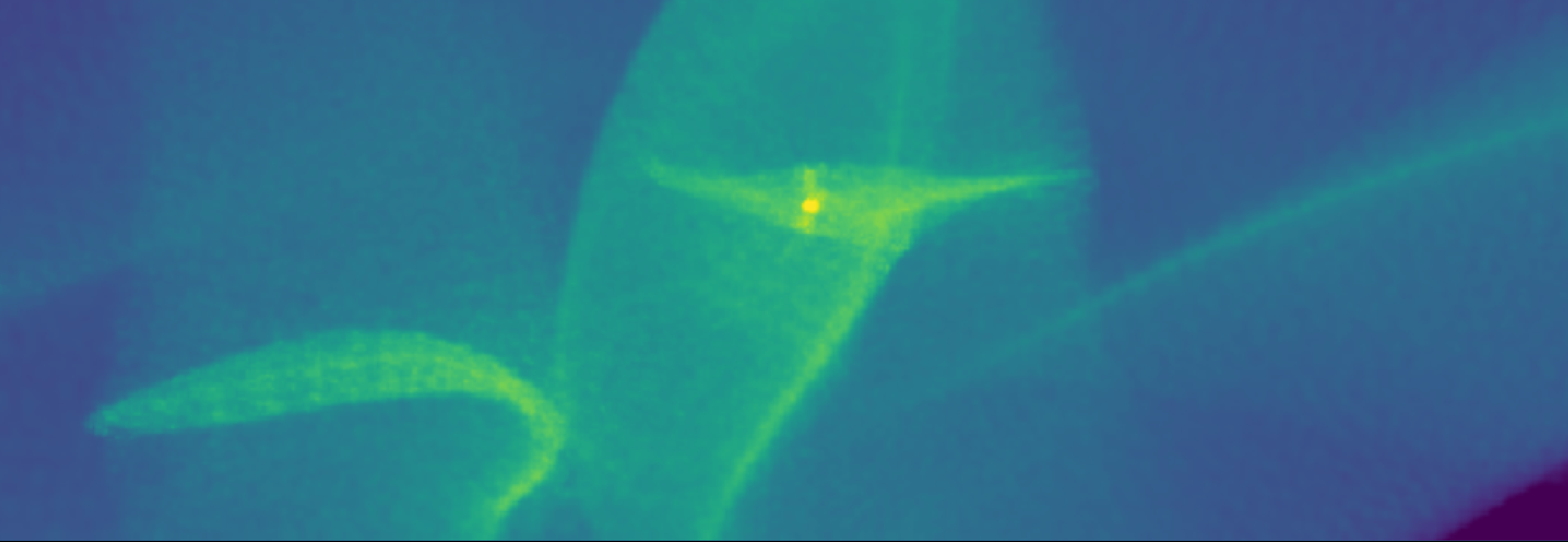
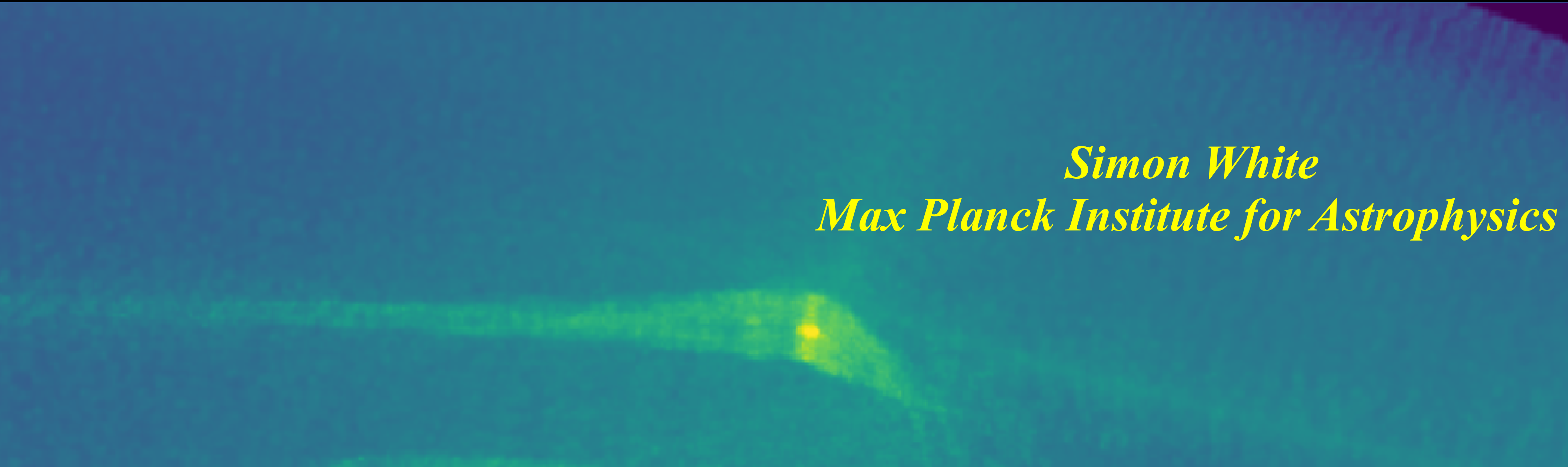


