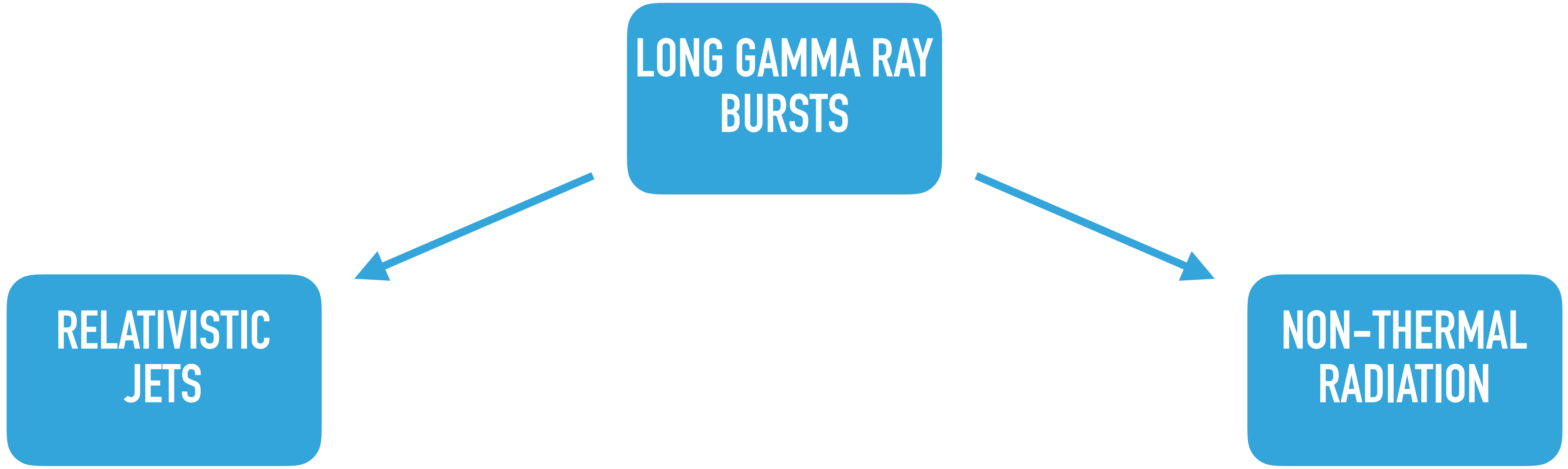
Oregon State University
College of Science

TYLER PARSOTAN

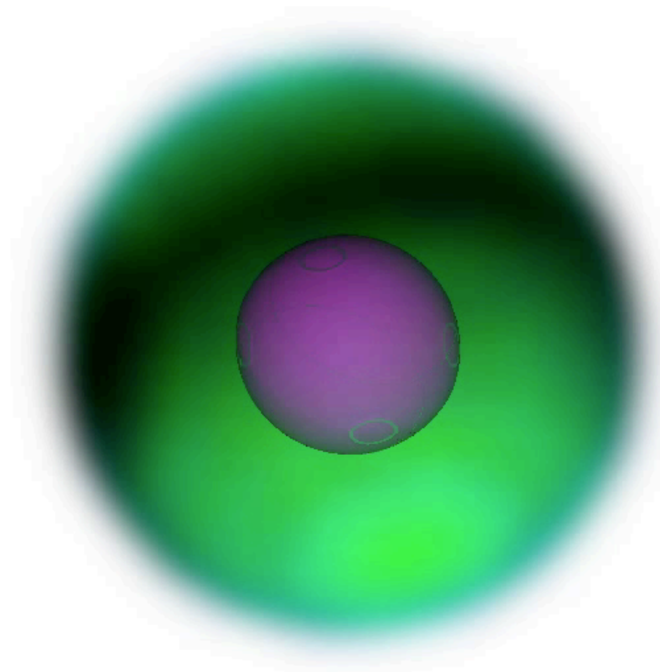
NUMERICAL SIMULATIONS OF THE DYNAMICS AND RADIATIVE PROPERTIES OF GAMMA-RAY BURST JETS

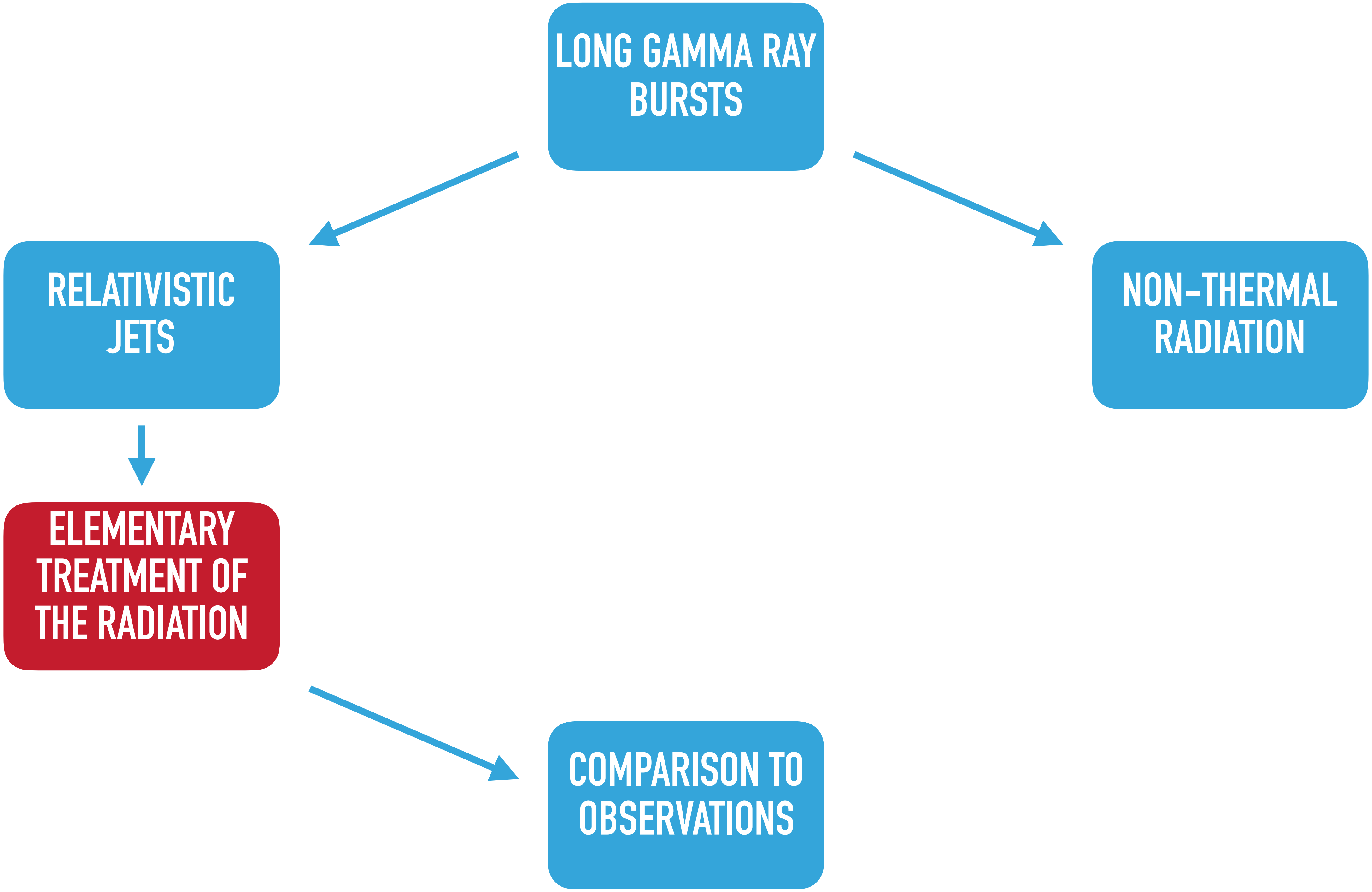
OUTLINE

- Introduction
  - Properties of GRBs
- Motivation
- Monte Carlo Radiation Transport
- Results
  - Photospheric Emission Can Reproduce Observational Band Parameters
  - Photospheric Emission Can Reproduce Various GRB Relationships
- Summary & Future Work


LONG GAMMA RAY BURSTS
RELATIVISTIC JETS
NON-THERMAL RADIATION

WE CAN MODEL THE STRUCTURE OF JETS BUT WE CAN'T EASILY DETERMINE THE RADIATION SIGNATURE




LONG GAMMA RAY BURSTS
RELATIVISTIC JETS
NON-THERMAL RADIATION
ELEMENTARY TREATMENT OF THE RADIATION
COMPARISON TO OBSERVATIONS

