MODELLING THE DARK MATTER DENSITY DISTRIBUTION AT THE GALACTIC CENTER WITH GAMMA RAYS

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AYUDAS PARA EL FOMENTO DE INVESTIGACIÓN ESTUDIOS MÁSTER-UAM

OUTLINE

- Dark Matter (DM) indirect detection at the Galactic Center (GC) with gamma rays
- Previous work: TeV-WIMP candidates
- 4 regions of interest: Very Inner Region (VIR), Diffuse, Ridge, Halo
- Preliminary results: J-factors and m_{DM}
- J-factor: constraints on the DM density profile

INDIRECT DETECTION: GAMMA RAYS

$$\frac{d\Phi_{\text{total}}}{dE} = \frac{d\Phi_{\text{DM}}}{dE} + \frac{d\Phi_{\text{Back}}}{dE}$$

$$\frac{d\Phi_{\text{DM}}}{dE} = \sum_{i}^{\text{channels}} \frac{\langle \sigma v \rangle_i}{2} \frac{dN_i}{dE} \frac{\Delta\Omega \langle J \rangle_{\Delta\Omega}}{4\pi m_{\text{DM}}^2}$$

Information about the DM density profile

$$\langle J \rangle_{\Delta\Omega} = \frac{1}{\Delta\Omega} \int_{\Delta\Omega} \mathrm{d}\Omega \int_0^{l(\hat{\theta})_{\max}} \rho^2[r(l)] dl(\hat{\theta})$$

Benchmark Navarro-Frenk-White profile

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

N.W. Evans et al., PhysRevD.69.123501

$$\langle \sigma v \rangle = 3 \cdot 10^{-26} cm^3 s^{-1}$$

EVANS:

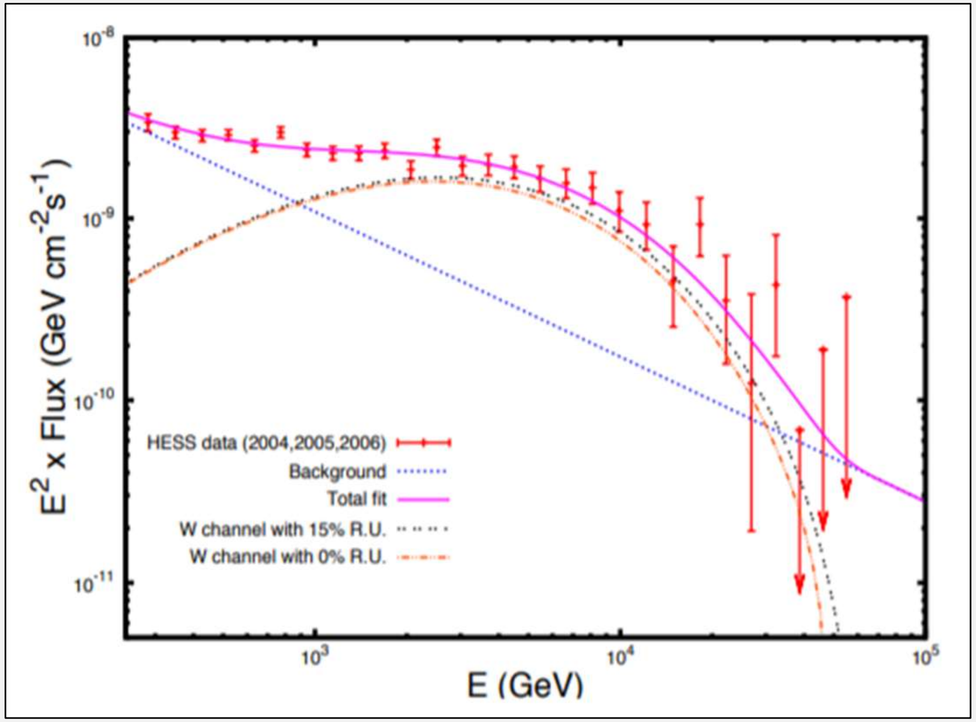
$$\rho_s = 5.38 \cdot 10^6 M_\odot Kpc^{-3}$$

$$r_s = 21.5 Kpc$$

PREVIOUS WORK

- GC observed by HESS within a region of 0,1° (Very Inner Region)
- Background + DM annihilation
- Channel W (PYTHIA 6)

$m_{DM}(TeV)$	$48{,}8 \pm 4{,}3$
γ	$2{,}80 \pm 0{,}15$
$\langle J \rangle_{\Delta\Omega}/J_{EVANS}$	1767 ± 416
χ^2 /ddof	0,84



Cembranos, J.A.R, V Gammaldi, and A.L Maroto. JCAP (2013): 051.

REGIONS OF INTEREST

- **Very Inner Region (VIR)**:
$\theta < 0{,}11°$ (r < 10 pc)
H.E.S.S. collaboration, Astron.Astrophys 503:817,2009

- **Diffuse**: $0{,}1° < \theta < 0{,}45°$
(10 pc < r < 66 pc)
H.E.S.S. collaboration, Nature 531, 476 (2016)

