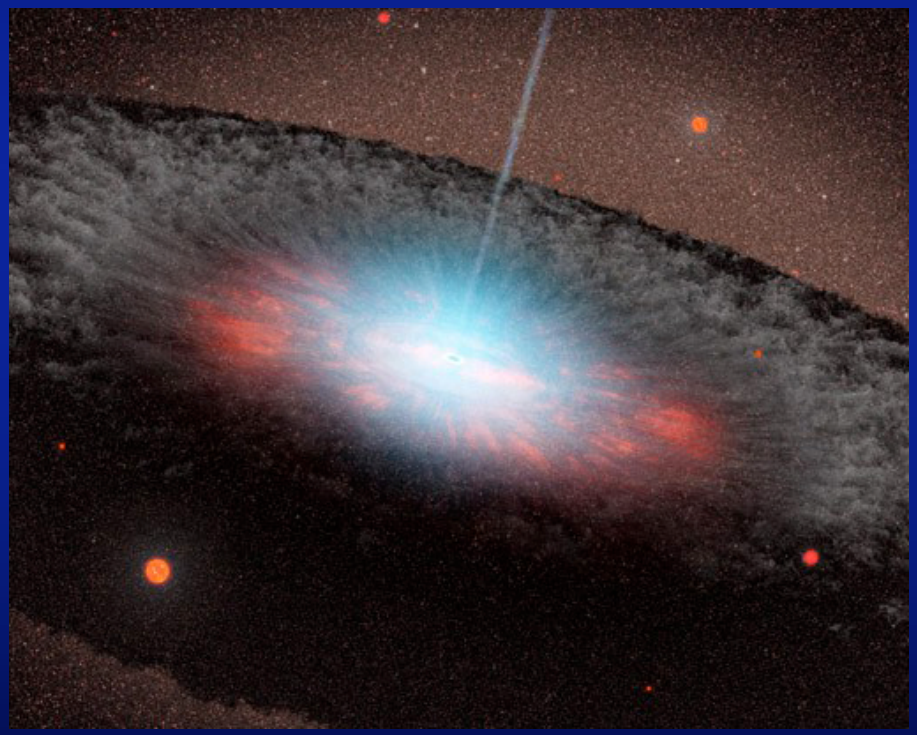
07.Dec 2nd Suzaku Conference

Suzaku view of Powerful Gamma-ray QSOs and TeV blazars

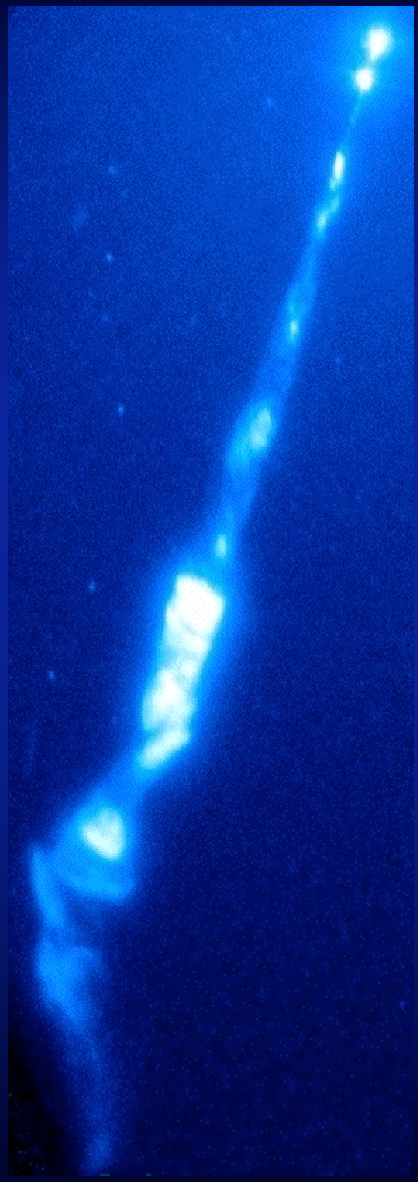


Thanks to:
T.Takahashi,
R.Sato.
M.Ushio,
G.Madejski,
GLAST-AGN team

Jun KATAOKA
(Tokyo Institute of Technology)

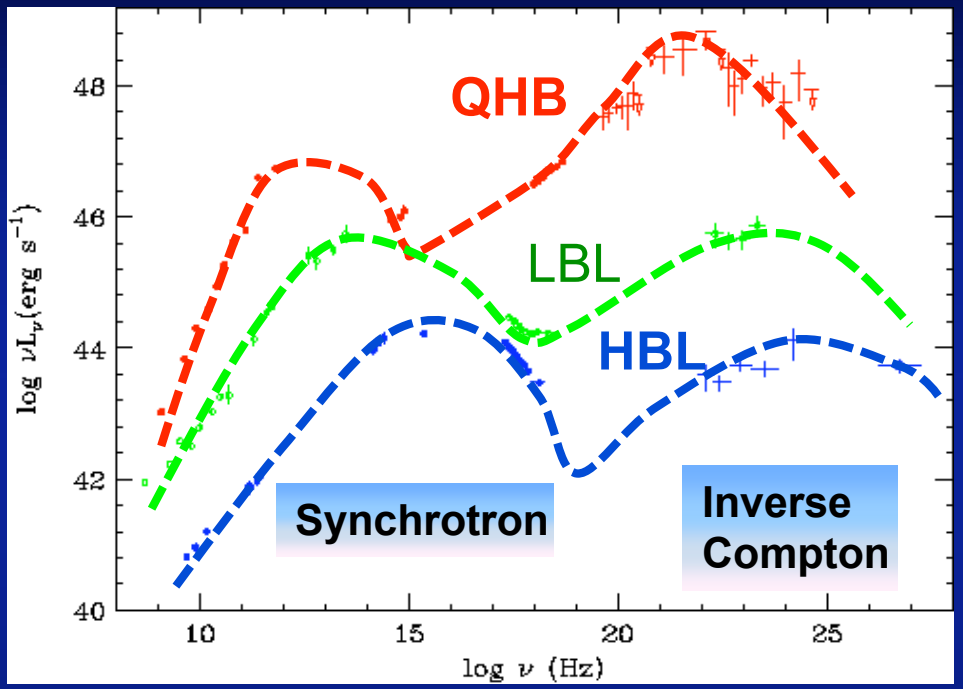
Outline

- Introduction to blazars
  - Blazar Sequence
  - underlying jet physics
- Suzaku view – TeV blazars
  - Mrk 421, 1ES1218++
  - Physics of γ_{max}
- Suzaku view – QHBs
  - PKS1510, Swift J0746++
  - Physics of γ_{min}
- Strategies in Suzaku/GLAST era
  - About future collaboration
  - Non blazar-type objects



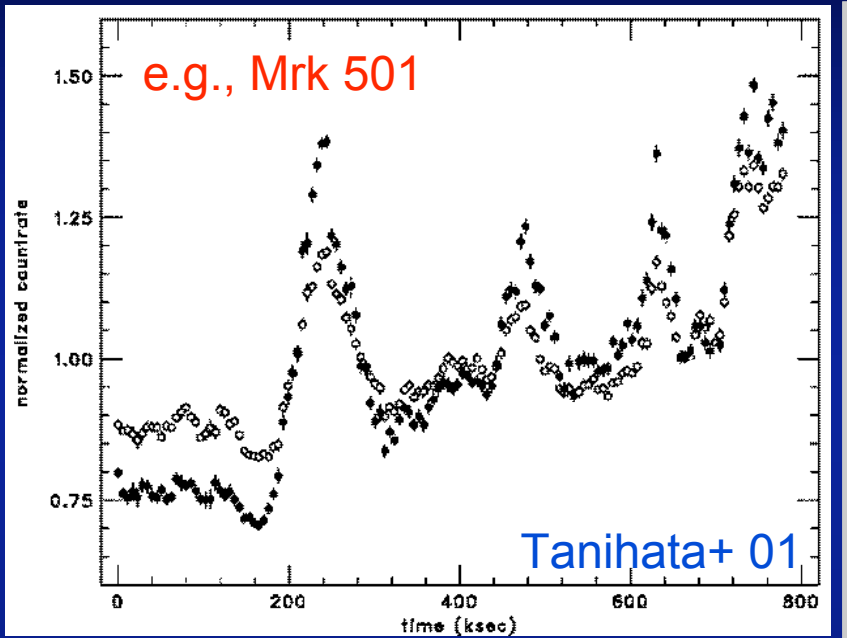
Blazar Varieties

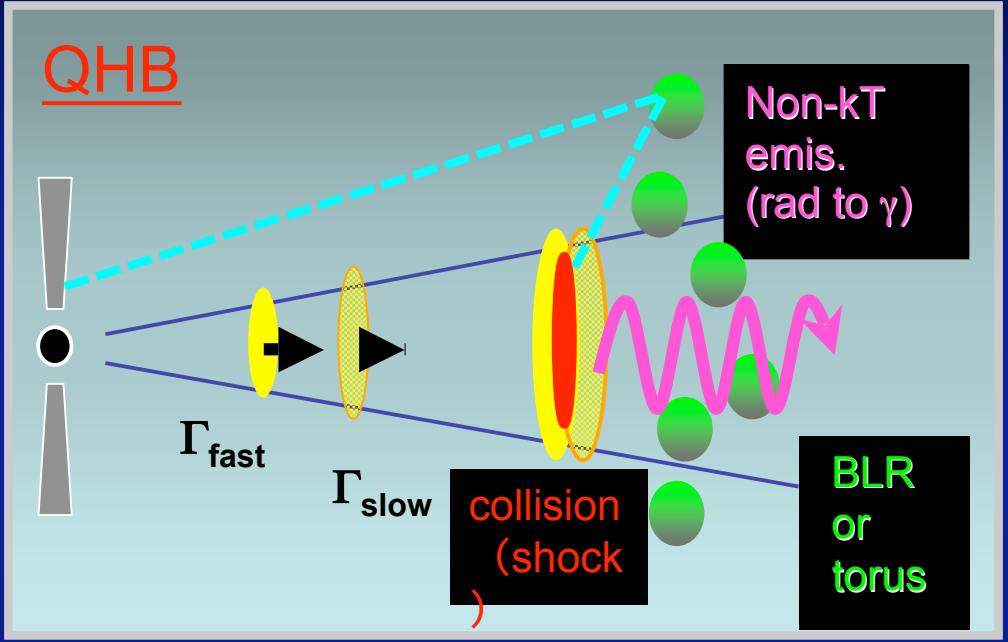
Kubo+ 98, Fossati+ 98, JK 02



- Blazars: jet closely aligned to our line of sight
  - SL motion, one-sided jet ➪ β_{jet} ~ 0.99 c or Γ_{jet} _ 10
- "Double peaks" over two decades in ν
  - Sync + Inv. Compton, but wide variety ➪ HBL, LBL, QHB
  - Most powerful objects peaks at lower ν ➪ "Blazar Sequence"

Energy Dissipation in Blazar Region

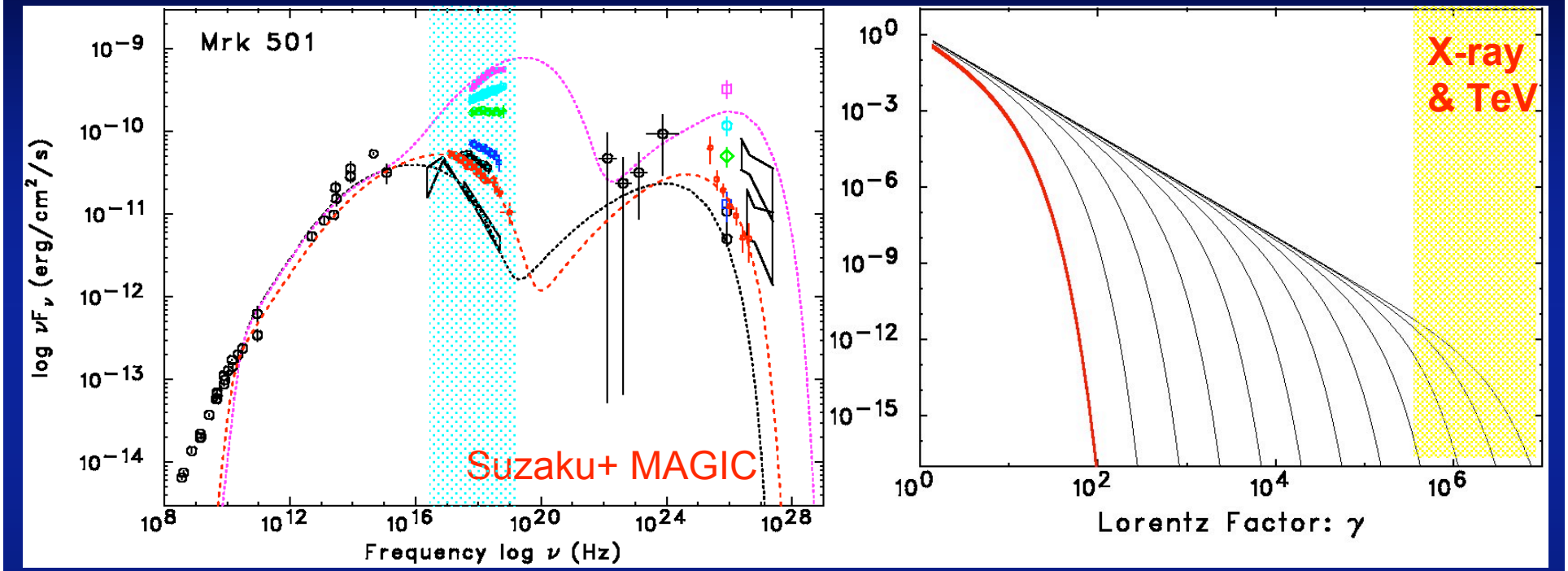




- Rapid variability suggests: $R \sim c\, t_{var}\, \delta \sim 0.001$ pc
- Lack of shorter time (t_{var} <<1d) variabity: "Internal shock" (JK+ 01)
  - Modulation of relativistic outflows - faster shell catches up with the slower one at $D \sim 10\, \Gamma_{jet}^{\,2}\, R_g \sim 10^3\, R_g \sim 0.01$ pc
    ➪ sub-pc jet (the first site of E-dissipation)
  - "Jet power" & "external photons" control the blazar sequence

