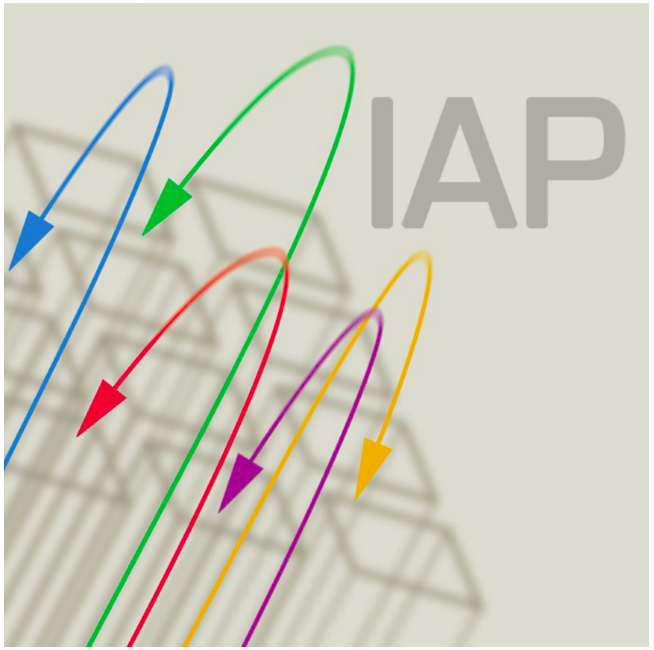
Probing the Inert Doublet Model and Minimal Dark Matter Scenarios with Cerenkov Telescopes

Camilo A. Garcia Cely

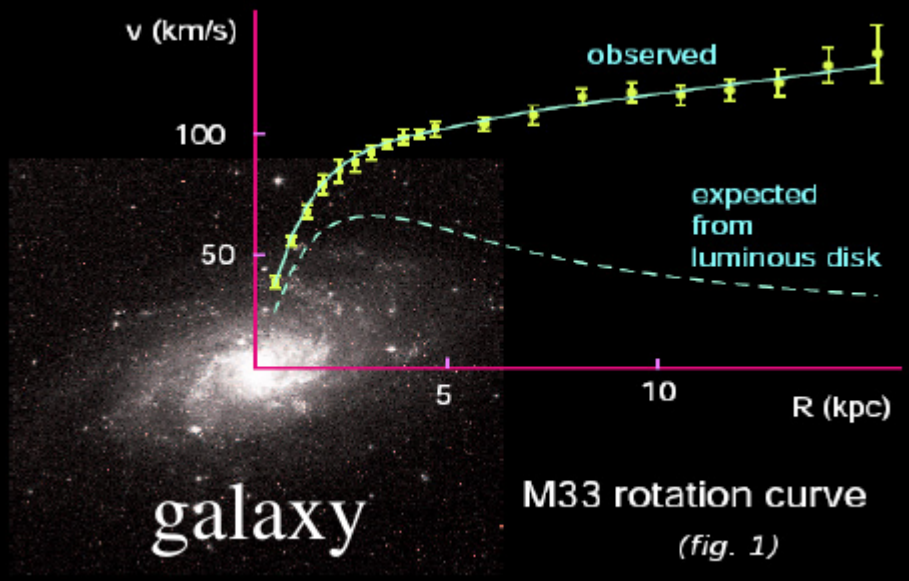
June 18th, 2015



Outline

- Motivation: WIMP Paradigm, TeV Dark Matter and Cerenkov telescopes
- Gamma-ray spectral features
- Inert Doublet Model and Minimal Dark Matter Scenarios
- CTA
- Conclusions

Evidence of Dark Matter



M33 rotation curve

(fig. 1)

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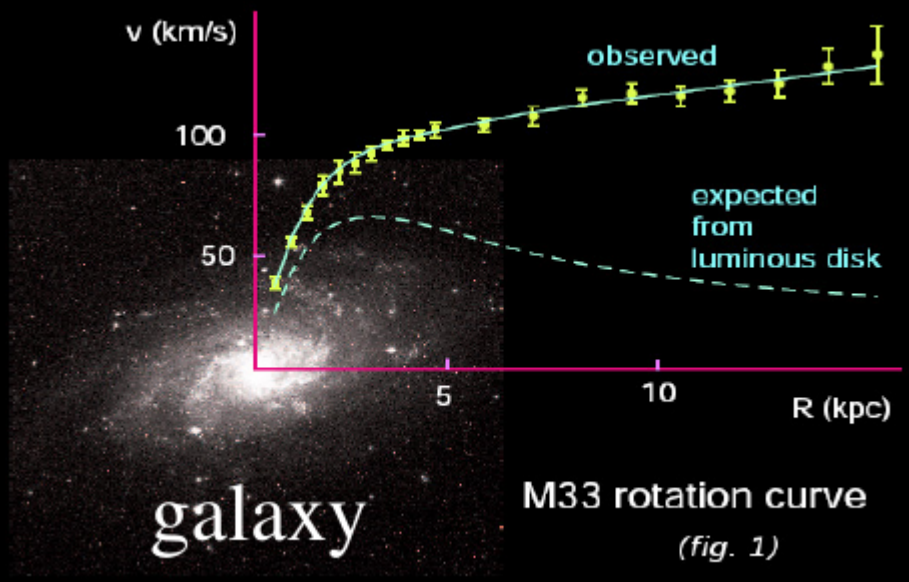

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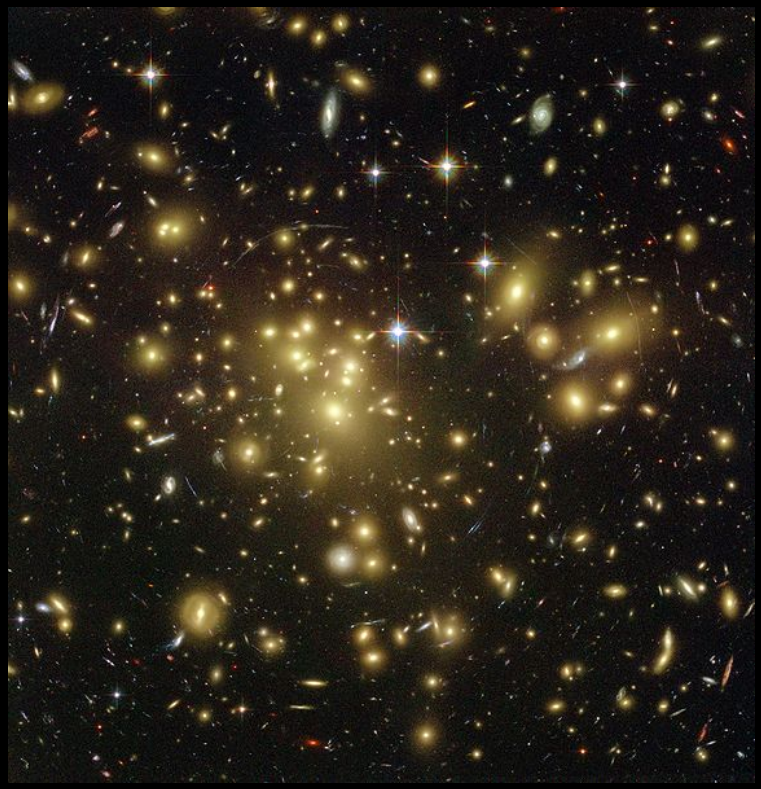

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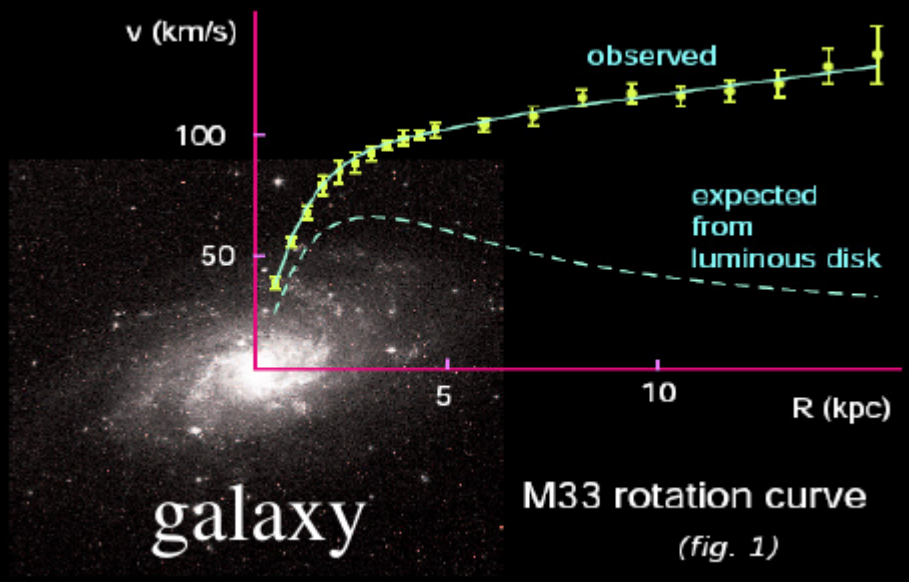

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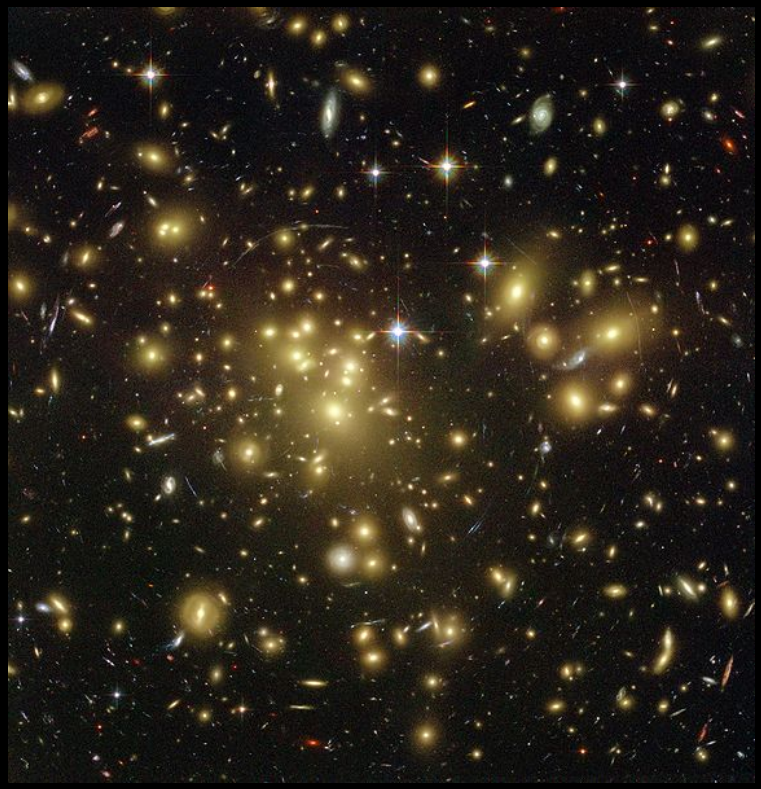

