

Event-level neutrino telescope likelihood extensions in DarkSUSY ... and applications to SUSY scans

Pat Scott

Department of Physics, McGill University

Based on:

- PS, Chris Savage, Joakim Edsjö & The IceCube Collab. (esp. Matthias Danninger + Klas Hultqvist) *JCAP* 2012 11:057, [arXiv:1207.0810](https://arxiv.org/abs/1207.0810)
- Hamish Silverwood, PS, Matthias Danninger, Chris Savage et al. *JCAP* 2013 03:027, [arxiv:1210.0844](https://arxiv.org/abs/1210.0844)

Slides available from <http://www.physics.mcgill.ca/~patscott>



Outline

- 1 How to find DM with neutrino telescopes
- 2 Likelihood functions
- 3 → SUSY scans



Outline

- 1 How to find DM with neutrino telescopes
- 2 Likelihood functions
- 3 → SUSY scans



Introduction

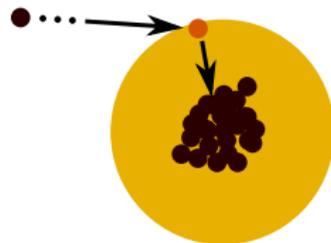
The short version:



Introduction

The short version:

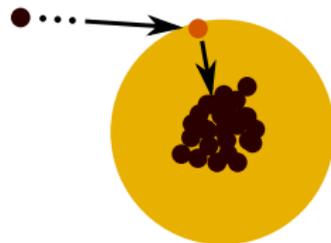
- 1 Halo WIMPs crash into the Sun



Introduction

The short version:

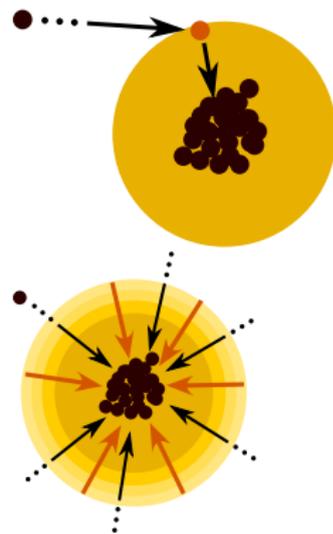
- 1 Halo WIMPs crash into the Sun
- 2 Some lose enough energy in the scatter to be gravitationally bound



Introduction

The short version:

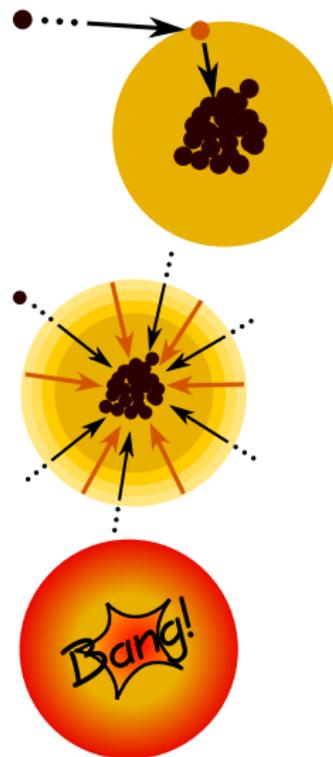
- 1 Halo WIMPs crash into the Sun
- 2 Some lose enough energy in the scatter to be gravitationally bound
- 3 Scatter some more, sink to the core



Introduction

The short version:

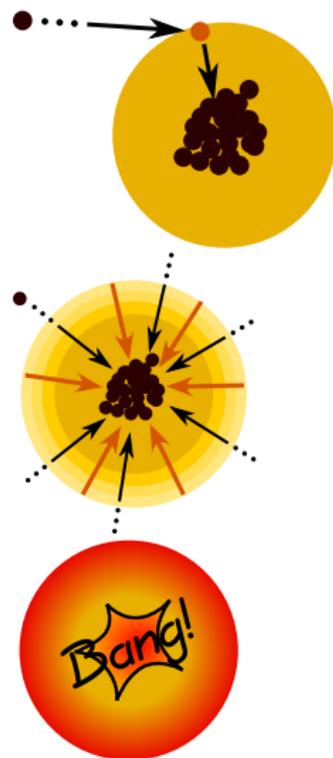
- 1 Halo WIMPs crash into the Sun
- 2 Some lose enough energy in the scatter to be gravitationally bound
- 3 Scatter some more, sink to the core
- 4 Annihilate with each other, producing neutrinos



Introduction

The short version:

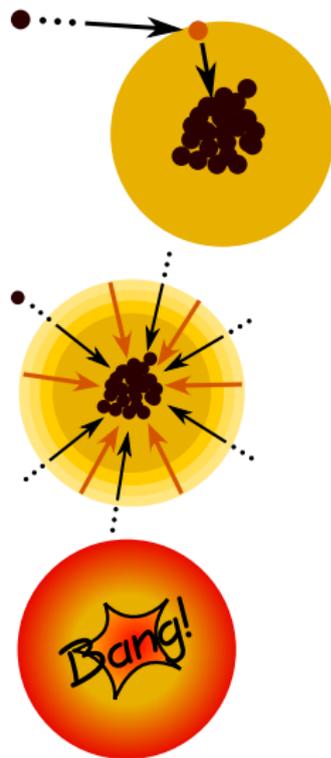
- 1 Halo WIMPs crash into the Sun
- 2 Some lose enough energy in the scatter to be gravitationally bound
- 3 Scatter some more, sink to the core
- 4 Annihilate with each other, producing neutrinos
- 5 Propagate+oscillate their way to the Earth, convert into muons in ice/water



Introduction

The short version:

- 1 Halo WIMPs crash into the Sun
- 2 Some lose enough energy in the scatter to be gravitationally bound
- 3 Scatter some more, sink to the core
- 4 Annihilate with each other, producing neutrinos
- 5 Propagate+oscillate their way to the Earth, convert into muons in ice/water
- 6 Look for Čerenkov radiation from the muons in **IceCube**, ANTARES, etc



What can the muon signal tell me?

