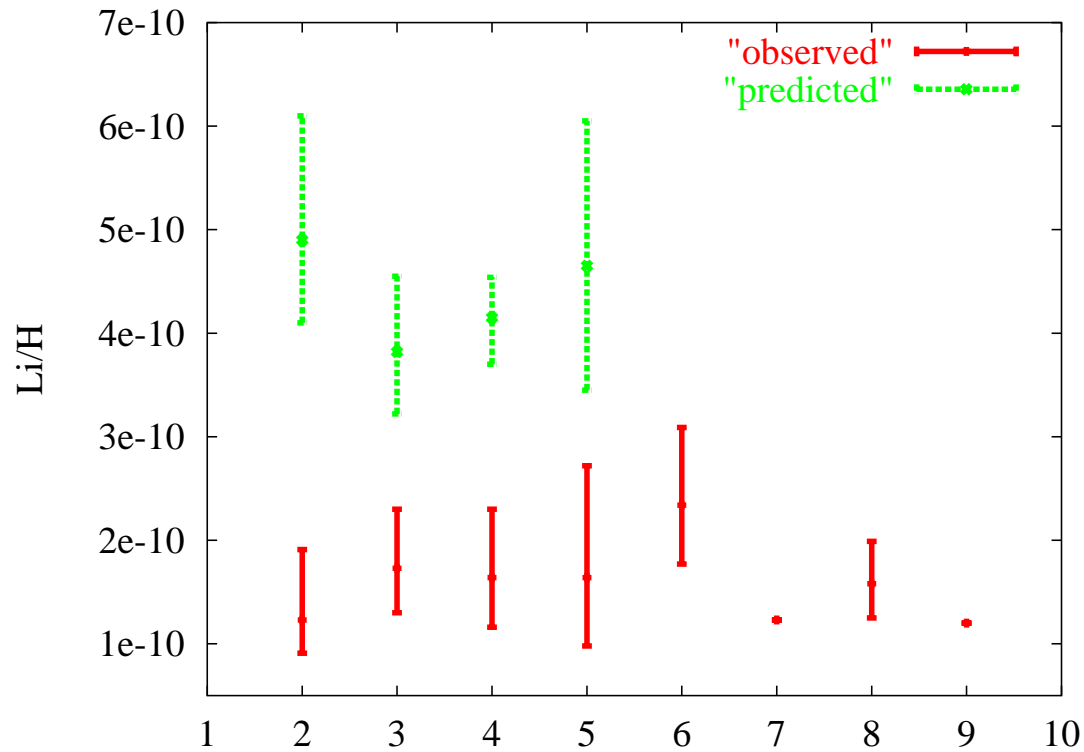


# The Cosmic Lithium Anomalies: Signs of the Dark Universe ?

Karsten JEDAMZIK<sup>†</sup>

<sup>†</sup> LPTA, Montpellier

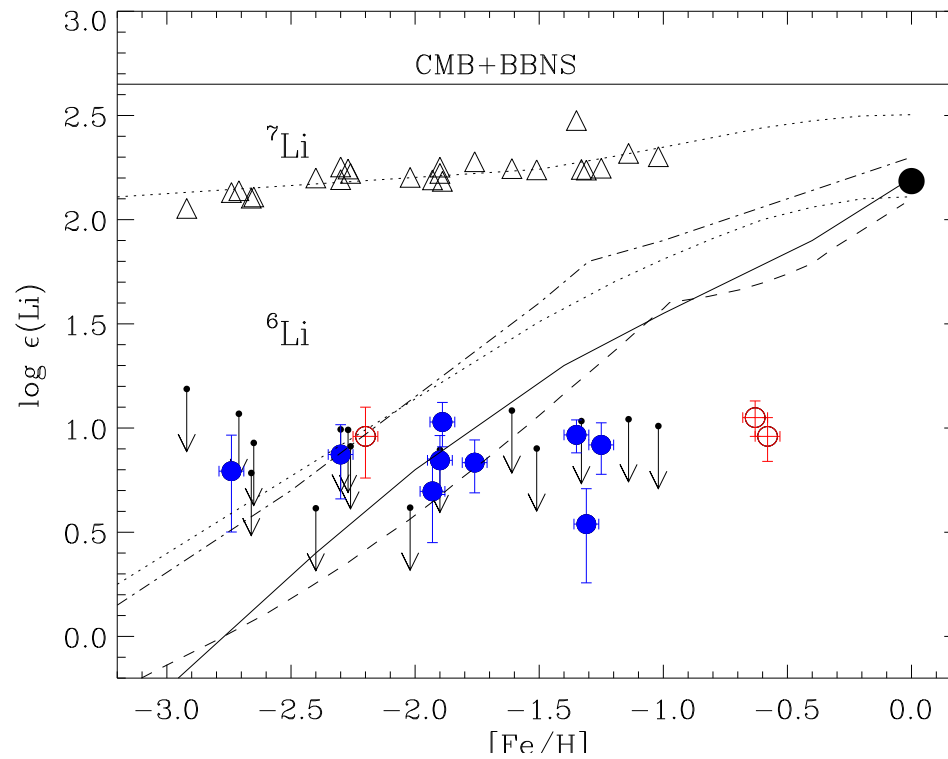
# The ${}^7\text{Li}$ Problem in standard BBN



