γ-ray/X-ray flux correlations in the BL Lac Mrk 421 using HAWC data

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Overview

● X-ray/\gamma-\textit{ray} correlation in blazars
● Leptonic Vs Hadronic models
● Mrk 421
  ○ HAWC LC
● X-ray/\gamma-\textit{ray} correlation for Mrk 421
  ○ data from 2014-11-26 to 2018-12-04
● Conclusions
HAWC operating since March 2015

Sky Survey

Instantaneous f.o.v. of 2sr

Extended sources (>1-2°)

Sources of the highest energies (>10 TeV)

Transient/variable sources

Long term monitoring
X-ray & gamma-ray correlation in blazars

● Electron Synchrotron emission is believed to be responsible of X-ray emission from blazars.
  ○ Low synchrotron peaked blazars
  ○ Intermediate synchrotron peaked blazars
  ○ High synchrotron peaked blazars

● For gamma-ray emission we have Inverse Compton (IC):
  ○ Energy is transferred to the photons $\gamma_e >> 1$
  ○ This scatters up the photon to higher energies.
  ○ The scattering can be made by $e^-/e^+$ and $p$

● Synchrotron self-compton (SSC)
  ○ The seeds photons of the IC scattering come from the synchrotron emission
  ○ These photos are up-scattered to higher energies by the same population of electrons which has produced them.
Leptonic Vs Hadronic models

- **Leptonic**
  - High energy component of SED
    - Synchrotron self-compton
      - One-zone, multi-zone SSC model
    - External compton
      - Seed photons comes from accretion disk (UV) and reflects in the BLR (Sikora et al. 1994)
      - If radiation originates from a largest distance, seed photons might come from dusty torus (DT), (Sikora et al. 2002)
Leptonic Vs Hadronic models

• Hadronic
  – High energy component of SED
    • Synchrotron proton blazar (SPB)
      – synchrotron radiation of relativistic protons and muons
    • Photo-meson production with subsequent synchrotron-pair cascading
Leptonic Vs Hadronic models

IC (SSC) model
High-energy peak

\( e^- \) Synchrotron radiation
Low-energy peak
(radio to optical/UV)

Synchrotron proton model
High-energy peak

Abdo et al. 2011
Jet power is larger for hadronic than for leptonic

Correlation possible
TeV gamma-rays and X-rays
Small magnetic field (< 100 mGauss)
No neutrino production

Correlation not straightforward
TeV gamma-ray and X-ray
Large magnetic field (50 Gauss)
Neutrino production
Mrk 421

- One of the closest (z = 0.03) and brightest blazars
- Emits at TeV energies
- Multiple dedicated observation campaigns
- Understanding correlation is very important
- Previous studies have shown evidence of positive correlation between X-ray and gamma-ray bands

- There is evidence that supports leptonic models
  - One-zone
  - Multi-zone

- Other scenarios still being studied
  - Hadronic
  - Lepto-Hadronic
Mrk 421 LC using HAWC data

- Flux measured in 1 transit/sidereal day
  - Data from Nov, 2014 to Dec 2018
  - Including days with coverage > 50% transit
  - Source transit of ~ 6 hr will be used to average X-ray data from SWIFT-XRT

- Other works related with Mrk 421 data from HAWC
  - NU6h (Mukharbek)
  - #PS2-52 (Coutiño)
X-ray/γ-ray correlation

- X-ray averaged within HAWC transit of ~ 6hr
  - Quasi-simultaneous data
- Very strong linear correlation
  - Consistent with leptonic scenario
  - Shows linear trend
- Hadronic component has not been excluded
  - γ-ray flux uncertainty is large, hard to extract possible higher order correlation
- Interpretation of results assumes one-zone SSC model

Conclusions

- We measured a strong X-ray/\(\gamma\)-ray correlation for Mrk 421
  - Consistent with leptonic model
  - Consistent with linear correlation
- Higher order correlation
  - Hadronic components?
  - HAWC data has large uncertainties but we can further investigate
- Further studies
  - Bayesian Blocks
    - Variability
    - High activity states
      - Harder when brighter?