TRYING TO MODEL OBSERVED GRB SPECTRA…

BAND FUNCTION

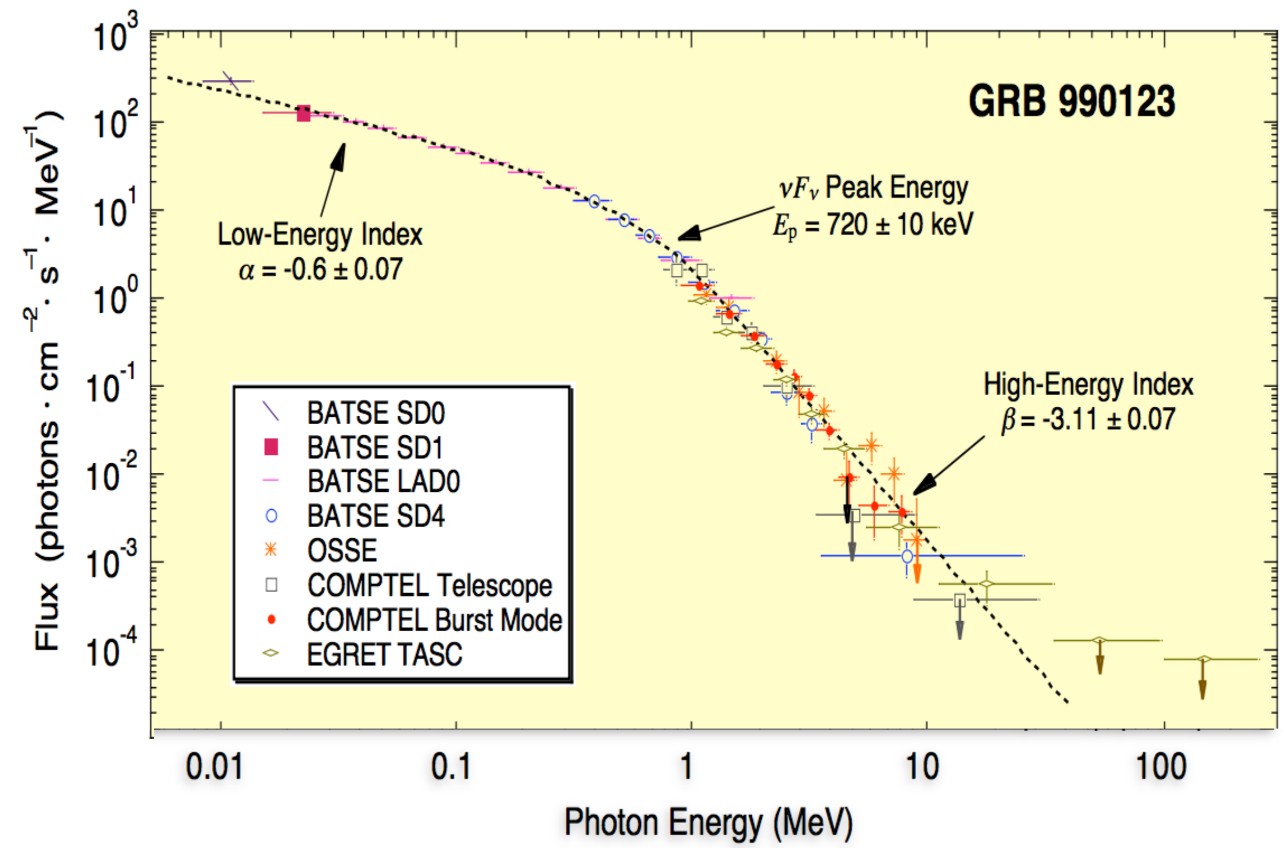
$$N(E) = A \cdot \left(\frac{E}{100\ \mathrm{keV}}\right)^{\alpha} \cdot \exp\left(-E/E_0\right),$$

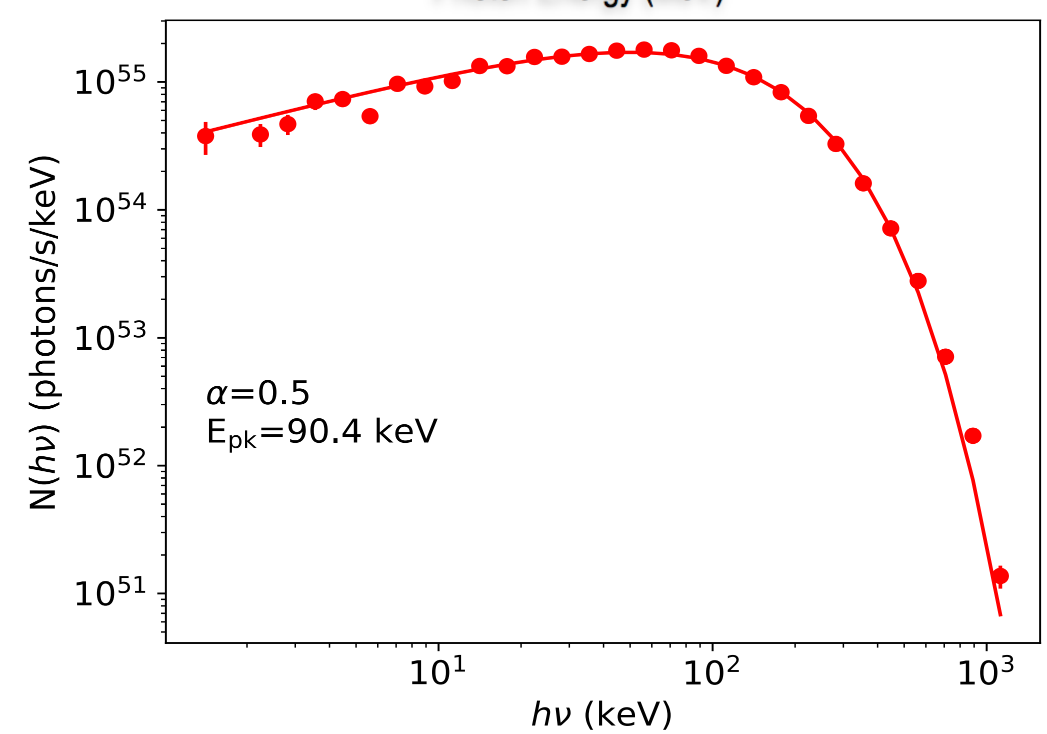
$$N(E) = A \cdot \left[\frac{(\alpha-\beta)\cdot E_0}{100\ \mathrm{keV}}\right]^{\alpha-\beta} \cdot \exp\left(\beta-\alpha\right) \cdot \left(\frac{E}{100\ \mathrm{keV}}\right)^{\beta}$$

$$E_{pk} = E_o(2+\alpha)$$

COMPTONIZED FUNCTION

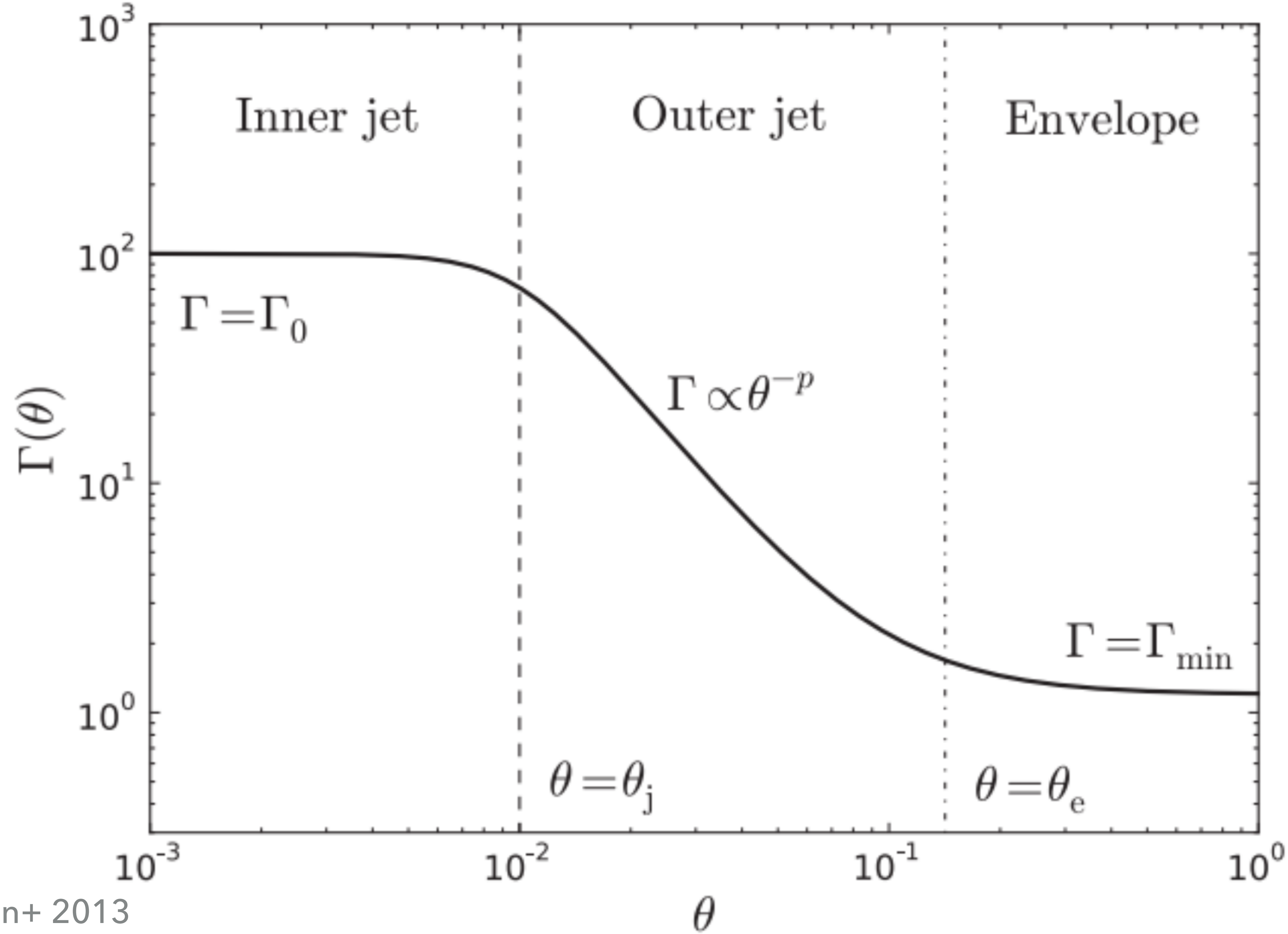
$$f_{\mathrm{COMP}}(E) = A\left(\frac{E}{100\ \mathrm{keV}}\right)^{\alpha} \exp\left[-\frac{(\alpha+2)E}{E_{\mathrm{p}}}\right]$$