Ryan *et al* 00; Bonifacio & Molaro 97; Charbonnel & Primas 05; Boesgard *et al* 05, Melendez & Ramirez 04; Asplund *et al* 05; Bonifacio *et al* 03, Zhangf & Zhao 04  
Burles *et al* 01; Cyburt *et al* 04; Coc *et al* 04; Cuoco *et al* 04

# ${}^6\text{Li}$ at low metallicity: A surprise

Asplund, Lambert, Nissen, Primas, and Smith 05 (astro-ph/0510636)



# $^6\text{Li}$ , $^7\text{Li}$ Situation Summary

$^7\text{Li}$  observed factor 2 – 3 lower in old stars than produced in SBBN  
Astrophysical Solutions: Depletion in stars, Nuclear cross sections, Stellar Atmospheres

# $^6\text{Li}$ , $^7\text{Li}$ Situation Summary

$^7\text{Li}$  observed factor 2 – 3 lower in old stars than produced in SBBN  
Astrophysical Solutions: Depletion in stars, Nuclear cross sections, Stellar Atmospheres

$^6\text{Li}$  observed factor 1000 higher in old stars than produced in SBBN  
Astrophysical Solutions: Very early cosmic ray population, solar flares, observational error

## ${}^6\text{Li}$ and ${}^7\text{Li}$ in cascade nucleosynthesis

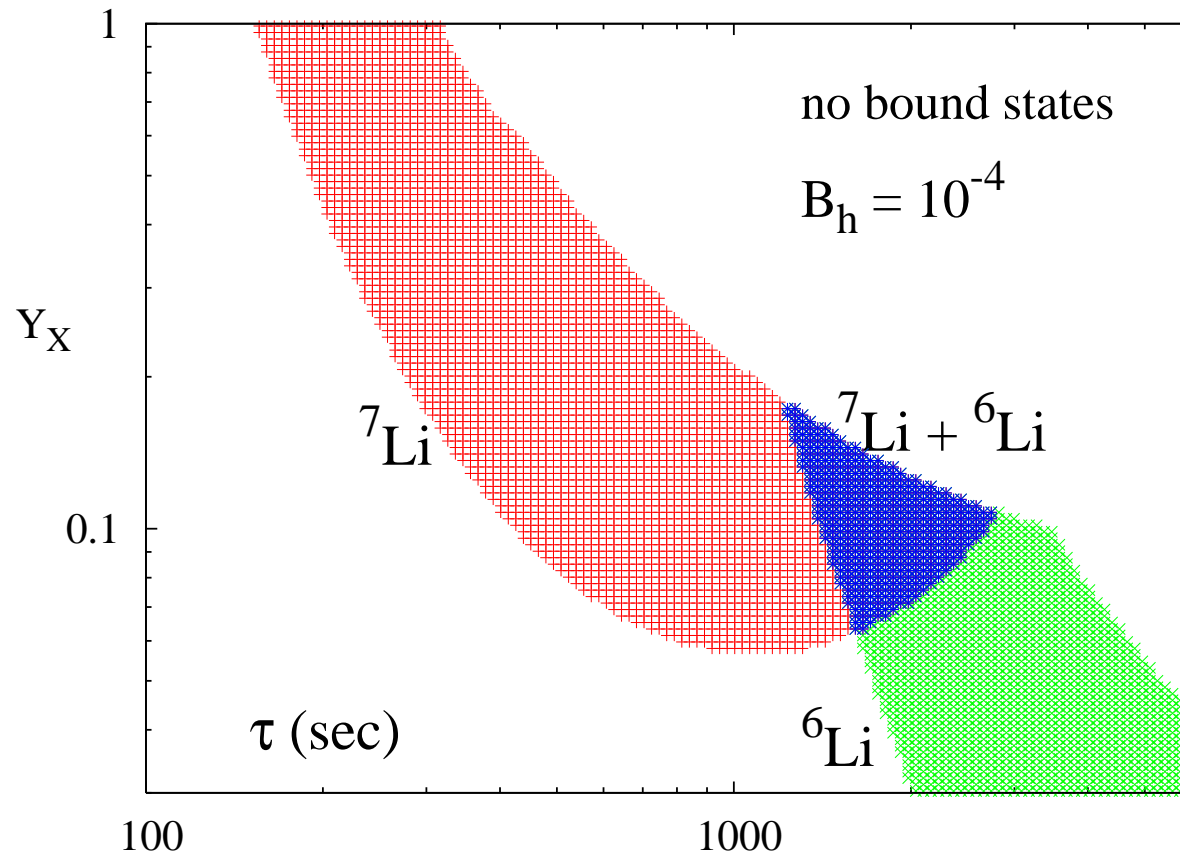
$n({}^4\text{He}, pn){}^3\text{H}(\alpha, n){}^6\text{Li}$  at  $T \approx 10 \text{ keV}$

