Constraining Emission Mechanism in AGN jets by Modeling Gamma-ray Rapid Variability

（ガンマ線短時間変動のモデル化による活動銀河核ジェットの放射への制限）

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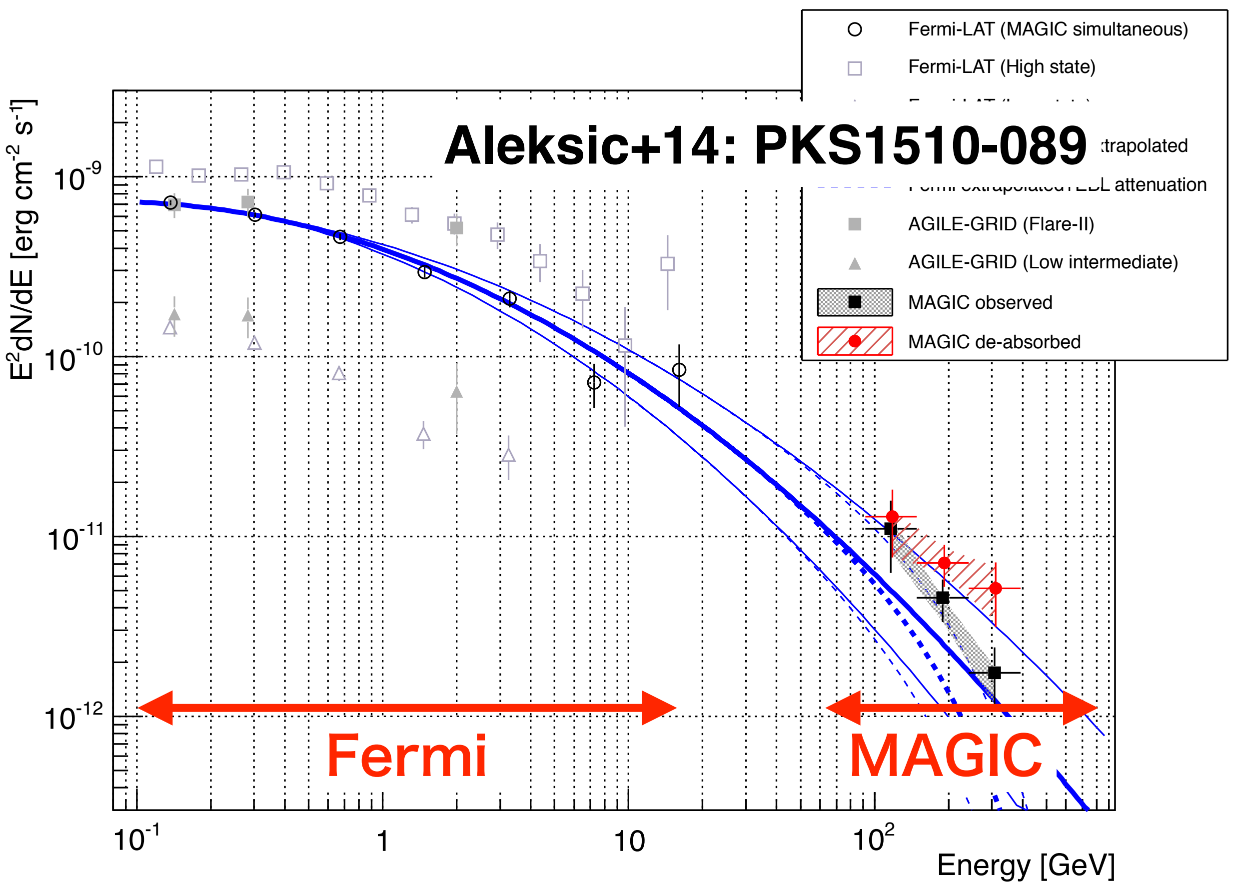
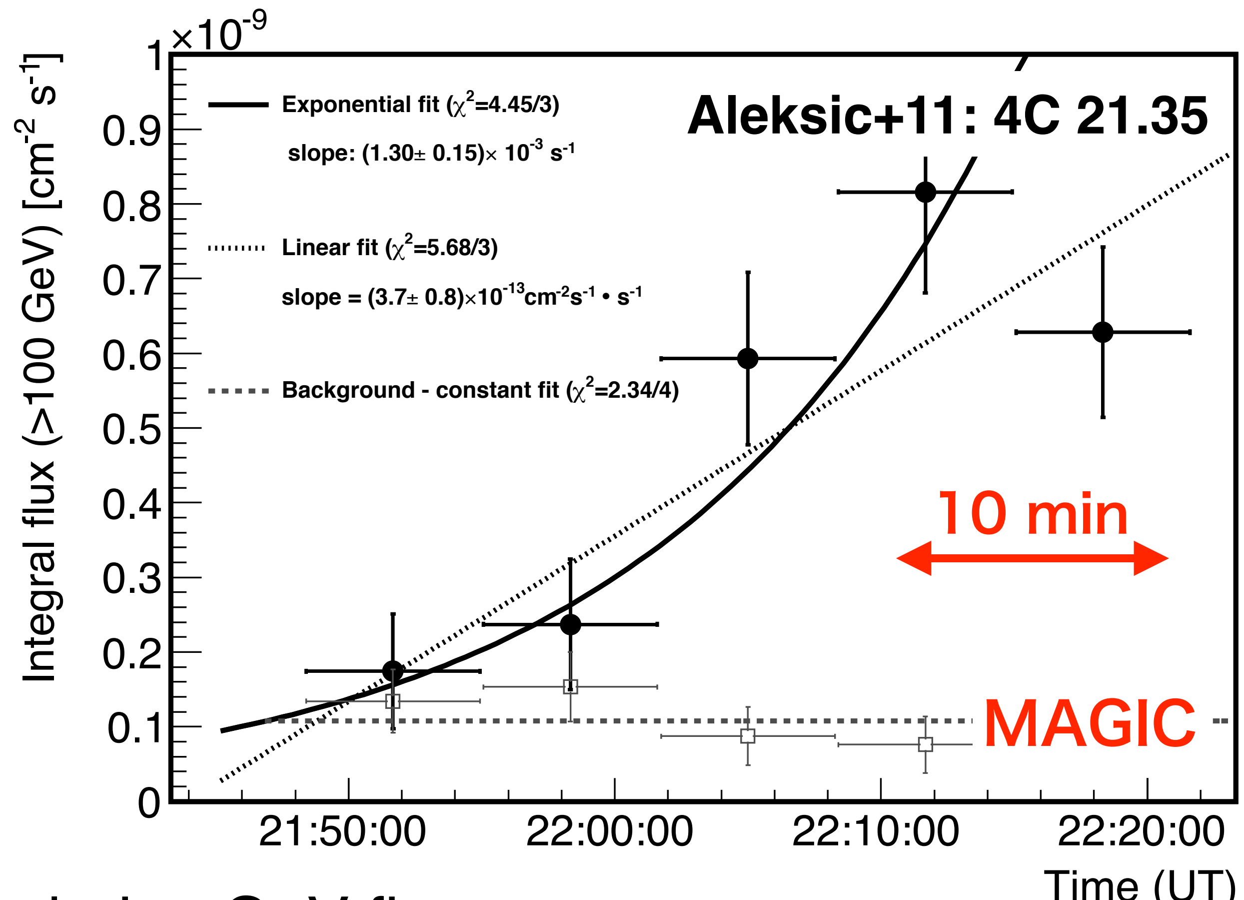
Location of Emission Zone in Blazars

