Measuring the dark matter content of dwarf spheroidal galaxies and globular clusters

Francesco G. Saturni

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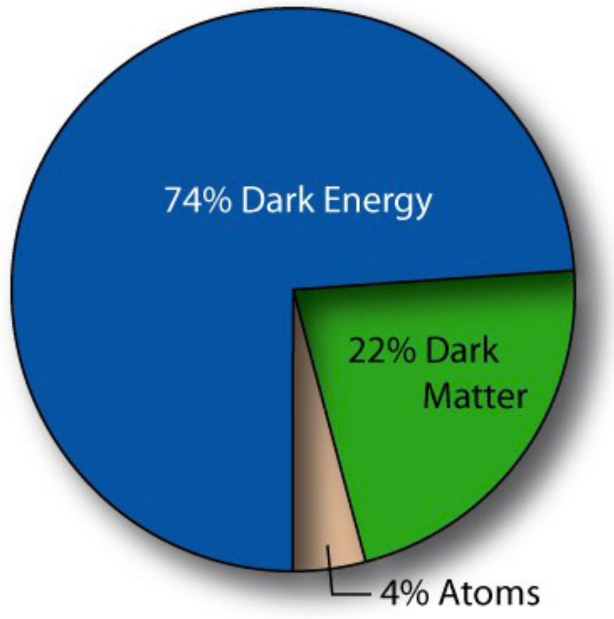
Outline

- The quest for dark matter in the Universe
- Main targets for indirect dark matter searches
- Measuring DM densities in sub-halos
  — dwarf spheroidal galaxies (dSphs)
  — globular clusters (the case of M15)
- Summary

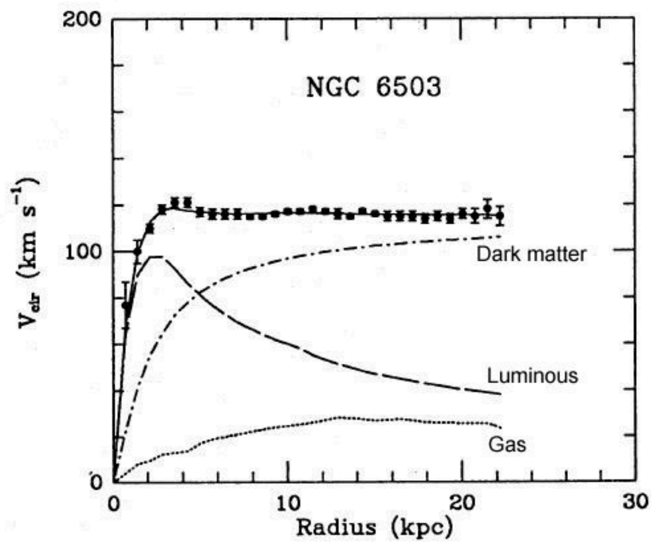

1. The quest for dark matter in the Universe

- Dark matter (DM) is one of the major “fillers” of the Universe:
  — ~85% of the Universe’s matter content;
  — ~22% of the total Universe’s energy budget.



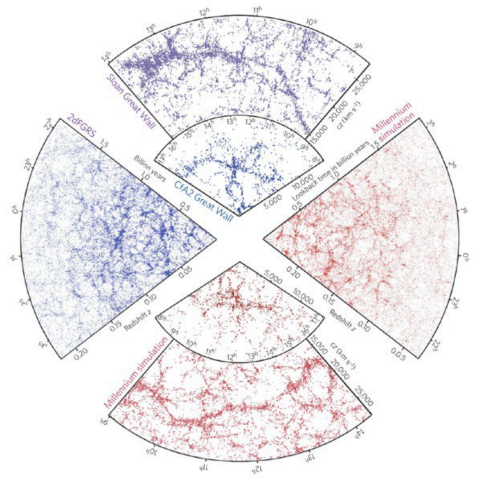
- Its existence is only indirectly inferred so far from several astrophysical/ cosmological observations.

Rotation curves of galaxies

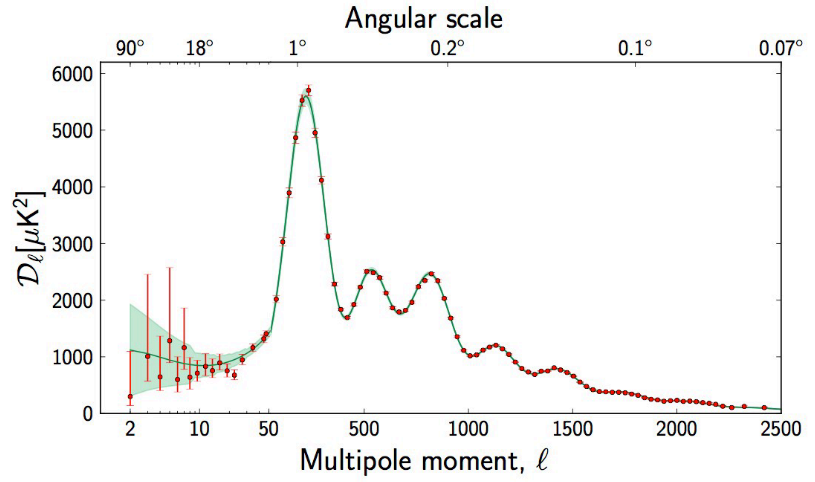


Peculiar objects (e.g. Bullet Cluster)

Cosmological large-scale structures



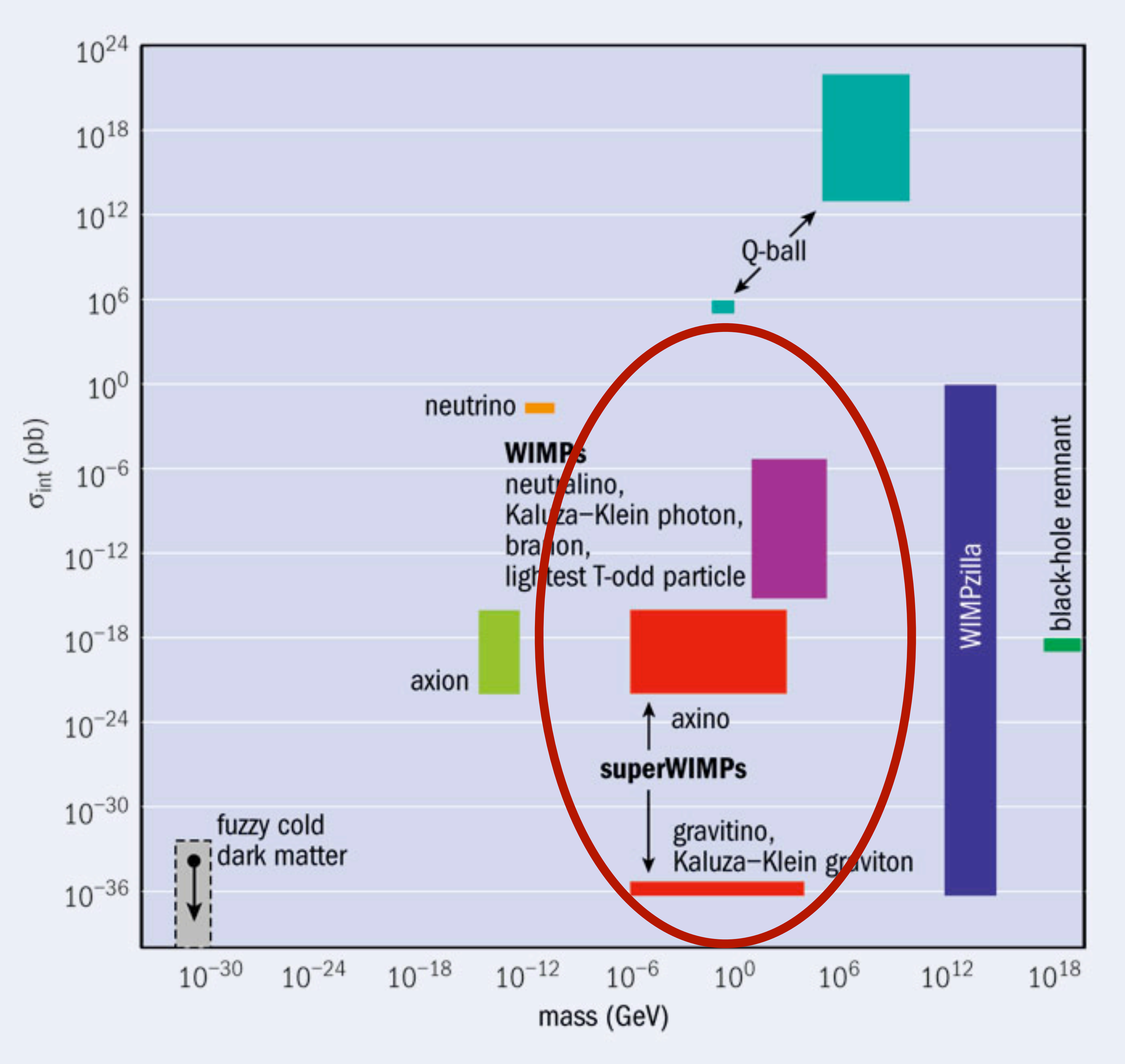
CMB oscillations



1. The quest for dark matter in the Universe

- The zoo of particle DM theories:
  — spread over 48 orders of magnitude in mass and >50 in interaction cross section;
  — origin of DM components from corruptions in the spacetime quantum structure to remnants of primordial macroscopic objects.

- Current preferred paradigm: DM is composed by **<u>particles belonging to the WIMP</u>** (weakly interacting massive particles) family.

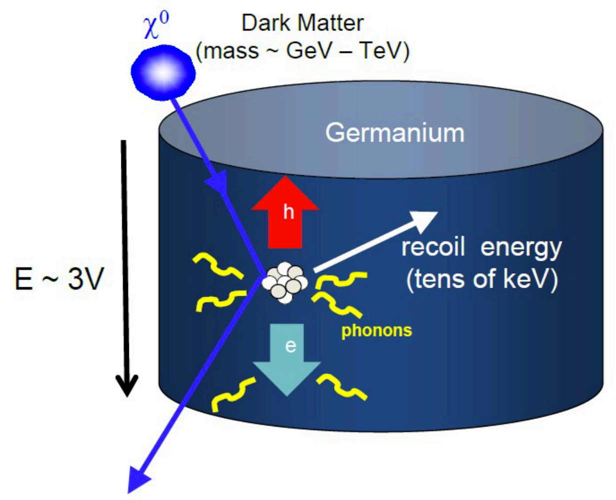


1. The quest for dark matter in the Universe

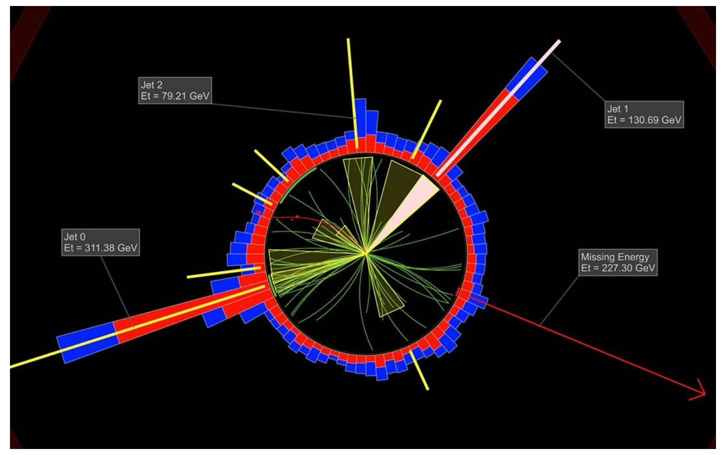
- Events of DM interaction with baryons never observed so far:
  — DM cross section for interaction with baryonic matter must be extremely small (order of weak interactions or below);

- Production of DM candidates in particle accelerators never achieved so far:
  — DM production must be a rare process that happens only in extreme conditions (e.g. the primordial Universe);

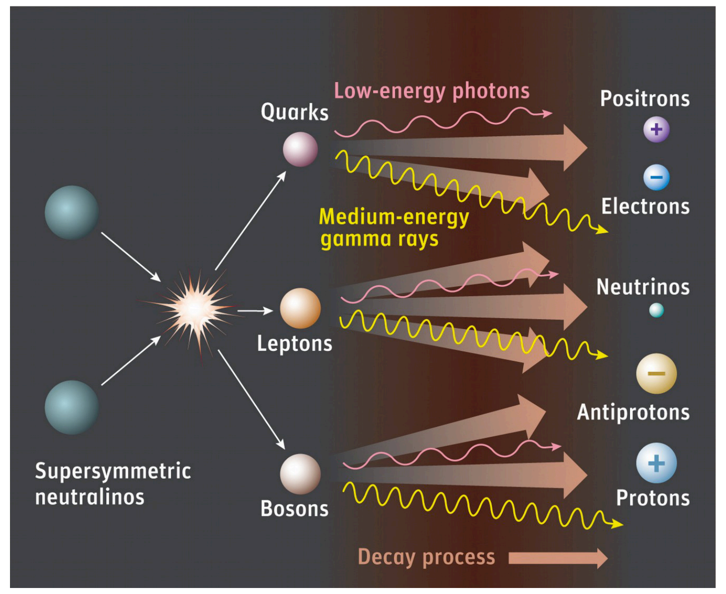
- **<u>Indirect detection</u>** to look for production of Standard Model (SM) particles from DM self-interaction, among which final-state γ-rays.



