

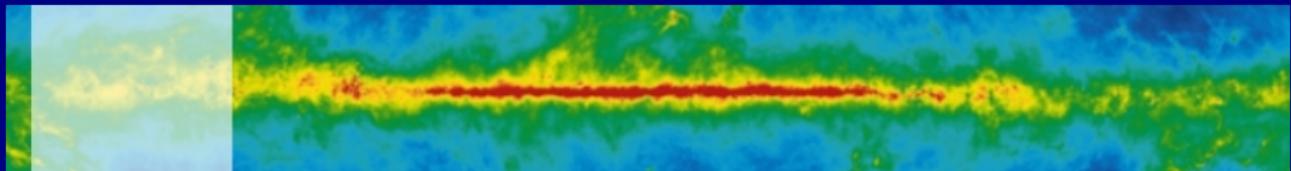
DMMW: A tool for multi-wavelength dark matter searches

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University of California, Santa Cruz

IDM 2010, Montpellier



Indirect Searches

- Prompt γ -ray emission: signal $\sim \rho_{DM}^2$ (or $\sim \rho_{DM}$), flux is just integral along line of sight:

$$\Phi_{DM}(E, \psi, \Delta\Omega) = \frac{\langle \sigma v \rangle}{4\pi} \cdot \sum_f \frac{dN}{dE} b_f \cdot \frac{1}{\Delta\Omega} \int_{\Delta\Omega} \int_{\text{line of sight}} \frac{1}{2} \frac{\rho_\chi(l)^2}{m_\chi^2} dl_\psi$$

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- BUT:** we also have **secondary emission** from stable decay/annihilation products:
 - $e^+ / e^- \Rightarrow \text{bremsstrahlung, IC, synchrotron}$
 - also: $p / \bar{p} \Rightarrow \pi^0$ -decay
- non-thermal e^- / e^+ produce multi-wavelength spectrum from radio to γ -ray frequencies

Motivation

- Dwarfs, clusters, GC: constraints from radio or X-ray observations can be more stringent than γ -ray constraints see e.g. [Profumo & Ullio, arXiv:1001.4086]
- => need reliable predictions for secondary emission and prompt γ -rays **for many different objects**

Modelling secondary emission

Calculation of **secondary emission** goes through (at least) two steps:

- 1 compute equilibrium distribution of e^-/e^+ , p :

$$\frac{\partial}{\partial t} \frac{dn}{dE} = \nabla K(E) \nabla \frac{dn}{dE} + \frac{\partial}{\partial E} b(E) \frac{dn}{dE} + Q(E, r)$$

- $Q(E, r)$: DM halo + initial spectrum/ CR sources

Modelling secondary emission

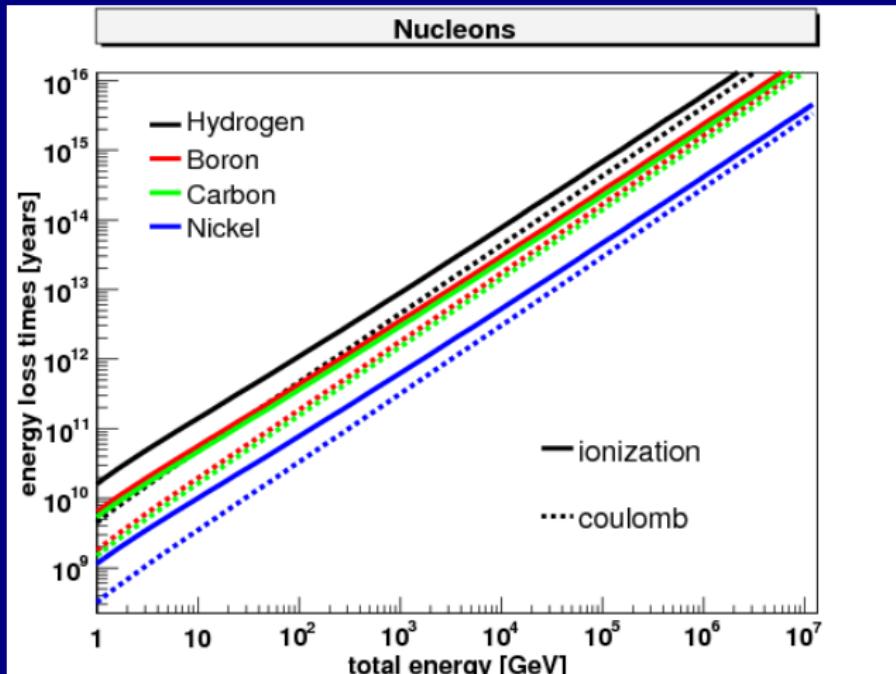
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Modelling secondary emission



