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Stellar cores live long and prosper in cuspy dark matter haloes

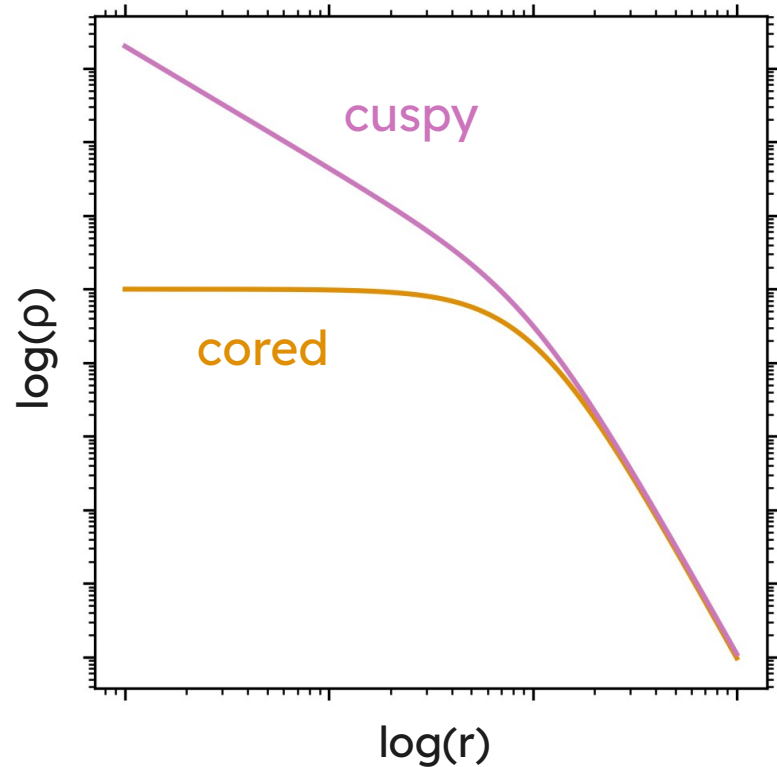
Nordic–Baltic Astronomy Days
May 27th 2026

Together with Alexander Rawlings, Till Sawala,
and Matthew G. Walker Carnegie Mellon University

Core-cusp problem in the Λ CDM model

In simulations, collisionless dark matter forms “**cuspy**” haloes
→ divergent central density

Observations of dwarf galaxies generally support “**cores**”
→ flat central density



Ultra-faint dwarfs (UFDs) as dark matter probes

Smallest dark matter haloes in the Universe with little stars

Dominated by dark matter

Density inference difficult and uncertain



Simulations show that **supernova feedback can induce cores** in originally cuspy dark matter haloes

→ **inefficient in UFDs**

→ dark matter cores in UFDs could **rule out Λ CDM**

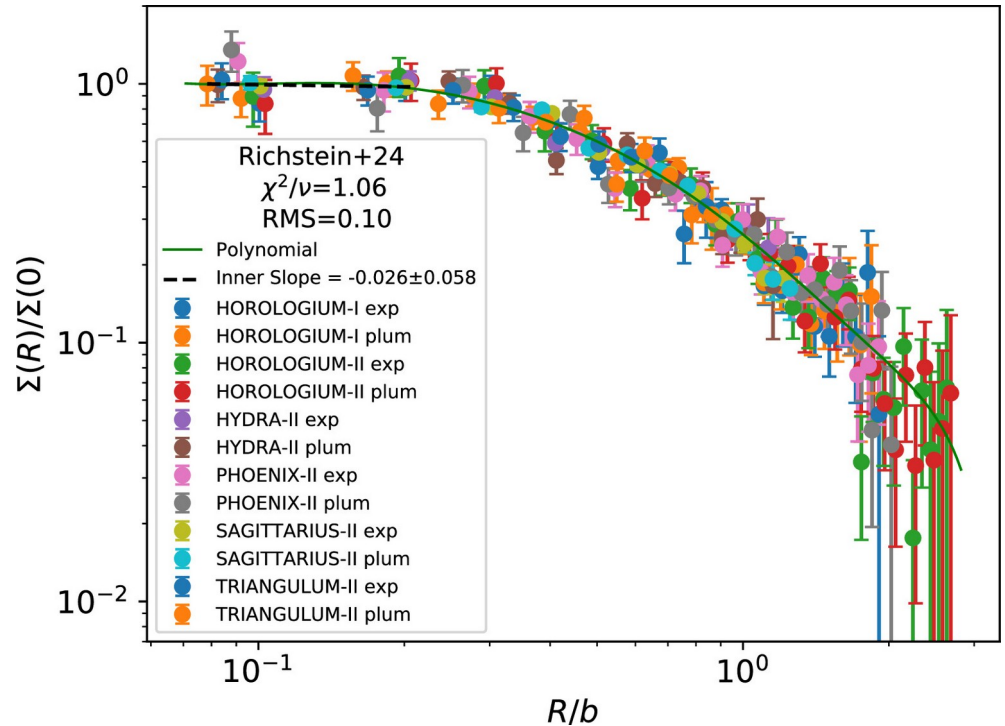
Evidence for dark matter cores in UFDs?