Direct detection
(collision with baryonic matter)



Direct detection
(production in particle accelerators)



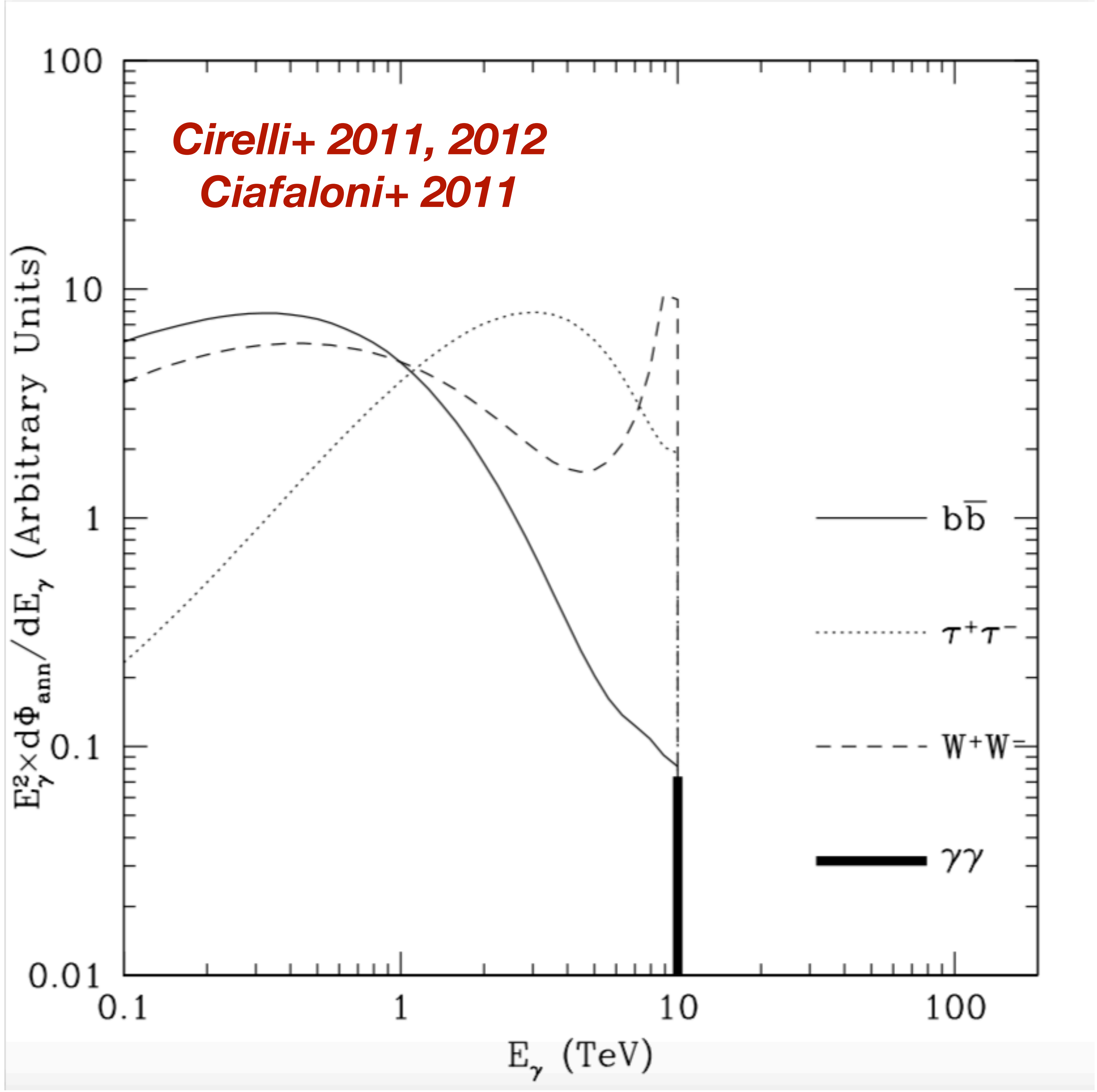
Indirect detection
(interaction into SM products)

1. The quest for dark matter in the Universe

- Expected γ-ray flux from WIMP interactions can be decomposed into:
  — particle-physics term (flux for single interactions);
  — **astrophysical term** — the so-called *J*-factor (for annihilation) or *D*-factor (for decay).

$$J(\Delta\Omega) = \int_{\Delta\Omega} d\Omega \int_{\mathrm{l.o.s.}} \rho^2_{\mathrm{DM}}(\ell;\Omega) d\ell$$

$$D(\Delta\Omega) = \int_{\Delta\Omega} d\Omega \int_{\mathrm{l.o.s.}} \rho_{\mathrm{DM}}(\ell;\Omega) d\ell$$



Spectral shapes expected for DM interaction into SM pairs

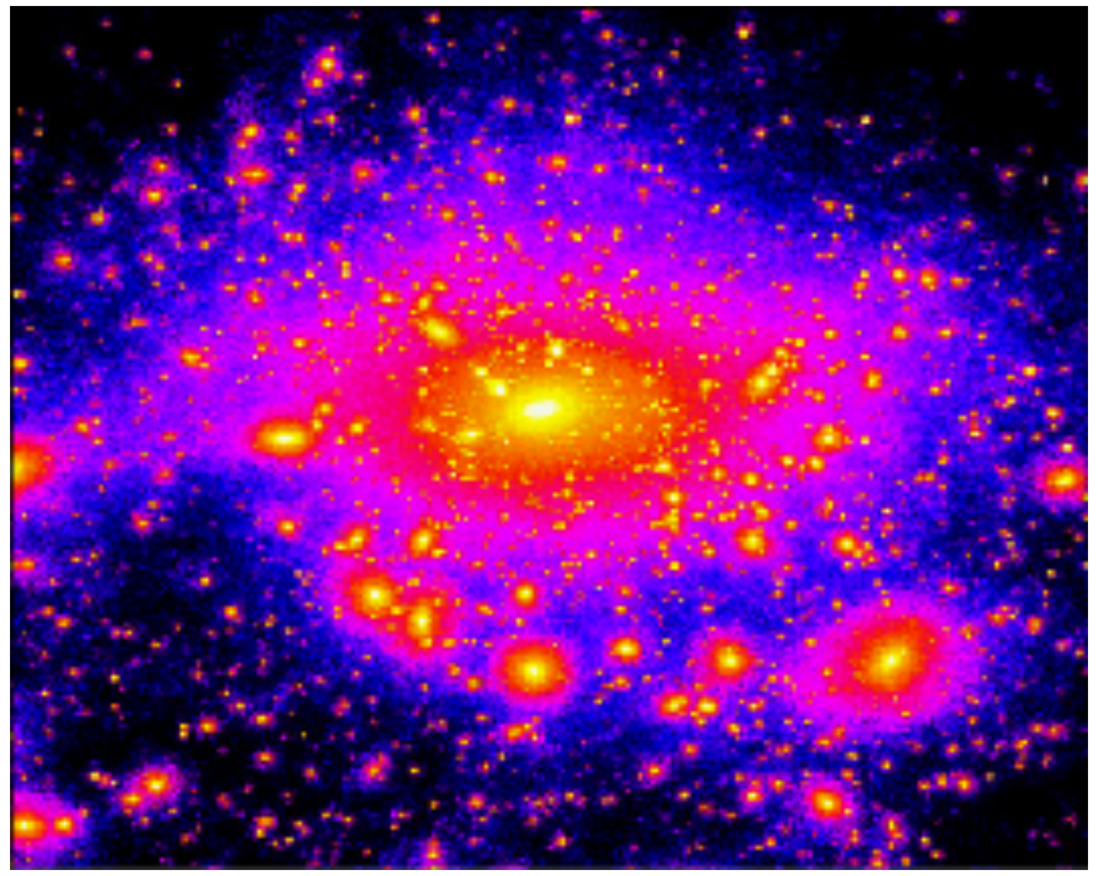
2. Main targets for indirect DM searches

Milky Way center & ridge
— very close
— highly bkg-contaminated
— uncertain DM profile

<u>Dwarf spheroidal galaxies and globular clusters</u>
— high M/L ratio
— no bkg
— small halos => intrinsically low signal

Galaxy clusters
— high DM content
— far
— possibly bkg-contaminated

Dark clumps
— galaxies without stars
— only theoretically predicted so far



2. Main targets for indirect DM searches

- Dwarf spheroidal galaxies (dSphs) are satellites of the Milky Way and other Local Group galaxies that exhibit virial masses much higher than what expected from their stellar luminosities (McConnachie 2012).

- Possible reason: **extreme DM domination**.

virial theorem	$2\langle \mathcal{T} \rangle + \langle U \rangle = 0$
vel. dispersion	$3 m_* \sigma_r^2 = \frac{G M_{tot} m_*}{R}$
gravitational mass	$M_{tot} = \frac{3 R \sigma_r^2}{G}$

$$m_* \approx 1\ \mathbf{M}_\odot \rightarrow M_* \approx N\ \mathbf{M}_\odot \Rightarrow L_{tot} \approx N\ \mathbf{L}_\odot$$

expected

$$\left(\frac{M_{tot}}{L_{tot}}\right)_{theo} = \frac{M_*}{L_{tot}} \lesssim 10$$