- Kinetic luminosity of FSRQs (*flat spectrum radio quasars*) is comparable to accretion power during flares.
- **The site and structure of the emission region is controversial.**
- Variability of a few hours is observed with Fermi-LAT. (Foschini+11, Saito+13, Brown +13, Rani+13, Hayashida+15)
  → Location of emission site: $R < c\delta\Gamma\Delta t/(1+z) \fallingdotseq$ **10^{16} cm ~ 100 R_G** (Δt=2hours, Γ=10)





- Smooth connection of GeV and TeV spectra during GeV flare.
  →Suggesting co-spatiality of GeV/TeV emission zone locating outside BLR; **>10^{17} cm**, since VHE photon is absorbed in BLR due to $\gamma\gamma \rightarrow e^+e^-$.

- Variability of several minutes in TeV range

Time-dependent modeling of FSRQ flares

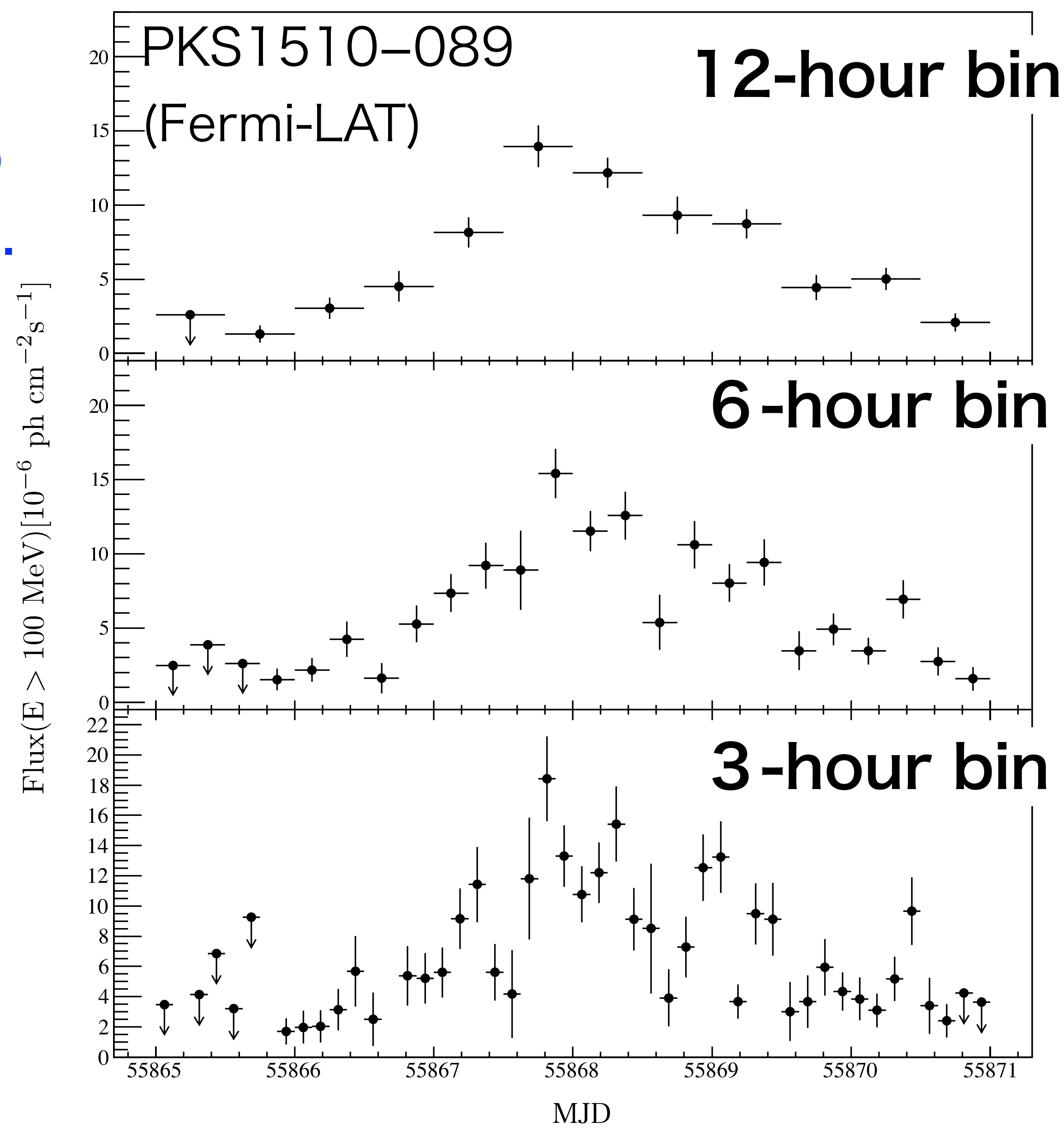
Constraining emission zone of FSRQs by

