Dark Matter – a status report

Lars Bergström
The Oskar Klein Centre for Cosmoparticle Physics

AlbaNova
Stockholm University
lbe@fysik.su.se

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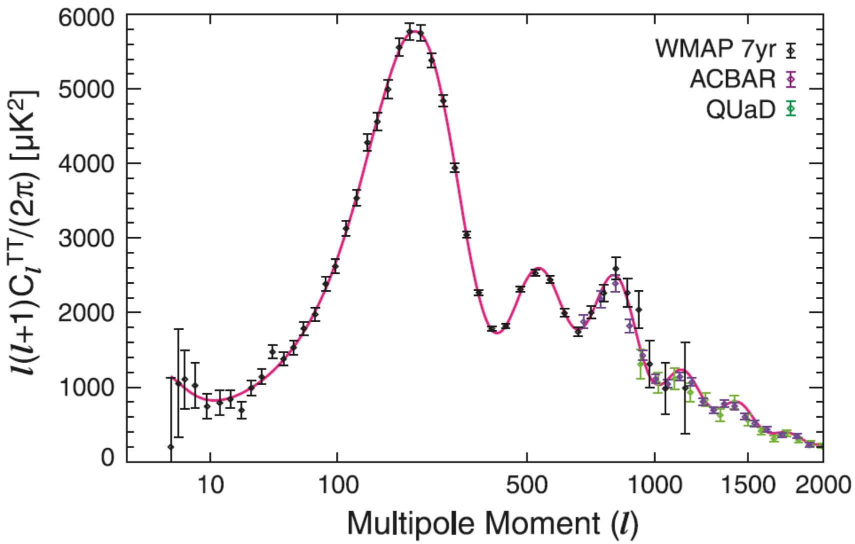
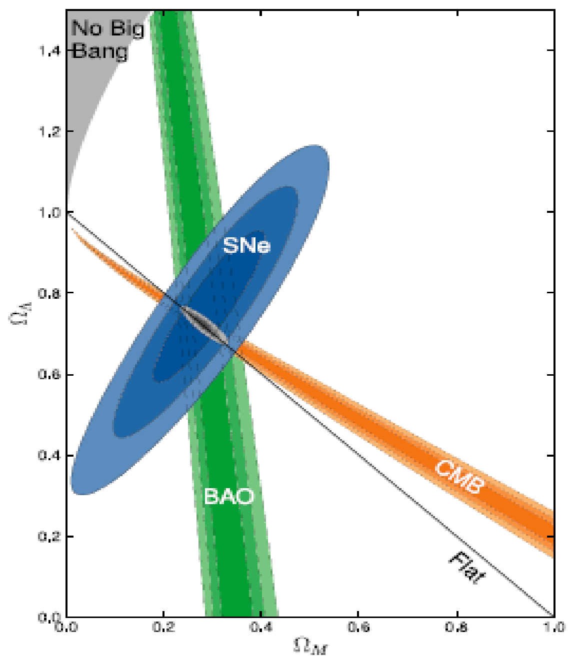
Fritz Zwicky, 1933: *"If this over-density is confirmed we would arrive at the astonishing conclusion that dark matter is present with a much greater density than luminous matter."*

Coma galaxy cluster



E. Komatsu et al. (WMAP team) , 2010



R. Amanullah et al. (SCP Collaboration), 2010

WMAP 2010:

$$\Omega_{tot} \equiv \frac{\rho_{tot}}{\rho_{crit}} \approx 1.003 \pm 0.01$$

$\Omega_\Lambda = 0.727 \pm 0.030$ $\Omega_{CDM} h^2 = 0.1120 \pm 0.0056$

$\Omega_B = 0.0455 \pm 0.0028$ $h = 0.704 \pm 0.025$

The ΛCDM Model:

Cold Dark Matter model meaning electrically neutral particles moving non-relativistically, i.e., slowly, when structure formed. In addition, the cosmological constant Λ being the dark energy, gives an accelerating expansion of the universe (cf. Nobel Prize 2011).

Ω_{CDM} h^2 = 0.11

Seems to fit all cosmological data!

Note: "Dark Matter" was coined by Zwicky; maybe "Invisible Matter" would have been a better name…

Dark matter needed on all scales!
$\Rightarrow$ Modified Newtonian Dynamics (MOND) and other *ad hoc* attemps to modify Einstein's or Newton's theory of gravitation do not seem viable

Einstein: $S = \frac{1}{16\pi G}\int d^4x\,\sqrt{-\tilde{g}}\,R\,.$

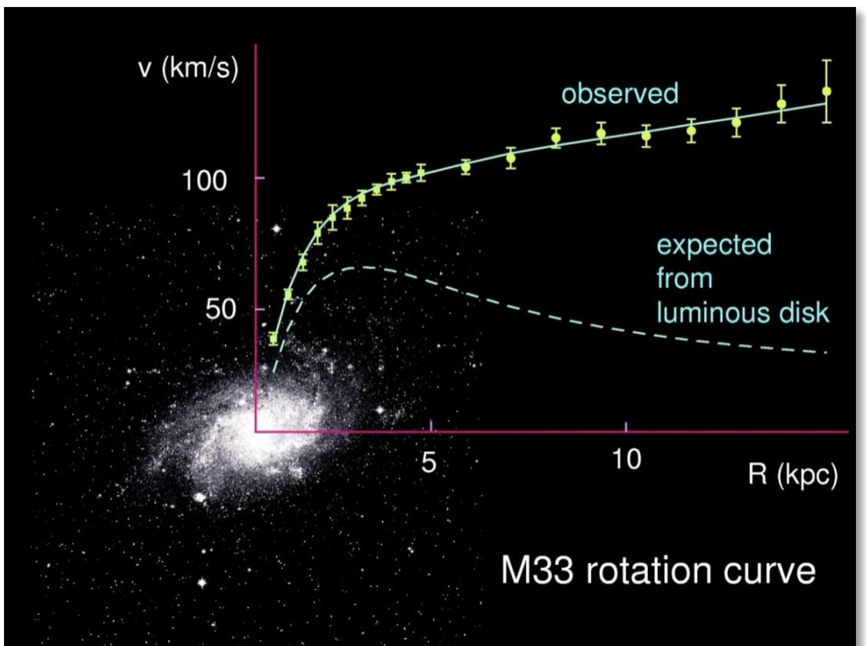
MOND:

$$S = \frac{1}{16\pi G}\int d^4x\,\sqrt{-\tilde{g}}\,\Big[\tilde{R} - \frac{1}{2}KF^{ab}F_{ab} + \lambda(A_a A^a + 1) - \mu(\tilde{g}^{ab} - A^a A^b)\nabla_a\phi\nabla_b\phi - V(\mu)\Big]$$

where $g^{ab} = e^{2\phi}\tilde{g}^{ab} + 2\sinh(2\phi)A^a A^b\,.$

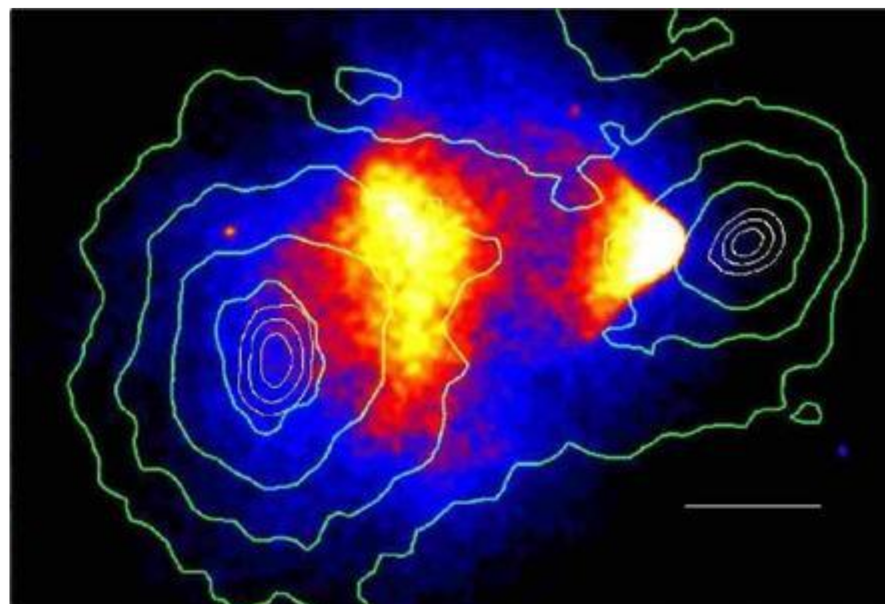
and $\frac{dV}{d\mu} = -\frac{3}{32\pi l_B^2\mu_0^2}\frac{\mu^2(\mu - 2\mu_0)^2}{\mu_0 - \mu}\,.$

Galaxy rotation curves



L.B., Rep. Prog. Phys. 2000

Colliding galaxy clusters



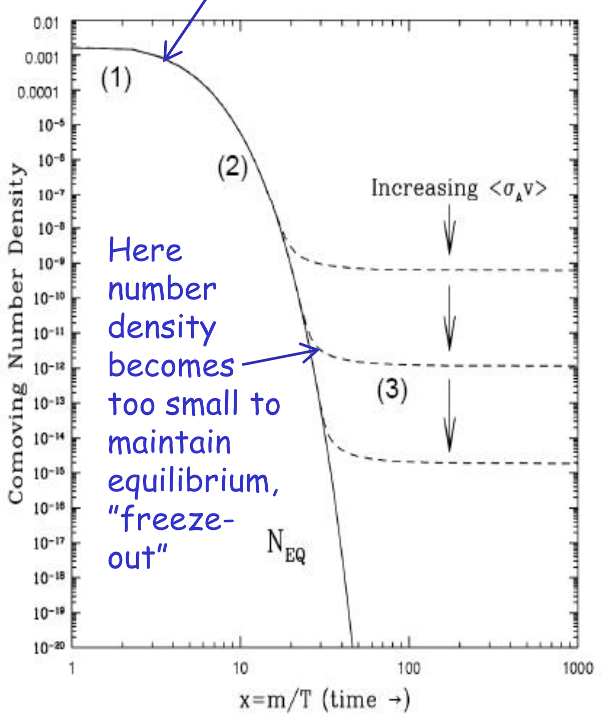
The bullet cluster, D. Clowe et al., 2006

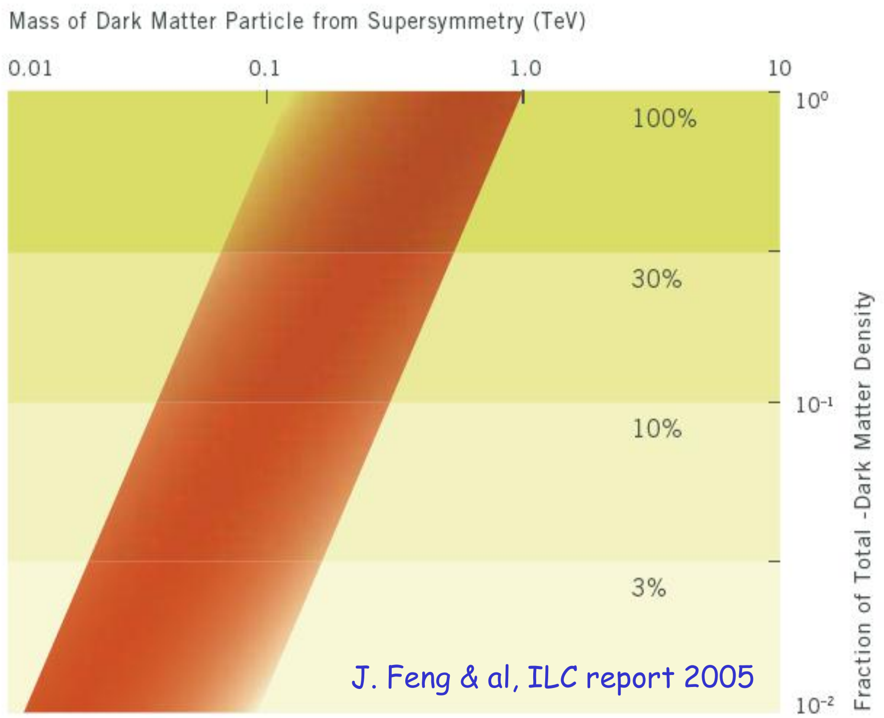
The particle physics connection: The "Weakly Interacting Massive Particle (WIMP) miracle". Is the CDM particle a WIMP?

Equilibirium curve for thermal production in the early universe. Here temperature was >> $2Mc^2$, so the particles were in thermal (chemical) equilibrium.

For thermal production, $\frac{\Omega_{WIMP}\, h^2}{0.11} \cong \frac{3\cdot 10^{-26}\, cm^3 s^{-1}}{\langle \sigma v \rangle}$

Example, supersymmetry:

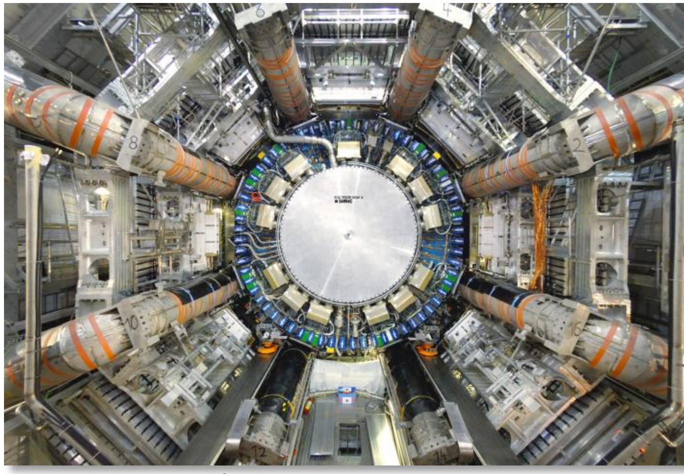




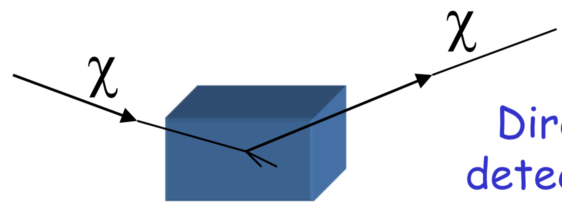
Other interesting WIMPs: Lightest Kaluza-Klein particle – mass scale 600 – 1000 GeV, Inert Higgs doublet – mass scale < 90 GeV, Right-handed neutrinos, … Non-WIMP: Axion.

Methods of WIMP Dark Matter detection:

- Discovery at accelerators (Fermilab, LHC, ILC…), if kinematically allowed. Can give mass scale, but no proof of required long lifetime.
- Direct detection of halo dark matter particles in terrestrial detectors.
- Indirect detection of particles produced in dark matter annihilation: neutrinos, gamma rays & other e.m. waves, antiprotons, antideuterons, positrons in ground- or space-based experiments.
- For a convincing determination of the identity of dark matter, plausibly need detection by at least two different methods. For most methods, the background problem is very serious.



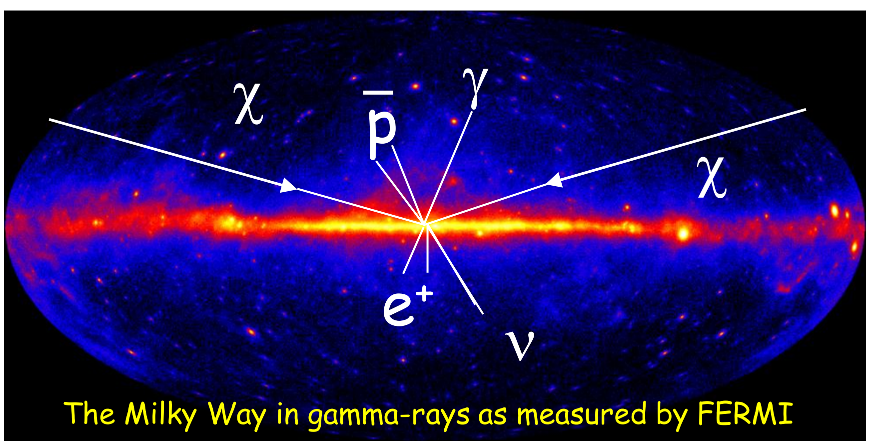
CERN LHC/ATLAS



Direct detection

$$\frac{d\sigma_{si}}{dq} = \frac{1}{\pi v^2}\left(Zf_p + (A-Z)f_n\right)^2 F_A(q) \propto A^2$$

Indirect detection



The Milky Way in gamma-rays as measured by FERMI

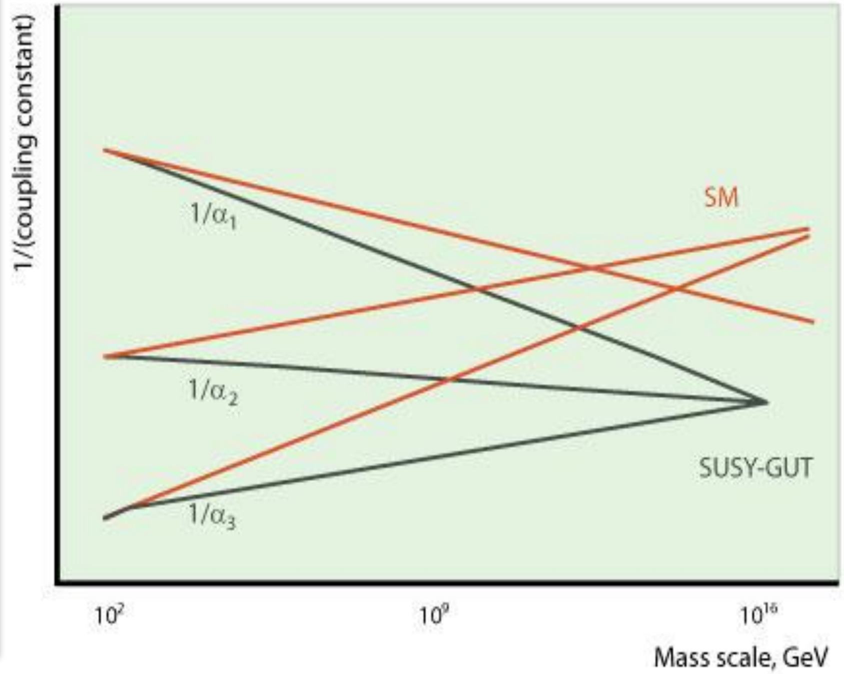
$$\Gamma_{ann} \propto n_\chi^2 \sigma v$$

Annihilation rate enhanced for clumpy halo; near galactic centre and in subhalos, also for larger systems like galaxy clusters, cosmological structure (as seen in N-body simulations).

