Broadband characterization and physical implications from the most extreme X-ray flaring activity of the high-peaked BL Lac **Mrk 501**

Josefa Becerra González
on behalf of MAGIC, FACT, Fermi-LAT collaborations and MWL collaborators
NASA Goddard Space Flight Center
University of Maryland
Instituto de Astrofísica de Canarias
josefa.becerra@nasa.gov

co-Is: D. Paneque, K. Noda, K. Ishio, F. Tavecchio

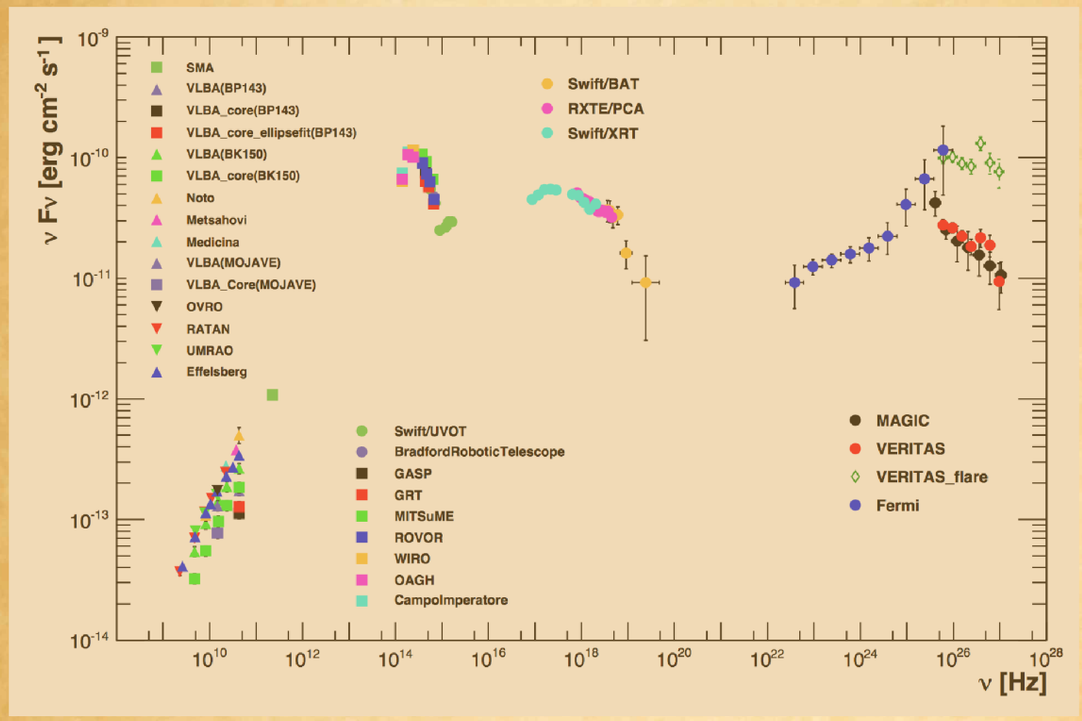
MWL Collaborators: E. Linfors, J. McEnery, M. Perri ++

WANTED

MRK 501

FLARING OR QUIESCENT

FOR JETS AND EBL STUDIES



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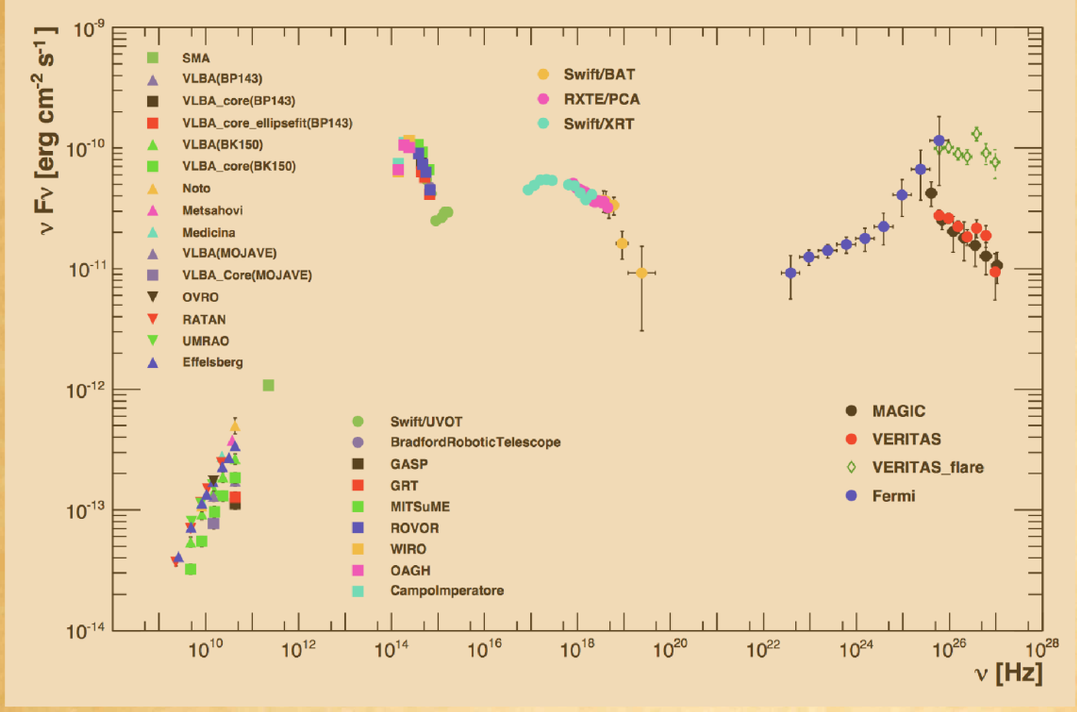

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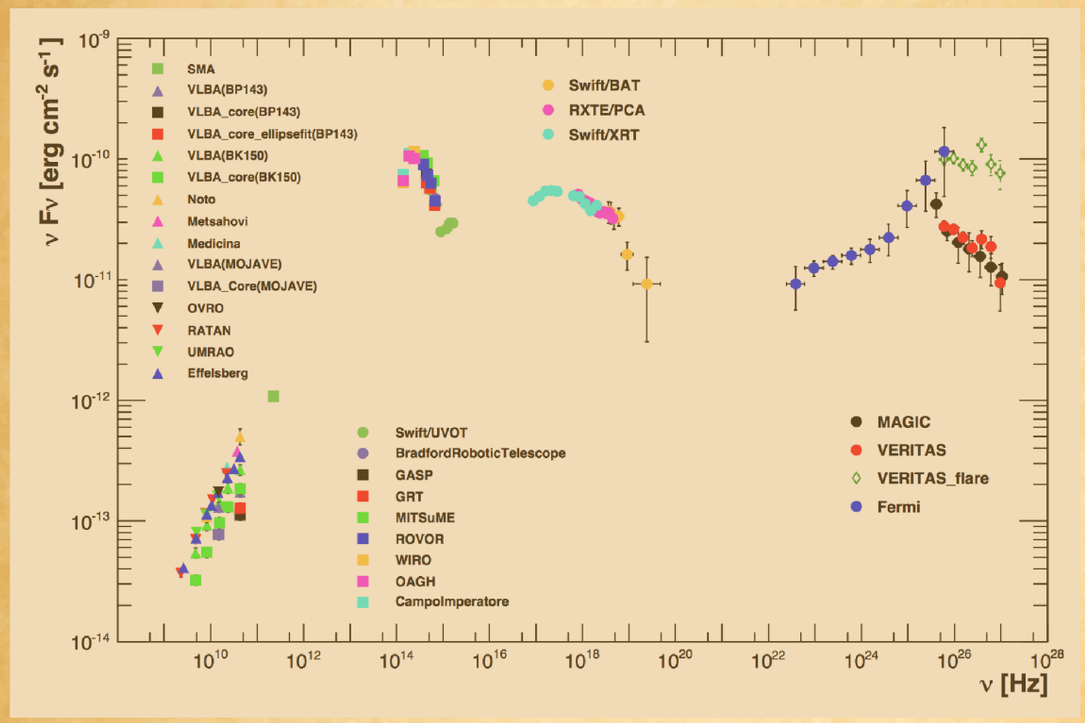

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Its persistent TeV emission during flaring and quiescent phases makes this blazar an excellent candidate for detailed multi-wavelength studies

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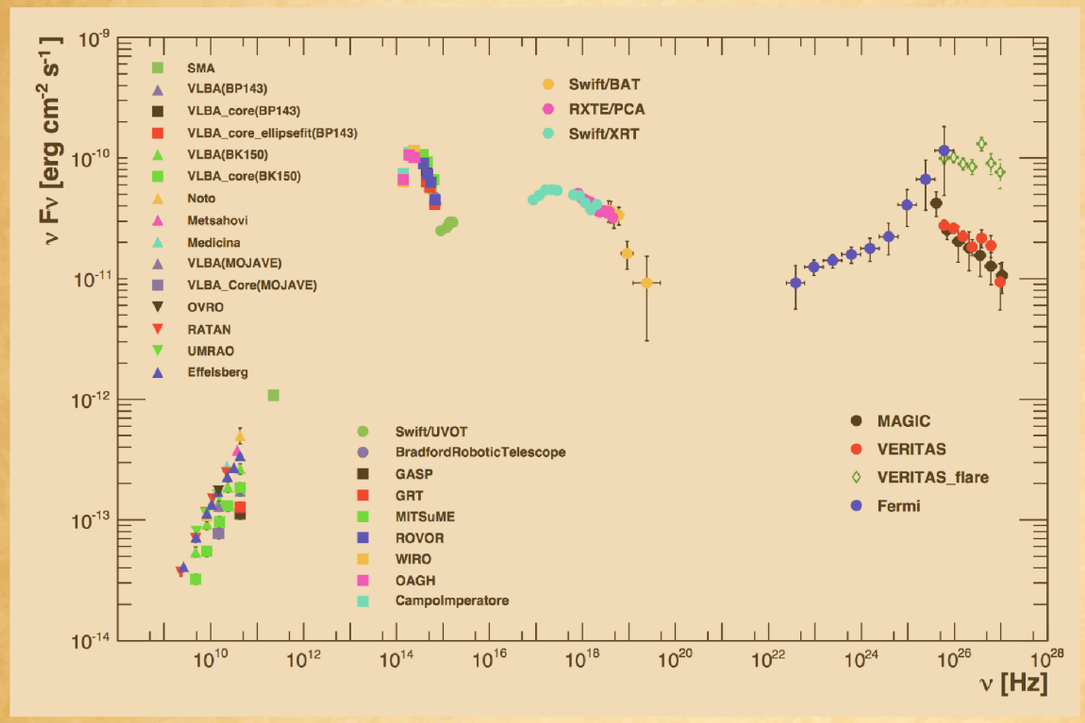

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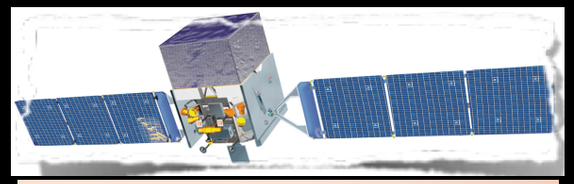

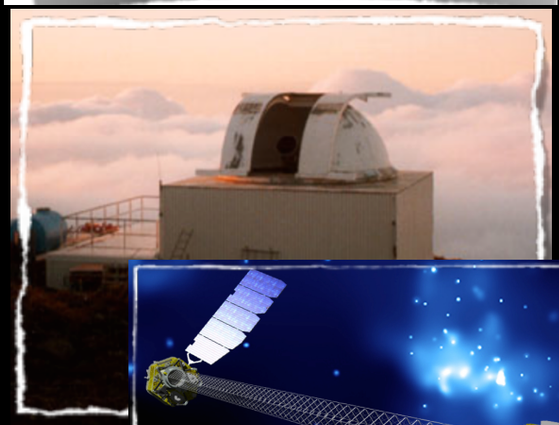
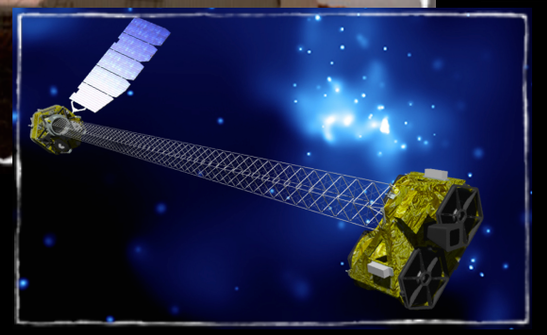


