

Title: Discussion: What will GLAST see?

Date: Jun 07, 2008 02:45 PM

URL: <http://pirsa.org/08060009>

Abstract:

SUMMARY

- **INTRODUCTION**

- WHAT ARE WE LOOKING FOR?
- PROPERTIES OF THE "GOOD DM CANDIDATE"

- **GLAST**

- WHY IS IT IMPORTANT?
- KEY FEATURES FOR PHENOMENOLOGICAL STUDIES

- **DM INDIRECT DETECTION**

- TARGETS
- HOW TO CONVINCE A PARTICLE PHYSICIST

- **CONCLUSIONS**

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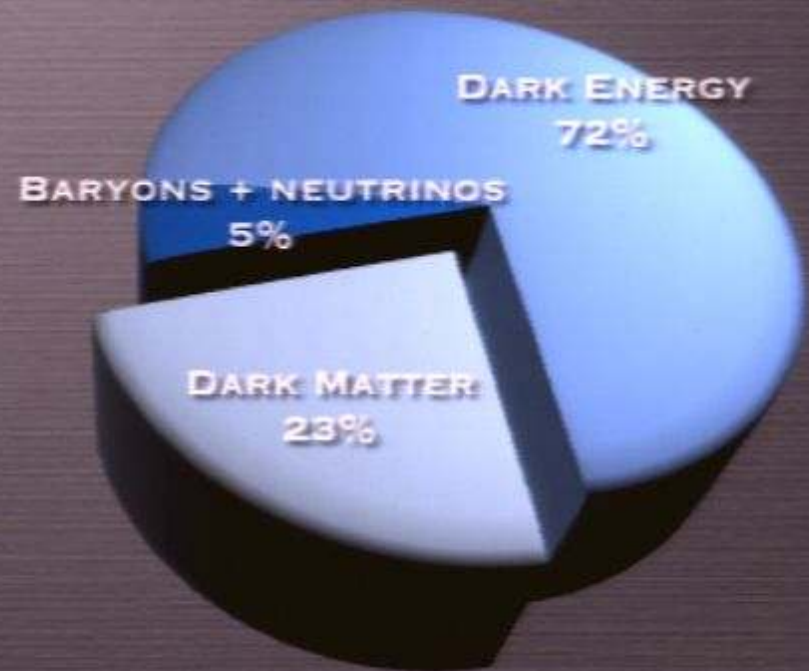
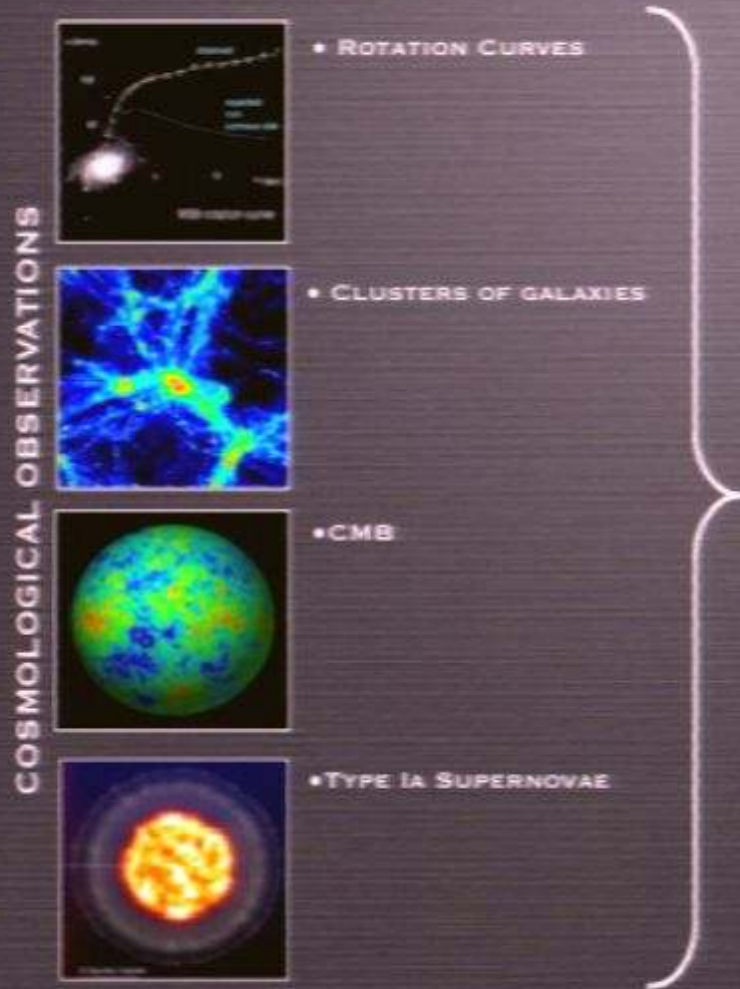
- **CONCLUSIONS**

EVIDENCE FOR DARK MATTER

EVIDENCE FOR THE EXISTENCE OF AN UNSEEN, "DARK", COMPONENT IN THE ENERGY DENSITY OF THE UNIVERSE COMES FROM SEVERAL INDEPENDENT OBSERVATIONS AT DIFFERENT LENGTH SCALES

COSMOLOGICAL OBSERVATIONS

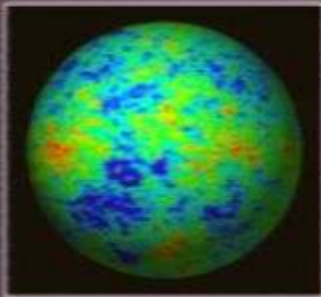
- ROTATION CURVES
- CLUSTERS OF GALAXIES
- CMB
- TYPE IA SUPERNOVAE



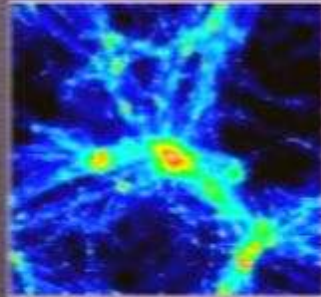
WHAT DO WE KNOW?

AN EXTRAORDINARILY RICH ZOO OF NON-BARYONIC DARK MATTER CANDIDATES HAS BEEN PROPOSED OVER THE LAST THREE DECADES. IN ORDER TO BE CONSIDERED A VIABLE DM CANDIDATE, A NEW PARTICLE HAS TO PASS THE FOLLOWING 10-POINT TEST

1) Ωh^2 OK?



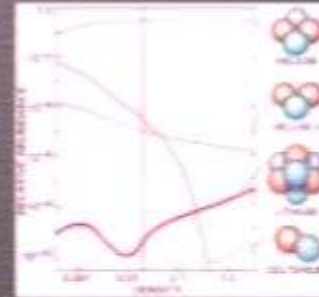
2) Is it cold?



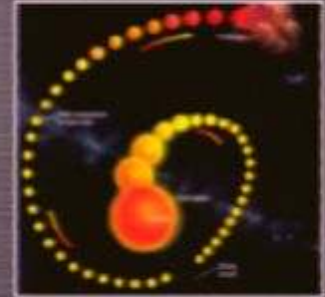
3) Is it neutral?



4) Is BBN ok?



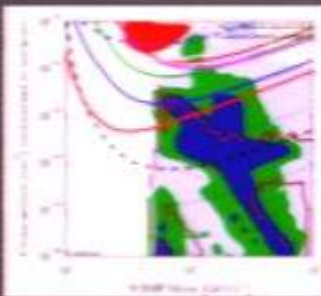
5) Stars OK?



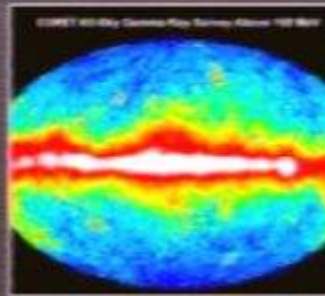
6) Collisionless?



7) Couplings OK?



8) γ -rays OK?



9) Astro bounds?

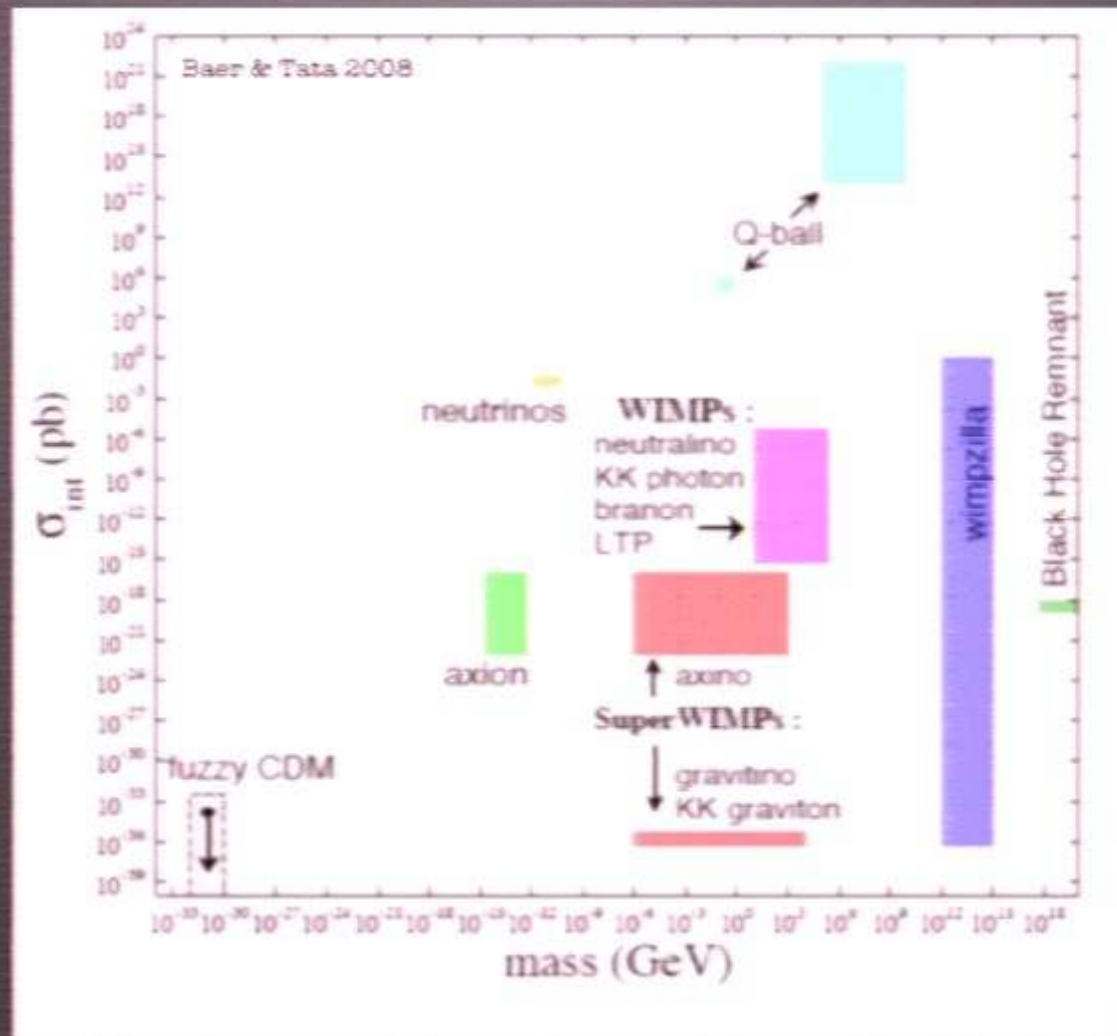


10) Can probe it?



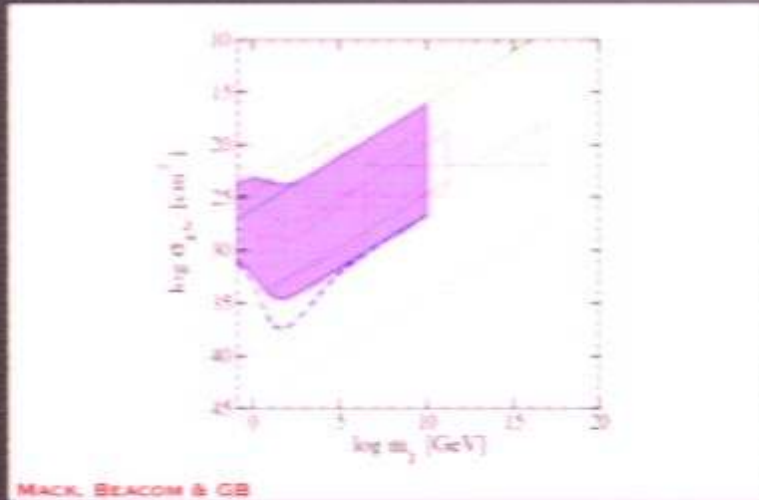
TAOSO, GB & MASIERO 2007

DM CANDIDATES

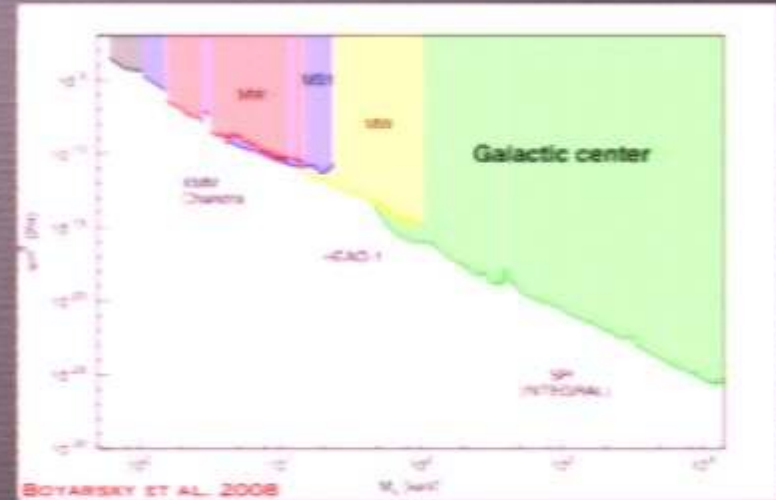


COSMOLOGY AND ASTROPHYSICS CONSTRAIN THE PROPERTIES OF DM

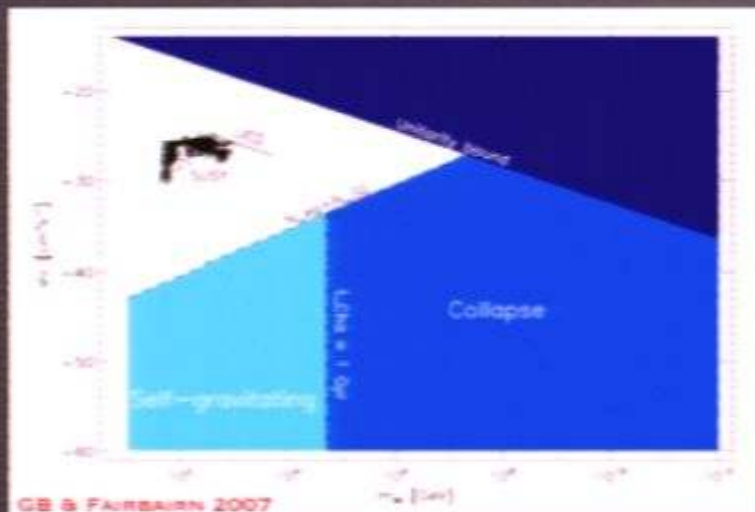
SCATTERING CROSS-SECTION



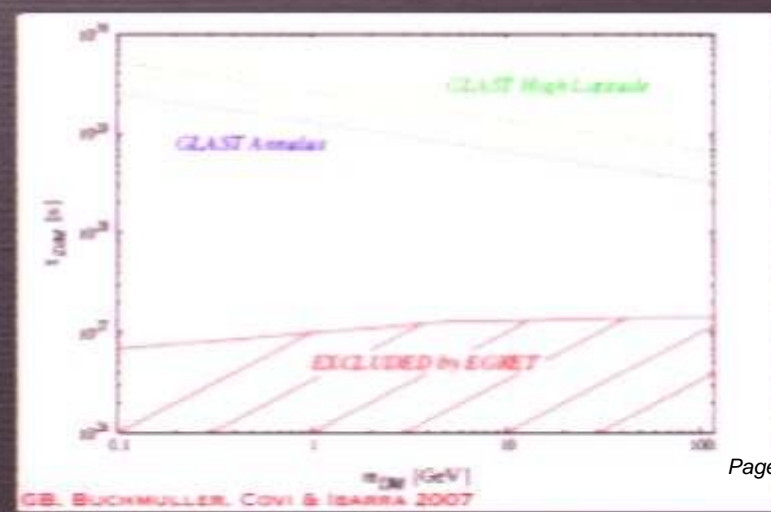
MIXING ANGLE (STERILE NEUTRINOS)



ANNIHILATION CROSS-SECTION

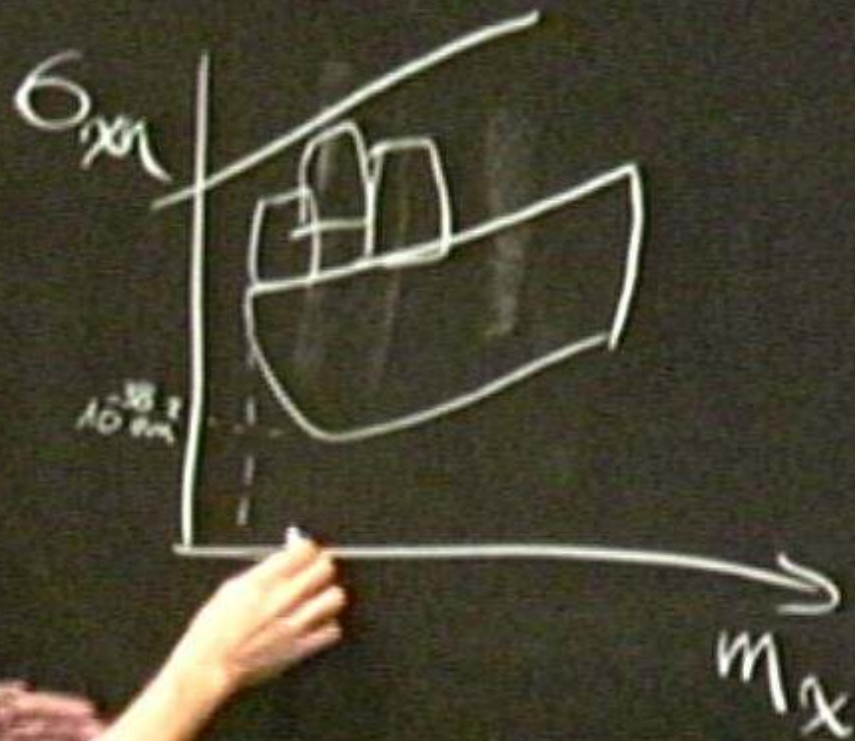


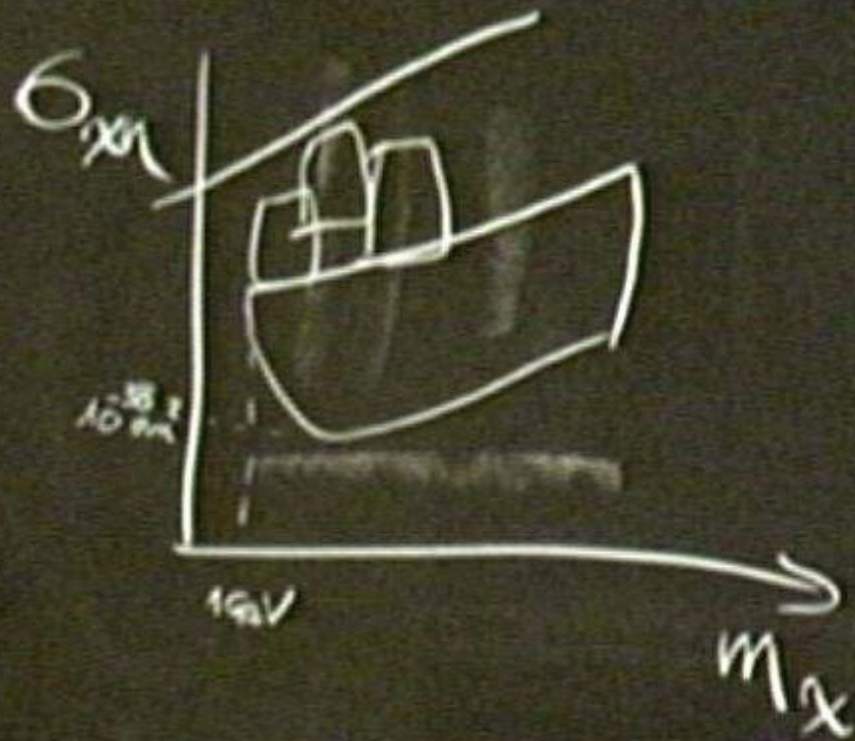
DECAY TIME



6,201



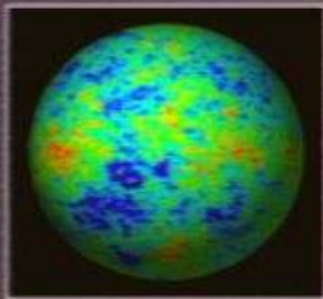




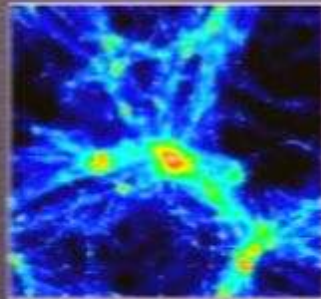
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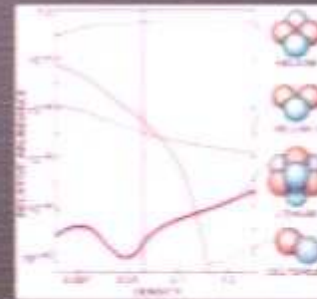
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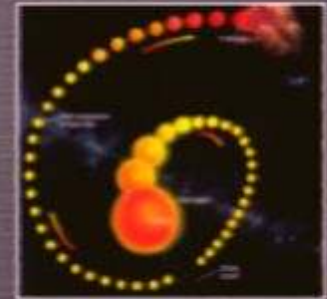
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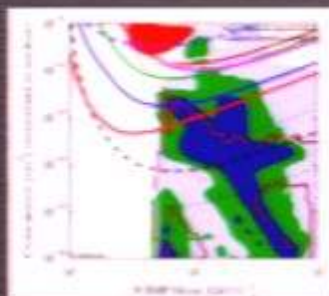
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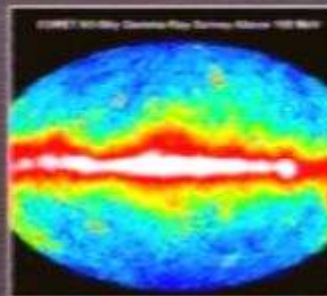
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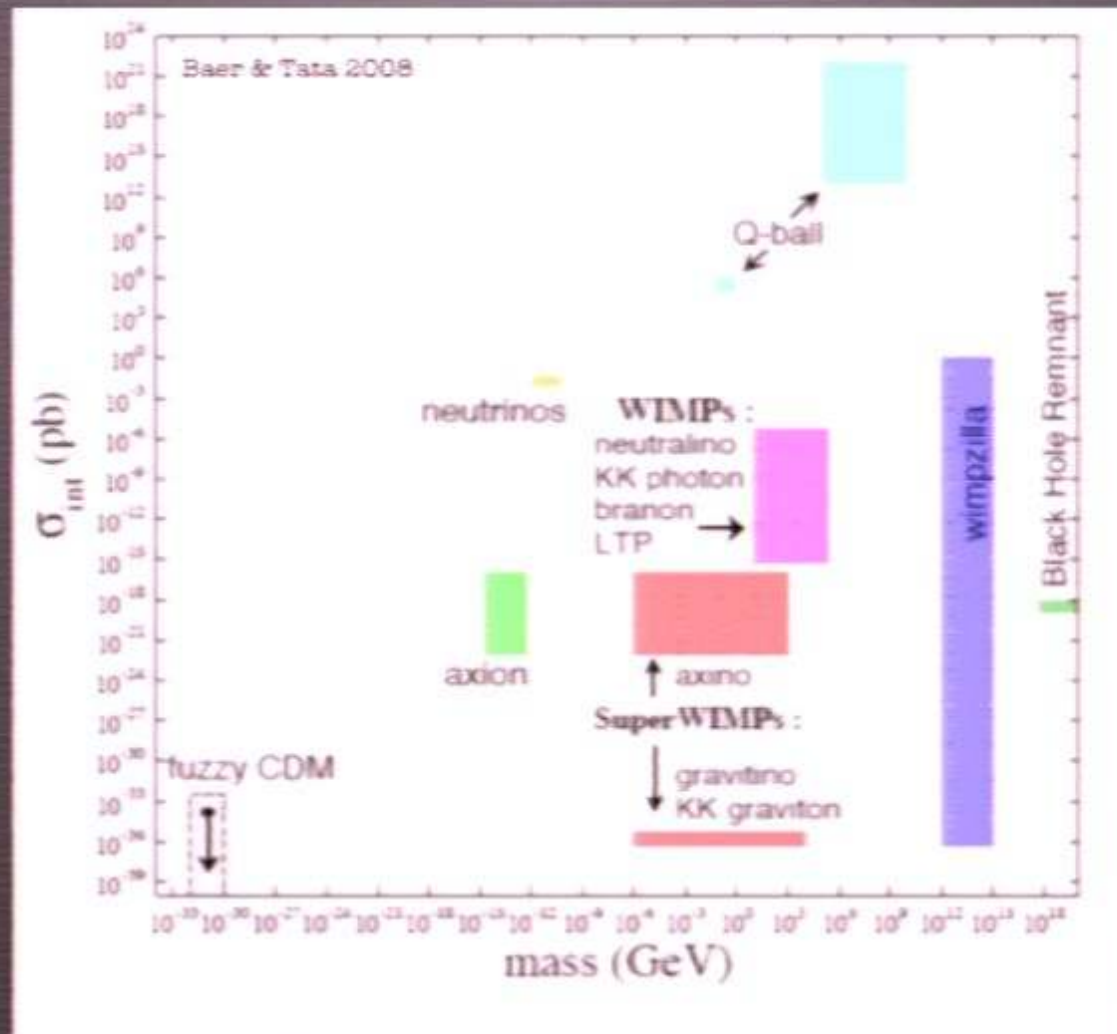


