Closing in on the velocity distribution of Dark Matter with direct detection and neutrino telescopes

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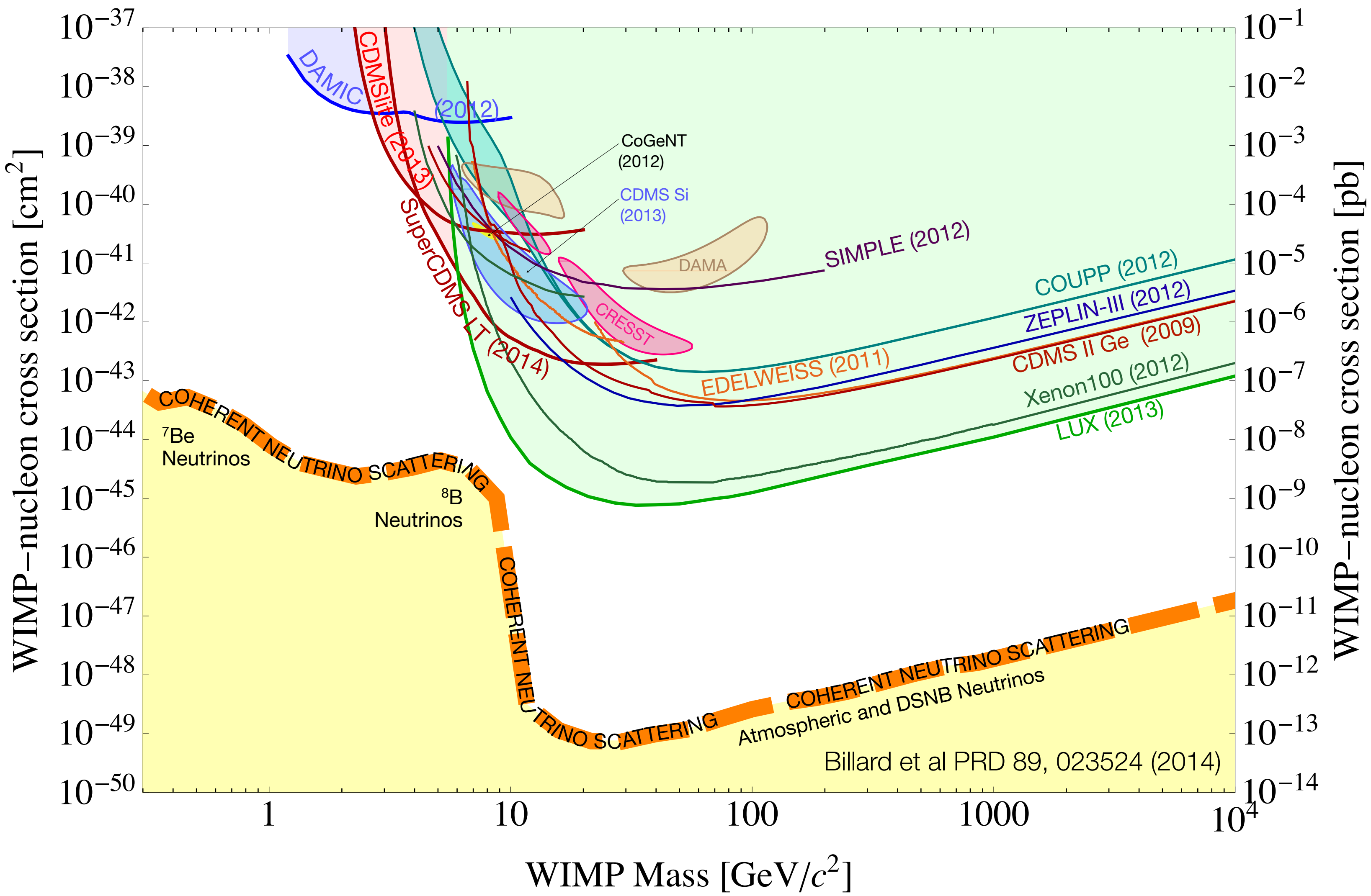


Speed distribution *f*(*v*)

$$\frac{\mathrm{d}R}{\mathrm{d}E_R} = \frac{\rho_0}{m_\chi m_\mathrm{N}} \int_{v_\mathrm{min}}^{\infty} v f_1(v) \frac{\mathrm{d}\sigma}{\mathrm{d}E_\mathrm{R}}\,\mathrm{d}v$$

