How can we conclusively distinguish a signal for DM in indirect detection from possible astrophysical sources?

L. Ali Cavasonza, M. Boudaud, R. Calkins,
E. Fossum, A. Kwa, S. Martocchia, H. Poon, F. Santoro

SLAC, August 14th, 2014

The question

How can we conclusively distinguish a signal for DM in indirect detection from possible astrophysical sources?

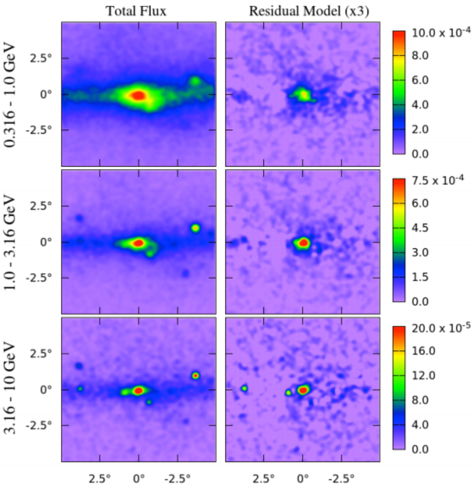
Ideally we would like to have

- Consistent signal in independent astrophysical search,
- Consistent signal in direct detection experiment,
- Production at present or future collider.

We discuss this issue in three cases

1. Fermi excess in the Galactic Center;
2. Anisotropy in diffuse γ-ray emission;
3. Positron excess.

Fermi GeV galactic center excess



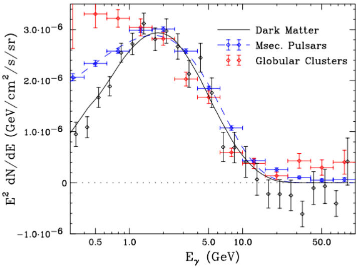
Daylan et al. 2014

DM model:

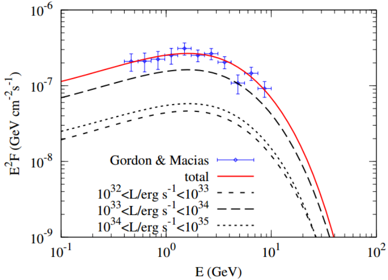
- $m_{DM} \sim 35$ GeV to $b\bar{b}$;
- standard annihilation cross-sections;

Viable astrophysical explanation: millisecond pulsars.

Millisecond pulsars (MSP)



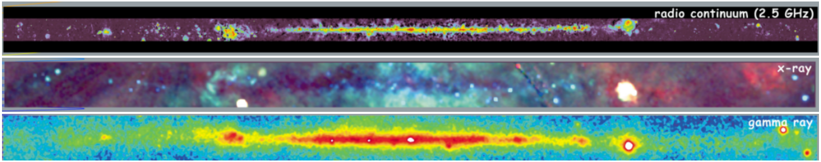
Cholis et al. '14– claim that MSPs **cannot** fit the observed spectrum from the galactic center.



Yuan+Zhang '14– claim that MSPs **can** fit the observed spectrum from the galactic center.

Possibility of fitting the excess flux with MSPs depends on the luminosity function assumed!

Multiwavelength observations

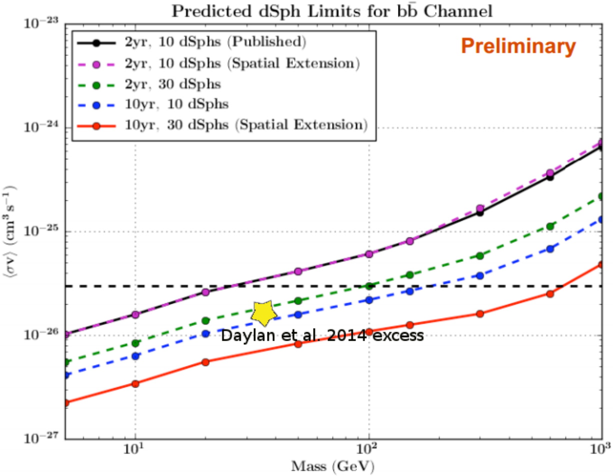


Multiwavelength Milky Way – NASA.

Radio observations of millisecond pulsars
\+ X-ray observations of low-mass x-ray binaries

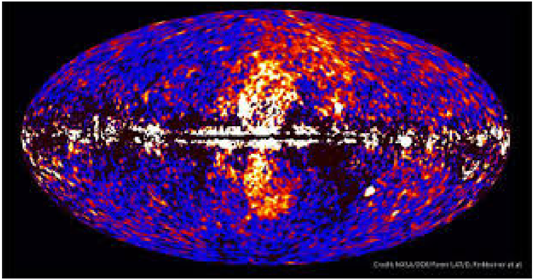
⇒ better knowledge of pulsars distribution;
⇒ better knowledge of luminosity function.