Dimopolous *et al* 88, K.J. 00

${}^7\text{Be}(n, p){}^7\text{Li}(p, \alpha){}^4\text{He}$  at  $T \approx 30 \text{ keV}$

K.J. 04

# Decaying neutral particles *during* BBN



K.J. Phys. Rev. D 70 063524 (2004); (astro-ph/0402344)

# Charged relic - nuclei bound states during/after BBN

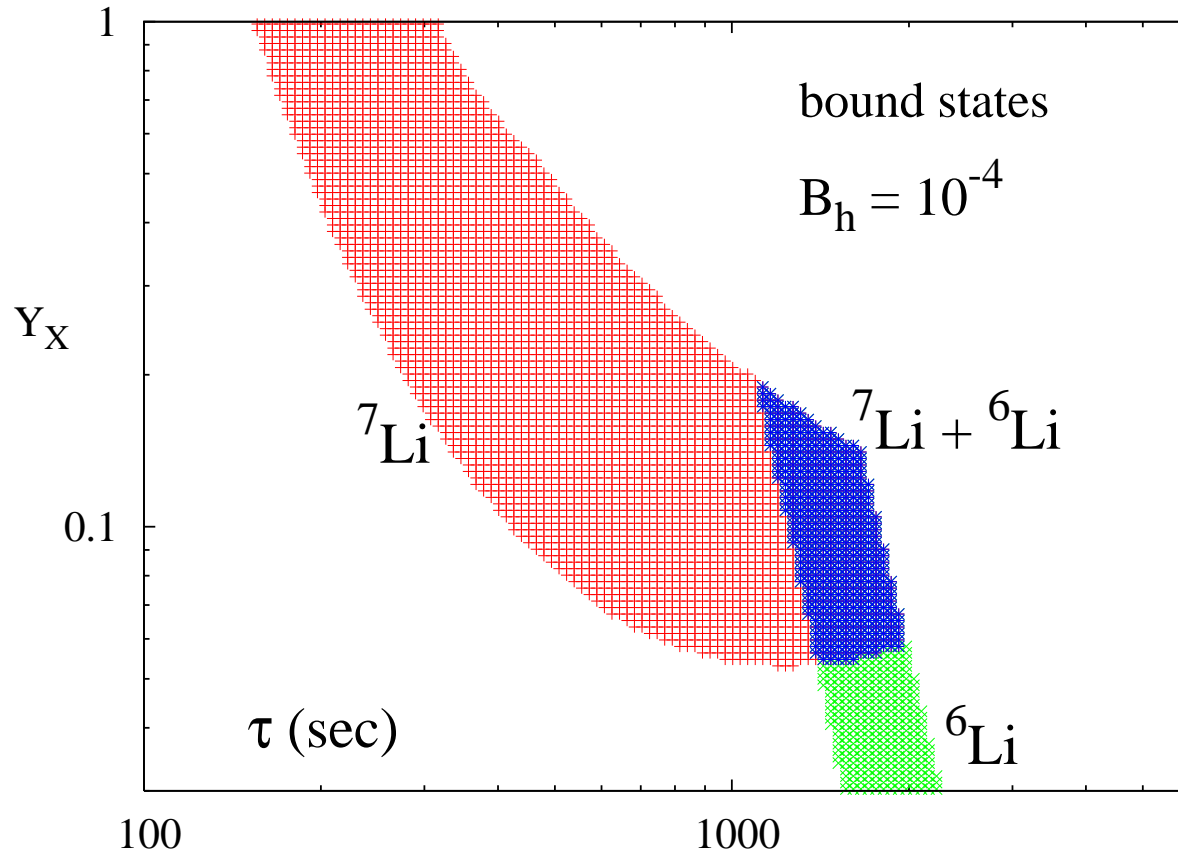
Pospelov 06 Kohri & Takayama 06, Kaplinghat & Rajaraman 06, Cyburt *et al* 06, Hamaguchi *et al.* 07, Bird, Koopmans, & Pospelov 07, Kawasaki *et al.* 07, Takayama 07, Jittoh *et al.* 07



