The Extraordinary Flare of CTA 102 in 2016 - 2017

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Based on Zacharias, M., et al., 2017, ApJ, 851, 72

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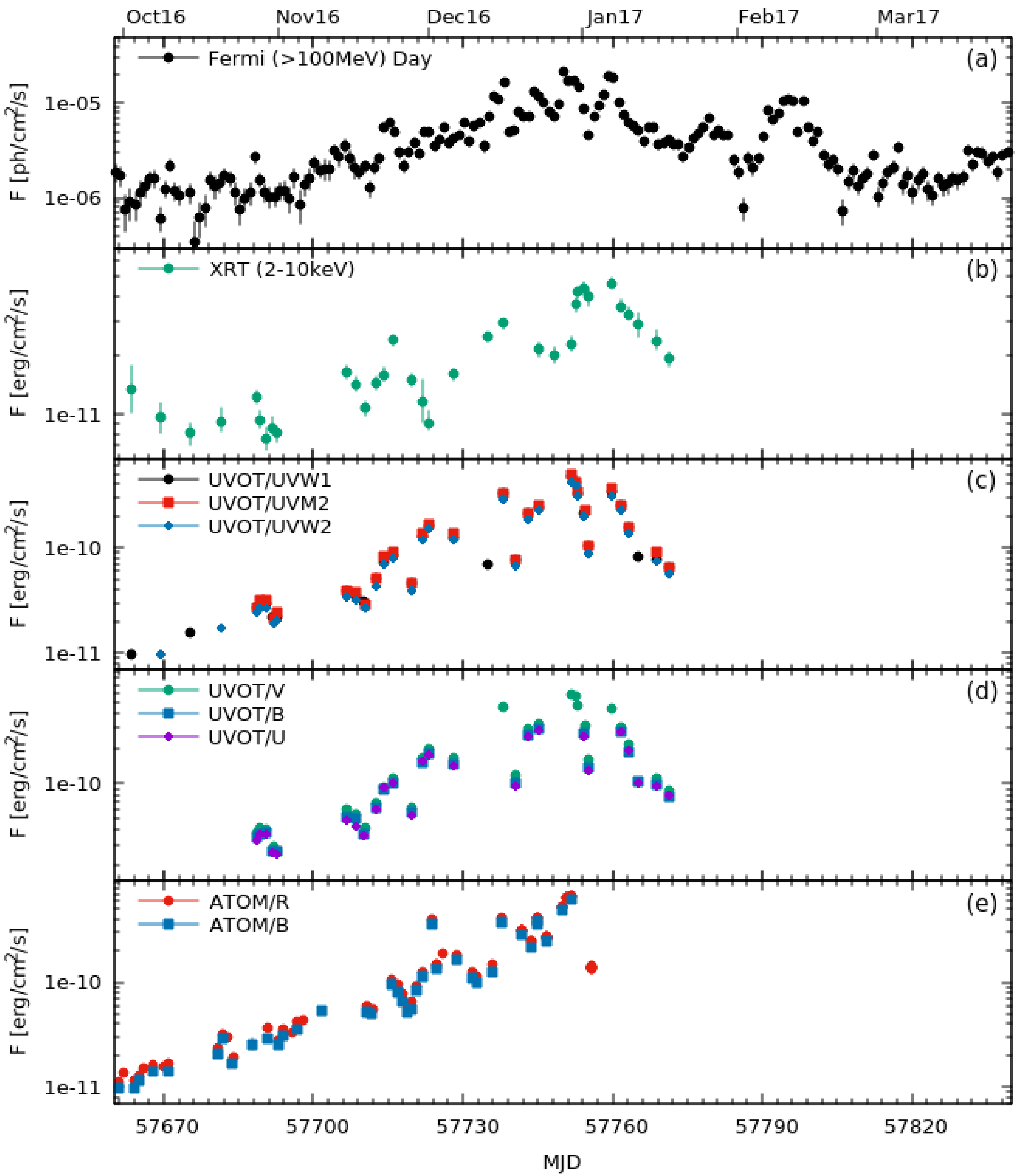
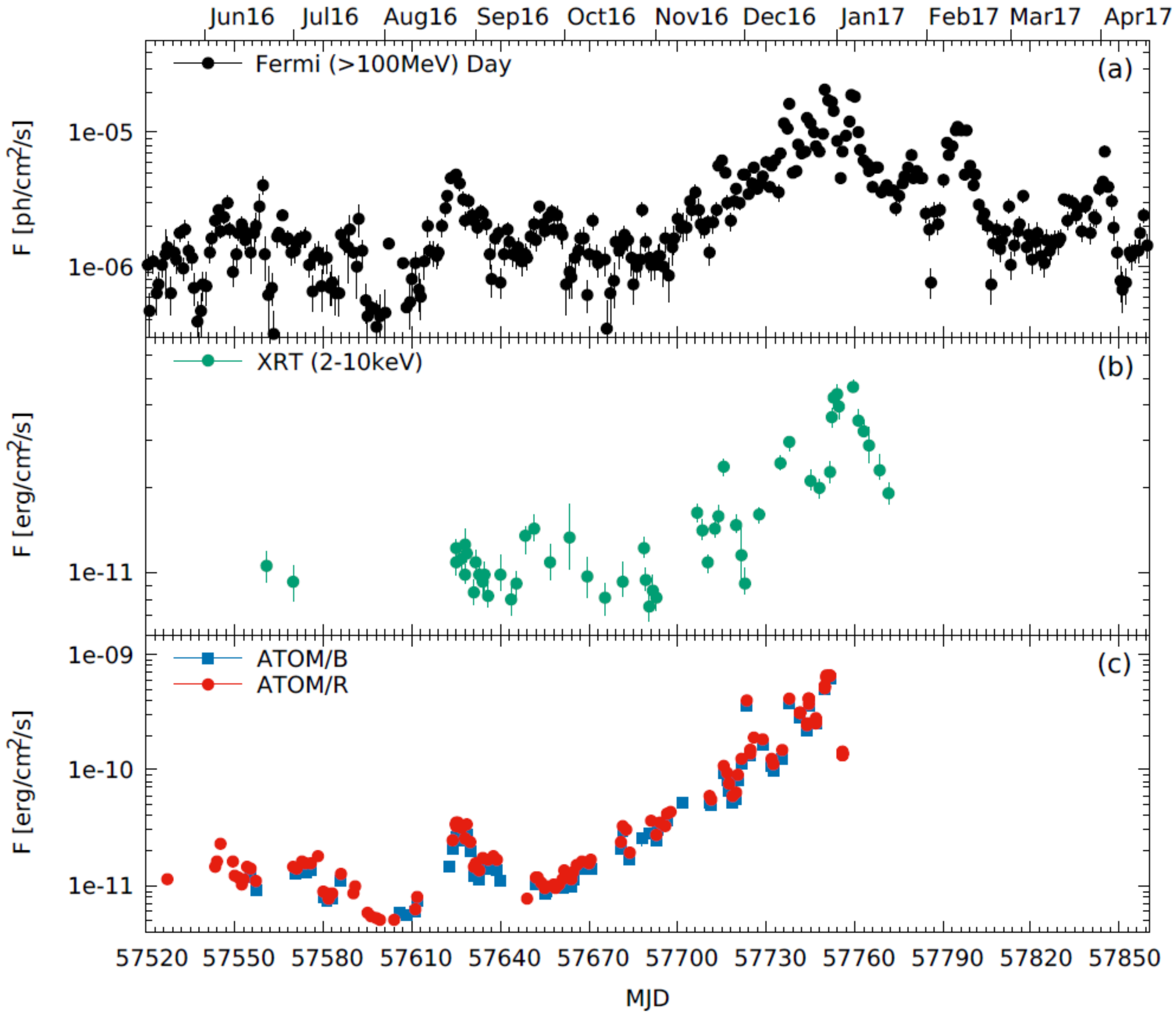
CTA 102

