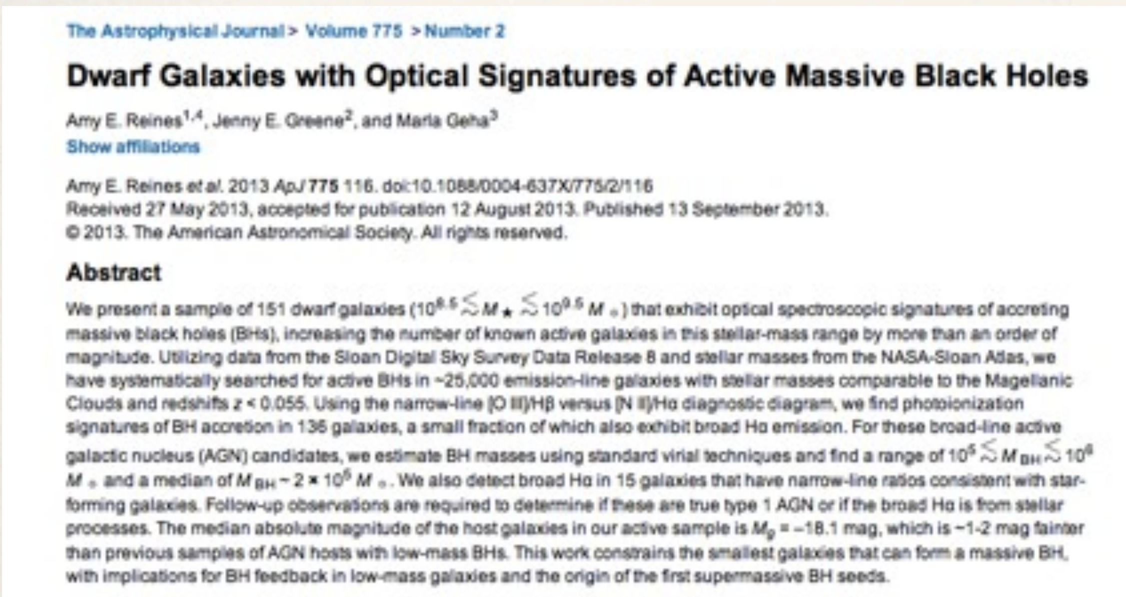
The effect of IMBH in Local dSphs on Gamma-Ray Constraints on Dark Matter Annihilation

Alma Gonzalez
SCIPP

with Stefano Profumo and Farinaldo Querioz

Why would we think dSphs host IMBHs?



The Astrophysical Journal > Volume 775 > Number 2

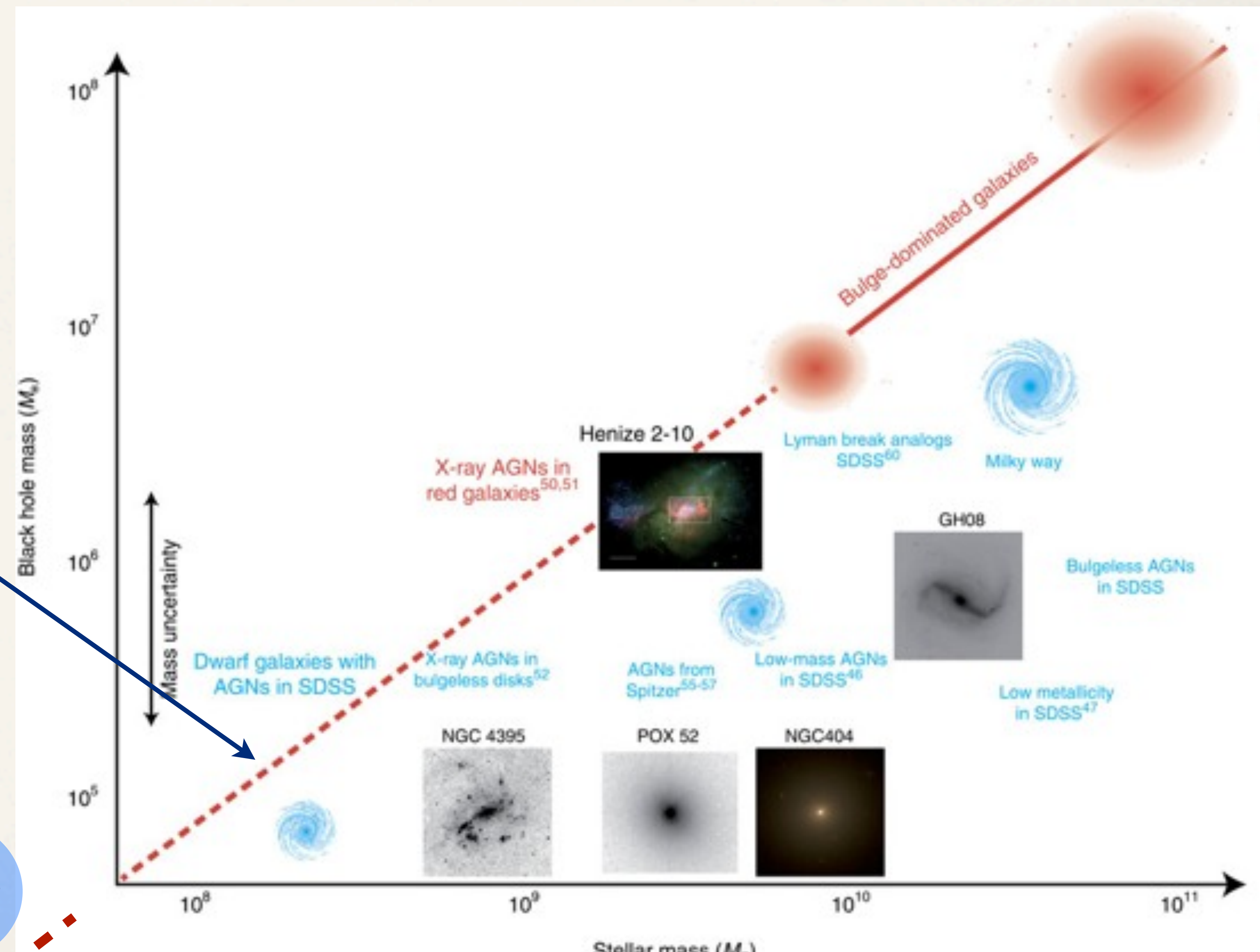
Dwarf Galaxies with Optical Signatures of Active Massive Black Holes

Amy E. Reines[1,4], Jenny E. Greene[2], and Maria Geha[3]
Show affiliations

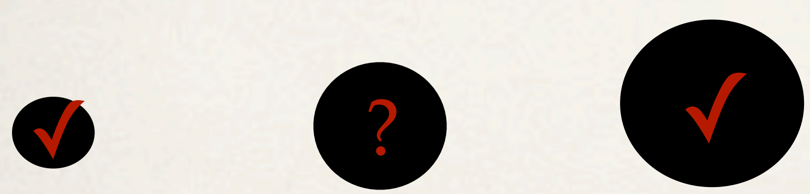
Amy E. Reines *et al.* 2013 *ApJ* **775** 116. doi:10.1088/0004-637X/775/2/116
Received 27 May 2013, accepted for publication 12 August 2013. Published 13 September 2013.

Abstract

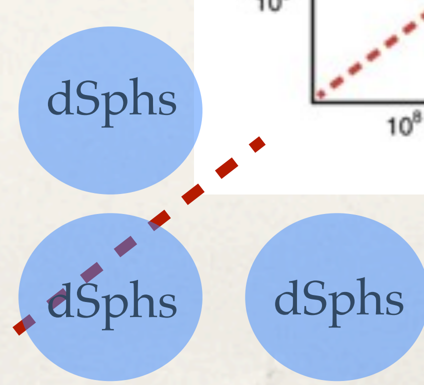
We present a sample of 151 dwarf galaxies ($10^{8.5} \lesssim M_\star \lesssim 10^{9.5}\,M_\odot$) that exhibit optical spectroscopic signatures of accreting massive black holes (BHs), increasing the number of known active galaxies in this stellar-mass range by more than an order of magnitude. Utilizing data from the Sloan Digital Sky Survey Data Release 8 and stellar masses from the NASA-Sloan Atlas, we have systematically searched for active BHs in ~25,000 emission-line galaxies with stellar masses comparable to the Magellanic Clouds and redshifts $z < 0.055$. Using the narrow-line [O III]/Hβ versus [N II]/Hα diagnostic diagram, we find photoionization signatures of BH accretion in 136 galaxies, a small fraction of which also exhibit broad Hα emission. For these broad-line active galactic nucleus (AGN) candidates, we estimate BH masses using standard virial techniques and find a range of $10^5 \lesssim M_{BH} \lesssim 10^6\,M_\odot$ and a median of $M_{BH} \sim 2 \times 10^5\,M_\odot$. We also detect broad Hα in 15 galaxies that have narrow-line ratios consistent with star-forming galaxies. Follow-up observations are required to determine if these are true type 1 AGN or if the broad Hα is from stellar processes. The median absolute magnitude of the host galaxies in our active sample is $M_g = -18.1$ mag, which is ~1-2 mag fainter than previous samples of AGN hosts with low-mass BHs. This work constrains the smallest galaxies that can form a massive BH, with implications for BH feedback in low-mass galaxies and the origin of the first supermassive BH seeds.



