Constraints on Dark Matter Annihilation in Clusters of Galaxies from Diffuse Radio Emission

Emma Storm[1]
Tesla Jeltema[1,2], Stefano Profumo[1,2], Lawrence Rudnick[3]

[1]Department of Physics, UCSC

[2]Santa Cruz Institute for Particle Physics, UCSC

[3]Department of Physics and Astronomy, UMN

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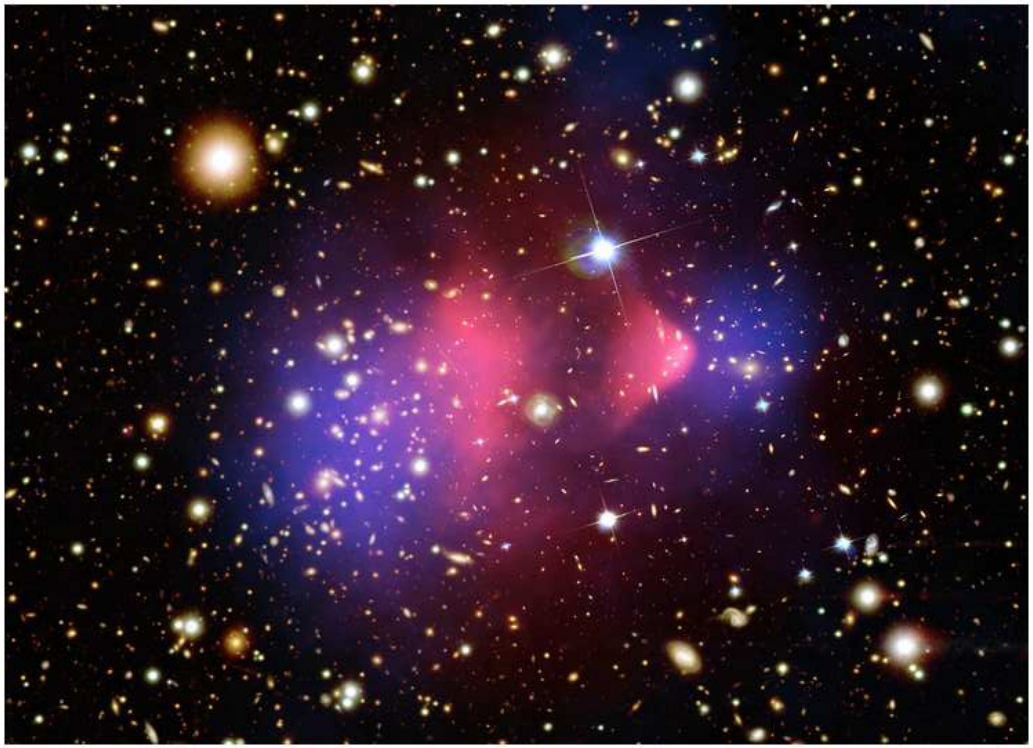
Clusters of Galaxies

