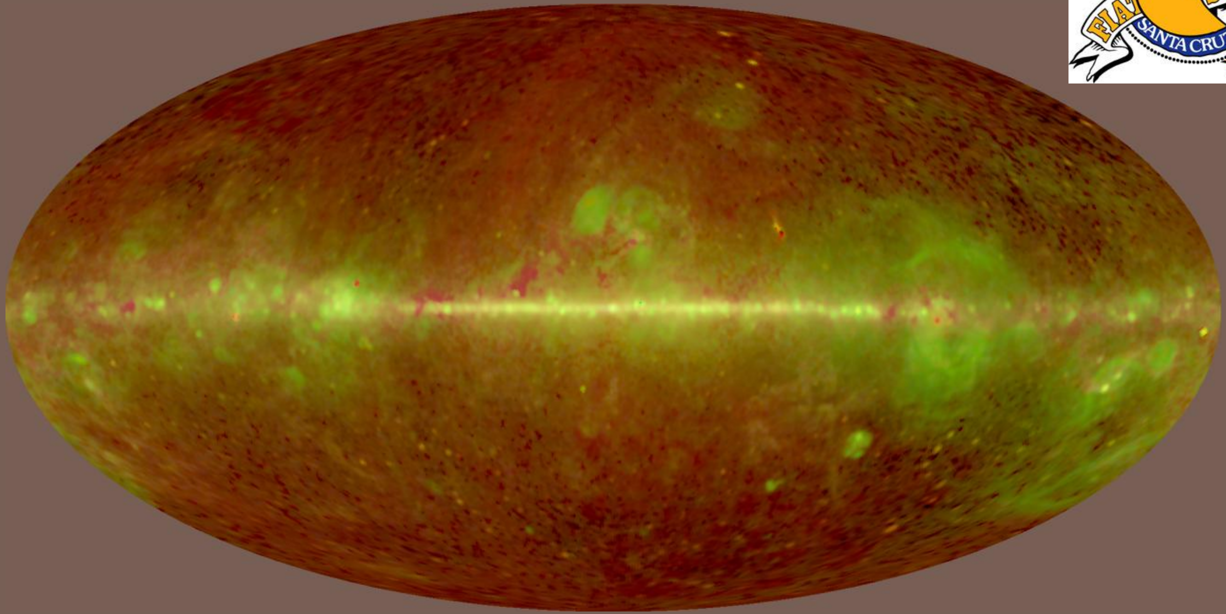
THE MORPHOLOGY OF THE DARK MATTER HAZE WITH SELF-CONSISTENT DIFFUSION MODELS



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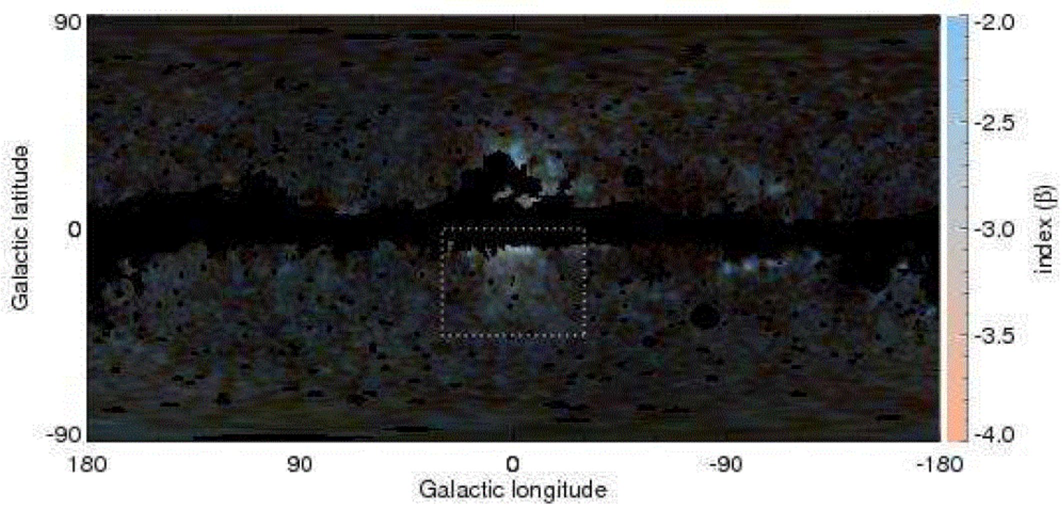
Overview

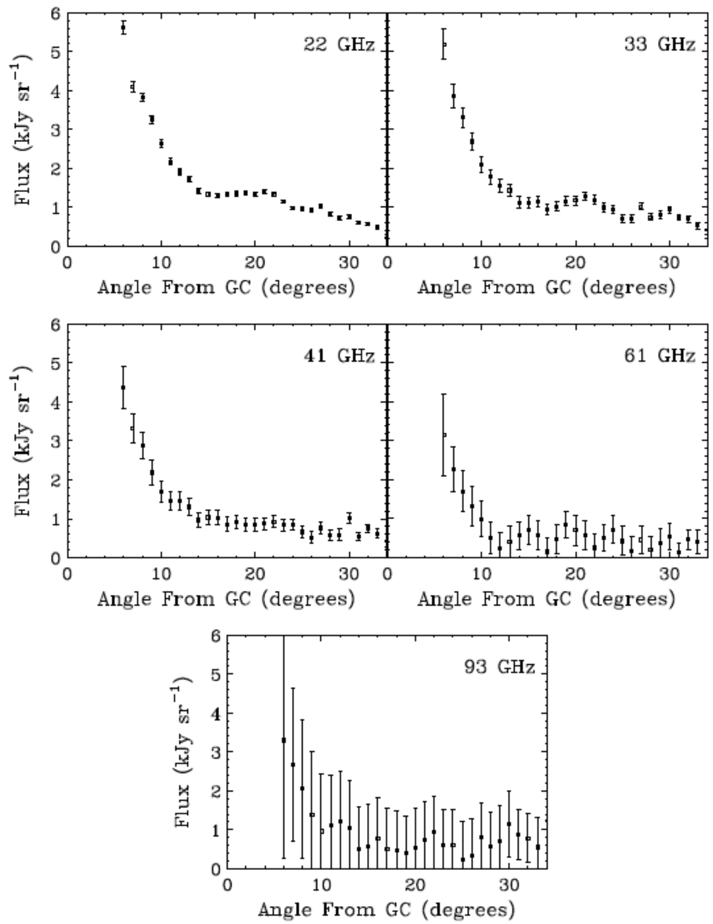
- What is the WMAP Haze?

- Can Dark Matter models match the spatial or frequency dependence of the haze?

WMAP Haze

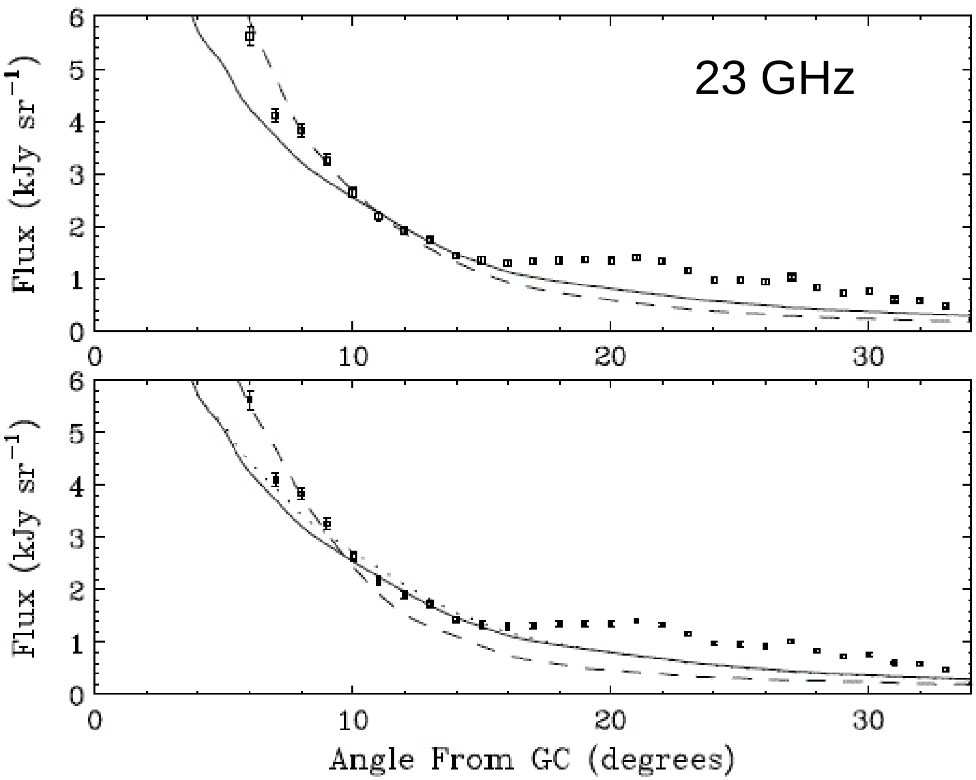
- Finkbeiner (2004) found an excess residual in the WMAP Haze, not explained by background subtraction





