

Two-zone (leptonic) modelling of 3C 279 - Motivations

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Advances in modeling high-energy
astrophysical sources: insights from recent
multimessenger discoveries workshop

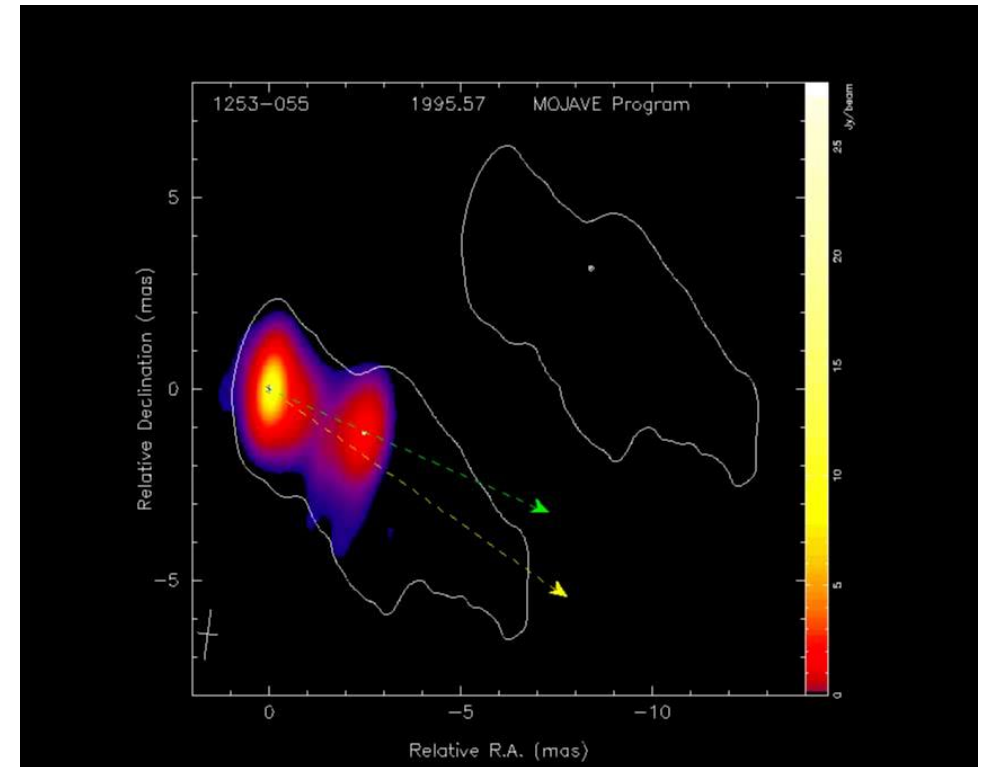
Sexten, Italy

1 July 2025

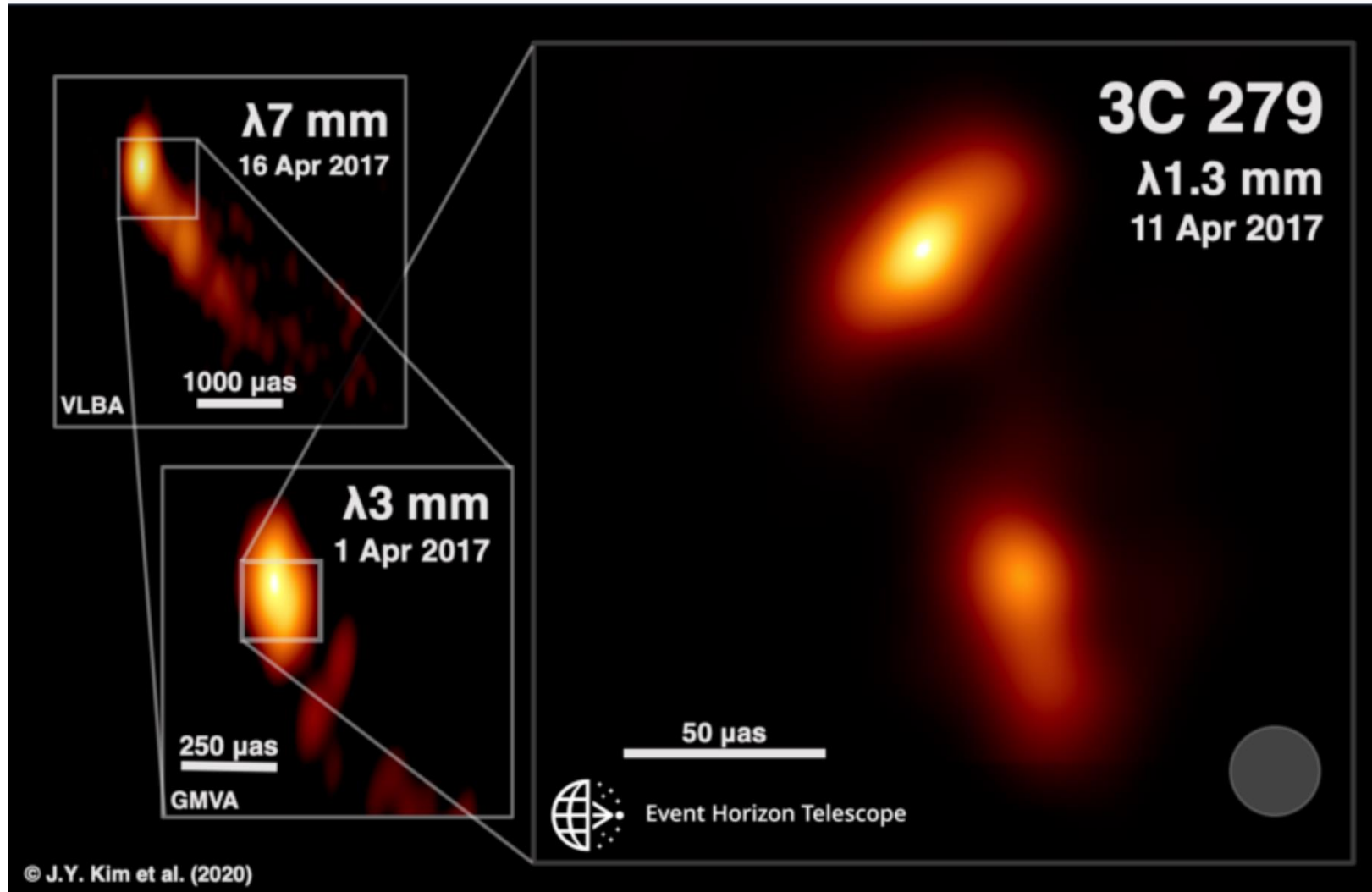
About 3C 279

- 3C 279 ($z = 0.536$): 1st FSRQ to be detected at VHE γ -ray energies ([MAGIC Collaboration \(2008\)](#), [H.E.S.S. Collaboration \(2019\)](#))
- Known for extreme variability across all frequency bands, especially at (V)HE γ -rays, with shortest timescales (days to