Modeling the SED and variability of 3C66A in 2003 -2004

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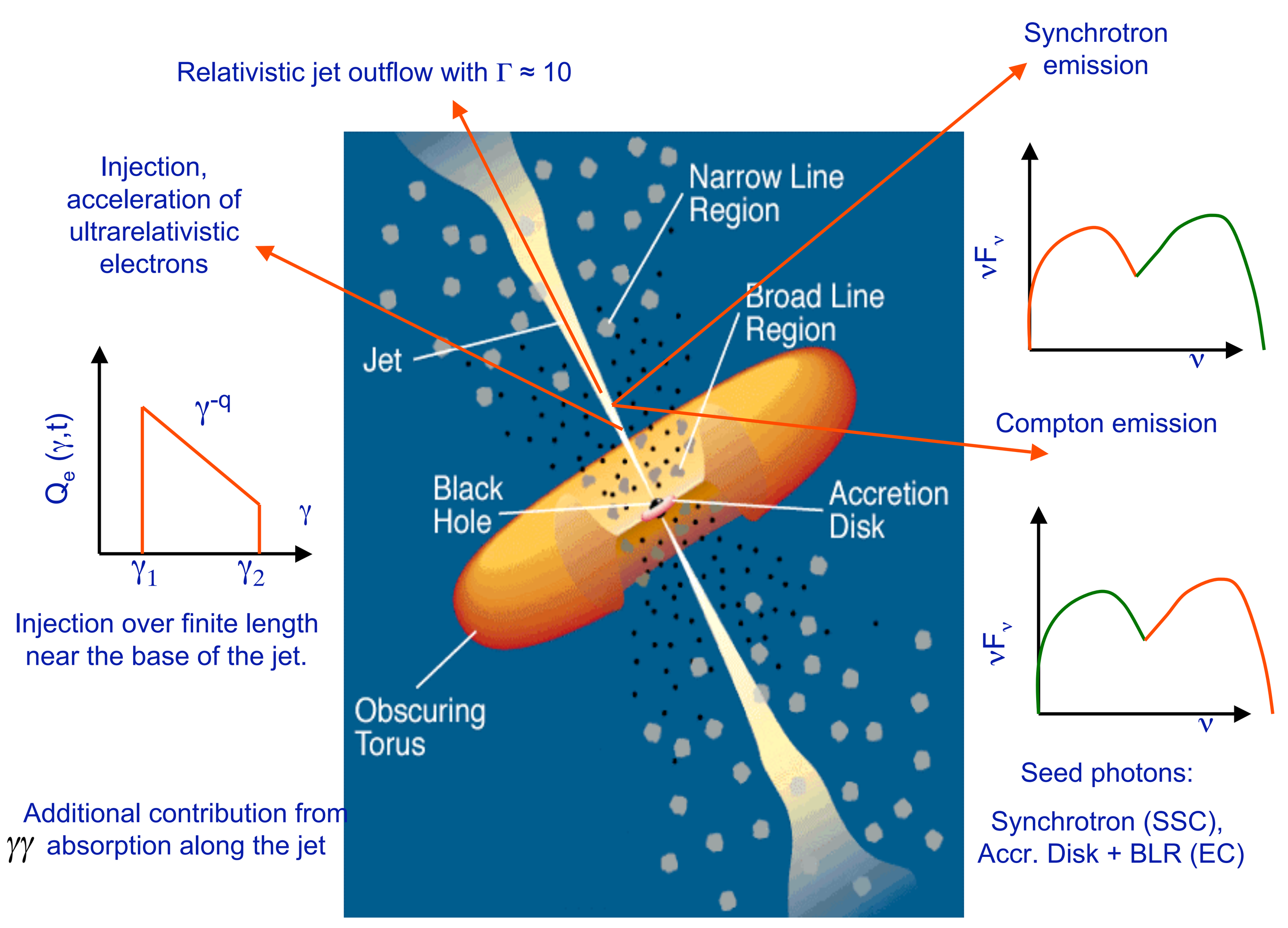
Abstract: An extensive multi-wavelength campaign was organized from July 2003 till April 2004 to monitor the BL Lac object 3C66A. The spectral energy distribution (SED) of 3C66A was measured over the entire electromagnetic spectrum with flux measurements taken from radio to X-ray frequencies. Upper limits in the very high energy (VHE) γ-ray were also obtained. Here, we discuss the modeling of the SED and the observed optical spectral variability pattern of 3C66A using a time-dependent leptonic jet model and make predictions regarding the possibility of an observable X-ray spectral variability pattern and VHE γ-ray emission.

