"The long-term broadband monitoring of the high-peaked BL Lac **Mrk 501** in **2014** including **the most extreme X-ray flaring activity**"

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AGN

Characteristics

- SMBH (10⁶-10¹⁰M \odot) at the center
- Brightest persistent objects in Universe
- Some have jets (Mpc scale at the largest)
- Some have absorption lines (BLR, NLR)
- Variable emission

Many key questions for Jet remain open:

- Launching engine, evolution and energetics
- Magnetic field (shape and strength),
- Particle acceleration (shocks? turbulence? reconnection?)
- Location of high-energy emission
- What produces variability on various timescales ?
 (years down to minutes in X rays to VHE gamma rays)

Mrk501 (source being investigated)

- Second extragalactic source discovered at TeV (Quinn et al 1996)

- It is a BL Lac blazar(jet pointing to us, and no BLR)



Pictorial description of an AGN Image Credit: C.M.Urry & P. Padovani

AGN classification



Mrk501 is an excellent candidate to study blazar physics

Bright — Easy to detect in short observations (<0.5 hour)

z ~ 0.03 — Small impact of EBL, and possible to perform morphology studies with radio instruments

No BLR — Easier to study than the powerful FSRQs

Challenges in studying Mrk501 (and blazars in general)



- <u>Because of broadband emission:</u>
 Need many instruments to cover many decades of energy range
- <u>Because of source variability:</u>
 Need simultaneous observations

Window for gamma ray opened just ~10years ago!

MWL observation of Mrk501 in 2014

Only some instruments shown

 \rightarrow Observations being reduced (i.e. VERITAS)



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Highest X-ray flux in 10 years of Swift operation!

VHE Gamma ray Variability also high during the high-X-ray activity period

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July 2014, period with historical highest X-ray flux



we can make broadband SED with simultaneous data (within ~2 hours) for essentially every single day.

Variability in 2014



$$F_{
m var} = \sqrt{rac{S^2 - \left<\sigma_{
m err}^2
ight>}{\left< F_\gamma \right>^2}}$$

Vaughan et al. (2003)

 $\begin{array}{l} S:= \mbox{ standard deviation of the points} \\ <\!\!\sigma_{\mbox{err}}^2\!\!>:=\!\!\mbox{mean of squared error} \\ & \mbox{ of the points} \\ <\!\!\!F_{\gamma}\!\!>:=\!\!\mbox{mean of flux} \end{array}$

- **Double bump structure** Similar to broadband SED

- Sharp increase in Fvar with Energy for X-rays and Gamma-rays

Highest variability in X-rays and VHE gamma rays

Important to investigate correlation

Compared to other years





- Very high variability in X and VHE

Typically, Fvar_VHE > Fvar_X
 although Fvar_X changes in time

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Variability of Mrk501 and Mrk421



- Lower F_{var} in optical band
- Higher dependence on E in the F_{var} in X-ray range
- Higher F_{var} in VHE gamma (and F_{var} _HE > F_{var} _X)

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Correlations among energy ranges

VHE gamma(<1TeV) to X



Clear correlation between Xrays and VHE gamma Within 0.2 days → Expected from leptonic scenarios

Relation between X-ray and VHE gamma rays change quickly with the energy band --> Important for source dynamics, work in progress...

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conclusions

- Mrk 501 is an excellent target to study **blazar physics** (bright, nearby, and no BLR)

- MW campaign in 2014 provides exquisite dataset for detail investigations of multi-band flux variability and correlation

- Light curve etc. are still preliminary. Further analysis needed.

- Historial maximum of the X-ray emission during the 10+ years of Swift-XRT operation.

Double bump structure in variability vs energy
 ->highest in X-rays and VHE gamma rays

- Strong correlation of flux between X-rays and VHE-gamma rays

Possibility to study

- Correlations over 3bands in X-rays and 2-bands in VHE gamma rays
- Spectral analysis with broadband SEDs every 1-2 days
- Comparison with another archetypical TeV blazar "Mrk421"

(Variability pattern already gives fundamental difference!)

—> Work in progress. Stay tuned !!

Consistent with emission within leptonic scenarios

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BACK UP

Correlation (DCF)

$$UDCF_{ij} = \frac{(a_i - \bar{a})(b_j - \bar{b})}{\sqrt{(\sigma_a^2 - e_a^2)(\sigma_b^2 - e_b^2)}}$$
$$DCF(\tau) = \frac{1}{M} UDCF_{ij}$$

Discrete Correlation Functions(DCF)

(M:= the number of discrete pairs)

Edelson & Krolik (1988)



Variability of Mrk501 and Mrk421





- Lower variability in optical band

- Higher in VHE gamma than X

Y. Inoue, LST meeting in Jan '14

Blazar SED Sequence



Two peaks

- Synchrotron
- Inverse Compton

BLLAC• Luminous blazars tend to have lower peak energies (Fossati+'98, Kubo+'98)