Walker et al. (2011), ApJL, 733, 46
Charbonnier et al. (2011), arXiv:1104.0412

University of Leicester

Dark matter annihilation in the Galaxy:

Gamma-rays from dwarf spheroidal galaxies

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Matt Walker (CfA, Cambridge, USA)
+ others...

Workshop on indirect DM searches, DESY, 14 June 2011

Gamma-ray flux from DM annihilation

The γ-ray flux is given by

$$\frac{d\Phi}{dE}(E,\phi,\theta,\Delta\Omega) = \frac{d\Phi^{\rm pp}}{dE}(E) \times \Phi^{\rm astro}(\phi,\theta,\Delta\Omega)$$

Particle physics

Astrophysics

Weakly Interacting Massive Particles

m_{WIMP} ~ 100 GeV – 100 TeV

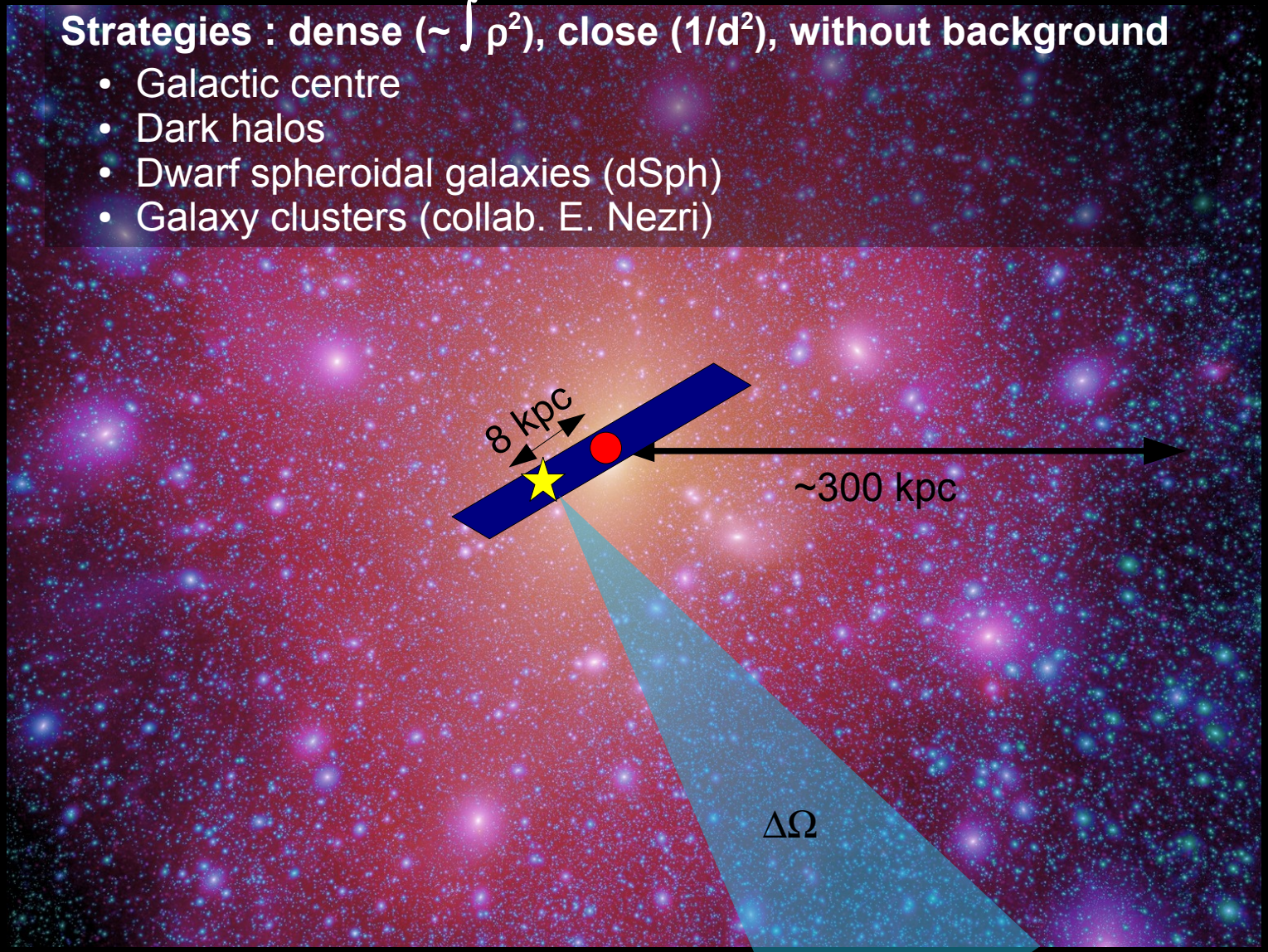
$$\frac{d\Phi^{\rm pp}}{dE} = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m^2_{\rm WIMP}} \cdot \sum_f \frac{dN^f}{dE} B_f$$

$$\text{J} \equiv \Phi^{\rm astro} = \int_{\Delta\Omega}\int_0^{l_{\rm max}} \rho^2(l,\Omega)\, dl\, d\Omega$$