- **Modeling time evolution of SEDs during flares.**
- **Fitting simulated GeV gamma-ray light curves to observed ones.**

(Saito et al., 2015, ApJ, 809, 171)

- “Finer time resolution” is important since an apparently coherent flare would be resolved into superposition of sub-flares with better resolution.

- The brightest gamma-ray flares with excellent photon statistics and apparently coherent time profile in three hour binning were modeled.



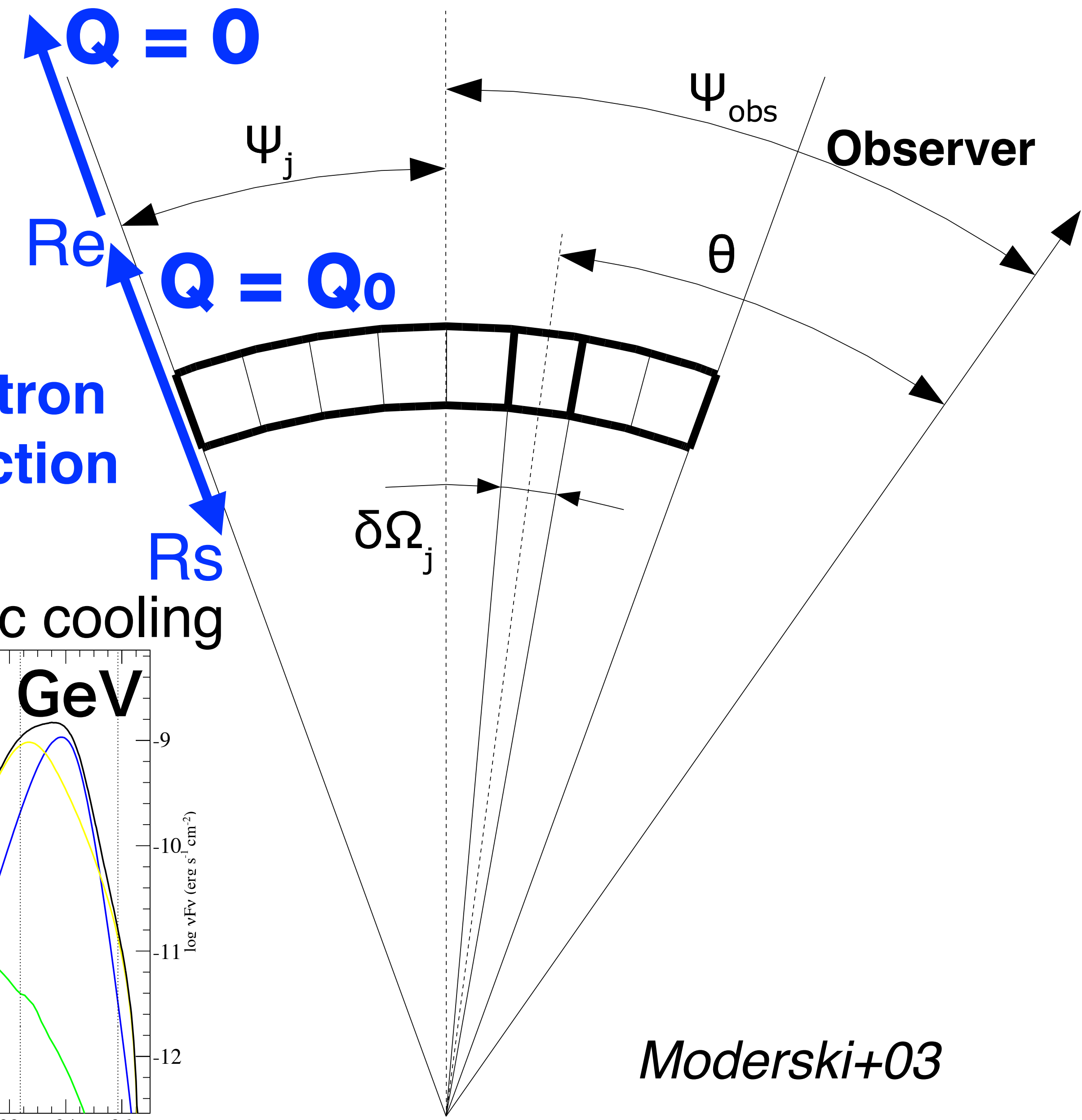
Modeling the Flaring Light Curves

- A single-zone model with underlying assumption of internal shock.
- **“BLAZAR” model (*Moderski+03, 05*)**

0. Assume a thin shell moving along the jet.
1. Electron injection (Q) during a certain section.
2. Calculate time evolution of electron energy distribution (N_γ).