Roughly:

Number – how much annihilation is going on in the Sun

⇒ info on σ_{SD} , σ_{SI} and $\langle\sigma v\rangle$

Spectrum – sensitive to WIMP mass m_χ and branching fractions BF into different annihilation channels X

Direction – how likely it is that they come from the Sun

In model-independent analyses a lot of this information is either discarded or not given with final limits

Goal:

Use as much of this information on σ_{SD} , σ_{SI} , $\langle\sigma v\rangle$, m_χ and $BF(X)$ as possible to directly constrain specific points and regions in WIMP model parameter spaces



What can the muon signal tell me?

The example in this talk is SUSY – but the first part of the talk is on a framework, applicable to any model.

Goal:

Use as much of this information on σ_{SD} , σ_{SI} , $\langle\sigma v\rangle$, m_χ and $BF(X)$ as possible to directly constrain specific points and regions in WIMP model parameter spaces

What can the muon signal tell me?

The example in this talk is SUSY – but the first part of the talk is on a framework, applicable to any model.

All methods discussed here are available in DarkSUSY from v5.0.6 (current is 5.1.1): www.darksusy.org

Goal:

Use as much of this information on σ_{SD} , σ_{SI} , $\langle\sigma v\rangle$, m_χ and $BF(X)$ as possible to directly constrain specific points and regions in WIMP model parameter spaces



What can the muon signal tell me?

The example in this talk is SUSY – but the first part of the talk is on a framework, applicable to any model.

All methods discussed here are available in DarkSUSY from v5.0.6 (current is 5.1.1): www.darksusy.org

All IceCube data used are available at <http://icecube.wisc.edu/science/data/ic22-solar-wimp> (and in DarkSUSY, for convenience)

Goal:

Use as much of this information on σ_{SD} , σ_{SI} , $\langle\sigma v\rangle$, m_χ and $BF(X)$ as possible to directly constrain specific points and regions in WIMP model parameter spaces



Outline

- 1 How to find DM with neutrino telescopes
- 2 Likelihood functions**
- 3 → SUSY scans



Number Likelihood

Simplest way to do anything is to make it a counting problem. . .

Compare observed number of events n and predicted number θ for each model, taking into account error σ_ϵ on acceptance:

$$\mathcal{L}_{\text{num}}(n|\theta_{\text{BG}} + \theta_{\text{sig}}) = \frac{1}{\sqrt{2\pi}\sigma_\epsilon} \int_0^\infty \frac{(\theta_{\text{BG}} + \epsilon\theta_{\text{sig}})^n e^{-(\theta_{\text{BG}} + \epsilon\theta_{\text{sig}})}}{n!} \frac{1}{\epsilon} \exp\left[-\frac{1}{2}\left(\frac{\ln \epsilon}{\sigma_\epsilon}\right)^2\right] d\epsilon. \quad (1)$$

From this, construct a modified p -value as

$$p(n) = \frac{p_{\text{signal+BG}}(n)}{p_{\text{BG}}(n)} = \frac{\sum_{n_i \leq n} \mathcal{L}_{\text{num}}(n_i|\theta_{\text{signal}} + \theta_{\text{BG}})}{\sum_{n_i \leq n} \mathcal{L}_{\text{num}}(n_i|\theta_{\text{BG}})} \quad (2)$$

Can now say immediately, for a single point, that the point is excluded at confidence level $CL = 1 - p$.

⇒ **model exclusion** exercise – IN/OUT analysis



Full Likelihood

Full unbinned likelihood with number (\mathcal{L}_{num}), spectral ($\mathcal{L}_{\text{spec}}$) and angular (\mathcal{L}_{ang}) parts

$$\mathcal{L} = \mathcal{L}_{\text{num}}(n|\theta_{\text{signal+BG}}) \prod_{i=1}^n \mathcal{L}_{\text{spec},i} \mathcal{L}_{\text{ang},i} \quad (3)$$

with

$$\mathcal{L}_{\text{spec},i}(N_i, \Xi) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{dN_i}(N_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \int_0^{\infty} E_{\text{disp}}(N_i|E'_i) \frac{dP_{\text{signal}}}{dE'_i}(E'_i, \Xi) dE'_i \quad (4)$$

and

$$\mathcal{L}_{\text{ang},i}(\cos \phi_i) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{d \cos \phi_i}(\cos \phi_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \text{PSF}(\cos \phi_i|1) \quad (5)$$



Full Likelihood

Full unbinned likelihood with number (\mathcal{L}_{num}), spectral ($\mathcal{L}_{\text{spec}}$) and angular (\mathcal{L}_{ang}) parts

$$\mathcal{L} = \mathcal{L}_{\text{num}}(n|\theta_{\text{signal+BG}}) \prod_{i=1}^n \mathcal{L}_{\text{spec},i} \mathcal{L}_{\text{ang},i} \quad (3)$$

with **Number of lit channels (energy estimator)**

$$\mathcal{L}_{\text{spec},i}(N_i, \Xi) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{dN_i}(N_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \int_0^\infty E_{\text{disp}}(N_i|E'_i) \frac{dP_{\text{signal}}}{dE'_i}(E'_i, \Xi) dE'_i \quad (4)$$

and

$$\mathcal{L}_{\text{ang},i}(\cos \phi_i) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{d \cos \phi_i}(\cos \phi_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \text{PSF}(\cos \phi_i|1) \quad (5)$$



Full Likelihood

Full unbinned likelihood with number (\mathcal{L}_{num}), spectral ($\mathcal{L}_{\text{spec}}$) and angular (\mathcal{L}_{ang}) parts

$$\mathcal{L} = \mathcal{L}_{\text{num}}(n|\theta_{\text{signal+BG}}) \prod_{i=1}^n \mathcal{L}_{\text{spec},i} \mathcal{L}_{\text{ang},i} \quad (3)$$

with **Number of lit channels (energy estimator)**

$$\mathcal{L}_{\text{spec},i}(N_i, \Xi) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{dN_i}(N_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \int_0^{\infty} E_{\text{disp}}(N_i|E'_i) \frac{dP_{\text{signal}}}{dE'_i}(E'_i, \Xi) dE'_i \quad (4)$$

and

SUSY parameters

$$\mathcal{L}_{\text{ang},i}(\cos \phi_i) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{d \cos \phi_i}(\cos \phi_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \text{PSF}(\cos \phi_i|1) \quad (5)$$



