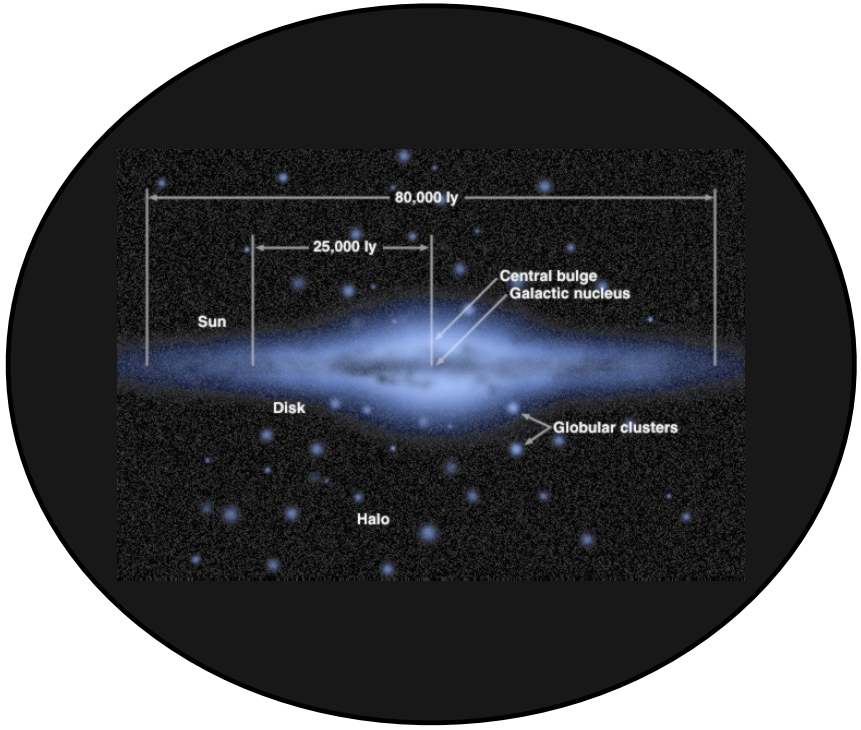
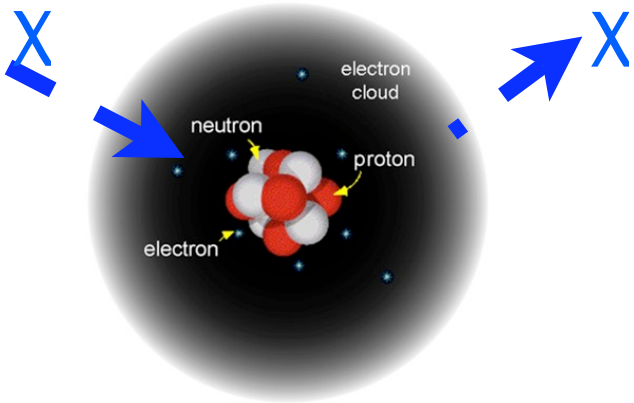
Constraining WIMP Properties at future direct detectors





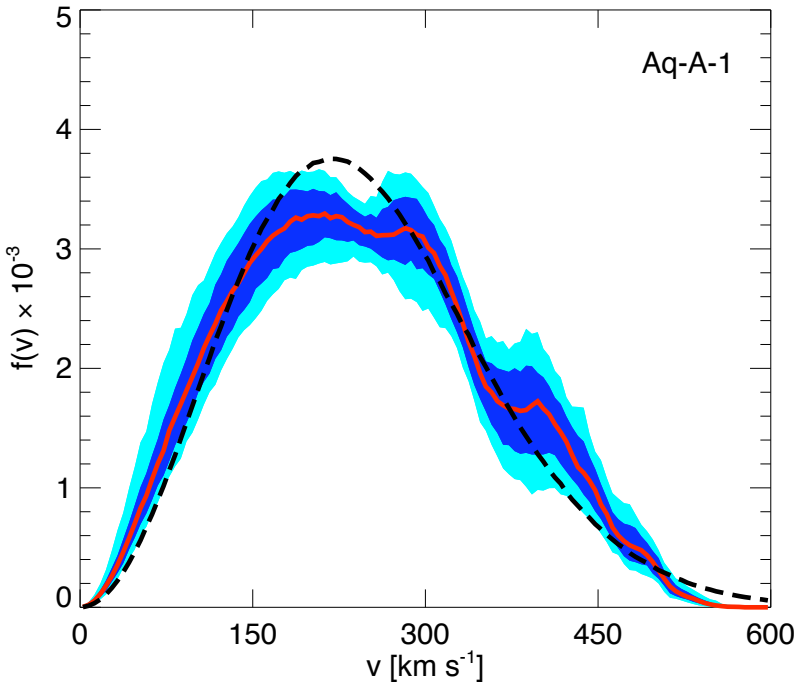
Louie Strigari (Stanford/KIPAC)

TeVPA, Stanford, July 2009

Based on work in collaboration with Roberto Trotta (Imperial College, London)

arXiv:0906.5361 [astro-ph.HE]

