Selecting Interesting Unidentified Sources

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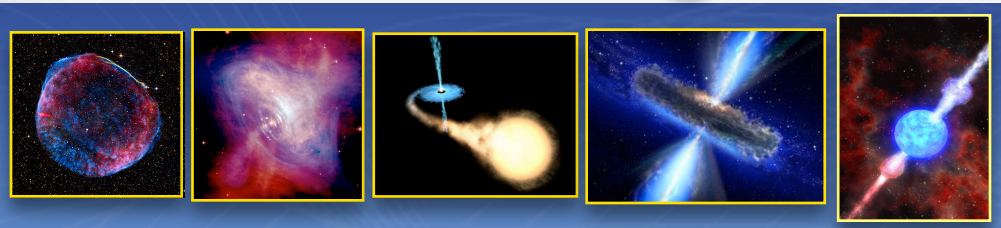
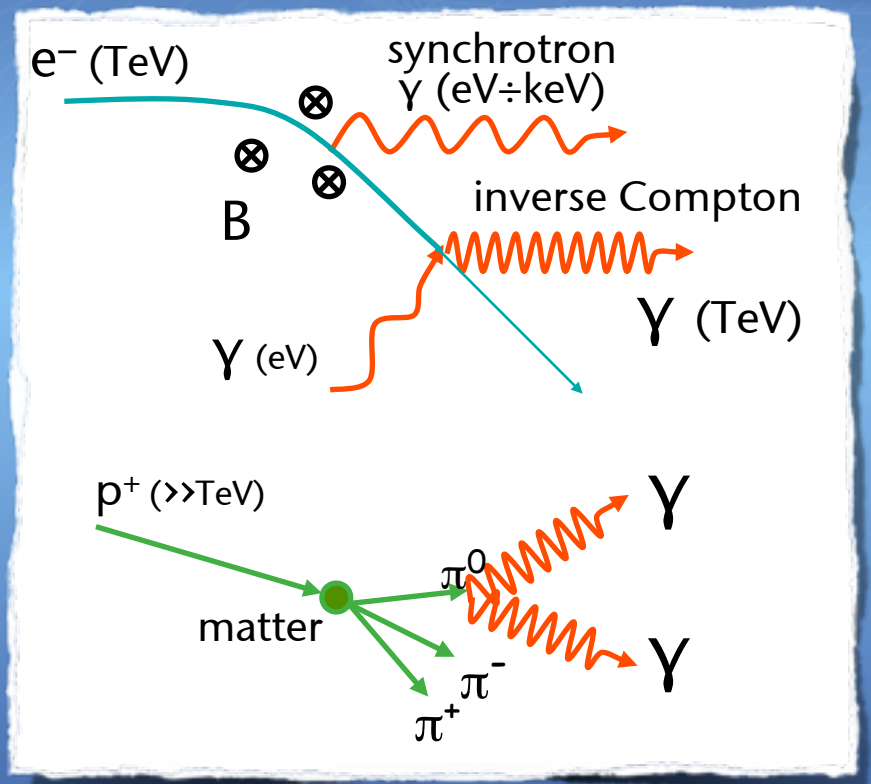
“Standard” origin of TeV γ-rays





γ-rays have nonthermal origin.

Do e⁻ or p act as seed particles?

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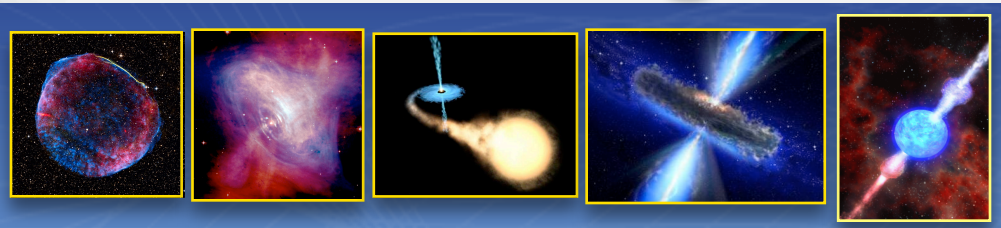
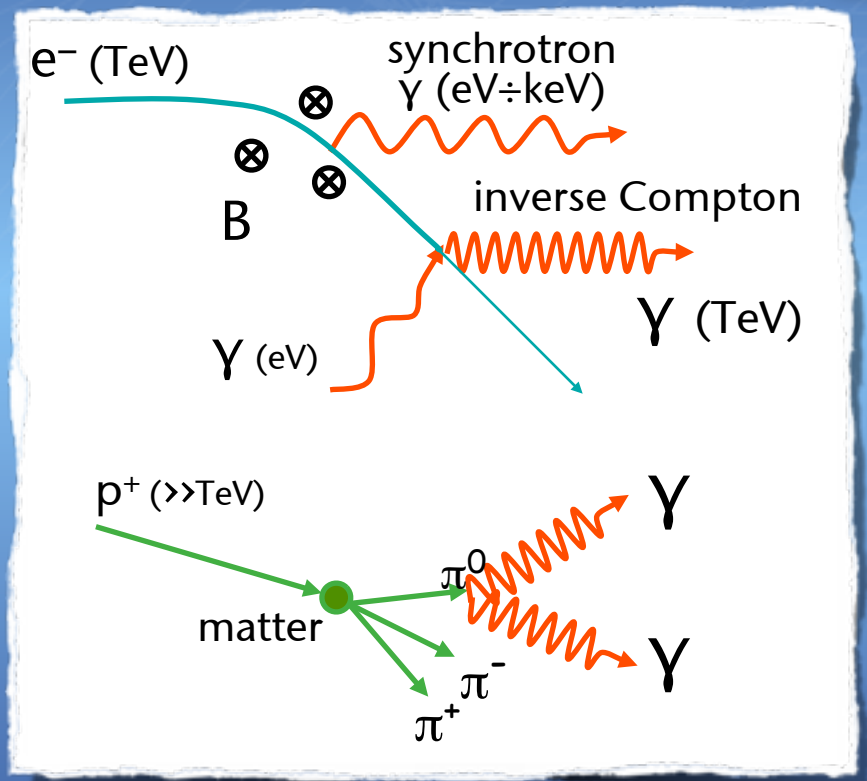
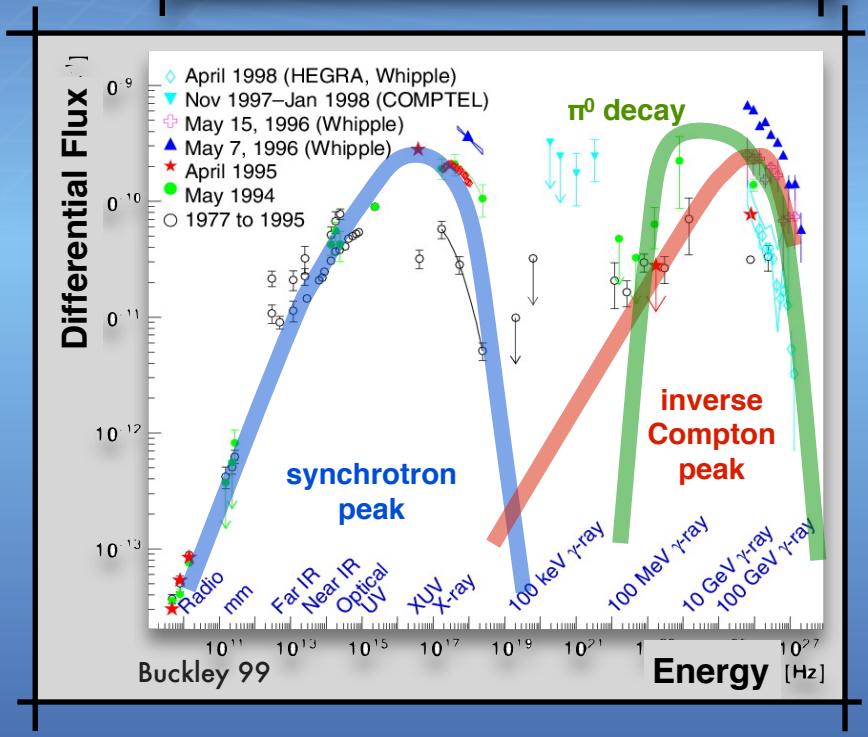