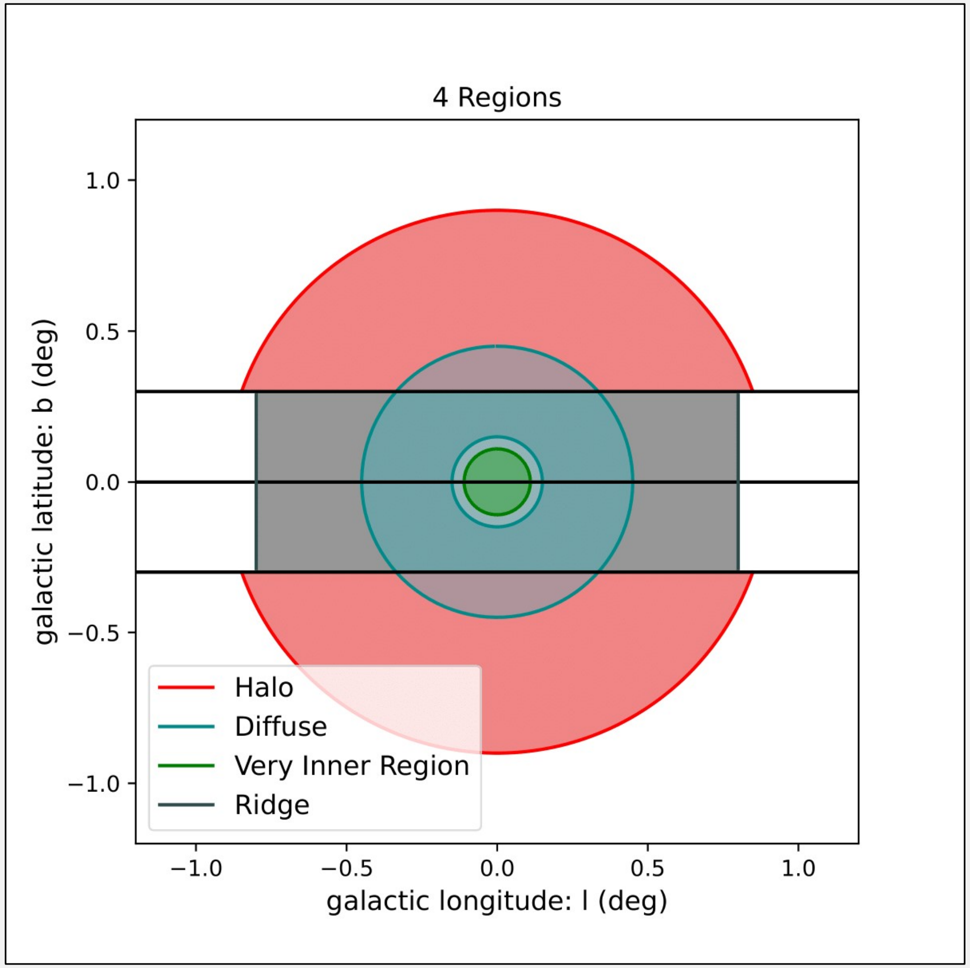
- **Ridge**: $b < \pm 0{,}3°$ (44 pc),
$l < \pm 0{,}8°$ (~ 150 pc)

H.E.S.S. collaboration, A&A 612, A9 (2018)

- **Halo**: $0{,}3° < \theta < 0{,}9°$, excluding
$b < \pm 0{,}3°$ (44 pc < r < 150 pc)

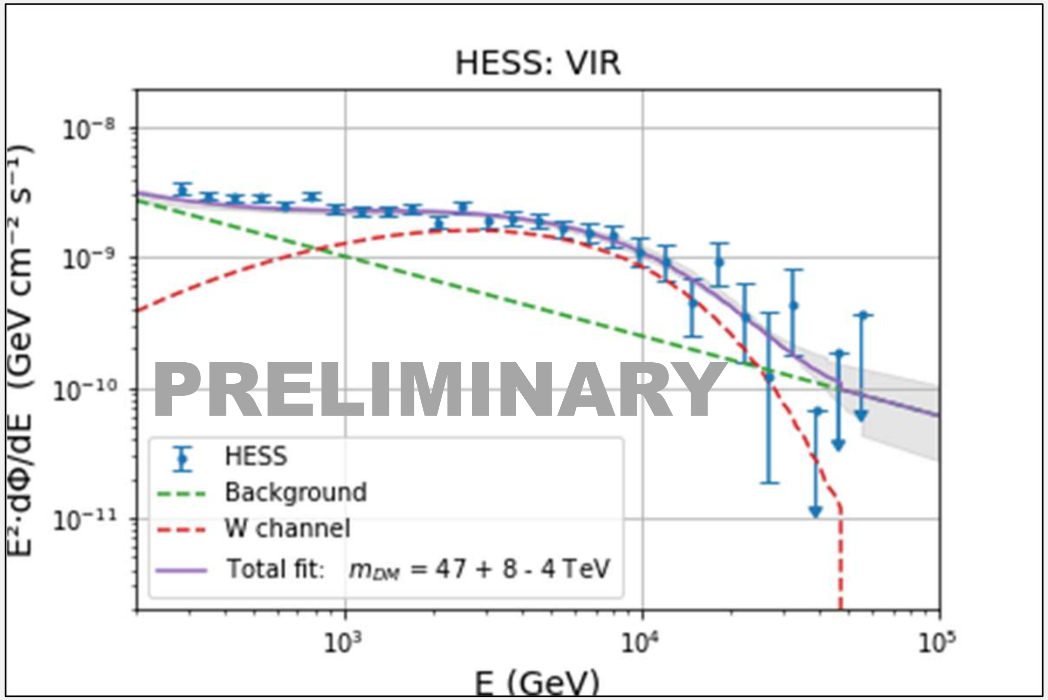
H.E.S.S. collaboration, Phys.Rev.Lett.106:161301 (2011)

H.E.S.S. collaboration, Phys. Rev. Lett. 117, 111301 (2016)