Milky Way Dark Matter Distribution

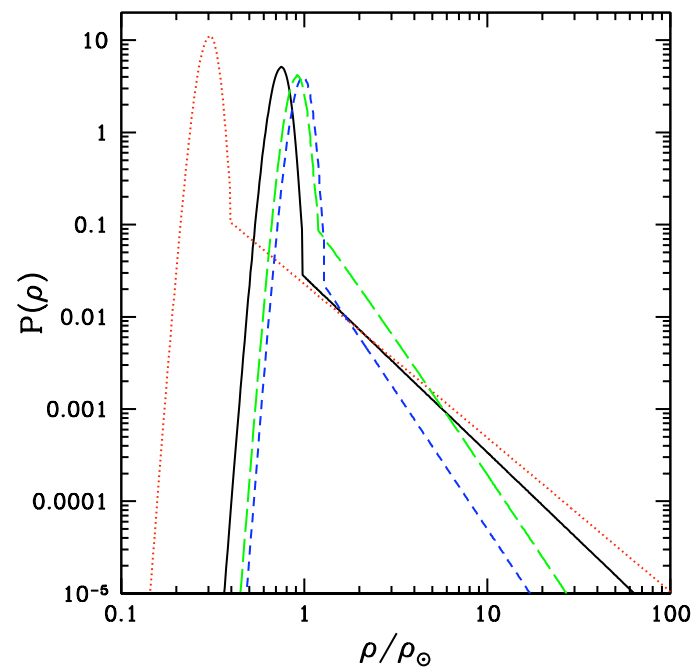


Vogelsberger et al., MNRAS 2009

Measured distribution of speeds near solar circle implies 10% variation relative to multivariate gaussian fit

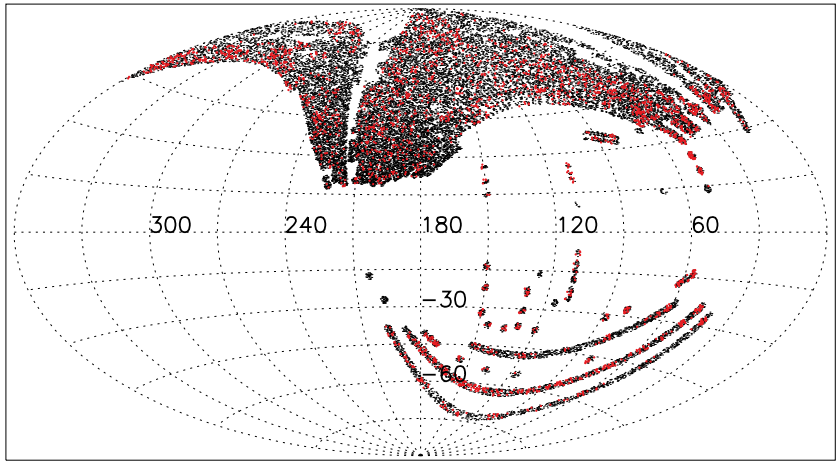
Including substructure, local density probably not less than 1/2 the canonical value

