THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

# Instrumental Tip-of-The-Iceberg Effects on the Prompt Emission of *Swift*/BAT GRBs

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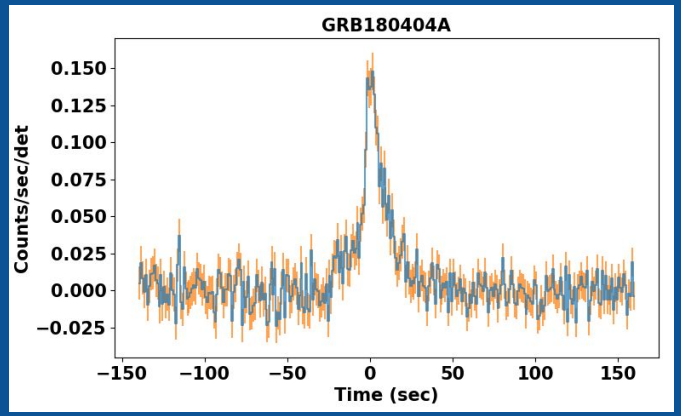
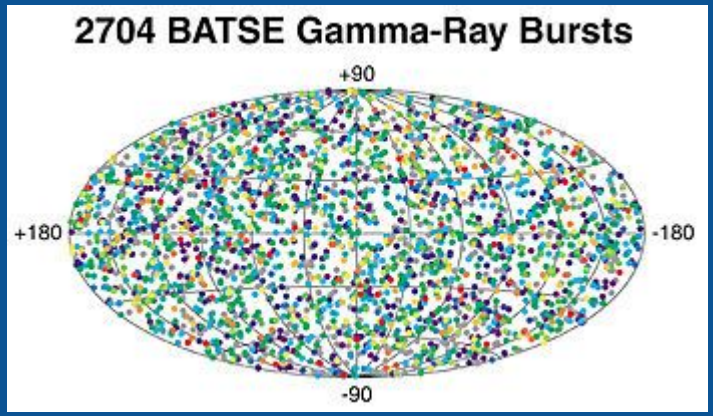
Arxiv: https://arxiv.org/abs/2111.13392

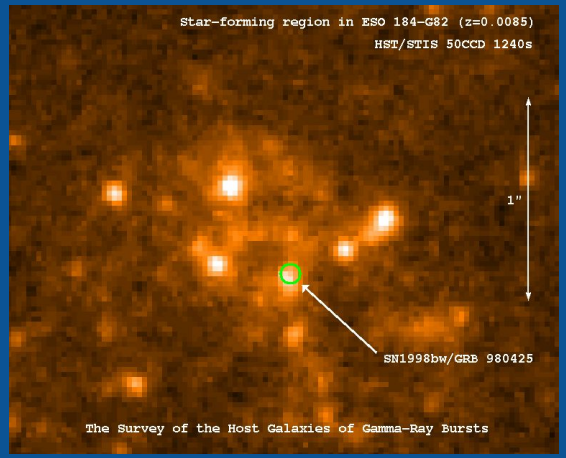
Collaborators:
Amy Lien (NASA/GSFC, CRESSTII, UMBC),
Sylvain Guiriec (NASA/GSFC, CRESSTII, GWU)
Brad S. Cenko (NASA/GSFC, UMD)
Takanori Sakamoto (AGU)

# Context - GRB Phenomena

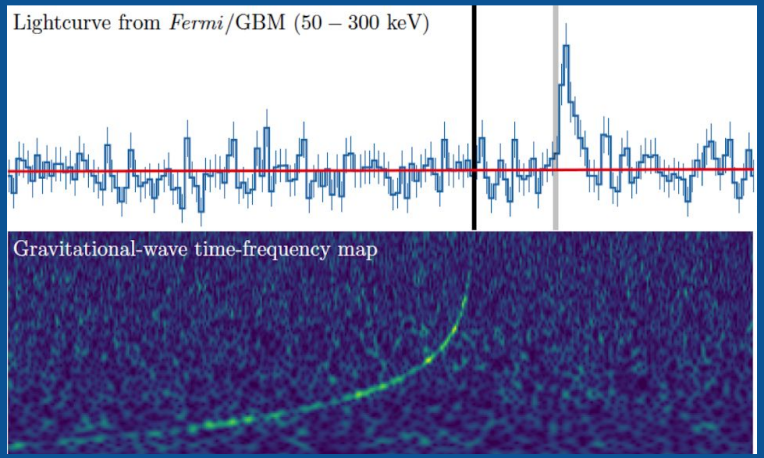



Meegan et al., 1992




Holland et al., GCN 704




LivingLigo post

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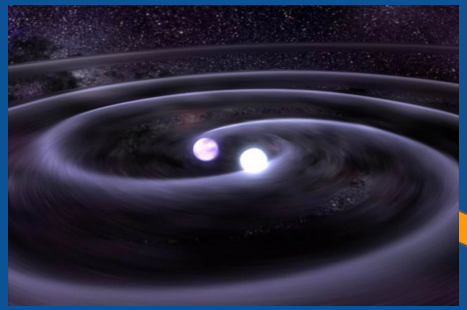

https://aasnova.org/

https://www.nasa.gov/


NASA/Goddard Space Flight Center

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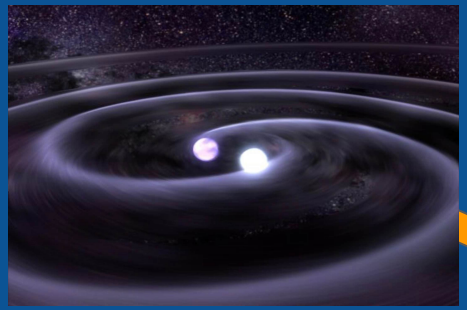

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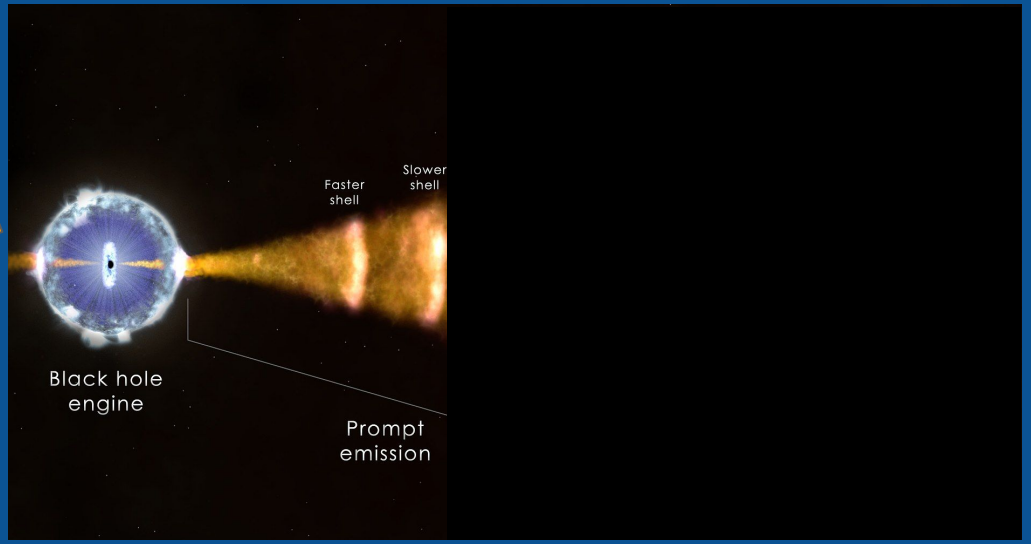


NASA/Goddard Space Flight Center

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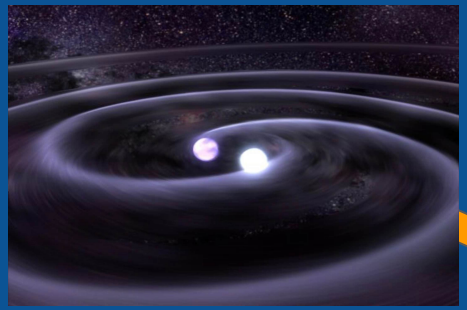

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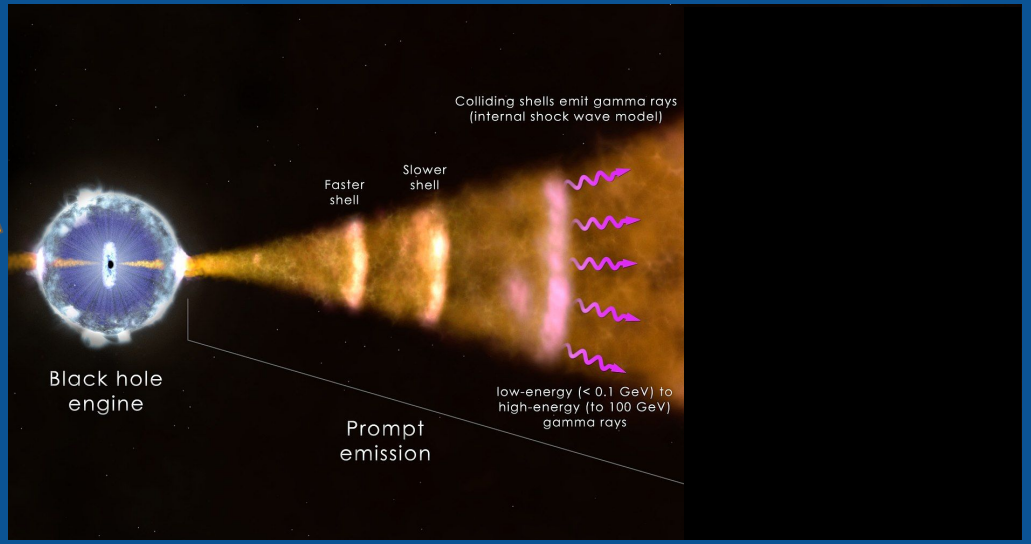


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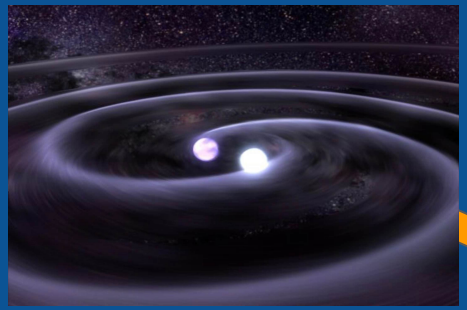

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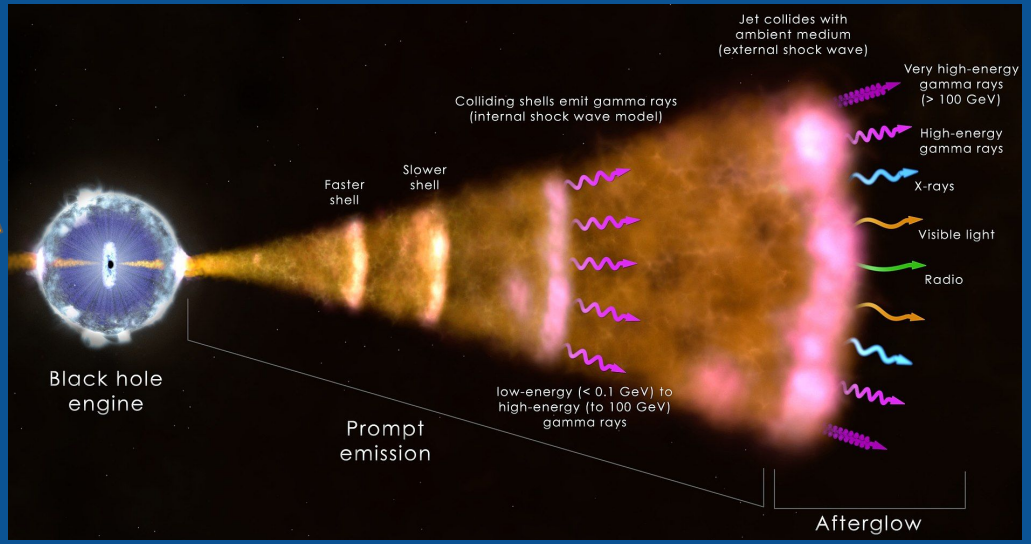


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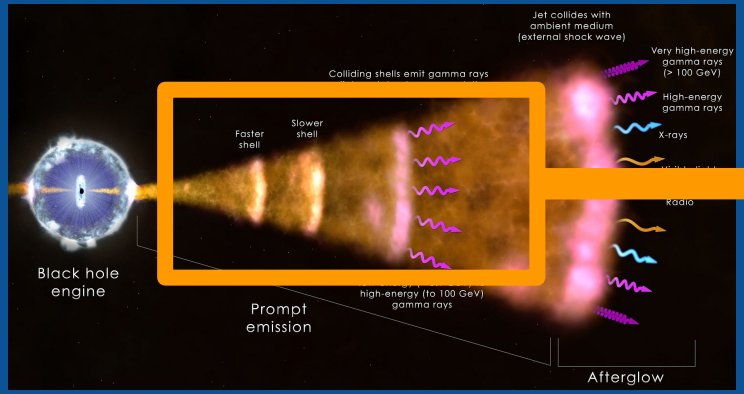
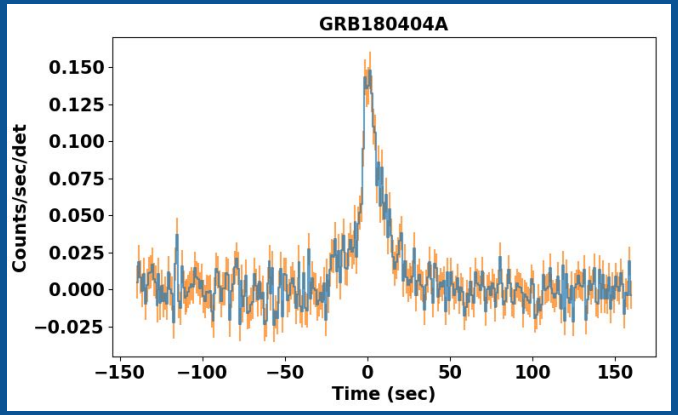