Full Likelihood

Full unbinned likelihood with number (\mathcal{L}_{num}), spectral ($\mathcal{L}_{\text{spec}}$) and angular (\mathcal{L}_{ang}) parts

$$\mathcal{L} = \mathcal{L}_{\text{num}}(n|\theta_{\text{signal+BG}}) \prod_{i=1}^n \mathcal{L}_{\text{spec},i} \mathcal{L}_{\text{ang},i} \quad (3)$$

with

Predicted signal spectrum (from theory)

$$\mathcal{L}_{\text{spec},i}(N_i, \Xi) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{dN_i}(N_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \int_0^{\infty} E_{\text{disp}}(N_i|E'_i) \frac{dP_{\text{signal}}}{dE'_i}(E'_i, \Xi) dE'_i \quad (4)$$

and

$$\mathcal{L}_{\text{ang},i}(\cos \phi_i) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{d \cos \phi_i}(\cos \phi_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \text{PSF}(\cos \phi_i|1) \quad (5)$$



Full Likelihood

Full unbinned likelihood with number (\mathcal{L}_{num}), spectral ($\mathcal{L}_{\text{spec}}$) and angular (\mathcal{L}_{ang}) parts

$$\mathcal{L} = \mathcal{L}_{\text{num}}(n|\theta_{\text{signal+BG}}) \prod_{i=1}^n \mathcal{L}_{\text{spec},i} \mathcal{L}_{\text{ang},i} \quad (3)$$

with

Predicted signal spectrum (from theory)

$$\mathcal{L}_{\text{spec},i}(N_i, \Xi) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{dN_i}(N_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \int_0^{\infty} E_{\text{disp}}(N_i|E'_i) \frac{dP_{\text{signal}}}{dE'_i}(E'_i, \Xi) dE'_i \quad (4)$$

and

Instrument response function

$$\mathcal{L}_{\text{ang},i}(\cos \phi_i) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{d \cos \phi_i}(\cos \phi_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \text{PSF}(\cos \phi_i|1) \quad (5)$$



Full Likelihood

Full unbinned likelihood with number (\mathcal{L}_{num}), spectral ($\mathcal{L}_{\text{spec}}$) and angular (\mathcal{L}_{ang}) parts

$$\mathcal{L} = \mathcal{L}_{\text{num}}(n|\theta_{\text{signal+BG}}) \prod_{i=1}^n \mathcal{L}_{\text{spec},i} \mathcal{L}_{\text{ang},i} \quad (3)$$

with

Predicted signal spectrum (from theory)

$$\mathcal{L}_{\text{spec},i}(N_i, \Xi) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{dN_i}(N_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \int_0^{\infty} E_{\text{disp}}(N_i|E'_i) \frac{dP_{\text{signal}}}{dE'_i}(E'_i, \Xi) dE'_i \quad (4)$$

and

Observed BG distribution

Instrument response function

$$\mathcal{L}_{\text{ang},i}(\cos \phi_i) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{d \cos \phi_i}(\cos \phi_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \text{PSF}(\cos \phi_i|1) \quad (5)$$



Full Likelihood

Full unbinned likelihood with number (\mathcal{L}_{num}), spectral ($\mathcal{L}_{\text{spec}}$) and angular (\mathcal{L}_{ang}) parts

$$\mathcal{L} = \mathcal{L}_{\text{num}}(n|\theta_{\text{signal+BG}}) \prod_{i=1}^n \mathcal{L}_{\text{spec},i} \mathcal{L}_{\text{ang},i} \quad (3)$$

with

$$\mathcal{L}_{\text{spec},i}(N_i, \Xi) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{dN_i}(N_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \int_0^{\infty} E_{\text{disp}}(N_i|E'_i) \frac{dP_{\text{signal}}}{dE'_i}(E'_i, \Xi) dE'_i \quad (4)$$

and

$$\mathcal{L}_{\text{ang},i}(\cos \phi_i) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{d \cos \phi_i}(\cos \phi_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \text{PSF}(\cos \phi_i|1) \quad (5)$$

Event arrival angle



Full Likelihood

Full unbinned likelihood with number (\mathcal{L}_{num}), spectral ($\mathcal{L}_{\text{spec}}$) and angular (\mathcal{L}_{ang}) parts

$$\mathcal{L} = \mathcal{L}_{\text{num}}(n|\theta_{\text{signal+BG}}) \prod_{i=1}^n \mathcal{L}_{\text{spec},i} \mathcal{L}_{\text{ang},i} \quad (3)$$

with

$$\mathcal{L}_{\text{spec},i}(N_i, \Xi) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{dN_i}(N_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \int_0^\infty E_{\text{disp}}(N_i|E'_i) \frac{dP_{\text{signal}}}{dE'_i}(E'_i, \Xi) dE'_i \quad (4)$$

and

$$\mathcal{L}_{\text{ang},i}(\cos \phi_i) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{d \cos \phi_i}(\cos \phi_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \text{PSF}(\cos \phi_i|1) \quad (5)$$

Predicted signal direction (δ function at Sun)



Full Likelihood

Full unbinned likelihood with number (\mathcal{L}_{num}), spectral ($\mathcal{L}_{\text{spec}}$) and angular (\mathcal{L}_{ang}) parts

$$\mathcal{L} = \mathcal{L}_{\text{num}}(n|\theta_{\text{signal+BG}}) \prod_{i=1}^n \mathcal{L}_{\text{spec},i} \mathcal{L}_{\text{ang},i} \quad (3)$$

with

$$\mathcal{L}_{\text{spec},i}(N_i, \Xi) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{dN_i}(N_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \int_0^{\infty} E_{\text{disp}}(N_i|E'_i) \frac{dP_{\text{signal}}}{dE'_i}(E'_i, \Xi) dE'_i \quad (4)$$

and

Instrument response function

$$\mathcal{L}_{\text{ang},i}(\cos \phi_i) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{d \cos \phi_i}(\cos \phi_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \text{PSF}(\cos \phi_i|1) \quad (5)$$