Sánchez Almeida et al. (2024b)

Six observed UFDs predicted to have stellar cores using their combined surface density profiles

The best-fit model producing the profiles has unphysical values in a cuspy dark matter potential

Conclusion: observed stellar cores cannot exist in cuspy halos



Can cored stellar systems survive in cuspy dark matter haloes?

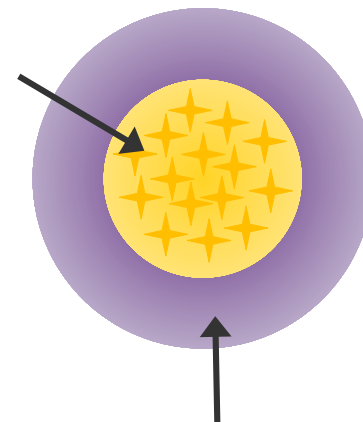
How well can the stellar density profiles of UFDs be constrained?

N-body simulation set-up

cored stellar component
Plummer profile

10 realisations of the fiducial system ($M_{\text{ext}} = M_{\text{IC}}$)
Comparable to the six UFDs in SA+2024b

7 simulations with an initially perturbed system ($M_{\text{ext}} \neq M_{\text{IC}}$)



cuspy dark
matter potential
NFW profile

dynamical
time ~ 25 Myr



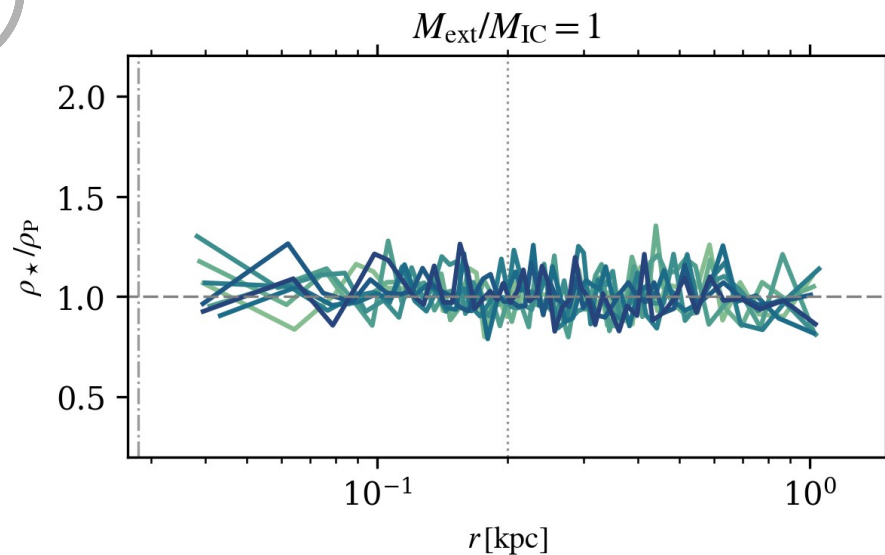
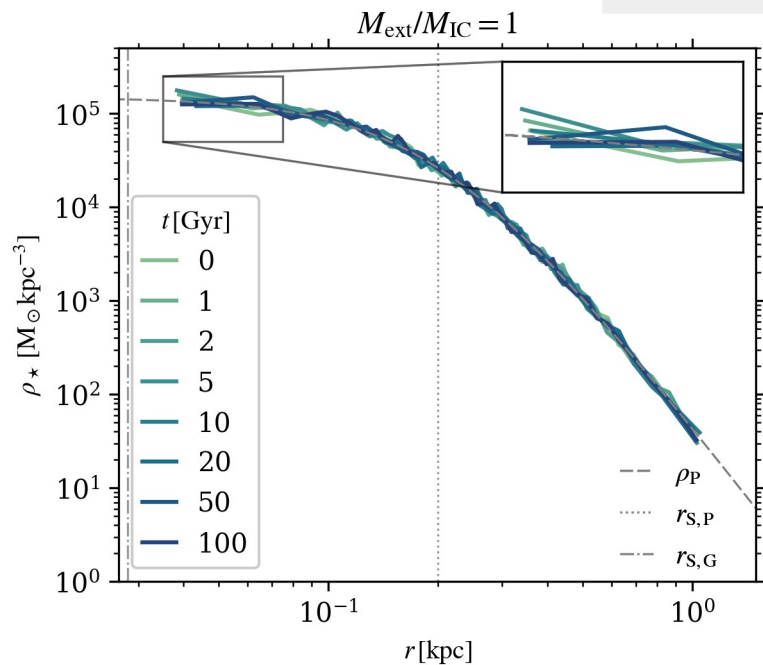
Hubble time ~ 14 Gyr

