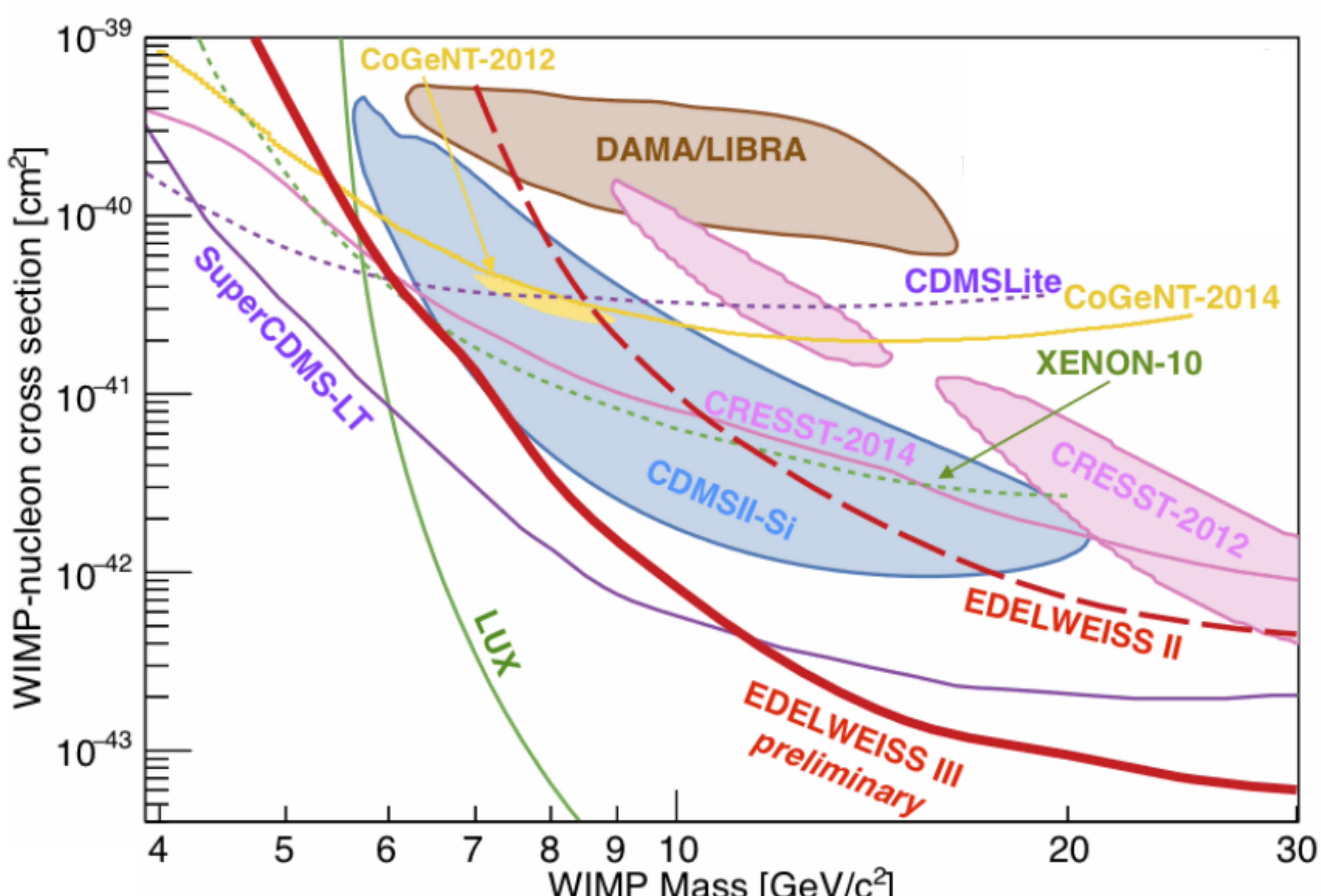
Low mass WIMP situation



Billard, UCLA Dark Matter 2016

Low mass WIMP situation

- Hints incompatible with null results. Take into account **uncertainties** in the results:
  - Compatibility could not be improved by astrophysics independent methods, or using velocity distributions extracted from simulations.
  - Consider various particle physics models? Haven't yet found a model to explain all signals…
- Possible issues: signal close to threshold, backgrounds hard to understand
- Maybe more models need to be explored? Can more data (e.g. from other NaI experiments) clarify the situation?

How Can We Better Constrain Feedback?

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?

?

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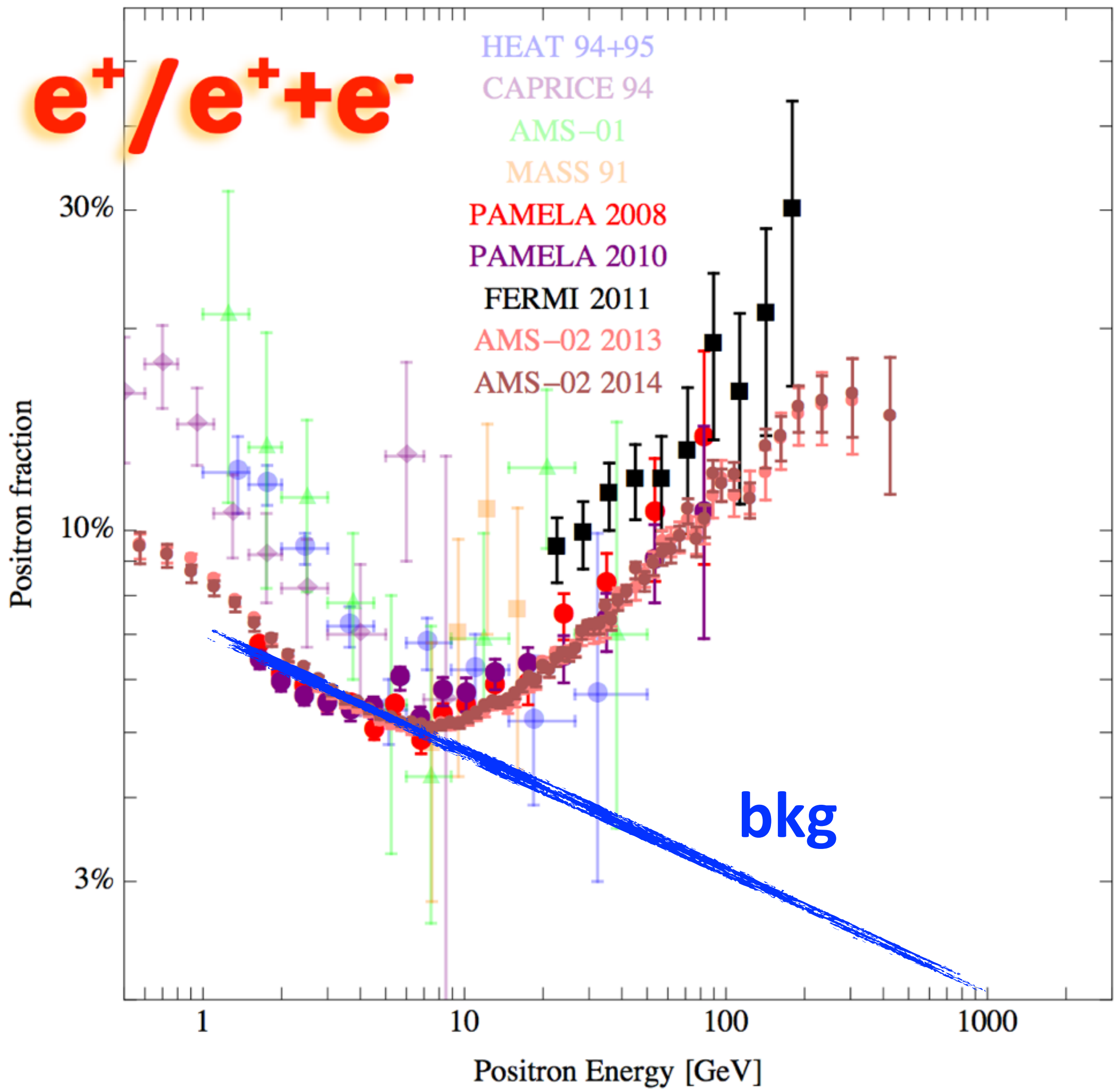
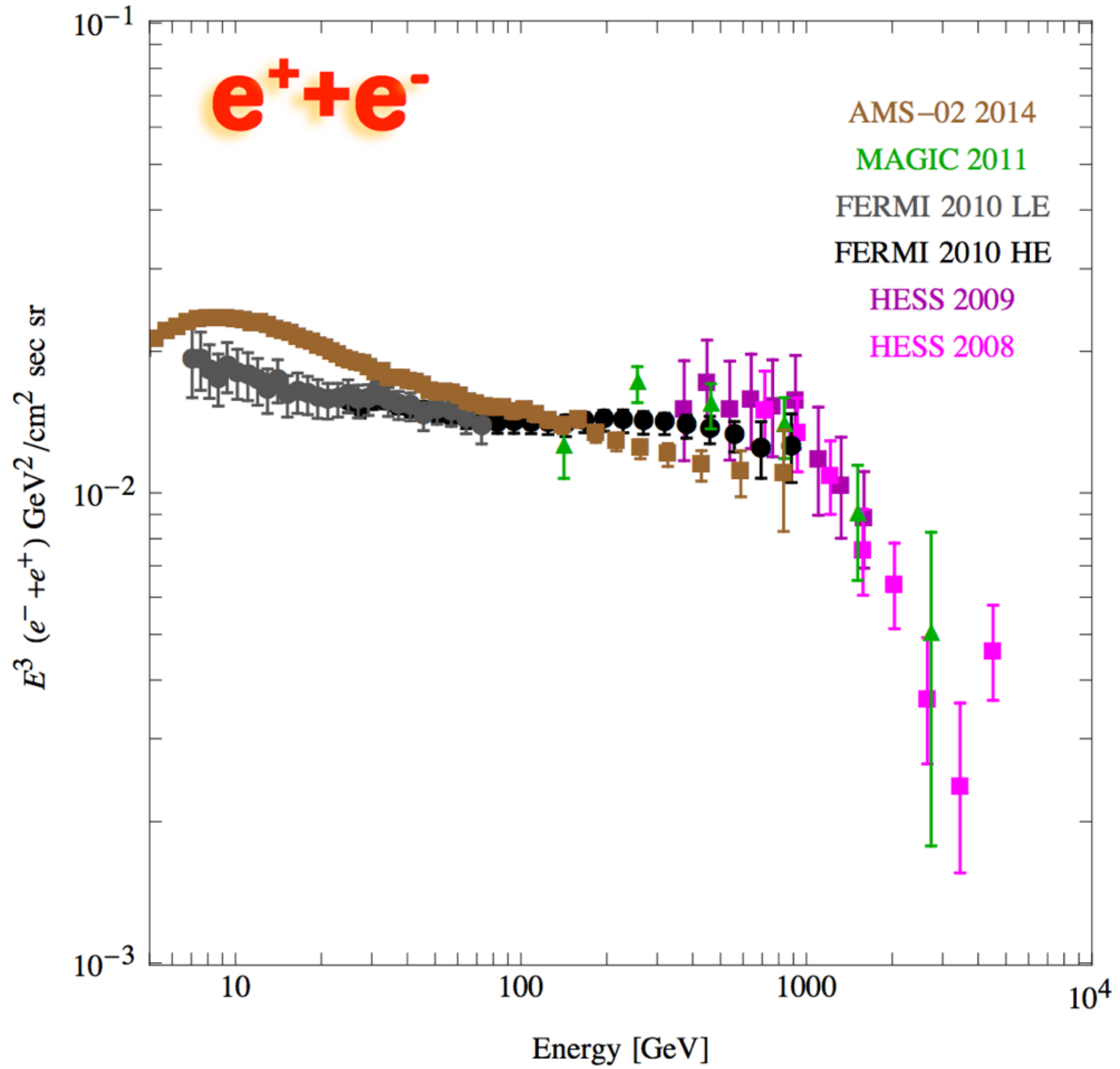
?

