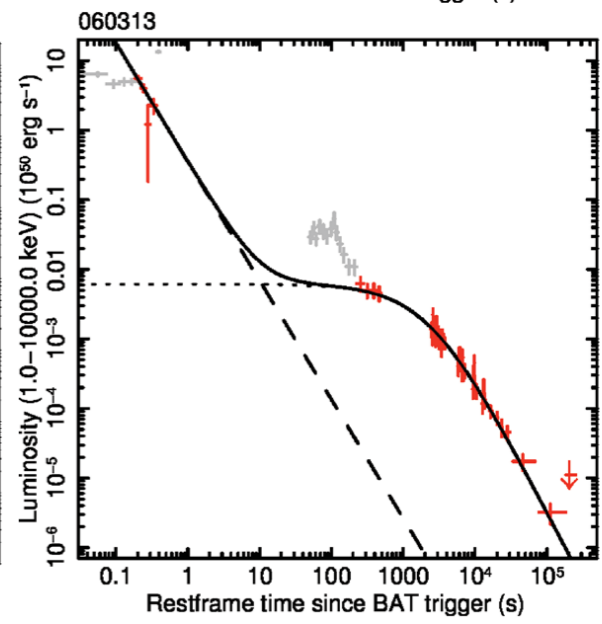
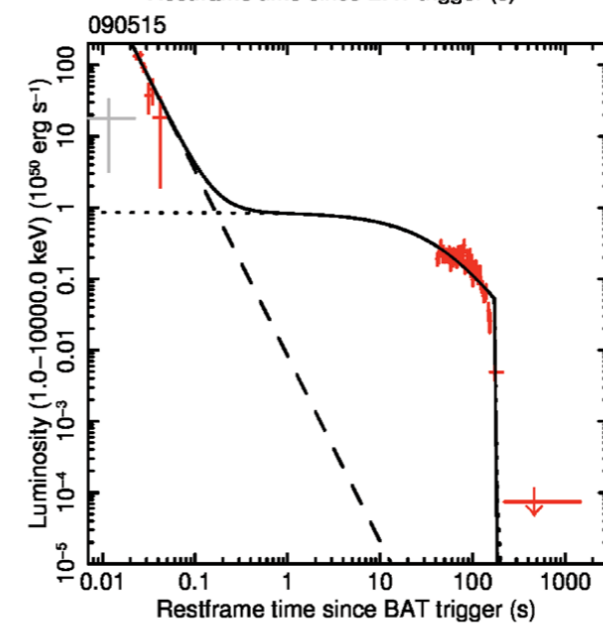
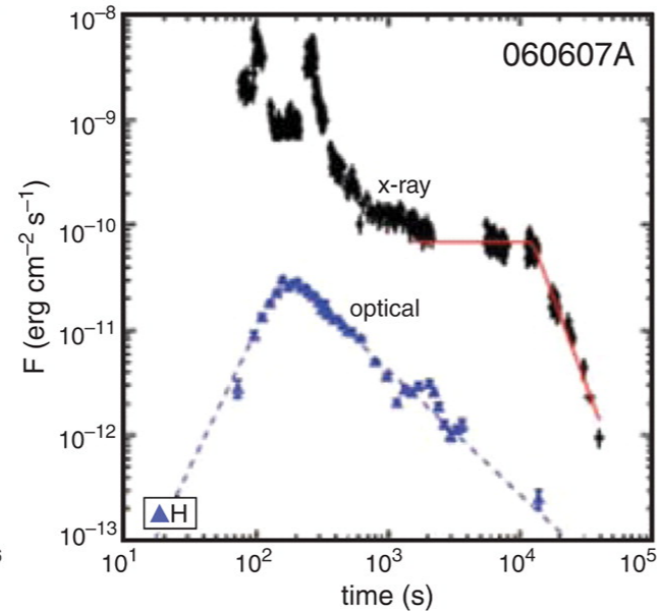
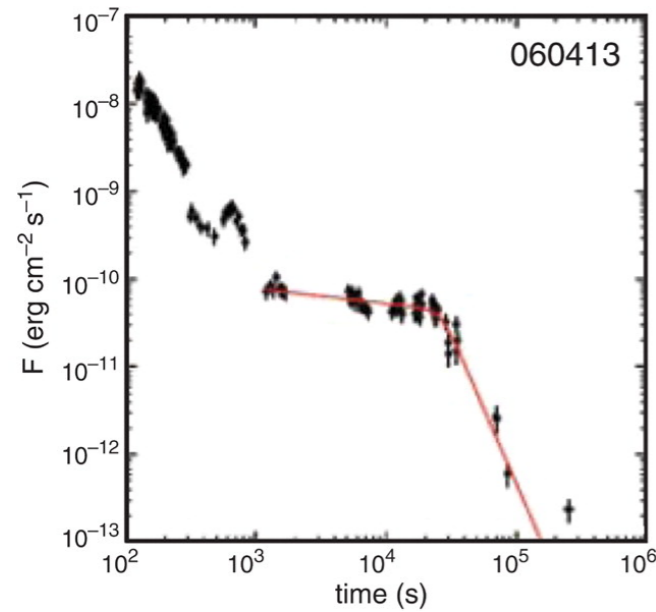
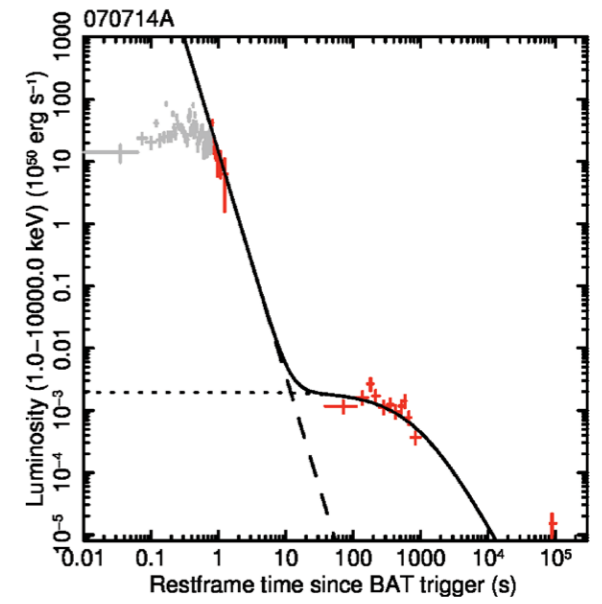
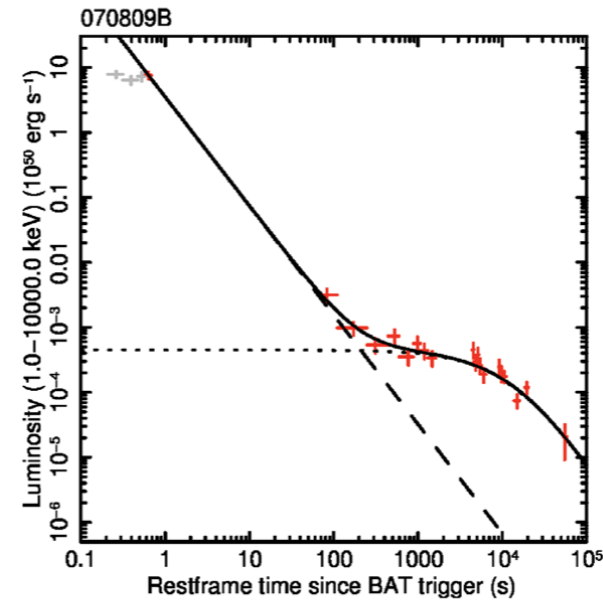
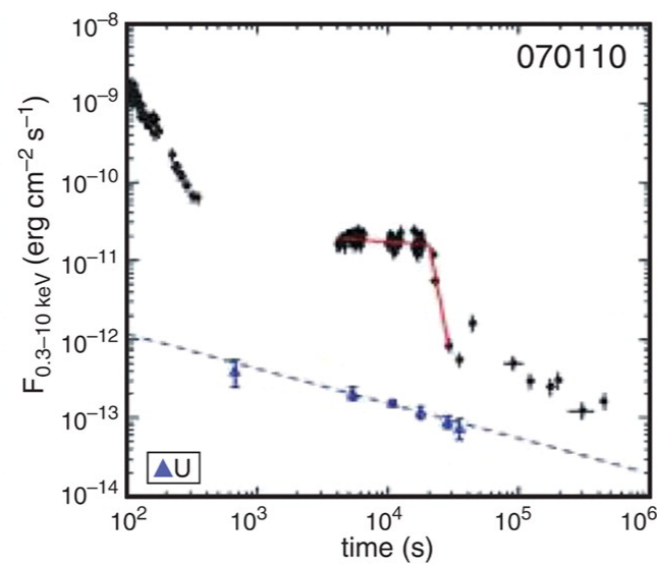
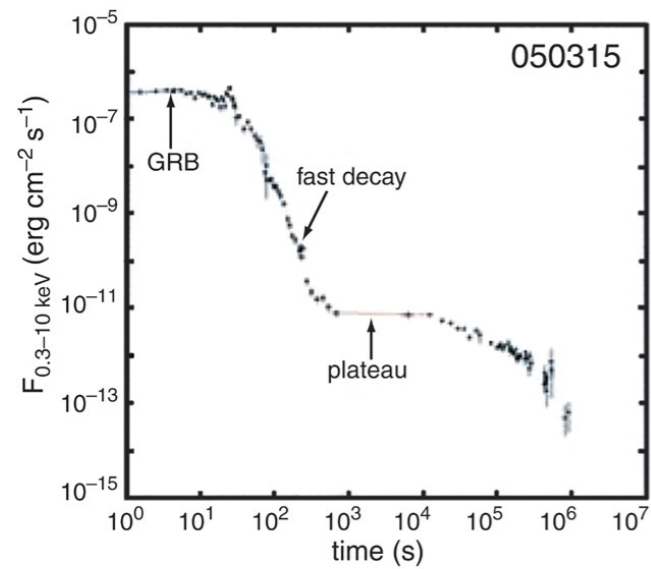


The Early Afterglow of Gamma-ray Bursts

Stefano Ascenzi (Gran Sasso Science Institute)

The Early X-ray lightcurves



The High Latitude Emission (HLE) Model

Kumar & Panaitescu 2000, Ap. J., 541, 2, L51-L54

The Recipe

The steep decay is the tail (in X-ray) of the **prompt emission**. The energy is released instantaneously by a curved surface in highly relativistic motion. The difference in the time of flight of photons from different regions of the emitting surface shapes the lightcurve