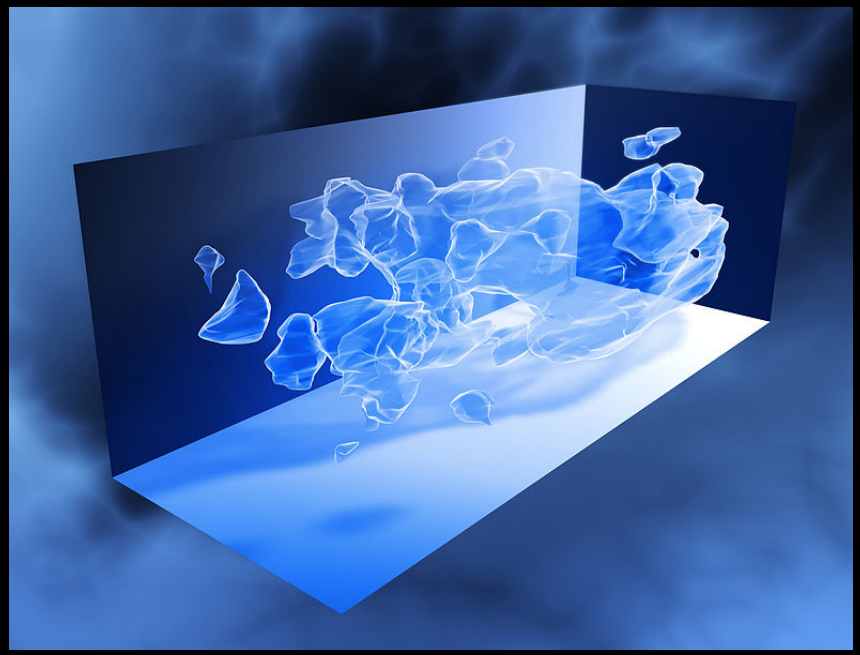

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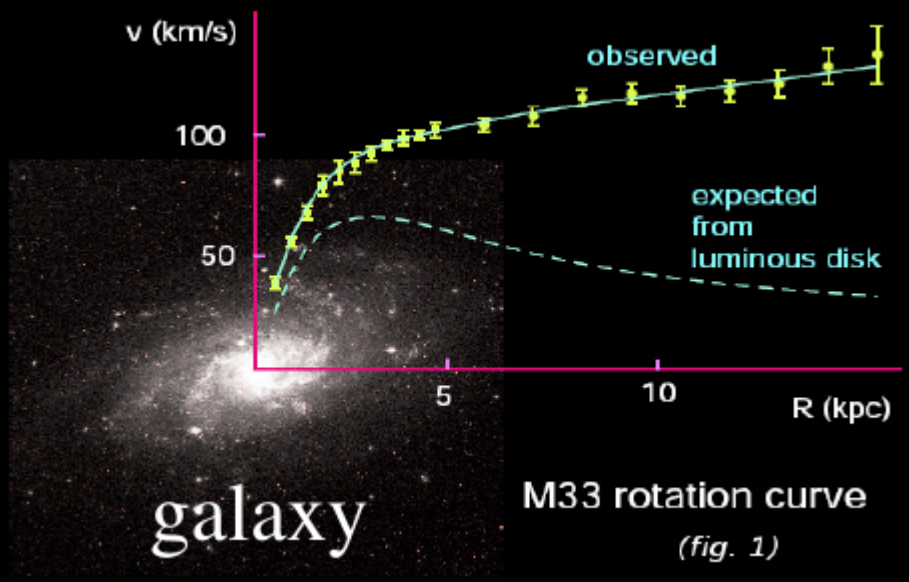

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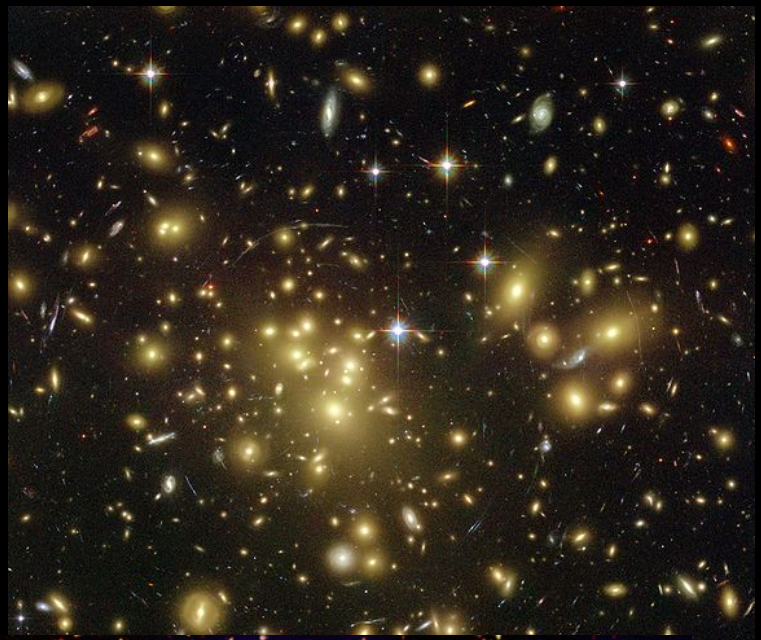

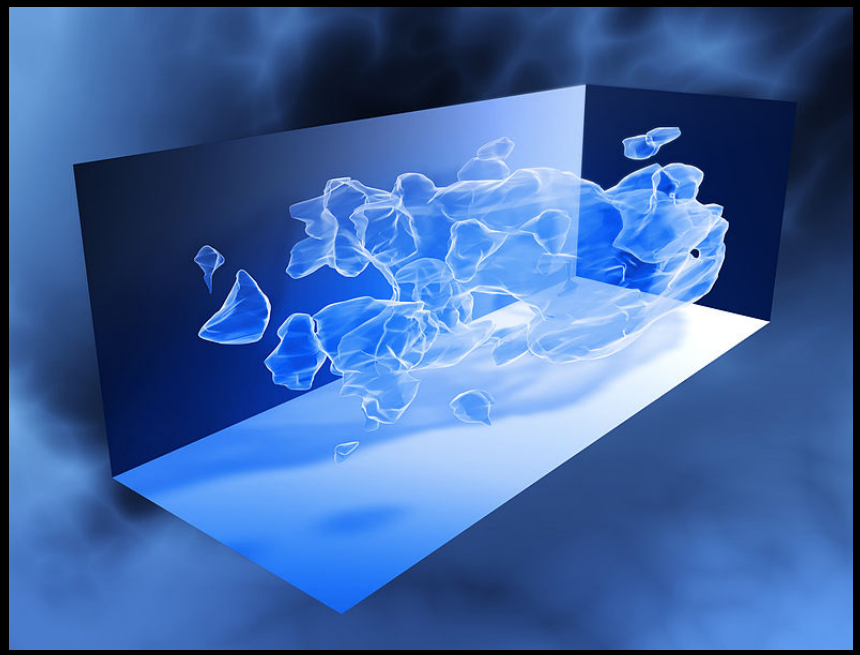

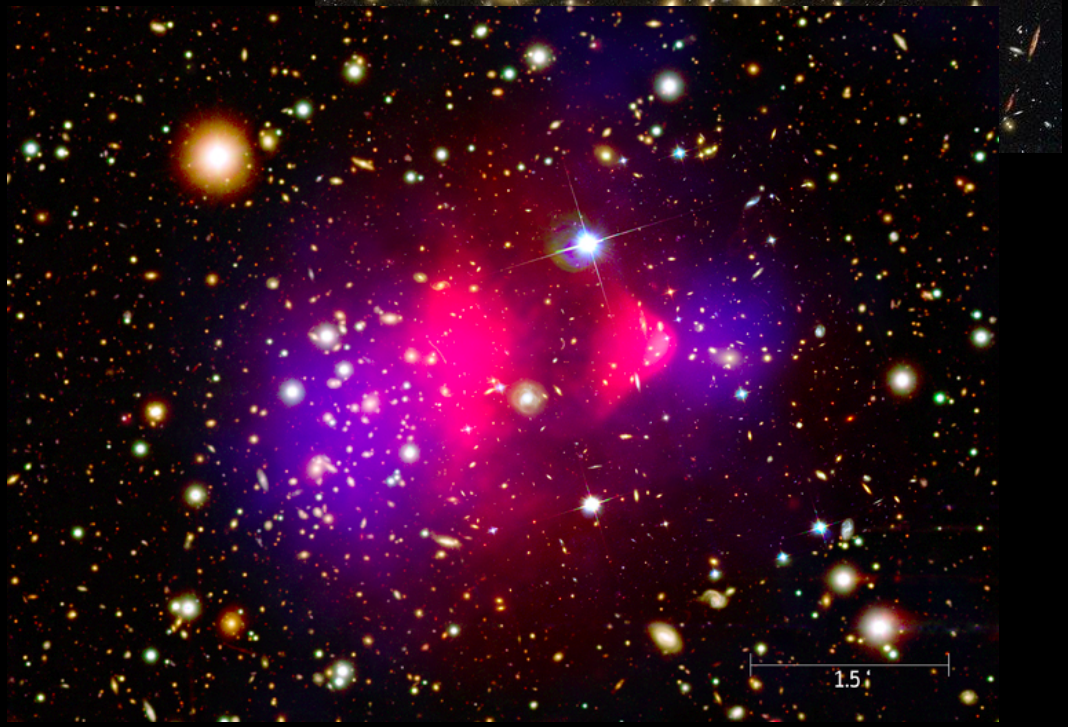

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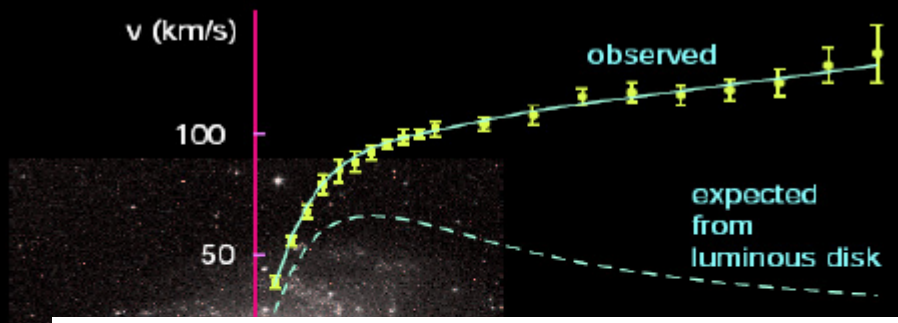

