Radio Detection of Dark Matter Annihilation in Dwarf Galaxies

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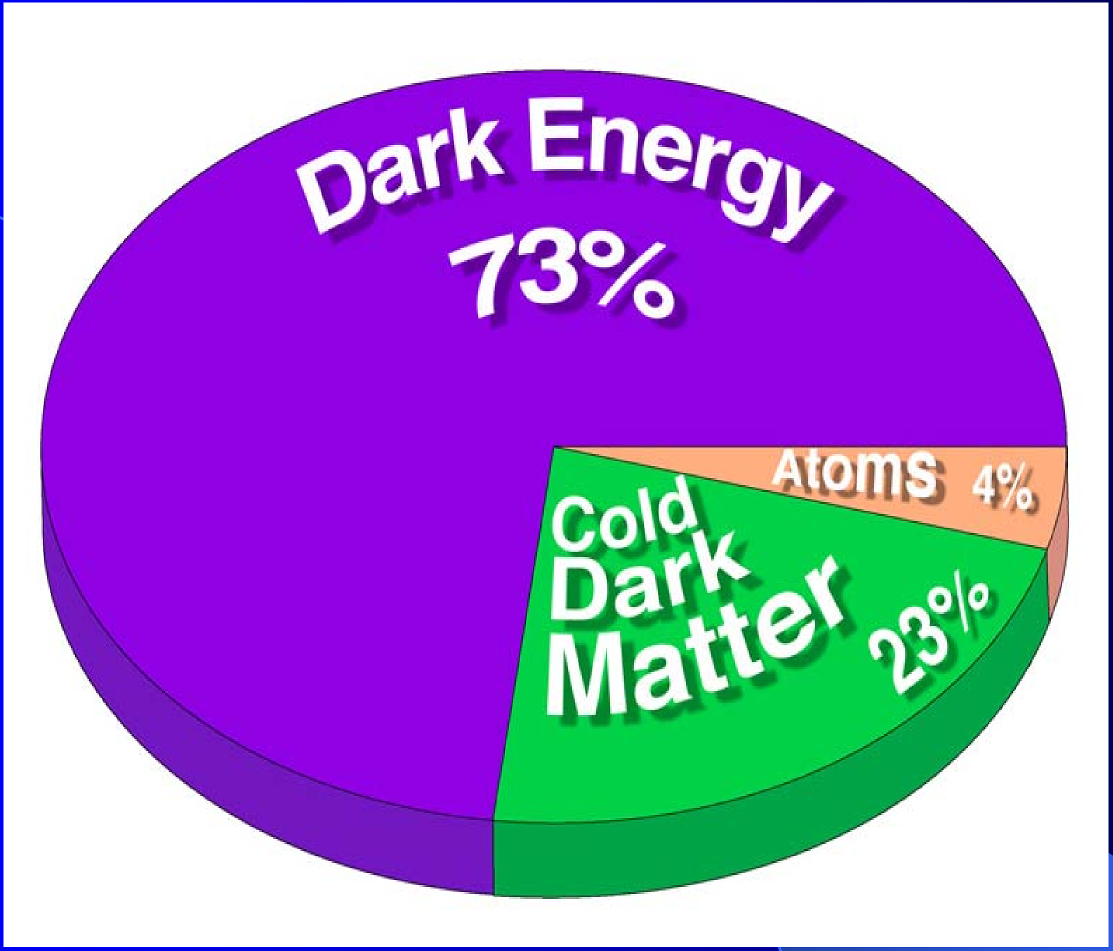
Outline

- Introduction
- Sunyaev-Zel'dovich (SZ) effect in dSphs
- Synchrotron emission in dSphs
- Summary