NASA/Goddard Space Flight Center



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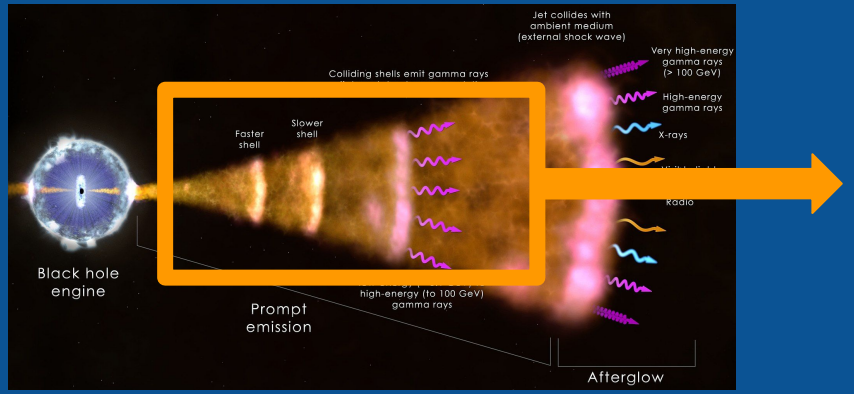
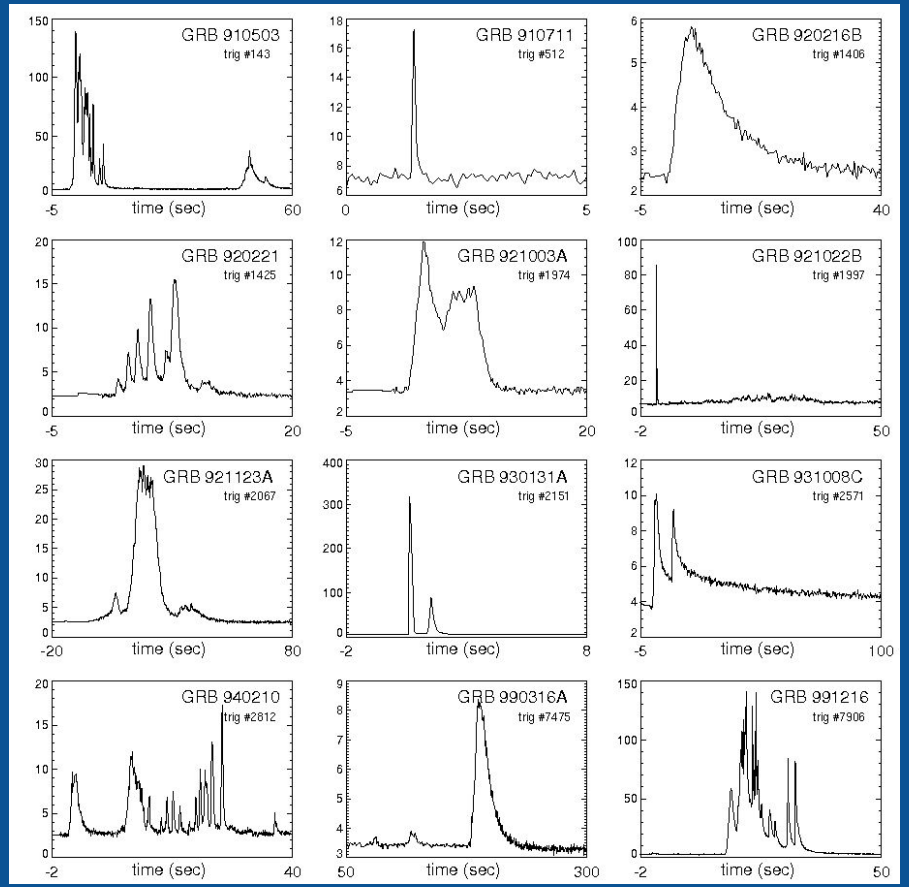
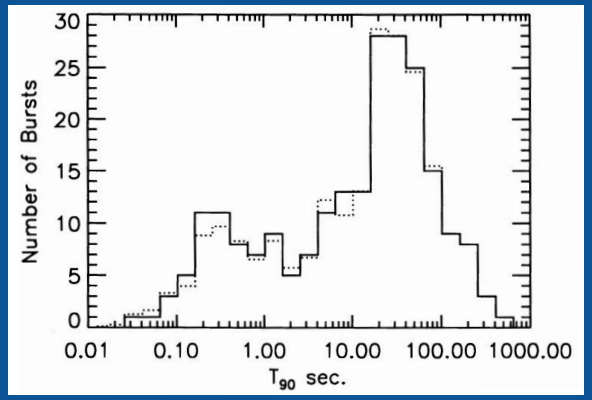



NASA/Goddard Space Flight Center



# Instrument Considerations




Kouveliotou et al., 1993

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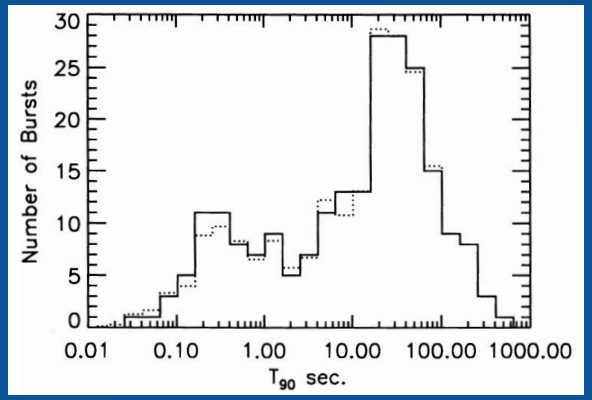


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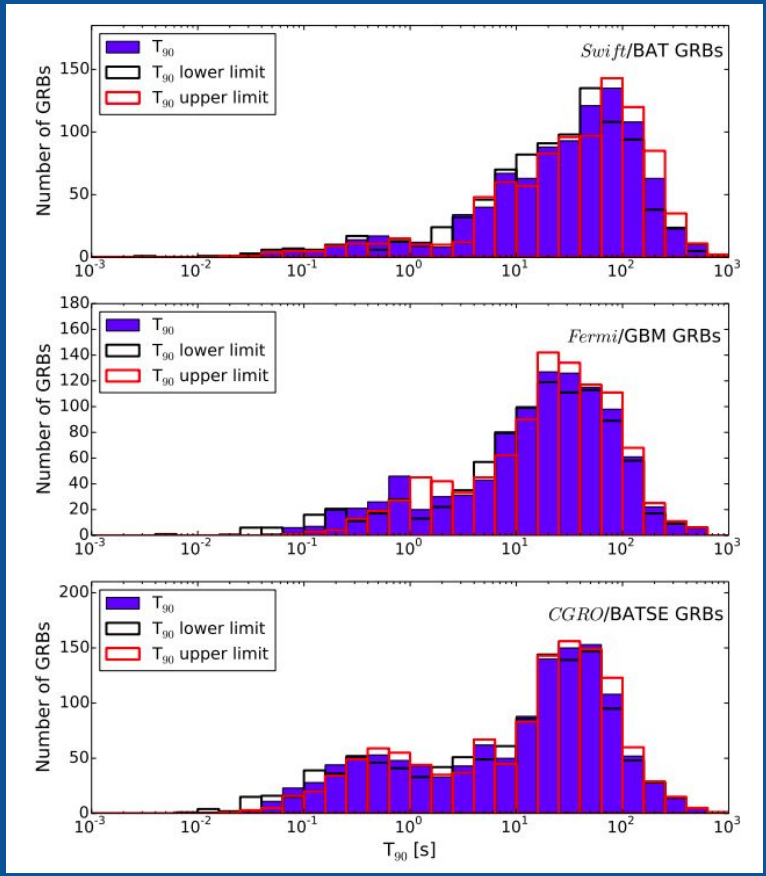


Lien A. et al., 2016

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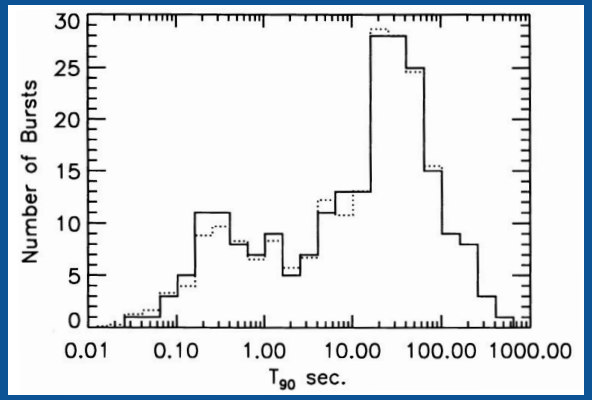


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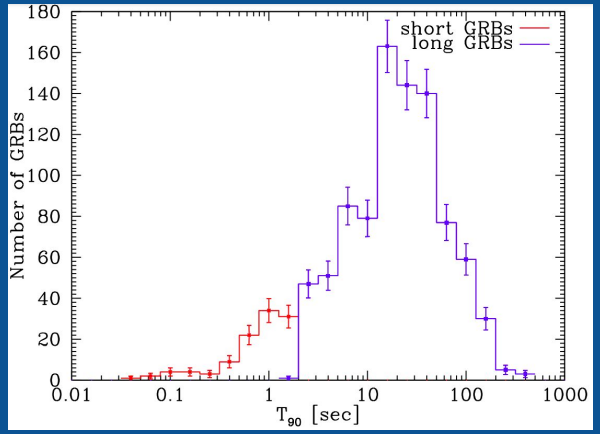
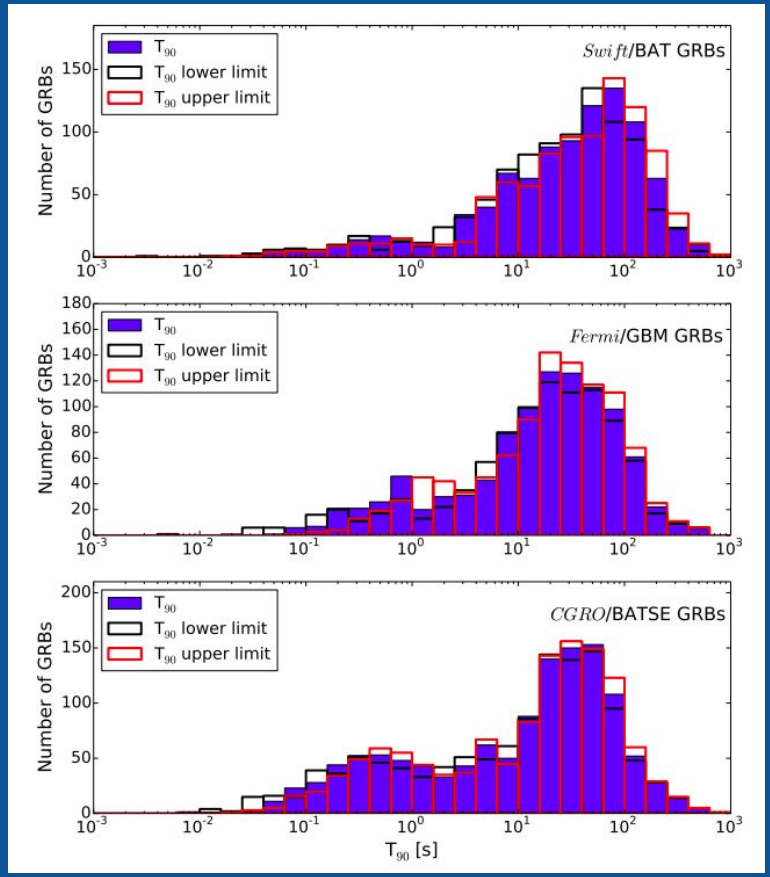
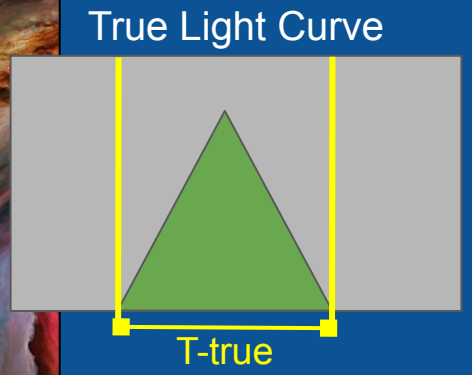



Frontera et al., 2009




Lien A. et al., 2016

# Instrumental Effects on GRB Light Curves



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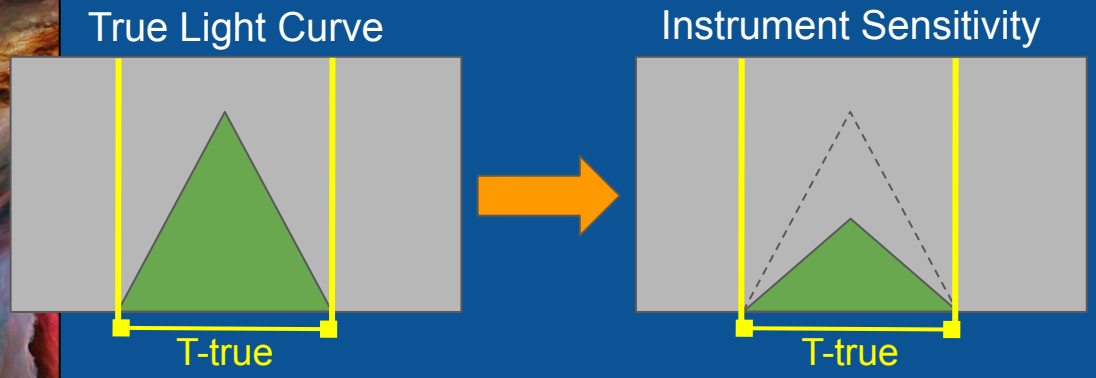

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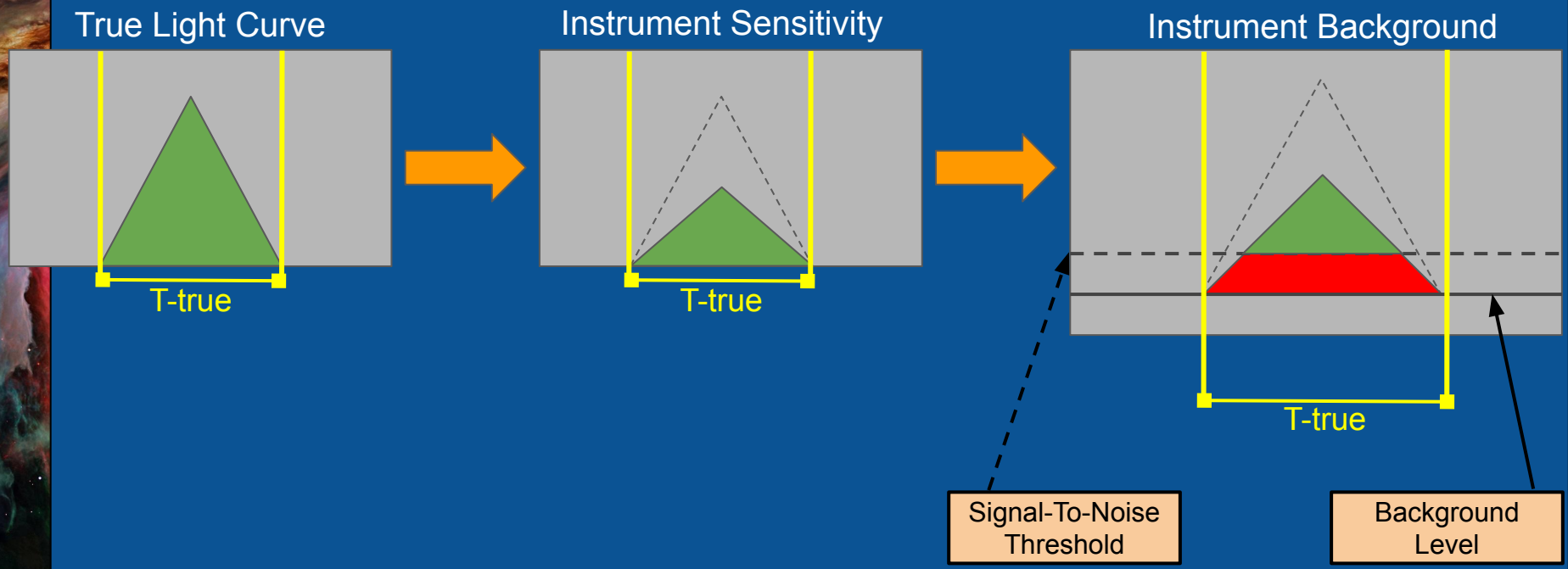