Kamionkowski & Koushiappas 2008



Milky Way Rotation Curve

Galactic Sky Coverage

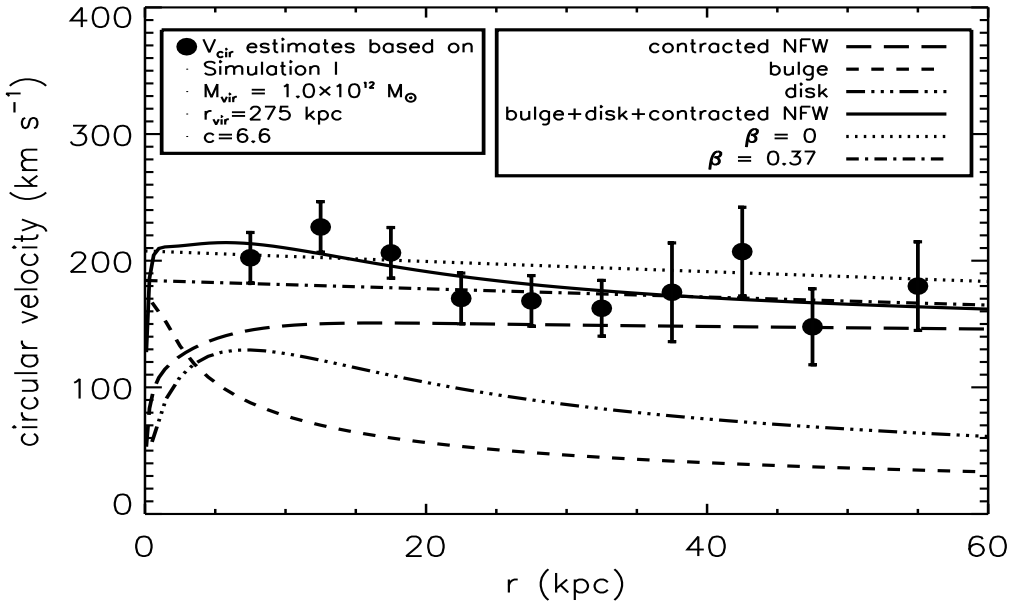


Xue et al. 2008 uses population of 2000 BHB stars out to 60 kpc

$$M(< 60 \text{ kpc}) = 4.0 \pm 0.7 \times 10^{11} M_\odot$$

$$M_{vir} = 1.0^{+0.3}_{-0.2} \times 10^{12} M_\odot$$

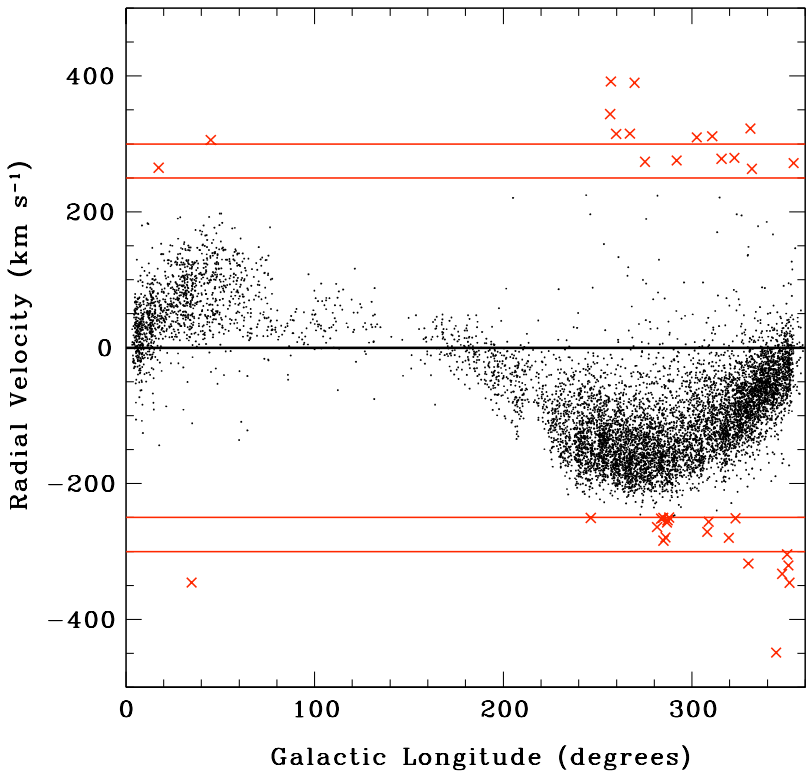
Mass estimates broadly consistent with those that use satellite dynamics (Frenk & White 1981, Little & Tremaine 1987, Kochanek 1996, Evans & Wilkinson 1999, Li & White 2008)

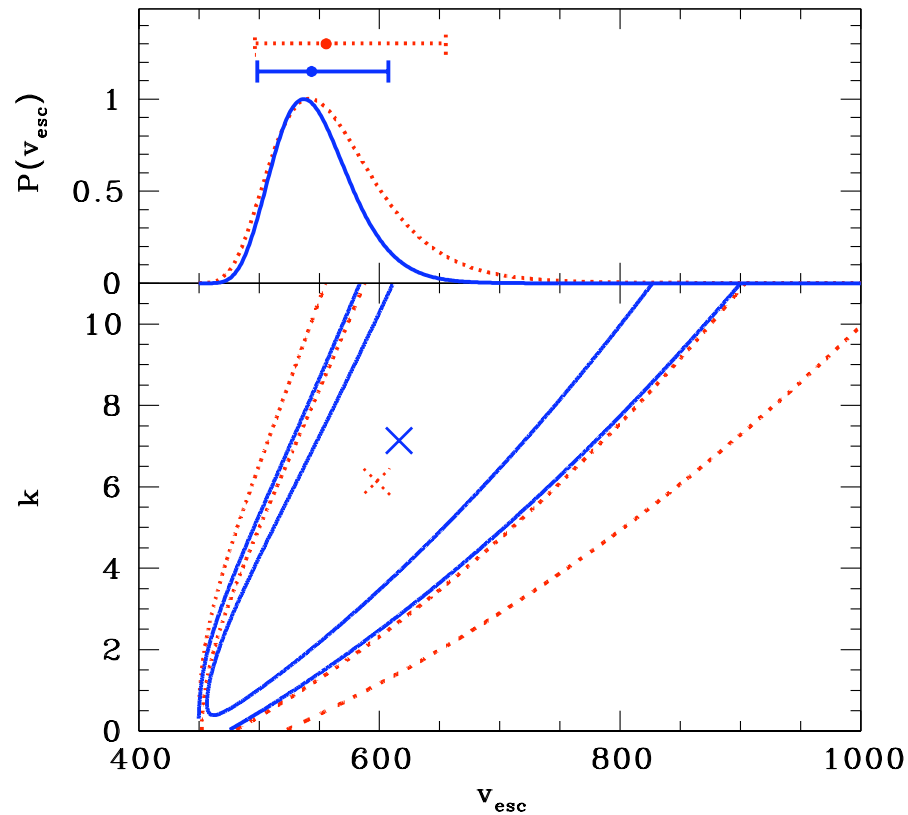


RAVE escape velocity constraints

$$f(|\mathbf{v}|\,|\,v_{\rm esc}, k) \propto (v_{\rm esc} - |\mathbf{v}|)^k, \quad |\mathbf{v}| < v_{\rm esc}$$

$$f(|\mathbf{v}|\,|\,v_{\rm esc}, k) = 0, \quad |\mathbf{v}| \geqslant v_{\rm esc},$$





