The synchrotron emission of the extreme blazar 1ES 0229+200

Sarah Kaufmann

Landessternwarte, Universität Heidelberg, Germany

Stefan Wagner, Omar Tibolla, Marcus Hauser

X-ray Universe 2011
Berlin
27 - 30. June 2011

bmb+f - Förderschwerpunkt
Astro-Teilchenphysik
Großgeräte der physikalischen Grundlagenforschung

ARI ITA LSW

1ES 0229+200

short introduction to 1ES 0229+200:

- located at: $\alpha_{J2000} = 2^h\ 32^m\ 48.62^s$, $\delta_{J2000} = +20°\ 17'\ 17.45''$ (Rector et al. 2003)

- redshift z=0.14 (Woo et al. 2005)

- discovered in the Einstein Slew survey (Elvis et al. 1992)

- classified as high frequency peaked BL Lac object:
  two peaks in the SED located in the UV-X-ray and the GeV-TeV band

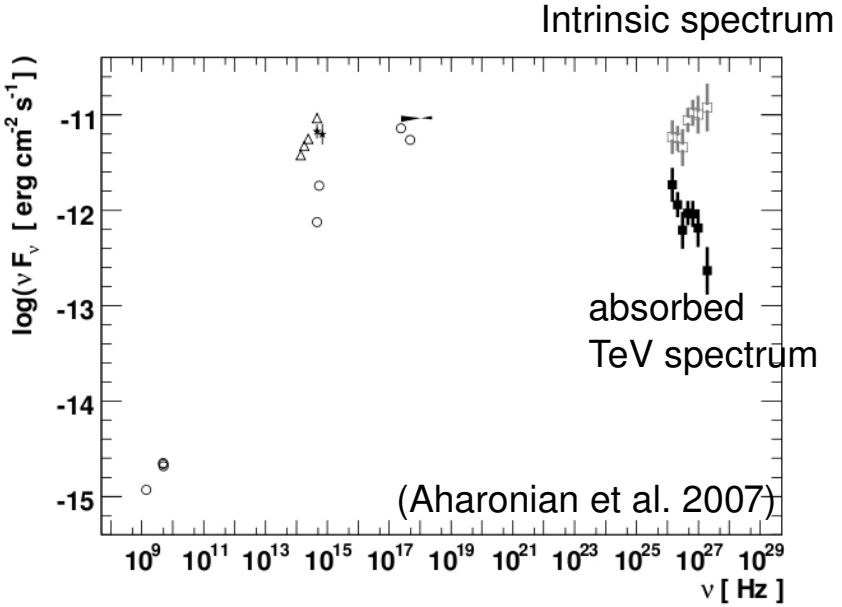
- Very high energy (E>100GeV) emission detected by H.E.S.S. in 2006 (Aharonian et al. 2007)

1ES 0229+200: unusual spectral characteristics

- BeppoSAX observations show that the synchrotron peak is in the X-ray domain

- TeV spectrum: photon index of $\Gamma = 2.5 \pm 0.19_{stat} \pm 0.1_{sys}$ was found → very hard intrinsic spectrum

- it is the 2nd source with z>0.1 measured up to 10TeV with such very hard TeV spectrum.



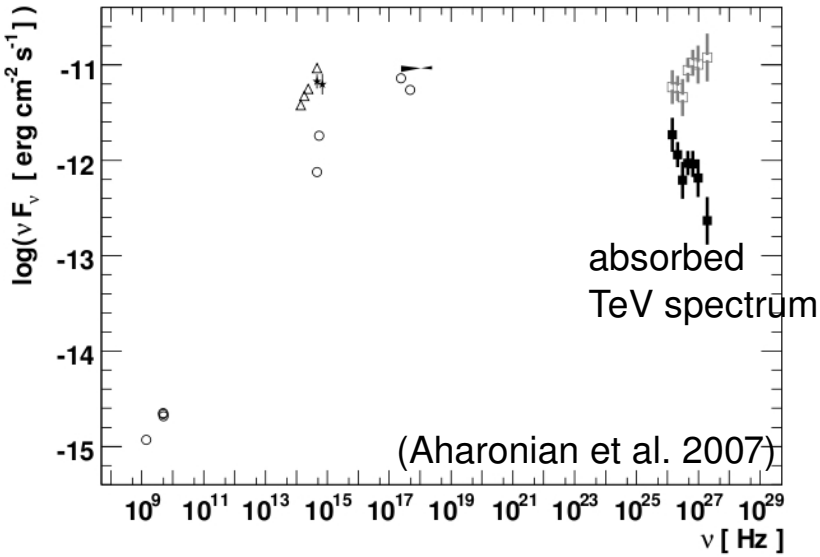
1ES 0229+200: unusual spectral characteristics

- BeppoSAX observations show that the synchrotron peak is in the X-ray domain

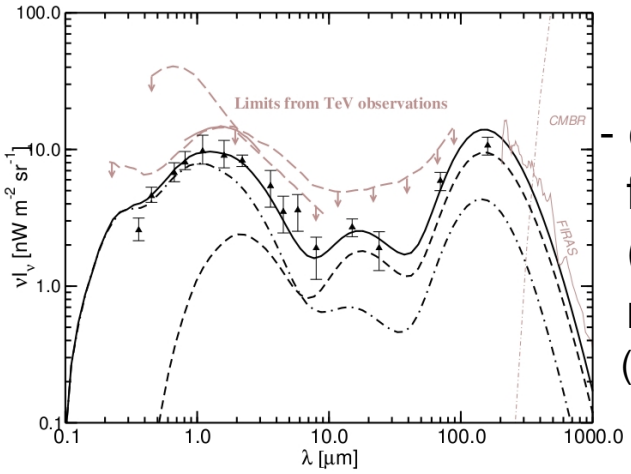
- TeV spectrum: photon index of $\Gamma = 2.5 \pm 0.19_{stat} \pm 0.1_{sys}$ was found → very hard intrinsic spectrum

- it is the 2nd source with z>0.1 measured up to 10TeV with such very hard TeV spectrum.