Chris Brook

Local cosmic-ray observations: leptons

M. Cirelli, compilation ICRC2015



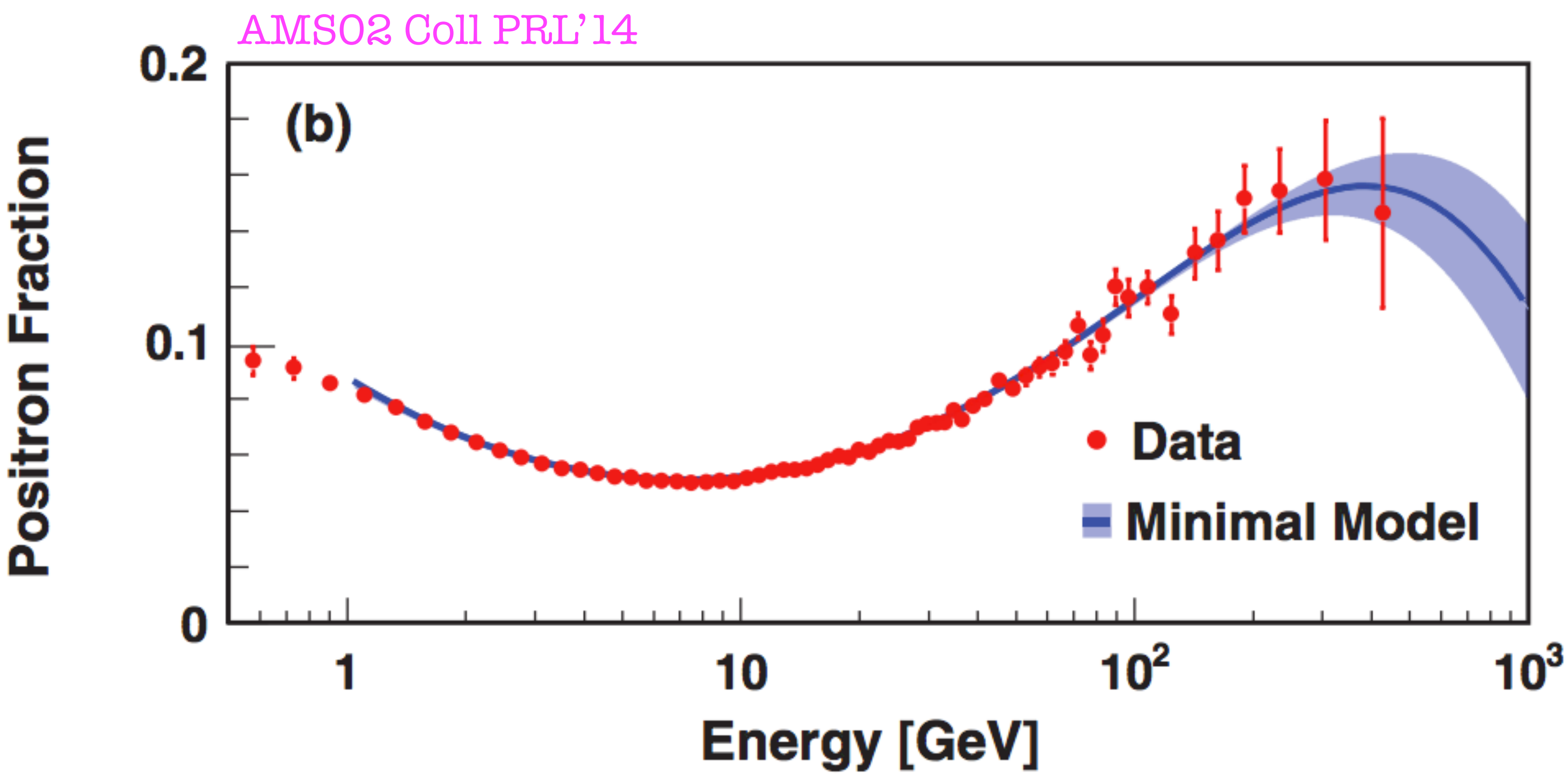


Anomaly: a rise in the positron fraction for E > 10 GeV

From CR propagation physics, the ratio is expected to decrease for all propagation models.

e.g. see Lavalle&Salati A&A'09

Why is it so exciting?



Minimal model requires an **extra-component** in the e^- and e^+ fluxes:

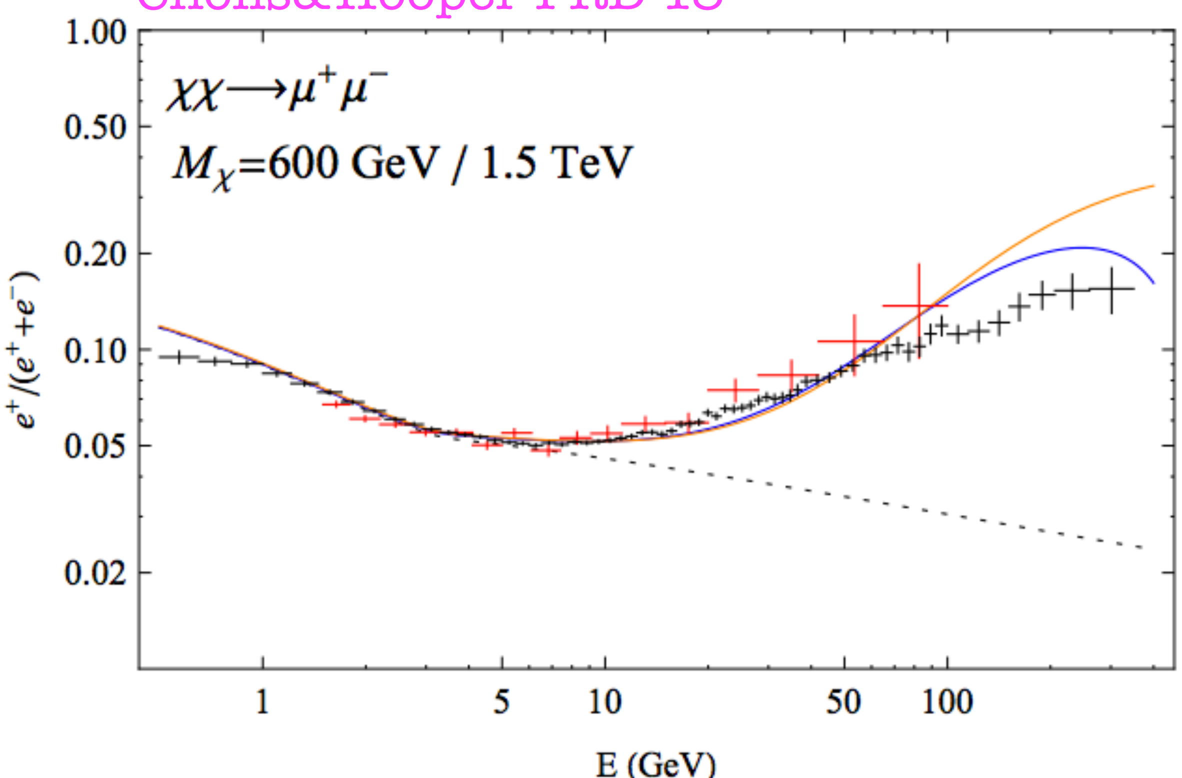
$$J(e^{\pm}) \propto E^{-\alpha_{\rm extra}} \; \exp\left(-E/E_{\rm cut}\right)$$

$\longrightarrow$ New common source of e^- and e^+

Possible explanations

Positron fraction's rise due to quite massive **dark matter particle annihilation** into leptons

Cholis&Hooper PRD'13

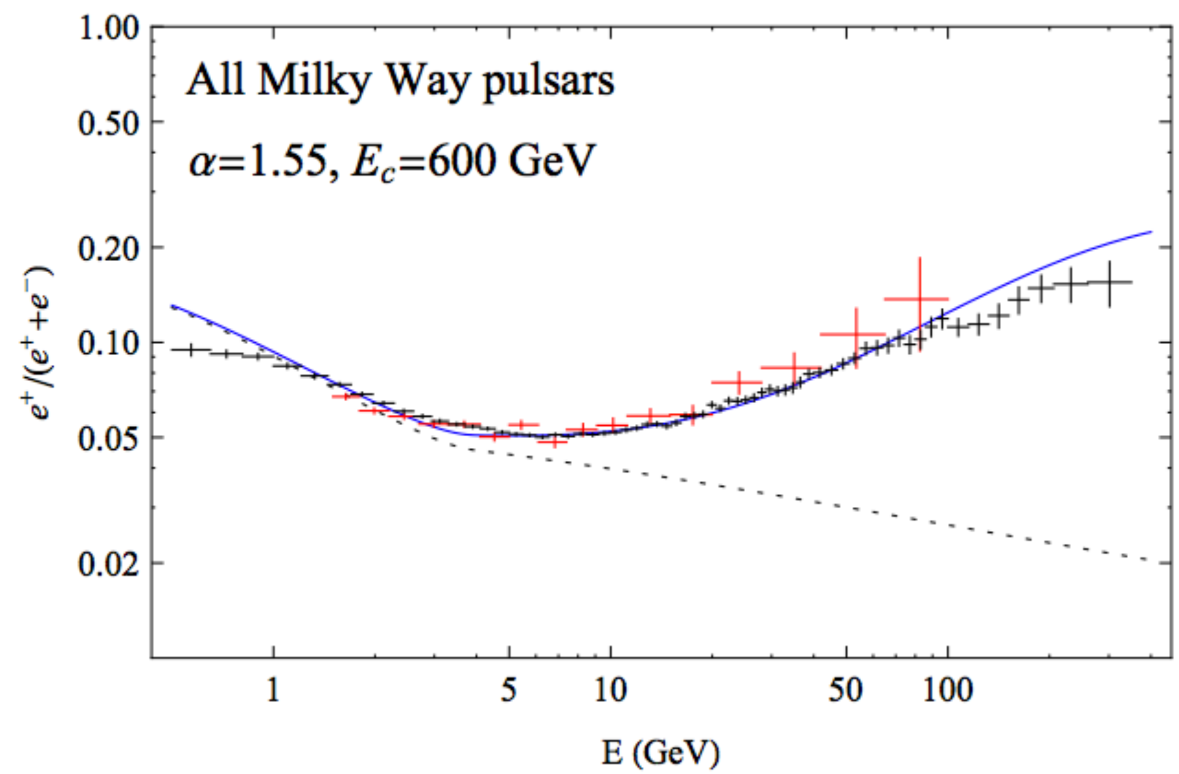


However:

- Accuracy of AMS02 data starts to exclude channels
- Tension with current constraints from gamma rays and CMB

Slatyer'15, Planck Coll'15

Primary positrons from pair production in **pulsar magnetosphere**



How to discriminate dark matter from astrophysics?

a. Shape of the spectrum (challenging)
b. Anisotropy (directional signal)

Taxidermy (Phenomenology-driven)

How prejudiced are we when constructing DM models?

