

Direct constraints on minimal supersymmetry from *Fermi*-LAT observations of the dwarf galaxy Segue 1

Pat Scott

on behalf of the *Fermi* collaboration

Oskar Klein Centre for Cosmoparticle Physics (OKC) &
Department of Physics, Stockholm University

Collaborators: Jan Conrad, Joakim Edsjö, Lars Bergström &
Yashar Akrami (Stockholm, OKC)

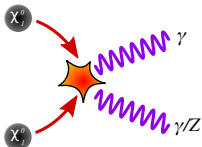
Christian Farnier (Montpellier II, LPTA/CNRS-UM2)

Slides available from www.fysik.su.se/~pat

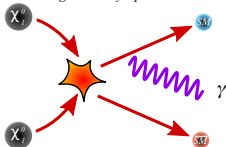


Gamma-rays from neutralino dark matter

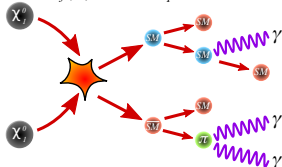
2 photons (or Z +photon):
monochromatic lines



Internal bremsstrahlung:
hard gamma-ray spectrum



Secondary decay:
soft(er) continuum spectrum



- Neutralinos: linear combinations of superpartners of γ , Z and H^0
- Specific example of WIMP dark matter
 - Neutral, carries $SU(2)_L$ charge, stable if R -parity conserved
- 3 main gamma-ray channels:
 - monochromatic lines
 - internal bremsstrahlung
 - continuum from secondary decay
- $\Phi \propto$ annihilation rate $\propto \rho_{DM}^2$
- Likely targets:
 - Galactic centre
 - Galactic halo
 - dwarf galaxies
 - dark clumps
 - clusters/extragalactic

Dwarf galaxies as observed with Fermi

Why dwarfs?

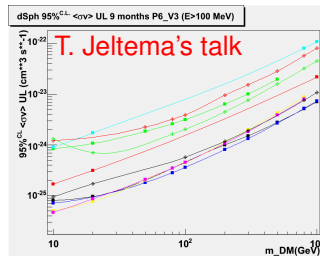
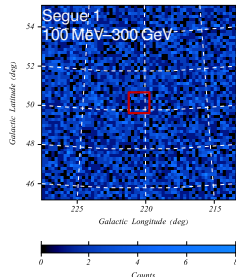
- Very high mass-to-light ratios
⇒ lots of DM, little BG
- High latitude ⇒ low BG
- ⇒ arguably the best targets for WIMP gammas

Why Segue 1?

- Close(ish) – 23 kpc
- $M/L \sim 1300$ (**large**)
- Arguably the best S/N dwarf for WIMP gammas (cf. e.g. Kulen, arXiv:0906.1822)
- Leading the pack (with Willman 1) in *Fermi* dwarf upper limit analysis

What limits? (100 MeV–300 GeV; see T. Jeltema's talk)

- 9 month *Fermi* 95% flux upper limit: $\Phi < 1.83 \times 10^{-9} \text{ cm}^{-2} \text{ s}^{-1}$



Scanning supersymmetric parameter spaces

Goal: given a particular version of SUSY, determine which parameter combinations fit all experiments, and how well

Issue 1: Combining fits to different experiments

Easy – composite likelihood ($\mathcal{L}_1 \times \mathcal{L}_2 \equiv \chi_1^2 + \chi_2^2$)

- dark matter relic density from WMAP
- precision electroweak tests at LEP
- LEP limits on sparticle masses
- B -factory data (rare decays, $B \rightarrow s\gamma$)
- muon anomalous magnetic moment

Issue 2: Finding the points with the best likelihoods

Tough – grid scans, MCMCs, nested sampling or **genetic algorithms** (cf Yashar Akrami's presentation yesterday)

Model: We focus on the Constrained MSSM (CMSSM)

- GUT boundary conditions on soft SUSY breaking parameters such that only 4 free parameters and 1 sign remain
- incorporates the simplest implementation of mSUGRA

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- dark matter relic density from WMAP m_0 scalar mass parameter
- precision electroweak tests at LEP $m_{\frac{1}{2}}$ gaugino mass parameter
- LEP limits on sparticle masses $\tan \beta$ ratio of Higgs VEVs
- B -factory data (rare decays, $B \rightarrow s\gamma$) A_0 trilinear coupling
- muon anomalous magnetic moment $\text{sgn } \mu$ Higgs mass parameter (+ve in our scans)