Prompt cusps and the dark matter annihilation signal

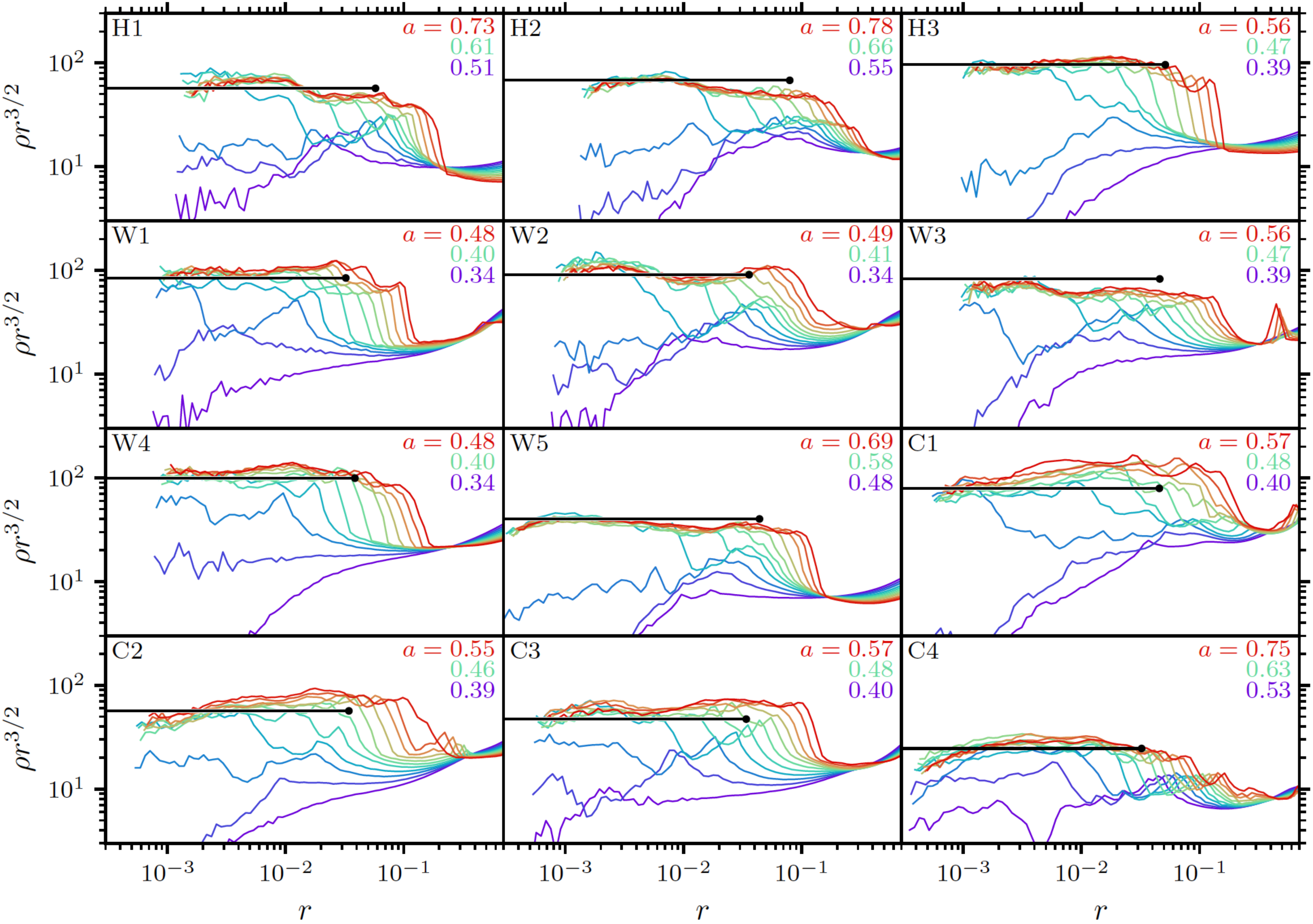


Simon White
Max Planck Institute for Astrophysics

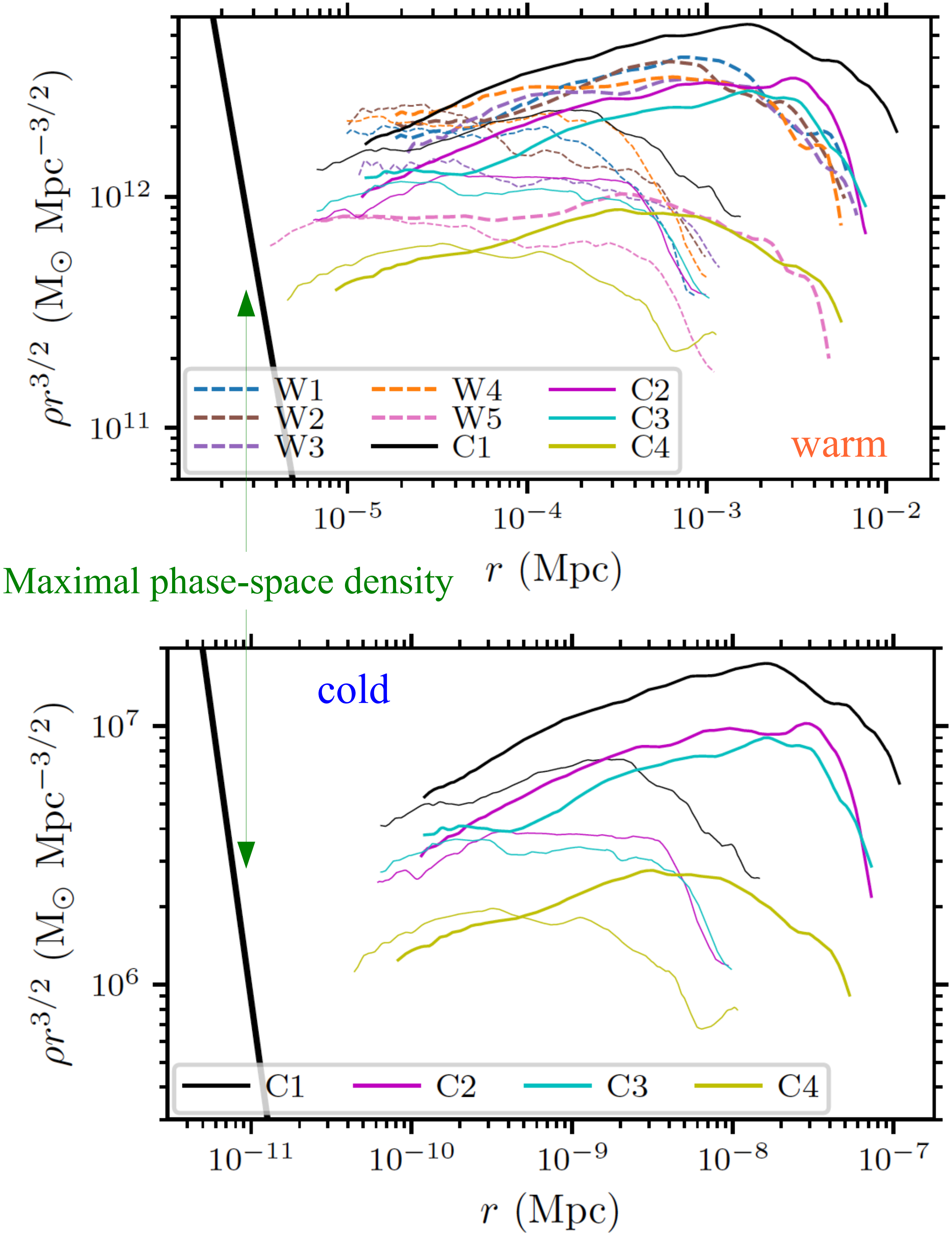
Prompt Cusps

- ...are relevant whenever P(k) is sharply truncated at high k
- ...form promptly as each initial density peak collapses
- ...have density profiles, $\rho(r) \approx 24\,\bar{\rho}\,(r / R)^{-1.5}$, where $\bar{\rho}$ is the mean cosmic DM density and $R = a_c(\delta / \nabla^2\delta)^{1/2}$ is the size of the linear overdensity peak (both measured at t_c, the time of peak collapse)
- ...have, by 1.2 t_c, mass, $M_{cusp} \sim 7\,R^3\,\bar{\rho}$, and size, $r_{cusp} \sim 0.1\,R$
- ...have an inner core radius set by phase-space constraints, thus dependent on the cosmological origin of the DM
- ...suffer late-time tidal disruption only in star-dominated regions of galaxies (through encounters with individual stars)
- ...dominate the dark matter annihilation signal in all but the very densest regions of galaxies

