Multiwavelength analysis of the FSRQs CTA 102, 3C 454.3, and B2 1633+382

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CONACYT
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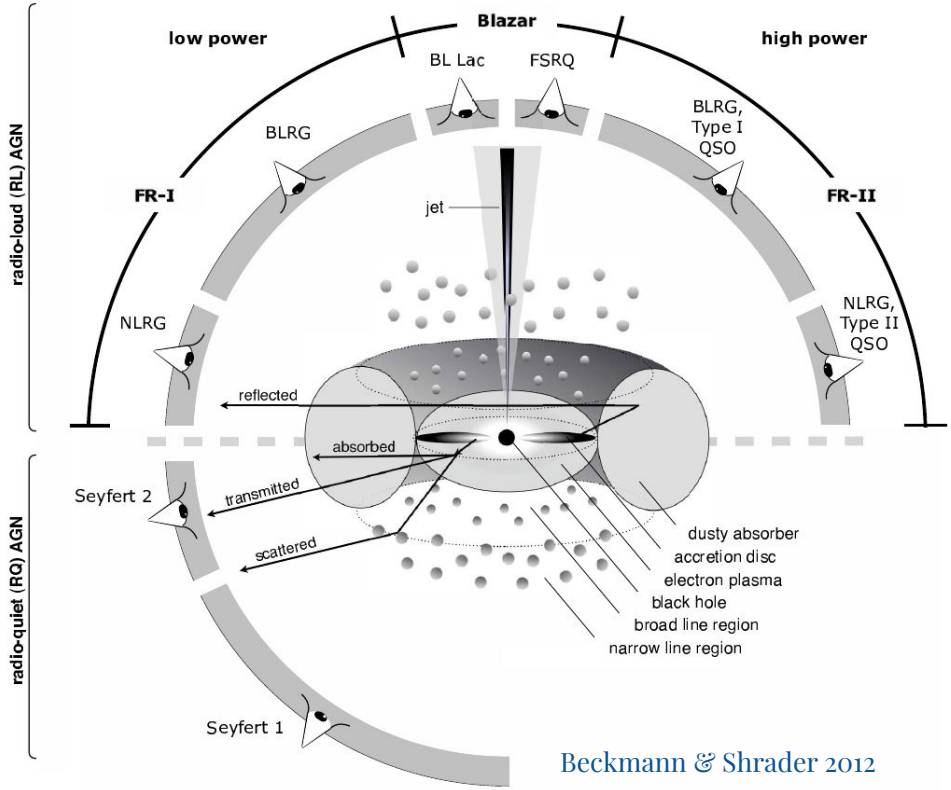
INAOE

Image Credit: ESA/Hubble, NASA, M. Kornmesser

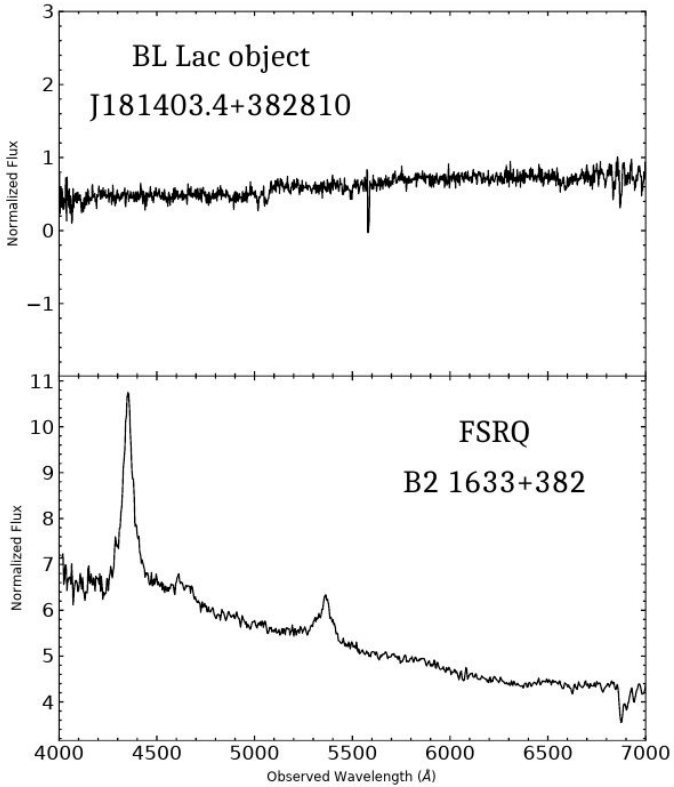
Outline

1. What is a FSRQ?
2. Why study FSRQs' emission in multiple wavelengths?
3. Scientific Objectives
4. The Gamma-ray Emission Region Location
5. Outflowing BLR component
6. The Origin of the Gamma-ray Flares
7. Implication on the black hole mass estimations
8. Conclusions

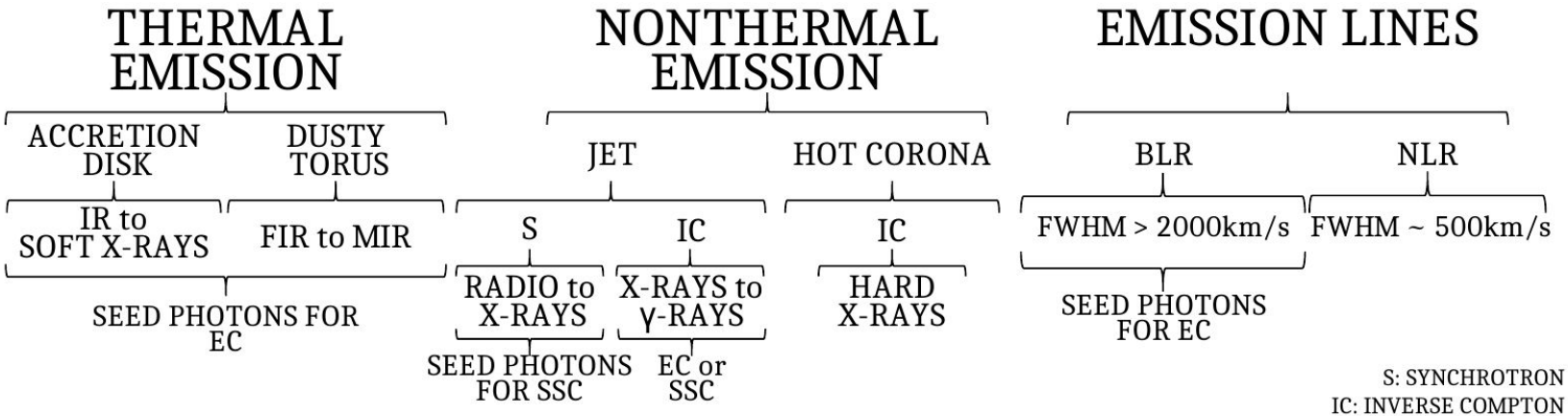
What is a FSRQ?

