

Scalar Dark Matter and DAMA

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S. Andreas, T. Hambye, M. H. G. Tytgat; *JCAP*, **2008**, 0810, 034 (arXiv:0808.0255)

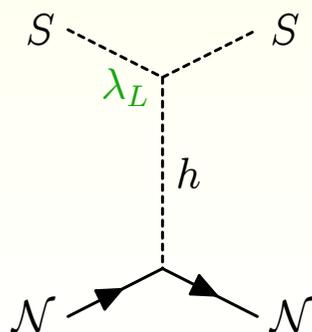
Scalar Dark Matter

- real scalar singlet S , odd under Z_2

$$\mathcal{L} \ni \frac{1}{2} \partial^\mu S \partial_\mu S - \frac{1}{2} \underbrace{\mu_S^2}_{m_S^2 - \lambda_L v^2} S^2 - \frac{\lambda_S}{4} S^4 - \lambda_L H^\dagger H S^2$$

- coupling to SM through Brout-Englert-Higgs boson h

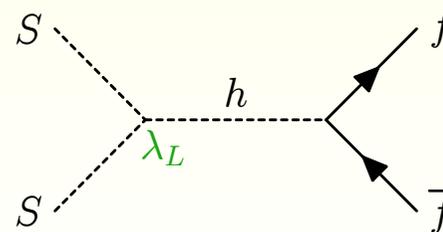
SI Scattering:



\Rightarrow DAMA ?

$$\sigma = \sigma\left(\frac{\lambda_L}{m_h^2}, m_S\right)$$

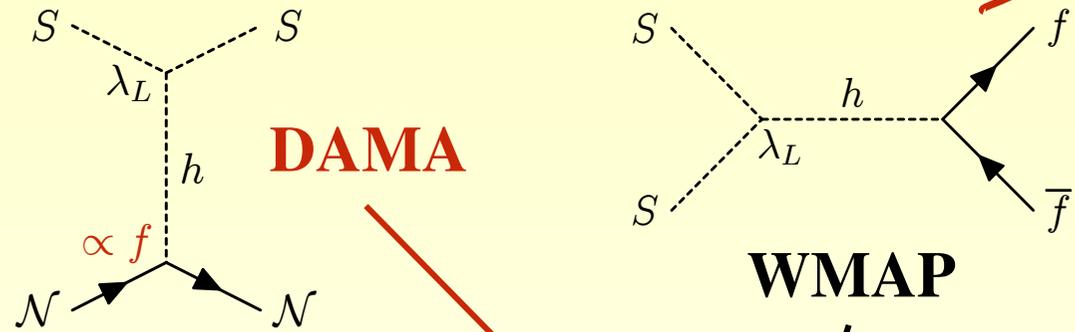
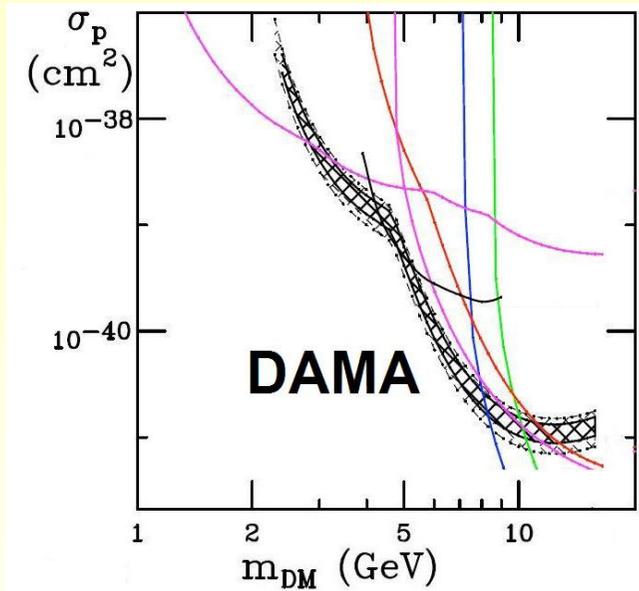
Annihilation:



\Rightarrow WMAP ?