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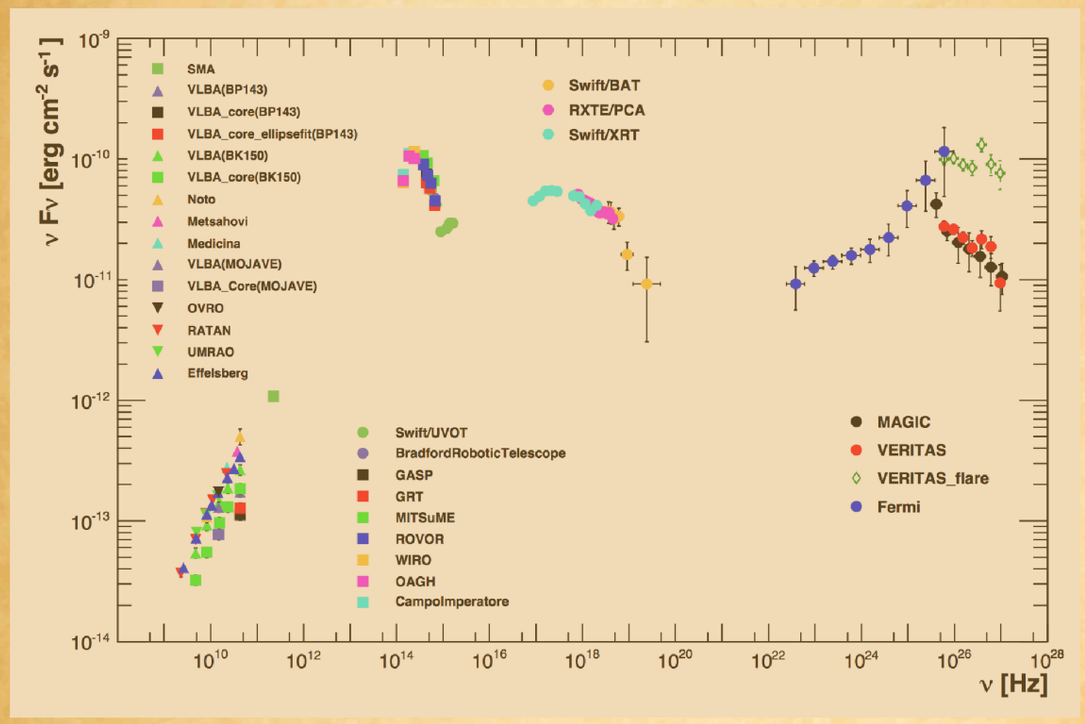

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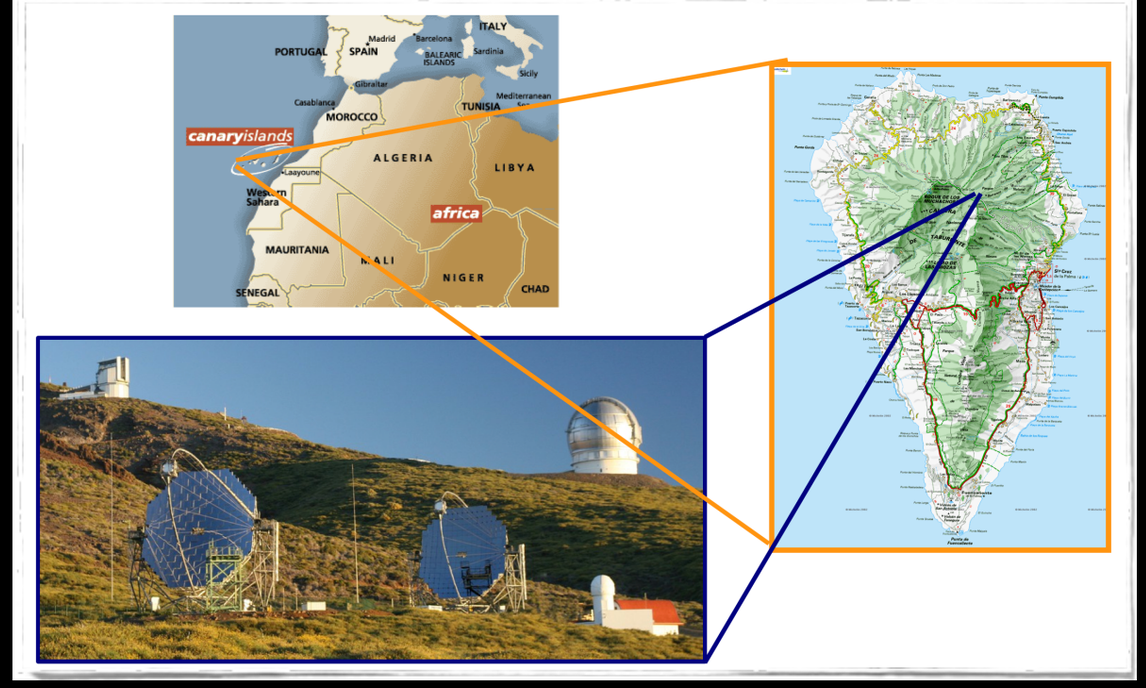
MAGIC telescopes



Energy threshold
E>50 GeV

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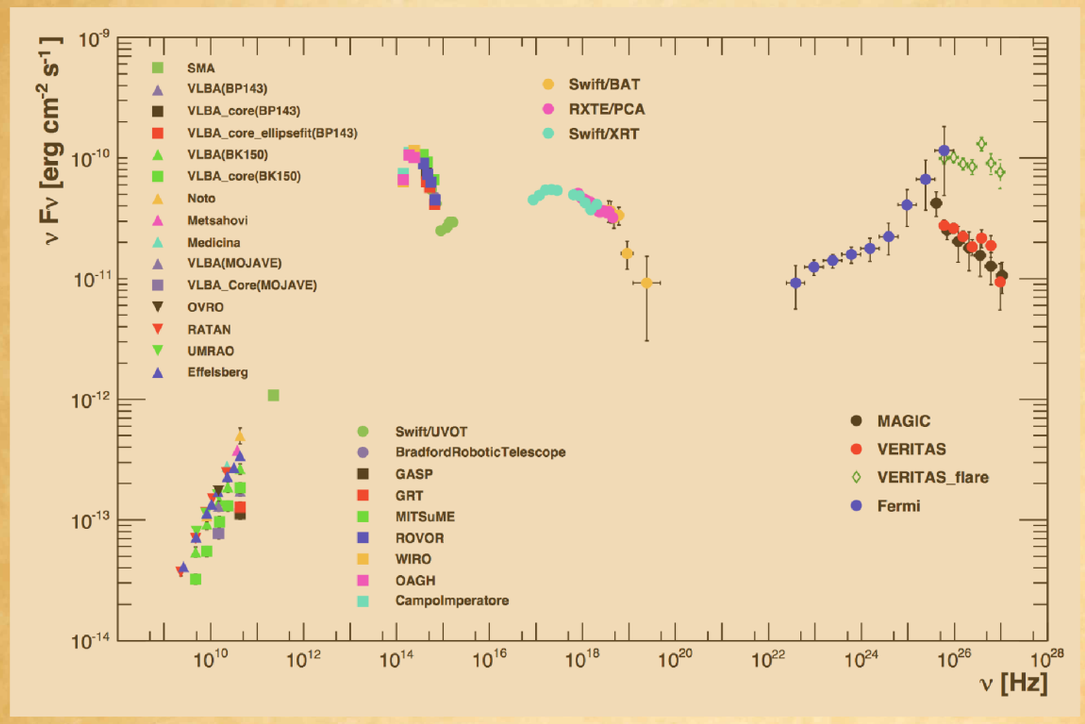

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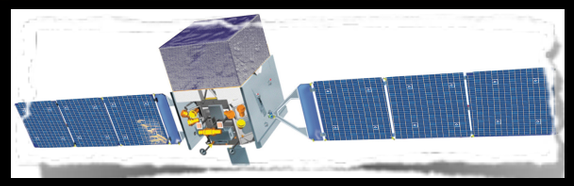

Multi-wavelength (MWL) variability in different timescales up to minutes. Extensive MWL campaigns are organized including radio to gamma-ray observations.

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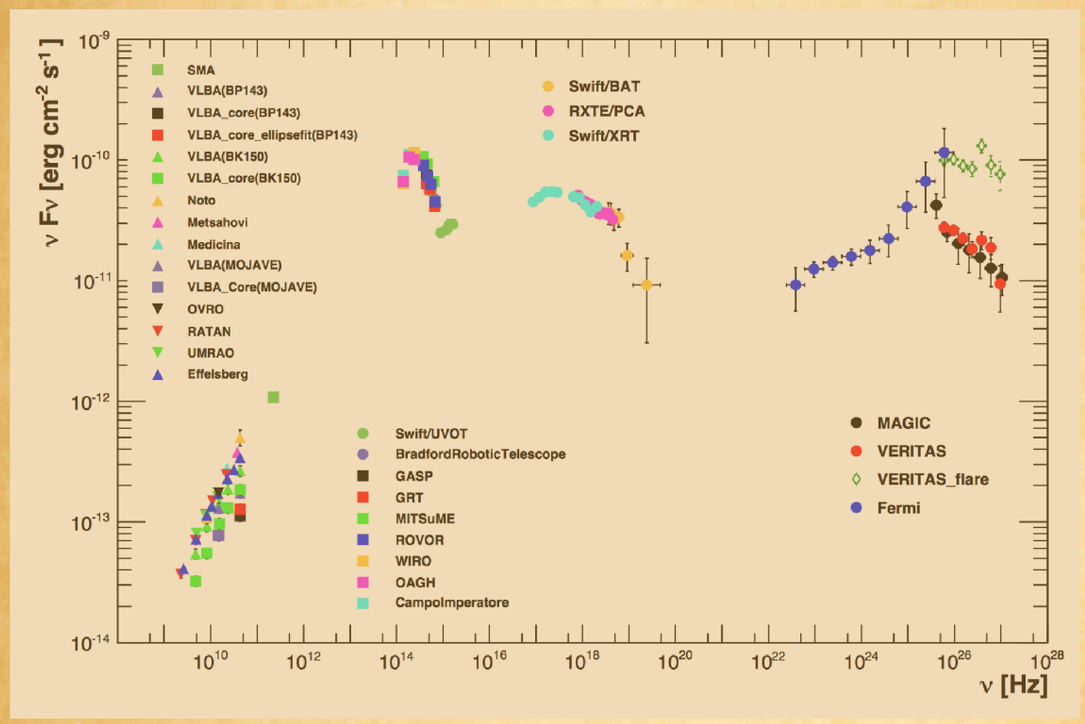

