Dark Radiation in the PQMSSM

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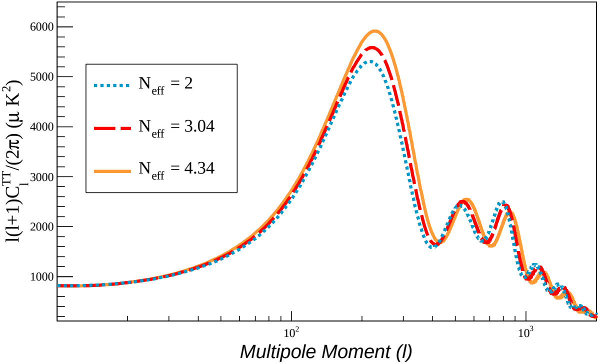
DFMA -USP

SILAFAE - December 14th, 2012

H. Baer, K. J. Bae, AL, arXiv:1212.xxxx

Why Dark Radiation?

- Why more "dark stuff"?



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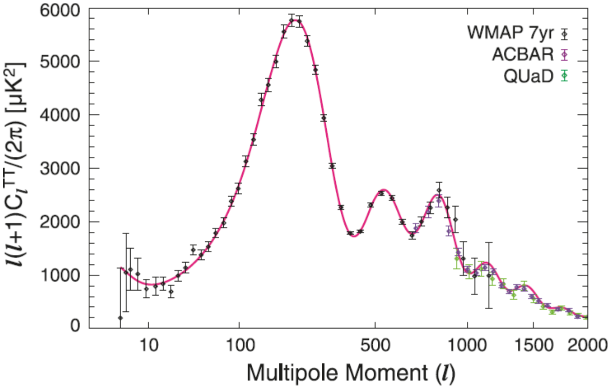

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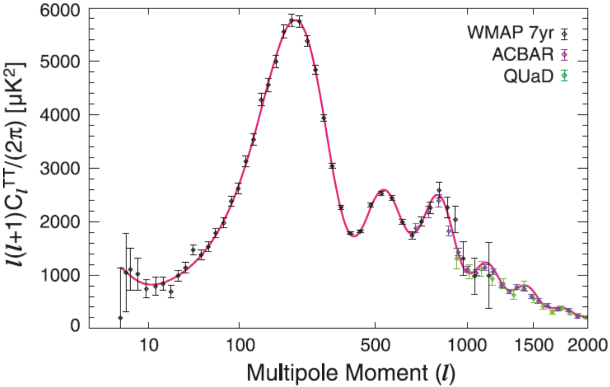

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- If the excess is real...
  - New relativistic species at $T \gtrsim eV$
  - $m_{DR} \ll$ eV (usually) $\to$ suppressed interactions with SM

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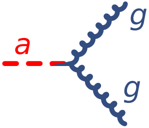

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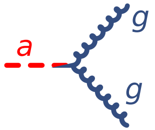

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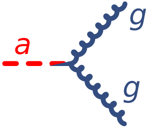

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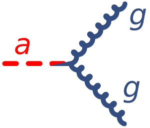

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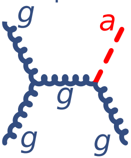

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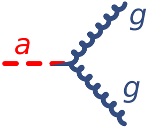

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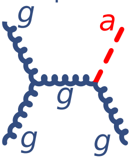

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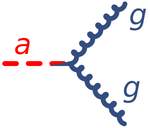

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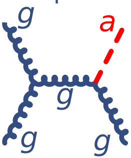

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$\rightarrow$ $\boxed{\Delta N_{eff} < 10^{-2}}$ ✘

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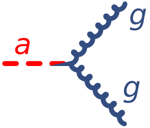

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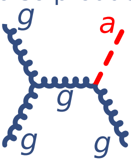

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- $f_a \gg$ EW scale $\rightarrow$ Hierarchy Problem

The PQMSSM

- SUSY version:

$$a \to \hat{A} \to \underset{saxion}{s} + \underset{axion}{i\,a} + \underset{axino}{\tilde{a}}$$