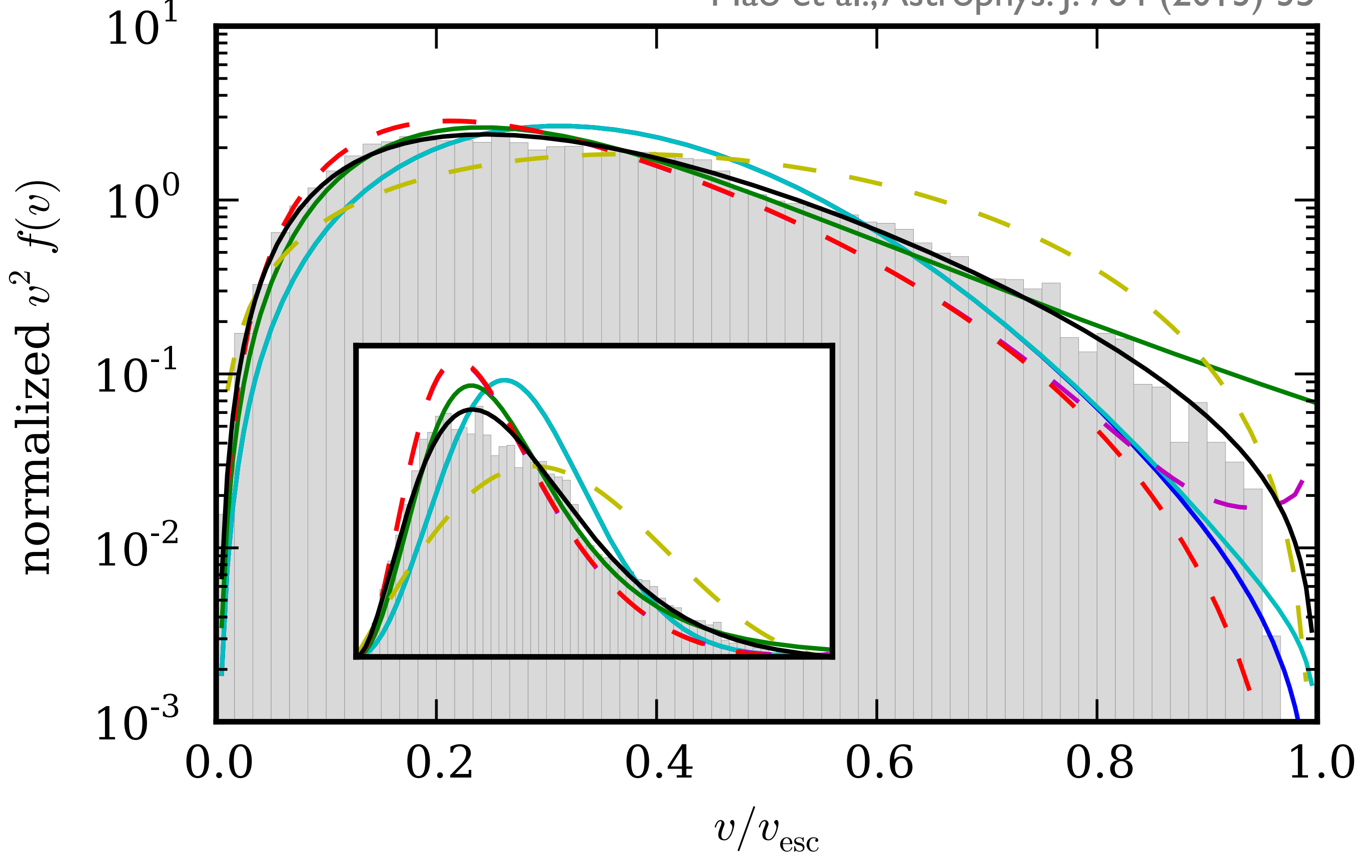
$$v_\mathrm{min} = \sqrt{\frac{m_\mathrm{N} E_\mathrm{R}}{2\mu_{\chi\mathrm{N}}^2}}$$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}E_\mathrm{R}} = \frac{\mathrm{d}\sigma_\mathrm{SD}}{\mathrm{d}E_\mathrm{R}} + \frac{\mathrm{d}\sigma_\mathrm{SI}}{\mathrm{d}E_\mathrm{R}}$$

$$\eta(v_\mathrm{min}) = \int_{v_\mathrm{min}}^{\infty} \frac{f_1(v)}{v}\,\mathrm{d}v$$

