EGRET constraints on (i) a specific IMBH scenario (ii) on nearby dark sources that could explain ... the PAMELA *excess*

Julien Lavalle
(Dept of Theoretical Physics, University of Turin)

Ref (arXiv) : 0902.3665

Collab: T. Bringmann, P. Salati

GDR Terascale — LPSC Grenoble

Thursday, March 31$^{\text{th}}$ 2009

Outline

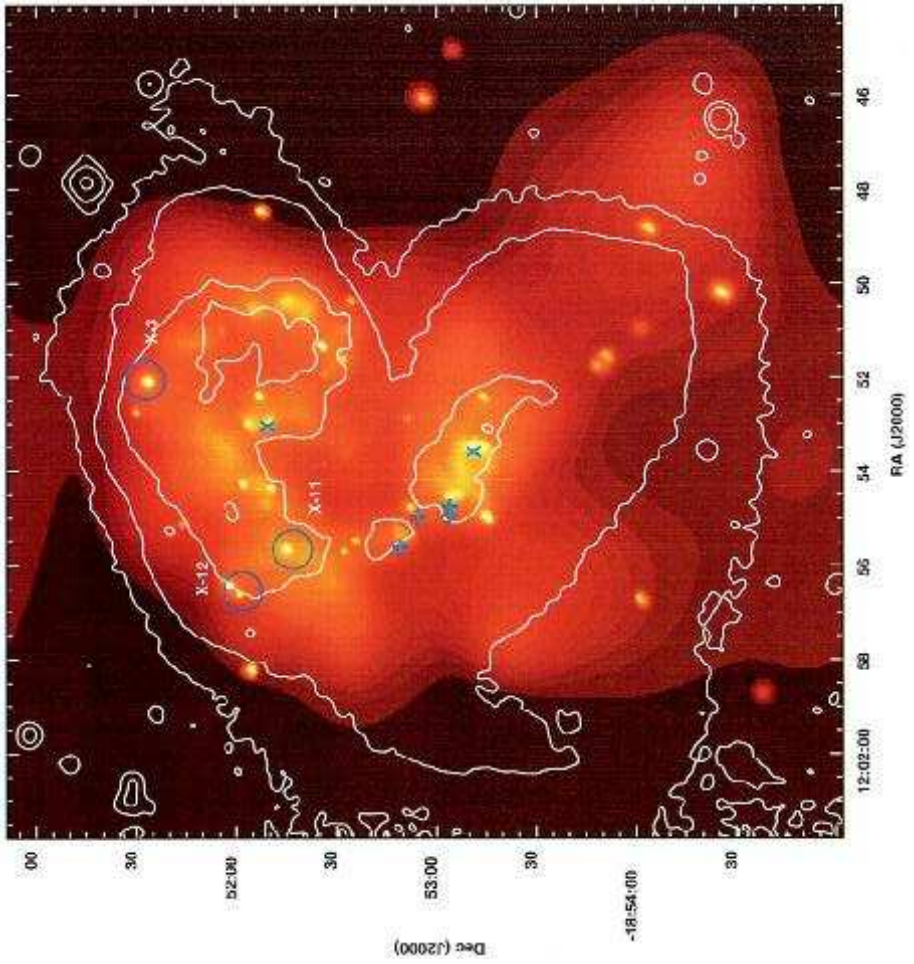
- **Intermediate mass black holes (IMBHs) in short**
- **Study of a specific scenario: the old-fashioned EGRET constraints**
- **PAMELA excess and the single dark matter source solution: the old-fashioned EGRET constraints**
- **Conclusion**

IMBHs in short

Review in Miller & Colbert — astro-ph/0308402
DM & BHs in Fornasa & Bertone — arXiv:0711.3148

- IMBH: black hole with mass between stellar BH and supermassive BH ($20 \leq M_{IMBH}/M_{\odot} \leq 10^6$)
- Hints (?) from ultra-luminous X-ray sources (ULX) not associated with AGN
- IMBHs may originate from remnants of 0-metallicity pop III stars, or from primordial gas (H_2) cooling in early-forming halos.
- Theoretically interesting because can be seeds for SMBHs that seemed to have formed early in the universe (1 Gyr)
- Mini-spikes of dark matter: proposed by Zhao & Silk (astro-ph/0501625), thoroughly developed since then by Bertone et al. (e.g. astro-ph/0509565).

Antennae galaxies
Fabbiano et al (2001)



IMBHs and dark matter minispikes

(e.g. **Fornasa & Bertone (2008)**).
Slow growth of BH $\longrightarrow$ adiabatic invariants. Adiabatic compression of DM around the BH (Gondolo & Silk, 1999): **spikes !!!**. Given $\rho \propto r^{-\gamma}$

