Primordial black holes and axions:
a tale of (galactic and extragalactic) light

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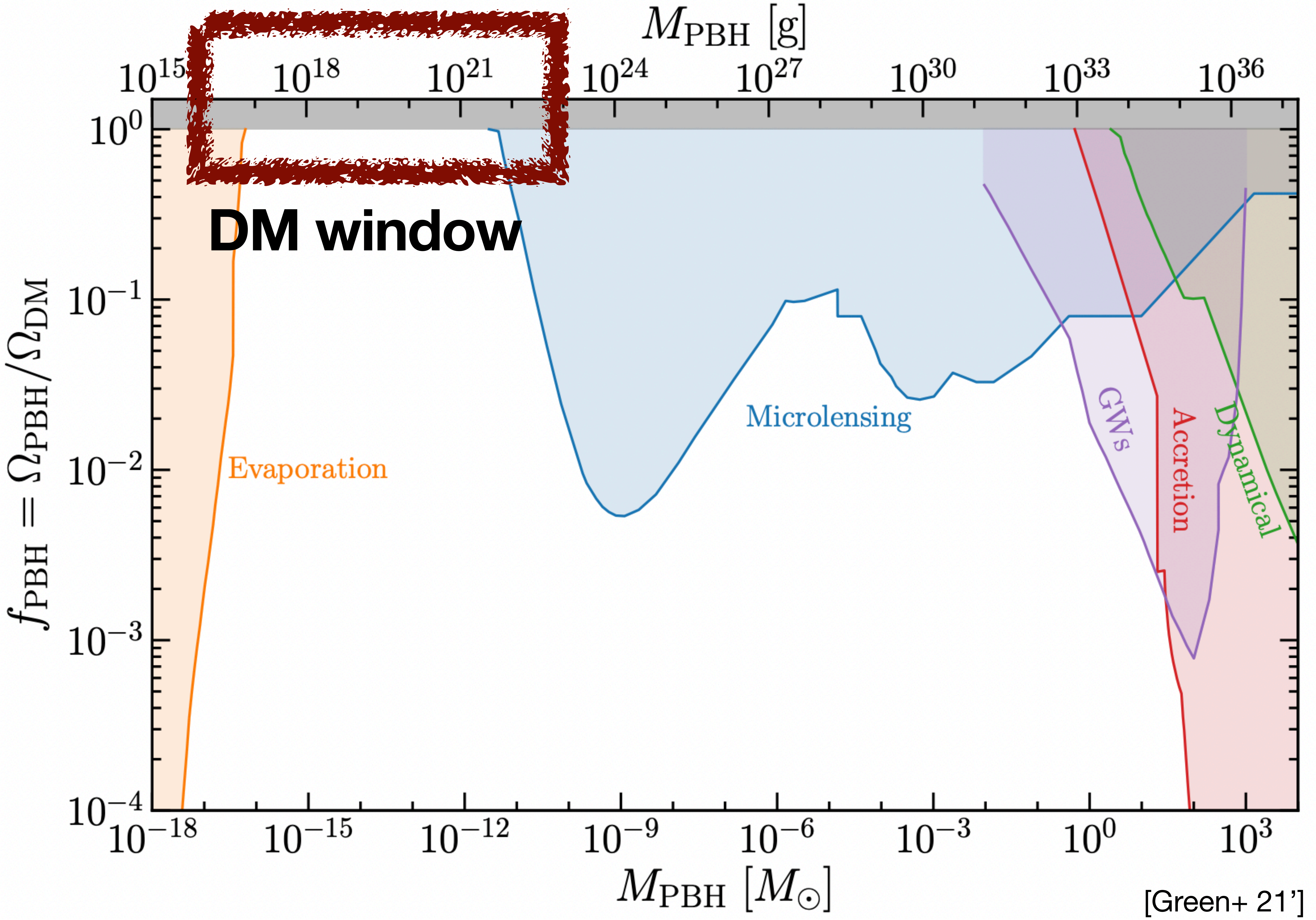
In collaboration with N. Branco & J. Rosa

Primordial black holes as dark matter



[Green+ 21']

- PBHs can only account for **all the DM** in the **asteroid** mass range ($10^{14} - 10^{18}$kg).
- Can we have some *indirect evidence* of this PBH population? Maybe with axion-like particles…?

