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

Presented

By

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Outline

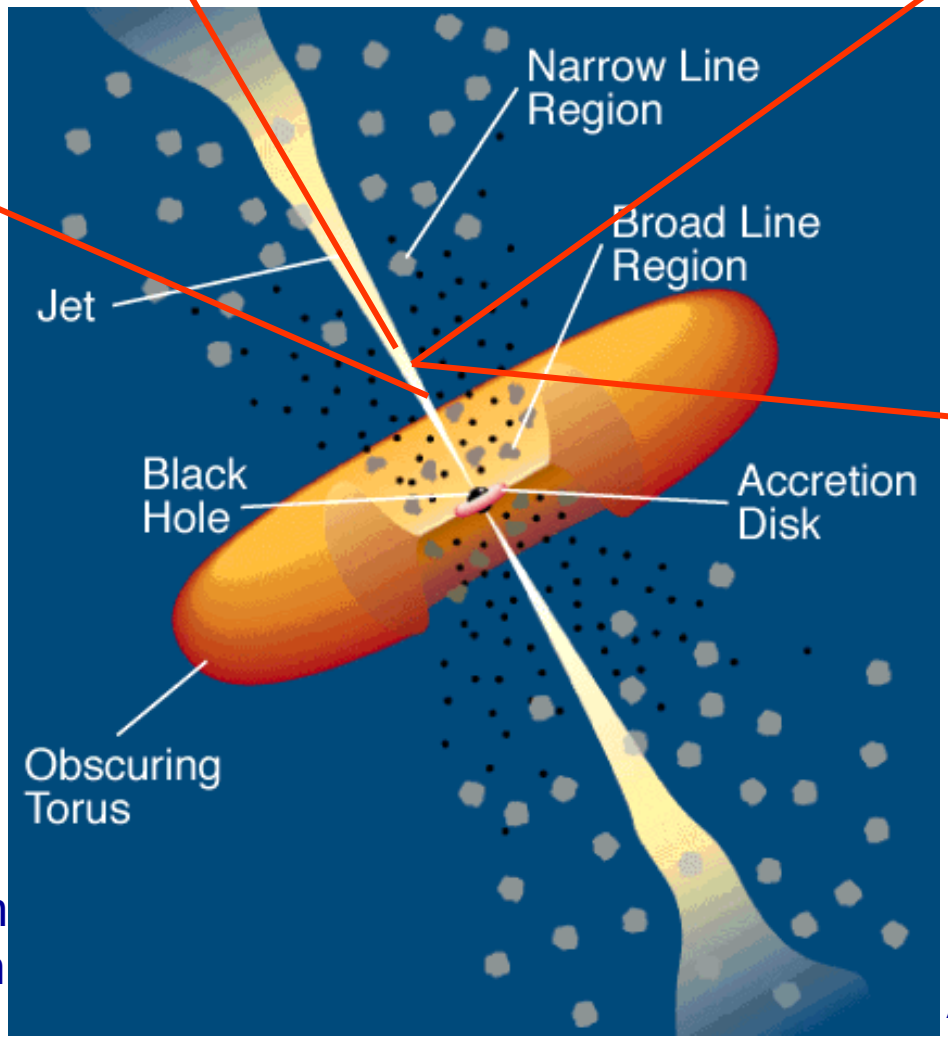
- Model Sketch
- Observational Constraints
- Parameter Estimates
- Motivation of Parameters
- Work In Progress

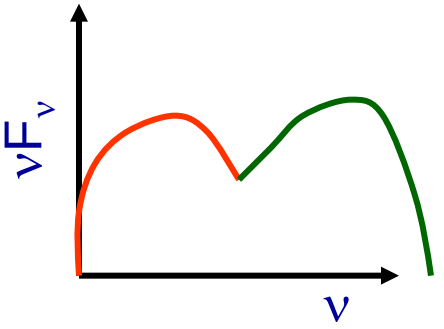
Blazar Modeling

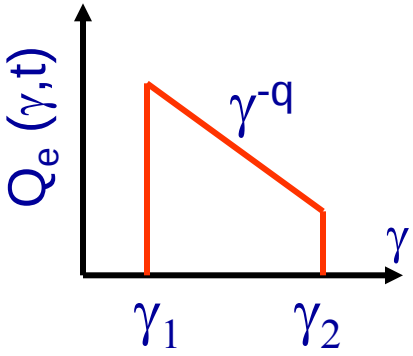
Relativistic jet outflow with $\Gamma \approx 10$

