OSU
Oregon State
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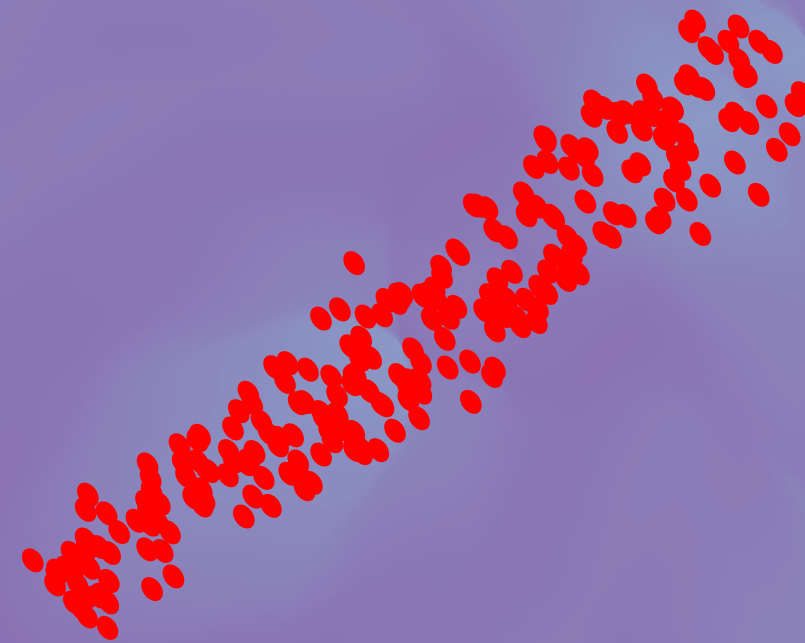
College of Science



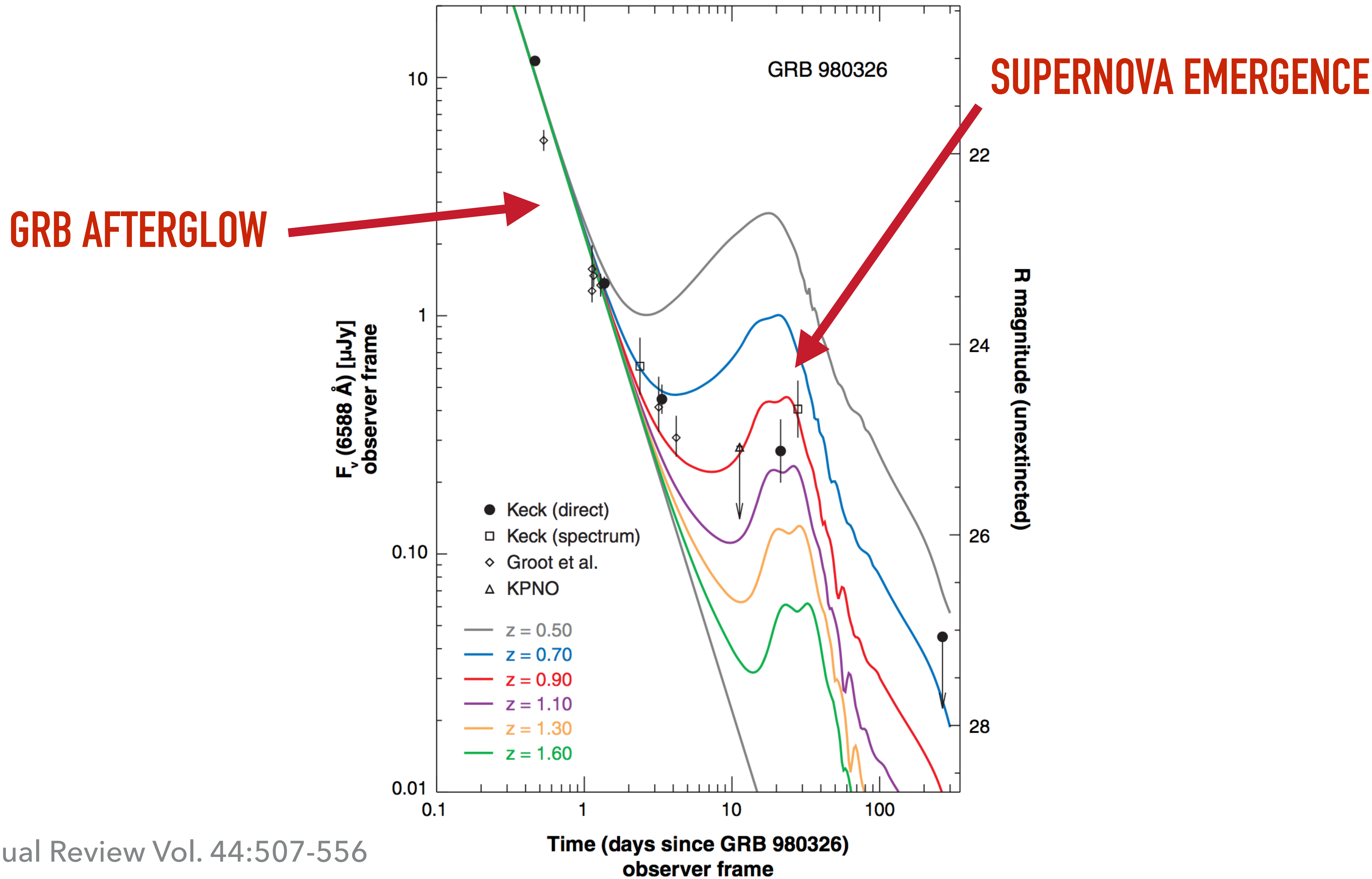
TYLER PARSOTAN

MONTE CARLO RADIATION TRANSFER IN LONG GRBS

OUTLINE

- Introduction
  - Properties of GRBs, Radiation Transfer Models
- Motivation
- Methods
- Results
  - Comparisons to Observations
  - L_{iso}-E_{pk} Tracking

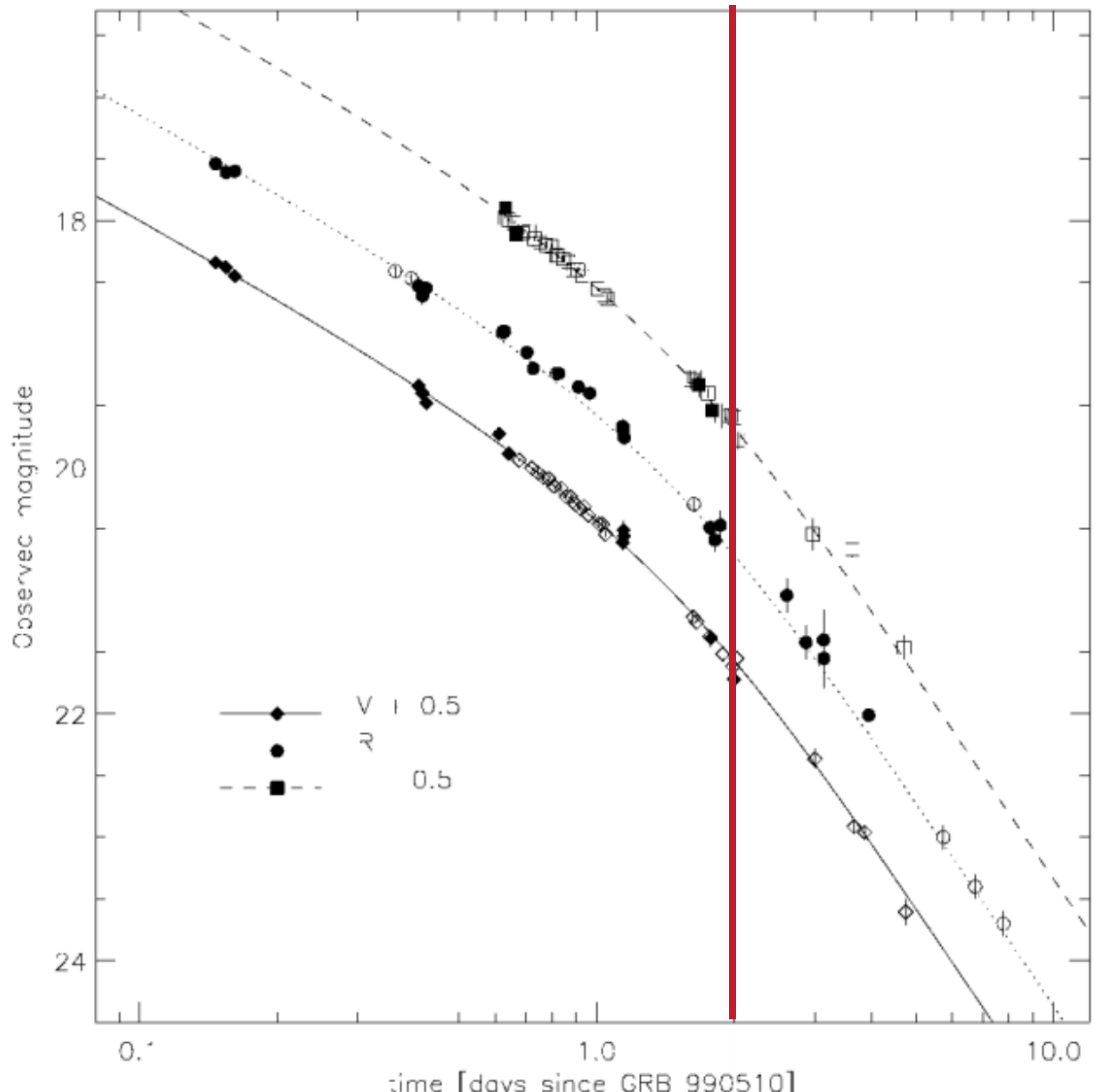
LGRBS ARE ASSOCIATED WITH CORE COLLAPSE SUPERNOVAE



Annual Review Vol. 44:507-556

GRBS ARE COLLIMATED, RELATIVISTIC OUTFLOWS

- How to account for the extremely high observed energies



ApJ 523:L121–L124

GRB SPECTRA ARE NON-THERMAL…

BAND FUNCTION

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

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

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

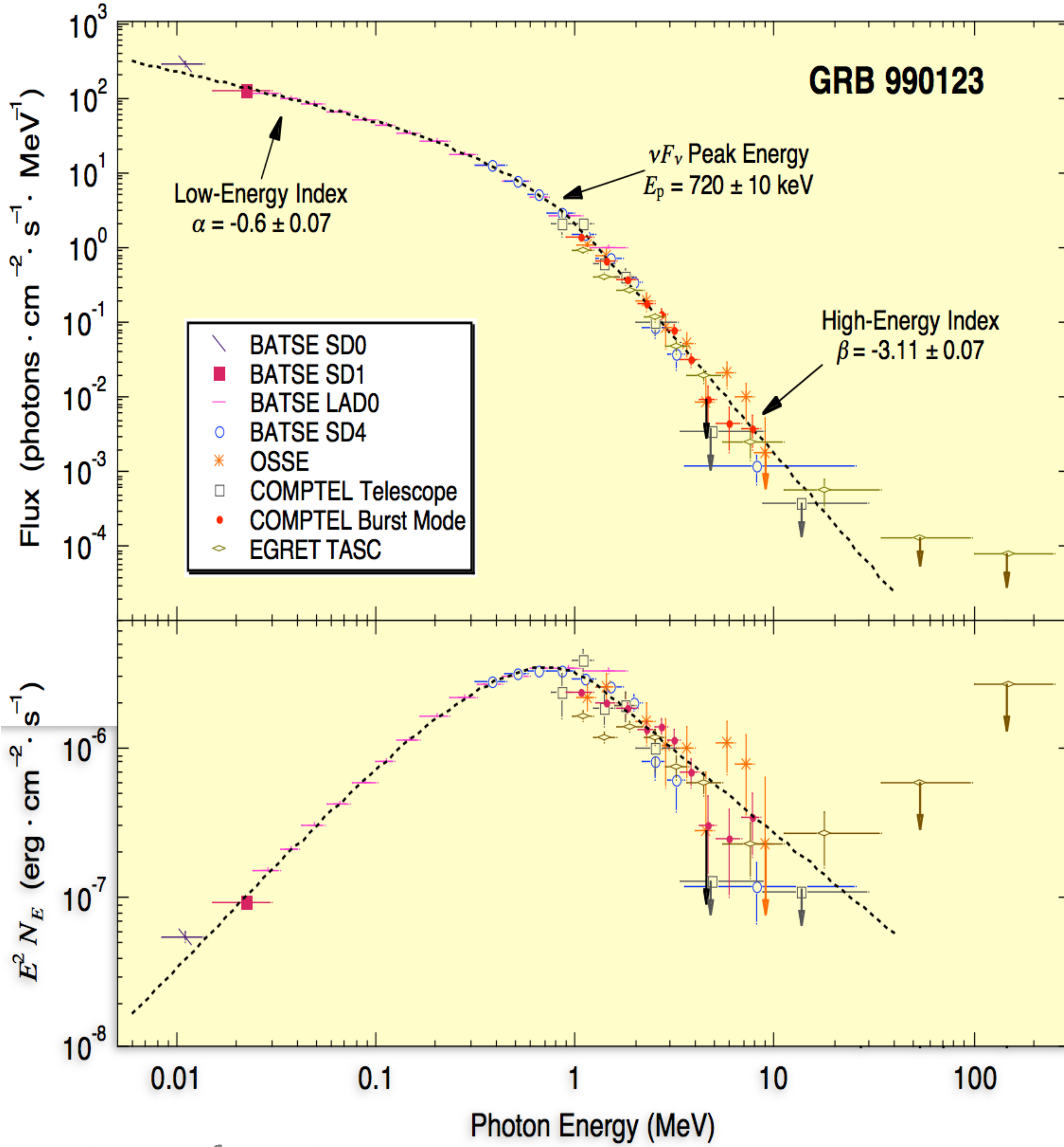


Figure from Preece

BUT THEY CAN BE FIT WITH A "THERMAL" SPECTRUM

BAND FUNCTION

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

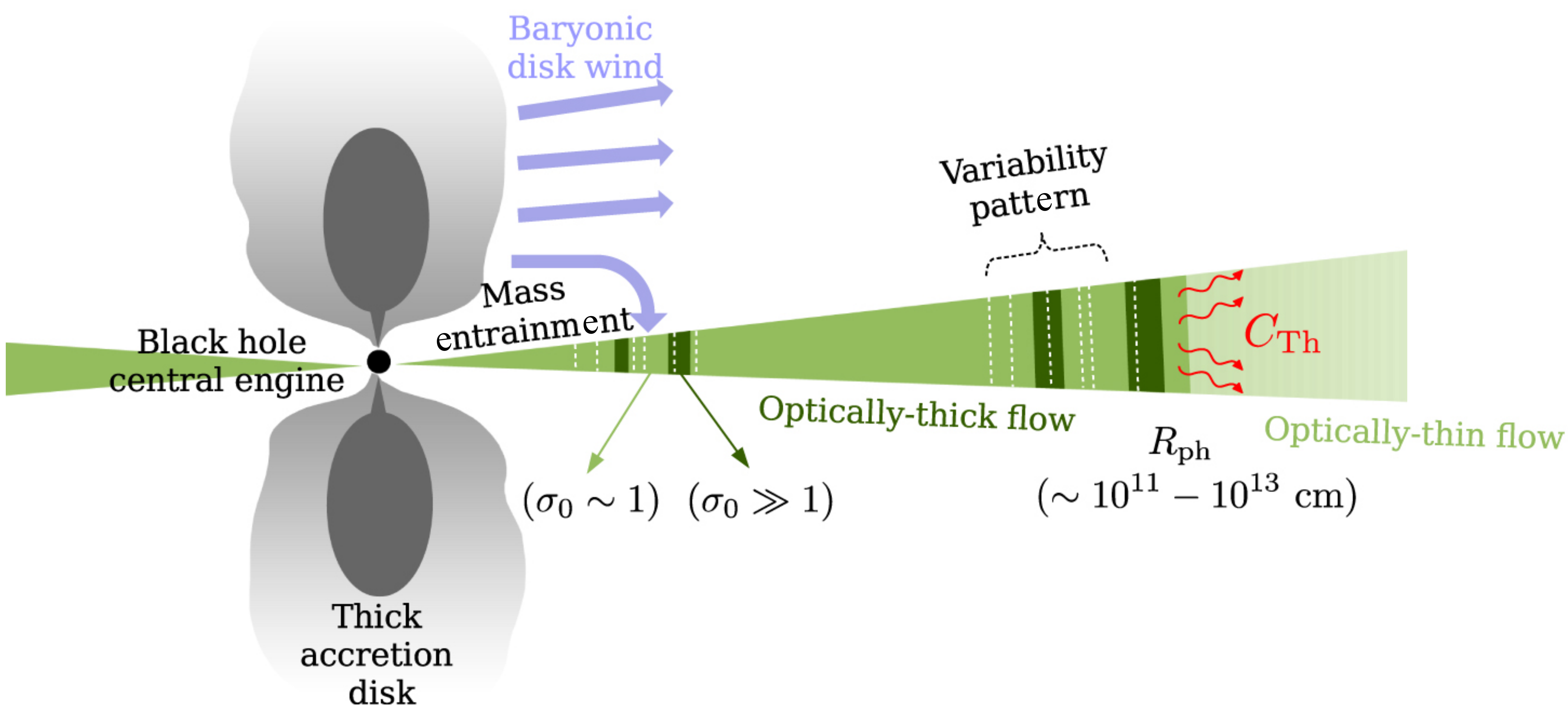
$$N(E) = A \cdot \left[\frac{(\alpha - \beta) \cdot E_0}{100\ \mathrm{keV}}\right]^{\alpha-\beta} \cdot \exp\left(\beta - \alpha\right) \cdot \left(\frac{E}{100\ \mathrm{keV}}\right)^{\beta}$$

COMPTONIZED FUNCTION

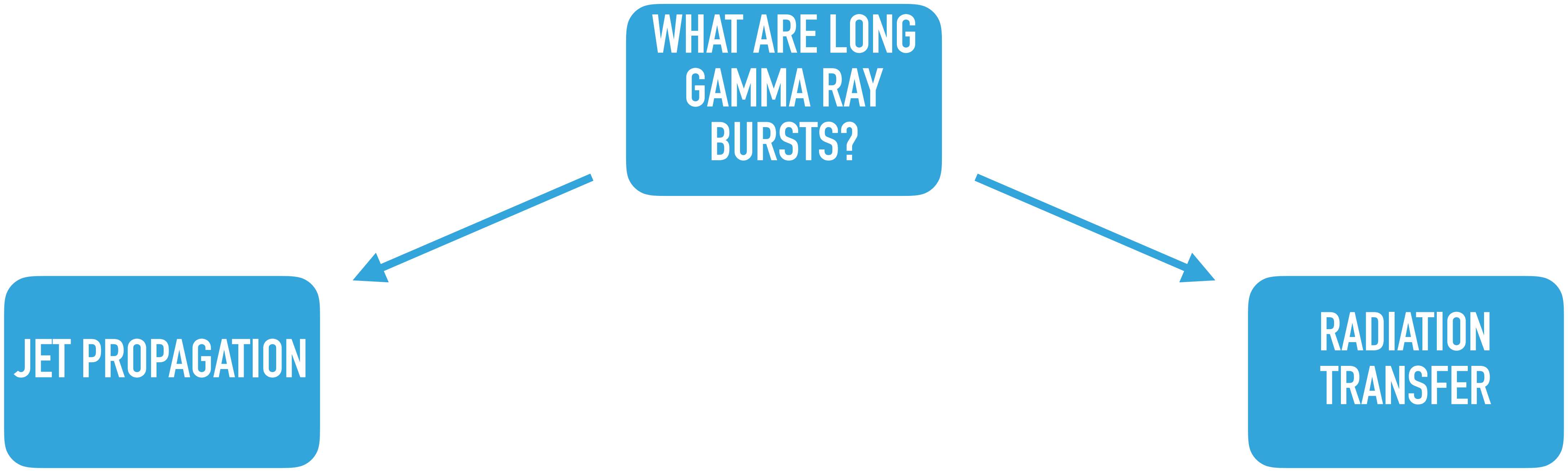
$$f_{\mathrm{COMP}}(E) = A\left(\frac{E}{100\ \mathrm{keV}}\right)^{\alpha} \exp\left[-\frac{(\alpha+2)E}{E_{\mathrm{p}}}\right]$$

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

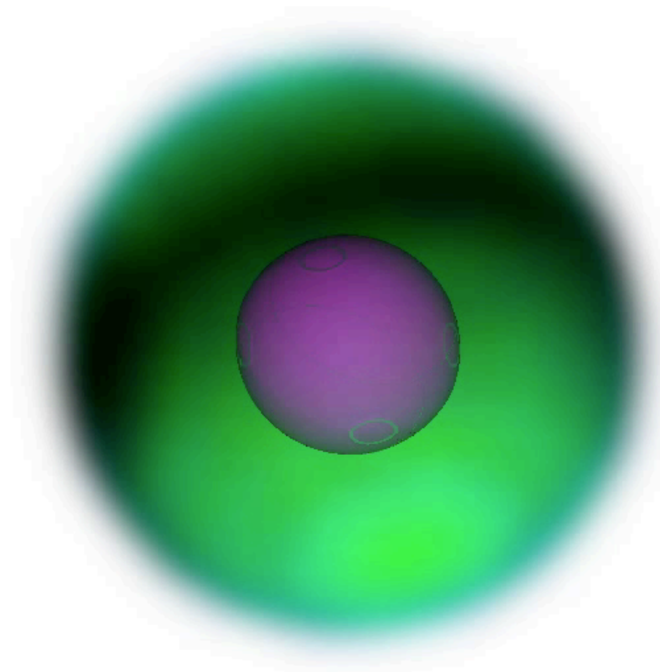
GRB RADIATION MODELS
PHOTOSPHERIC MODEL



Adapted from: S. Guiriec et al. 2016 The Astrophysical Journal Letters **831** L8


