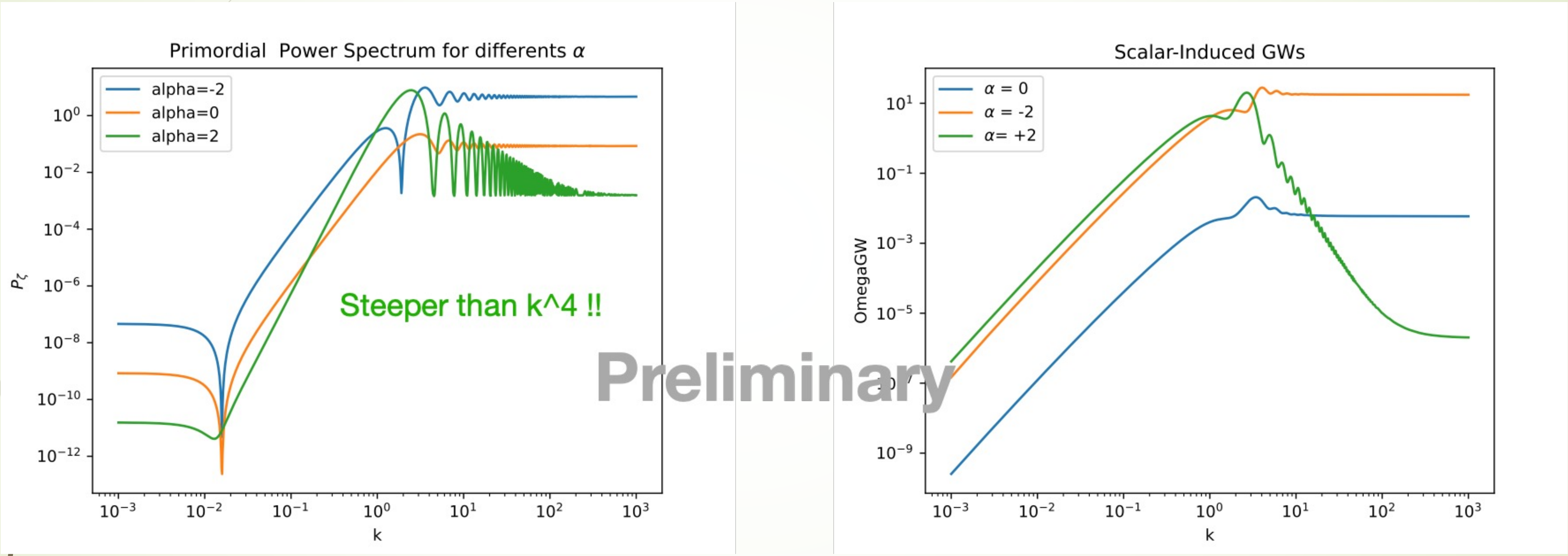
$$V(\phi) = \begin{cases} V_0 + A_+ (\phi - \phi_0), & \text{for } \phi > \phi_0; \\ V_0 + A_- (\phi - \phi_0), & \text{for } \phi \leq \phi_0. \end{cases}$$



Tesi magistrale di T. Bozzaotra, in progress

$$\zeta_k(\tau) = C_{i,k}\sqrt{-k\tau}H_\nu^{(1)}(-k\tau) + D_{i,k}\sqrt{-k\tau}H_\nu^{(2)}(-k\tau)$$

What if we have a non trivial vacuum state?



M. Cielo. G. Mangano, O. Pisanti, D. Wands
On the arXiv soon

Inflating with Axions and Gauge Fields

Chromo Natural Inflation, an intriguing example

$$S = \int d^4x \sqrt{-g} \left[\frac{M_p^2}{2} R - \frac{1}{4} F^a_{\mu\nu} F^{a,\mu\nu} - \frac{1}{2} (\partial\chi)^2 - V(\chi) - \frac{\lambda}{8\sqrt{-g}\, f} \chi\, \epsilon^{\mu\nu\alpha\beta} F^a_{\mu\nu} F^a_{\alpha\beta} \right]$$

INTERESTING PHENOMENOLOGY

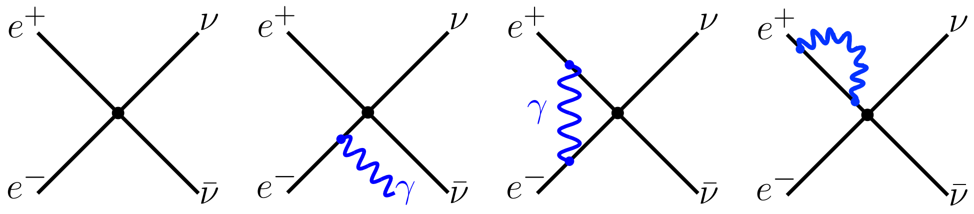
- Chiral GWs production
- Primordial Black Hole (2403.13581 E. Dimastrogiovanni, M. Fasiello, A. Papageorgiou)
- …