Synchrotron emission

Injection, acceleration of ultrarelativistic electrons

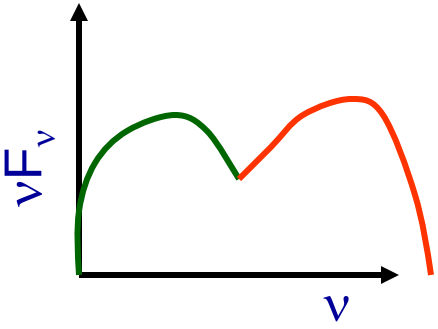






Injection over finite length near the base of the jet.

Compton emission



Seed photons:

Synchrotron (SSC), Accr. Disk + BLR (EC)

Additional contribution from $\gamma\gamma$ absorption along the jet

- One-zone homogenous, time-dependent leptonic model considered.
- Particle distribution and spectrum of emitted radiation calculated self-consistently.
- Instantaneous and time-integrated spectra calculated for various sets of parameters.

Basic assumptions:

1. Emitting region as a sphere of constant co-moving radius R_B.

2. Homogenous and tangled magnetic field B.

3. Ultra-relativistic non-thermal e^-s injected at a time-dependent rate into the blob.

- Solve simultaneously for evolution of electron distribution,

$$\frac{\partial n_e(\gamma,t)}{\partial t} = -\frac{\partial}{\partial \gamma}\left(\dot{\gamma} n_e\right) + Q_e(\gamma,t) - \frac{n_e(\gamma,t)}{t_{esc,e}}$$

e^- density | Rad. + Adiab. losses | el./pair inj. | escape

and co-moving photon distribution,

$$\frac{\partial n_{ph}(\varepsilon,t)}{\partial t} = \dot{n}_{ph,em}(\varepsilon,t) - \dot{n}_{ph,abs}(\varepsilon,t) - \frac{n_{ph}(\varepsilon,t)}{t_{esc,ph}}$$

Photon density | Sy., comp. emission | SSA, γγ absorption | escape

- Synchrotron self absorption calculated self-consistently.
- Pair production negligible for present choice of parameters.
- For SSC, isotropic (co-moving frame) radiation field assumed.
- EIC component not considered yet.