  - SM + a $\to$ MSSM + $a, s, \tilde{a}$ = PQMSSM

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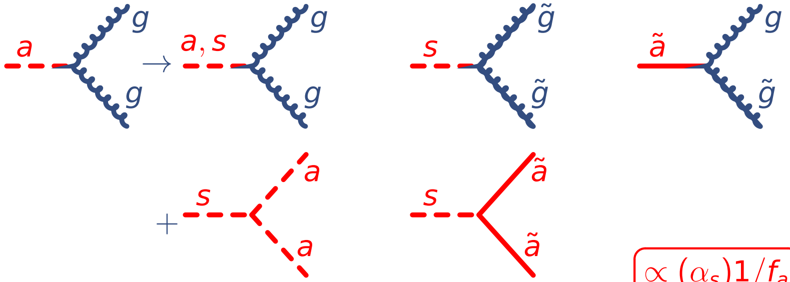
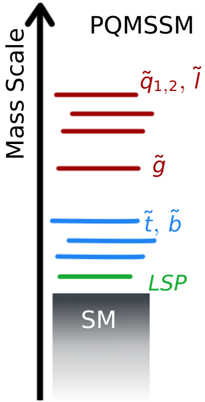
  - Couplings:



$$\propto (\alpha_s) 1/f_a$$

The PQMSSM

- PQMSSM Masses:



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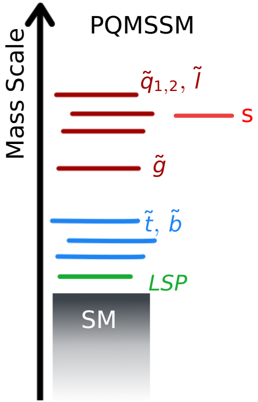

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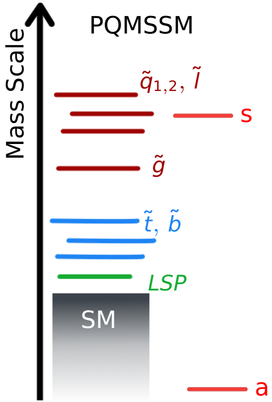

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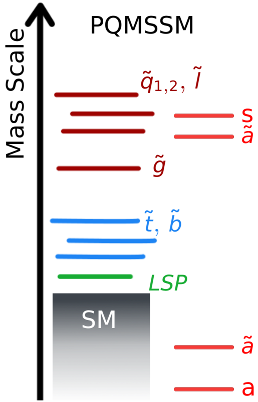

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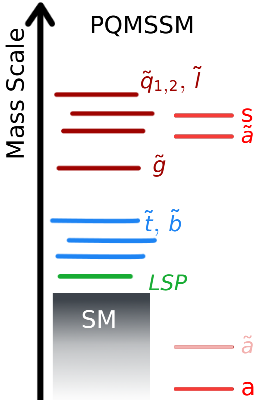
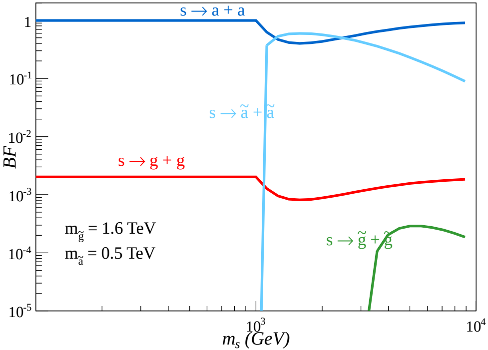
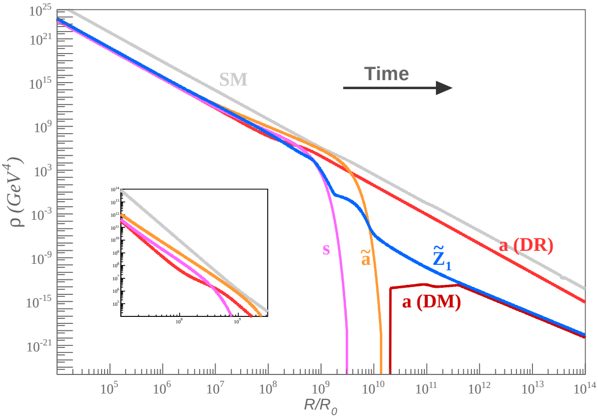