Detection or non-detection
→ Need J to put any constraints on DM candidate

MW's dark matter halo

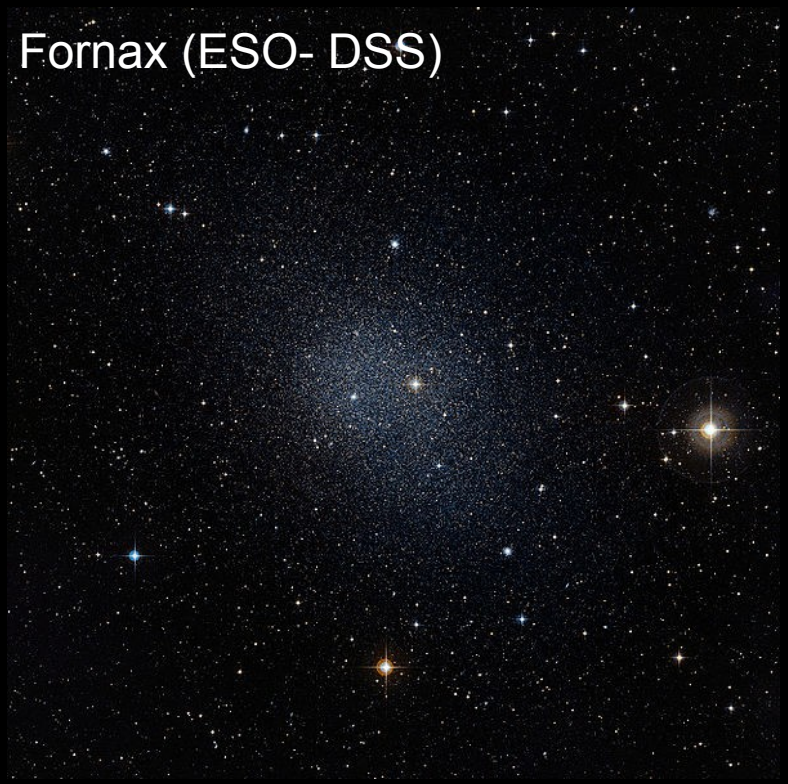
Aquarius – Springel et al (2008) – MW-like halo - ΛCDM

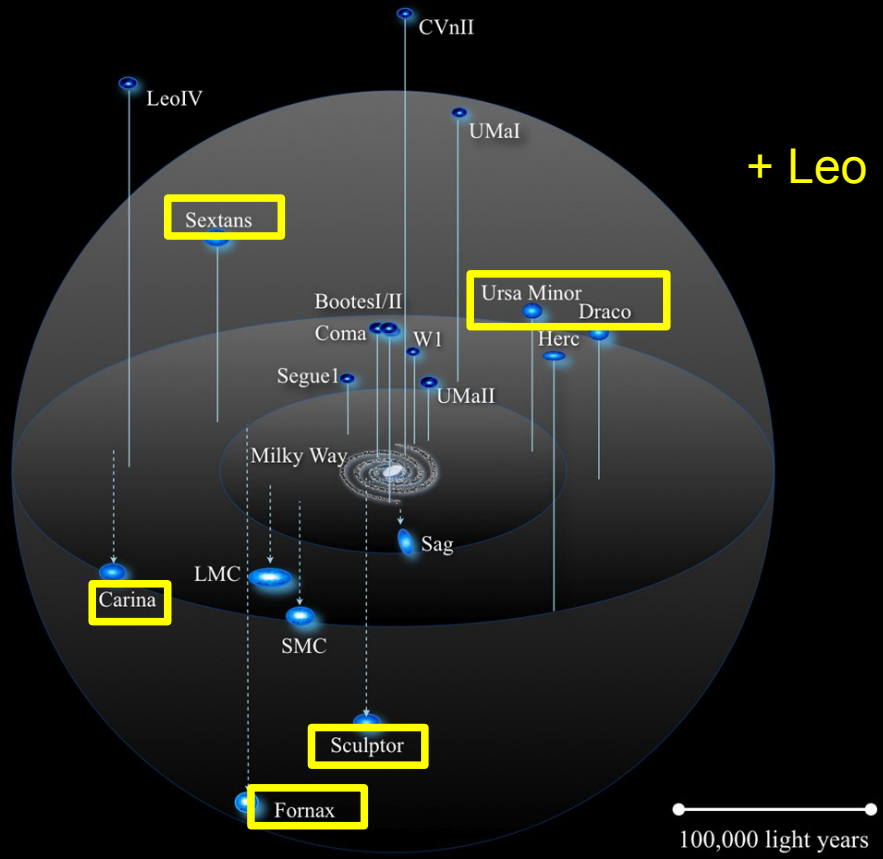


Dwarf spheroidal galaxies

DM dominated + no astro. sources → good alternative to the galactic centre

- 8 ”classical” dSphs (before SDSS, 2005)
- Brightest satellites → more kinematical data