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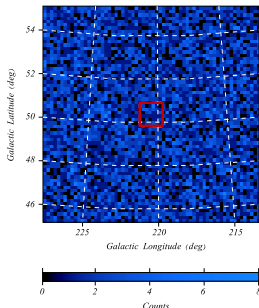
Including Segue 1 in SUSY scans

Purposes:

- see if Segue observations do/will impact real models at all, considering ‘soft bounds’
- attempt to validate dwarf UL analysis via an independent, rather different analysis

Same cuts as dwarf UL analysis

- “DIFFUSE” event class
- 105° zenith angle cut
- 10° ROI
- 14 energy bins from 100 MeV–300 GeV



Binned Poissonian likelihood (similar to dwarf UL analysis)

Spatial-spectral fit to inner 6×6 bins of 64×64 ROI (dwarf UL analysis assumes point source)

Segue 1 halo profile from best fit Einasto profile by Martinez et al

(2009; *JCAP* 6:14) (NFW in dwarf UL analysis) + marginalisation

Galactic diffuse BG from *Fermi* all-sky GALPROP fits

Isotropic powerlaw extragalactic BG (as per dwarf UL analysis)

BG normalisations from dwarf UL fits (i.e. full $10^\circ \times 10^\circ$)

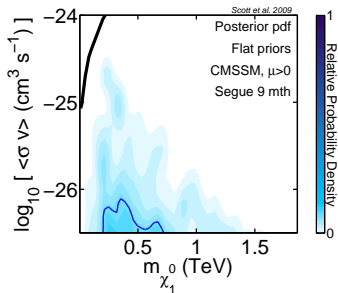
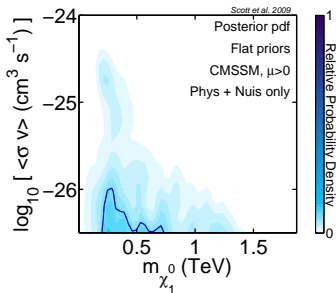
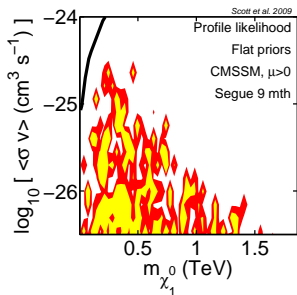
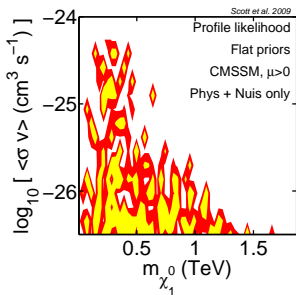
Integration over energy-dependent IRFs (P6v3) with FLATLIB –
fast – (dwarf UL analysis skips energy dispersion)

Inclusion of systematic errors from effective area and
theoretical calculations – (dwarf UL analysis skips systematics)

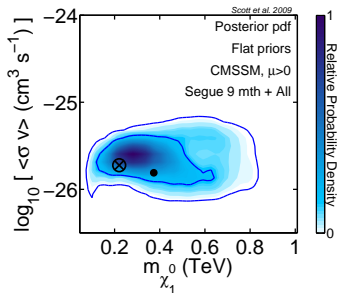
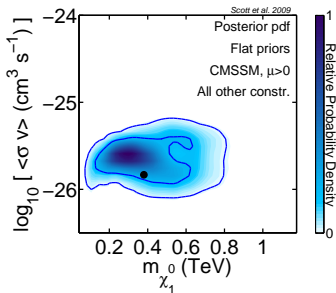
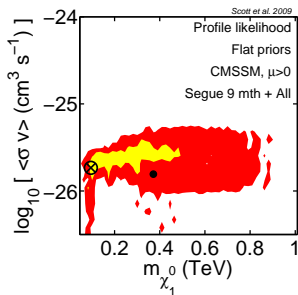
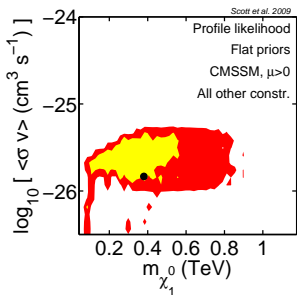
Integration into SUPERBAYES, upgraded with DARKSUSY 5
(**including internal bremsstrahlung**), bug fixes, etc.