arXiv: 0712.1038 **arXiv: 0705.3655**

Dark Matter Modeling of WMAP



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Hooper et al. (2007) used Galprop models to simulate the WMAP Haze

M_X = 100 GeV

B = 10 μG

XX → e^+e^-

NFW Profile

D_0 = 1.58 x 10^{28} cm^2s^{-1} (4 GeV)

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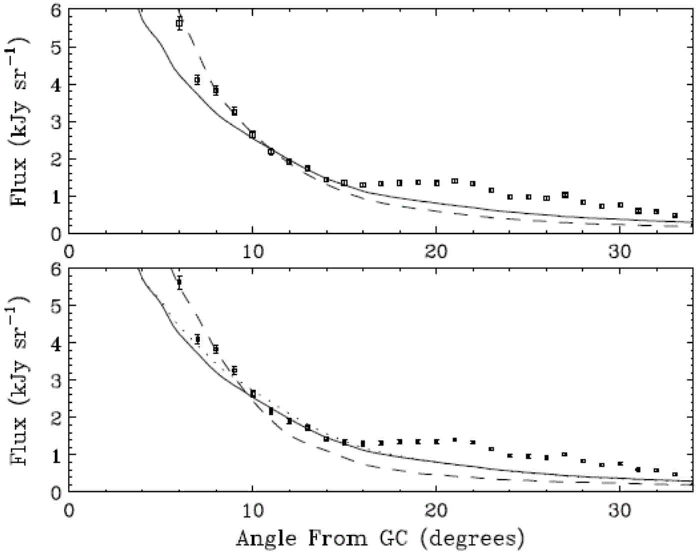

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Not Consistent with current best fit cosmic ray propagation models

arXiv: 0705.3655

Research Goals

- Evaluate a select range of well motivated annihilating WIMP theories
- Test the DM interpretation of the WMAP haze using cosmic ray propagation models that are consistent with all current observations and data

Simulation Models

- 1.) Use DarkSUSY to calculate the primary e^+e^- spectrum for a range of well motivated DM models
- 2.) Use Galprop to determine the synchrotron emission and nuclear abundances in each propagation model
- 3.) Isolate the simulated DM haze by subtracting the synchrotron component from the corresponding simulation with DM disabled.

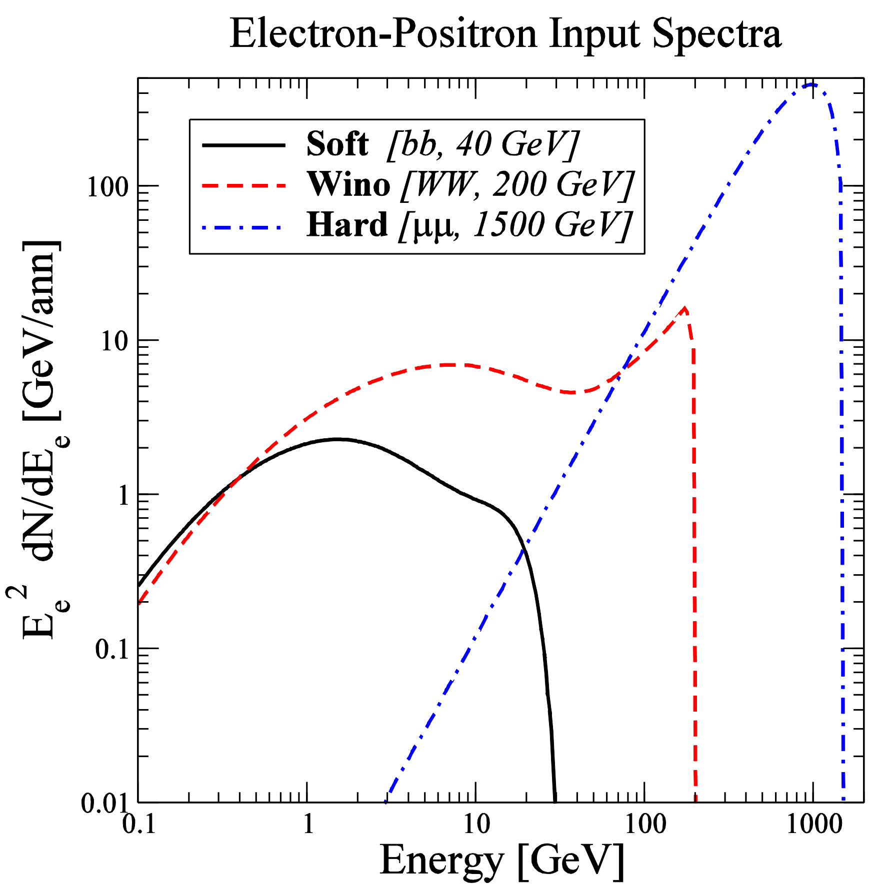
Dark Matter Models

- We test three DM annihilation channels which span a range of motivated WIMP decay models

Soft (40 GeV XX → b b-bar)

Wino (200 GeV XX → W^+W^-)

Hard (1500 GeV XX → $\mu^+\mu^-$)