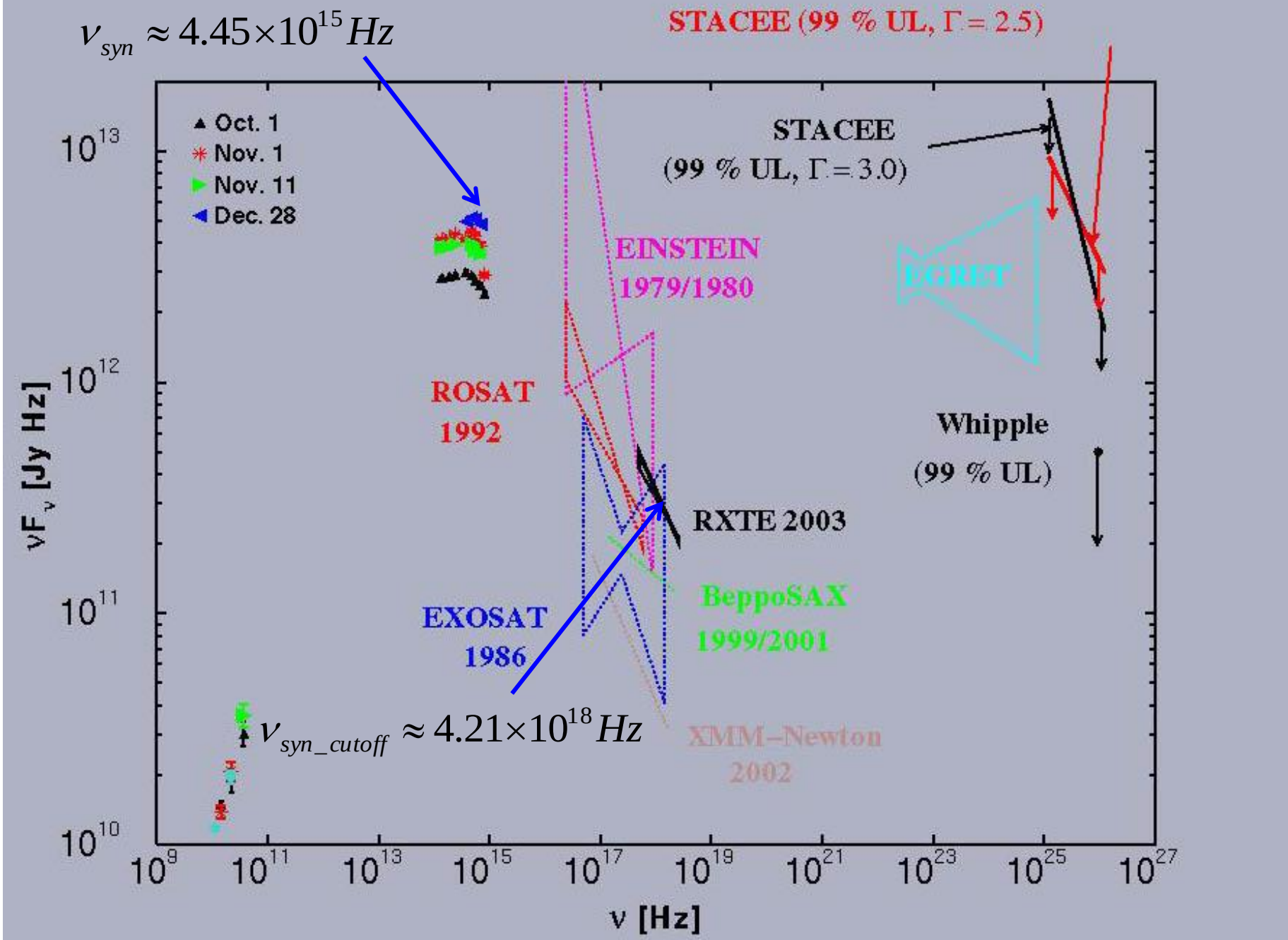
Modeling Strategy

- Code of Boettcher & Chiang (2002) used.

1. Reproduce broadband spectrum of 3C66A for equilibrium situation (quiescent state).

2. Adjust parameters to fit both (time-averaged) SEDs and optical spectral variability patterns.

Spectral Energy Distribution



Observational Constraints

- SL motion up to $\beta_{app} \sim 9 \Rightarrow \Gamma \geq 9$
- Optical variability, $\Delta t_{\min} \sim 2$ hr, $R_B \leq 2.2 \times 10^{15} D_1$ cm
- Doppler Factor, $\Gamma = D = 10 D_1 \sim 15$
- Peak synchrotron flux $f_{\varepsilon}^{sy} \sim 5 \times 10^{-11}$ ergs cm^{-2} s^{-1}

Analytical Parameter Estimates

- $D_1 \approx 1.5$ and $e_B = 1$
- Magnetic field, $B_{e_B} = 4.4 D_1^{-1} e_B^{2/7}$ G
- Electron Lorentz Factor,

$$\gamma \approx 3.1 \times 10^3 \nu_{15}^{1/2} \left(\frac{D}{15} \right)^{-1/2} \left(\frac{B}{2.9G} \right)^{-1/2}$$