Jet Physics - HBL

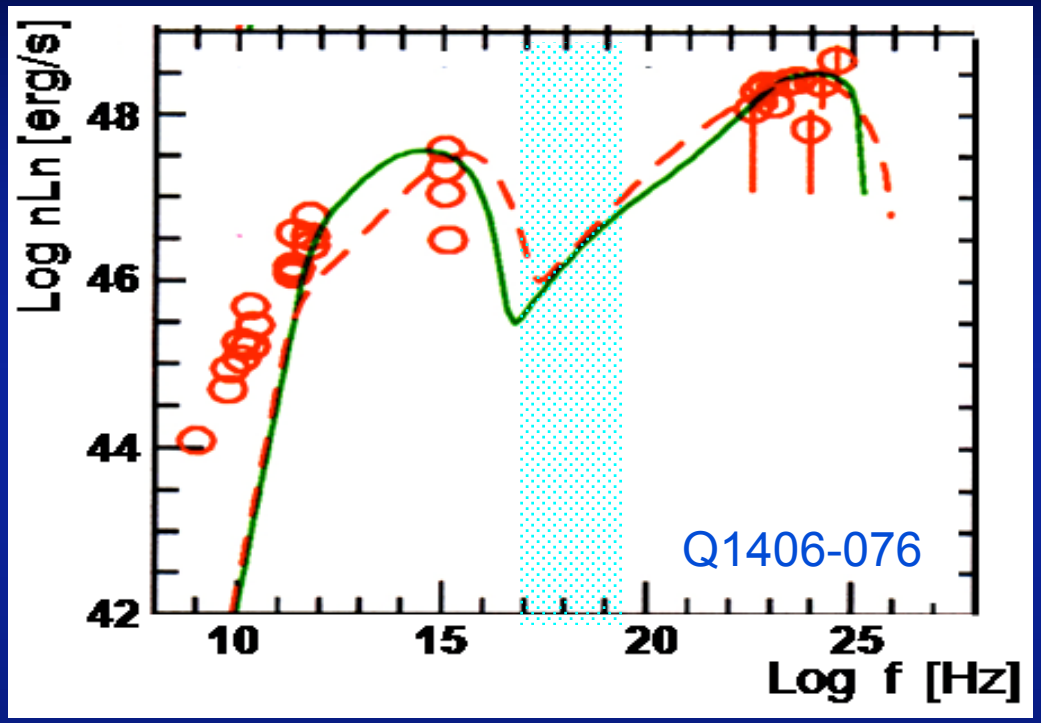
JK+ 99, Sato+ 08

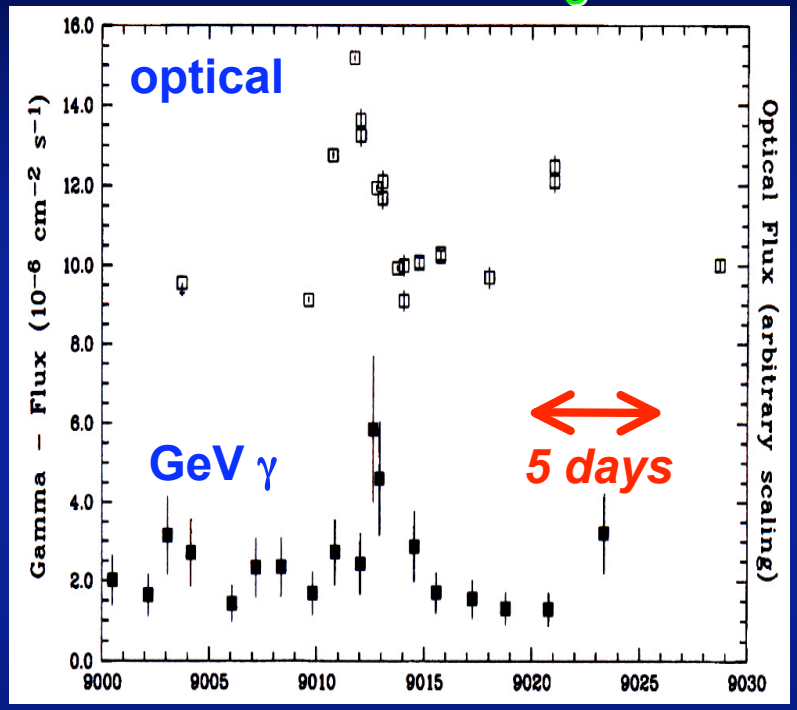


- Highly correlated X-ray/TeV flares, suggesting same electrons are responsible for *both* X-ray (Sync) and TeV γ-rays (SSC) emissions.
- Physics of "high-energy end" : γ_{max}
  - $t_{acc} \propto \gamma$, $t_{cool} \propto 1/\gamma$ ➡ $t_{acc}(\gamma_{max}) = t_{cool}(\gamma_{max})$
- Parameters in sub-pc scale jet : B, R, δ ++

Jet Physics - QHB

Wagner+ 95



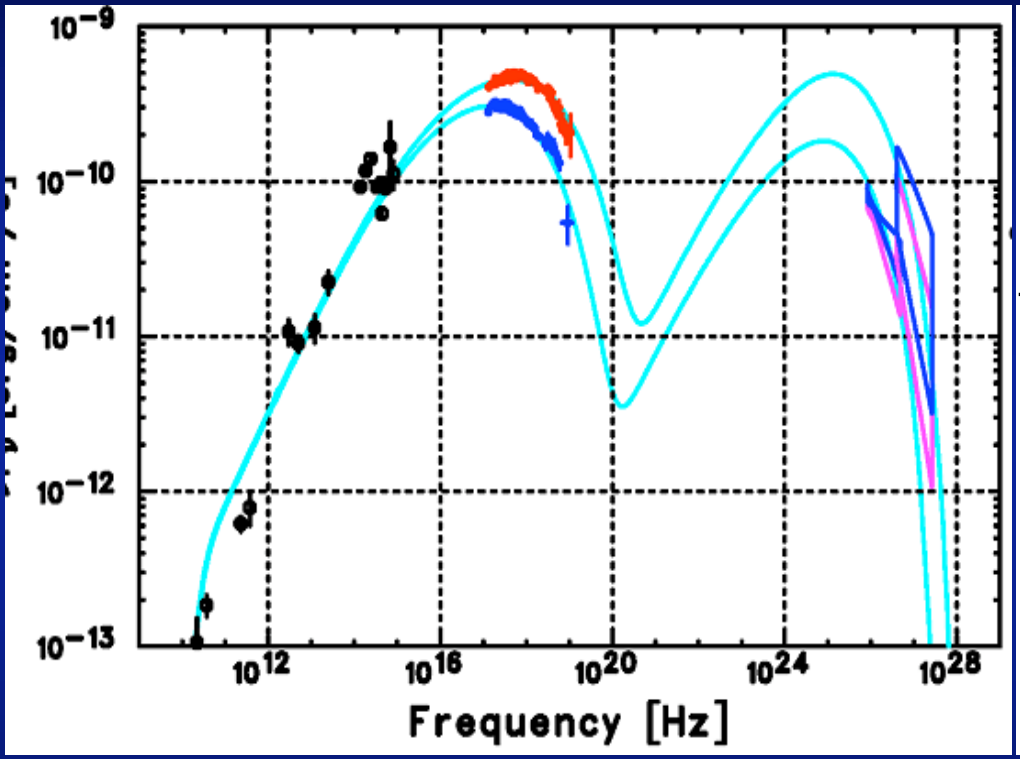


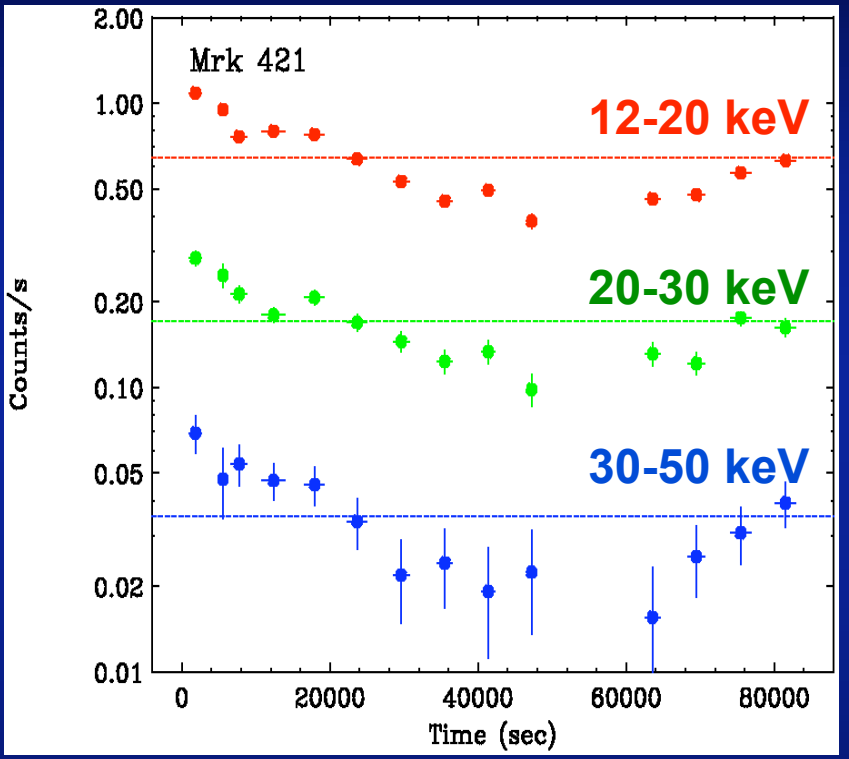
- Correlated flares, but in optical and GeV γ -rays
- Physics of "low-energy end" : γ_{min}
  - Jet power carried by low-E electrons: $\gamma \sim \gamma_{min}$
  - Intrinsic e^- spectrum
  - Particle content (Faraday depol., BC ++)

X-rays are only tool to measure γ_{min}

Suzaku View of HBL: Mrk 421

Takahashi + 08, Ushio+ 08



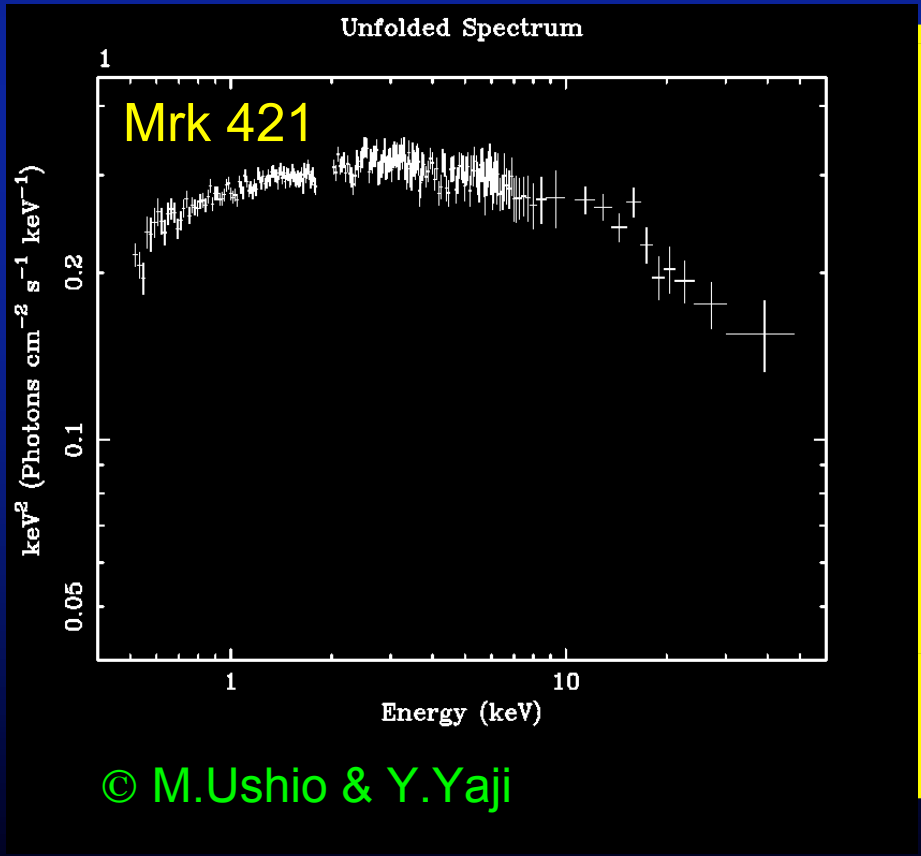


- Observed in Apr 2006 for a ~ 1day by Suzaku
  - Very bright phase, 1/3 of historical flare in 2001-02 (e.g., Cui 2004).
- X-ray spectrum gradually curves toward high energies:
  - $\Gamma_1 \sim 1.9$ (E<3 keV), $\Gamma_2 \sim 2.2$ (3<E<18 keV), $\Gamma_3 \sim 3.0$ (E>18 keV)
- Detection of Intra-day variability above 30 keV

