A novel approach in the WIMP quest:

Cross-correlation of gamma-rays and cosmic shear

Based on: Camera, Fornasa, Fornengo and MR, arXiv:1212.5018, ApJ Letter 2013.
Camera, Fornasa, Fornengo and MR, in preparation.

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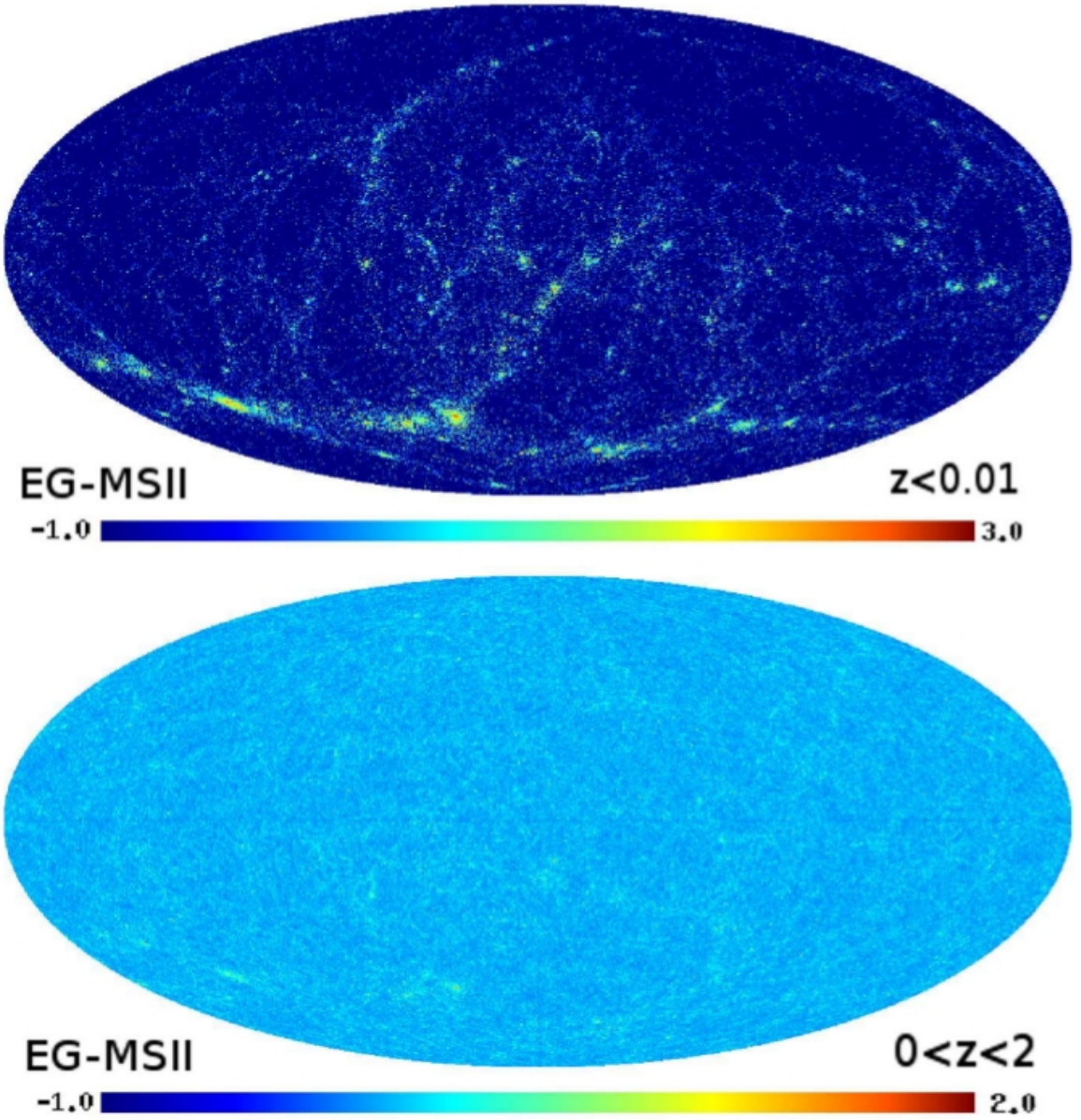
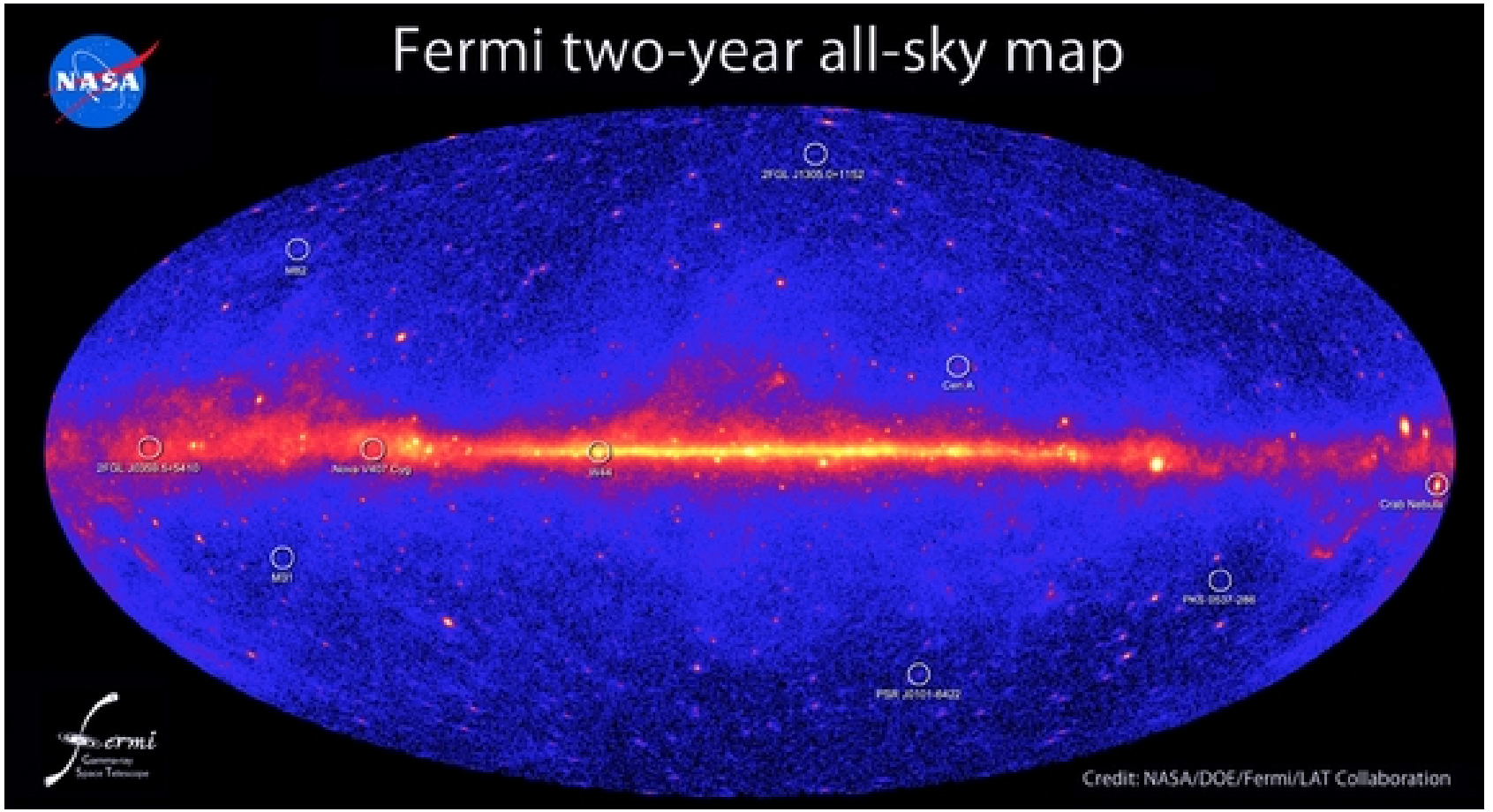
Extragalactic γ-ray background