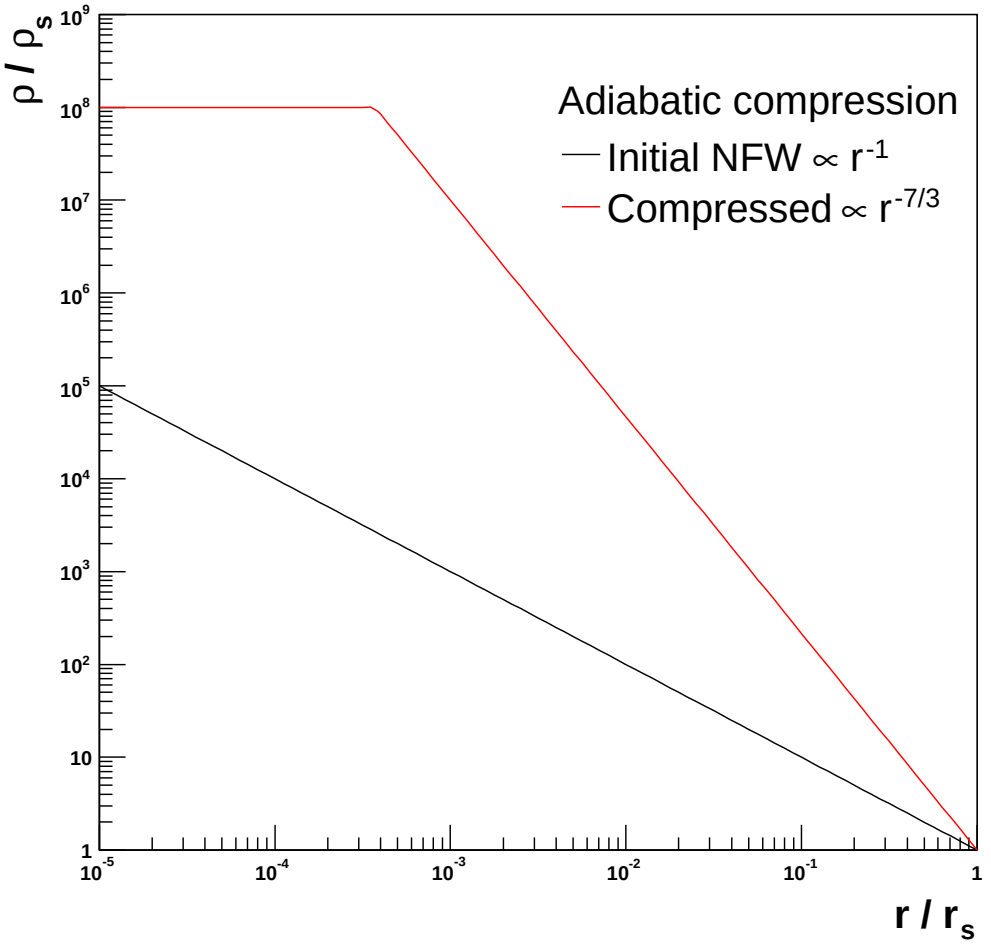
$$\boxed{\gamma_{\rm in} \quad \longrightarrow \quad \gamma_{\rm fin} = \frac{9-2\gamma_{\rm in}}{4-\gamma_{\rm in}}}$$

We define the **intrinsic effective volume**:

$$\xi_{\rm bh} \equiv \int_{V_{\rm dm}} d^3\vec{x} \left(\frac{\rho_{\rm bh}}{\rho_0}\right)^2$$

such that the **intrinsic luminosity** is:

$$\begin{aligned} L_{\rm bh} &= \{S = \frac{\delta\langle\sigma v\rangle}{4\pi}\left(\frac{\rho_0}{m}\right)^2\} \times \xi_{\rm bh} \\ &\propto \langle\sigma v\rangle^{2/7} \times {m_\chi}^{-9/7} \\ &\sim \mathcal{O}(L_{\rm MW}) \end{aligned}$$



Appealing for indirect searches.

IMBHs and dark matter minispikes

(e.g. **Fornasa & Bertone (2008)**).
Slow growth of BH $\longrightarrow$ adiabatic invariants. Adiabatic compression of DM around the BH (Gondolo & Silk, 1999): **spikes !!!**. Given $\rho \propto r^{-\gamma}$

$$\boxed{\gamma_{\rm in} \quad \longrightarrow \quad \gamma_{\rm fin} = \frac{9-2\gamma_{\rm in}}{4-\gamma_{\rm in}}}$$

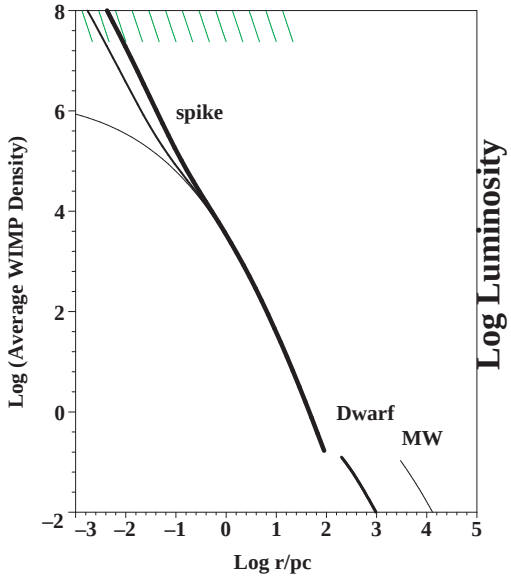
We define the **intrinsic effective volume**:

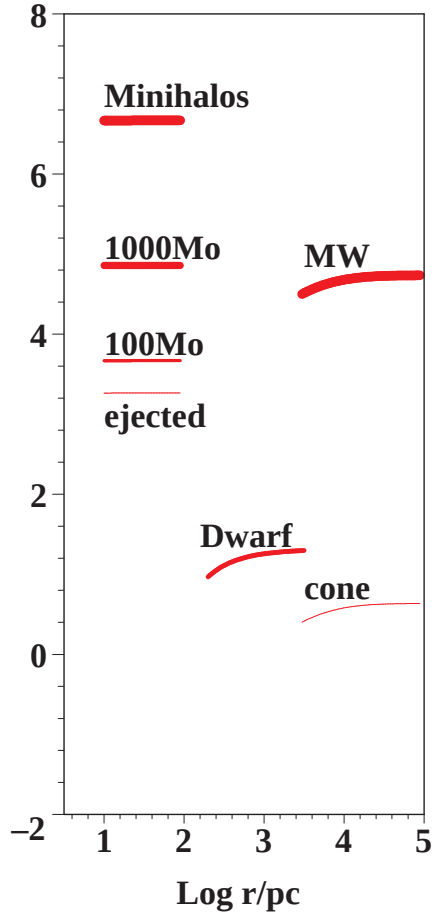
$$\xi_{\rm bh} \equiv \int_{V_{\rm dm}} d^3\vec{x} \left(\frac{\rho_{\rm bh}}{\rho_0}\right)^2$$

such that the **intrinsic luminosity** is:

$$\begin{aligned} L_{\rm bh} &= \{S = \frac{\delta\langle\sigma v\rangle}{4\pi}\left(\frac{\rho_0}{m}\right)^2\} \times \xi_{\rm bh} \\ &\propto \langle\sigma v\rangle^{2/7} \times {m_\chi}^{-9/7} \\ &\sim \mathcal{O}(L_{\rm MW}) \end{aligned}$$

Appealing for indirect searches.