minutes) (e.g. [Emery et al. \(2019\)](#), [Shukla et al. \(2020\)](#), [Hayashida et al. \(2015\)](#))
- Chaotic MWL behaviours, orphan flares that simple one-zone radiation models fail to reproduce
- Complex inner jet structure/dynamics; radio \leftrightarrow (V)HE γ -rays?
- One of the most studied blazar, but not well understood.

MOJAVE program
Homan et al., 2003



3C 279 – EHT target



2017 April observations

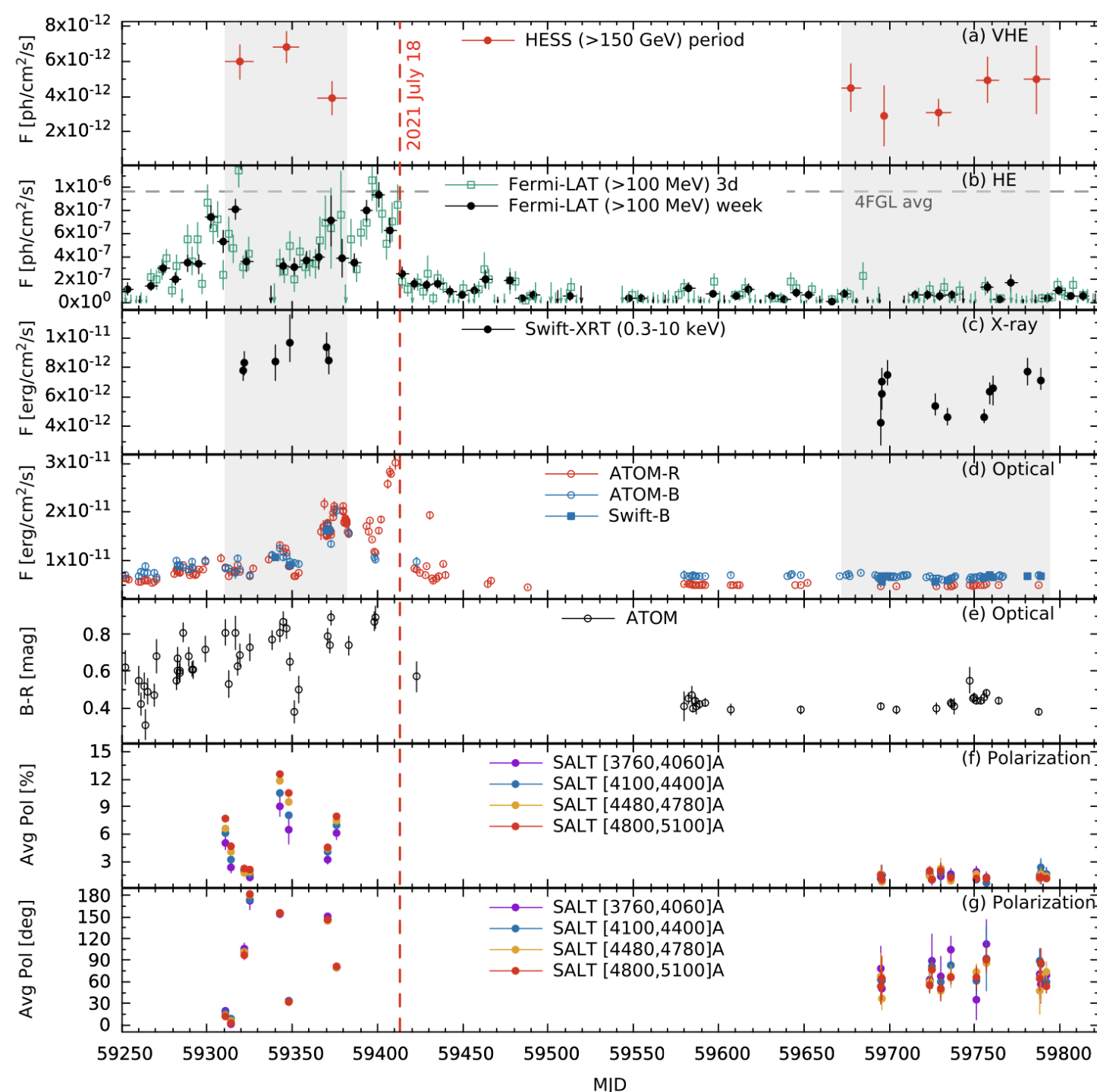
Kim + 2020:

*"20 μ as (at a redshift of $z = 0.536$ this corresponds to ~ 0.13 pc
 ~ 1700 Schwarzschild radii with a black hole mass $M_{BH} = 8 \times 10^8 M_{sun}$."*