Identify some basic features from a **positive observation**

(Galactic Centre Emission)

Taxidermy **(Phenomenology-driven)**

Identify some basic features from a **positive observation**

(Galactic Centre Emission)

Perform a **complementary measurement** with other search technique

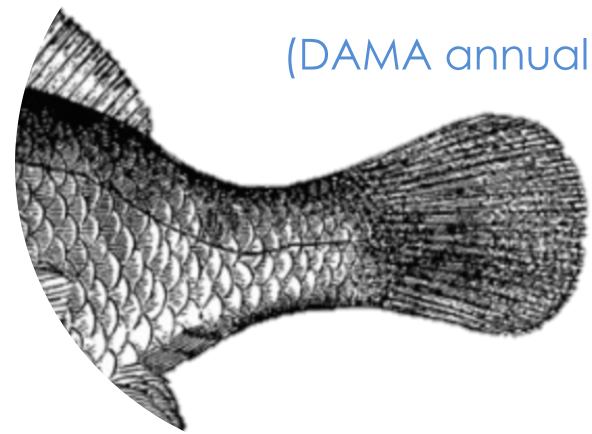
(Signal in various direct detection targets or at the LHC)

Taxidermy (Phenomenology-driven)

Some data might be more difficult to explain in terms of “standard” DM models

(DAMA annual modulation)

Identify some basic features from a **positive observation**



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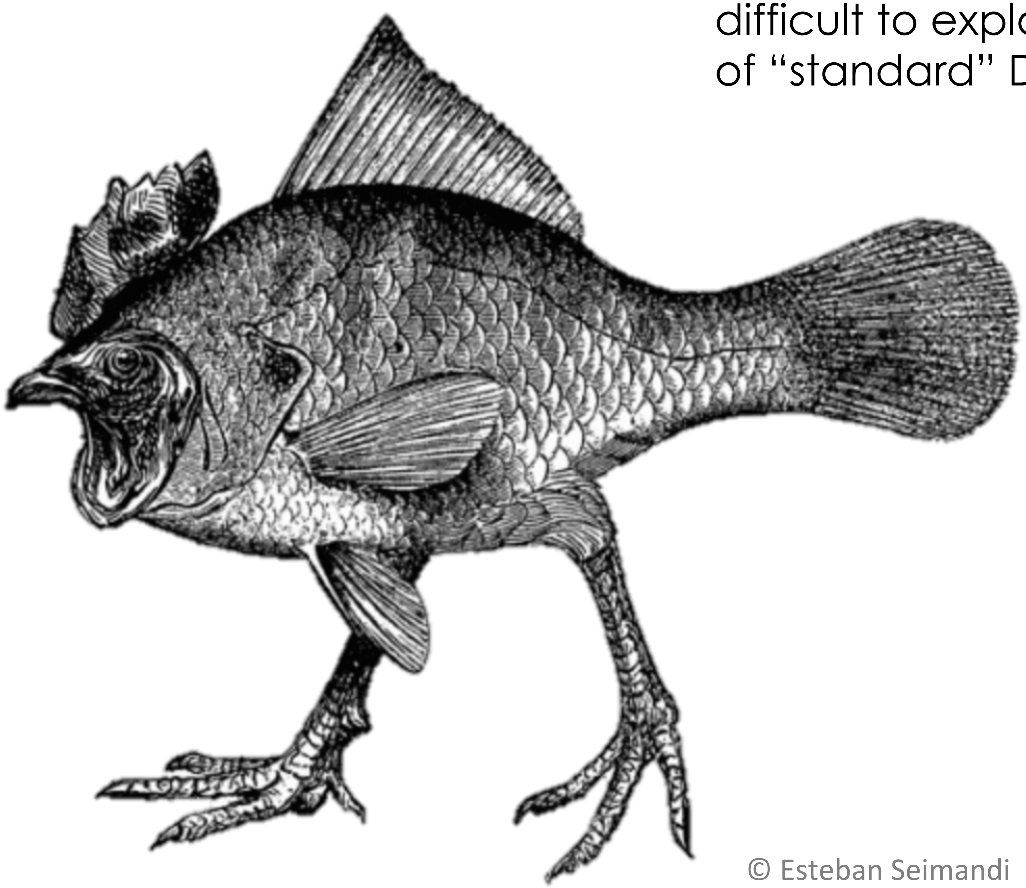


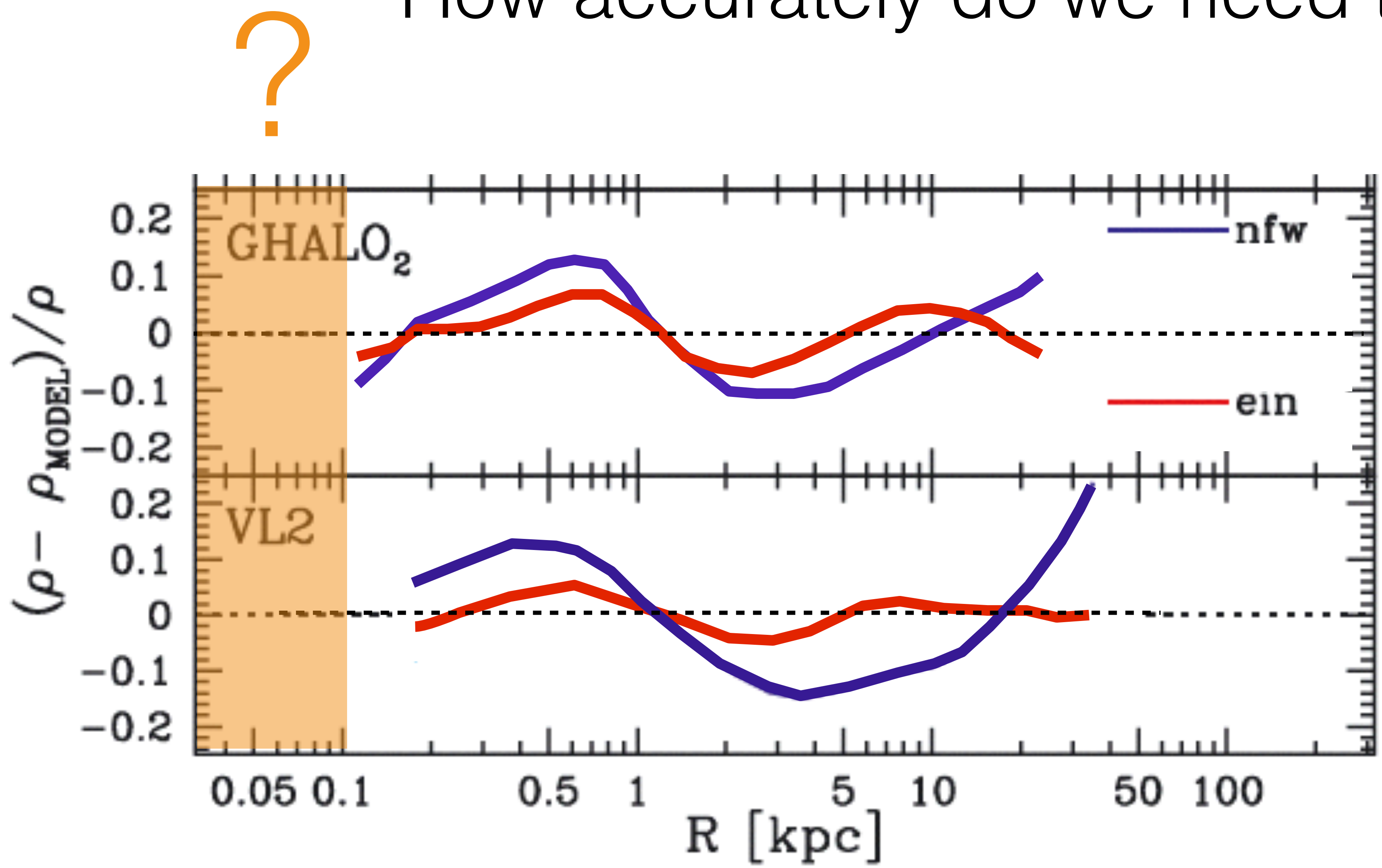
Perform a **complementary measurement** with other search technique

© Esteban Seimandi
Animalia Exstinta

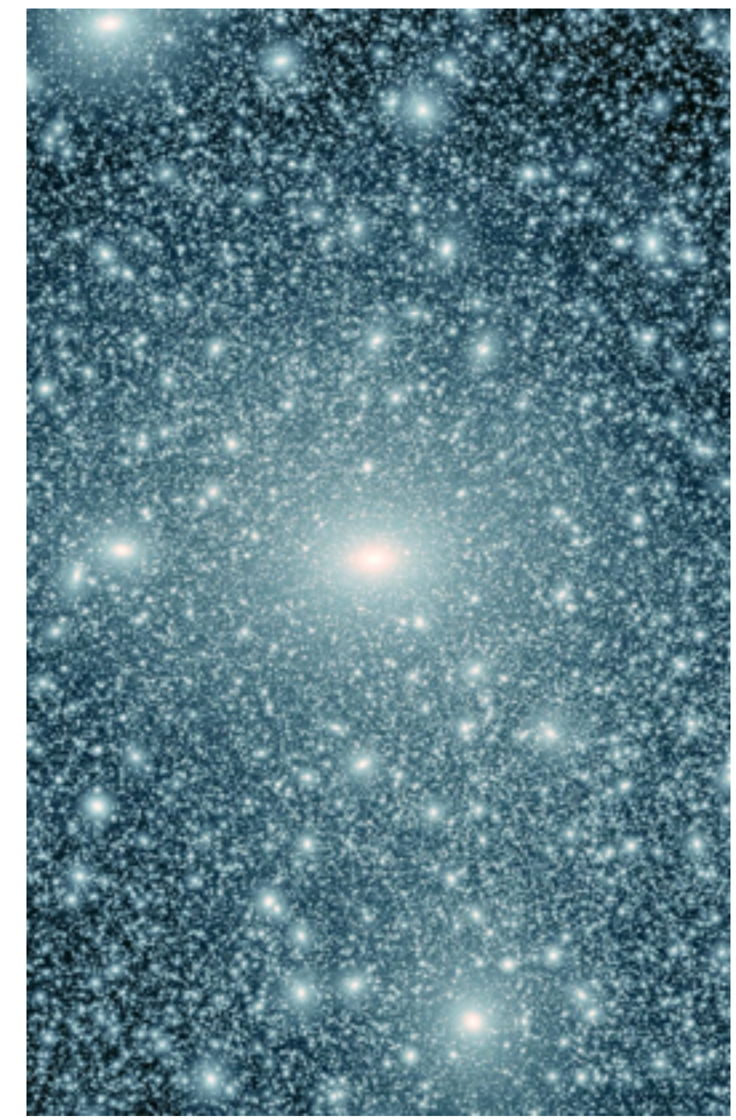
This motivates working with general frameworks, where little or nothing is assumed for the DM particle

How do we predict the structure of Milky Way (cold) dark matter haloes below 100pc?