Spectral evolution on ~ hour scale

- Extremely low BGD of Suzaku enables *for the first time* to monitor spectral evolution on ~hr scale, up to 50 keV

➪ see, M.Ushio's poster



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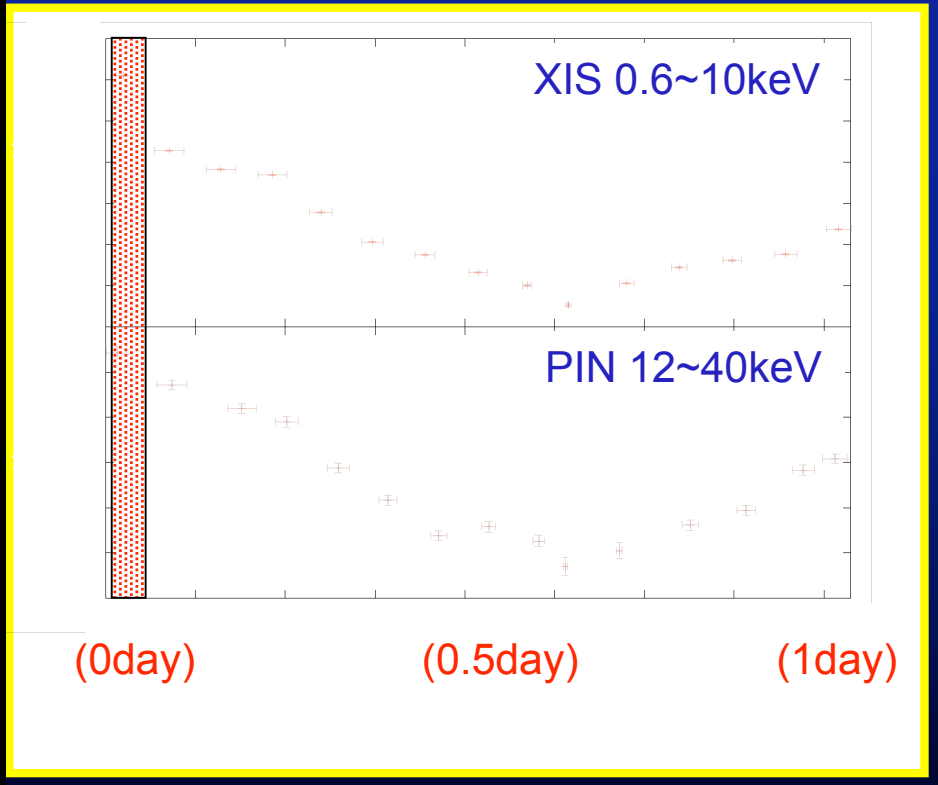
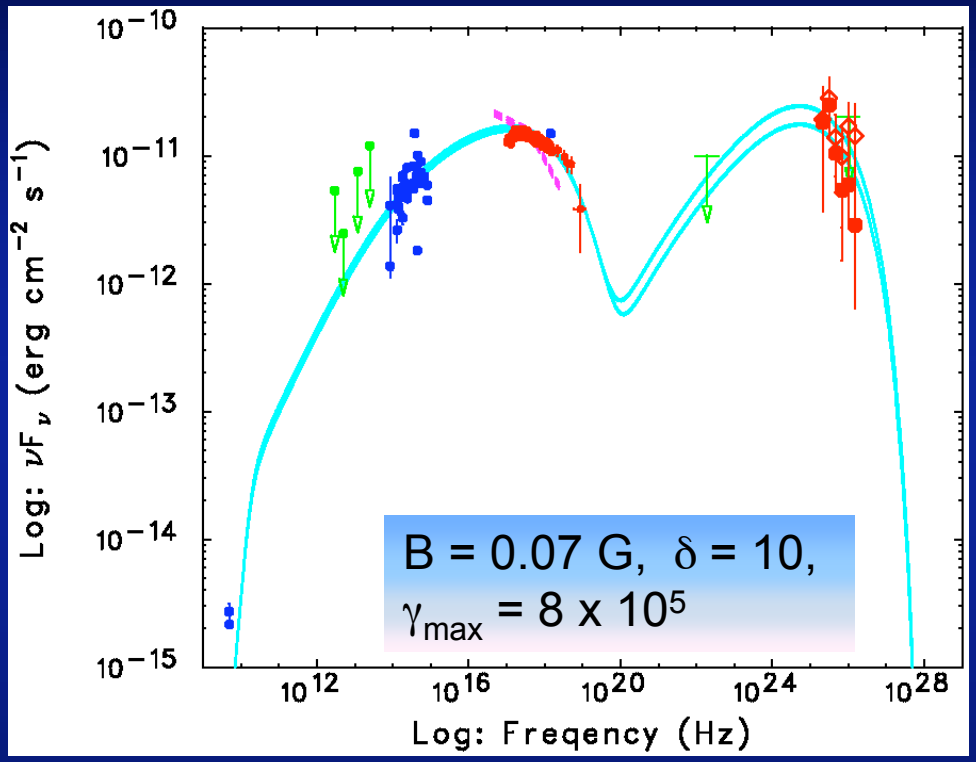
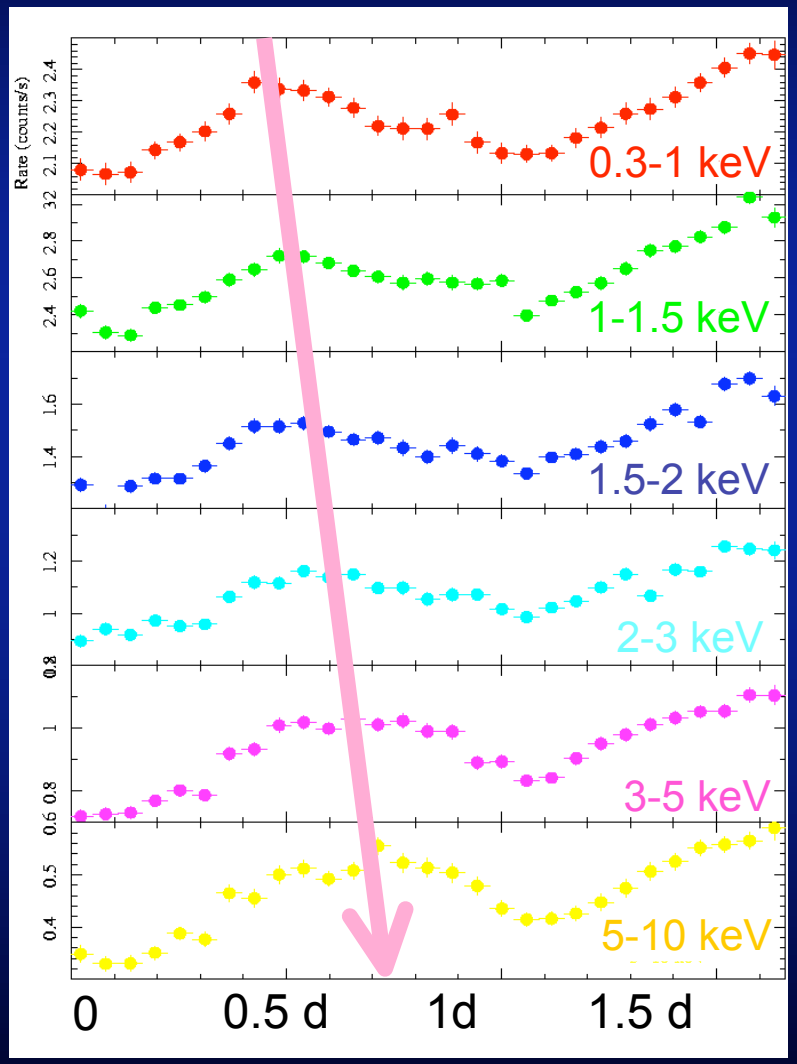


Suzaku View of HBL1ES1218-304

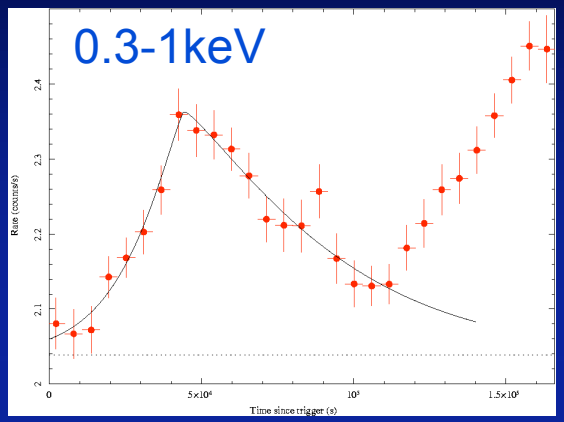
Sato, JK+ 08

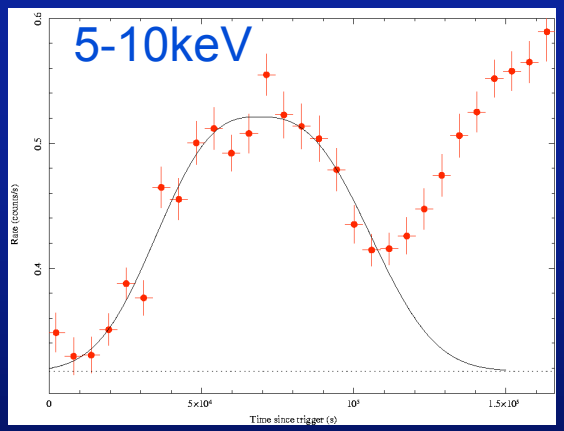


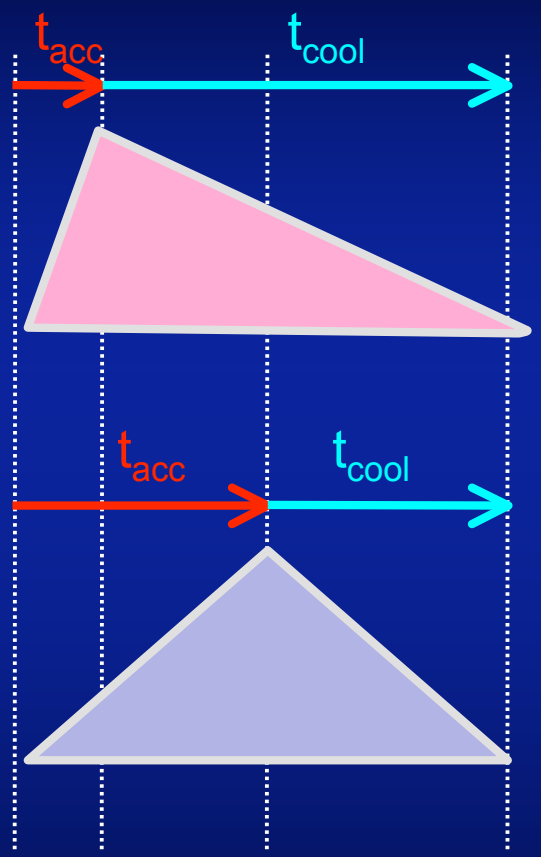


- A distant TeV blazar at z = 0.182
  - ➪ new challenges to EIRB models
- SYNC peaking at E ~ 10 keV
- The first clear detection of "hard-lag"

Why Hard-Lag?