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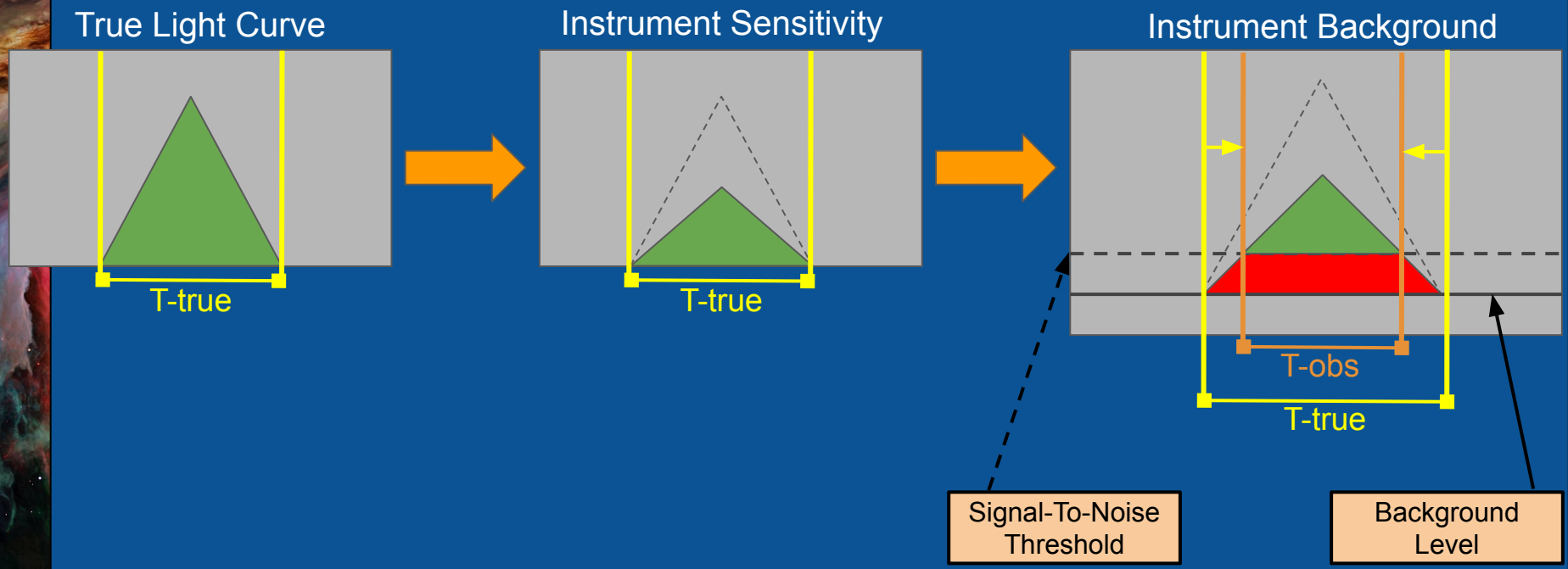
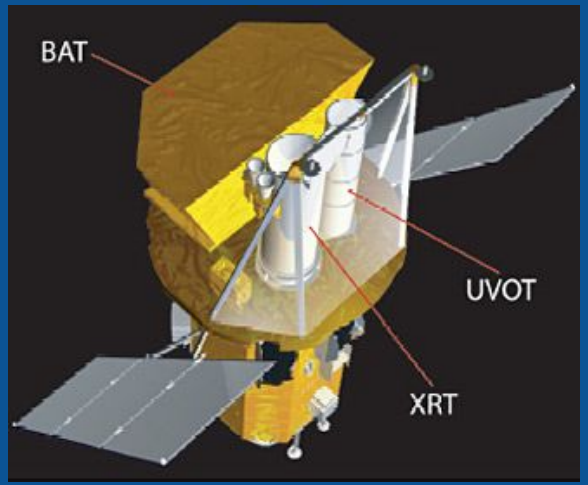
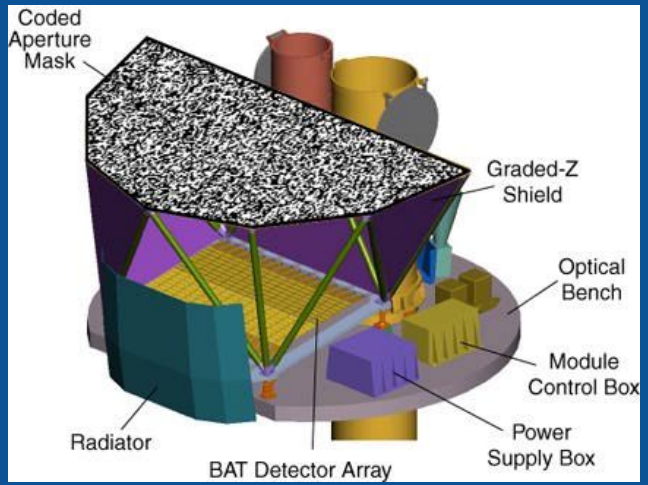


# The *Neil Gehrels Swift Observatory*
# Burst Alert Telescope




https://www.nasa.gov/mission_pages/swift/spacecraft/
https://swift.gsfc.nasa.gov/about_swift/bat_desc.html

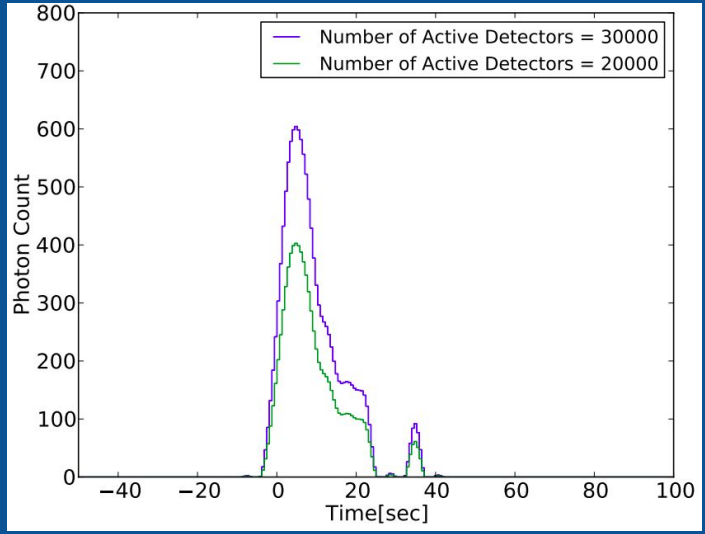
# *Swift*/BAT Instrumental Parameters

Relevant Parameters:

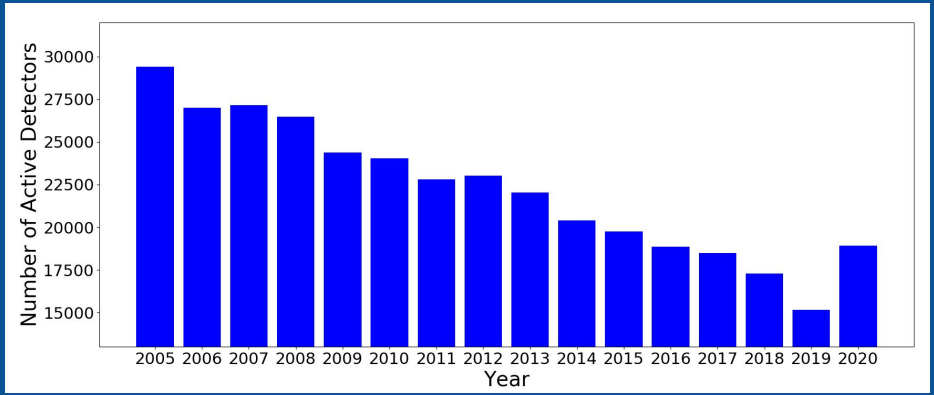
- **Number of Active Detectors (NDETS)**
- Incident angle (PCODE)
- Background

Not Relevant:

- Energy band




Lien A. et al., 2014



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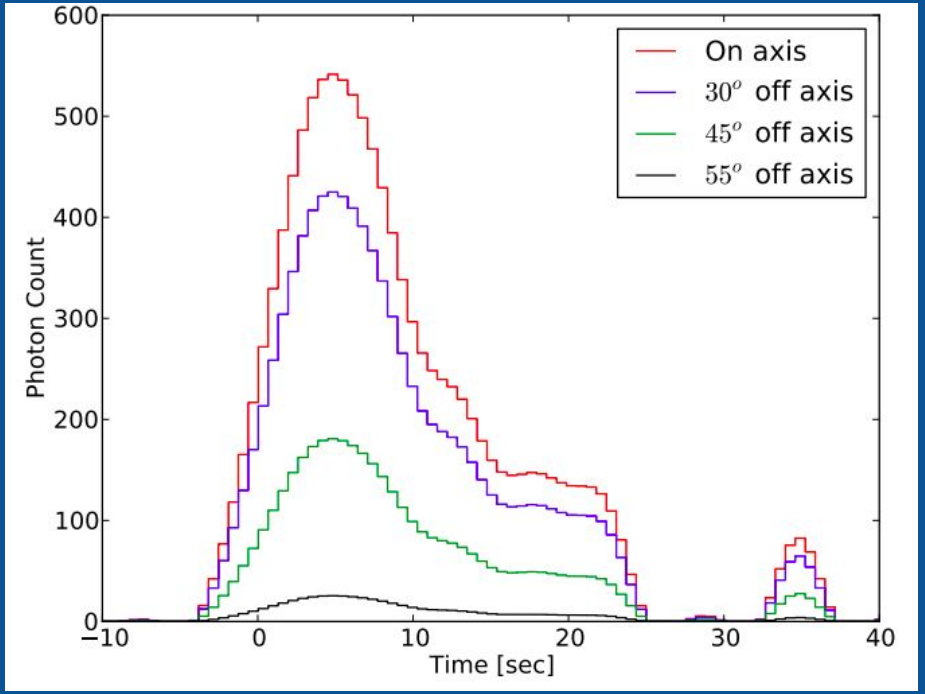


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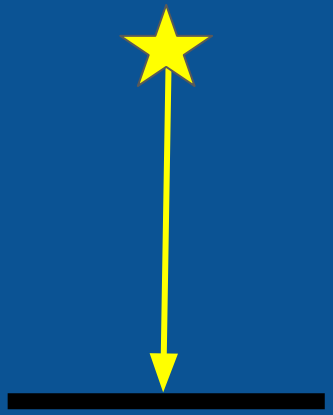
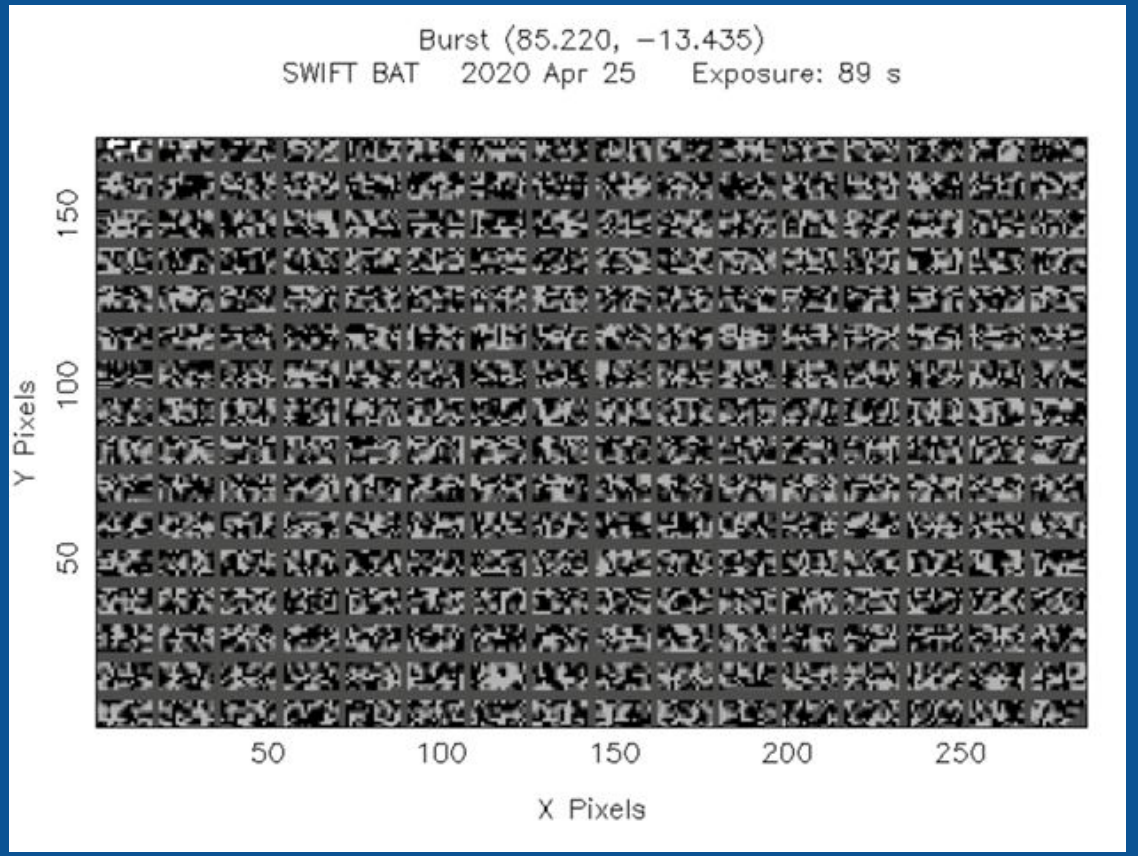
# PCODE and Incident Angle



Incident Angle = 0 deg
PCODE = 1



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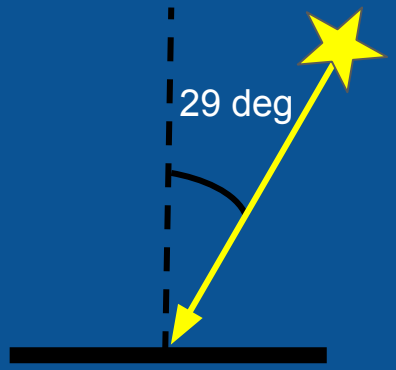
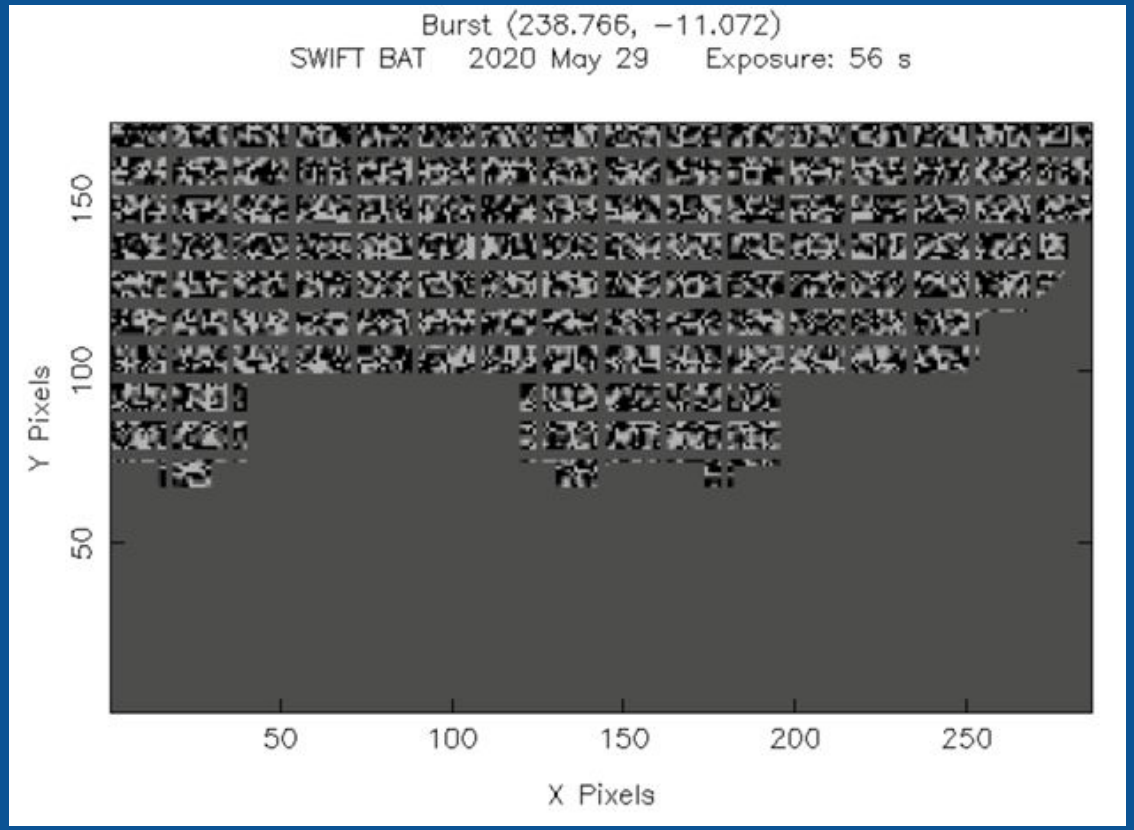



