BEAMING IN FAST RADIO BURSTS

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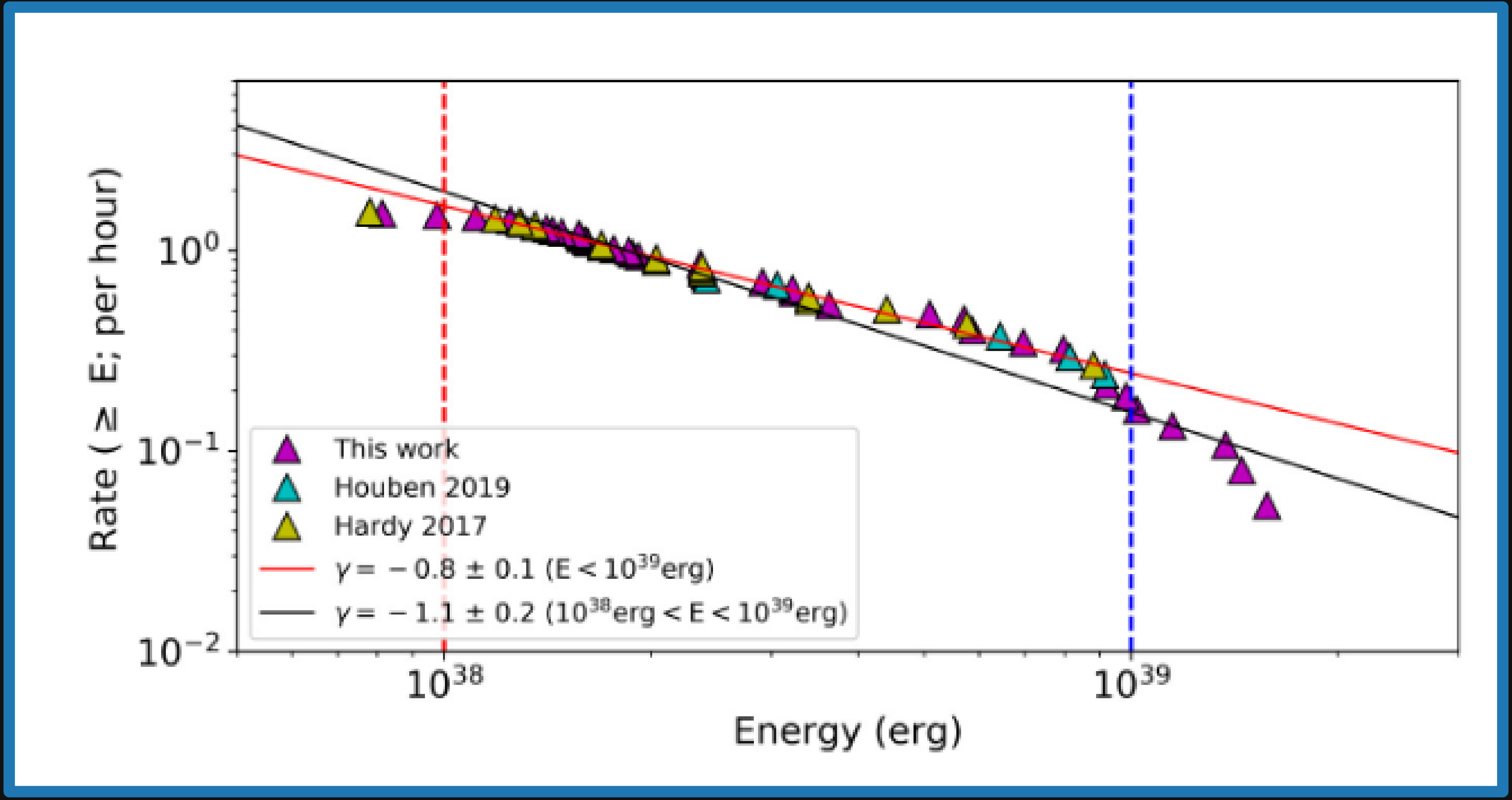
BEAMING IN FAST RADIO BURSTS

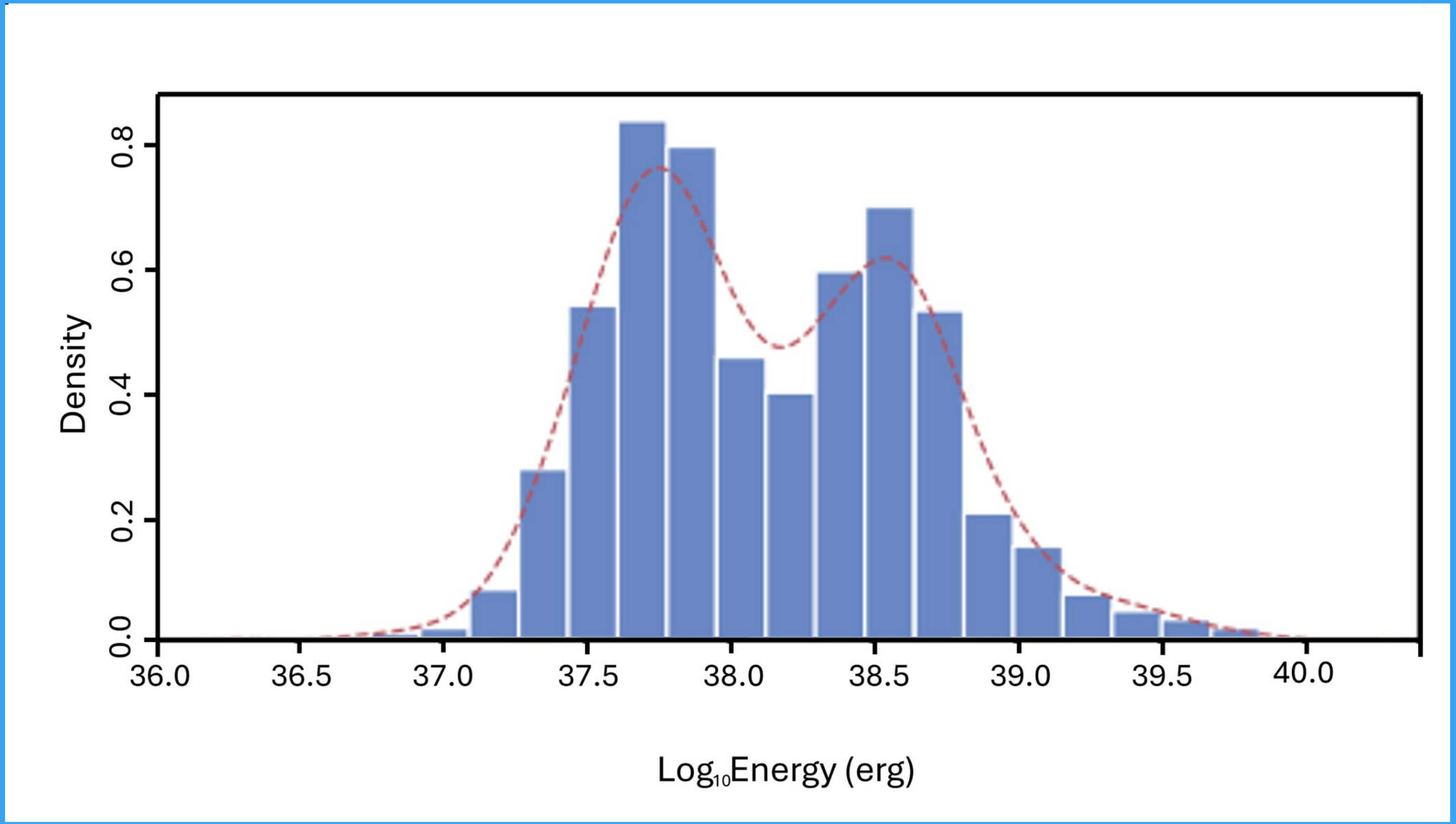
Simulate the directional dependence of emission from FRBs

Understand how the beaming affects the observed energy distribution



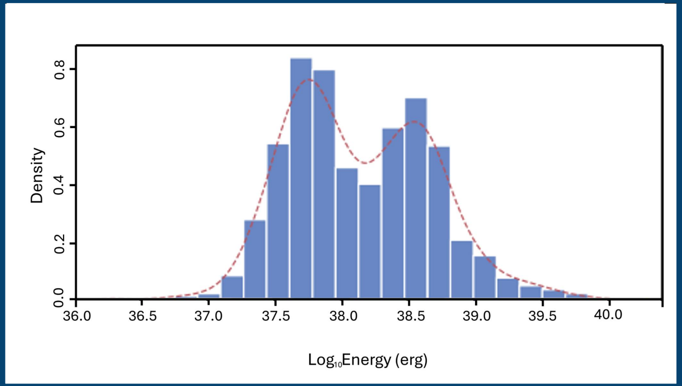
The cumulative distribution function of FRB121102 can be well modelled with a power-law.

Cruces, M., Spitler, L., Scholz, P., et al. 2021, Monthly Notices of the Royal Astronomical Society, 500, 448