Ongoing work

- Effect of scalar back-reaction on observables
- Numerical implementation in high performance codes (Python & Julia)

N_{eff} a NLO

Goal: **Obtain Neff including processes of this type:**

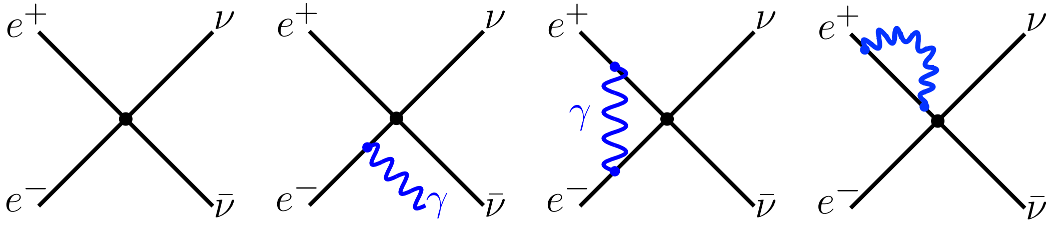


First calculation in:
Cielo, M.E.A., Mangano & Pisanti [2306.05460]

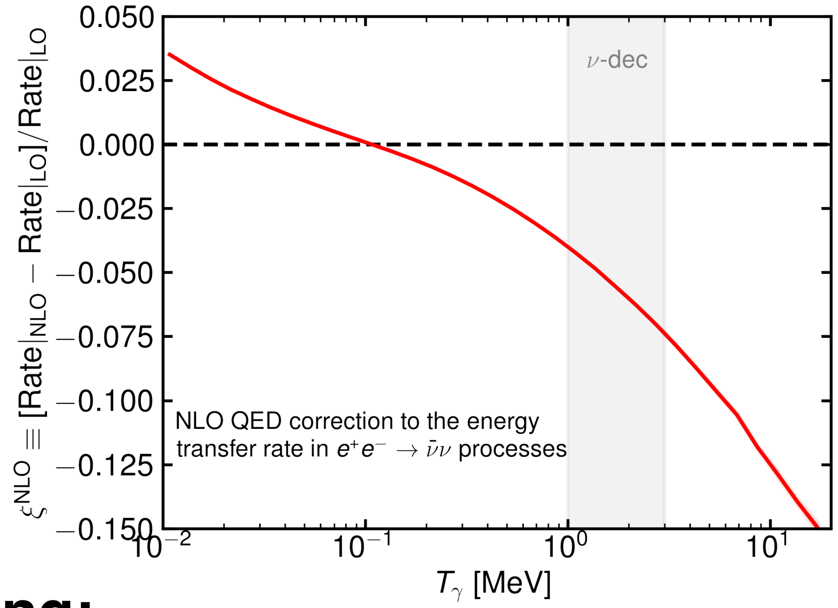
$$N_{\rm eff}^{\rm SM} = 3.044(1)$$

Mangano et al. hep-ph/0506164
de Salas & Pastor 1606.06986
Bennett, Buldgen, Drewes & Wong 1911.04504
Escudero Abenza 2001.04466
Akita & Yamaguchi 2005.07047
Froustey, Pitrou & Volpe 2008.01074
Gariazzo, de Salas, Pastor et al. 2012.02726
Hansen, Shalgar & Tamborra 2012.03948

1) Calculation performed following the real time formalism in thermal field theory



See Esposito, Mangano, Miele, Picard & Pisanti astro-ph/0301438 & astro-ph/0112384 for the thermal corrections
and Passera for the radiative corrections in vacuum [hep-ph/0011190]



2) Solve for the process of neutrino decoupling:

Solving the Liouville equation in the presence of an additional particle is simply unfeasible!

$$\frac{dT_\nu}{dt} = -H\,T_\nu + \frac{\frac{\delta\rho_{\nu_e}}{\delta t} + 2\frac{\delta\rho_{\nu_\mu}}{\delta t}}{3\,\frac{\partial\rho_\nu}{\partial T_\nu}}$$

Add here the correction!

3) Result at NLO: $\Delta N_{\rm eff} \simeq -\,0.0007$ $\quad N_{\rm eff}^{\rm SM} = 3.0432(2) = 3.043$

Cielo, Escudero, Mangano & Pisanti 2306.05460

PRD 108, L121301 (2023)

Mixing of four neutrino states?