Introduction



Evidence: Rotation Curves, CMB, BBN, LSS …

What's the particle nature?
—remain a puzzle

Dark Matter Candidates

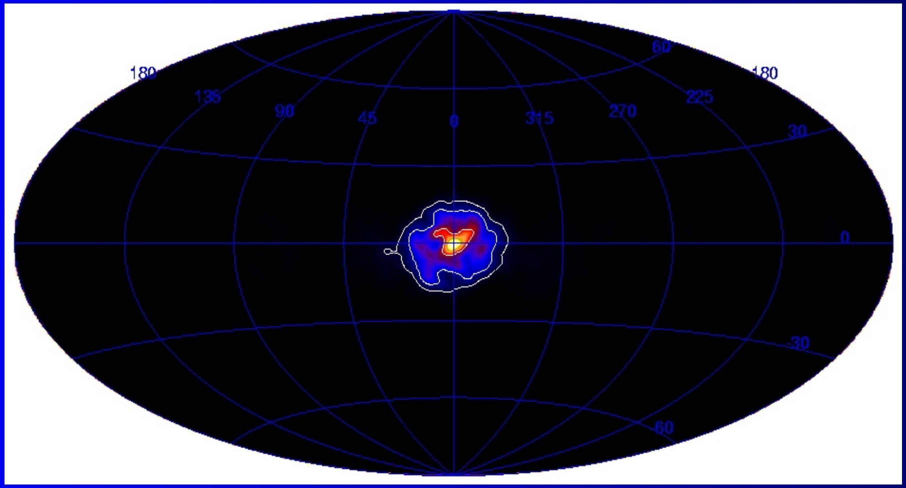
Neutralino : 10GeV~TeV

correct DM abundance

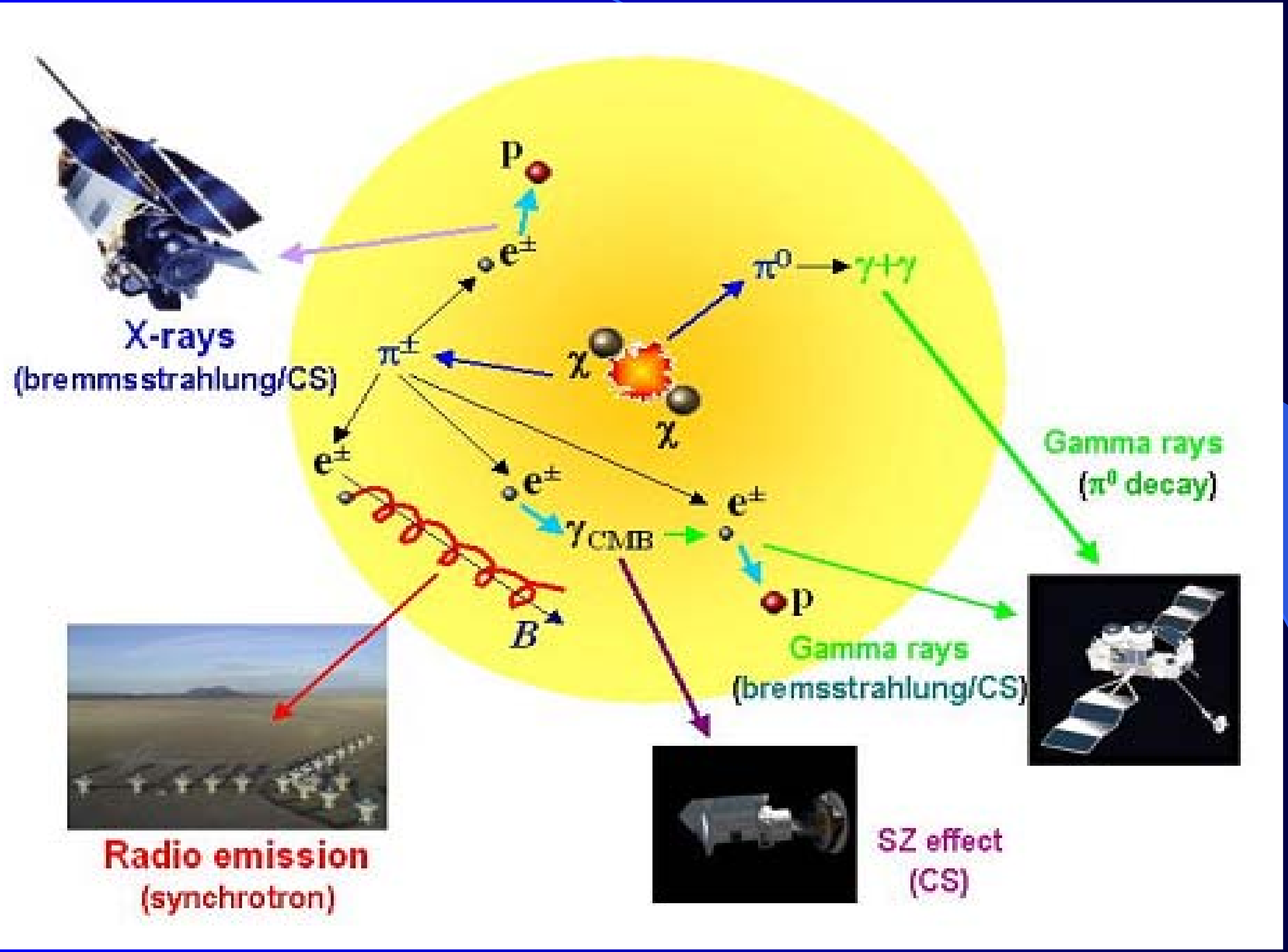
natural from super symmetry

Light Dark Matter: 1~100 MeV

511keV emission line



DM Annihilation Signals

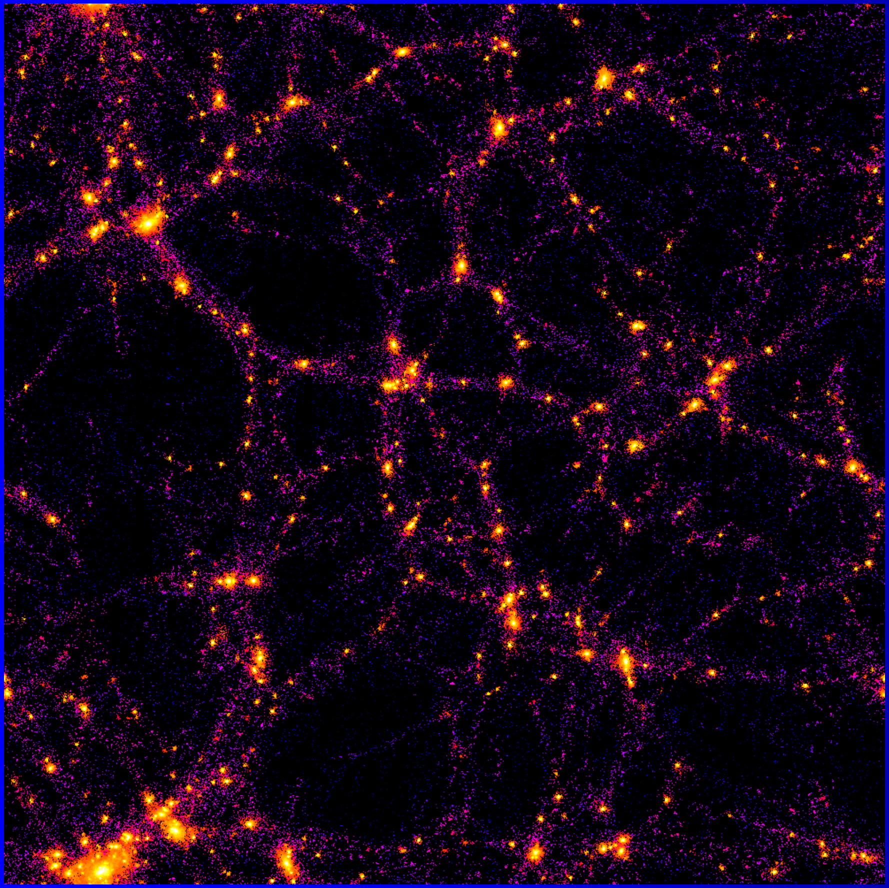


Radio Detection

Colafrancesco, IoP/RAS Meeting 2007

Dark halo

Annihilation rate $\propto \rho^2$



Density profile of dark halo

$$\rho_{NFW}(r) = \frac{\rho_s}{(r/r_s)(1+r/r_s)^2}$$

$$\rho_{Moore}(r) = \frac{\rho_s}{(r/r_s)^{1.5}(1+(r/r_s)^{1.5})}$$

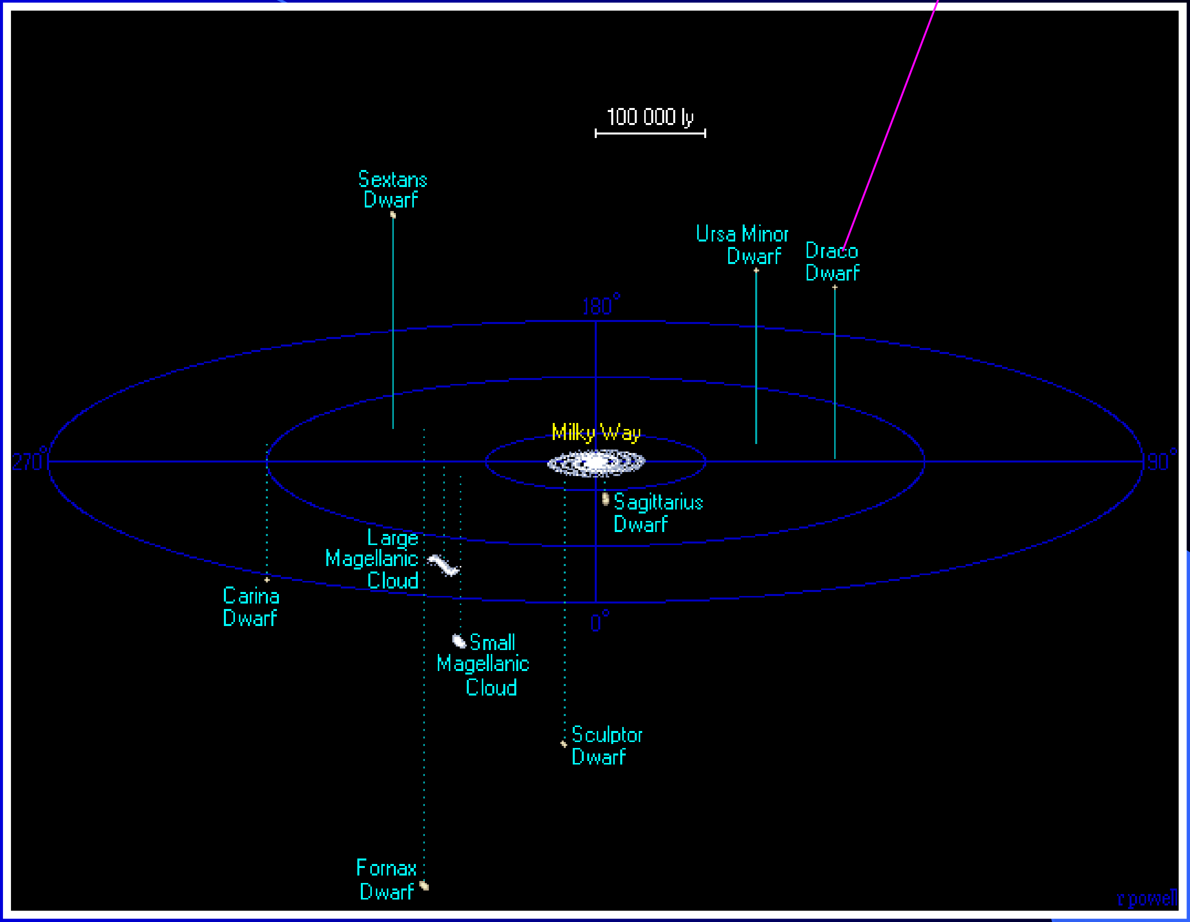
$$\rho_{cored} = \frac{v_a^2}{4\pi G}\frac{3r_c^2+r^2}{(r_c^2+r^2)^2}$$