How accurately do we need to know it?



3 billion particles



ghalo

2 million CPU hours
(1000 cores x 12 weeks)

Is there a way to measure the local velocity distribution *f*(*v*) of DM?

- For stars we have (and will have) data on positions and velocities
- They can be used to infer their phase-space distribution function or to determine the properties of the gravitational potential in which they move (assuming a certain distribution function)

$$\mathrm{qDF}(\mathbf{x},\mathbf{v}) = f_{\sigma_R}(J_R, L_Z) \times \frac{\nu}{2\pi\sigma_Z^2}\,\exp\left(-\frac{\nu J_Z}{\sigma_Z^2(R_c)}\right)$$

$$\begin{aligned}\ln \mathcal{L}_{i,\mathrm{DF}} &= \ln \mathrm{qDF}(\mathbf{J}[\mathbf{x}_i,\mathbf{v}_i]|\mathbf{p}_\Phi,\mathbf{p}_{\mathrm{DF}}) \\ &\quad - \ln \int \mathrm{d}l\,\mathrm{d}b\,\mathrm{d}D\,\mathrm{d}\mathbf{v}\,\mathrm{d}r\,\mathrm{d}(g-r)\,\mathrm{d}[\mathrm{Fe/H}] \\ &\quad\quad \boxed{\lambda(l,b,D,\mathbf{v},r,g-r,[\mathrm{Fe/H}]|\mathbf{p}_\Phi,\mathbf{p}_{\mathrm{DF}})}\end{aligned}$$

$$\begin{aligned}\lambda(l,b,D,\mathbf{v},r,g-r,[\mathrm{Fe/H}]) = \\ \rho(r,g-r,[\mathrm{Fe/H}]|R,Z,\phi) \times \mathrm{qDF}(\mathbf{x},\mathbf{v}) \\ \times |J(R,Z,\phi;l,b,D)| \times S(\mathrm{plate},r,g-r)\end{aligned}$$

Is there a way to measure the local velocity distribution $f(v)$ of DM?

- Dynamics of tracers can be used to infer the gravitational potential of the Milky Way (and, then, the amount of DM)
- What about the DM velocity distribution $f(v)$?

  - Simulations (not a real measurement)
  - Direct detection or neutrinos from the Sun (if we will even get a detection)
  - Self-consistent approach (only works in specific simplified cases)
  - Anything else?

Dark Matter in the Milky Way @MITP, Mainz (Germany)
2-13 May 2016

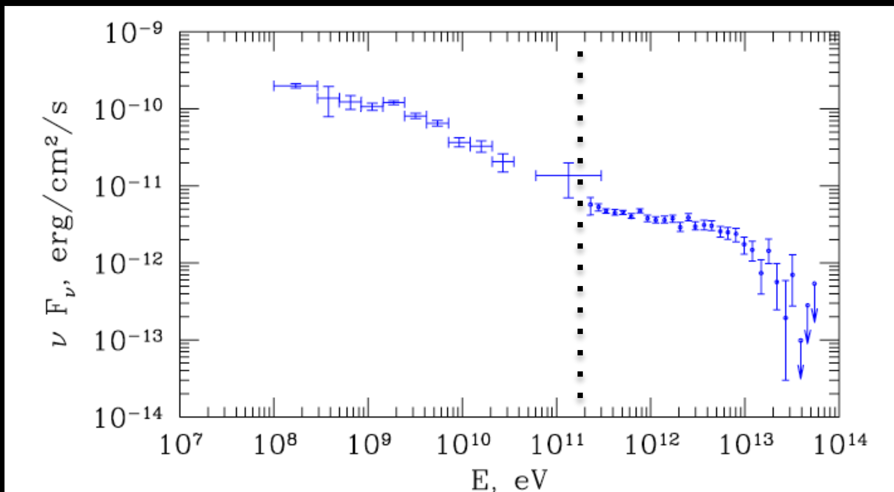
The Galactic Center gamma-ray emission

Viviana Gammaldi

ma per seguir virtute e canoscenza
SISSA

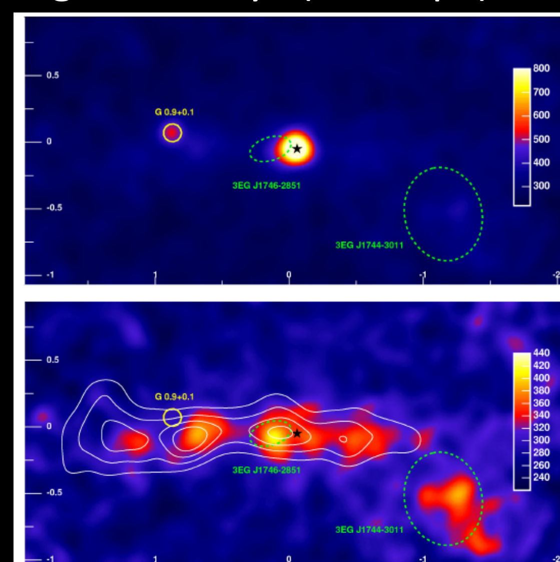
The Galactic Center gamma-ray emission

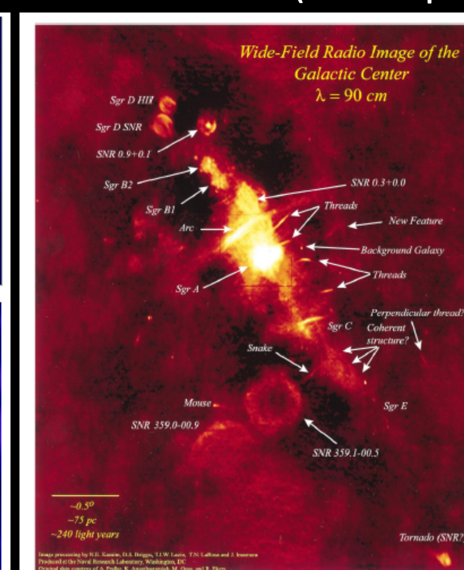
[C. Eldik arXiv:1505.06055v1]



FERMI-LAT High Energy (HE) (0.3 - 100 GeV) source 2FGL J1745.6 2858
and
H.E.S.S. J1745-290 Very HE (VHE) (200 GeV - 70 TeV) data
from the inner 10 pc
at the Galactic Center Region
seem to have a common origin

HESS gamma rays (< 300 pc) VLA 90 cm radio(< 300 pc)





Identification of the sources and comparison with other wavelengths
is very difficult due to low angular resolution in gamma-ray observations

The Galactic Center gamma-ray emission

- Due to complicate formal shape, an identification of a single emission process is difficult.

- The signal may be associated with the Black Hole at the Galactic Center Sgr A* (a convincing signature could be the discovery of a correlated emission in X or IR or the detection of time variability) , with the Supernova Remnants Sgr A East or with the Pulsar G359.95-0-04 (the last two alone may not explain the HE emission).

- There is no hint for flux variability.

- It may be produced by cumulative effect of many astrophysical sources or (why not?) an astrophysical component with a dark matter signal.

1 slider

Is it useful to use a self-interacting dark matter simulation with baryons (for contact interactions and long range interactions) and compare the various properties?

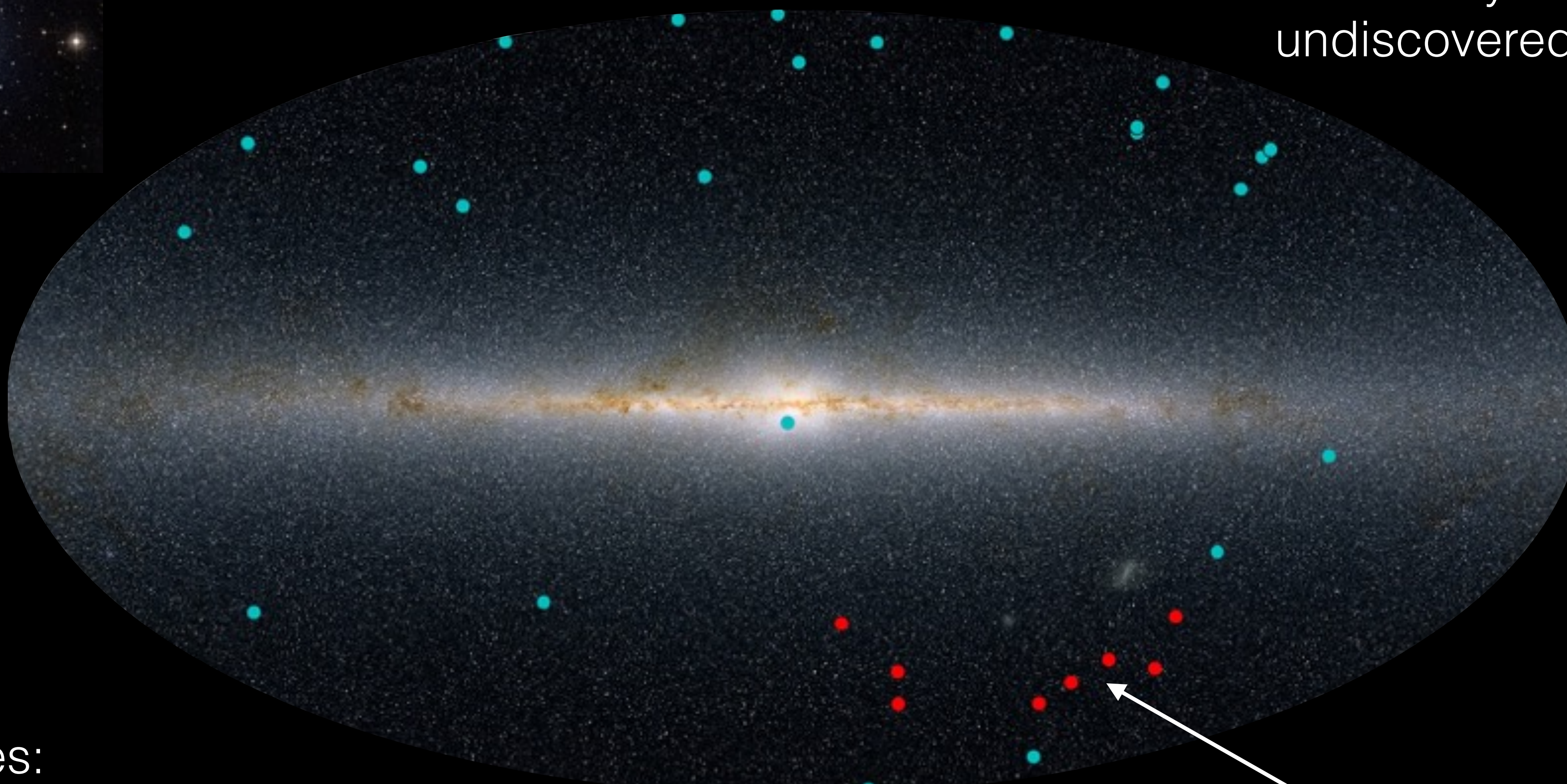
(1308.3419, 1504.06576, 1501.00497)