The Main Ingredients

- Difference in time of flight of photons
- Relativistic motion

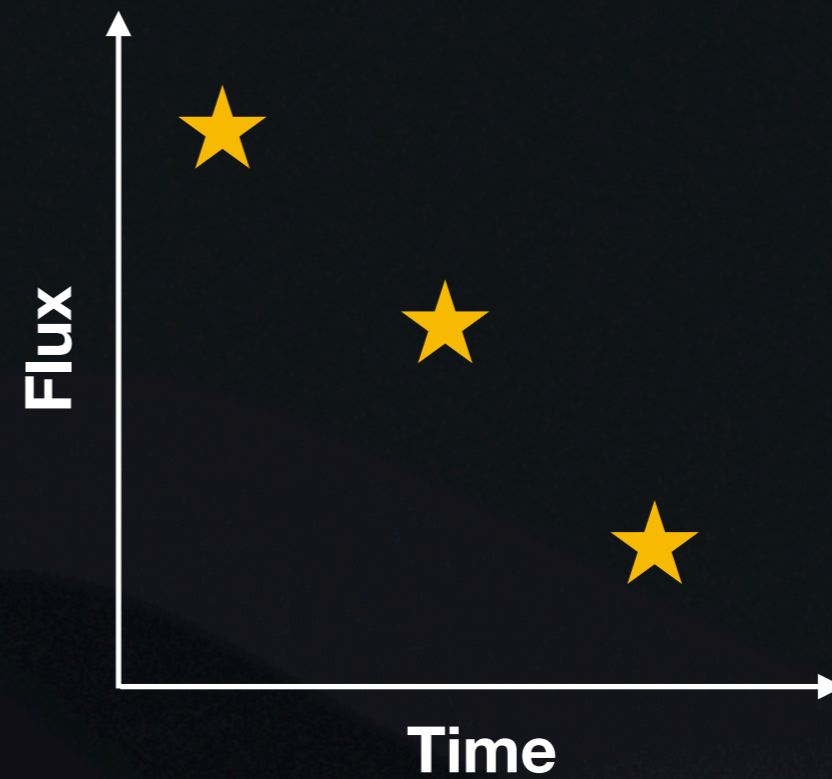
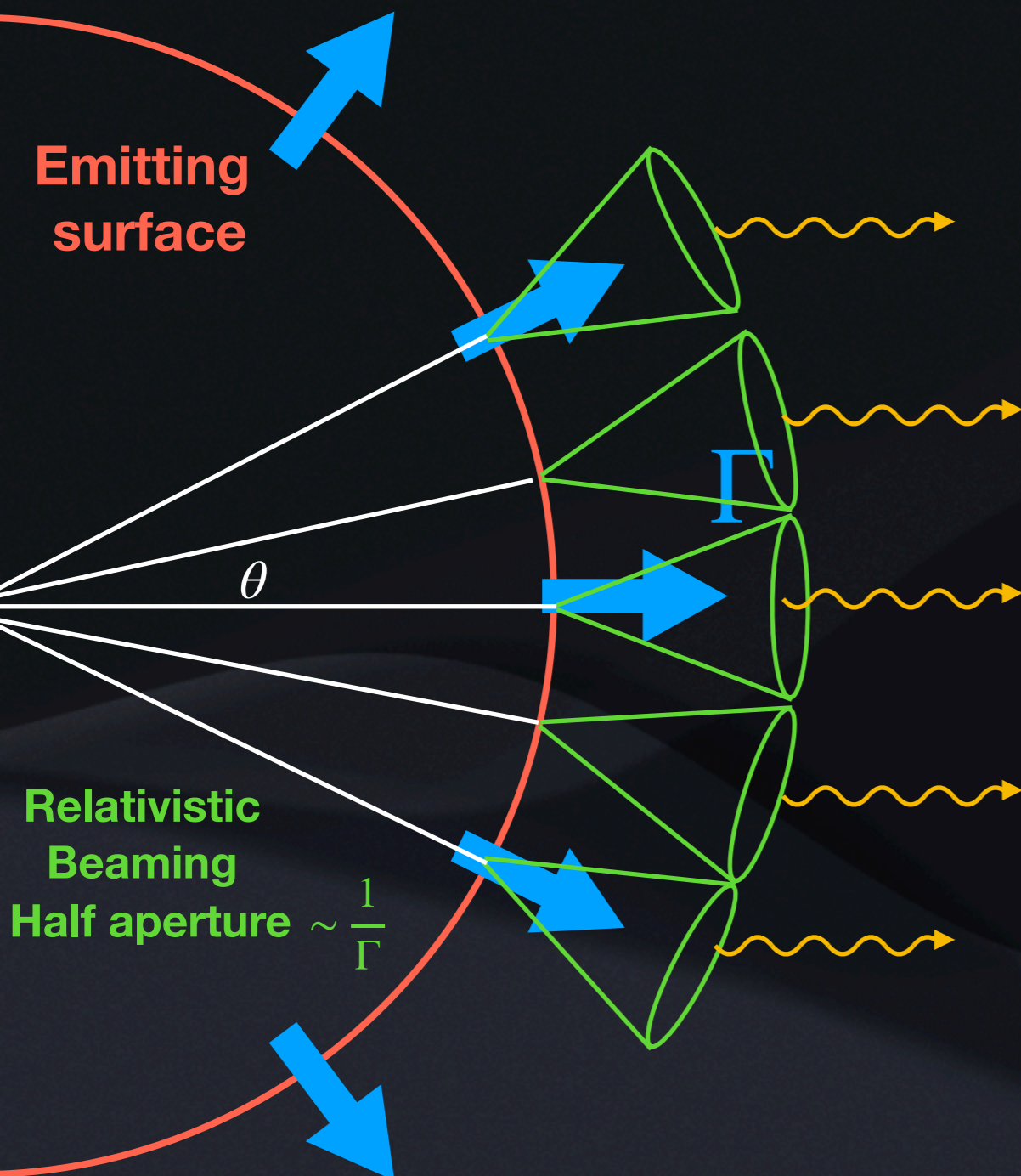
The Assumption

- Instantaneous emission
- Spherical emitting surface
- (Power law spectrum)