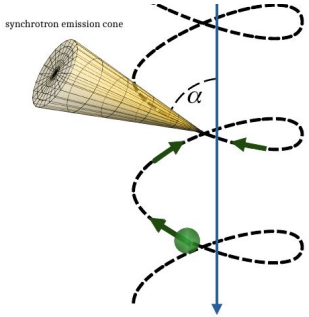


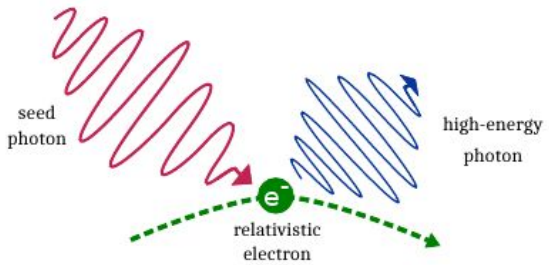
Beckmann & Shrader 2012



Why study FSRQs' emission in multiple wavelengths?

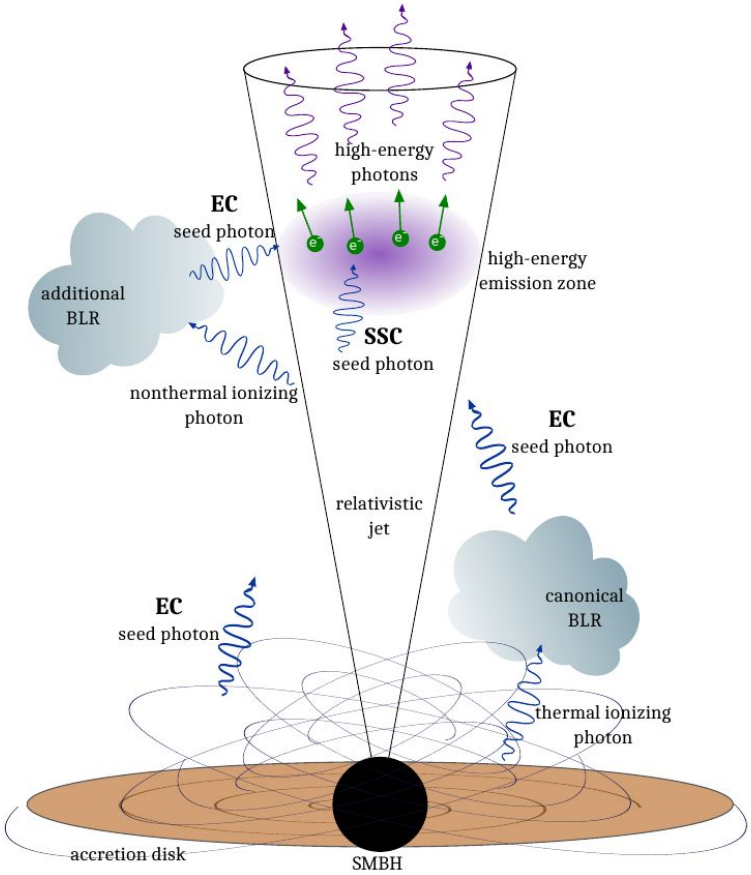






Scientific Objectives

- Locate the gamma-ray emission region
  - Within the central parsec?
  - Downstream the jet?
  - Multiple regions?
- Determine the dominant gamma-ray emission mechanism
  - Are the seed photons enabling inverse Compton coming from outside or within the jet? is it changing?
- Is there an outflowing BLR component?
- Should we use reverberation mapping and/or single epoch techniques to estimate BH mass of FSRQs?



The Gamma-ray Emission Region Location

CTA 102

~25 pc from the black hole
Chavushyan et al. 2020

Moving component traversing the recollimation shock.
Casadio et al. 2019

3C 454.3

Multiple gamma-ray emission regions
Amaya-Almazán et al. 2021

Flares of 2010 and 2014
Ejection from the radio core.
Jorstad et al. 2017
43 GHz core located at ~9 pc.
Kutkin et al. 2014
Flare of 2015
Quasi-stationary component flux greater than the core.
Liodakis et al. 2020
Probably a moving component collided with this quasi-stationary component.
Amaya-Almazán et al. 2021

B2 1633+382

Located at ~37 pc from the jet apex or ~4 pc from the 15 GHz core
Delay of approx. 70 days between 15 GHz and gamma-rays.
Amaya-Almazán et al. 2022

Distance of ~41 pc from the 15 GHz core to the base of the jet.
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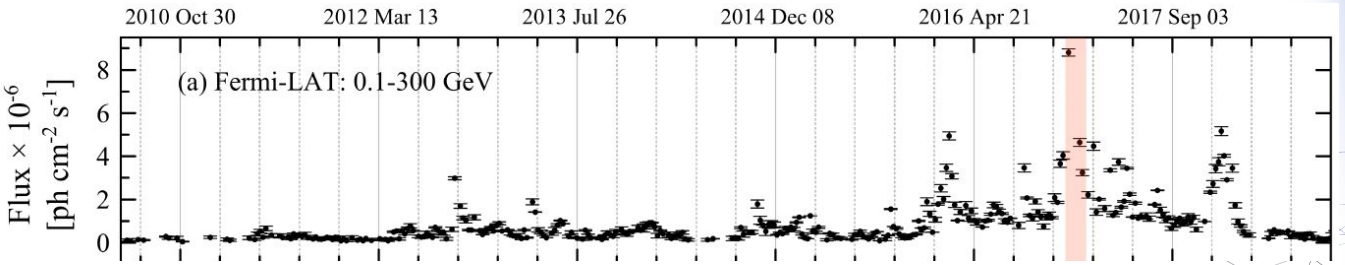

