New Bounds on Monopoles from Cosmic Magnetic Fields

Speaker:
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DP, T. Kobayashi
Phys.Rev.D 106 (2022) 6, 063016

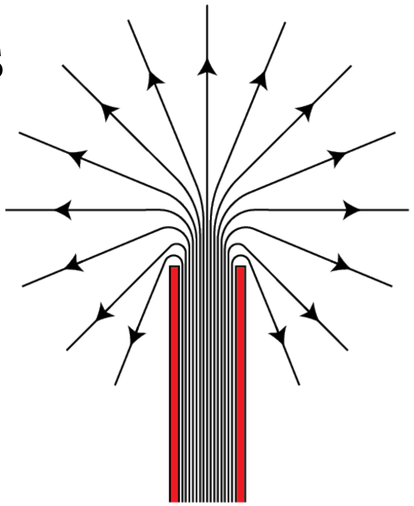
DP, K. Bondarenko, M. Doro, T. Kobayashi
arXiv:2401.00560

DP, M. Doro, T. Kobayashi
arXiv:2406.xxxxx

EuCAPT 2024 - 14/05/24

Can a Monopole Really Exist?

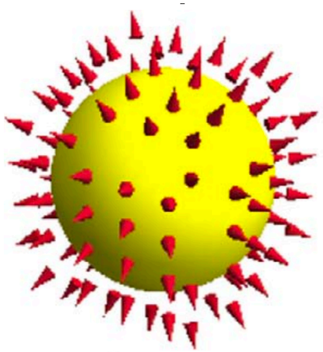
- In 1948 Dirac was the first to suppose the existence of magnetic monopoles as *semi-infinite string solenoids*.



- The existence of magnetic monopoles is consistent with quantum theory once imposed the *charge quantization condition*:

$$g = 2\pi n/e = n g_{\mathrm{D}}$$

  - In 1974 'T Hooft and Poliakov proposed a model of monopoles as *topological defects* linked to non-trivial second homotopy groups of the vacuum manifold:



$$G \to H,\ \pi_2(G/H) \neq \mathrm{I}$$

Monopoles are *inevitable predictions* of Grand Unified Theories

Magnetic fields and Parker Bounds

In 1970 Parker proposed a bound on the monopole flux from the observation of the Galactic magnetic fields:

- The Galactic magnetic fields accelerate the monopoles losing their energy;
- The survival of the fields provides a bound on the monopole flux today.

An analogous of the Parker bound can be derived from primordial magnetic fields.

