2002, GLAST meeting

X-ray and γ-ray Observations of Blazars; Recent Progress and Future Perspectives

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- Variability patterns (intra-day/long-term)
- Spectral evolutions
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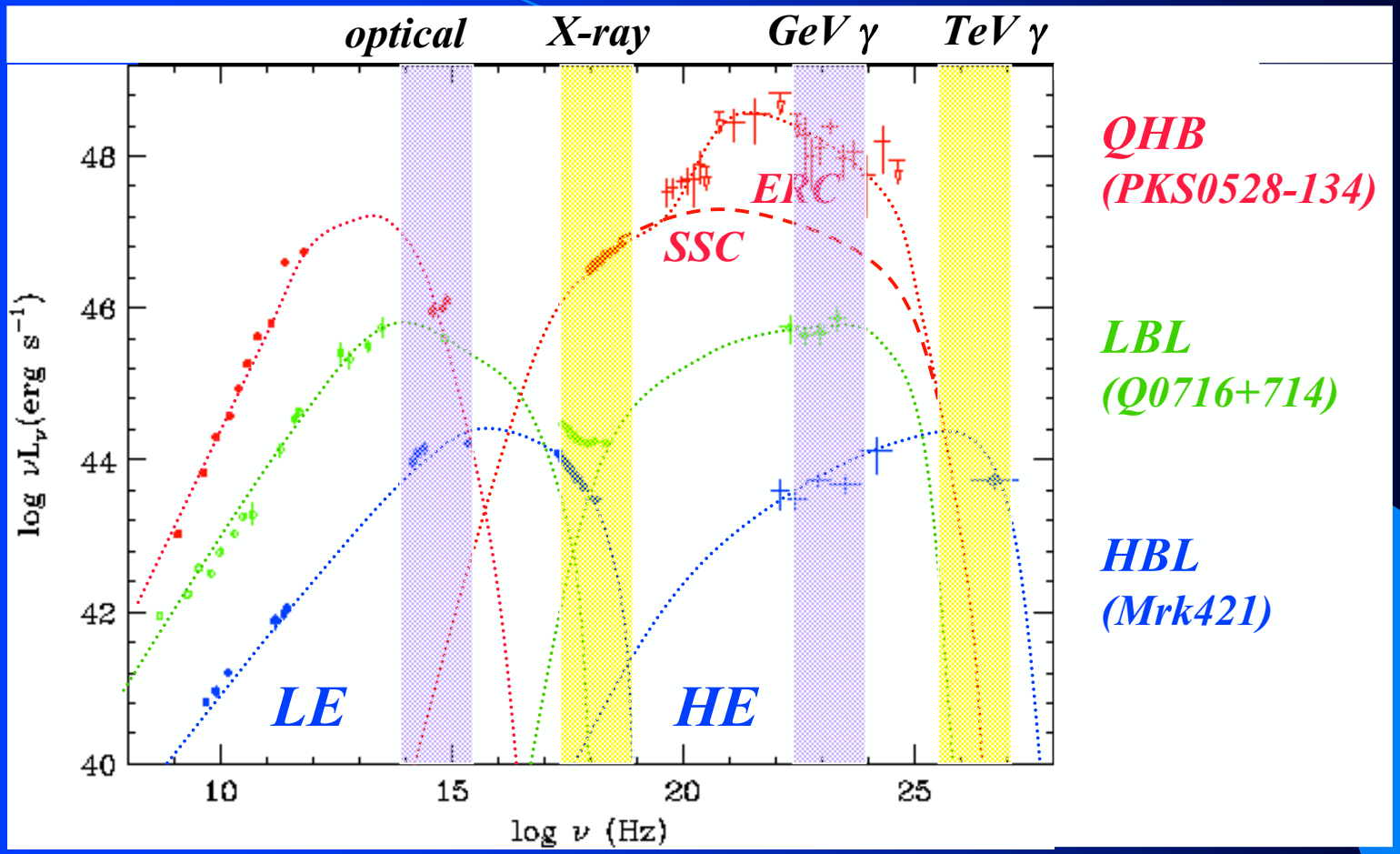
Unified View of Blazars



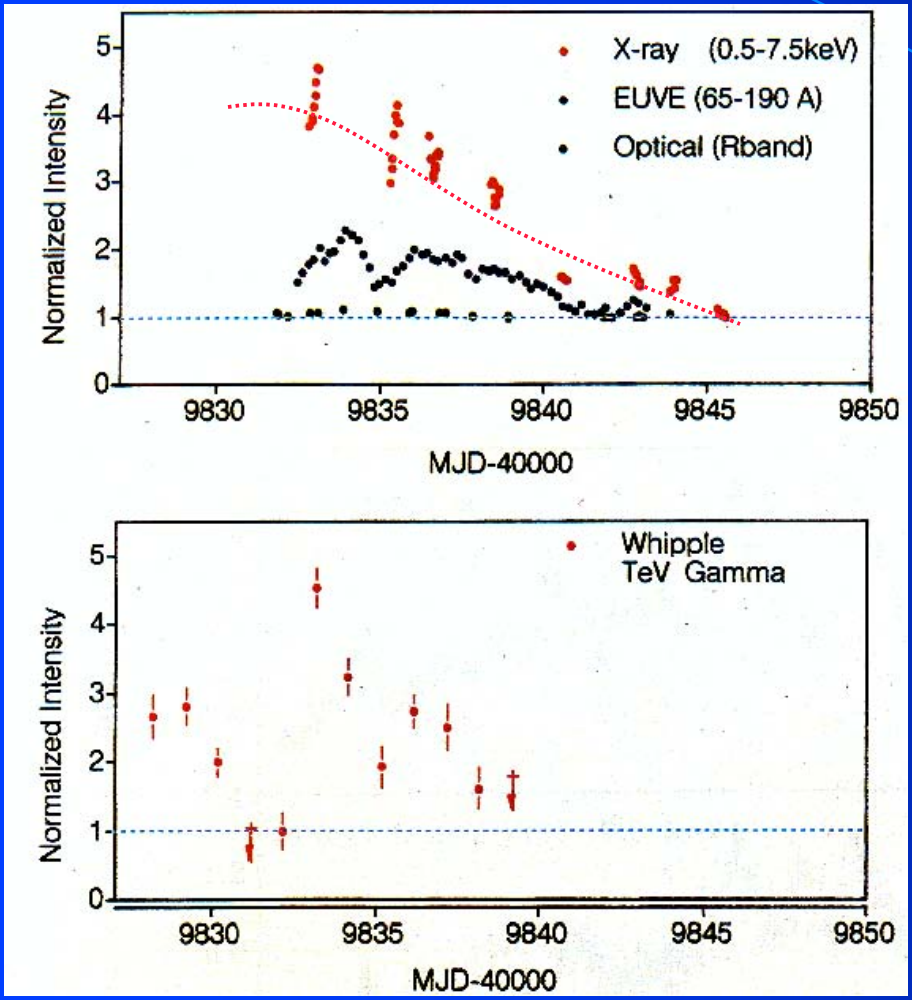
- High energy end of emission components;

LE….. X-ray (HBL) ⟷ Optical (QHB)

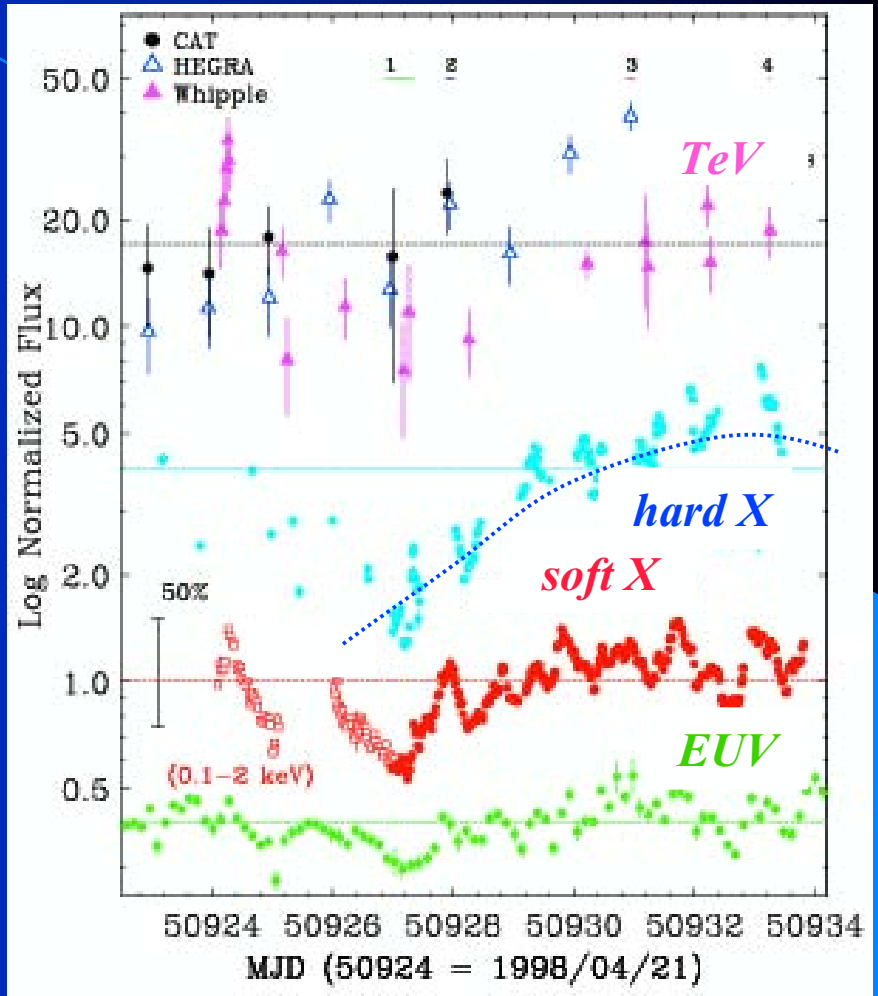
HE….. TeV γ (HBL) ⟷ GeV γ (QHB)