- reduction of Coulomb barrier  $\rightarrow$  enhancement of nuclear reactions
- radiative capture reactions, e.g.  ${}^2\text{H} + {}^4\text{He} \rightarrow {}^6\text{Li} + \gamma$  are replaced by  ${}^2\text{H} + ({}^4\text{He}X^-) \rightarrow {}^6\text{Li} + X^-$  when  ${}^4\text{He}$  is in bound state  $\rightarrow$  strong factor enhancement of rate
- shifting binding energies may make reaction proceeding over nuclear resonances at thermal energies available, i.e.  ${}^7\text{Be} - X^- + p \rightarrow {}^8\text{B} - X^- + \gamma$

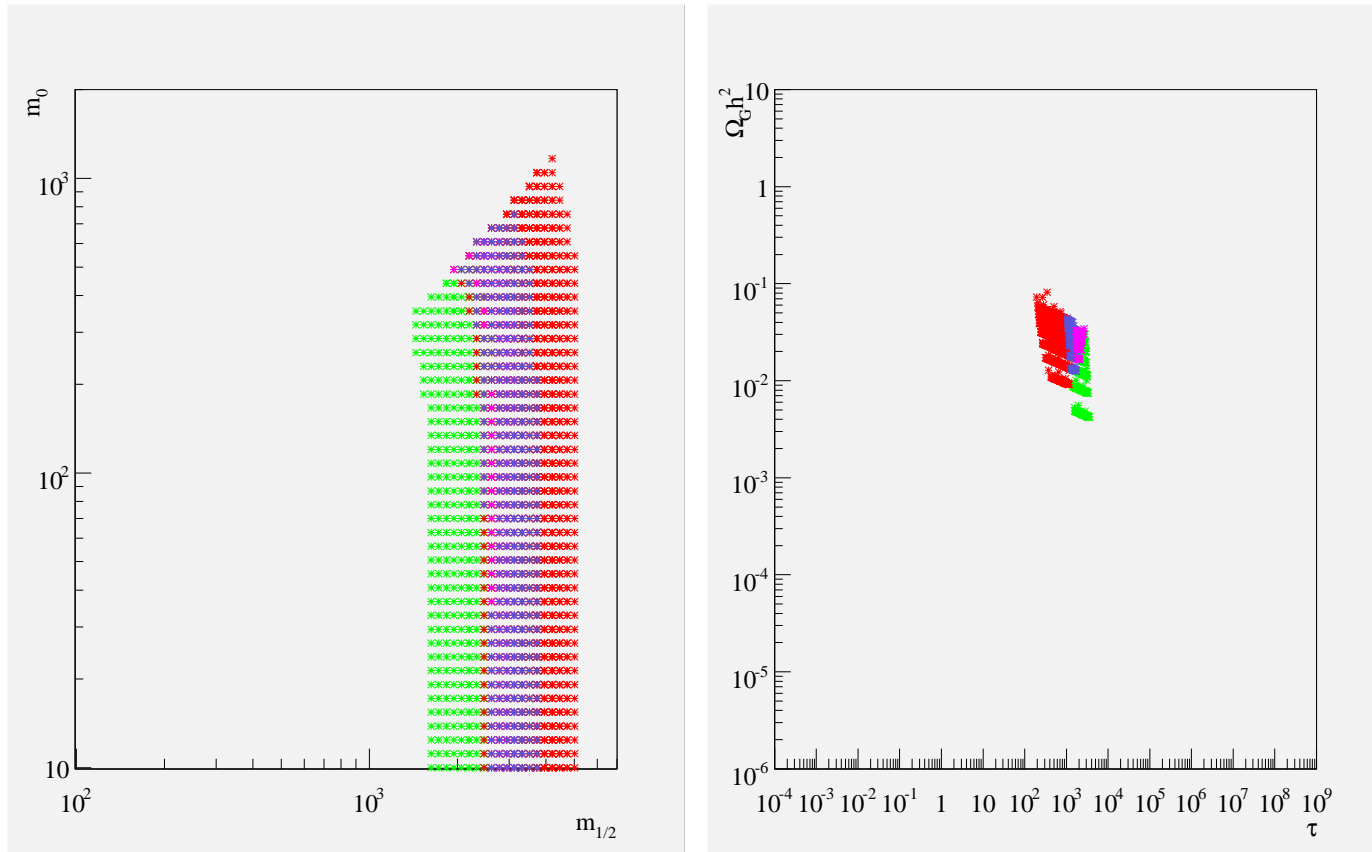


# Decaying charged particles *during* BBN



# The Cosmic Lithium Problems solved by Gravitino Warm DM

mSUGRA with gravitino LSP:



K.J., Choi, Roszkowski, Ruiz de Austri 05, Bailly, K.J., Moutaka 07

## Further solutions to the ${}^6\text{Li}$ and ${}^7\text{Li}$ problems ?

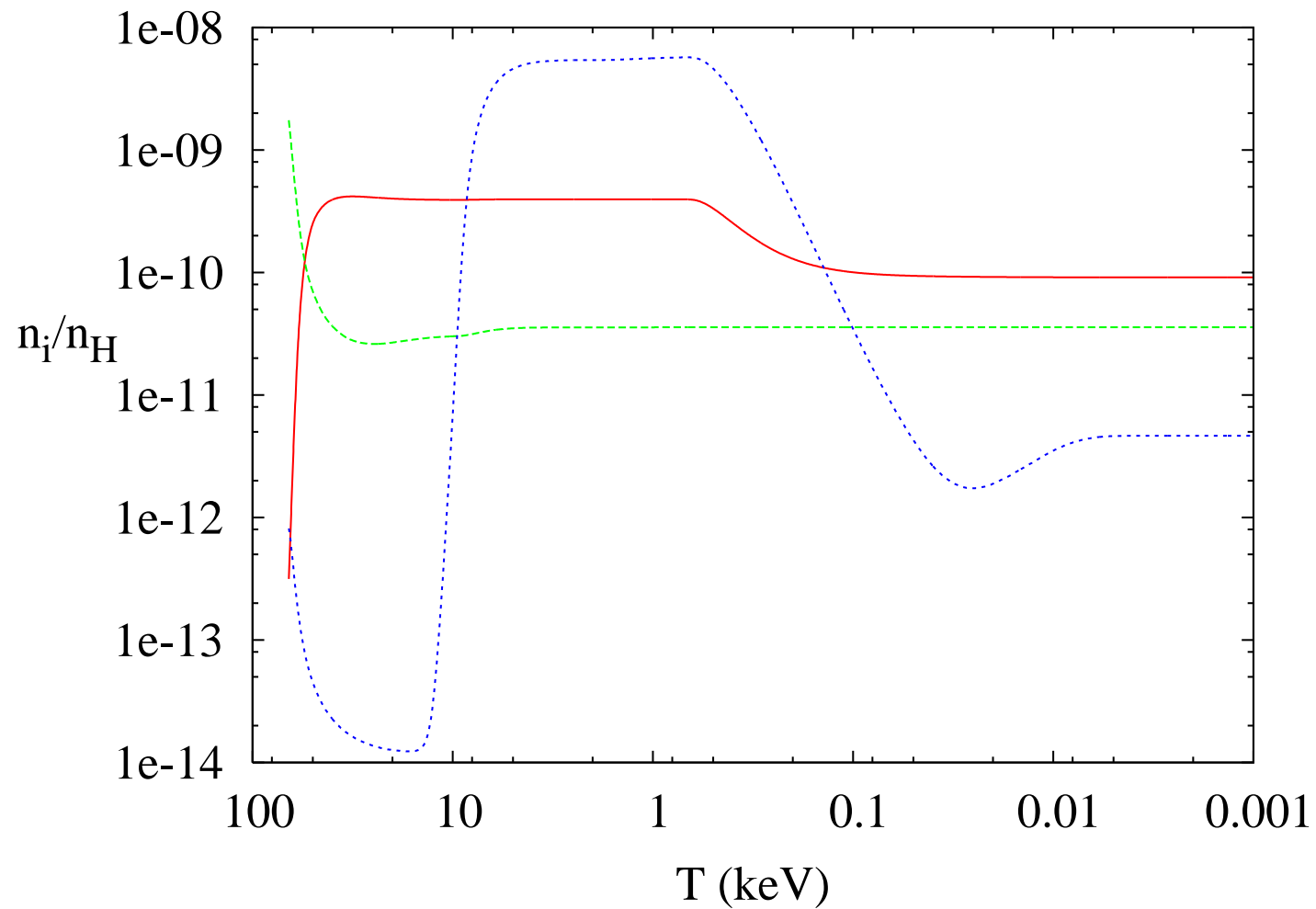
- Presence of  $X^-$  leads to significant production of  ${}^6\text{Li}$

