Fermi and Intergalactic Magnetic Fields

Or: How to find a diffuse, obscured source

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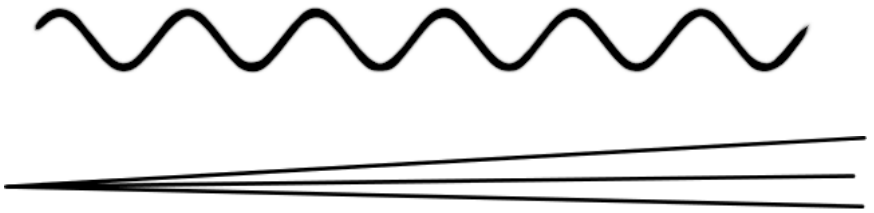
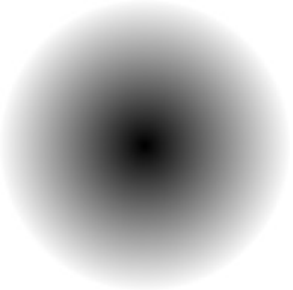
The Question of Interest

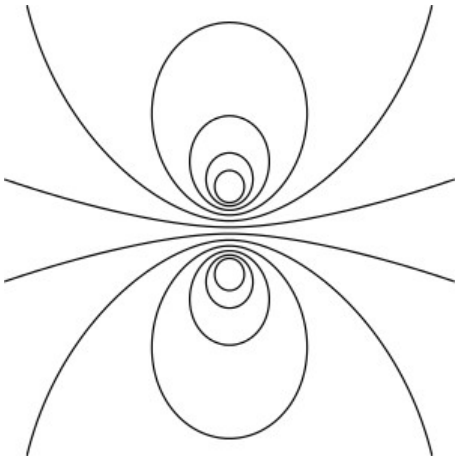
Space is not empty

- Photons (CMB, EBL)
- Cosmic Rays
- Dark Matter Halos, etc.





- Electric and Magnetic Fields



Magnetic Fields in Space

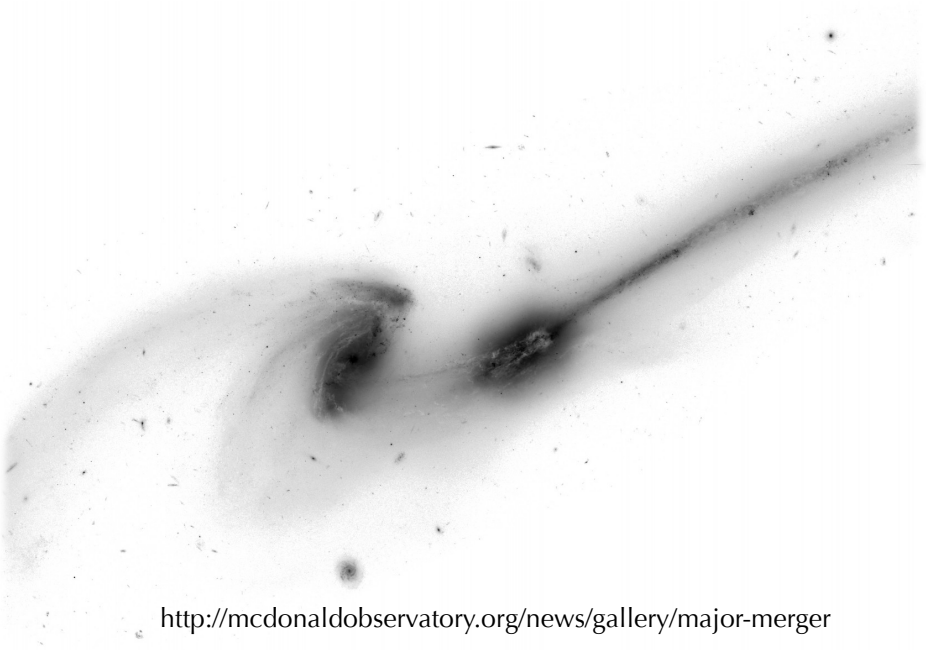
- Galaxies have them (2-10 μG)
- Clusters have them (Intercluster region, 0.2-3 μG)
- What about Intergalactic Space? (away from everything else)
  - Experimentally, we have upper and lower limits (10^{-18}-10^{-15}G < B < 10^{-14} G)
  - But we have never seen them

L. M. Widrow, Rev.Mod.Phys. 74, 775 (2002).
I. Vovk, A. M. Taylor, D. Semikoz, and A. Neronov, ApJ Letters (2012), To appear.
A. Taylor, I. Vovk, and A. Neronov, Astron.Astrophys. 529, A144 (2011).
W. Essey, S. Ando, and A. Kusenko, Astroparticle Physics 35, 135 (2011).