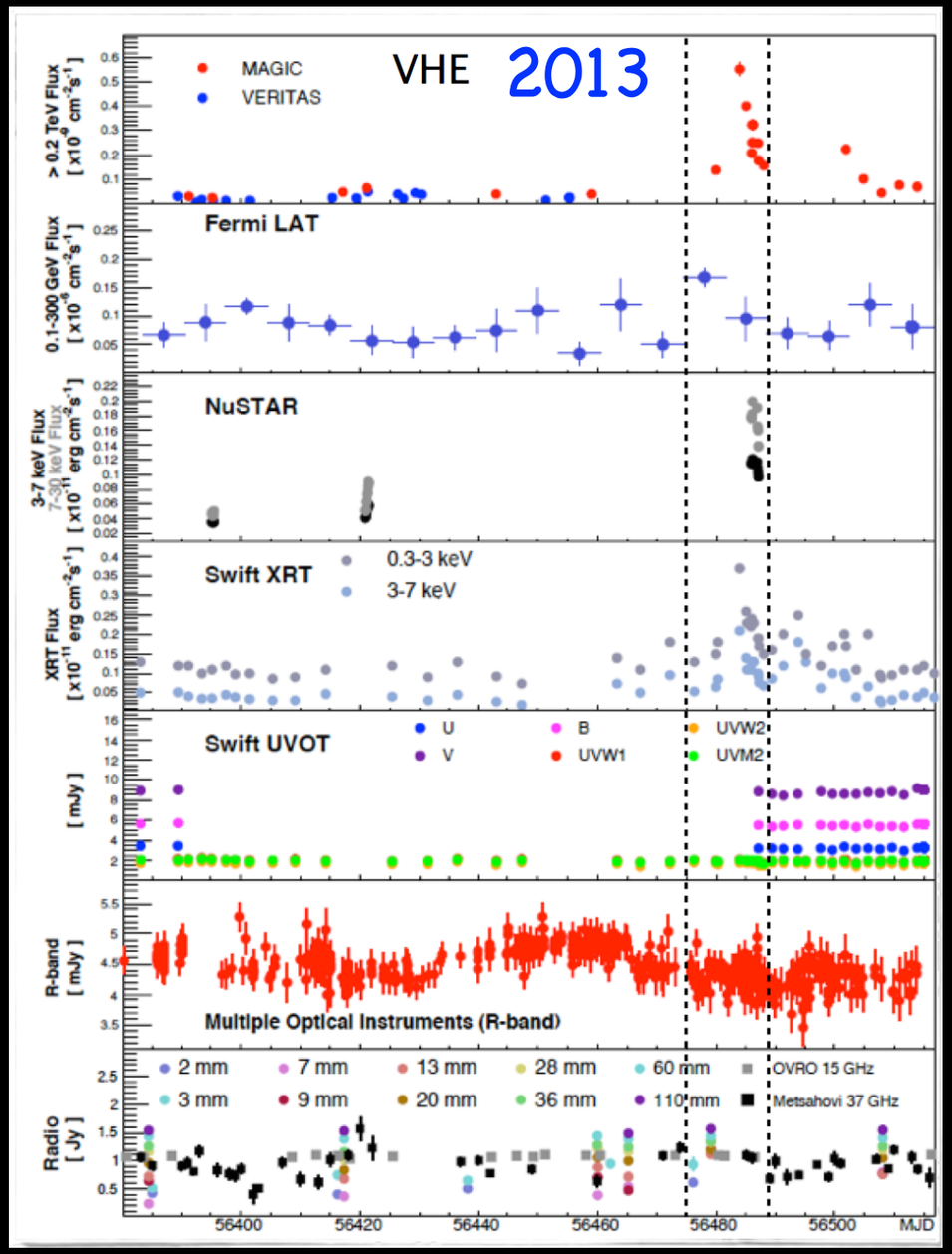

Furnis et al., 2015, ApJ **812,** 65

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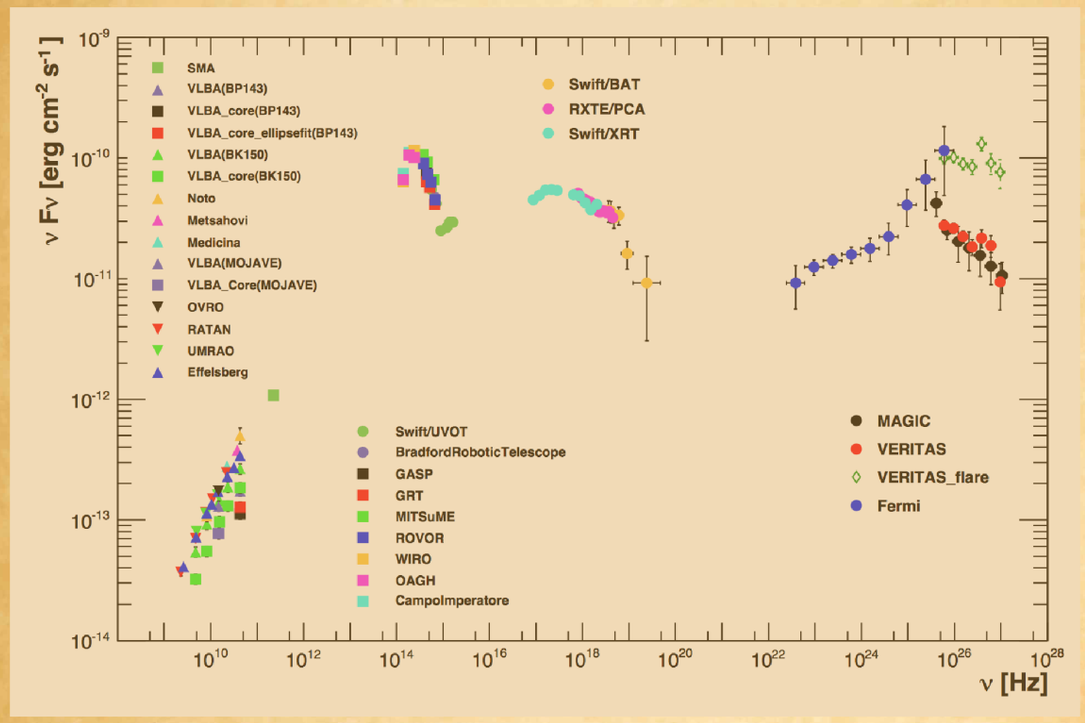

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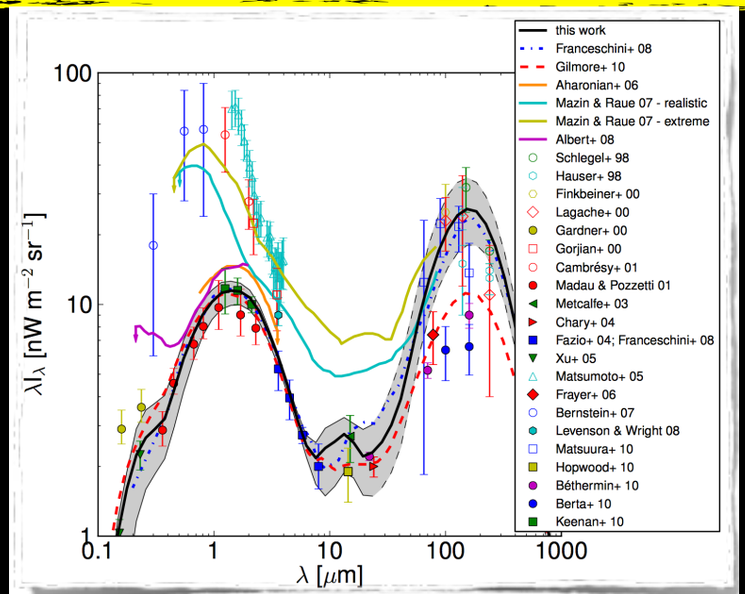
Mrk 501:
high-peaked BL Lac at z=0.03
a famous TeV emitter

Its persistent TeV emission during flaring and quiescent phases makes this blazar an excellent candidate for detailed multi-wavelength studies

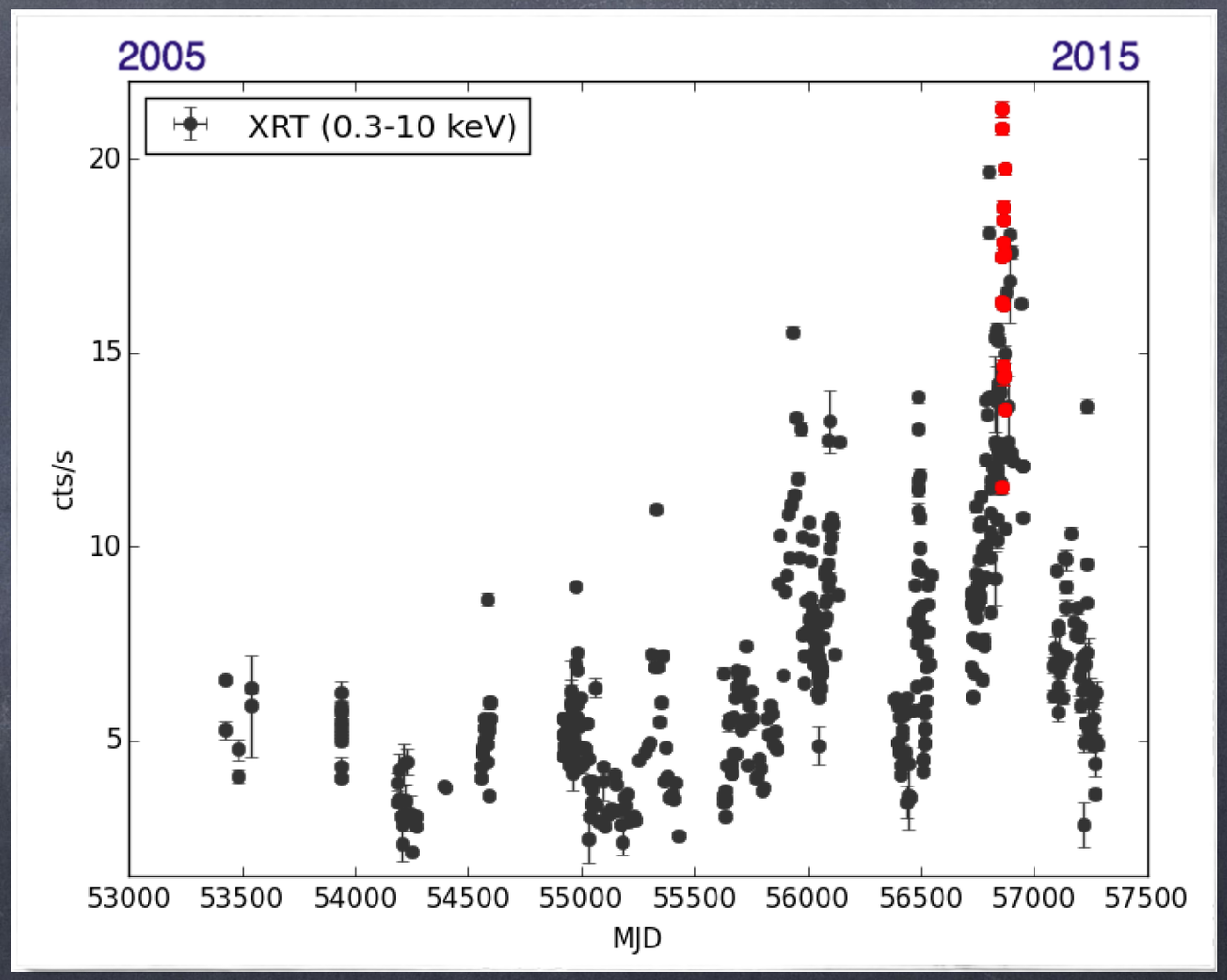
Mrk 501 and Mrk 421 (the closest TeV blazar) have been detected up to few tens of TeV during extreme flares which allow us to probe the extragalactic background light (EBL) up to higher wavelength than any other known TeV blazar



Extreme X-ray flaring activity in 2014

Outstanding X-ray activity during one of our MWL campaigns, in July 2014.

Largest X-ray flux detected by Swift-XRT in 11 years of operation.