Variability of HBLs (Mrk 421)

1995



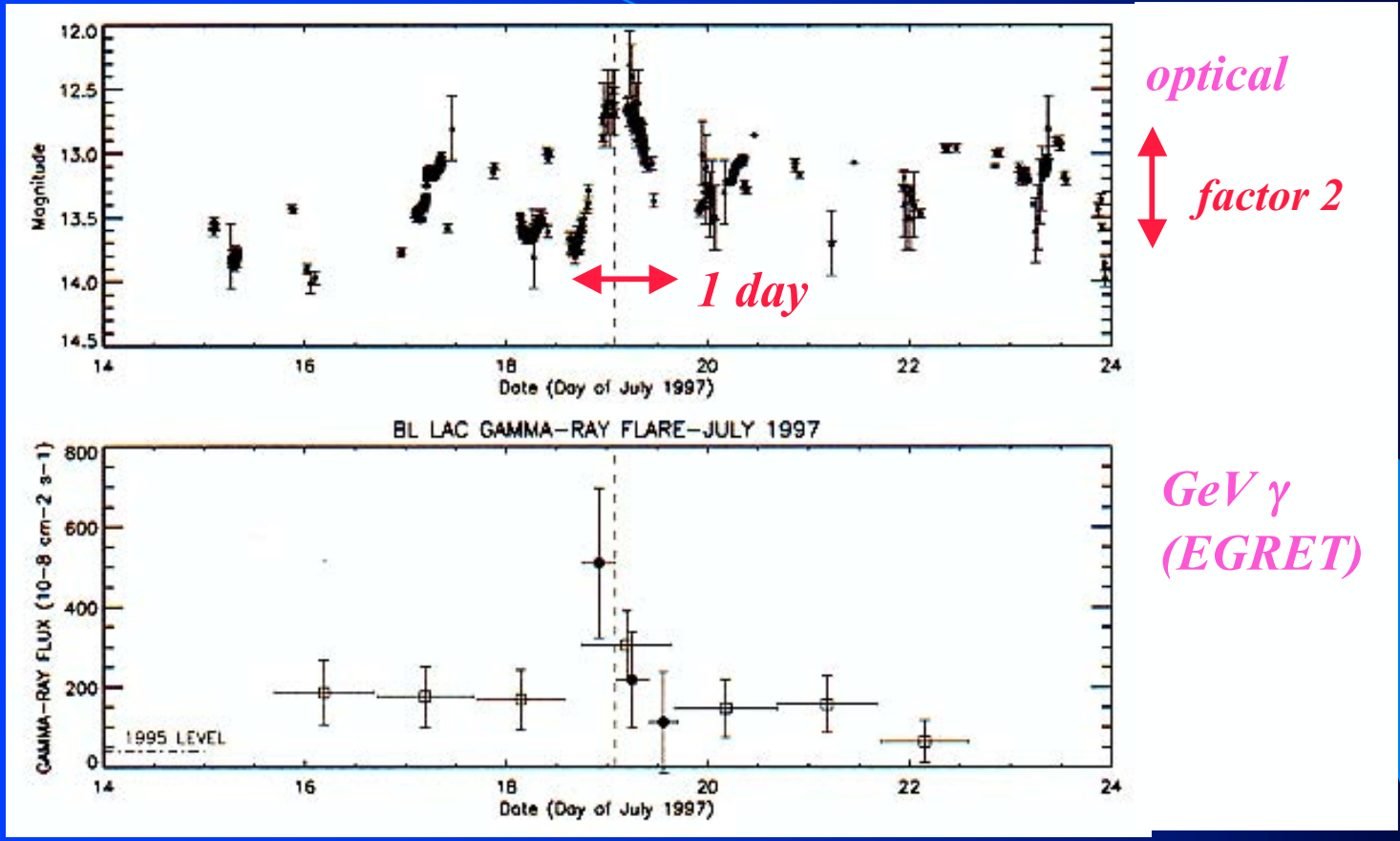
1998



- Rapid "shots" + long-term trend
- X-ray/ TeV γ ray variabilities >> optical, EUVE

Optical & GeV γ Variability of LBL (BL Lac)

Bloom et al. 1998



- Variability of factor 2 on time scale of ~ 1 day
- Optical & GeV fluxes are well correlated

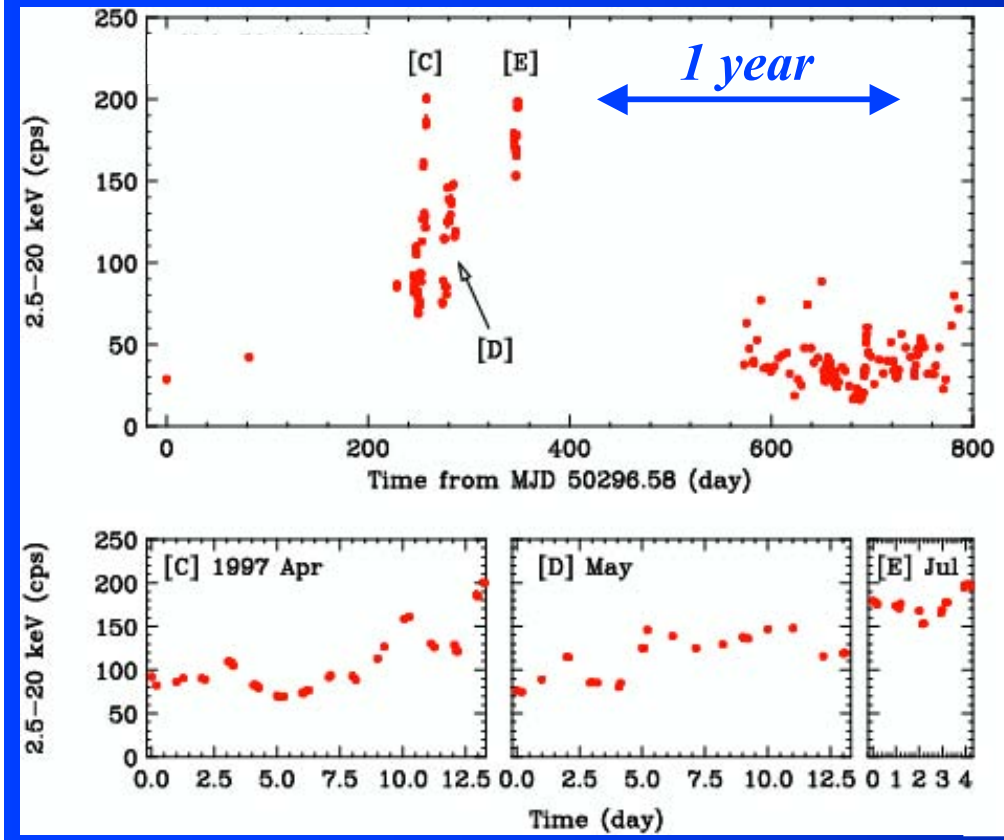
→ Similar to the X-ray and TeV correlation of HBLs

"Long-term" Monitoring of Blazars

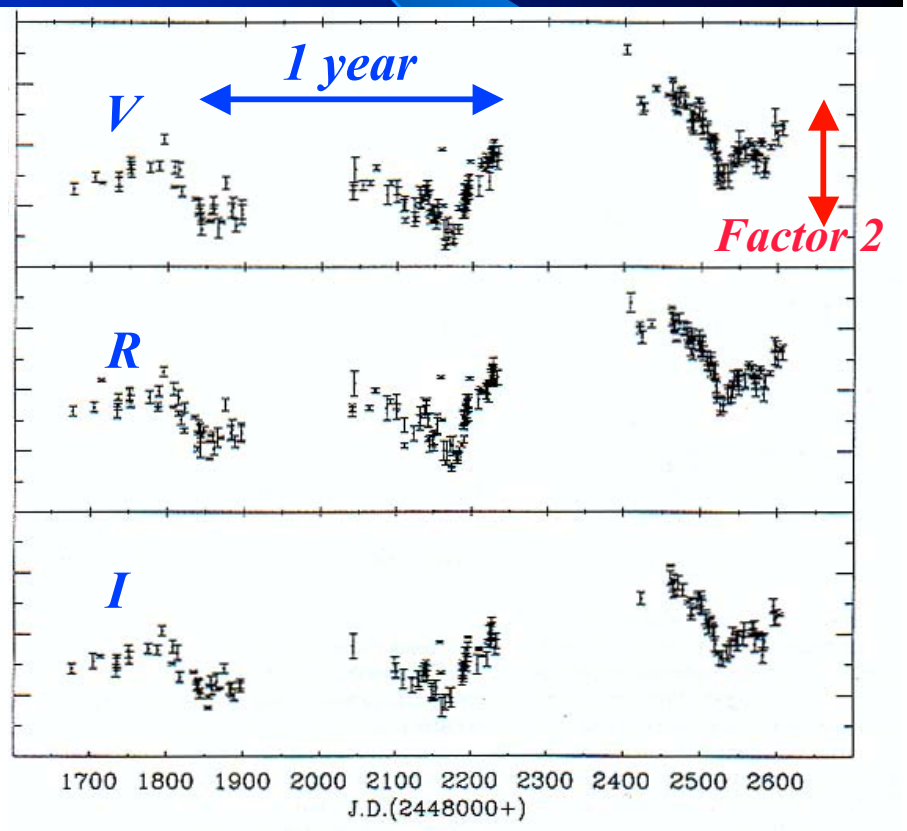
- Blazars are *always* active regardless of their flux states
- Long-term variabilities are observed in radio/optical bands