Jenny E. Greene
Nature Communications 2012



stellar BH	IMBH	SMBH
$< 80 M_\odot$	$10^2 - 10^5 M_\odot$	$\gtrsim 10^6 M_\odot$



Hints of IMBH in dSphs?

ACCEPTED TO ApJ: 29 NOVEMBER 2011
Preprint typeset using LaTeX style emulateapj v. 5/2/11

THE DARK MATTER DENSITY PROFILE OF THE FORNAX DWARF

JOHN R. JARDEL AND KARL GEBHARDT
Department of Astronomy, University of Texas at Austin, 1 University Station C1400, Austin, TX 78712;
jardel;gebhardt@astro.as.utexas.edu
ACCEPTED TO ApJ: 29 November 2011

ABSTRACT

We construct axisymmetric Schwarzschild models to measure the mass profile of the local group dwarf galaxy Fornax. These models require no assumptions to be made about the orbital anisotropy of the stars, as is the case for commonly used Jeans models. We test a variety of parameterizations of dark matter density profiles and find cored models with uniform density $\rho_c = (1.6 \pm 0.1) \times 10^{-2} M_\odot$ pc^{-3} fit significantly better than the cuspy halos predicted by cold dark matter simulations. We also construct models with an intermediate-mass black hole, but are unable to make a detection. We place a 1-σ upper limit on the mass of a potential intermediate-mass black hole at $M_\bullet \leq 3.2 \times 10^4 M_\odot$.
Subject headings: dark matter—galaxies: dwarf—galaxies: individual (Fornax)—galaxies: kinematics and dynamics—Local Group

THE ASTROPHYSICAL JOURNAL, 699:L113–L117, 2009 July 10 doi:10.1088/0004-637X/699/2/L113

AN UPPER LIMIT ON THE MASS OF THE BLACK HOLE IN URSA MINOR DWARF GALAXY

V. LORA[1], F. J. SÁNCHEZ-SALCEDO[1], A. C. RAGA[2], AND A. ESQUIVEL[2]
[1] Instituto de Astronomía, Universidad Nacional Autónoma de México, Ciudad Universitaria, Ap. 70-468, C.P. 04510 Mexico City, Mexico; vlora@astroscu.unam.mx, jsanchez@astroscu.unam.mx
[2] Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Ciudad Universitaria, Ap. 70-543, C.P. 04510 Mexico City, Mexico; raga@nucleares.unam.mx, esquivel@nucleares.unam.mx
Received 2009 March 4; accepted 2009 May 16; published 2009 June 22

ABSTRACT

The well-established correlations between the mass of massive black holes (BHs) in the nuclei of most studied galaxies and various global properties of their hosting galaxy lend support to the idea that dwarf galaxies and globular clusters could also host a BH in their centers. Direct kinematic detection of BHs in dwarf spheroidal (dSph) galaxies is seriously hindered by the small number of stars inside the gravitational influence region of the BH. The aim of this Letter is to establish an upper dynamical limit on the mass of the putative BH in the Ursa Minor (UMi) dSph galaxy. We present direct *N*-body simulations of the tidal disruption of the dynamical fossil observed in UMi, with and without a massive BH. We find that the observed substructure is incompatible with the presence of a massive BH of $(2–3) \times 10^4$ $M_\odot$ within the core of UMi. These limits are consistent with the extrapolation of the M_{BH}–σ relation to the $M_{BH} < 10^6$ $M_\odot$ regime. We also show that the BH may be off-center with respect to the center of symmetry of the whole galaxy.

Mem. S.A.It. Vol. 84, 645

Memorie della

The high energy search for IMBHs in close dSph Milky Way satellites

A&A 550, A18 (2013)
DOI: 10.1051/0004-6361/201220152

Astronomy & Astrophysics

An *XMM-Newton* search for X-ray sources in the Fornax dwarf galaxy

A. A. Nucita[1,2], L. Manni[1,2], F. De Paolis[1,2], D. Vetrugno[1,2], and G. Ingrosso[1,2]
[1] Dipartimento di Matematica e Fisica "Ennio De Giorgi", Università del Salento, CP 193, 73100 Lecce, Italy
e-mail: nucita@le.infn.it

Hint for a faint intermediate mass black hole in the Ursa Minor dwarf galaxy

A.A. Nucita, F. De Paolis, L. Manni, G. Ingrosso

Abstract

We report the results of the analysis of an archive *Chandra* observation of the Ursa Minor spheroidal galaxy, one of the closest Milky Way satellites, searching for signatures from the intermediate mass black hole possibly hosted in the center of the galaxy. We identified an X-ray source with a detection confidence as low as $\simeq 2.5\sigma$ and with an estimated unabsorbed flux in the 0.5–7 keV band of $\simeq 4.9 \times 10^{-15}$ erg s^{-1} cm^{-2} and at a few arcseconds from the reported center of the galaxy. The source is spatially coincident with a radio object (having flux density of $\simeq 7.1$ mJy at 1.4 GHz) already observed in the NRAO VLA Sky Survey. In the accreting black hole scenario, depending on the used fundamental plane relation, one estimates an accretor mass of $(2.9^{+33.6}_{-2.7}) \times 10^6$ M$_\odot$ or $(11.7^{+57.1}_{-9.7}) \times 10^6$ M$_\odot$. Relaxing the assumption for a flat radio spectrum, the minimum black hole mass would result in the range 5×10^4 M$_\odot$ $- 5 \times 10^5$ M$_\odot$, i.e. still consistent with an intermediate mass black hole scenario. The compact object seems to radiate at a very tiny fraction of the associated Eddington luminosity.

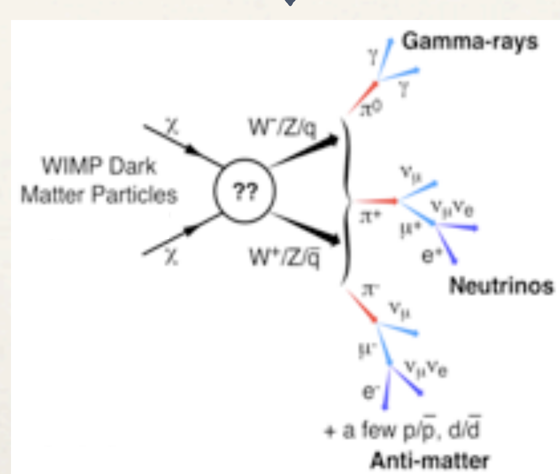
Gamma Rays from DM annihilation

Gamma-Ray Flux

Particle Physics

Astrophysics

$$\phi(\Delta\Omega) = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_\chi}\left(\int_{E_{\rm min}}^{E_{\rm max}}\frac{dN_\gamma}{dE_\gamma}dE_\gamma\right) J_{\Delta\Omega}$$