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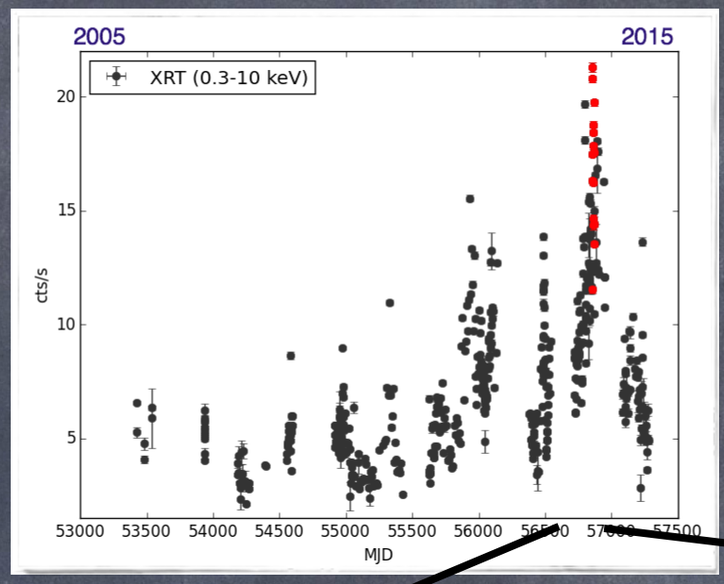
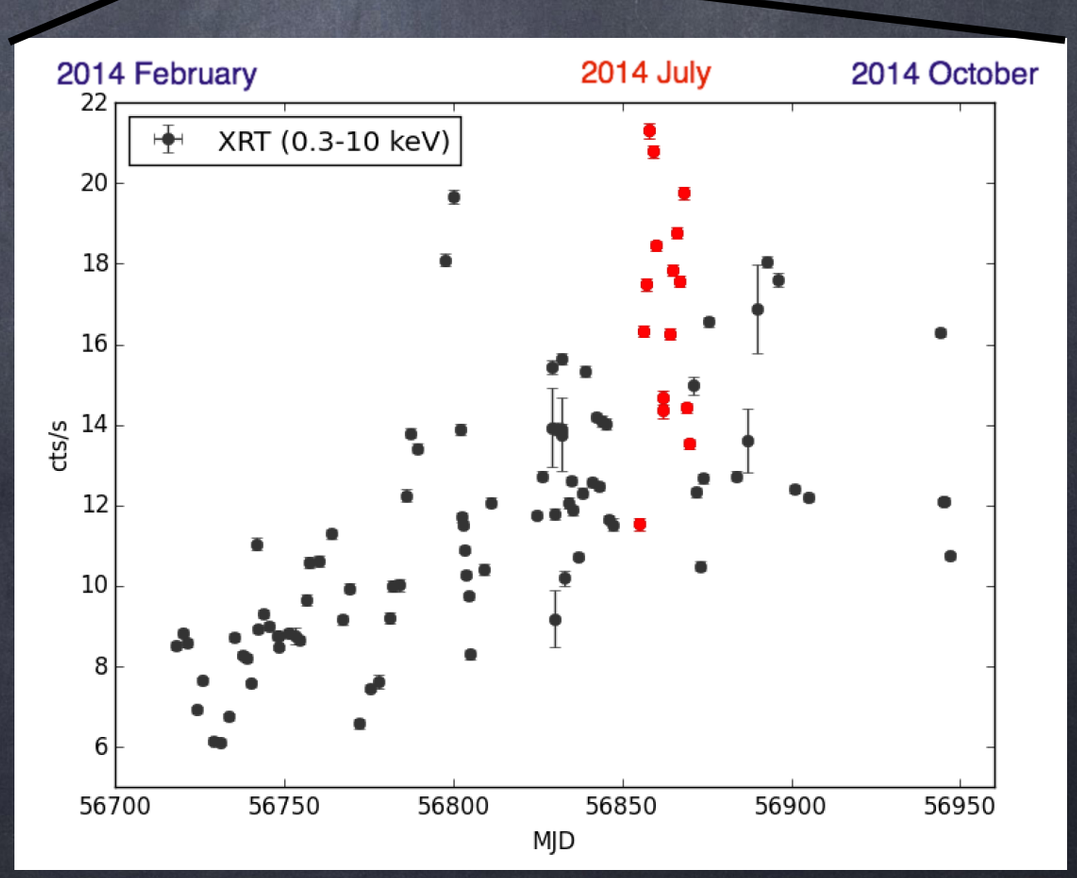
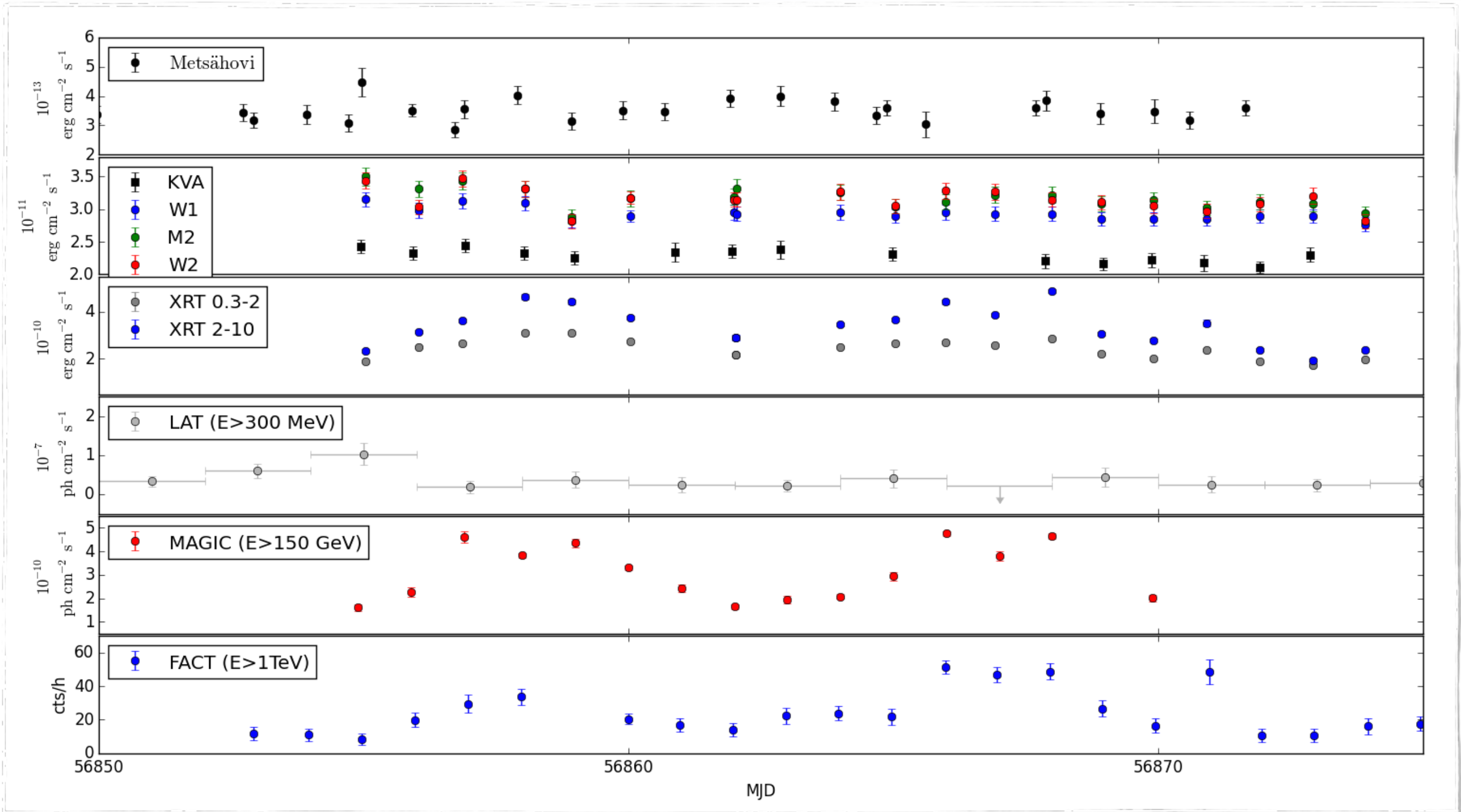
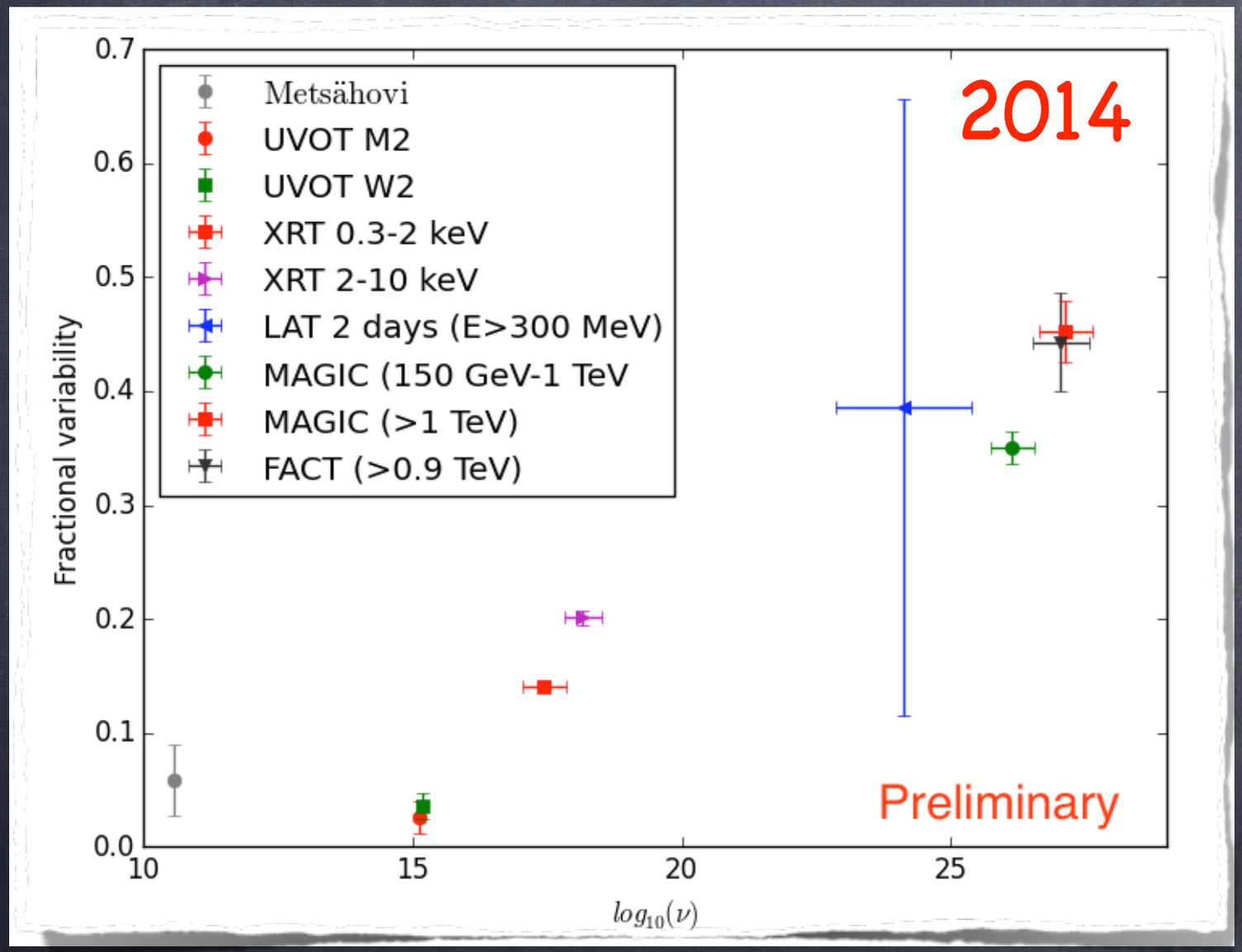




MWL flux evolution during the 2014 flare



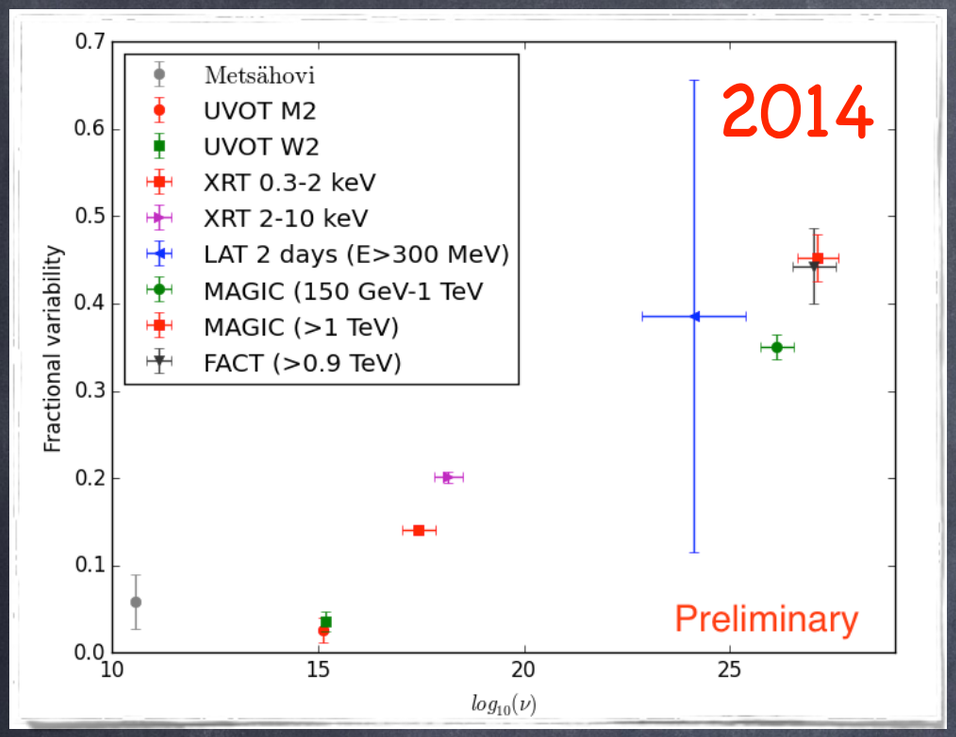
Fractional variability Mrk 501

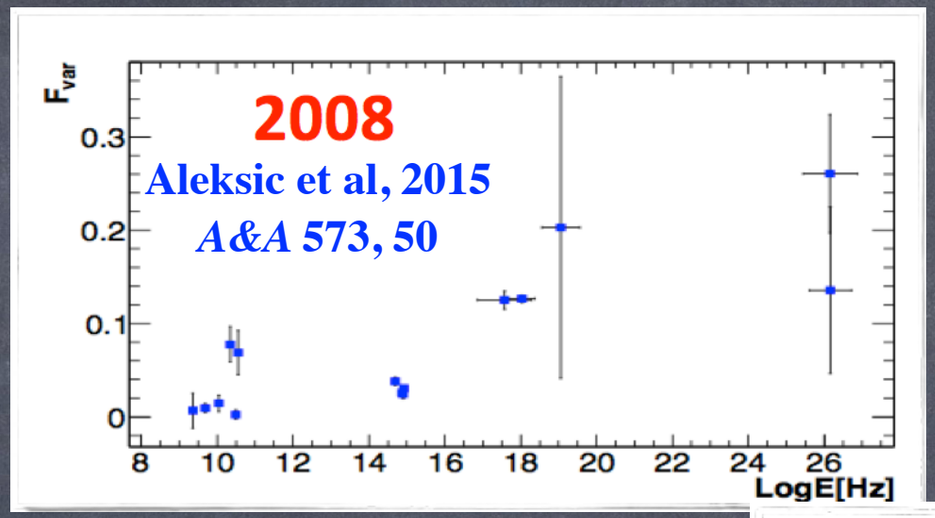


Variability quantified following prescription from Vaughan et al. 2003:

$$F_{\mathrm{var}} = \sqrt{\frac{S - \langle \sigma_{err} \rangle^2}{\langle Flux \rangle^2}}$$