Nearby dSphs: satellites of Milky Way

High latitude
Highest mass/light

Name	Year Discovered
LMC	1519
SMC	1519
Sculptor	1937
Fornax	1938
Leo II	1950
Leo I	1950
Ursa Minor	1954
Draco	1954
Carina	1977
Sextans	1990
Sagittarius	1994
Canis Major	2003
Ursa Major I	2005
Willman I	2005
Ursa Major II	2006
Bootes	2006
Canes Venatici I	2006
Canes Venatici II	2006
Coma	2006
Leo IV	2006
Hercules	2006
Leo T	2007

Census of Milky Way Satellites (Circa 2007)



dSphs: small halo forms first close to be pure dark halo

Energy spectrum of $e^{\pm}$ produced by DM annihilation

Diffuse transport equation of electrons (positrons) produced by DM annihilation

$$\frac{\partial}{\partial t}\frac{dn_e}{dE_e} = \nabla\left[D(E,r)\nabla\frac{dn_e}{dE_e}\right] + \frac{\partial}{\partial E}\left[b(E,r)\frac{dn_e}{dE_e}\right] + q_e(E,r)$$

Diffusion coefficient: $D(E) = D_0(E/B)^{\delta}$

Energy loss term: $b(E) = b_{Syn} + b_{ICS} + b_{Coul}$

Source spectrum: $q_e(E,r) = \frac{1}{2\,M_{\chi}^2}\sum_f \frac{dN_e^f}{dE_e}(E)B_f\,\rho^2(r)$

Basic Formulas

Stationary transport equation:

$$\frac{\partial}{\partial t}\frac{dn_e}{dE_e} = \nabla\left[D(E,r)\nabla\frac{dn_e}{dE_e}\right] + \frac{\partial}{\partial E}\left[b(E,r)\frac{dn_e}{dE_e}\right] + q_e(E,r)$$

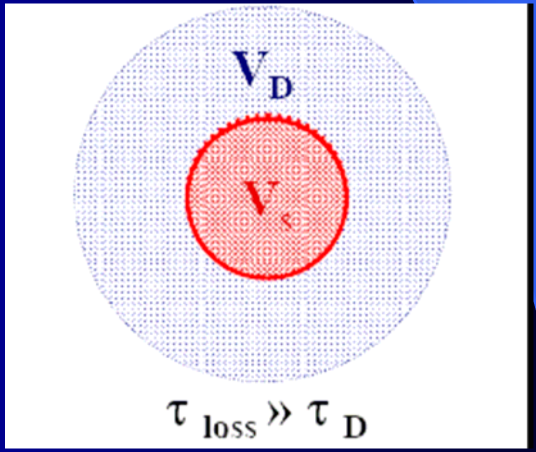
Qualitative Electrons equilibrium spectrum

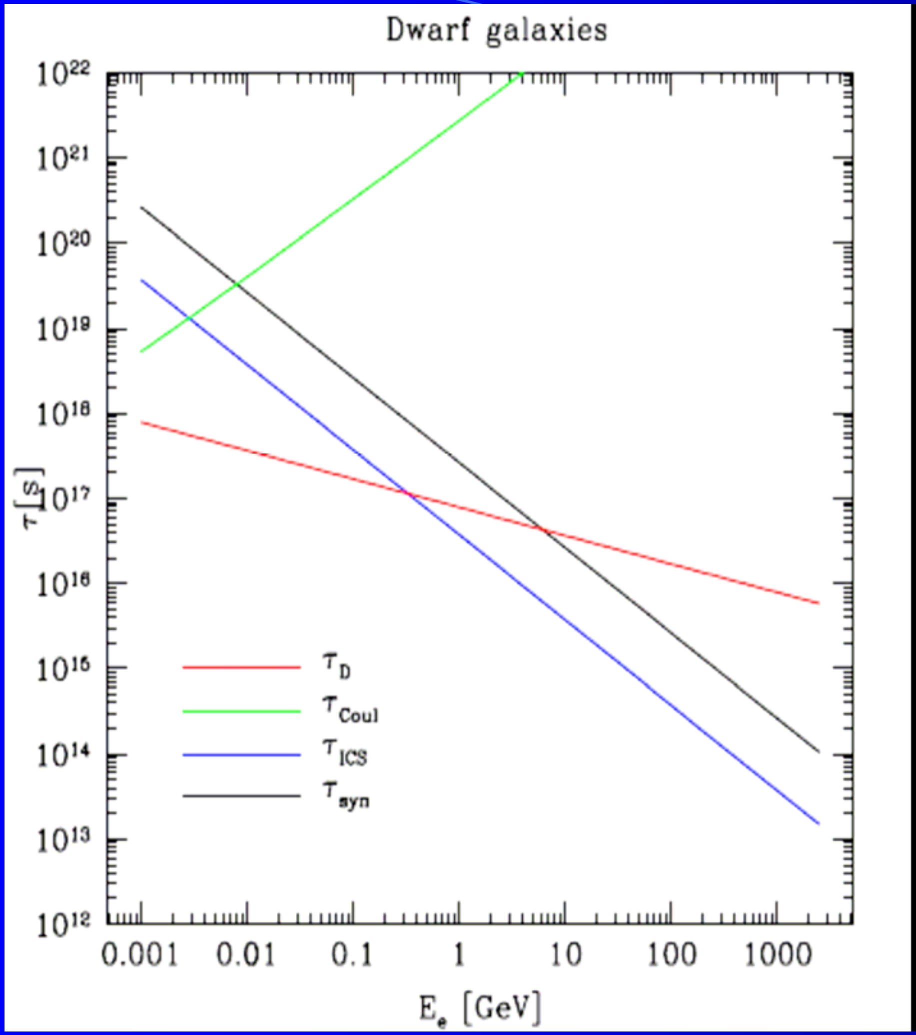
$$\frac{dn_e(E,r)}{dE_e} \approx [q_e(E,r)\tau_{loss}] \times \frac{V_s}{V_s+V_o} \times \frac{\tau_D}{\tau_D+\tau_{loss}}$$