Cosmological Evolution



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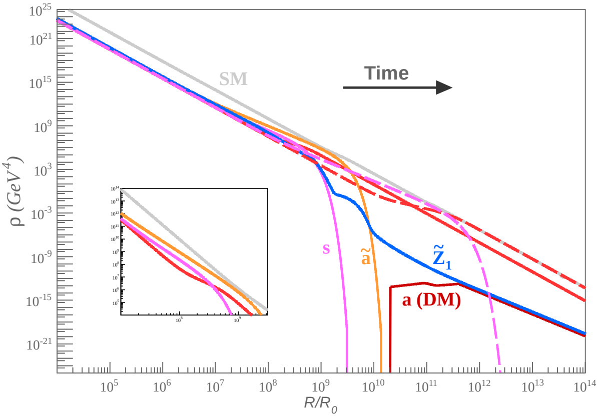

- ΔN_{eff} increases with τ_s

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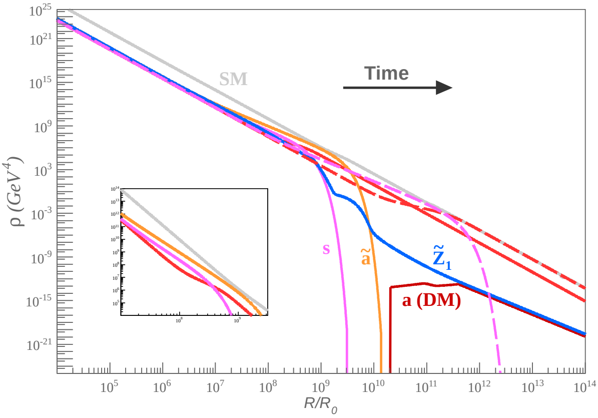
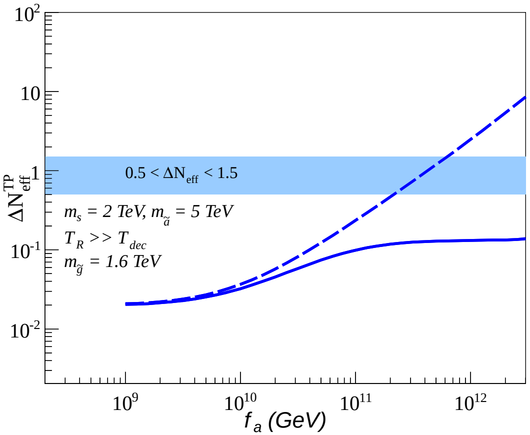


- ΔN_{eff} increases with τ_s
- $\Delta N_{eff} \propto \frac{n_s m_s}{T_D^s} \propto \frac{f_a}{\sqrt{m_s}}$

ΔN_{eff} in the PQMSSM



$\Delta N_{eff} \propto \frac{f_a}{\sqrt{m_s}}$ ✗

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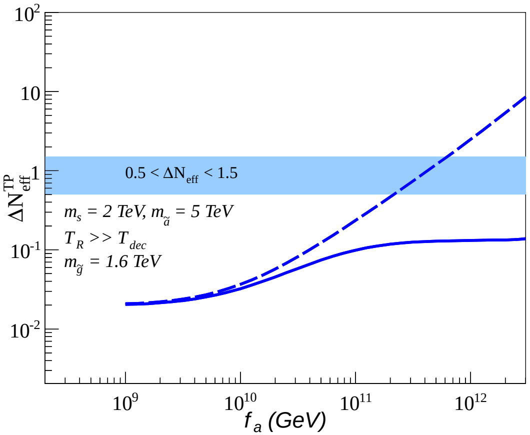

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$\rightarrow \Delta N_{eff} \sim$ constant at large f_a

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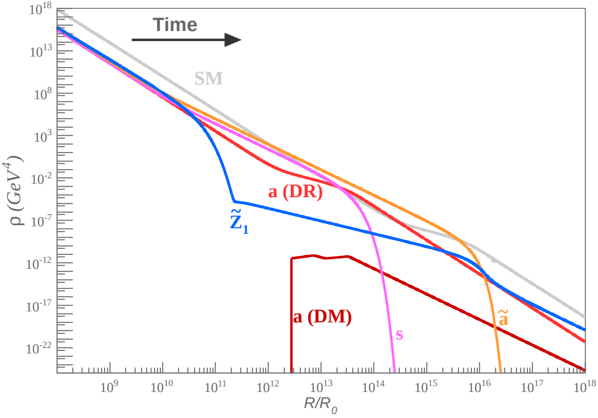