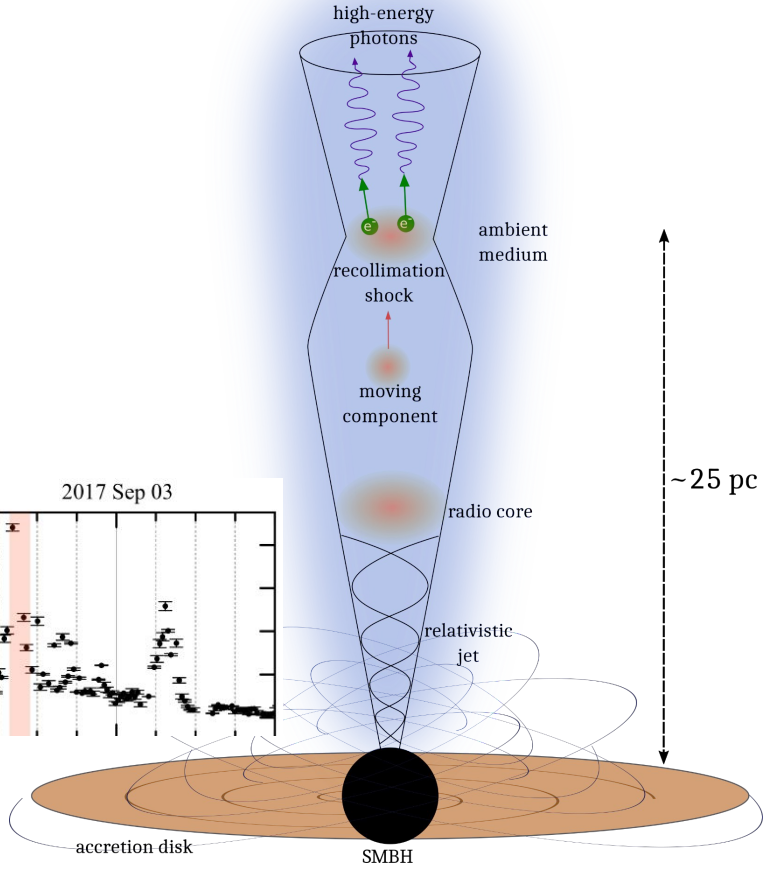

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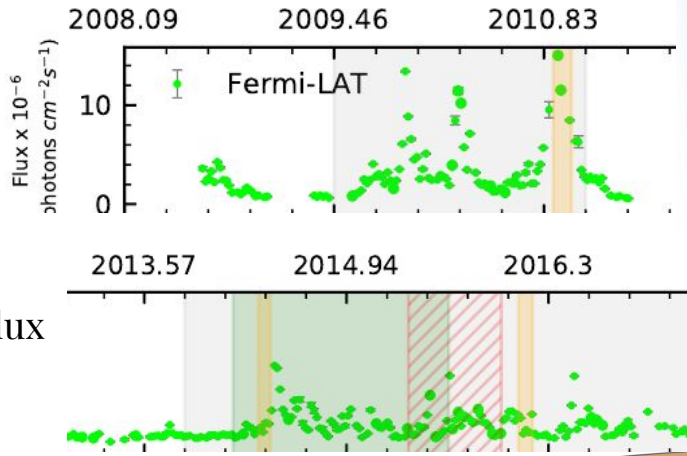

