An Anatomy of Coannihilation with a Scalar Top Partner

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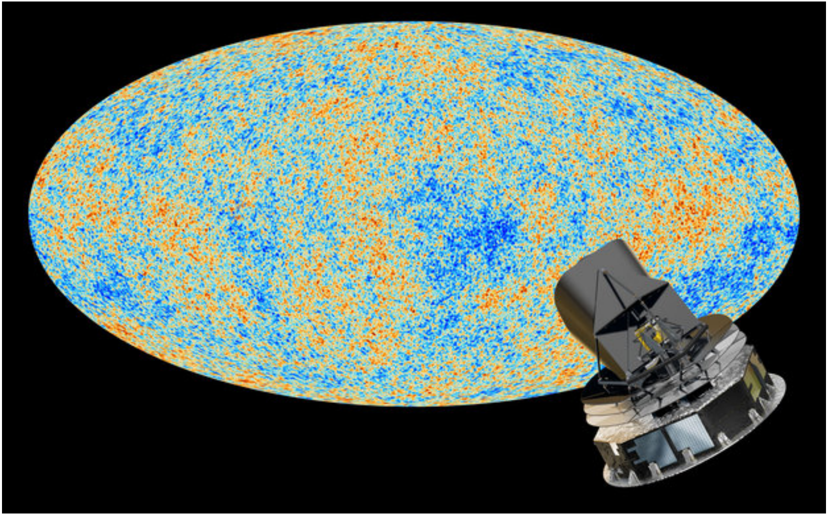
We know the DM abundance!



The name of the game

- get the relic density right
- confront thermal DM with experiments

t-channel mediator

- Majorana fermion χ as dark matter
- χ: SM singlet
- interactions $\rightarrow$ scalar top partner $\tilde{t}$
- Yukawa interactions with the top-quarks

$$\mathcal{L}_{int} = -y \bar{t}_R \chi \tilde{t} + \text{h.c.}$$

- consider y as a free variable

Why could this be interesting?

- It is simple
  - quite significant ongoing efforts to characterize DM using simplified model
  - LHC produces chiefly colored particles

    $\rightarrow$ What are the constraints?

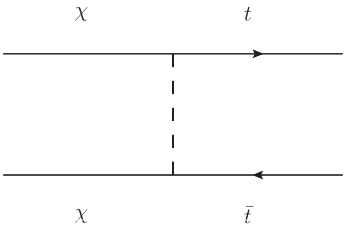
    $\rightarrow$ Can they be avoided?
  - DM interactions with light quarks: stringent constraints from LHC and DD

    $\rightarrow$ What about heavy flavor?
- It could be more exotic SUSY
  - great interest in light stops
  - realized in some extensions of MSSM?
  - allow for modified stop DM couplings
  - gain greater control over physics (instead of parameter scan)
- Has similarities with models for flavored dark matter Agrawal et al 2014

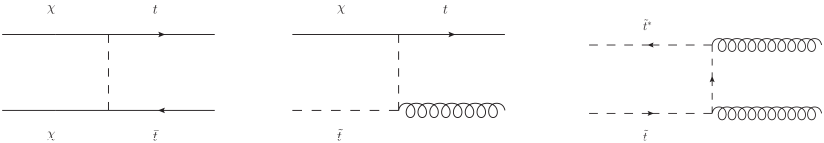
  Caveat: those models have a Dirac fermion – Majorana mass term will break flavor symmetry

Thermal relic abundance from freeze-out

$$\Omega_{DM} h^2 \approx 0.12 \approx \frac{3 \times 10^{-26} cm^3 s^{-1}}{\sigma v}$$



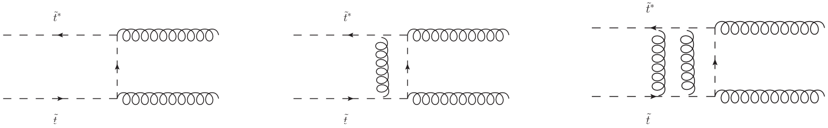
Thermal Dark Matter: Coannihilations



- if Δm is small:

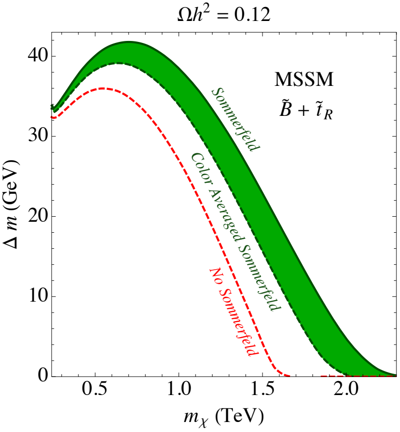
$$\sigma v \to \sigma v_{eff} \approx \sigma_{\chi\chi} v + \sigma_{\chi\tilde{t}} v\, e^{-\Delta m/T} + \sigma_{\tilde{t}\tilde{t}} v\, e^{-2\Delta m/T}$$ Griest Seckel 1991