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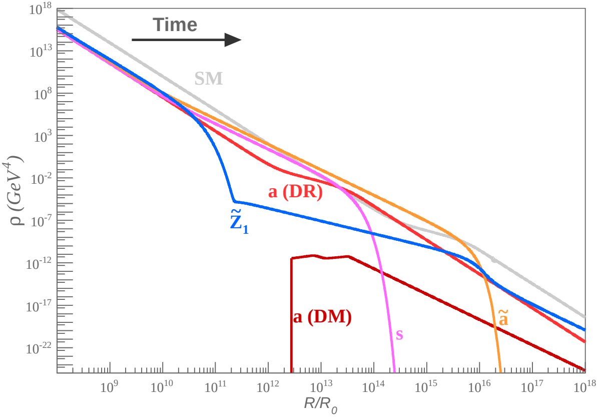

$\tilde{a} \to \tilde{g} + g \to \ldots \to \tilde{Z}_1 +$ radiation $\to$ Entropy injection!

$$\to \Delta N_{eff} \sim \frac{\rho(s \to aa)}{\rho_\gamma + \rho(\tilde{a} \to \tilde{Z}_1 + \gamma)} \to \frac{\rho(s \to aa)}{\rho(\tilde{a} \to \tilde{Z}_1 + \gamma)} \sim \text{constant } (f_a \gg 10^9 \text{ GeV})$$

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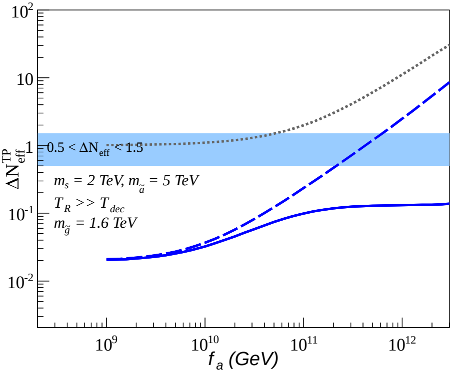

$$\Delta N_{eff} \lesssim 0.1\sqrt{\frac{m_{\tilde{a}}}{m_s}}$$

$$\Delta N_{eff} \sim 1 \rightarrow m_{\tilde{a}} \gtrsim 100 m_s!$$

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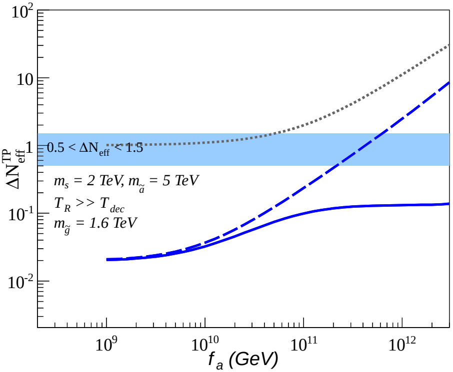

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But...

$m_{\tilde{a}} \lesssim m_{3/2} \sim m_s$ (J. E. Kim, M.-S. Seo, Nucl.Phys. B864 (2012) 296)

ΔN_{eff} in the PQMSSM

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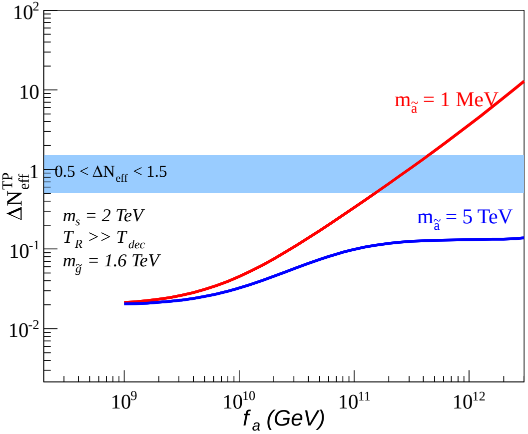
- $\tilde{a}$ LSP:



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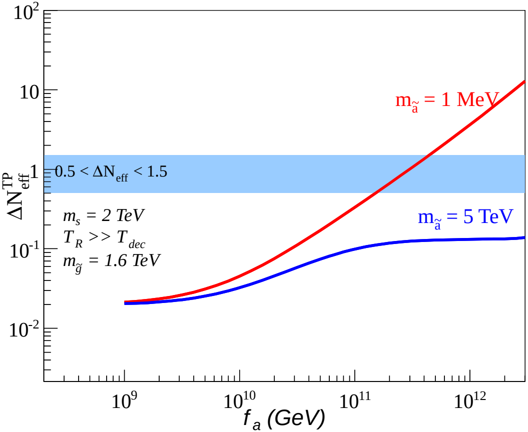