$$\tau \approx 10^{10} - 10^{12} \text{ yrs}$$

$$K \approx 10^{28} - 10^{30} \frac{\text{cm}^2}{\text{s}}$$

$$\Rightarrow d \approx 10 - 10^3 \text{ kpc}$$

(lower limit)

assuming Galactic gas densities: $n_{H\text{I}} = n_{H\text{II}} = 0.01 \text{ cm}^{-3}$

Modelling secondary emission

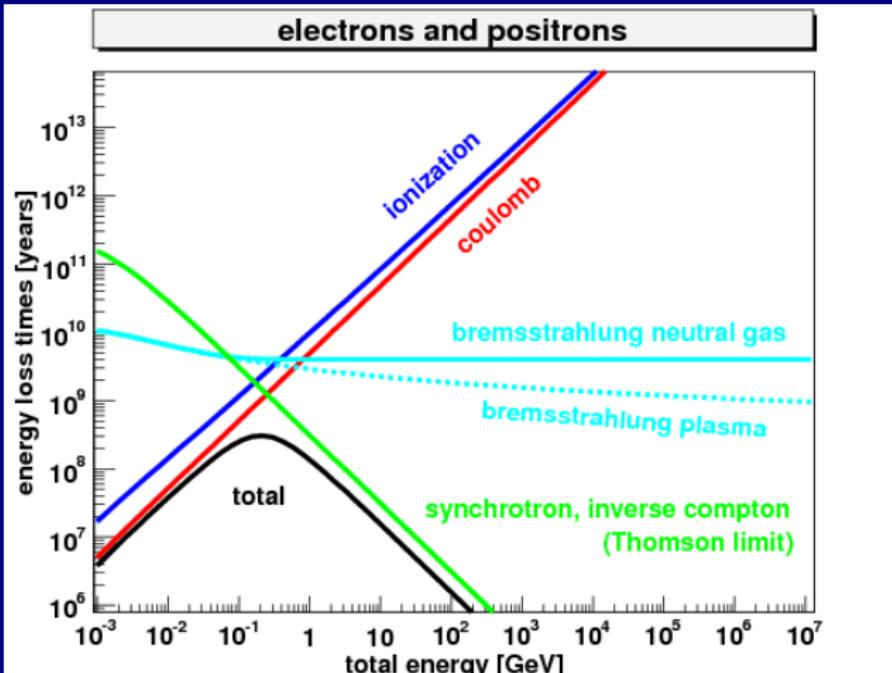
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- $b(E)$: energy losses (IC, synchrotron, bremsstrahlung, coulomb/ionisation losses)=>relevant for electrons

Modelling secondary emission



$$\tau \approx 10^8 \text{ yrs}$$

$$K \approx 10^{28} - 10^{30} \frac{\text{cm}^2}{\text{s}}$$

$$\Rightarrow d \approx 1 - 10 \text{ kpc} \\ (\text{galactic scales})$$

$$n_{HI} = n_{HII} = 0.01/\text{cm}^3. \text{ ISRF}, B = 1 \text{ eV}/\text{cm}^3$$

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- 2 compute emissivities

$$\mathbf{j}_i(E_\gamma, r) = \int dE \frac{dn}{dE} P_i(E_\gamma, E)$$

$i =$ synchrotron, IC, bremsstrahlung, π^0

DMMW: A Multi-Wavelength fitter

Problem

- field/gas densities, transport parameters not well known
- need to fit DM particle properties and transport properties of object at the same time
- background from conventional CRs

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Need

- simple tool: no spatial dependence of transport parameters, use spherical symmetry
- needs to be fast: semi-analytical solution

DMMW: A Multi-Wavelength fitter

Input

- Radio, γ -ray spectra

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Fit parameters

- DM particle properties: $\langle \sigma v \rangle$, b_f , m_χ
- DM halo profile: ρ_{DM}/ρ_{DM}^2
- conventional CR sources
- transport parameters: $K(E)$
- field densities: B, ISRF, gas=> $b(E)$