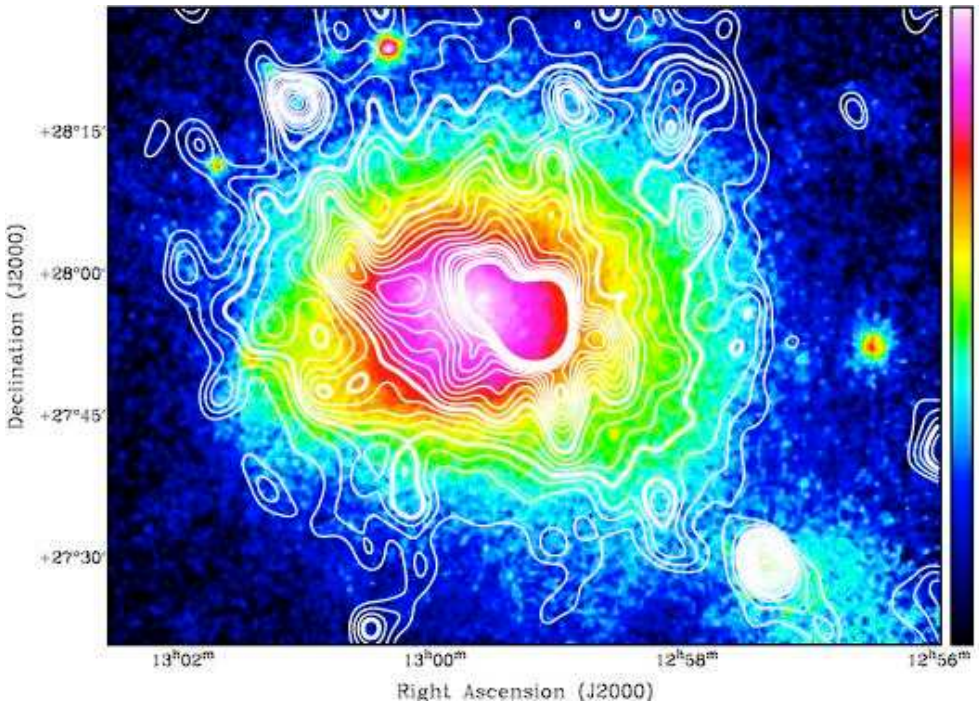


Bullet Cluster. Credit: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.

- Galaxies
- Intracluster Medium (ICM)
- Dark Matter

Diffuse Radio Emission in Clusters

- Radio Haloes
  - diffuse synchrotron emission
  - $\sim$1 Mpc
  - typically found in merging clusters
- Mini-Haloes
  - hundreds of kpc, found in relaxed (cool-core) clusters



Coma Cluster. Radio contours overlaid on X-ray.
Brown & Rudnick, 2011, MNRAS, 412, 2.

Most clusters: no diffuse radio emission!
Use radio UL to constrain annihilation cross section.

Radio to Dark Matter

Diffuse radio is due to synchrotron radiation
$\rightarrow$ Cosmic ray electrons/positrons + μG-scale magnetic fields present

Dark matter annihilation products include electrons/positrons

$\Rightarrow$ Calculate UL on $\langle \sigma v \rangle$ required for DM annihilation to produce observed radio emission/UL

Inputs into Model

- Cluster Mass *(observable)*
  - larger mass $\rightarrow$ smaller $\langle \sigma v \rangle$
- Radio Flux, Detection or UL *(observable)*
  - smaller $S_\nu \rightarrow$ smaller $\langle \sigma v \rangle$
- Magnetic Field Value *(inferable from observations)*
  - larger B $\rightarrow$ smaller $\langle \sigma v \rangle$
- Substructure Model *(literature)*
  - more substructructre $\rightarrow$ smaller $\langle \sigma v \rangle$
- Dark Matter Mass, Final State *(free parameters)*