Stellar density evolution

1 system for 8 times

$M_{\text{ext}} = M_{\text{IC}}$

inner region within $r = 0.075$ kpc

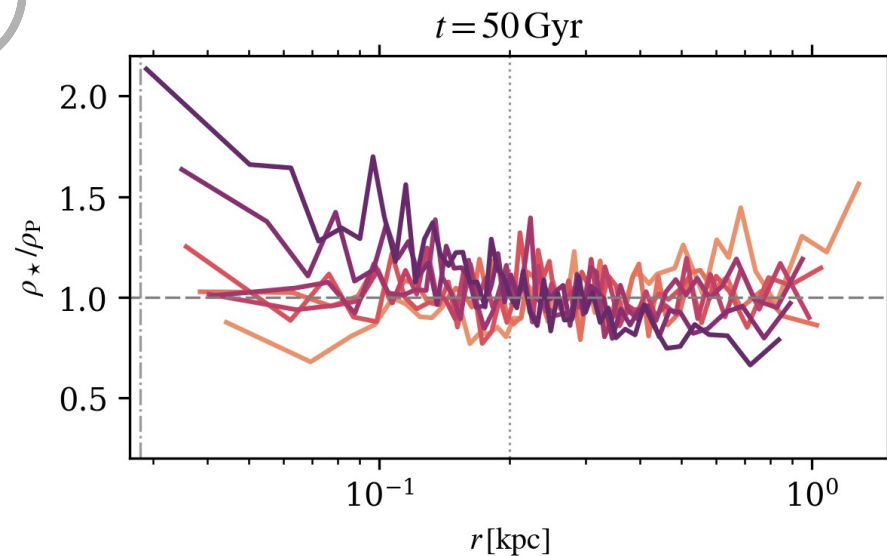
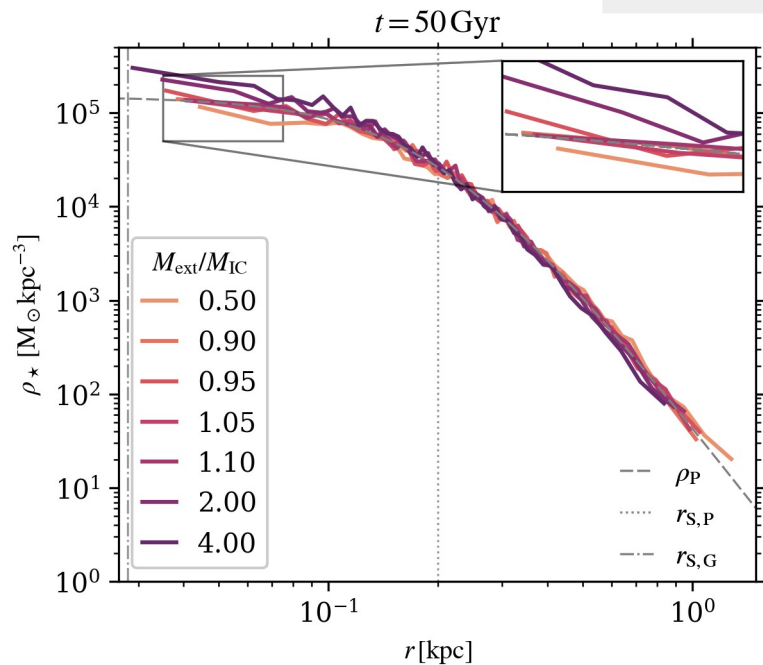