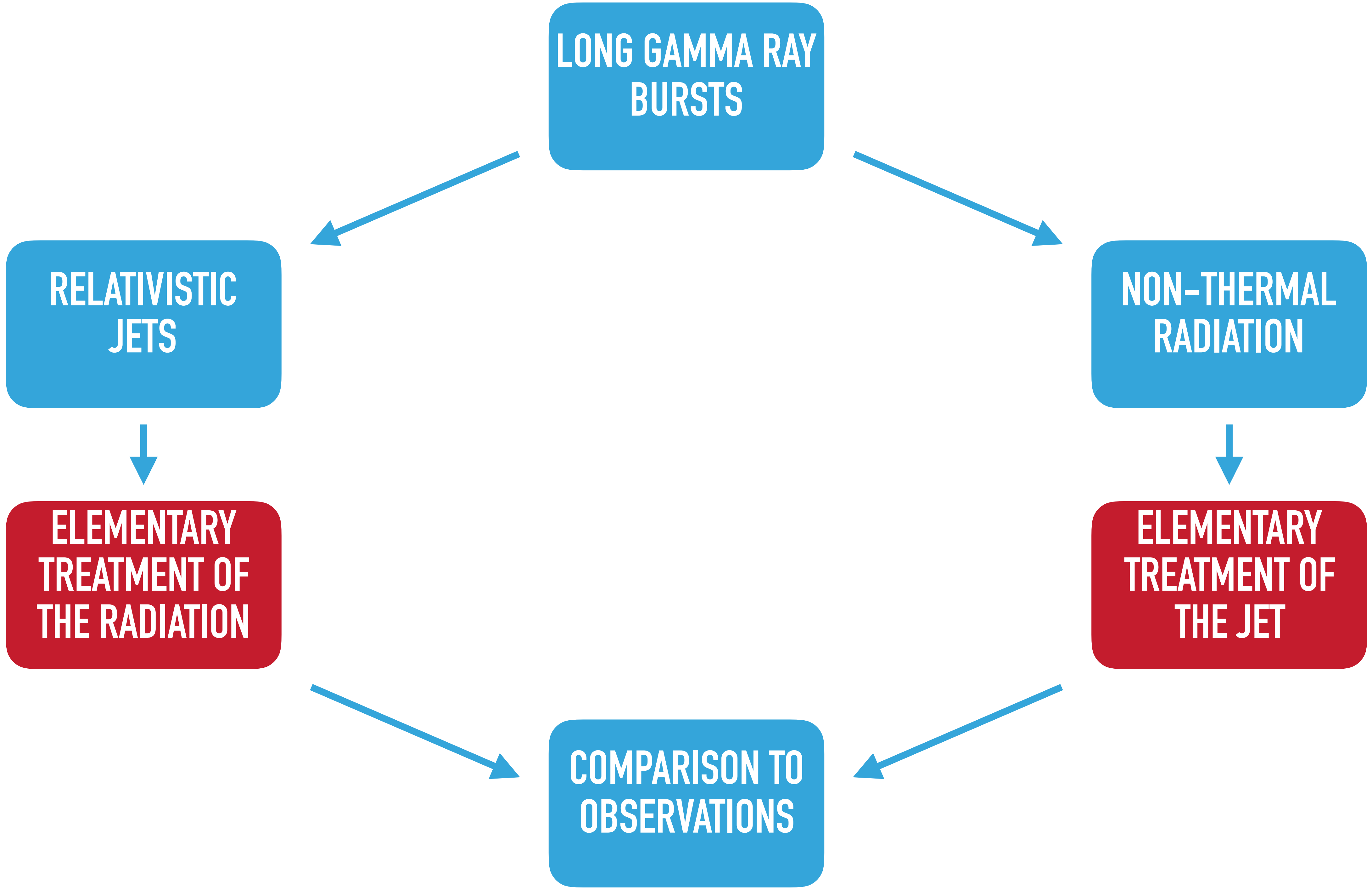


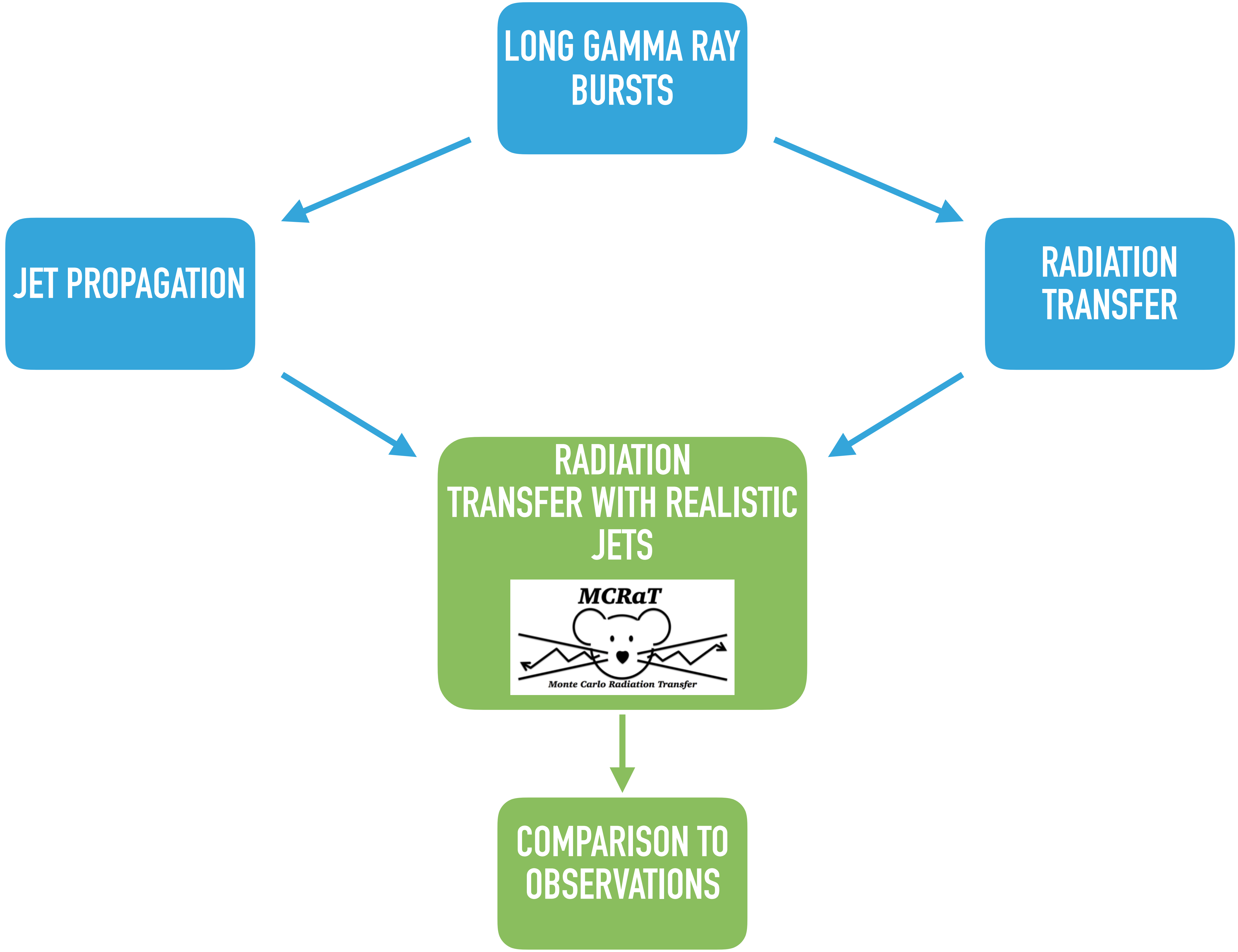
Briggs+ 1999

…ON SIMPLE OUTFLOWS



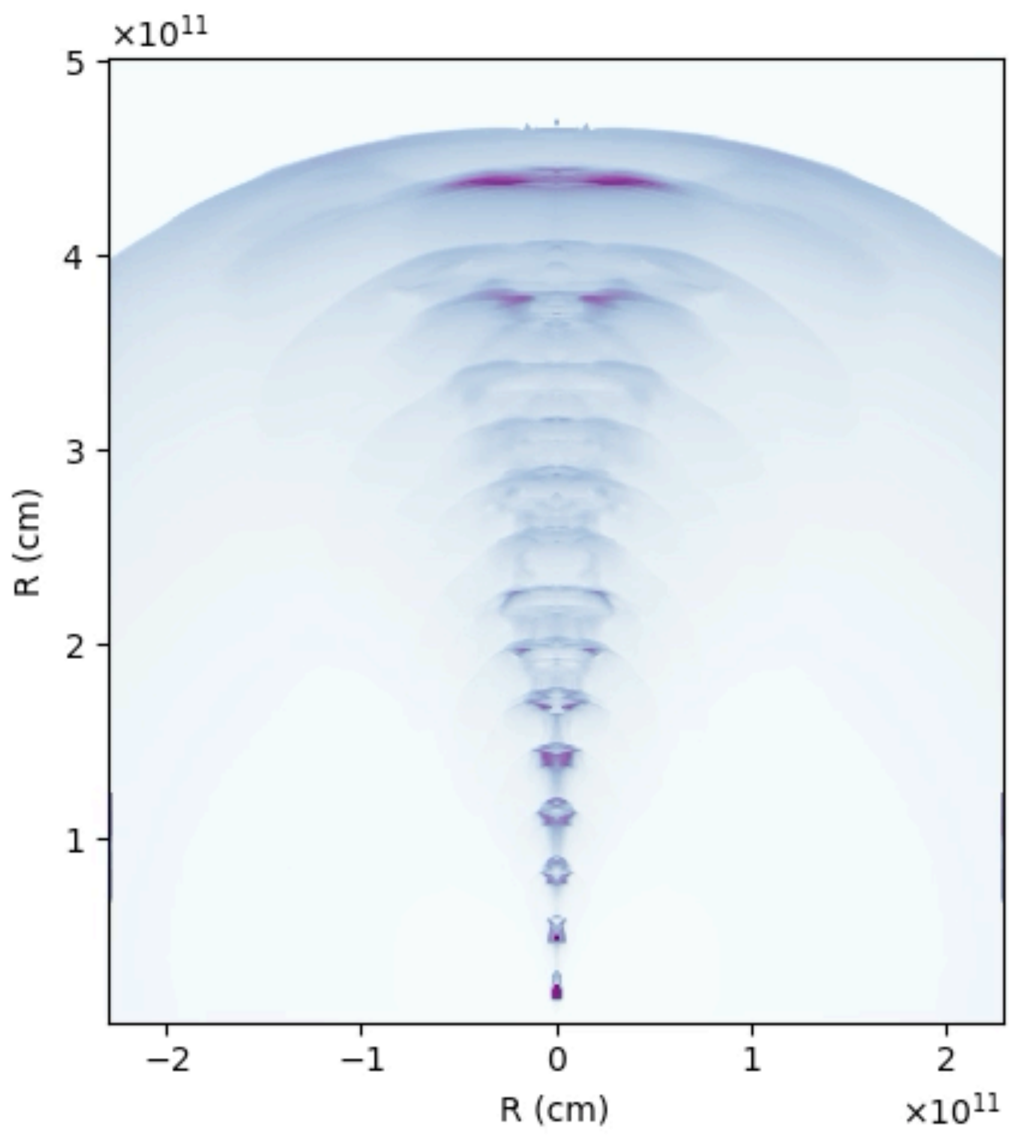
Lundman+ 2013


LONG GAMMA RAY BURSTS
RELATIVISTIC JETS
NON-THERMAL RADIATION
ELEMENTARY TREATMENT OF THE RADIATION
ELEMENTARY TREATMENT OF THE JET
COMPARISON TO OBSERVATIONS


LONG GAMMA RAY BURSTS
JET PROPAGATION
RADIATION TRANSFER
RADIATION TRANSFER WITH REALISTIC JETS
MCRaT
Monte Carlo Radiation Transfer
COMPARISON TO OBSERVATIONS