Supersymmetry

- Invented in the 1970's
- Necessary in most string theories
- Restores unification of couplings
- Solves the hierarchy problem
- Can give right scale for neutrino masses
- Predicted a light Higgs (< 130 GeV)
- May be detected at LHC
- Gives an excellent dark matter candidate (If R-parity is conserved ⇒ stable on cosmological timescales; needed for proton stability)
- Useful as a template for generic WIMP

Freely available software package, written by P. Gondolo, J. Edsjö, L. B., P. Ullio, M. Schelke, E. Baltz, T. Bringmann and G. Duda.
http://www.darksusy.org



The lightest neutralino: The most natural SUSY dark matter candidate

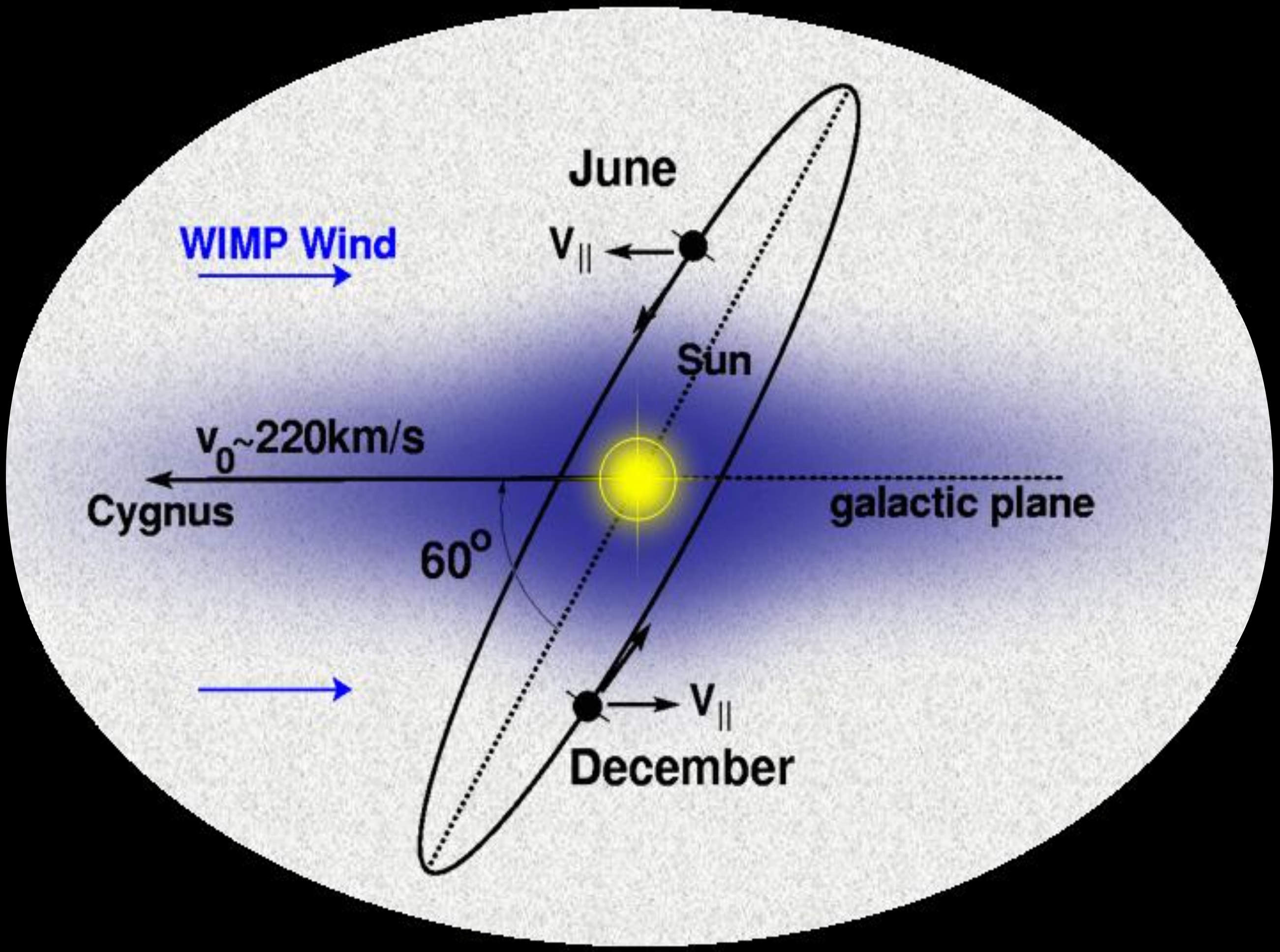
$$\tilde{\chi}^0 = a_1\tilde{\gamma} + a_2\tilde{Z}^0 + a_3\tilde{H}_1^0 + a_4\tilde{H}_2^0$$

Gaugino part Higgsino part

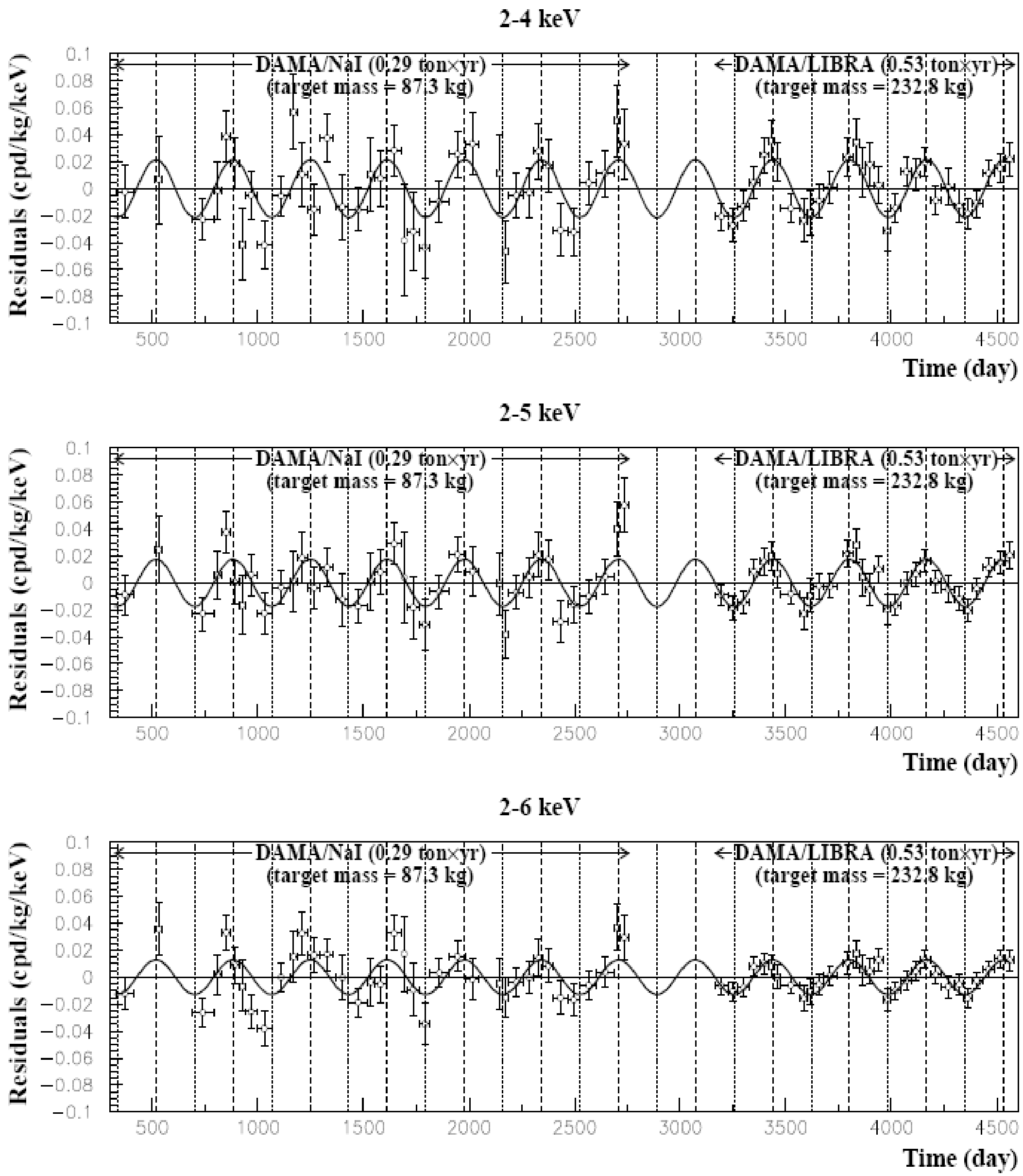
Due to requirement of supersymmetry, the neutralino is a Majorana fermion, i.e., its own antiparticle

Direct and indirect detection of DM:
There have been many (false?) alarms during the last decade. Many of these phenomena would need contrived (non-WIMP) models for a dark matter explanation:

Indication	Status
DAMA annual modulation	Unexplained at the moment – in tension with other experiments
CoGeNT and CRESST excess events	Tension with other experiments (CDMS-II, XENON100)
EGRET excess of GeV photons	Due to instrument error (?) - not confirmed by Fermi-LAT collaboration
INTEGRAL 511 keV γ-line from galactic centre	Does not seem to have spherical symmetry - shows an asymmetry following the disk (?)
PAMELA: Anomalous ratio e^+/e^-	May be due to DM, or pulsars - energy signature not unique for DM
Fermi-LAT positrons + electrons	May be due to DM, or pulsars - energy signature not unique for DM
Fermi-LAT γ-ray excess towards g.c.	Unexplained at the moment – very messy astrophysics
γ-ray excess from galaxy clusters	Very weak indications, may be CR emission?
New: Fermi-LAT 130 GeV line (T. Bringmann, C.Weniger & al.)	3.1 σ – 4.6 σ effect, using public data, unexplained, no Fermi-LAT statement yet



A. Drukier, K. Freese and D. Spergel, 1986



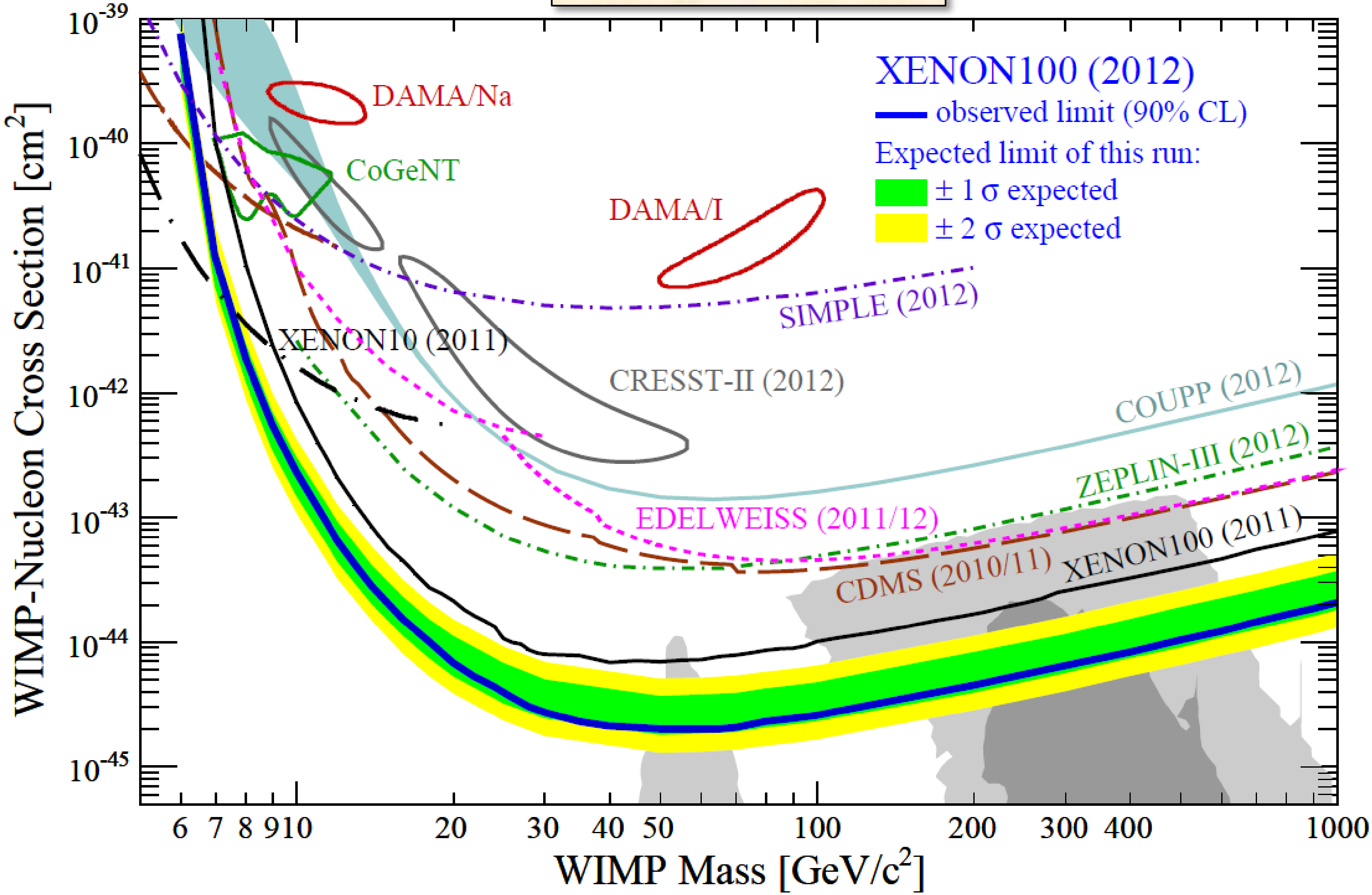
DAMA/LIBRA: Annual modulation of unknown cause. Consistent with dark matter signal (but not confirmed by other experiments).

Claimed significance: More than 8σ (!)

What is it? Does not fit in in standard WIMP scenario…

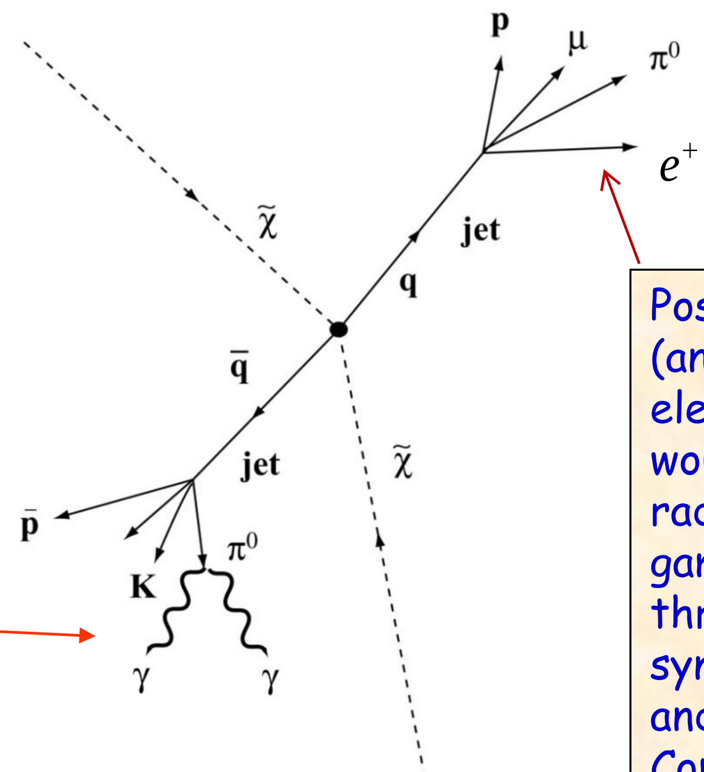
Direct detection limits, Xenon100 data, July 2012:

CoGeNT and DAMA seem well excluded...