⇒ actually, *no* quiescent state in the true sence

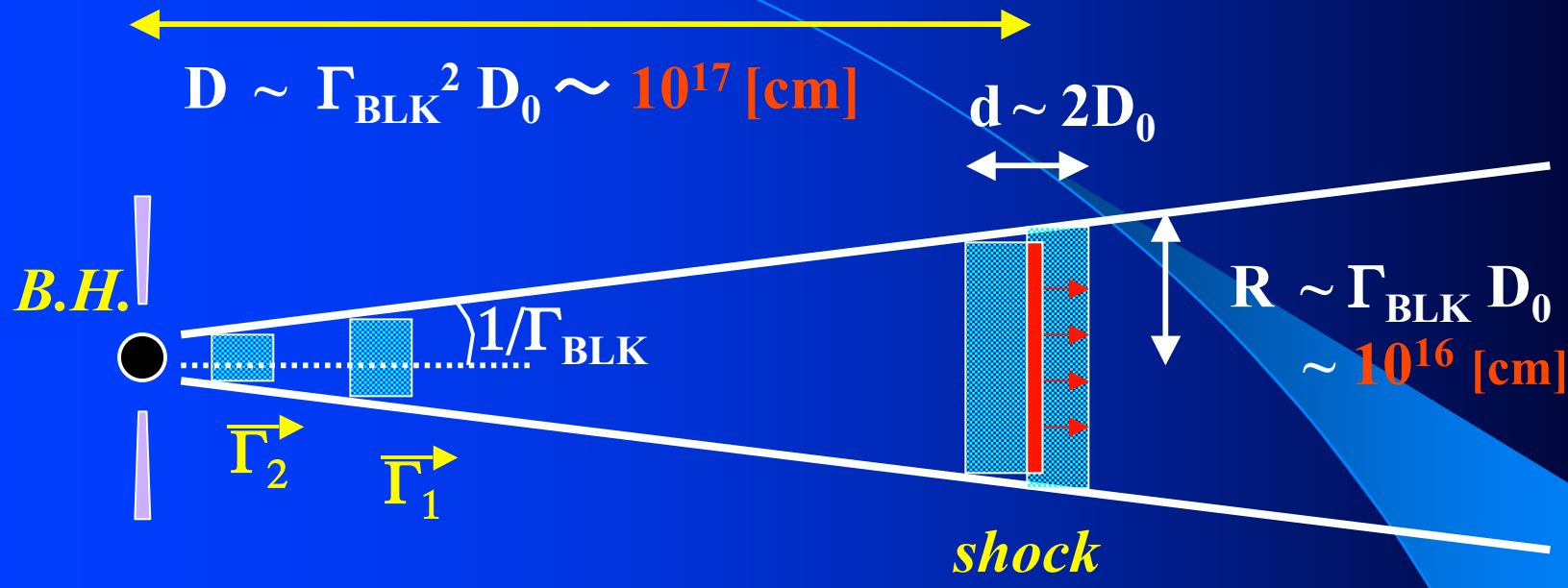
Mrk 501 (X-ray: Kataoka et al. 2001)



Mrk 421 (optical: Tosti et al. 1998)



Intra-day Variability: Internal Shocks



- Central black-hole mass: $10^9\ M_\odot$
- D_0: initial separation : $\sim 10\ R_g$
- Central engine intermittently expels shells of material with various Lorentz factors ($\Gamma_{BLK} \sim 10$), which collides at

$$D \sim \Gamma_{BLK}^2\ D_0 \sim 10^{17}\ [cm]$$

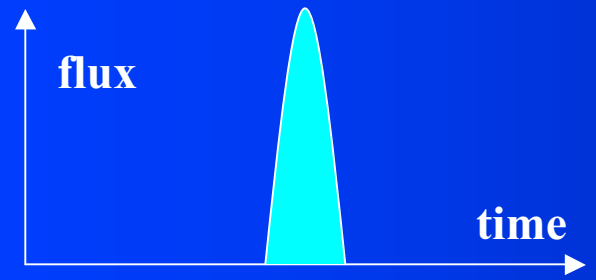
Flare Profiles

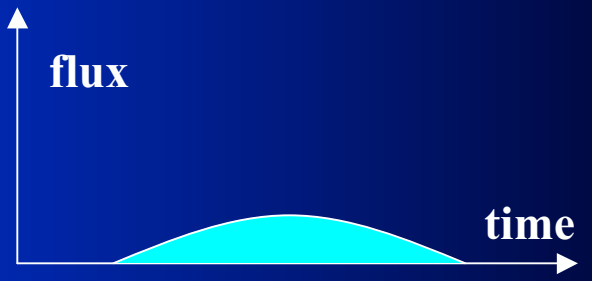
- Time-scale of the flare : $t_{crs} = \frac{2}{c\Gamma_m^2} \left[\frac{1}{\Gamma_{rs}^2} - \frac{1}{\Gamma_2^2} \right]^{-1}$

- Energy Dissipation: $E_m = Mc^2 (\Gamma_1 - \Gamma_m) + Mc^2 (\Gamma_2 - \Gamma_m)$

- Maximum energy $\gamma_{max} \propto \frac{v_s}{c} \propto D^{-1}$

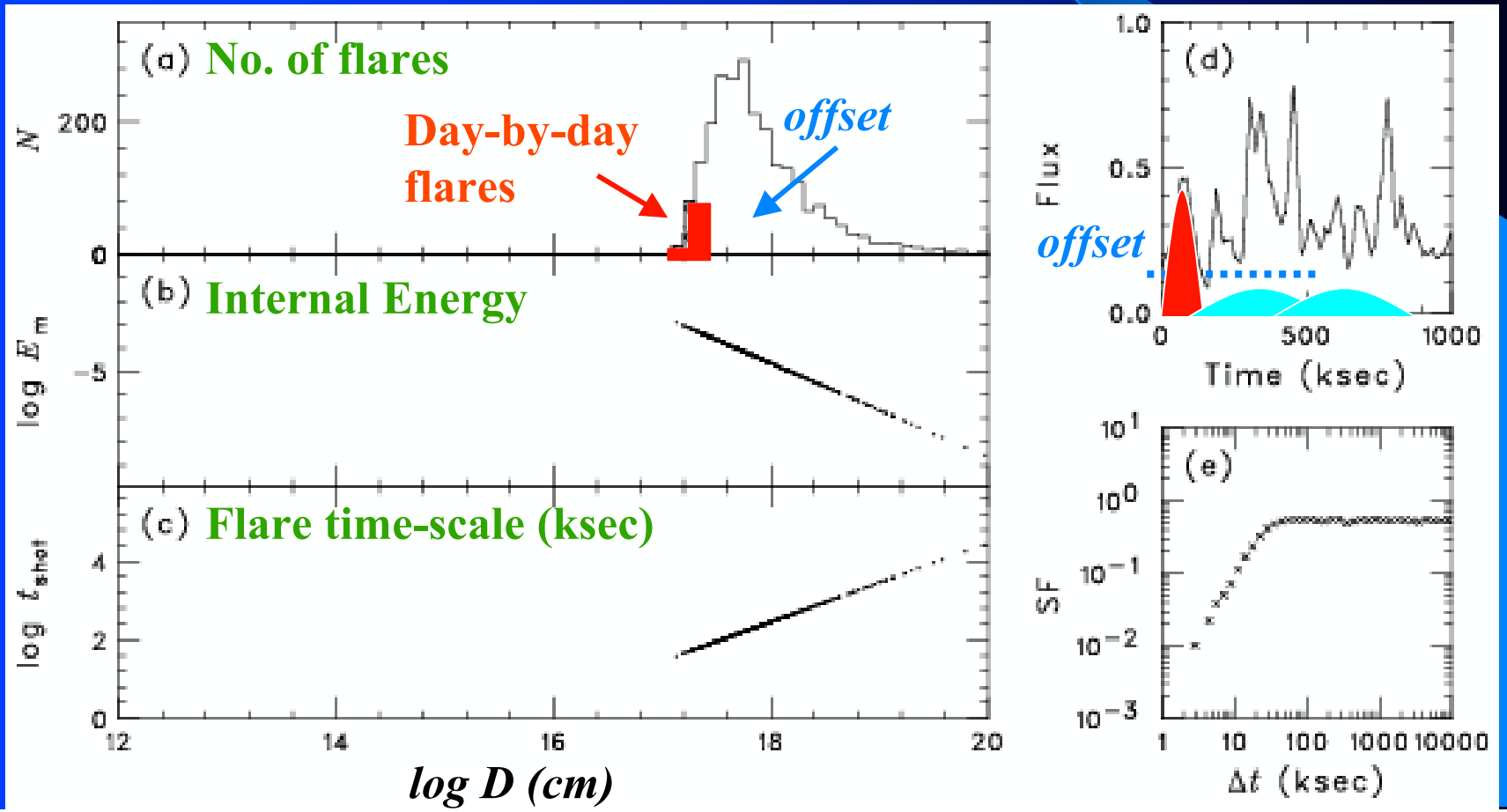
if $\Gamma_2 >> \Gamma_1$	if $\Gamma_2 \sim \Gamma_1$
- Small distance & short flare	- Large distance & long flare
- Large variations in flux	- Small variations in flux
- γ_{max} increases significantly	- Only little changes in γ_{max}