Delos+White 2022



Delos+White 2022

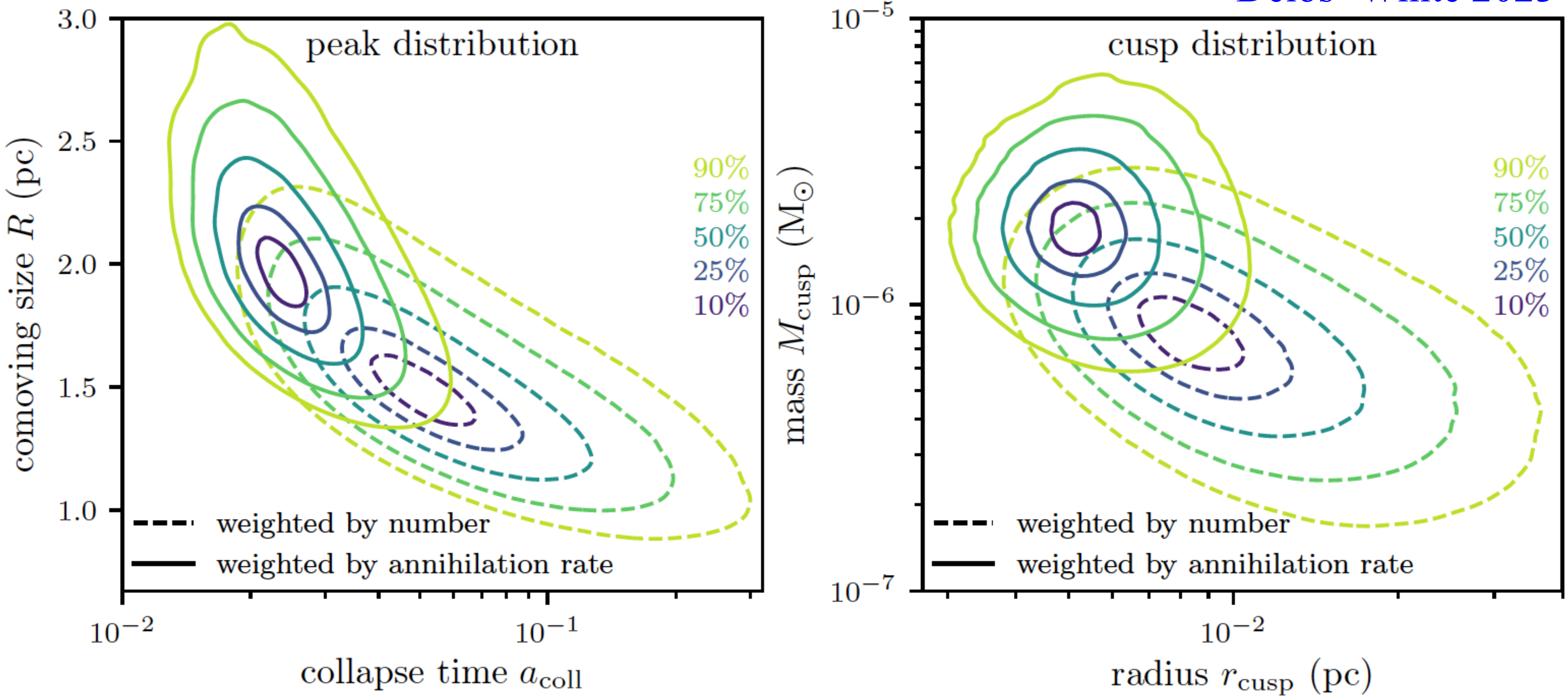


The core radii of prompt cusps are set by the phase-space density at thermal decoupling.

They are factors of 2 – 5 or 5 – 20 smaller than the simulation resolution limit in the warm (3.5 keV WDM) and cold (100 GeV CDM) cases, respectively.