Motivation: 3C66A suggested to be a promising candidate for detection by H.E.S.S, MAGIC, or VERITAS. It has been studied in radio, IR, optical, X-rays and γ-rays in the past but multi-wavelength SED and correlated broadband spectral variability have not been completely understood. This led to the organization of an intensive multi-wavelength campaign from July 2003-April 2004.



Schematic of an AGN model.
Credit: C. M. Urry and P. Padovani

Table 1: Model Parameters used to reproduce the quiescent and flaring state of 3C66A as shown in Figure 1.

Fit	L_{inj} [10^{41} ergs/s]	γ_1 [10^3]	γ_2 [10^4]	p	Profile	e_B	B [G]	Γ	R_b [10^{15} cm]	θ_{obs} [deg]
1	2.7	1.8	3.0	3.1	———	1	2.4	24	3.59	2.4
2	8.0	2.1	4.5	2.4	Gaussian	1	2.8	24	3.59	2.4

Note: L_{inj}: luminosity of the injected electron population in the blob, $\gamma_{1,2}$: low- and high-energy cutoffs of electron injection spectrum, p: particle spectral index, Profile: flare profile used to simulate the optical variability pattern, e_B: equipartition parameter, B: equipartition value of the magnetic field, Γ: bulk Lorentz factor, R_b: comoving radius and θ_{obs}: viewing angle.

Results:

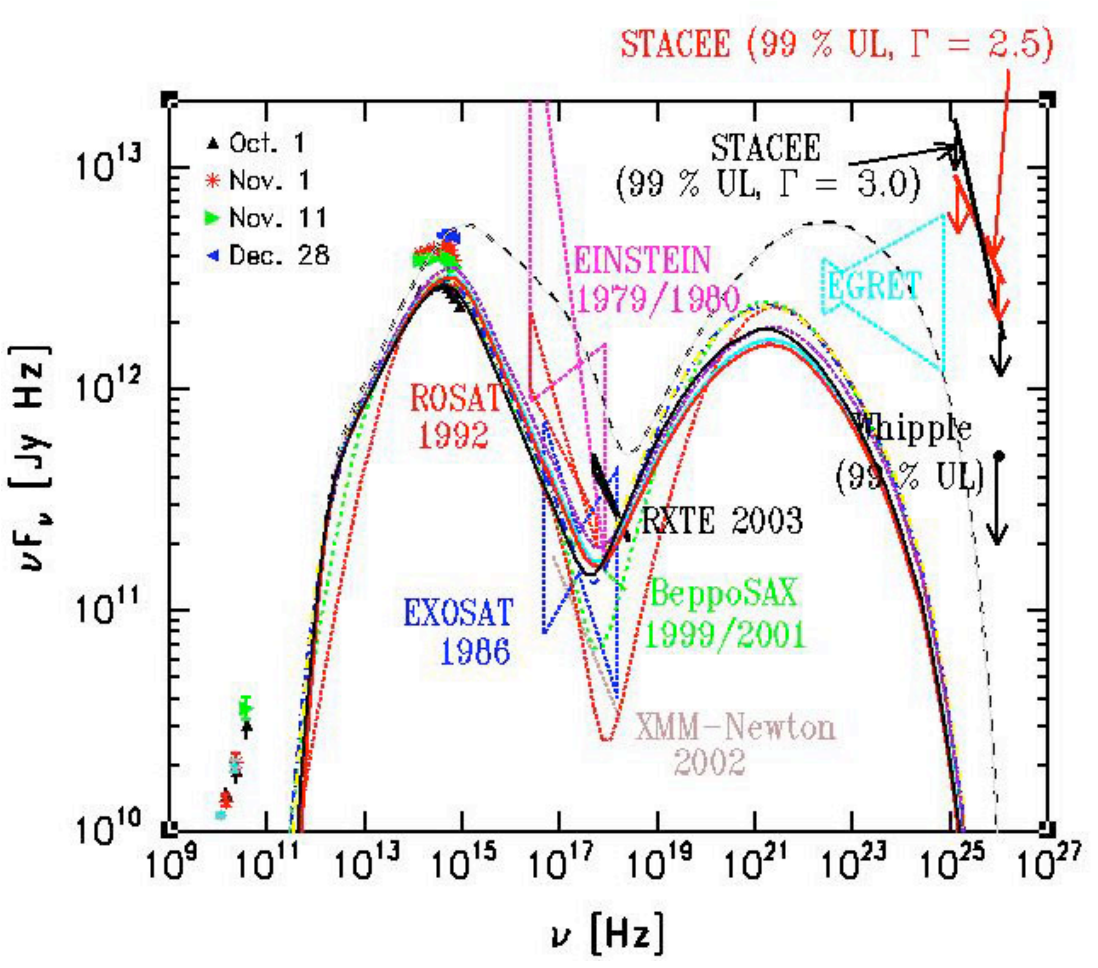


Fig. 1: Simulation of the quiescent state of 3C66A observed around Oct. 1st 2003 and the flaring state for a generic 10 day flare corresponding to the timescale of several major outbursts observed in the optical regime. Black solid line indicates the quiescent state. Synchrotron component peaks at ~10^{14} Hz and SSC component peaks at ~10^{21} Hz. Rest of the curves are the instantaneous spectra in the flaring state at several different times in the observer's frame. Synchrotron component peaks at ~10^{15} Hz and SSC component peaks at ~10^{22} Hz.