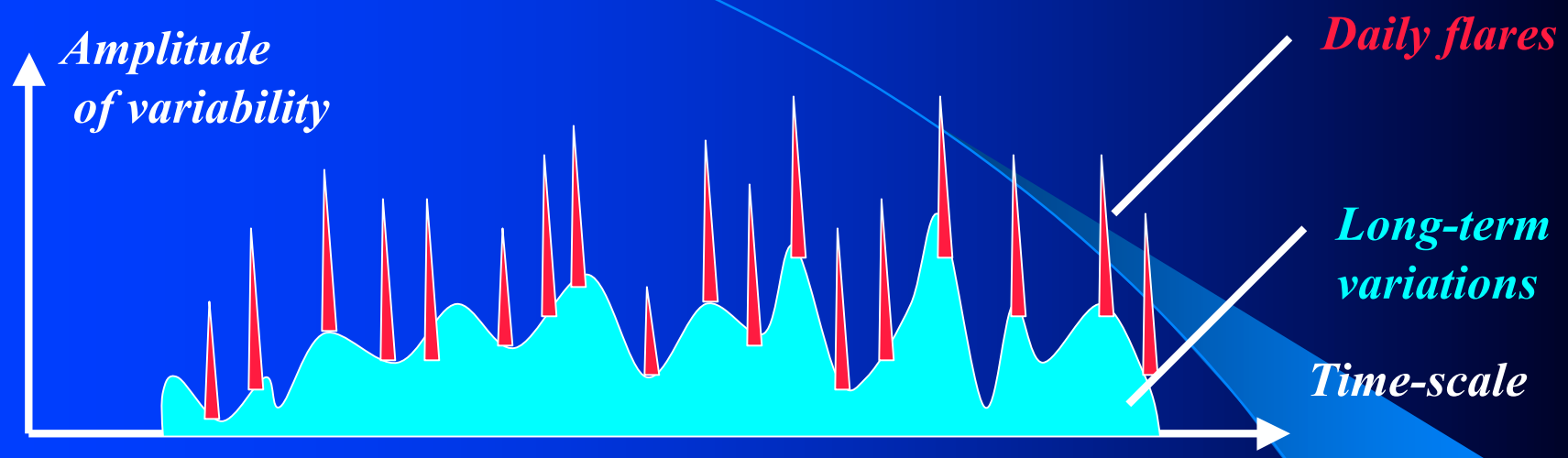


Simulation Study

- $\Gamma_m = 10$, $\sigma_\Gamma = 0.005$, $D_0 = 3 \times 10^{13}$ [cm]
- Shells mainly collide at $D \sim 10^{3\text{-}4} D_0 = 10^{17\text{-}20}$ [cm]
- Only the flares due to collisions at the smallest distance will be appeared as "shots (daily flares)"



Variability Pattern of Blazars



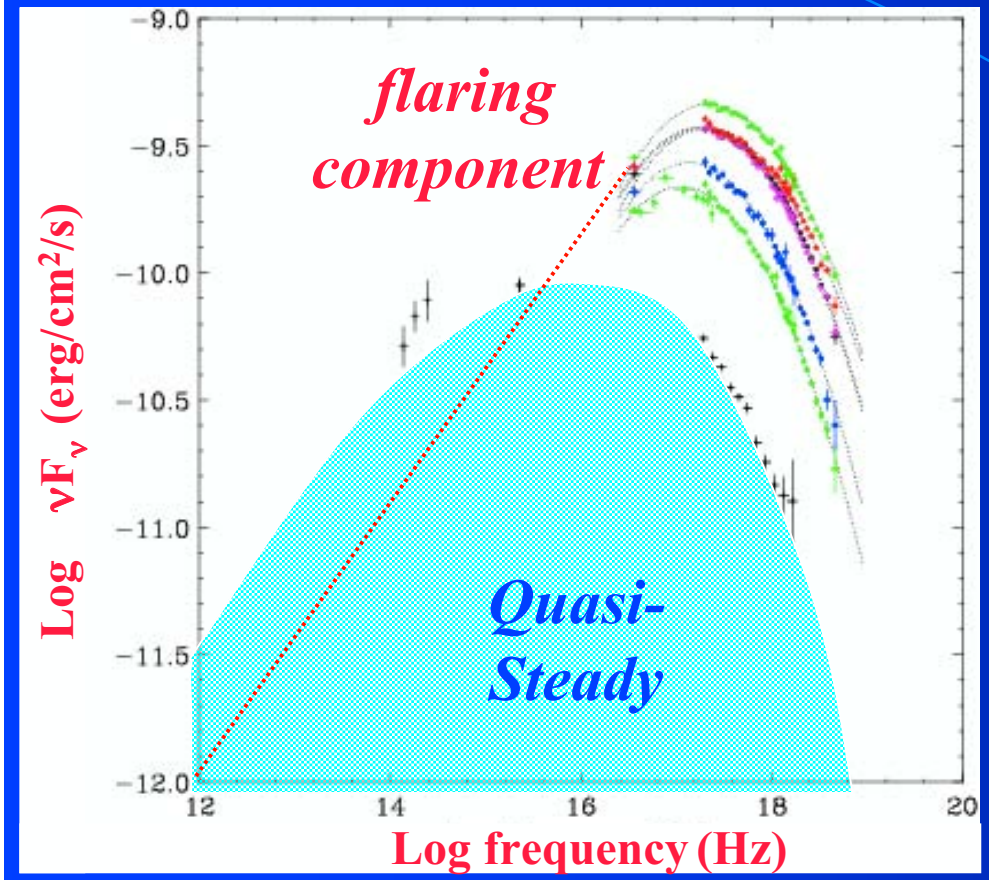
Short-term (daily flares)

- Acceleration,cooling, and/or shock-crossing time in the jet
- Only visible at the high energy end of *e*-population

Long-term (quasi-steady)

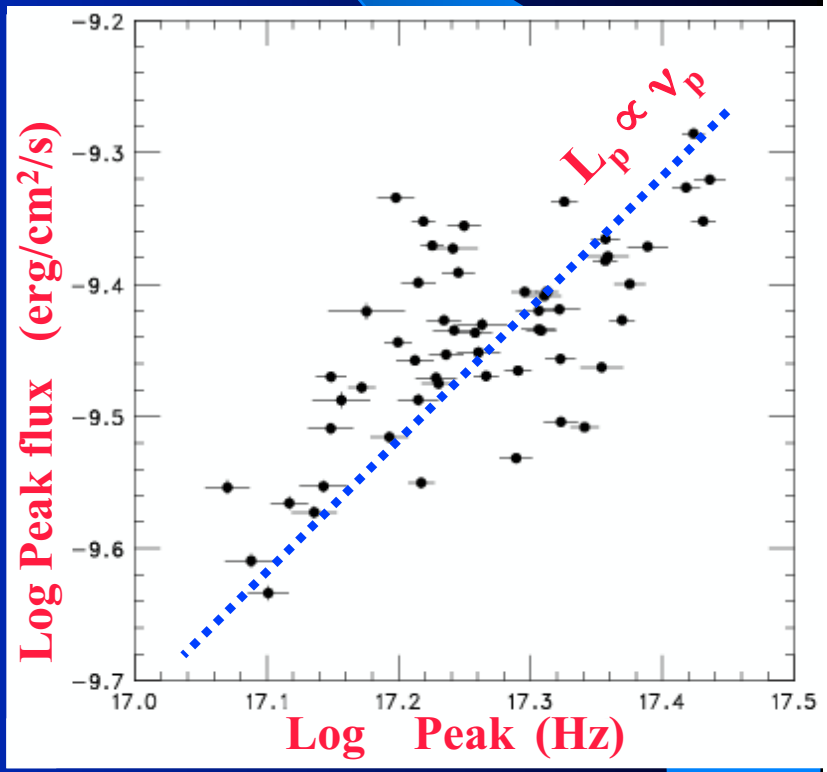
- Changes in mass accretion rate to the B.H
- Commonly observed from radio to γ-ray

Spectral Evolution of Mrk 421



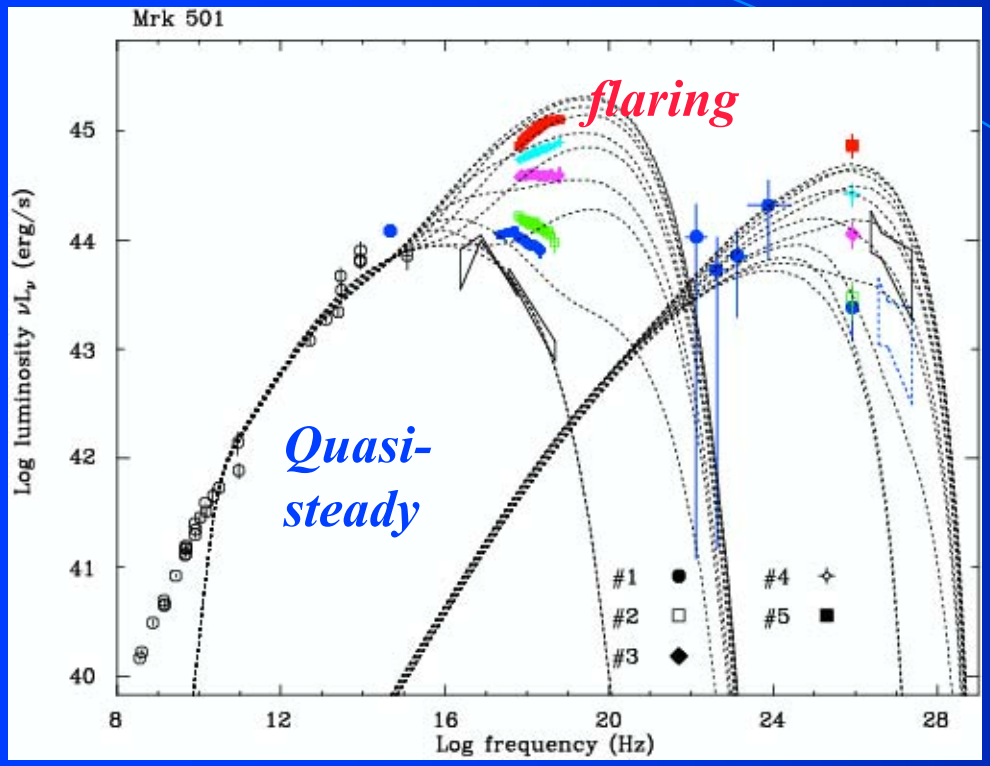
- Wide-band X-ray data from 0.1 keV to 30 keV *(Beppo-SAX+ASCA+RXTE)*

- Two components are visibile in the synchrotron emission?



