New Bounds on Monopoles from Cosmic Magnetic Fields [arXiv:2207.08246, 2401.00560, 2406.XXXXX]

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1. Introduction

Magnetic monopoles are elusive objects very strongly motivated from the theoretical point of view. In literature, it is usually assumed for the monopoles a velocity comparable to the proper motion of the Milky Way. We show that in the presence of intergalactic and Galactic magnetic fields the monopoles can reach relativistic velocities. We then discuss how this affects indirect and direct bounds on the monopole flux. We also show that if the intergalactic magnetic fields have a primordial origin we can infer additional bounds on the monopole flux. This work is based on [1, 2, 3]

2. Monopoles and magnetic fields

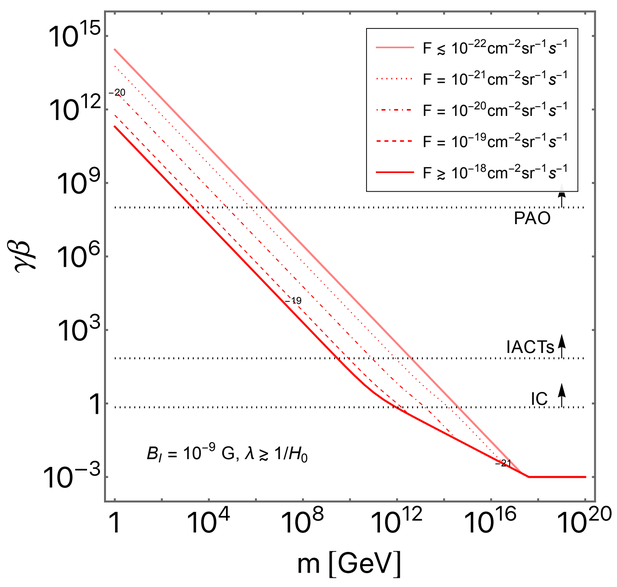
Magnetic monopoles (MMs) with mass m and charge g are accelerated in cosmic voids by magnetic fields as

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

At cosmic scales, the most relevant contributions are those from **intergalactic magnetic fields (IGMFs)** in the cosmic voids (acceleration on large distances) and **Galactic magnetic fields (GMFs)** (acceleration in strong fields).

3. Acceleration in cosmic fields

We study MM acceleration in IGMFs and GMFs.

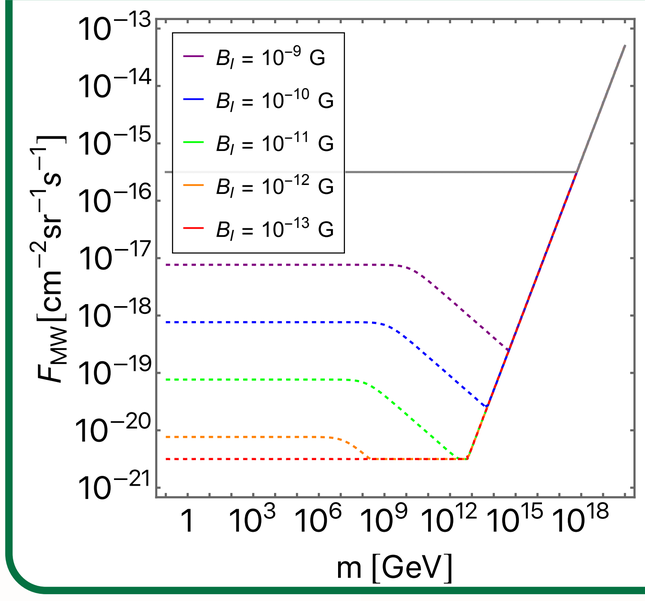


Acceleration in IGMFs depends on the MM flux when the flux is large enough to cause **back-reaction on the fields** (dotted and dashed curves). For smaller fluxes the velocity is flux independent (pink curve).

For large fluxes the velocity is set by the Galactic acceleration (red curve). The Galactic contribution is always dominant for

$$B_{\rm I} \lesssim 5\times 10^{-11}\left(\frac{1\ {\rm Mpc}}{\min\left(\lambda_{\rm I}, 1/H_0\right)}\right)^{1/2}.$$

4. Modification of the Galactic Parker bounds



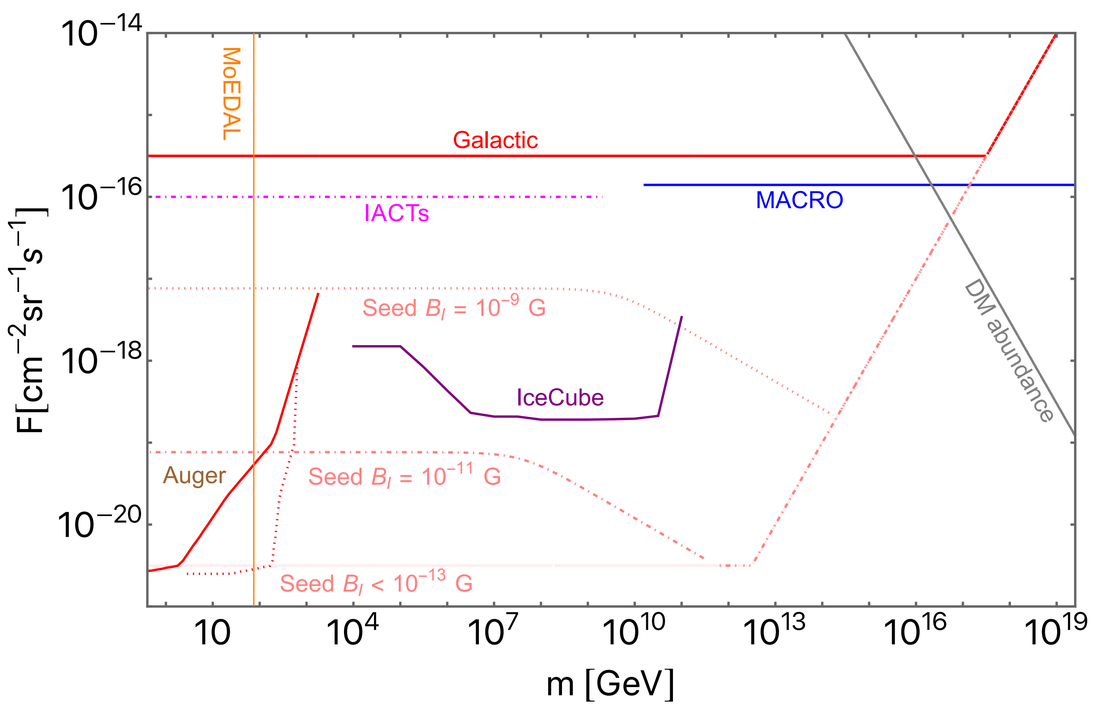
The survival of the GMFs allowed Parker [4] to obtain upper bounds on the MM flux. The **Parker bounds** depends on the velocity of the MMs at the entrance of the Milky Way.

