DARK MATTER ANNIHILATION IN THE MOST LUMINOUS AND THE MOST MASSIVE ULTRACOMPACT DWARF GALAXIES (UCD)

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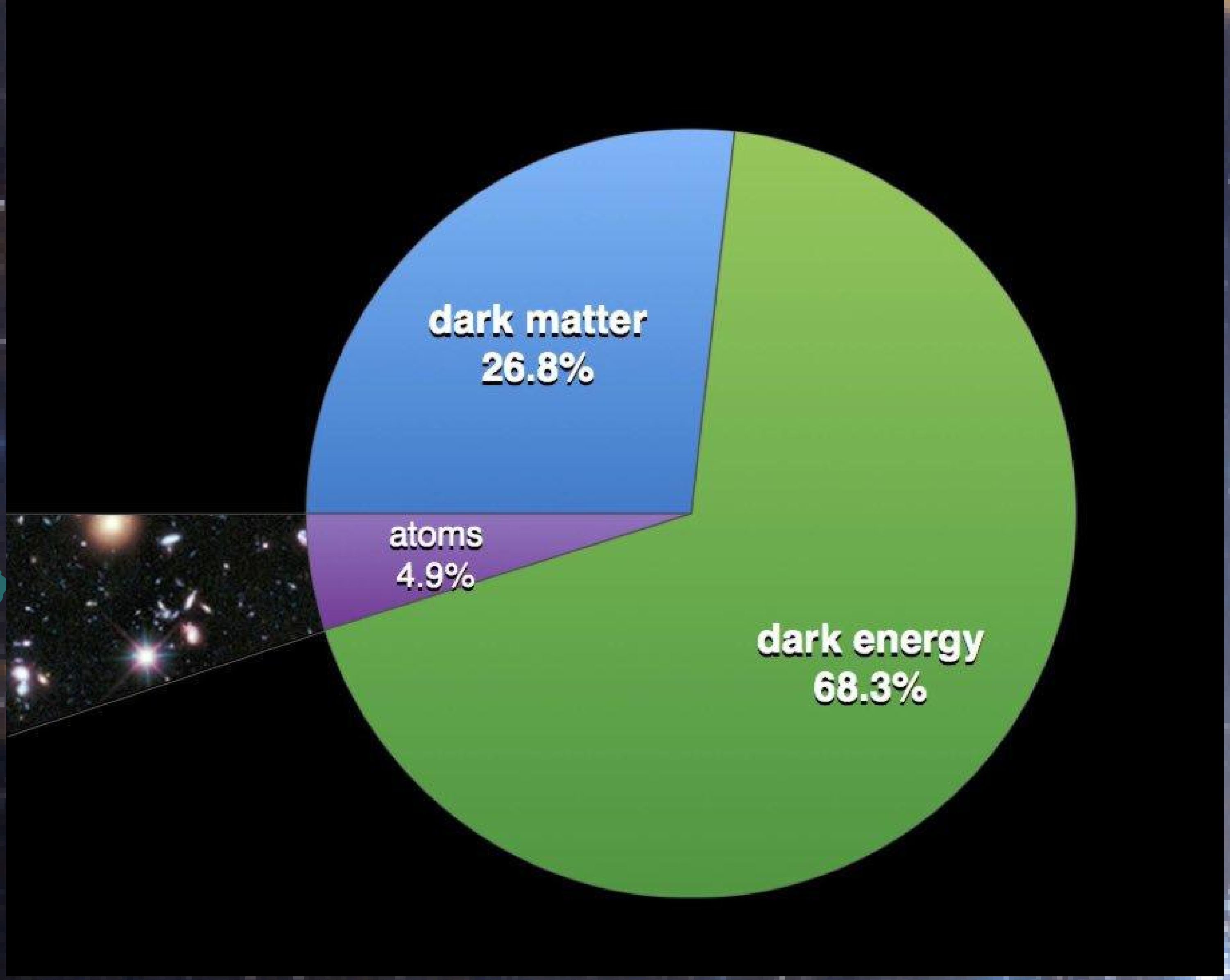
in Collaboration with Oswaldo D. Miranda, Floyd W. Stecker and C. A. Wuensche

Talk based on arXiv:2003.02383

Universe Composition



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Introduction

ULTRACOMPACT DWARF GALAXIES (UCDS)

- UCDs are densest stellar systems, brighter and larger than globular clusters with M > 2 x 10^6 solar masses and radii r>10 pc;
- They exhibit properties such as mass, luminosity, and size that challenge the conventional understanding of them in comparison to canonical stellar systems;
- Their nature, origin, formation and dynamical evolution are intensively studied.

Introduction

ULTRACOMPACT DWARF GALAXIES (UCDS)

- Interpretations suggest UCDs as the result of the evolution of primordial density fluctuations or formed through mergers of globular clusters;
- They are also dubbed as dwarf-globular transition objects (DGTOs) in attempt to express their uncertain origin.