BBKS-predicted peak and cusp distributions in ΛCDM

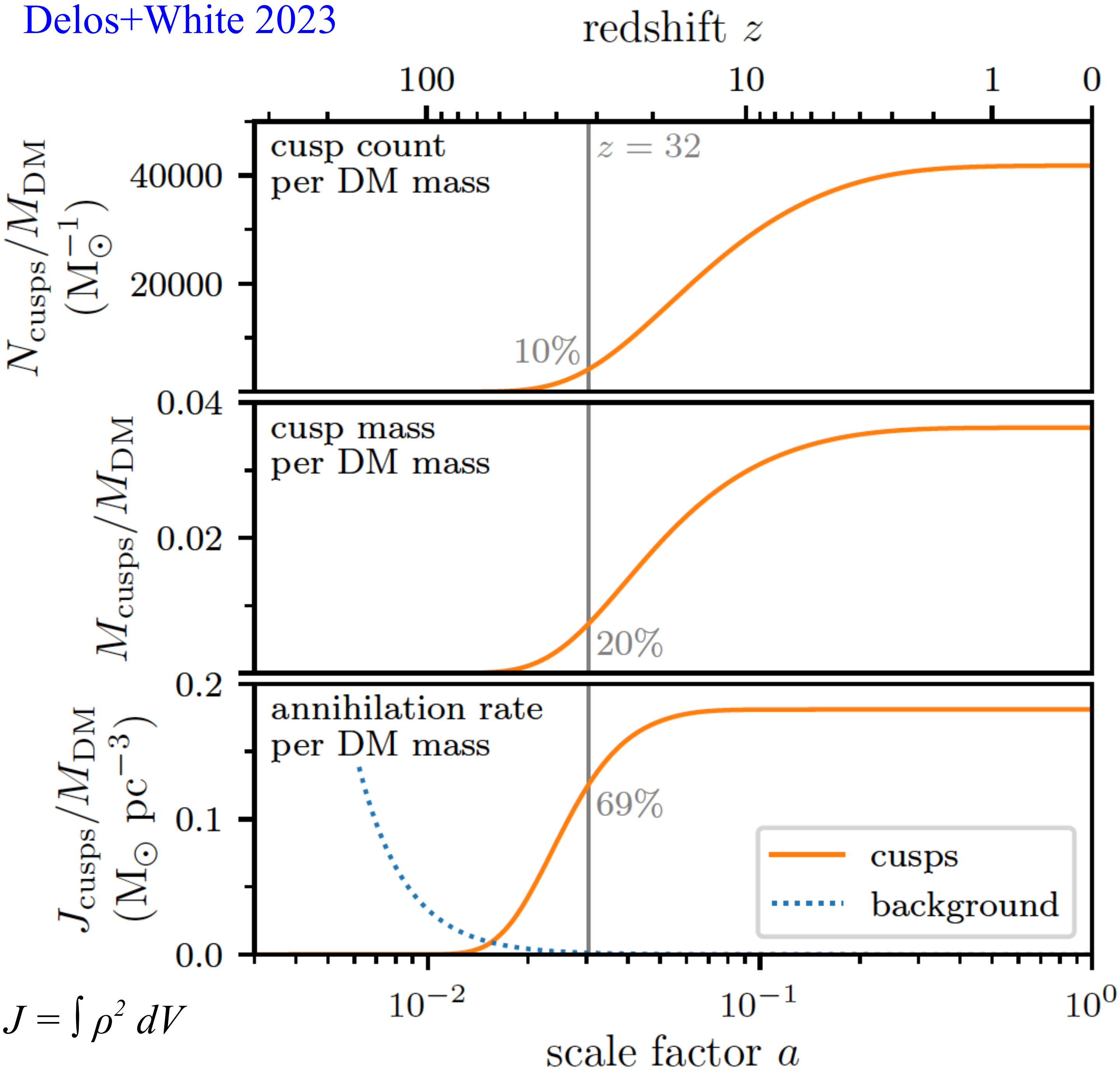
Delos+White 2023



$m_\chi = 100$ GeV, $T_{kd} = 30$ GeV

$J = \int \rho^2 \, dV$

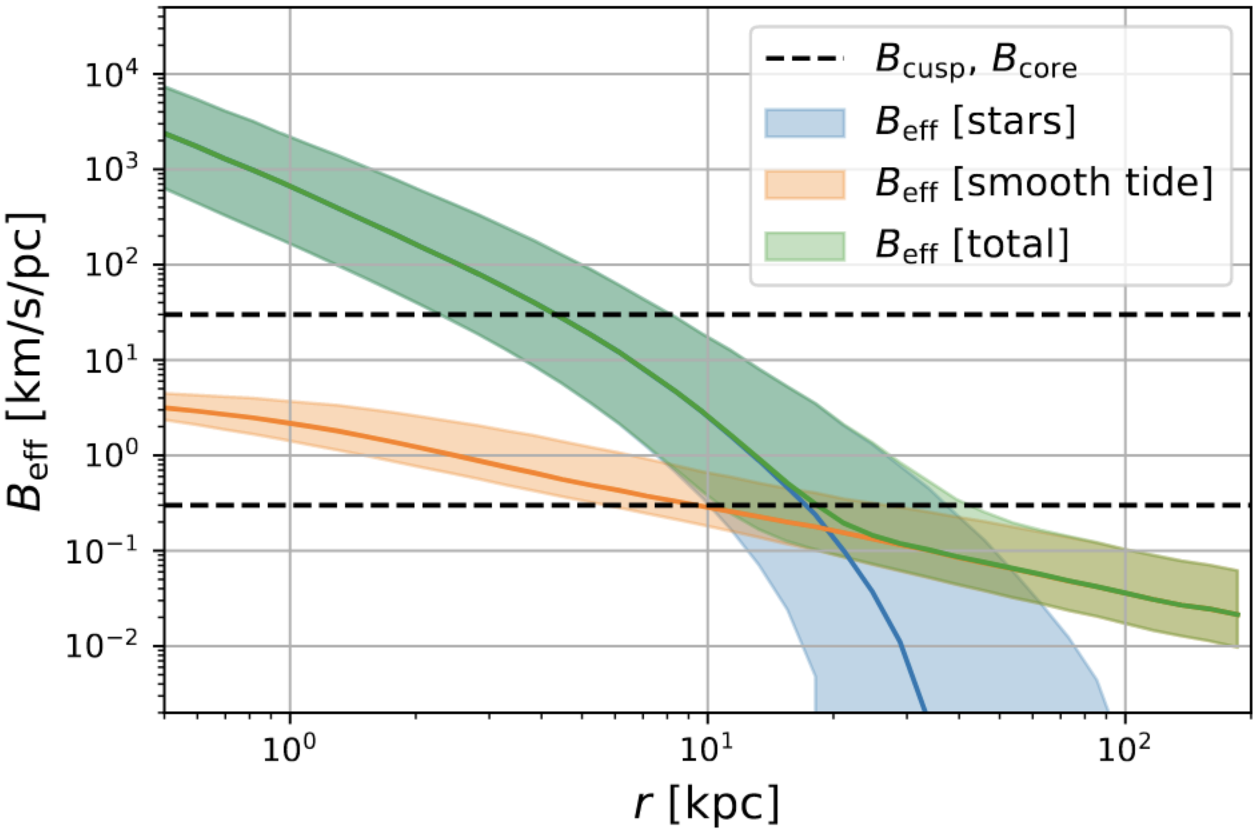
Delos+White 2023



$J = \int \rho^2 \, dV$