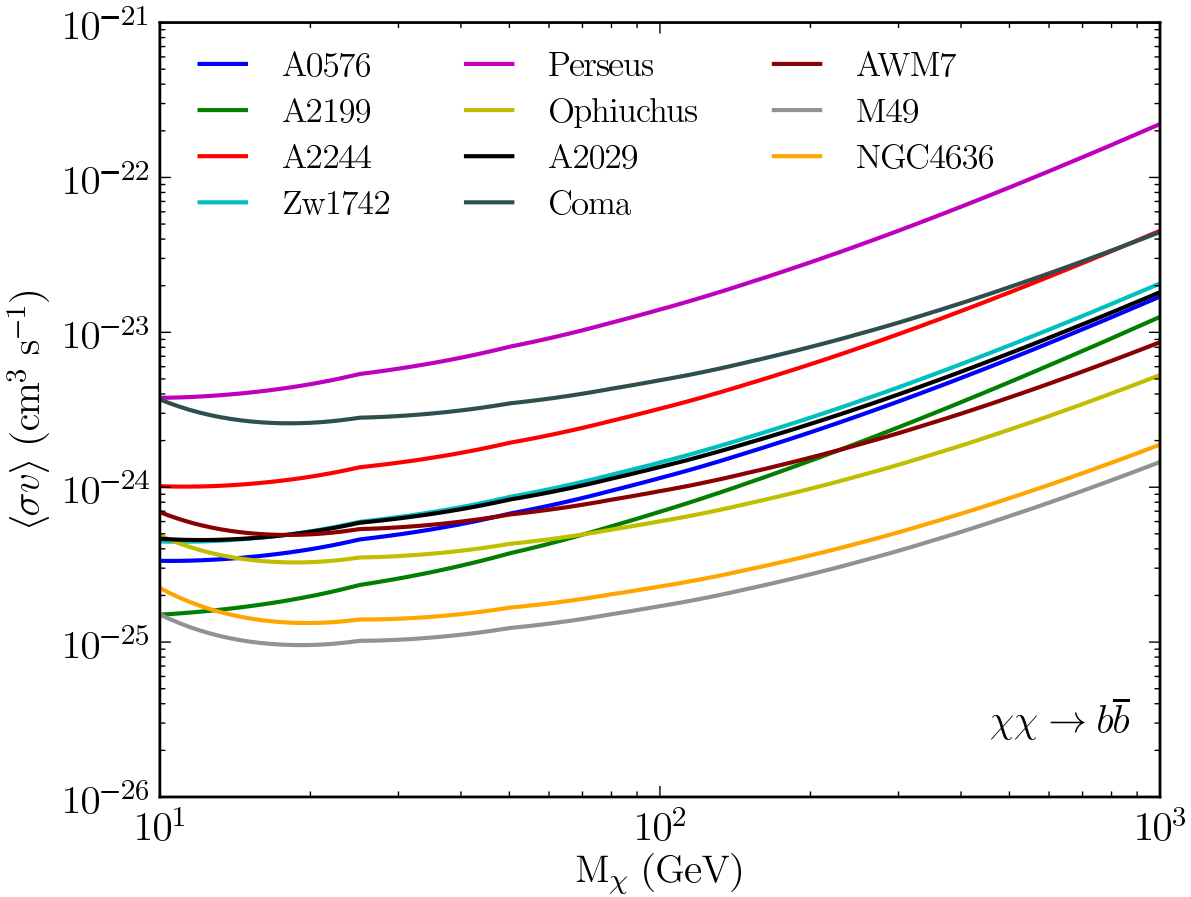
Cluster Sample

Name	ν (MHz)		B_0 (μG)
A0576	327	UL	...
A2199	327	UL	11.7
A2244	327	UL	...
Zw1742	327	UL	...
Perseus	1400	D (MH)	25
Ophiuchus	1400	D (MH)	...
A2029	1400	D (MH)	16.0
Coma	1400	D (H)	4.7
AWM7	1400	UL	...
M49	1400	D	...
NGC4636	1400	D	...

UL = Upper Limit, D = Detected Diffuse Emission, MH = Mini Halo, H = Halo

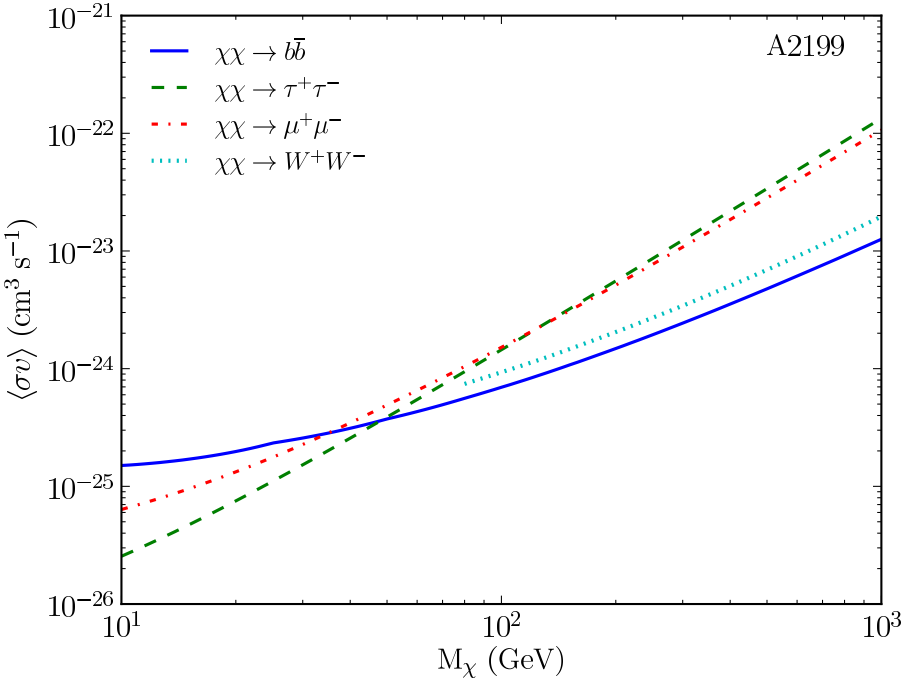
(See Storm, et al, 2013, ApJ, 768, 106 for references.)