Why do we care?

- Nearby to matter
  - Preserves a record of major events

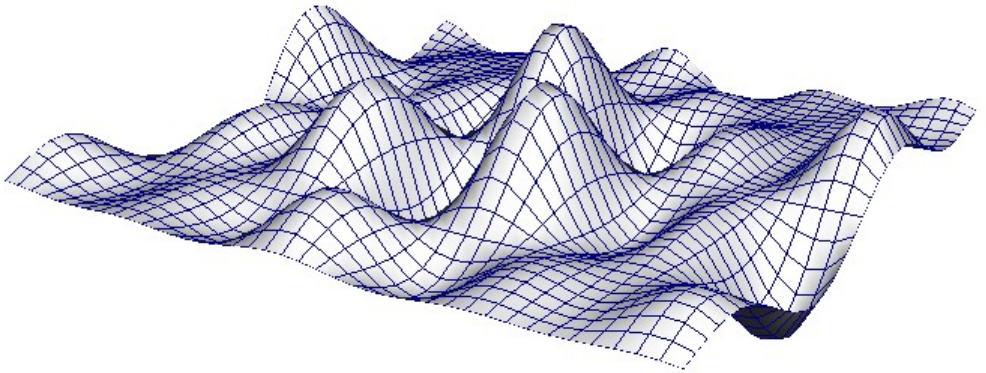
    D. Ryu, H. Kang, J. Cho, and S. Das, Science 320, 909 (2008).



http://mcdonaldobservatory.org/news/gallery/major-merger

- Away from matter
  - May exhibit characteristics of pre-inflation seed fields

    D. G. Yamazaki, et al, Phys. Rev. D 74 (2006) 123518.

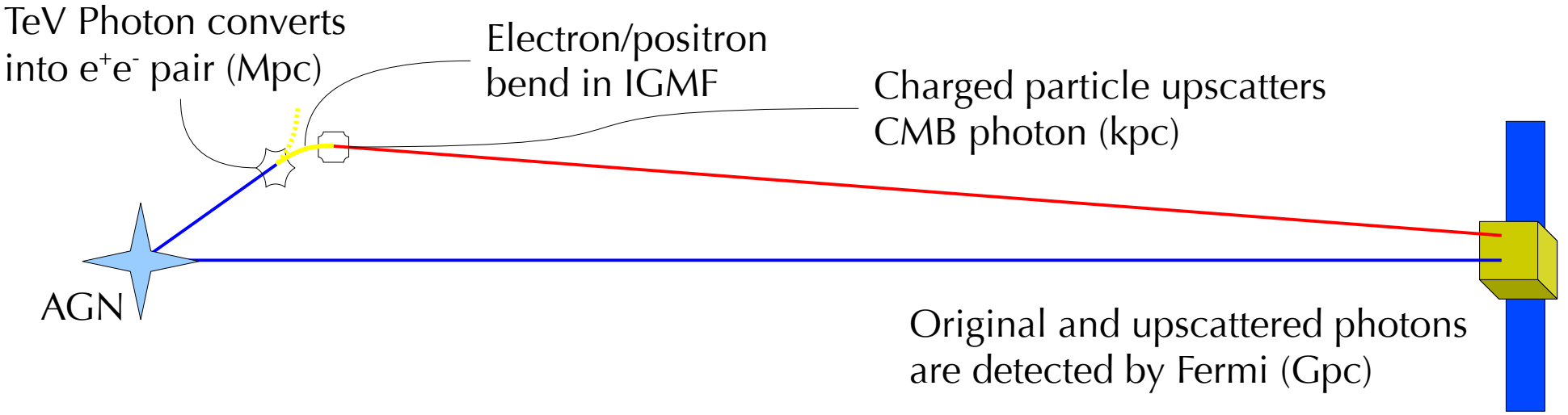


How to probe a magnetic field

Need a charged particle

- TeV photons can pair-convert with optical and IR EBL photons
  - For this work, the primary source of TeV photons are blazars

