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VERITAS Dark Matter Search Program

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Argonne VERITAS Group

Presentation to VERITAS External Science Advisory Committee

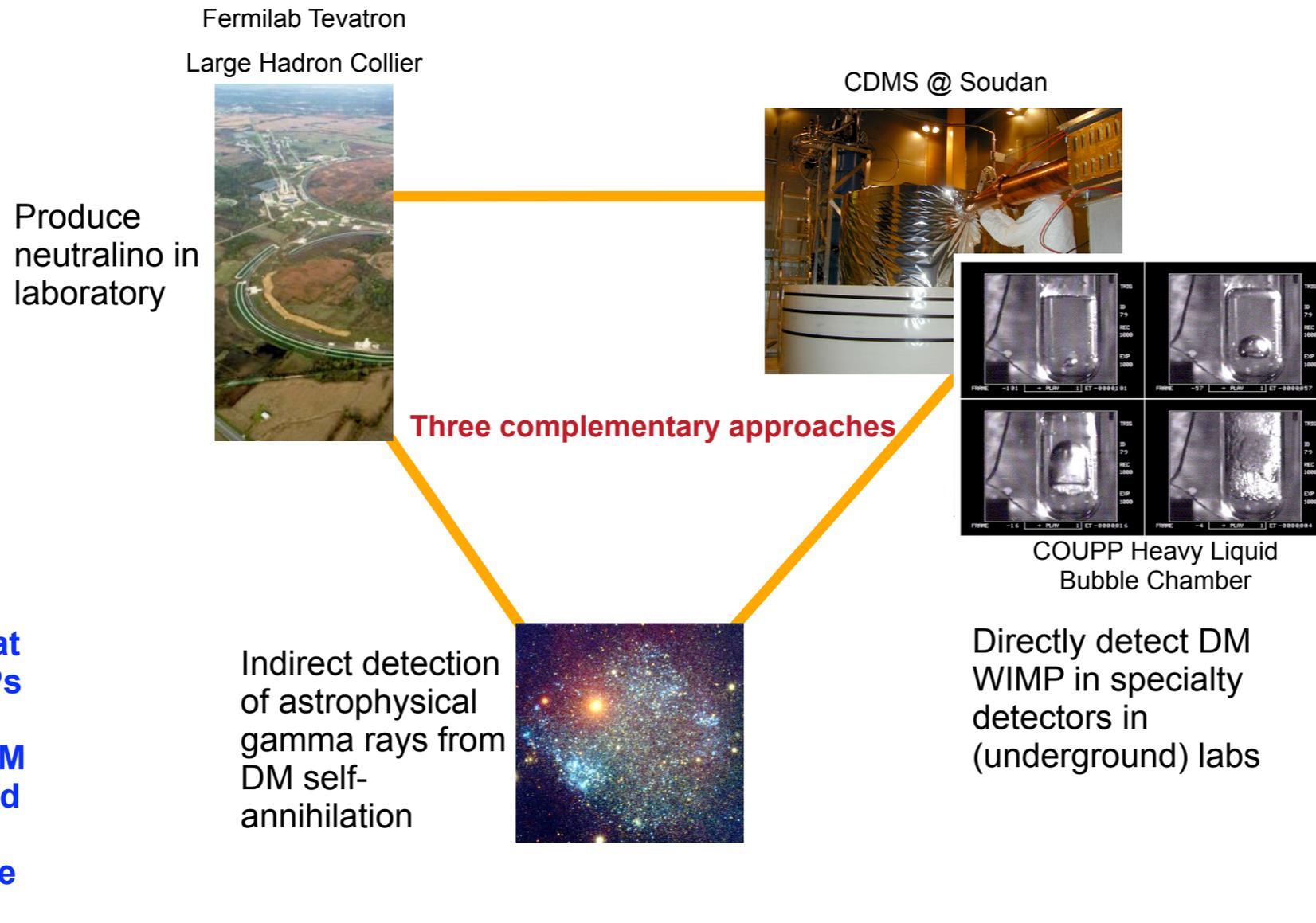
Friday 17 April 2009

VERITAS Dark Matter Science Working Group

■ **Primary objective of DMSWG is to carry out program for indirect detection of particle Dark Matter**