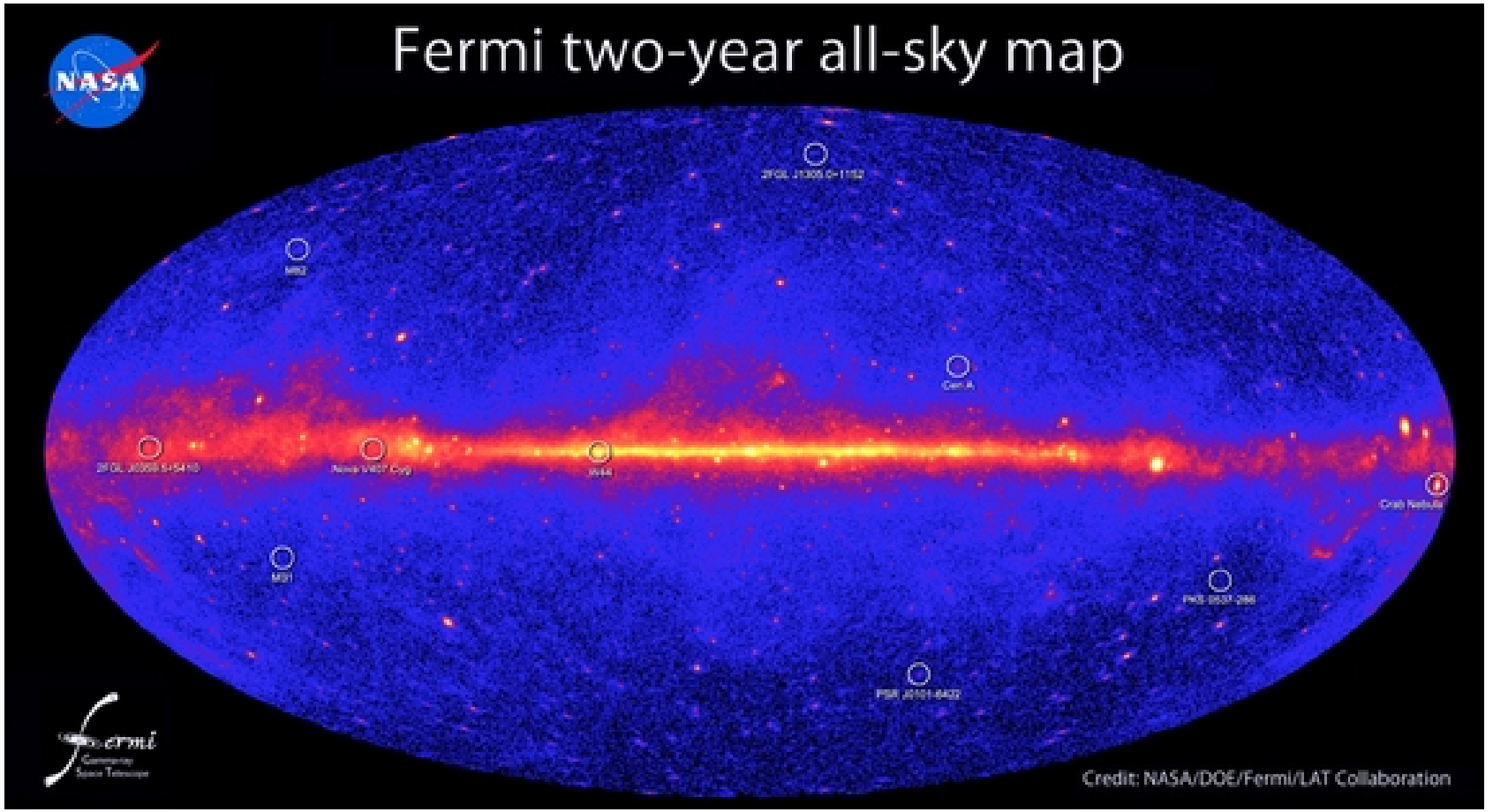


Fornasa et al., 2013

Extragalactic γ-ray background



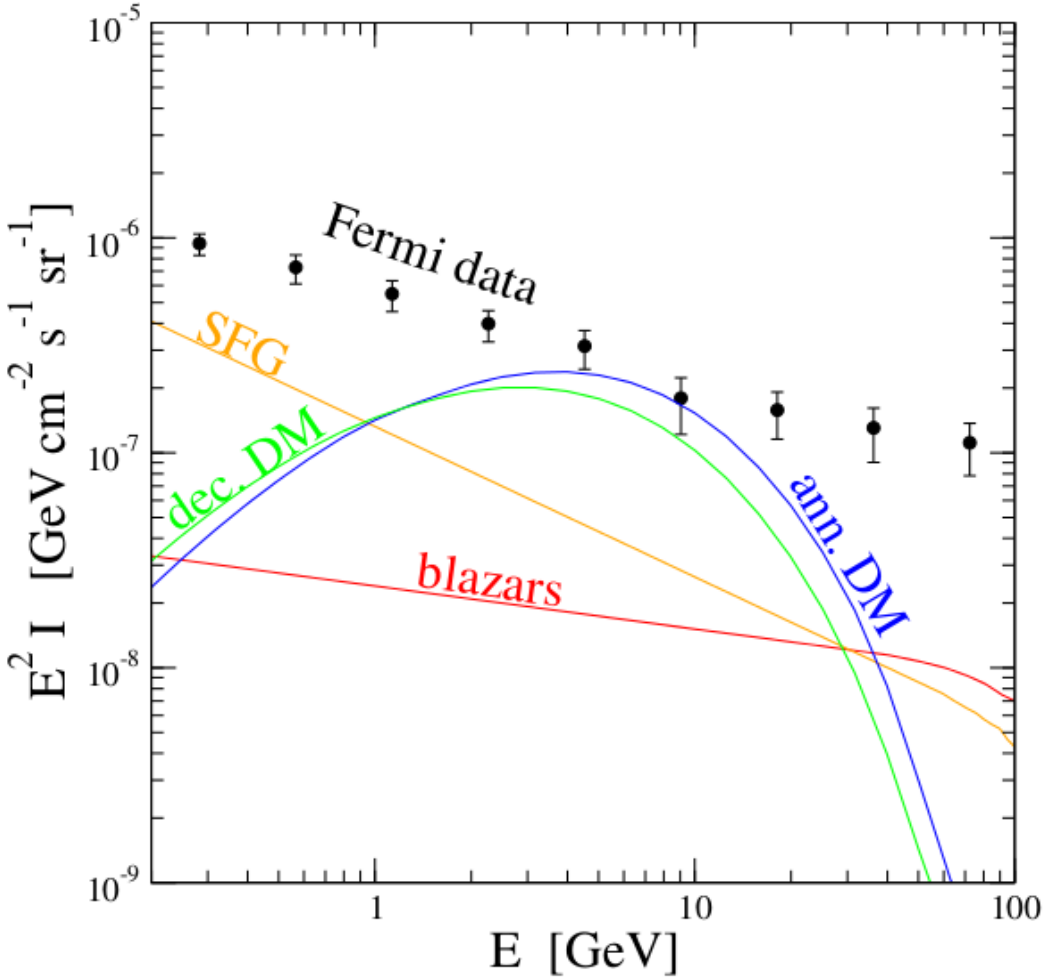
Extragalactic γ-ray background



At present the picture is depressing!

What's wrong with γ-rays alone?

Let's take a typical WIMP model with an interaction rate such that the EGB is saturated in a given energy range.