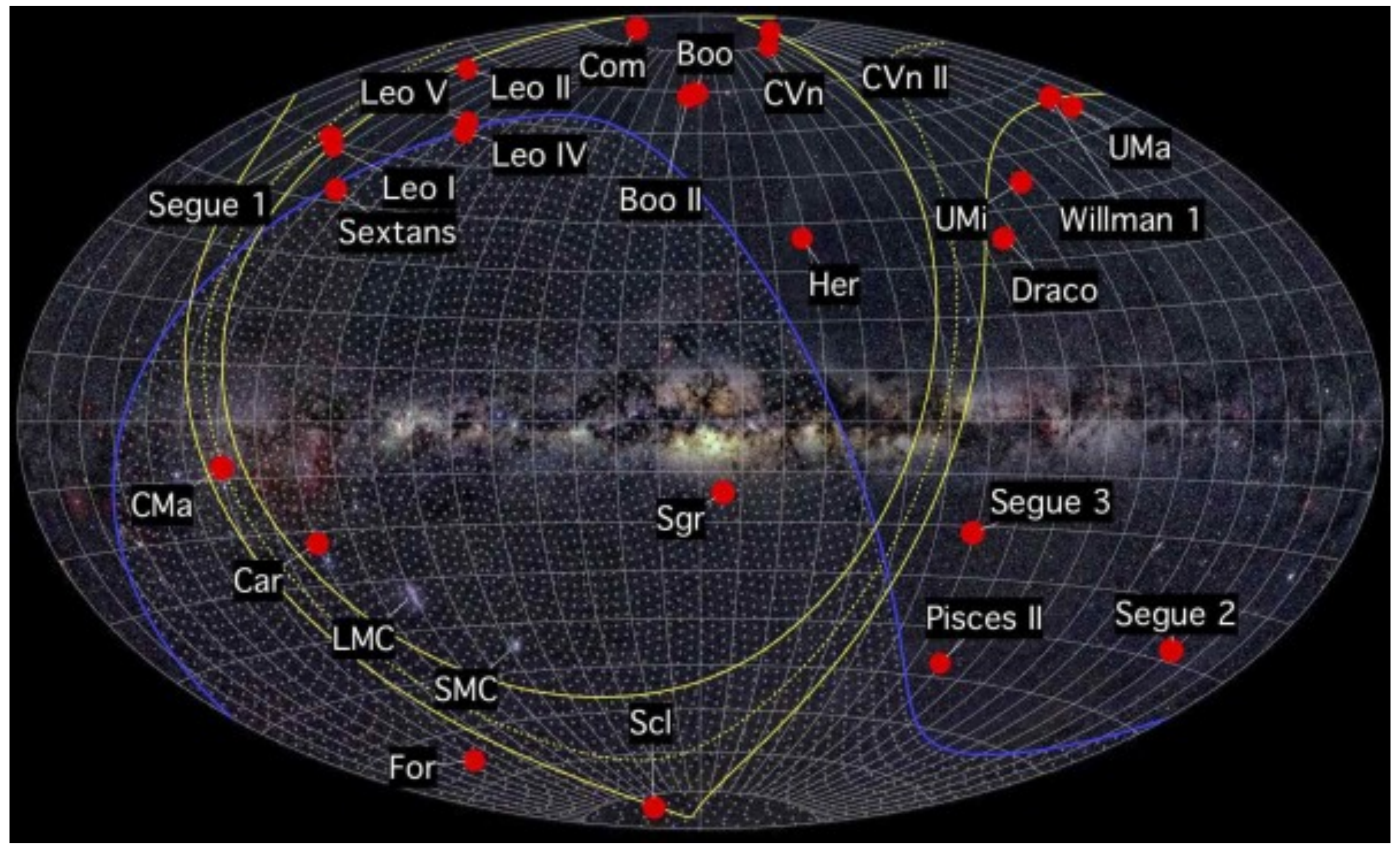
measured

$$10 \lesssim \left(\frac{M_{tot}}{L_{tot}}\right)_{meas} \lesssim 1000$$

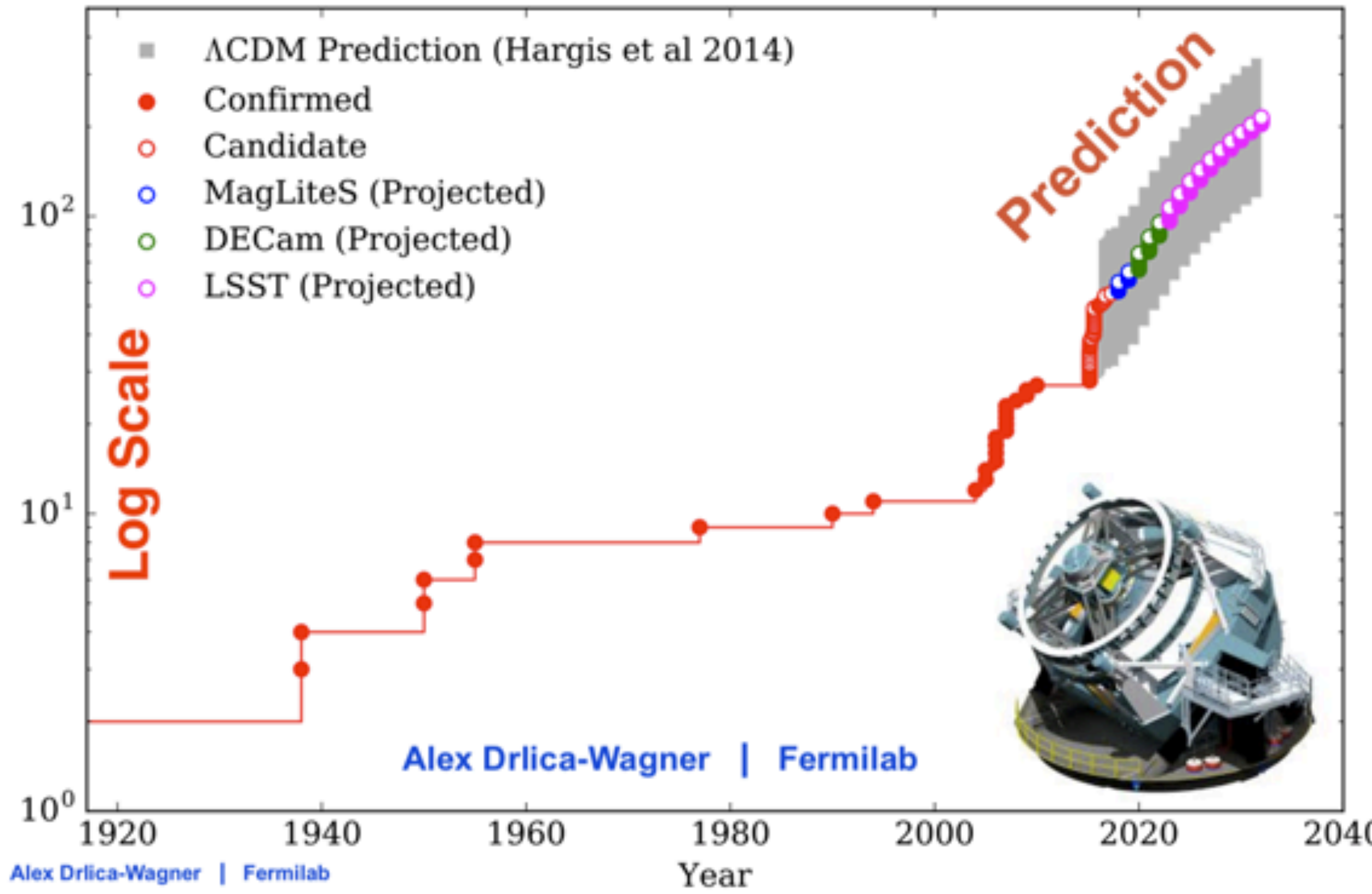
The Sculptor dSph (credits: D. Malin/AAO)

2. Main targets for indirect DM searches

- Several dSphs known around the MW.
- Two main categories:
  1. classical dSphs — $O(100)$ to $O(1000)$ member stars
  2. ultra-faint dSphs — less than $O(10)$ to less than $O(100)$ member stars
- Many more (ultra-faint) dSphs are being discovered now thanks to performance improvements of telescope technologies.



Sky distribution of dSphs



Prospects for future discoveries of dSphs

2. Main targets for indirect DM searches

- Globular clusters (GCs) are the oldest objects in galaxies, born at most right after the formation of their parent galaxy.
- According to the Λ-CDM scenario, GCs should be embedded in a dark matter (DM) halo since the beginning of their life.
- However, their measured mass-to-light (M/L) ratio is generally ~1 => GCs are mostly DM-free objects (Conroy+ 2011).
- Nevertheless, there could still be the possibility of **DM domination for some GCs that are formed within massive halos** (Williamson+ 2016).

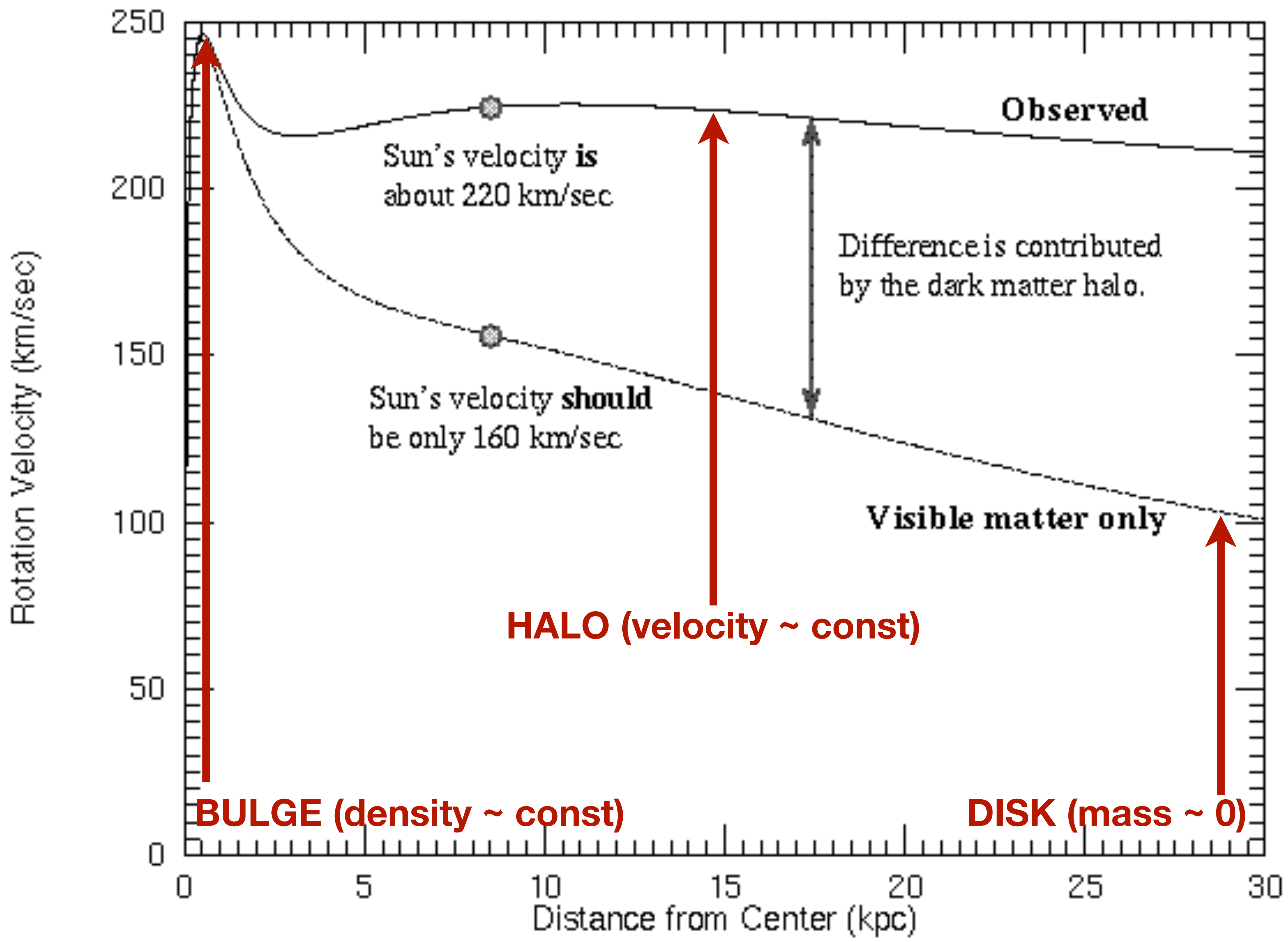
The globular cluster M15
(credits: A. Block/Mt. Lemmon SkyCenter/Univ. of Arizona)

3. Measuring DM densities in sub-halos

- DM was introduced to explain the velocity distribution of galaxies in the Coma cluster (Zwicky 1930) and later adopted to successfully describe the flattening of rotation curves in spiral galaxies (Zwicky 1933, Bertone & Hooper 2016).

- Rotation curves of spiral galaxies usually derived from measurements of gas clouds; for other types of objects, problems are:
  — no or little rotational support;
  — no gas to measure rotation velocity.

- Need of a paradigm change (equations + velocity tracer): **<u>Jeans analysis</u>**.



The gravity of the visible matter in the Galaxy is not enough to explain the high orbital speeds of stars in the Galaxy. For example, the Sun is moving about 60 km/sec too fast. The part of the rotation curve contributed by the visible matter only is the bottom curve. The discrepancy between the two curves is evidence for a **dark matter halo**.

3. Measuring DM densities in sub-halos

- Jeans analysis assumptions:
  — collisionless system
  — steady state
  — negligible rotational support
  — spherical symmetry (not essential)

DISCLAIMER: such assumptions lead to several caveats that must be taken into account when interpreting results!

- Second-order development of the Jeans equations (Binney & Tremaine 2008):

$$\frac{1}{n_*}\left[\frac{d}{dr}\left(n_*\overline{v_r^2}\right)\right]+\frac{2}{r}\beta_{\rm ani}(r)\overline{v_r^2}=-\frac{G\left[M_{\rm DM}(r)+M_*(r)\right]}{r^2}$$