UCDs

FORNAX UCD3

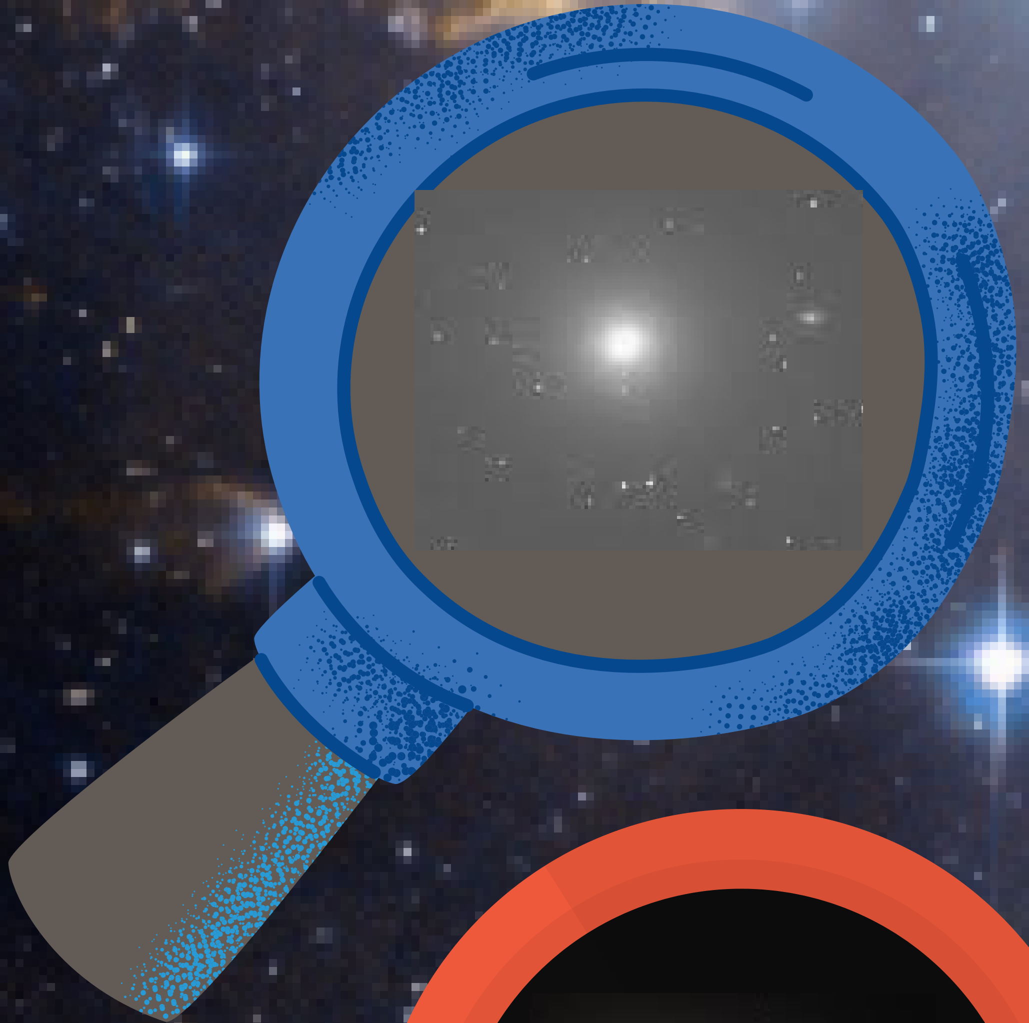
- is the most luminous UCD;
- its distance from Earth is 20.9 Mpc;
- a BH with mass ~3.3 x 10^6 Solar masses was detected in the center of Fornax UCD3, corresponding to 4% of the stellar mass.

M59 UCD3

- is the most massive UCD;
- is located 10.2 kpc in projection from the center of M59 host galaxy;
- its distance from Earth is ~14.9 Mpc;
- a possible SMBH of mass ~4.2 x 10^6 solar masses is estimated to inhabit M59 UCD3.

Could there be *dark matter* in UCDs?

DATA FOR FORNAX UCD3 AND M59 UCD3



Fornax UCD3

M59 UCD3

Characteristics of UCD Galaxies		
	Fornax UCD3	M59 UCD3
d(Mpc)	20.9 ±0.3 ± 1.4	14.9± 0.4
t_{BH}(Gyr)	~5	8.6 ± 2.2
$M_{BH}(M_{\odot})$	$\sim 3.3 \times 10^6$	$\sim 4.2 \times 10^6$
σ_*(km/s)	33.0± 4.7	77.8 ± 1.6
R_a(pc)	92.2	20± 4.2 ± 0.54
M/L	3.35	4.2 ±0.4

Radio Flux From DM Annihilation

A complete treatment of DM synchrotron emission must consider the diffusion and energy-loss contribution from secondary particles.

$$\frac{\partial}{\partial t}\frac{dn_e}{dE} = \nabla\left[D(E,r)\,\nabla\frac{dn_e}{dE}\right] + \frac{\partial}{\partial E}\left[b_{loss}(E,r,z)\frac{dn_e}{dE}\right] + Q(E,r)$$