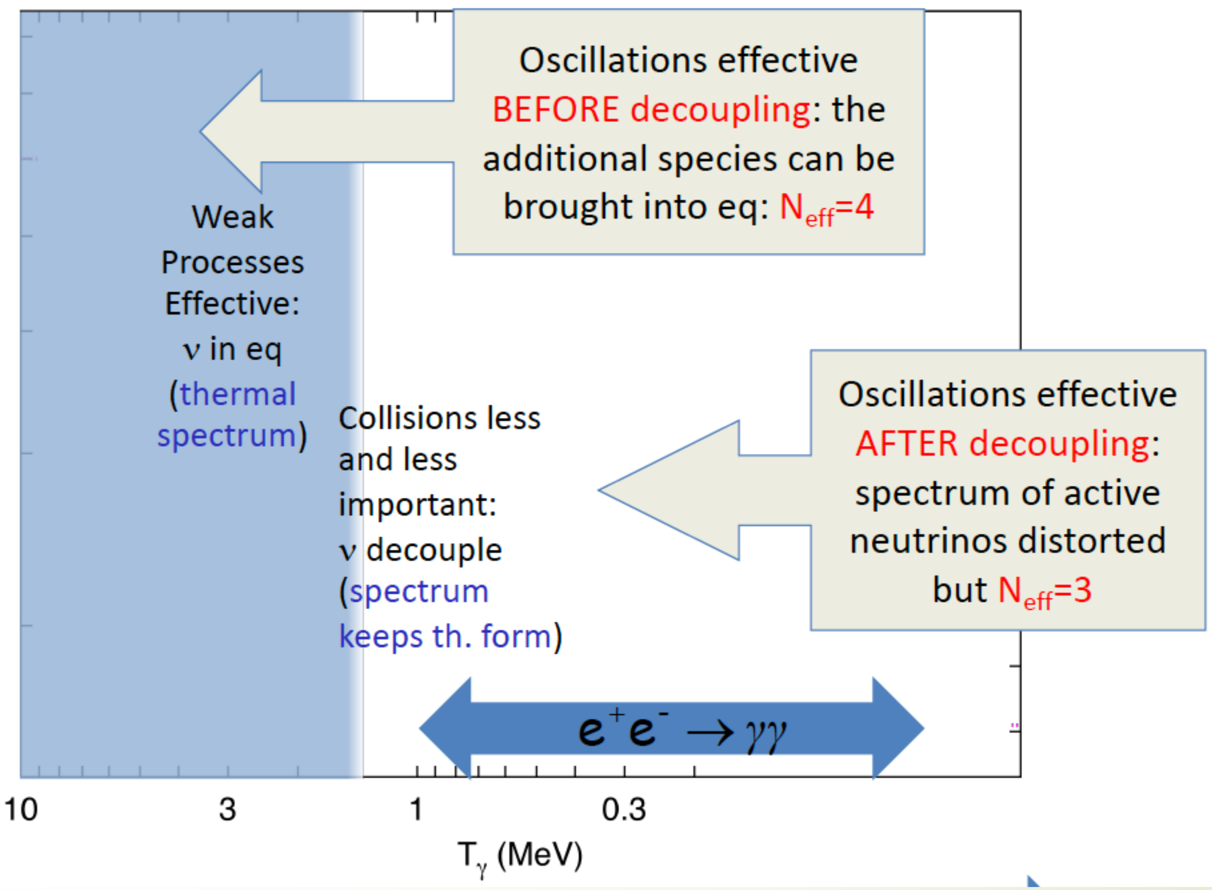
Additional neutrino (sterile) **states** introduced in order to explain some anomalies in experimental data

4 flavour neutrinos, **4** massive neutrinos

4x4 mixing matrix $\begin{pmatrix} U_{e1} & U_{e2} & U_{e3} & U_{e4} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} & U_{\mu 4} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} & U_{\tau 4} \\ U_{s_1 1} & U_{s_1 2} & U_{s_1 3} & U_{s_1 4} \end{pmatrix}$

We consider **3 (active)** + **1 (sterile)**, a perturbation of the 3-neutrino case

$$
\begin{aligned}
|U_{e4}|^2 &= \sin^2\theta_{14}, \\
|U_{\mu 4}|^2 &= \cos^2\theta_{14}\sin^2\theta_{24}, \\
|U_{\tau 4}|^2 &= \cos^2\theta_{14}\cos^2\theta_{24}\sin^2\theta_{34}, \\
|U_{s4}|^2 &= \cos^2\theta_{14}\cos^2\theta_{24}\cos^2\theta_{34}.
\end{aligned}
$$