synchrotron peak, $\gamma_1 \approx 3.1 \times 10^3$

synchrotron high-energy cutoff , $\gamma_2 \geq 1.5 \times 10^5$

- Synchrotron cooling time scale in observer's frame

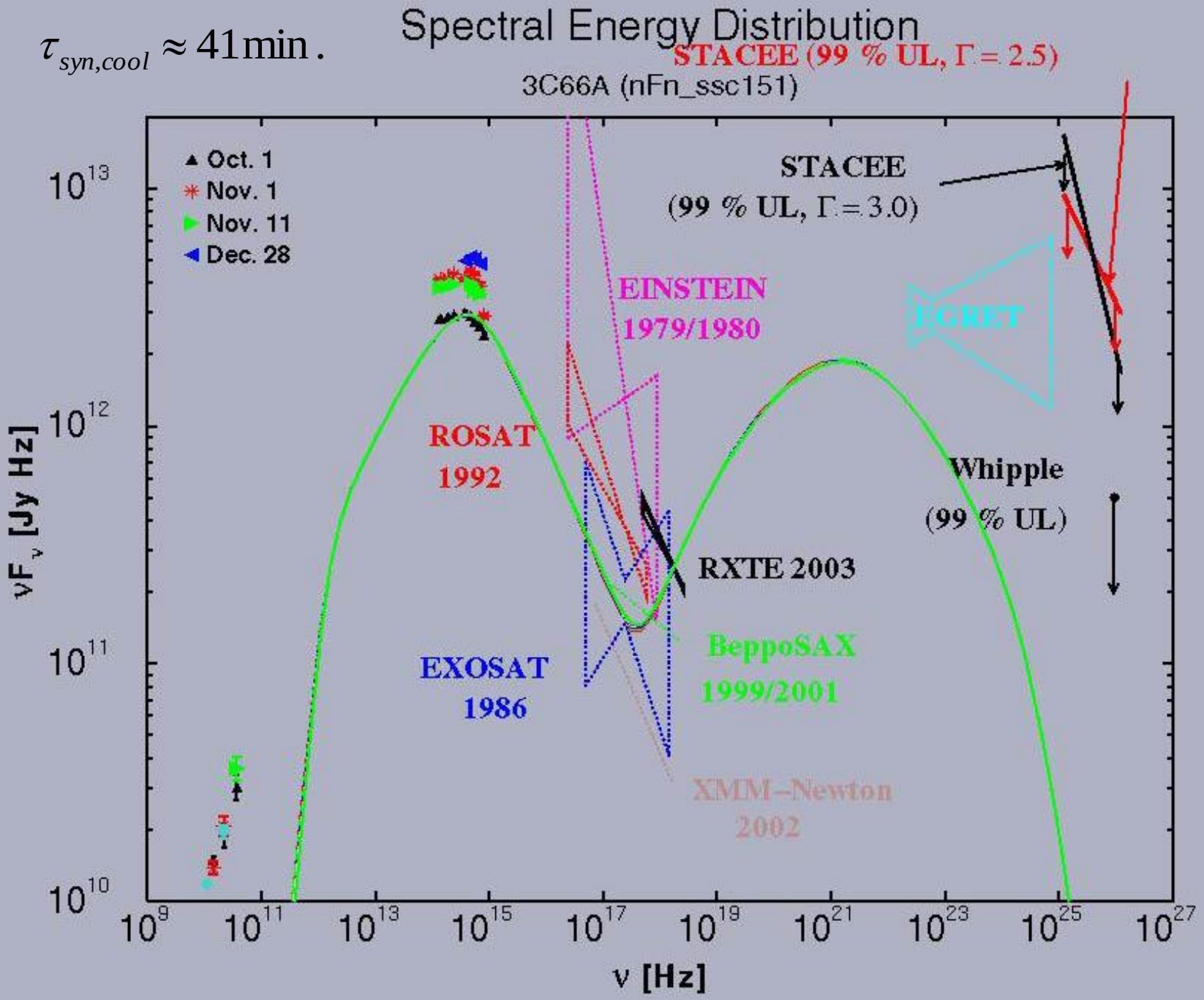
$$\tau_{cool,sy}^{obs} \approx 2.8\times10^{3}\left(\frac{D}{15}\right)^{-1/2}\left(\frac{B}{2.9G}\right)^{-3/2}\nu_{15}^{-1/2}\,\mathrm{s}$$

- For optical frequencies, $\tau_{cool,sy}^{obs} \approx 2$ hr
- Particle spectral index, p ~ 4
- Particle injection spectral index, q ~ 3
- Disk injection luminosity, $L_{inj} \approx 6.8\times10^{41}$ ergs/sec