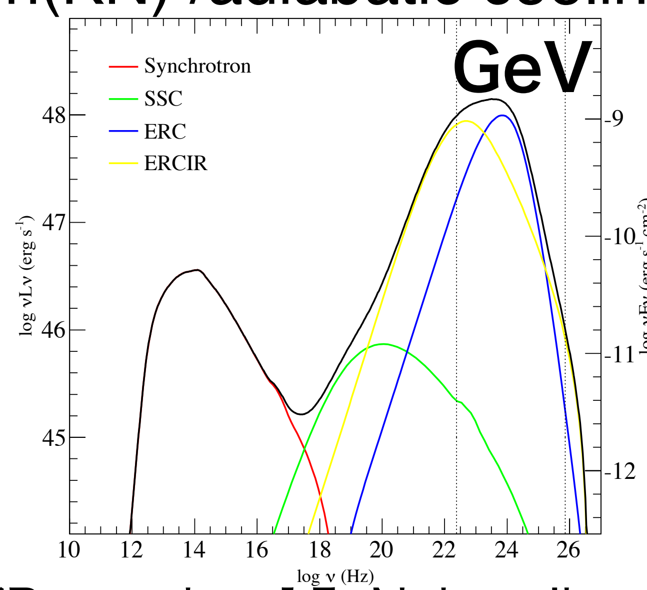
$$\frac{\partial N_\gamma}{\partial t'} = -\frac{\partial}{\partial \gamma}\left(N_\gamma \frac{\mathrm{d}\gamma}{\mathrm{d}t'}\right) + Q$$

synchrotron /inverse Compton(KN) /adiabatic cooling



Moderski+03

3. Calculate observed spectra at each moment.
4. Extract GeV band and make GeV light curves.



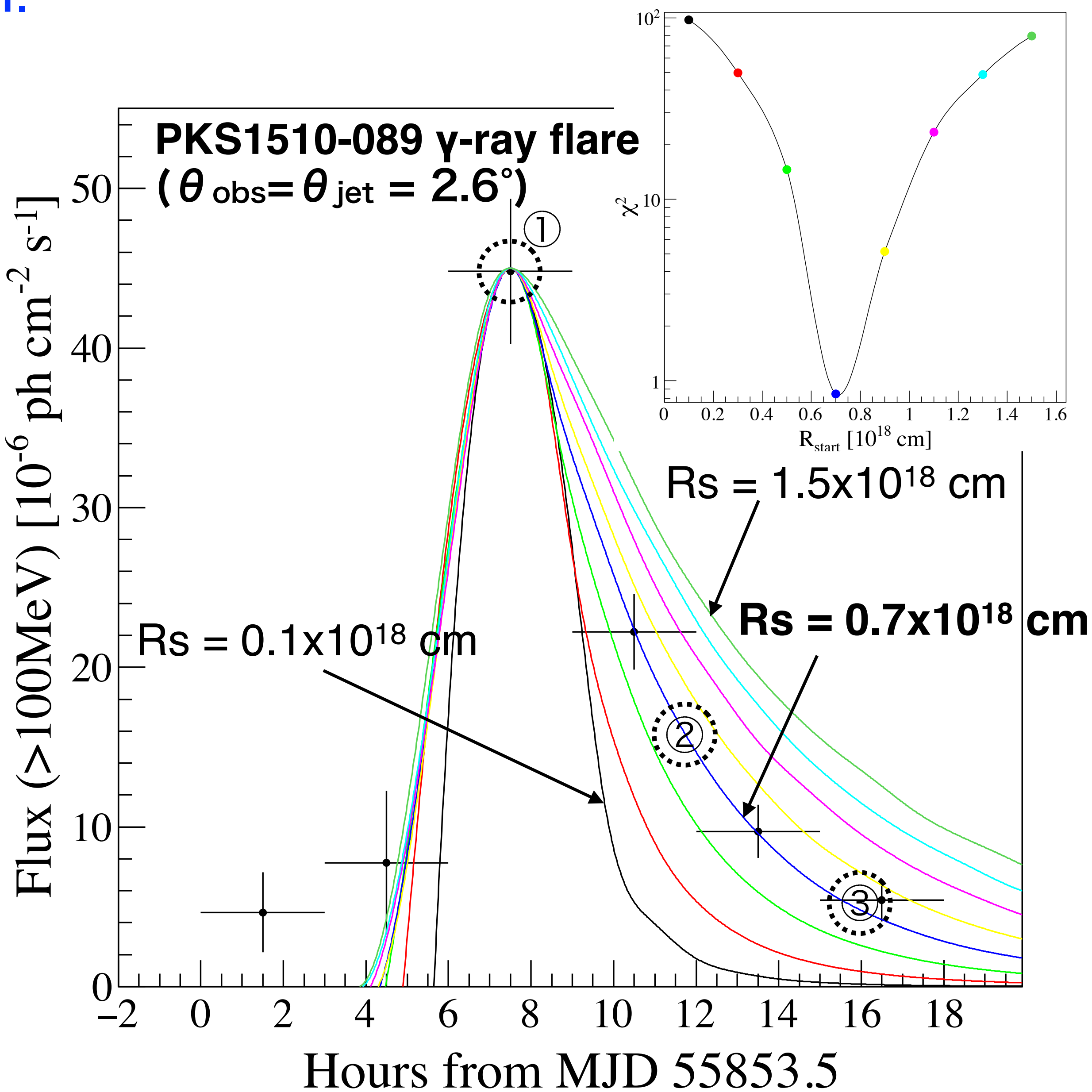
Model parameters (PKS1510-089) (Barnacka+15, Nalewajko+12)