Predicted signal direction (δ function at Sun)



Full Likelihood

Full unbinned likelihood with number (\mathcal{L}_{num}), spectral ($\mathcal{L}_{\text{spec}}$) and angular (\mathcal{L}_{ang}) parts

$$\mathcal{L} = \mathcal{L}_{\text{num}}(n|\theta_{\text{signal+BG}}) \prod_{i=1}^n \mathcal{L}_{\text{spec},i} \mathcal{L}_{\text{ang},i} \quad (3)$$

with

$$\mathcal{L}_{\text{spec},i}(N_i, \Xi) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{dN_i}(N_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \int_0^{\infty} E_{\text{disp}}(N_i|E'_i) \frac{dP_{\text{signal}}}{dE'_i}(E'_i, \Xi) dE'_i \quad (4)$$

and Observed BG distribution Instrument response function

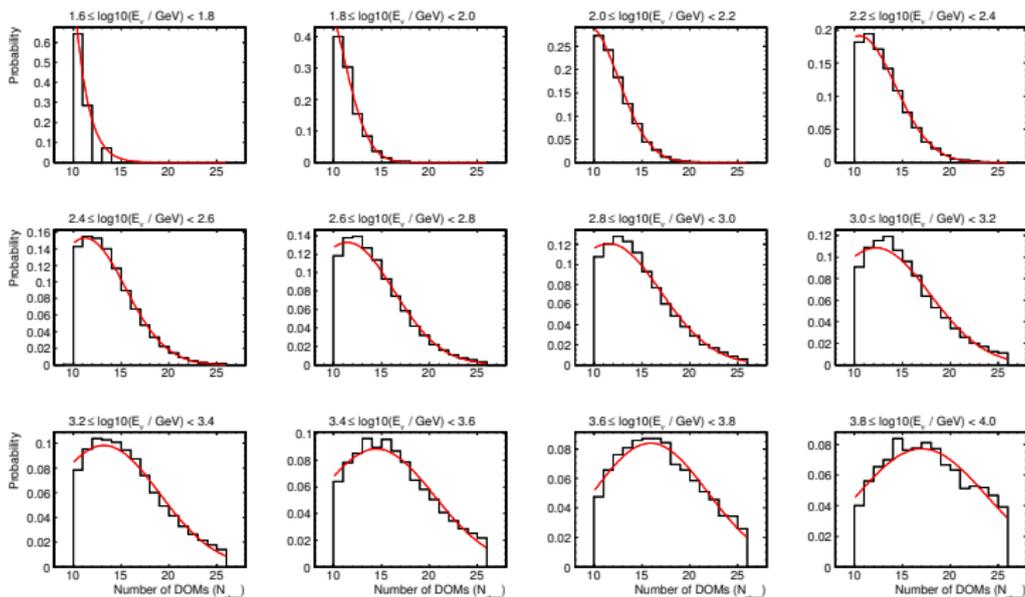
$$\mathcal{L}_{\text{ang},i}(\cos \phi_i) = \frac{\theta_{\text{BG}}}{\theta_{\text{signal+BG}}} \frac{dP_{\text{BG}}}{d \cos \phi_i}(\cos \phi_i) + \frac{\theta_{\text{signal}}}{\theta_{\text{signal+BG}}} \text{PSF}(\cos \phi_i|1) \quad (5)$$

Predicted signal direction (δ function at Sun)



Instrument responses

- Effective area: IC22 official $\nu+\bar{\nu}$, IC86 sensitivity study $\nu+\bar{\nu}$
- PSF: IC22 paraboloid σ , IC86 simulated paraboloid σ
- ‘Energy’ response: IC22 N_{chan} MC study, not yet for IC86



Outline

- 1 How to find DM with neutrino telescopes
- 2 Likelihood functions
- 3** → SUSY scans



Theory Model Scanning with IceCube – Physics

DarkSUSY for computing neutrino fluxes:

- No assumption of equilibrium between capture and annihilation
- No assumption of particular annihilation final state
- Full numerical capture, SD and SI scattering on many more isotopes than just ^1H
- Full neutrino production, propagation and oscillation via tabulated WIMPSim results

Explicit example models – lightest neutralino in SUSY, as realised in:

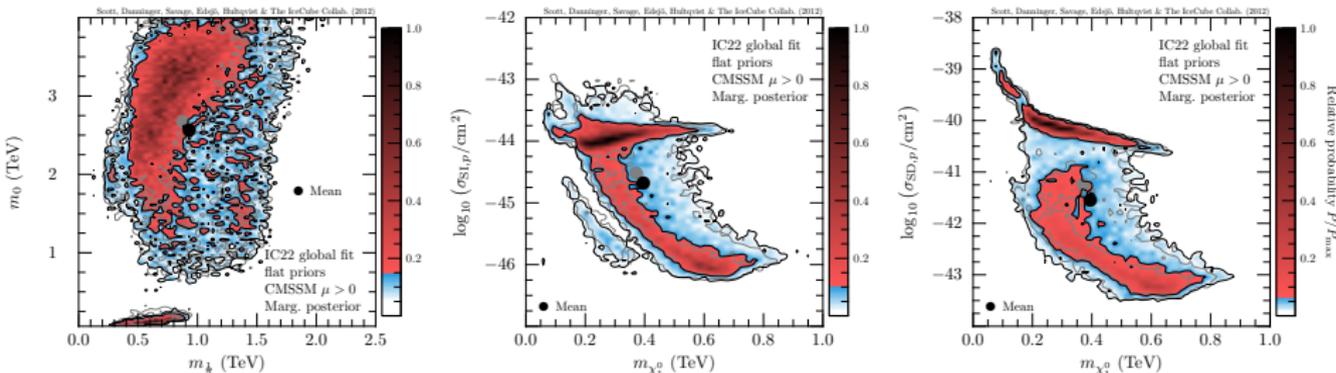
- CMSSM ($m_0, m_{1/2}, A_0, \tan \beta, \text{sgn} \mu$)
- MSSM-7 ($M_2, m_f^2, A_t, A_b, \mu, m_A, \tan \beta$)
- MSSM-25 ($M_1, M_2, M_3, 15 \times m_f^2, A_t, A_b, A_\tau, A_{e/\mu}, \mu, m_A, \tan \beta$)



