Cosmological WIMPs, Higgs Dark Matter and GLAST

Alexander Sellerholm
Stockholm university, CoPS

Outline

- CoPS of Stockholm
- GLAST :
  - ★ GLAST Sweden
  - ★ GLAST Dark Matter & New Physics
- Cosmological WIMPs
  - ★ Generic WIMPs
  - ★ Inert Higgs Doublet

CoPS people working on DM

Seniors

- Lars Bergström (prof)
- Jan Conrad (fo-ass)
- Joakim Edsjö (fo)
- Christine Meurer (Post-doc)

PhD students

- Yashar Akrami
- Michael Gustafsson
- Erik Lundström
- Anders Pinzke
- Sara Rydbeck
- Patrick Scott
- AS

+ string-theory, GR, SN cosmology...

Further info :

www.cops.physto.se

What are we working on?

- Dark matter: distribution in halos, neutralinos, Inert Higgs and Kaluza Klein particles
- GLAST: Indirect detection, Cosmological WIMPs, Extragalactic Gamma-ray Background
- Dark SUSY: MSSM Dark Matter calculations; vertices, Mass spectrum, Relic density...
- Dark Stars
- Modified Gravity (not MOND!)
- ...

GLAST SWEDEN

Research

- Dark Matter & New Physics (J. Conrad is working group coordinator)
- High-Energy Emission in Gamma-Ray Bursts
- Active Galactic Nuclei
- Beam Tests

CoPS

- Lars Bergström
- Jan Conrad (PI)
- Joakim Edsjö
- Christine Meurer
- AS

Additional people

- Stefan Larsson (Astro-SU)
- Felix Ryde (KTH)
- Per Carlson (KTH)
- Tomi Ylinen (KTH)
- Niklas Karlsson (KTH-SLAC)
- Wlodzimierz Klamra (KTH)
- Staffan Carius (Kalmar)

Further info :

http://www.particle.kth.se/~tomiy/glast-sweden/

GLAST Dark Matter & New Physics Working Group

-The GLAST LAT team pursuis complementary searches for signatures of particle dark matter.

-GLAST has the potential to either discover or to constrain particle dark matter and establish contact between LHC discovery and Dark Matter

- GLAST will be able to image Dark Matter Halo structure

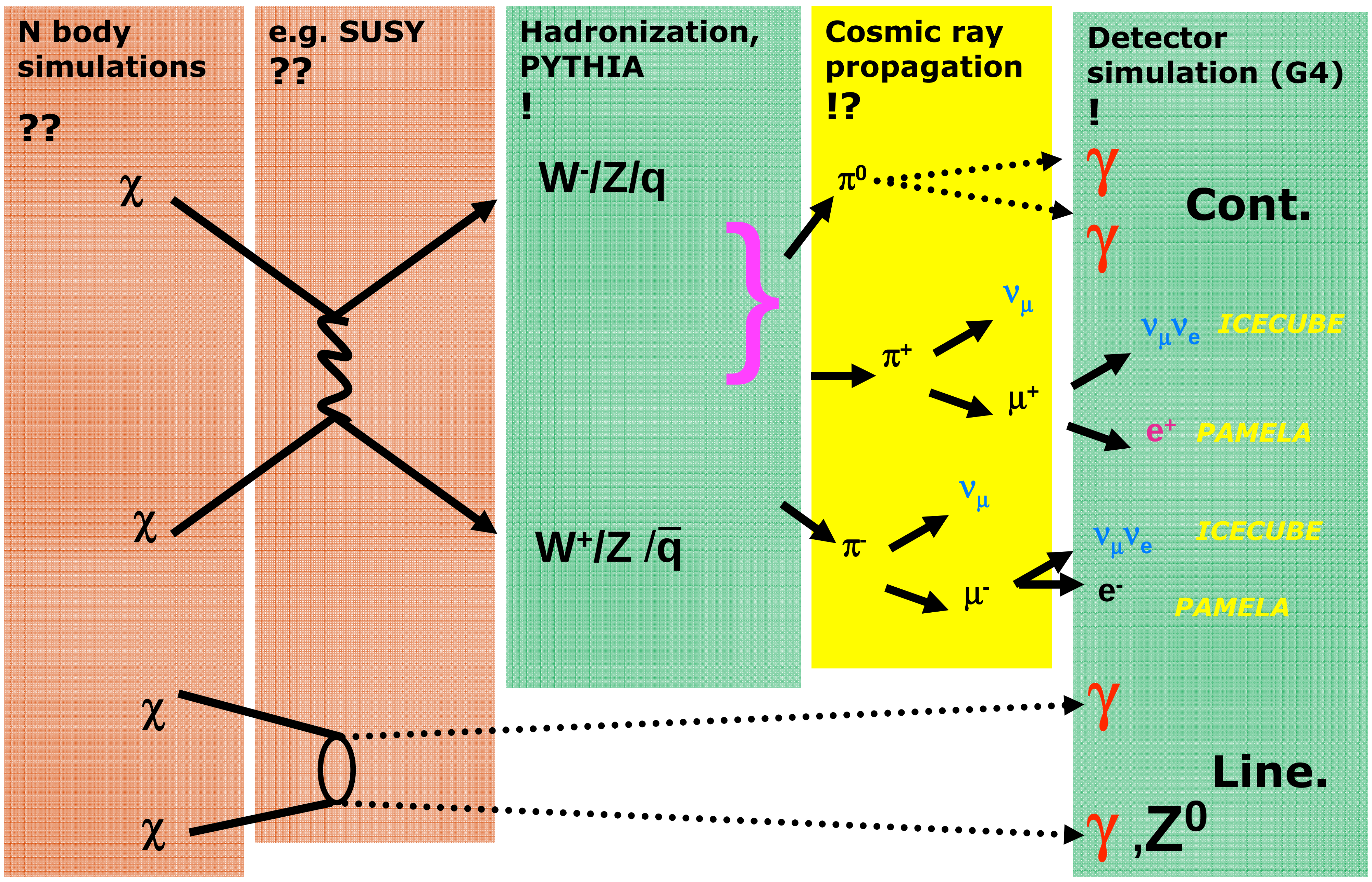
- GLAST Launch foreseen for end ~~of~~ this year. Stay tuned !

next

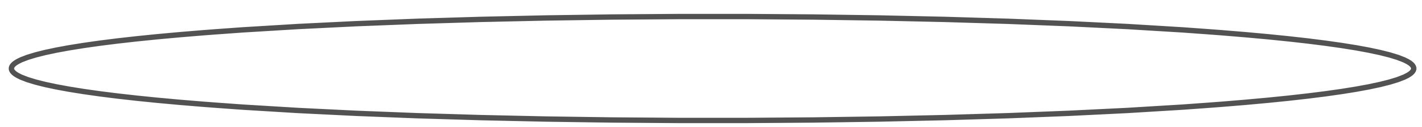
Together with people from

SLAC - Stanford, Ohio State, Laboratoire de Physique Théorique et stroparticules, INFN and Università degli Studi di Roma, Tor Vergata...