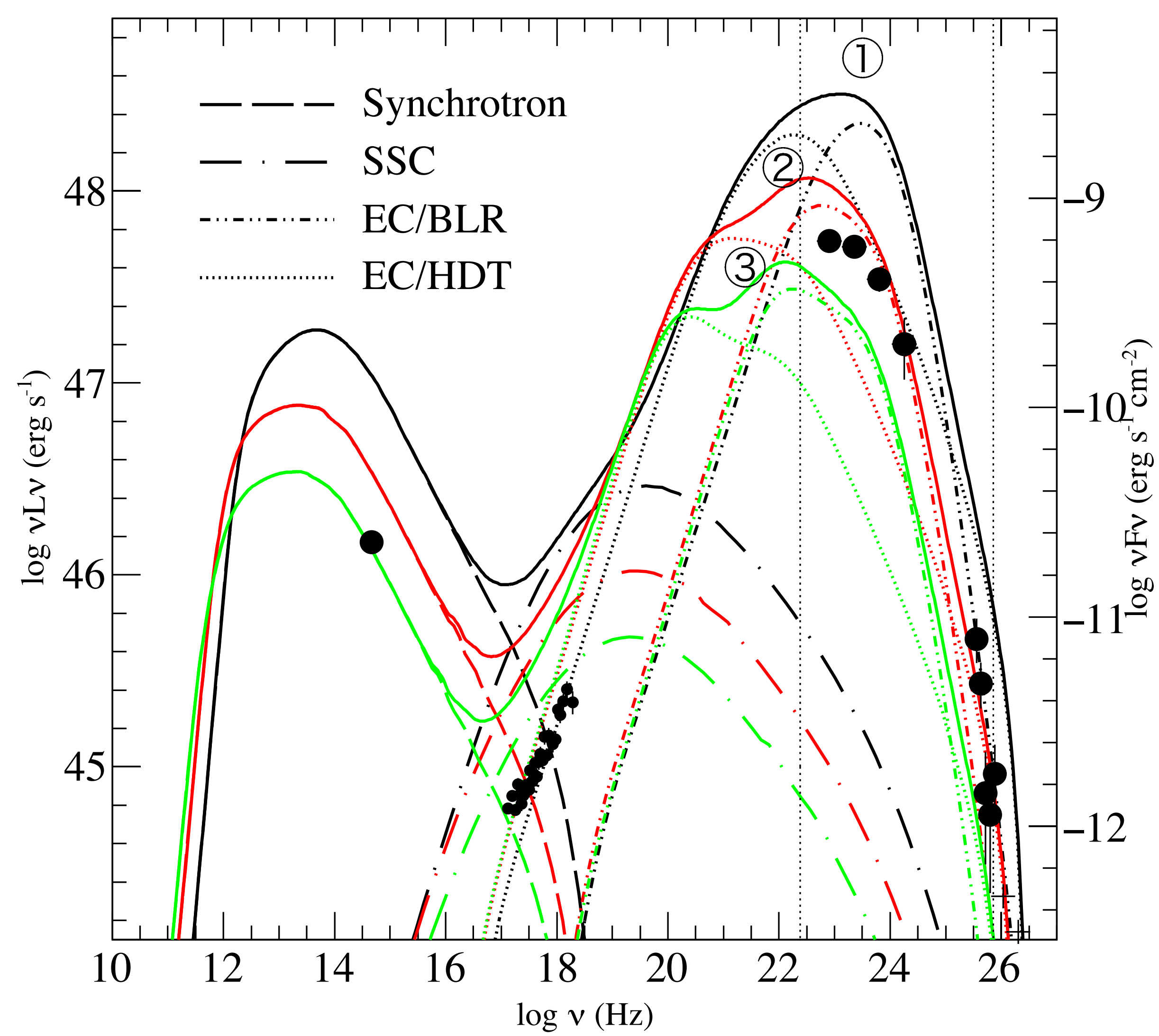
e distribution: $Q(\gamma) = K_e \gamma^{-p}\left(1 + (\gamma/\gamma_b)^4\right)^{(p-q)/4}$ (p=1.2, q=3.4, γ_b=900, γmin=1, γmax=10^5)
BLR(0.12e18 cm, 0.055 erg/cm3, 10 eV), **HDT**(1.9e18 cm, 5e-3 erg/cm3, 0.15 eV)
Γ = 22
$\boldsymbol{\theta_{jet}} = \boldsymbol{\theta_{obs}} = 0.3°$

Constraints on the Location of Emission Zone

- Length of section with electron injection (Re-Rs) was estimated to be 0.2×10^{18} cm.
- Simulations were performed for various locations of emission zone.