Motivation of Parameters

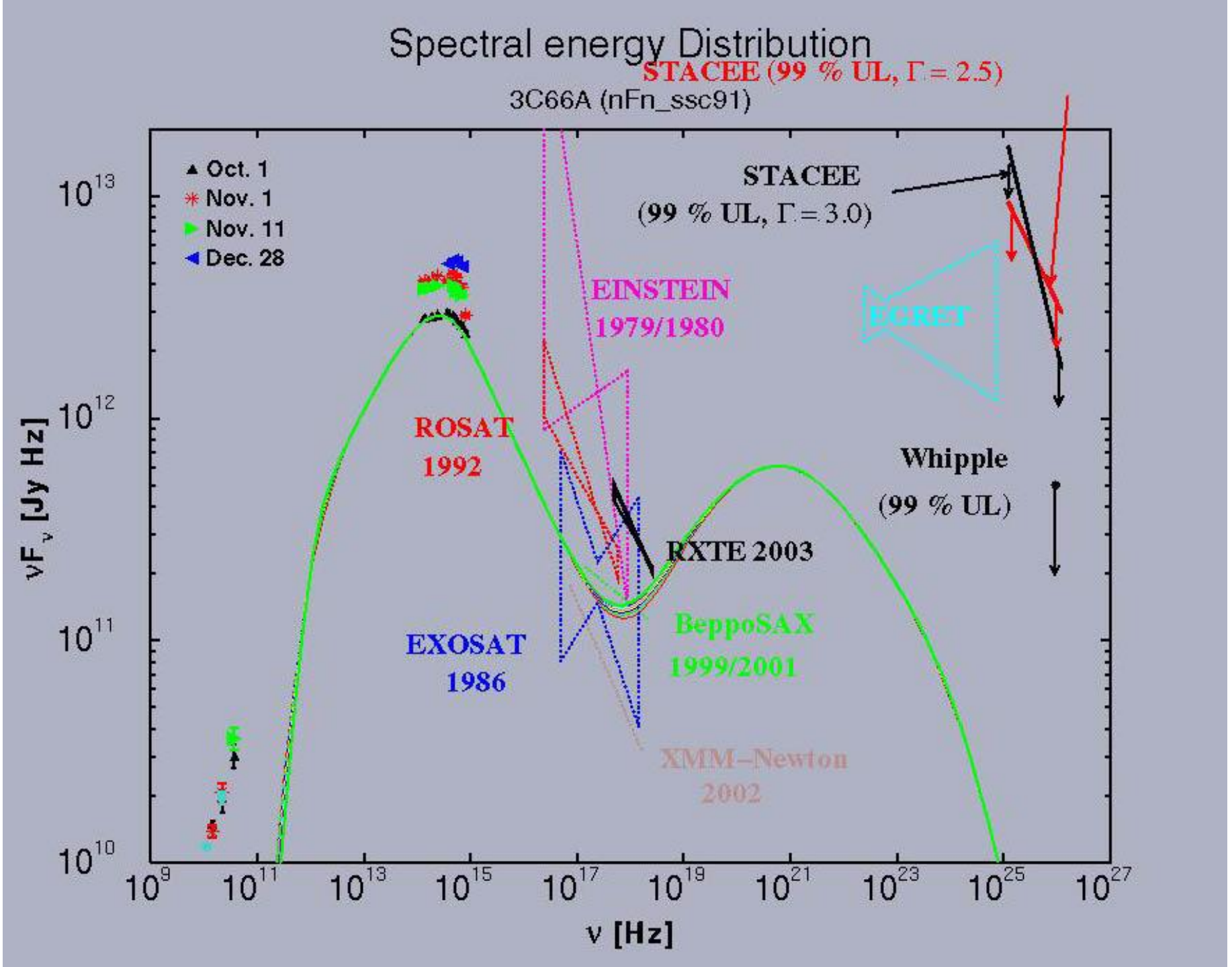
- VLBA observations indicate bending of jet in the line of sight
- Viewing angle, $\theta_{obs} \sim 2.4^{\circ}$ assuming $\theta \approx \frac{1}{\Gamma}$
- Jet components don't exhibit superluminal motion except one, hence Doppler Factor not well constrained.
- $D = \Gamma = 24$ gives good fit.
- X-rays being dominated by outbursts.