γ-rays are **messenger particles**, may allow to probe properties of:

- leptonic acceleration
- hadronic acceleration



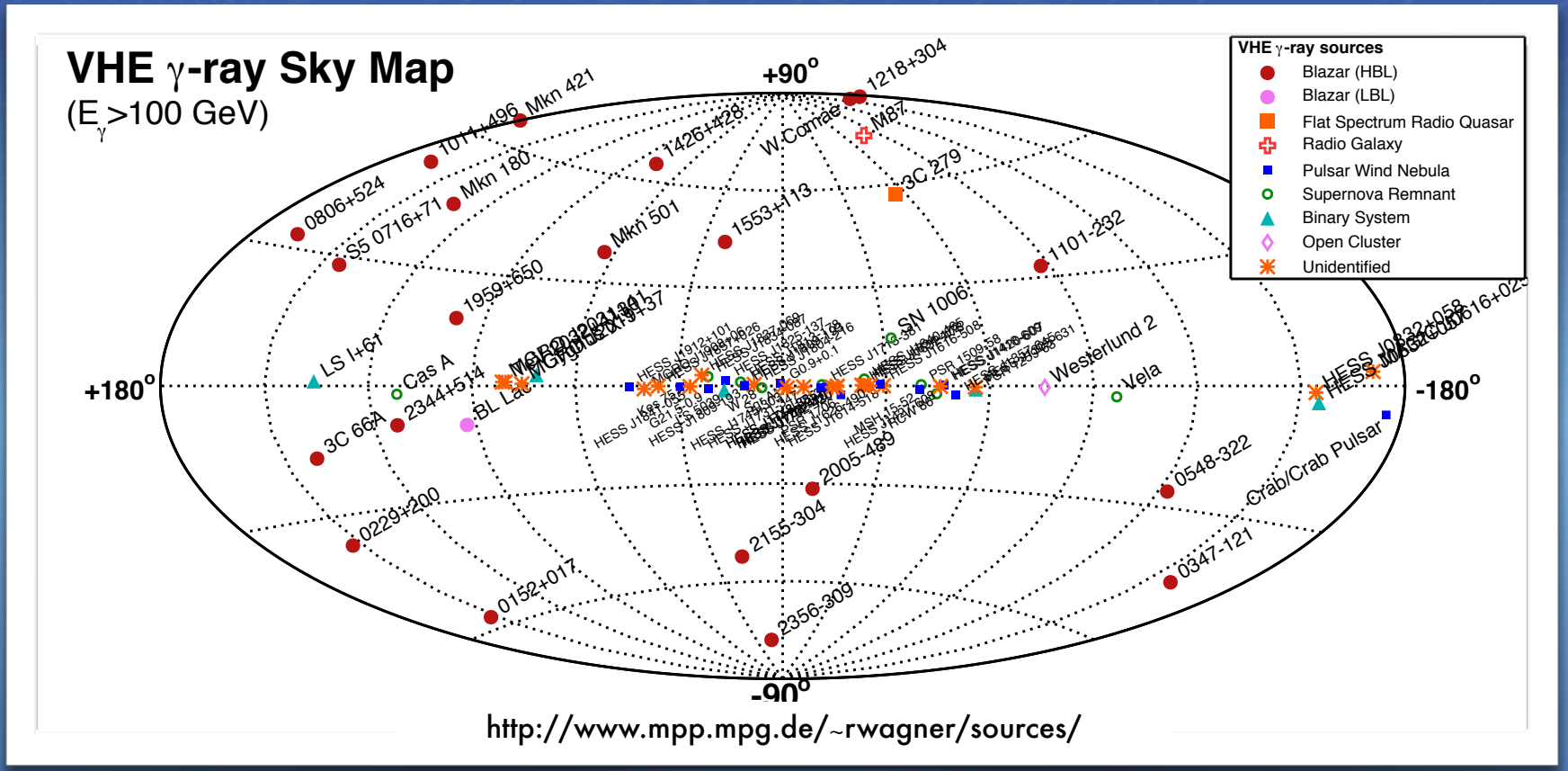


γ-rays have nonthermal origin.
Do e⁻ or p act as seed particles?

Distinguish hadronic vs. leptonic acceleration:
Shape of spectrum, correlations, multi-wavelength

Selection Procedure

TeV astronomy reviews e.g.,
Hinton 07, Horns 08, De Angelis+08



http://www.mpp.mpg.de/~rwagner/sources/

Dark Matter

- Strong evidence about the existence of Dark Matter (DM) in the Universe.
- Most probably new kind of fundamental particle
  - massive, stable, electrically neutral, and having only weak interaction with standard matter.
- ΛCDM at least 6 times more DM than baryonic matter

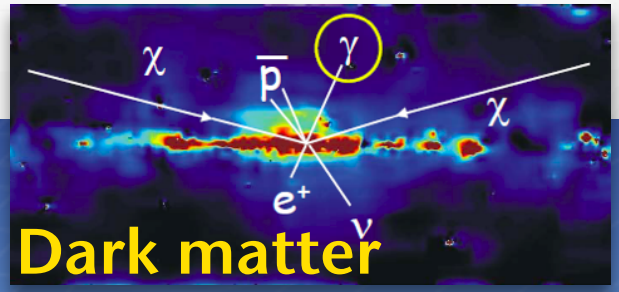
How to identify DM?