PBH superradiance of ‘heavy’ axions

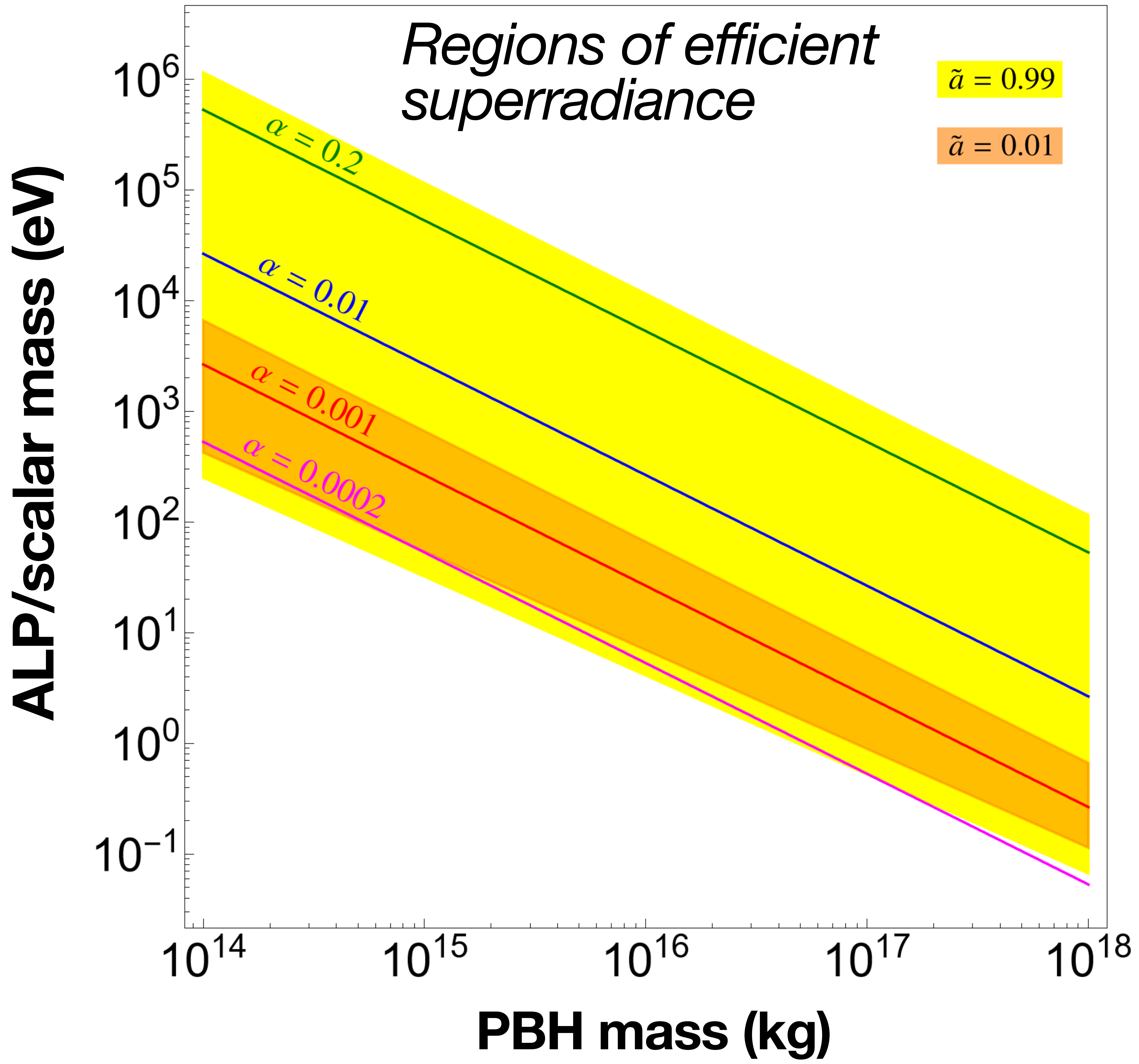
[N.Branco, **RZF**, J.Rosa]