No entropy injection

$\rightarrow \Delta N_{eff} \sim 1$, if $f_a \gtrsim 10^{11}$ GeV

ã LSP

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$NLSP \rightarrow$ ã $\rightarrow$ DM = ã + a

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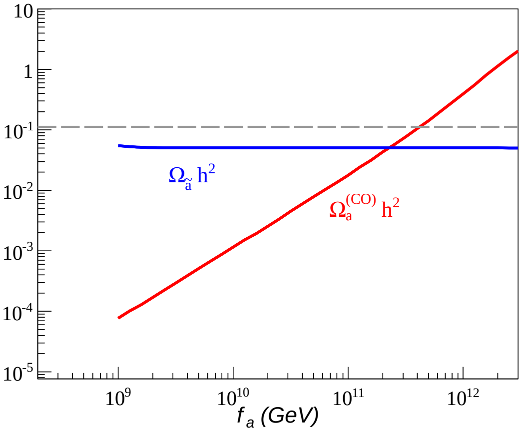

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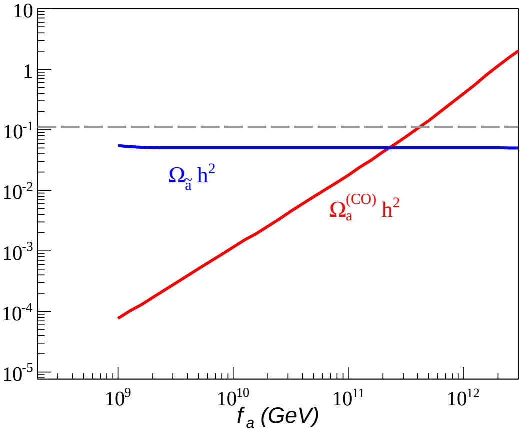

DM $\sim a$, if $f_a \gtrsim 10^{11}$ GeV

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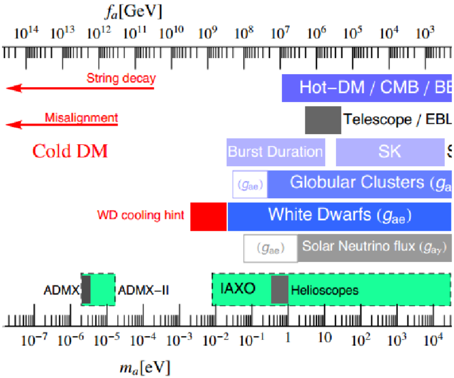
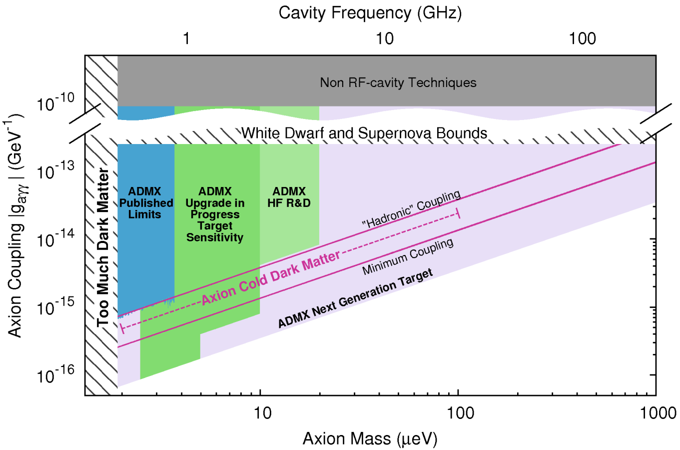
  - Within reach of ADMX-II
    (but not IAXO!)





Cavity Frequency (GHz)
1
10
100
Non RF-cavity Techniques
White Dwarf and Supernova Bounds
Too Much Dark Matter
ADMX Published Limits
ADMX Upgrade in Progress Target Sensitivity
ADMX HF R&D
"Hadronic" Coupling
Axion Cold Dark Matter
Minimum Coupling
ADMX Next Generation Target
10^-10
10^-13
10^-14
10^-15
10^-16
Axion Coupling |g_aγγ| (GeV^-1)
10
100
1000
Axion Mass (μeV)