Gamma-ray searches for DM clumps in the Milky Way with a baryonic potential

M. Hütten, M. Stref, C. Combet, J. Lavalle, D. Maurin

Back in 2016…

Dark matter substructure modelling and sensitivity of the Cherenkov Telescope Array to Galactic dark halos

arXiv:1606.04898

M. Hütten,[a,c] C. Combet,[b] G. Maier,[a] D. Maurin.[b]

Objectives:

- Detectability study of dark clumps with CTA
- Thorough exploration of uncertainties in the subhalo description

Systematic study of all subhalo-related quantities and impact on subhalo population and brightest clump properties

	Model	VAR0	LOW	VAR1	VAR2	VAR3	VAR4	VAR5	VAR6a	VAR6b	HIGH
Varied parameters	inner profile	NFW	E	E	E	E	E	E	E	E	E
	α_m	1.9	1.9	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9
	σ_c	0.14	0.14	0.14	0.24	0.14	0.14	0.14	0.14	0.14	0.14
	$\bar{\varrho}_{subs}$	E-AQ	E-AQ	E-AQ	E-AQ	M-VLII	E-AQ	E-AQ	E-AQ	E-AQ	M-VLII
	$N_{\rm calib}$	150	150	150	150	150	300	150	150	150	300
	sub-subhalos?	no	no	no	no	no	no	yes	no	no	no
	$c(m)$	SP	SP	SP	SP	SP	SP	SP	Moliné	P-VLII	P-VLII

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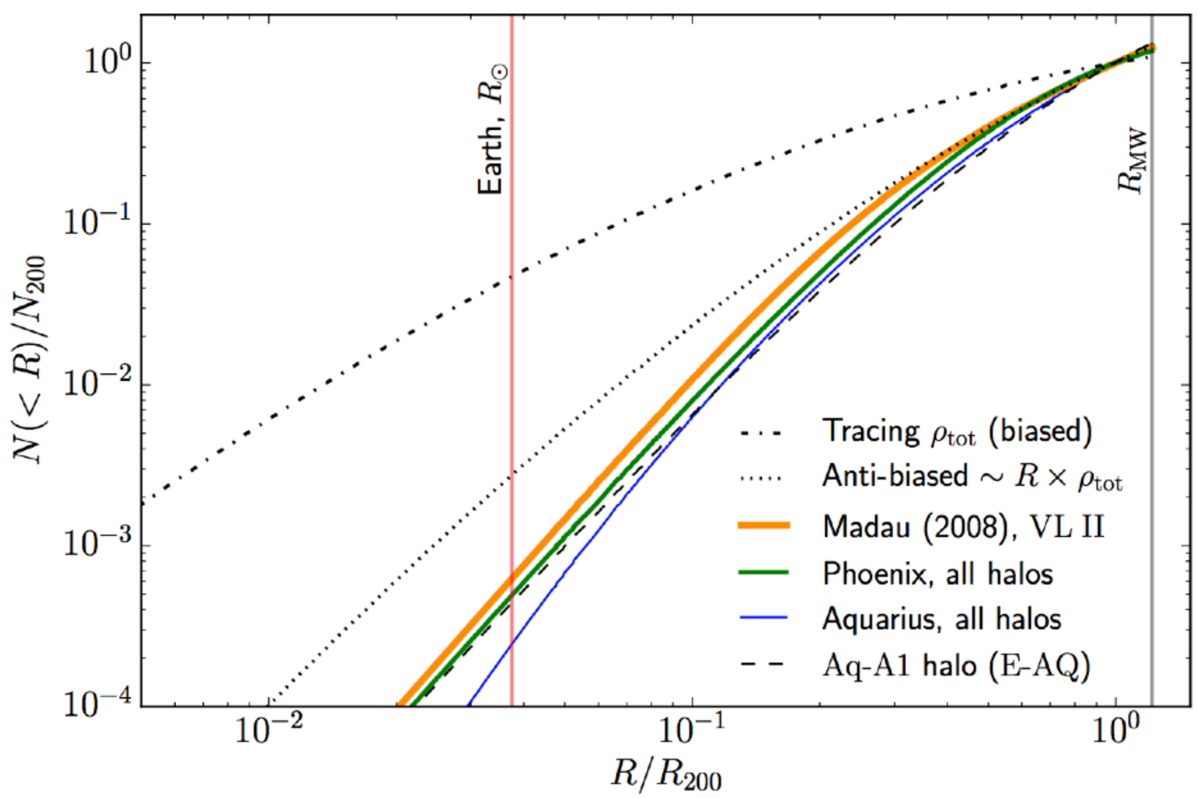
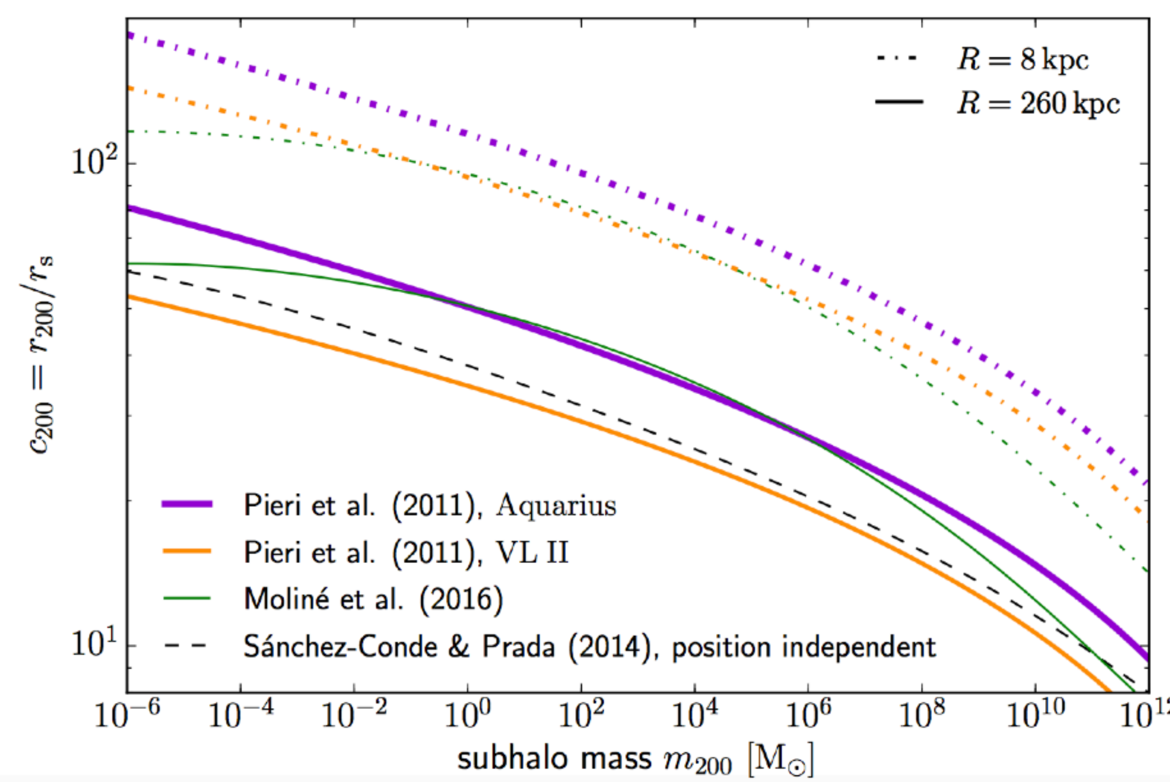
Spatial distribution

