GRB Durations and Fluences are Underestimated

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Takanori Sakamoto (AGU)

Introduction

GRBs are bright transients.

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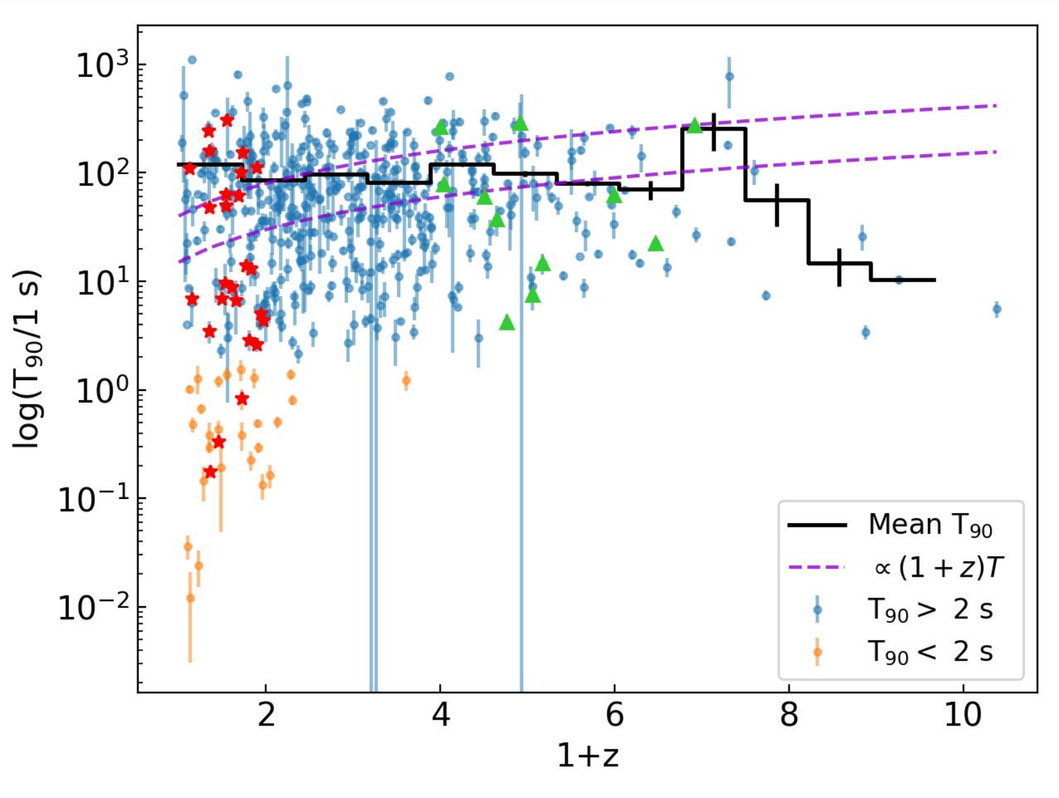
Have a measurable duration

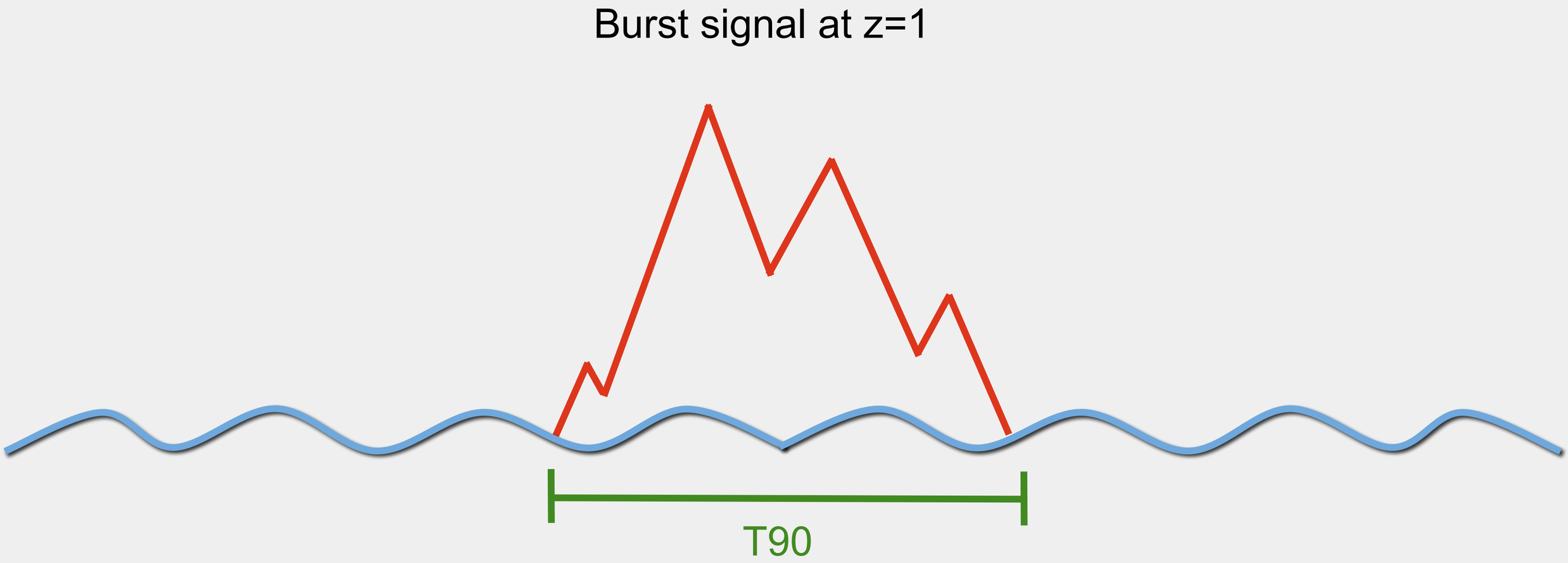
Allows us the see them at great distances

Time-Dilation Signatures

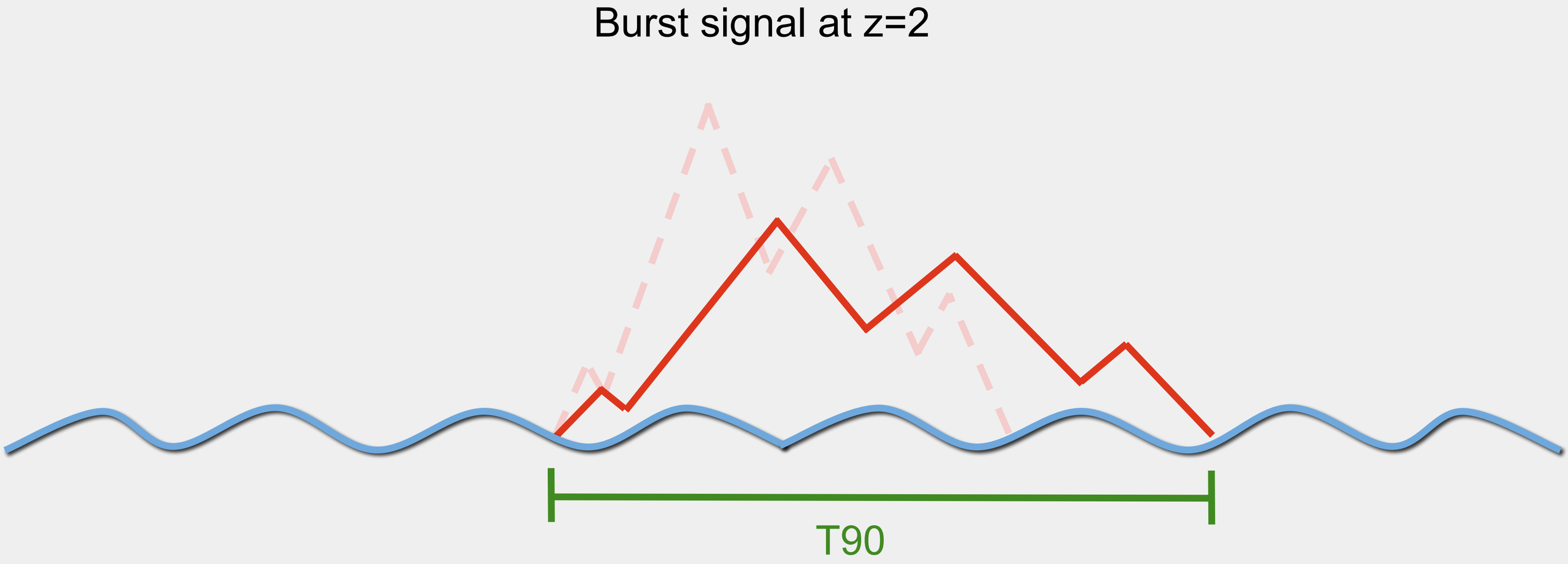
GRBs are bright transients.



Tip-of-the-Iceberg Effect



Tip-of-the-Iceberg Effect



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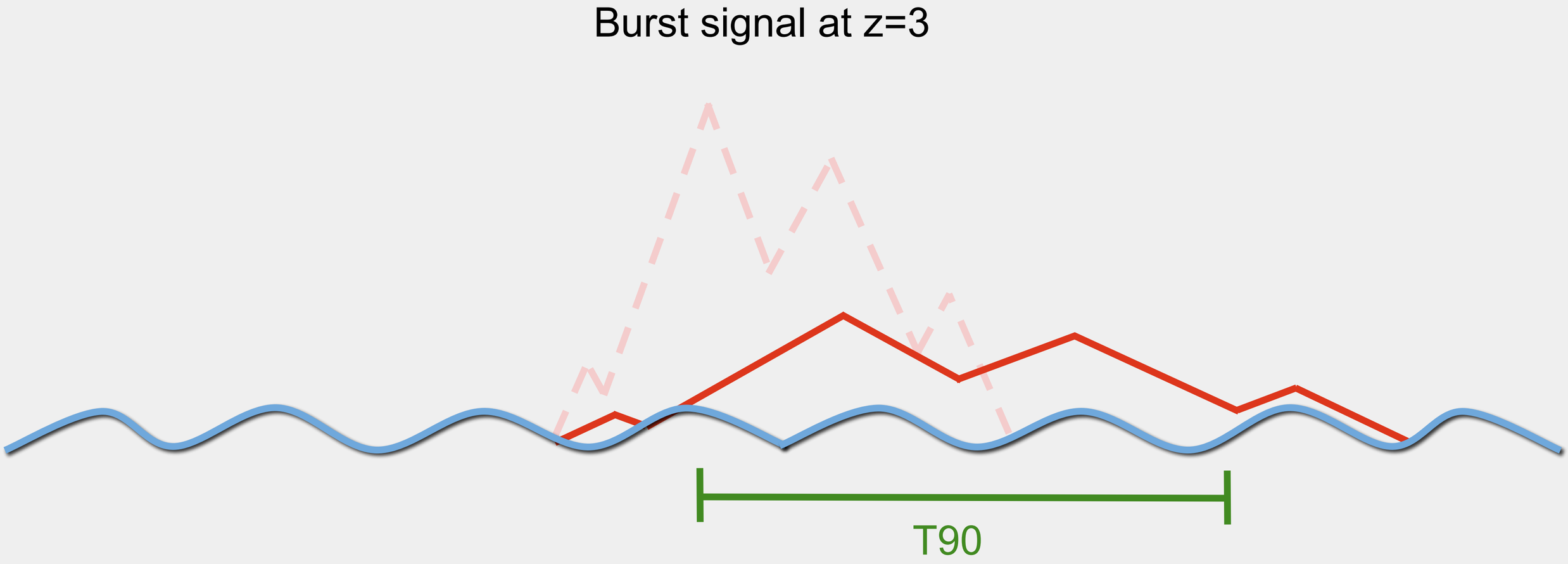
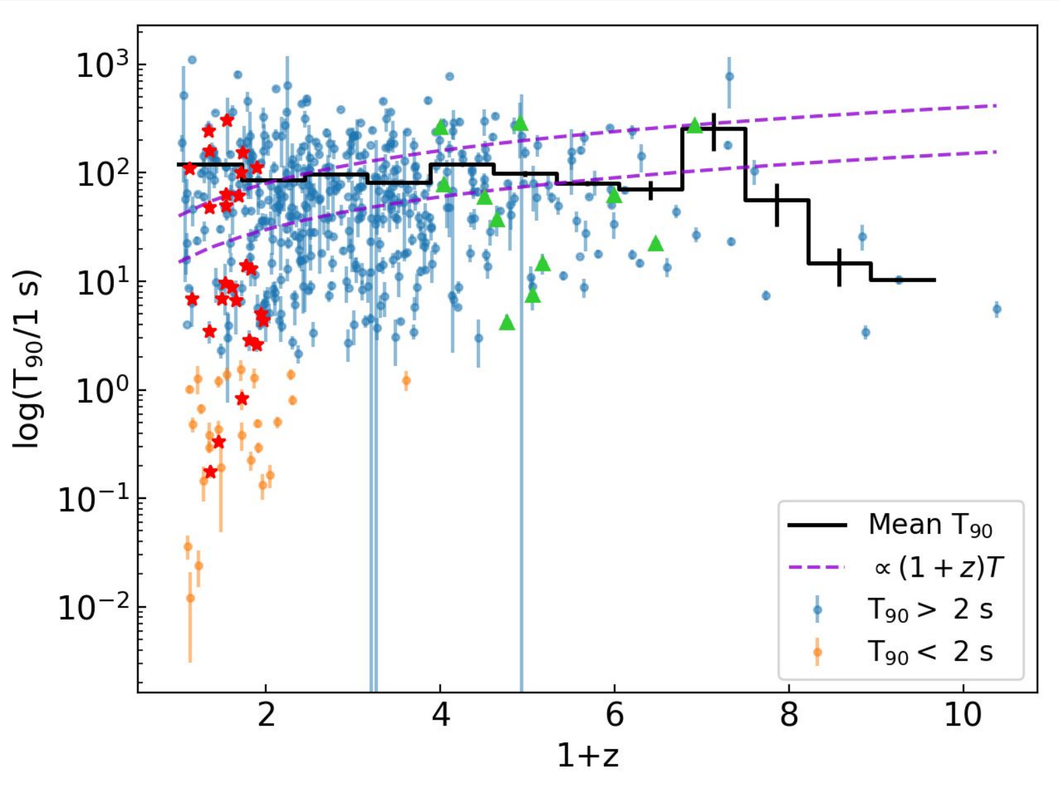


Time-Dilation Signatures

GRBs are bright transients.



Time-Dilation Signatures

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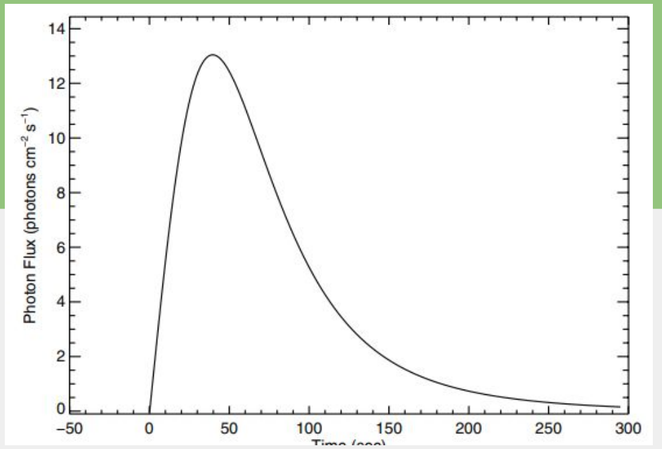
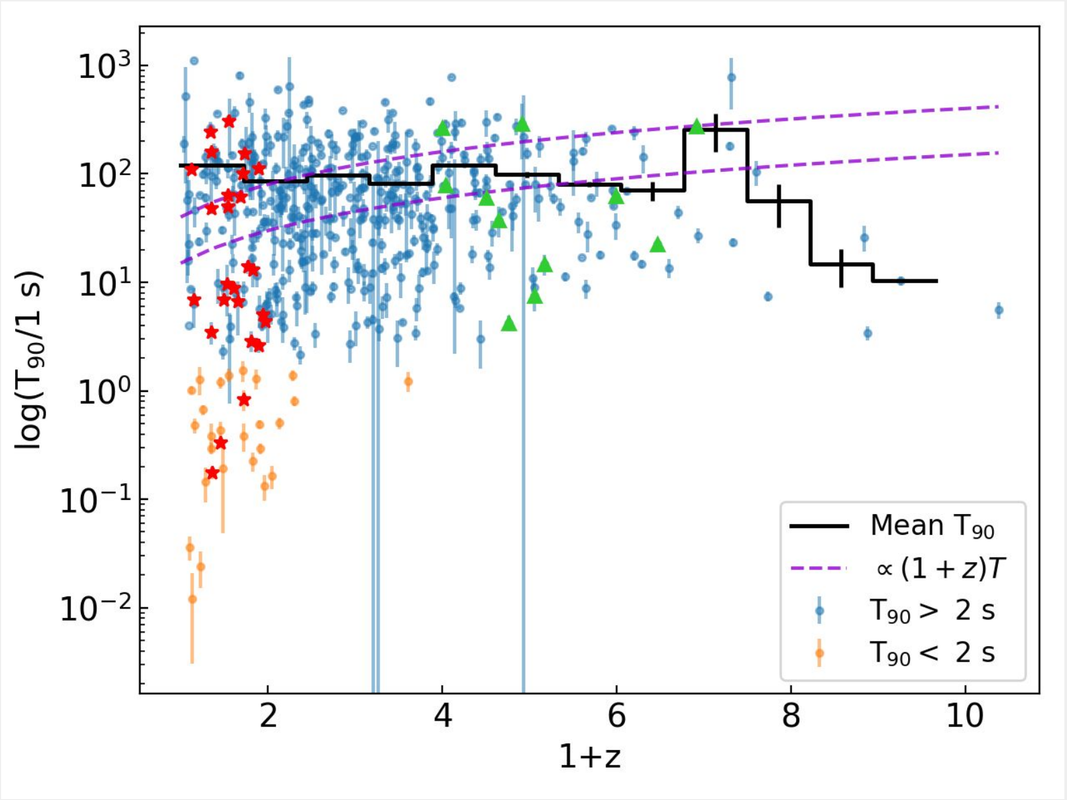
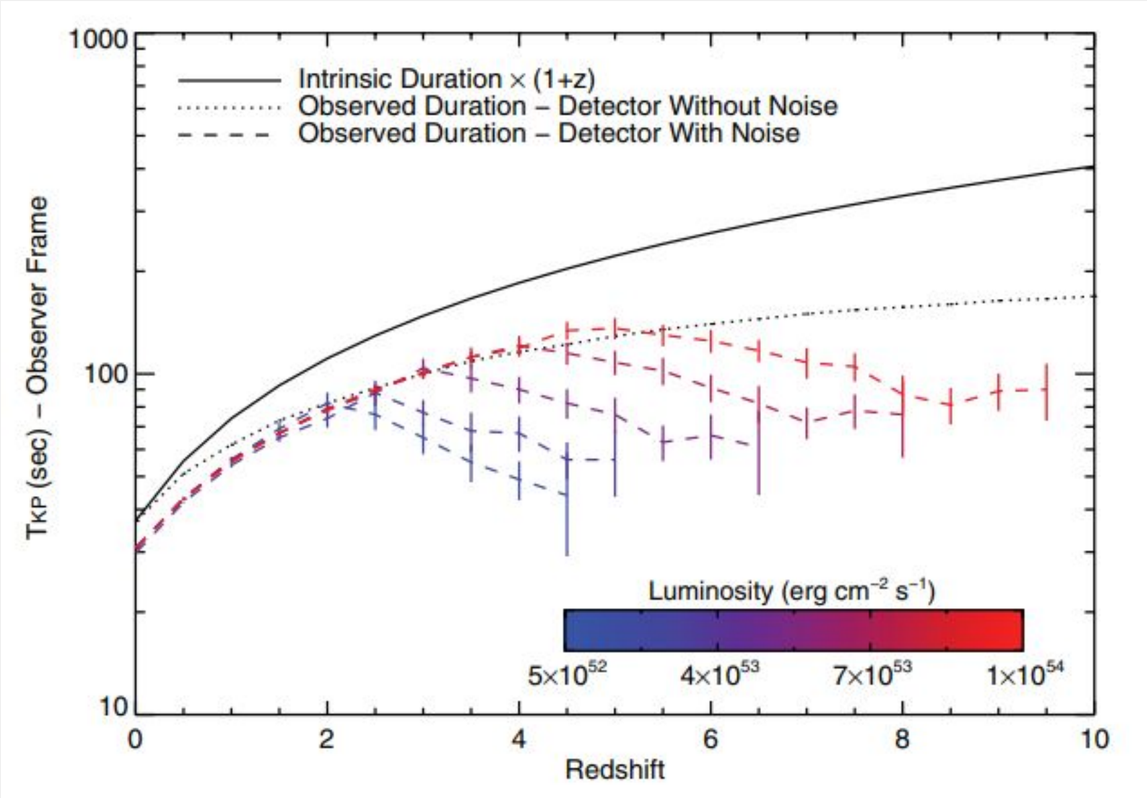