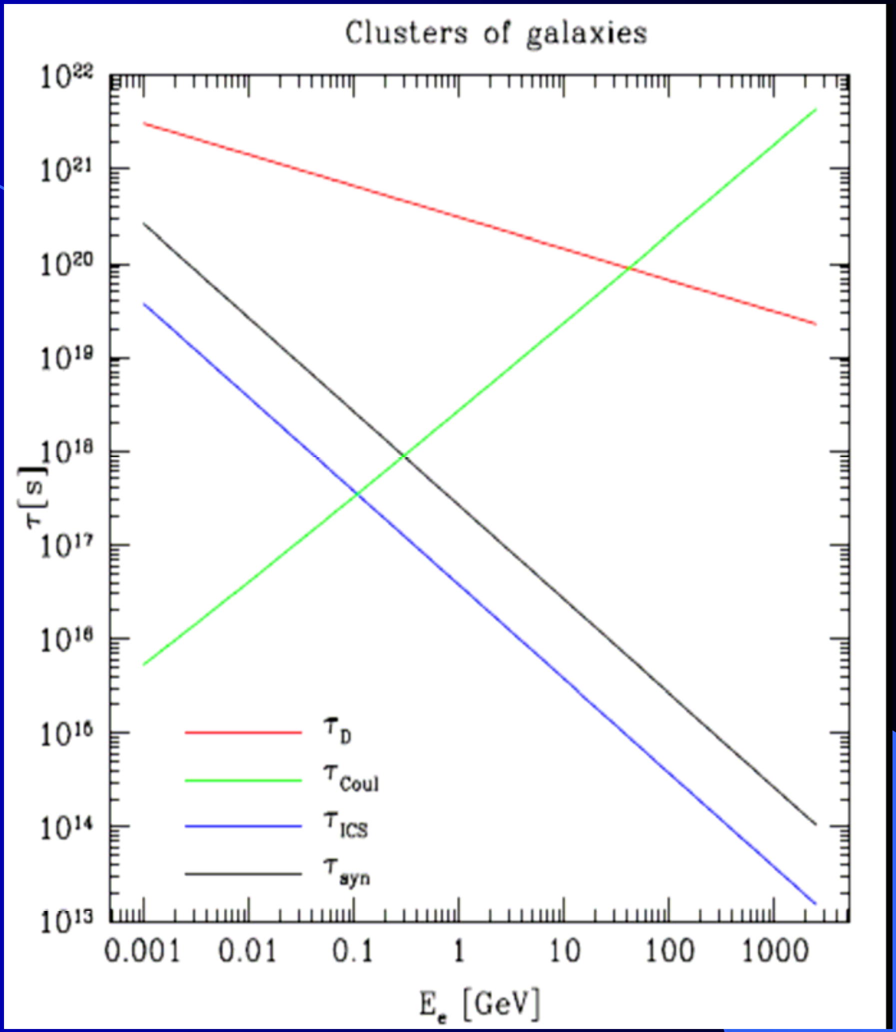
time scales:

$$\tau_D = R_{halo}^{\ 2} / D(E)$$

$$\tau_{loss} = E / b(E)$$



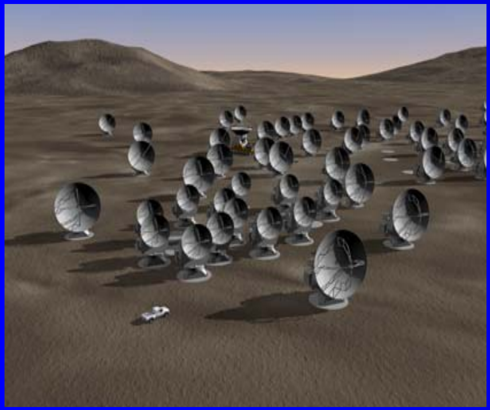


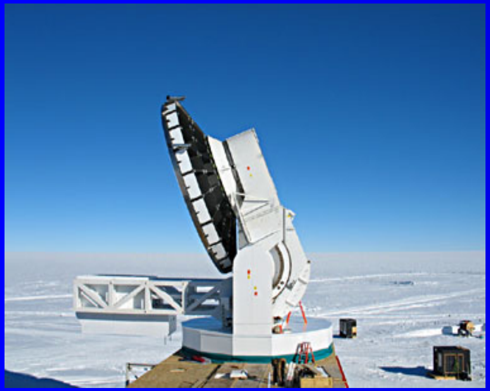


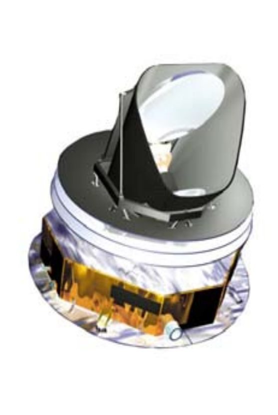
$$\frac{dn_e(E,r)}{dE_e} = q_e(E,r)\cdot\tau_D\cdot\frac{V_s}{V_D}$$

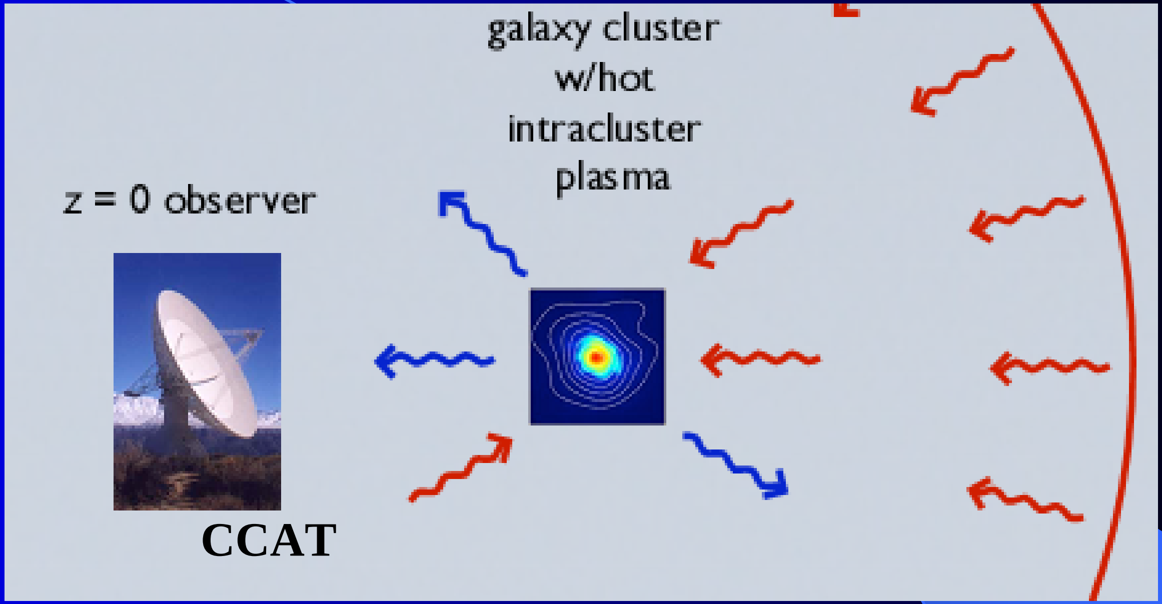
$$\frac{dn_e(E,r)}{dE_e} = q_e(E,r)\cdot\tau_{loss}$$

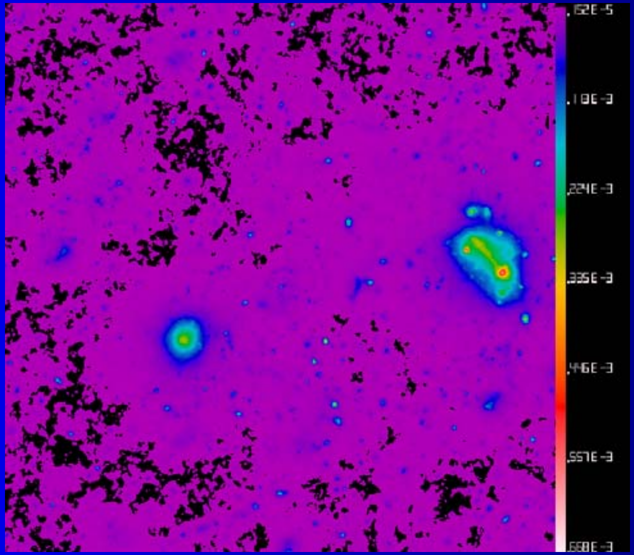
Thermal SZ effect











Clusters with hot/warm gas

DSphs?