- Subhalo spatial distribution does not follow the smooth DM

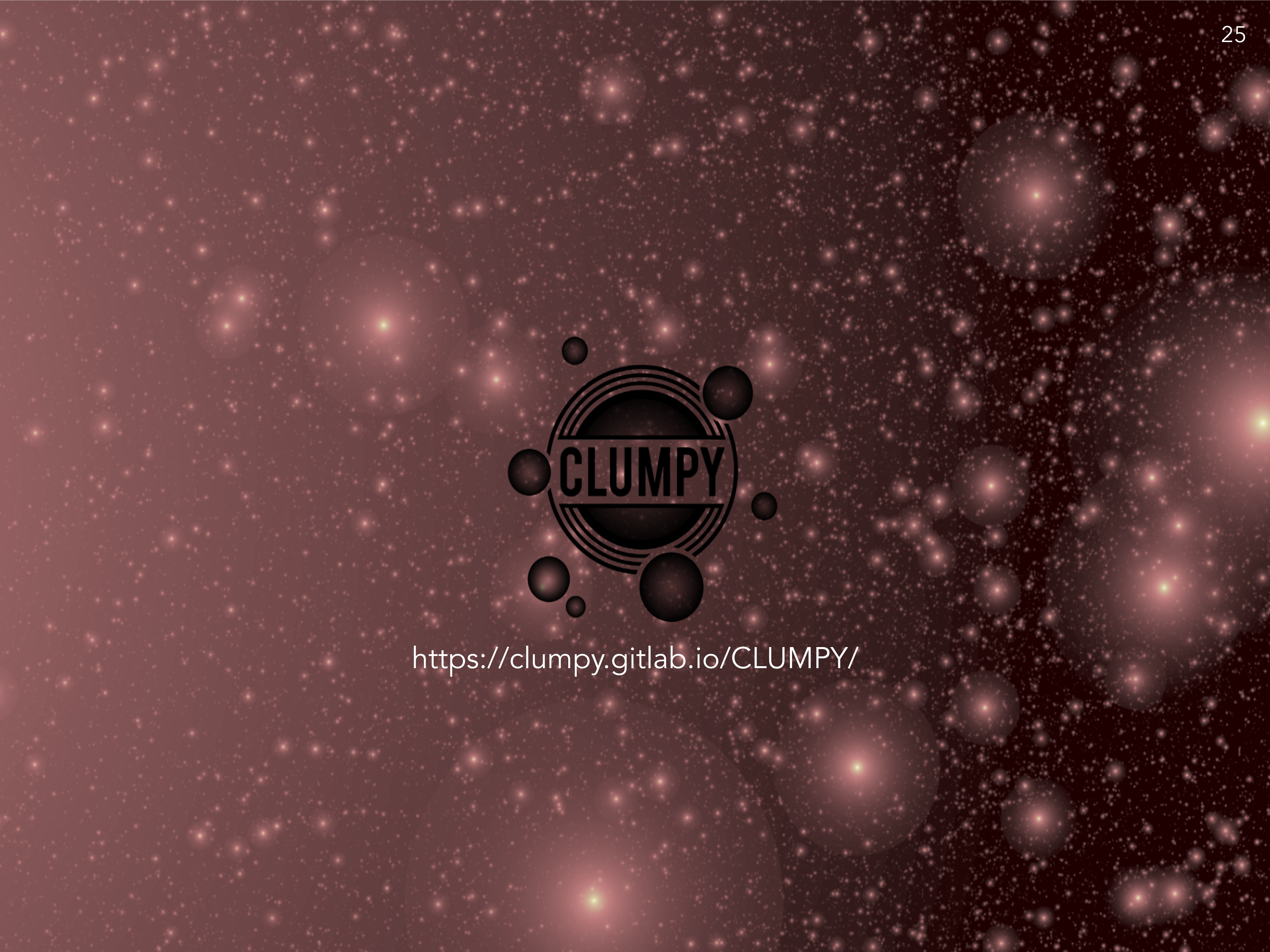


Mass-concentration

- field halos: c(M)
- subhalos: c(M,r) - population evolves in the Galactic potential



All parametrisations based on DM-only simulations
(i.e. tidal effects only from the DM halo included)



https://clumpy.gitlab.io/CLUMPY/

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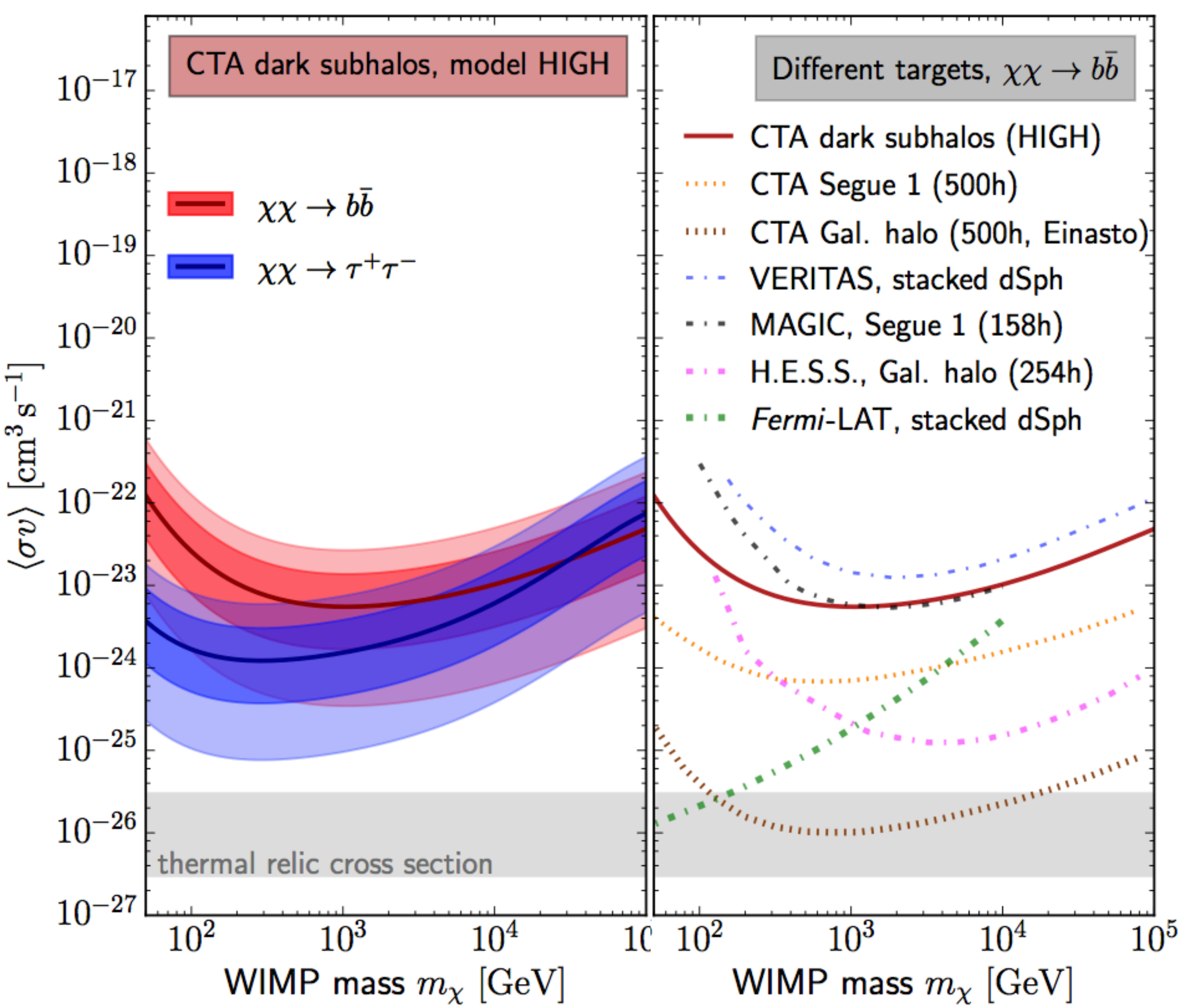


