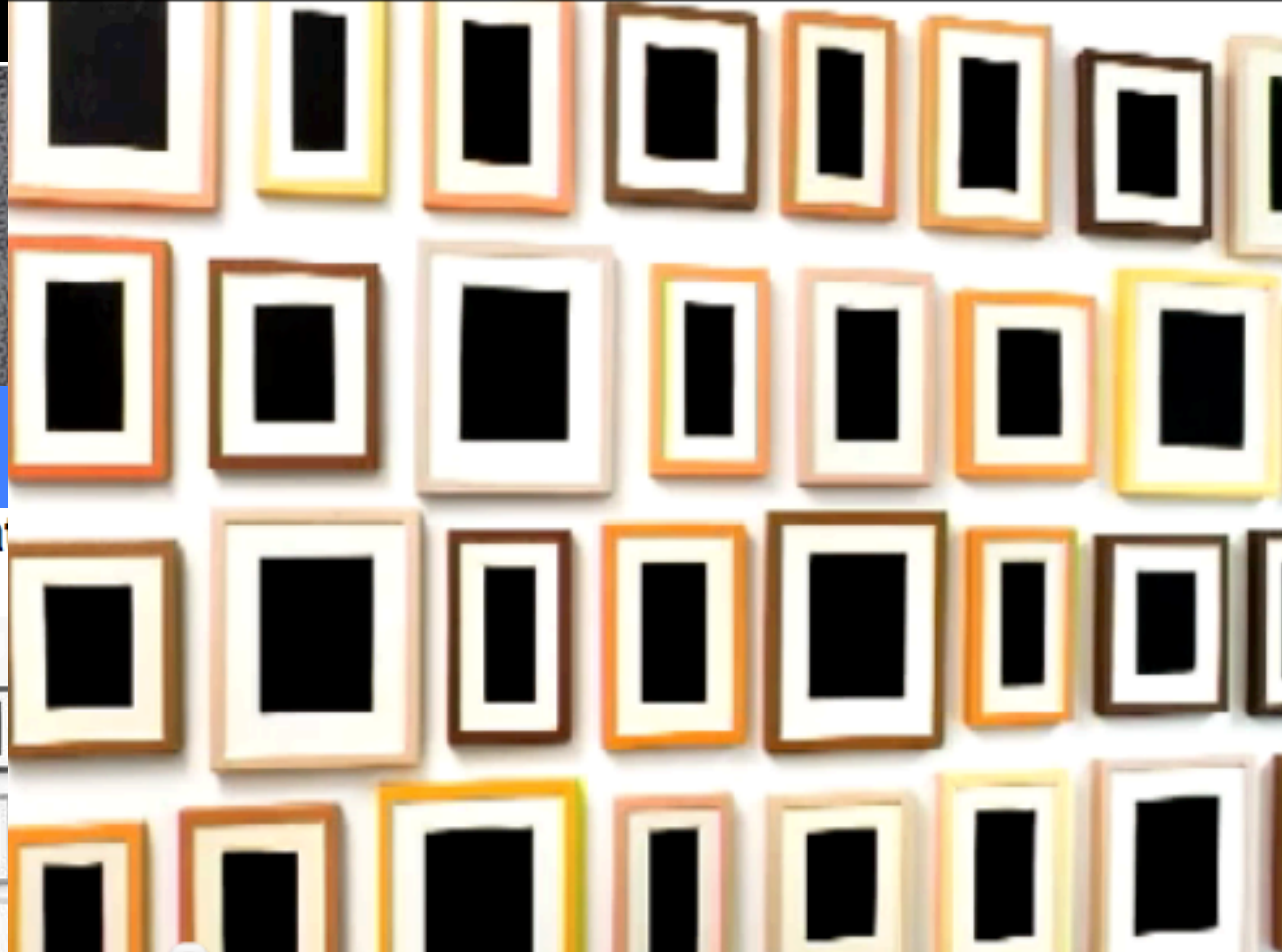
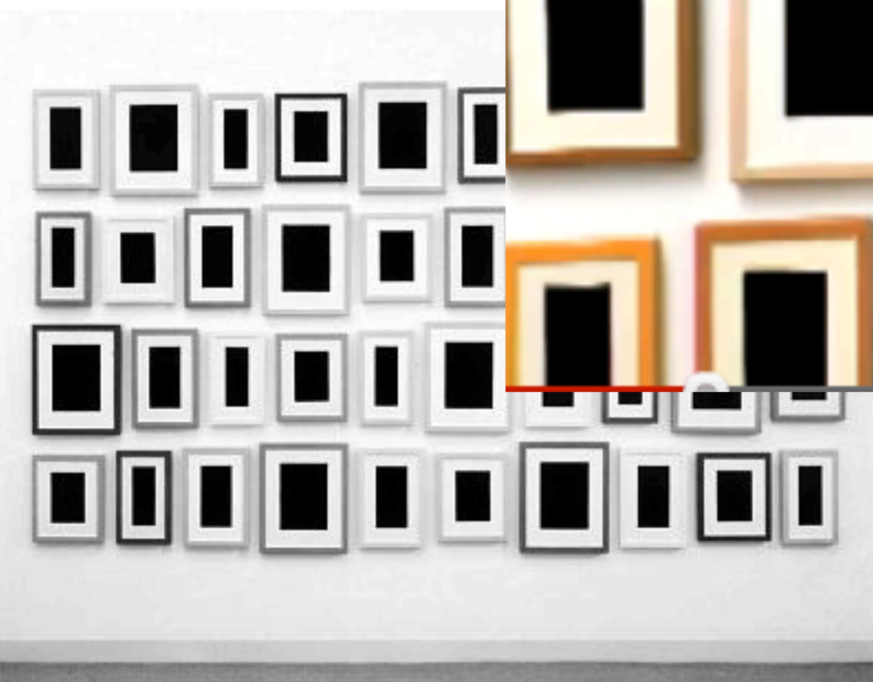
SEARCHING FOR DARK MATTER

SACLAY May 2014

Joe Silk (IAP, JHU)



40 Plaster Surrogat



Accession Number: 90.22

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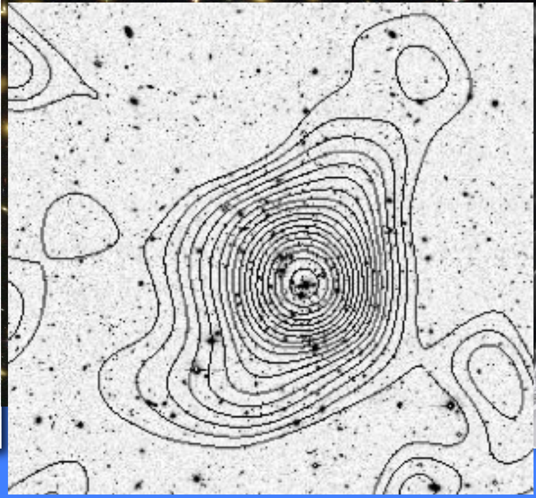
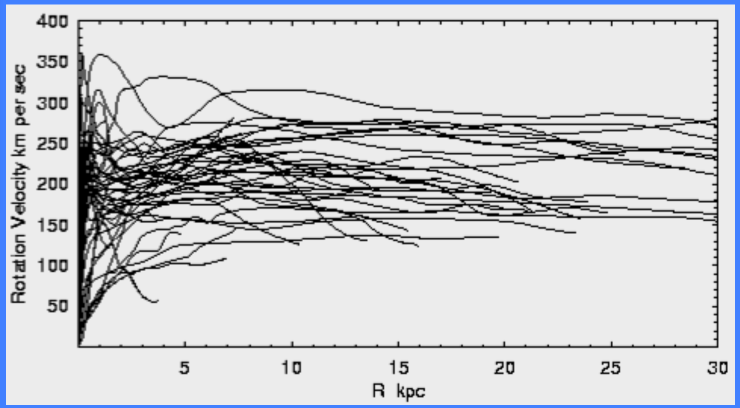




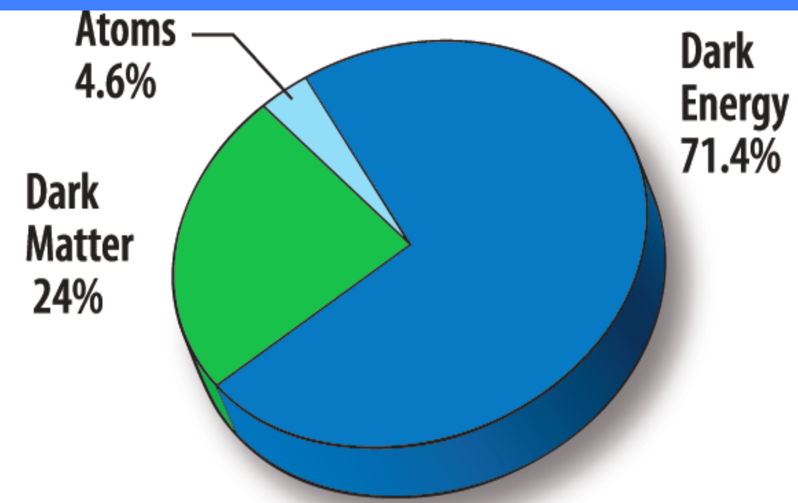


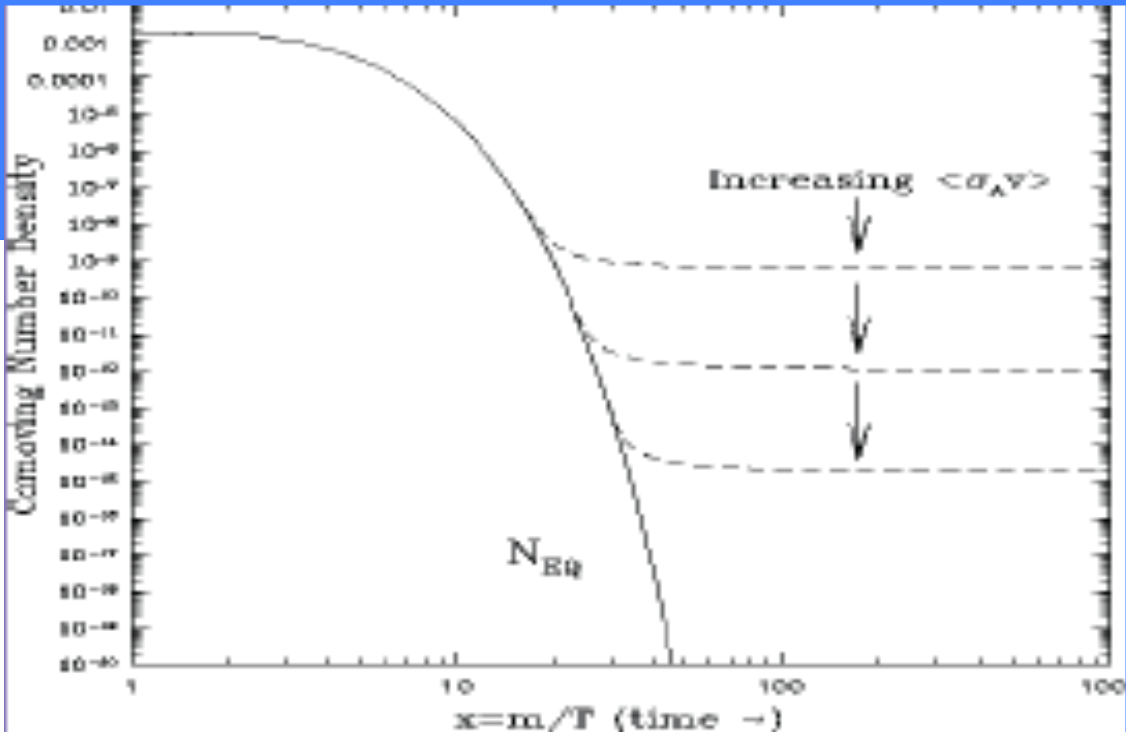
SUSY WIMP in thermal equilibrium

relic abundance if $<\sigma v>$~$3x10^{-26}$ cm^3/s ~$1/\Omega_x$

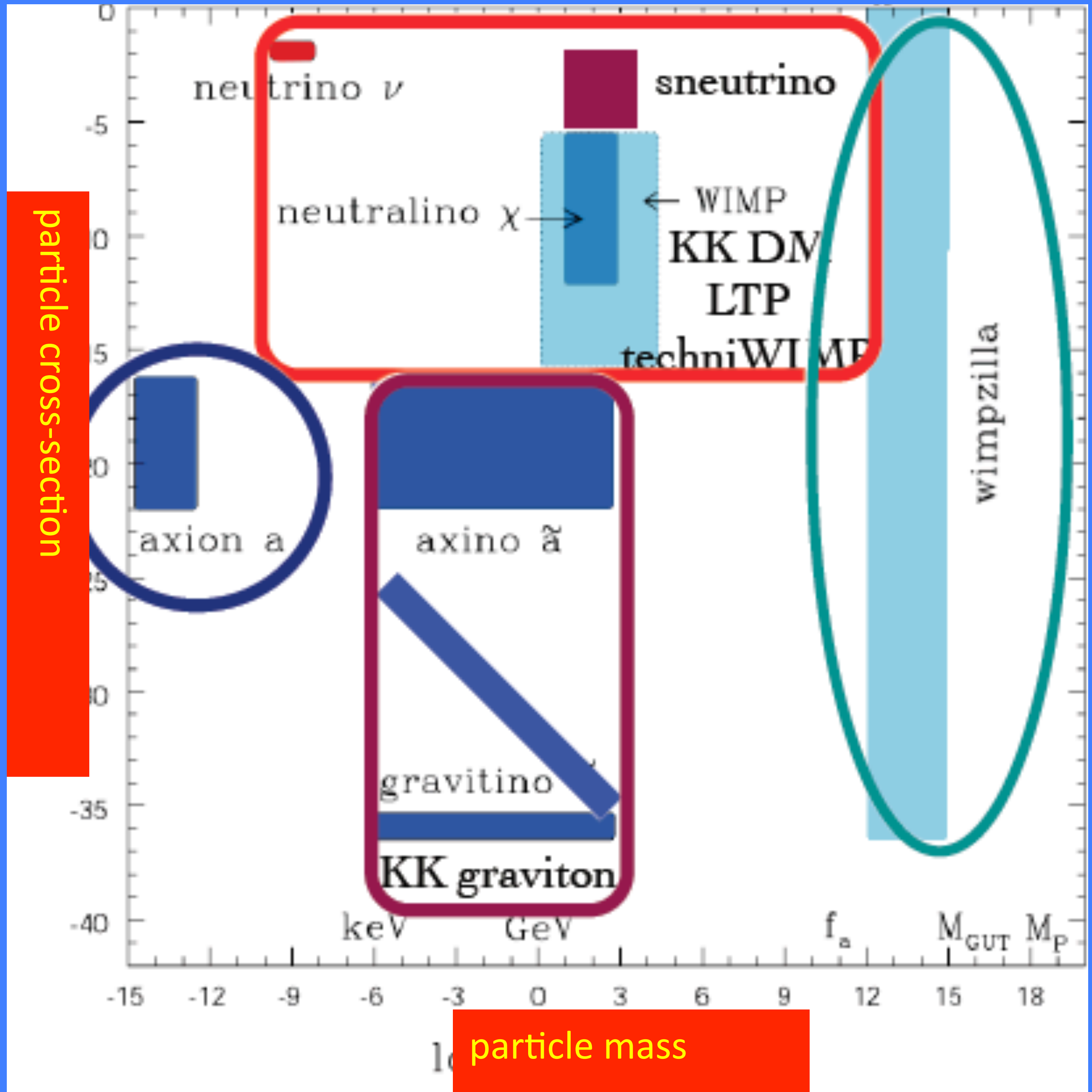
SUSY has 100+ free parameters

m_x =0.01-10 TeV





WIMPS or nonWIMPs

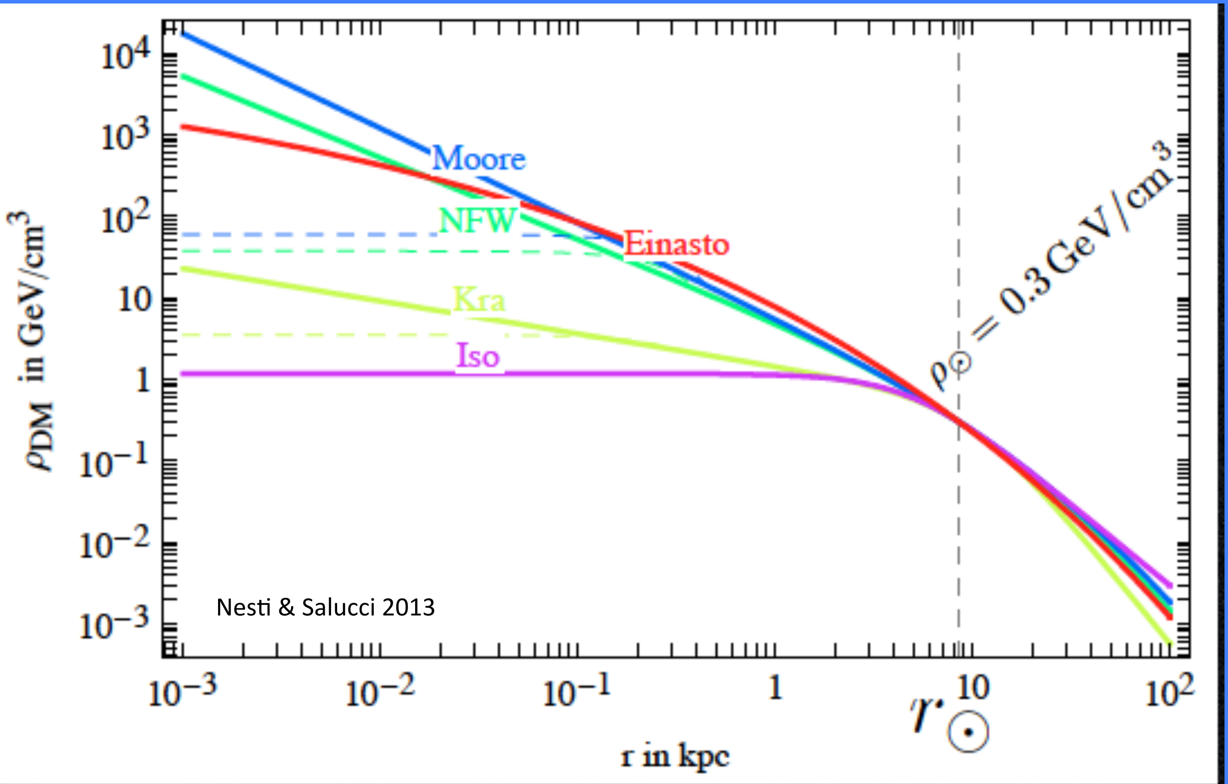


L. Roszkowski

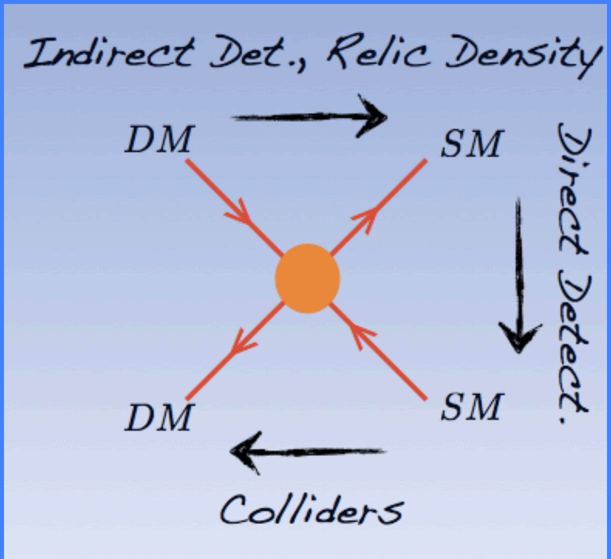
UNCERTAINTIES

Dark matter distribution
profiles, streams, clumps, velocity distribution
Cosmic ray propagation
diffusion, solar modulation, energy losses
Particle physics issues
fragmentation codes,
higher order corrections at TeVscales
Astrophysical backgrounds

Dark matter profiles



DARK MATTER DETECTION



$<\sigma v> \sim 3\text{x}10^{-26}$ cm^3/s

$\sigma_{ann} \sim 10^{-36}$ cm^2

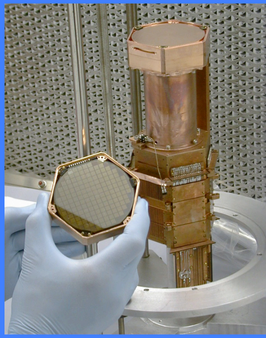
$\sigma_{sca} \sim 10^{-38}$ cm^2

Indirect detection
of high energy γ, ν, e^+…

direct detection
and
colliders

DIRECT DETECTION

DAMA/Libra,CDMS,XENON,CoGeNT,Edelweiss,LUX..