- Assumes mechanism for γ -ray production is self-annihilation of MSSM-type neutralino or Kaluza-Klein particle
- Mechanism, mass, cross section, astrophysical flux all highly uncertain, so survey a variety of sources
 - *Local large galaxies:* M31, M32, M33
 - *Globular clusters:* M15, M5
 - *Galaxy clusters:* Coma
 - *Dwarf spheroidal galaxies:* Draco, Ursa Minor, Willman I, Boötes 1
 - *Study feasibility of verifying/falsifying electron/positron results from PAMELA/ATIC*
- Several of the targets are of interest to and were proposed by other SWGs
- Dwarf galaxies are the one class of target unique to DMSWG

Dark Matter Search Triangle



Two Years of Dark Matter Target Observations

Target	Dates	Observed Hours	Usable Hours	Significance
M15	Sept 2006	10	0	n/a
M5	Feb/Mar 2009	15.6	12	no signal of significance (prelim)
M33	Nov 2007- Feb 2008	15.8	11.8	0.412
M31/M32	Oct 2008- Jan 2009	13.2	12	0.6 (prelim)
Coma Cluster	Mar 2008- Apr 2008	20.6	18.6	<1.5% Crab 99% c.l.
Draco dSph	Apr/May 2007	23.7	18.4	-1.51
Ursa Minor dSph	Feb/May 2007	26.2	18.9	-1.77
Willman I dSph	Dec 2007- Feb 2008	15.4	13.7	-0.08
Boötes 1 dSph	Mar/Apr 2009	13	11.6	0.7 (prelim)

The Appeal of Dwarf Galaxies

■ **Dark Matter Dominated**

- Indicated by velocity dispersion (e.g. Strigari *et al.*, ApJ **678**, (2008) 614)
- Generally $M/L > 100$