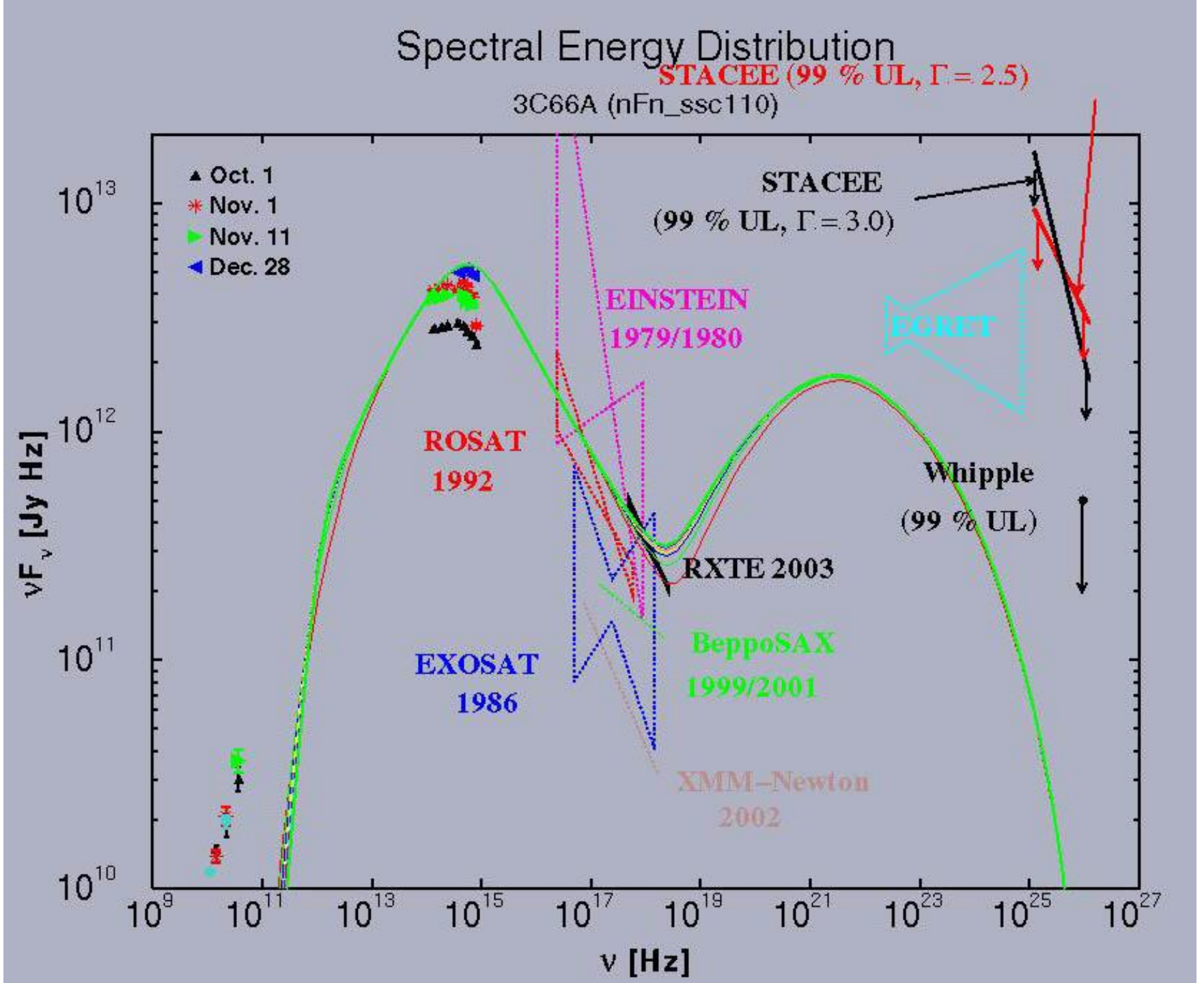
$\tau_{syn,cool} \approx 41\,\mathrm{min}.$



Work In Progress

- Suitable set of parameters to explain the optical variability observed.
- Specific predictions concerning potentially observable X-ray spectral variability patterns and γ-ray emission.
- Investigate possible presence of EIC in γ-ray emission.


Spectral energy Distribution
STACEE (99 % UL, Γ = 2.5)
3C66A (nFn_ssc91)
Oct. 1
Nov. 1
Nov. 11
Dec. 28
STACEE
(99 % UL, Γ = 3.0)
EINSTEIN
1979/1980
EGRET
ROSAT
1992
Whipple
(99 % UL)
RXTE 2003
BeppoSAX
1999/2001
EXOSAT
1986
XMM–Newton
2002
νF_ν [Jy Hz]
ν [Hz]
10^13
10^12
10^11
10^10
10^9
10^11
10^13
10^15
10^17
10^19
10^21
10^23
10^25
10^27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νF_ν [Jy Hz]
ν [Hz]
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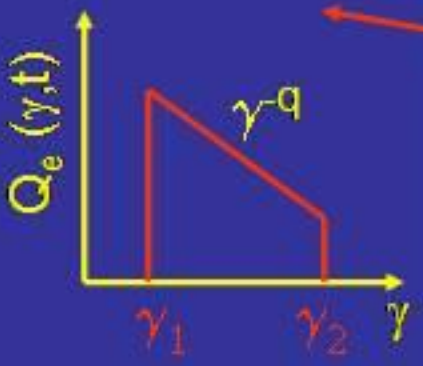