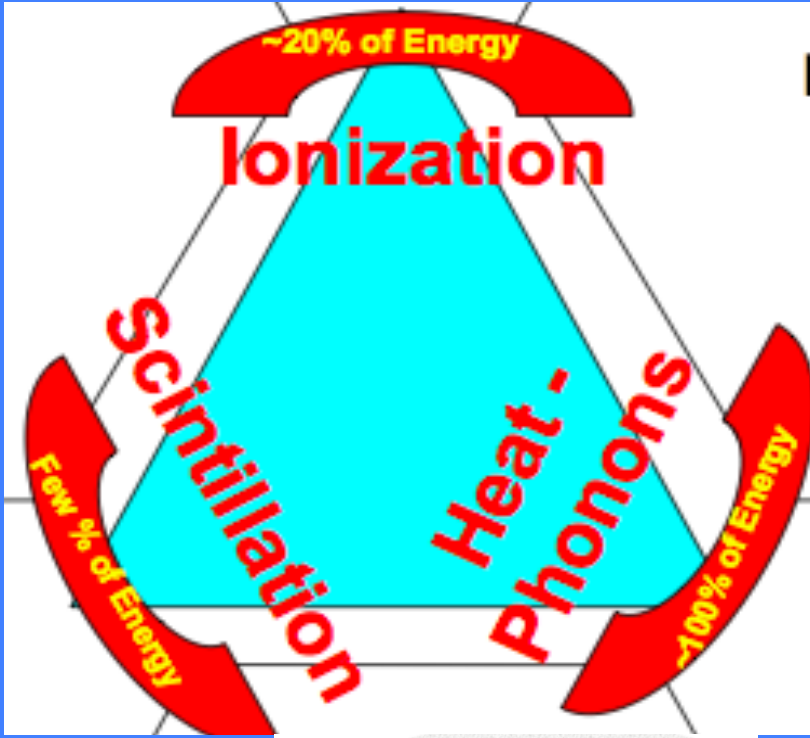


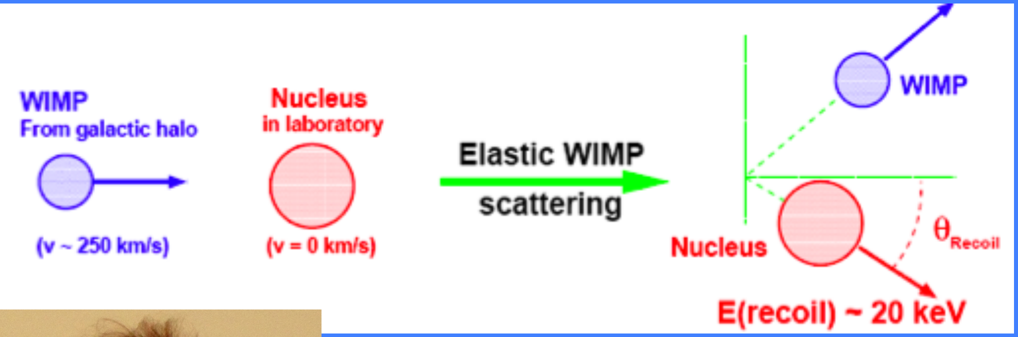
Production at colliders

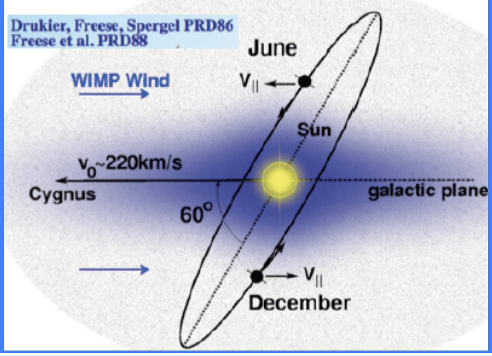
LHC

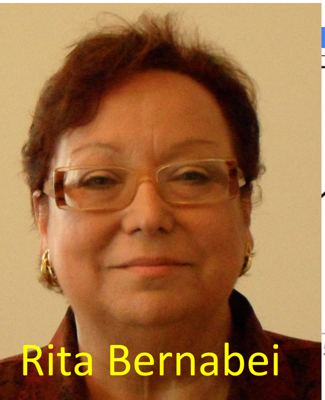
DIRECT DETECTION

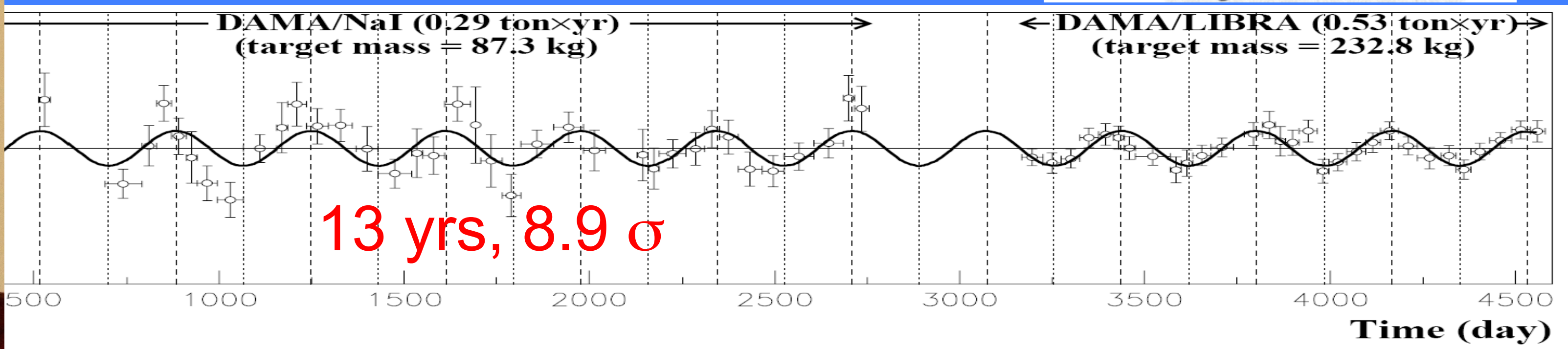
many WIMPs pass through lab per second

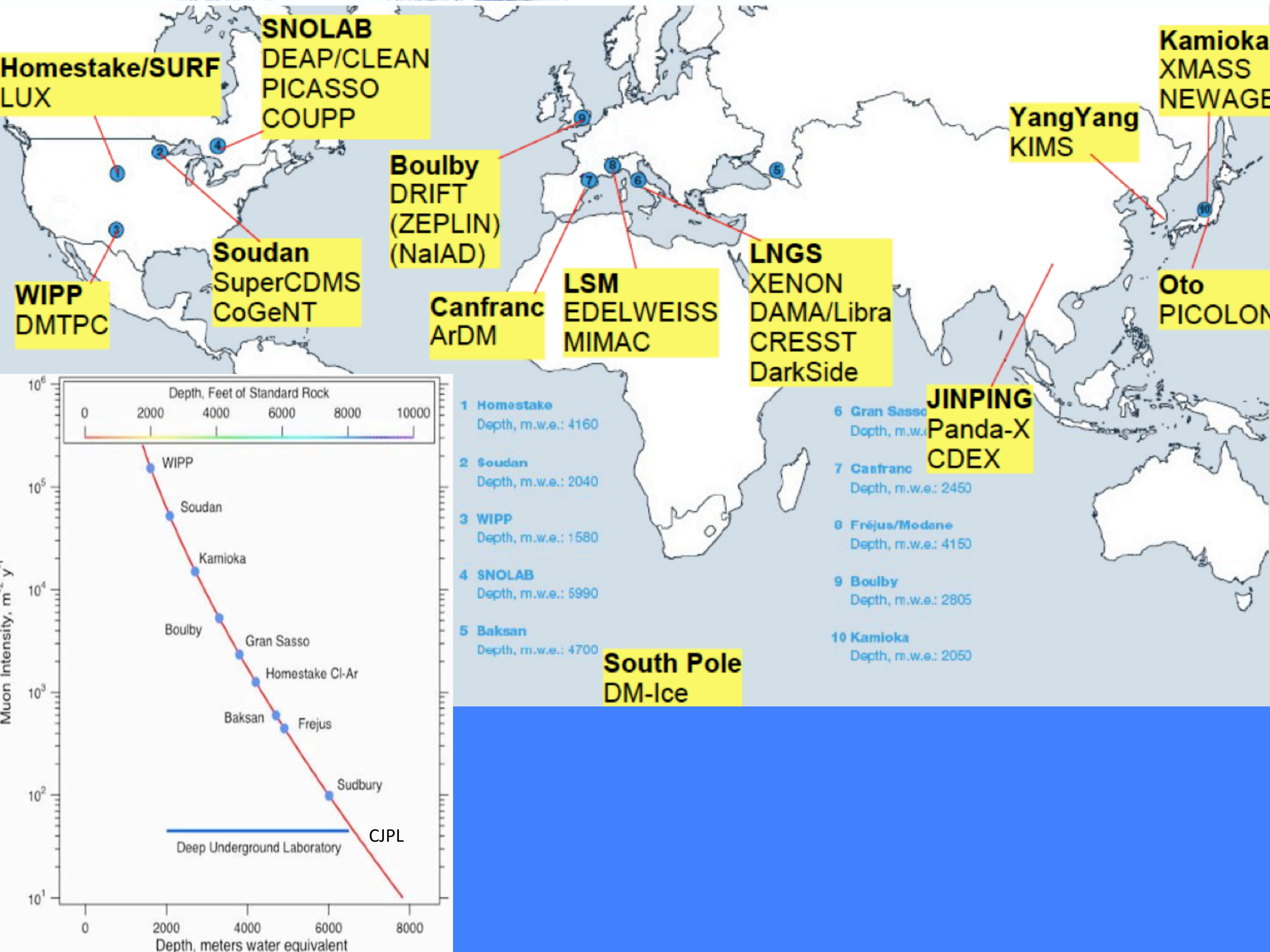








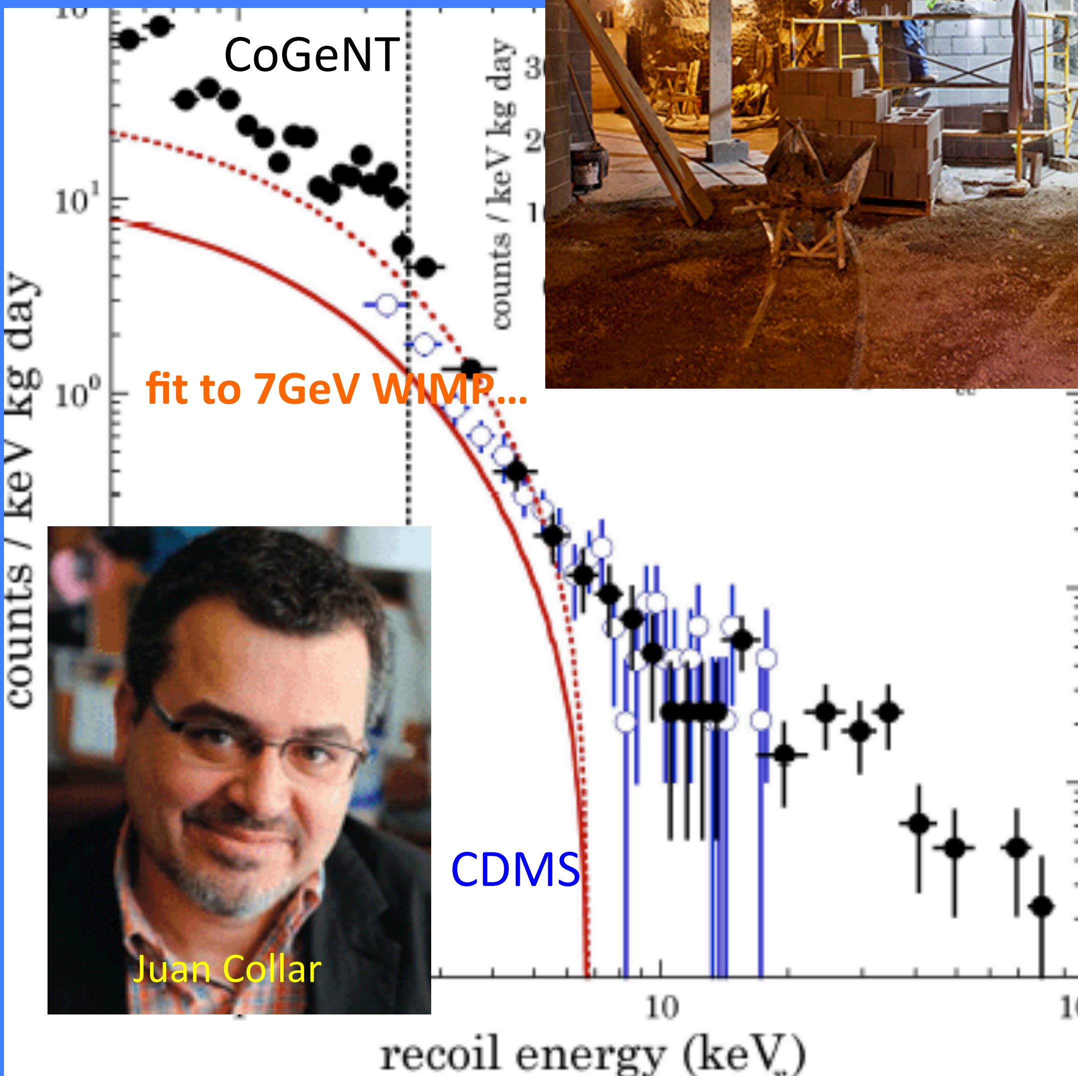


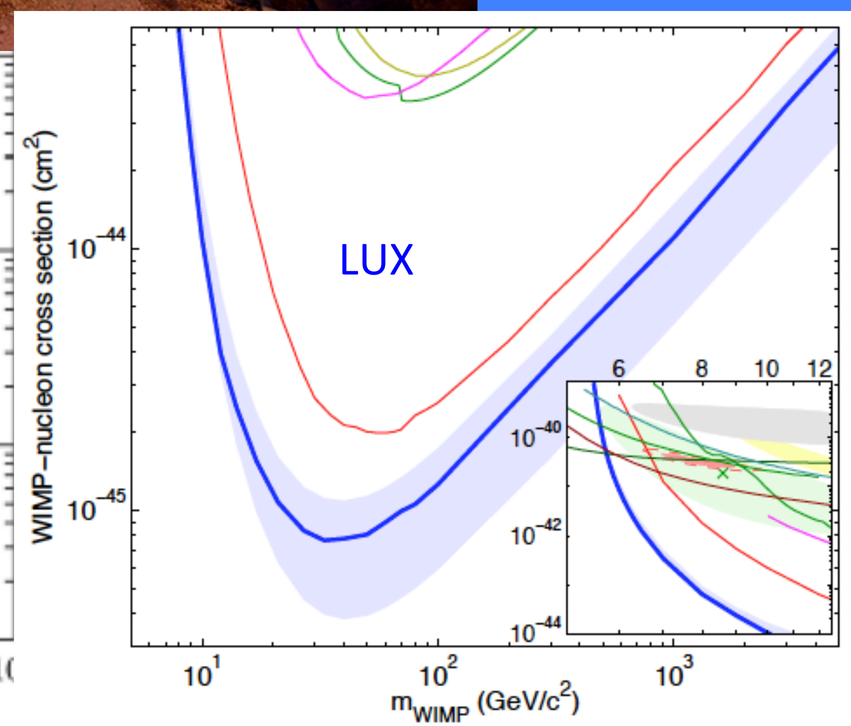

Homestake/SURF
LUX
SNOLAB
DEAP/CLEAN
PICASSO
COUPP
Boulby
DRIFT
(ZEPLIN)
(NaIAD)
Soudan
SuperCDMS
CoGeNT
WIPP
DMTPC
Canfranc
ArDM
LSM
EDELWEISS
MIMAC
LNGS
XENON
DAMA/Libra
CRESST
DarkSide
YangYang
KIMS
Kamioka
XMASS
NEWAGE
Oto
PICOLON
JINPING
Panda-X
CDEX
South Pole
DM-Ice
1 Homestake
Depth, m.w.e.: 4160
2 Soudan
Depth, m.w.e.: 2040
3 WIPP
Depth, m.w.e.: 1580
4 SNOLAB
Depth, m.w.e.: 5990
5 Baksan
Depth, m.w.e.: 4700
6 Gran Sasso
7 Canfranc
Depth, m.w.e.: 2450
8 Fréjus/Modane
Depth, m.w.e.: 4150
9 Boulby
Depth, m.w.e.: 2805
10 Kamioka
Depth, m.w.e.: 2050
Depth, Feet of Standard Rock
0 2000 4000 6000 8000 10000
WIPP
Soudan
Kamioka
Boulby
Gran Sasso
Homestake Cl-Ar
Baksan
Frejus
Sudbury
CJPL
Deep Underground Laboratory
Muon Intensity, m⁻² y⁻¹
10^1 10^2 10^3 10^4 10^5 10^6
0 2000 4000 6000 8000
Depth, meters water equivalent

Spin-independent elastic scattering is coherent, and all nucleons contribute

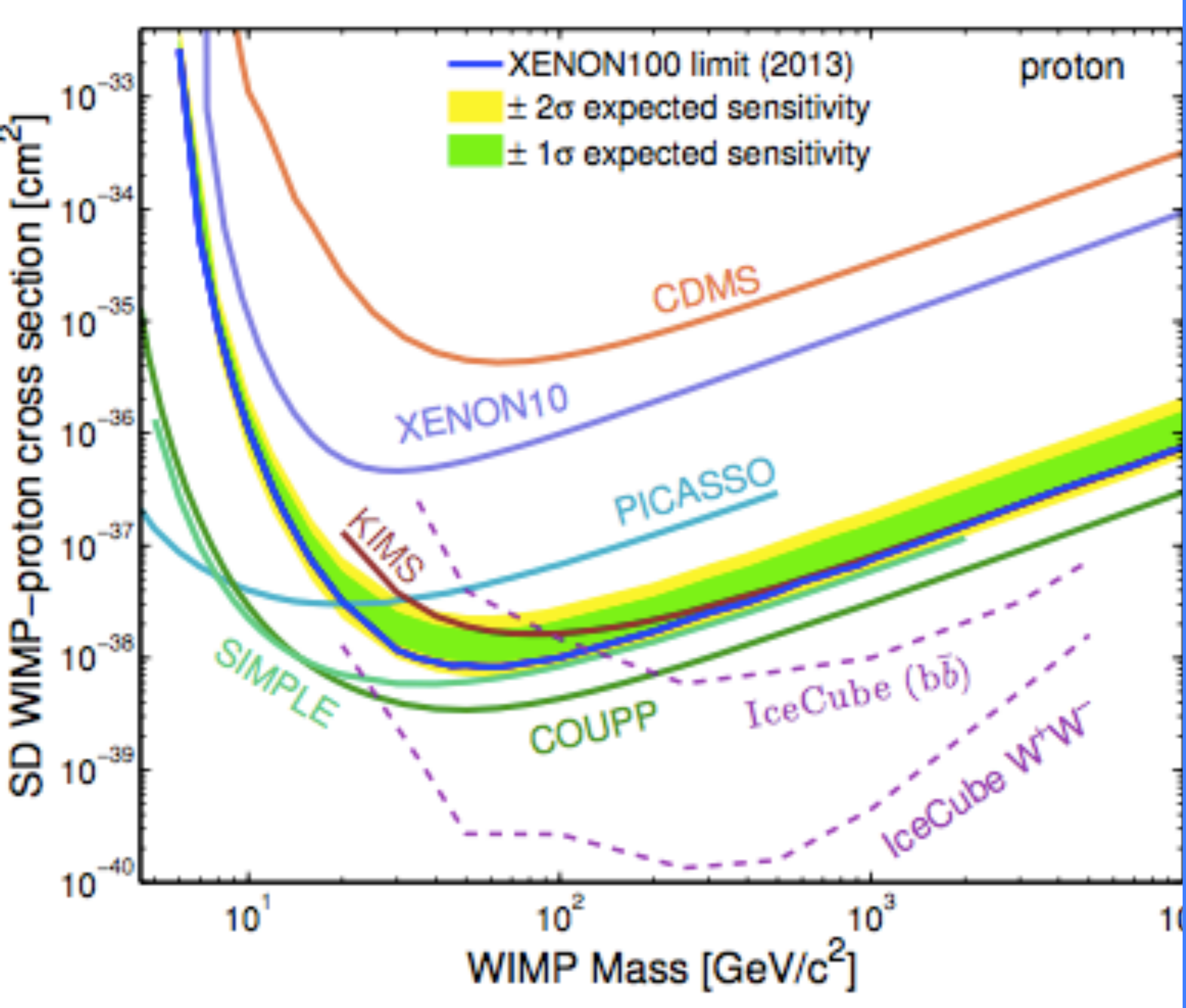
$$\sigma_{SI} \sim A^2 \quad \text{eg } A_{Xe}=134$$

Rick Gaitskell

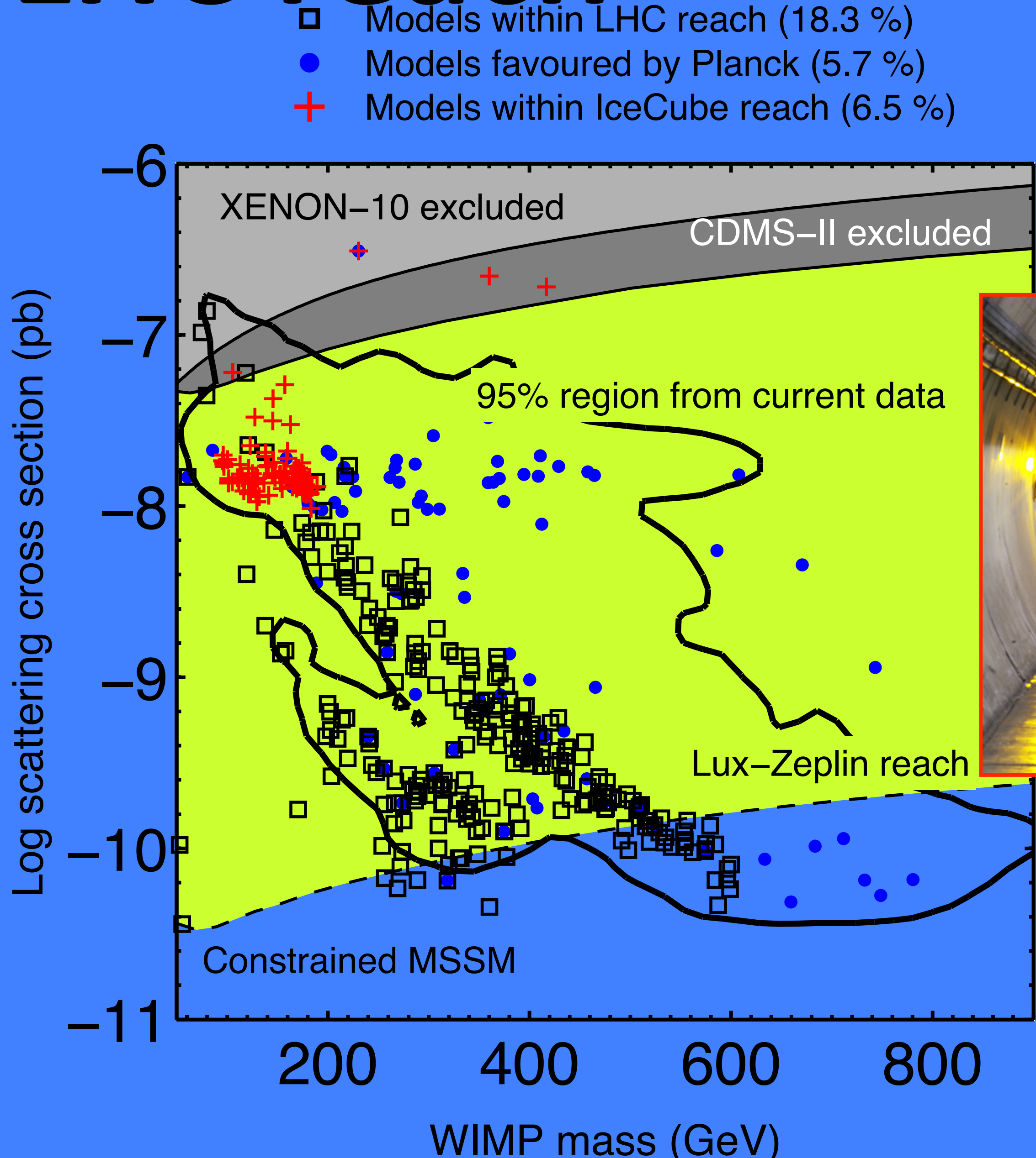




Spin-dependent elastic scattering sums incoherently
(couples to nucleon spin, cancels in pairs)