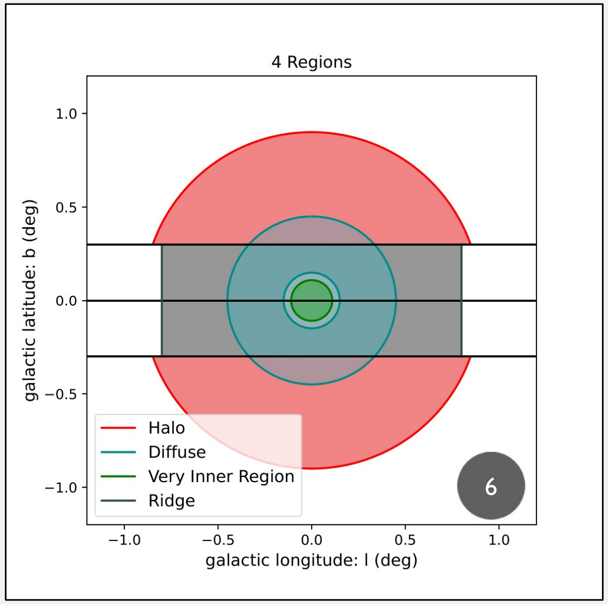


Taking the center in Sgr A*

VIR

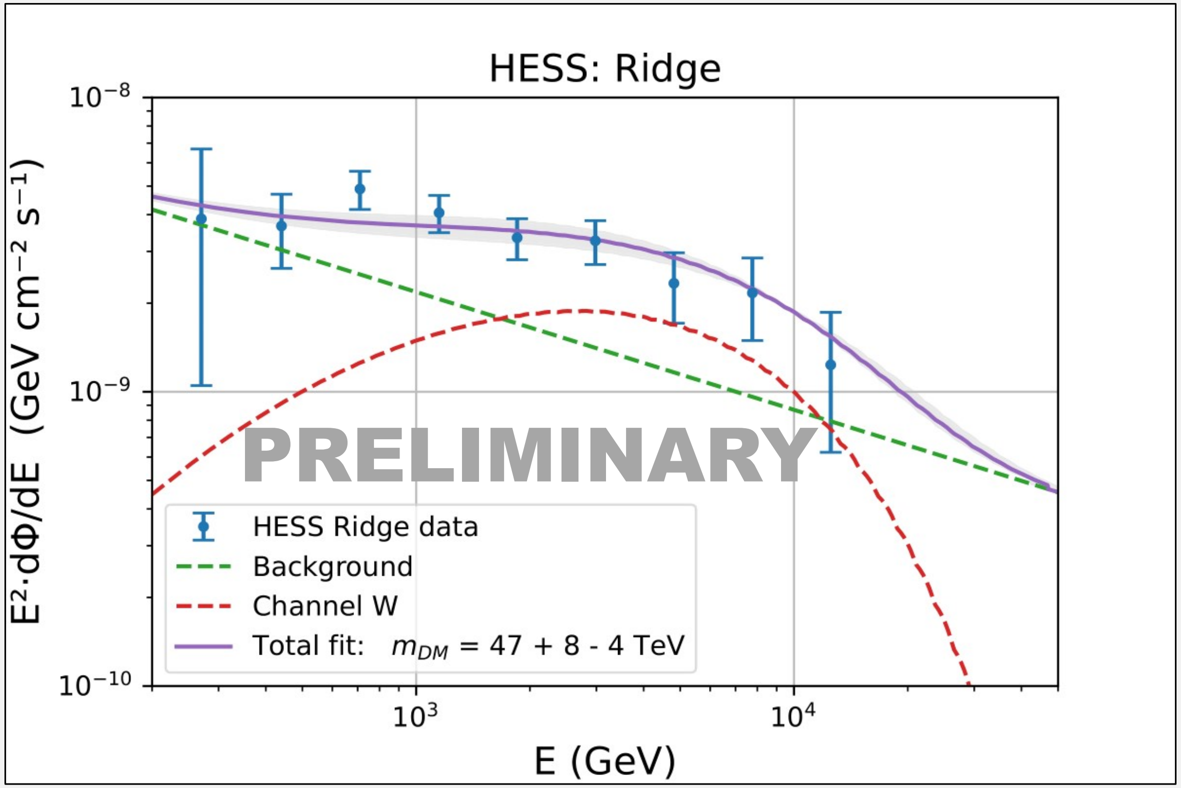


Parameter	*Previous work*	*This work*
$m_{DM}(TeV)$	$48{,}8 \pm 4{,}3$	$47{,}0^{+8{,}5}_{-4{,}5}$
γ	$2{,}80 \pm 0{,}15$	$2{,}61^{+0{,}15}_{-0{,}11}$
$\langle J \rangle_{\Delta\Omega}/J_{EVANS}$	1767 ± 416	2748 ± 590
χ^2 /ddof	0,84	1,2
CODE	*PYTHIA 6*	*PYTHIA 8*

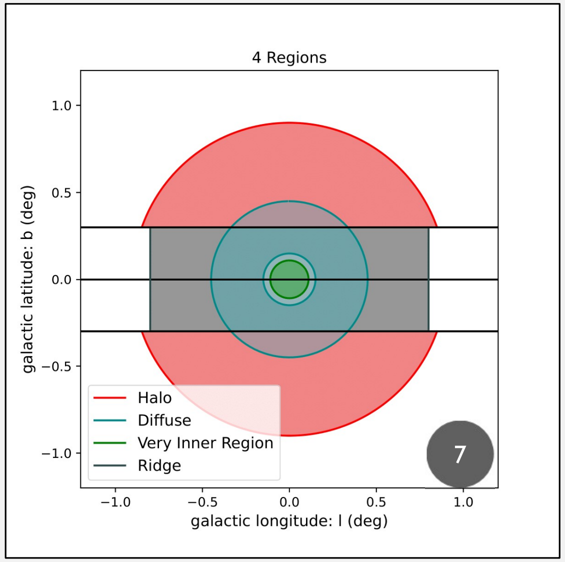


$$\frac{d\Phi_{Back}}{dE} = E^{-\gamma} \qquad \frac{d\Phi}{dE} = B^2 \frac{d\Phi_{\rm Back}}{dE} + D^2 \frac{\langle \sigma v \rangle}{m_{DM}^2} \frac{dN}{dE}$$