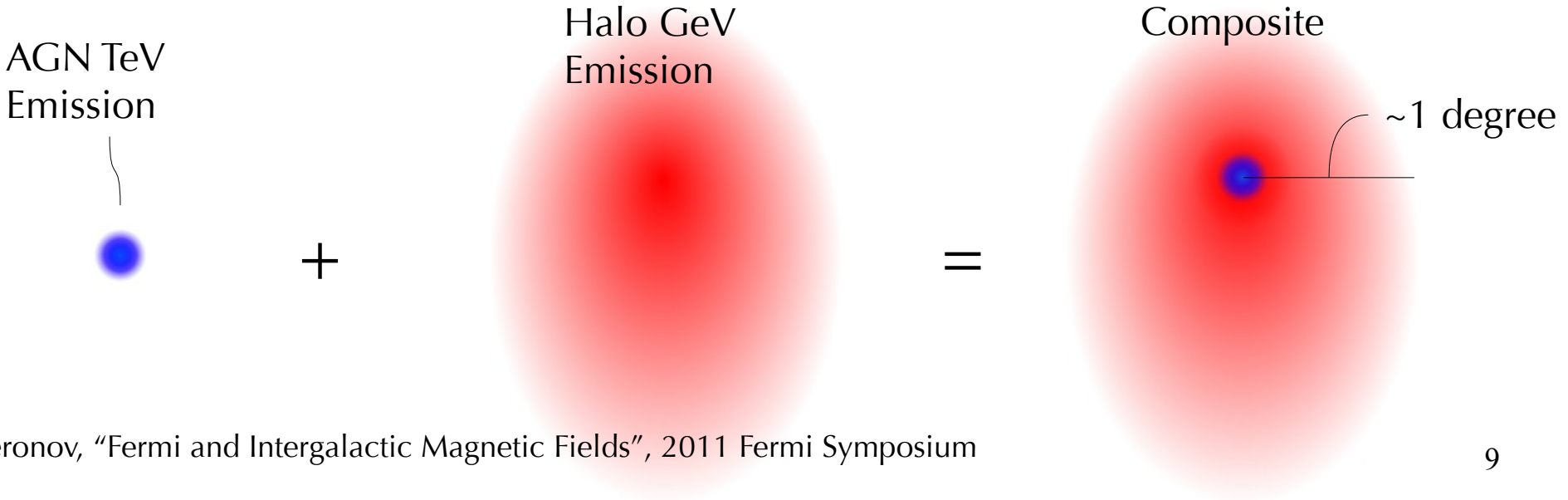
"Pair-conversion Halo"



- The pair-converted electrons and positrons will bend in the presence of a magnetic field, and upscatter CMB light to GeV Energies, detectable by Fermi