Non-thermal SZ effect induced by electrons&positrons produced by DM annihilation

$$\Delta T \propto y_{DM} \cdot \tilde{g}(x)$$

$$y_{DM} = \frac{\sigma_T}{m_e c^2} \int P_{DM} d\ell$$

Compton parameter

Spectral shape

$$\tilde{g}(x) = \frac{m_e c^2}{\langle k_B T_e \rangle} \left\{ \frac{1}{\tau} \left[\int_{-\infty}^{+\infty} i_0(xe^{-s}) P(s) ds - i_0(x) \right] \right\}$$

$$\langle k_B T_e \rangle \equiv \frac{\sigma_T}{\tau} \int P d\ell = \frac{\int P d\ell}{\int n_e d\ell} = \int_0^{\infty} dp f_e(p) \frac{1}{3} p v(p) m_e c$$

(Enβlin&Kaiser: astro-ph/0001429
Colafrancesco: astro-ph/0211649……)

SZ effect induced by neutralino self-annihilation

$m_\chi = 100\ GeV$		
	$\nu = 35\ GHz$	$\nu = 22\ GHz$
NFW	$-1.57 \cdot 10^{-11}$	$-1.74 \cdot 10^{-11}$
Moore	$-3.12 \cdot 10^{-8}$	$-3.47 \cdot 10^{-8}$
Cored	$-2.95 \cdot 10^{-17}$	$-3.28 \cdot 10^{-17}$

$m_\chi = 10\ GeV$		
	$\nu = 35\ GHz$	$\nu = 22\ GHz$
NFW	$-3.69 \cdot 10^{-9}$	$-4.1 \cdot 10^{-9}$
Moore	$-6.94 \cdot 10^{-6}$	$-7.71 \cdot 10^{-6}$
Cored	$-6.05 \cdot 10^{-15}$	$-6.73 \cdot 10^{-15}$

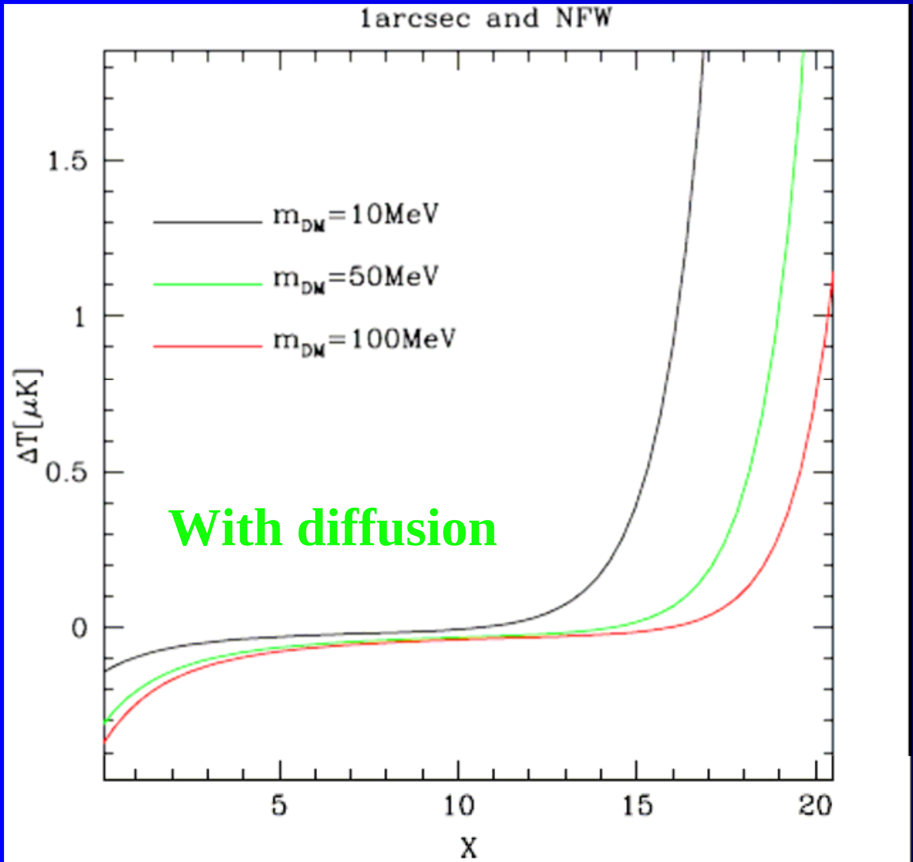
Diffusion is important in DSphs.

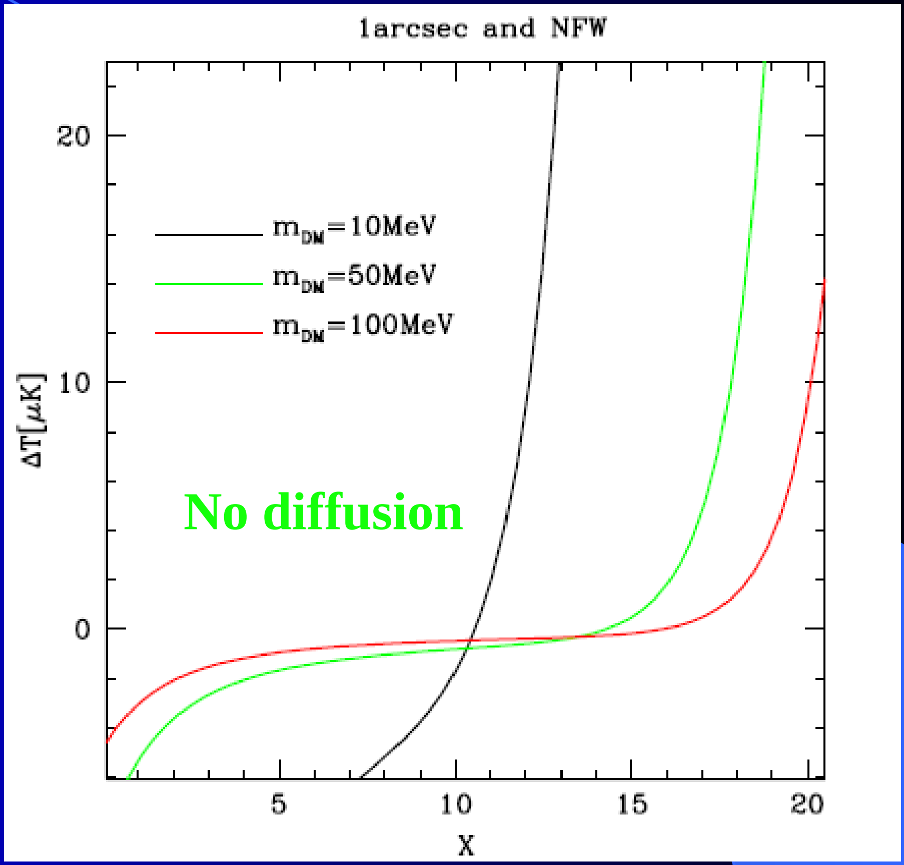
Predicted amplitude of decrements are much smaller
than the results in previous paper (Colafrancesco:astro-ph/0602093)