- Several **theoretical models** are available for *f*(*v*)
- **Standard Halo Model** (SHM) is the most widely used
- *f*(*v*) can also be derived from *N*-body simulations

Mao et al., Astrophys. J. 764 (2013) 35

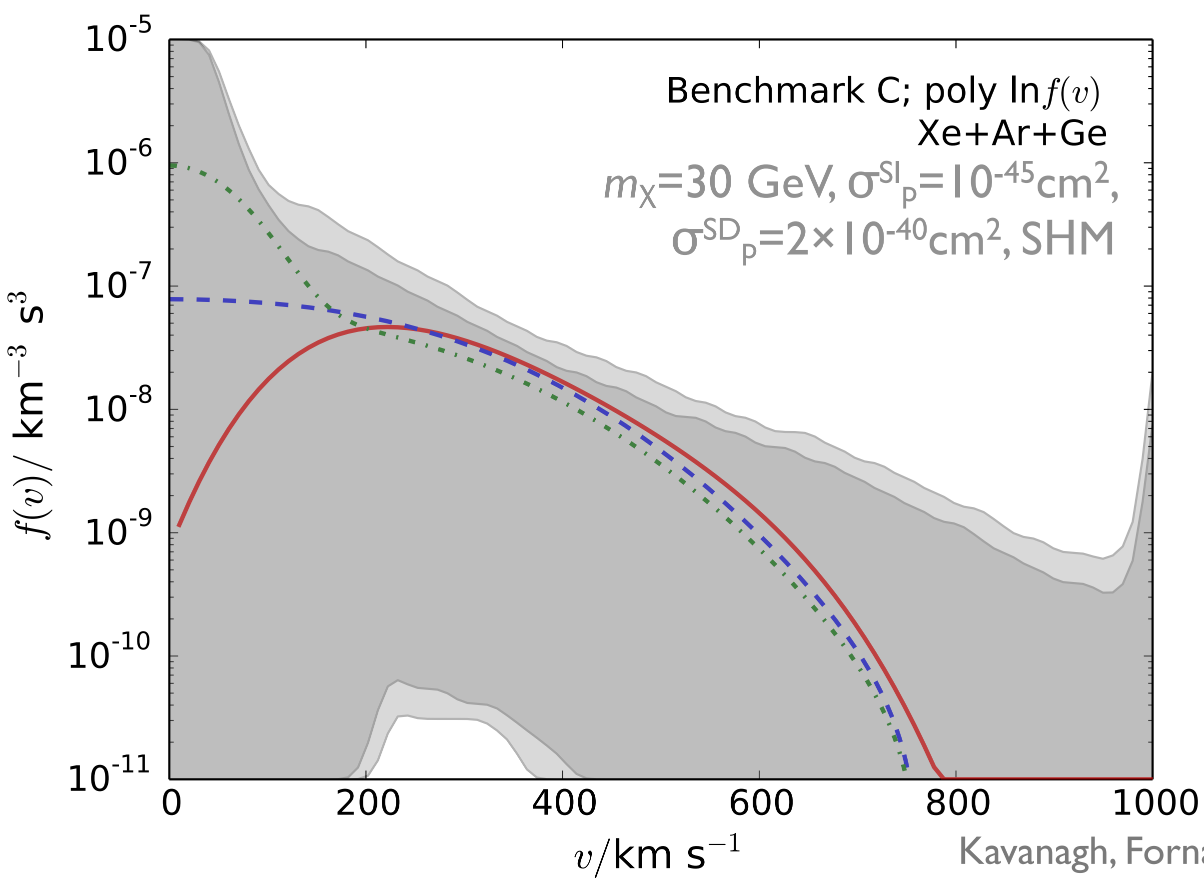


Determining *f*(*v*) with direct detection

Express *f*(*v*) in terms of a **handful of parameters** and, **assuming data** from a set of future direct detection experiments, **determine** them alongside m_χ, σ^{SI}_p and σ^{SD}_p