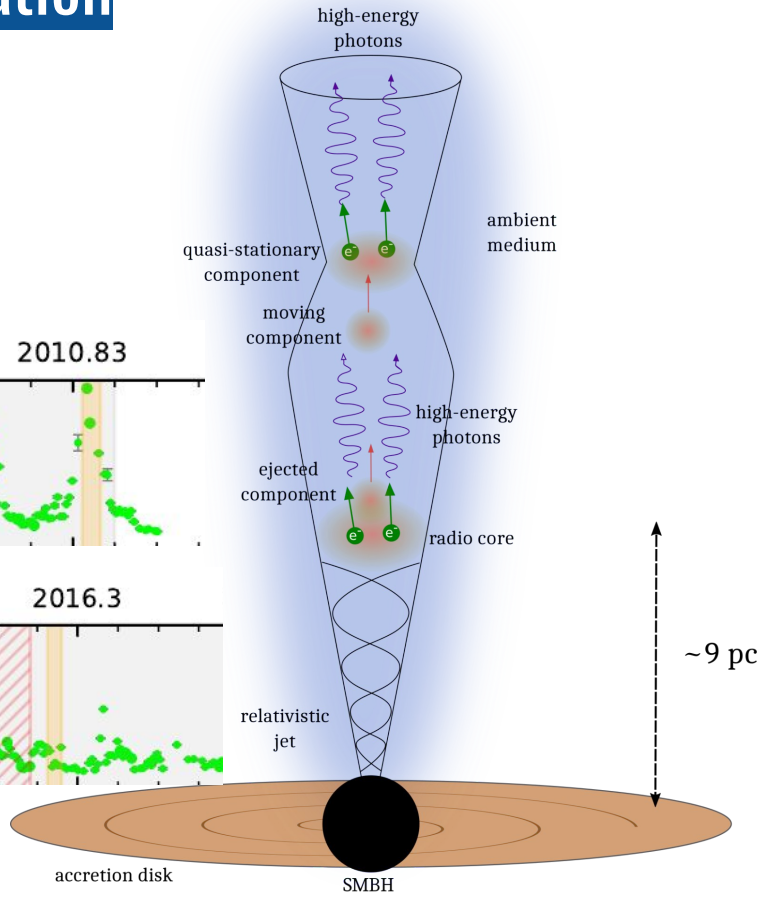

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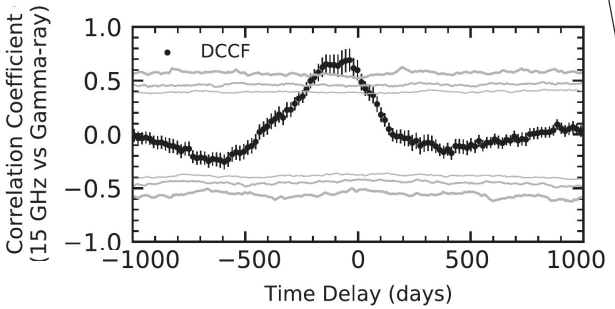

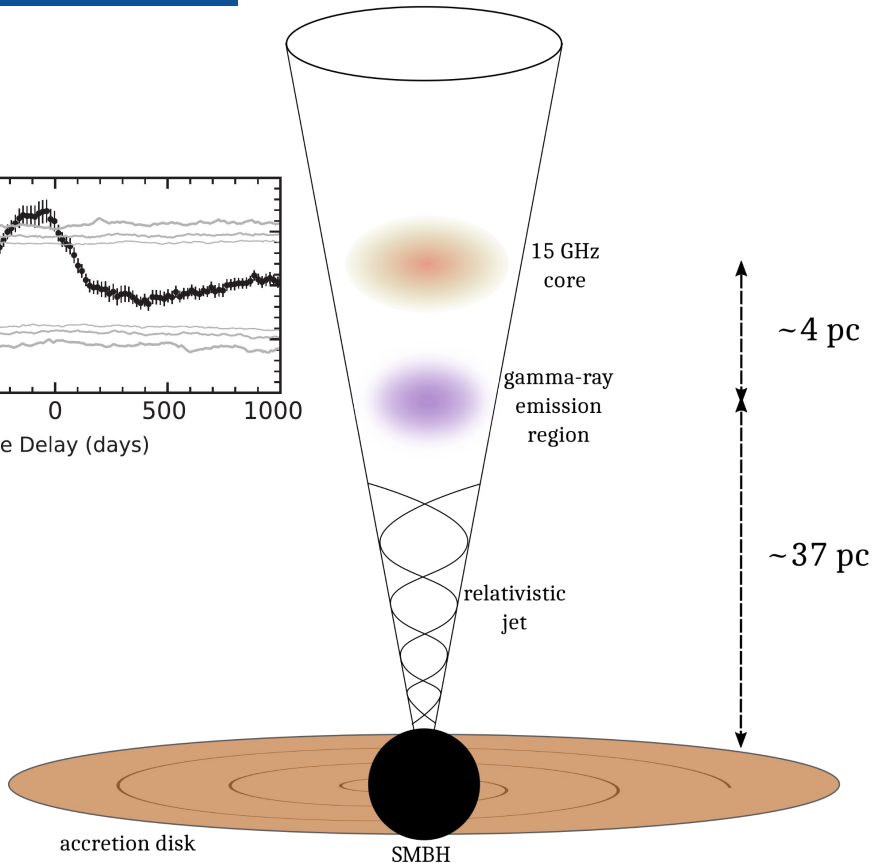

Additional BLR component related to the jet

CTA 102

Chavushyan et al. 2020

Mg II and UV Fe II respond to changes in the jet-dominated (J-D) continuum.

Blue-shifted broad component.

Outflow

Location of this region would be very close to 25 pc from the black hole (43 GHz core location).

3C 454.3

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Flaring period 1:
Mg II and UV Fe II respond to changes in the J-D continuum. Same result found as in:
León-Tavares et al. 2013 and Isler et al. 2013.

Flaring period 2:
Mg II and UV Fe II loose traction, behaving monotonically during this period despite the large continuum variability.

- *Different ionizing spectrum*
- *Not dense enough BLR*
- *The BLR clouds moved*

B2 1633+382

Amaya-Almazán et al. 2022

Larger variable component of the emission line in the blue side of the profile.

Anti-correlation between the emission line and the continuum in 2011.

The jet is stealing BLR material

Not dense enough to be ionized.

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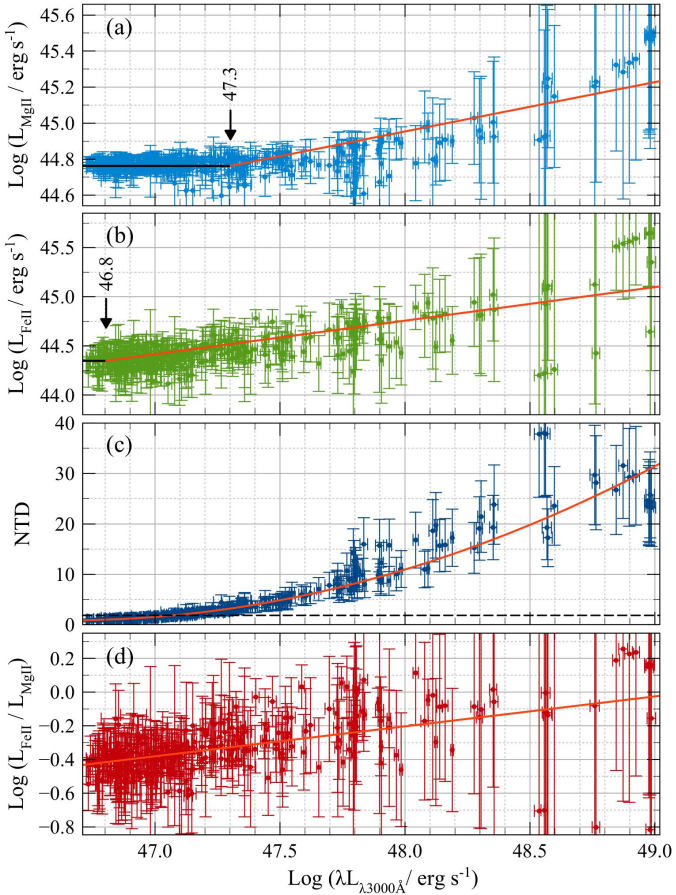