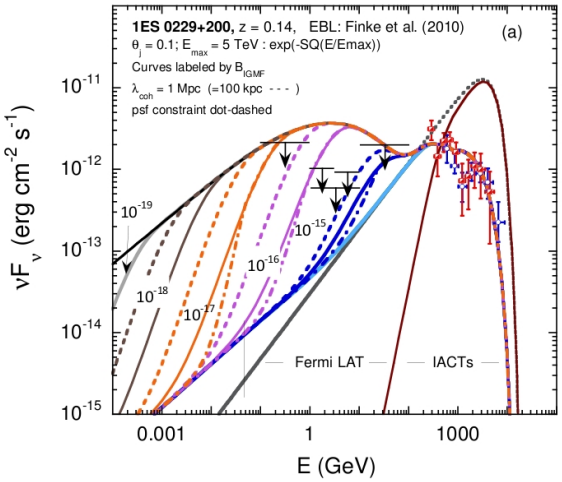
Intrinsic spectrum



- often used probe for EBL studies (extragalactic background light)
(Kneiske et al. 2010)



- often used probe for IGMF studies (intergalactic magnetic field)
(Dermer et al. 2010)

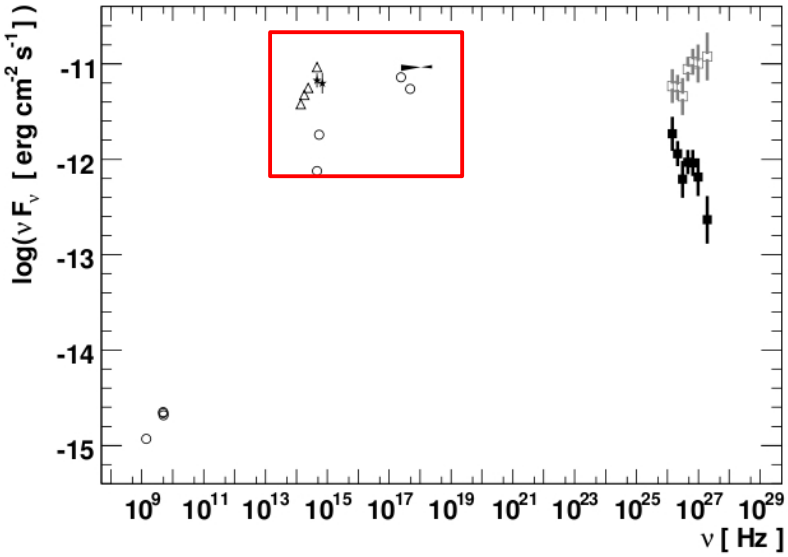


New Multi-wavelength observations

- We proposed XMM-Newton observations in order to determine the synchrotron emission in more detail with simultaneous UV and broad X-ray spectra.

- optical monitoring over years

- Swift/BAT long 58 months spectrum (Baumgartner 2010)