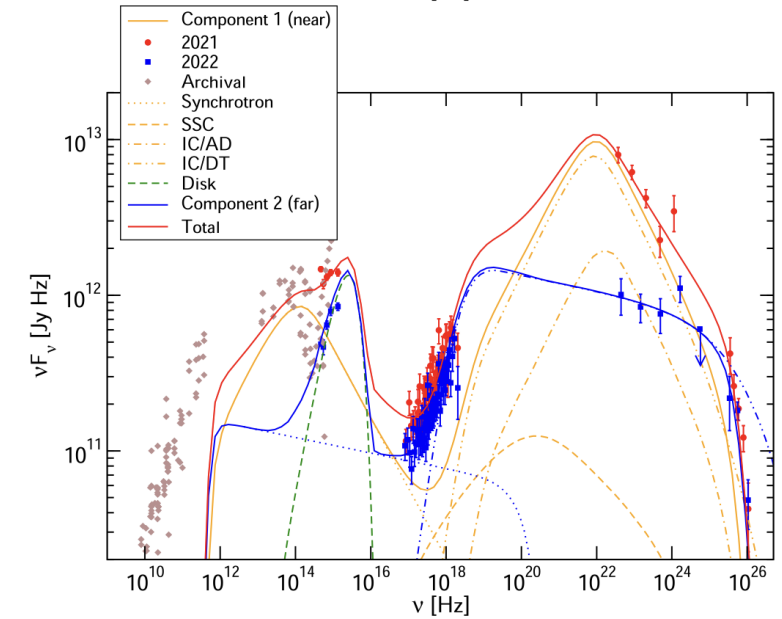
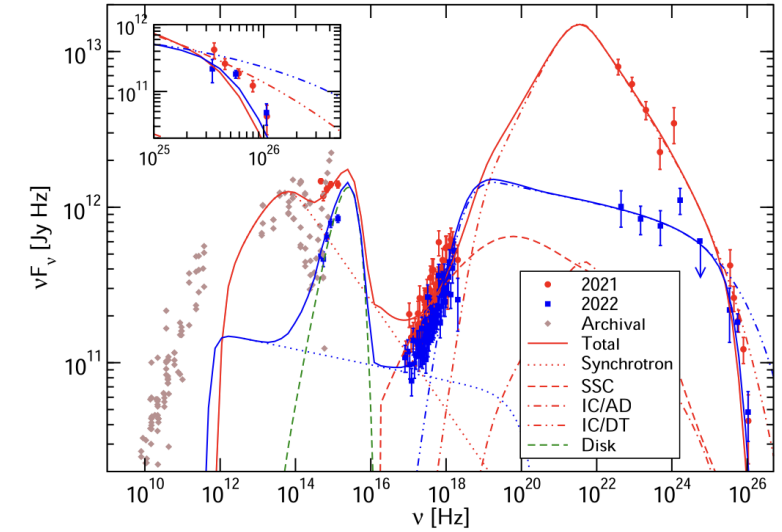
Perpendicular inner jet components moving at app. speeds $\sim 15c$ and $20c$.

Innermost jet regions – where one expects the rapidly variable HE&VHE gamma-ray emission to be produced.

Presentation @ ICRC2025 on 3C 279 EHT-MWL campaigns



PKS 1510-089 example

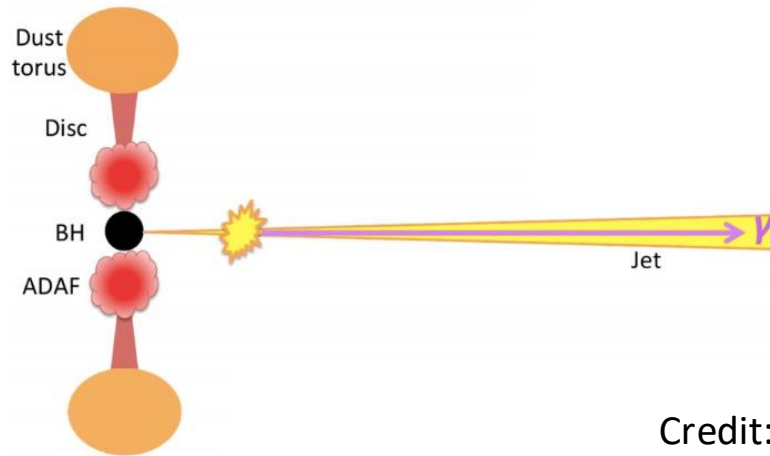


H.E.S.S. Collaboration (2023)

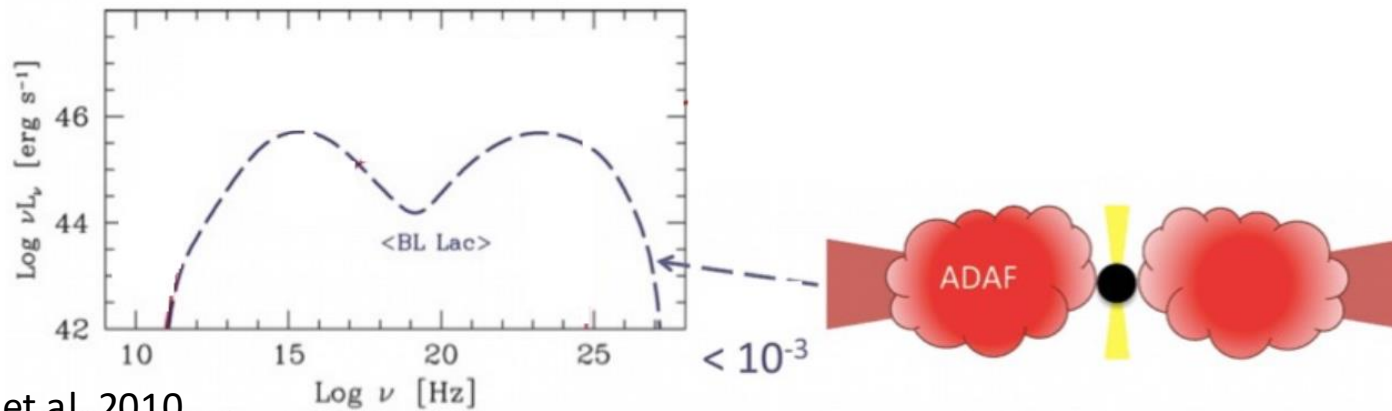
Blazar sub-classes - Reminder

SSC (Synchrotron self Compton)