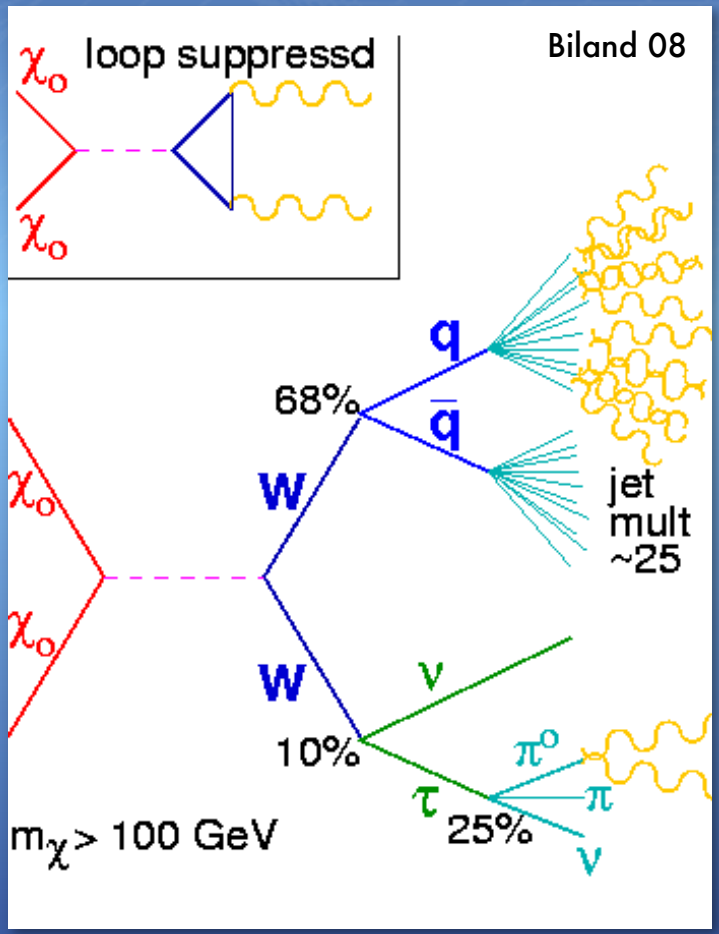
- direct production in collider experiments Kane+Watson08
- direct detection through scattering off ordinary matter Cerdeno+Green10
- search for annihilation or decay products Bertone+Merrit05
  - annihilation of neutralinos into γ-ray photons (in SUSY)
- A γ-ray signal from DM origin would provide one of the clearest and most robust evidences for DM
  - annihilation lines, internal bremsstrahlung, cut-off
  - spectrum must be universal
  - smoking gun: several γ-ray sources, no counterpart at other wavelenghts