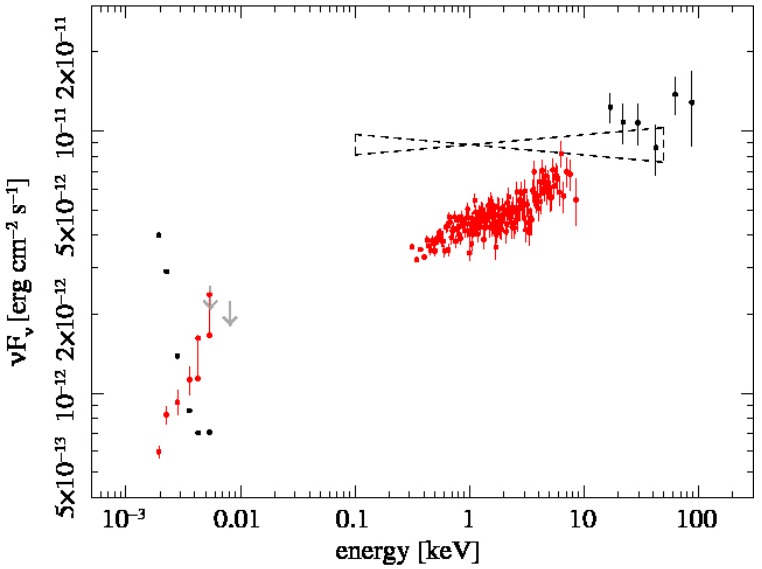


- new strict simultaneous UV, X-ray (XMM-Newton) and optical observations in red

- host galaxy correction in optical/UV

- extinction correction in optical/UV

- absorption correction in X-ray spectrum



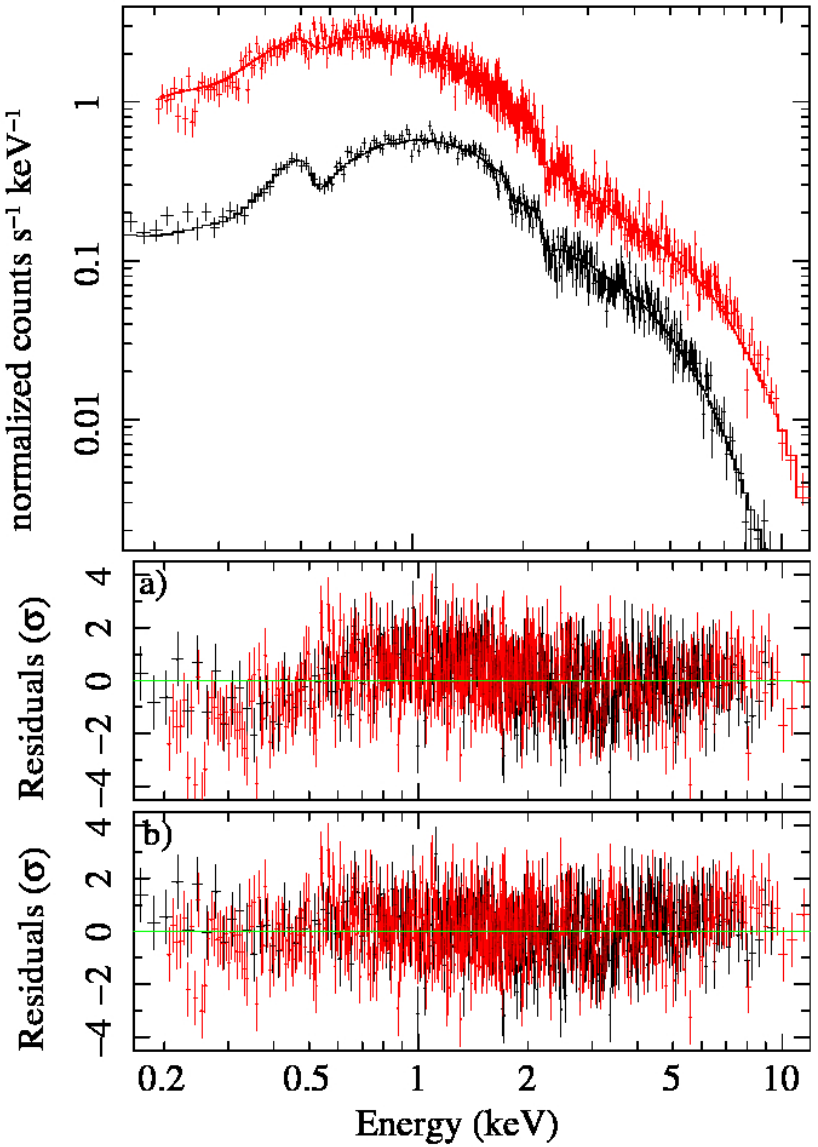
XMM-Newton results on 1ES 0229+200

Observations conducted on 21 and 23 August 2009:

- MOS (0.1 – 10keV) and PN (0.2-15keV) spectra show deviation from a power law taking into account the Galactic absorption of $N_H = 7.9 \times 10^{20}$ cm^2 (LAB Survey, Kalberla et al. 2005) → see Residuals (a)

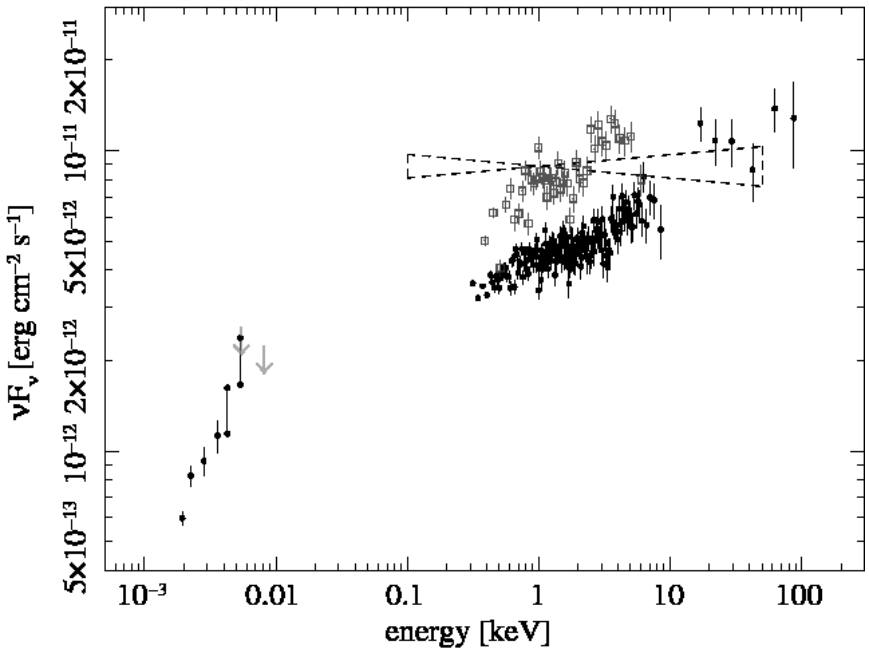
- better fit with power law with free absorption:
  $\Gamma = 1.84 \pm 0.02$, $N_H = 1.1 \times 10^{21}$ cm^2
  $(\chi^2/\mathrm{dof}) = 959/888$

- as well as with broken power law and Galactic abs.:
  $\Gamma_1 = 0.8 \pm 0.3$, $\Gamma_2 = 1.78 \pm 0.01$, $E_{break} = 0.6 \pm 0.1$ keV
  $(\chi^2/\mathrm{dof}) = 935/887$



Other X-ray spectral information

Further new x-ray observations in 2010 by Swift and RXTE

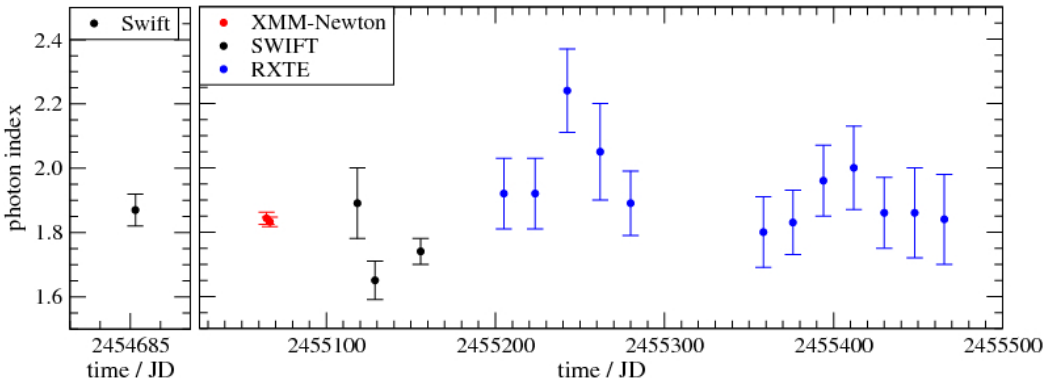


- Swift: 0.2 – 10 keV
  power law with free absorption
  Γ = 1.73 ± 0.03, N_H = 1.1x10^{21} cm^2