LHC reach



1 1/fb at 14 TeV energy

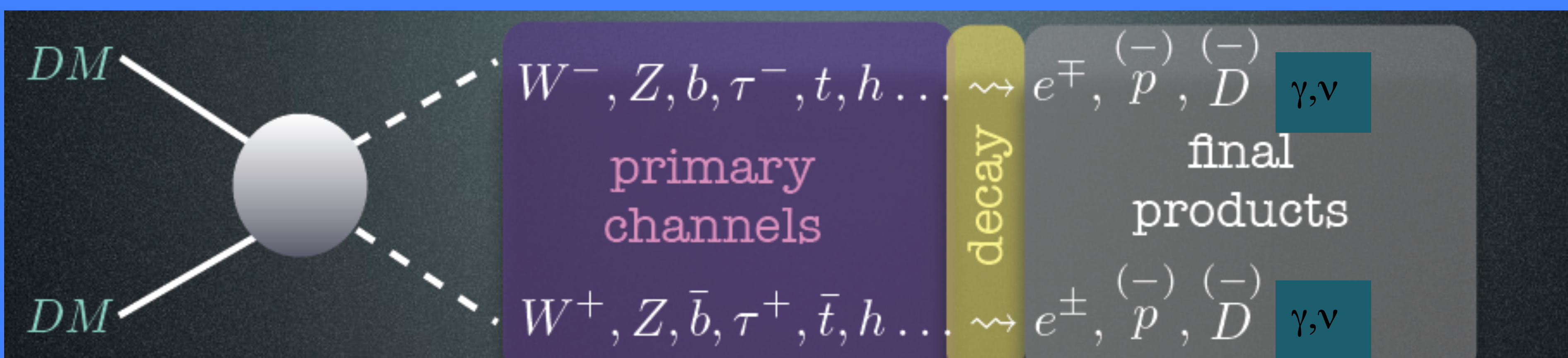
WMAP mean with 5-σ Planck uncertainty

5-σ for 1 yr of 80 strings data

Cumberbatch, Trotta et al. 2011

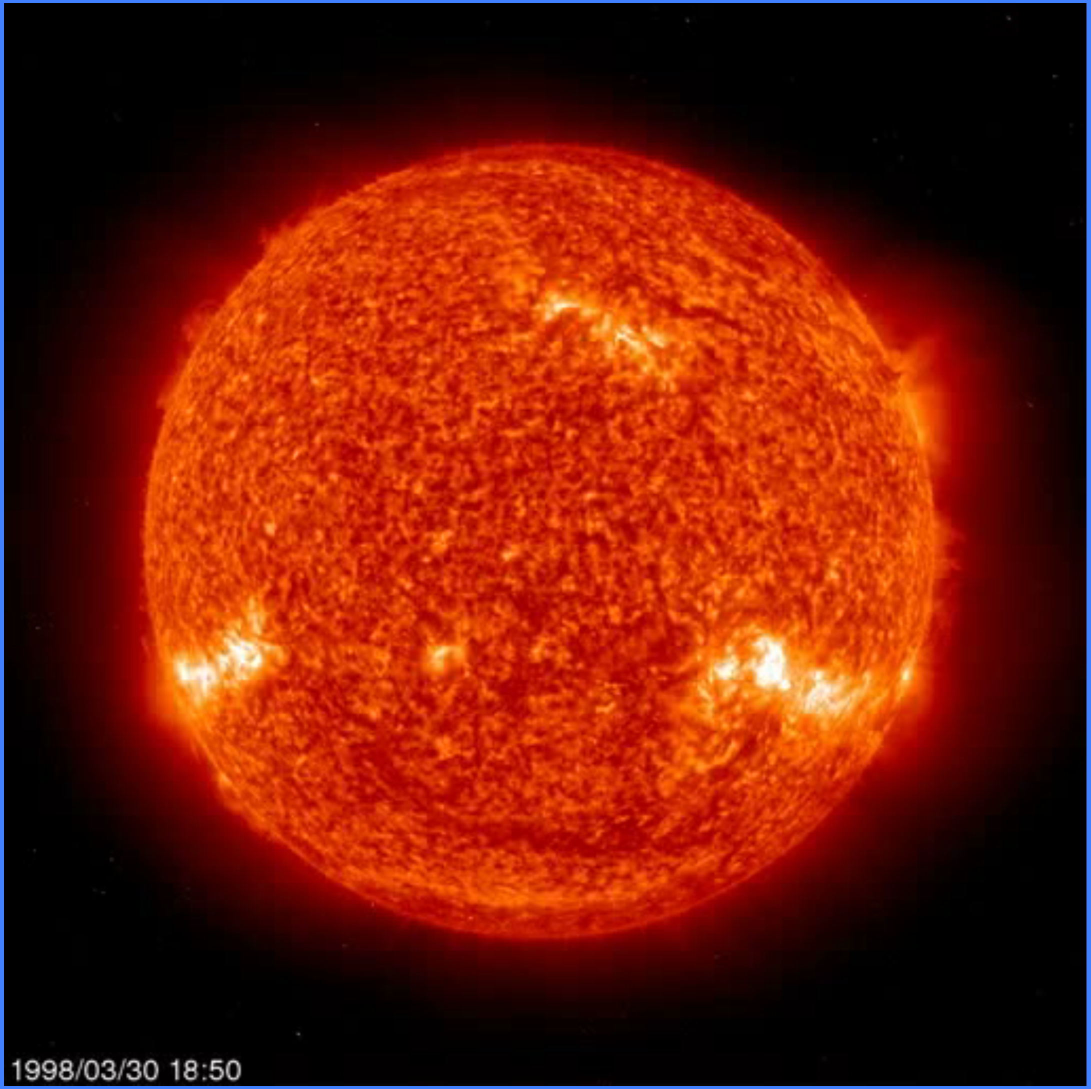
INDIRECT DETECTION

halo WIMPS occasionally annihilate today

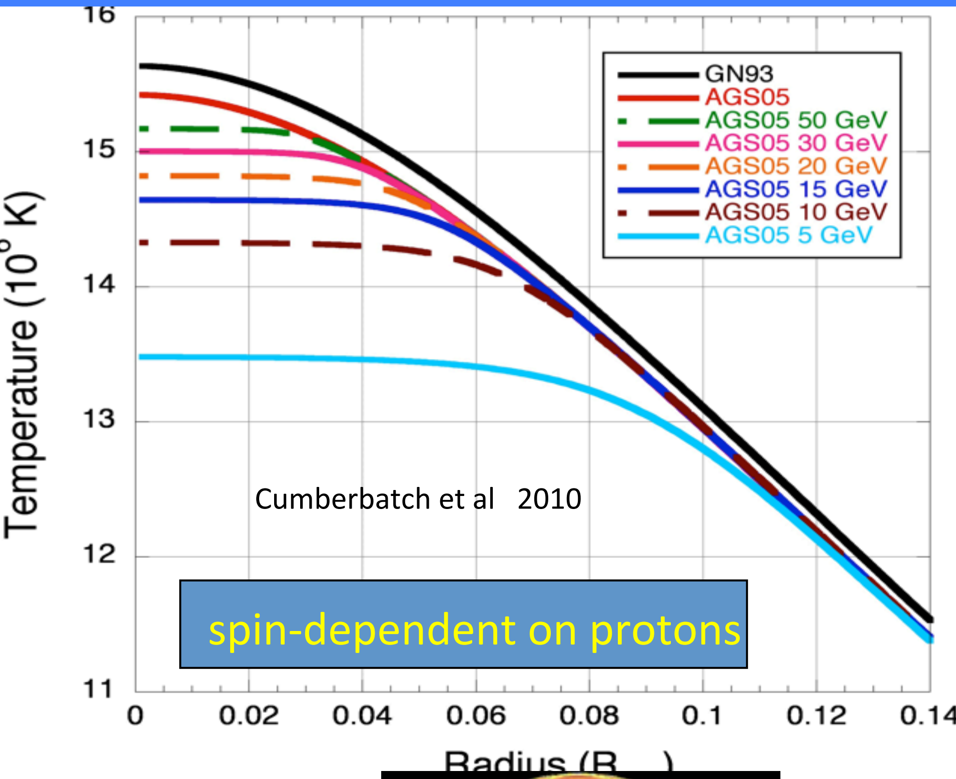


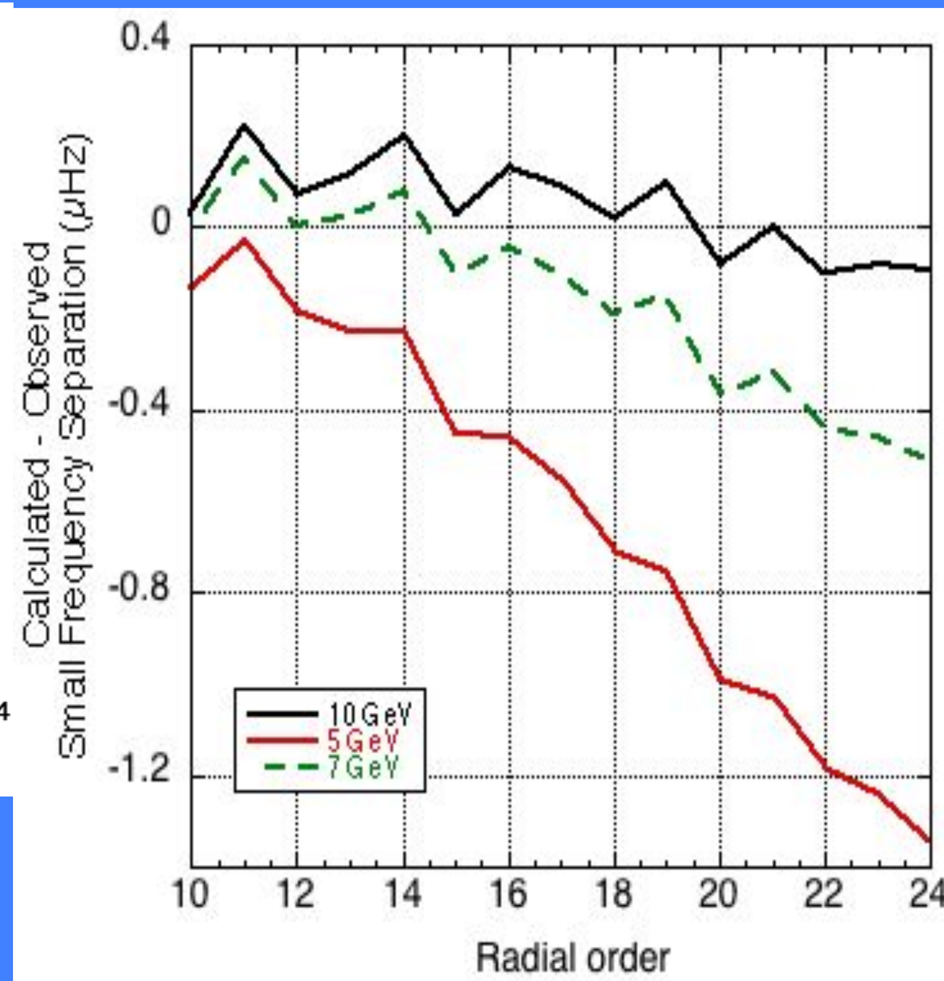
into energetic particles

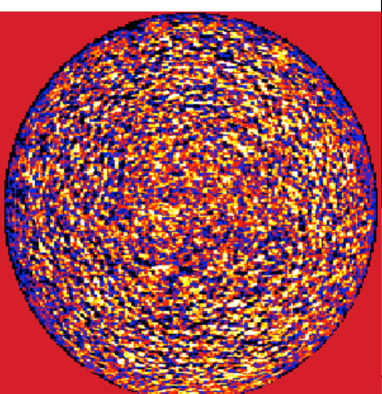
THE SUN

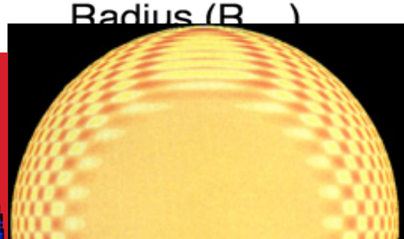


low mass (m_x ~5-10 GeV) WIMPS are trapped, fill the solar core…. and modify T(r) if non-annihilating



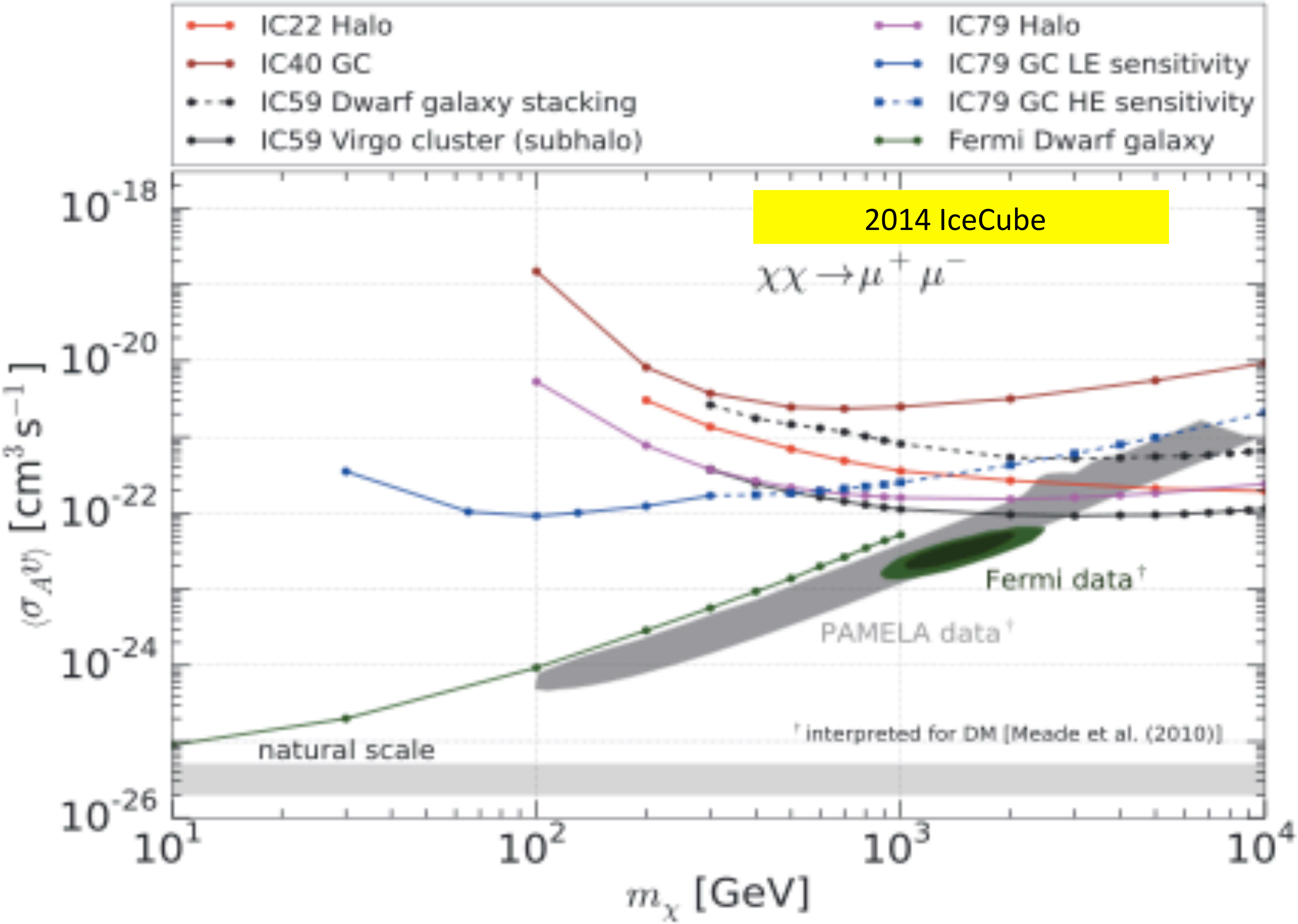




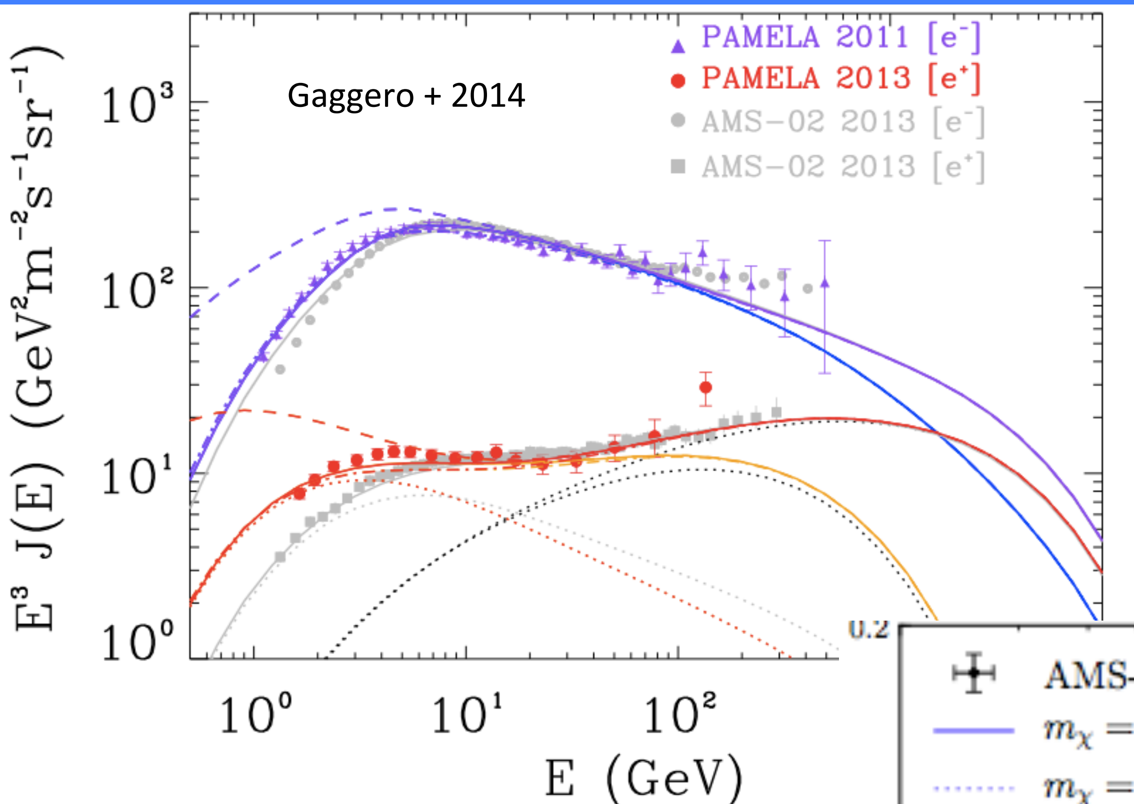


helioseismology rules out 5 GeV
in some cases…

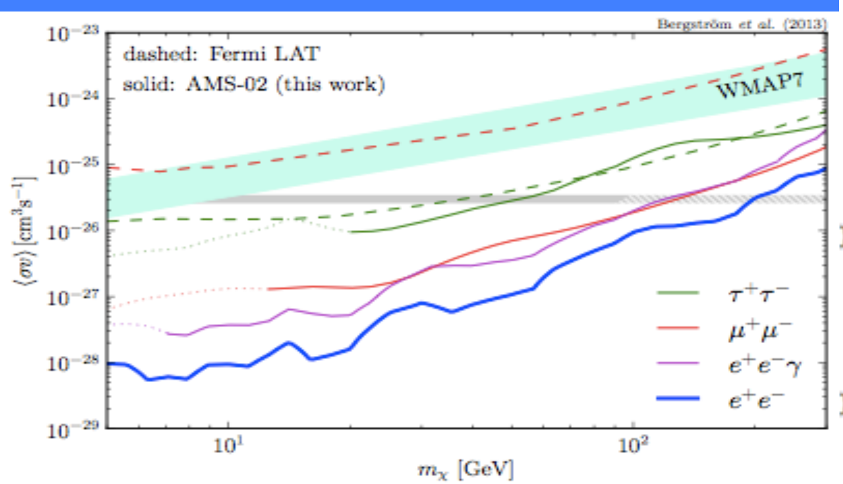
ENERGETIC NEUTRINOS FROM WIMPs TRAPPED IN THE SUN