Escape Velocity

Smith et al.,

Mon.Not.Roy.Astron.Soc.379:755-772,2007

Algorithm

Generate los velocity data sets and analyze with spherical jeans equation

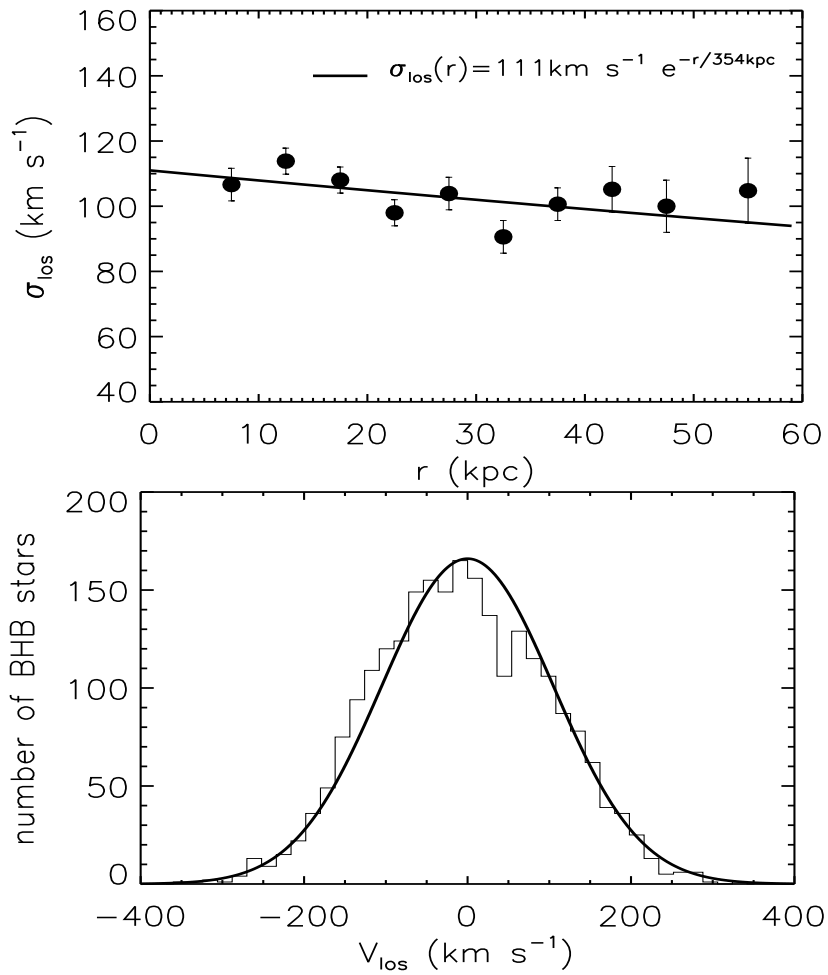
MW potential given by bulge, (spherical) disk, and halo components

Free parameters:
1) Bulge scalelength
2) Velocity anisotropy of stars
3) 5 parameter DM halo model

$$\rho(r) = \frac{\rho_0}{(r/r_0)^a[1+(r/r_0)^b]^{(c-a)/b}}$$

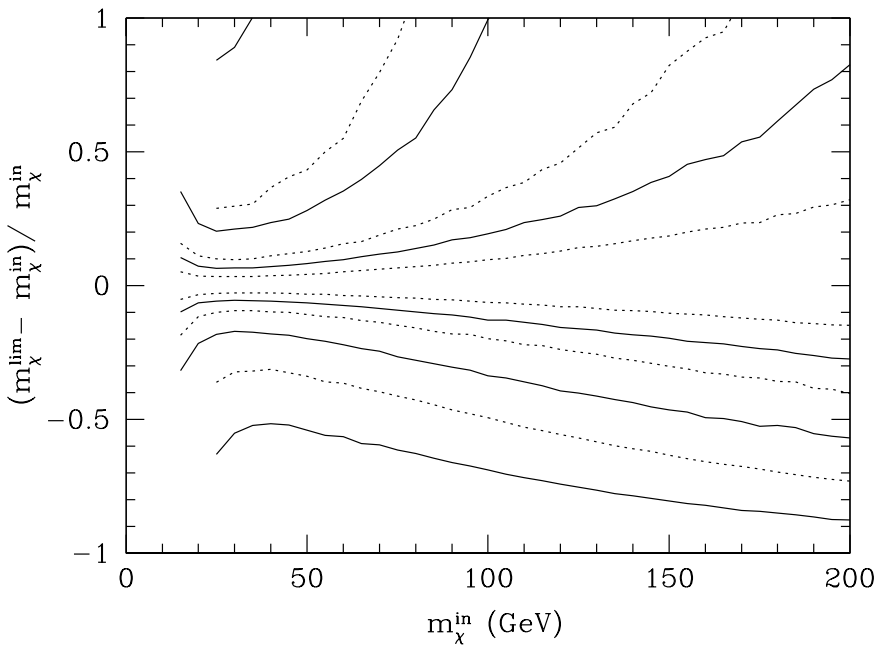
$$\phi_{\rm disk} = -GM_{\rm disk}(1-e^{-b_{\rm disk}/r})/r$$

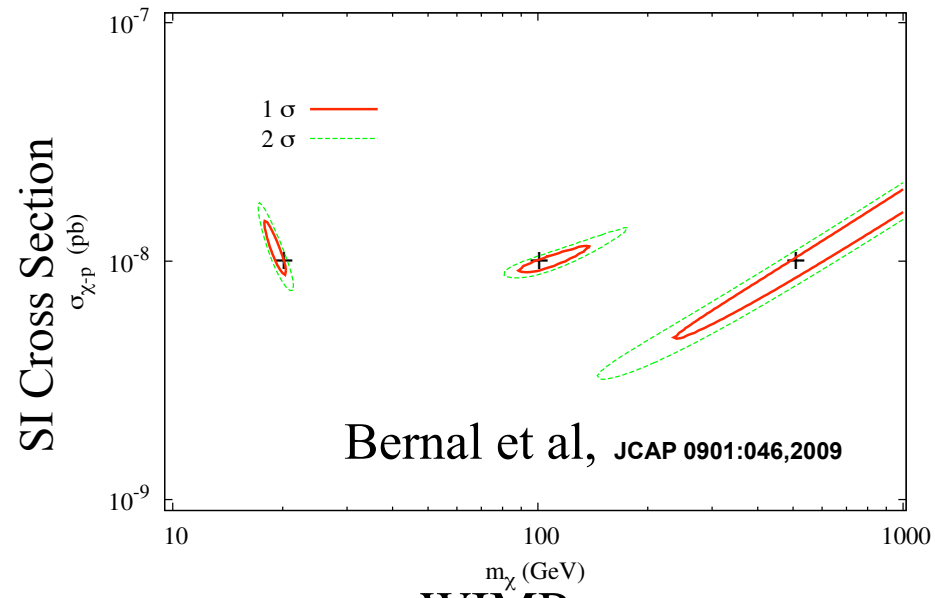
Xue et al., 2008



Metropolis-hastings method determines parameters, subject to escape velocity constraints