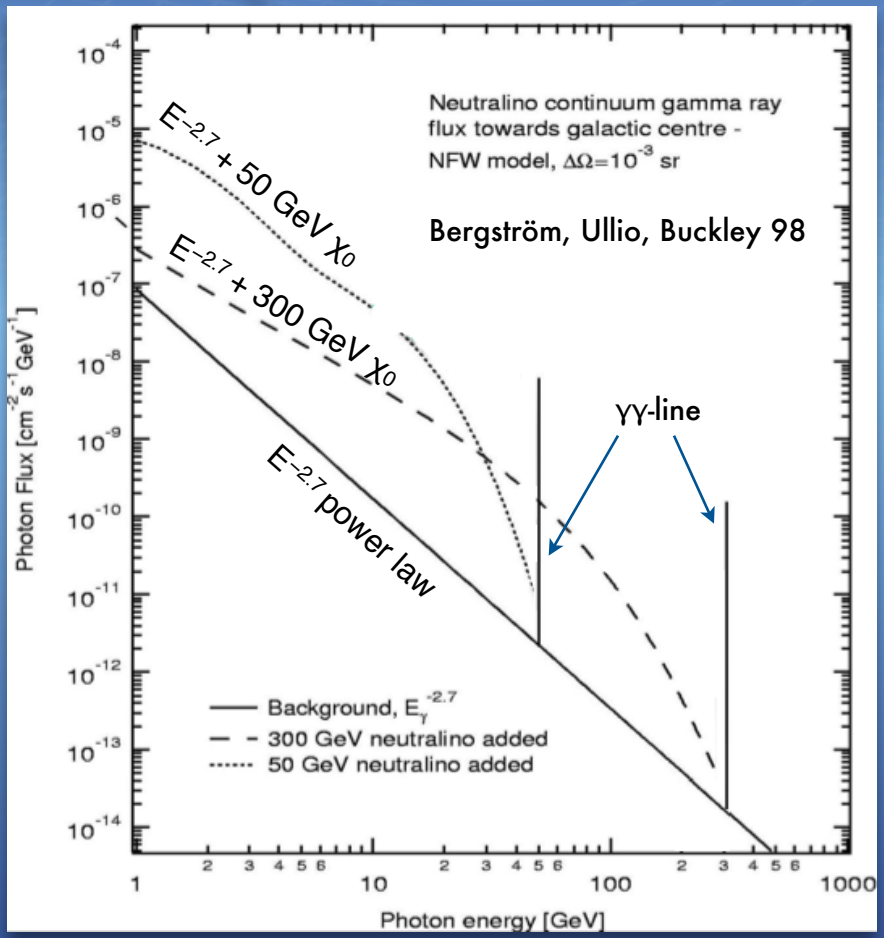
VHE γ from χ_0-annihilation

χ_0 does not directly couple to γ, **hence "dark"**,

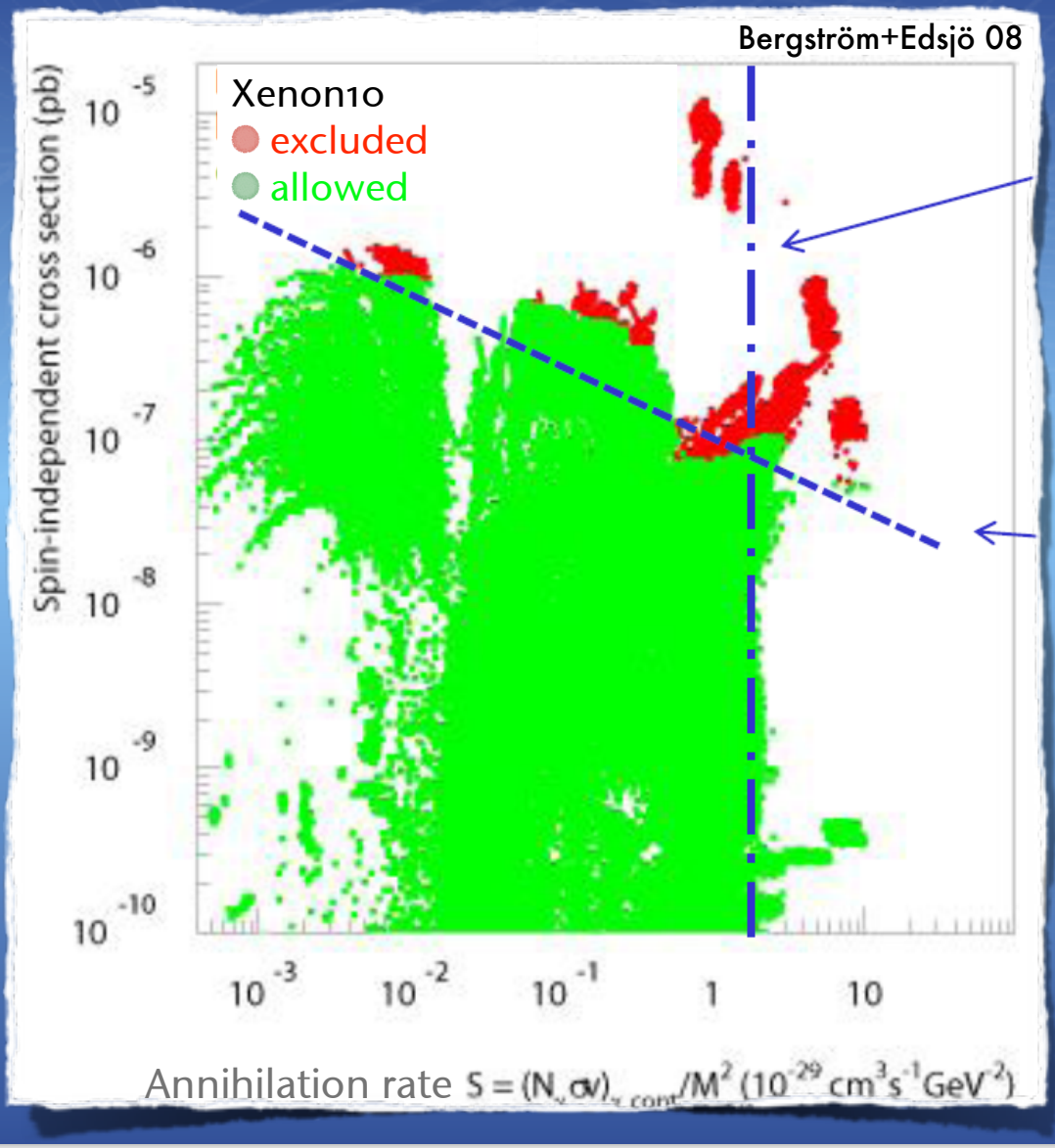
- Some important γ production processes







Complementarity DM searches



Approximate reach *Fermi*/IACT

Approximate limits from direct searches

Direct and indirect searches test complementary regions of SUSY phase space!

Where to look for CDM?

Flux calculation:
Uncertainties $\mathcal{O}(10^x)$

$$\Phi = \frac{N(\sigma v)}{2\pi m_\chi^2} \times \frac{1}{\Delta\Omega} \int \mathrm{d}\Omega \int \rho^2 \mathrm{d}s$$

Particle physics:
velocity-weighted cross section

Astrophysics:
line-of-sight integrated CDM density distribution

Need region with high ρ_{DM}

- Galactic center: obscured by strong VHE source;
  DM origin unlikely (Aharonian+06; Albert+06; Horns 04)

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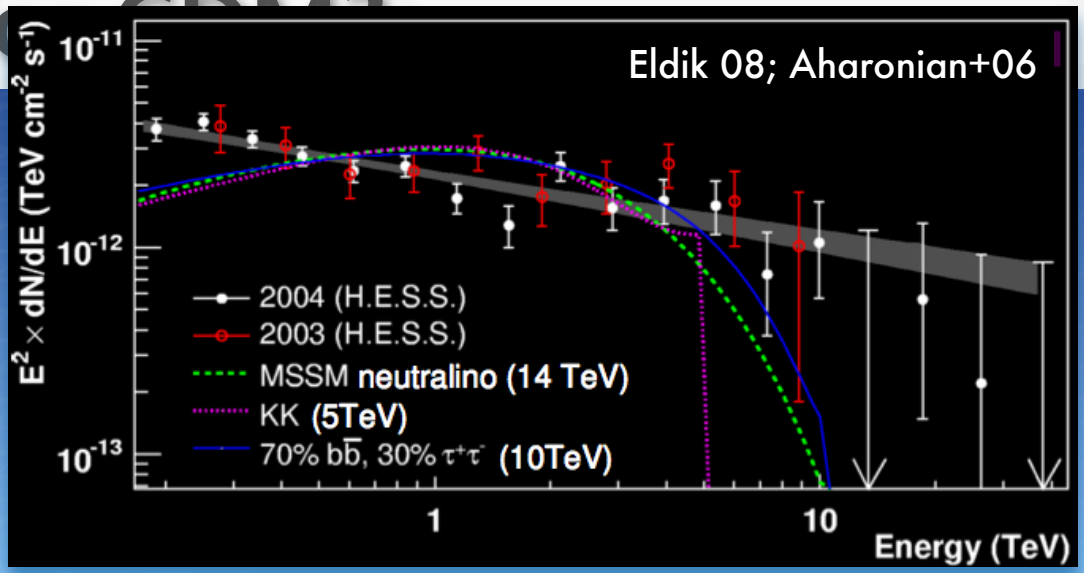

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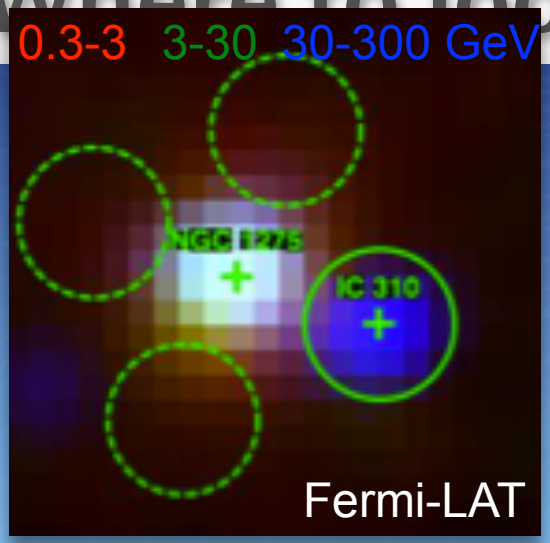

