Ruling out thermal dark matter with a black hole induced spiky profile in the M87 galaxy

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Introduction

- Indirect detection promising avenue to look for DM particles using astrophysical observations
- Here focus on DM annihilations
- Annihilation signals $\propto \rho^2$
  $\Rightarrow$ especially interesting at the centers of galaxies due to overdensities
- Challenging to disentangle DM signatures from more conventional sources
  $\Rightarrow$ look for characteristic features

DM spike

Slow growth of supermassive black hole (BH) at the center of a galaxy
$\Rightarrow$ dense DM spike $\rho(r) \propto r^{-7/3}$ (Gondolo & Silk 1999)
$\Rightarrow$ Strong annihilation signals

Caveats

- Spike can be destroyed by mergers; weaker cusp if BH growth not exactly at the center (Gnedin & Primack 2004): $\rho(r) \propto r^{-1/2}$
  $\longrightarrow$ Lots of uncertainty on these processes
- Most importantly: scattering of DM particles off stars (Gnedin & Primack 2004, Vasiliev & Zelnikov 2008)
  $\Rightarrow$ smoother profile $\rho(r) \propto r^{-3/2}$
  $\longrightarrow$ Unavoidable in principle

Why is M87 interesting?

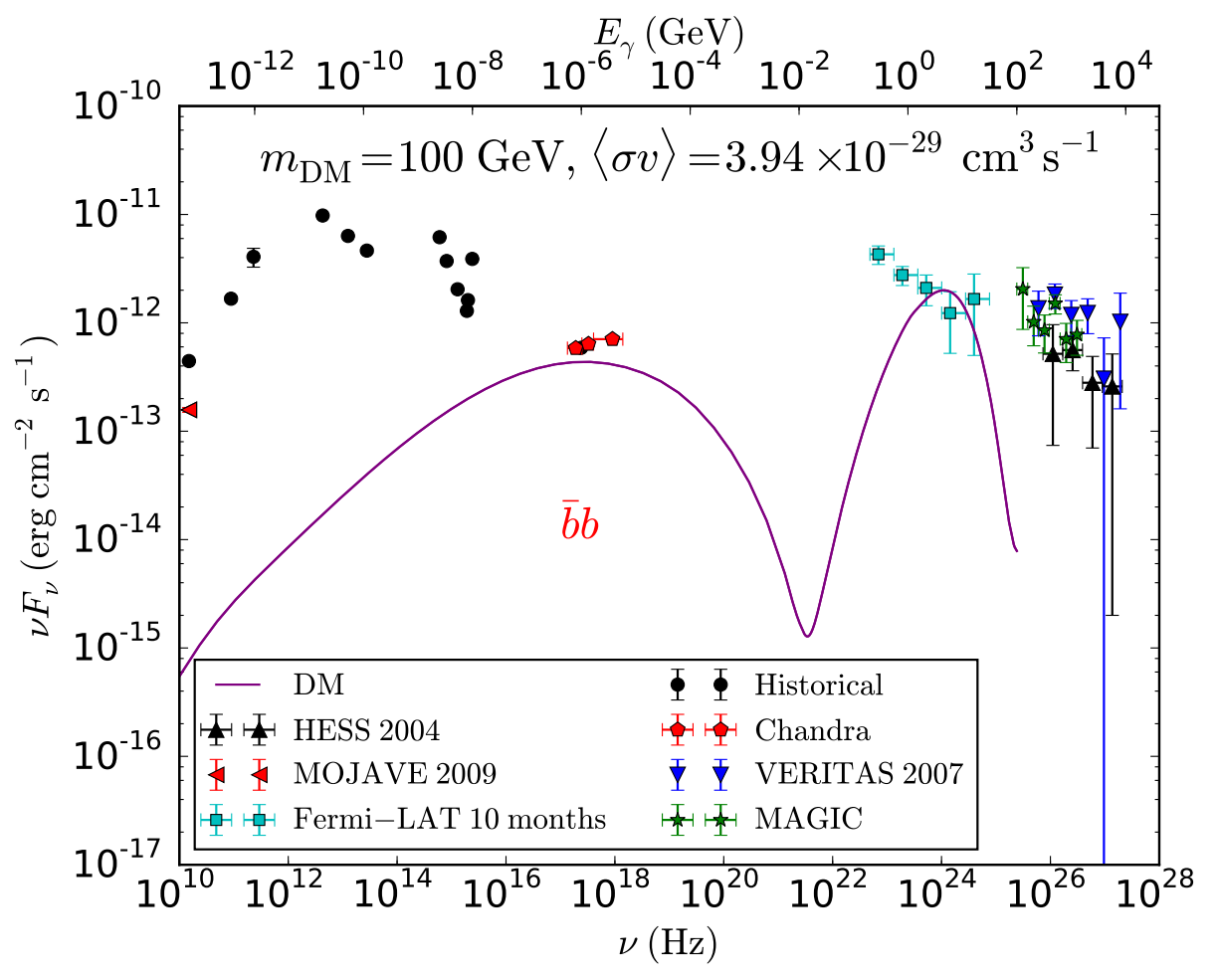
Dynamical relaxation time in M87: 10^5 Gyr vs several Gyr for the Milky Way