WHAT ARE LONG GAMMA RAY BURSTS?
JET PROPAGATION
RADIATION TRANSFER

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



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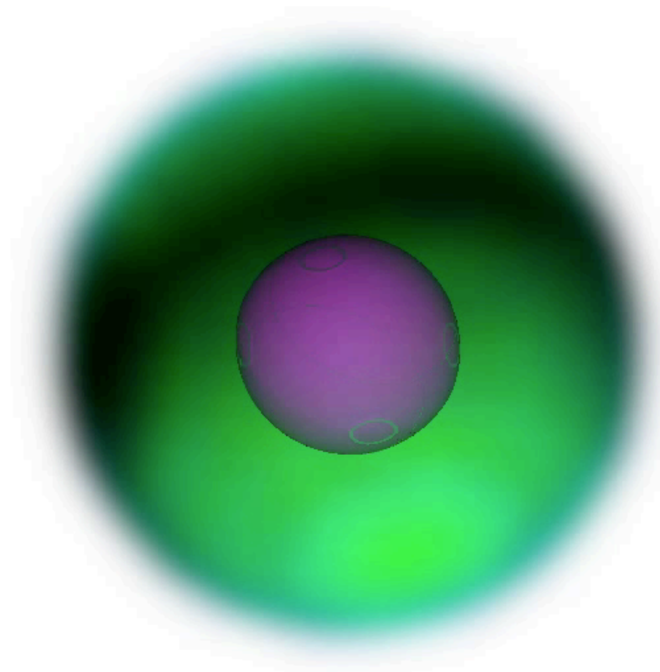
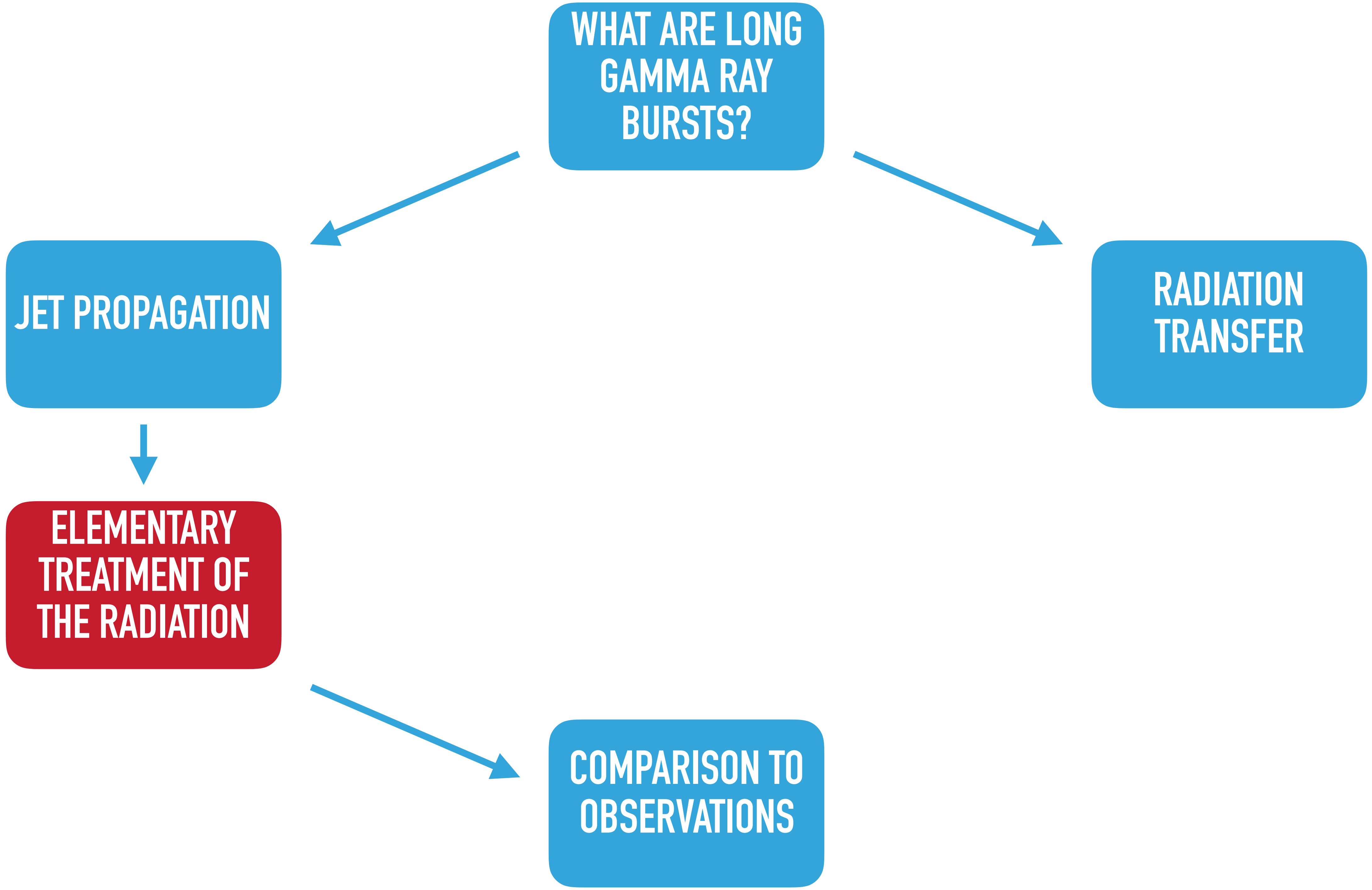
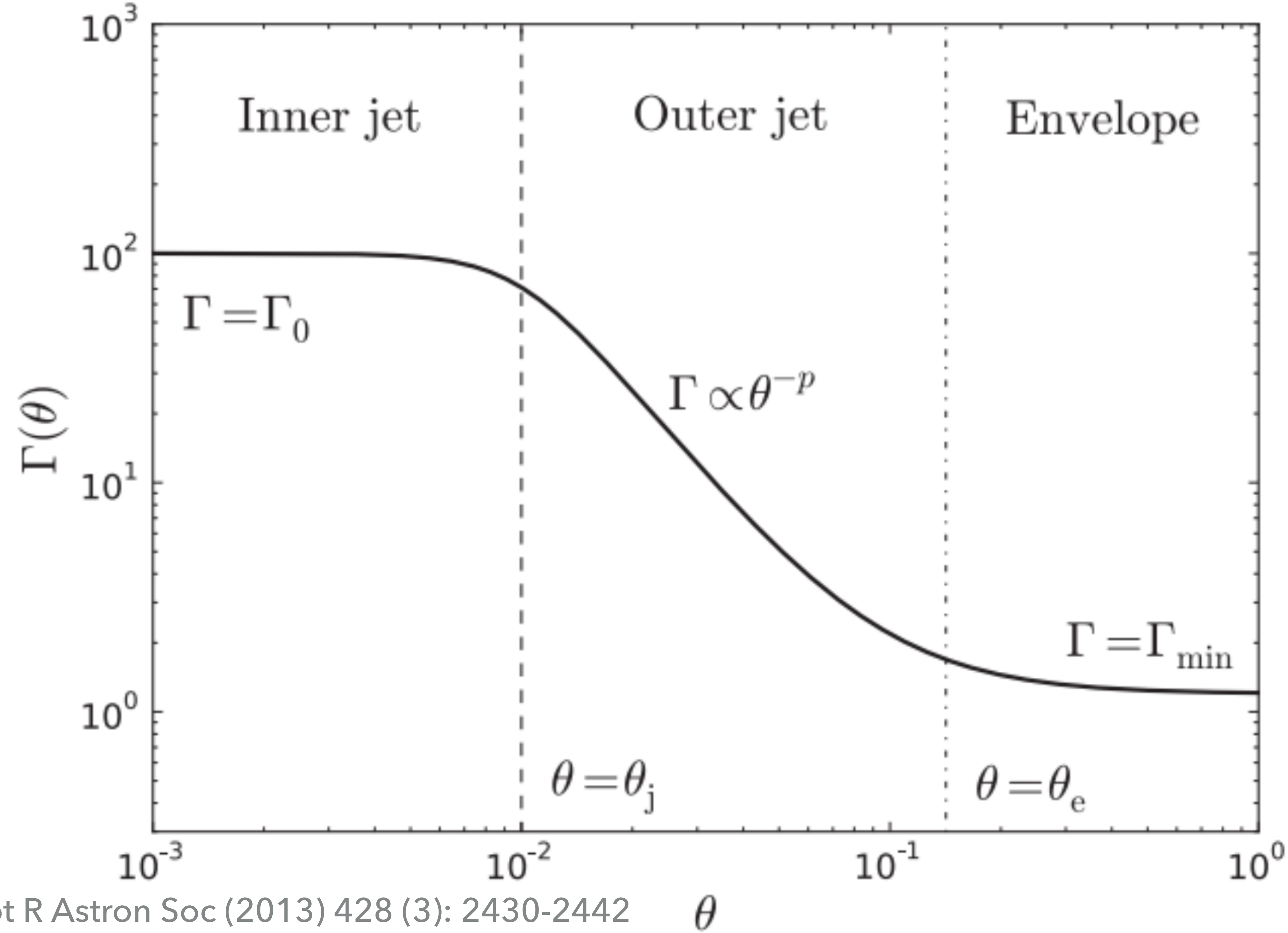
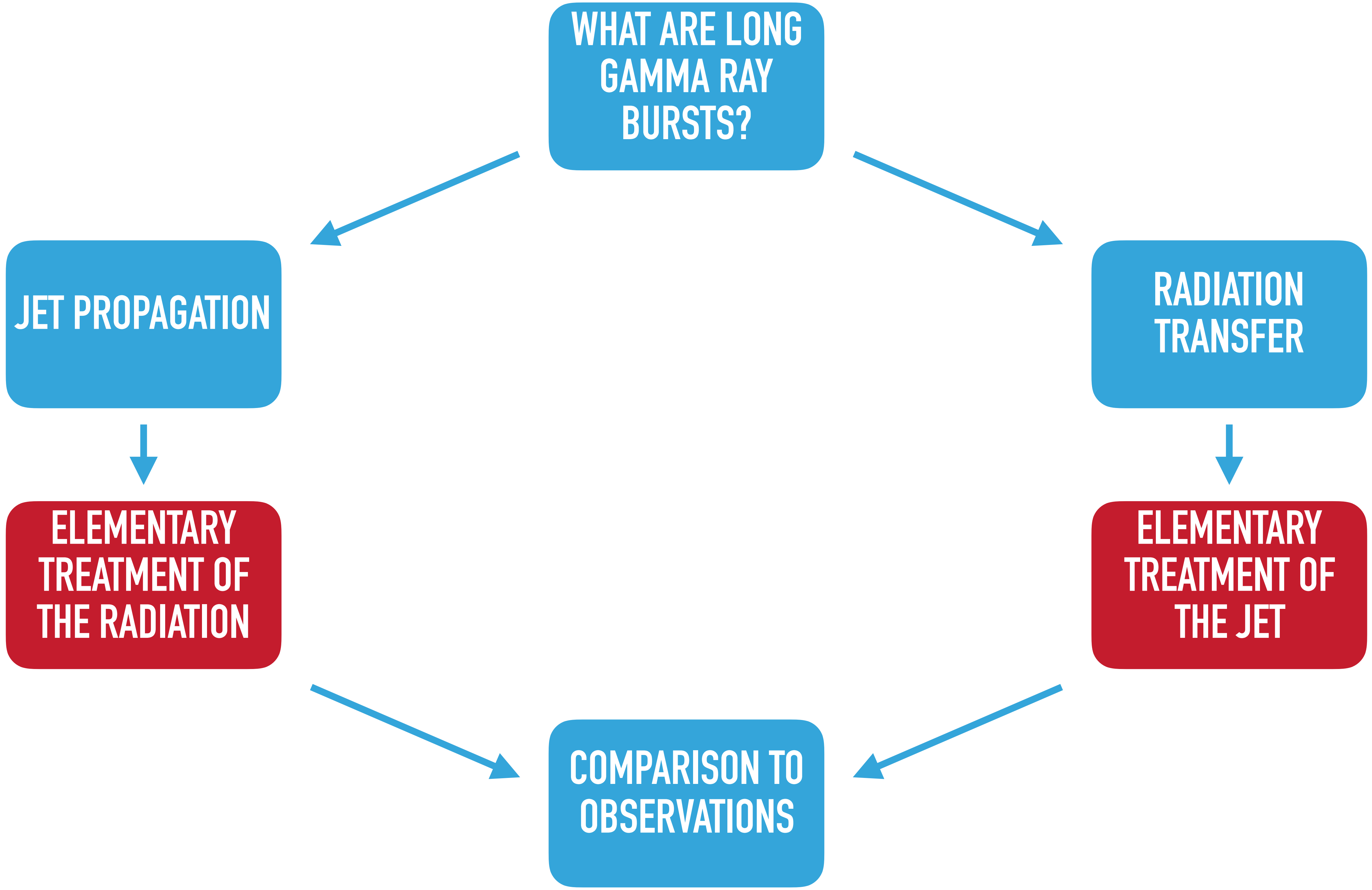


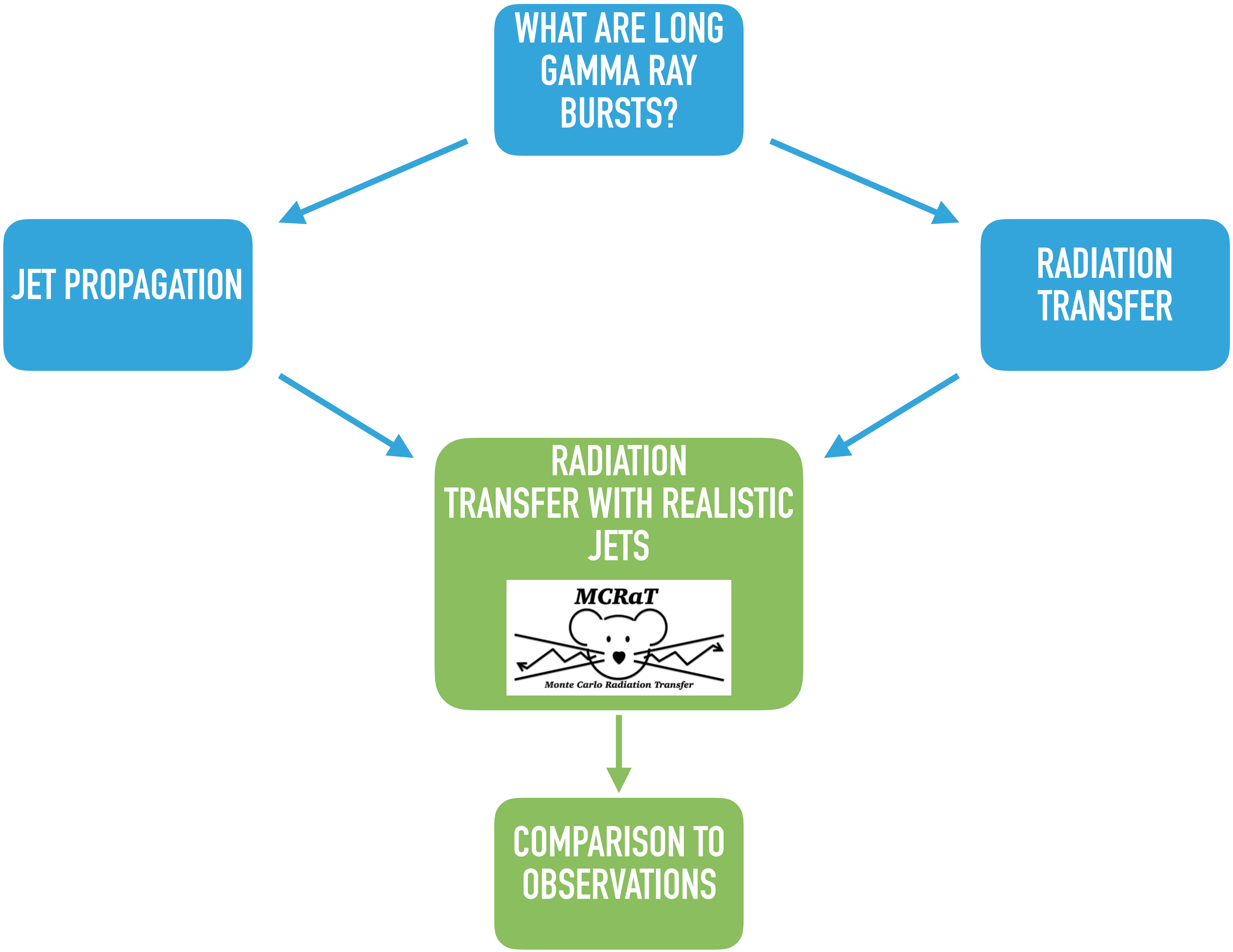

WHAT ARE LONG GAMMA RAY BURSTS?
JET PROPAGATION
RADIATION TRANSFER
ELEMENTARY TREATMENT OF THE RADIATION
COMPARISON TO OBSERVATIONS

WE CAN CONDUCT SELF CONSISTENT RADIATION TRANSFER CALCULATIONS ON SIMPLE OUTFLOWS

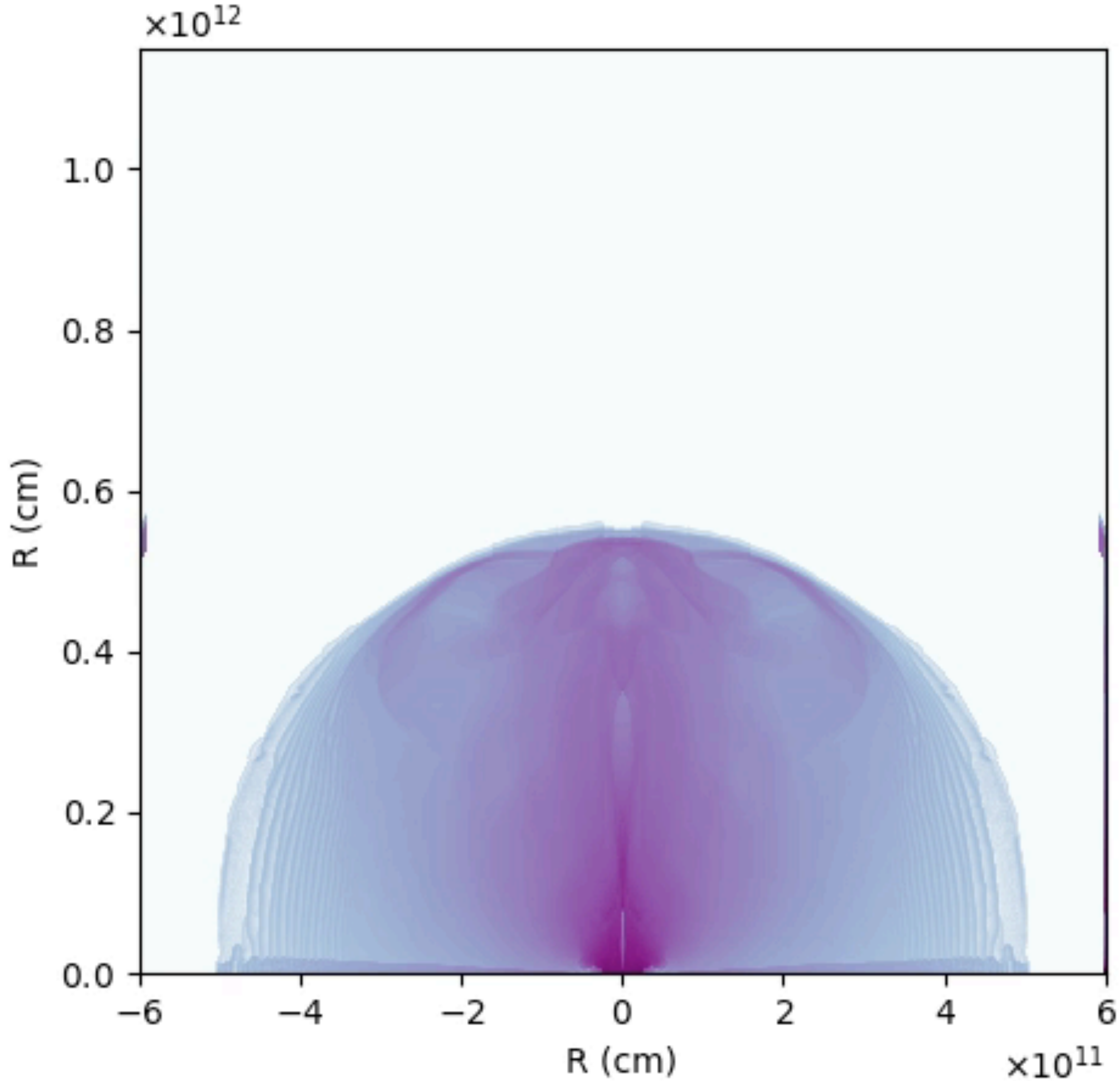


Mon Not R Astron Soc (2013) 428 (3): 2430-2442

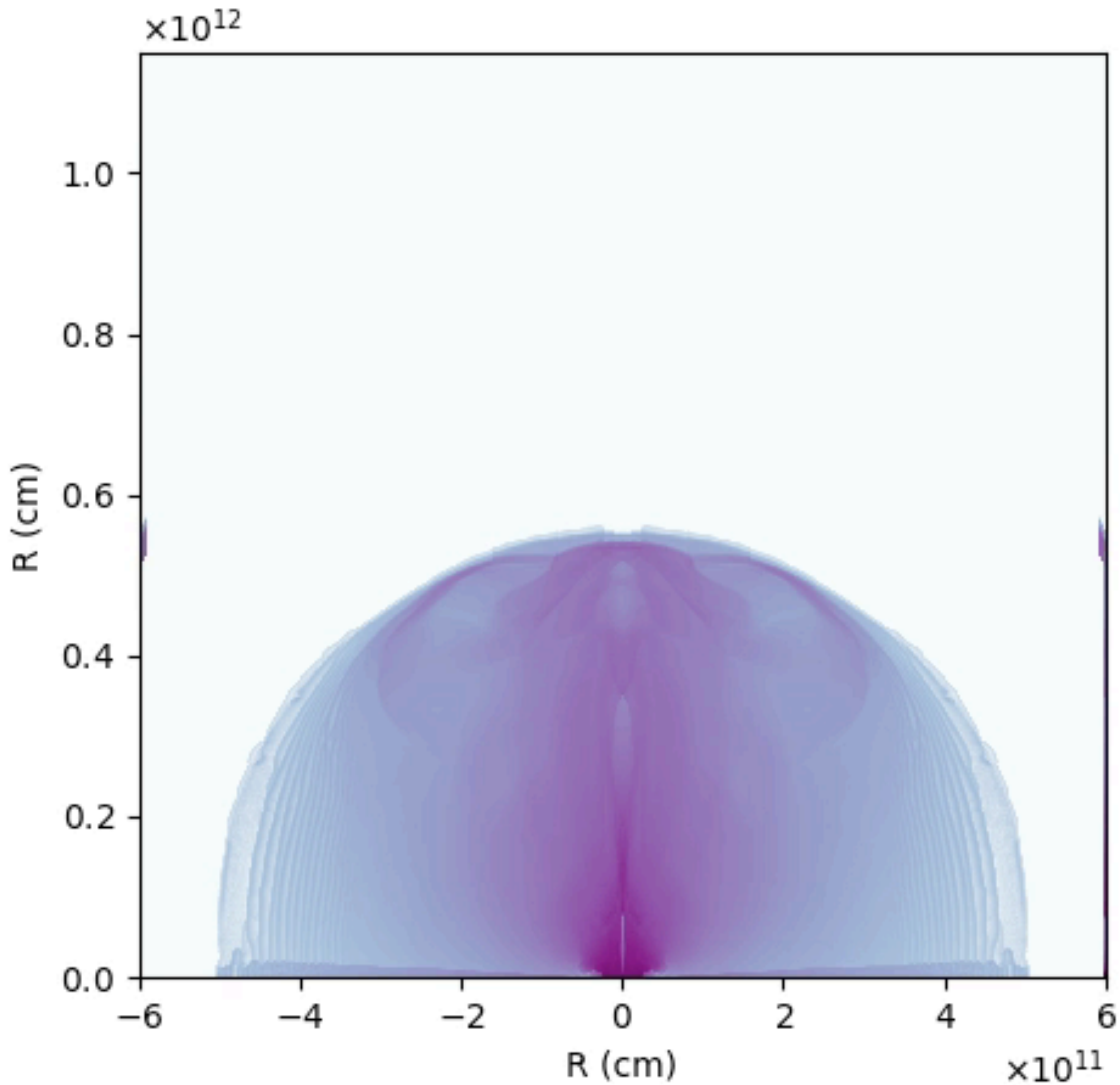

WHAT ARE LONG GAMMA RAY BURSTS?
JET PROPAGATION
RADIATION TRANSFER
ELEMENTARY TREATMENT OF THE RADIATION
ELEMENTARY TREATMENT OF THE JET
COMPARISON TO OBSERVATIONS


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

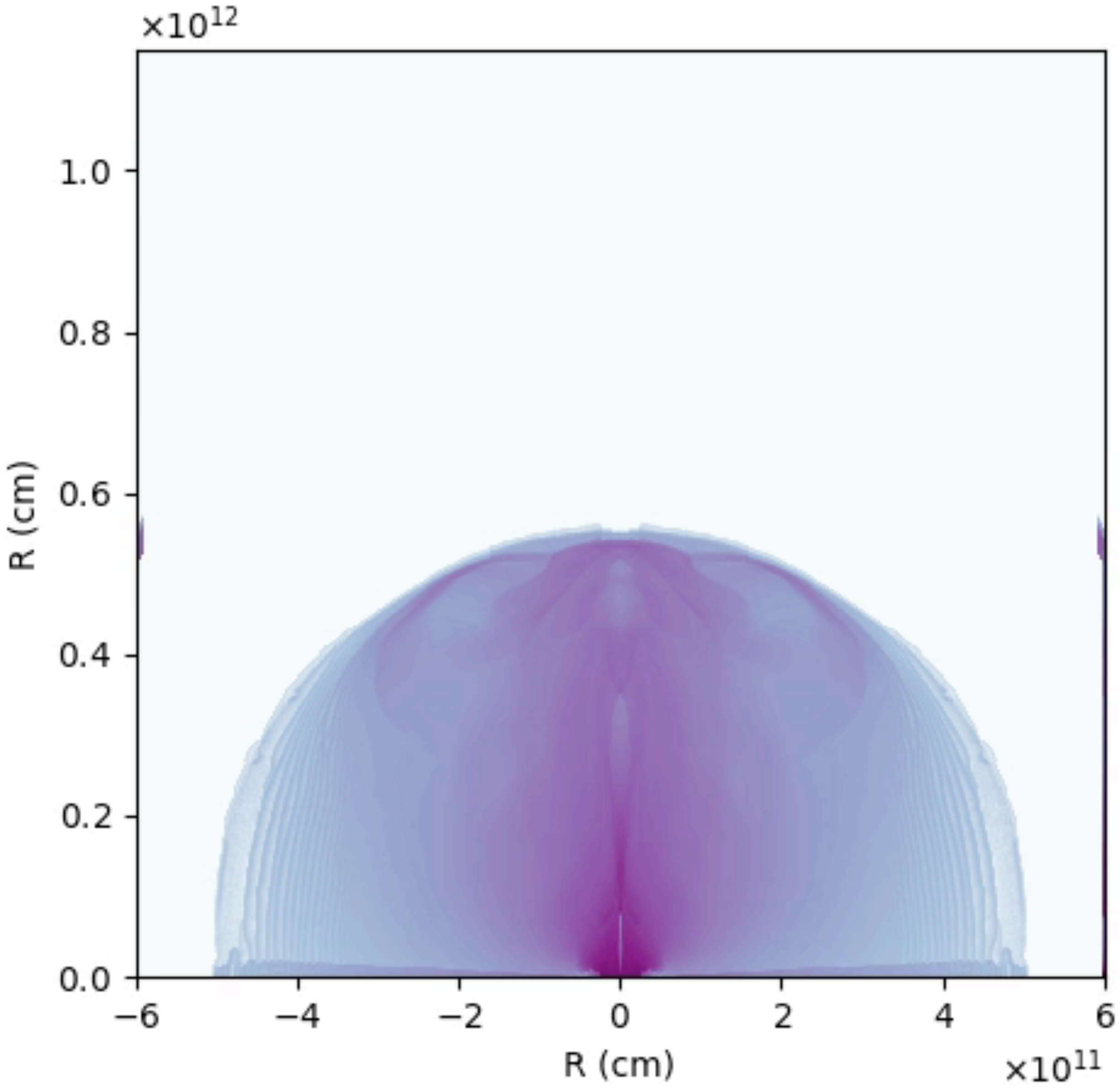
MONTE CARLO SCATTERING OF PHOTONS IN THE JET

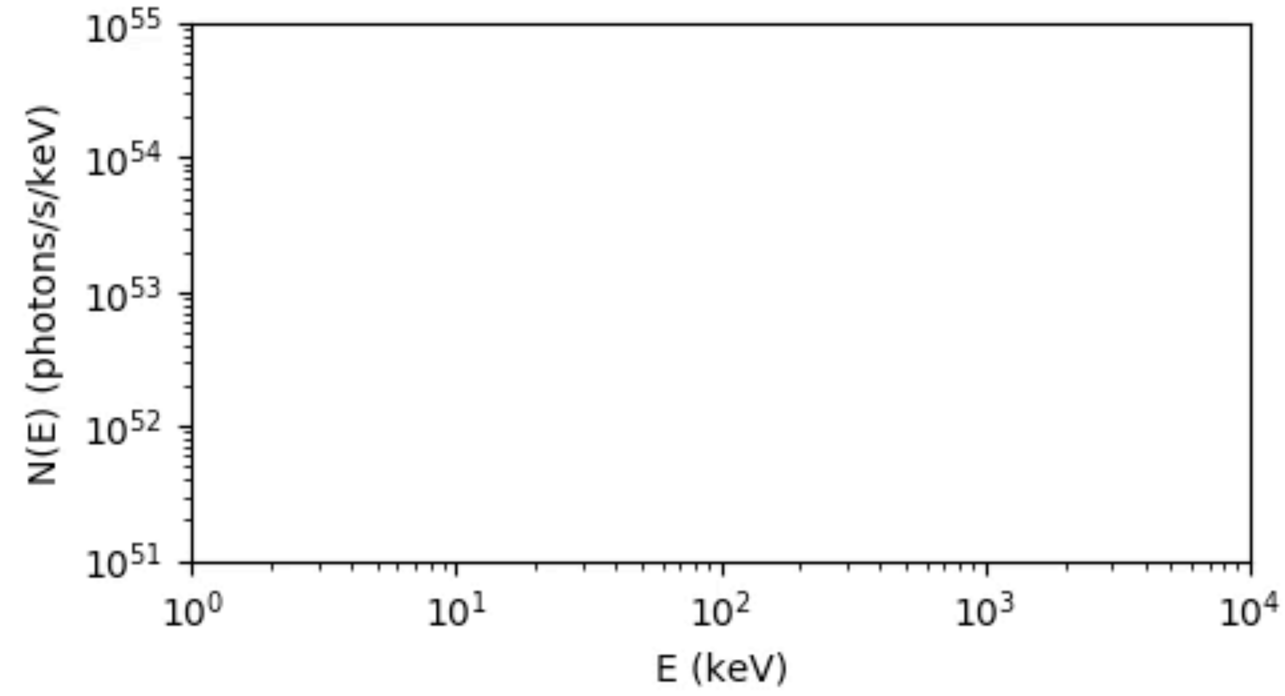


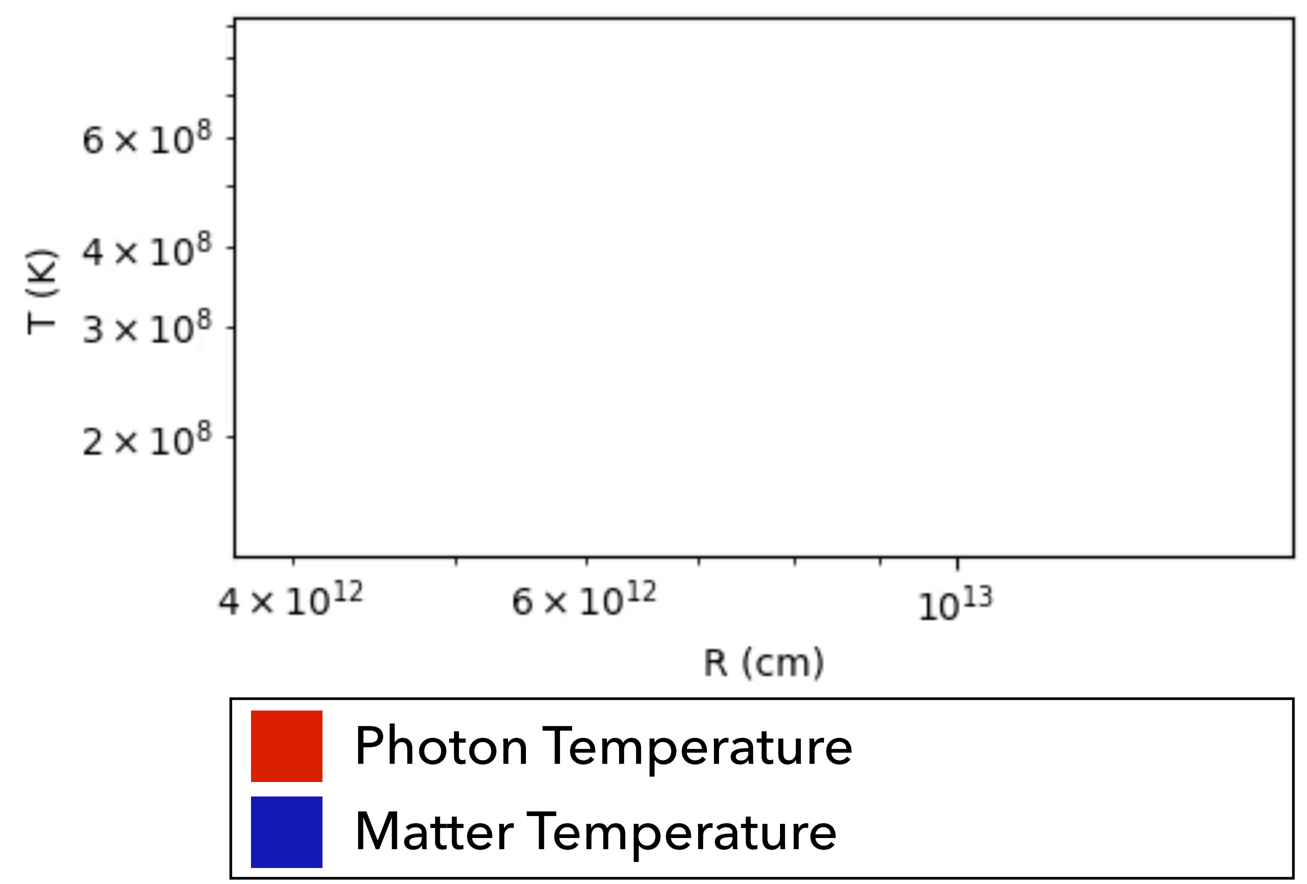
MONTE CARLO SCATTERING OF PHOTONS IN THE JET