$\bar{b}$-b final state

M_χ=100 GeV (annihilating)

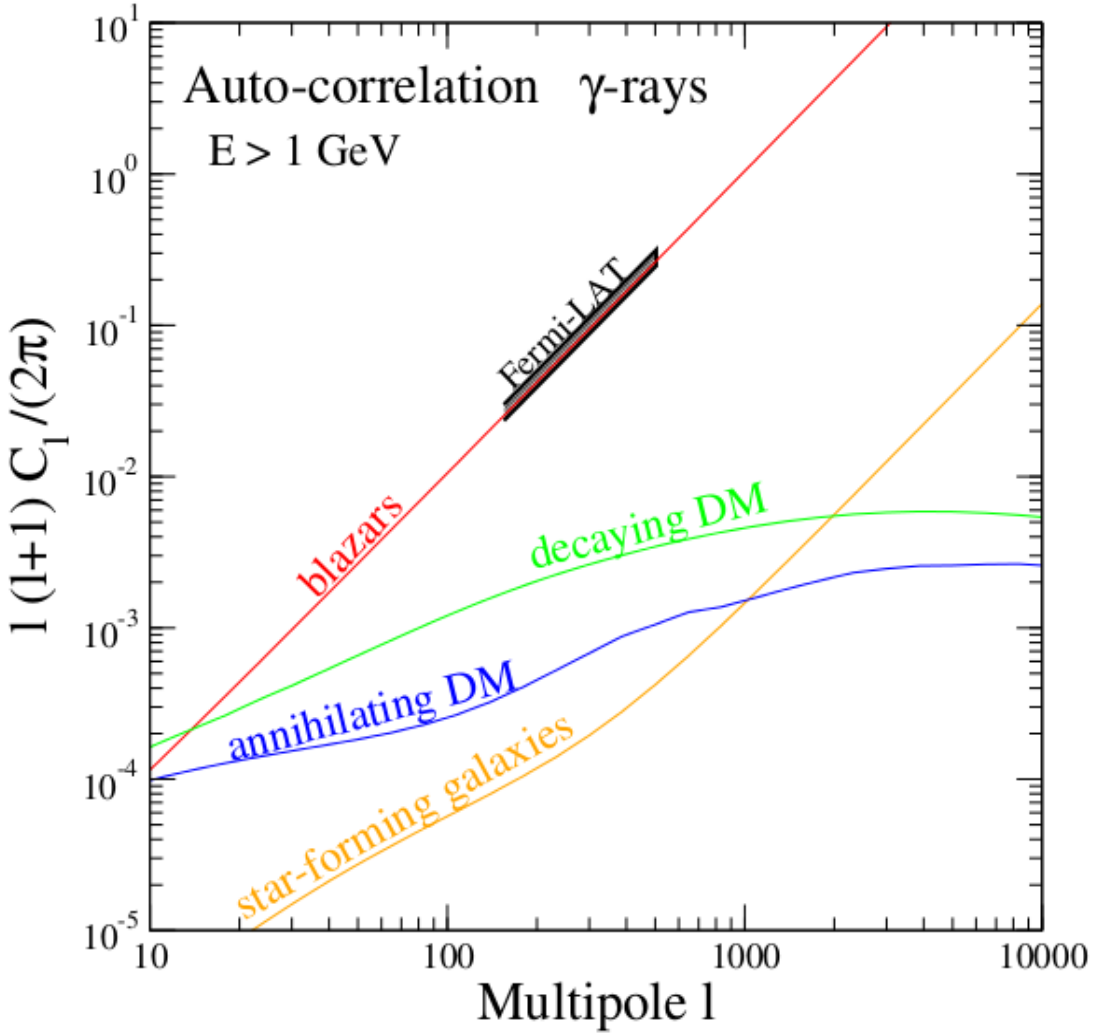
M_χ=200 GeV (decaying)

Blazars model from (Harding & Abazajian, 2012)

SFG model from (Ackermann et al. 2012)

(see also A. Cuoco's talk)

What's wrong with γ-rays alone?

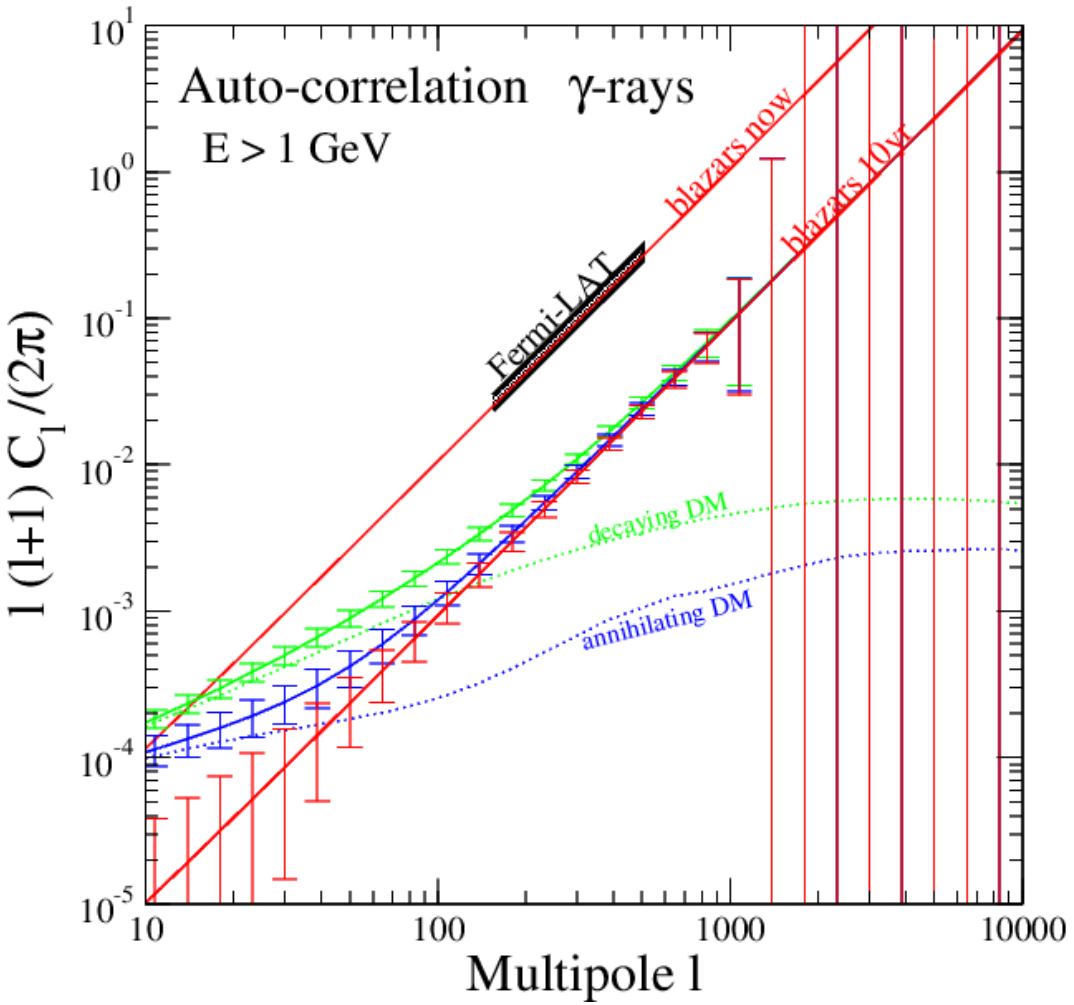


CURRENT PICTURE

Featureless EGB and anisotropies dominated by blazars

Very difficult to extract a clear WIMP signature from the extragalactic gamma-ray background alone.