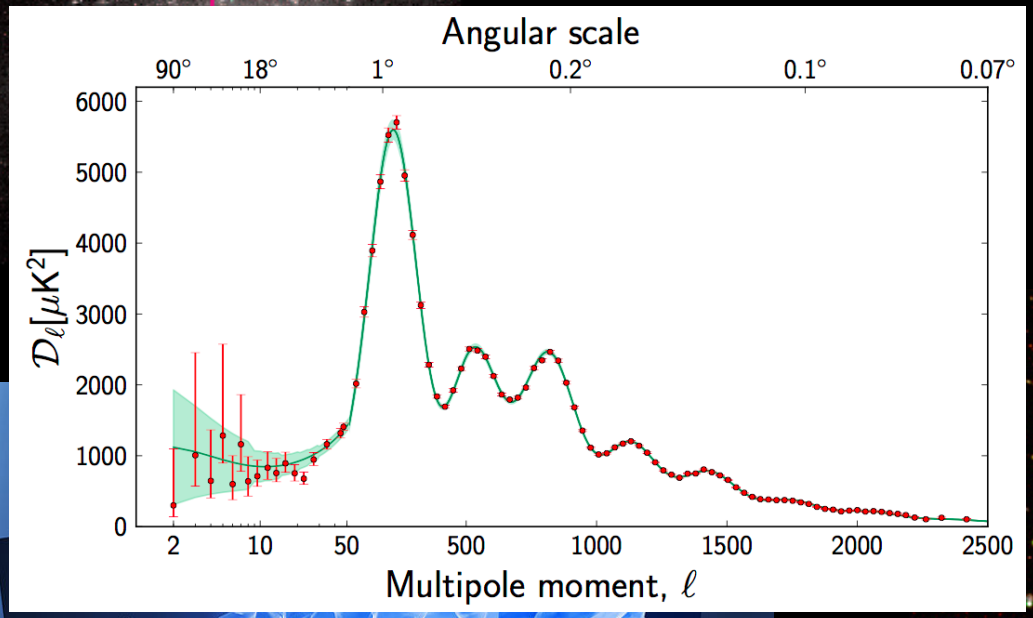

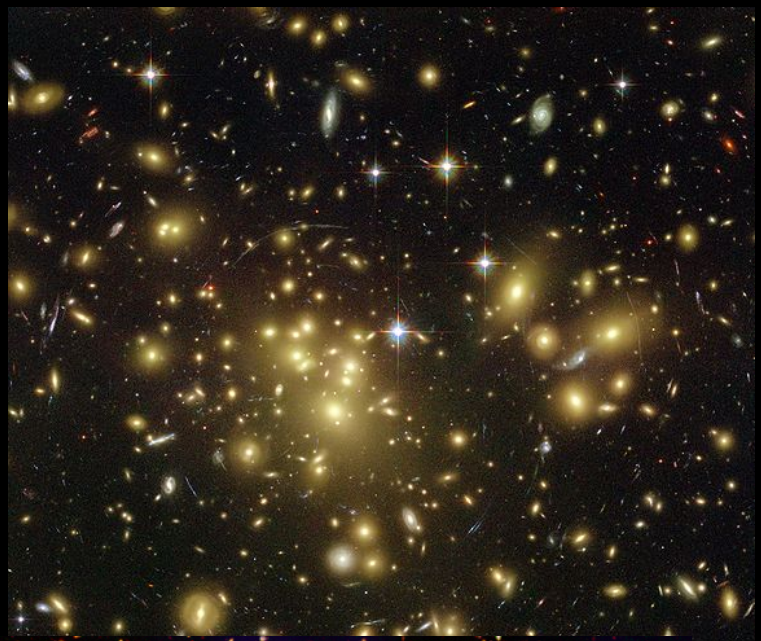

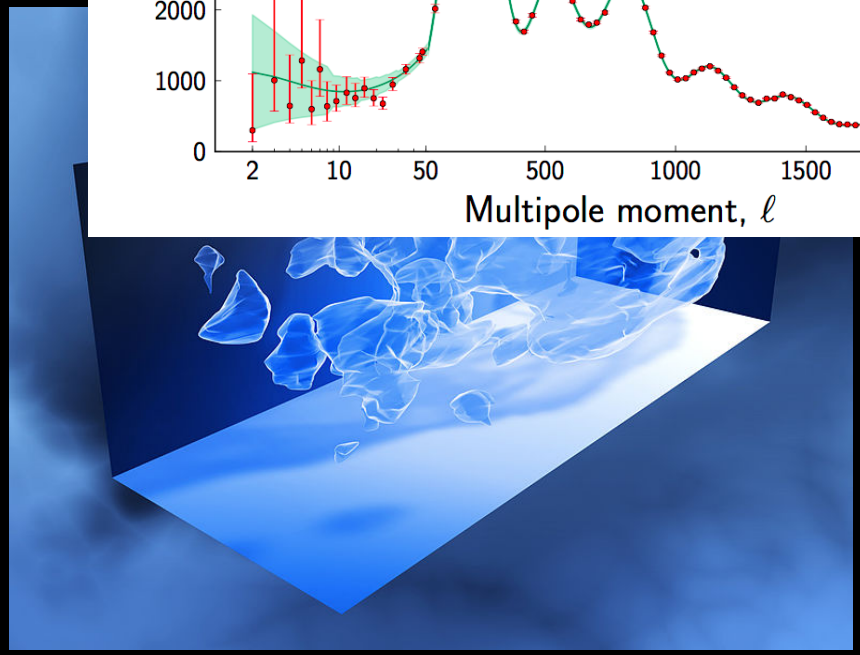

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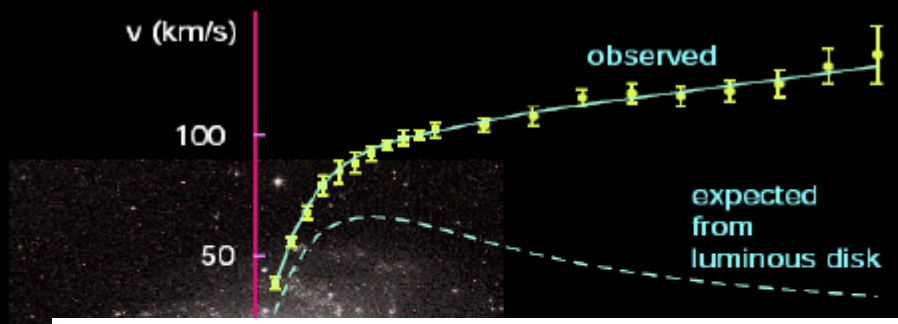

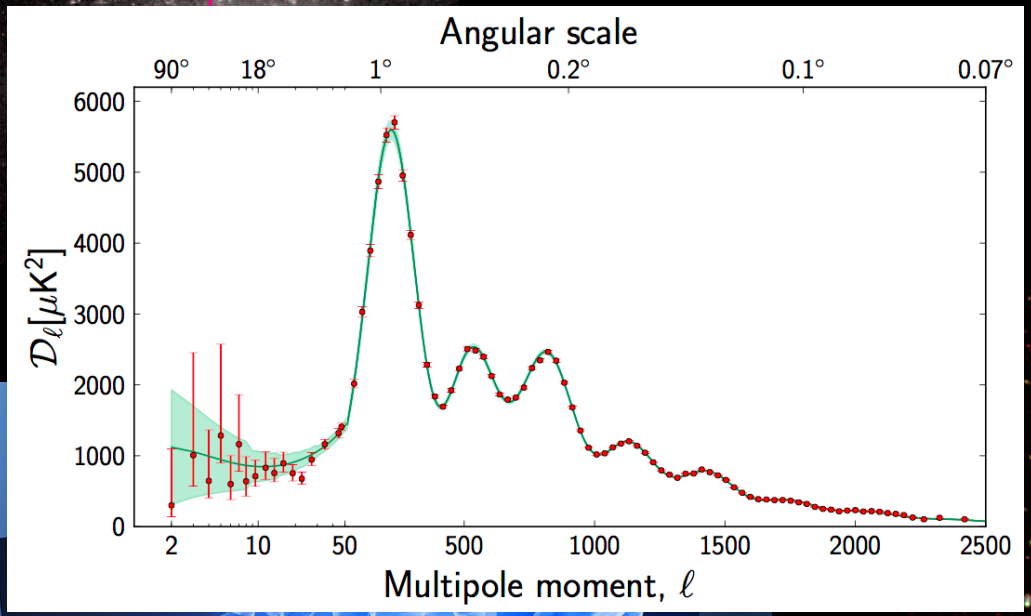

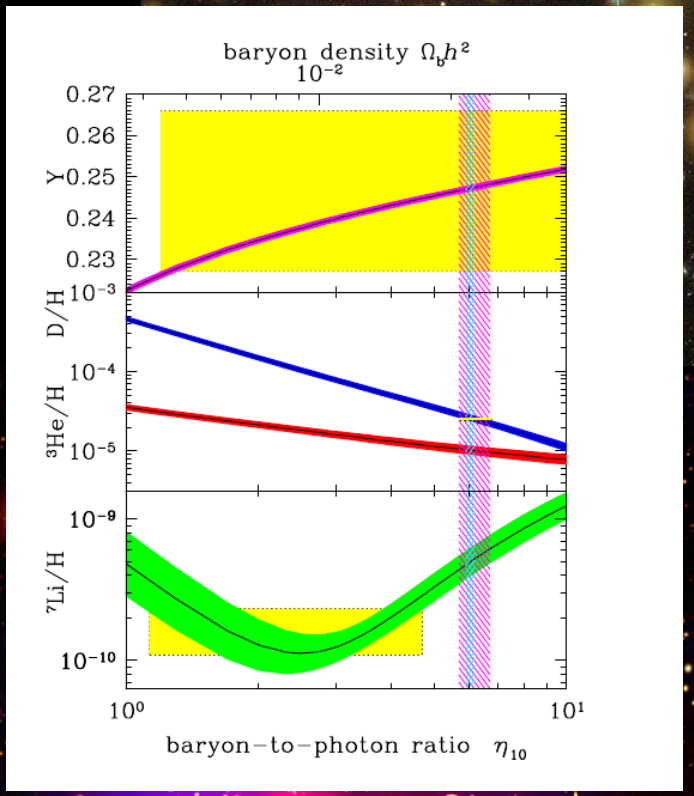

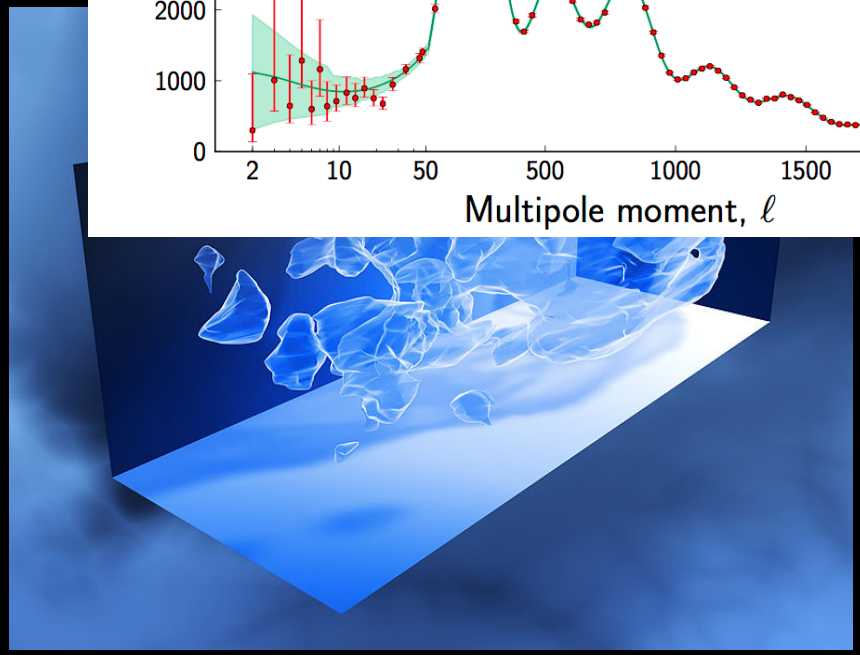

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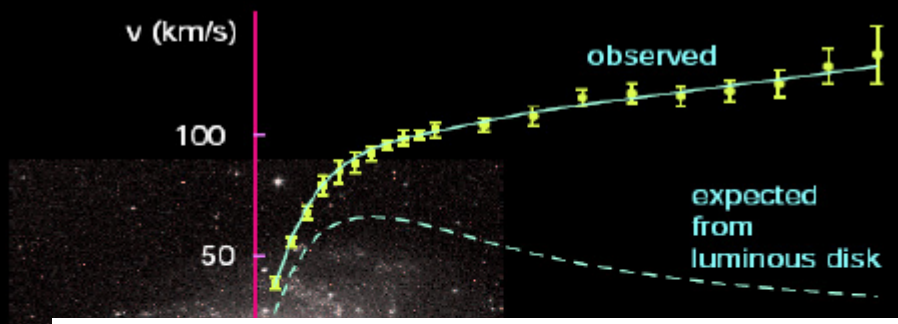
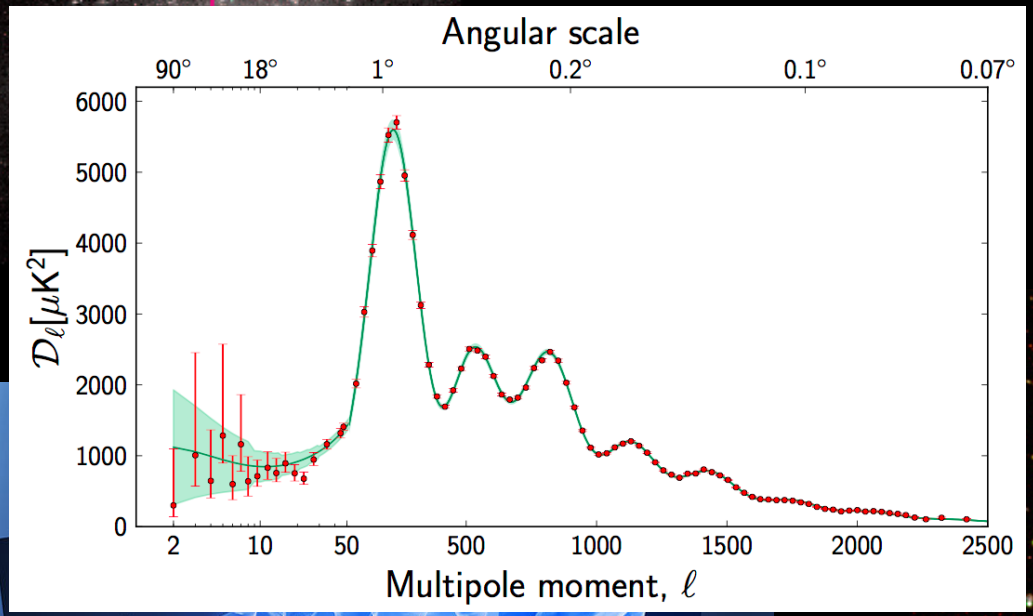
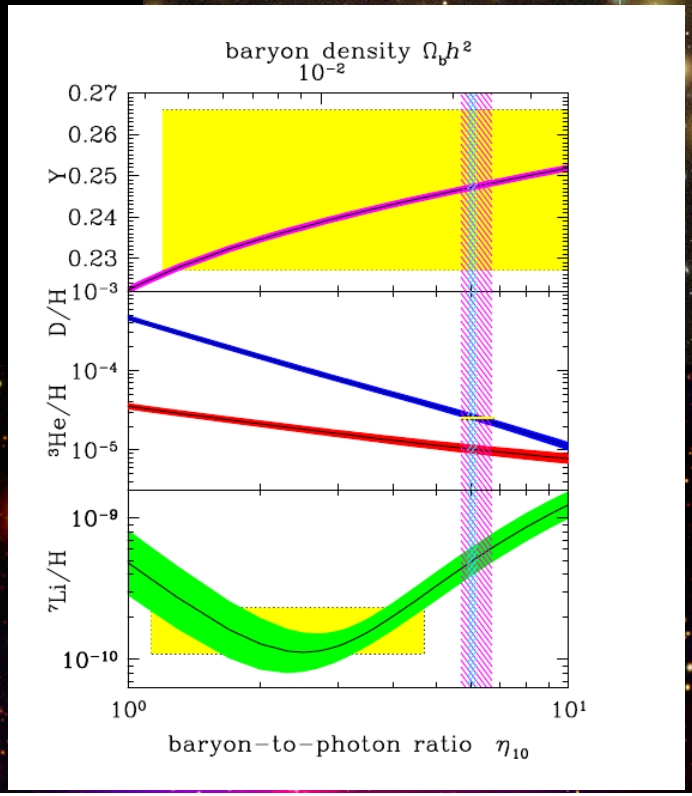
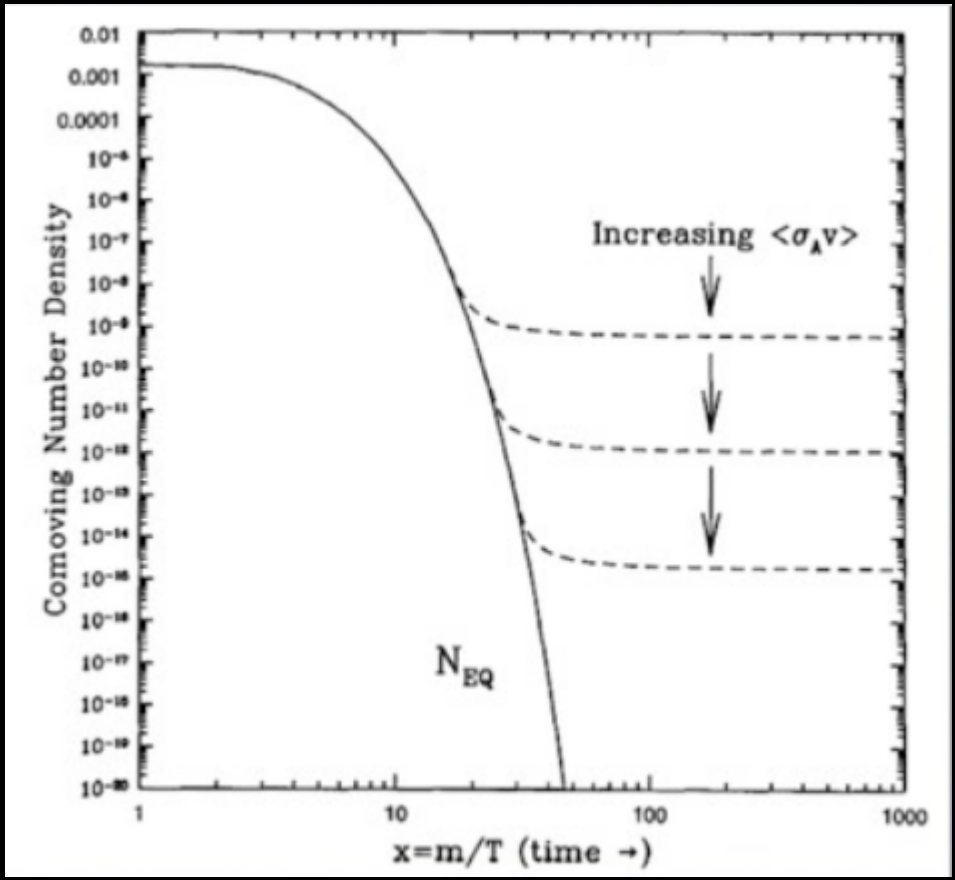