(i) low -E ($\gamma < \gamma_{max}$)

- Rapid rise & slow decay
- Asymmetric LC

(ii) high-E ($\gamma \sim \gamma_{max}$)

- Slow rise & fast decay
- Symmetric LC ($t_{acc} \sim t_{cool}$)

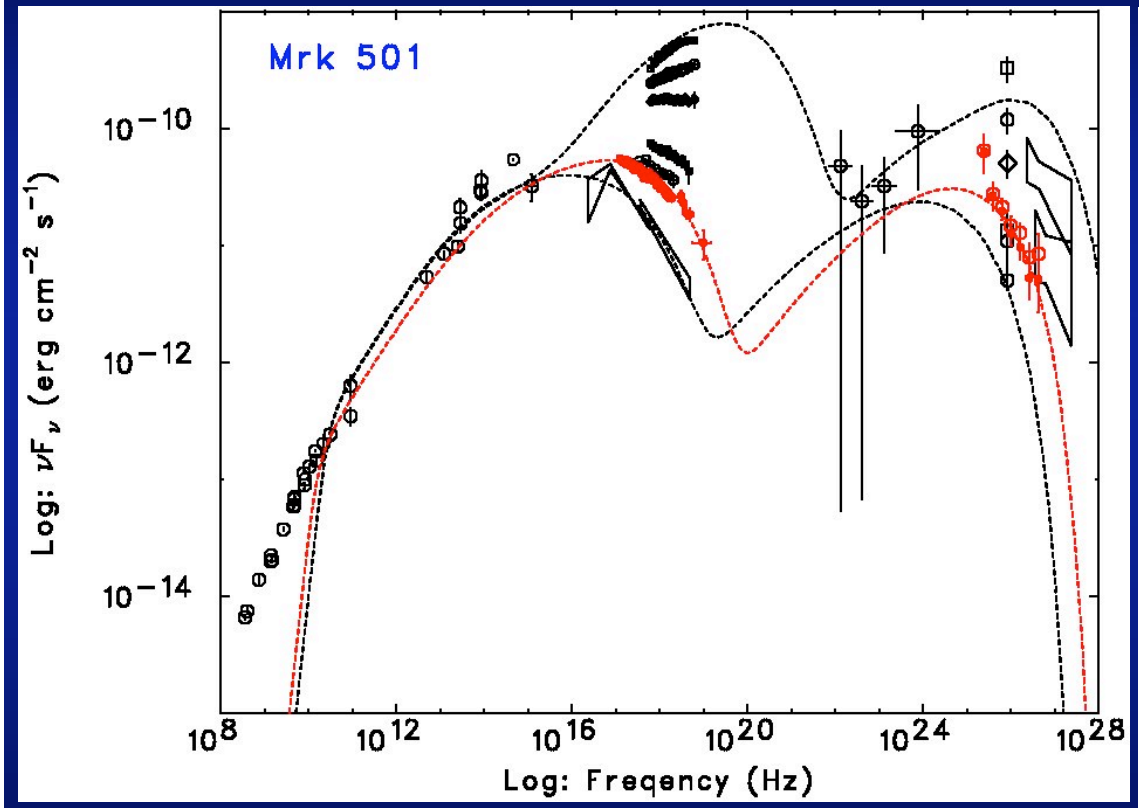
- Toy model: "rise time" ~ t_{acc} & "fall time" ~ t_{cool}

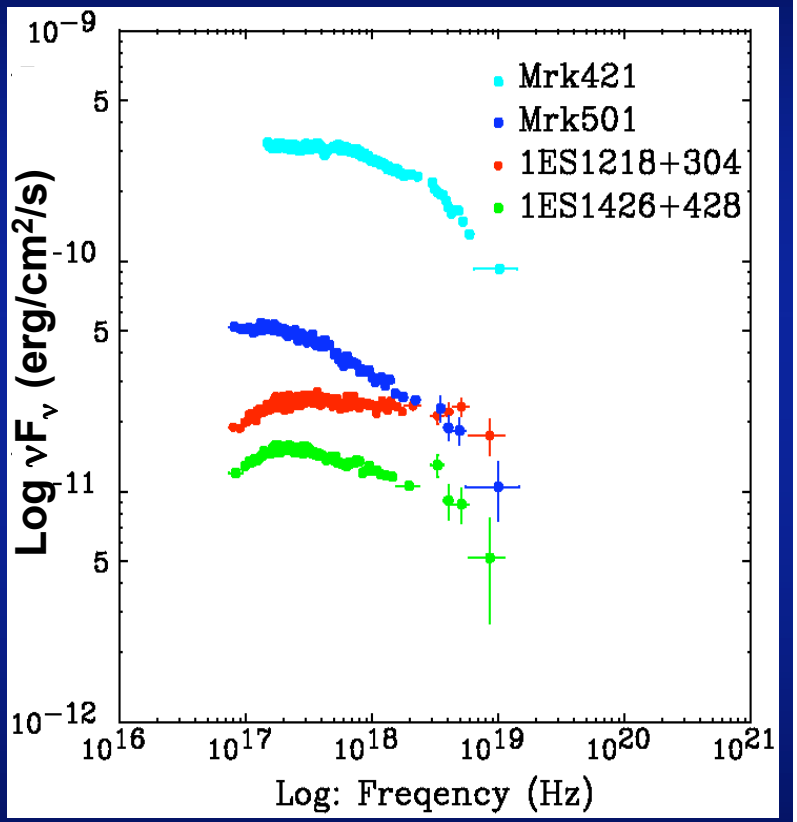
- $t_{acc}(E) = 9.65 \times 10^{-2} (1+z)^{3/2} \xi B^{-3/2} \delta^{-3/2} E^{1/2}$
- $t_{cool}(E) = 3.04 \times 10^{3} (1+z)^{1/2} B^{-3/2} \delta^{-1/2} E^{-1/2}$

⇨ B = 0.077±0.008 G (c/s with SED)

Qucick Overview of other HBLs

Sato+ 08, Kohmura+ 08

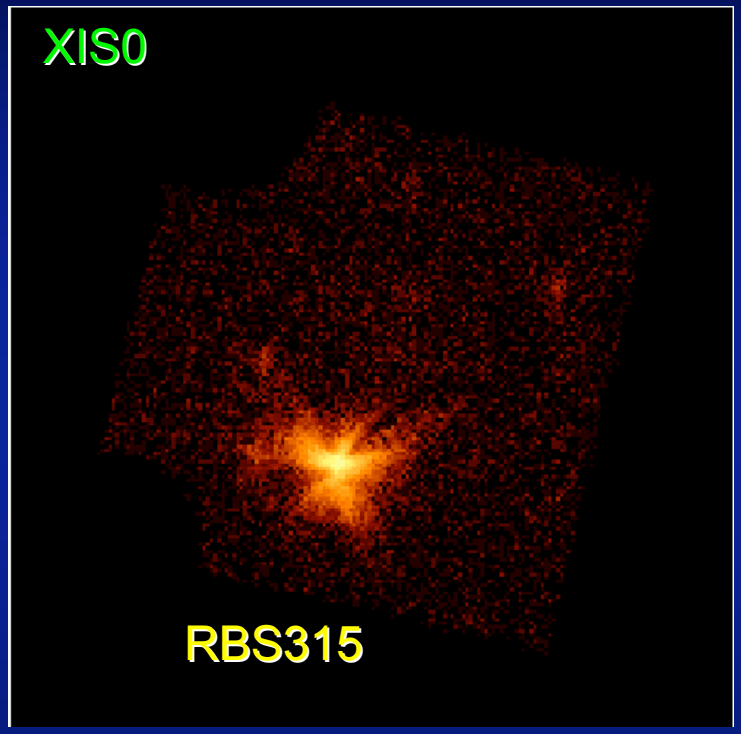


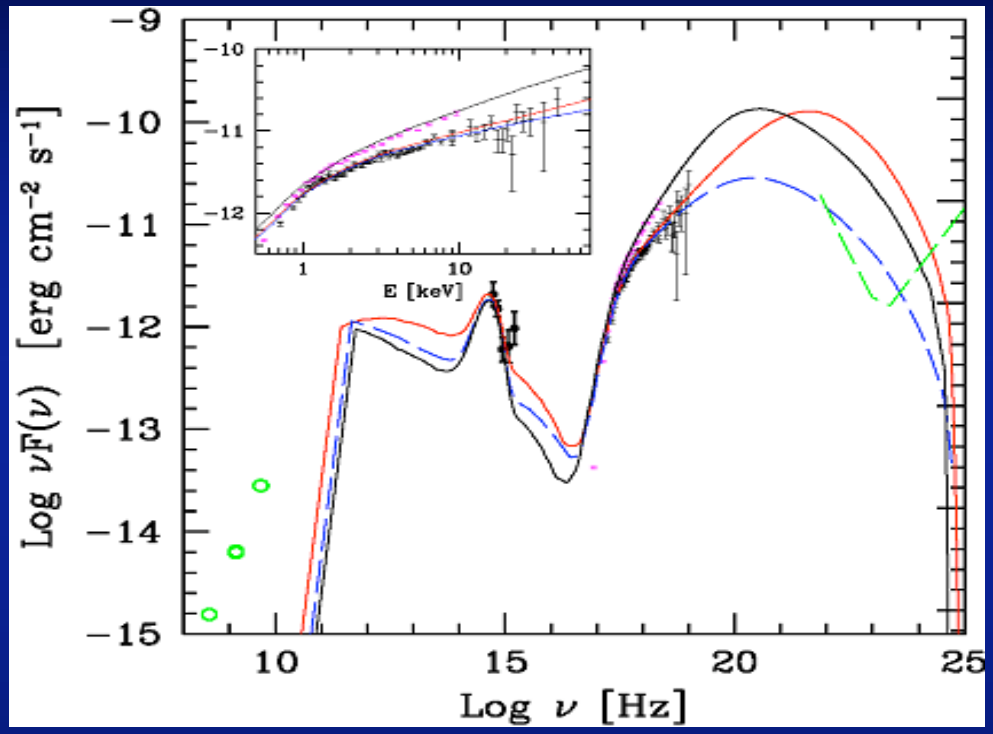


- Many & many are in progress for TeV blazars !
  (Takahashi+ 08, Sato+ 08, Ushio+ 08, Kohmura+ 08…)

Suzaku view of RBS 315 (Sambruna's talk)

Tavecchio+ 07

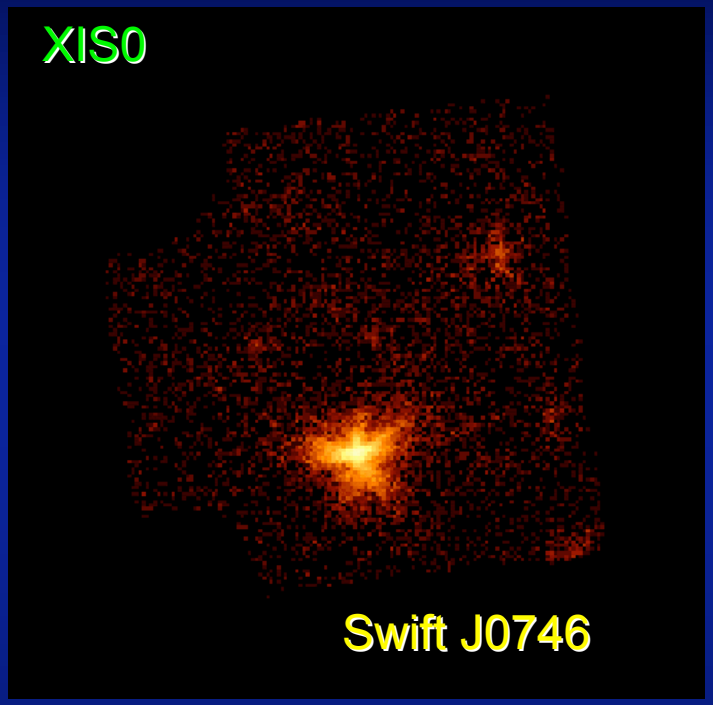


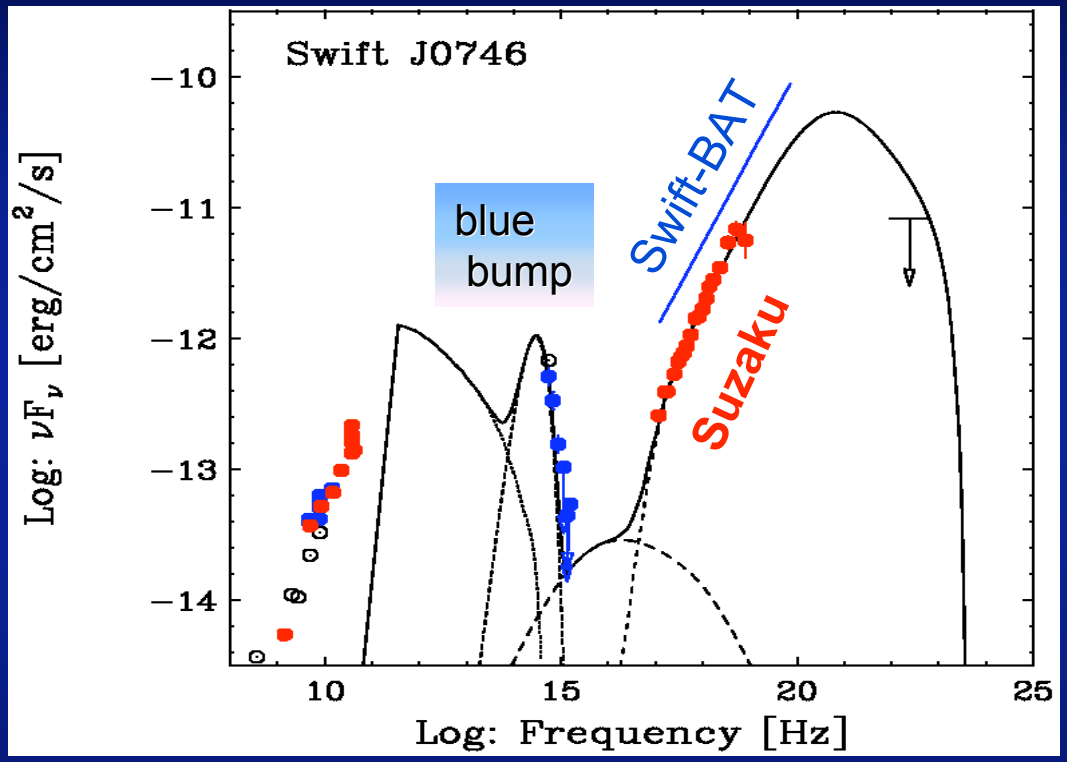


- A very distant QSO at z = 2.69
- Suzaku spectrum up to 50 keV (~ 200 keV @src frame)
- Two important discovery:
  - γ_{min} must be ~ 1 (c.f., VLBI results of 3C 279)
  - extremely hard PL (Γ = 1.2) ➪ $N(\gamma) \propto \gamma^{-1.4}$