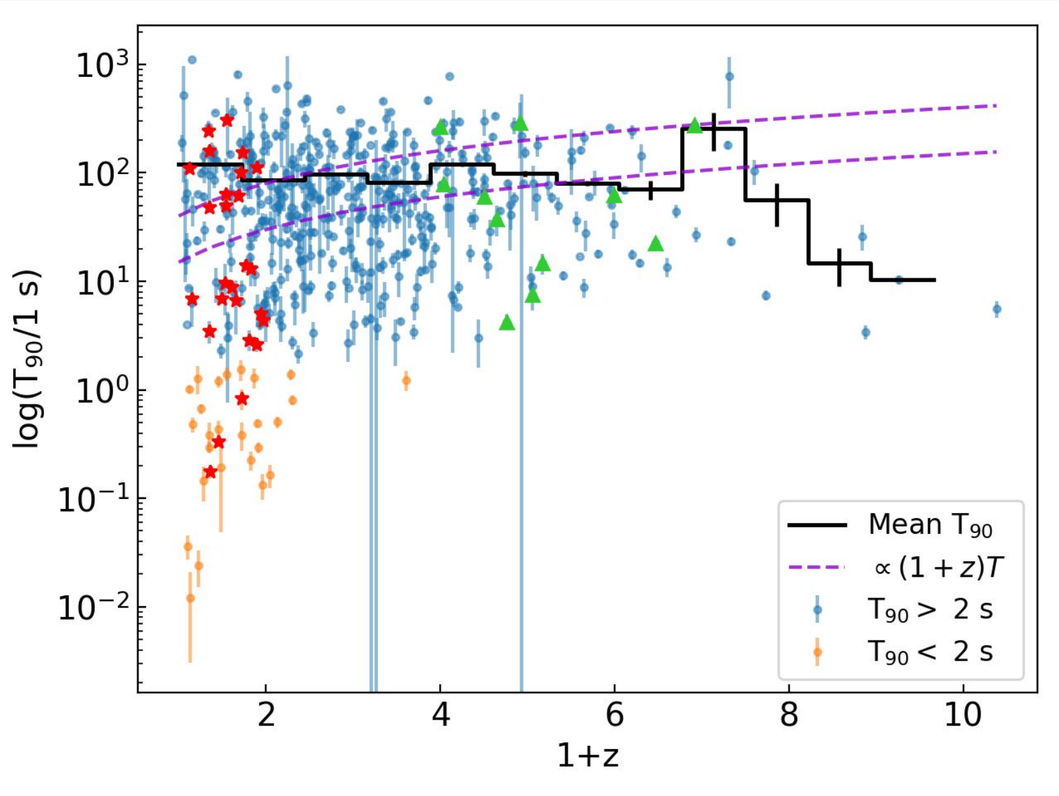


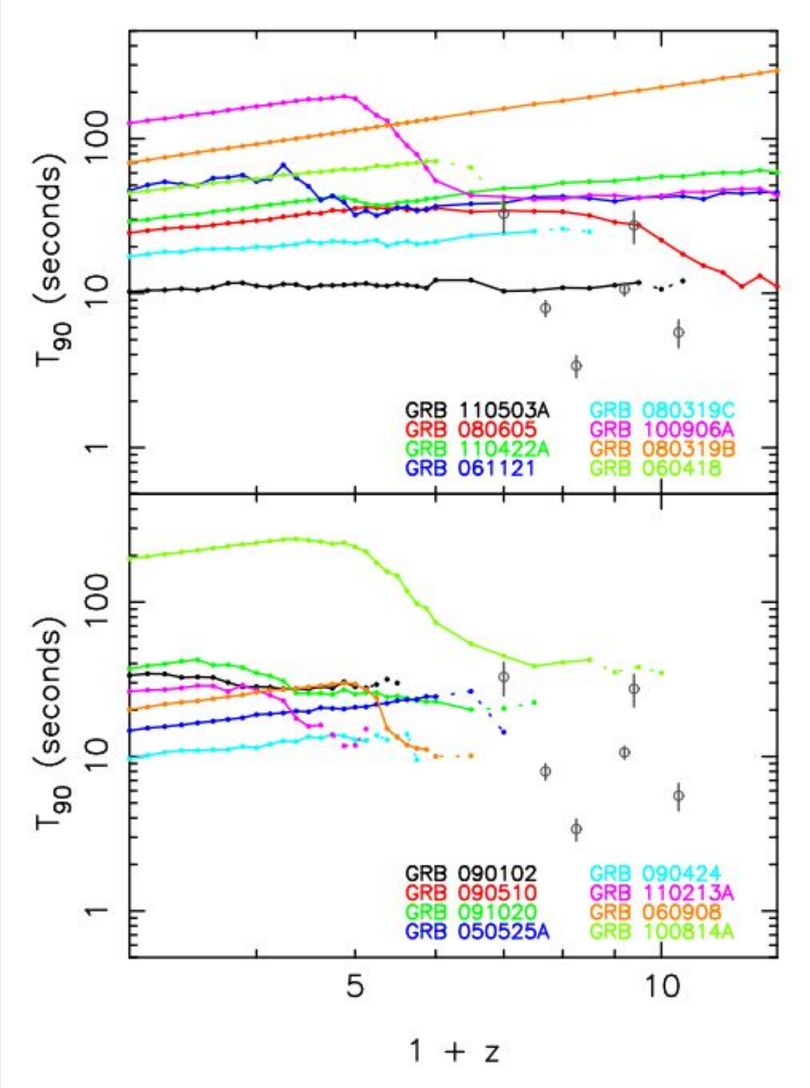


Kocevski and Petrosian 2013

Time-Dilation Signatures

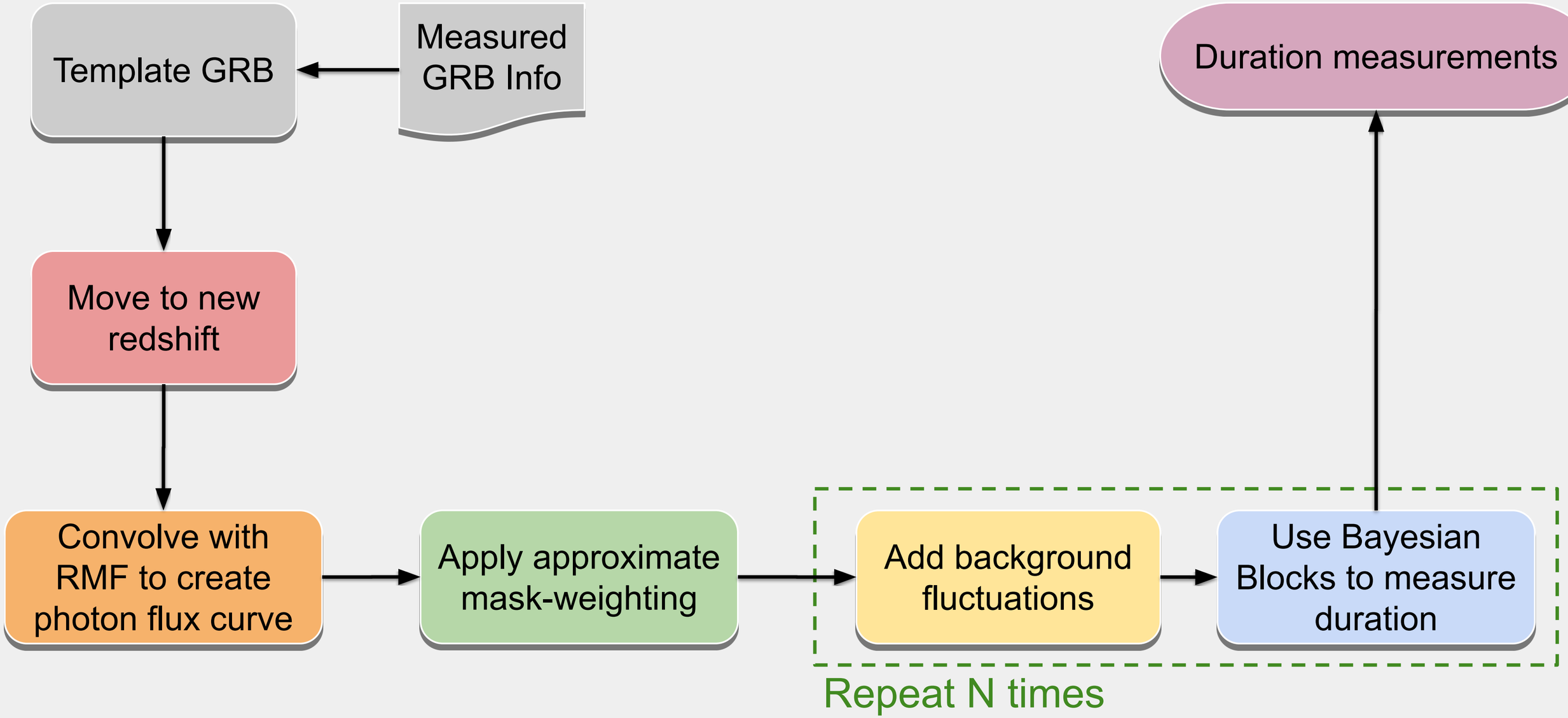
GRBs are bright transients.



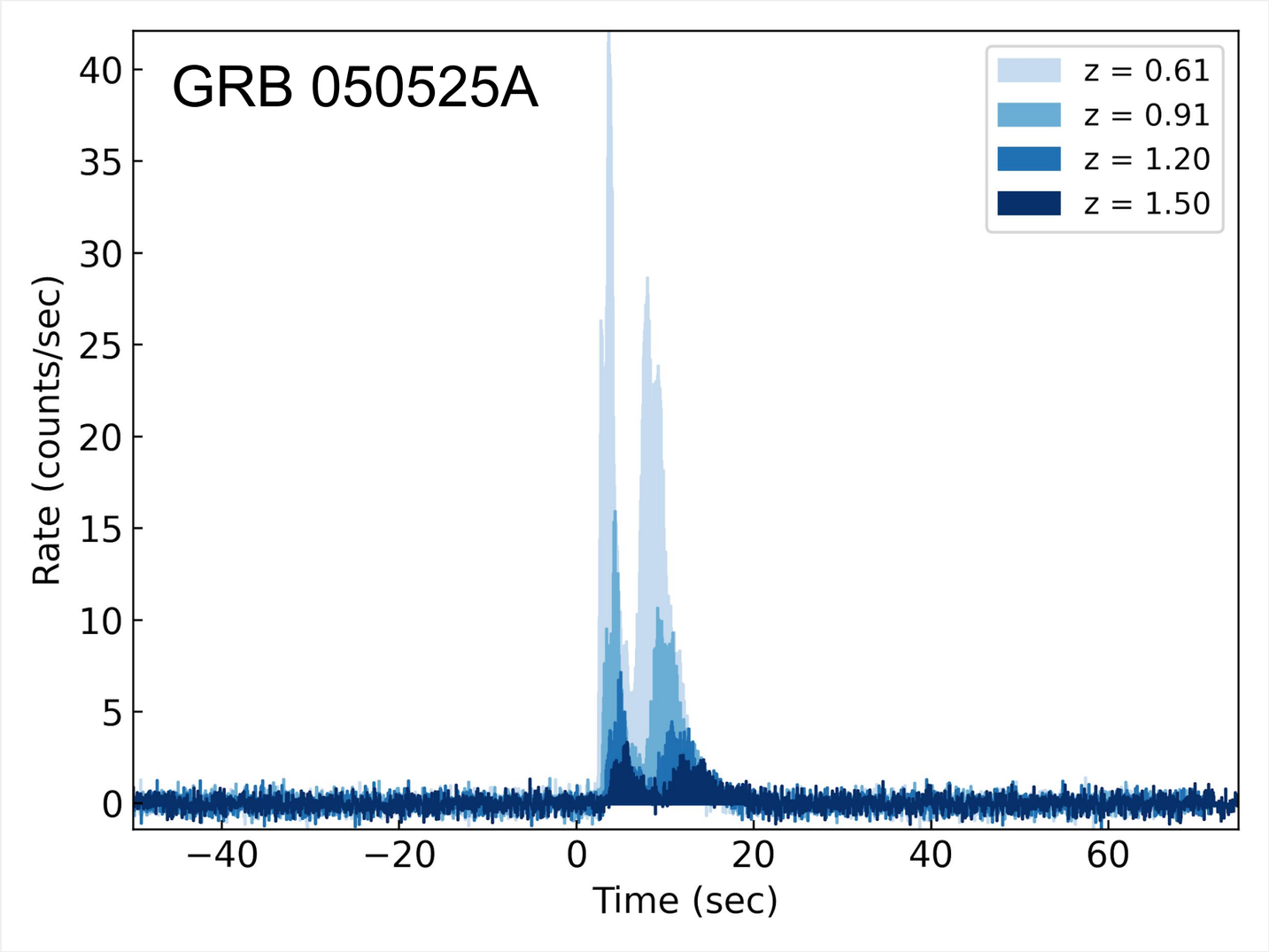


Littlejohns et al. 2013

Methods

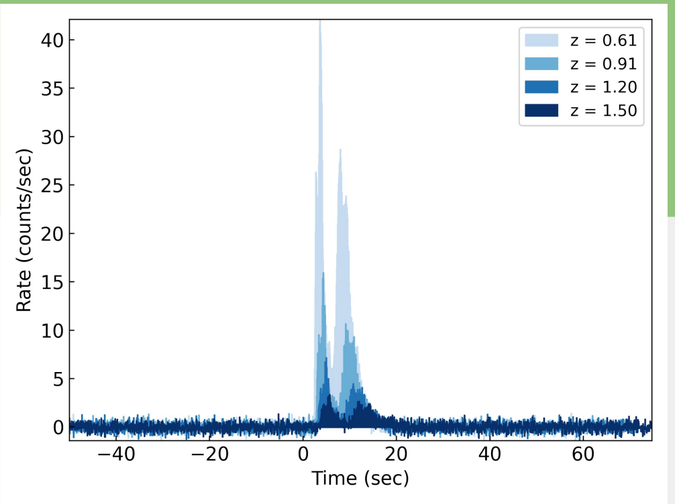

Template GRB
Measured GRB Info
Duration measurements
Move to new redshift
Convolve with RMF to create photon flux curve
Apply approximate mask-weighting
Add background fluctuations
Use Bayesian Blocks to measure duration
Repeat N times

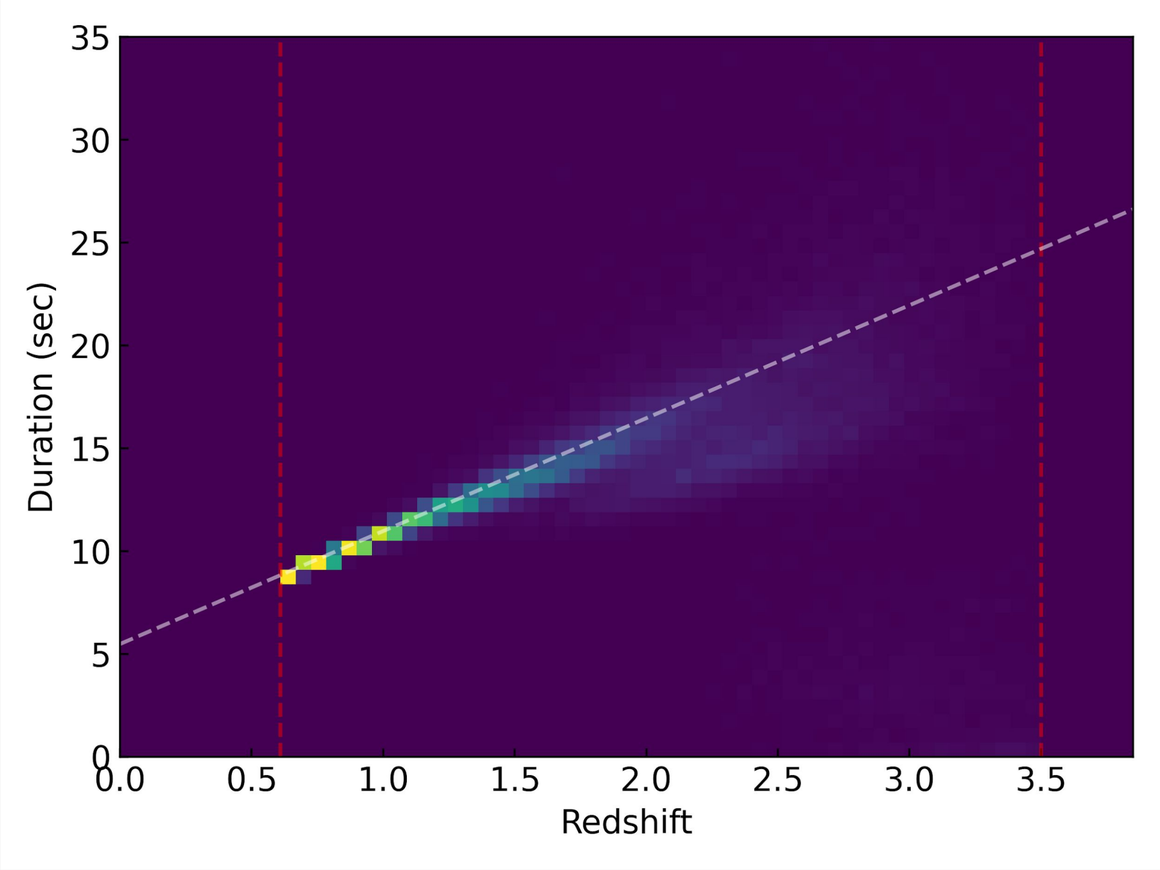
Results

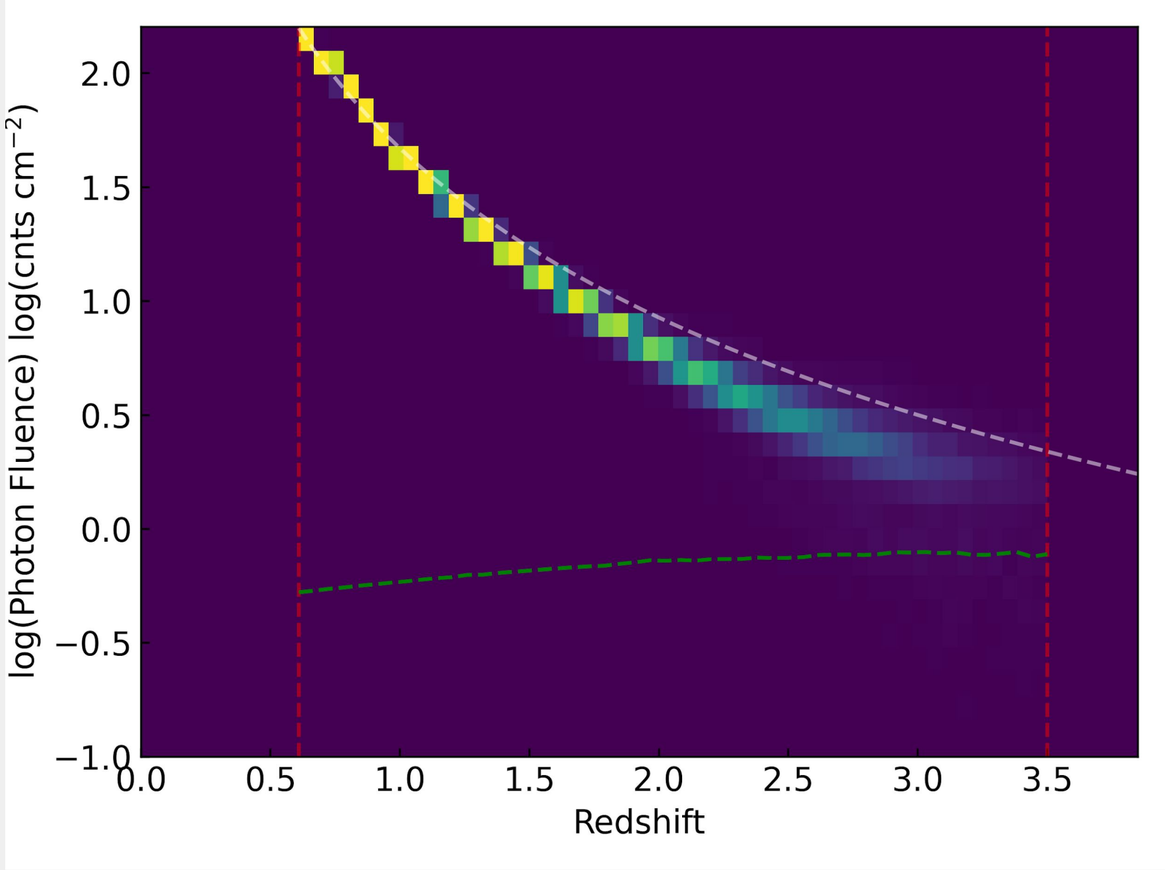

GRB 050525A
z = 0.61
z = 0.91
z = 1.20
z = 1.50
Rate (counts/sec)
Time (sec)
40
35
30
25
20
15
10
5
0
−40
−20
0
20
40
60