Radio Flux From DM Annihilation

$$\frac{dn_e}{dE}(E,r) = \frac{\langle \sigma v \rangle \rho(r)^2}{2m_{DM}^2 b_{loss}(E,r)} \int_E^{m_{DM}} dE' \frac{dN}{dE'_{inj}}$$

$$Q(E,r) = \frac{\langle \sigma v \rangle \rho(r)^2}{2m_{DM}^2} \frac{dN}{dE_{inj}}$$

$$b_{loss}(E,r,z) = b_{syn} + b_{IC} + b_{brem} + b_{coul}$$

DM DENSITY PROFILES

NFW

Non Spike

$$\rho_{NFW} = \rho_s \frac{r_s}{\mathrm{r}}\left(1 + \frac{\mathrm{r}}{r_s}\right)^{-2} \qquad (r \leq r_{vir})$$

DM DENSITY PROFILES

Spike Profiles

NFW+Spike

$$\rho(r) = \begin{cases} \rho_s \dfrac{r_s}{r} \left(1 + r/r_s\right)^{-2} & r > R_{sp} \\ \rho_{sat} \left(\dfrac{r}{r_{sat}}\right)^{-\gamma_{sp}} & r_{sat} < r \leqslant R_{sp} \\ \rho_{sat} & r \leqslant r_{sat} \end{cases}$$

DM DENSITY PROFILES

Spike Profiles

Mini-Spike

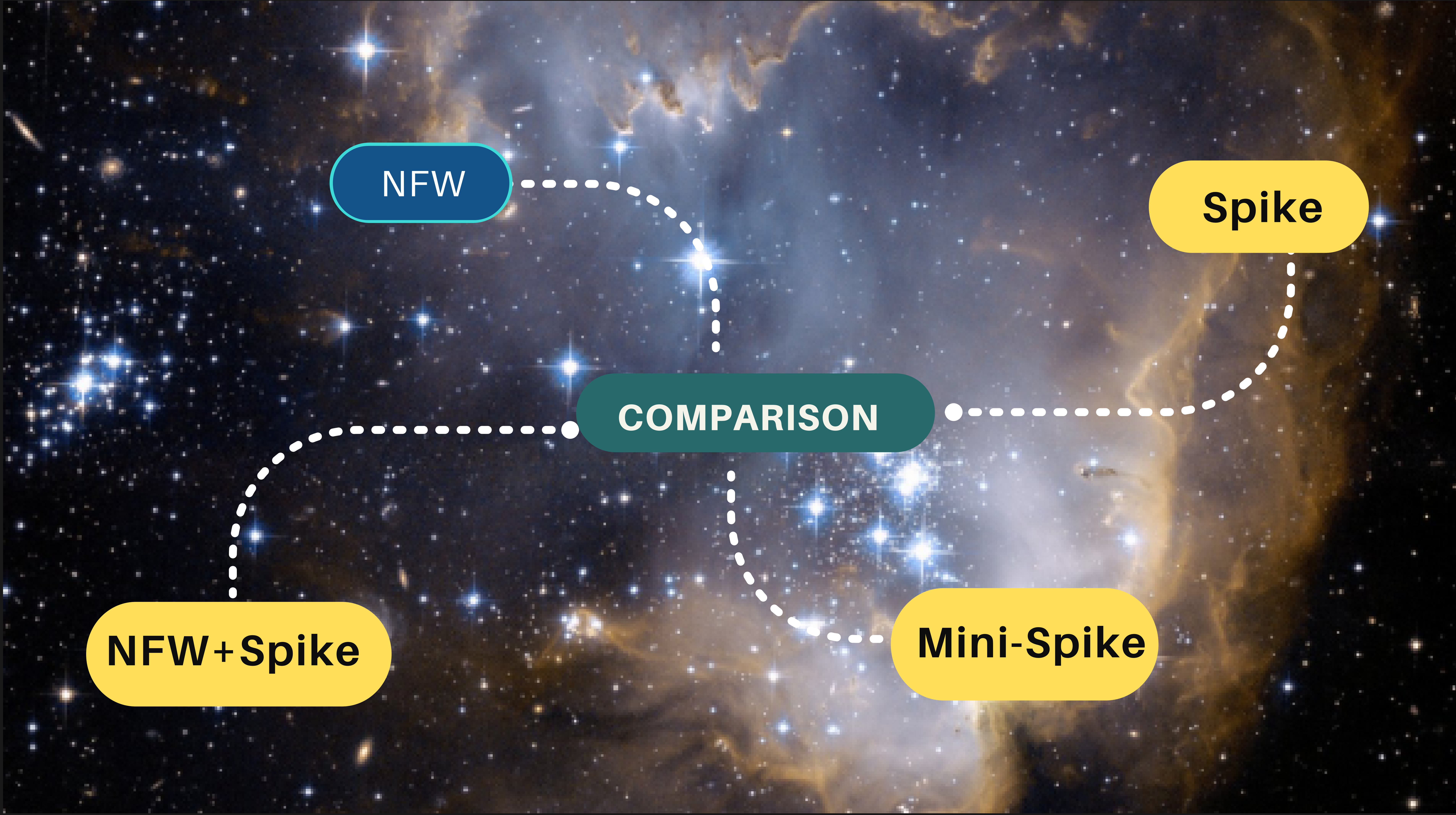
$$\rho(r) = \begin{cases} 0 & r \leqslant 2R_s \\ \rho_{sat} & 2R_s < r \leqslant R_{sat} \\ \rho_0 \left(\dfrac{r}{R_{sp}}\right)^{-\gamma_{sp}} & R_{sat} < r \leqslant R_{sp} \end{cases}$$

