A decade of joint MOJAVE–Fermi AGN monitoring
Localisation of the gamma-ray emission region

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**Inverse Compton**

Possible sources of seed photons:

1. Up-scattered synchrotron photons (SSC)

2. External sources: from accretion disk, BLR, torus, CMB, ...
Problem statement

Fermi/LAT + MOJAVE (VLBA 15 GHz)

1. Whether gamma-ray photons originate within the 15 GHz VLBA core
2. Whether gamma-ray emission zone is located within the BLR
331 MOJAVE AGNs that have positionally associated $\gamma$-ray counterparts from 4FGL-DR2

- $\geq$ 5 radio epochs
- galactic latitude $|b| > 10^\circ$
gamma-ray data

- Adaptive (Lott et al. 2012) and weekly binning
- 4FGL-DR2
- August 4, 2008 – August 2, 2018
- 0.1 – 300 GeV
Radio/\gamma\text{-ray time delay}

Observer’s frame

\begin{align*}
\text{Source frame: } (1 + z)^{-1} \text{ correction}
\end{align*}

\gamma\text{-ray emission precedes radio}

typical delay: 3-5 months (obs. frame), 2-3 months (source frame)

\[ r_c \propto \nu^{-1} \rightarrow \text{time delay} \]
Radio/$\gamma$-ray time delay

“External” VLBA components: correlation at greater time lags!

$\gamma$-ray emission is produced within the 15 GHz VLBA core region
Time delays of individual sources

73 sources

Radio/γ-ray time delay (days)

median: 96 days
$r_{\gamma, \text{proj}} = \text{distance between the BH and the place of the } \gamma\text{-ray emission production (in projected scale)}$

De-projected scale: $\sim 3 \text{ pc}$

16 sources: $r_{\gamma, \text{proj}} > 0 \ (1\sigma)$

Outside the BLR!
1. There is a significant correlation between gamma-ray photon flux and VLBA core flux density (3-5 months delay in the observer’s frame; 2-3 months in the source frame).

2. Gamma-ray emission is likely to be produced within the compact region of the 15 GHz VLBA core.

3. Gamma-ray emission is likely to be produced at parsec distances from the BH (outside the BLR).
Extra material: correlation method

**z-transformed discrete correlation function** (zDCF, Alexander 1997)

- ≥ 11 data points (42% of the sample)
- Monte Carlo simulations for errors accounting
- Stacked correlation curves: median correlation coefficient in each bin
Extra material: weekly binned LC

Radio/γ-ray time delay (months)

Pearson's $r$

15 GHz VLBA core

< 1σ

< 2σ

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