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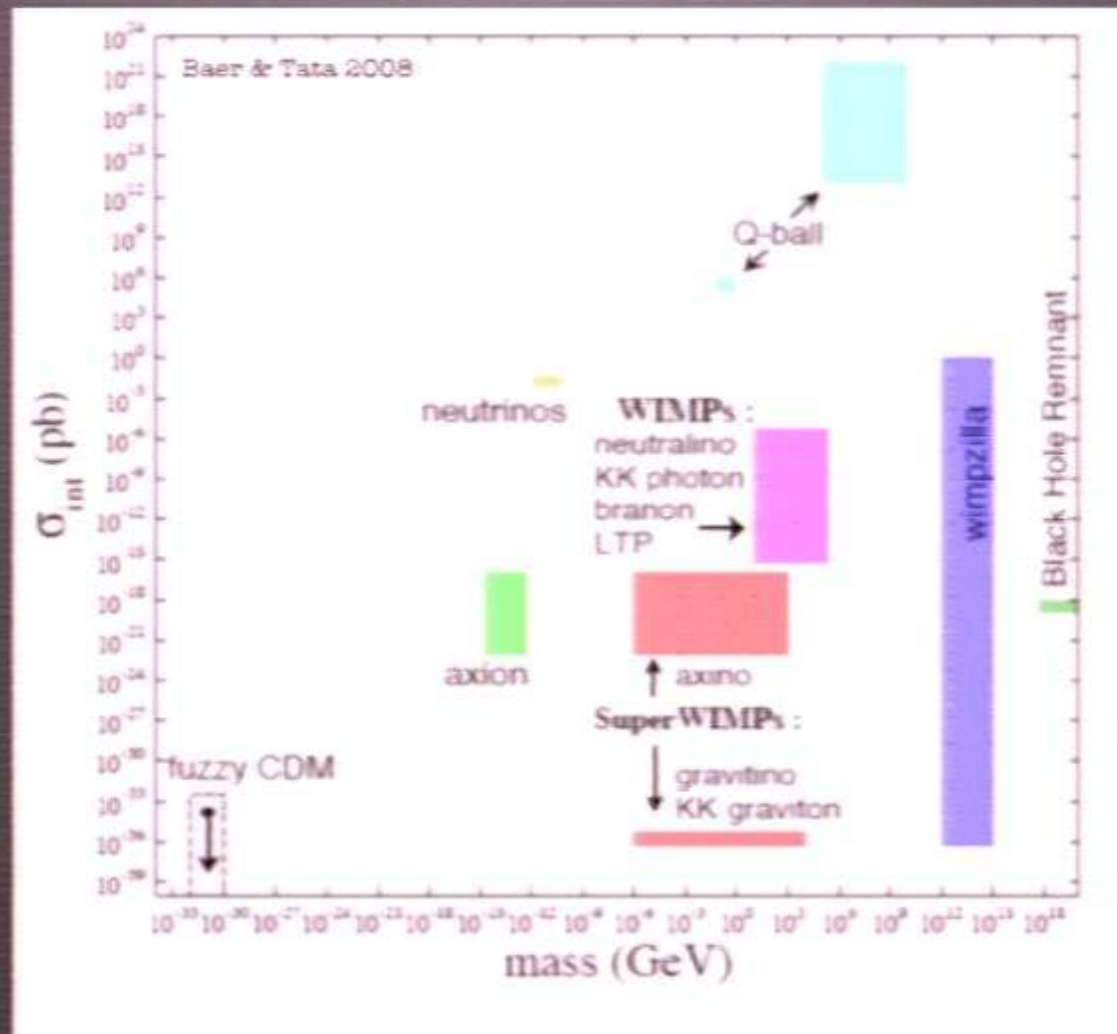


TAOSO, GB & MASIERO 2007

DM CANDIDATES

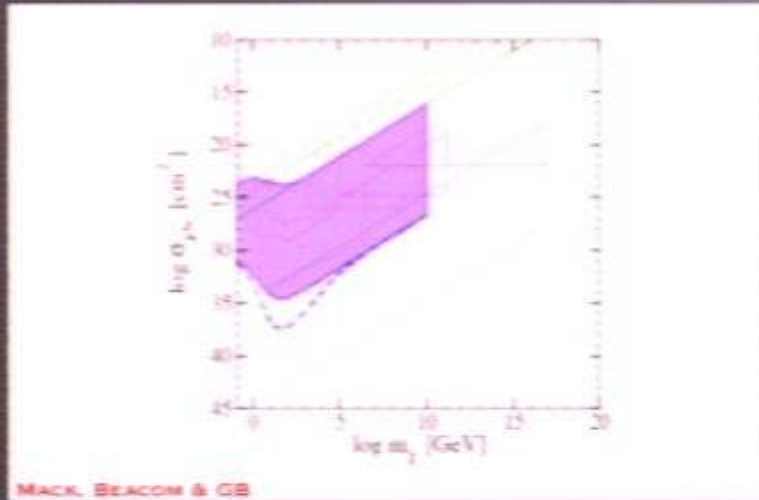


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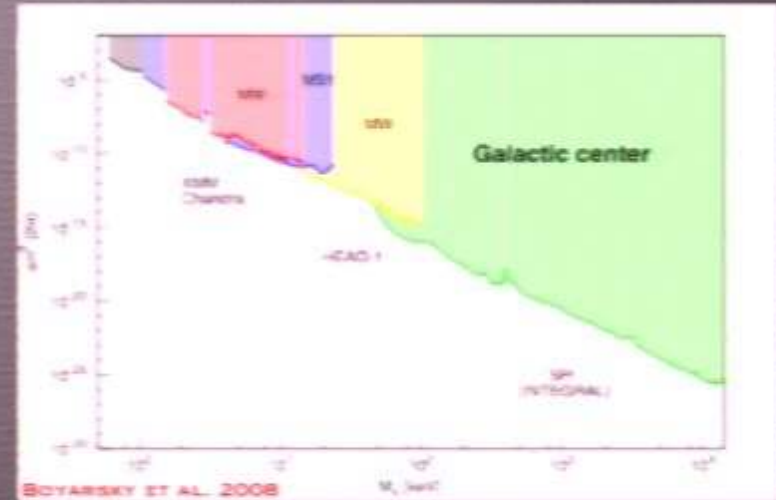


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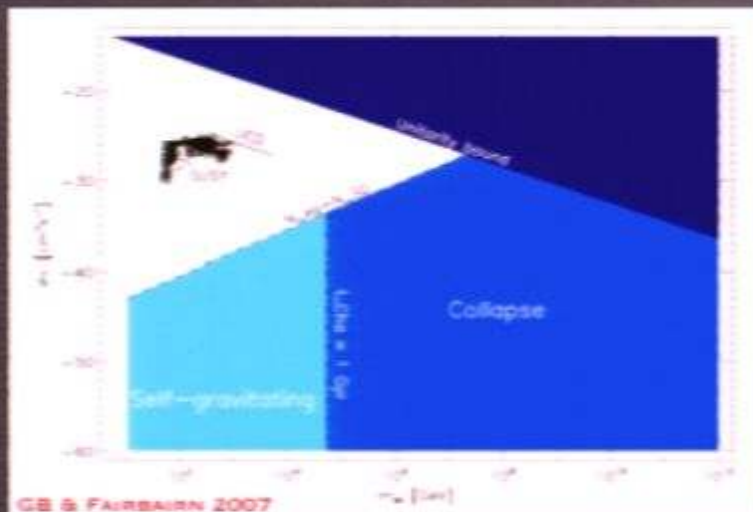
SCATTERING CROSS-SECTION



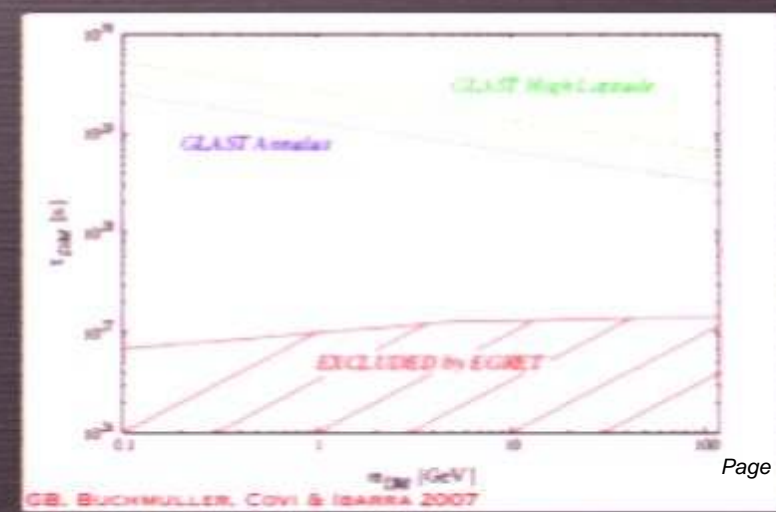
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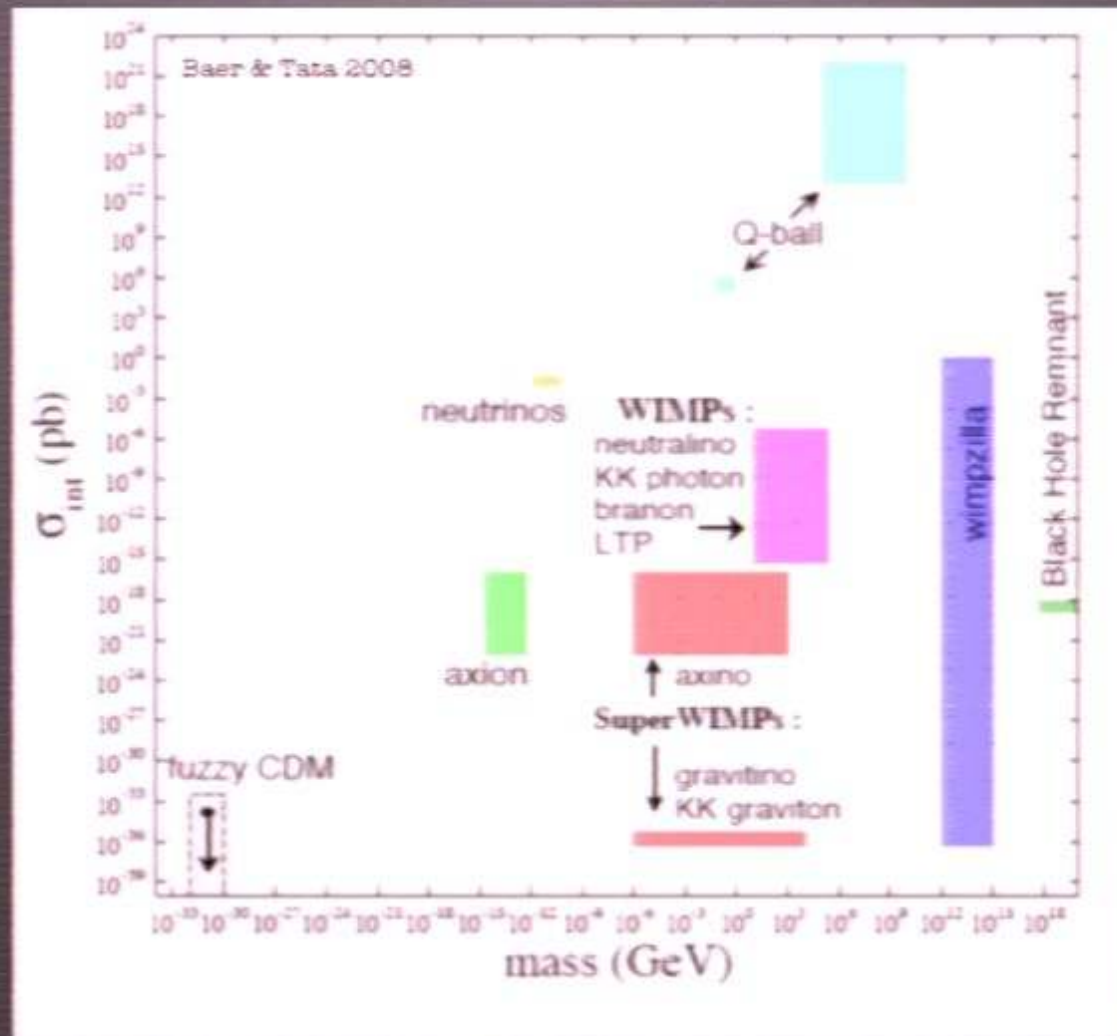
ANNIHILATION CROSS-SECTION



DECAY TIME

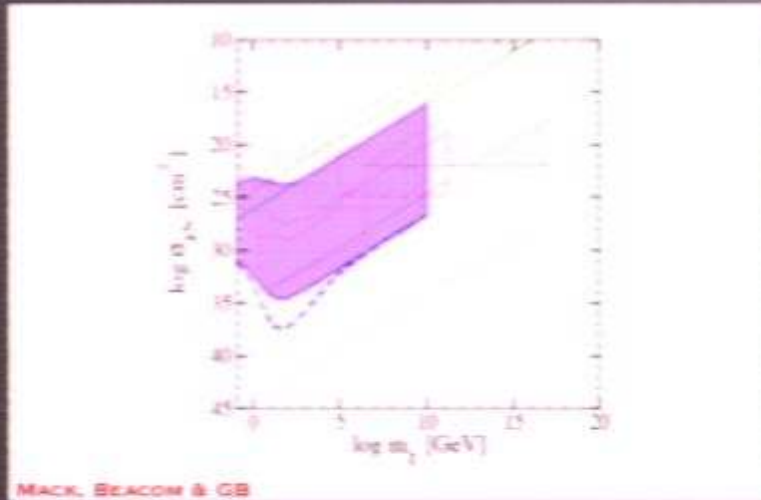


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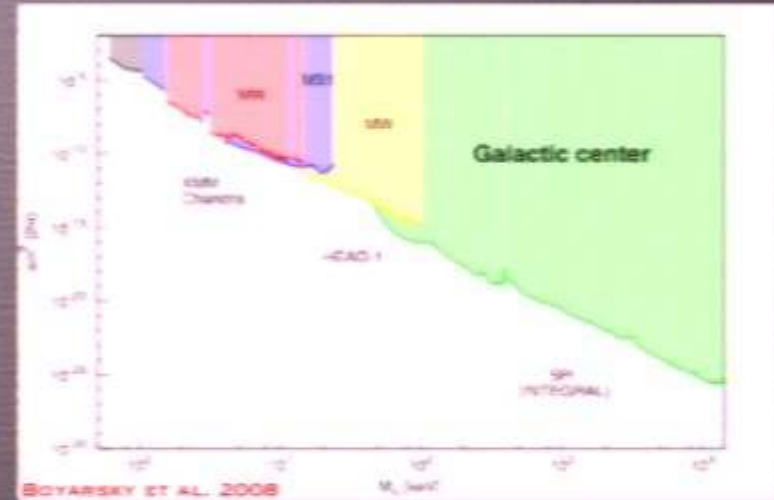


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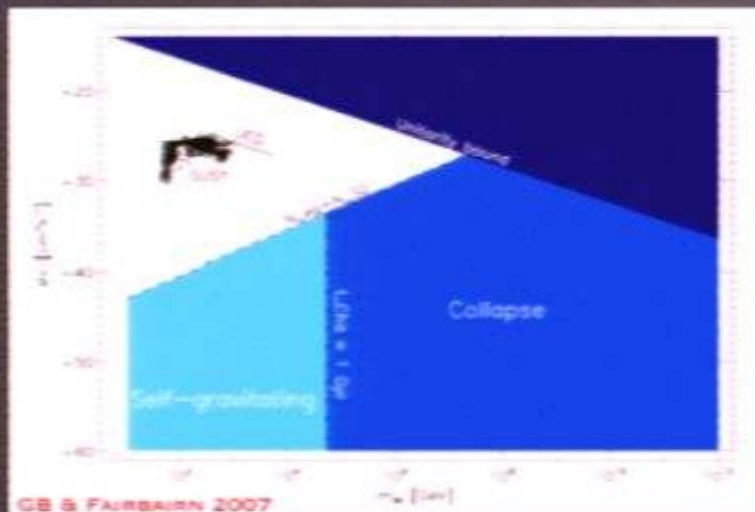
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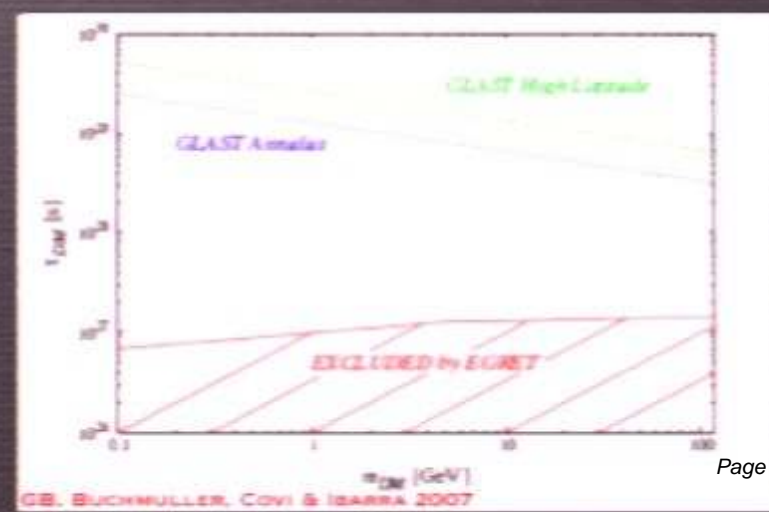
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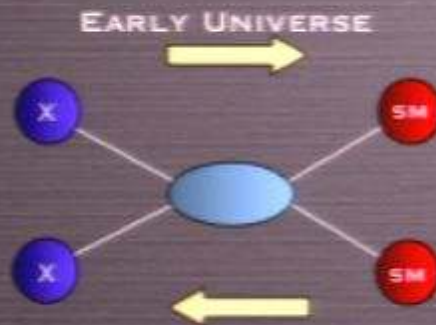


DECAY TIME



THERMAL RELICS, WIMPS

WHY "ANNIHILATIONS"?

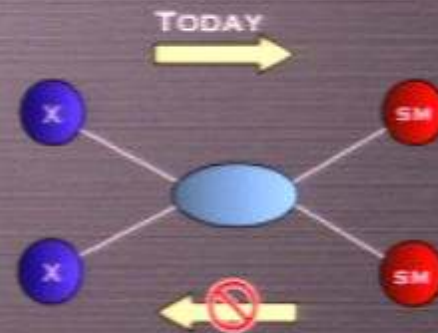


$$\frac{dn_\chi}{dt} + 3Hn_\chi = -\langle\sigma v\rangle[n_\chi^2 - (n_\chi^{\text{eq}})^2]$$

ROUGH ESTIMATE OF THE RELIC DENSITY:

$$\Omega_\chi h^2 \approx \frac{3 \times 10^{-27} \text{cm}^3 \text{s}^{-1}}{\langle\sigma v\rangle}$$

ELECTROWEAK-SCALE CROSS SECTIONS CAN REPRODUCE CORRECT RELIC DENSITY. LSP IN SUSY SCENARIOS KK DM IN UED SCENARIOS ARE OK!!



$$\dot{n}_\chi(r, t) = -\sigma v n_\chi^2$$

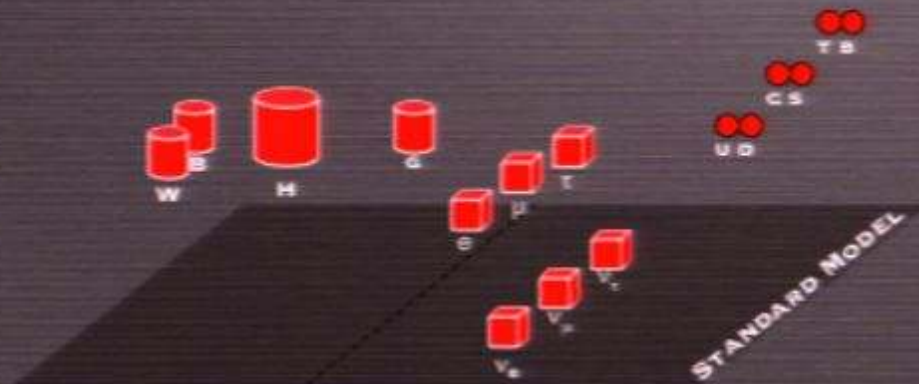
FLUX OF SECONDARY PARTICLES FROM DM ANN.

$$\Phi(\Delta\Omega, E) = \Delta\Omega \frac{dN}{dE} \frac{\langle\sigma v\rangle}{4\pi m^2} \bar{J}_{\Delta\Omega}$$

PARTICLE PHYSICS INPUT FROM EXTENSIONS OF THE STANDARD MODEL. NEED TO SPECIFY DISTRIBUTION OF DM ALONG THE LINE OF SIGHT

BEYOND THE STANDARD MODEL

THE STANDARD MODEL PROVIDES AN ACCURATE DESCRIPTION OF ALL KNOWN PARTICLES AND INTERACTIONS, HOWEVER THERE ARE GOOD REASONS TO BELIEVE THAT THE STANDARD MODEL IS A LOW-ENERGY LIMIT OF A MORE FUNDAMENTAL THEORY



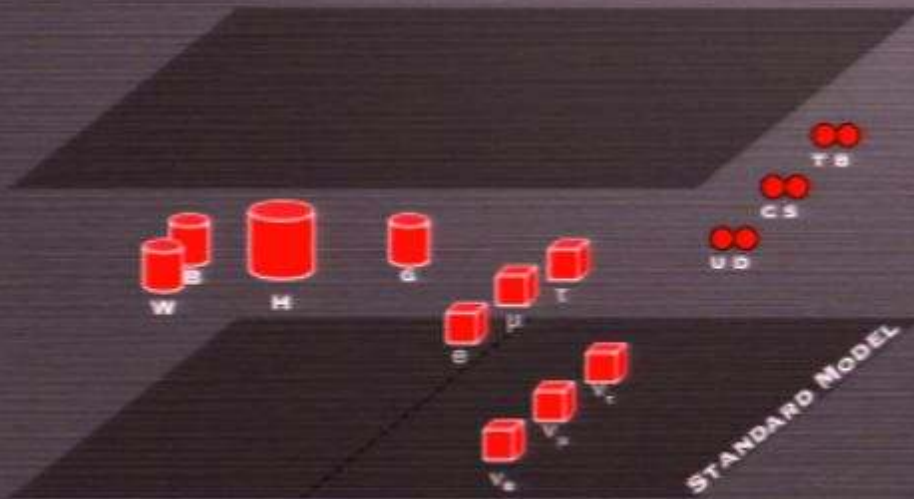
STANDARD MODEL
PARTICLES

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NEW THEORY
(SUSY, EXTRA-DIM, ETC.)

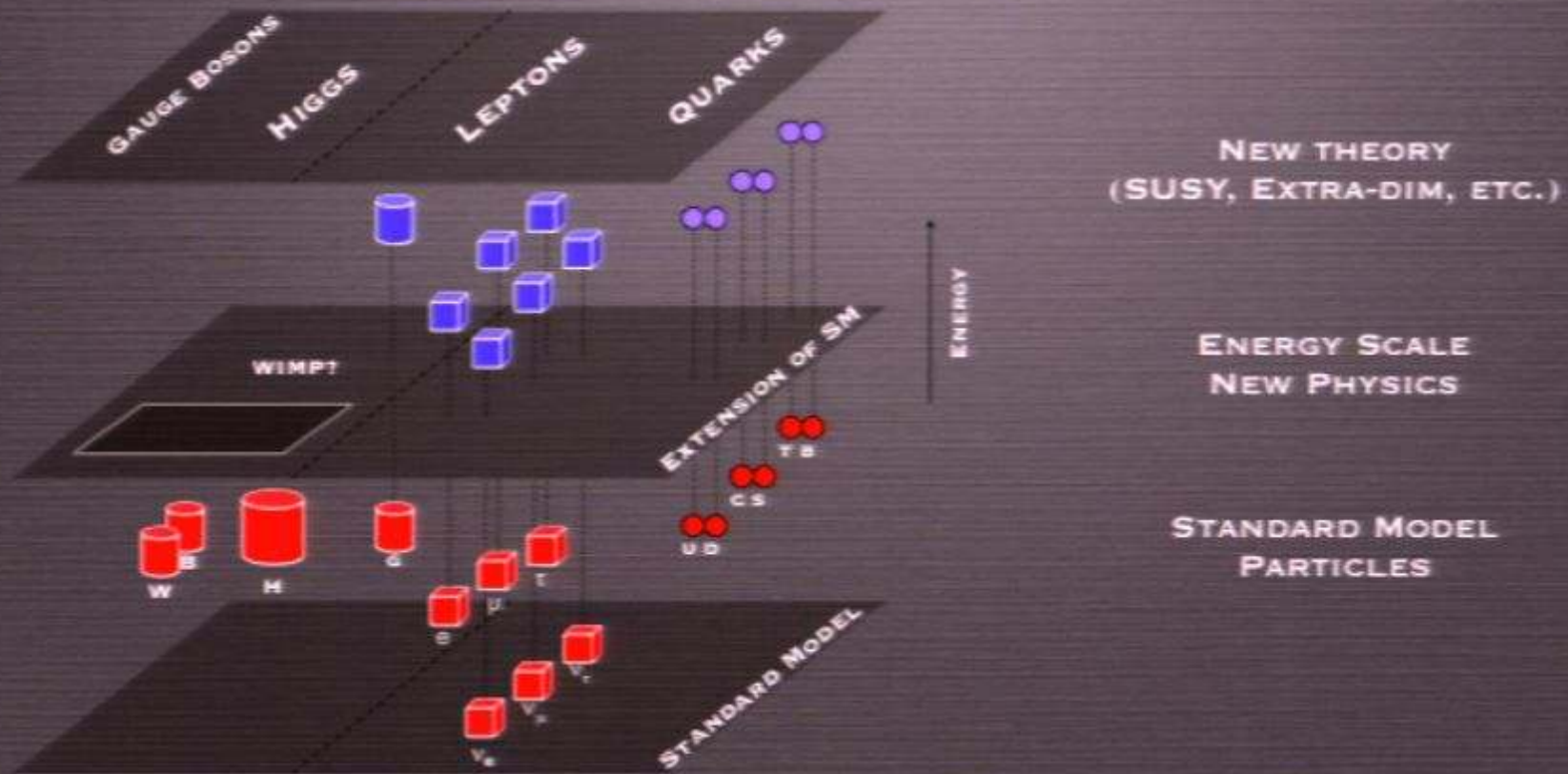


ENERGY SCALE
NEW PHYSICS

STANDARD MODEL
PARTICLES

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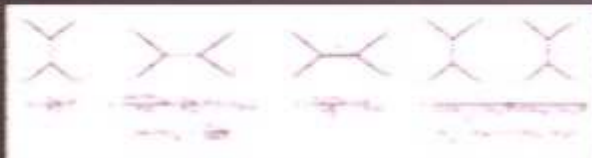
BEYOND THE STANDARD MODEL

2 EXAMPLES

MINIMAL SUPERSYMMETRY

Standard Model particles and bosons		Supersymmetry partners			
Spin	Name	Spin	Name	Spin	Name
$\frac{1}{2}$	quark	0, 1/2	squark	0, 1/2	squark
$\frac{1}{2}$	lepton	0, 1/2	stop squark	0, 1/2	lepton
0	gauge boson	1/2	gluino	1/2	gaugino
0	photon	1/2	photon	1/2	photon
0	W boson	1/2	Wino	1/2	Wino
0	Z boson	1/2	zino	1/2	zino
0	Higgs boson	1/2	higgsino	1/2	higgsino
0	H field	1/2	higgs	1/2	higgs
0	W [±] boson	1/2	Wino	1/2	Wino
0	Higgs boson	1/2	higgsino	1/2	higgsino
0	Higgs boson	1/2	higgsino	1/2	higgsino
0	Higgs boson	1/2	higgsino	1/2	higgsino

E.G. GB, HOOPER & SILK 2005



E.G. NEZRI ET AL. 2001

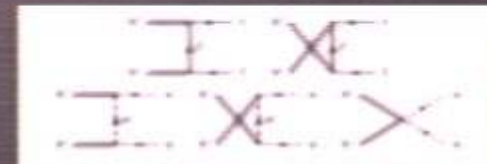
WIMP: NEUTRALINO

ALTERNATIVES: GRAVITINO, AXINO, SNEUTRINO...