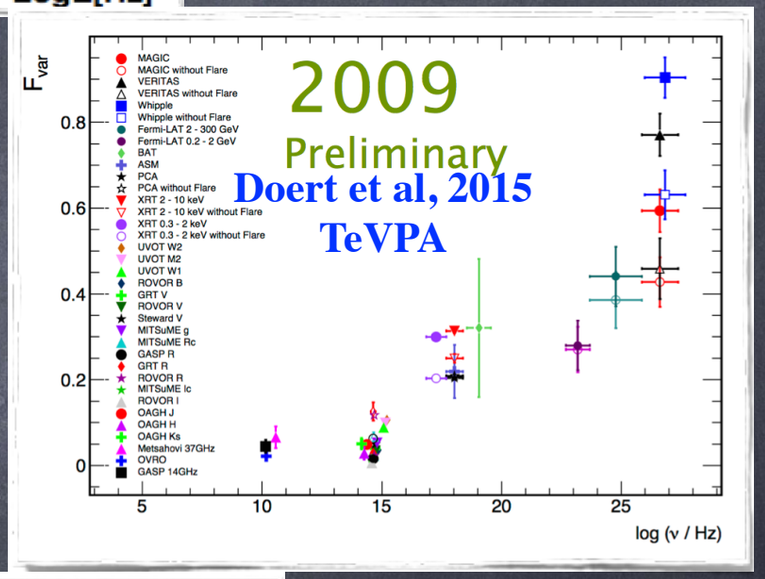
Fractional variability Mrk 501

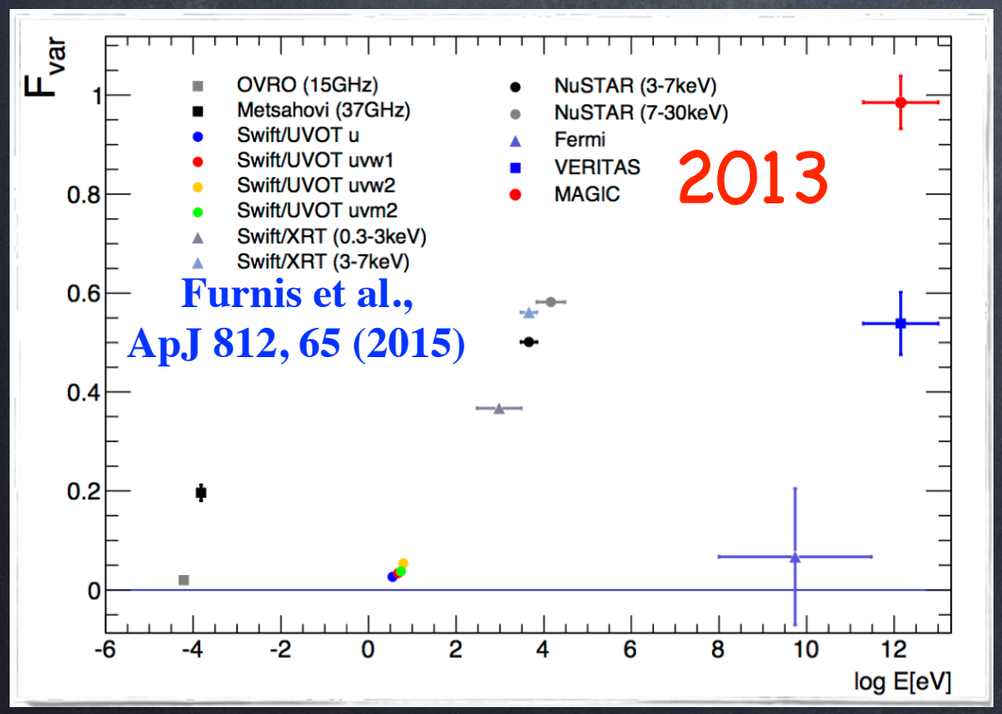


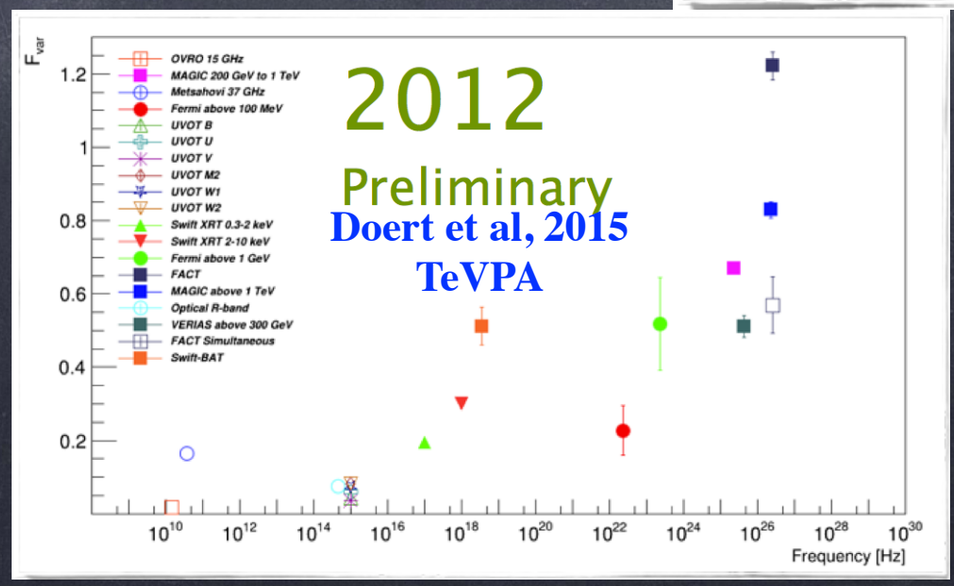


Fvar typically increases with energy

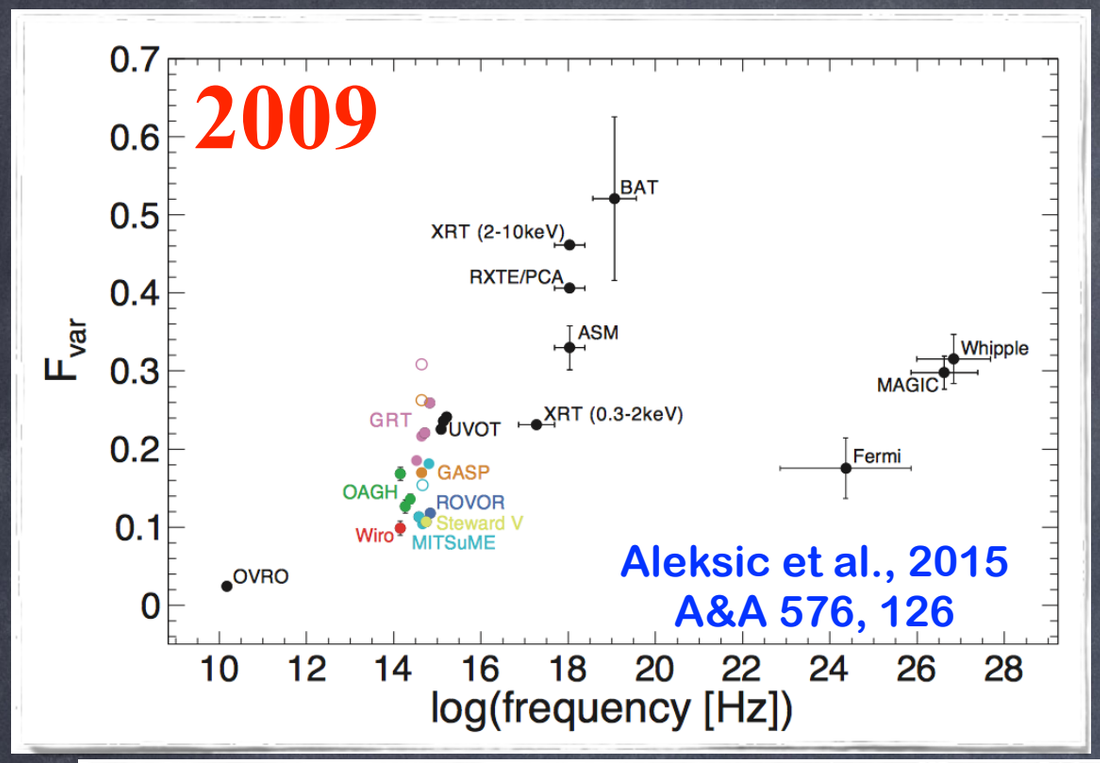
($Fvar_{VHE} > Fvar_{X\text{-}ray}$)