DMMW: A Multi-Wavelength fitter

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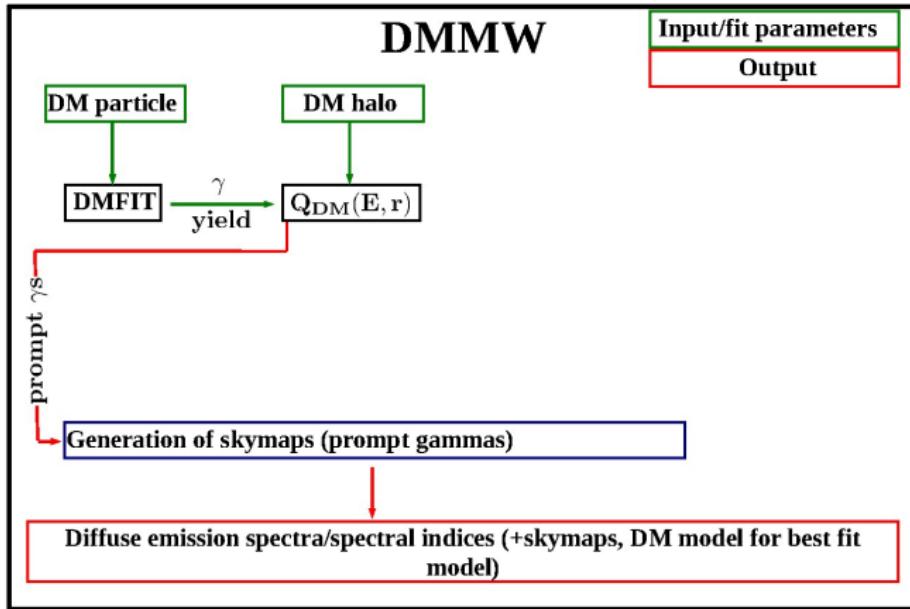
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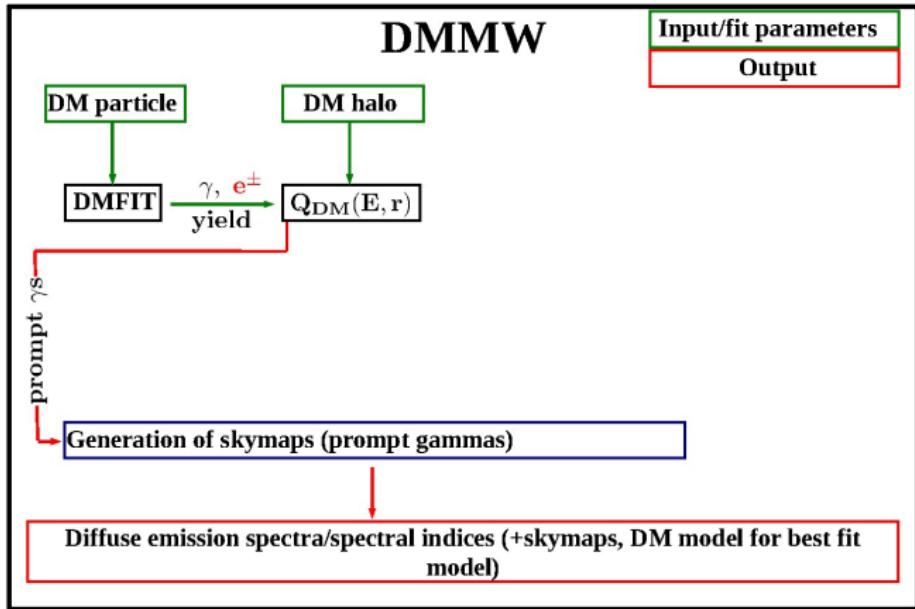
Output

- spectra/intensity profiles (skymaps, CR distributions +best fitting DM particle properties/transport parameters)