515 data points in new global fit, vs 11 previously with
SUPERBAYES 1.35

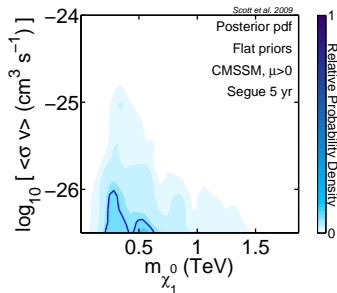
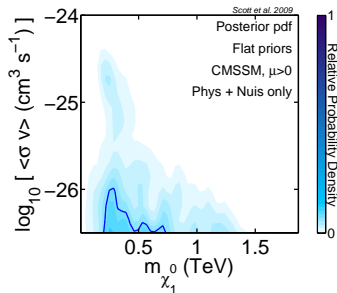
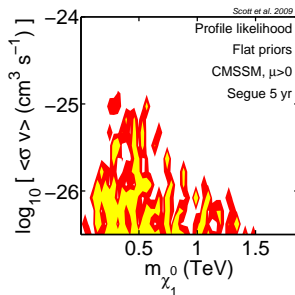
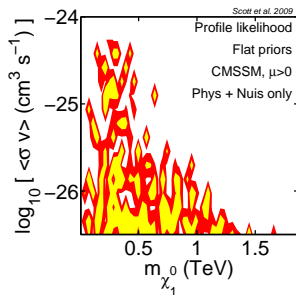
Results - Segue 1 only



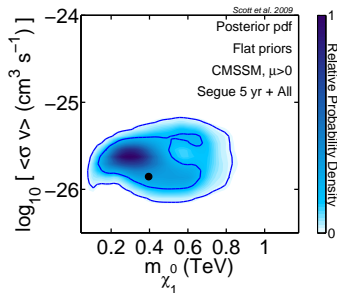
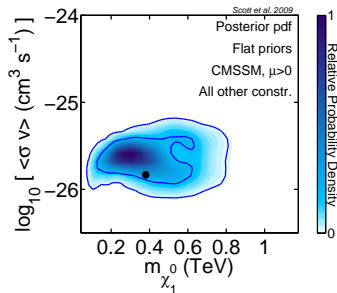
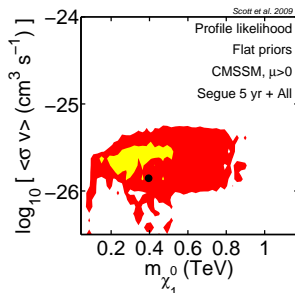
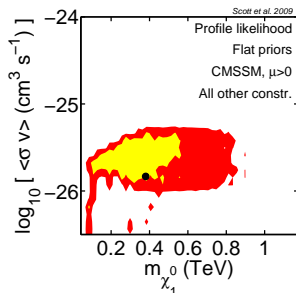
Results - all observables + Segue 1



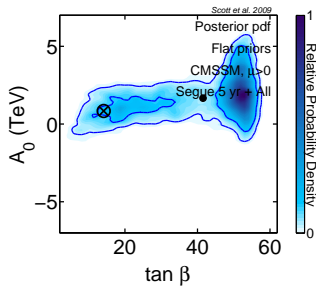
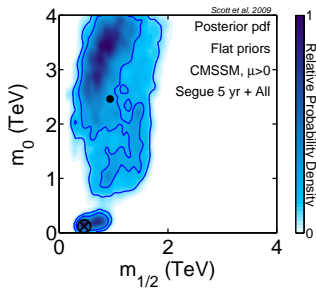
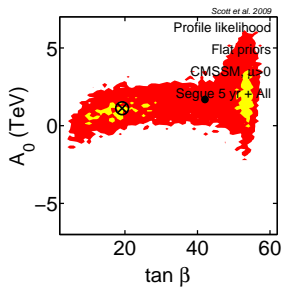
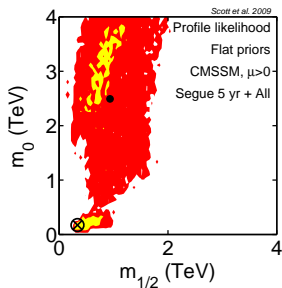
Prospects - Segue 1 after 5 years



Prospects - all observables + Segue 1 after 5 years



Prospects - all observables + Segue 1 after 5 years



Conclusions

- Existing 9 month dataset does constrain the CMSSM by itself, but only weakly
- 5 years of data will provide significantly better constraints, but...
- Not quite good enough to impact models which are not already disfavoured by other constraints (eg relic density)
- In the (unlikely) event of a later *signal* from Segue 1, we can zero in on the preferred CMSSM model and cross-section very quickly, and provide confidence intervals
- Strongly vindicates the limits placed in the dwarf upper limit analysis
- FLATLIB source freely available from www.fysik.su.se/~pat/flatlib