Polynomial parametrisation

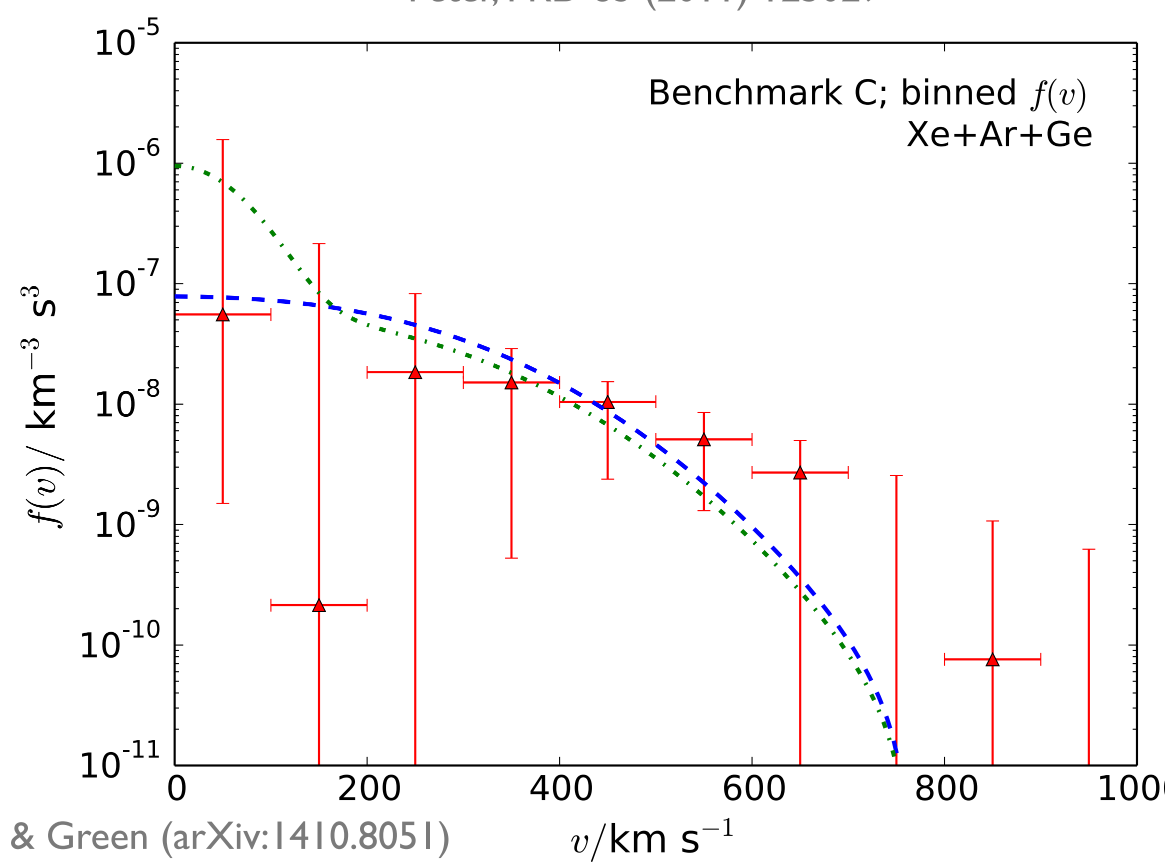
$$f(v) = \exp\left[\sum_{k=0}^{N-1} a_k P_k(2v/v_{\max} - 1)\right]$$



