Marco Taoso
INFN-Torino

Istituto Nazionale di Fisica Nucleare

Theoretical Astroparticle Physics

TH retreat
11-12 November 2023

Theoretical Astroparticle Physics

Current members in Torino: A. Cuoco - M. Di Mauro - F. Donato - N. Fornengo - C. Giunti - L. Orusa - M. Regis - A. Rubiola - M. Taoso - E. Todarello

INFN Iniziativa Specifica **Theoretical Astroparticle Physics (TAsP)**

PI: Fiorenza Donato (UniTo)

12 nodes: Bari, Bologna, Ferrara, Lecce, LNF, LNGS, Napoli, Padova, Pisa, Roma1, Torino, Trieste

Research lines

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Main research lines of our group in Torino:

Dark Matter

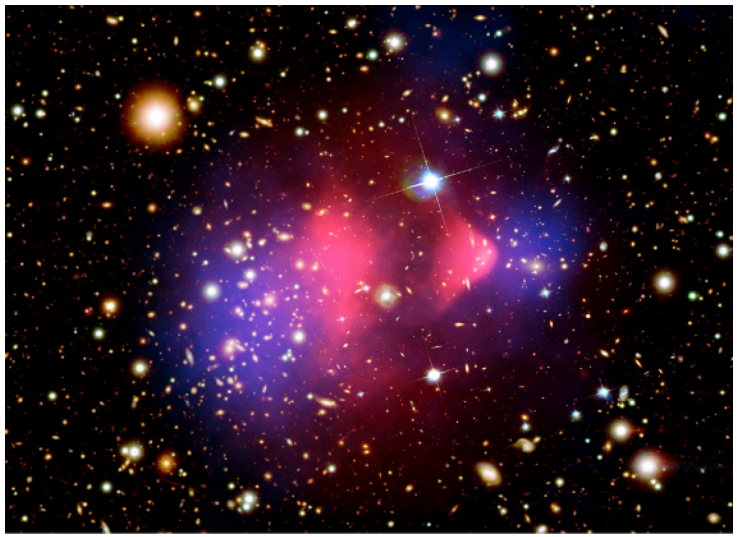
Neutrino Physics

Cosmic-rays and multi messenger astrophysics

Particle cosmology

Dark Matter

Dark Matter is out there!



Dark Matter

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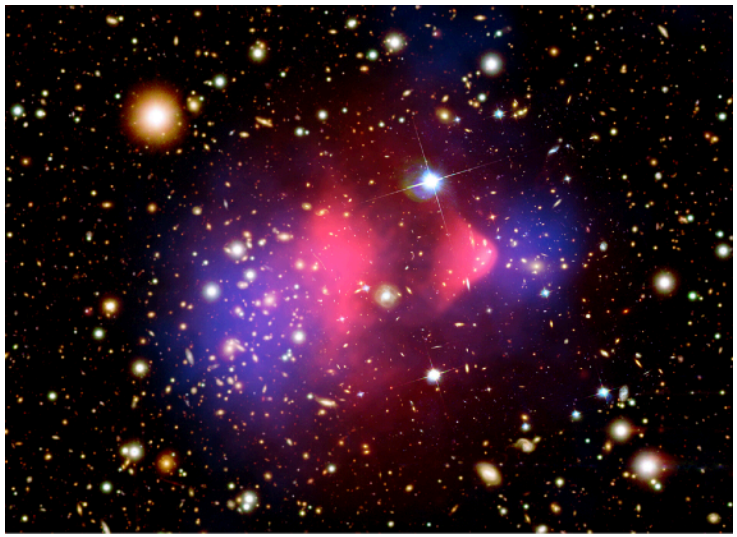
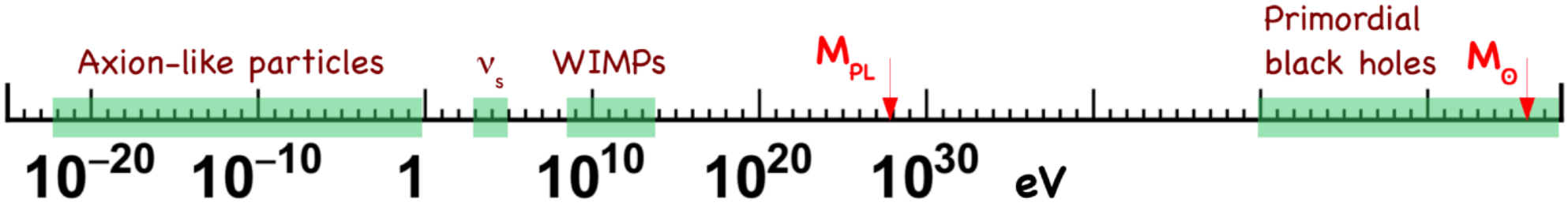


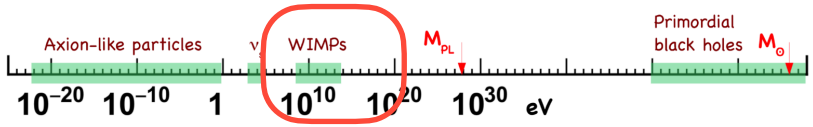
Mass range of dark matter candidates is largely unconstrained