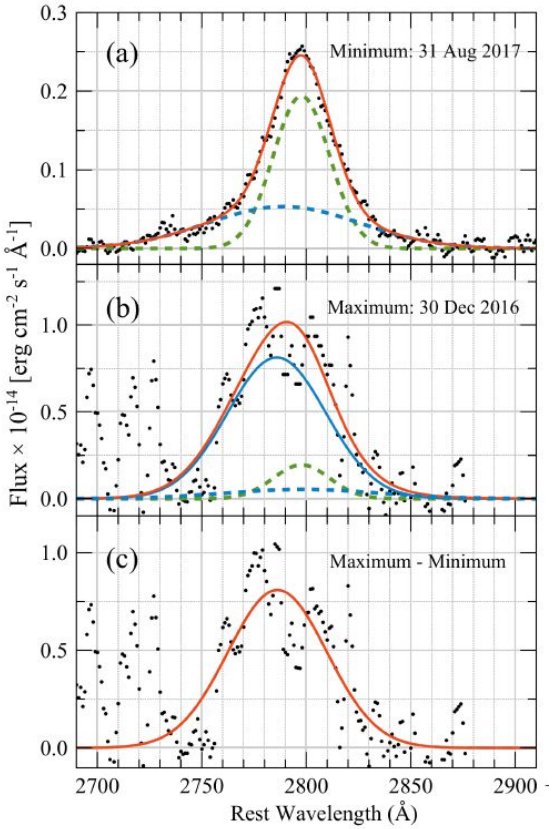

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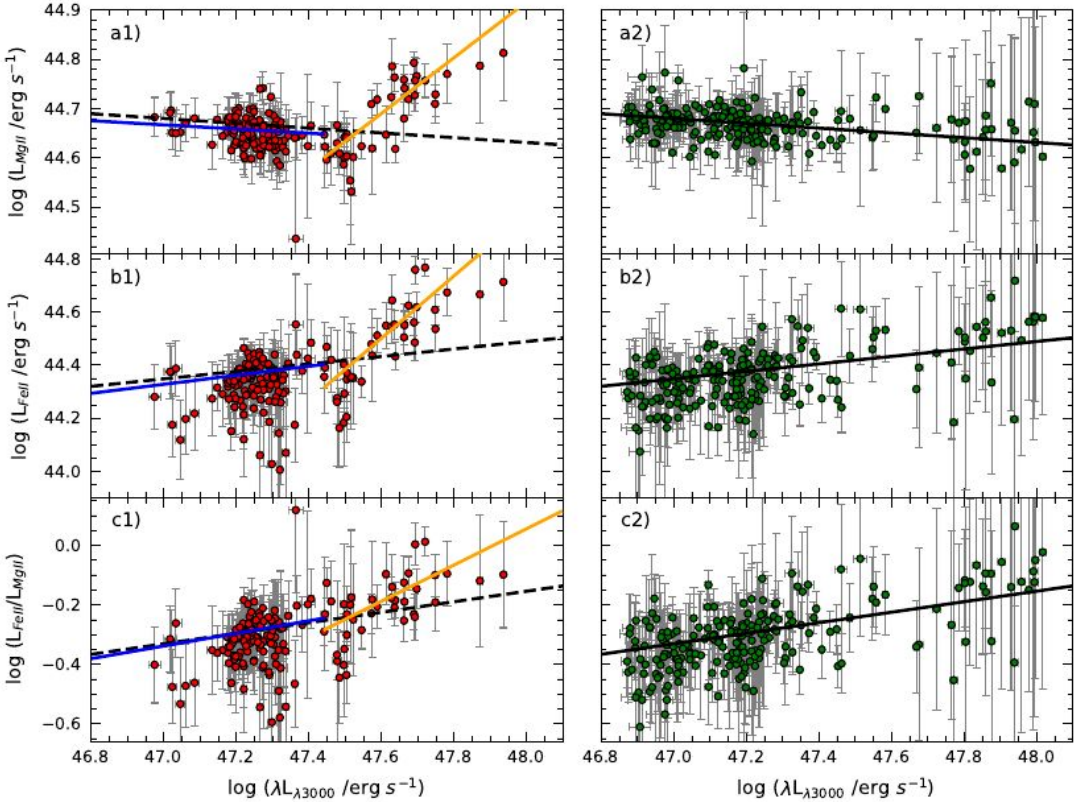

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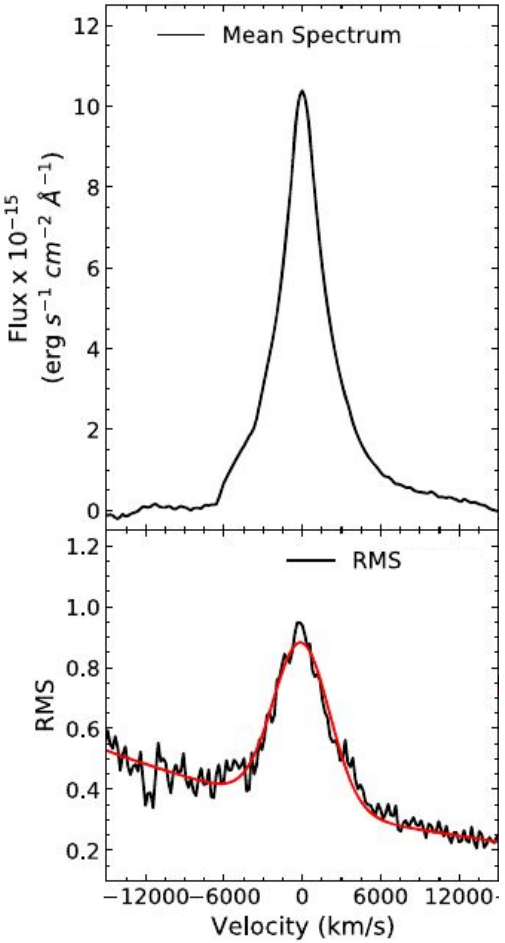