Indirect Detection



Targets

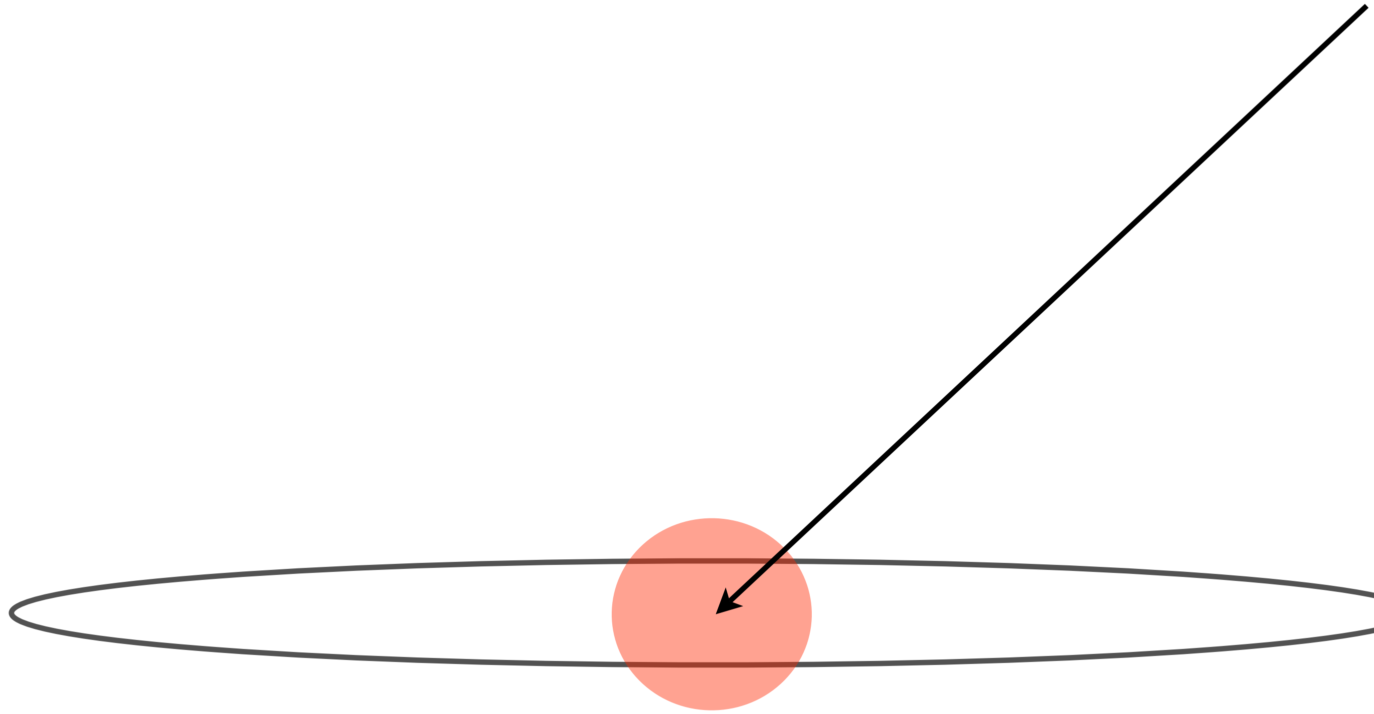


Targets

Galactic Center

+ High DM density

- High Background



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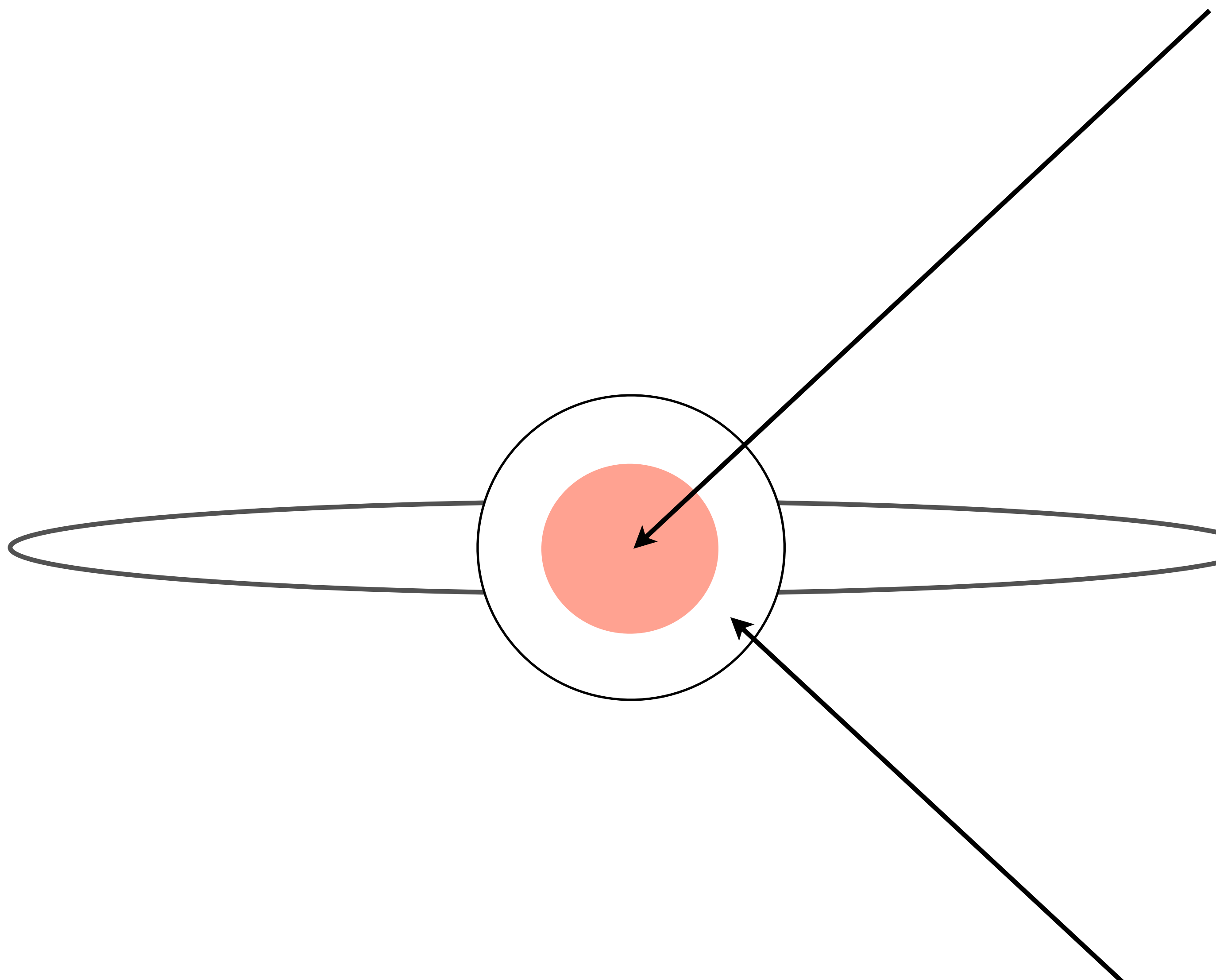

Galactic Center

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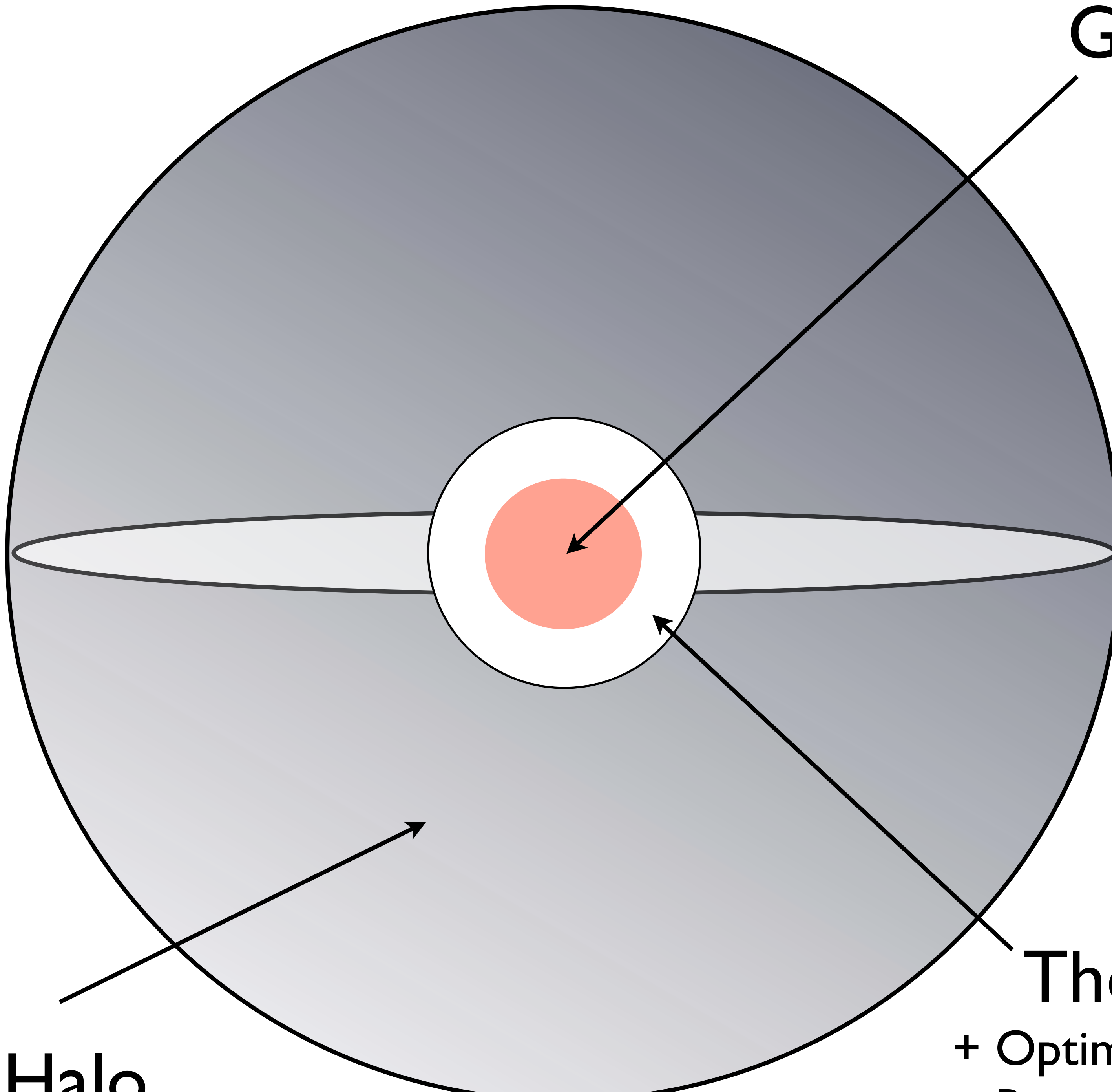
The "Annulus" [25°,35°]

+ Optimized sign/bkg (Stoehr et al. 2003)
+ Better understood background

Targets



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Galactic Halo
+ High Statistics
- Galactic diffuse emission

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Extra Galactic
+ High Statistics
- Challenging Analysis