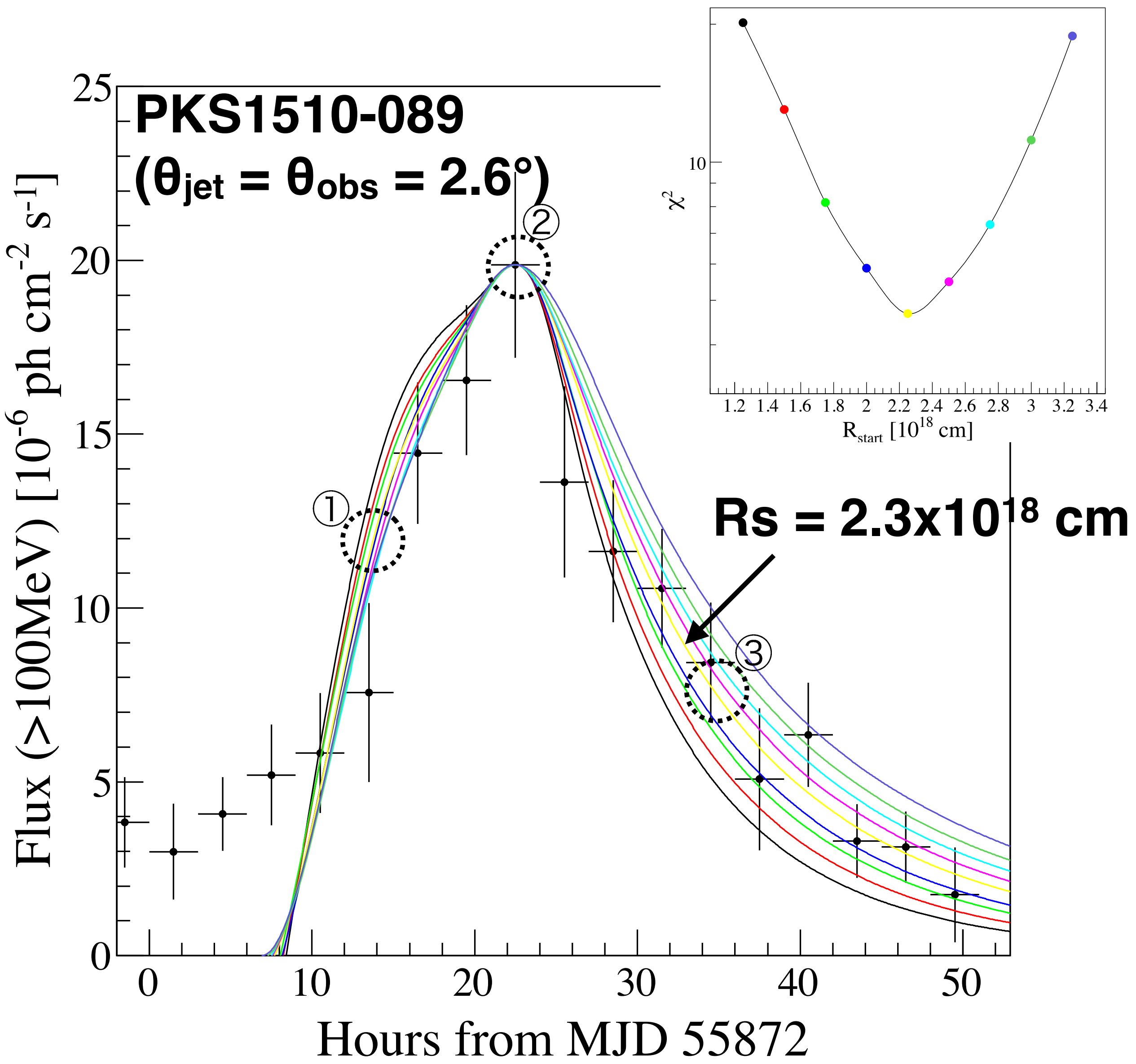
→ Location of gamma-ray emission zone was estimated to be $(0.7 \pm 0.2) \times 10^{18}$ cm from the SMBH.