All this supports the existence of a particle that is not described in the Standard Model of particle physics. Such particle must be electrically neutral, colorless, stable on cosmological scales and massive enough to have been cold during the formation of the first structures in the Early Universe.

WIMP Paradigm



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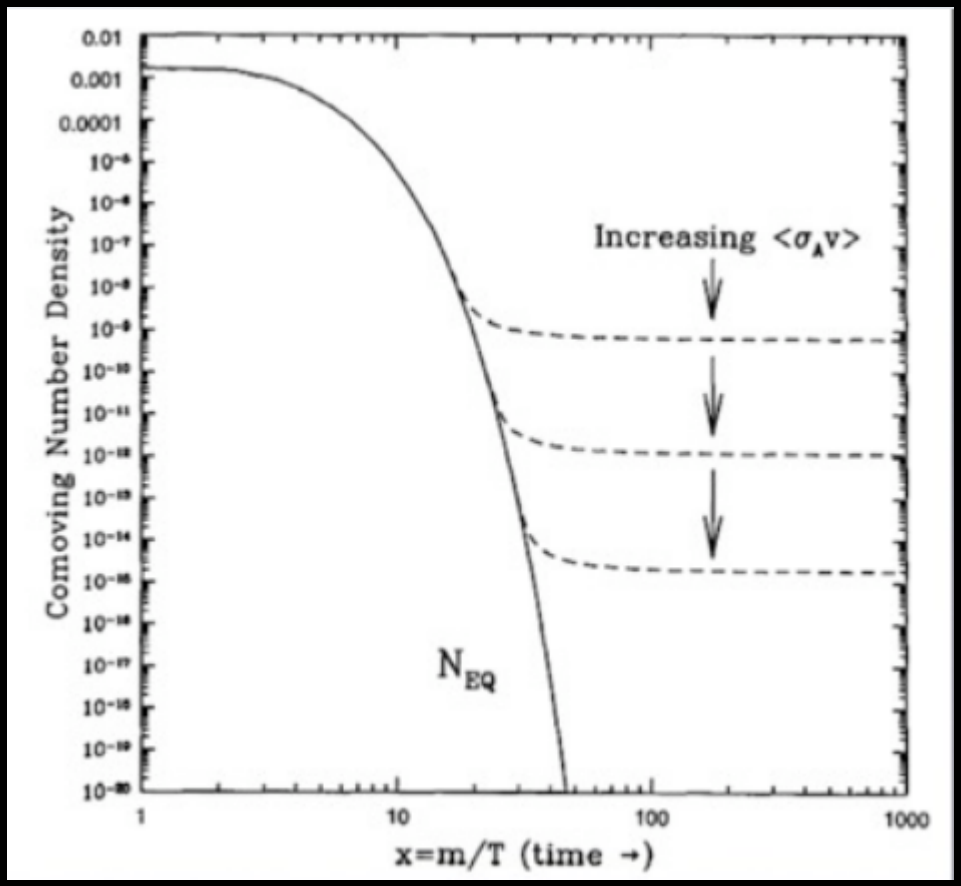

Relic abundance of DM particles

$$\Omega h^2 \simeq \frac{3 \times 10^{-27}\,\mathrm{cm}^3\,\mathrm{s}^{-1}}{\langle \sigma_A v \rangle}$$

Correct relic density if

$$\langle \sigma_A v \rangle \simeq 3 \times 10^{-26}\,\mathrm{cm}^3\,\mathrm{s}^{-1} = 1\,\mathrm{pb} \cdot c$$

$$\sigma_A \sim \frac{g^4}{m_{\mathrm{DM}}^2} = 1\,\mathrm{pb}$$

$$m_{\mathrm{DM}} \sim 100\,\mathrm{GeV} - 1\,\mathrm{TeV}$$

(provided $g \sim g_{\mathrm{weak}} \sim 0.1$)

WIMP Paradigm

Direct detection experiments continue to tighten limits on O(100 GeV) mass WIMPs.

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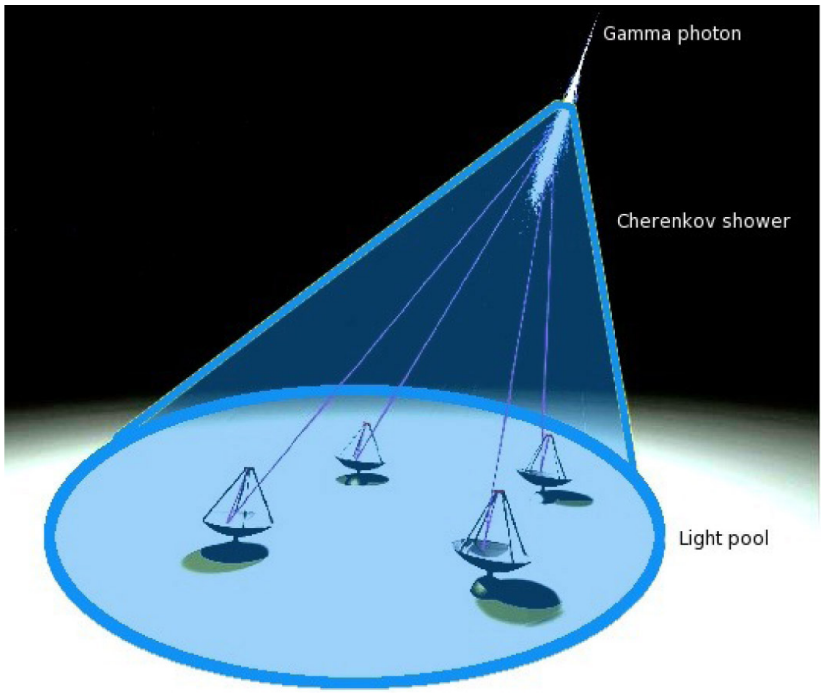
It is crucially important to look into TeV-scale WIMPs.

H.E.S.S. Experiment
(High Energy Stereoscopic System)



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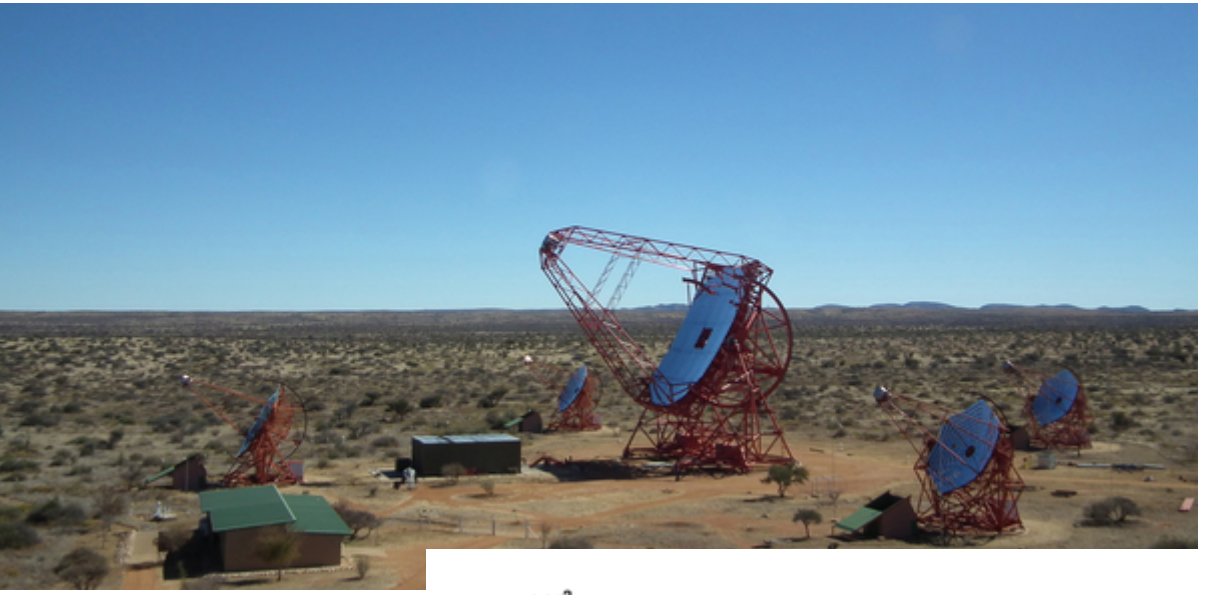