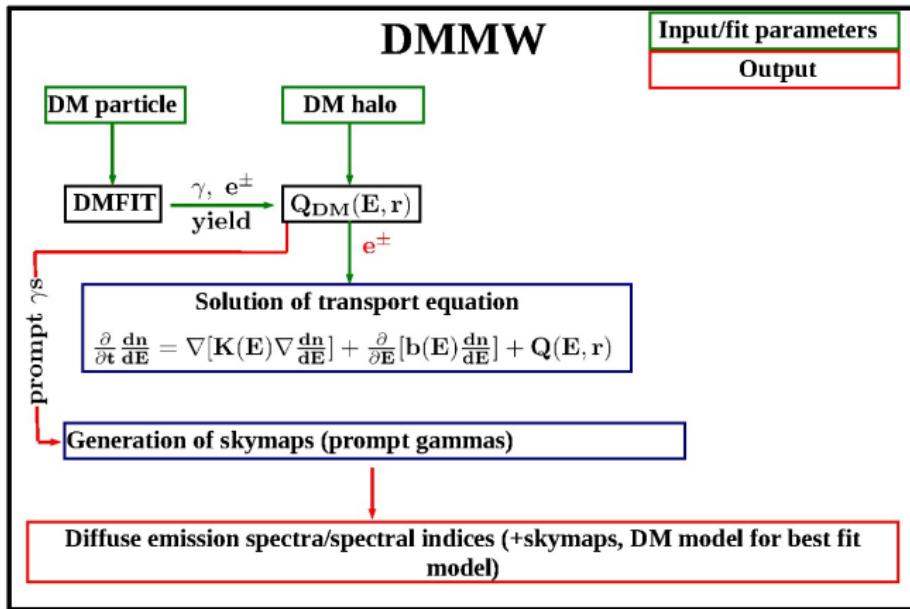
classical
search in
 γ -rays

DMFIT: Jeltema&Profumo arXiv:0808.2641



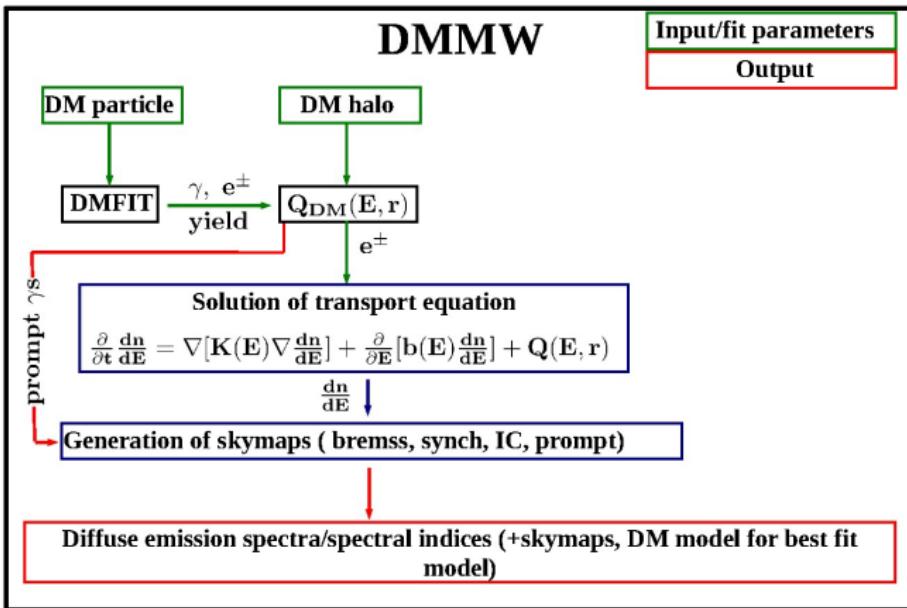
add e^+/e^-

DMFIT: Jeltema&Profumo arXiv:0808.2641

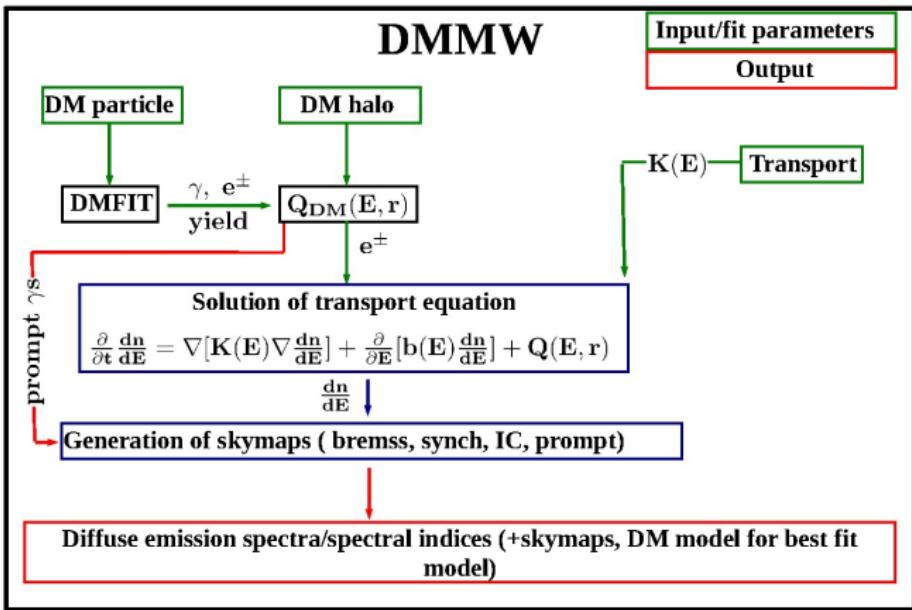