Binned parametrisation

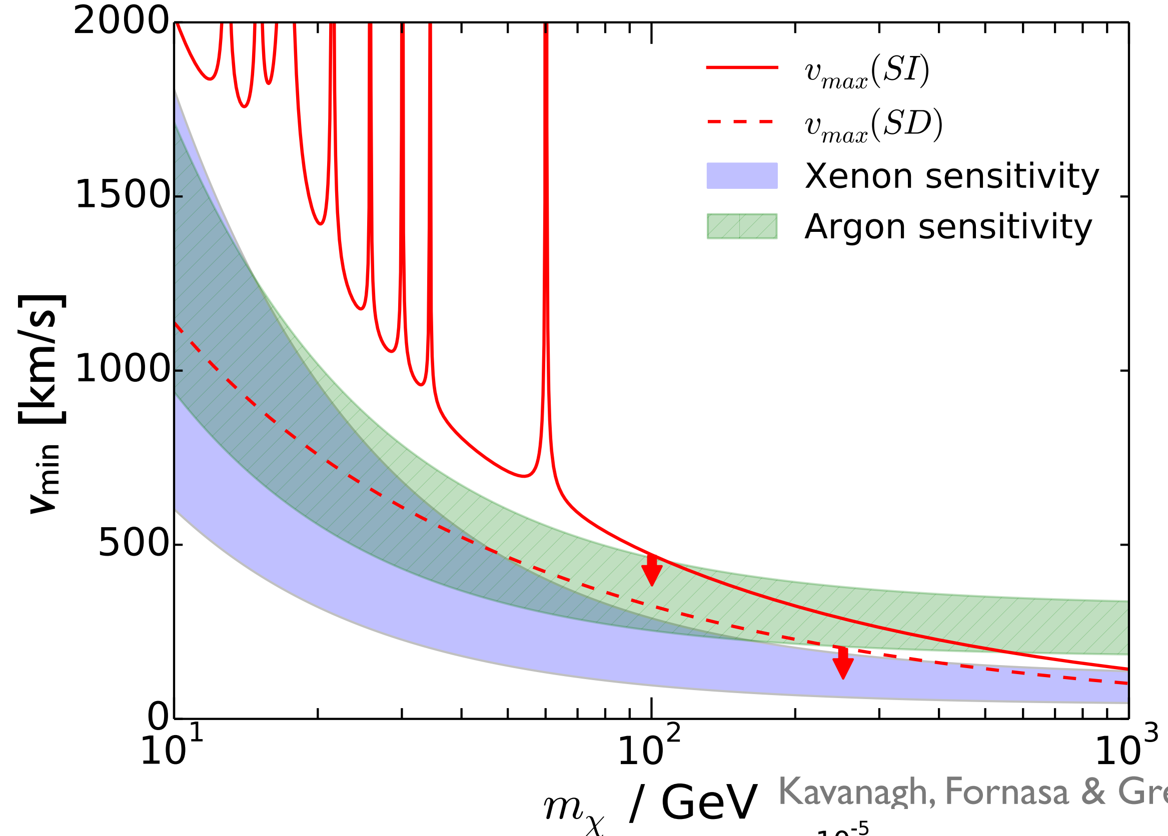
$$f(v) = \sum_{i=1}^{N} \frac{3g_i\, W(v;\tilde{v}_i,\Delta v)}{(\tilde{v}_i+\Delta v)^3 - \tilde{v}_i^3}$$