MONTE CARLO SCATTERING OF PHOTONS IN THE JET

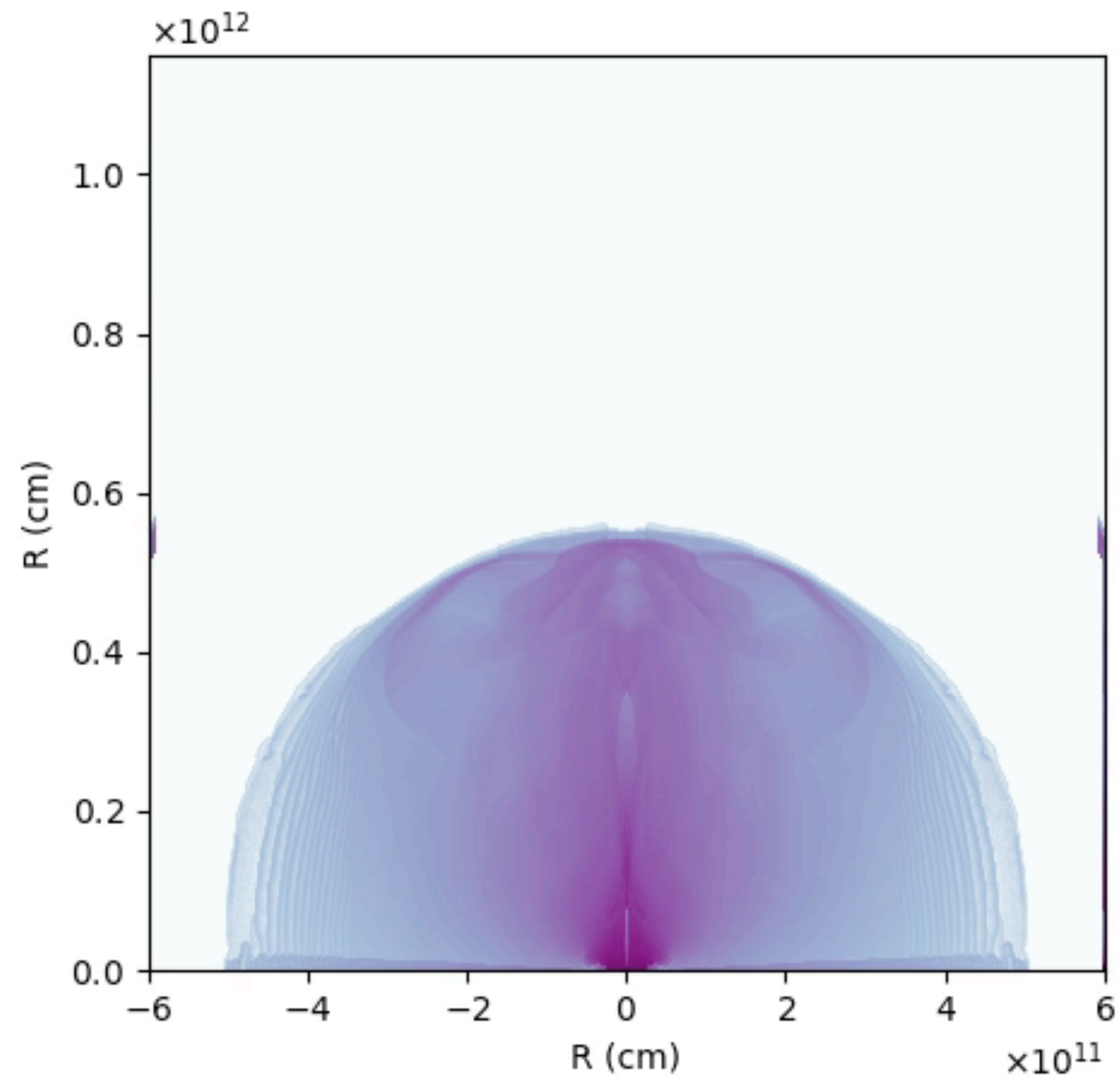
VARIABLE SIMULATION SET



- 1SPIKE
- 40SPIKES
- 40SP_DOWN

Lopez-Camara+ 2014

CONSTANT SIMULATION SET

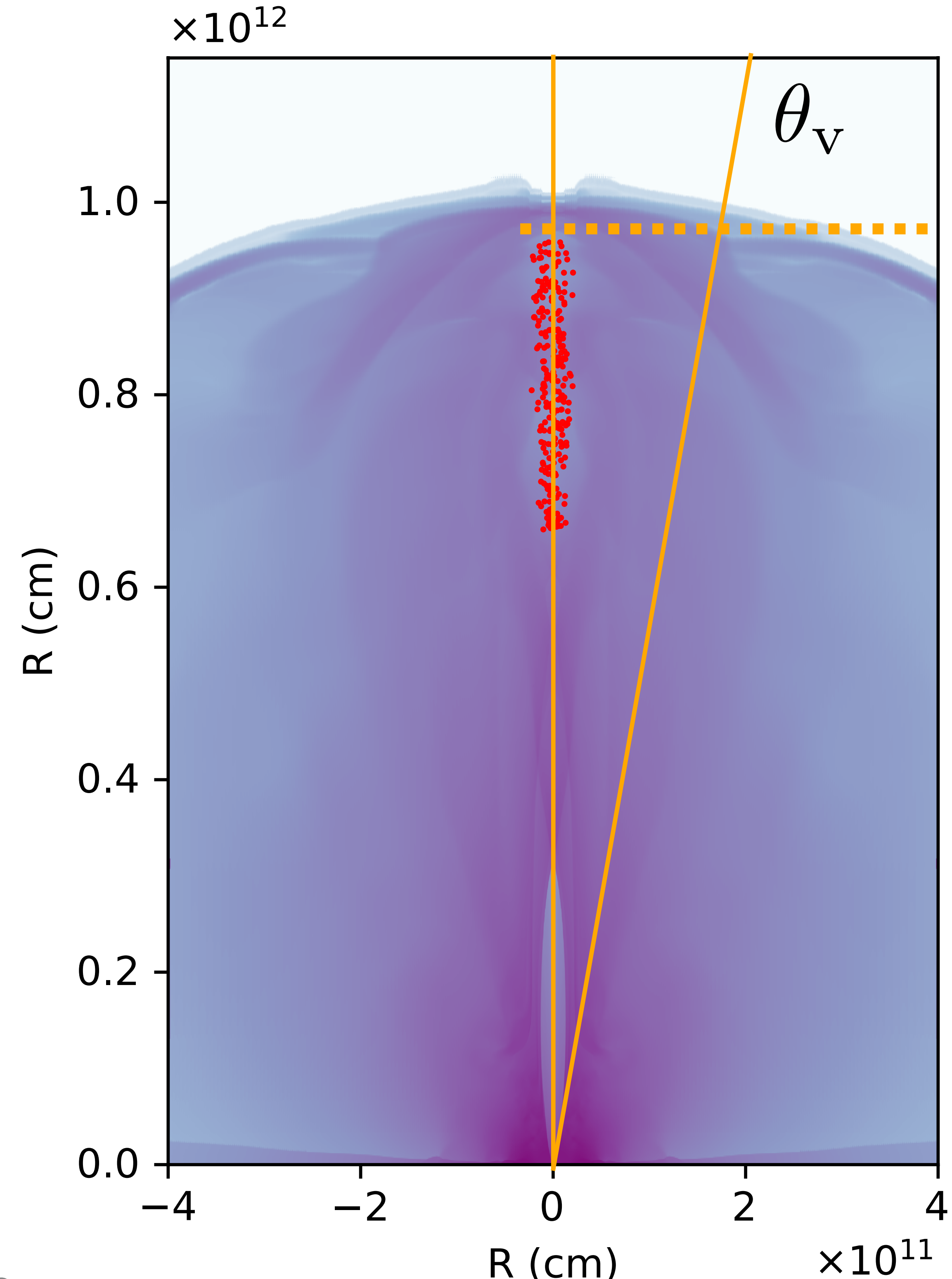


- 16TI
- 16OI
- 35OB

Lazzati+ 2013a

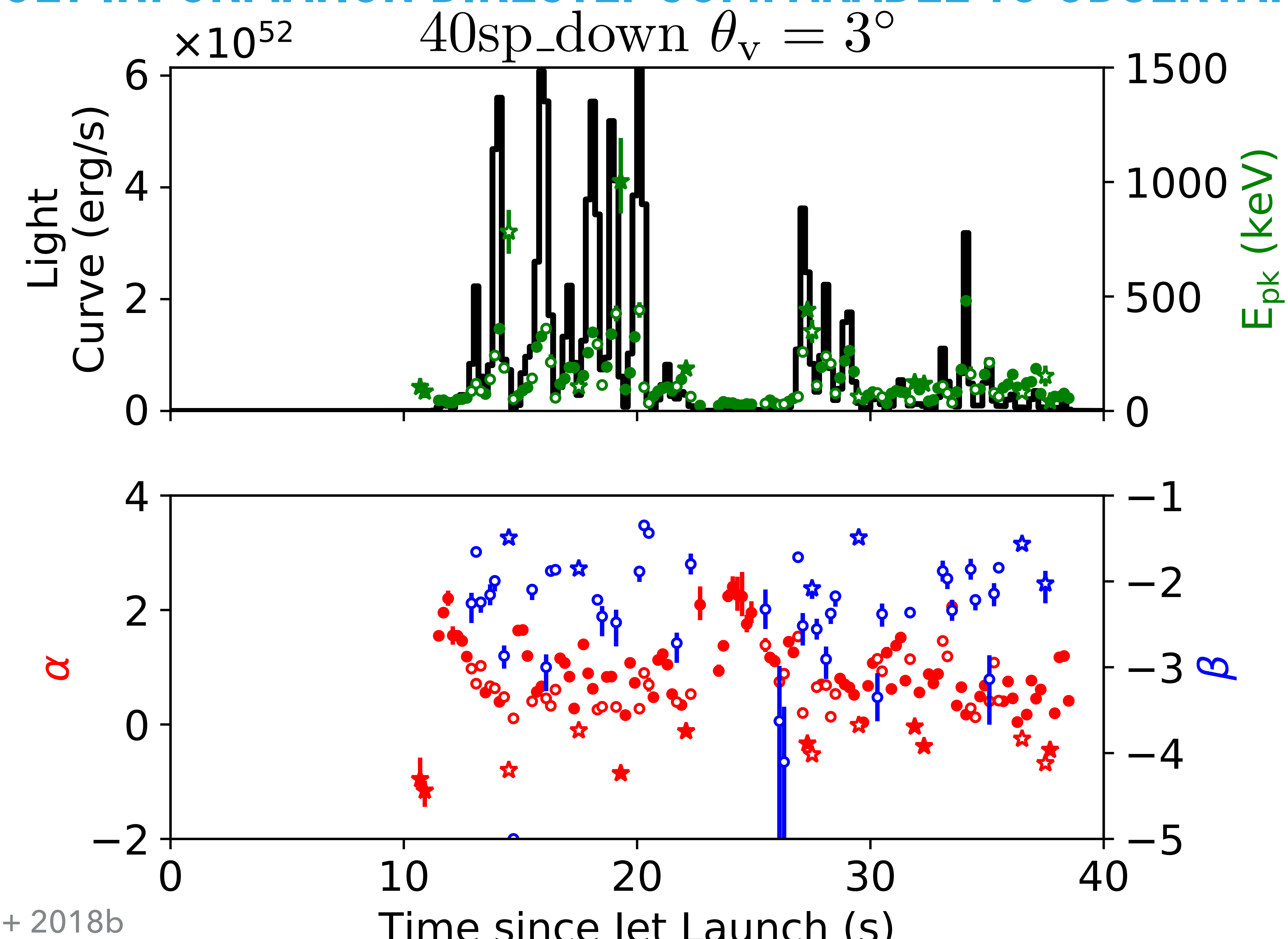
COLLECTING THE PHOTONS LEADS TO OBSERVATIONS OF THE SIMULATED EVENT