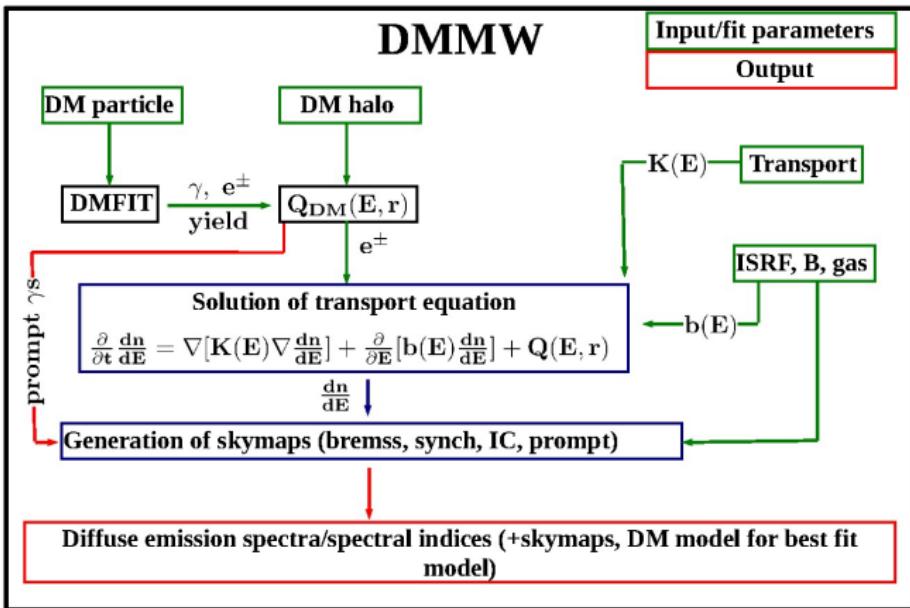
solve
transport
equation

Solution: Colafrancesco et al. astro-ph/0507575



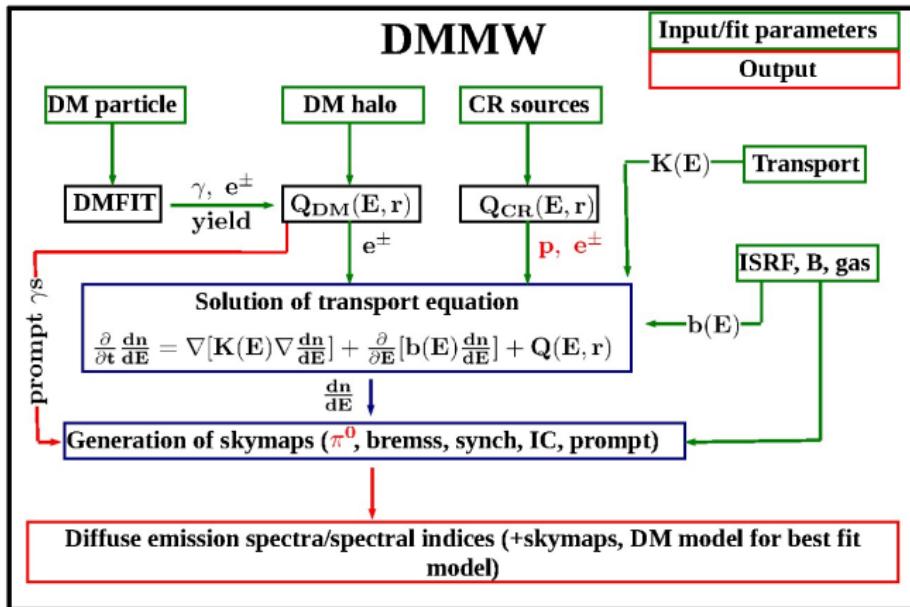
generate
multi-
wavelength
emission





need diffusion coefficient

need energy losses/field densities