+ Leo I & II

Image Credit: Bullock, Geha, Powell

Dwarf spheroidal galaxies

DM dominated + no astro. sources → good alternative to the galactic centre

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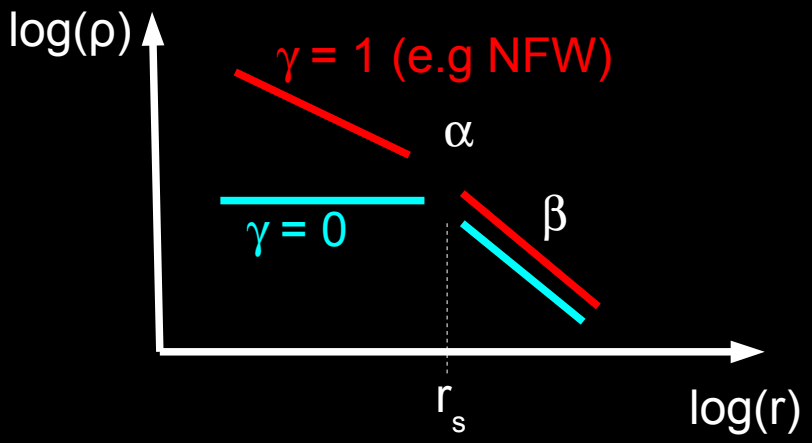
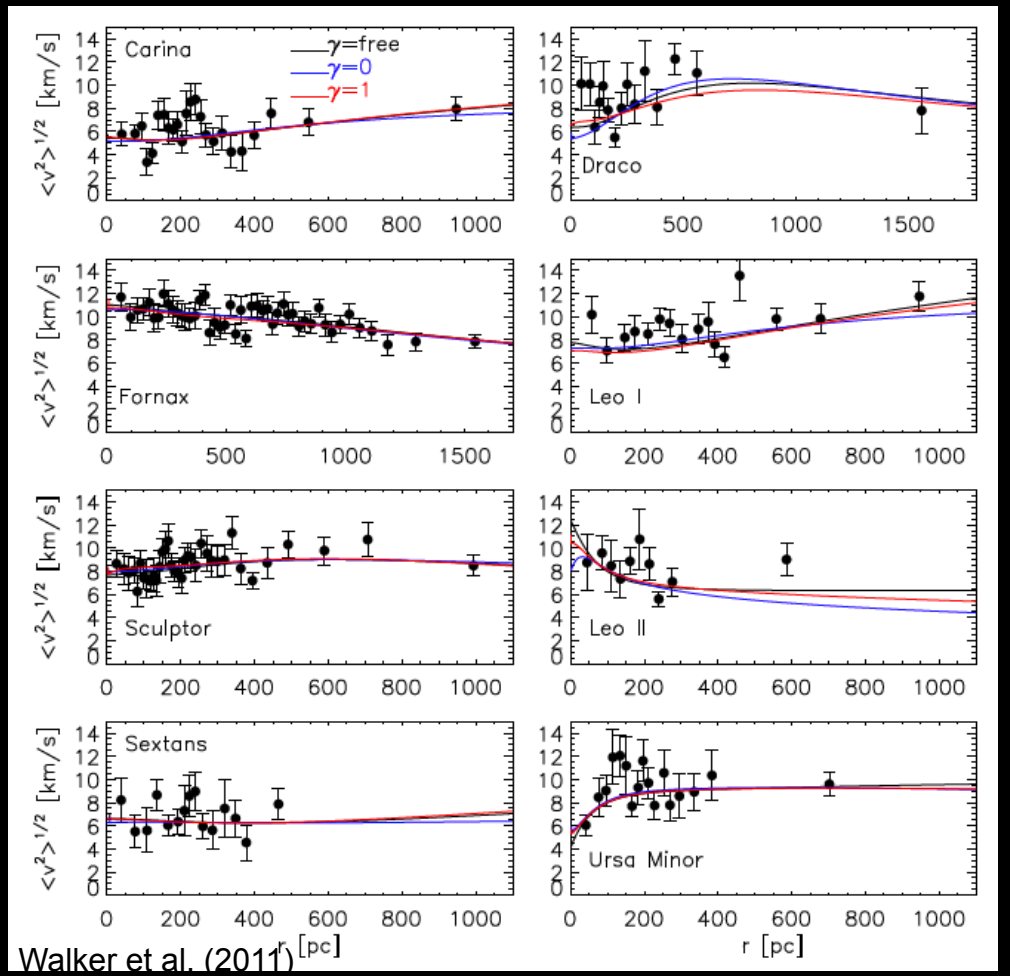
Jeans' method : $\langle v_*^2 \rangle^{1/2} \longrightarrow \rho_{DM}(r)$

$$\rho(r) = \frac{\rho_s}{(r/r_s)^\gamma \cdot [1 + (r/r_s)^\alpha]^{(\beta-\gamma)/\alpha}}$$



$\rho_{DM}(r) \longrightarrow J(\gamma, d, \alpha_{int})$



Walker et al. (2011)