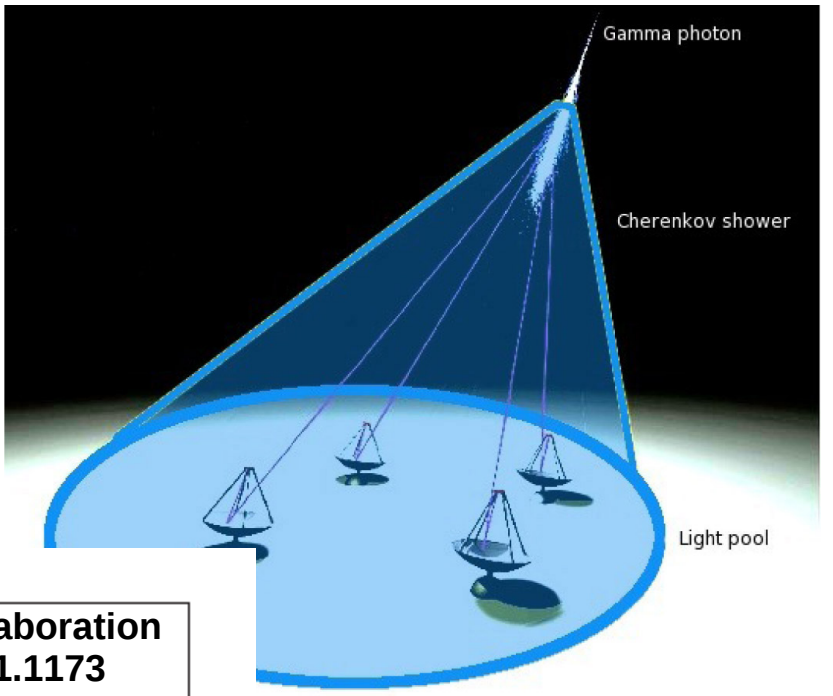

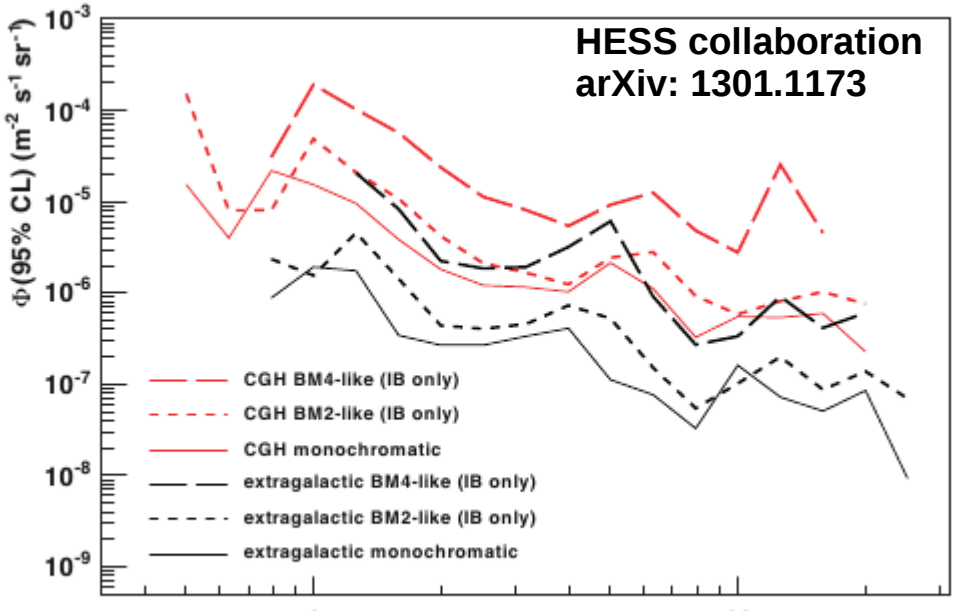

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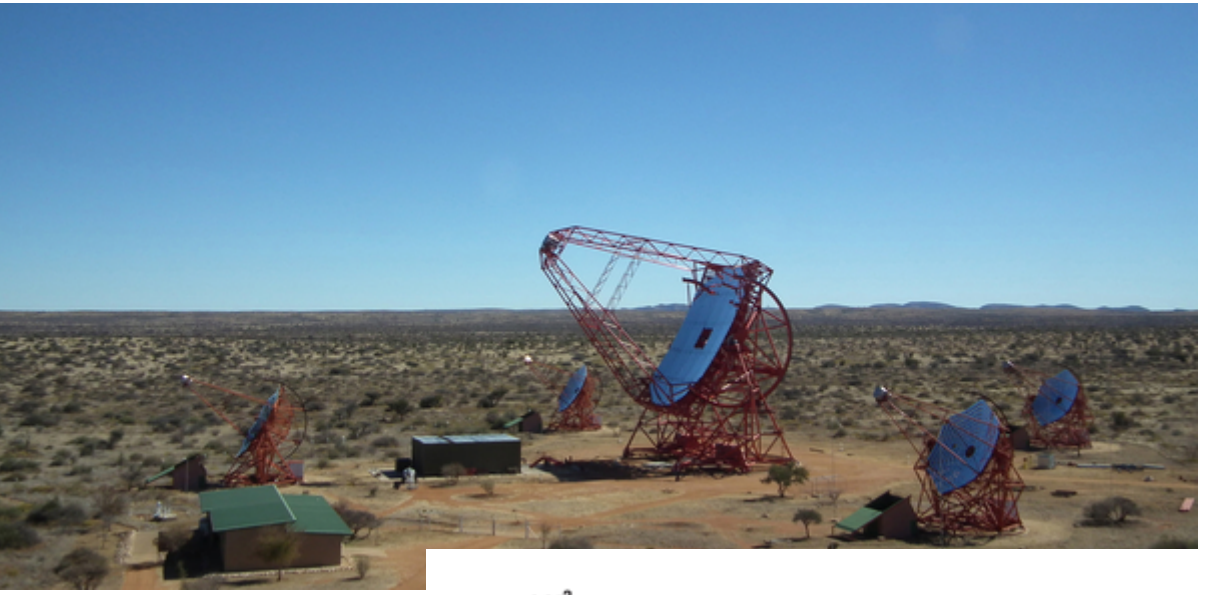
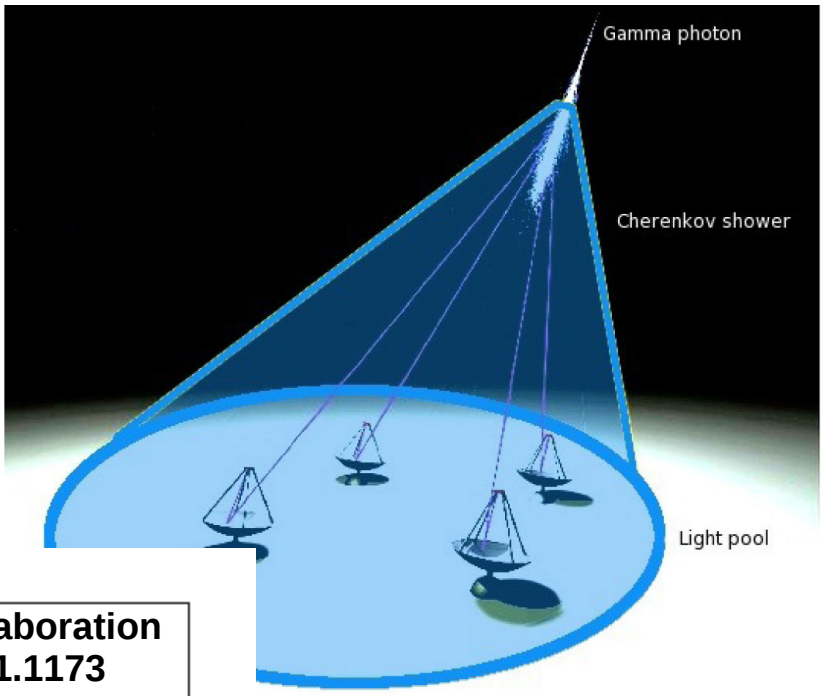
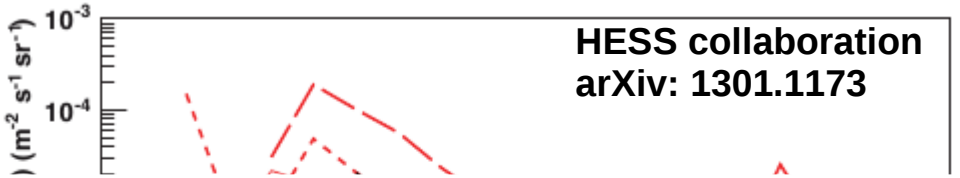
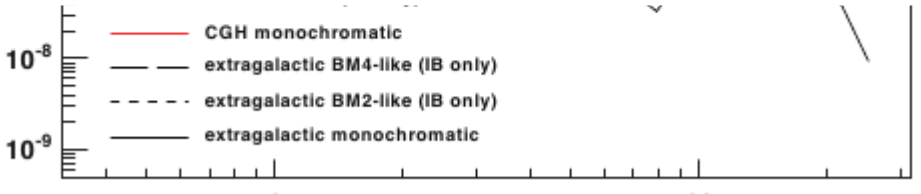




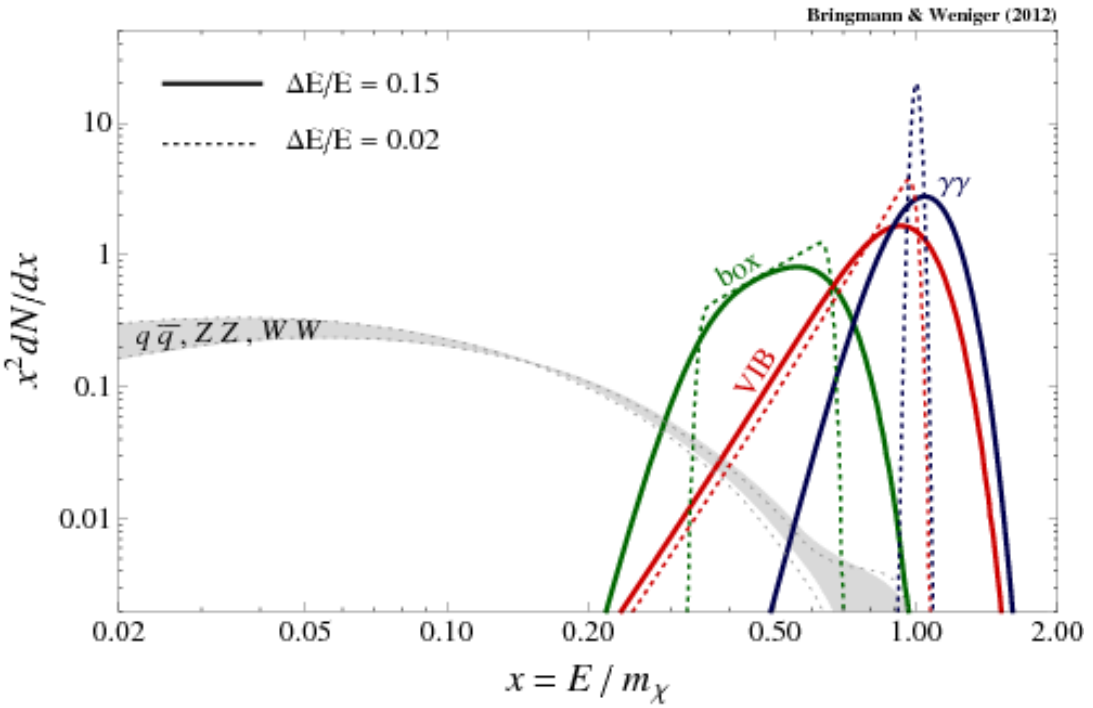


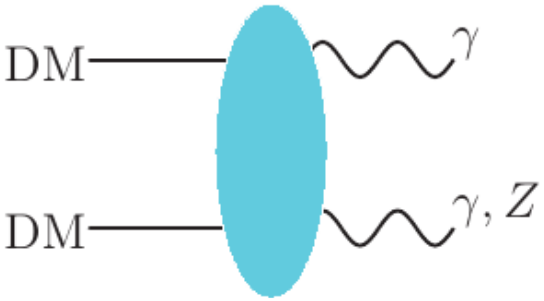
It can probe the TeV Scale!!!



Gamma-ray spectral features

Smoking gun signature for dark matter: no astrophysical process is known to produce a sharp feature in the gamma-ray spectrum





Annihilation into Photons

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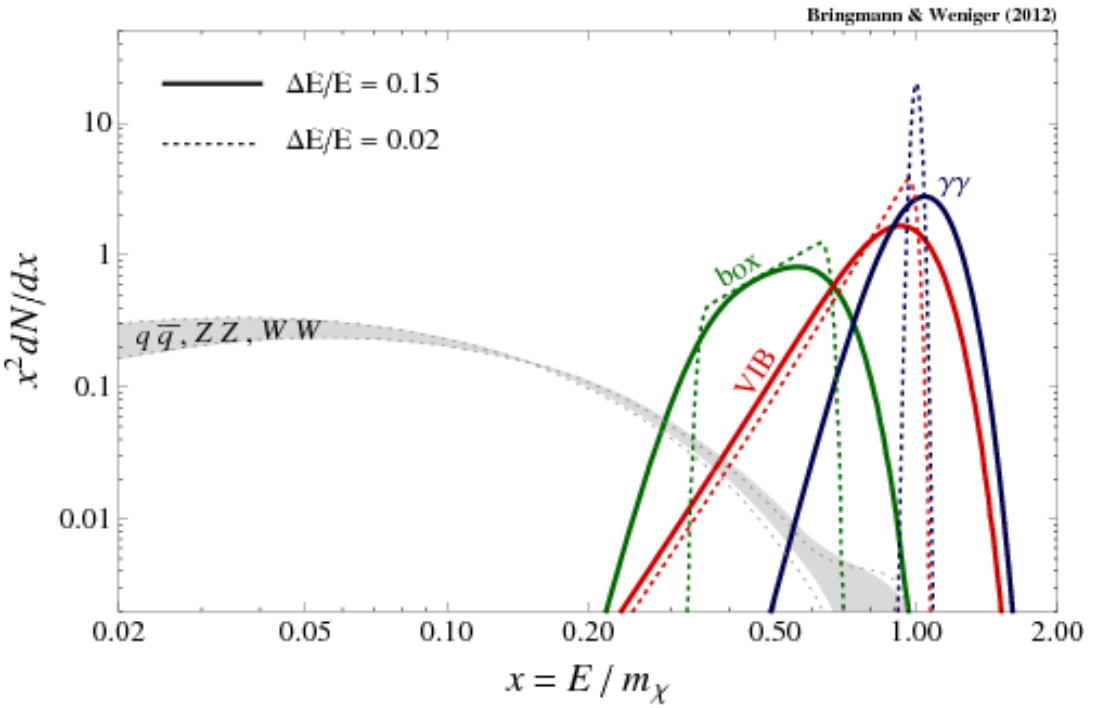