From thousands for CLUMPY runs, mean properties of **the brightest subhalo:**

- Close to us (D~7 - 8 kpc)
- Mass ~ 10^6 - 10^8 Msun

⟶ **could be a dark clump**

Given the uncertainties, **competitive/ complementary with dSph**

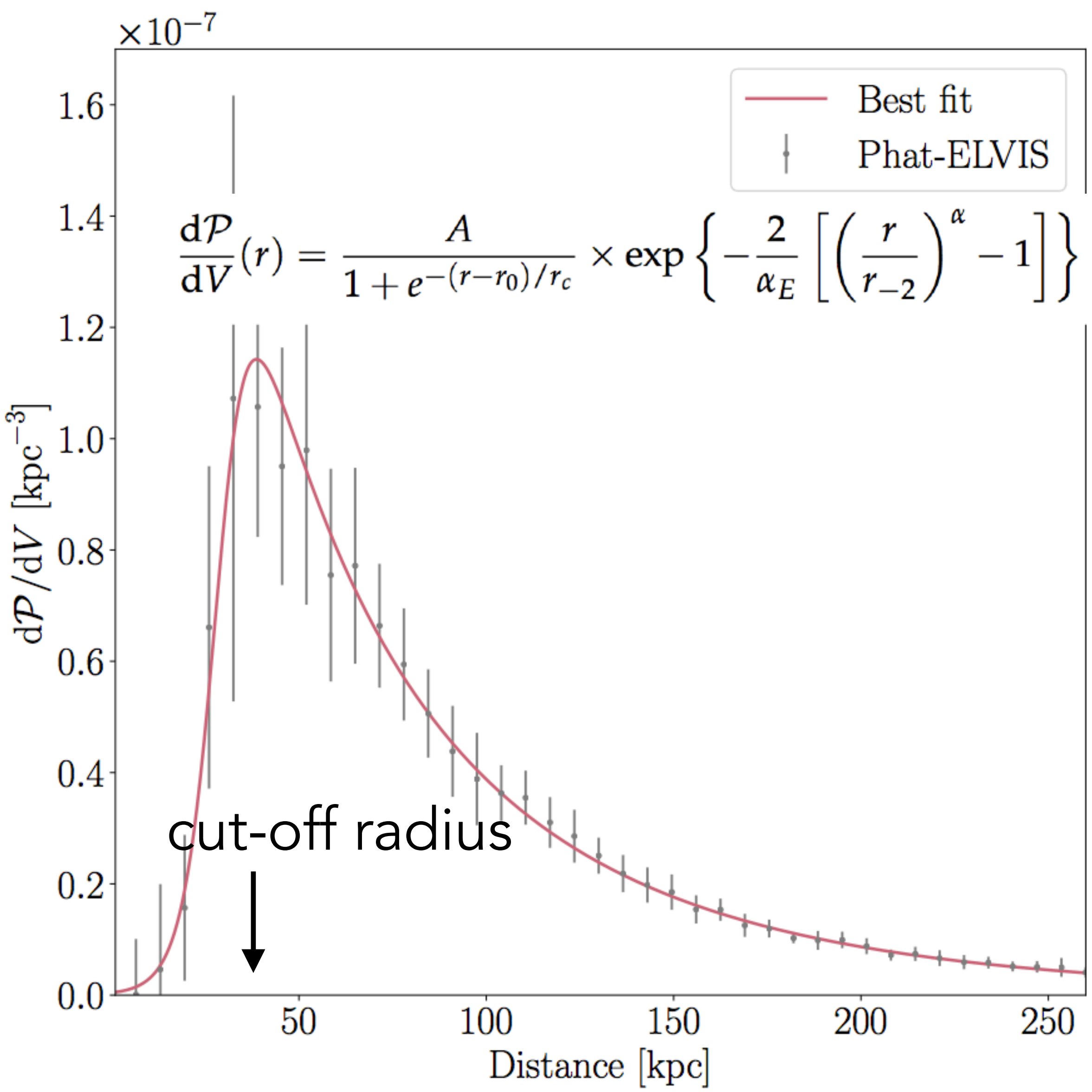
IFT DM substructure workshop - 2018

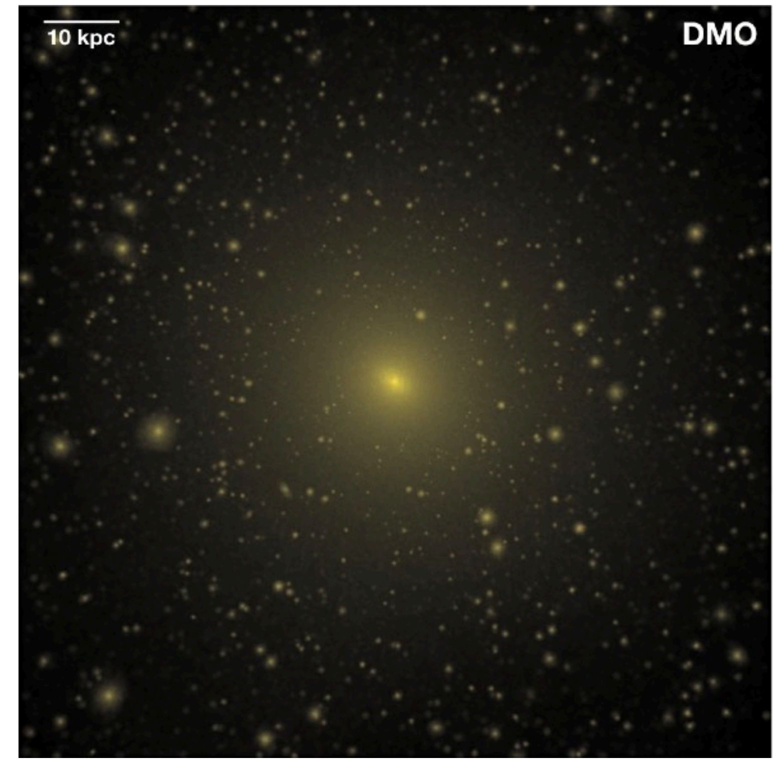
Recent results from Phat-ELVIS simulations (Kelley, Bullock, et al. 2018)

MW's baryonic potential may strongly affect the spatial distribution of the subhalos, especially in the inner regions

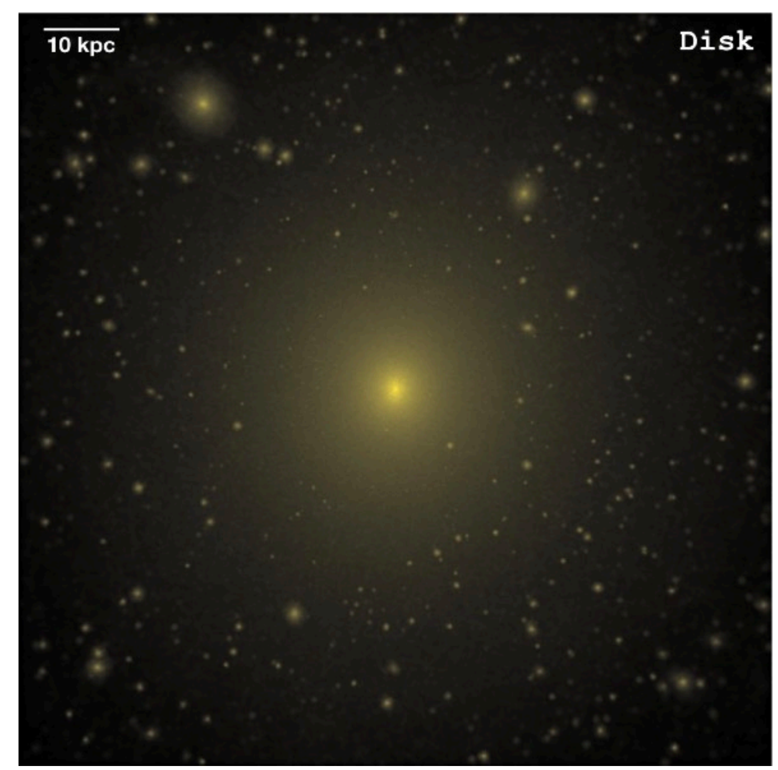
Spatial distribution when including a "baryonic" potential

Phat-ELVIS simulations
(from subhalo catalog provided by T. Kelley)