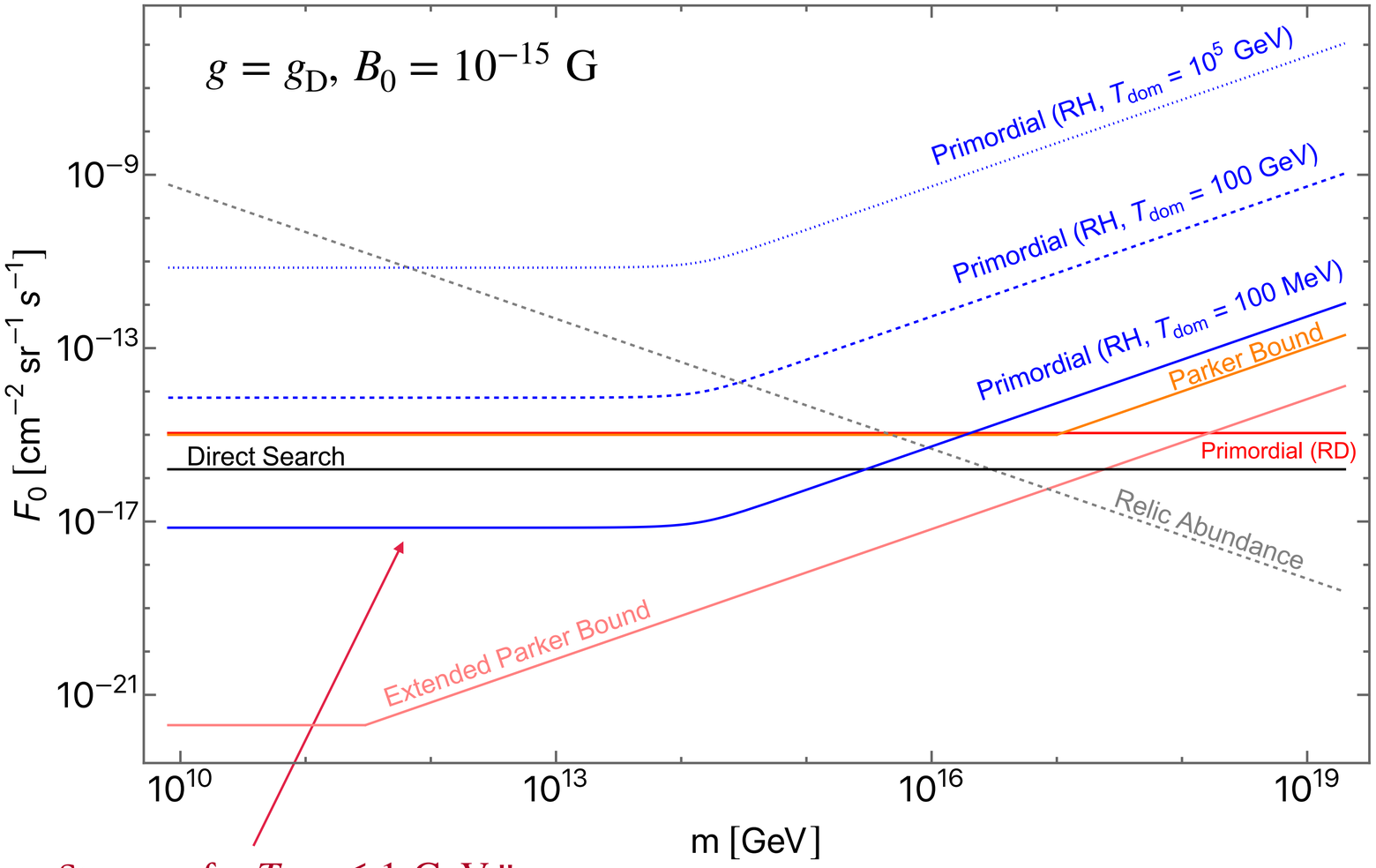
Long, Vachaspati (2015)
arXiv:1504.03319

$$\frac{\dot{\rho}_{\rm B}}{\rho_{\rm B}} = -\,\Pi_{\rm red} - \Pi_{\rm acc}$$

$$\Pi_{\rm red}(t) = 4H(t) \qquad \Pi_{\rm acc}(t) = \frac{4g}{B(t)} v(t) n(t)$$

Magnetic fields and Parker Bounds

The primordial magnetic fields survive under the condition $\Pi_{\rm acc}/\Pi_{\rm red} \lesssim 1$.



Stronger for $T_{\rm dom} \lesssim 1$ GeV !!

1) During radiation domination:

$$n_0 \lesssim \max\left\{ 10^{-21}\ {\rm cm}^{-3},\ 10^{-21}\ {\rm cm}^{-3} \left(\frac{m}{10^{19}\ {\rm GeV}}\right) \left(\frac{g_{\rm D}}{g}\right)^2 \right\}$$

2) During reheating:

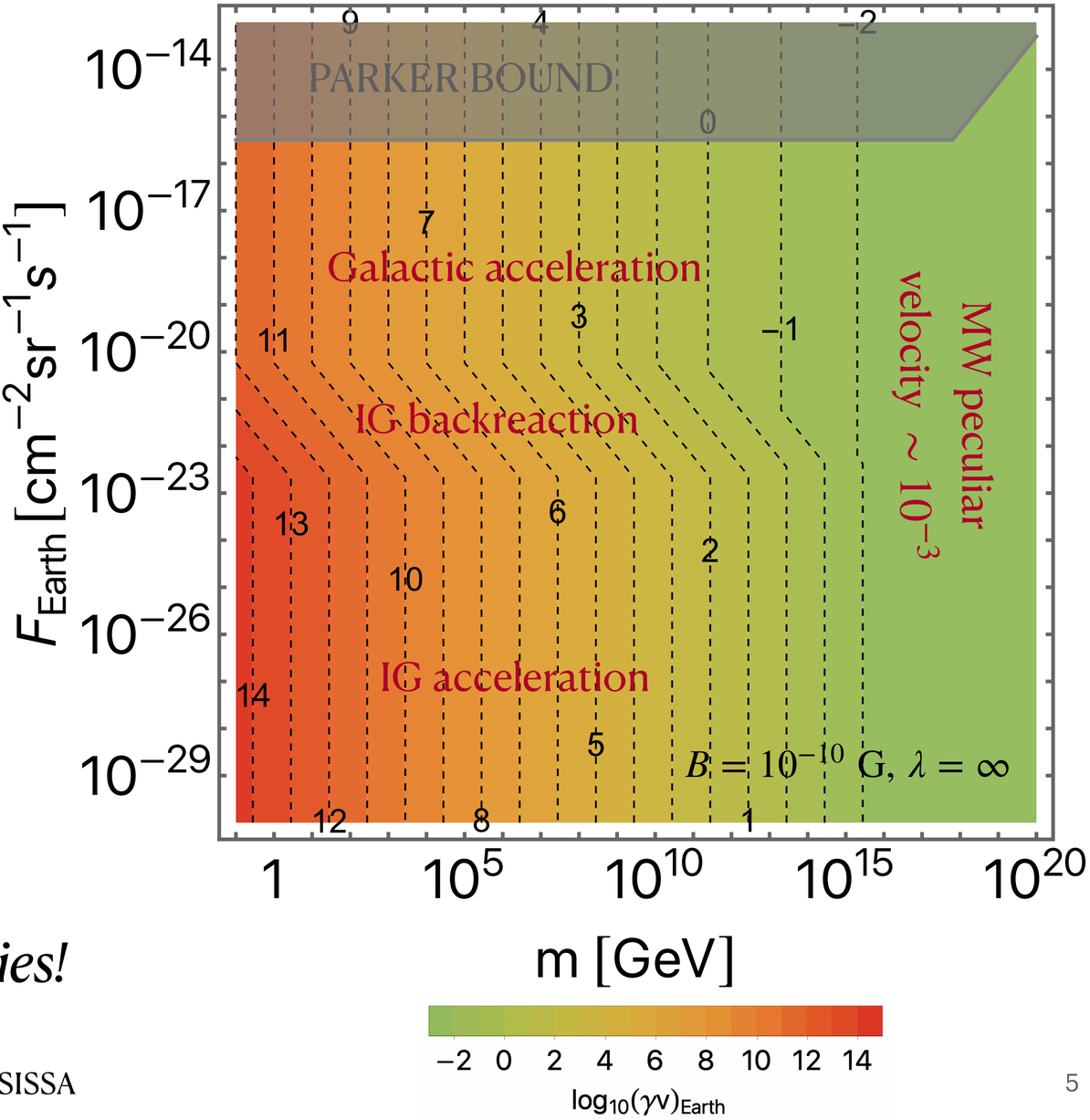
$$n_0 \lesssim \max\left\{ 10^{-16}\ {\rm cm}^{-3} \left(\frac{B_0}{10^{-15}\ {\rm G}}\right)^{3/5} \left(\frac{T_{\rm dom}}{10^{6}\ {\rm GeV}}\right) \left(\frac{g_{\rm D}}{g}\right)^{3/5},\right.$$
$$\left. 10^{-16}\ {\rm cm}^{-3} \left(\frac{m}{10^{14}\ {\rm GeV}}\right) \left(\frac{T_{\rm dom}}{10^{6}\ {\rm GeV}}\right) \left(\frac{g_{\rm D}}{g}\right)^2 \right\}$$

Acceleration in Intergalactic Magnetic Fields

In literature the monopole velocity on Earth is usually assumed to be comparable to the MW peculiar velocity $\sim 10^{-3}$.

However intergalactic and Galactic magnetic fields accelerate the monopoles:

$$m\frac{d}{dt}(\gamma v) = gB$$



Monopoles can be accelerated to relativistic velocities!