Example: SUSY Scanning with IceCube – Global Fits

CMSSM, IceCube-22 events

m_0 – $m_{1/2}$ and $m_{\chi_1^0}$ –nuclear scattering cross-sections



Contours indicate 1σ and 2σ credible regions

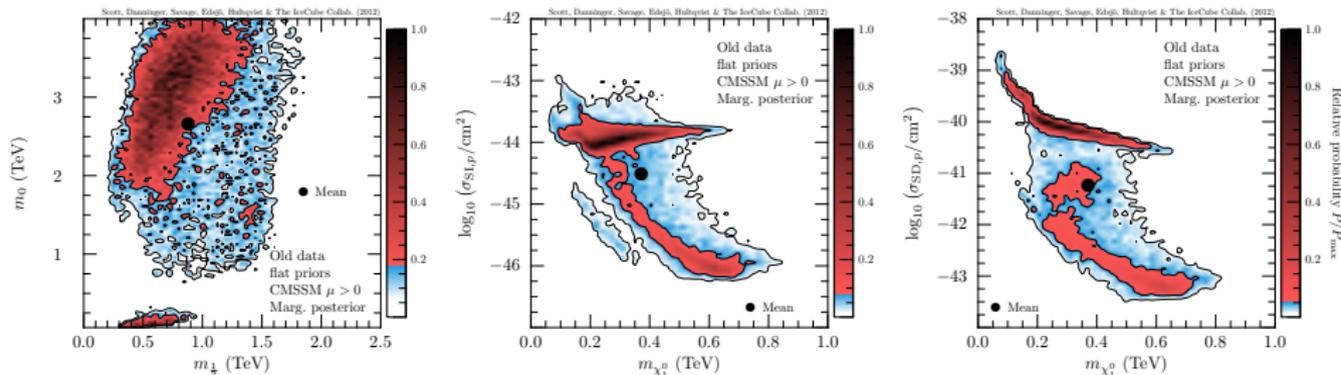
Grey contours correspond to fit *without* IceCube data

Shading+contours indicate **relative** probability only, not overall goodness of fit



Example of Direct + Indirect + LHC constraints

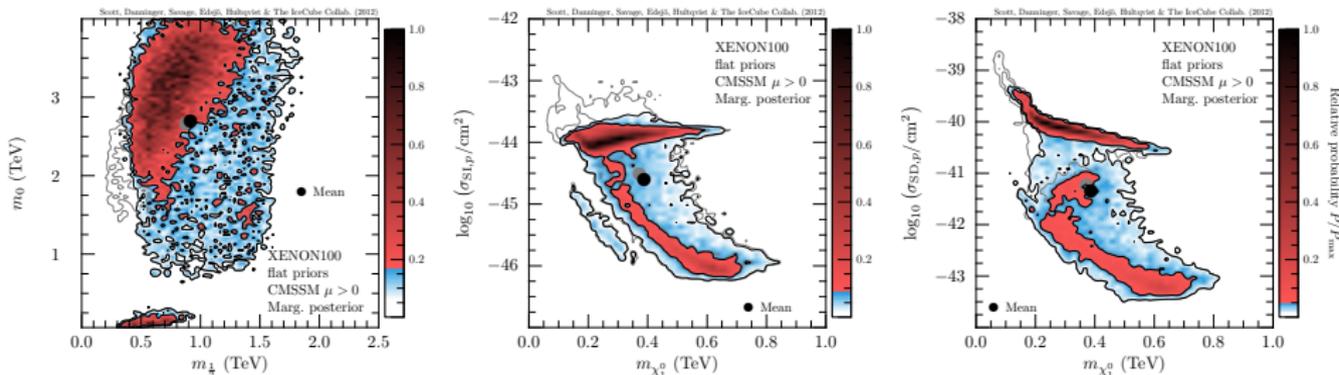
Base Observables



Example of Direct + Indirect + LHC constraints

Base Observables + XENON-100 (2011)

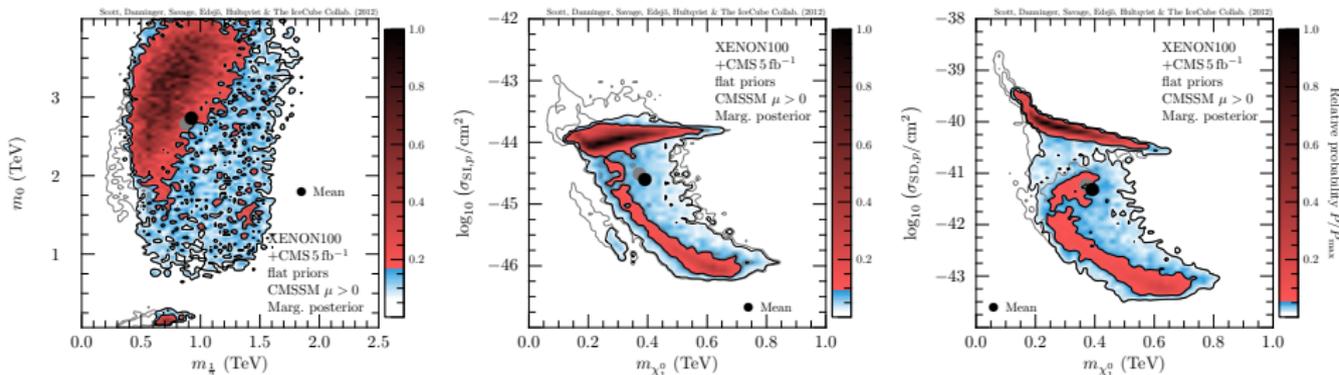
Grey contours correspond to Base Observables *only* (without IceCube data)