Suzaku view of Swift J0746 (z=2.98)

Watanabe+ 08

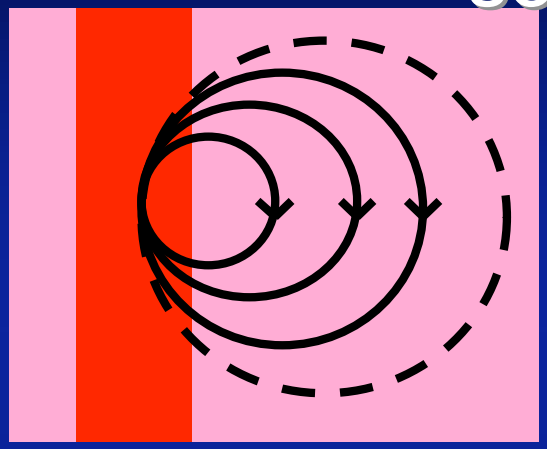




- More distant "MeV Blazar" discovered by Swift (Sambruna+ 06).
- HXD/PIN detection up to ~ 30 keV (~ 120 keV in the src frame) though a fator of ~3 fainter than in the Swift/BAT exposure.
- An extremely hard PL with no sign of low-E cutoff; $\Gamma \sim 1.15$.

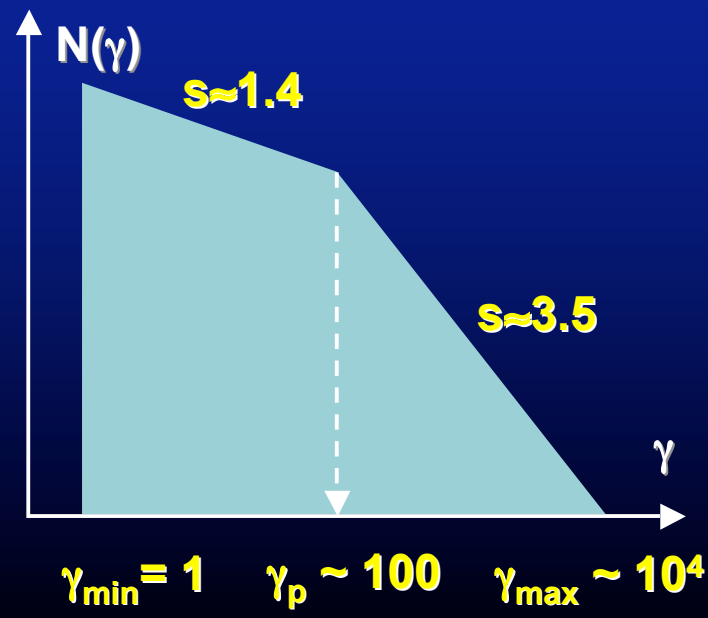
Why the electron spectrum being so "hard "?

e.g., Sikora+ 02



Shock front

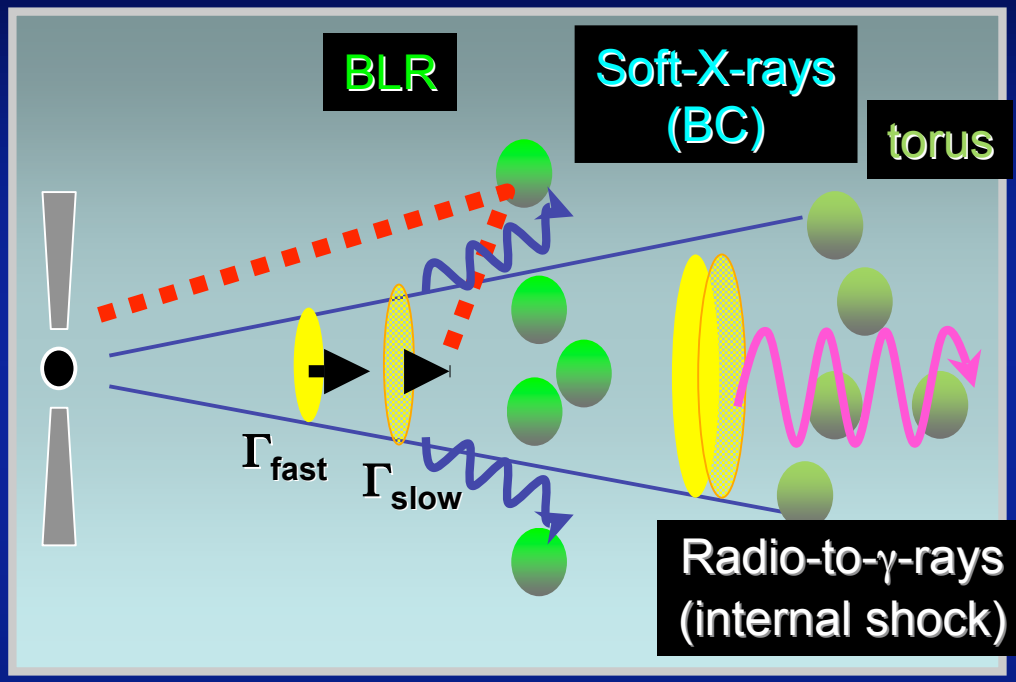
- Electron Gyro-radius is $R_g = \gamma\, mc^2/eB \propto E_e$
- Low-E e^- cannot travel across the shock ($\Delta < R_g$; Δ ~ Gyro radius of "thermal" protons)
- Critical point: γ_p ~100-1000 _ m_p/m_e

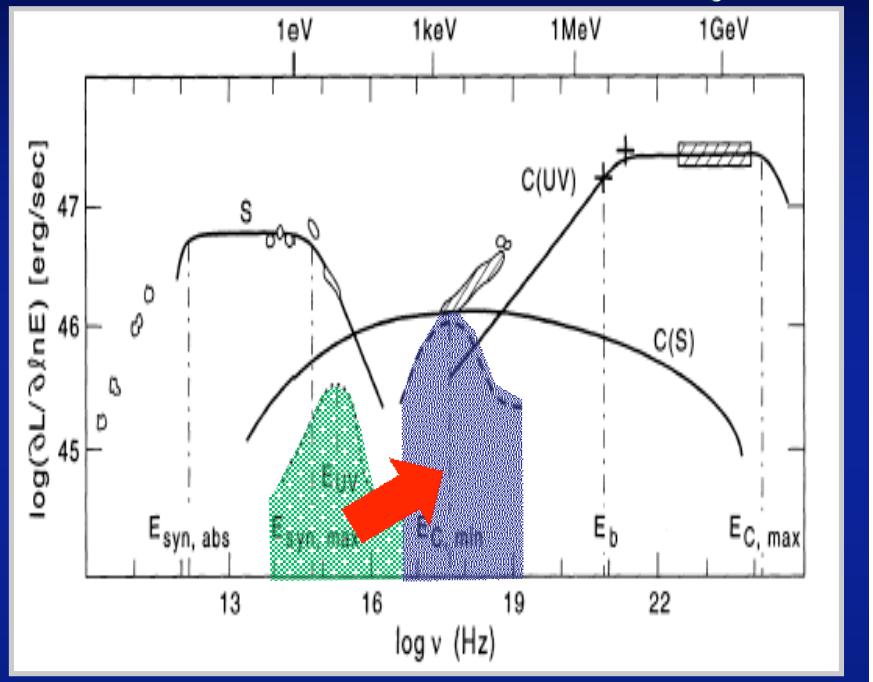


- $\gamma_{min} \rightarrow \gamma_p$ (~m_p/m_e)
  - Stochastic accel. (2nd order)
  - Two-stm instabilities …Hoshino+ 92
  - B-recn. ? …Ramanova & Lovelace 92
- $\gamma_p \rightarrow \gamma_{max}$
  - "Standard" shock accel. (1st order)

QHB: challenges to jet content

Sikora+ 94, Sikora & Madejski00

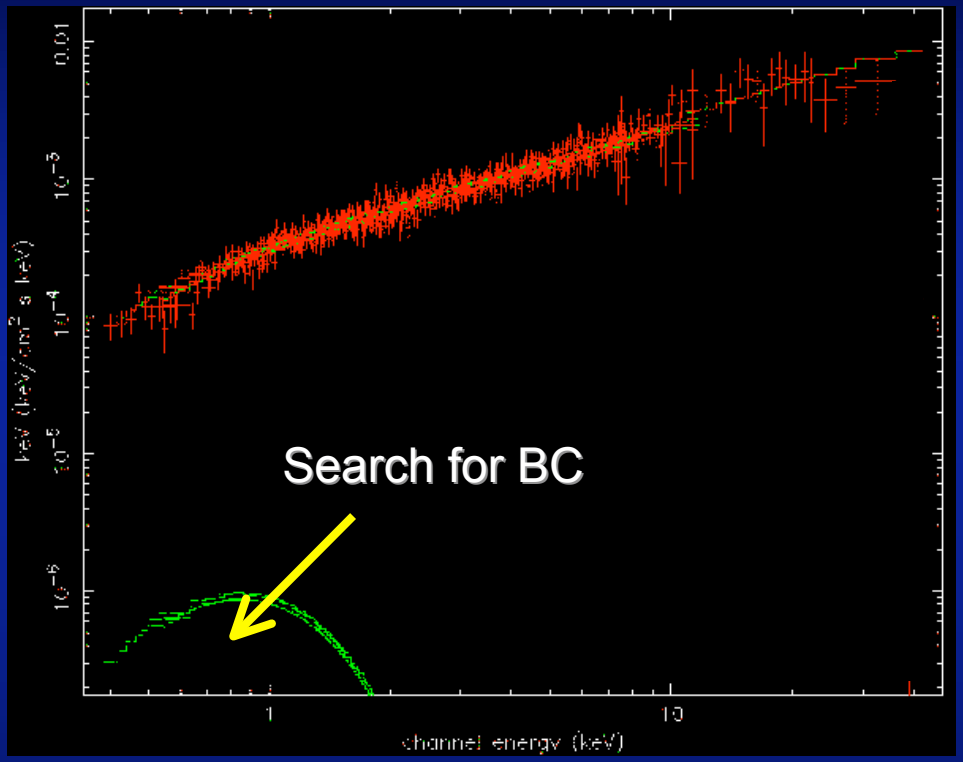




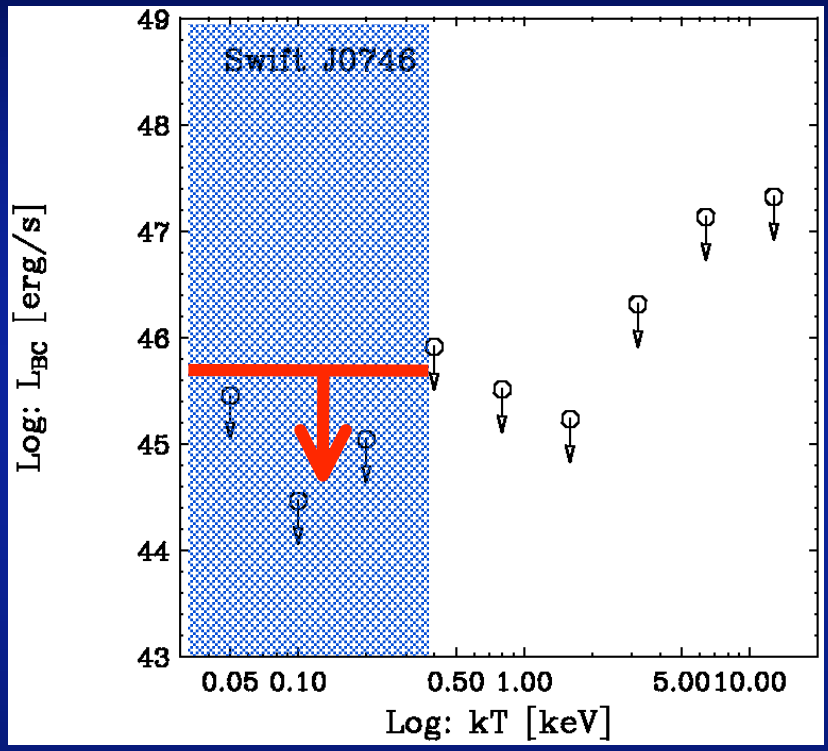
Sync, SSC, ERC ++ …?