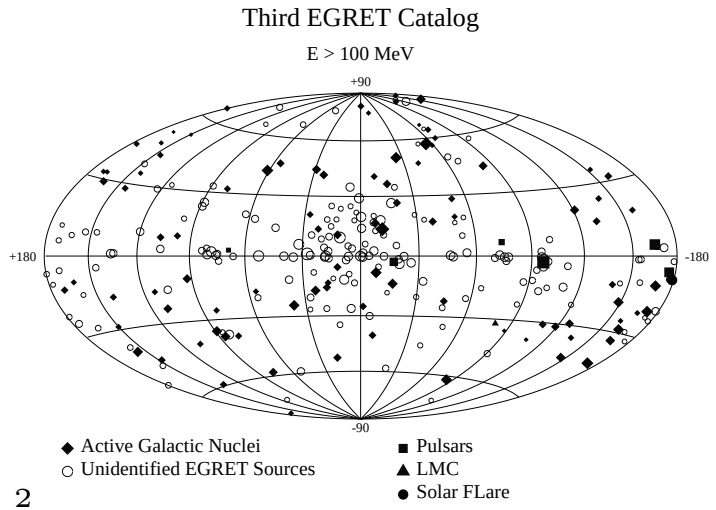




Zhao & Silk (2005)

IMBHs: Statistical properties

Hartmann et al (1999)



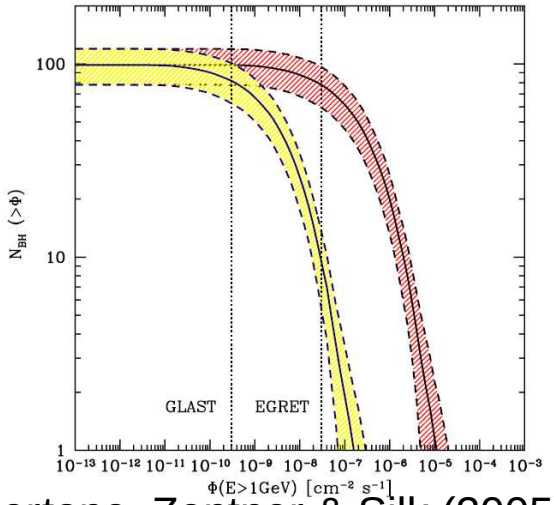
We focus on scenario B of Bertone, Zentner & Silk (2005). The γ-ray flux can be written:

$$\Phi_{\rm bh}^{\gamma} \equiv \frac{\Gamma}{4\pi\, d^2}$$

$$\approx 3.31 \cdot 10^{-7} \left(\frac{N_\gamma}{100}\right) {\rm cm}^{-2}{\rm s}^{-1}$$

$$\times \left(\frac{\tilde{\xi}/d^2}{10^4 {\rm kpc}}\right) \left(\frac{m_\chi}{\rm TeV}\right)^{-\frac{9}{7}} \left(\frac{\langle\sigma v\rangle}{3\cdot 10^{-26}{\rm cm}^3{\rm s}^{-1}}\right)^{\frac{2}{7}}$$

$\sim$ 100 IMBHs wandering in the Galaxy, most of them above the sensitivity limit of EGRET. Could stand for some of the unidentified EGRET sources.



Bertone, Zentner & Silk (2005)

IMBHs: Statistical properties

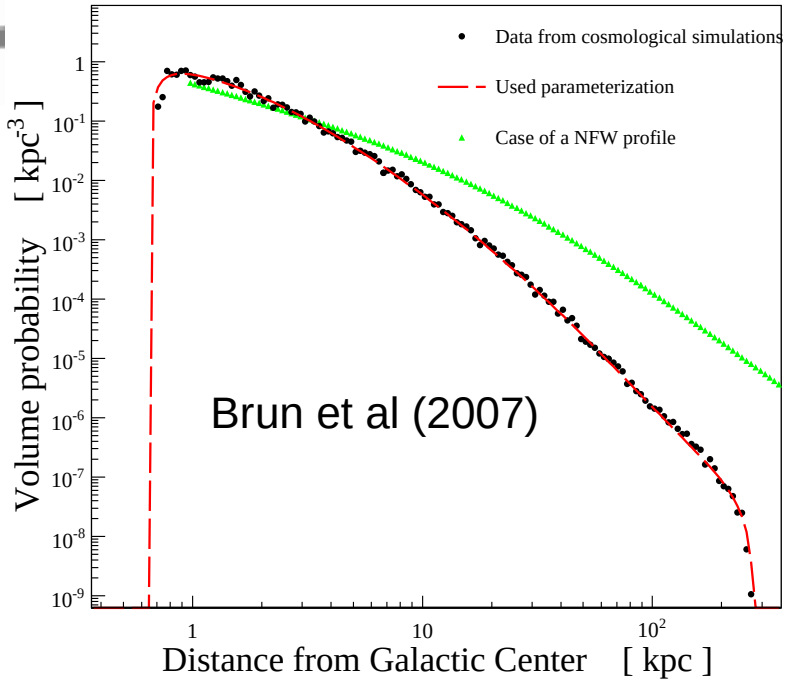
We focus on scenario B of Bertone, Zentner & Silk (2005). The γ-ray flux can be written:

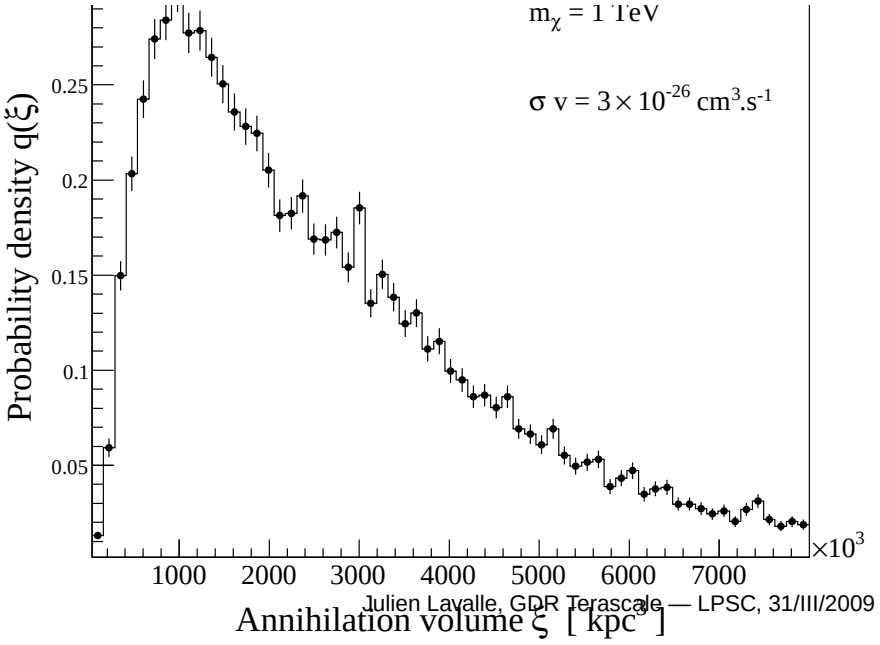
$$\Phi_{\rm bh}^{\gamma} \equiv \frac{\Gamma}{4\pi\, d^2}$$

$$\approx 3.31 \cdot 10^{-7} \left(\frac{N_\gamma}{100}\right) \mathrm{cm}^{-2}\mathrm{s}^{-1}$$

$$\times \left(\frac{\tilde{\xi}/d^2}{10^4 \mathrm{kpc}}\right) \left(\frac{m_\chi}{\mathrm{TeV}}\right)^{-\frac{9}{7}} \left(\frac{\langle\sigma v\rangle}{3 \cdot 10^{-26} \mathrm{cm}^3 \mathrm{s}}\right.$$

$\sim$ 100 IMBHs wandering in the Galaxy, most of them above the sensitivity limit of EGRET. Could stand for some of the unidentified EGRET sources.





Scenario B of Bertone, Zentner & Silk (2005)

Bringmann, Lavalle & Salati (arXiv:0902.3665)

P_c: probability for an IMBH to satisfy a condition c.

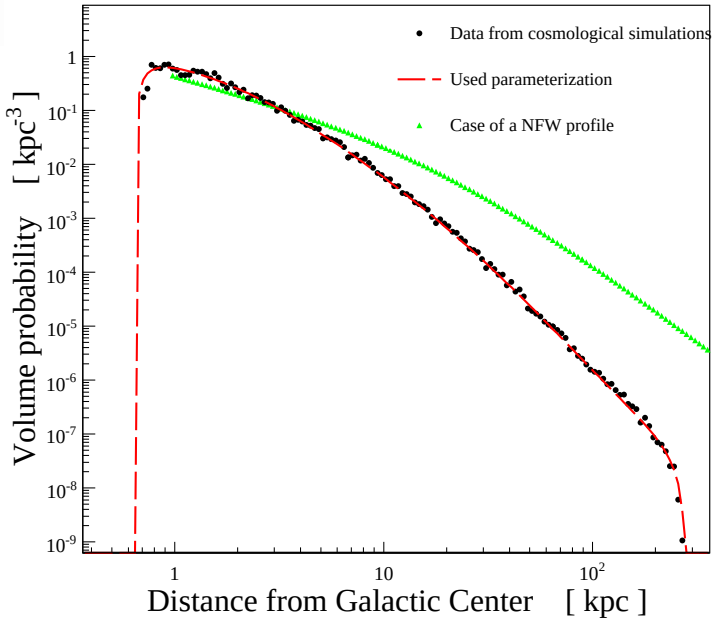
The probability for n out of m IMBHs to satisfy c is

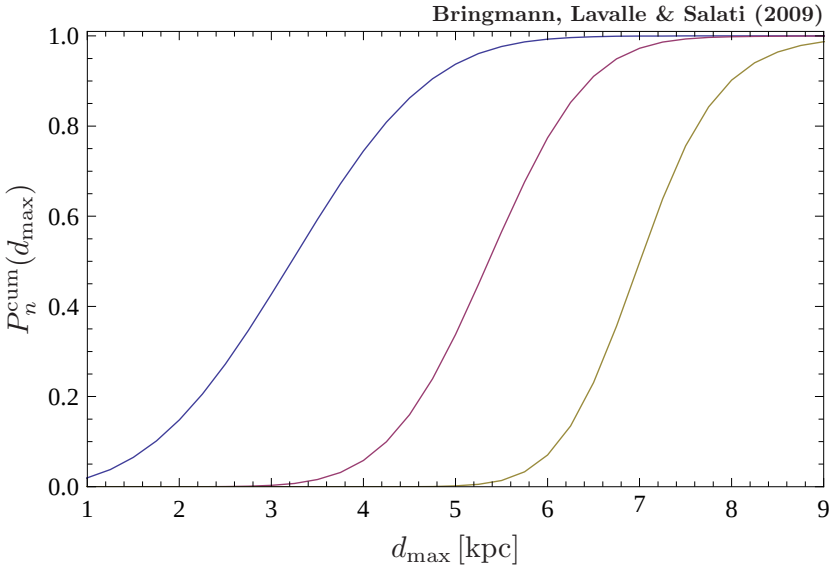
$$P_{n,m}(P_c) \equiv \left(\begin{array}{c} m \\ n \end{array} \right) P_c^n \, (1 - P_c)^{m-n}$$

Given an arbitrary realization with $p_N(N)$ the probability to have N IMBHs in the MW

$$P_n^{\rm int}(P_c) \equiv \int_n^\infty dN \, p_N(N) \, P_{n,N}(P_c)$$

Compute the probability to have at least n IMBHs within a distance $d_{\rm max}$ to the Earth, and with a luminosity greater than $\xi_{\rm min}$.





Scenario B of Bertone, Zentner & Silk (2005)

Bringmann, Lavalle & Salati (arXiv:0902.3665)

P_c: probability for an IMBH to satisfy a condition c.