■ **No recent star formation**

- Low “standard” backgrounds

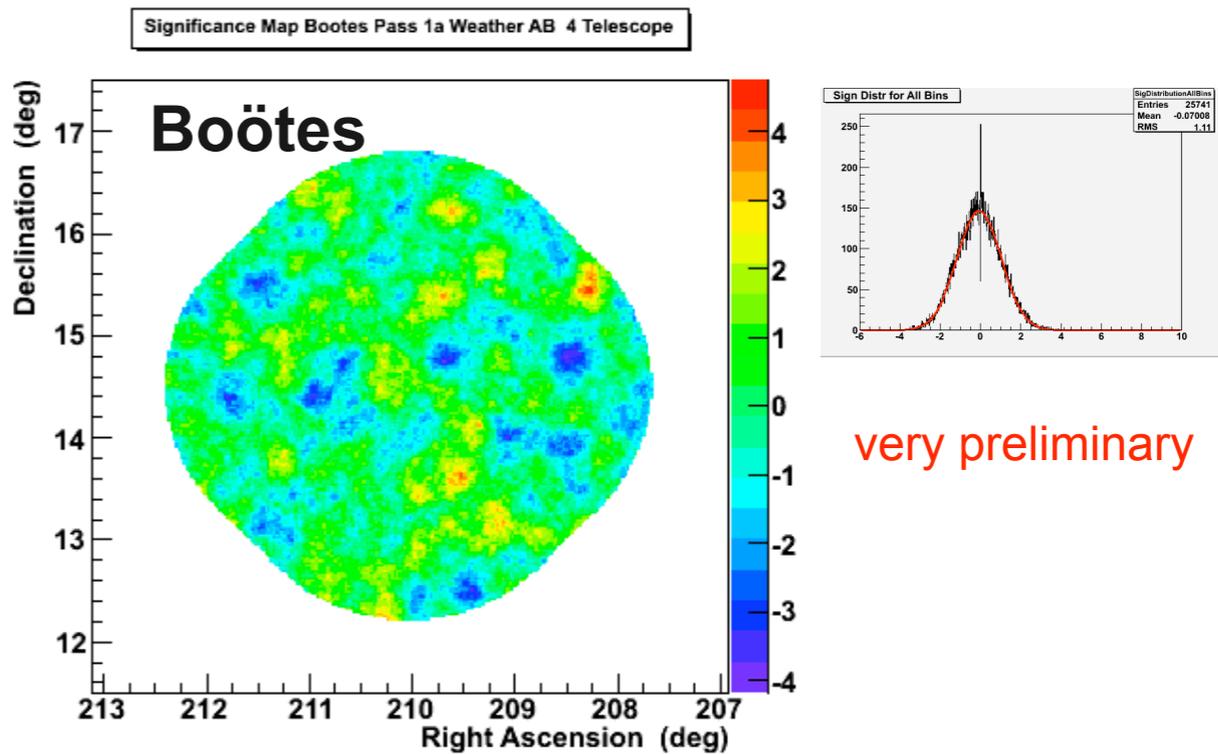