Pospelov 06

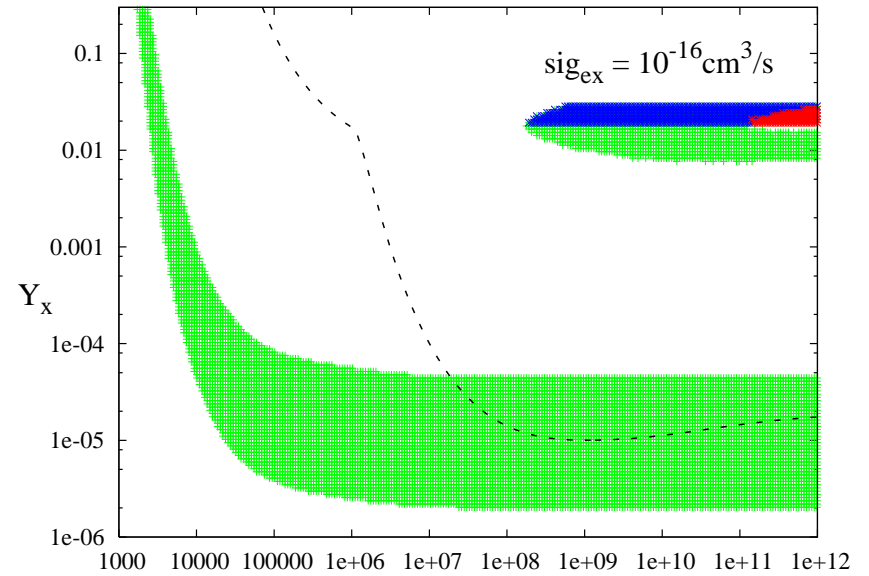
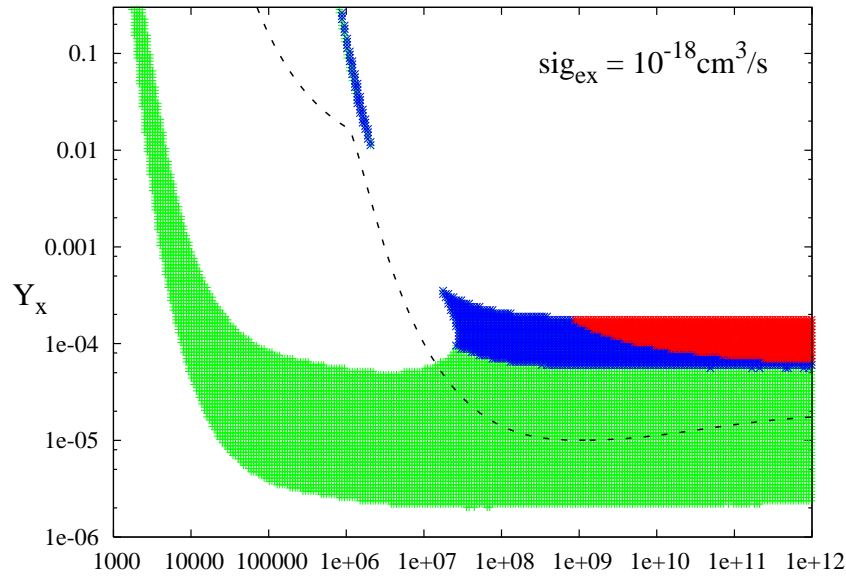
## Further solutions to the ${}^6\text{Li}$ and ${}^7\text{Li}$ problems ?