- Synchrotron peak shifts to higher *E* in the brightening phase, indicating that γ_{max} increased during the flares.

Spectral Evolution of Mrk 501



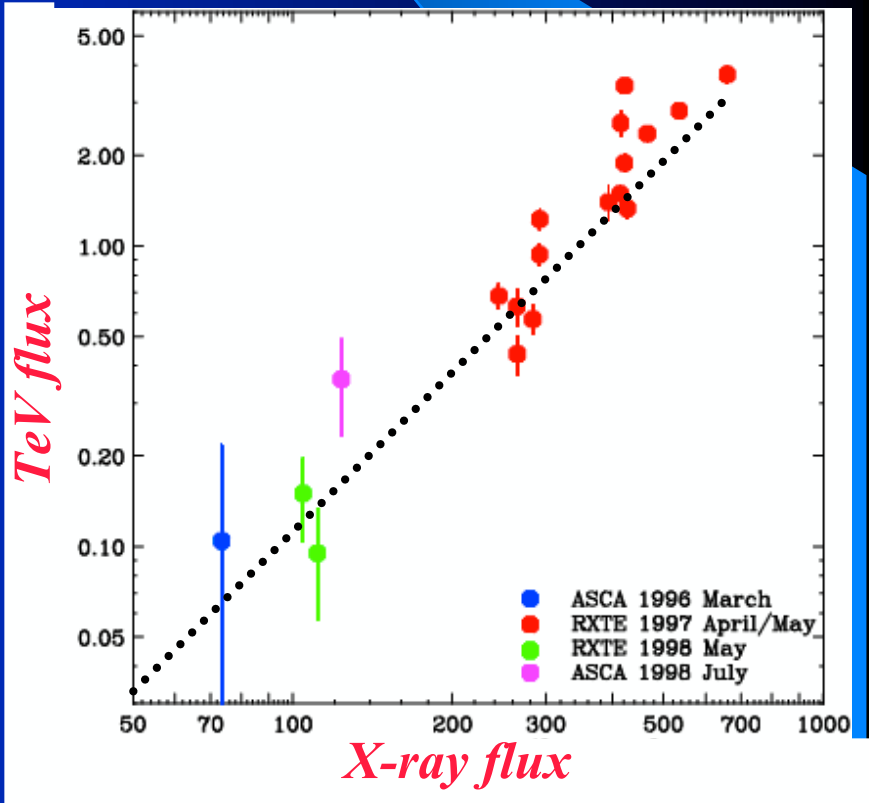
- X-ray/TeV correlation
- Variability amplitude becomes maximum at keV and TeV energies

-Quasi steady

(accumulation of small flares at large distance)

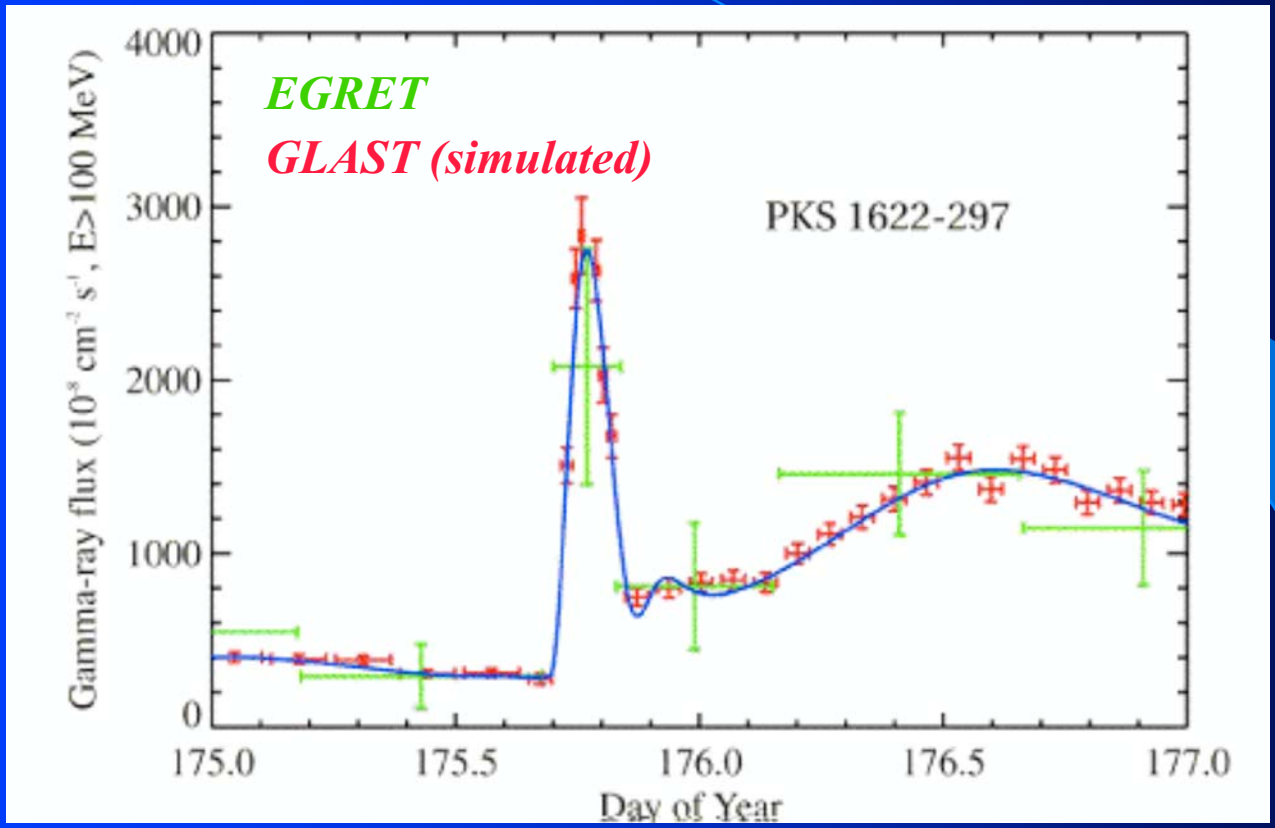
+ *flaring component*

(collision takes place at smallest distance)