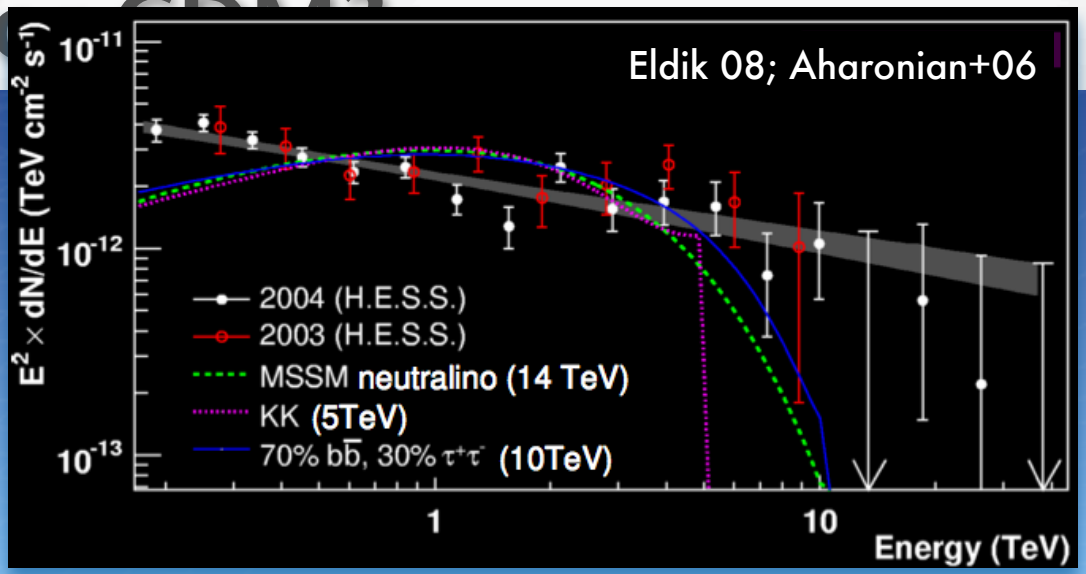

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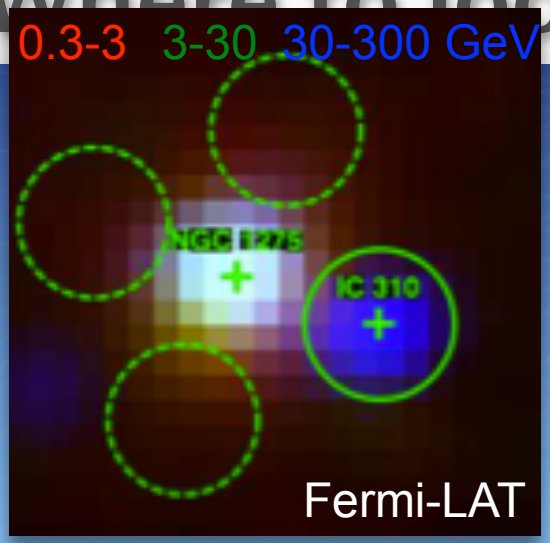

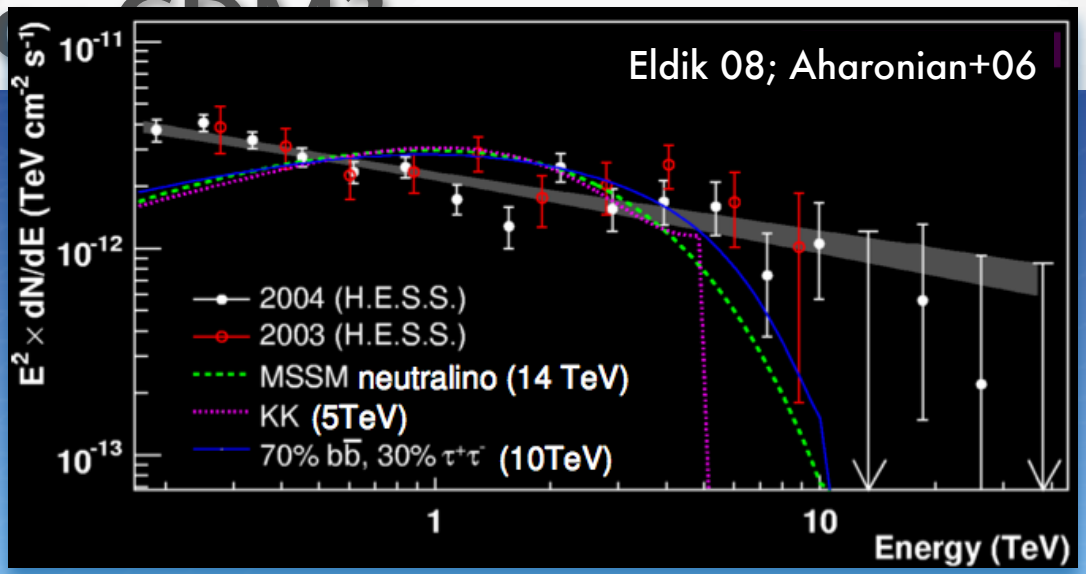

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- Other galaxies, galaxy clusters: expect other VHE sources (Baltz+99)
- Center of Sun, Earth, moon: not observable with IACT
- Spheroidal dwarf galaxies: expect to be rather dim (Dra, Sgr, CMa, Willman 1, ...) (Albert+08a,b; Aharonian+08a,b, Acciari+08)
- Mini-halos, IMBHs, ...: don't know where they are (yet) (none found in H.E.S.S. galactic scan data: Aharonian+08c → limits; neither in Fermi-LAT data)

Where else...?

- Cosmological N-body simulations predict hierarchical and highly clustered state Diemand+08 Springel+08

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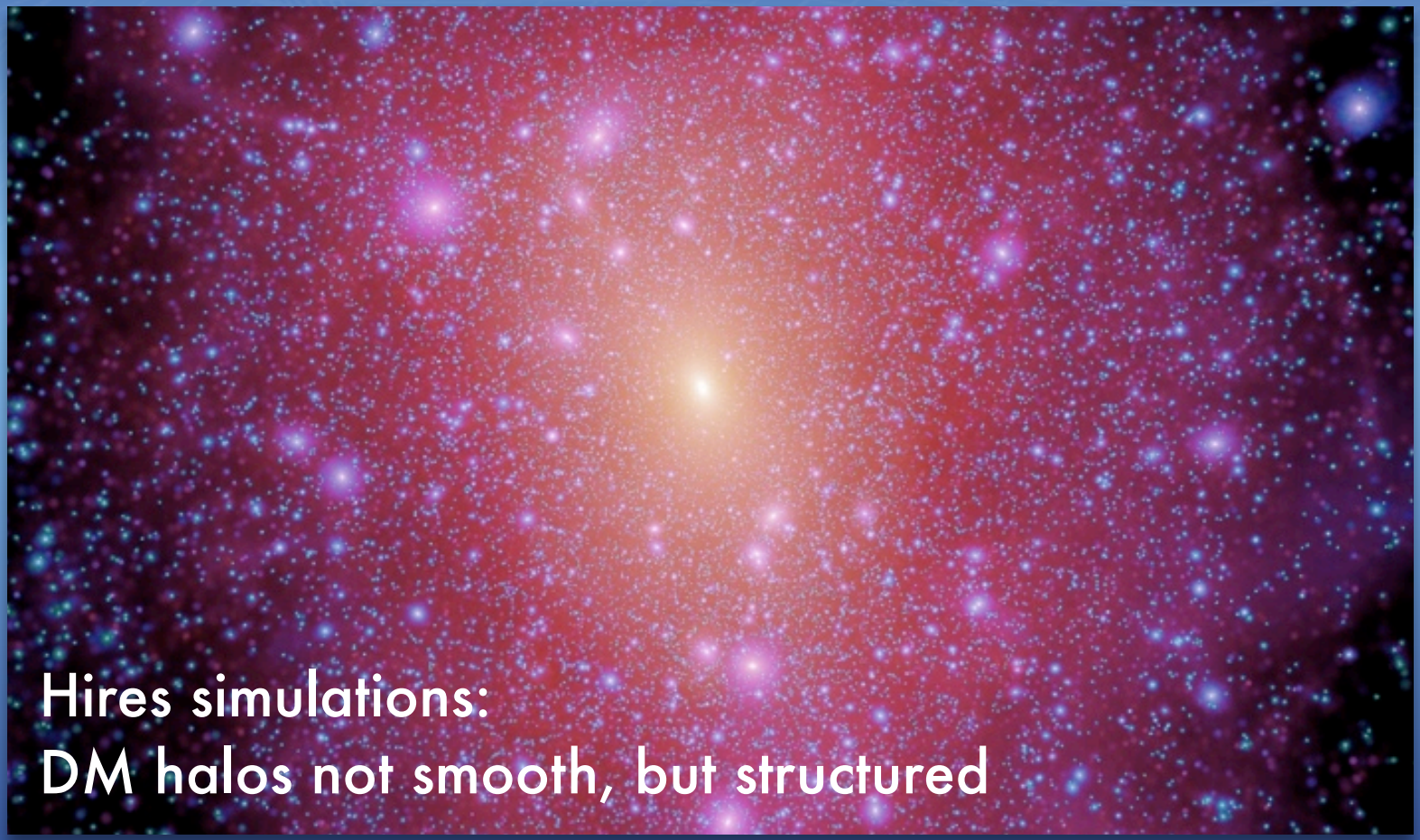