DM DENSITY PROFILES

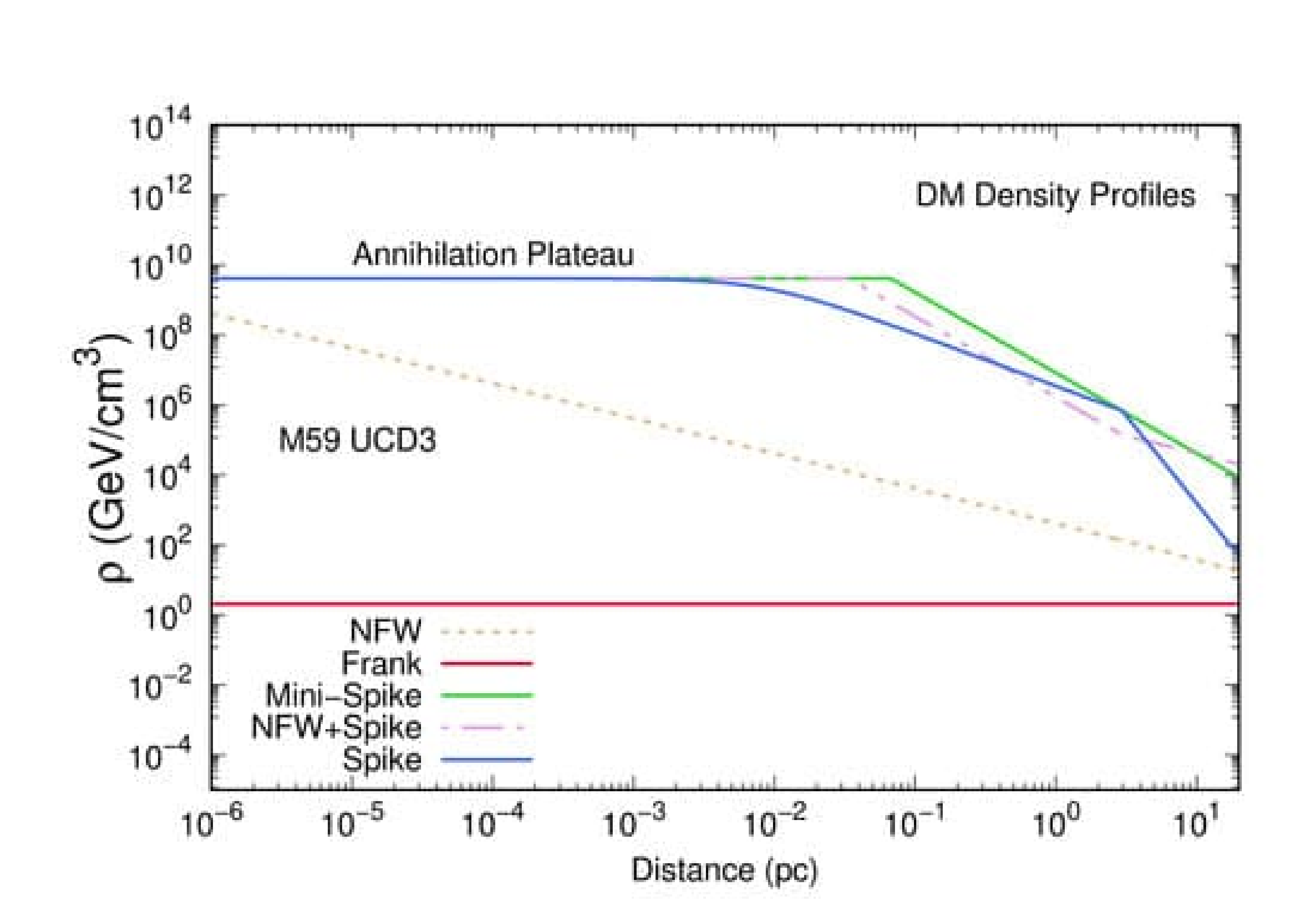
Spike Profiles

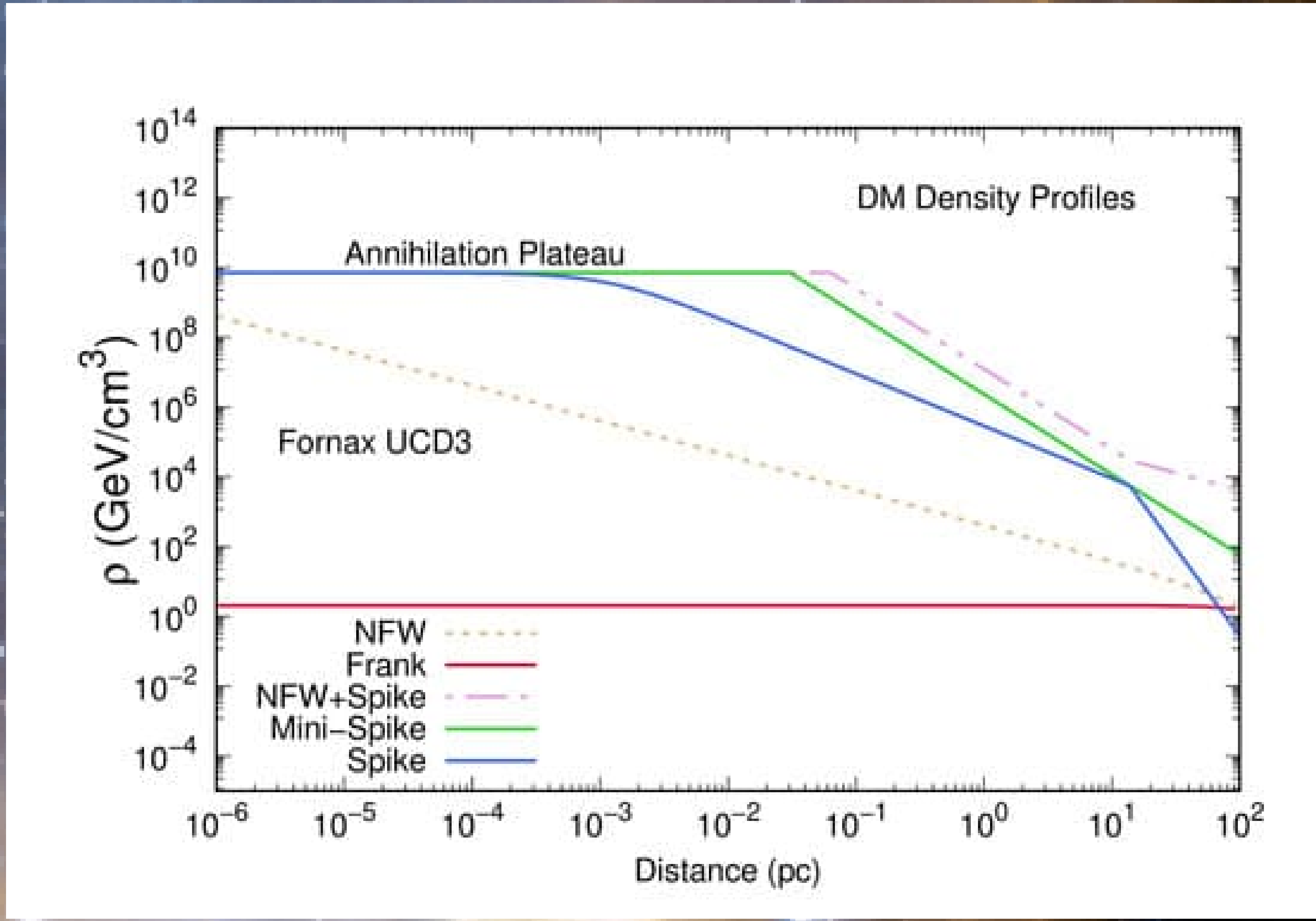
Spike

$$\rho(r) = \begin{cases} 0 & r < 2R_s \\ \dfrac{\rho_{sp}(r)\rho_{sat}}{\rho_{sp}(r) + \rho_{sat}} & 2R_s \leqslant r < R_{sp} \\ \rho_0 \left(\dfrac{r}{R_{sp}}\right)^{-5} & r \geqslant R_{sp} \end{cases}$$