- For a given viewing angle collect the photons propagating in that direction
- Identify which photons arrive at what time
- Use this info to construct light curves and time resolved spectra
- Fit the spectral bins with the Band or "Comptonized" function as determined by a statistical F-Test



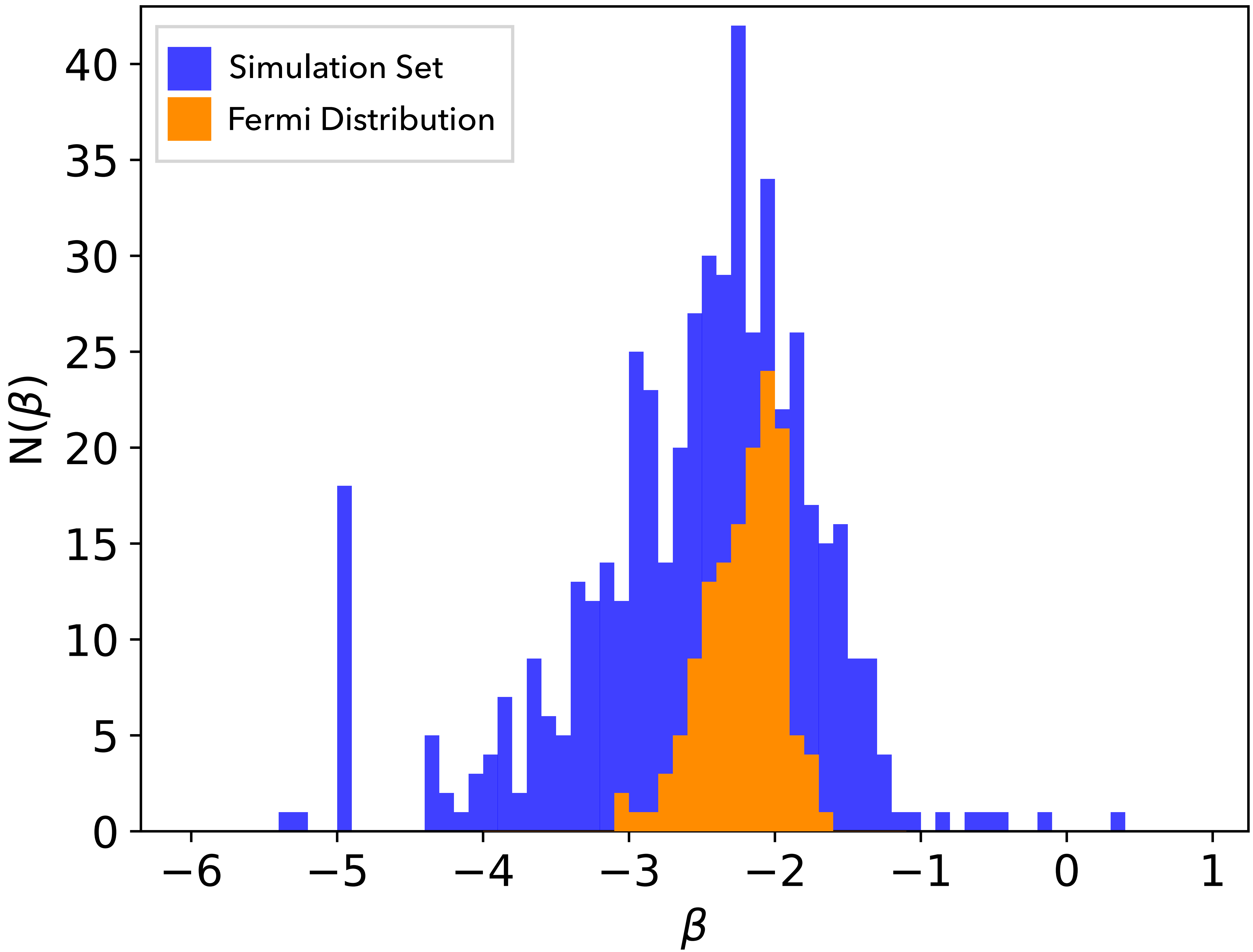
Lazzati 2016; Parsotan & Lazzati 2018a, Parsotan+ 2018b