RIDGE



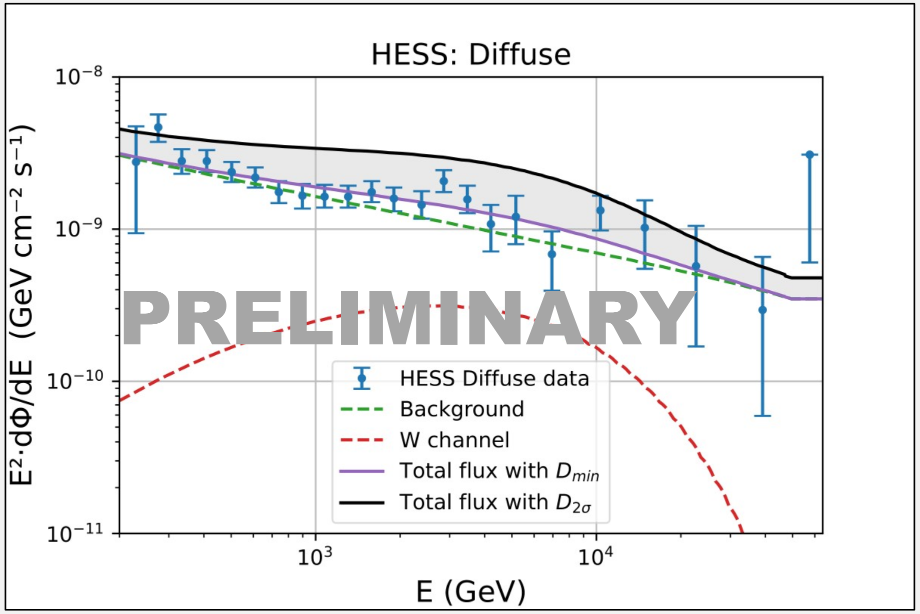
$m_{DM}(TeV)$	$47{,}0^{+8{,}5}_{-4{,}5}$
γ	$2{,}40^{+0{,}33}_{-0{,}33}$
$\langle J \rangle_{\Delta\Omega}/J_{EVANS}$	539 ± 46
χ^2 /ddof	0,51



$$\frac{d\Phi_{Back}}{dE} = E^{-\gamma} \qquad \frac{d\Phi}{dE} = B^2\frac{d\Phi_{\text{Back}}}{dE} + D^2\frac{\langle\sigma v\rangle}{m_{DM}^2}\frac{dN}{dE}$$

DIFFUSE

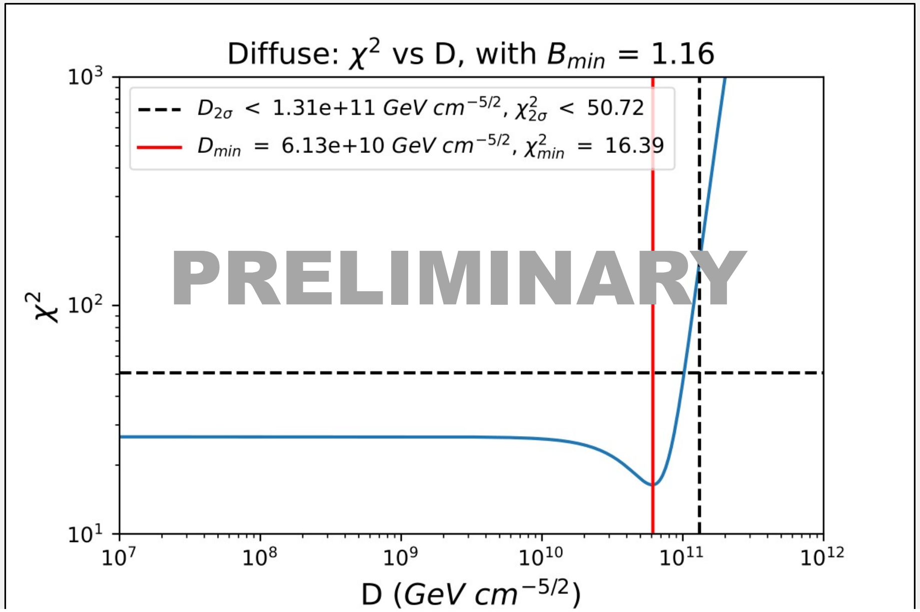
Background DRAGON Model: Background is the most predominant flux

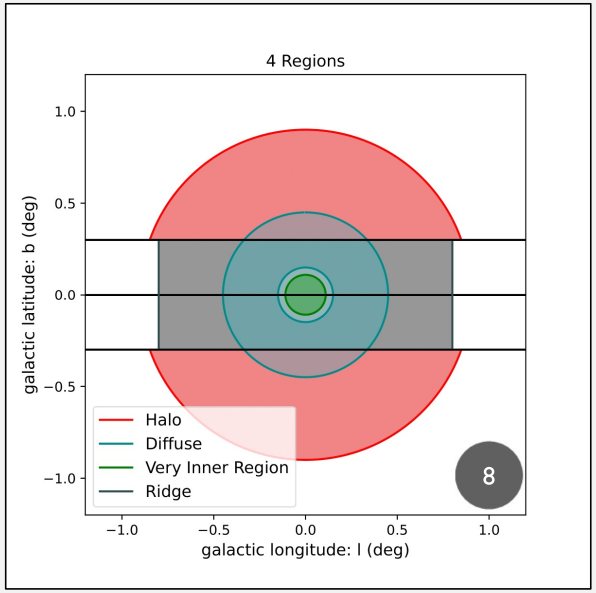


Parameter	Upper limit	2σ
$m_{DM}(TeV)$	$47{,}0^{+8{,}5}_{-4{,}5}$	$47{,}0^{+8{,}5}_{-4{,}5}$
$\langle J\rangle_{\Delta\Omega}/J_{EVANS}$	69	< 315
χ^2 /ddof	0,74	2,3