Indirect detection: How dark matter shines - annihilation of WIMPs in the galactic halo

Note: equal amounts of matter and antimatter are created in annihilations - this may be a good signature! (Positrons, antiprotons, anti-deuterons.)



Positrons (and electrons) would also radiate gamma rays through synchrotron and inverse Compton radiation

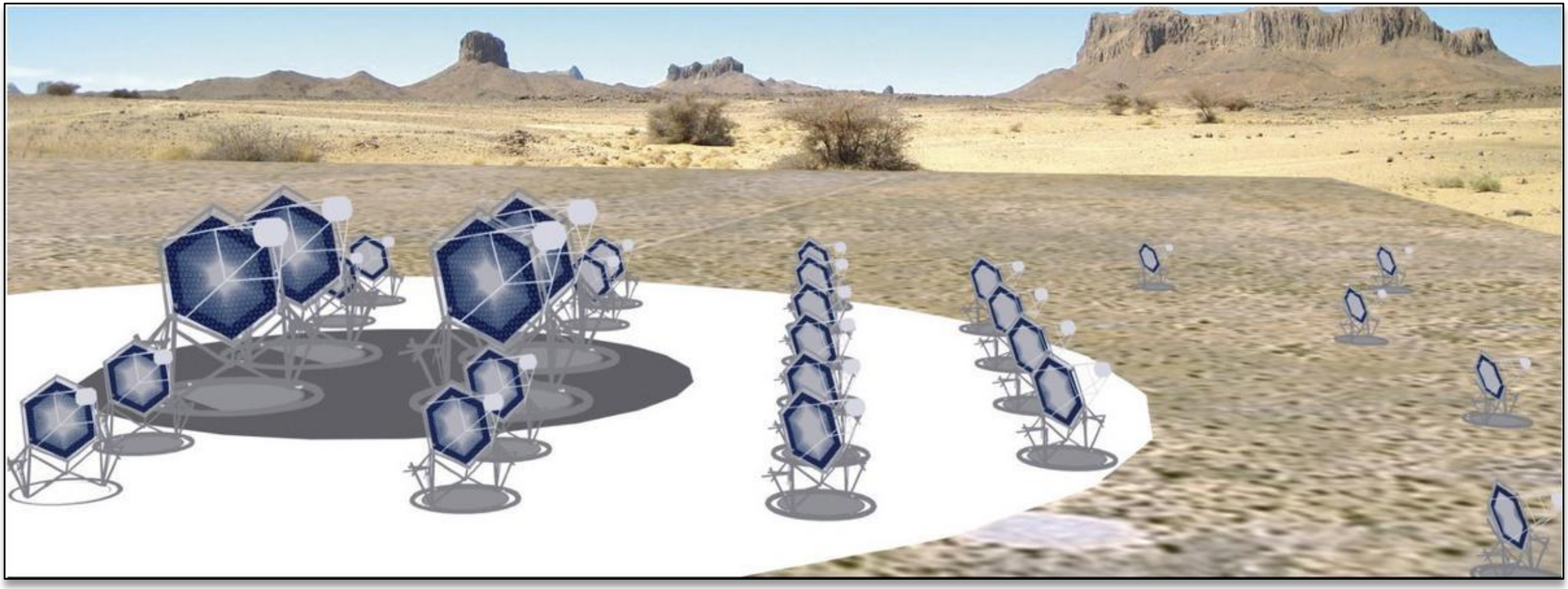
Photons (gamma-rays, i.e. very energetic light) come from decays of particles like neutral pions. Also direct annihilation to 2 gamma-rays is possible: would give a "smoking gun" gamma-ray line at the energy $m_\chi c^2$.

Indirect detection through γ-rays from DM annihilation

Fermi-LAT (Fermi Large Area Telescope)

H.E.S.S. & H.E.S.S.-2

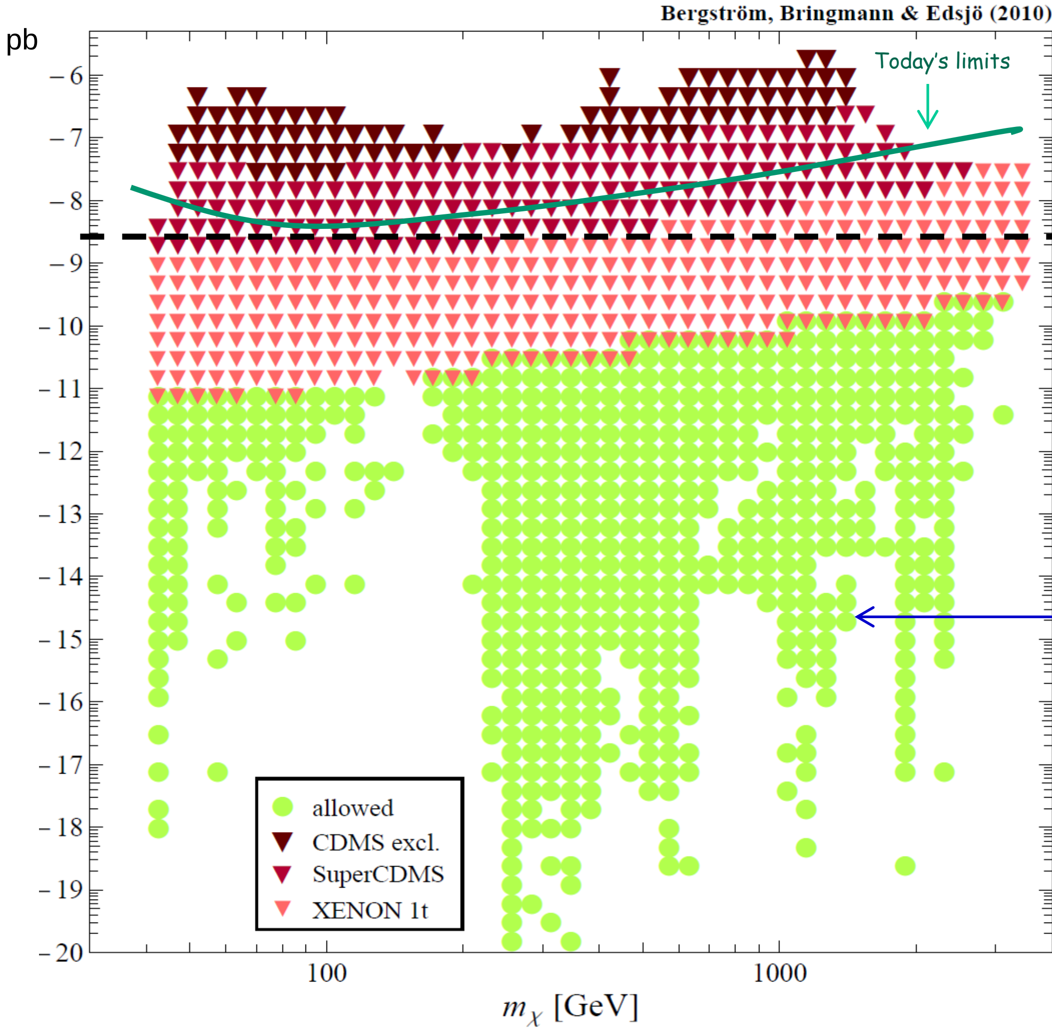
VERITAS

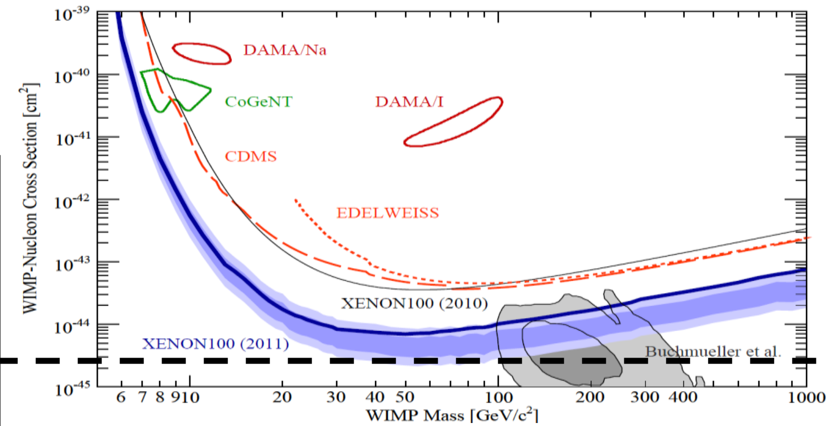


CTA (Cherenkov Telescope Array)

The Dark Matter Array (DMA) – a dedicated DM experiment?

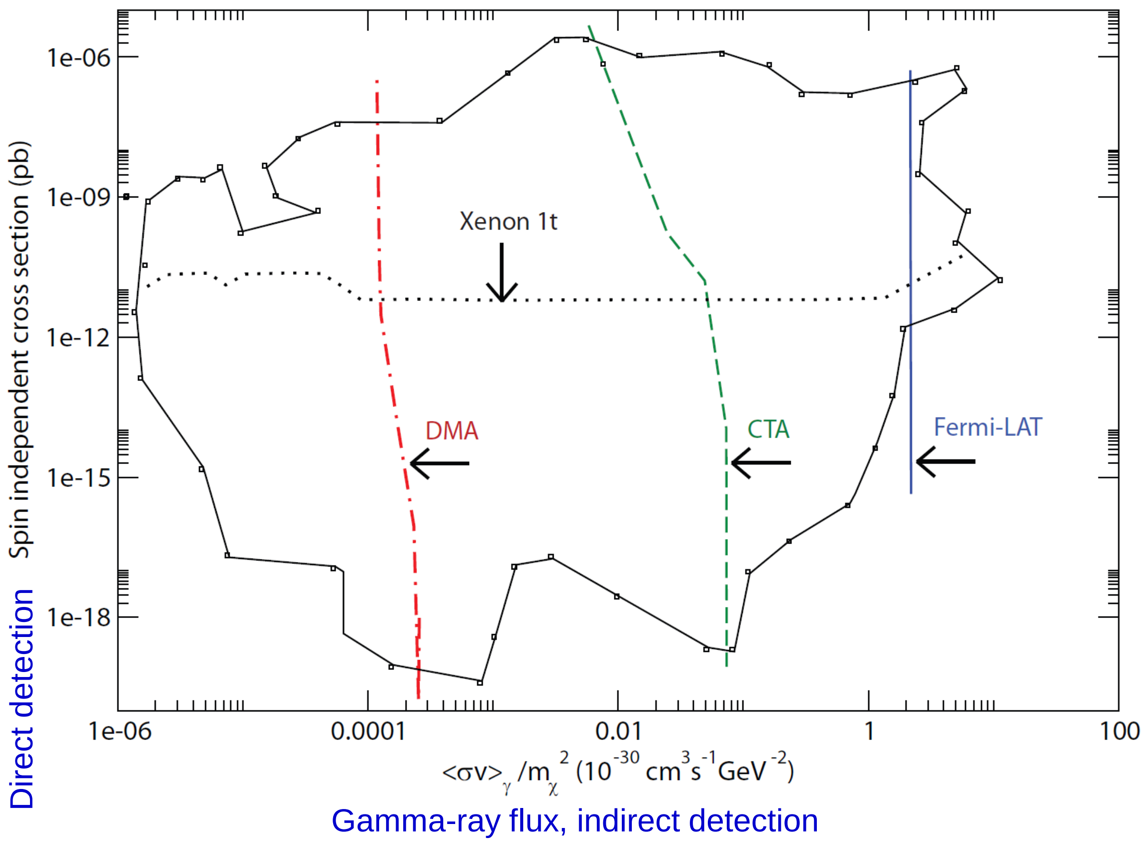
WMAP-compatible models in pMSSM





The parameter space continues, 10 more orders of magnitude in direct detection cross section!

Complementarity between LHC, direct & indirect detection. DM search in γ-rays may be a window for particle physics beyond the Standard Model!

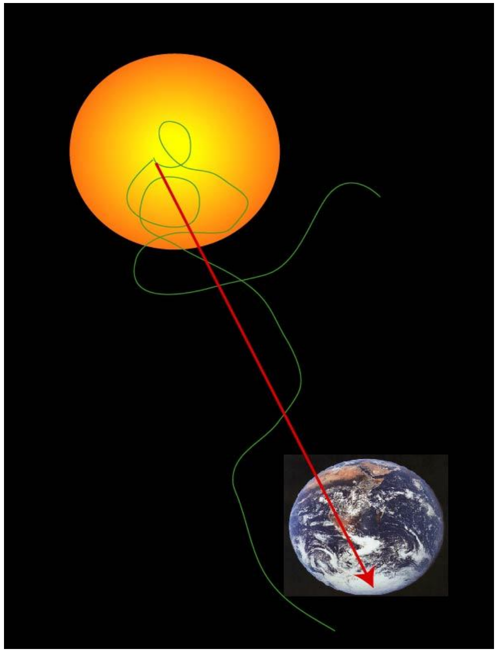


DMA: Dark Matter Array - a dedicated gamma-ray detector for dark matter? (T. Bringmann, L.B., J. Edsjö, 2011)

General pMSSM scan, WMAP-compatible relic density. Check if $S/(S+B)^{0.5} > 5$ in the "best" bin (and demand $S > 5$)

DMA would be a particle physics experiment, cost ~ 1 GEUR. Challenging hard- and software development needed.

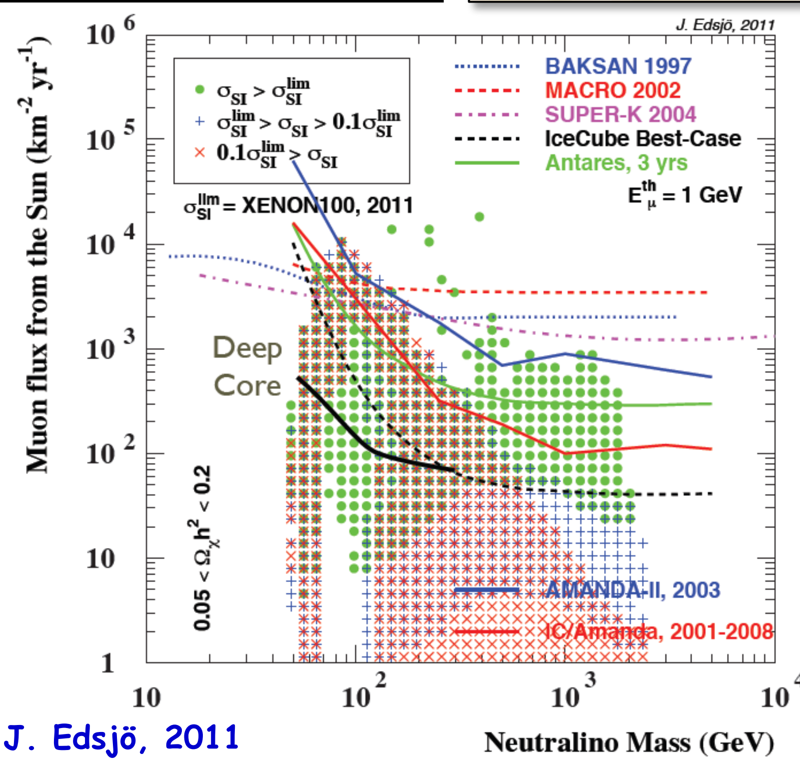
Construction time ~ 10 years, with principle tested in 5@5-type detector at 5 km in a few years...



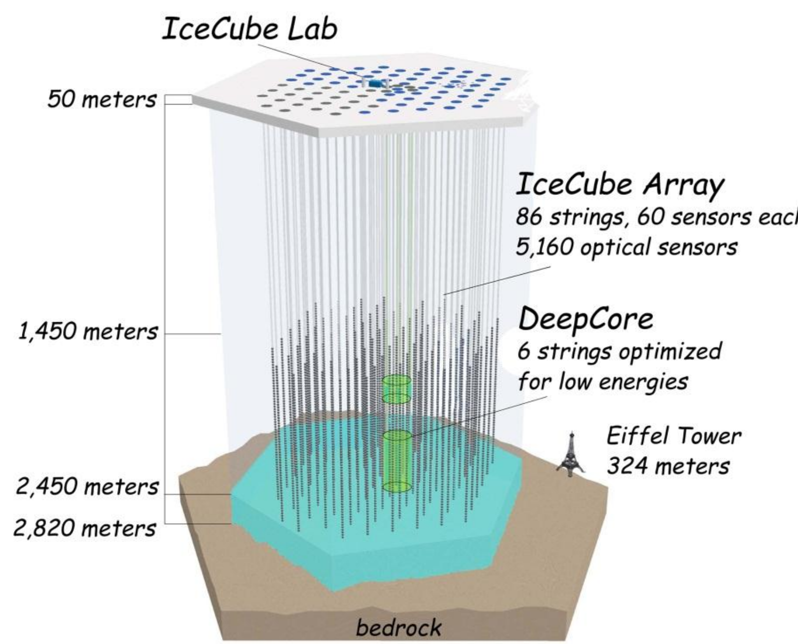
Indirect detection by neutrinos from annihilation in the Sun:

Competitive, due to high proton content of the Sun ⇒ sensitive to spin-dependent interactions. With full IceCube-80 and DeepCore-6 inset operational now, a large new region will be probed. The Mediterranean detector ANTARES has just started to produce limits. (Might be expanded to a km^3 array – KM3NET?)

