CTA 102 – year over year receiving you

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The Variable Multi-Messenger Sky
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Introduction

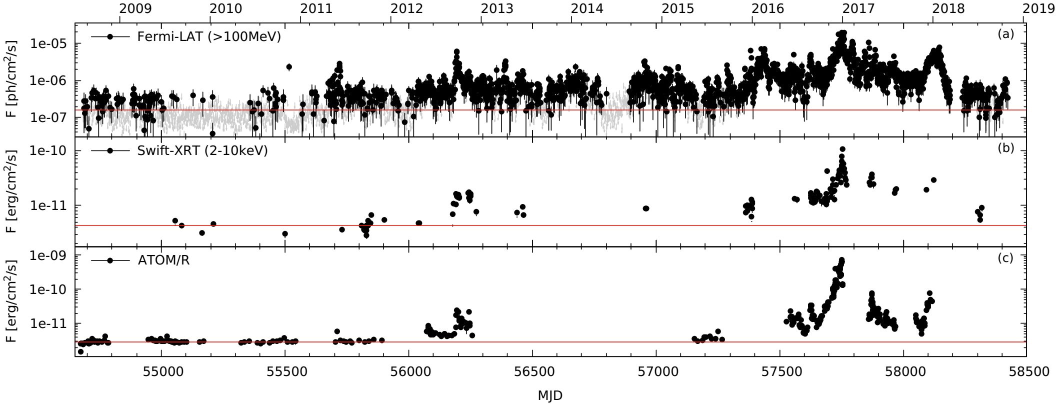


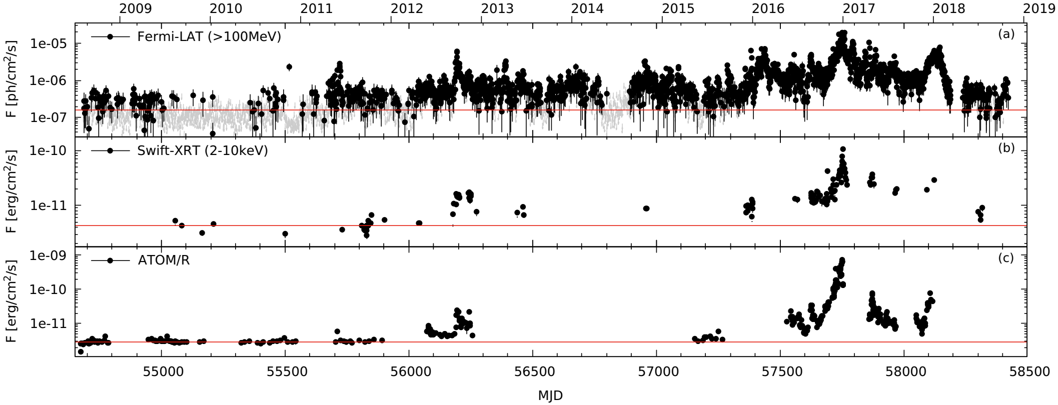
Figure 1: γ-ray, X-ray, and optical light curves of CTA 102 from 2009 to 2019 (logarithmic flux axis!) [Zacharias+19]

- CTA 102 is an FSRQ at $z = 1.032$
- One of the first observed quasars

- Underwent some dramatic changes in the first 10 years of Fermi operations

What caused these changes?

Introduction



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Disclaimer

This talk is about models focusing on the long-term changes. Therefore, lots of papers about the flare are not covered:

- Li et al., 2018, ApJ
- Shukla et al., 2018, ApJL
- Gasparyan et al., 2018, ApJ
- Kaur & Baliyan, 2018, A&A
- Prince et al., 2018, ApJ
- Sahakyan, 2020, A&A
- Chavushyan et al., 2020, ApJ
- Sarkar et al., 2020, A&A
- Kim et al., 2022, MNRAS
- Geng et al., 2022, ApJS
- Sahakyan et al., 2022, MNRAS
- . . .