- PBHs have **spin.**
  Can they trigger superradiance?
  - Leading **superradiant condition**

$$\alpha = GM\mu < \frac{\tilde{a}}{2\left(1+\sqrt{1-\tilde{a}^2}\right)}$$

  - **“Efficient”** superradiance:

$$\Gamma_{SR}^{-1} < t_{uni}$$

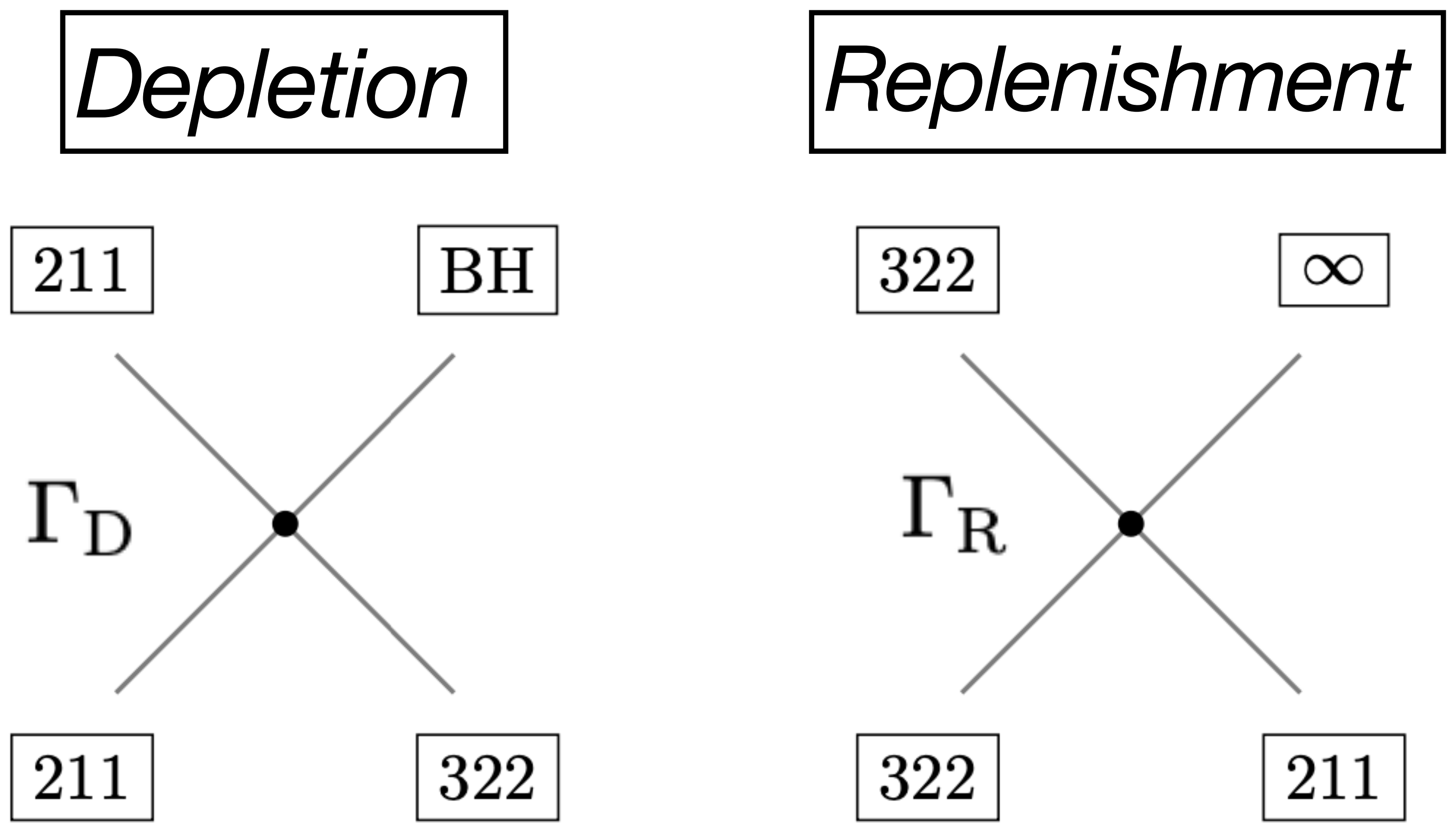


Role of axion self-interactions

- Self-interactions

$$\mathcal{L}_a \supset \frac{1}{2}\partial_\mu a\,\partial^\mu a + \mu^2 f^2 \left[1 - \cos\left(\frac{a}{f}\right)\right]$$

- Main processes:



ψ_{nlm} = bounds states in the cloud.
$|nlm\rangle = |211\rangle$ leading superradiant level

[Baryakhtar+ 20']