Incident Angle = 29 deg
PCODE = 0.5



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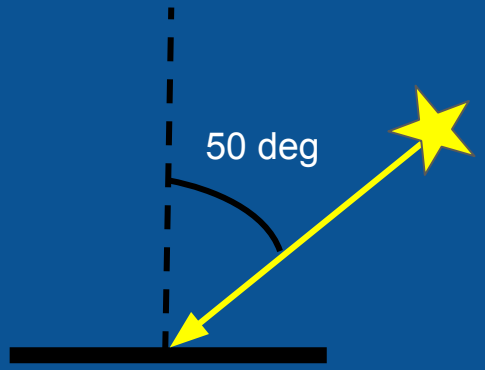
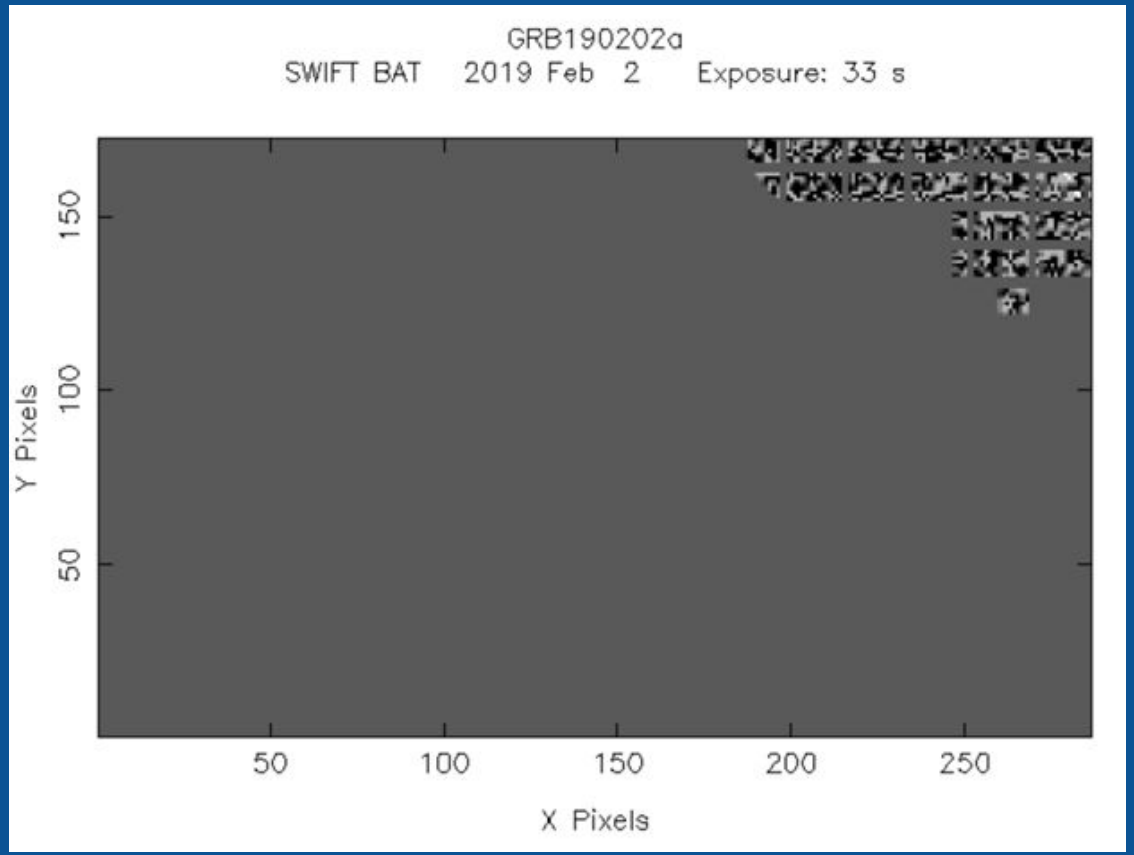
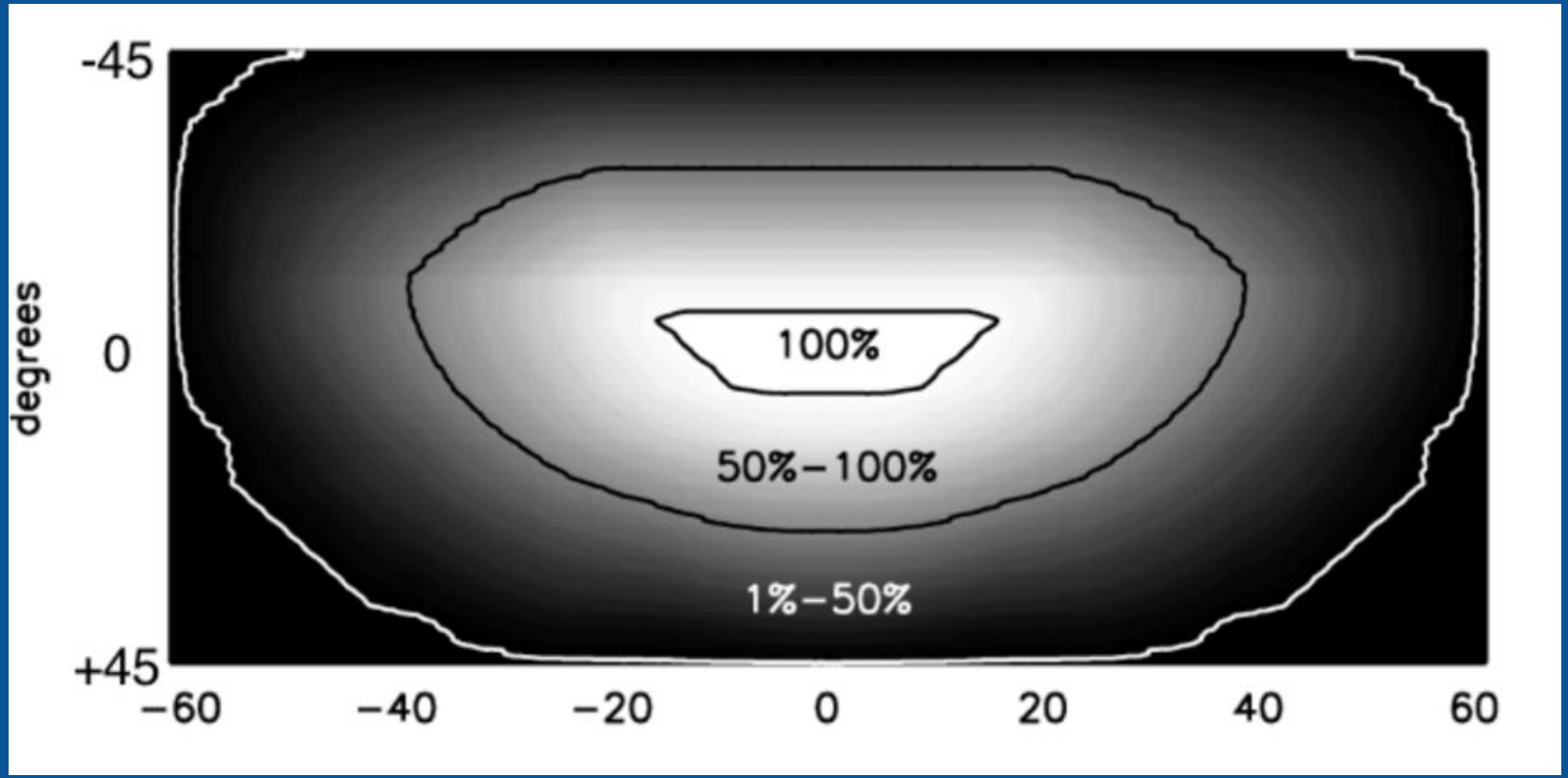



Incident Angle = 50 deg
PCODE = 0.04



# PCODE vs BAT Field of View

Not exactly one-to-one with incident angle



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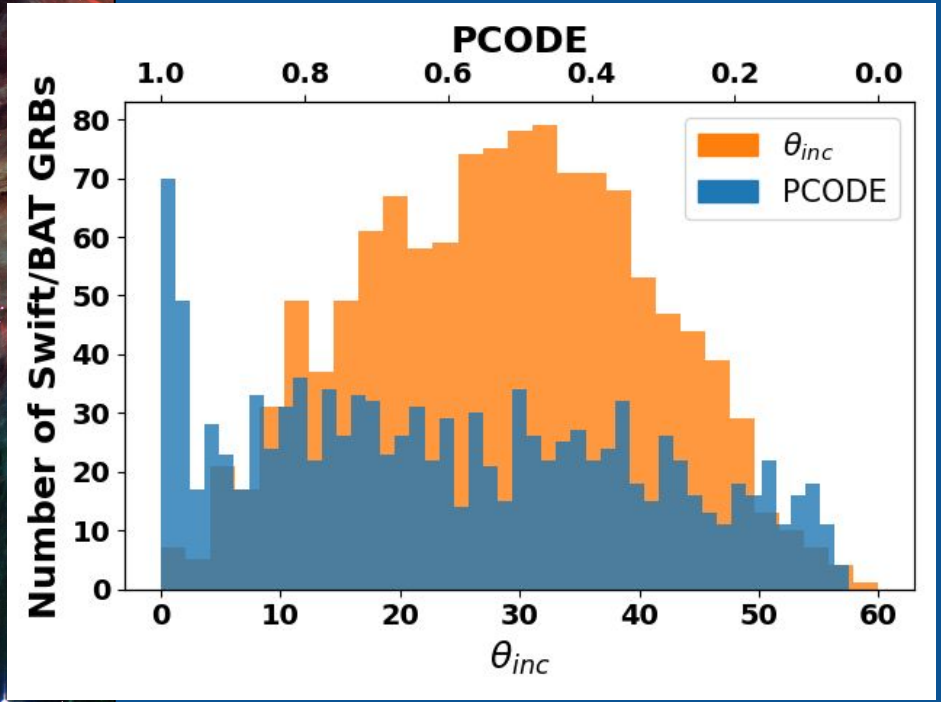


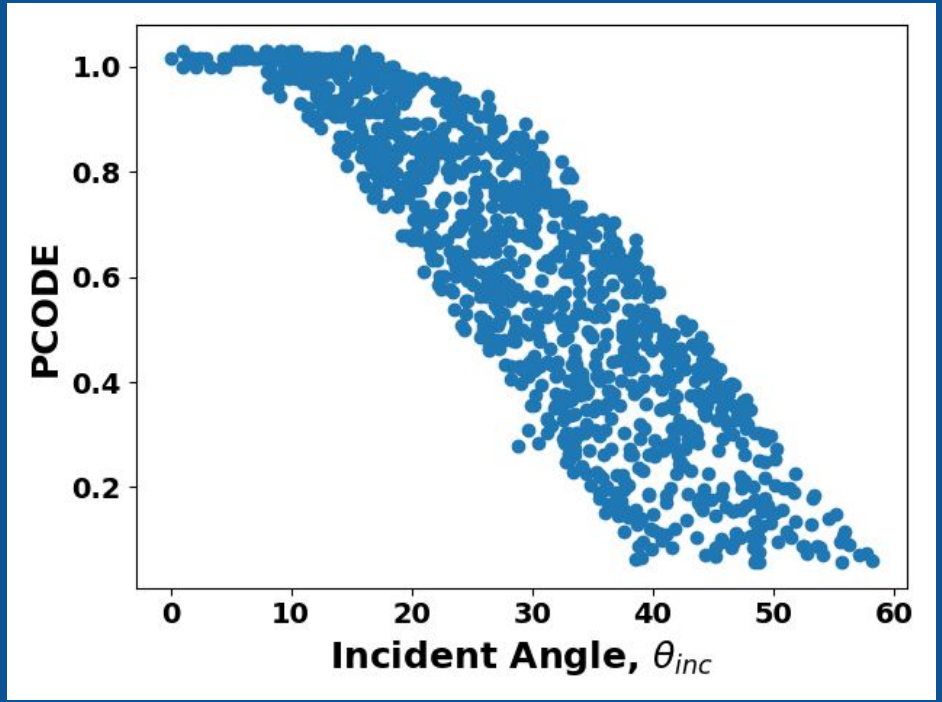

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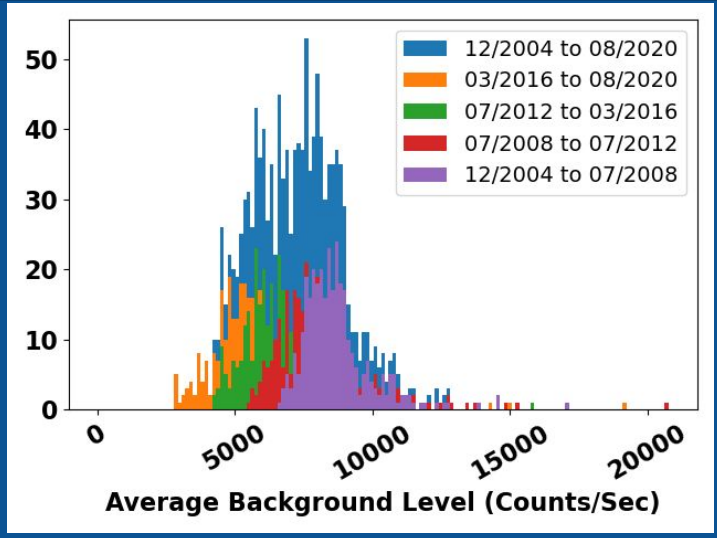


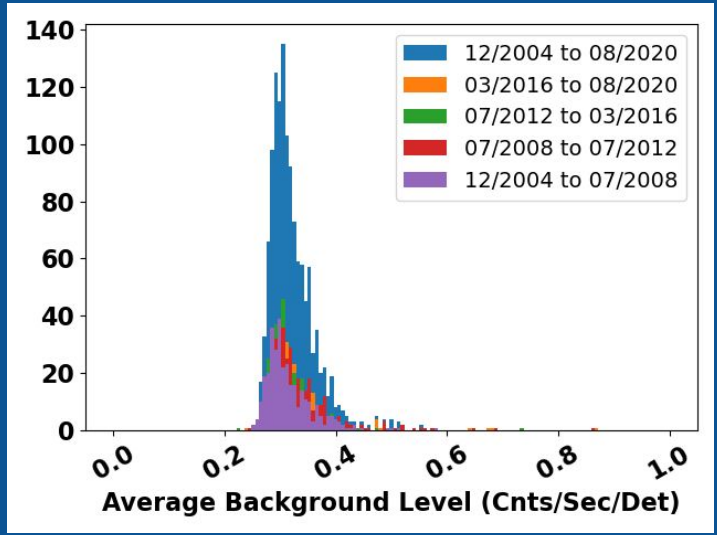

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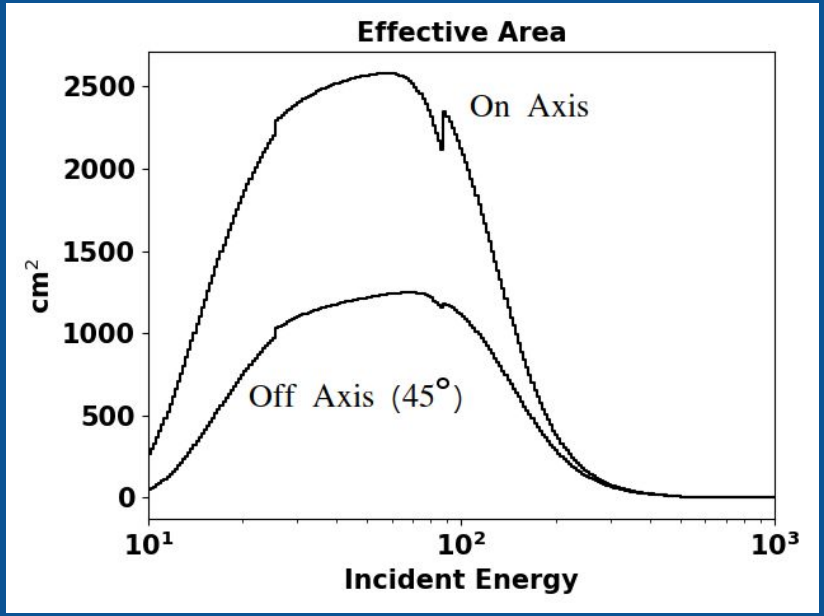
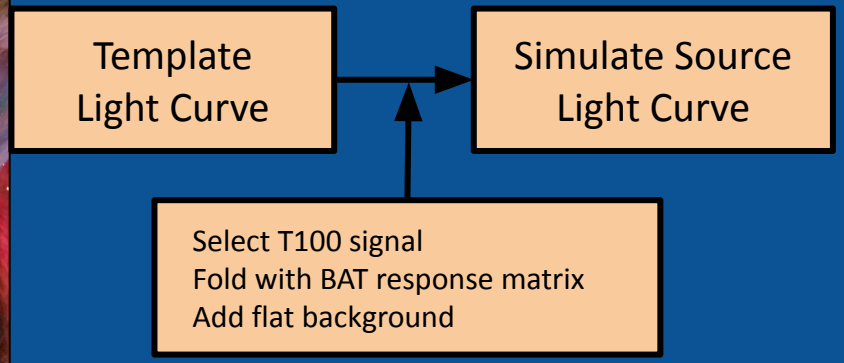