Kelley+ (2019) https://arxiv.org/abs/1811.12413



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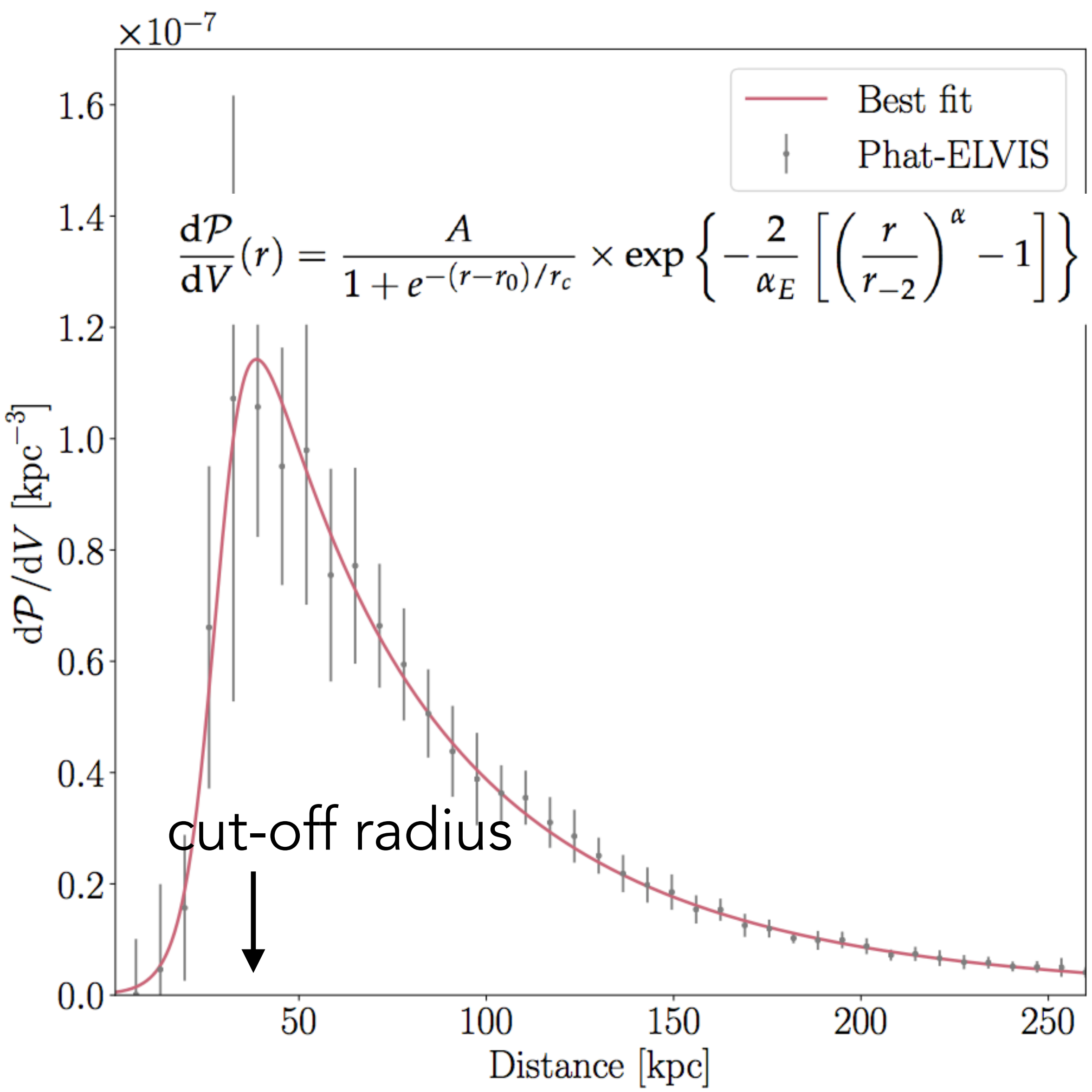
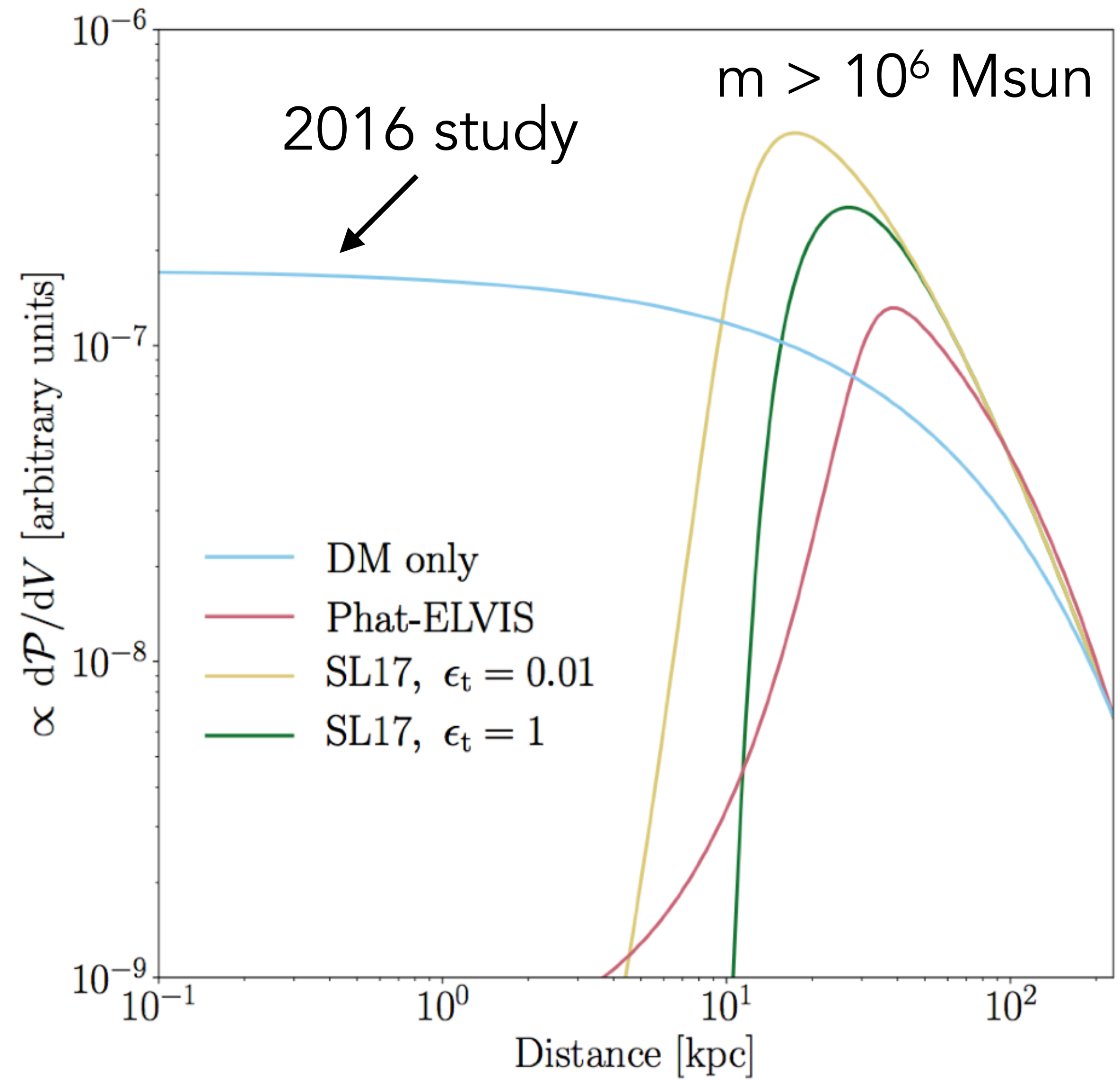