- Evolution of the cloud described by set of coupled differential equations:

$$\frac{dN_2}{dt} = N_2\left[\Gamma_2 + N_3\left(\Gamma_{\rm R}N_3 - 2\Gamma_{\rm D}N_2\right)\right]$$

$$\frac{dN_3}{dt} = N_3\left[\Gamma_3 + N_2\left(\Gamma_{\rm D}N_2 - 2\Gamma_{\rm R}N_3\right)\right]$$

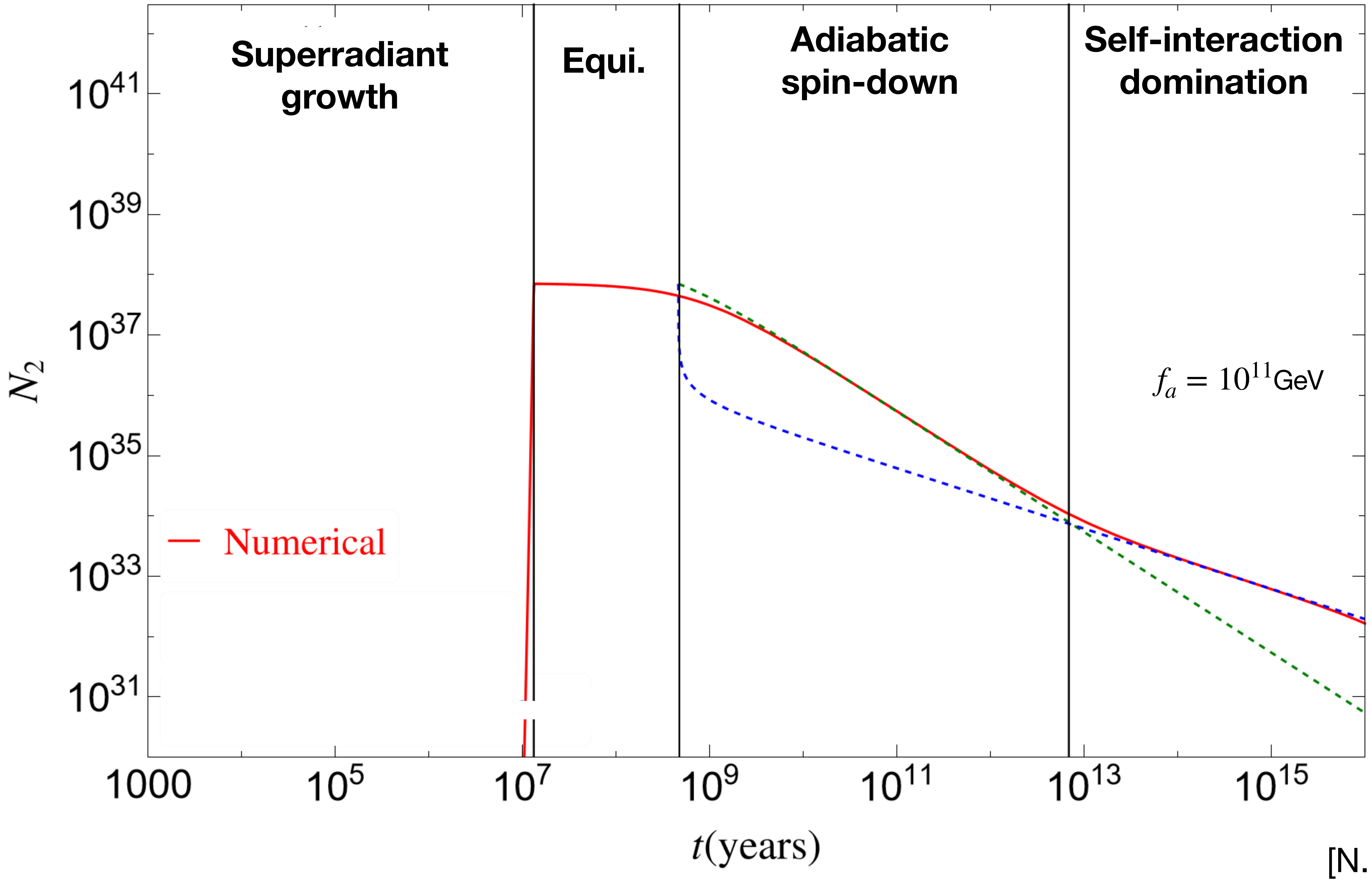
$$\frac{dM}{dt} = -\mu\left(\Gamma_2N_2 + \Gamma_3N_3 - \Gamma_{\rm D}N_2^2N_3\right)$$