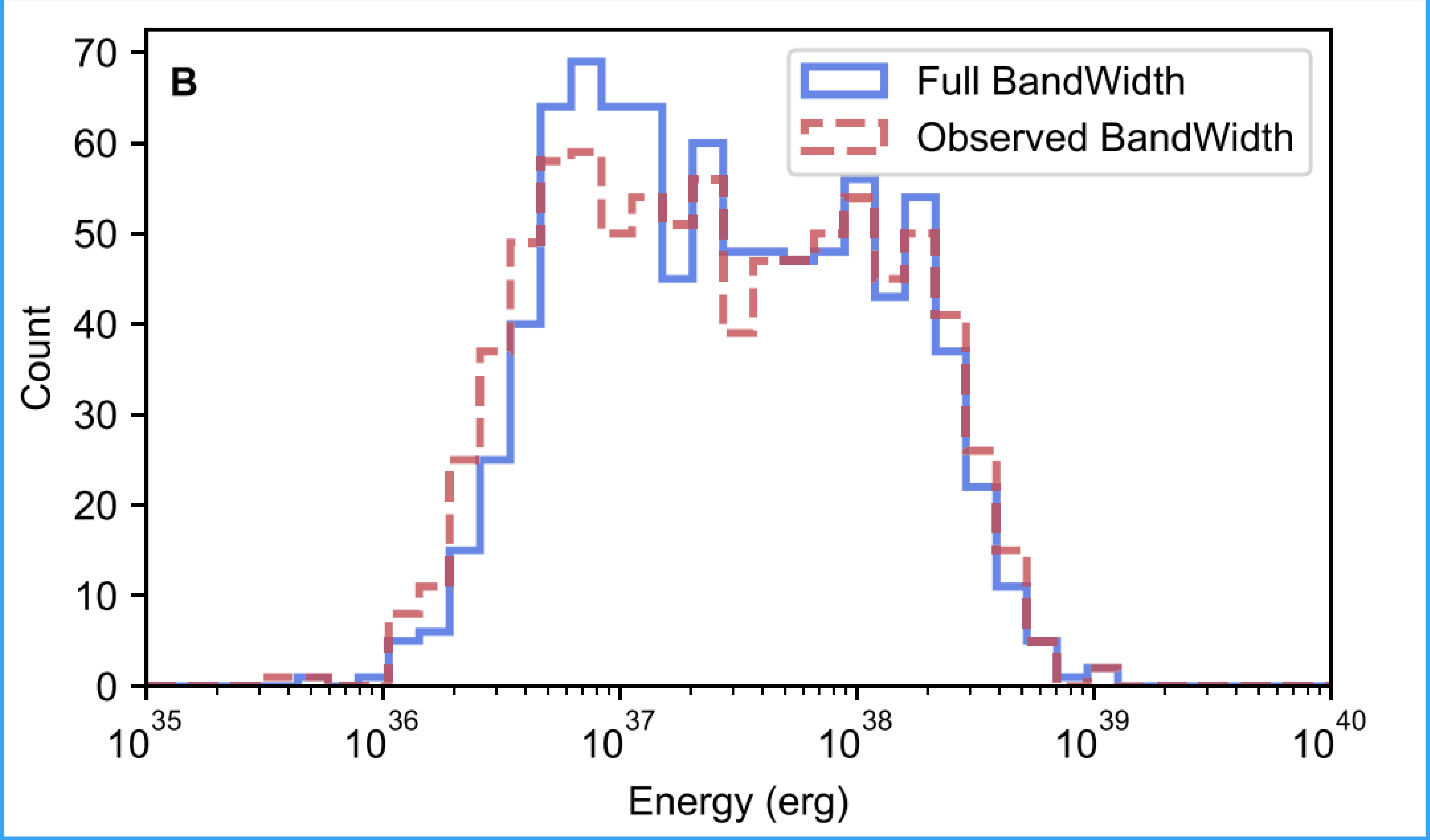
- Analysis over a period of over 1600 bursts from FRB121102, over the span of 47 days
- Bimodality that appeared over time & then disappeared
- Modelled by a generalized Cauchy function and a log-normal function

Li, D., Wang, P., Zhu, W. et al. (2021). A bimodal burst energy distribution of a repeating fast radio burst source. Nature, 598(7880), 267-271.



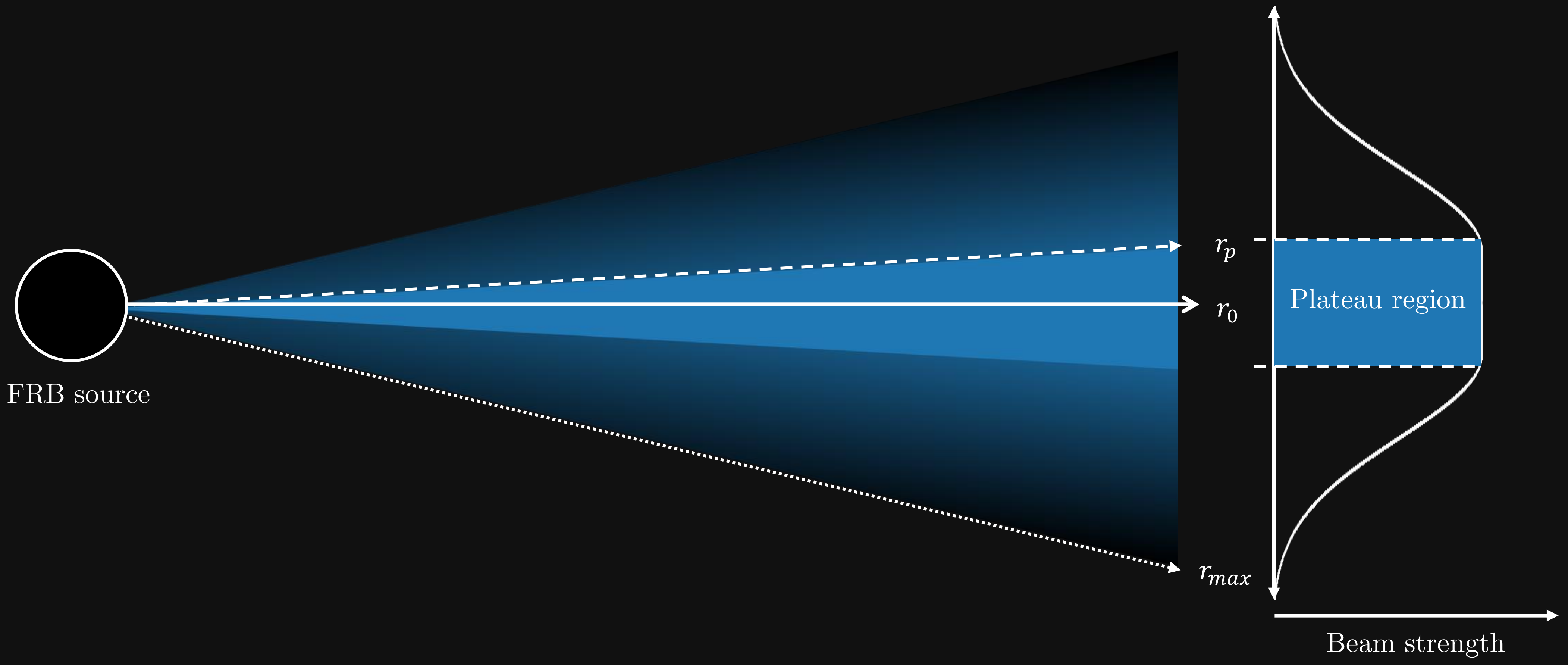
- Analysis over a period of over 800 bursts from FRB201124A, over the span of 4 days.

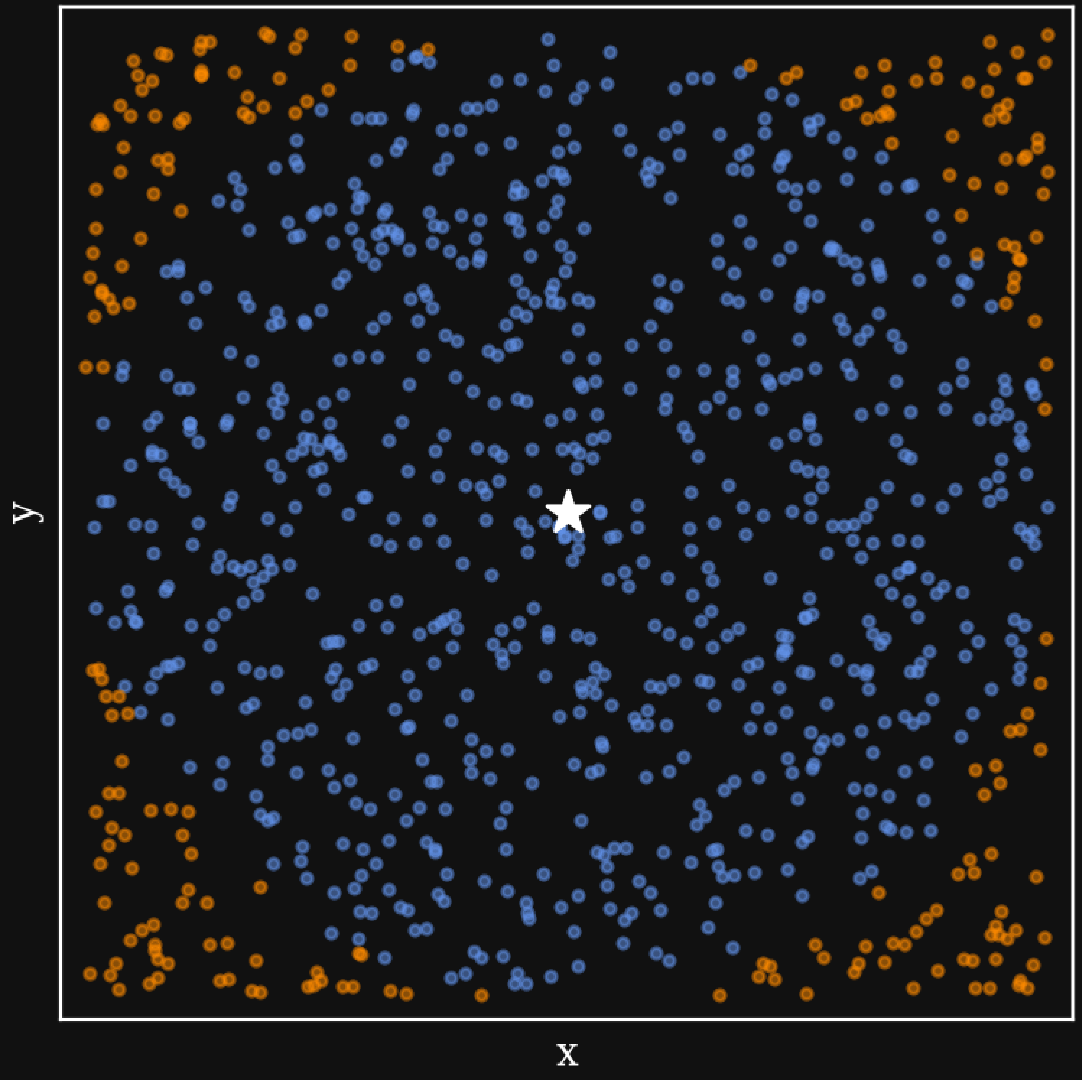
- Modelled by a exponentially connected broken power-law



Zhang, Y. K., Wang, P., Feng, Y., et al. (2022). FAST observations of an extremely active episode of FRB 20201124A. II. energy distribution. Research in Astronomy and Astrophysics, 22(12), 124002.

