Cosmological Constraints on Magnetic Monopoles as Accelerating Dark Matter

In preparation

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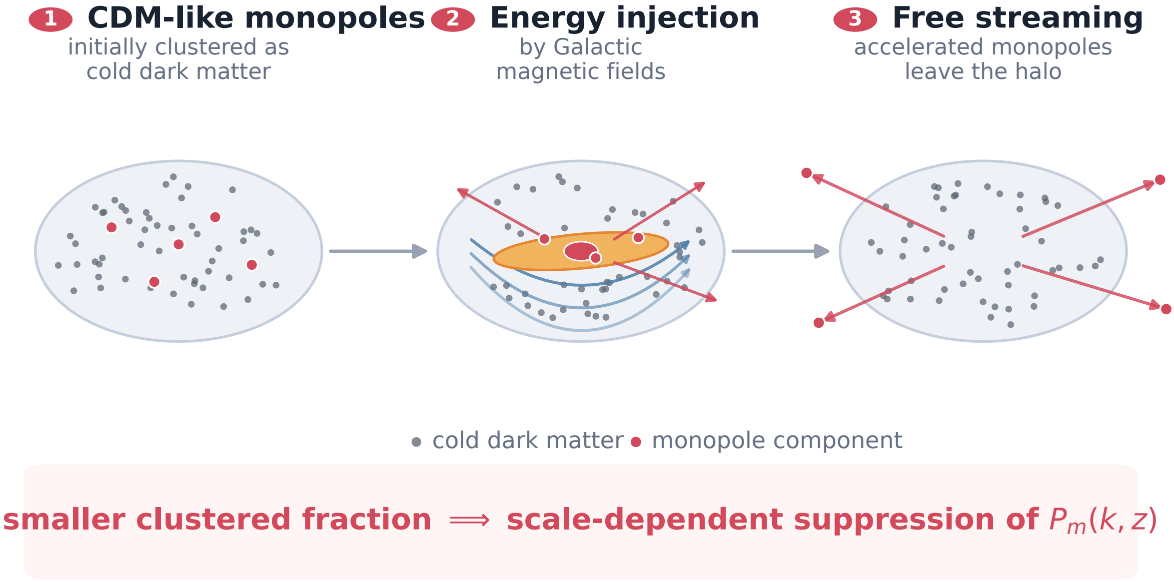


1 CDM-like monopoles
initially clustered as
cold dark matter
2 Energy injection
by Galactic
magnetic fields
3 Free streaming
accelerated monopoles
leave the halo
cold dark matter
monopole component
smaller clustered fraction $\Longrightarrow$ scale-dependent suppression of $P_m(k,z)$

Late-time acceleration model

Cold-component density

$$\rho_{\text{cdm}}(a) = \frac{\rho^0_{\text{cdm}}}{a^3}\left[1 + f_{\text{acc}}\frac{1 - a^{\kappa}}{1 + (a/a_t)^{\kappa}}\right].$$

$$(a^3\rho_{\text{cdm}})_{\text{early}} = (1 + f_{\text{acc}})(a^3\rho_{\text{cdm}})_{\text{today}}$$

f_{acc}	a_t	κ	η
transfer amplitude	transition epoch	transition sharpness	kinetic-energy gain

Energy: $E_{\text{acc}} = m_{\text{acc}}(1 + \eta)$ **Consistency:** $\eta m_{\text{acc}} \ll \rho_{\text{crit}}(a_{\text{acc}})H^{-3}_{\text{acc}}$.