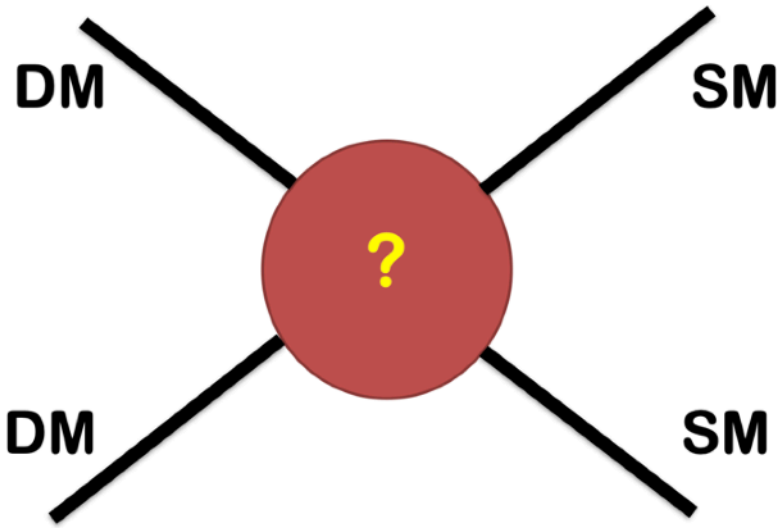


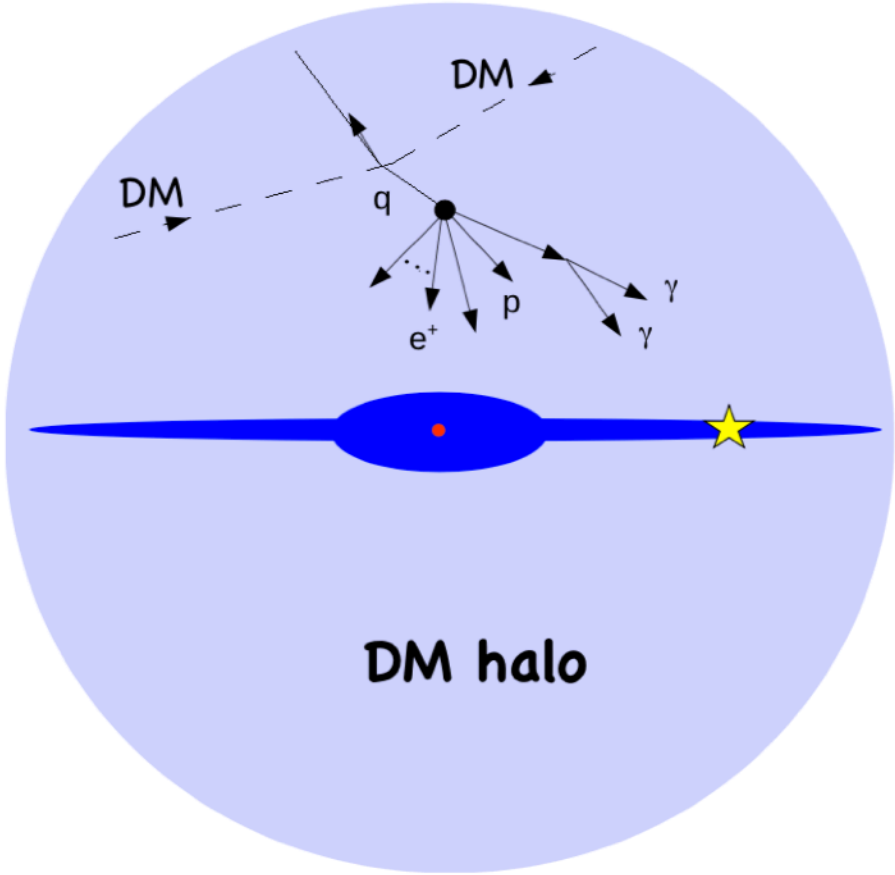
Annihilation and decay signals

Search for DM annihilations or decays products:

- **photons**
- **neutrinos**
- **anti-matter**: anti-protons, positrons, anti-nuclei







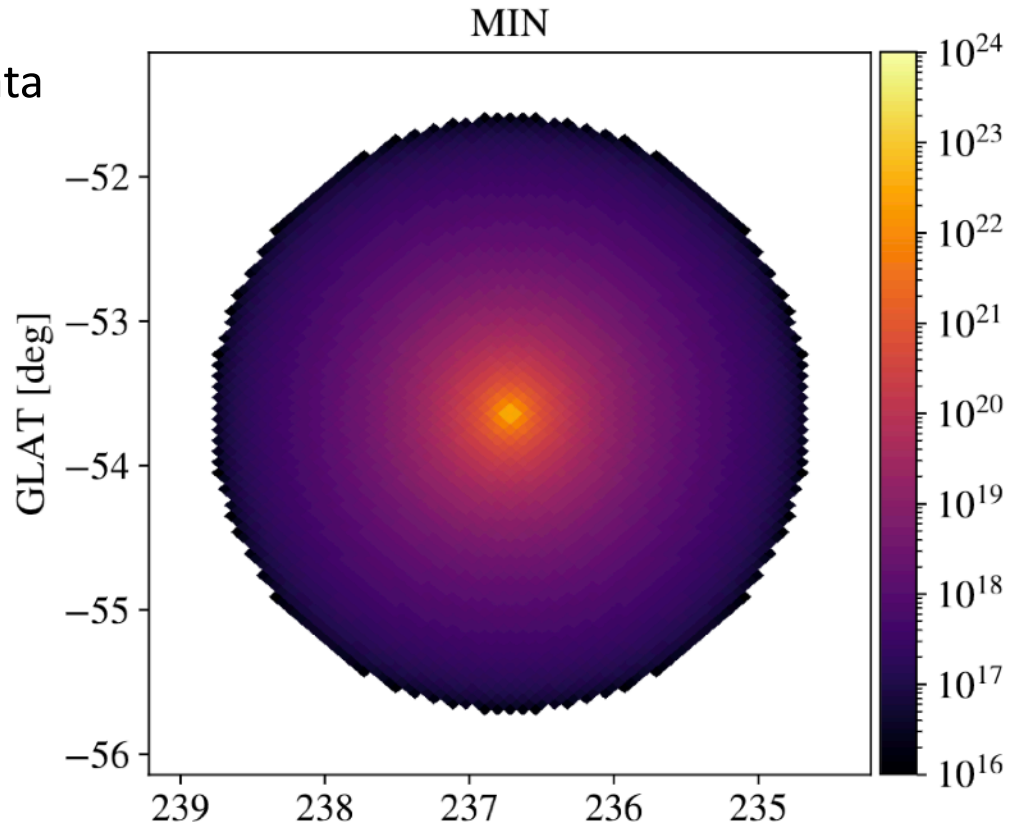
Annihilation and decay signals

Gamma-ray emission in clusters of galaxies: dark matter vs astrophysical emission

Galaxy clusters contains lots of dark matter! Among the best targets for indirect DM searches