How many Milky Way satellite galaxies are there?

The answer will constrain galaxy formation
and dark matter physics

e.g. Fornax

Each dot is a satellite.
How many remain
undiscovered?

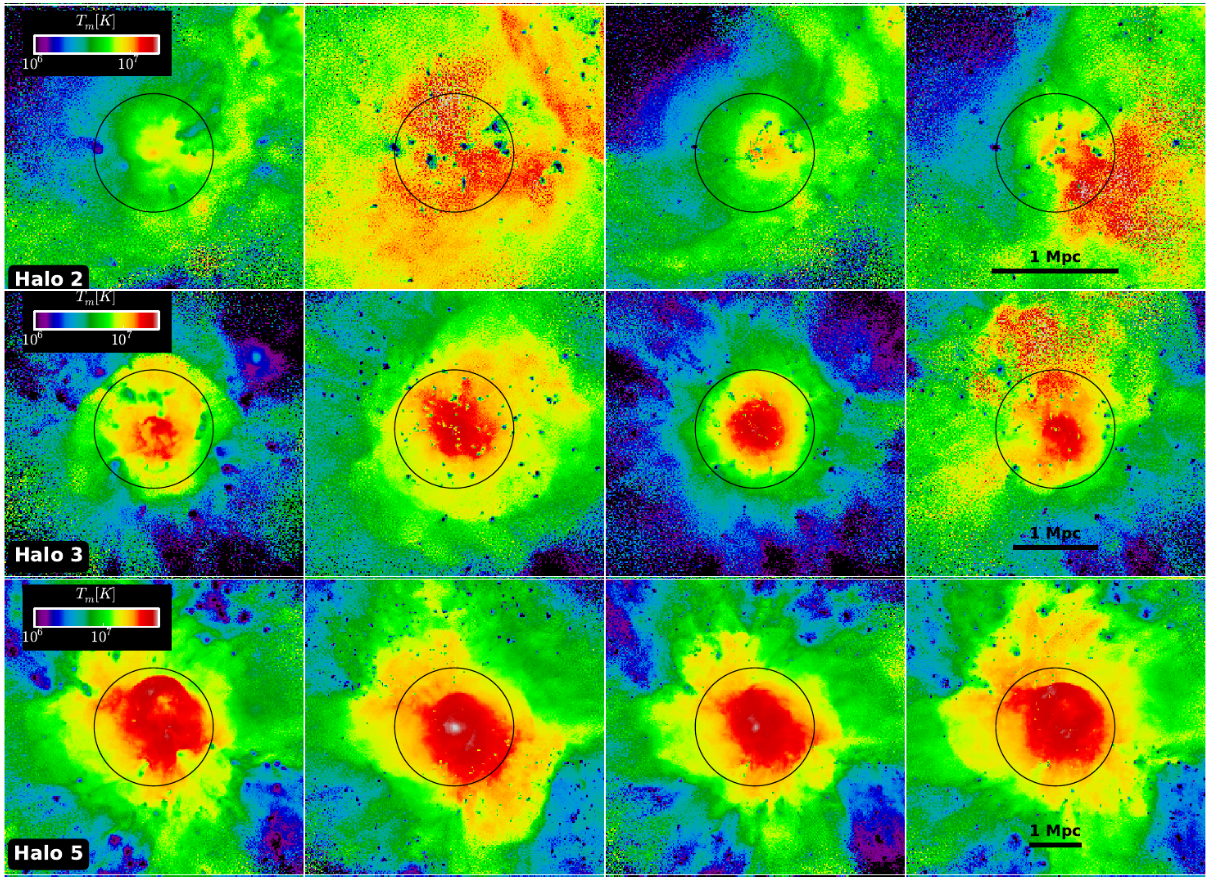


#Satellites:
-> #Dark matter subhaloes
-> Strength of baryonic feedback

Overdense region
Anisotropy?
Or just better observations?

Sky map credit: Fermilab
Fornax credit: ESO

Impact of AGN feedback in simulations

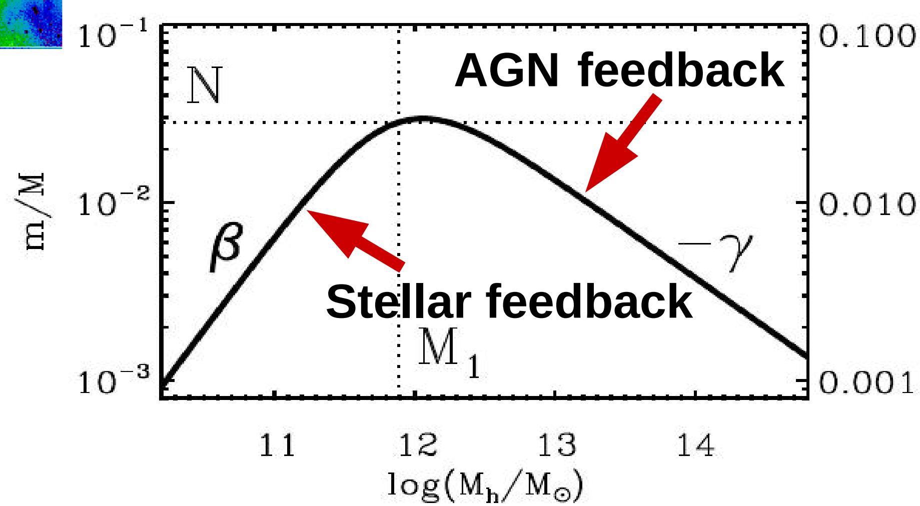


Halo mass

AGN feedback model

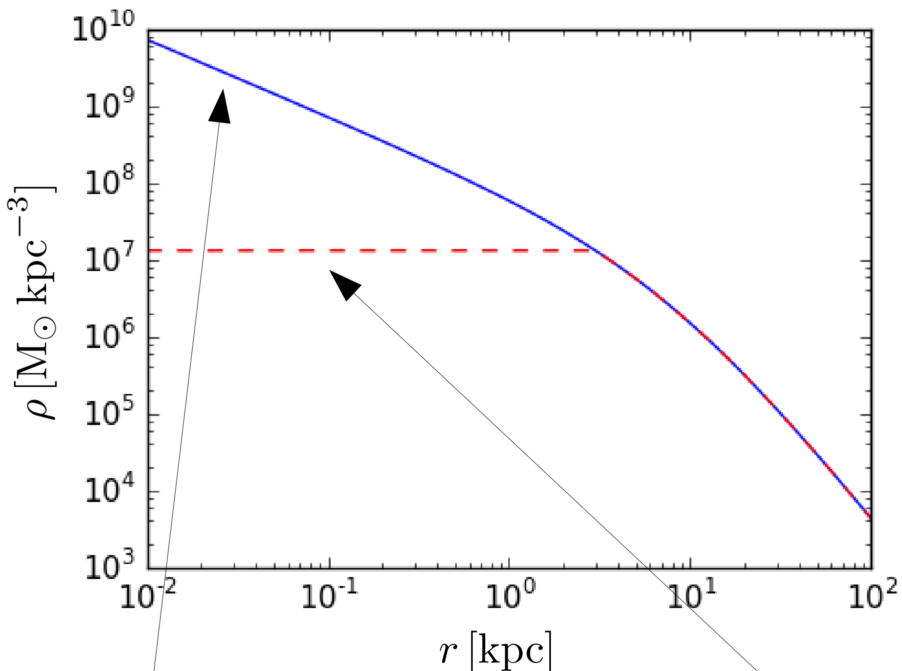
Energy injection by an AGN on the gas can lead to (violent) outflows

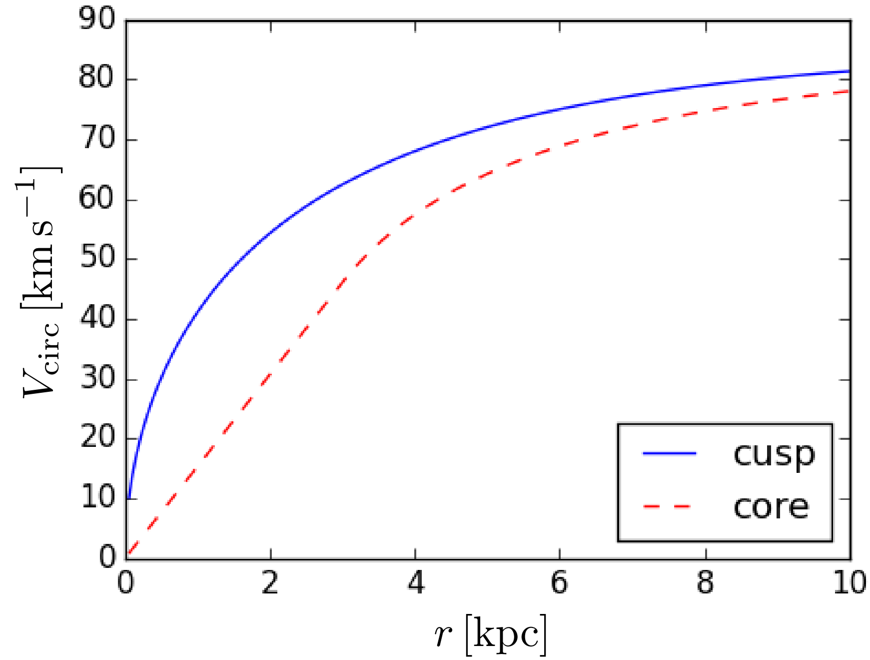
Can it have an influence on the DM at MW scales?