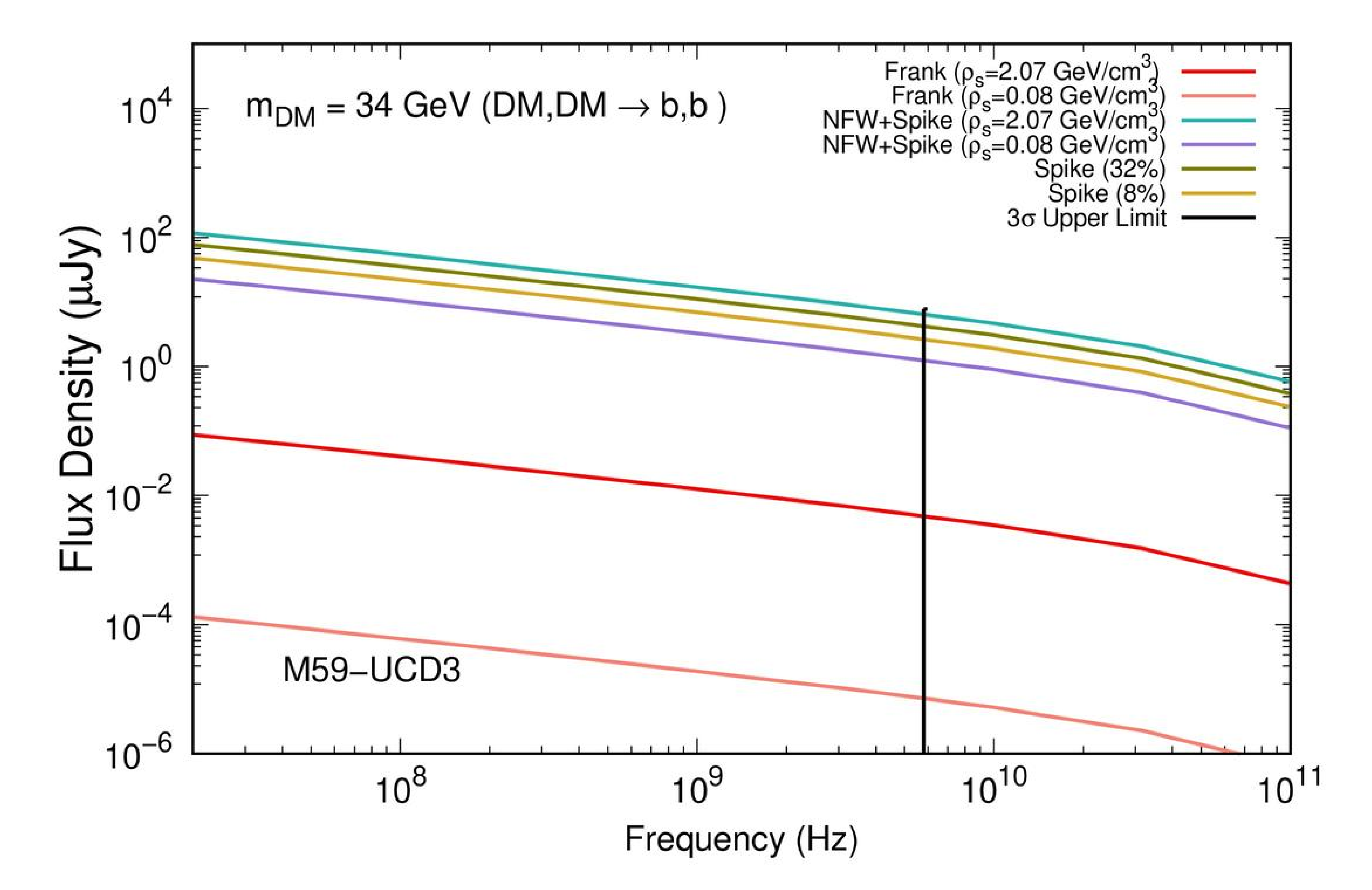

NFW
Spike
COMPARISON
NFW+Spike
Mini-Spike

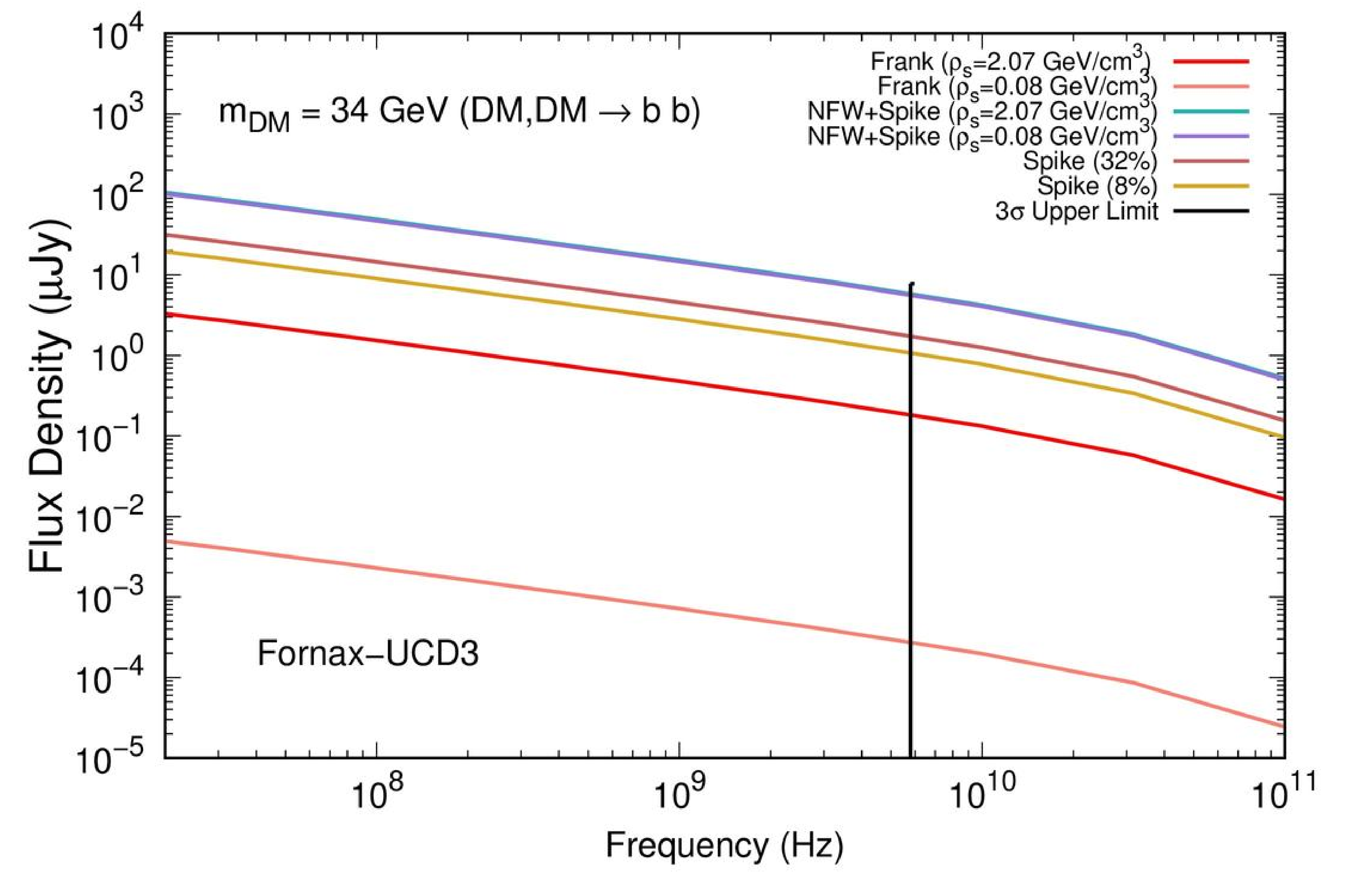
SPIKE DENSITY PROFILES AROUND THE SMBH IN UCD'S