Constraining WIMP mass





WIMP mass

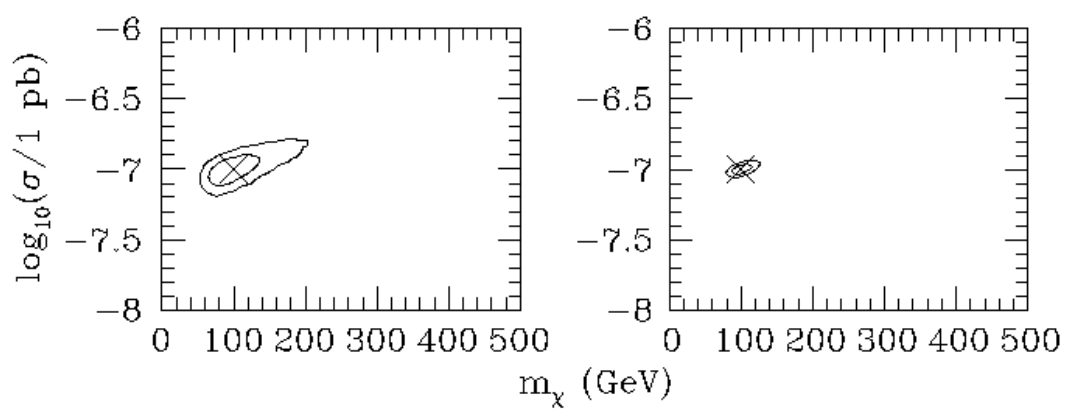
Variable but fixed circular velocity

10^3-10^5 kg/day exposure for Ge

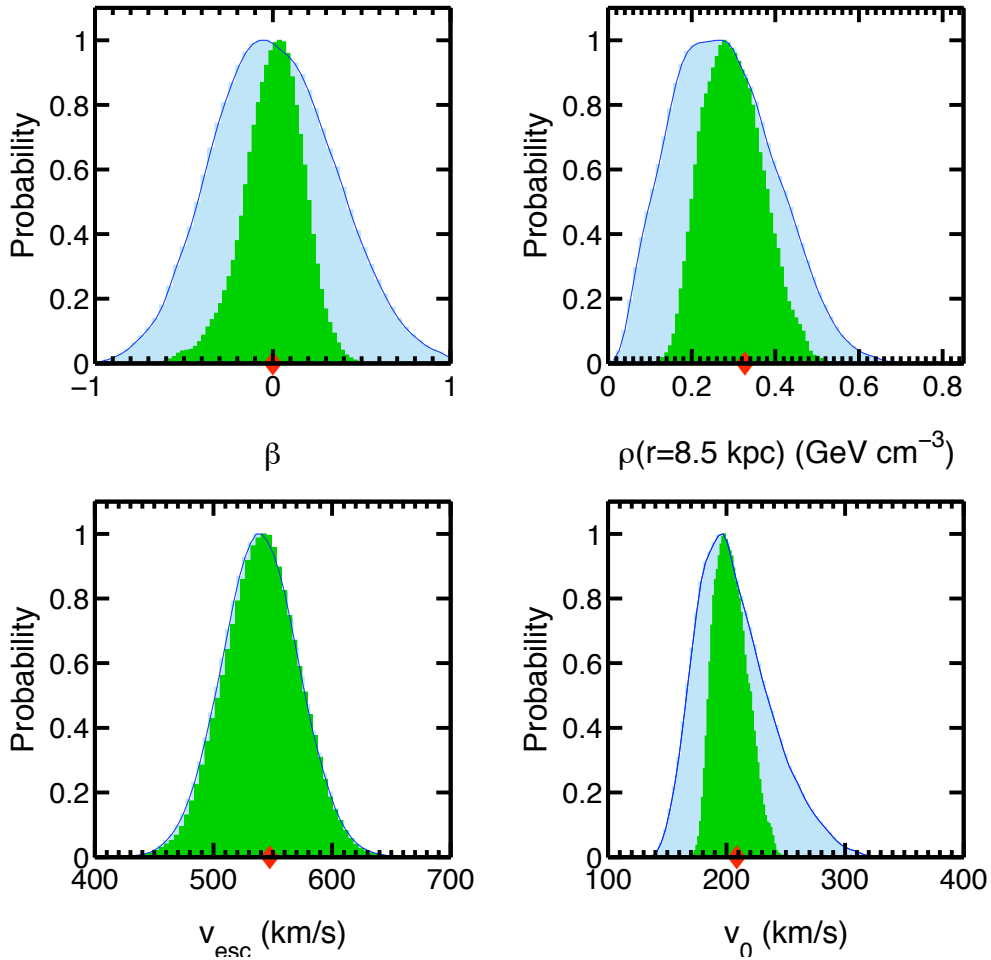
Low mass WIMPs more strongly constrained

Anne Green, **JCAP 0807:005,2008**

Shan, arXiv:0903.4320 [hep-ph]