Only highly cusped dark halos produce μ**K**

$\Delta T \sim (m_\chi)$^-2 ⟶ Larger distortion expected in the case of Light dark matter

SZ effect induced by Light DM self-annihilation

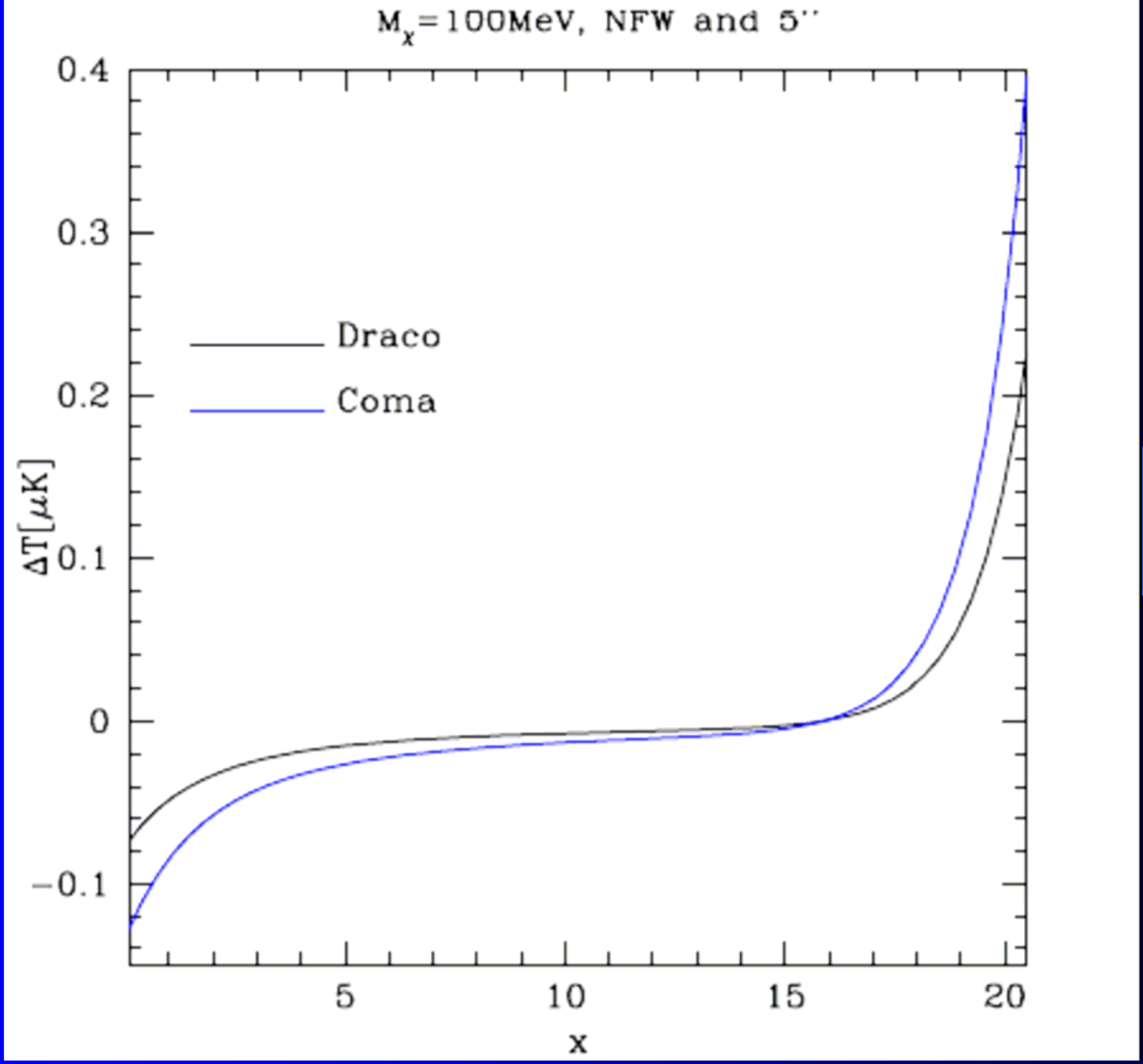




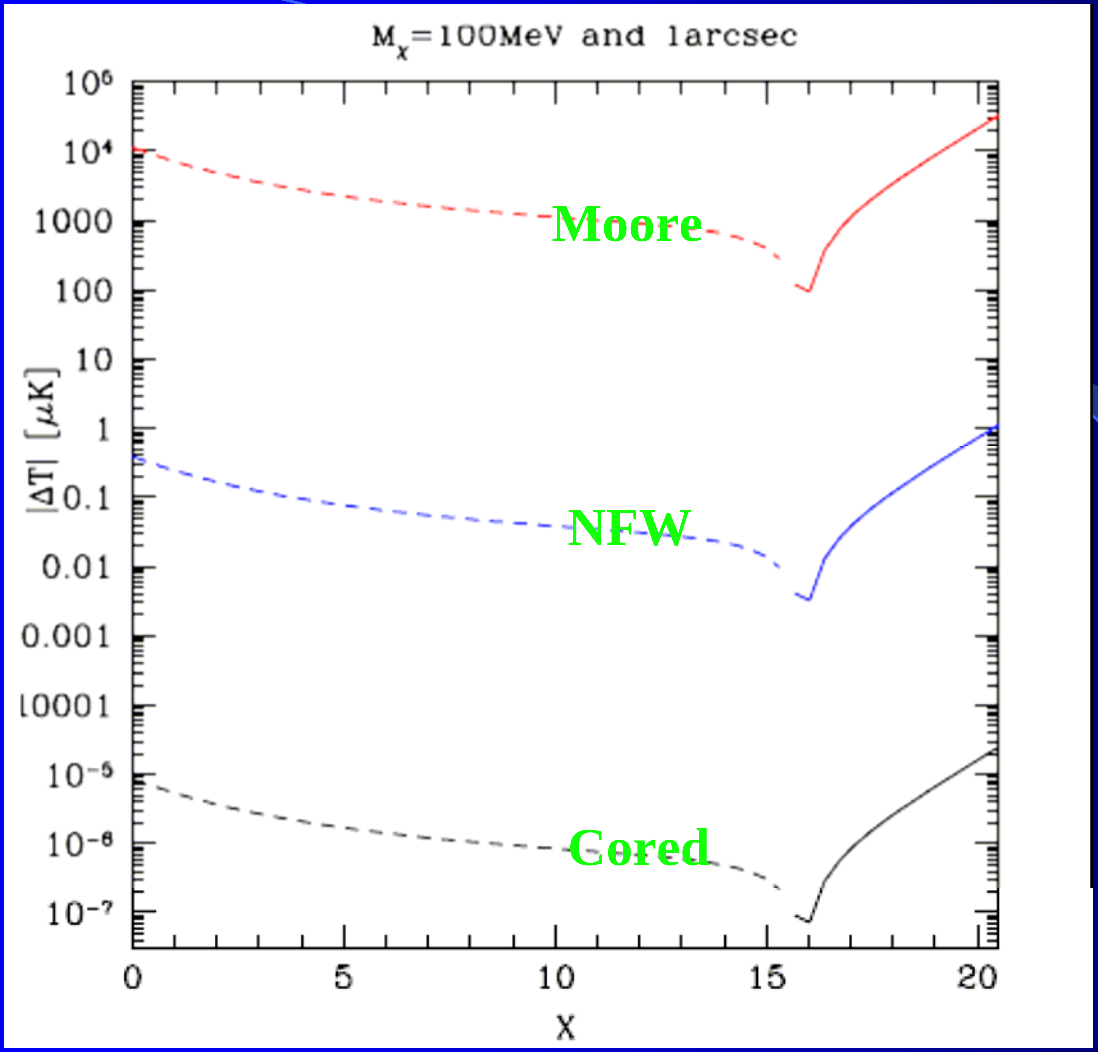
$<\sigma v>(1\text{MeV}/m)^2 \sim 10^{-30} cm^3/s$