Results

GRB 050525A -- straightforward behavior

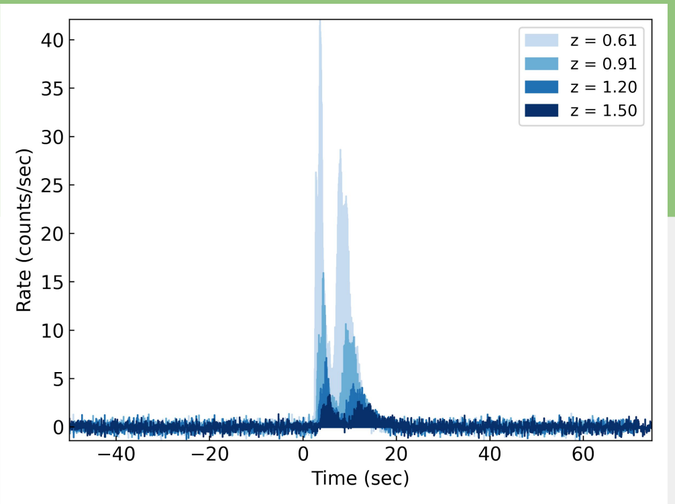


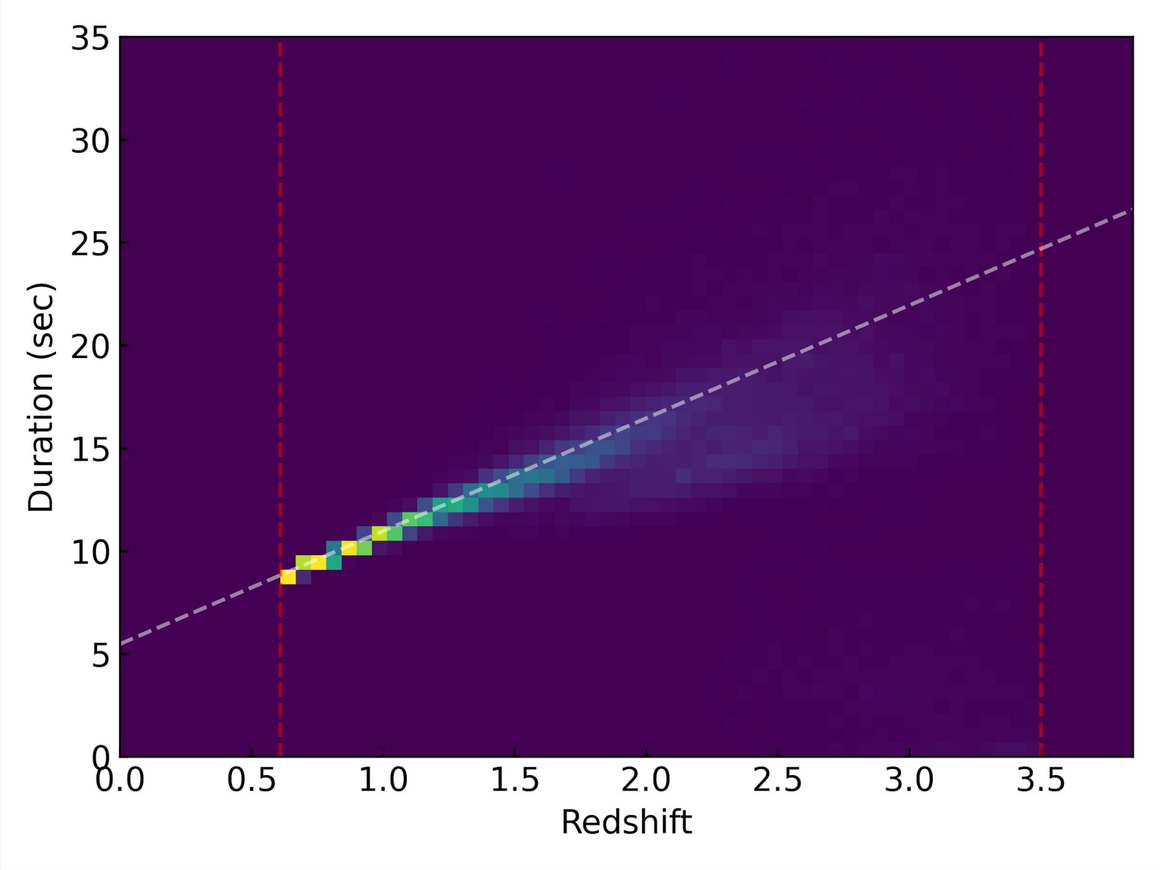


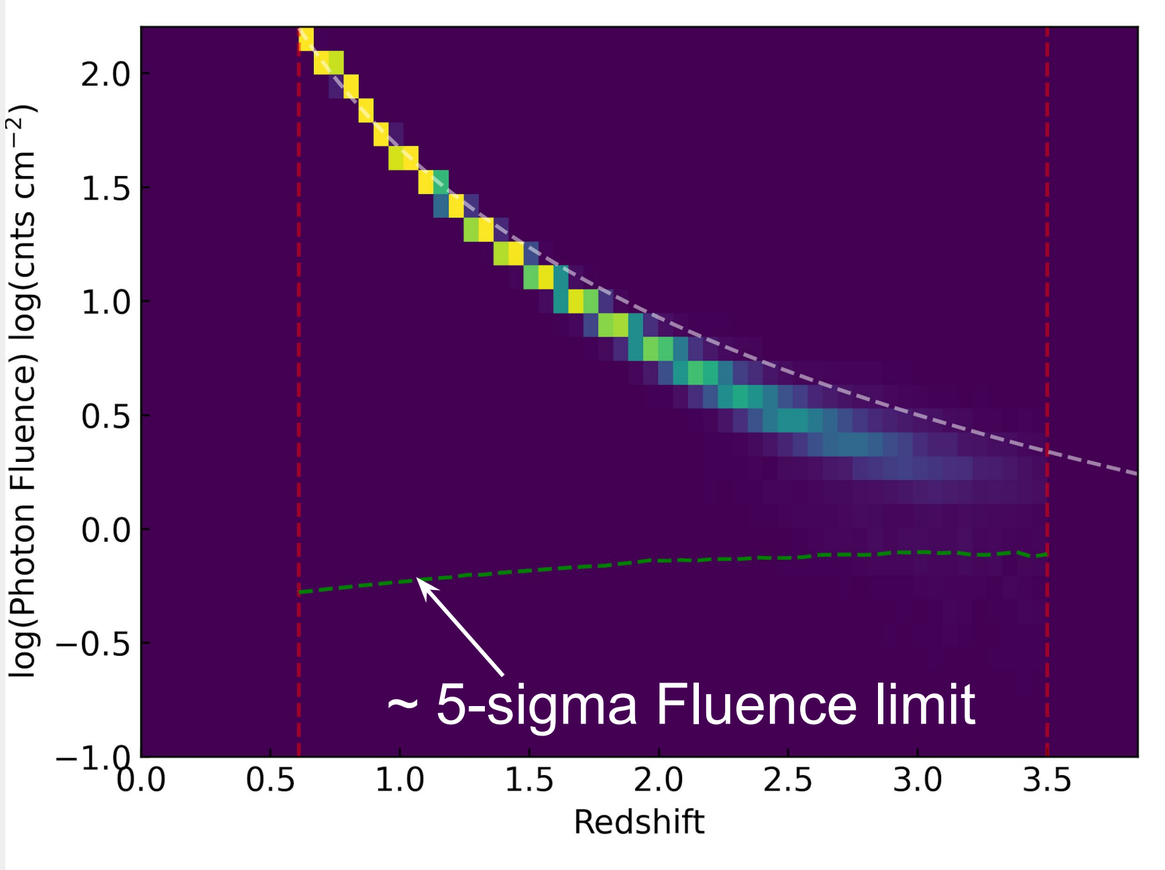


Results

GRB 050525A -- straightforward behavior

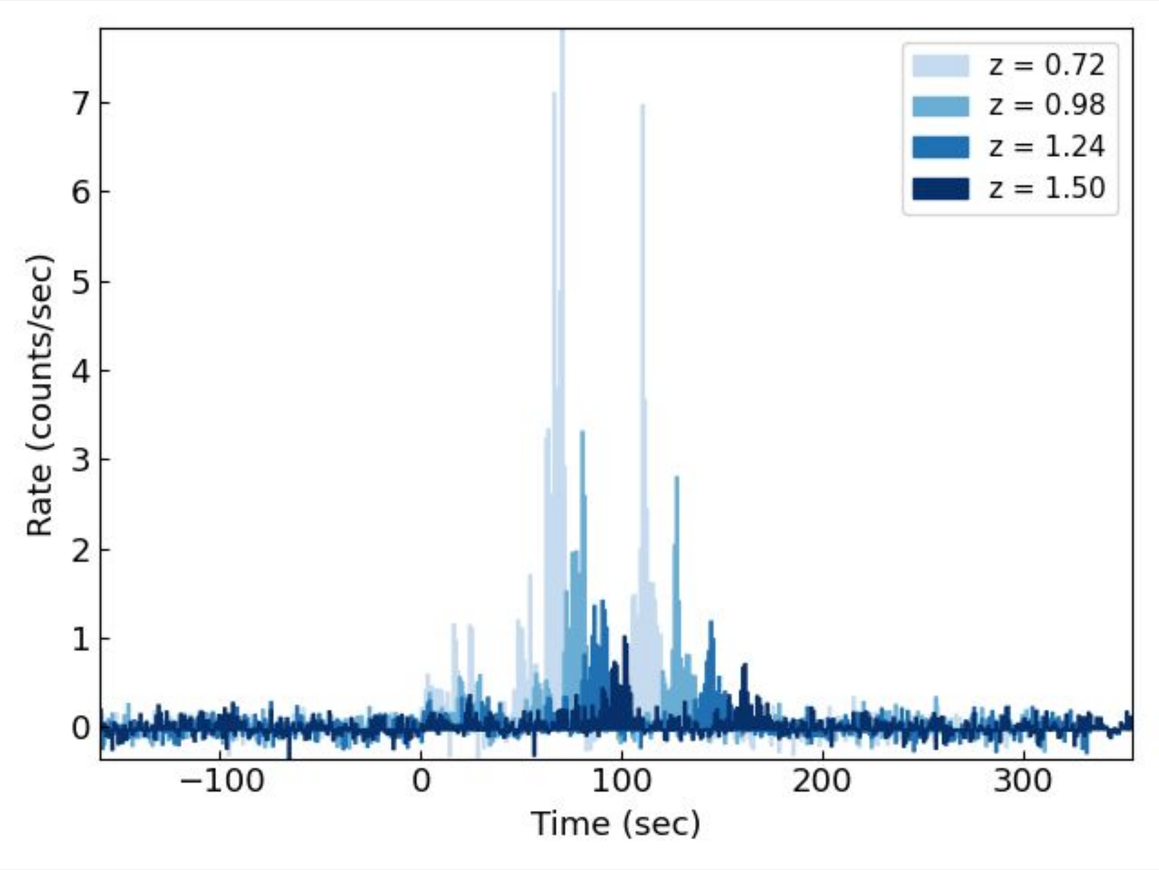






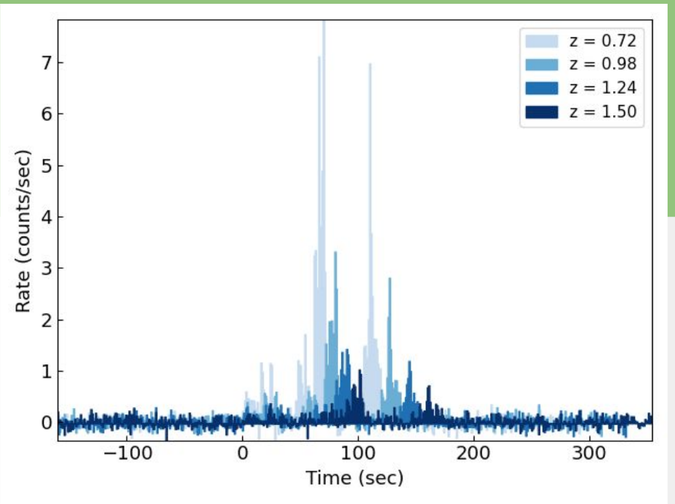
Results

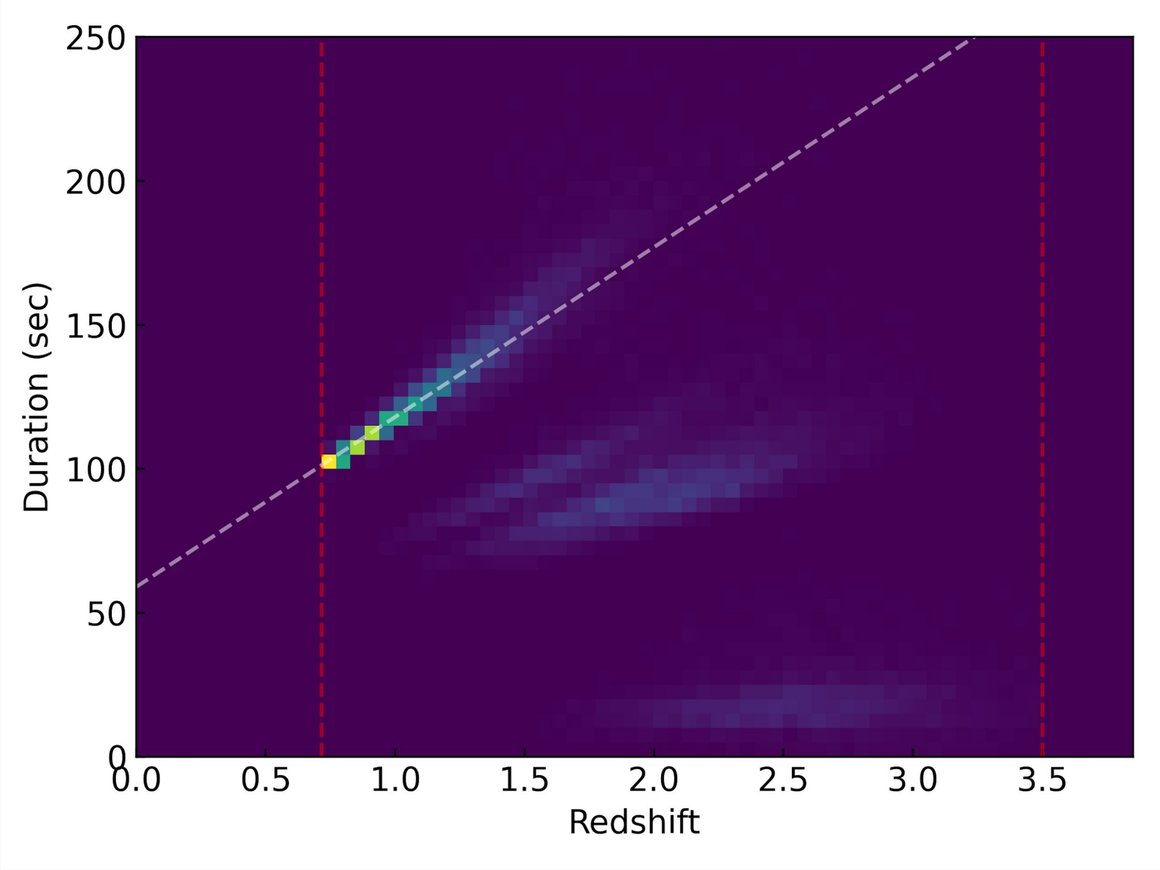
GRB 111228A -- annoying behavior

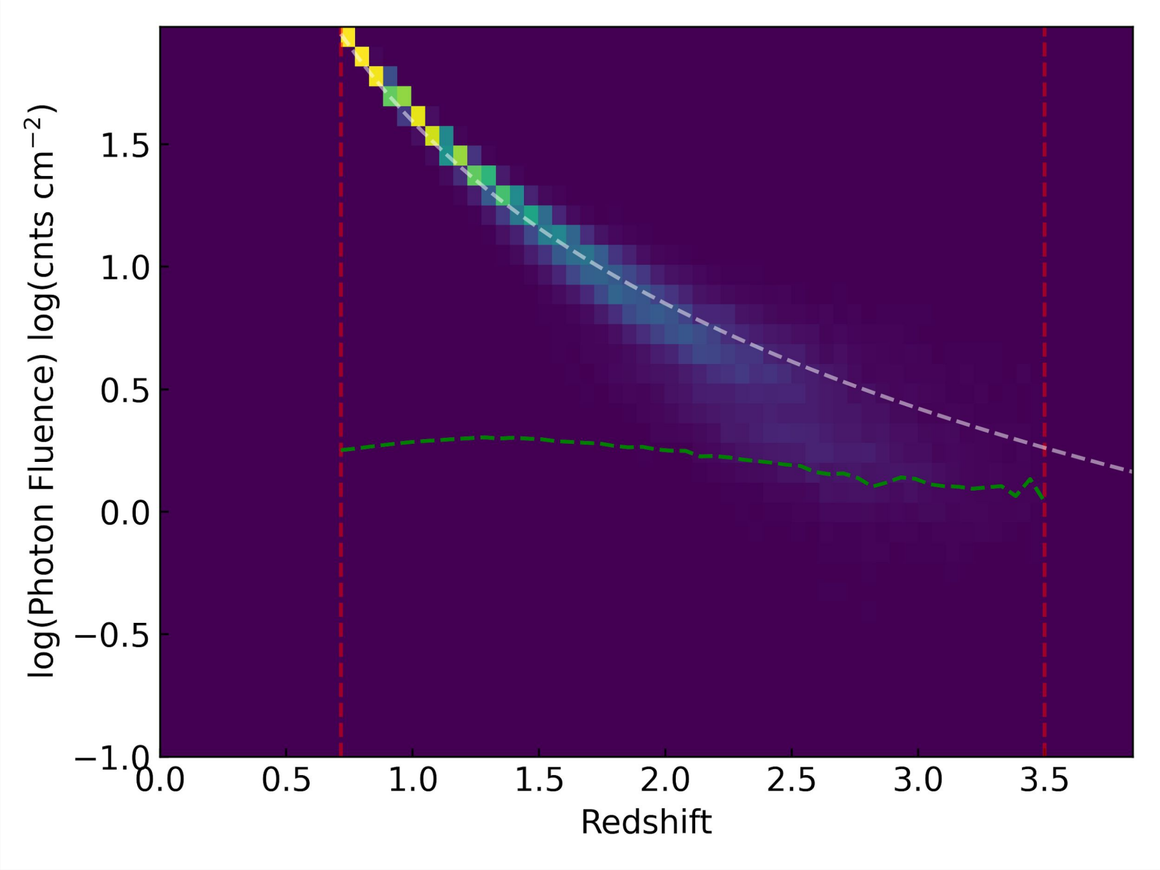


Results

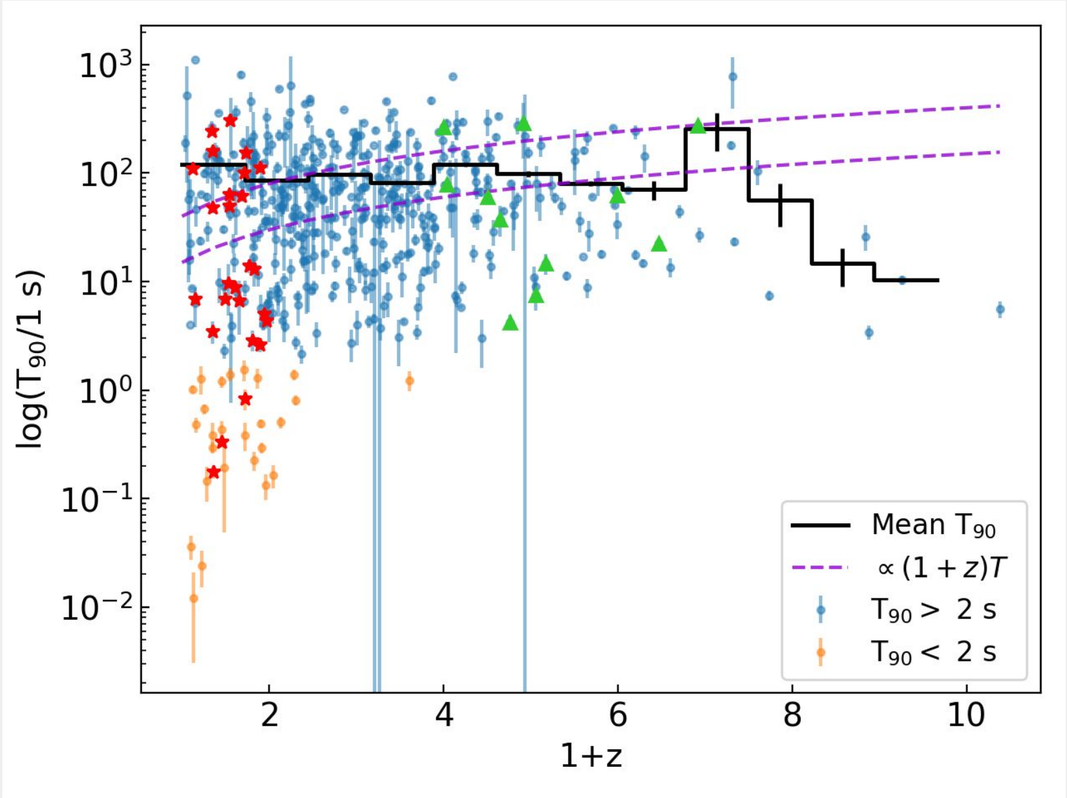
GRB 111228A -- annoying behavior







