Dark Matter, Supersymmetry, and Accounting for the WMAP Haze

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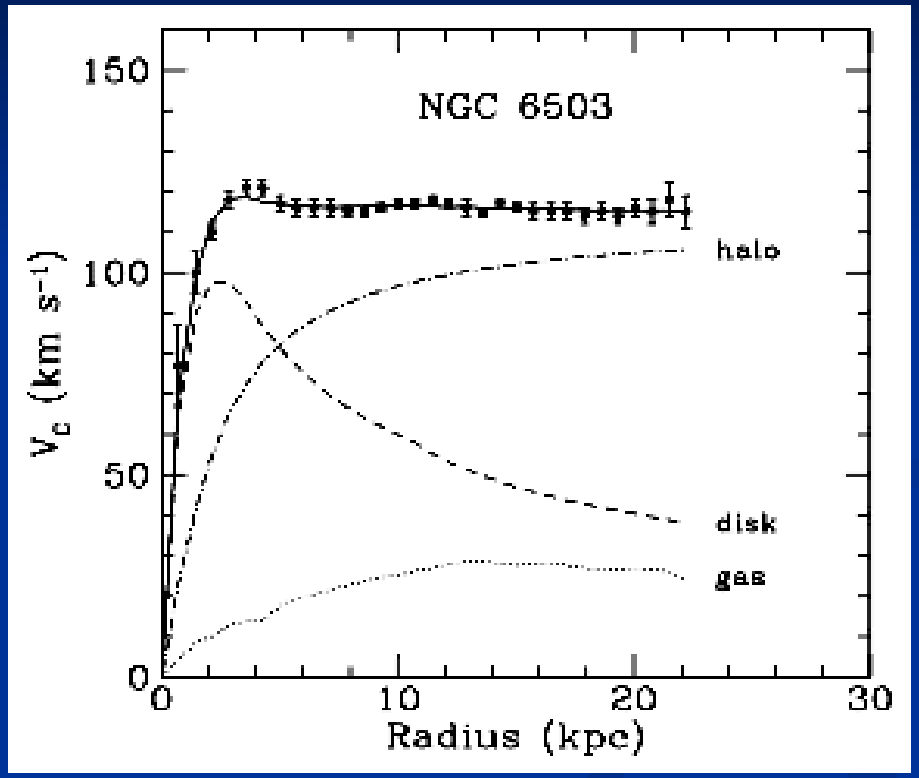
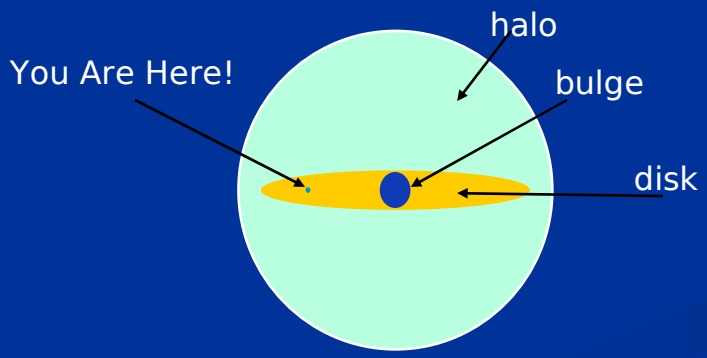
Dark Matter

Galactic Scale:

- Rotational Curves show that galaxies rotate faster than what is expected from the luminous mass. This also gives us an idea of the distribution of dark matter

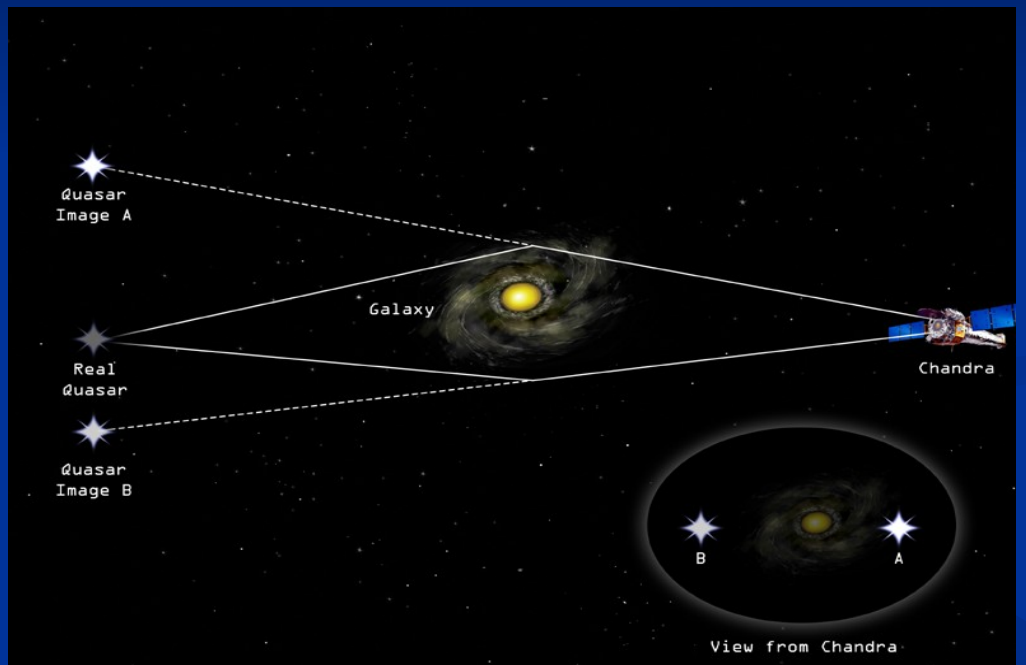




Dark Matter

Cluster Scale:

- Gravitational lensing shows that there's more mass than what can be observed

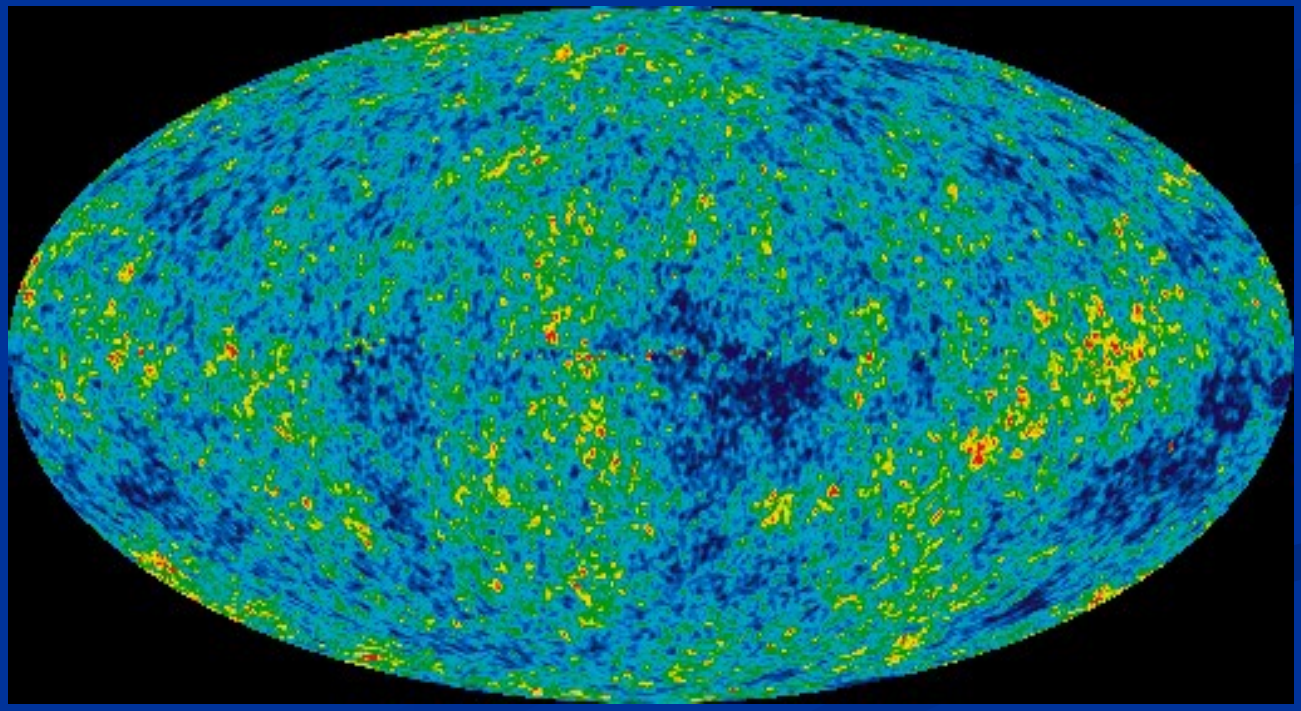


http://chandra.harvard.edu/photo/2003/apm08279/more.html

Dark Matter

Cosmological Scale:

- From the Cosmic Microwave Background (CMB) we can tell that the universe is made up of ~23% DM (compared to ~5% baryonic matter)



Dark Matter

Candidates and Detection

- Main Focus:

  Weakly Interacting Massive Particle (WIMP)

- Many Proposed Explanations:
  - Axions
  - Massive Compact Halo Object (MACHOs)
  - Modified Gravity
  - And More!

Dark Matter

Candidates and Detection

- Main Focus:

  Weakly Interacting Massive Particle (WIMP)

  - Non-baryonic matter

- Many Proposed Explanations:
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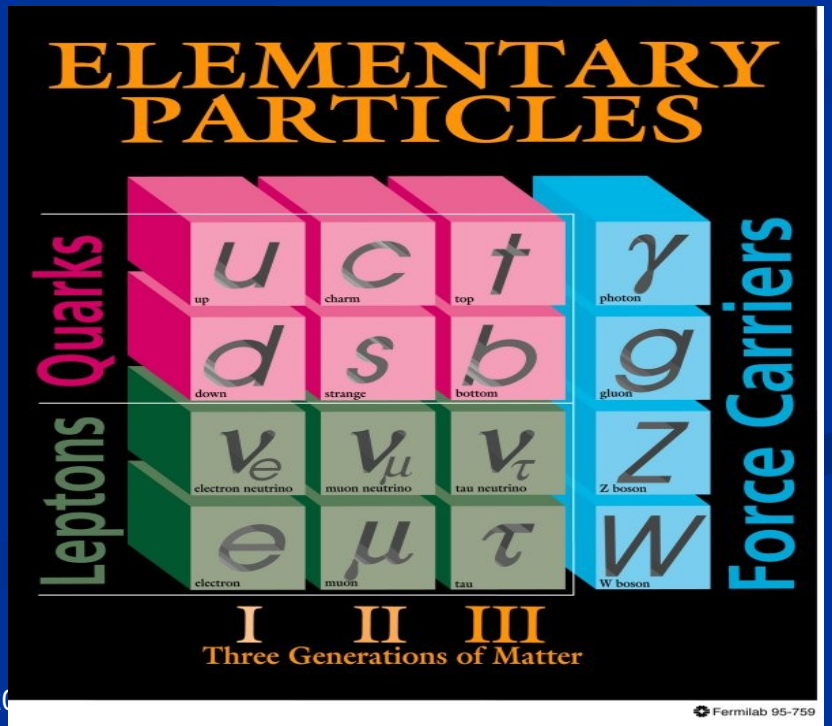
  - And More!