Steep Decay

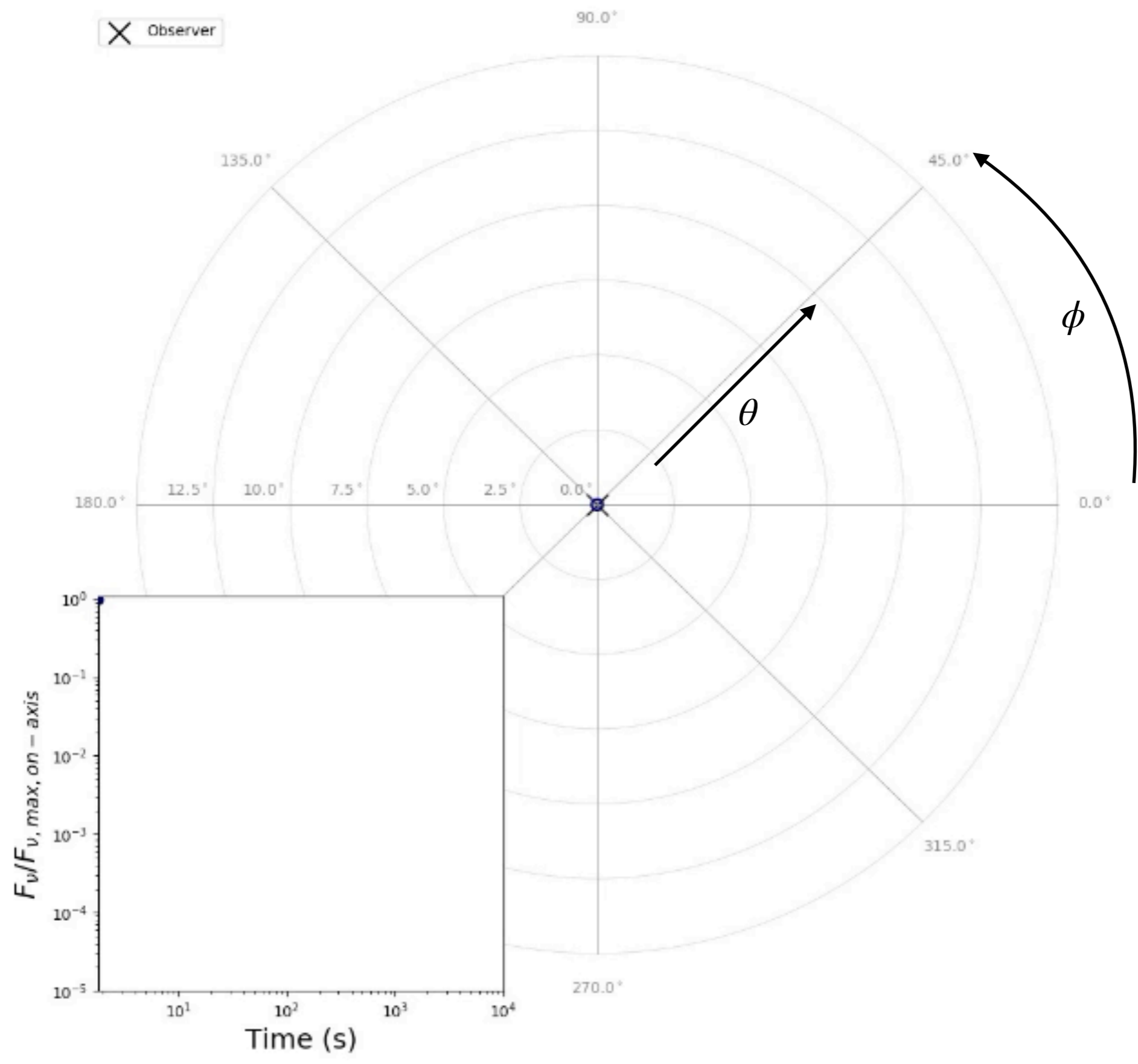
The High Latitude Emission (HLE) Model

Kumar & Panaitescu 2000, Ap. J., 541, 2, L51-L54

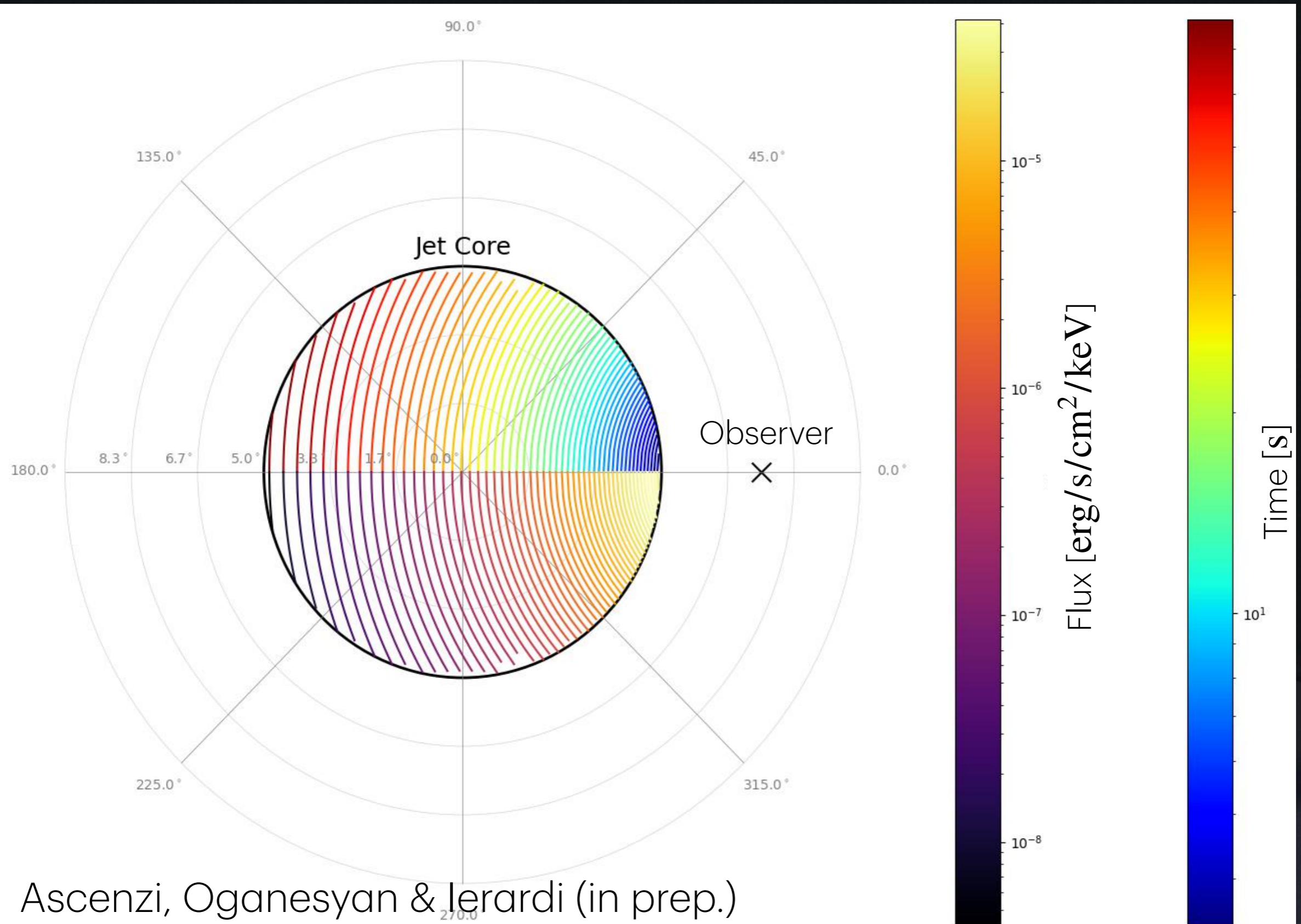


$$F_{\nu} = \int_S I_{\nu} \cos \theta_{\text{obs}} d\Omega_{\text{obs}} \propto \nu^{-\delta} t^{-\gamma}$$

$$\gamma = 2 + \delta$$

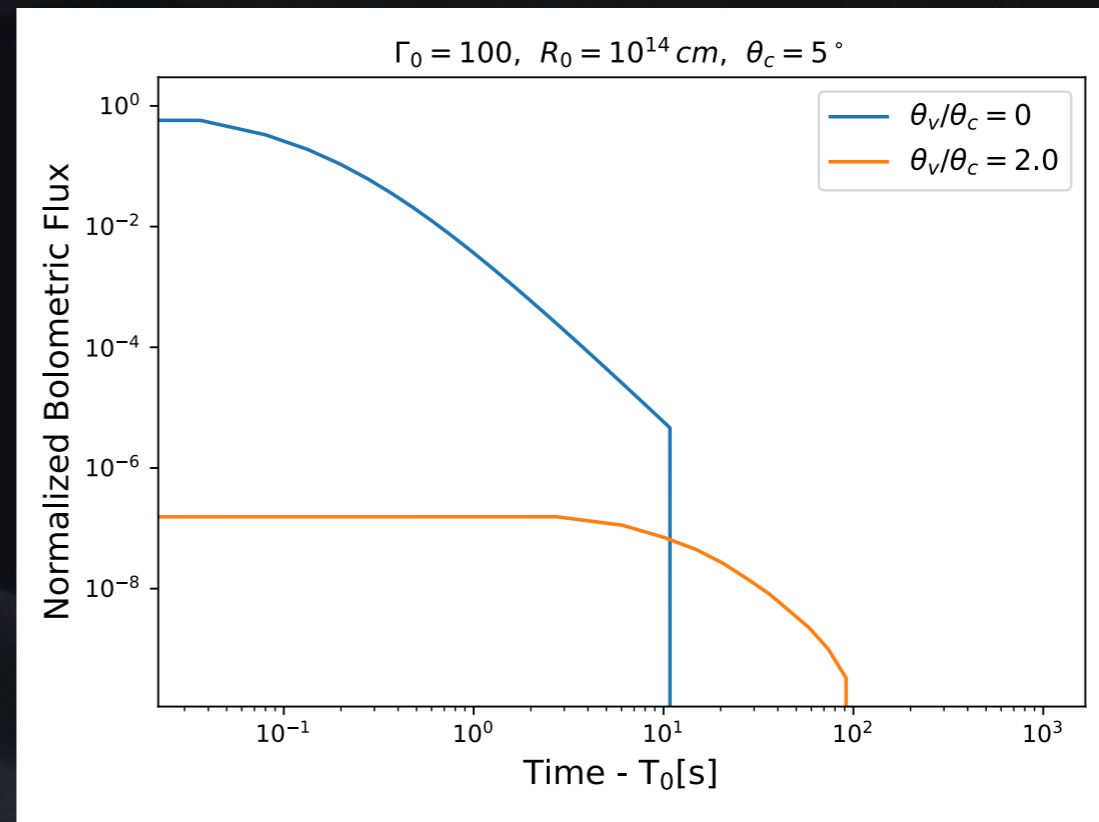
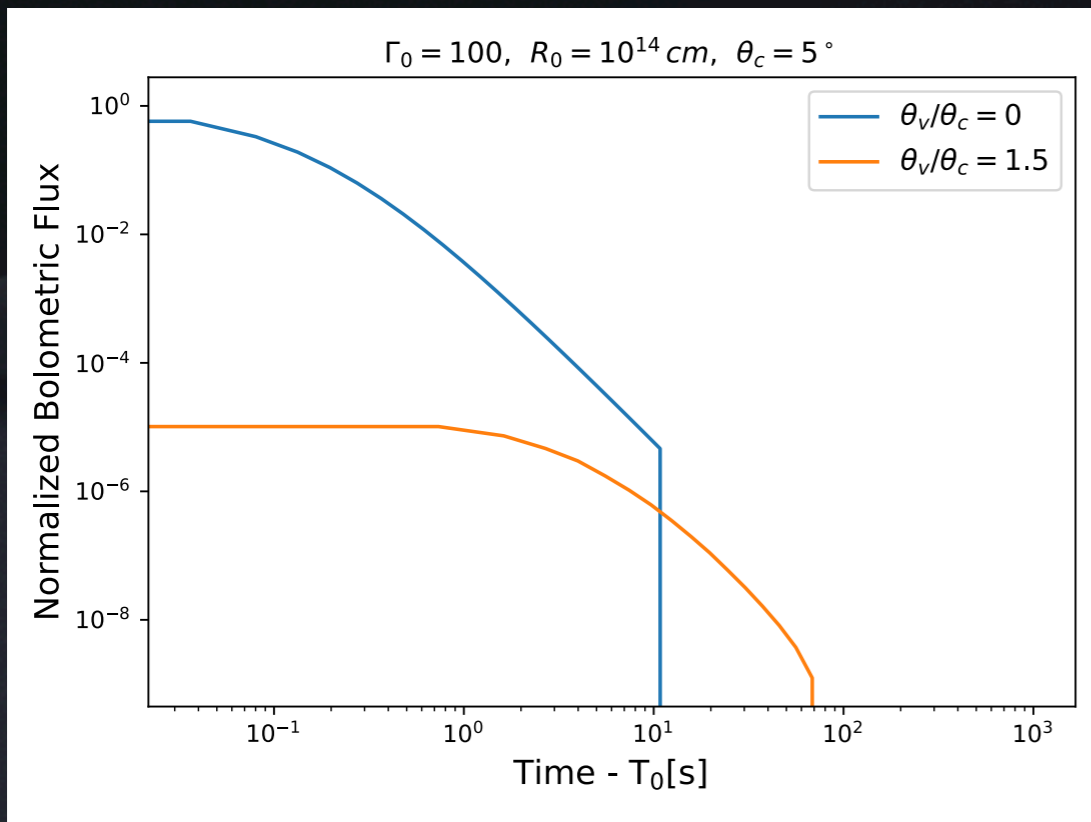
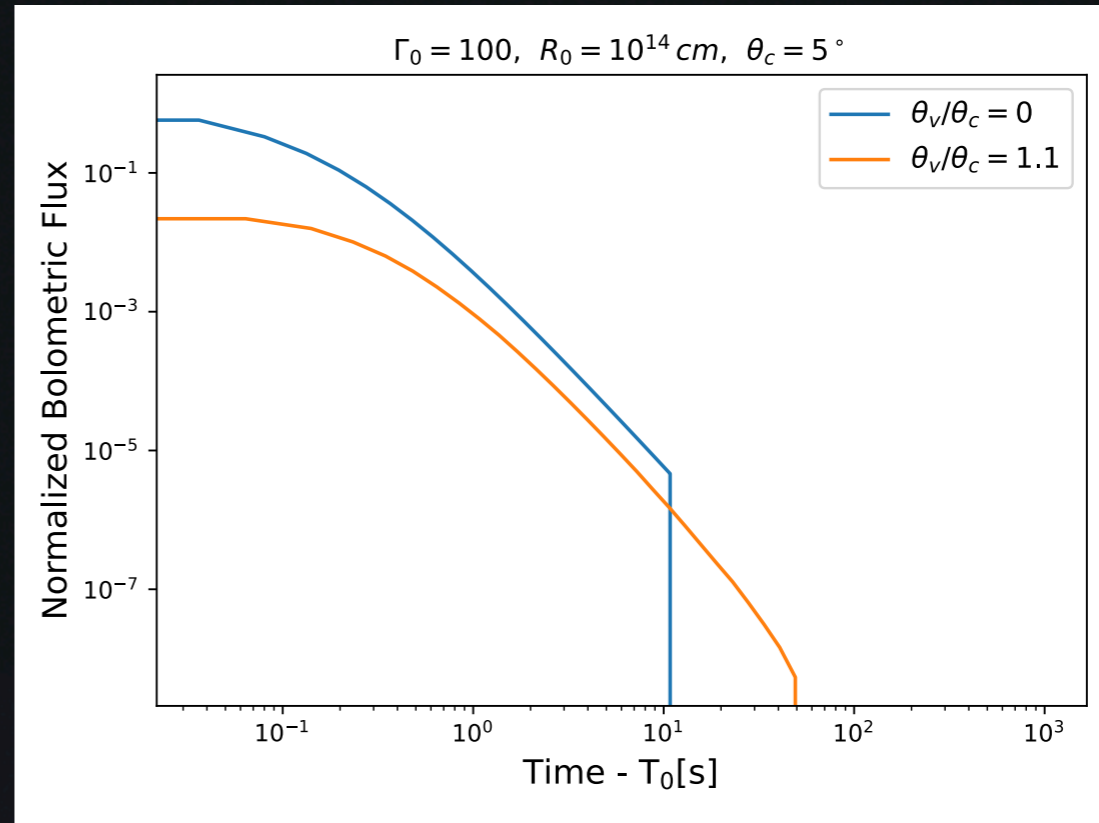
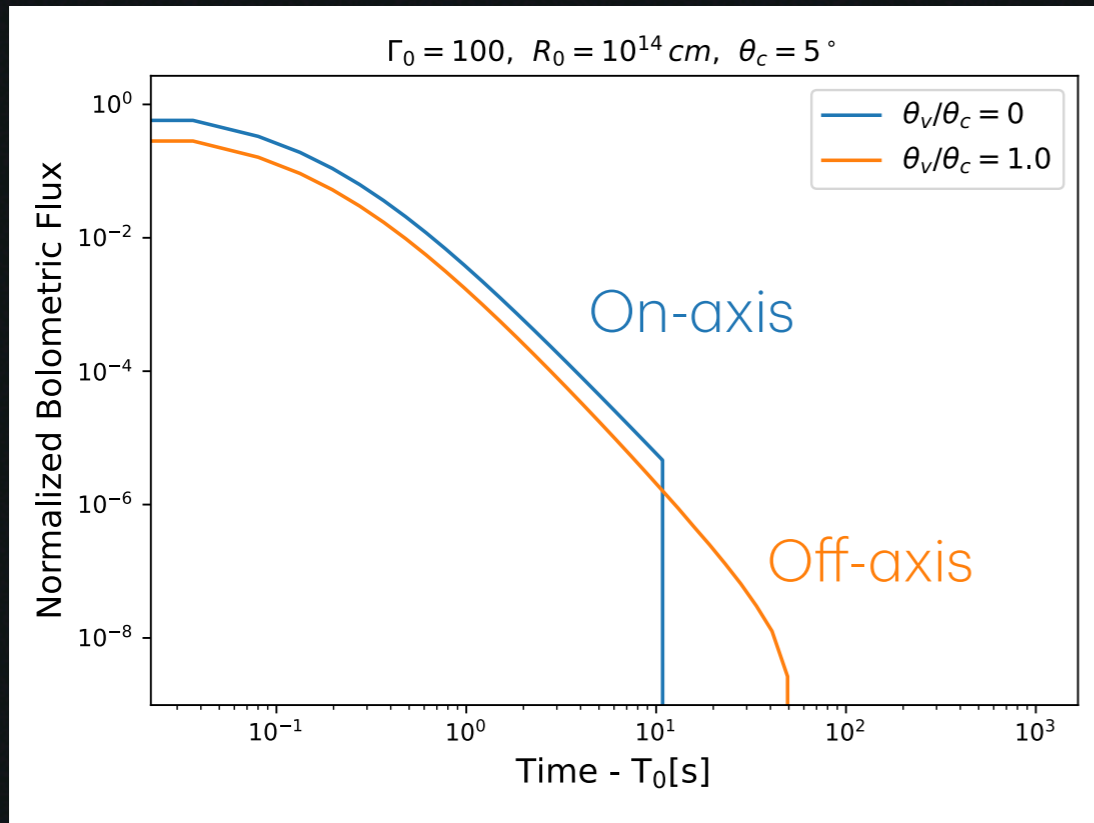