Sample Selection



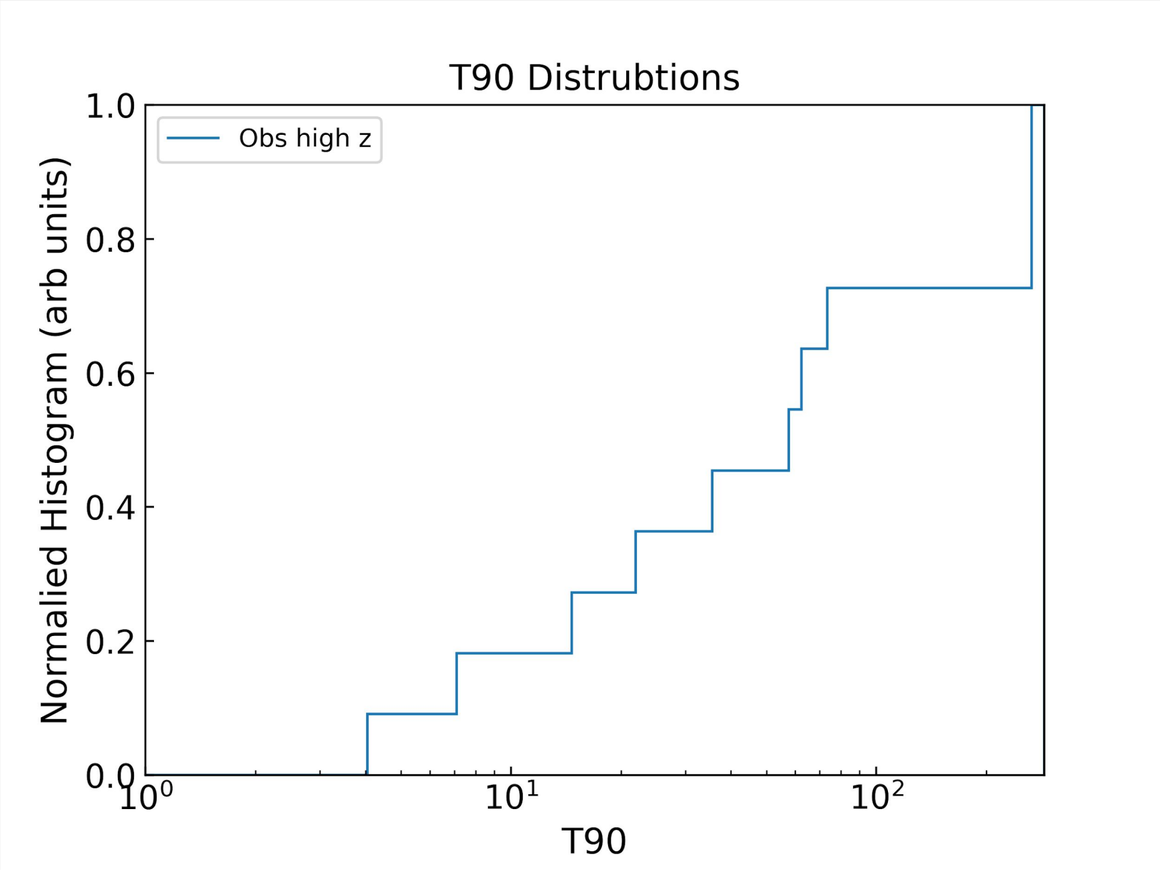
Redshift complete sample observed with ESO VLT X-shooter spectrograph (Selsing et al. 2019)

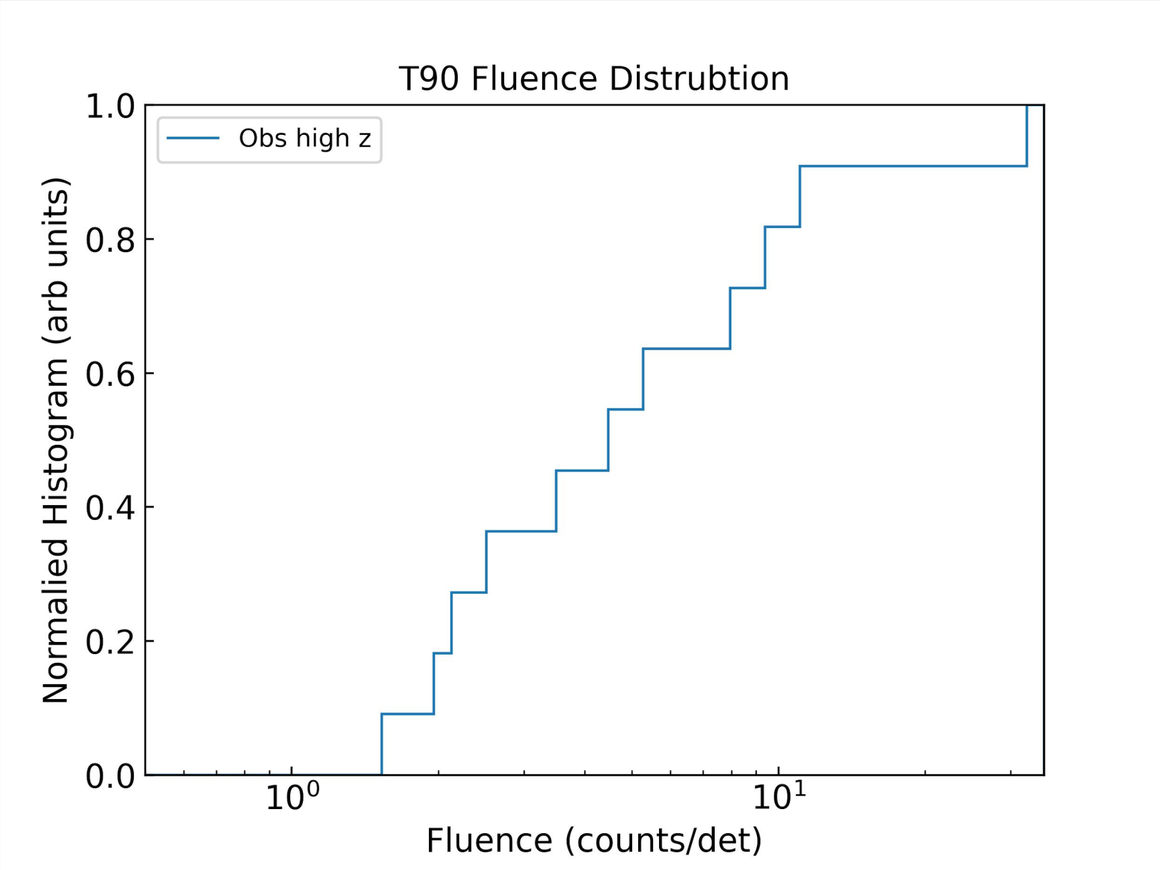
- Further cut: peak Flux > 2.6 cnts s^{-1} cm^{-2} (following BAT6 sample definition, Salvaterra et al. 2012)

Low-z (z<1) sample size = 26

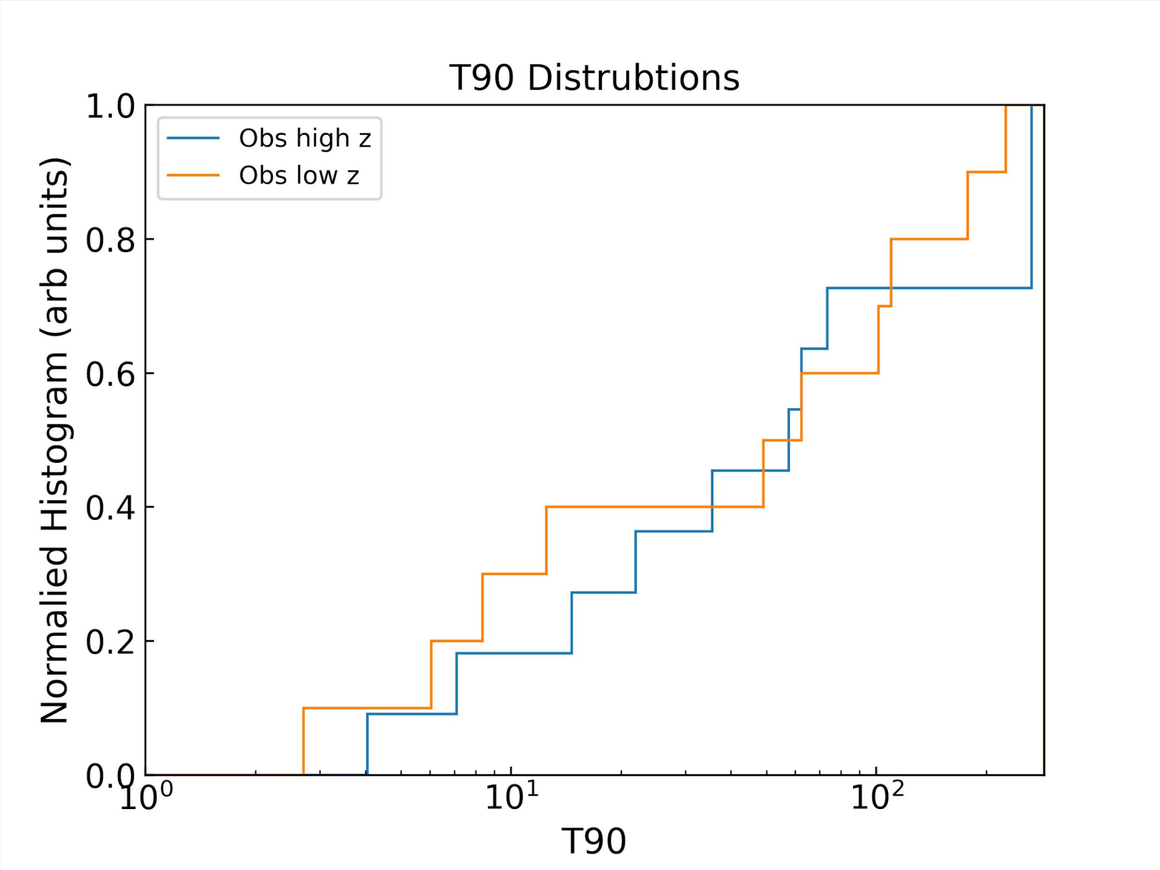
High-z (z>3) sample size = 11

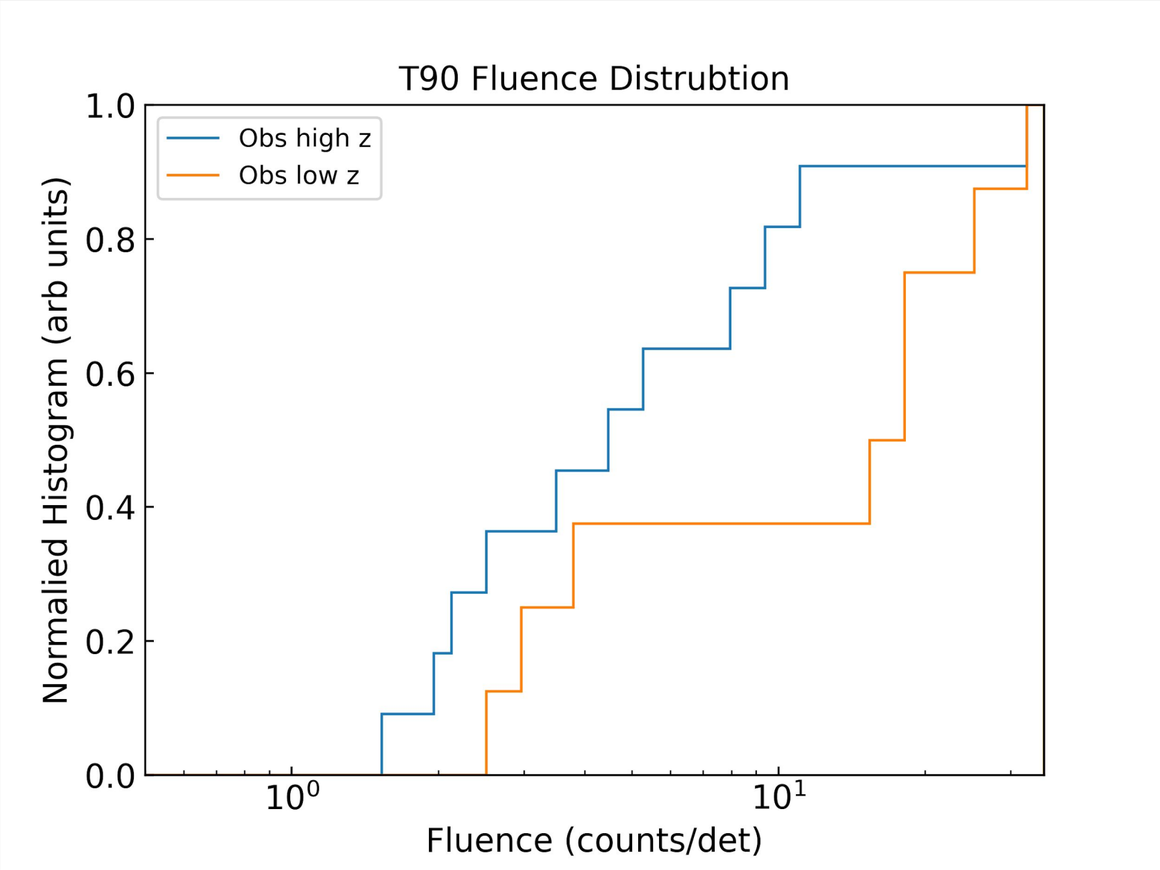
Are Low-z and High-z GRBs the same population?





Are Low-z and High-z GRBs the same population?