$$n_* = n_*(r)$$

luminosity profiles

$$\beta_{\rm ani}(r)=1-\frac{\overline{v_\theta^2}}{\overline{v_r^2}}$$

velocity anisotropy

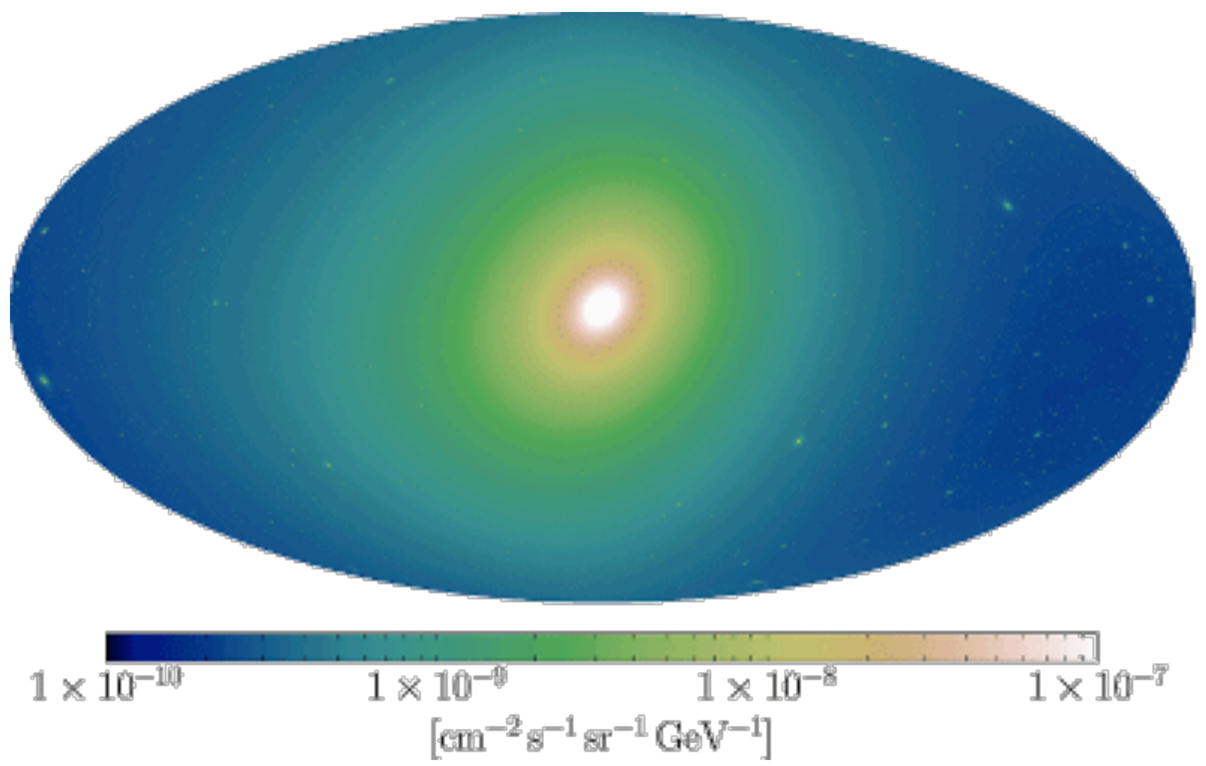
$$M_*(r)\approx 0$$

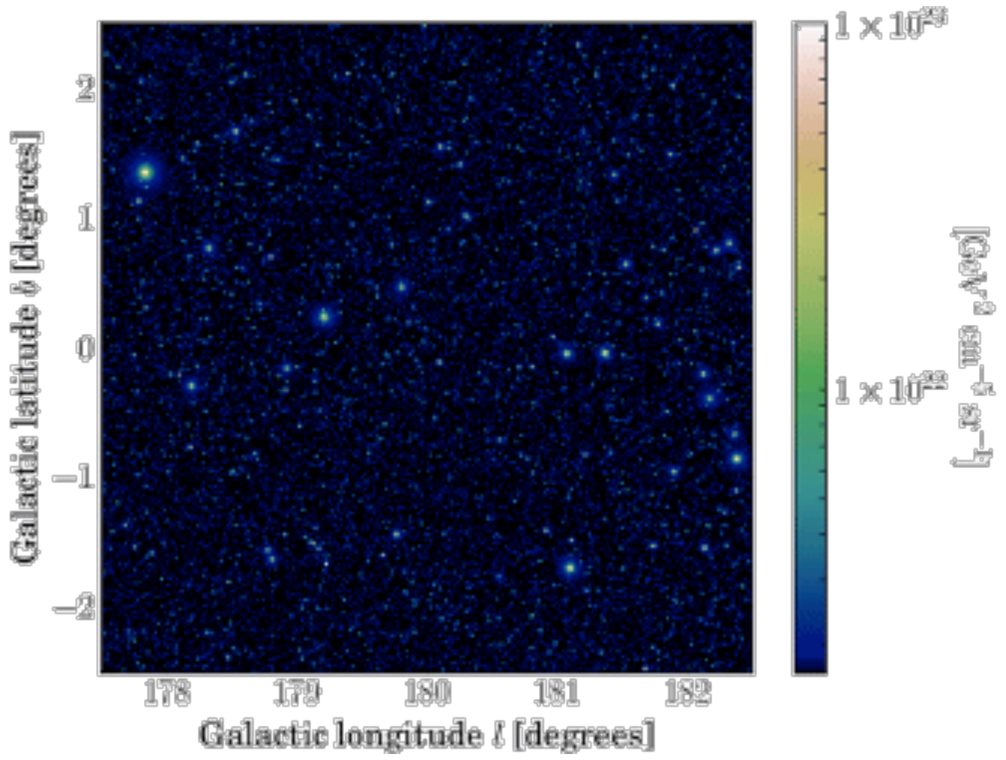
DM domination (if verified)

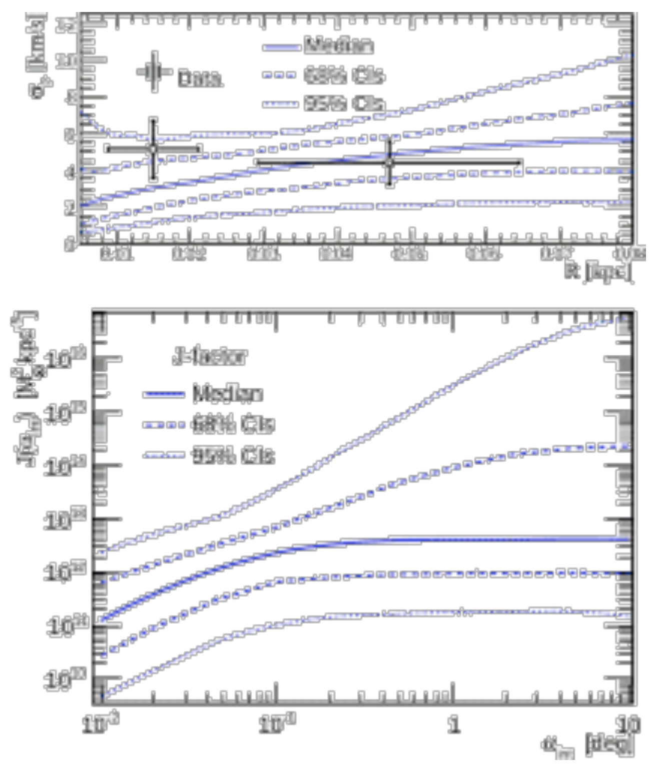
3. Measuring DM densities in sub-halos

- The Jeans analysis of stellar kinematics is one of the methods that provides the most robust constraints on the DM amount in sub-halos.

- Main tool: **MCMC Jeans analysis of stellar kinematics with CLUMPY** (Charbonnier+ 2012, Bonnivard+ 2016, Hütten+ 2019).







3. Measuring DM densities in sub-halos

- Empirically driven DM density profiles:
  — cuspy (Einasto 1965; NFW)
  — cored (Burkert 1995)

$$\rho_{\rm DM}^{\rm Ein}(r) = \rho_s \exp\left\{-\frac{2}{\alpha}\left[\left(\frac{r}{r_s}\right)^{\alpha} - 1\right]\right\}$$

$$\rho_{\rm DM}^{\rm Bur}(r) = \frac{\rho_s}{\left(1 + r/r_s\right)\left[1 + \left(r/r_s\right)^2\right]}$$

- Light profile from surface luminosity fitting:
  — 2D King (1962)
  — 3D Zhao-Hernquist (generalized NFW)

$$\Sigma_*(R) = 2\int_R^{+\infty} \frac{n_*(r)r}{\sqrt{r^2 - R^2}} dr$$

- Most general solution for velocity anisotropy profile:
  — Baes & van Hese (2007)

$$\rho_{\rm DM}(r) = \tilde{\rho}_{\rm DM}\left[\psi(r), r\right] = f(\phi)g(r) \Rightarrow \beta_{\rm ani}(r) = -\frac{1}{2}\left(\frac{d\ln g}{d\ln r}\right) = \frac{\beta_0 + \beta_\infty (r/r_a)^\eta}{1 + (r/r_a)^\eta}$$

3. Measuring DM densities in sub-halos: the dwarf spheroidal galaxies

- Optimal dSphs selected according to:
  1. Distance (<100 kpc)
  2. Availability of brightness and/or kinematic data

- Surviving sample:
  — 8 Northern dSphs (2 classical + 6 ultra-faint)
  — 6 Southern dSphs (3 classical + 3 ultra-faint)

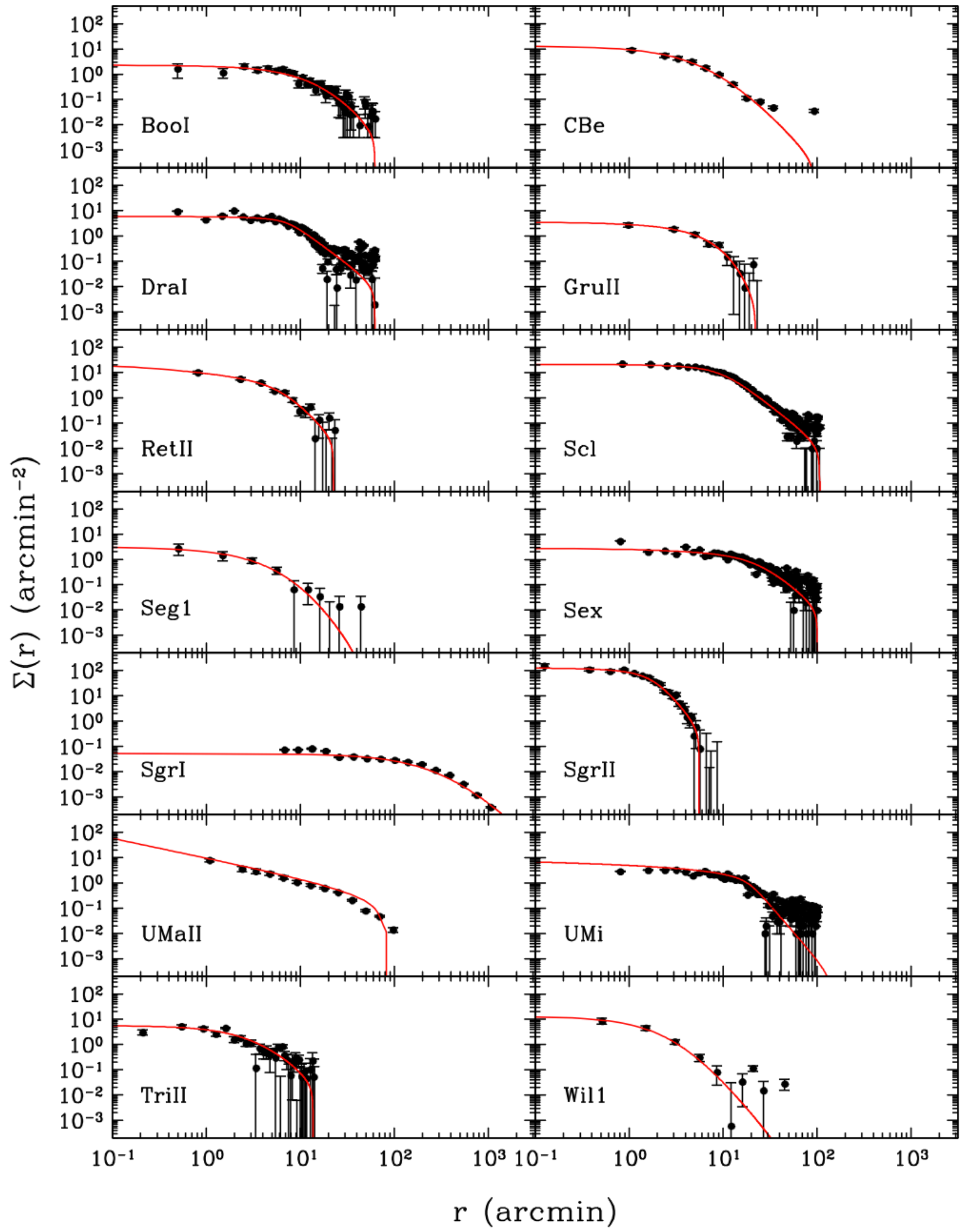
Name	Abbr.	Type	R.A. (hh mm ss)	dec. (dd mm ss)	Distance (kpc)	ZA_{culm} N (deg)	ZA_{culm} S (deg)	Month	Ref.
Boötes I	BoöI	uft	14 00 06.0	+14 30 00	65 ± 3	14.3	39.1	Apr	1,2
Boötes II	BoöII	uft	13 58 00.0	+12 51 00	39 ± 2	15.9	37.5	Apr	1,3
Boötes III	BoöIII	uft	13 57 12.0	+26 48 00	46 ± 2	2.0	51.4	Apr	1,3
Coma Berenices	CBe	uft	12 26 59.0	+23 54 15	42 ± 2	4.9	48.5	Mar	1,4
Draco I	DraI	cls	17 20 12.4	+57 54 55	75 ± 4	29.2	82.5	Jun	1,5
Draco II	DraII	uft	15 52 47.6	+64 33 55	20 ± 3	35.8	89.2	May	6
Laevens 3	Lae3	uft	21 06 54.3	+14 58 48	67 ± 3	13.8	39.6	Aug	7
Segue 1	Seg1	uft	10 07 04.0	+16 04 55	23 ± 2	12.7	40.7	Feb	1,8
Segue 2	Seg2	uft	02 19 16.0	+20 10 31	36 ± 2	8.6	44.8	Oct	1,9
Triangulum II	TriII	uft	02 13 17.4	+36 10 42	30 ± 2	7.4	60.8	Oct	10
Ursa Major II	UMaII	uft	08 51 30.0	+63 07 48	35 ± 2	34.4	87.8	Feb	1,11
Ursa Minor	UMi	cls	15 09 08.5	+67 13 21	68 ± 2	38.5	—	May	1,12
Willman 1	Wil1	uft	10 49 21.0	+51 03 00	38 ± 7	22.3	75.7	Mar	1,8
Carina II	CarII	uft	07 36 26.3	−58 00 00	36 ± 1	86.7	33.3	Jan	13
Carina III	CarIII	uft	07 38 31.2	−57 54 00	28 ± 2	86.7	33.3	Jan	13
Cetus II	CetII	uft	01 17 52.8	−17 25 12	30 ± 3	46.2	7.2	Oct	14
Eridanus III	EriIII	uft	02 22 45.5	−52 16 48	95 ± 27	81.0	27.7	Oct	15
Grus II	GruII	uft	22 04 04.8	−46 26 24	53 ± 5	75.2	21.8	Aug	14
Horologium I	HorI	uft	02 55 28.9	−54 06 36	87 ± 13	82.9	29.5	Oct	15
Horologium II	HorII	uft	03 16 26.4	−50 03 00	78 ± 8	77.5	26.7	Nov	16
Hydrus I	HyiI	uft	02 29 33.7	−79 18 36	28 ± 1	—	53.3	Oct	17
Indus I	IndI	uft	21 08 48.1	−51 09 36	69 ± 16	79.9	26.5	Aug	15
Phoenix II	PheII	uft	23 39 57.6	−54 24 36	95 ± 18	83.2	29.8	Sep	15
Pictor II	PicII	uft	06 44 43.1	−59 54 00	45 ± 5	88.3	35.8	Jan	18
Reticulum II	RetII	uft	03 35 40.9	−54 03 00	32 ± 2	82.8	29.4	Nov	15
Reticulum III	RetIII	uft	03 45 26.3	−60 27 00	92 ± 13	89.2	35.8	Nov	19
Sagittarius I	SgrI	cls	18 55 19.5	−30 32 43	31 ± 1	59.3	5.9	Jul	1,20
Sagittarius II	SgrII	uft	19 52 40.5	−22 04 05	67 ± 5	50.8	2.6	Jul	7
Sculptor	Scl	cls	01 00 09.4	−33 42 33	84 ± 2	62.5	9.1	Oct	1,21
Sextans	Sex	cls	10 13 03.0	−01 36 53	84 ± 3	30.4	23.0	Feb	1,22
Tucana II	TucII	uft	22 52 16.7	−58 33 36	58 ± 6	87.3	33.9	Sep	15
Tucana III	TucIII	uft	23 56 35.9	−59 36 00	25 ± 2	88.4	35.0	Sep	14
Tucana IV	TucIV	uft	00 02 55.3	−60 51 00	48 ± 4	89.6	36.2	Sep	14
Tucana V	TucV	uft	23 37 23.9	−63 16 12	55 ± 9	—	38.3	Sep	23
Virgo I	VirI	uft	12 00 09.1	−00 40 52	87 ± 11	40.0	24.2	Mar	24

3. Measuring DM densities in sub-halos: the dwarf spheroidal galaxies

- Surface brightness of dSphs fitted with 3D Zhao-Hernquist profiles projected onto 2D data.