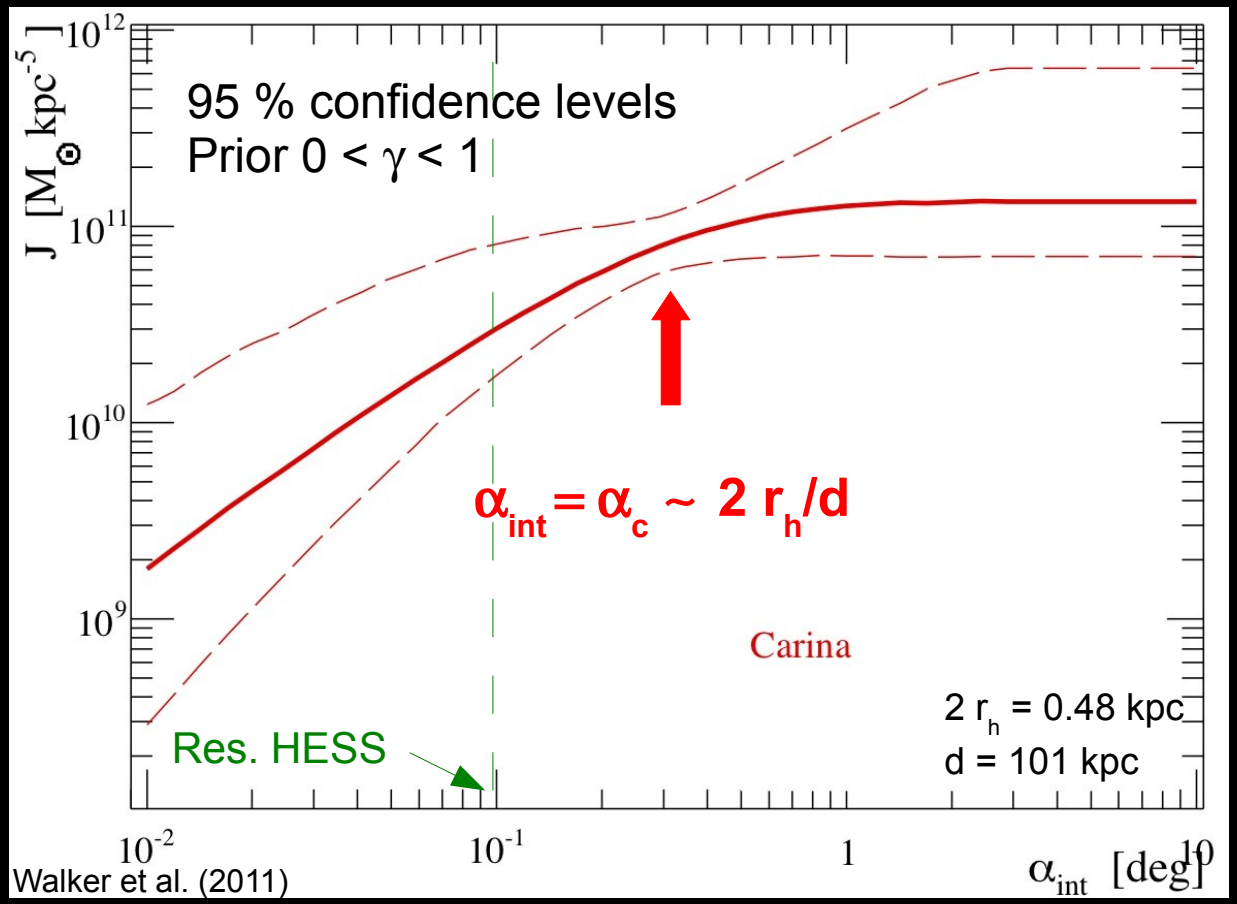
Constraining J in dSph galaxies

MCMC → PDF of all parameters + correlations

$$J = \int_0^{2\pi} d\beta \int_0^{\alpha_{\rm int}} \sin\alpha d\alpha \int_0^{l_{\rm max}} \rho^2 dl d\alpha d\beta$$

→ Median value + confidence levels of J

Thousands of models to run CLUMPY + Alice cluster (+validated using fake data)



Walker et al. (2011)

- Optimal angle for the integration
- α_c > angular resolution

→ Implication on instrumental sensitivity for Cherenkov instr.

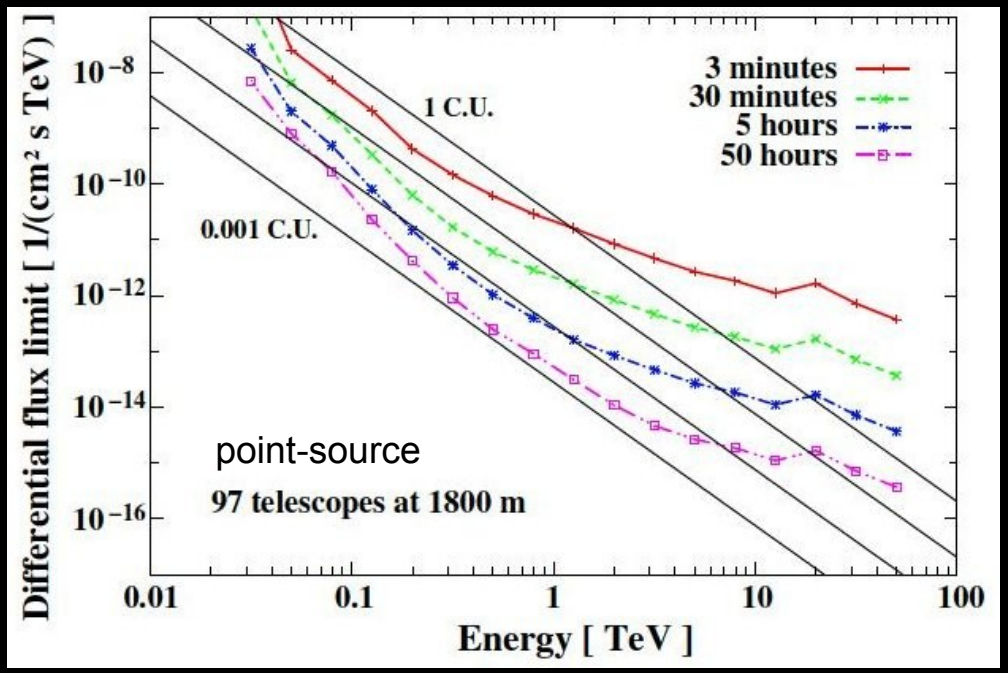
Define the best strategy for (non-)detection in dSphs