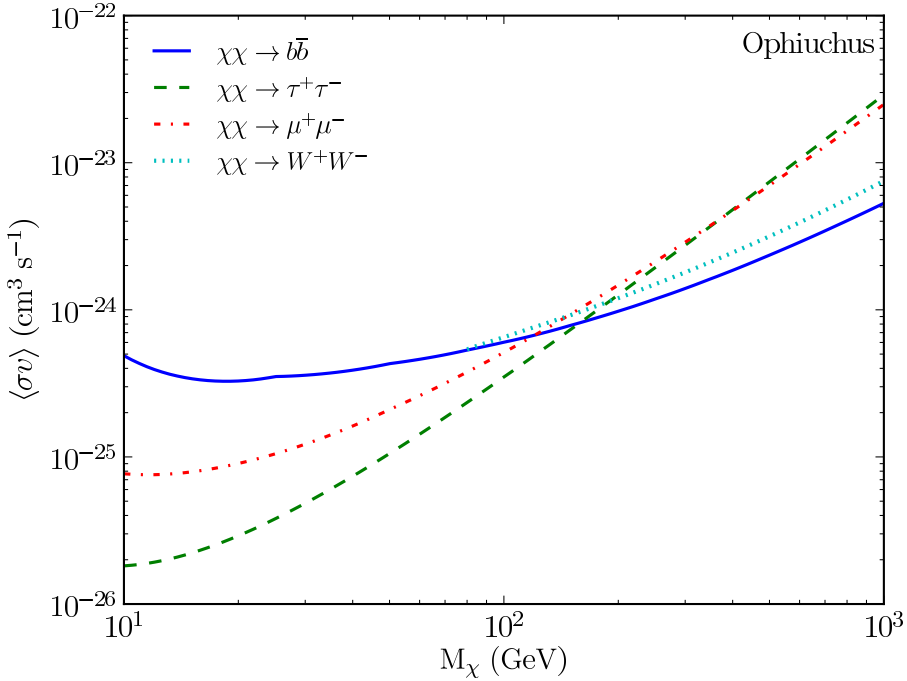
Results for Full Cluster Sample



NFW dark matter profile. Radio emission measured at different frequencies.
Storm, E., Jeltema, T. E., Profumo, S., & Rudnick, L., 2013, ApJ, 768, 106