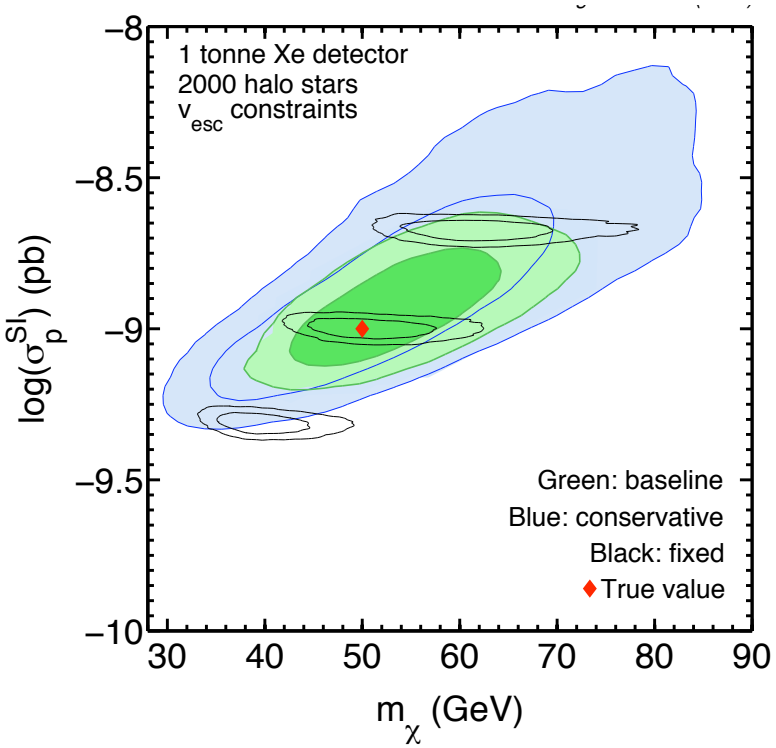
Constraints on Milky Way Halo Parameters

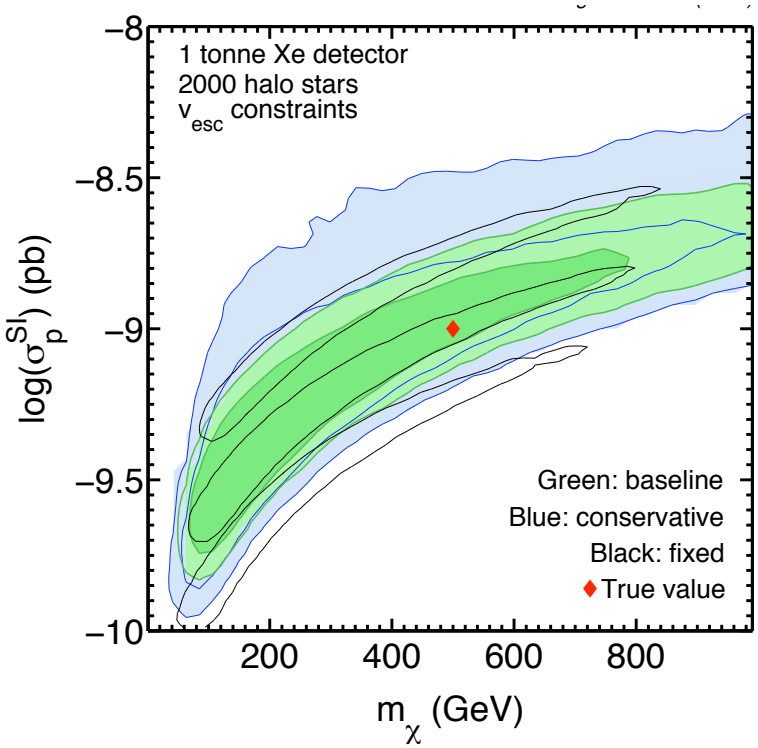


Escape velocity Circular velocity

With 2000 halo stars and local escape velocity data, project about 20% constraint on the (smooth) local dark matter density

