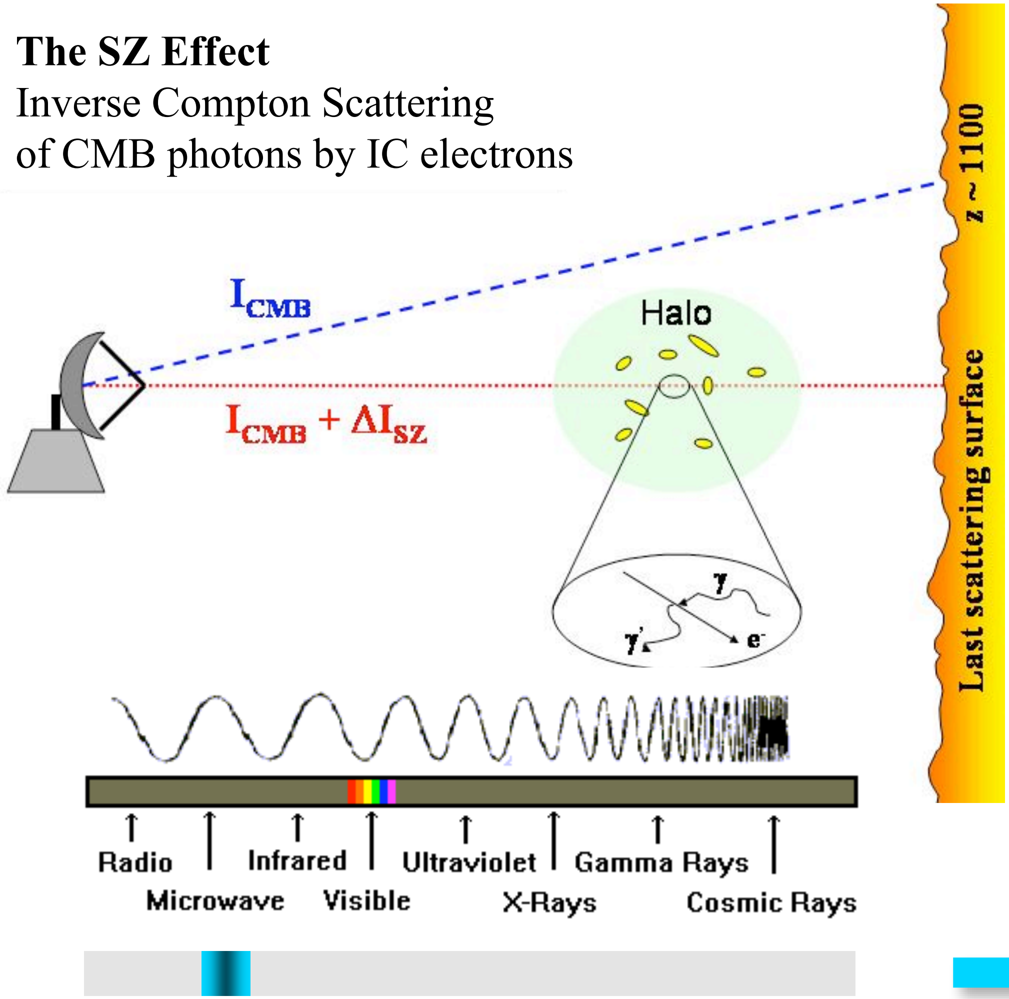
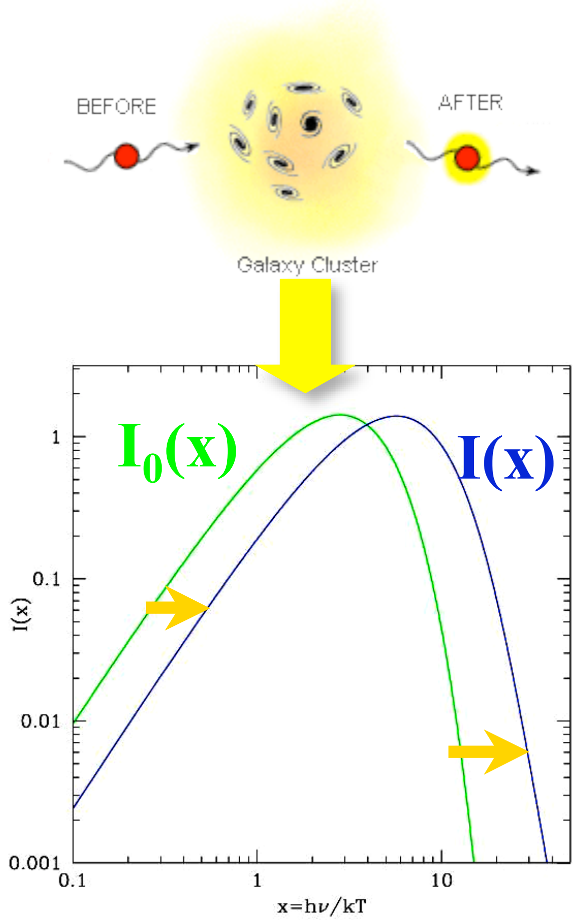
III

SZ effects with ALMA

Credit: S. Colafrancesco

SZ effect: the standard lore





thermal, non-rel. e⁻

$$\frac{\Delta\nu}{\nu} \approx 4\frac{kT_e}{m_e c^2}$$

The origin of the SZ effect

Non-coherent Compton Scattering

Fall-out effect of the Cold War

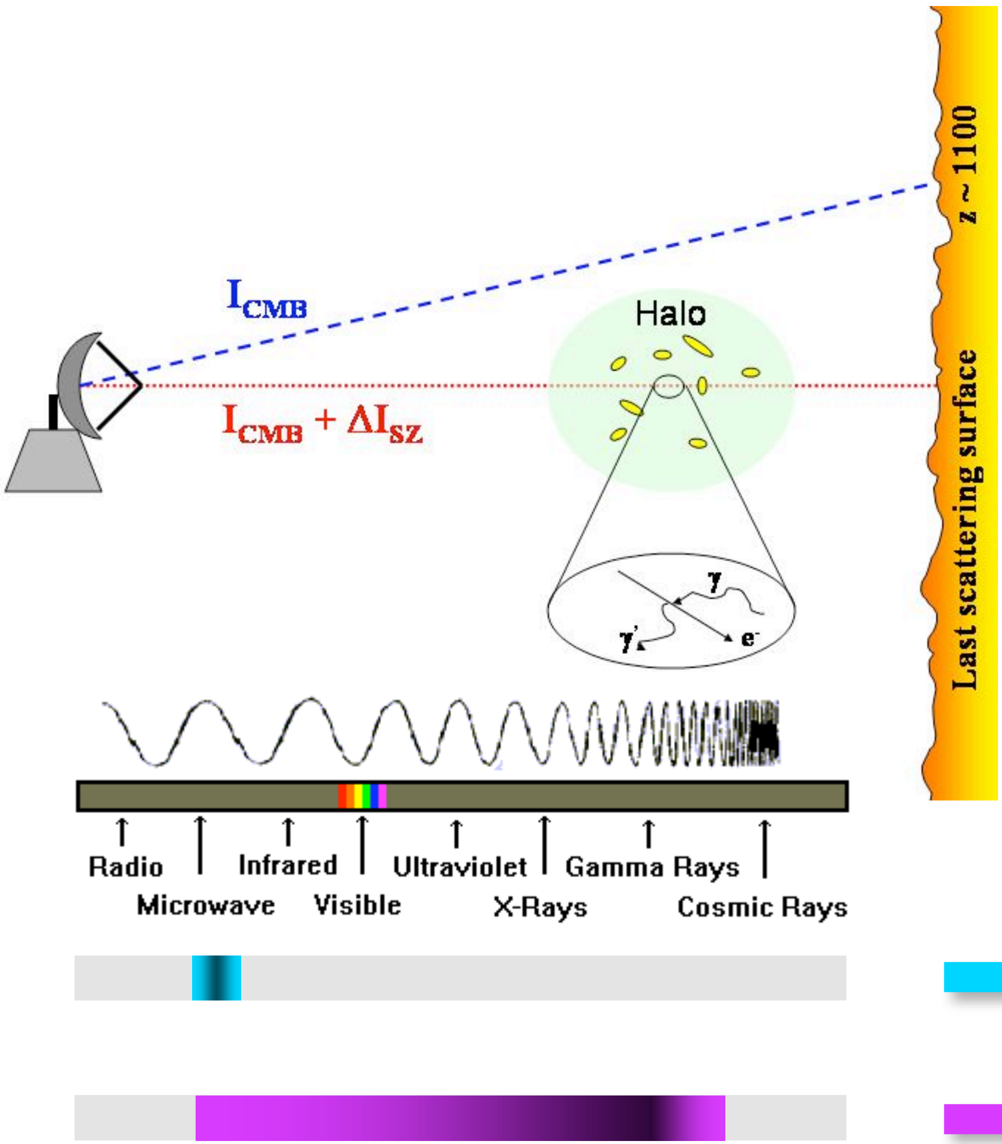
1957 A.S. Kompaneets publishes his Compton scattering Fokker-Planck equation