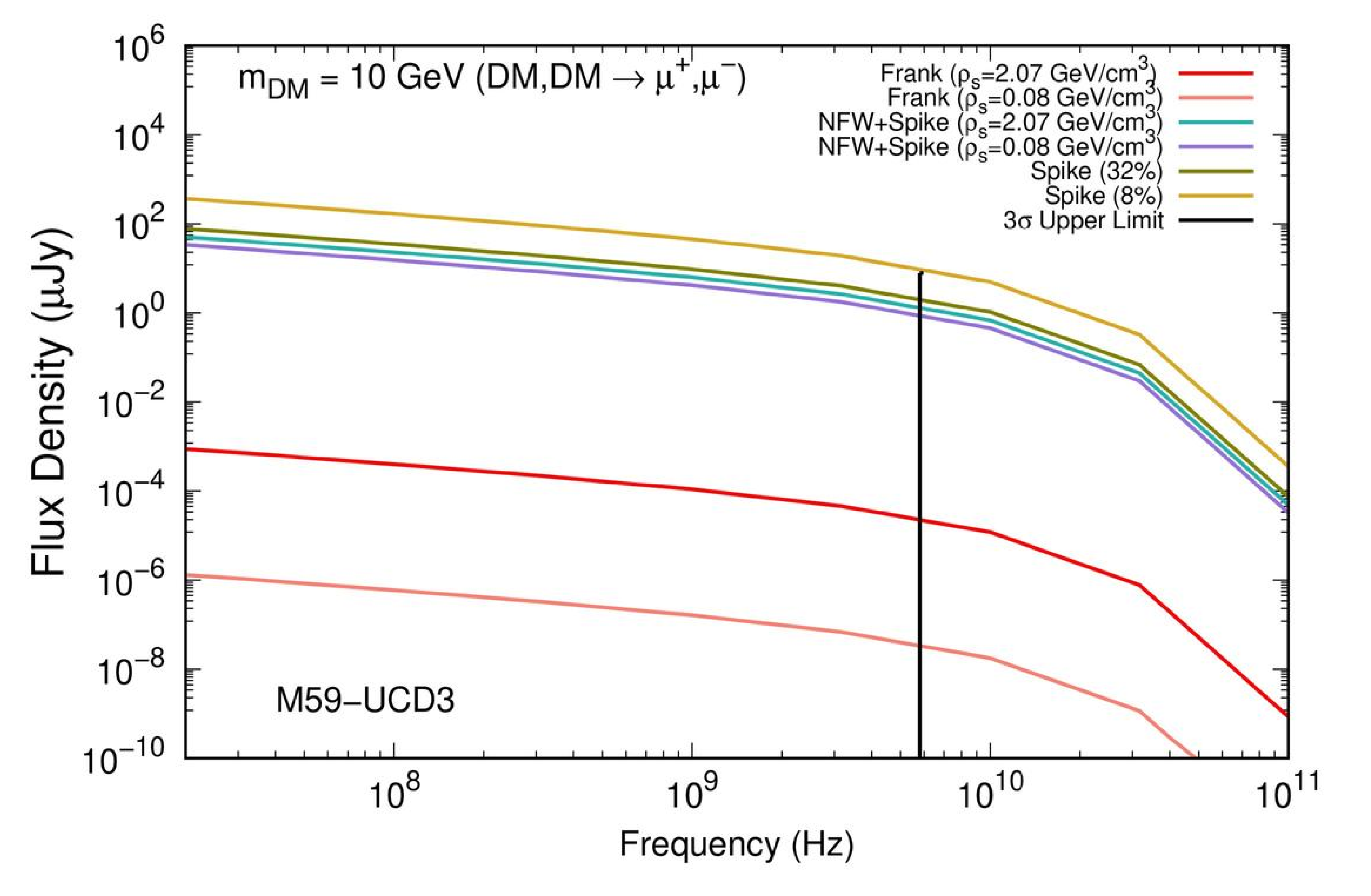


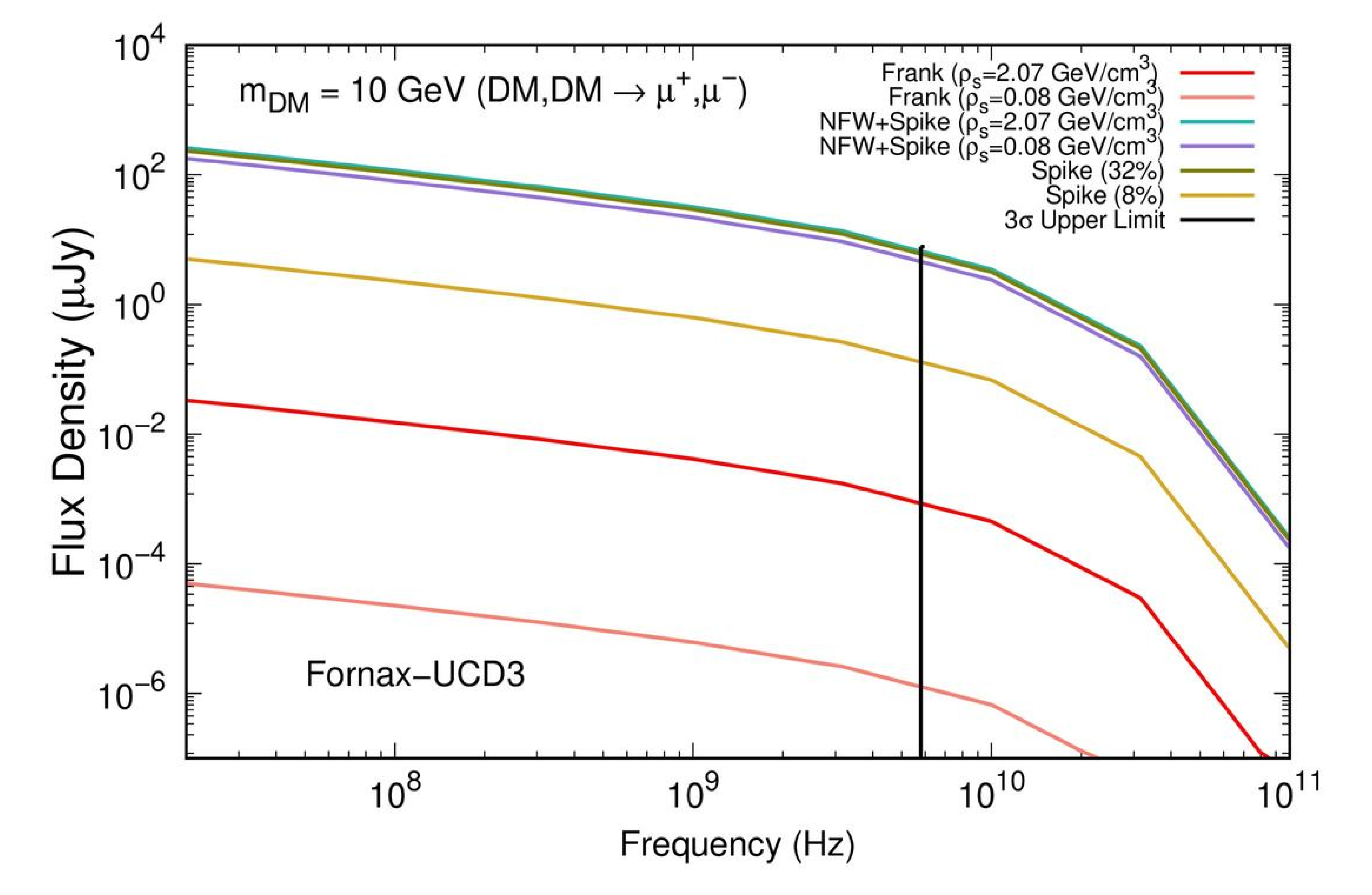
NUMERICAL RESULTS – FLUX DENSITY





NUMERICAL RESULTS – FLUX DENSITY





Conclusion

- The size of the spike and the internal properties of the black hole at UCDs can leave their imprint in synchrotron flux;
- This imprint can be very strong as compared to those predicted from simulations of Fornax UCDs;
- The DM density distribution that mimics DM in Fornax UCD3 produces radio fluxes well below the upper limits predicted for M59 UCD3 when the annihilation cross-section is in the same order or two orders of magnitude below the thermal one.

Conclusion

- Considering the set of parameter studied here and the spikes profiles, the annihilation cross-sections should be many orders of magnitude below the thermal cross-section to agree with the upper limits for these UCDs;
- In the absence of gamma-rays signal, synchrotron emission is an interesting method for testing potential astrophysical signature of DM.

THANK YOU!