$$\frac{dJ}{dt} = -\left(\Gamma_2N_2 + 2\Gamma_3N_3\right)$$

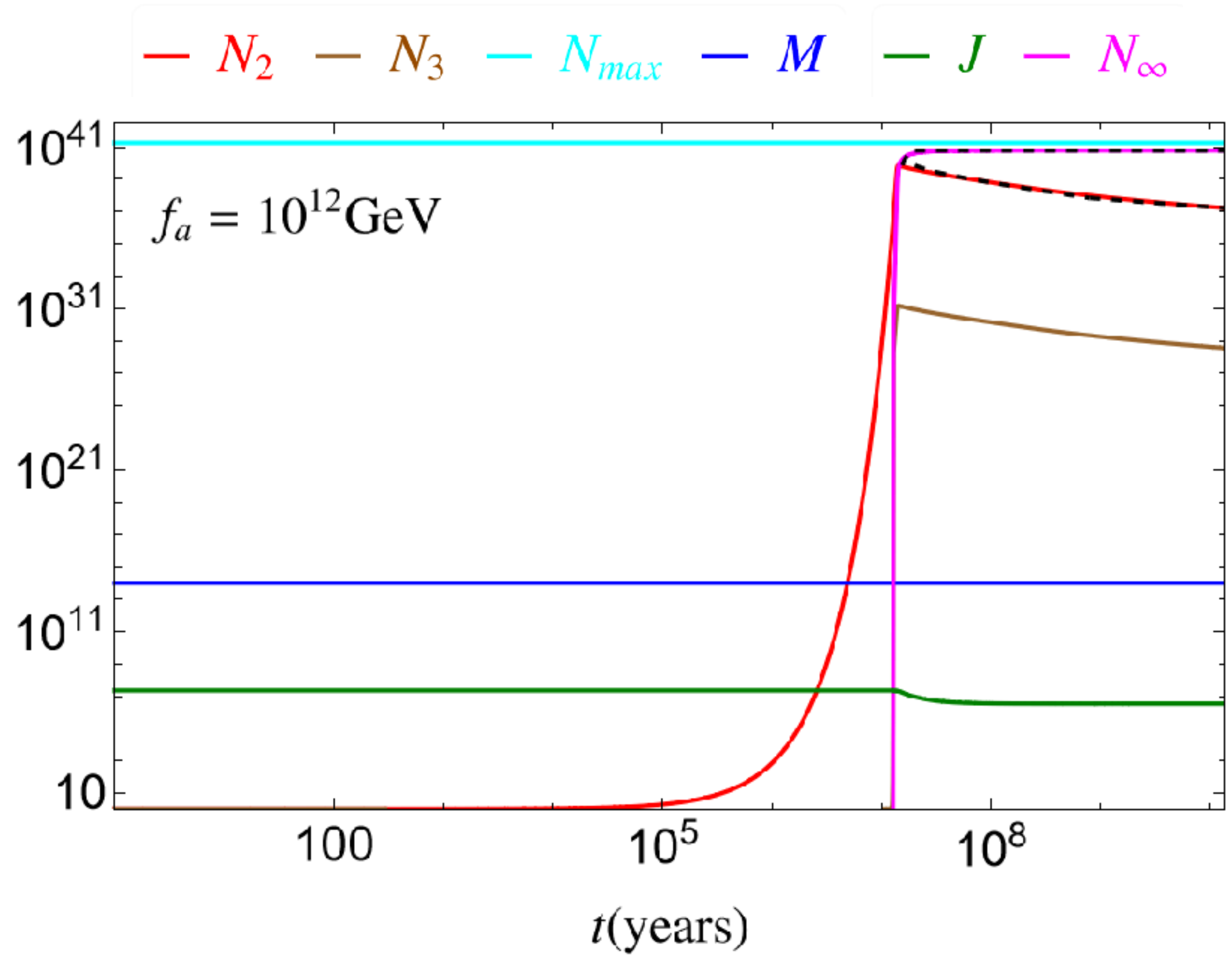
[N.Branco, **RZF**, J.Rosa]

Dynamics of the cloud

- 4 different regimes identified in the evolution of the cloud
- Duration and existence depend on f_a