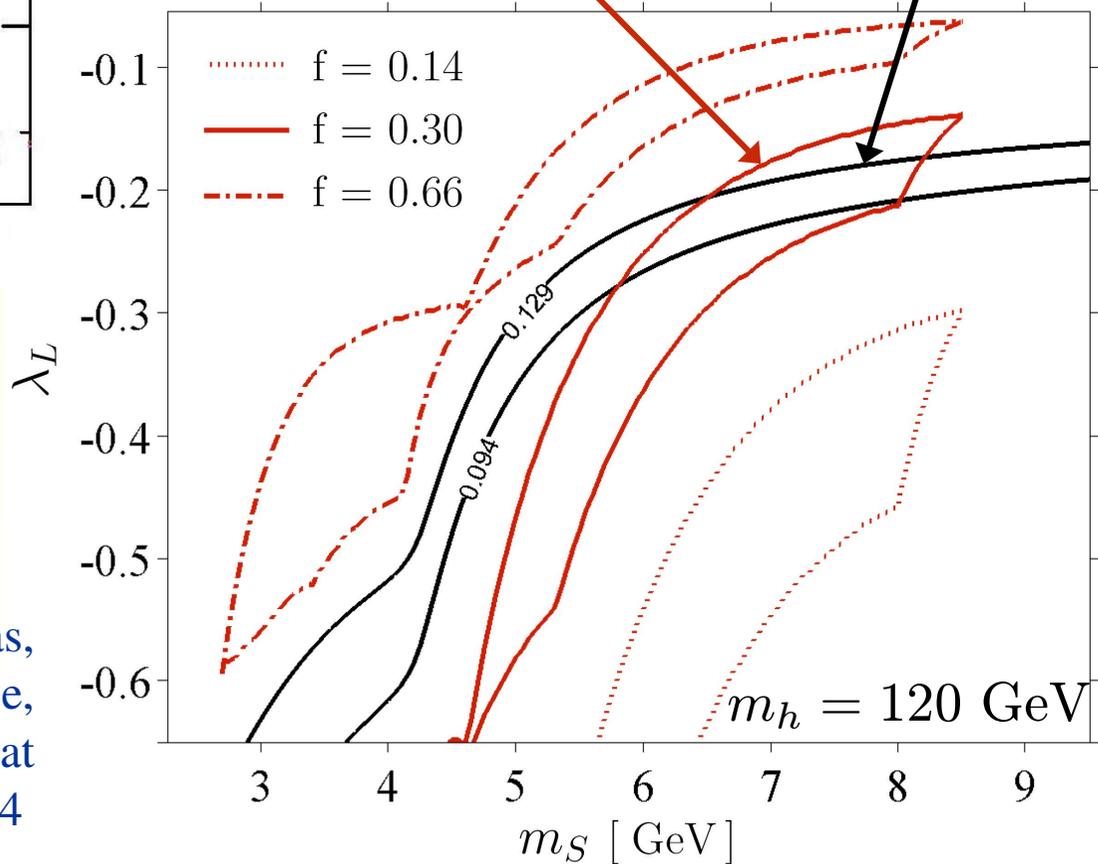
DAMA and WMAP

F. Petriello, K. M. Zurek (2008)



**DAMA and WMAP
can be satisfied**

S. Andreas,
T. Hambye,
M. H. G. Tytgat
JCAP, **2008**, 0810, 034



Gammas from the GC

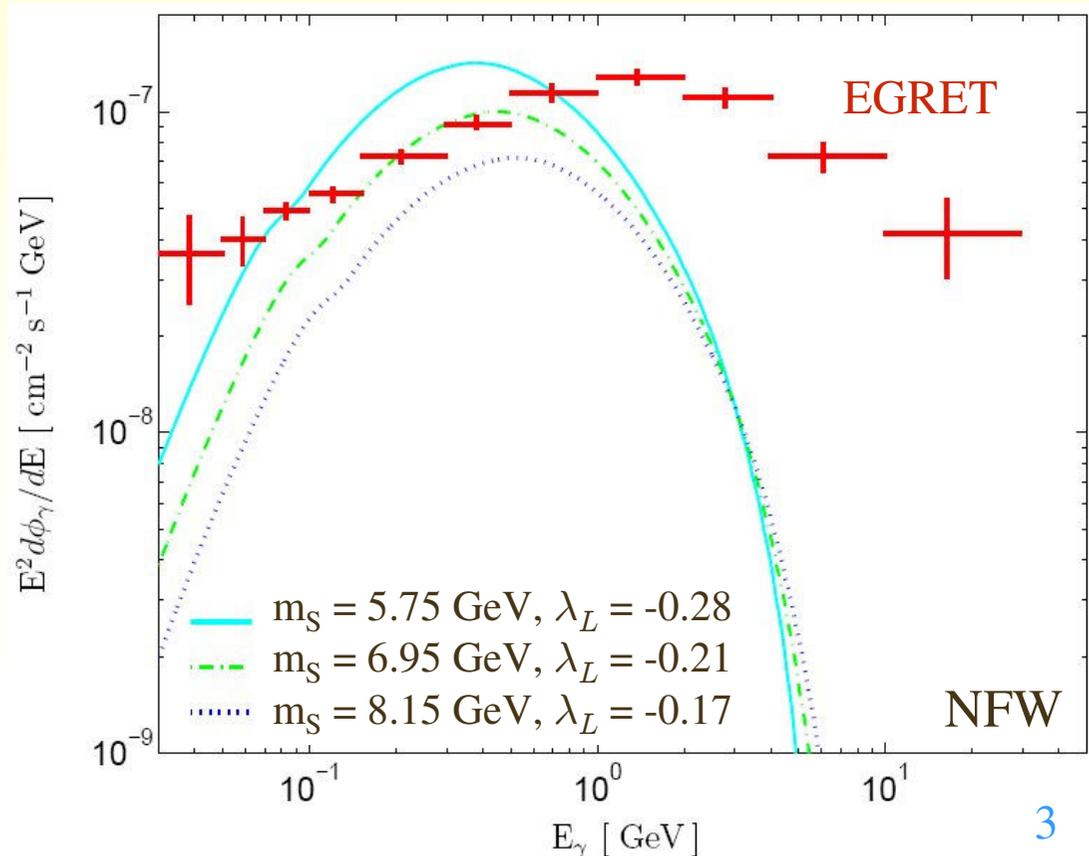
High DM density at GC

→ DM annihilation

→ Flux of secondary γ s

In reach of
Fermi/GLAST
satellite

S. Andreas,
T. Hambye,
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JCAP, **2008**, 0810, 034