DRAGON model Background

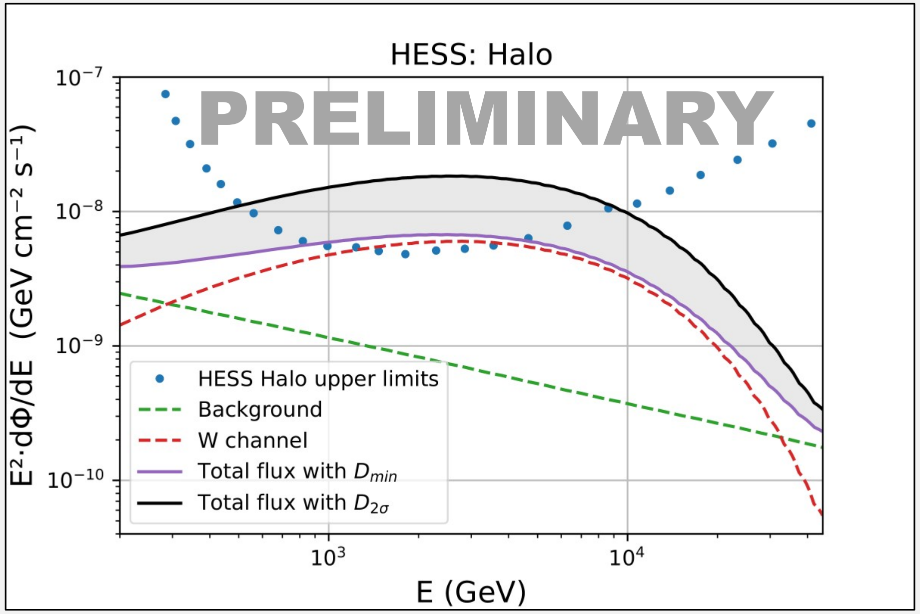
Evoli, Carmelo and Graggero, Daniele et. al. JCAP (2008): 18.





HALO

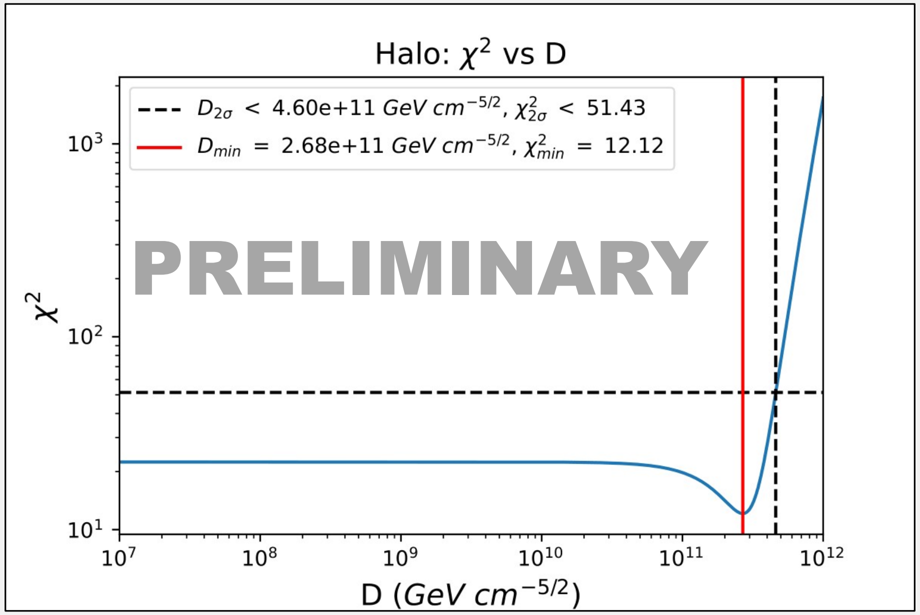
Background DRAGON Model: Background is the most predominant flux

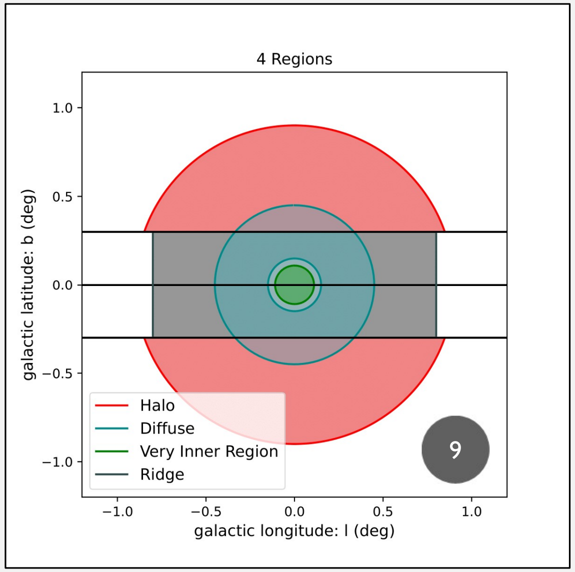


Parameter	*Upper limits*	2σ
$m_{DM}(TeV)$	$47{,}0^{+8{,}5}_{-4{,}5}$	$47{,}0^{+8{,}5}_{-4{,}5}$
$\langle J \rangle_{\Delta\Omega}/J_{EVANS}$	4412	< 7301
χ^2 /ddof	0,47	1,97

DRAGON model Background

Evoli, Carmelo and Graggero, Daniele et. al. JCAP (2008): 18.