- "Seed" for the ERC process is UV photons reflected by the BLR.
  E_{diff} ~ 10 eV, L_{diff} ~ 10^{46} erg/s
- Before the "blazar zone", fast /slow shells upscatter UV via the "bulk-Comptonization" to $E_{BC} \sim \Gamma_{BLK}^2 E_{diff}$ ~ 1 keV.
- BC luminosity depends on the jet composition : $L_{BC} \propto (n_e/n_p) L_{jet}$

Swift J0746 ; search for BC peak



Watanabe +08

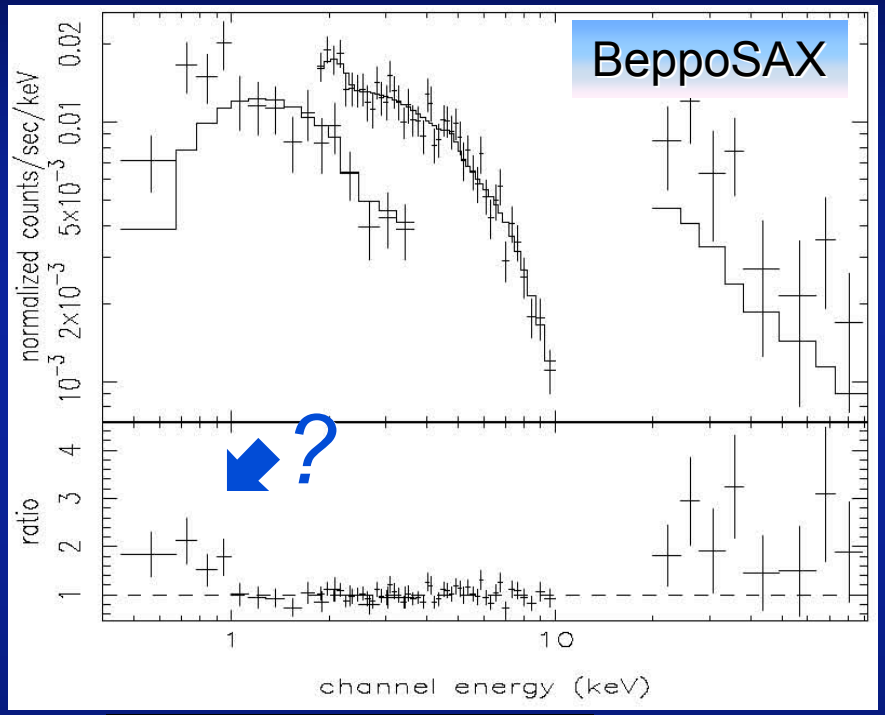


- Negative detection, but stringent UL. (assuming black body-type emission).
- Expected position of BC: $\nu_{BC} \approx \Gamma_{BLK}^2 \nu_{BB}$ ⇔ 0.03 keV < kT < 0.3 keV
- $L_{BC} < 3 \times 10^{45}$ erg/s ⇨ $L_{e,cold} < 6 \times 10^{42}$ erg/s

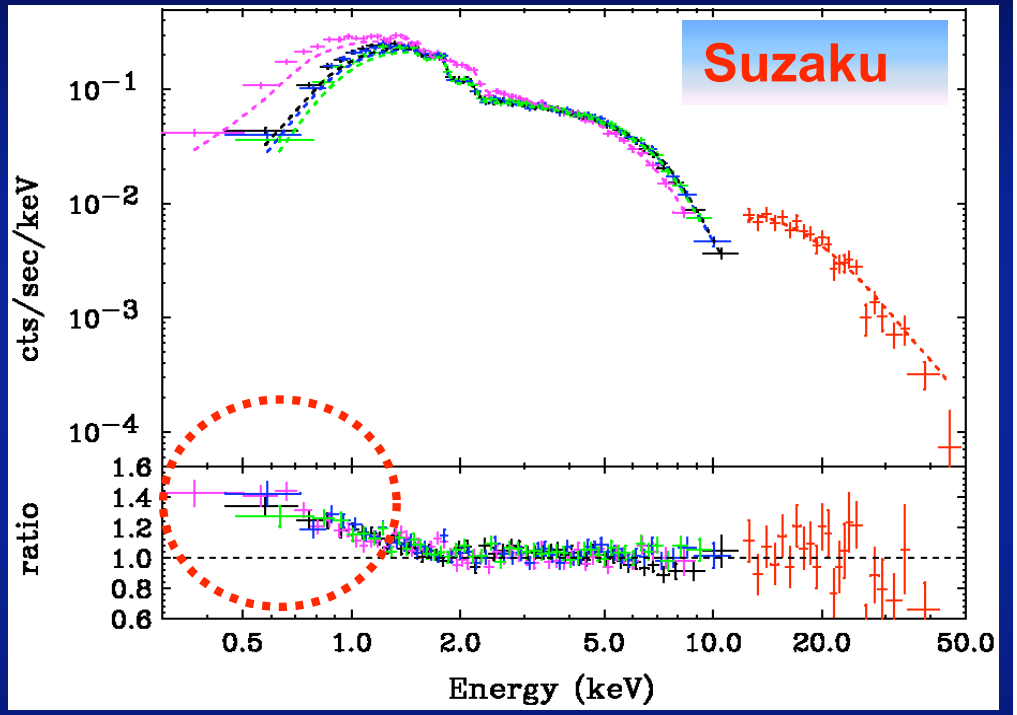
$L_{e,hot} / L_{e,cold} \gtrsim 300$; Significant power carried by pr

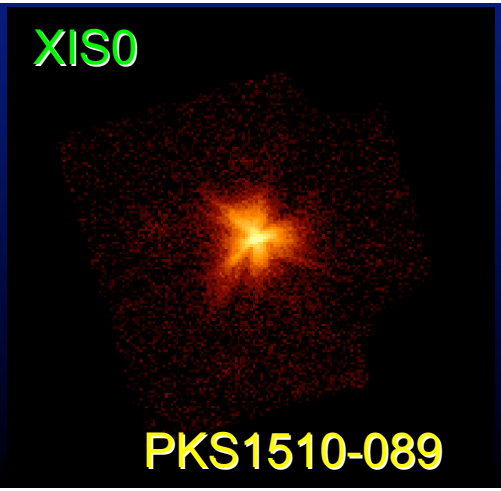
Suzaku view of PKS 1510-089 (z=0.361)

Tavecchio+ 00



JK+ 07

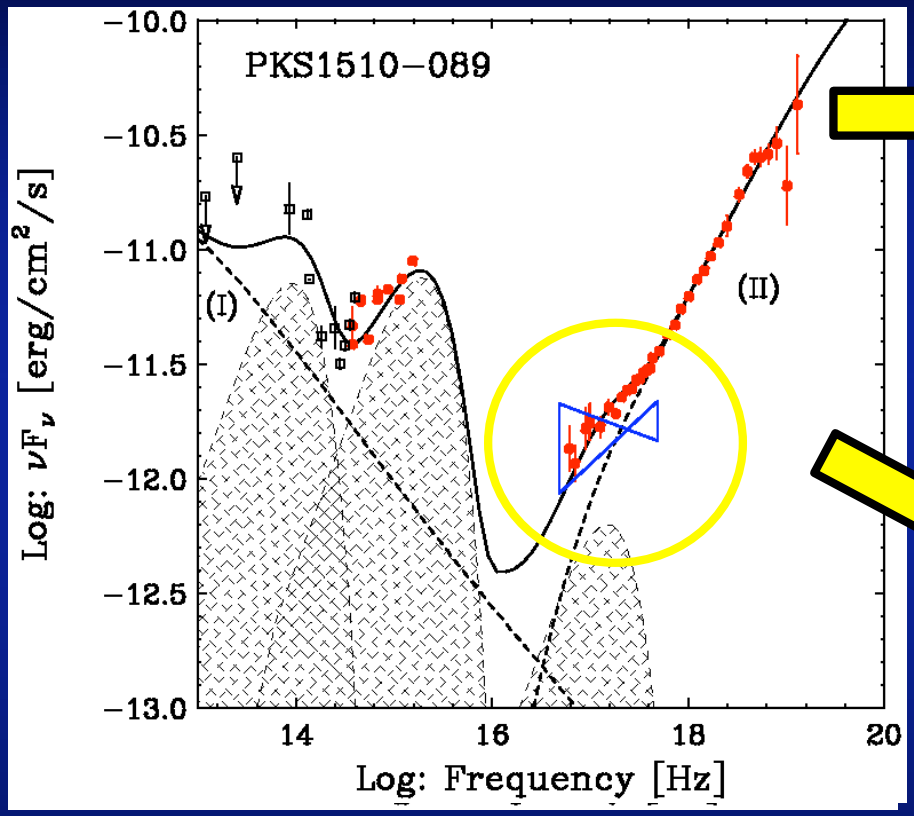


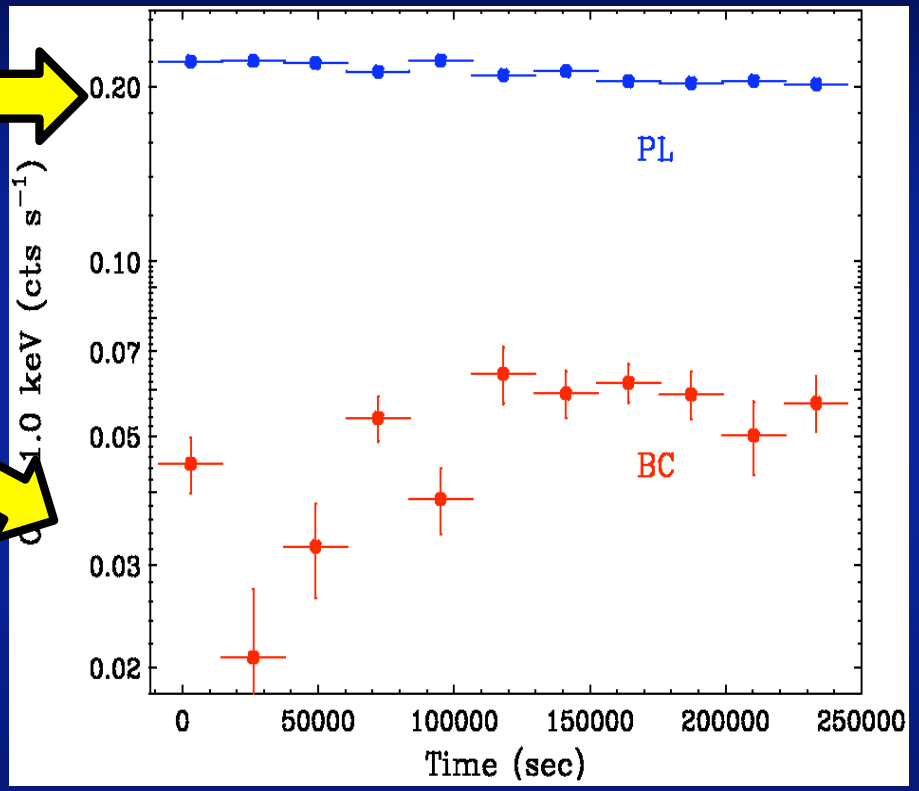


- Intensive monitoring over 3 days to confirm an excess emission suggested by *BeppoSAX*
- Hard spectrum (**Γ = 1.2**) up to 50 keV, with positive detection of excess at **kT ~ 0.2 keV**

Practice to the GLAST : PKS 1510 (z = 0.361)