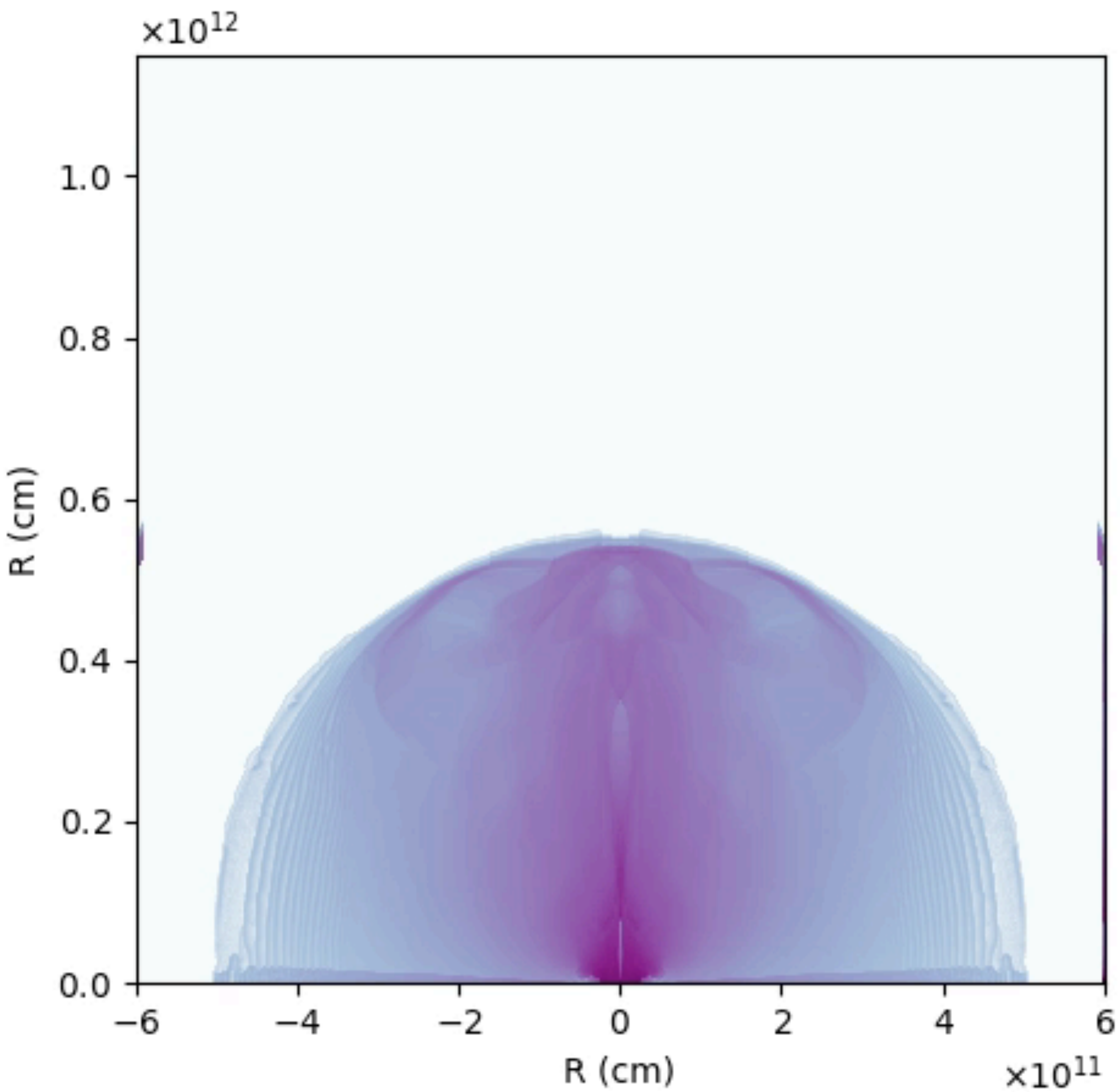
TRACKING THE TEMPERATURES SHOW HOW THE PHOTONS AND MATTER EVOLVE

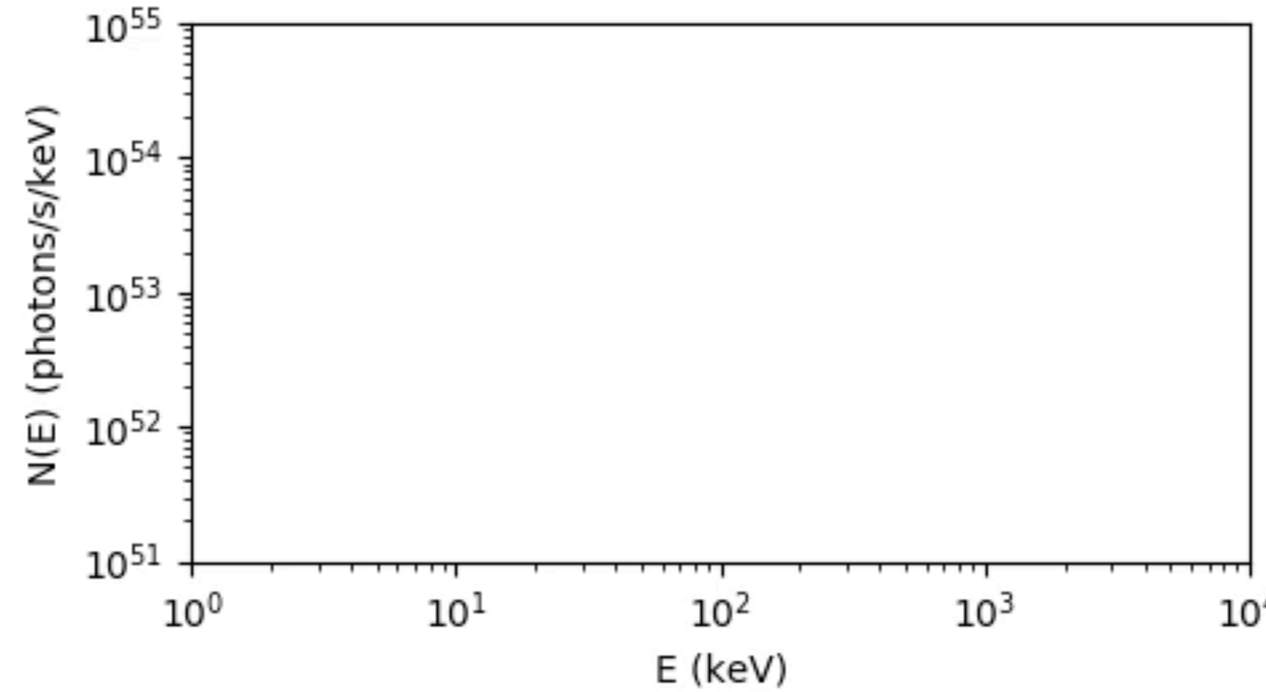


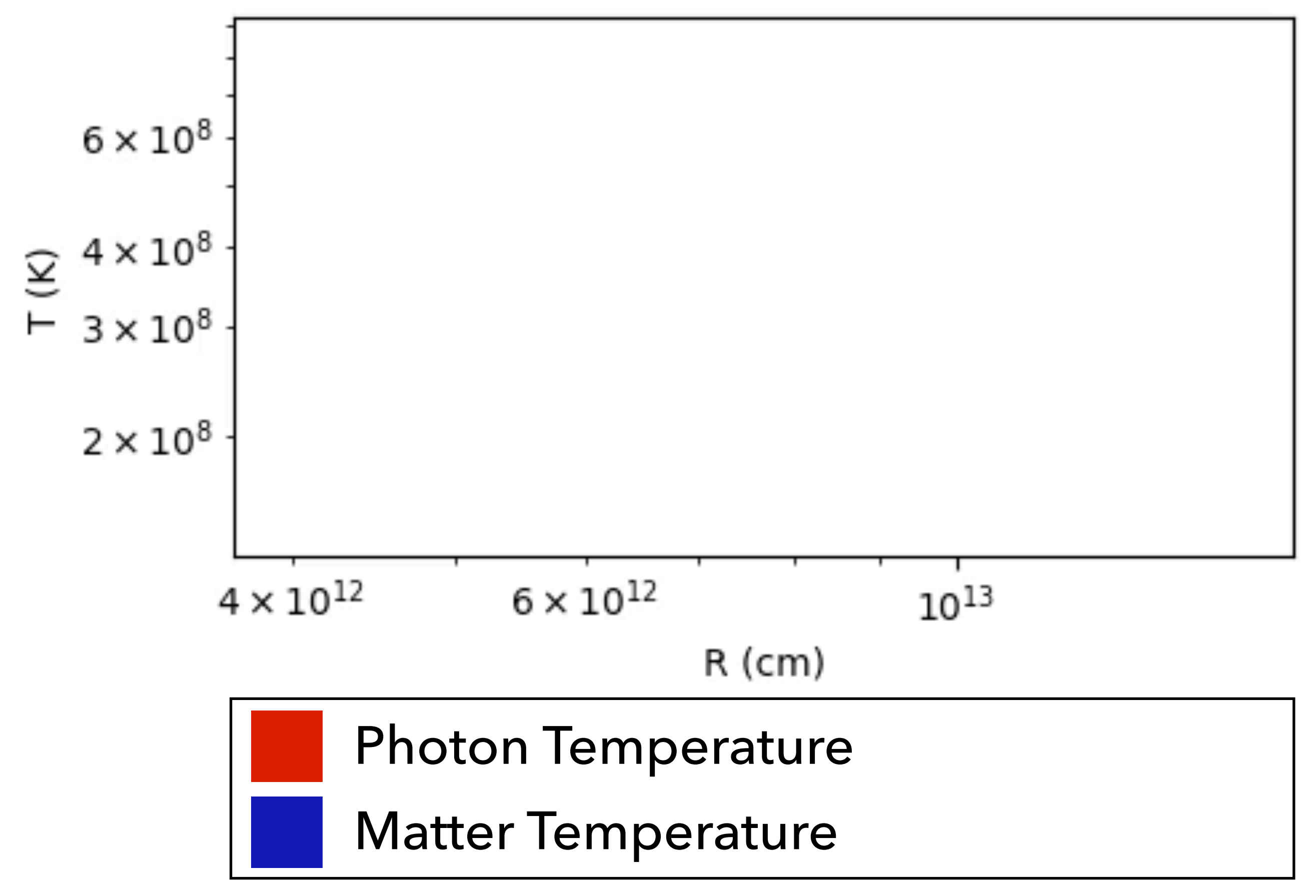




TRACKING THE TEMPERATURES SHOW HOW THE PHOTONS AND MATTER EVOLVE





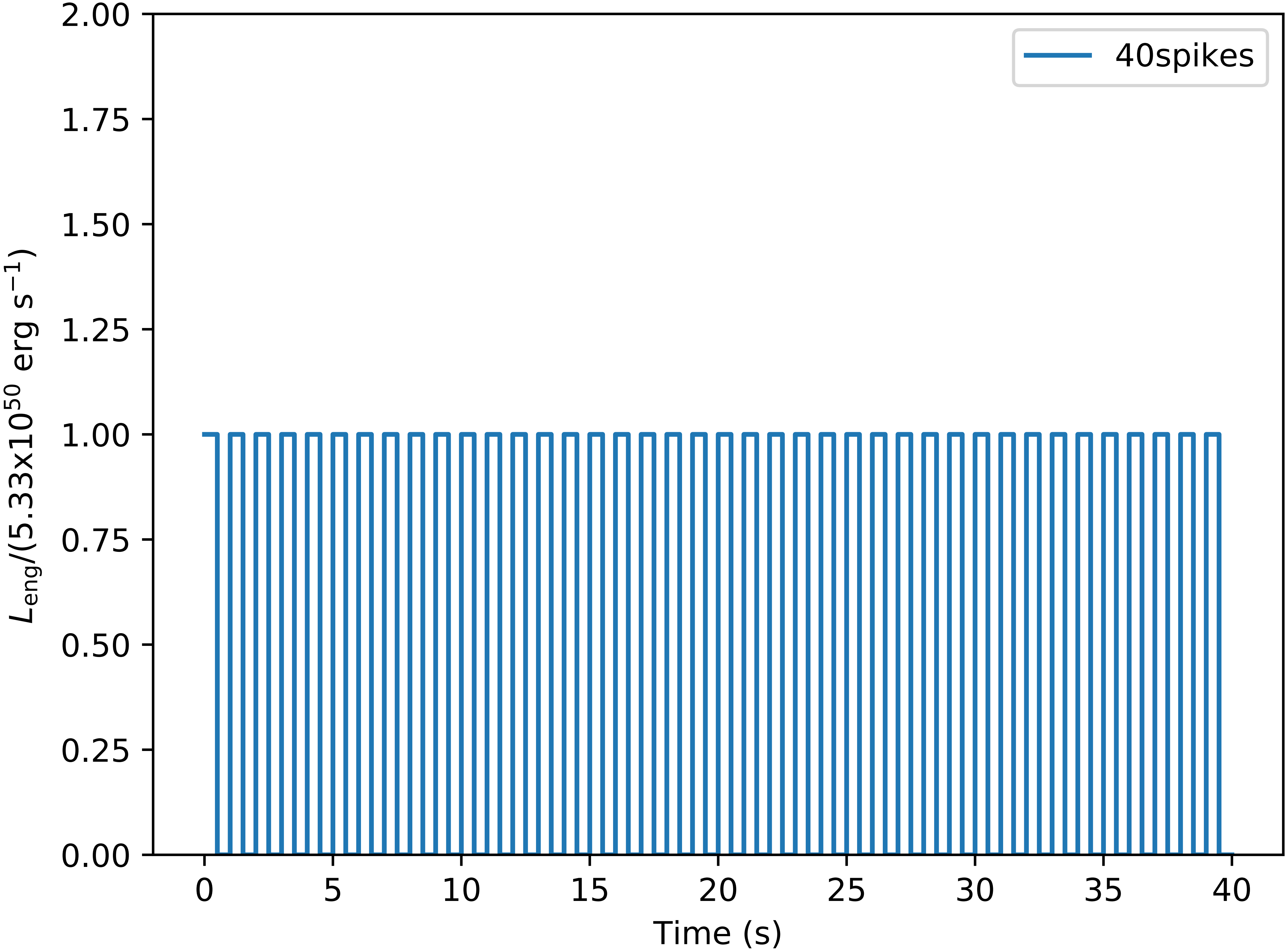


THE “CONSTANT” SIMULATION SET

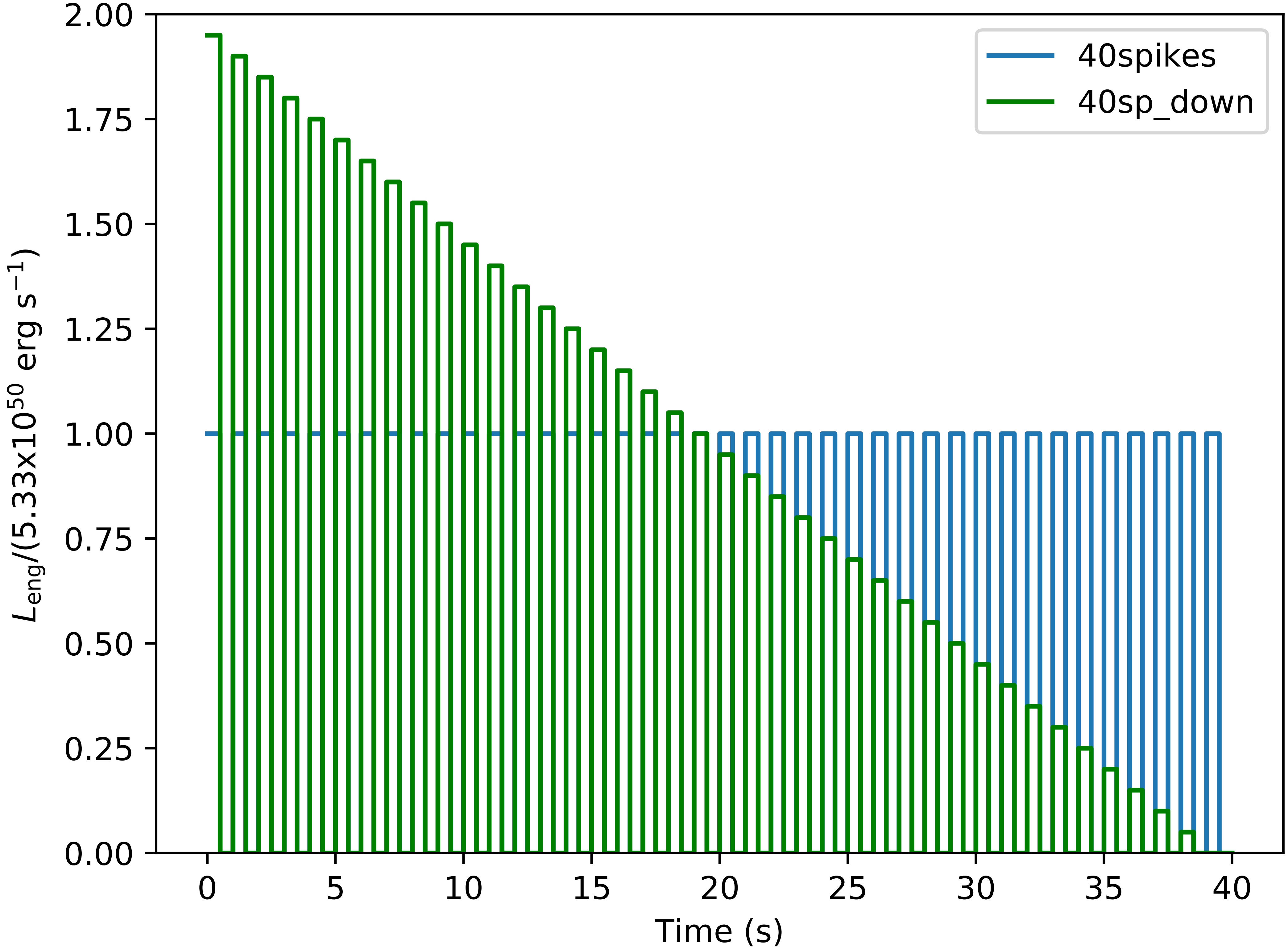
Simulation Name	Progenitor	Jet Luminosity (erg/s)	Γ_∞ [a]
16OI	16OI	5.33×10^{50}	400
35OB	35OB	5.33×10^{50}	400
16TI	16TI	5.33×10^{50}	400
16TI.e150	16TI	1×10^{50}	400
16TI.e150.g100	16TI	1×10^{50}	100

[a] Asymptotic Lorentz factor

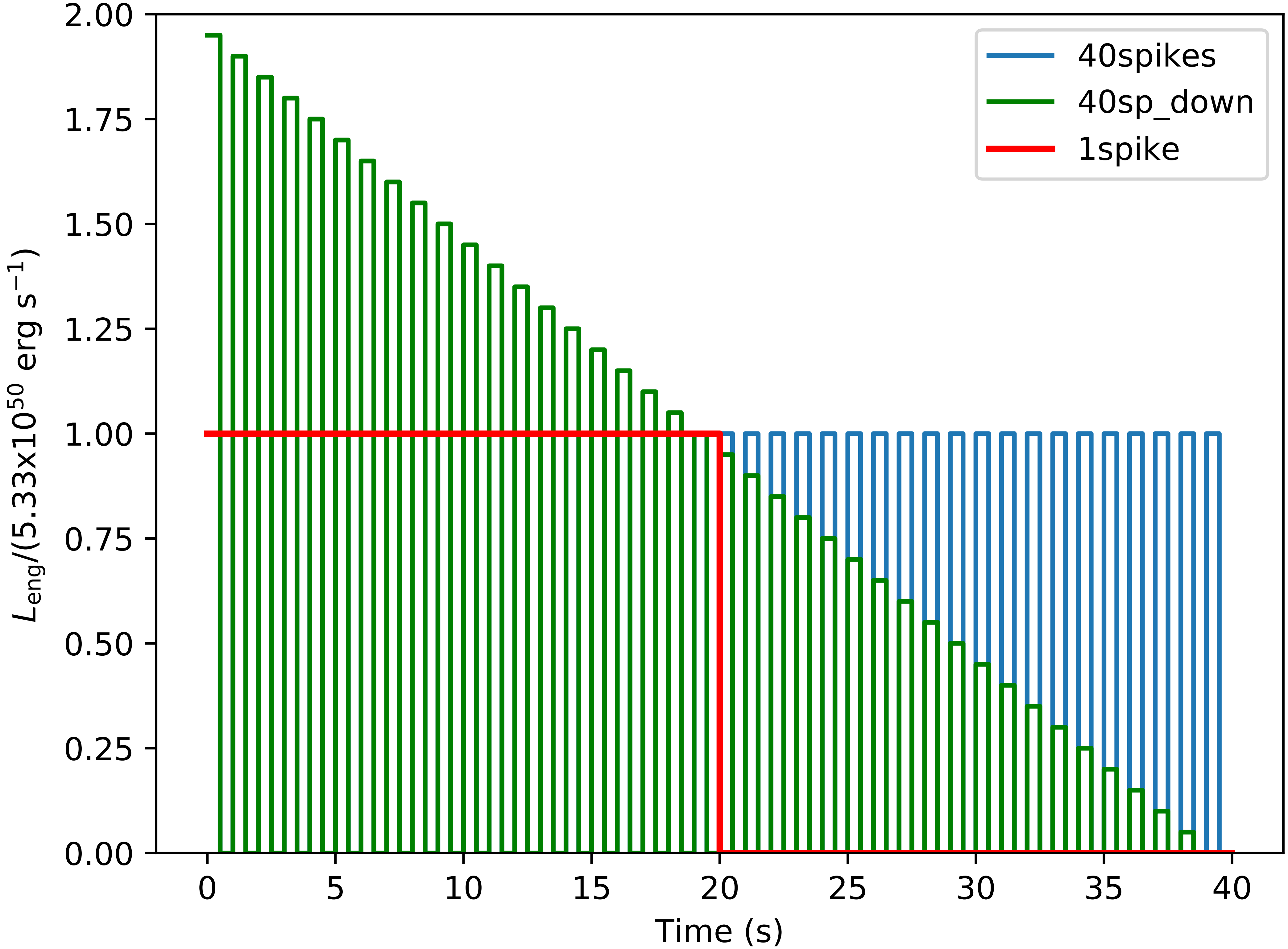
THE “VARIABLE” SIMULATION SET



THE “VARIABLE” SIMULATION SET

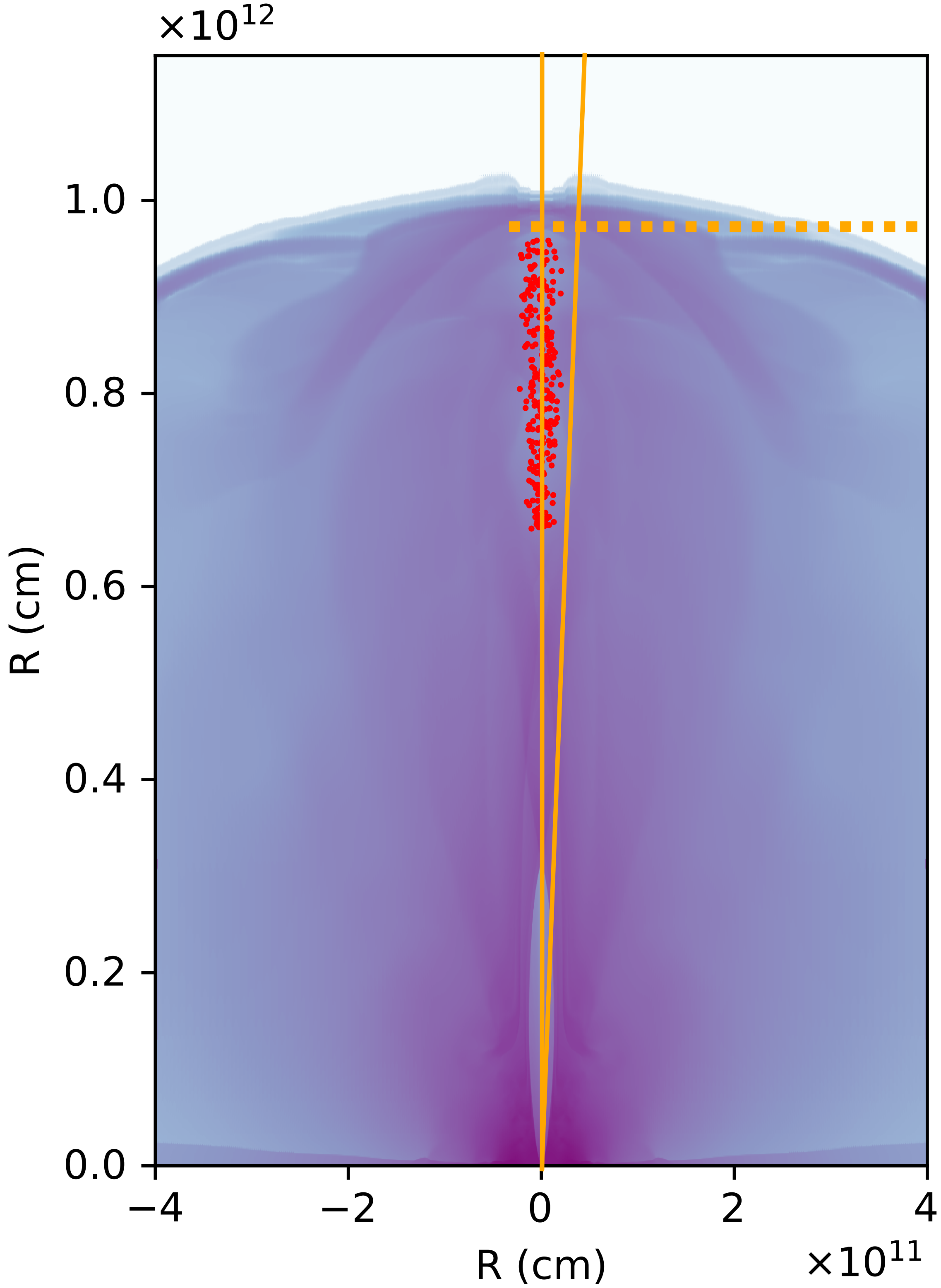


THE "VARIABLE" SIMULATION SET

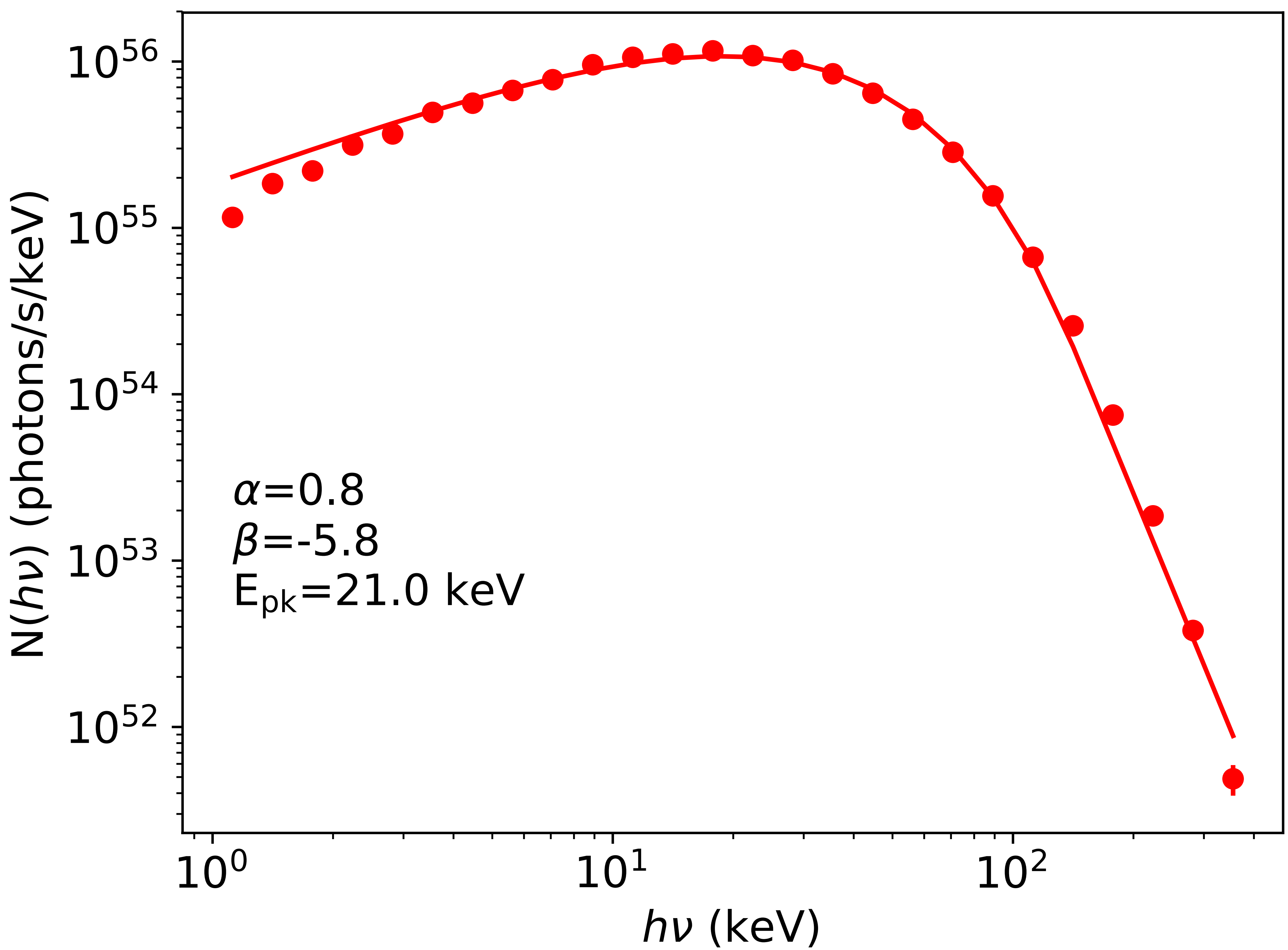


WE CAN CONSTRUCT OUR OWN OBSERVATIONS AND DIG DEEPER

- Collect photons at a given viewing angle, θ_v
- Break up the photons into those that arrived during a given time interval
- Produce spectra and light curves