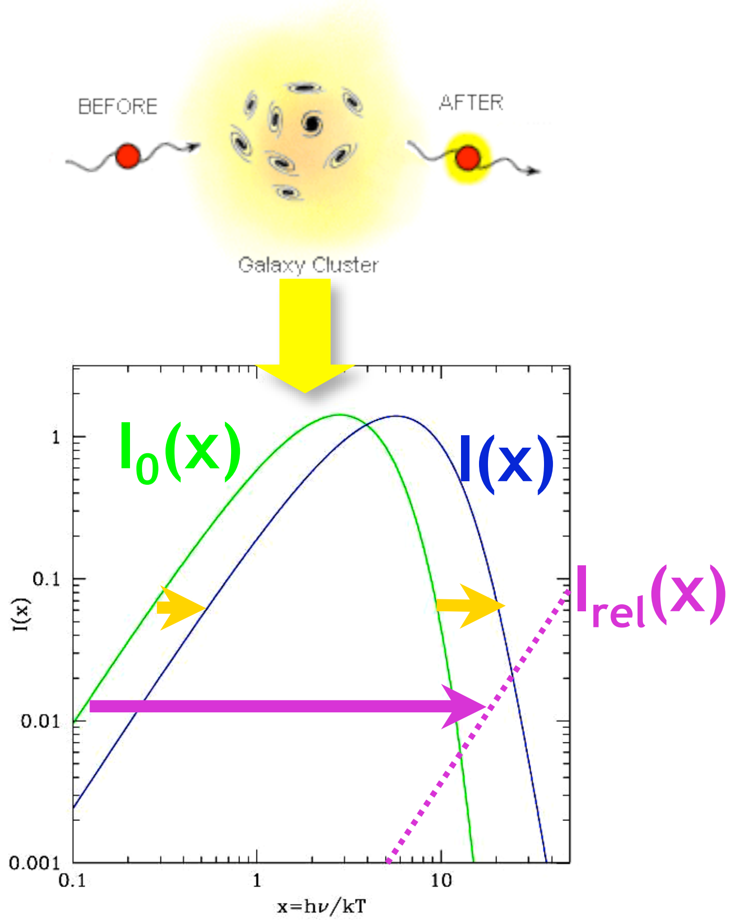
$$\frac{\partial n}{\partial y} = \frac{1}{x^2}\frac{\partial}{\partial x}x^4\left(\frac{\partial n}{\partial x} + n + n^2\right)$$

(derived by A.S. Kompaneets in Soviet Union ~1950 but was classified due to bomb research until 1956)

1969 Ya. B. Zel'dovich & R. Sunyaev derive the SZ effect (i.e., applied the Kompaneets eq. for a thermal intracluster plasma)

SZ effect: ...more than basics





thermal NR e^- $\quad \frac{\Delta\nu}{\nu} \approx 4\frac{kT_e}{m_e c^2}$

relativistic e^- $\quad \frac{\Delta\nu}{\nu} \approx \frac{4}{3}\gamma^2$

SZE: general derivation

Intensity change

$$\Delta I(x) = 2\frac{(k_B T_0)^3}{(hc)^2} y \bar{g}(x)$$

$$y = \frac{\sigma_T}{m_e c^2} \int P d\ell.$$

spectral shape

electron "Pressure"

depends on electrons energy distribution

in thermal case

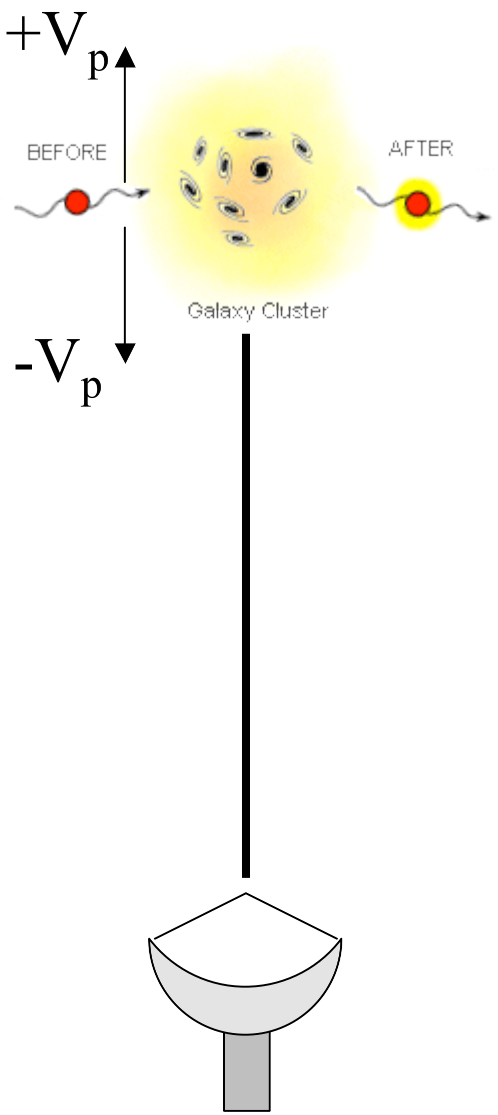
$P_{th} = n_e k_B T_e$ → Mass

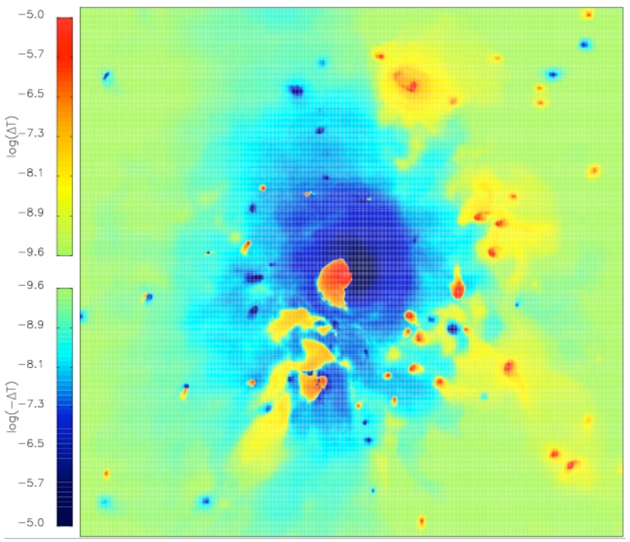
Note: **redshift not involved** ⇒ detectability independent of redshift (provided that the angular resolution is appropriate)

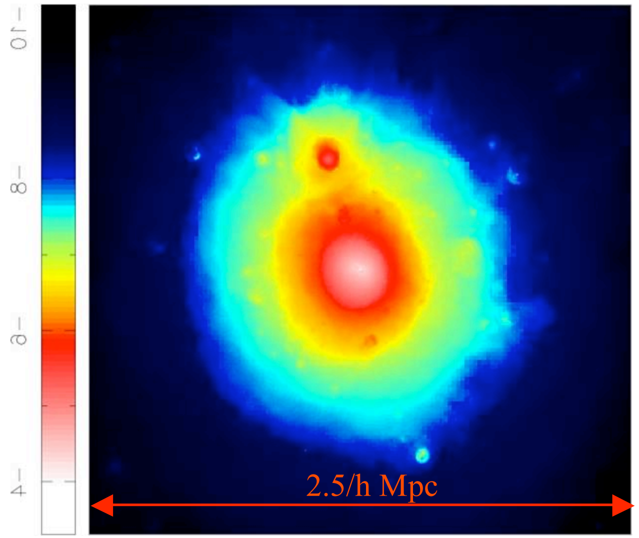
SZE: other sources

Kinematic SZE

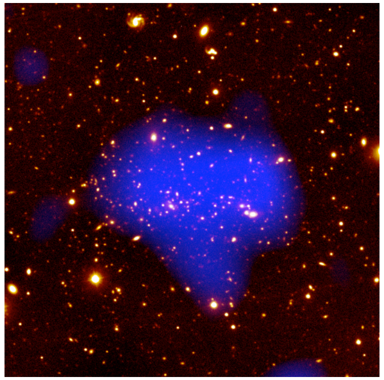
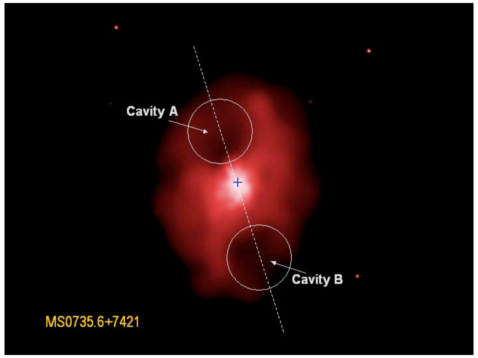
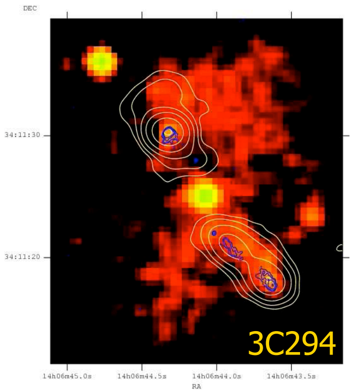
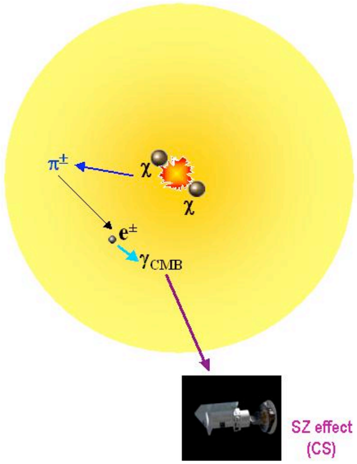
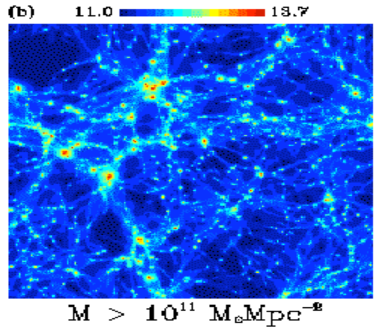
$$\frac{\Delta T}{T} = \frac{\pm V_p}{c}\tau$$