JK+ 07



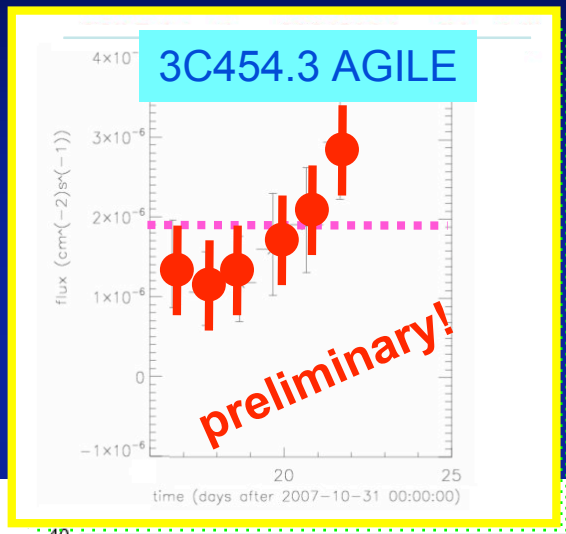


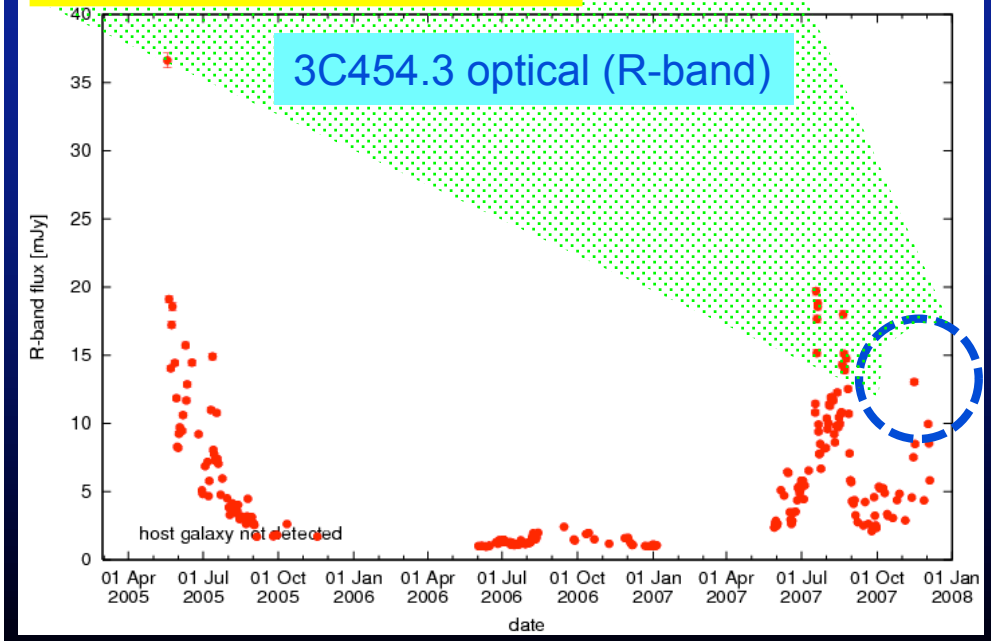
- Highly variable, though underlying PL is stable (e.g., Celotti+ 07)
- Expected BC luminosity; $L_{BC} \approx 2\times10^{44}$ erg/s ⇔ $L_{exc} \approx 2.6\times10^{44}$ erg/s
- Soft X-ray excess can be naturally explained if **$N_e/N_p \approx 10$.**

Suzaku ToO : 3C 454.3 (z=0.859)

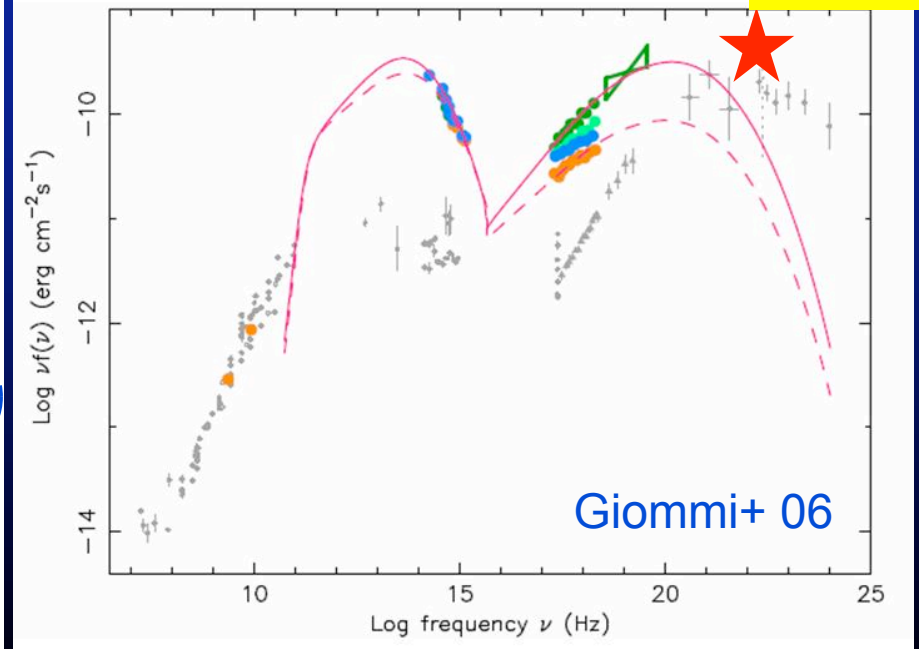
- Observed in Dec.5/6 (data not available yet)
- Strong flare detected with AGILE:
  > 2×10^{-6} ph/cm^2/s (@ E> 100 MeV)
- "Historical flare": only 4 src in CGRO life

➪ Future collaboration with GLAST important

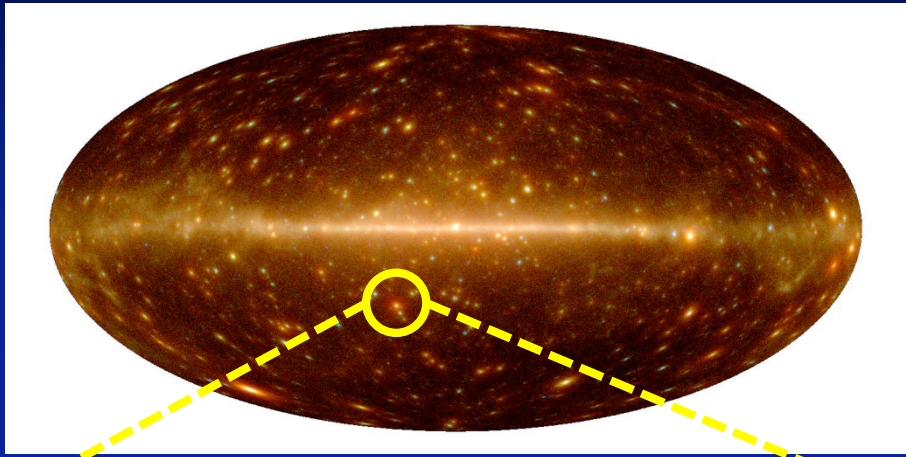


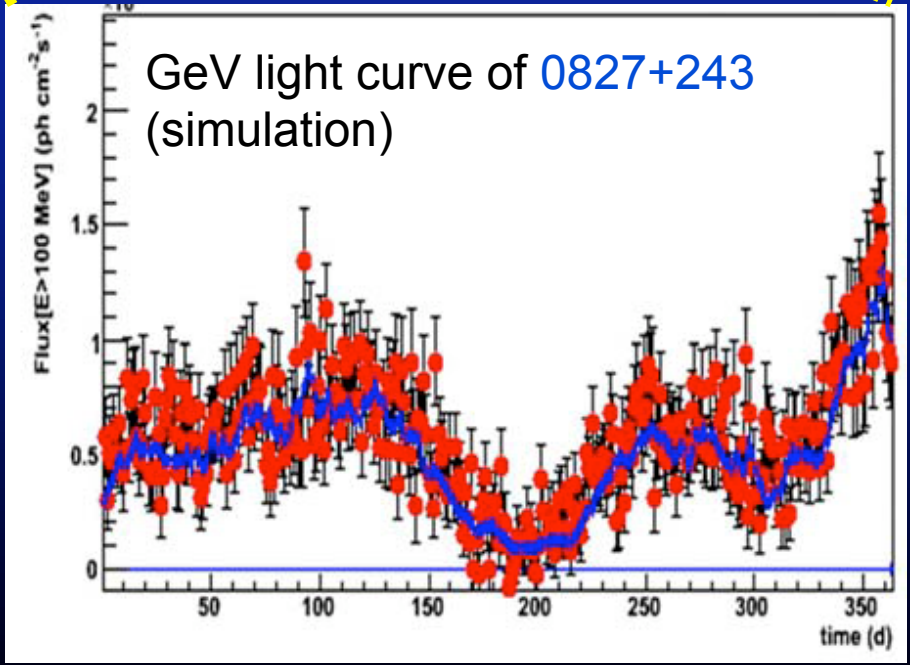


AGILE



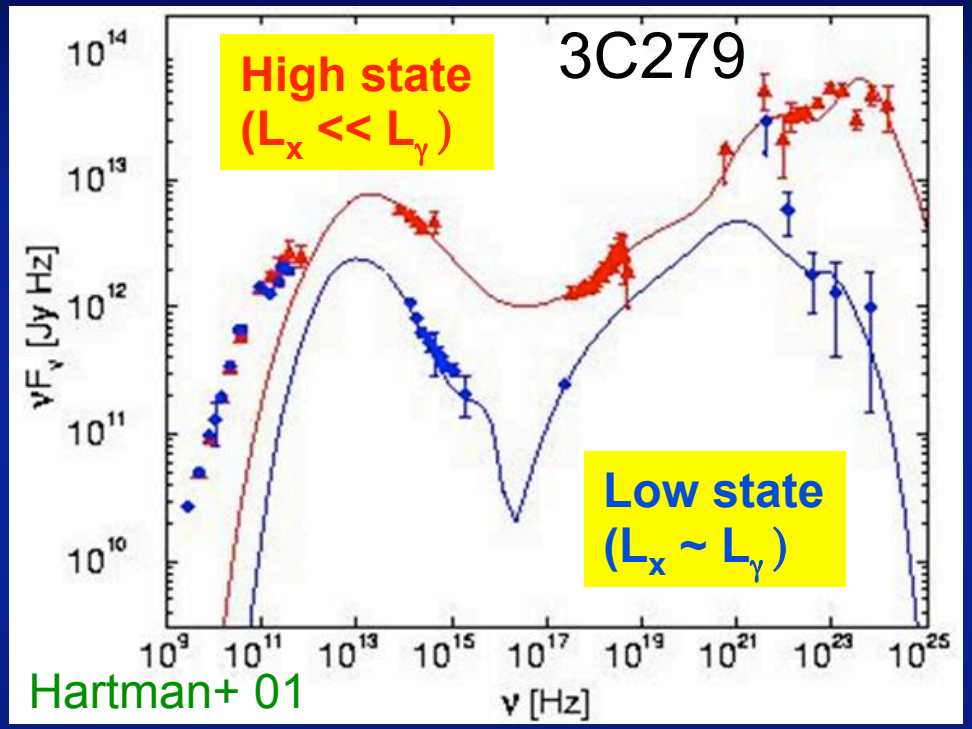
GLAST Launch: Fast Approaching!

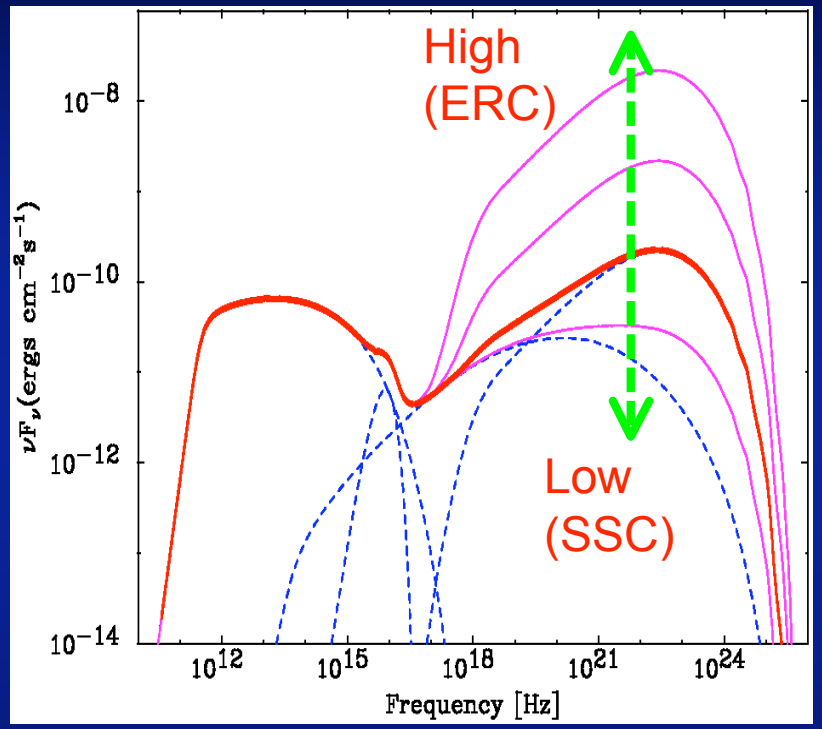




- Expected launch date: 5/29. 2008
- Expose all sky every 3hrs
- More than 1000 blazars, mostly QHBs expected.
- International collb. between Suzaku/GLAST strongly awaited!