Searches for DM signals with Fermi-LAT data

Di Mauro, Perez-Romero, Sanchez-Conde, Fornengo PRD 107 (2023) 8



Galactic center excess

An **excess of photons** detected by Fermi-LAT from the **galactic center**

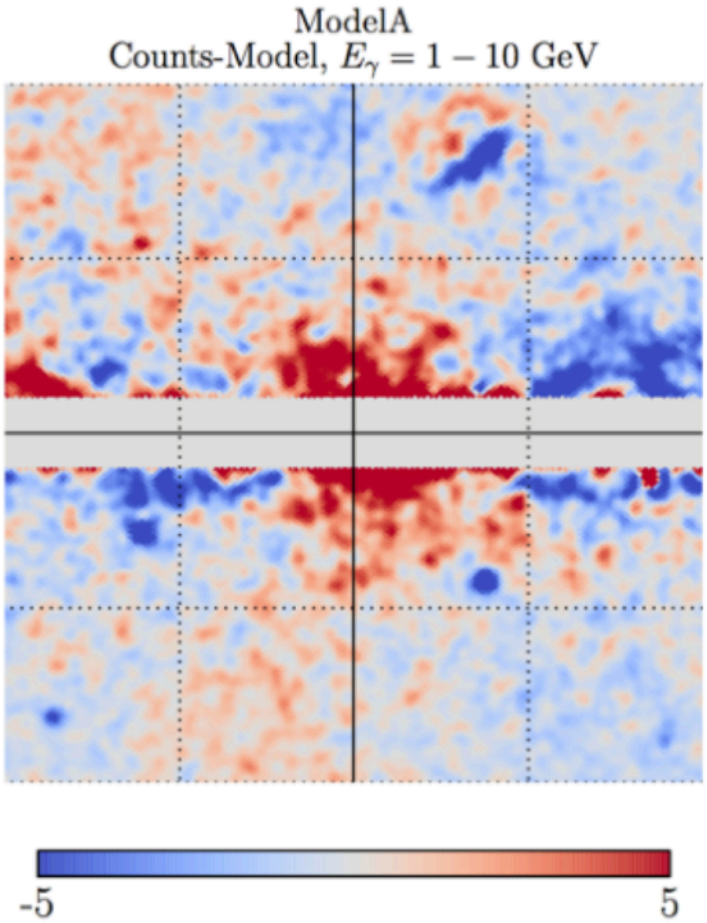
Characterise the galactic center excess and constrain the dark matter interpretation with multi messenger observations

Di Mauro, Winkler PRD 103 (2021) 12

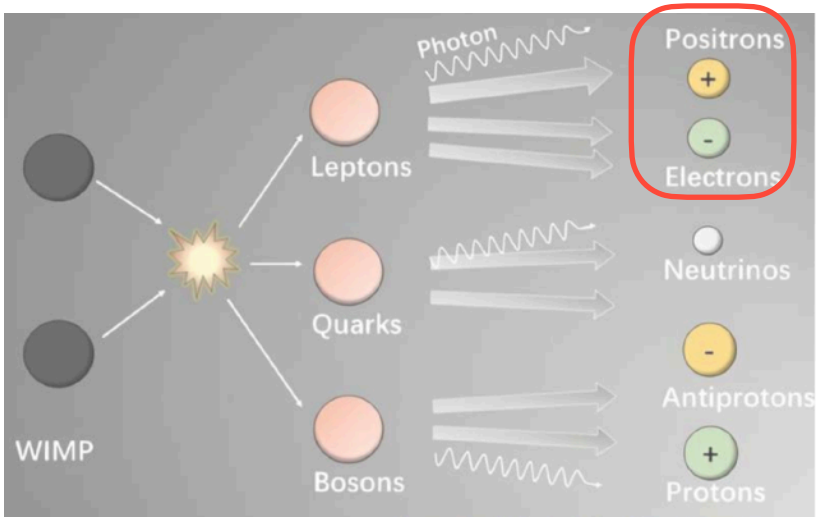
Dissecting the Galactic Center with pixel count statistics observations

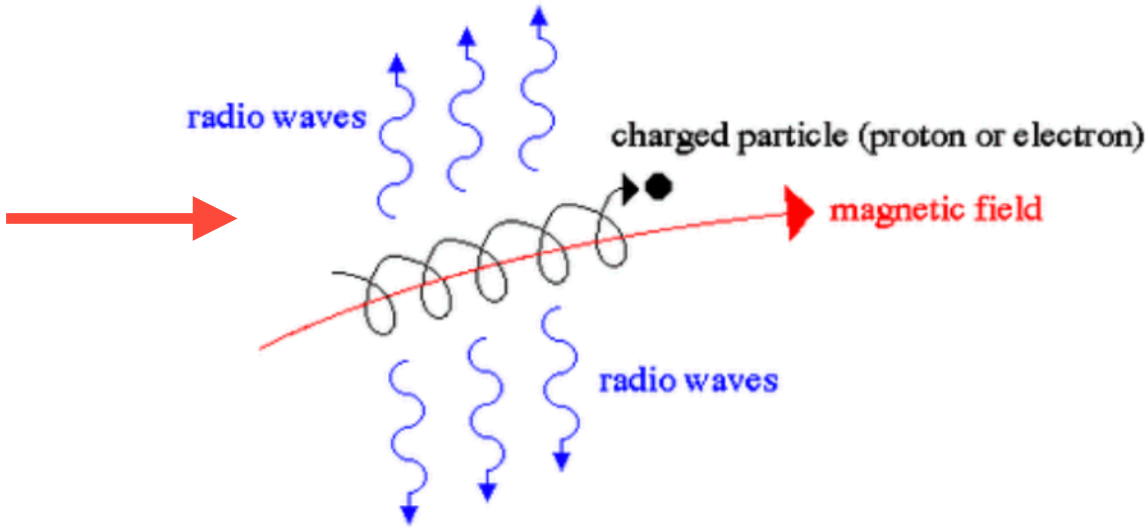
Calore, Donato, Manconi PRL 2022

Combine adaptive template fitting and pixel counts statistics to determine the nature of the excess



Secondaries emissions





Dark matter constraints from Planck observations of the Galactic polarized synchrotron emission