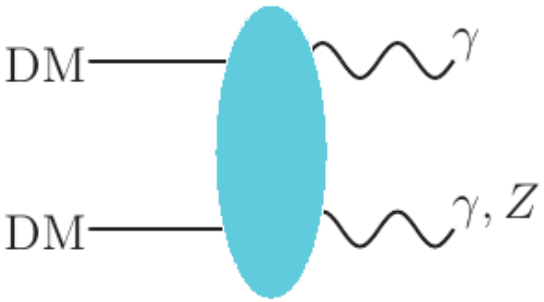

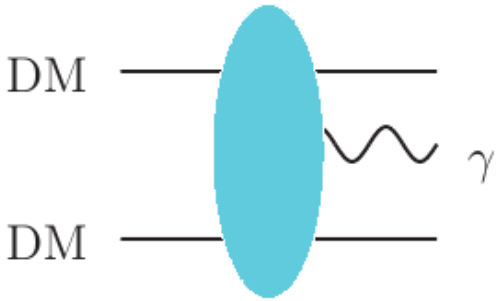

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Virtual Internal Bremsstrahlung

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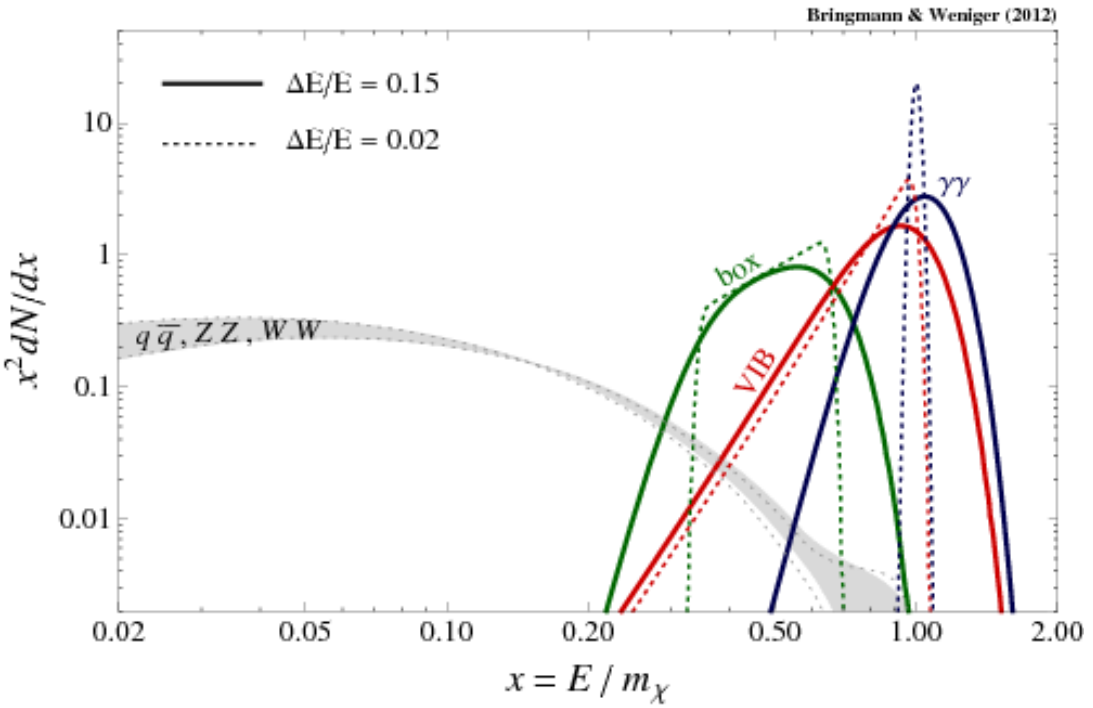

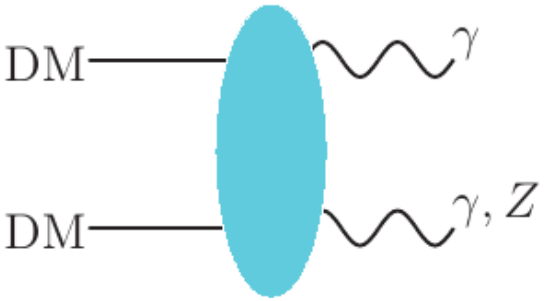

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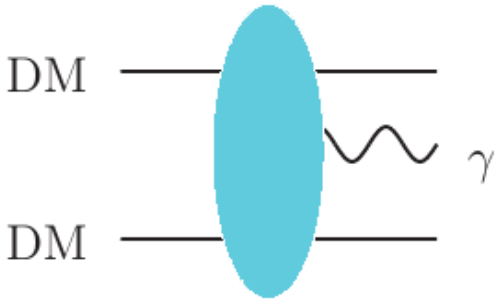

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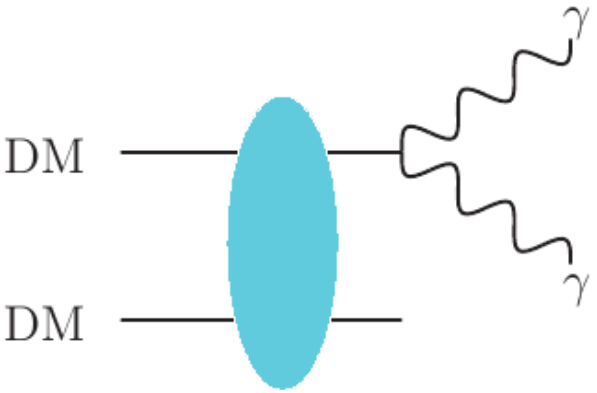

Box-shaped spectra

Inert Doublet Model

SM scalar belongs to a doublet

$$\Phi = \begin{pmatrix} G^+ \\ \frac{v_h + h + iG^0}{\sqrt{2}} \end{pmatrix}$$

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If the lightest particle is charged under Z_2 is neutral : we have a **WIMP**!!!

Inert Doublet Model

$m_{H_0} \lesssim m_W$: GeV range

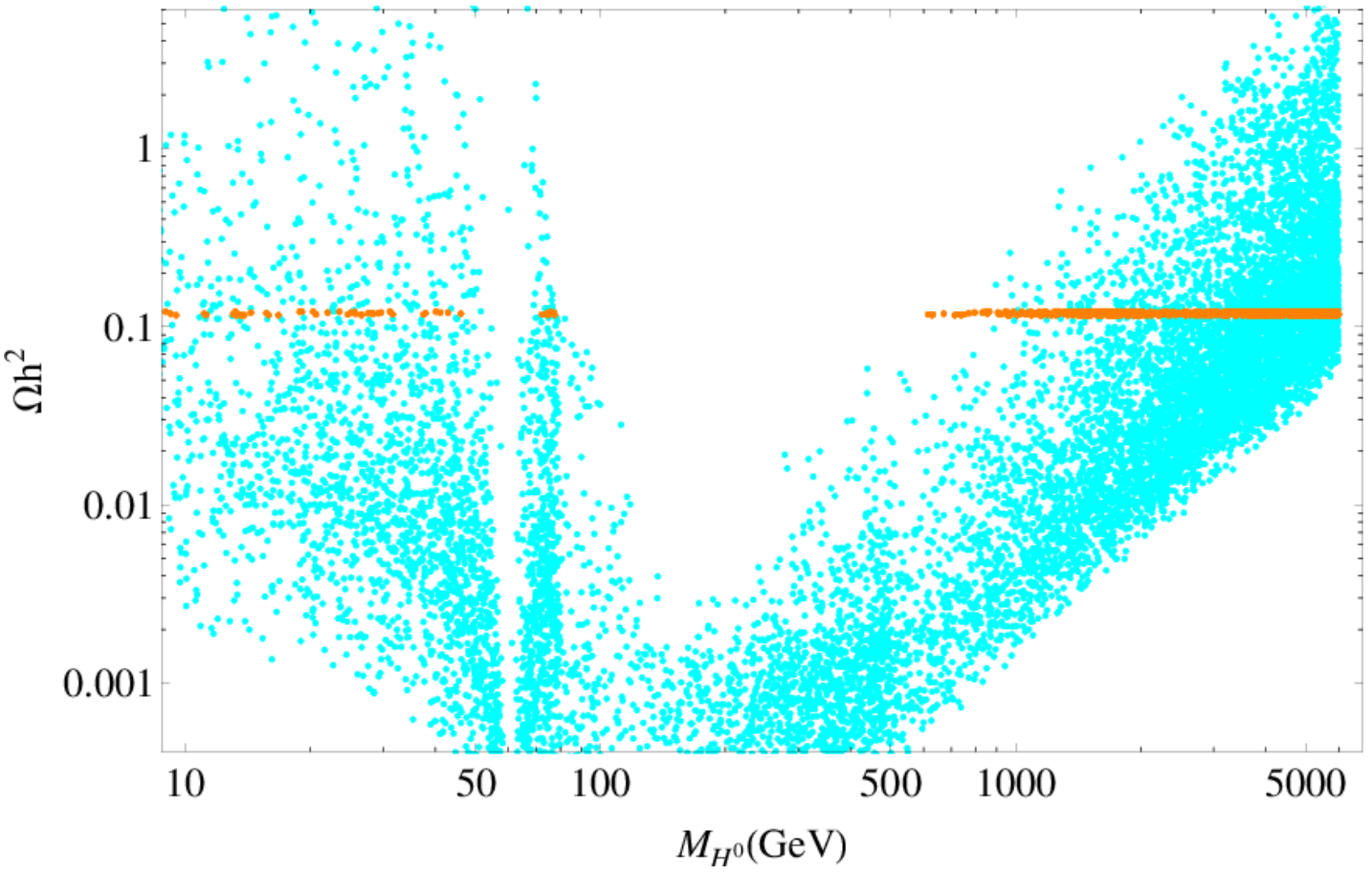
$H_0 H_0 \to h^* \to \bar{f} f$ and $H_0 A_0 \to Z^* \to \bar{f} f$

Barbieri PRD06, LLH JCAP06,Gustafsson PRL07, Cao PRD07, Andreas JCAP08,...