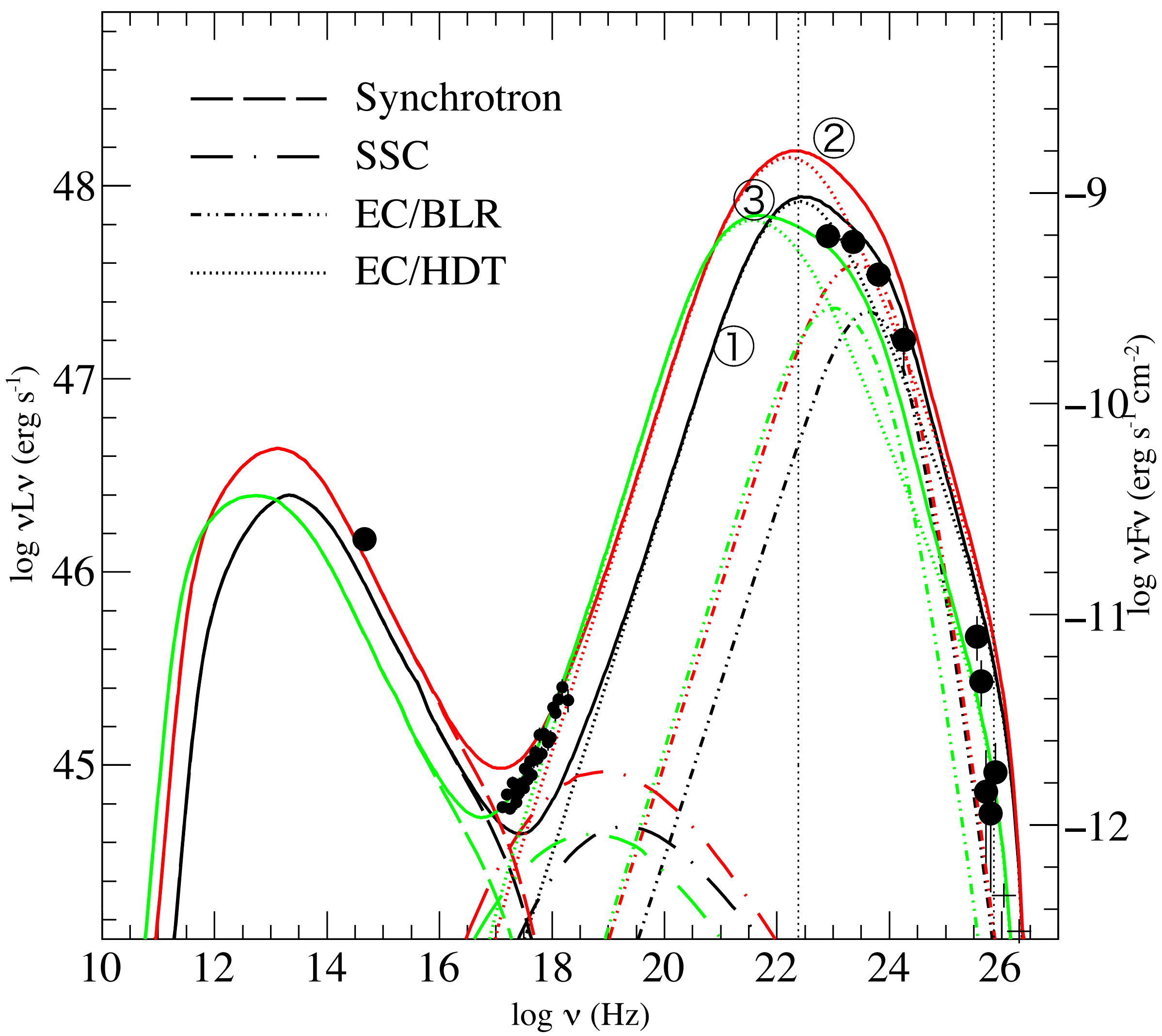




Constraints on the Location of Emission Zone

- Light curve modeling of another flare in PKS 1510-089 also suggests emission zone locating around ~10^{18} cm from the SMBH.