We consider **beaming** to be the effects of the observers position relative to the centre of the beam on the *observed* energy distribution



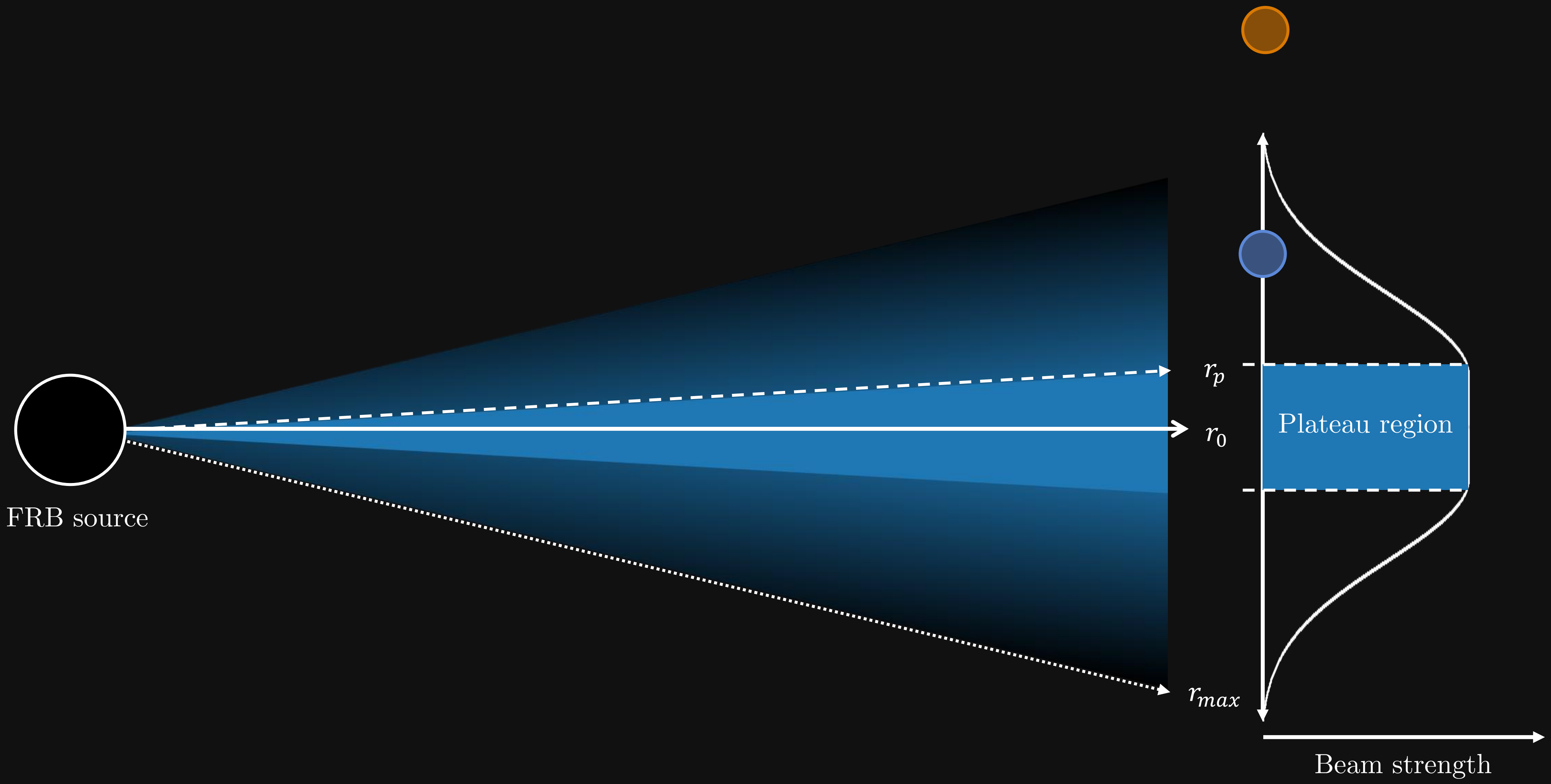


$n_{bursts} = 1000$

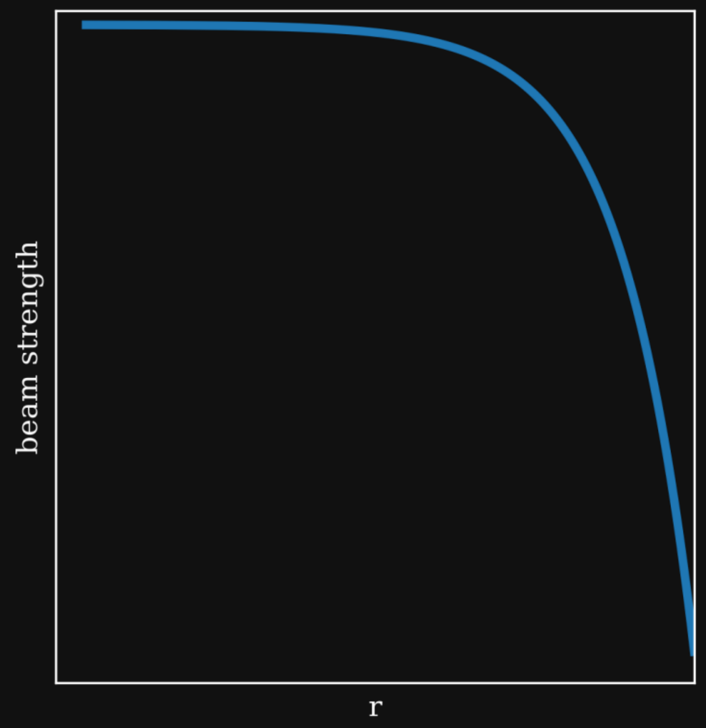
included angles

angles outside of r_{max} that get discarded

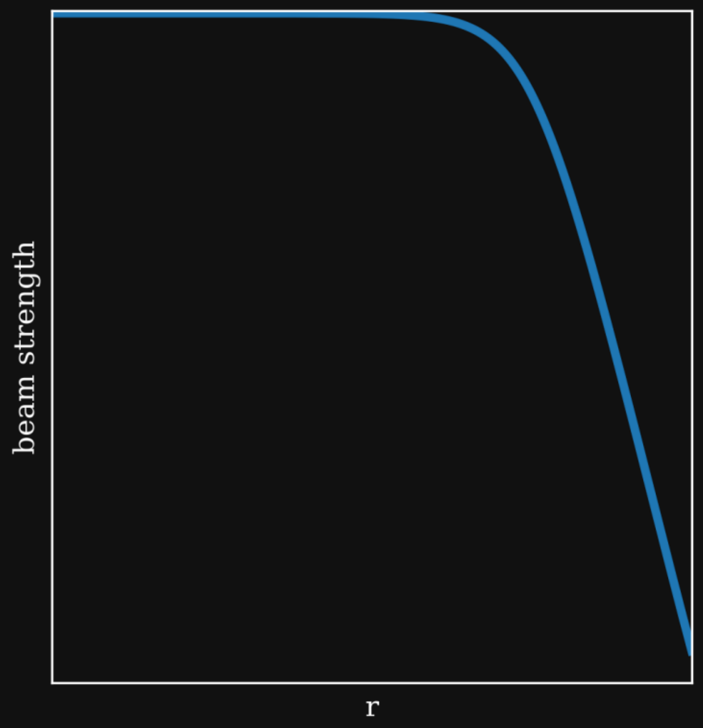
FRB



FRB source
r_p
r_0
r_{max}
Plateau region
Beam strength



Gaussian



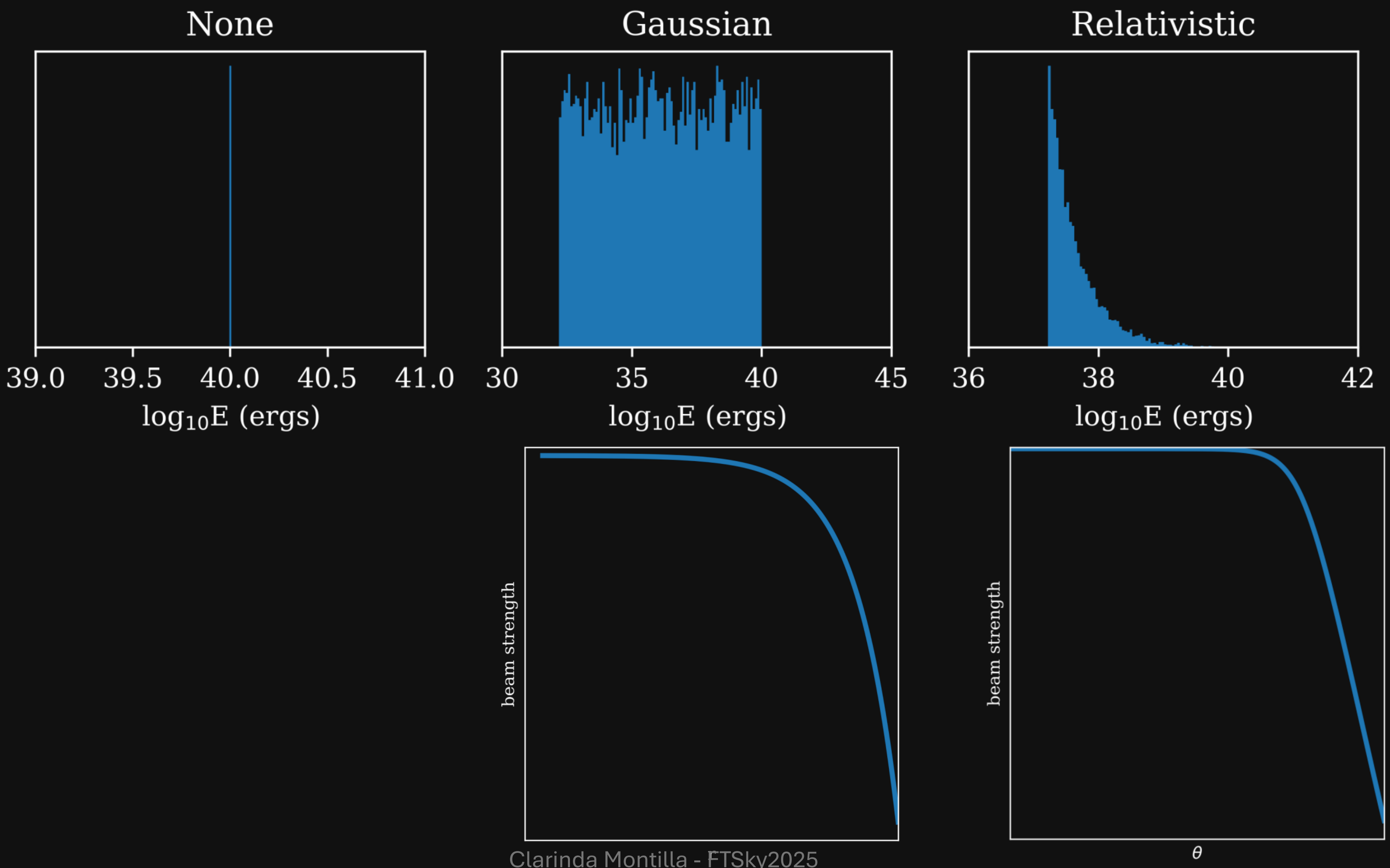
Relativistic

BEAM SHAPES

$$B = E_0$$

$$B = \mathrm{E}_0 \exp\left(\frac{-r^2}{2\sigma_r^2}\right)$$

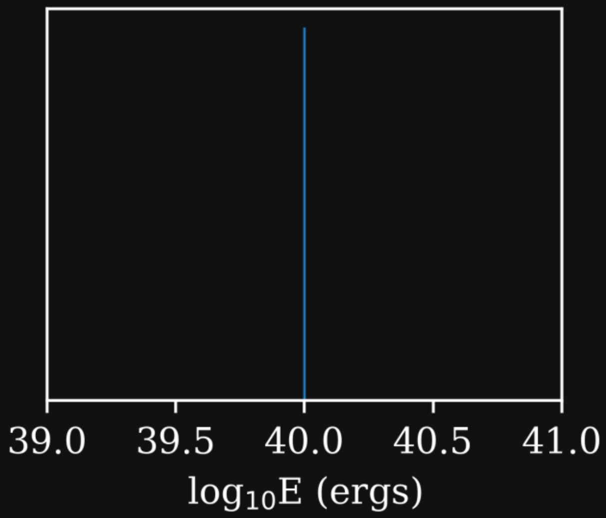
$$B = \frac{E_0}{\Gamma(1 - \beta\cos\theta)}$$



BEAM SHAPES