Science with *GLAST*: variability monitoring

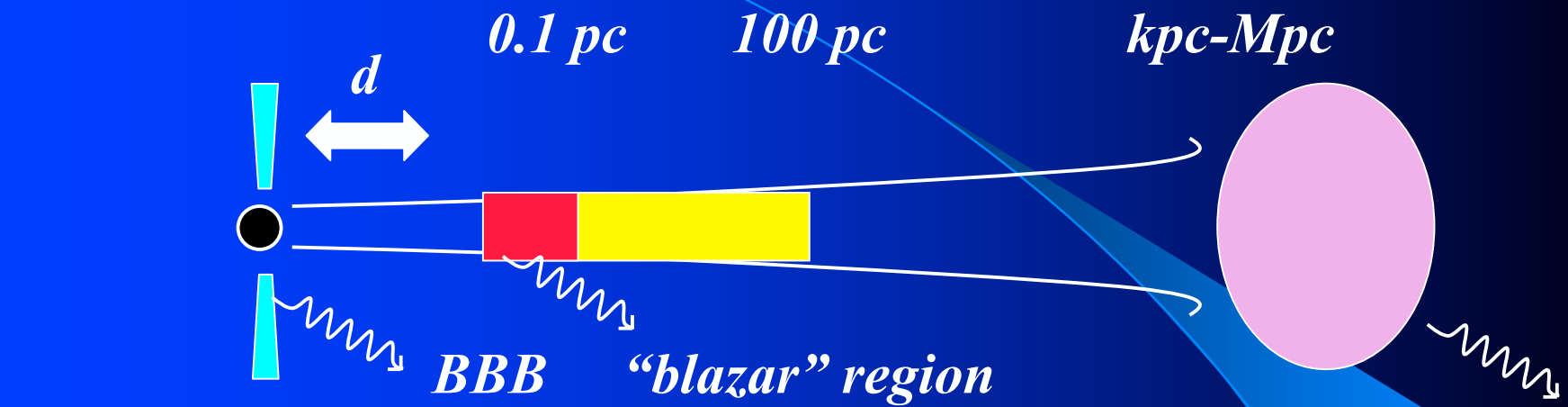
Credit: Mattox, Bertsch, & Dermer

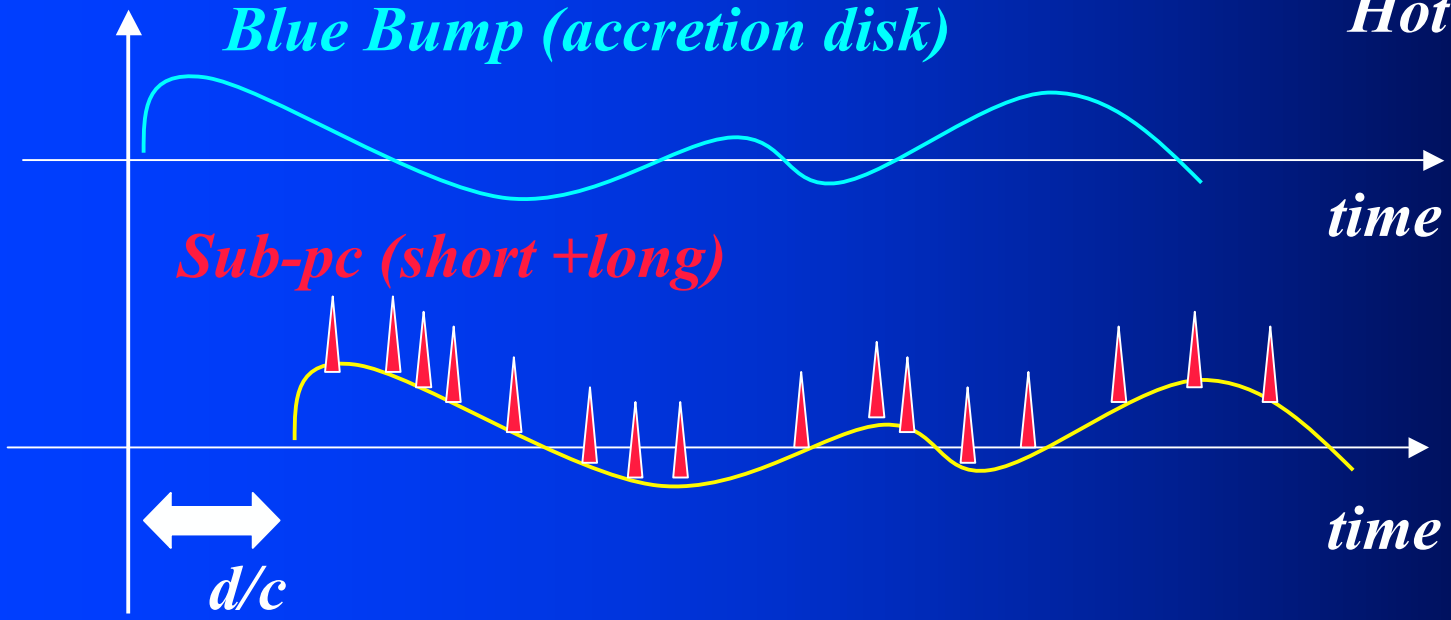


- Monitoring both intra-day and long-term variabilities

Probing the activity of central engine and dynamics in the jet at the same time

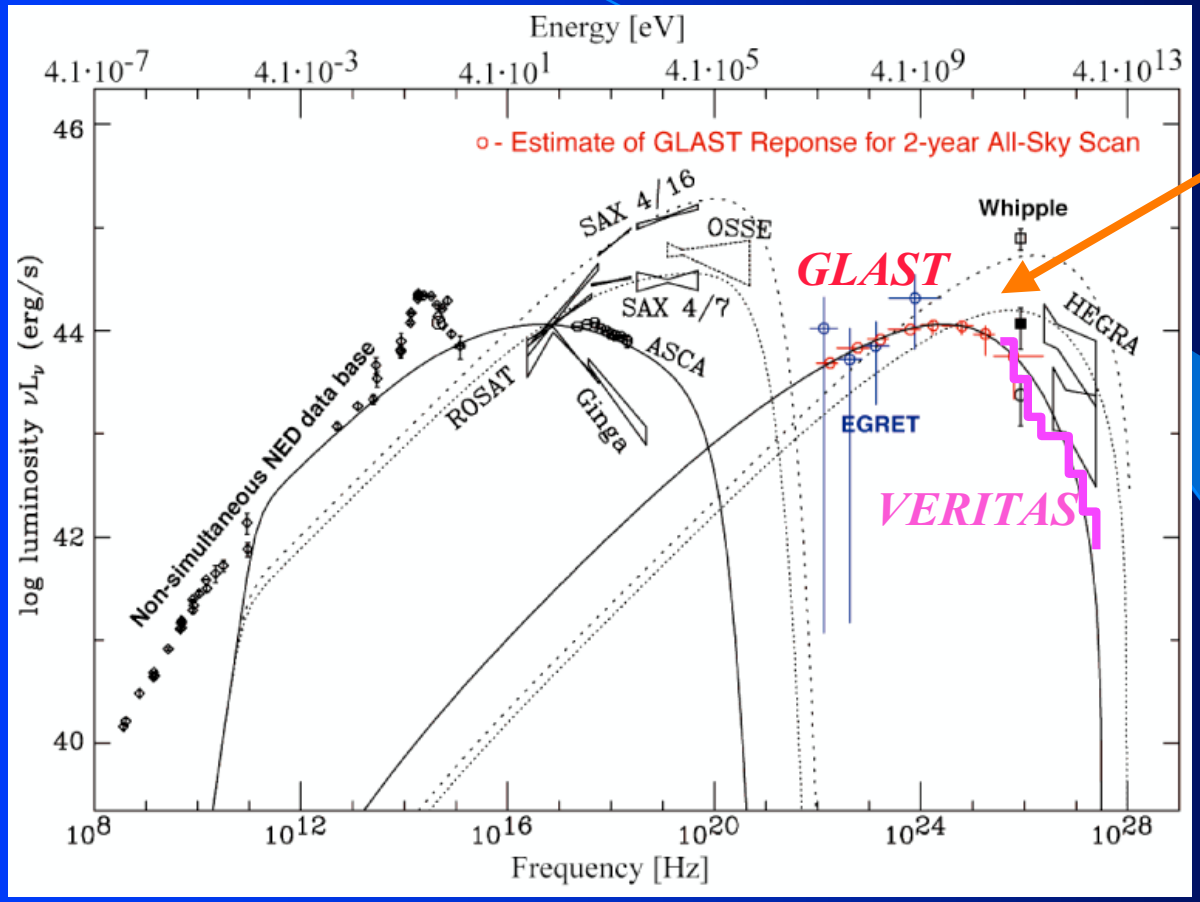
Kinematics from *Upstream* to *Downstream*





Science with *GLAST*: Spectra

Credit: Kataoka & Bloom



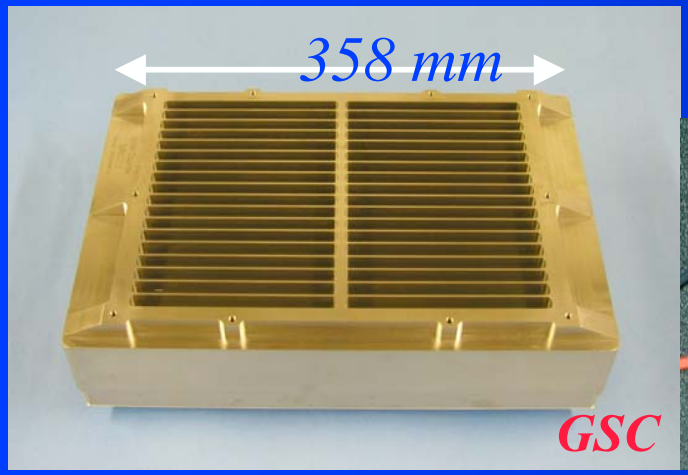
- *GLAST* can monitor the spectral evolution of "inverse-Compton" component, as for the "synchrotron" peak!

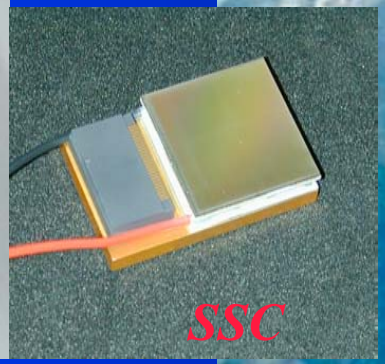
⇒ SSC or ERC?, absorption by DIRB, K-N effect …

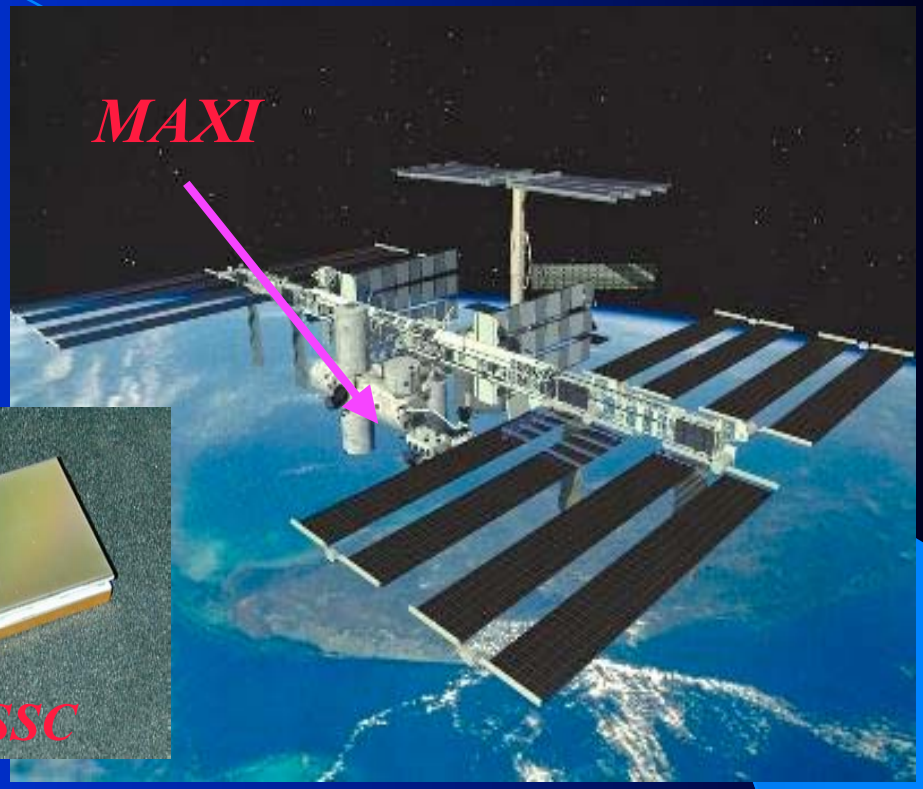
Collaboration with Other Missions

MAXI
NASDA RIKEN

-Monitor of All-sky X-ray Image (MAXI)