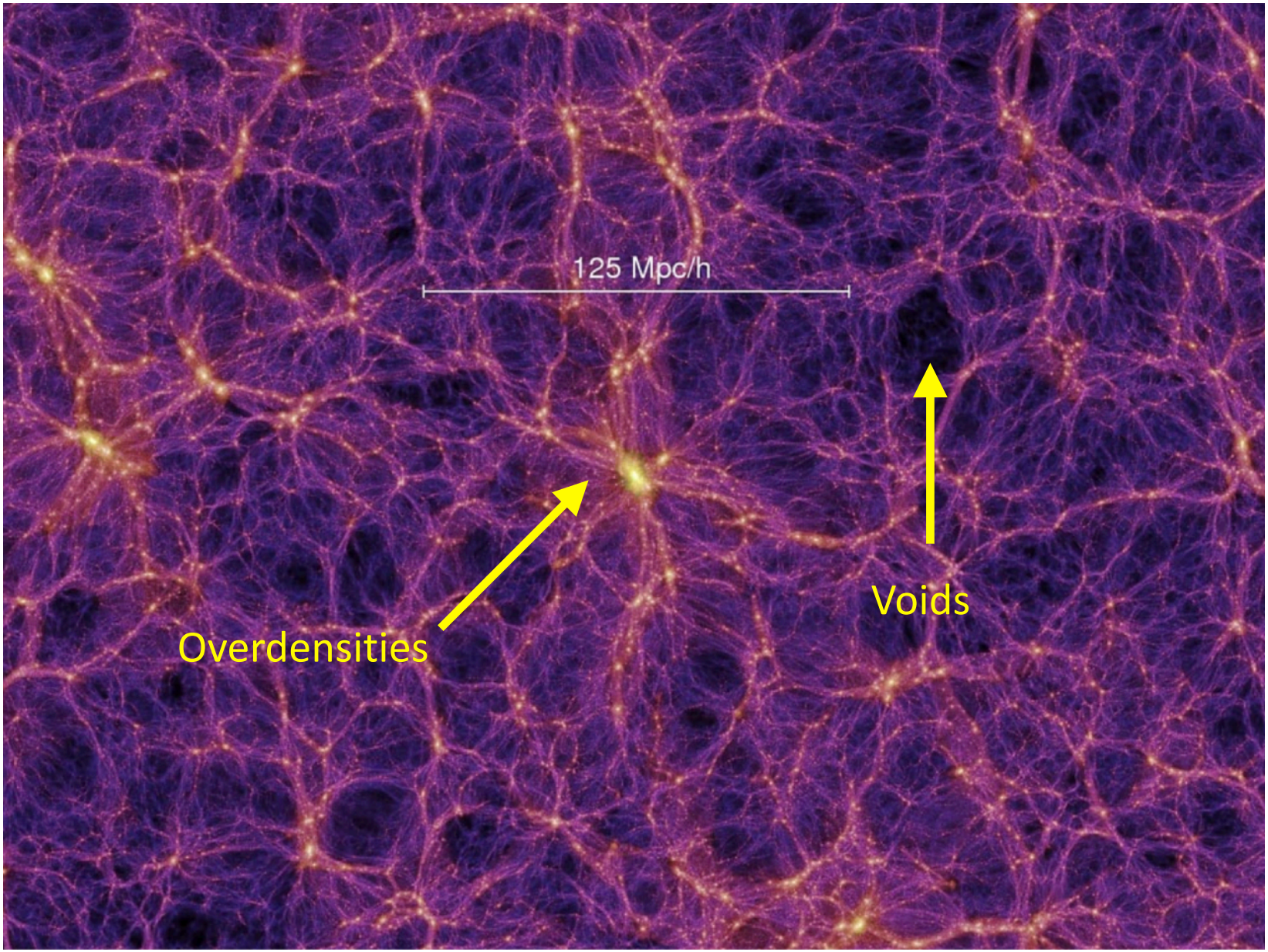
Manconi, Cuoco, Lesgourgues PRL 129 (2022) 11

How much electrons electrons diffuse inside structures? Crucial ingredient for the signal

Lower limit on confinement from **self-turbulence** on the magnetic field generated by the electrons themselves

Regis, Korsmeier, Bernardi, Pignataro, Reynoso-Cordova, Ullio JCAP 08 (2023) 030

Cross correlations



Cross correlations

Gravitational tracers **X** *Electromagnetic signals*

Galaxy catalogues
Weak lensing
Neutral hydrogen

Gamma-rays
X-rays
Radio waves
Infrared

DM searches through cosmic voids cross correlations

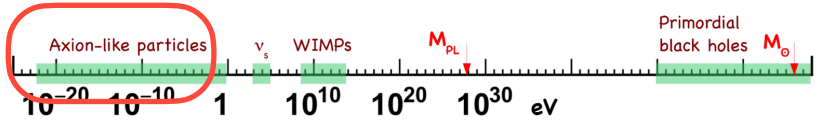
Arcari, Fornengo, Pinetti JCAP 11 (2022) 011

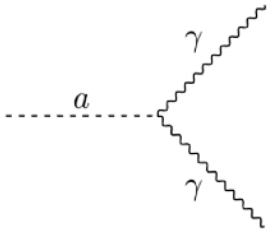
Enhancing DM cross-correlations signals with Wiener filtering

Camera, Fornengo, Rubiola

Axion-like particles

Axions originally introduced to solve the strong CP problem
Cold Dark Matter candidate!





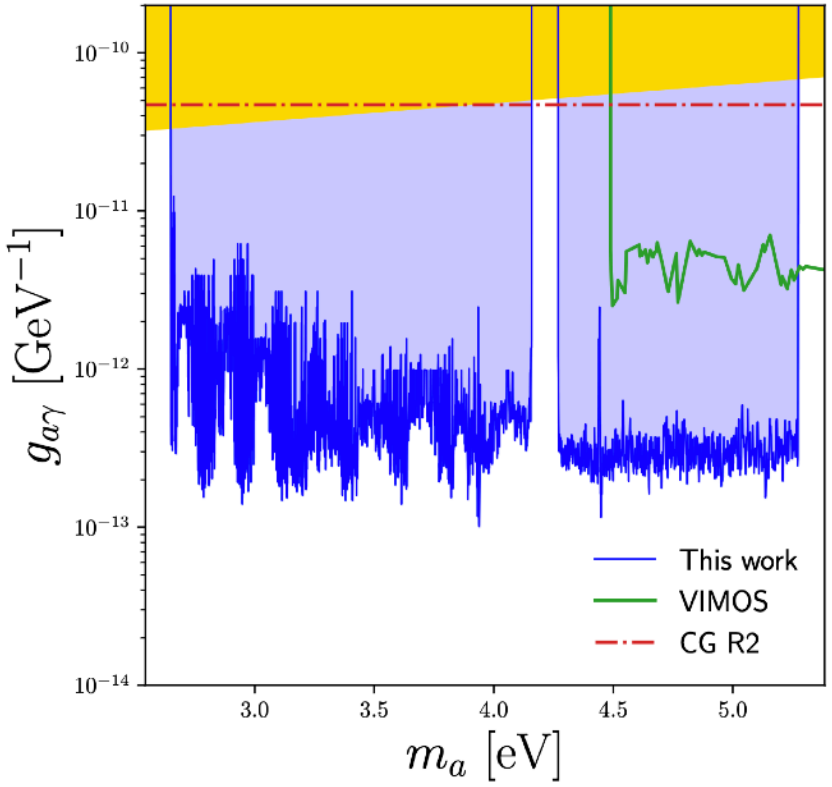
Axion couplings to photons $\mathcal{L} = \frac{1}{4} g_{a\gamma\gamma}\, a\, F_{\mu\nu}\tilde{F}_{\mu\nu} = -g_{a\gamma\gamma}\, a\, \vec{E}\cdot\vec{B}$