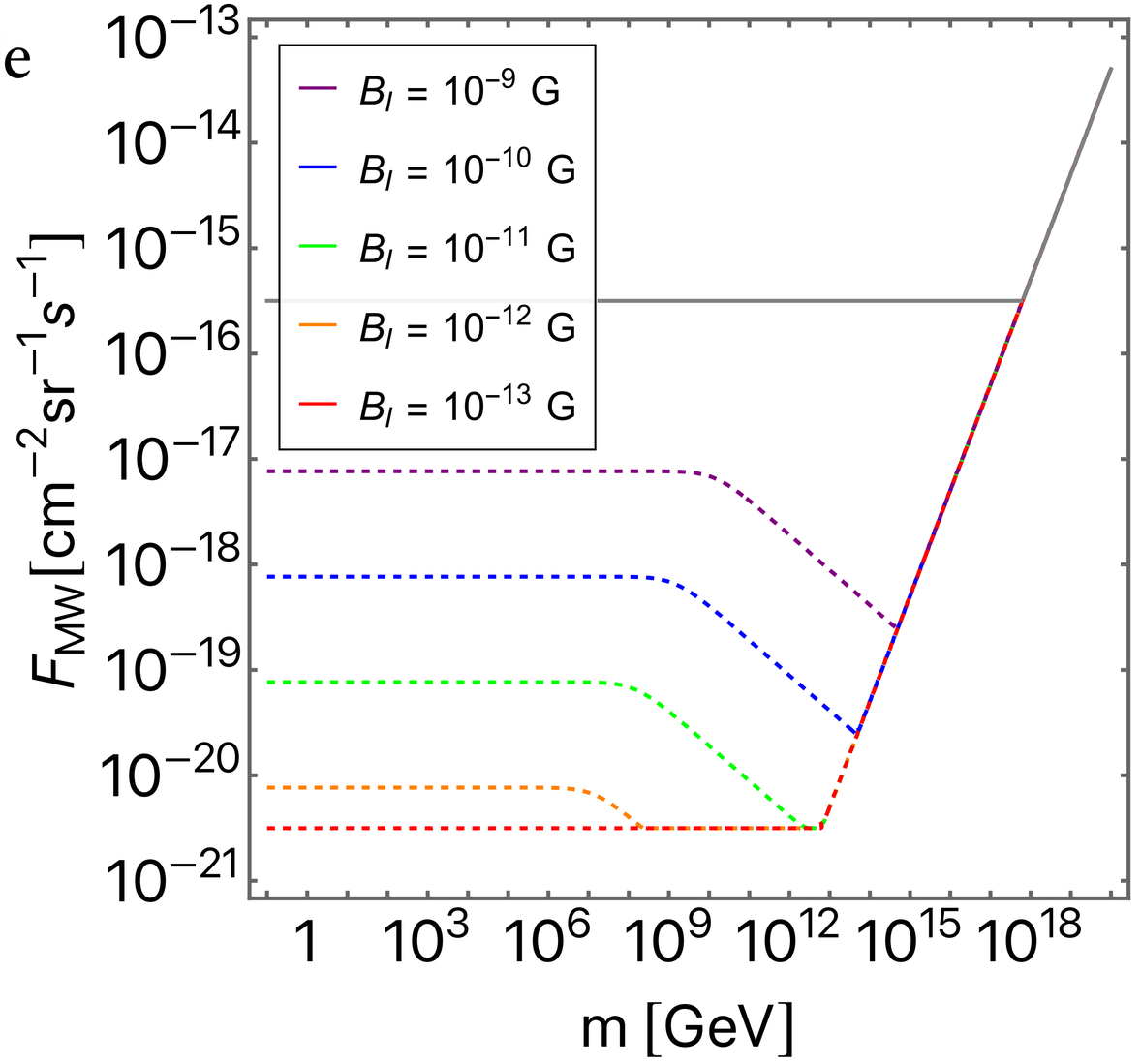
Modification of Galactic Parker bounds

Galactic Parker bounds depend on the monopole incident velocity on the Milky Way.