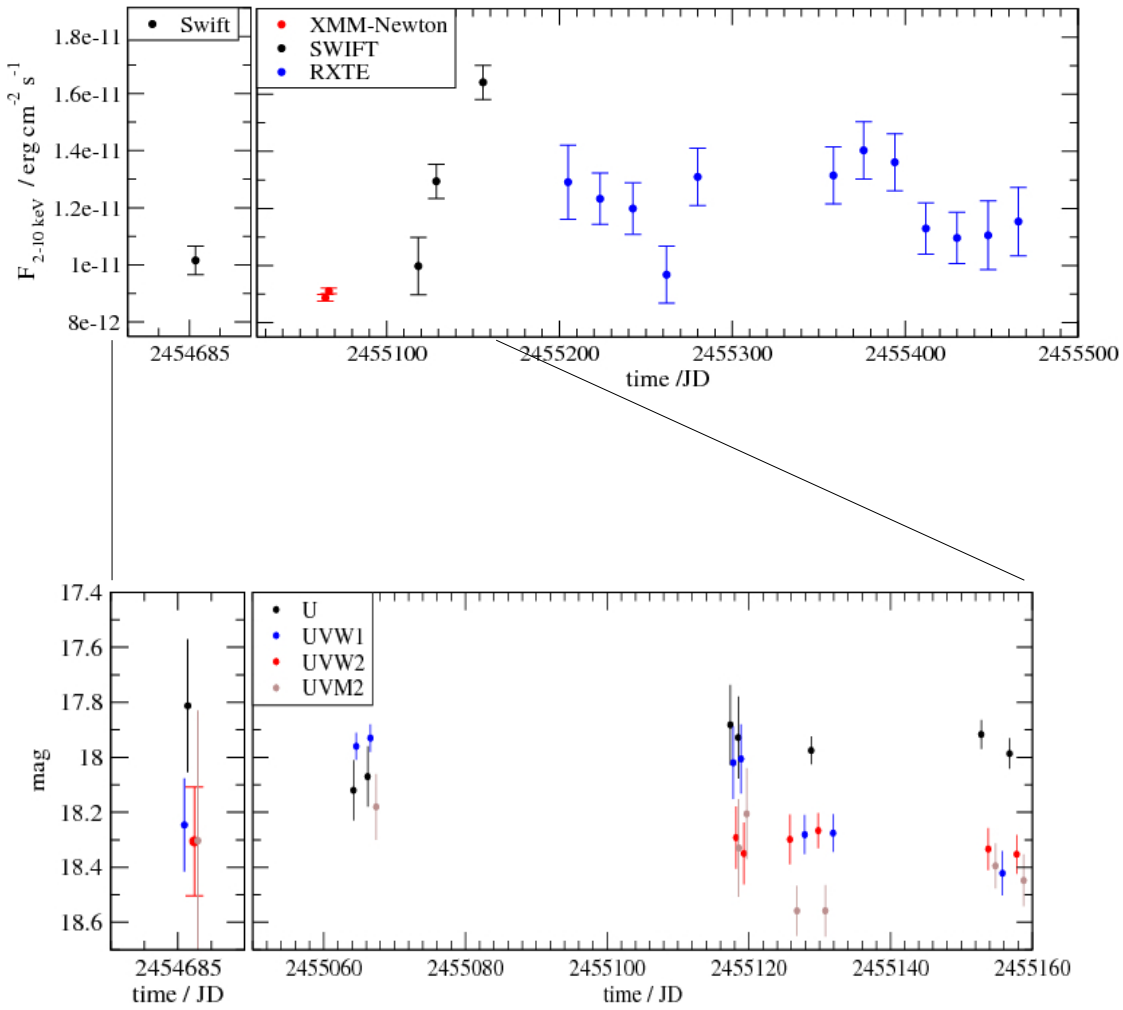
- RXTE: 3-60keV
  power law
  Γ = 1.92 ± 0.05

- BeppoSAX: 0.1 – 50 keV
  power law with free absorption
  Γ = 1.99 ± 0.05, N_H = 1.0x10^{21} cm^2

- only marginal spectral change from 2008 to Oct. 2010 in XMM-Newton, Swift and RXTE spectra



X-ray, UV and optical light curves



- optical emission in R, B band constant over 5 years of monitoring.

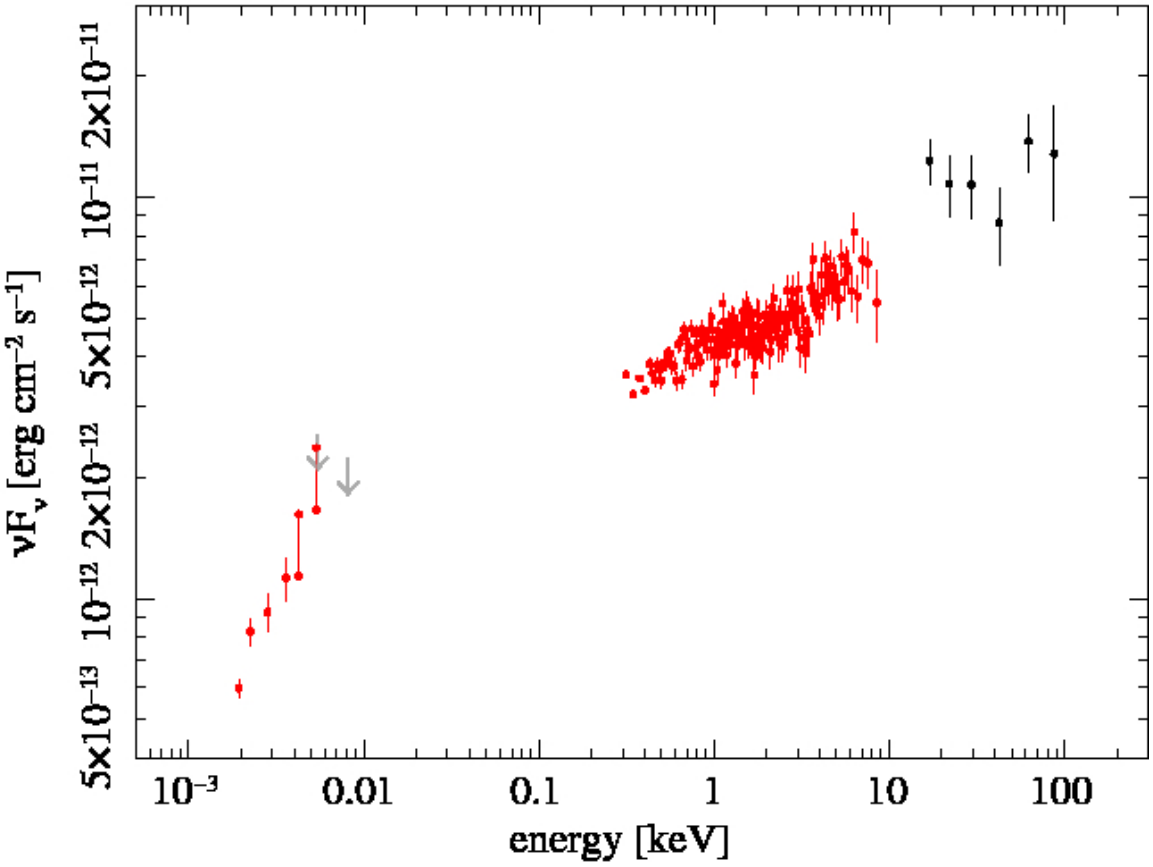
- X-ray emission change by factor of 2

- UV: marginal drop in UVW1 and UVM2 around time of increase in X-ray flux

Synchrotron emission

- red: strict simultaneous optical, UV, X-ray spectra corrected for absorption and host galaxy influence

- Swift/BAT spectra no cutoff detected up to 100keV
  → extreme blazar!!