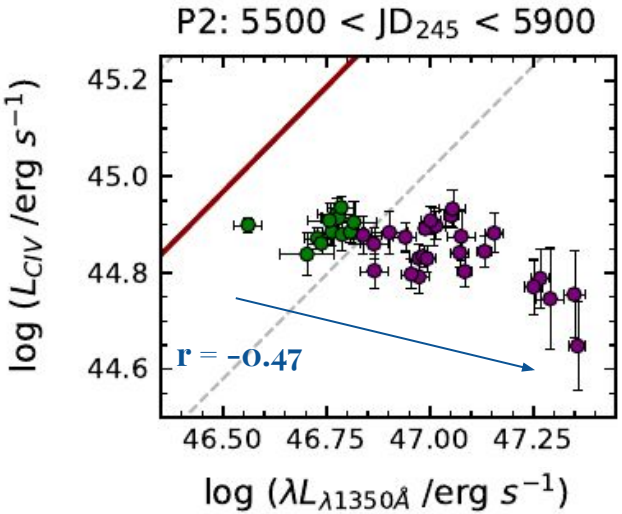

The Origin of the Gamma-ray Flares

CTA 102

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Electrons are accelerated due to the interaction of a moving component with the stationary component (recollimation shock).

Part of the seed photons could be coming from of an additional BLR component close to the stationary component.

3C 454.3

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Seed photons are mostly coming from within the jet.
SSC or spine-sheath model?

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Flares of 2009, 2010, 2012, and 2013:

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The interaction of outflowing BLR with the jet causing oscillations at its base helping to induce instabilities.

Electrons accelerated by magnetic reconnection.

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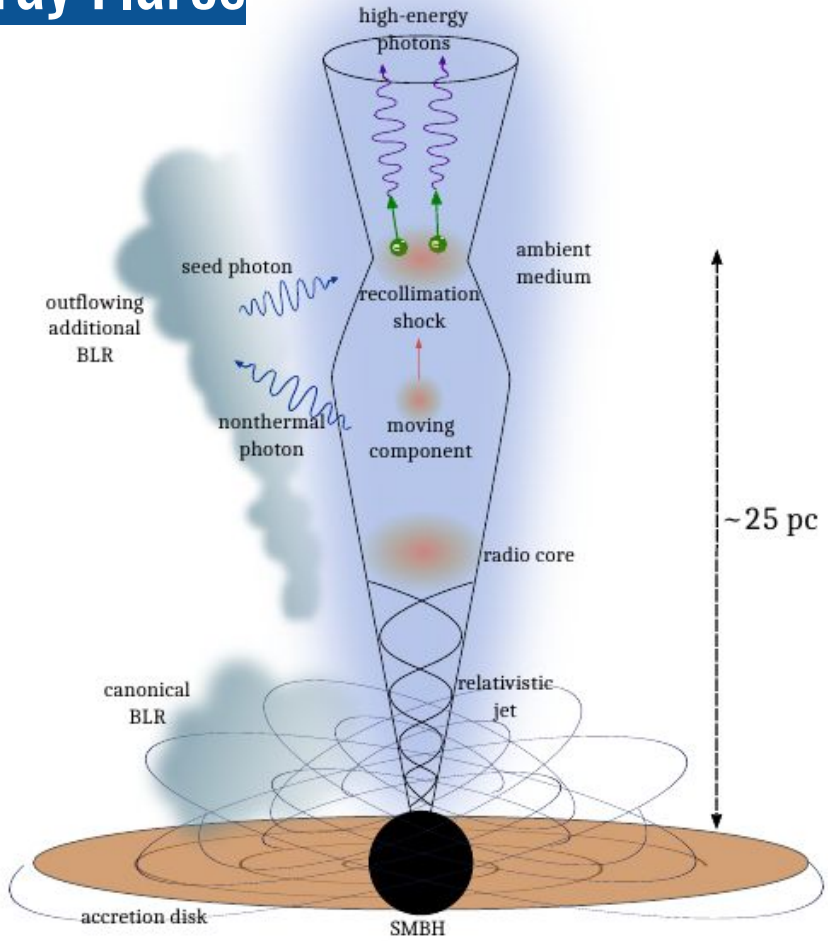

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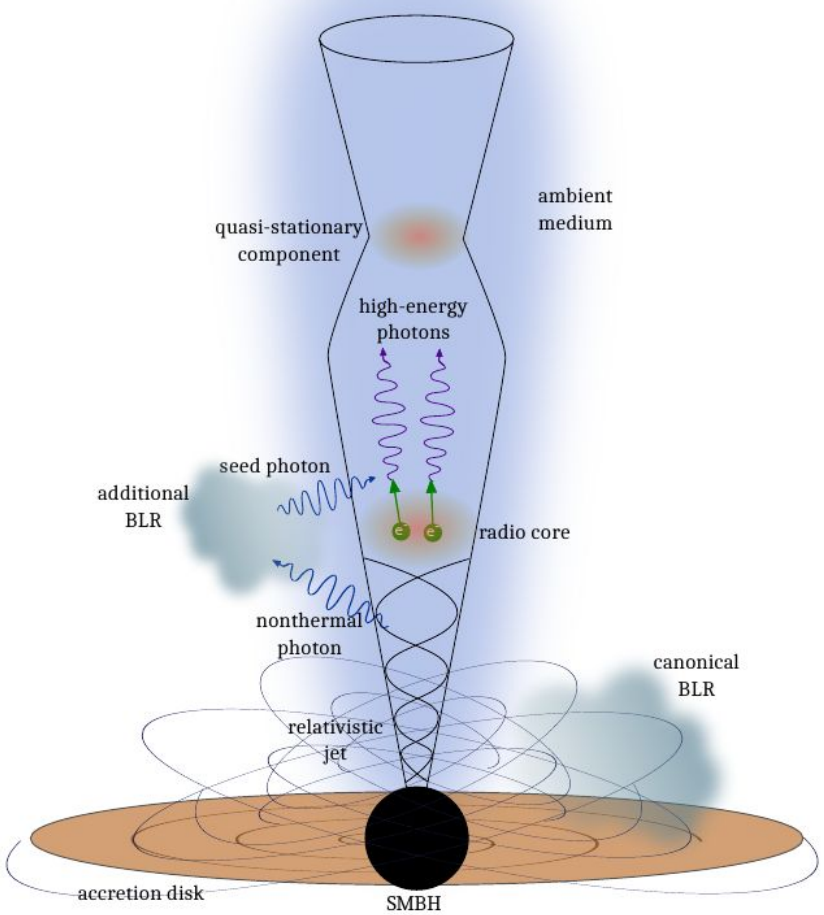