Example of Direct + Indirect + LHC constraints

Base Observables + XENON-100 + CMS 5 fb⁻¹

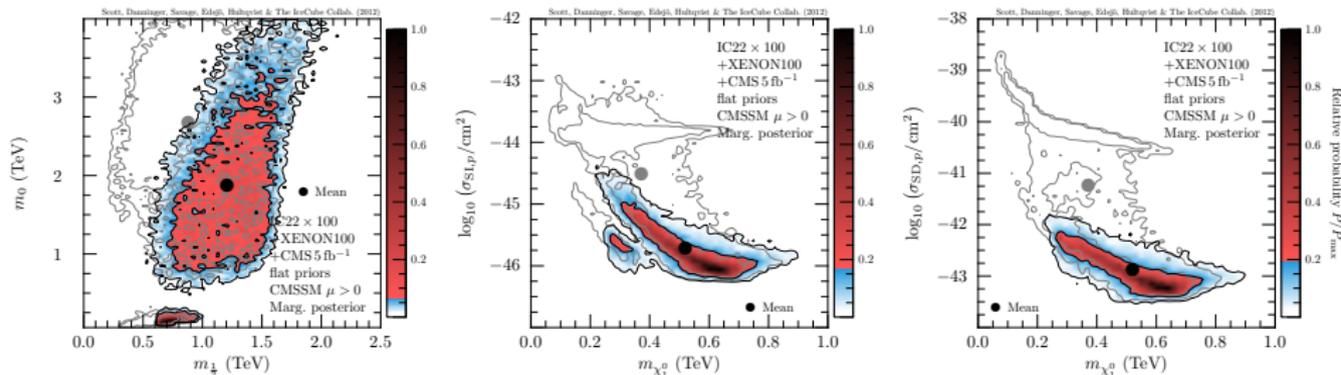
Grey contours correspond to Base Observables *only* (without IceCube data)



Example of Direct + Indirect + LHC constraints

Base Observables + XENON-100 + CMS 5 fb⁻¹
+ IC22 × 100

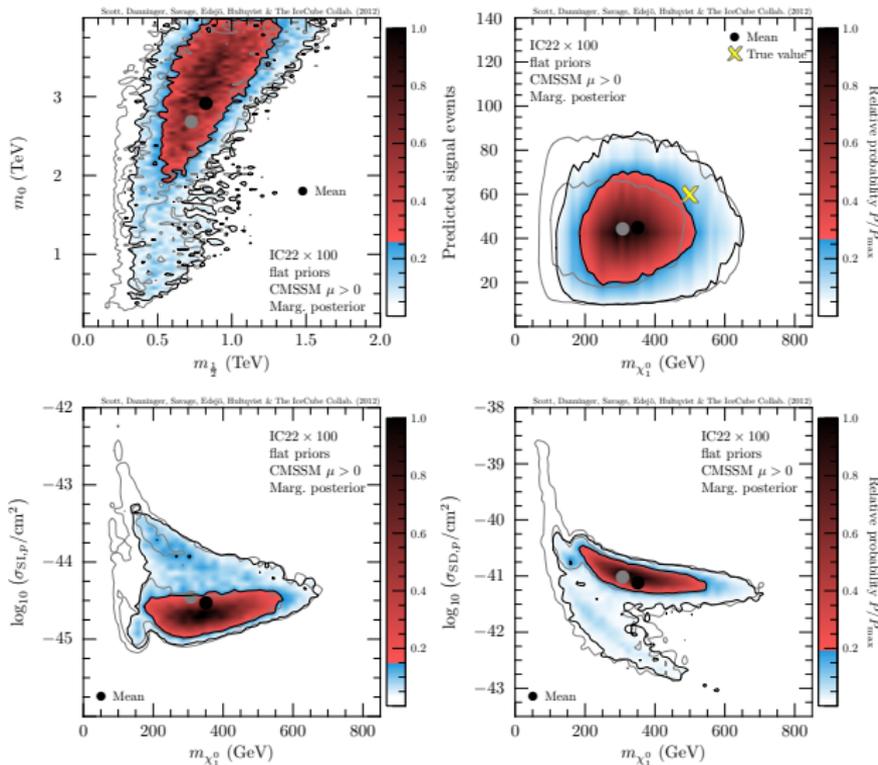
Grey contours correspond to Base Observables *only* (without IceCube data)



CMSSM, IceCube-22 with 100× boosted effective area
(kinda like IceCube-DeepCore)



Example: SUSY Scanning with IceCube – Global Fits

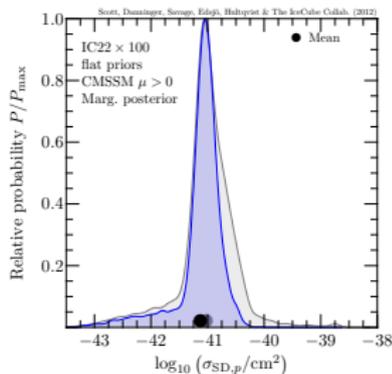
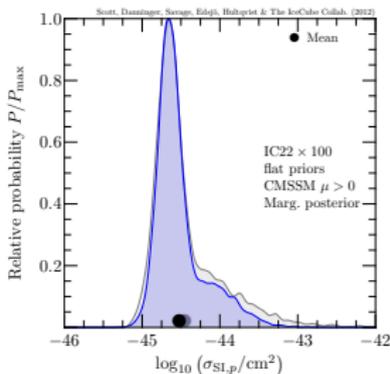
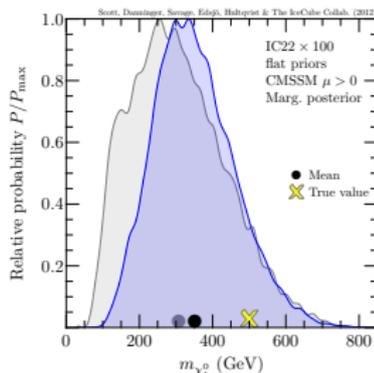
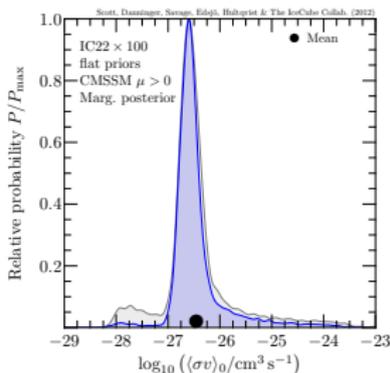