BL Lac



Credit: D. Kynoch

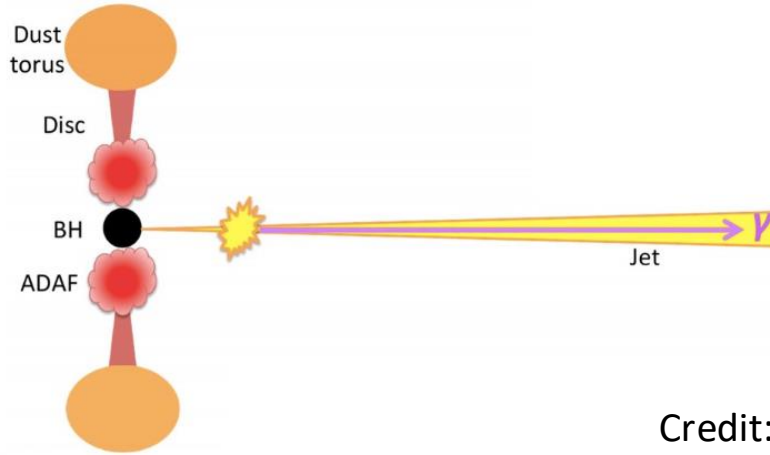


Ghisellini et al. 2010

Blazar sub-classes - Reminder

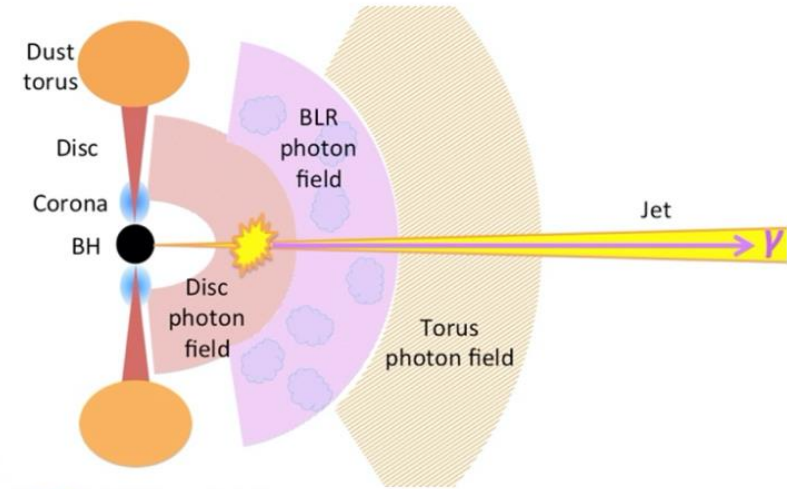
SSC (Synchrotron self Compton)