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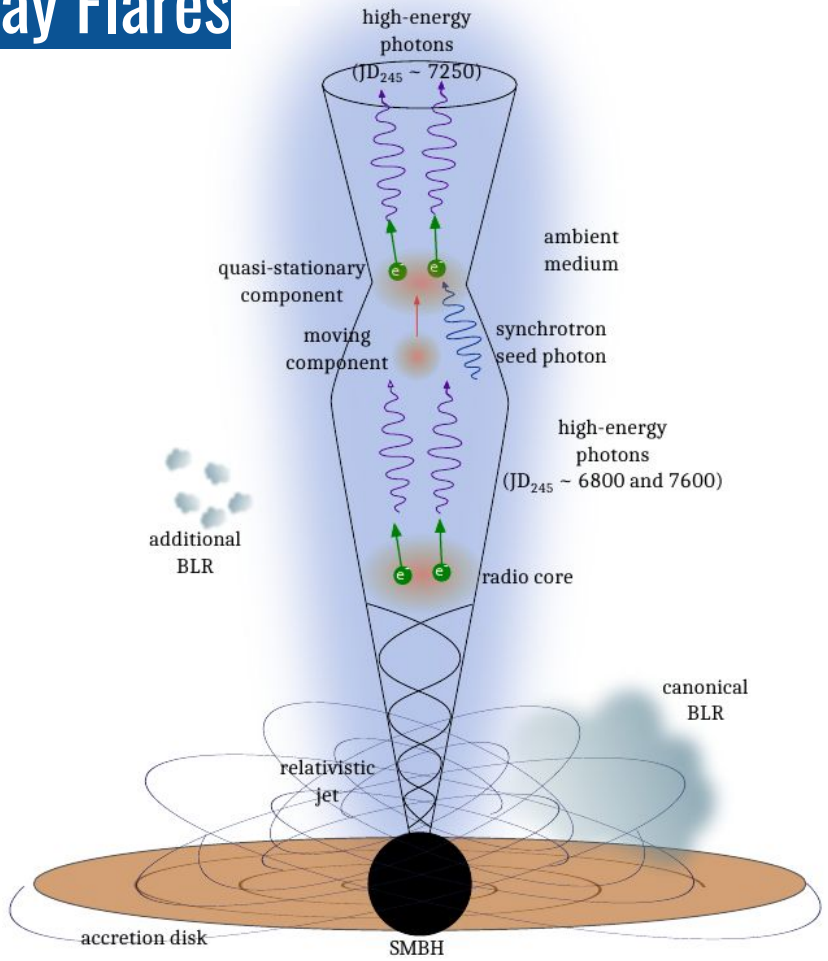

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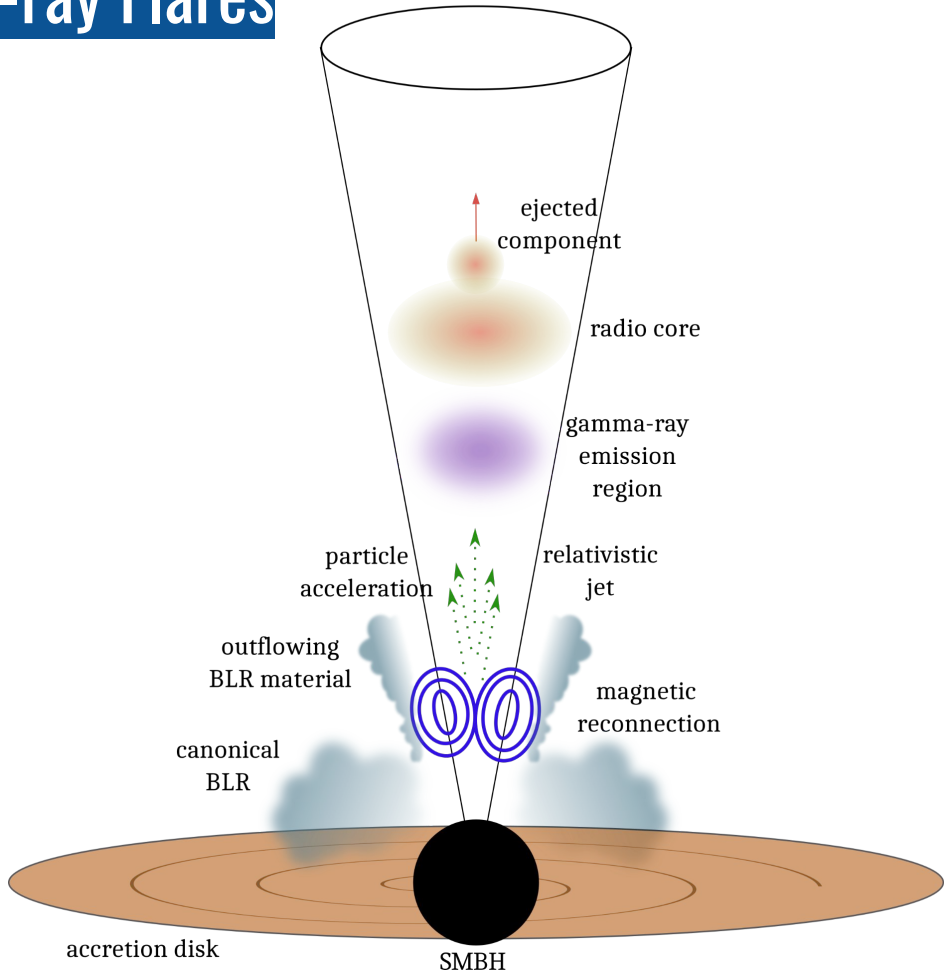
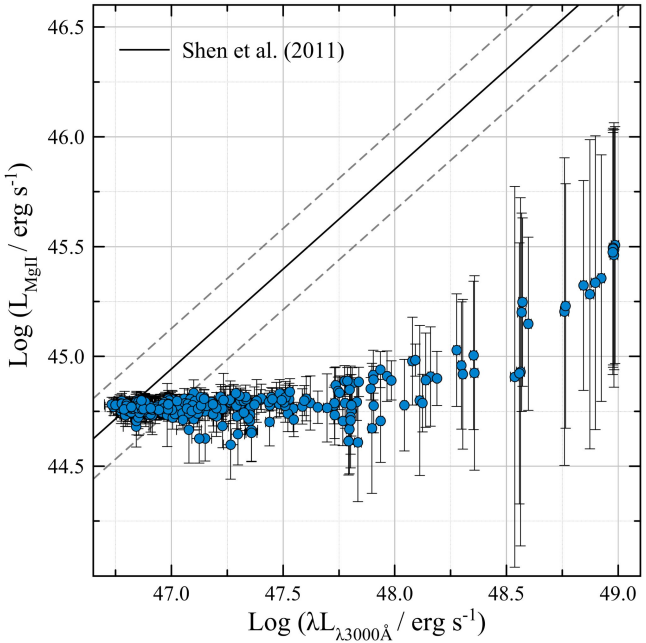