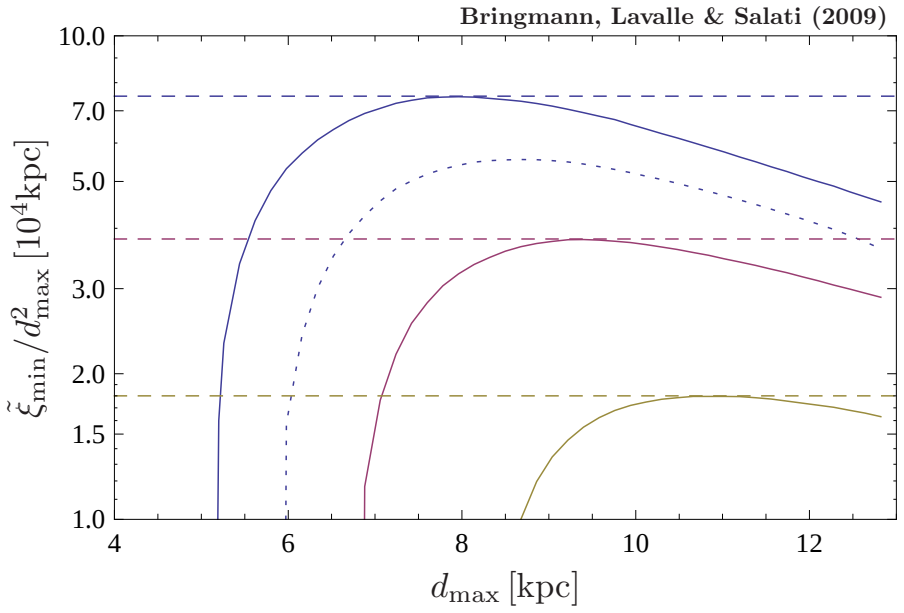
The probability for n out of m IMBHs to satisfy c is

$$P_{n,m}(P_c) \equiv \left(\begin{array}{c} m \\ n \end{array} \right) P_c^n \, (1 - P_c)^{m-n}$$

Given an arbitrary realization with $p_N(N)$ the probability to have N IMBHs in the MW

$$P_n^{\rm int}(P_c) \equiv \int_n^\infty dN \, p_N(N) \, P_{n,N}(P_c)$$

Compute the probability to have at least n IMBHs within a distance $d_{\rm max}$ to the Earth, and with a luminosity greater than $\xi_{\rm min}$.



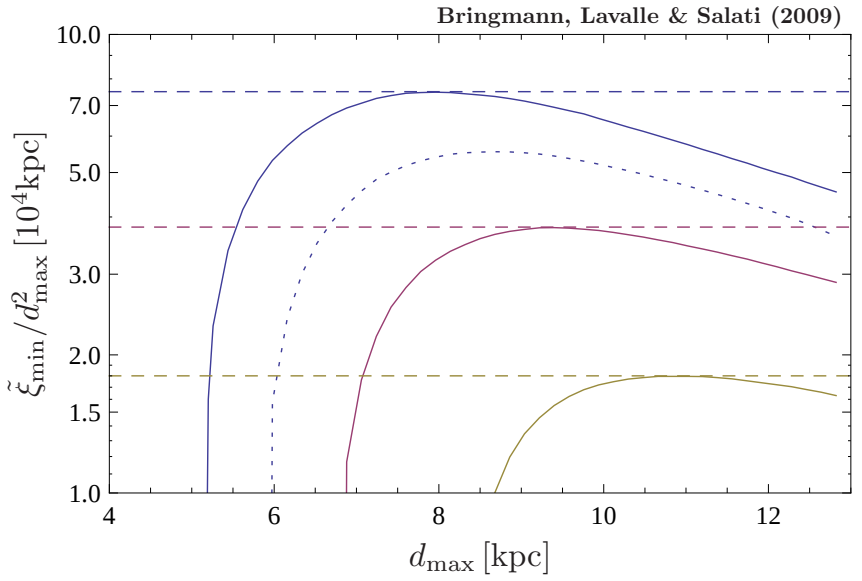
EGRET constraints

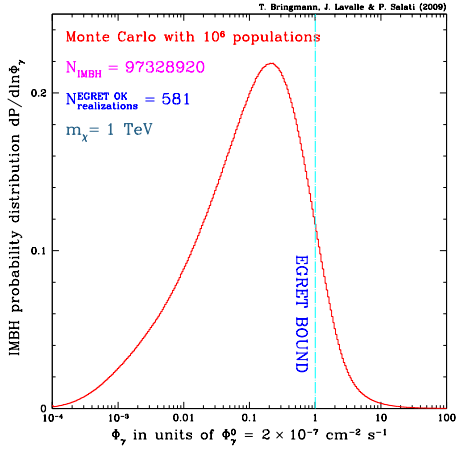
Bringmann, Lavalle & Salati (arXiv:0902.3665)
2 types of constraints:

- conservative: 1, 4 or 10 of the brightest EGRET unidentified sources are IMBHs (though observational dispersion)
- tough: no IMBH is observed (sensitivity limit)

Apply the condition

$$\Phi^{\gamma}_{\mathrm{bh,\,max}} = f(m_\chi, \langle\sigma v\rangle) \times \max\left[\frac{\xi_{\mathrm{min}}}{d^2_{\mathrm{max}}}\right] \leq \Phi_{\mathrm{egret}}$$