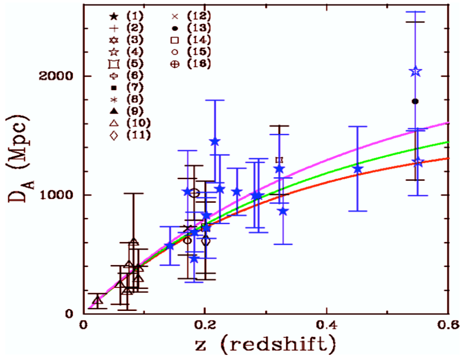
Sources of SZ

Galaxy clusters	AGN jets/cavities	Dark Matter	WHIM
	 	 	

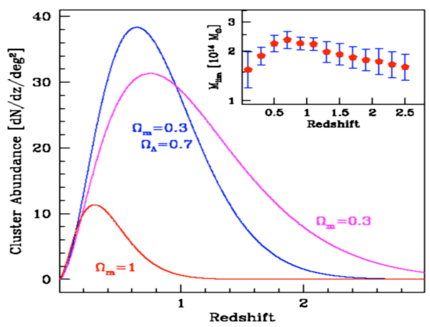
Astrophysical relevance

Galaxy clusters

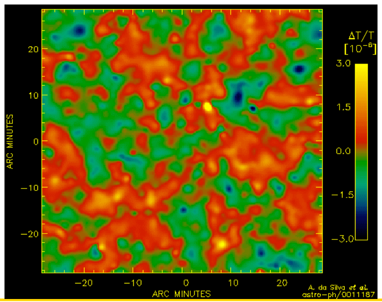
Hubble diagram



Cluster counts/masses

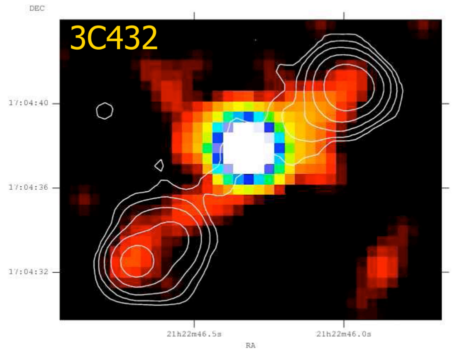


Cluster velocities



AGN jets/cavities

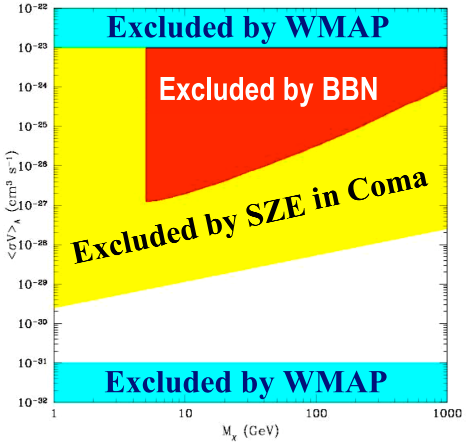
$T_{CMB}(z)$



$$\frac{\Delta T}{F_{IC}} \propto (kT_{CMB})^{-3} \times \gamma_{min}^{-(\alpha-1)} \cdot E_{X\,min}^{-(\alpha-1)/2}$$

