Connections between GeV and TeV gamma-ray observations

Stefan Funk, Erlangen Center for Astroparticle Physics (ECAP)
GeV-TeV connection so far
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Search for direct pair production of a chargino and a neutralino decaying to the 125 GeV Higgs boson in TeV collisions with the ATLAS detector
(2015EPJC...75..208A)
Citations: 10, Reads: 86
GeV-TeV connection so far

TeV Gamma Rays from Geminga and the Origin of the GeV Positron Excess
(2009PhRvL.103e1101Y)
Citations: 253, Reads: 39
GeV-TeV connection so far

GeV/TeV gamma-ray emission from dense molecular clouds overtaken by supernova shells (1994A&A...285..645A)
Citations: 107, Reads: 11
My task (from the SOC)

• We'd very much like you to give a talk on the connections between GeV and TeV astrophysics (i.e. a forward looking talk on what kinds of things we can do with good statistics that comes with more years of Fermi data and new capabilities for the ground based instruments).
New capabilities (IACTs)

4 x 107 m² (since 2003)
1 x 614 m² (since 2012)
New capabilities (HAWC)
... long-term: CTA
The current situation
The overall picture - Spectral studies

Funk 2015
2 FHL (360 sources)

- 51,000 photons $E > 50$ GeV
- 18,000 photons $E > 100$ GeV
- 2,000 photons $E > 500$ GeV

See Talk by M. Ajello
282 2FHL sources not yet detected by IACTs

94 (out of 142) TeVCat sources detected in 2FHL

Ackermann et al. (2015)
2FHL versus TeVCat

- Spectral Index
- $F_{50}$ [ph cm$^{-2}$ s$^{-1}$]
... extrapolated to higher energies

Extrapolated to 200 GeV

100 h H.E.S.S.
30 h H.E.S.S. sensitivity
2FHL & TeVCat

only 2 FHL

Index

log10(F(> 200 GeV)) [ph/cm^2/s]
... extrapolated to higher energies

Extrapolated to 1 TeV

2FHL & TeVCat

only 2 FHL
Detailed spectral and morphological studies > 100 GeV

- Exposure: 170 h
- Angular resolution: 0.05º
- Energy threshold: 250 GeV

Analysis: Model with HiRes cuts (de Naurois & Rolland, 2007)

Suzaku spectral fits performed with naima, see poster by V. Zabalza

Modelling the spectral energy distribution

Fermi-LAT

H.E.S.S.

leptonic model

hadronic model

preliminary

Excess

68% PSF

Energy [eV]
Inferred particle population

- Definitely need a break in the spectrum (thanks to GeV + TeV data)
  - Either protons in "cold clumps"
  - … or significant cooling in a leptonic scenario … infers high magnetic field (70 μG), at odds with the low magnetic field inferred from the synchrotron/IC ratio

H.E.S.S. preliminary
Mapping the magnetic field

The X-ray hotspots

B-field map

H.E.S.S. preliminary
... can start to constrain the physics of sources
HAWC

See Talk by H. Zhou

38σ Crab

180°

Galactic Plane

Galactic

Geminga* - 6σ

Crab Nebula - 38σ

0σ Statistical Significance 6σ
HAWC

Significance Map for 3 years of HAWC observations

a) Fermi Bubbles follow power-law spectrum with $\Gamma = 2$

b) Fermi Bubbles follow power-law spectrum with $\Gamma = 2$ and cutoff at 150 GeV
Mrk 501

• The era of multi-wavelength campaigns
• SSC model can reproduce data (decrease in B-field coinciding with increase in luminosity and hardness of electrons).

Furniss et al. (2015)
Mrk 501

• The era of multi-wavelength campaigns
• SSC model can reproduce data (decrease in B-field coinciding with increase in luminosity and hardness of electrons).

Furniss et al. (2015)
TeV sources without GeV detection

- Absence of GeV emission from distant blazars: constraints on intergalactic magnetic field

  e.g. Finke et al., 2015
TeV sources without GeV detection

- Absence of GeV emission from distant blazars: constraints on intergalactic magnetic field

![Graph showing IGMF strength vs. IGMF coherence length](image)

Significance with which a pair of values can be ruled out

E.g. Finke et al., 2015
GeV sources without TeV detection

e.g. MAGIC observations of Novae

- total power of accelerated protons must be \( \leq 15\% \) of the total power of accelerated electrons.

Ahnen et al. (2015)
Non-detections
The future
CTA - the future

• Core science program in the first years in KSPs
  • Surveys:
    • Galactic
    • Extragalactic (1/4 sky)
    • LMC
  • Fundamental physics (DM)
  • Individual classes
    • AGN
    • Galaxy clusters
    • Star-forming systems
    • Pevatrons
Galactic Plane Survey

- Will clearly run into some of the same difficulties Fermi-LAT is facing (source confusion, some level of diffuse emission, ...)
- Will provide a trove of data for joint GeV/TeV studies
The extragalactic survey

See Talk by M. Di Mauro

- Source density: $\sim 0.02 \text{ deg}^{-1}$
- $\sim 800$ sources all over the sky

CTA Sensitivity

Ackermann et al. 2015 (1511.00693)
Spectral studies

e.g. PKS 2155-304

log (v F_v [erg cm^2 s^{-1}])

100 GeV

log (v [Hz])

CTA

SSC

proton synchrotron

muon synchrotron

synch from sec. pairs from pi0 decay

sum of hadronic components

synch from sec. pairs from pi+ decay
Boosting the time domain $> 25$ GeV

Funk & Hinton (2013)
Example: CTA observations of Crab Nebula Flares
Probing extreme environments

- Simulated CTA lightcurve for 2006 flare of PKS 2155-304

Sol et al. (2013)
Fermi-LAT and its impact on TeV instruments

• Extremely powerful mission for every aspect of TeV science
  • Spectral response > 50 GeV (background free)
  • Variability alerts
  • Interpretation of scientific results
• Still lots to come …