CMSSM constraints from *Fermi*-LAT observations of the dwarf galaxy Segue 1

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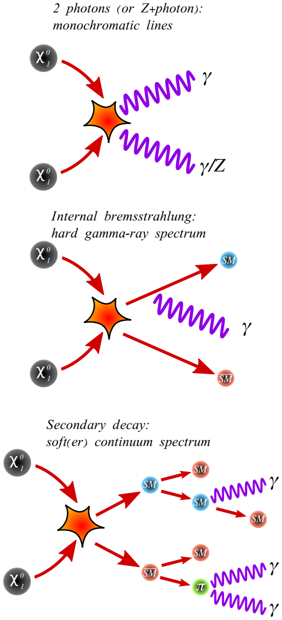
Based on arXiv:0909.3300

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

Gamma-rays from neutralino dark matter



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

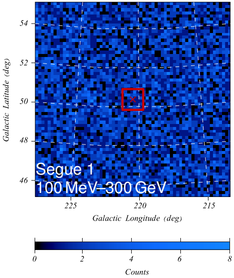
Dwarf galaxies as observed with Fermi

Why dwarfs?

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

Why Segue 1?

- Close(ish) – 23 kpc
- $M/L \sim 1300$ (**large**)
- The best S/N dwarf for WIMP gammas
- Leading the pack in *Fermi* dwarf upper limit analysis



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, $b \to s\gamma$)
- muon anomalous magnetic moment

Issue 2: Finding the points with the best likelihoods
Tough – grid scans, MCMCs, nested sampling or genetic algorithms (see e.g. arXiv:0910.3950 for genetic)

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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m_0	scalar mass parameter
$m_{\frac{1}{2}}$	gaugino mass parameter
$\tan\beta$	ratio of Higgs VEVs
A_0	trilinear coupling
$\mathrm{sgn}\,\mu$	Higgs mass parameter (+ve in our scans)

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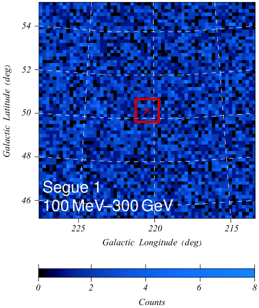
Including Segue 1 in SUSY scans

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)

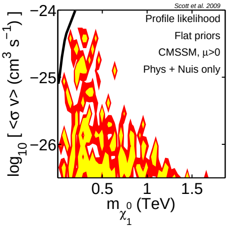
Spatial-spectral fit to inner 6 × 6 bins of 64 × 64 ROI (dwarf UL analysis assumes point source)

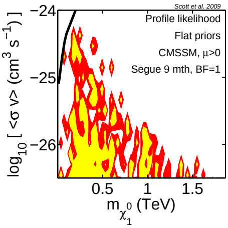
Segue 1 halo profile from best fit Einasto profile by Martinez et al (2009; *JCAP* **6**:14) (NFW in dwarf UL analysis)

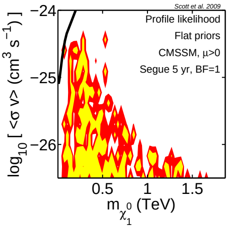
Including Segue 1 in SUSY scans

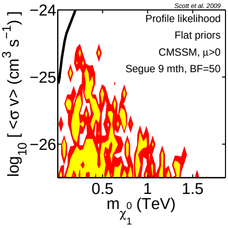
- Galactic diffuse BG from preliminary *Fermi* all-sky GALPROP fits
- Isotropic powerlaw extragalactic BG (as seen by *EGRET*)
- BG normalisations from dwarf UL fits (i.e. full $10^\circ \times 10^\circ$)
- Fast integration over energy-dependent IRFs (P6v3) with FLATLIB – (dwarf UL analysis skips energy 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 (admittedly not such a fair comparison)

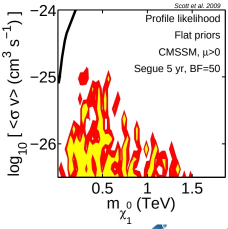
Results - Segue 1 only



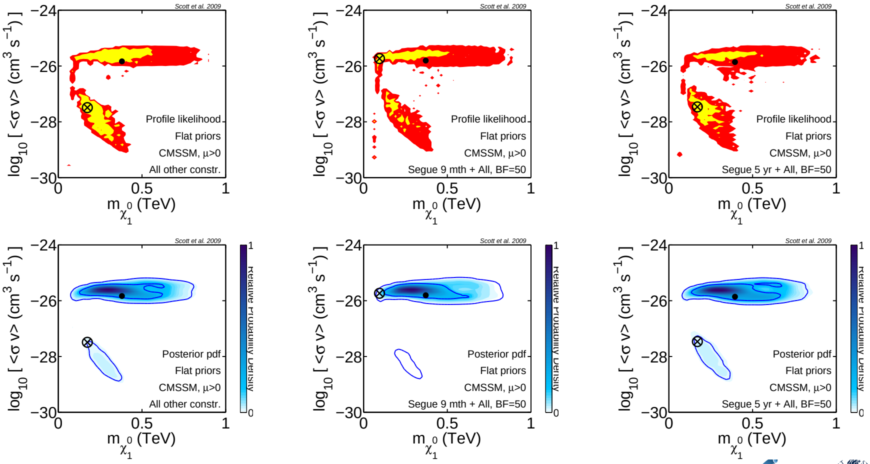




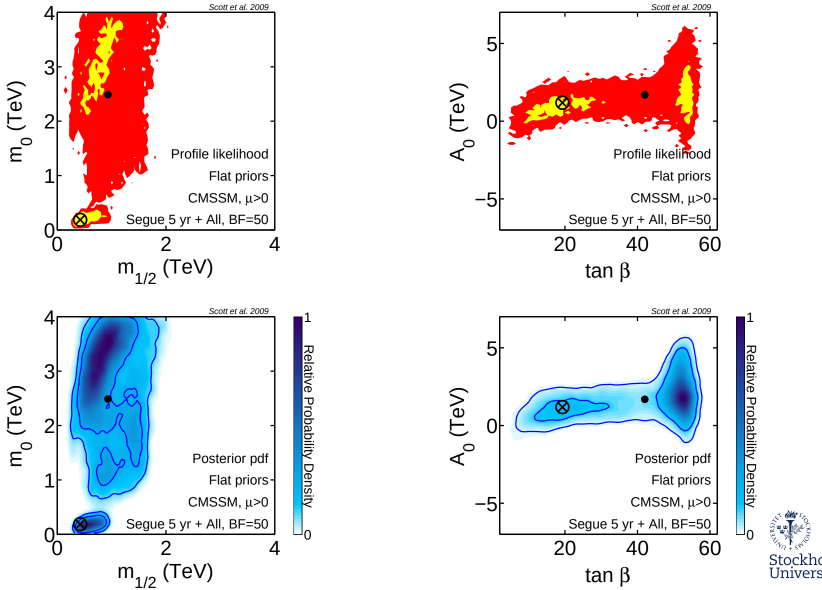




Results - all observables + Segue 1



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
- Consistent with limits found in the dwarf upper limit analysis
- FLATLIB source freely available from `www.fysik.su.se/~pat/flatlib`

Fermi Gamma-ray Space Telescope

Stockholm University