The density history determines $Q^{(0)}$

$$Q^{(0)}(a) = \frac{H(a)\,\kappa\rho^0_{\mathsf{cdm}}}{a^3}\, f_{\mathsf{acc}} \frac{a^\kappa + (a/a_t)^\kappa}{[1+(a/a_t)^\kappa]^2}.$$

Background transfer

$$\dot\rho_{\mathsf{cdm}} + 3\mathcal{H}\,\rho_{\mathsf{cdm}} = -aQ^{(0)},$$
$$\dot\rho_{\mathsf{acc}} + 3\mathcal{H}(1+w)\rho_{\mathsf{acc}} = (1+\eta)aQ^{(0)}.$$

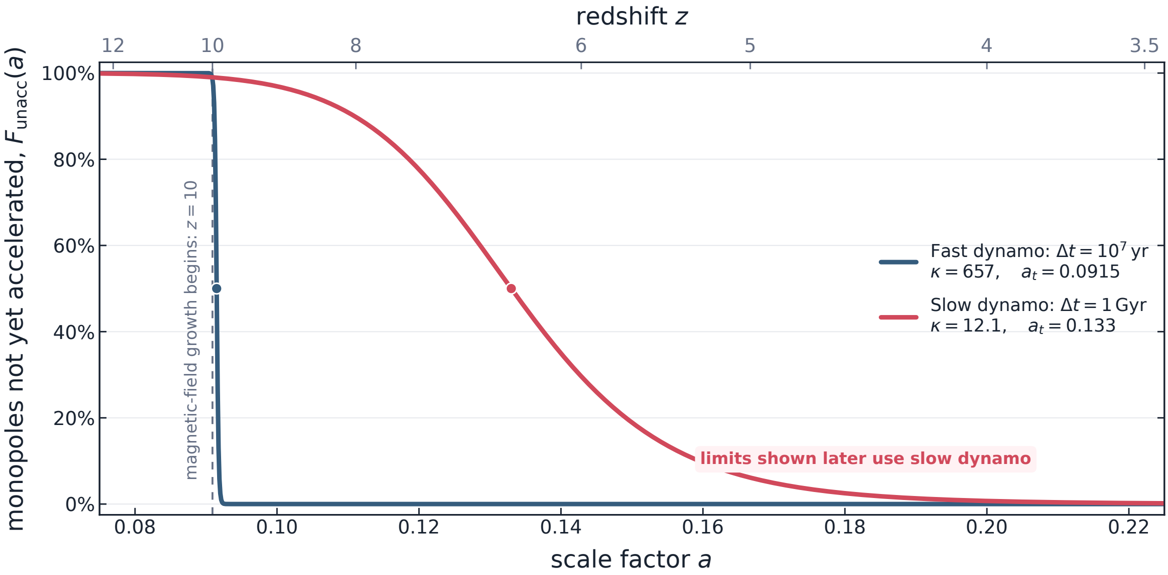
Perturbation ansatz

$$Q^{(1)} = Q^{(0)}\delta_{\mathsf{cdm}}$$

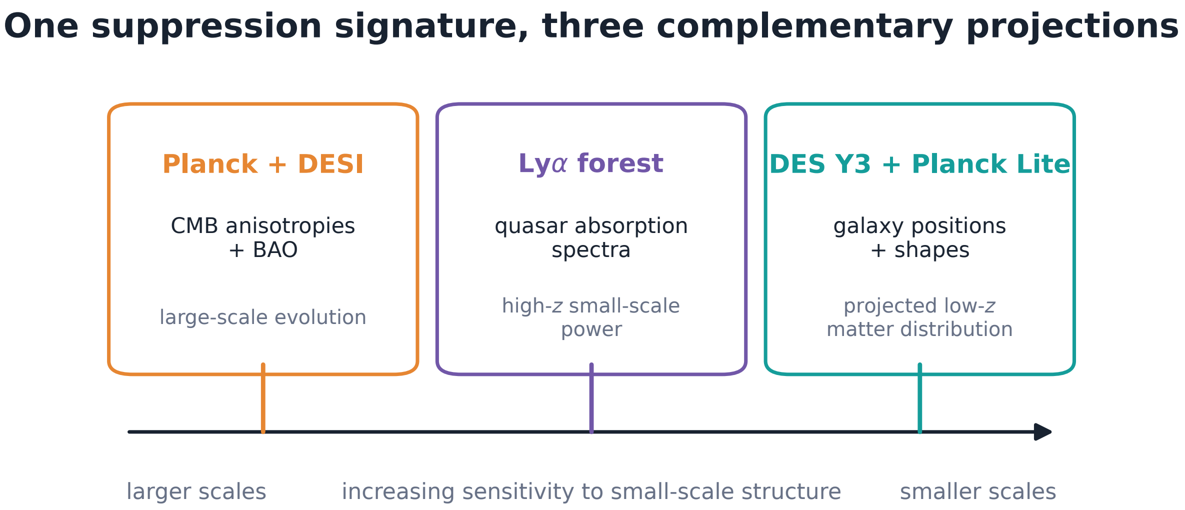
Injected momentum

$$\frac{p_{\mathsf{inj}}}{m_{\mathsf{acc}}} = \sqrt{\eta(\eta+2)} > 0$$

Free streaming suppresses accDM clustering.



redshift z
12
10
8
6
5
4
3.5
100%
80%
60%
40%
20%
0%
monopoles not yet accelerated, $F_{\mathrm{unacc}}(a)$
magnetic-field growth begins: $z = 10$
Fast dynamo: $\Delta t = 10^7$ yr
$\kappa = 657, \quad a_t = 0.0915$
Slow dynamo: $\Delta t = 1$ Gyr
$\kappa = 12.1, \quad a_t = 0.133$
limits shown later use slow dynamo
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
scale factor a


One suppression signature, three complementary projections
Planck + DESI
CMB anisotropies + BAO
large-scale evolution
Lyα forest
quasar absorption spectra
