Investigating the Nature of Flat-Spectrum Radio Quasars
3C 279 and PKS 1222+216

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Outline

I. High Energy Astronomy
   A. Types
   B. Detection

II. Sources
   A. Active Galactic Nuclei
   B. Flat-Spectrum Radio
      Quasars
         1. Leptonic Model
         2. Hadronic Model

III. Scientific Motivation
   A. Extragalactic Background Light
   B. Previous Investigation

IV. My Research
   A. Data Collection
   B. Analysis
   C. Results
High-Very High Energy Astronomy

- Opacity problem
- Detection:
  - Direct methods
  - Indirect methods

Image: NASA
Direct: The Neil Gehrels Swift Observatory and Fermi-LAT

- **X-Ray Telescope**: 0.2-10 keV
- **Burst Alert Telescope**: 15-150 keV
- **UV/Optical Telescope**: 170 - 650 nm
Direct: Fermi Large Area Telescope

- Detects energies of pair produced particles

20 MeV - 300 GeV
Indirect: VERITAS

- Cherenkov Light
- Optical PMT detectors
- Telescope array for direction

Images: CTA, VERITAS
Sources: Active Galactic Nuclei

- Composition
  - SMBH
  - Accretion Disk
  - Astrophysical Jet
- Variable
- Subclassification

Image: NASA
Blazars

- Small angle
- FSRQs
  - Qualities
  - Problems
Blazars

- Small angle
- FSRQs
  - Qualities
  - Problems
FSRQ Modelling

Image: Bottacini et. al.
Leptonic Model

Electron Synchrotron Radiation

Image: physics.byu.edu
Leptonic Model

Inverse Compton Scattering: External Compton and Synchrotron Self Compton

Electron Synchrotron Radiation
Lepto-hadronic Model

Electron Synchrotron Radiation
Lepto-hadronic Model

Electron Synchrotron Radiation

Hadronic Processes
Extragalactic Background Light

- Cosmic Optical BG + Cosmic Infrared BG
- Light from galaxies and star forming systems
- Interaction with gamma rays

\[ \gamma + \gamma = e^- + e^+ \]

Image: Dole et. al.
Extragalactic Background Light

- FSRQs as tools to constrain EBL

Image: Dole et. al.
3C 279
\[ z = 0.536 \]

PKS 1222+216
\[ Z = 0.434 \]

(Simbad images)
3C 279

PKS 1222+216

VERITAS: VHE upper limits (TeV range) ; Fermi-LAT: VHE (GeV range)
### 3C 279

<table>
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<th>Instrument</th>
<th>Energy Range</th>
<th>Date Range</th>
<th>Exposure (ks)</th>
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### PKS 1222+216

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Swift-XRT

- XSelect and XSpec
- Deabsorb neutral hydrogen
- Modelling
  - 3C 279
  - PKS 1222+216
Swift-XRT

3C 279 Power Law

- XSelect and XSpec
- Deabsorb neutral hydrogen
- Modeling
  - 3C 279
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Swift-XRT

3C 279 Power Law

- XSelect and XSpec
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\[
\frac{dN}{dE} = K \left( \frac{E}{1 \text{ keV}} \right)^{-\alpha}
\]

K : normalization
E : energy
\(\alpha\) : photon index
Swift-XRT

PKS 1222+216 Broken Power Law

- XSelect and XSpec
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Swift-XRT

PKS 1222+216 Broken Power Law

\[
\frac{dN}{dE} = \begin{cases} 
KE^{-\alpha_1} & \text{if } E \leq E_{\text{break}} \\
K(E_{\text{break}})^{\alpha_2-\alpha_1}(\frac{E}{1 \text{ keV}})^{-\alpha_2} & \text{if } E > E_{\text{break}}
\end{cases}
\]

- XSelect and XSpec
- Deabsorb neutral hydrogen
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K : normalization

\(E_{\text{break}}\) : breaking energy

\(E\) : energy

\(\alpha_1\) : photon index for \(E \leq E_{\text{break}}\)

\(\alpha_2\) : photon index for \(E > E_{\text{break}}\)
Swift-UVOT

- Analysis tools from VERITAS collaborator (Karlen Shahinyan, University of Minnesota)
  - Combined observations by filter
- Dust Absorption
Archival Data

3C 279

PKS 1222+216

- Important to remember: unconstrained
3C279 Broadband SEDs with Archival Data (Jan 2014, Apr 2014, Jun 2015)
PKS 1222+216 SED and Modeling

Modeling: Qi Feng
Summary and Outlook

● Benefits of building broadband SEDs for FSRQs
  ○ Learning about the characteristics of the source
  ○ Constraining the EBL model

● Broadband SEDs disfavor one zone SSC model

● Next Steps:
  ○ Modeling using external Compton