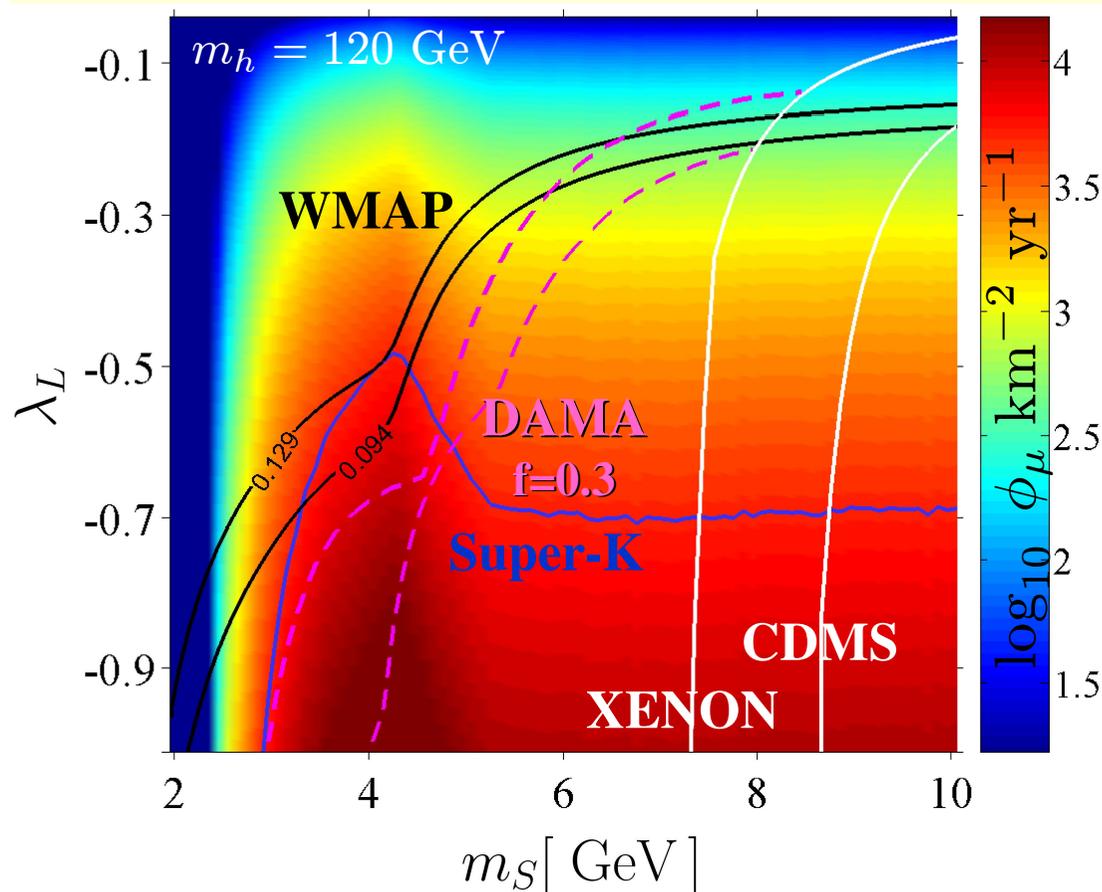


Neutrinos from the Sun

DM captured & annihilated in Sun

→ Flux of secondary neutrinos

→ Neutrino induced muons



Neutrino flux
might be tested
by Super-K

S. Andreas,
M. H. G. Tytgat,
Q. Swillens

submitted to JCAP, 2009

Conclusions

Light scalar Dark Matter can

- ✓ **account for DAMA result**
and
- ✓ **give correct WMAP abundance**

This scenario can be tested through

- ✓ **gammas from the GC**
and
- ✓ **neutrinos from the Sun**

S. Andreas, T. Hambye, M. H. G. Tytgat; *JCAP*, **2008**, 0810, 034 (arXiv:0808.0255)

S. Andreas, M. H. G. Tytgat, Q. Swillens; *submitted to JCAP*, **2009** (arXiv:0901.1750)

Backup Slides

Cross sections

$$\sigma(SS \rightarrow \bar{f}f)v_{rel} = n_c \frac{\lambda_L^2}{\pi} \frac{m_f^2}{m_h^4 m_S^3} (m_S^2 - m_f^2)^{3/2}$$

$$\sigma(SN \rightarrow SN) = \frac{\lambda_L^2}{\pi} \frac{\mu_r^2}{m_h^4 m_S^2} f^2 m_N^2$$