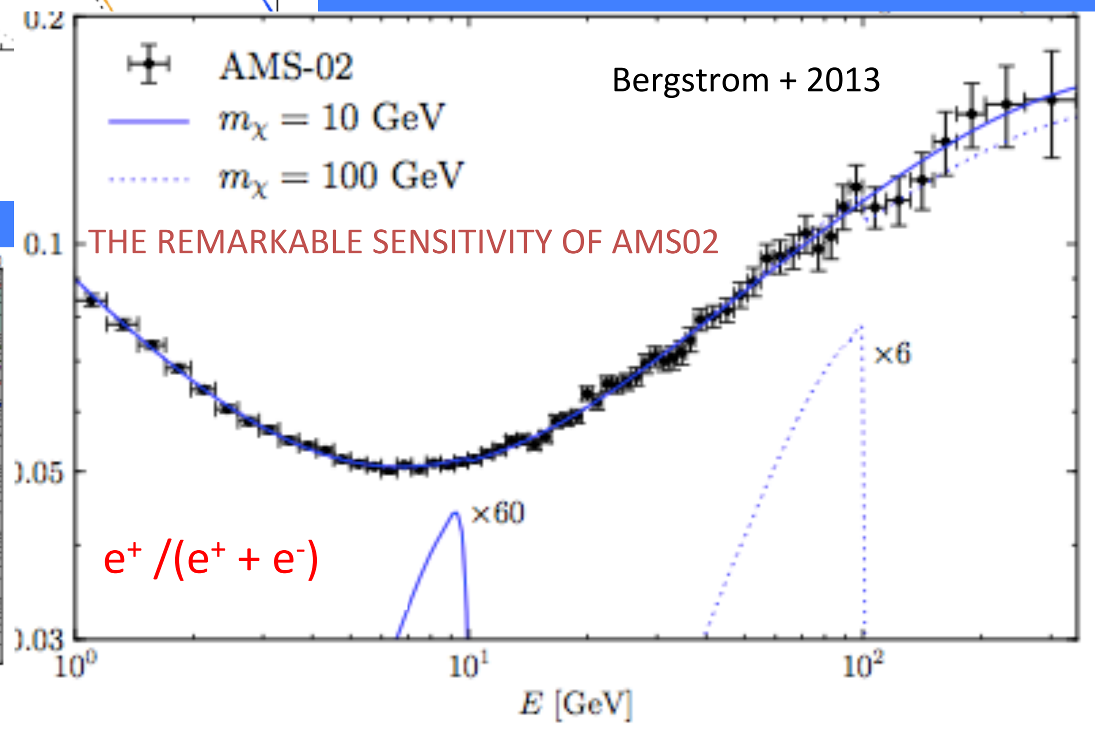


High energy electrons and positrons



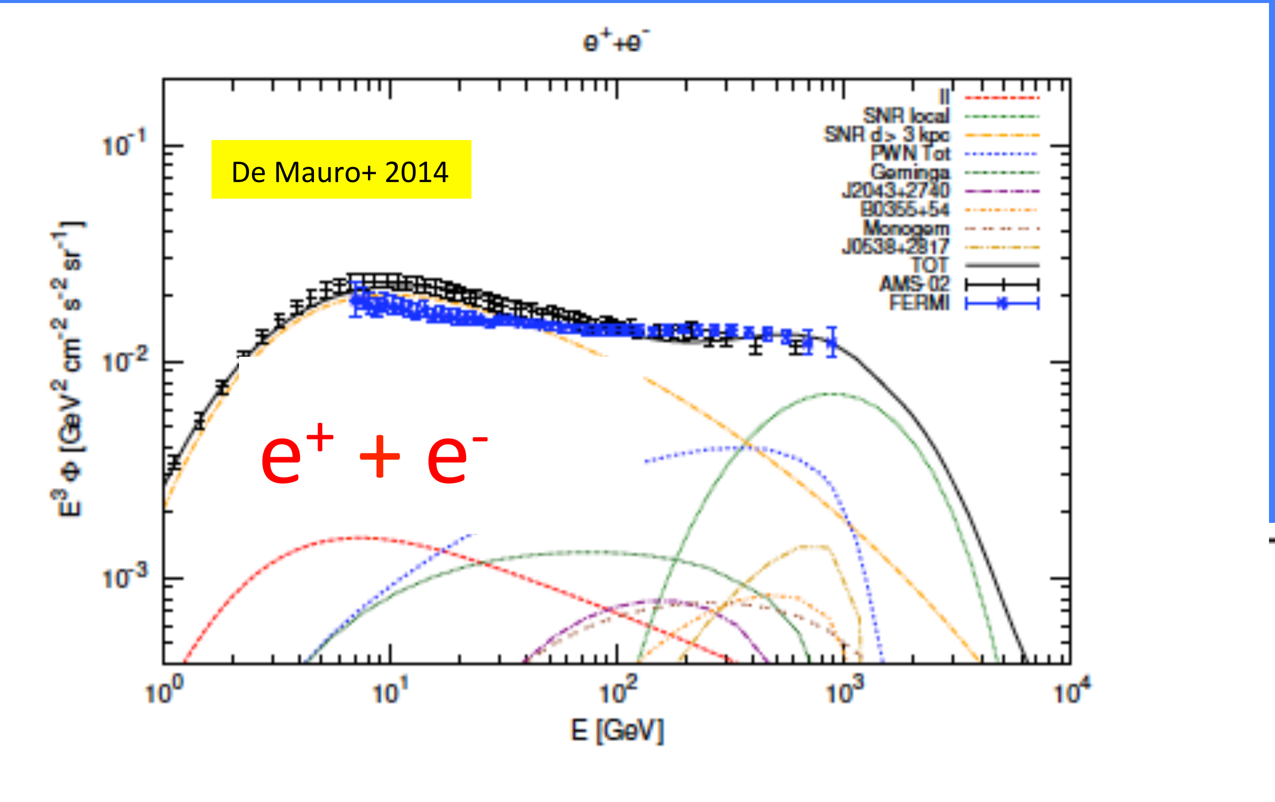
New symmetric TeV component needed

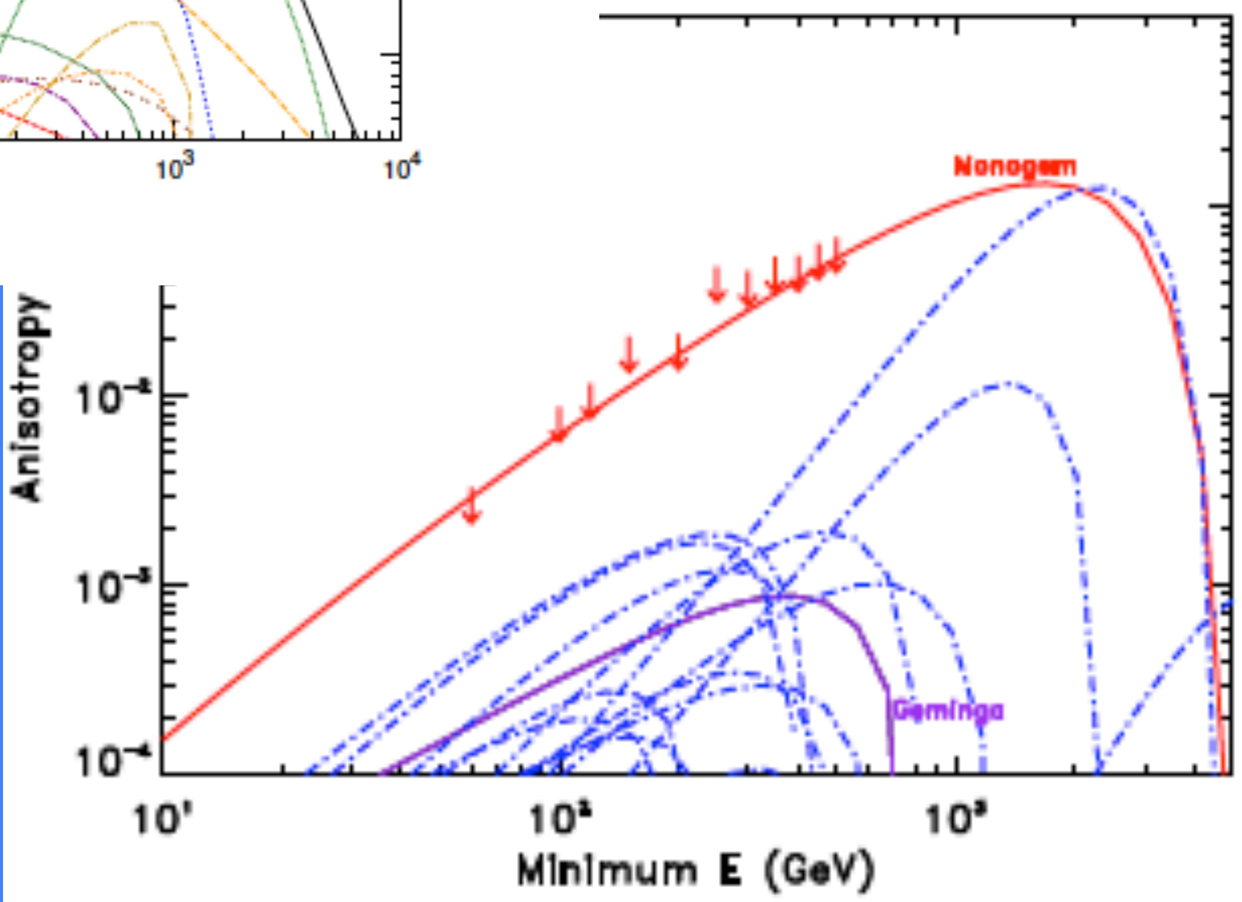




astrophysical origin

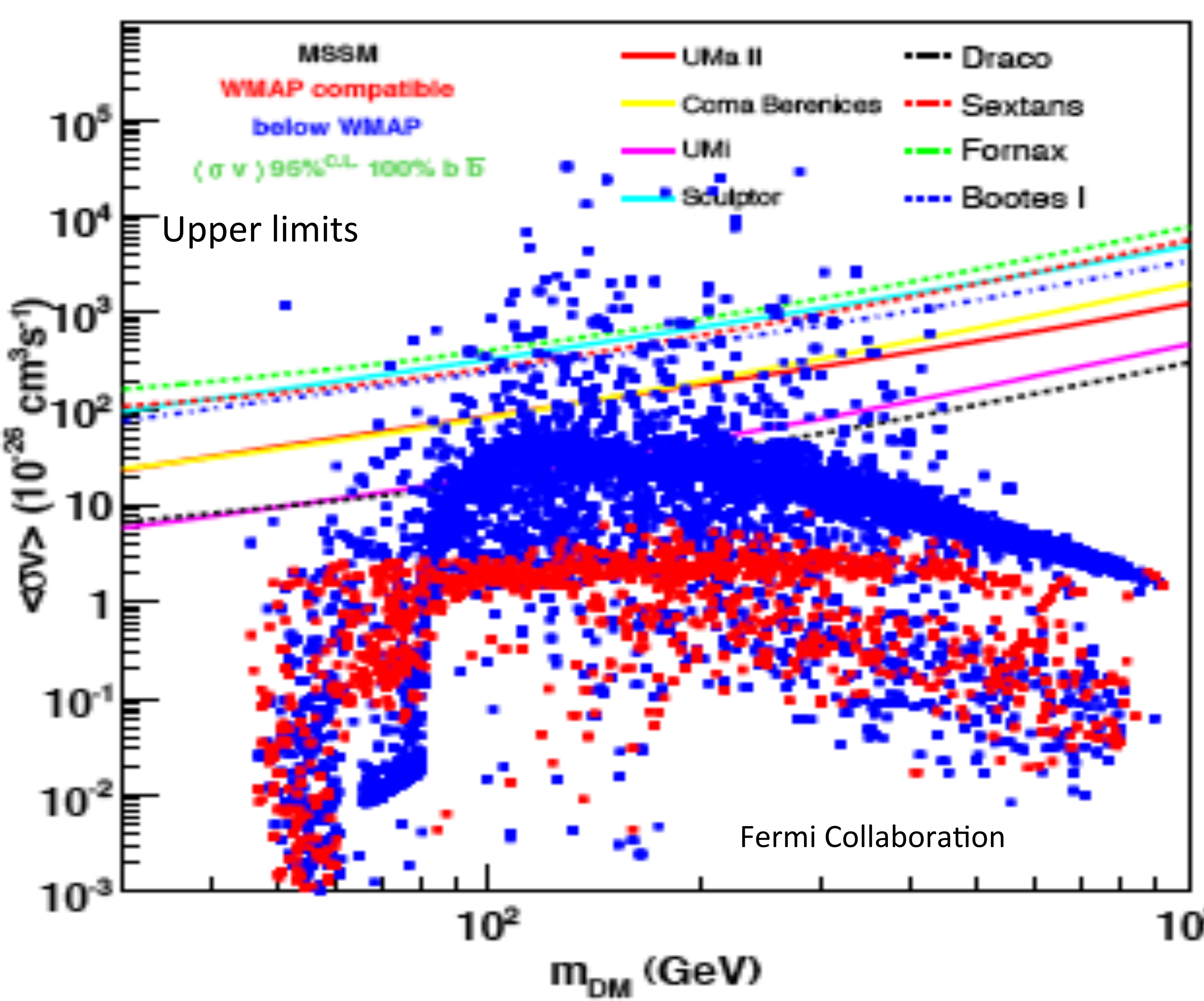
via PULSAR WIND

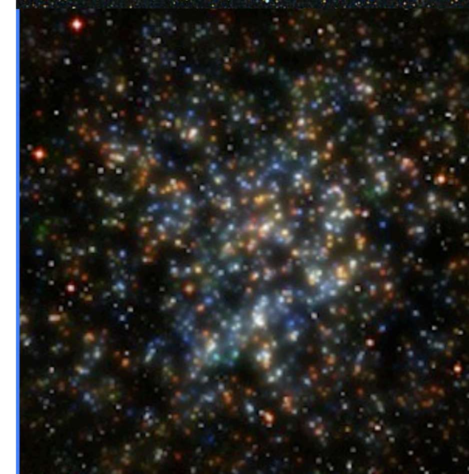




γ-rays

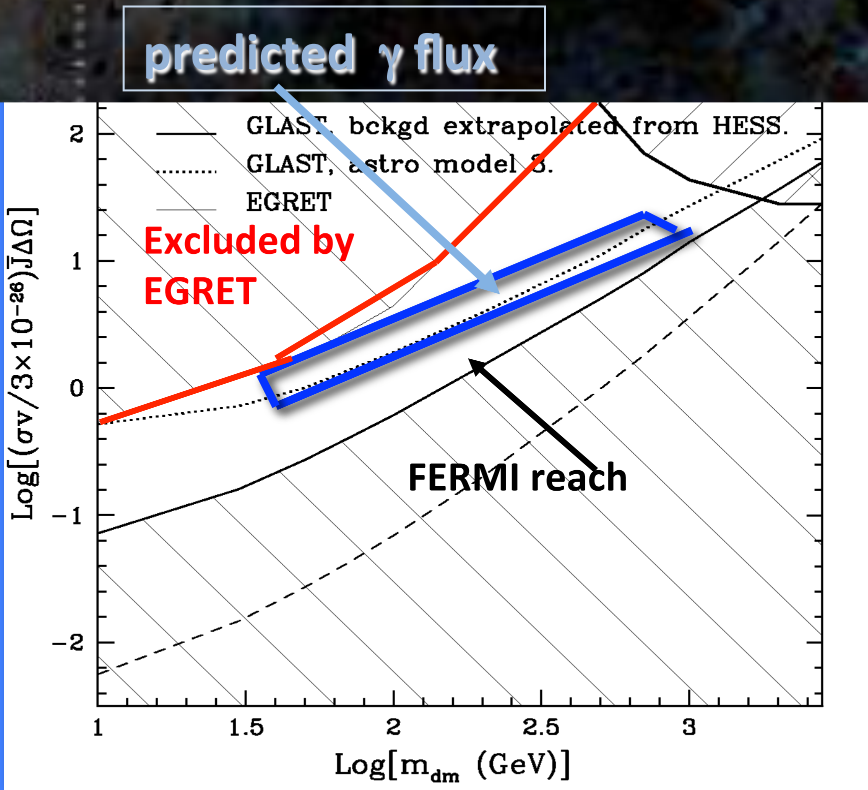
Ultrafaint dwarf spheroidal galaxies



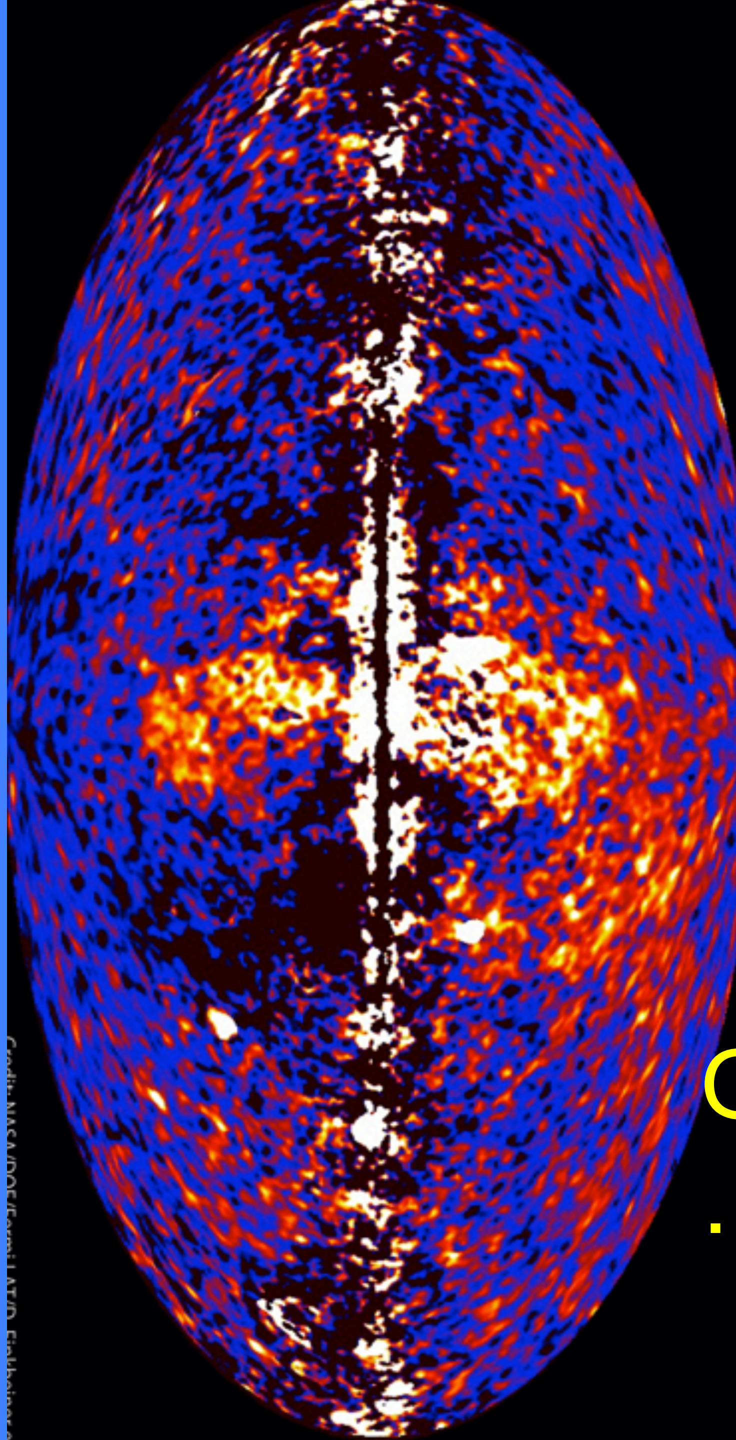


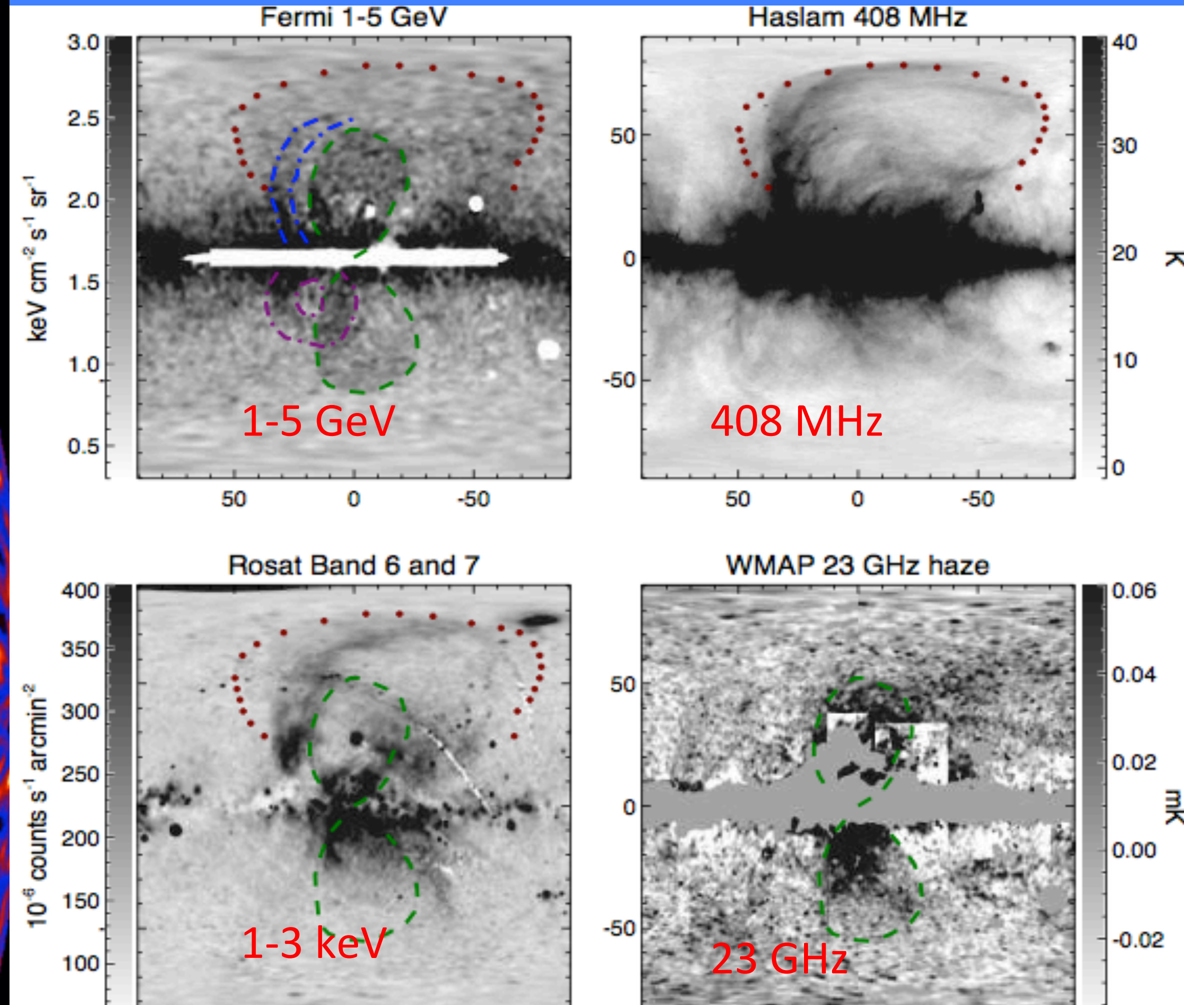
Radio synchrotron emission

The WMAP microwave haze



Hooper and Zaharias 2007

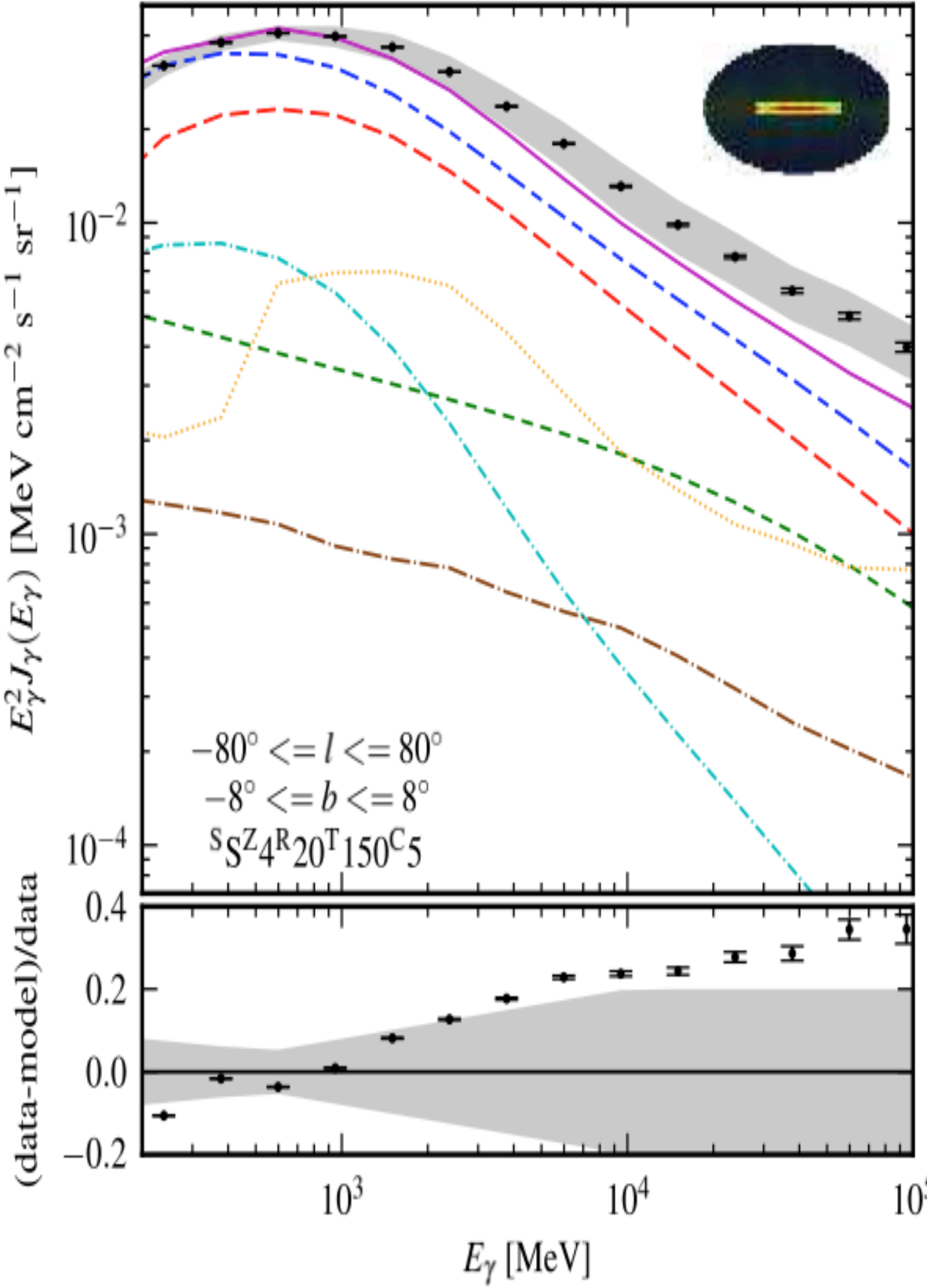




Giant gamma ray bubbles …not dark matter

Fermi haze is inverse Compton of e^+e^- on interstellar radiation