$\Rightarrow$ M87 dynamically young

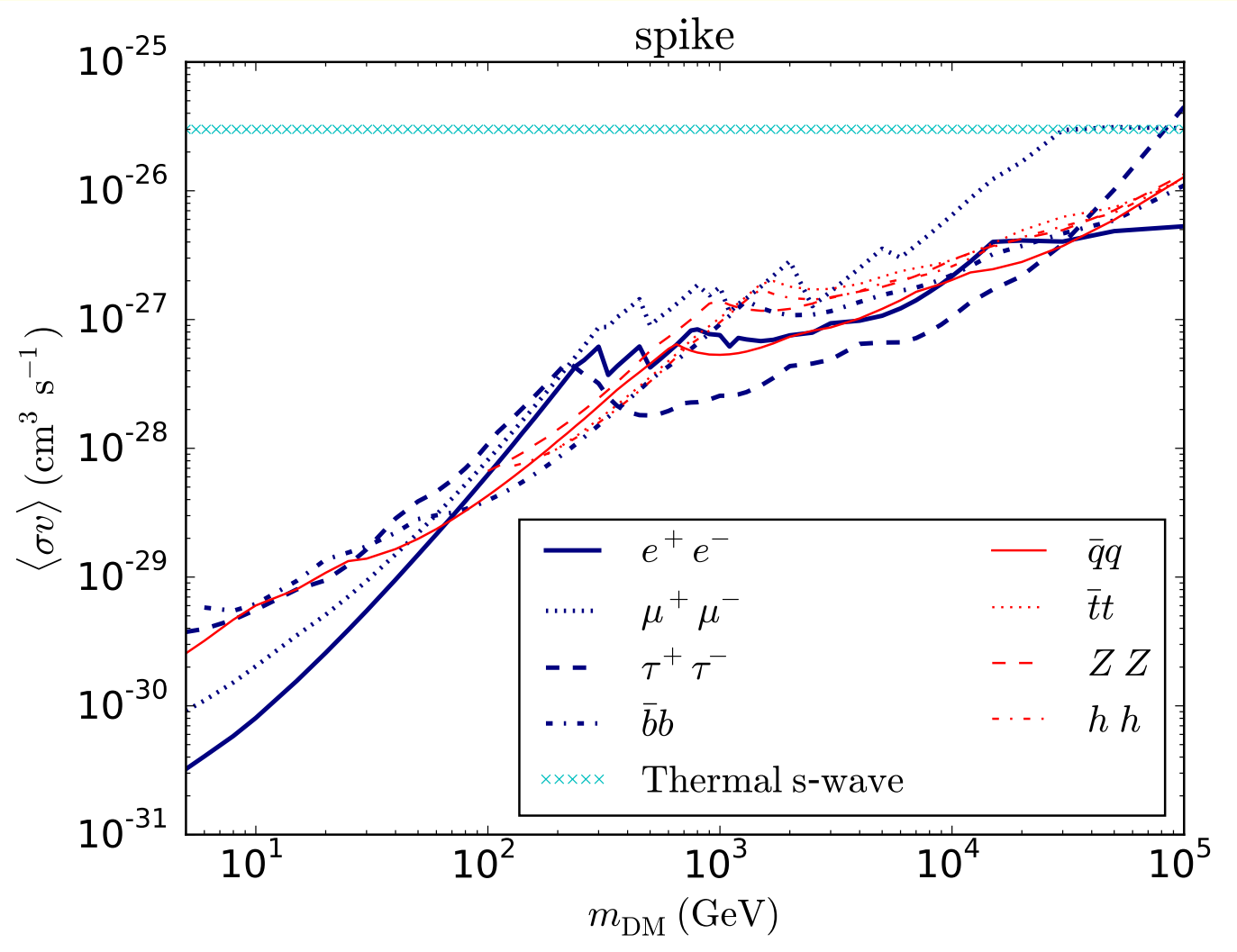
$\Rightarrow$ spike much more likely to have survived in M87