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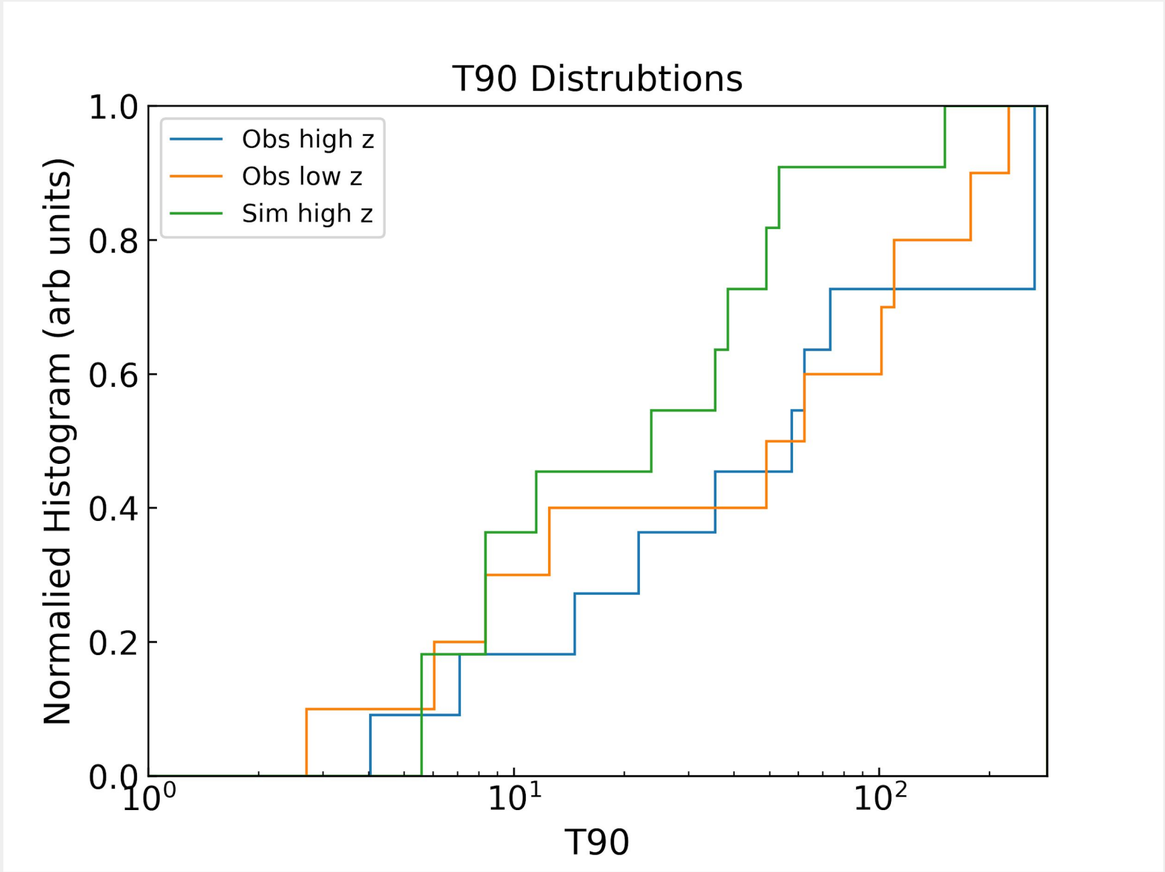
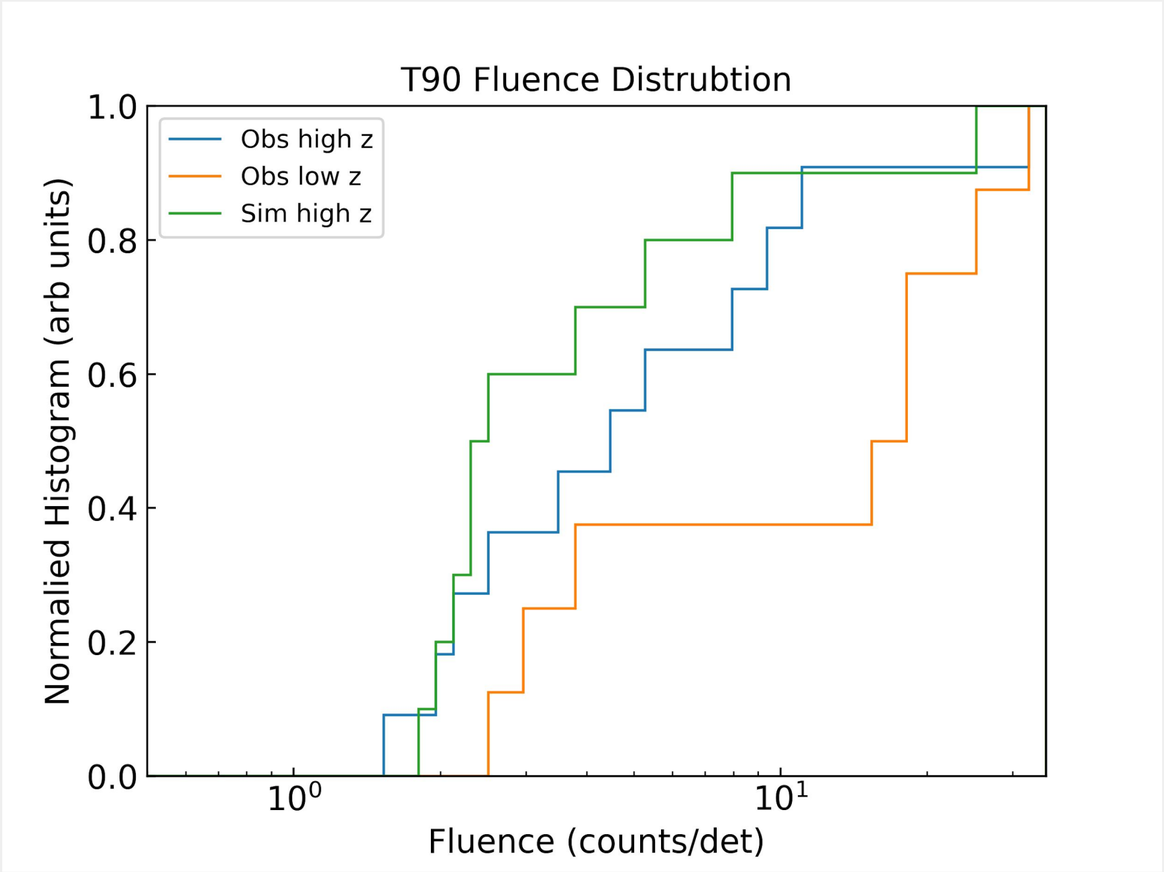
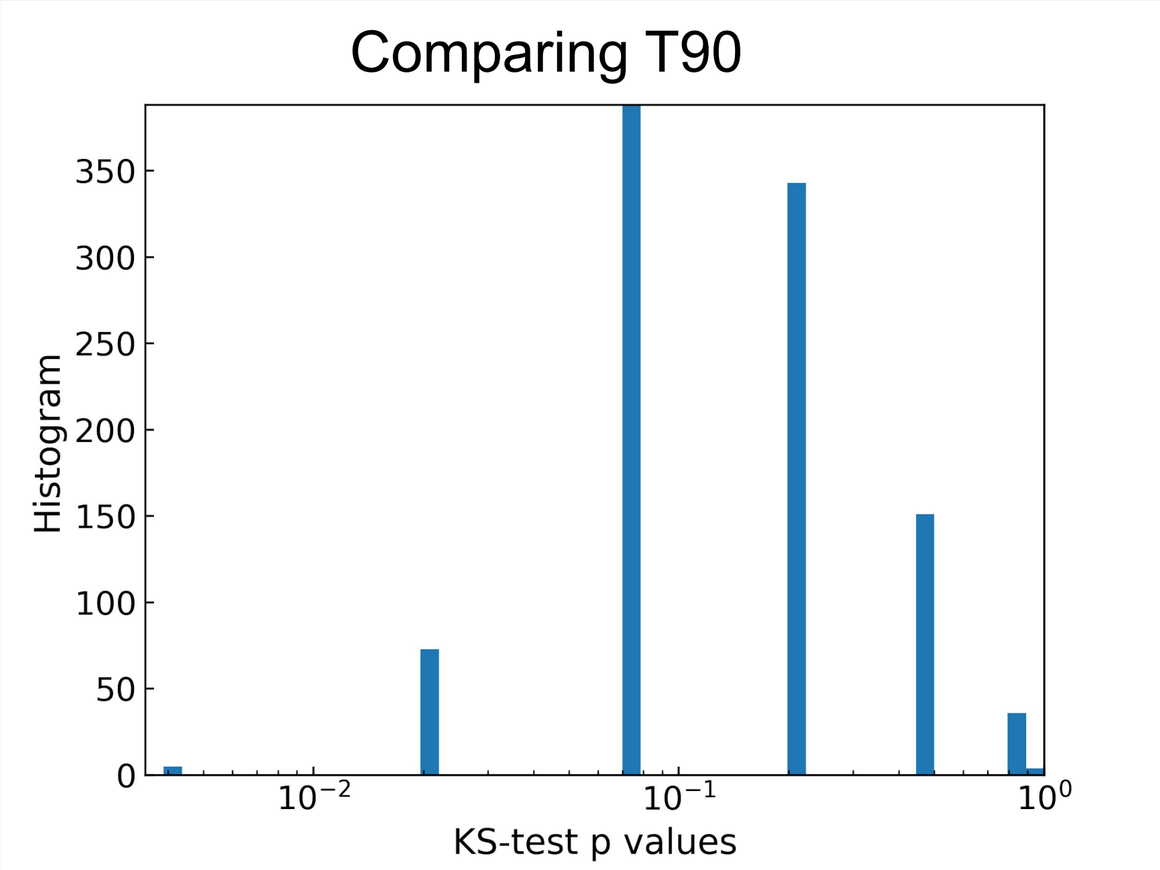
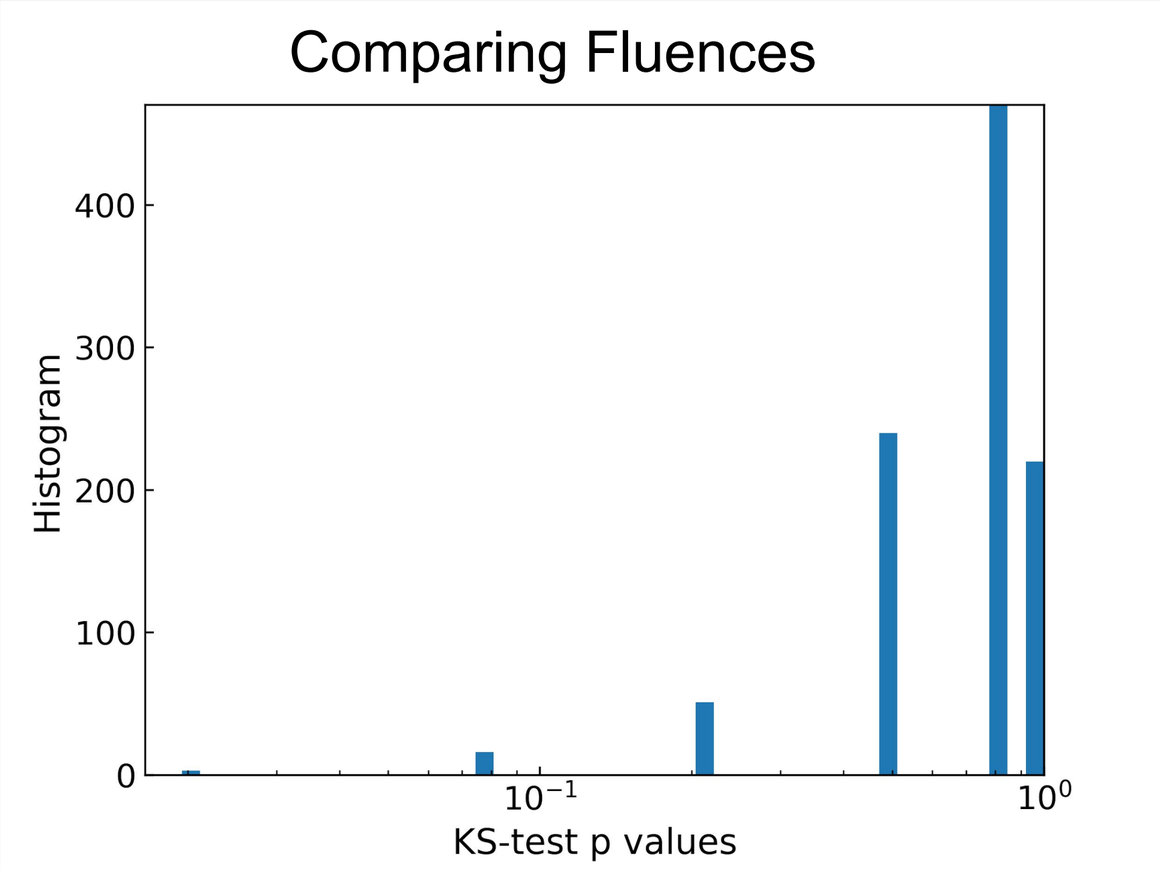




Are Low-z and High-z GRBs the same population?

KS-test between Observed and Simulated high-z samples

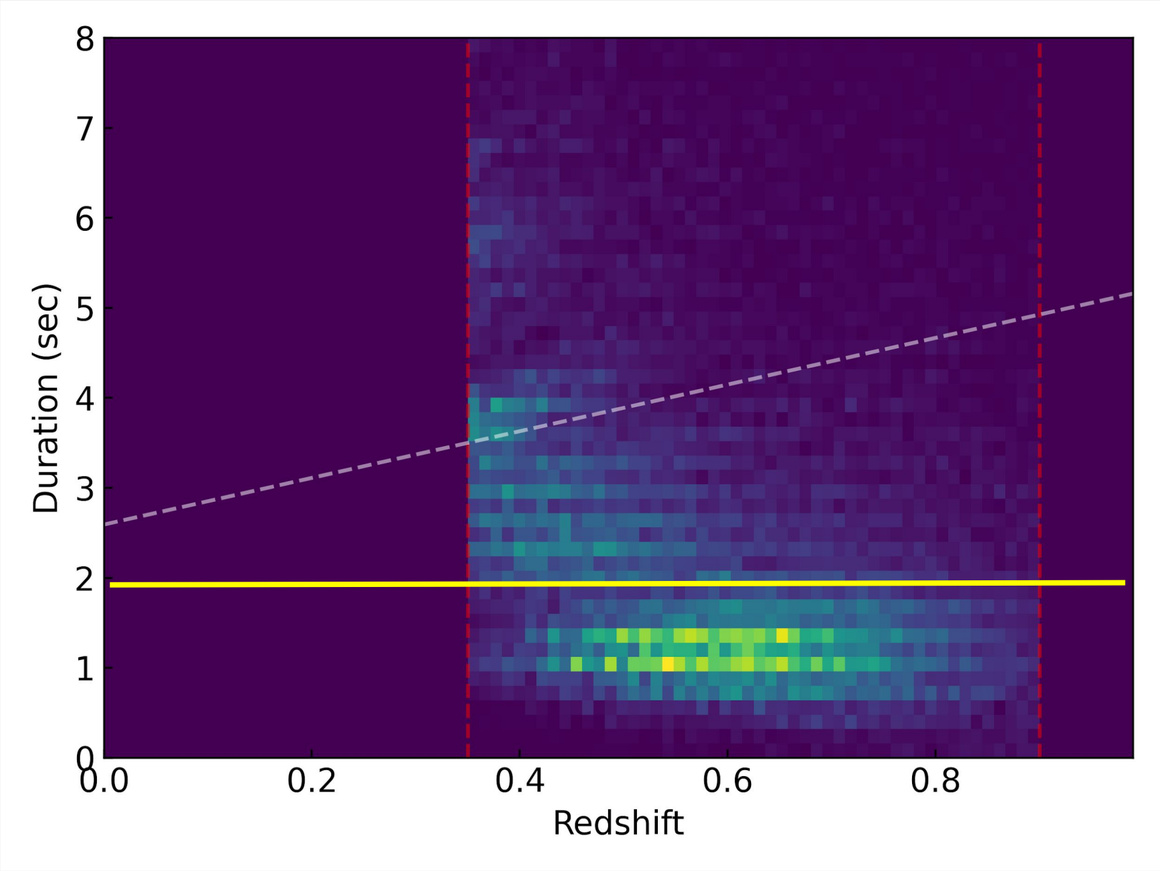


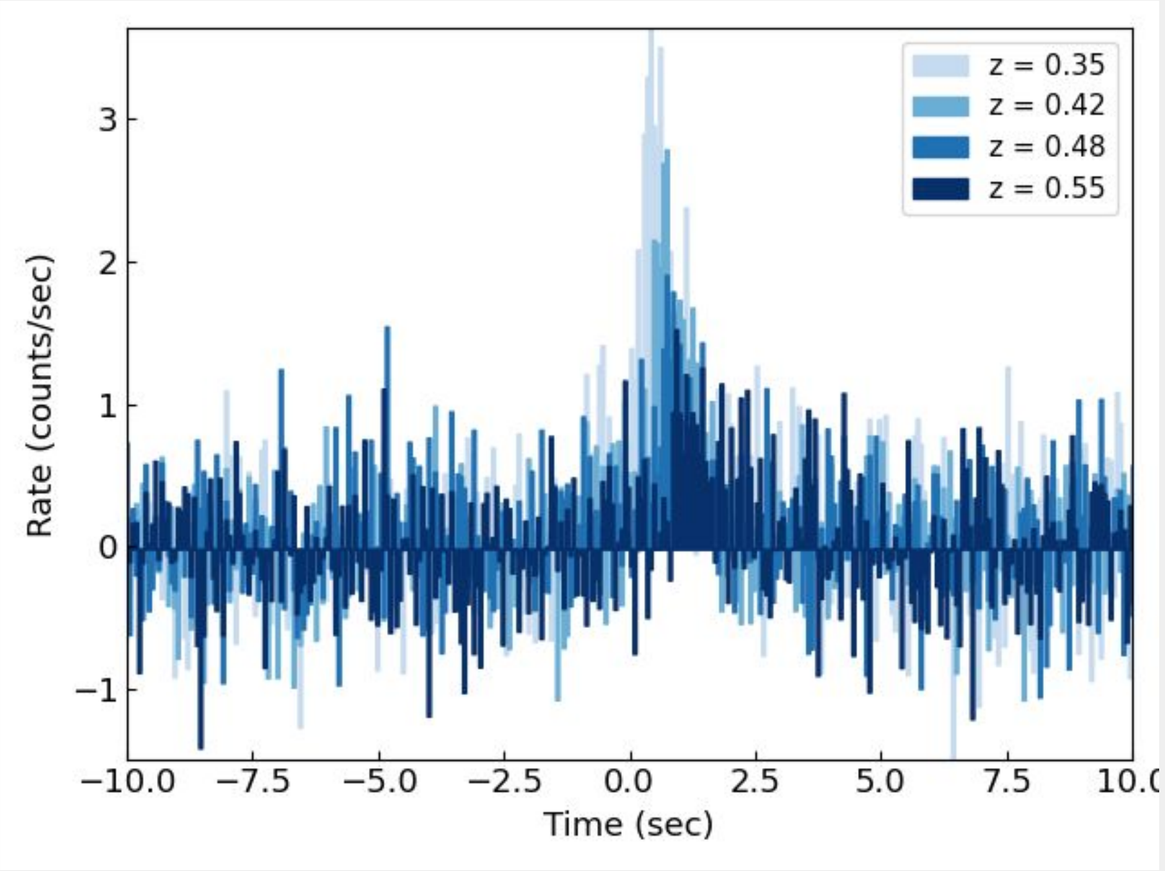


Long GRBs Becoming Short

Possible, but not typical

GRB 120311A



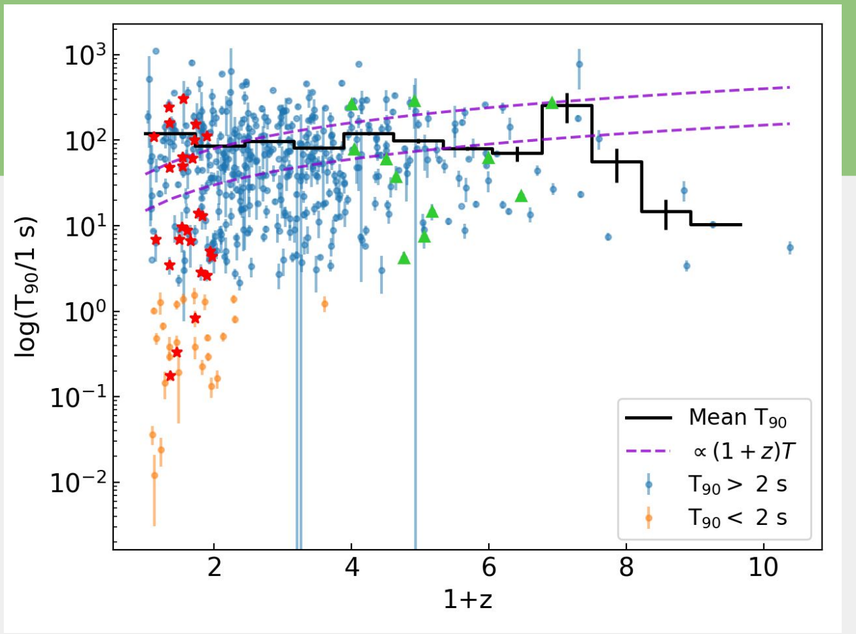


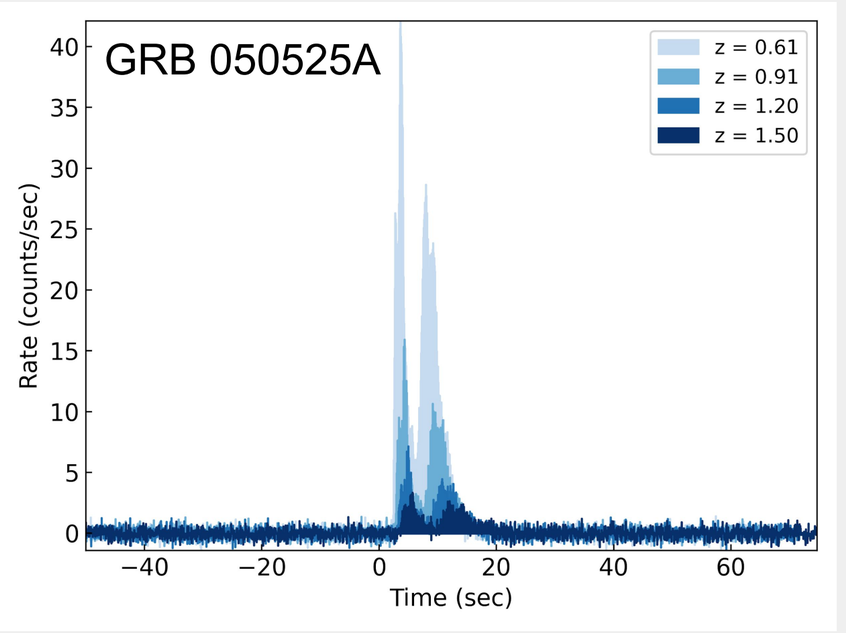
Conclusions -- Thank you!