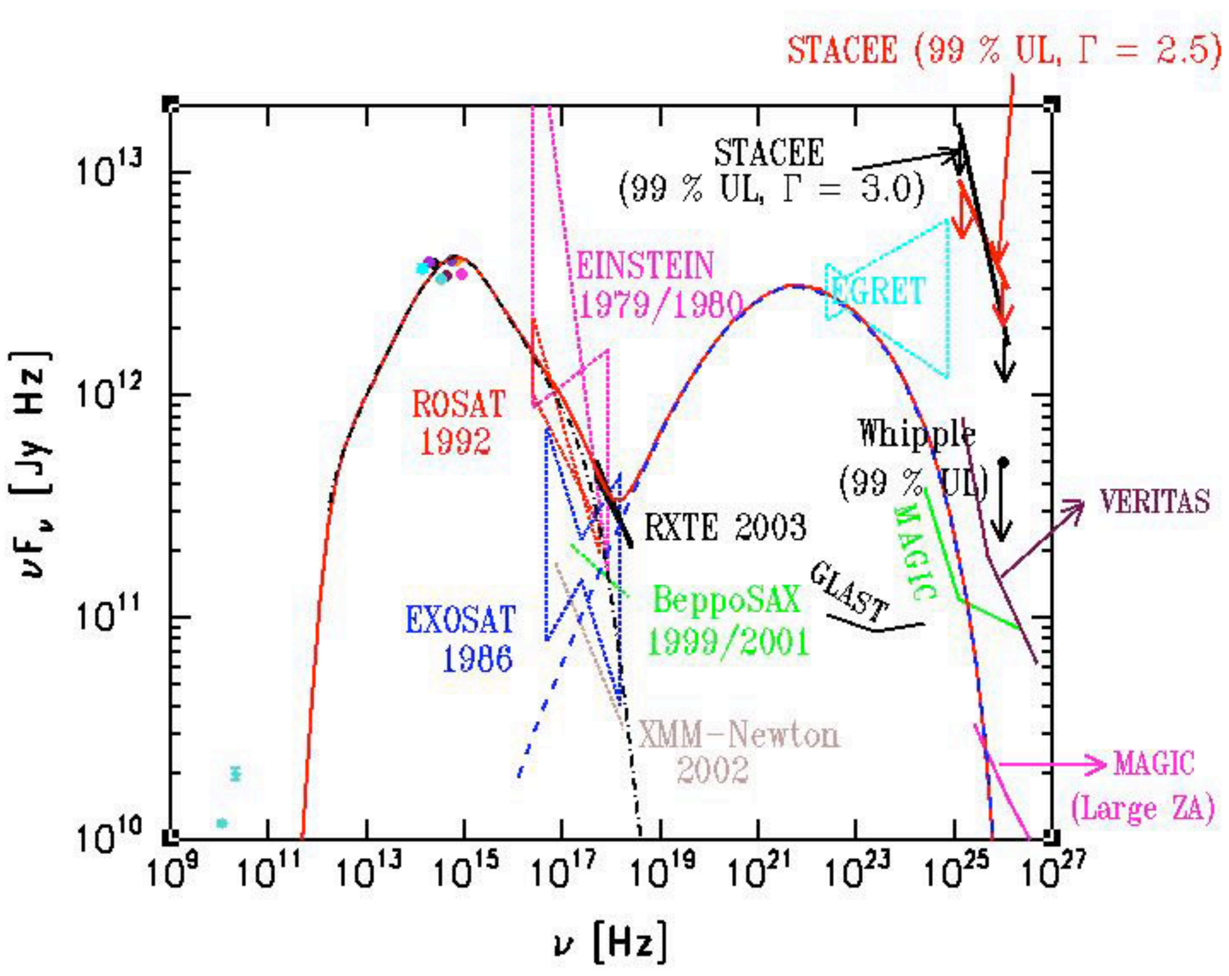


Fig. 2: Time-averaged SED of 3C66A around a flare as shown in Figure 1. Filled colored circles are time-averaged optical and IR data points for the entire campaign period. "RXTE 2003" denotes the time-averaged X-ray data points. Dot-dashed black line and long-dashed blue line denotes the synchrotron and SSC components. Black line indicates sensitivity limit for GLAST (1 month observation time) and green, maroon and magenta lines indicate that for MAGIC, VERITAS and MAGIC (Large ZA) (50 hours).