WE GET INFORMATION DIRECTLY COMPARABLE TO OBSERVATIONS



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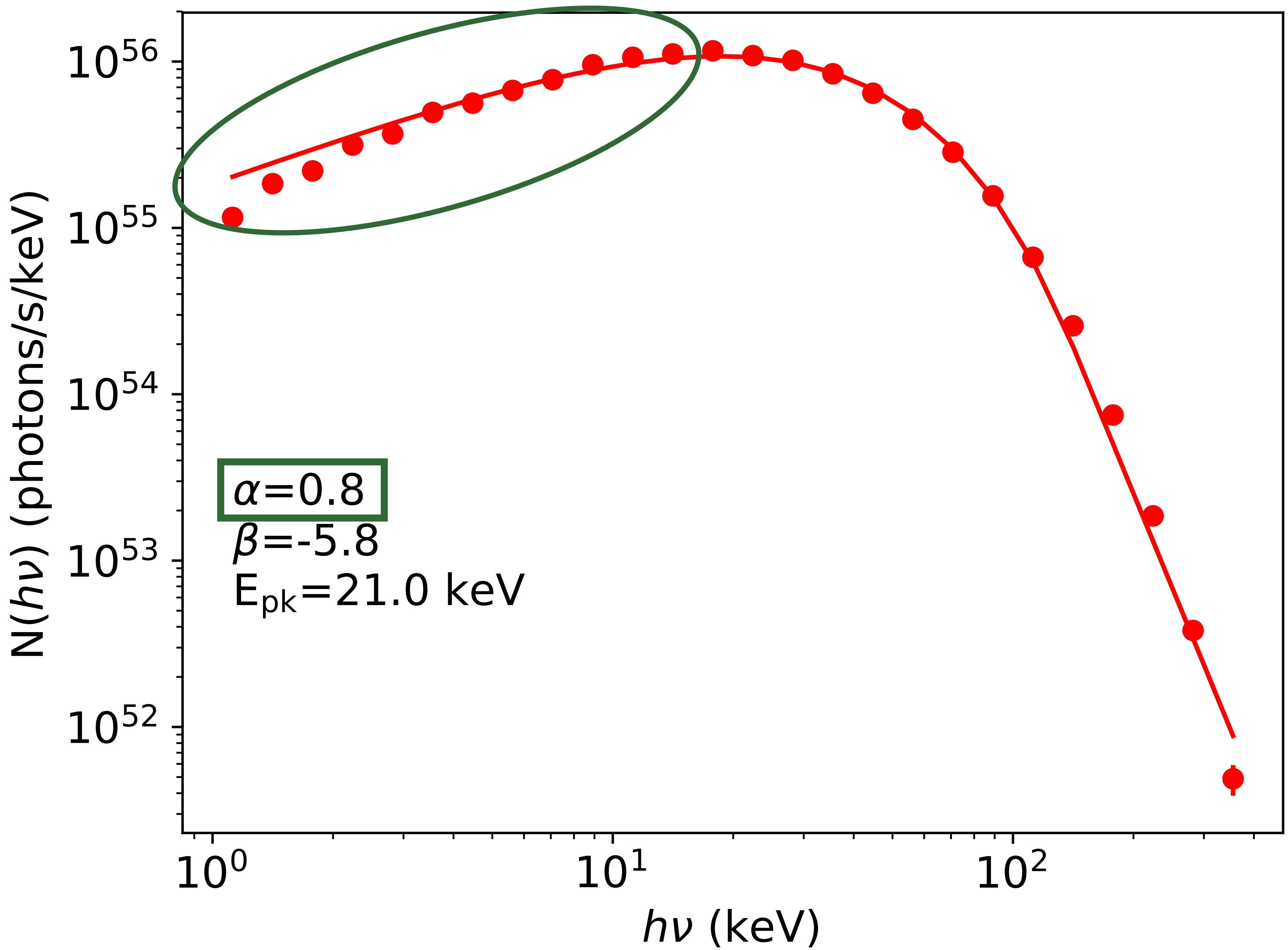

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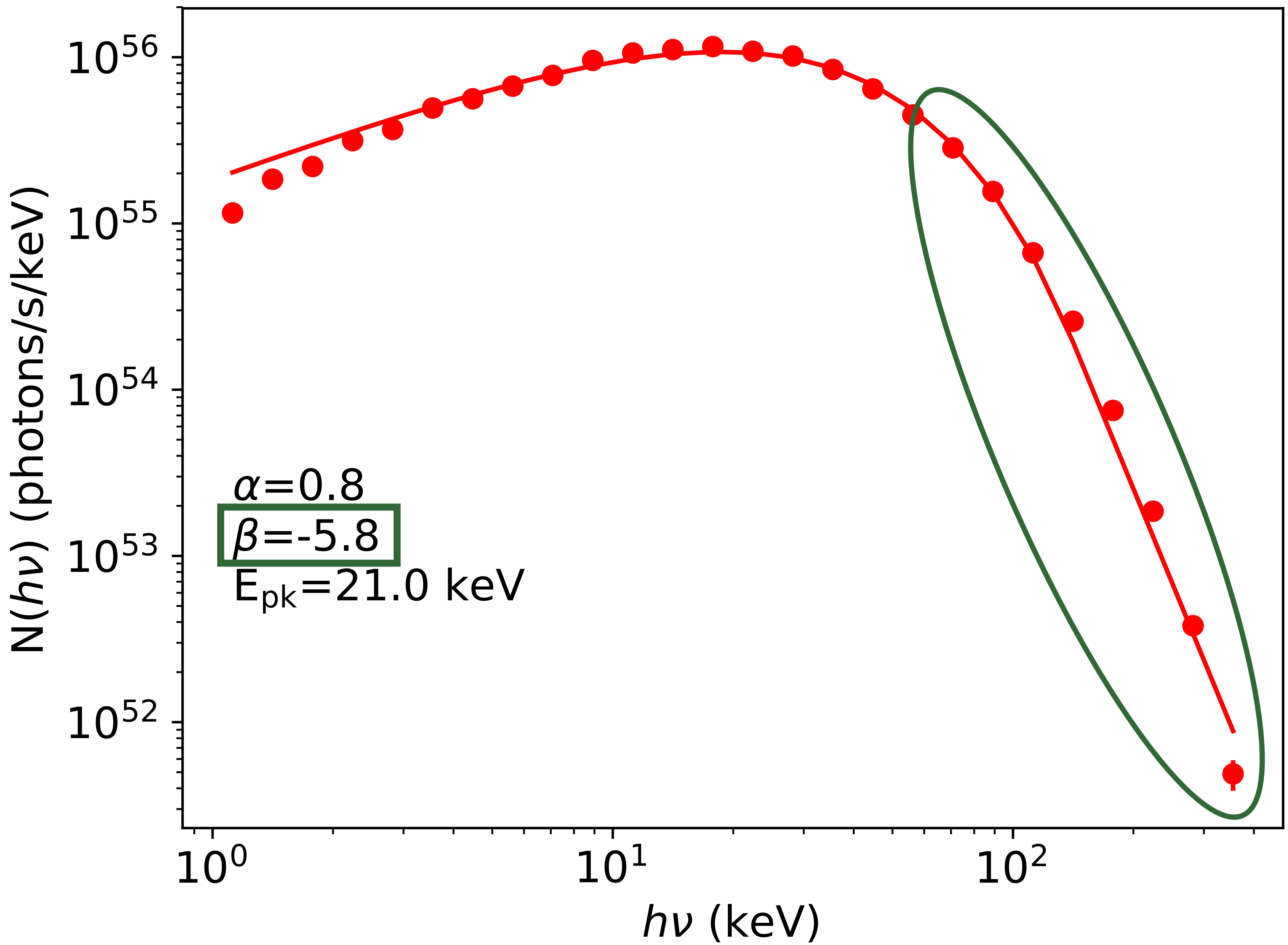

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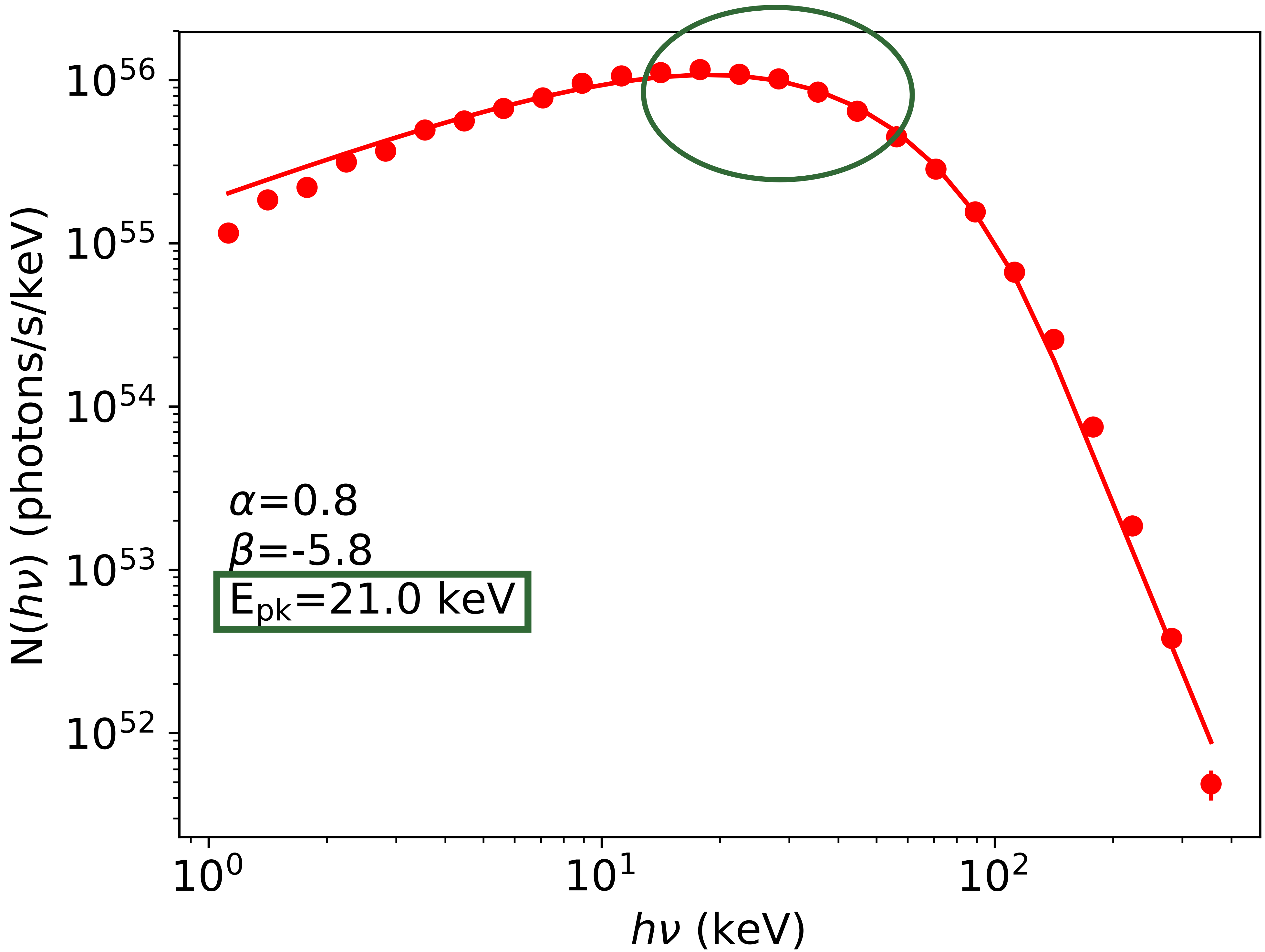

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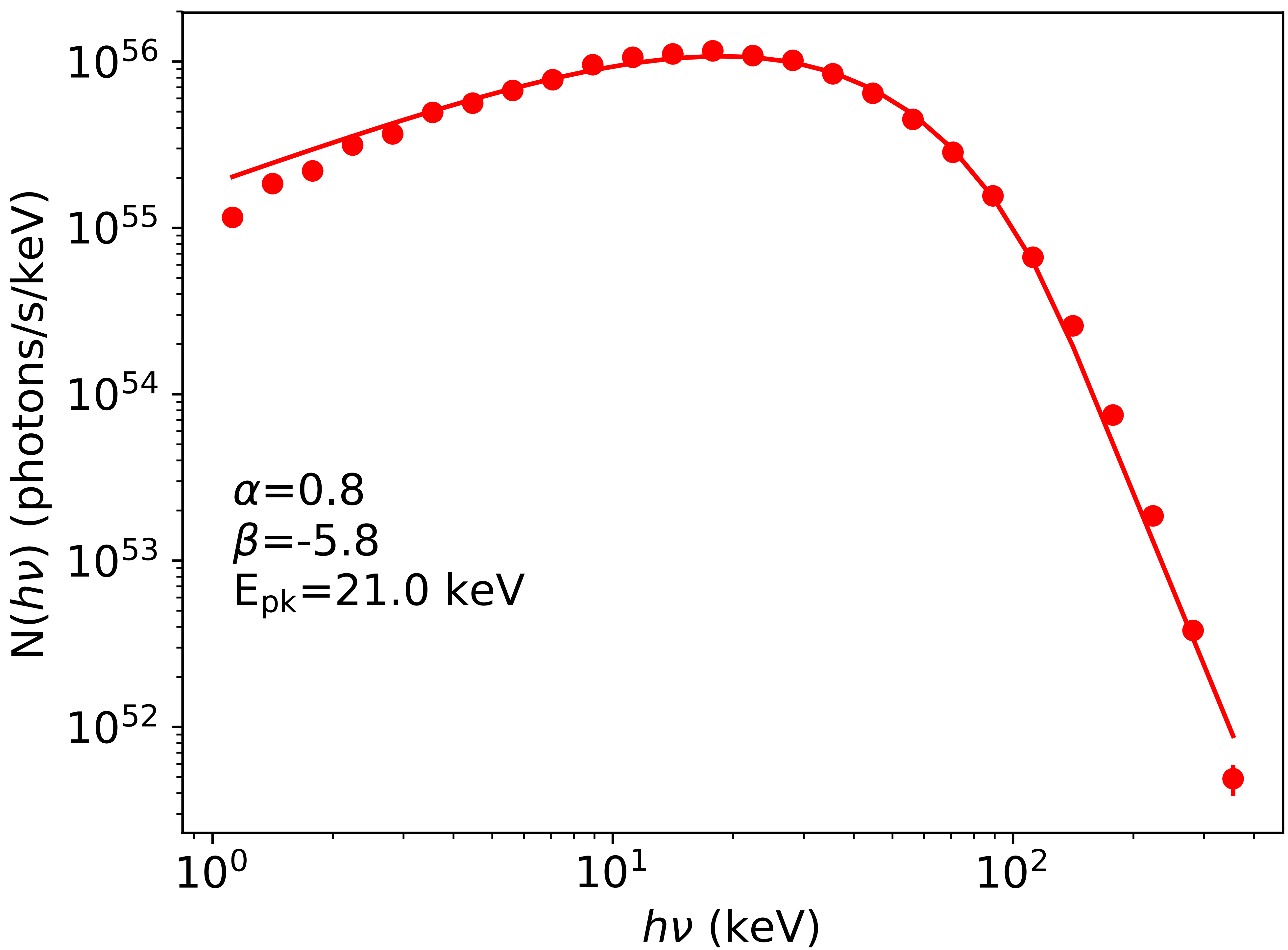

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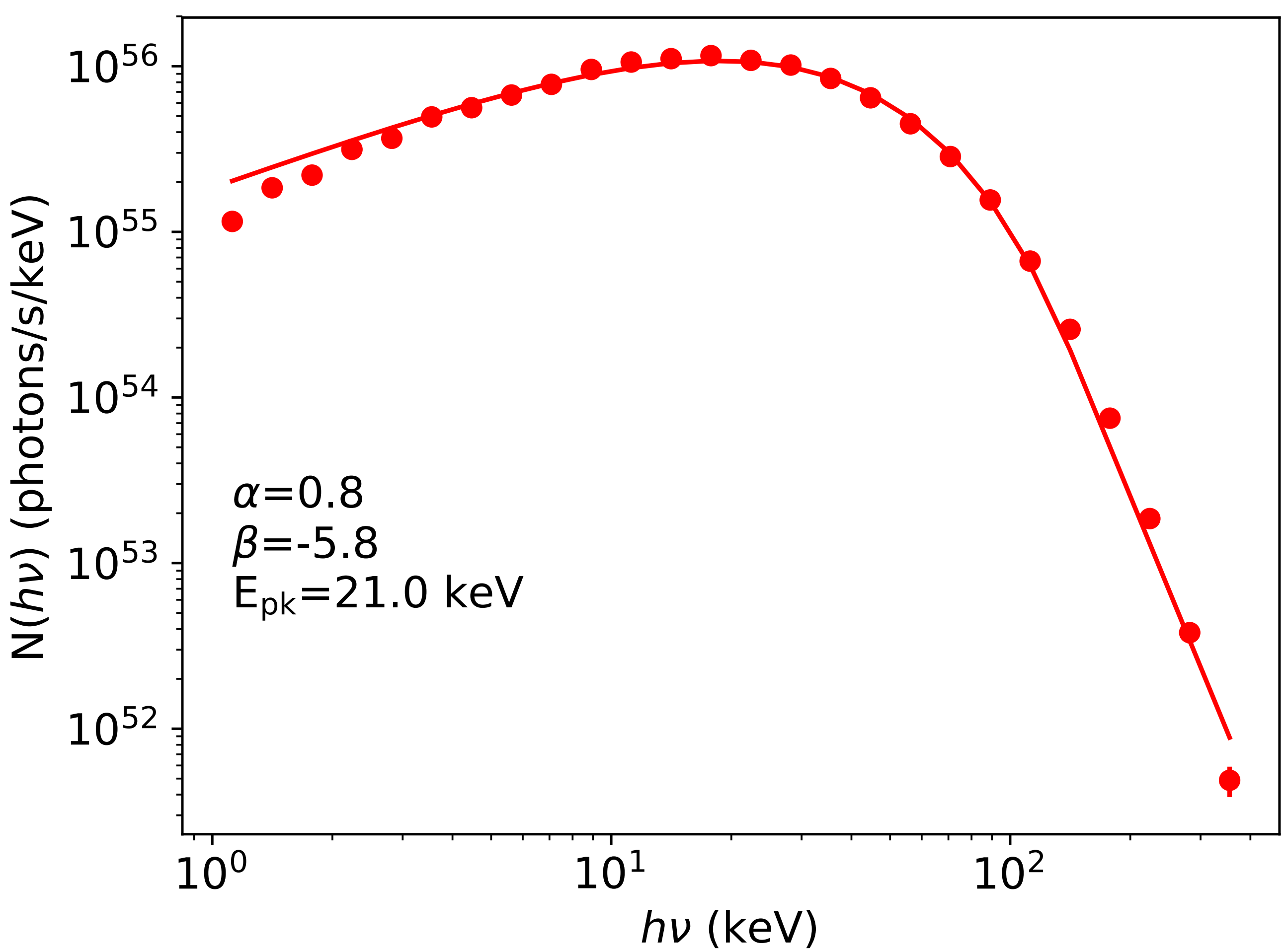
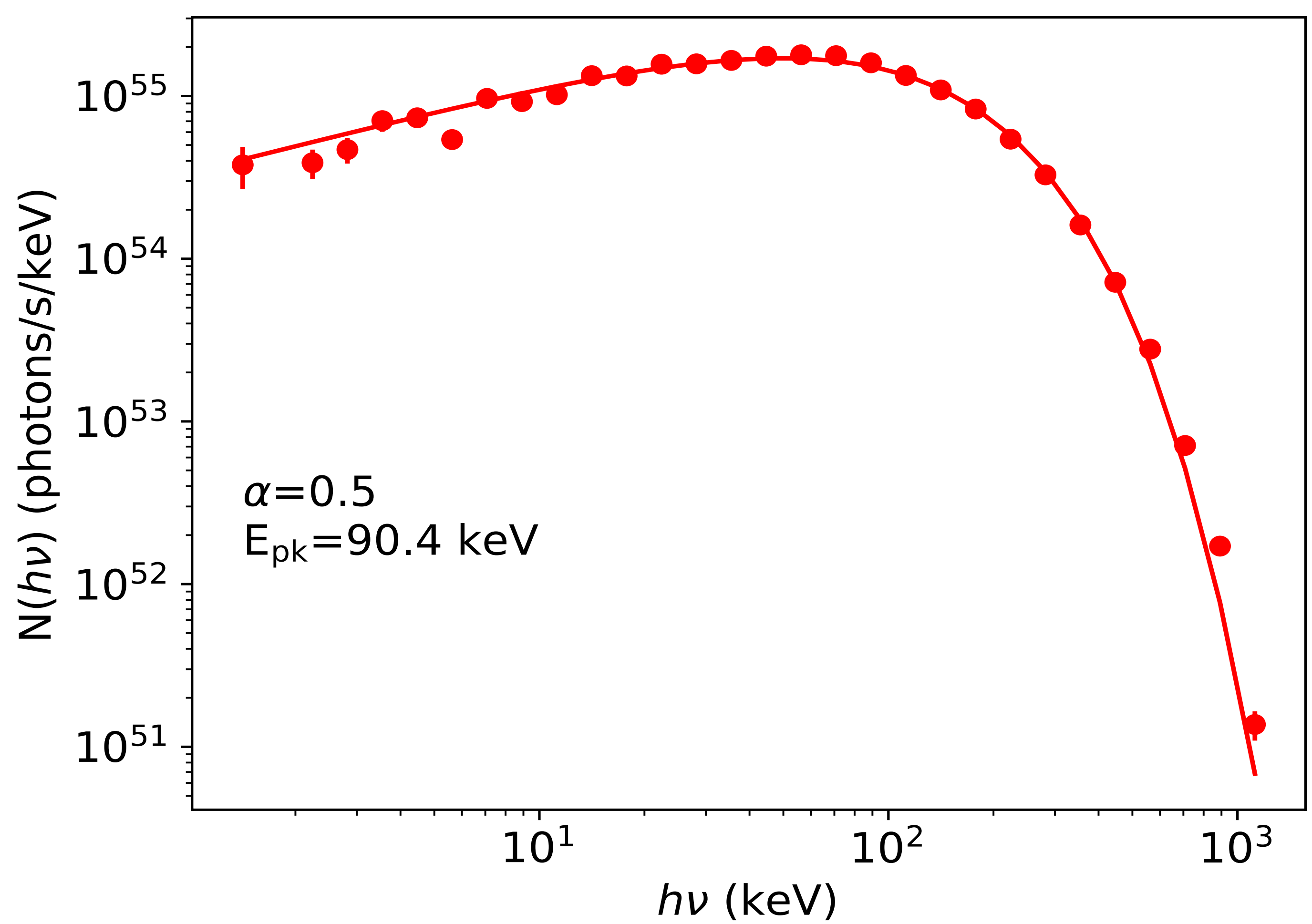
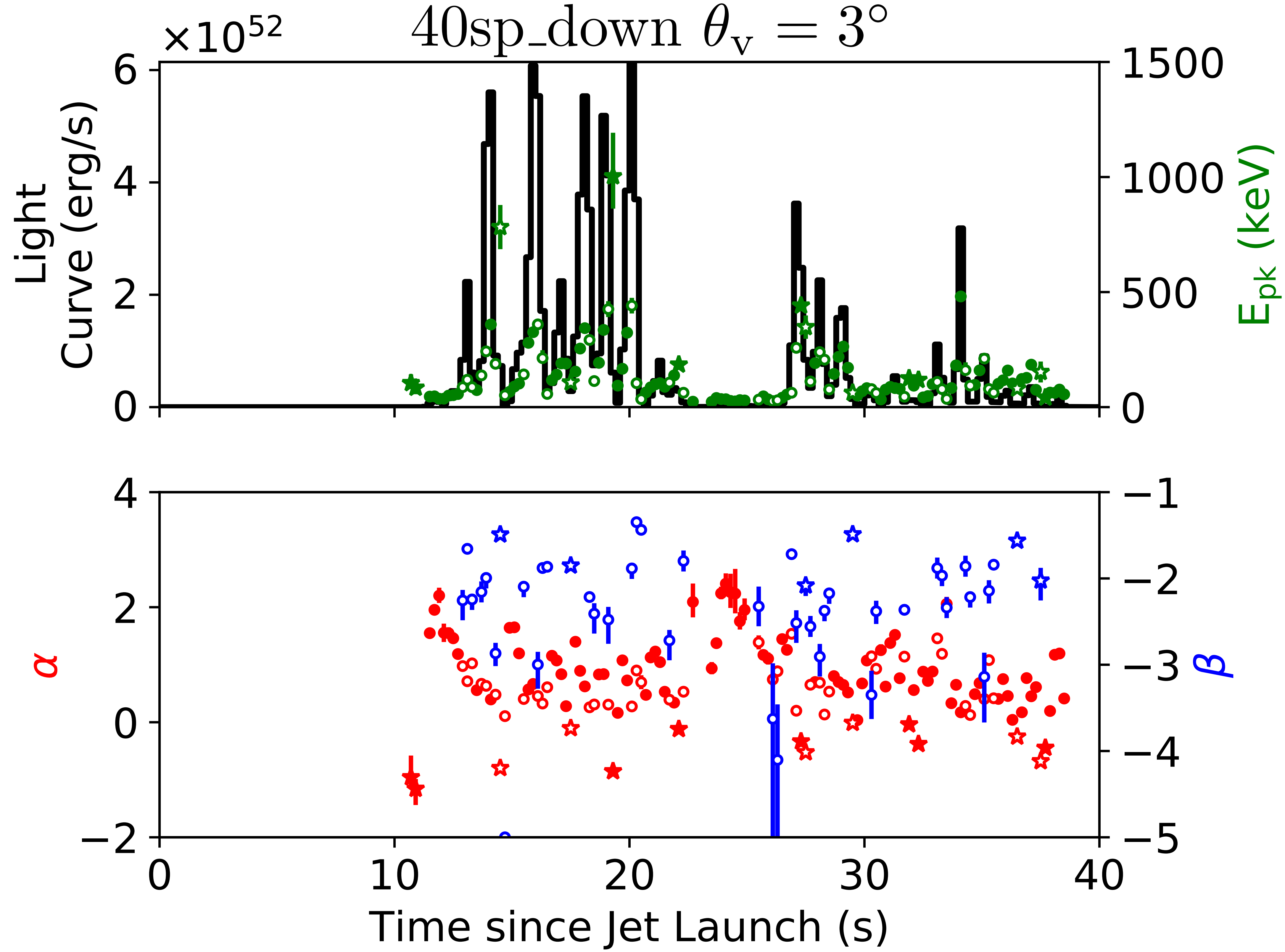
Best Fit: Band Function