Dark Matter

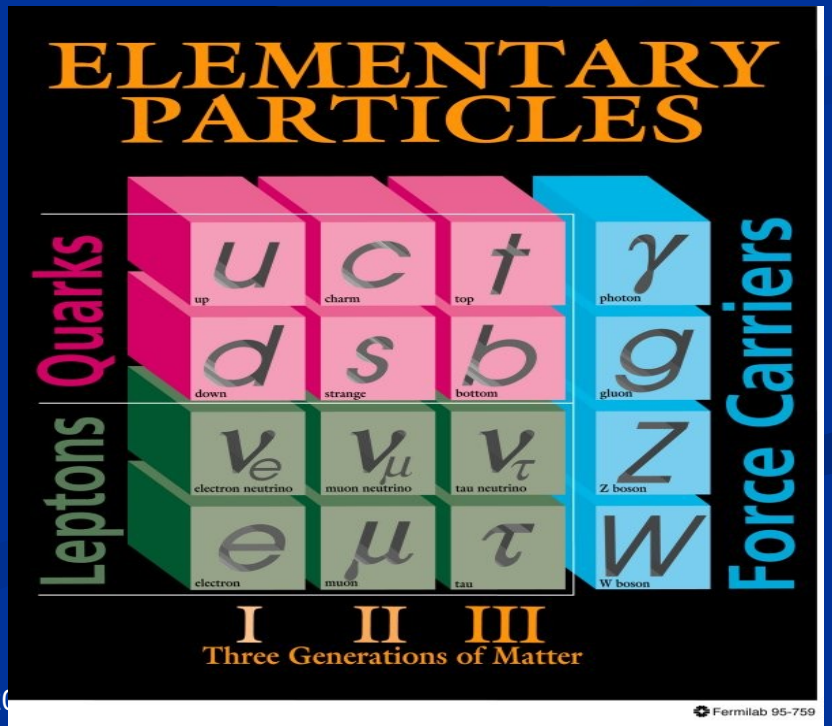
Candidates and Detection

- Main Focus:

  Weakly Interacting Massive Particle (WIMP)

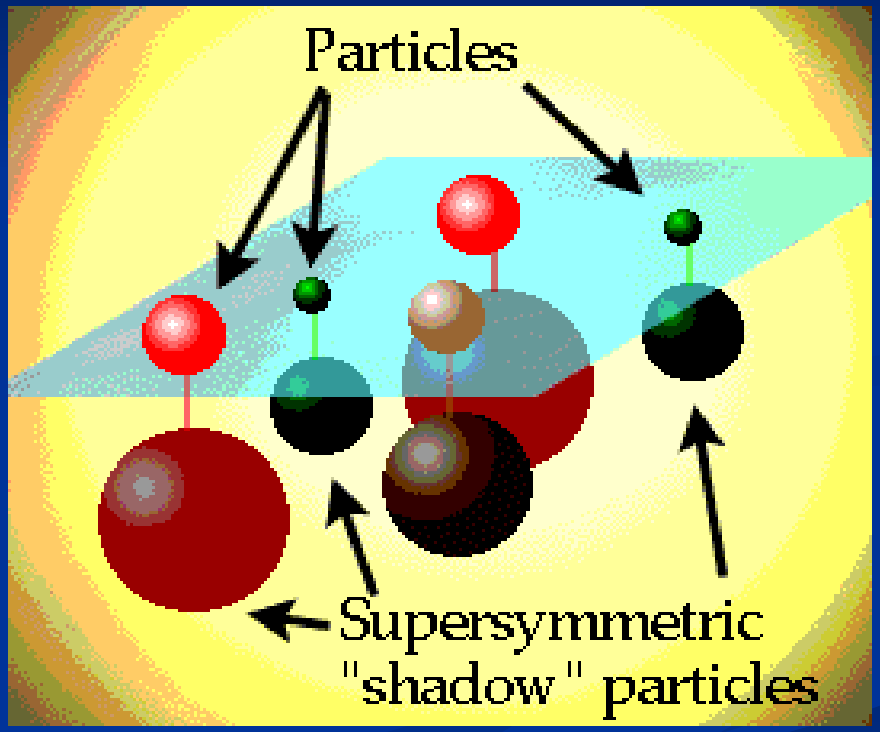
  - Non-baryonic matter
  - Doesn't interact through the electromagnetic or the strong force

- Many Proposed Explanations:
  - Axions
  - Massive Compact Halo Object (MACHOs)
  - Modified Gravity
  - And More!



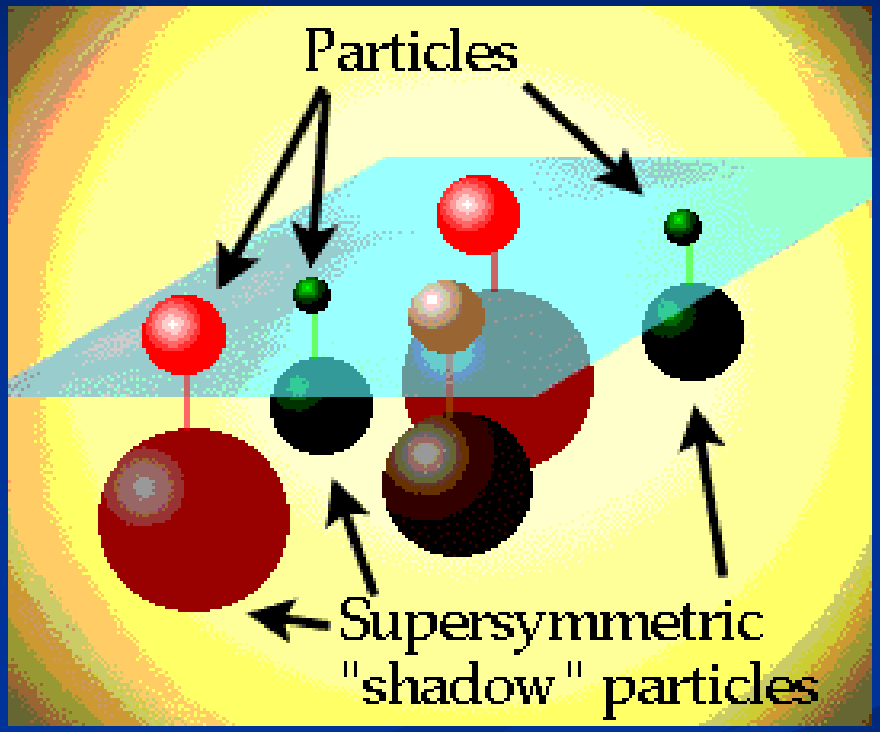
Supersymmetry

- Broken symmetry between Fermions (spin ½) and Bosons (integer spin)



Supersymmetry

- Broken symmetry between Fermions (spin ½) and Bosons (integer spin)
- New particles introduced



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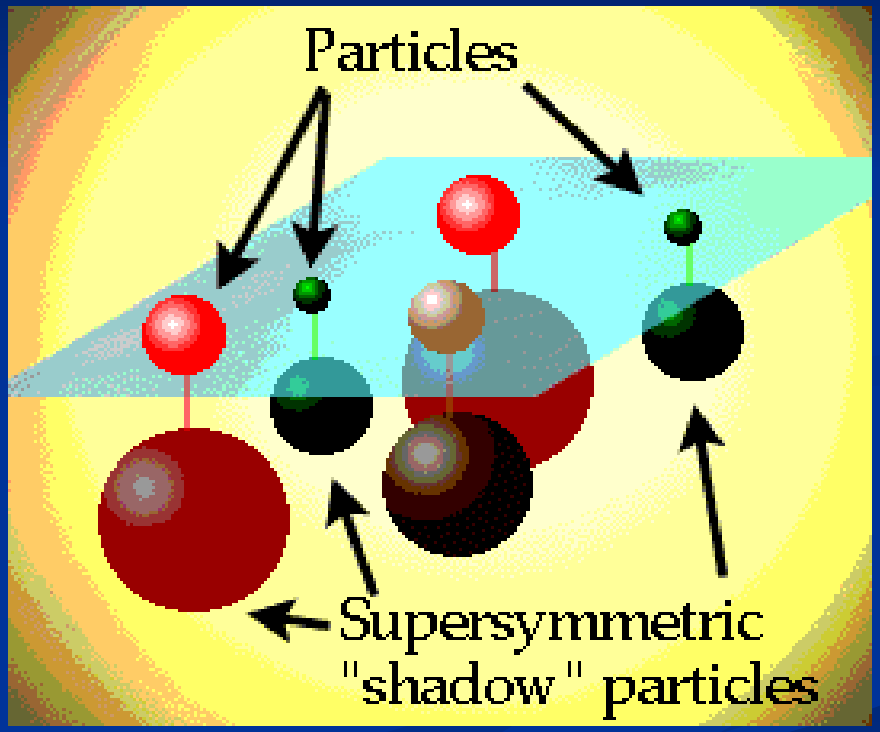
- Neutralino LSP, Dark Matter candidate



Supersymmetry

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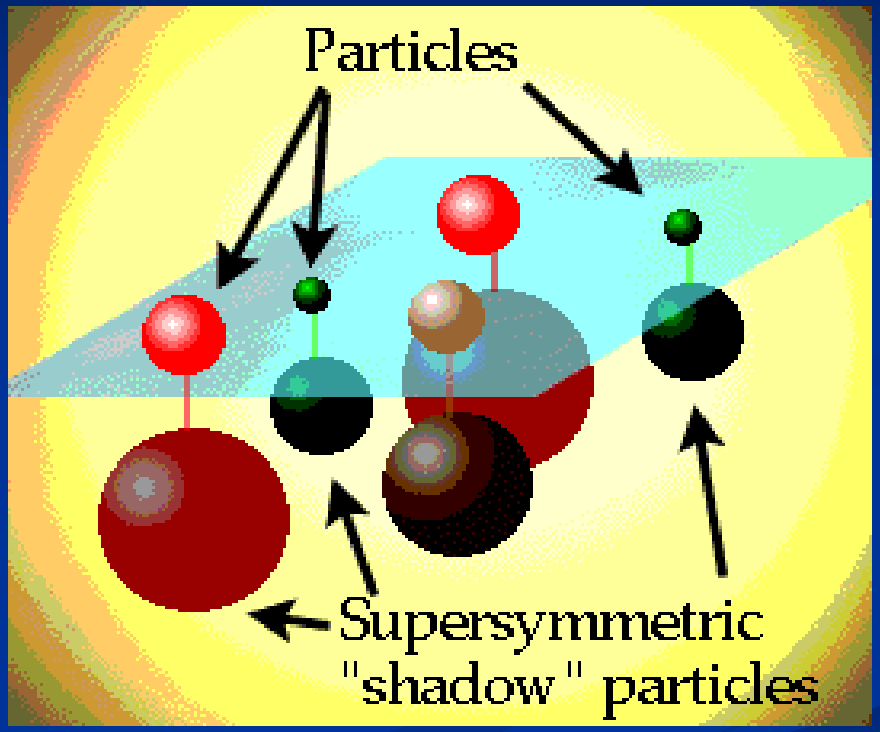
- New particles introduced
- Neutralino LSP, Dark Matter candidate
- ~120 free parameters



CMSSM

- Constrained Minimal Supersymmetry Standard Model (CMSSM) reduces free parameters through theoretically oriented assumptions

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- Through 5 parameters, the entire particle spectrum can be calculated (here using the DarkSUSY package):

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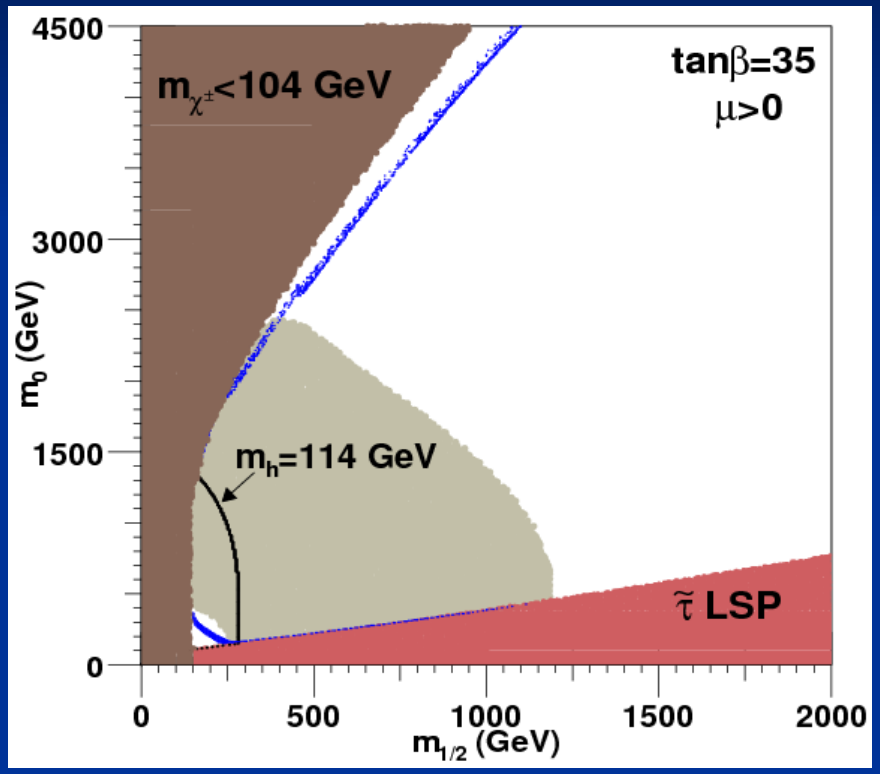
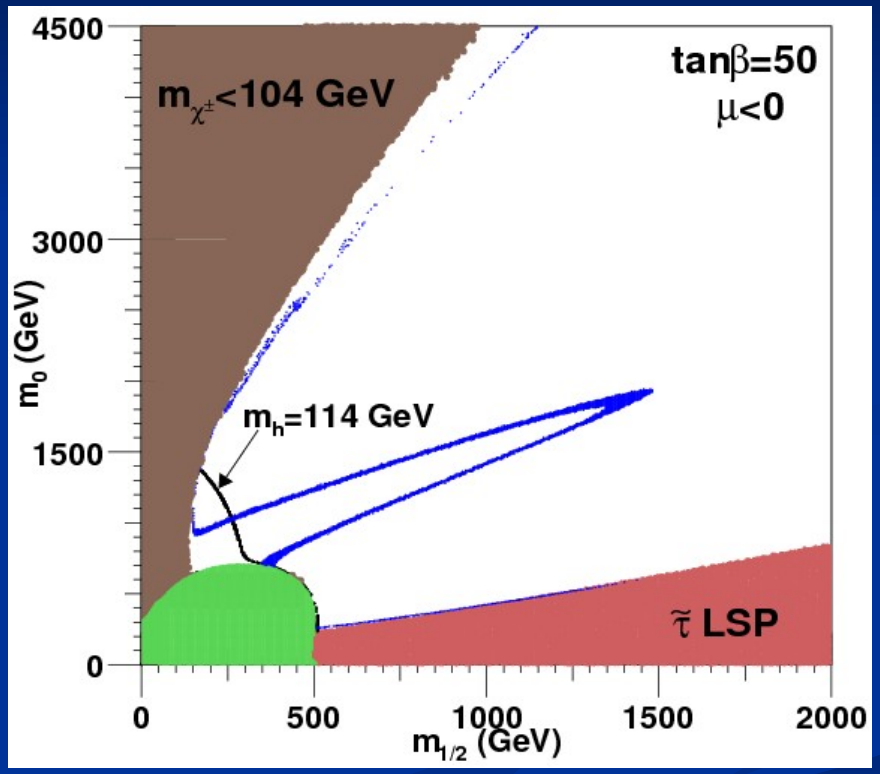
- Through 5 parameters, the entire particle spectrum can be calculated (here using the DarkSUSY package):
  - Universal gaugino mass: $m_{1/2}$
  - Universal scalar mass: m_0
  - Universal tri-linear scalar coupling: A_0
  - Ratio of v.e.v. of the two Higgs doublets: $\tan \beta$
  - Sign of the Higgsino mass parameter: μ