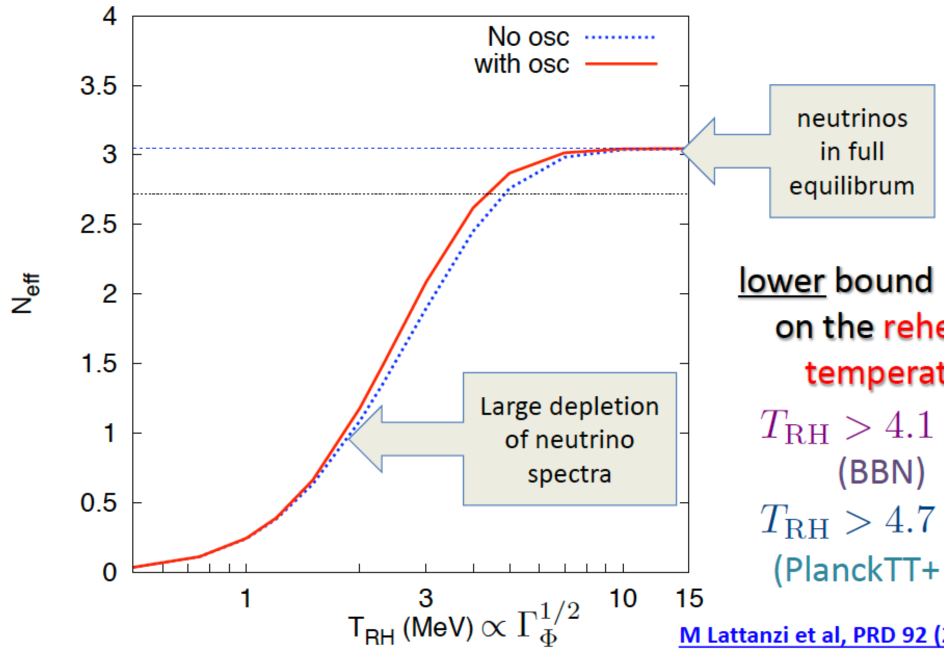
How to reconcile 3+1 oscillations with $N_{eff} < 4$

We would need

- a mechanism to suppress oscillations and full thermalization of ν_s
- to compensate $\Delta N_{\rm eff} = 1$ with additional mechanisms in Cosmology

→ **Very low-reheating scenarios**

3ν in very low-reheating scenarios

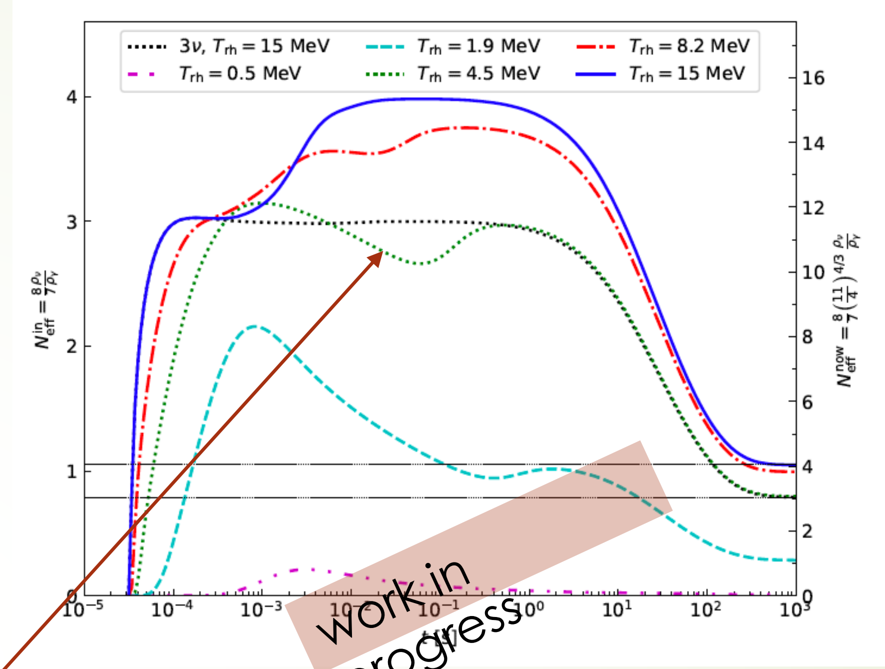


lower bound (95%CL) on the reheating temperature

$T_{RH} > 4.1$ MeV (BBN)

$T_{RH} > 4.7$ MeV (PlanckTT+ lowP)