UNIVERSAL EXTRA-DIMENSIONS



CHENG, MATCHEV & SCHWALTZ 2002



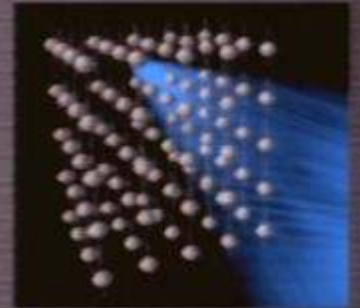
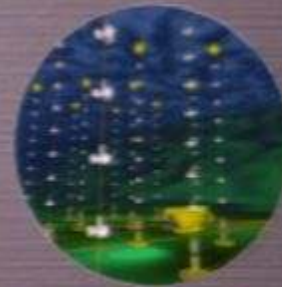
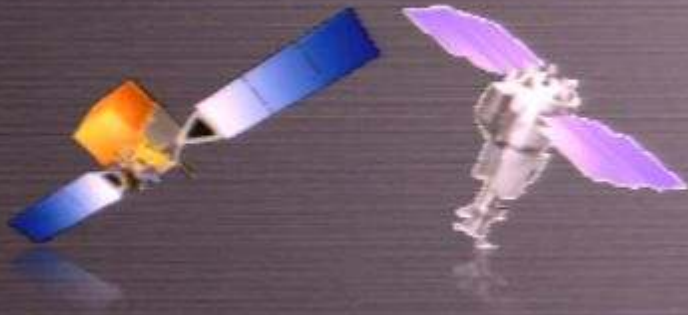
SERVANT AND TAIT 2002

WIMP: B¹

ALTERNATIVES: Z¹, H¹, γ^H ...

IN BOTH CASES: VIABLE DM CANDIDATE, WITH MASS ~ TEV AND WEAK CROSS SECTIONS

INDIRECT DETECTION



GAMMA-RAY TELESCOPES

- GROUND BASED (CANGAROO, HESS, MAGIC, MILAGRO, VERITAS)
- SPACE SATELLITE GLAST
- PLANS FOR A FUTURE CHERENKOV TELESCOPE ARRAY

NEUTRINO TELESCOPES

- AMANDA, ICECUBE
- ANTARES, NEMO, NESTOR
- KM3

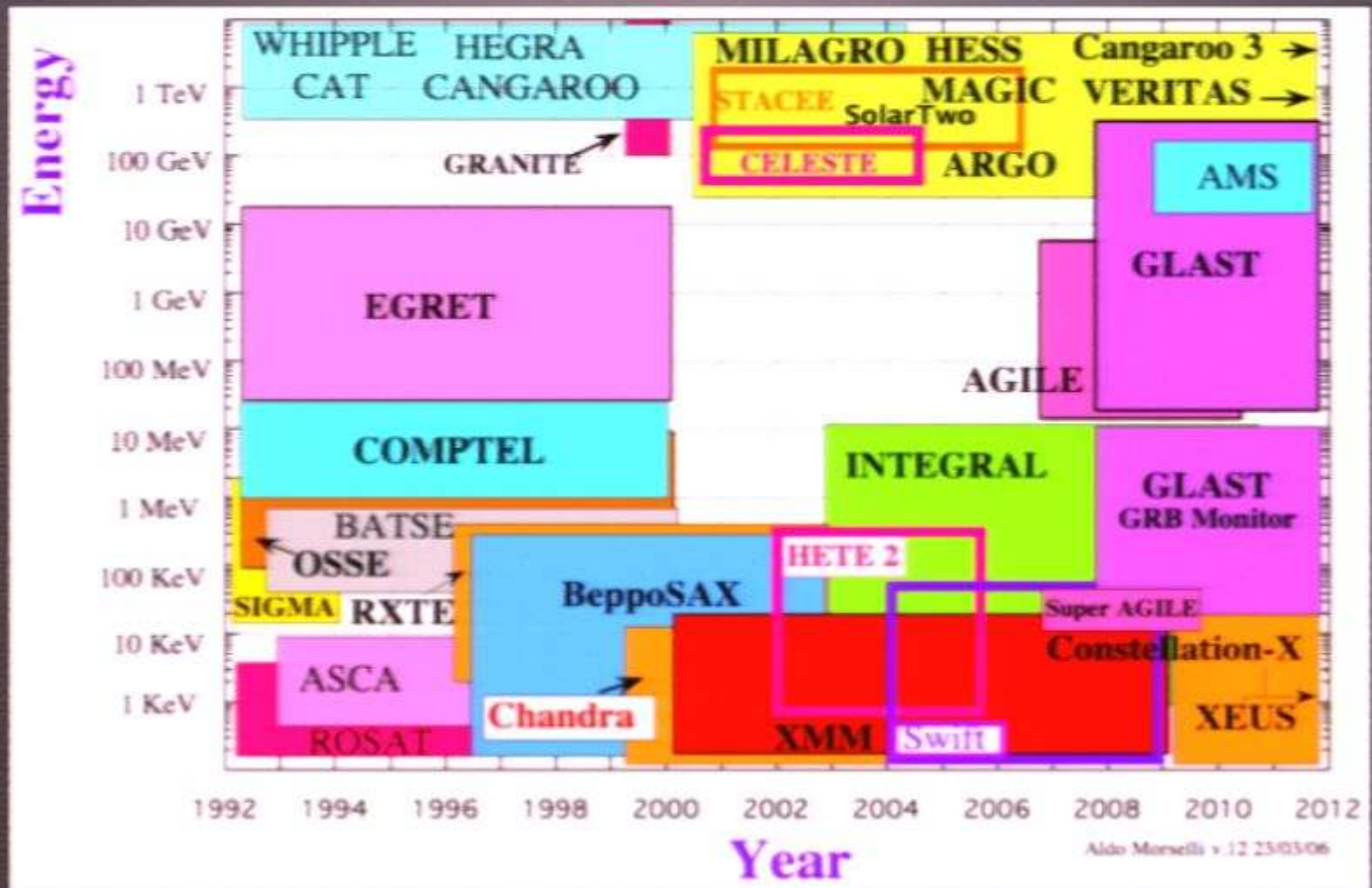
ANTI-MATTER SATELLITES

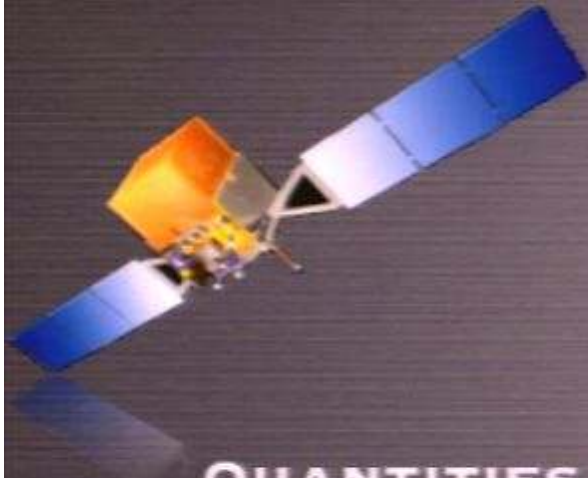
- PAMELA
- AMS-02

OTHER

- SYNCHROTRON EMISSION
- SZ EFFECT
- EFFECT ON STARS

X AND γ -RAY EXPERIMENTS





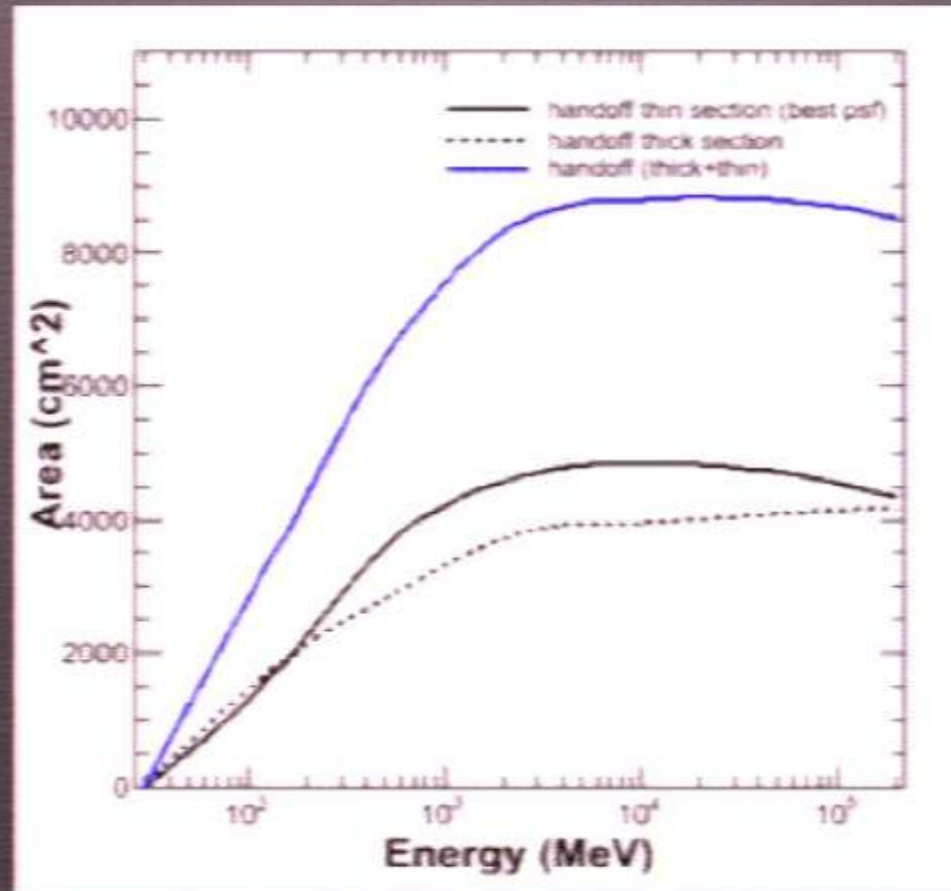
GLAST

QUANTITIES OF INTEREST FOR PHENO. STUDIES

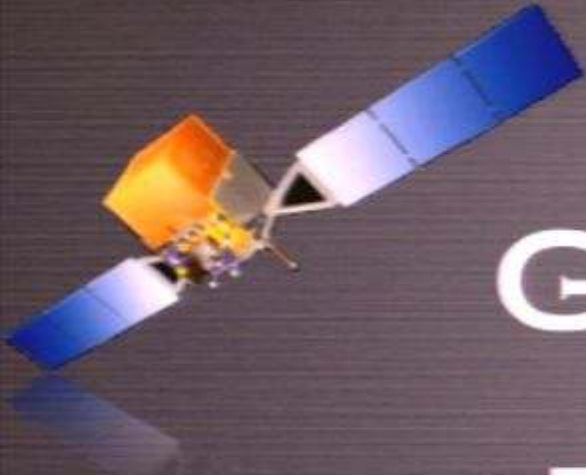
- ENERGY RANGE
- EFFECTIVE AREA
 - IMPORTANT TO HAVE GOOD SENSITIVITY
- ANGULAR RESOLUTION / PSF
 - IMPORTANT FOR DISCRIMINATION AGAINST BCKGND
- ENERGY RESOLUTION
 - IMPORTANT FOR LINE /FEATURES SEARCHES
- FIELD OF VIEW / EXPOSURE
 - CRUCIAL FOR ALL-SKY / SERENDIPITOUS SEARCHES



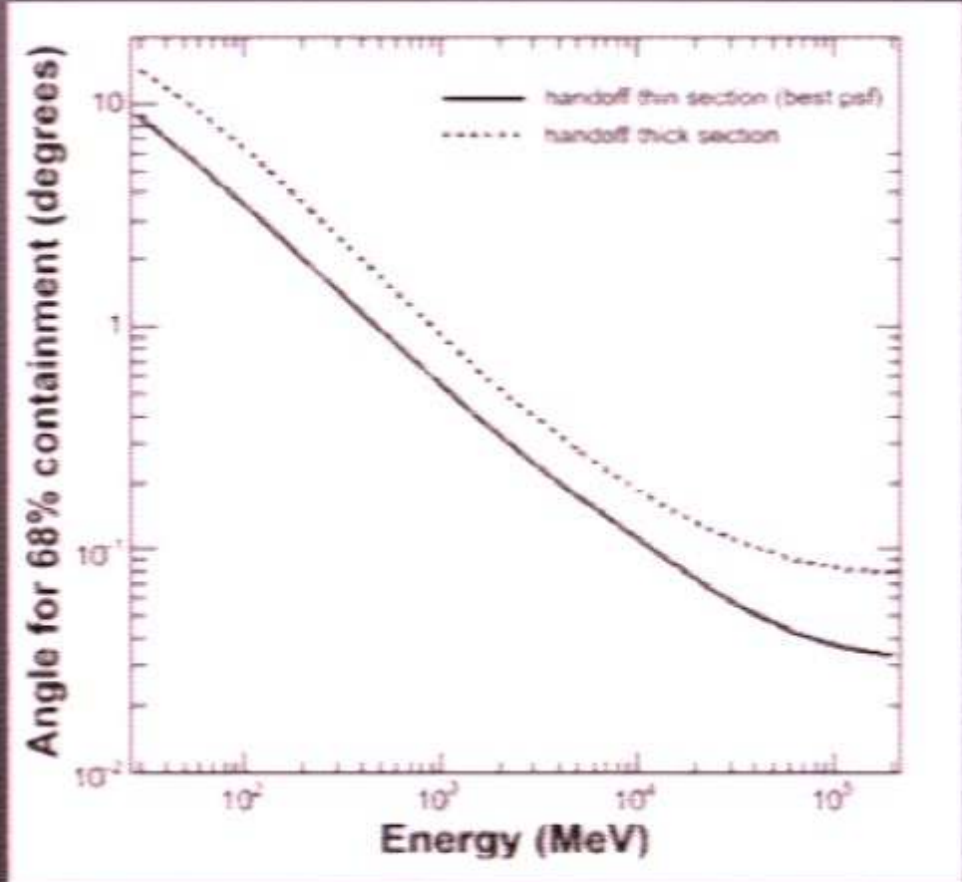
GLAST EFFECTIVE AREA



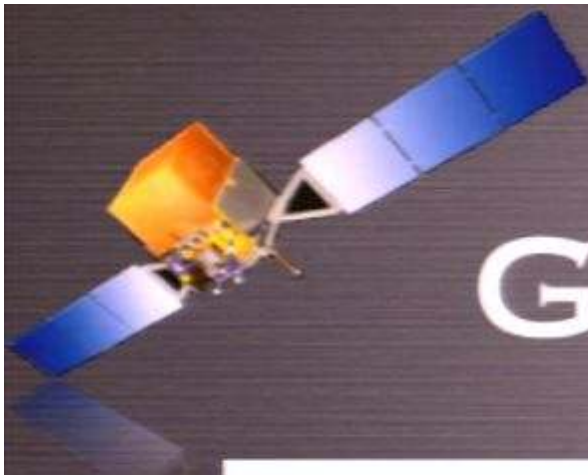
[HTTP://WWW-GLAST.SLAC.STANFORD.EDU/SOFTWARE/IS/GLAST_LAT_PERFORMANCE.HTM](http://www-glast.slac.stanford.edu/software/IS/GLAST_LAT_PERFORMANCE.HTM)



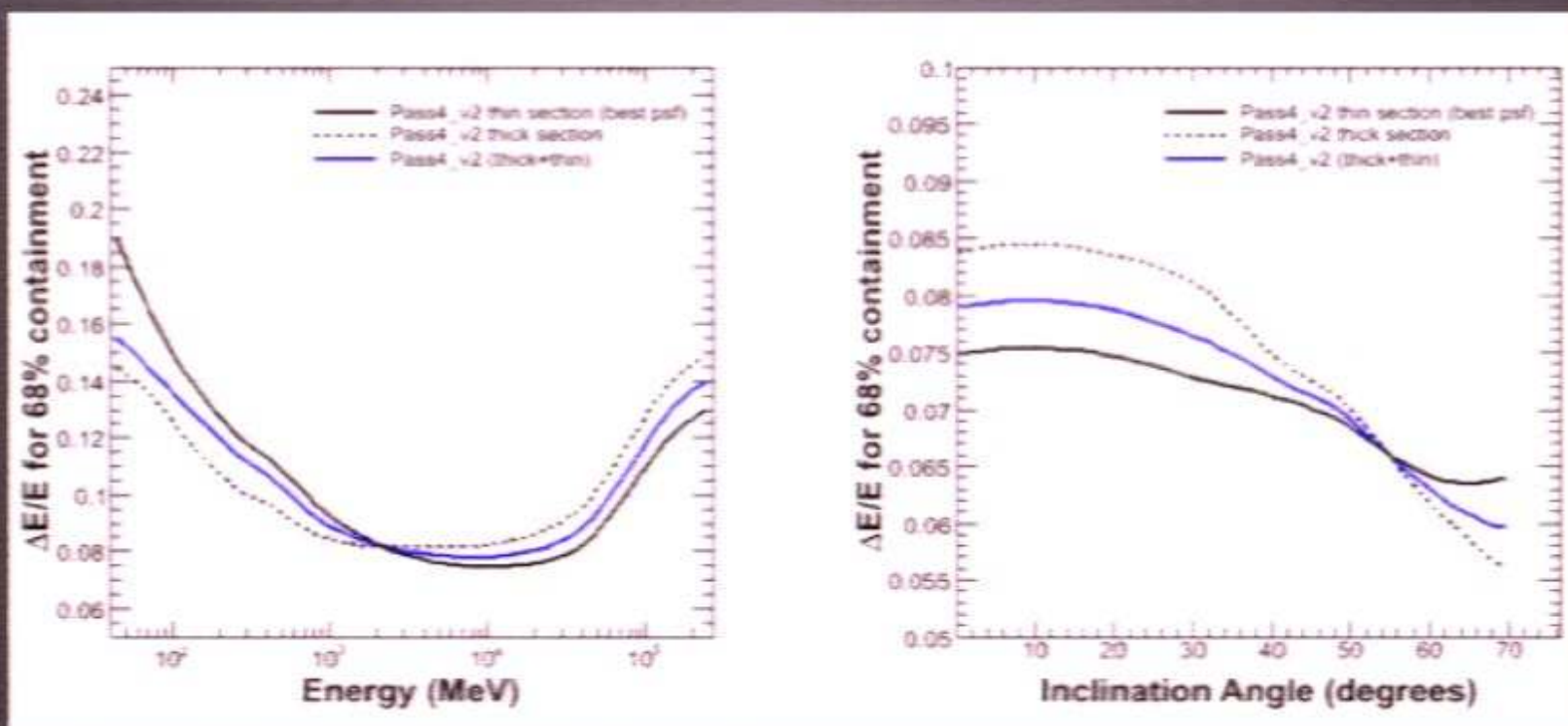
GLAST PSF



[HTTP://WWW-GLAST.SLAC.STANFORD.EDU/SOFTWARE/IS/GLAST_LAT_PERFORMANCE.HTM](http://www-glast.slac.stanford.edu/software/IS/GLAST_LAT_PERFORMANCE.HTM)



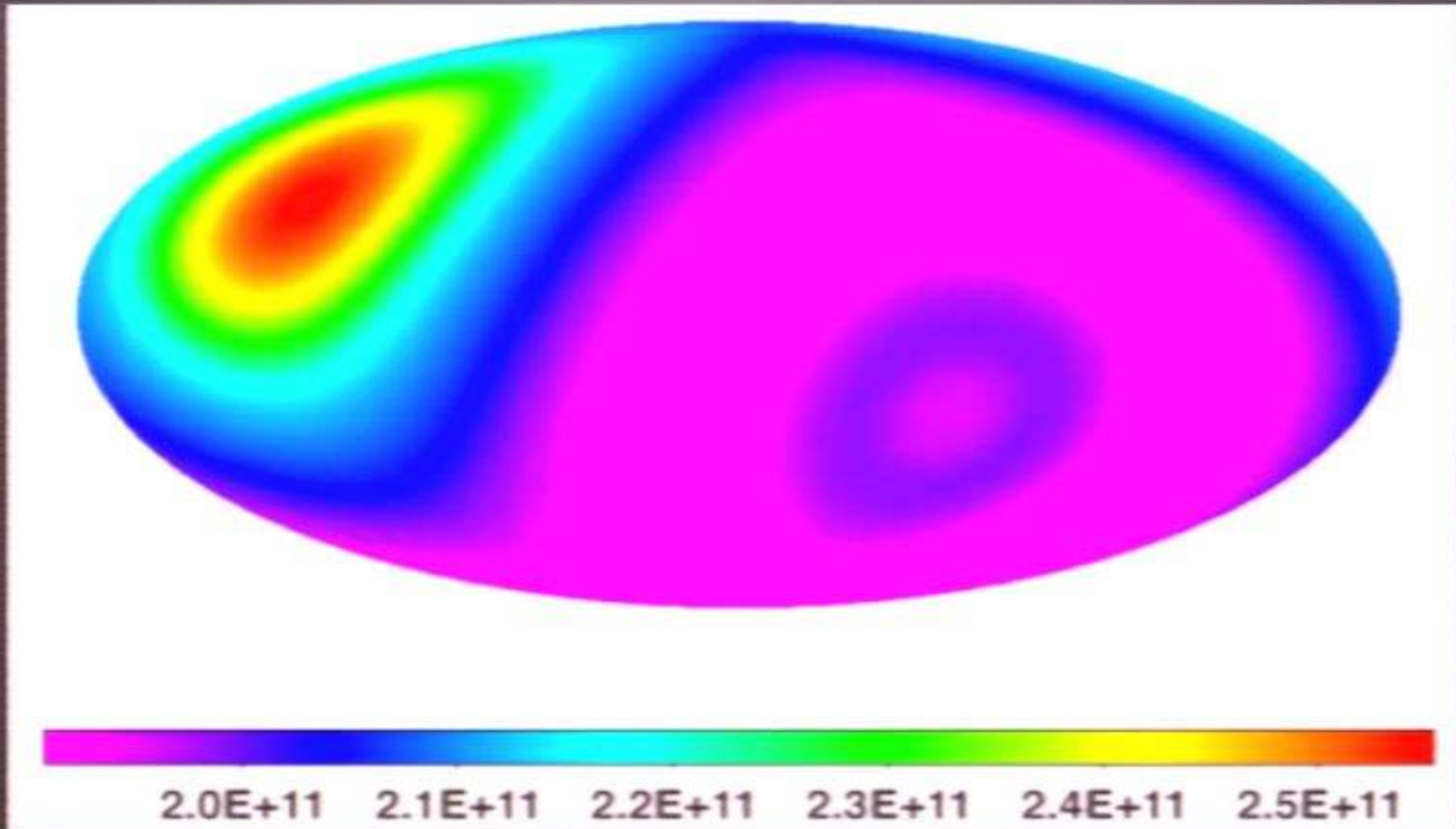
GLAST $\Delta E/E$



[HTTP://WWW-GLAST.SLAC.STANFORD.EDU/SOFTWARE/IS/GLAST_LAT_PERFORMANCE.HTM](http://www-glast.slac.stanford.edu/software/IS/GLAST_LAT_PERFORMANCE.HTM)