Signal

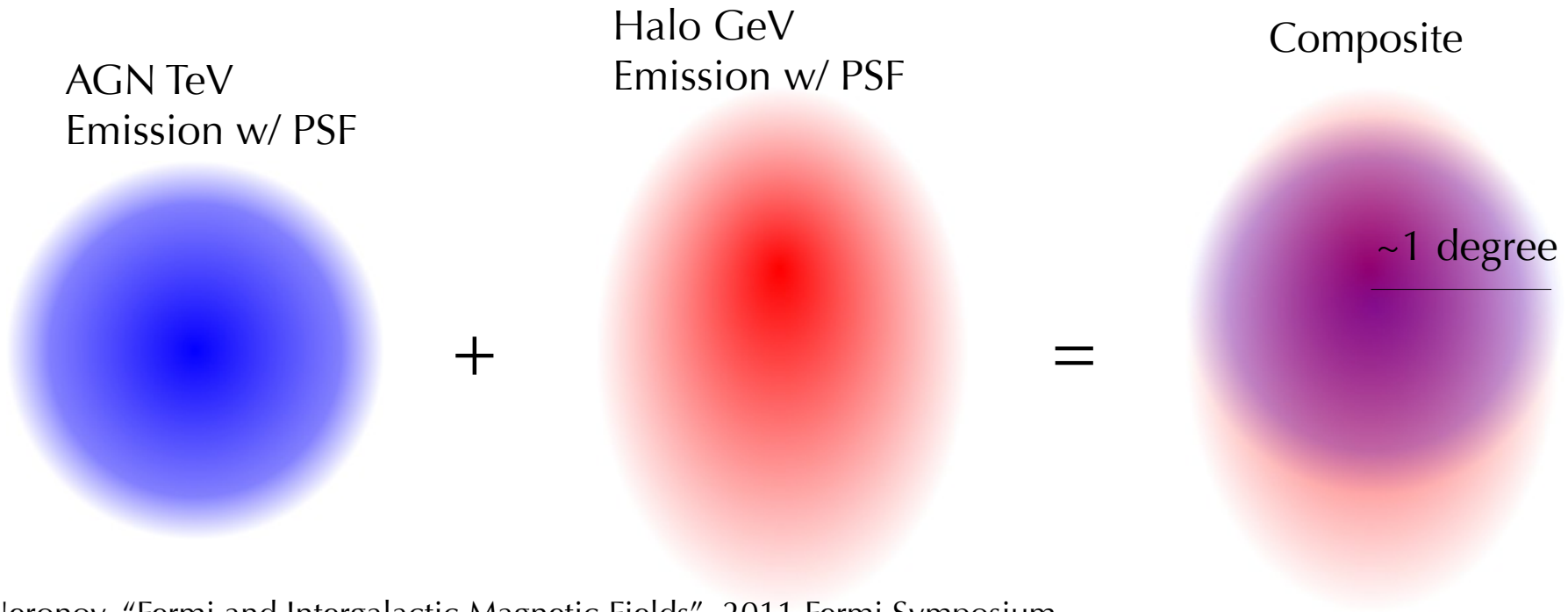
- The expected signal is the AGN plus a diffuse, asymmetric cloud around it
  - The size of the halo reflects the magnitude of the IGMF
  - Relative intensity depends on which portion of the spectrum is visible to Fermi (i.e. where it peaks)



A. Neronov, "Fermi and Intergalactic Magnetic Fields", 2011 Fermi Symposium

Signal + PSF

- However, recall that the PSF blurs the AGN
  - The resulting size is about that of the halo
  - The PSF is energy dependent—go to higher energy to reduce PSF, but then you loose statistics

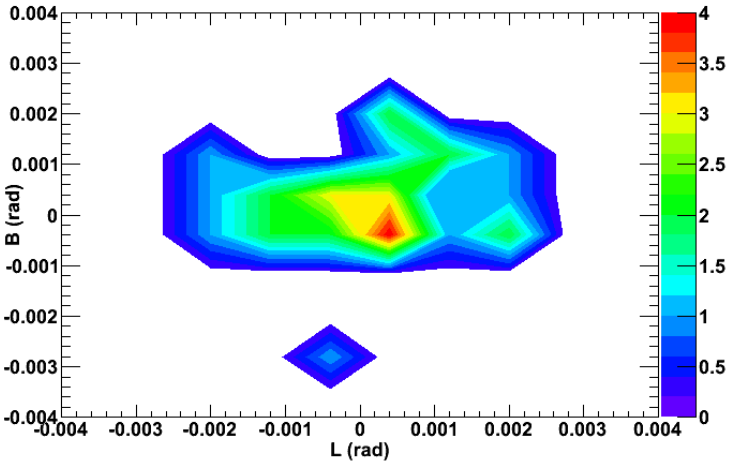


A. Neronov, "Fermi and Intergalactic Magnetic Fields", 2011 Fermi Symposium

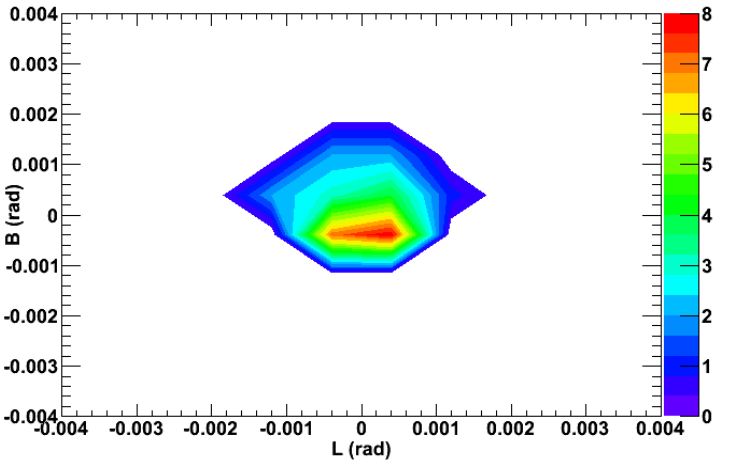
Finding the diffuse source

Method 1: Make the PSF Smaller

- There's a difference between good photons and bad photons, but that difference is *averaged* with the current psf
- When you use the covariance error matrix, you discriminate between them
- This study was generated with 30 sets of 3000 independent MC photons. When averaged using the PSF or Covariant methods, the 30 sets form the given distributions.
- Will go into ScienceTools