- Gamma-ray Loud FSRQ at z = 1.036
- Long-term flare (~ 4 months) in 2016 – 2017
- Almost symmetrical time profile
- Short-term fluctuations overlaid on top of long-term trend.



The Flare of 2016 - 2017

- Optical flux rose by factor of ~ 100
- Fermi γ-ray flux rose by factor of ~ 50
- Rise / decay time scales of > 20 months clearly longer than microphysical time scales.
- Cause of the long-term flare? - Likely external to the jet.
- Suggestion: Jet interaction with a gas cloud

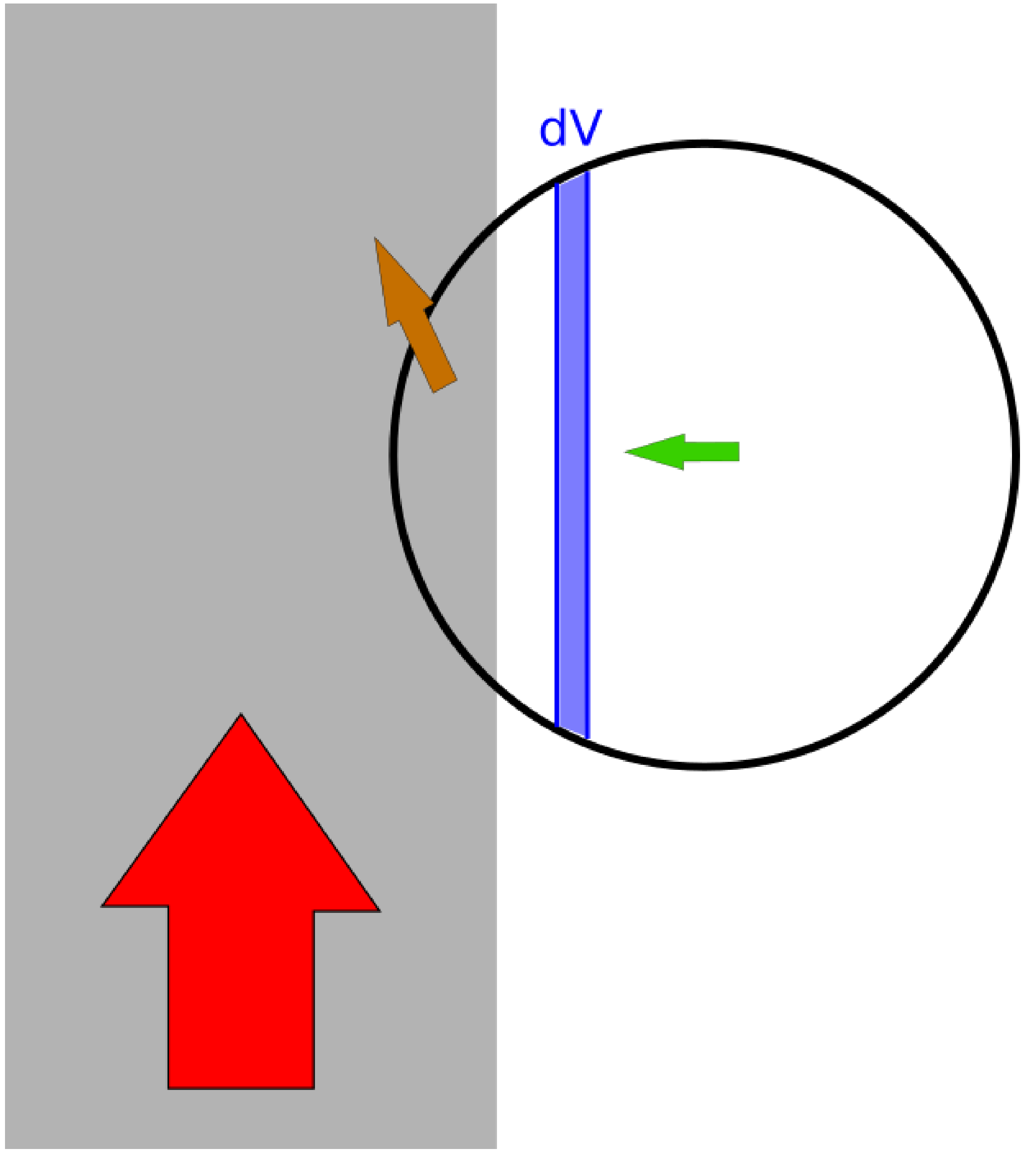


Ablation of a Gas Cloud by the Jet

- Gas cloud (BLR?) traversing the jet trajectory

- Ablation of the cloud
  -> Increased injection of relativistic particles into the jet