$\Rightarrow$ huge potential for indirect detection signals

- Prompt emission dominant contribution to γ-rays
- Large magnetic fields expected in the inner region $\Rightarrow$ significant contribution from synchrotron emission

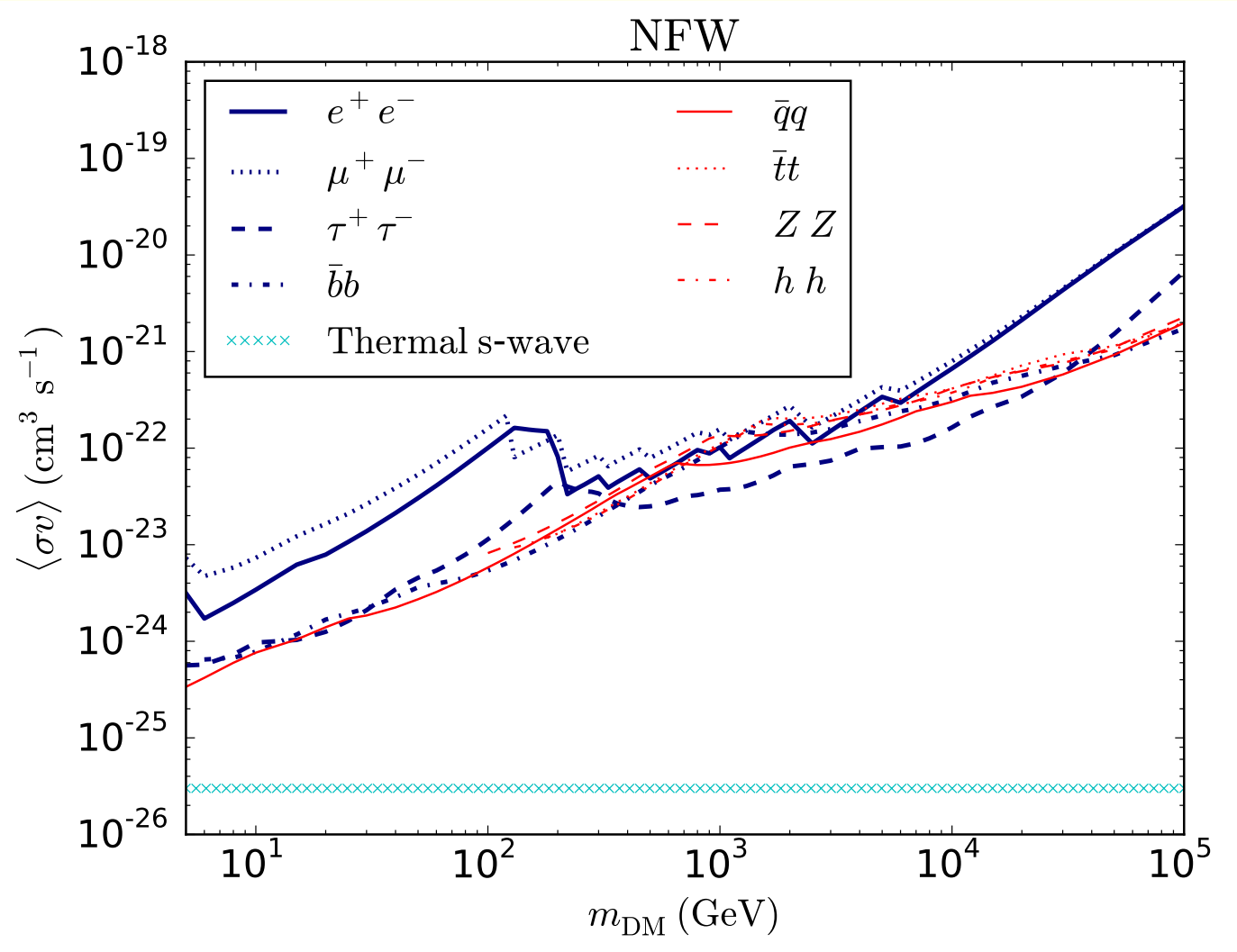


Upper limits from requirement that DM-induced signal do not overshoot the data

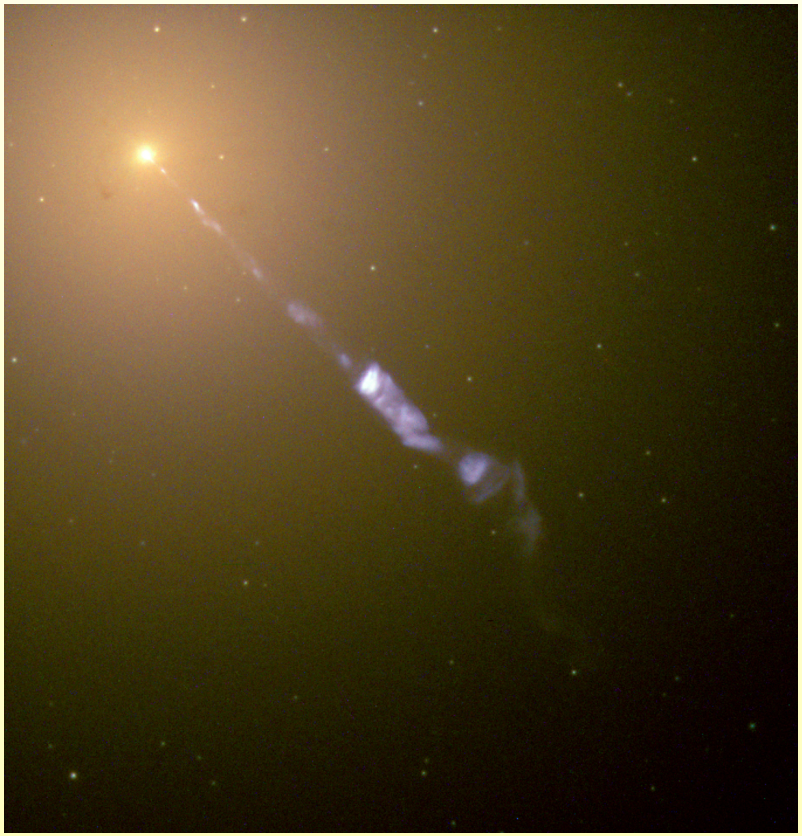


- These limits exclude thermal s-wave DM up to 100 TeV!