Peter, PRD 83 (2011) 125029

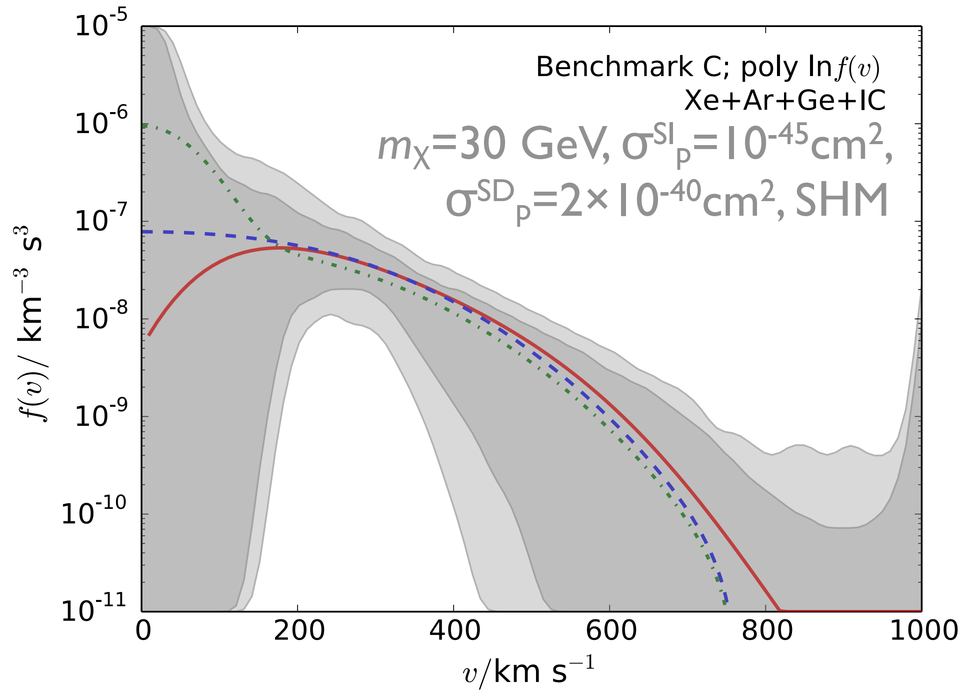


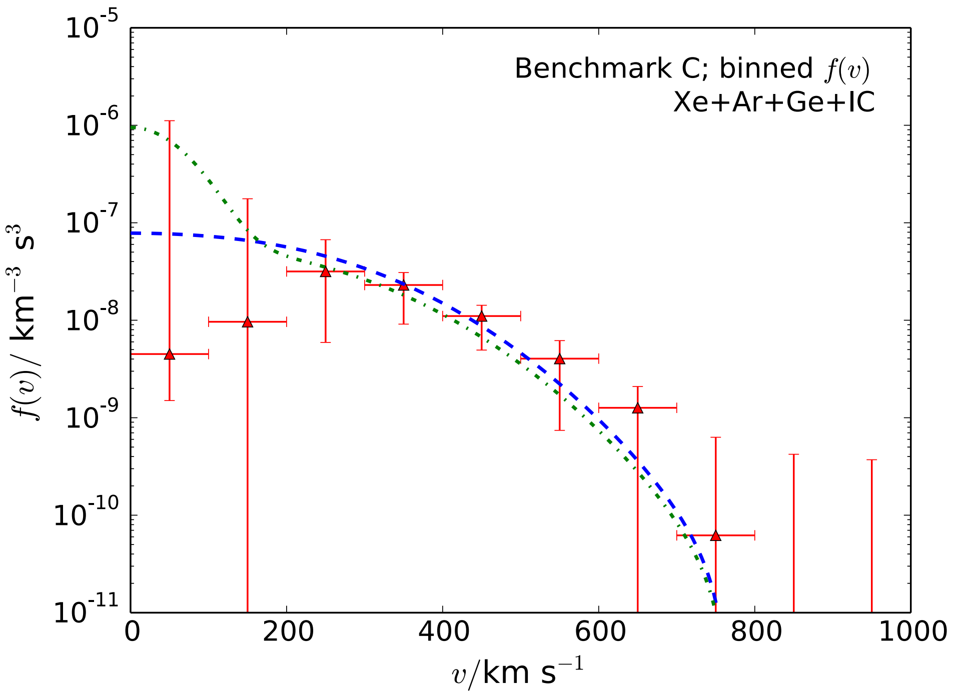
Kavanagh, Fornasa & Green (arXiv:1410.8051)

The challenge of the low-speed tail



Kavanagh, Fornasa & Green (arXiv:1410.8051)