(Neutrinos from the Earth: Not competitive with spin-independent direct detection searches due to spin-0 elements only in the Earth).



J. Edsjö, 2011



One major uncertainty for indirect detection, especially of gamma-rays: The halo dark matter density distribution at small scales is virtually unknown. Gamma-ray rates towards the Galactic Center may vary by factor of 1000 or more. Adiabatic contraction of DM may give a more cuspy profile.

Fits to N-body simulations – (almost) singular

$$\rho_{\text{Einasto}}(r) = \rho_s e^{\left(-\frac{2}{\alpha}\left[\left(\frac{r}{a}\right)^{\alpha} - 1\right]\right)}, \quad \alpha \approx 0.17$$

$$\rho_{\text{NFW}}(r) = \frac{c}{r(a+r)^2};$$

Fits to rotation curves (cored)

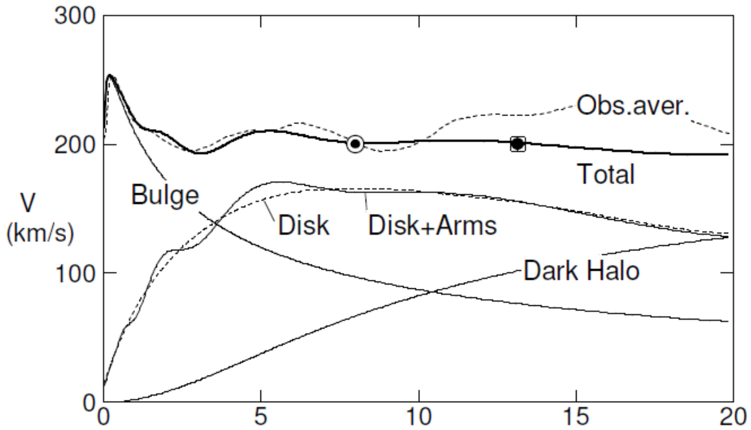
$$\rho_{\text{Burkert}}(r) = \frac{c}{(r+a)(a^2+r^2)};$$

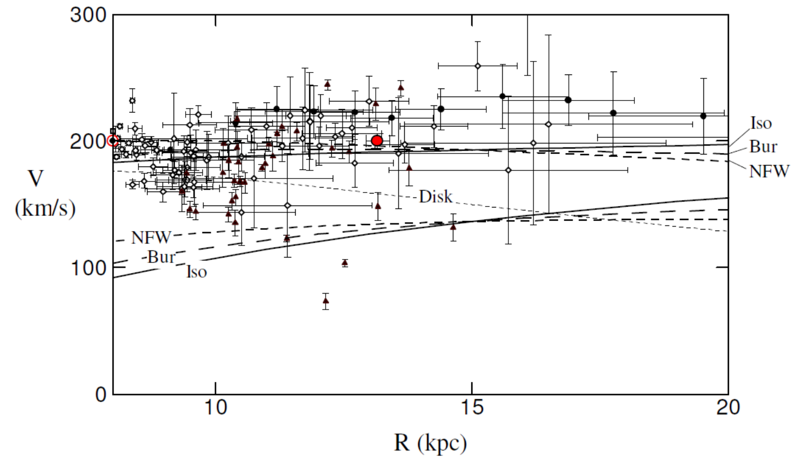
$$\rho_{\text{Isothermal}}(r) = \frac{c}{a^2+r^2};$$

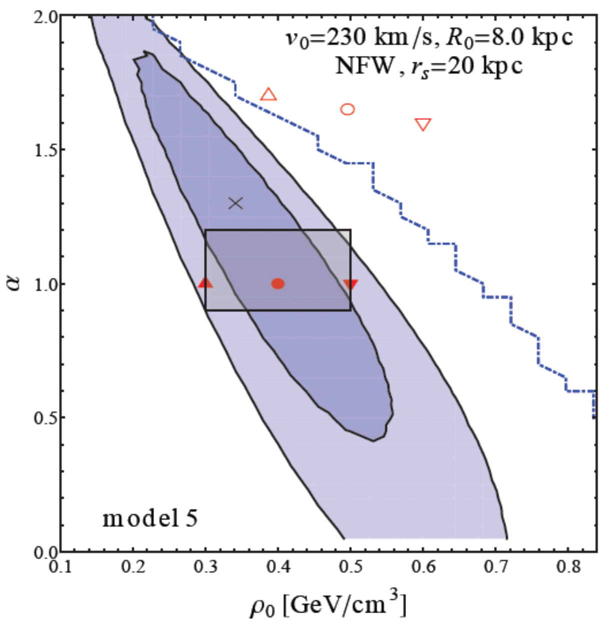
At the solar position, the local density, assuming spherical symmetry, is 0.39 ± 0.03 GeV/cm^3 (R. Catena & P. Ullio, 2010)

Can't we determine right halo model from the Milky Way rotation curve?

No, unfortunately not: Y. Sofue, M. Honma & T. Omodaka, 2008







$$\rho_{DM}(r) = \bar{\rho}_s (r/r_s)^{-\alpha}(1 + r/r_s)^{-3+\alpha} \quad \text{(NFW)}$$

Using also microlensing data, F. Iocco, M. Pato, G. Bertone and P. Jetzer, 2011

Science NOW UP TO THE MINUTE NEWS FROM SCIENCE

Has Dark Matter Gone Missing?

by Adrian Cho on 19 April 2012, 5:41 PM | 14 Comments

FLAWED!

Kinematical and chemical vertical structure of the Galactic thick disk[1,2] II. A lack of dark matter in the solar neighborhood

C. Moni Bidin

Departamento de Astronomía, Universidad de Concepción, Casilla 160-C, Concepción, Chile

cmbidin@astro-udec.cl

G. Carraro[1]

European Southern Observatory, Alonso de Cordova 3107, Vitacura, Santiago, Chile

R. A. Méndez

Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile

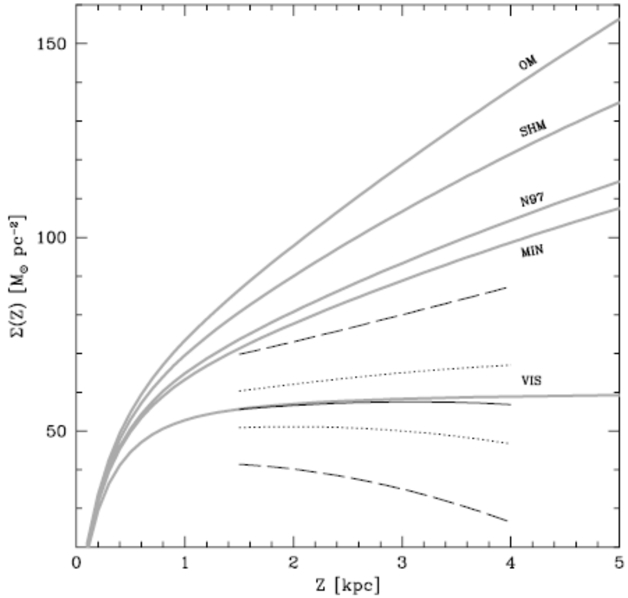
and

R. Smith

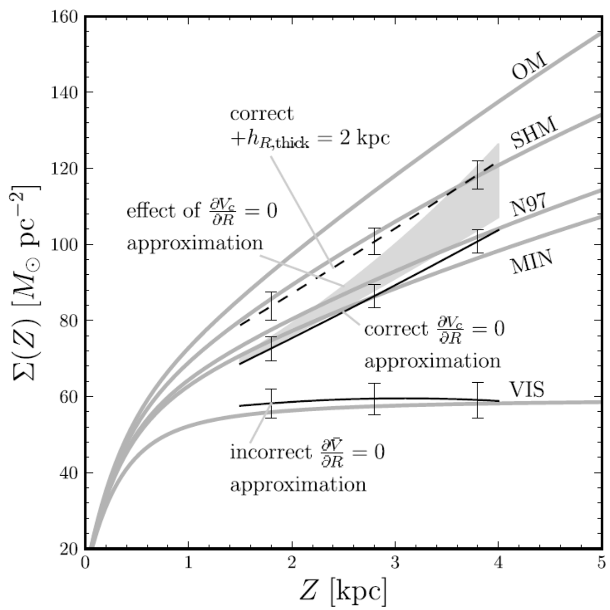
Departamento de Astronomía, Universidad de Concepción, Casilla 160-C, Concepción, Chile

ABSTRACT

We estimated the dynamical surface mass density Σ at the solar position between Z=1.5 and 4 kpc from the Galactic plane, as inferred from the kinematics of thick disk stars. The formulation is exact within the limit of validity of a few basic assumptions. The resulting trend of $\Sigma(Z)$ matches the expectations of visible mass alone, and no dark component is required to account for the observations. We extrapolate a dark matter (DM) density in the solar neighborhood of 0 ± 1 $mM_\odot$ pc^{-3}, and all the current models



C. Moni Bidin & al.



J. Bovy & S. Tremaine.

arXiv:1205.4033v1 [astro-ph.GA] 17 May 2012

On the local dark matter density

Jo Bovy[1] and Scott Tremaine

Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540, USA

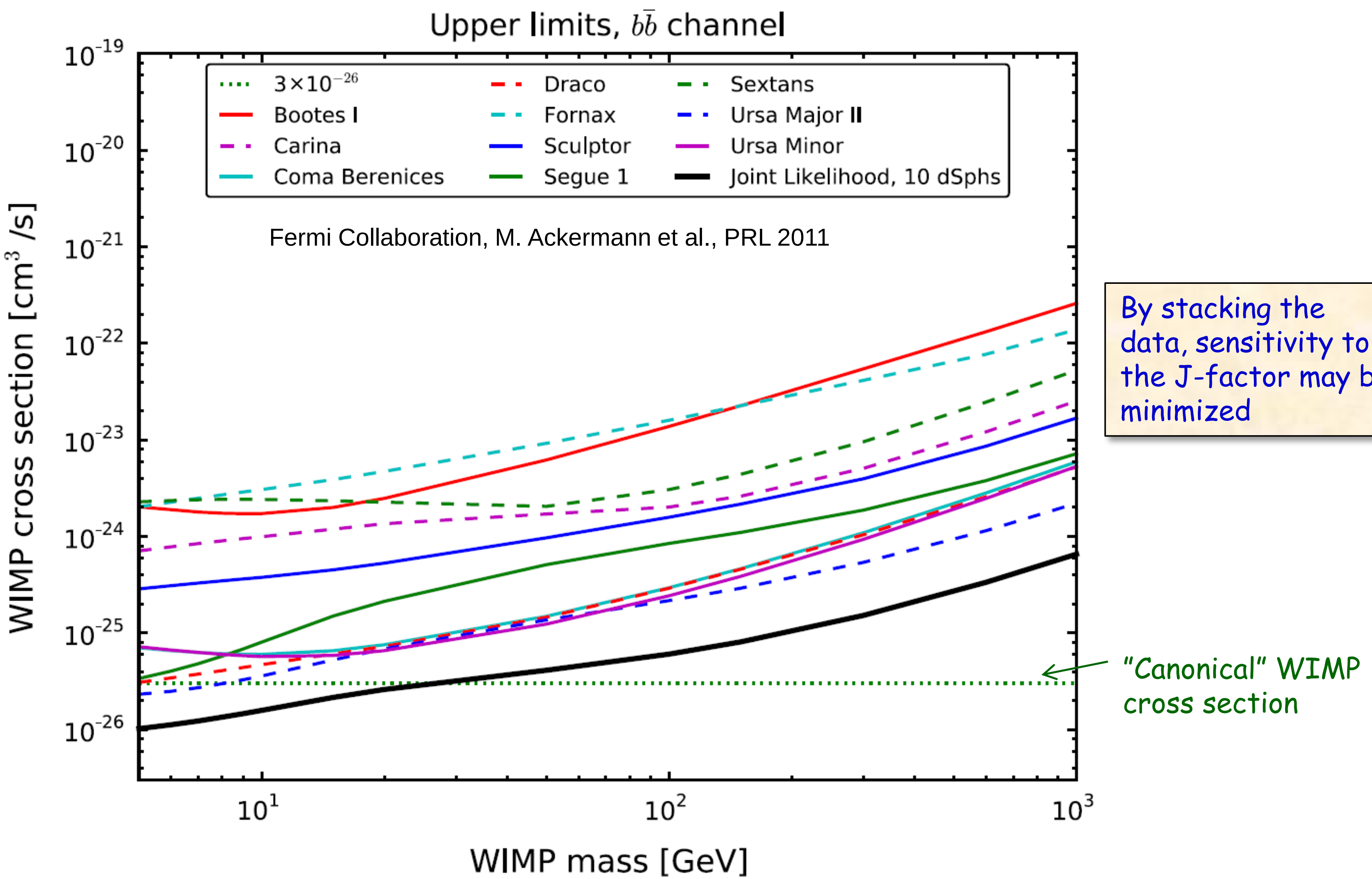
ABSTRACT

An analysis of the kinematics of 412 stars at 1–4 kpc from the Galactic mid-plane by Moni Bidin et al. (2012) has claimed to derive a local density of dark matter that is an order of magnitude below standard expectations. We show that this result is incorrect and that it arises from the invalid assumption that the mean azimuthal velocity of the stellar tracers is independent of Galactocentric radius at all heights; the correct assumption—that is, the one supported by data—is that the circular speed is independent of radius in the mid-plane. We demonstrate that the assumption of constant mean azimuthal velocity is physically implausible by showing that it requires the circular velocity to drop more steeply than allowed by any plausible mass model, with or without dark matter, at large heights above the mid-plane. Using the correct approximation that the circular velocity curve is flat in the mid-plane, we find that the data imply a local dark-matter density of $0.008 \pm 0.002\, M_\odot\,\mathrm{pc}^{-3} = 0.3 \pm 0.1\,\mathrm{Gev\ cm}^{-3}$, fully consistent with standard estimates of this quantity. This is the most robust direct measurement of the local dark-matter density to date.

Subject headings: Galaxy: disk — Galaxy: fundamental parameters — Galaxy: kinematics and dynamics — Galaxy: halo — Galaxy: solar neighborhood — Galaxy: structure

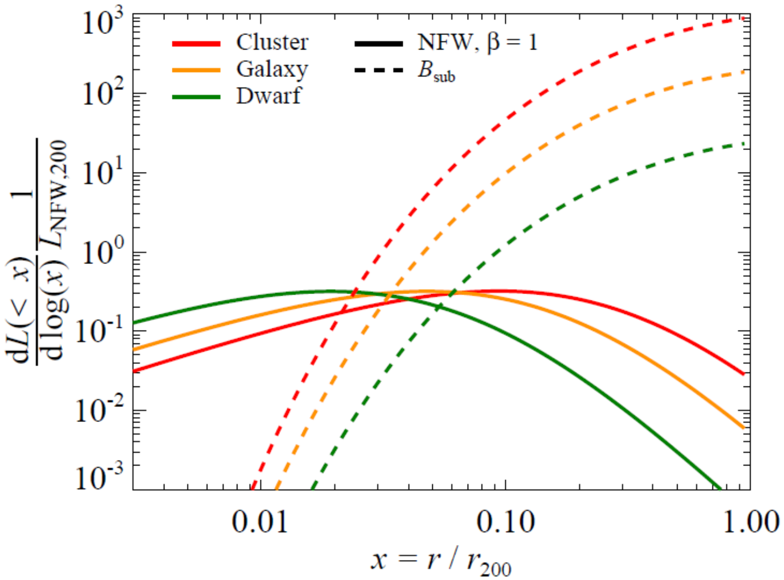
Here, results from GAIA will be important!

New promising experimental DM detection method: Stacking data from many dwarf galaxies, FERMI Collaboration, esp. Maja Garde & Jan Conrad, (Phys. Rev. Letters, December, 2011)

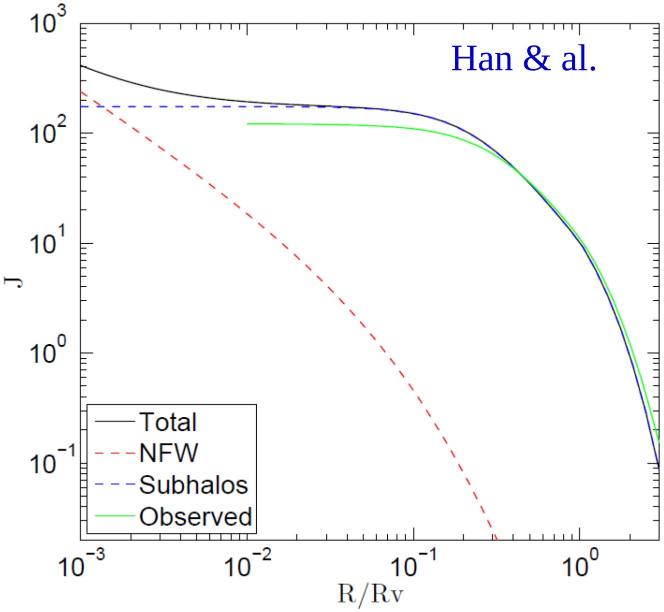


By stacking the data, sensitivity to the J-factor may be minimized

Recent development: Galaxy clusters - Fritz Zwicky would be pleased...