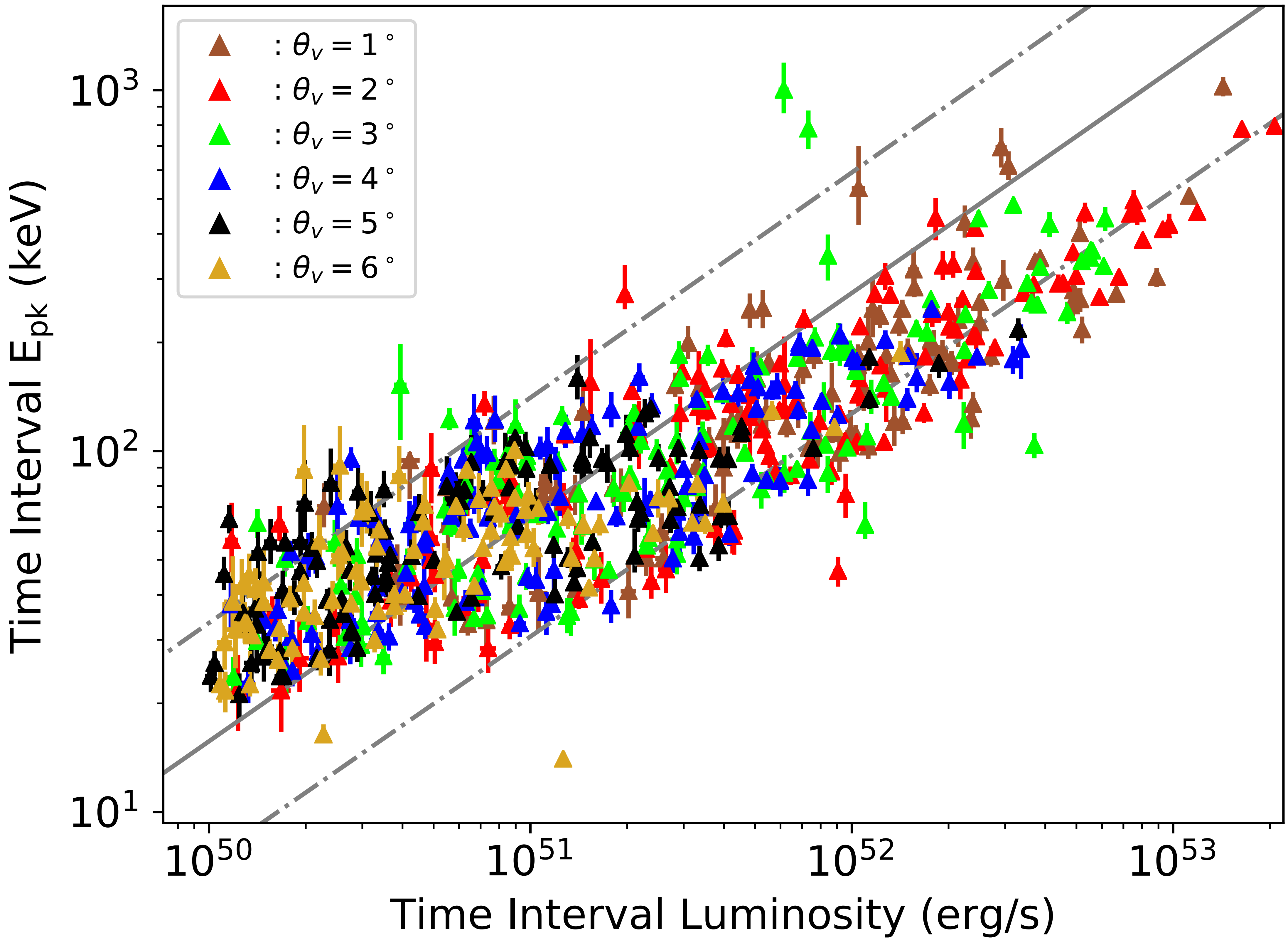
Best Fit: COMP Function



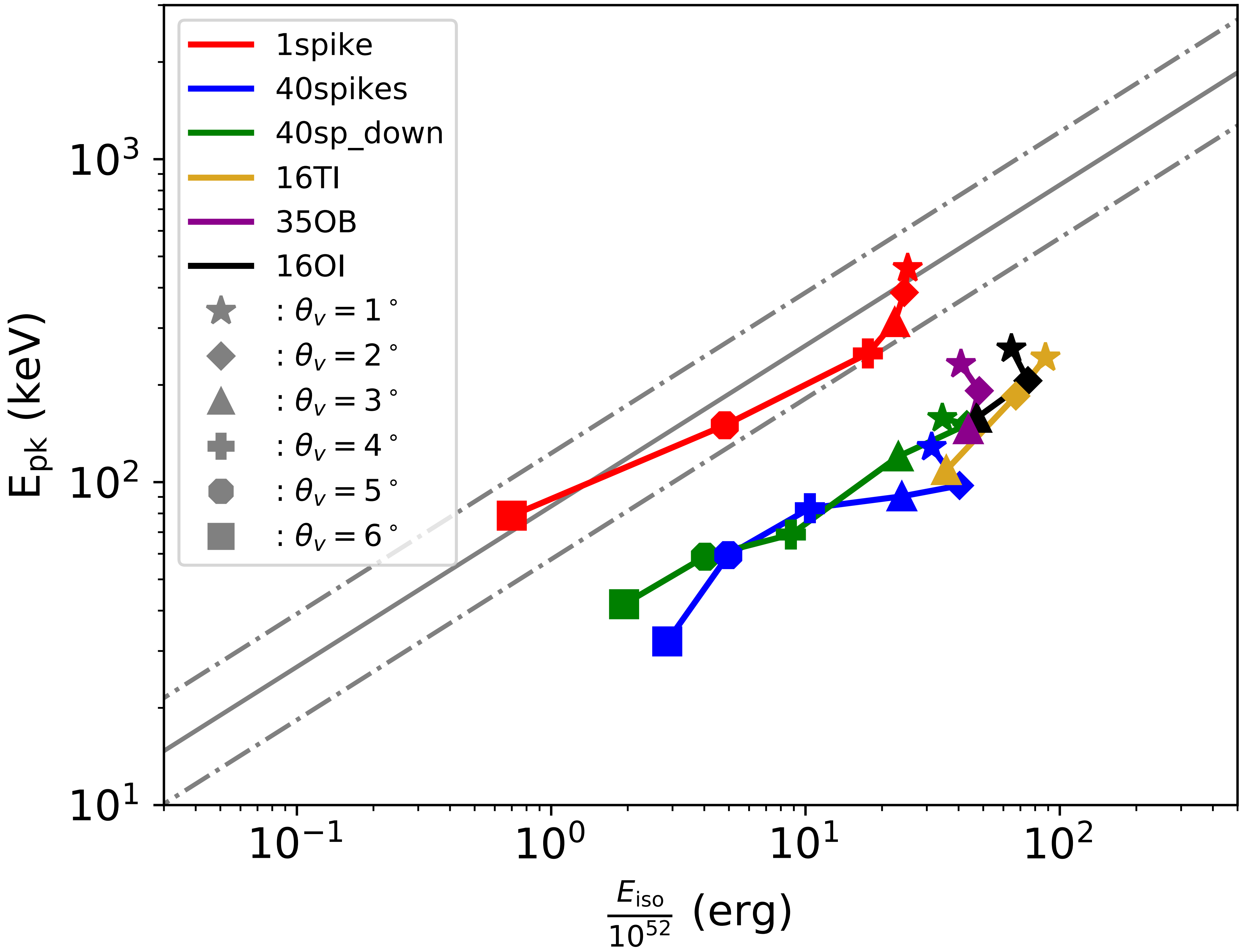
WE GET INFORMATION DIRECTLY COMPARABLE TO OBSERVATIONS



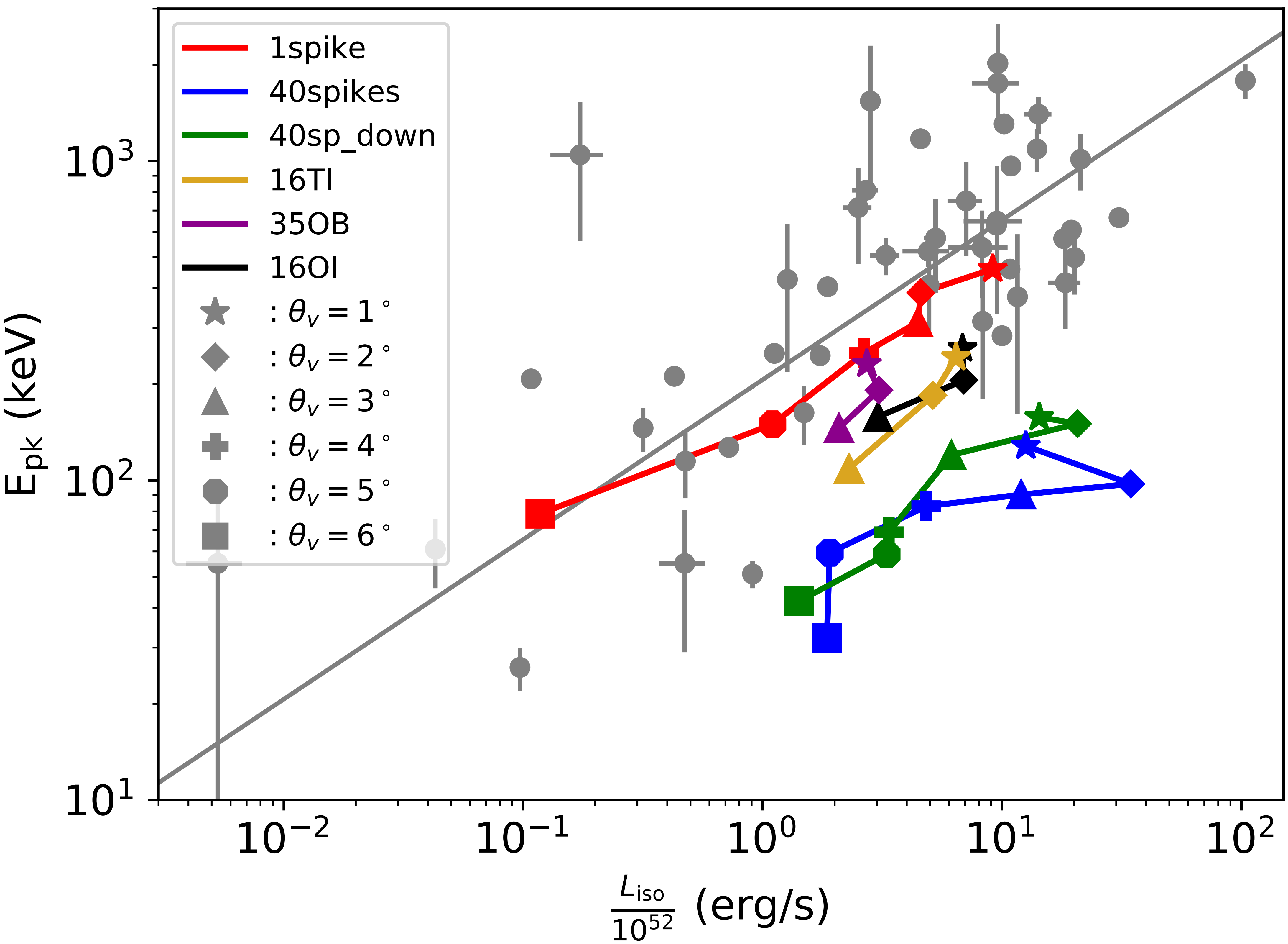
THE SIMULATION SET IS CONSISTENT WITH THE GOLENETSKII RELATION



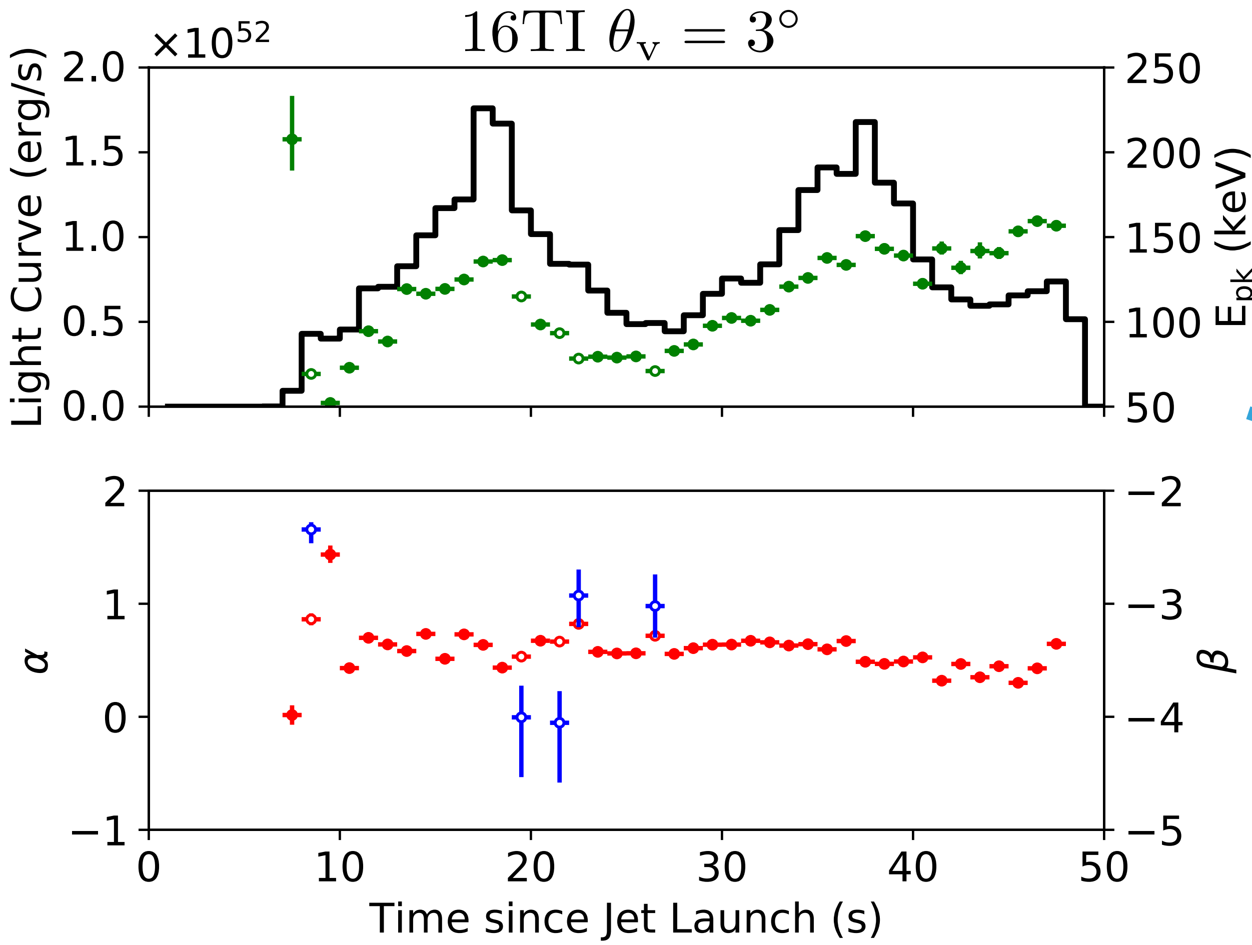
THE SIMULATION SET IS NOT CONSISTENT WITH THE AMATI RELATION

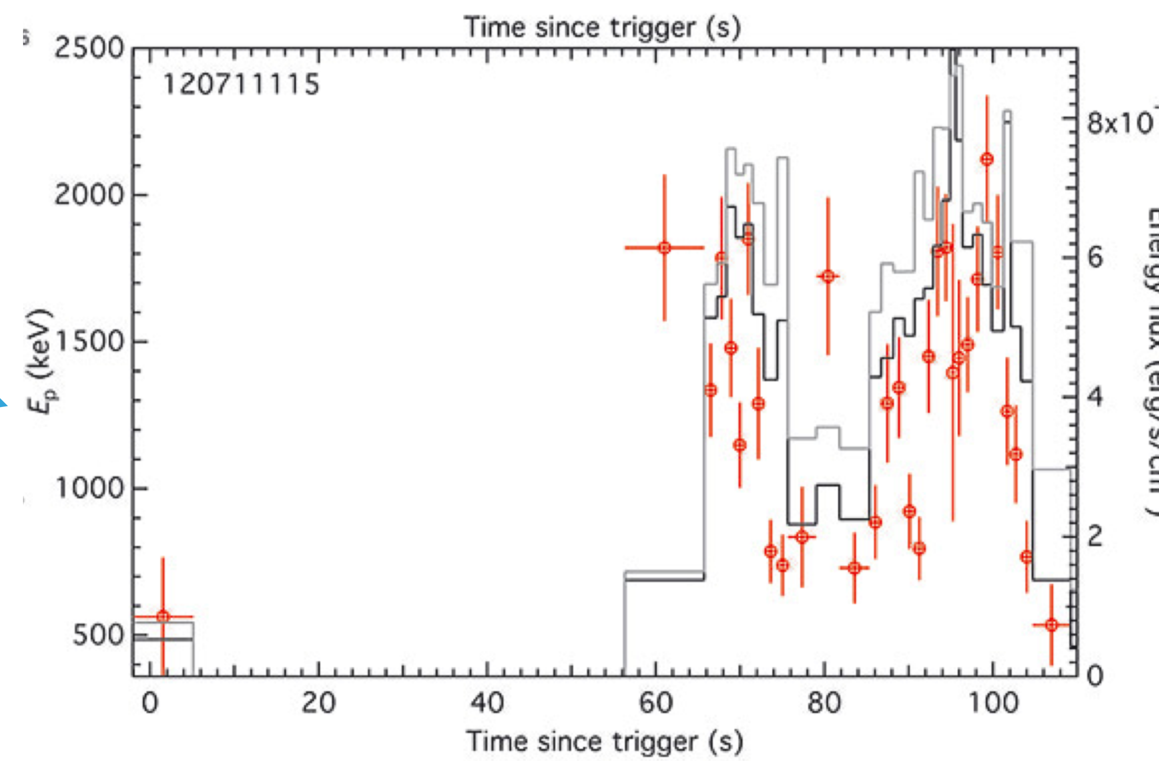


THE SIMULATION SET IS RELATIVELY CONSISTENT WITH THE YONETOKU RELATION



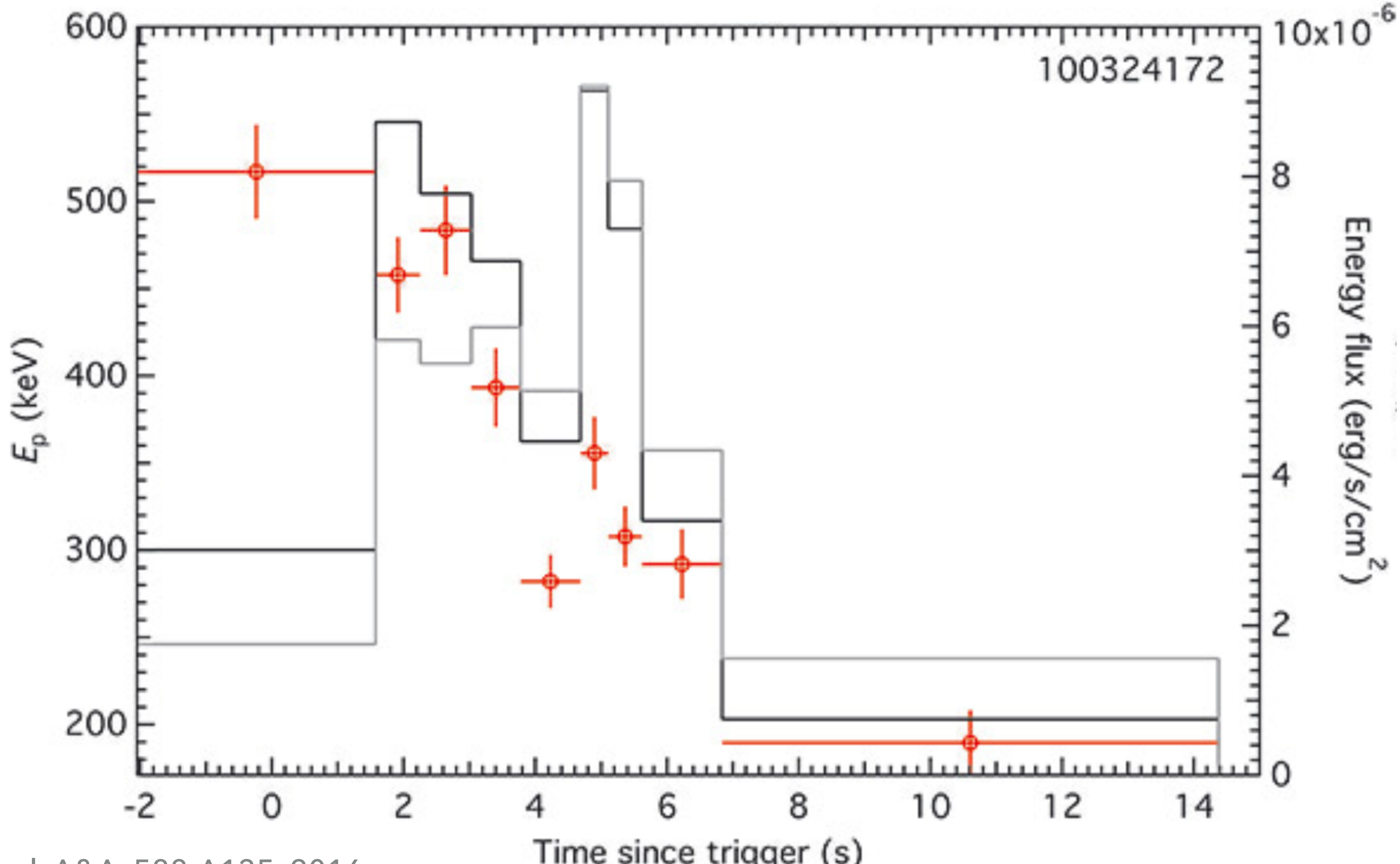
COMPARING "CONSTANT" SIMULATION SET LIGHT CURVES TO OBSERVED LIGHT CURVES





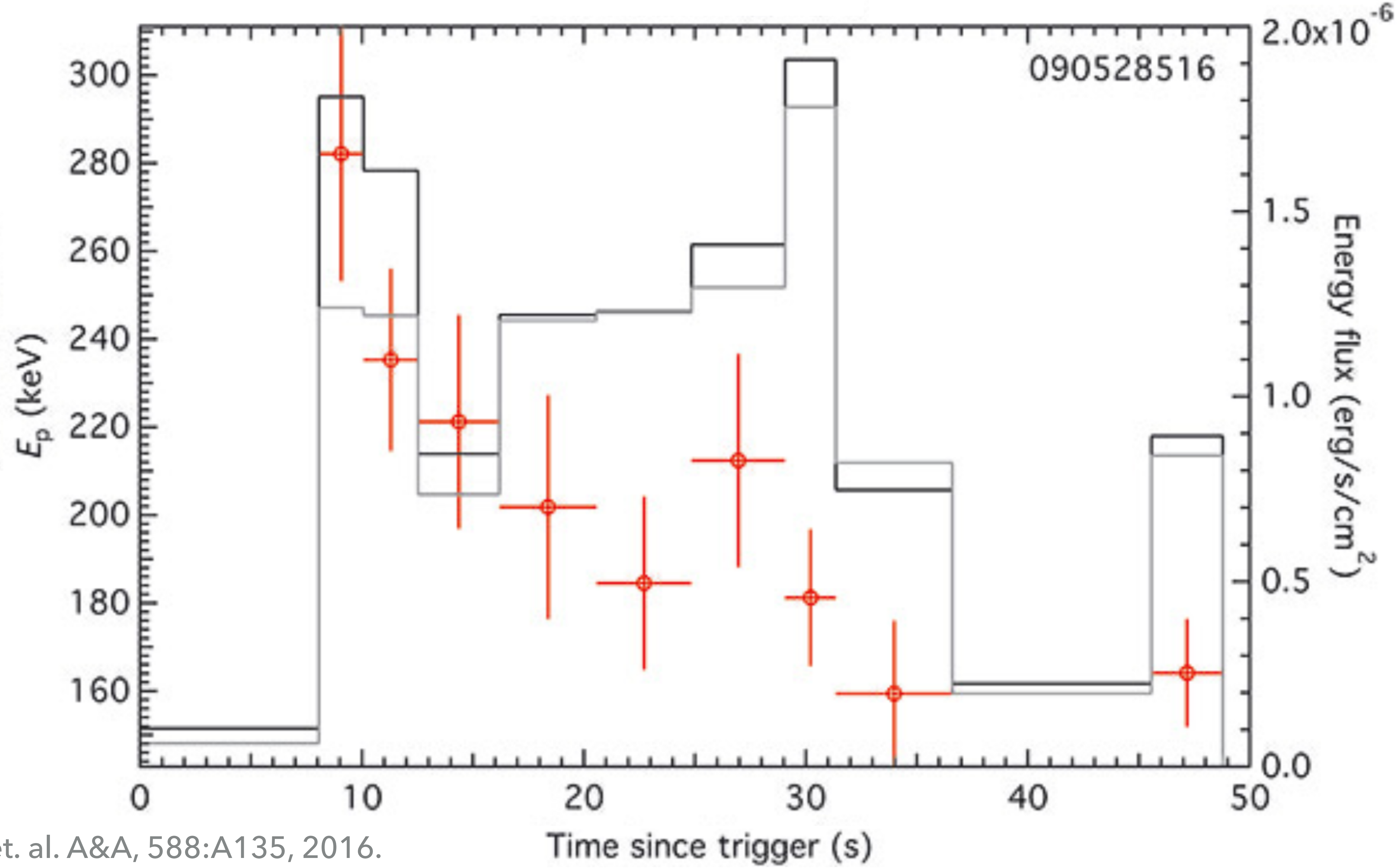
Yu et. al. A&A, 588:A135, 2016.

SOME GRBS EXHIBIT A L_{ISO}–E_{PK} TRACKING…



Yu et. al. A&A, 588:A135, 2016.

. . . AND SOME DO NOT EXHIBIT TRACKING



Yu et. al. A&A, 588:A135, 2016.