1. GRB Duration measurements are underestimated
   a. Quantification is difficult due to dependence on light curve structure
   b. and so are the uncertainties!
   c. (Also fluence, but to a lesser degree)

2. Are low-z and high-z GRBs populations consistent?
   a. We find yes (mostly)

Next step: other instruments





Backup Slides

Sample

Table 1. Low-z GRBs (i.e., $z < 1$)

GRB Name	z	$T_{90,true}$ (sec)
050416A	0.65	4.20
050525A	0.61	8.83
060614	0.1254	109.10
060912A	0.94	11.50
061021	0.35	56.12
080430	0.77	20.872
080916A	0.69	61.348
081007	0.5295	12.50
090424	0.54	49.46
091018	0.97	6.37
091127	0.49	9.35
100621A	0.54	63.52
100625A	0.54	16.34
100816A	0.805	2.88
101219A	0.718	2.17
110715A	0.823	13.00
111228A	0.716	101.24
120311A	0.35	8.86
130427A	0.34	331.48
130603B	0.356	0.19
130925A	0.347	285.73
140506A	0.889	111.10
160425A	0.555	125.69
160804A	0.736	185.87
161001A	0.891	12.20
161219B	0.148	21.80

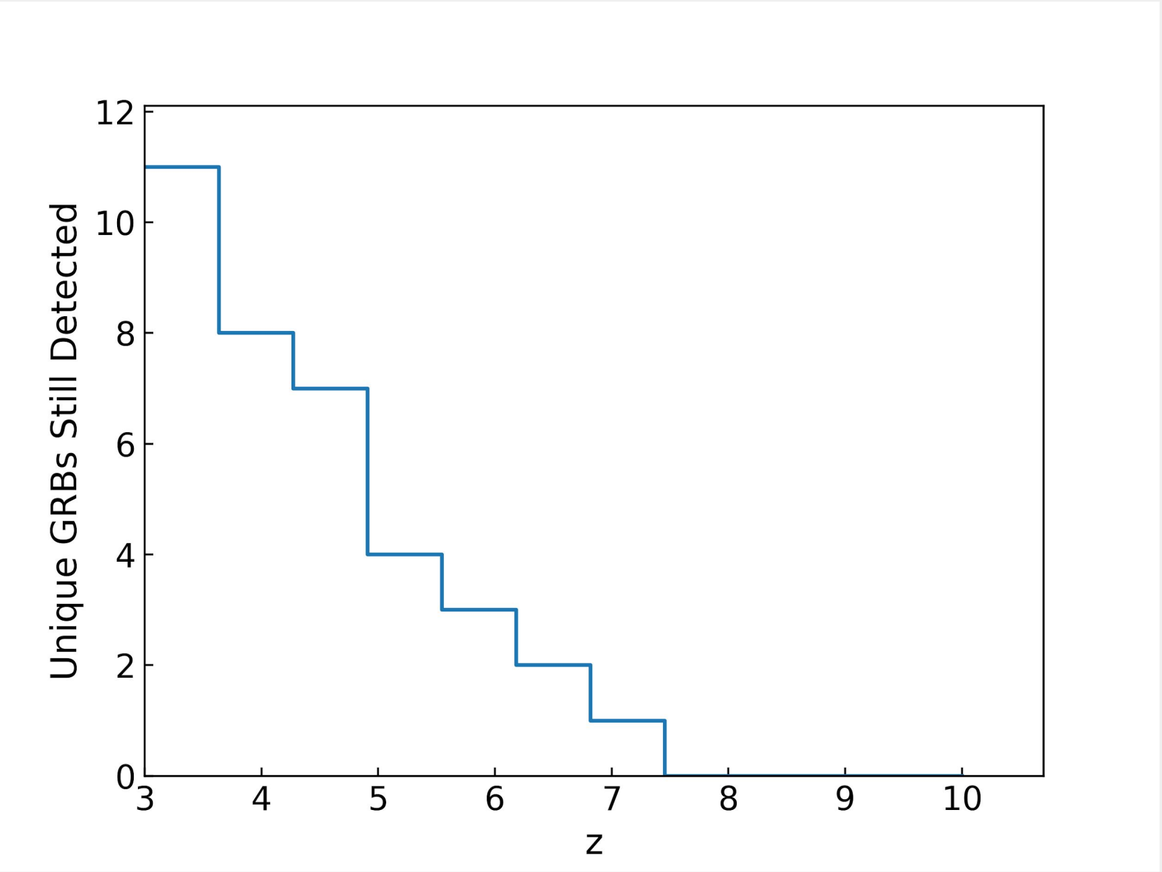
Table 2. High-z GRBs (i.e., $z > 3$)

GRB Name	z	$T_{90,true}$ (sec)
060206	4.05	7.552
060210	3.91	288.00
060306	3.5	60.94
060927	5.47	22.416
080607	3.04	78.97
090715B	3.00	266.40
111008A	4.99	62.85
120712A	4.175	14.808
130408A	3.758	4.24
130606A	5.91	276.66
170202A	3.645	37.76

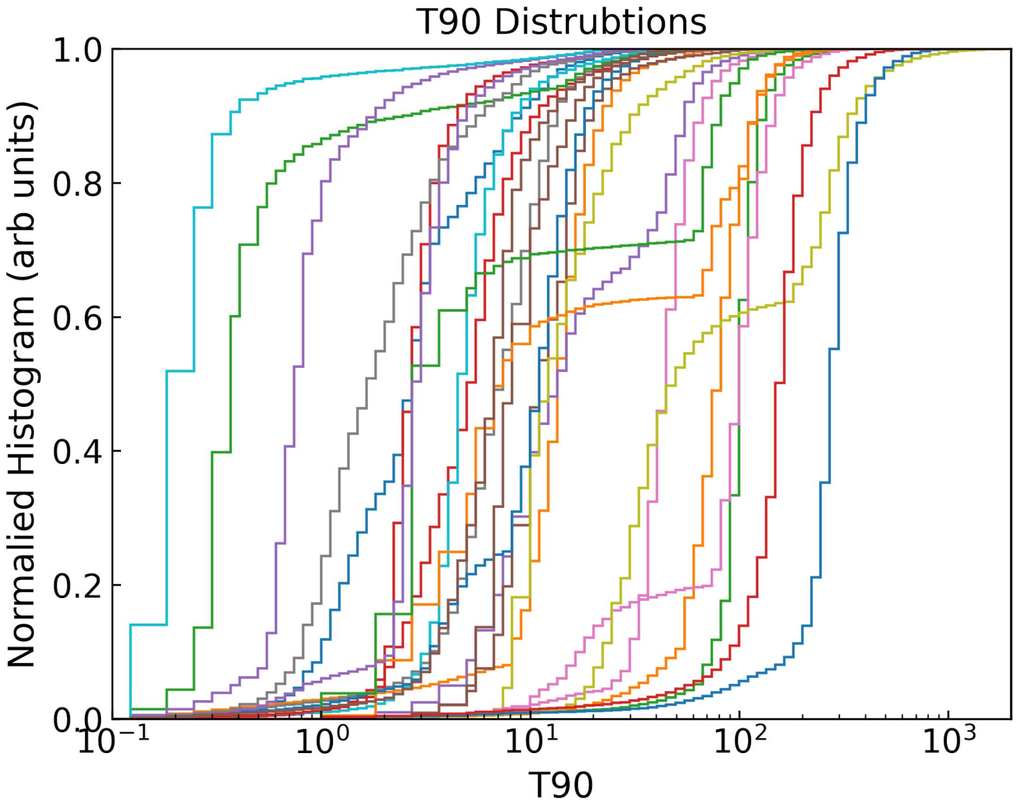
Simulated High-z GRBs

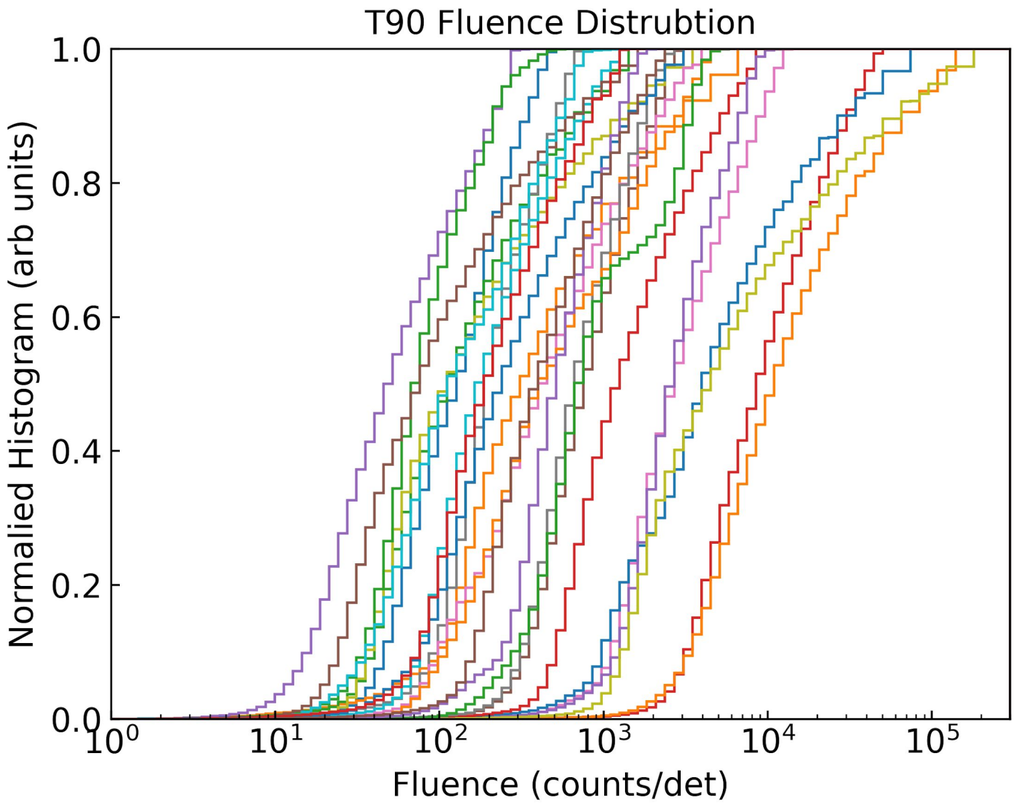
GRBs that were detected at z > 3 (of original 26)