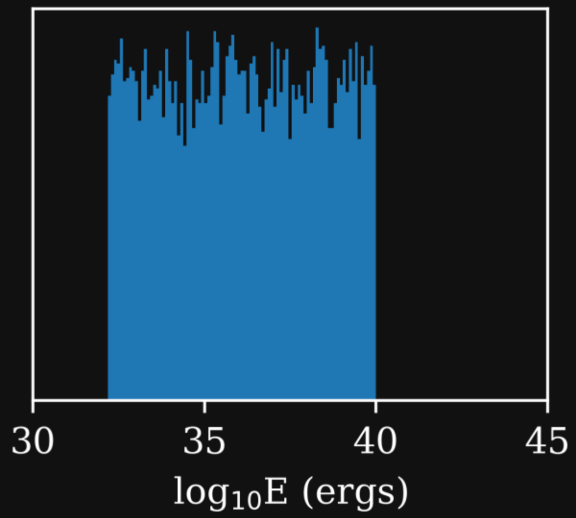
$$B = E_0$$

None



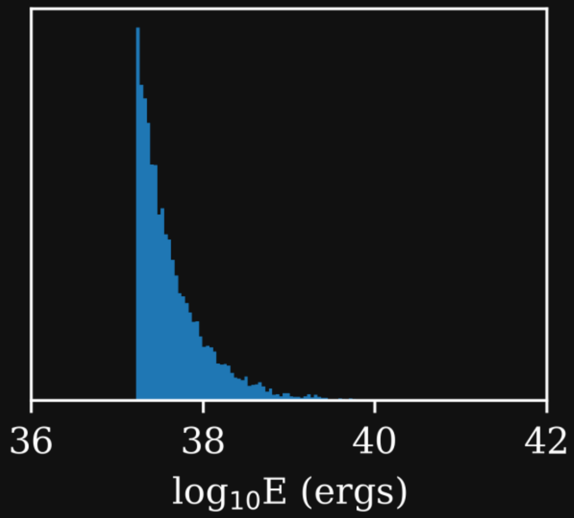
$$B = \mathrm{E}_0 \exp\left(\frac{-r^2}{2\sigma_r^2}\right)$$

Gaussian



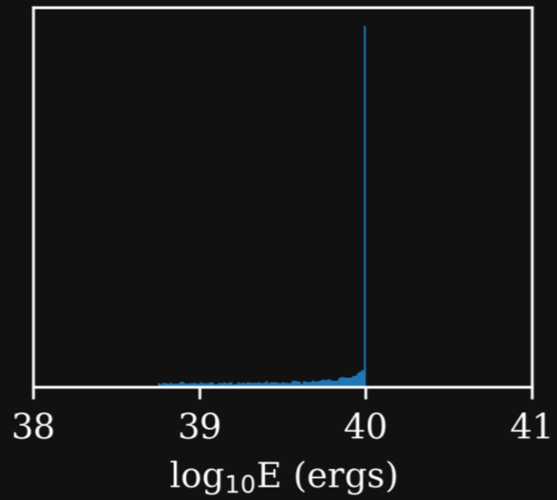
$$B = \frac{E_0}{\Gamma(1 - \beta\cos\theta)}$$

Relativistic

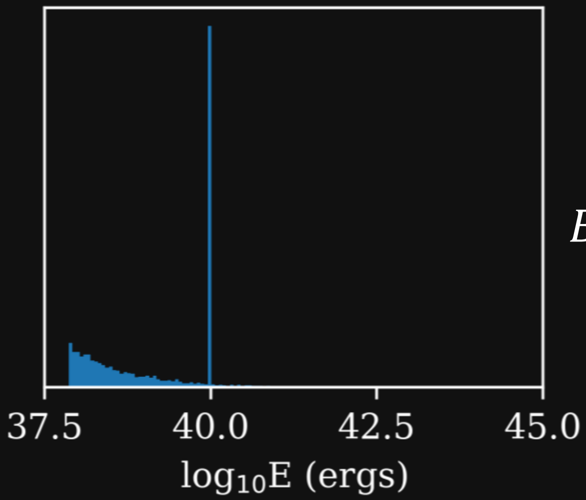


$$B = \begin{cases} E_0 & r \leq r_p \\ \mathrm{E}_0 \exp\left(\frac{-r^2}{2\sigma_r^2}\right) & r > r_p \end{cases}$$

Gaussian & Plateau

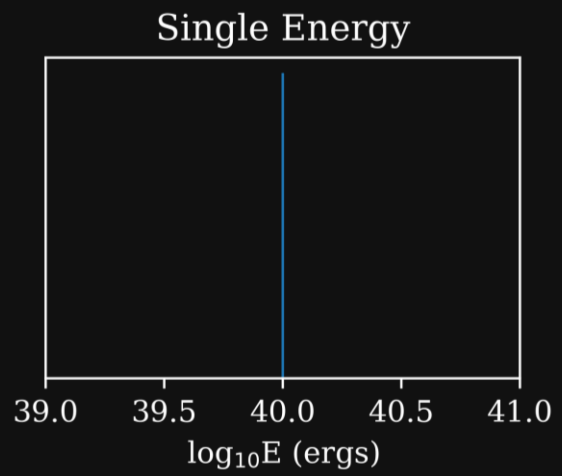


Relativistic & Plateau

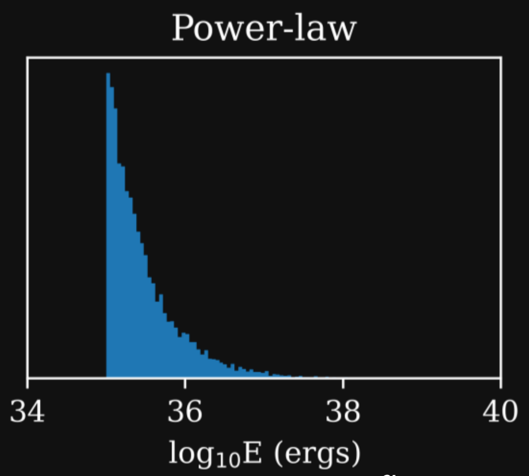


$$B = \begin{cases} E_0 & r \leq r_p \\ \frac{\mathrm{E}_0}{\Gamma(1 - \beta cos\Delta\theta)} & r > r_p \end{cases}$$