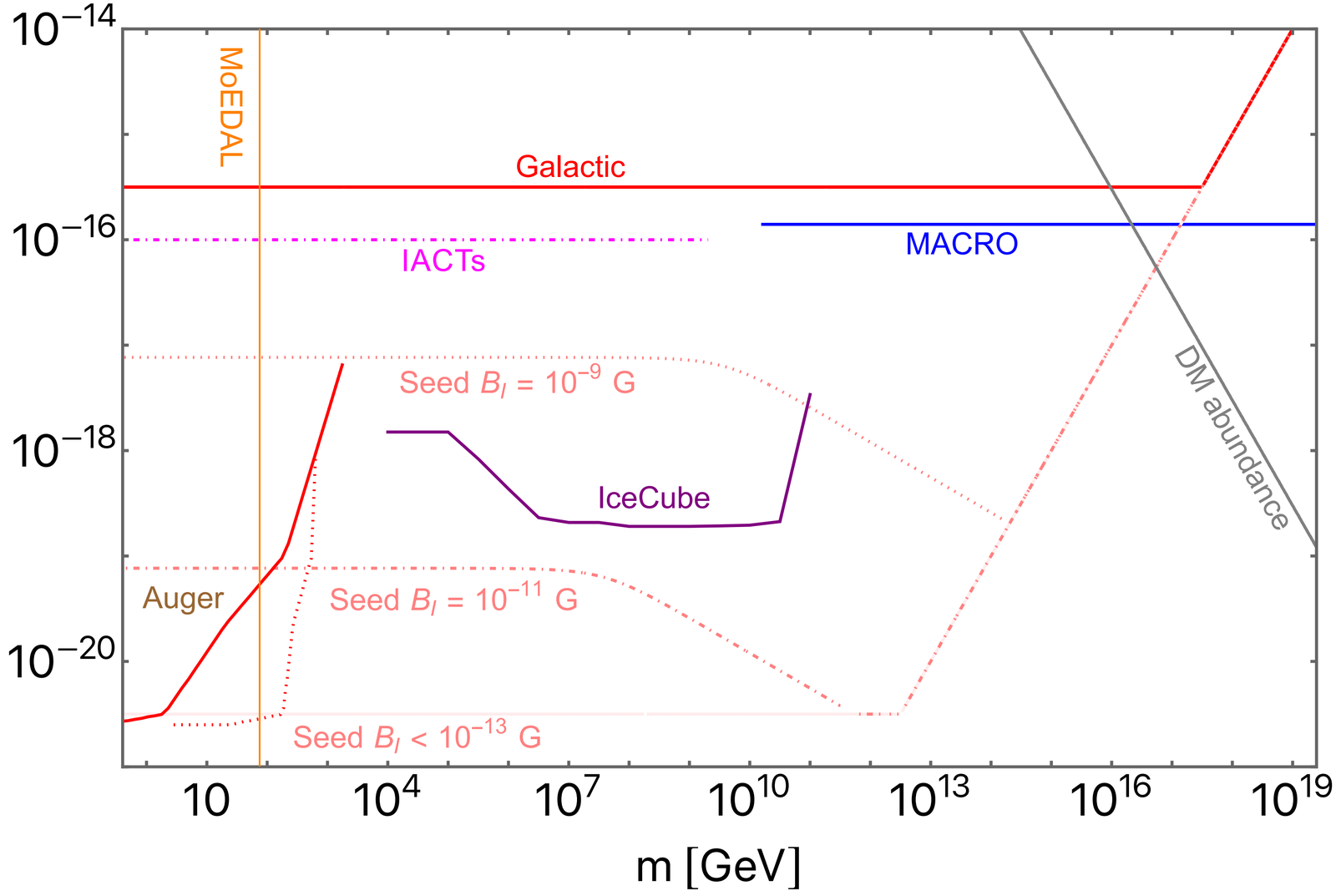
The bounds are weakened for very large values of the monopole velocity:

1. *The Galactic bound is not affected by acceleration in intergalactic magnetic fields.*

2. *The seed Galactic bound is strongly affected by the acceleration.*



Recasting bounds from experiments



- Many experiments (ex. IceCube, Auger) put bounds in terms of the velocity at the detector.
- The bounds can be recasted in terms of the mass once an acceleration mechanism is fixed.

Monopole acceleration drastically affects the bounds on the flux (search with cosmic rays detectors!)

Thank You!!

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