050525A
090424
091018
091127
100621A
100816A
110715A
111228A
130427A
140506A
160804A



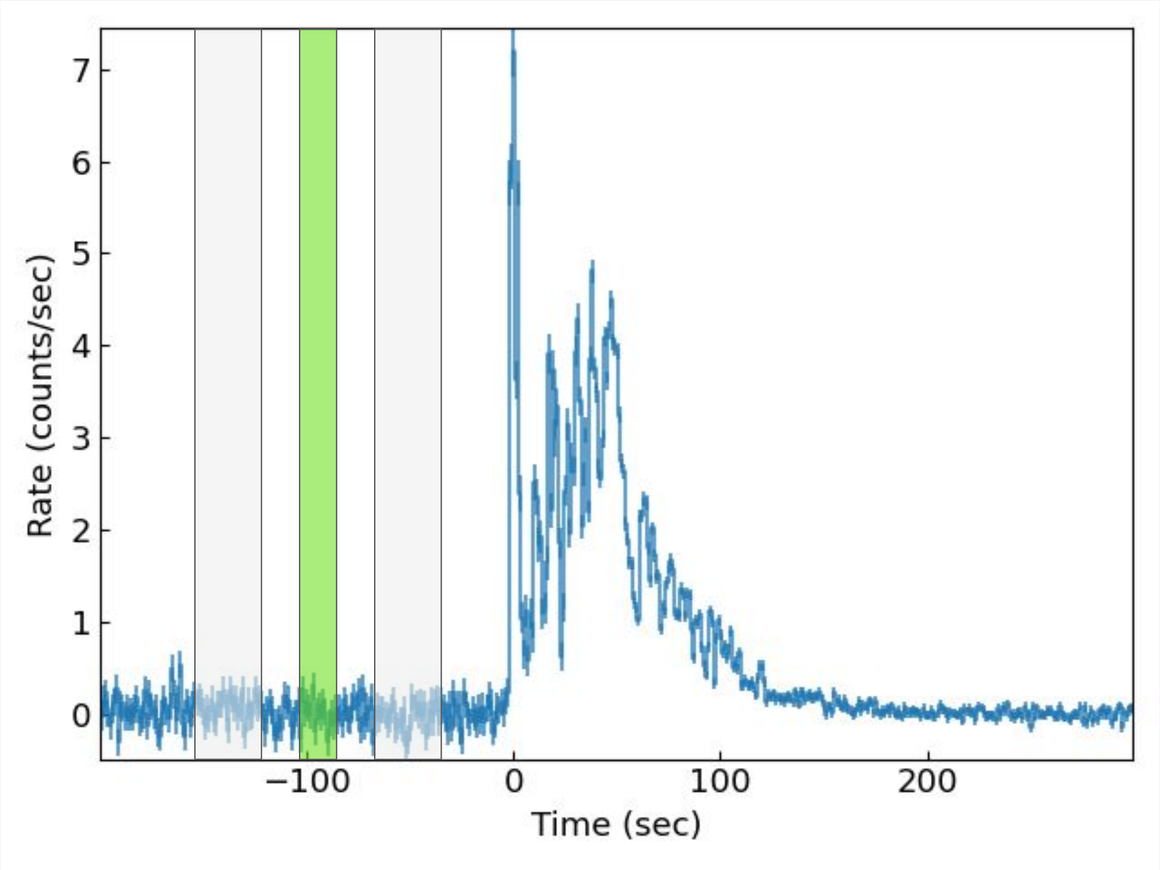
Cumulative Sums

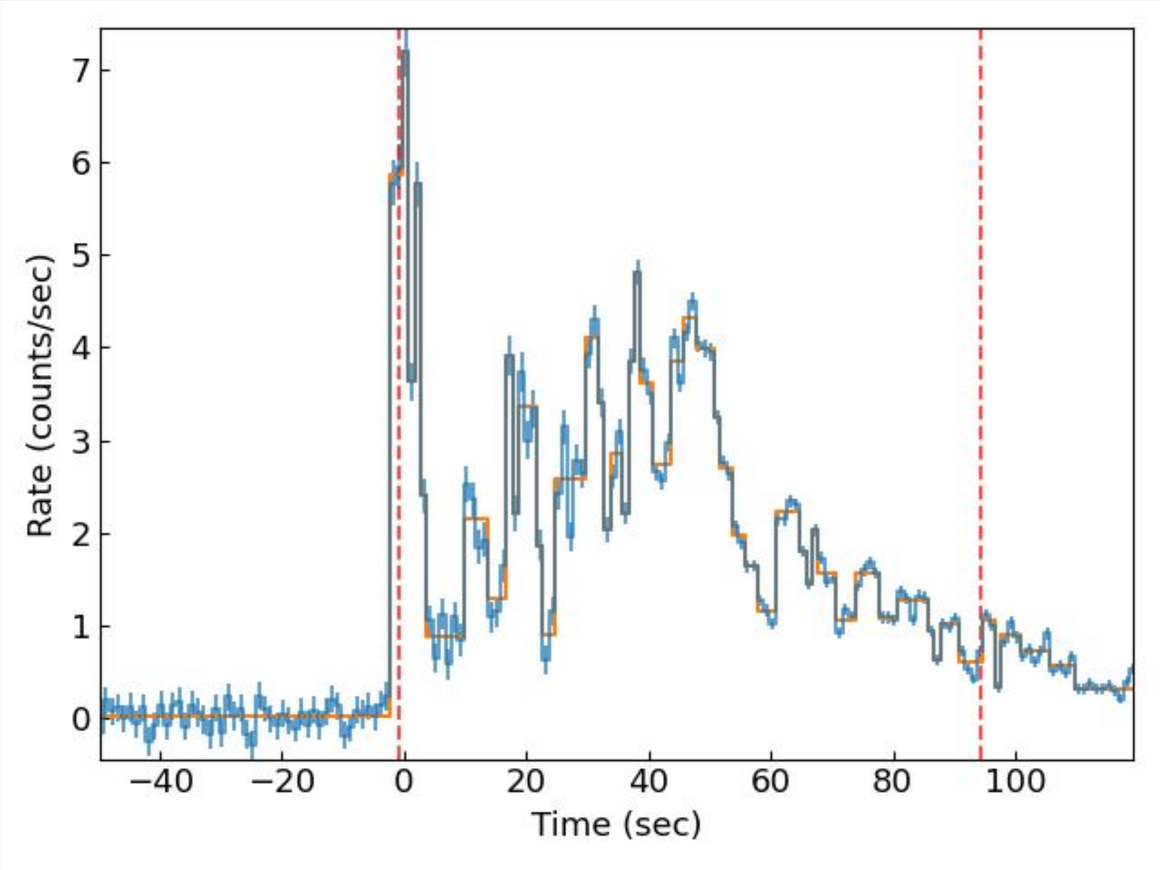




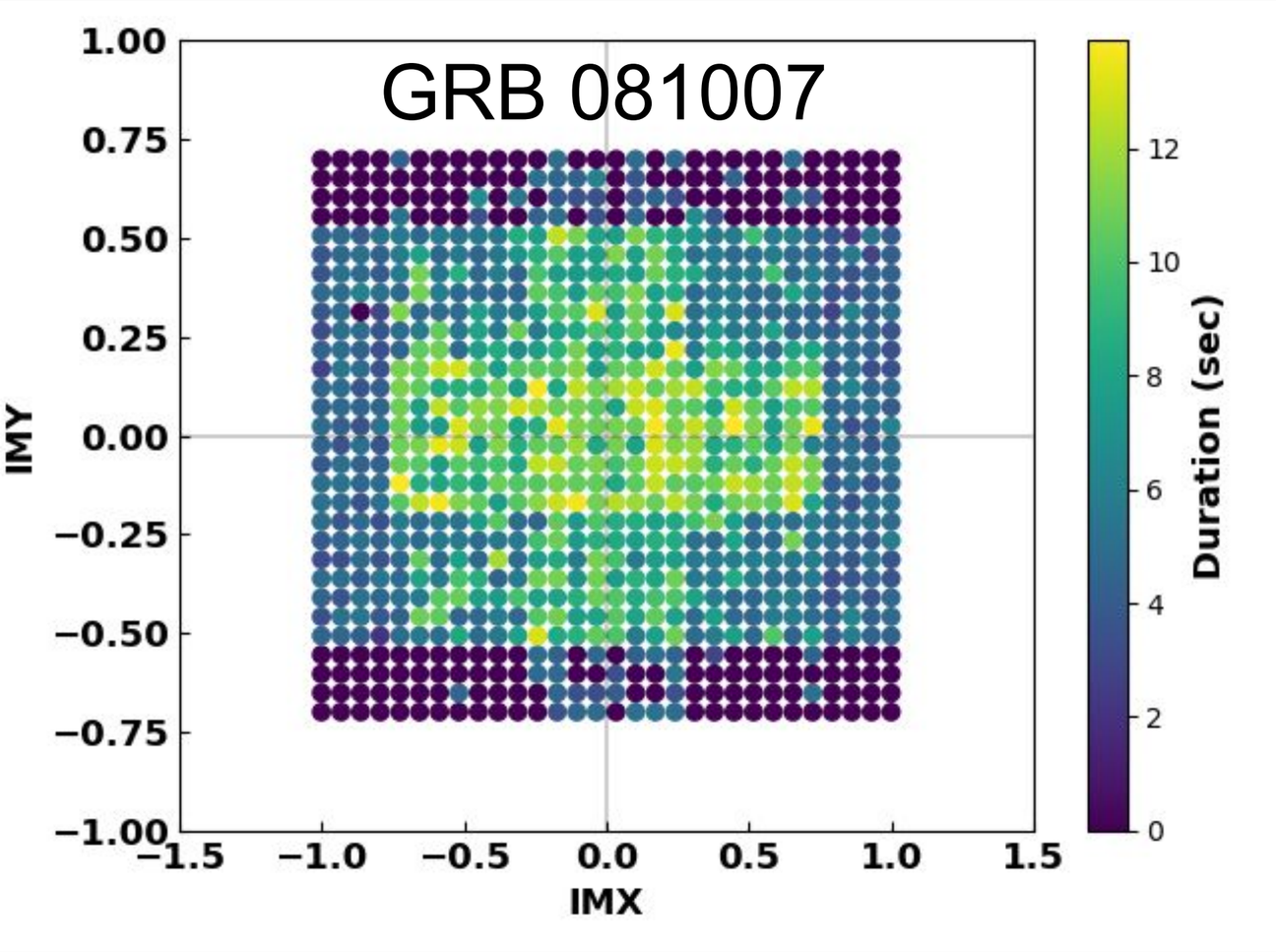
Methods

Bayesian Blocks



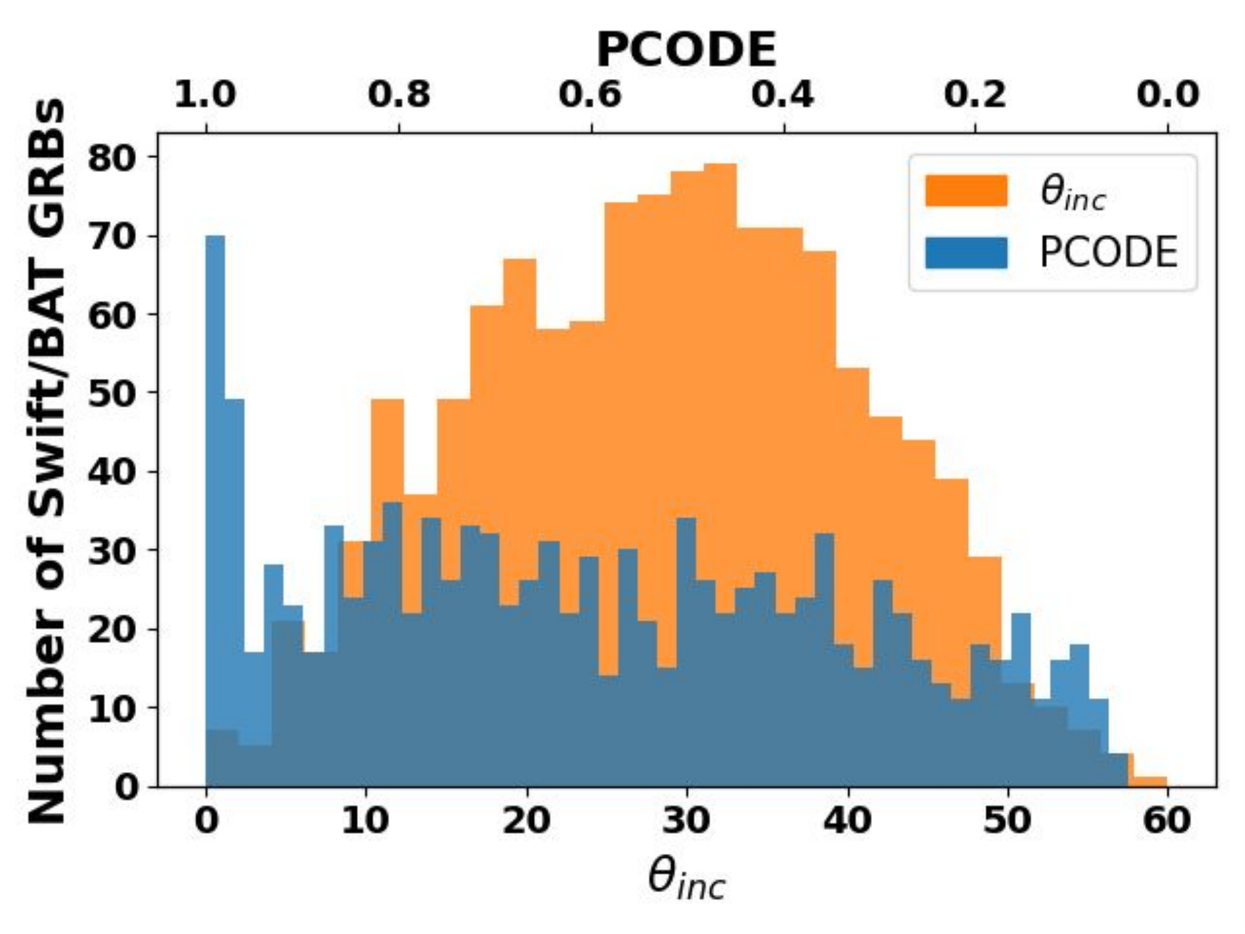


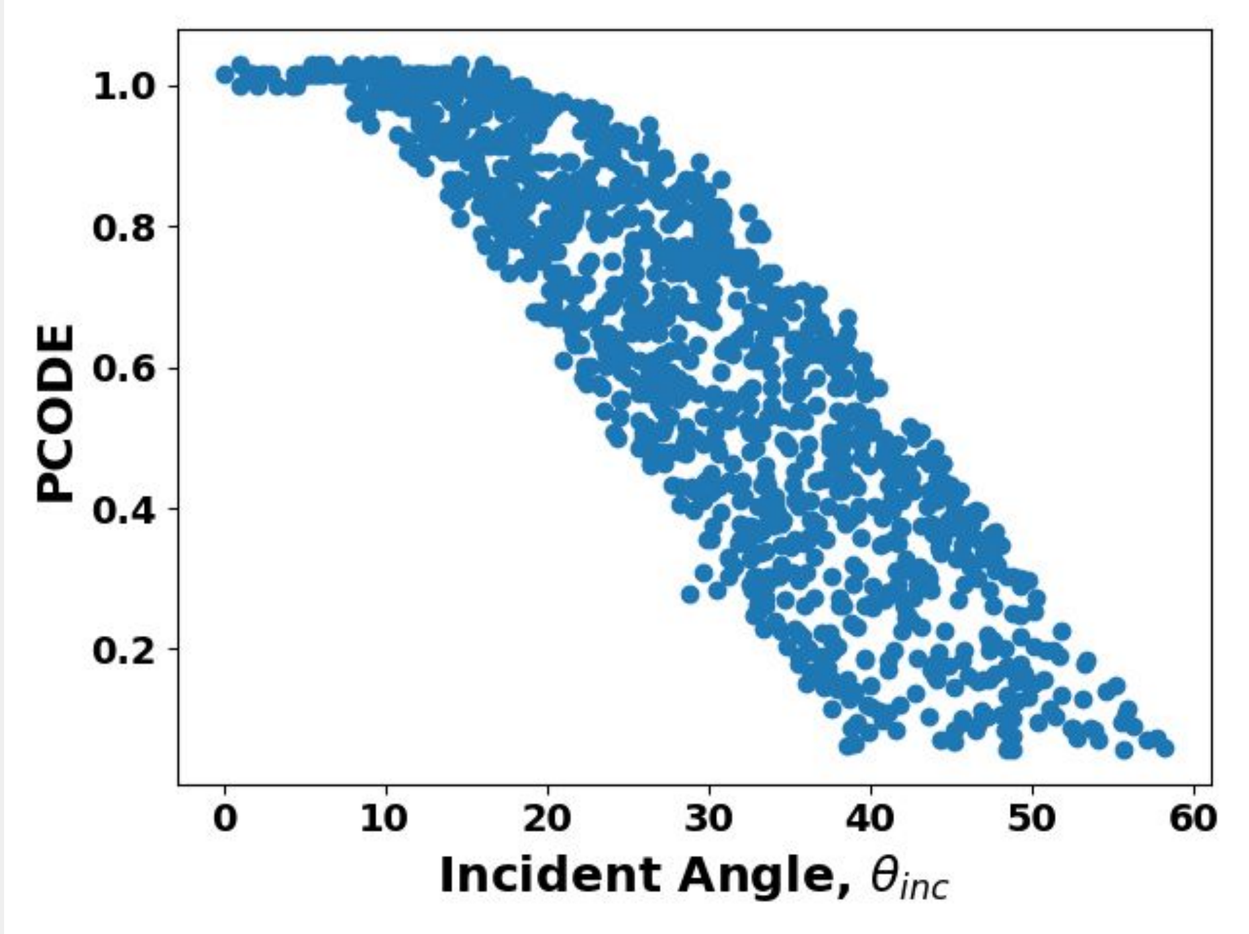
Off-axis (of detector) dependence



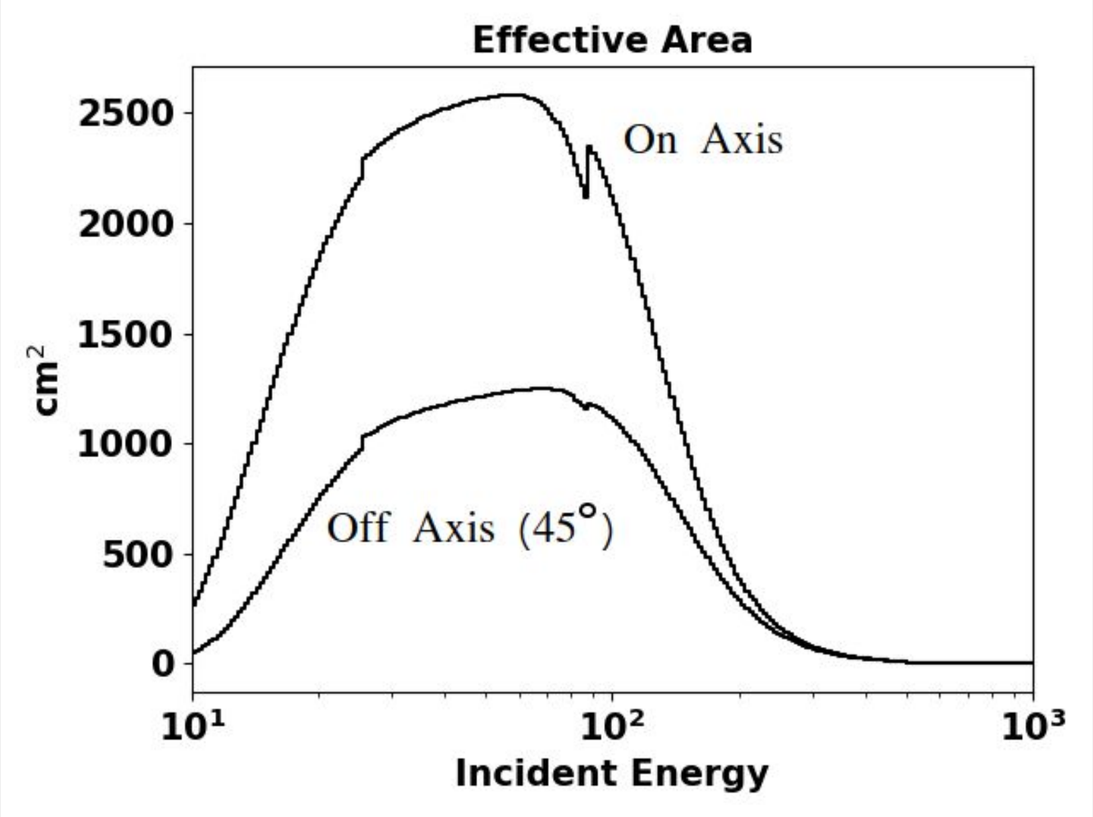
PCODE vs BAT Field of View

Not exactly one-to-one with incident angle





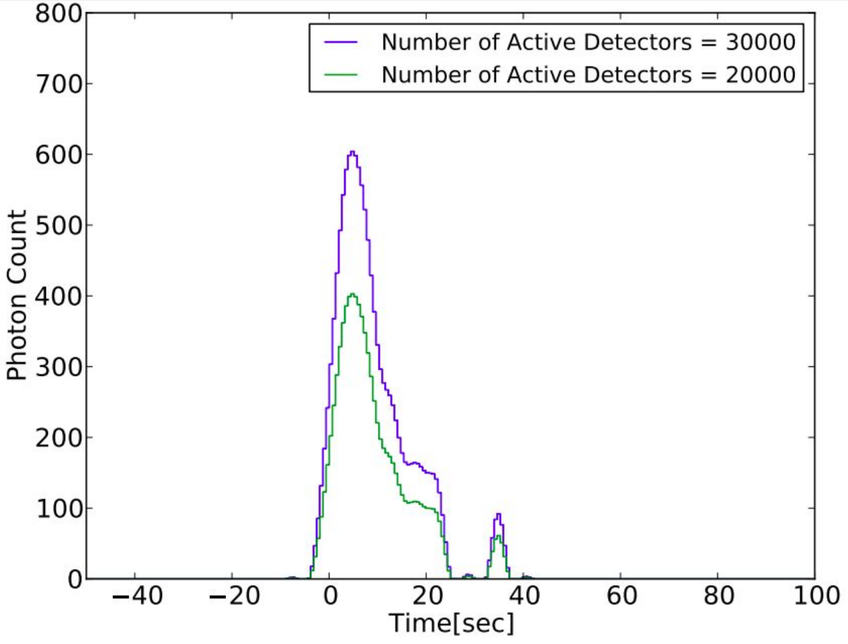
Swift/BAT Effective Area (w.r.t. Source incident angle)



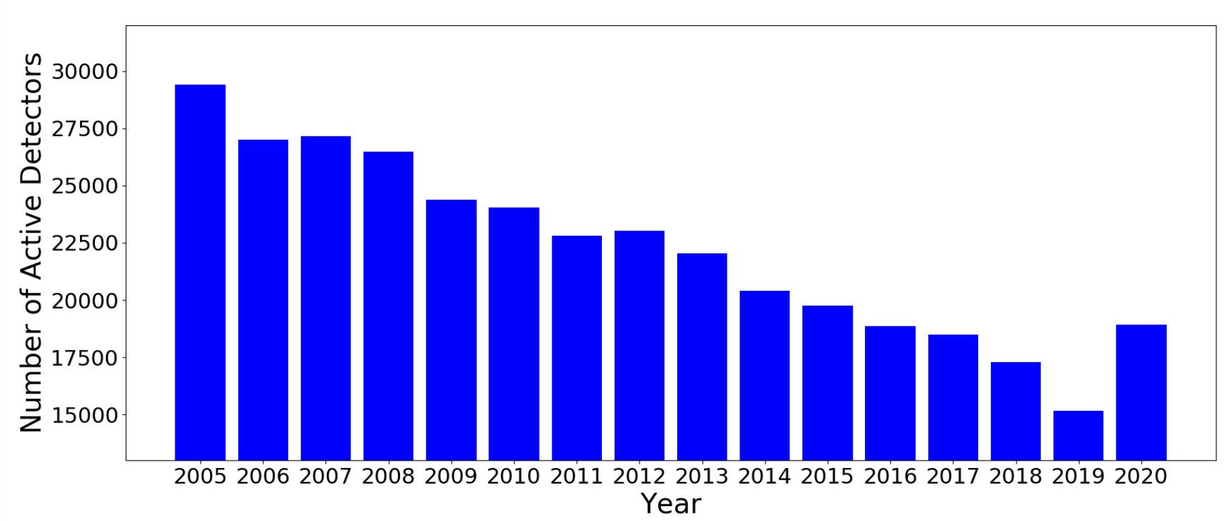
Reelevant *Swift*/BAT Parameters

Number of Active Detectors (NDETS)

Incident angle (PCODE)



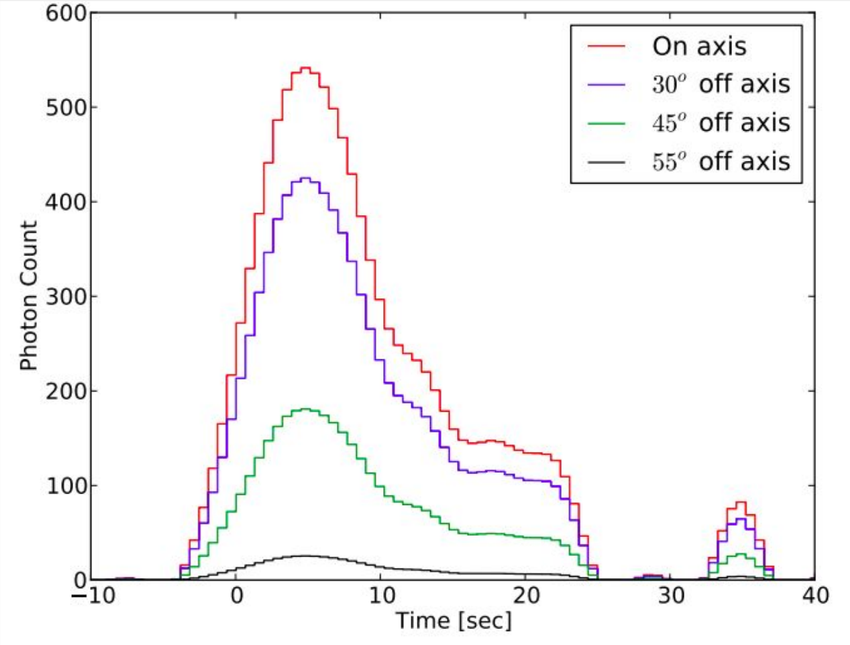
Lien A. et al., 2014



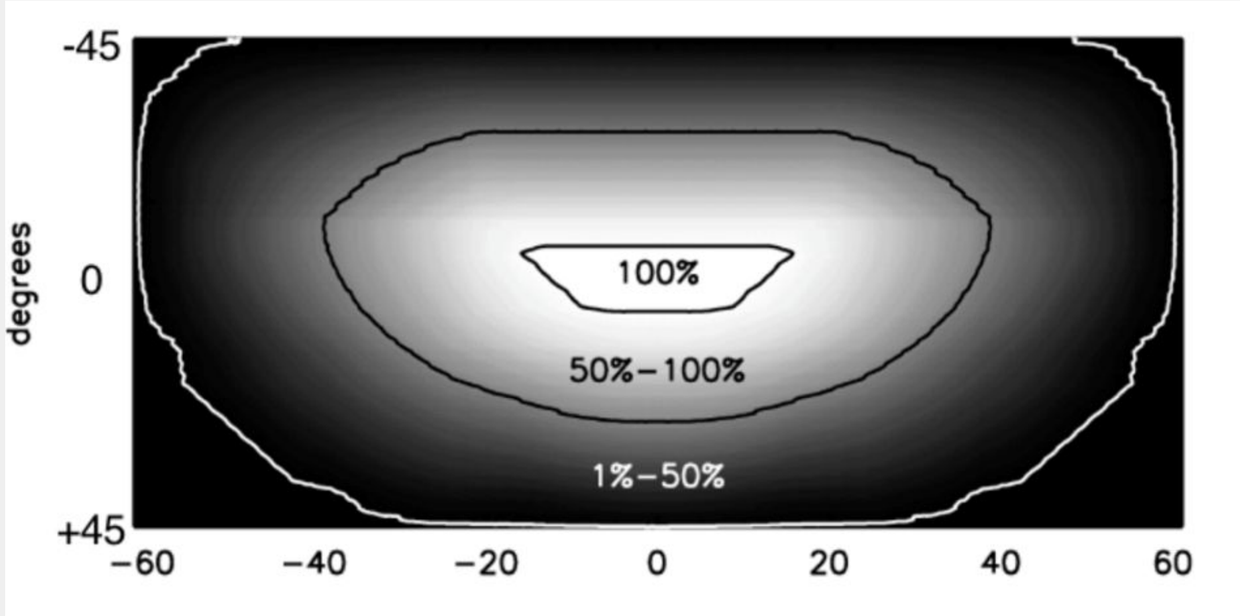
Reelevant *Swift*/BAT Parameters

Number of Active Detectors (NDETS)

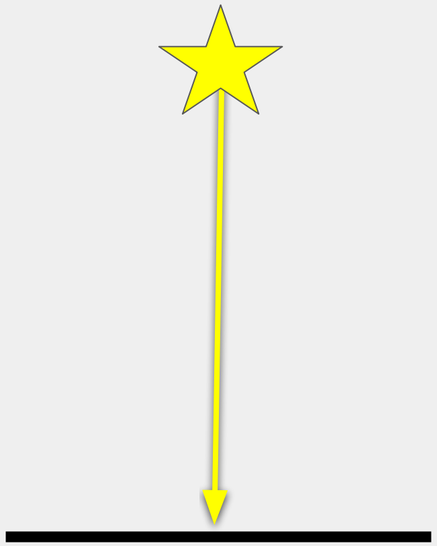
Incident angle (PCODE)