What happens when we are off-axis?

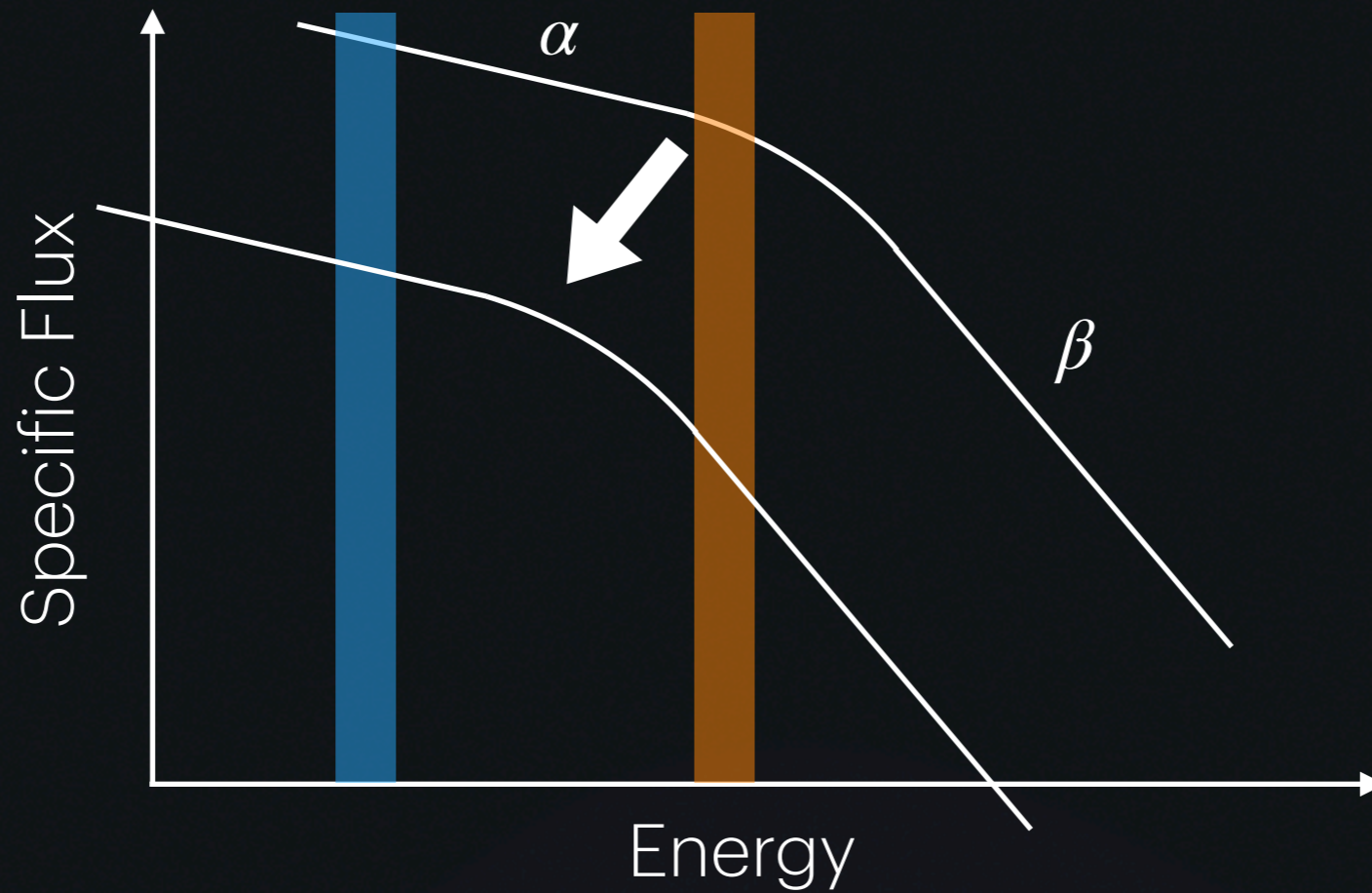


Ascenzi, Oganesyan & Ierardi (in prep.)