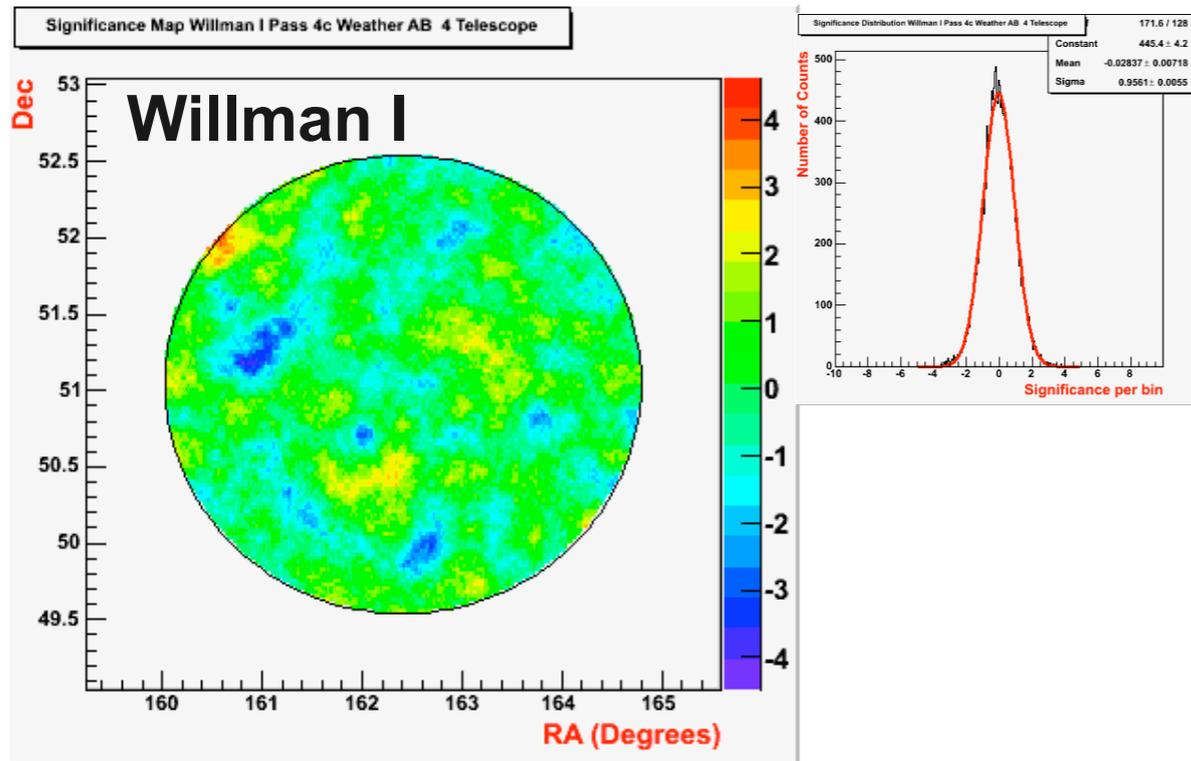
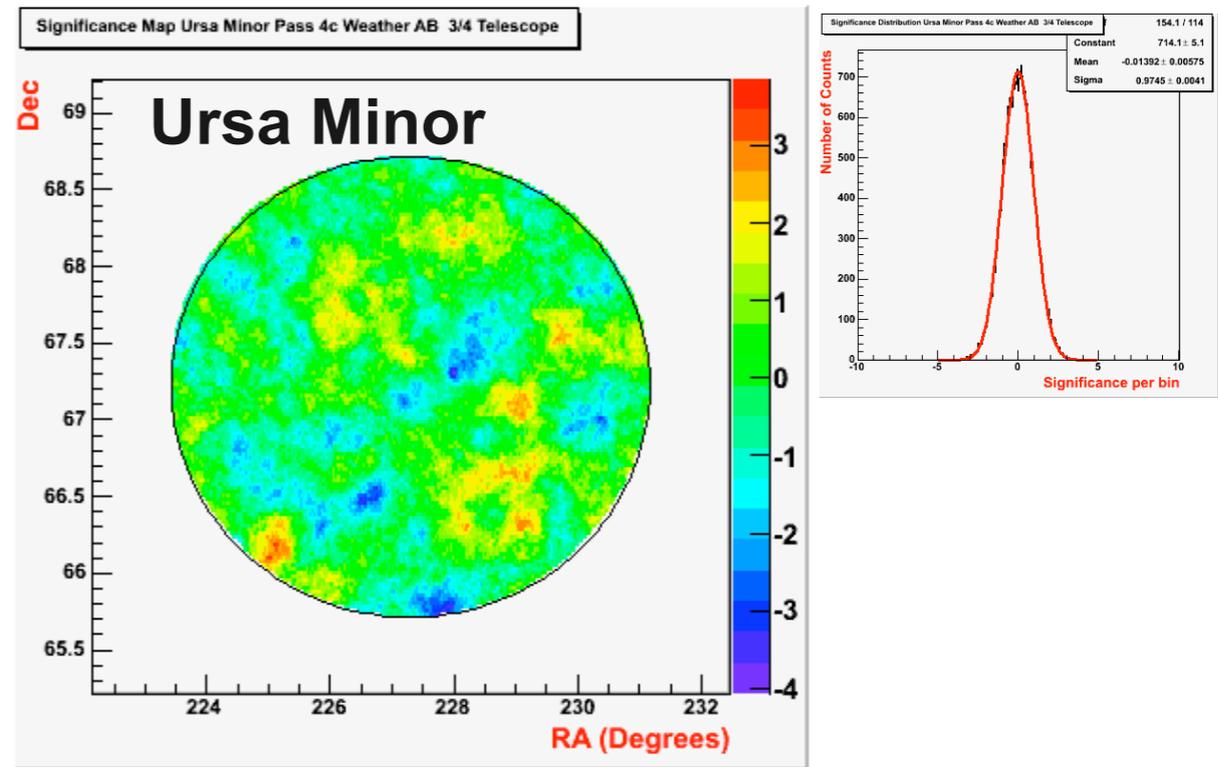