GLAST EXPOSURE MAP



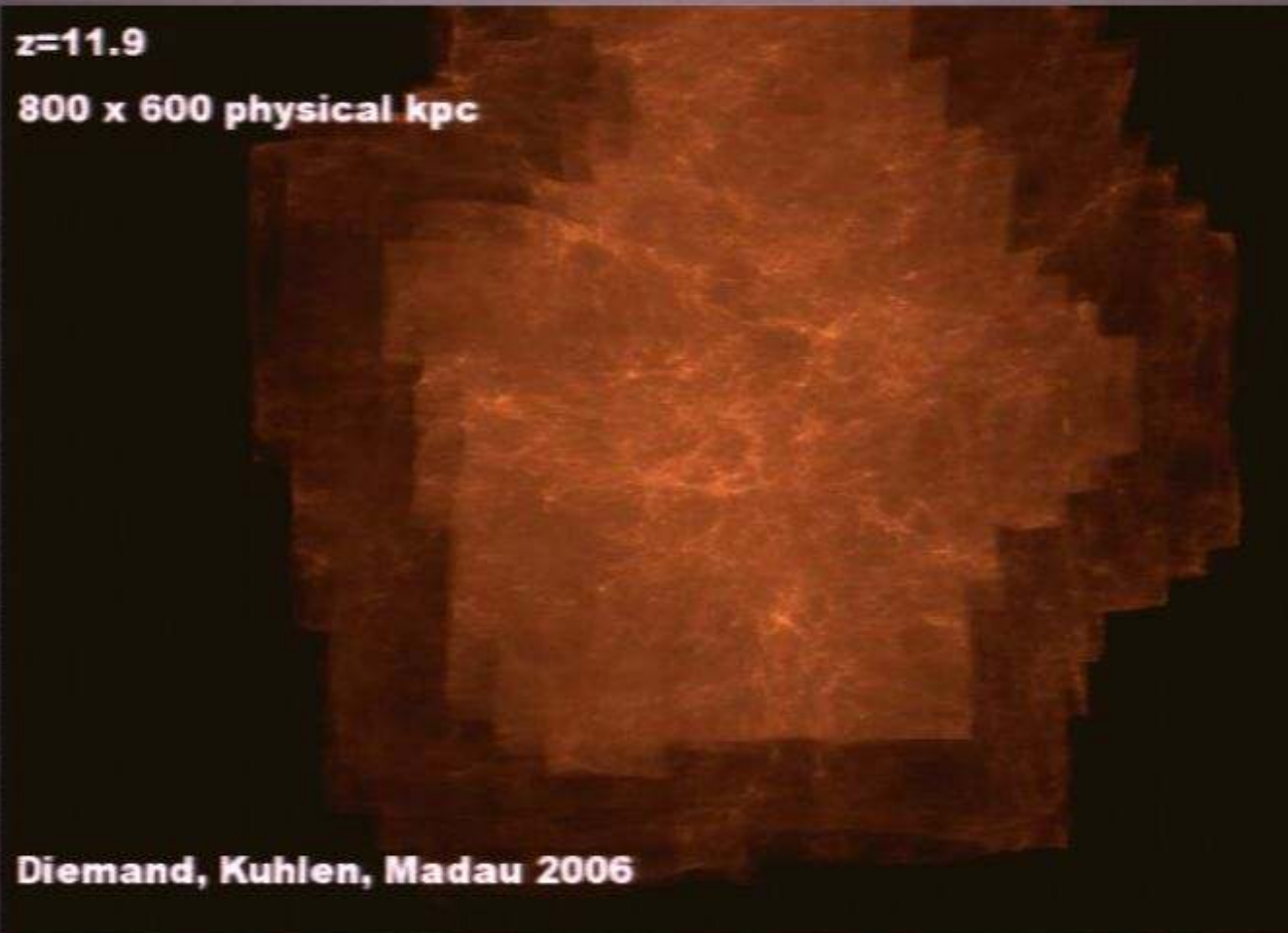
SIMULATED 5-YEARS EXPOSURE AT 100 GEV IN CM2 SEC

N-BODY SIMULATIONS

PROJECTED DARK MATTER DENSITY-SQUARE MAPS OF THE SIMULATED MILKY WAY-SIZE HALO VIA LACTEA. ENTIRE FORMATION HISTORY ($z=11.9 \rightarrow 0$), PLUS ROTATION AND ZOOM AT $z=0$. DIEMAND, KUHLEN & MADAU 2006

$z=11.9$

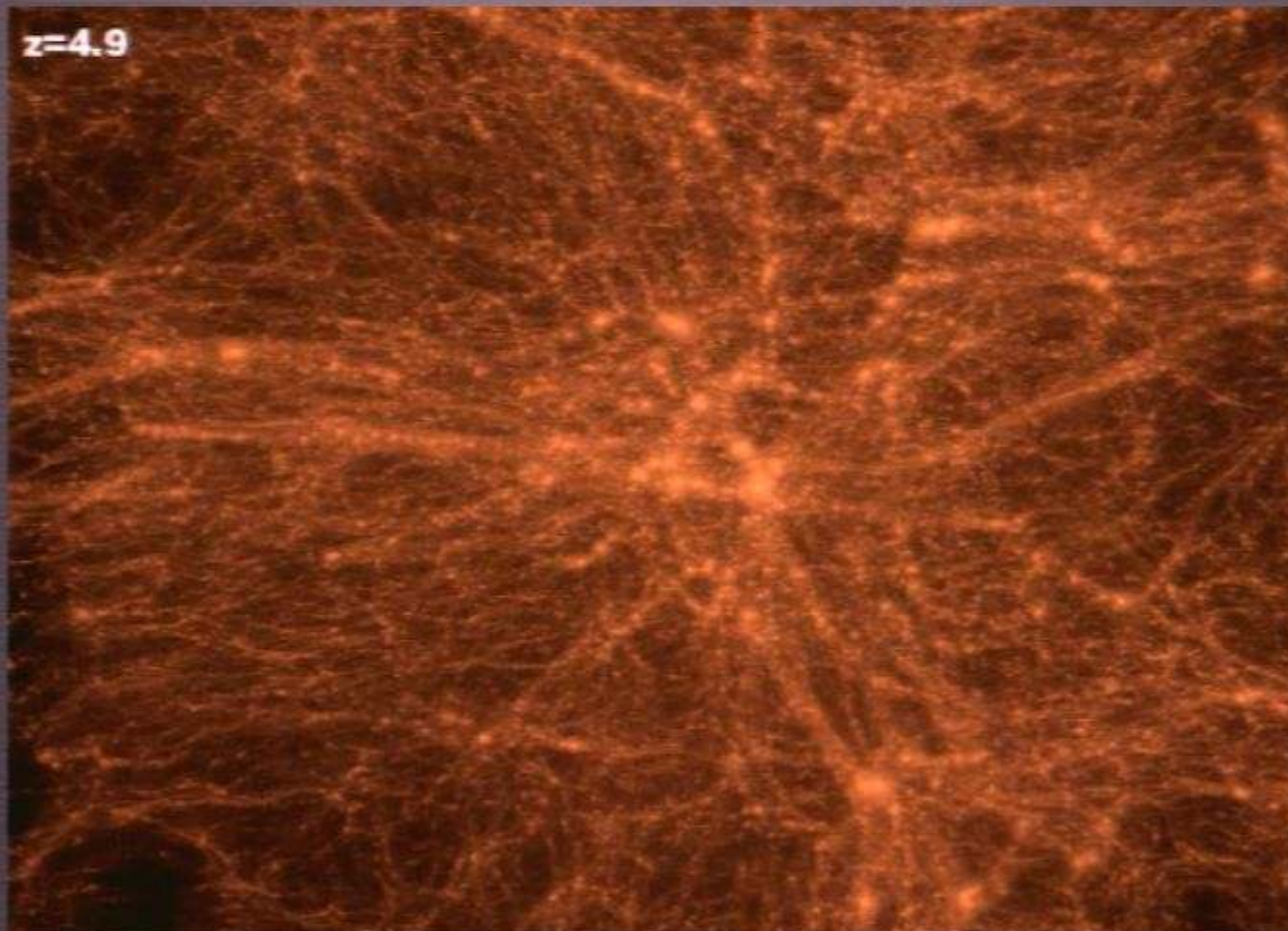
800 x 600 physical kpc



Diemand, Kuhlen, Madau 2006

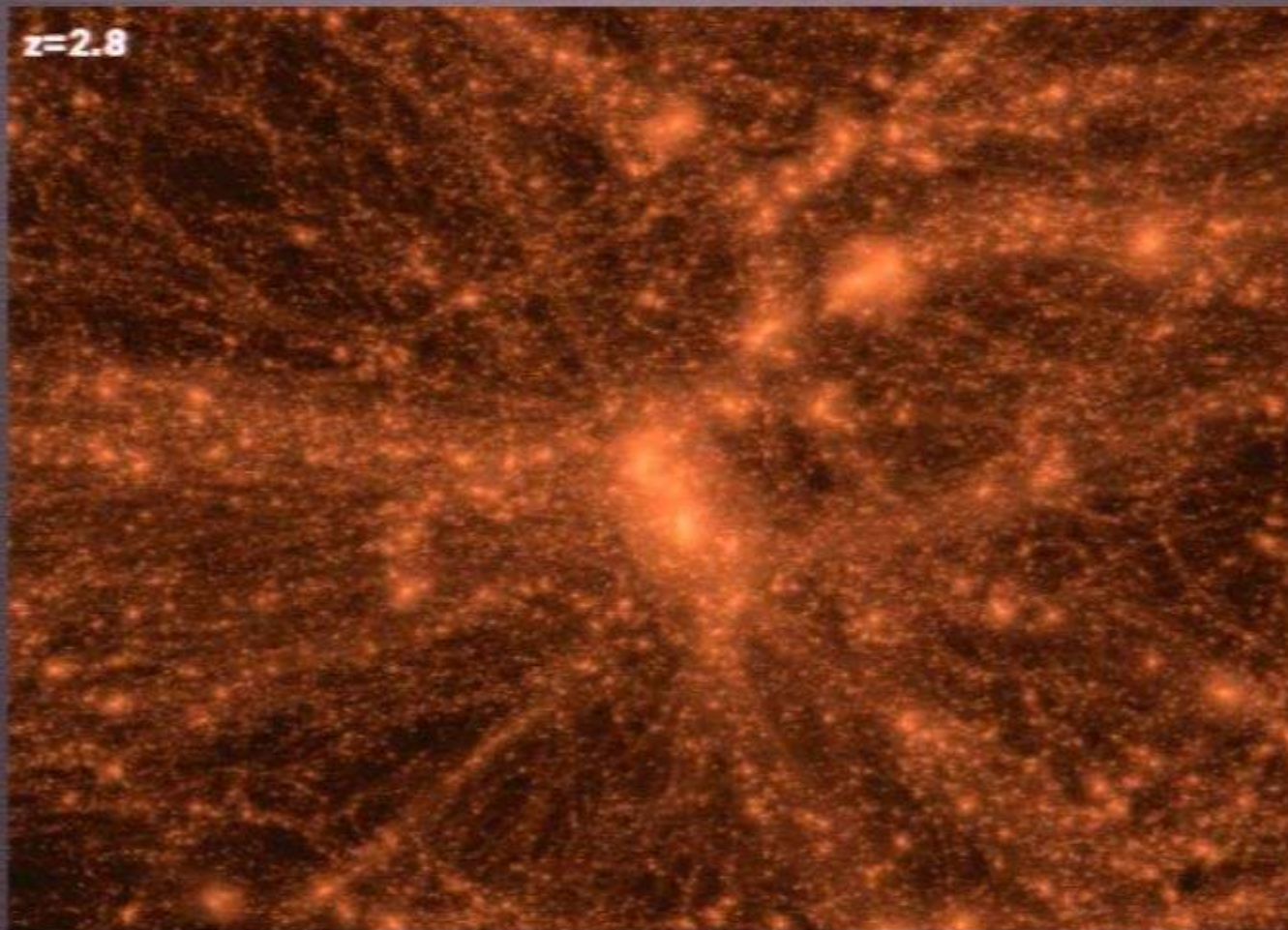
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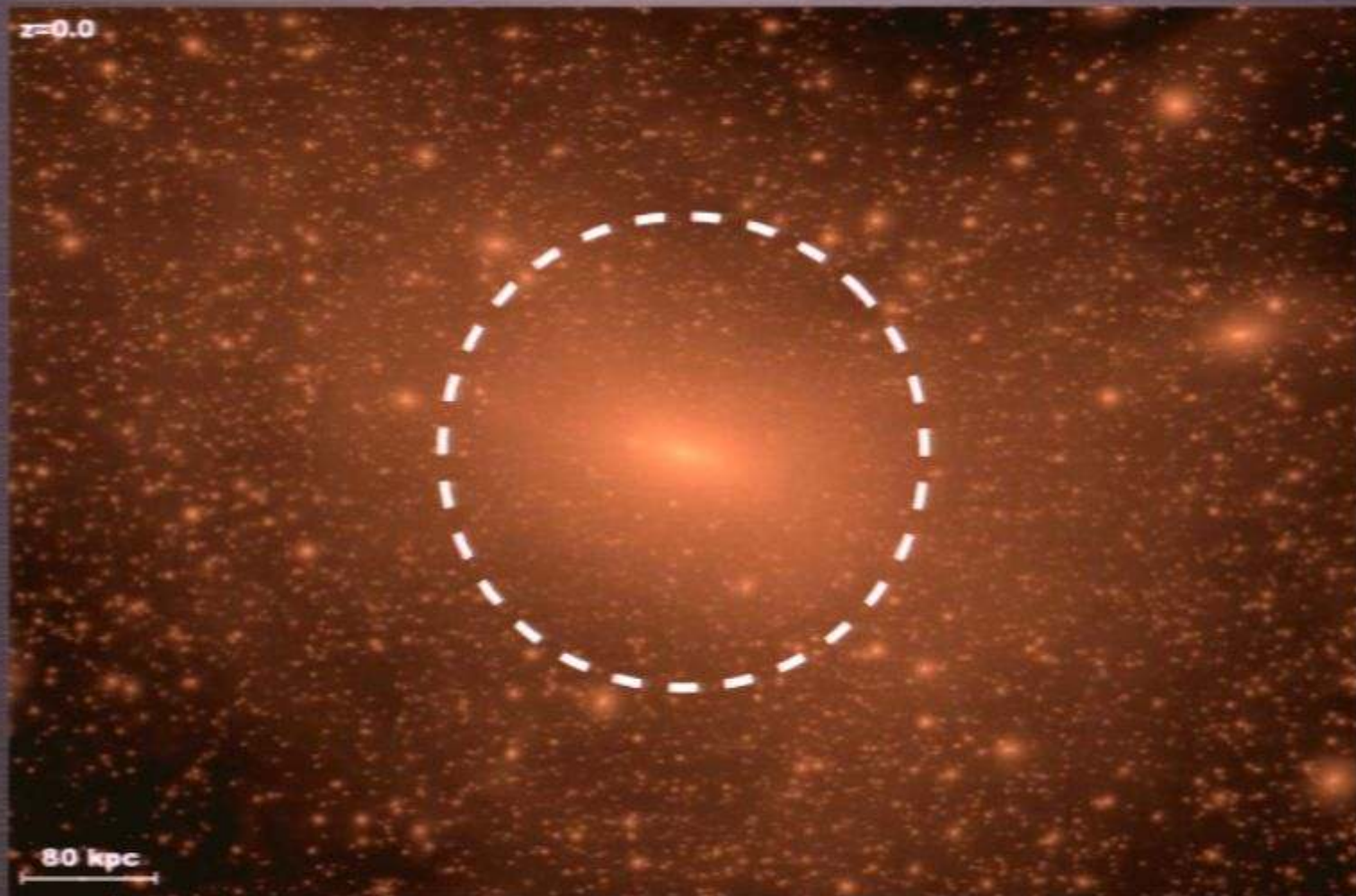
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TARGETS FOR INDIRECT DETECTION

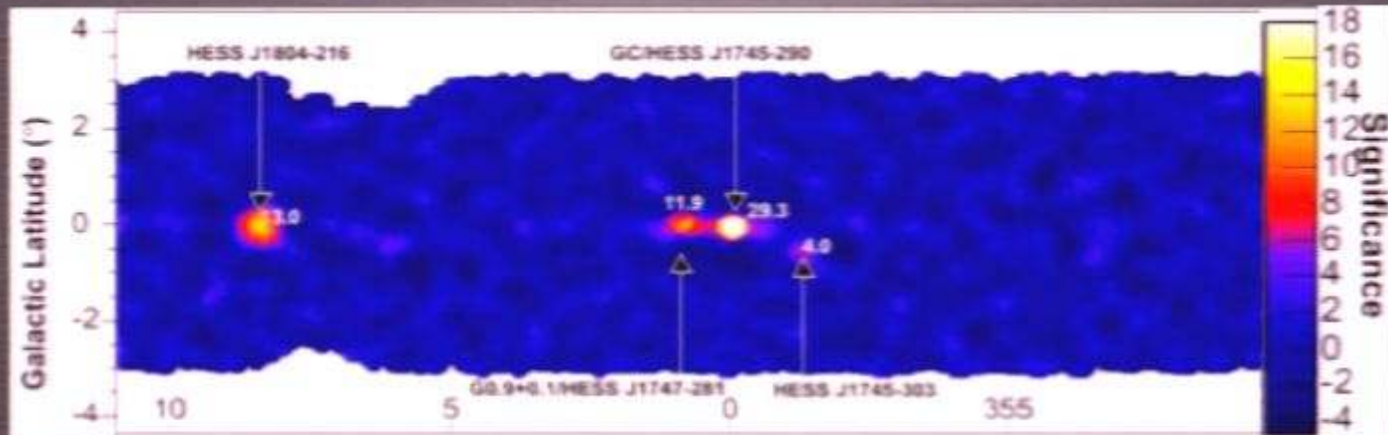


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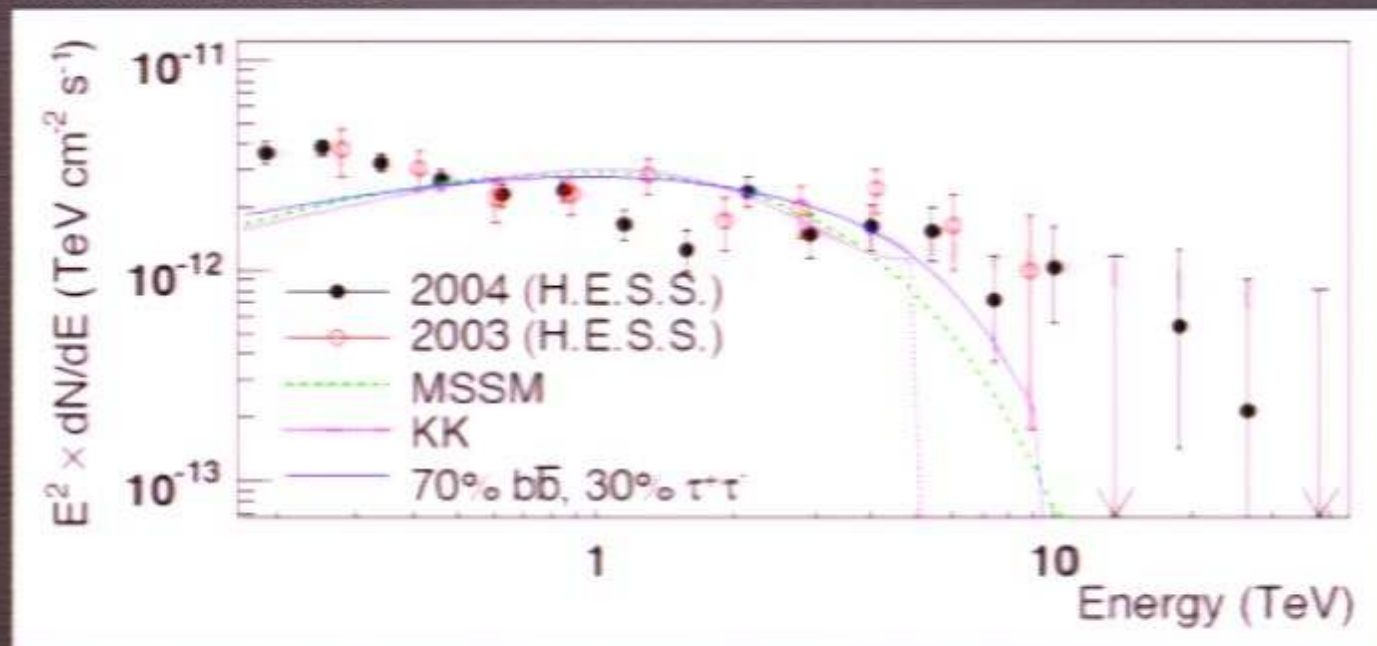