Stref & Lavalle (2017) semi-analytical model



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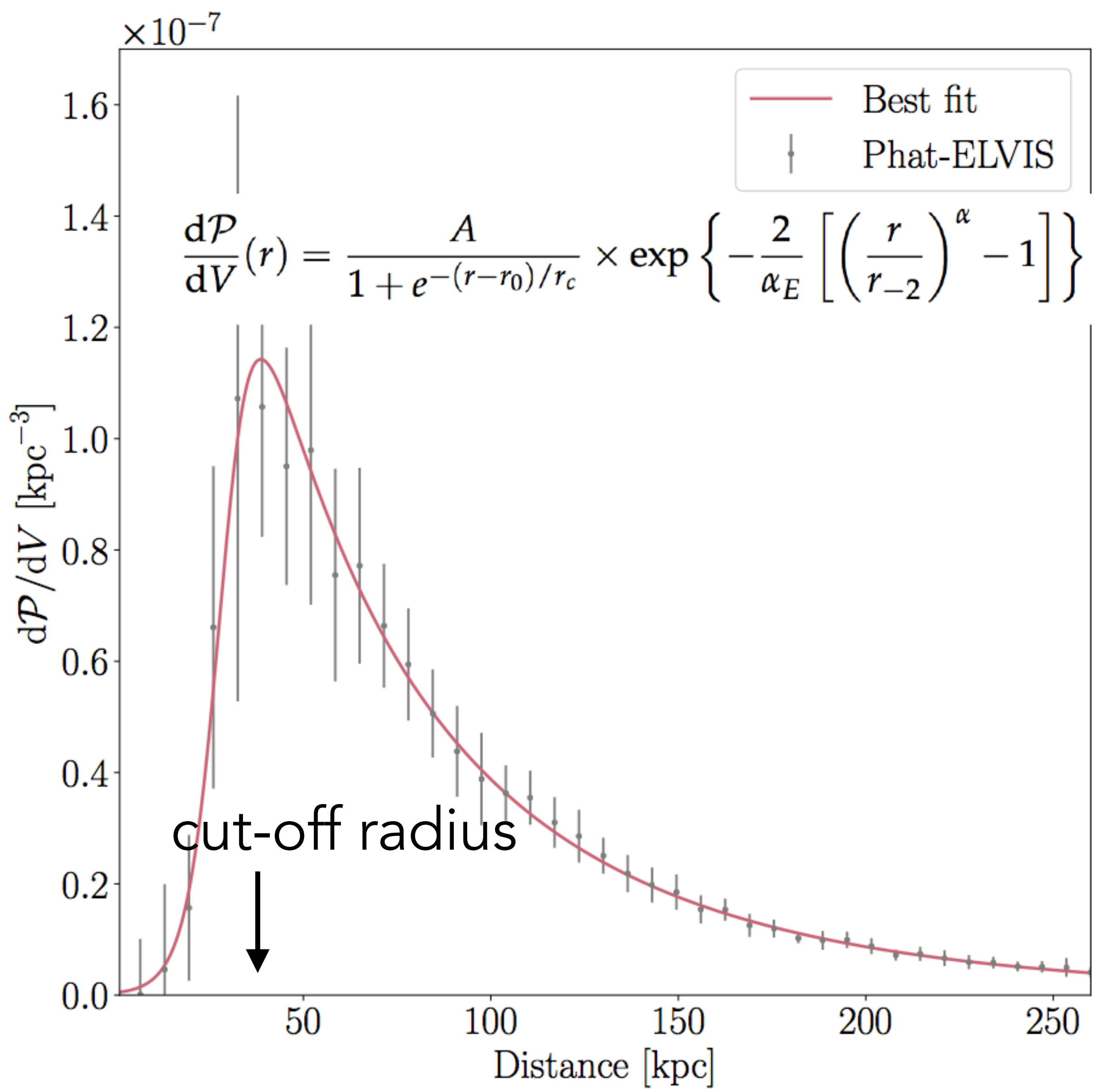

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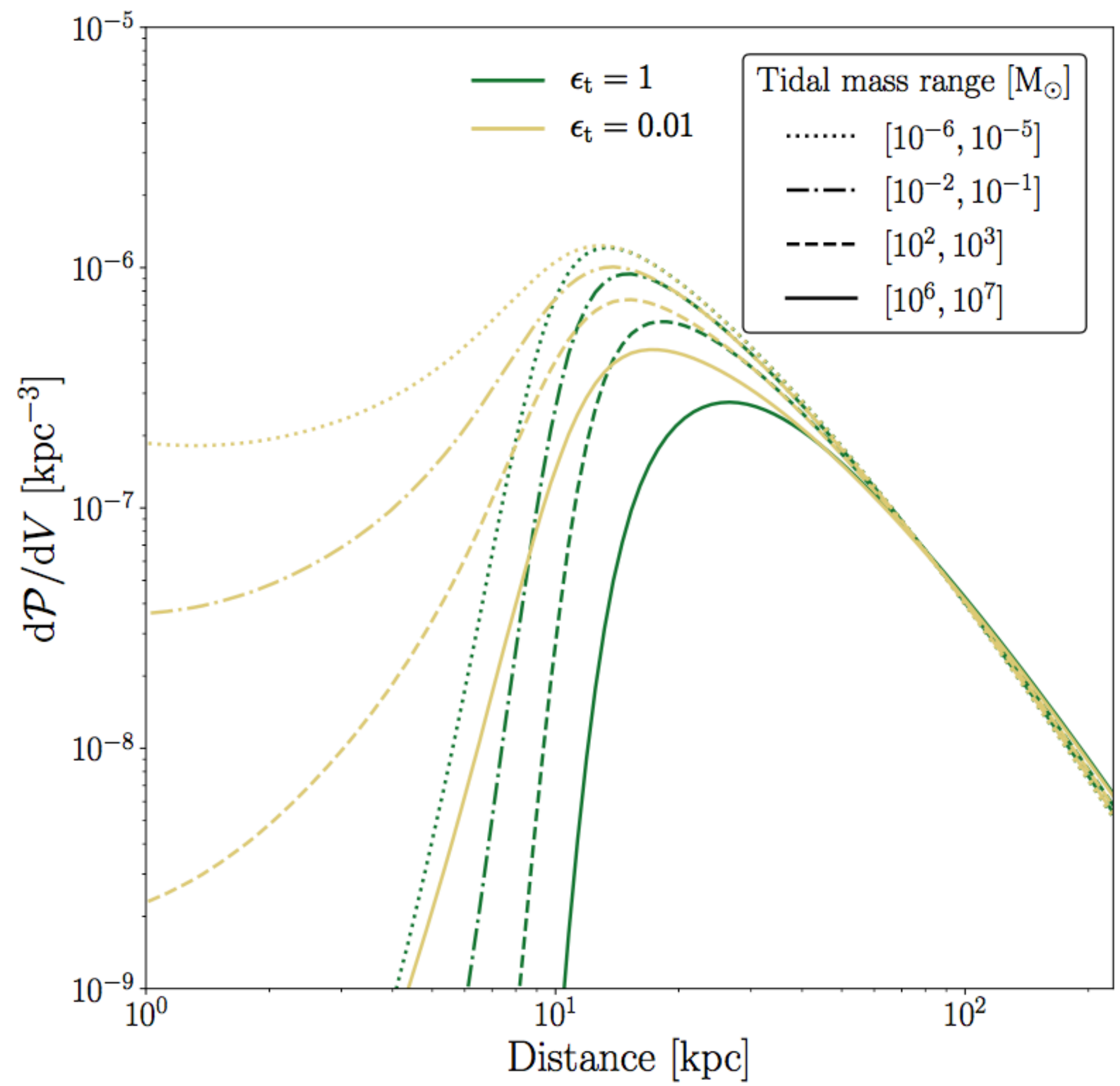