Stellar density evolution

7 systems for 1 time

$M_{\text{ext}} \neq M_{\text{IC}}$

inner region within $r = 0.075$ kpc



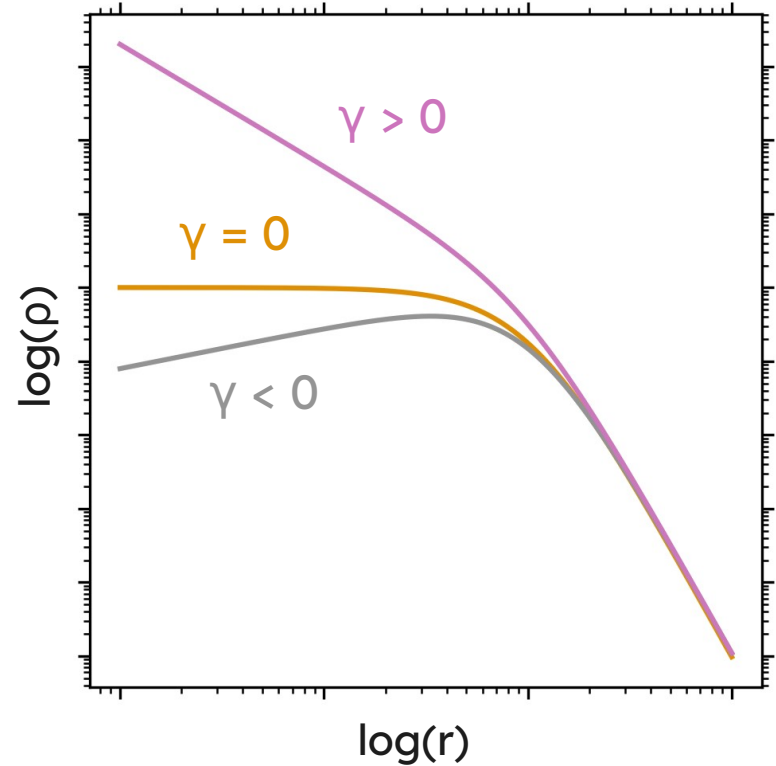
Cored stellar systems can persist in cuspy dark matter haloes, if they have formed in initial equilibrium

How well can the stellar density profiles of UFDs be constrained?

The inner density slope parameter γ

Plummer profile $\rightarrow \gamma = 0$
NFW profile $\rightarrow \gamma = 1$

Conclusion by SA+2024b
 $\gamma \leq 0 + \text{NFW} \rightarrow \text{unphysical}$