THE GALACTIC CENTER

BRIGHT POINT SOURCE DETECTED BY HESS AND MAGIC

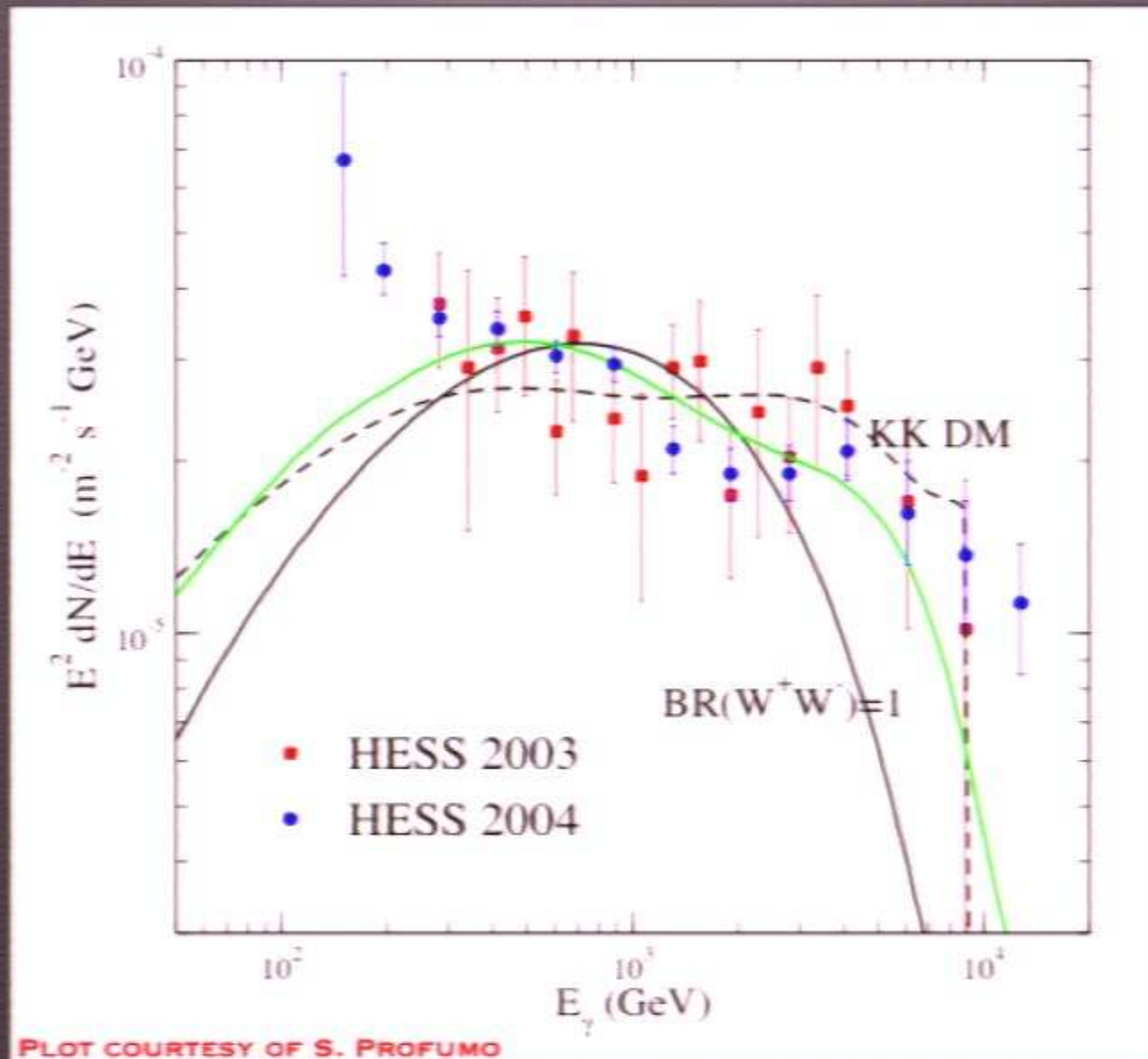


AHARONIAN ET AL. 2007

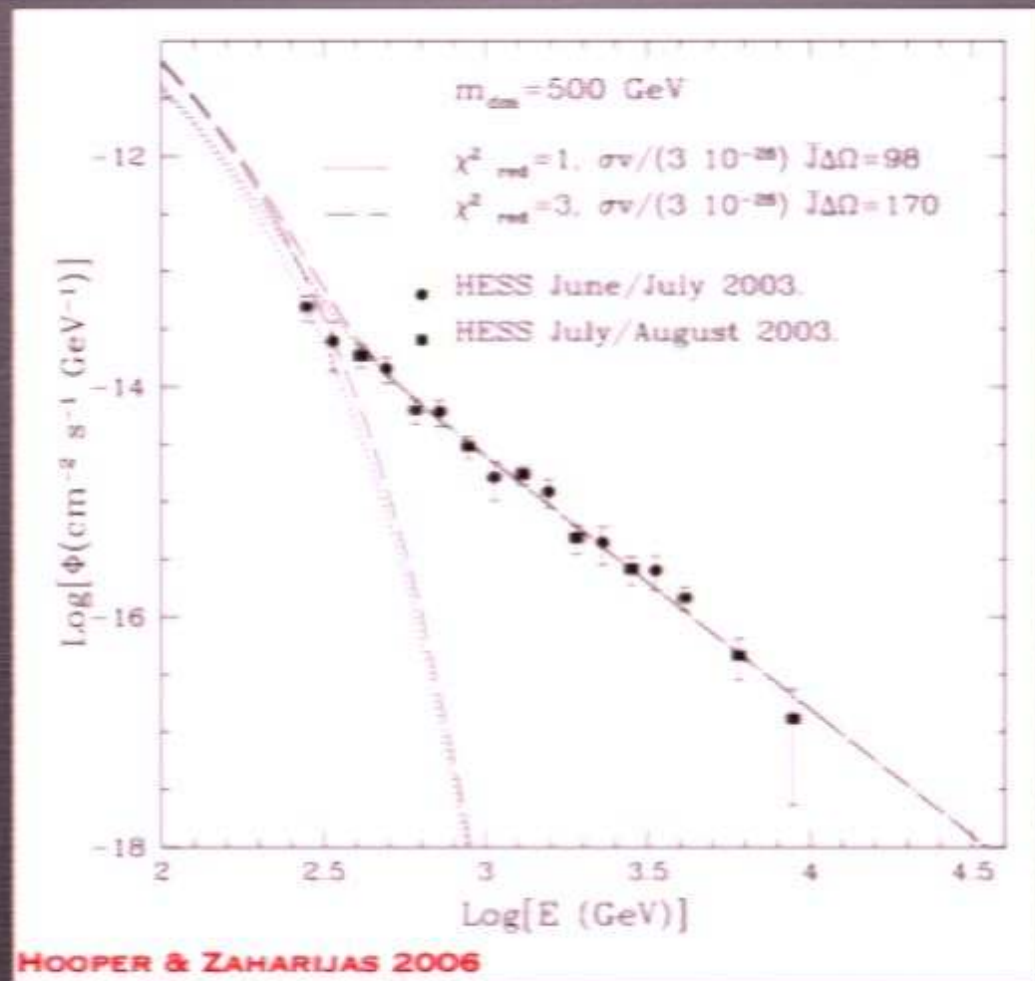


AHARONIAN ET AL. 2006

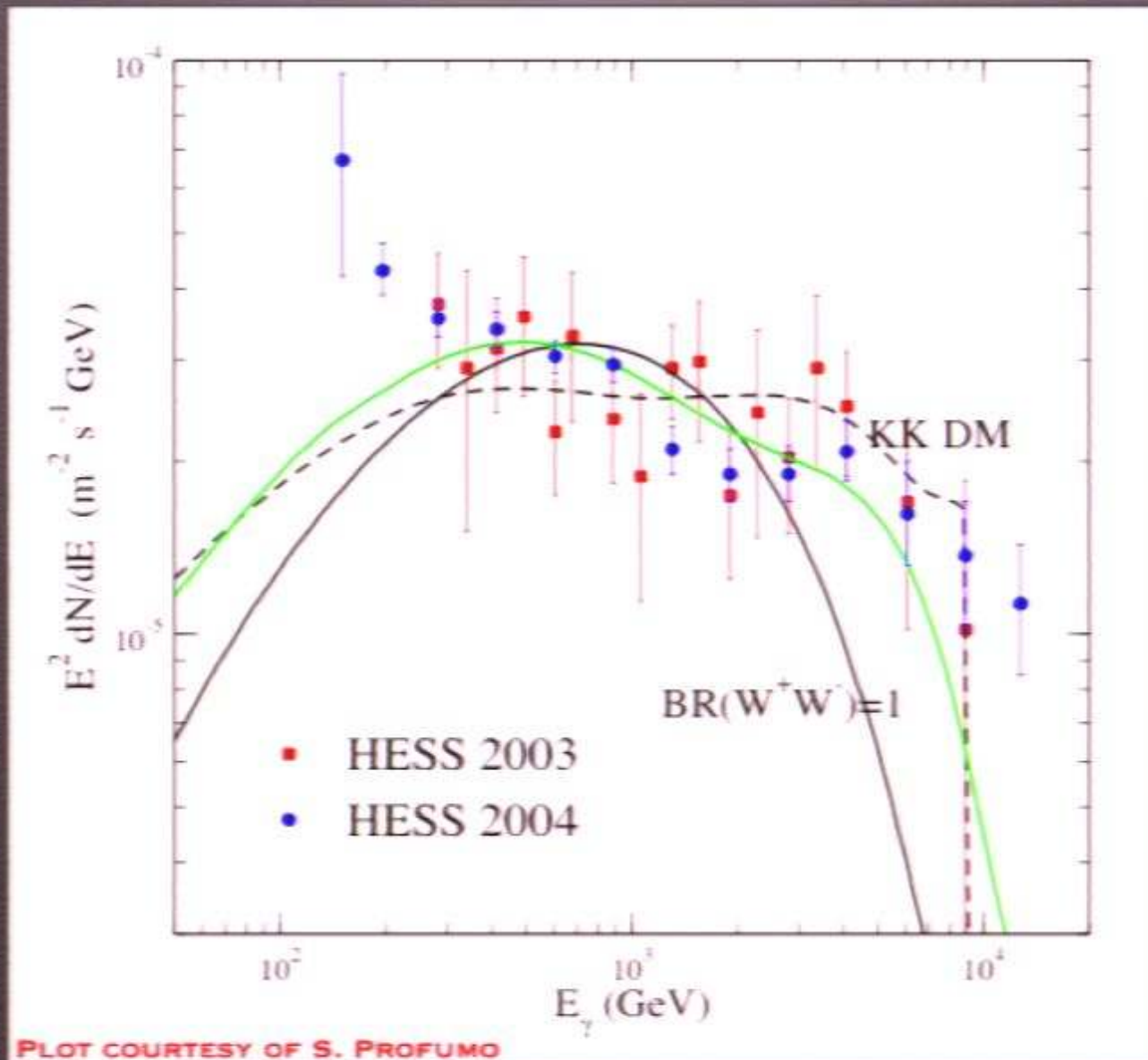
DM ANNIHILATIONS?



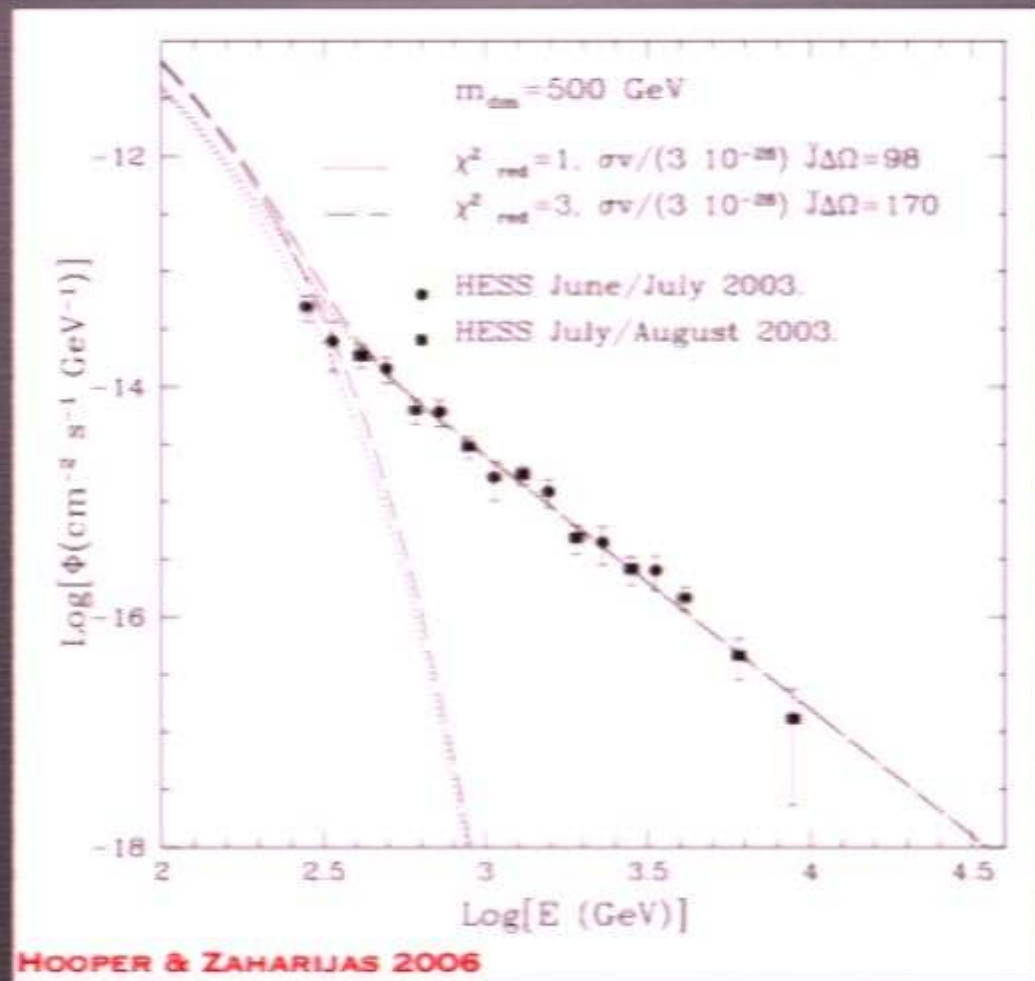
PROSPECTS FOR GLAST IN LIGHT OF THE HESS (AND MAGIC) RESULTS



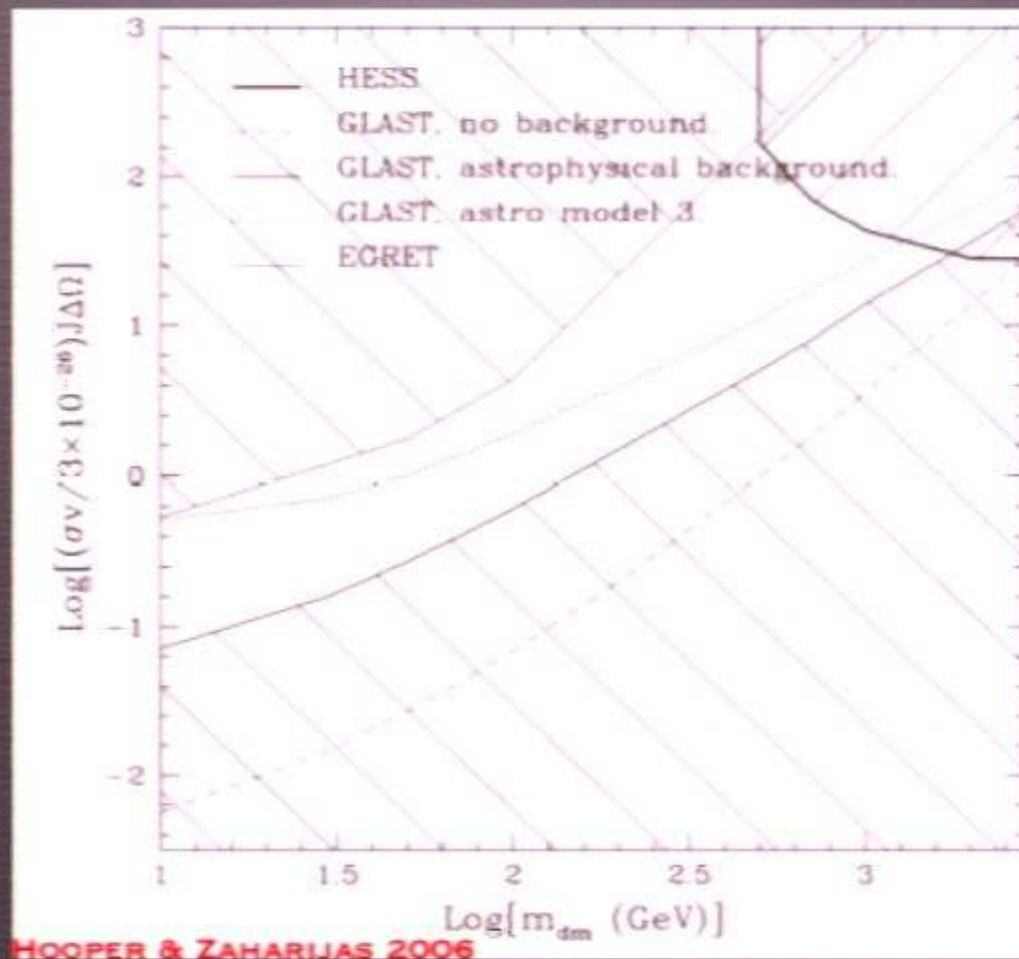
DM ANNIHILATIONS?



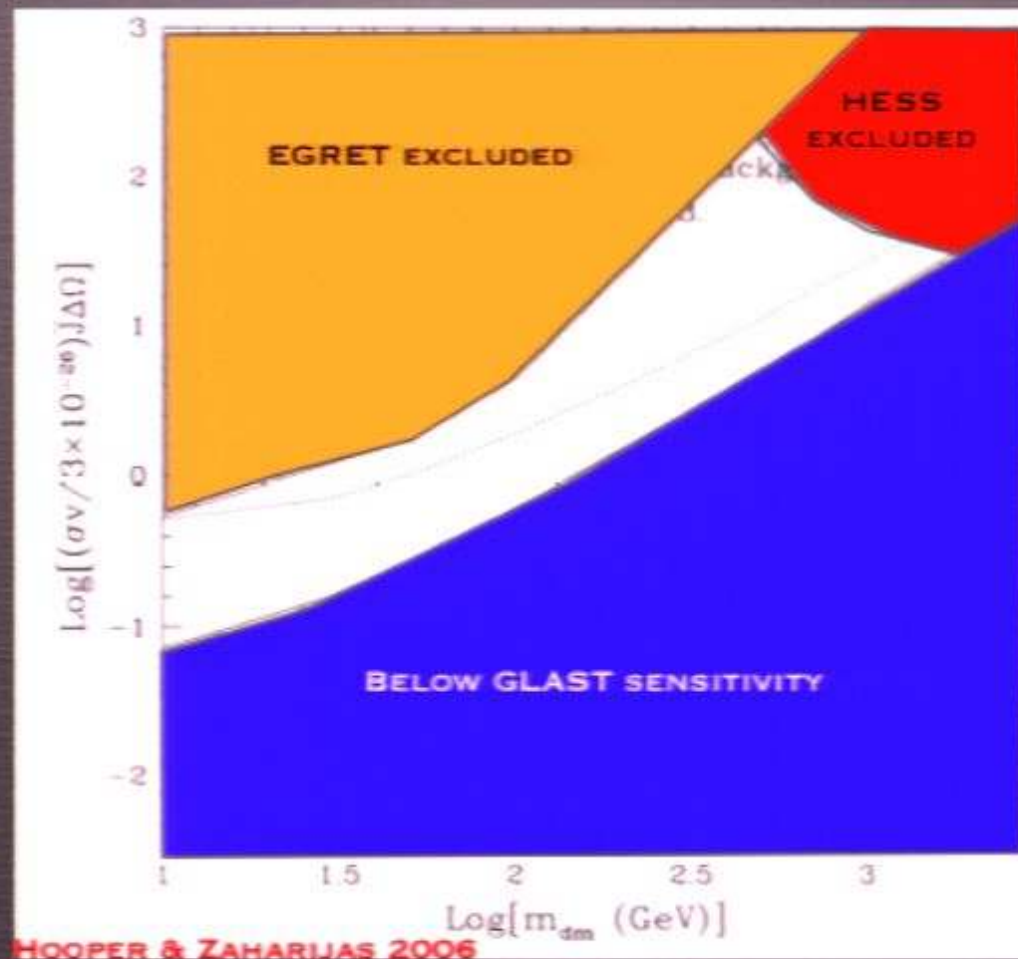
PROSPECTS FOR GLAST IN LIGHT OF THE HESS (AND MAGIC) RESULTS



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PROSPECTS FOR GLAST IN LIGHT OF THE HESS (AND MAGIC) RESULTS



THE GALACTIC CENTER

...MIGHT BE MORE INTERESTING TO FOCUS
ON AN “ANNULUS” AROUND THE CENTER

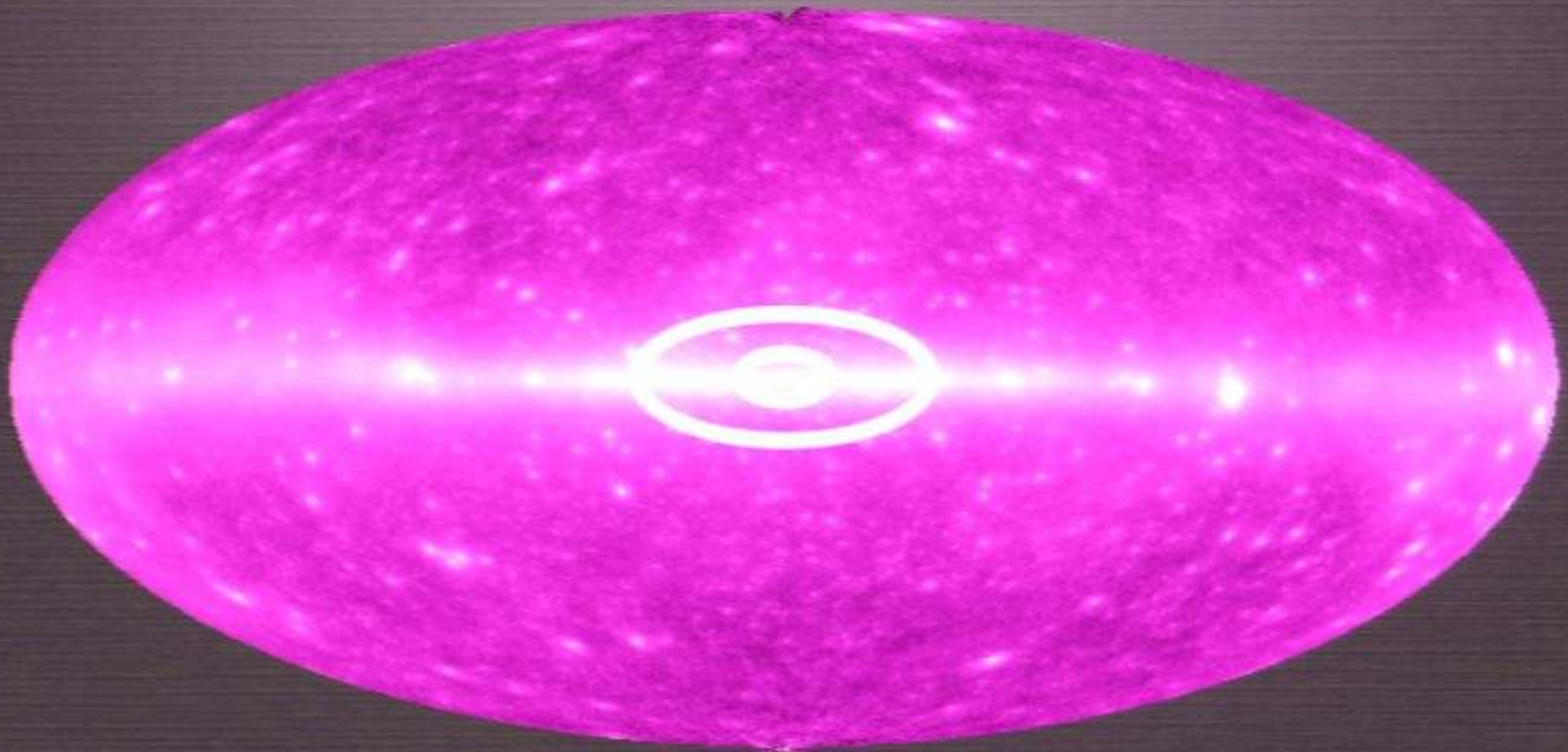
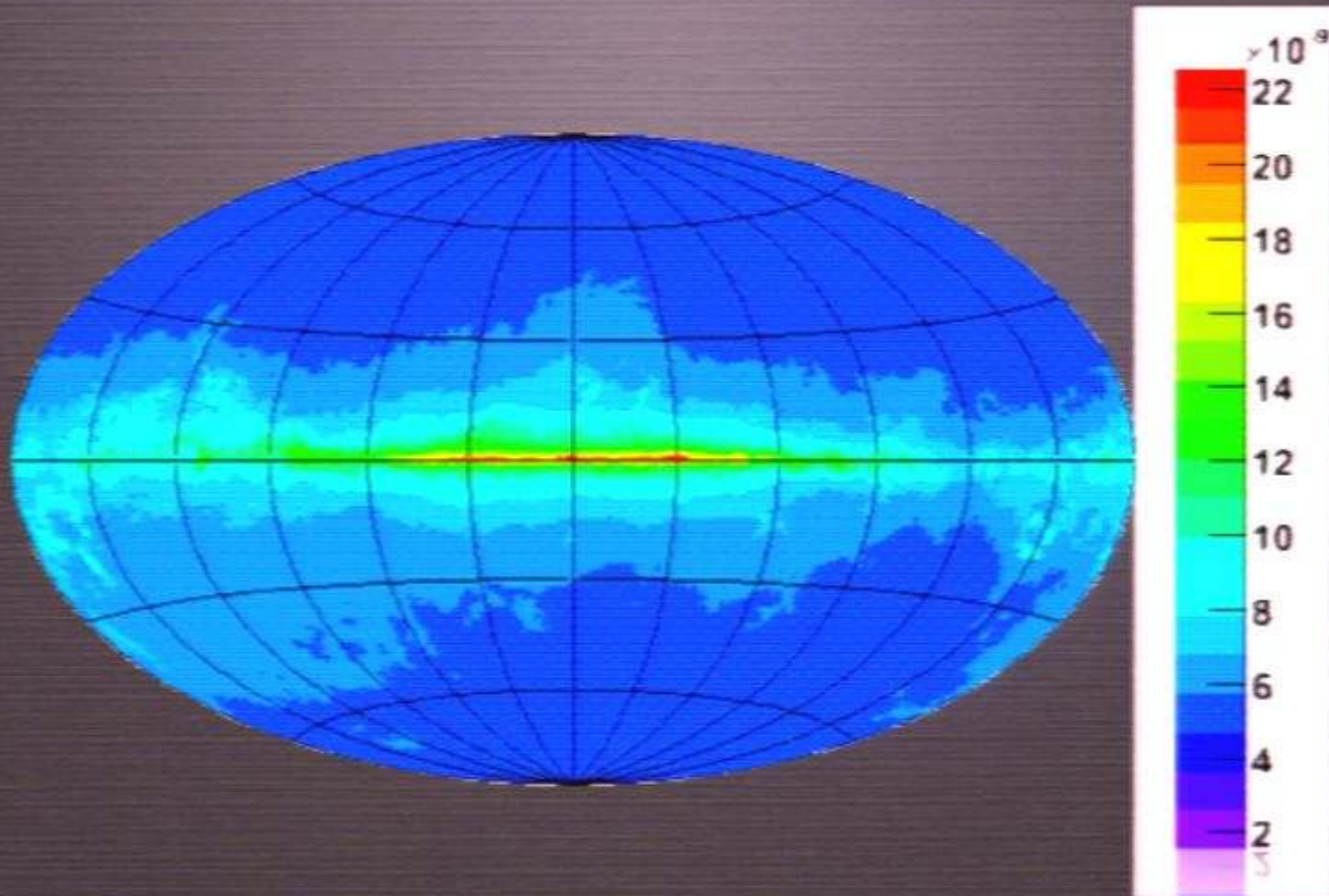


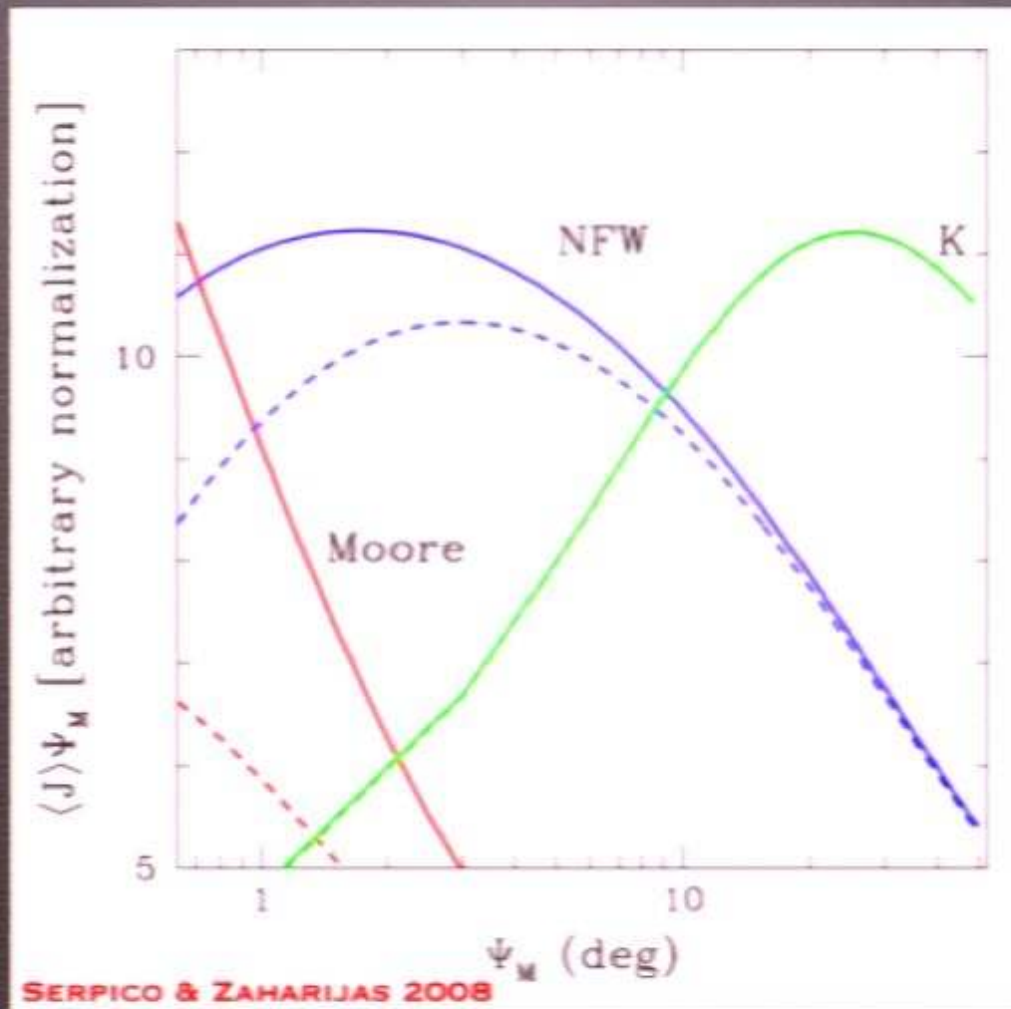
IMAGE FROM [HTTP://GLAST.GSFC.NASA.GOV](http://GLAST.GSFC.NASA.GOV). SEE STOEHR ET AL. 2002, SERPICO & ZAHARIJAS 2007