Search for axion decay with the optical observations of the MUSE-Faint Survey

Todarello, Regis, Taoso + MUSE 2307.07403

Stimulated decays of axions induced by astrophysical radio beams

Todarello, Regis, Calore 2311.00051



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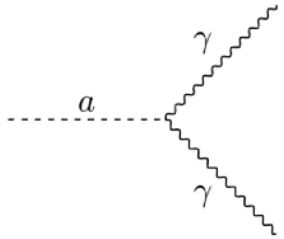

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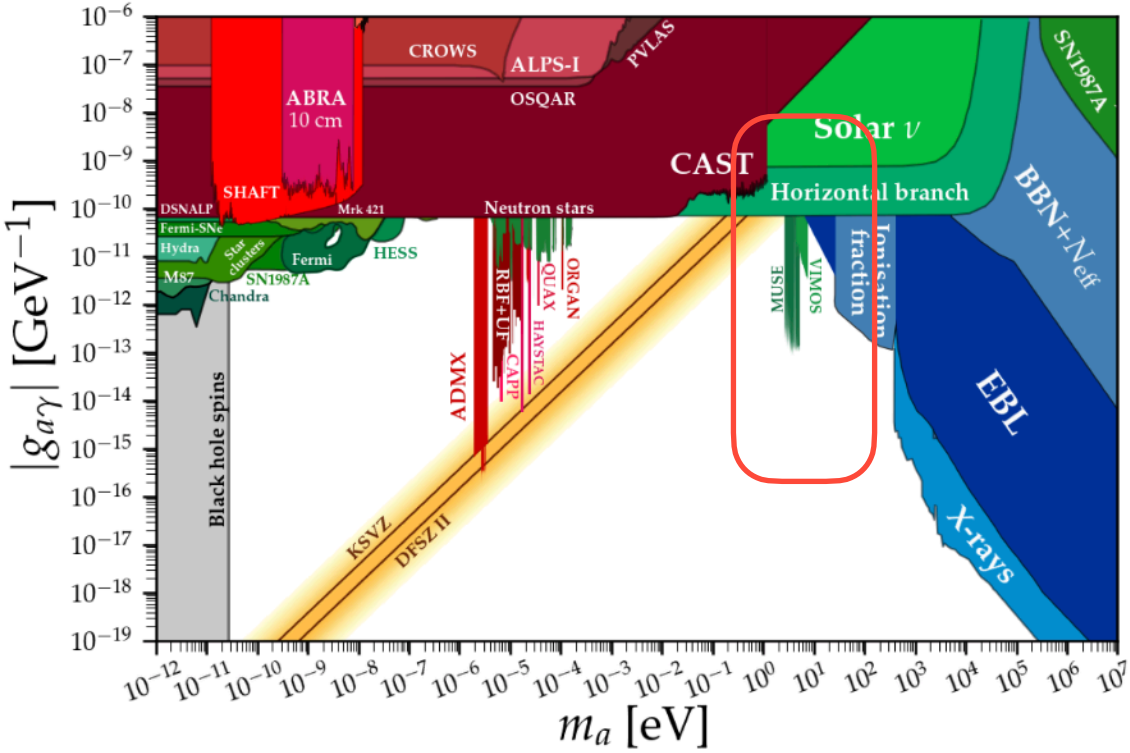
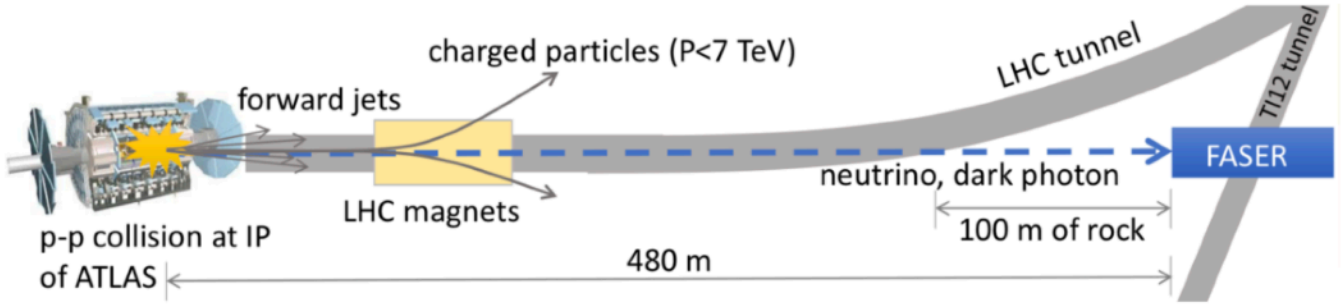


Dark sectors at accelerators

Dark sectors can contain **long-lived particles (LLPs)**

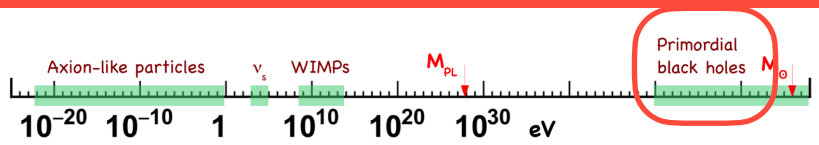
Probe LLPs and light dark sectors at dedicated LHC detectors, FASER + other proposals, and at beam dump experiments (NA64, NA62, SHiP, LDMX, nu-experiments…)