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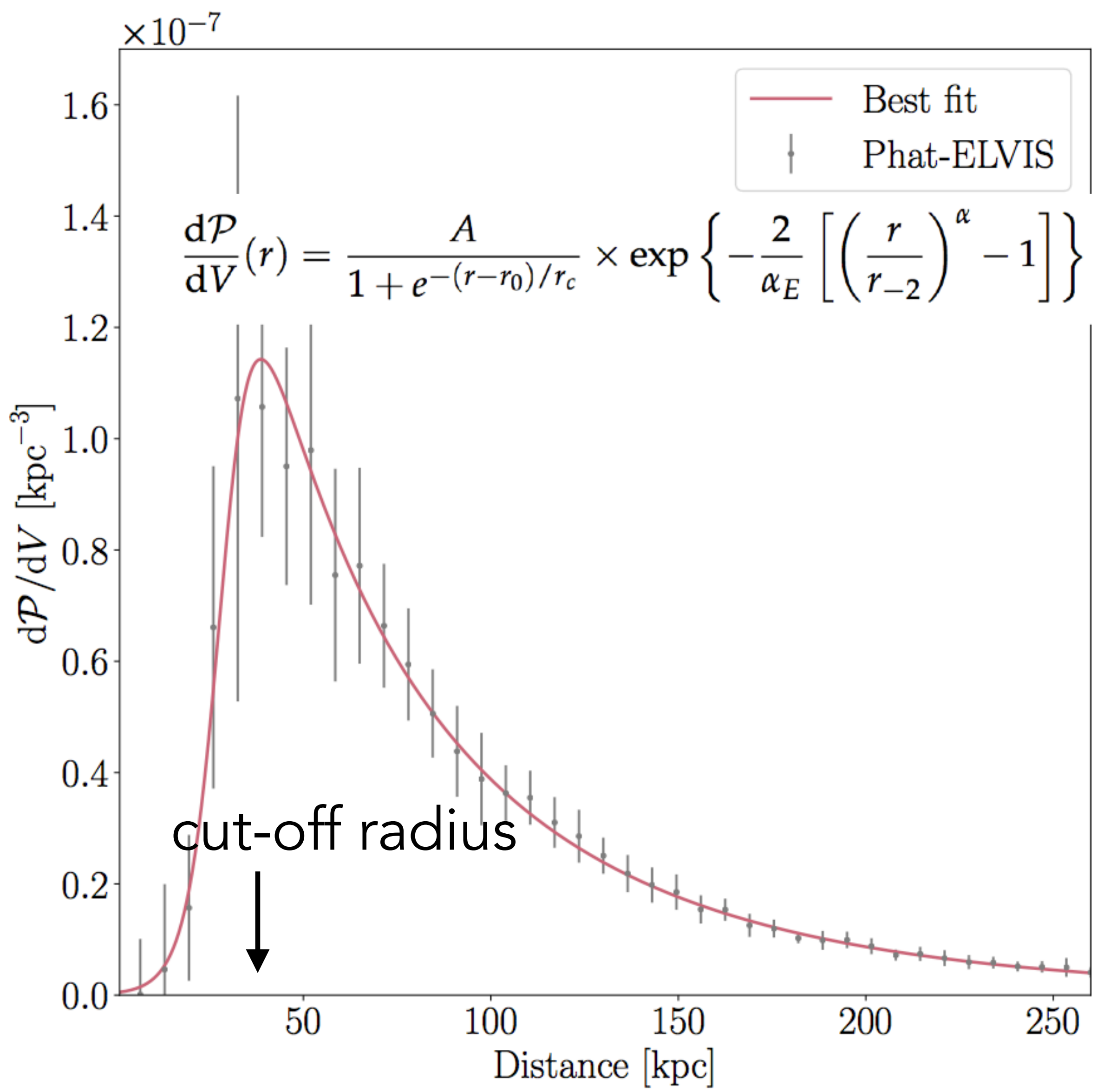

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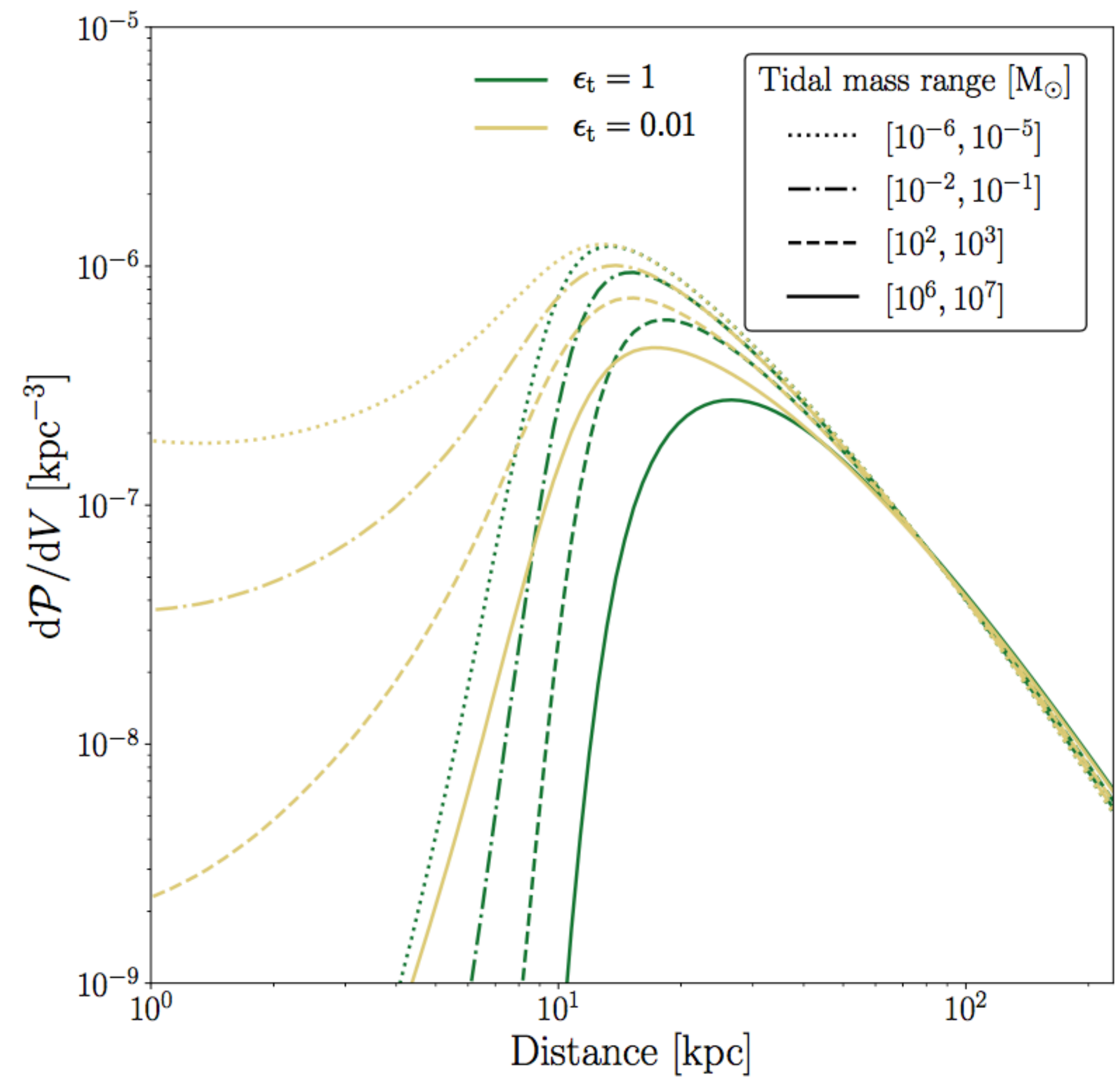


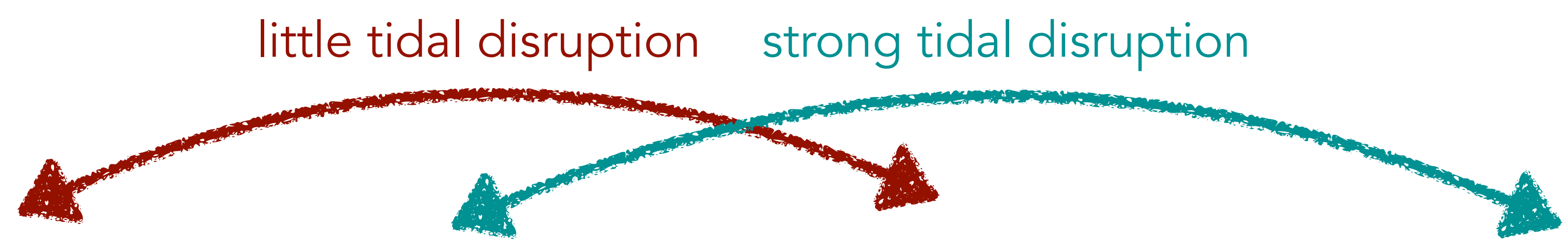
Include both models in CLUMPY and update the 2016 study

So in 2019…

γ-ray and ν Searches for Dark-Matter Subhalos in the Milky Way with a Baryonic Potential

Moritz Hütten [1,*], Martin Stref [2,*], Céline Combet [3], Julien Lavalle [2] and David Maurin [3]

arXiv:1904.10935



	Model #1	Model #2	Model #3	Model #4
$\frac{d\mathcal{P}}{dV}$	Aquarius [74]	Phat-ELVIS [10]	SL17 [15] with $\epsilon_t = 10^{-2}$	SL 17 [15] with $\epsilon_t = 1$
	Einasto	Sigmoid-Einasto Eq. (5)	$\propto \rho_{sm}$	$\propto \rho_{sm}$
	$\alpha_E = 0.68$	$\alpha_E = 0.68$	NFW ⋆	NFW ⋆
	$r_{-2} = 199$ kpc	$r_{-2} = 128$ kpc	$r_{-2} = r_s = 19.6$ kpc ⋆	$r_{-2} = r_s = 19.6$ kpc ⋆
	-	$r_0 = 29.2$ kpc	-	-
	-	$r_c = 4.24$ kpc	-	-
N_{calib}	300	-	276 ⋆	276 ⋆
$N_{surviving}$	-	90	114 ± 11	112 ± 10
$c(m)$	Moliné *et al.* [75]	Moliné *et al.* [75]	Sánchez-Conde & Prada [63]	Sánchez-Conde & Prada [63]