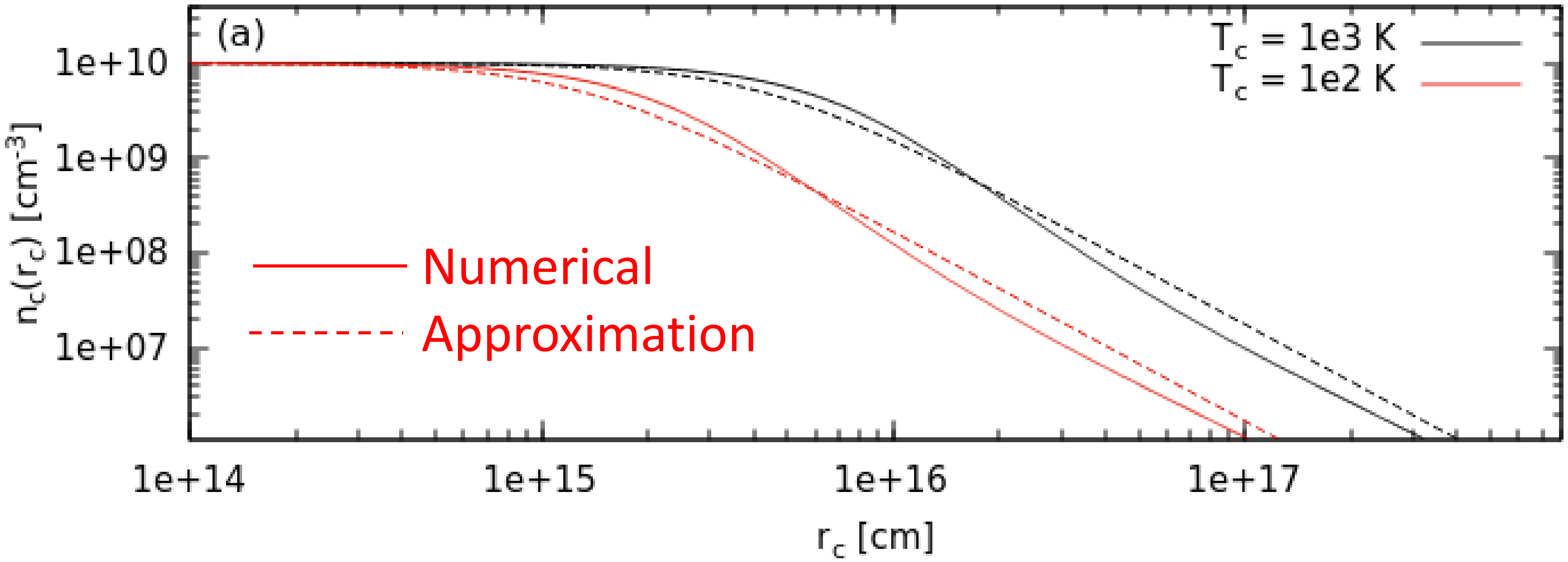
- Assume isothermal gas cloud in hydrostatic equilibrium