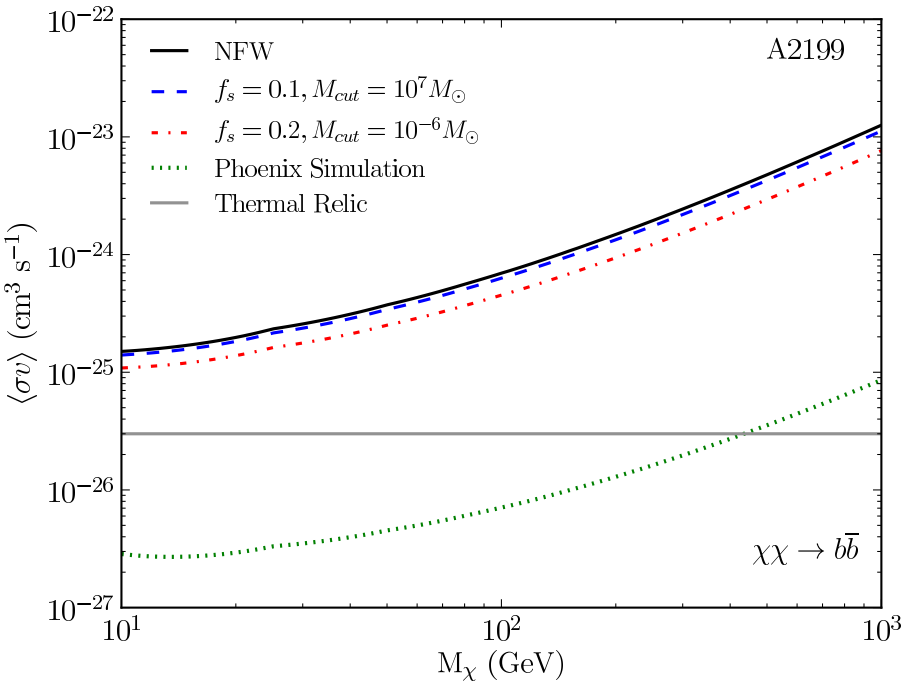
Effects of Annihilation Channel

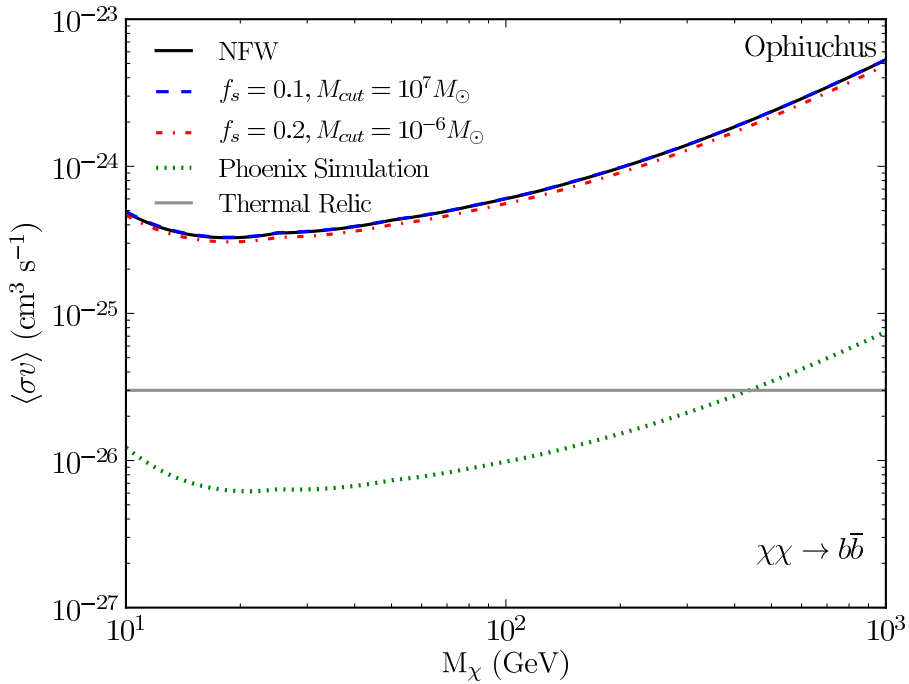




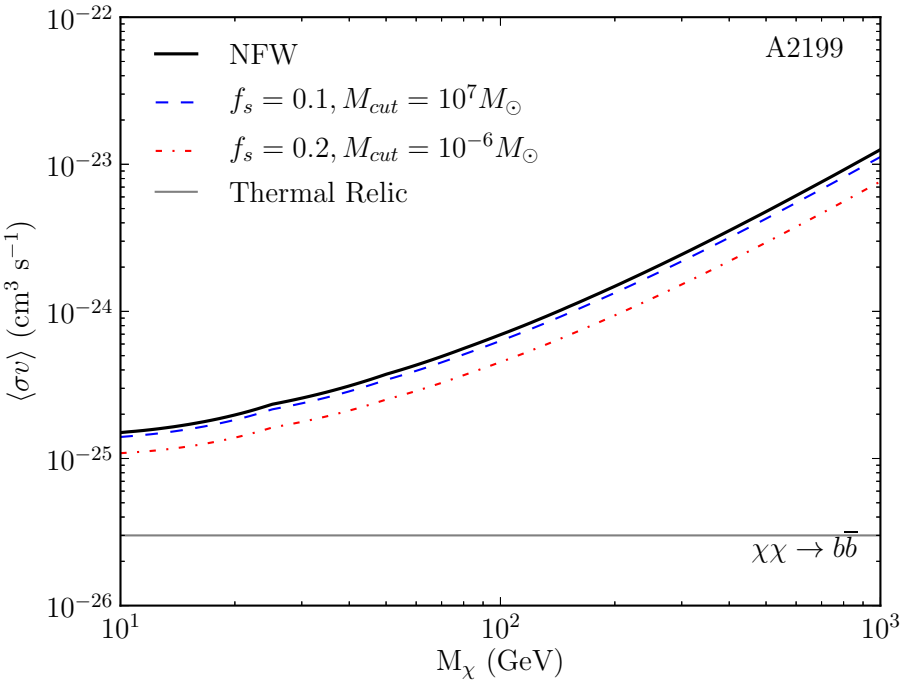
NFW dark matter profile.