DM nature

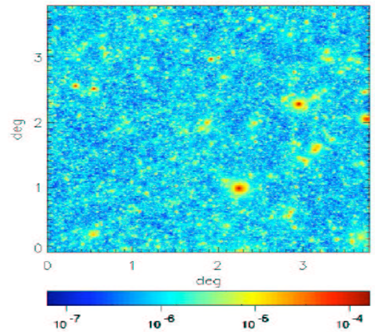
SUSY DM



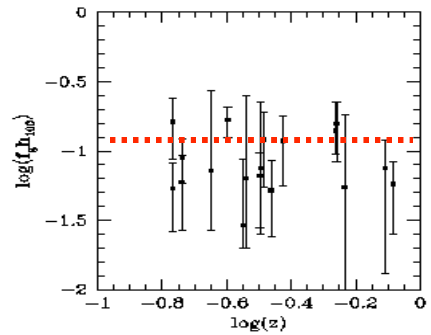
Non-SUSY DM

- MeV DM
- sterile ν
- …

WHIM

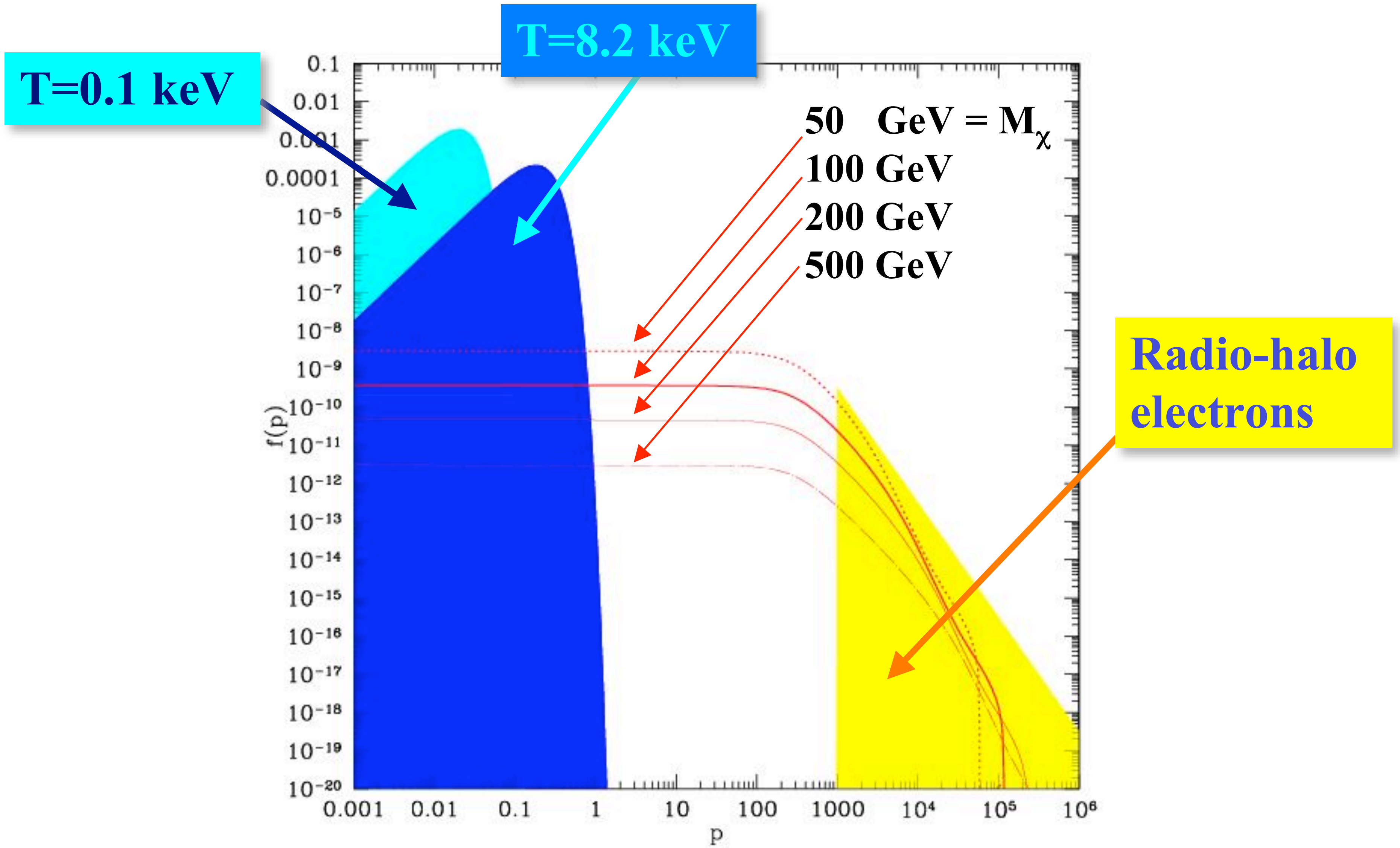


Baryon fraction



The e± distribution in clusters

COMA: warm gas + hot gas + radio halo + DM halo

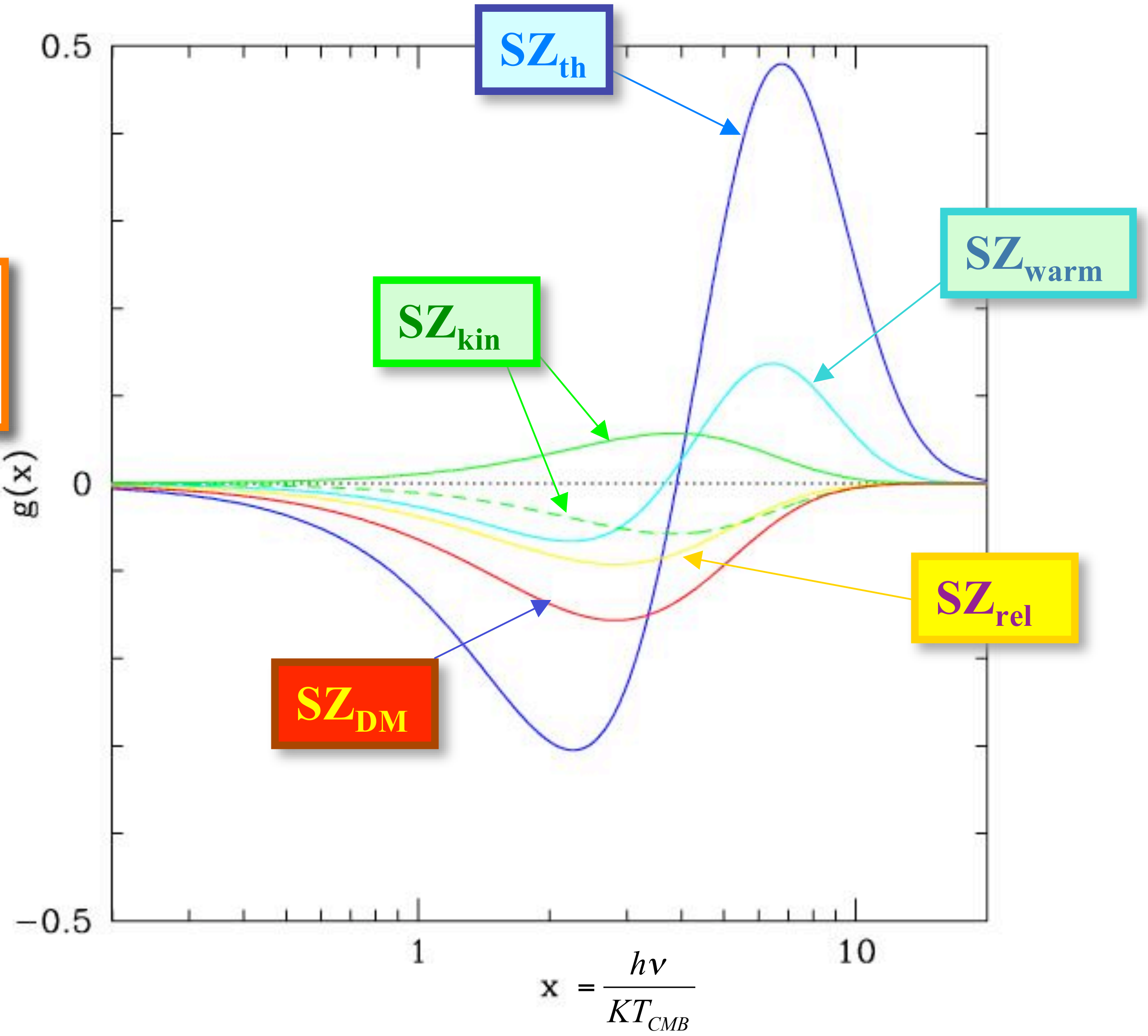


The SZE from various e± pops.

Colafrancesco 2007

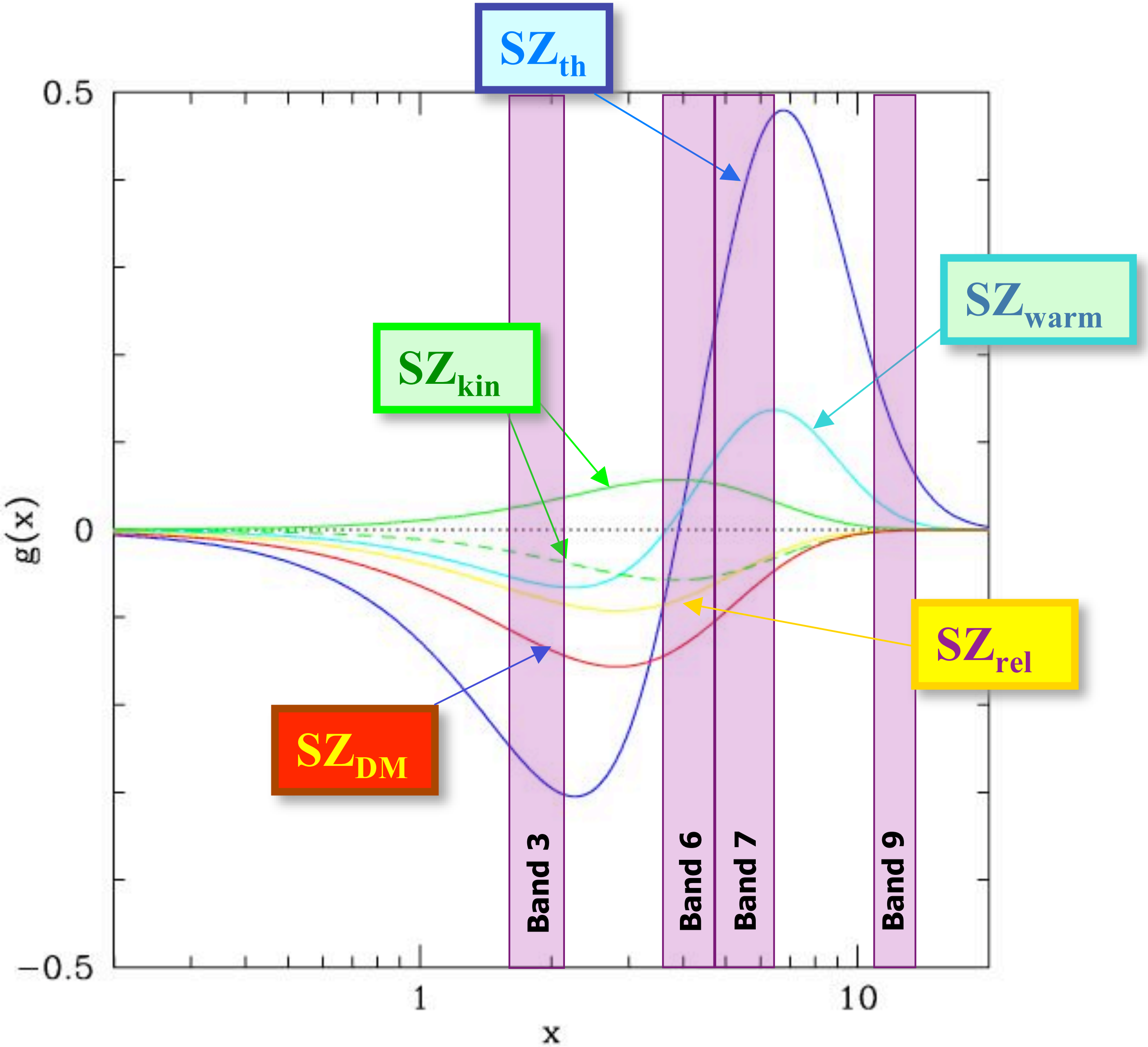
$$\Delta I(x) = 2\frac{(k_B T_0)^3}{(hc)^2} y \tilde{g}(x)$$