BL Lac

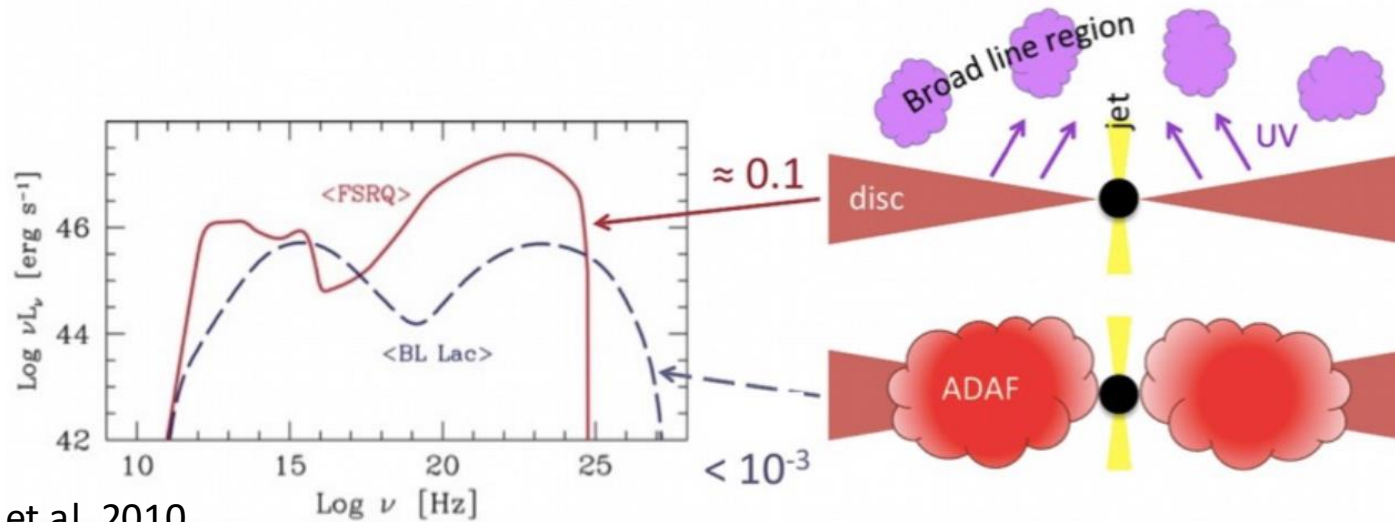


SSC + external photon field interactions

FSRQ

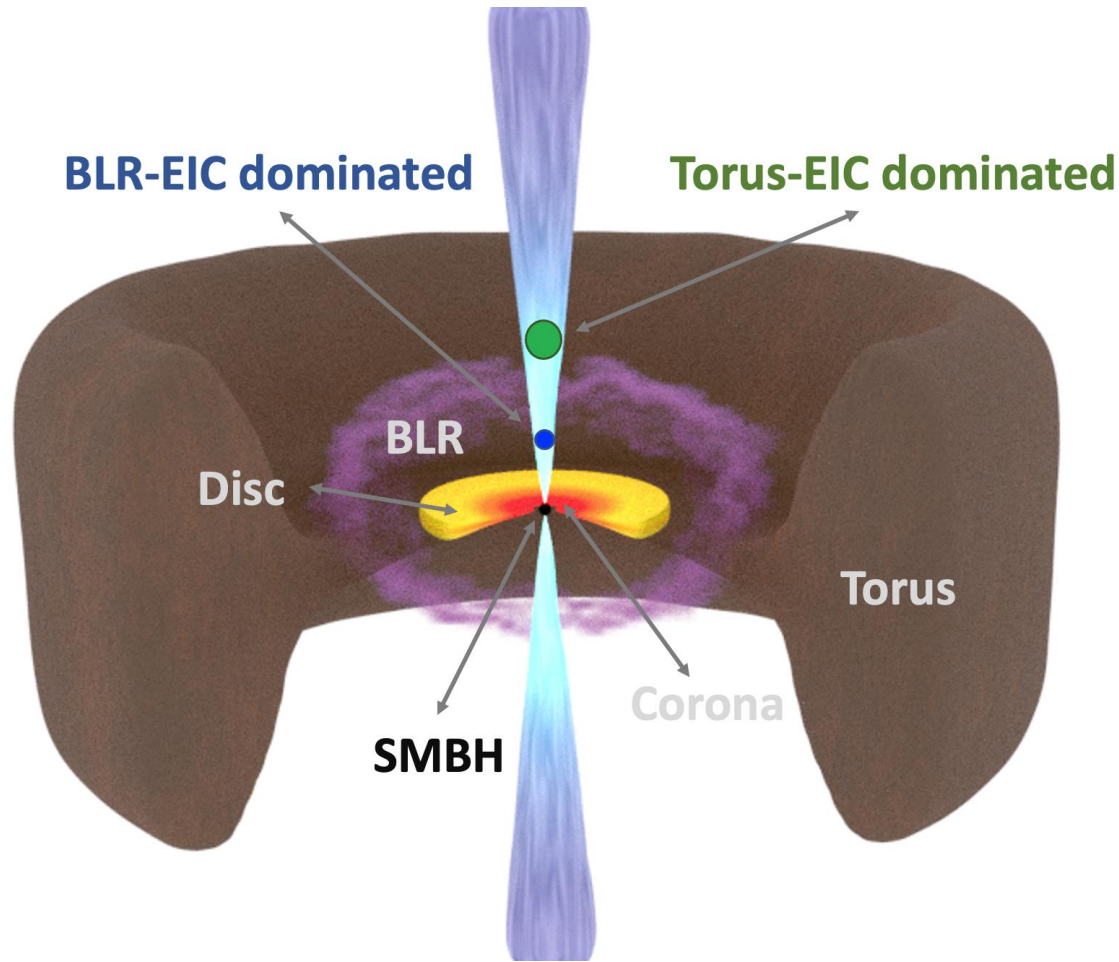


Credit: D. Kynoch