Growth with time of the prompt cusp population and its annihilation signal

Tidal effects on prompt cusps in the Milky Way



Stücker et al 2023

Cusp cores disrupted

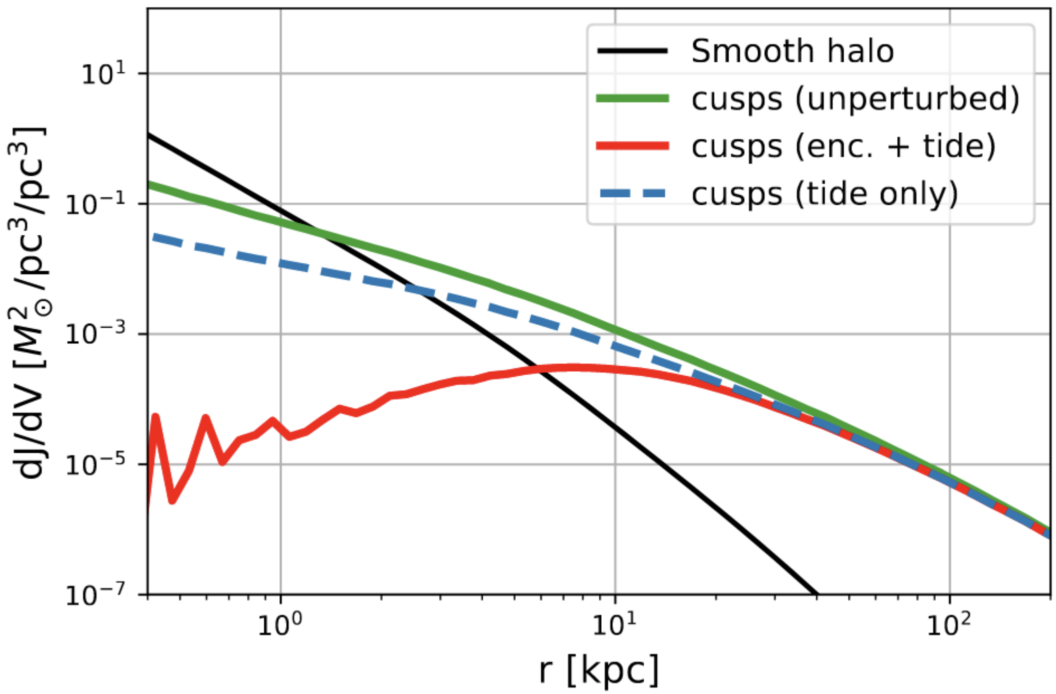
Cusp outskirts disrupted

A impulsive stellar encounter is characterised by strength, $B = 2GM_*/Vb^2$