- Caveat: assumption that spike with $\rho \propto r^{-7/3}$ was effectively produced and survived
- Constraints essentially given by prompt γ-ray emission
  $\Rightarrow$ independent of the magnetic field model
- Robust to absorption processes
- Conversely if thermal s-wave DM confirmed, spike ruled out
  $\Rightarrow$ information on history of the galaxy

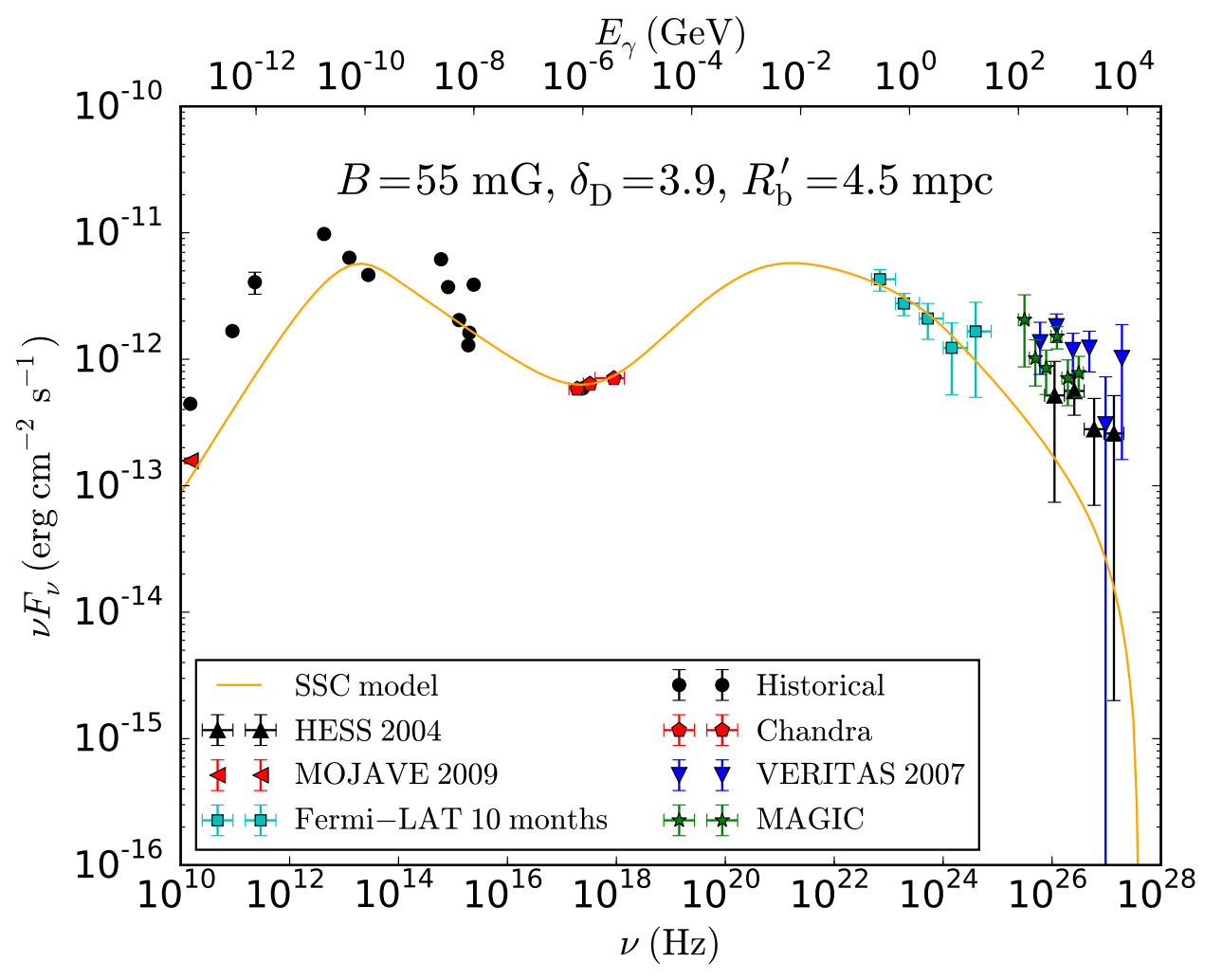
Much weaker constraints in the absence of a spike (NFW only)