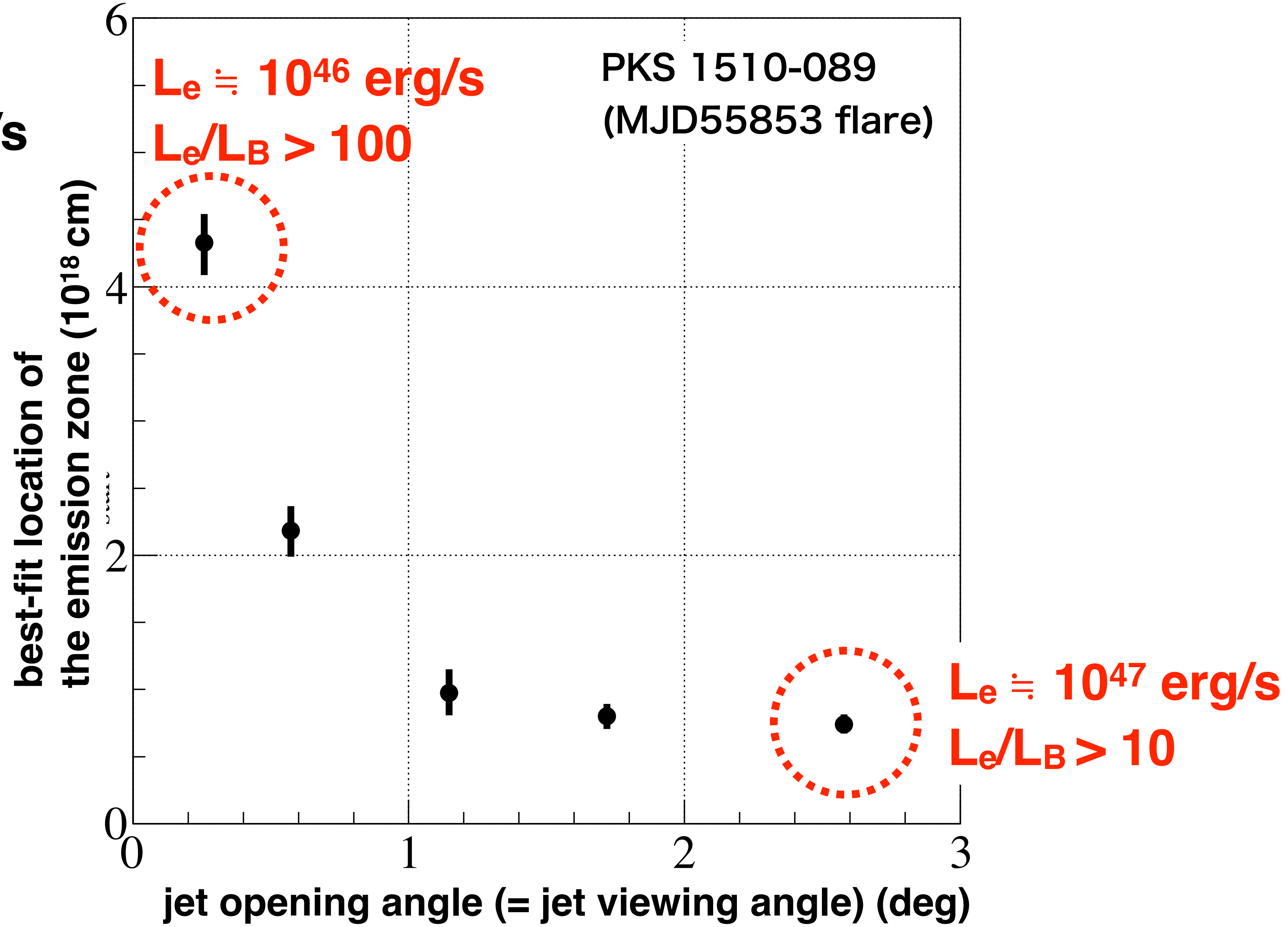




Emission zone for a highly collimated jet

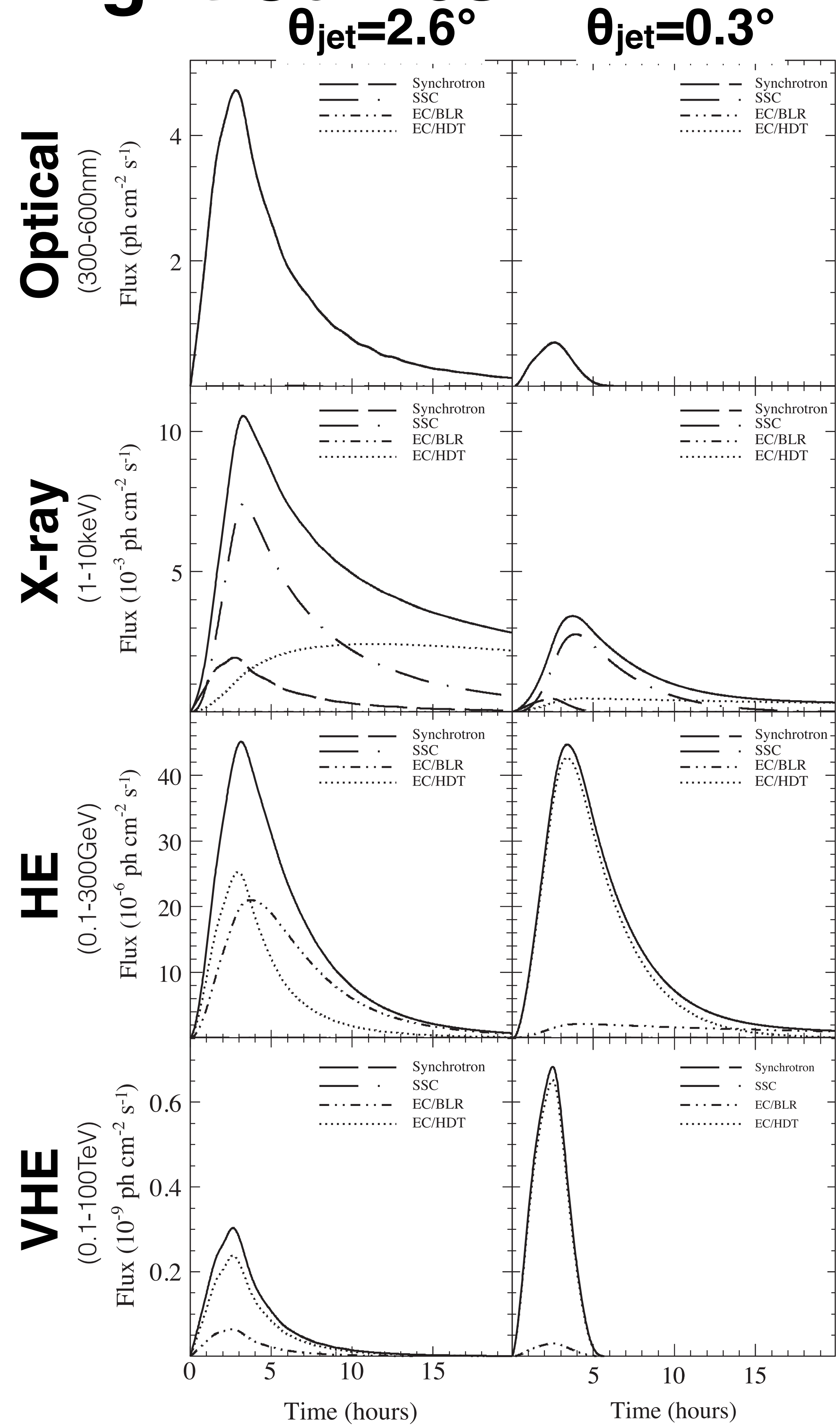
- Gamma-ray flaring light curves were simulated for a well-collimated jet (smaller jet opening angle of down to 0.3°: $\Gamma\theta_{jet} \fallingdotseq 0.1$), which is suggested by radio studies (*e.g. Jorstad+05, Clausen-Brown+13*).

$L_{acc} \fallingdotseq 5 \times 10^{45}$ erg/s



Expected Broadband Light Curves

- Different geometries give different timescales and flux levels of the flare in other wavelengths.
- VHE flux will be enhanced for the collimated jet due to pronounced emission from HDT.
- Monitoring flux change with timescale down to hours will resolve the model degeneracy.



Summary

- We collected the brightest samples of gamma-ray flares, and performed time-dependent modeling of gamma-ray flares in FSRQs with time resolution as good as three hours.
- The estimated location of emission zone during gamma-ray flares in PKS 1510-089 is around $\sim 10^{18}$ cm from the central SMBH, which is reconciled with detection of VHE photons reported during GeV flares.
- Observed time profile a flare was found to be characterised not only by electron cooling timescale, but also geometrical effect.
- Exactly simultaneous observation of flares with time resolution down to hours will remove the degeneracy of model parameters.