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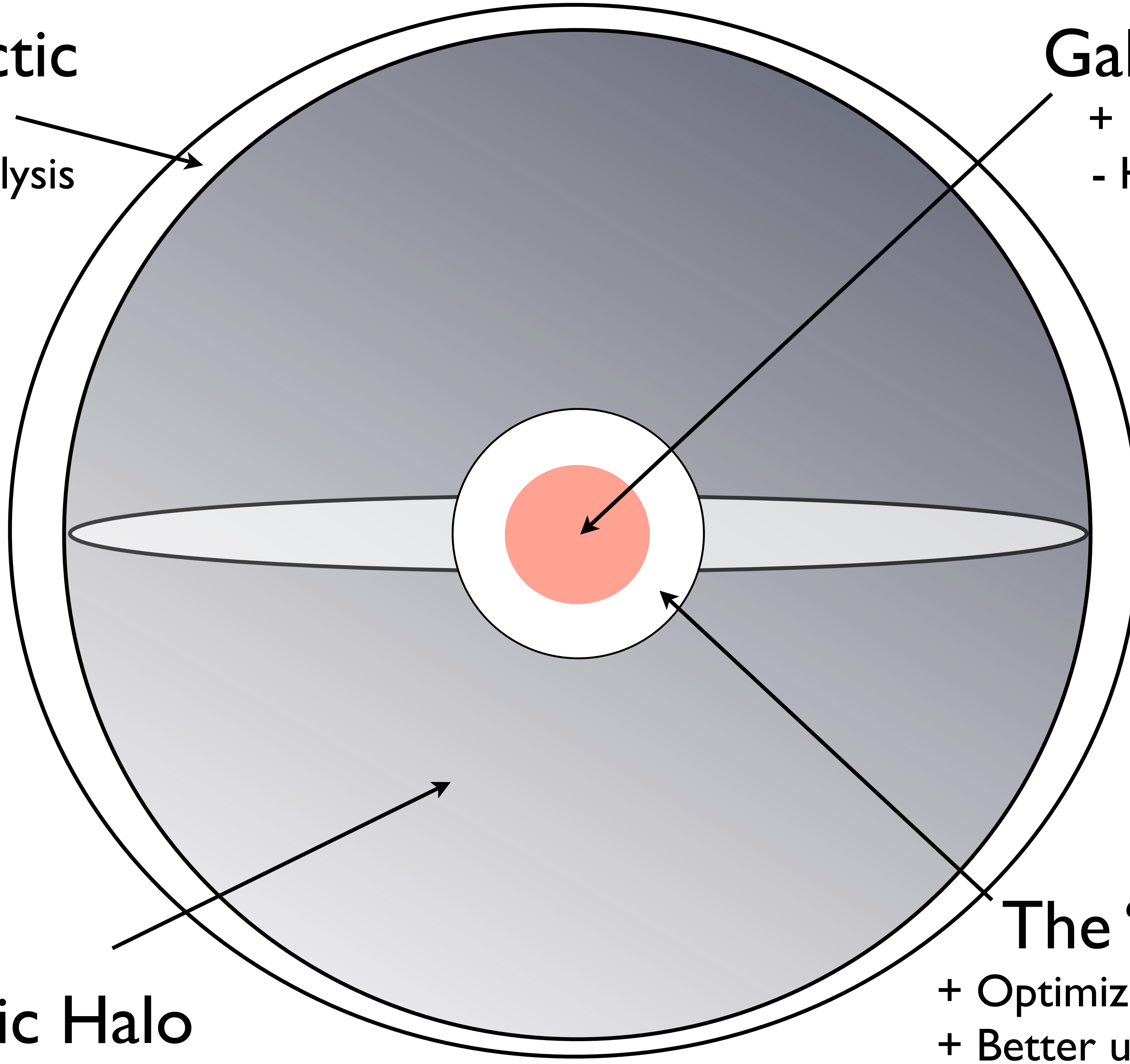

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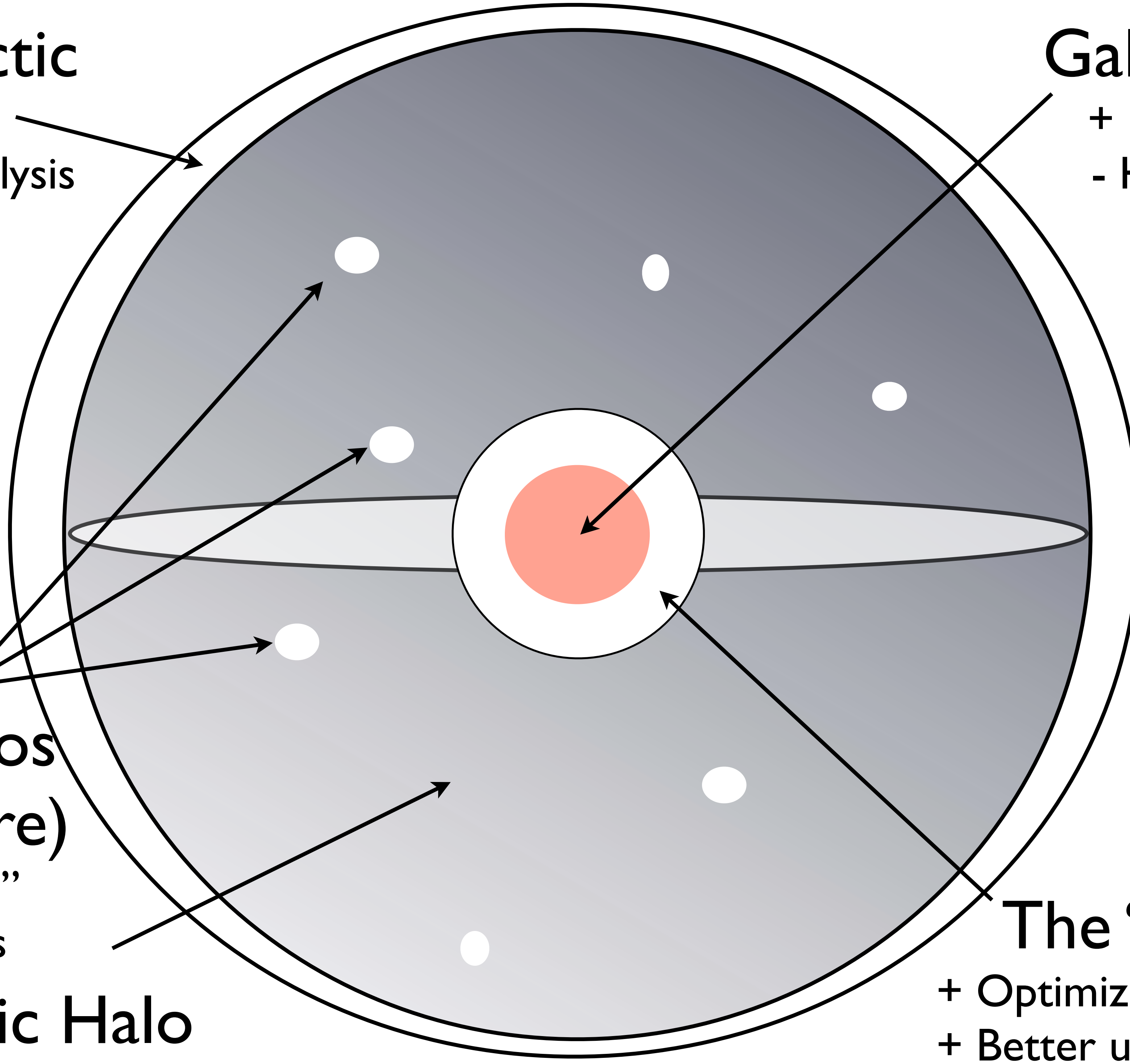

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Satelite Halos (SubStructure)
+ "Smoking gun"
- Low Statistics

