Dynamical friction in fuzzy dark matter

Internship oral defense

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Internship at LIRA, Observatory of Paris

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Scientific context

- **Standard cosmological model** : ΛCDM , 27% of the universe made of **Cold Dark Matter (CDM)**. Outstandingly successful on cosmological scales $(> \mathrm{Mpc})$.

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1 Introduction

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Objective : compare the dynamics of globular clusters in Cold and Fuzzy dark matter.

Globular clusters

- Very **dense** and **compact** object, composed of **millions of stars** $(M_{\text{obj}} \sim 10^6 \, \mathrm{M}_{\odot})$.
- Orbit in the **dark matter** halo and undergo **dynamical friction**.

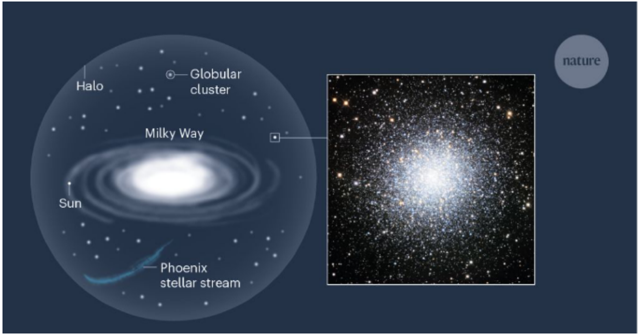

Figure: Credits : Nature.

Dynamical friction

- **Energy loss** mechanism.
- Object M_{obj} orbiting in a field of particles $m_\star$, such that $M_{\text{obj}} \gg m_\star$.
- **Deflection** of particles $\rightarrow$ **overdensity** $\rightarrow$ **drag force** (*Chandrasekhar, 1943*).

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$$\vec{F}_{\text{DF}} \propto -\frac{M_{\text{obj}}^2 \rho(r)}{v^3} \vec{v},$$

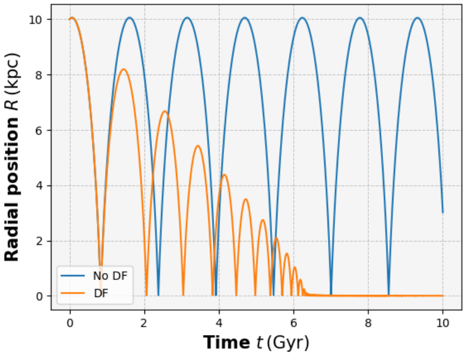

Figure: Orbit of a $10^6\,\mathrm{M}_\odot$ globular cluster in a $10^9\,\mathrm{M}_\odot$ dark matter halo.

Fuzzy Dark Matter

- Lies on an **ultralight** boson of mass $m_{\text{FDM}} \sim 10^{-22}$ eV.

- Very large De Broglie wavelength ($\sim$ kpc) $\Longrightarrow$ **Quantum effects affect the halo density**.

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- Very large De Broglie wavelength ($\sim$ kpc) $\Longrightarrow$ **Quantum effects affect the halo density**.
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- The effect depends on the **FDM particle mass m_{FDM}**.

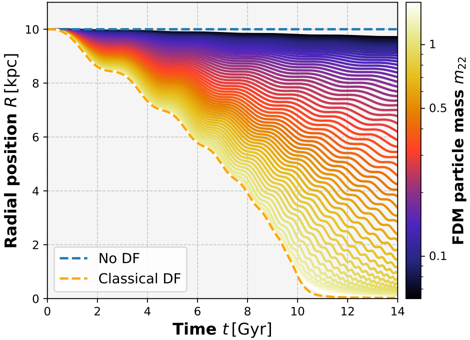

Figure: Orbit in a dark matter halo as a function of the value of the FDM particle $m_{22} = \frac{m_{\text{FDM}}}{10^{-22}\,\text{eV}}$.

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Orbits integration with galpy

I. Set the components

- **Dark Matter halo** (mass $\mathcal{M}_{\text{halo}}$, scale radius r_s)
- **Globular clusters** (mass $M_{\text{obj}} = 10^6\,\mathrm{M}_\odot$, half-mass radius $r_{\text{hm}} = 10\,\mathrm{pc}$)

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4500 globular clusters **gravitationally bound**, for radial positions within 0.1 - 10 scale radius r_s of the halo.

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IV. Calculate the fall-in times

Find the time for which the orbit **definitively falls** below 10% of the scale radius r_s of the halo.

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3 Results : comparison Cold/Fuzzy Dark Matter

Comparison of the fall-in times

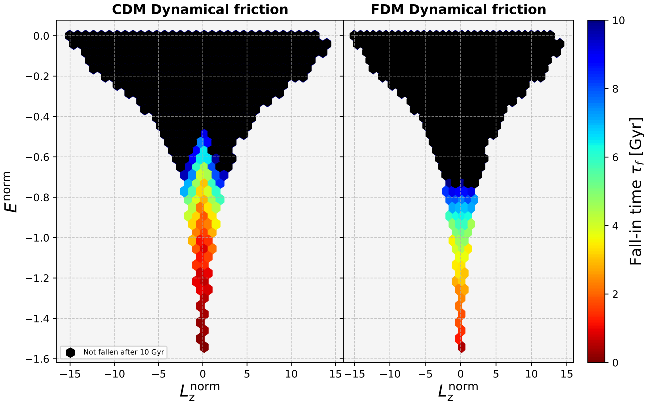
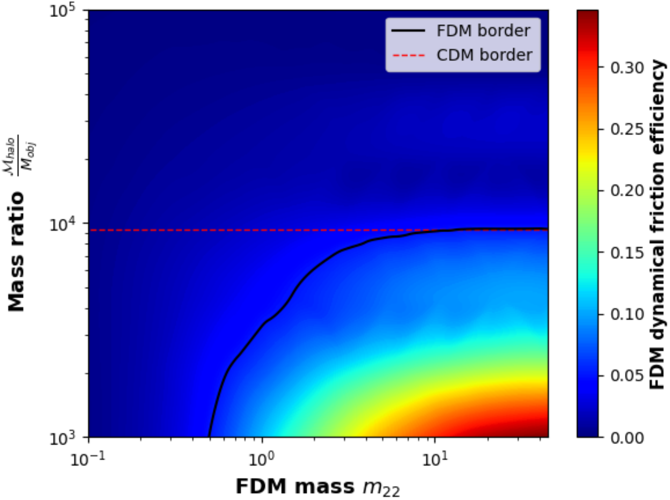


Figure: Orbits in a CDM halos, with a halo-GC mass ratio of 10^3 and concentration $c = 18$. Left panel : CDM DF. Right panel : FDM DF, with $m_{22} = 5$.

Impact of the mass ratio halo-GC and FDM particle mass



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4 Conclusion

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- **New contributions**: new `galpy` class for FDM dynamical friction - Better understanding of dynamical friction - New tests on FDM physics.

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- Configurations identified to look for **FDM signatures** (dwarf galaxy and FDM mass range: $0.1 < m_{22} < 30$)
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Perspectives : modify the dark matter profile according to FDM and add baryonic components : publication in preparation.

Thank you for listening!
Any questions?