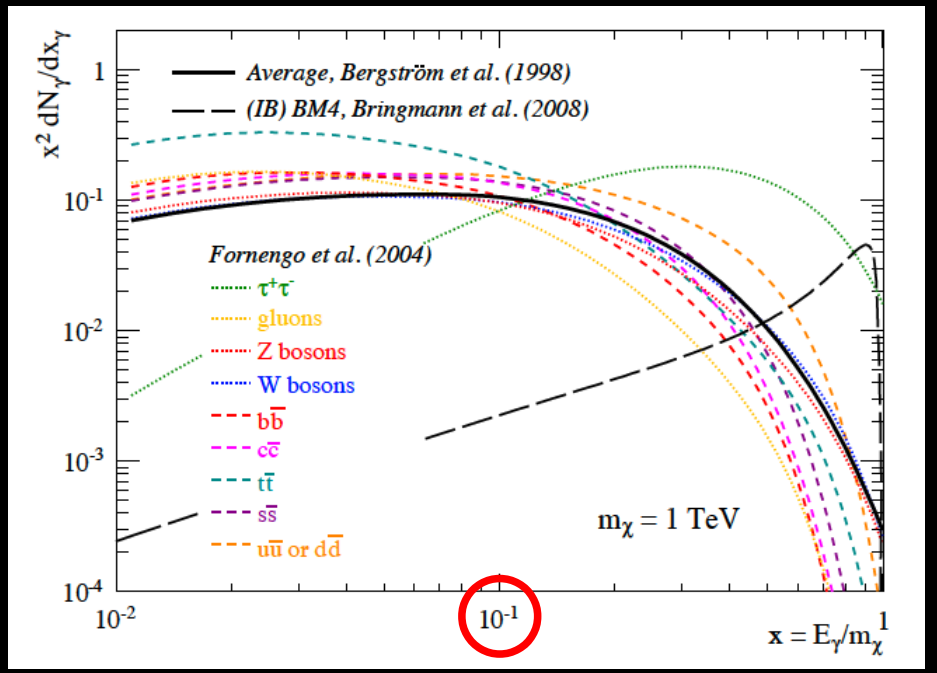
Detectability with CTA

$$\underbrace{\frac{d\Phi}{dE}(E,\alpha_{\rm int})}_{\text{sensitivity}} = \underbrace{J(\alpha_{\rm int})}_{\text{constrained}} \times \frac{d\Phi^{pp}}{dE}(E)$$

$$\frac{d\Phi^{pp}}{dE}(E) = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_\chi^2}\sum_f \frac{dN^f}{dE}B_f$$