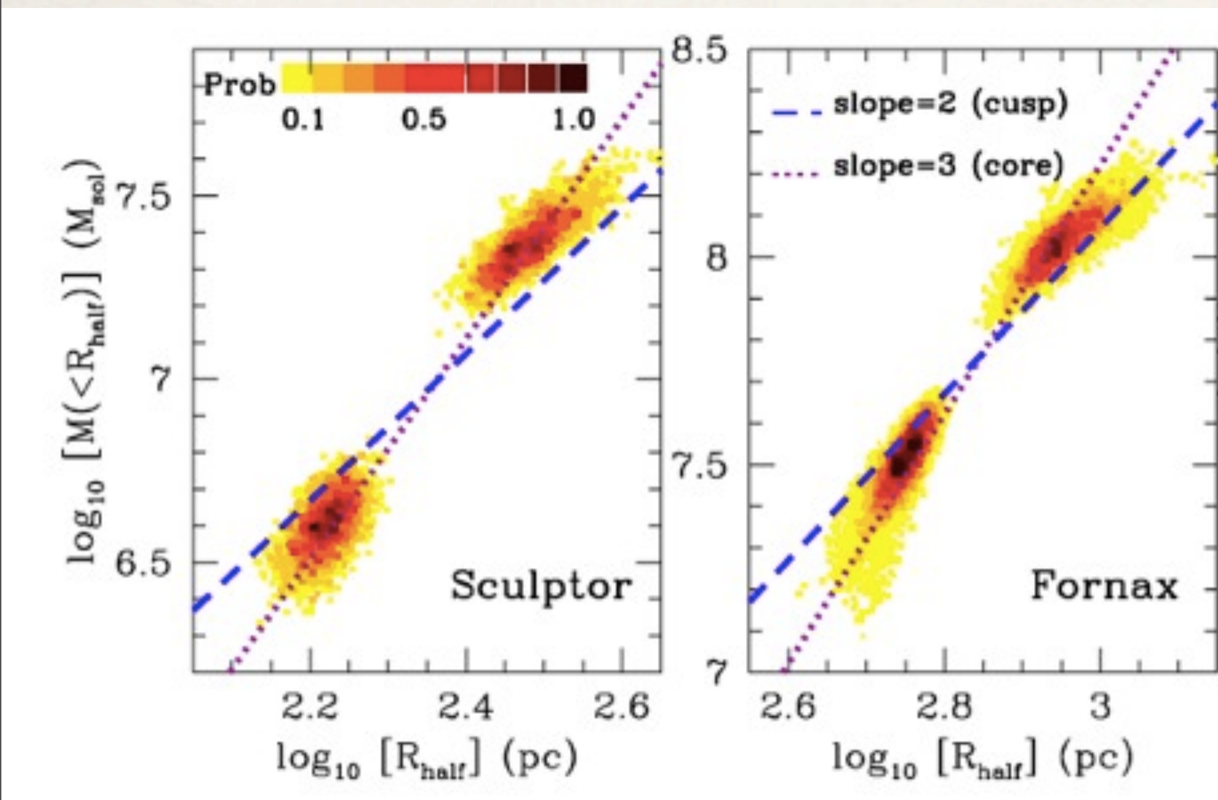
With black hole :

$$J_{\Delta\Omega} = \int_{\Delta\Omega}\int_{los}\rho^2\, dl d\Omega.$$

$$J_{\Delta\Omega} = \int_{\Delta\Omega}\int_{los}\rho^2(r(l,\theta),\langle\sigma v\rangle,m_\chi)\, dl d\Omega$$

Dark Matter Distribution

The DM density profile of dSphs



Walker & Peñarrubia 2011

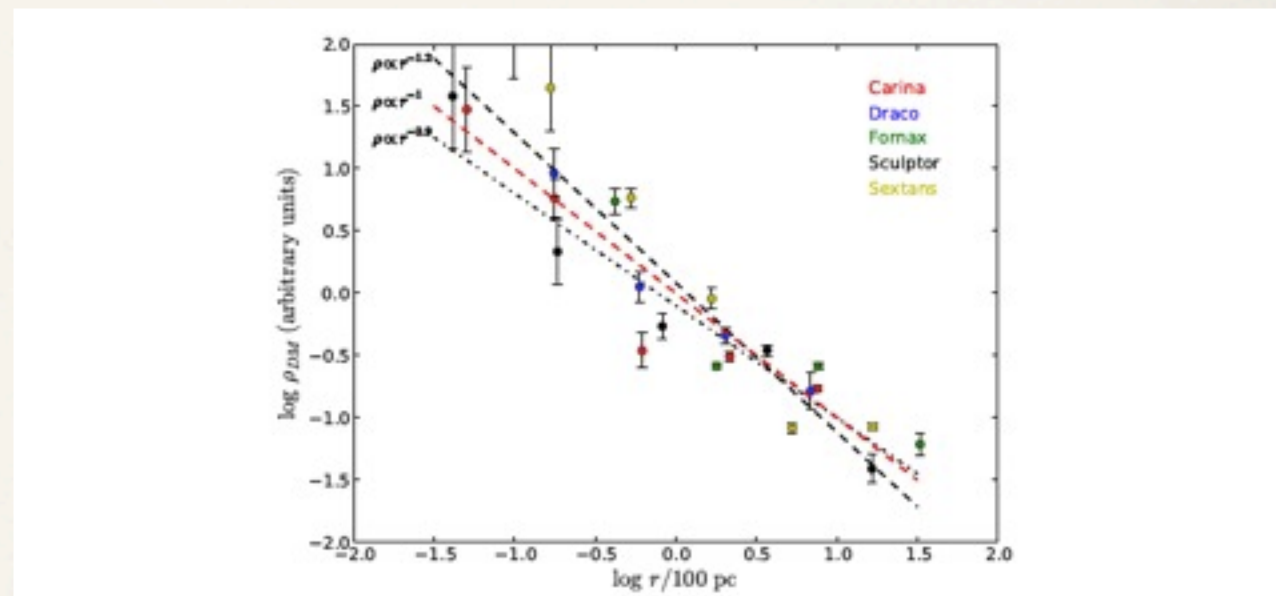
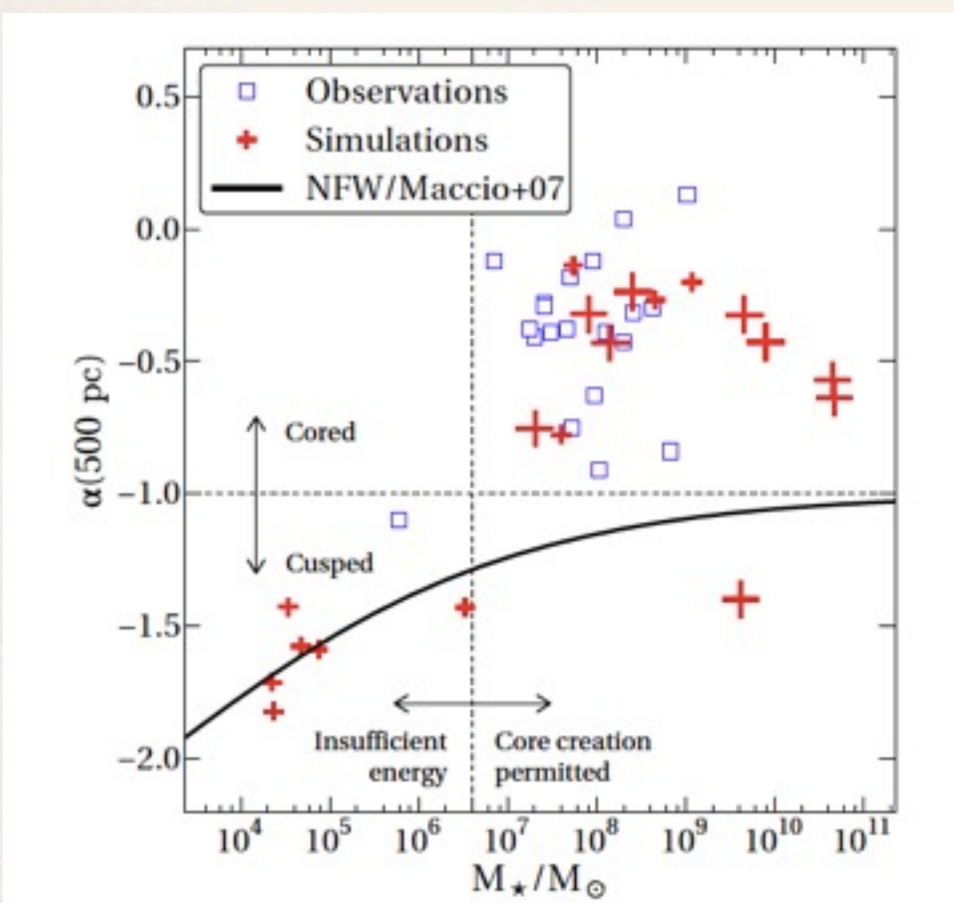


FIG. 2.— Combined dark matter density profiles of all the dSphs plotted on the same axes. Each galaxy's profile is plotted with the same colored points. Uncertainties on these points are the $\Delta\chi^2 = 1$ uncertainties from Figure 1. We plot the derived best-fit line with slope $\alpha = 1.2 \pm 0.5$ as a dashed line as well as the NFW profile with $\alpha = 1.0$ as a red dashed line. A fit excluding the points where we have no kinematics available is shown as a dotted line. The individual profiles have been scaled to a common height.