GLAST SENSITIVITY



THE GALACTIC CENTER

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THE GALACTIC CENTER

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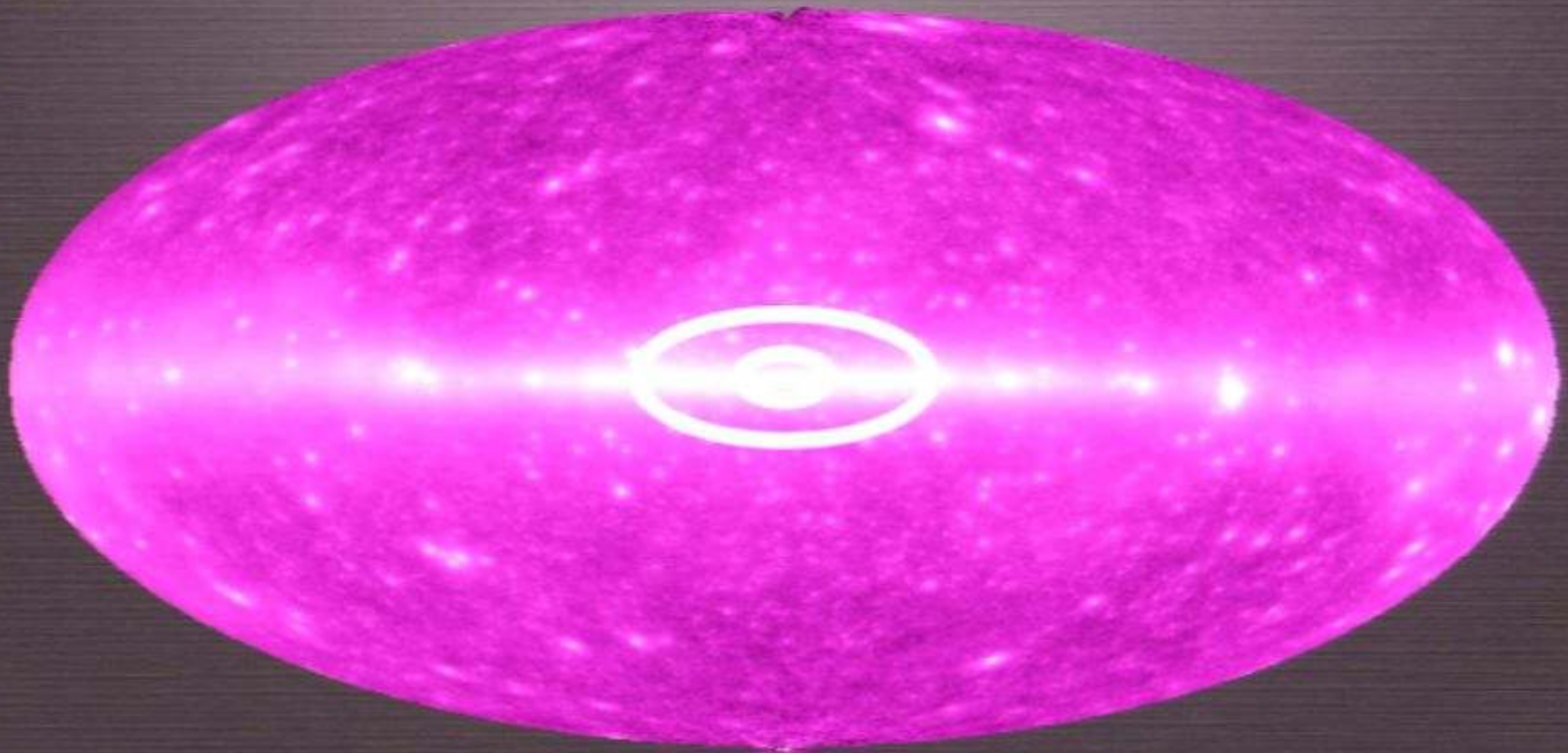
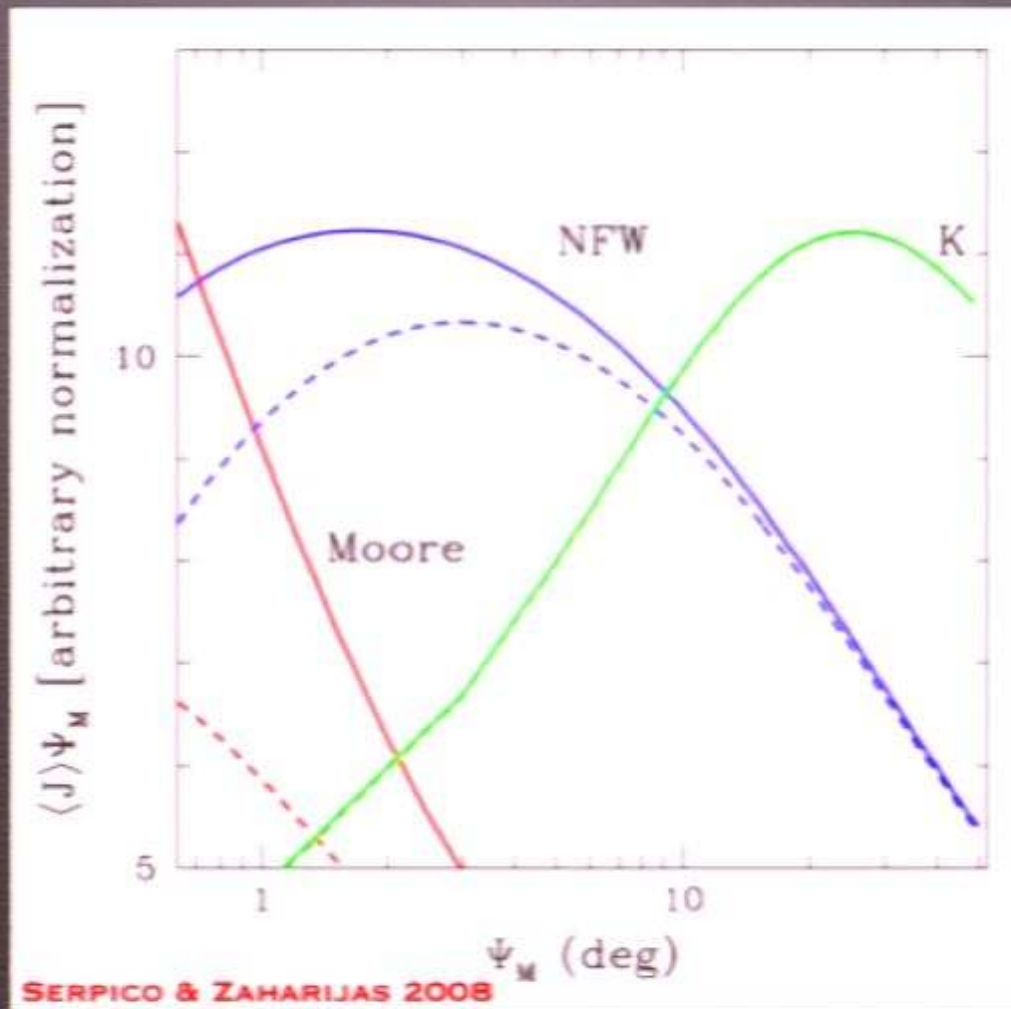


IMAGE FROM [HTTP://GLAST.GSFC.NASA.GOV](http://GLAST.GSFC.NASA.GOV). SEE STOEHR ET AL. 2002, SERPICO & ZAHARIJAS 2007

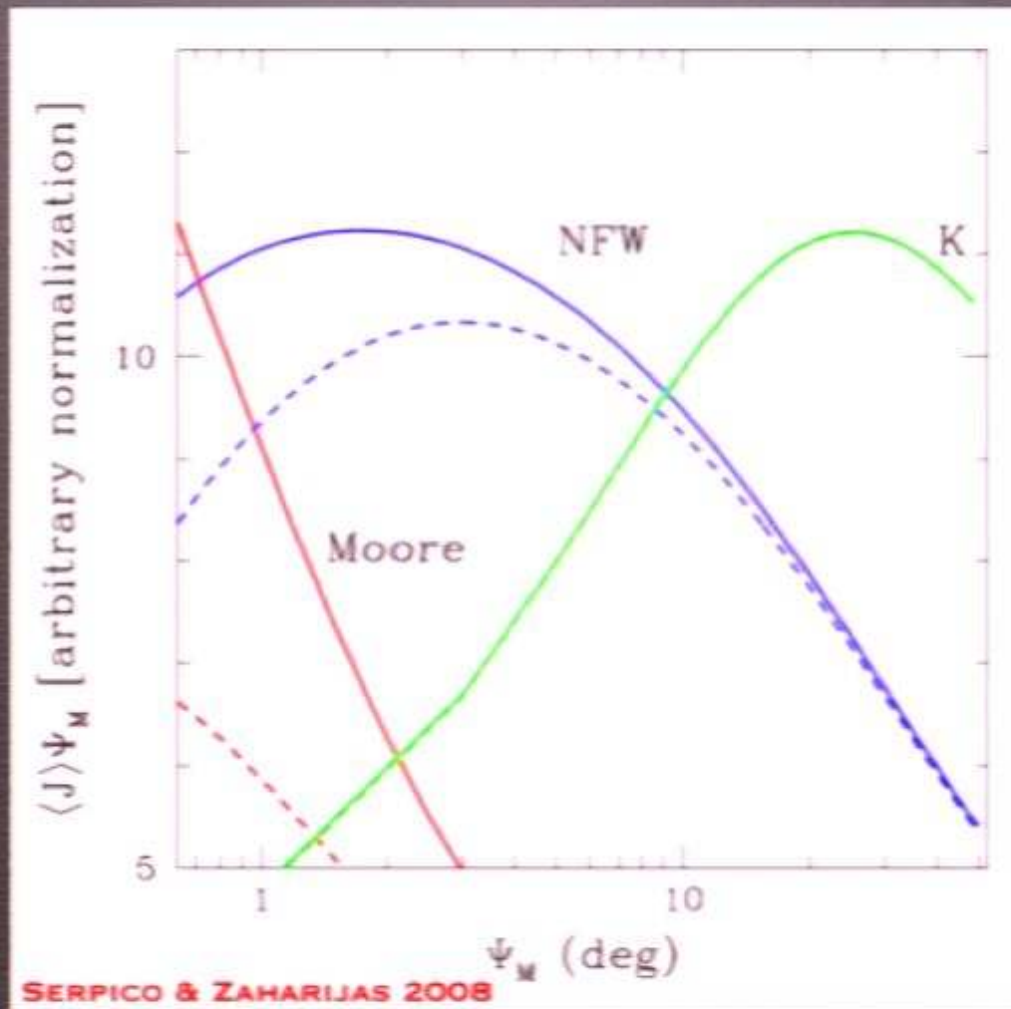
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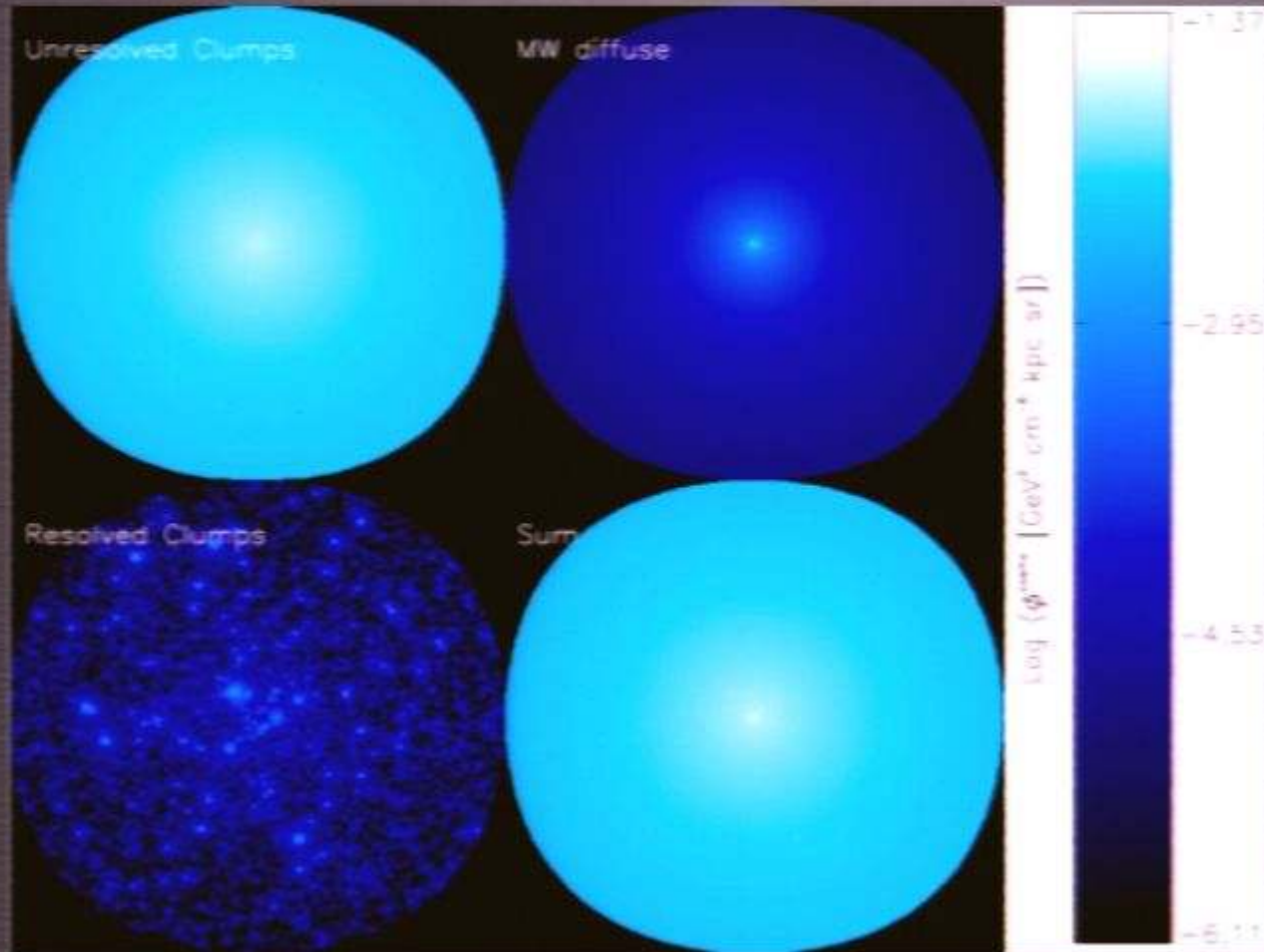


THE GALACTIC CENTER

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ON AN “ANNULUS” AROUND THE CENTER



DM SUBSTRUCTURES



PIERI, GB & BRANCHINI 2008

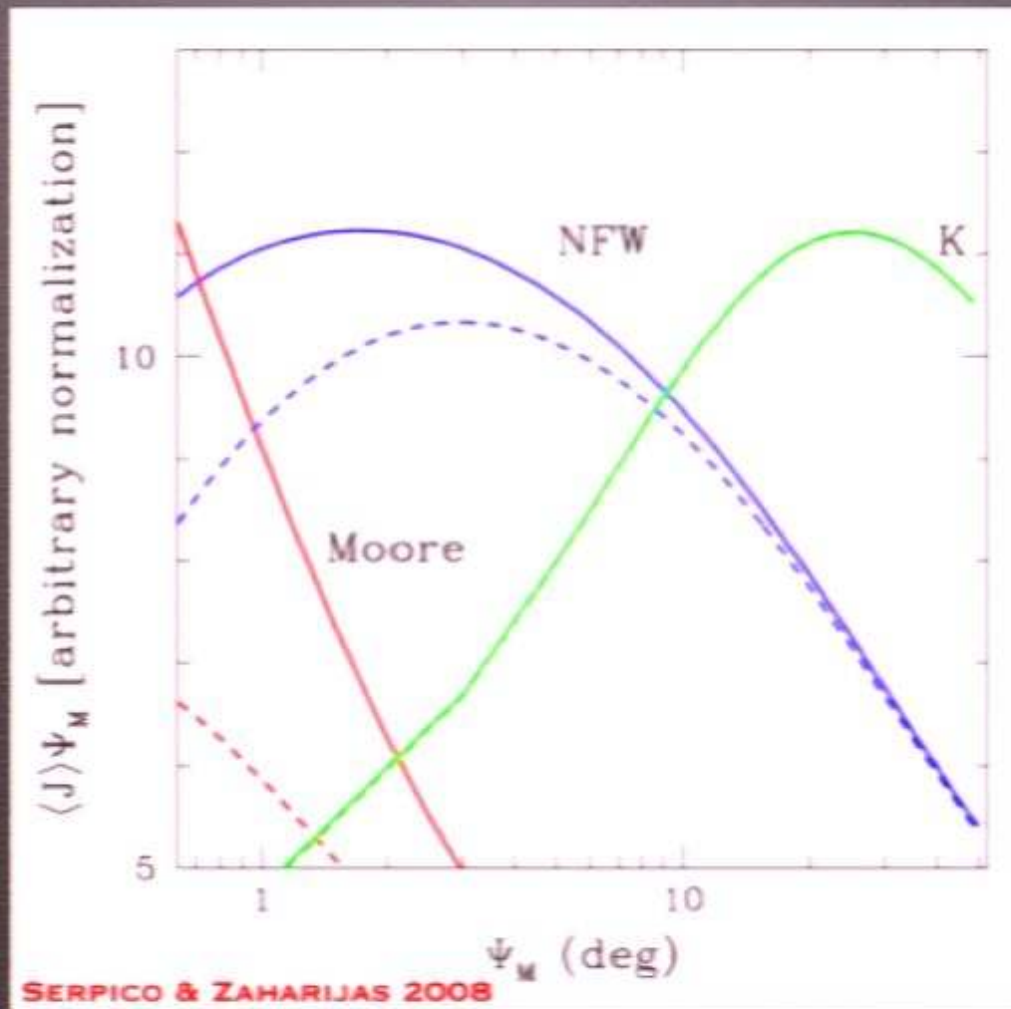
2 EFFECTS:

- UNRESOLVED CLUMPS “BOOST” THE DIFFUSE FLUX
- RESOLVED ONES CAN BE IDENTIFIED AS (DIFFUSE?) SOURCES.

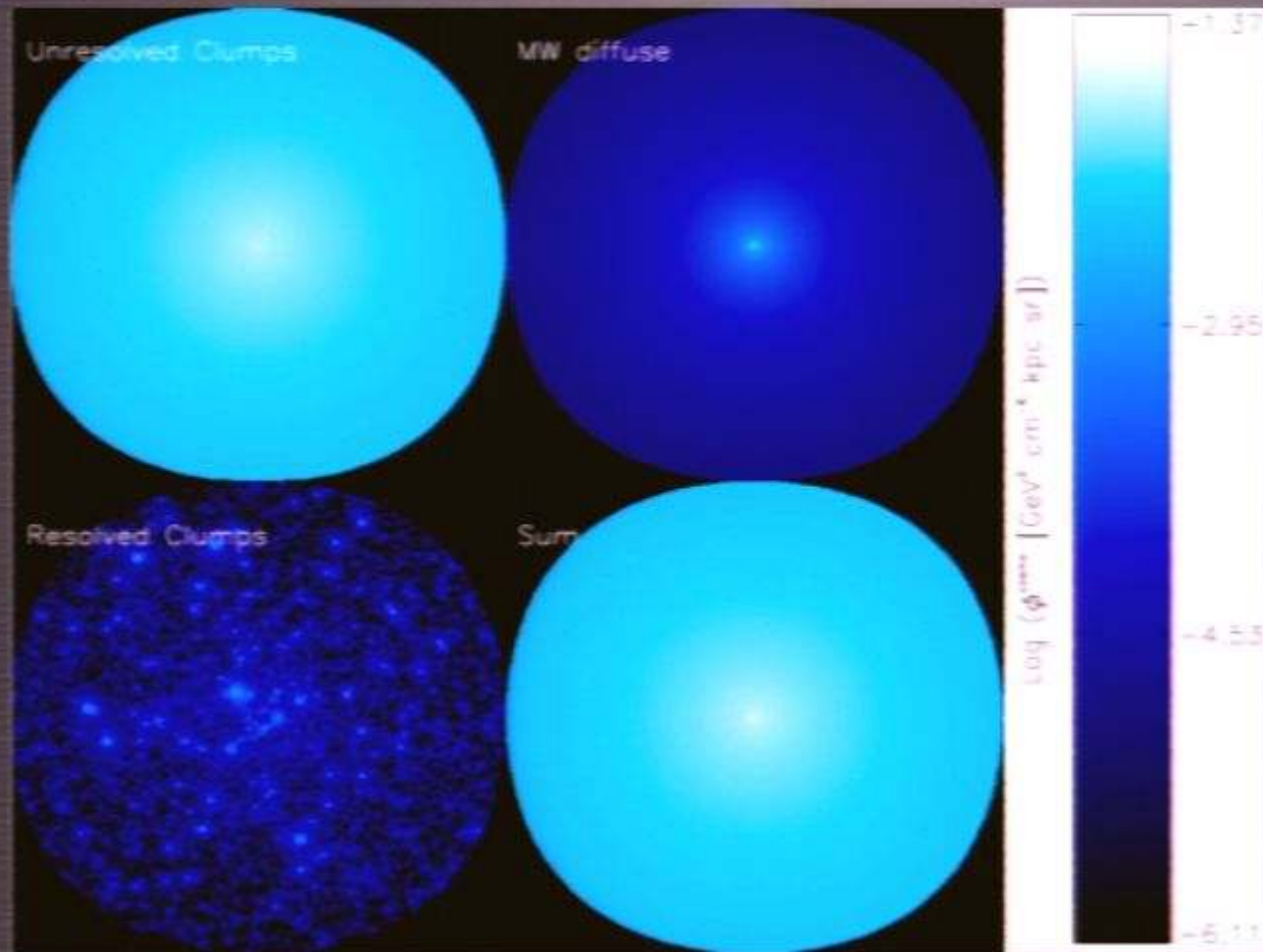
DEPENDING ON THE PARTICLE PHYS. AND ASTROPHYS. ASSUMPTIONS, UP TO 10 - 100 LARGE MASS SUBHALOS COULD BE DETECTED WITH GLAST. SEE ALSO DIEMAND, KUHLEN & MADAU 2008 FOR RESULTS BASED ON THE VIA LACTEA SIMULATION.

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DM SUBSTRUCTURES



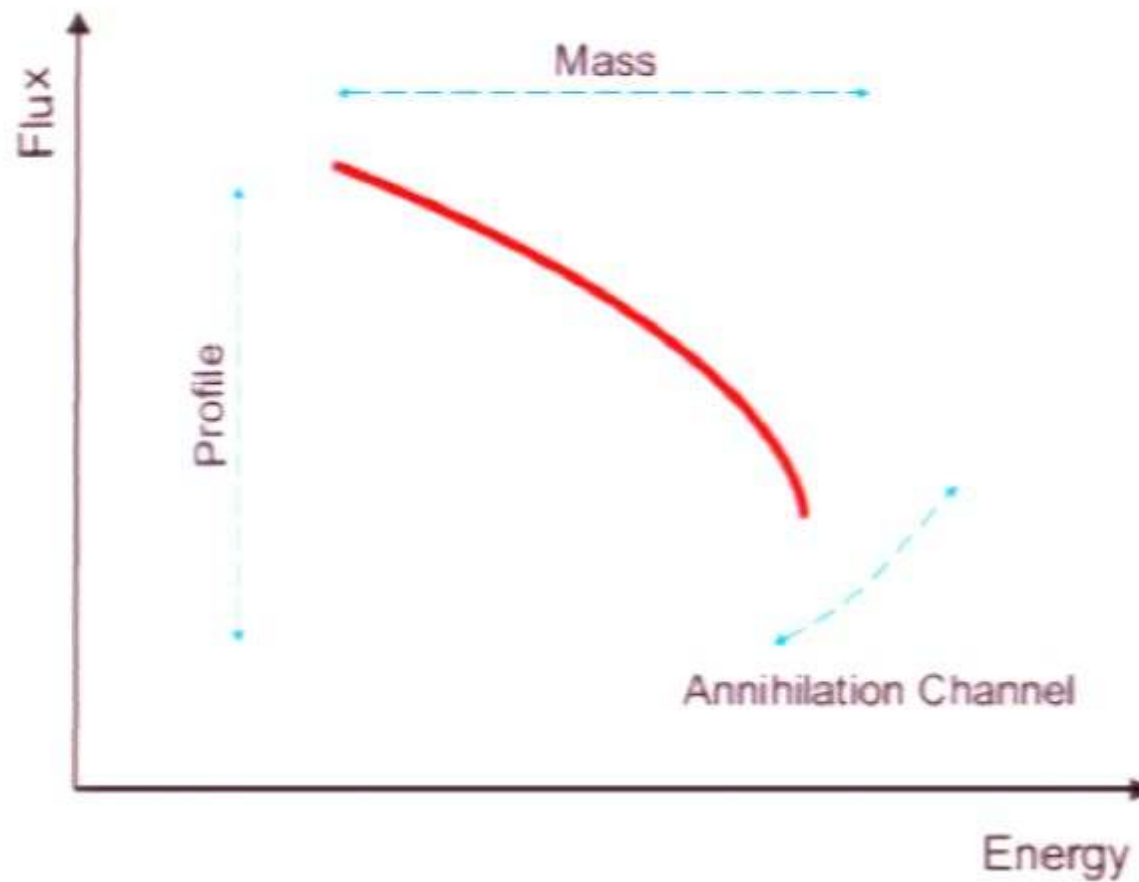
PIERI, GB & BRANCHINI 2008

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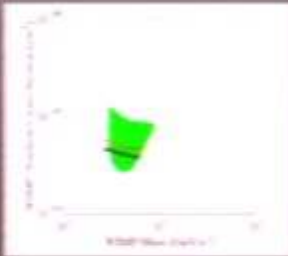
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THE PROBLEM WITH INDIRECT SEARCHES

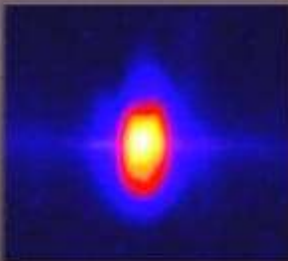


HINTS OF DM?