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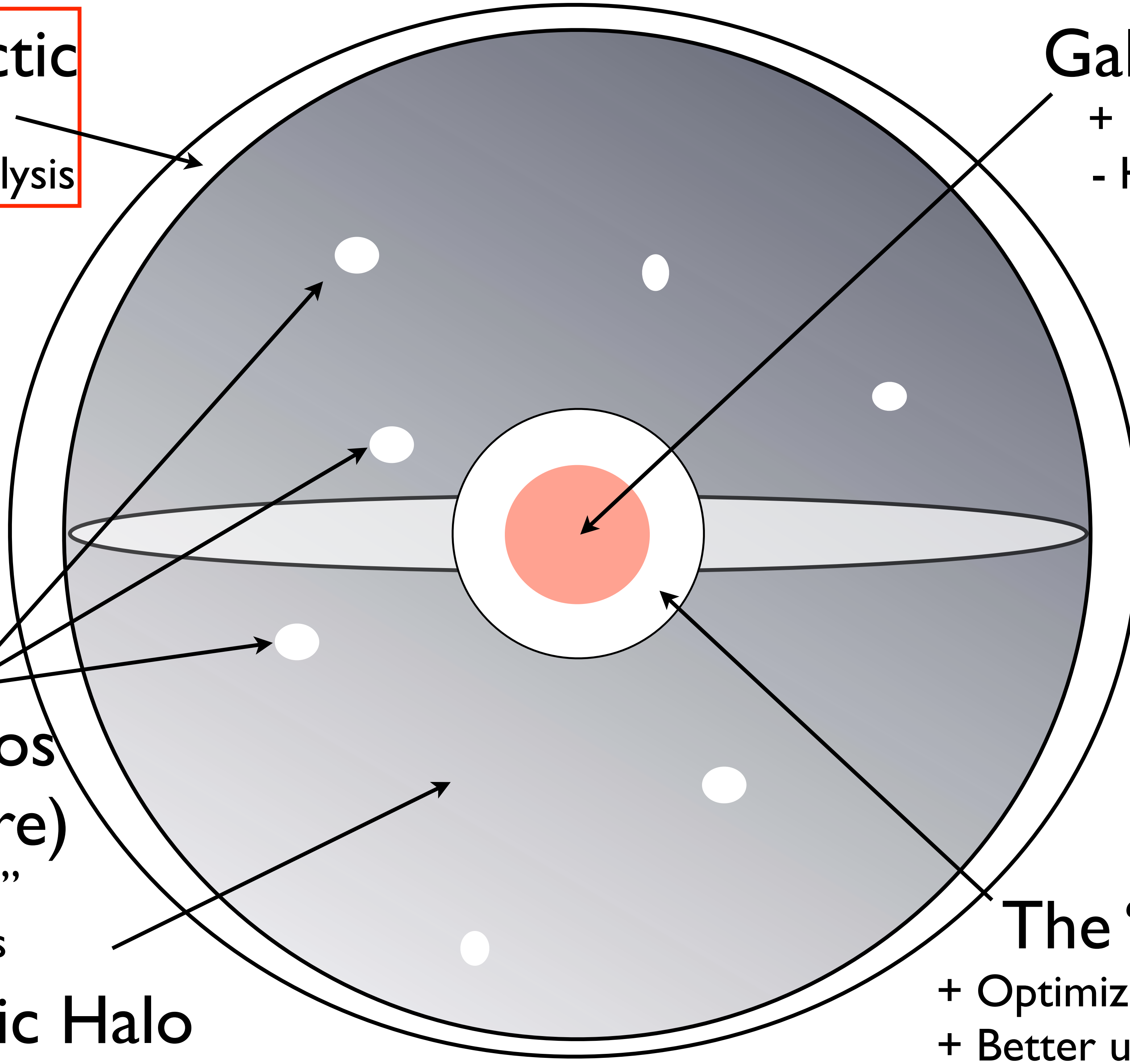

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Cosmological WIMPs

- Indirect detection of DM using γ - rays
- Diffuse signal with contributions summed over all redshifts.
- Unique spectral features;
  Broaded, asymmetrical lines & continuum bump.
- Signal less sensitive to DM halo profiles

The Signal

The differential γ - ray flux: (Ullio, Bergström, Edsjö & Lacey Phys.Rev. D66 (2002) 123502.)

$$\frac{d\phi_\gamma}{dE_0} = \frac{\sigma v}{8\pi}\frac{c}{H_0}\frac{\bar{\rho}_0^2}{M_\chi^2}\int dz\ (1+z)^3\frac{\Delta^2(z)}{h(z)}\frac{dN_\gamma(E_0\,(1+z))}{dE}e^{-\tau(z,E_0)}$$

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- Particle physics
- Astro physics
- Cosmology

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  Cross section
- Astro physics
- Cosmology

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- Particle physics
  - Cross section
  - WIMP Mass
- Astro physics
- Cosmology

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- Particle physics
  - Cross section
  - WIMP Mass
  - γ - ray yield per annihilation
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- **Particle physics**
  - Cross section
  - WIMP Mass
  - γ - ray yield per annihilation
- **Astro physics**
  - Optical depth
- **Cosmology**

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  - DM structure, halo properties and evolution
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- **Particle physics**
  - Cross section
  - WIMP Mass
  - γ - ray yield per annihilation
- **Astro physics**
  - Optical depth
  - DM structure, halo properties and evolution
- **Cosmology**
  - Expansion of the universe
  - Cosmological parameters

Particle physics

Yield:

$$\frac{dN_\gamma(E)}{dE} = \sum_X b_{\gamma X} n_{\gamma X} \delta\left(E - M_\chi\left(1 - M_X^2/4\,M_\chi^2\right)\right) + \sum_F b_F \frac{dN^F_{\rm cont}}{dE}(E)$$

Typical Cross section:

$\sigma v \sim 3\times10^{-26}\ \mathrm{cm}^3\,\mathrm{s}^{-1}$ (Thermal Relic)

$b_{\gamma\gamma} \sim b_{z\gamma} \sim 10^{-3}$ (1-loop suppression)

Masses:

- MSSM 50 GeV < M_χ < few TeV
- KK ~ 0.5 < M_χ < few TeV
- IDM 45 < M_χ < 75 GeV and M_χ > 0.5 TeV
- ...

HALO properties I

Halo profiles

$\frac{d\phi_\gamma}{dE_0} \propto \rho^2$: structure severely boosts the signal!

$$10^4 < \Delta^2(z) < 10^6$$

Depending on choice of profile and concentration parameter dependence of mass and redshift.

Profiles

$$\rho(\mathrm{r}) = \rho_{\mathrm{S}}/[(\mathrm{r}/\mathrm{r_S})^\gamma[1+(\mathrm{r}/\mathrm{r_S})^\alpha]^{(\beta-\gamma)/\alpha}]$$

- $(\alpha, \beta, \gamma) = (1, 3, 1)$ NFW
- $(\alpha, \beta, \gamma) = (1, 3, 1.5)$ Moore

Concentration parameter

$c(M,z) = \mathrm{r_{vir}} / \mathrm{r}_{-2}$, (modeled by i.e. Bullock et al., 1999)

- $\mathrm{r}_{-2} = \mathrm{r}_s$ NFW
- $\mathrm{r}_{-2} = 0.8\ \mathrm{r}_s$ Moore

Largest contribution from small halos, formed in an earlier, denser universe. We cutoff at $10^5\ M_\odot$.

Extending to lower masses: Increases signal but increases uncertainties.

HALO properties II

Sub Structure

- Higher concentration parameters than parent halo
  - generally formed in higher density environments
  - outskirts depleted by tidal stripping

ρ^2 plot of "Via Lactea", Diemand et al.