Projections for 1 tonne Xe



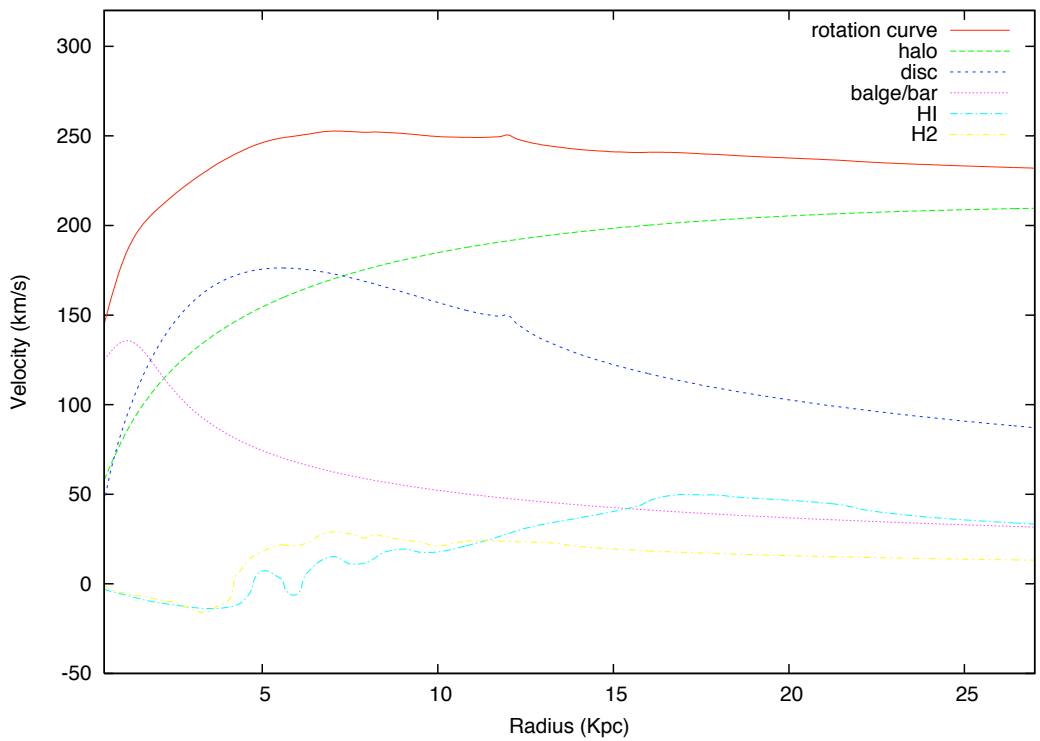


Approx. 300 (100) events for 50 (500) GeV WIMP

Assuming the incorrect local density leads to a 15 (5) sigma bias in the reconstruction for low (high) mass WIMPs

(Strigari & Trotta, **arXiv:0906.5361** [astro-ph.HE] 2009*)*

New Local Density Result



Catena & Ullio 2009

As determined from following data sets:

1) Terminal velocities
2) VBLI high mass SF regions
3) Cepheid PMs from Hipparcos
4) Local surface density
4) BHB stars
5) Satellite dynamics

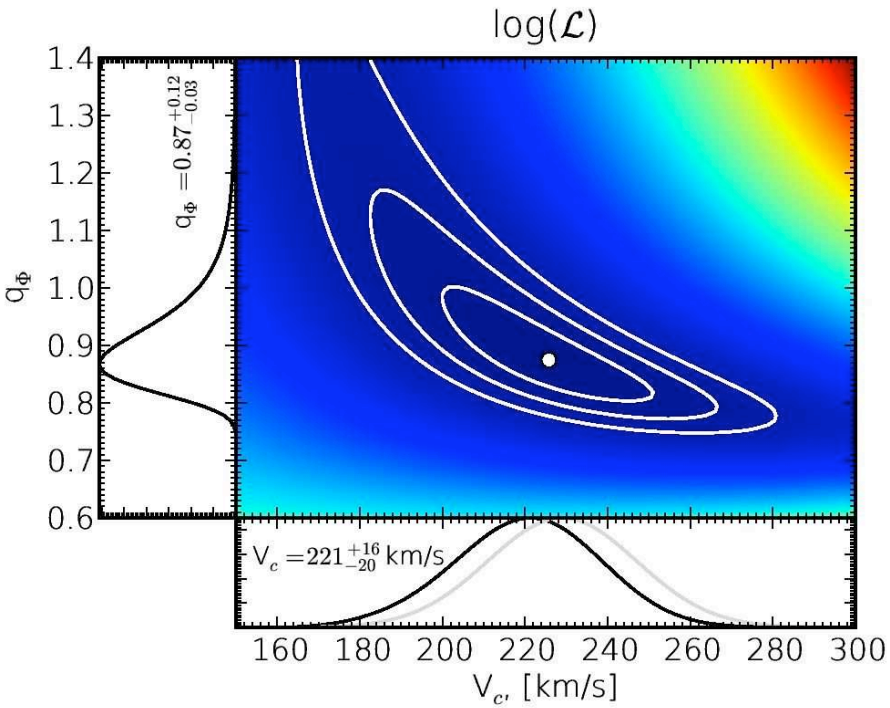
For Einasto profile, local dark matter density is

0.385 +/ 0.027 GeV cm^{-3}

(Similar result for NFW)

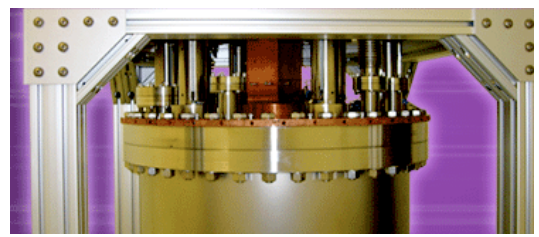
Further improvements

Dark Matter Halo Triaxiality/
Non-maxwellian DF

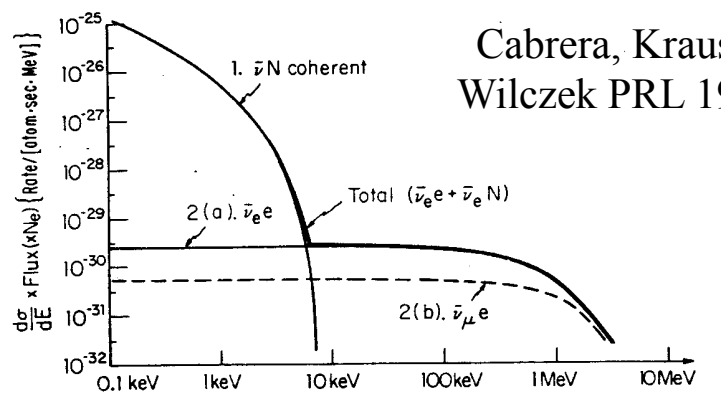


Koposov et al., **arXiv:0907.1085** [astro-ph.GA]

``Complementiarity”