- Employ NFW profile with R_{SC} = 22 kpc

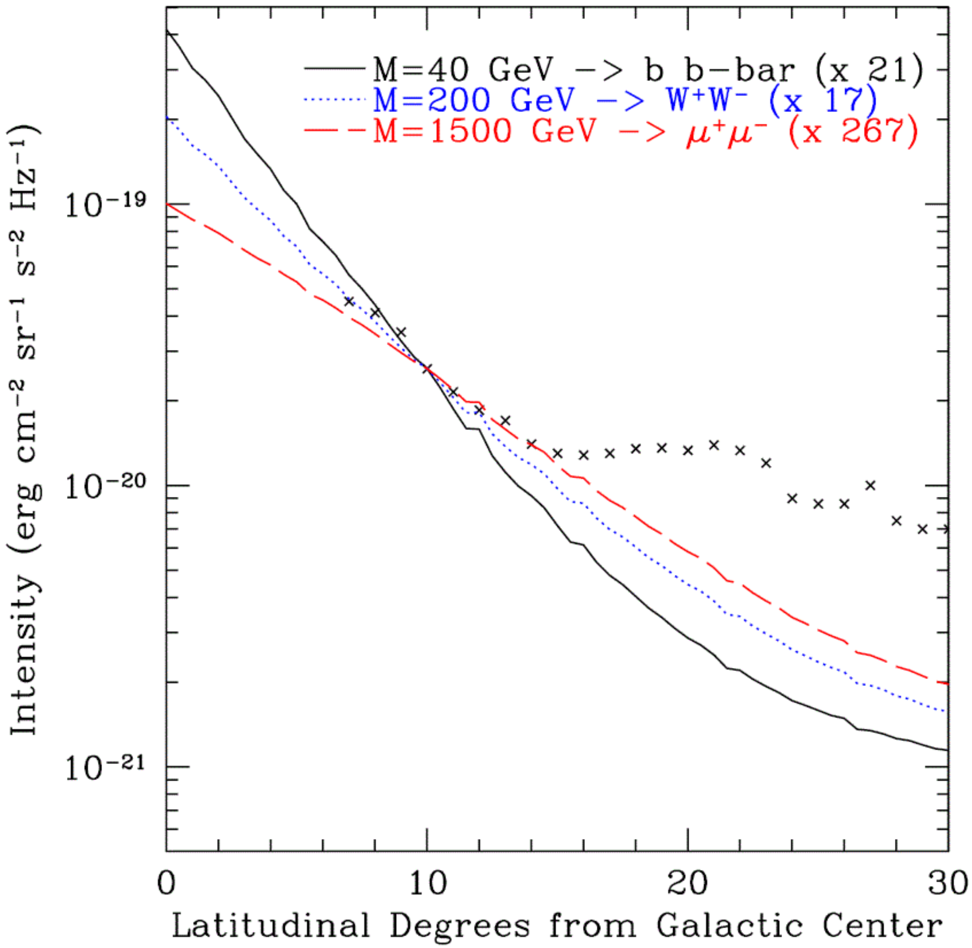
Galprop Models

- We use Galprop (v. 53[1]) and take standard values for several important propagation parameters
  - $D_0 = 5.8 \times 10^{28}$ $cm^2 s^{-1}$
  - Simulation Height = 4 kpc
  - $V_{alfven} = 30$ km s^{-1}
- We multiply the simulated haze by a universal constant to match the observed WMAP haze at 10 degrees latitude and 23 Ghz.

[1] Galdef file 02X_varh7S

Default Model Predictions

- Our default parameters predict a steeper decline in the DM haze as a function of galactic latitude than observed in the WMAP haze



Parameter Space

- We test variations in three regimes of parameter space, checking our results against the best constraint on each model
  - Cosmic Ray diffusion parameters
    - Affect primary to secondary nuclei ratios
  - Galactic magnetic fields
    - Affect synchrotron emission from all galactic sources
  - DM density profiles
    - Affect both direct and indirect DM detection, as well as galactic rotation curves

Diffusion Parameters

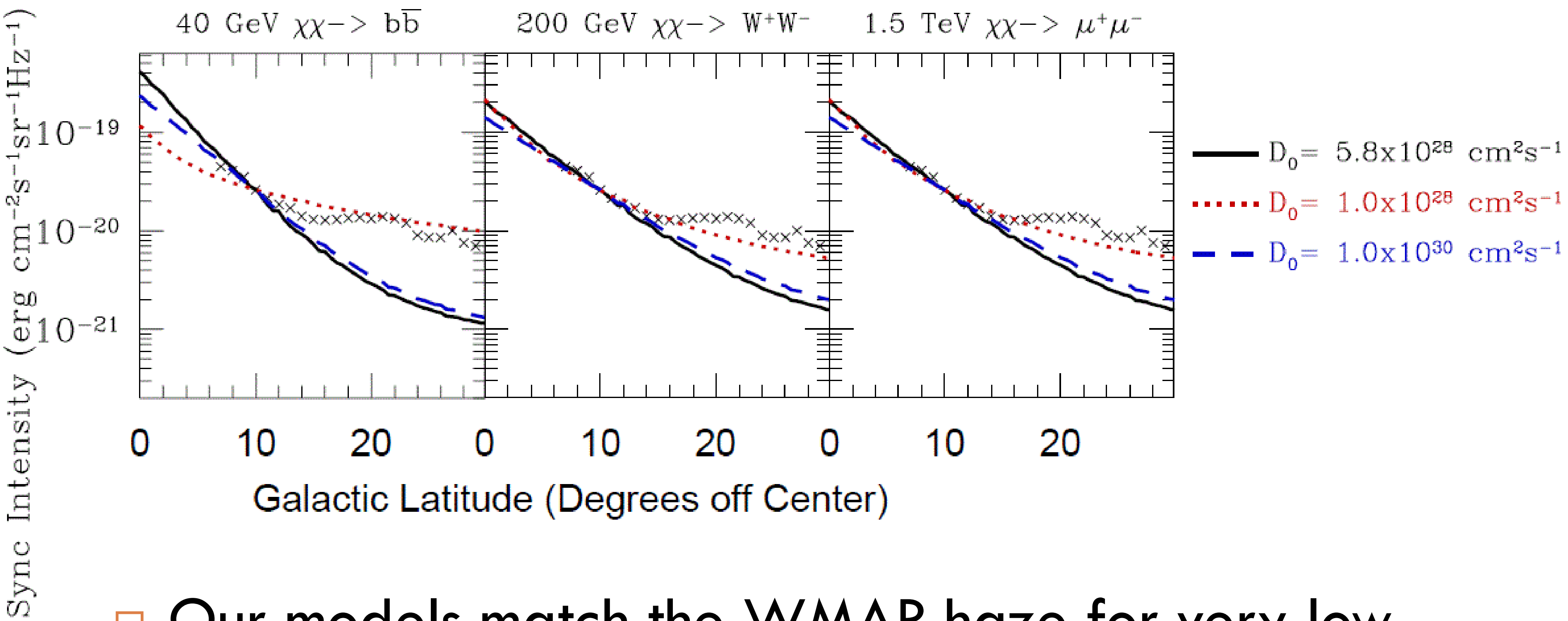
- We test four important diffusion parameters

  - 1.) Diffusion constant (5.8 x 10^{28} $cm^2 s^{-1}$)

  - 2.) Simulation height (4 kpc)

  - 3.) Alfven velocity (30 km s^{-1})