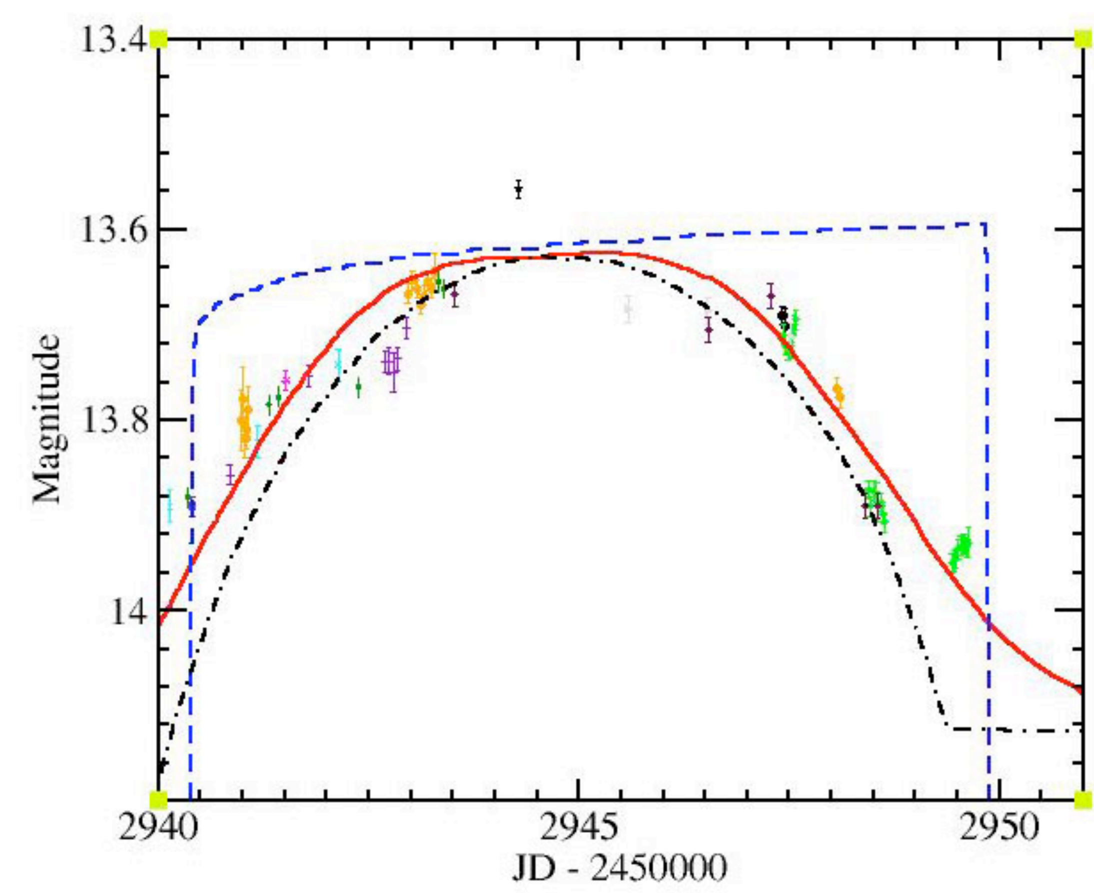
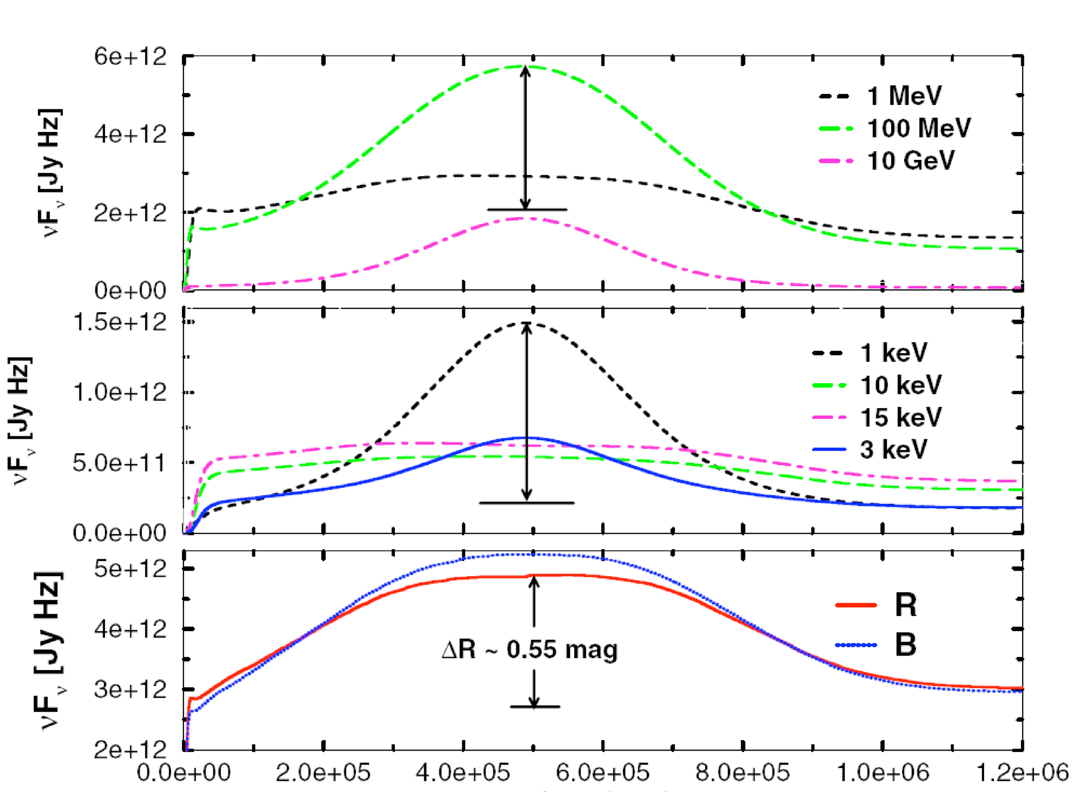


Fig. 3: Simulated light curves for various flaring profiles superimposed on the observed R-band light curve for an outburst on ~November 1st 2003. Solid red line shows a flaring profile Gaussian in time as used for the flare in Figure 1, dot-dashed black line is a triangular flaring profile and dashed blue line is top-hat in time. Gaussian flaring profile closely matches the width as well as the profile of the observed flare.