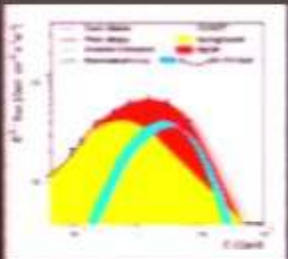
DAMA Direct Detection

Evidence for: 50 GeV WIMP
Bernabei et al (1996,2000,2005)



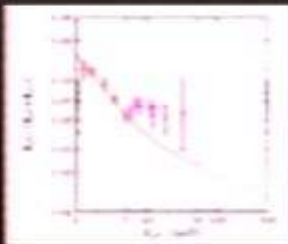
INTEGRAL 511 keV

Evidence for: MeV Dark Matter
Boehm et al (2003,2004)



GC: EGRET, HESS, WMAP 'Haze'

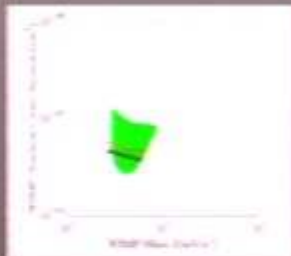
Evidence for: GeV / multi-TeV DM
E.g.: *De Boer (2005)*



HEAT Positron flux

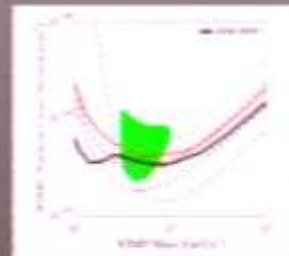
Evidence for: GeV DM
See e.g. *Coutu et al. 1997*

MAYBE...



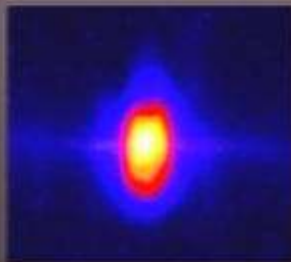
DAMA Direct Detection

Evidence for: 50 GeV WIMP
Bernabei et al (1996,2000,2005)



DAMA Direct Detection

Not consistent with more recent searches, in particular Edelweiss and CDMS II. See experimental papers, plus Gelmini & Gondolo 2005 for possible explanation



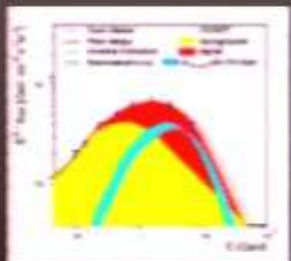
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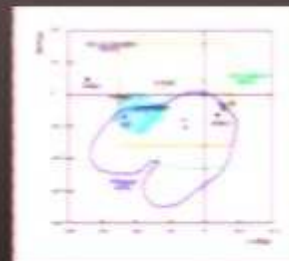
INTEGRAL 511 keV

Scenario is severely constrained: Beacom, Bell & Bertone 2003, Beacom and Yüksel 2004, Hooper, Sigl and Fayet 2006



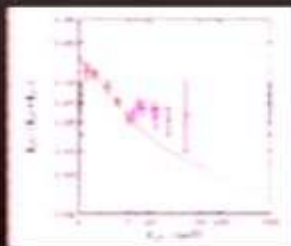
GC: EGRET, HESS, WMAP 'Haze'

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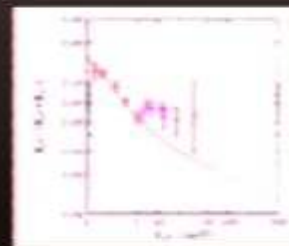
GC: EGRET, HESS...

Anti-proton flux in conflict with De Boer et al. HESS: Mass scale "not natural", astrophys. source! See papers by: Bergstrom, Bertone, Hooper, Profumo, Ullio...



HEAT Positron flux

Evidence for: GeV DM
See e.g. Couto et al. 1997

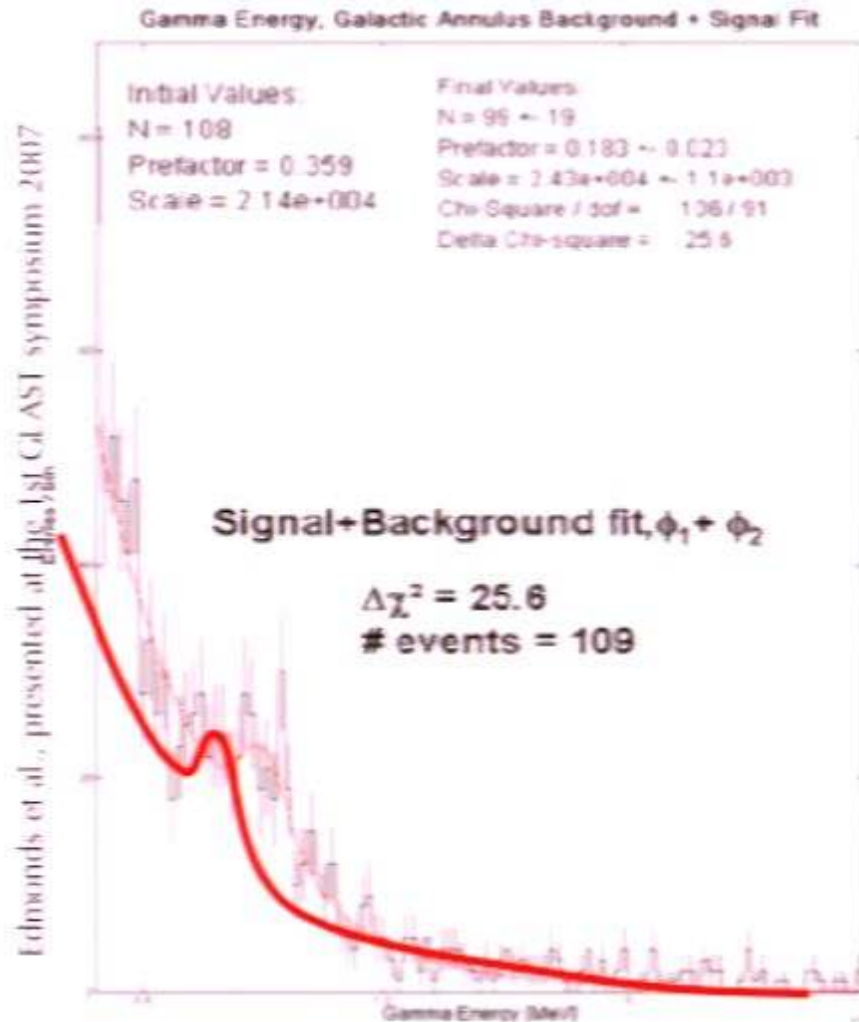


HEAT Positron flux

Possible, but typically need large boost factors. Discussion in Bertone et al 2005, Bergstrom 2003

THE QUEST FOR THE SMOKING-GUN
OR
“HOW TO CONVINCING A PARTICLE
PHYSICIST?”

1. Look for Spectral Lines!



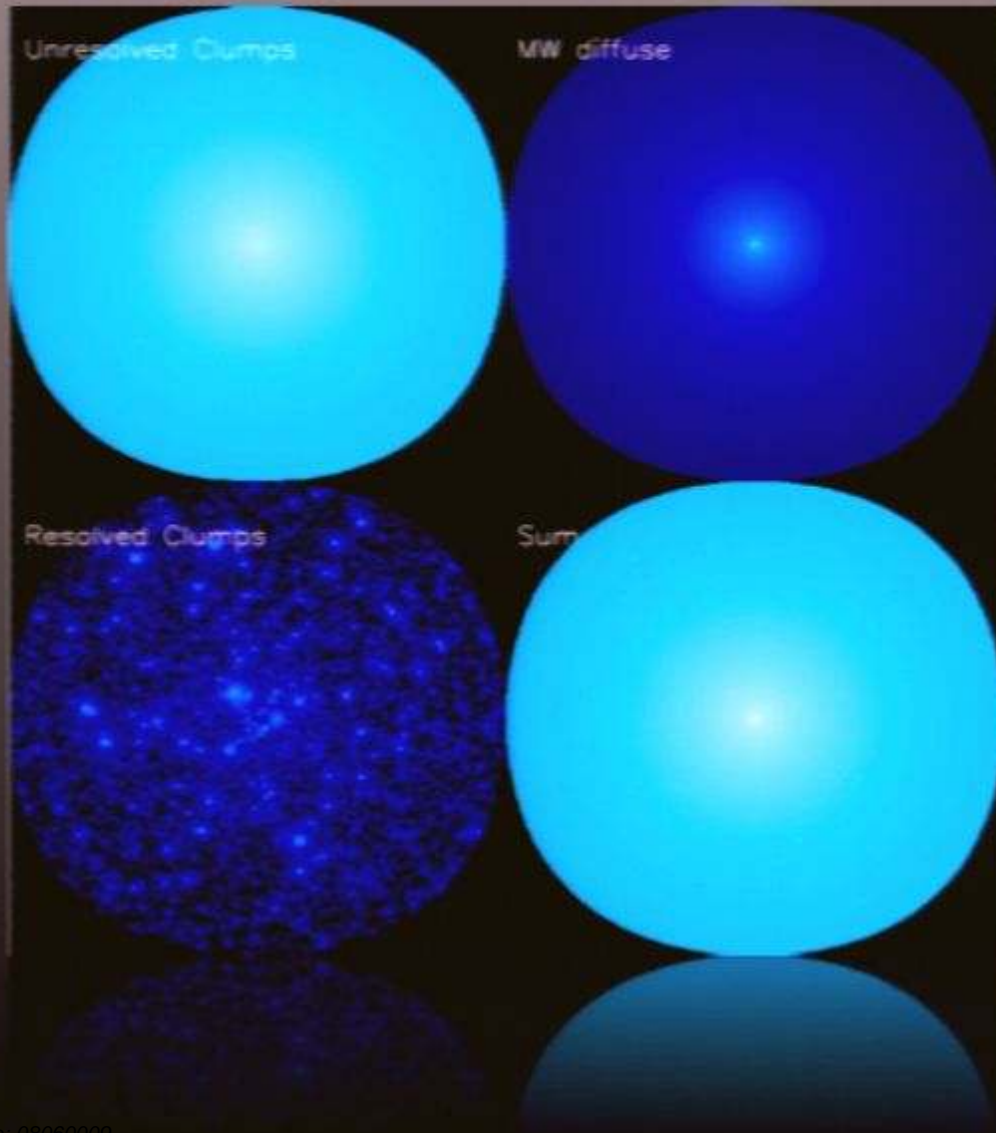
Predictions made e.g. for:

- Neutralinos (e.g. *Bergstrom and Ullio 1997*)
- KK Dark Matter in UED (*Bringmann et al. 2005*)
- Inert Higgs DM (*Gustafsson et al. 2007*)
- (Decaying) gravitinos in SUSY with R-parity violation (*GB, Buchmueller, Covi and Ibarra*)

Relevant experiments:

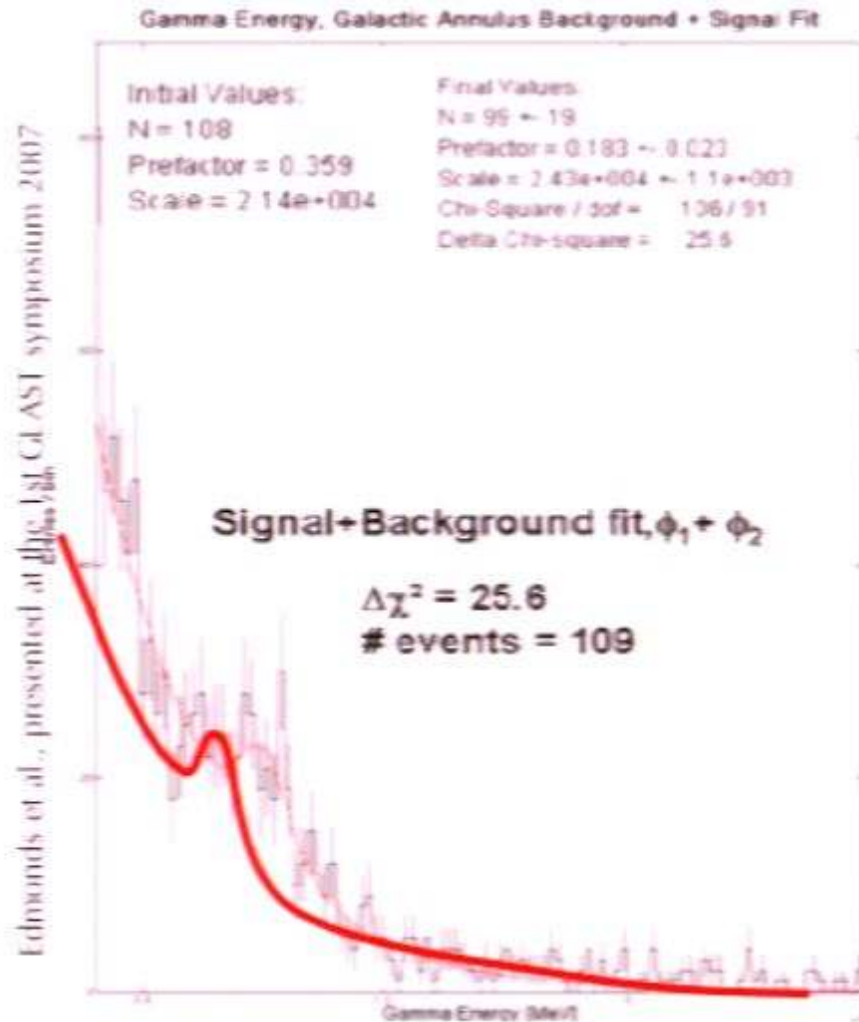
GLAST, Ground based Gamma-ray telescopes (energy resolution 10-15%)

2. Look for multiple sources with *identical* spectra



OR...

1. Look for Spectral Lines!



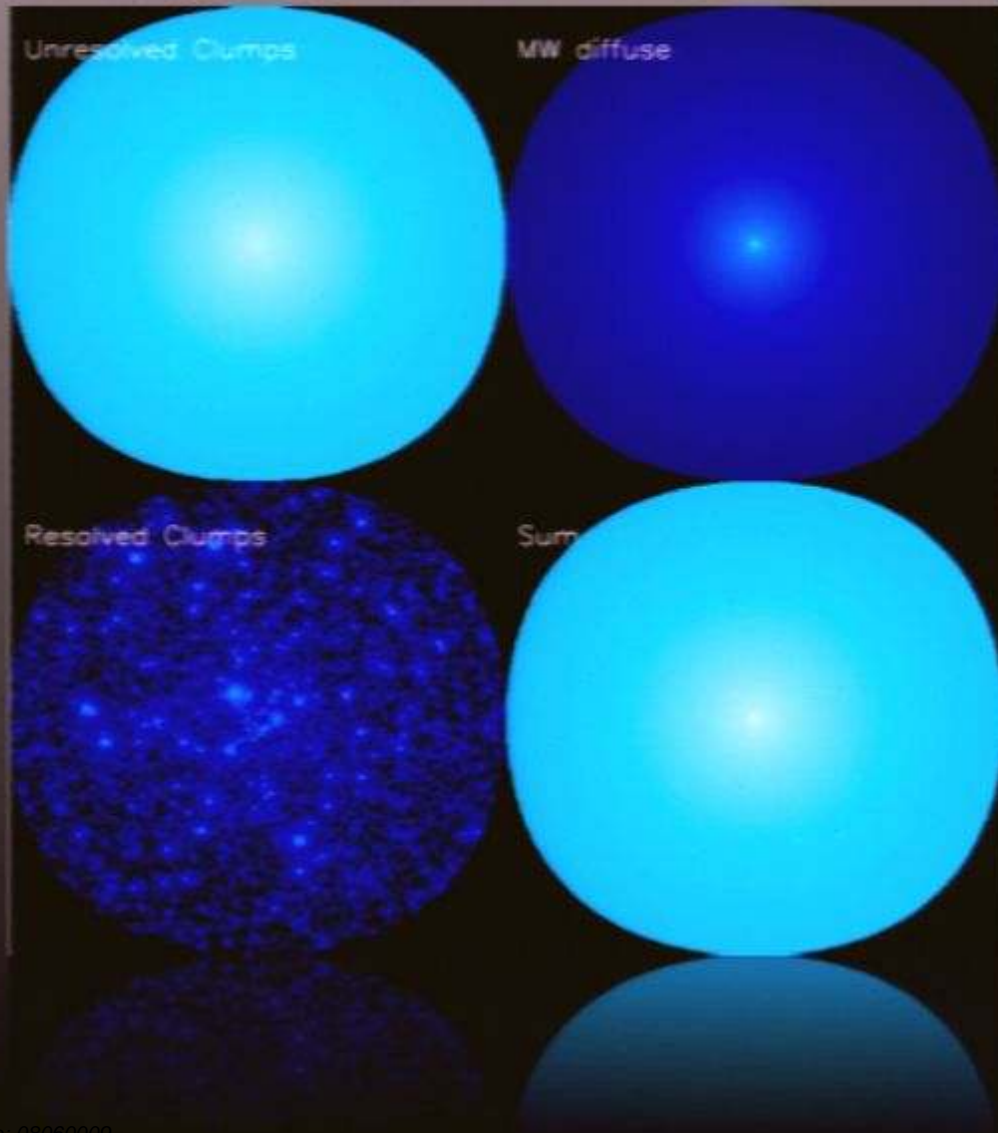
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Relevant experiments:

GLAST, Ground based Gamma-ray telescopes (energy resolution 10-15%)

2. Look for multiple sources with *identical* spectra



OR...

(SOMEWHAT ARBITRARY) BLACK HOLES: DEFINITIONS

$$M \leq 10^2 M_{\odot}$$



STELLAR MASS BHs

- ENDPOINT OF STELLAR EVOLUTION
- INDIRECTLY OBSERVED
- ROBUST EVIDENCE
- LOWER LIMITS ON MASS FROM OBS.

$$10^2 M_{\odot} \leq M \leq 10^6 M_{\odot}$$



INTERMEDIATE MASS BHs

- MAYBE FORM IN GLOB. CLUSTERS
- MAYBE OBSERVED AS ULXs
- SEED FOR SMBHs?
- SPECULATIVE BUT PROBABLE!

$$10^6 M_{\odot} \leq M \leq 10^9 M_{\odot}$$



SUPERMASSIVE BHs

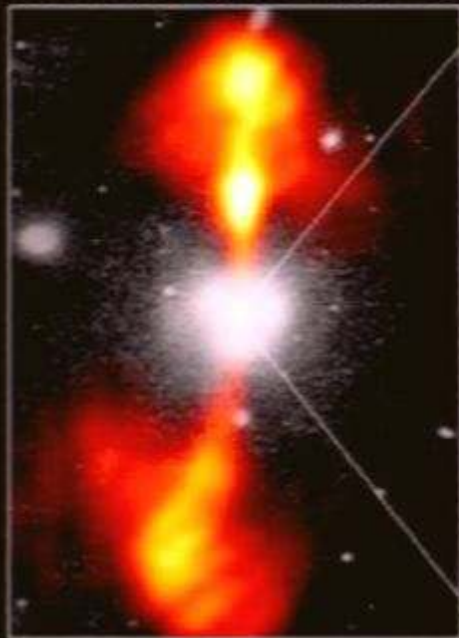
- UNKNOWN ORIGIN
- UBIQUITOUS!
- ROBUST EVIDENCE
- MASS CORR. WITH HOST HALO

EVIDENCE FOR BLACK HOLES

Core of Galaxy NGC 4261

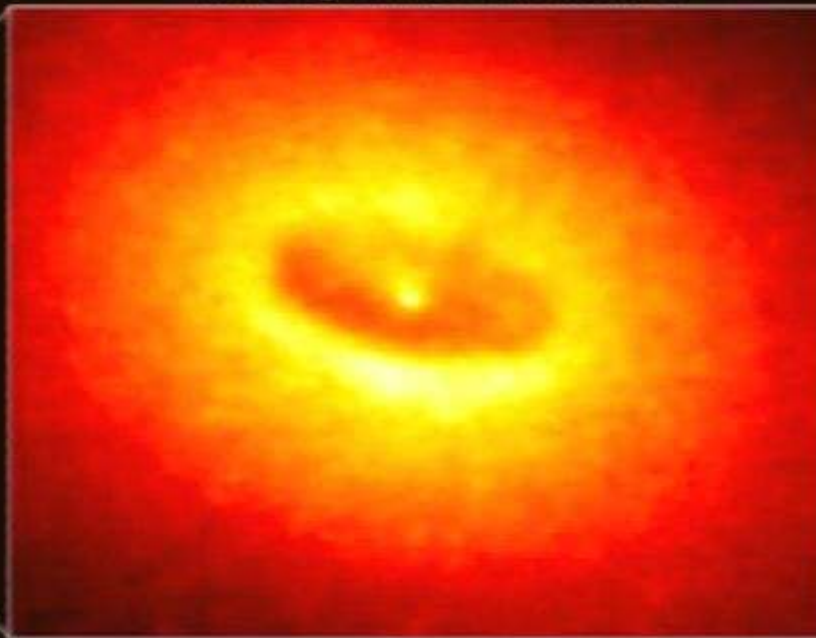
Hubble Space Telescope
Wide Field / Planetary Camera