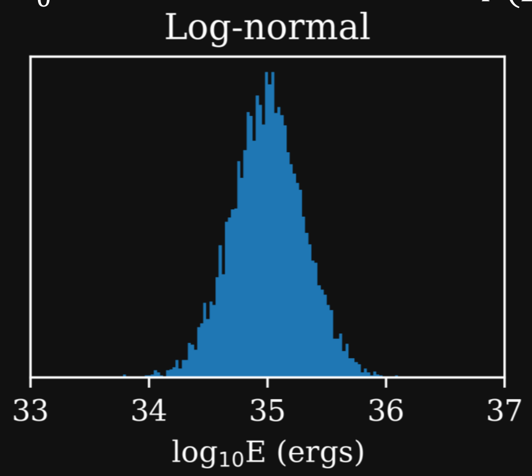
INTRINSIC ENERGY



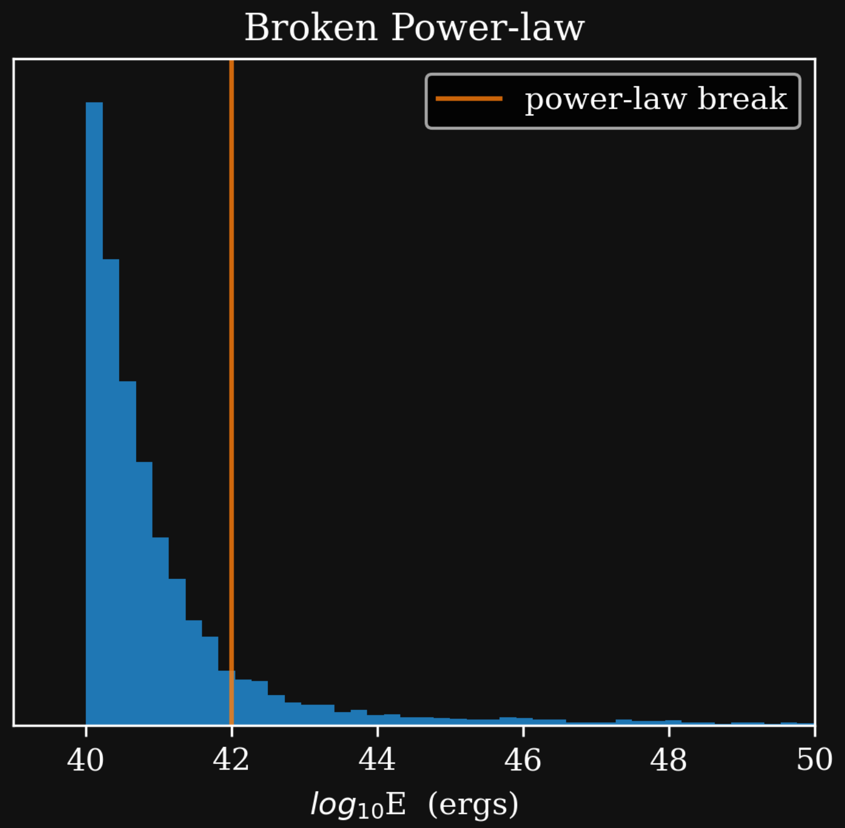
$$P(E) = E_0$$



$$P(E) = \left(\frac{E}{E_0}\right)^{\alpha}$$

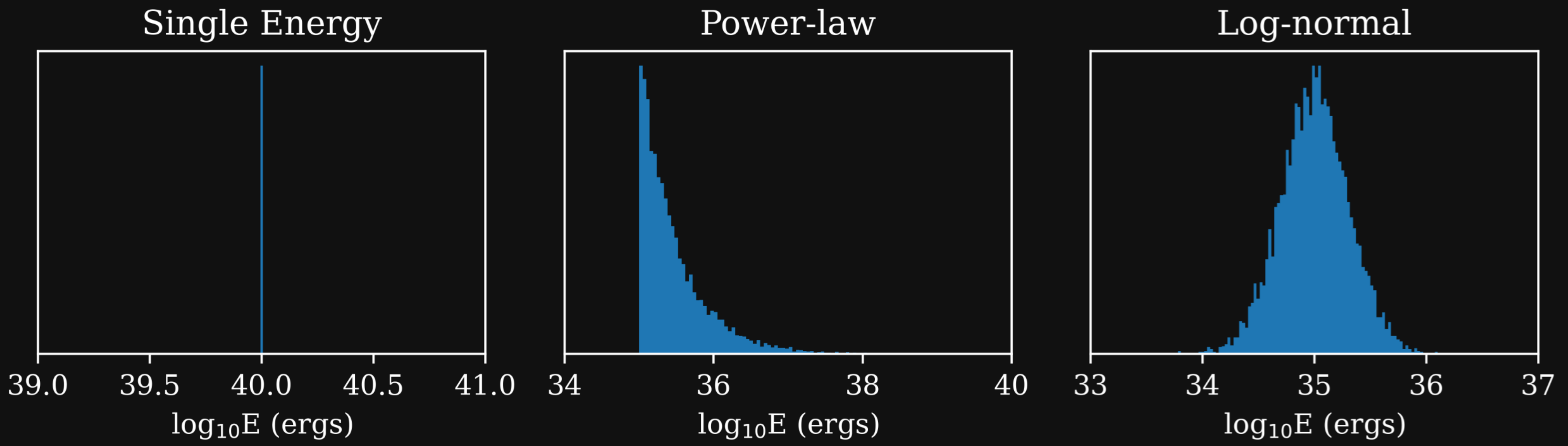


$$P(E) = \frac{1}{sx\sqrt{2\pi}} \exp\left(-\frac{\log^2 E}{2s^2}\right)$$



$$P(E) = \begin{cases} \left(\frac{E}{E_0}\right)^{\alpha_1} & E \leq E_B \\ \left(\frac{E}{E_0}\right)^{\alpha_2} & E > E_B \end{cases}$$

INTRINSIC ENERGY

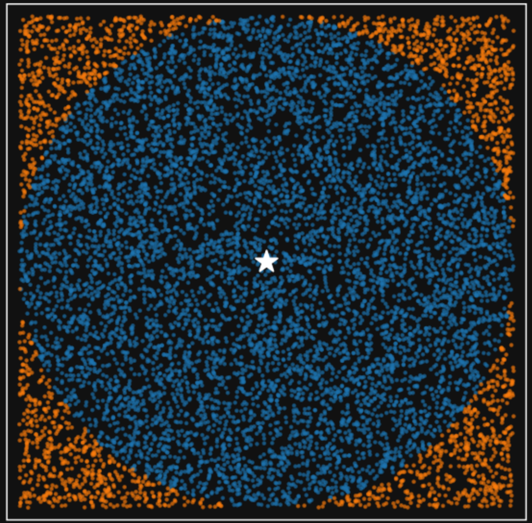


$$P(E) = E_0$$

$$P(E) = \left(\frac{E}{E_0}\right)^{\alpha}$$

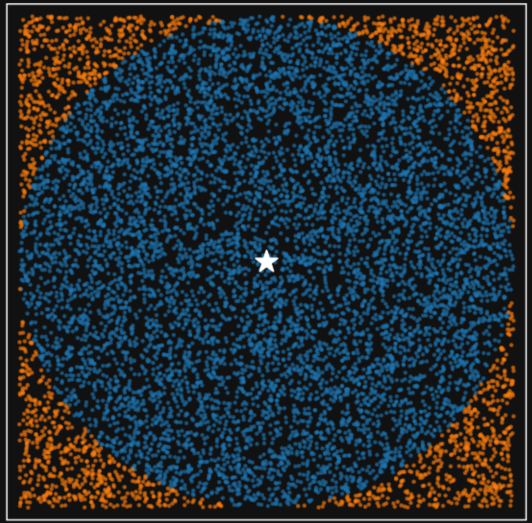
$$P(E) = \frac{1}{sx\sqrt{2\pi}} \exp\left(-\frac{\log^2 E}{2s^2}\right)$$

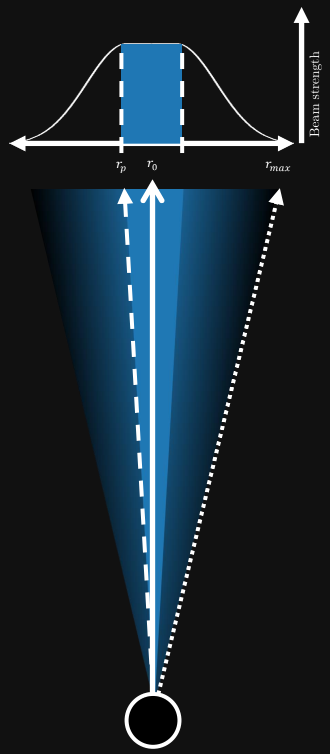
METHOD



Generate a set of uniformly distributed observing angles

METHOD

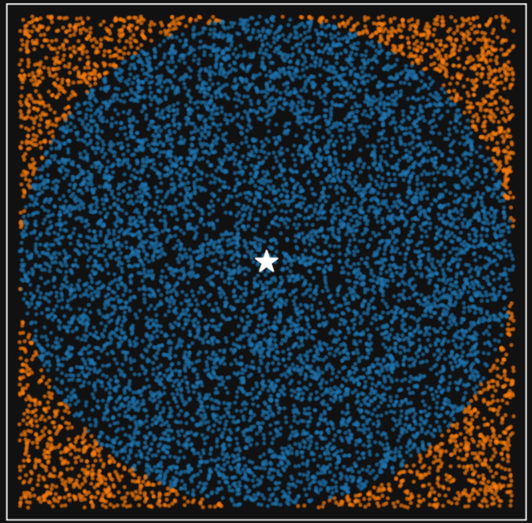


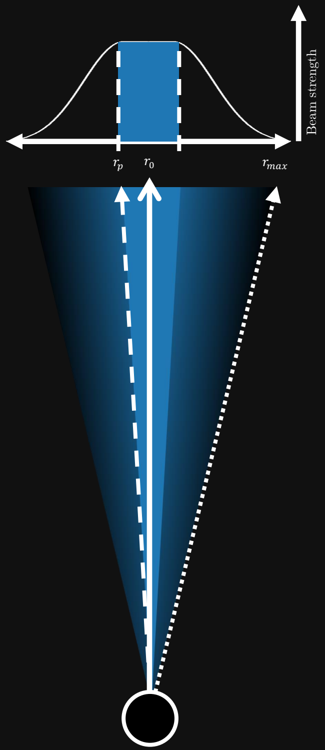


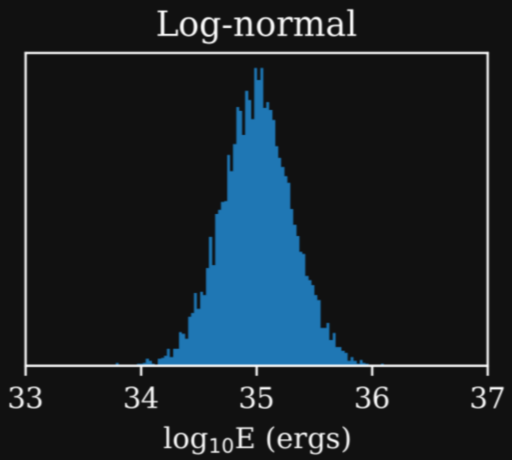
Generate a set of uniformly distributed observing angles

Set a beam shape & input any additional parameters

METHOD





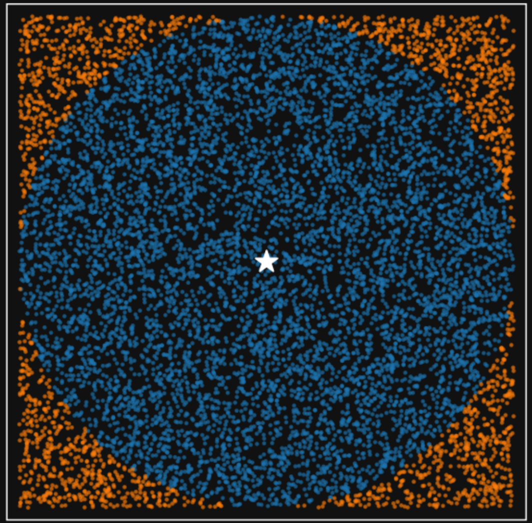


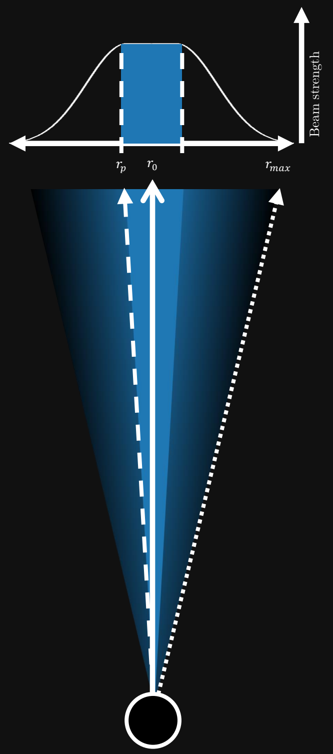
Generate a set of uniformly distributed observing angles