Probing decays of sterile neutrinos through dipole operators

Barducci, Bertuzzo, Taoso, Toni, JHEP 03 (2023) 239

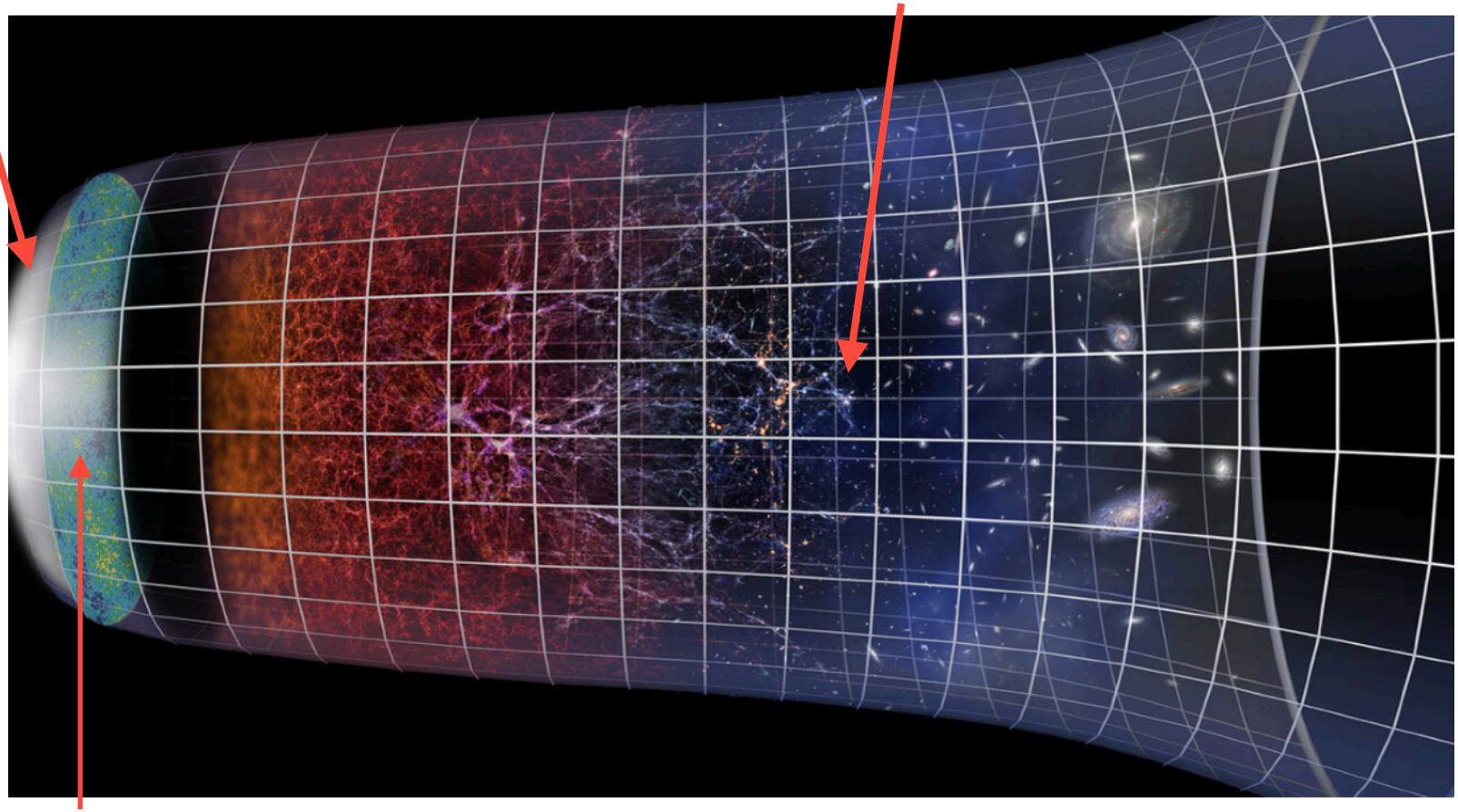
Primordial black-holes



Primordial black holes

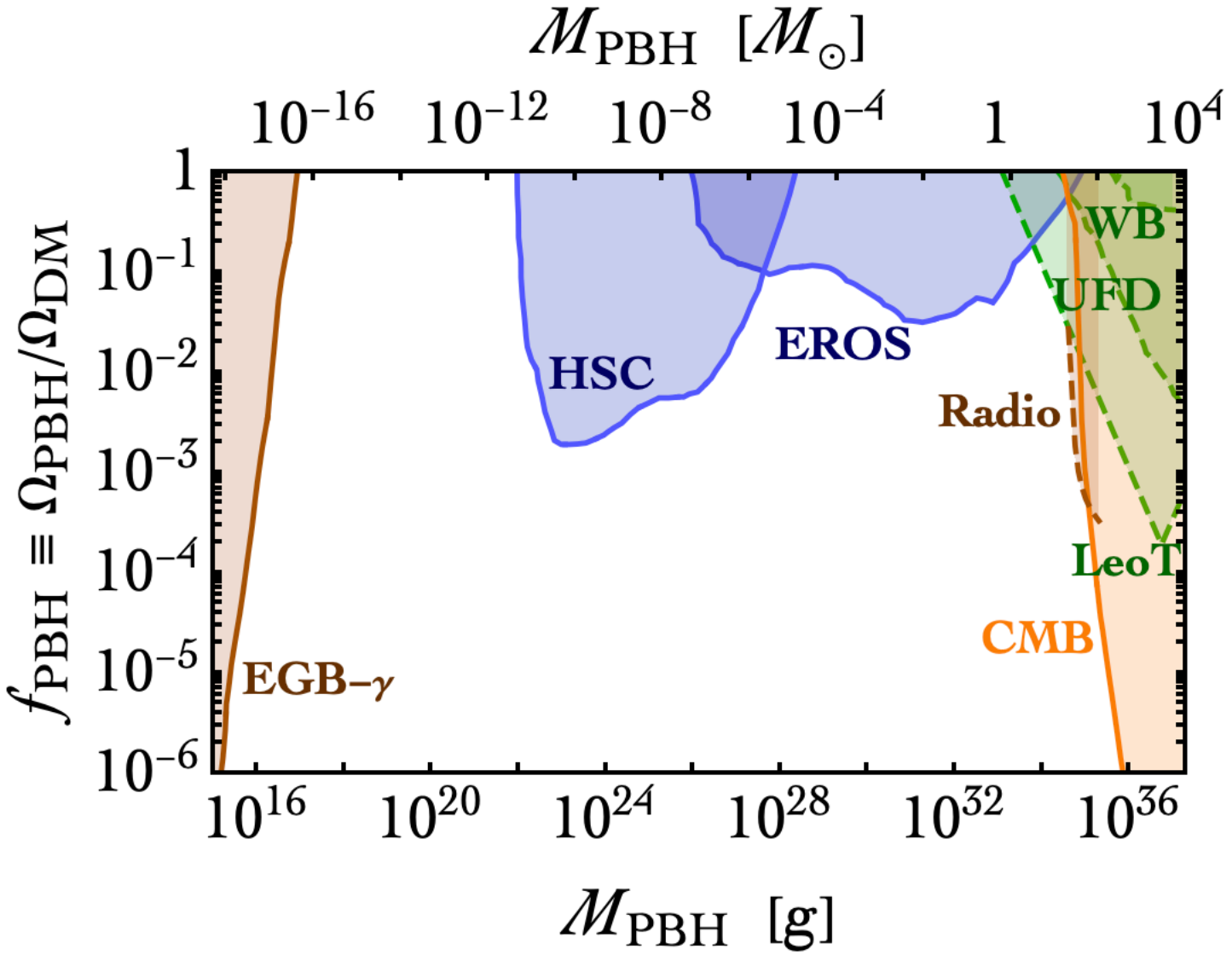
Astrophysical black holes

Inflation



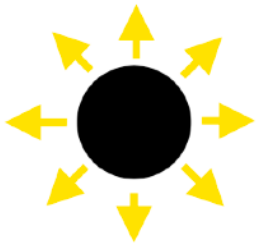
Cosmic Microwave background

Observational constraints

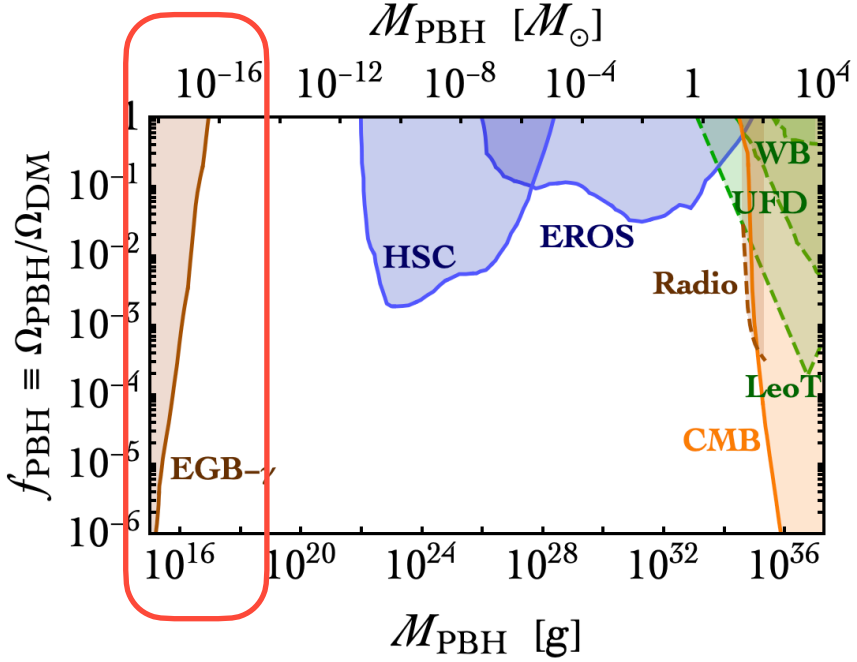


Observational constraints

Prospects for detection of photons from primordial black hole **evaporation** with the future gamma-ray mission COSI