# Simulation Method Summary



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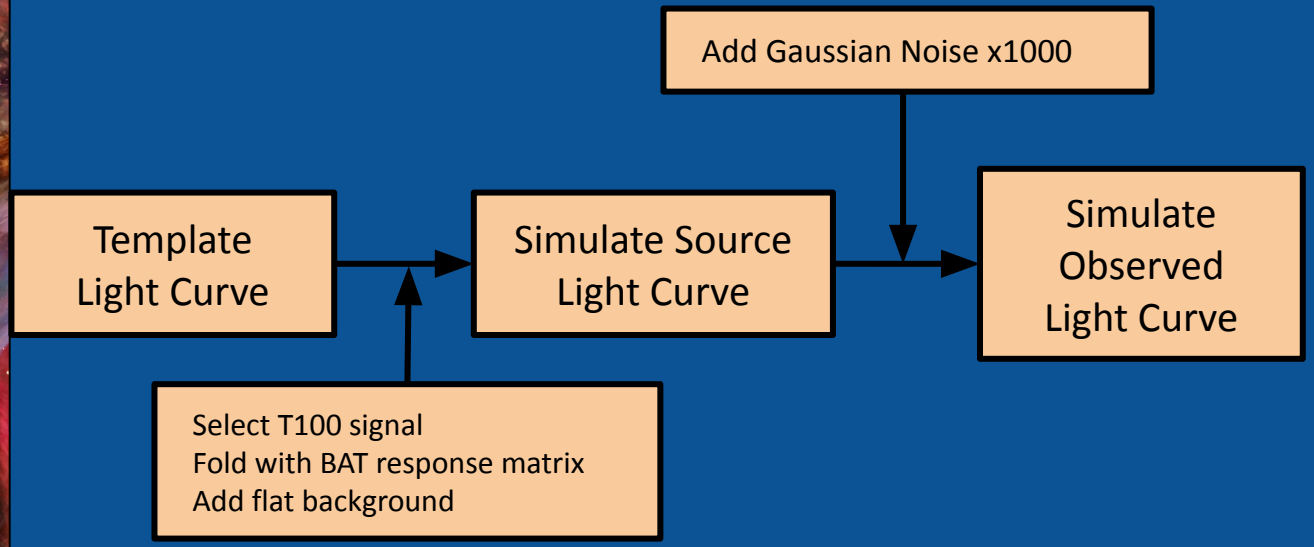

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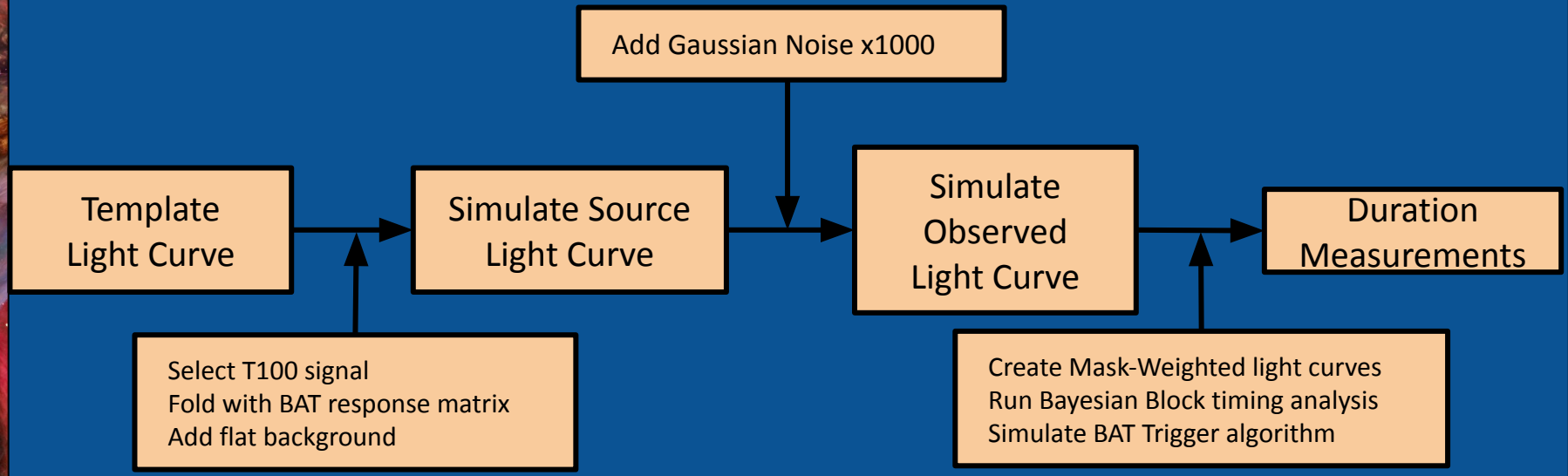
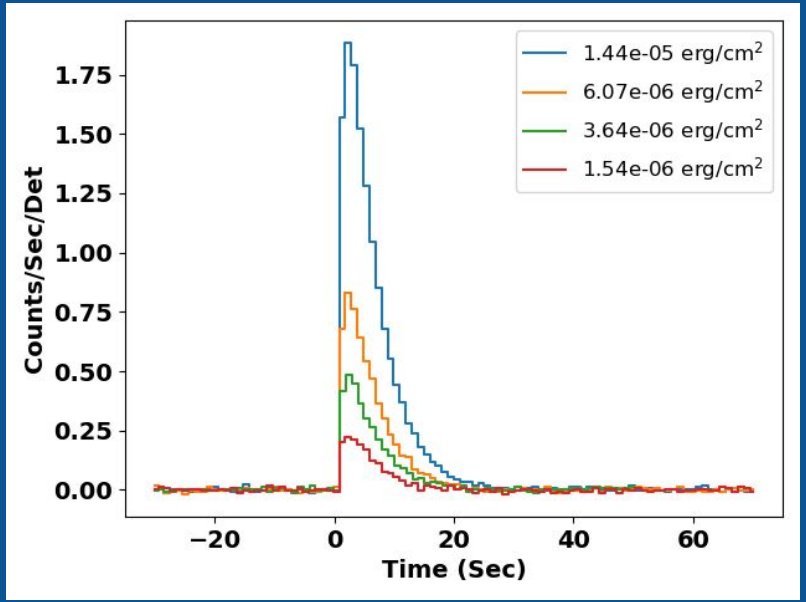


# Light Curve Sample for Simulations

FRED Light Curves

$$I(t) = A\lambda e^{[-\tau_1/(t-t_s)-(t-t_s)/\tau_2]}$$

Hakkila and Preece, 2014




Observed GRB Light Curves:

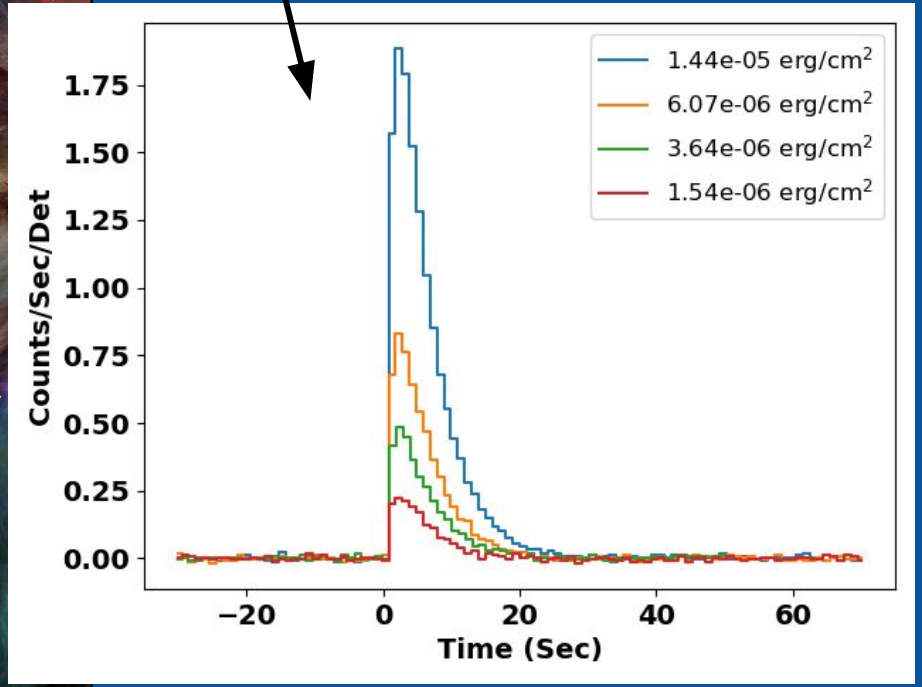
GRB050219A
GRB051111
GRB071010B
GRB090510
GRB110422A
GRB120119A
GRB150314A
GRB160314A

Template Light Curve

Simulate Source Light Curve

Simulate Observed Light Curve

Duration Measurements



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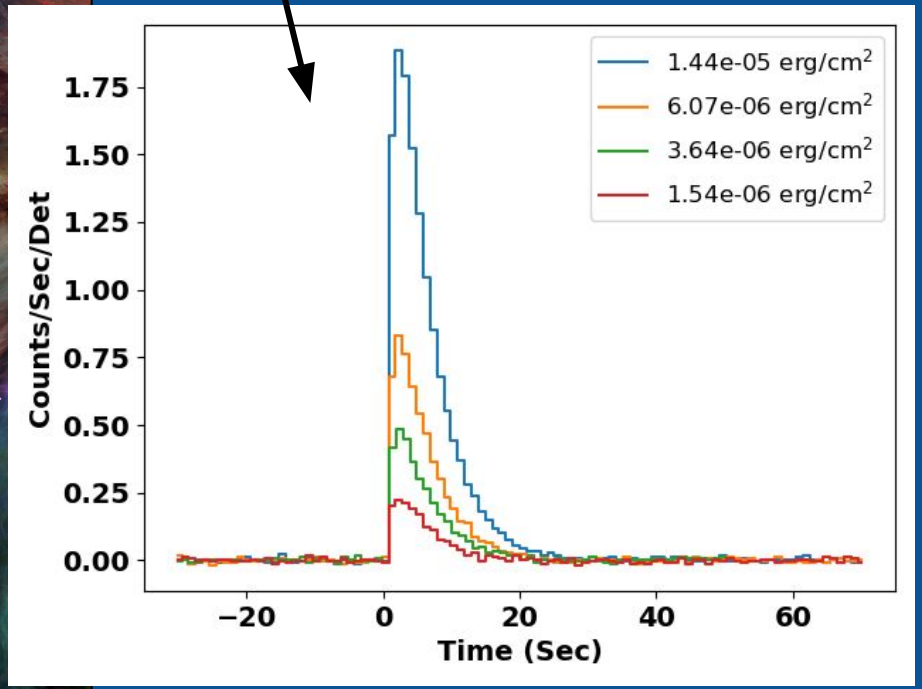