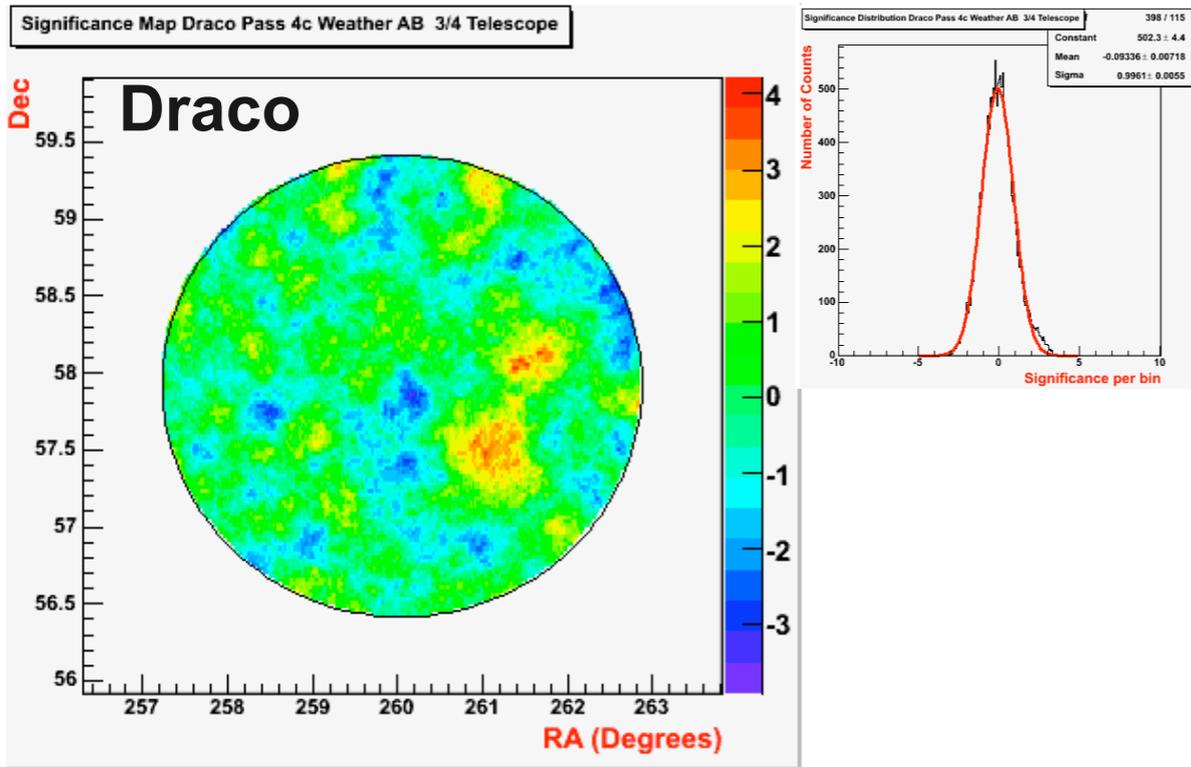
■ **Close proximity**