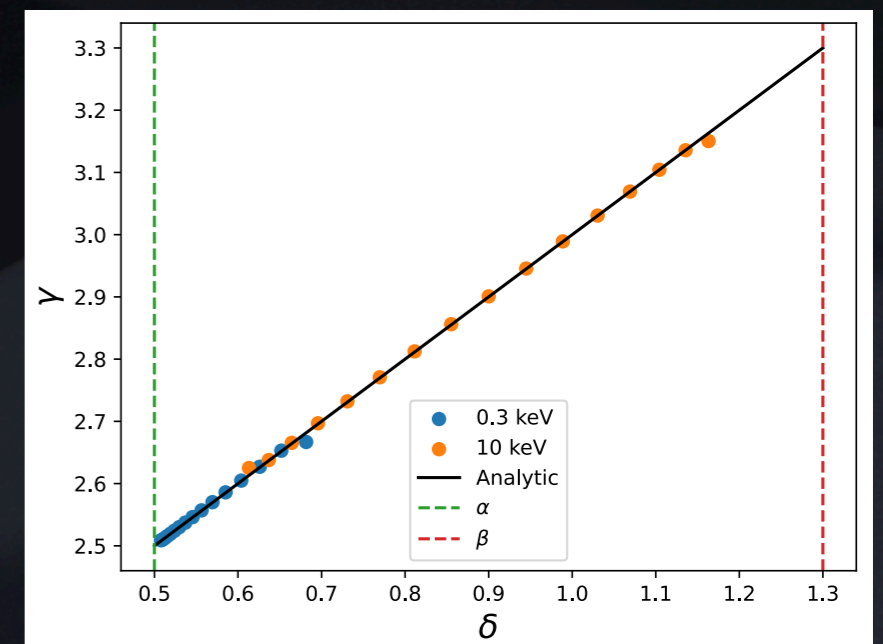
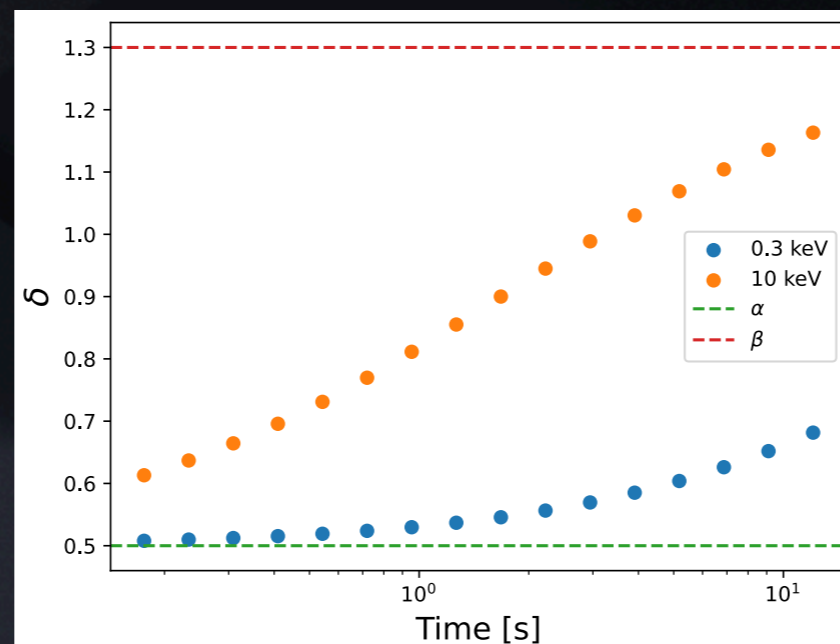
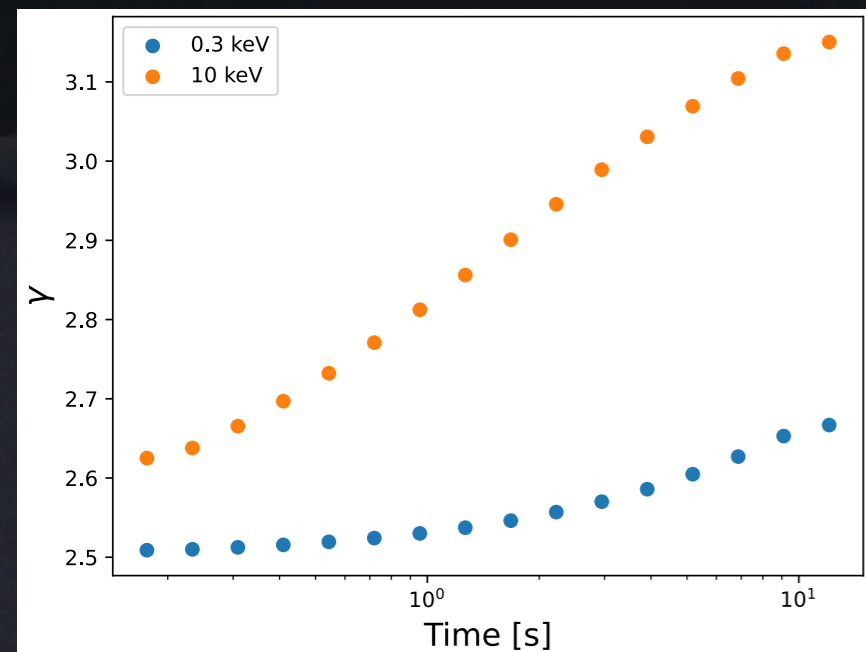
Bolometric Lightcurves



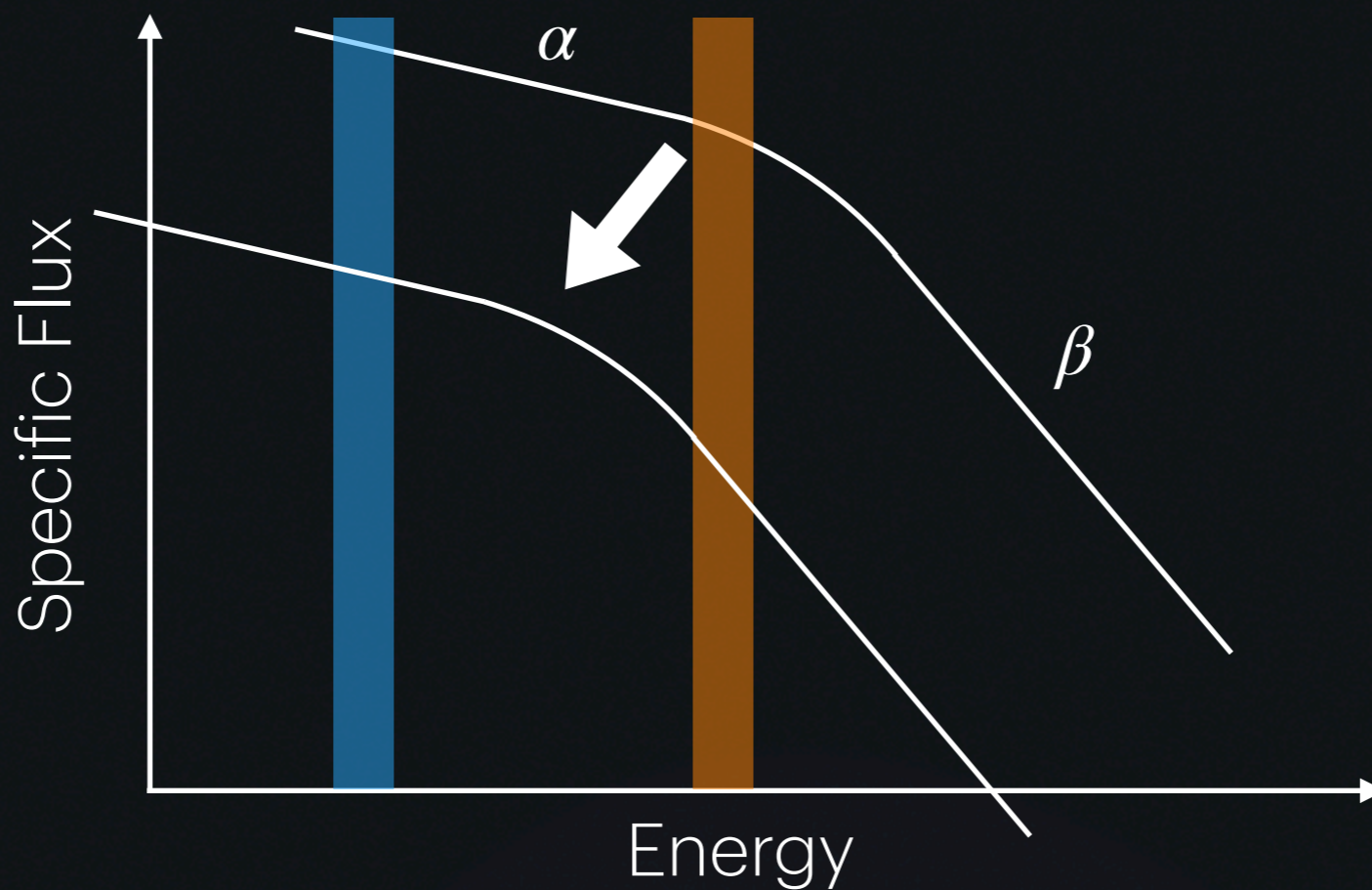
Temporal & Spectral Evolution



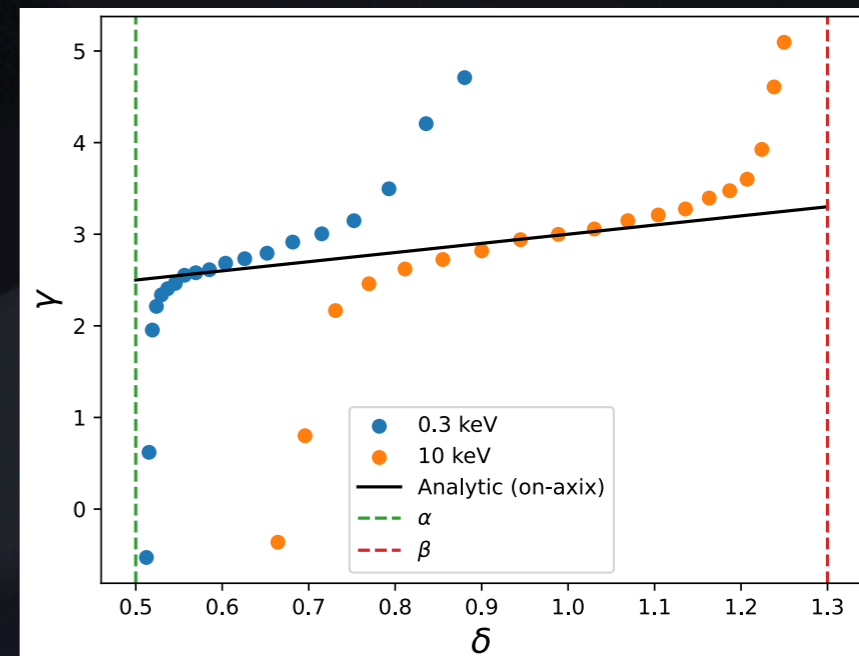
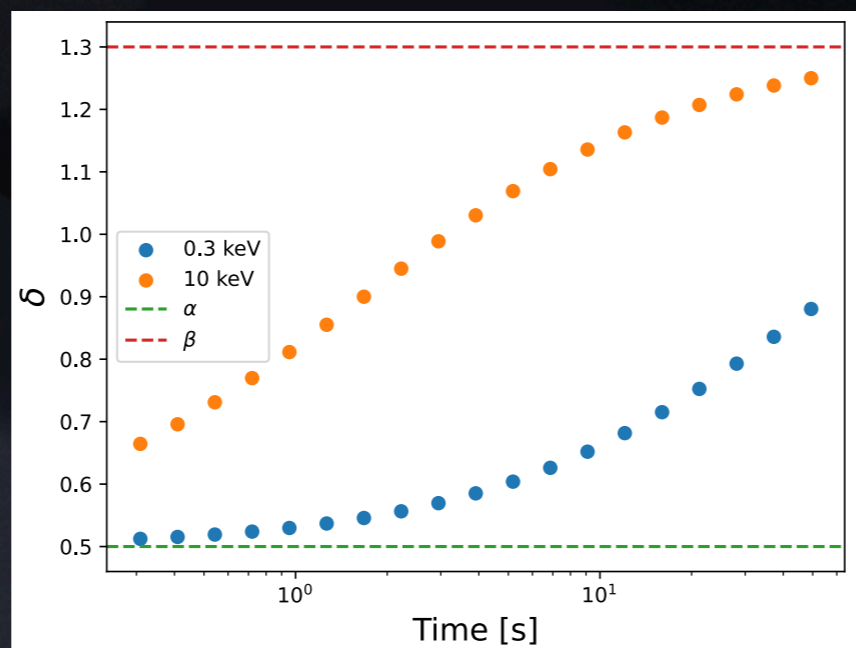
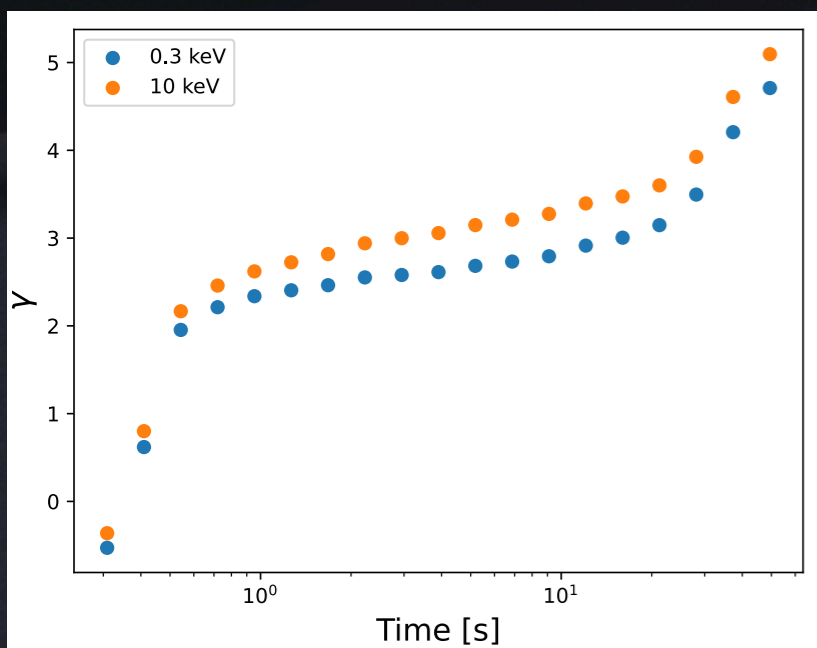
On-Axis