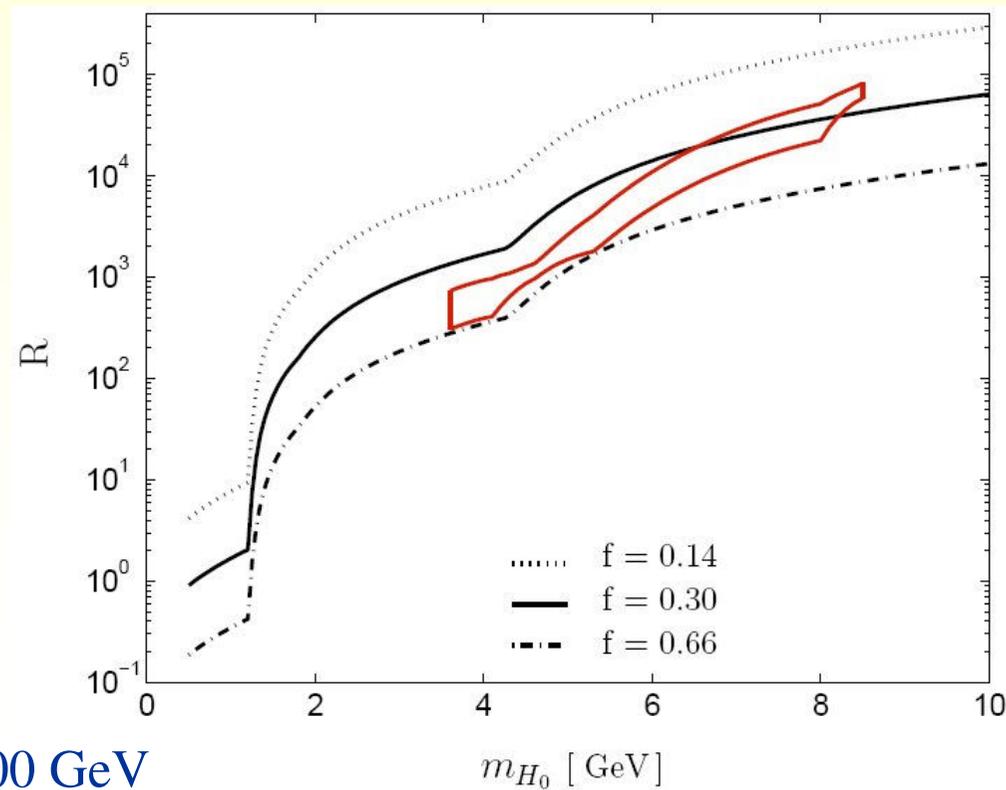
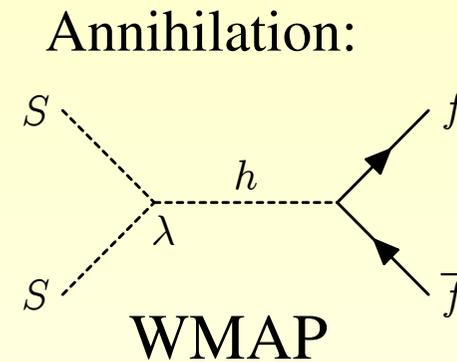
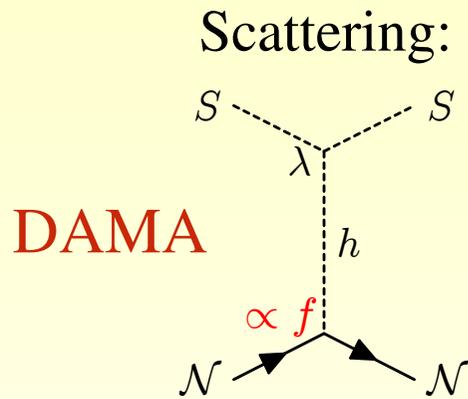
$$R \equiv \sum_f \frac{\sigma(SS \rightarrow \bar{f}f)v_{rel}}{\sigma(SN \rightarrow SN)} = \sum_f \frac{n_c m_f^2}{f^2 m_N^2 \mu_r^2} \frac{(m_S^2 - m_f^2)^{3/2}}{m_S}$$

- same DM-h coupling λ_L
- same dependence $\propto m_h^{-4}$
- Yukawa coupling to N and f known
(up to uncertainties)