The cusp-core problem

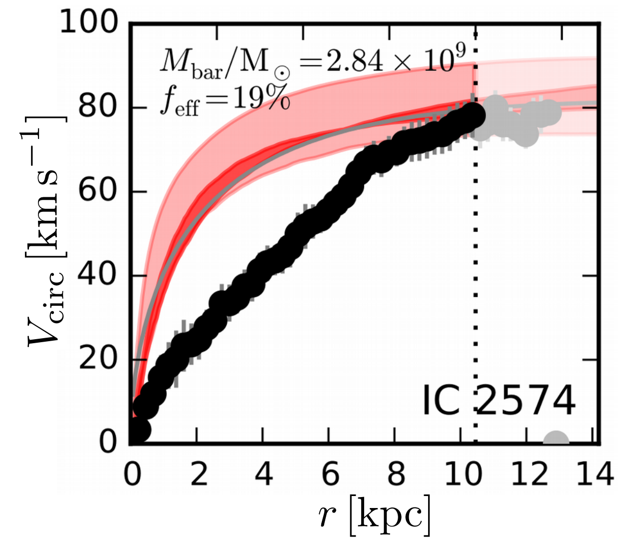
Kyle Oman (Victoria)





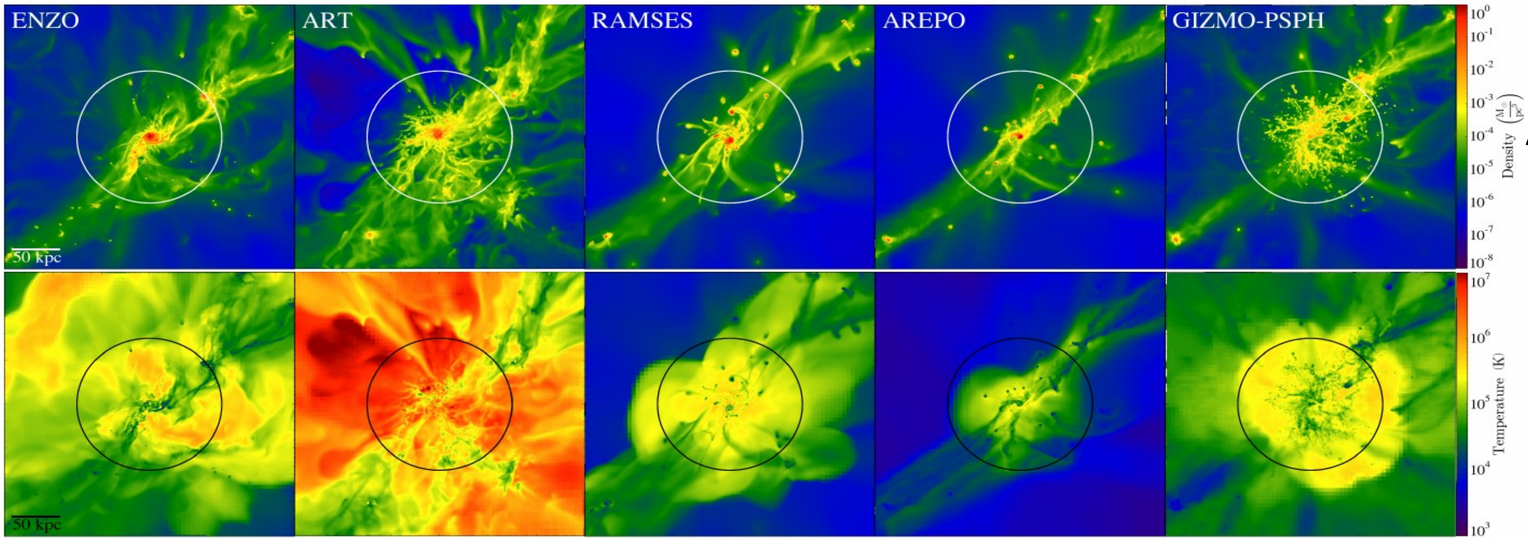
APOSTLE Project

APOSTLE/Stephen Leshin



How well do we know the gas distribution in halos?

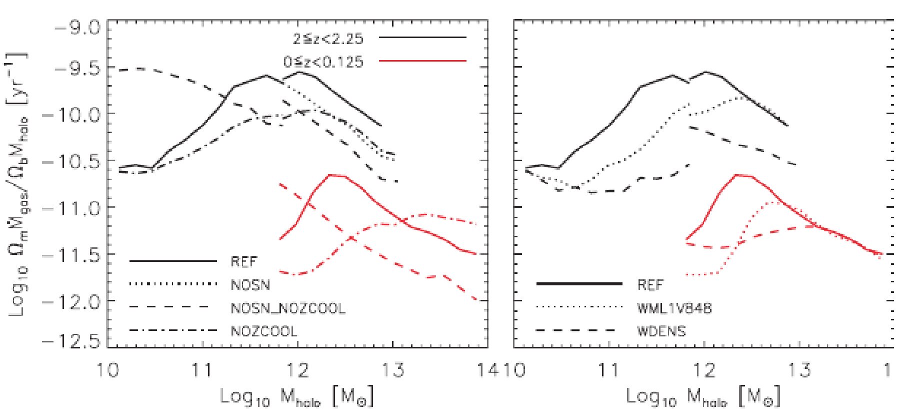
Or what is the real resolution of an hydrodynamical simulation?

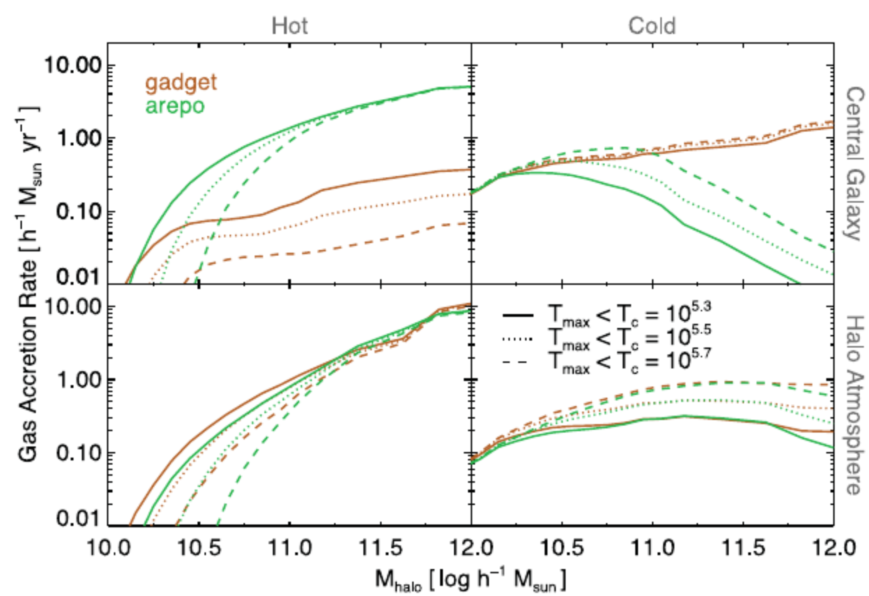


Scylla Project

- Cold vs Hot Accretion
- Recycled gas: Supernova, winds
- Reionization: the UV Background

Van de Voort+2011





Nelson+2013

Jose Oñorbe

onorbe@mpia.de

Are we ever going to determine the quantum numbers of the dark matter particle?

Assume it's WIMP-like for simplicity.

Assume we know its annihilation cross section

Assume we know its scattering cross section (SI or SD)

given the variety of models that can reproduce the same observables, are we ever going to determine the quantum numbers of the dark matter particle (mass, spin, charge under hidden symmetry)?

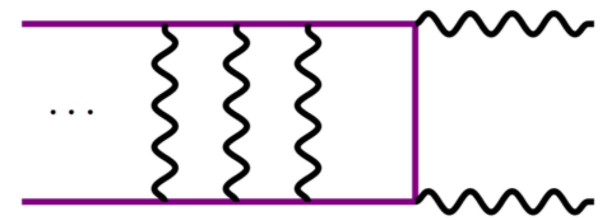
Even if we know its mass by a combination of the direct and indirect detection measurements.

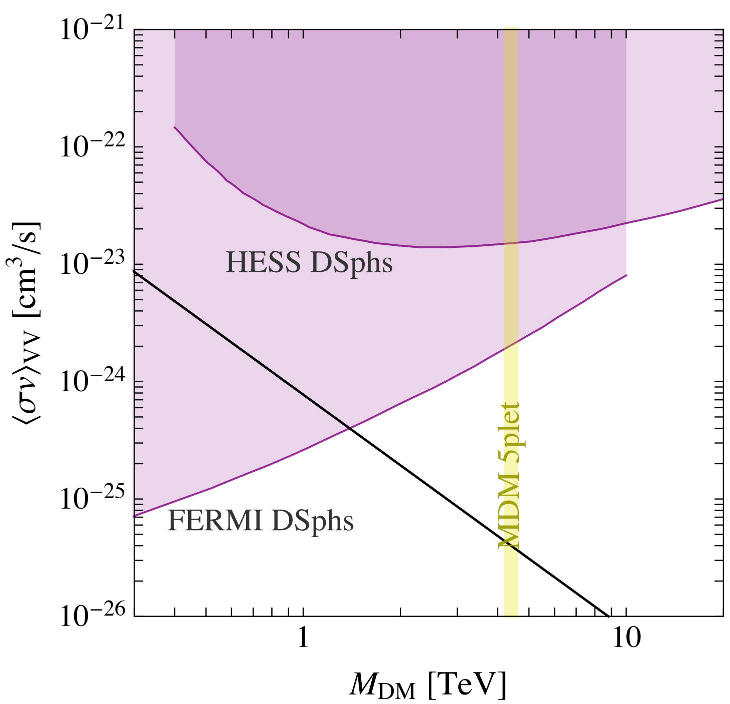
Still...