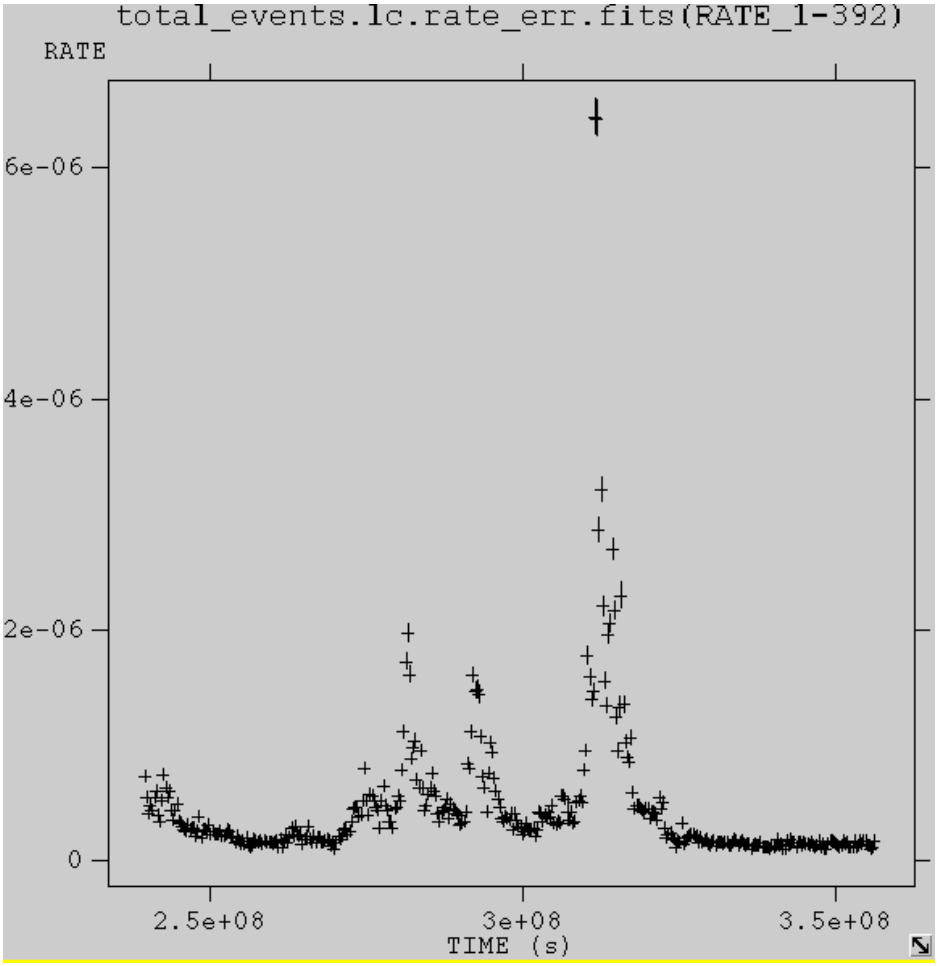
PSF Reconstruction



Covariant Reconstruction

Method 2: Time-domain analysis

- The AGN can vary with time, and the halo does not
  - This allows us to look at the real signal as a two-component model, and try and extract the halo
  - This is very preliminary, and has a large number of possible complications



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Conclusion

- The IGMF is an interesting probe into cosmology, and we can in principle measure it with Pair Halos
- The PSF is the major obstacle, so we need to find a way to reduce it
- The techniques we develop can be used on many different analyses, and will be included in the Science Tools

Todo

- Work through the covariance technique
  - This will include transforming into local coordinates and applying all math at that level
  - It will be included in the Science Tools
- Work through the time-domain technique
  - Includes understanding errors and demonstrating it can find a null result
- Simulate the signal
  - A full physical photon simulator starting with the TeV electrons

Thanks to Steve Ritz, Bill Atwood,
and the rest of our working group

Are there any questions?