Cloud Density Profile

- Isothermal hydrostatic equilibrium profile approximated by

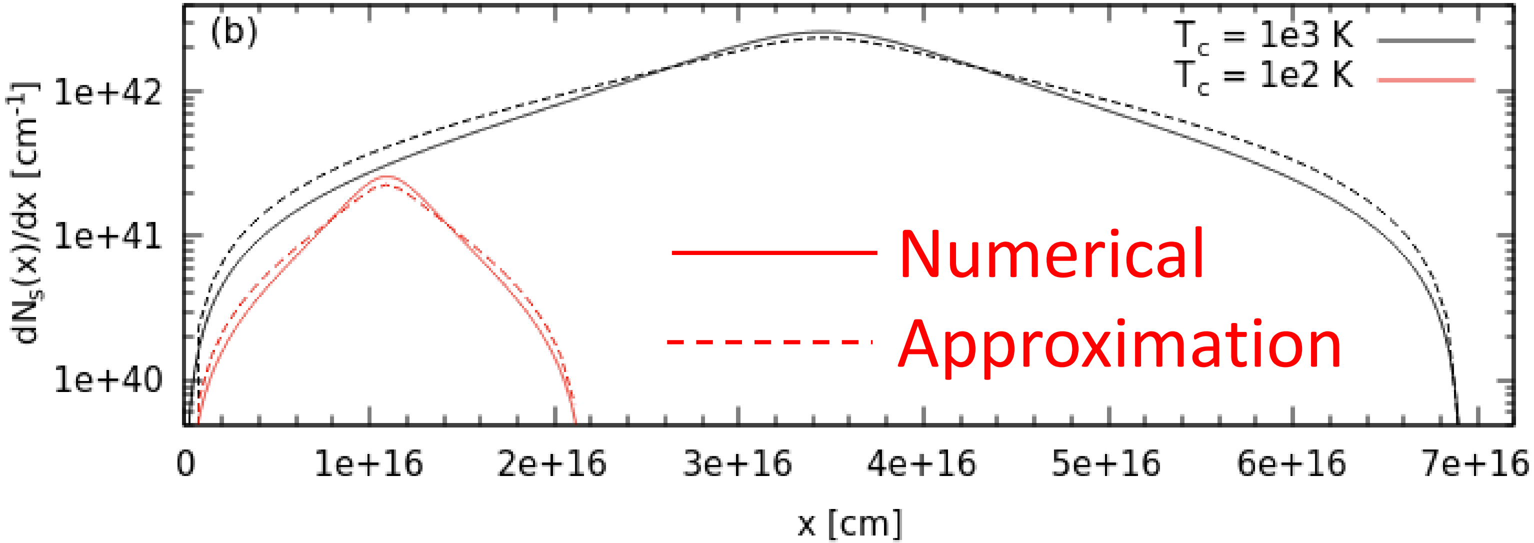
$$n_c(r) = \frac{n_0}{1+\left(\frac{r}{r_0}\right)^2} \qquad r_0 = \left(\frac{3k_B T}{4\pi\, m_p^{\,2}\, G\, n_0}\right)^{1/2}$$