BOUND DM STATES and Indirect Detection

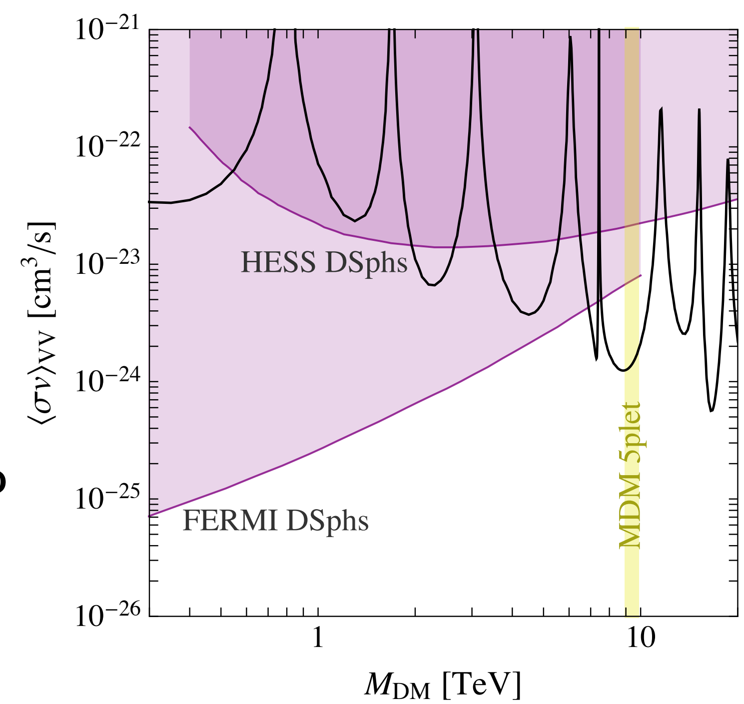
You might have heard of the **Sommerfeld** enhancement

Sommerfeld 1931, Hisano et al. 2004 (first time DM), ….





SOMMERFELD



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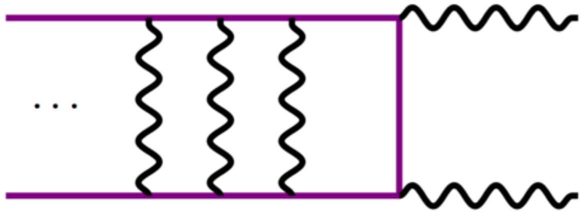
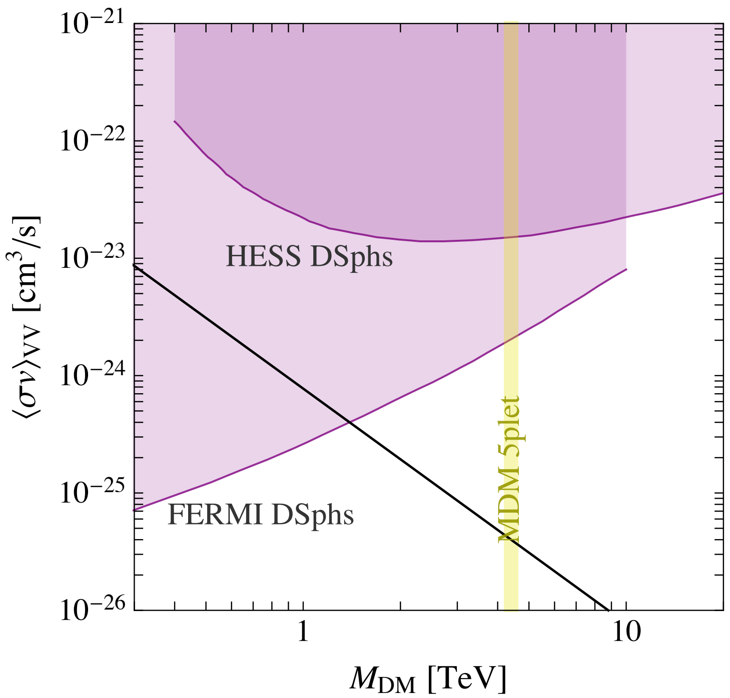
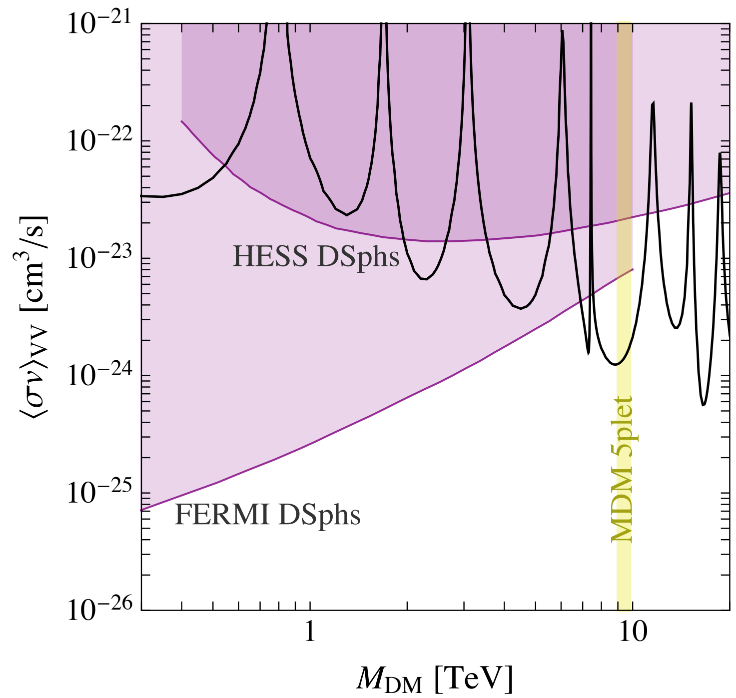




SOMMERFELD



BOUND STATES ???

It is less known that **Dark Matter** can form **bound states**… Von Harling Petraki 2014,…

BOUND DM STATES and Indirect Detection

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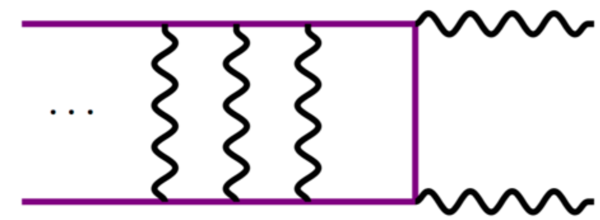
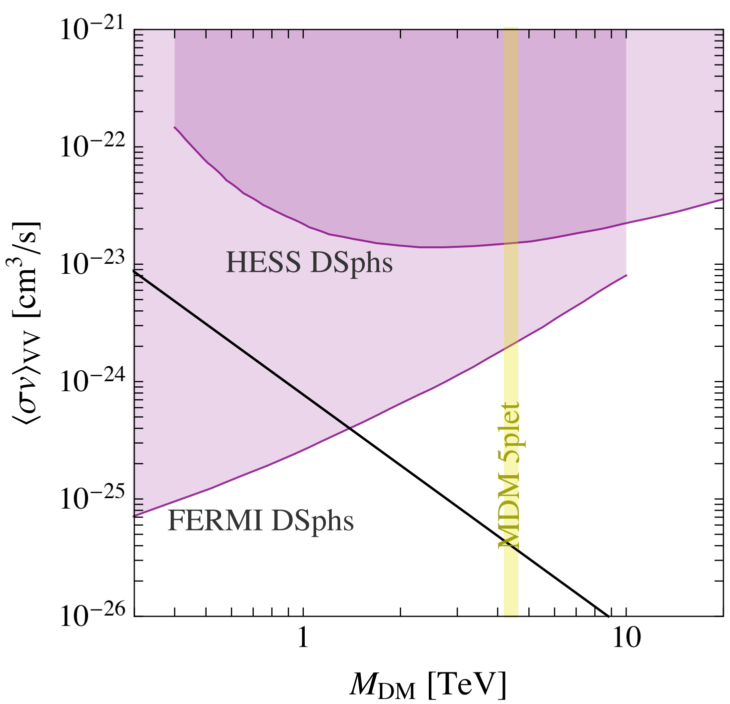
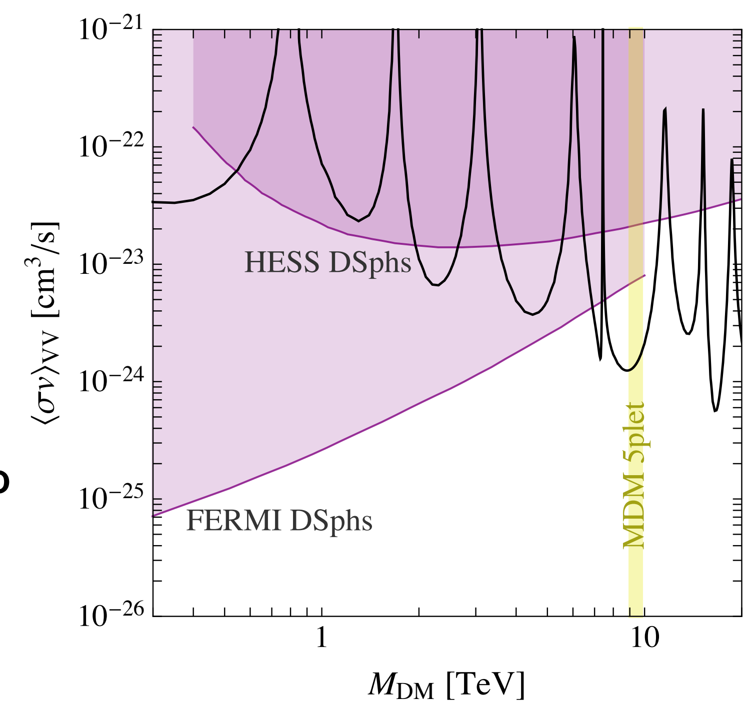




SOMMERFELD

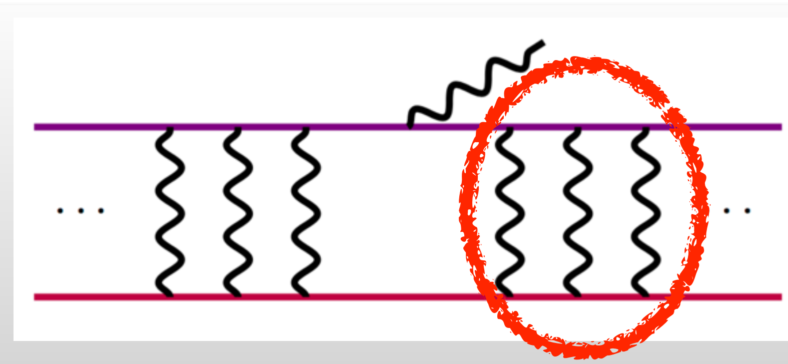


BOUND STATES ???