$m_{H_0} \gg m_W$: TeV range

$H_0 H_0 \to ZZ, WW, hh$

Cirelli NPB06, Hambye JHEP09



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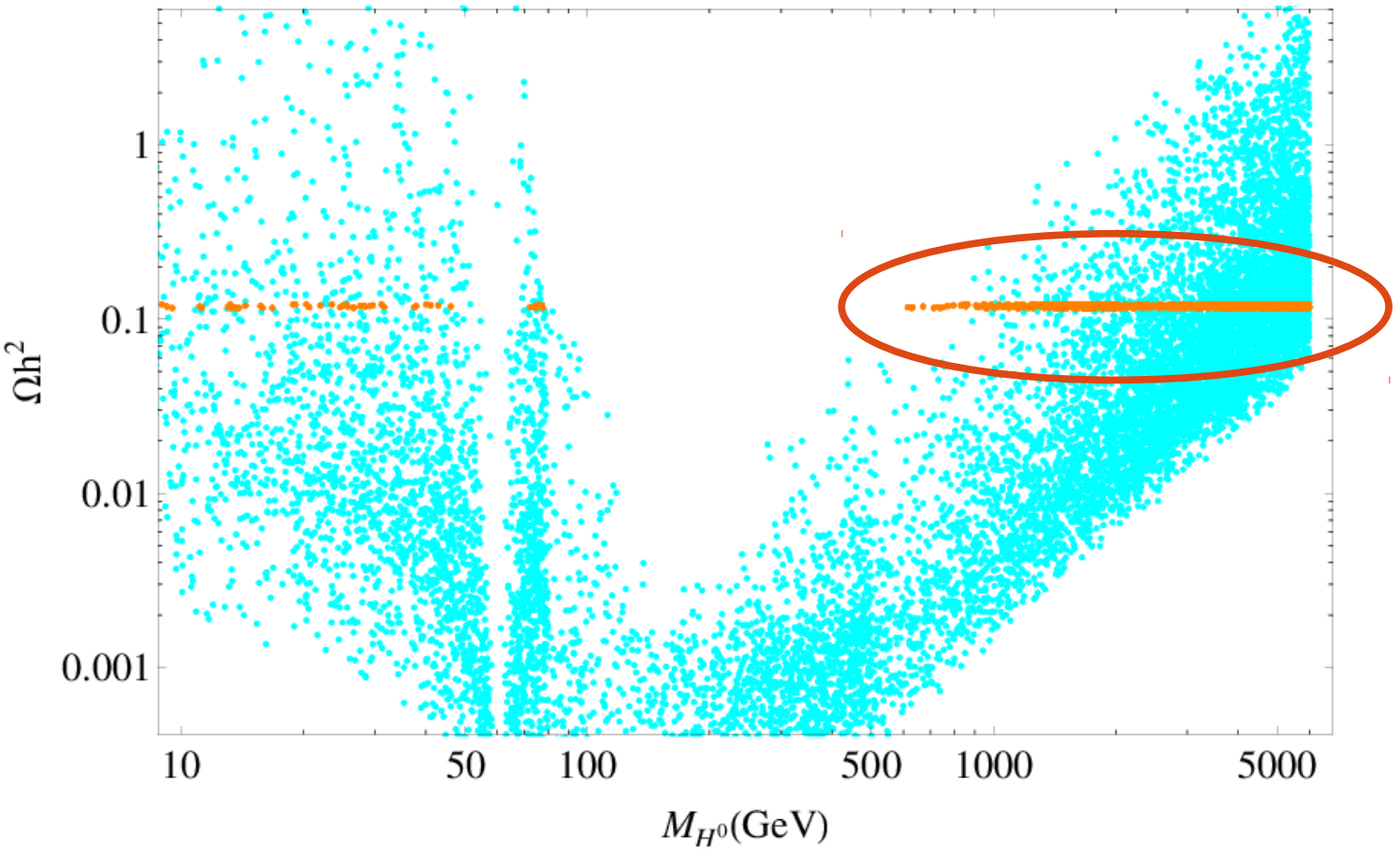
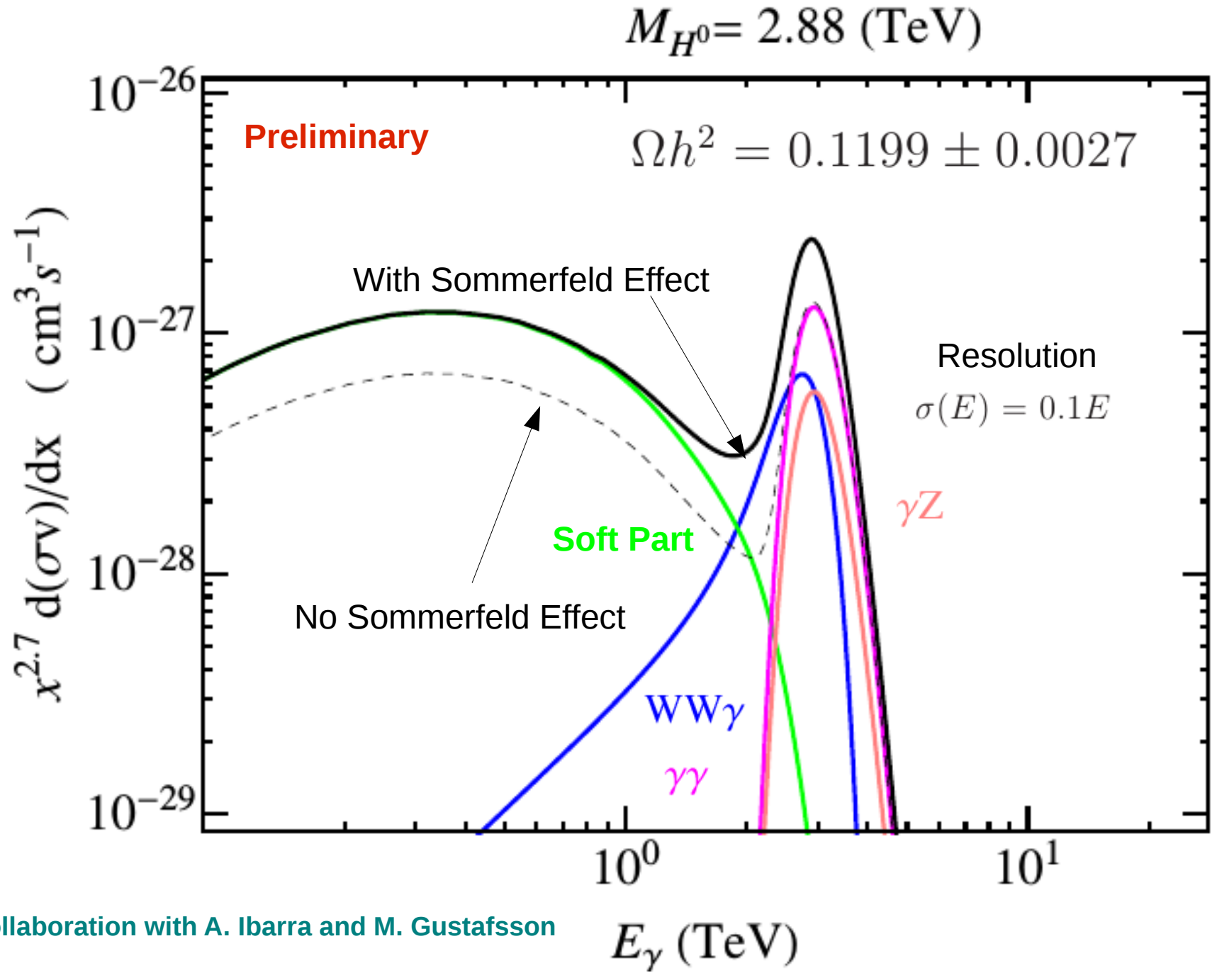


One Benchmark

The lines dominate over IB



In collaboration with A. Ibarra and M. Gustafsson

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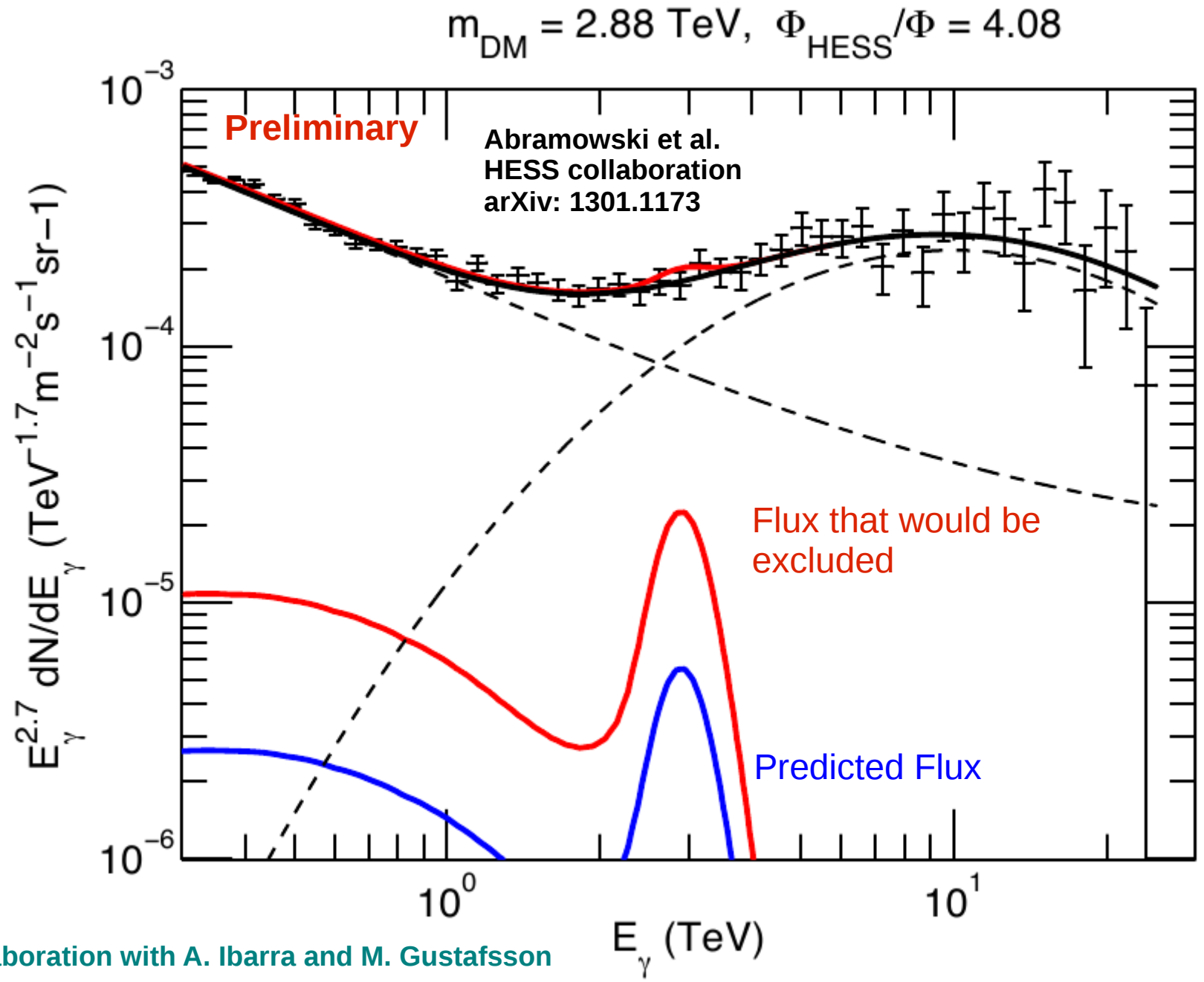

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Minimal Dark Matter Scenarios

Inert Doublet Model →

Quantum numbers		
$SU(2)_L$	$U(1)_Y$	Spin
2	1/2	0

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Inert Doublet Model →

Wino DM model →

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3	0	0
3	0	1/2
3	1	0
3	1	1/2
4	1/2	0
4	1/2	1/2
4	3/2	0
4	3/2	1/2
5	0	0
5	0	1/2
7	0	0

Cirelli et. al 2005

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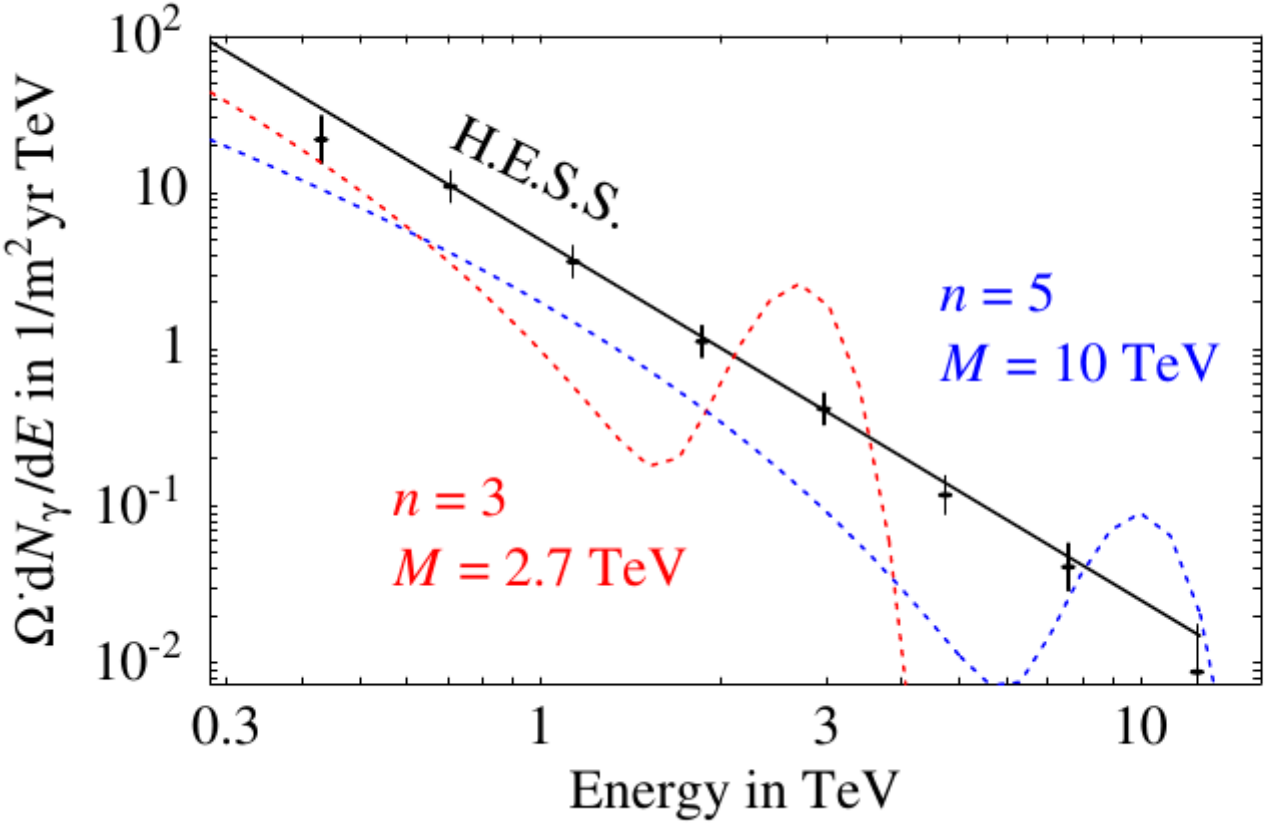