SUSY - LSP
Neutralino : “good” WIMP candidate



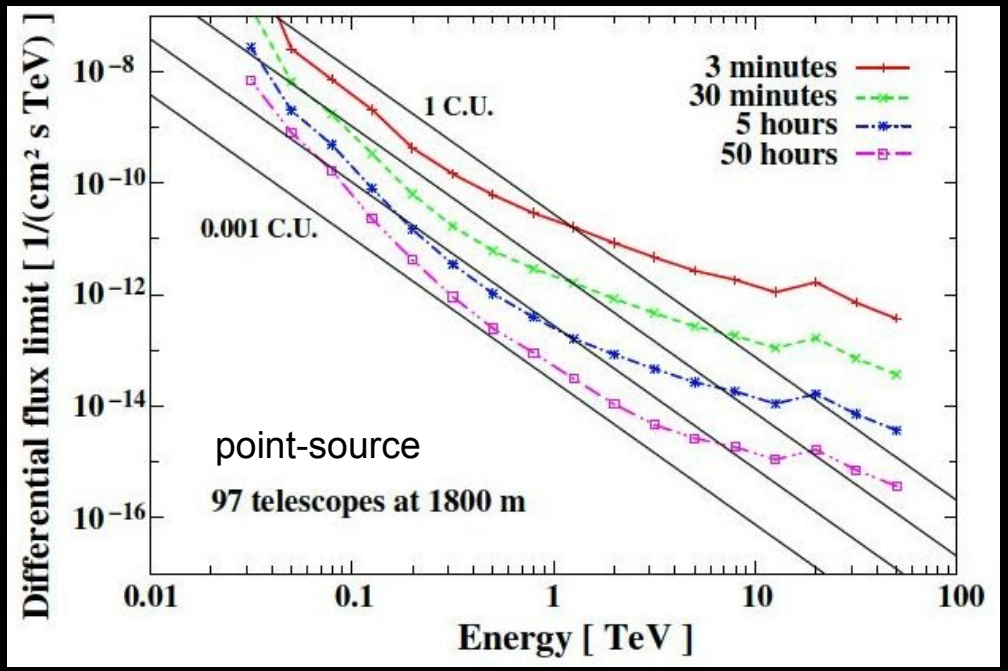


Bernlöhr et al. (2008) – prospection for CTA

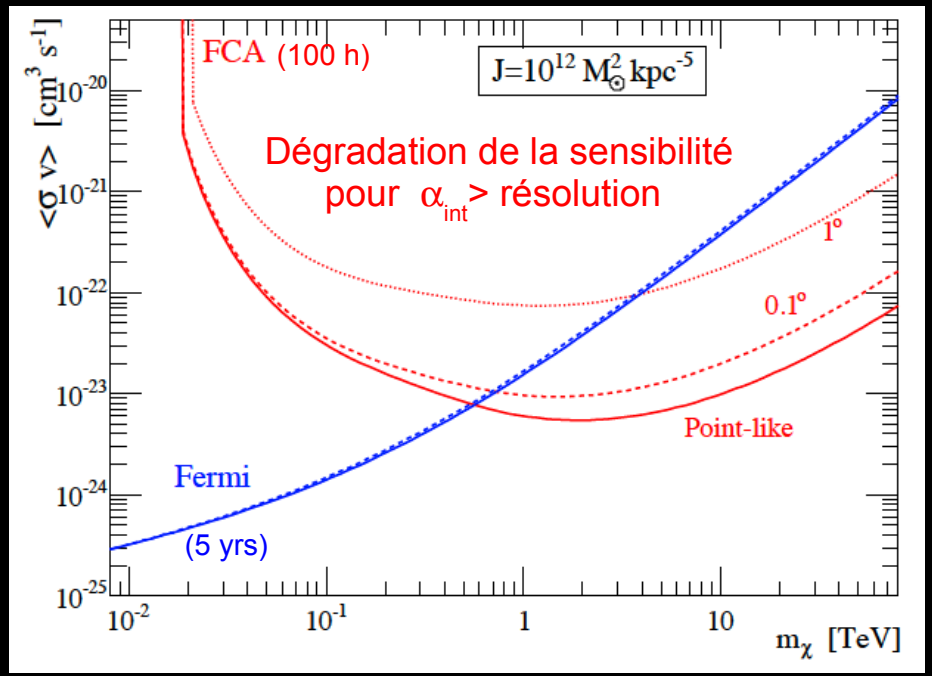
Detectablity with CTA

$$\langle \sigma v \rangle \propto m_\chi^2 \cdot \underbrace{J(\alpha_{\rm int})}_{\text{constrained}} \cdot \underbrace{\mathrm{Sensib}(E, \alpha_{\rm int})}_{\text{Bernlöhr}} \cdot \underbrace{\frac{dN^{pp}}{dE}}_{\text{Bergström}}$$