Dwarf spheroidals: a straightforward test



Drlica-Wagner '12.

Diffuse emission anisotropy



Known γ-ray point sources include blazars, radio galaxies, starburst galaxies, high lat. pulsars, gamma-ray bursts

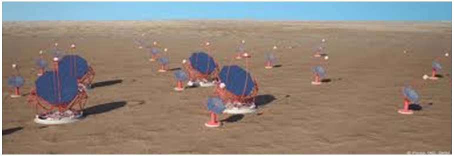
Massive number of unresolved γ-ray point sources (as shown above)

Basic idea:
Observations of γ-ray diffuse emission to search for anisotropies in the angular power spectrum.

Pattern in the angular spectrum consistent with DM models.

Cherenkov Telescope Array

Angular resolution of γ-ray telescopes:
Anisotropy scale $\sim 0.1°$
Fermi: $< 3.5°$ ($E > 100$ MeV)
$< 0.15°$ ($E > 10$ GeV)
HESS: $< 0.1°$
CTA: $0.05° - 0.2°$



- Estimator of the power spectrum : C_l;
- For purely astrophysical sources: $C_l^A \sim 10^{-5}$;
- For diffuse background with 40% DM: $C_l^{DM} \sim 10^{-3}$.

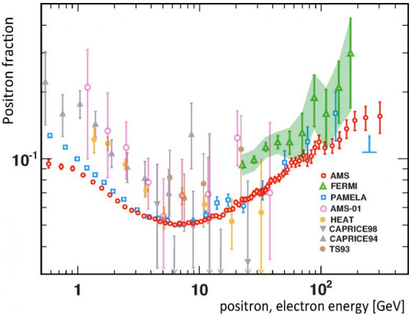
Enough to probe anisotropy!

CTA E_{th}=300 GeV

Observation time [h]	Bg. rate [Hz]	$\sigma_{fov} = 4°$ Sens.	$\sigma_{fov} = 4°$ N_{sig}	$\sigma_{fov} = 5°$ Sens.	$\sigma_{fov} = 5°$ N_{sig}	N_{bg}
100	1	55%	4262	30%	6659	3.6×10^5
	10	$\gtrsim$ 100%		95%		3.6×10^6
300	1	30%	12785	20%	19976	1.08×10^6
	10	80%		60%		1.08×10^7
1000	1	15%	42617	10%	66587	3.6×10^6
	10	45%		30%		3.6×10^7
10×100	1	30%	42617	20%	66587	3.6×10^6
	10	85%		65%		3.6×10^7

arXiv 1211.6922, 1206.2923

Positron fraction excess



Non standard scenario to explain it in terms of DM annihilation [1]:

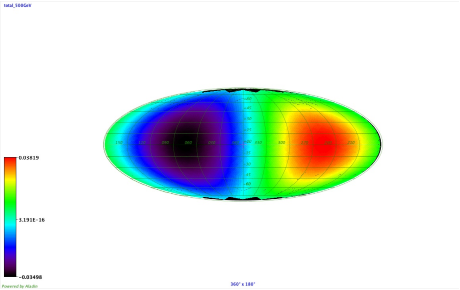
- $m_{DM} > 350$ GeV;
- produce excess in e^+ but not in $\bar{p}$;
- very large annihilation x-section $(\langle \sigma v \rangle \sim 10^{-24} - 10^{-23} cm^3/s)$;
- pulsars [1,2];
- supernova remnants [3].

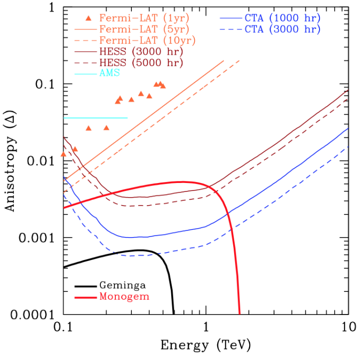
[1] I. Cholis, D. Hooper, "Dark Matter and pulsar origin of the rising cosmic ray positron fraction in light of new data of AMS" arXiv:1304.1840 [astro-ph];

[2] T. Linden, S. Profumo, "Probing the pulsar origin of the anomalous positron fraction with AMS-02 and CTA", arXiv:1304.1791 [astro-ph]

[3] P. Mertsch, S. Sarkar, "AMS-02 data confronts acceleration of cosmic ray secondaries in nearby sources" arXiv:1402.0885 [astro-ph]

Bin by bin analysis to confirm astrophysical origin





- fit of AMS-02 data with 3 pulsars scenario, using semi-analytical diffusion model;
- compute e^+ flux on last diffusion sphere;
- compute the dipole anisotropy and compare with known pulsars distribution.