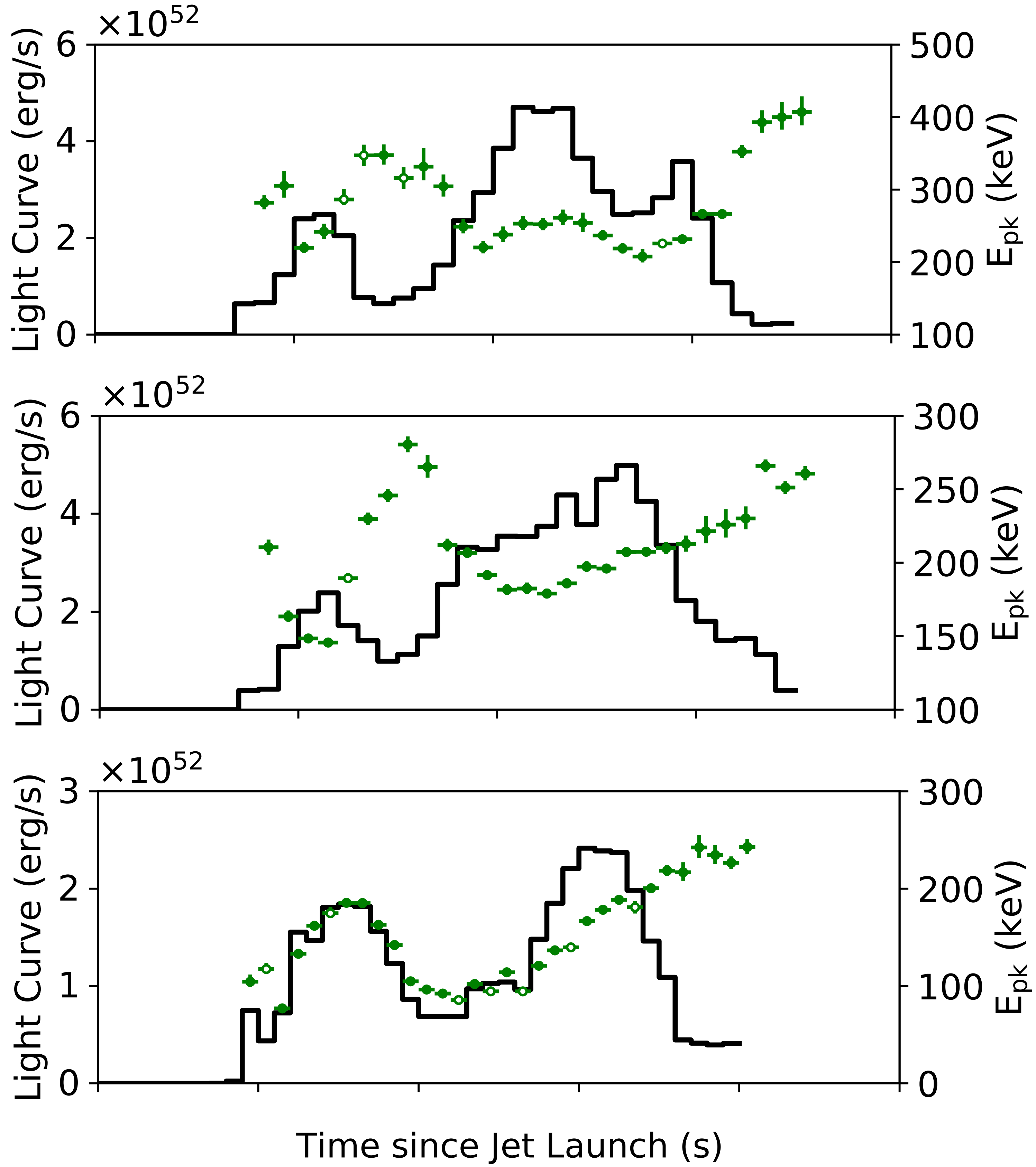
WE CAN INVESTIGATE THE L_{ISO}–E_{PK} TRACKING

16OI PROGENITOR

$\theta_v = 1^\circ$

$\theta_v = 2^\circ$

$\theta_v = 3^\circ$



LESS TRACKING

MORE TRACKING

SUMMARY

- Photons gradually decouple from the jet
- We are in agreement with the Yonetoku and Golenetskii relations but not the Amati relation
- The Band alpha parameters can be reproduced
- We can recreate observational aspects not reproduced before

IMPROVEMENTS WILL BE MADE TO MCRAT

- Larger domain hydrodynamical simulations of Gamma Ray Bursts
- Need more low energy photons
  - Add a subdominant radiation mechanism
- Use the Klein Nishina Cross Section with polarization

MCRaT

Monte Carlo Radiation Transfer

PARSOTAN & LAZZATI 2018 APJ 853 8

ARXIV: 1805.10327

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THANK YOU

QUESTIONS?

New Results

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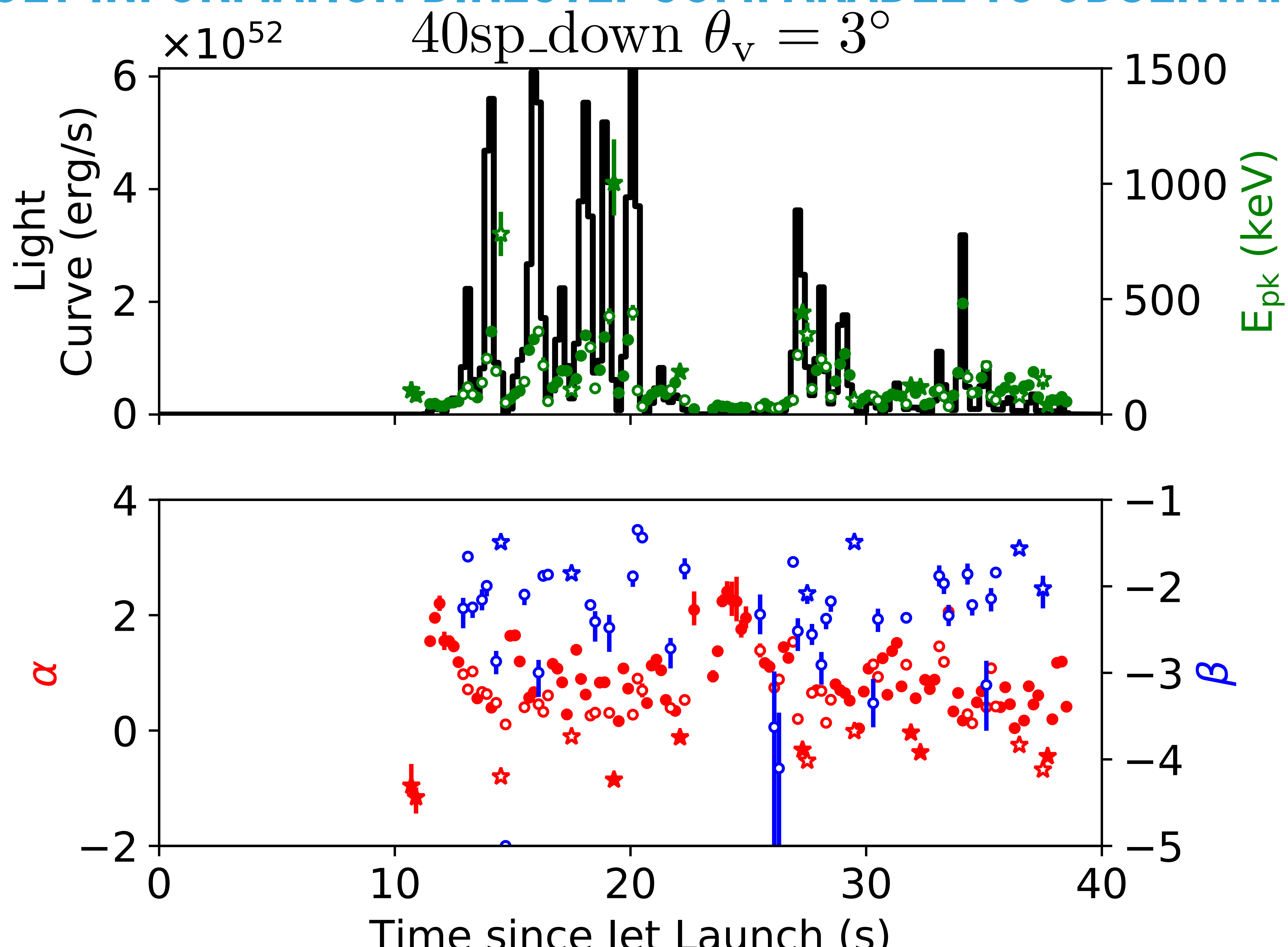
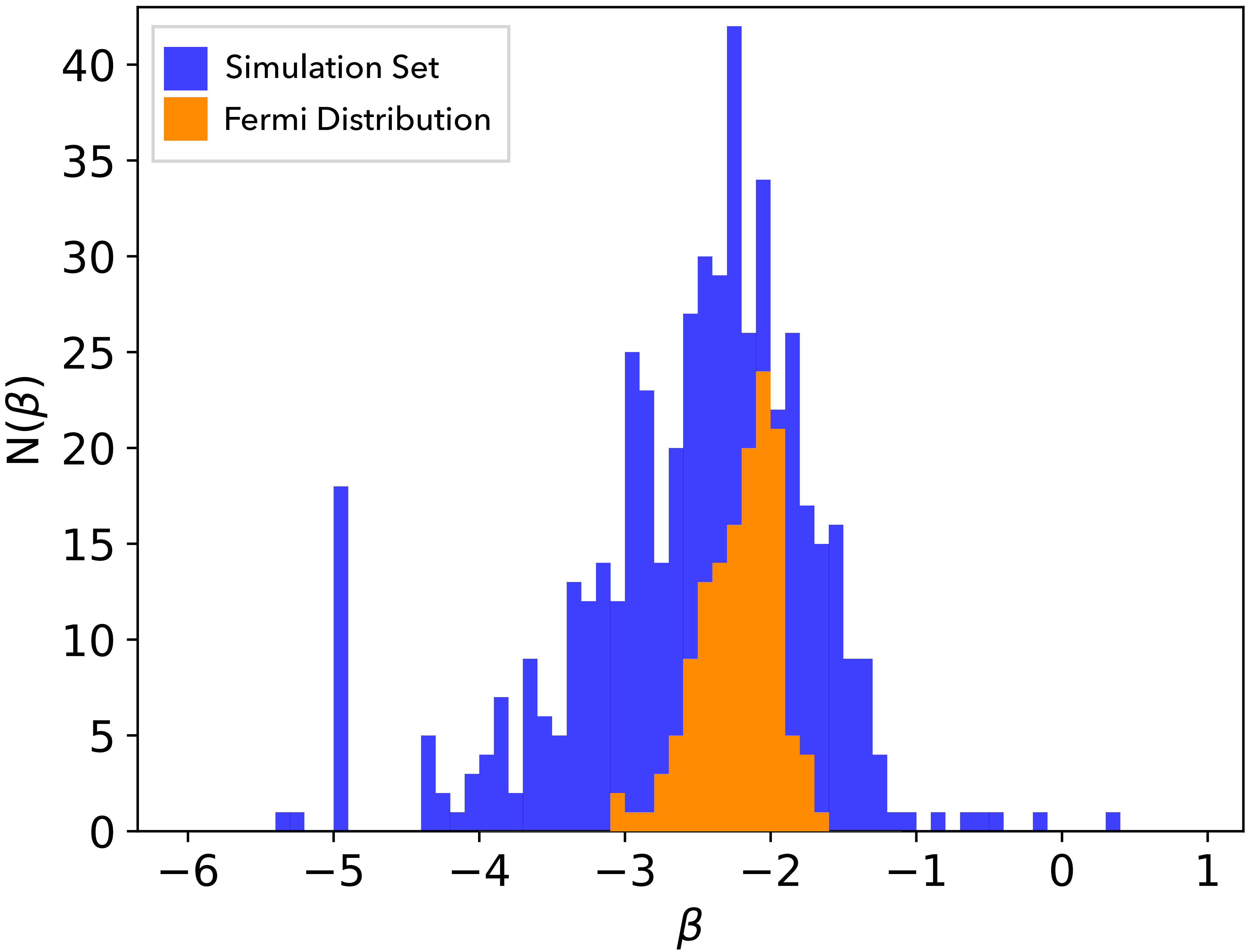
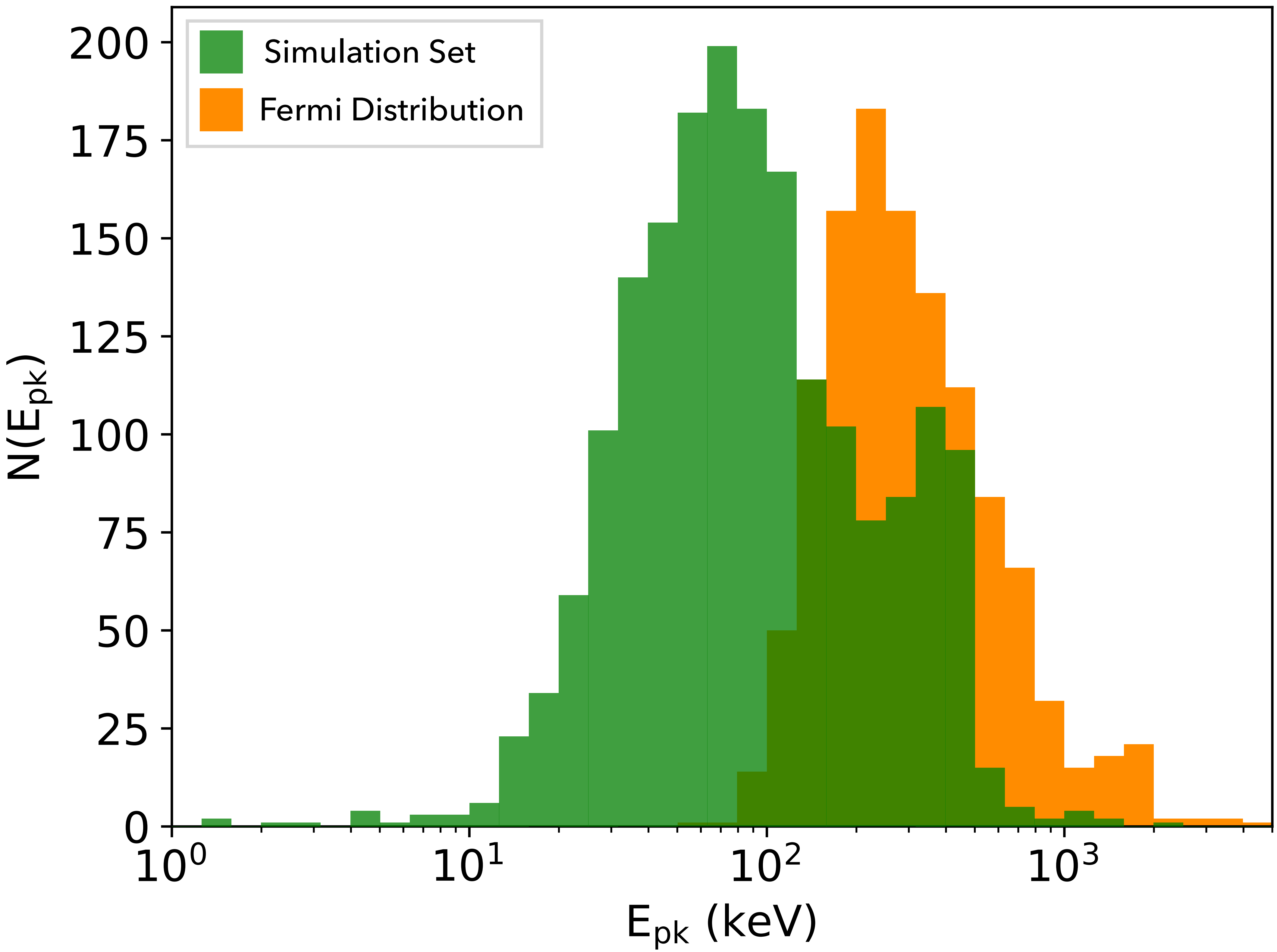


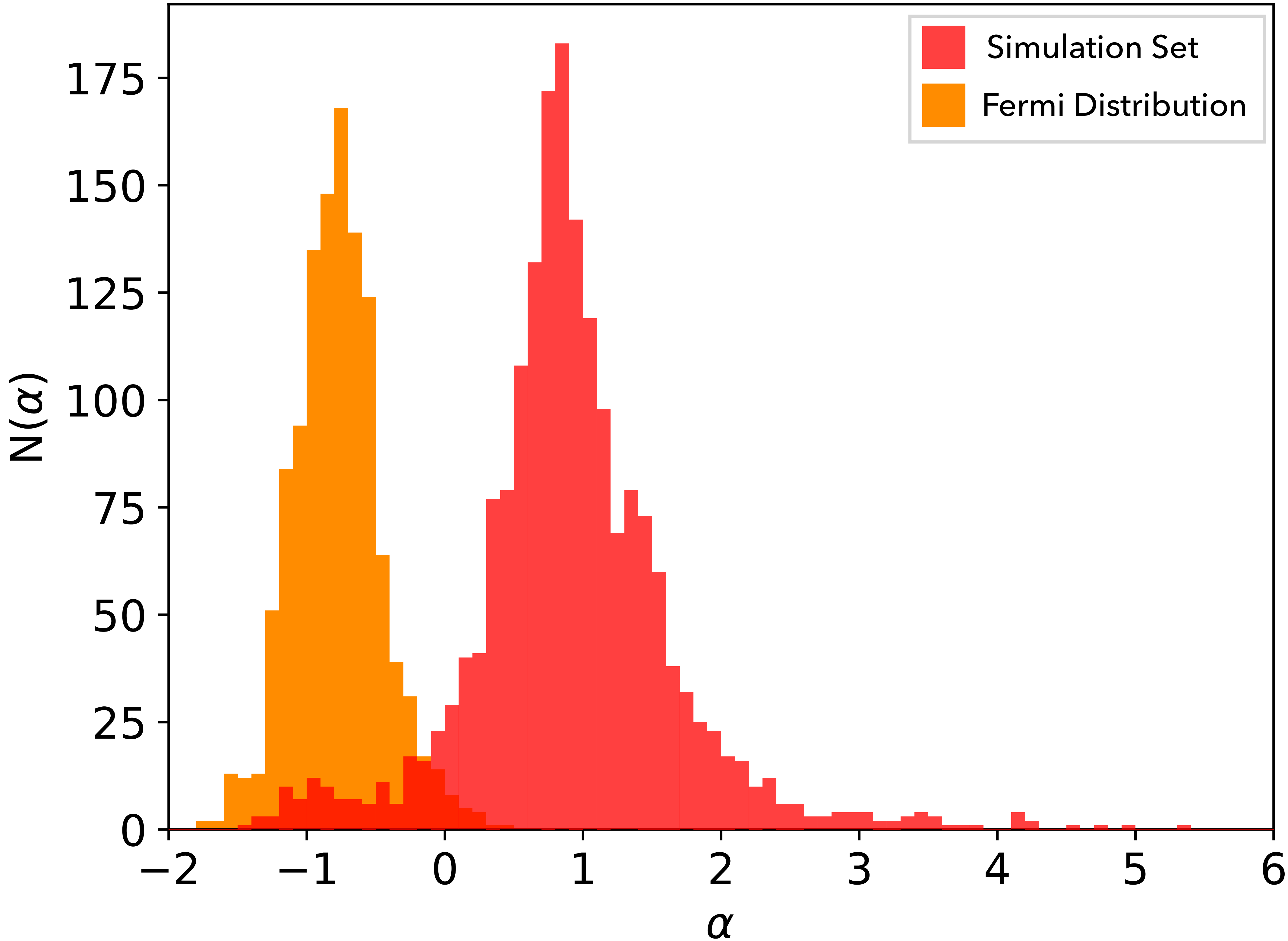
COMPTON SCATTERING CAN RECREATE THE BAND β PARAMETER



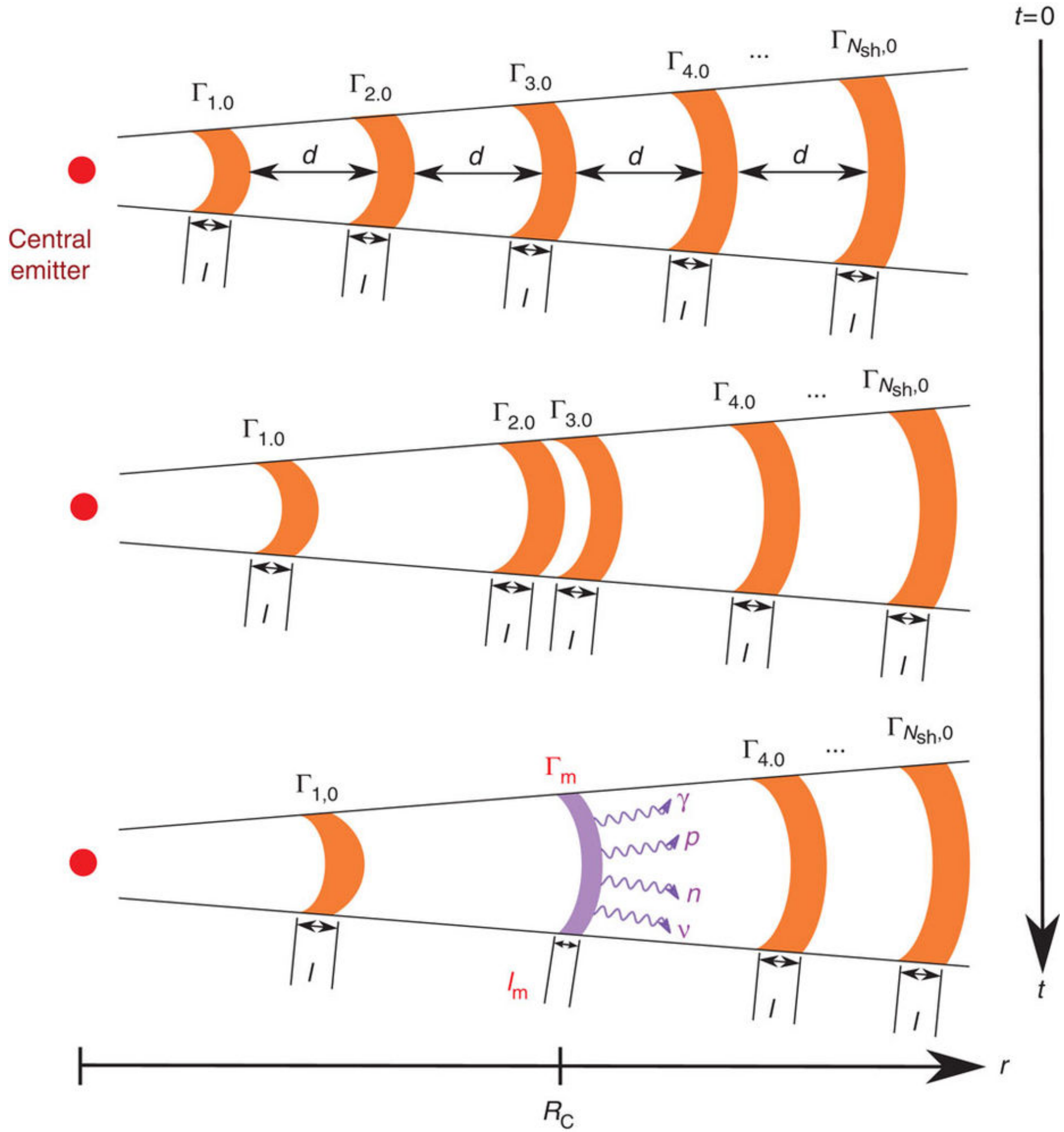
COMPTON SCATTERING CAN RECREATE THE PEAK ENERGIES



COMPTON SCATTERING CAN RECREATE THE BAND LOW ENERGY PARAMETERS



GRB RADIATION MODELS
SYNCHROTRON SHOCK MODEL



Nature Communications **6**, Article number: 6783 (2015)

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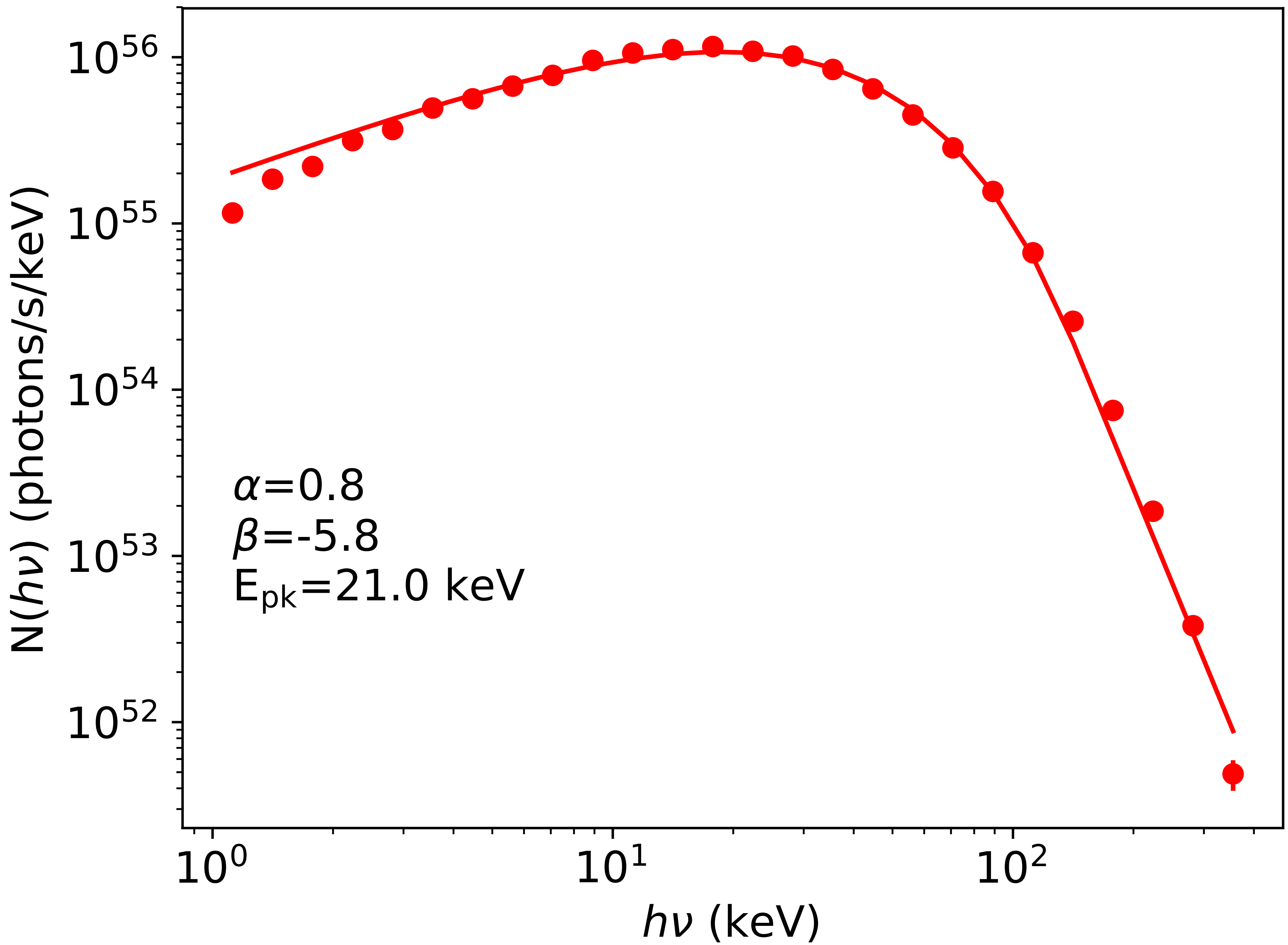