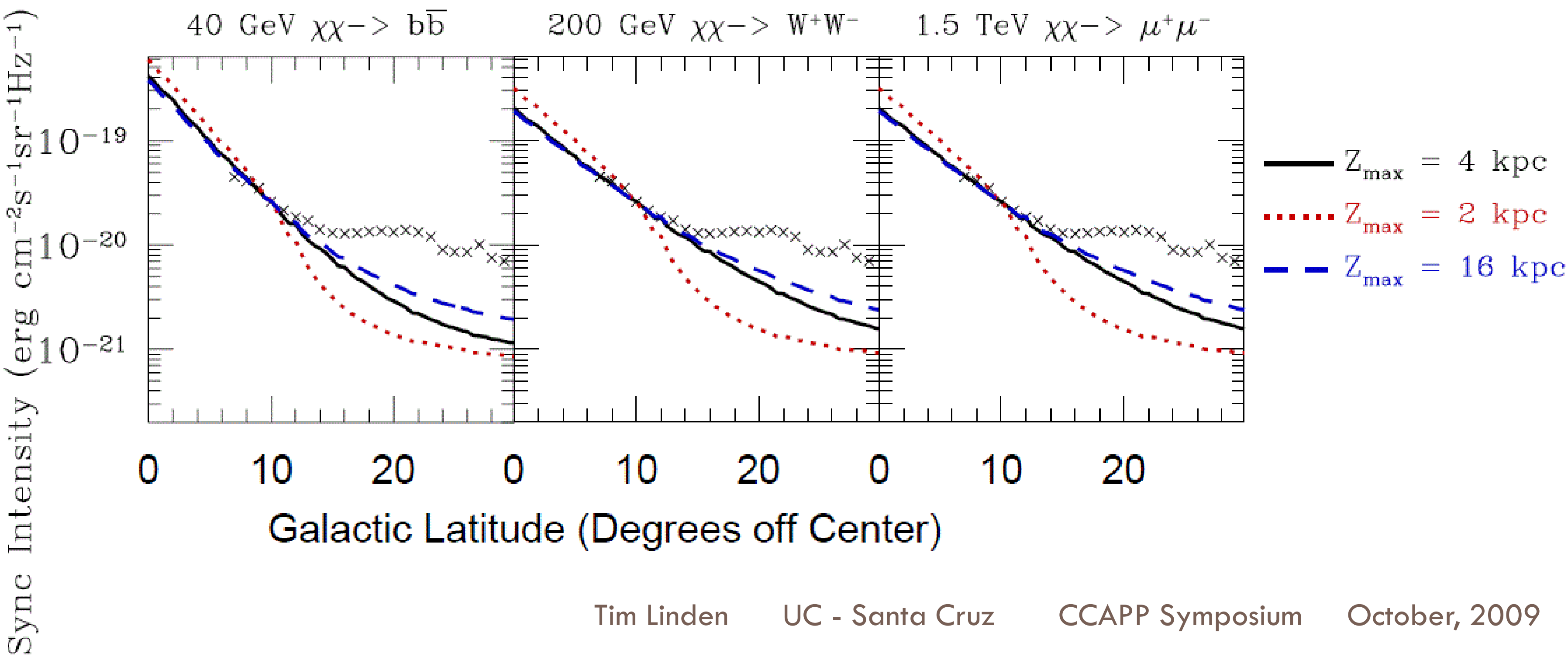
Match to WMAP Haze



- Our models match the WMAP haze for very low diffusion coefficients such as $D_0 = 1.0 \times 10^{28}$ cm^2s^{-1}

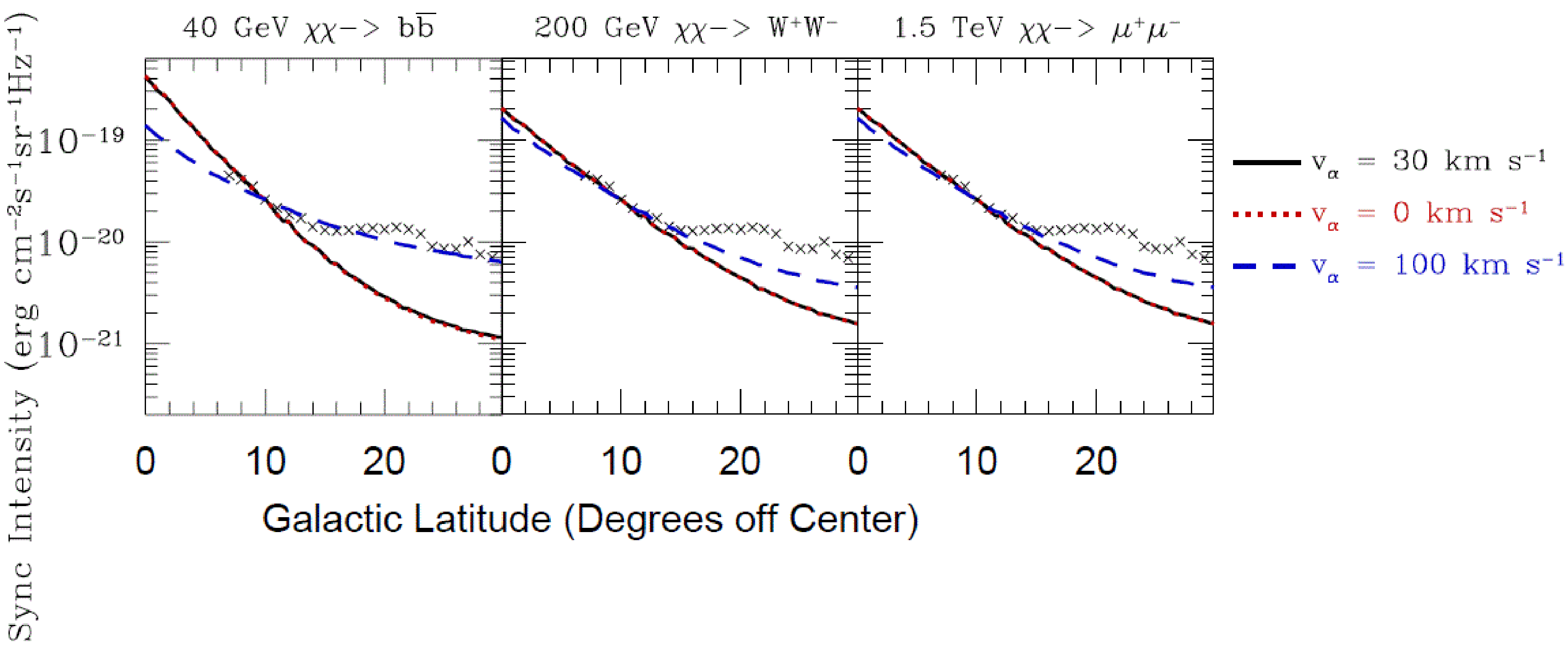
Changes in Simulation Height

- We are restricted by the angular range of the haze observations (8.5 kpc * sin(30) = 4.25 kpc)
- Signal is not affected by including higher latitudes



Match to WMAP Haze

- Our models match the WMAP Haze for very high Alfven velocities (near 100 km s^{-1})

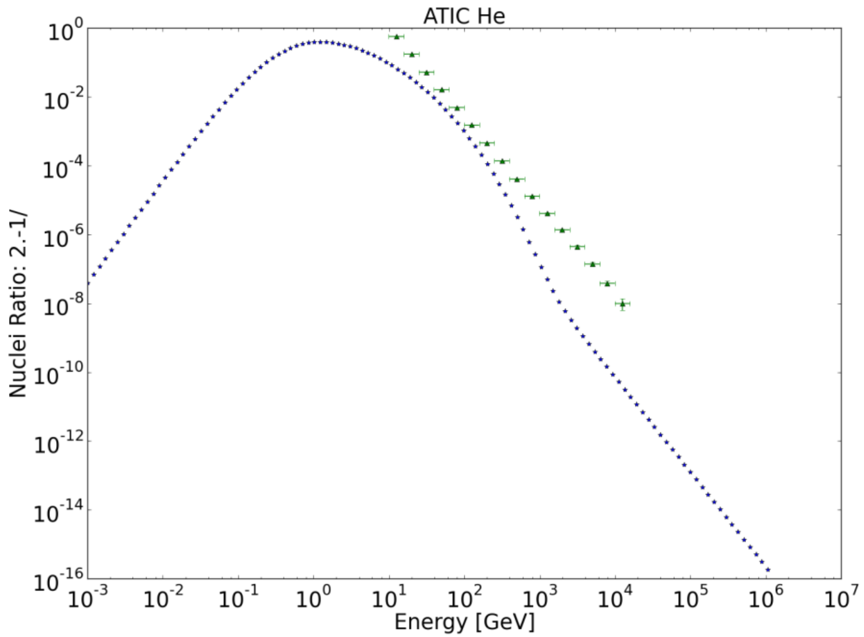


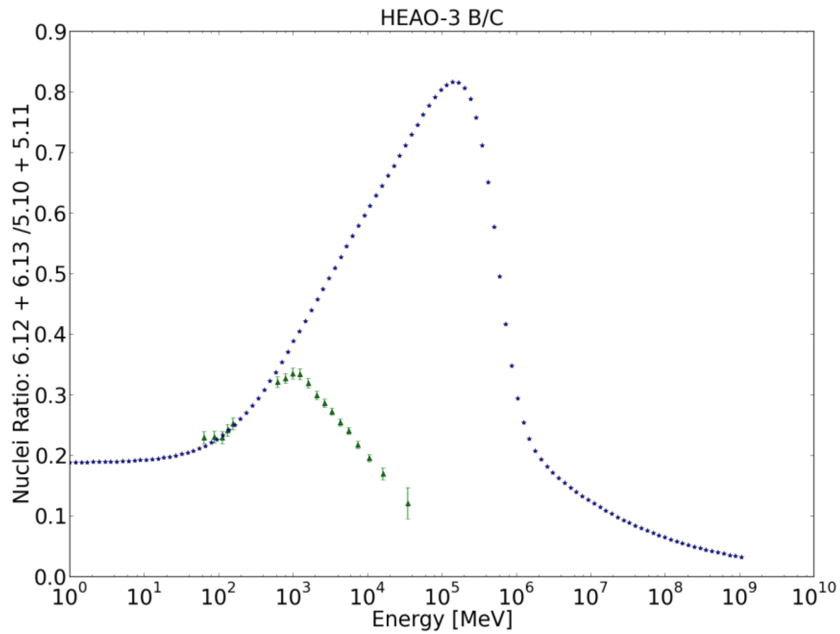
Primary/Secondary Ratios

- We test our matching choices of diffusion constant and Alfven velocity against the observed primary/secondary ratios