M Lattanzi et al, PRD 92 (2015) 123534

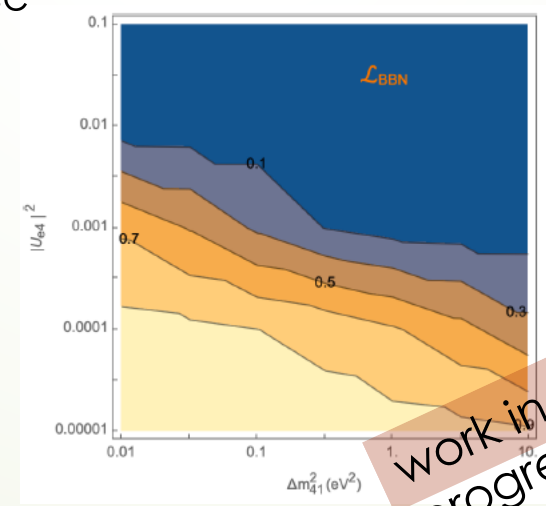


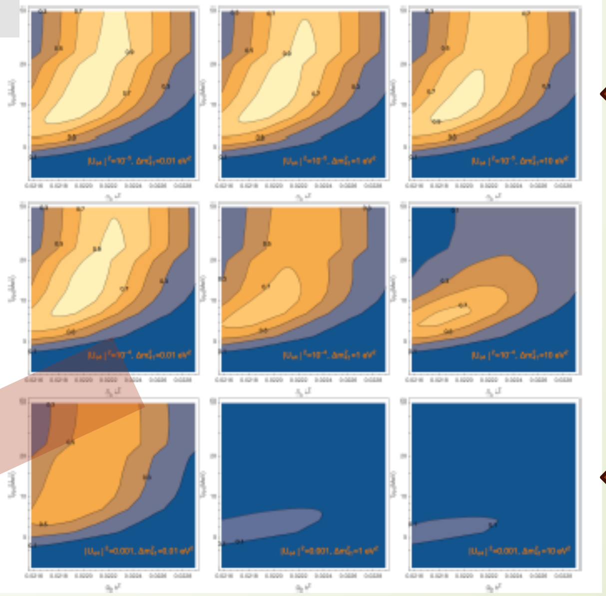
work in progress

T_{rh}=4.5 MeV mimicks standard case

low mass

high mass





low angle

high angle

work in progress

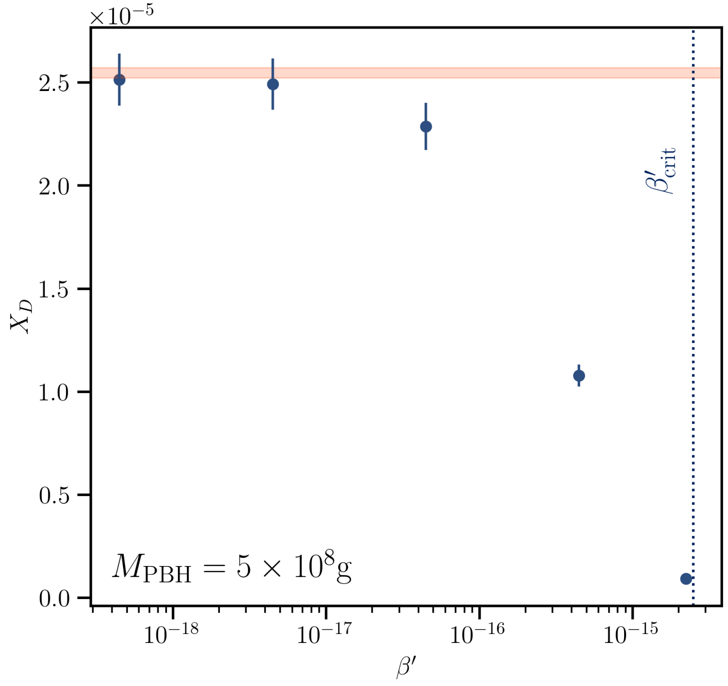
New paper in preparation:

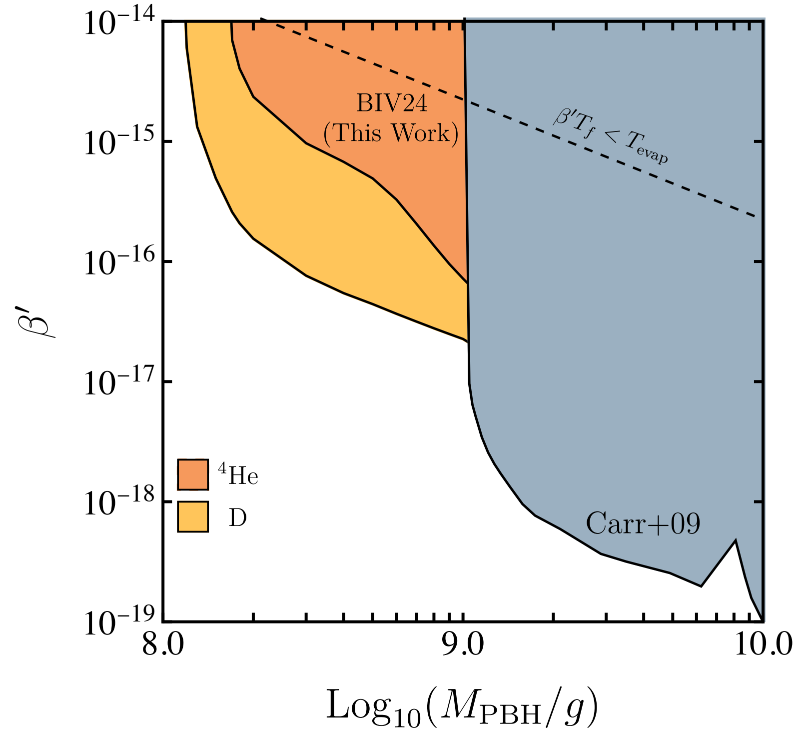
- L goes to constant at high T_{rh} and prefers low oscillation angles
- relatively high L for T_{rh}~ 5-6 MeV at high angle and low mass, when ν production is less efficient
- CMB analysis in progress