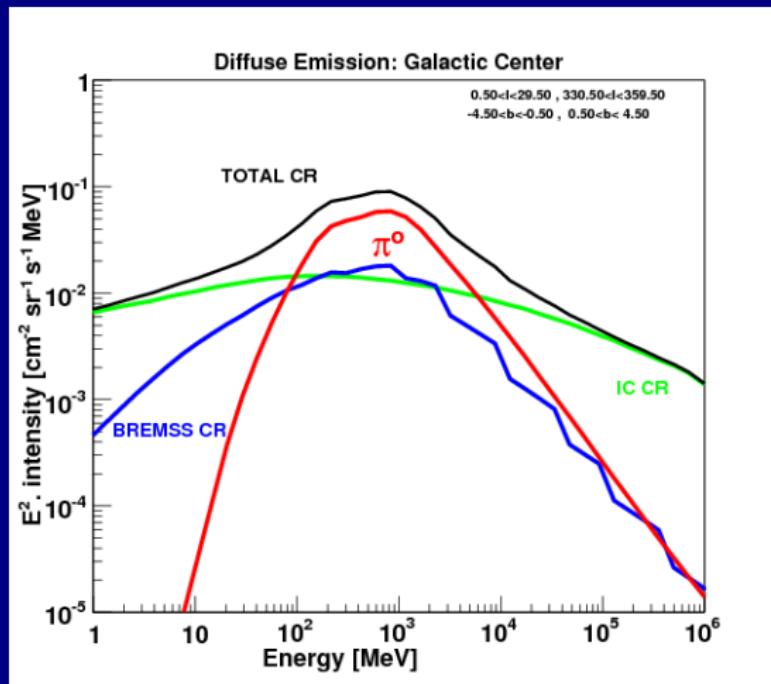


Output: spectral indices + CR densities and skymaps (FITS)

Very First Results from DMMW

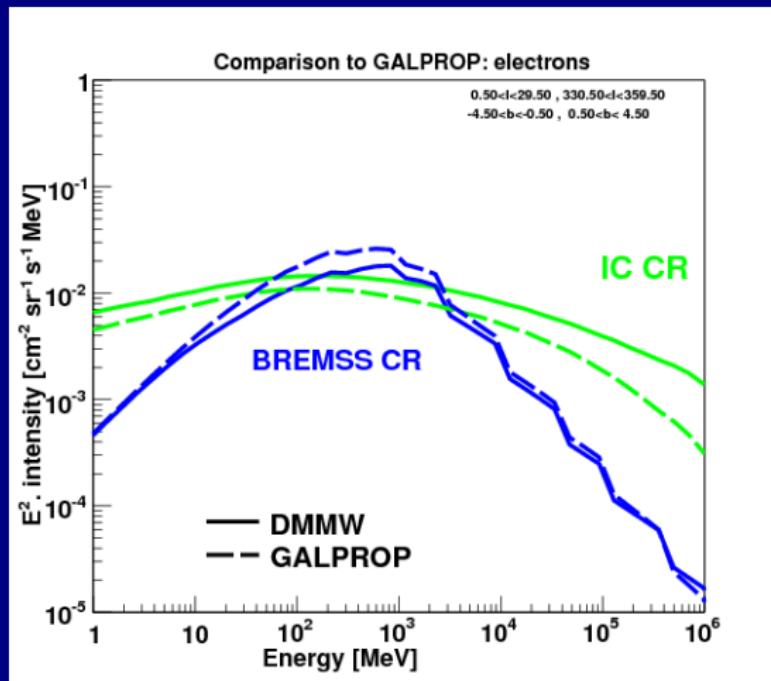
- look at “conventional CRs”
- use GALPROP as a cross-check for propagation