Su et al. 2010



Fermi inner galaxy excess

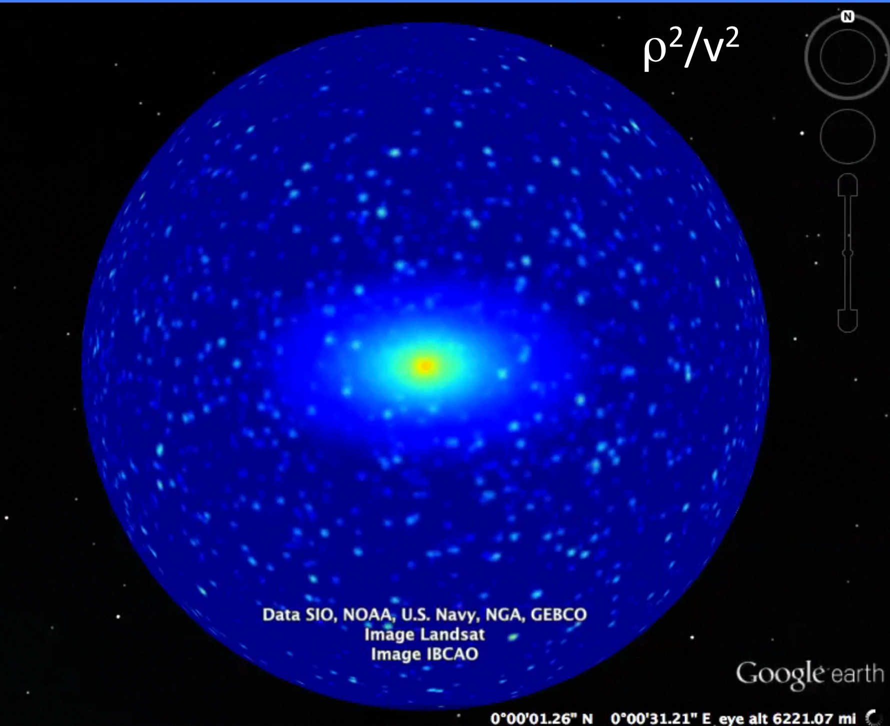
Via Lactea 2 simulation
(10^9 particles of 4000 M_O)

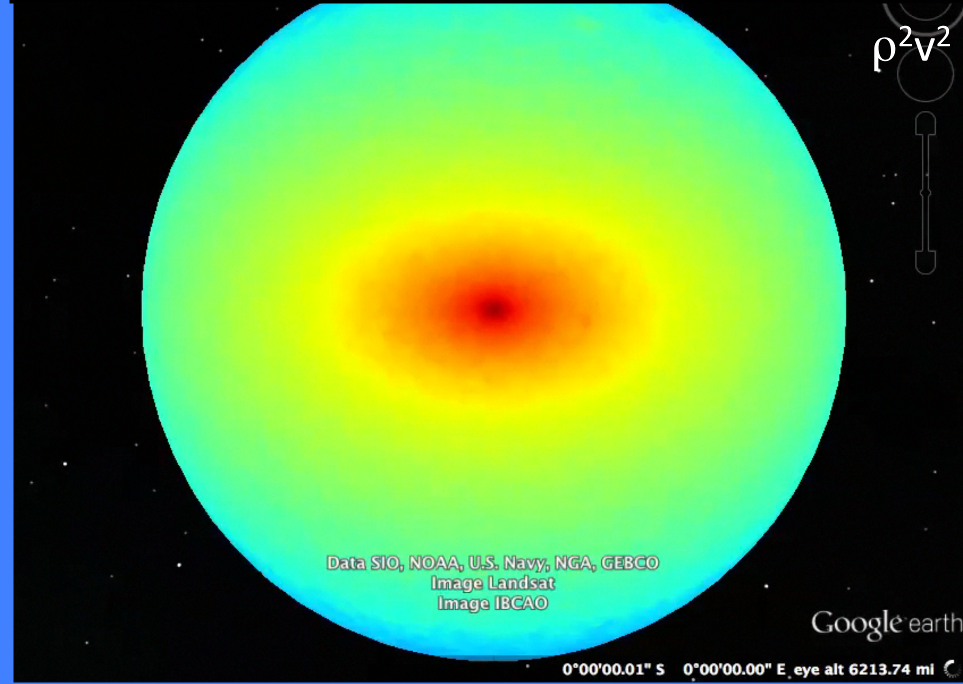
DM renderings by
Lin Forrest Yang (2013)

A precursor simulation by
Diemand, Kuhlen, Madau

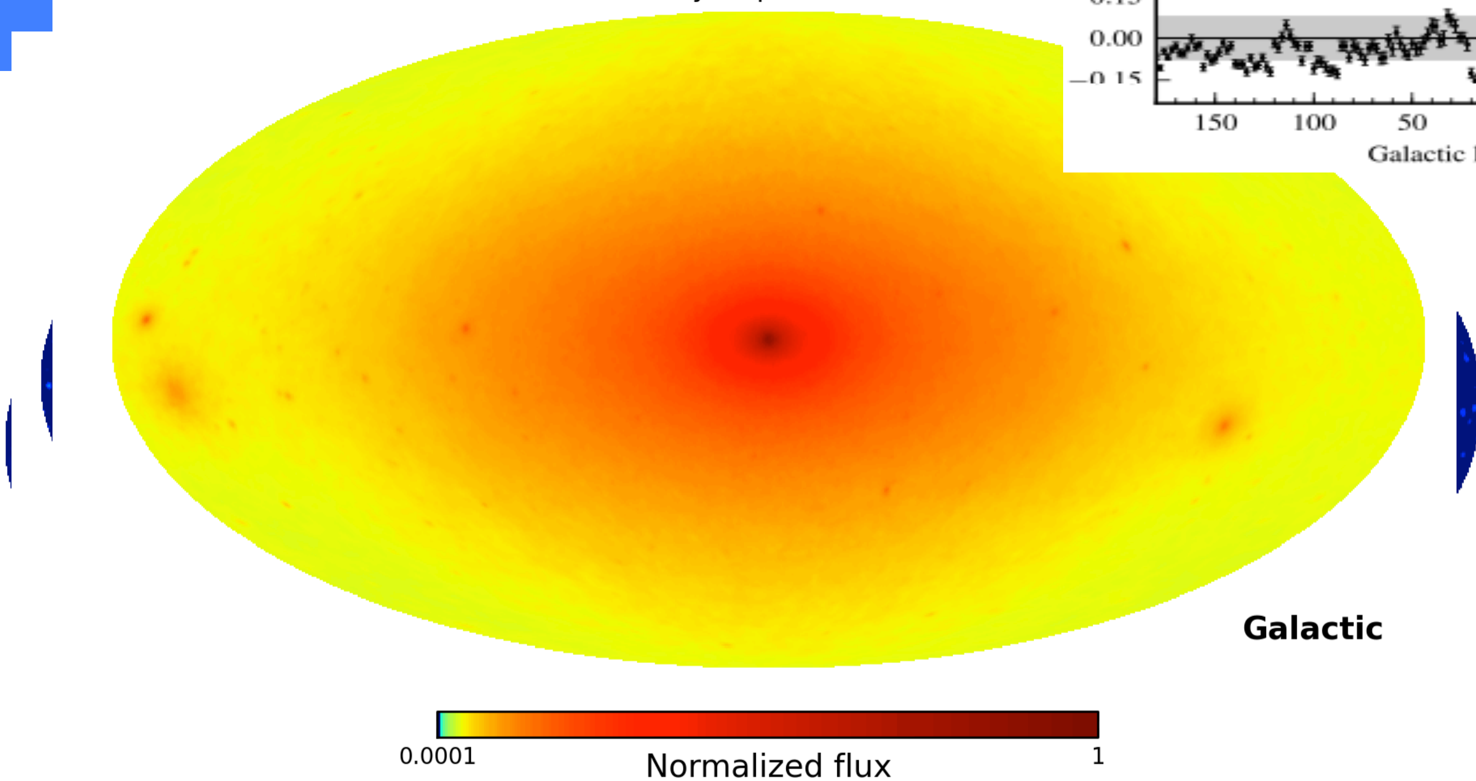
ρ^2

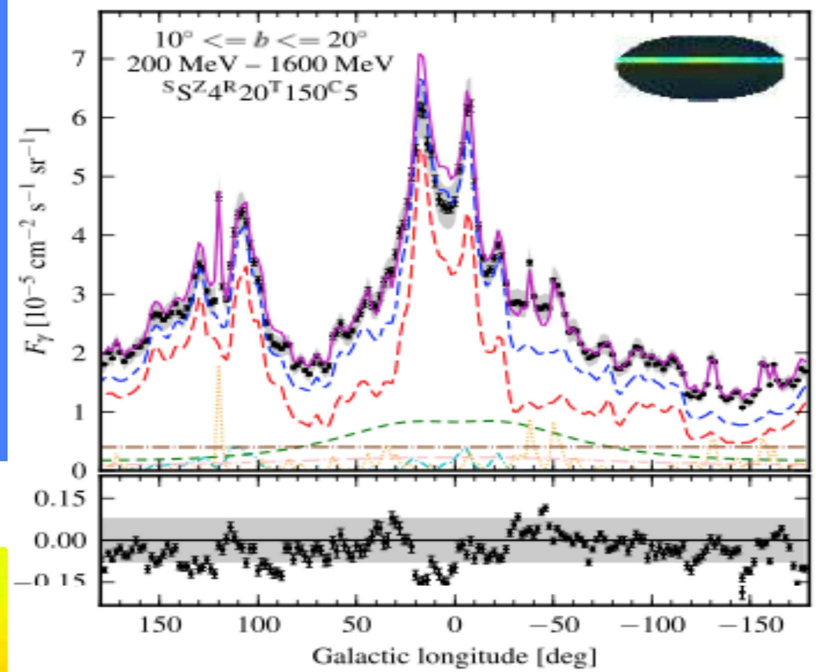
ρ


ρ^2/v^2
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
Image IBCAO
Google earth
0°00'01.26" N 0°00'31.21" E eye alt 6221.07 mi

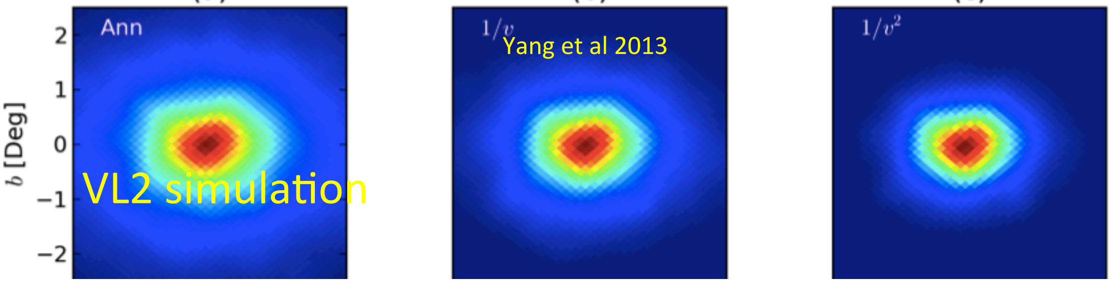

ρ^2v^2
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
Image IBCAO
Google earth
0°00'00.01" S 0°00'00.00" E eye alt 6213.74 mi