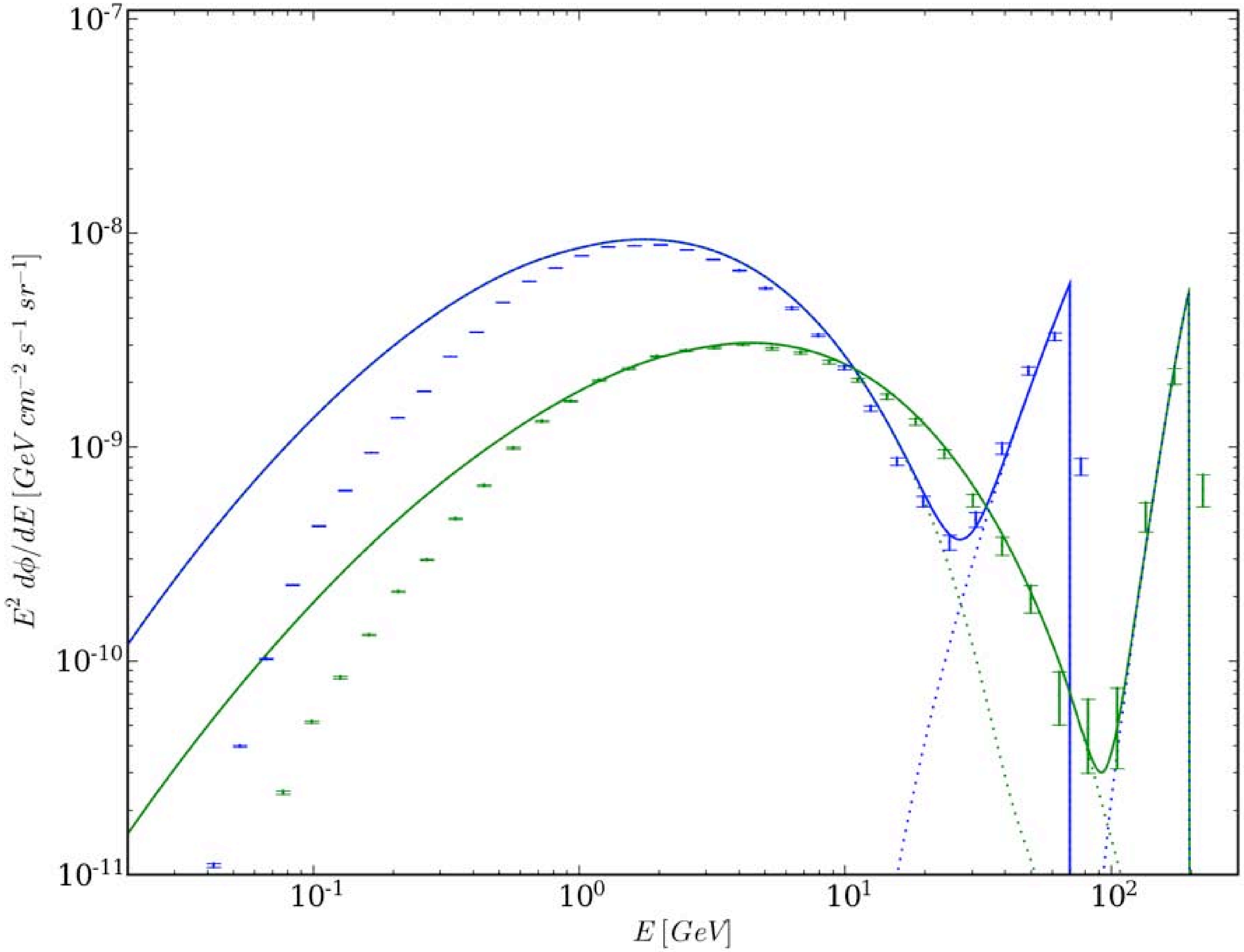
Spectra

$M_\chi = 70\ ,\ 200$ GeV

$\sigma v = 3\times10^{-26}\ \mathrm{cm^3s^{-1}}$

$b_{\gamma\gamma} = 10^{-3}$

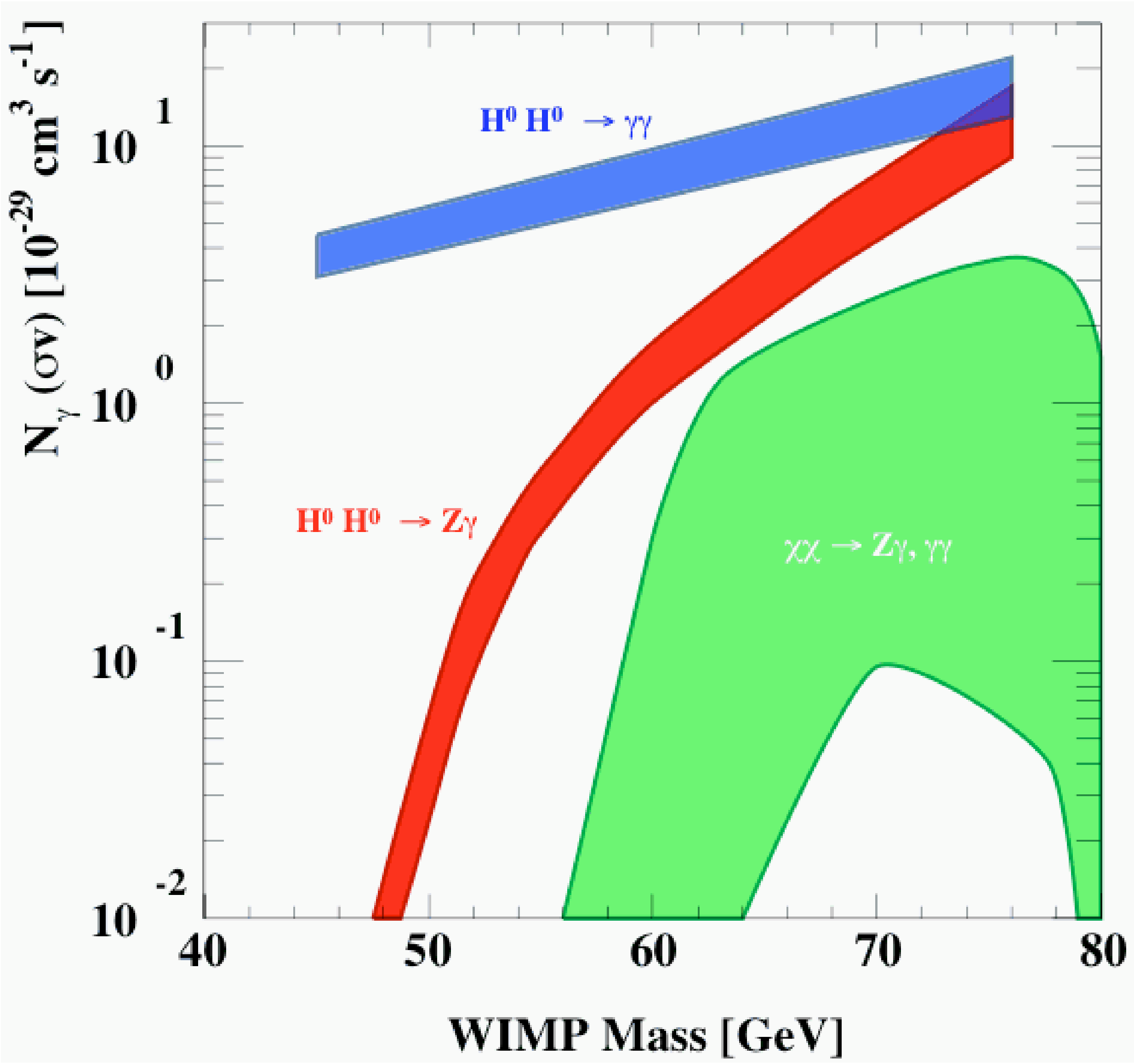
Data points from GLAST simulation



Inert (Higgs) Doublet Model

Extra scalar doublet with no direct coupling to fermions

(odd under Z_2 symmetry)



(Gustafsson et al. 2007)

Three new fields:

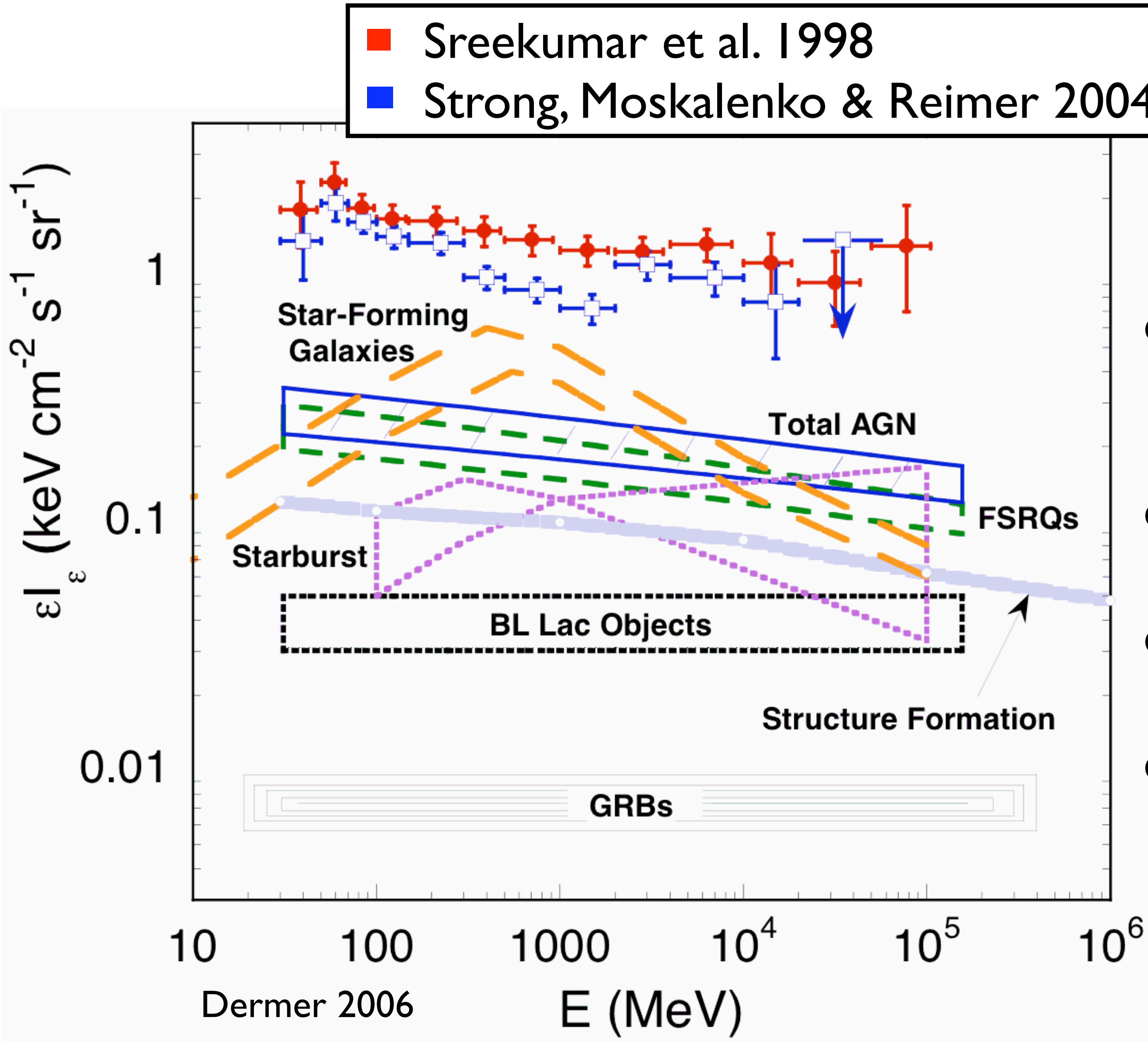
- 1 charged
- 2 scalar,

the lightest one could be the WIMP!