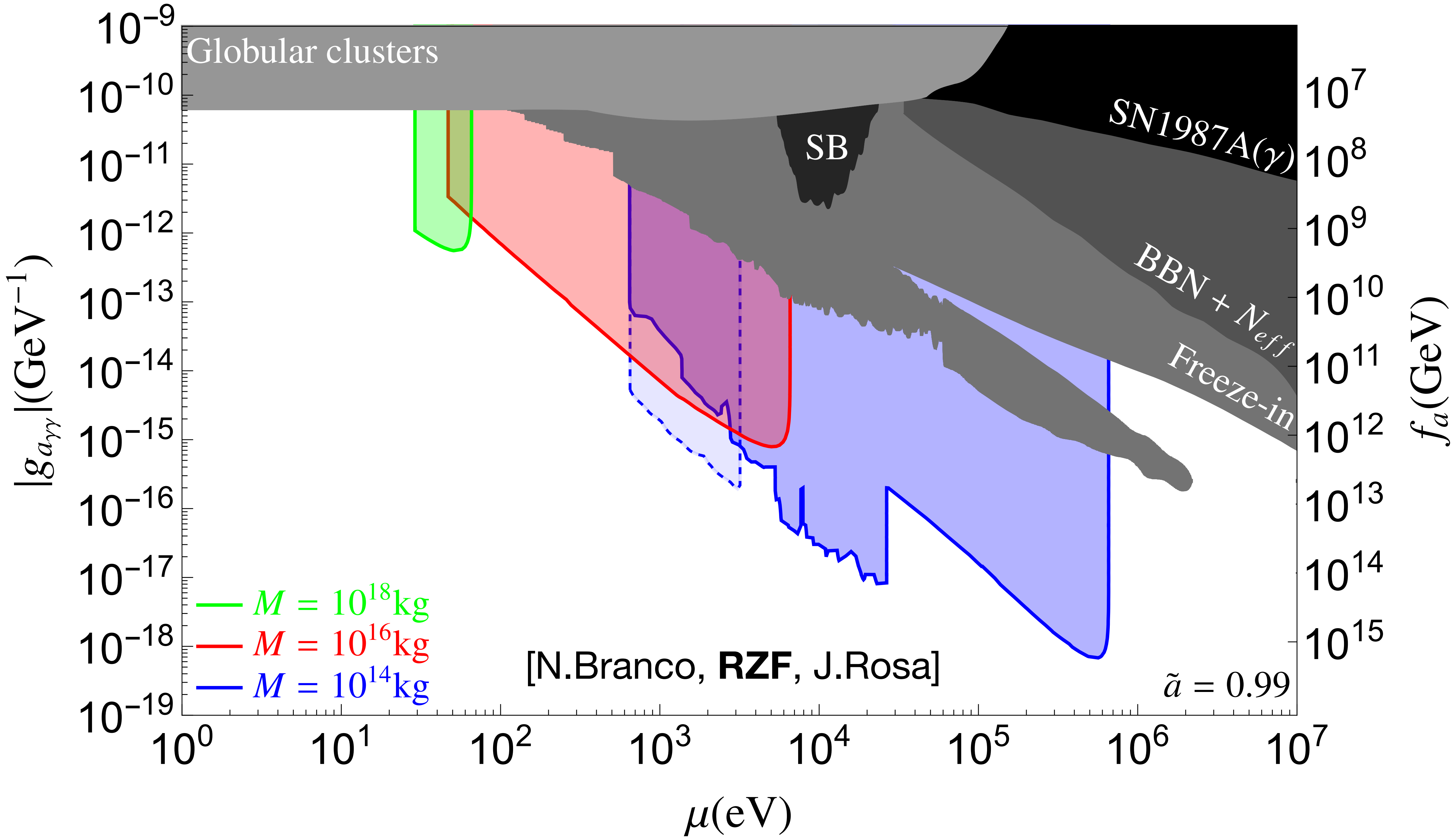
Cloud is quenched but axions that escape the cloud accumulate
⇒ **galactic and extragalactic axion population**

