DM Constraints from the Cosmic Dawn

Work in Progress
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Cosmic Dawn

Big Bang and Inflation

Recombination

Cosmic Dark Ages

First Stars and Galaxies

Epoch of Reionisation

Now

z = 1100  z = 100  z = 30  z = 10
Dark Matter Annihilation In and Around High Redshift Halos

DM annihilates, heats and ionises >>> potentially modifies baryonic structure

Diffuse DM Background

Stars/Gas

DM Halos

Circumgalactic Medium

Nearest Neighbour halo

Drive evolution of the IGM

DM Halos/ Structure in Cosmic web

21cm Signal
DM Annihilation in Halos

DM Halo Model

* Density profile (gas + DM)
* Mass concentration parameter
DM Annihilation in Halos

DM Particle Model

* self-annihilating
* mass, cross-section
* annihilation products
DM Annihilation in Halos

Energy Transfer

* Interactions with H, He, free electrons and the CMB
* Assume halo is static
* Photons: pair productions, Compton, photo-ionisation
* Electrons: IC, Coulomb, electro-ionisation, excitation, recombination
* Positrons: same as electron + annihilation
Energy Transfer
Comparing dark matter annihilation energy (over Hubble time) to gas binding energy.

- Redshift (z) range: 10 to 50
- Mass range: $10^3$ to $10^9$ $M_{\text{Sun}}$
- Log₁₀($F_{\text{eff}}$) range: -1 to 2

5 GeV via muon

Finasto constant
DM Halo Heating
A Simple Gas Infall Model

DM virializes, producing a potential, with gas in hydrostatic equilibrium

$$\nabla p_b = -\rho_b \nabla \phi$$

Assuming adiabatic evolution,

$$\frac{p_b}{\bar{p}_b} = \left( \frac{\rho_b}{\bar{\rho}_b} \right)^{\frac{5}{3}}$$

gives

$$\frac{\rho_b}{\bar{\rho}_b} = \left( 1 - \frac{2}{5} \frac{\mu m_p \phi}{k_b \bar{T}} \right)^{\frac{3}{2}}$$

for

$$T_{vir} = -\frac{1}{3} \frac{m_p \phi}{k_b}$$

$$\bar{T} = \bar{p}_b \mu m_p / k_b \bar{\rho}_b$$

$$\delta_b = \frac{\rho_b}{\bar{\rho}_b} - 1 = \left( 1 + \frac{6}{5} \frac{T_{vir}}{\bar{T}} \right)^{\frac{3}{2}} - 1$$

$$\delta_b = \left( 1 + \frac{6}{5} \frac{T_{vir}}{(\bar{T} + \Delta T)} \right)^{\frac{3}{2}} - 1$$
Minimal Baryonic Objects
Cosmic Dawn

- Big Bang and Inflation
- Recombination
- Cosmic Dark Ages
- First Stars and Galaxies
- Epoch of Reionisation
- Now

$z = 1100 \quad z = 100 \quad z = 30 \quad z = 10$
Global 21-cm Signal

\[ \delta T_b = \frac{3}{32\pi} A_{10} c^3 h \bar{n}_H^0 \frac{T_s - T_\gamma}{T_s} \left(1 + \frac{z}{2}\right)^2 \frac{H(z)}{m} (1 + \delta) \bar{x}_{HI} \quad \tau_\nu \ll 1 \]

\[ P_{21}(k, z) = \left\langle |\delta \tilde{T}_b(k, z)|^2\right\rangle_k = \frac{1}{m} \sum_{i=1}^m |\delta \tilde{T}_{b,i}(k, z)|^2 \]
consistent reionisation histories

radiation background

low-mass cut-off

heating/ionization of intergalactic gas

H₂ abundance

structure of first stars

internal heating of dark matter halos

black hole formation

unified simulation of galaxy formation & evolution

high-redshift 21cm signal

high-redshift galaxies

image credit: Swinburne/ICRAR/Cambridge/ASTRON

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