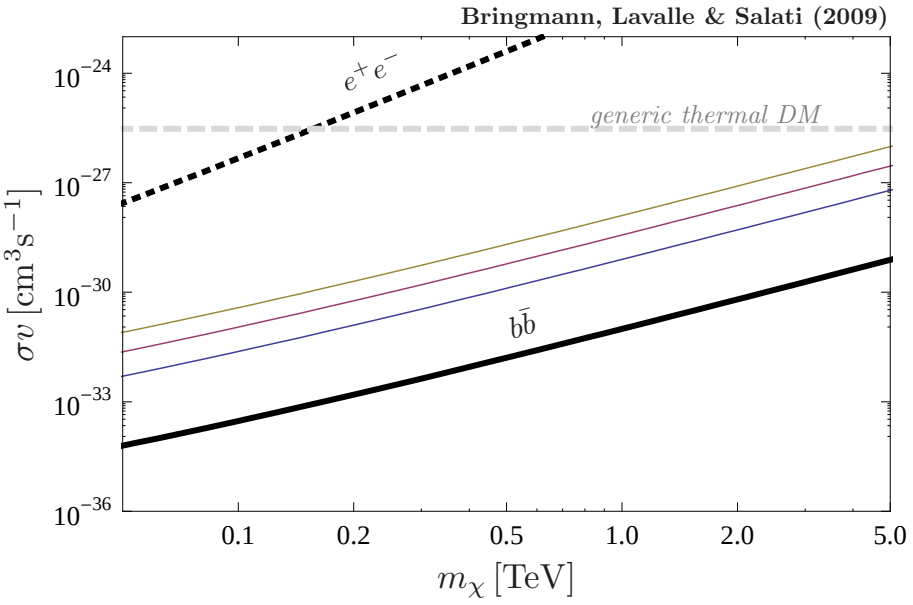
EGRET constraints

Bringmann, Lavalle & Salati (arXiv:0902.3665)
2 types of constraints:

- conservative: 1, 4 or 10 of the brightest EGRET unidentified sources are IMBHs (though observational dispersion)
- tough: no IMBH is observed (sensitivity limit)

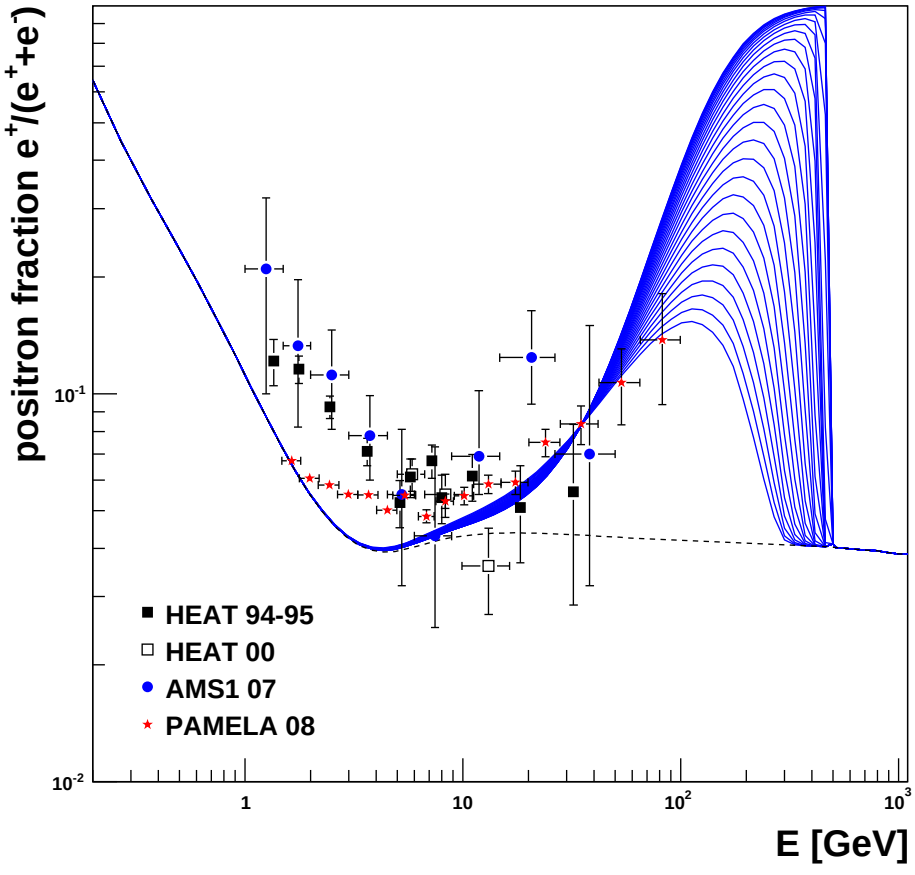
Apply the condition

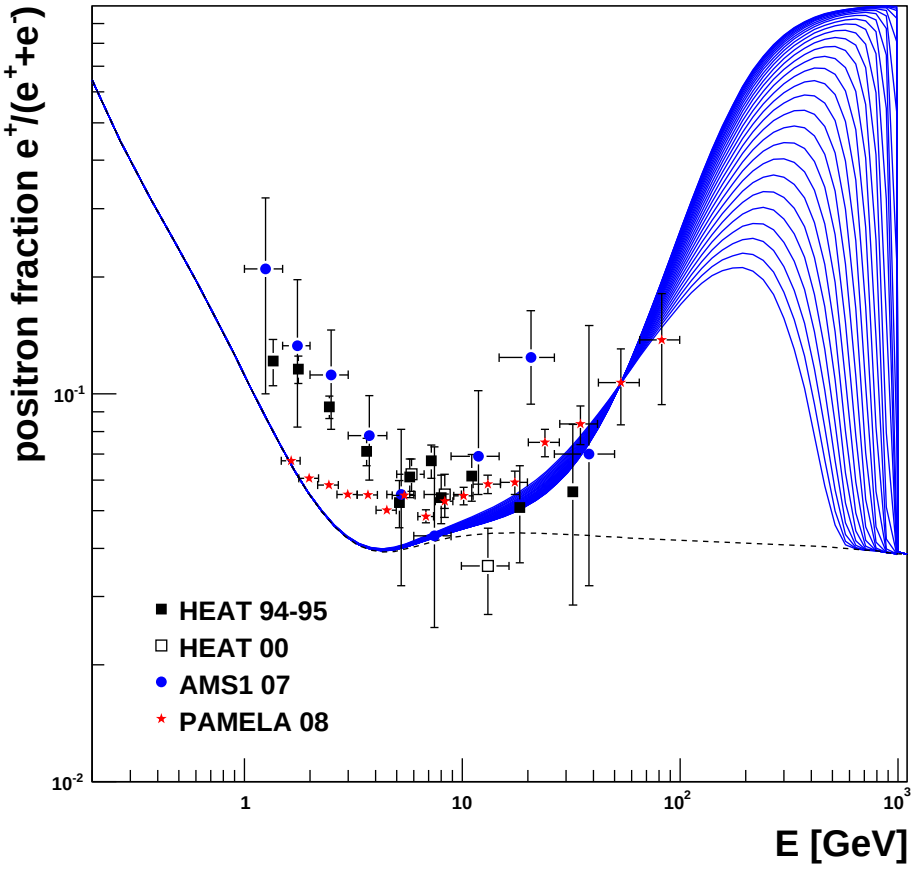
$$\begin{aligned} \Phi^{\gamma}_{\mathrm{bh,\,max}} &= f(m_\chi, \langle\sigma v\rangle) \\ &\quad \times \max\left[\frac{\xi_{\mathrm{min}}}{d^2_{\mathrm{max}}}\right] \\ &\leq \Phi_{\mathrm{egret}} \end{aligned}$$



PAMELA excess: nearby dark sources?