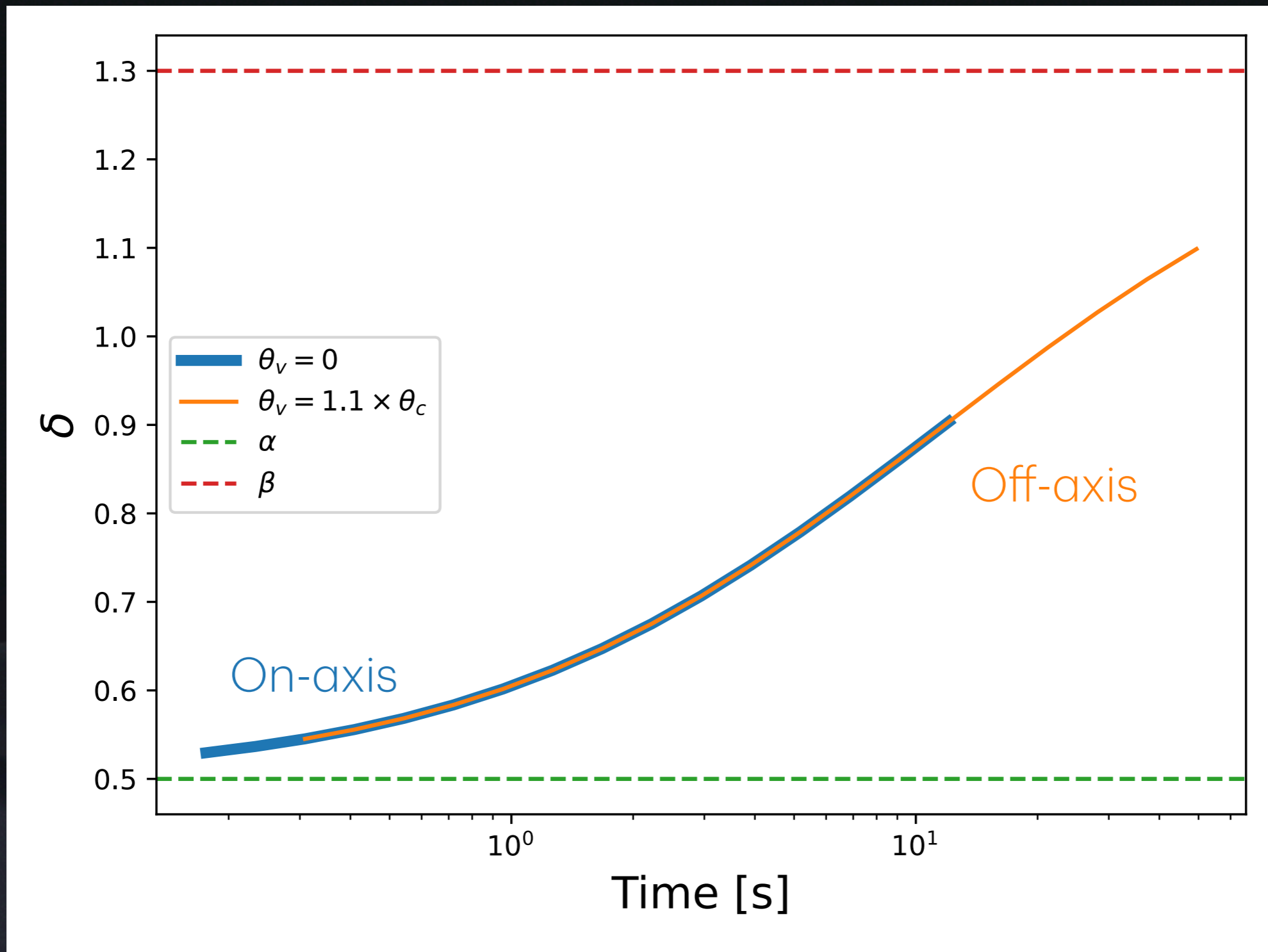
Temporal & Spectral Evolution



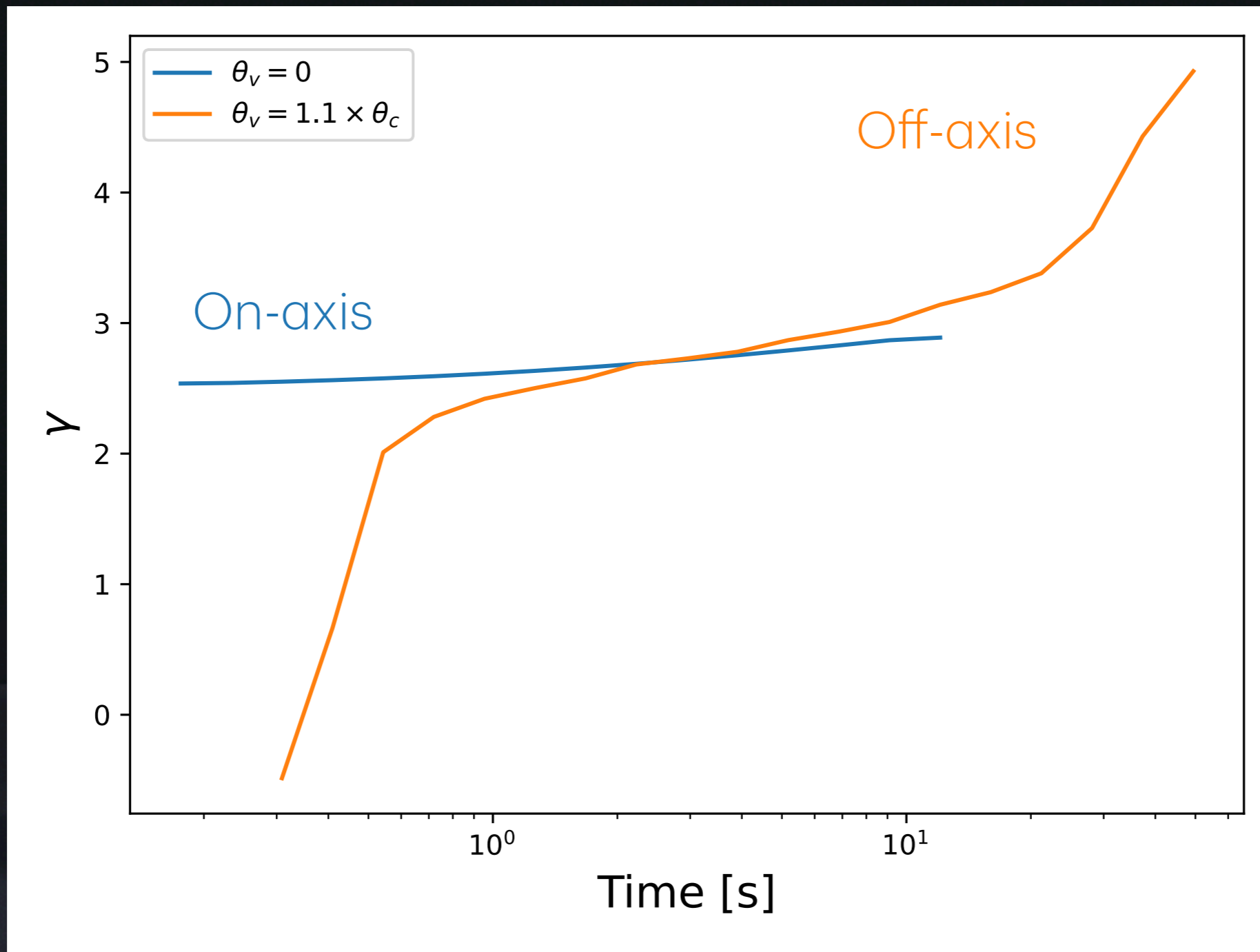
Off-Axis



Spectral Index temporal evolution



Temporal slope vs Time



High Latitude Emission with a structured surface

Oganesyan, SA et al. 2020

The Assumptions

- Instantaneous emission
- Structured emitting surface
- Negligible opacity everywhere
- Observer along the jet axis
- Same spectrum everywhere