Ablation of a gas cloud

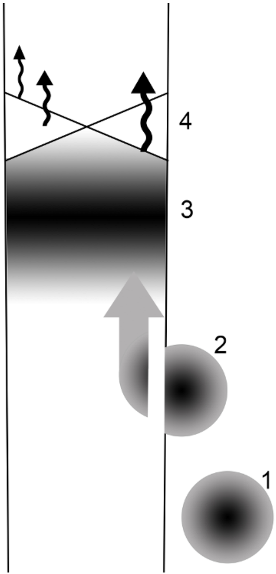


Figure 2: Cloud ablation process
[Heil&Zacharias20]

(1) Cloud approaches the jet
(2) Cloud material is gradually ablated
(3) Cloud material is incorporated in the jet flow leading to a specific density structure
(4) Particles are accelerated at a shock and radiate

Ablation of a gas cloud

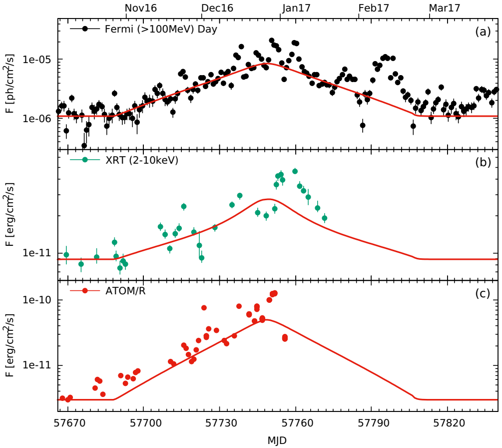
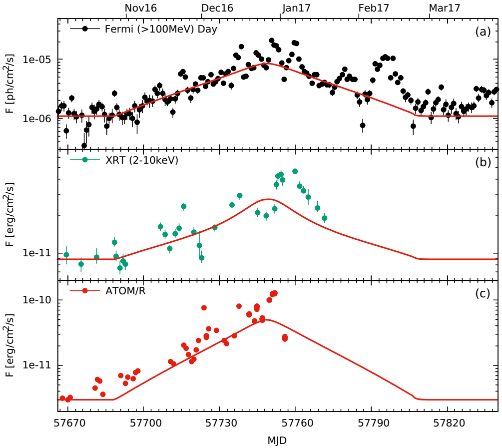


Figure 3: Leptonic model of the main flare reproducing γ-ray, X-ray, and optical light curves [Zacharias+17]

- Model reproduces well the months-long evolution of the main flare
- Cloud parameters:
  - Radius: 1.3×10^{15} cm
  - Mass: $> 3.9 \times 10^{30}$ g
  - Temperature: $> 0.5\,$K
- Values are lower limits due to the messy nature of the ablation process
- Nature of the cloud remains open

Ablation of a gas cloud



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Twisting inhomogeneous jet

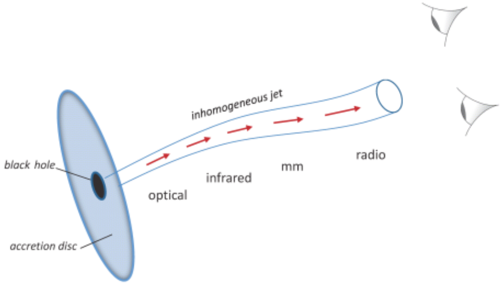


Figure 4: Viewing angles to emitting regions in a twisted jet
[Raiteri+17]

- Due to cooling, expansion, etc., the main contribution of the various energy bands may originate at different locations in the jet
- Twists and turns of jets will move various regions of the jet towards the line-of-sight
- Varying Doppler factor enhances the variability

Twisting inhomogeneous jet

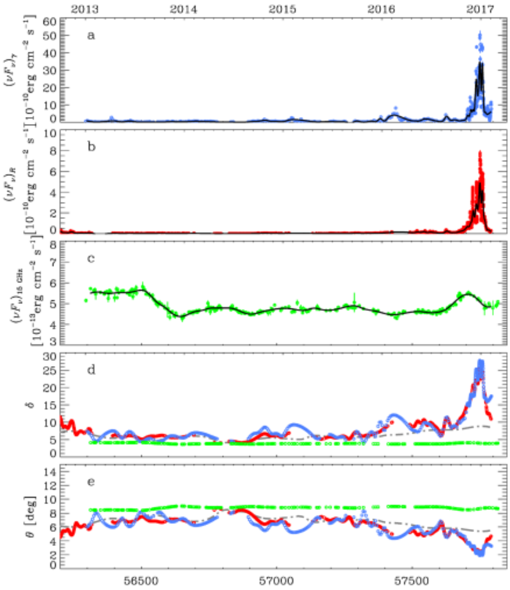
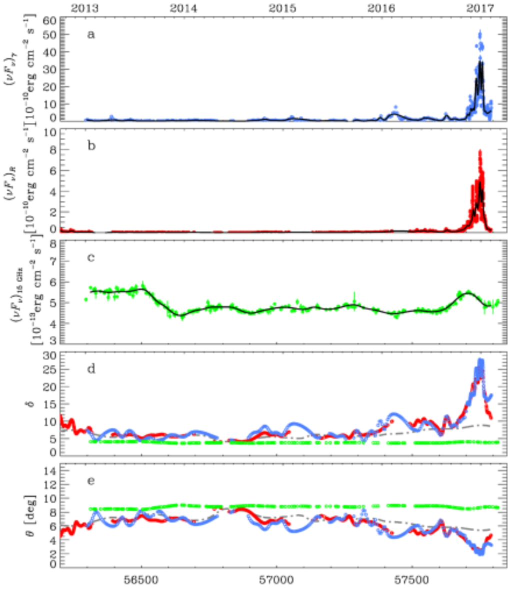