Implication on the black hole mass estimation

CTA 102



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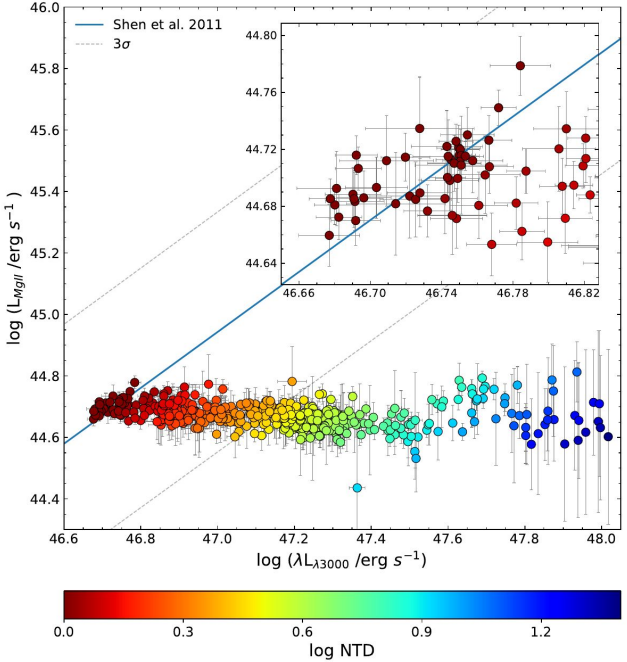

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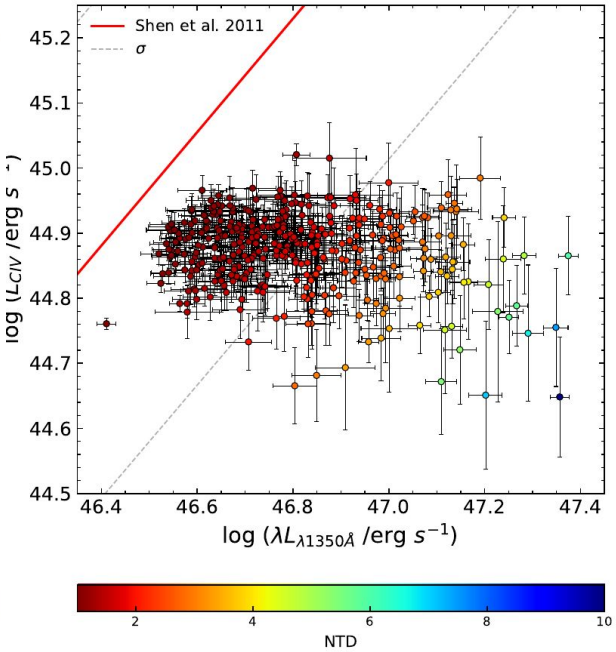

Amaya-Almazán et al. 2022

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Implication on the black hole mass estimation

Neither of these sources follows the luminosity relation between the emission line and the continuum for radio-quiet sources.

Reverberation mapping and single epoch techniques require these conditions:

- Single ionizing source: the accretion disk
- Virialized BLR

Neither of these conditions is met by these sources.

The use of these techniques with FSRQs might need the use of observations when the continuum is dominated by the accretion disk and a possible spectral decomposition to use only the line component corresponding to the virialized central BLR.

Conclusions

1. The **location of the gamma-ray emission region** cannot be pinpointed in all blazars. The gamma-ray production depends on the physical properties and the environment of each source. Allowing it to **change locations** from one flaring event to the other.
2. The **gamma-ray production mechanism** is not simple. The dominant source of seed photons for inverse Compton **might change with time**. Multiple zone jet models are highly suggested for these sources e.g. spine-sheath, TEMZ.
3. There is evidence of an **outflowing BLR component**, which in turn might help the production of gamma-rays downstream the jet by providing a **new low-energy photon field**.
4. The evidence of a **non-virial BLR component** and the **jet being able to ionize** these clouds demands considering these facts for the black hole mass estimation through spectroscopic methods.

THANK YOU!