Finite size effects are important

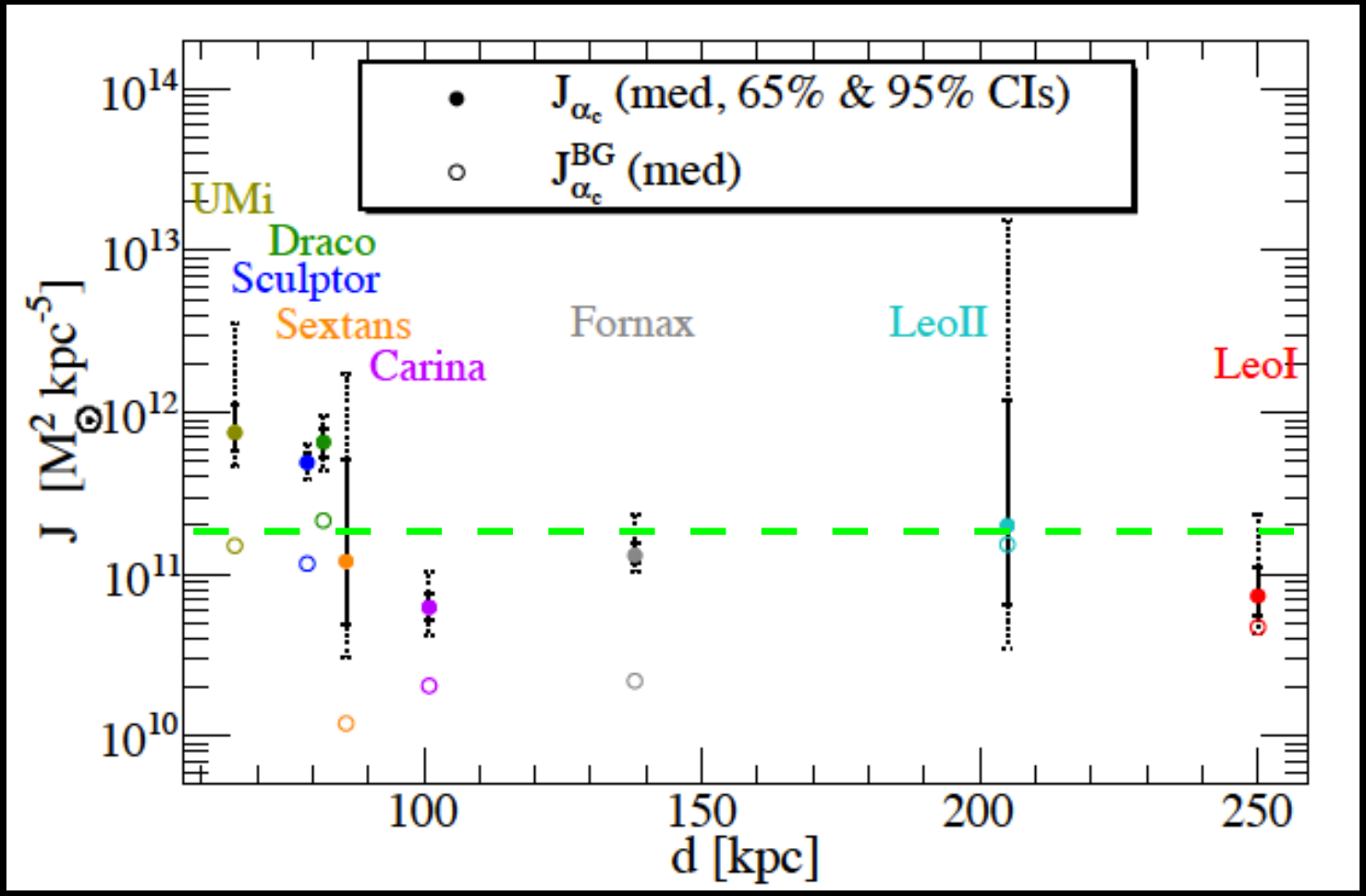


Bernlöhr et al. (2008) – prospection for CTA



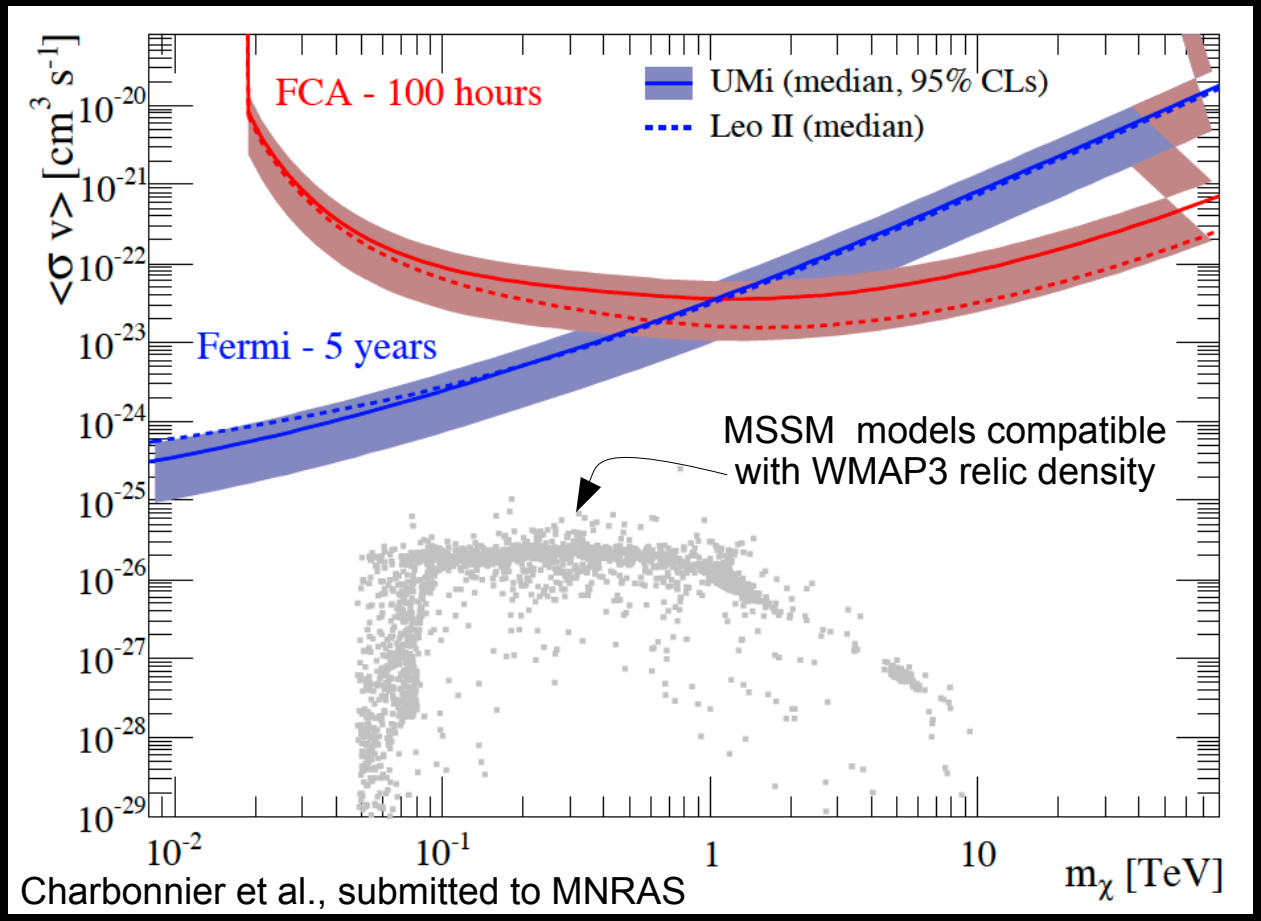
Charbonnier et al., submitted to MNRAS

Ranking



UMi, Sculptor, Draco
+ Leo II (very uncertain)