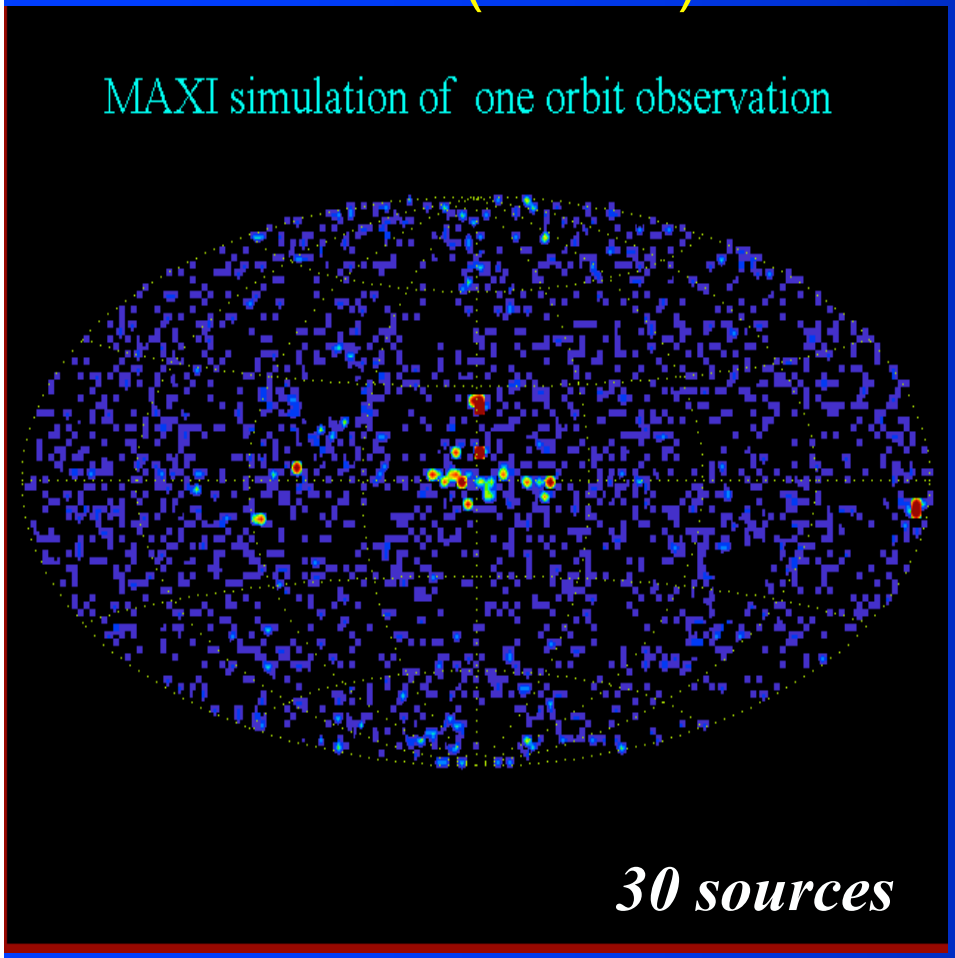


- To be placed on the International Space Station in 2007
- Energy range is 0.5 – 30 keV for combined CCD camera and Gas Slit Camera (effective area of GSC is 5350 cm^2)

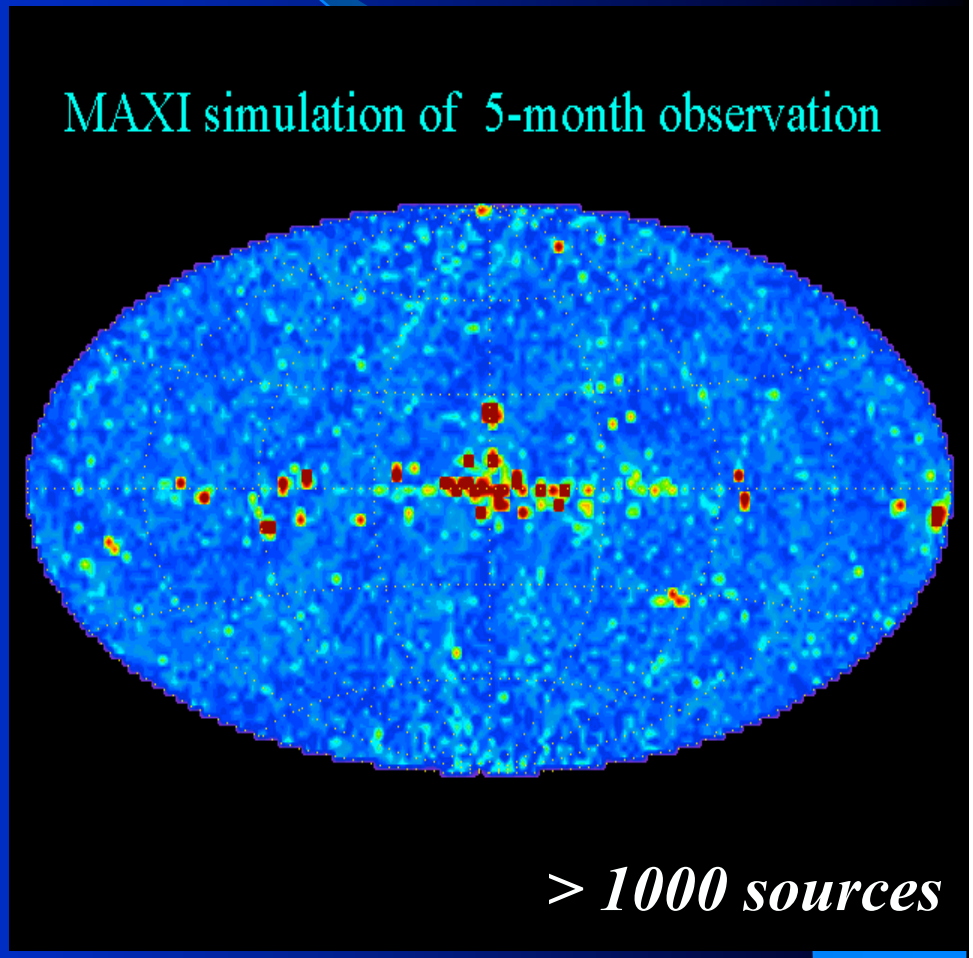
Simulation of MAXI Observation

- MAXI scans all sky every 90 minutes

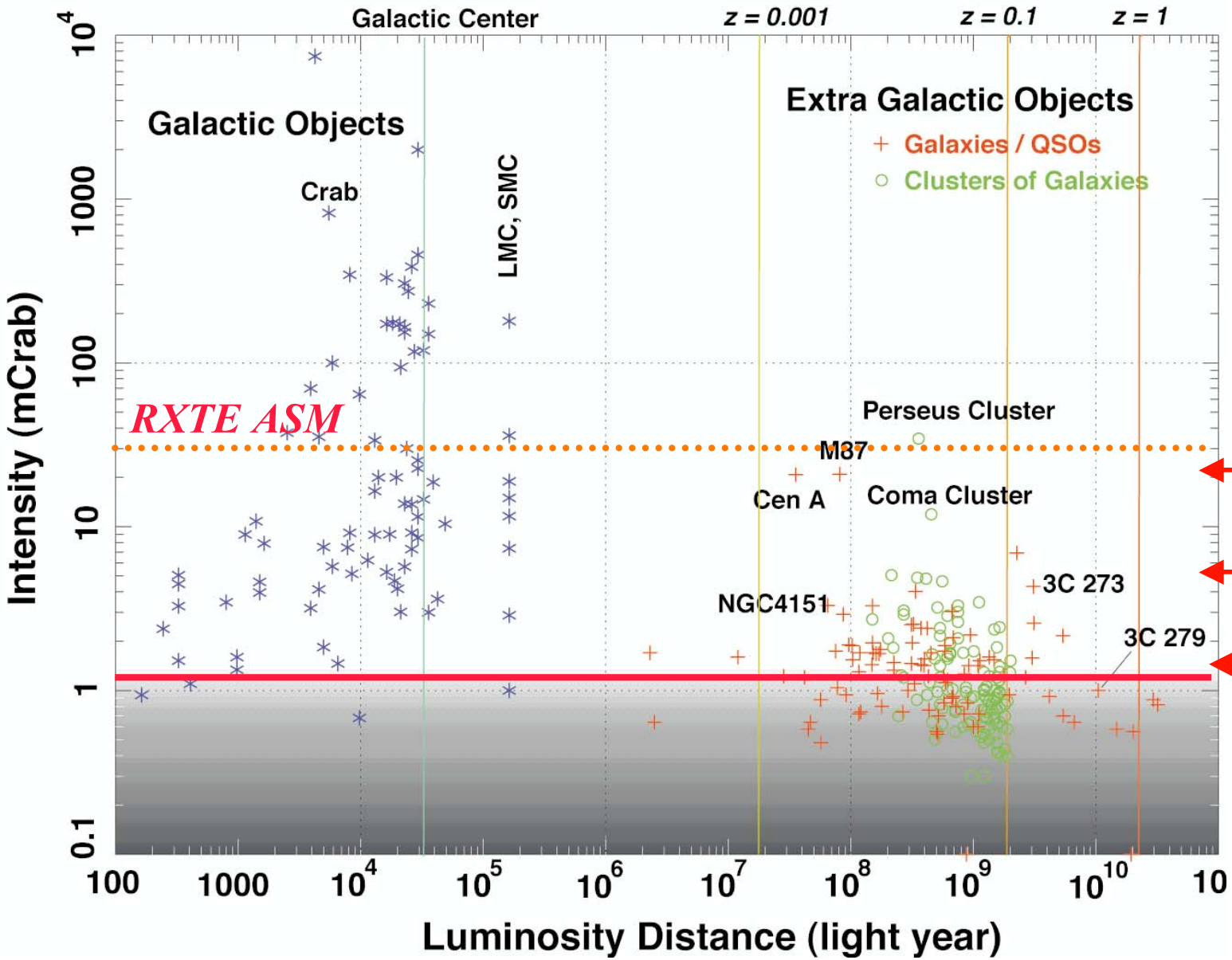
One Orbit (90 min)



5-month



Sensitivity of MAXI



1 orbit (30 sources)

1 day (100 sources)

MAXI 1week (1000 sources)