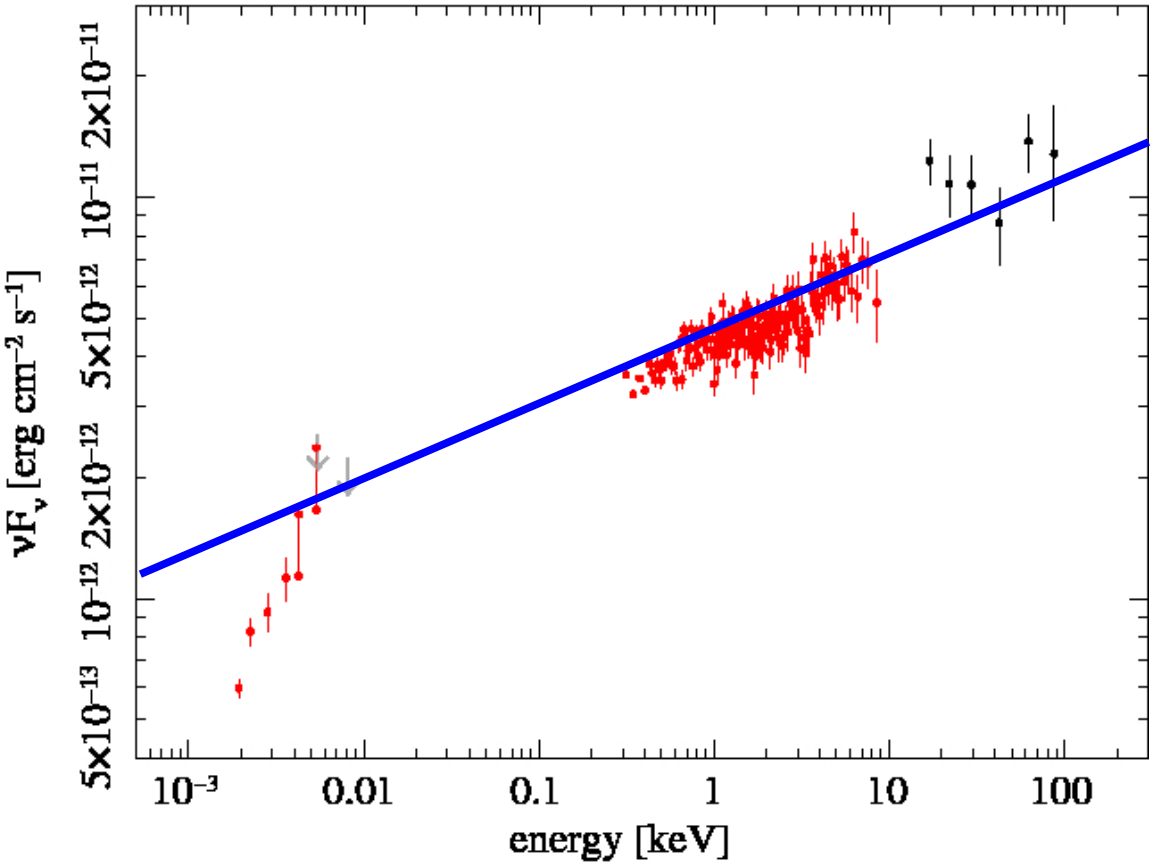


Synchrotron emission

- red: strict simultaneous optical, UV, X-ray spectra corrected for absorption and host galaxy influence

- Swift/BAT spectra no cutoff detected up to 100keV
  → extreme blazar!!

- spectral index of XMM spectrum describe 0.005 – 100 keV
  → constrains spectral index of the electron distribution