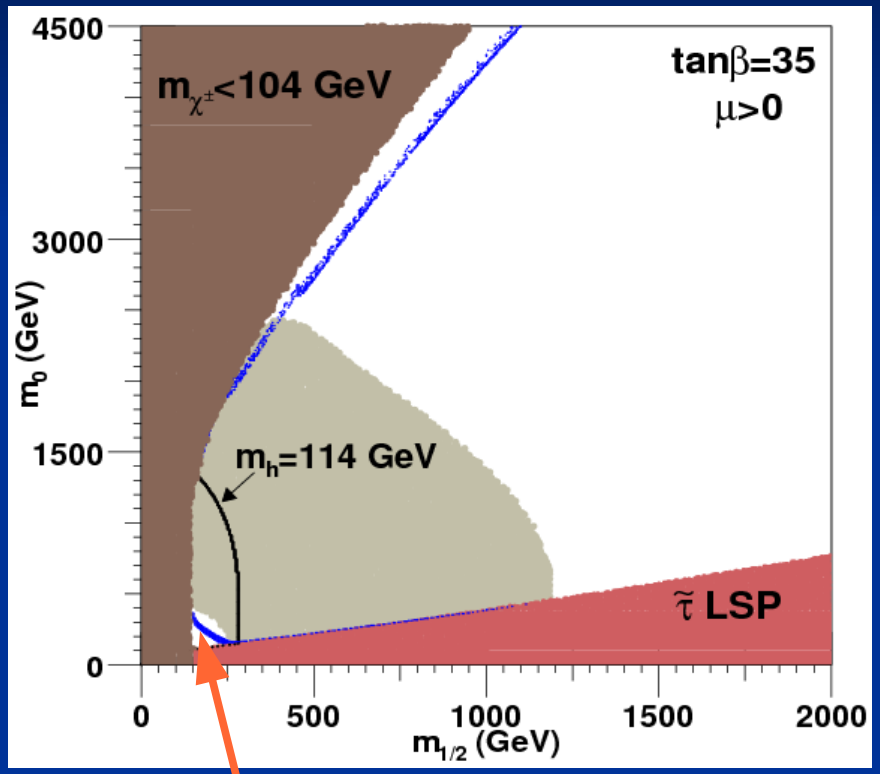
CMSSM



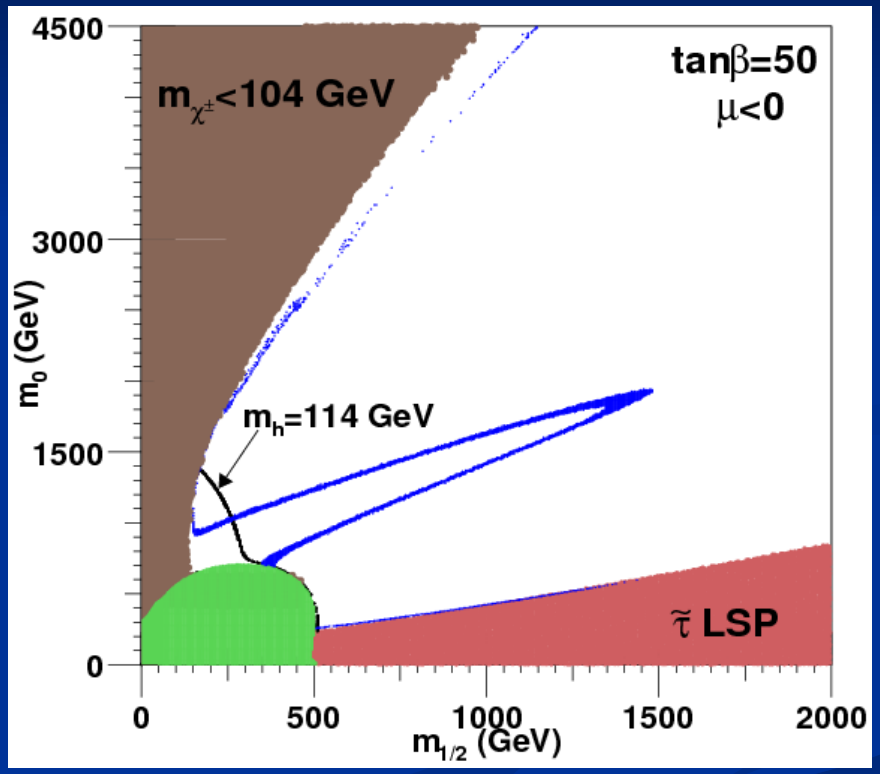


(Done for μ>0, tanβ 3,10,35,50
and μ<0, tanβ 35,50)

CMSSM



Bulk



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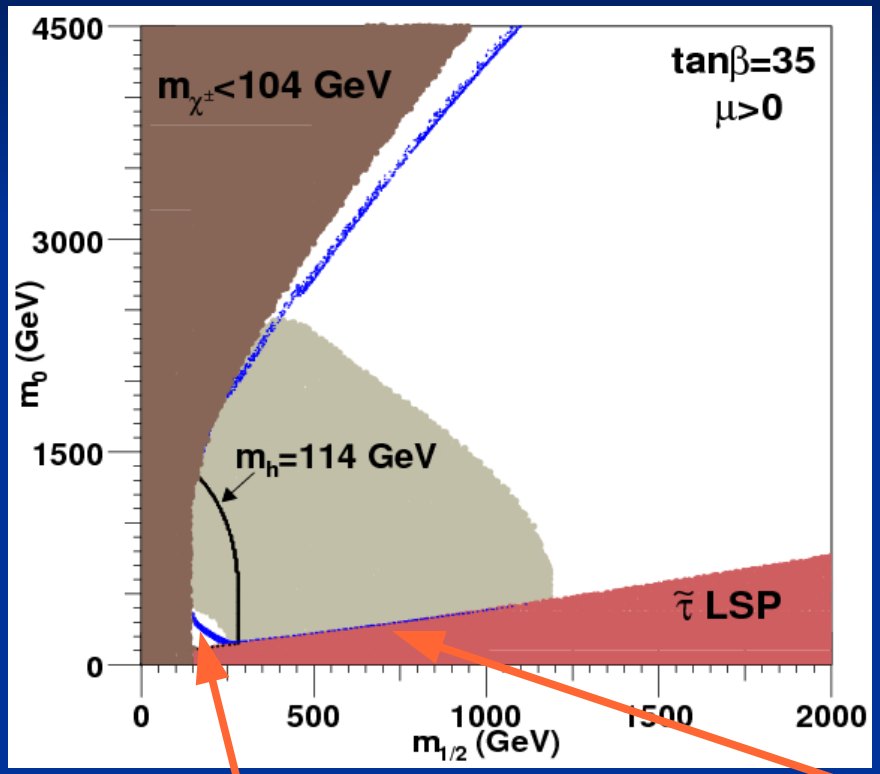
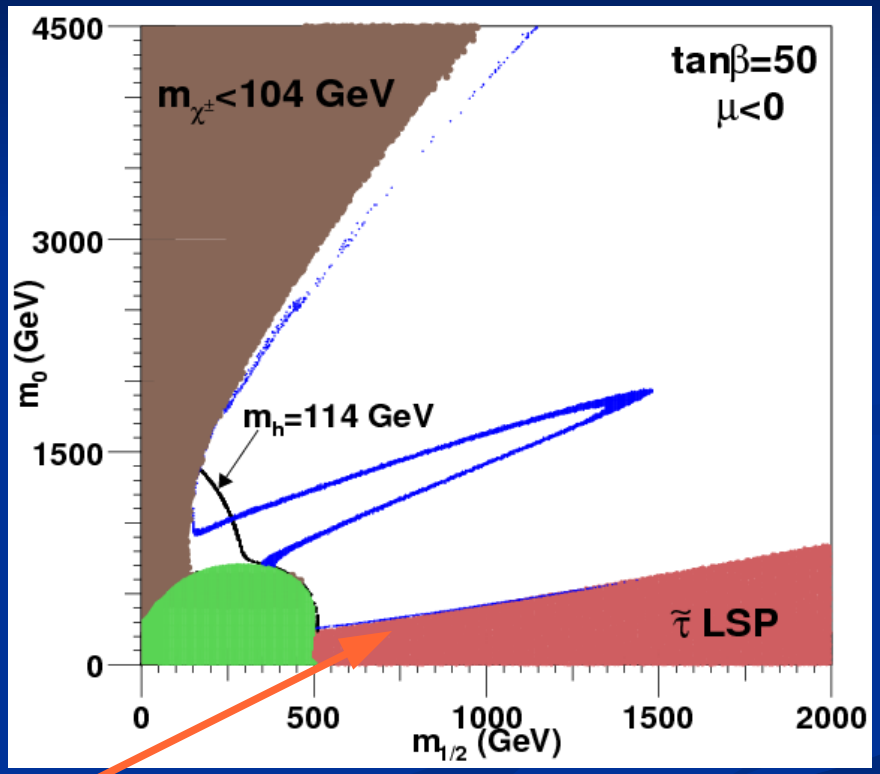
CMSSM





Bulk

Coannihilation

(Done for μ>0, tanβ 3,10,35,50
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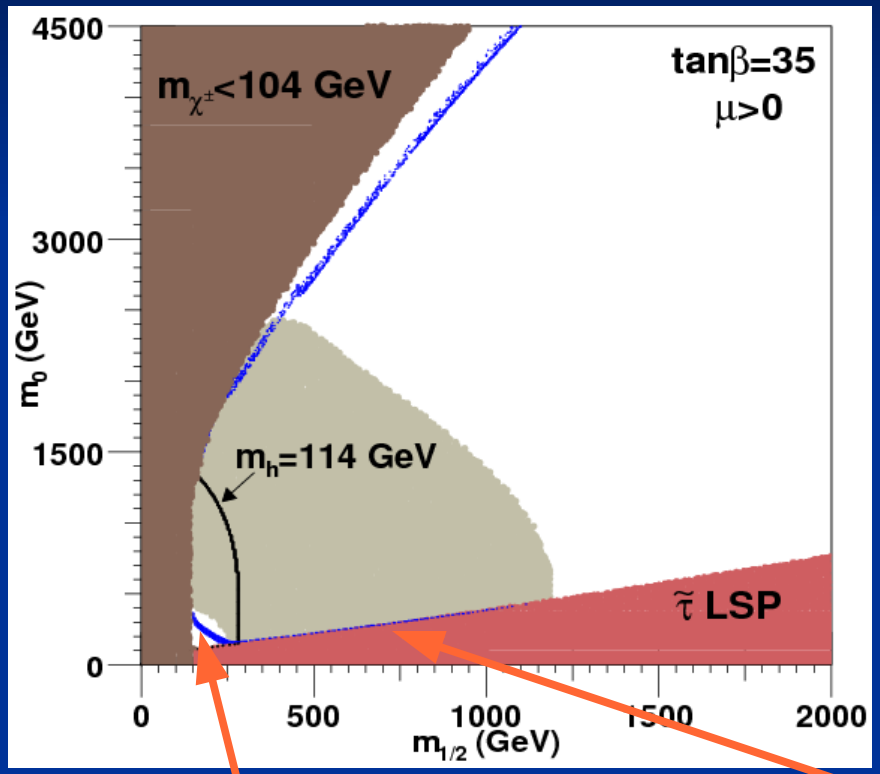
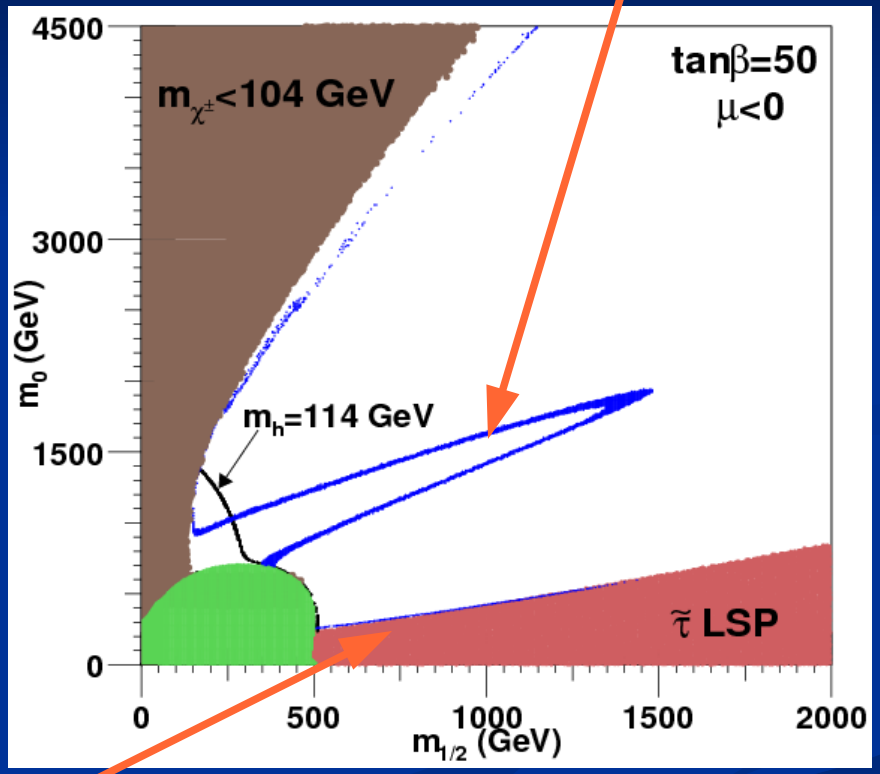
CMSSM