CMSSM,
IceCube-22 \times 100
signal reconstruction
60 signal events,
500 GeV, $\chi\chi \rightarrow W^+W^-$

Grey contours
correspond to
reconstruction *without*
energy information



Example: SUSY Scanning with IceCube – Global Fits



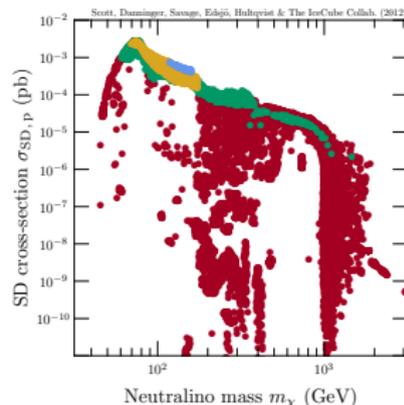
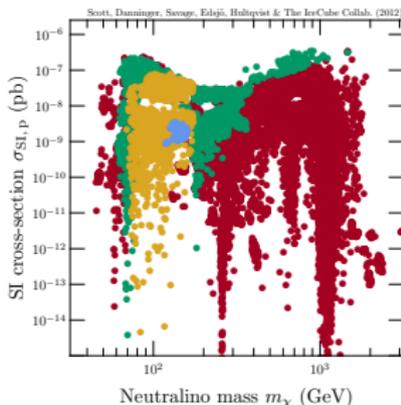
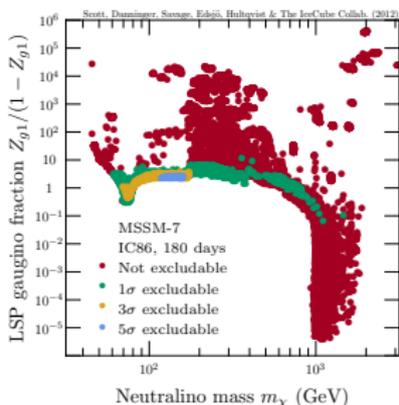
CMSSM,
IceCube-22 × 100
signal reconstruction
60 signal events,
500 GeV, $\chi\chi \rightarrow W^+W^-$

Grey contours
correspond to
reconstruction *without*
energy information



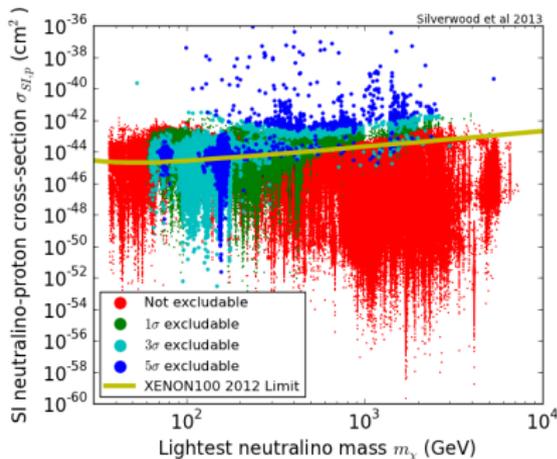
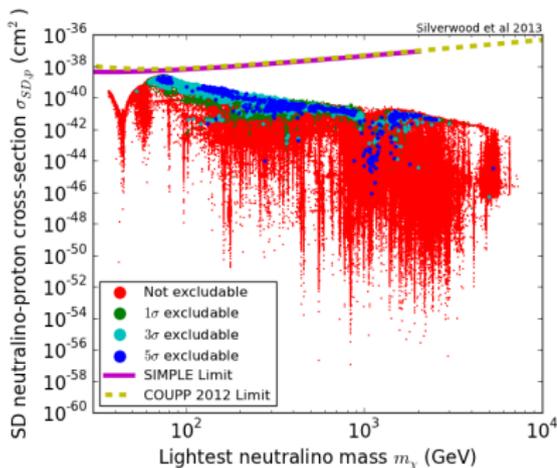
Simple IN/OUT type analyses: MSSM-7

Assuming preliminary estimate of IC-86 effective area
(arXiv:1111.2738)



Simple IN/OUT type analyses: MSSM-25

86-string IceCube vs Direct Detection (points pass $\Omega_\chi h^2$, $b \rightarrow s\gamma$, LEP)

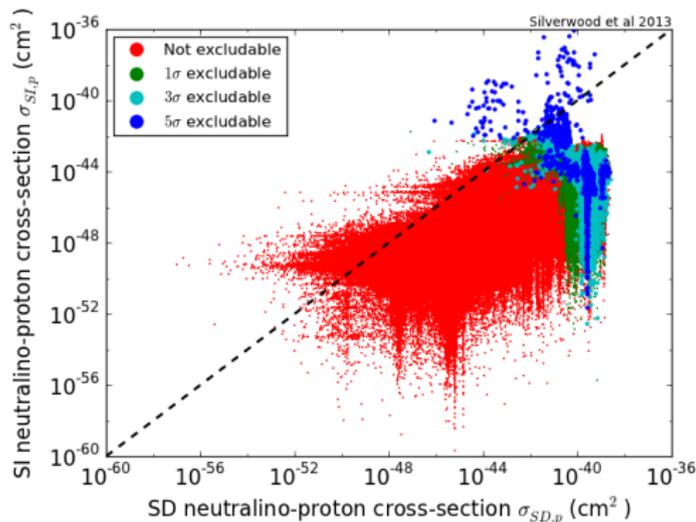


Many models that IceCube-86 can see are not accessible to direct detection. . .