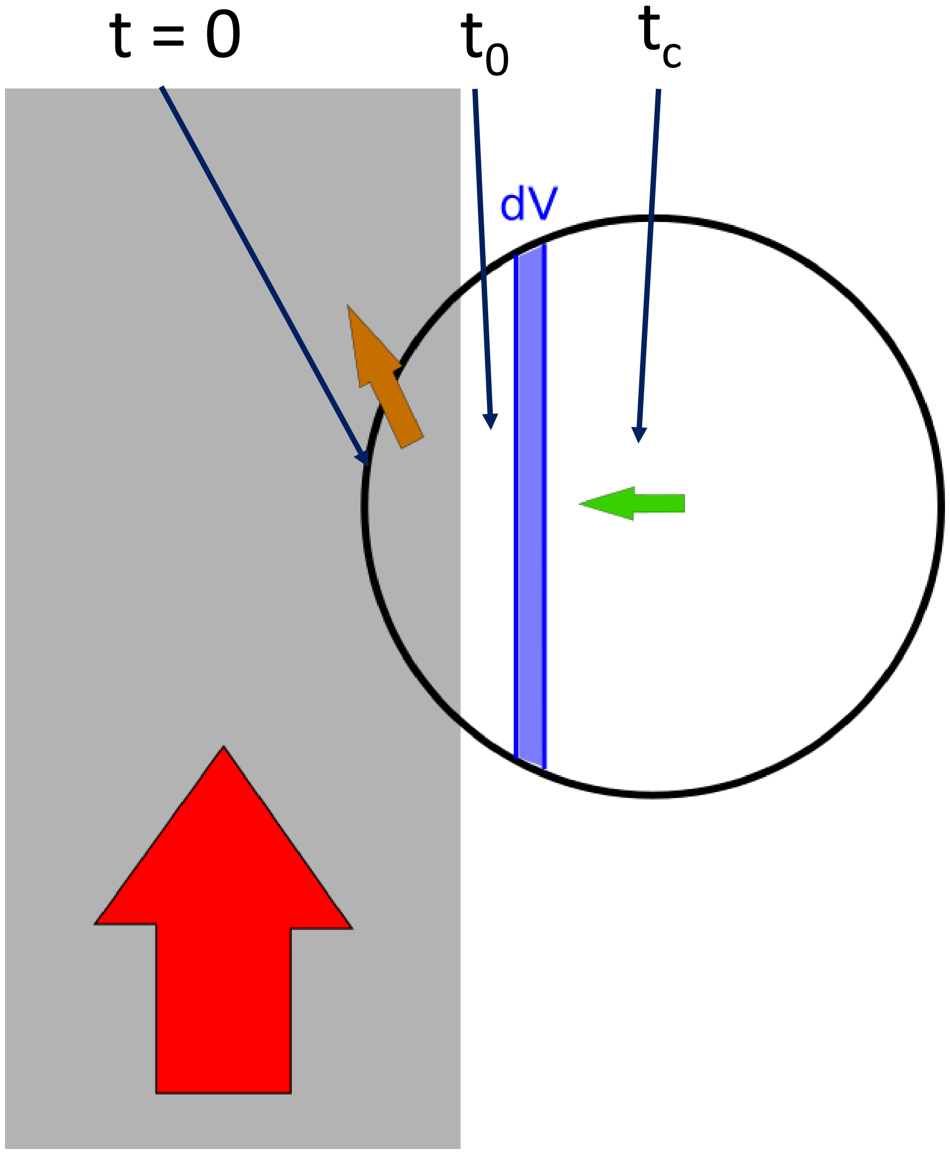


Particle Injection Profile

- Assume Keplerian motion (const. speed) of the cloud around the BH