WE GET INFORMATION DIRECTLY COMPARABLE TO OBSERVATIONS

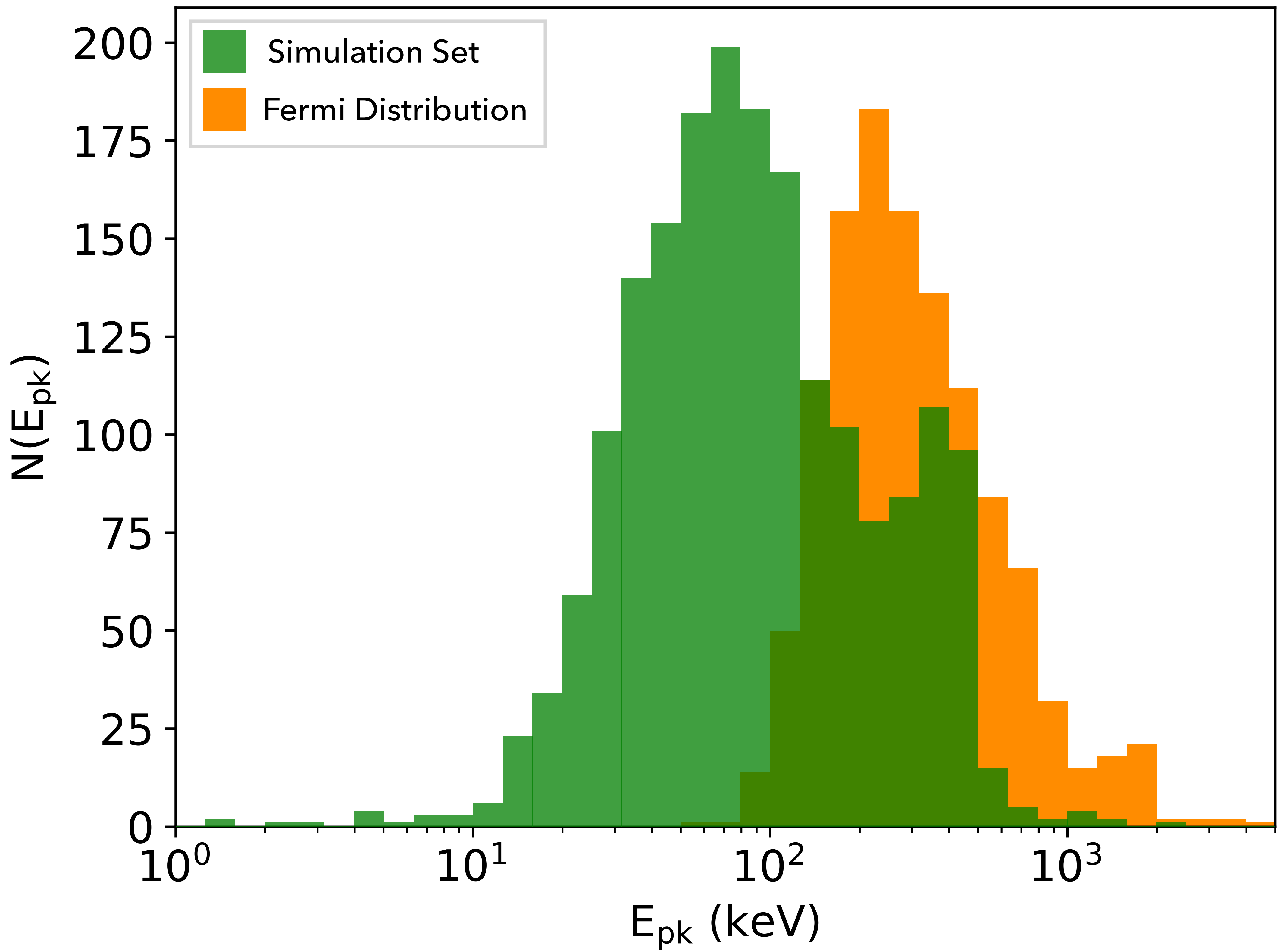


Parsotan+ 2018b

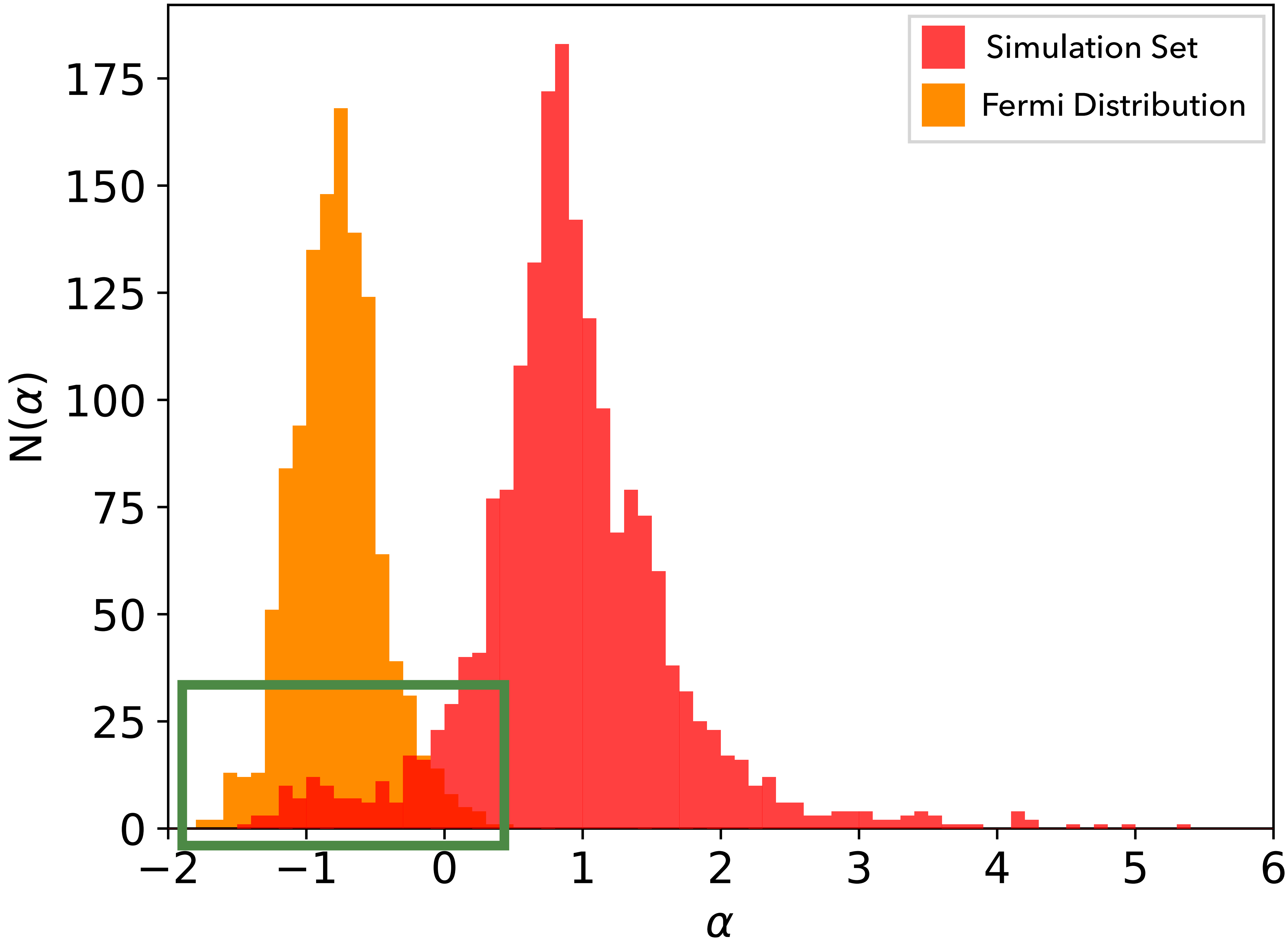
COMPTON SCATTERING CAN RECREATE THE BAND β PARAMETER



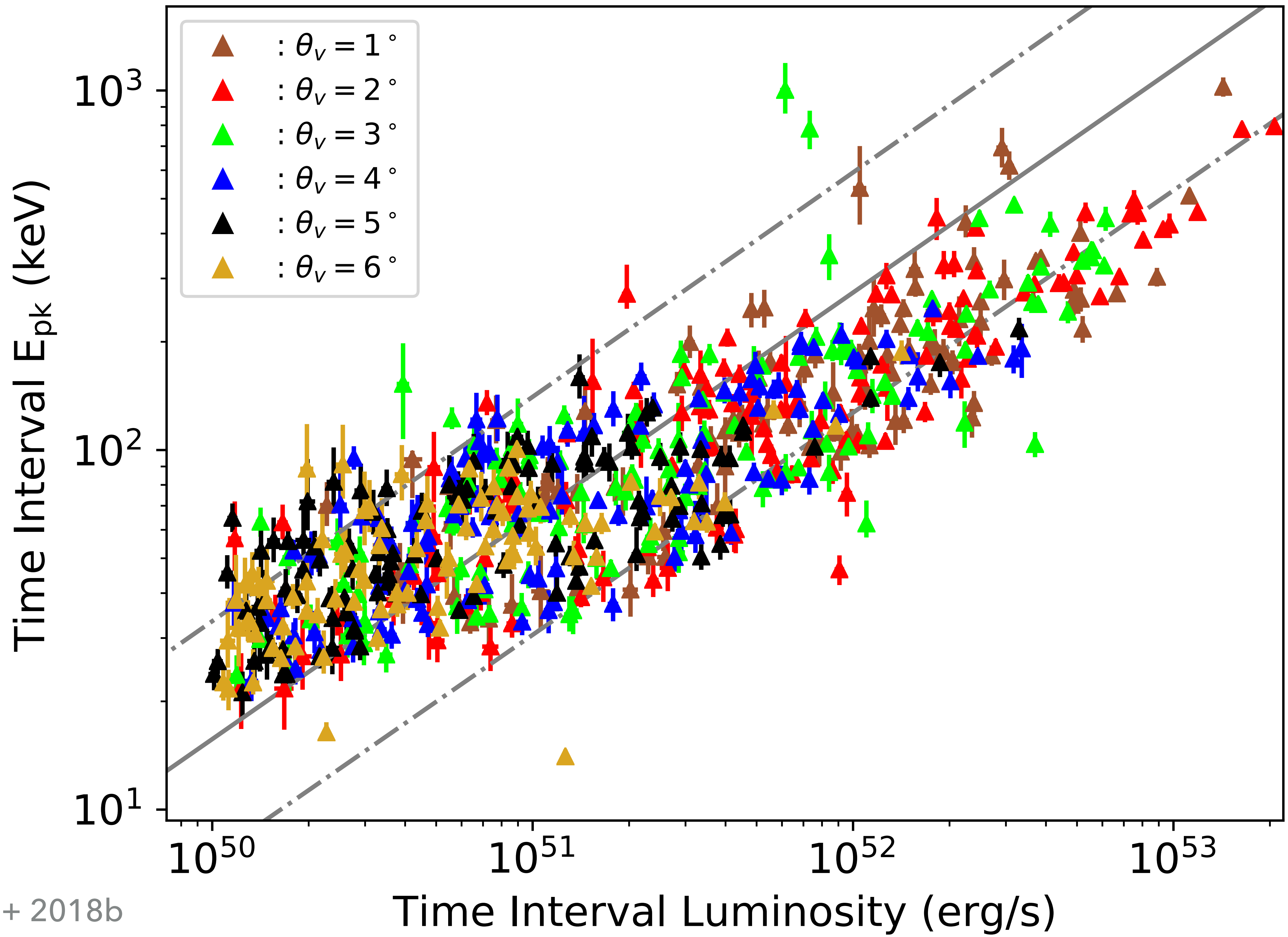
COMPTON SCATTERING CAN RECREATE THE PEAK ENERGIES



