Evidence for 130 GeV gamma-ray line emission from the Fermi LAT data

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Dark Attack, Monte Verità
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Topic: “130 GeV line” in the Fermi LAT data

Based on: [1205.1045] and [1207.4466] ← today!
In same topic: Weniger et al [1203.1312], Weniger [1204.2797], Su & Finkbeiner [1206.1616]
In collaboration with Martti Raidal and Elmo Tempel
Welcome to the world of amateur (γ-ray) astronomy!
Motivation
The Ten Commandments (in short version)

- There is Dark Matter!
- You shall have no other beliefs beside Dark Matter (especially MOND!)
- Do not try to imagine Dark Matter!
- Do not serve other theories than WIMP! If you do no one cites you upon the children unto the third and fourth generation of them!
- There are many glory, grants and positions for committed believers!
Energy distribution between the final state particles
DM annihilation & $\gamma$-rays
Annihilation of DM

- Nonlinear development of DM distribution: DM forms clumps
- Nearest big clump is the Centre of the Galaxy
- One can see only the gamma rays (and probably neutrinos) directly from the GC
- Intense background/foreground

- Smaller yet “cleaner” clumps: subhalos, galaxy clusters, dwarf galaxies, extragalactic isotropic
By Yuan et al [arXiv:1203.5636]
γ-rays: Galactic subhalos, resolved

By Yuan et al [arXiv:1203.5636]
\section*{Introduction}

DM annihilation & $\gamma$-rays

\section*{$\gamma$-ray lines}

\section*{$\gamma$-ray line from Galaxy clusters}

\section*{Conclusions}

$\gamma$-rays: Galactic subhalos, unresolved

By Yuan et al [arXiv:1203.5636]
By Yuan et al [arXiv:1203.5636]
\( \gamma \)-rays: Galactic total + background

By Yuan et al [arXiv:1203.5636]
What about dwarfs and extragalactic?
Problem of the dwarfs

No positive signal, strong constraints of $\langle \sigma v \rangle$, e.g. Geringer-Sameth & Koushiappas [arXiv:1108.2914]
DM profile seems to be different than expected, e.g. Frusciante et al [arXiv:1206.0314]
Gamma-ray window and the complementarity between extragalactic \( \gamma \)-rays and CMB observables [Hütsi et al (1004.2036), Cirelli et al (1012.4515)]
Halo distribution function $dn/dM(M, z)$: extrapolation and cut-off

Extrapolation of $dn/dM$

$M_{\text{min}}=10^{-9} M_{\odot}$ $M_{\text{min}}=10^{-6} M_{\odot}$

The main fraction of DM annihilation energy is produced here!

Blue: Sheth & Tormen; Dashed: Press & Schechter; Red: N-body simulation; Vertical horizontal dashed: the limit of the simulations. [Millennium Run]
Pros & cons

**Galactic halo + subhalos**
- Strong background & foreground

**Dwarfs**
- DM profile?

**Cosmological isotropic $\gamma$-rays**
- Too much freedom in the models: minimal halo mass $M_{\text{min}}$?
Lines in the $\gamma$-ray spectrum
Lines in the $\gamma$-ray spectrum

- No good explanation in astrophysics
- Some (but not many!) explanations in particle physics
- Astrophysical BG has power-law spectrum, line is very "visible"

- $\gamma$-ray line is a smoking-gun signature of new physics!
Fermi data, photons in energy range 120...140 GeV

From Tempel et al [arXiv:1205.1045]
Fermi data, significance of the signal

From Tempel et al [arXiv:1205.1045]
“130 GeV line” in the Fermi LAT data

From Tempel et al [arXiv:1205.1045]
"130 GeV line" in the Fermi LAT data from Weniger

An example of the target region, "Reg3" by Weniger [arXiv:1204.2797]
“130 GeV line” in the Fermi LAT data from Weniger

From Weniger [arXiv:1204.2797]
"130 GeV line" in the Fermi LAT data from Su & Finkbeiner [arXiv:1206.1616]
Analysis by the Fermi Collaboration, the region

Fermi Collaboration [arXiv:1205.2739]
Analysis by the Fermi Collaboration, the constraint of $\gamma + \gamma$

Fermi Collaboration [arXiv:1205.2739]
Analysis by the Fermi Collaboration, the constraint of $\gamma + Z$
Constraint of dwarf galaxies

Geringer-Sameth & Koushiappas [arXiv:1206.0796]
What about galaxy clusters?
Selected clusters (with strongest annihilation signal)
Monte Carlo trials

1 set...
Monte Carlo trials

2 sets...
Monte Carlo trials

3 sets...
Monte Carlo trials

10 sets...
Monte Carlo trials

30 sest...
Selection of Fermi LAT data

- Fermi LAT photon event data of 206 weeks (from 4 Aug 2008 to 8 July 2012) within energy region from 20 to 300 GeV
- Zenith-angle cut $\theta < 100^\circ$ in order to avoid contamination with the earth limb
- Quality-filter cut DATA\_QUAL = 1, LAT\_CONFIG = 1, and ABS(ROCK\_ANGLE) < 52.
- ULTRACLEAN events selection (Pass 7 Version 6)
- Tools: 18 April 2012 version of ScienceTools v9r27p1
Exclusions: Fermi point sources, Galactic plane and centre

- Fermi point sources, the exclusion angle:
  \[ R_{\text{excl}} = 0.2 \text{ deg} \ (0, 0.15, 0.25, 0.5) \]
- Galactic plane exclusion (for MC trials):
  \[ |b| > 5 \text{ deg} \ (10, 15) \]
Results: spectrum
Results: the size of clusters and the boost factor
Conclusions
Conclusions

- Excess in the $\gamma$-ray spectrum at 130 GeV and at the Galactic centre ($4-6\, \sigma$) and galaxy clusters ($\sim 3\, \sigma$)
- Probably **annihilation** of DM
- Only $\gamma$-ray line signal is very restrictive for particle physics model building

Next?

- From Fermi LAT Collaboration: clarification of possible detector effects
- Next1: the morphology of the signal at the Galactic centre signal
- Next2: better energy resolution (CALET, TANSUO)
Thank you!