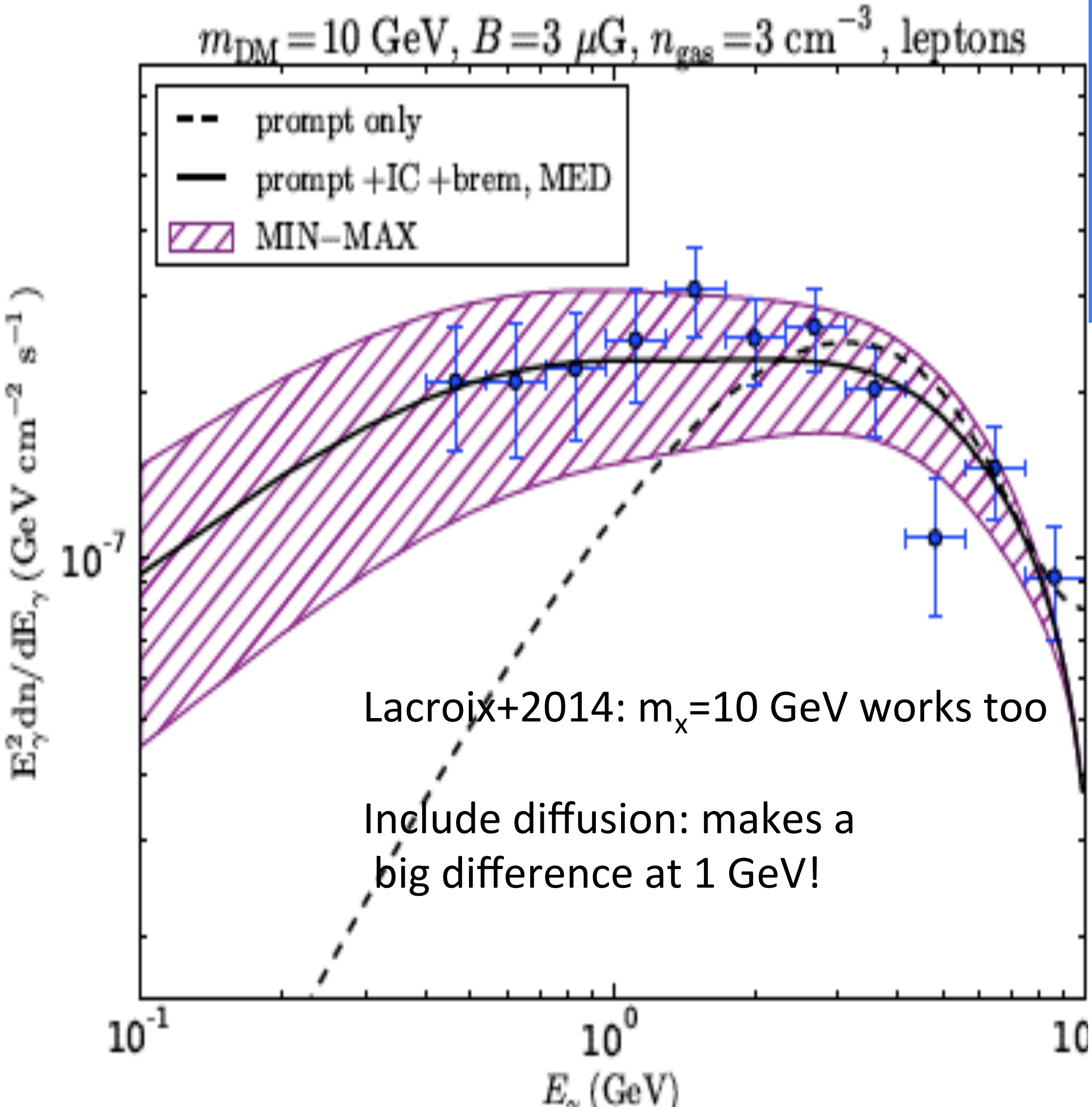
DM Decay Map No Correction

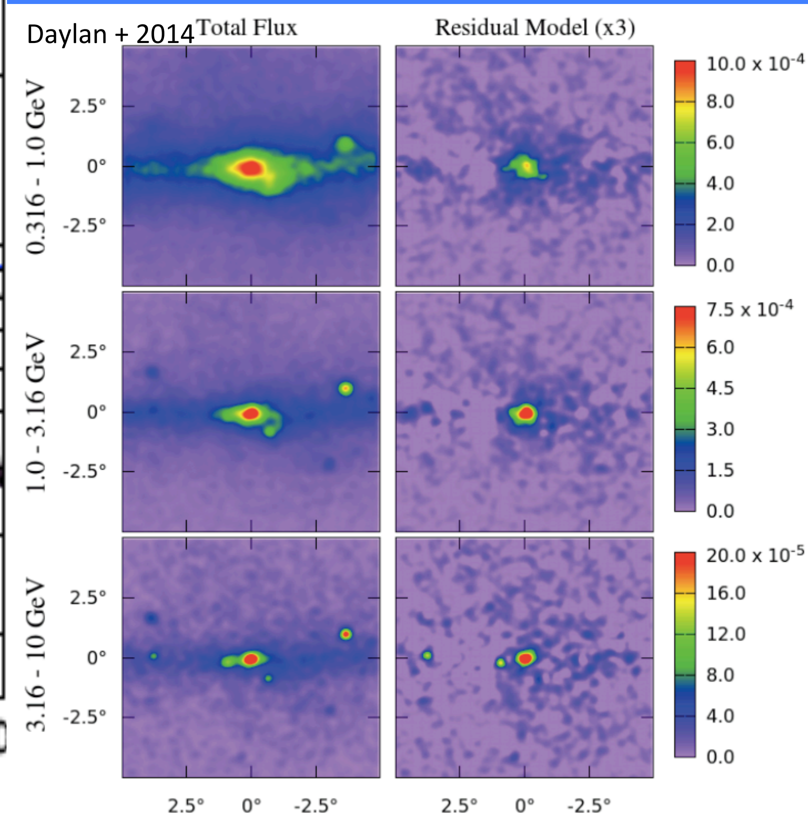




THE GALACTIC CENTER 7ºx7º

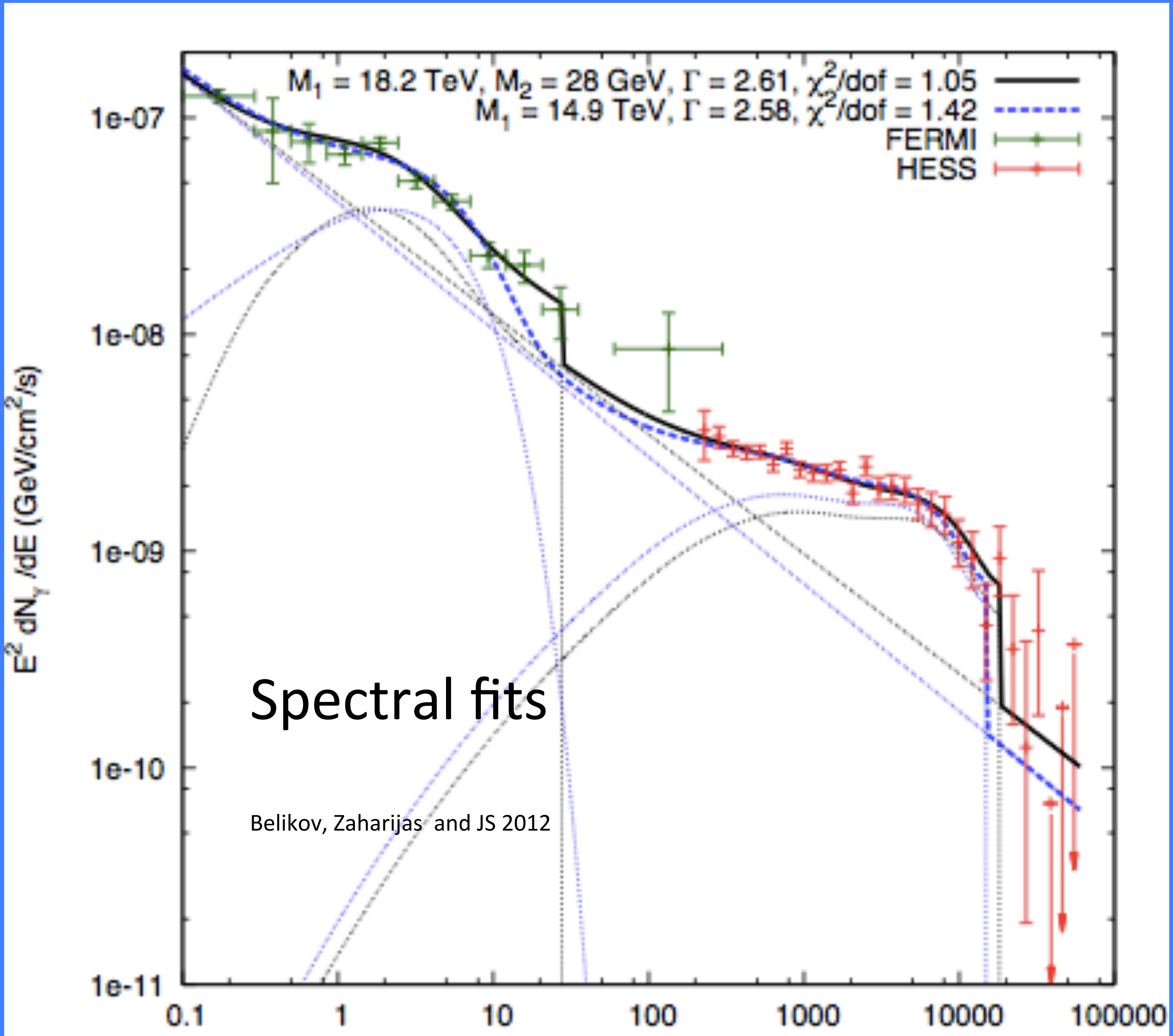

Ann
1/v
Yang et al 2013
1/v²
VL2 simulation
b [Deg]
2
1
0
−1
−2


m_{DM} = 10 GeV, B = 3 μG, n_{gas} = 3 cm^{-3}, leptons
prompt only
prompt + IC + brem, MED
MIN–MAX
$E_\gamma^2 dn/dE_\gamma$ (GeV cm^{-2} s^{-1})
10^{-7}
10^{-1}
10^{0}
E_γ (GeV)
Lacroix+2014: m_x=10 GeV works too
Include diffusion: makes a
big difference at 1 GeV!

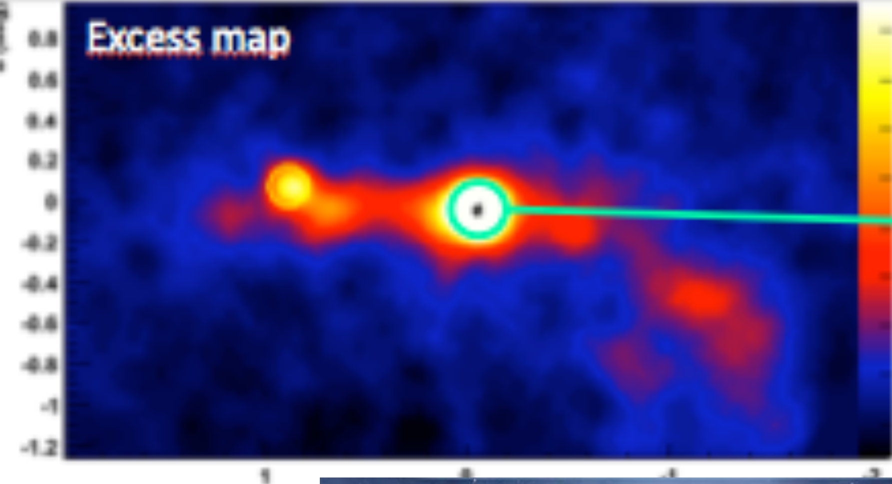

Daylan + 2014
Total Flux
Residual Model (x3)
0.316 - 1.0 GeV
1.0 - 3.16 GeV
3.16 - 10 GeV
2.5°
0°
-2.5°
10.0 x 10⁻⁴
8.0
6.0
4.0
2.0
0.0
7.5 x 10⁻⁴
6.0
4.5
3.0
1.5
0.0
20.0 x 10⁻⁵
16.0
12.0
8.0
4.0
0.0

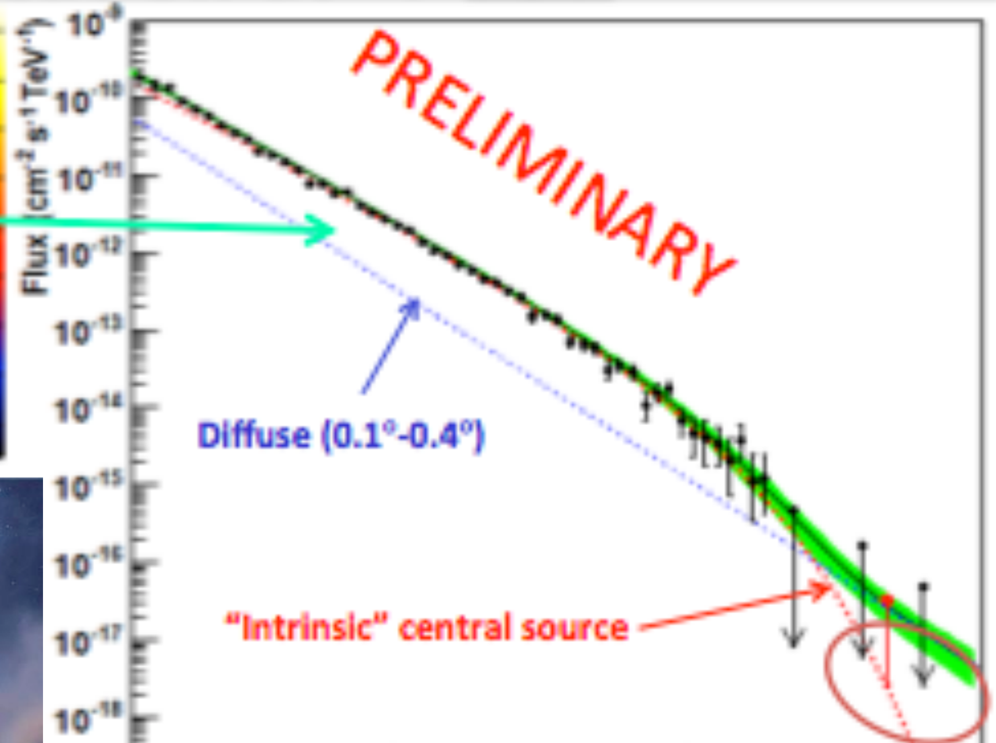
Dark Matter around our SMBH

Galactic Center SagA* HESS J1745-290

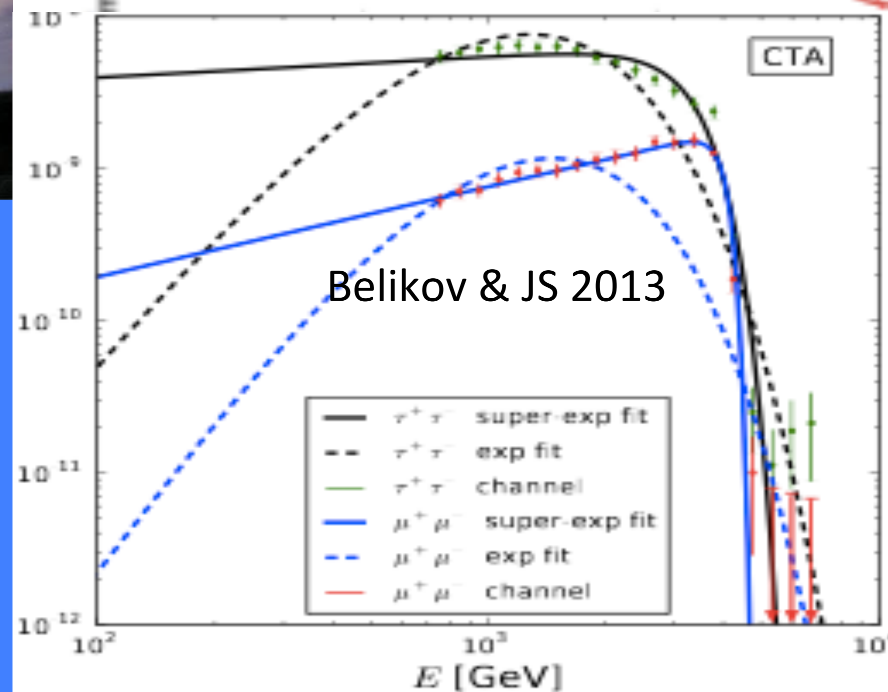


Belikov, Zaharijas and JS 2012





Vaiana, Moulin 2014

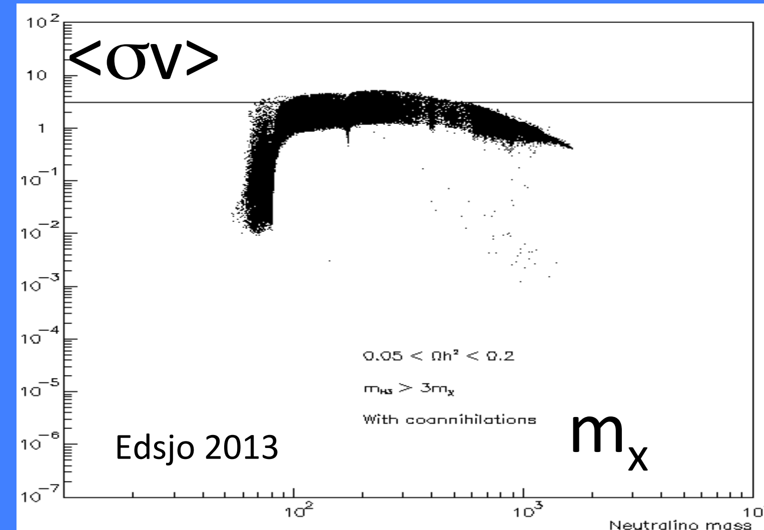


A prediction for CTA: superexponential signature of TeV DM annihilations

NEARBY AGN

CDM cusp steepens by adiabatic growth of IMBH: $\rho \propto r^{-\gamma} \Rightarrow \rho \propto r^{-\gamma'}$, **with** $\gamma' = \frac{9-2\gamma}{4-\gamma}$

Annihilation rate is amplified within a radius $GM_{bh}/\sigma^2 \sim 0.003(M_{BH}/10^5 M_\odot)\mathrm{pc}$

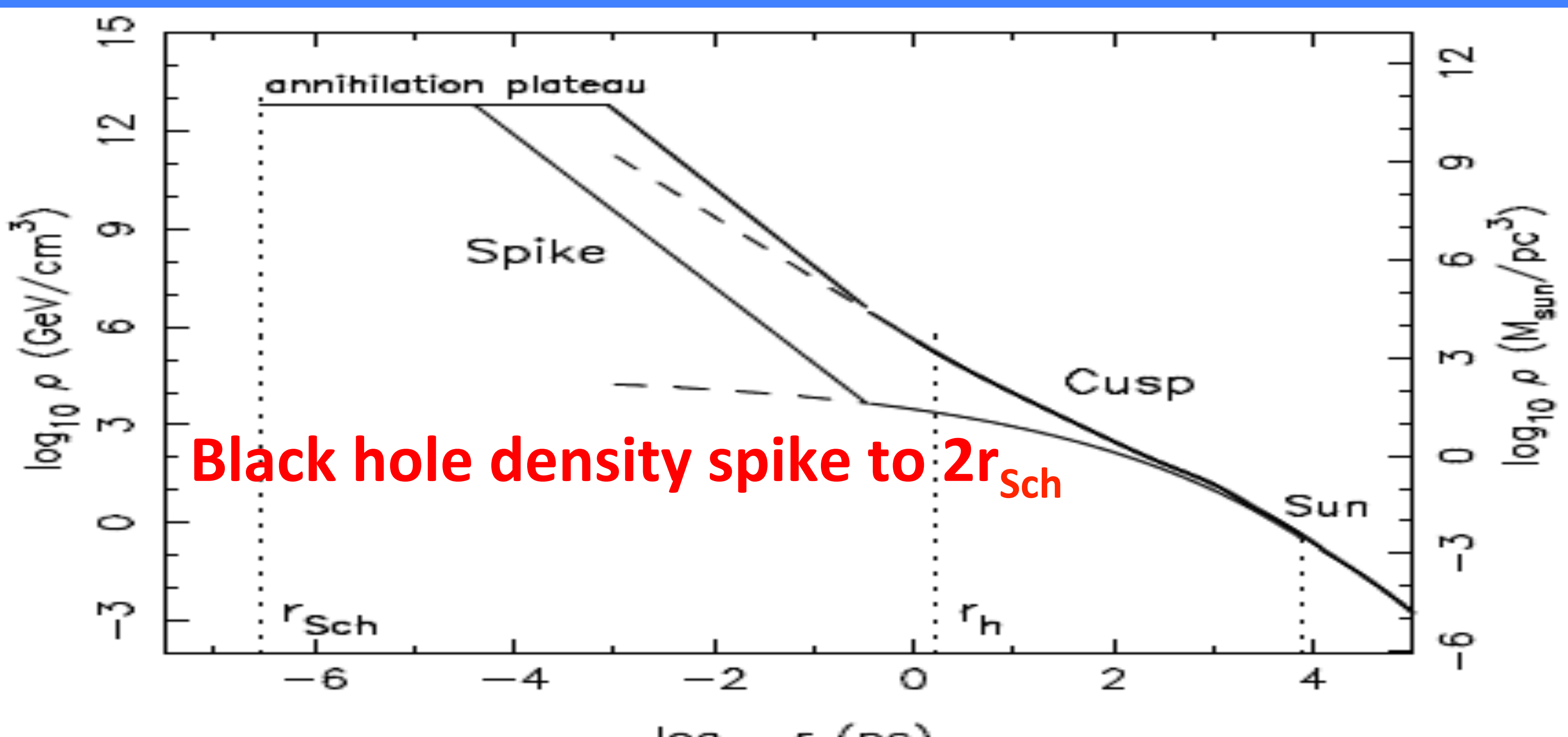


FLUX ~ $n_x^2\langle\sigma v\rangle (2r_g)^3$ ~ $M_{BH}^3/\langle\sigma v\rangle$

Plateau: 1 ~ $n_x\langle\sigma v\rangle\, t_{BH}$

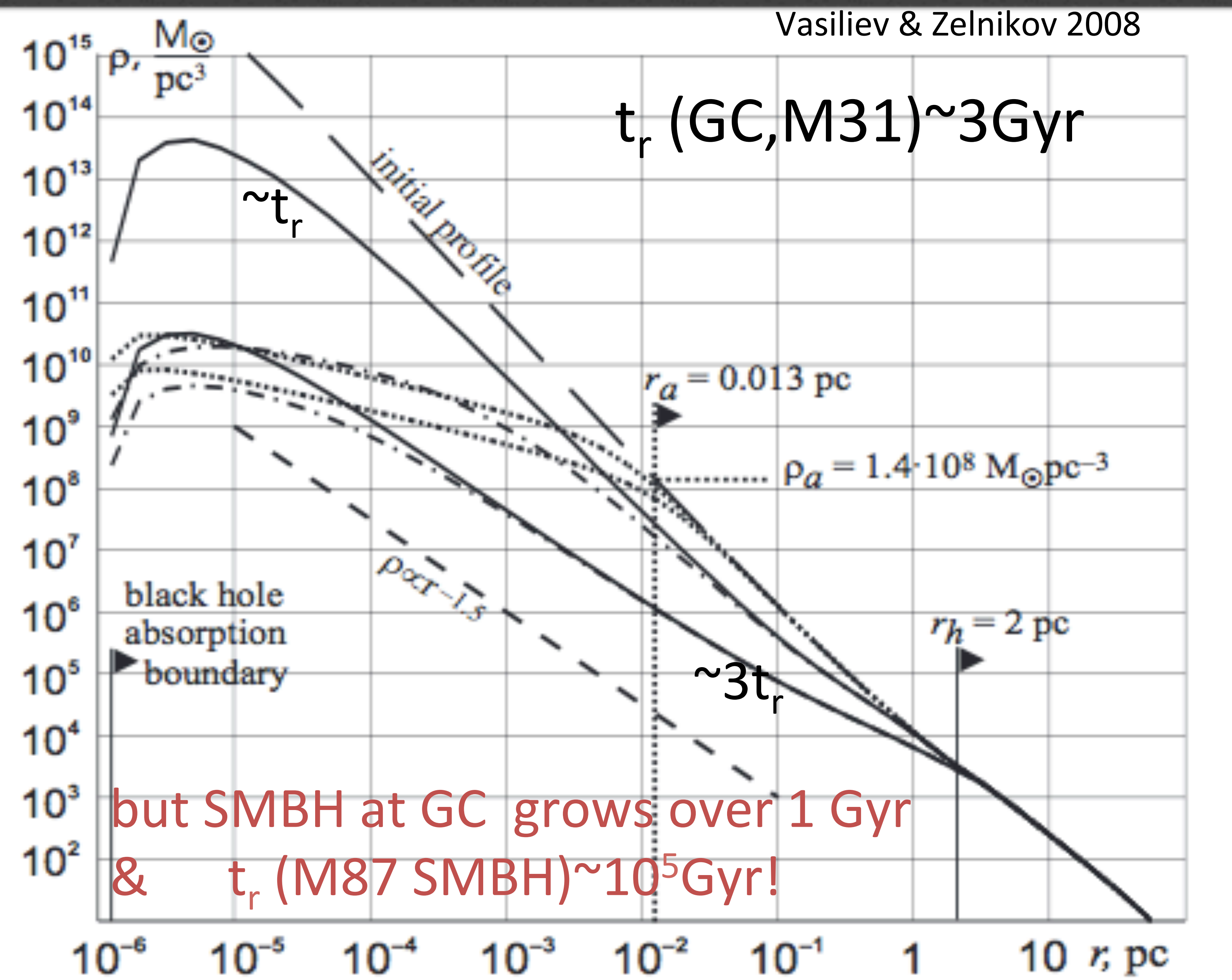
So M87 is a very attractive target !!!