- We take nuclei observations from a wide variety of sources including:
  - ATIC
  - HEAO-3

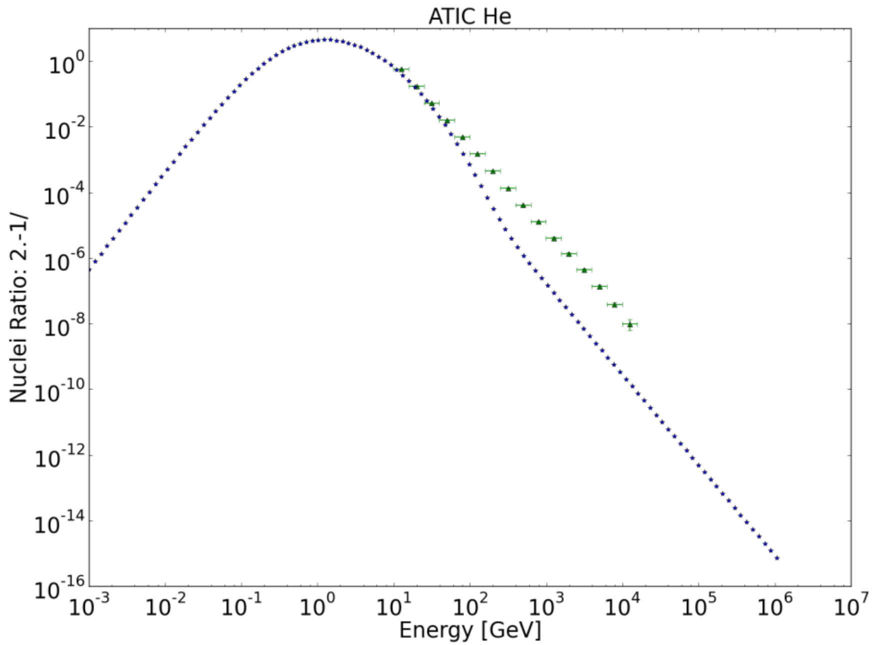
Diffusion Constant Nuclei Ratios

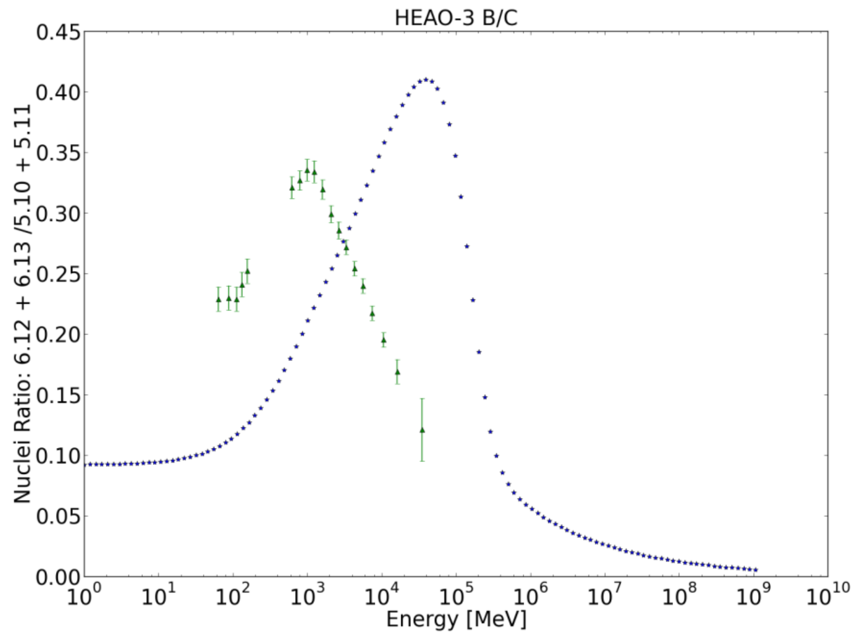




- Large changes in the diffusion constant create nuclei primary/secondary ratios which are <u>not</u> consistent with observation

Alfven velocity nuclei ratios





- Similarly, large changes in the Alfven velocity creates nuclei ratios which are not compatible with observation

Propagation Parameters - Conclusion

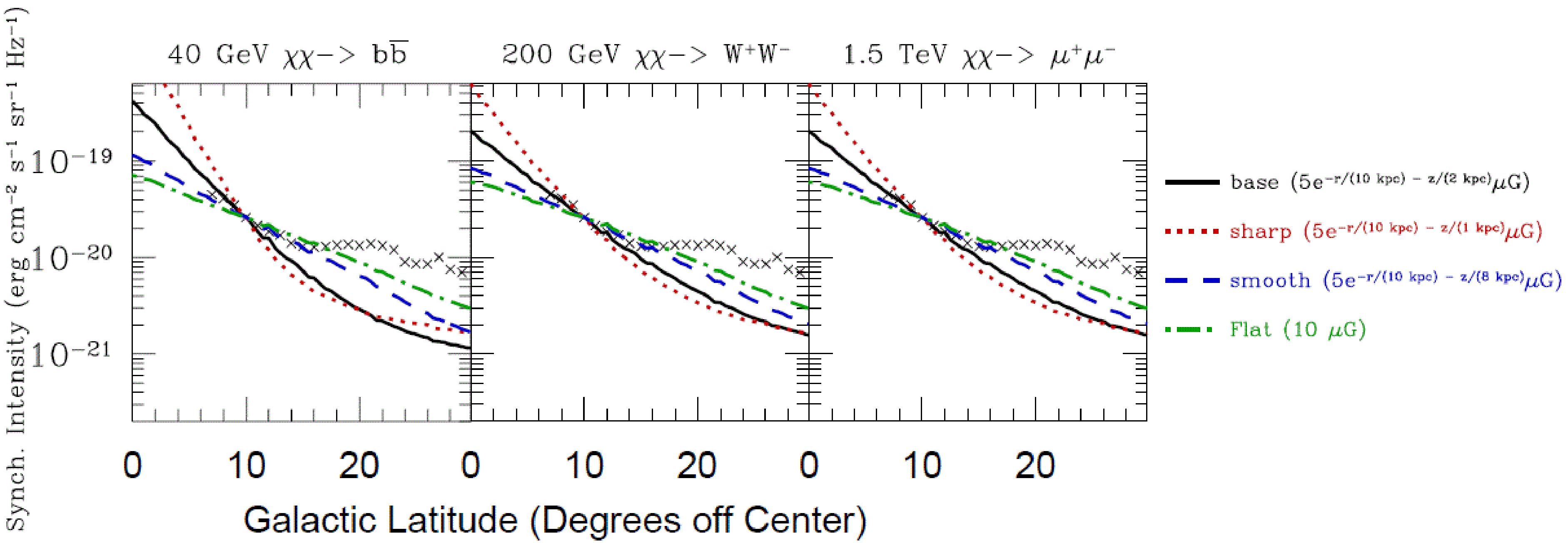
- Changes in the parameters for cosmic ray propagation cannot reproduce the WMAP haze while remaining consistent with nuclei observational constraints

Magnetic Fields

- Changing the angular dependence of magnetic fields will greatly change the angular dependence of synchrotron radiation in the galaxy