Constraining the abundance of primordial black holes through Big Bang nucleosynthesis

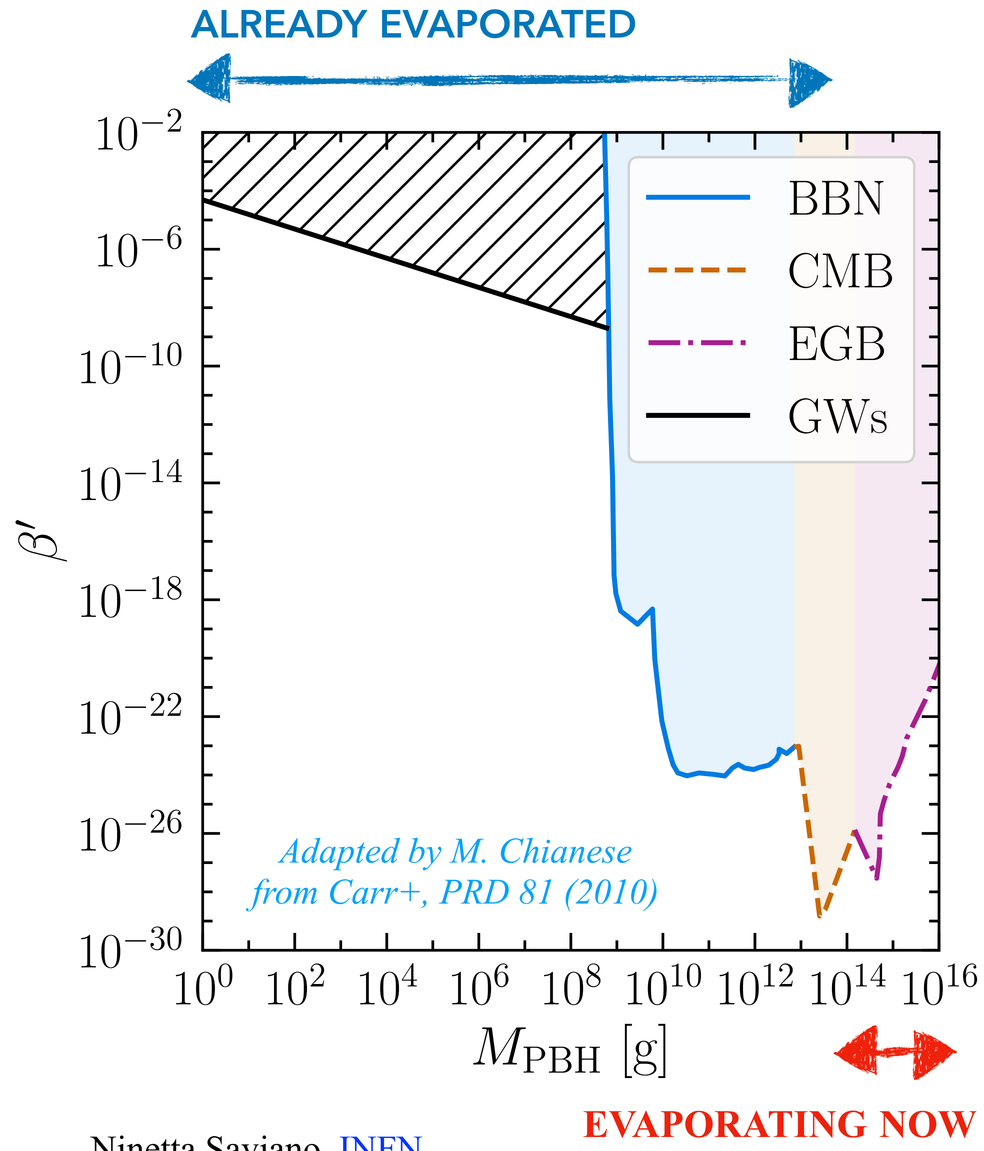
Andrea Boccia, Fabio Iocco, Luca Visinelli arXiV:2405.18493; submitted to PRD

PBHs evaporating before BBN modify the expansion rate of the Universe and inject entropy in the hot plasma, eventually altering the light nuclei abundances and leading to strongest constraints.