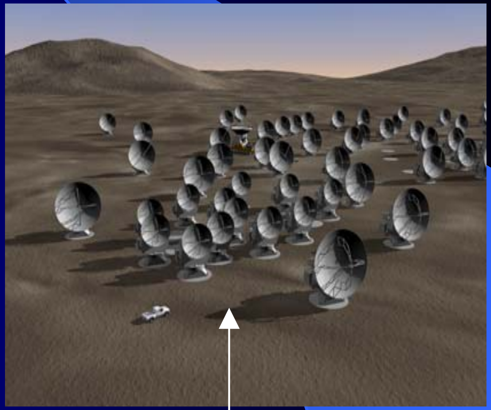
(PRL, 2004, 92, 101301)

← 511keV emission @GC



Non-thermal SZ_DM in DSphs is comparable to that in Cluster of Galaxies

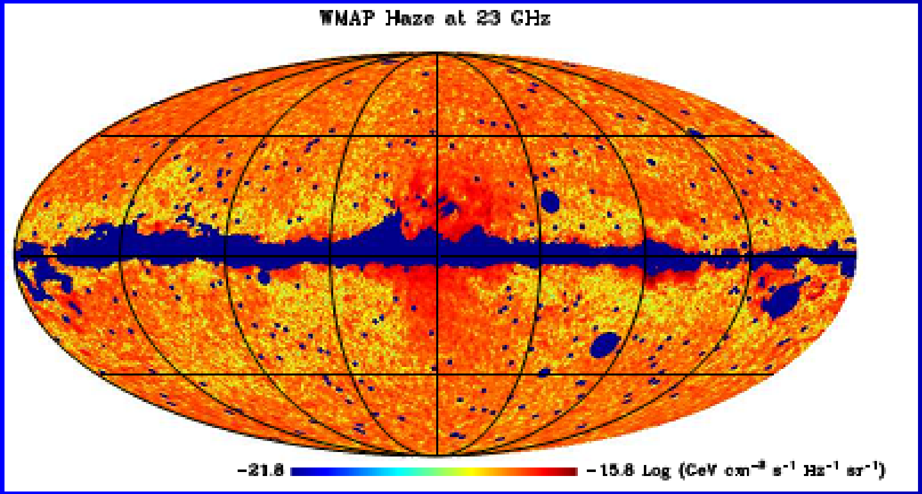




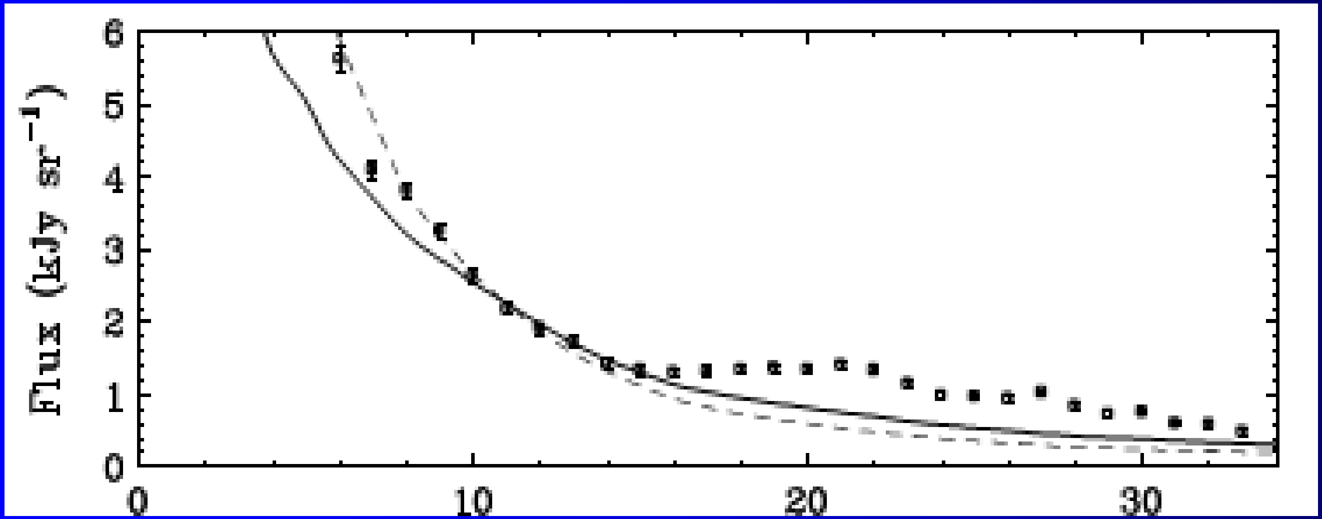
Density profile of the DM halo is crucial in determining the amplitude.
Only the highly cusped profile predicted sizable distortion <u>***μ*****K ~ mK**</u>