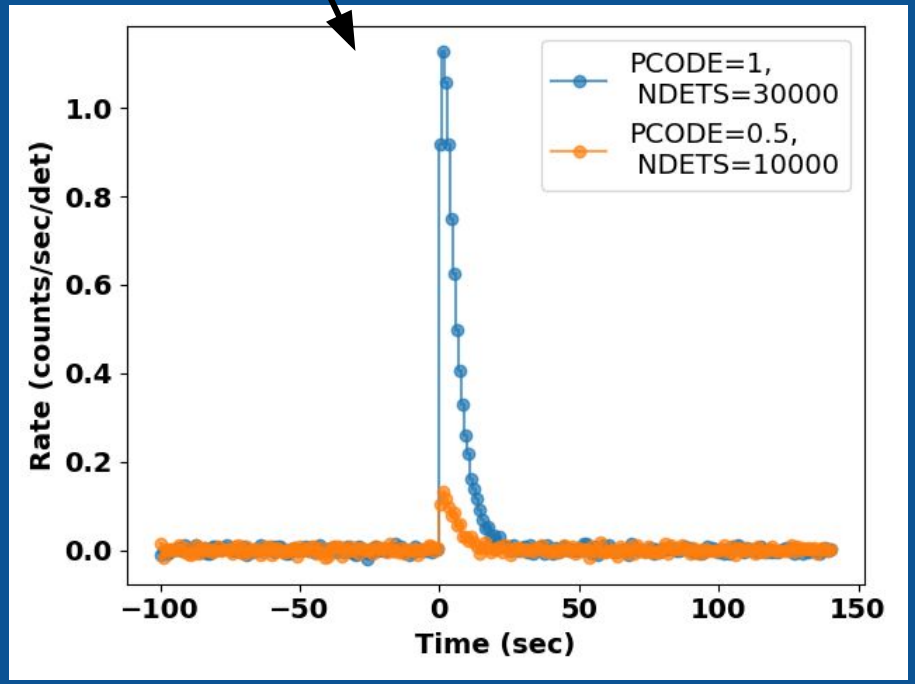

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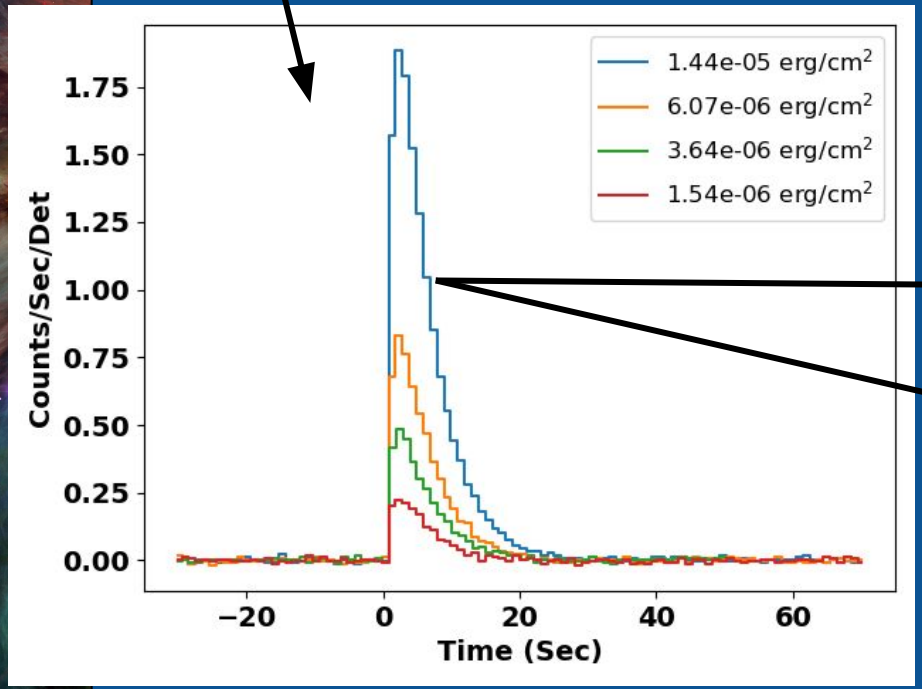
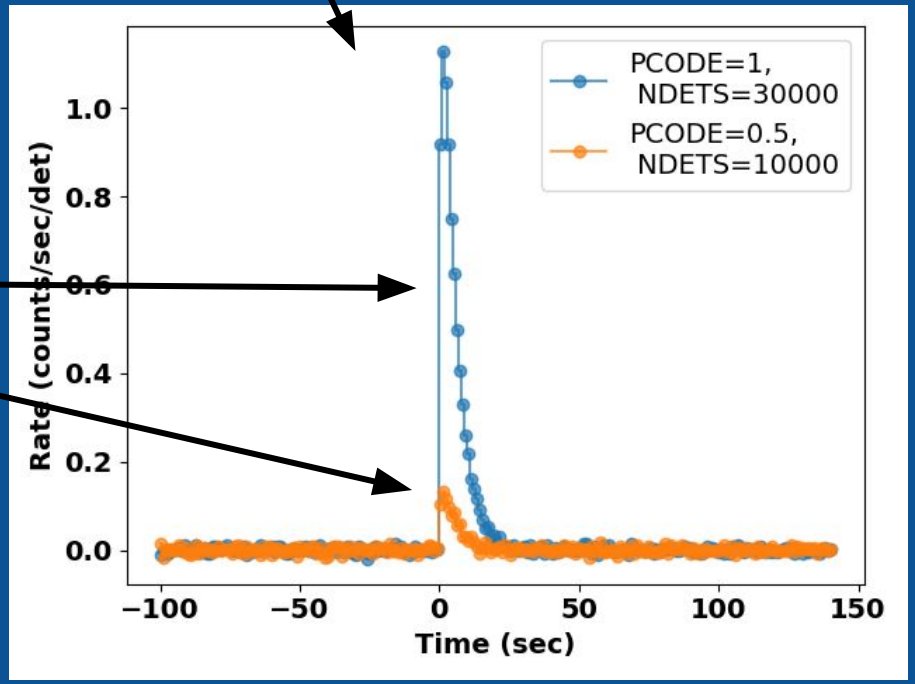
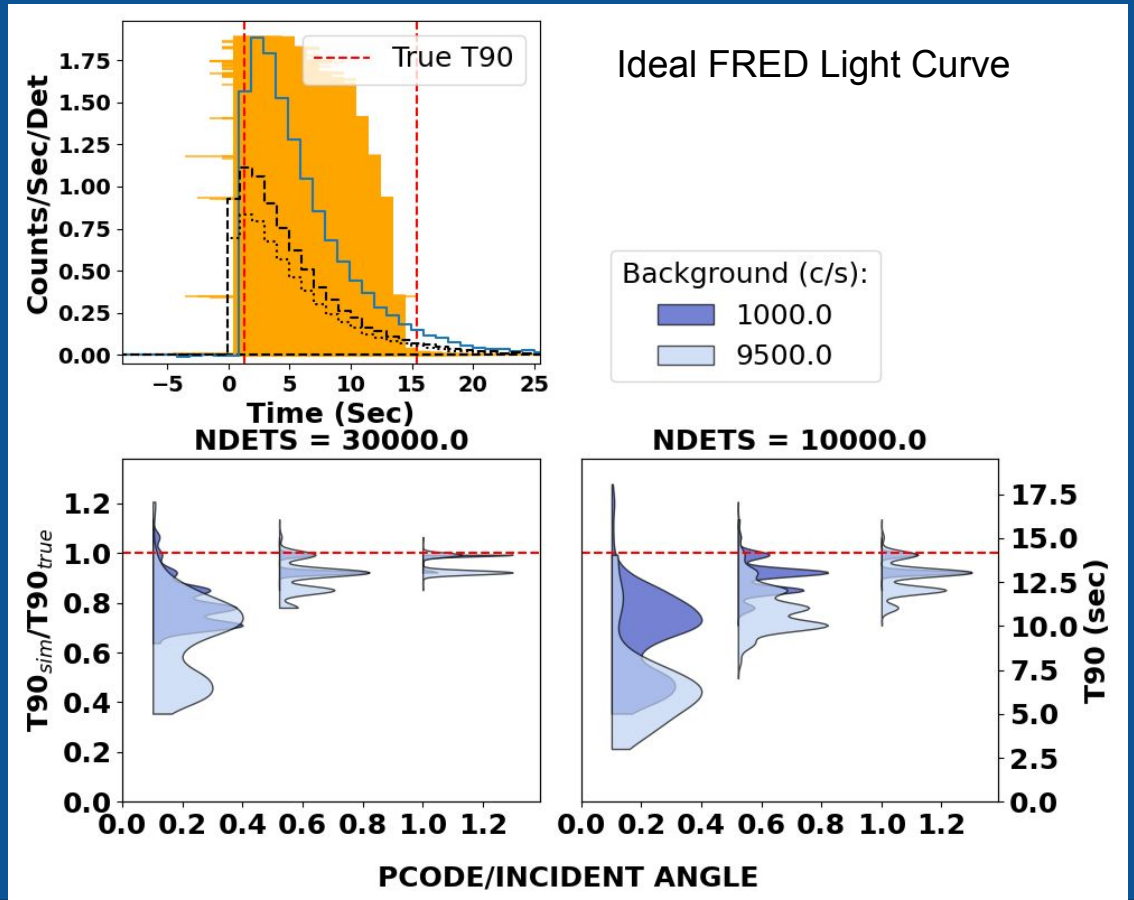


Template Light Curve → Simulate Source Light Curve → Simulate Observed Light Curve → Duration Measurements



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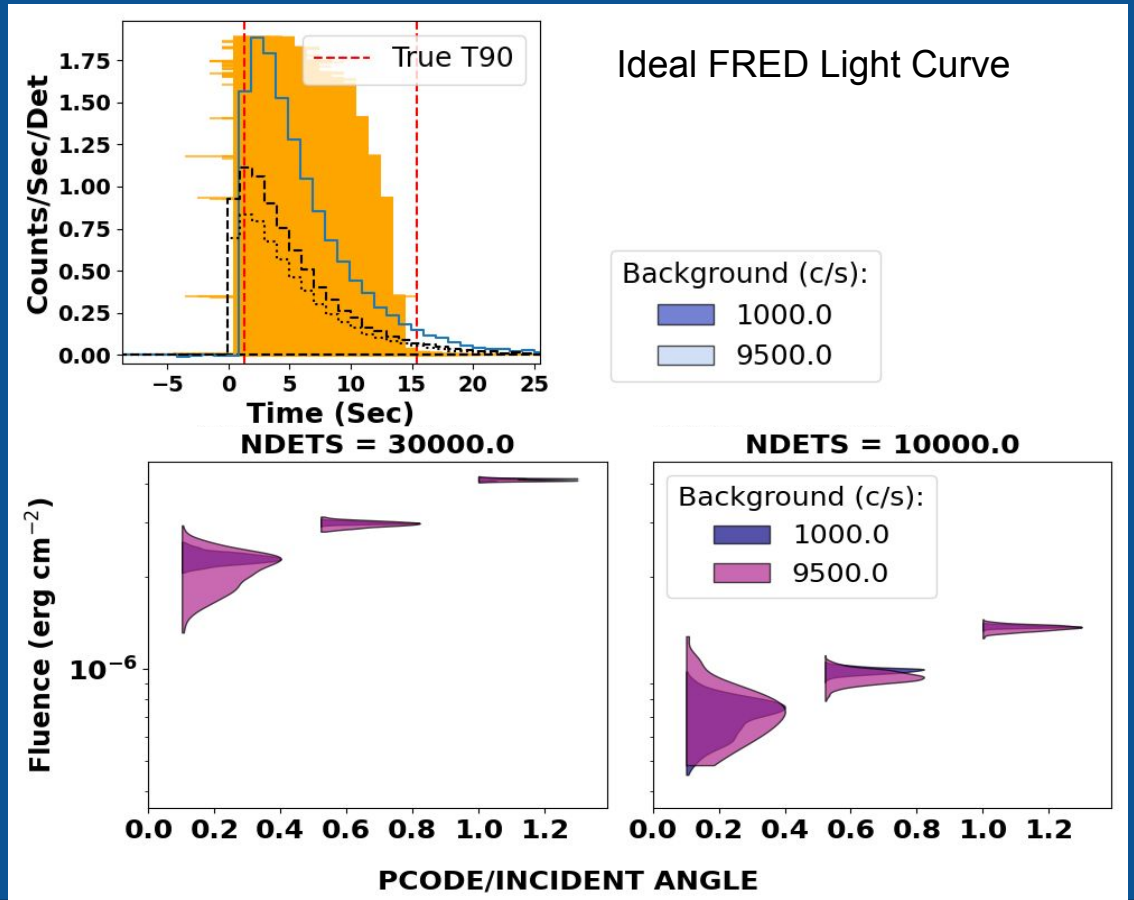
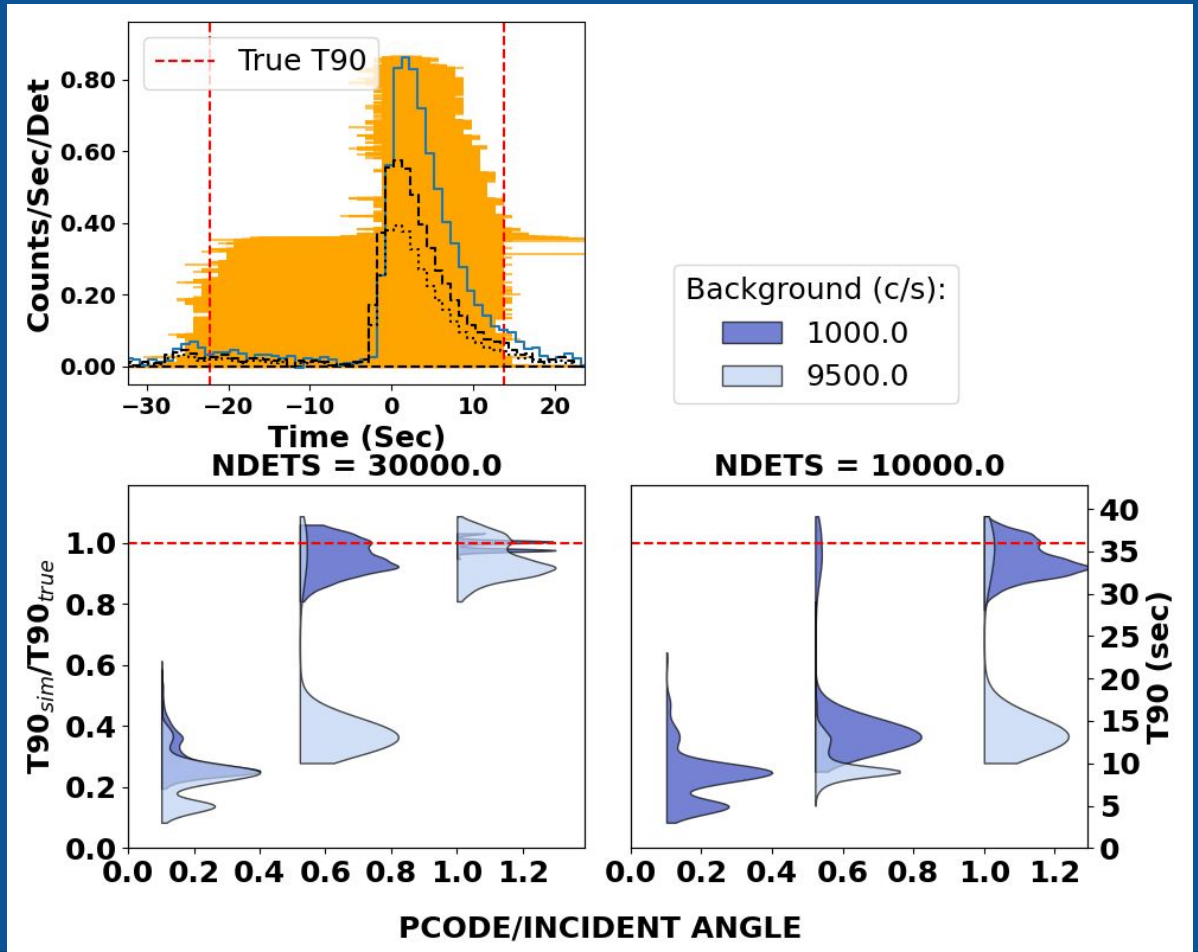
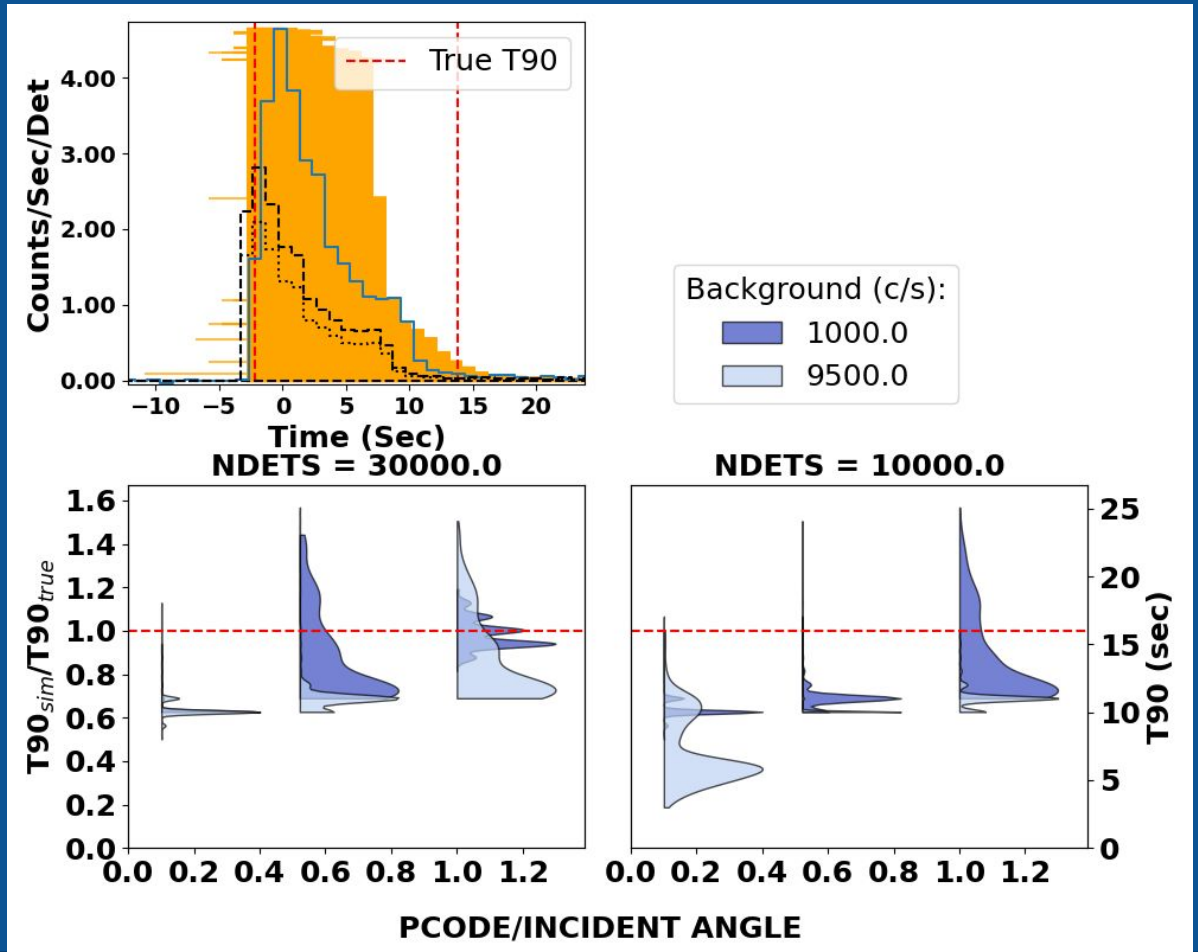