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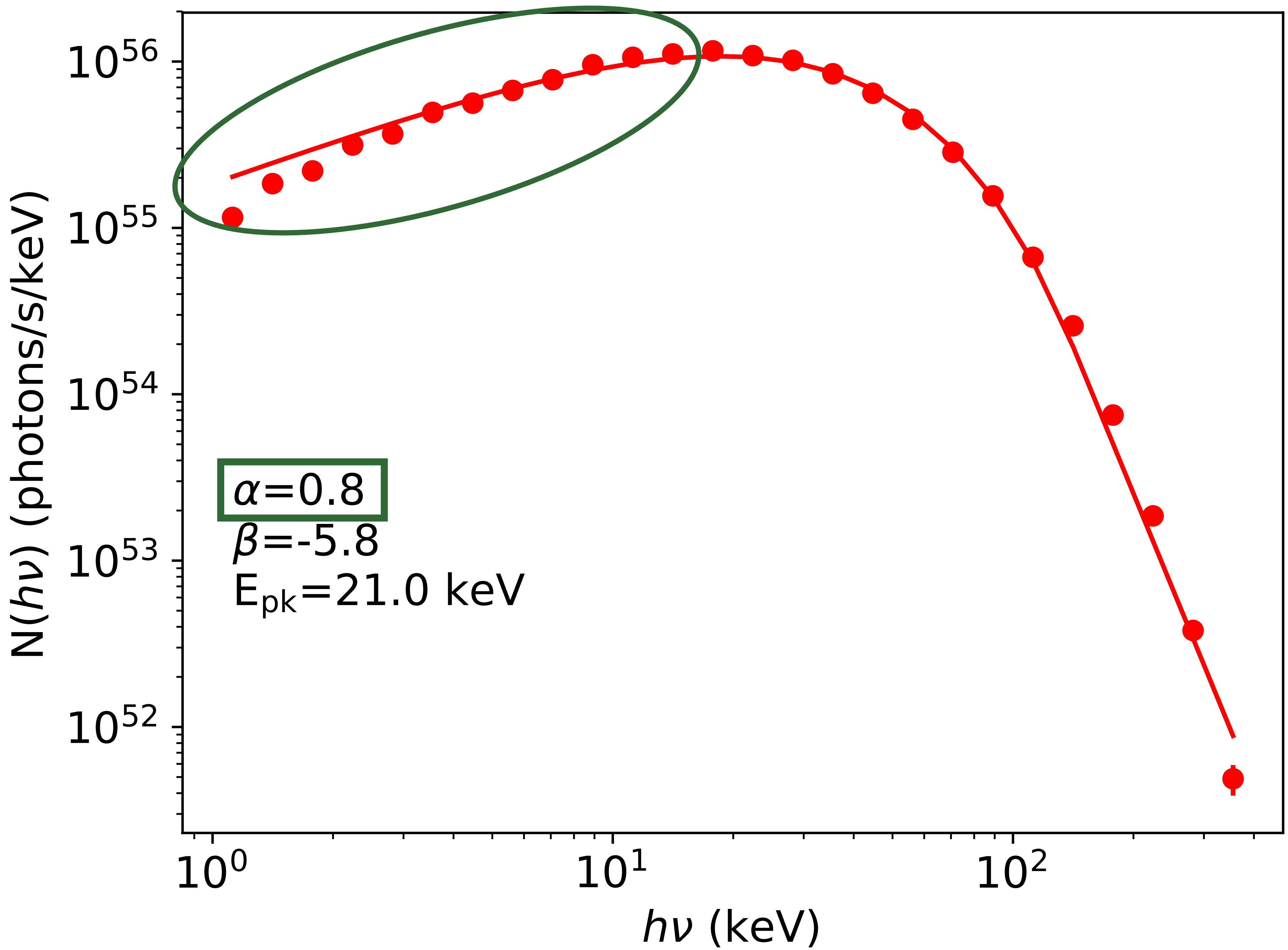

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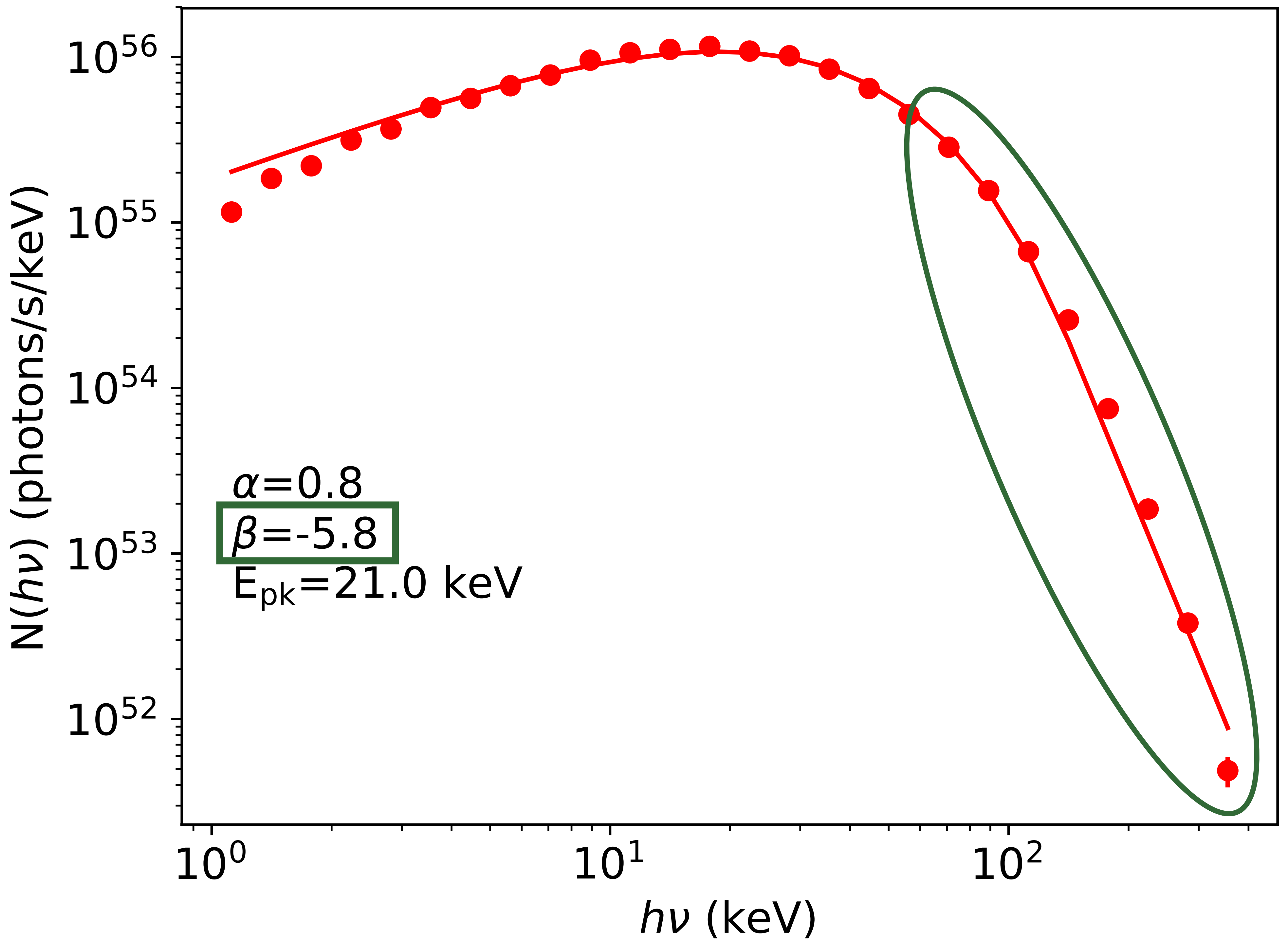

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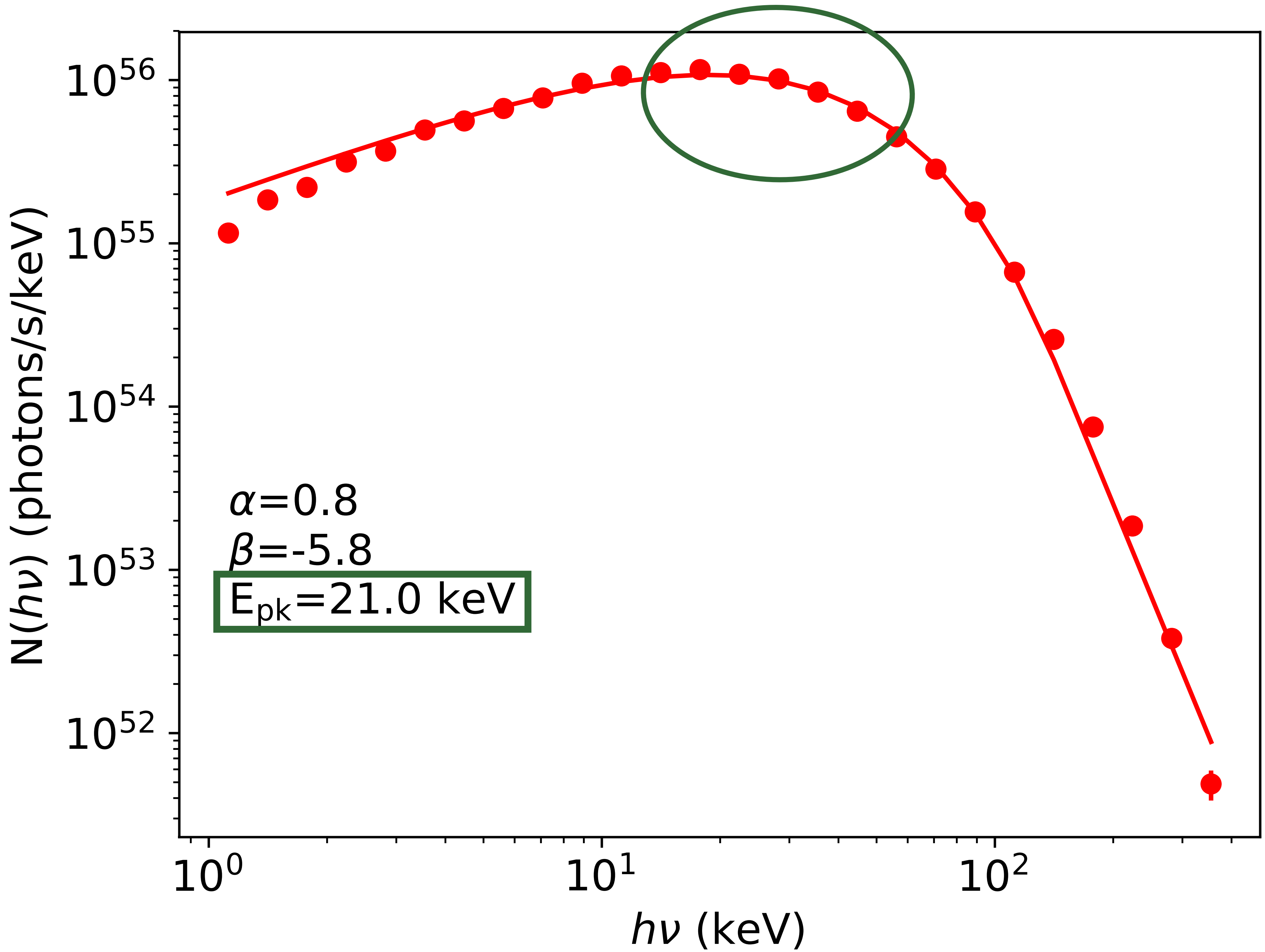

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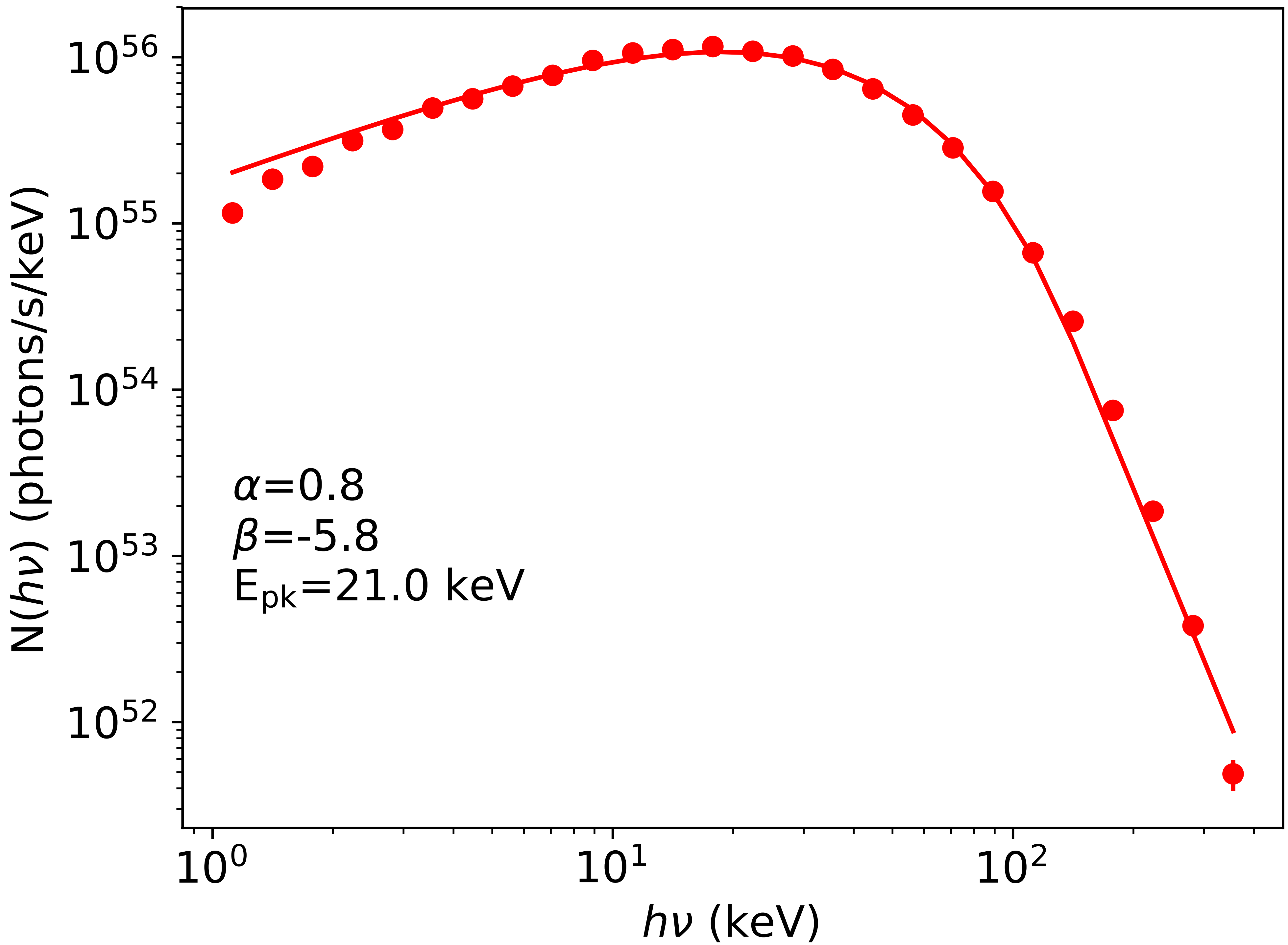

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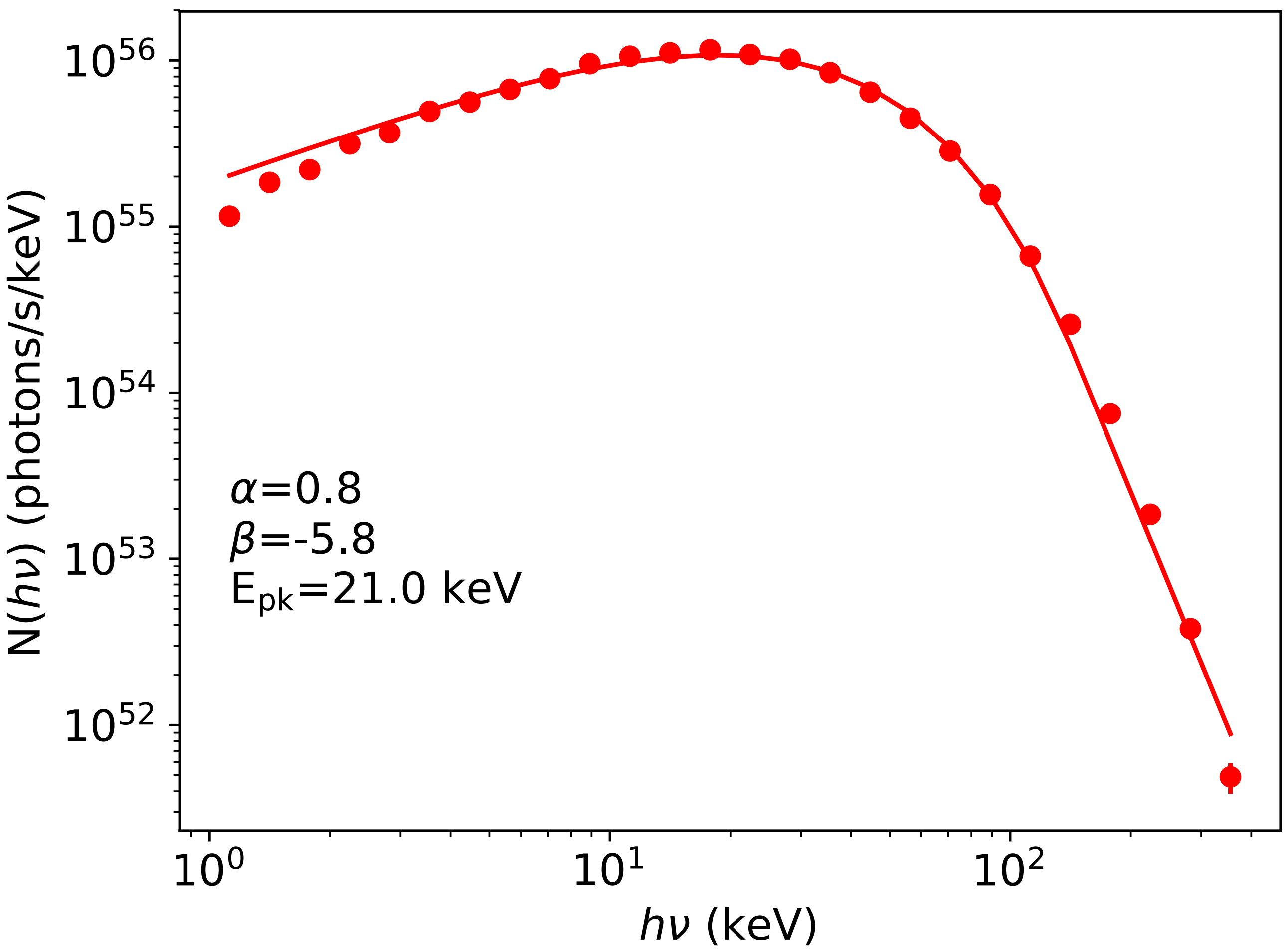
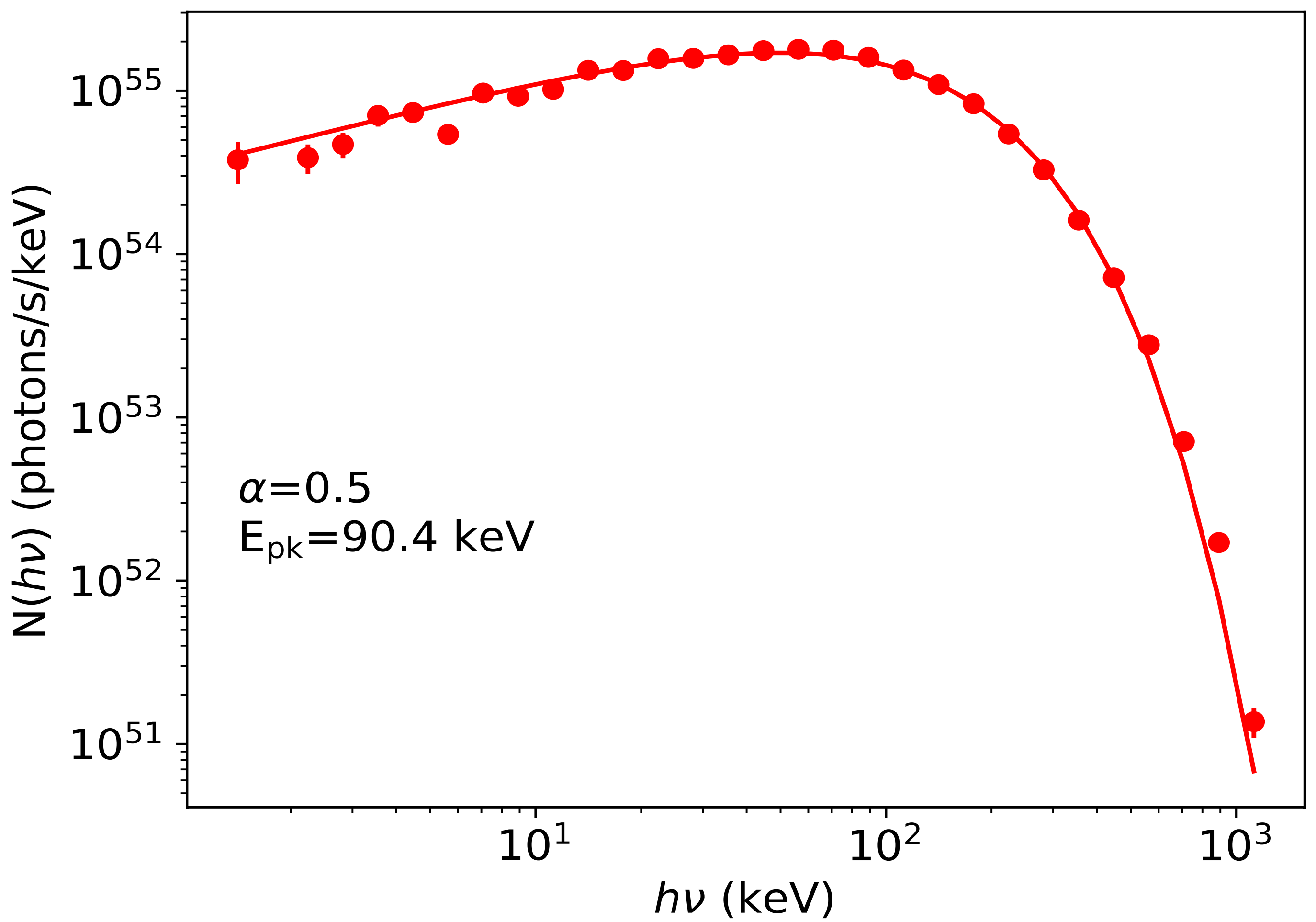
Best Fit: Band Function



Best Fit: COMP Function



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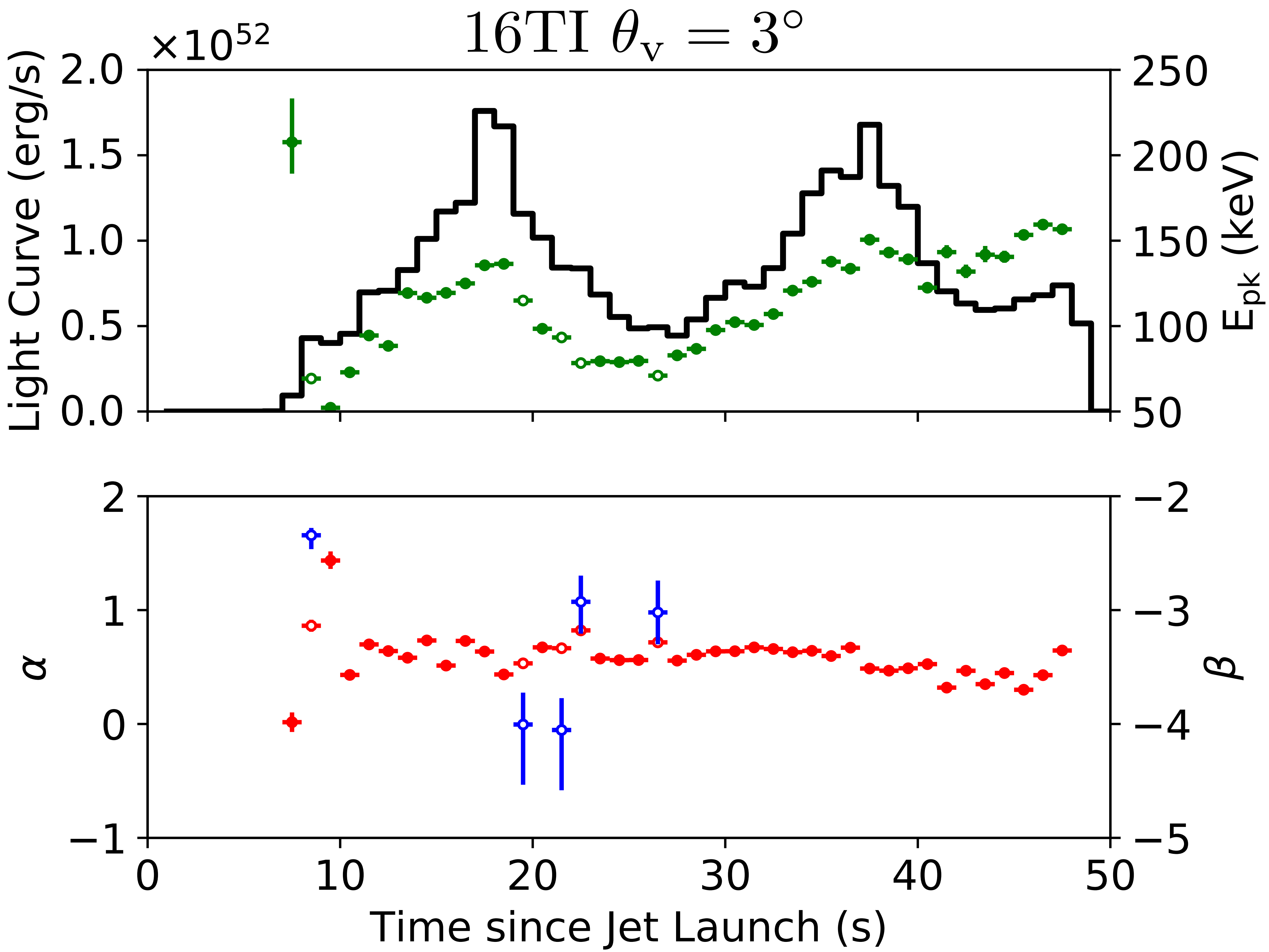

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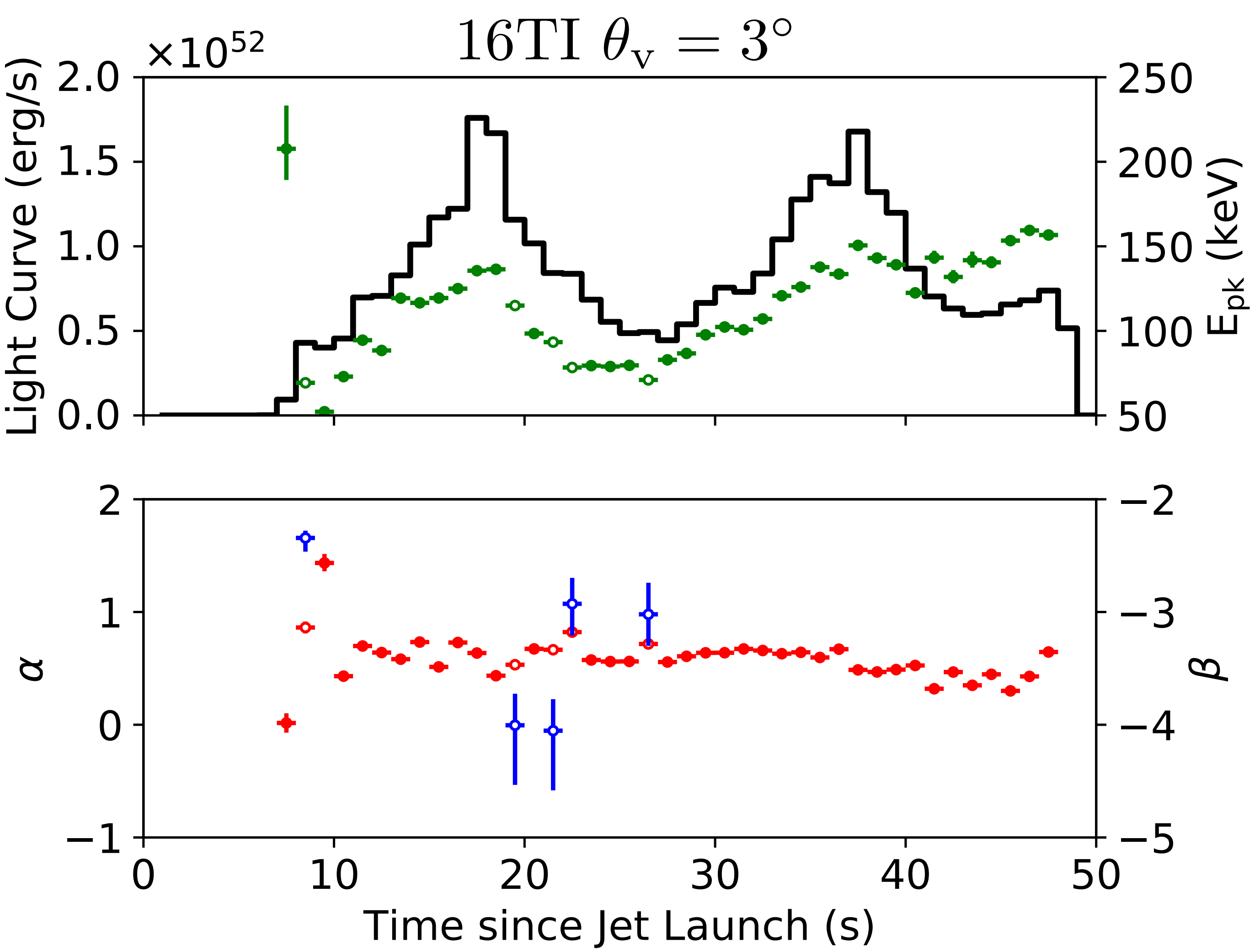