Synchrotron emission induced by DM annihilation

WMAP Haze ← DM annihilation



B=10μGs @ Galactic center

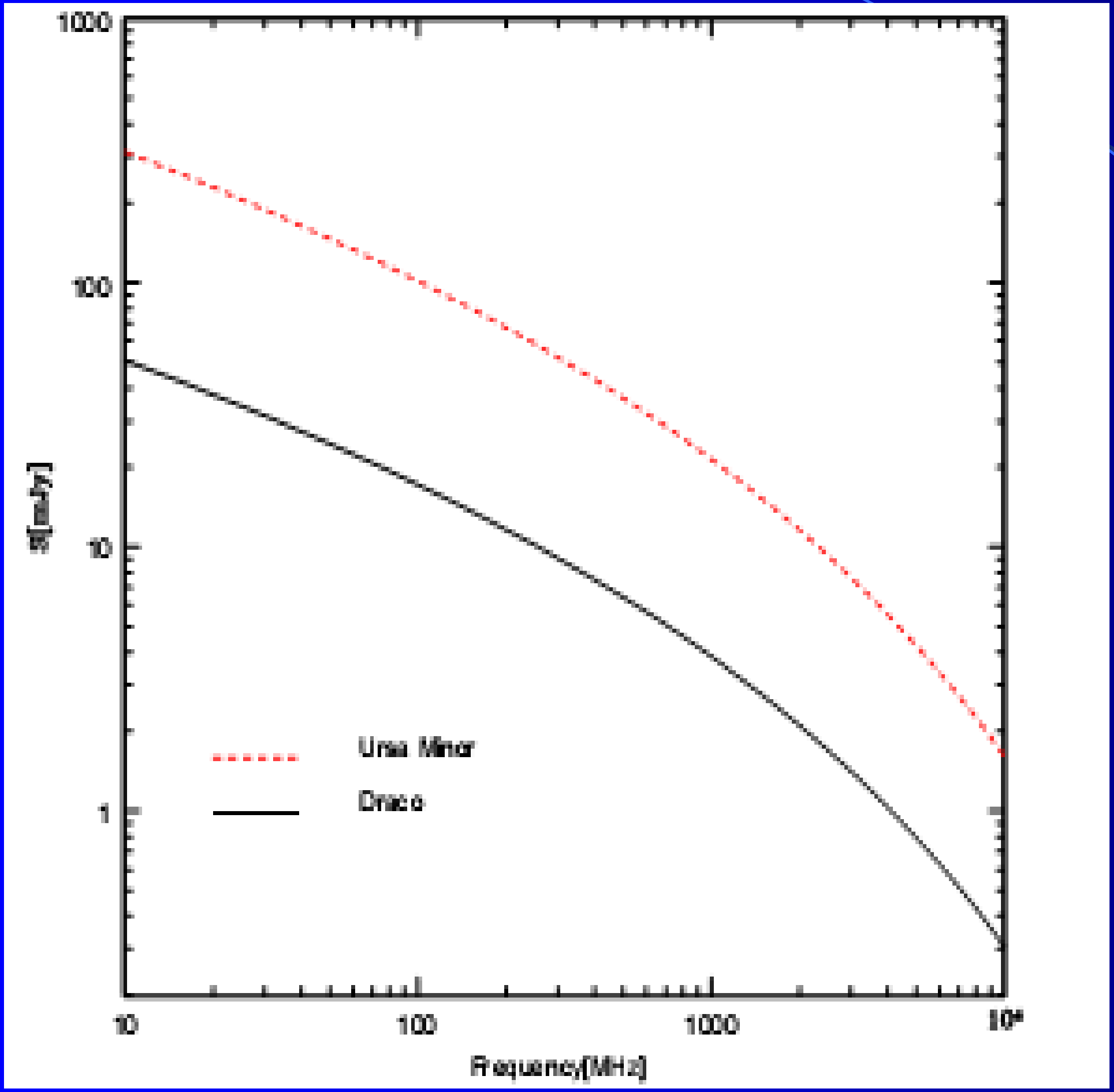


Dashed----Moore

Solid -------NFW

D. Hooper astro-ph/0705.3655

Synchrotron emission in DSphs



B=1μGs

NFW

Typical neutralino:

Mχ=100GeV

Flux increases with frequency decreasing

Radio emission in dSphs: diffuse and weak

Table 2. Related results (θ: half of the angular diameter)

	Flux(mJy) from Draco			Flux(mJy) from Ursa Minor		
	4.89GHz	1.42GHz	0.7GHz	4.89GHz	1.42GHz	0.7GHz
$\theta = 6'$	0.2	0.7	1.1	0.4	1.5	2.7
$\theta = 30'$	0.8	2.9	5.1	4.4	15.9	28.6
$\theta = 60'$	0.9	3.2	5.7	6.2	22.8	40.9

~90% of the total flux is from the central region of 2 degree
~50% is within central 50 arcmin region.

What's the implication for observation?

Radio Observation Requirement

Fomalont *et. al*. with VLA at 4.885GHz in 1979

very center region (within 4arcmin)
no detectable radio emission (<2mJy)

Updated observation required

Diffuse emission -------- large field view
weak emission -------- high sensitivity

Proposed ATA observation

Figure 2: Rendering of the completed ATA-350 at the Hat Creek Radio Observatory.

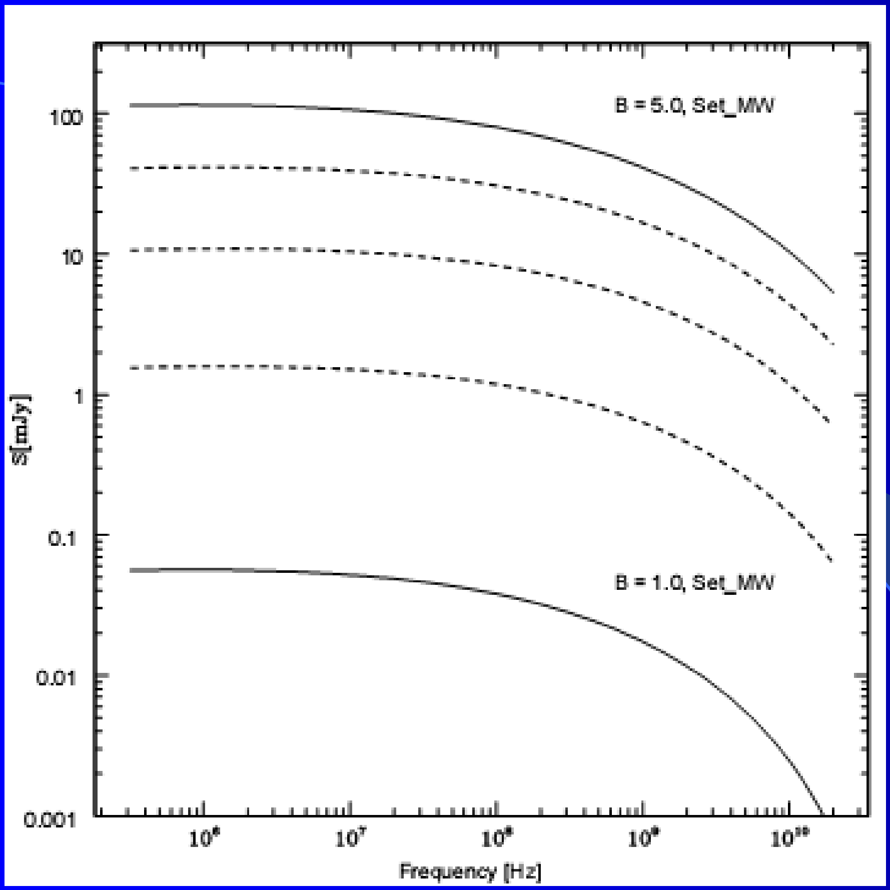
F.o.V at 1.4GHz: 2.5 degree
42 working antennas
Effective bandwidth :103MHz
6hrs on-source time.

↓

rms: 0.1mJy/beam @ 1.4GHz

peak/rms >10

Crucial factor: local magnetic field B



$$S[mJy] \approx 11.25 < \sigma v >_{26} B^{4.5}(1 - 0.3B + 0.022B^2)$$

Non-detection

B is smaller

Dark matter

GLAST: gamma ray

Summary

- **Electrons&positrons produced by DM annihilating in DSphs will suffer diffuse loss and energy loss**

- **SZ effect : μK @ arcsec for neutralino**
- **μK~ mK @ arcsec for light DM**
- **for highly cusped density profile**

- **Synchrotron emission : diffuse and weak**
  searching for extended source

Thank You

Thank You