Conclusion

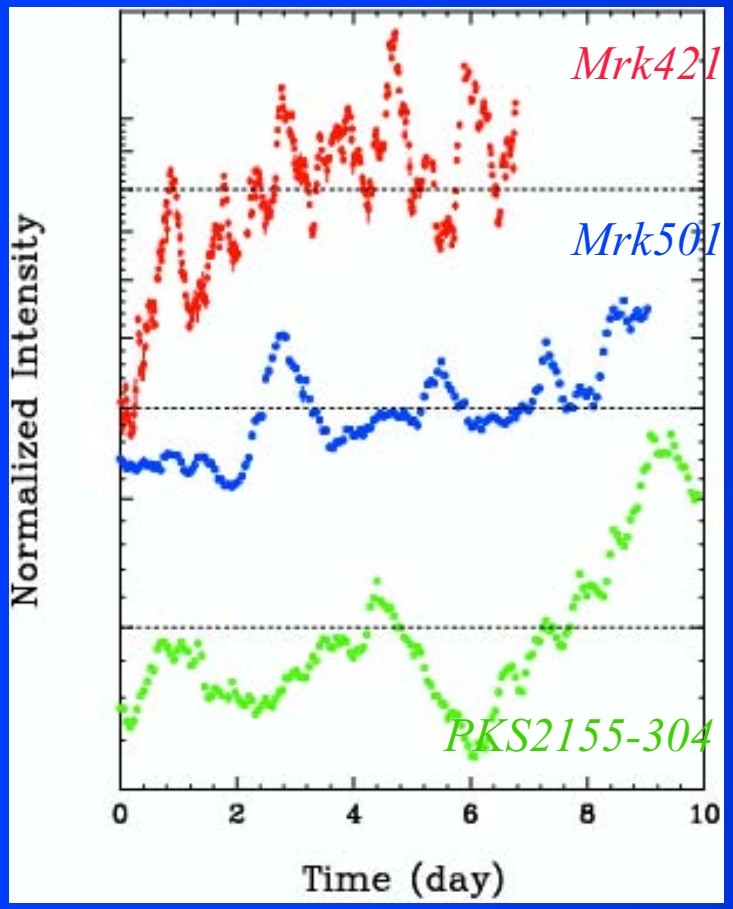
- Recent simultaneous campaigns have confirmed that continuous monitorings of blazars in various energy bands are important to understand jet physics

- Monitoring the long-term variability would be a key to understand jet B.H. connection

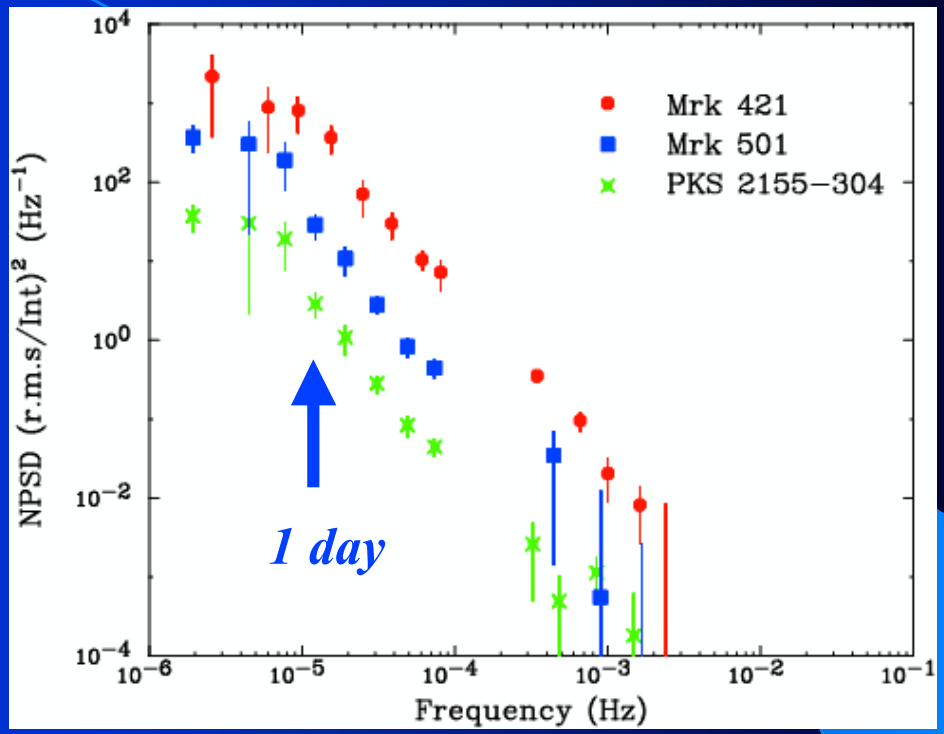
- Future collaboration with *GLAST* and other missions will open a "NEW ERA" for blazar study

X-ray long-look of HBLs *(ASCA)*

X-ray Light Curves



Power Spectrum Density

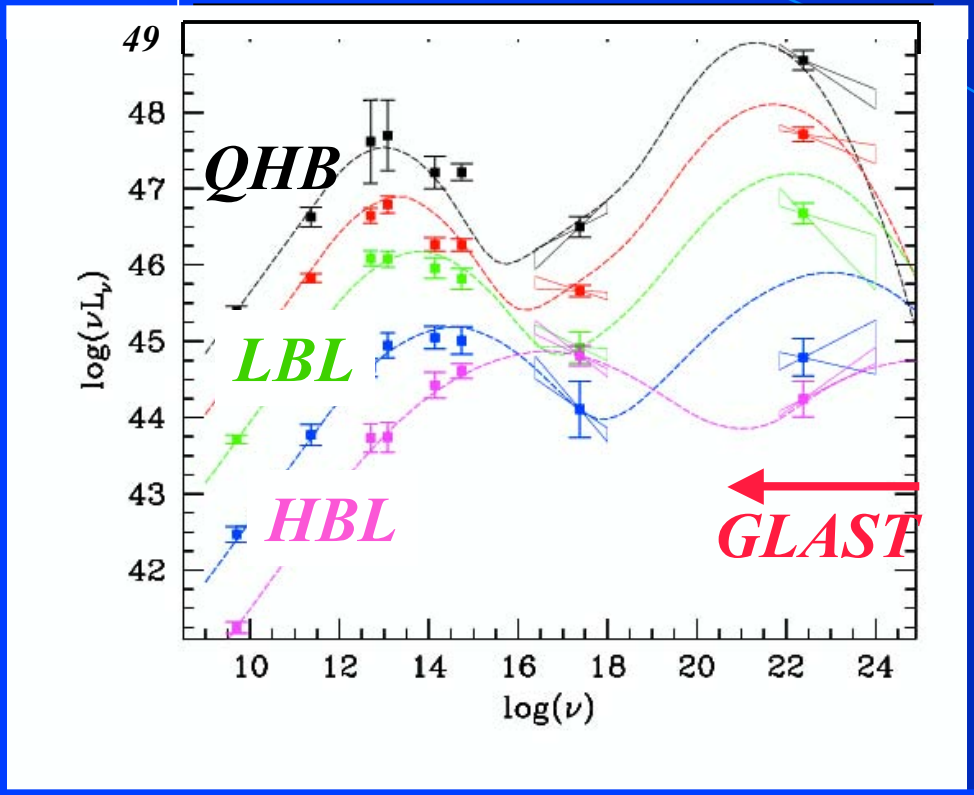


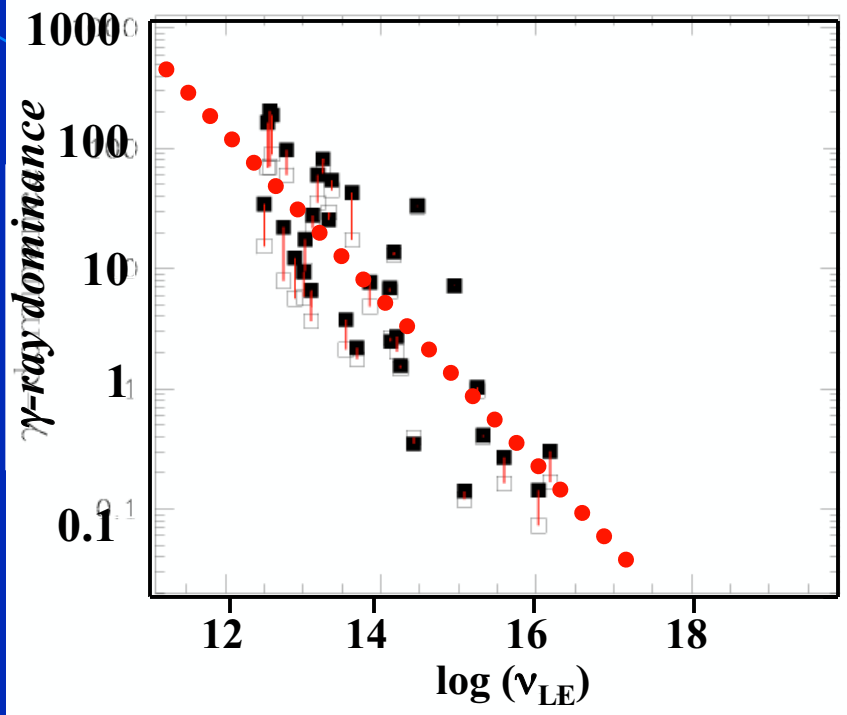
- **Daily flares** are commonly obseved
- Steep PSD for t < 1 day

➡ $R \sim ct_{var}\delta \sim 10^{16}$ [cm]

- *NO "quiescent"* period in any of the light curves
- Longer time scale variability (>> 1 day) is also present

Unified Picture of Blazars





Fossatto et al. 1997; Ghisellini et al. 1998, Kubo et al. 1998

- Low energy;synchrotron, high energy; inverse Compton
- Fainter sources have higher peak frequencies
- However, most of data are obtained non-simultaneously