Fig. 4: Simulated light curves for optical, X-rays and γ-ray energy regimes. Simulated variability in R band is ~0.55 mag. B band has a higher variability of ~0.7 magnitude, consistent with our observations. Simulated light curve at 1 keV exhibits an amplitude variation of ~10^{12} Jy Hz. The 3, 10 & 15 keV light curves do not exhibit much variability. In the VHE regime, 100 MeV light curve exhibits an amplitude variation of ~10^{12} Jy Hz.



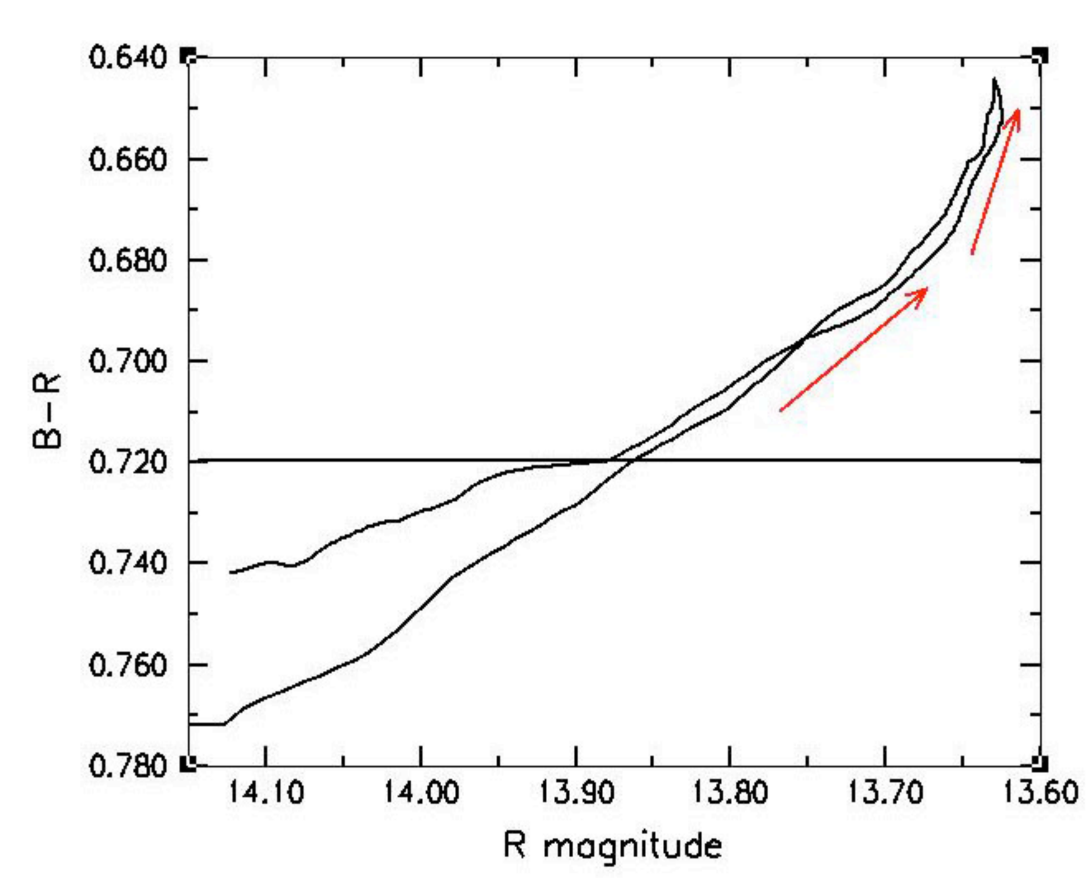


Fig. 5: Simulated hardness-intensity diagram indicating a positive correlation between R- and B- band for an outburst lasting for ~10 days. The object becomes brighter in R and harder in B-R as indicated by the arrows. The spectral upturn takes place at B-R ~0.72 magnitude where the flux in B equals that in R (corresponding to α_{BR} = 0).

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