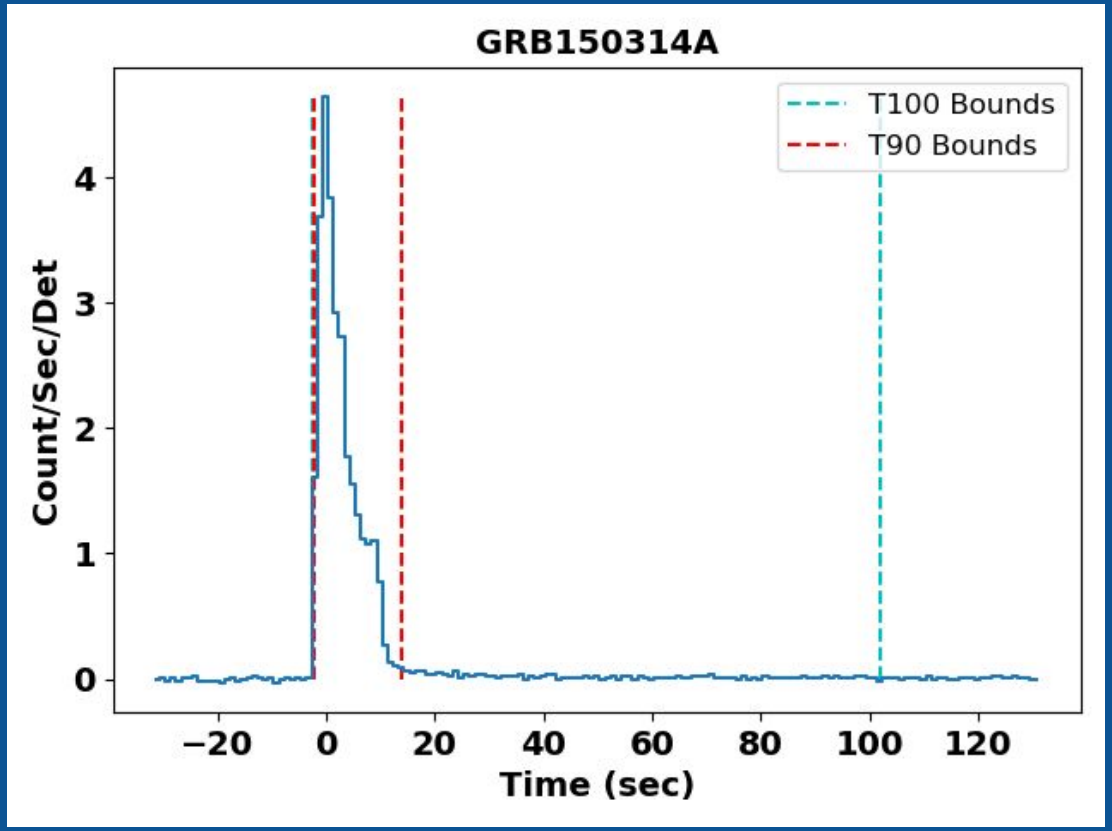
# GRB071010B: Early, Dim Emission



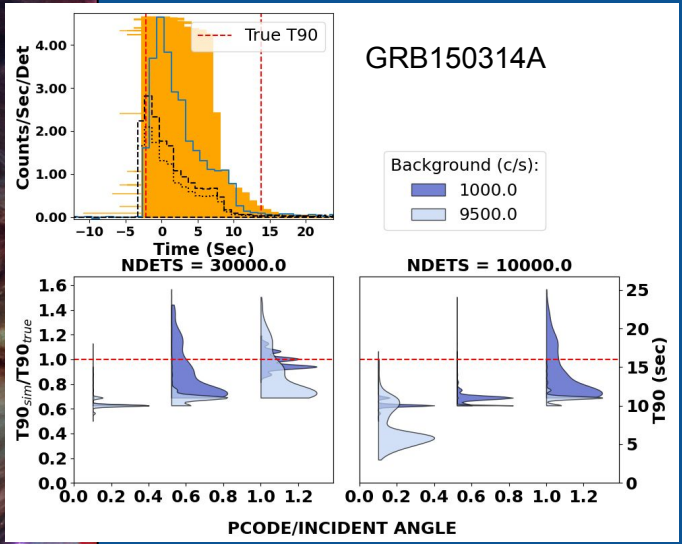
# GRB150314A: LGRB with Extended Emission