Distance 2000 x GC but BH mass 1000 x larger

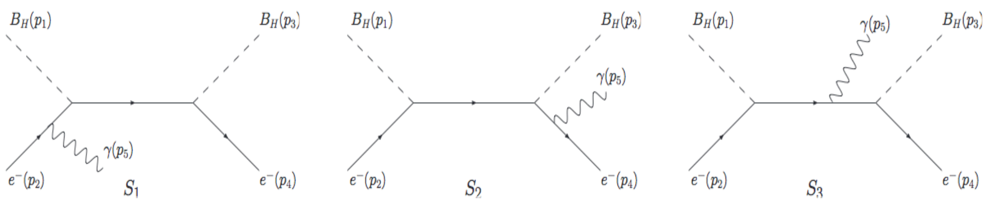


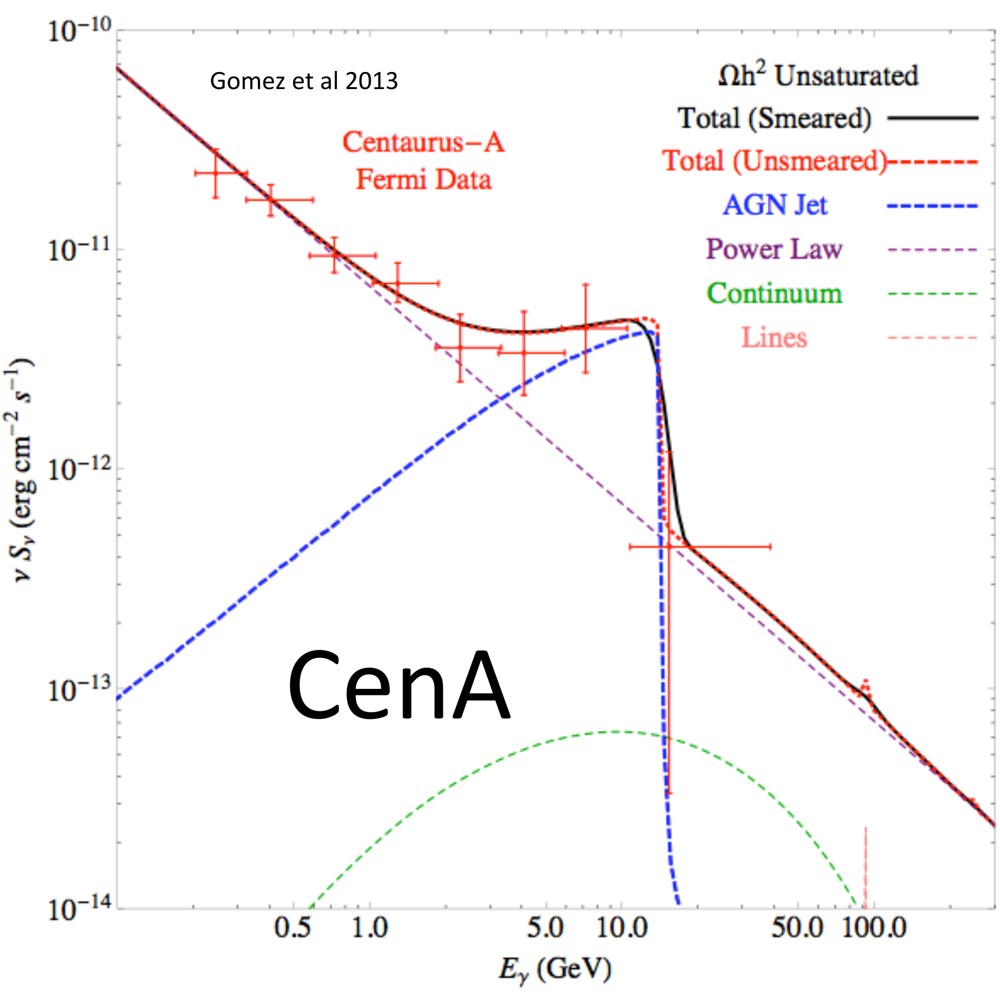
Gondolo + JS 1999, Gnedin & Primack 2004, Sadeghian, Ferrer + Will 2013

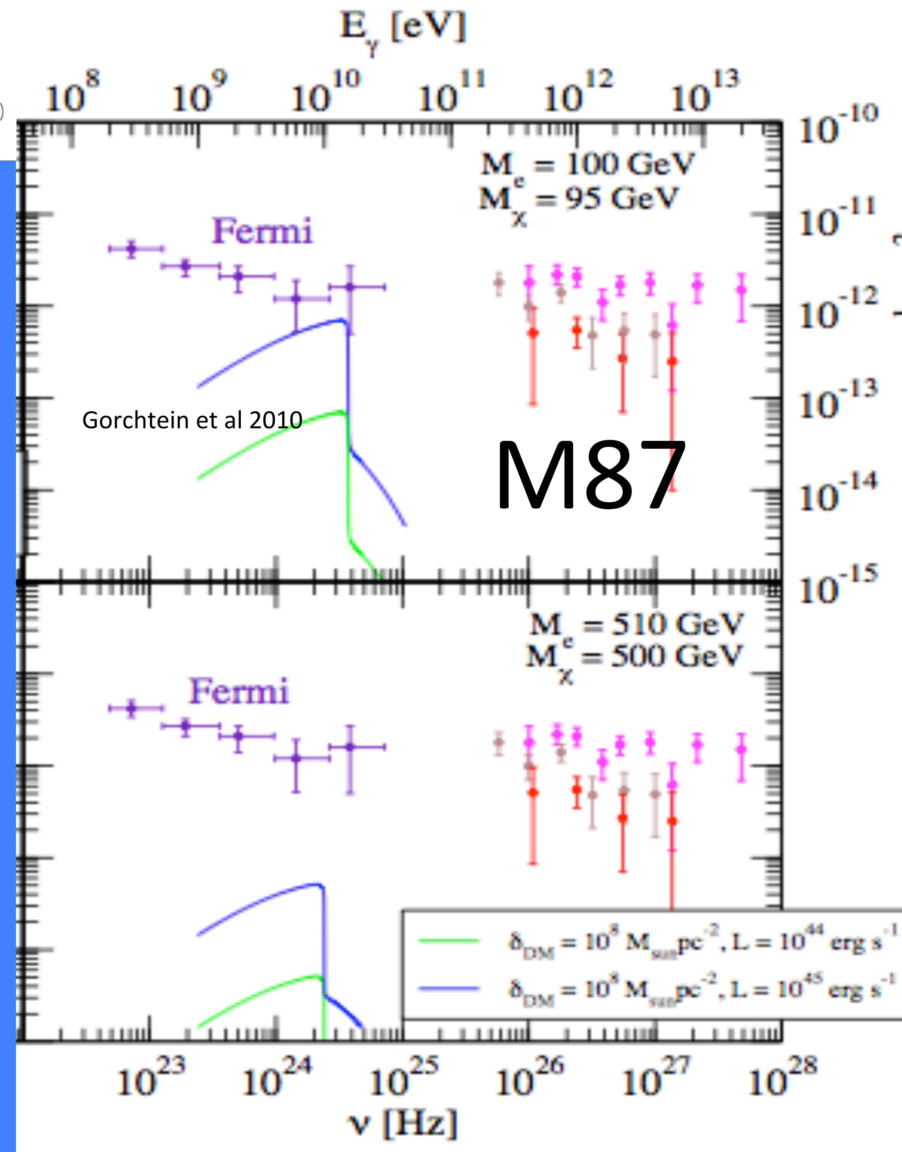
Does cusp survive? MAYBE!



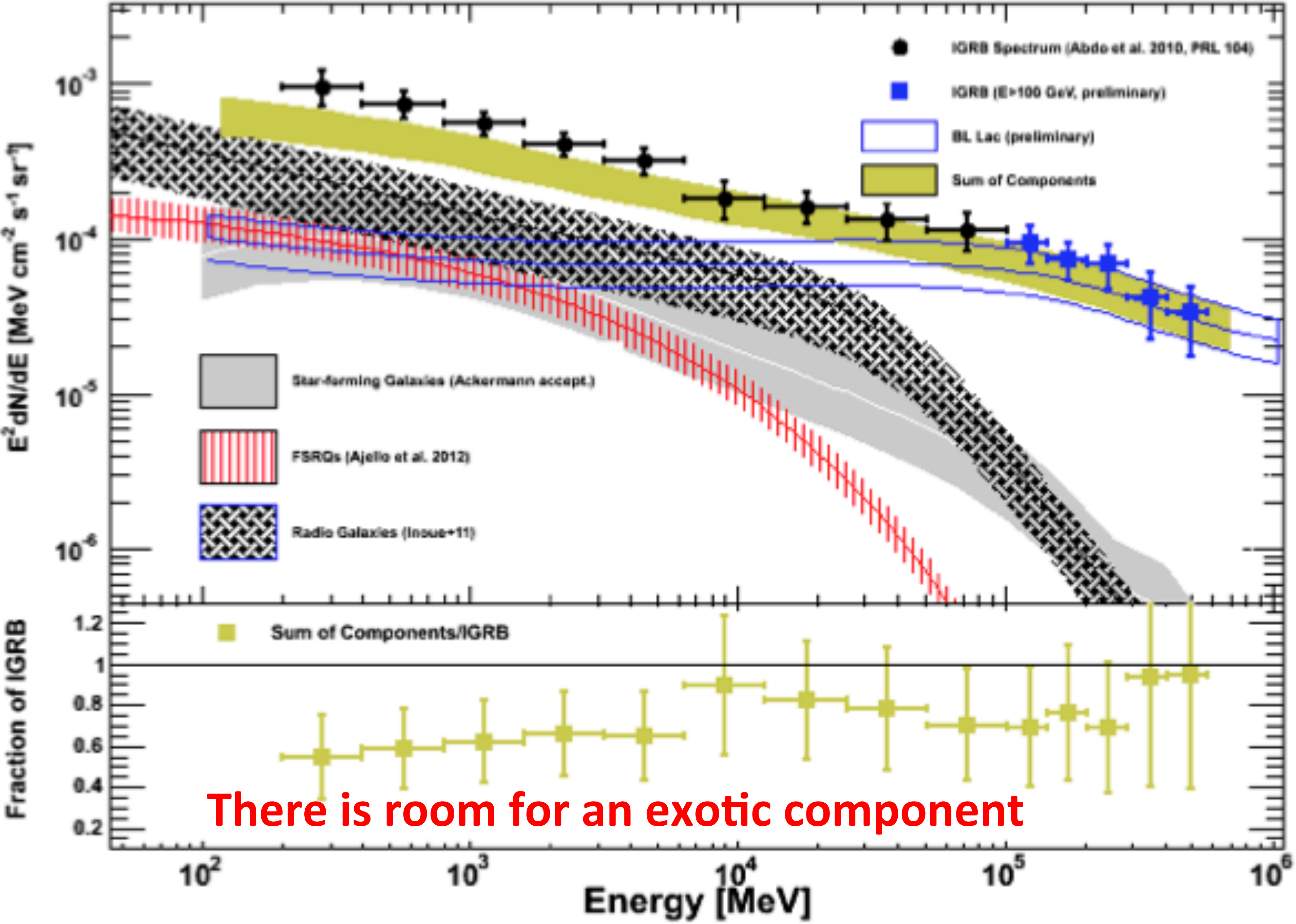
relativistic jets emanate from ergosphere, so high energy e,p collide with DM spike particles!



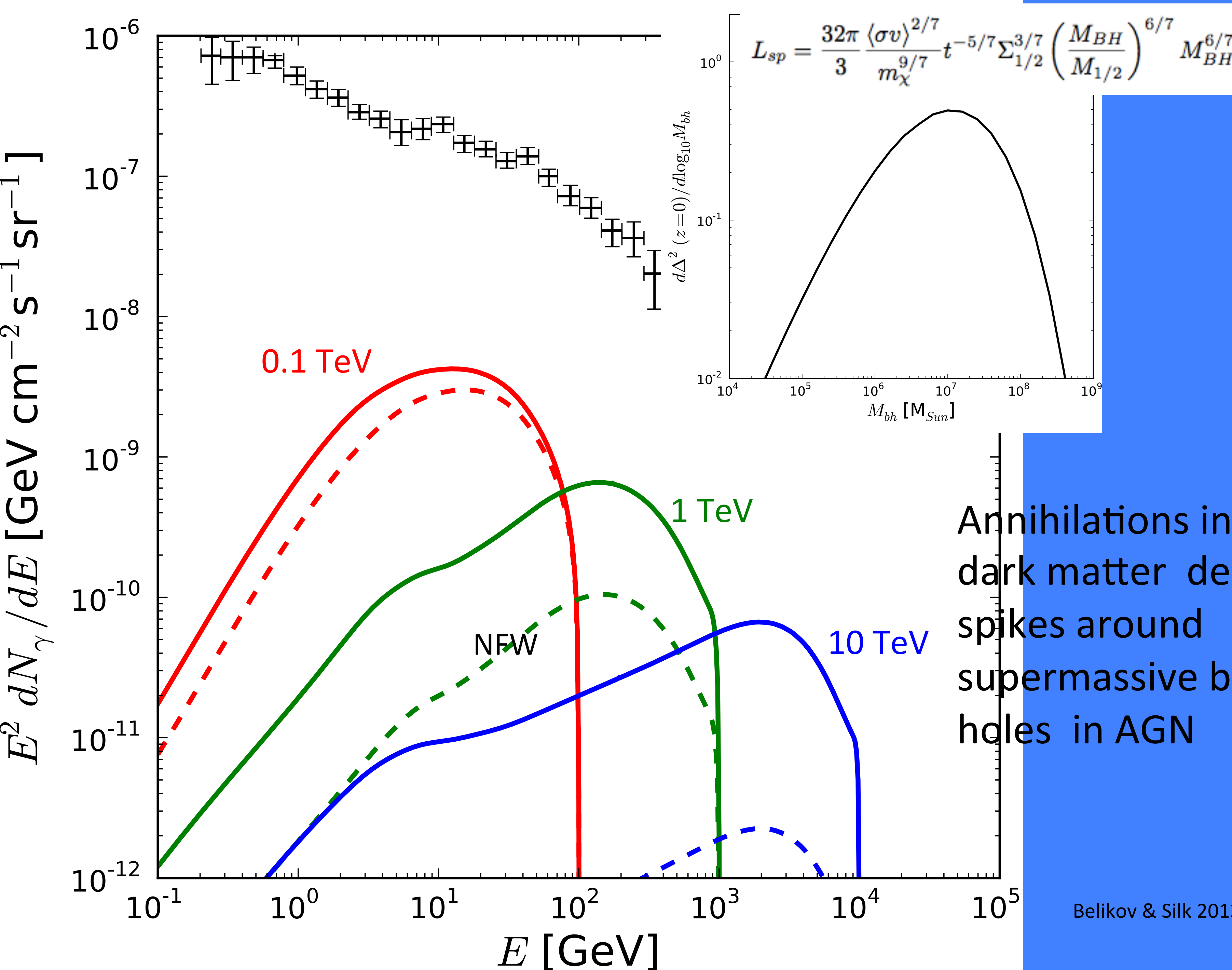




EXTRAGALACTIC GAMMA RAY BACKGROUND



There is room for an exotic component

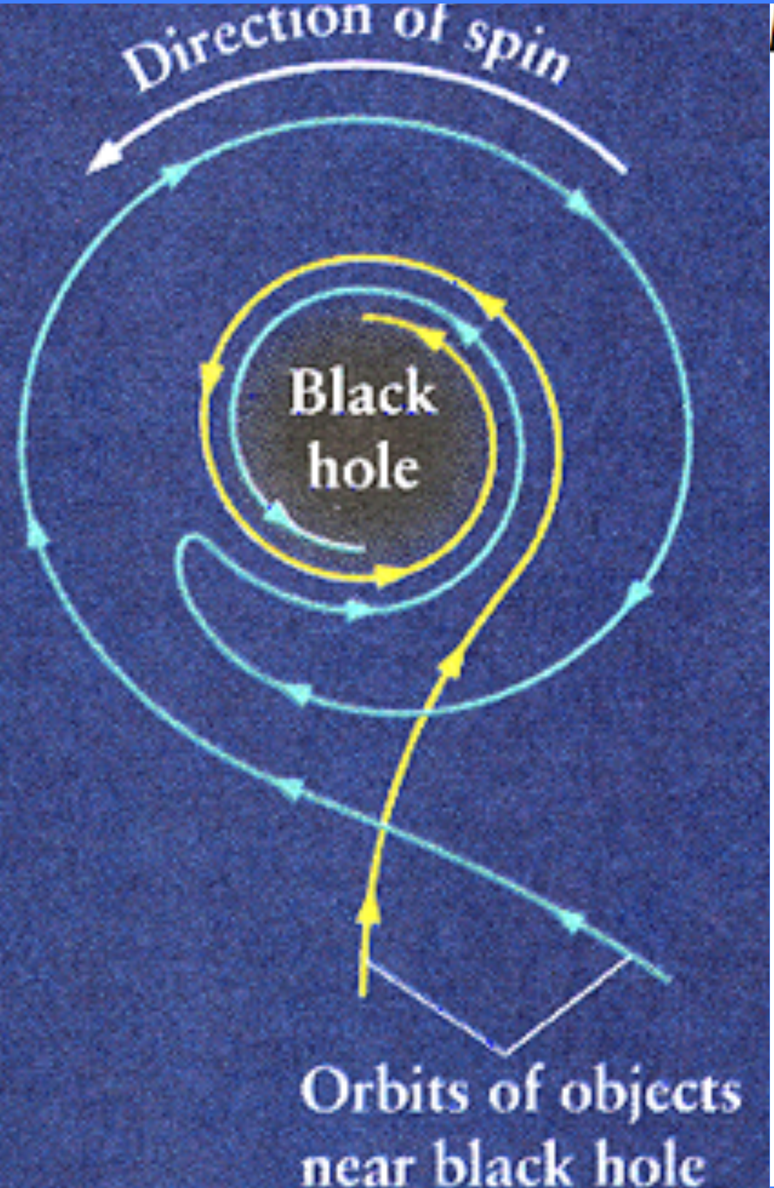


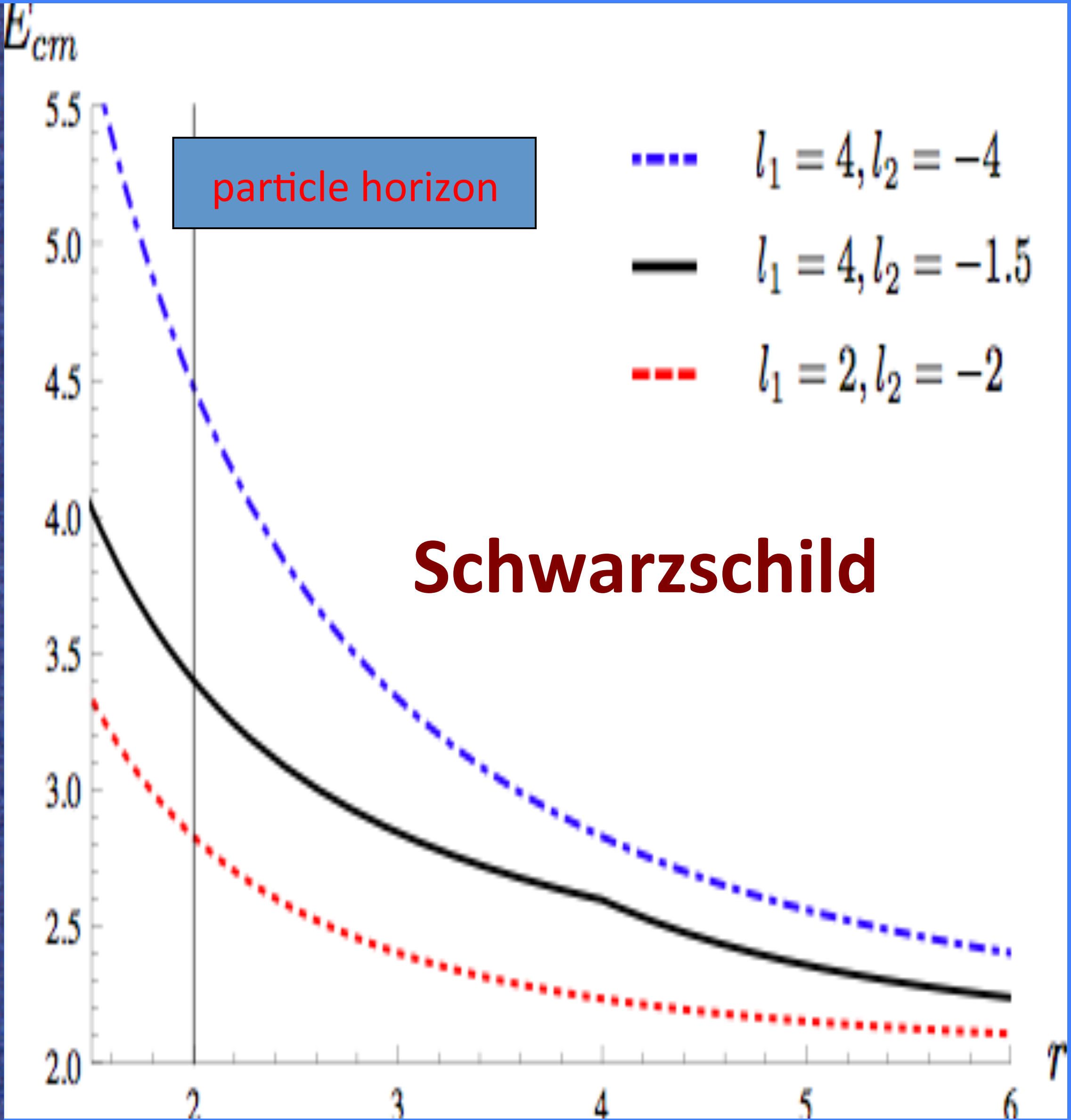
Annihilations in dark matter density spikes around supermassive black holes in AGN