high-z small-scale power
DES Y3 + Planck Lite
galaxy positions + shapes
projected low-z matter distribution
larger scales
increasing sensitivity to small-scale structure
smaller scales

Planck + DESI: CMB and BAO

Planck 2018 CMB + DESI DR2 BAO

CMB anisotropies and lensing, combined with BAO distances

modified CLASS

background + perturbations

→

CMB + BAO prediction

joint likelihood at fixed m_{acc}

→

Bayesian fit

sample f_{acc}, cosmology and nuisance parameters

Bayesian: 95% posterior upper limit on f_{acc}

Lyα forest: small-scale flux power

BOSS/eBOSS DR14 Lyα forest

245 measurements of transmitted-flux power, $3.0 \leq z \leq 4.2$

modified CLASS

linear density and velocity spectra

→

one-loop + flux model

matter fields to $P_F^{\mathrm{1D}}(k_\parallel, z)$

→

profile likelihood

profile IGM nuisance at fixed m_{acc}

Frequentist: 95% profile-likelihood upper limit on f_{acc}

DES Y3: clustering and weak lensing

DES Y3 galaxy positions and shapes + Planck Lite
Galaxy clustering, galaxy–galaxy lensing and cosmic shear

modified CLASS
background + perturbations

→

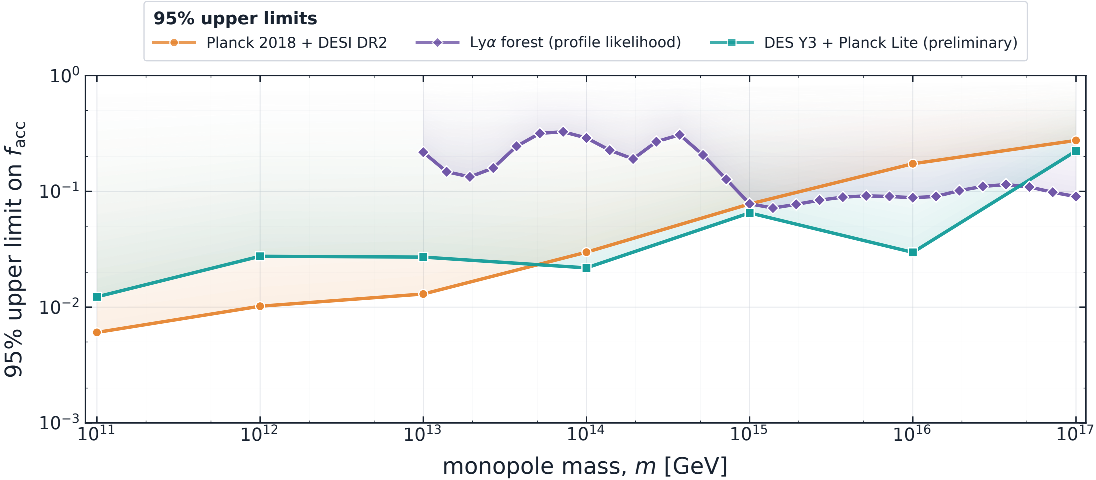
PyFowl
one-loop projections EFT treatment of baryons