Ghisellini et al. 2010

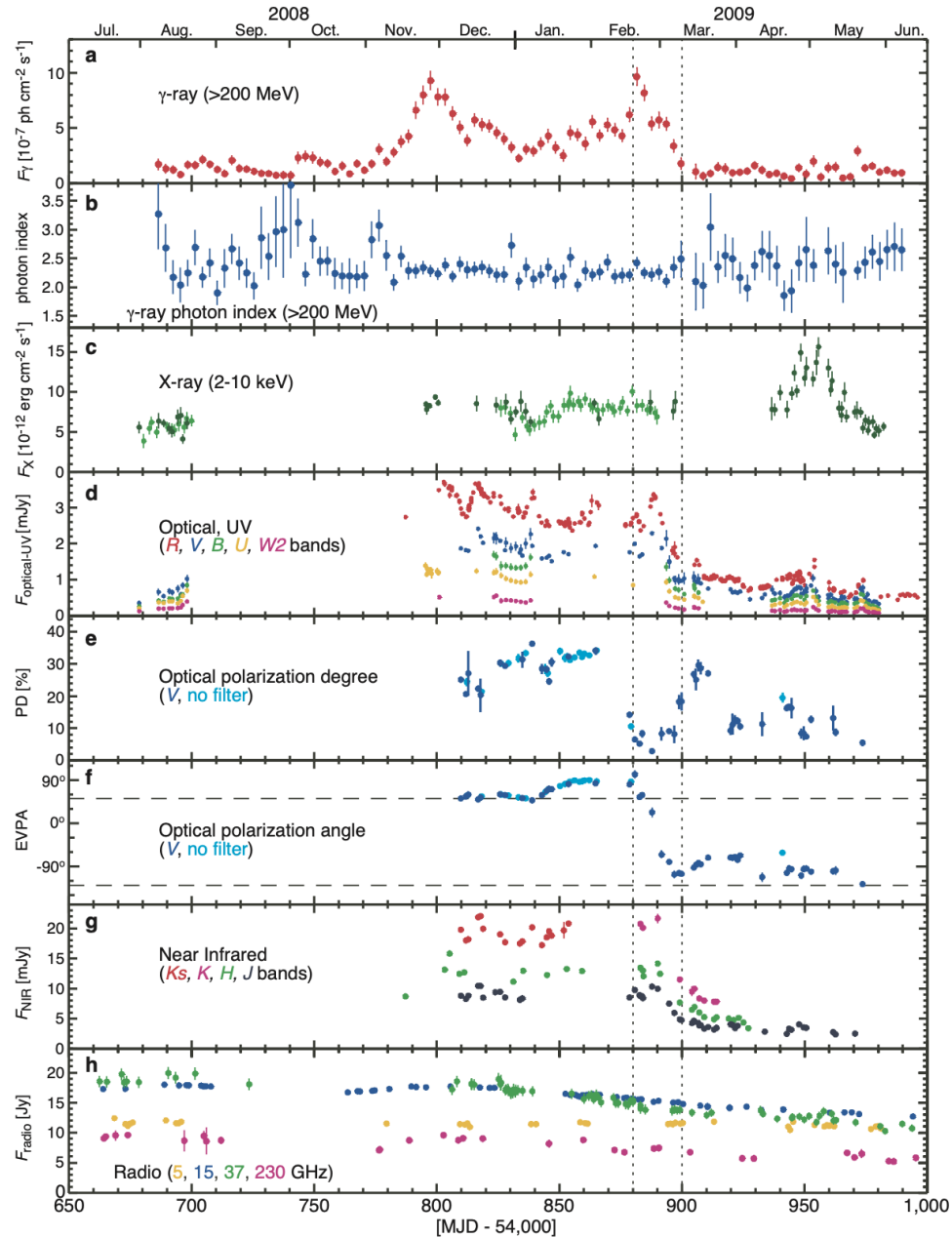
Two-zone leptonic model



Bottcher + 2013 stationary lepto-hadronic code (only leptonic part here)