Simple IN/OUT type analyses: MSSM-25

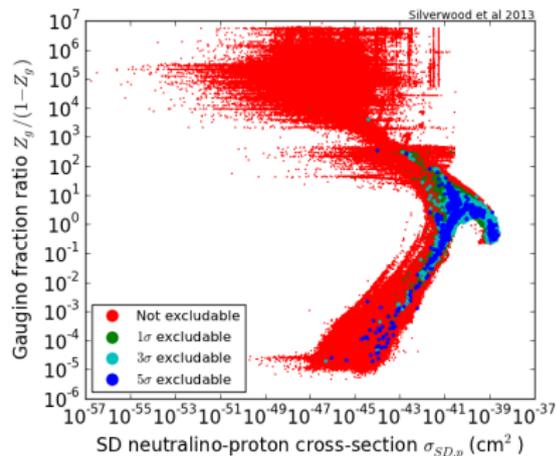
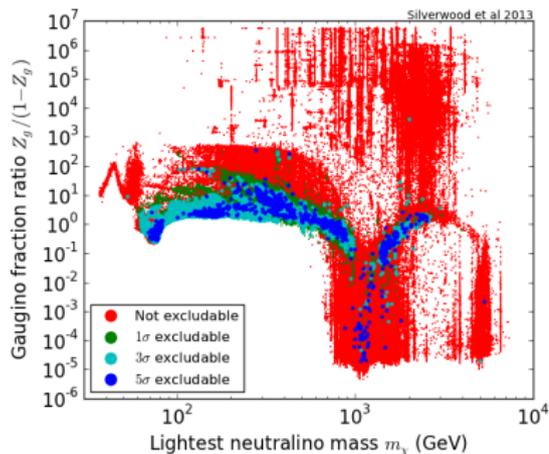
86-string IceCube SD vs SI



Unsurprisingly, most of the models that IceCube can get at have large SD couplings

Simple IN/OUT type analyses: MSSM-25

Gaugino fractions

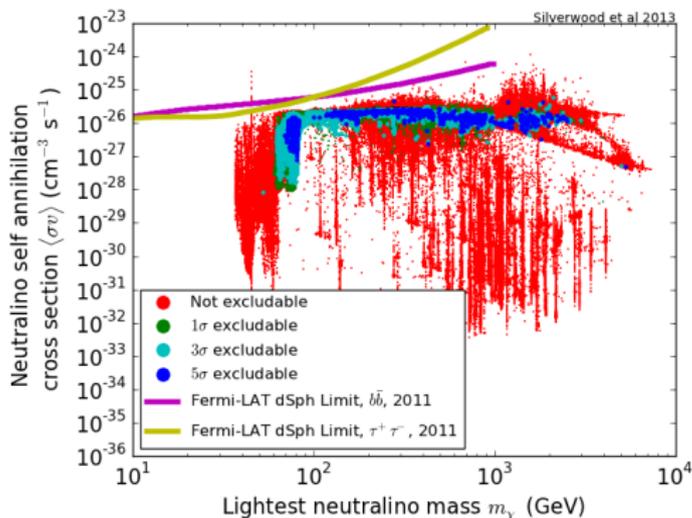


Mainly mixed models, a few essentially pure Higgsinos



Simple IN/OUT type analyses: MSSM-25

86-string IceCube vs Gamma Rays



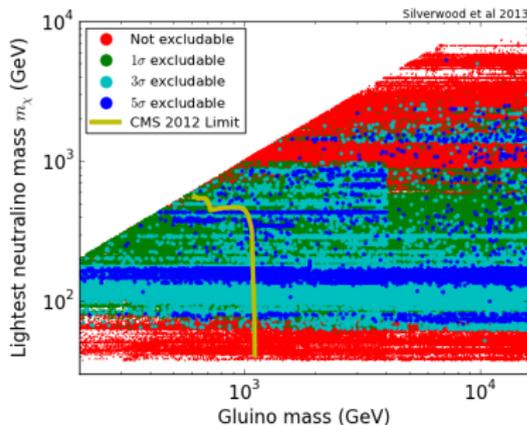
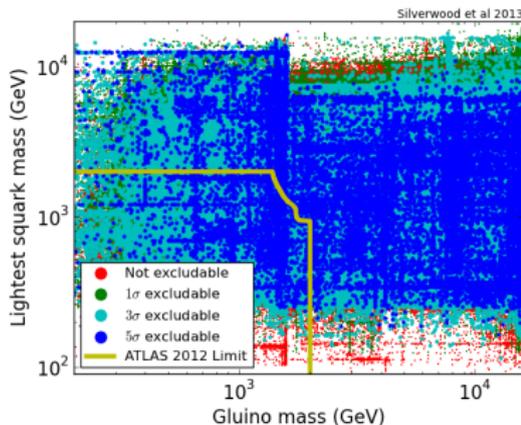
Many models that IceCube-86 can see are not accessible by other indirect probes. . .



Simple IN/OUT type analyses: MSSM-25

86-string IceCube vs LHC (very naively)

SMS limits: 7 TeV, 4.7 fb^{-1} , jets + $E_{T,miss}$; 0 leptons (ATLAS), razor + M_{T2} (CMS)



Many models that IceCube-86 can see are also not accessible at colliders.



Closing remarks

- A framework for directly comparing event-level neutrino telescope data to individual points in theory parameter spaces is in place
- These ‘iclike’ extensions are available in DarkSUSY
- IceCube event data has been released in a form digestible by DarkSUSY
- Direct SUSY analyses of IC79 data are on the way
- Many models exist in low-energy (p)MSSM variants that only IC86 will be sensitive to
- The extensions can be used equally well for non-SUSY BSM scenarios too