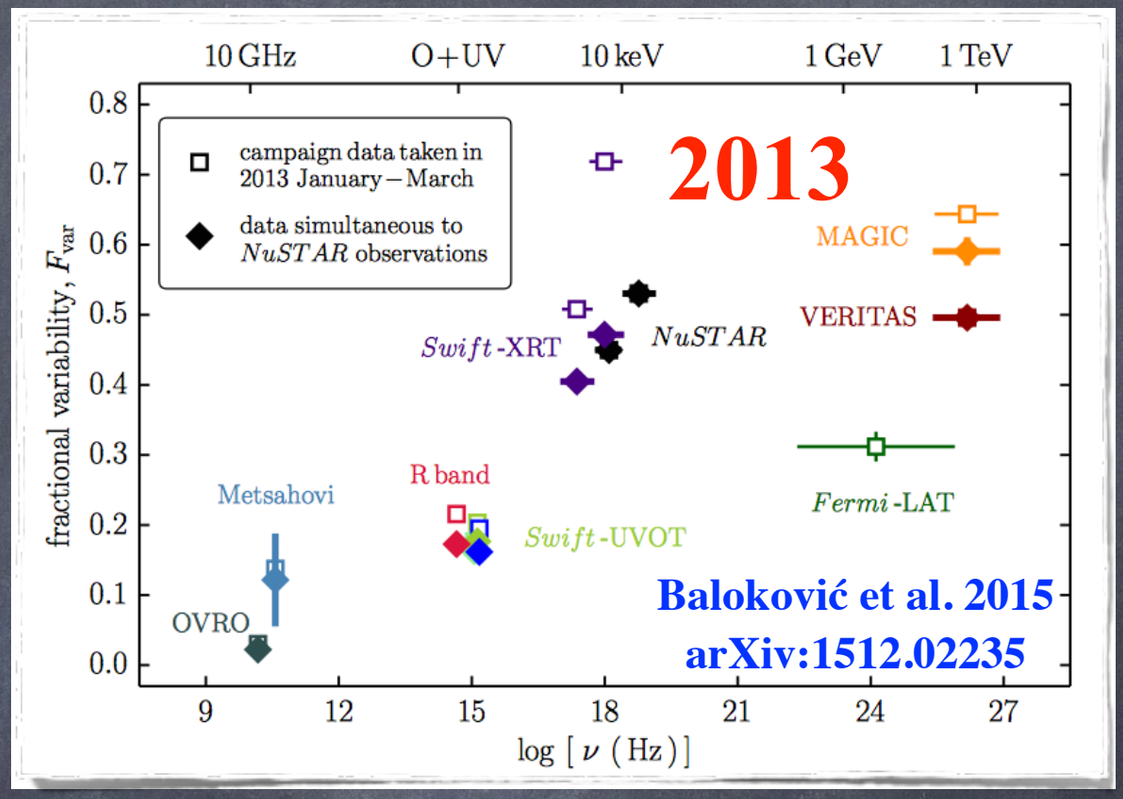


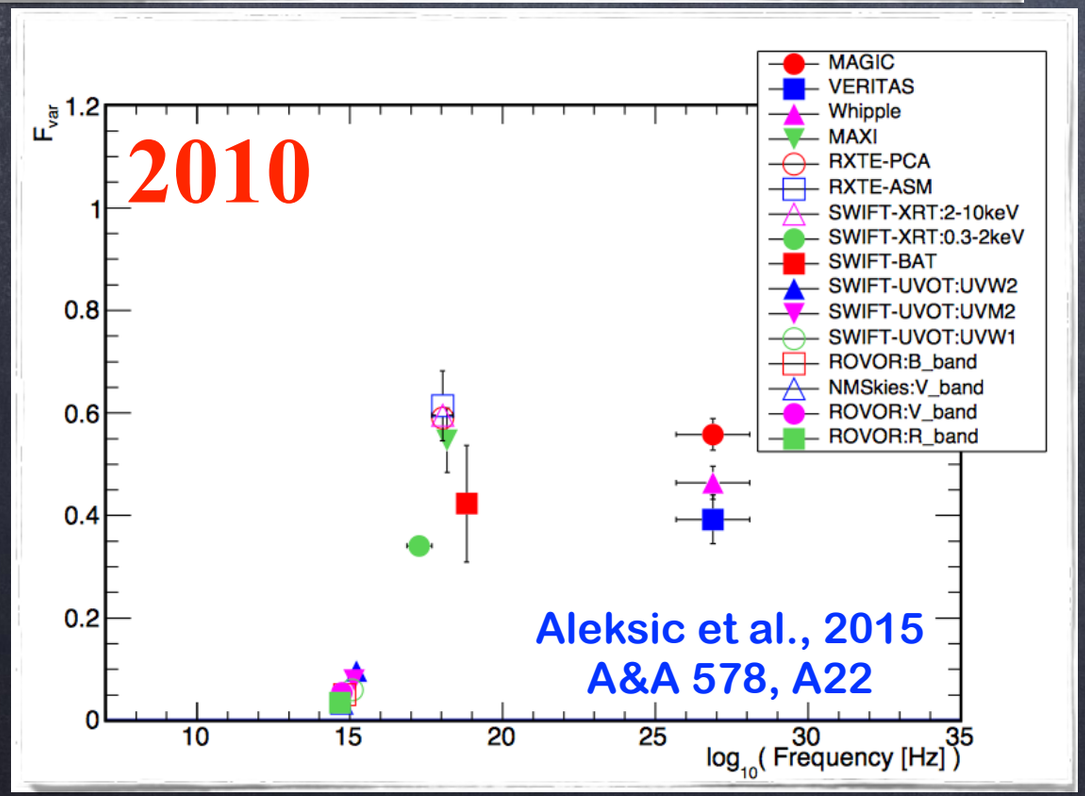




Fractional variability Mrk 421



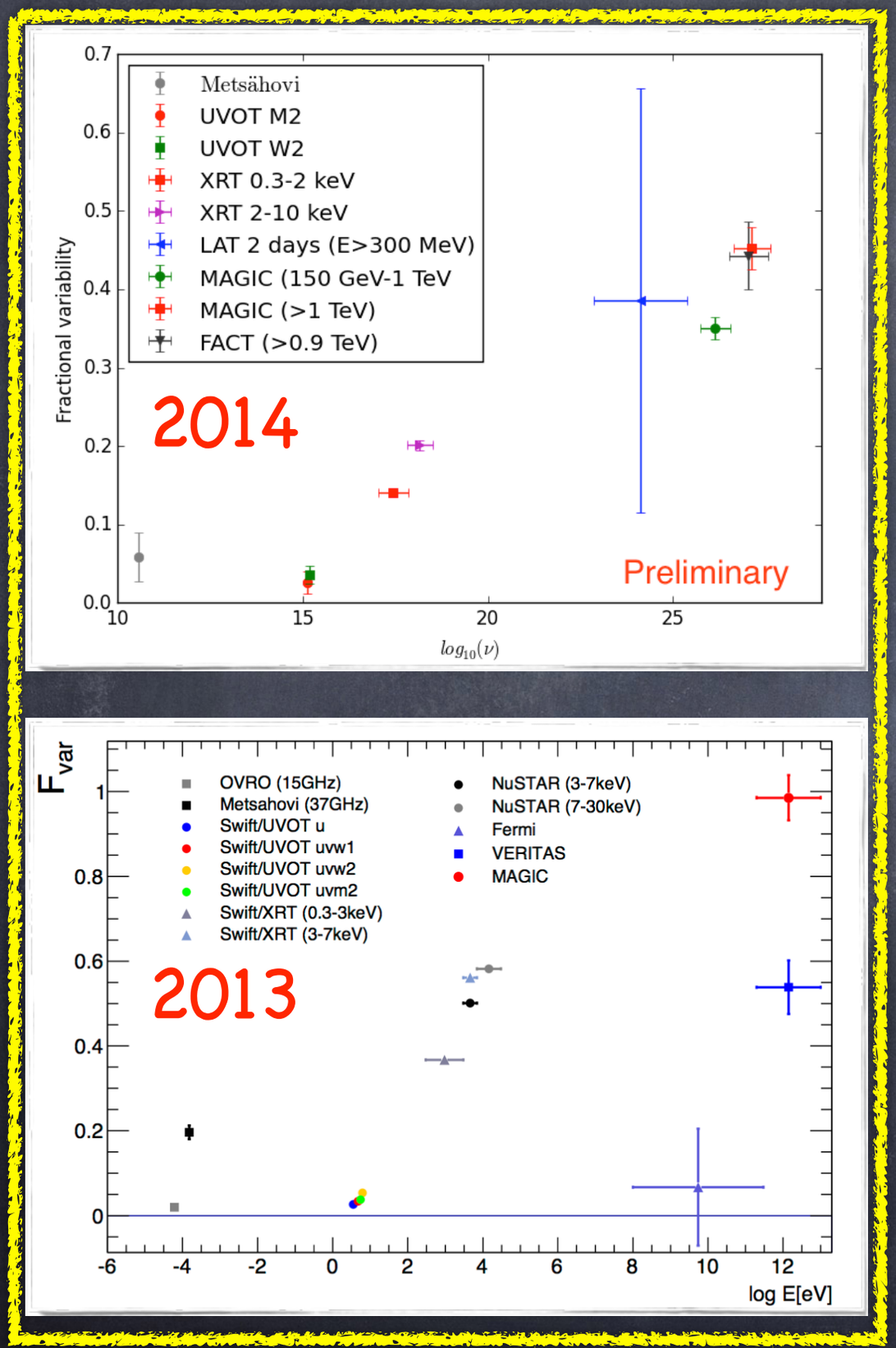


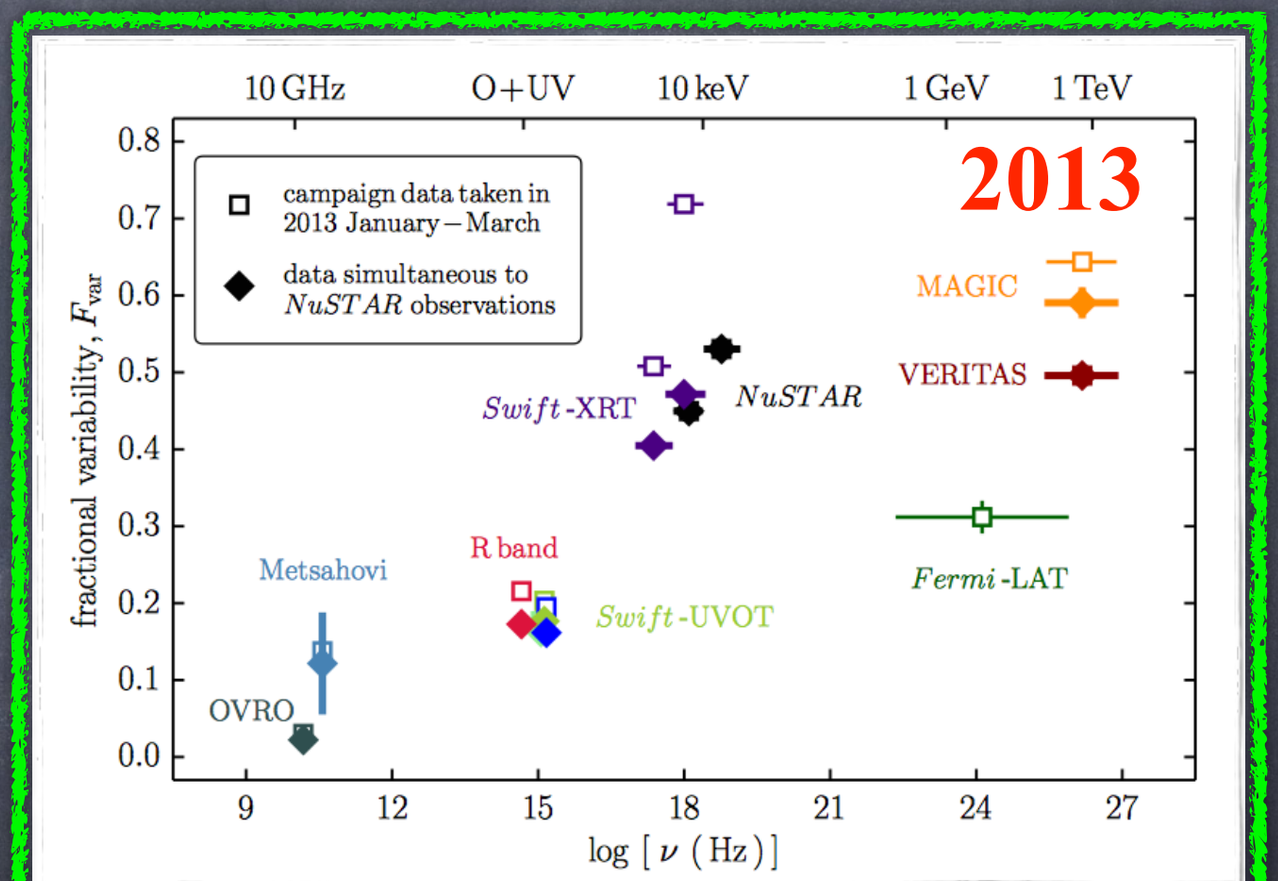


Fvar shows a more clear double-peak structure than Mrk501

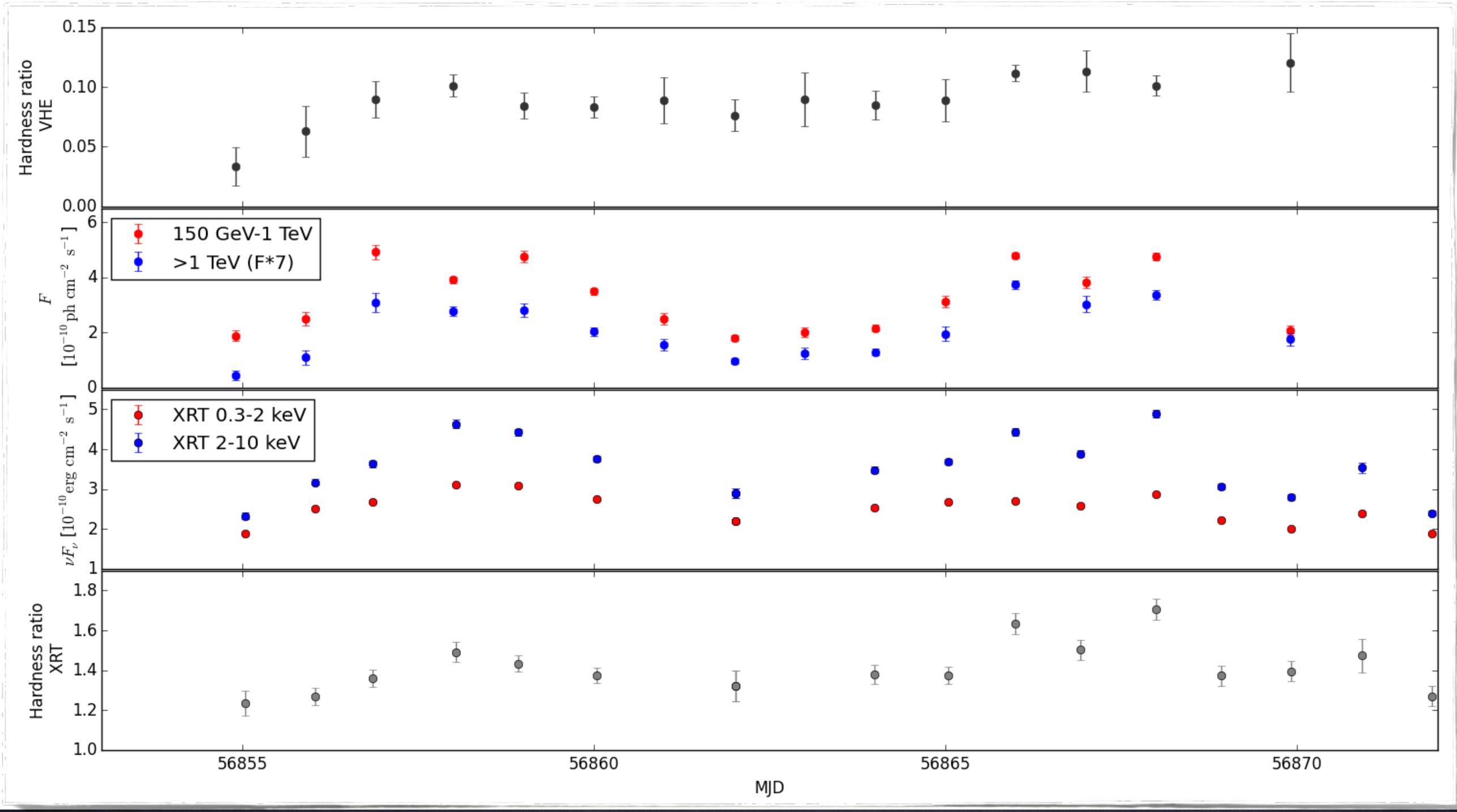
($Fvar_{VHE} \approx Fvar_{X\text{-}ray}$)