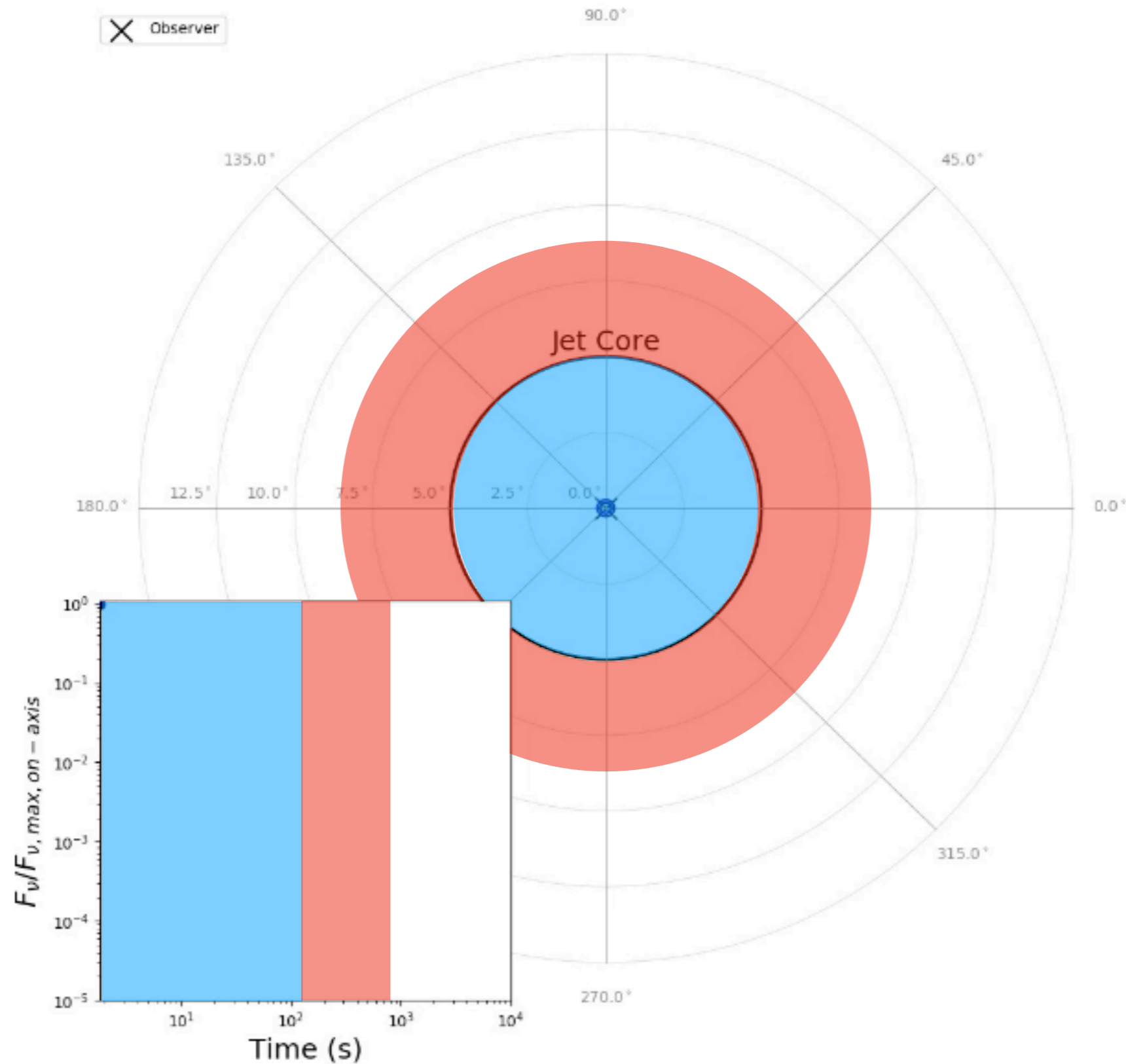
Gaussian structure

$$\Gamma(\theta) = 1 + (\Gamma_c - 1)\exp\left[-\frac{\theta^2}{\theta_c^2}\right]$$

$$\Gamma_c = 100$$

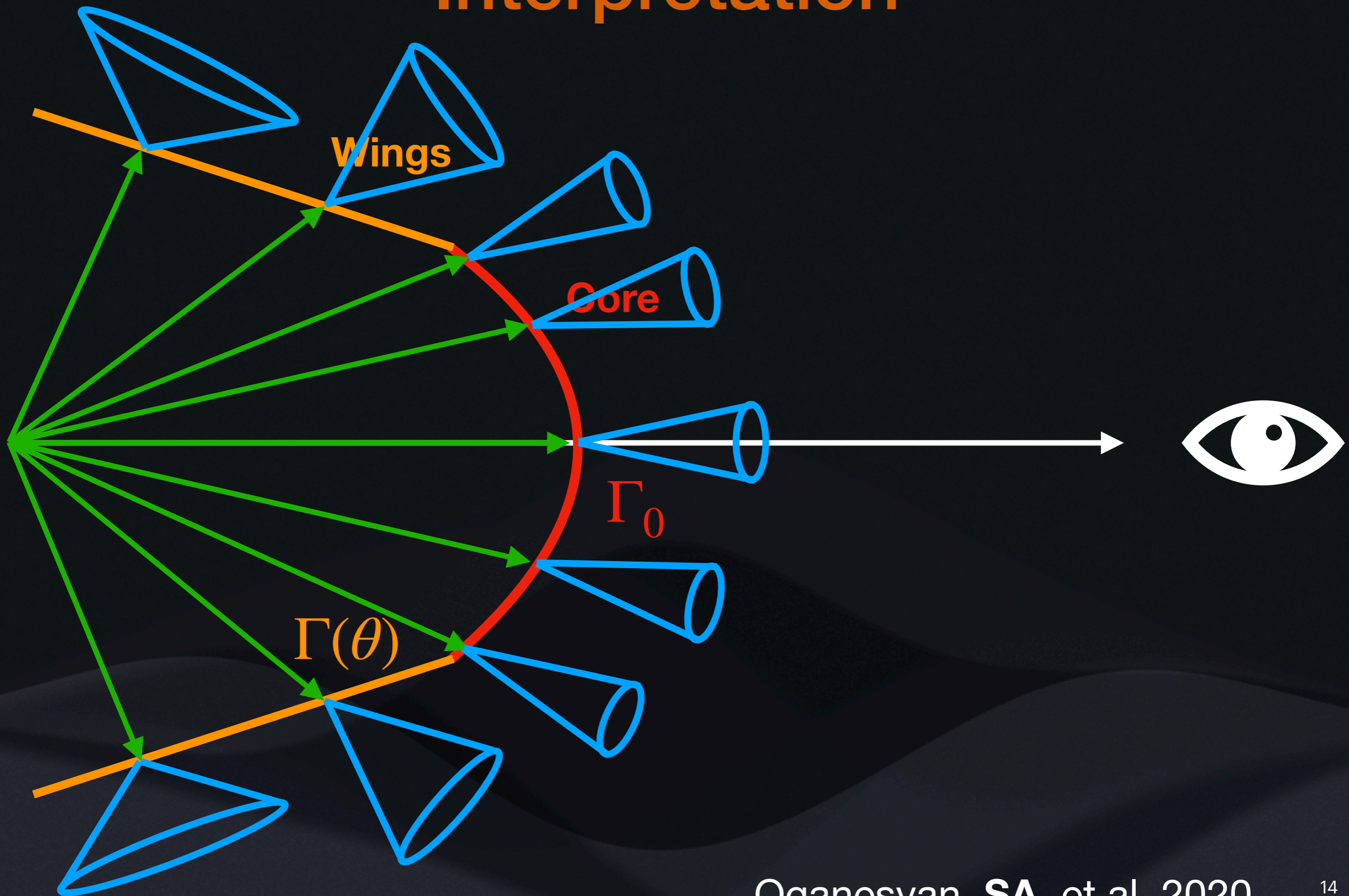
$$\theta_c = 5^\circ$$

$$R_0 = 10^{15} \text{ cm}$$



Found also by Dyks + 2005: [arXiv:astro-ph/0511699](https://arxiv.org/abs/astro-ph/0511699)