A. Pinzke, C. Pfrommer and L.B., Phys. Rev. D, 2011 (arXiv:1105.3240).



J. Han, C.S. Frenk, V.R. Eke, L. Gao and S.D.M. White, arXiv:1201.1003.

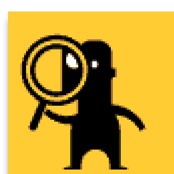
Tidal effects are smaller for clusters ⇒ boost factor of the order of 1000 possible (without Sommerfeld enhancement!). Predicted signal/noise is roughly a factor of 10 better for clusters than for dwarf galaxies! (See also L. Gao et al.)

Clusters may also be suitable for stacking of FERMI data (J. Conrad, S. Zimmer & al).

Conclusion so far:

Despite candidates for DM signals existing it is difficult to prove that a viable dark matter particle is the cause.

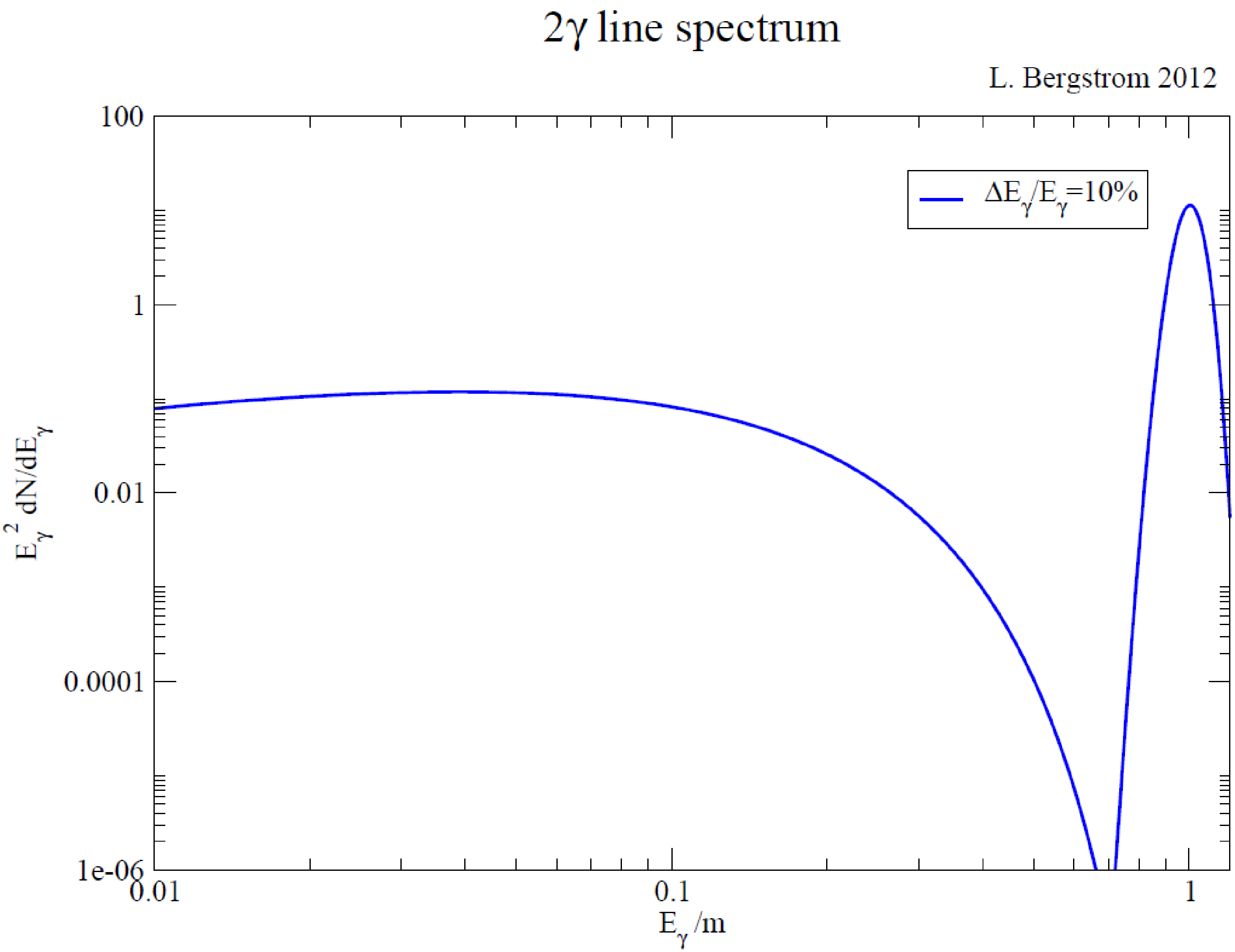
There are well-motivated, other astrophysical and detector-related processes that may give essentially identical distributions.



How do we find the DM suspect?

Smoking gun →

The "smoking gun" signal



Computing the gamma-ray line (L.B. & H. Snellman, 1988; L.B. & P. Ullio, 1997):

My road to this:

I had around 1982-83 computed, in view of the CELSIUS-WASA detector to be built in Uppsala,
$\pi^0 \rightarrow e^+e^-\gamma$ and the loop process
$\pi^0 \rightarrow e^+e^-$
(where there still is an anomaly compared to the Standard Model prediction, by the way).
I also computed in 1985 (with G. Hulth) the Higgs decays
$H^0 \rightarrow \gamma\gamma$ and
$H^0 \rightarrow Z\gamma$
(which are currently very "hot" at CERN).

Here

$$F(x)=\begin{cases}\arcsin^2\sqrt{x}\,, & x<1\,,\\ [\pi^2-\ln^2(\sqrt{x}+\sqrt{x-1})^2]/4 & \\ \quad +i\pi\ln(\sqrt{x}+\sqrt{x-1}), & x>1\,.\end{cases} \tag{28}$$

This gives

$$\sigma(\lambda\bar{\lambda}\rightarrow\gamma\gamma)=m_\lambda^2 a_\lambda^2 \alpha^2 v_{\rm rel}^{-1}\pi^{-3} \times \left|\sum_f \mu_f^2 a_f Q_f^2 F(1/\mu_f^2)\right|^2 , \tag{29}$$

where the sum is over all quarks and leptons (including a factor N_C for color) and a top-quark mass of 50 GeV has been assumed (our results are quite insensitive to this).

To calculate the branching ratio for $\lambda\bar{\lambda}\rightarrow\gamma\gamma$ to $\lambda\bar{\lambda}\rightarrow c\bar{c}$ we assume a common mass $\tilde{m}$ for all squarks and

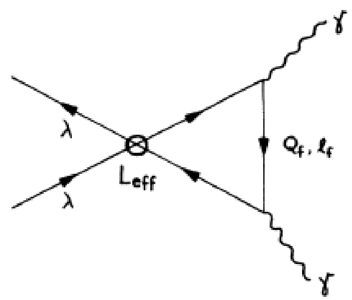
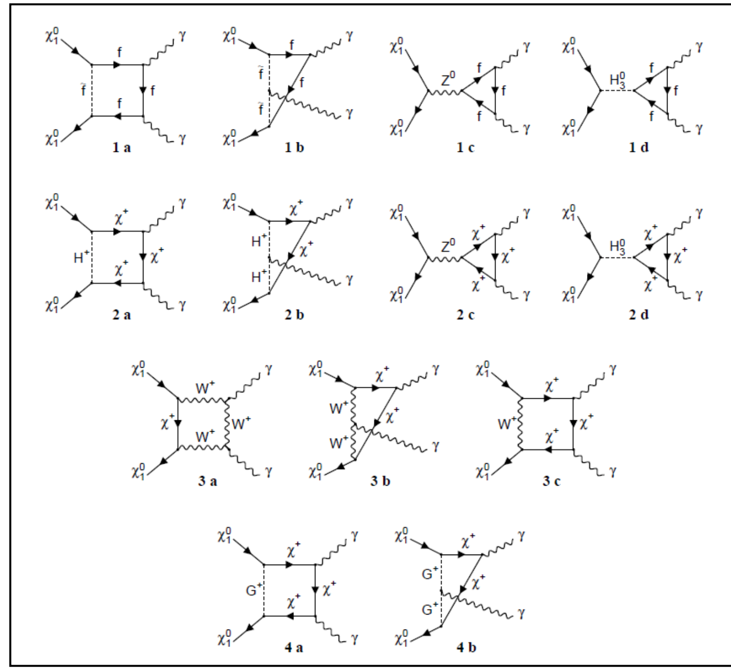


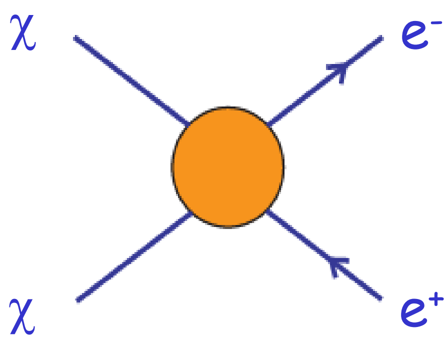
FIG. 3. Effective loop diagrams that contribute to the process $\lambda\bar{\lambda}\rightarrow\gamma\gamma$.

L.B. & H.Snellman, Phys. Rev. D (1988)



L.B. & P. Ullio, Nucl. Phys. B (1997)

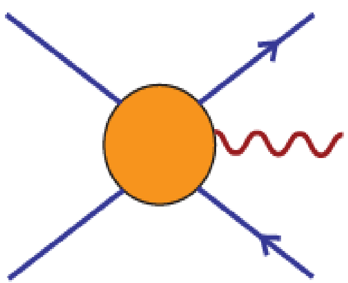
Internal bremsstrahlung: The surprising size of QED "corrections" for slowly annihilating Majorana particles. Example: e^+e^- channel



Annihilation rate $(\sigma v)_0 \sim 3\cdot 10^{-26}$ $cm^{-3}s^{-1}$ at freeze-out, due to p-wave at $(v/c)^2 \sim 0.3$. $\Omega_{CDM}h^2 = 0.1$ for mass ~ 100 - 500 GeV.

Annihilation rate today is in the s-wave, since $v/c \sim 10^{-3}$ i.e. almost at rest. This is suppressed by factor $(m_e/m_\chi)^2$ for Majorana particles.

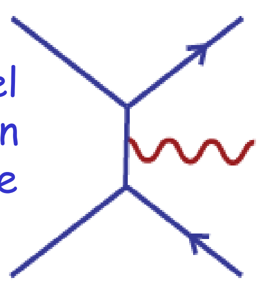
Impossible to detect! Even adding p-wave, it is too small, by orders of magnitude.



Direct emission (inner bremsstrahlung) QED "correction":
$(\sigma v)_{QED}/\ (\sigma v)_0 \sim (\alpha/\pi)\ (m_\chi/m_e)^2 \sim 10^9 \Rightarrow 10^{-28}\ cm^3s^{-1}$

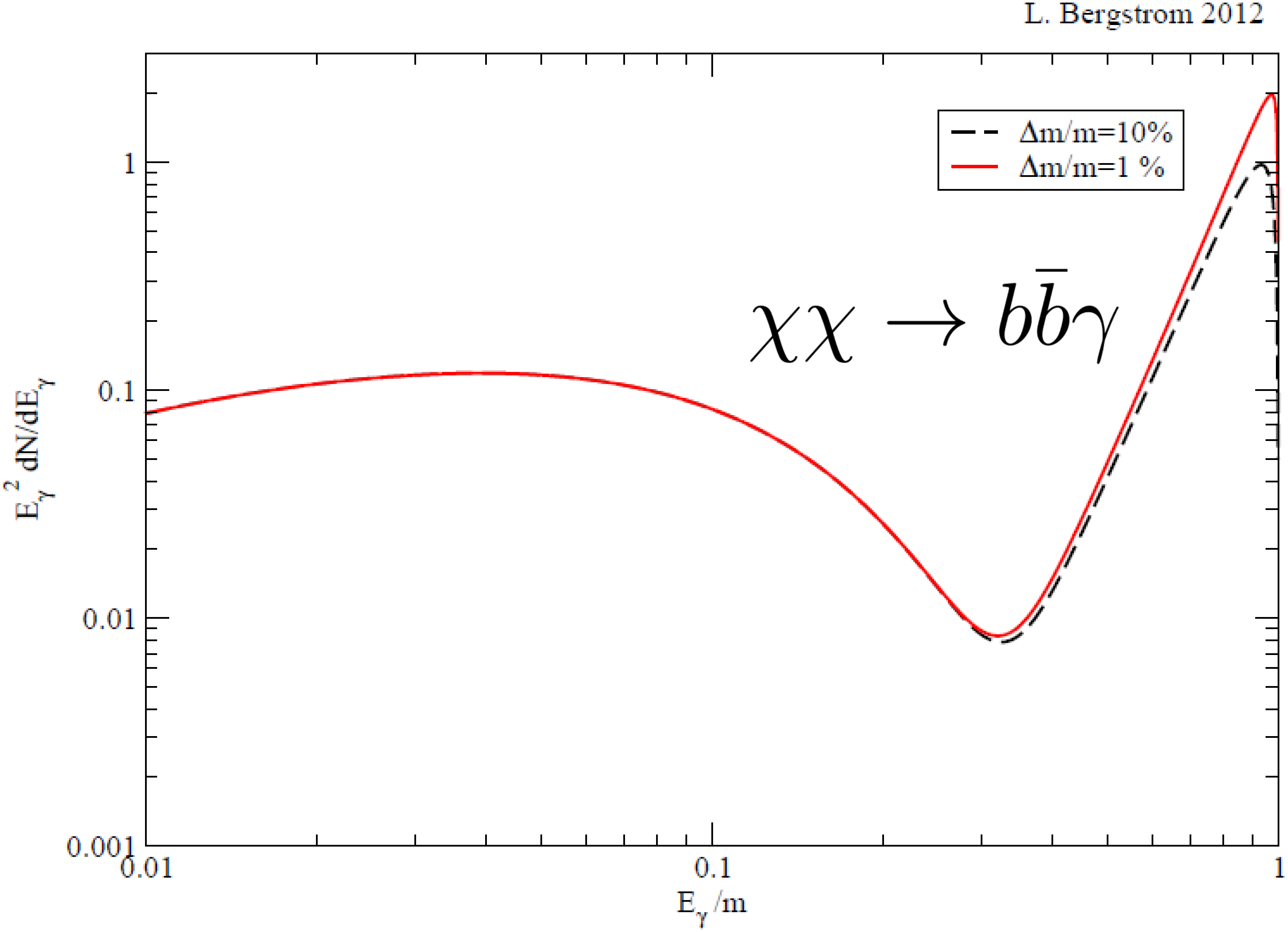
The "expected" QED correction of a few per cent is here a factor of 10^8 instead! May give detectable gamma-ray rates – with good signature!

t-channel selectron exchange



(L.B. 1989; E.A. Baltz & L.B. 2003, T. Bringmann, L.B. & J. Edsjö, 2008; M. Ciafalone, M. Cirelli, D. Comelli, A. De Simone, A. Riotto & A. Urbano, 2011; N. F. Bell, J.B. Dent, A.J. Galea,T.D. Jacques, L.M. Krauss and T.J.Weiler, 2011)

Inner bremsstrahlung spectrum



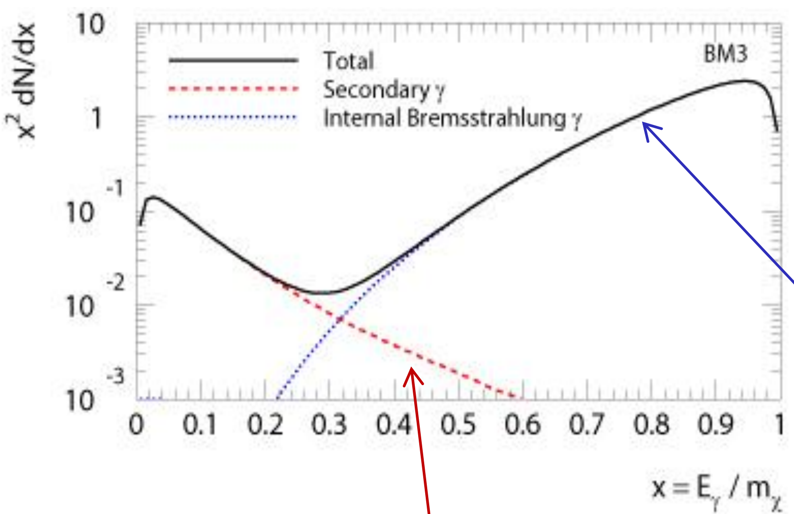
QED corrections (Internal Bremsstrahlung) in the MSSM: good news for detection probability in gamma-rays:

New Gamma-Ray Contributions to Supersymmetric Dark Matter Annihilation

JHEP, 2008

Torsten Bringmann*
SISSA/ISAS and INFN, via Beirut 2 - 4, I - 34013 Trieste, Italy

Lars Bergström† and Joakim Edsjö‡
Department of Physics, Stockholm University, AlbaNova University Center, SE - 106 91 Stockholm, Sweden
(Dated: October 16, 2007)



Example: DM mass = 233 GeV, has WMAP-compatible relic density (stau coannihilation region).