Number of surviving subhalos in [10^8 - 10^{10}] Msun in SL17 ~ matches that of Phat-ELVIS

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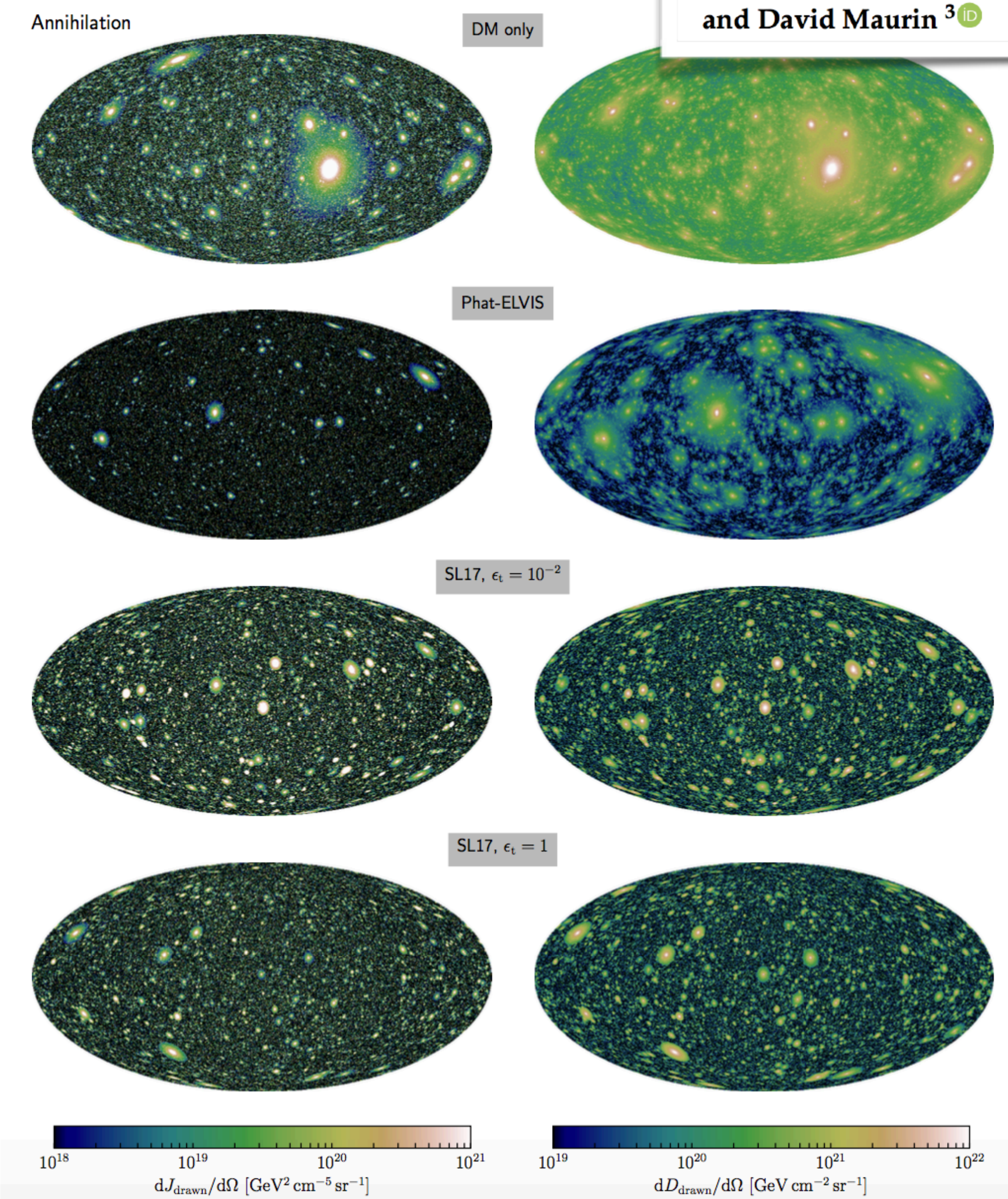