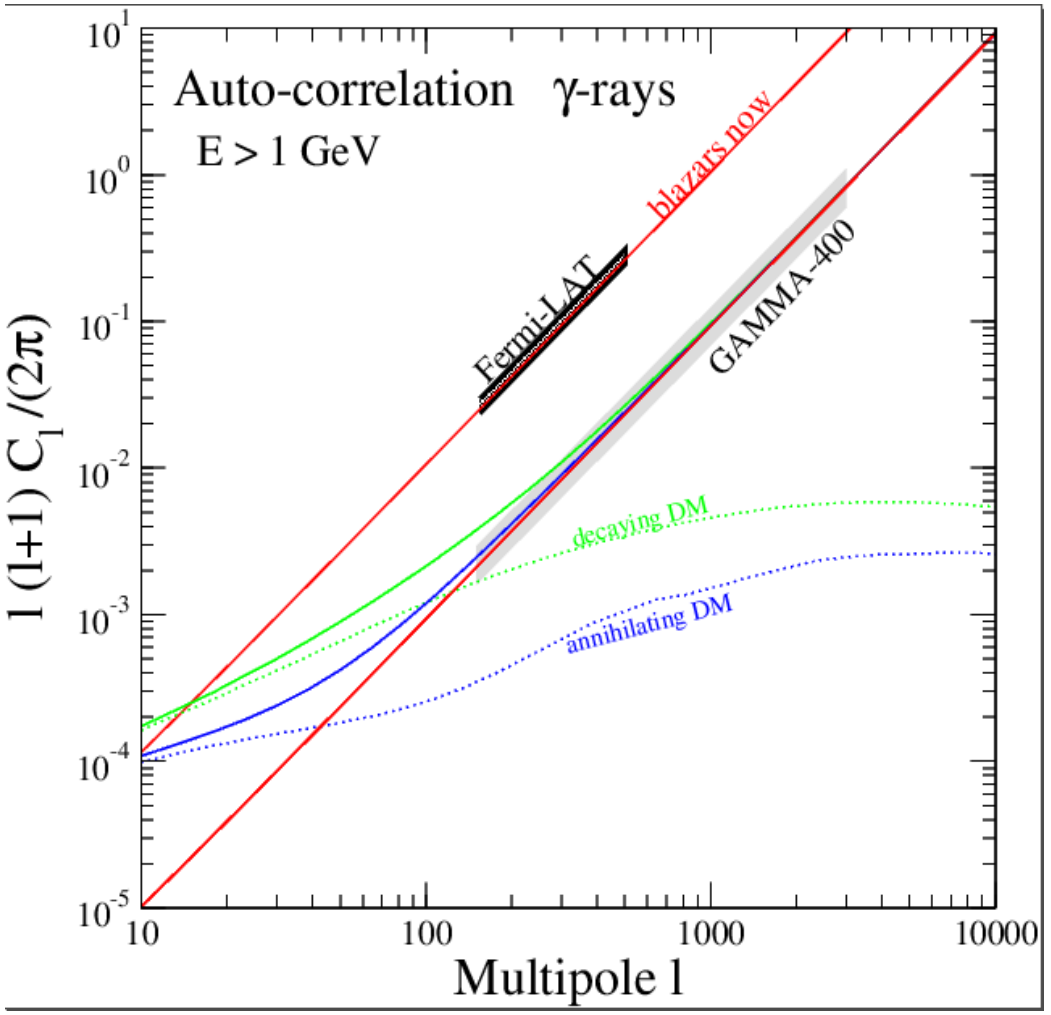
What's wrong with γ-rays alone?



NEAR FUTURE

Very difficult to extract a clear WIMP signature from the extragalactic gamma-ray background alone.

What's wrong with γ-rays alone?



NEAR FUTURE

Very difficult to extract a clear WIMP signature from the extragalactic gamma-ray background alone.

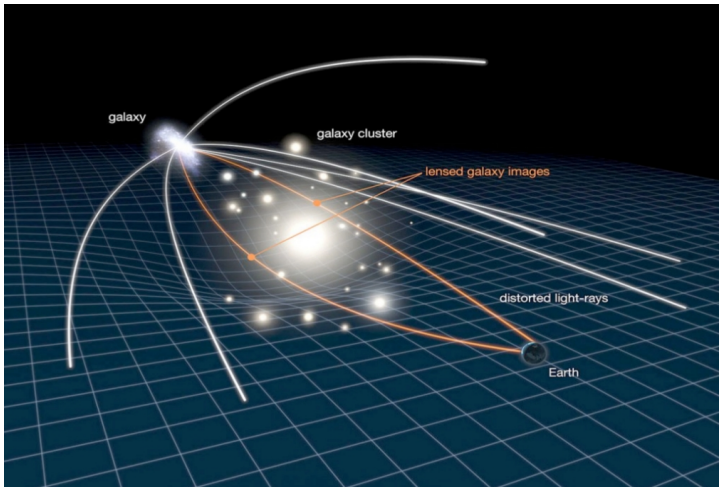
Typical problem for physicists

We need to find a way to isolate a **signal** which is there but is hidden by a large "noise".

Correlation with gravitational lensing:

Both gamma-rays from DM and lensing signals are set by the (dark) matter density.

The lensing map could be the filter we need.