PBH Searches



- ✦ Formed at $T_{\rm form}$ after inflation with an abundance

$$\beta'(M_{\rm PBH}) = \gamma^{1/2} \frac{\rho_{\rm PBH}(T_{\rm form})}{\rho_R(T_{\rm form})}$$

- ✦ Hawking radiation: emission of particles with a mass $m \leq T_{\rm PBH} \simeq 10\left(10^{15}\ {\rm g}/M_{\rm PBH}\right)$ MeV

- ✦ The evaporation lifetime is $\simeq 4 \times 10^{17}\left(M_{\rm PBH}/10^{15}{\rm g}\right)^3$ s

PBH PAPERS

- ✦ Light PBHs ($M_{\rm PBH} \lesssim 10^9$ g) strongly modify the parameter space of leptogenesis

Calabrese, Chianese, Gunn, Miele, Morisi, Saviano,
PRD 109.103001 (2024), PRD 107.123537 (2023)

Imprints on the GW spectrum

GOAL: probing high-energy models with specific spectral features in the GWs today

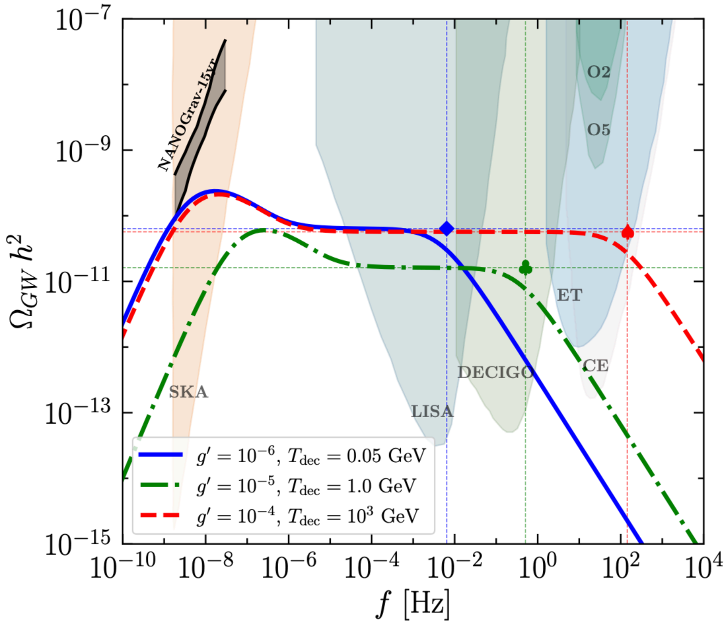
Example 1: Characteristic spectral features, induced by different flavour regimes of leptogenesis, are detectable in multiple frequency bands with current and future GW experiments in case of Blue GWs (BGWs) described by a power-law with a positive spectral index (nT > 0)

Chianese, Datta, Samanta and Saviano, arXiv:2405.00641

Example 2: Cosmic strings radiate detectable Gravitational Waves in models featuring high-scale symmetry breaking, e.g., high-scale leptogenesis.

We show that different flavored regimes of high-scale leptogenesis can be tested distinctly with the spectral features in cosmic string-radiated gravitational waves.

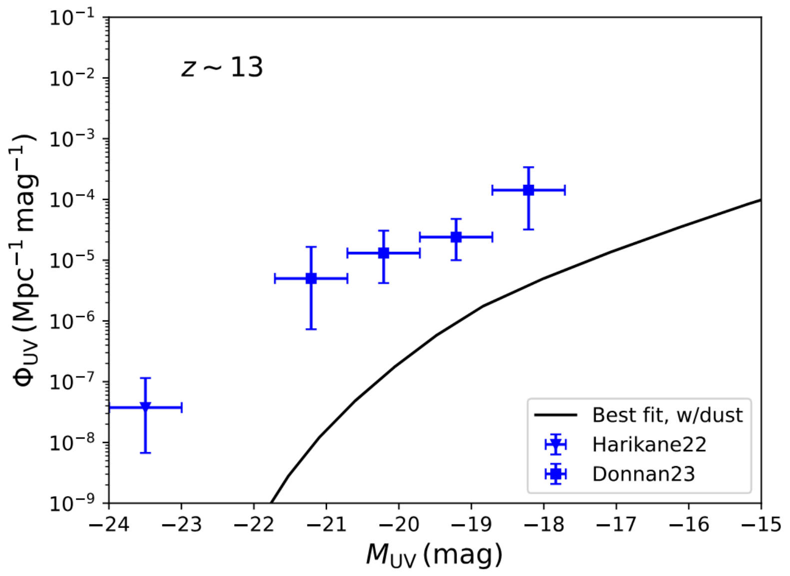
Chianese, Datta, Miele, Samanta and Saviano, arXiv:2406.01231