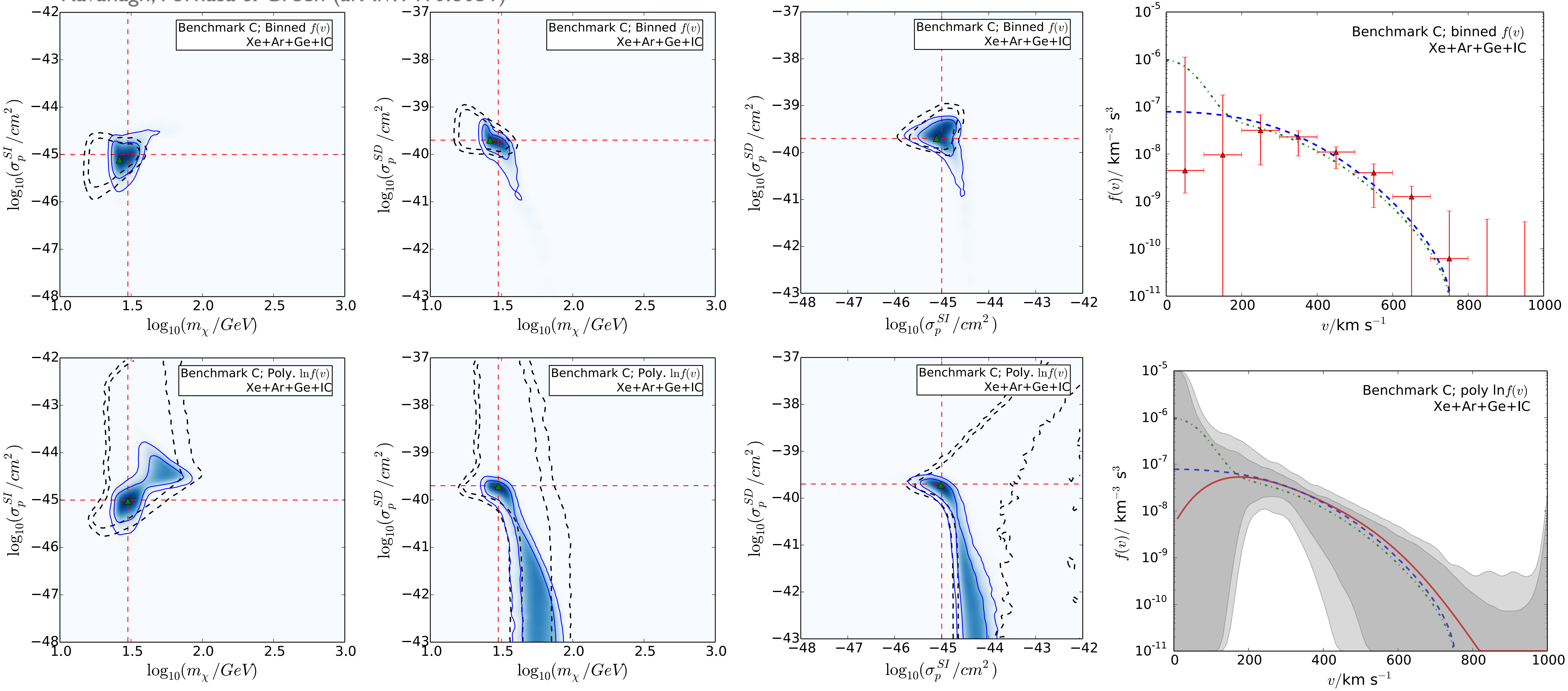




m_χ=30 GeV, $\sigma^{SI}_p=10^{-45}cm^2$, $\sigma^{SD}_p=2\times10^{-40}cm^2$, SHM

Binned parametrisation

Kavanagh, Fornasa & Green (arXiv:1410.8051)

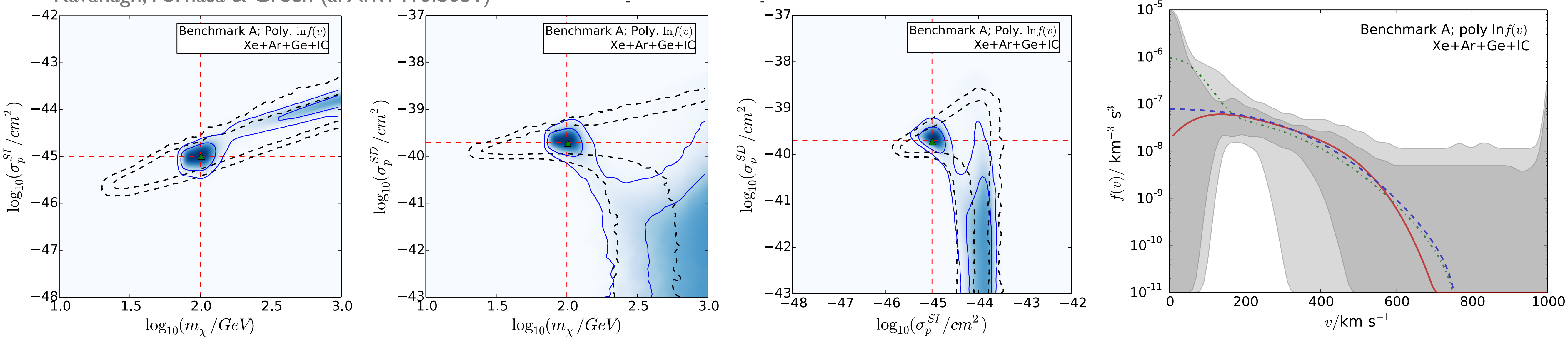


Polynomial parametrisation

$m_\chi = 100$ GeV, $\sigma^{SI}_p = 10^{-45}\,\mathrm{cm}^2$, $\sigma^{SD}_p = 2\times10^{-40}\,\mathrm{cm}^2$, SHM

Kavanagh, Fornasa & Green (arXiv:1410.8051)

Polynomial parametrisation



- A DM signal from neutrino telescope gives sensitivity to the **low-speed tail** of *f*(*v*)
- Achieve a reconstruction of *f*(*v*) with an uncertainty of a **factor 10 (3)** for polynomial (binned) parametrisation over a **range 200-300 km/s wide**
- Binned par. cannot be used with direct detection only (**solved** by IceCube data)
- Polynomial par. leads to very large uncertainties (**solved** by IceCube data)
- **Flexibility** of the polynomial parametrisation corresponds to **more degeneracy**