Jardel & Gebhardt 2013



Pontzen & Governato 2013

For the Fermi analysis

NFW

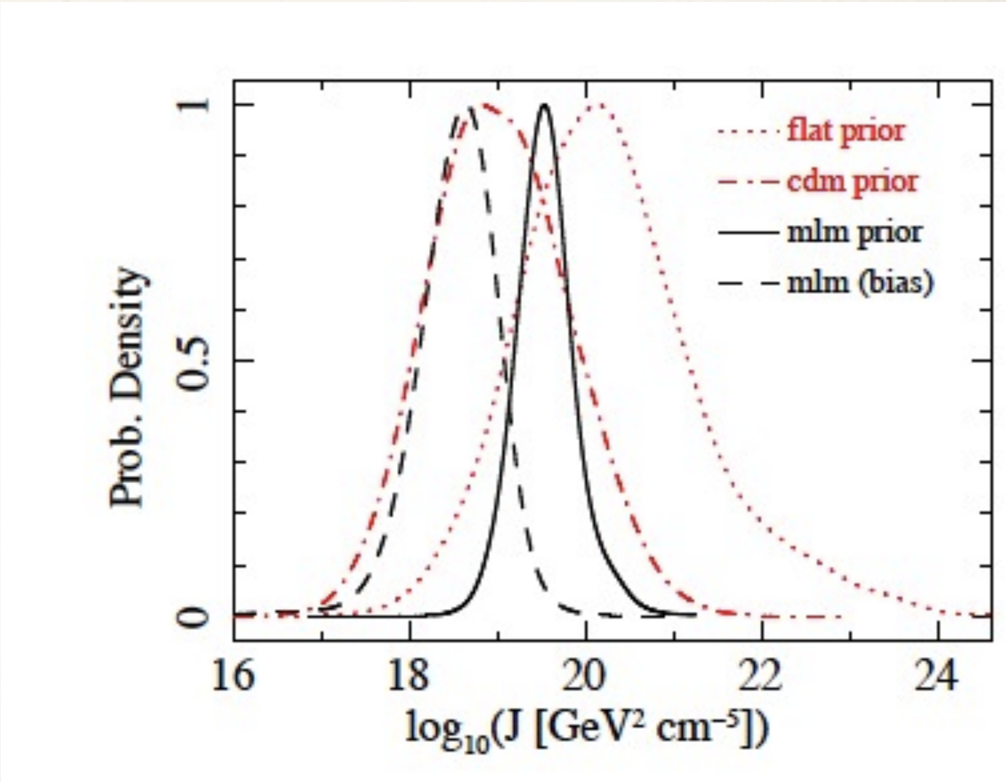
$$\rho = \frac{\rho_0}{\frac{r}{r_s}\left(1+\frac{r}{r_s}\right)^2}$$

Burkert

$$\rho = \frac{\rho_0}{\left(1+\frac{r}{r_s}\right)\left(1+\frac{r^2}{r_s^2}\right)}$$

Consistent with the velocity dispersion of each galaxy.

Used a bayesian multilevel model to minimize the effect of the priors and uncertainties in the determination of the J-factor.