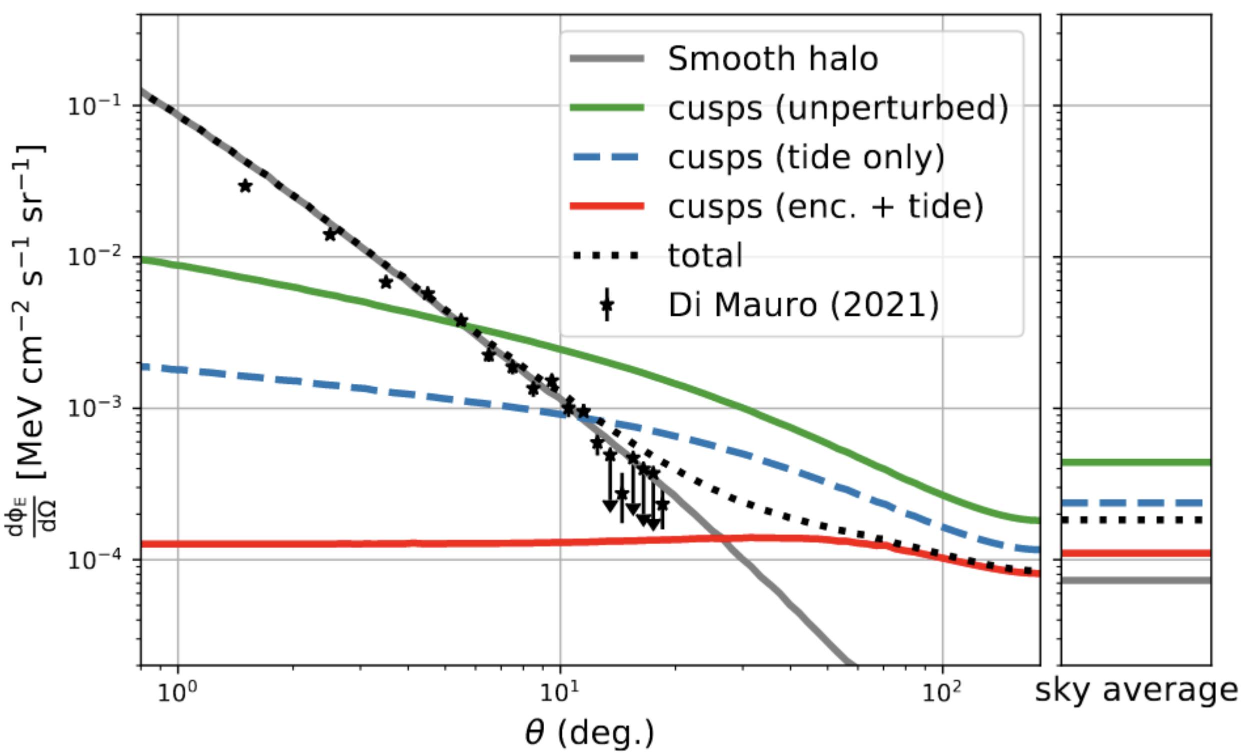
For a given cusp, $d\bar{N}/dB = 2\pi G B^{-2} \int \rho_*(\mathbf{x}(t))\, dt$; $\quad B_{eff} = (\Sigma\, B_i^{1.2})^{1/1.2}$

Mean field truncation is approximated by $B_{mean} = (42.2\, |r^{-2}\, \partial_r\, r^2\, \partial_r\, \Phi|_{peri})^{1/2}$