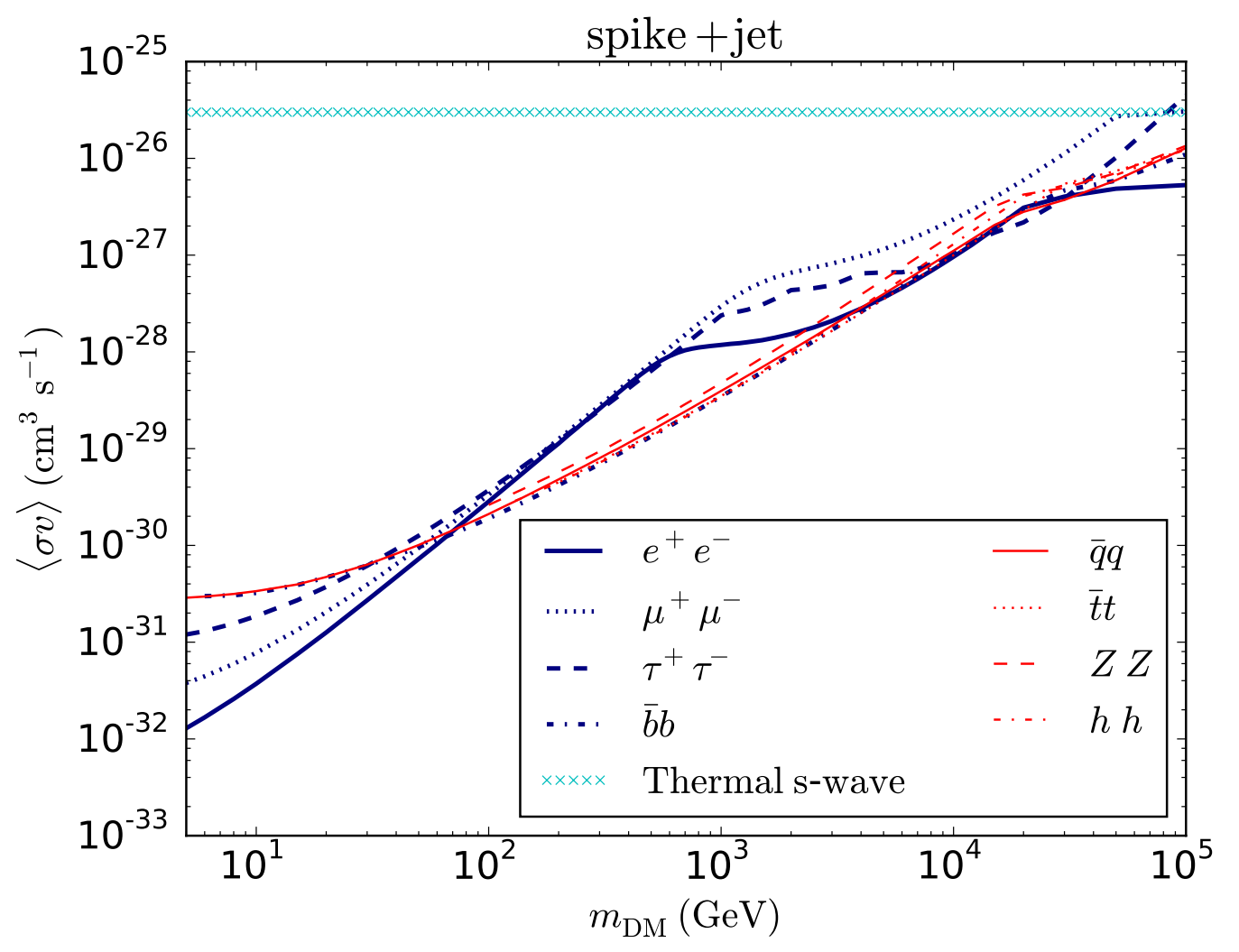
- Powerful jet in M87
- Look for emission brighter than the jet
- But jet model not yet perfectly constrained