Angular power spectrum

ISOTROPIC INTENSITY $\langle I_g \rangle = \int d\chi \; W(\chi)$

W = window function

χ = comoving distance

k = wavenumber, Limber approx: $k = \ell/\chi$

f_g is (related to) the density field of emission

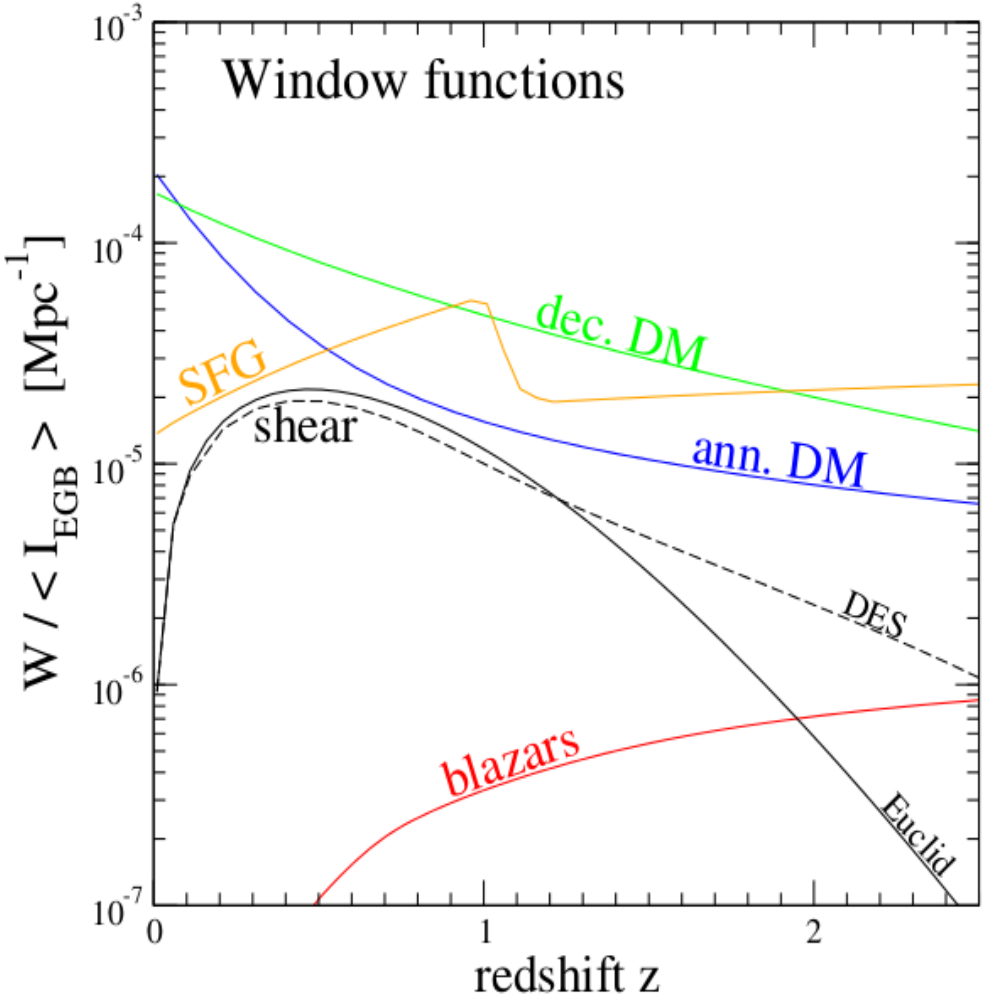
3D POWER SPECTRUM

$$\langle \hat{f}_{g_i}(\chi, \boldsymbol{k}) \hat{f}^*_{g_j}(\chi', \boldsymbol{k}') \rangle = (2\pi)^3 \delta^3(\boldsymbol{k} - \boldsymbol{k}') P_{ij}(k, \chi, \chi')$$

TWO-POINT ANGULAR POWER SPECTRUM

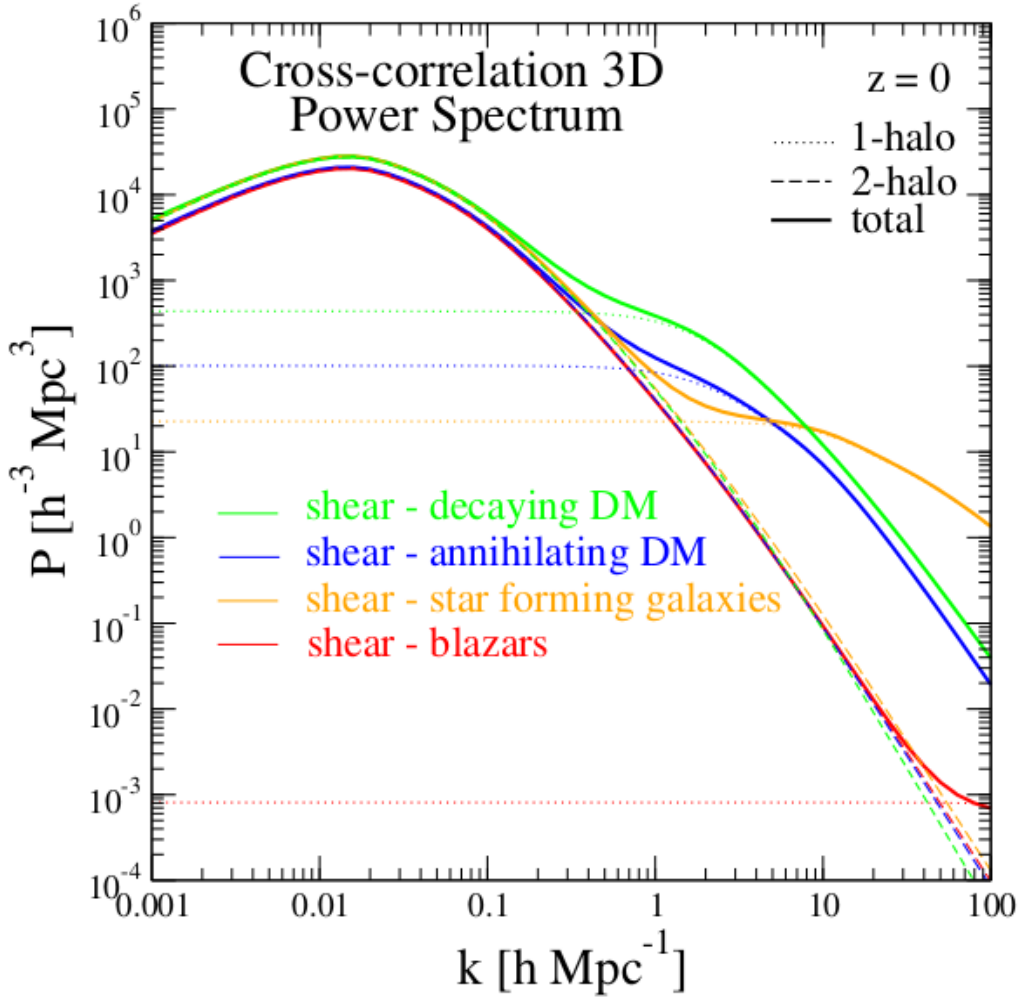
$$C_\ell^{(ij)} = \frac{1}{\langle I_i \rangle \langle I_j \rangle} \int \frac{d\chi}{\chi^2} W_i(\chi) \, W_j(\chi) P_{ij}(k = \ell/\chi, \chi)$$

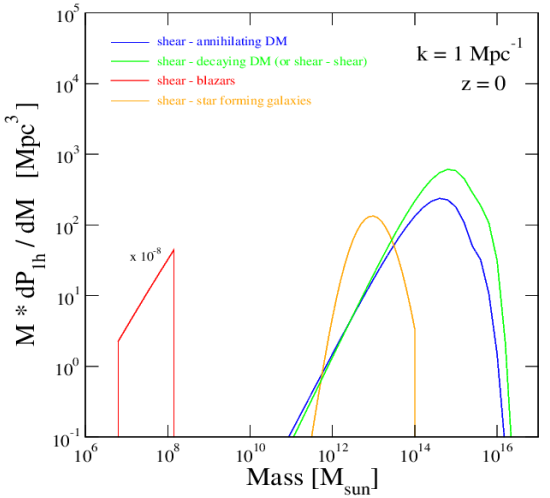
APS ingredients / window function



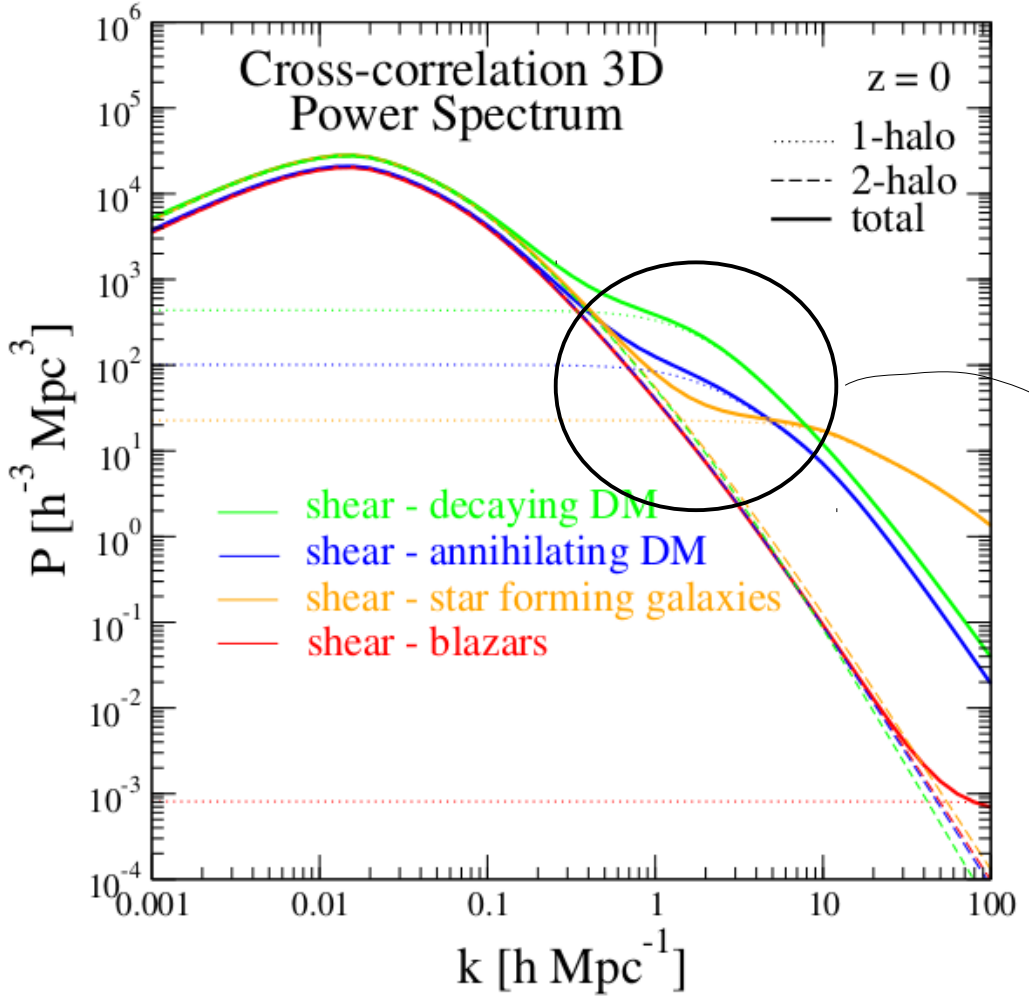
The peak of the WIMP **window function** is **at lower z** than for astrophysical sources.