Galactic Center



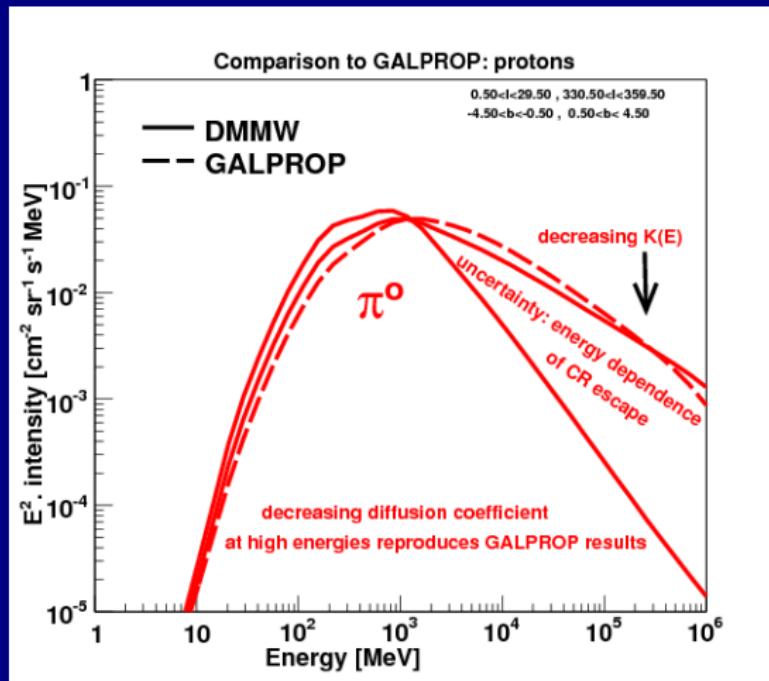
- Transport parameters= GALPROP conventional model
- Runtime $O(10s) \Rightarrow$ fit to data possible

Galactic Center: Electrons



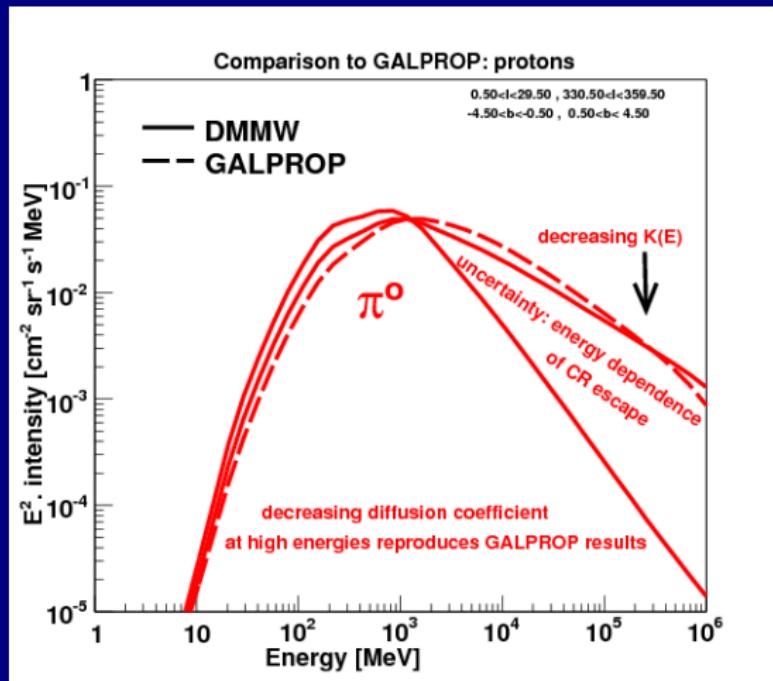
- Electron emission spectra agree with GALPROP prediction
- Slightly higher IC prediction due to spherical symmetry

Galactic Center: Protons



- CAVEAT: energy dependence of CR escape important for protons
- GALPROP: boundary at 4 kpc (free escape)
- DMMW: boundary “at infinity”