COMPTON SCATTERING CAN RECREATE THE BAND LOW ENERGY PARAMETERS

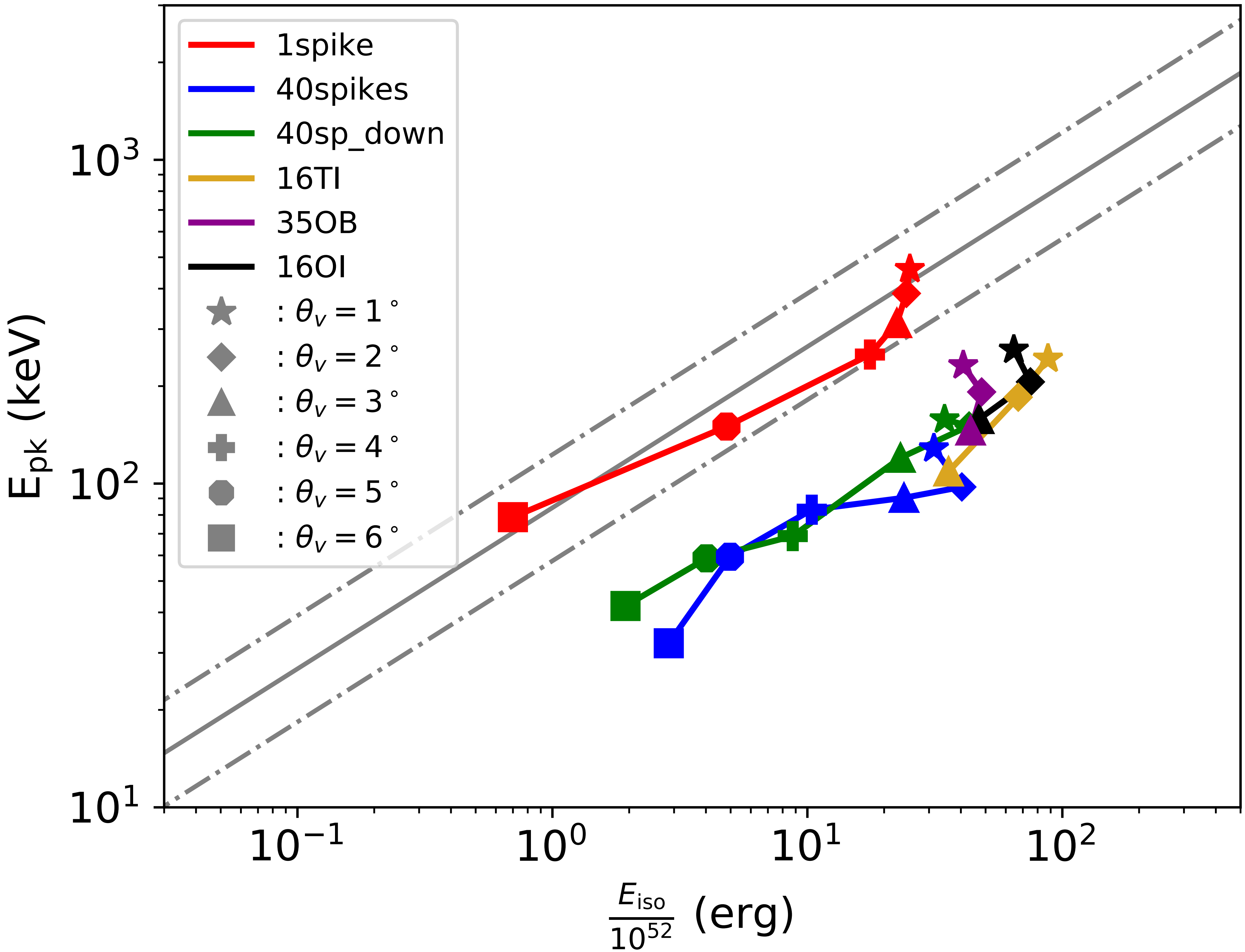


THE SIMULATION SET IS CONSISTENT WITH THE GOLENETSKII RELATION

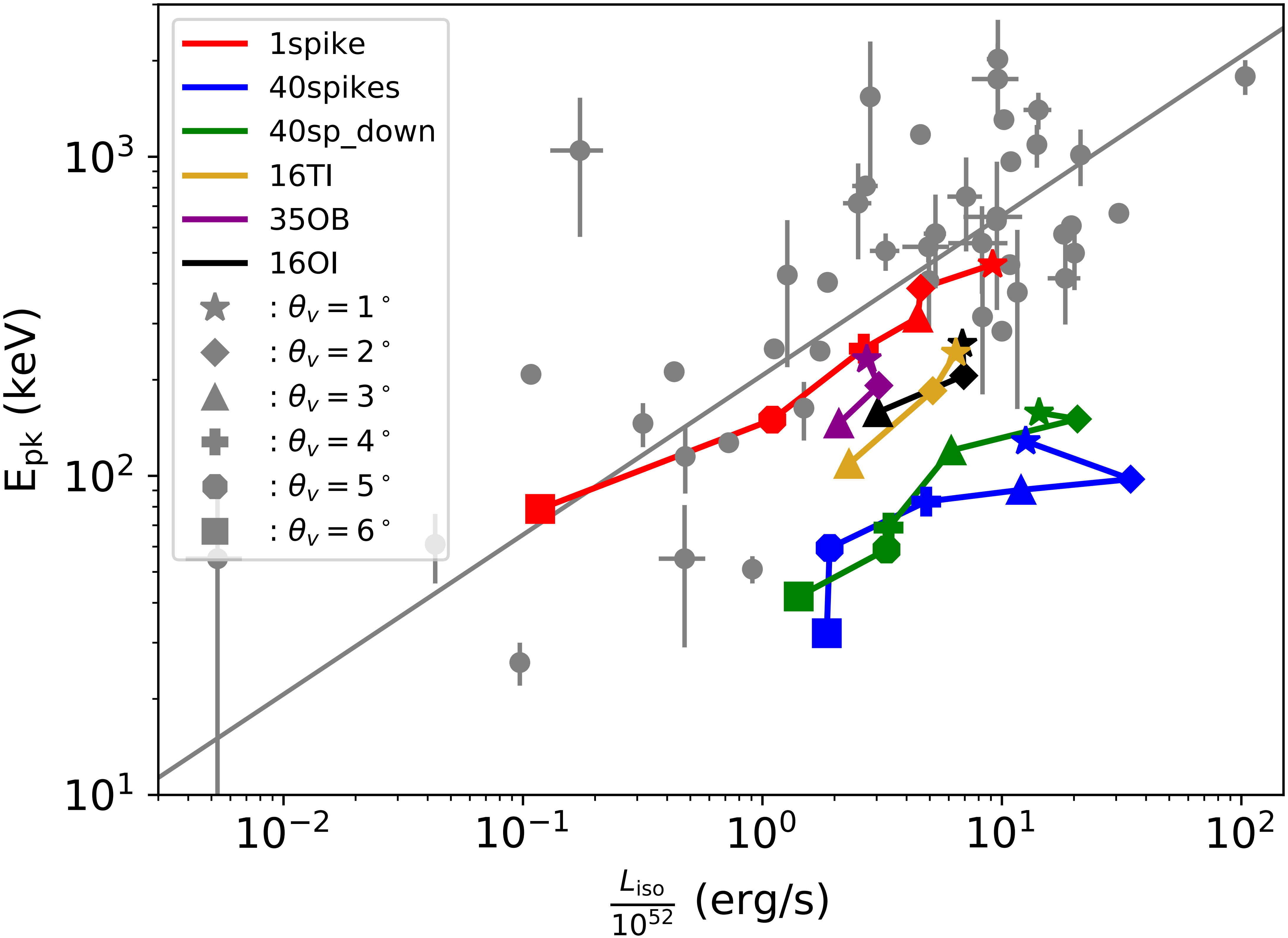


Parsotan+ 2018b

THE SIMULATION SET IS NOT CONSISTENT WITH THE AMATI RELATION



THE SIMULATION SET IS RELATIVELY CONSISTENT WITH THE YONETOKU RELATION



SUMMARY

- We can conduct global radiative transfer simulations of synthetic GRBs using realistic jet profiles
- We can investigate the effects that varying central engine temporal properties have on the resulting radiation
- We are in agreement with the Yonetoku and Golenetskii relations but not the Amati relation
- The Band parameters can be reproduced with photospheric emission

IMPROVEMENTS WILL BE MADE TO MCRAT

- Need more low energy photons
  - Add synchrotron radiation
- Conduct this analysis for simulations of SGRBs and try to understand the emission from GRB170817A
- Include instrumental effects in synthetic observations

PARSOTAN & LAZZATI 2018 APJ 853 8

PARSOTAN+ 2018 APJ 869 103

RESEARCHGATE.NET/PROFILE/TYLER_PARSOTAN

SCIENCE.OREGONSTATE.EDU/~PARSOTAT/

GITHUB.COM/LAZZATI-ASTRO/MCRAT

THANK YOU

QUESTIONS?