Conclusions



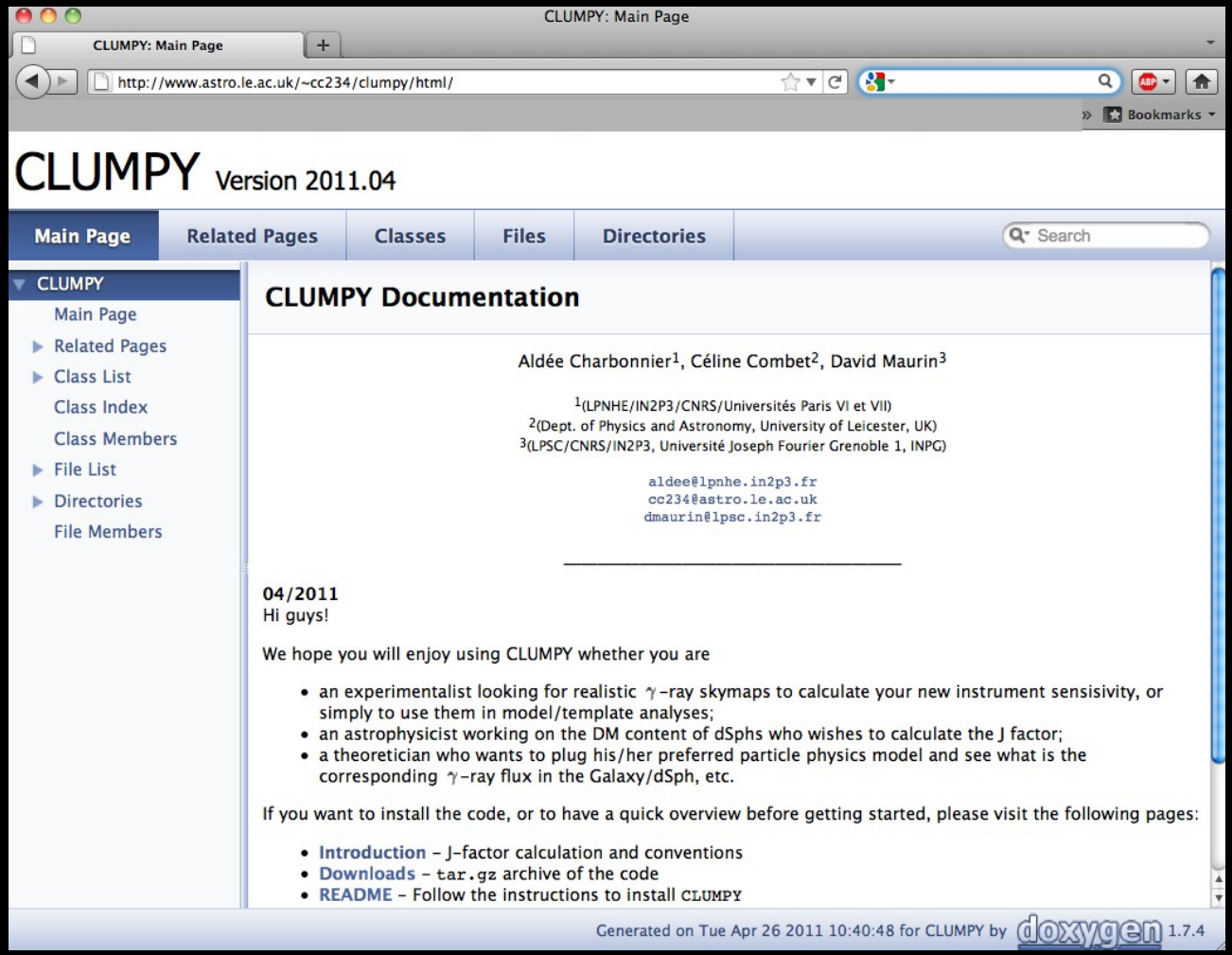
Charbonnier et al., submitted to MNRAS

- Got robust exclusion plots
- Still far from SUSY space
- Classical dSph may not be the best targets
- Pipeline ready for ultra-faint dSph (in progress)
- Galaxy clusters (in progress)

Note:
- Very conservative spectrum
- Does not mean we shouldn't look

CLUMPY

http://www.astro.le.ac.uk/~cc234/clumpy/l



- Public
- C/C++
- Interfaced with ROOT
- Fully documented

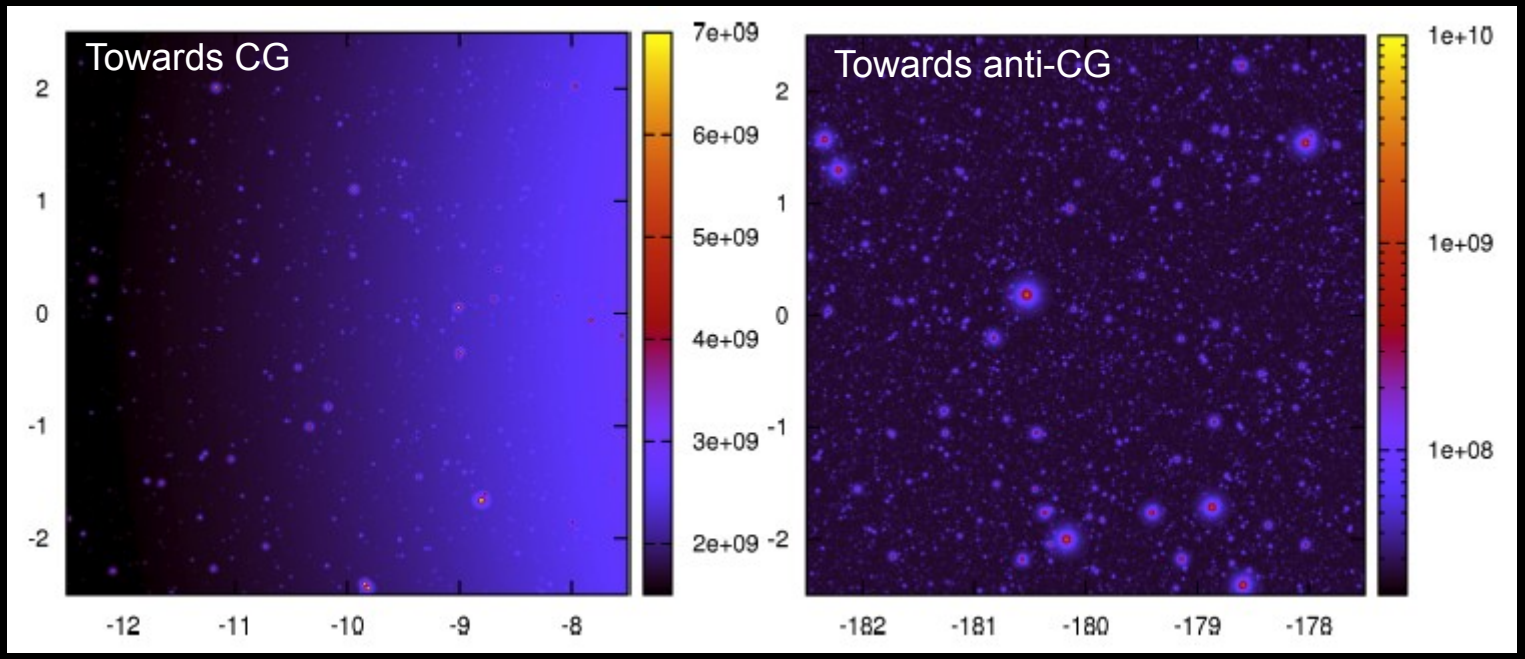
Calculates J in several configurations:

- dSph + statistics
- Skymaps:

  smooth + sub-structures

Charbonnier, Combet, Maurin, submitted to Comp. Phys. Comm.

C LUMPY's skymaps



- Fast
- "Scan" parameter space
  → Dark clumps
  → prospect for CTA

dSphs maps