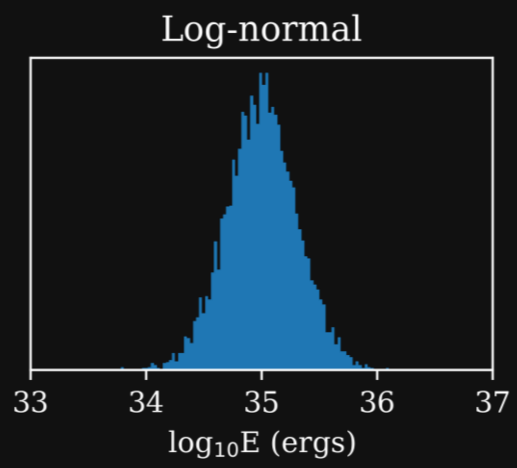
Set a beam shape & input any additional parameters

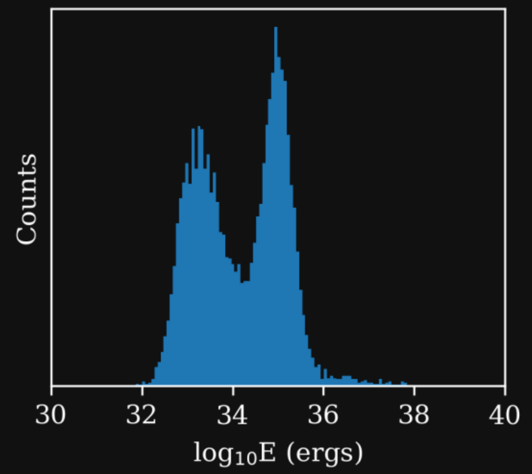
Chose an intrinsic energy distribution

METHOD









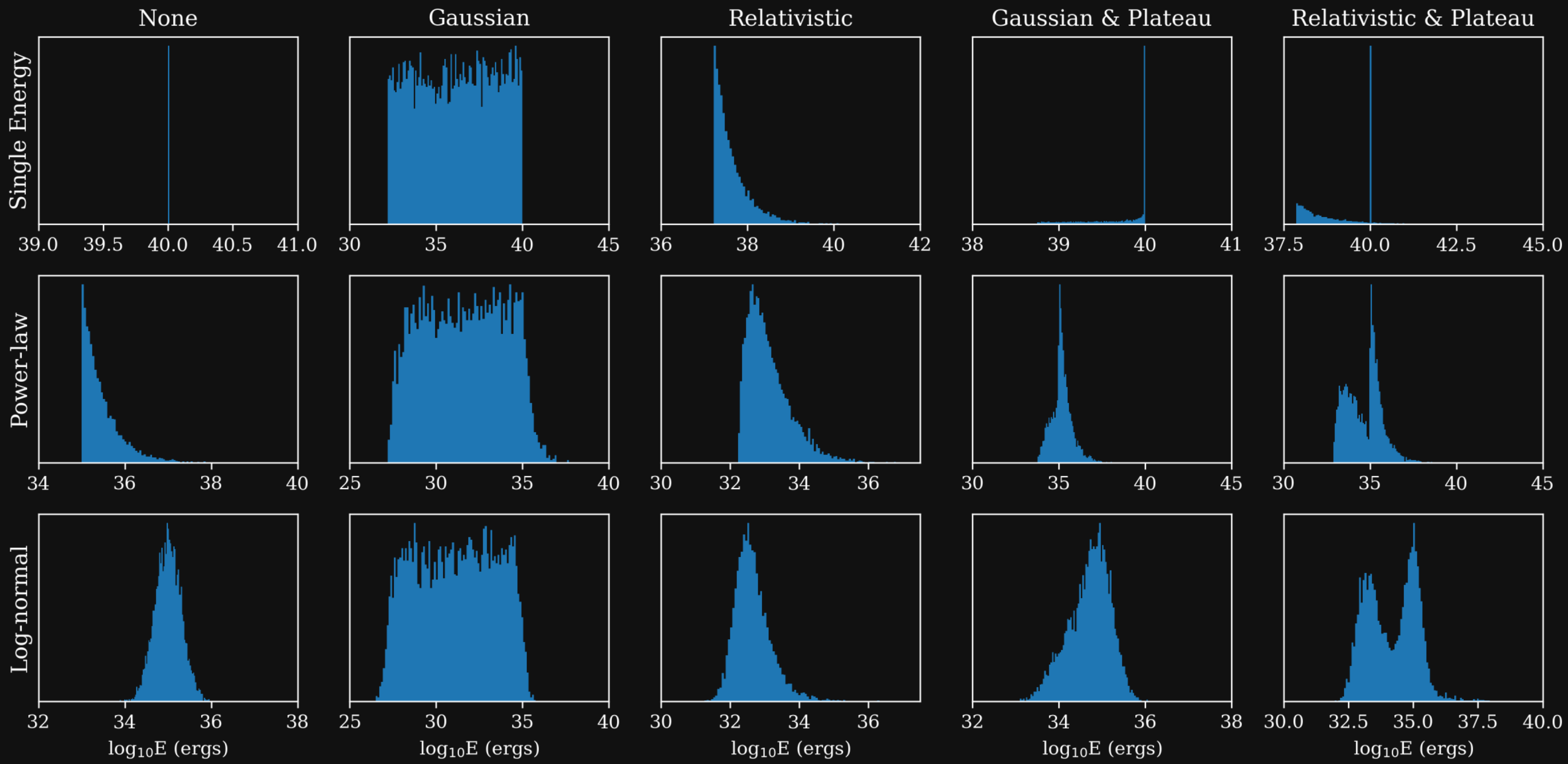
Generate a set of uniformly distributed observing angles