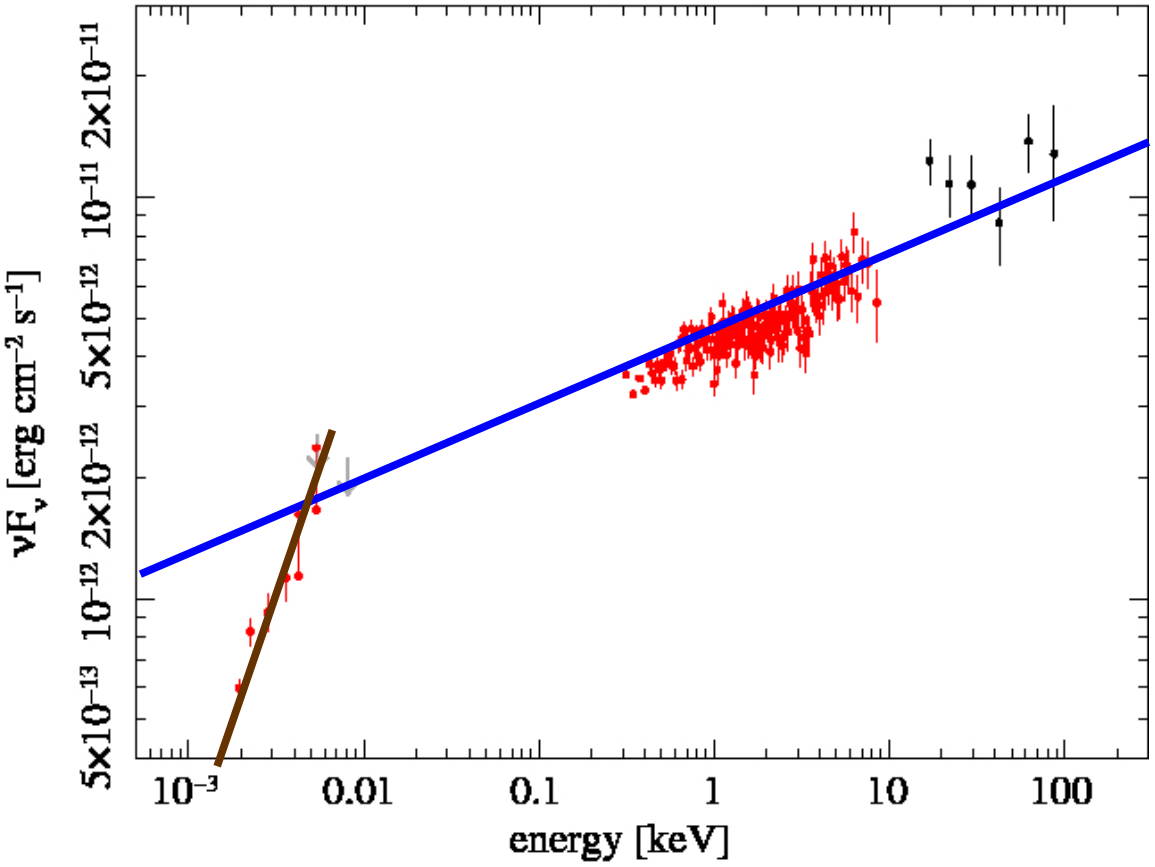
Synchrotron emission

- red: strict simultaneous optical, UV, X-ray spectra corrected for absorption and host galaxy influence

- Swift/BAT spectra no cutoff detected up to 100keV
  → extreme blazar!!

- spectral index of XMM spectrum describe 0.005 – 100 keV
  → constrains spectral index of the electron distribution

- clear cutoff in the optical/UV regime
  → high minimum energy of electron distribution



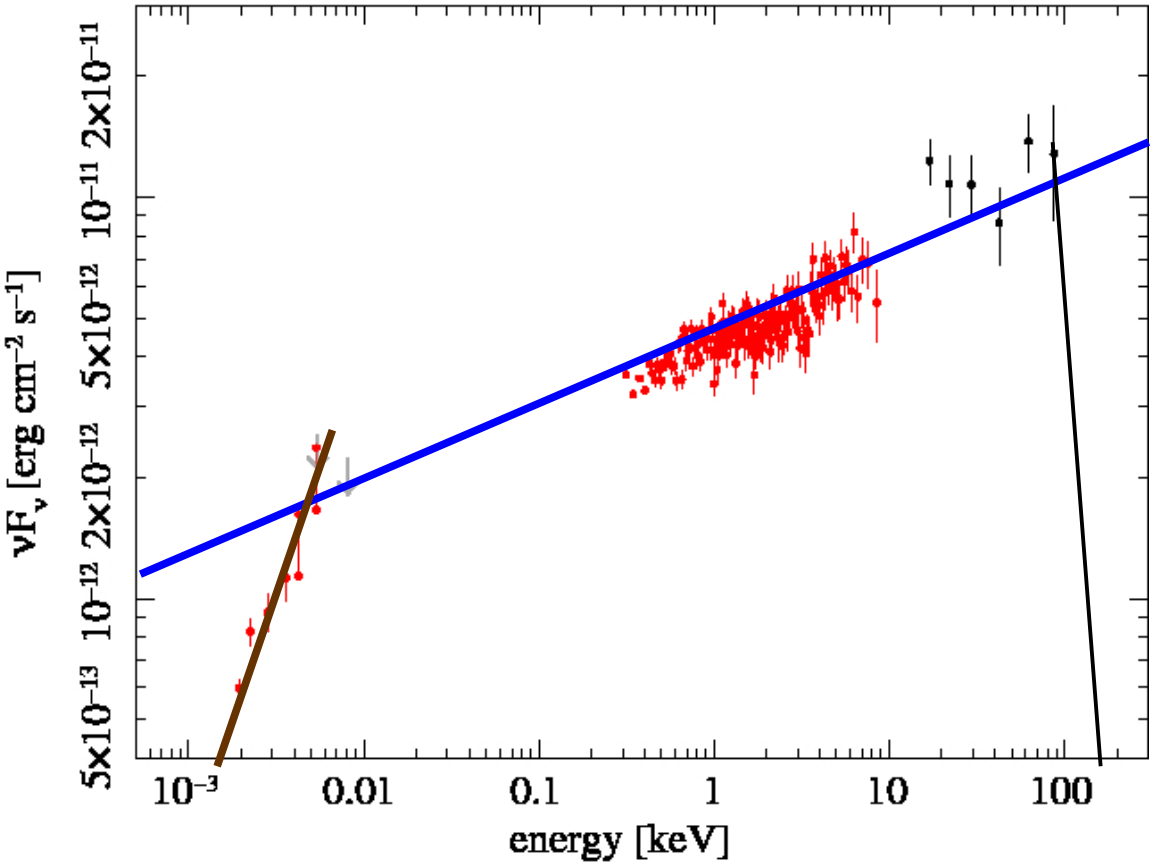
Synchrotron emission

- red: strict simultaneous optical, UV, X-ray spectra corrected for absorption and host galaxy influence

- Swift/BAT spectra no cutoff detected up to 100keV
  → extreme blazar!!

- spectral index of XMM spectrum describe 0.005 – 100 keV
  → constrains spectral index of the electron distribution