Ground-Based Optical/Radio Image



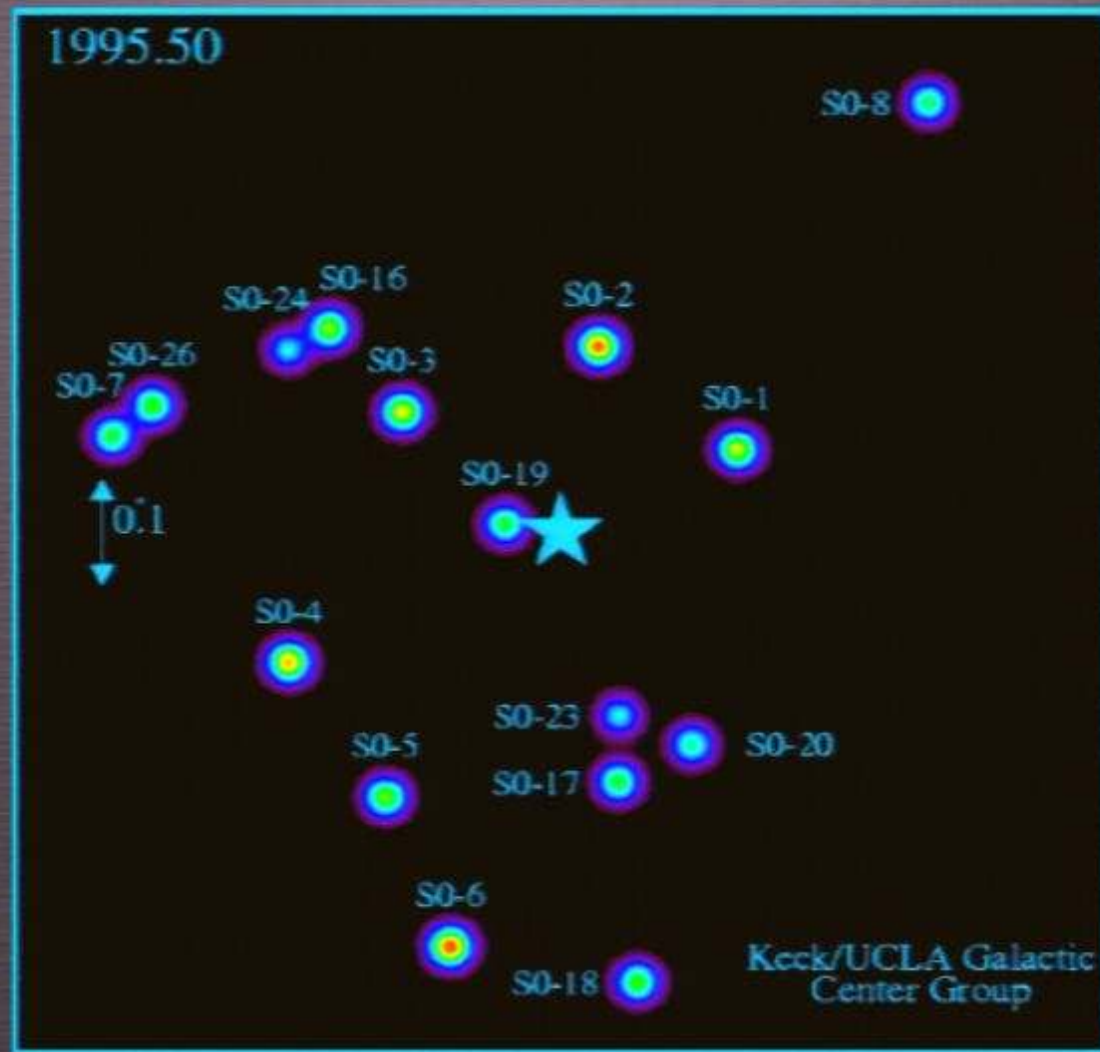
380 Arc Seconds
88,000 LIGHTYEARS

HST Image of a Gas and Dust Disk

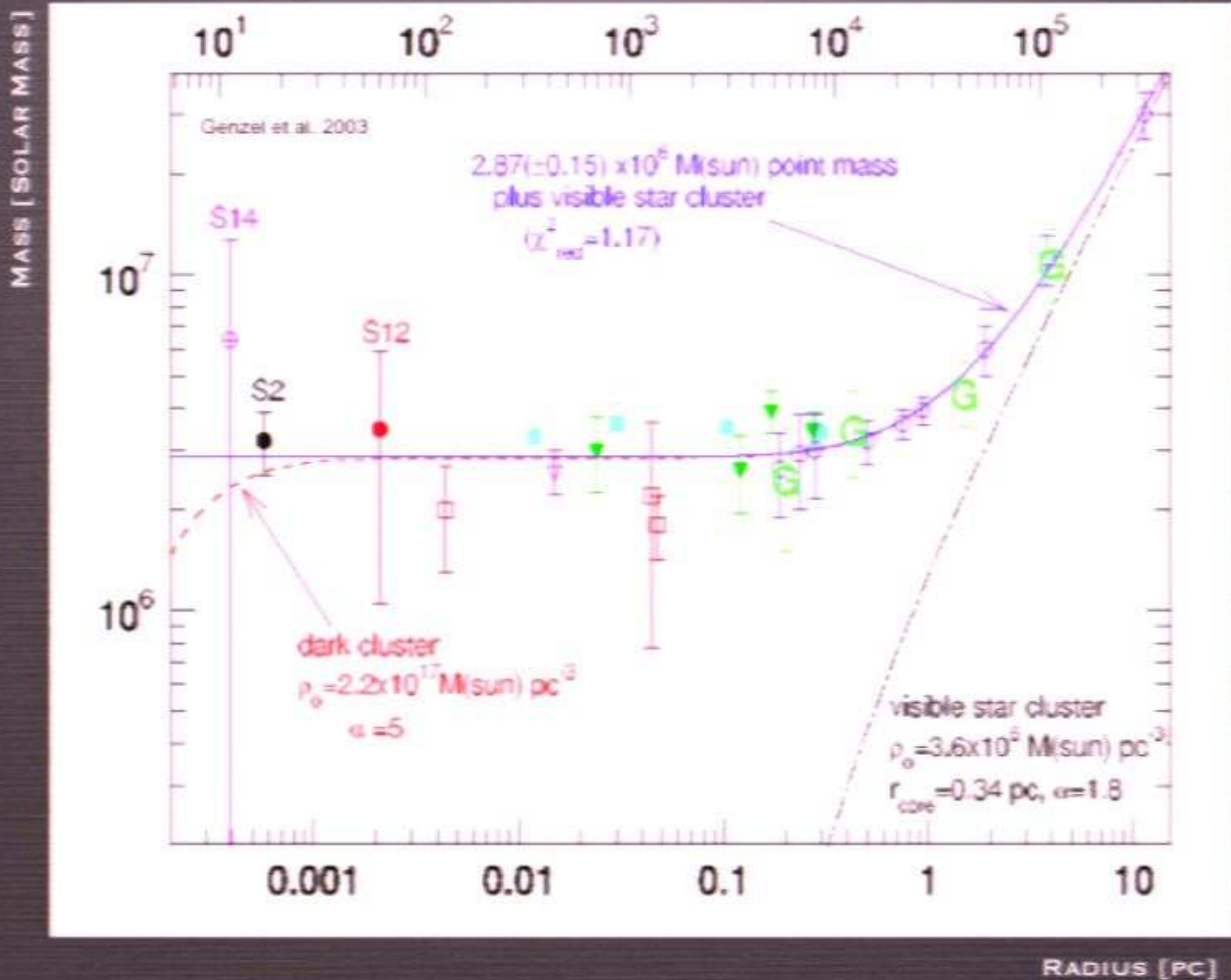


17 Arc Seconds
400 LIGHTYEARS

THE BH AT THE GALACTIC CENTER

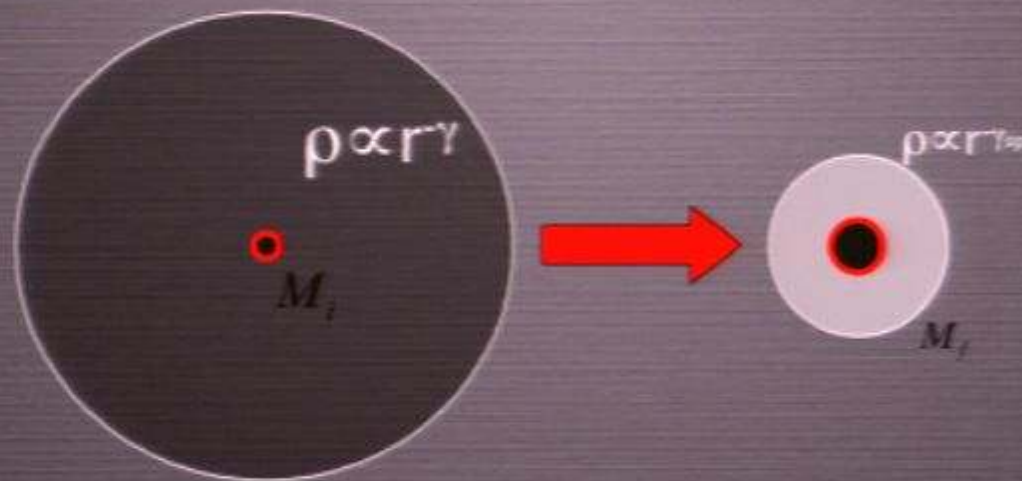


EVIDENCE FOR A SMBH AT THE GC



FORMATION OF DM 'SPIKES'

ADIABATIC ACCRETION OF BHs MODIFIES THE SURROUNDING DM DISTRIBUTION
(GONDOLO & SILK 2000)



CONSERVE MASS & ANGULAR MOMENTUM:

$$\gamma_{sp} = \frac{9-2\gamma}{4-\gamma}$$

ANY OVERDENSITY AT THE GC LIKELY DESTROYED DUE TO GRAVITATIONAL SCATTER OFF THE CENTRAL STELLAR CUSP
(GB & MERRITT 2005)

A "SPIKE" AT THE GC?

WHAT HAPPENS IN THE INNER PARSEC?

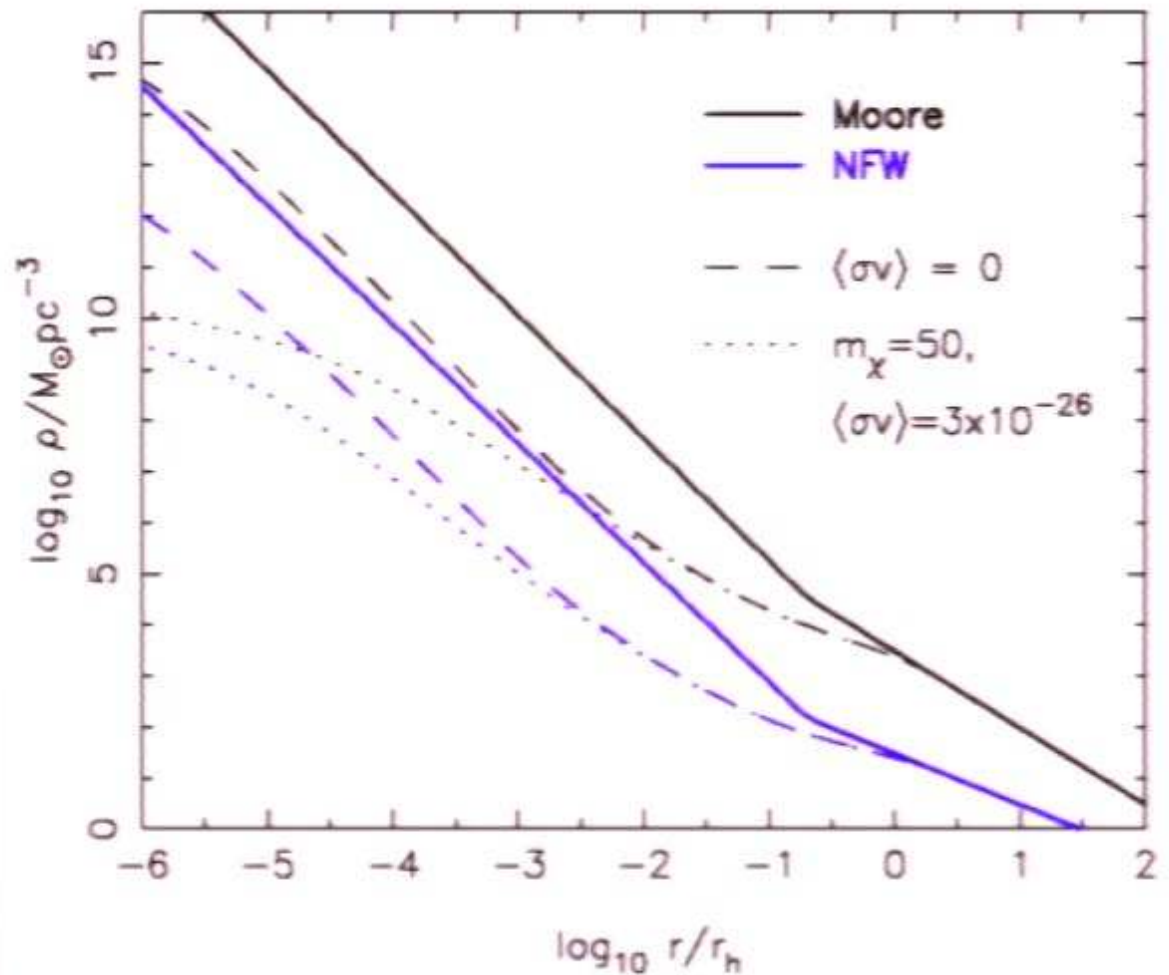
PROFILES ARE MODIFIED DUE TO

- THE PRESENCE OF THE SMBH (SPIKE) GONDOLO AND SILK 2000

- SCATTERING OFF THE STELLAR CUSP (HEATING OF DM, SCATTER INTO THE SMH) MERRITT 2004

- ANNIHILATIONS

COMBINED EVOLUTION OF DARK AND BARYONIC MATTER

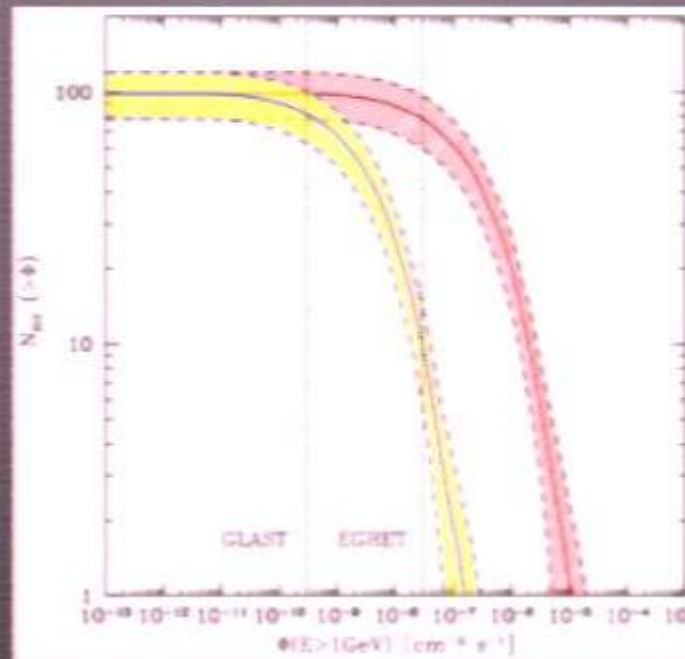


GB and Merritt 2005

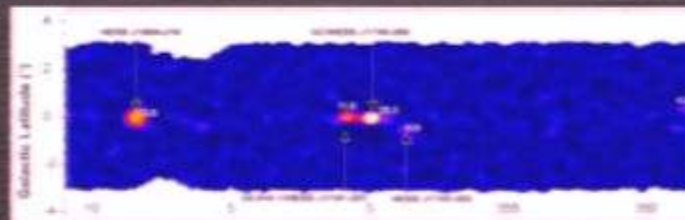
INTERMEDIATE-MASS BLACK HOLES

INTERMEDIATE-MASS BLACK HOLES

OVERDENSITIES AROUND IMBHs LIKELY SURVIVE, MAKING THEM INTERESTING TARGETS



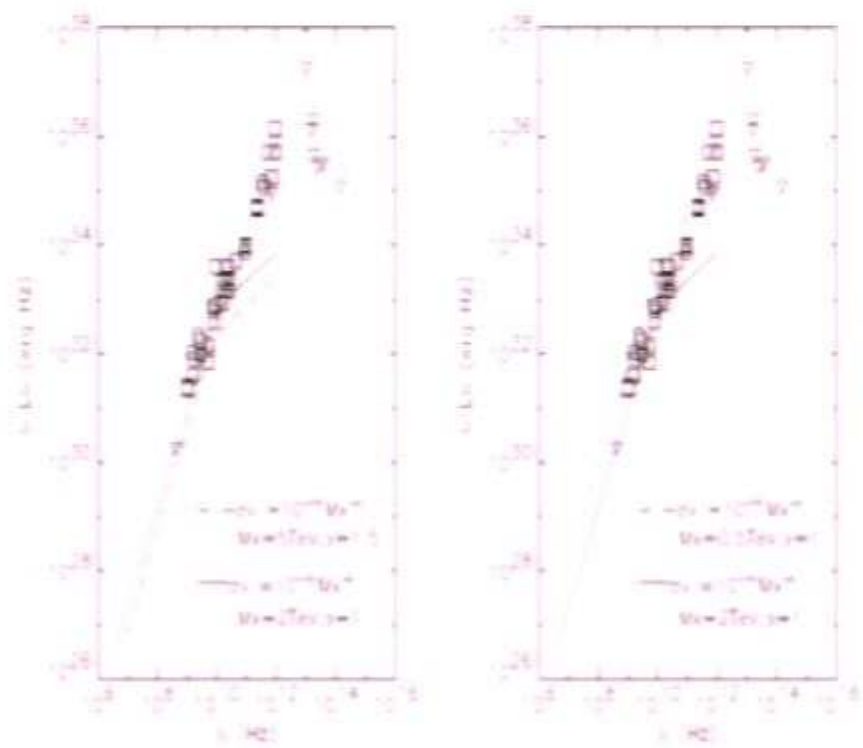
GB, ZENTNER & SILK 2005



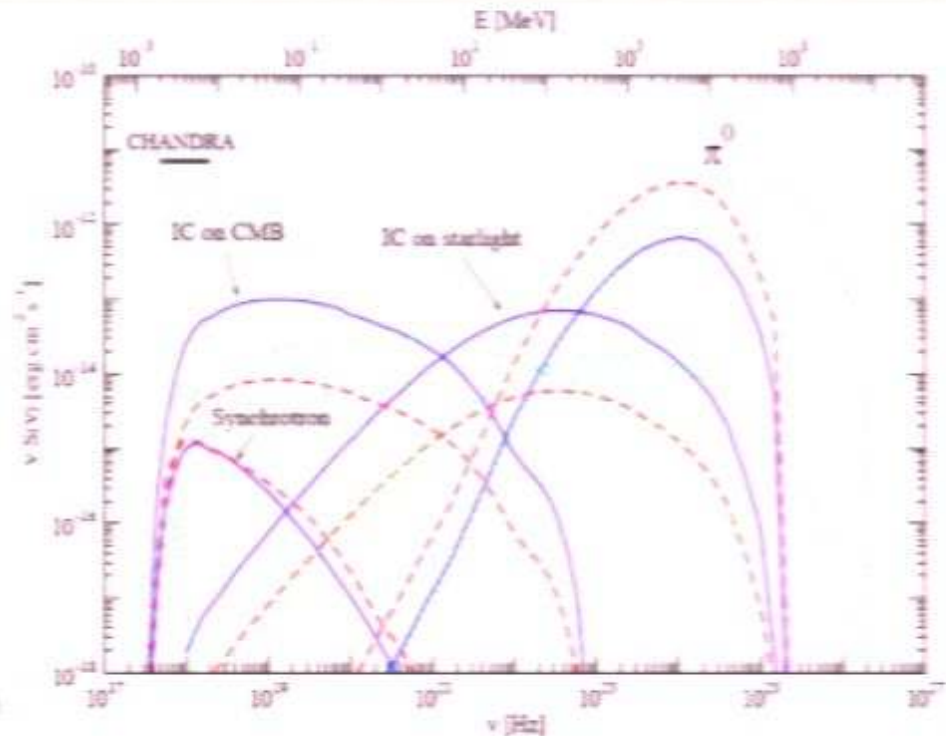
HESS GALACTIC SCAN CONSTRAINS THESE MODELS. RESULTS SOON TO APPEAR ON PRD AHARONIAN ET AL. 2008

3. MULTI-WAVELENGTH / MULTIMESSENGER APPROACH

- FOLLOW ALL THE PRODUCTS OF ANNIHILATIONS. BUILD A CONSISTENT MULTI-WAVELENGTH SPECTRUM AND COMPARE WITH OBSERVATIONS!



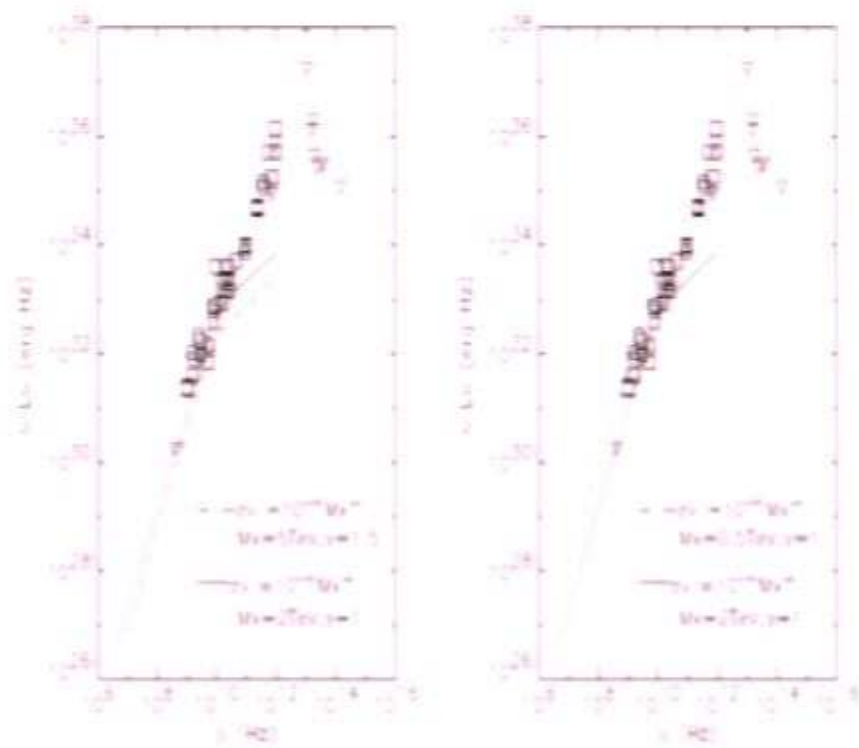
GB, Sigl & Silk 2001



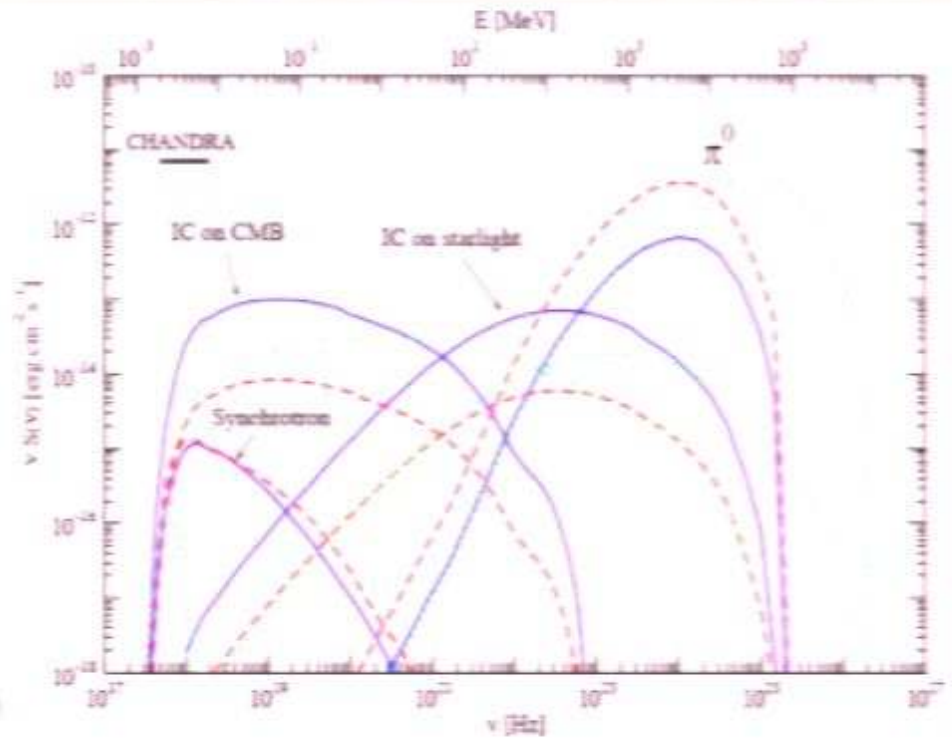
Regis and Ullio 2008

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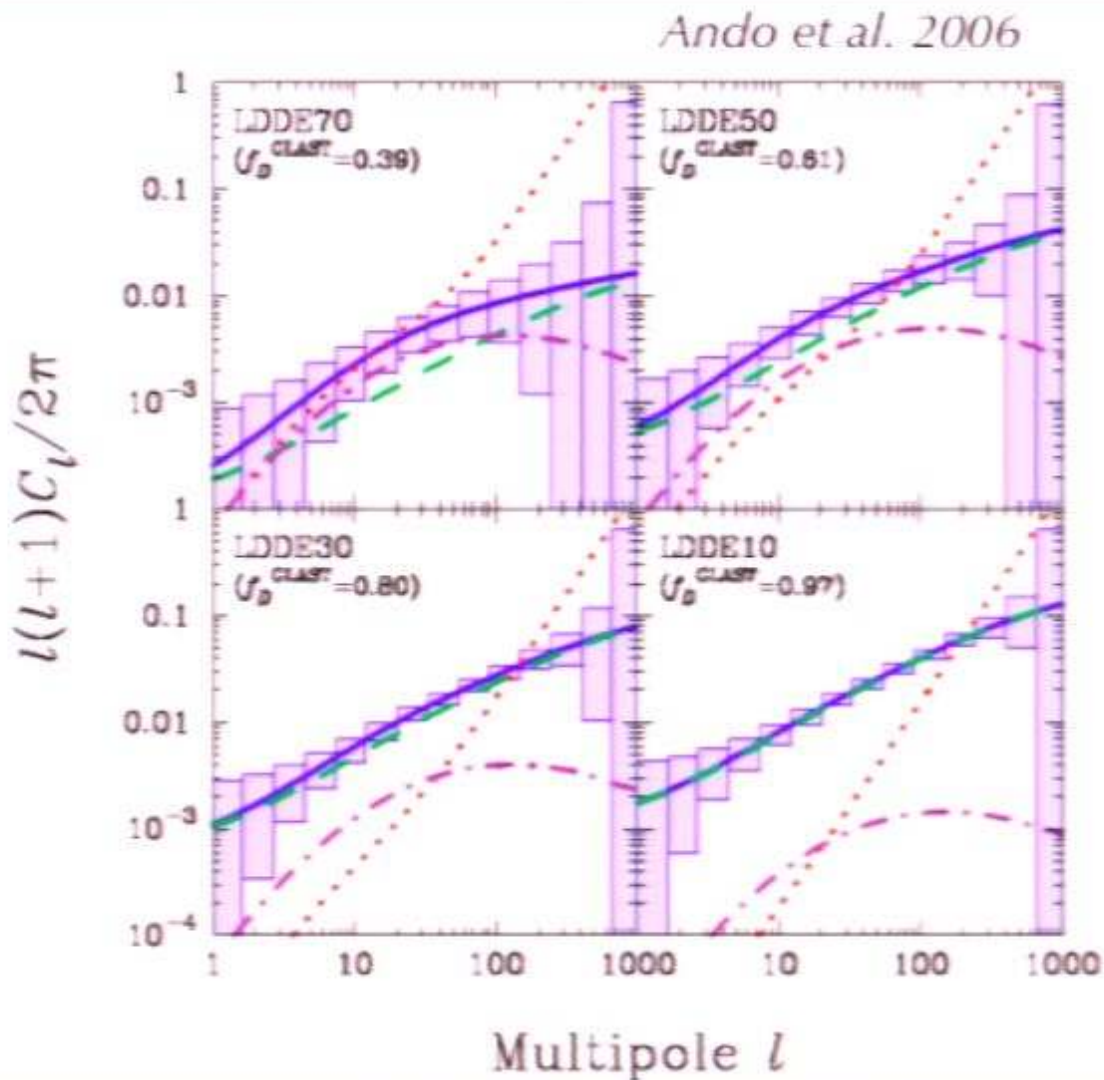


GB, Sigl & Silk 2001



Regis and Ullio 2008

4. GAMMA-RAY BACKGROUND (ANGULAR POWER SPECTRUM)



- How to discriminate against astrophysical background?

- Look at angular power spectrum (similar to CMB!)

- Depending on the relative importance of the DM signal vs. astrophysical, possibility to identify it with GLAST!

CONCLUDING THOUGHTS

- REALISTIC DM SCENARIOS LEAD TO DETECTABLE SIGNALS IN GLAST
- TO ACTUALLY SEE SOMETHING, WE NEED TO BE LUCKY
- TO OBTAIN UNAMBIGUOUS EVIDENCE FOR DM, WE NEED TO BE VERY VERY LUCKY
- THE TIME OF SPECULATIONS IS ALMOST OVER, GET READY TO ANALYZE SOME DATA!