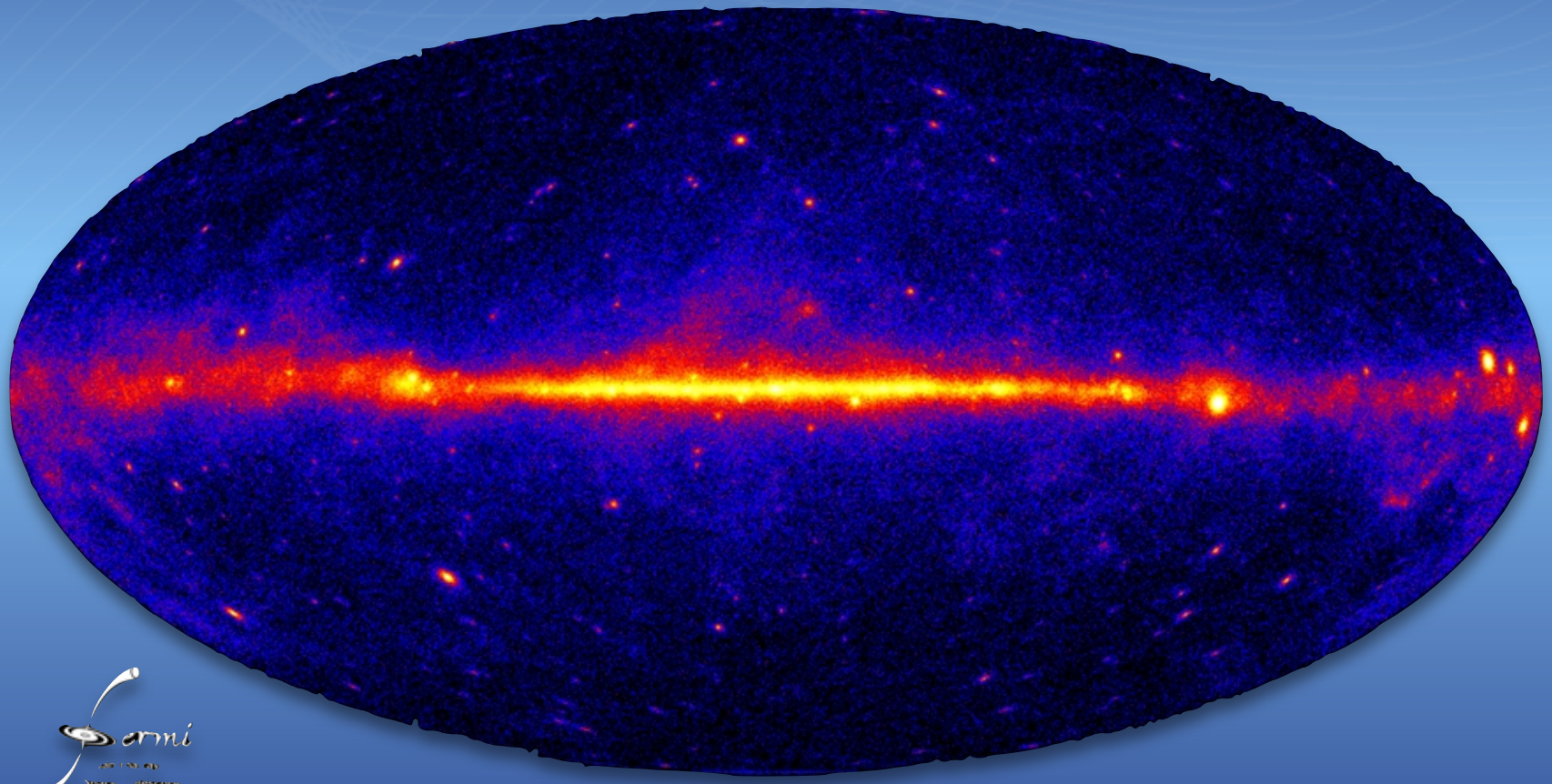
Kuhlen+08
Stadel+08

Subhalo DM structure

- Cosmological N-body simulations predict hierarchical and highly clustered state Diemand+08 Springel+08
- Hires simulations: DM halos not smooth, but structured Kuhlen+08 Stadel+08
- Could be too small to launch star-formation: invisible?
- Close-by and VHE-bright Pieri+08
- DM high density regions around IMBH? Bertone+09
- May only be visible at HE-VHE
- cut-off in Fermi-LAT range ...or beyond
- such hypothetical sources become visible in long-term all-sky monitoring programs

Unidentified Fermi Objects

- Fermi-LAT long-term data ideal dataset
- Emerge as otherwise dark and thus unid sources



1FGL 1452 Sources

Unidentified Fermi Objects

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- Synergy LAT-Cherenkov tels may thus become crucial

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Utilize requirements expected from DM annihilation/decay

- steady, hard sources
- having no obvious counterpart at other wavelengths
- in the accumulated Fermi-LAT data, so, e.g., in the first year Point Source Catalog, 1FGL
- Universal cutoff or signature expected required

Identifying candidates

based on work of MAGIC Astroparticles working group

1. **no association** in the 1FGL, i.e.,
   no γ-ray associations in any of the 1AGL, 3EG, EGR catalogs
   nor any association or identification in any other catalog considered by Fermi

2. certain **distance from the galactic plane**, e.g., $|b| > 10°$

3. **hard spectrum** in Fermi-LAT HE range,e.g., $\Gamma_{1FGL} < 2$

4. **steady**, non-variable source:
   variability index reported in the 1FGL

5. simple power law into VHE domain
   exclude possibility of having a **cutoff** in LAT energy range:
   curvature index below 11 (may want to relax?)