- Presence of  $X^-$  leads to significant production of  ${}^6\text{Li}$   
Pospelov 06
- at  $T \lesssim 1$  keV significant fraction of  $p$  are in bound states  
→ absence of Coulomb barrier
- reactions  $(pX^-) + {}^6\text{Li} \rightarrow X^- + {}^4\text{He} + {}^3\text{He}$  and  
 $(pX^-) + {}^7\text{Be} \rightarrow {}^8\text{B} + X^-$  may destroy priorly synthesized  ${}^6\text{Li}$   
and  ${}^7\text{Li}$  Jedamzik 07
- importance of charge exchange reaction  
 $(pX^-) + {}^4\text{He} \rightarrow p + {}^4\text{He}X^-$

# ${}^6\text{Li}$ and ${}^7\text{Li}$ with bound states at late times



# Solutions to the ${}^6\text{Li}$ and ${}^7\text{Li}$ problems due to bound states

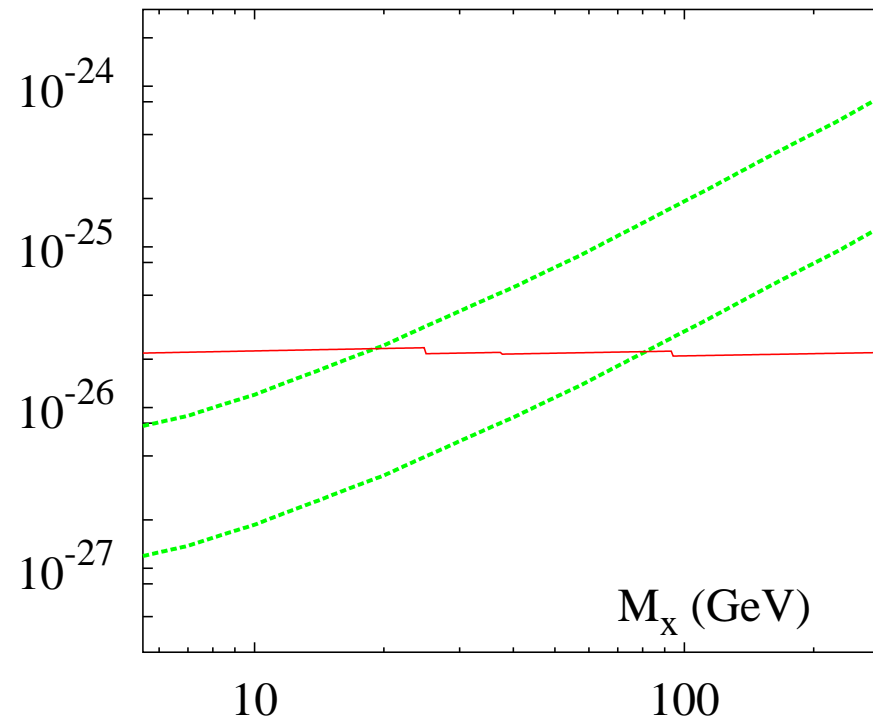


K.Jedamzik (astro-ph/07072070)

# Conclusions

- standard BBN predicts factor 2 – 3 more  ${}^7\text{Li}$  than observed at low  $[Z]$
- ${}^6\text{Li}$  is observed in abundance at low metallicity, inconsistent with cosmic ray nucleosynthesis
- the  ${}^6\text{Li}$  and/or  ${}^7\text{Li}$  problems may be explained by decaying (annihilating) particles during BBN
- if the decaying particle is charged (e.g.,  $\tilde{\tau}$ )  ${}^6\text{Li}$  may be first synthesized in abundance, and subsequently be again destroyed at  $T \lesssim 1$  keV along with  ${}^7\text{Li}$
- may be realised by gravitino dark matter in the CMSSM

# ${}^6\text{Li}$ due to residual dark matter annihilation during BBN



K.J. Phys. Rev. D 70 083510 (2004) (astro-ph/0405583)