Name	Site	M_V (mag)	ϵ	ρ_s^* (10^5 L$_\odot$ kpc^{-3})	r_s^* (kpc)	α^*	β^*	γ^*	Ref.
BoöI	N	-6.3 ± 0.2	0.39 ± 0.06	1.14 ± 0.21	0.461 ± 0.021	1.1	7.7	0.0	1,2
CBe	N	-4.1 ± 0.5	0.38 ± 0.14	1.08 ± 0.50	0.0740 ± 0.0035	1.1	5.4	0.0	1,3
DraI	N	-8.8 ± 0.3	0.31 ± 0.02	4.5 ± 1.3	0.1473 ± 0.0079	6.8	3.8	0.0	1,4
GruII	S	-3.9 ± 0.2	~ 0.2	1.58 ± 0.29	0.166 ± 0.016	1.3	7.6	0.0	5
RetII	S	-3.6 ± 0.2	0.6 ± 0.2	2.04 ± 0.19	0.0408 ± 0.0026	3.5	4.7	1.1	6
Scl	S	-11.1 ± 0.5	0.32 ± 0.03	23 ± 11	0.2100 ± 0.0050	3.2	4.0	0.6	1,4
Seg1	N	-1.5 ± 0.8	0.48 ± 0.13	1.21 ± 0.89	0.0739 ± 0.0064	1.1	9.2	0.2	1,7
Sex	S	-9.3 ± 0.5	0.35 ± 0.05	0.56 ± 0.26	0.493 ± 0.018	2.7	4.0	0.6	1,4
SgrI	S	-13.5 ± 0.3	0.64 ± 0.02	0.277 ± 0.076	1.869 ± 0.060	1.1	4.9	0.0	1,8
SgrII	S	-5.2 ± 0.4	~ 0.2	42.9 ± 3.9	0.0371 ± 0.0028	3.5	5.7	0.1	9,10
TriII	N	-1.8 ± 0.5	~ 0.2	7.3 ± 3.4	0.0342 ± 0.0023	1.2	5.3	0.0	11
UMaII	N	-4.2 ± 0.6	0.63 ± 0.05	49.4 ± 27.3	0.0265 ± 0.0015	0.1	2.1	2.0	1,3
UMi	N	-8.8 ± 0.5	0.56 ± 0.05	21.7 ± 10.0	0.336 ± 0.010	4.0	7.3	0.7	1,4
Wil1	N	-2.7 ± 0.8	0.47 ± 0.08	4.4 ± 3.3	0.0251 ± 0.0046	1.2	5.9	0.0	1,7

Name	Site	Membership	$N_{\rm mem}$	$\langle v_r \rangle$ (km s^{-1})	σ_v (km s^{-1})	Ref.	$R_{\rm tid}^{(\rm Em)}$ (kpc)	$R_{\rm tid}^{(\rm Bur)}$ (kpc)
BoöI	N	bin	37	100.6	4.3	12	$5.1^{+10.7}_{-2.2}$	$15.1^{+30.4}_{-9.6}$
CBe	N	bin	59	97.8	5.8	13	$6.3^{+9.5}_{-3.4}$	19^{+55}_{-16}
DraI	N	EM	466	-292.4	9.5	14	$4.83^{+1.16}_{-0.84}$	$4.30^{+0.86}_{-0.54}$
GruII	S	bin	21	-109.8	1.8	15	$0.35^{+1.01}_{-0.32}$	$\lesssim 9.5$
RetII	S	bin	18	64.0	3.6	16	$1.66^{+4.46}_{-0.97}$	$5.8^{+19.3}_{-5.3}$
Scl	S	EM	1120	111.5	9.1	17	$2.95^{+0.55}_{-0.30}$	$3.71^{+0.30}_{-0.18}$
Seg1	N	EM	154	206	15	18	$0.43^{+3.23}_{-0.35}$	$\lesssim 28$
Sex	S	EM	356	224	11	17	$7.8^{+4.4}_{-2.9}$	$9.9^{+5.7}_{-3.4}$
SgrI	S	EM	288	140	17	19	$1.56^{+0.34}_{-0.73}$	$\lesssim 1.7$
SgrII	S	bin	21	-175.7	5.0	20	$3.7^{+13.9}_{-2.7}$	$4.2^{+36.4}_{-2.8}$
TriII	N	bin	13	-381.7	2.5	21	$0.36^{+3.20}_{-0.35}$	$\lesssim 56$
UMaII	N	bin	20	-116.1	8.1	13	$2.15^{+1.69}_{-0.99}$	$2.23^{+6.48}_{-0.98}$
UMi	N	EM	467	-247	12	22	$14.7^{+6.6}_{-4.1}$	$15.3^{+8.6}_{-3.9}$
Wil1	N	bin	40	-13.6	6.3	23	$1.20^{+4.08}_{-0.51}$	$1.35^{+26.35}_{-0.48}$



3. Measuring DM densities in sub-halos: the dwarf spheroidal galaxies

- Stellar memberships estimated through an EM algorithm (Walker+ 2009) with a cut at 95% CL (cls + Seg1) or adopted as binary (0/1, uft).

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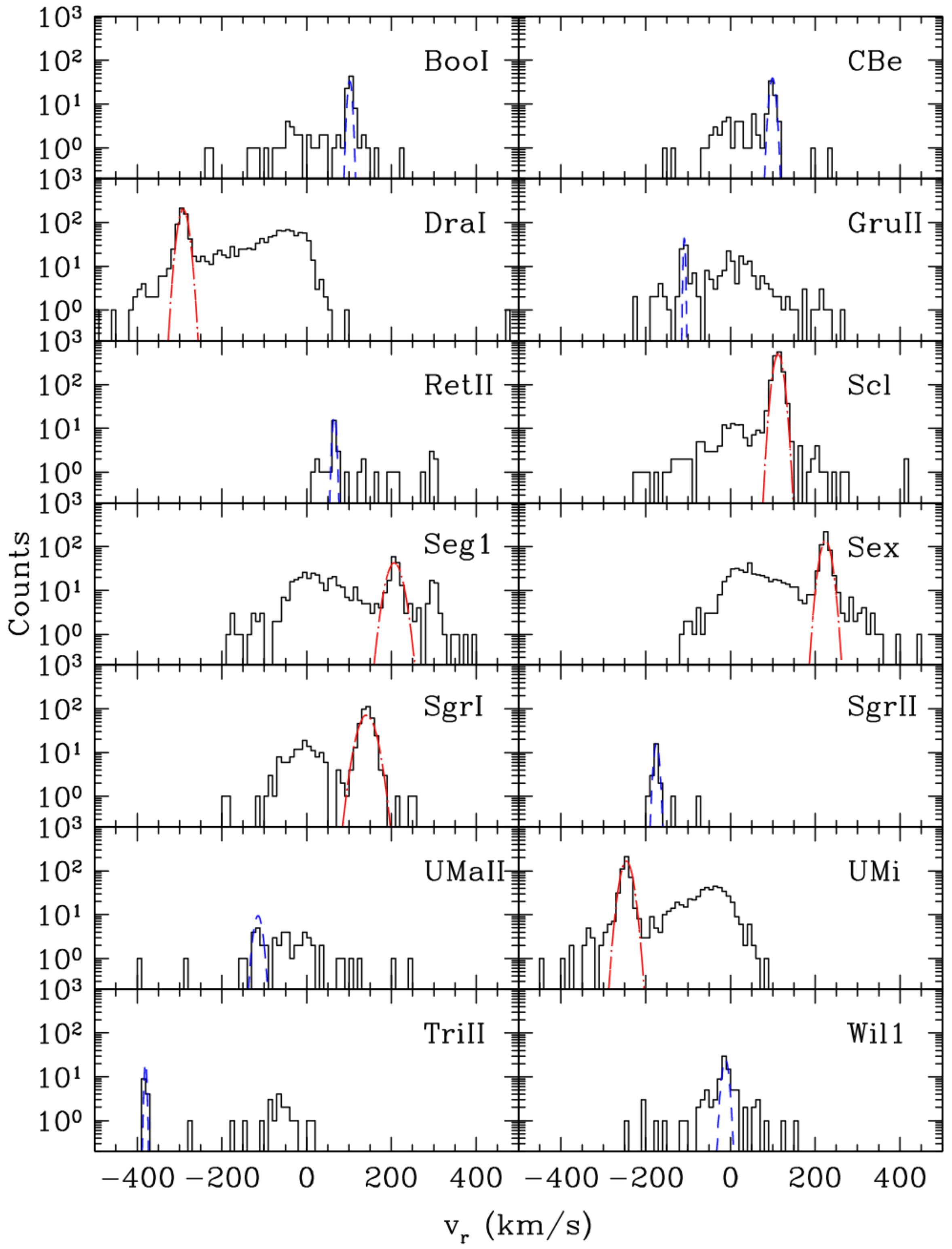
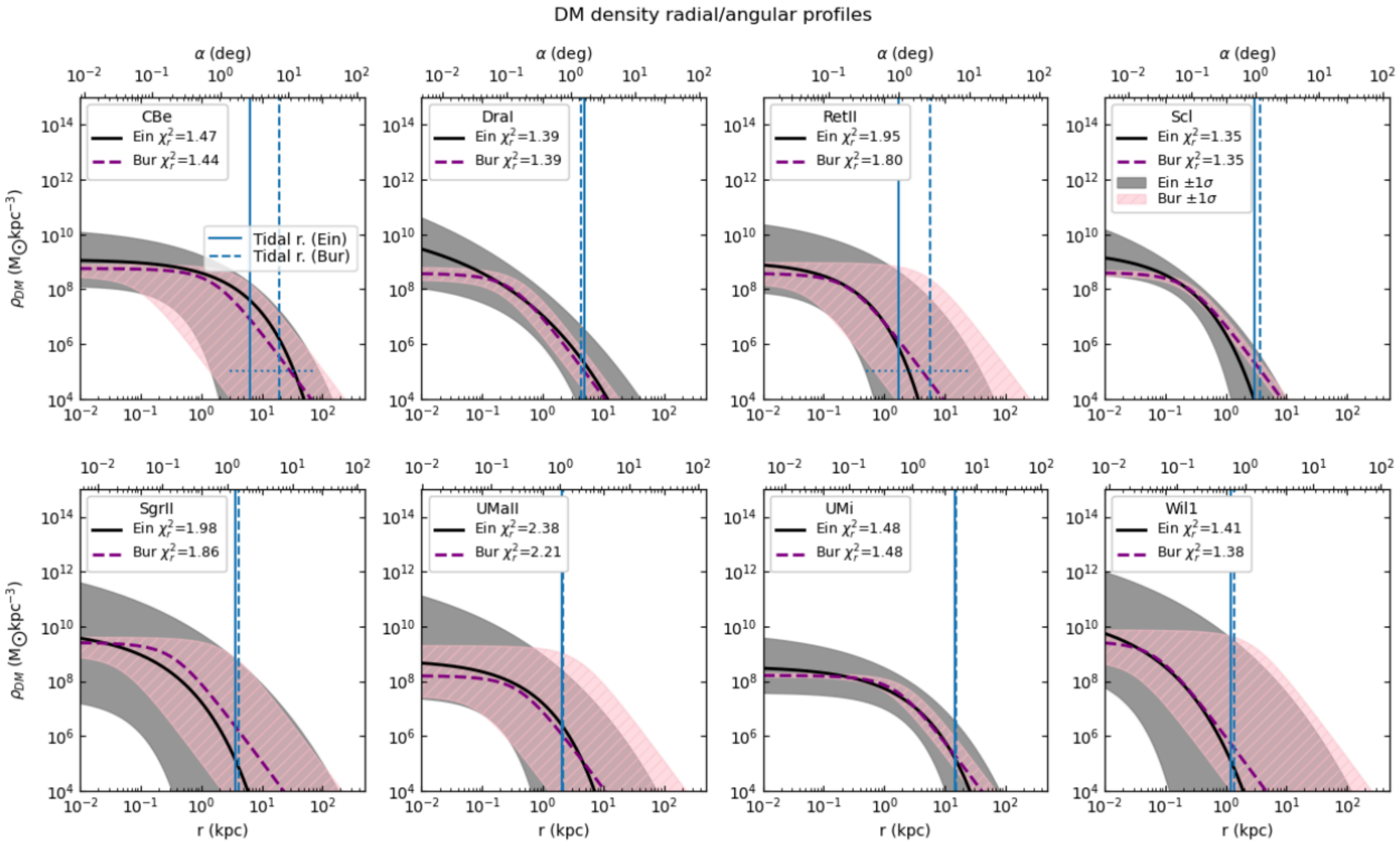
Wil1	N	-2.7 ± 0.8	0.47 ± 0.08	4.4 ± 3.3	0.0251 ± 0.0046	1.2	5.9	0.0	1,7