Identifying candidates

6. observational constraints: low minimum zenith angle to warrant low energy threshold of Cherenkov telescope at observational site.

- 2.8% of all 1FGL sources survive these cuts, O(50).
- If one embarks on dedicated searches for counterparts, Nieto&Pardo for MAGIC candidates reduce by a factor 4.
- currently O(<10) in either hemisphere

- Search in major astronomical catalogs (Hearsarc)
- 10' search radius corresponding to LAT PSF at 10 GeV
- XMM-Newton, Rosat, Suzaku, CGRO, Fermi-LAT, Chandra, Swift, WMAP, RXTE, VLA...

- **No requirements for flux strength yet**
- If anticipating deep LAT catalog until CTA comes up, and assuming x10 sensitivity for CTA, we may end up with some ten candidate objects

Summary and Outlook

- Clumpy DM structure offers possibility to look for steady, point-like sources
- "Dark emitters" only reveal themselves in the GeV-TeV regime,
- cutoff expected beyond Fermi's energy range
- Search in extragalactic all-sky dataset

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  overlap with satellite detector Fermi-LAT

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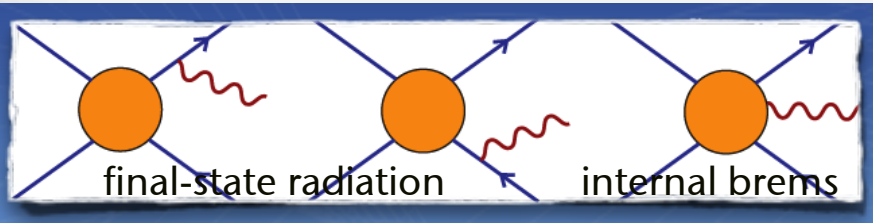
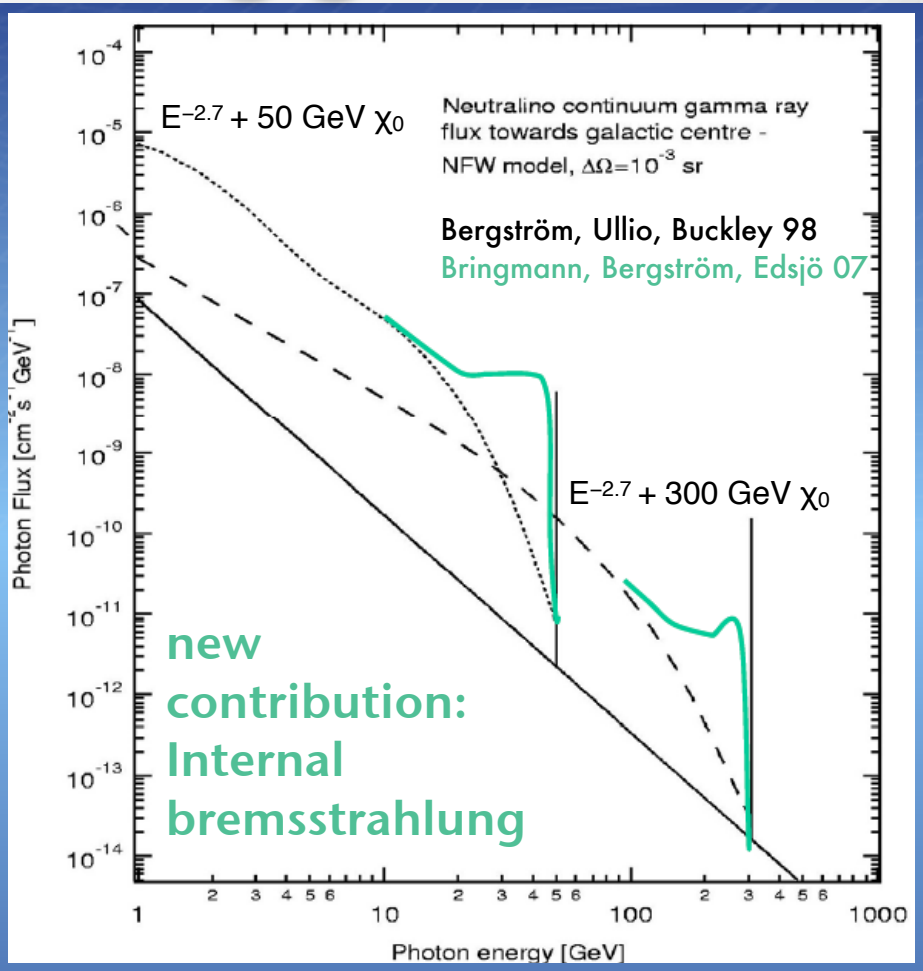
- ***Lowest Cherenkov Telescope Energies Mandatory***
  overlap with satellite detector Fermi-LAT
- Identification of candidate sources in Fermi data
- Imposing various cuts to ensure requirements, foremost
  - non-variability, hard spectrum
- only a handful of sources expected
- a CTA all-sky survey may be as efficient in finding candidates
  - will be studied
- on the bright side: they may be highly interesting irrespective of being DM candidates