IDM Dark Matter:

- E. Ma, Phys. Rev. D 73, 077301 (2006)
- R. Barbieri et. al., Phys.Rev.D 74 (2006) 015007
- L. Lopes Honorez et. al., JCAP 0702, 028 (2007)
- M. Gustafsson et. al., accepted in PRL (2007)

Backgrounds I

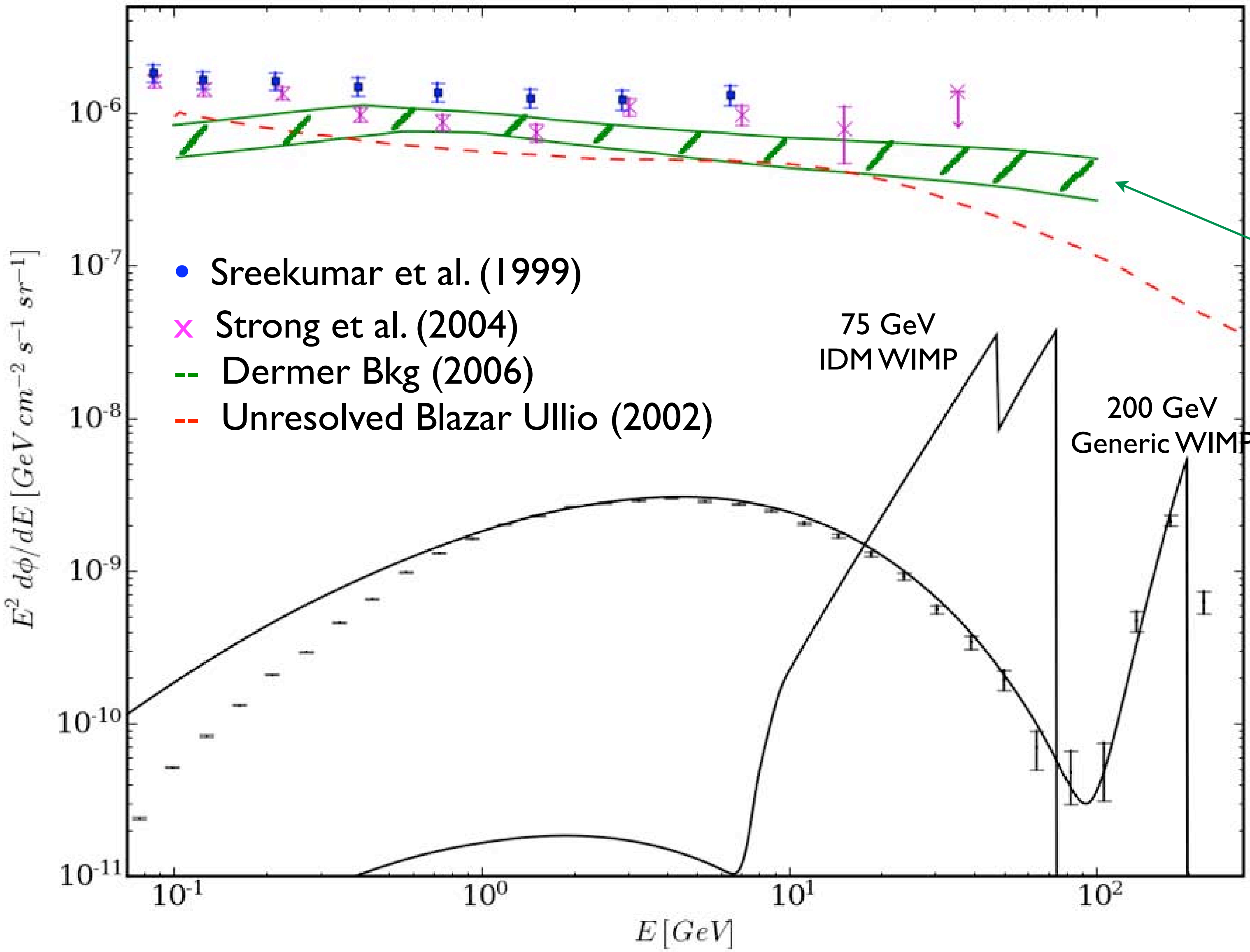


Unresolved point sources

- AGNs (Dermer 2006)
  (varies between 20 % - 50 % of total EGBR)
- Starburst galaxies (Thompson et al. 2006)
- Starforming galaxies (Pavlidou & Fields 2002)
- Structure formation (Keshet et al. 2002)

  ...

Backgrounds



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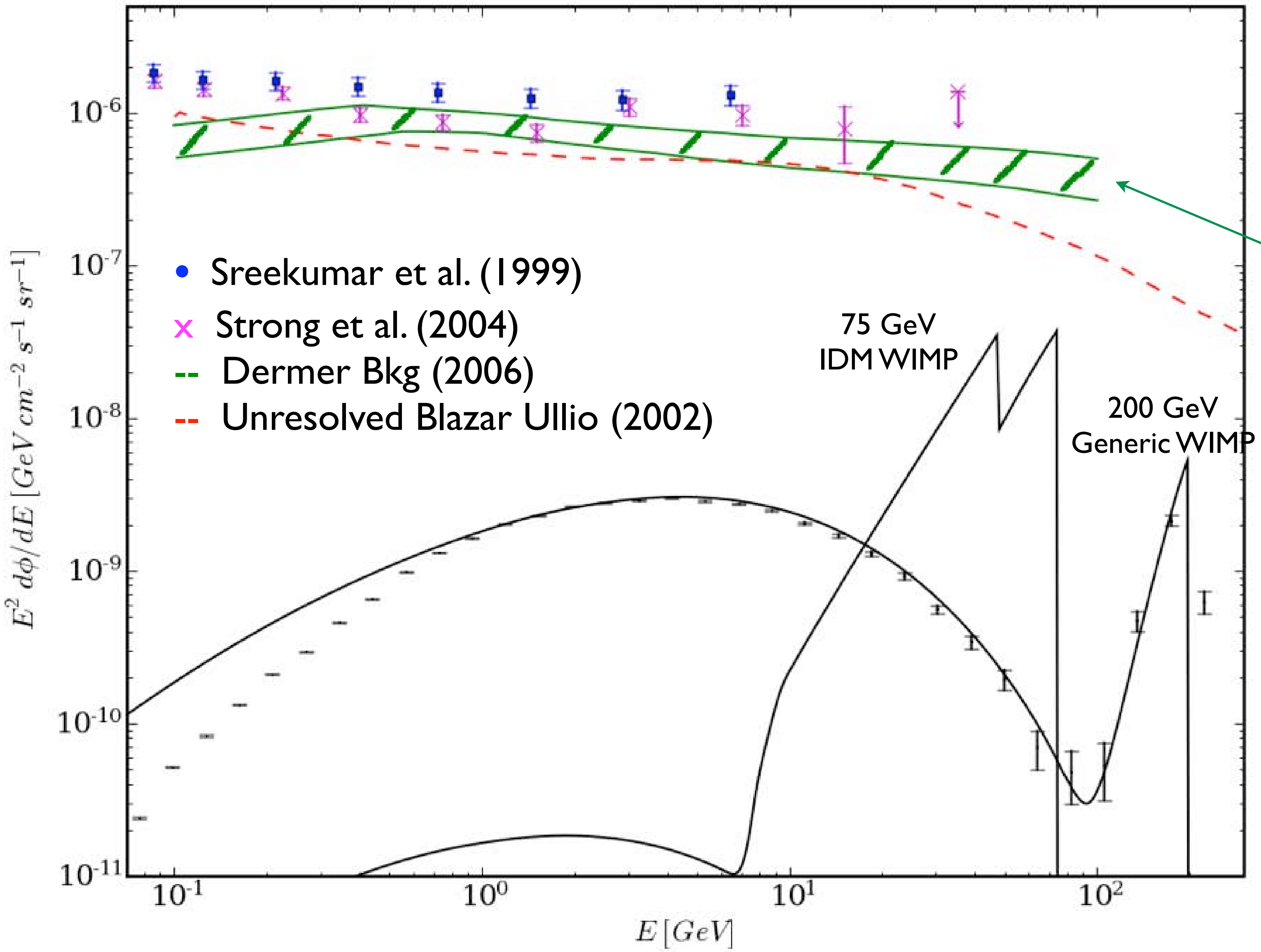

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EGRET GeV anomaly

Instrumentation error?