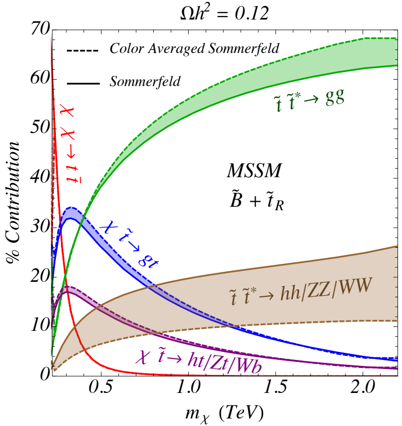
Coannihilations: QCD Sommerfeld Effect



- particles in annihilation only mildly relativistic/non-relativistic
- non perturbative QCD correction to cross section $\rightarrow$ QCD Sommerfeld effect Freitas 2007; De Simone, Giudice, Strumia 2014
- essentials
  - gluon exchange creates effective potential between initial state particles
  - potential deforms initial wave function
  - cross section enhanced (attractive potential) or suppressed (repulsive potential)

Impact of QCD Sommerfeld Effect





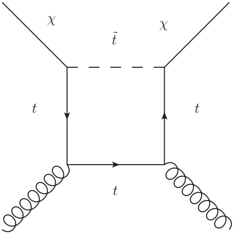
DM nucleon scattering

http://wouter.coekaerts.be/files/puzzles/clowns-car.gif

http://feelgrafix.com/data_images/out/24/947203-elephant.jpg

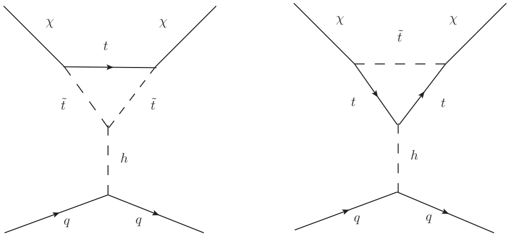
- no top-quarks in the nucleus $\rightarrow$ no tree level coupling
- DD cross section can only arise at loop level
- can we afford a loop suppression?

DM nucleon scattering: gluons



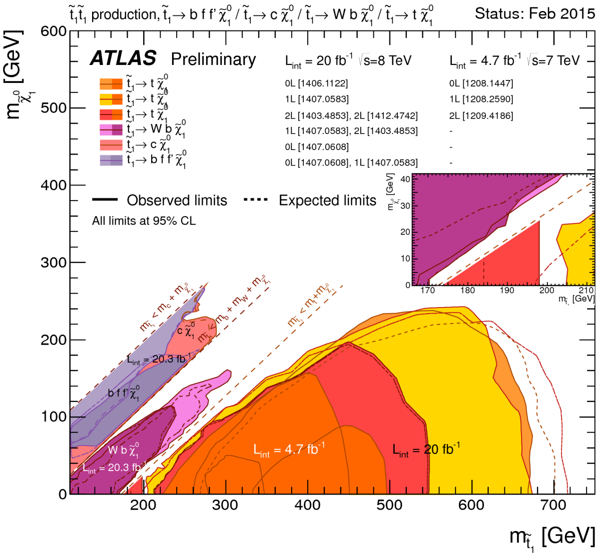
- loop induced dark matter gluon coupling via box diagram Drees, Nojiri 93
- tends to be undetectably small (close to neutrino floor or below)

DM nucleon scattering: Higgs



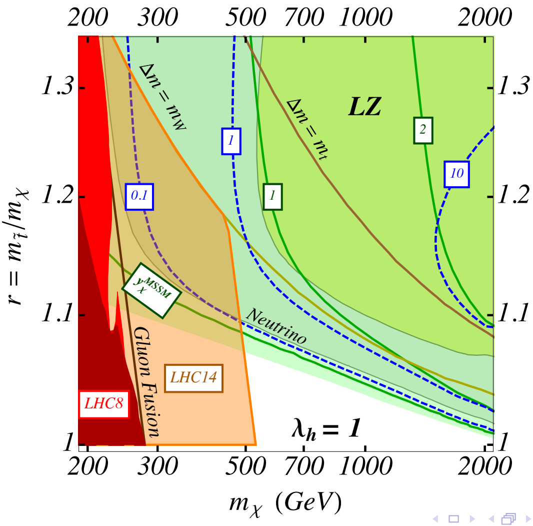
- top coupling to Higgs large
- loops induced DM Higgs coupling Djouadi et al 2001
- typically not considered for DD
- typically dominant
- negative interference with gluon box
  $\rightarrow$ signal suppressed close for DM mass close to top mass

LHC searches



- $\tilde{t}$ decay: 2-body, 3-body, 4-body ???

Exclusion prospects for thermal Dark Matter: top quarks



Conclusions

- substantial corrections to relic density from QCD Sommerfeld
- DD cross section still beyond current constraints
- good prospects for detection with upcoming experiments (LHC13, LZ ...)

Exclusion prospects for thermal Dark Matter: top quarks