Figure 5: γ-ray, optical, and radio light curves; model Doppler factor, and viewing angle [d'Ammando+19]

- Flux variation only through wobbling of the jet
- γ-ray and optical light curves co-spatial (same Doppler factor and angle)
- γ-ray and optical Doppler factor within reasonable range
- Radio region is downstream with much less variations

- Cause of wobbling remains open

Twisting inhomogeneous jet



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The radio knot

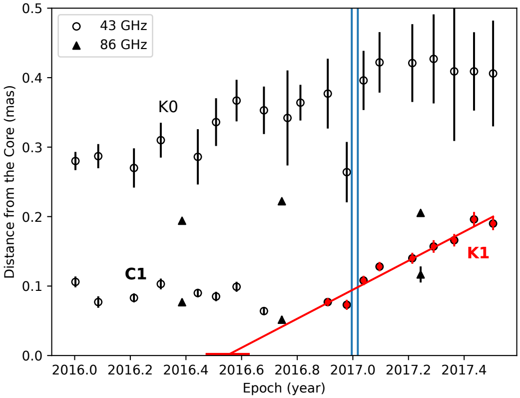
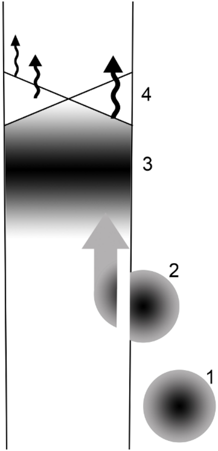
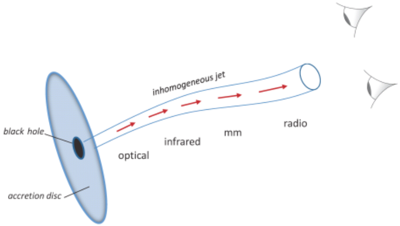


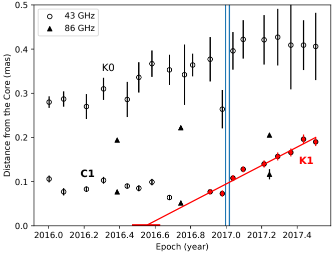
Figure 6: Distance versus time for various radio components; vertical lines mark the giant flare [Casadio+19]

- The radio knot K1 passed through a stading radio feature (C1) around the time of the flare
- K1 has $\beta_{\rm app} \sim$ 11c, Doppler factor $\sim$ 34, and viewing angle $\theta \sim$ 0.9°

So, what happened?







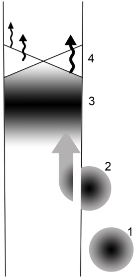
Let’s speculate. . .

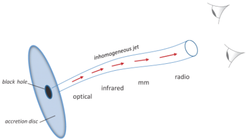
- A cloud approached the jet
- The intrusion injected some material into the jet and pushed the jet to the side
- The overdensity created the radio knot
- Its interaction with C1 and the wobbling of the jet caused the long-lasting flare

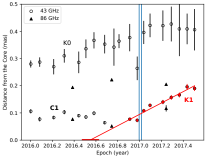
Read all about it

All details are given in

- Zacharias et al., 2017, ApJ
- Raiteri et al., 2017, Nature
- Casadio et al., 2019, A&A
- Zacharias et al., 2019, ApJ
- D’Ammando et al., 2019, MNRAS
- Heil & Zacharias, 2020, A&A







Thank you for your attention!