Interpretation



The High Latitude Emission (HLE) Model for a Structured Emitting Surface

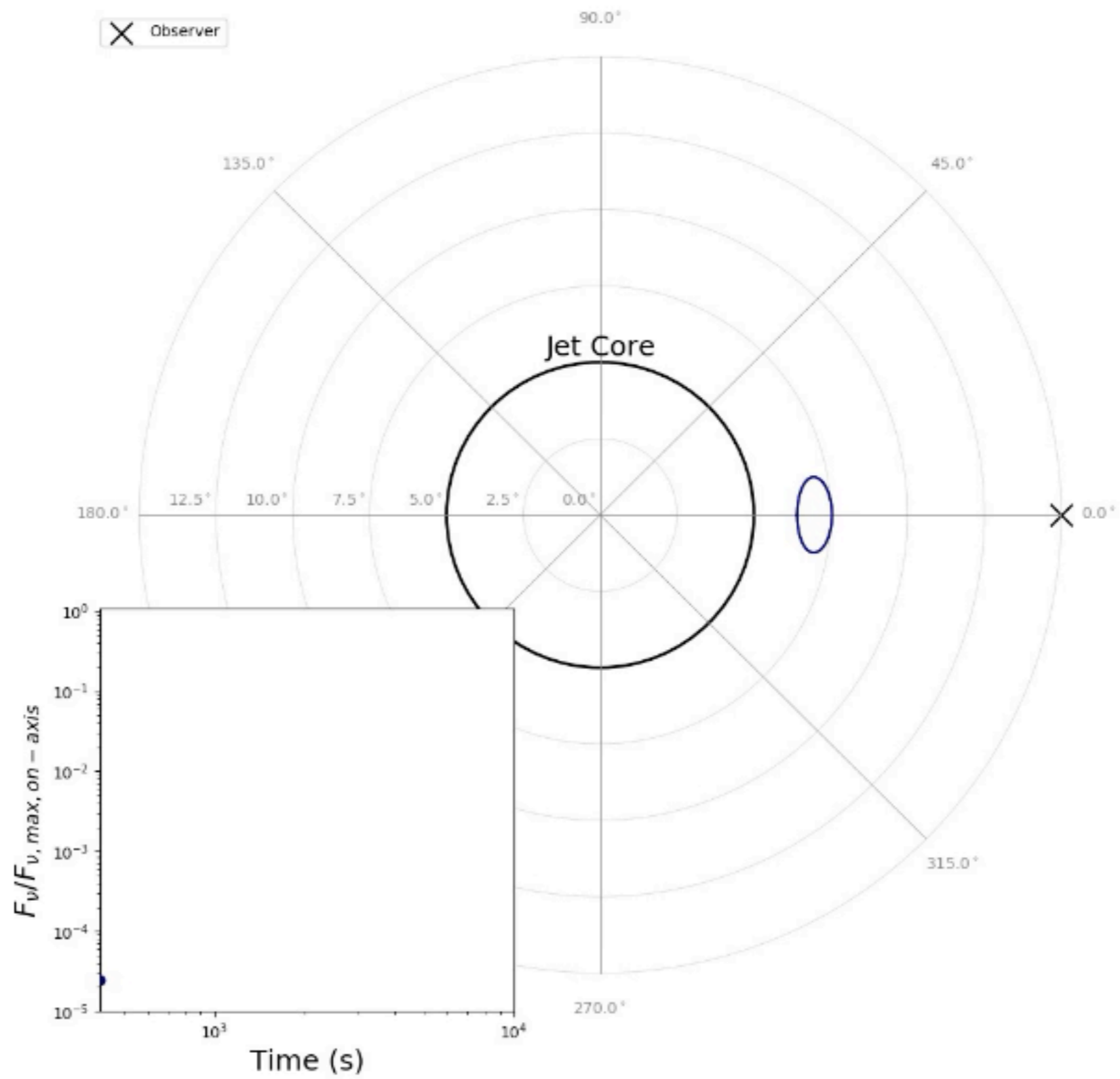
SA, Oganesyanyan et al. 2020

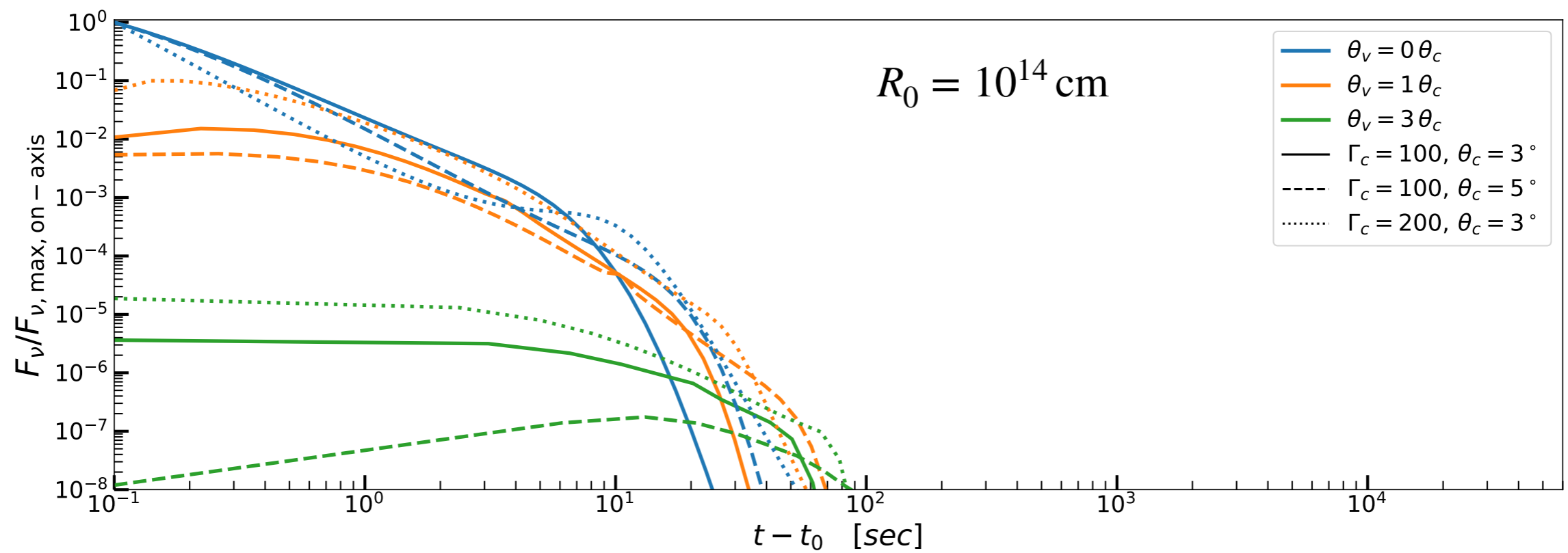
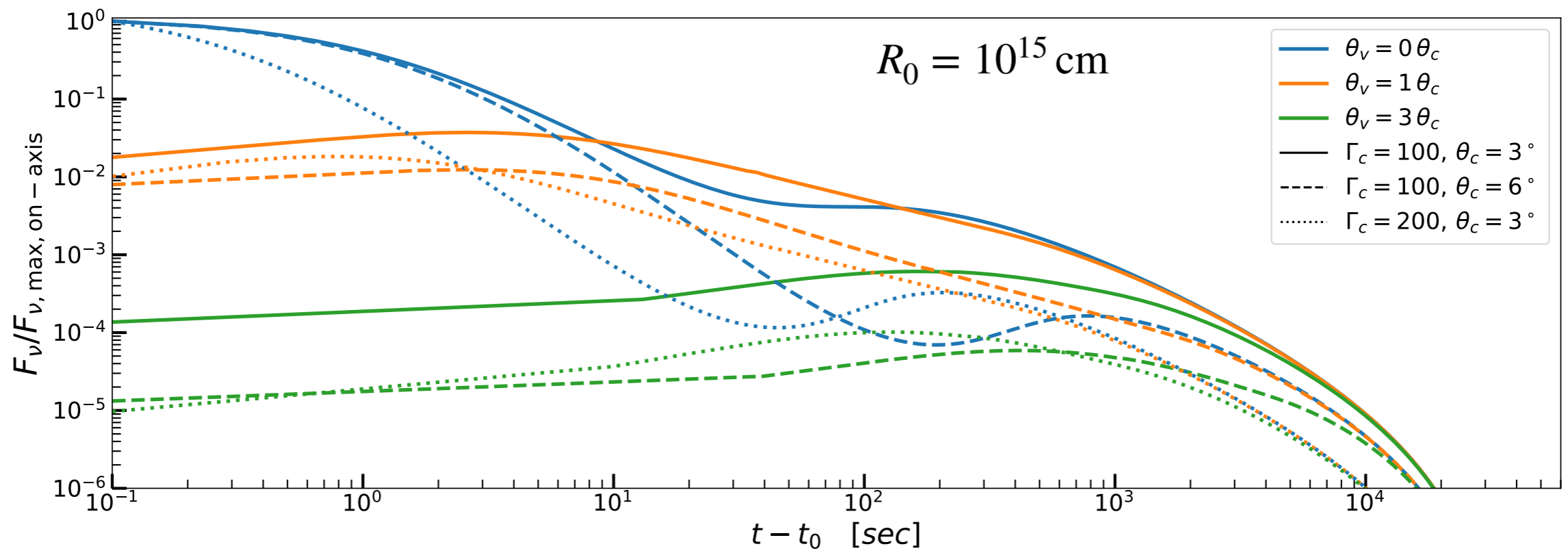
Same Assumptions

- Structured emitting surface
- Same spectrum everywhere

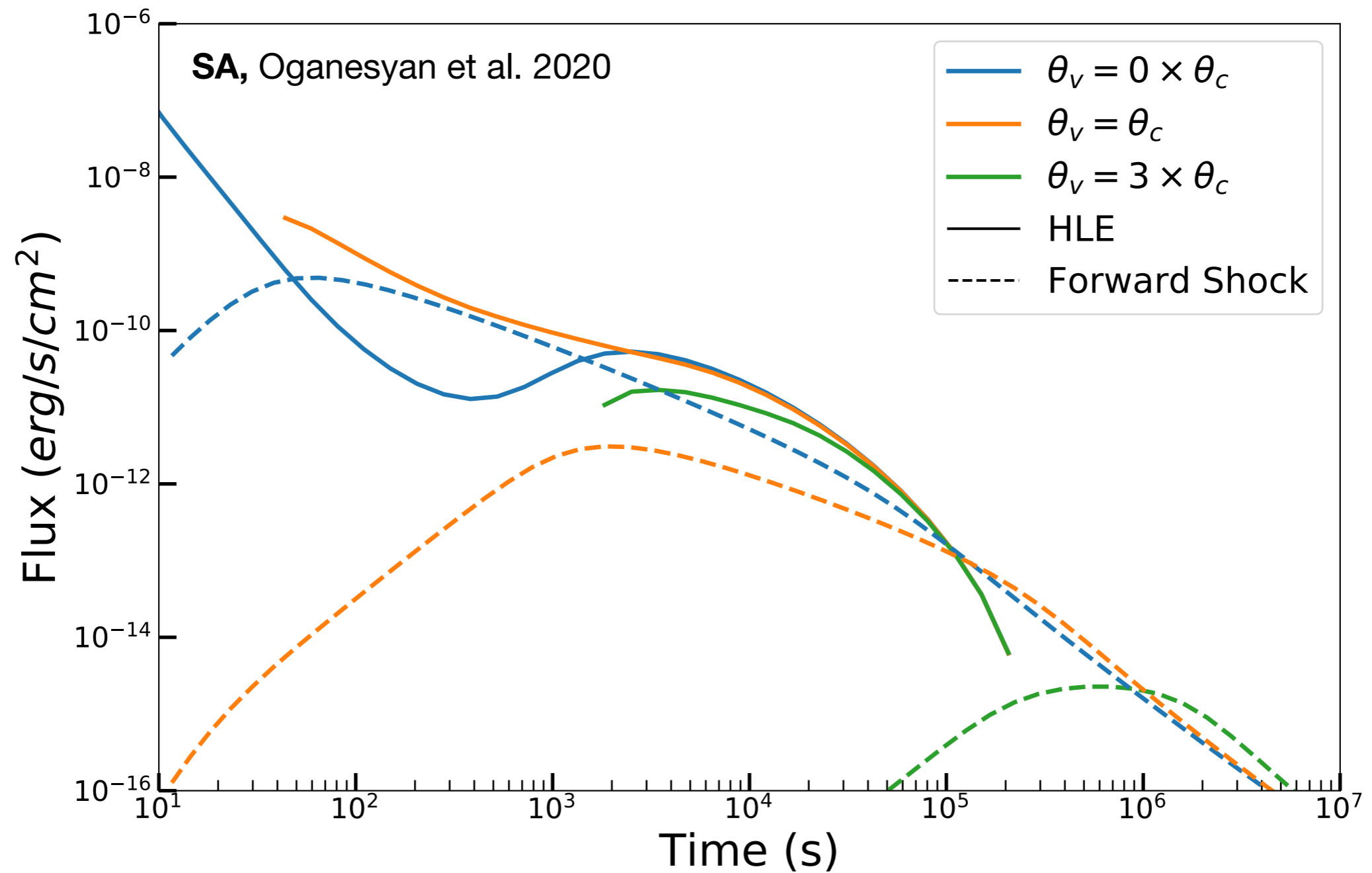
Relaxed Assumptions

- Instantaneous and non-instantaneous emission
- Structured opacity
- Arbitrary observer





Comparison with the forward-shock



Summary and Conclusions

Emission (off-axis) within the core

- The HLE last longer and the temporal index is not (approximately) constant
- The spectral index evolves along the same track on and off-axis. It reaches higher value off-axis due to the longer duration.
- Closure relation between temporal and spectral index affected by the viewing angle when sufficiently off-axis

Emission (if any) outside of the core

- When the jet is structured the HLE has a flattening at later times
- The flattening is present only on-axis. Off-axis we see a transient of ~hr duration, flat at the beginning and with a later fast decay.