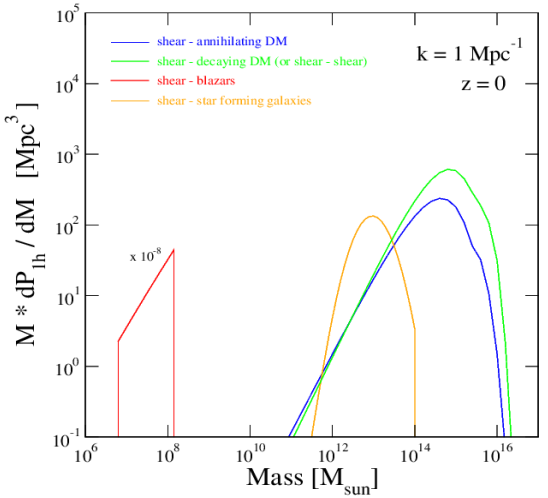
APS ingredients / 3D power spectrum





APS ingredients / 3D power spectrum



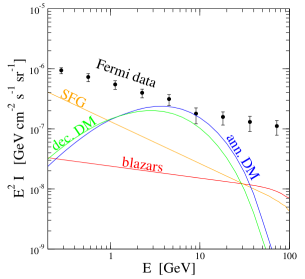


It is (roughly speaking) mapped in the multipole range $100 < l < 1000$

The WIMP **power spectrum** has more power at intermediate scales (k~1-10 h Mpc^{-1}).

Lessons

Lesson from slide 3

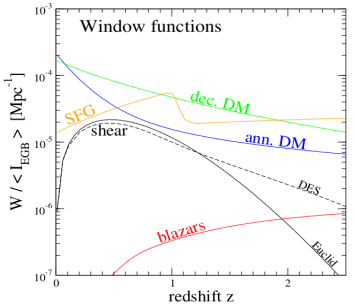


: use spectral information

(as customary for gamma-ray WIMP searches)

→ C. Weniger's talk

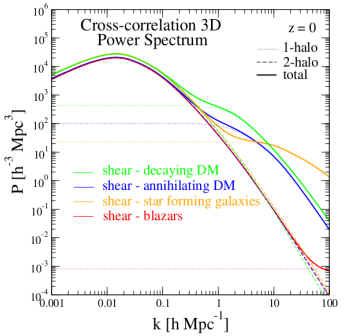
Lesson from slide 11



: use a tomographic approach

(not possible with gamma-rays alone)

Lesson from slide 13

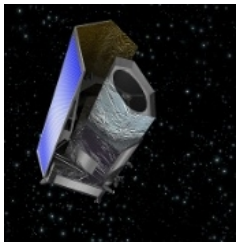


: use angular information

(not possible with the autocorrelation alone due to the blazars domination)

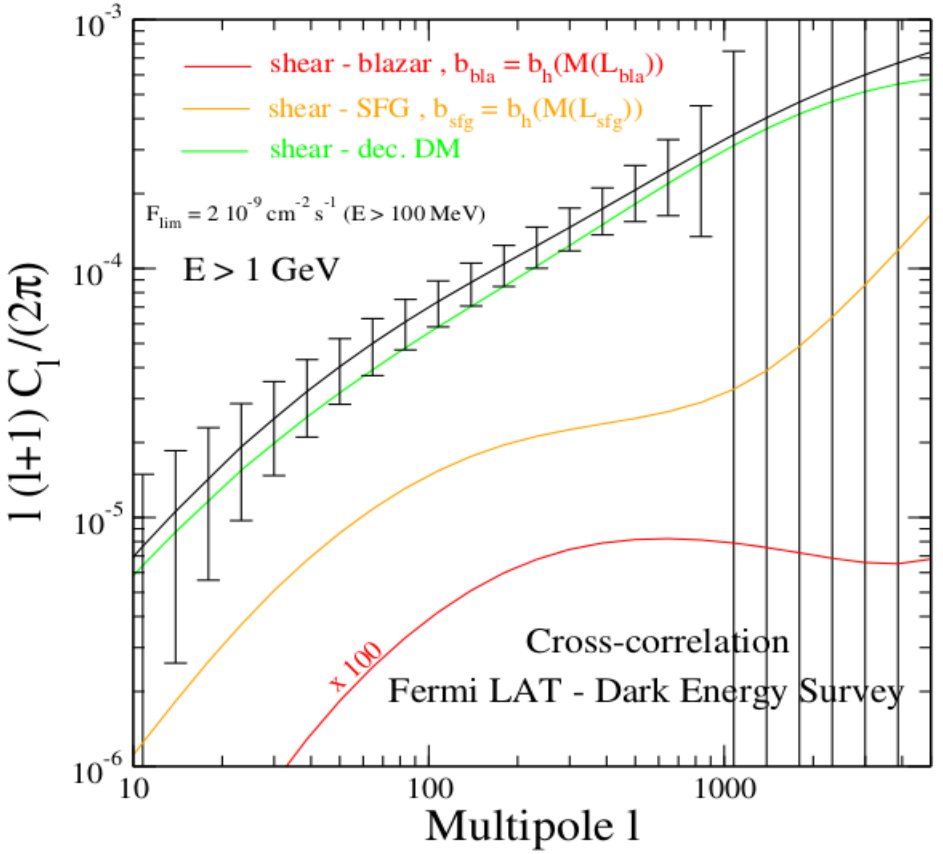
The cross-correlation lensing - gamma-rays allows us to effectively combine different pieces of information