Calculation including Internal Bremsstrahlung (DarkSUSY 5.1).

Previous estimate of gamma-ray spectrum

Predictions for the standard WIMP template, SUSY:

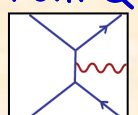
Indirect detection of SUSY DM through γ-rays. Three types of signal:

• Continuous from π^0, K^0, … decays.

• Monoenergetic line from quantum loop effects, $\chi\chi \rightarrow \gamma\gamma$ and $Z\gamma$.

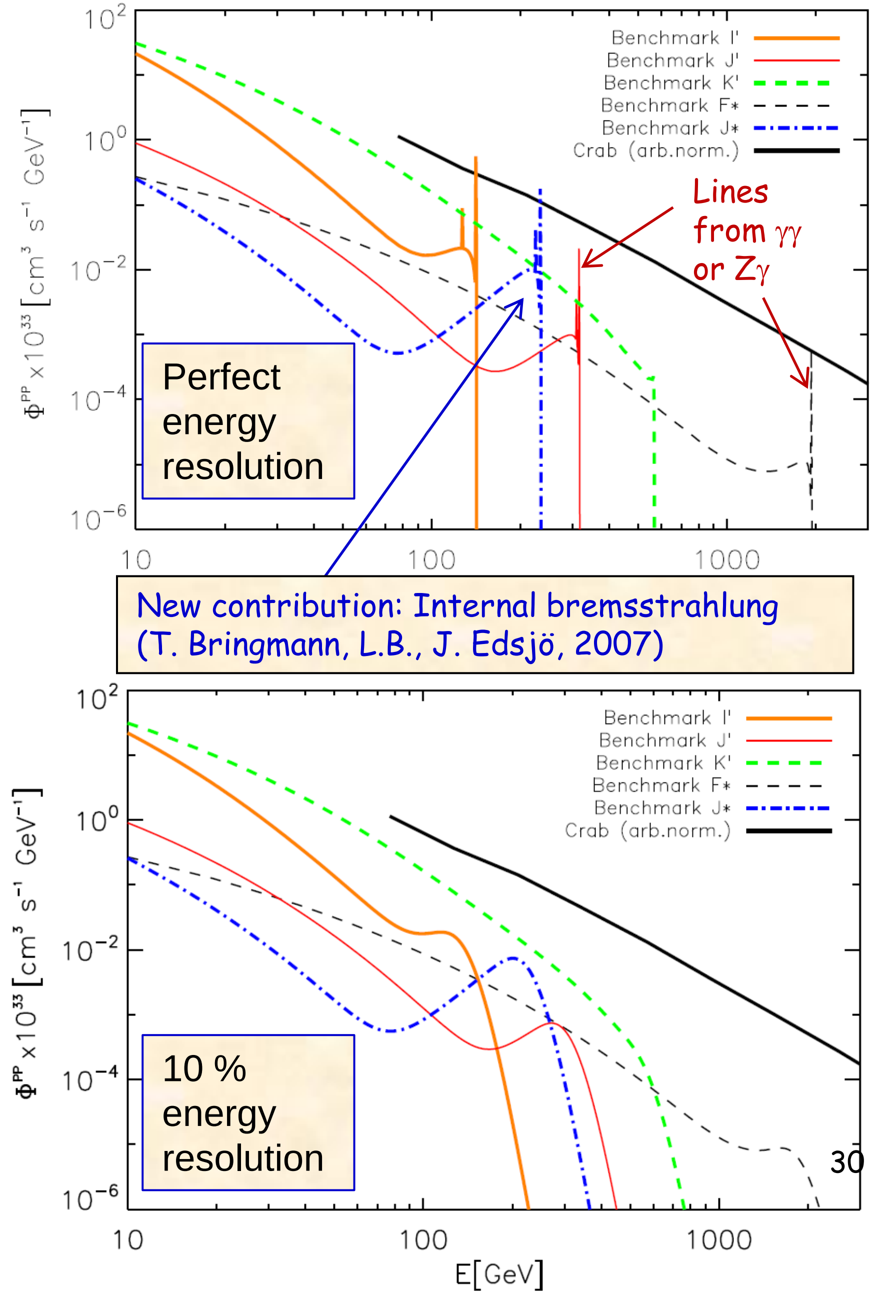
Smoking gun →

• Internal bremsstrahlung from QED process.



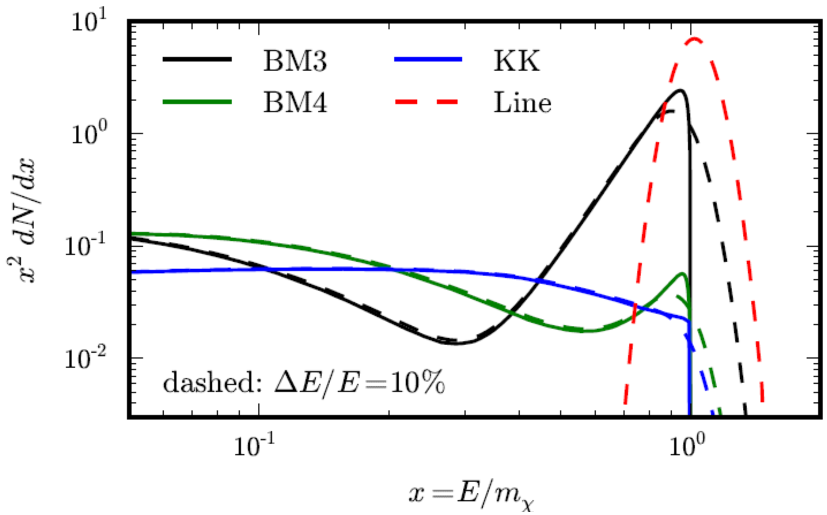
Enhanced flux possible thanks to halo density profile and substructure (as predicted by N-body simulations of CDM).

Good spectral and angular signatures! But uncertainties in the predictions of absolute rates, due e.g. to poorly known DM density profile.

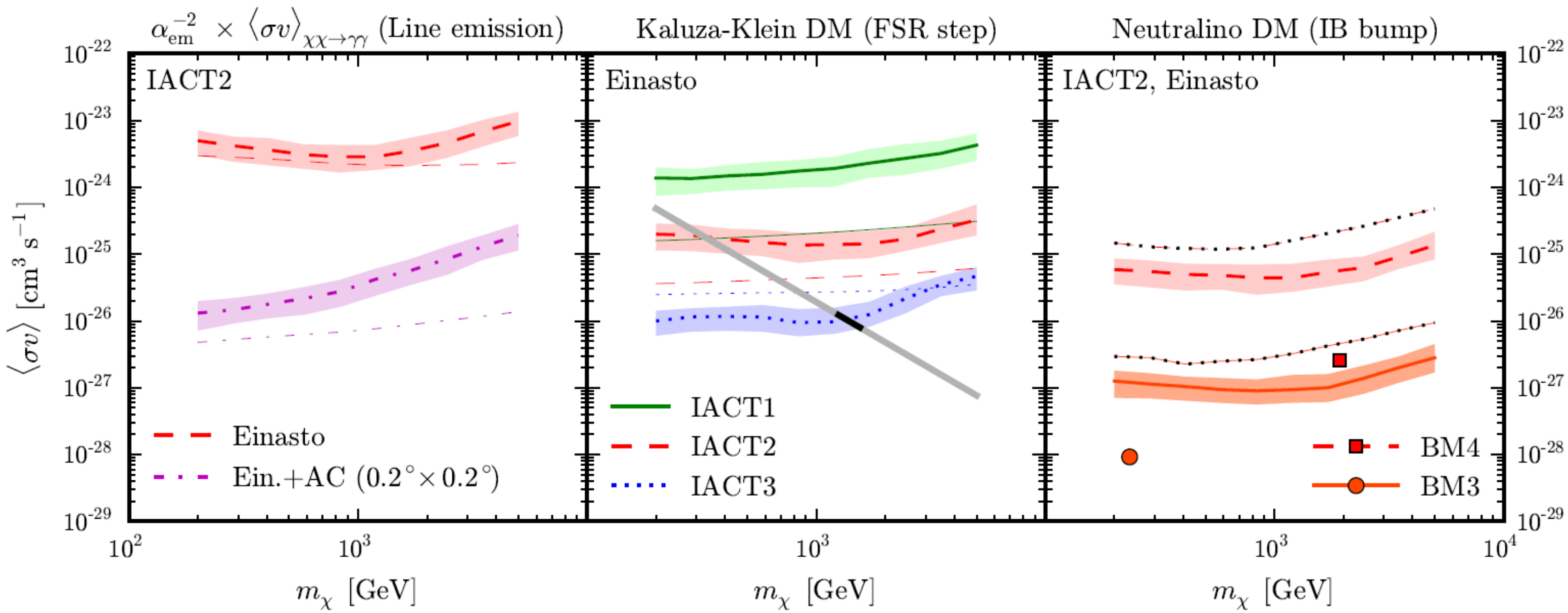


T. Bringmann, M. Doro & M. Fornasa, 2008; cf. L.B., P.Ullio & J. Buckley 1998.

T. Bringmann, F. Calore, G. Vertongen & C. Weniger Phys. Rev. D, 2011



Can one make use of the peculiar spectral features?



PREPARED FOR SUBMISSION TO JCAP

TUM-HEP 828/12
MPP-2012-54

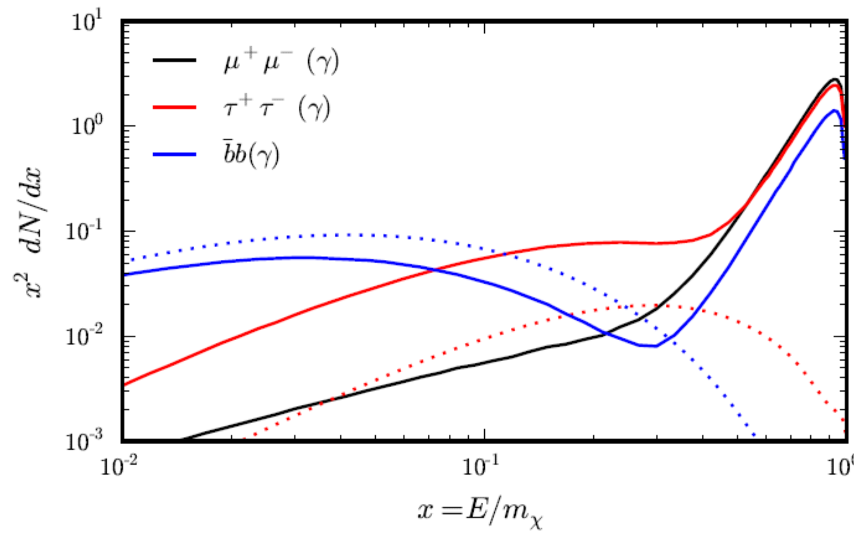
Fermi LAT Search for Internal Bremsstrahlung Signatures from Dark Matter Annihilation

Torsten Bringmann[a] Xiaoyuan Huang[b] Alejandro Ibarra[c] Stefan Vogl[c] Christoph Weniger[d]

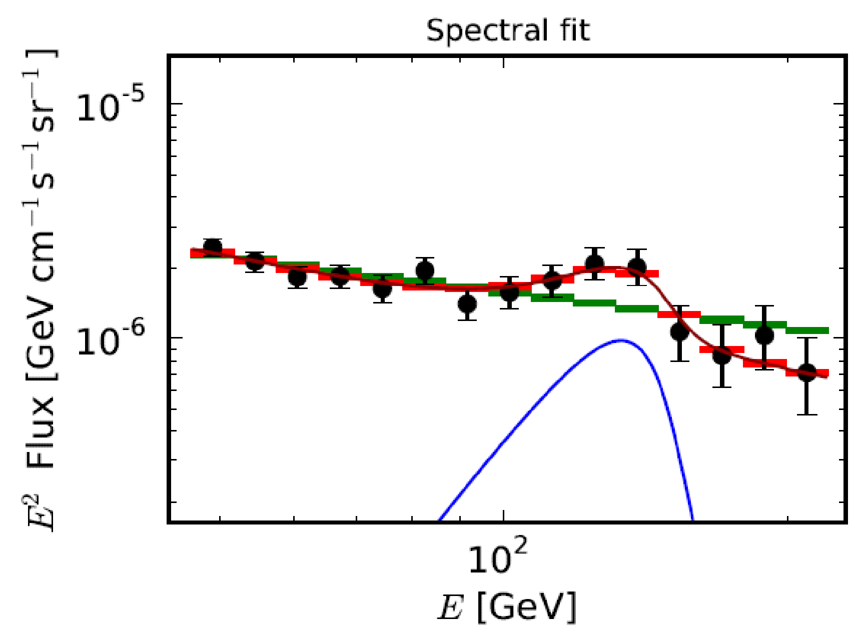
[a]II. Institute for Theoretical Physics, University of Hamburg, Luruper Chaussee 149, DE-22761 Hamburg, Germany
[b]National Astronomical Observatories, Chinese Academy of Sciences, Beijing, 100012, China
[c]Physik-Department T30d, Technische Universität München, James-Franck-Straße, 85748 Garching, Germany
[d]Max-Planck-Institut für Physik, Föhringer Ring 6, 80805 Munich, Germany

E-mail: torsten.bringmann@desy.de, huang@mppmu.mpg.de, ibarra@tum.de, stefan.vogl@tum.de, weniger@mppmu.mpg.de

Abstract. A commonly encountered obstacle in indirect searches for galactic dark matter is how to disentangle possible signals from astrophysical backgrounds. Given that such signals are most likely subdominant, the search for pronounced spectral features plays a key role for indirect detection experiments; monochromatic gamma-ray lines or similar features related to internal bremsstrahlung, in particular, provide smoking gun signatures. We perform a dedicated search for the latter in the data taken by the Fermi gamma-ray space telescope during its first 43 months. To this end, we use a new adaptive procedure to select optimal

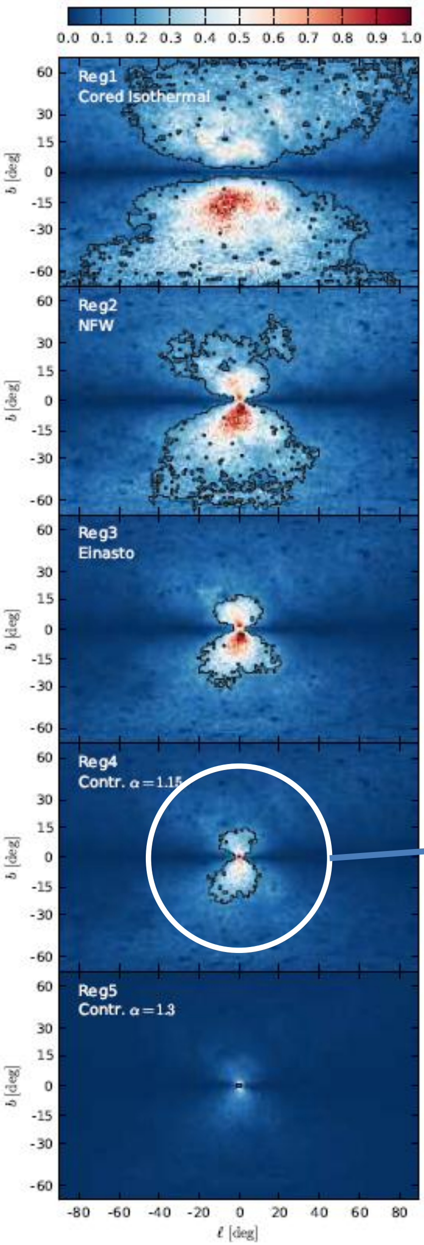


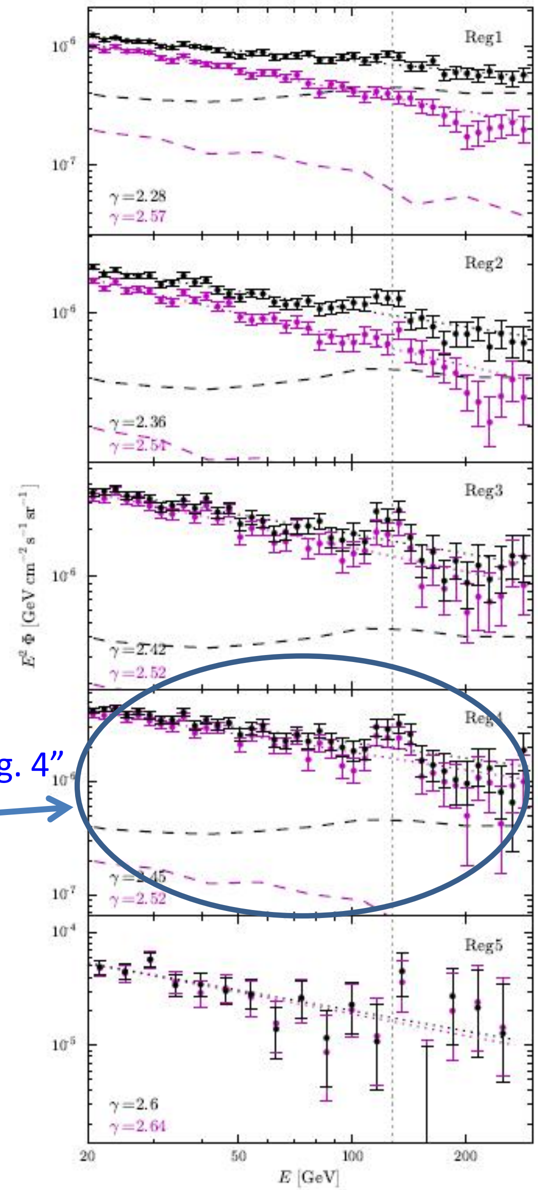
43 months of (public) Fermi data



Mass = 149 GeV
Significance 4.3σ (3.1σ if "look elsewhere" effect included)