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Leaky Box

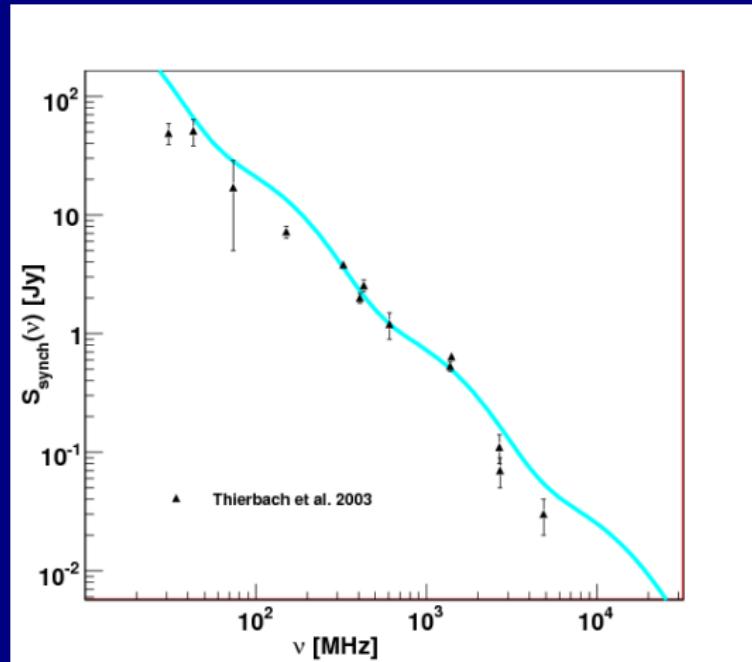
$L^2/\tau \sim K \Rightarrow$ decrease in $K(E)$ simulates small box

Target Applications

- Dwarf galaxies (e.g. limits on n_{gas} and τ_{conf})
- Neighbouring galaxies
- Clusters of galaxies (e.g. origin of large radio halos)

Coma radio halo¹

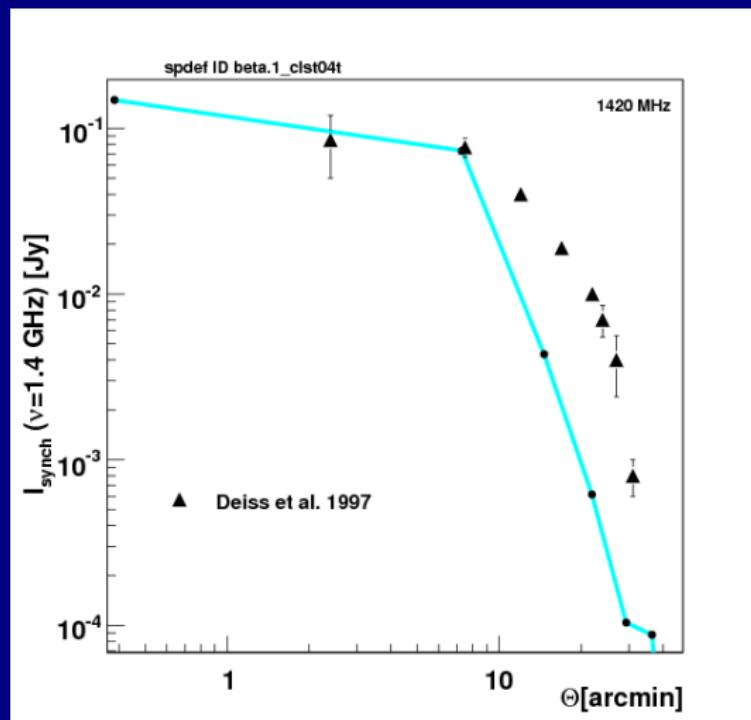
- $K(E) \approx 10^{29} \frac{cm^2}{s}$
- $B \sim 10 \mu G$
- tune primary e^- for synch spectrum



¹work in progress

Coma radio halo

- significant reacceleration?
 - secondary electrons from proton-gas collisions?=>constraints from B , π^0 -decay emission
 - other electron sources?
- ...work in progress



Conclusion

- DMMW is a tool for a wide range of applications, both Galactic and extragalactic
- can be used for "conventional" CR studies and DM searches in clusters, dwarf galaxies, neighbouring galaxies...
- code is FAST=>DM particle properties, transport parameters and gas/field densities can be fitted at the same time
- good agreement with GALPROP, but aims at different applications: ask general questions, get quick answer
- DMMW will be made public within the next few weeks

Simple, but very powerfull tool - test it!