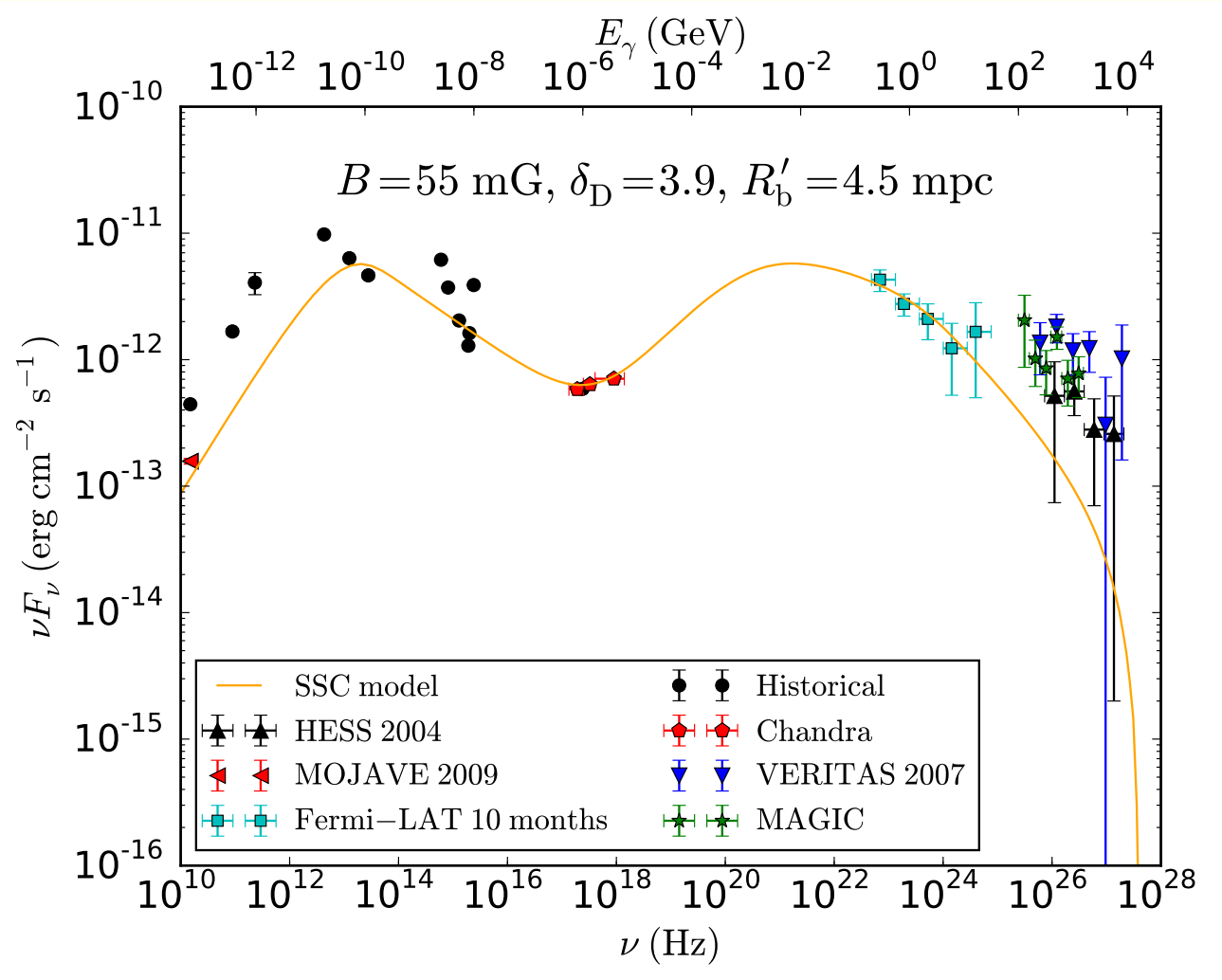
SSC model from Finke *et al.* 2008, parameters from Abdo *et al.* 2009