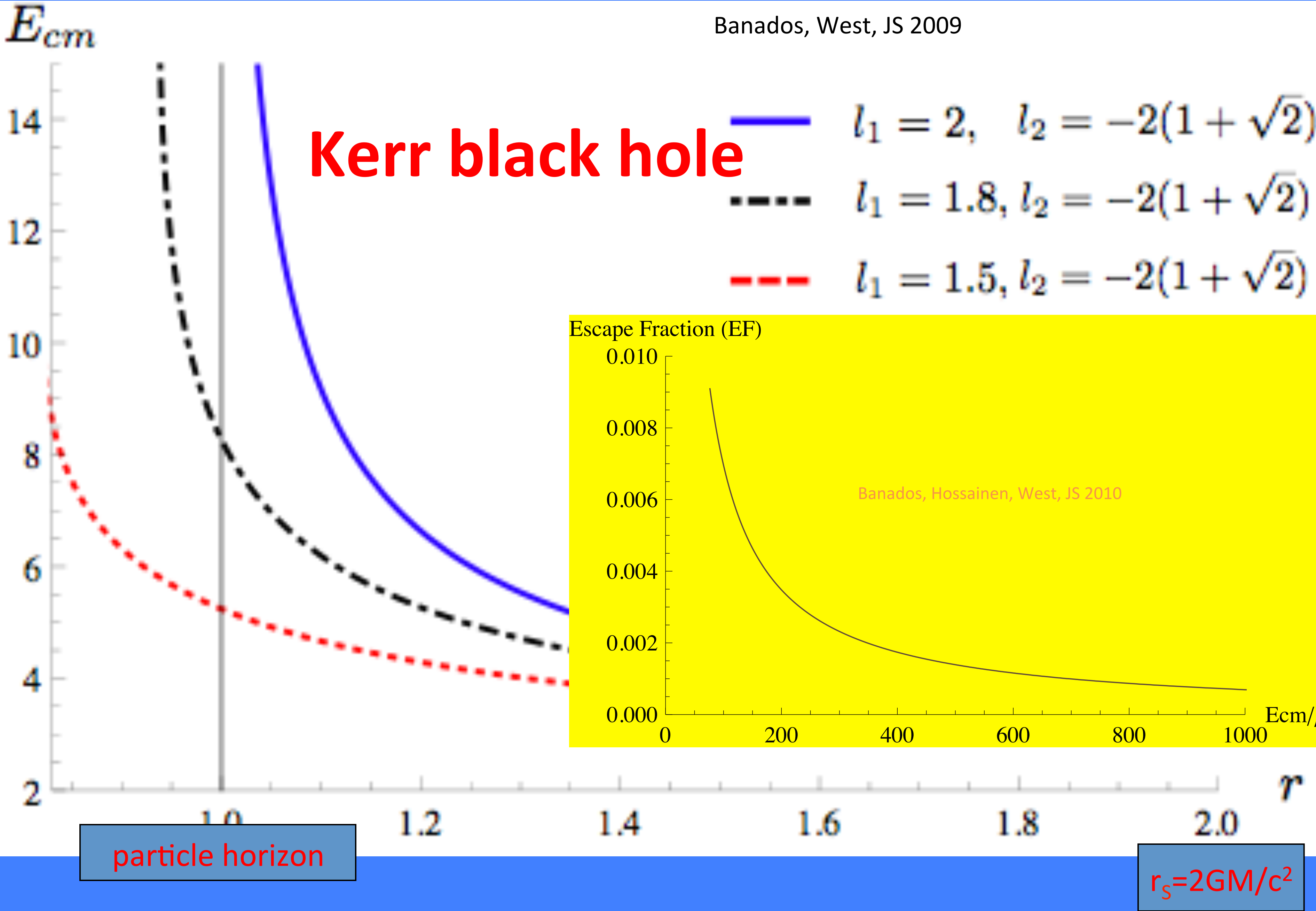
Belikov & Silk 2013

BLACK HOLES

THE ULTIMATE PARTICLE ACCELERATOR: dark matter cusp around black hole

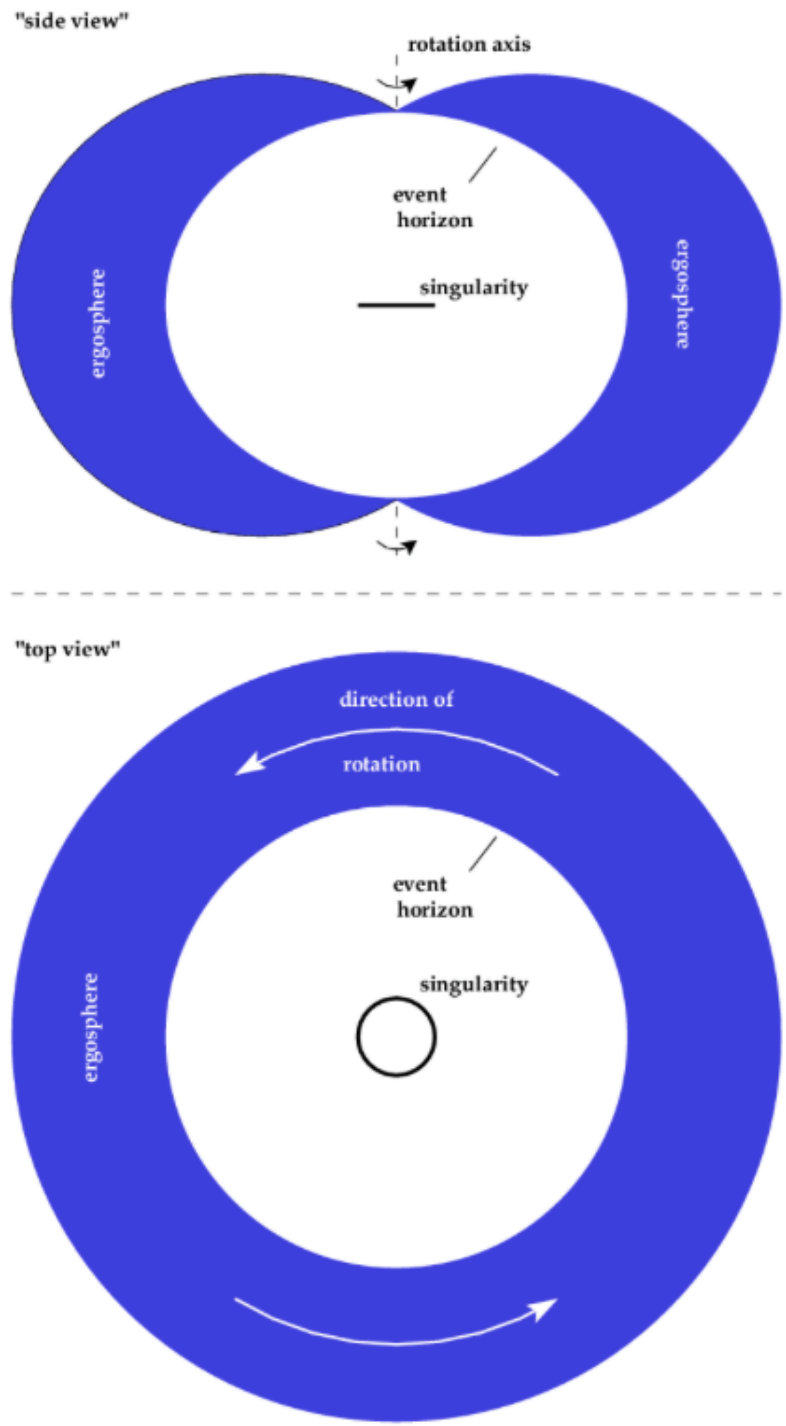




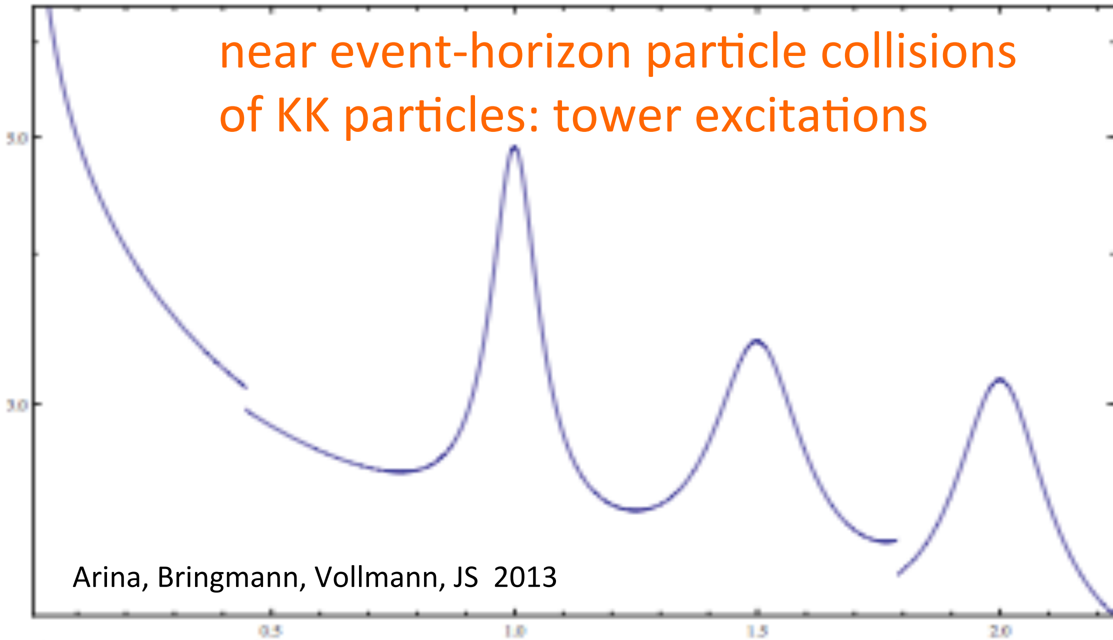


Highly controversial…but the dust hasn't settled yet!

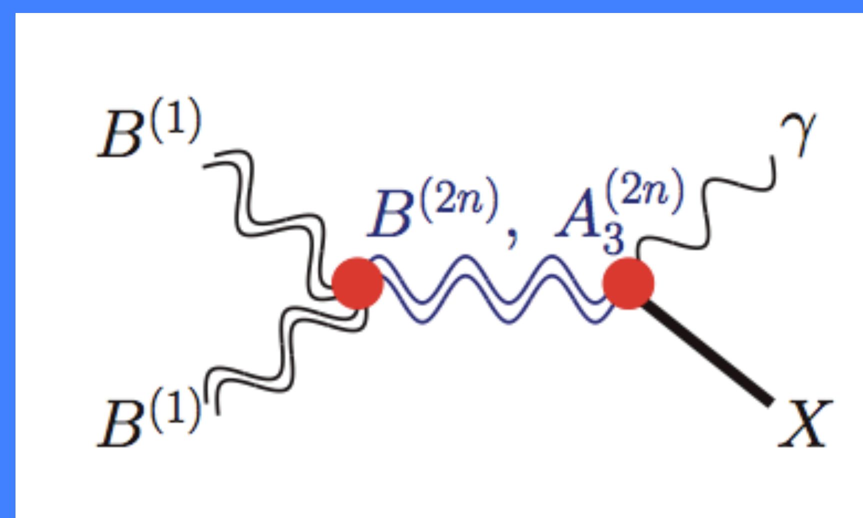
Kerr rotation energy can be tapped to overcome gravitational redshift: Penrose effect



near event-horizon particle collisions of KK particles: tower excitations

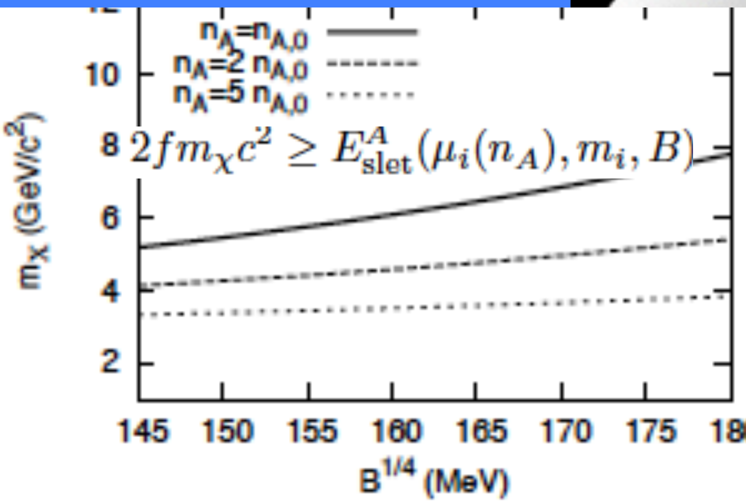


Arina, Bringmann, Vollmann, JS 2013

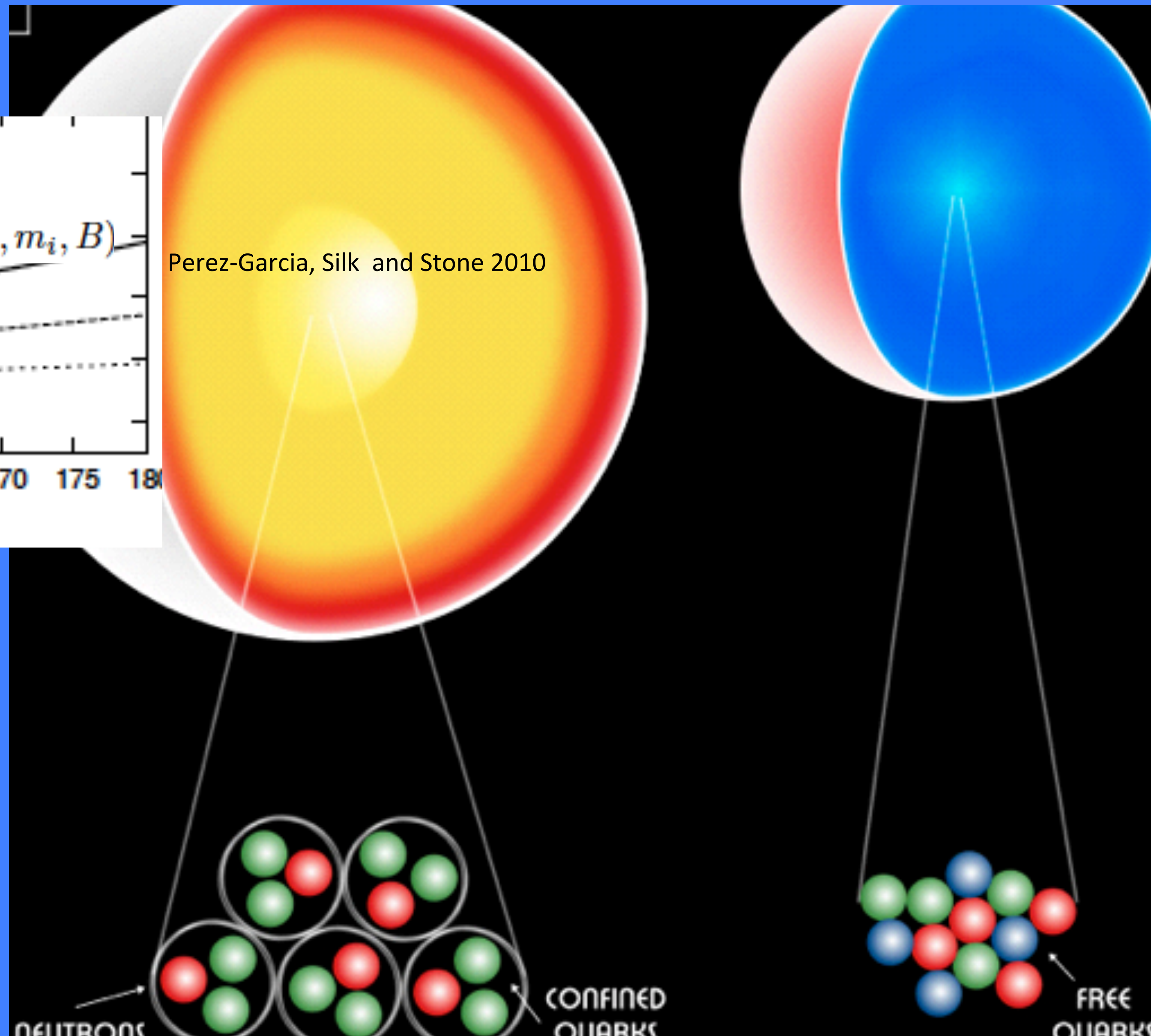


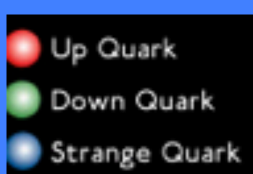
NEUTRON STARS

WIMP ANNIHILATIONS MAY CONVERT A NEUTRON STAR TO A QUARK STAR if neutron matter is metastable

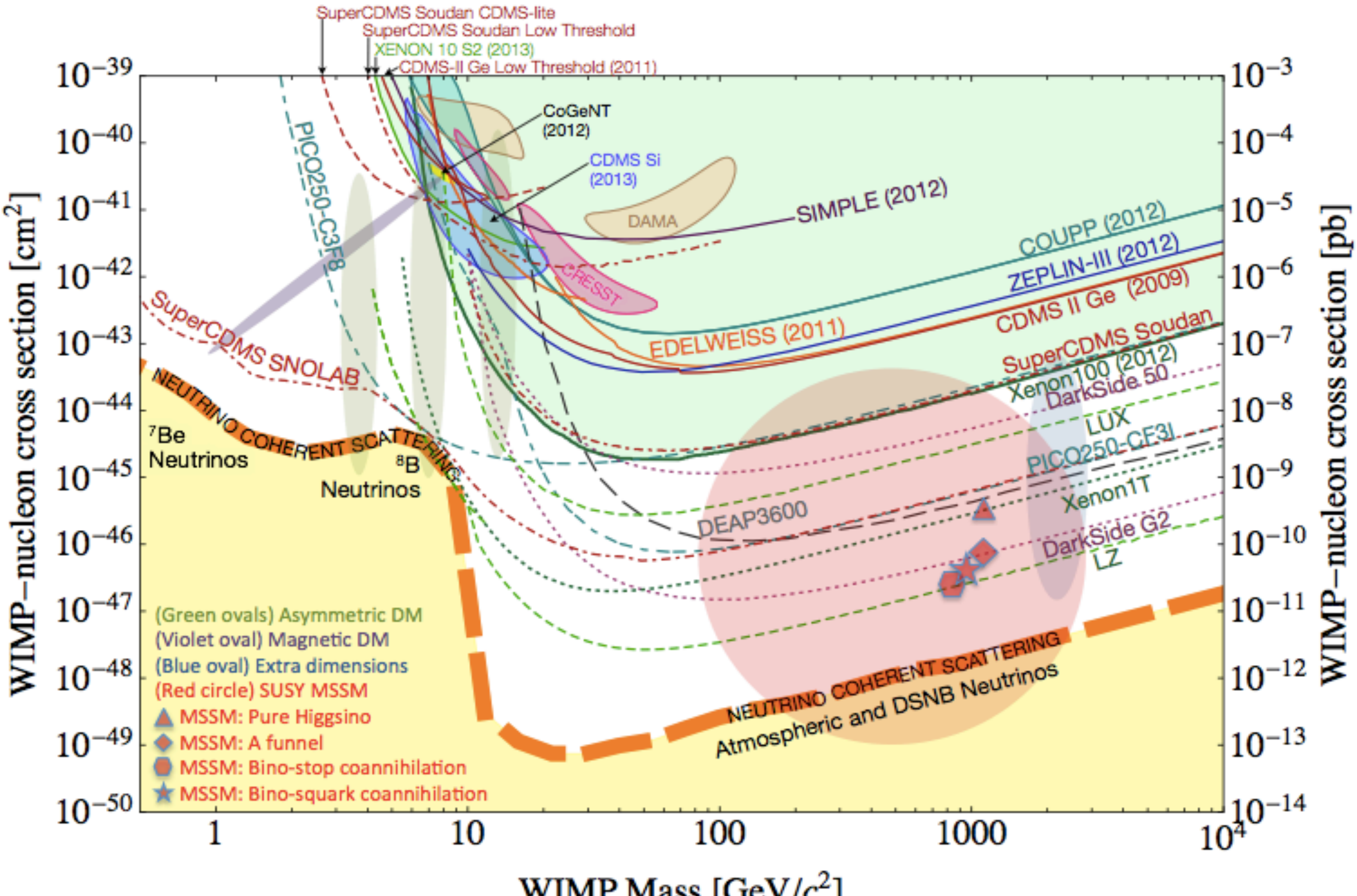


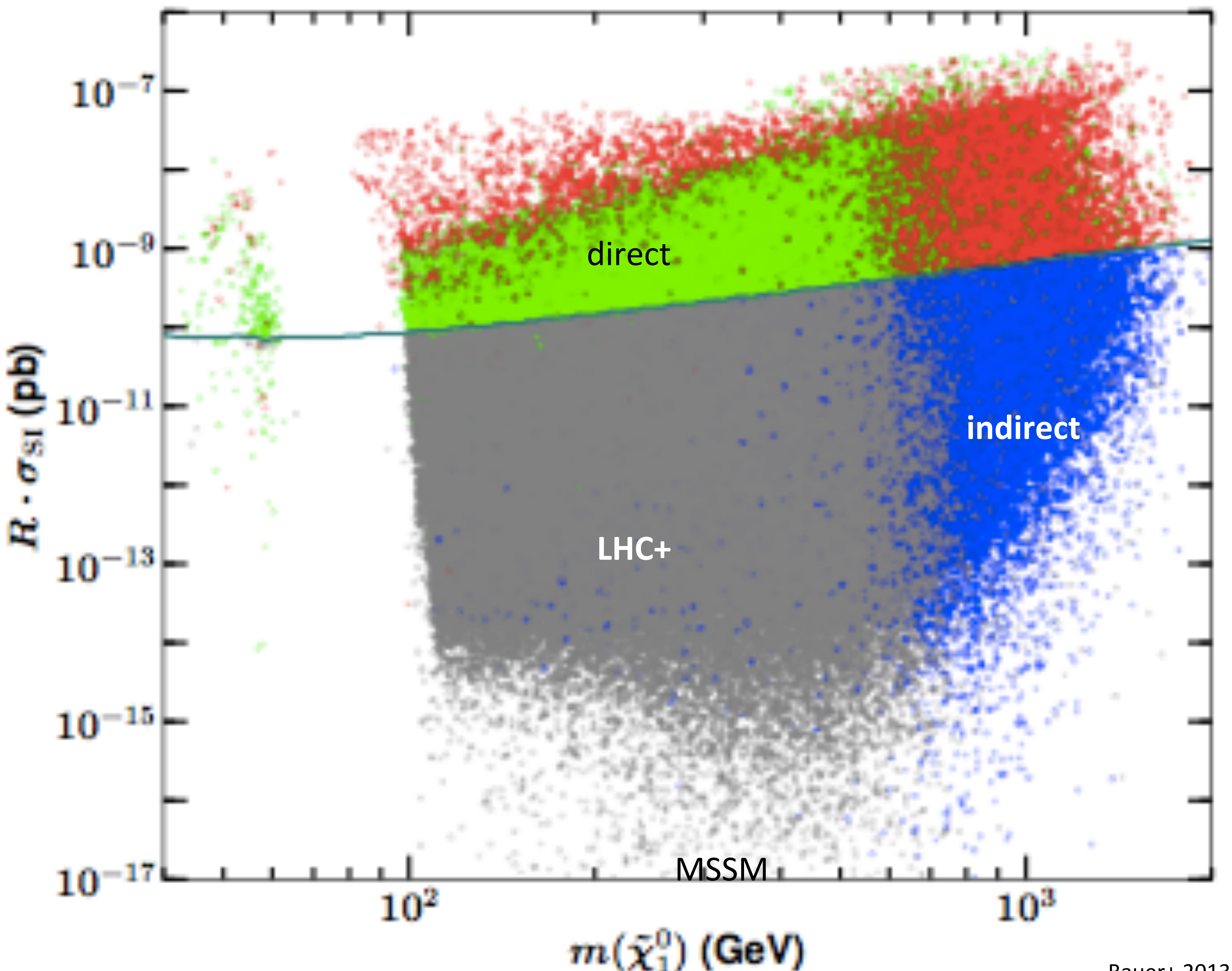
Perez-Garcia, Silk and Stone 2010





The ultimate limit




10^{-7}
10^{-9}
10^{-11}
10^{-13}
10^{-15}
10^{-17}
$R \cdot \sigma_{SI}$ (pb)
direct
indirect
LHC+
MSSM
10^2
10^3
$m(\tilde{\chi}_1^0)$ (GeV)

Bauer+ 2013