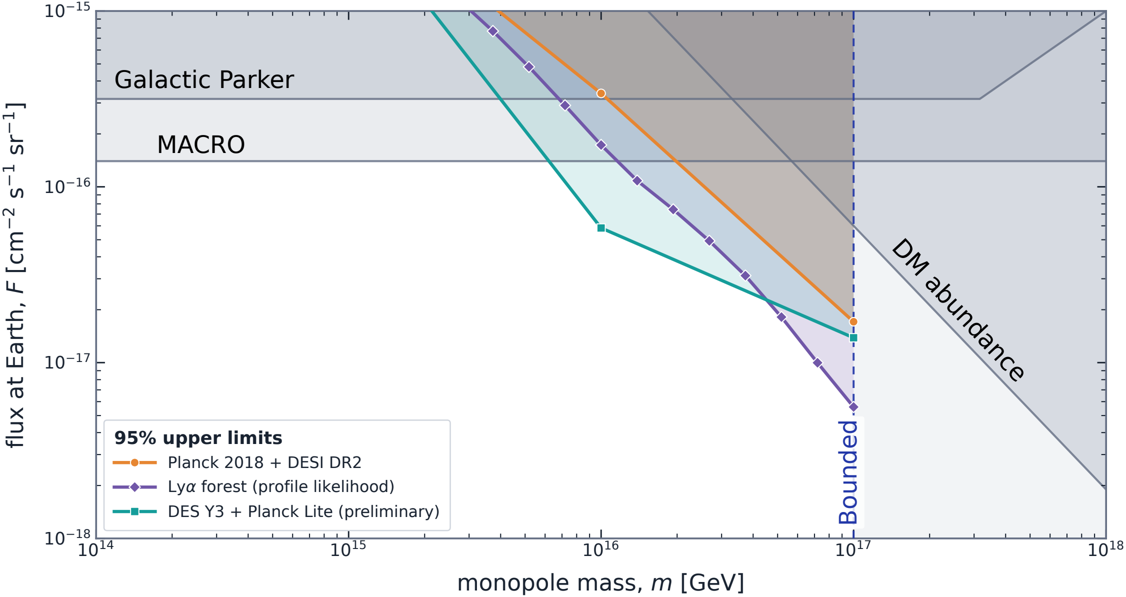
→

Bayesian fit
DES Y3 + Planck Lite at fixed m_{acc} bias + nuisance

Bayesian: 95% posterior upper limit on f_{acc} (preliminary)

Limits on f_{acc}





Galactic Parker
MACRO
DM abundance
Bounded
95% upper limits
Planck 2018 + DESI DR2
Lyα forest (profile likelihood)
DES Y3 + Planck Lite (preliminary)
flux at Earth, F [cm⁻² s⁻¹ sr⁻¹]
monopole mass, m [GeV]
10^-15
10^-16
10^-17
10^-18
10^14
10^15
10^16
10^17
10^18

Conclusions

1. **Model:** a source-based CLASS implementation connects $Q^{(0)}$, collisionless perturbations and suppressed clustering.
2. **Constraints:** CMB+BAO, the Lyα forest and DES Y3 provide separate limits on f_{acc}.
3. **Monopoles and beyond:** $f_{\mathrm{acc}}(m)$ becomes an Earth-flux bound and the same framework applies to other late-accelerated dark matter.

Thank you

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