- We test 4 models of the form $B = B_0 e^{-(r/r0) - (z/z0)}$
  - $B_0 = 5\mu G$ $r_0 = 10$ kpc $z_0 = 2$ kpc (default)
  - $B_0 = 5\mu G$ $r_0 = 10$ kpc $z_0 = 1$ kpc (smooth)
  - $B_0 = 5\mu G$ $r_0 = 10$ kpc $z_0 = 8$ kpc (sharp)
  - $B_0 = 10\mu G$ $r_0 = 99.9$ kpc $z_0 = 99.9$ kpc (flat)

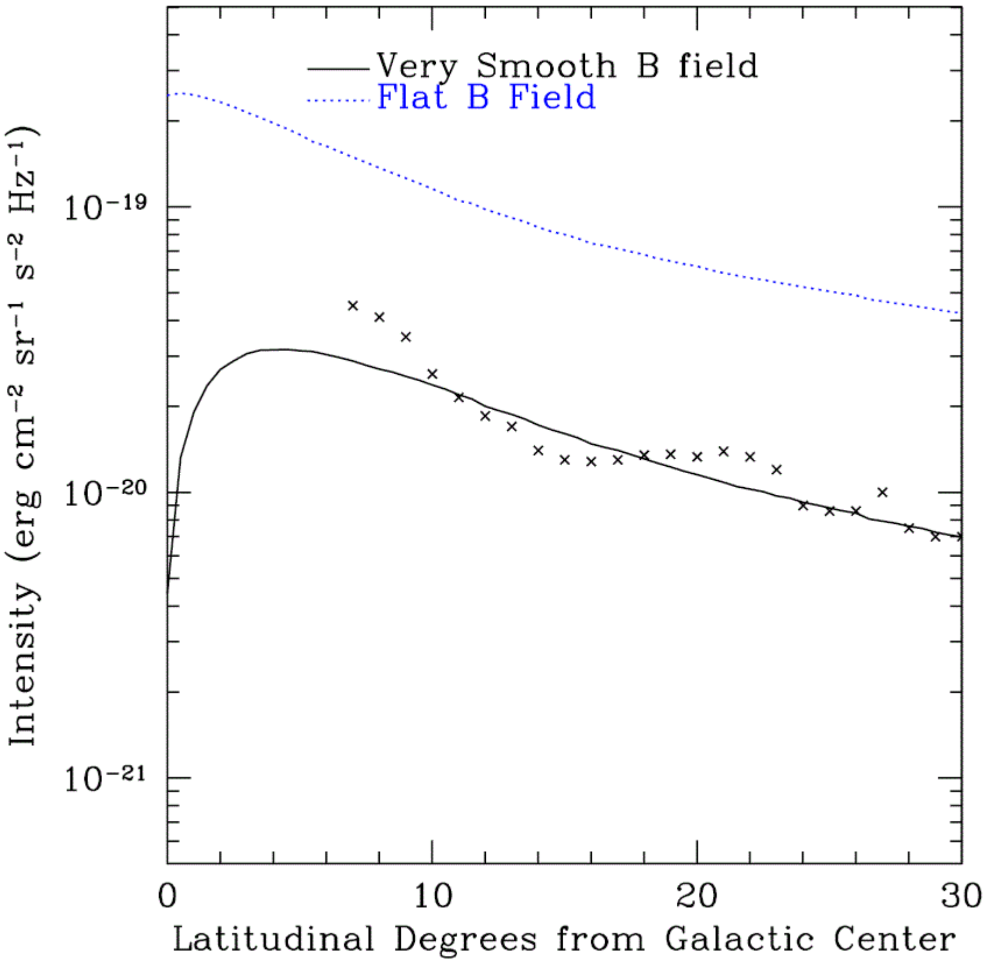
Match to WMAP Haze



We note that changing magnetic fields can greatly change the angular dependence of the DM haze. However, even for the most optimistic (flat) profile, we are unable to generate a great match to the WMAP Haze. This scenario requires more thorough investigation

Magnetic field subtraction

Changing magnetic fields can greatly change the synchrotron intensity of non-DM electrons, changing which residual we would call the WMAP haze



DM Density Profiles

- We test four models supported by N-body simulations and theoretical arguments

1.) NFW Profile (R_C = 22 kpc)

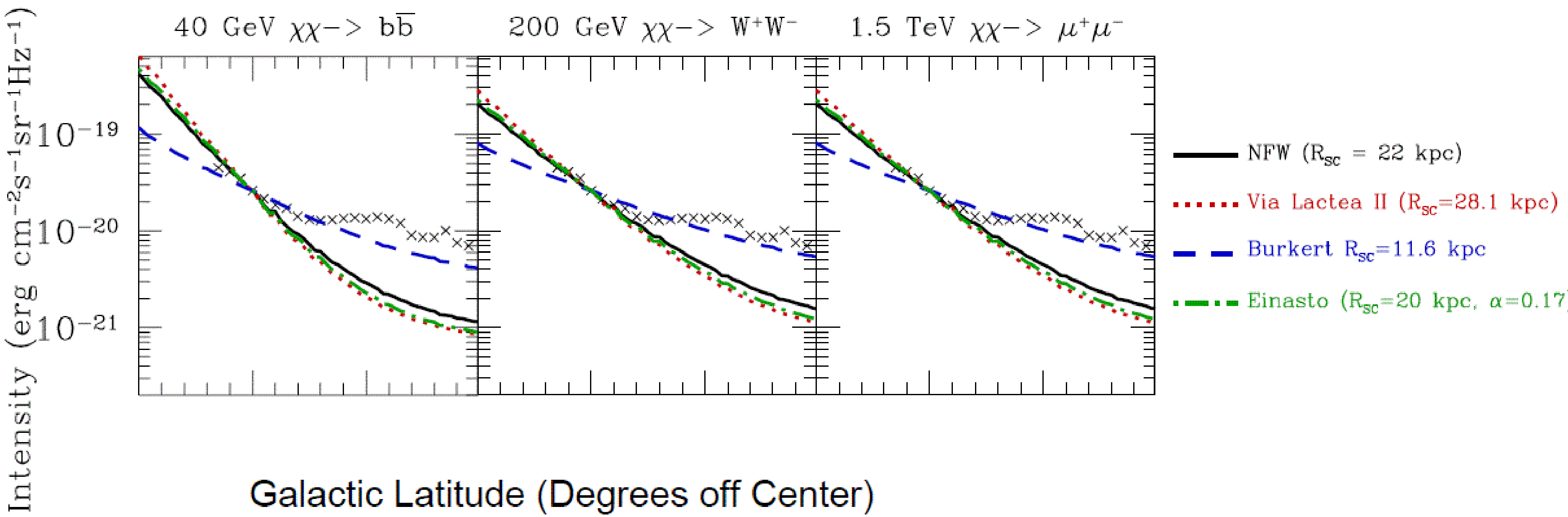
2.) Via Lactea II Simulation (R_C = 28.1 kpc)

3.) Einasto Profile (Aquarius Simulation) (R_C = 11.6 kpc α=0.17)

4.) Burkert Profile (R_C = 11.6 kpc)