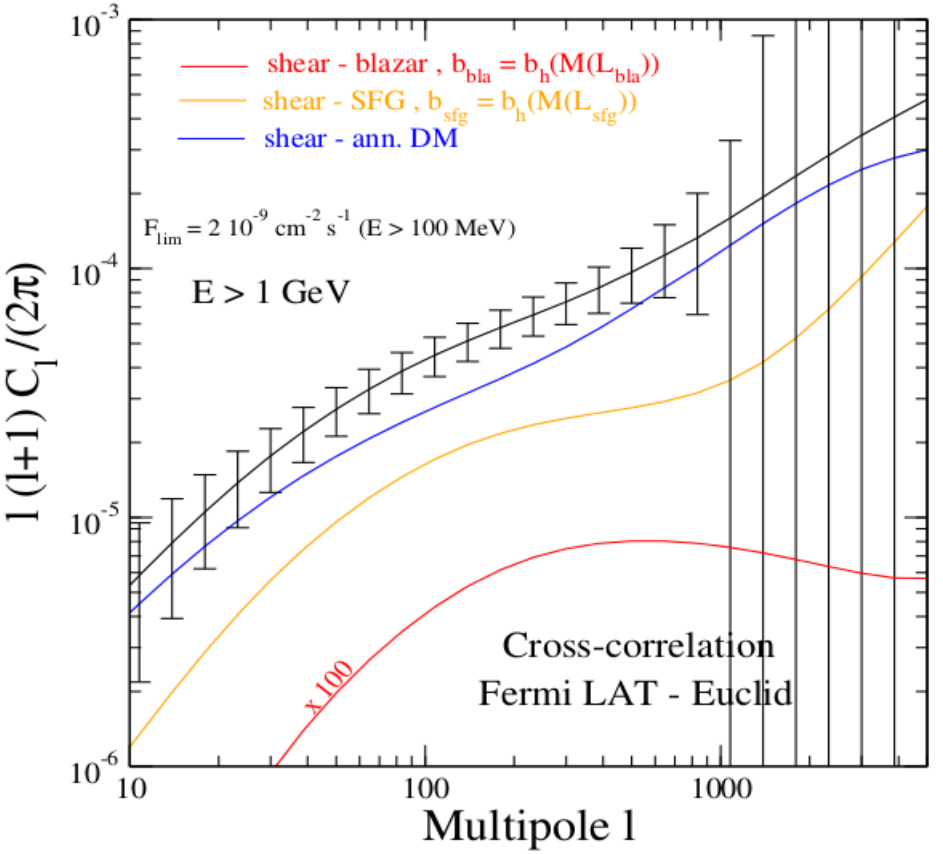
Experiments



	FERMI-LAT	Dark Energy Survey	EUCLID
	Gamma-ray telescope	Photometric redshift survey	Photometric/spectroscopic survey
	$0.3 < E/GeV < 300$	$0.3 < z < 1.5$	$0 < z < 2.5$
Sensitivity and angular resolution	$\sim 10^{-9} cm^{-2} s^{-1}$ 0.1deg @ HE	13.3 gal / arcmin^2	30 gal / arcmin^2
Sky coverage	66%	5000 sq. degree	20000 sq. degree
Operational phase	2008-2018	2012-2017	2020-2026

Results





A WIMP model, which is undetectable with gamma-rays alone, can be instead clearly **detected** through the **correlation with cosmic shear**.

This test can be performed in the forthcoming future (DES + Fermi LAT).

Fisher Matrix forecasts

Tomographic approach (for cosmic shear observations) and **energy binning** (for γ-ray observations) make the method much more powerful

Preliminary

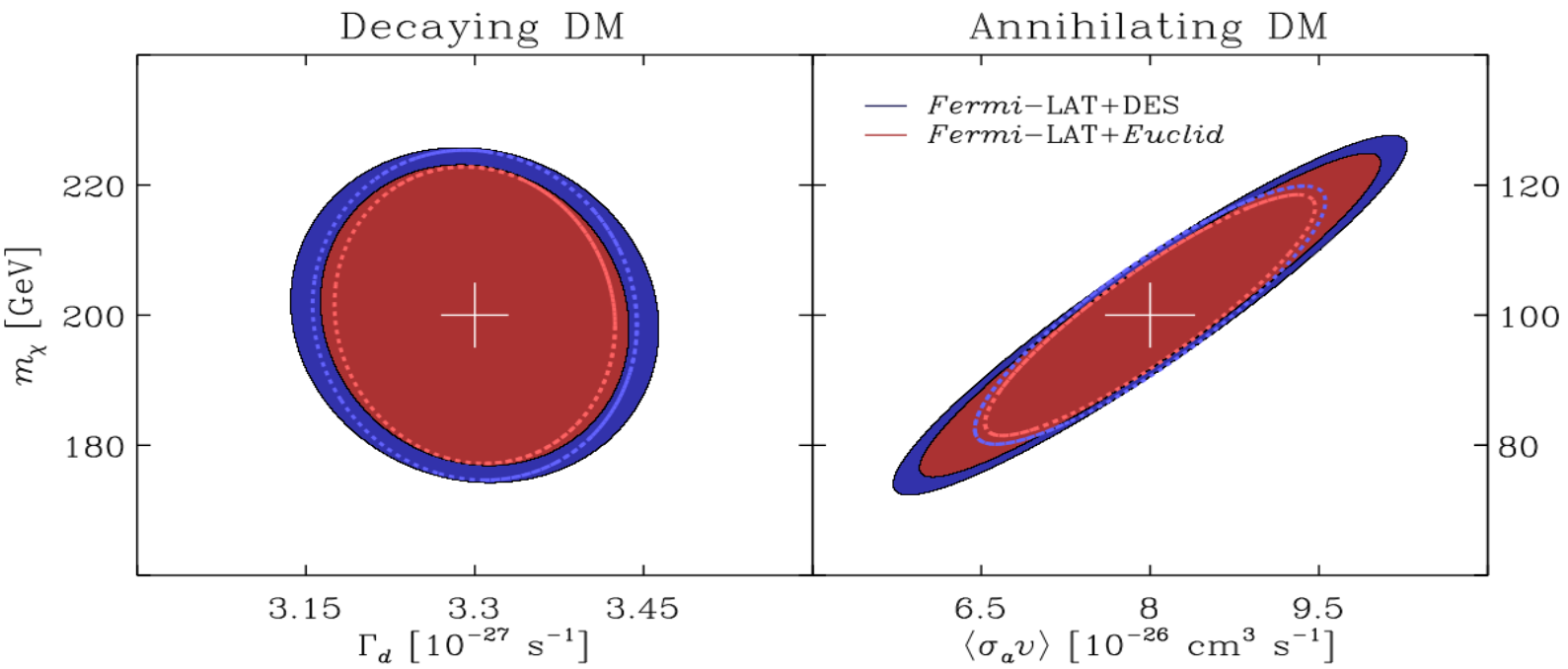
Marginal errors on DM model parameters

dec. DM

	Fermi-LAT+DES			
	m_χ	Γ_d	$\mathcal{A}_B$	$\mathcal{A}_{\rm SFG}$
binning	[GeV]	$[10^{-27}\,{\rm s}^{-1}]$	[–]	[–]
—	2.3×10^4	2.45	1.9×10^7	3.05×10^3
E_γ-z	17	0.1	4.1×10^4	0.95

ann. DM

	Fermi-LAT+DES			
	m_χ	$\langle\sigma_a v\rangle$	$\mathcal{A}_B$	$\mathcal{A}_{\rm SFG}$
binning	[GeV]	$[10^{-26}\,{\rm cm}^3\,{\rm s}^{-1}]$	[–]	[–]
—	2.6×10^4	2.1×10^3	1.4×10^7	2.4×10^2
E_γ-z	18	1.5	4.1×10^4	0.95



Conclusions

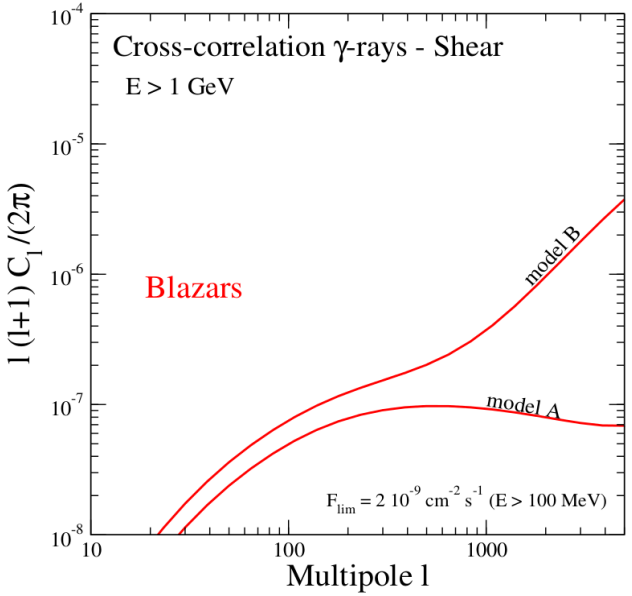
Detection prospects for the extragalactic gamma-ray background induced by WIMPs are not very bright if we look at gamma-rays alone.