GLAST challenges to QHB: SED evolution

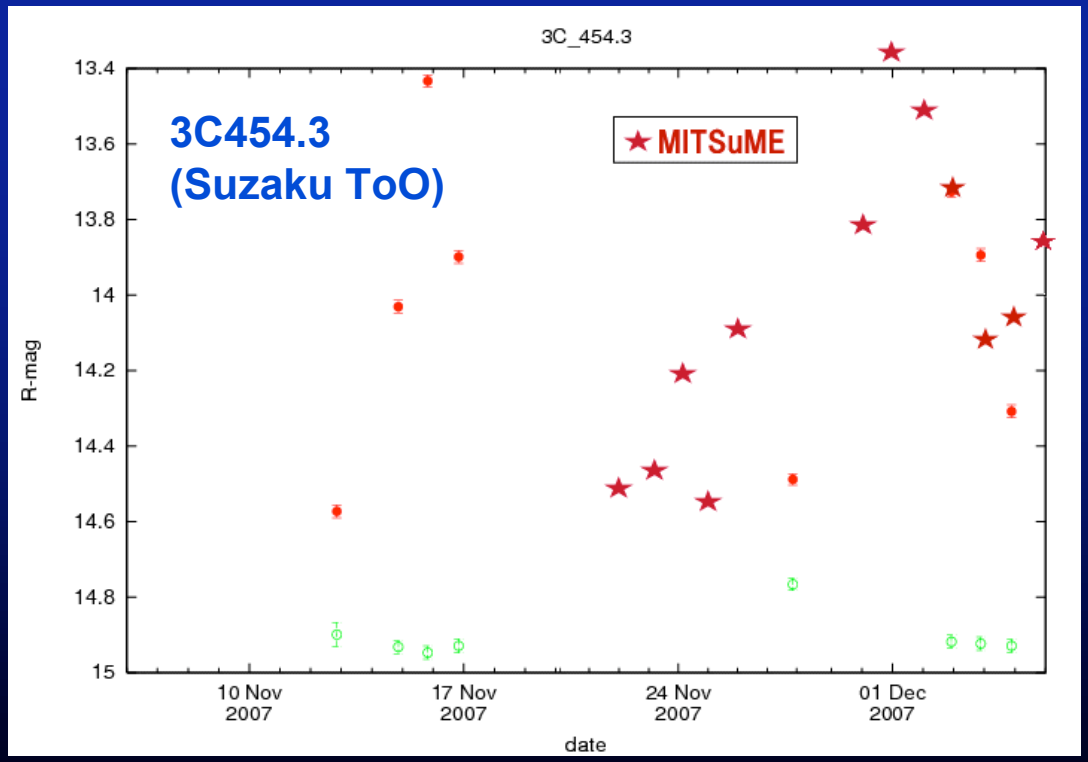




- Most EGRET blazars were detected "only once" in its flaring state
  - ➪ Sampling bias … reality of blazar sequence?
- ex.3C279 : transition between "QHB-like" & "HBL-like" SEDs
  - ➪ Cosmological evolution
    Unification of HBL/LBL/QHB ++

Suzaku/GLAST Strategies: AO-3

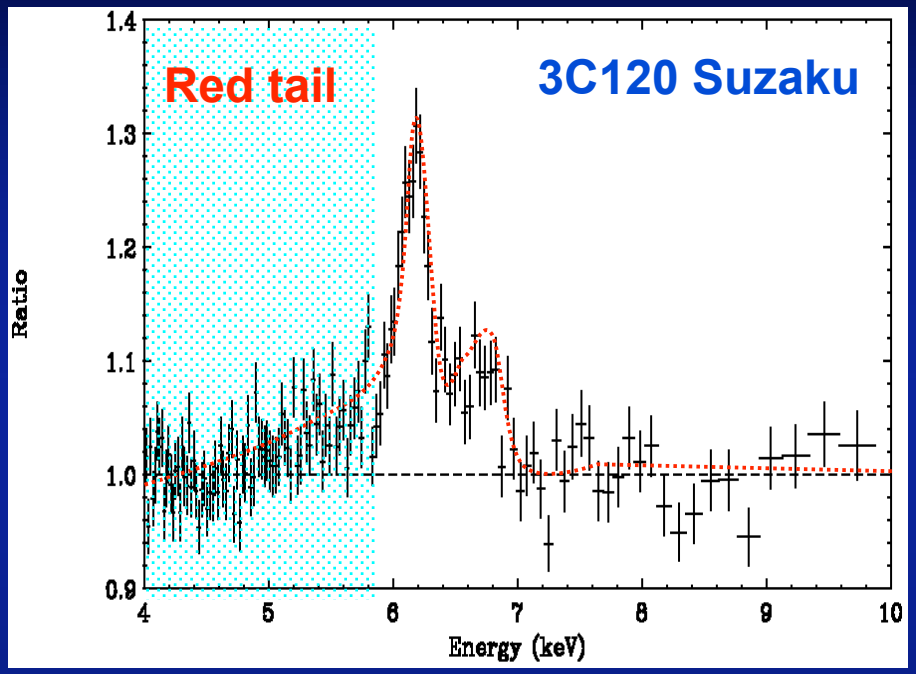
- We have submitted 2 GLAST-oriented proposals for Suzaku-AO3.
  - 40 ksec x 11 QHBs (PI: JK, Tad, Gino, ++, on behalf of GLAST team)
  - 200 ksec x 2 QHBs (PI: Greg++, on behalf of GLAST team)
- World-wide ground-based observations: already started

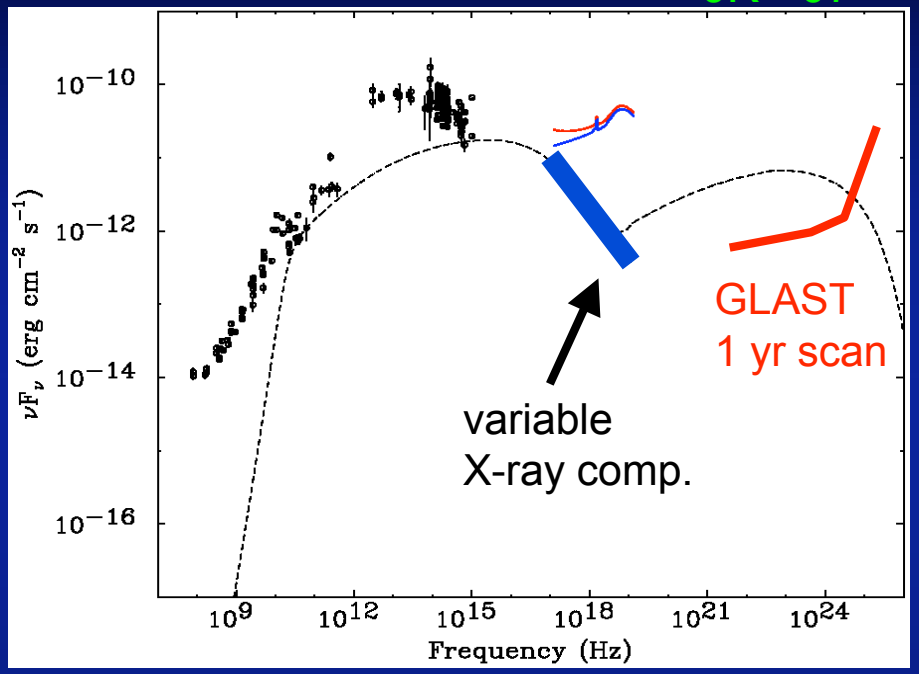


MITSuME (Tokyo Tech)

GLAST challenges to BLRG: non-blazars

JK+ 07





- BLRG: mis-aligned blazar (i.e., both disk and jet visible)
- Suzaku reveals asymmetric Fe line, that may suggest $R_{in} \sim 10\ R_g$
  - Disk structure ? ➪ "Grand unification" of radio-quiet /radio-loud AGN
- Steep, variable component? ➪ "hidden jet" ?
  - Many BLRGs (e.g., 3C111, 390.3, 382, 445 ++) will be detected by GLAST near future (Sambruna's talk)

Summary

I have reviewed recent observational highlights from Suzaku observations of blazars and γ-loud QSOs

- Unprecedented sensitivity of Suzaku provides new challenges to the blazar physics in sub-pc scale jets.
  - HBL … Physics of γ_{max}
    : ultimate limit for the particle acceleration
  - QHB … Physics of γ_{min}
    : particle content, intrinsic electron spectrum
- Non-bias GLAST surveys, in collaboration with Suzaku, Swift and ground based observations are awaited for further break-through
  - BLAZAR monitoring important, of course !!! ☺
  - BLRG … Physics of disk-jet connection

Back-up slides

However… alternative model ?

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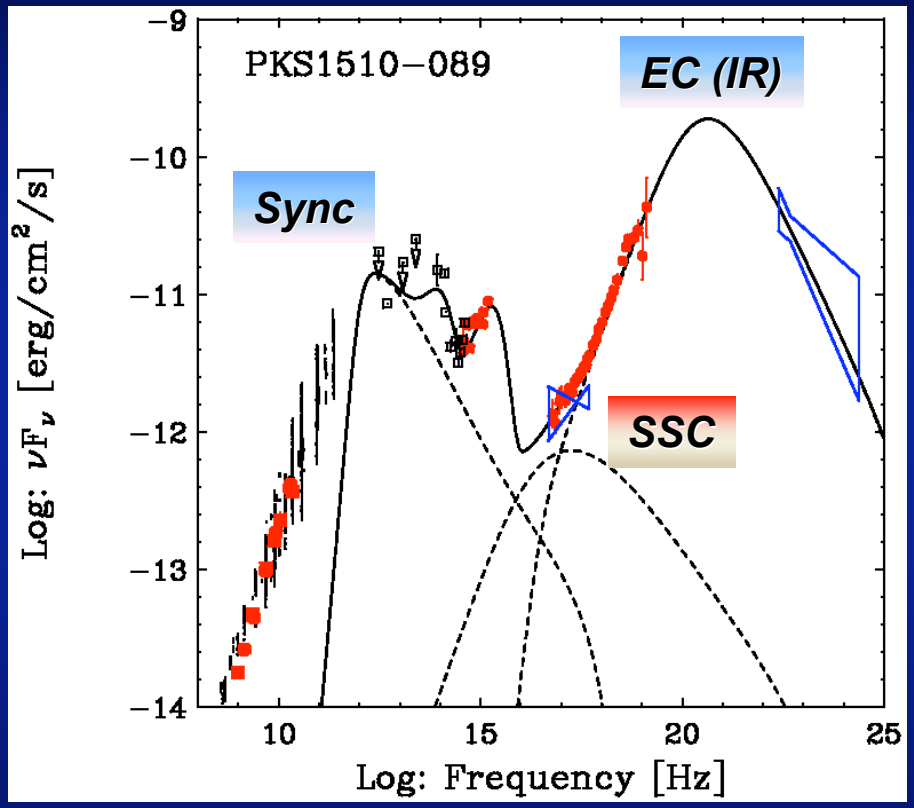

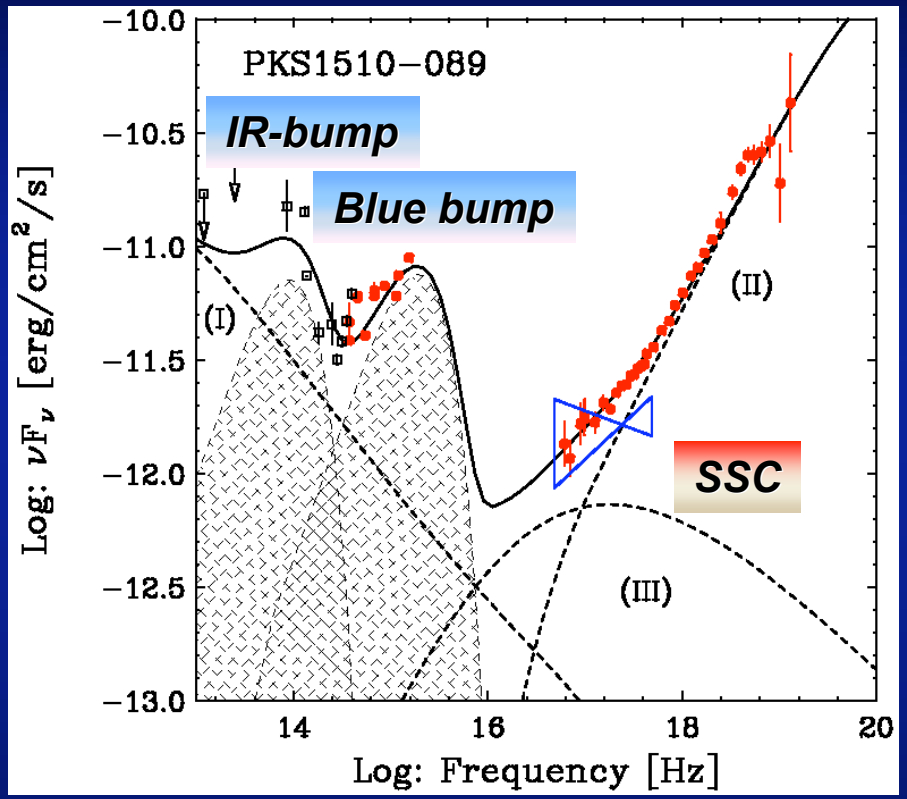

- More significant contribution of the SSC mimic the excess below 1keV.
  - ⇨ We should conservatively take $L_{exc} \approx 2.6 \times 10^{44}$ erg/s as an UL.
- But why BC feature not visible?
  - ⇨ Jet may still be in acceleration phase while traversing BLR?
    Need further study and a large # of samples.