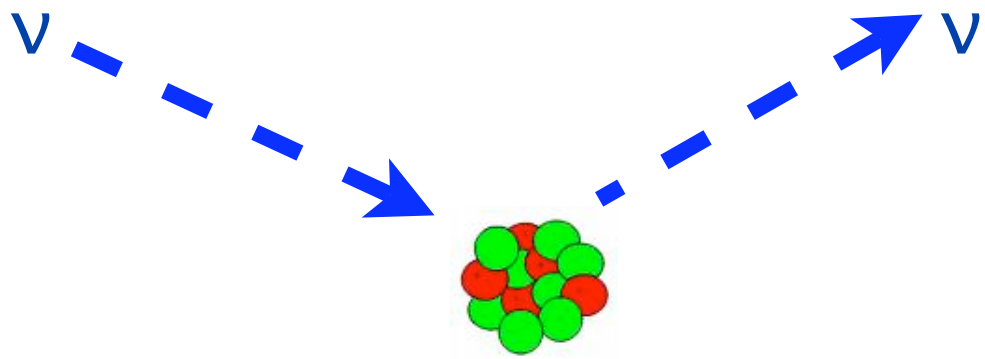


Astrophysical ``backgrounds”



Cabrera, Krauss,
Wilczek PRL 1985

Neutrino Coherent Scattering



Cross Section: $\sigma \sim G_f^2 \, Q_w^2 \, E_\nu^2 \, F(Q^2)^2$

Weak charge: $Q_w^2 = N - (1 - 4\sin^2 \theta_w)Z$

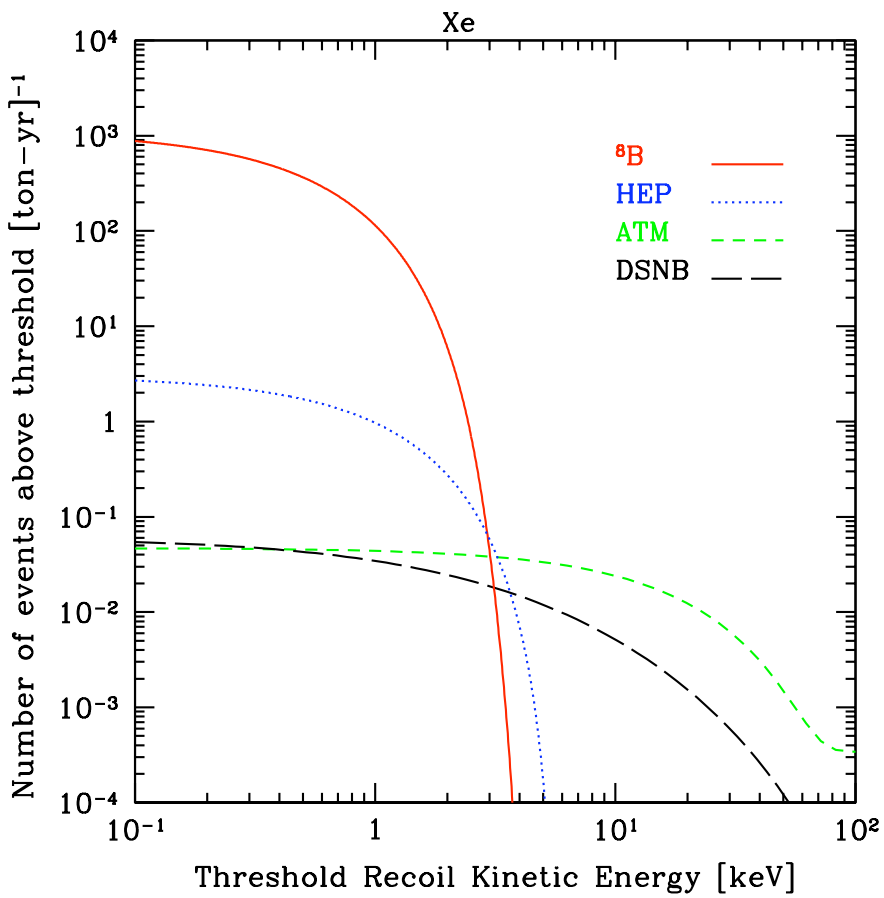
Coherence condition: [three-momentum] x [nuclear radius] ≤ 1

Implies sensitivity to neutrinos ~ 10 MeV

Fundamental prediction of the Standard Model, but not yet detected

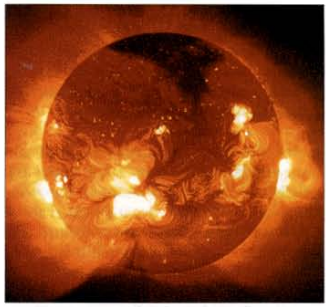
Freedman 1974 PRD, Tubbs & Schramm 1975

Neutrino Backgrounds/Signals



Monroe and Fisher PRD 2008
Strigari, NJP 2009

Solar Neutrinos



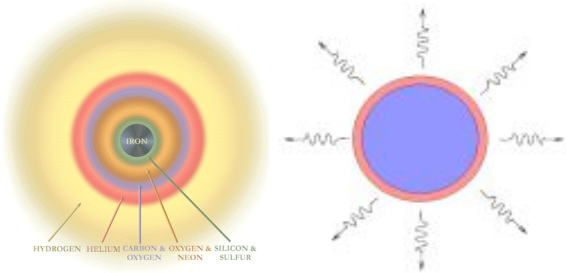
$$\pi^{\pm} \rightarrow \quad \mu^{\pm} \quad + \nu_{\mu}(\overline{\nu}_{\mu})$$

$$\searrow$$

ATM Neutrinos

$$e^{\pm} + \nu_e(\overline{\nu}_e) + \overline{\nu}_{\mu}(\nu_{\mu})$$

SN Neutrinos



Conclusions

- Present and future confluence of astronomical/ underground data
- Incorporating all data sets important for interpreting WIMP detections/limits
- In the (bad news) of lack of WIMP signal, interesting neutrino signals are observable