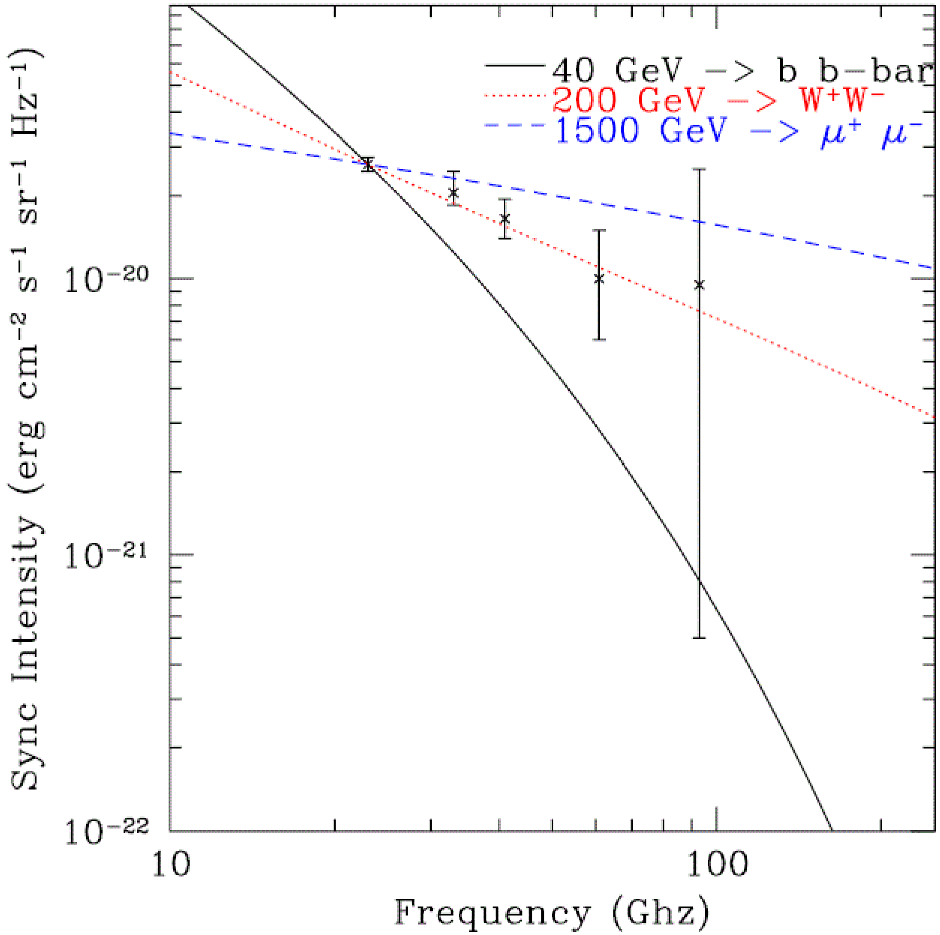
Effect on DM Haze

- All cored profiles show a striking (and consistent) disagreement with the WMAP haze. However baryonic simulations agree with observation



Frequency Dependence

- Spectrum of e+/e- injection controls the frequency dependence of WMAP Haze
- Show the necessity of a hard primary spectrum in model



Modeling of WMAP Haze

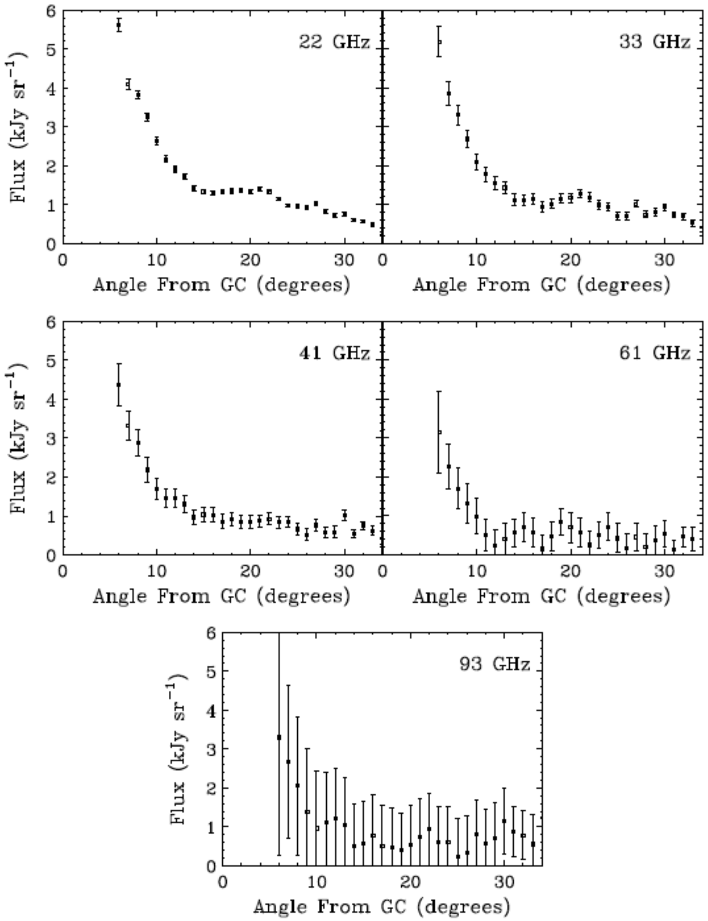
- Large astrophysical uncertainties make it difficult to claim any firm conclusion from a DM match to the WMAP haze

- However, if the Pamela/Fermi positron/electron spectrum is believed to be universal (non-local), then a WMAP haze is necessary. It is interesting evidence that such a Haze has previously been found

Extra Slides

Spatial Dependence of WMAP Haze

- Haze is primary found at high galactic latitudes
- Clearest in southern hemisphere, due to dust contamination in north
- Stretches up to 30° (4.25 kpc) above galactic bulge



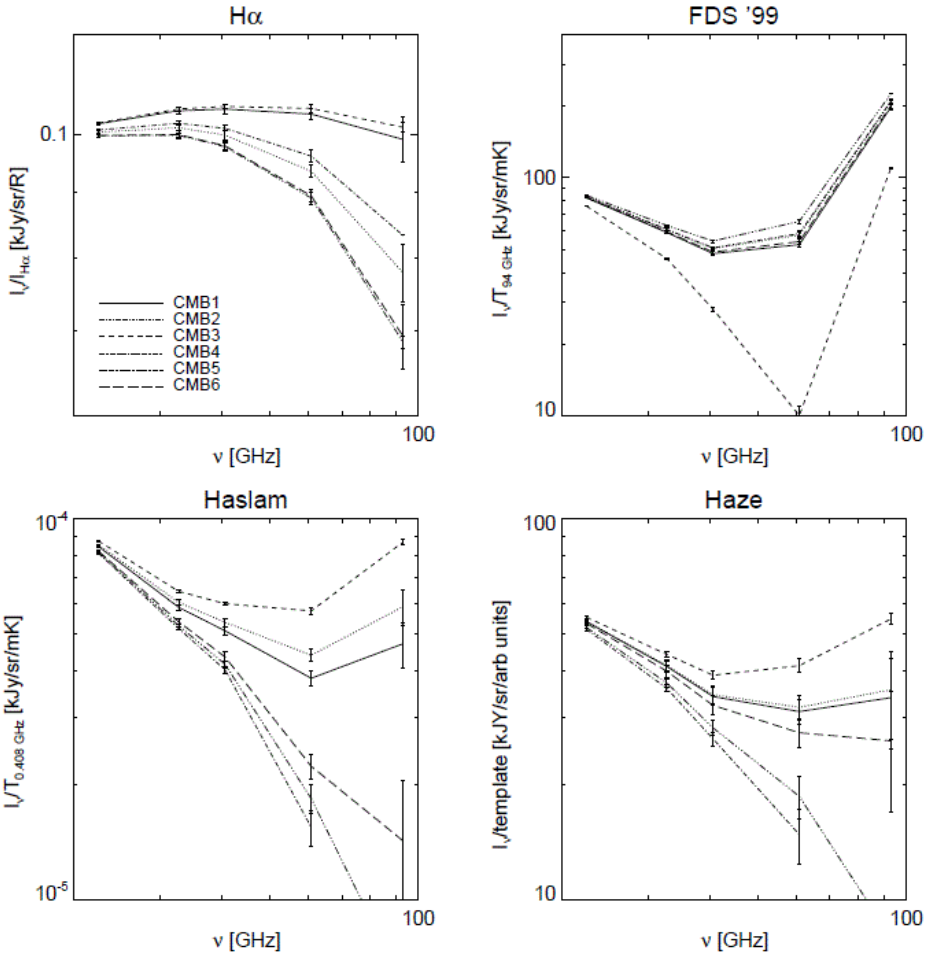
Energy Dependence of WMAP Haze

Haze spectrum is highly dominant to Hα emission, has a different energy dependence than thermal dust, and is dominant to soft synchrotron extrapolated from Haslam