A-funnel

Bulk

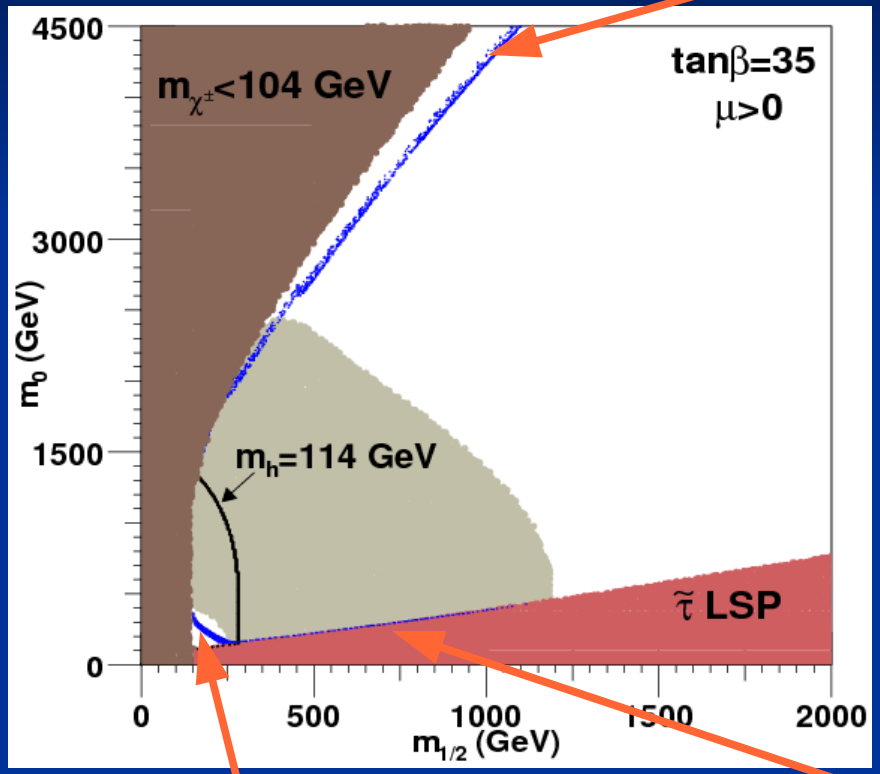
Coannihilation

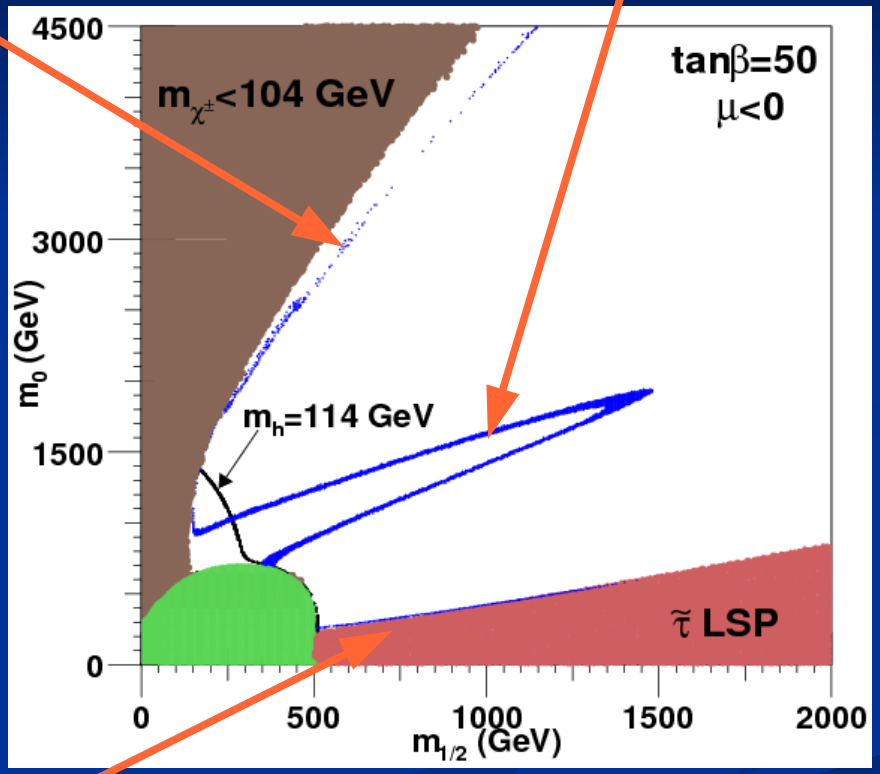
(Done for μ>0, tanβ 3,10,35,50
and μ<0, tanβ 35,50)

CMSSM

Focus Point

A-funnel





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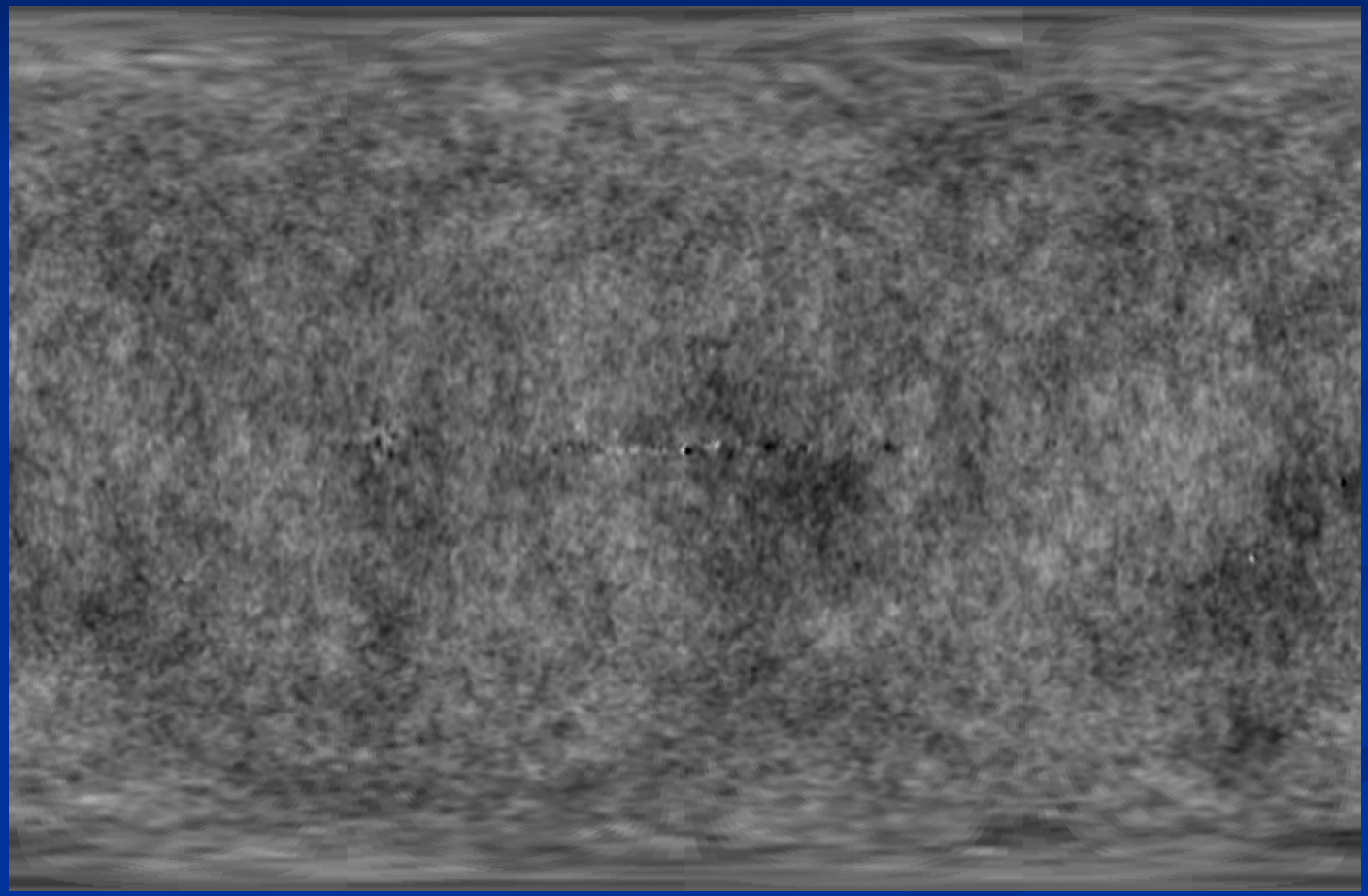
WMAP Haze