Supplementary

The return of the smoking gun

Bringmann, Bergström, Edsjö 08





Good discrimination from usual power laws

IACT prospects: Bringmann, Doro, Fornasa 08

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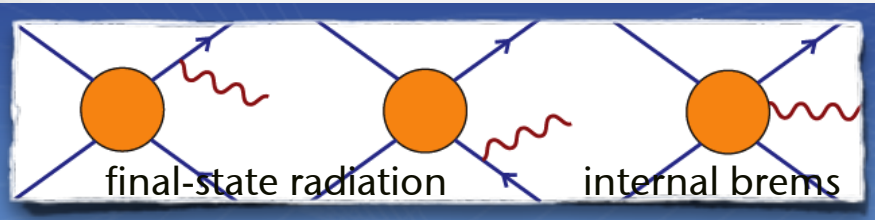
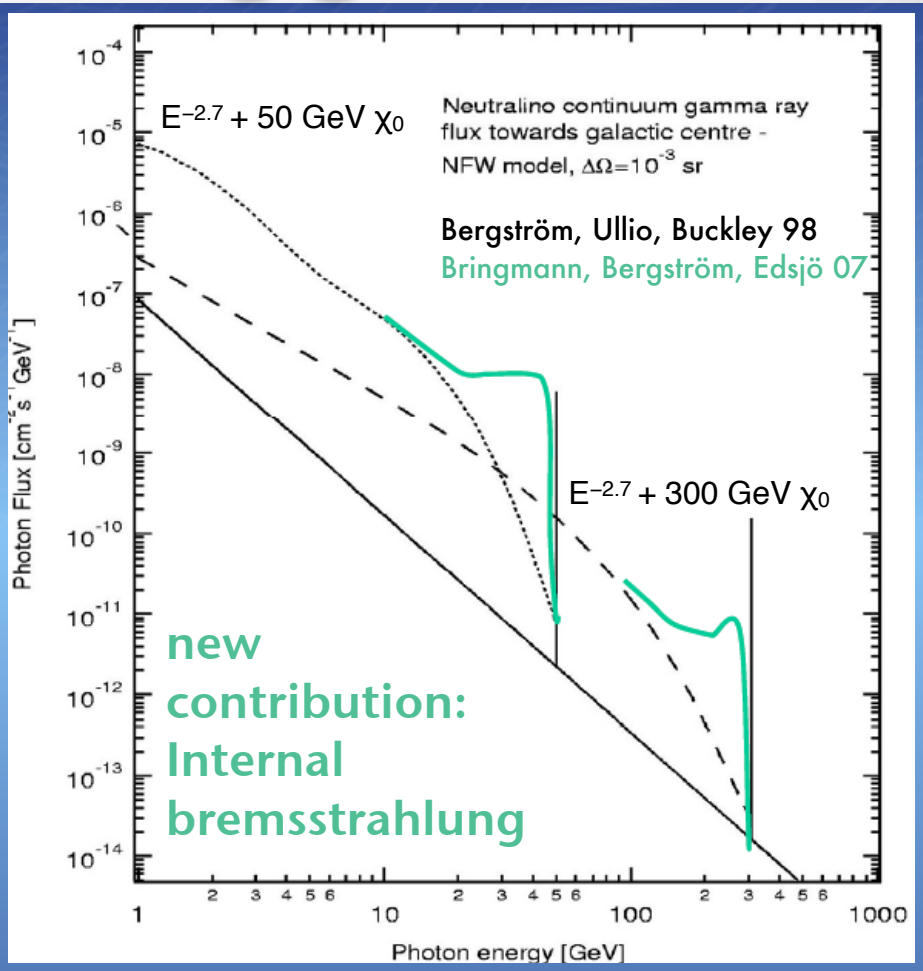


EM radiative corrections to LO annihilation processes:

- Internal bremsstrahlung (QED effect) important
  - ✓ hitherto neglected contribution
  - ✓ additional γ in the final state
  - ✓ much higher cross section $O(10^6)$ as compared to final-state radiation $O(10^{-2})$
  - ✓ dominates close to kinematic cutoff at χ_0 mass; $E>0.5\ m(\chi_0)$
- Effect largely depends on specific χ_0 nature, but:
- Generally pronounced bump close to kinetic cutoff at χ_0 mass



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Latest News

MAGIC Coll., ATel 2510

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MAGIC Stereo

April 2010

IC 310: A Head-Tail Radio Galaxy

NGC 1265, also in the Perseus Cluster; O'Dea & Owen (1998)

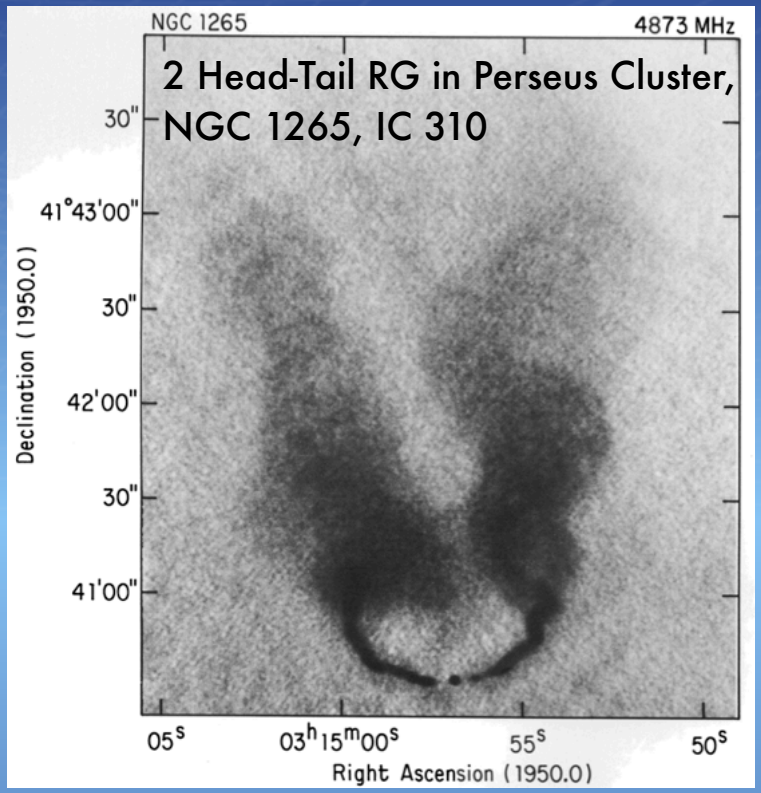
Radio Galaxy IC 310

MAGIC Coll., ATel 2510

- Member of the Perseus Cluster
- ≥6 sigma significance from 38 hrs
- ≈2.3% Crab nebula flux
- **Radio galaxy** at z=0.019
- 22×/5× further away than Cen A, M87
- must be intrinsically much more luminous
- Mechanism?
  - Close to Black Hole
  - at Shocks with Cluster Medium?

- MAGIC Astronomer's Telegram
  (MAGIC Coll, ATel 2510, 2010-03-25)

Publication in Preparation



O'Dea & Owen (1998)

Perseus Cluster

MAGIC Coll., ApJ 710 (2010) 634

- Galaxy clusters: "ecosystem":
  a volume that is a high-density microcosm of the rest of the Universe.
- largest and most massive gravitationally bound structures in the Universe
- galaxies, gas, and dark matter contribute roughly for
  5%, 15% and 80%, respectively
- actively evolving objects, contain large amounts of gas;
  intercluster medium as energy reservoir
- Perseus cluster brightest X-ray cluster, high central gas densities, z=0.018
- NGC 1275, central radio galaxy
- 24.4 hr observation during 2008 November and December.
- Upper limits on the gamma-ray emission (E>100 GeV)
  4.6 to 7.5 x 10^{-12} cm^{-2} s^{-1} (Γ=–1.5 to –2.5)

Perseus Cluster

MAGIC Coll., ApJ 710 (2010) 634

- Upper limits on the gamma-ray emission constraining the emission produced by
  - cosmic rays: CR-to-thermal pressure <4% for cluster core, <8% for entire cluster
  - dark matter annihilation: limit consistent with boost factors of ≈10^4
  - central radio galaxy NGC1275,
    compatible with recent Fermi-LAT detection.
    Extremely large Doppler factors required for the jet one-zone synchrotron self-Compton model is implausible spine-layer model instead