Name	Site	Membership	$N_{\rm mem}$	$\langle v_r \rangle$ (km s^{-1})	σ_v (km s^{-1})	Ref.	$R_{\rm tid}^{\rm (Ein)}$ (kpc)	$R_{\rm tid}^{\rm (Bur)}$ (kpc)
BoöI	N	bin	37	100.6	4.3	12	$5.1^{+10.7}_{-2.2}$	$15.1^{+30.4}_{-9.6}$
CBe	N	bin	59	97.8	5.8	13	$6.3^{+9.5}_{-3.4}$	19^{+55}_{-16}
DraI	N	EM	466	-292.4	9.5	14	$4.83^{+1.16}_{-0.84}$	$4.30^{+0.86}_{-0.54}$
GruII	S	bin	21	-109.8	1.8	15	$0.35^{+1.01}_{-0.32}$	$\lesssim 9.5$
RetII	S	bin	18	64.0	3.6	16	$1.66^{+4.46}_{-0.97}$	$5.8^{+19.3}_{-5.3}$
Scl	S	EM	1120	111.5	9.1	17	$2.95^{+0.55}_{-0.30}$	$3.71^{+0.30}_{-0.18}$
Seg1	N	EM	154	206	15	18	$0.43^{+3.23}_{-0.35}$	$\lesssim 28$
Sex	S	EM	356	224	11	17	$7.8^{+4.4}_{-2.9}$	$9.9^{+5.7}_{-3.4}$
SgrI	S	EM	288	140	17	19	$1.56^{+0.34}_{-0.73}$	$\lesssim 1.7$
SgrII	S	bin	21	-175.7	5.0	20	$3.7^{+13.9}_{-2.7}$	$4.2^{+36.4}_{-2.8}$
TriII	N	bin	13	-381.7	2.5	21	$0.36^{+3.20}_{-0.35}$	$\lesssim 56$
UMaII	N	bin	20	-116.1	8.1	13	$2.15^{+1.69}_{-0.99}$	$2.23^{+6.48}_{-0.98}$
UMi	N	EM	467	-247	12	22	$14.7^{+6.6}_{-4.1}$	$15.3^{+8.6}_{-3.9}$
Wil1	N	bin	40	-13.6	6.3	23	$1.20^{+4.08}_{-0.51}$	$1.35^{+26.35}_{-0.48}$



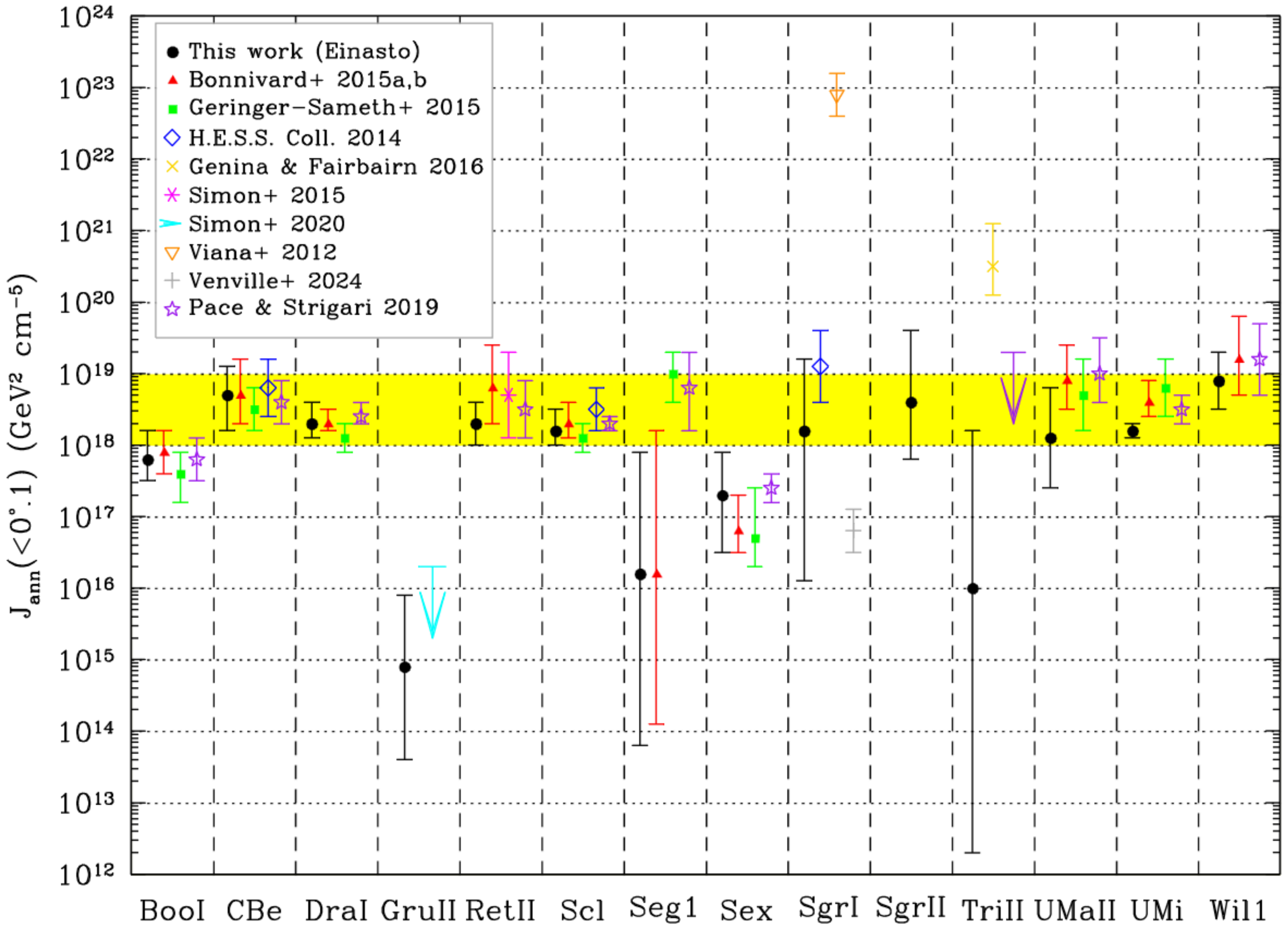
3. Measuring DM densities in sub-halos: the dwarf spheroidal galaxies

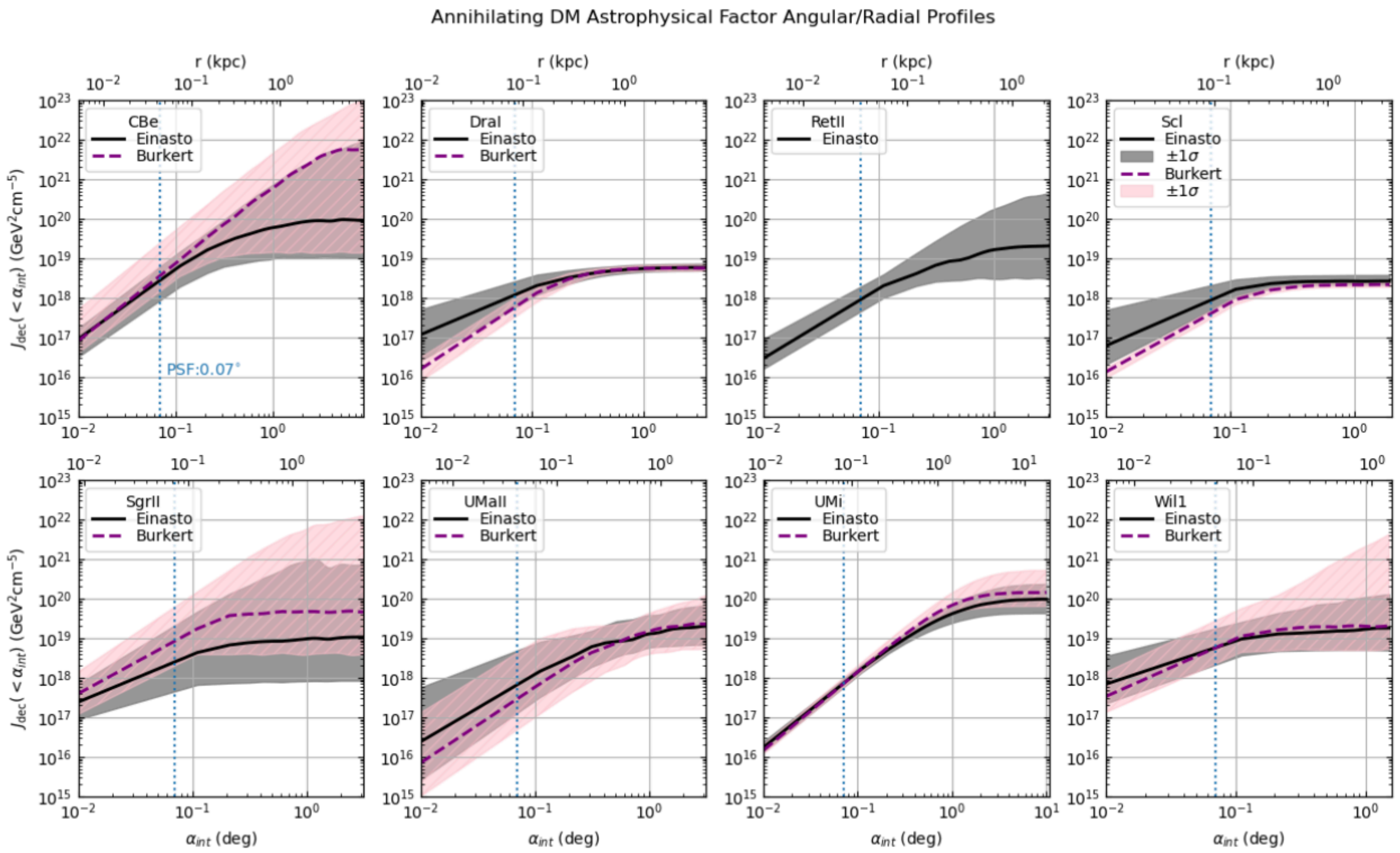
- DM density profiles computed from posterior distributions of best-fit parameters.



3. Measuring DM densities in sub-halos: the dwarf spheroidal galaxies

- Astrophysical factors for DM interaction computed from posterior distributions of best-fit parameters as a function of the integration angle.