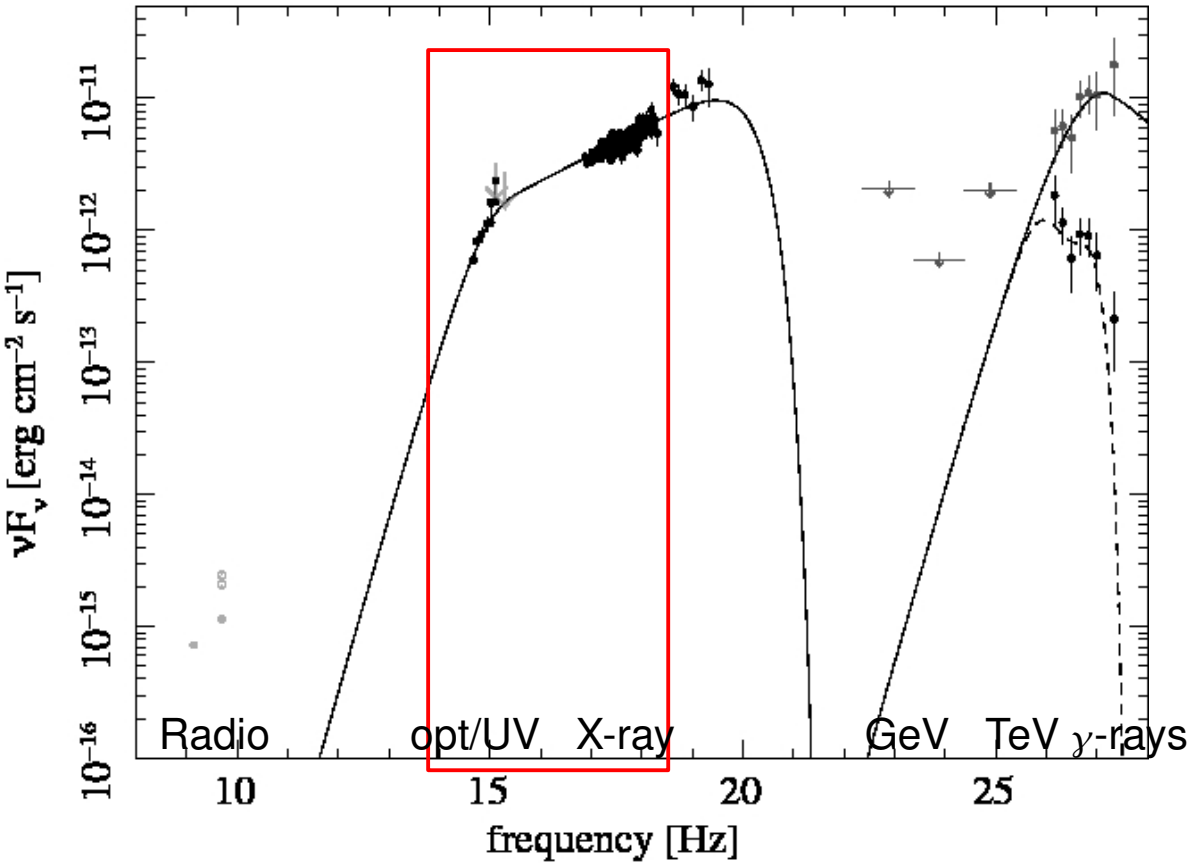
- clear cutoff in the optical/UV regime
  → high minimum energy of electron distribution



- assuming cut-off around 100keV and the clear cut-off in the optical/UV
  → very narrow electron distribution

Spectral energy distribution

Strict simultaneous data



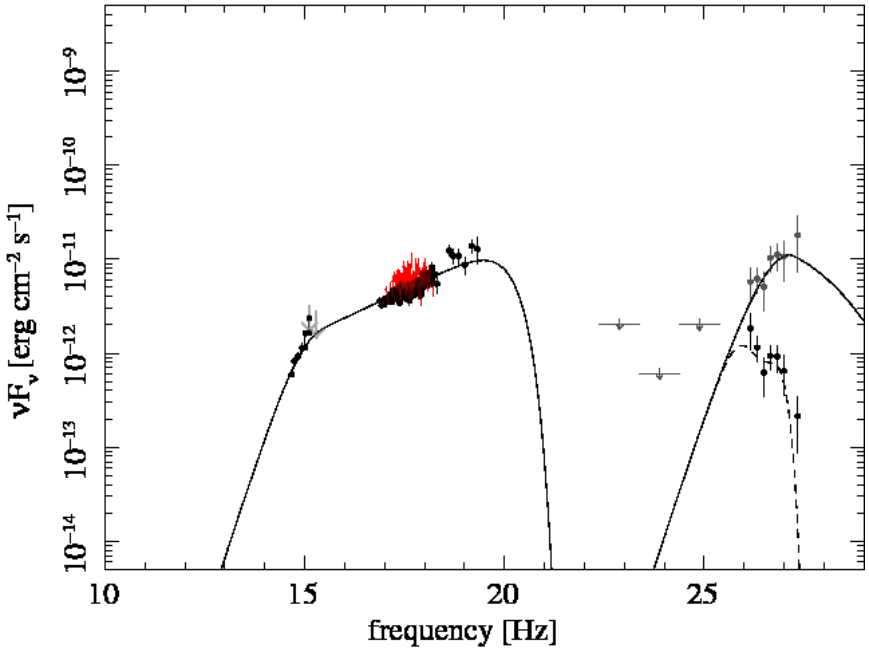
- simultaneous optical/UV/X-ray spectra cover well the synchrotron emission

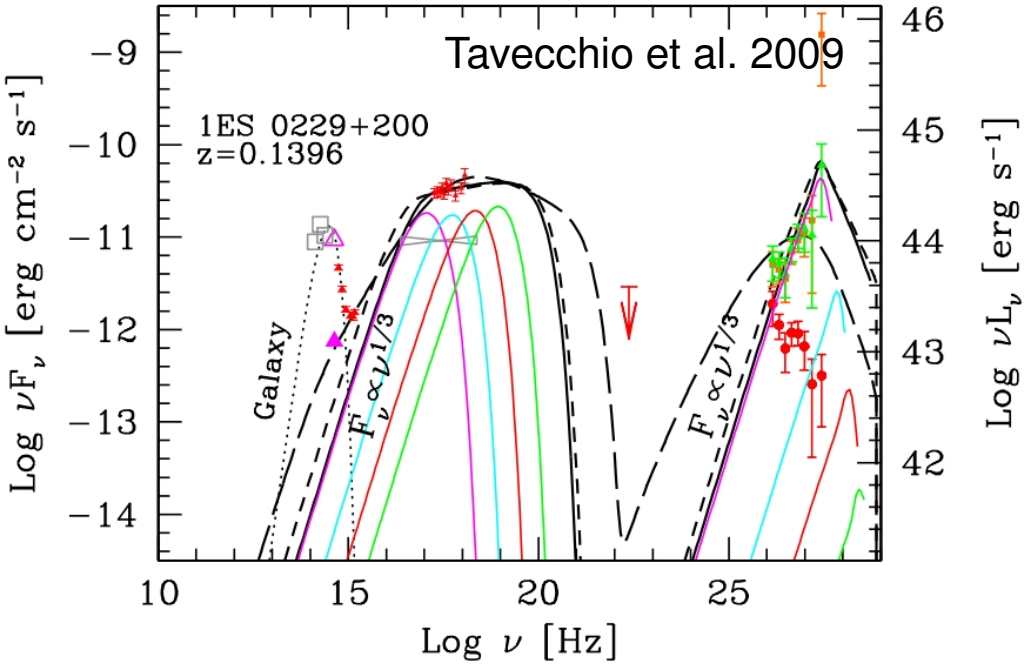
- optical/UV: corrected for the host galaxy and extinction
  → indicate clearly the cutoff of the synchrotron emission