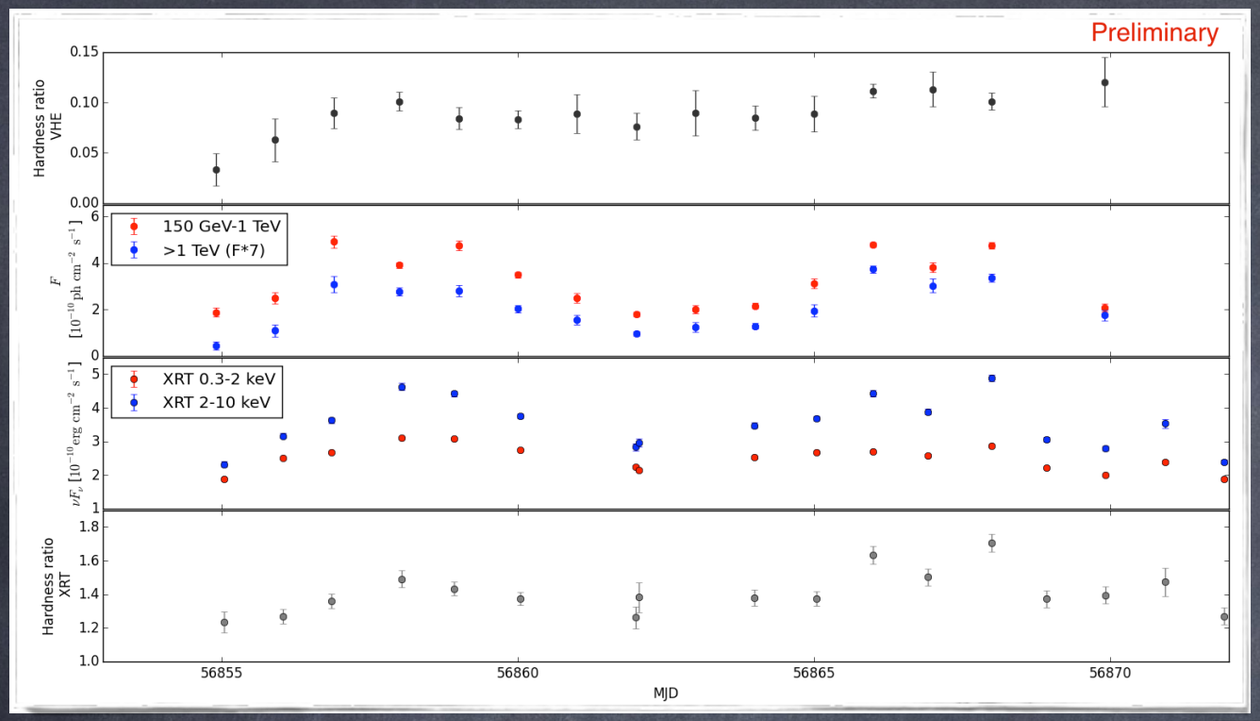
Mrk 501 vs Mrk 421





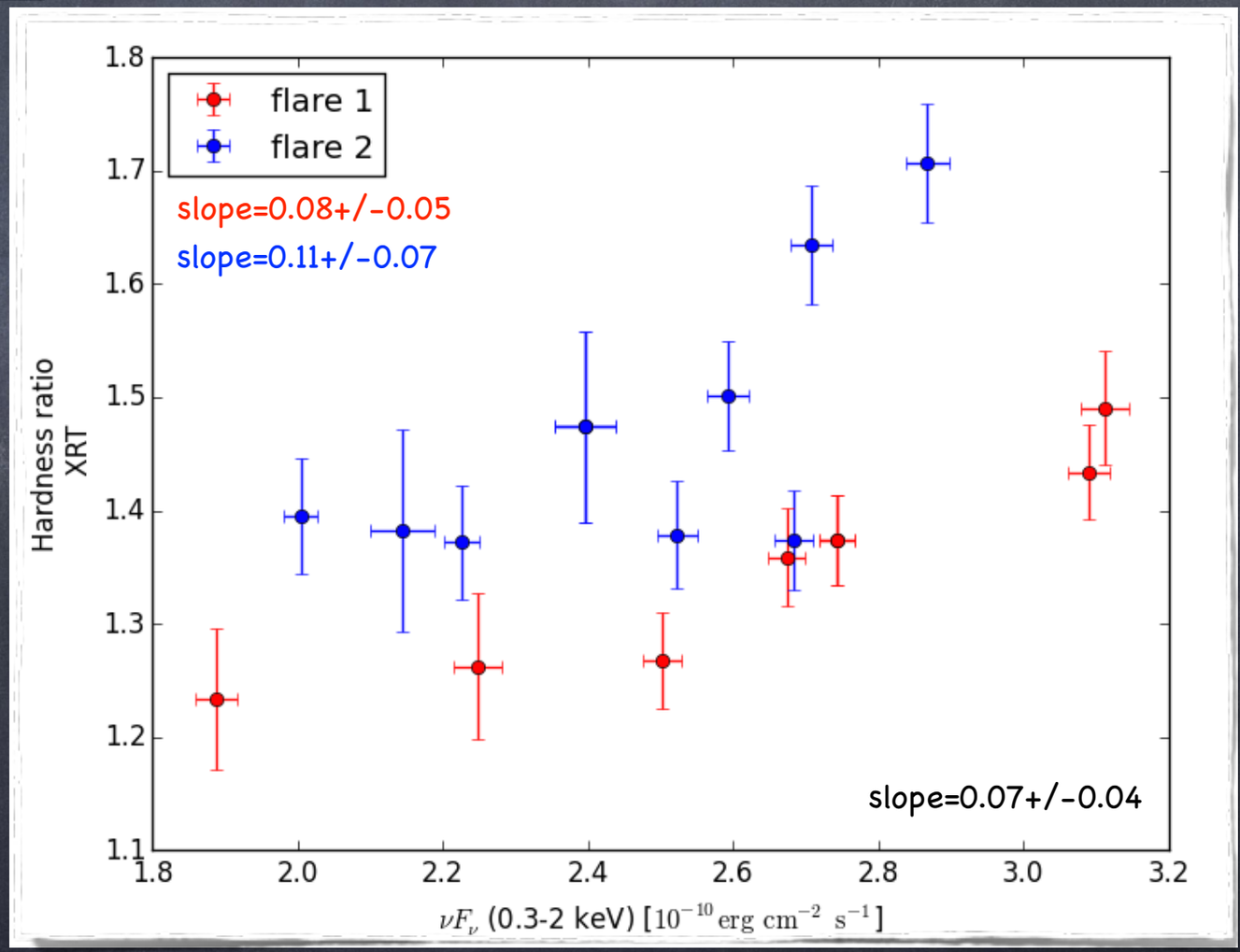
VHE vs X-ray evolution



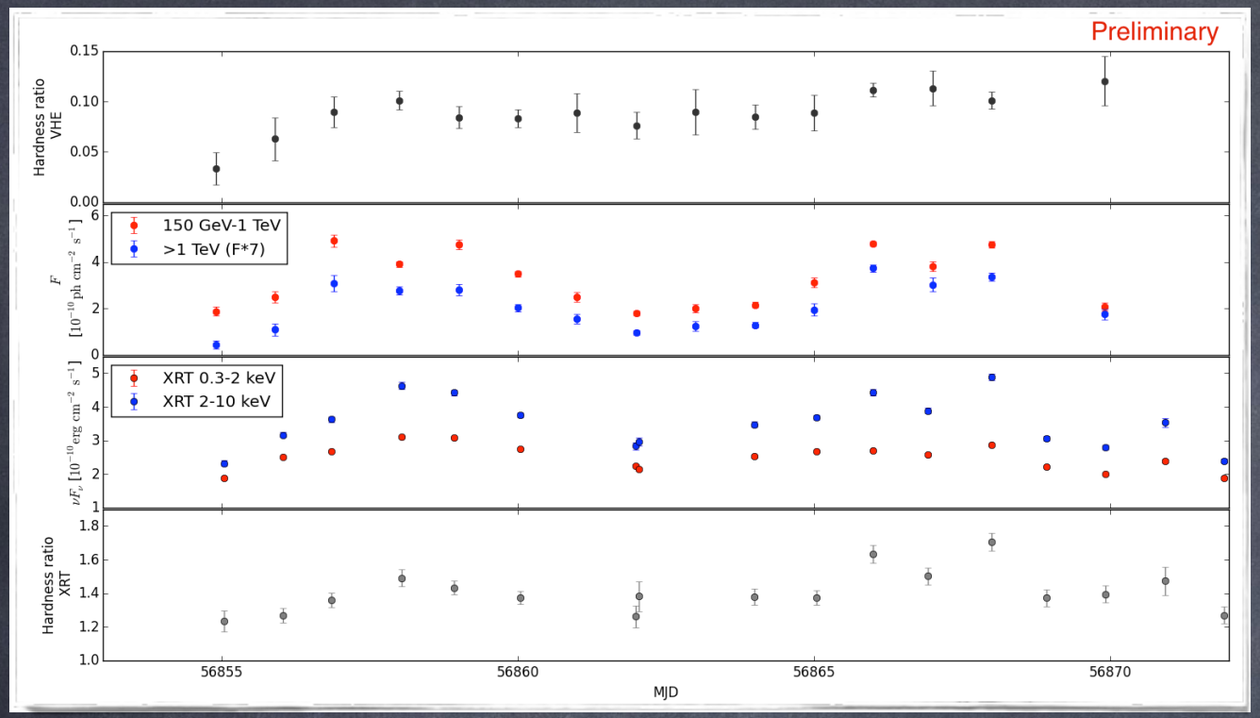


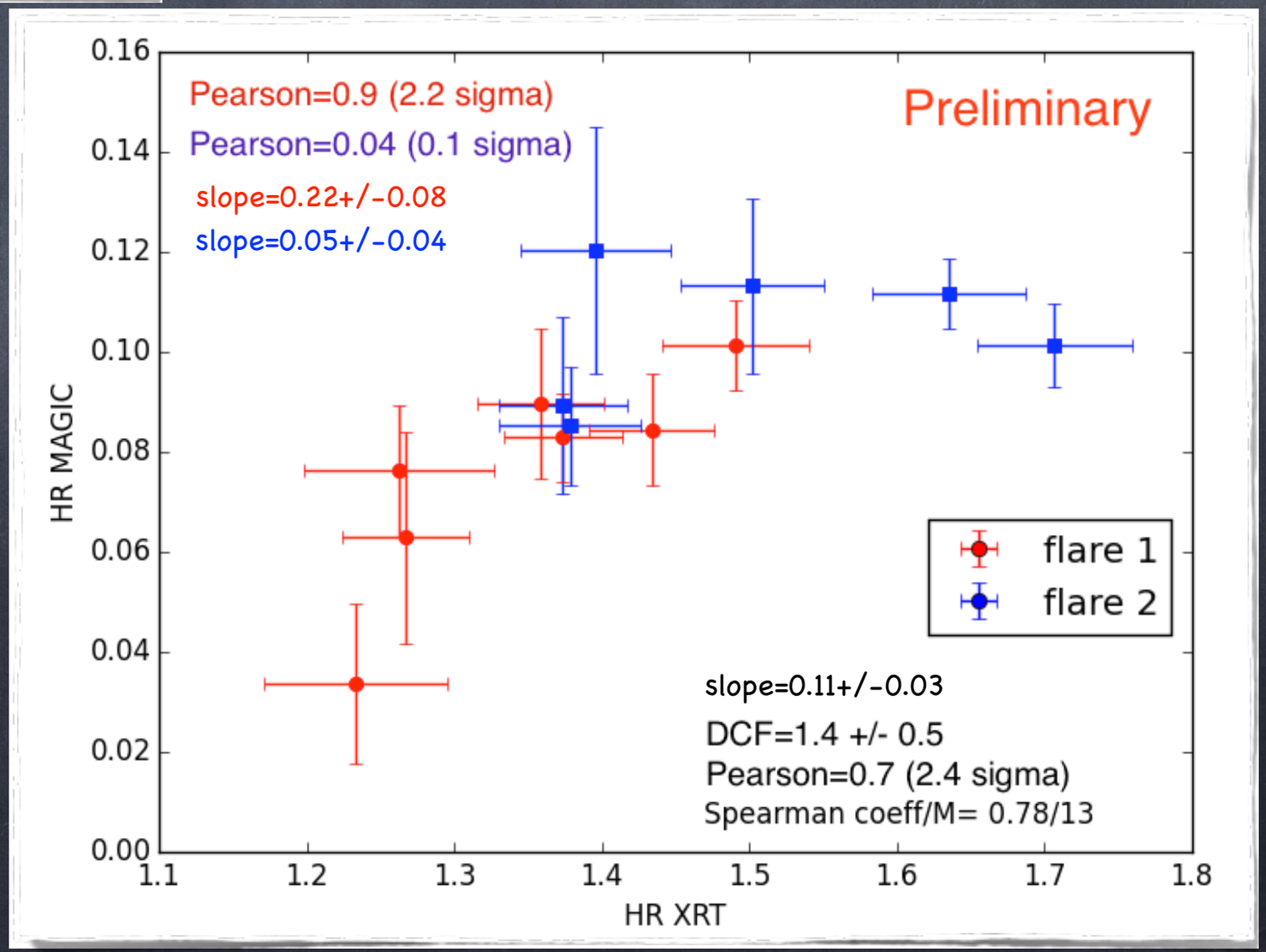
Hardness ratio vs X-ray flux

Marginally significant harder when brighter behavior in the X-rays



VHE vs X-rays
Hardness ratio evolution





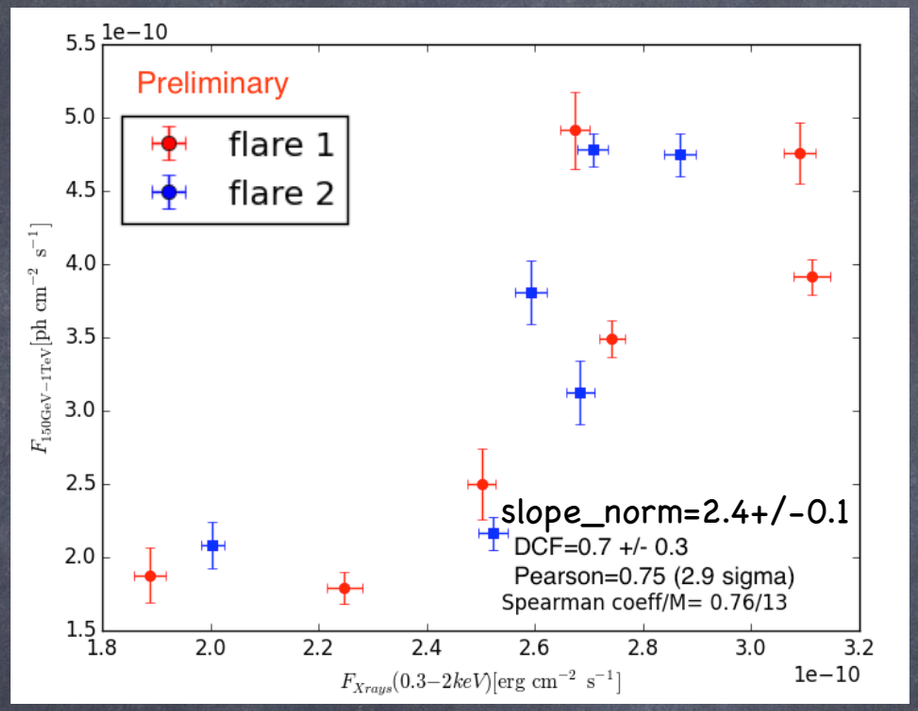
VHE vs X-ray correlations

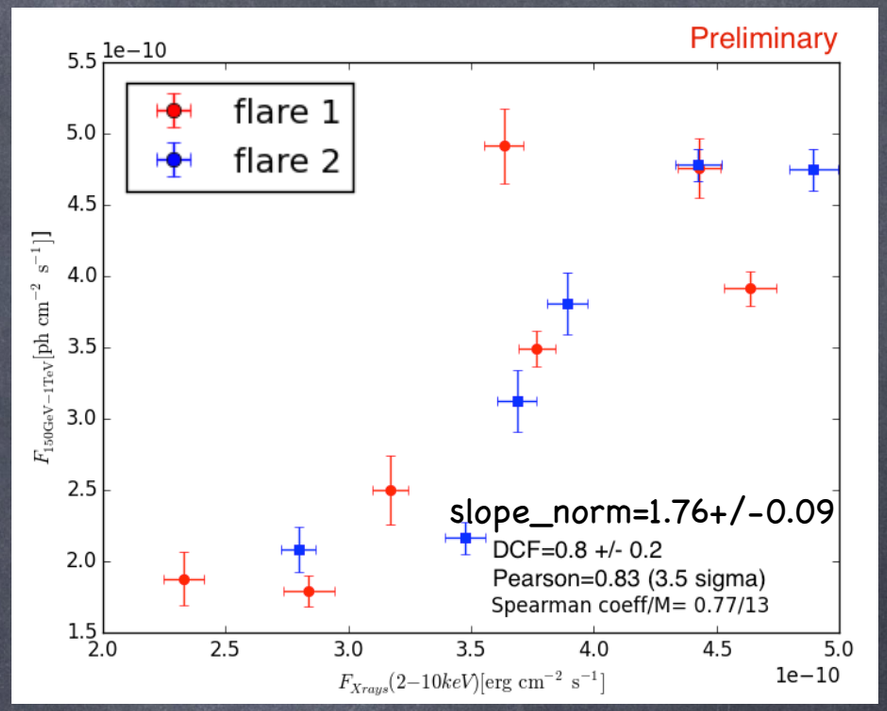
X-ray:
0.3-2 keV

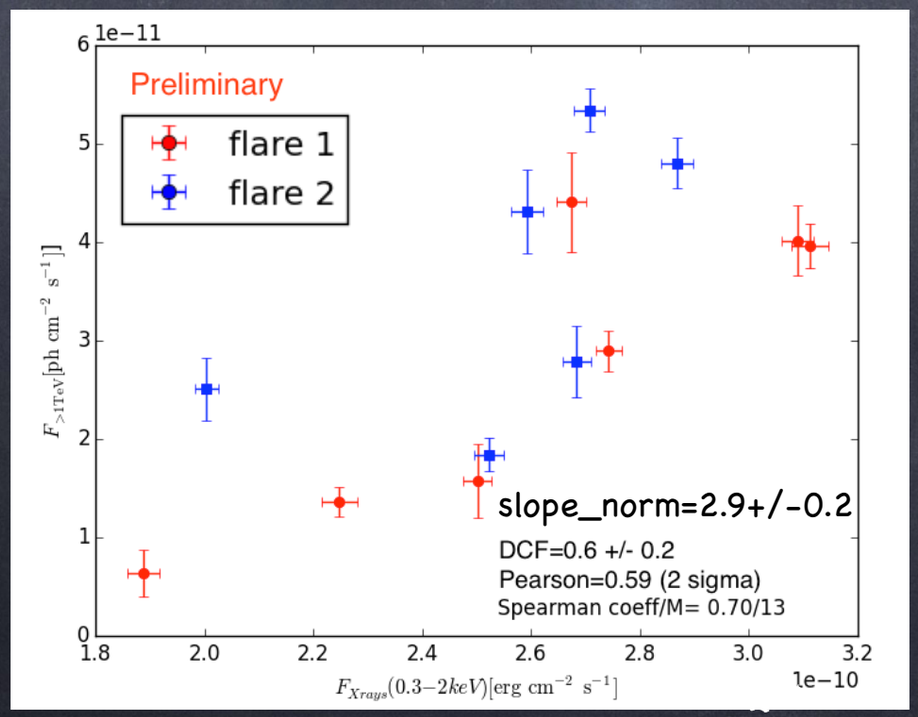
X-ray:
2-10 keV

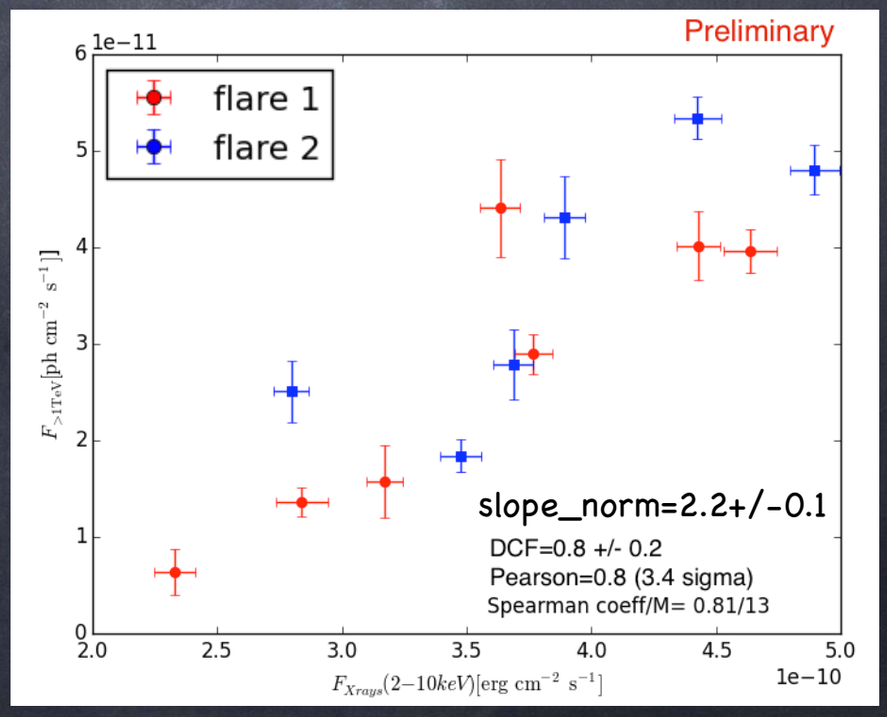
VHE:
150 GeV-1 TeV

VHE:
E>1 TeV









Take home message

- Mrk 501 and Mrk 421 are ideal TeV blazars to perform unbiased MWL studies
- Detection of the historical maximum of the X-ray emission during the 11 years Swift-XRT operation.
- Variability in VHE is typically higher than in the X-ray band (different to Mrk421 where they are similar). It might point to fundamental differences in these two archetypical sources.
- Marginal correlation between X-rays and VHE (~3σ) during the super-big flare in July 2014.
- Measurements from various campaigns show NO keV/TeV correlation for Mrk501 (i.e. 2009 and 2012) (very different from Mrk421, which shows a persistently strong keV/TeV correlation during both low and high activity)
- A stronger variability and correlation to TeV emission may occur at hard X-rays (>10 keV) for Mrk501 —> Need instruments like NuSTAR and Astro-H
- Spectral analysis in process, stay tuned!

Thanks!