

Baryon - Dark Matter Interactions:
Cosmic-ray and Nucleosynthesis
Constraints

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Motivation

Possible *discrepancy* between:

Collisionless Dark Matter simulations
& galactic scale observations



Strongly *Self-Interacting Dark Matter*

(Spergel & Steinhardt 2000 ; Kamionkowski talk)

Are strong interactions between
baryons & dark matter allowed?

Interesting & fundamentally important question
in itself

Phenomenological approach,
considering observational consequences
of baryon – DM interactions (BDMIs)

Consequences of BDMIs

BDMIs can:

- ✓ Destabilize Galactic disc
- ✓ Show up in cosmic ray detectors

Relevant energies: $\sim \text{keV}$

Considered by Wandelt et al (2000)

exclude $M_D < 10^5 \text{ GeV}$,
but for larger masses
allow $\sigma \sim \sigma_{\text{BB}}, \sigma_{\text{DD}}$

- ✓ Alter light element abundances

Relevant energies: $\sim \text{MeV}$

- ✓ Overproduce γ -rays originating from cosmic rays

Relevant energies: $\sim \text{GeV}$

this work

BBN, Cosmic-Ray Constraints

Cannot constrain *both* mass and cross-section
Instead, constrain:

$$s = \sigma / M_D$$

cross section per unit mass of DM particle

where

$$s_{DD}, s_{BB} \sim 1 \text{ cm}^2 / \text{g} \sim 1 \text{ barn} / \text{GeV}$$

BBN Constraints

Side-Effect of BDMIs :

Deuterium destruction $D + d \rightarrow D + n + p$



onset of BBN delayed

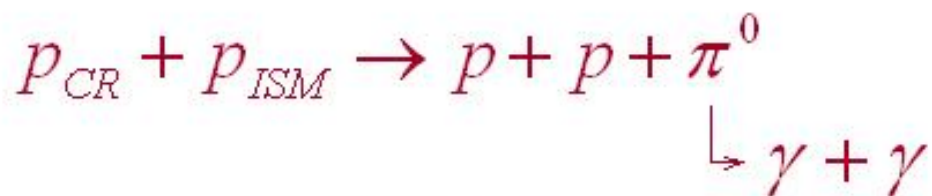


primordial element abundances altered

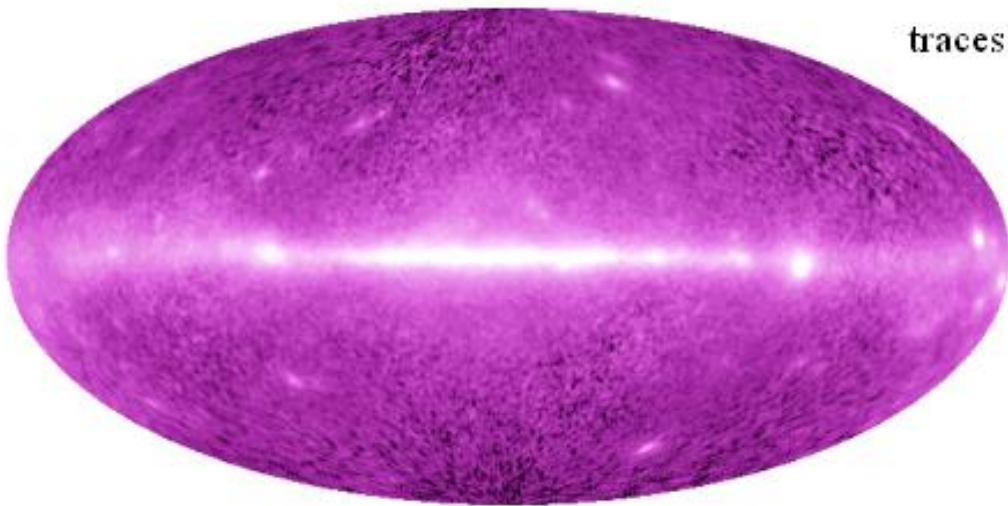
Result: very weak constraint, $s < 10^8 \text{ cm}^2/\text{g}$
BBN OK with baryon-interacting dark matter

Cosmic Ray Constraints

Cosmic Rays: relativistic nuclei
penetrating Milky Way
manifest themselves through



traces ISM

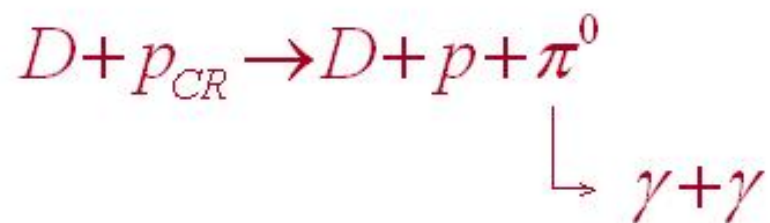


EGRET all-sky image for energies > 100 MeV
in Galactic coordinates (from Hunter et al 2001)