In literature, the MM velocity is often the peculiar velocity of the Milky Way $\sim 10^{-3}$. However, Parker bounds are **sensible to the acceleration in the IGMFs**.

In particular, the bounds obtained from the survival of the Galactic seed field are **significantly relaxed** for IGMFs with $B_I > 10^{-13}$ G.

5. Modification of terrestrial bounds

Terrestrial experiments often put bounds on the MM flux in function of the MM velocity. Once a model for the MM acceleration is assumed, taking into account the characteristics of the experiments, we **recast the limits in terms of the MM mass**.



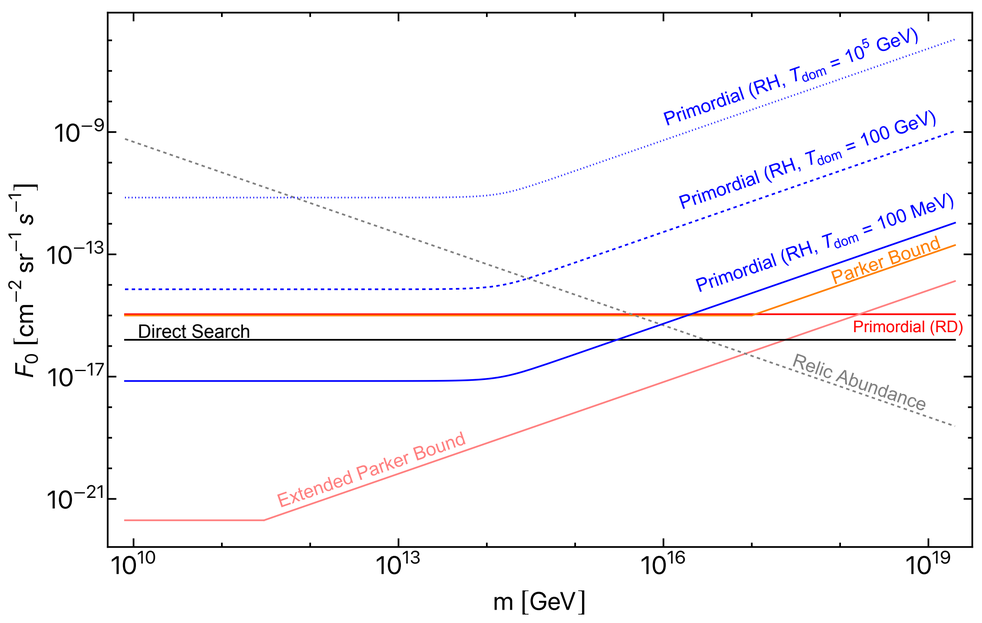
Most of the experiments are only sensible to the Galactic acceleration. However, PAO is capable to test flux regions where the acceleration is dominated by the IGMFs (brown dotted curve). Increasing the statistics or the sensibility will help in the future in **testing the IGMFs**.

6. Bounds on the monopole flux from primordial fields

The equation of motion in a FRW metric from the time of the primordial magnetic field generation to the epoch of e^+e^- annihilation is:

$$m\frac{d}{dt}(\gamma v) = gB - (f_{\rm p} + mH\gamma)\,v,$$

where $-f_{\rm p}v$ is the **frictional force** for the interactions with the particles of the primordial plasma.



If IGMFs have **primordial origins**, from their survival we derive new bounds. During radiation domination the result is the same of [5] (red line). During reheating the new bounds depend on the temperature at the end of reheating, $T_{\rm dom}$ (blue lines).

We assume **thermal equilibrium for the plasma** during the reheating epoch, but stronger bounds can be obtained without this assumption.

8. References

[1] Kobayashi and Perri. Parker bound and monopole pair production from primordial magnetic fields. *Phys. Rev. D*, 106(6):063016, 2022.

[2] Doro Perri, Bondarenko and Kobayashi. Monopole acceleration in intergalactic magnetic fields. arXiv:2401.00560 2023.

[3] Doro Perri and Kobayashi. Revisiting experimental bounds on magnetic monopoles due to cosmic acceleration. In Prep. 2024.

[4] Parker. The Origin of Magnetic Fields. *Astrophys. J.*, 160:383, 1970.

[5] Long and Vachaspati. Implications of a primordial magnetic field for magnetic monopoles, axions and dirac neutrinos. *Phys. Rev. Lett. D*, 91:103522, 2015.