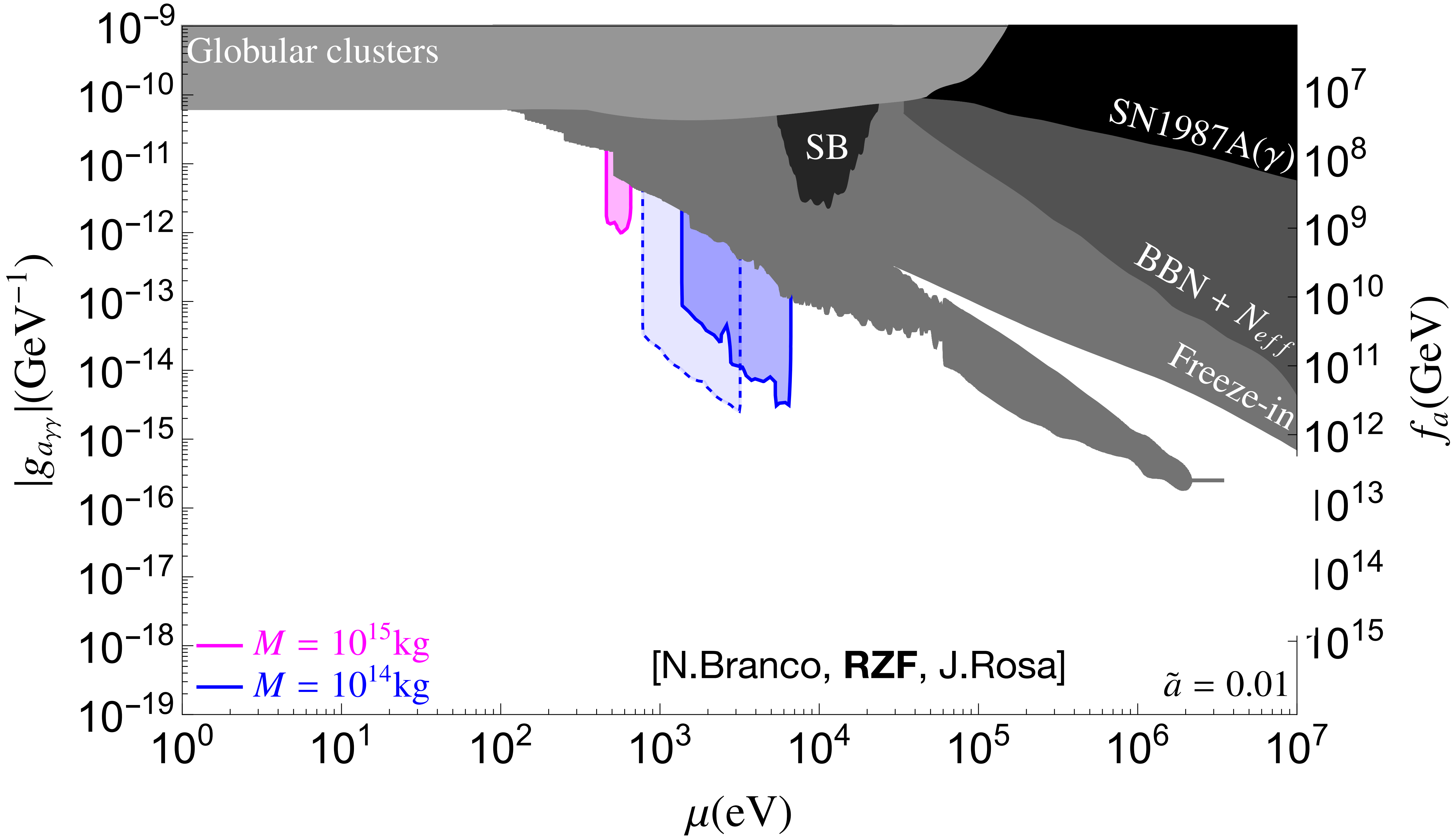


[N.Branco, **RZF**, J.Rosa]

X-Ray and gamma-ray signatures

- If axions couple to photons they can decay in two photons at a rate $\Gamma_{a\to\gamma\gamma} \simeq 10^{-6}\mu^3/f^2$:
  $a \to 2\gamma$ => ***galactic and extragalactic flux***
- Current data already places strong bounds on the co-existence of certain PBH-axion pairs. Future X-ray telescopes (e.g. Athena) will further probe this scenario.





Outlook

- Primordial black holes with **asteroid** masses (10^{14-18}kg) can be the **dark matter** but are **hard to probe**.

- However, PBHs can give rise to a large **population of axions** in the mass range ($0.1 - 10^6$ eV) via superradiance. Axion self-interactions quench the cloud but a **large number** of **“free” axions** accumulates.

- If such axions couple to photons they contribute to the **galactic and extragalactic background** fluxes and provide an indirect probe of PBH dark matter. Current data is already able to exclude large range of parameters.