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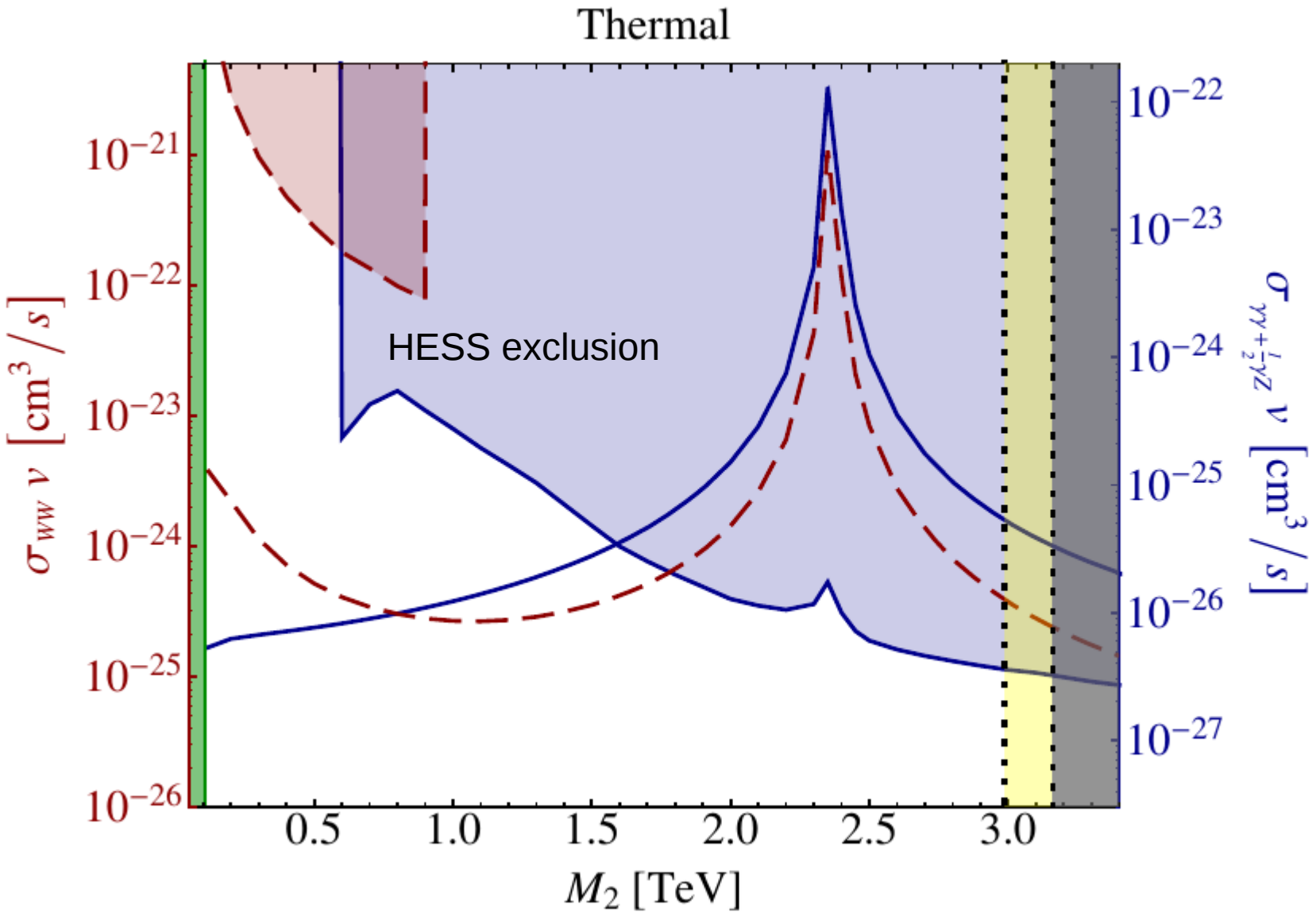
4	3/2	0
4	3/2	1/2
5	0	0
5	0	1/2
7	0	0

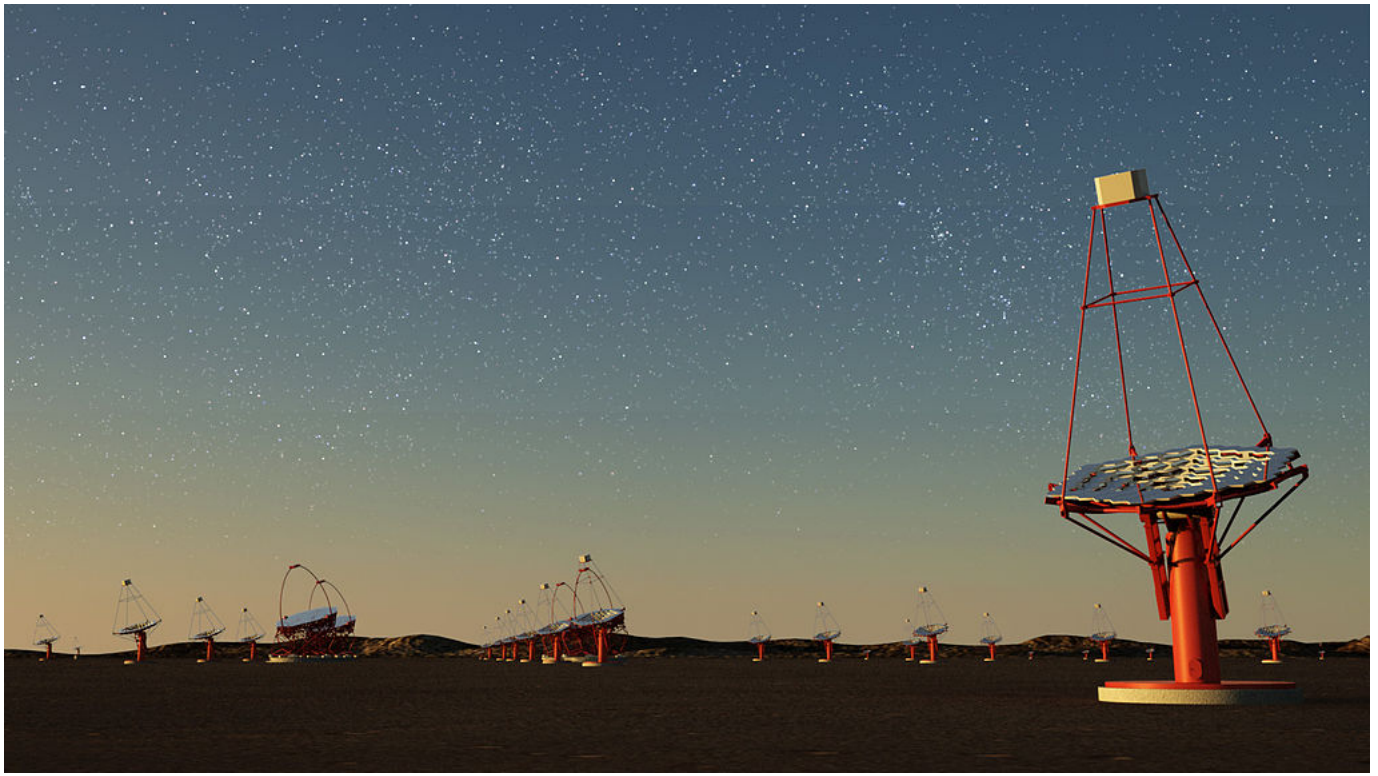
Wino DM under siege!!



Cohen et. al 2013

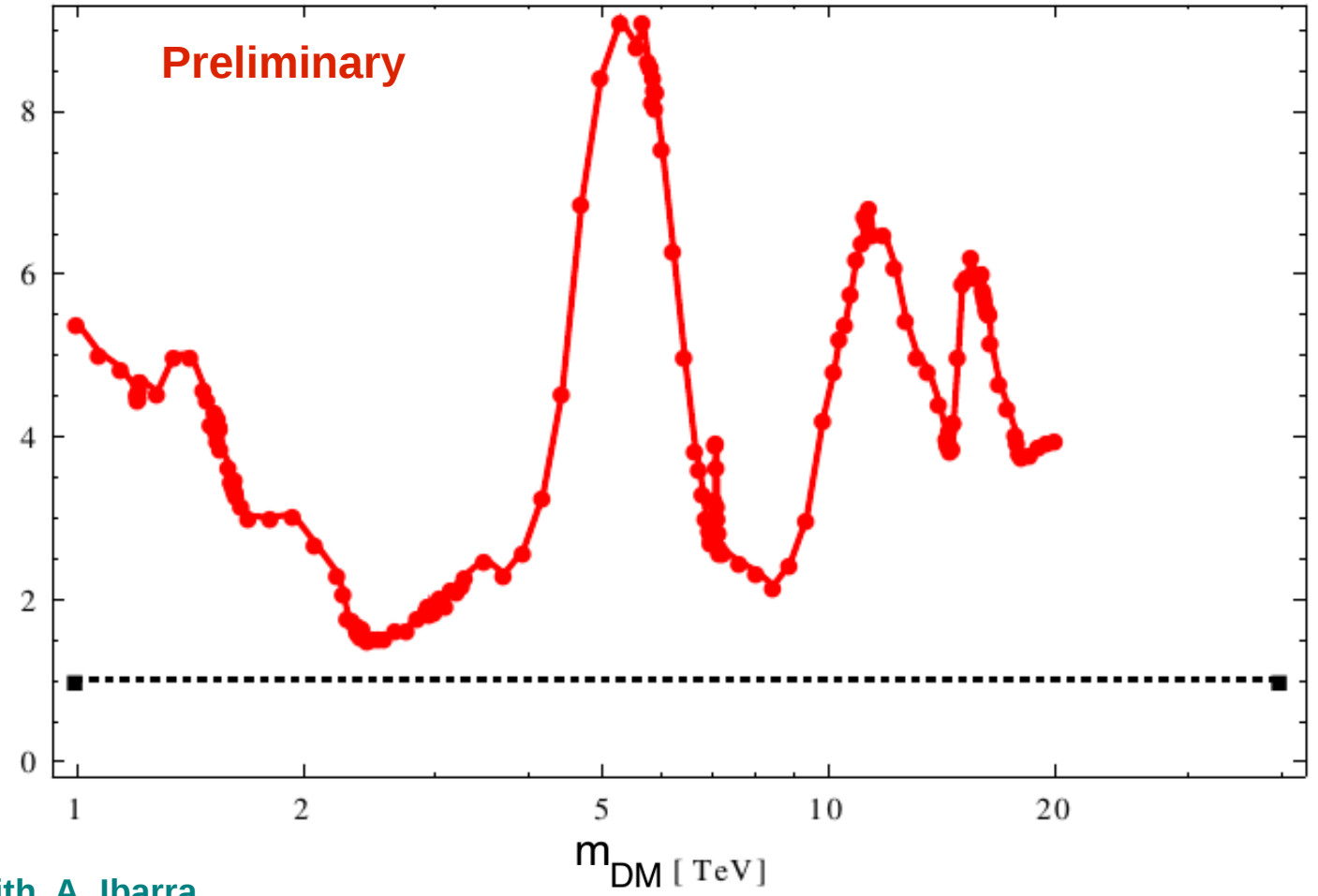
C.T.A.

(Cherenkov Telescope Array)



It will consist of two sites, one in each hemisphere, equipped with three different kinds of telescopes in order to cover a wide energy range from 10 GeV to about 100 TeV.

Prospects for the ratio of HESS to CTA limits (Quintuplet)



In collaboration with A. Ibarra, A. Lamperstorfer and M. Tytgat

Many TeV Dark Matter models on the verge of being excluded!!!!!

Conclusions

- TeV Dark Matter models predict internal bremsstrahlung process and annihilation into photons which generate sharp gamma-ray spectral features.

- These spectral features can be searched for with gamma-ray telescopes, and eventally found or excluded in the near future.