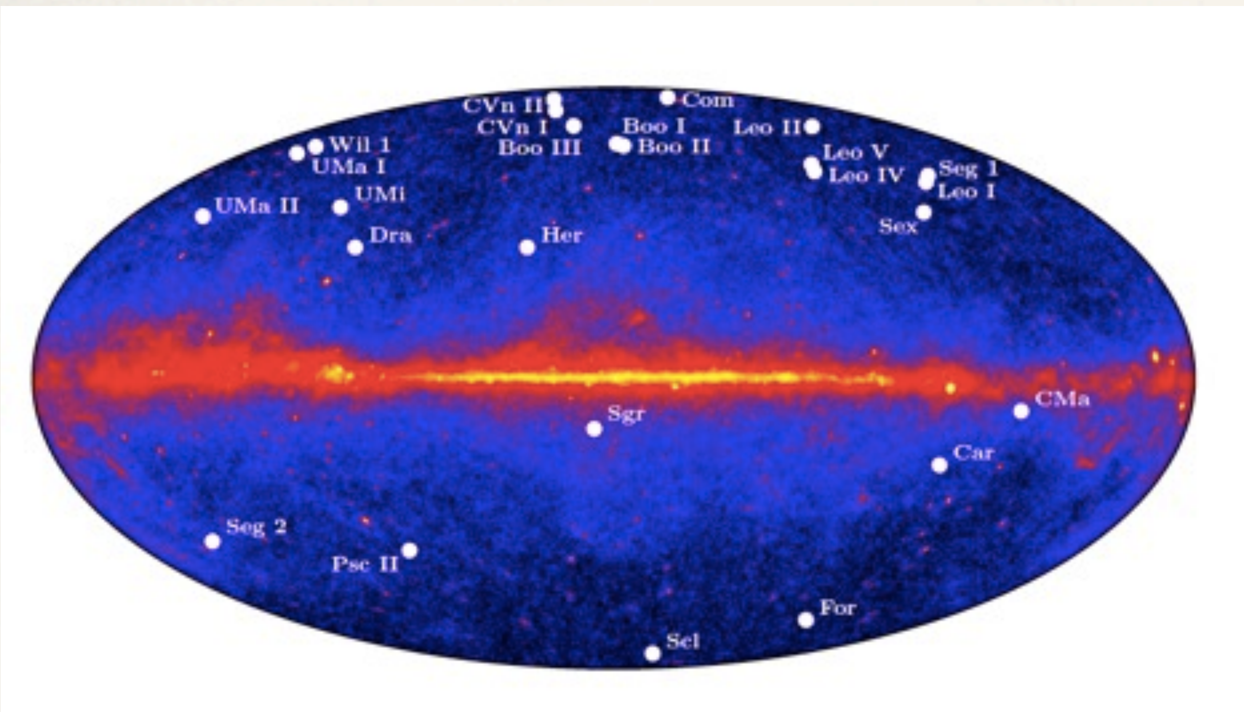


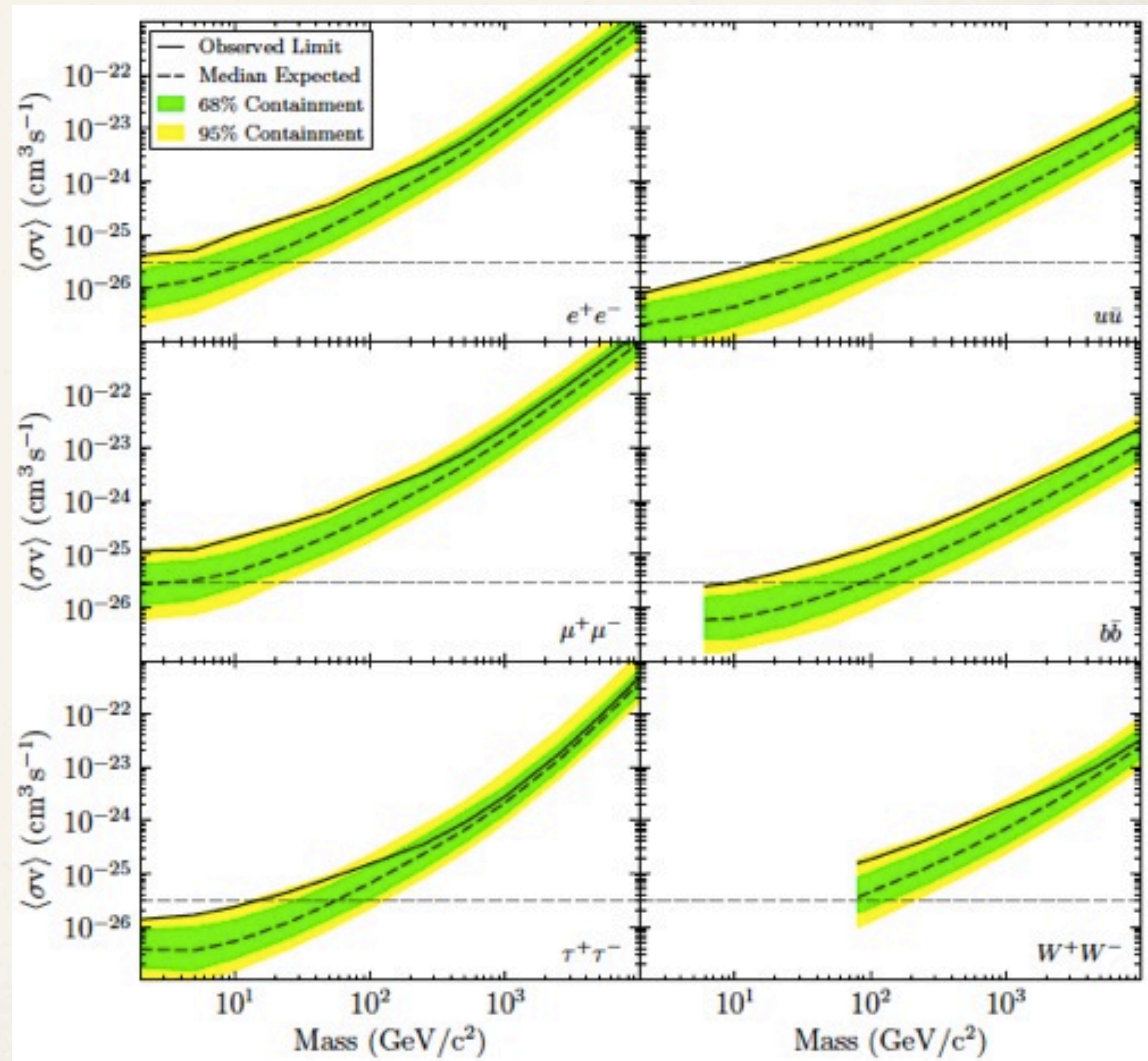
Gregory D. Martinez 2013

DM constraints from observations of 25 Milky Way Satellite Galaxies with FERMI LAT

No signal

DM constraints





$$\phi(\Delta\Omega) = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_\chi}\left(\int_{E_{\min}}^{E_{\max}}\frac{dN_\gamma}{dE_\gamma}dE_\gamma\right) \quad J_{\Delta\Omega}$$

Common to all dSphs

FERMI accounted for uncertainties in density profile as long as the inner profile scales as:

$\rho \propto r^{-\gamma}$ with $\gamma < 1.2$

Ackerman et. al. 2014

The Effect of the Black Holes....

The adiabatic grow of the IMBH would lead to the formation of a DM spike due to adiabatic contraction

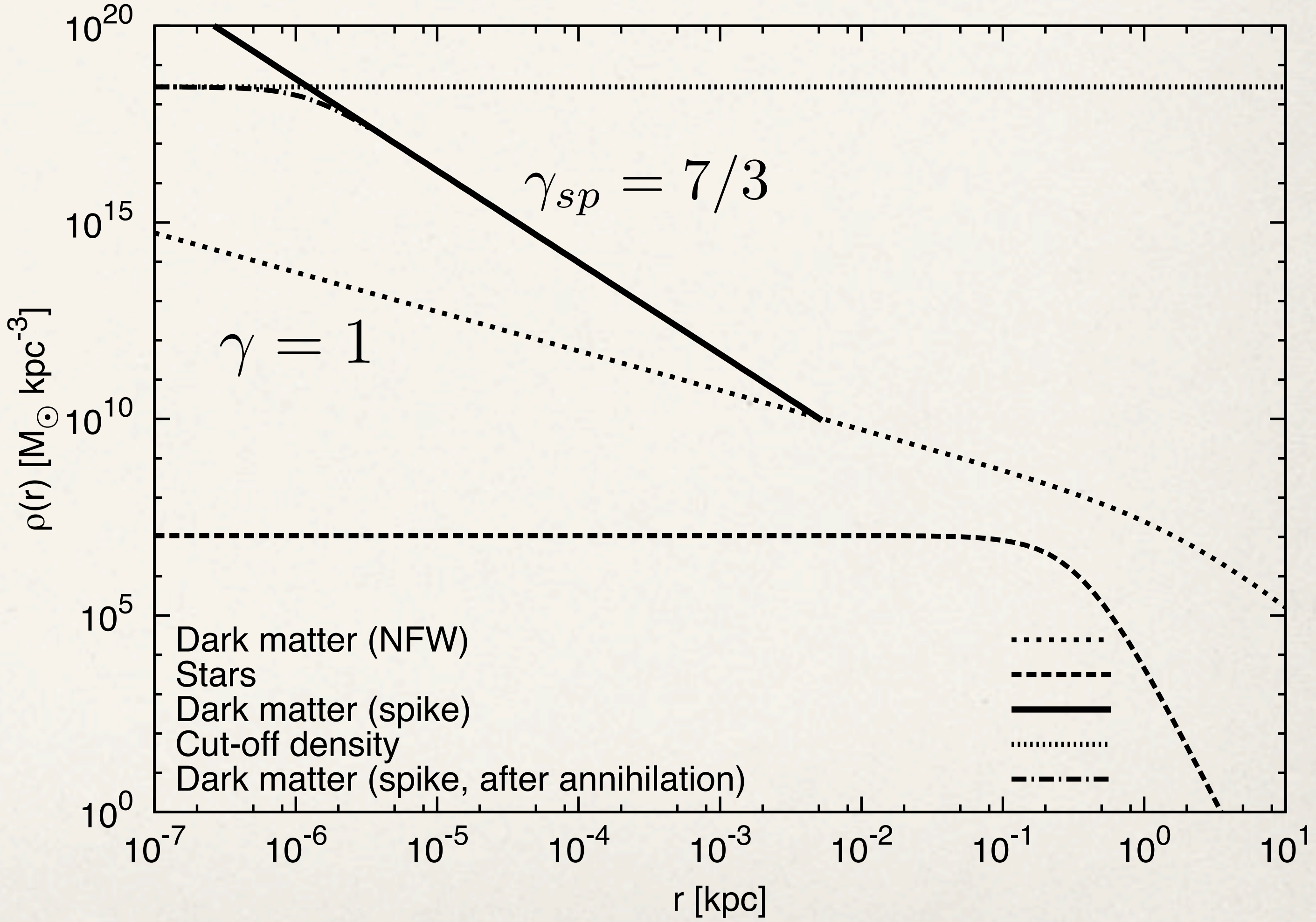
Quinlan, Hernquist, & Sigurdsson 1995, Gondolo &Silk 1999, Ullio,Zhao &Kamionkowski 2001, Bertone, Zetner & Silk 2005.

The final slope is

$$\gamma_{sp} = \frac{9-2\gamma}{4-\gamma}$$

Many factor can smooth out the spike:

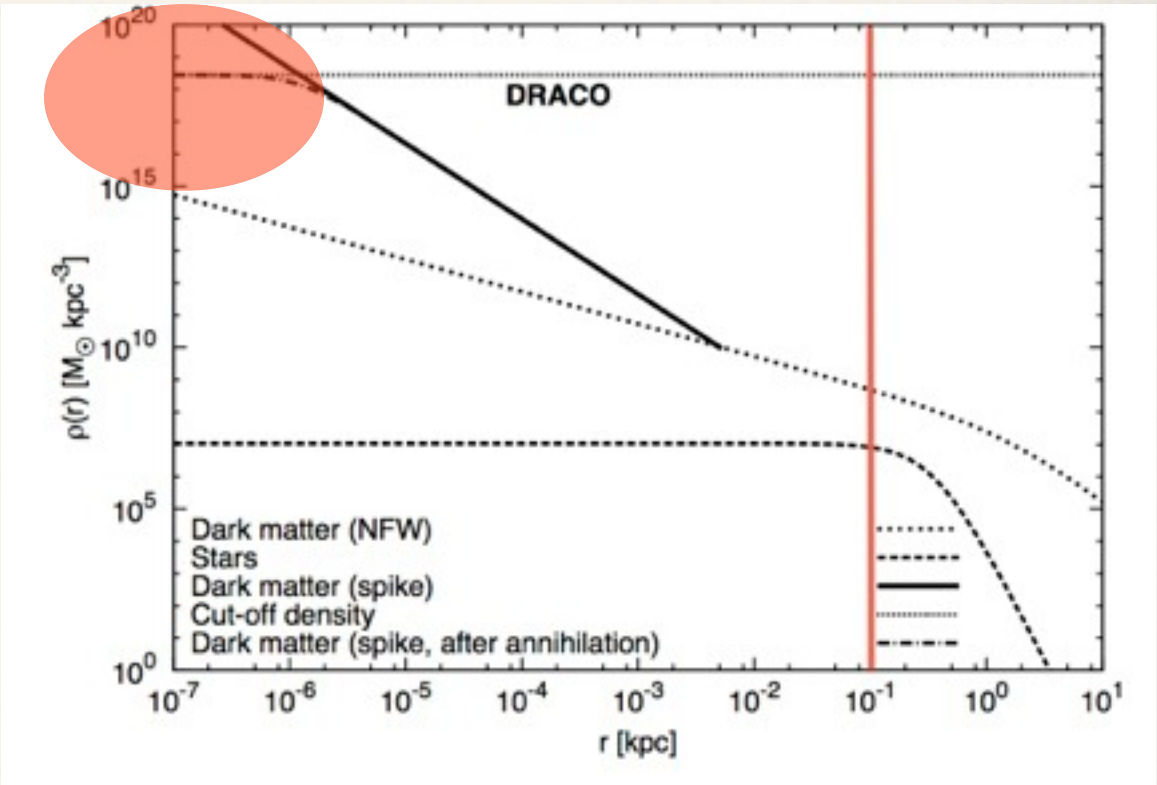
- Scatter off dark matter by stars: more important for the GC than for dSphs (Bertone,Zetner &Zilk 2005)
- Formation of the BH off-center
- Major mergers



Now the J-factor depends also on the particle physics...

$$\dot{n_\chi} = \langle\sigma v\rangle n_\chi^2 \qquad n_\chi = \frac{n_\chi}{1 + n_\chi \Delta t}$$

Annihilation Core



$$\rho_{\max} = 3 \times 10^{18} \left(\frac{m_\chi}{100\text{GeV}}\right) \left(\frac{10^{-26}\text{cm}^3\text{s}^{-1}}{\langle\sigma v\rangle}\right) M_\odot \text{kpc}^{-3}$$

$$J_{\Delta\Omega} = \int_{\Delta\Omega} \int_{los} \rho^2(r(l,\theta), \langle\sigma v\rangle, m_\chi)\, dl d\Omega$$

Constraints to DM annihilation

(1) Pick an initial halo model consistent with the observed velocity dispersion for each dSph. We use both initial density profiles choices (NFW and Burkert).

(2) Assign to each dwarf galaxy a black hole mass:

We bracket the dependence on the mass of the BH by the extrapolation of three of the widely known relations between the black hole mass and galaxy observables :

-Magorrian relation: $M_{bh} = 0.0013 L_*$

-Tremaine:

$$\frac{M_{\rm bh}}{M_\odot} = \begin{cases} 10^{6.91} \left(\frac{\sigma_*}{100\,{\rm km/s}} \right)^4 & (\sigma_* \geq 6\,{\rm kms}) \\ 100 & (\sigma_* < 6\,{\rm km/s}). \end{cases}$$

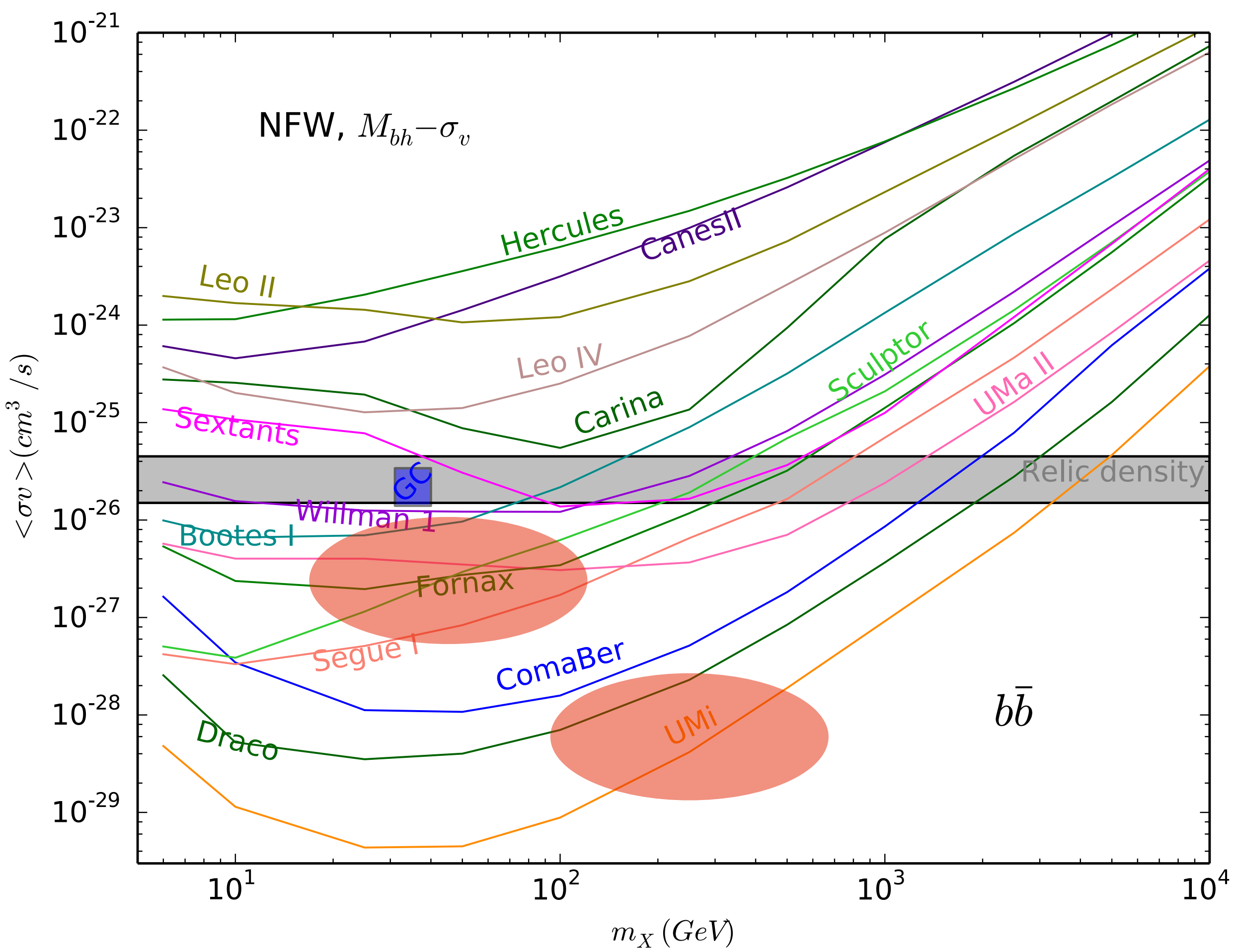
-McConell & Ma:

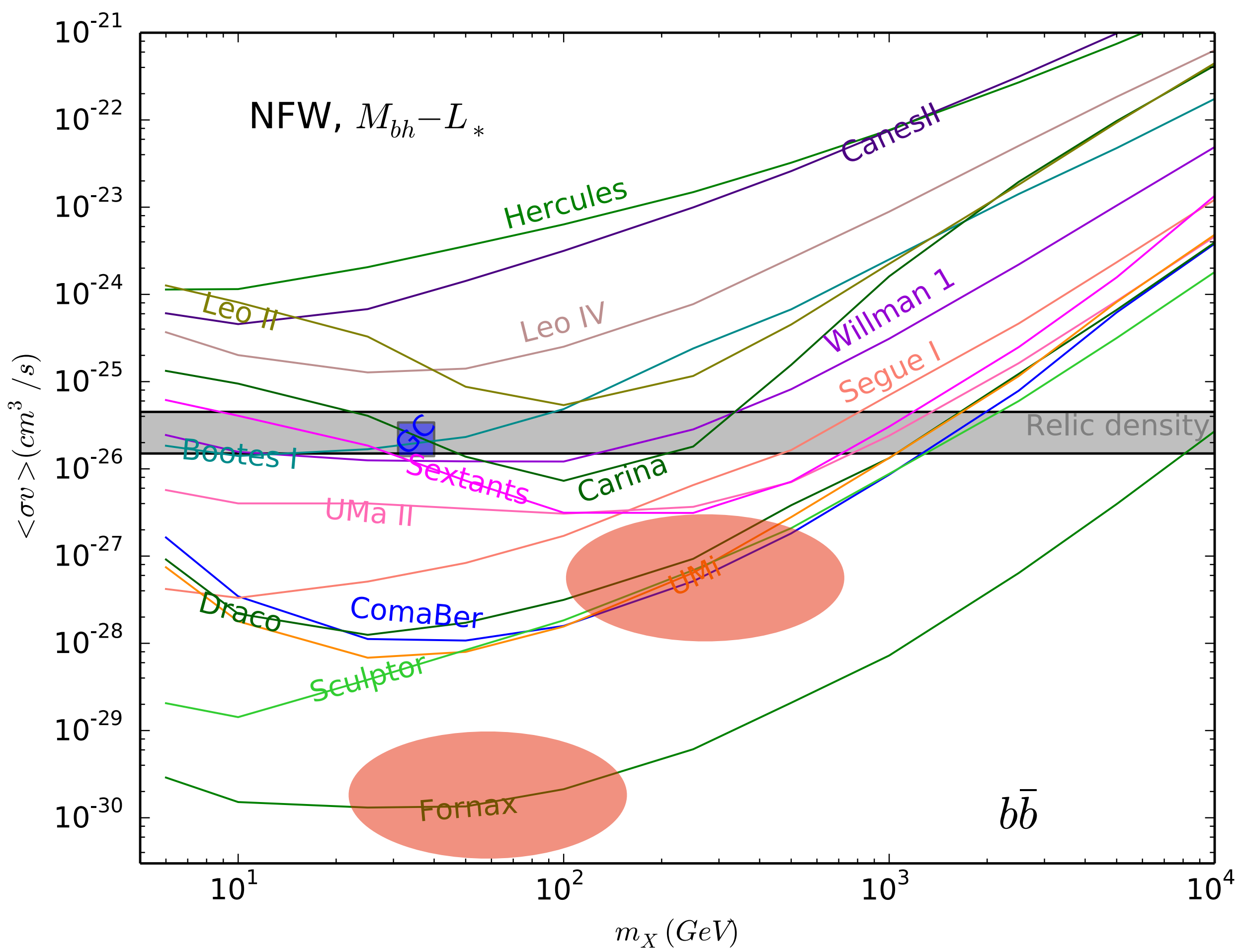
$$\frac{M_{\rm bh}}{M_\odot} = \begin{cases} 10^{8.32} \left(\frac{\sigma_*}{200\,{\rm kms}^{-1}} \right)^{5.64} & (\sigma_* \geq 15\,{\rm kms}) \\ 100 & (\sigma_* < 15\,{\rm km/s}). \end{cases}$$

Using FERMI previous constraints as a base

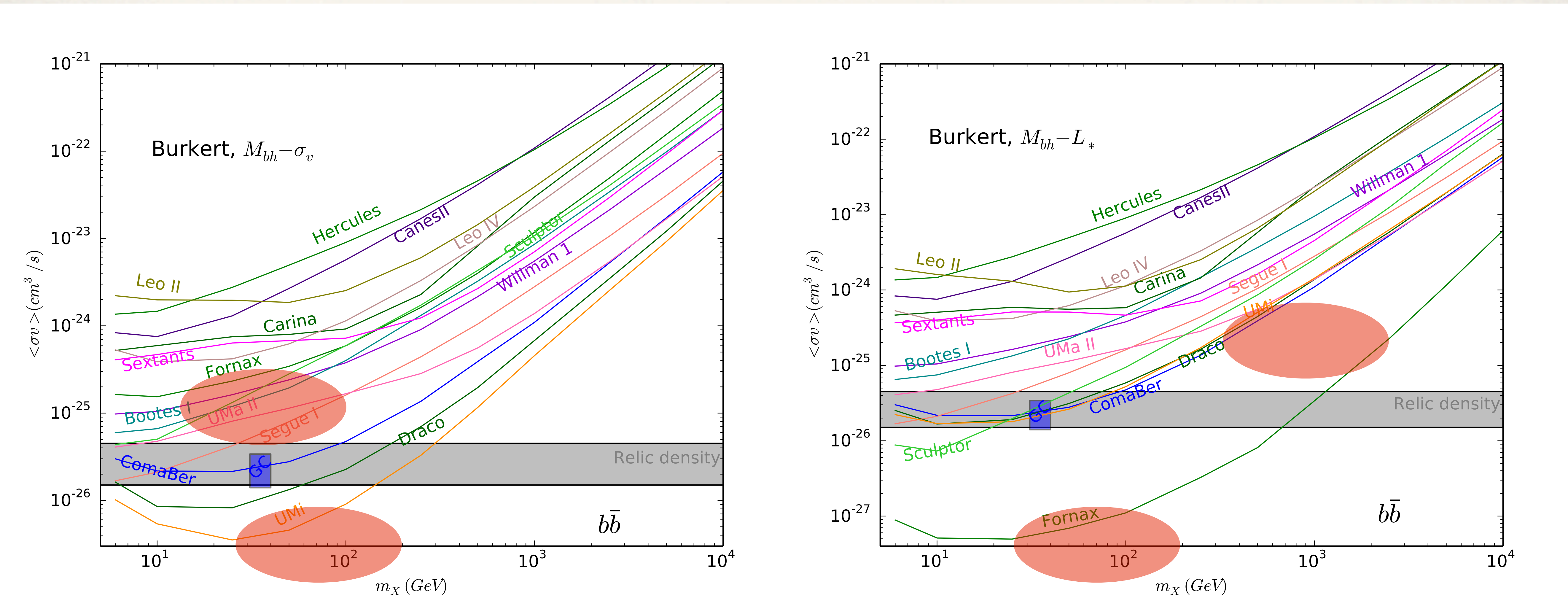
$$\langle\sigma v\rangle J = \langle\sigma v\rangle_{bh} J_{bh}\left(\langle\sigma v\rangle_{bh}, m_\chi\right) \quad \forall \quad m_\chi.$$