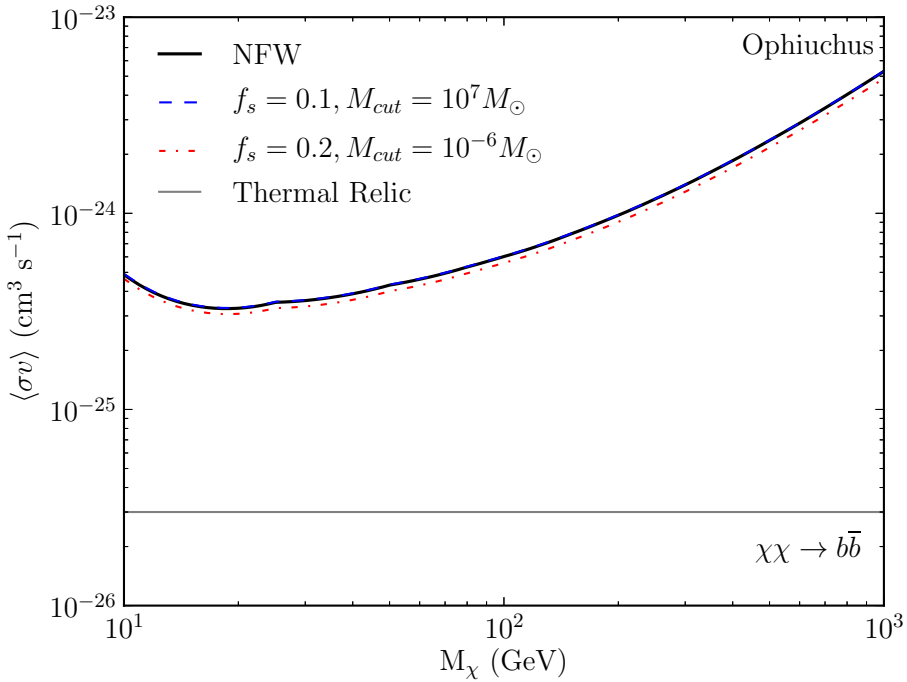
Effects of Substructure



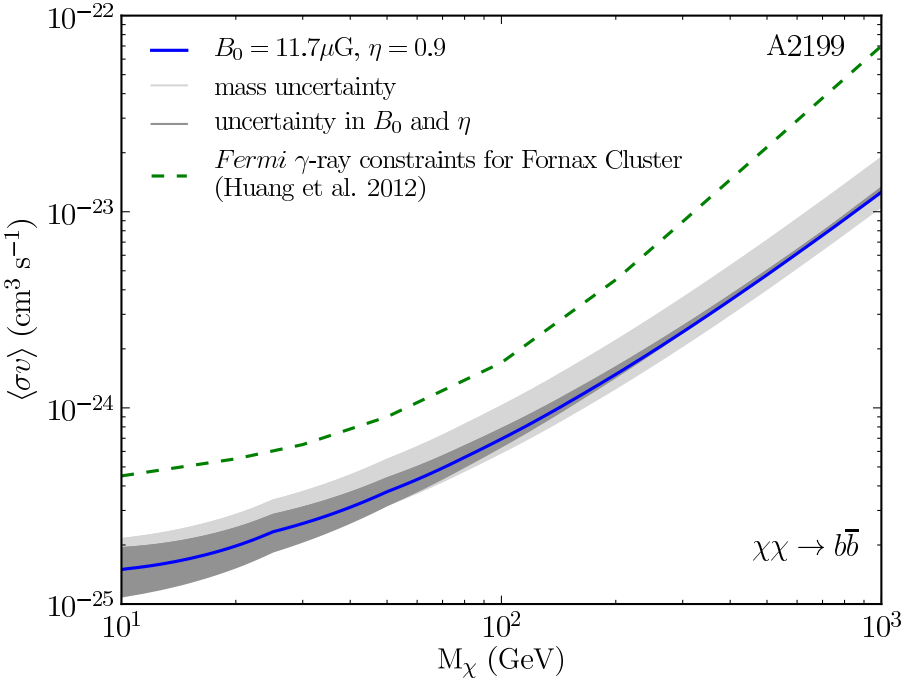


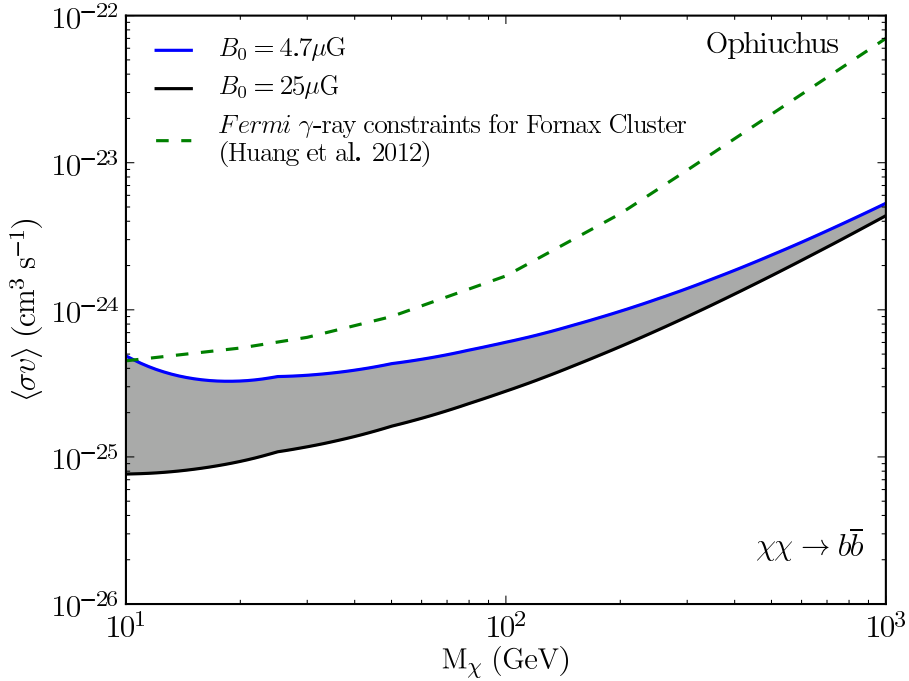
Effects of Substructure





Uncertainties, Comparison to Limits from Gamma Rays





NFW dark matter profile.

Constraints on Dark Matter Annihilation in Clusters from Radio

- Diffuse radio emission $\Rightarrow$ cosmic rays, magnetic fields
- Radio can be used to probe dark matter annihilation
- Constraints on $\langle \sigma v \rangle$ from radio are comparable to or better than limits from gamma rays
- Different samples of clusters are better for radio analysis vs gamma ray analysis
- Primary uncertainty: magnetic fields