- hard X-ray spectra show no significant cutoff
  → synchrotron emission up to ~100keV

radio: VLBA,VLA core fluxes by Rector et al. 2003, VLA total flux by Schachter et al. 1993, Perlman et al. 1996)
add. UV: GALEX (upper limits since host galaxy influence unknown)
Hard X-ray: Swift/BAT 58months spectrum (Baumgartner 2010)
GeV γ-ray: Fermi upper limits by Dermer et al. 2010
TeV γ-ray: H.E.S.S. spectrum by Aharonian et al. 2007

Comparing to previous presented SED

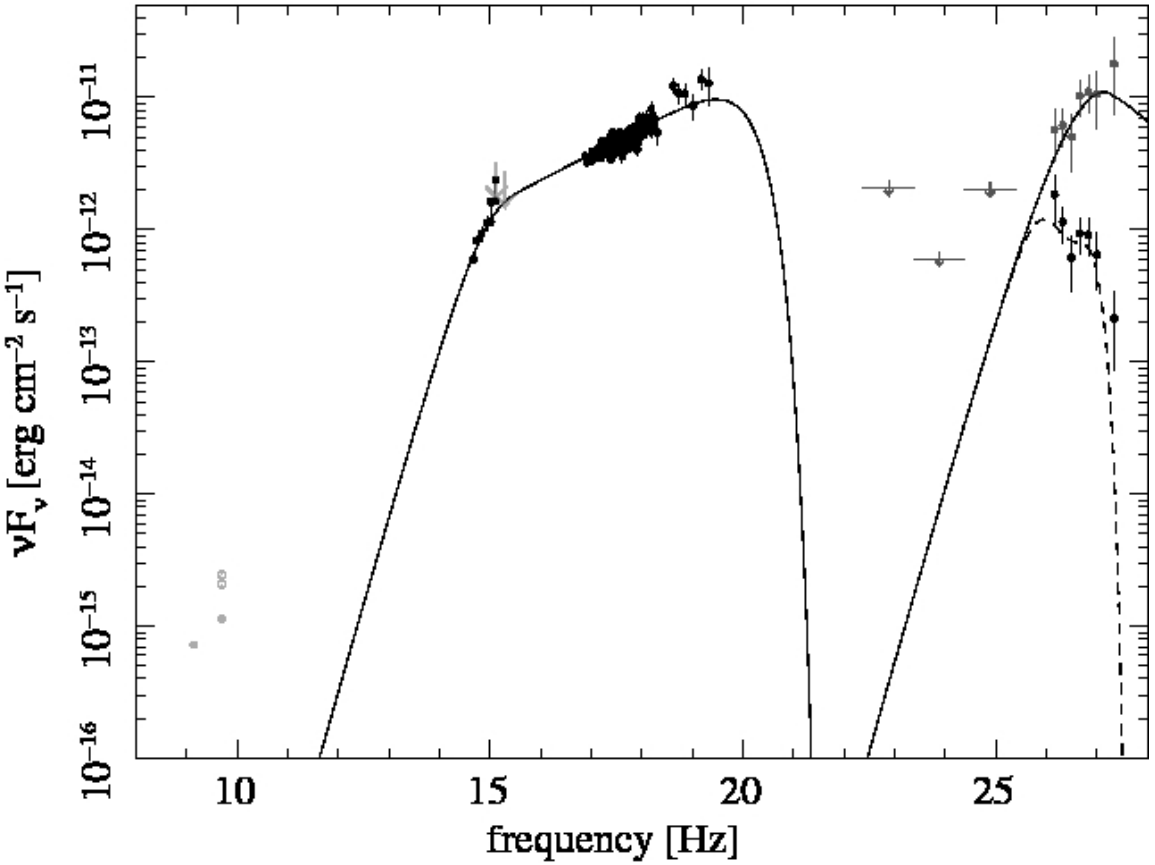




- different X-ray flux detected in our re-analysis of the 2008 Swift observations
- therefore different set of parameters for the SED

- in common the need for a very narrow electron distribution
- in common also a SSC model using a single power law energy distribution is a good description of the SED

SED modelling



solid line: SSC model with this set of parameters:
n=-2.6, radius=1x10^{16} m, magnetic field = 3.2x10^{-5} G,
Doppler factor=40, γ_{min} =3.9x10^{5}, γ_{max} = 1.9x10^{8}

dashed line: absorption by EBL by Franceschini et al. 2008

SSC (Synchrotron Self-Compton) model with:

- photon index of the XMM-Newton spectrum give direct estimate of spectral index of the electron distribution

- narrow electron distribution:
  – with a high minimum Lorentz factor
  – simple power law
  – cut off assumed around 100keV

- radius determination based on variability time scale

- Doppler factor of 40 lowest possible to account for the high IC peak

Conclusions

- 1ES 0229+200 is classified as high frequency peaked BL Lac object

- high quality XMM-Newton spectra show deviation from power law form, indicating additional absorption or broken power law

- broken power law disfavored due to the mismatch of the extrapolation to the UV/optical fluxes

- Synchrotron emission clear break in the optical regime and extends up to 100keV.

- A very narrow electron distribution with a high minimum Lorentz factor of $\gamma_{min} = 3.9 \times 10^5$ fits well the synchrotron emission and can reproduce the hard intrinsic TeV spectrum

- 1ES 0229+200 is an extreme blazar and has the highest IC peak frequency and the narrowest electron distribution among the extreme blazars known up to date.

Thanks for your attention.