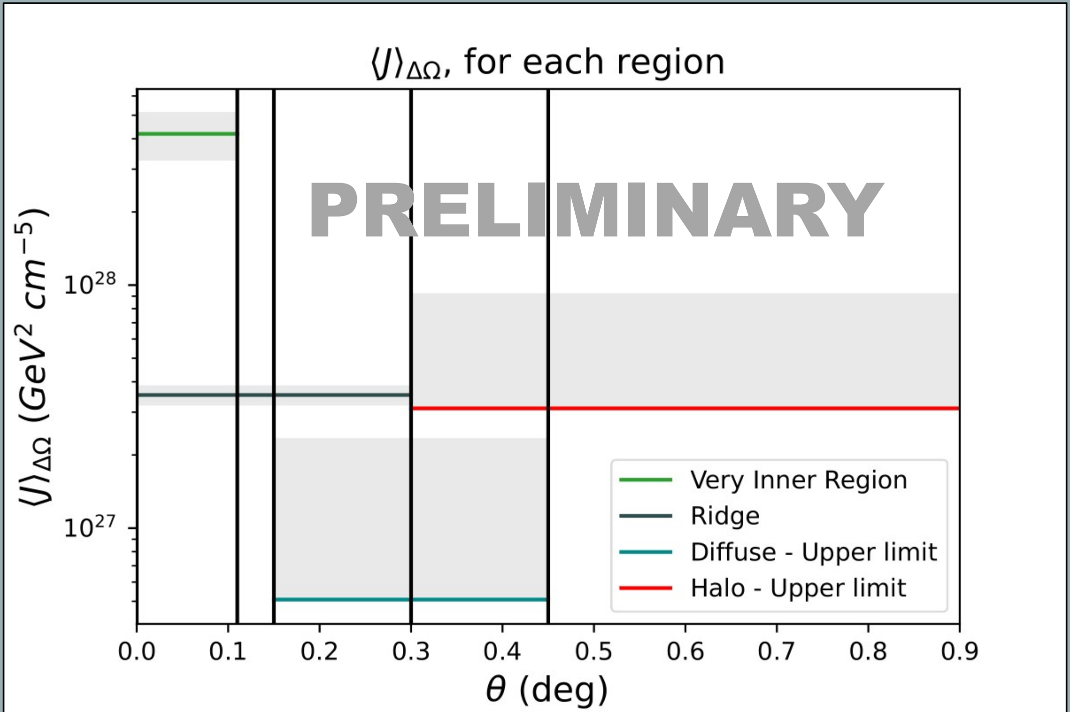
PARAMETERS

$$\frac{d\Phi_{Back}}{dE} = E^{-\gamma}$$

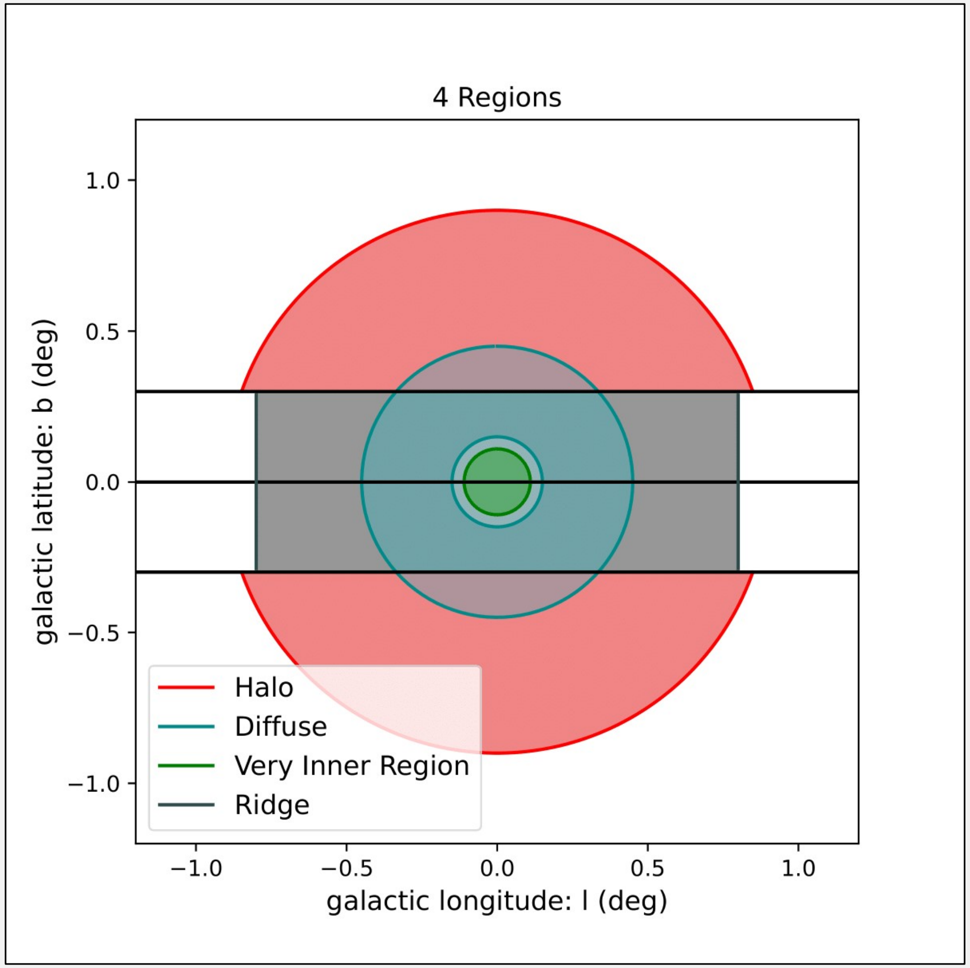
$$\frac{d\Phi}{dE} = B^2 \frac{d\Phi_{\text{Back}}}{dE} + D^2 \frac{\langle\sigma v\rangle}{m_{DM}^2} \frac{dN}{dE}$$