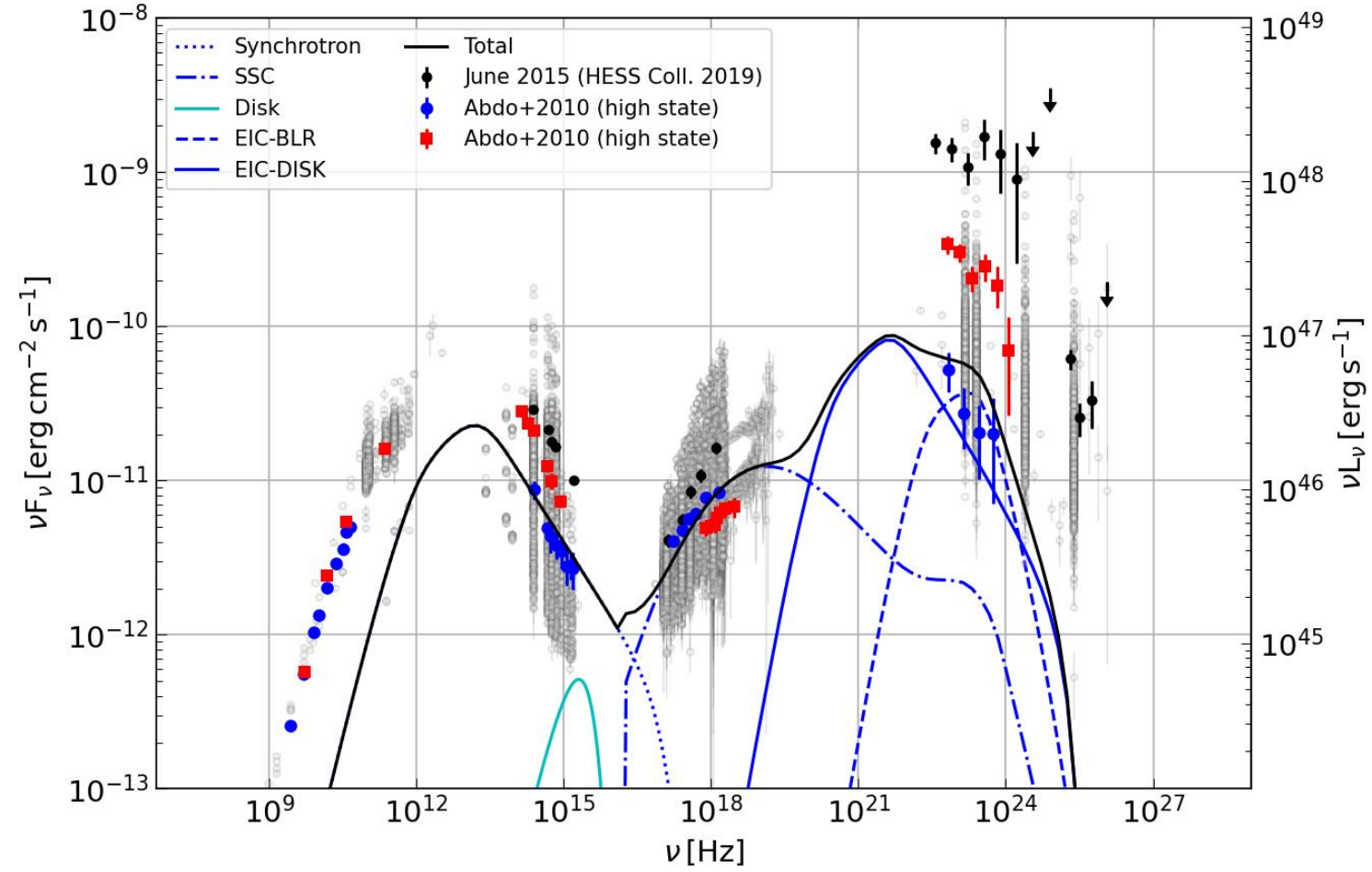
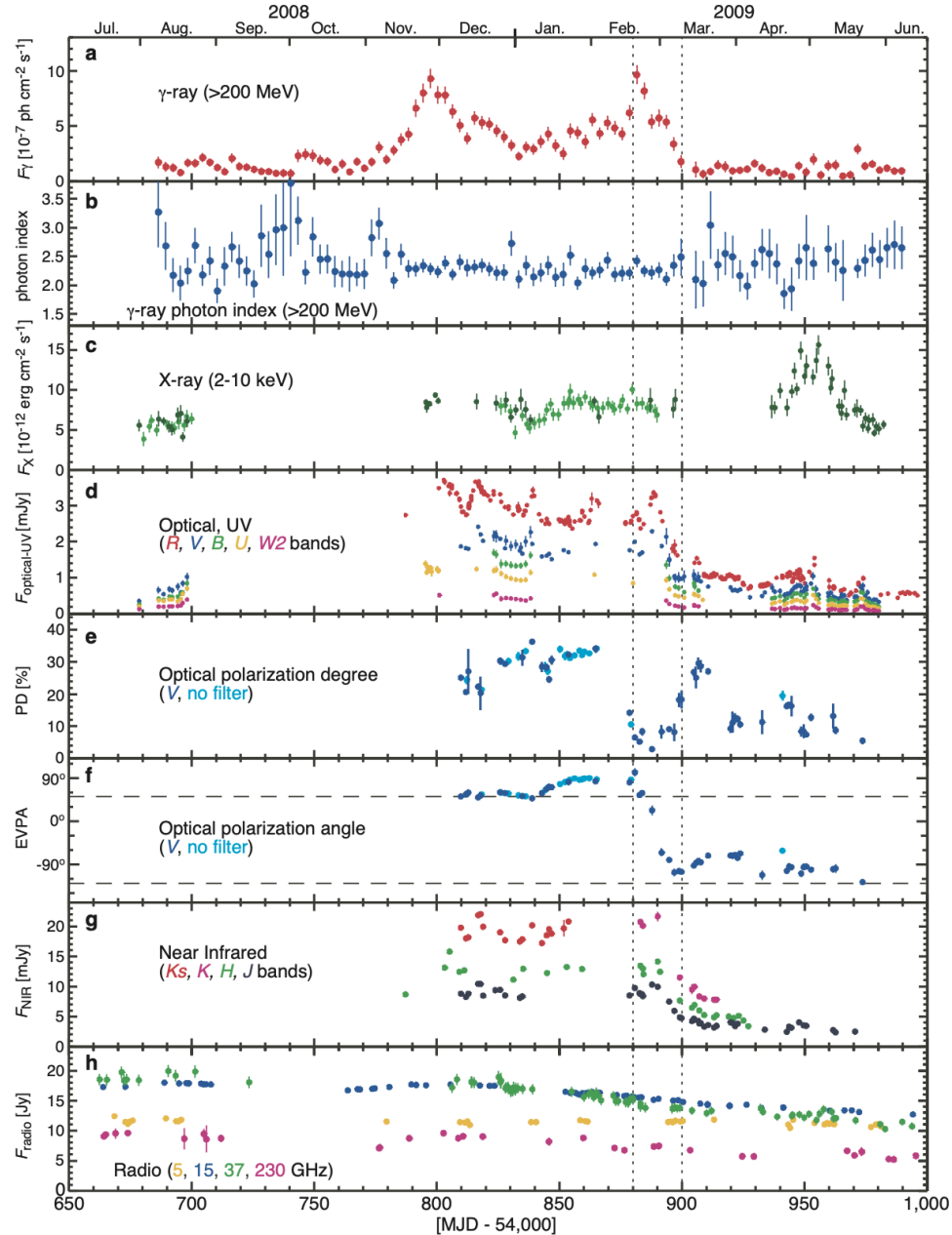
$R_\gamma < R_{BLR,in}$: BLR-EIC dominates
 $R_\gamma > R_{BLR,out}$: Torus-EIC dominates