$$y = \frac{\sigma_T}{m_e c^2} \int P d\ell.$$

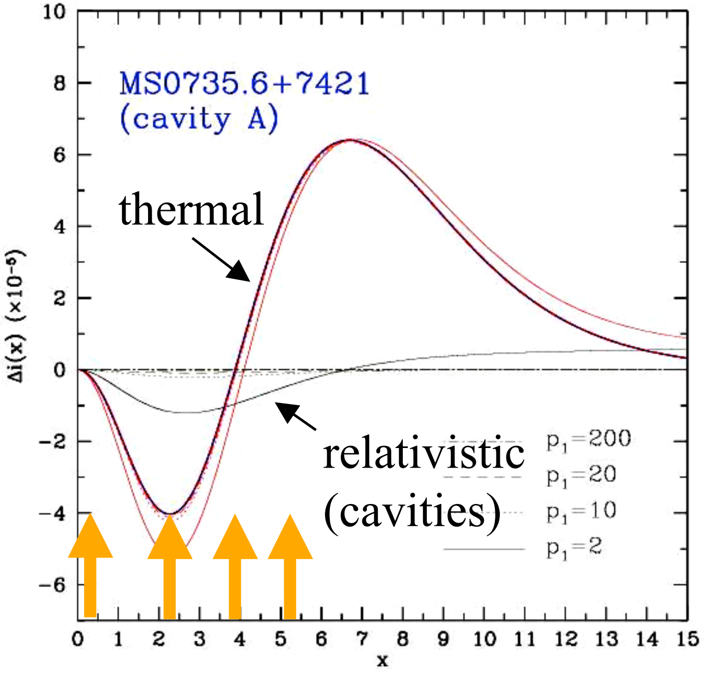


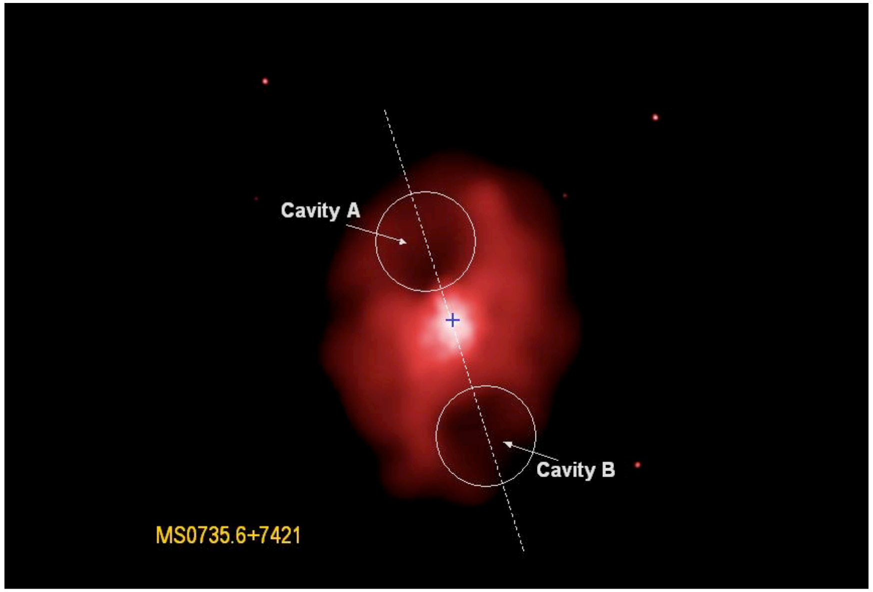
SZE: ALMA ν-coverage

ALMA reference ν-bands	
Band 3	86 – 116 GHz
Band 6	211 – 275 GHz
Band 7	275 – 370 GHz
Band 9	602 – 720 GHz



SZE & cavities in clusters





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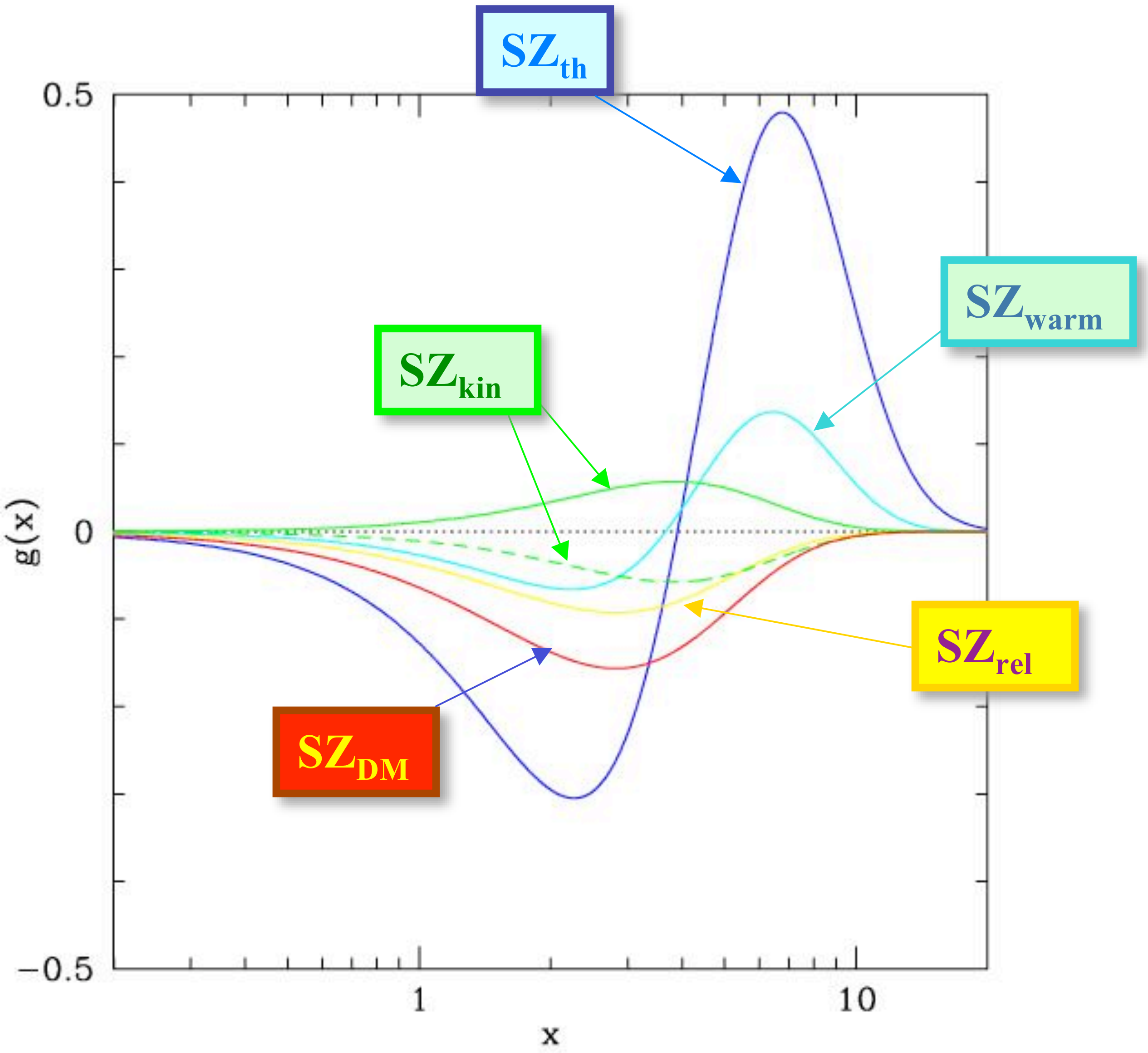
SZE in DM halos

A structure with:

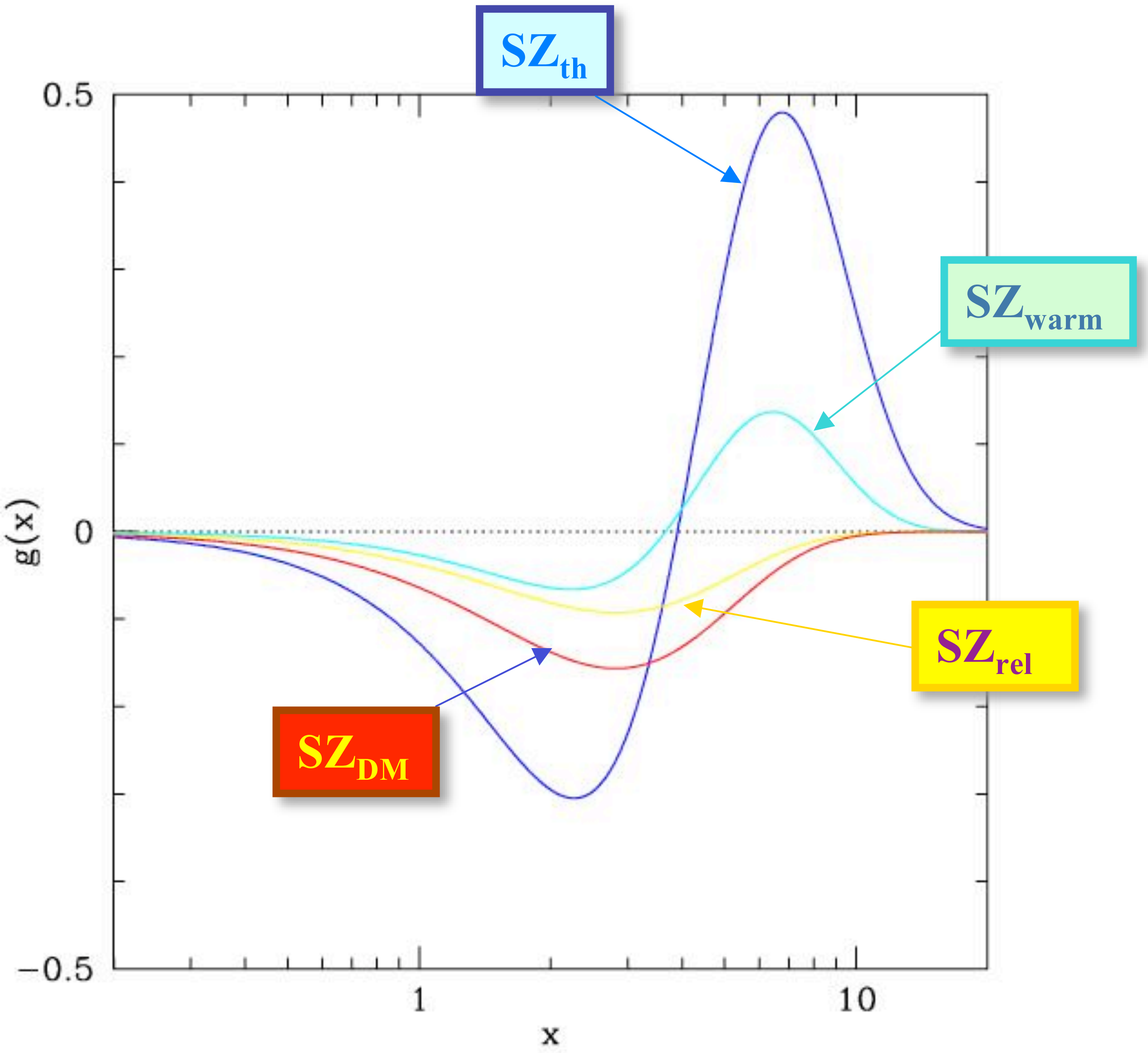
- Hot gas
- Warm gas
- Rel. Plasma
- DM
- Distant & V_r