Cosmic Microwave Background



WMAP Haze

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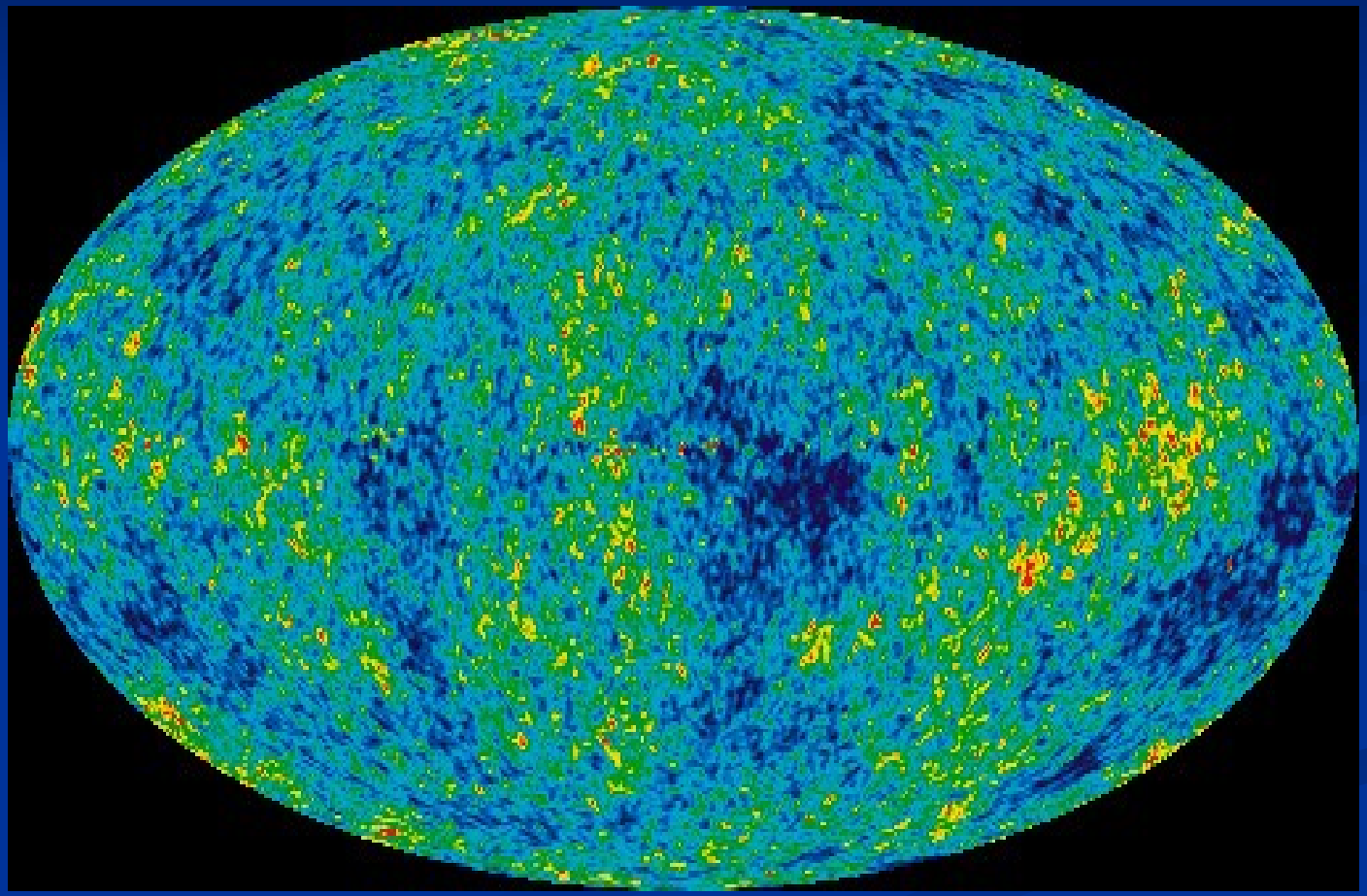
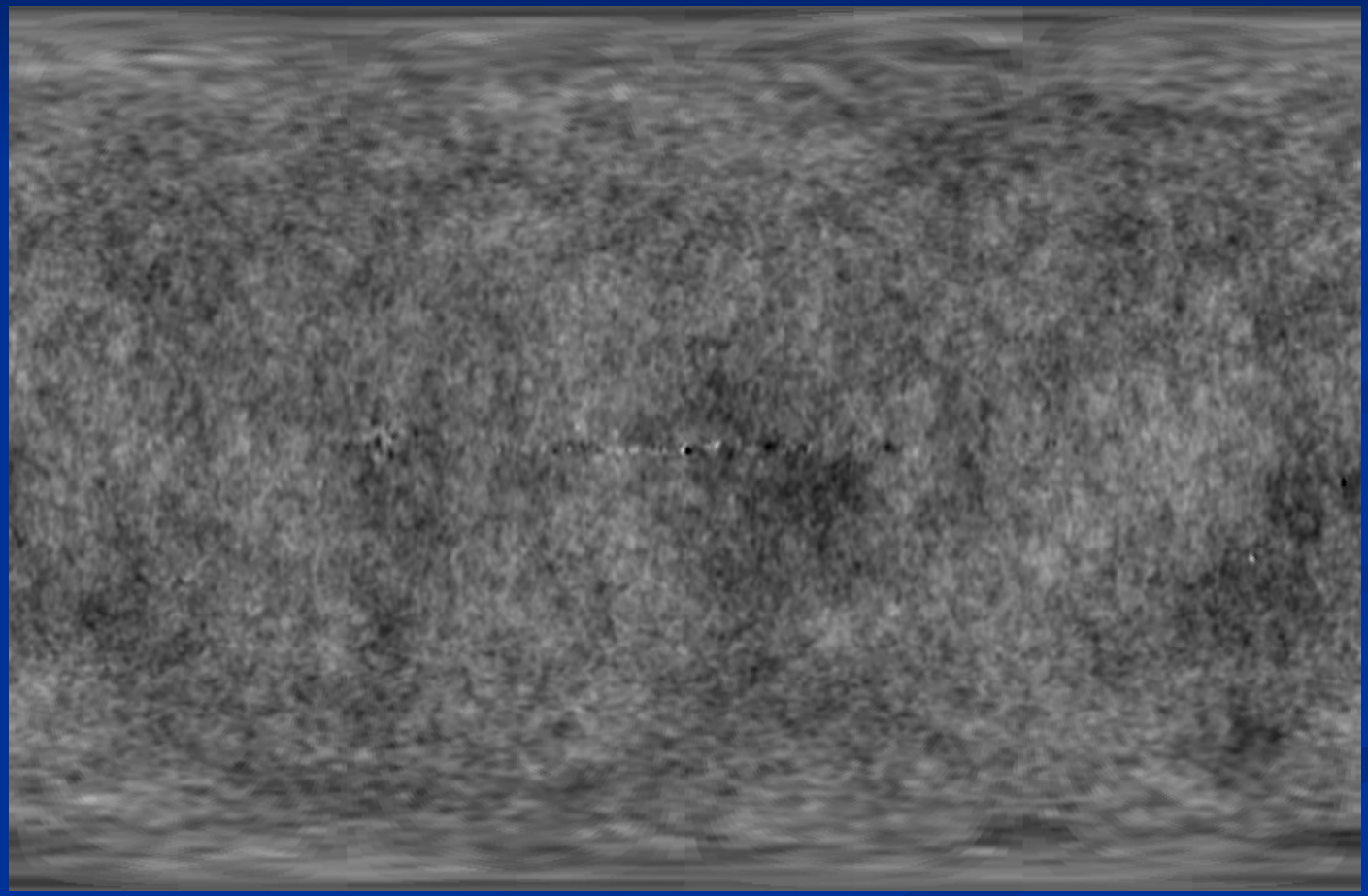


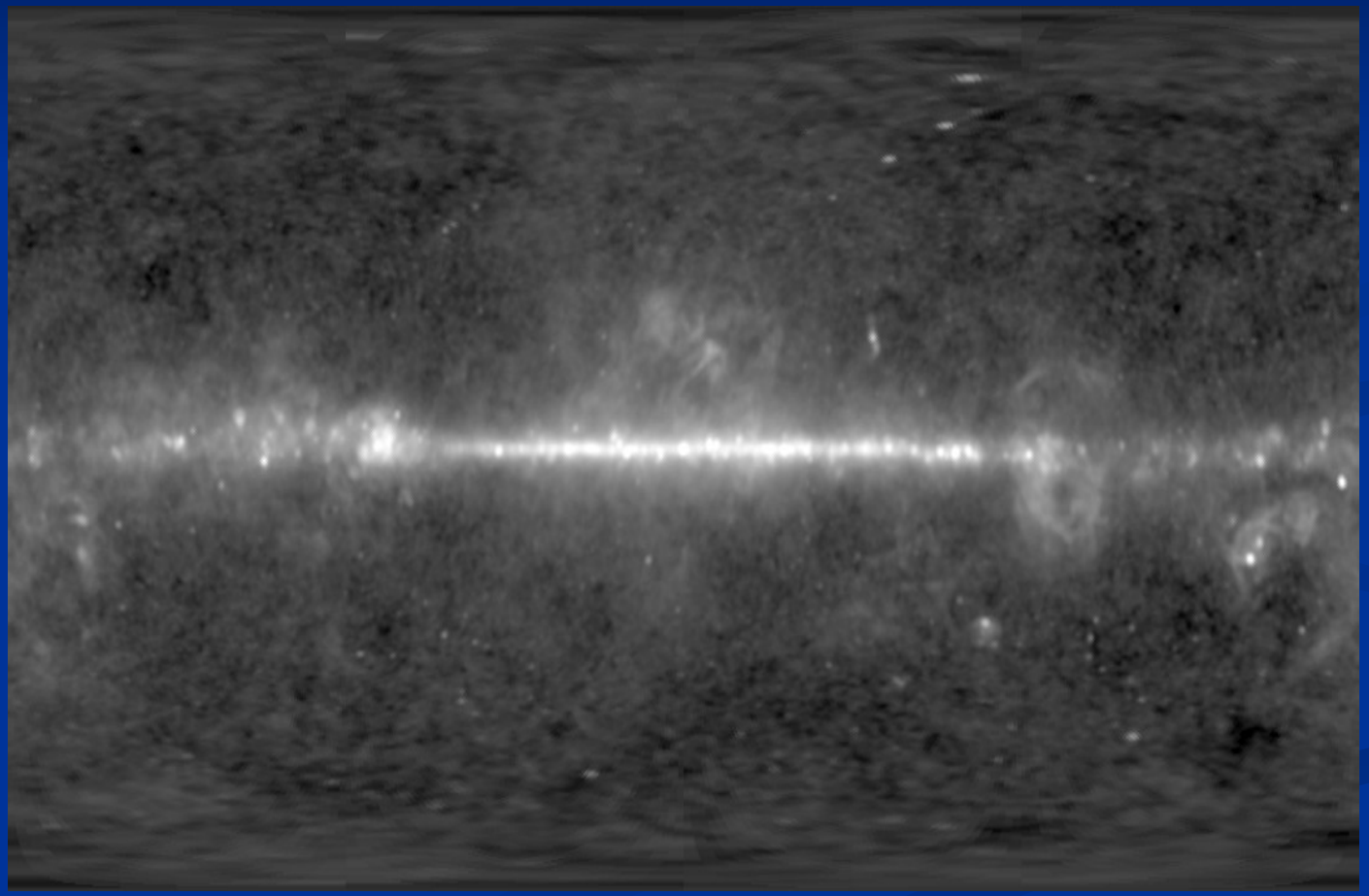
WMAP Haze

Cosmic Microwave Background



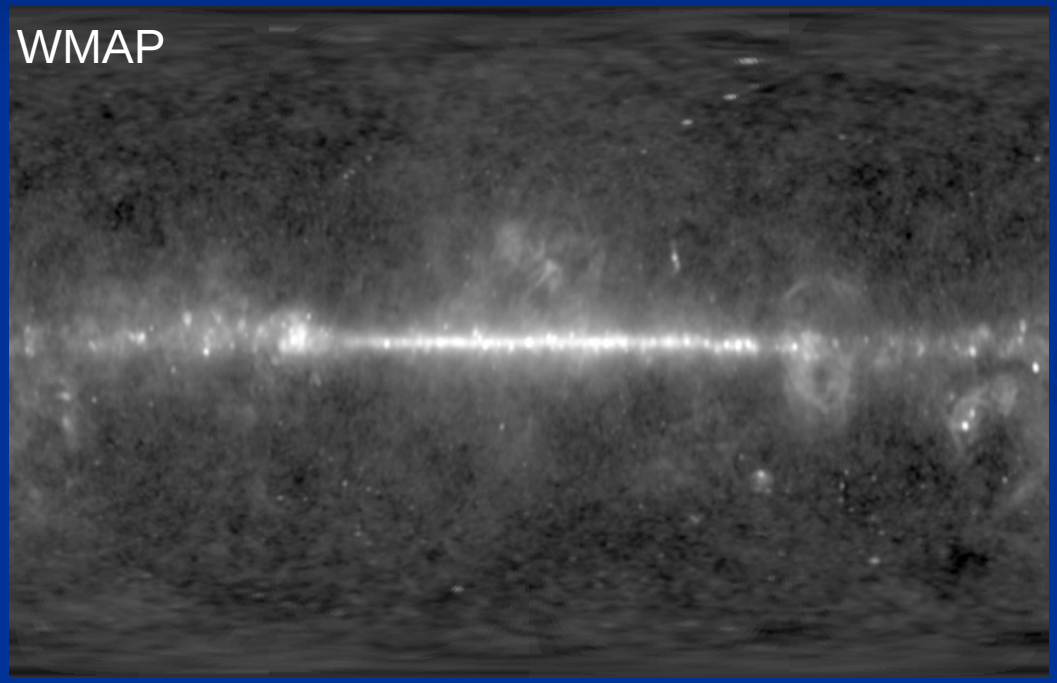
WMAP Haze

WMAP



WMAP Haze

- WMAP: CMB & Galactic Foregrounds...



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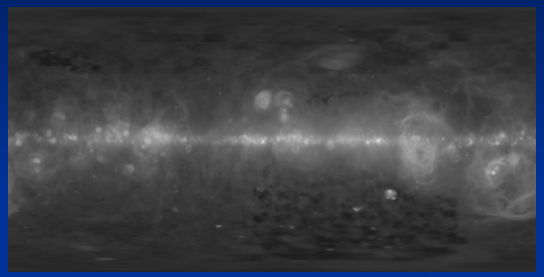

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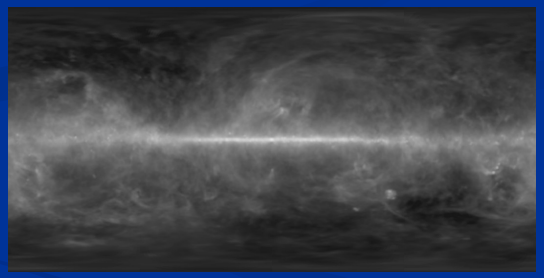