Pretty pictures: one random realisation of each model

↓

Repeat 1000 times and derive statistical properties of the brightest halo

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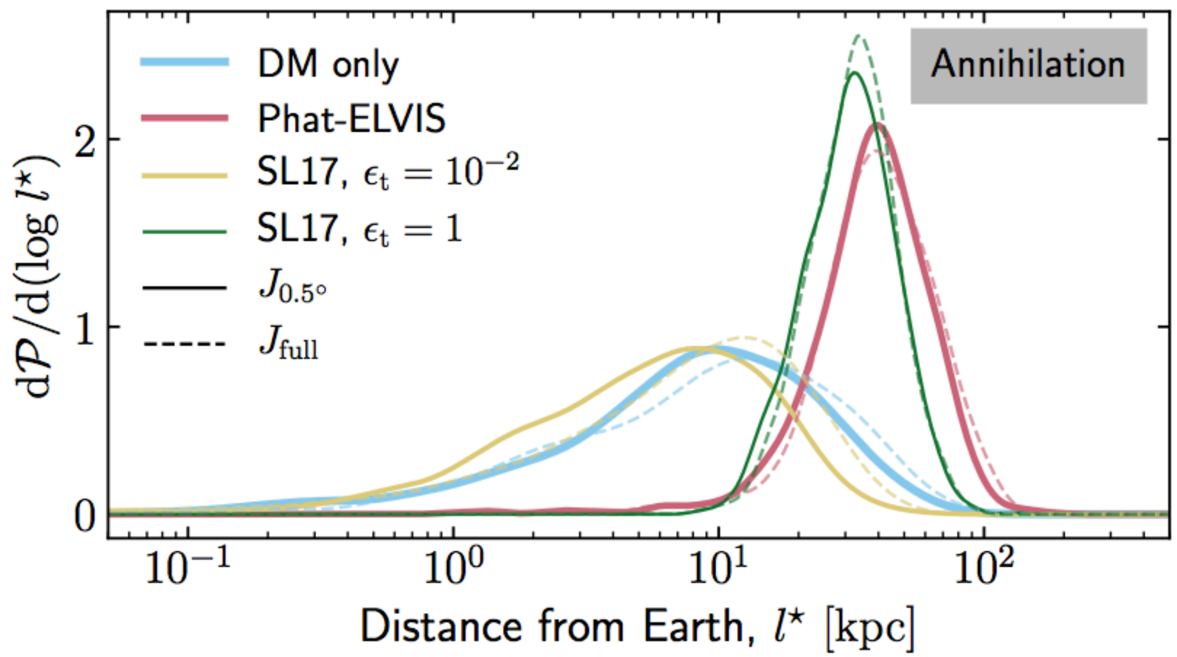
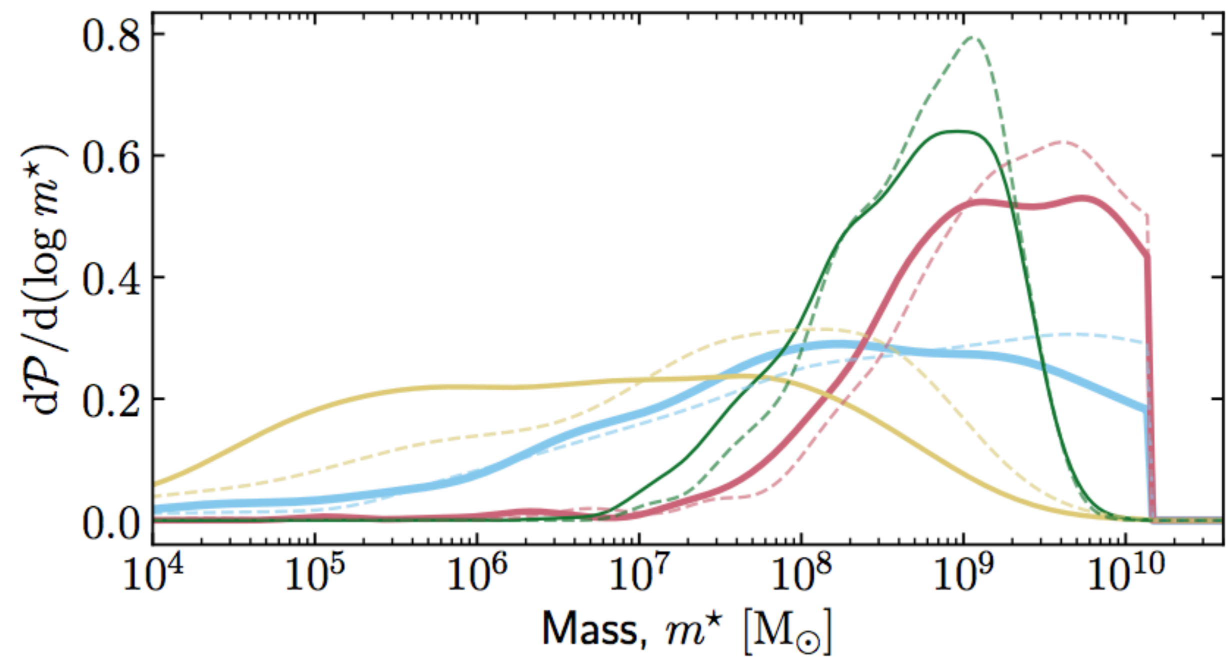
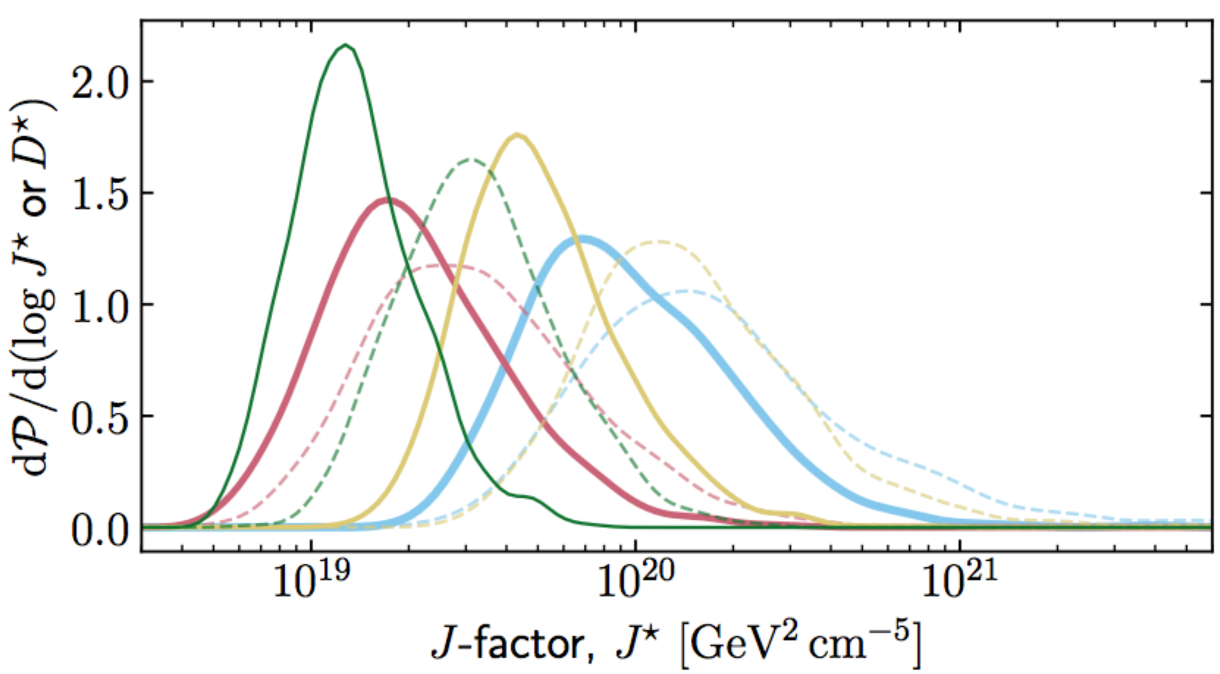






Tidal stripping and disruption by baryonic potential implies that the brightest subhalo:

- is located at larger distances
- is more massive (most likely a dSph)
- has lower J factor

compared to the DM-only/low tidal stripping case.

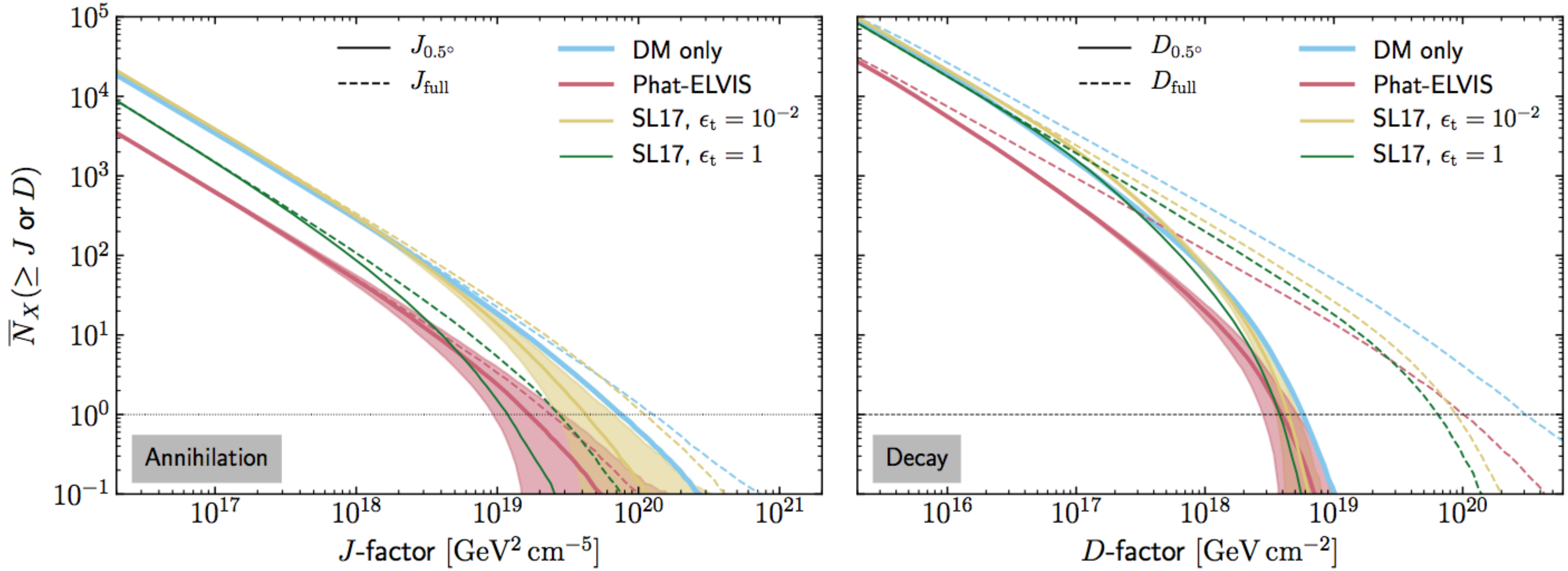
Conclusions

2016 study: DM-only potential

- brightest halo could be a dark clump
- limit competitive with that of dSph when considering all possible sources of uncertainties

2019 update: consider additional baryonic potential

- far less subhalos "close to us"
- properties of the brightest subhalo suggest dSph
- smaller J-factor, i.e. less promising for indirect searches
- D-factor (decay) is not affected



$J_{0.5°}$
$J_{\rm full}$
DM only
Phat-ELVIS
SL17, $\epsilon_t = 10^{-2}$
SL17, $\epsilon_t = 1$
Annihilation
$\overline{N}_X(\geq J$ or $D)$
J-factor $[\rm GeV^2\,cm^{-5}]$
$D_{0.5°}$
$D_{\rm full}$
Decay
D-factor $[\rm GeV\,cm^{-2}]$