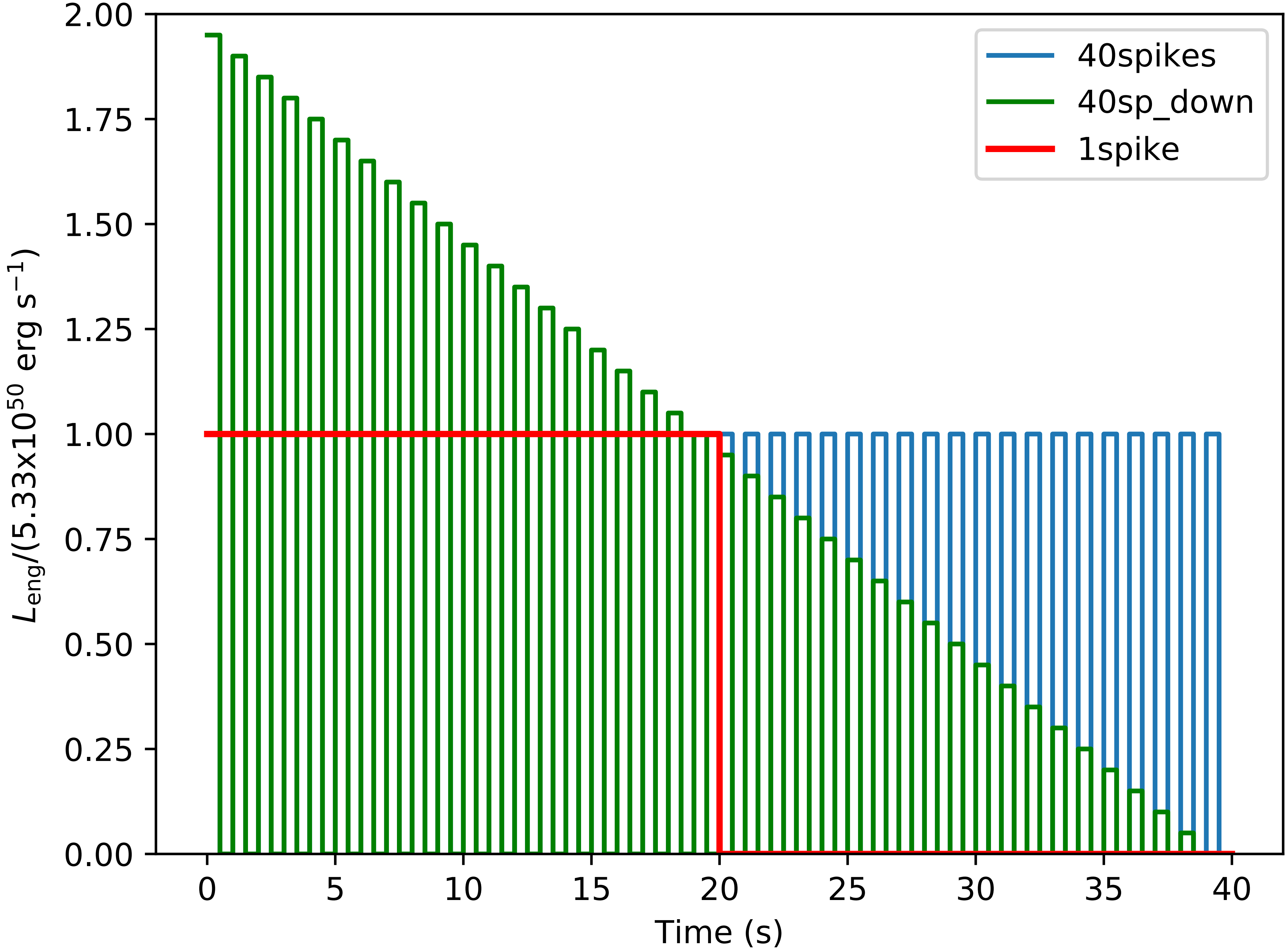
BACKUP SLIDES

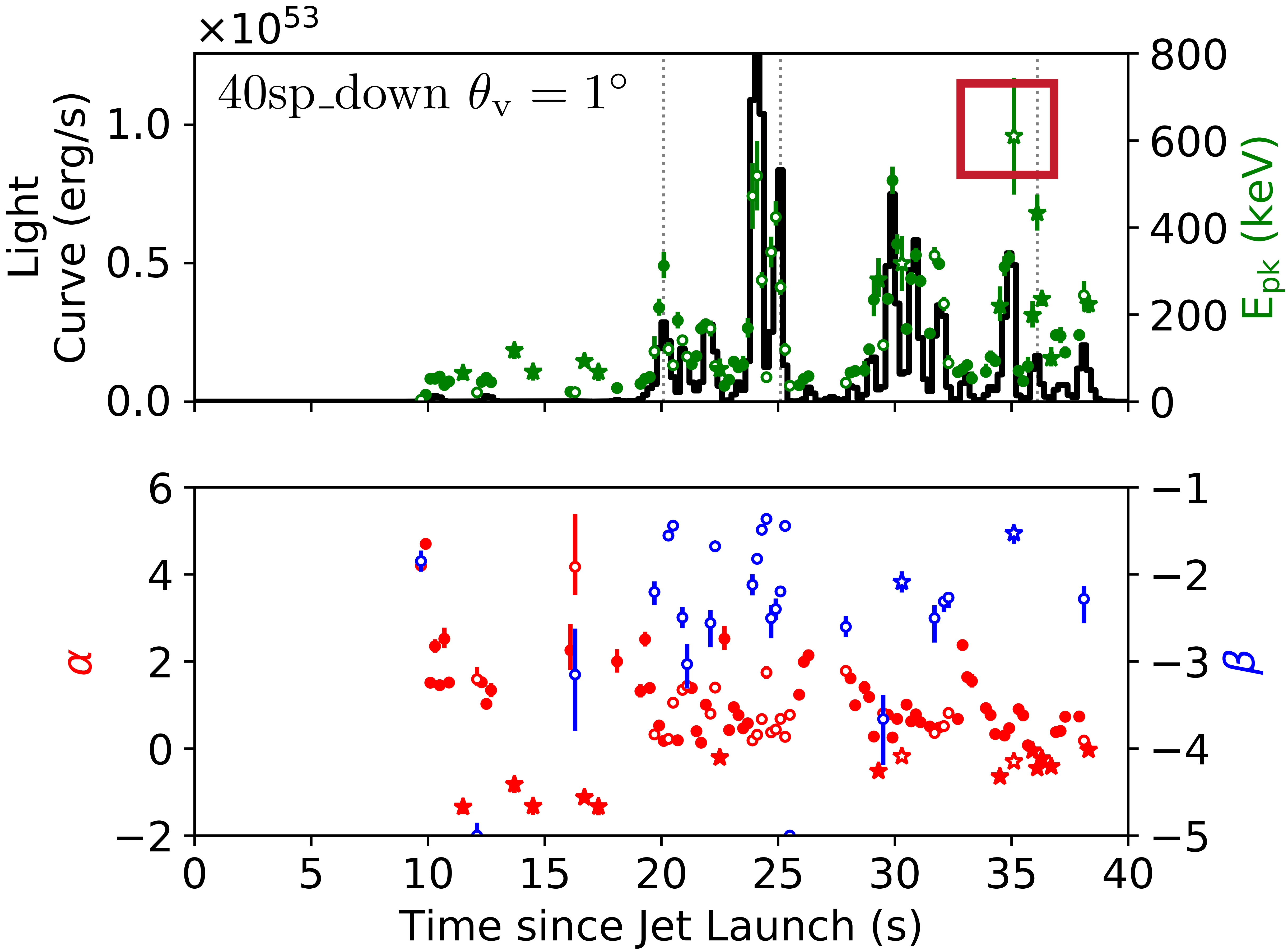
THE "CONSTANT" SIMULATION SET

Simulation Name	Progenitor	Jet Luminosity (erg/s)	Γ_∞ [a]
16OI	16OI	5.33×10^{50}	400
35OB	35OB	5.33×10^{50}	400
16TI	16TI	5.33×10^{50}	400
16TI.e150	16TI	1×10^{50}	400
16TI.e150.g100	16TI	1×10^{50}	100

[a] Asymptotic Lorentz factor

THE "VARIABLE" SIMULATION SET




×10^53
40sp_down θv = 1°
Light Curve (erg/s)
Epk (keV)
α
β
Time since Jet Launch (s)

HIGH LATITUDE PHOTONS CONTRIBUTE TO THE LOW ENERGY TAIL OF SPECTRA