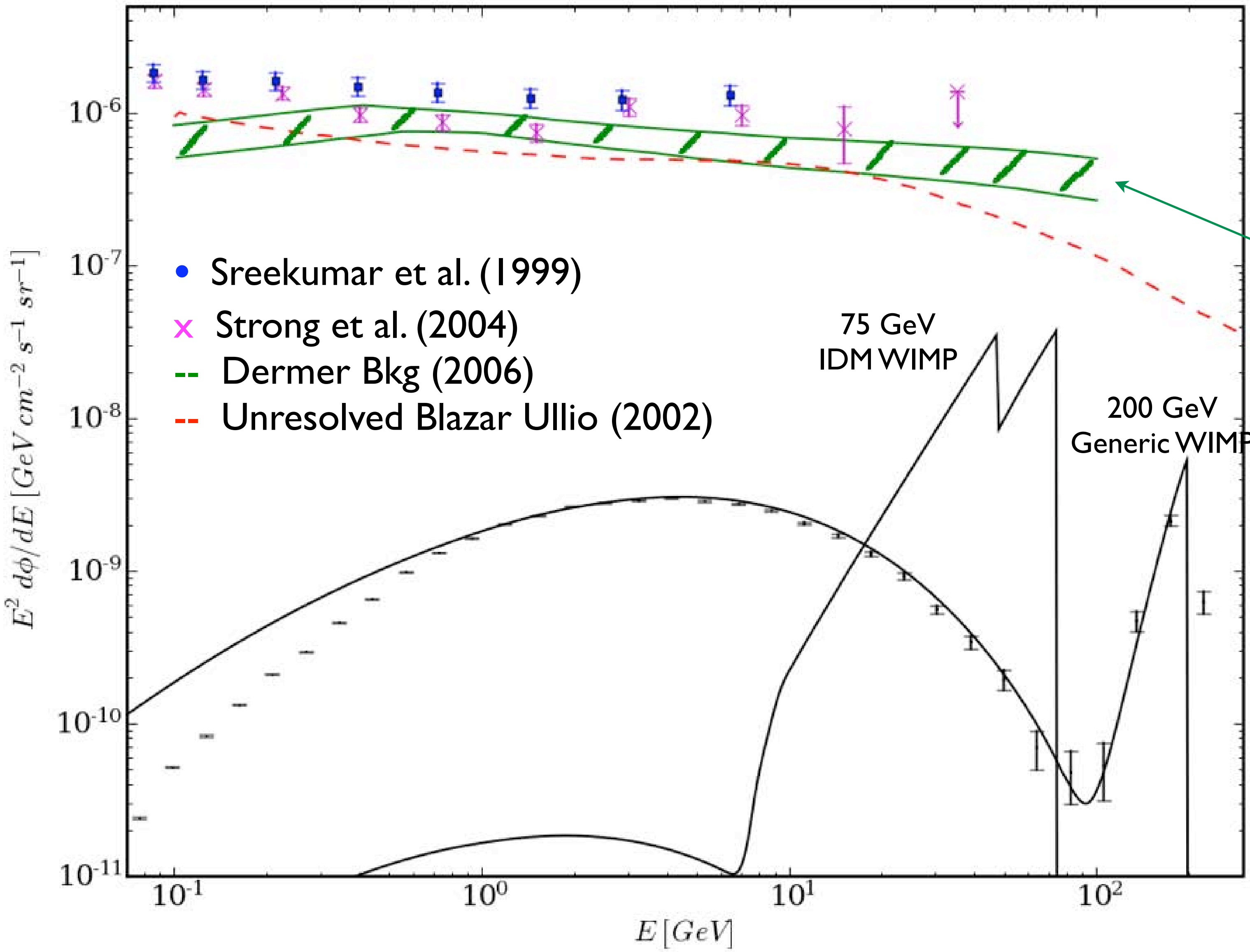
Larger? Baughman et al. 2007

Smaller? Stecker et al. 2007

Astrophysical origin? Strong et al. 2004

Exotic origin? De Boer 2005

Backgrounds



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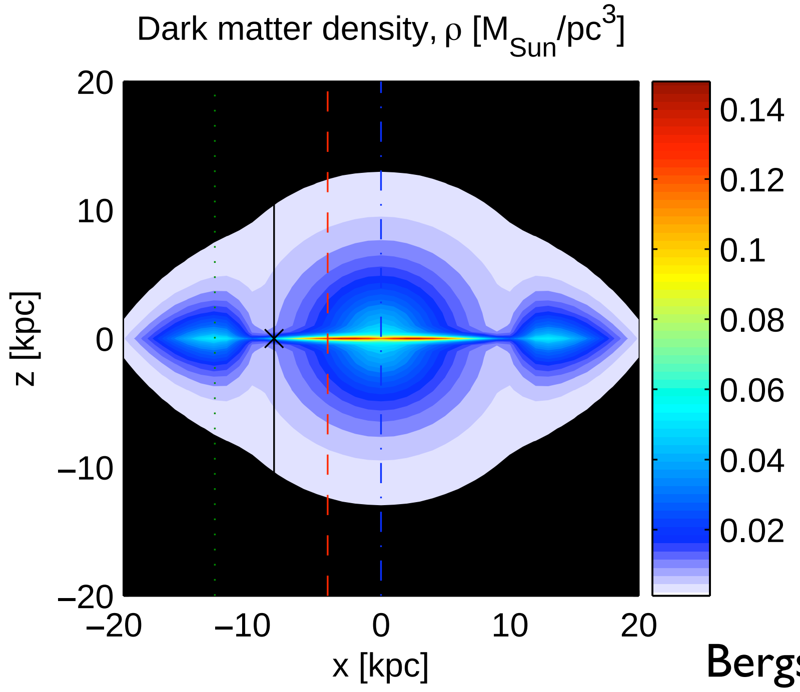
A 60 GeV WIMP? I

Claim by De Boer et al.(2005) that the EGRET data is compatible with a 60 GeV WIMP, if the DM is distributed in a non-standard way,

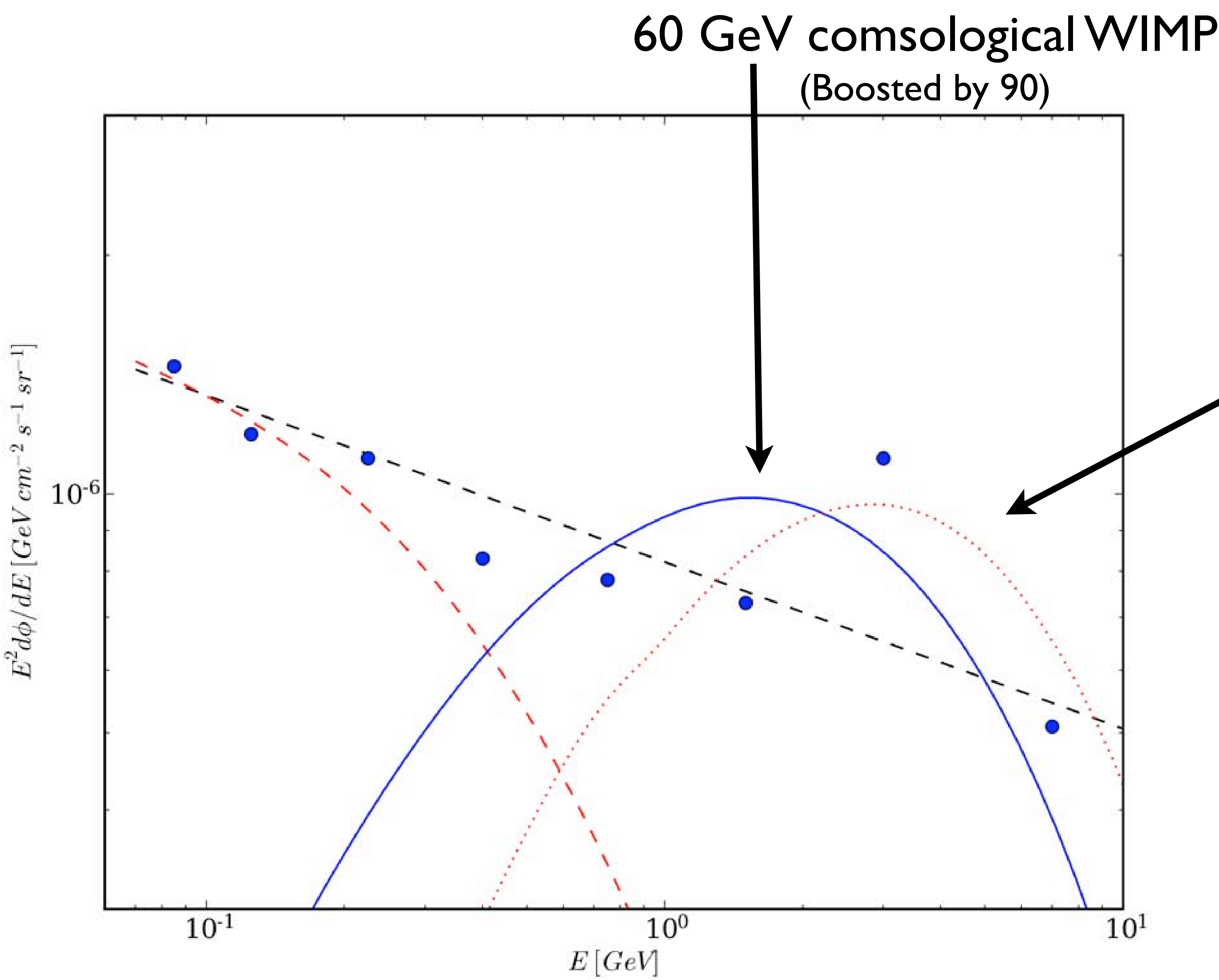
i.e. the EGRET GeV anomaly originates from WIMP annihilations