- < 100 kpc

■ **Possible enhanced emission**

- Dark Matter halo substructure
- Internal bremsstrahlung (c.f. Bringmann, Doro, Fornasa arXiv:0809.2269)
- Velocity dependent cross sections (Sommerfeld effect)

Dwarf Spheroidal Galaxy Observations



very preliminary

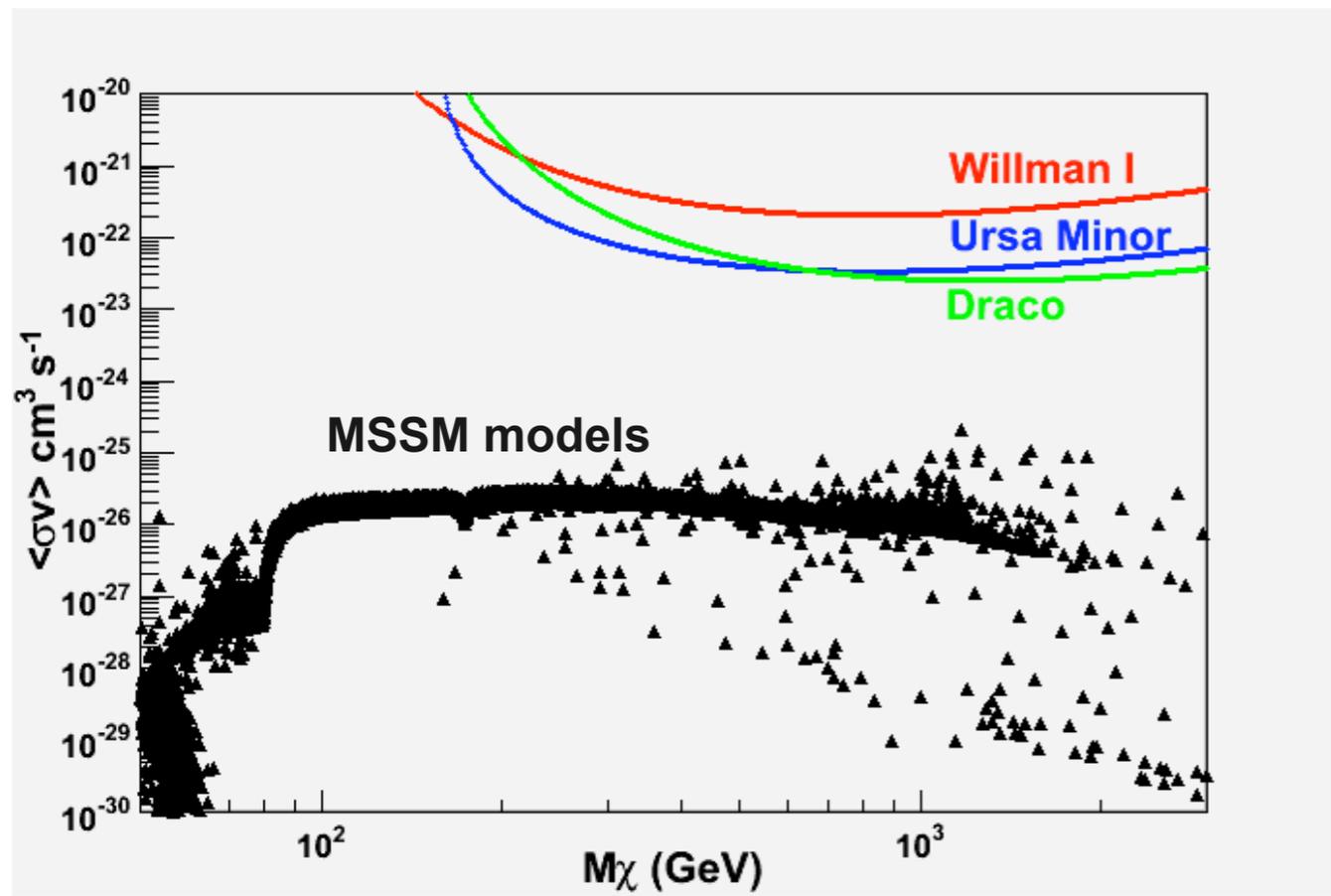
Limits on Neutralino Parameters

Particle Physics

$\langle\sigma v\rangle$ Limit: $\frac{\langle\sigma v\rangle}{3 \times 10^{-26}} < R_\gamma(95\% \text{ C.L.}) \left(\frac{m_\chi}{100 \text{ GeV}}\right)^2 \times \left(\frac{1.45 \times 10^4 \text{ GeV}}{J}\right) \left\{ \phi_{1\%} \int_{200 \text{ GeV}}^{\infty} A(E) \left[\frac{dN(E, m_\chi)/dE}{10^{-2} \text{ GeV}^{-1}} \right] dE \right\}^{-1}$

Astrophysical Factor

$$J(\psi, \Delta\Omega) = \left(\frac{2\pi\rho_s^2}{\rho_c^2 R_H}\right) \int_{\cos(0.115^\circ)}^1 \int_{\lambda_{min}}^{\lambda_{max}} \left(\frac{r(\lambda)}{r_s}\right)^{-2} \left[1 + \left(\frac{r(\lambda)}{r_s}\right)\right]^{-4} d\lambda d(\cos\theta),$$



dSph	$R_\gamma(95\% \text{ c.l.})$ counts/min	flux (95% c.l.) $\text{cm}^{-2} \text{s}^{-1}$	J
Draco	0.0079	1.05×10^{-12}	4 (2-9)
Ursa Minor	0.0029	0.29×10^{-12}	7 (4-20)
Willman I	0.045	2.23×10^{-12}	22

Dark Matter Group Plan for Future Observations

- **Remain as Key Science Project**
- **Deeper Observation of 2-3 dSphs on continuing basis**
 - Choice based on theoretical guidance + collaborative effort of Fermi, MAGIC, HESS, CANGAROO groups
 - *Coordination of ACT DM searches initiated by Jim Buckley & Jan Conrad (Fermi DMSWG)*
 - *Goal to develop common framework for Dark Matter limits allowing combining of data*
 - Accumulate statistics over several observing seasons
 - Can we stack results from aggregate of dSph observations?
- **Support efforts to study feasibility of addressing PAMELA/ATIC results (c.f. Hooper & Hall, arXiv:0811.3362)**
 - Difficult analysis; easy to find false signals from systematic effects
- **Be prepared for follow-up on guidance from Fermi**

DMSWG Summary

- ***Indirect Dark Matter Search is high-risk, but high payoff***
 - If conservative estimates correct, will need to wait for AGIS/CTA
 - Boosted flux from DM annihilation is well-motivated; halo substructure....
 - Dark Matter nature may be something totally different than WIMP
 - Success would be discovery of fundamental importance
- ***Program is focused on Dwarf Spheroidal Galaxies although have addressed a variety of possible DM sources***
 - Setting best current indirect limits on Dark Matter fluxes
 - Concentrate on limited number of dSphs in future program
- ***Can anticipate improvement in sensitivity from***
 - Push to lower energy threshold
 - Possible VERITAS trigger and camera upgrades
 - Improvement of analysis techniques