Cosmic Ray Constraints

Side Effect of BDMI's :

γ -rays now also produced by



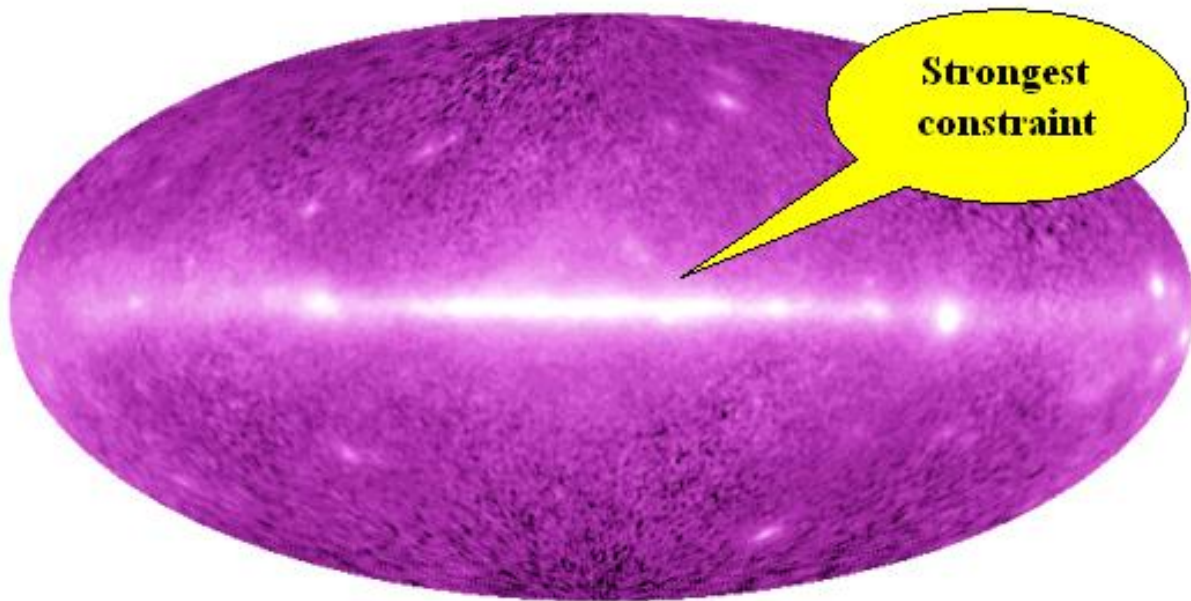
\Downarrow

If $D + p_{CR}$ cross section too large:
produce more γ -rays than observed

Result: Most conservative constraint
if we attribute all γ flux
to DM – CR interactions

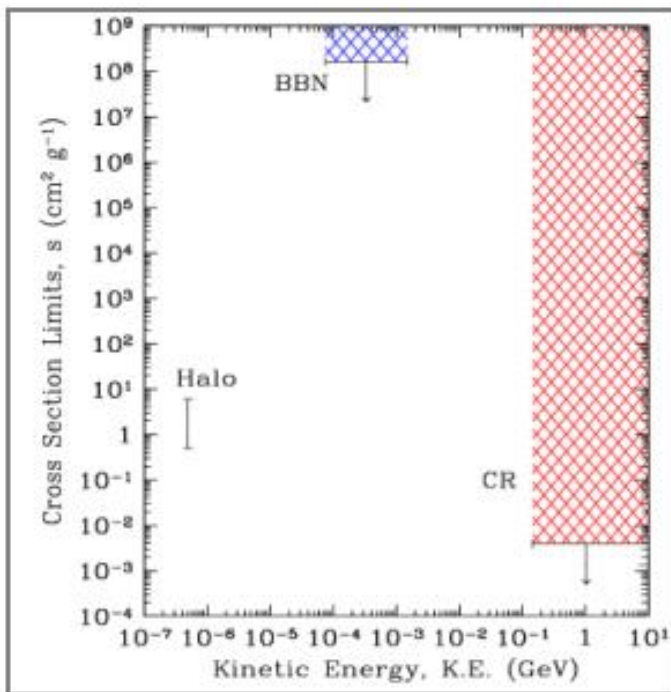
Even so, $s < 5 \times 10^{-3} \text{ cm}^2/\text{g}$

Cosmic Ray Constraints



EGRET all-sky image for energies > 100 MeV in Galactic coordinates (from Hunter et al 2001)

Conclusions



- Strongly interacting dark matter allowed by BBN

- Very strong limits on s from CR-DM interactions:

- ✓ If cross section indep. of E :

 - s_{BD} 1000 times smaller than s_{DD}

- ✓ If we allow energy dependence:

 - need $s \propto 1/v$ (or steeper) to have $s_{\text{BD}} \sim s_{\text{DD}}$

- For other constraints: CMB, LSS

 - (see Chen e-poster ; Chen, Hannestad & Scherrer)