Parameter		m_{DM} (TeV)	γ	$\langle J\rangle_{\Delta\Omega}/J_{EVANS}$	χ^2 $/ddof$
VIR		$47{,}0^{+8{,}5}_{-4{,}5}$	$2{,}61^{+0{,}15}_{-0{,}11}$	2748 ± 590	1,2
Ridge		$47{,}0^{+8{,}5}_{-4{,}5}$	$2{,}40^{+0{,}33}_{-0{,}33}$	539 ± 46	0,51
Diffuse	Upper limit	$47{,}0^{+8{,}5}_{-4{,}5}$	–	69	0,74
	2σ		–	< 315	2,3
Halo	Upper limit	$47{,}0^{+8{,}5}_{-4{,}5}$	–	4412	0,47
	2σ		–	< 7301	1,97

ASTROPHYSICAL FACTOR



$$\langle J \rangle_{\Delta\Omega} = \frac{1}{\Delta\Omega} \int_{\Delta\Omega} d\Omega \int_0^{l(\hat{\theta})_{\max}} \rho^2[r(l)]dl(\hat{\theta})$$



DM DENSITY PROFILES

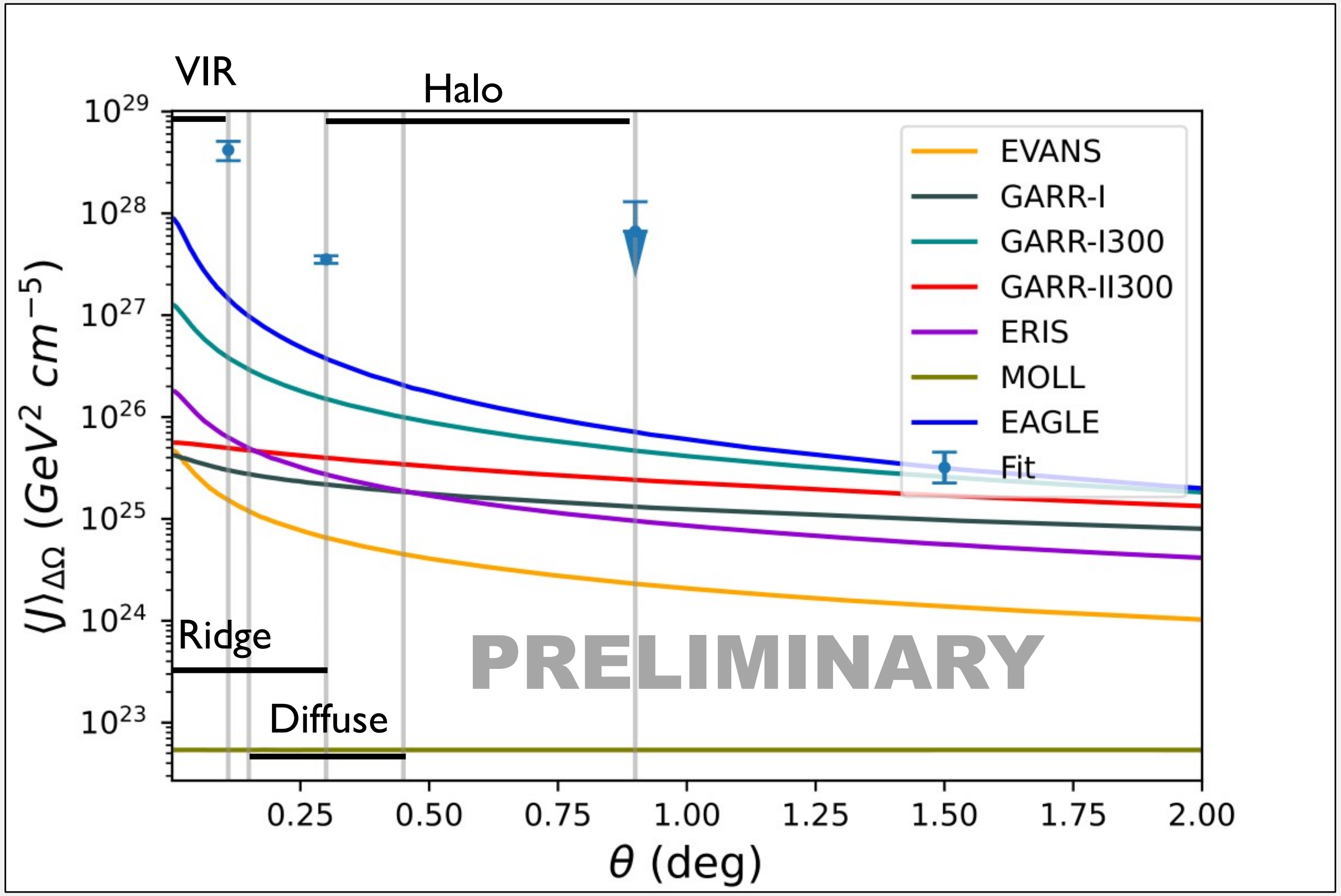
Profile	ρ_s $(M_\odot/Kpc^{-3})$	r_s (Kpc)	r_{vir} (kpc)	γ	α	β	$\rho_\odot(GeVcm^{-3})$	R_{sp} (pc)	θ°_{sp}(deg)
EVANS	5.38×10^6	21.5	215	1	1	3	0.27	24	0.16
GARR-I	4.97×10^8	2.3	230	0.59	1	2.70	0.33	16	0.11
GARR-I300	1.01×10^8	4.6	230	1.05	1	2.79	0.33	11	0.07
GARR-II300	2.40×10^{10}	2.5	230	0.02	0.42	3.39	0.34	2.3	0.01
ERIS	2.25×10^7	10.9	239	1	1	3	0.35	16	0.11
MOLL	4.57×10^7	4.4	234	~ 0	2.89	2.54	0.29	0.034	0.0002
EAGLE	2.18×10^6	31.2	239	1.38	1	3	0.31	6.4	0.04