We solve for $\langle\sigma v\rangle_{bh}$



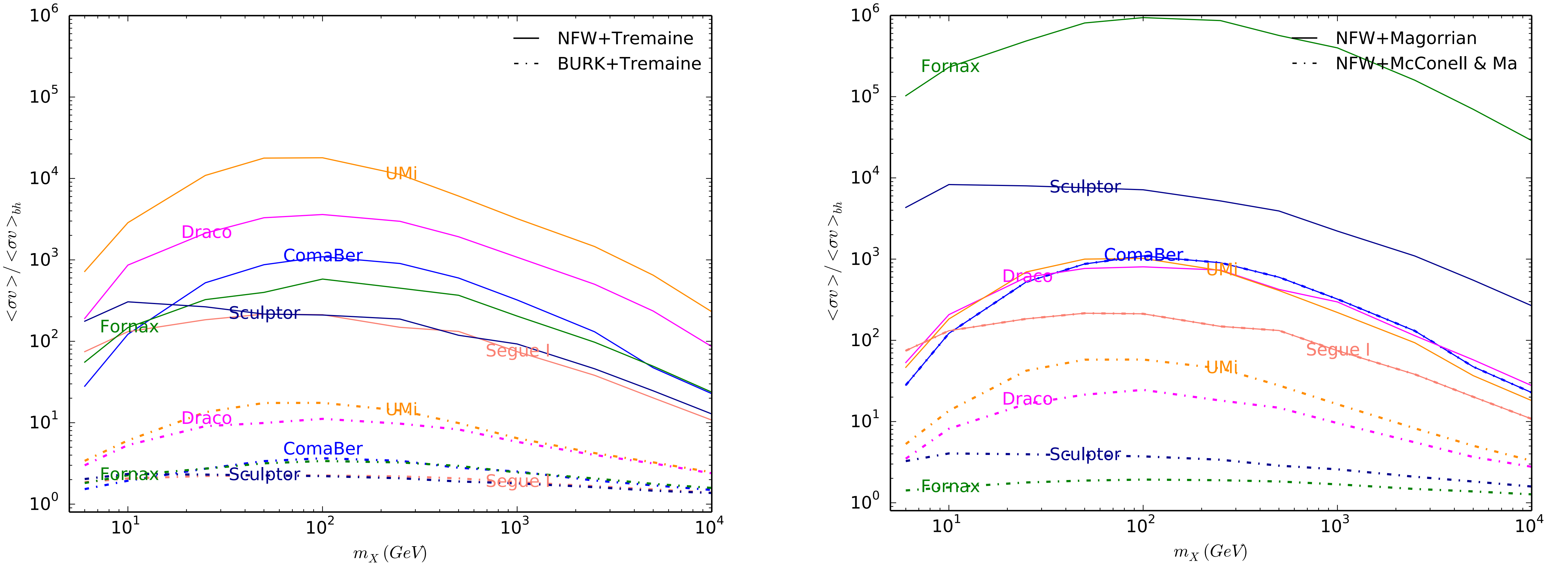


The same for Burkert profile…

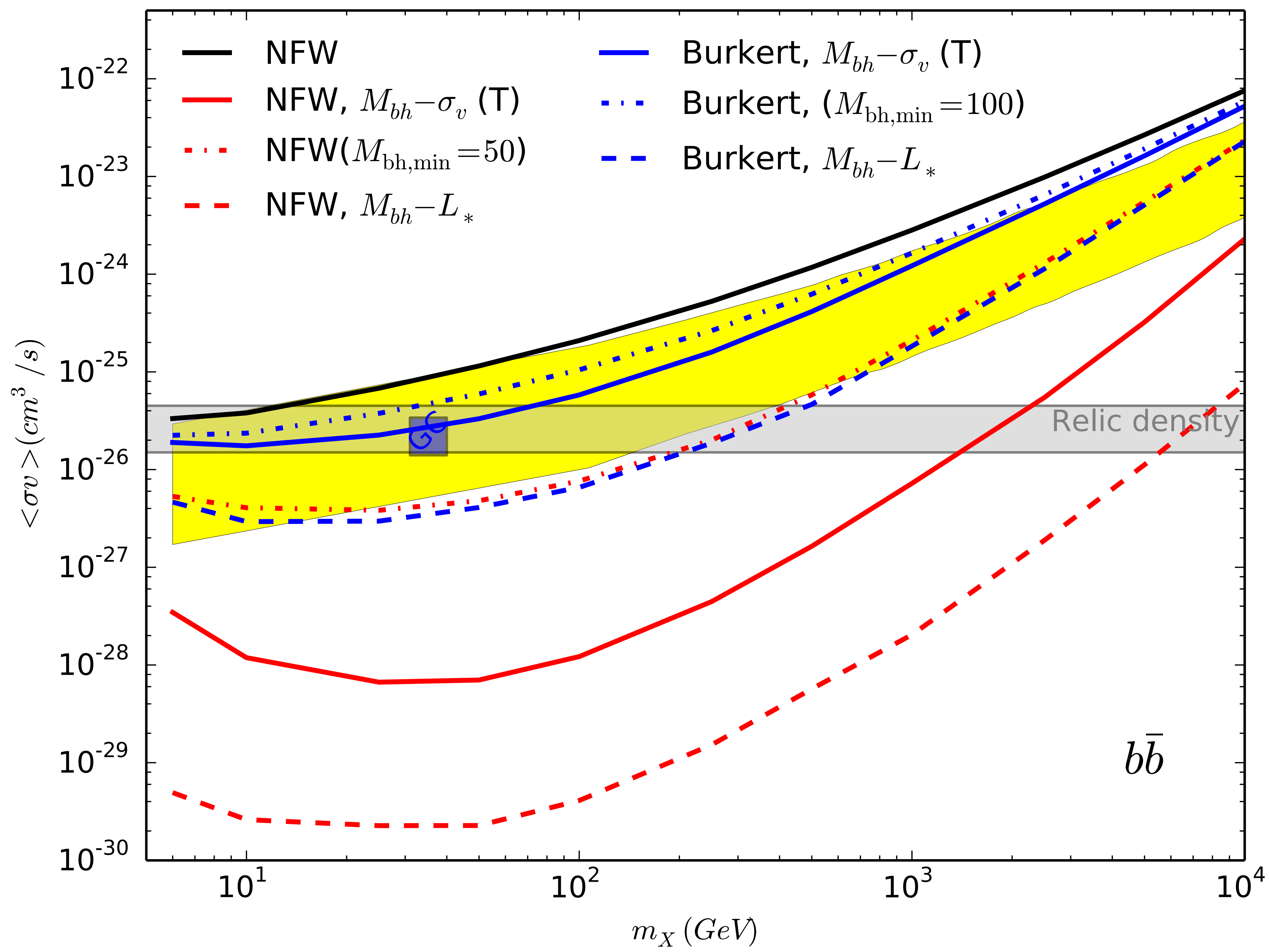


If Fornax an UMi do host IMBh they would put the strongest constraints to DM annihilation (Even if the spikes are mild)

Compared to FERMI original constraints

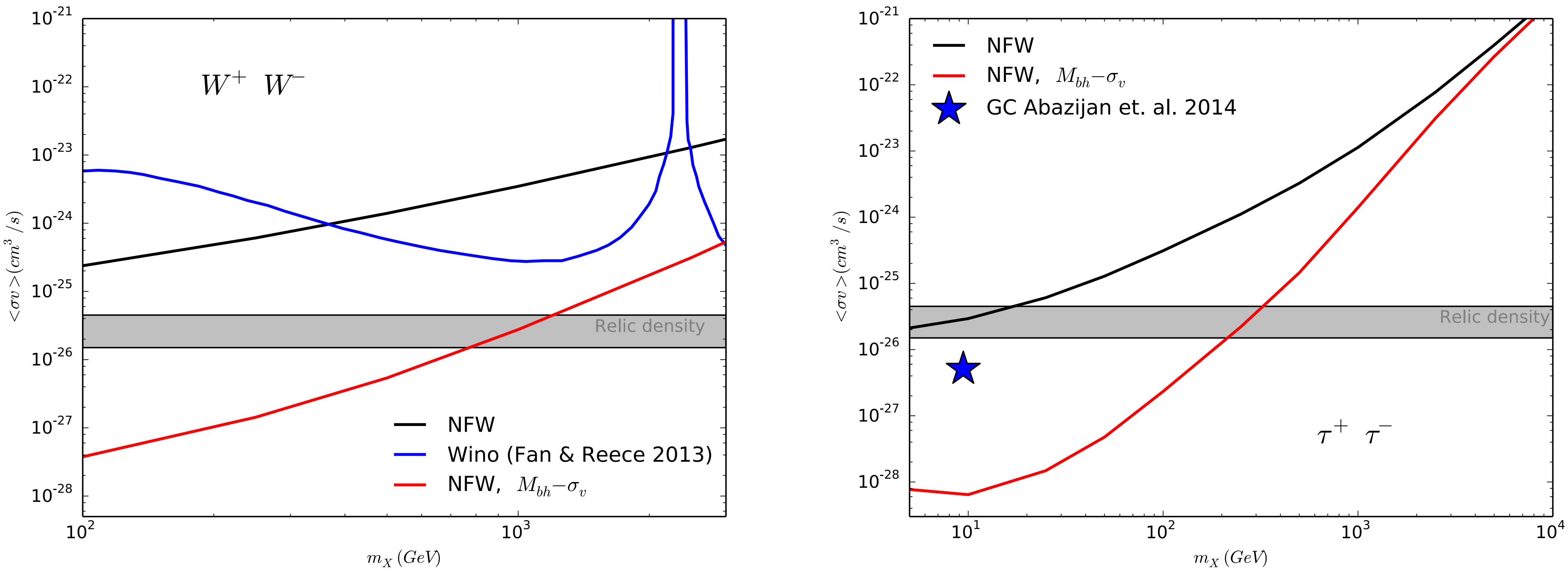


All dSphs together



Fermi current analysis cover some of the scenarios with IMBHs.

Other annihilation channels



IMBHs can set very strong constraints to DM annihilation for different DM models


Thanks!