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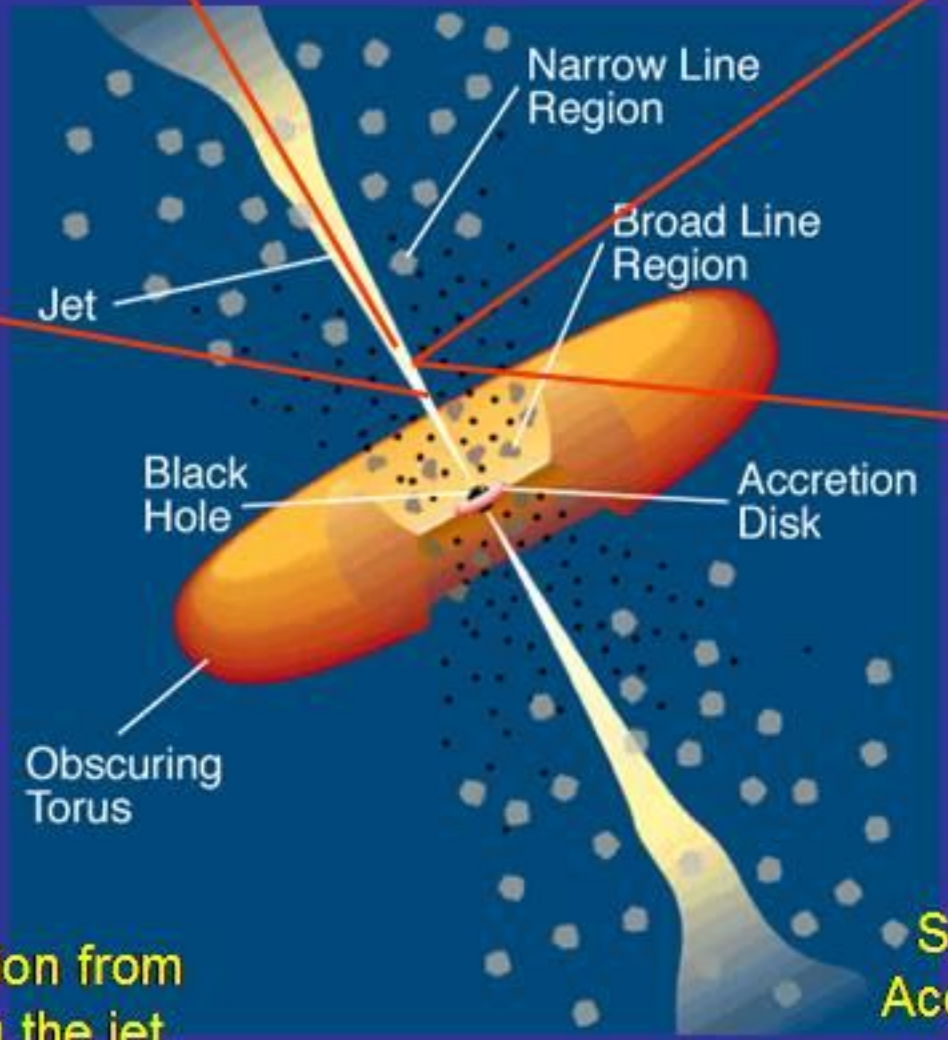
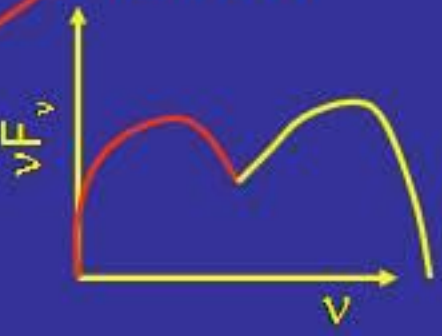
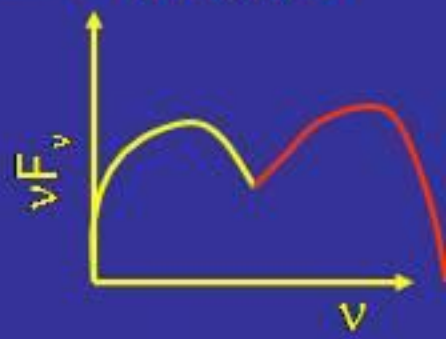


Synchrotron emission



Compton emission



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