Comparison: EVANS DM-only simulation and hydrodynamical simulations GARR, ERIS, MOLL, and EAGLE

V. Gammaldi et al, Phys. Rev. D 94, 121301 (2016)

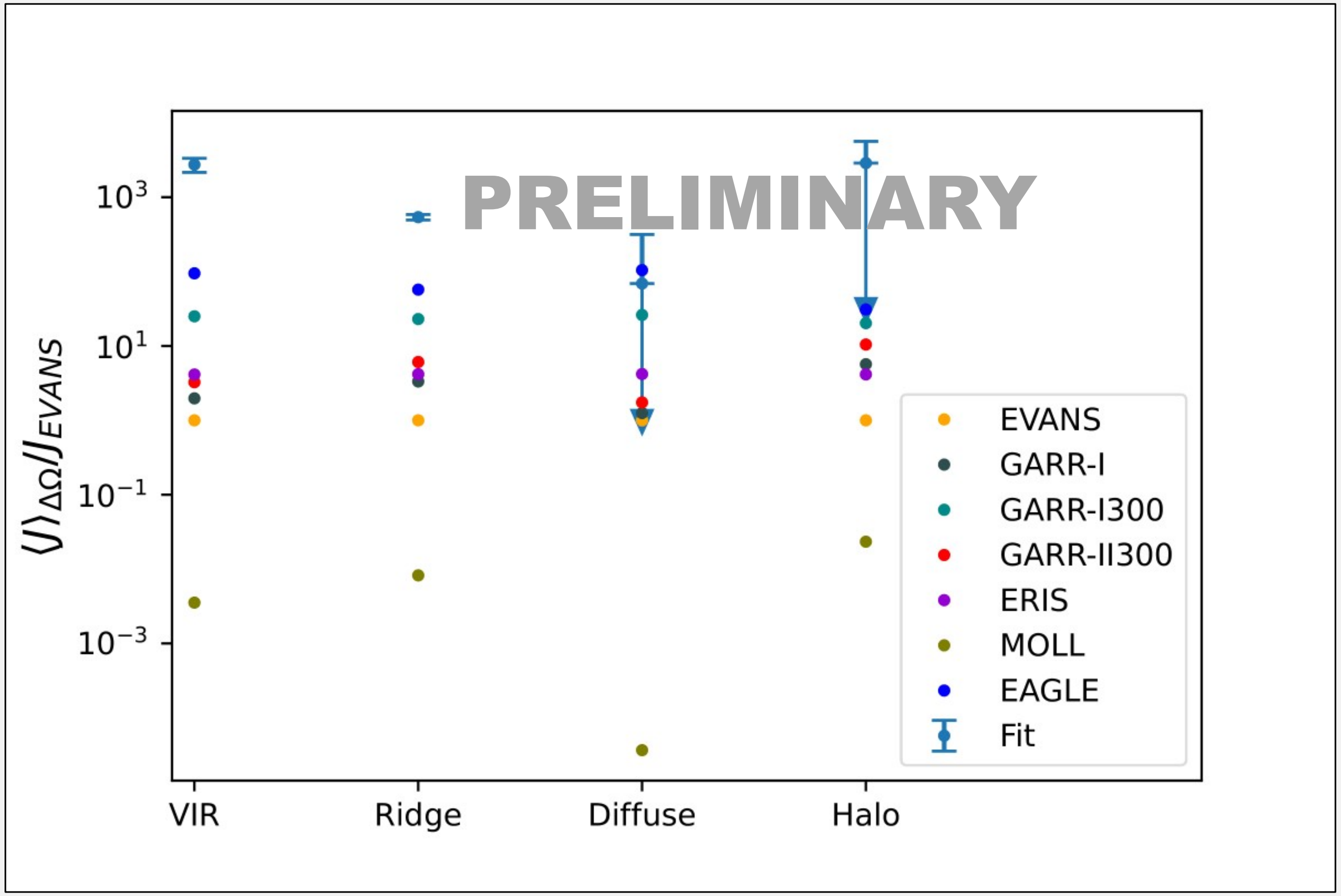
$$\rho = \frac{\rho_s}{(\frac{r}{r_s})^\gamma (1 + (\frac{r}{r_s})^\alpha)^{\frac{\beta-\gamma}{\alpha}}}$$

DM DENSITY PROFILES



$$\langle J\rangle_{\Delta\Omega} = \frac{1}{\Delta\Omega}\int_{\Delta\Omega} d\Omega \int_0^{l(\hat{\theta})_{\max}} \rho^2[r(l)]dl(\hat{\theta})$$

DM DENSITY PROFILES



CONCLUSIONS

GAMMA-RAY SPECTRA

- We reproduce the results from the VIR: annihilation of TeV DM candidate
- We analyse 3 new regions: Ridge, Diffuse and Halo
- We use DRAGON to model the background for both Diffuse and Halo regions
- Overall agreement with the hypothesis of TeV DM candidate

J-FACTORS

- J-factor obtained at different angular scale
- We reproduce the boost of the previous work in the VIR up to $\sim 10^3$
- Boost factor required in all the regions
- We compare our results with N-body simulations
- EAGLE profile gives the highest J-factor value in VIR, but some boost is still needed

NEXT STEPS

- Background model at subparsec scale
- BH dynamics and other dynamical constraints

THANK YOU FOR YOUR ATTENTION