- Density profile approximation yields injection profile

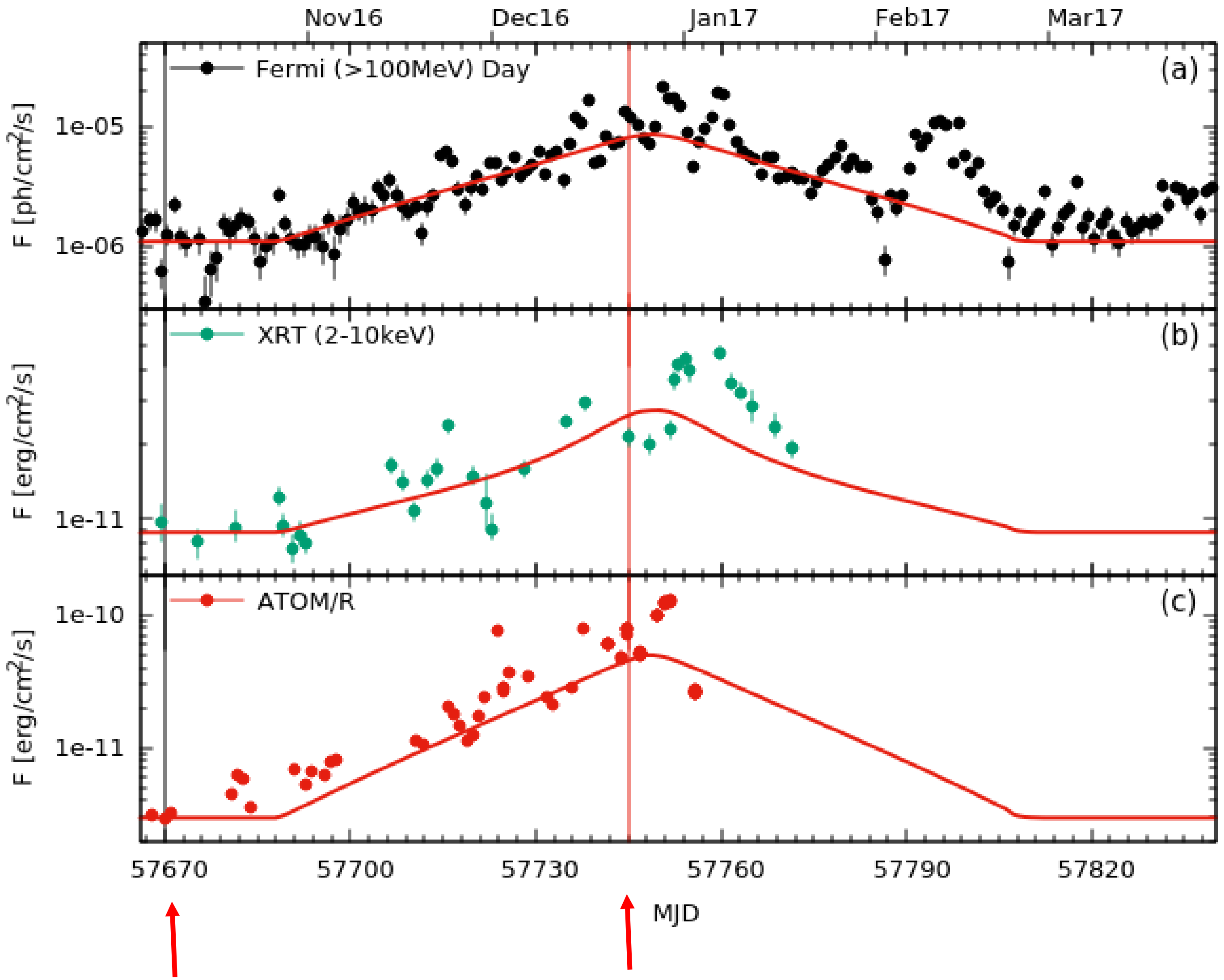
$$Q(t) = Q_0 \ln\left(\frac{t_0{}^2 + t_c{}^2}{t_0{}^2 + (t_c - t)^2}\right)$$