\Rightarrow Ratio of cross sections only depends on m_{DM} :

$$R = \frac{\langle \sigma_{ann} v \rangle}{\sigma_{scatt}} = R(m_S) \Rightarrow \text{one-to-one relation}$$

$$\text{Ratio } R = \langle \sigma_{ann} \mathbf{v} \rangle / \sigma_{scatt}$$



Ratio λ_L/m_h^2 has
to be kept fixed
($\simeq 10^{-5} \text{ GeV}^{-2}$)

$$\lambda_L \lesssim 2\pi \Rightarrow m_h \lesssim 800 \text{ GeV}$$

Model: cross sections

Annihilation	$\sigma(SS \rightarrow \bar{f}f)v_{rel}$	=	$n_c \frac{\lambda_L^2}{\pi} \frac{m_f^2}{m_h^4 m_S^3} (m_S^2 - m_f^2)^{3/2}$
Scattering	$\sigma(SN \rightarrow SN)$	=	$\frac{\lambda_L^2}{\pi} \frac{\mu_r^2}{m_h^4 m_S^2} f^2 m_N^2$
Mass S	m_S^2	=	$\mu_S^2 + \lambda_L v^2$ with $v = 246$ GeV
Yukawa coupling	Y_i	=	$\sqrt{2}m_f/v$
Relative velocity	v_{rel}	=	$(s - 4m_S^2)^{1/2}/m_S$
Reduced mass	μ_r	=	$m_S m_N / (m_S + m_N)$
h-N coupling	$f m_N$	\equiv	$\langle N \sum_q m_q \bar{q}q N \rangle = g_{hNN} v$
Nuclear form factor	$0.14 < f < 0.66$		
Abundance	$\sigma_{tot} v_{rel} \sim 1 pb$	\rightarrow	$0.094 < \Omega_{DM} h^2 < 0.129$

Inert Doublet Model

- Replacements:

$$m_S \rightarrow m_{H_0}, \quad \mu_S \rightarrow \mu_2, \quad \lambda_L \rightarrow \lambda_L$$

- Extra components of the doublet: A_0, H^\pm

- Z invisible decay requires $m_{H_0} + m_{A_0} > m_Z$

$$\Rightarrow m_{A_0} \gtrsim m_Z$$

- Prevent large radiative corrections to Z and W

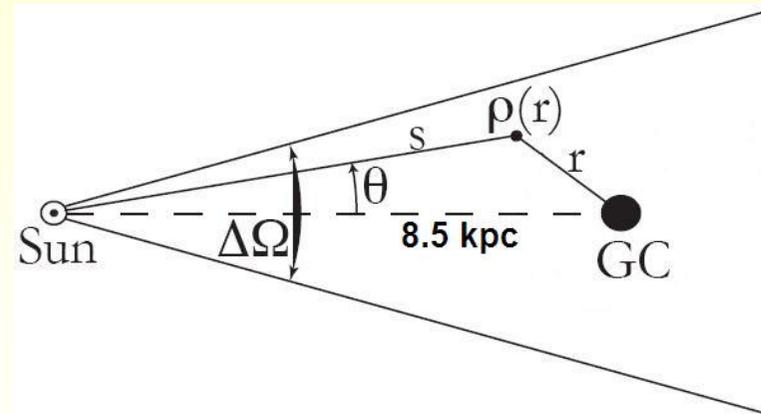
$$\Rightarrow m_{A_0} \simeq m_{H^\pm}$$

Results apply to any scalar DM model with annihilation & scattering dominantly through h-channel

Fluxes from GC & Sun

Differential flux from the GC:

$$\frac{d\phi_i}{dE} = \frac{1}{8\pi} \frac{\langle \sigma_{ann} v \rangle}{m_S^2} \frac{dN_i}{dE} \int_{\Delta\Omega} d\Omega \int_{\text{line of sight}} ds \rho_{DM}^2(r(s, \theta))$$



Differential flux from the Sun:

$$\frac{d\phi_i}{dE} = \frac{1}{2} \frac{C F_{\text{EQ}}}{4\pi R^2} \sum_F BR_F \left(\frac{dN}{dE} \right)_{F,i}$$