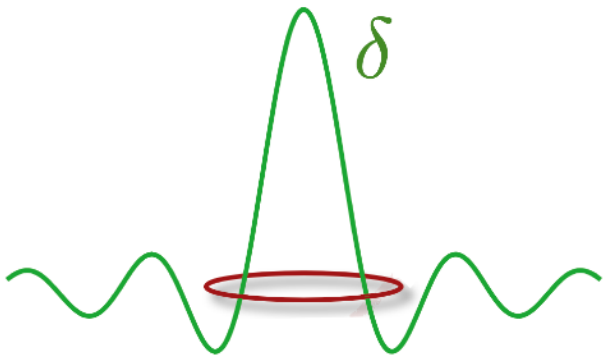
Caputo, Negro, Regis, Taoso JCAP 02 (2023) 006



Origin of the **primordial fluctuations** producing PBHs from an epoch of inflation

Franciolini, Irvine, Taoso, Urbano 2304.03491

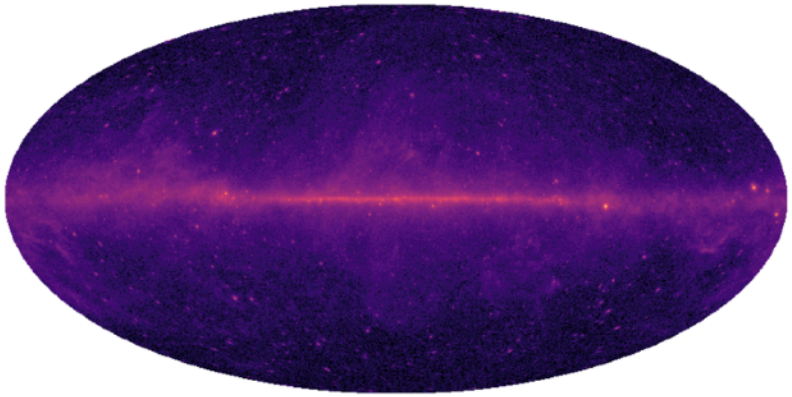
Riccardi, Taoso, Urbano JCAP 08 (2021) 016

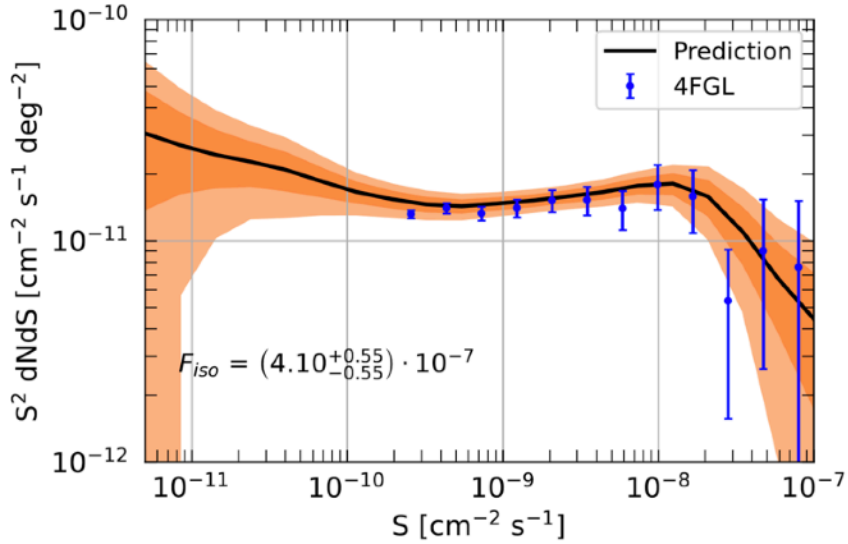


Machine learning for astrophysics

Extract the gamma-ray source-count distribution below the Fermi-LAT detection limit with **deep learning**