Set a beam shape & input any additional parameters

Chose an intrinsic energy distribution

Output of observed energy distribution

RESULTS



None
Gaussian
Relativistic
Gaussian & Plateau
Relativistic & Plateau
Single Energy
Power-law
Log-normal
39.0
39.5
40.0
40.5
41.0
30
35
40
45
36
38
40
42
38
39
40
41
37.5
40.0
42.5
45.0
34
36
38
40
25
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36
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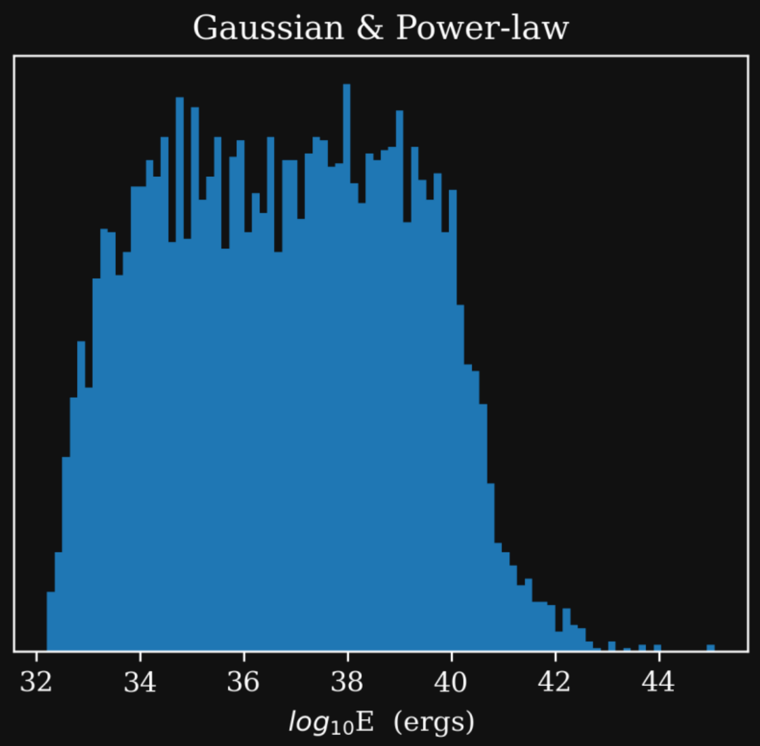
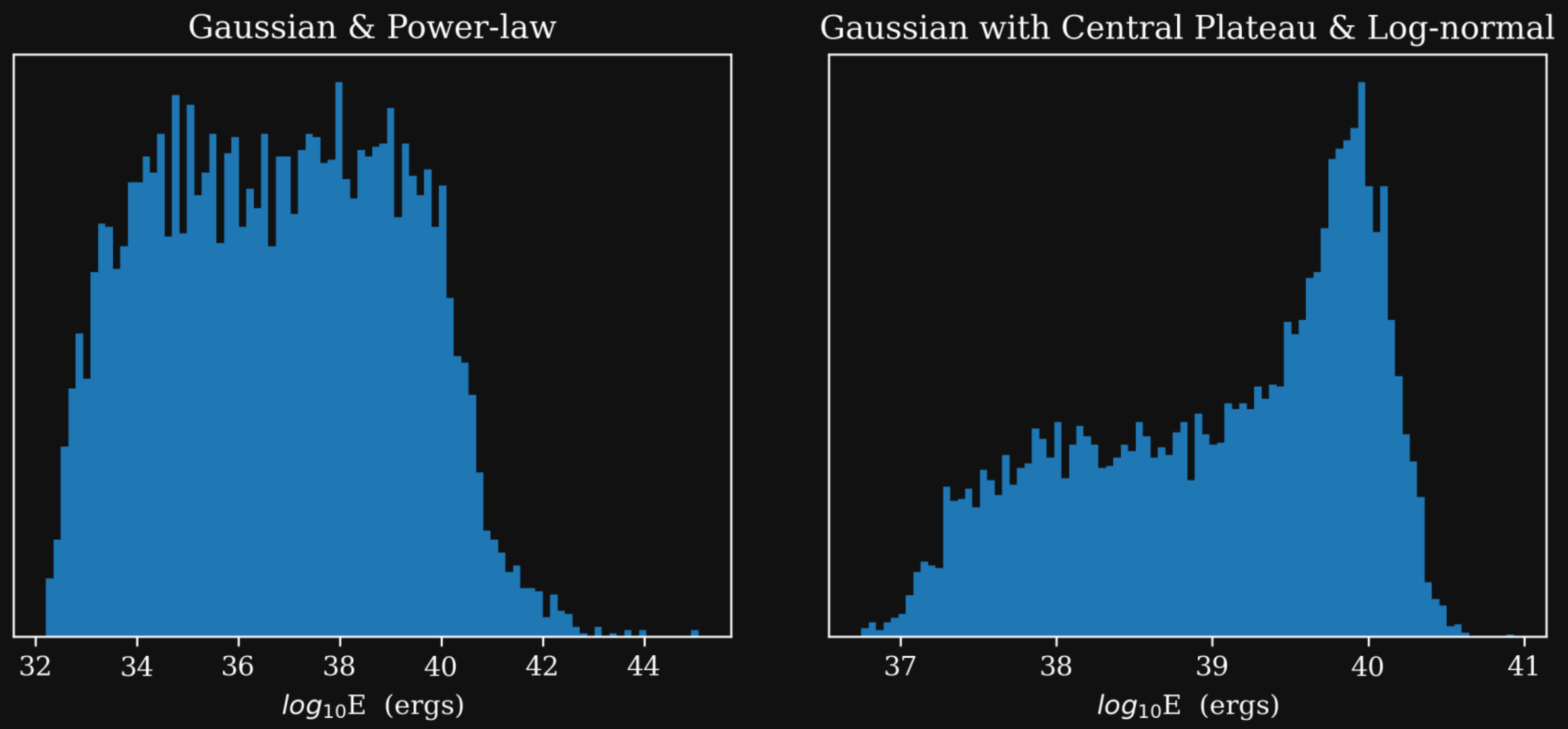
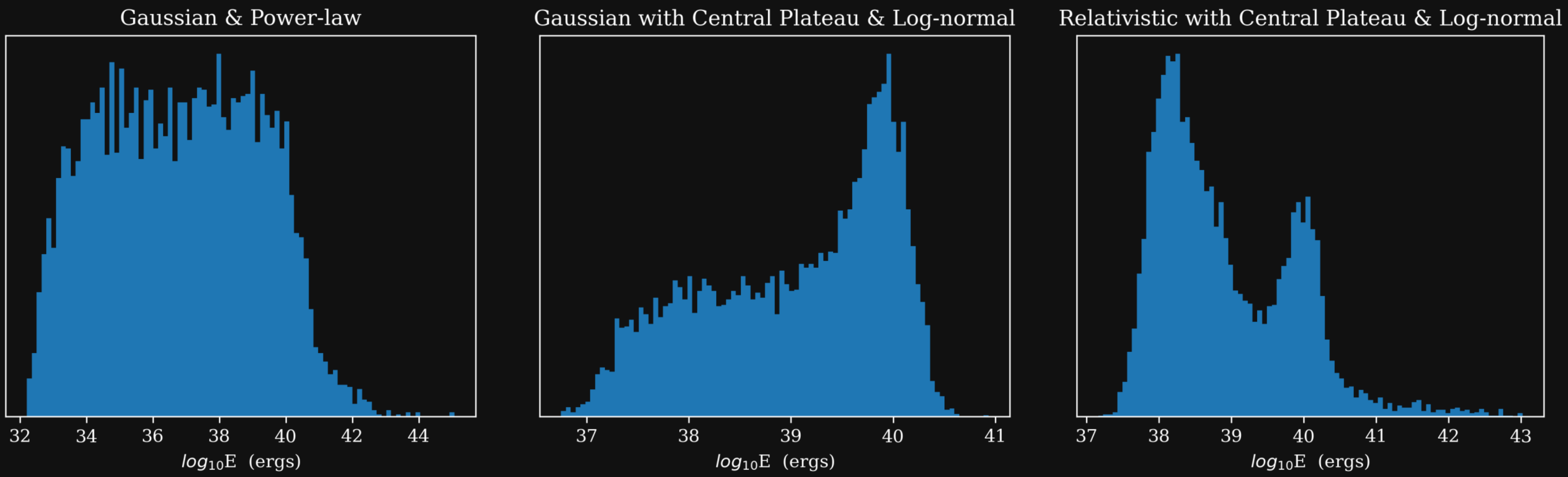
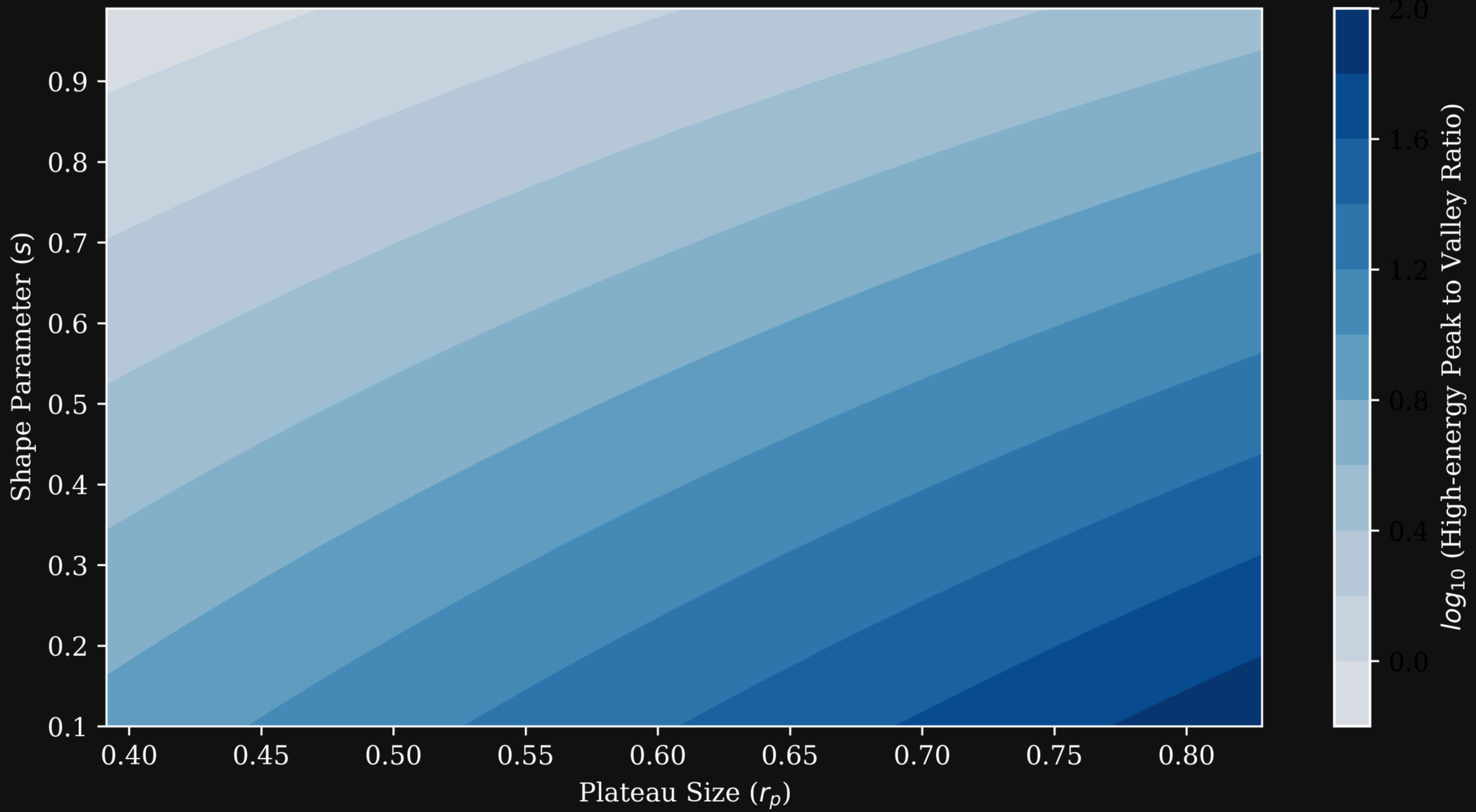
30
35
40
30
32
34
36
32
34
36
38
30.0
32.5
35.0
37.5
40.0
log10E (ergs)
log10E (ergs)
log10E (ergs)
log10E (ergs)
log10E (ergs)


Gaussian & Power-law
32
34
36
38
40
42
44
log10E (ergs)


Gaussian & Power-law
32
34
36
38
40
42
44
log_{10}E (ergs)
Gaussian with Central Plateau & Log-normal
37
38
39
40
41
log_{10}E (ergs)