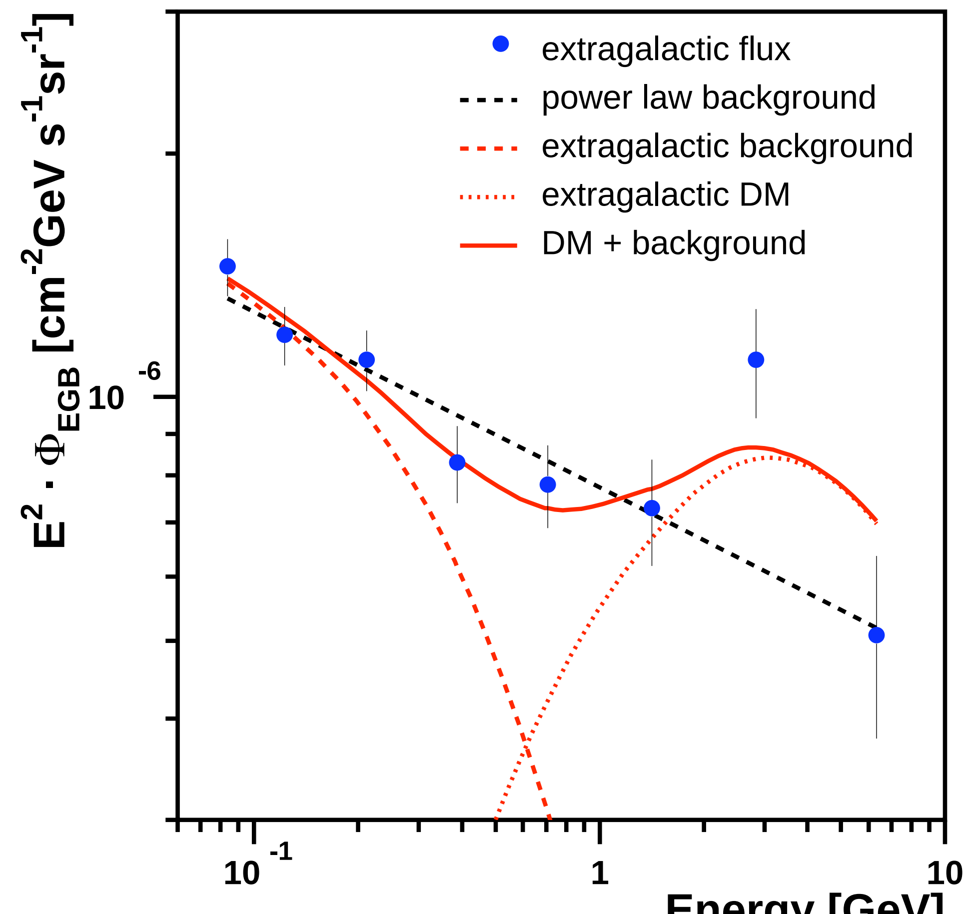
However, it was showed that the model overproduced positrons.... Bergström et al. (2005)



Bergström et al. (2005)

A 60 GeV WIMP? II





De Boer et al. 2007

Cosmology not taken into consideration!?

EG background + WIMP vs. power law ?

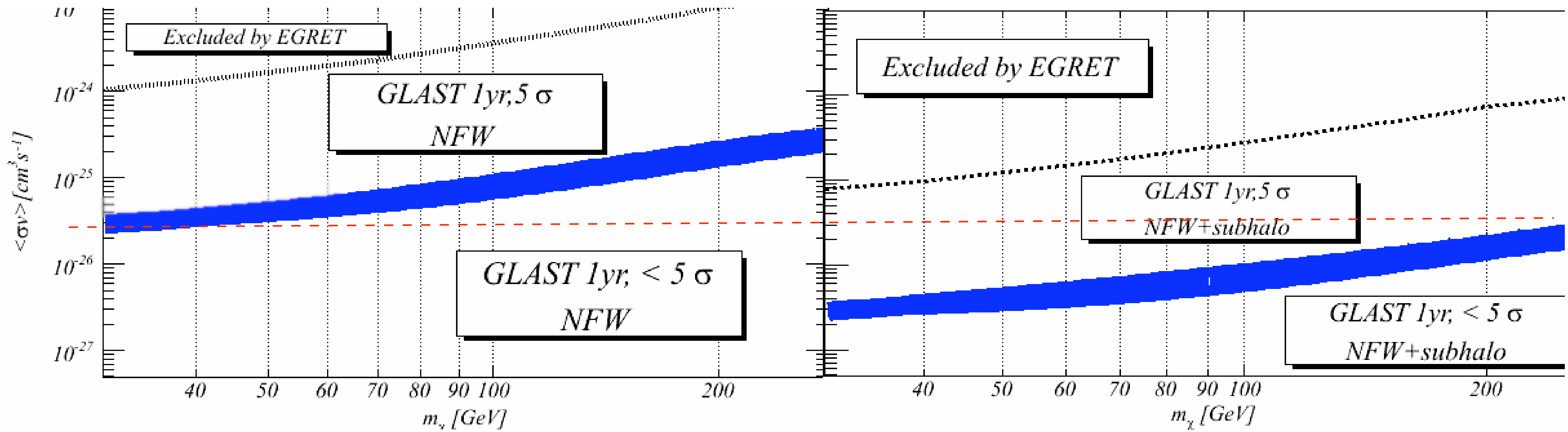
Prospects for GLAST

Fast GLAST simulation for Generic WIMPs:

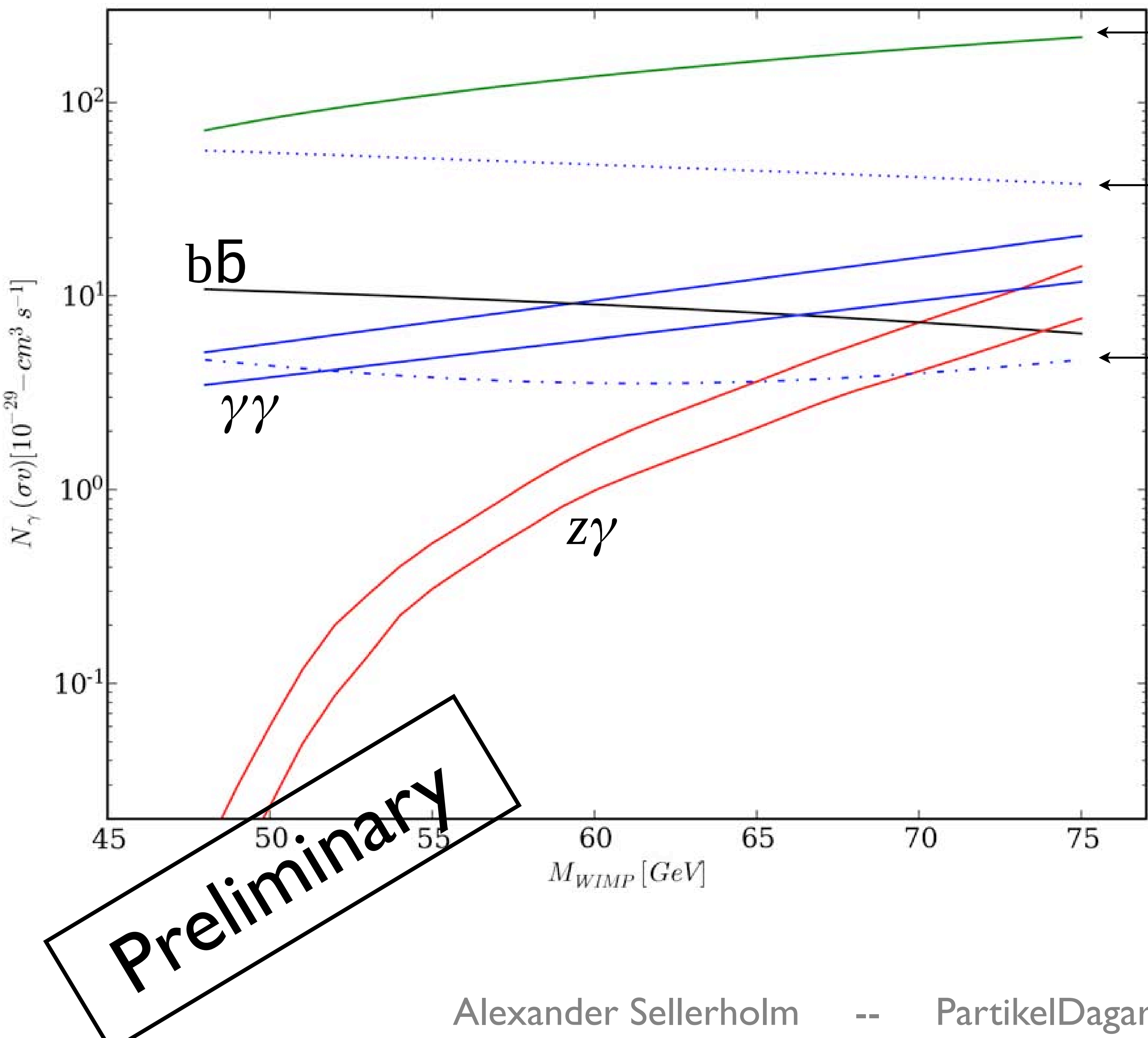
$$\chi\chi \rightarrow \begin{array}{l} 99.999\ \%\ b\bar{b} \\ 0.001\ \%\ \gamma\gamma \end{array}$$

Assumptions:

- Perfect analysis.
- Charged particle contamination: +10 % of the blazar background



Line sensitivity for GLAST and IDM



Excluded by EGRET (with sub structure)

5 σ sensitivity with NFW

5 σ sensitivity with NFW and sub structures (f = 5%, c_{sub}/c = 4)

(Standard Higgs mass = 500 GeV)

Conclusions:

- WIMPs could possible give an interesting contribution to the EGBR.
- GLAST is sensitive to a range of DM models and astrophysical scenarios.