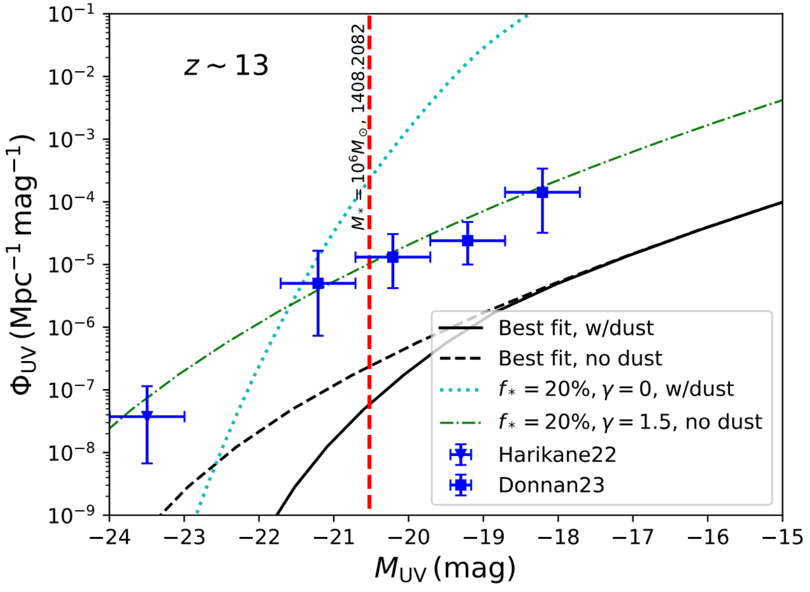


Compatibility of JWST results with exotic halos

Fabio Iocco, Luca Visinelli arXiV:2403.13068 Published in Physics of the Dark Universe

Results from JWST at z>10 seem in slight contrast with “standard” structure formation scenario. Can the friction be explained by exotic objects, such as “Dark Matter powered stars”?





This year, as part of the Archimedes experiment, the possibility of using the balance to detect (light) dark photons coupled with a B-L (J^{μ}_{B-L}) current was investigated:

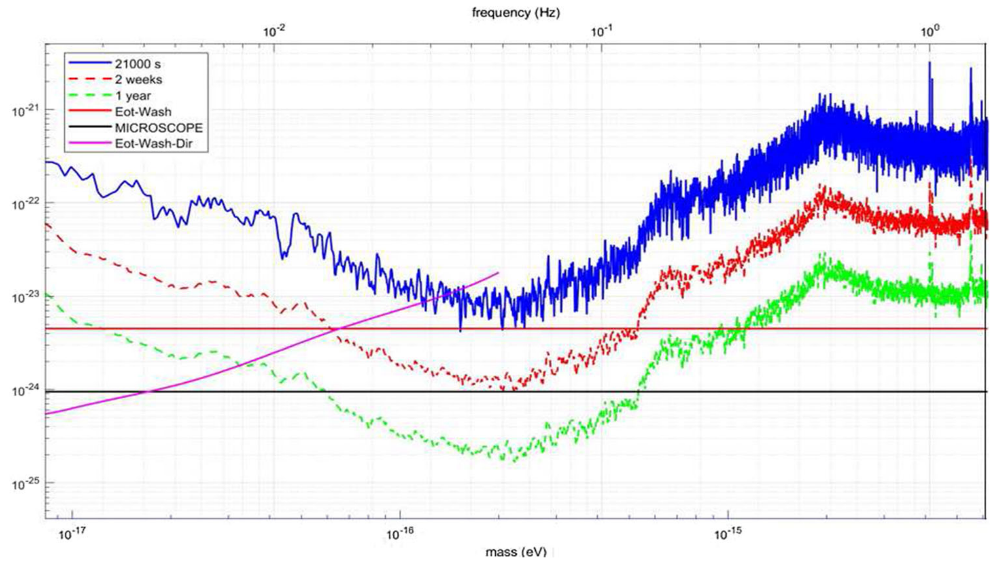
$$\mathscr{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}m_A^2 A_\mu A^\mu - \epsilon_{B-L} e J^{\mu}_{B-L} A_\mu$$

In order to make the apparatus sensitive to the B-L difference, the balance was equipped with a weight and counterweight made of different material in order to maximise the effect. The maximum sensitivity occurs in a mass range between 10^{-16} and $10^{-15} eV$.

An initial (very short) test run was carried out. The results (*Eur.Phys.J.Plus* 139 (2024) 2,158) are very promising to the point of planning new measures for next year.

The figure shows the results obtained and the forecast for the next runs

Fig. 7 Limits on coupling ϵ_{B-L} of the present experiment (blue curve) and expected limits with 2 weeks (red dashed) or one year (green dashed) integration time. The horizontal lines are the present limits from Eot-Wash (red) and MICROSCOPE (black) with free fall experiments and at low frequency limits from torsion balance direct search



Sorgenti astrofisiche (Marinelli)

- Studio della emissione adronica da regioni della Via Lattea ricche di nubi molecolari (Central Molecular Zone, Cigno…).
- Nuova stima della emissione diffusa di neutrini della nostra galassia e aggiornamento del modello "KRA-gamma".
- Analisi di tipo "template fitting" fra le nuove mappe di emissione Galattica di LHAASO e i dati dell'esperimento ANTARES.
- Nuovo studio della emissione di neutrini fino a redshift z=4 da galassie di tipo "starburst" utilizzando i nuovi dati di Fermi-LAT.
- Studio della emissione adronica nel jet di 1 kpc della galassia "Seyfert" NGC1068.