April, 2012: C. Weniger

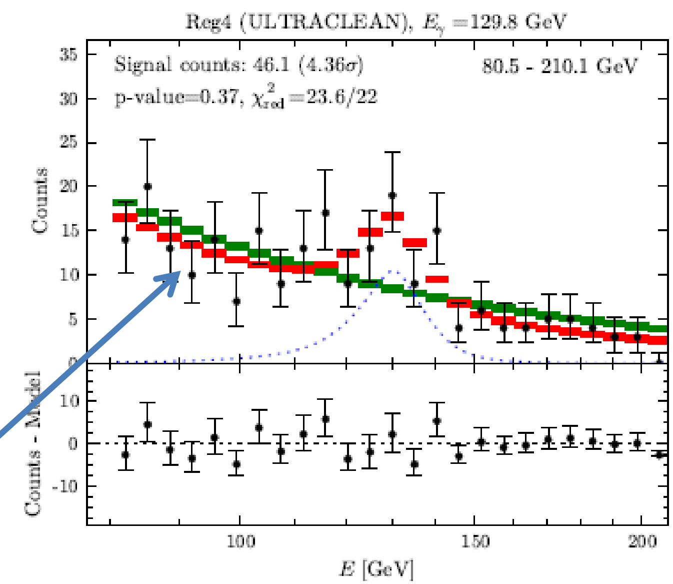




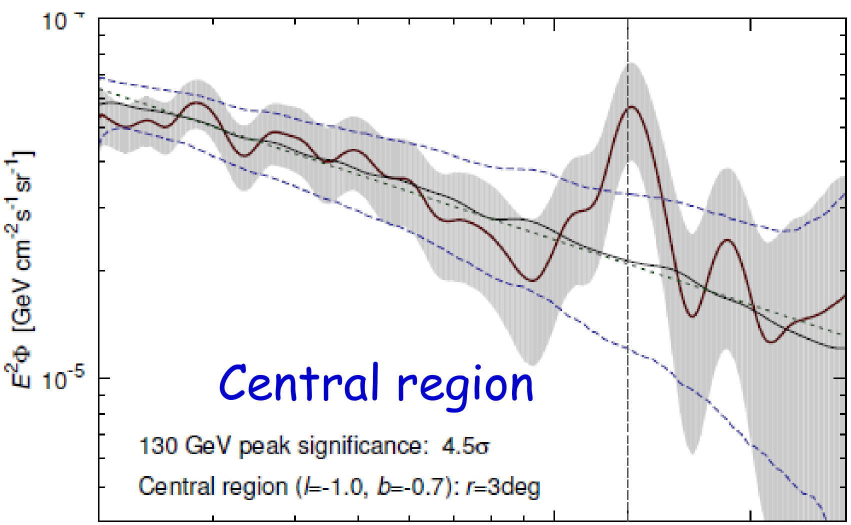
"Reg. 4"

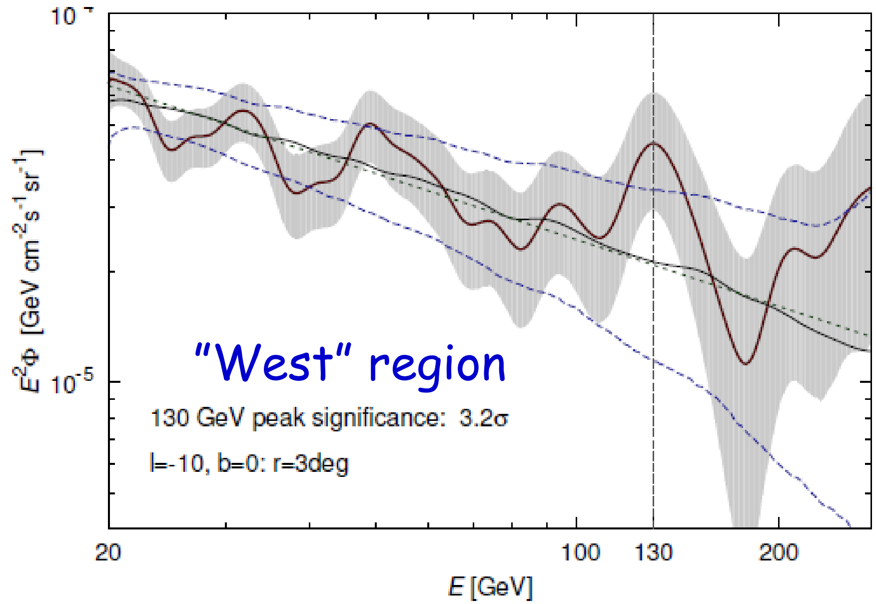
43 months of (public) Fermi data

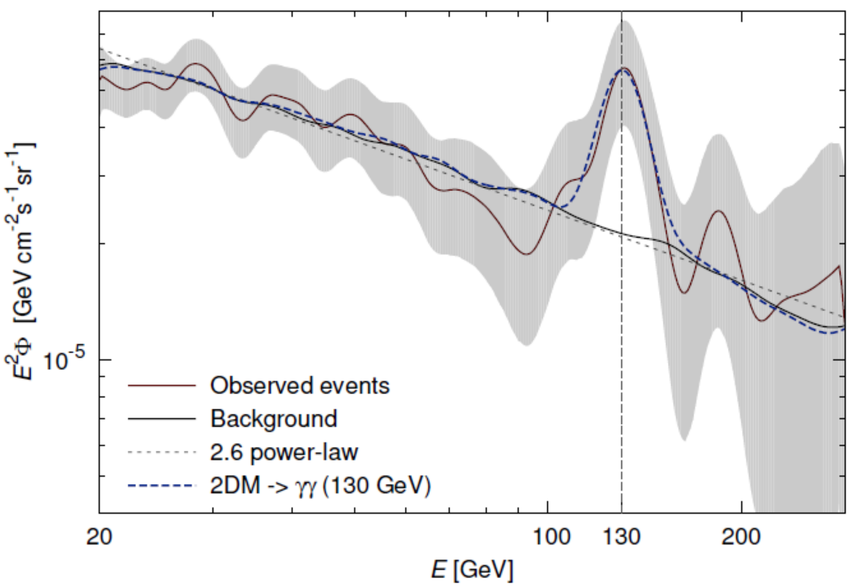
γ-ray line fit:



Mass = 130 GeV
Significance 4.6σ (3.3σ if "look elsewhere" effect included)

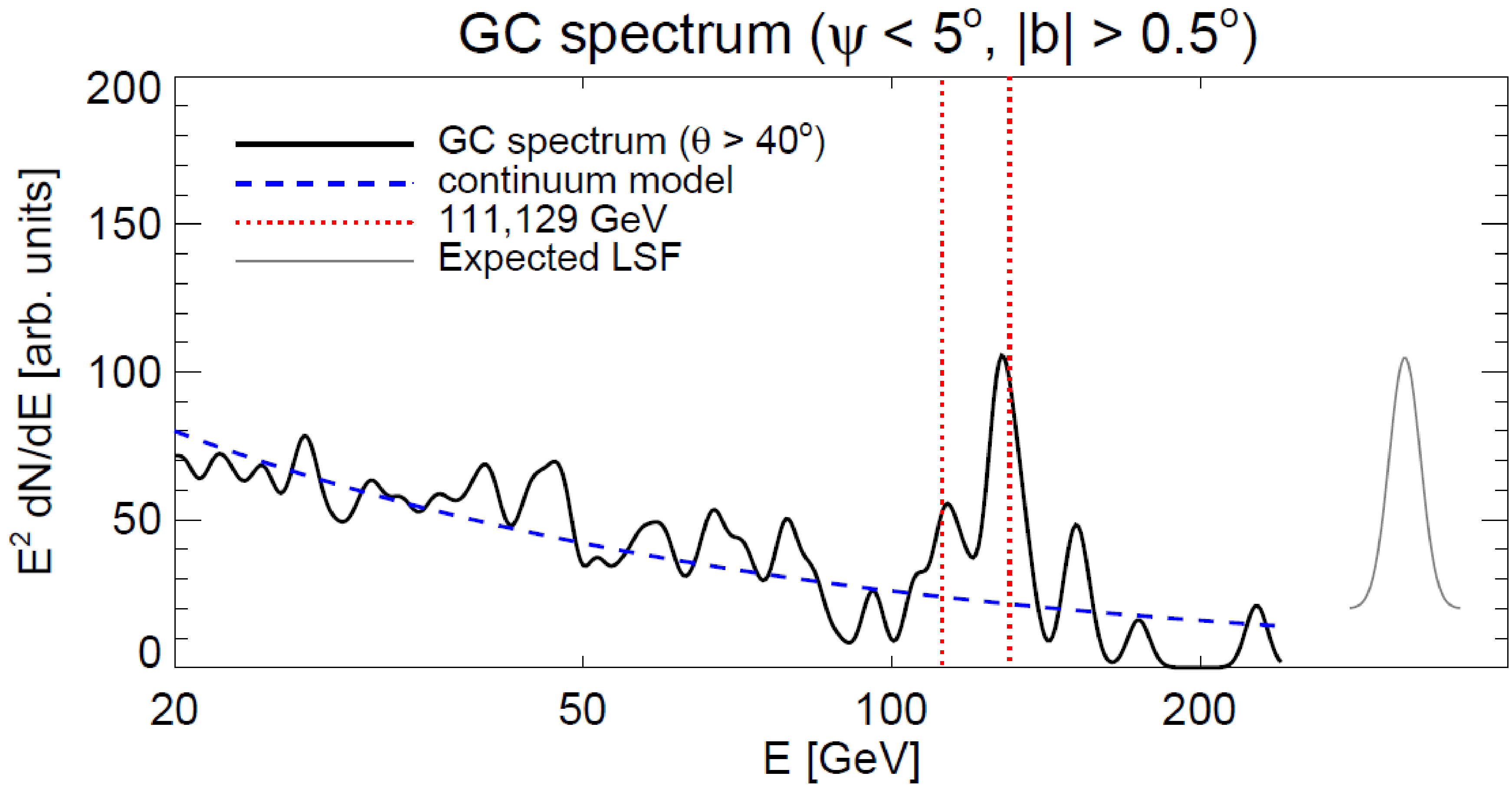






E. Tempel, A. Hektor and M. Raidal, May 2012:
Independent confirmation of the existence of the excess, and that it is not correlated with Fermi bubbles.

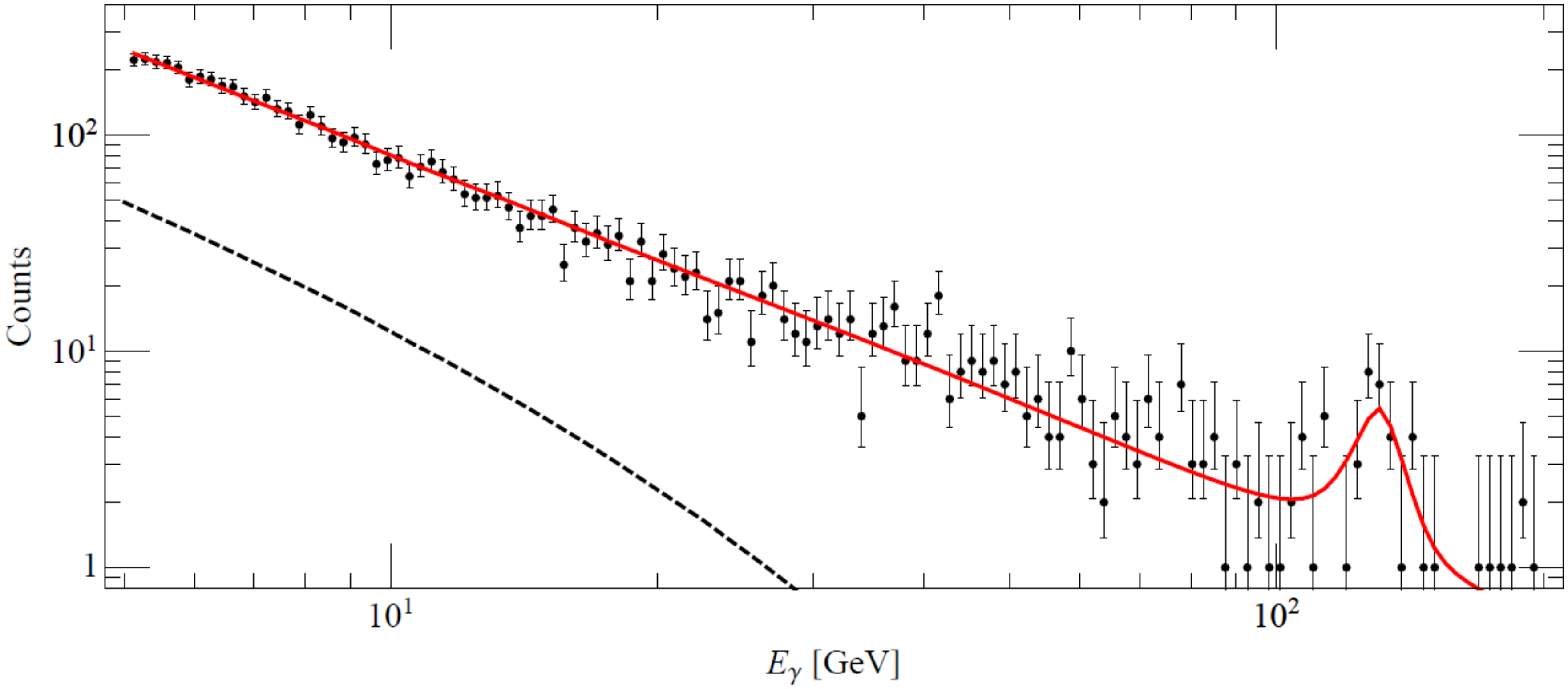
Best fit: $\gamma\gamma$ line, mass m_χ = 130 GeV



Another independent verification: M. Su and D. Finkbeiner, June 2012

T. Cohen, M. Lisanti, T. Slatyer & J. Wacker, arxiv:1207.0800:

Very little room for a continuum contribution -> some SUSY models ruled out



Fermi-LAT public data

L.B. & E.A. Baltz, Phys Rev D, 2002

The right-handed neutrino N_R (in "radiative see-saw" models) may be the dark matter candidate, and internal bremsstrahlung plus $\gamma\gamma$ annihilation will give a peculiar spectrum