It is less known that **Dark Matter** can form **bound states**… Von Harling Petraki 2014,…

“Same” physics of Sommerfeld:

Non rel. Quantum mechanics,
“like" hydrogen atom

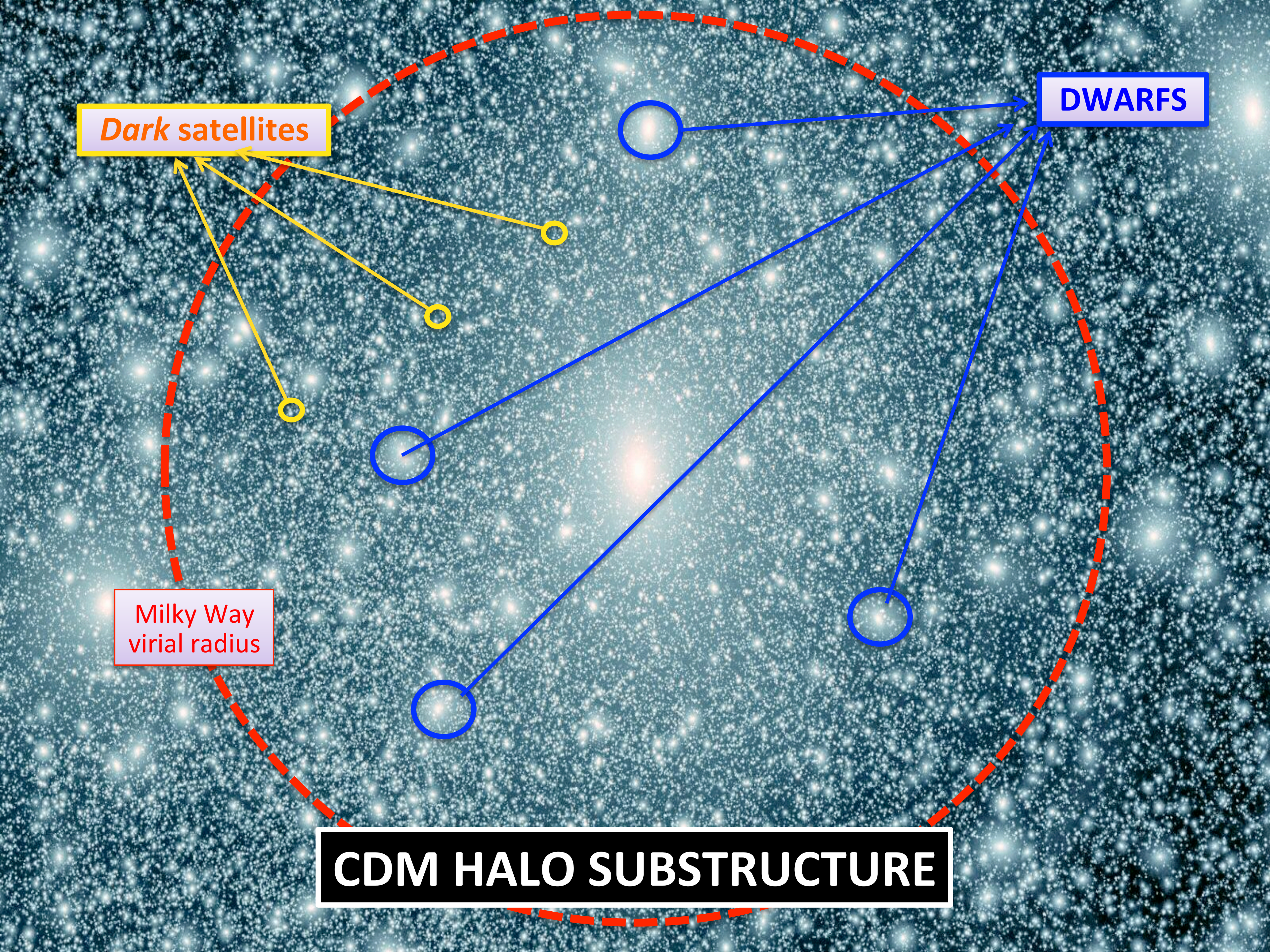


The DM bound state decays and gives you <u>more</u> signal at telescopes!

(e.g. people used QCD bound states to explain the 750 GeV $\gamma\gamma$ at CERN)

Exciting New Avenue
lot of work ahead!

Stay tuned…


Dark satellites
DWARFS
Milky Way virial radius
CDM HALO SUBSTRUCTURE

What's the exact role of
CDM substructure in dark matter searches?

1. *Subhalos will boost the DM annihilation signal* → **SUBHALO BOOSTS**
2. *Some could be excellent DM targets* → **SUBHALO DETECTABILITY**

There are no precise answers to these points.

(Some) OPEN ISSUES

→ Precise structural properties of DM subhalos, including low-mass ones?

→ Exact radial distribution?

→ How many? Mass function, survival probability…

→ How do baryons affect them?

→ Should we already see some dark satellites with current γ-ray experiments?

→ Observational evidences? (lensing, Galactic disk 'gaps', etc)

→ Could they affect DM direct experiments in some way?

The 3.55 KeV Emission Line

Beatriz B. Siffert - Federal Univ. of Rio de Janeiro

In 2014: X-ray emission excess at 3.55 KeV from M31 and galaxy clusters with XMM-Newton and Chandra data.

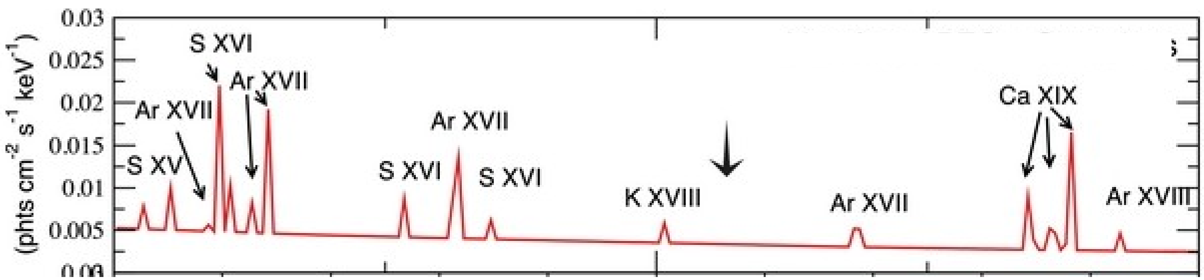
(A. Boyarsky et al., PRL 113 & E. Bulbul et al., ApJ 789).

DM decay? ν_s → γ with $E = m_{\nu s}/2$; active ν

Sterile neutrino as DM:

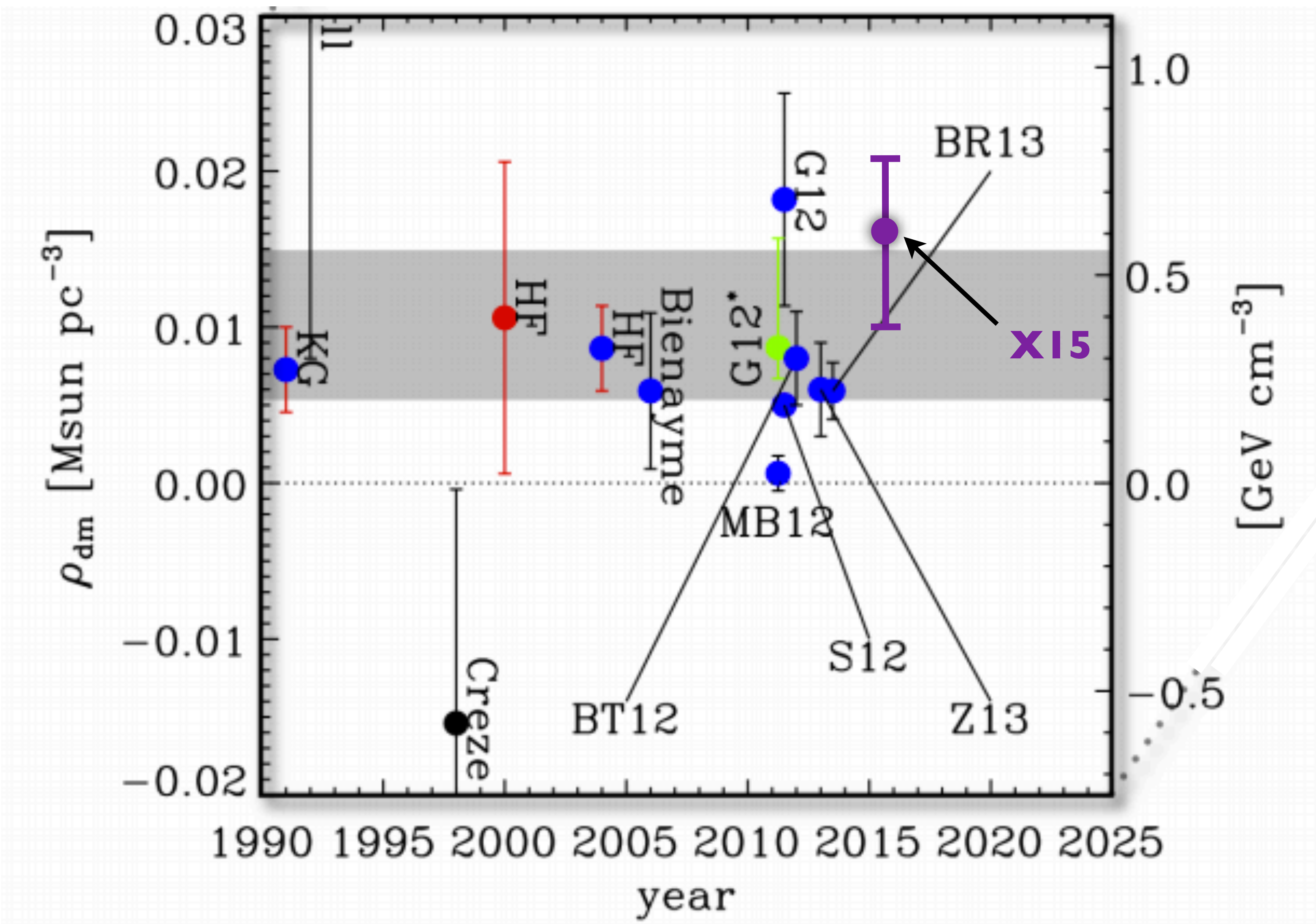
$0,5 < m_{\nu s} < 100$ KeV

Just an atomic emission line?



What is the Uncertainty on the Local Dark Matter Density?

Hamish Silverwood
GRAPPA, Amsterdam.



Justin Read, 2014

Importance:

- Interpretation of Direct and Indirect Detection rates, limits
- These rates feed into analysis of Beyond the Standard Model theories (e.g. SUSY Global Scans)

Methods:

- interpolation from global measurements (rotation curves, eg Iocco+ 2015)
- local measurements of stars (usually vertical motions in the disc)

Questions:

1. How precise can we get the baryon distribution?

In a small volume (~100pc) around the sun we have

$\rho_B = 84 \pm 12$ mM$_{sun}$ pc^{-3} = 3.19 ± 0.45 GeV cm^{-3} (McKee et al.)

$\rho_{DM} \sim 10$ mM$_{sun}$ pc^{-3} ~ 0.4 GeV cm^{-3}.

So we need to assume ~constant vertical ρ_{DM} and use high-z measurements

2. What is the structure of the stellar disc and how does this affect our measurements?

Radial and axial variation, spiral arms, chemo-spatial distribution ('thin and thick' discs)...

3. Are the steady state solutions still valid?

Radial migration, spiral arms, warping of disc from recent satellite mergers...

4. Can we detect a flattened halo, co-rotating accreted dark disc, or even a thin dark disc (eg. the Randall Dinosaur Killer)?