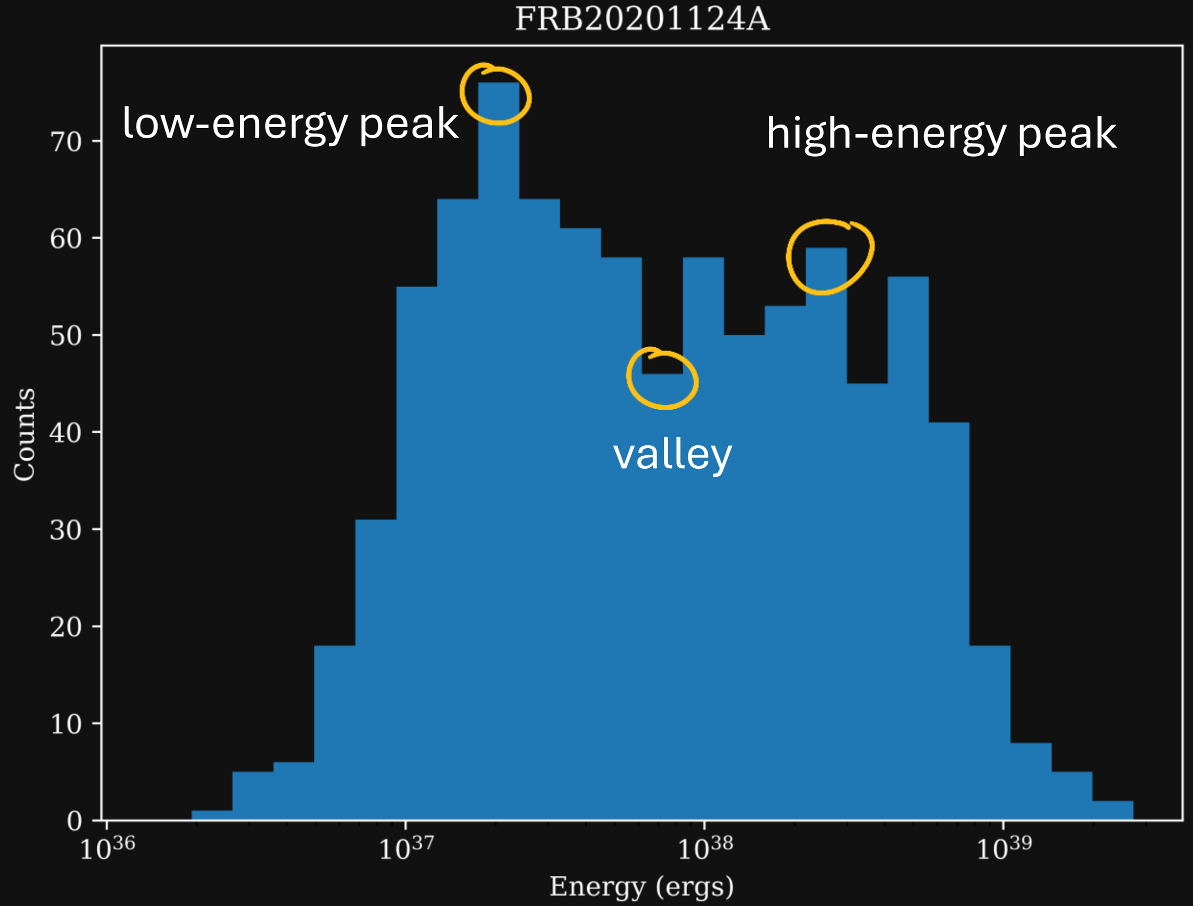

Gaussian & Power-law
32 34 36 38 40 42 44
log_{10}E (ergs)
Gaussian with Central Plateau & Log-normal
37 38 39 40 41
log_{10}E (ergs)
Relativistic with Central Plateau & Log-normal
37 38 39 40 41 42 43
log_{10}E (ergs)

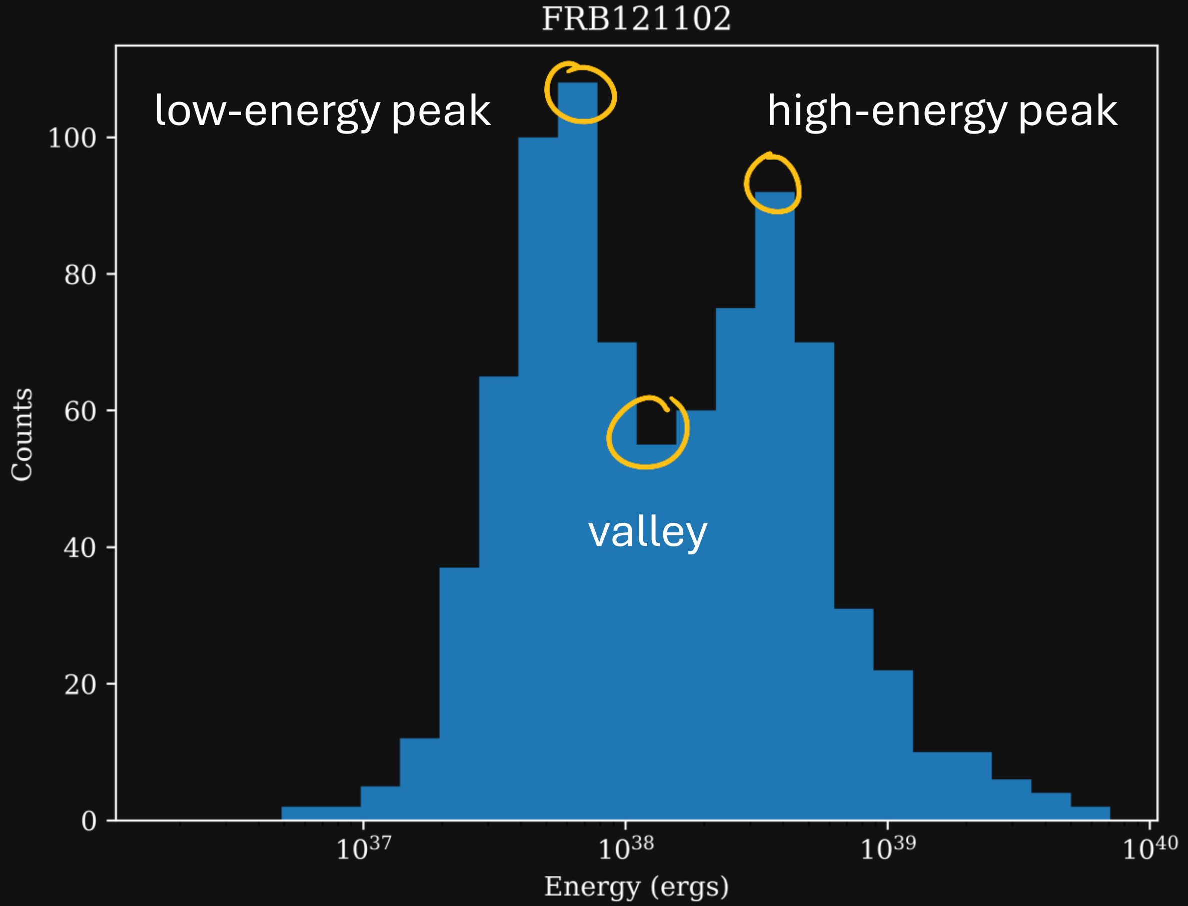
RESULTS



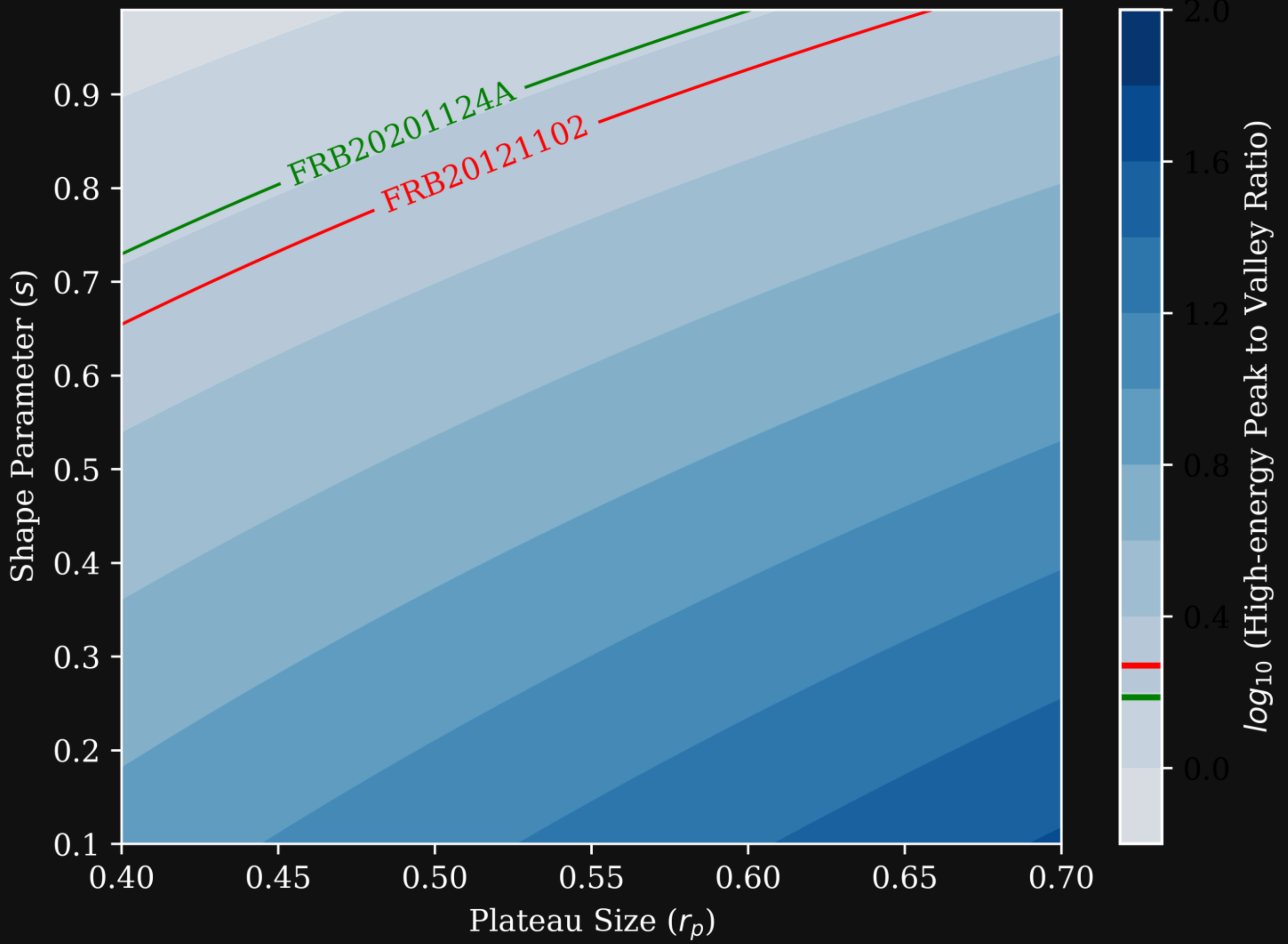
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Shape Parameter (s)
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
Plateau Size (r_p)
2.0
1.6
1.2
0.8
0.4
0.0
log_{10} (High-energy Peak to Valley Ratio)

COMPARISON TO REAL FRBS





COMPARISON TO KNOWN FRBS



By fitting to the observed energy distributions, we can determine the theoretical beam parameters for a given time epoch.

*(Using a bin size of 30 and the times specified for bimodality in the relevant papers)

SUMMARY

We find we can create an **observed bimodal energy** distribution using a combination of a relativistic beam and a uniform central core, with a log-normal intrinsic energy distribution.

The energy distributions of FRB20201124A and FRB20121102 **fall within our bimodal regime**. This result will allow us to constrain the plateau size, the parameters of the intrinsic distribution, and possibly the value of the Lorentz factor.

SUMMARY

We find we can create an **observed bimodal energy** distribution using a combination of a relativistic beam and a uniform central core, with a log-normal intrinsic energy distribution.

The energy distributions of FRB20201124A and FRB20121102 **fall within our bimodal regime**. This result will allow us to constrain the plateau size, the parameters of the intrinsic distribution, and possibly the value of the Lorentz factor.

contact me!

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Paper currently in prep.