Fits to MWL Light Curves

- One-zone leptonic EIC (BLR) model of Diltz & Böttcher (2014)
- Injection profile modifies electron injection power + spectral index
- Cloud parameters:
  - $r_0 = 1.6\times10^{14}$ cm
  - $v_c = 5.1\times10^{8}$ cm/s
  - $n_0 = 2.5\times10^{8}$ cm^{-3}

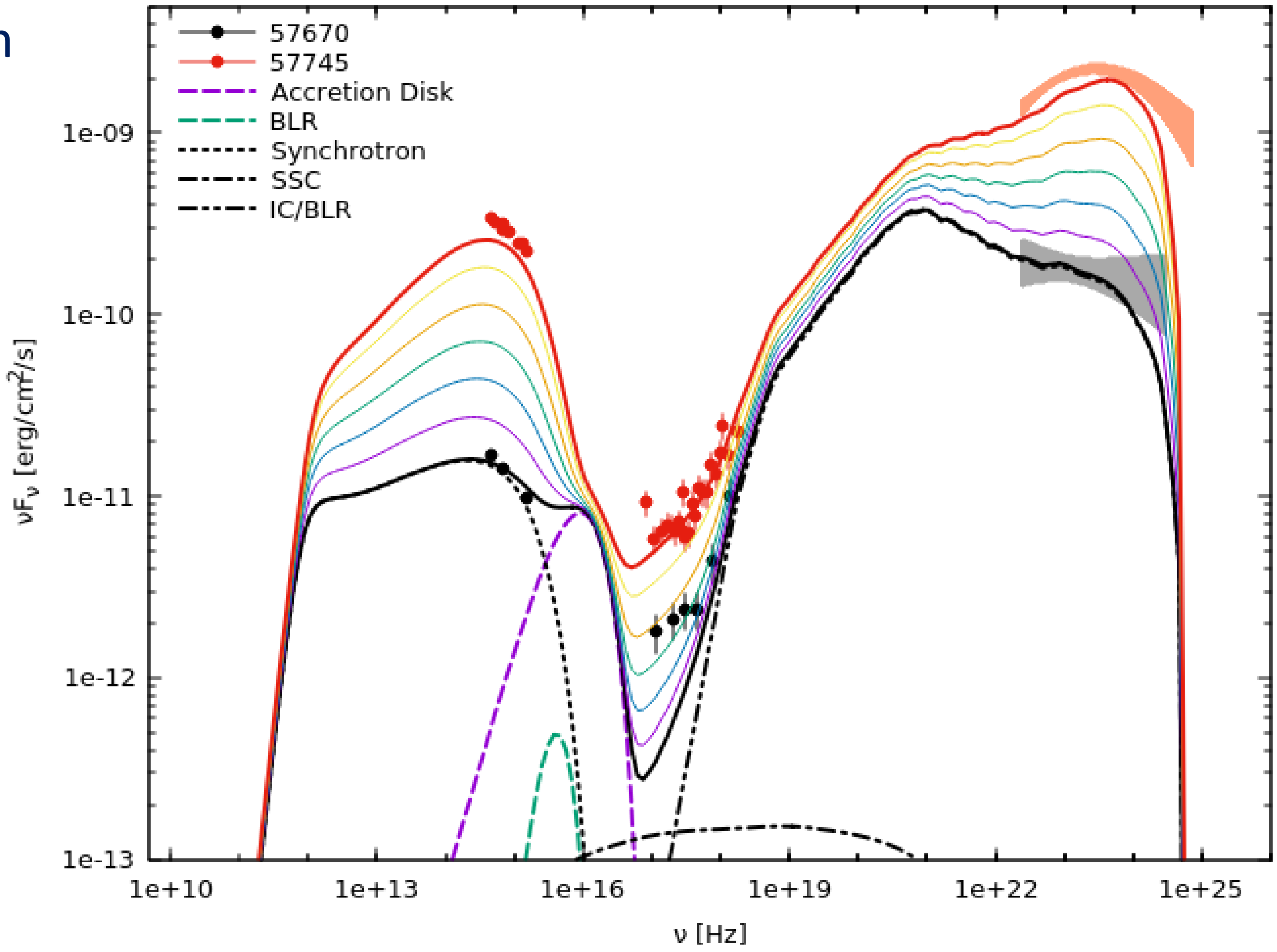


Snap-shot SEDs extracted: Quiescent Flare

Fits to Snap-Shot SEDs

Parameters:

- Doppler factor $\delta = 35$
- Distance from BH: $d_{em} = 6.5\times10^{17}$ cm
- $R_{em} = 2.5\times10^{16}$ cm
- B = 3.7 G
- Electron Injection Luminosity
  $L_{inj,e,qu} = 2.2\times10^{43}$ erg/s
  $L_{inj,e,max} = 3.95\times10^{43}$ erg/s
- Electron Injection Spectral Index:
  $s_{qu} = 2.4$
  $s_{max} = 1.8$
- Electron Injection $\gamma_{min} = 13$
- Electron Injection $\gamma_{max} = 3.0\times10^3$



Origin of the Cloud

- Cloud parameters:
  - $r_0 = 1.6 \times 10^{14}$ cm
  - $v_c = 5.1 \times 10^{8}$ cm/s
  - $n_0 = 2.5 \times 10^{8}$ cm^{-3}
  - $d_{BH} = 6.5 \times 10^{17}$ cm

$$r_0 = \left(\frac{3 k_B T}{4\pi \, m_p{}^2 \, G \, n_0} \right)^{1/2} \quad \Rightarrow \quad T_c \approx 0.5 \text{ K}$$

⇒ Density must be much higher to allow for typical BLR temperatures.

⇒ Only part of the cloud actually enters the jet.

⇒Jet "shielded" by B-field?

Summary / Discussion

- 4-month-long flare of CTA is successfully fited by cloud-jet interaction
- Cloud at typical BLR distances, but density of material actually entering the jet too low to allow for reasonable BLR cloud parameters
- Jet probably “shielded” by B-field
- Short-term variations plausibly due to density inhomogeneities in the cloud
- Ongoing work: Including hadronic processes: Seems also able to fit long-term trend -> Stay tuned.

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