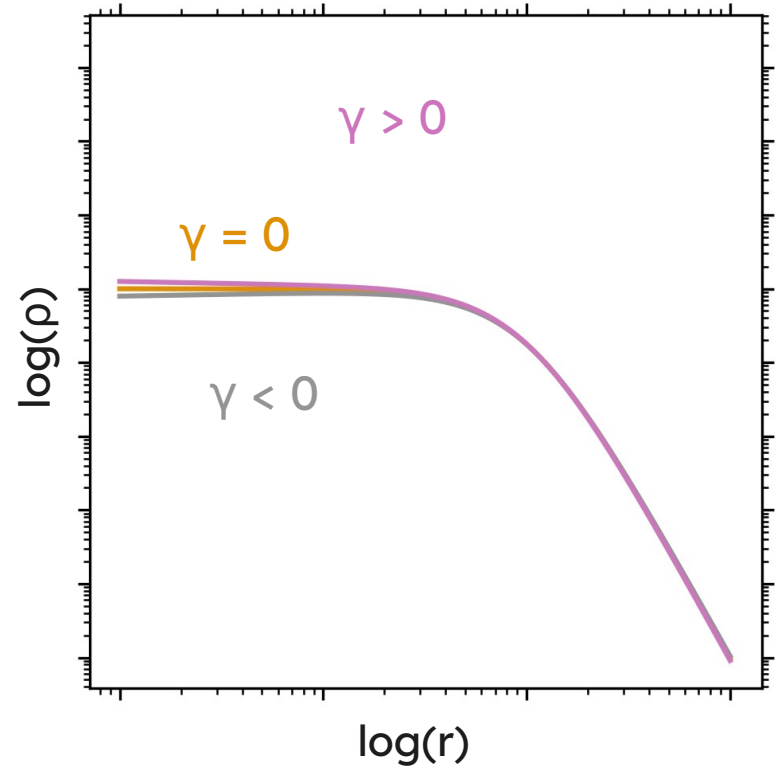


The inner density slope parameter γ

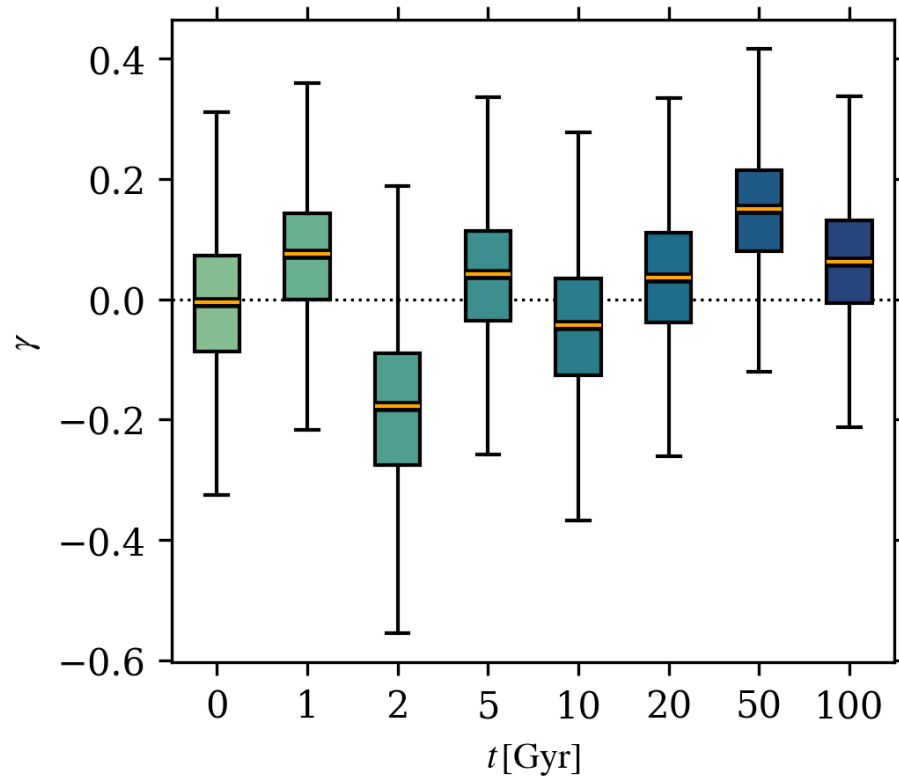
Plummer profile $\rightarrow \gamma = 0$
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Conclusion by SA+2024b
 $\gamma \leq 0$ + NFW \rightarrow unphysical

How well can we **constrain**
the inner density slope?



Evolution of the inner density slope



At all times

γ is consistent with being 0
→ true value

γ cannot be constrained as
strictly-positive
→ needed for SA+2024b

The probability that $\gamma \leq 0$
is found to be 52%

Cored stellar systems can persist in cuspy dark matter haloes, if they have formed in initial equilibrium

Even with a conservative sample size and no observational errors, it is very difficult to constrain the inner density of UFDs

Conclusions

Cored stellar systems can persist in cuspy dark matter haloes, if they have formed in initial equilibrium

Even with a conservative sample size and no observational errors, it is very difficult to constrain the inner density of UFDs

For now, the existence of stellar cores in UFDs provides no concrete evidence against the Λ CDM model