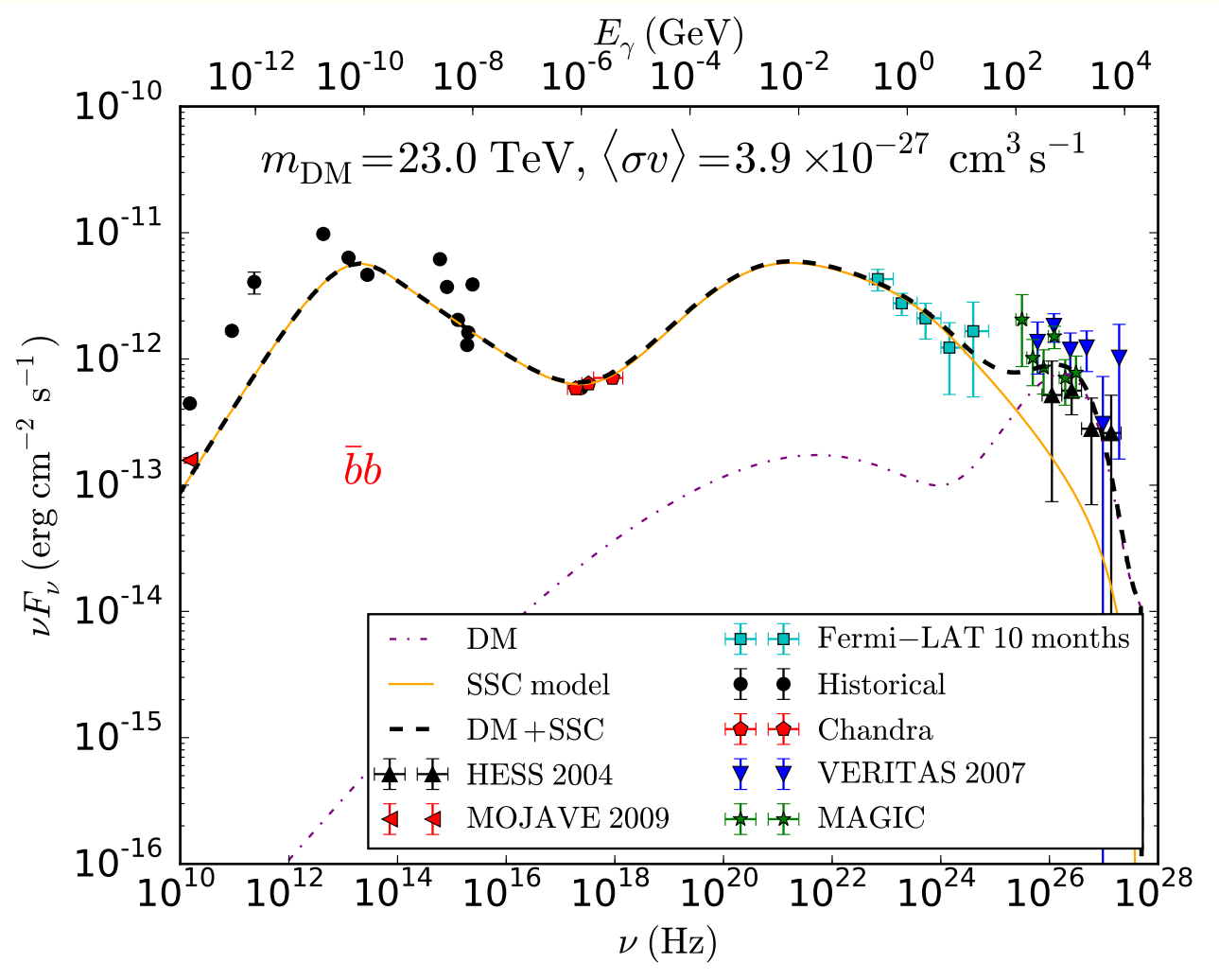
Exclusion if departure from the best fit at 2σ



SSC model underestimates the TeV emission...