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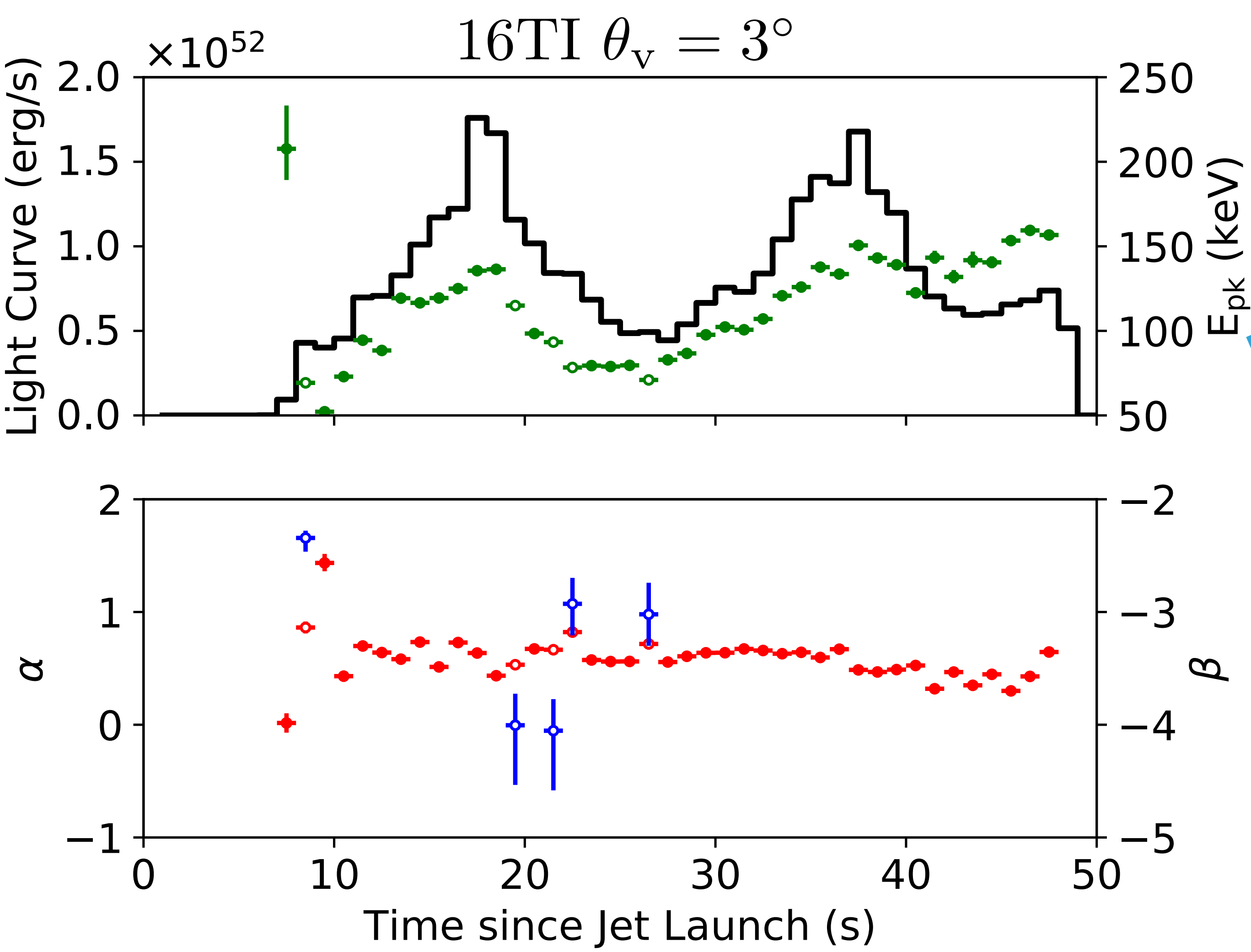
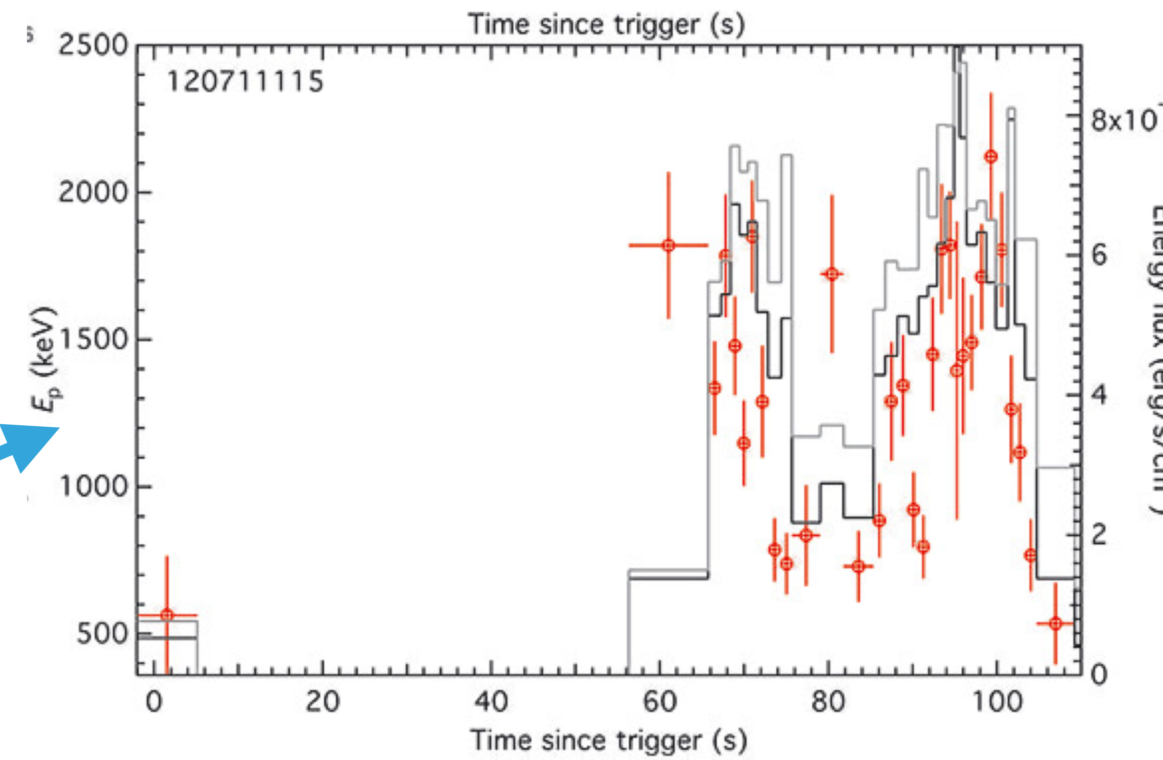
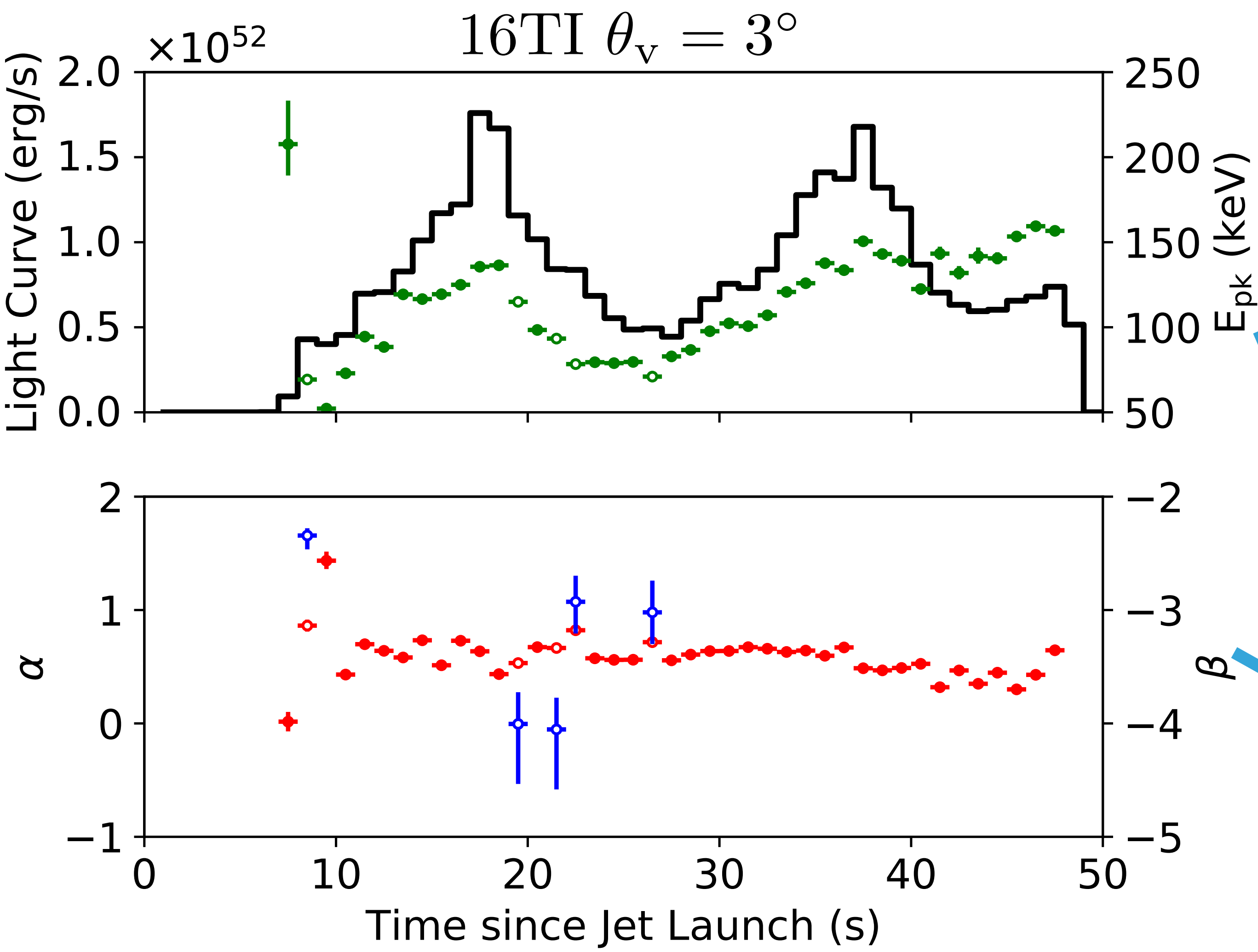
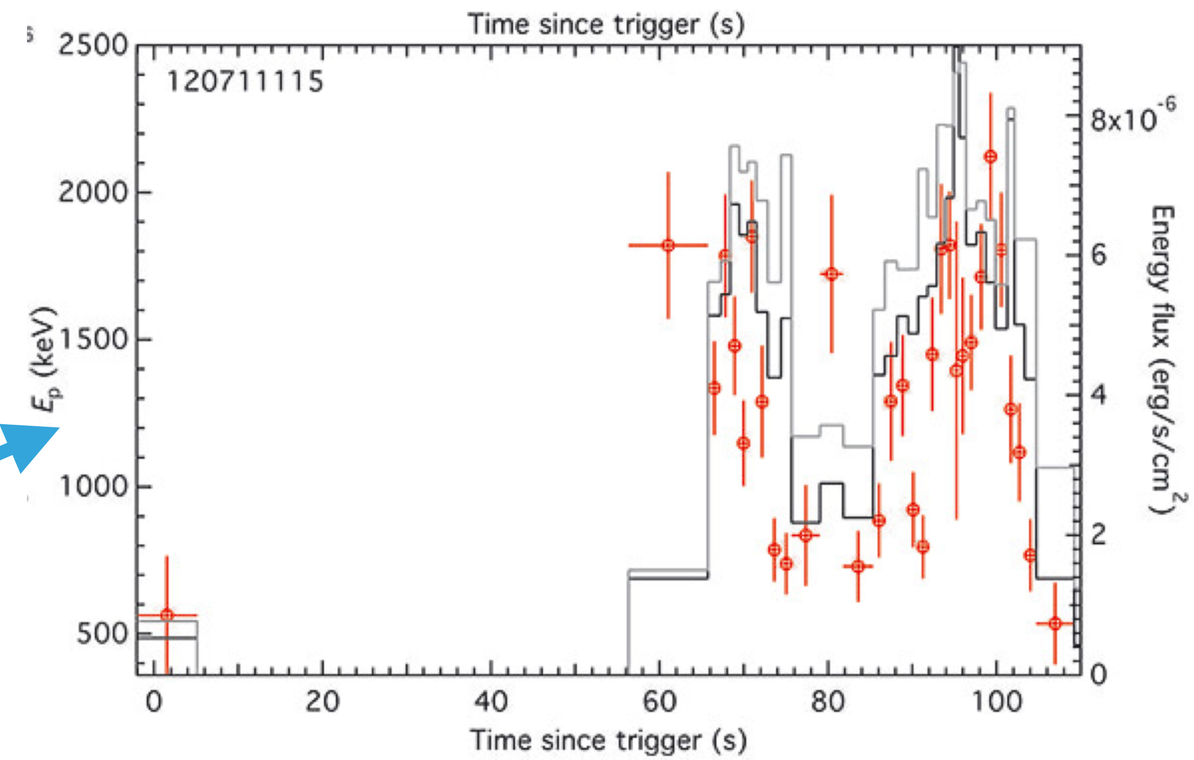


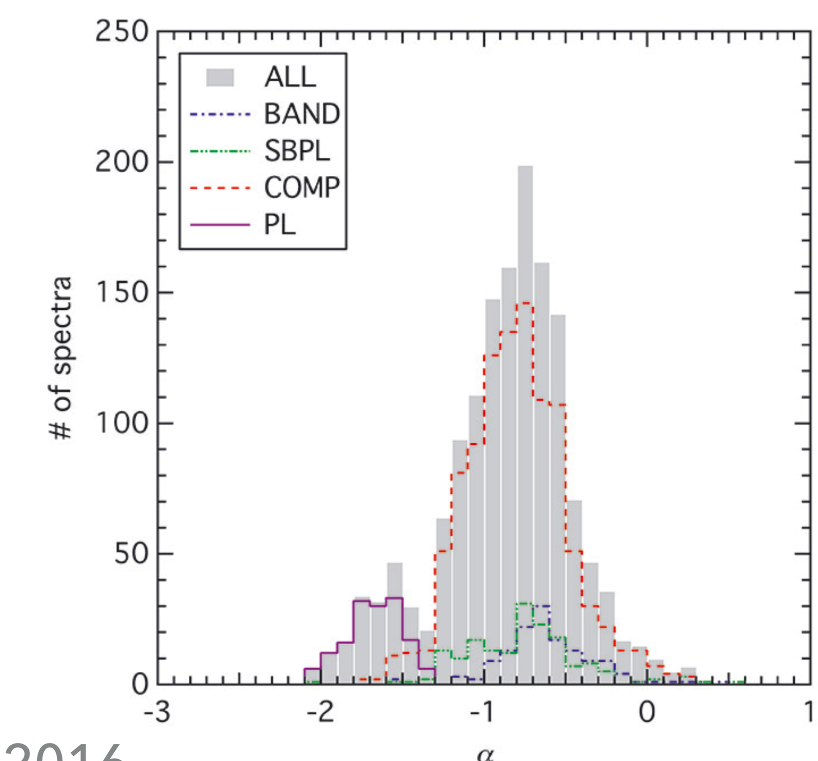


Yu et. al. A&A, 588:A135, 2016.

WE GET INFORMATION DIRECTLY COMPARABLE TO OBSERVATIONS

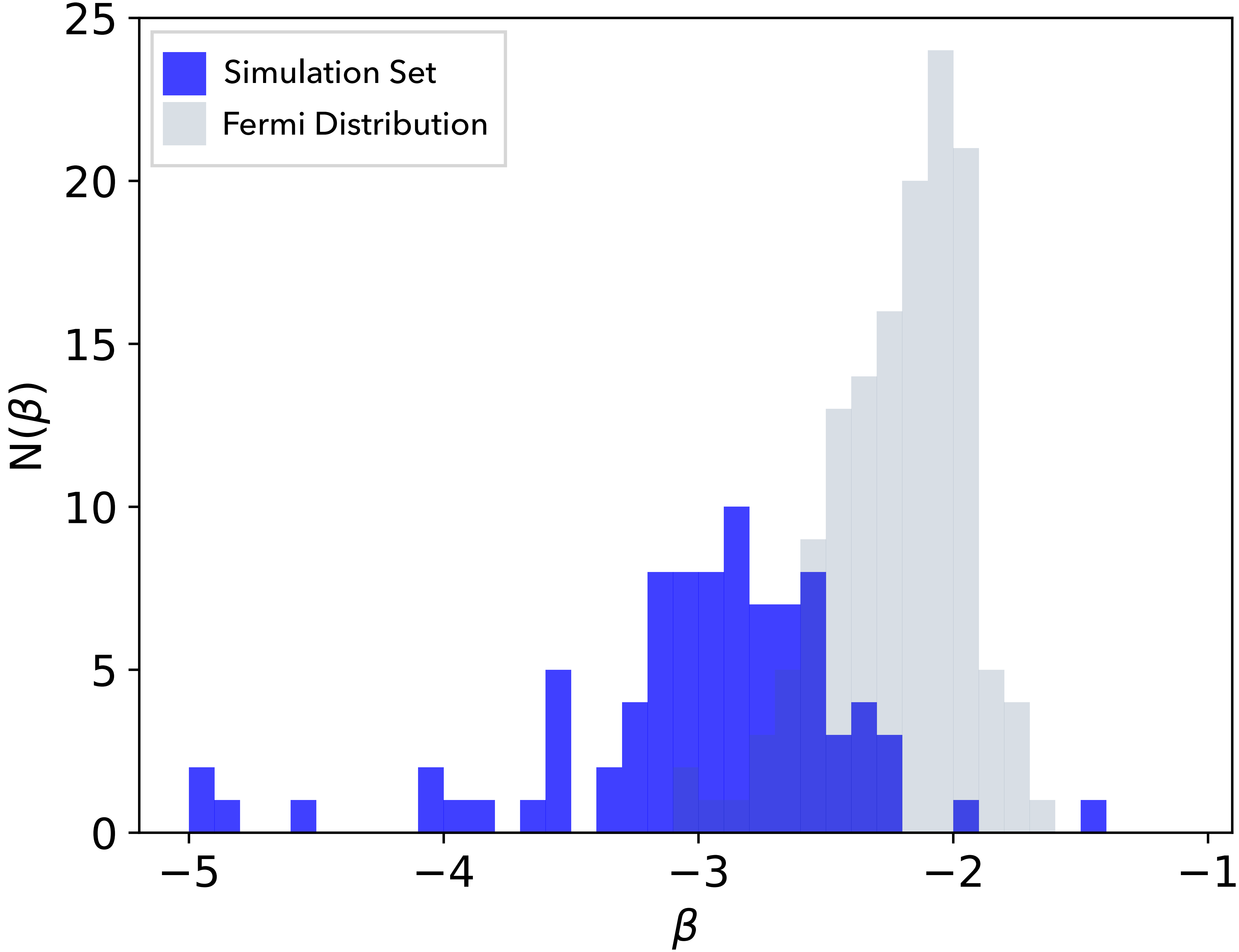




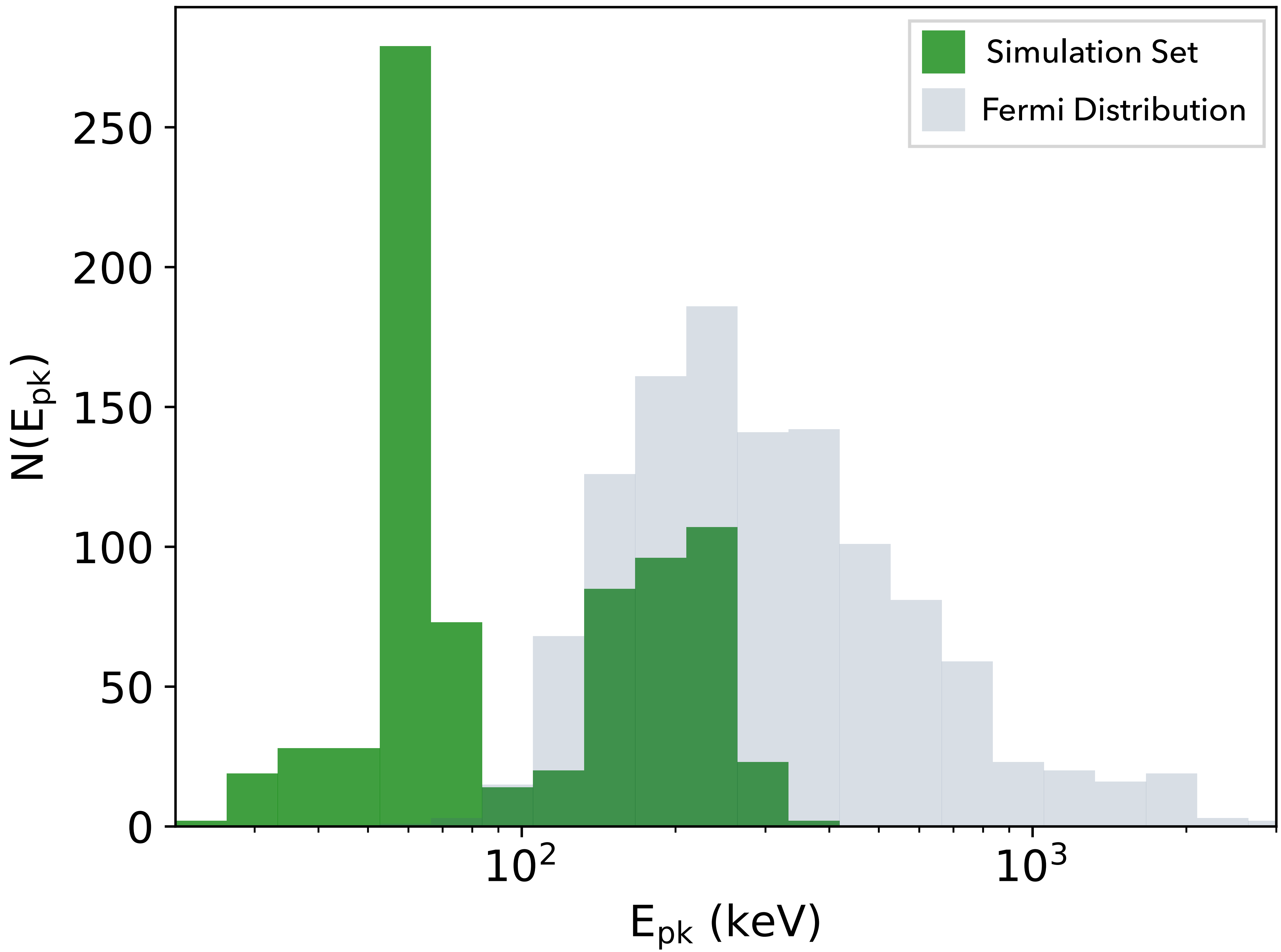


Yu et. al. A&A, 588:A135, 2016.

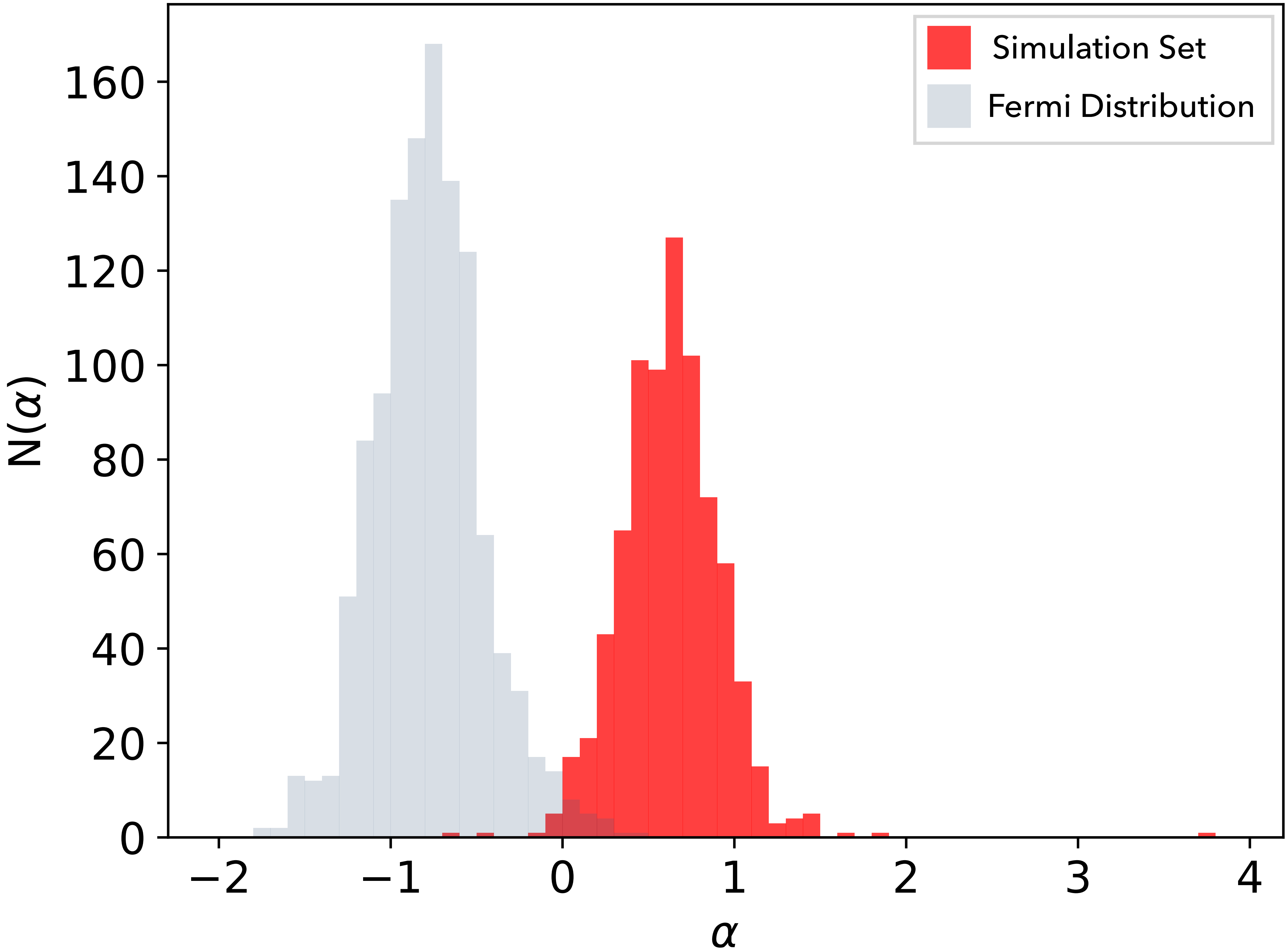
COMPTON SCATTERING CAN RECREATE THE BAND β PARAMETER



COMPTON SCATTERING CAN RECREATE THE PEAK ENERGIES



COMPTON SCATTERING CANNOT RECREATE THE BAND LOW ENERGY PARAMETERS



THE PHOTOSPHERE IS A DYNAMIC SURFACE