Dark point sources (IMBHs, big clumps) ... but conventional scenarios **excluded by EGRET**

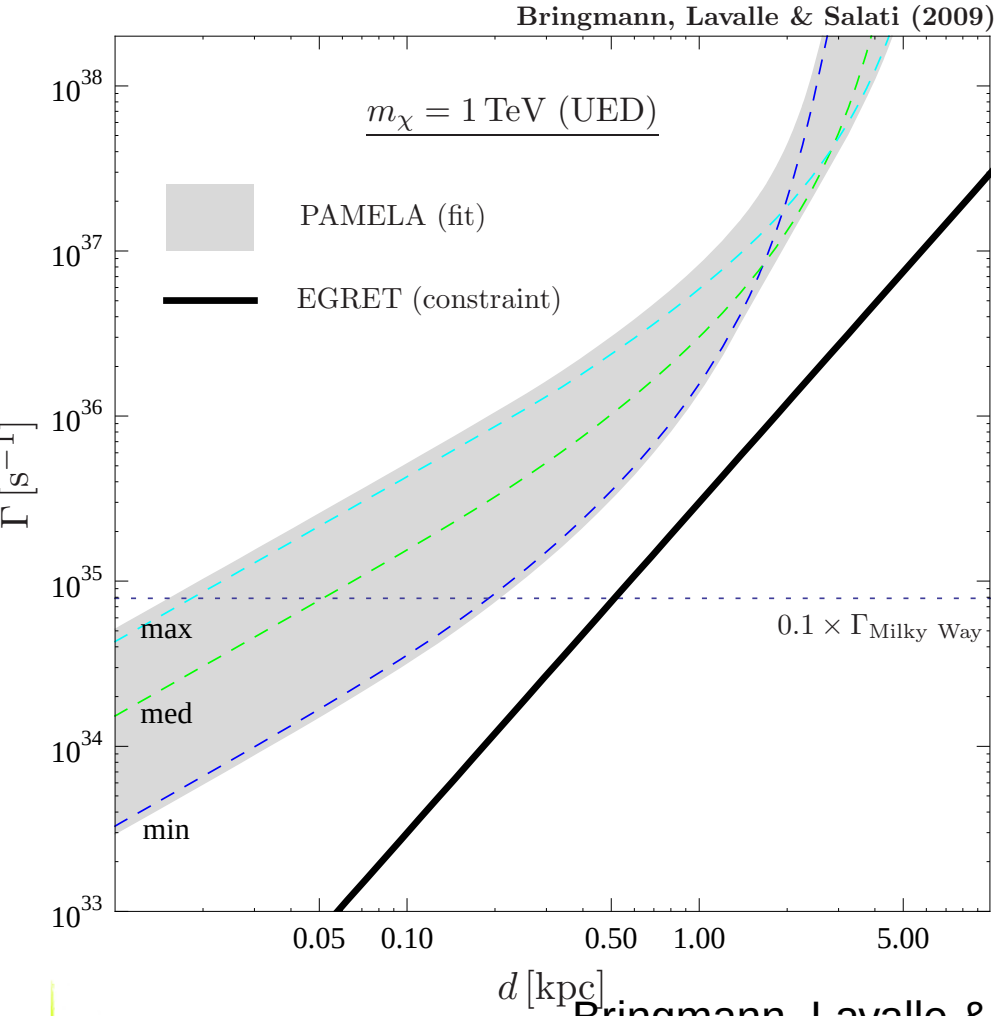


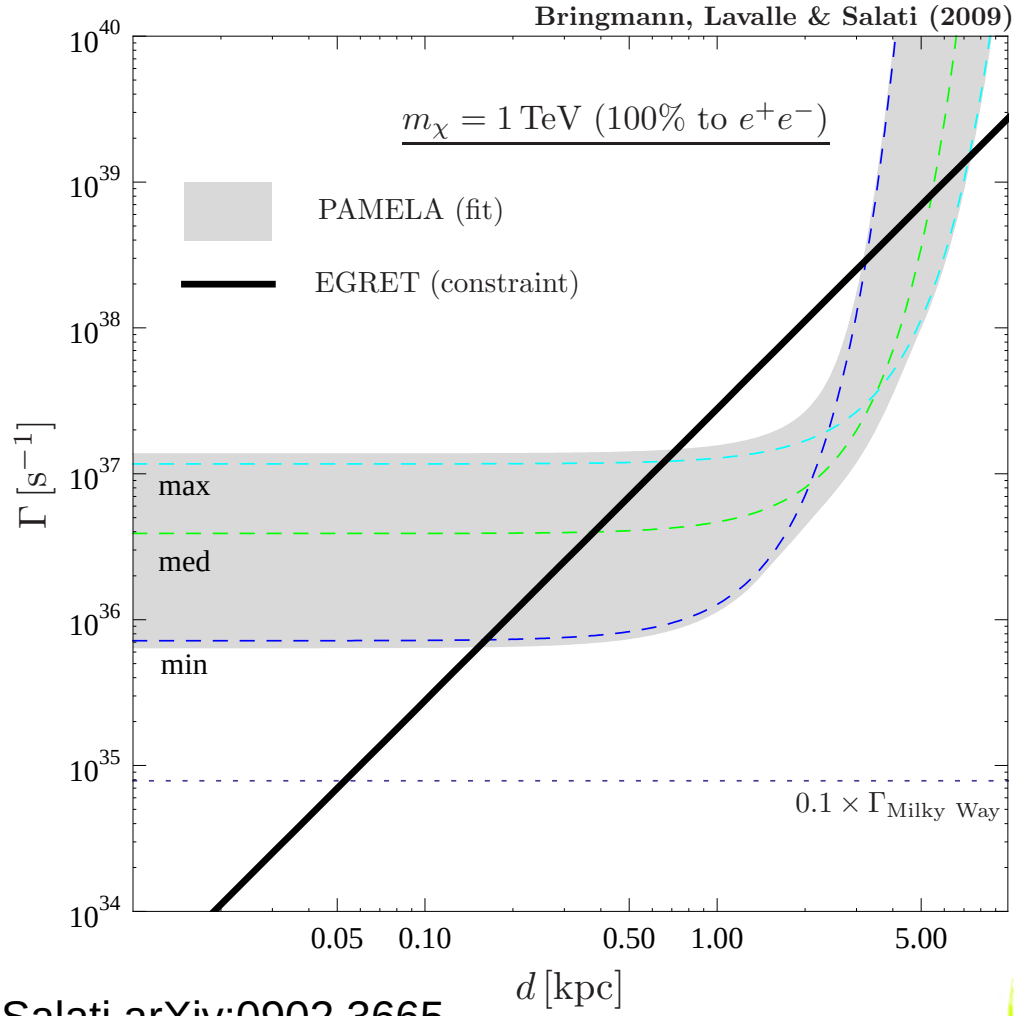


Bringmann, Lavalle & Salati arXiv:0902.3665

PAMELA excess: nearby dark sources?

Dark point sources (IMBHs, big clumps) ... but conventional scenarios **excluded by EGRET**



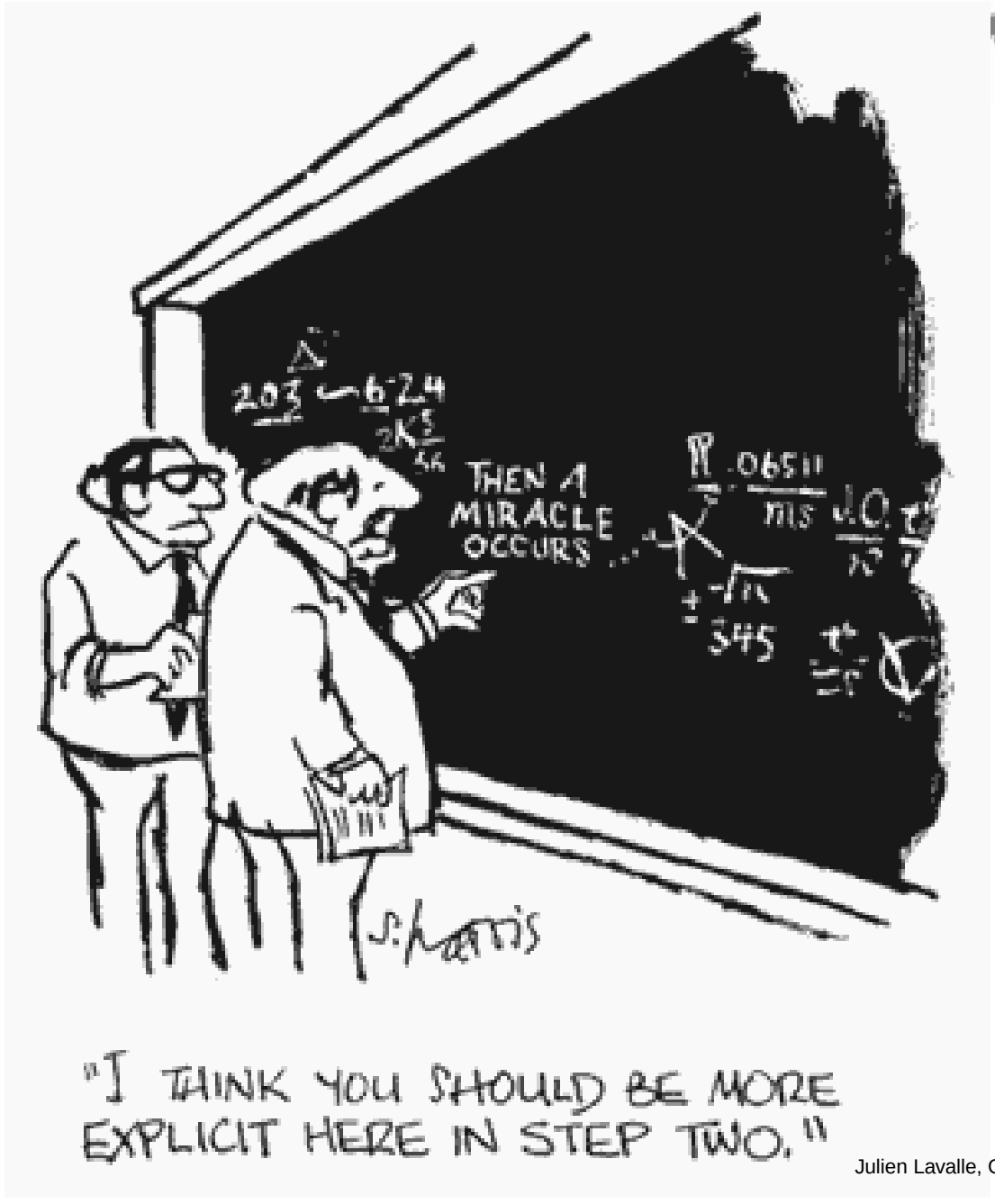


Bringmann, Lavalle & Salati arXiv:0902.3665

Summary

- **IMBHs well motivated objects**
- **Many scenarios exist: large theoretical uncertainties**
- **Appealing for DM searches (spikes may form and survive)**
- **Optimistic scenarios (e.g. B of Bertone et al (2005)) might be too optimistic (observational constraints, e.g. EGRET)**
- **Fermi + other experiments will provide better hints/constraints**

Backup


THEN A MIRACLE OCCURS ...
"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."