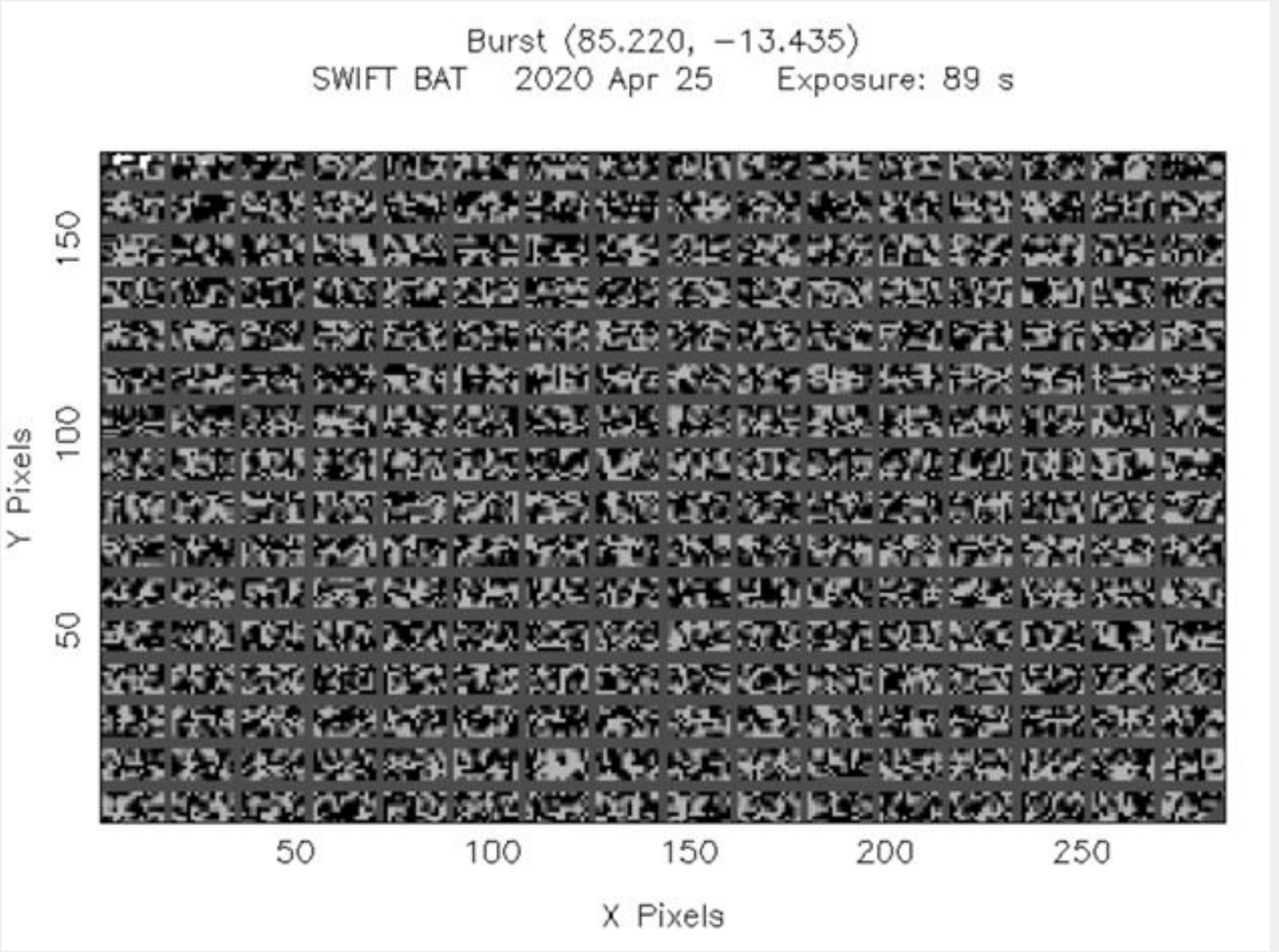
Lien A. et al., 2014



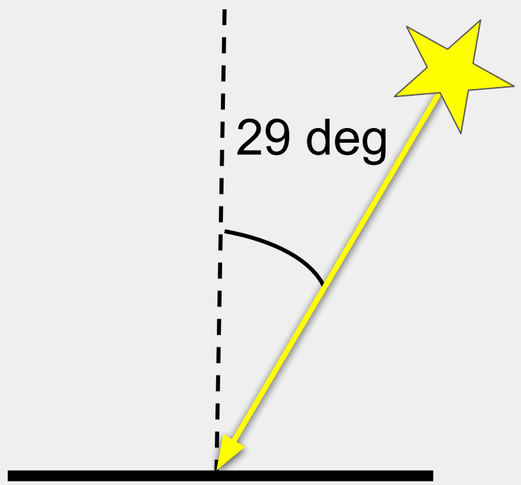
PCODE and Incident Angle



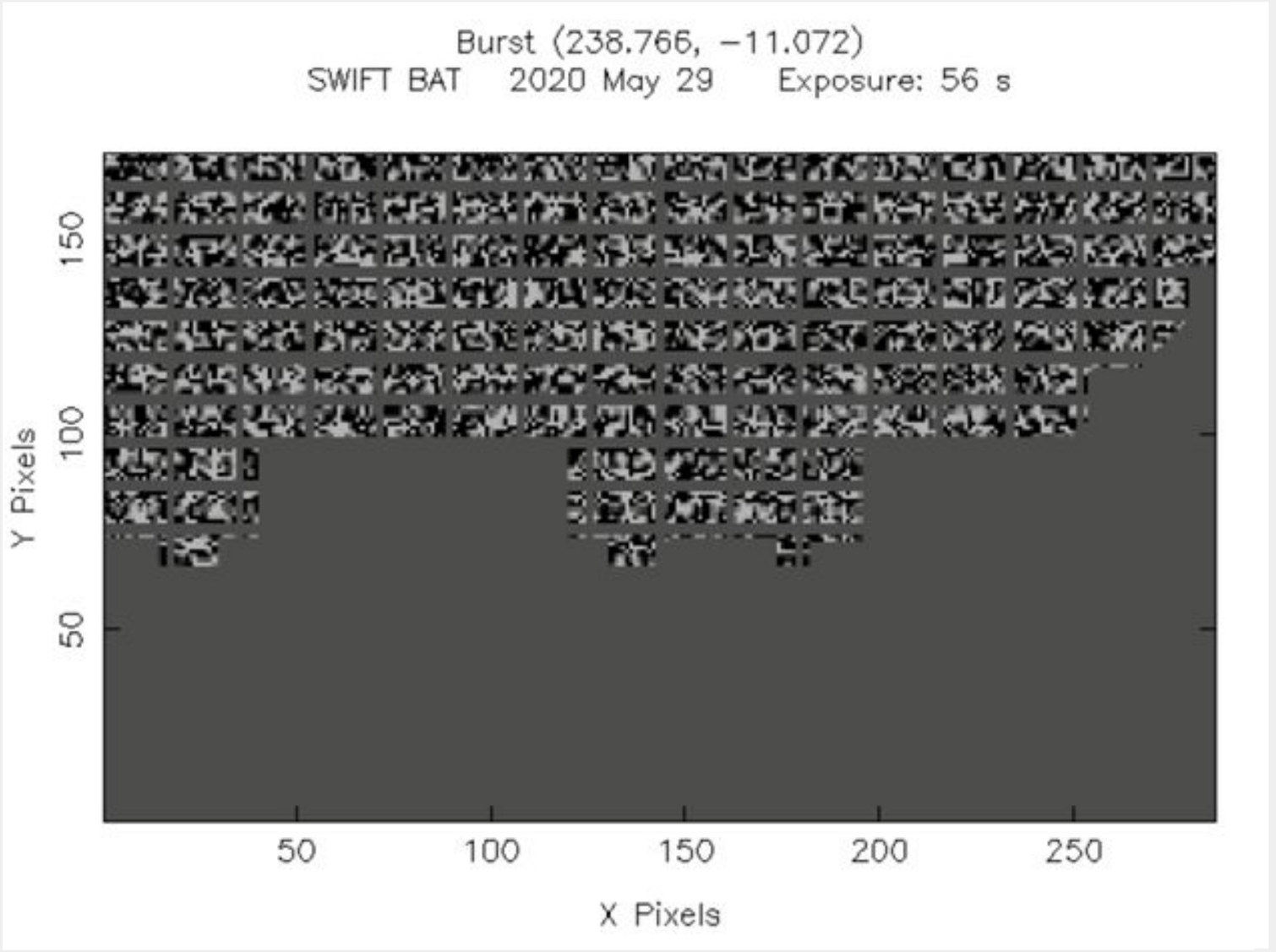
Incident Angle = 0 deg
PCODE = 1



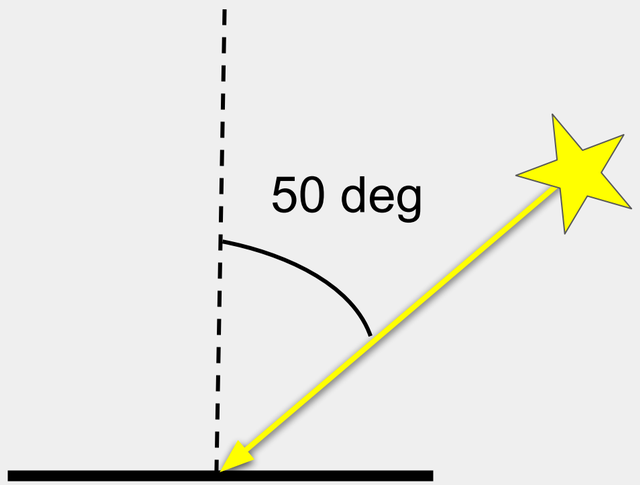
PCODE and Incident Angle



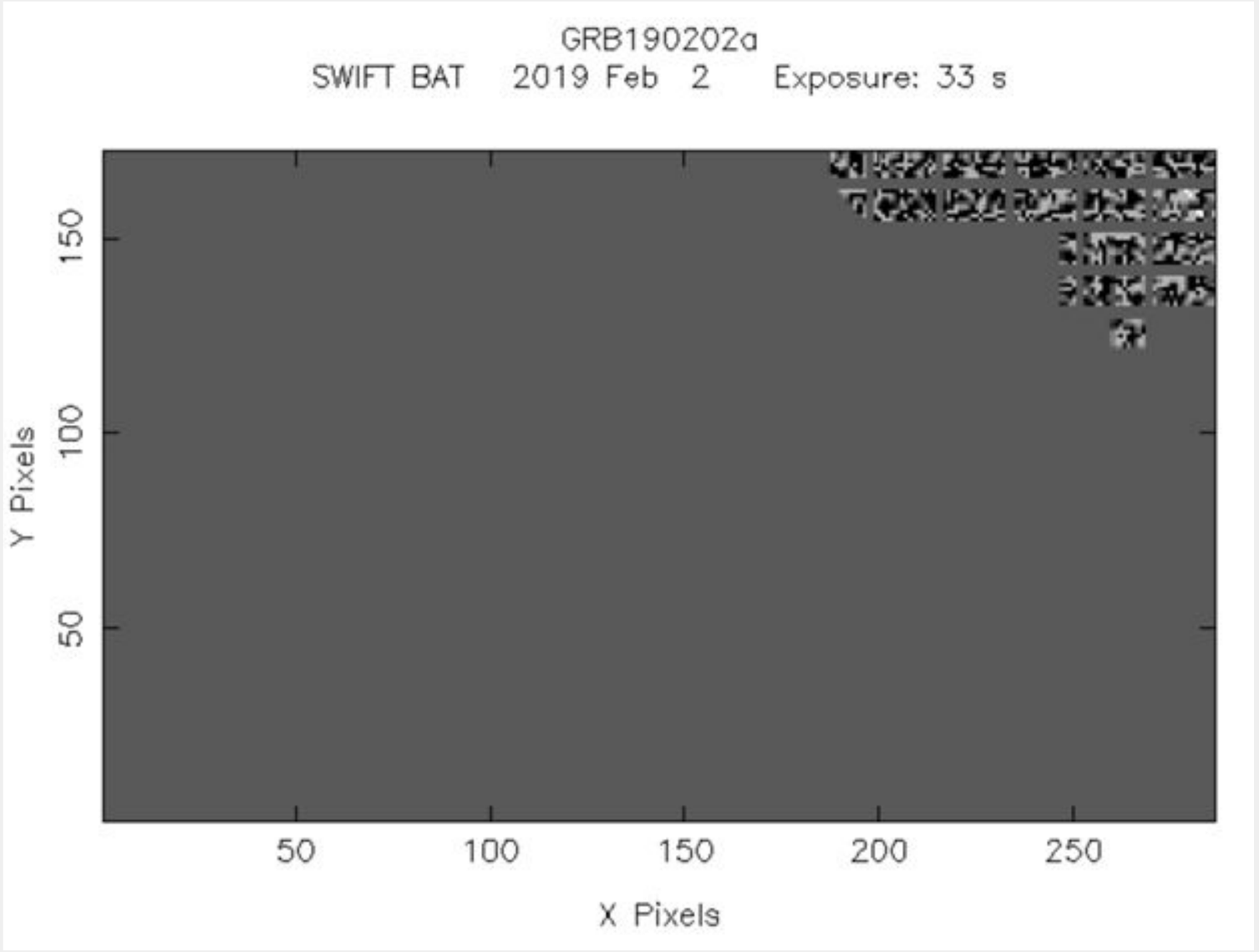
Incident Angle = 29 deg
PCODE = 0.5



PCODE and Incident Angle



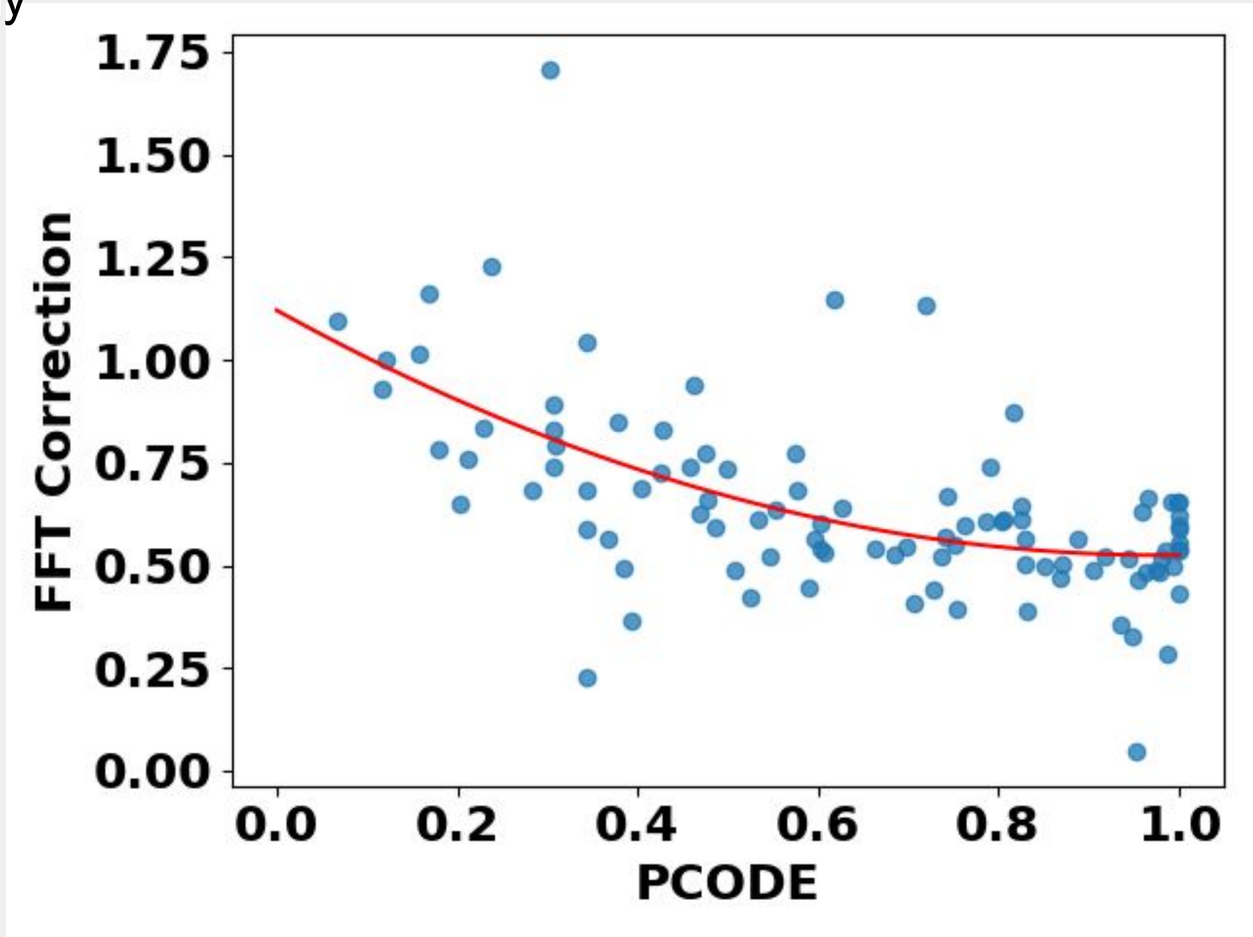
Incident Angle = 50 deg
PCODE = 0.04



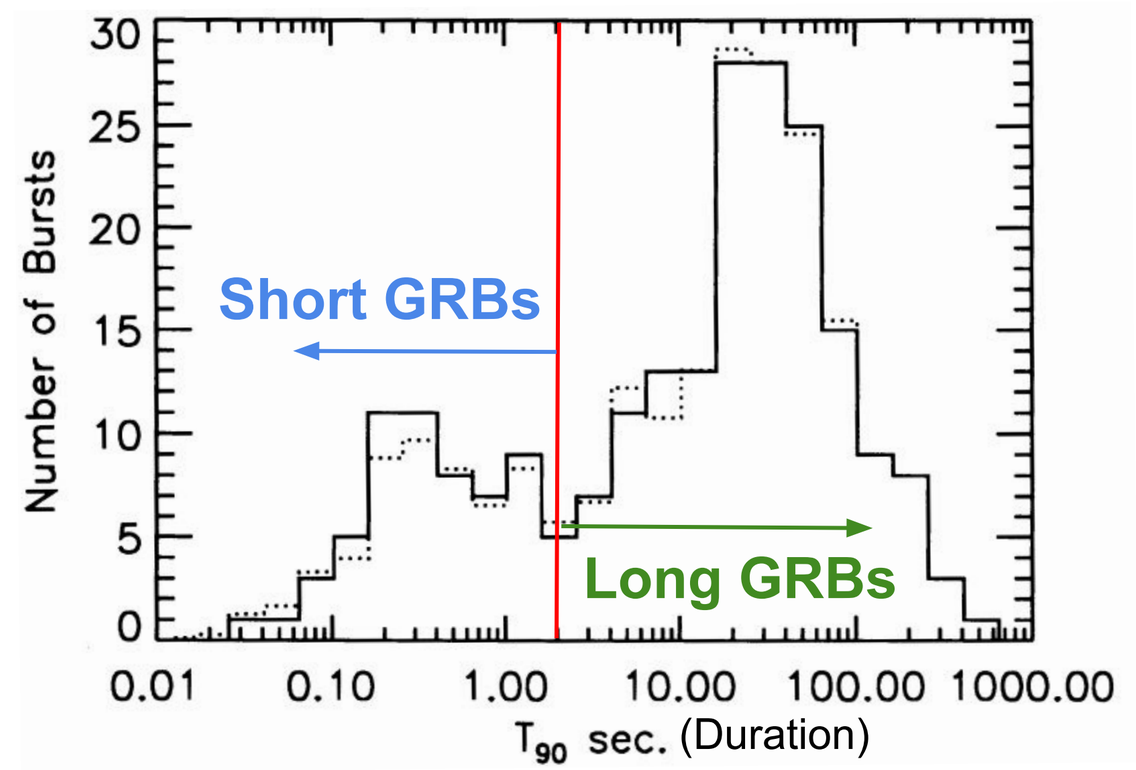
FFT Loss Factor

FFT causes additional loss of signal, but it’s really difficult to estimate this loss

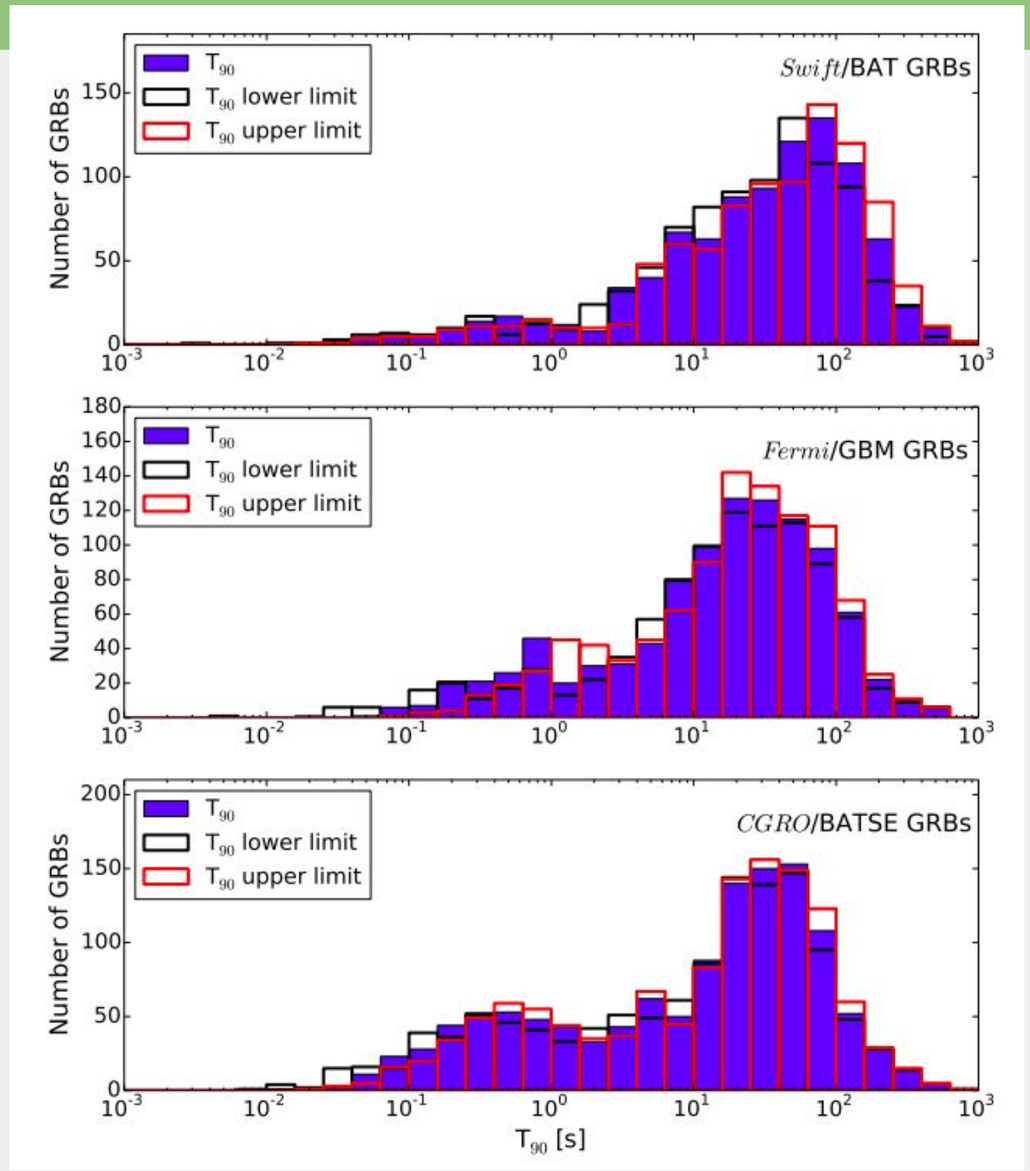
We calculated the loss for 100 GRBs and Fit a line as a function of PCODE.



Prompt Emission Durations



Kouveliotou et al., 1993



Lien A. et al., 2016