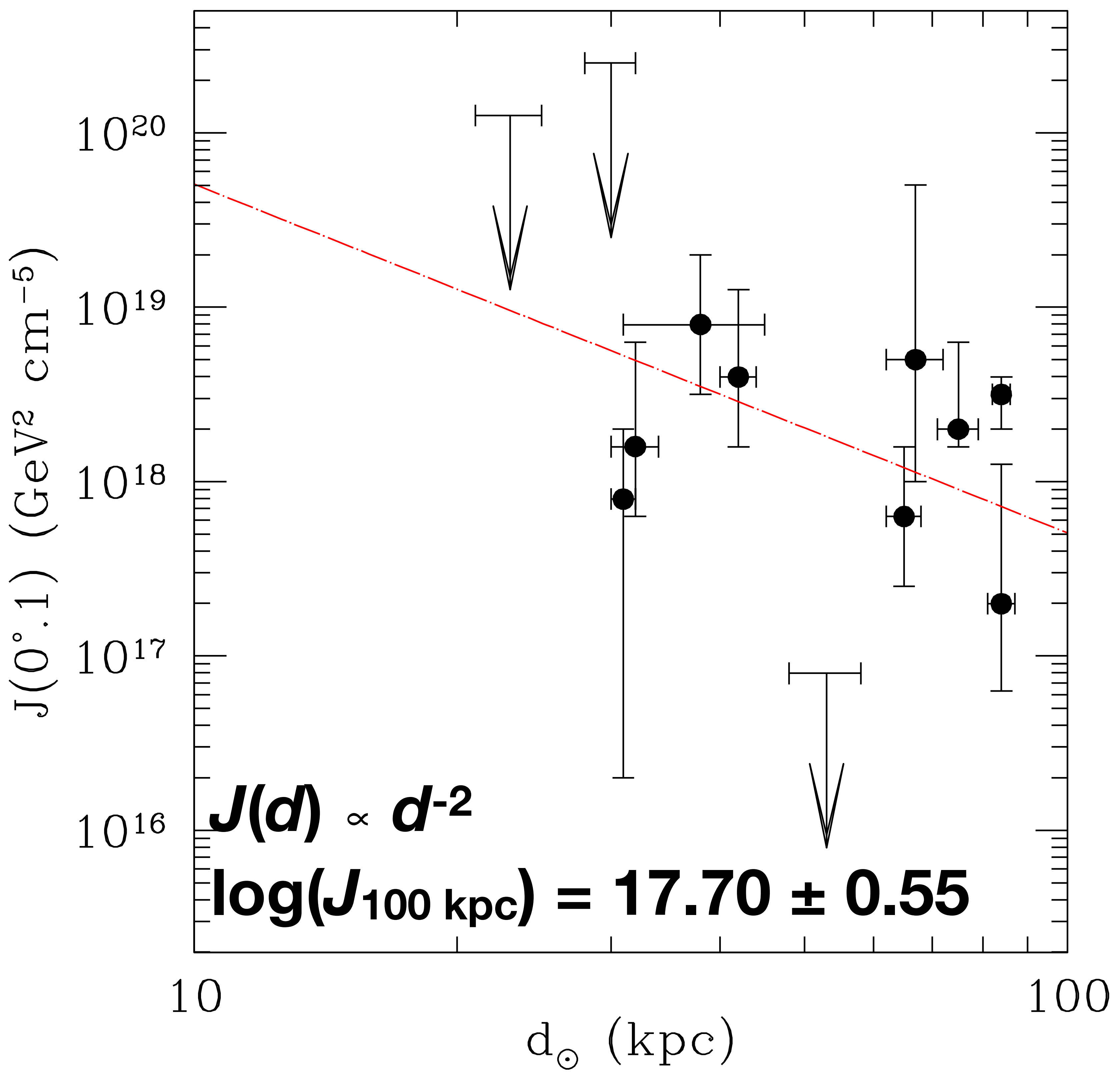


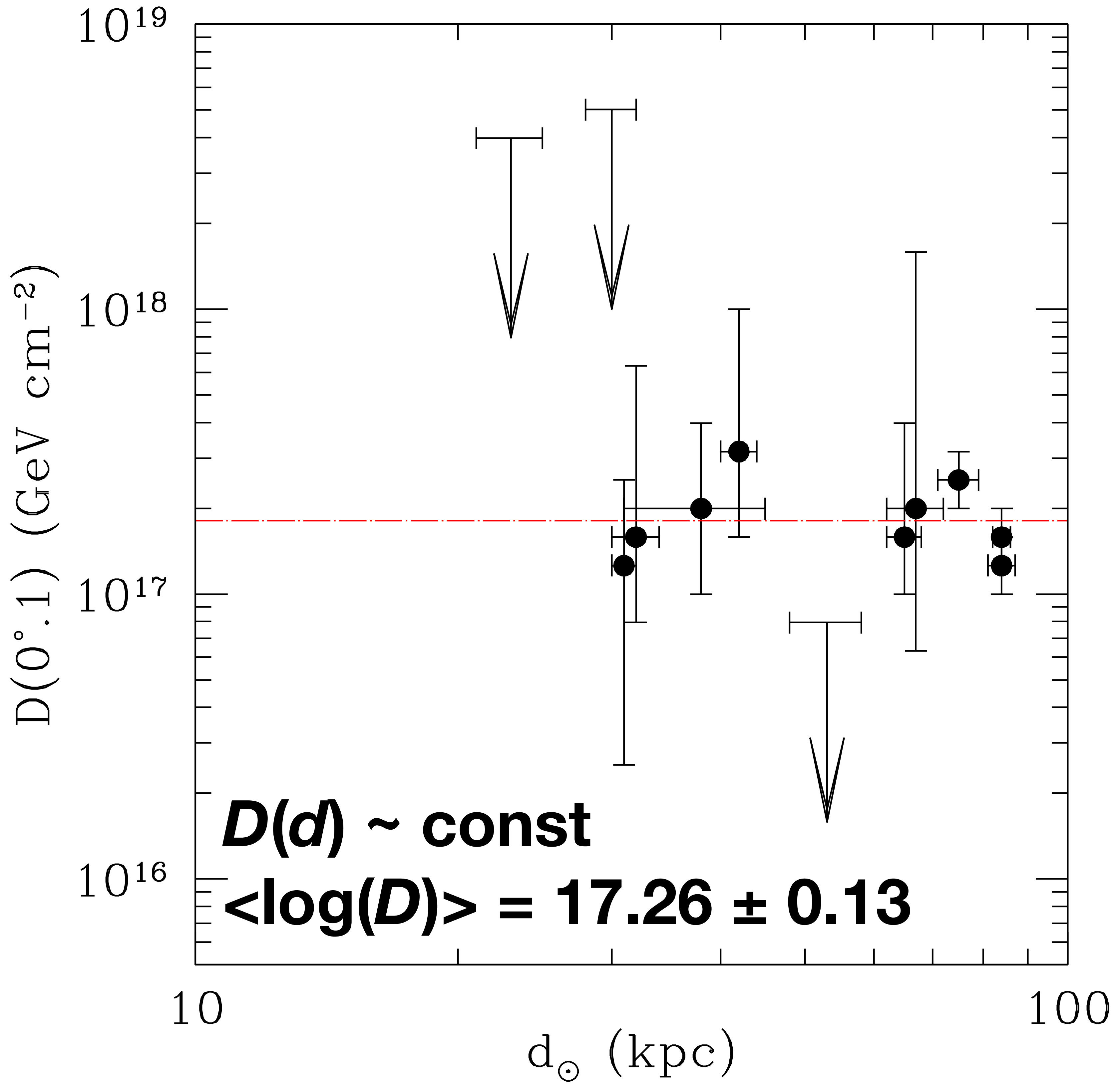


See also N. E. Araneda Munoz's poster!

3. Measuring DM densities in sub-halos: the dwarf spheroidal galaxies

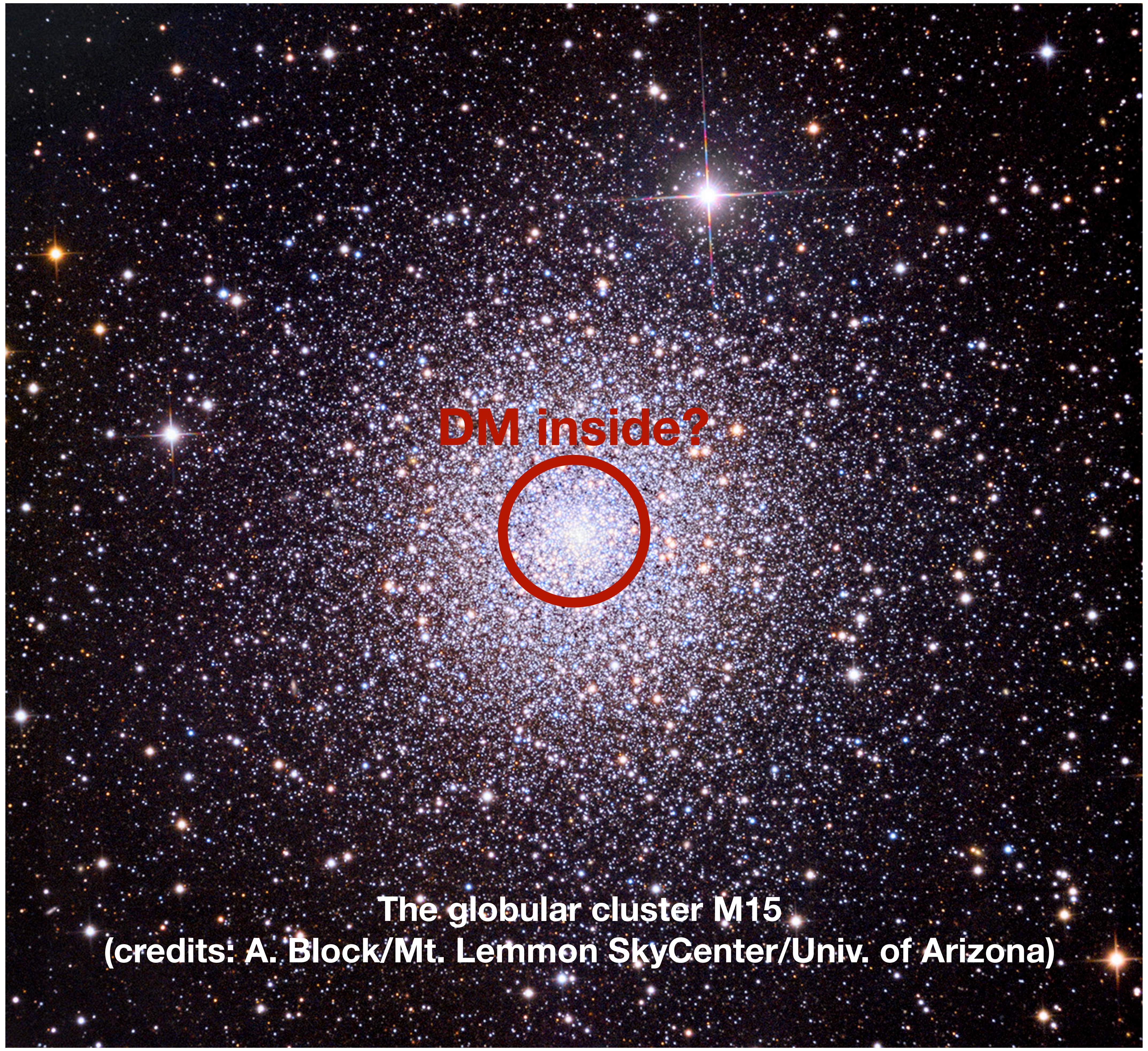
- Scaling relations of the astrophysical factors as a function of the dSph distance.





3. Measuring DM densities in sub-halos: the globular clusters (M15 case)

- Solar distance: 10.9 kpc (Bhardwaj+ 2021)
- Galactocentric distance: 10.4 kpc (Harris 1996, Kayser+ 2008)
- Luminosity: 3.4e5 $L_\odot$
- Mass: 5.6e5 $M_\odot$ (Marks & Kroupa 2010)
- **Home to a steep central cusp surrounded by a high stellar density (Gerssen+ 2003)**



The globular cluster M15
(credits: A. Block/Mt. Lemmon SkyCenter/Univ. of Arizona)

3. Measuring DM densities in sub-halos: the globular clusters (M15 case)

- DM amount in M15 already estimated by Whipple (Wood+ 2008) and H.E.S.S. (Abramowski+ 2011)
- Whipple (NFW / NFW + ad. comp.): $\log[J/(\mathrm{GeV}^2\ \mathrm{cm}^{-5})] \sim 18.4 \div 21.9$
- H.E.S.S. (NFW + ad. comp. + dyn. heat.): $\log[J/(\mathrm{GeV}^2\ \mathrm{cm}^{-5})] \sim 25.4$
- Here we recompute *J* through the **<u>MCMC Jeans analysis performed with CLUMPY</u>**.

$$\frac{d\Phi_\gamma}{dE_\gamma} = \frac{\langle \sigma_{\mathrm{ann}} v \rangle}{8\pi m_\chi^2} \sum_i \mathrm{BR}_i \frac{dN_\gamma}{dE_\gamma} \cdot J(\Delta\Omega)$$

$$J(\Delta\Omega) = \int_{\Delta\Omega} \int_{\mathrm{l.o.s.}} \rho_{\mathrm{DM}}^2(\ell, \Omega)\, d\ell\, d\Omega$$

Part of I. Villegas Pérez's master thesis @ Oslo University

3. Measuring DM densities in sub-halos: the globular clusters (M15 case)

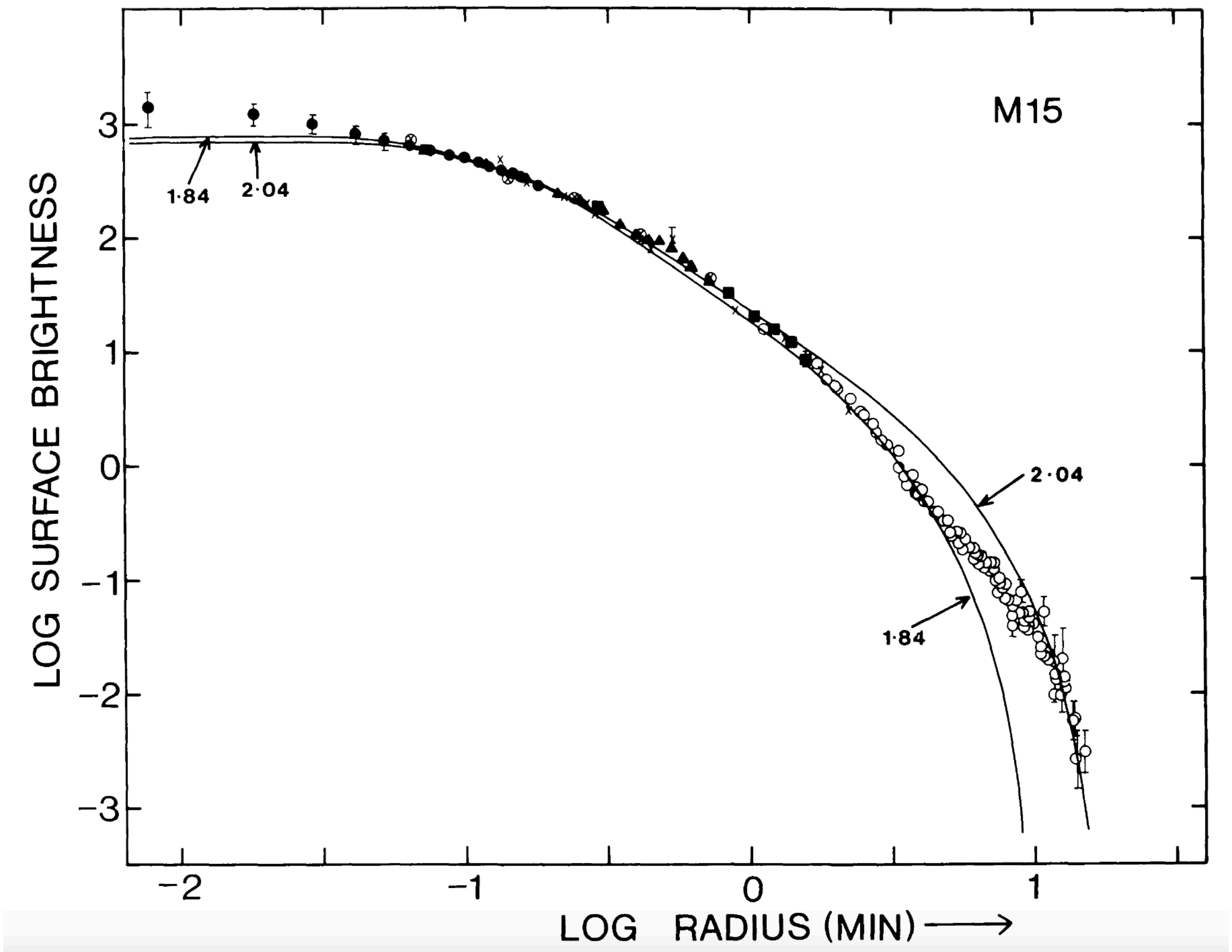
- Input priors:
  — parametrization of brightness profile
  — parametrization of vel. aniso. profile
  — parametrization of DM density profile
  — kinematics of member stars