Milky Way annihilation radiation profiles



Stücker et al 2023



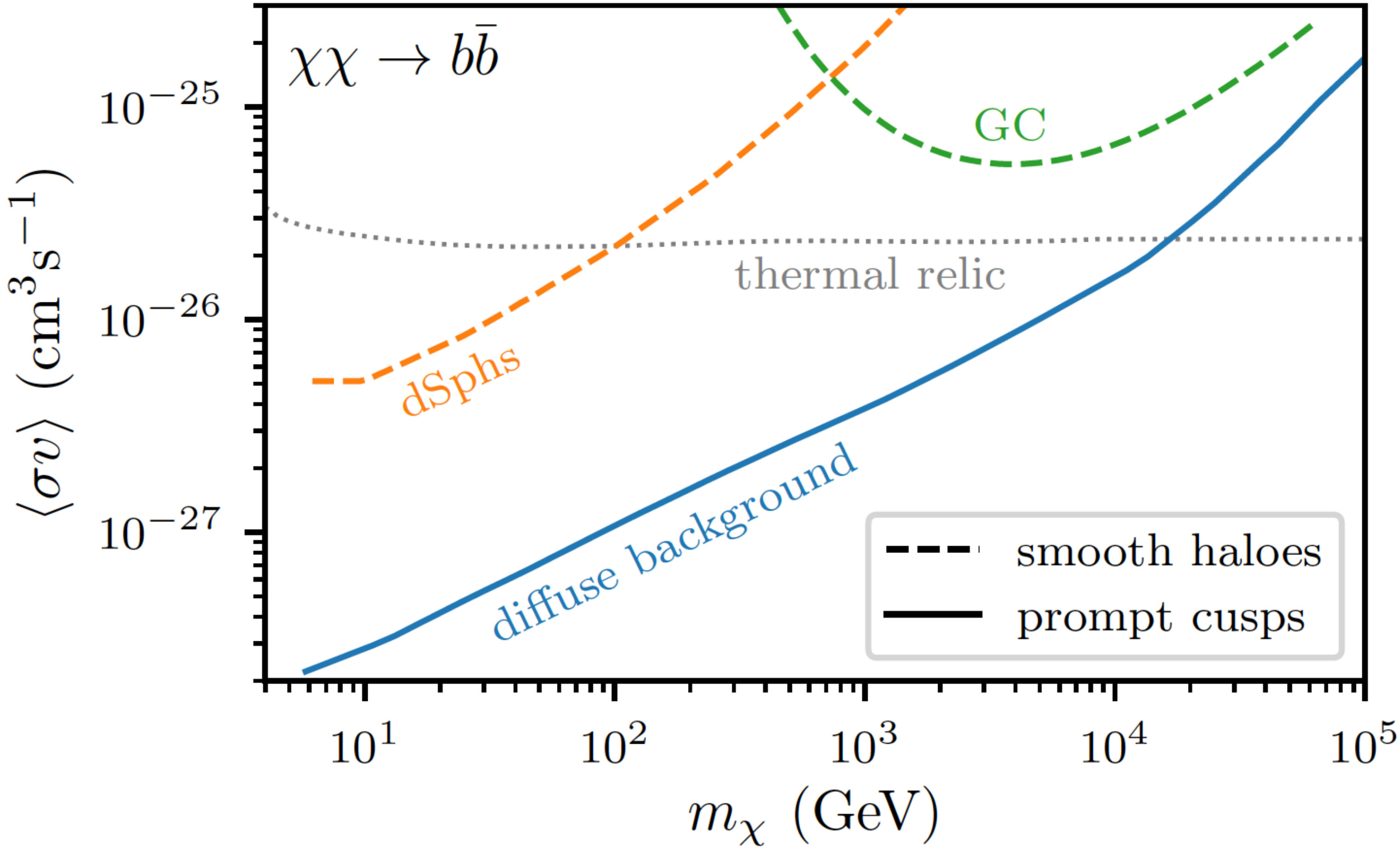
The profile due to cusps is much shallower than that due to the smoothly distributed dark matter

Cusp emission dominates at >1 kpc neglecting tides, at >3 kpc including the mean tide, and at >7 kpc including stellar encounters also

Prompt cusps do not affect the Fermi Galactic Centre Excess, but if this is due to annihilation then they contribute much of the 1 – 10 GeV background

Bounds on the mass of a thermal WIMP

Delos+White 2023



Curves are 95% upper bounds based on Fermi's measurement of the isotropic γ-ray background after subtraction of known source populations

Inclusion of prompt cusps raises the lower limit on mass by a factor of 150

Prompt cusps

- The origin and structure of prompt cusps differ from those of "normal" halos
- For a $m = 100$ GeV, $T_{kd} = 30$ GeV WIMP, prompt cusps have Earth mass and are a million times more abundant than Earth-mass planets in the Milky Way, accounting for a percent or two of all dark matter
- In the Milky Way they are significantly disrupted by tides and by stellar encounters within ~20 kpc
- They have no observable dynamical or gravitational lensing effects
- They dominate the dark matter annihilation signal from the outer halo of the Milky Way and from all extragalactic objects, leading to a local luminosity density that is proportional to $\bar{\rho}_{dm}$ rather than $\bar{\rho}_{dm}^2$