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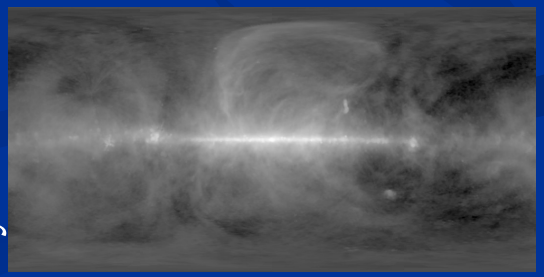
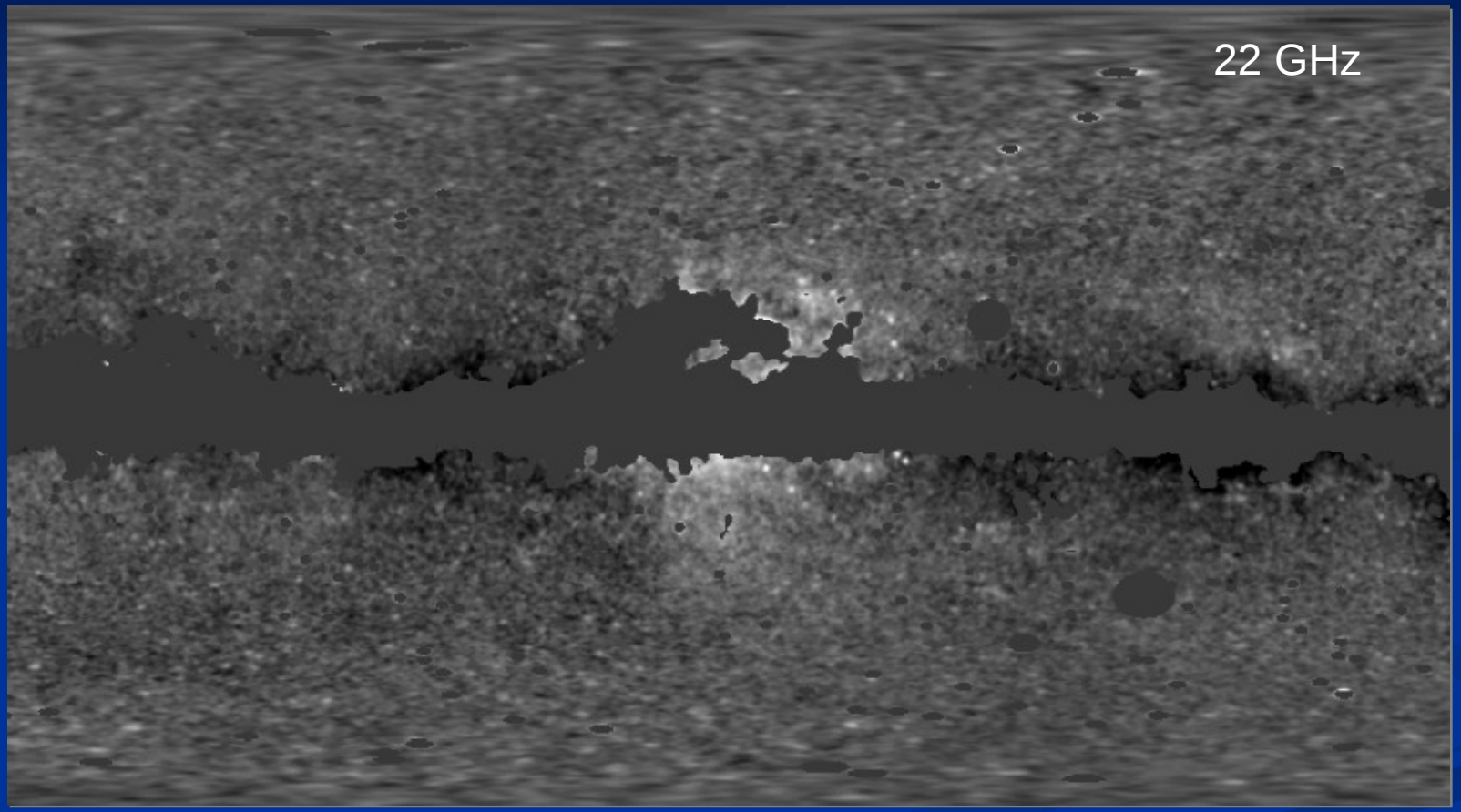
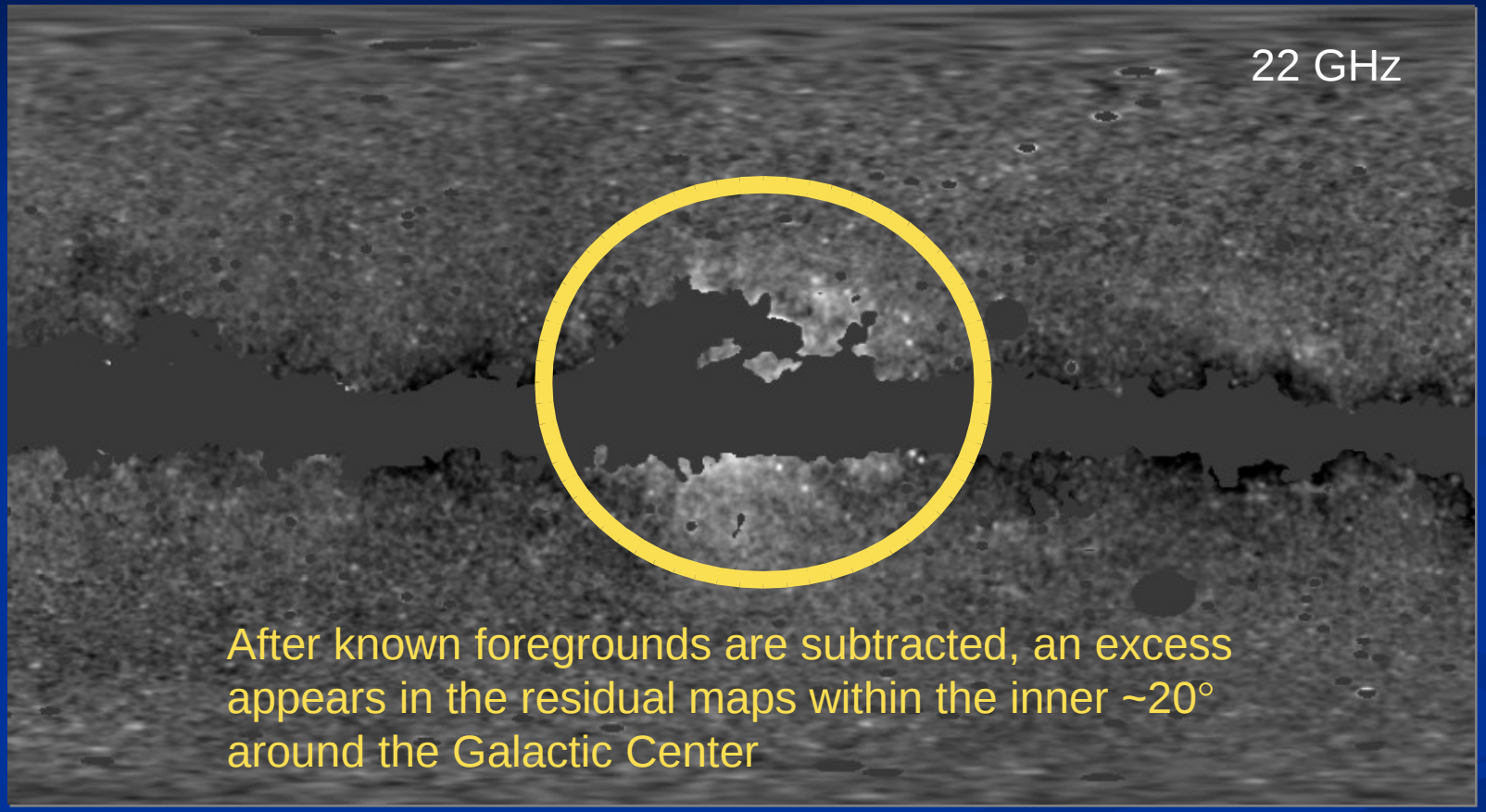


WMAP Haze

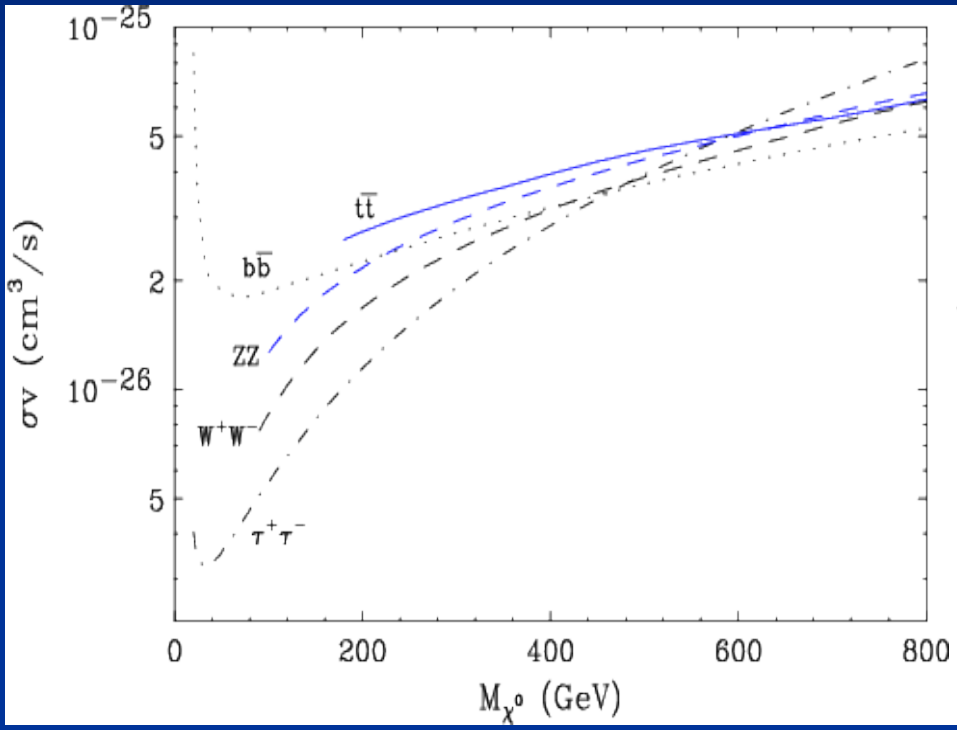


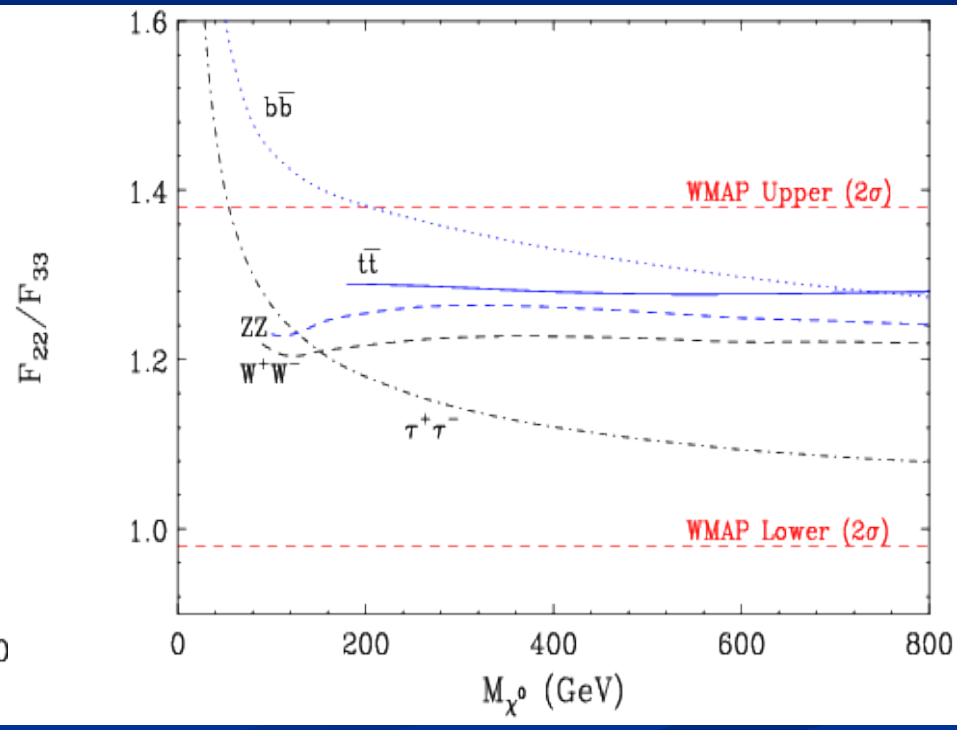
WMAP Haze


22 GHz
After known foregrounds are subtracted, an excess appears in the residual maps within the inner ~20° around the Galactic Center

WMAP Haze

- Dark Matter requirements to produce Haze:

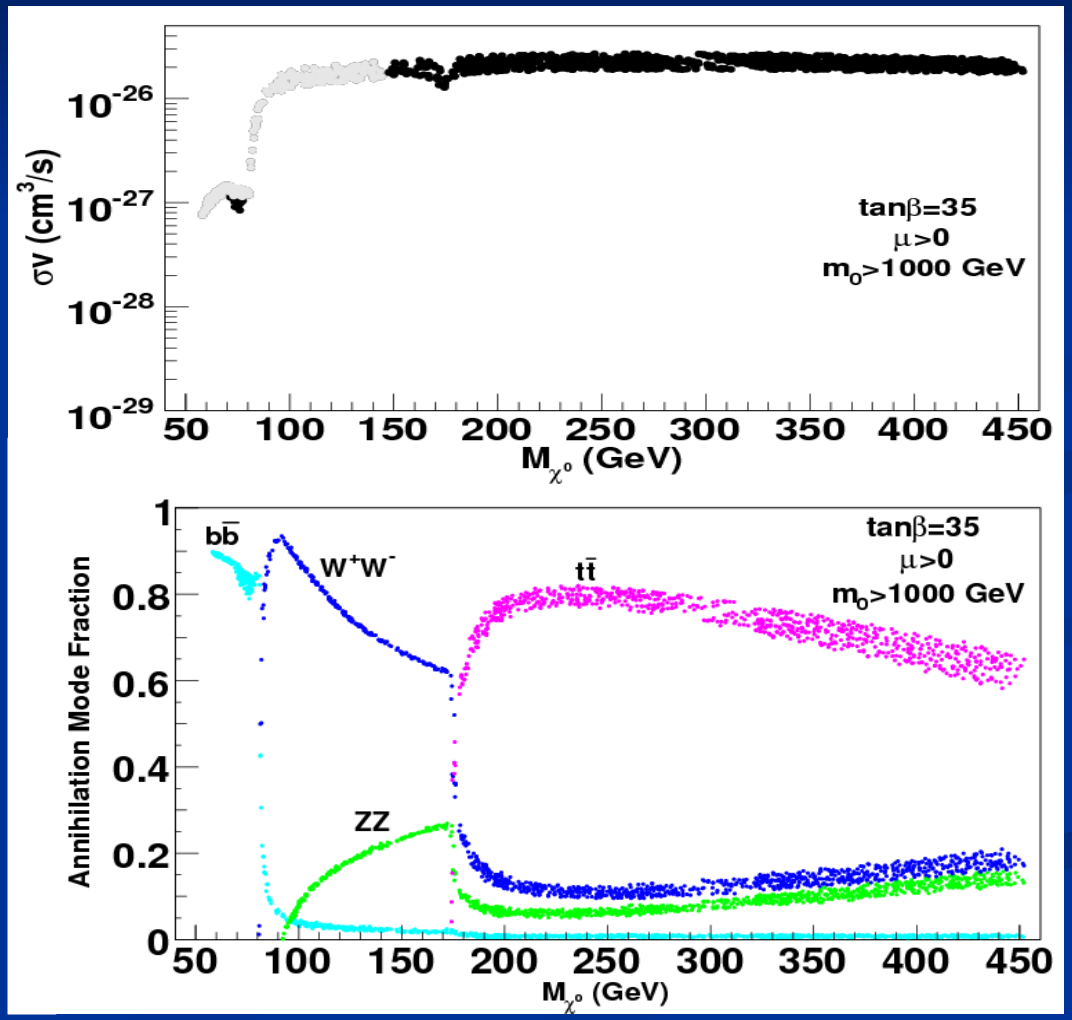




Hooper, Finkbeiner, Dobler 2007

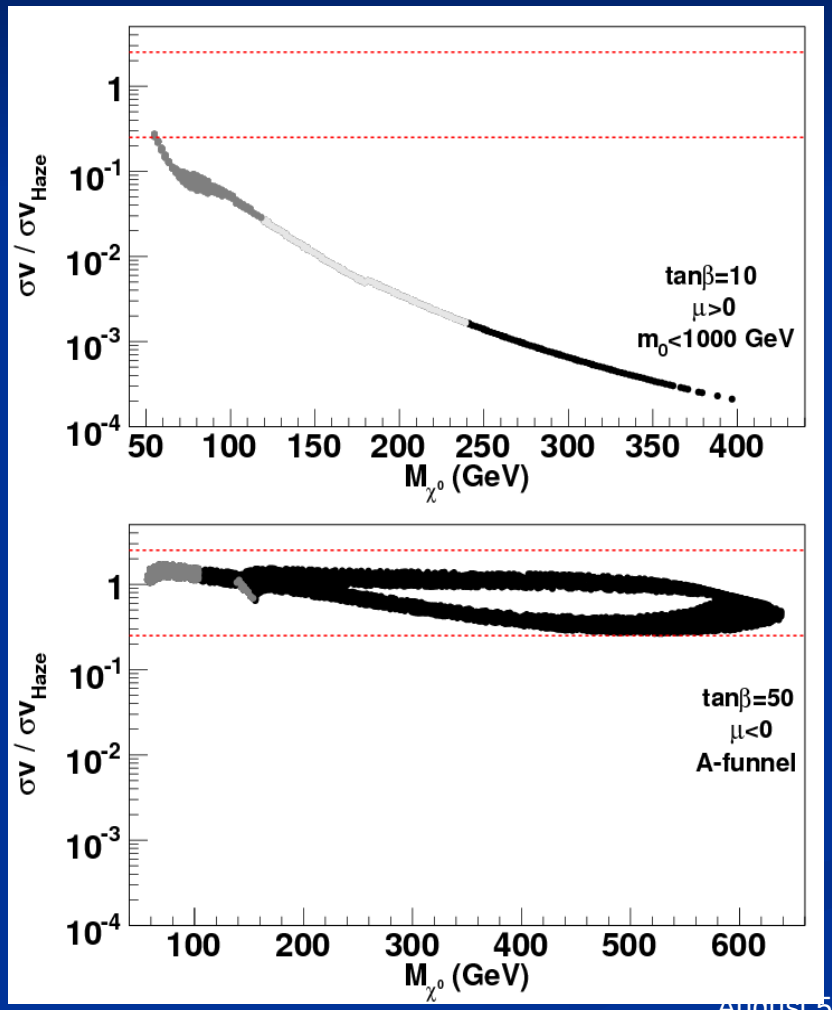
CMSSM Analysis

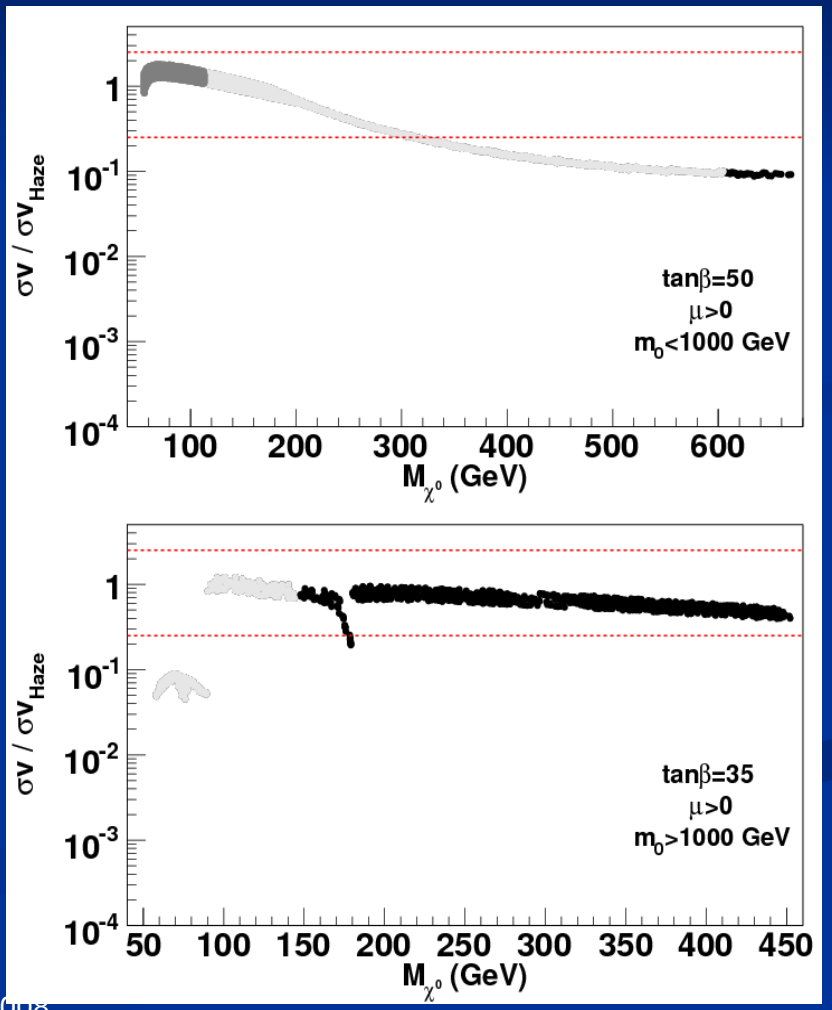
- Take CMSSM data and calculate cross-section and annihilation modes
- Sample:



CMSSM Analysis

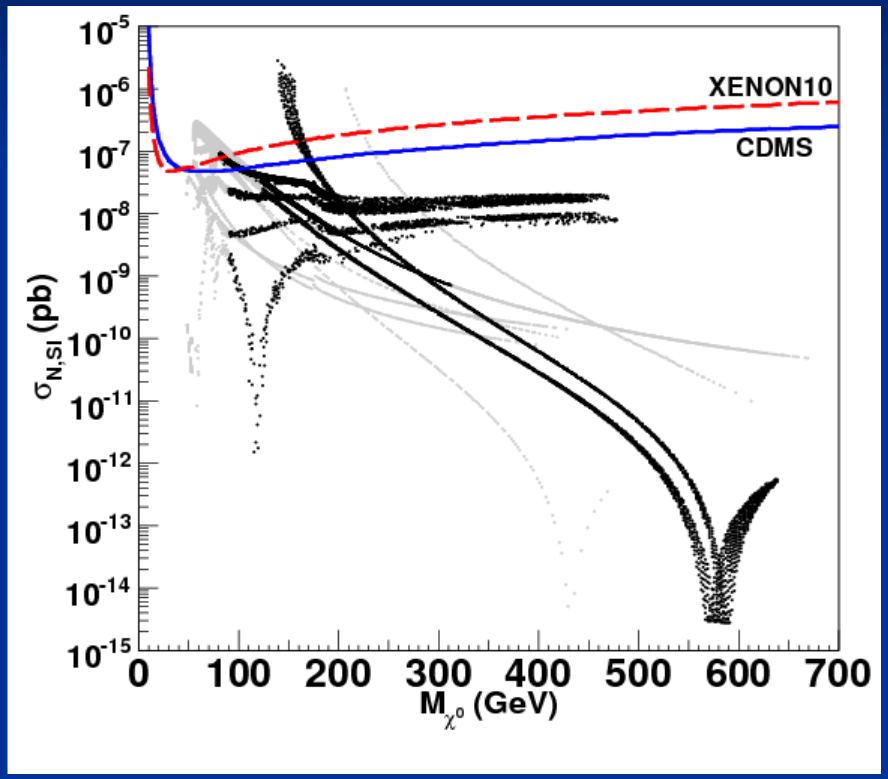
- Compare with Haze requirements
- Sample:



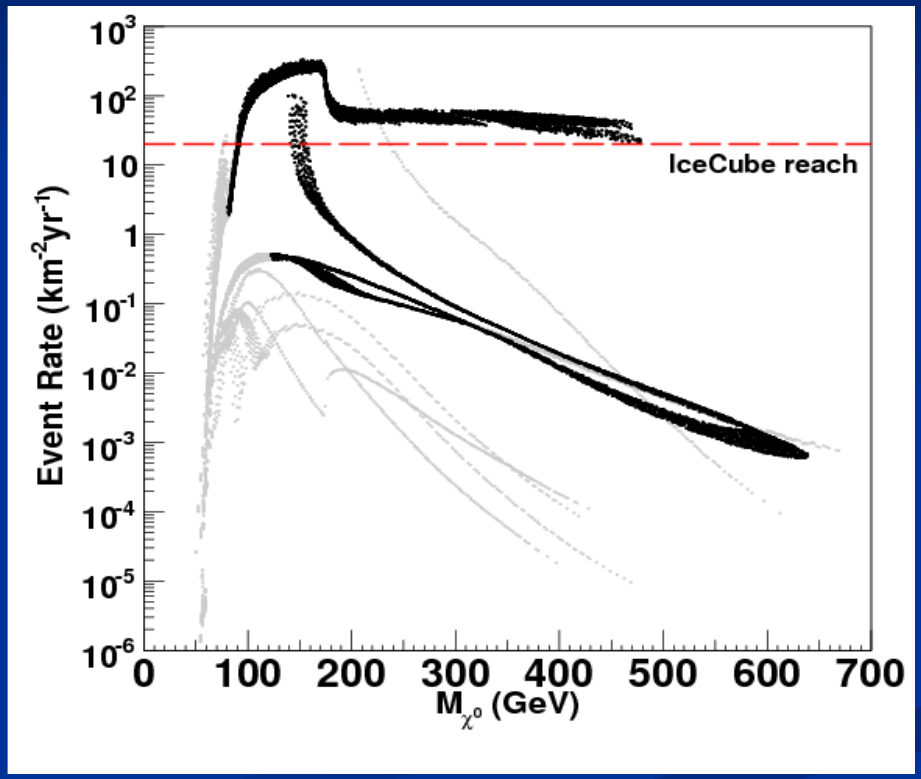


Detection Prospects

Direct Detection



Neutrino Detection



Conclusions

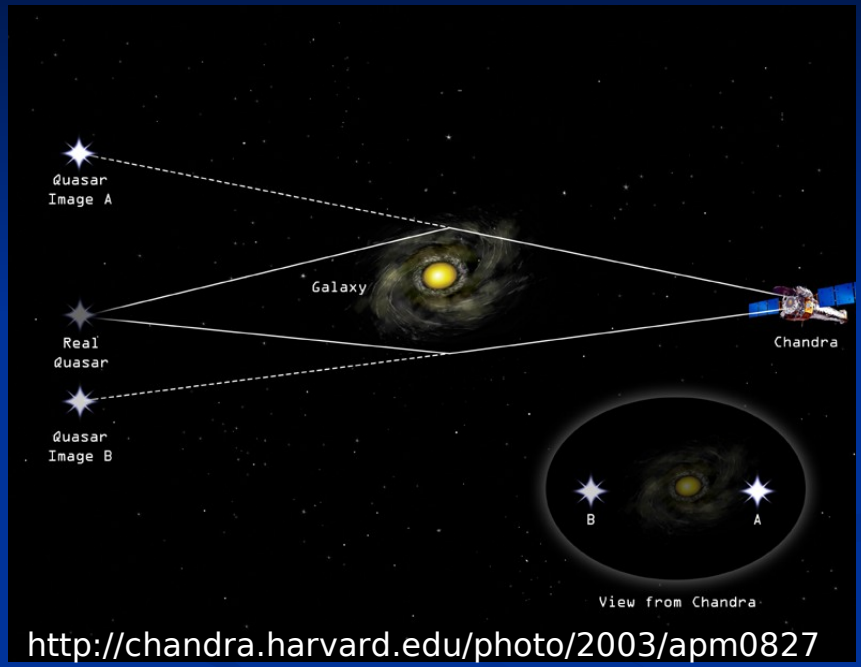
- Much of the CMSSM parameter space provides us with a WIMP which is capable of producing the WMAP Haze
- In particular:
  - Most of the Focus Point and A-funnel regions provide a viable candidate
  - At high tanβ, a fraction of the Bulk region can accommodate a WIMP of the desired properties
  - The stau coannihilation region does not give a WIMP that satisfies the requirements of the WMAP Haze
- Very positive detection prospects for models in the Focus Point region
- For more information see arXiv:0808.0508v1 [hep-ph]

Questions?