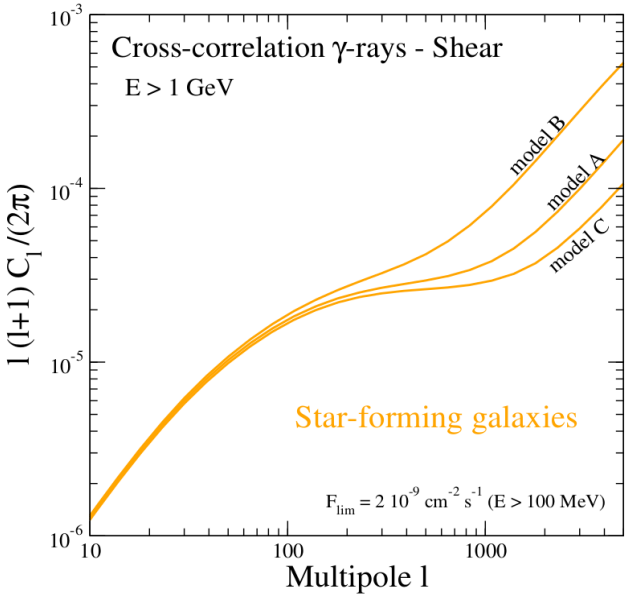
The cross-correlation of gamma-rays with weak-lensing cosmic-shear can act as a sort of filter and help to isolate a WIMP signature.

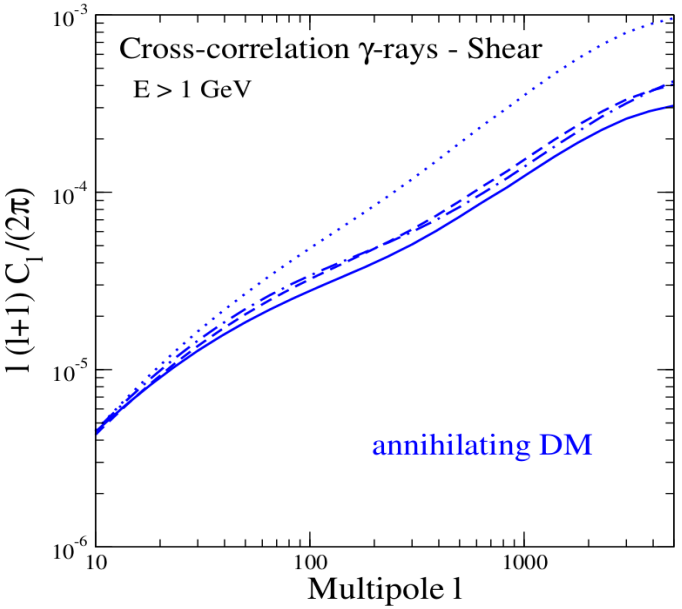
This technique will be tested in the near future:
Fermi-LAT – Dark Energy Survey

Backup slides

APS uncertainties



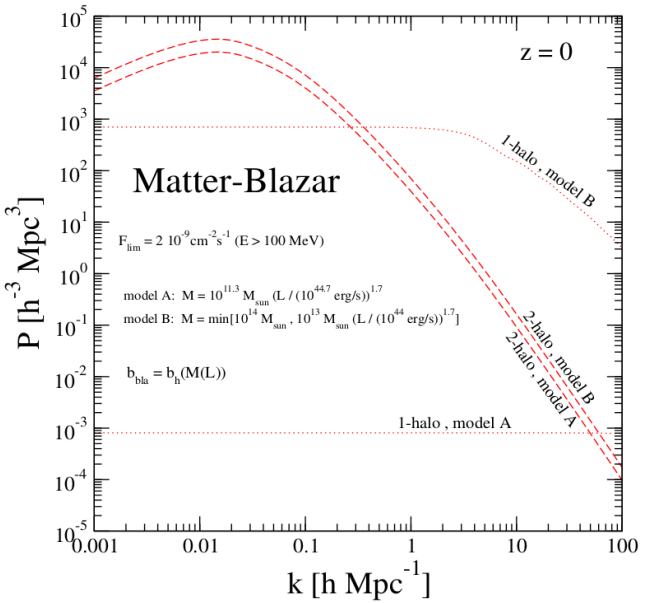


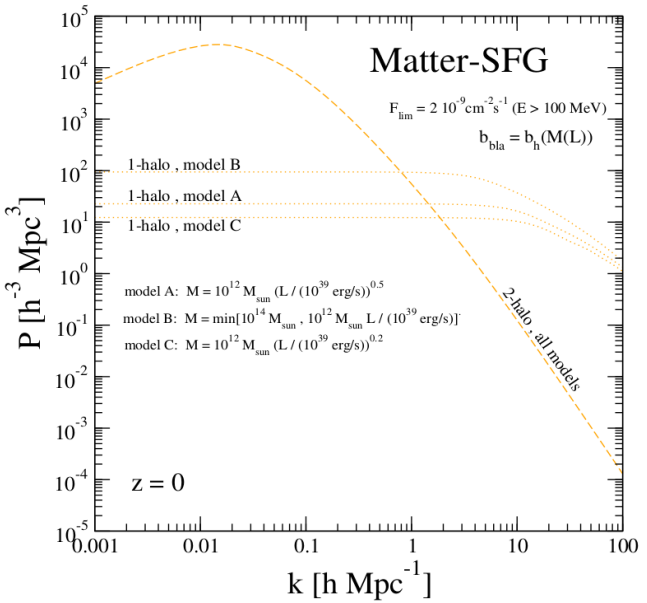


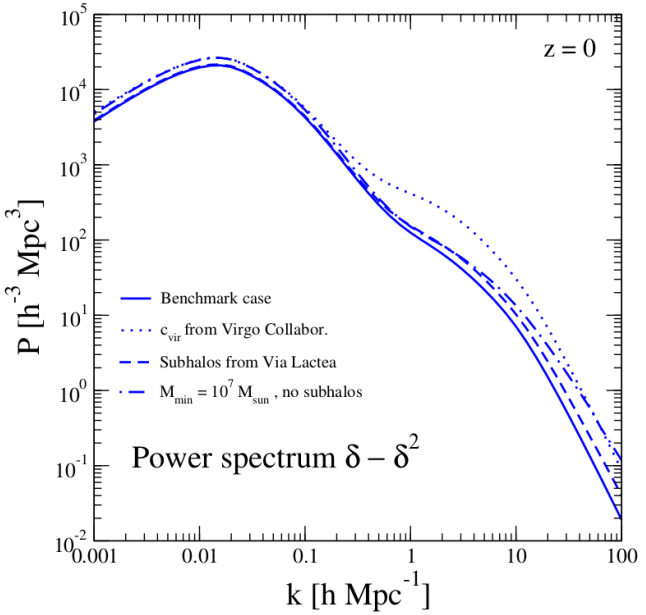
Uncertainties in the power spectrum estimate do not seem to significantly affect the possibility of detecting a WIMP signal

(provided the WIMP emission is a relevant component of the EGB)

3D PS uncertainties







The relation between **galaxy mass and gamma-ray luminosity** is the key ingredient of the 3D power spectrum of astrophysical sources.

Uncertainties are lower than in the autocorrelation case for annihilating DM.