Amerio, Cuoco, Fornengo JCAP 09 (2023) 029





Constraining Below-threshold Radio Source Counts With Machine Learning

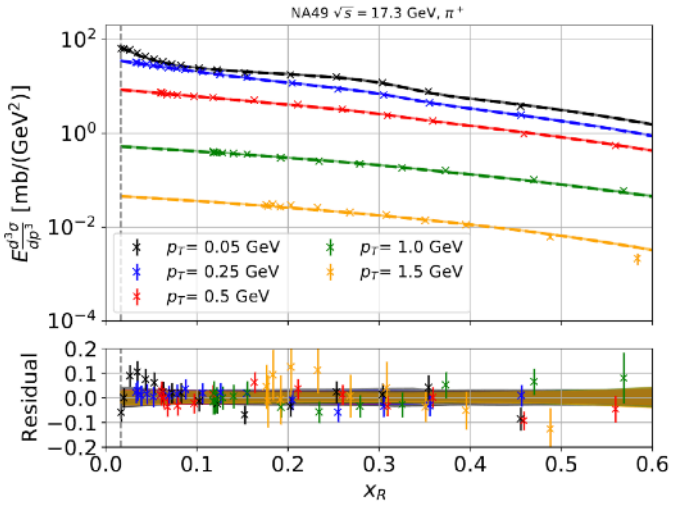
Todarello, Scaffidi, Regis, Taoso 2306.15720

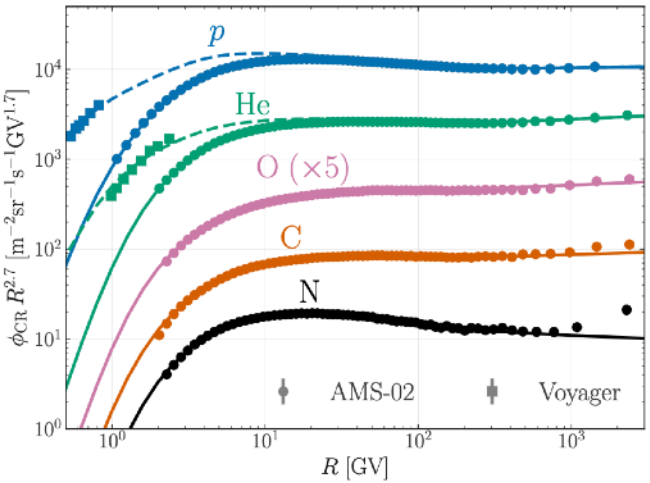
State of the art models for cosmic-rays

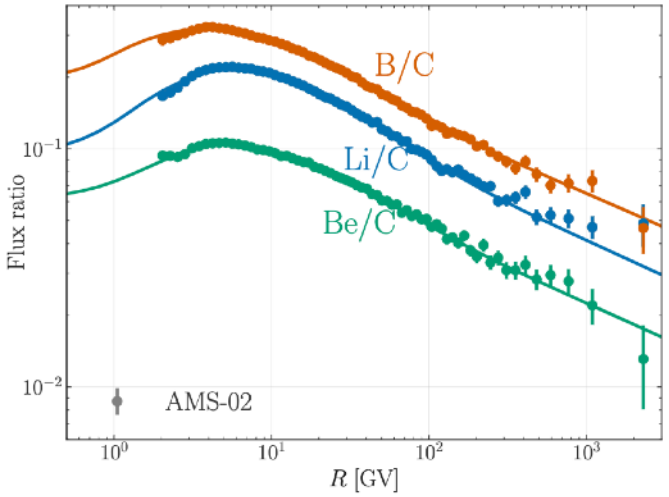
Determination of **cross-sections** for the production of e+,e-, gamma from inelastic collisions of cosmic-rays nuclei with the interstellar medium

Exploit data from laboratory experiments (NA49, NA61,CMS+…)

Orusa, Di Mauro, Donato, Korsmeier PRD 105 (2022) 12, PRD 108 (2023) 6







Neutrino physics

Neutrino oscillations proved that neutrinos are massive. Important **open questions**:

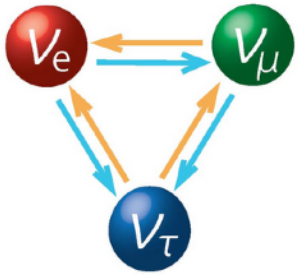
Are neutrinos Dirac or Majorana particles?
Which is the origin of neutrino masses and mixing?
Are there sterile neutrinos?

A combined analysis of experiments in the electron-neutrino sector rules out the sterile neutrino explanation of the Gallium anomaly

Giunti, Ternes et al. PLB 2023

Neutrinos and sterile neutrinos in cosmology

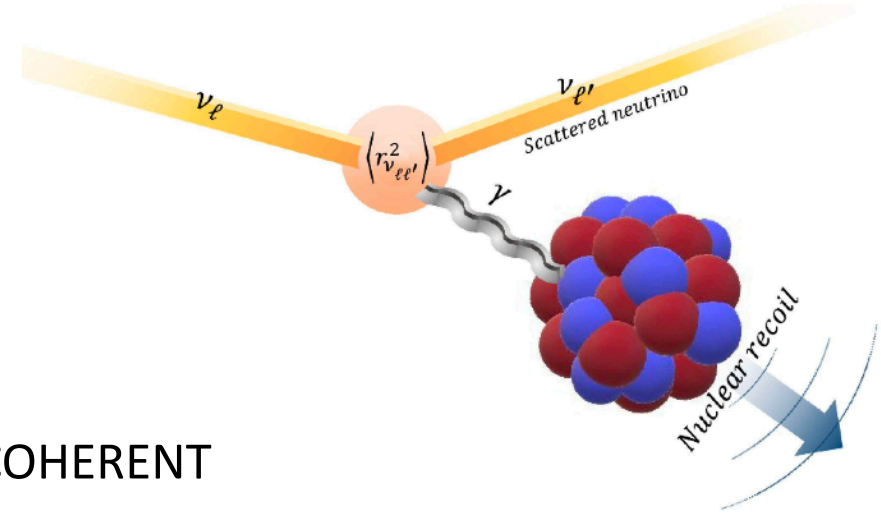
Gariazzo Giunti et al. JCAP 2022



Neutrino physics

Coherent Elastic Neutrino-Nucleus Scattering (CEvNS)

Observed in 2017 by the COHERENT experiment



Probe of:
- the nuclear neutron distribution
- neutrino Beyond the Standard Model interactions

Models with new light vector-boson mediators at COHERENT

Giunti, Ternes et al. JHEP 2022

Neutrino elastic scattering with electrons: data from dark matter direct detection experiments PandaX-4T, LZ and XENONnT

Giunti, Ternes et al. PRD 2023


THANKS