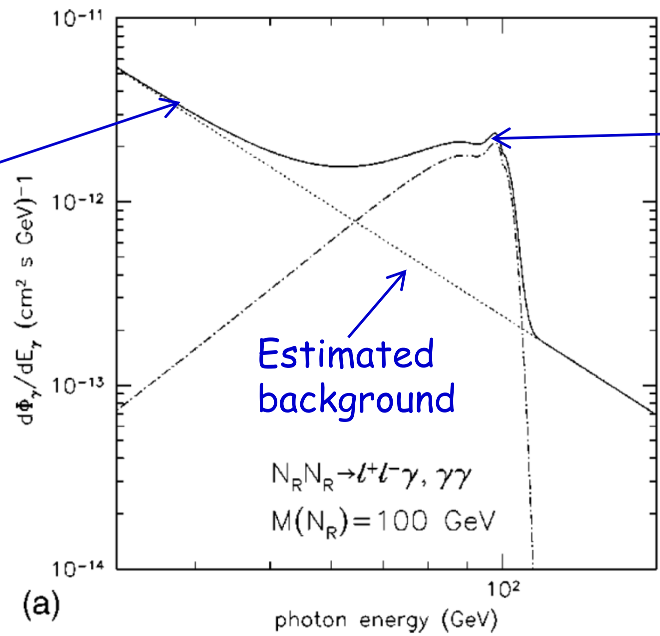
$$\sigma v \left(N_R N_R \to \ell^+\ell^-\right) = \frac{g_\ell^4}{8\pi m_N^4 (1+f^2)^2}\left[m_\ell^2 + \frac{2}{3}\left(\frac{1+f^4}{(1+f^2)^2}\right) m_N^2 v^2 + \dots\right]$$

s wave part

p wave part

$f = m_S/m_N$

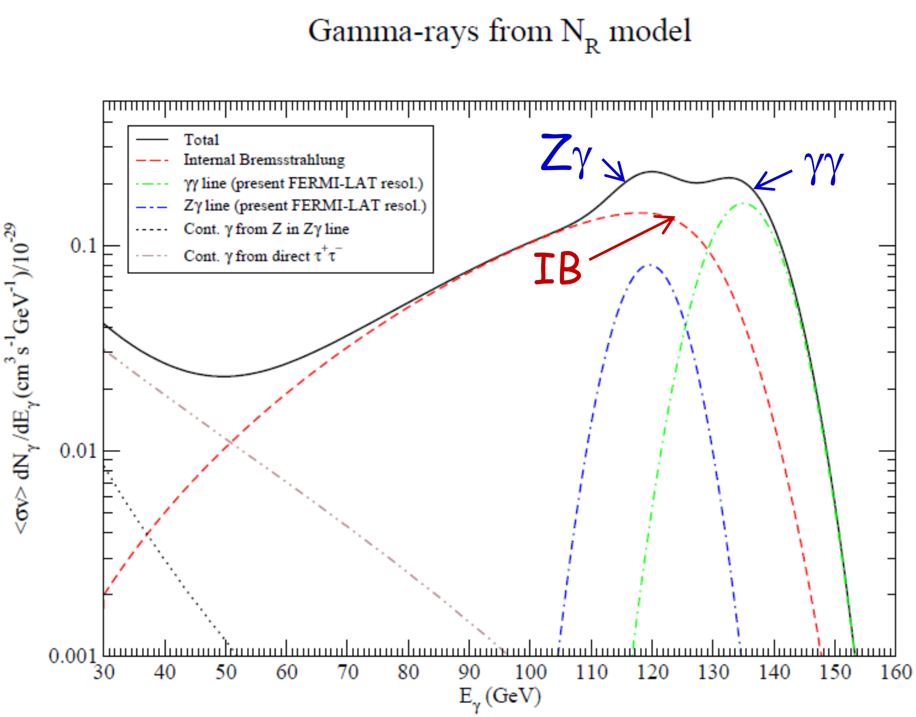
Note: no continuum here

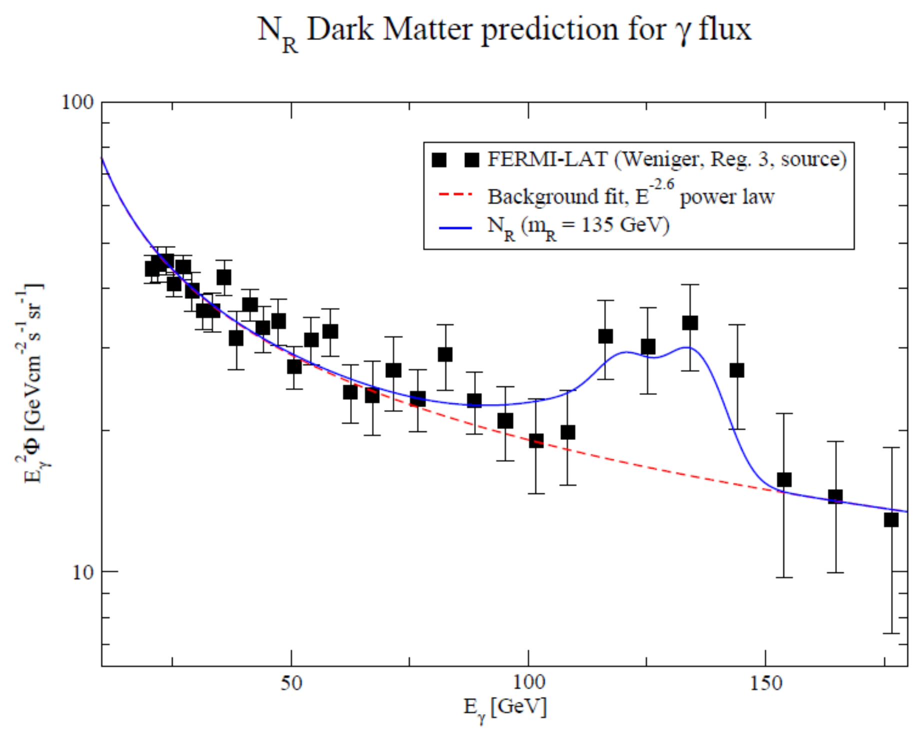


$\gamma\gamma$ peak

L.B., 2012: Re-analysis of N_R model, mass 135 GeV (Phys Rev D, in press):

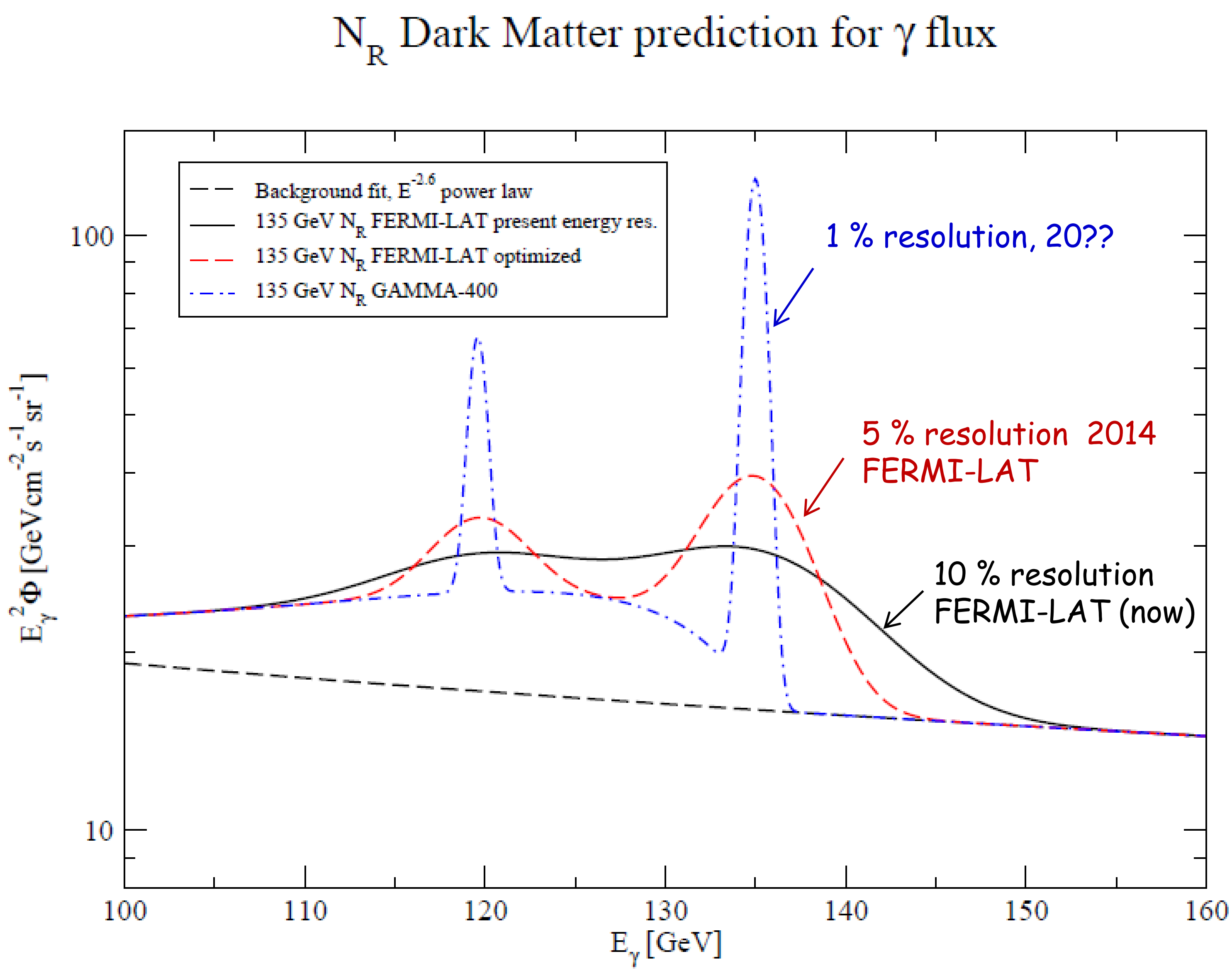
- Add $Z\gamma$ line (neglected in paper with Baltz)
- Adjust absolute rate
- Compare with data





Assume Fermi-LAT energy resolution, ~ 10 %

The future:


N_R Dark Matter prediction for γ flux
Background fit, E^-2.6 power law
135 GeV N_R FERMI-LAT present energy res.
135 GeV N_R FERMI-LAT optimized
135 GeV N_R GAMMA-400
1 % resolution, 20??
5 % resolution 2014
FERMI-LAT
10 % resolution
FERMI-LAT (now)
100
10
100
110
120
130
140
150
160
E_γ [GeV]
E_γ^2 Φ [GeVcm^-2 s^-1 sr^-1]

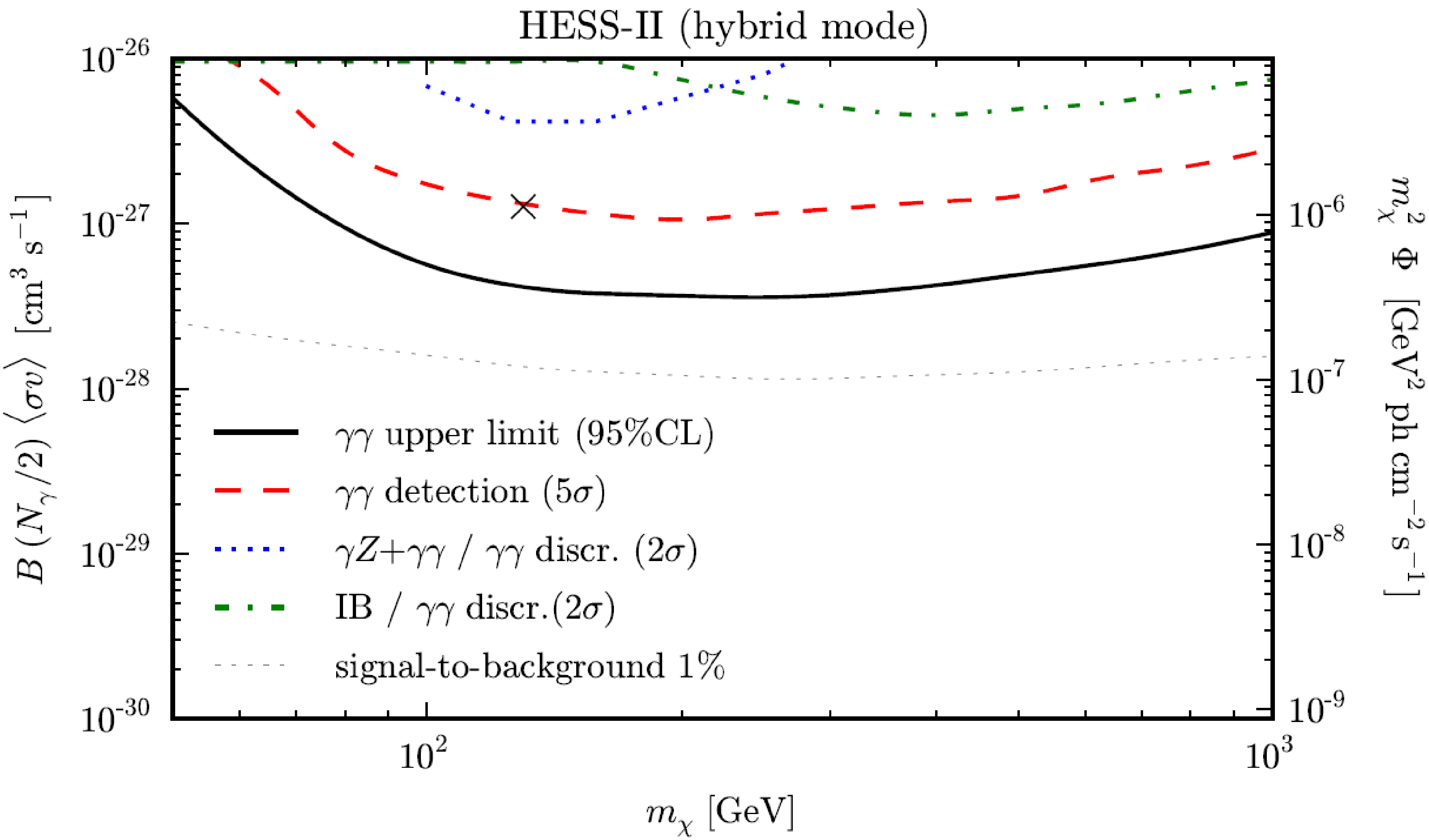
A new player in the game: HESS-II in Namibia

300 mirror segments financed by 5 MSEK K&A Wallenberg grant (J.Conrad & L.B.)

Saw first light in August, 2012

Ideal viewing conditions for galactic centre April - August

L.B., G. Bertone, J. Conrad, C. Farnier & C. Weniger, arXiv:1207.6773 (JCAP, in press):



5 σ detection after 50 hours of observation

Two reasons for still being skeptical:

- Statistics is relatively low, and background not well studies in this energy range.
- The Fermi-LAT collaboration have not yet confirmed the effect. They have some spurious signal from the Earth's limb also appearing at ~ 130 GeV – may this point to an (unknown) instrumental effect?

The good news is that within one or two years we will definitely know: Fermi-LAT may have collected data with higher energy resolution, and HESS-II may have conclusively either verified or ruled out the signal.

The future for gamma-ray space telescopes?

GAMMA-400, 100 MeV – 3 TeV, an approved Russian γ-ray satellite. Planned launch 2017-18.
Energy resolution (100 GeV) ~ 1 %. Effective area ~ 0.4 m^2 . Angular resolution (100 GeV) ~ 0.01°

DAMPE: Satellite of similar performance.
An approved Chinese γ-ray satellite. Planned launch 2015-16.

HERD: Instrument on Chinese Space Station. Energy resolution (100 GeV) ~ 1 %. Effective area ~ 1 m^2. Angular resolution (100 GeV) ~ 0.01°. Planned launch around 2020.

All three have detection of dark matter as one key science driver

Ideal, e.g., for looking for spectral DM-induced features, like searching for γ-ray lines! If the 130 - 135 GeV structure exists, it should be seen with more than 10σ significance (L.B., G. Bertone, J. Conrad, C. Farnier & C. Weniger, JCAP, in press). Otherwise, the parameter space of viable models will be probed with unprecedented precision.

NEWS & ANALYSIS

SCIENCE, May 20, 2011

SPACE SCIENCE

Chinese Academy Takes Space Under Its Wing

LOFTY AMBITIONS

Mission	Chief scientist	Goals	Estimated launch
HXMT	Li Tipei, CAS Institute of High Energy Physics and Tsinghua University	Survey of x-ray sources; detailed observations of known objects	2014
Shijian-10	Hu Wenrui, CAS Institute of Mechanics	Study physical and biological systems in microgravity and strong radiation environment	Early 2015
KuaFu Project	William Liu, Canadian Space Agency and CAS Center for Space Science and Applied Research	Study solar influence on space weather	Mid-2015
Dark Matter Satellite	Chang Jin, CAS Purple Mountain Observatory	Search for dark matter; study cosmic ray acceleration	Late 2015
Quantum Science Satellite	Pan Jianwei, University of Science and Technology of China	Quantum key distribution for secure communication; long-distance quantum entanglement	2016

The Chinese initiative: The Dark Matter Satellite (DAMPE)

Conclusions

- Most of the experimental DM indications are not particularly convincing at the present time.

- Fermi-LAT already has competitive limits for low masses, but maybe indications of line(s) and/or internal bremsstrahlung at 130 - 135 GeV. We will soon know whether it is a real effect.

- IceCube has a window of opportunity for spin-dependent DM scattering.

- The field is entering a very interesting period: CERN LHC is running at 8 TeV at full luminosity, and in a couple of years at 14 TeV; XENON 1t is being installed; IceCube and DeepCore are operational; Fermi will collect at least 5 more years of data; CTA, Gamma-400, DAMPE and HERD may operate by 2018, and perhaps even a dedicated DM array, DMA some years later.

- However, as many experiments now enter regions of parameter space where a DM signal *could* be found, we also have to be prepared for false alarms.

- These are exciting times for dark matter searches !

The End