Dark Matter

(Sample of) Current Evidence

- Gravitational lensing shows that there's more mass than visible stars.

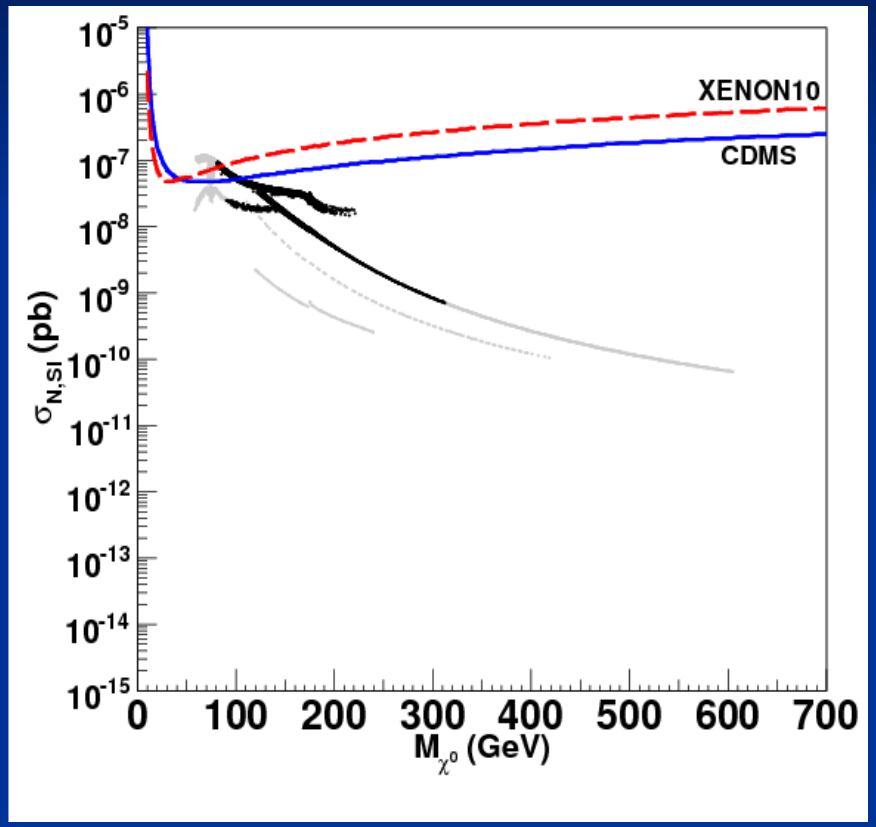


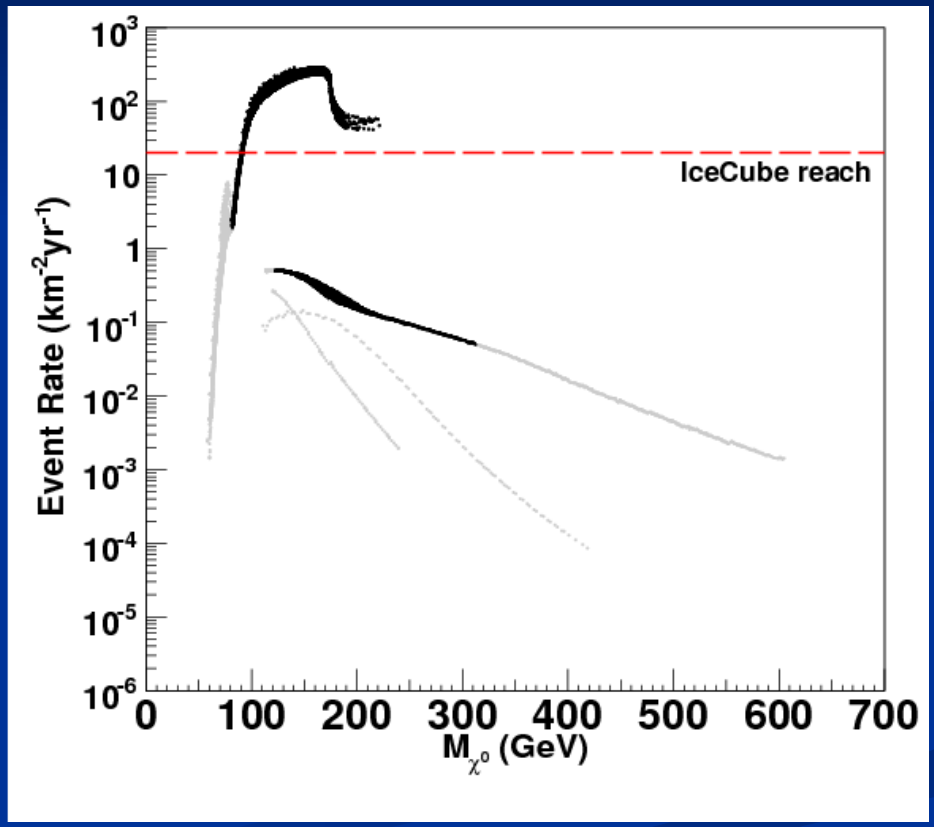
http://chandra.harvard.edu/photo/2003/apm08279/more.html

http://chandra.harvard.edu/photo/2006/1e0657/index.html

- Bullet Cluster shows two clusters colliding leaving the intergalactic gas behind as the dark matter and galaxies continue forward.

Detection Prospects





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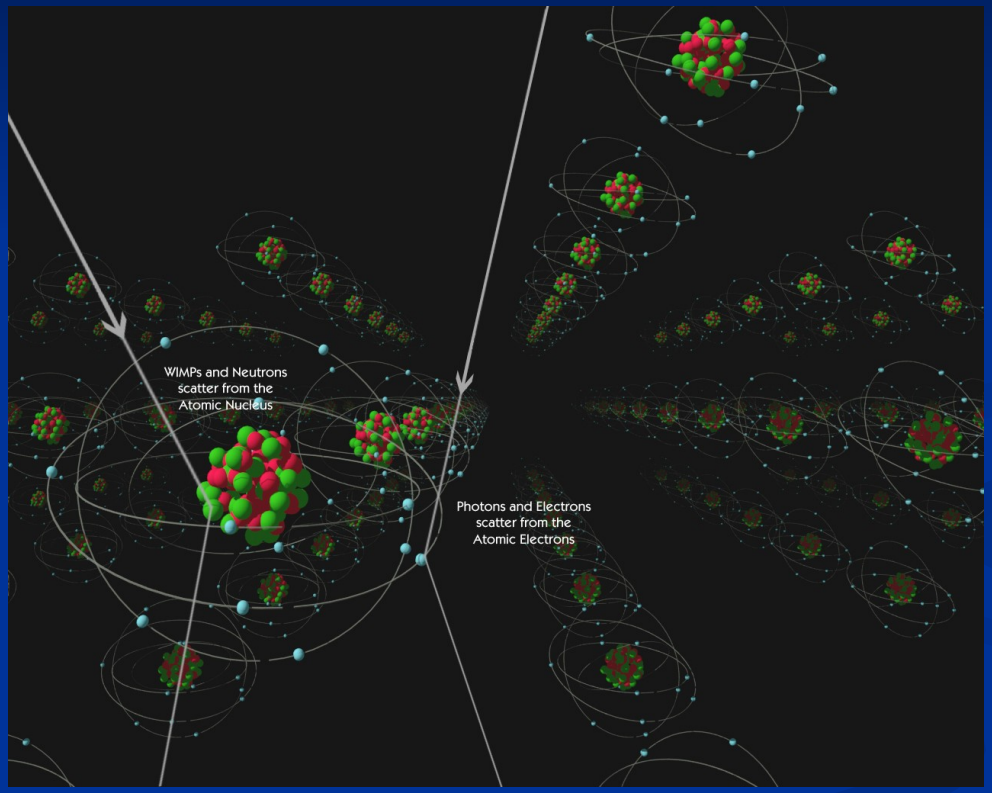
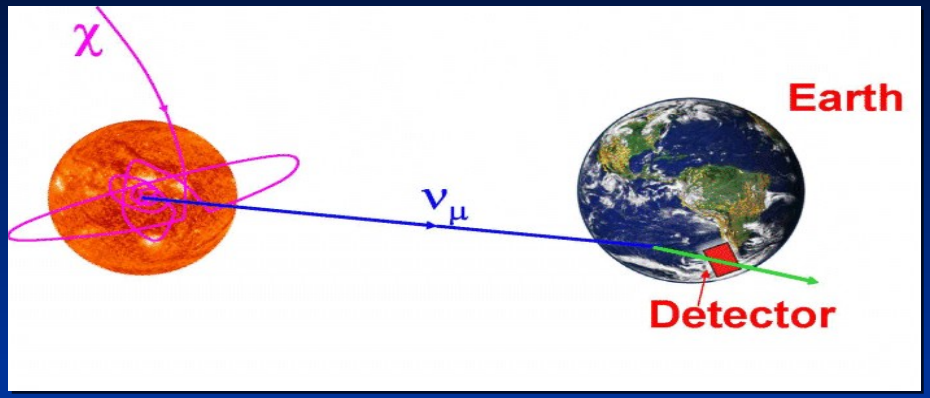
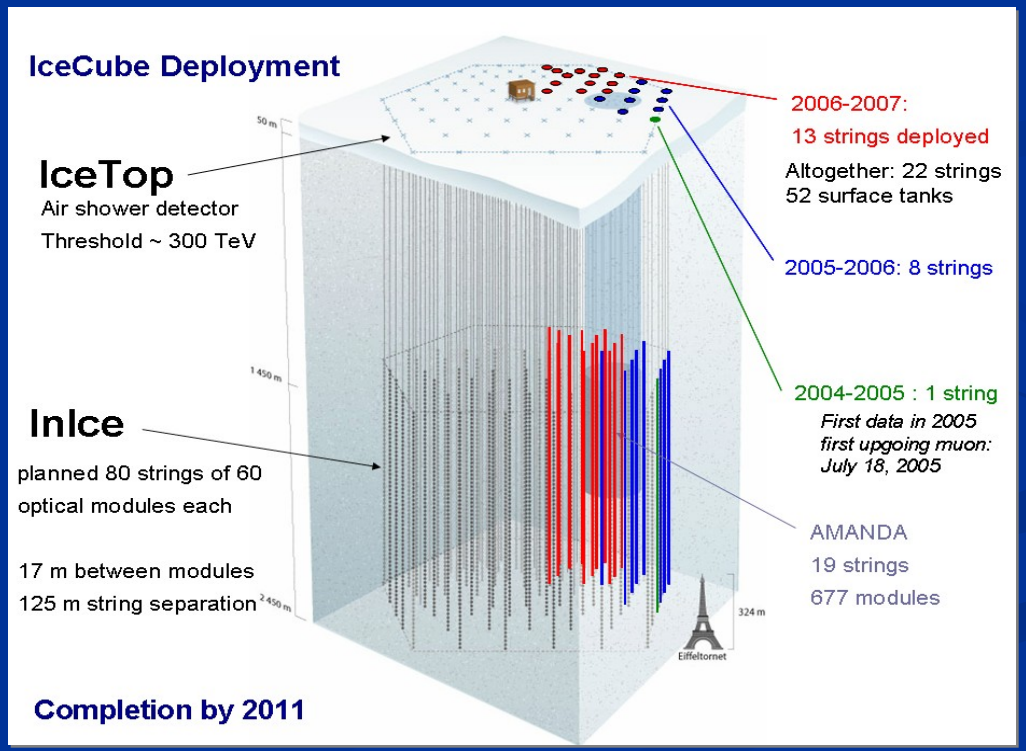


Indirect Detection





WMAP Haze

- WMAP: CMB & Galactic Foregrounds...