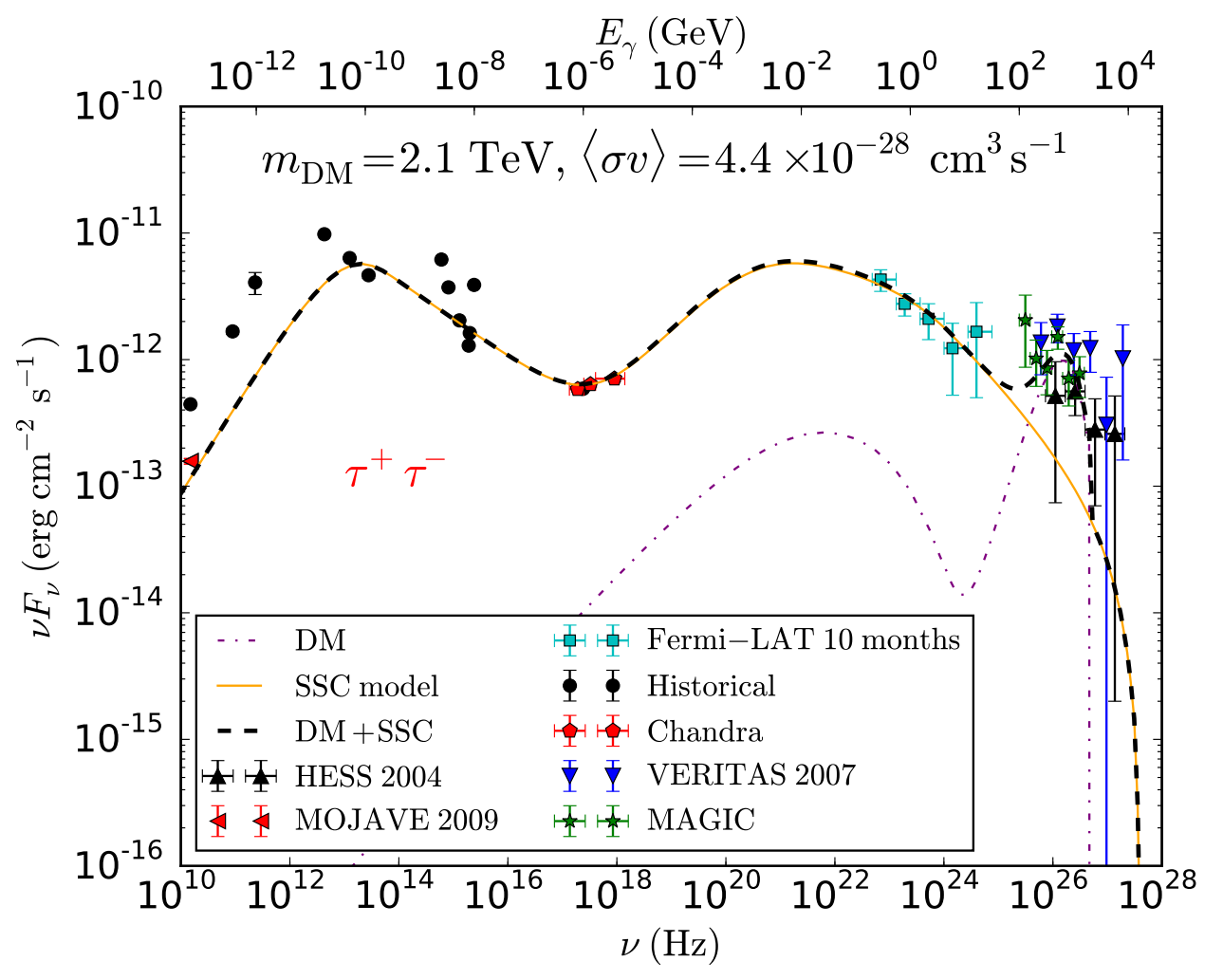


Unless we include TeV DM! Suggested by Saxena *et al.* 2011 for NFW



But with spike much smaller cross section needed

Good fit for channels with spectra softer than electrons and muons



Conclusion

- Strong case for a DM spike with $\rho \propto r^{-7/3}$ in M87 (heating by stars negligible)
- Extremely stringent constraints on $\langle \sigma v \rangle$ vs $m_{\rm DM}$ that exclude thermal s-wave DM up to ~ 100 TeV
- Requirement: spike effectively formed and not destroyed
- TeV DM can account for the TeV γ-ray emission for annihilation cross sections $\lesssim 10^{-27}$ cm^3 s^{-1} in the presence of a spike
- Similar results expected for galaxies with similar SMBH
- Strong motivations to look for DM spikes!

Thank you for your attention!