SZE in DM halos

A structure with:

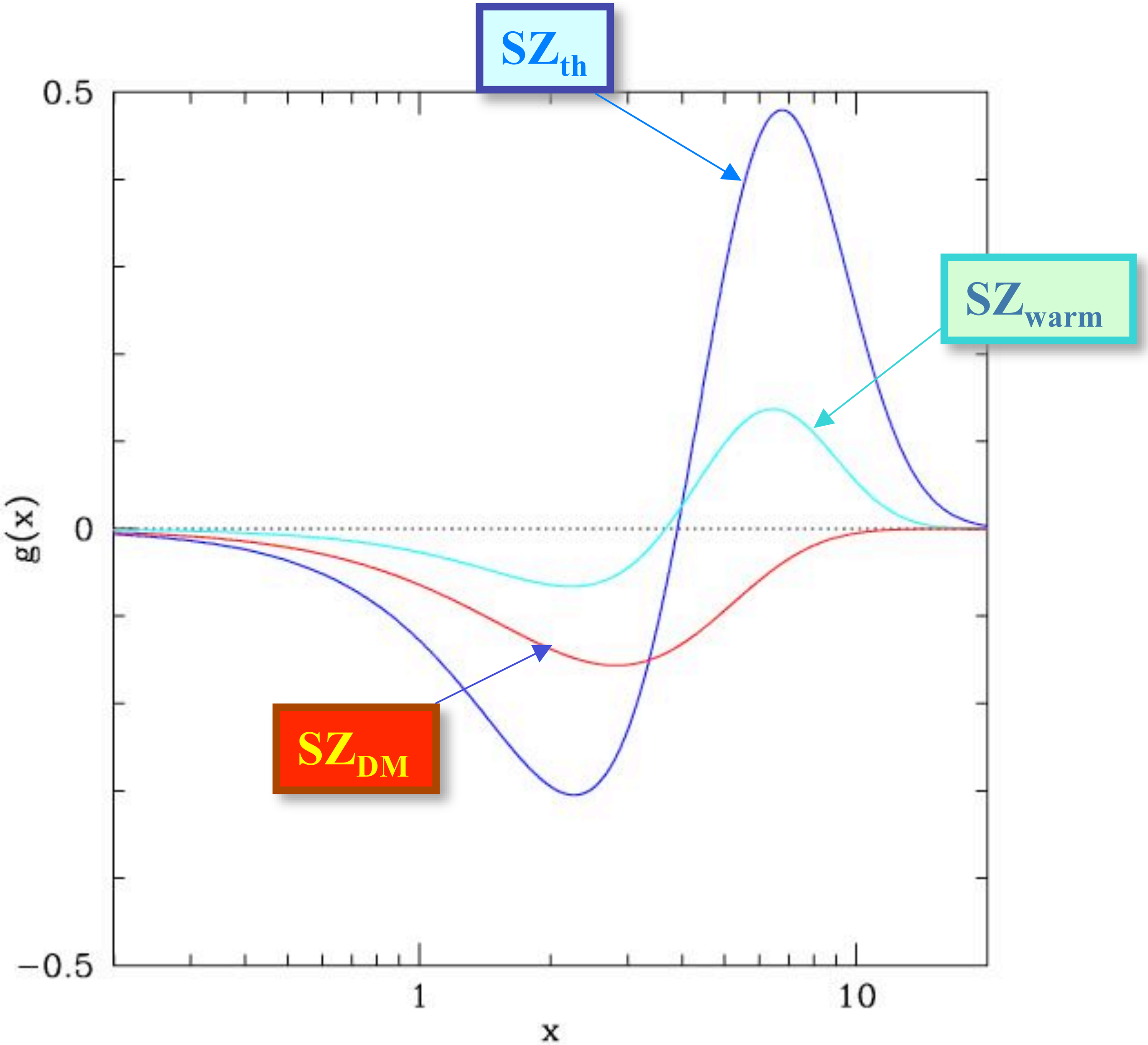
- **Hot gas**
- **Warm gas**
- **Rel. Plasma**
- **DM**
- **Nearby ($V_r \approx 0$)**



SZE in DM halos

A structure with:

- **Hot gas**
- **Warm gas**
-
- **DM**
- **Nearby ($V_r \approx 0$)**

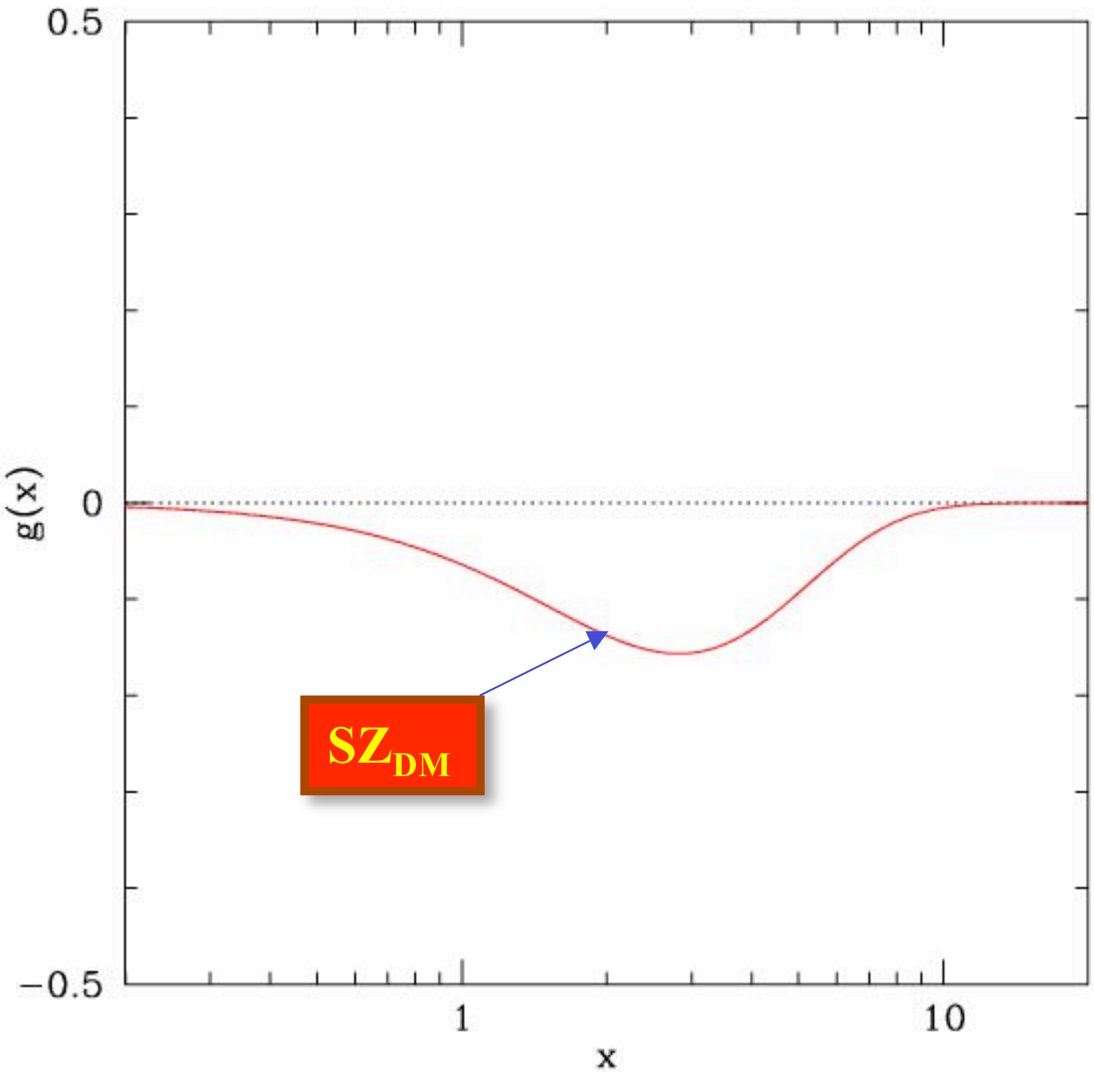


SZE in DM halos

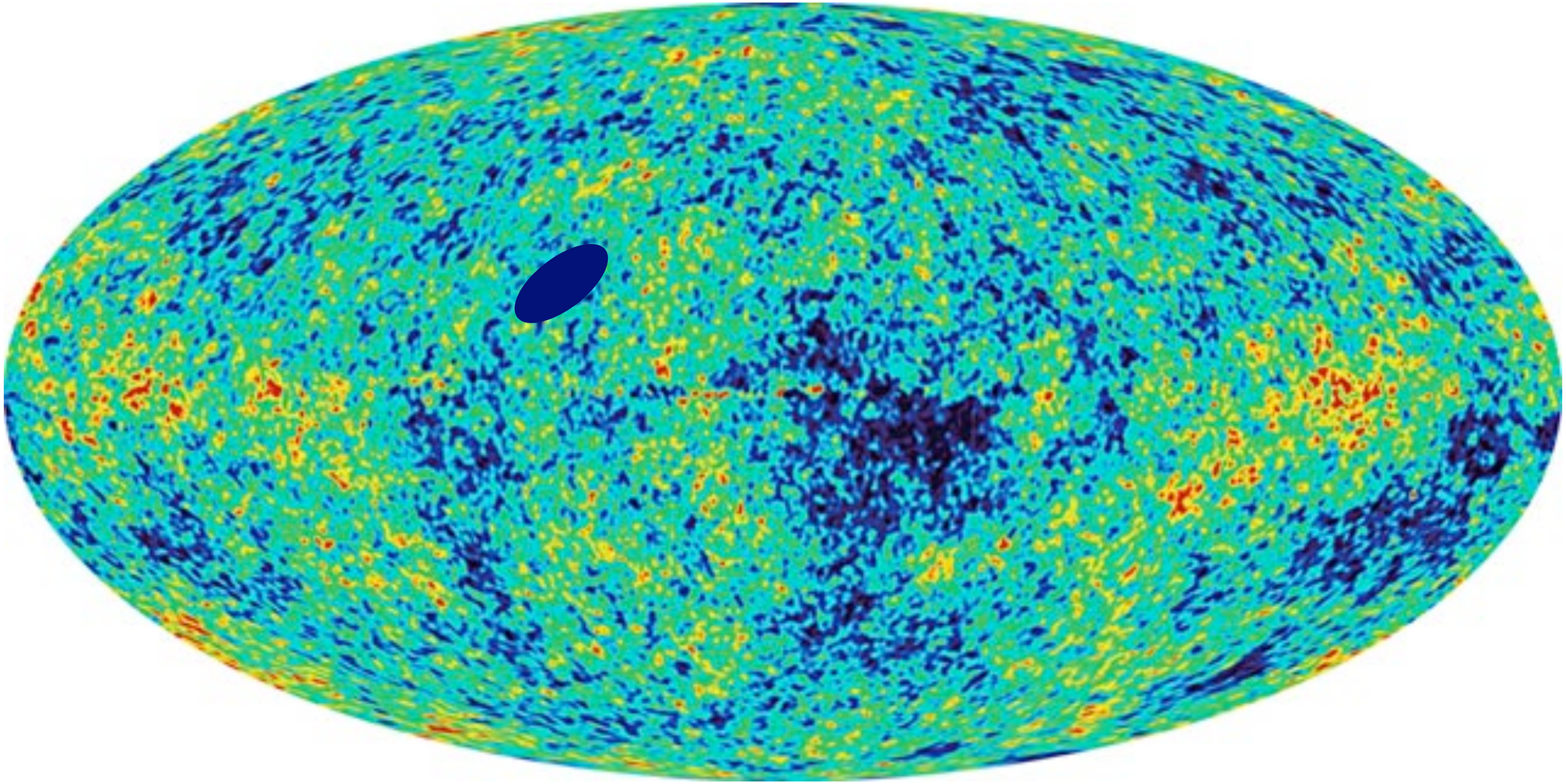
A structure with:

-
-
-
- **DM**
- **Nearby ($V_r \approx 0$)**

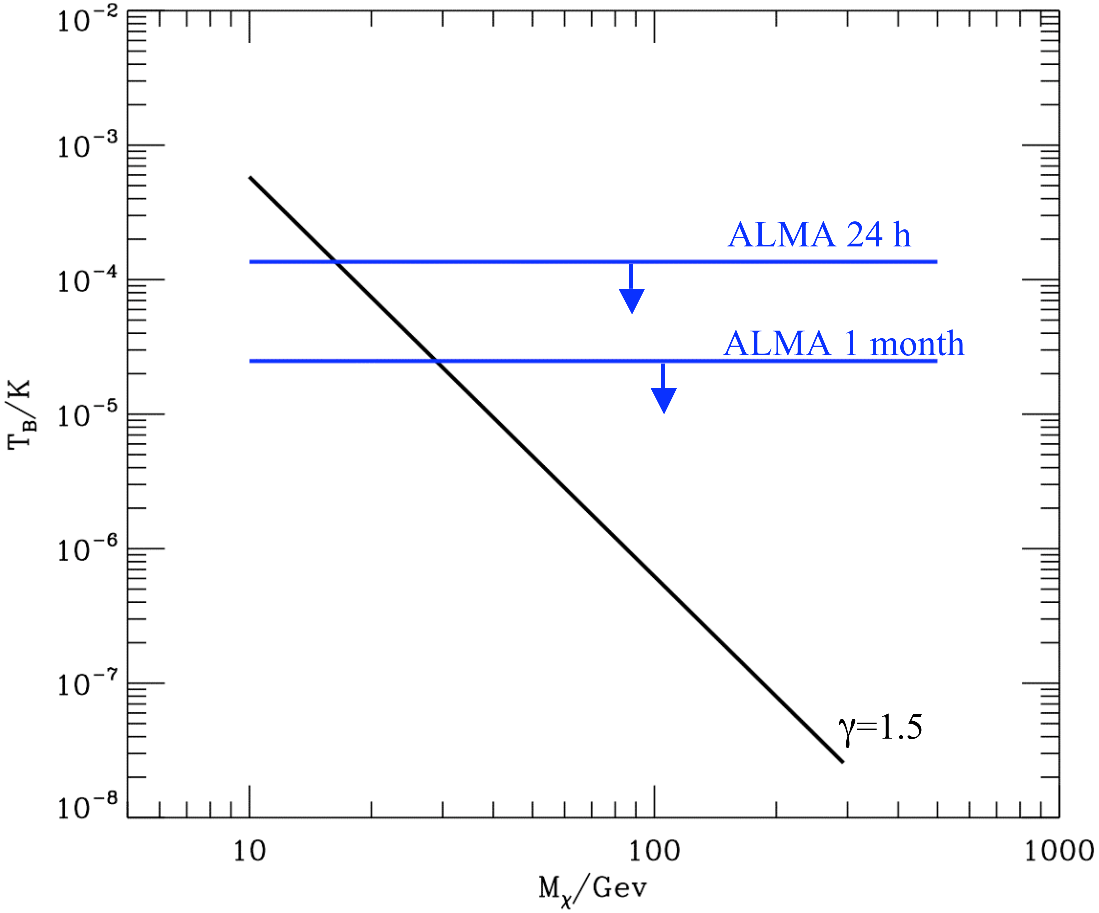
low surface brightness galaxies



CMB maps & DRACO



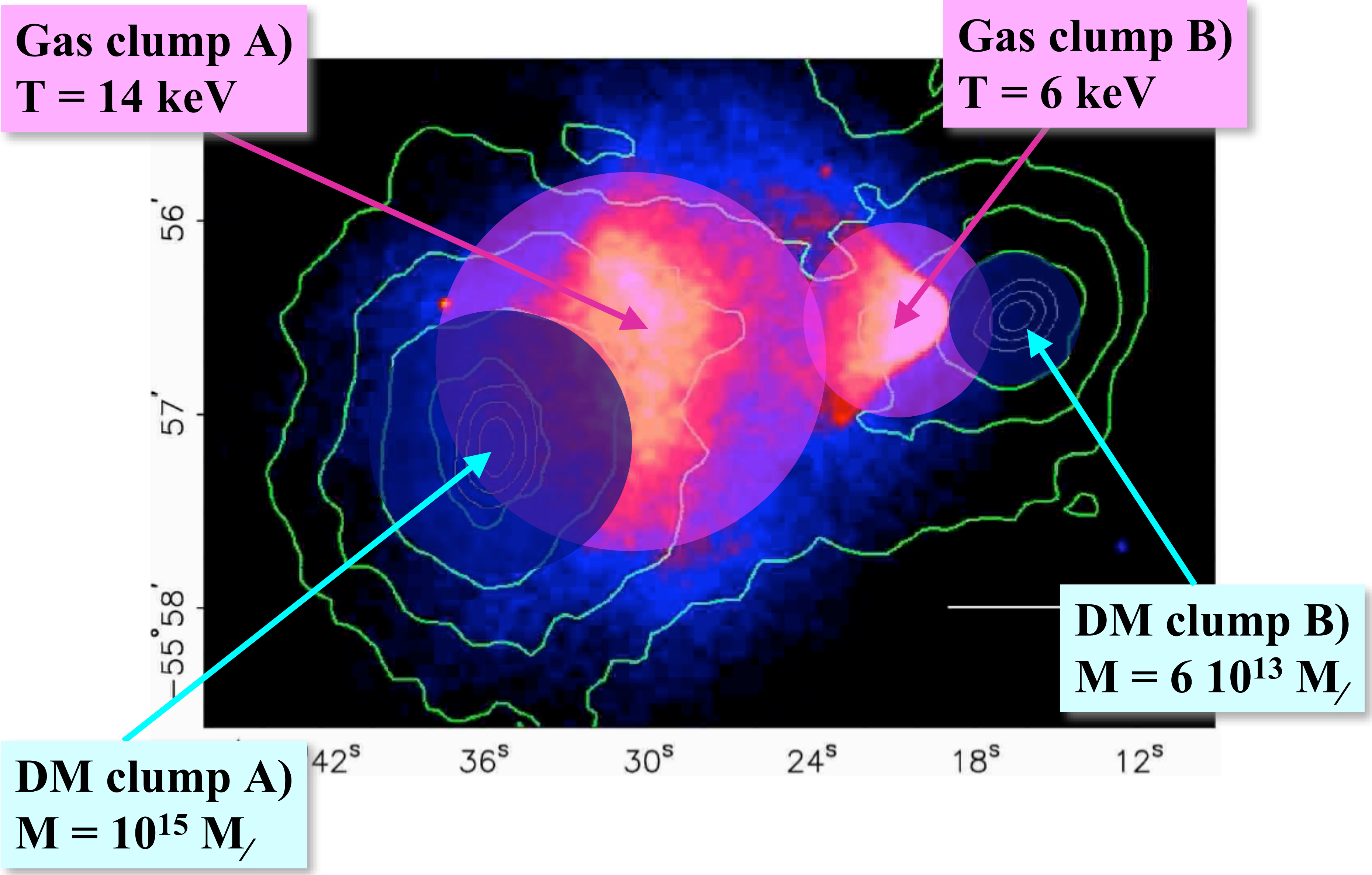
SZ_{DM} in Draco



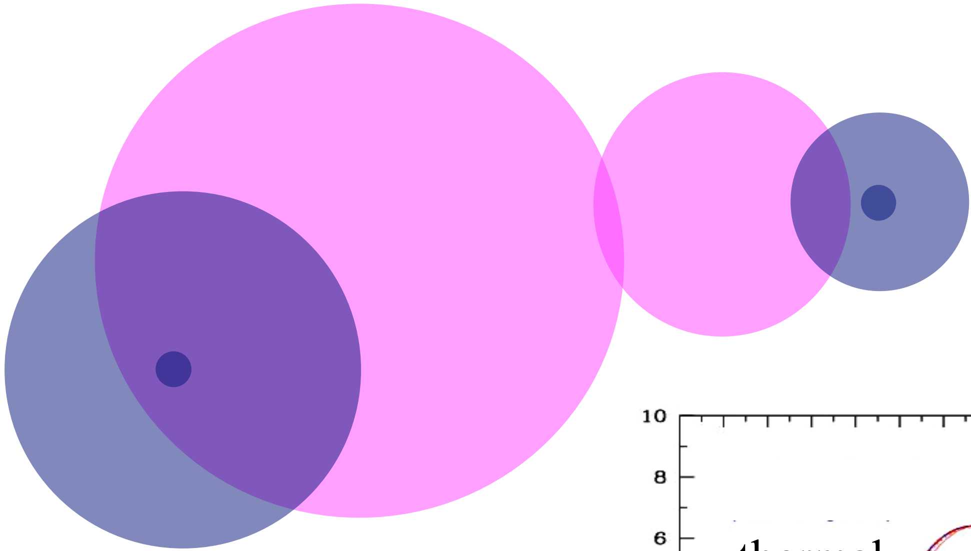
limits without ACA

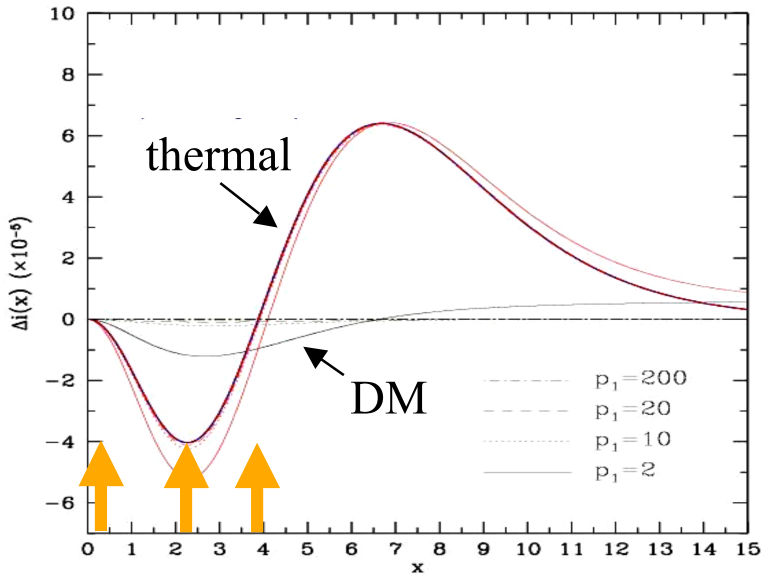
adapted from Culverhouse+06

The cluster 1ES0657-556

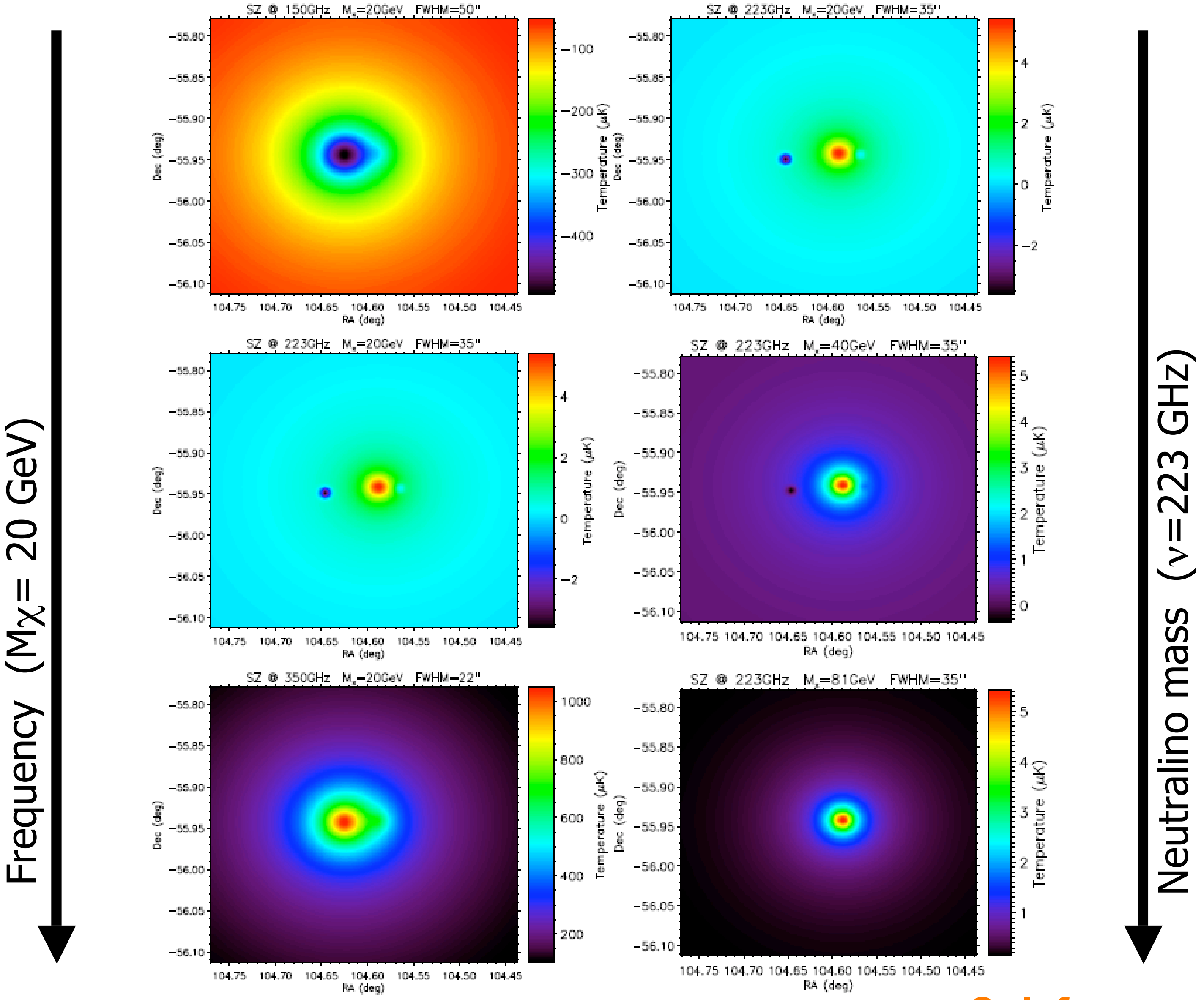


The SZ_{DM} from 1ES0657-556





Isolating SZ_{DM} at ~223 GHz



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SZE science: requirements