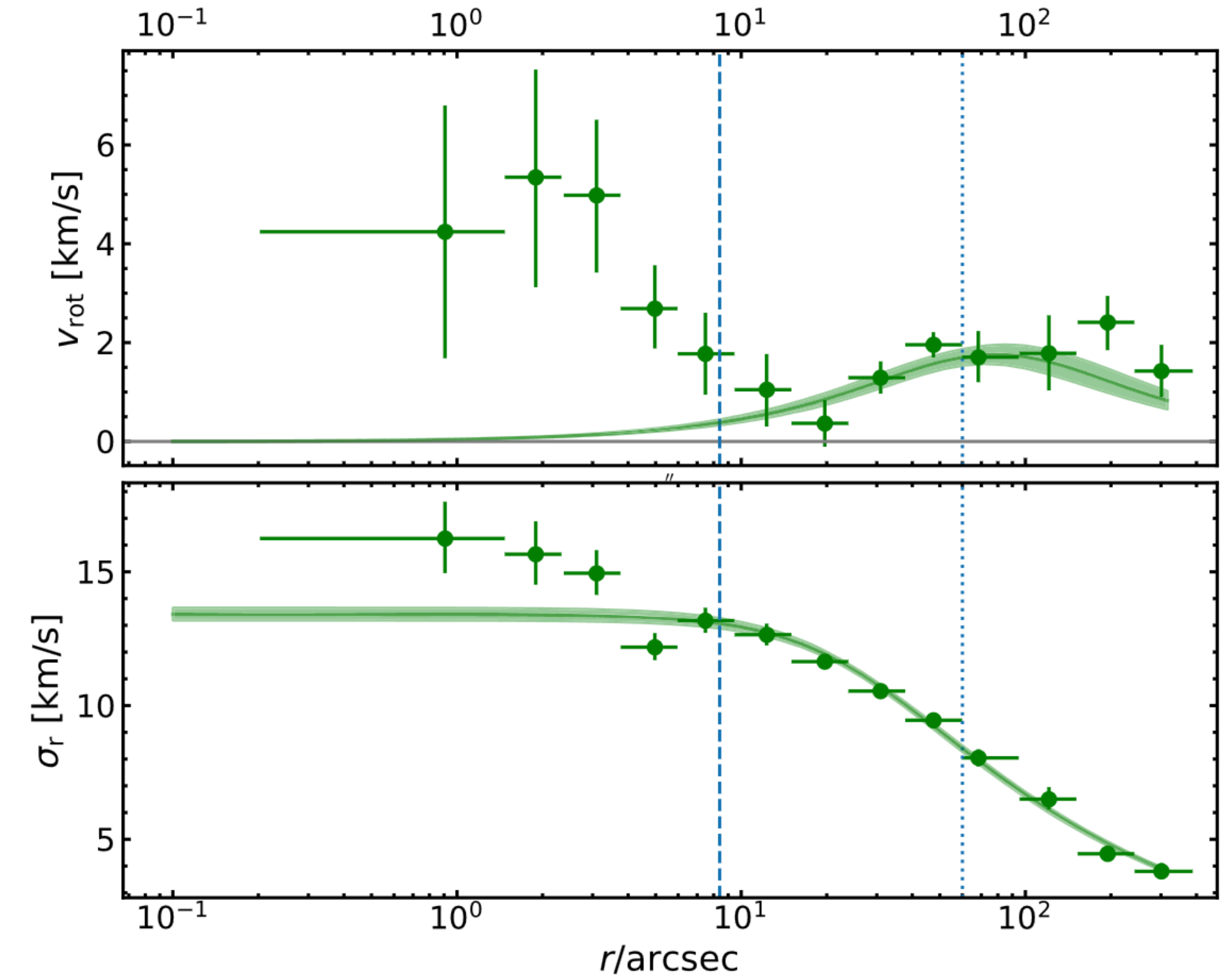
- Brightness profile: King 2D (Newell & O'Neil 1978)
  — scale density of 7.3e10 $L_\odot/kpc^2$
  — scale radius of 5.5e-4 kpc

- Velocity anisotropy profile: Baes & van Hese (2007)
  — 4 free parameters

- DM density profile: Einasto (1965)
  — 3 free parameters (scale density, scale radius, sharpness index)

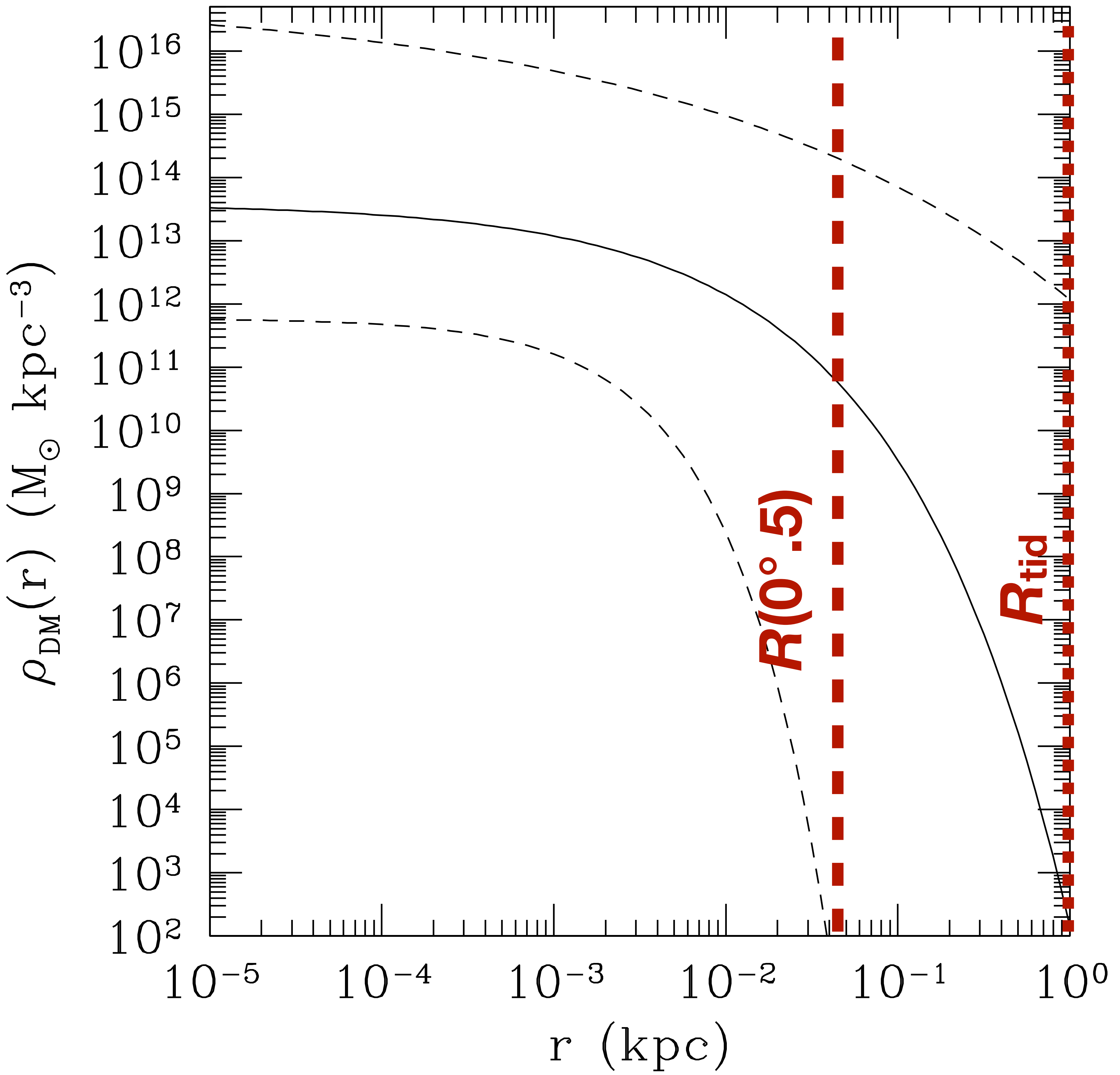
- Kinematics of member stars: Usher+ (2021)
  — 863 confirmed members
  — velocity dispersion of 16.40 ± 0.25 km/s

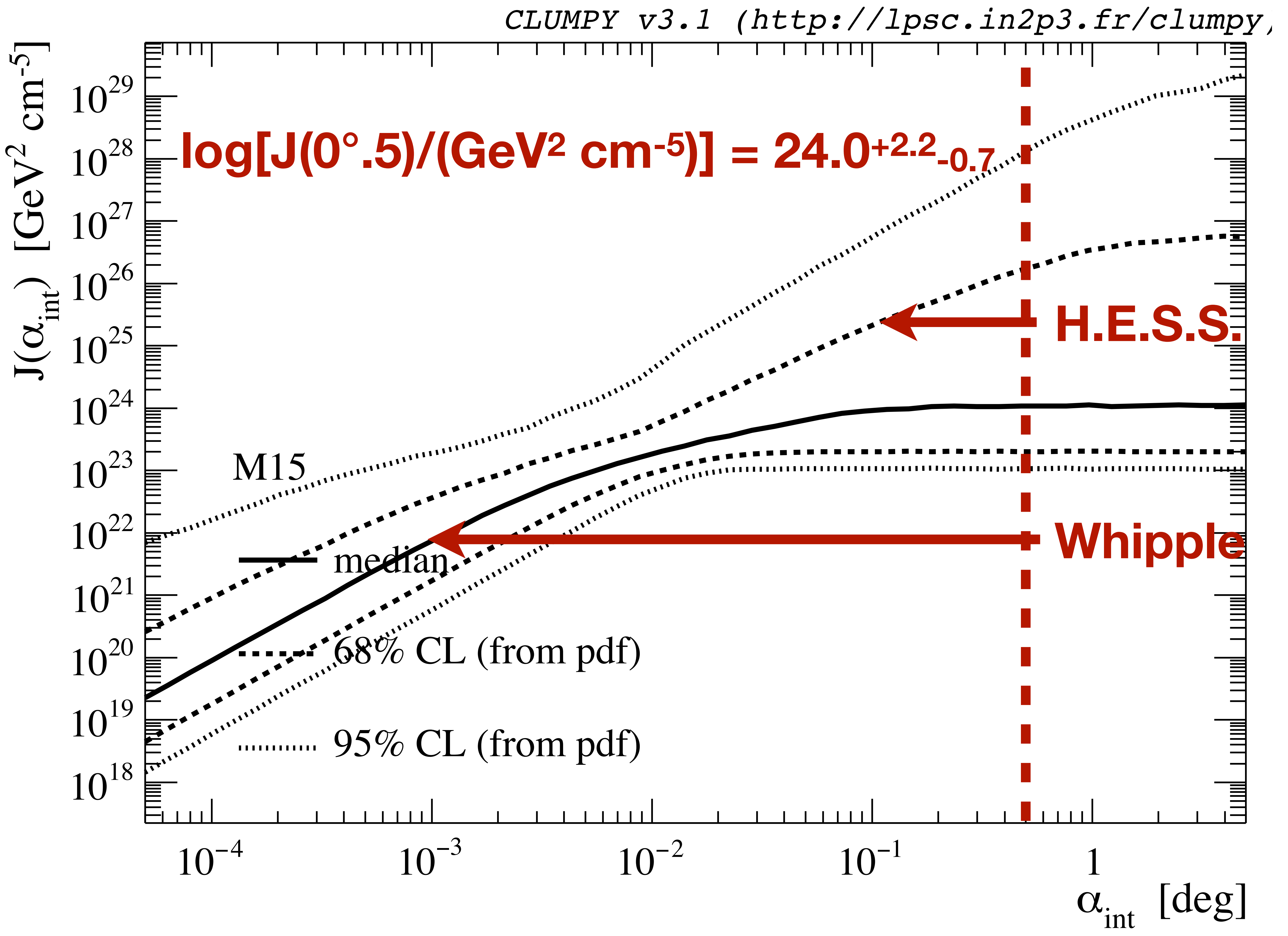




3. Measuring DM densities in sub-halos: the globular clusters (M15 case)

- Run of 200 MC chains with 10^5 realizations each and 1% num. accuracy:





4. Summary

- Indirect DM searches are a hot topic in modern astrophysics.
  — Constraining DM parameters (particle mass, cross section, decay time)
  — Inferring the physical conditions of the primordial Universe

- Reliable determination of the precise amount and distribution of DM in halos around astrophysical sources is of paramount importance.
  — Need of developing robust techniques dedicated to such an issue
  — Need of targeting robust objects (dSphs, DM-dominated globular clusters)

- DM density profiles of dSph halos can be computed from MCMC Jeans analysis on their confirmed member stars.
  — Calculation of astrophysical factors for DM interaction processes
  — Selection of best targets for indirect DM searches

- The same can be done for DM-rich globular clusters
  — Recomputation of the astrophysical factor for M15 with no strong *a priori* assumptions
  — Values in line with the highest values from the literature.

Thank you!