Thus, Dobler and Finkbeiner (2007) conclude that the Haze results from a new primary source of energetic positron/electron pairs

But is it Dark Matter?

arXiv:0712.1038



Boost Factors

- Boost factors describe deviations of the DM annihilation rate from that given by the DM density and annihilation cross-section

$$\Phi = \rho^2(x)/M_{DM}^2 \ \langle\sigma v\rangle \qquad \langle\sigma v\rangle \sim 3 \times 10^{-26}\ cm^2 s^{-1}$$

- 1.) Changes in $\langle\sigma v\rangle$
- 2.) Density fluctuations in DM substructure
- 3.) Sommerfield enhancements

Alfven Velocity

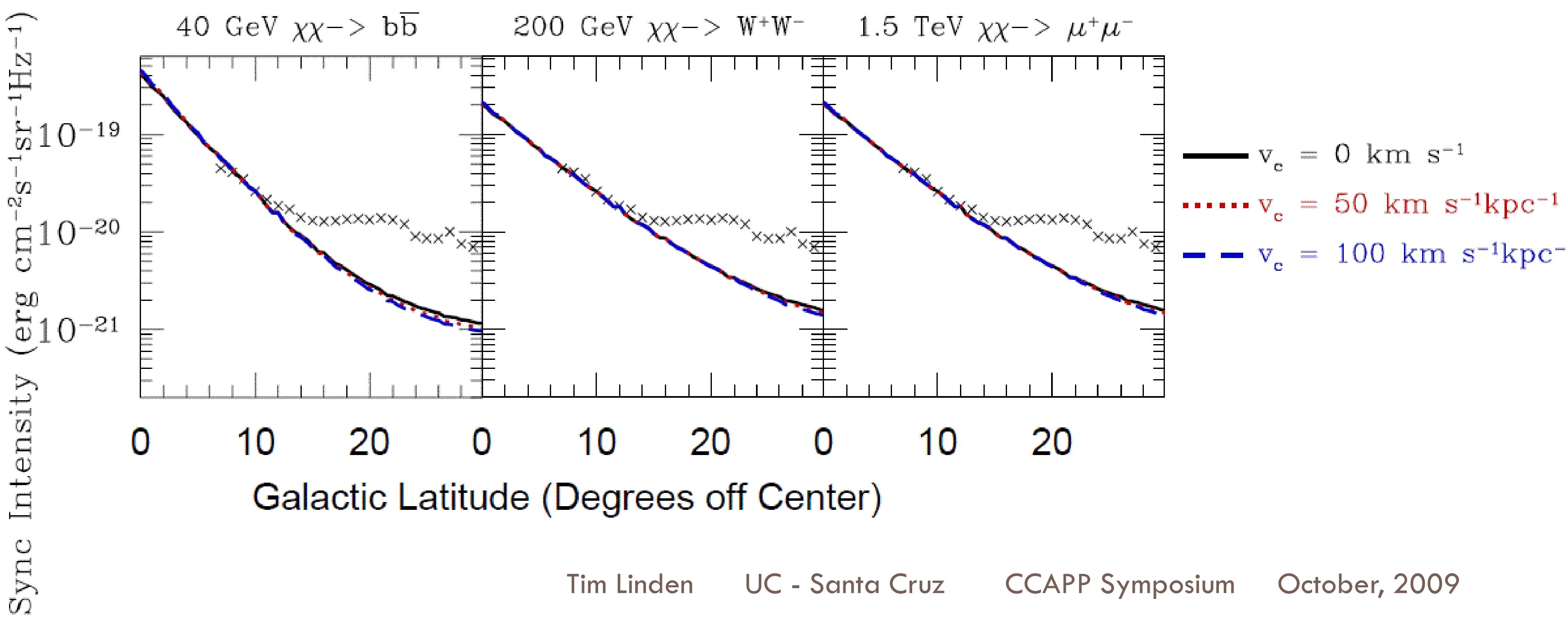
- Alfven velocity helps control the reacceleration of particles throughout the ISM
- Can become the dominant source of particle motion for high values of the v_α
- Will also have the effect of transporting nuclei out of the galactic plane

Diffusion Coefficient

- Changes in the diffusion coefficient can affect the angular dependence of the DM haze in two ways
  - 1.) Changing the number of $e^{+}e^{-}$ pairs which travel out of the top of the simulation region
  - 2.) Changing the number of $e^{+}e^{-}$ pairs which travel out of the galactic center into the low latitude regions of the simulation region

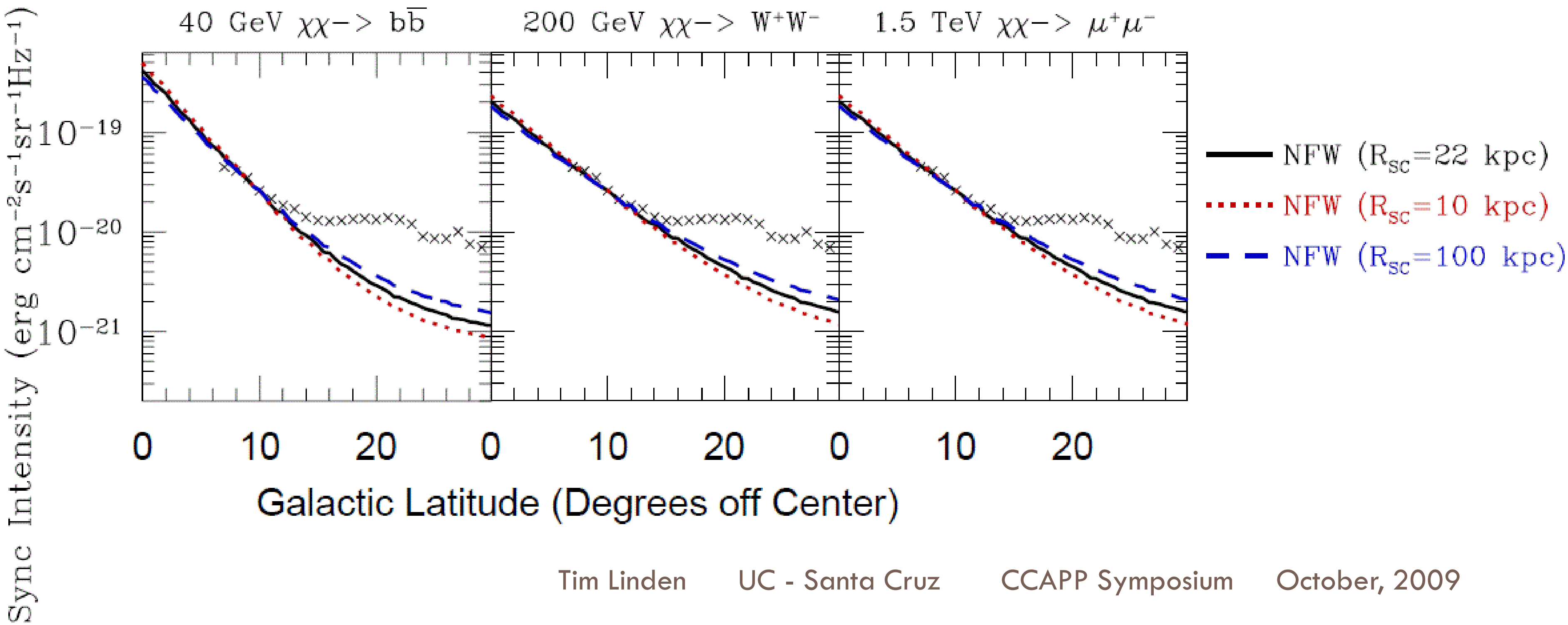
Convection Velocity

- Convection velocity only serves to move material out of the top of our simulation. Our original choice to disable convection velocity is optimal



NFW Profile

- We test several different NFW profile scale radii
- Even extreme choices for R_{SC} do not show agreement with the WMAP Haze



Burkert Profile

- Slightly larger scale radii in the Burkert profile may provide a match for the WMAP Haze