Need for two emission zones in 3C 279?



Abdo et al. 2010

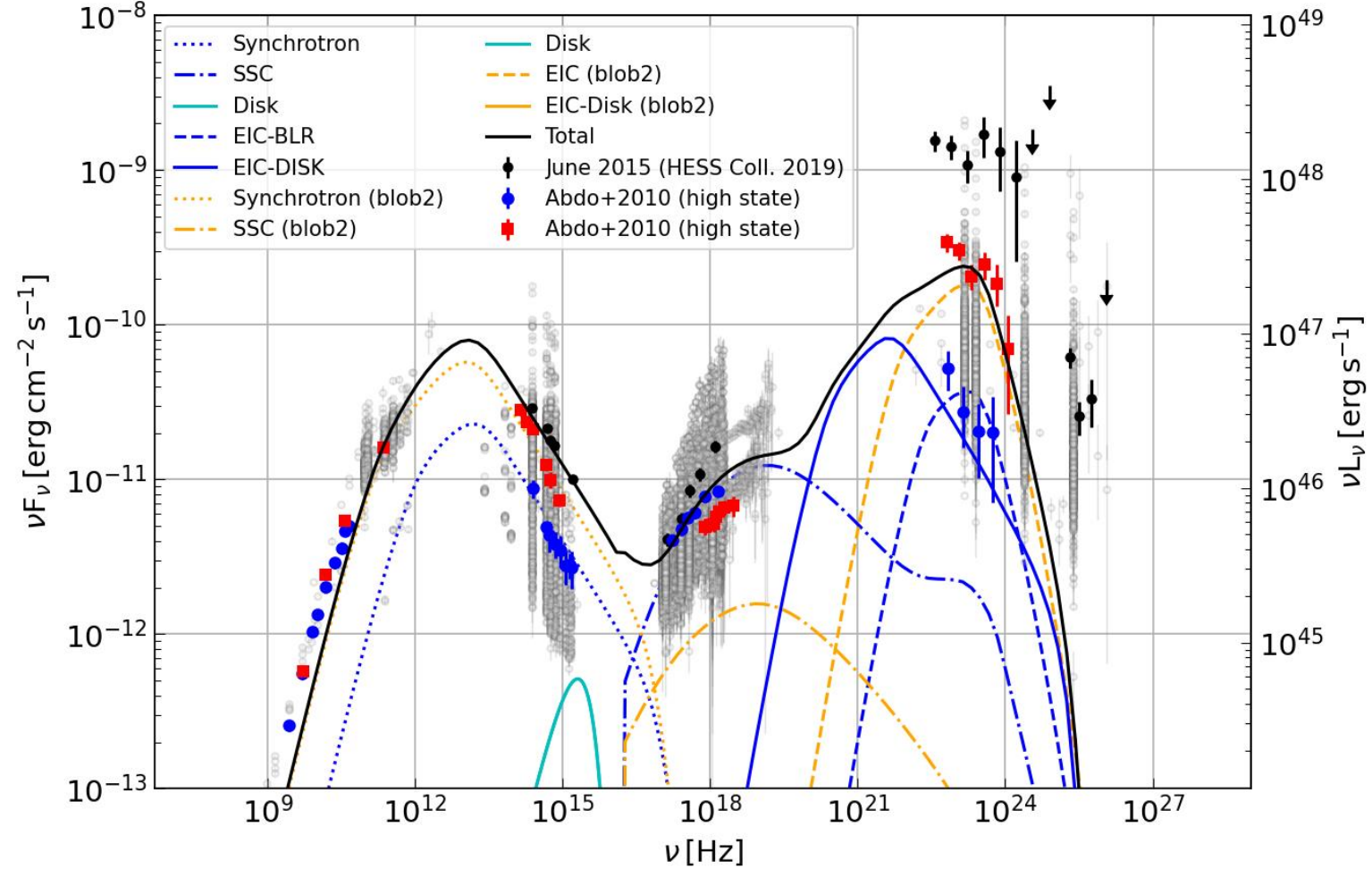
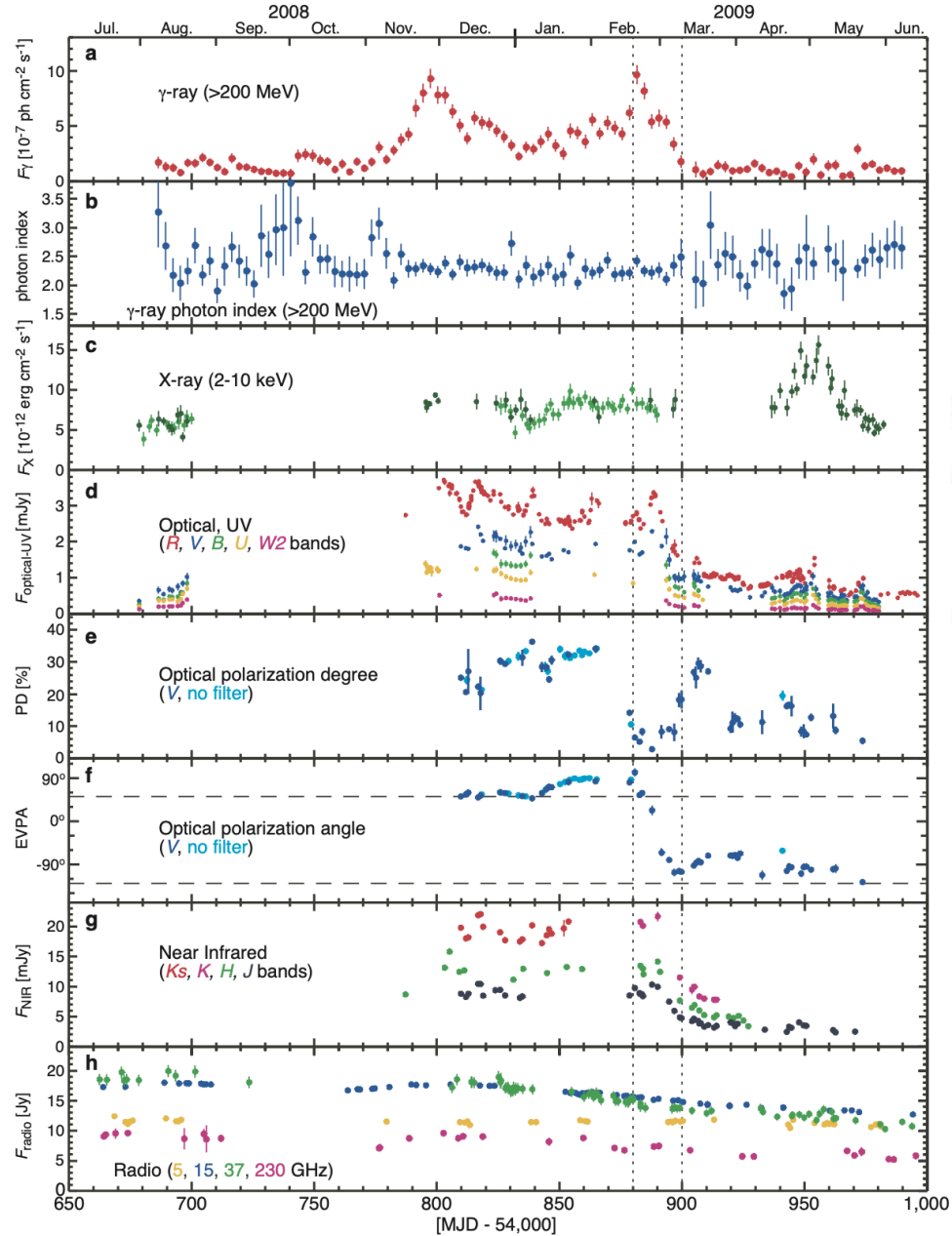
Need for two emission zones in 3C 279



Inner blob $\ll R_{\text{BLR}}$

Abdo et al. 2010

Need for two emission zones in 3C 279



Abdo et al. 2010

Inner blob $\ll R_{\text{BLR}}$

Far away blob $> R_{\text{BLR}}$

Conclusion/outlook

- One-zone models usually reproduce well blazar SEDs, but some sources at specific epochs indicate more complex scenarios
- Two-zone model applied to 3C 279 during periods of drastic MWL changes
+ Optical polarization - very preliminary!
- Search for similar behaviors in other sources of this class.
Two-zone interpretation?
- Origin of VHE γ -ray emission? One-zone lepto-hadronic models failed to reproduce the MWL behavior of the source (2015 flare, [H.E.S.S. Collaboration \(2019\)](#)).
- Time-dependent radiative modelling for the 2018 epochs – among the most extreme flares
- Constraints from radio jet kinematics + optical polarization – suggestions/ideas welcome!



Thank you!