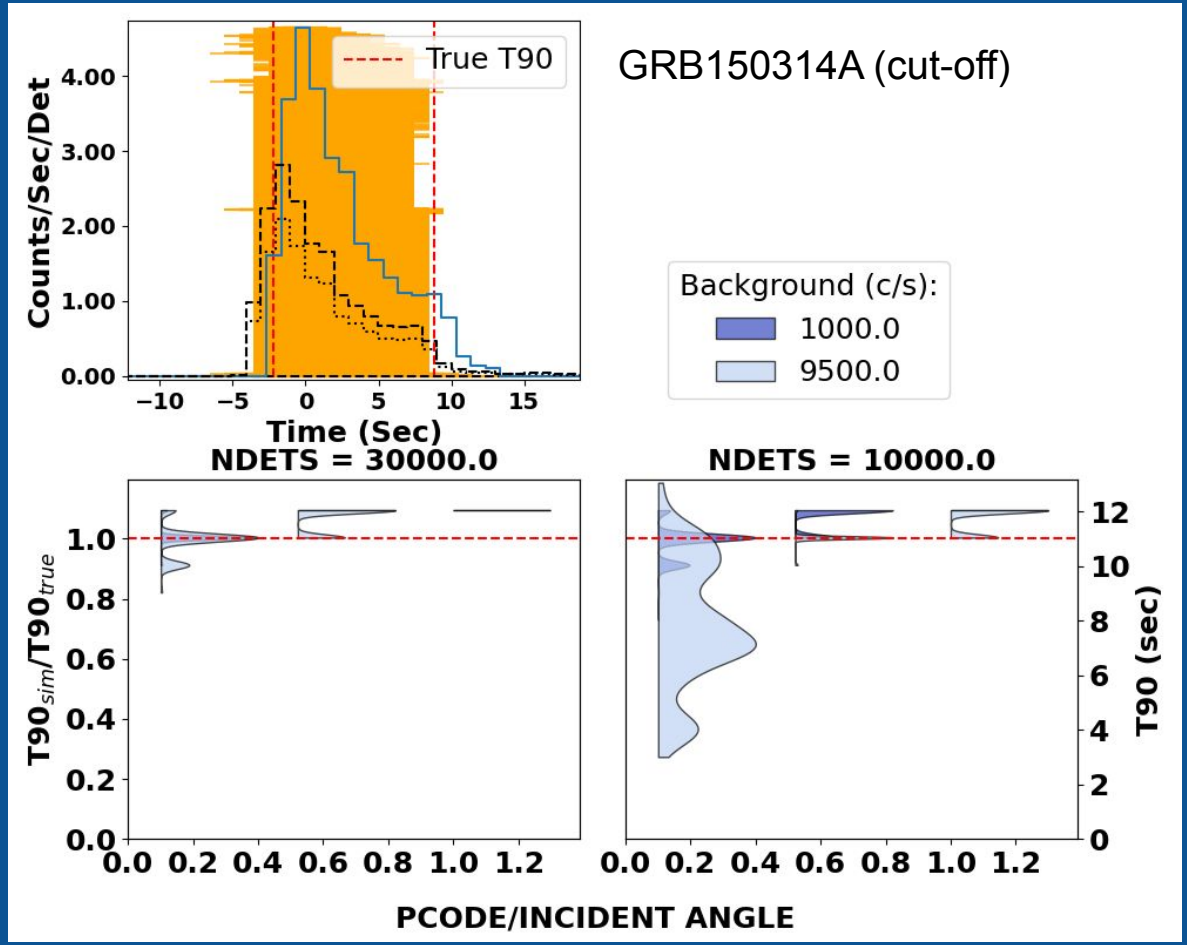


# GRB150314A: LGRB with Extended Emission

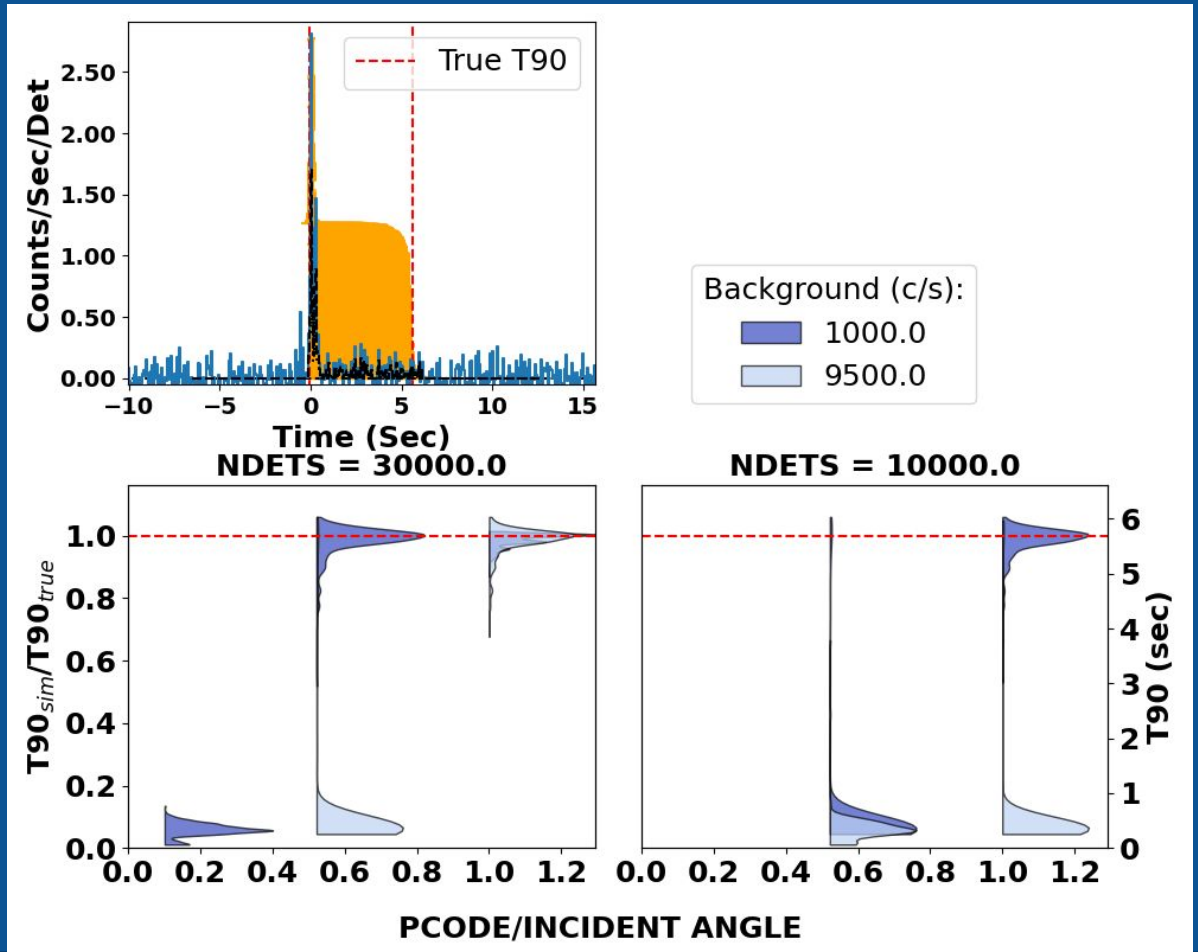


# GRB150314A: LGRB with Extended Emission

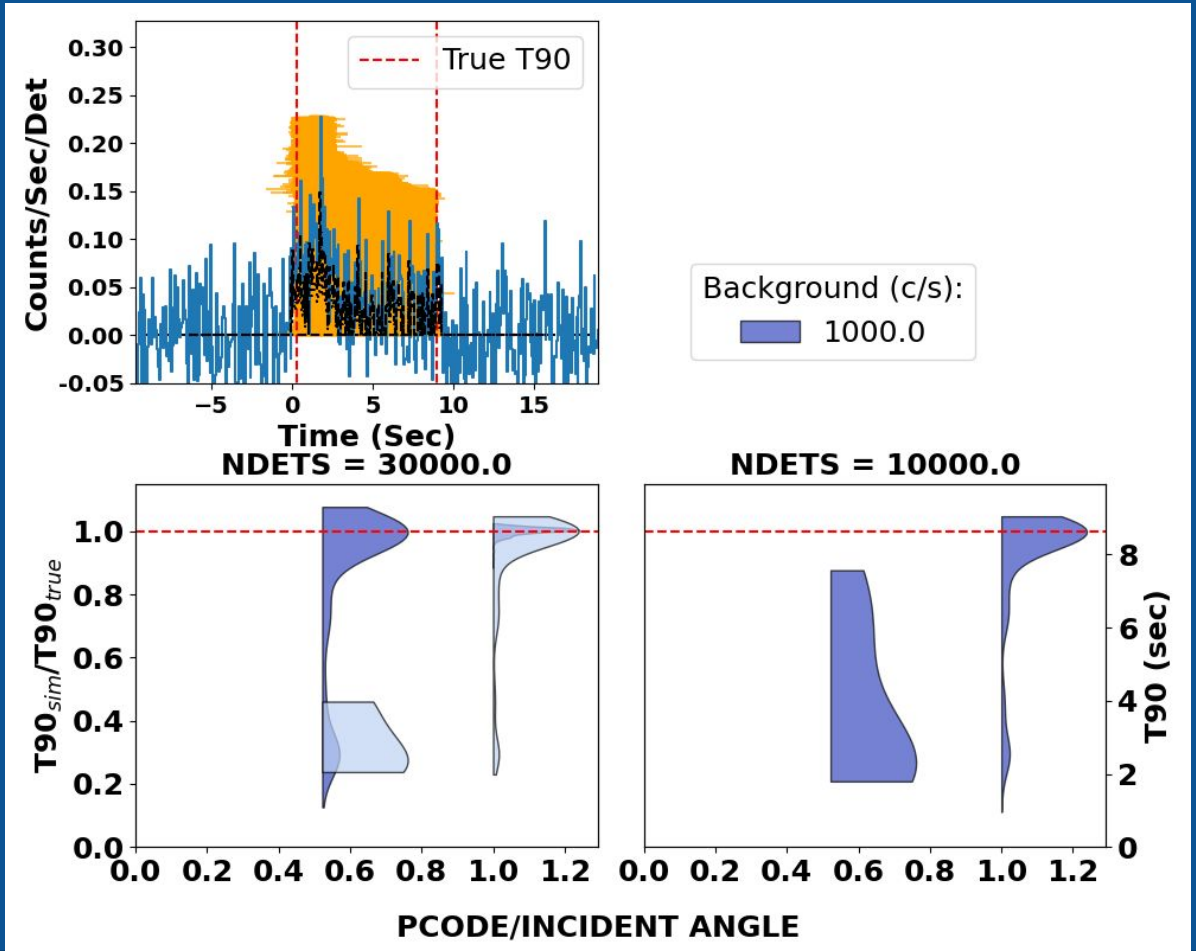


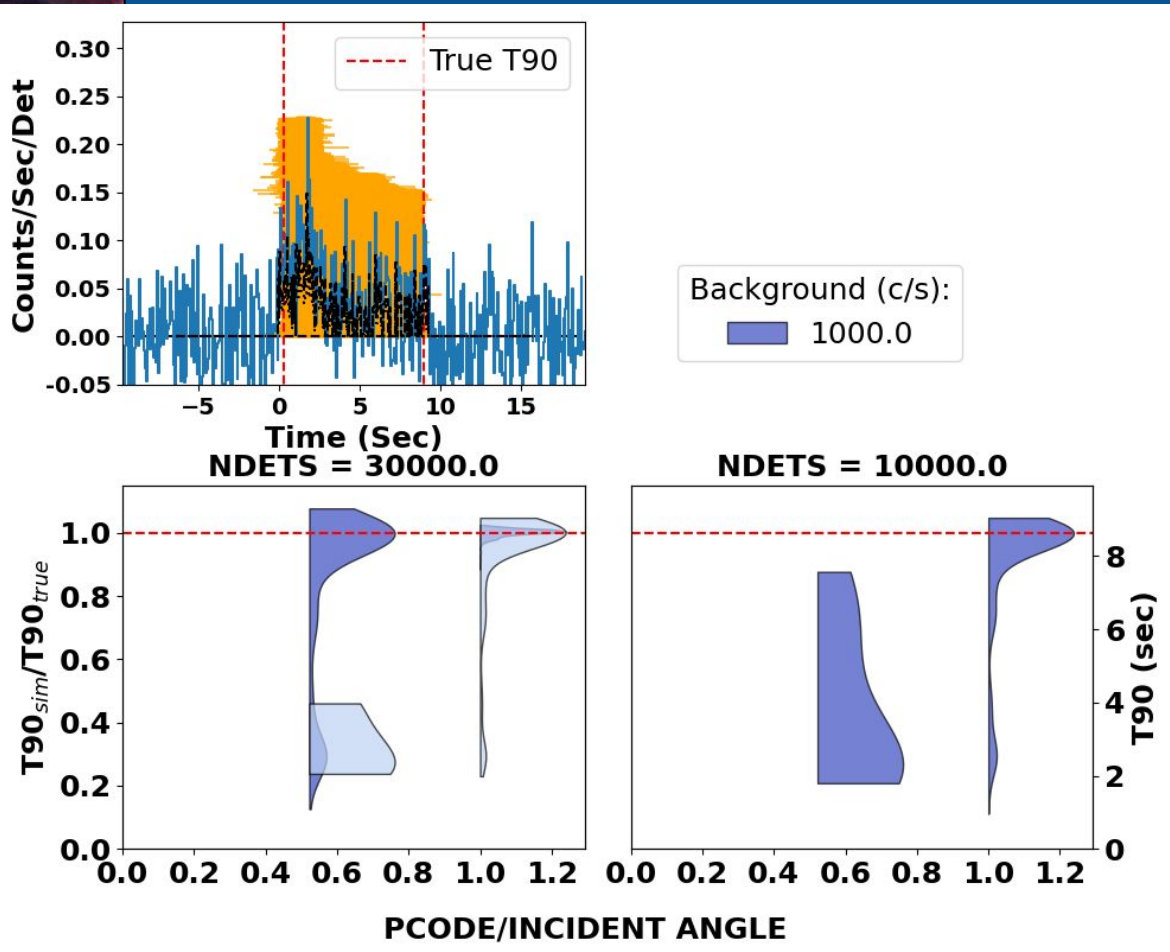
# GRB090510: SGRB with trailing Emission

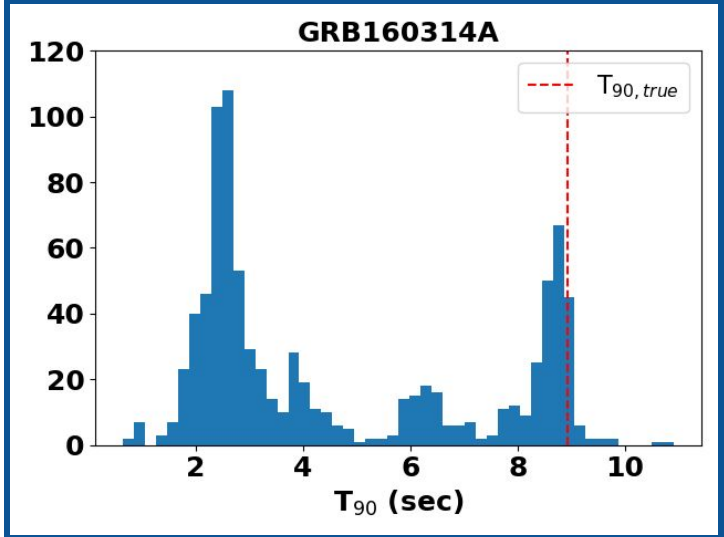


# GRB160314A: Short or Long?



# GRB160314A: Short or Long?



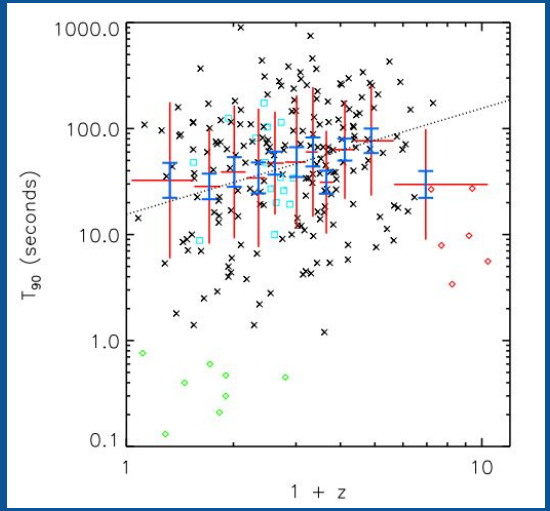



| GRB Name | $f$(measurable) | $f$(consistent, $3\sigma$) | $f$(consistent, $1\sigma$) | $T_{90,true}$ (sec) | Ave. $T_{90,sim}$ (sec) | 90% CI (sec)<br>68% CI (sec) |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| FRED1 | 0.914 | 0.826 | 0.271 | 14.14 | 11.62 | [4.008, 15.108] |
| ($1.44 \times 10^{-5}$ erg/cm$^2$) | | | | | | [6.008, 14.108] |
| FRED2 | 0.787 | 0.828 | 0.329 | 14.13 | 10.86 | [5.008, 14.108] |
| ($6.07 \times 10^{-6}$ erg/cm$^2$) | | | | | | [6.008, 14.108] |
| FRED3 | 0.709 | 0.618 | 0.259 | 14.17 | 10.22 | [4.008, 15.108] |
| ($3.64 \times 10^{-6}$ erg/cm$^2$) | | | | | | [5.008, 14.108] |
| FRED4 | 0.571 | 0.468 | 0.224 | 14.14 | 8.64 | [4.008, 14.108] |
| ($1.54 \times 10^{-6}$ erg/cm$^2$) | | | | | | [5.008, 12.108] |
| GRB160314A | 0.289 | 0.440 | 0.346 | 8.64 | 6.95 | [0.942, 9.442] |
| | | | | | | [2.042, 9.042] |
| GRB150314A | 0.990 | 0.120 | 0.069 | 16.0 | 11.14 | [4.003, 19.103] |
| | | | | | | [6.003, 15.103] |
| GRB120119A | 0.911 | 0.182 | 0.074 | 83.0 | 47.41 | [10.014, 107.314] |
| | | | | | | [11.014, 89.214] |
| GRB110422A | 0.999 | 1.000 | 0.880 | 25.0 | 24.35 | [17.033, 27.133] |
| | | | | | | [24.033, 26.133] |
| GRB071010B | 0.799 | 0.516 | 0.472 | 36.0 | 20.988 | [4.007, 39.208] |
| | | | | | | [5.008, 38.208] |
| GRB051111 | 0.704 | 0.472 | 0.383 | 65.0 | 41.491 | [7.017, 77.317] |
| | | | | | | [8.017, 75.317] |
| GRB050219A | 0.811 | 1.000 | 0.767 | 24.0 | 21.787 | [13.013, 25.113] |
| | | | | | | [19.013, 24.113] |
| GRB150314A | 0.989 | 1.000 | 0.260 | 11.0 | 11.149 | [4.004, 12.104] |
| (no dim-tail) | | | | | | [11.004, 12.104] |
| GRB090510 | 0.652 | 0.432 | 0.402 | 5.69 | 2.70 | [0.064, 6.064] |
| | | | | | | [0.164, 5.864] |

| GRB Name | $f$(measurable) | $f$(consistent, $3\sigma$) | $f$(consistent, $1\sigma$) | $T_{90,true}$ (sec) | Ave. $T_{90,sim}$ (sec) | 90% CI (sec)<br>68% CI (sec) |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| FRED1 | 0.914 | 0.826 | 0.271 | 14.14 | 11.62 | [4.008, 15.108] |
| ($1.44 \times 10^{-5}$ erg/cm$^2$) | | | | | | [6.008, 14.108] |
| FRED2 | 0.787 | 0.828 | 0.329 | 14.13 | 10.86 | [5.008, 14.108] |
| ($6.07 \times 10^{-6}$ erg/cm$^2$) | | | | | | [6.008, 14.108] |
| FRED3 | 0.709 | 0.618 | 0.259 | 14.17 | 10.22 | [4.008, 15.108] |
| ($3.64 \times 10^{-6}$ erg/cm$^2$) | | | | | | [5.008, 14.108] |
| FRED4 | 0.571 | 0.468 | 0.224 | 14.14 | 8.64 | [4.008, 14.108] |
| ($1.54 \times 10^{-6}$ erg/cm$^2$) | | | | | | [5.008, 12.108] |
| GRB160314A | 0.289 | 0.440 | 0.346 | 8.64 | 6.95 | [0.942, 9.442] |
| | | | | | | [2.042, 9.042] |
| GRB150314A | 0.990 | 0.120 | 0.069 | 16.0 | 11.14 | [4.003, 19.103] |
| | | | | | | [6.003, 15.103] |
| GRB120119A | 0.911 | 0.182 | 0.074 | 83.0 | 47.41 | [10.014, 107.314] |
| | | | | | | [11.014, 89.214] |
| GRB110422A | 0.999 | 1.000 | 0.880 | 25.0 | 24.35 | [17.033, 27.133] |
| | | | | | | [24.033, 26.133] |
| GRB071010B | 0.799 | 0.516 | 0.472 | 36.0 | 20.988 | [4.007, 39.208] |
| | | | | | | [5.008, 38.208] |
| GRB051111 | 0.704 | 0.472 | 0.383 | 65.0 | 41.491 | [7.017, 77.317] |
| | | | | | | [8.017, 75.317] |
| GRB050219A | 0.811 | 1.000 | 0.767 | 24.0 | 21.787 | [13.013, 25.113] |
| | | | | | | [19.013, 24.113] |
| GRB150314A | 0.989 | 1.000 | 0.260 | 11.0 | 11.149 | [4.004, 12.104] |
| (no dim-tail) | | | | | | [11.004, 12.104] |
| GRB090510 | 0.652 | 0.432 | 0.402 | 5.69 | 2.70 | [0.064, 6.064] |
| | | | | | | [0.164, 5.864] |

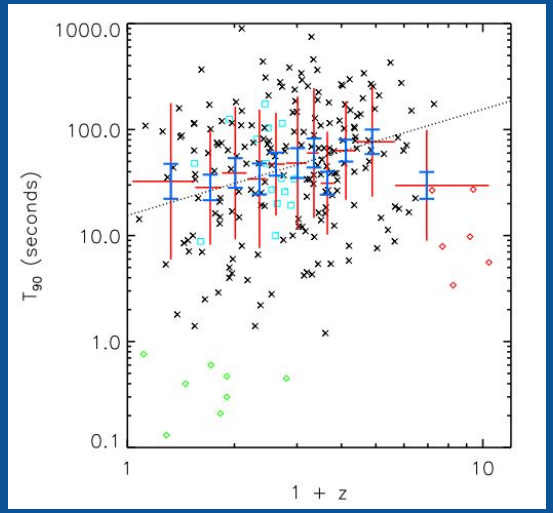
# Distance Considerations

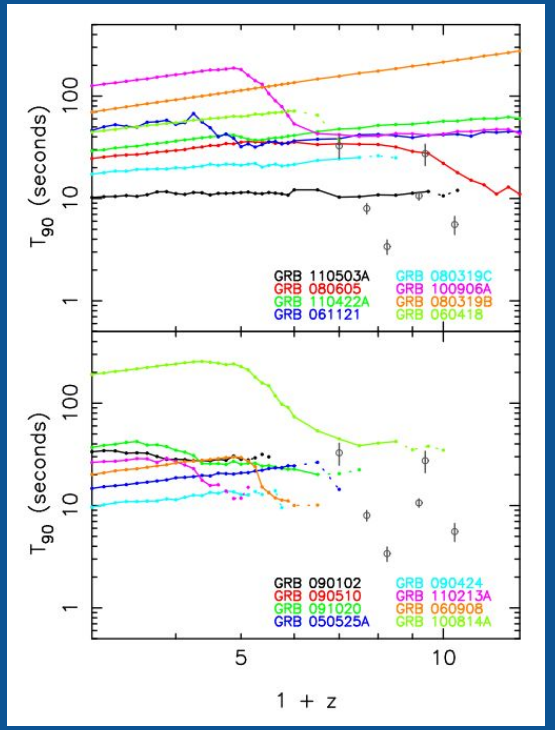
# Distance Considerations




Littlejohns et al., 2013

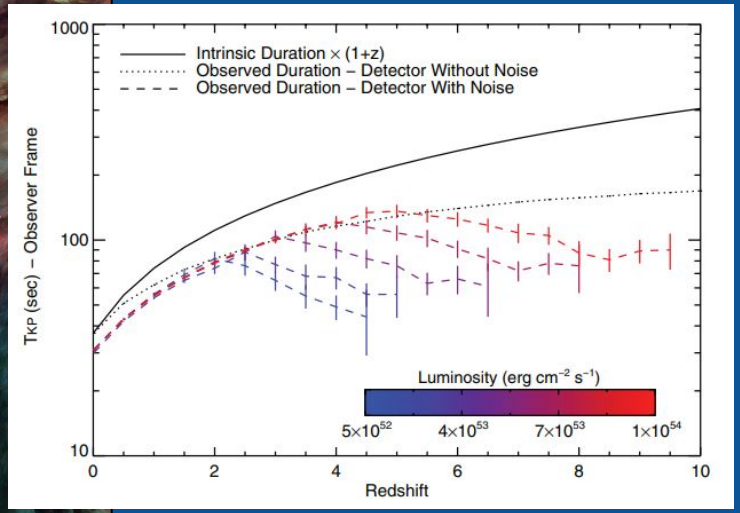
# Distance Considerations



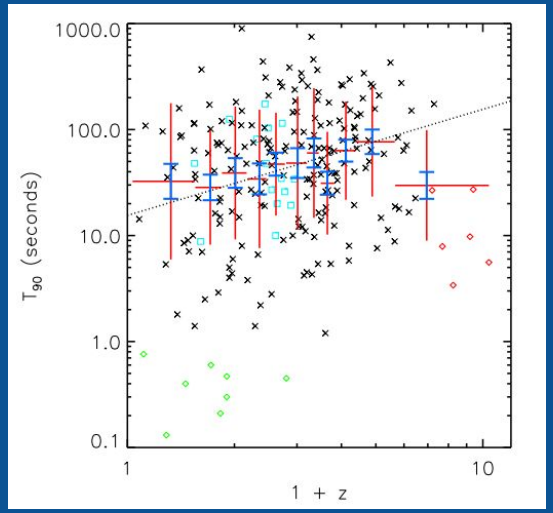



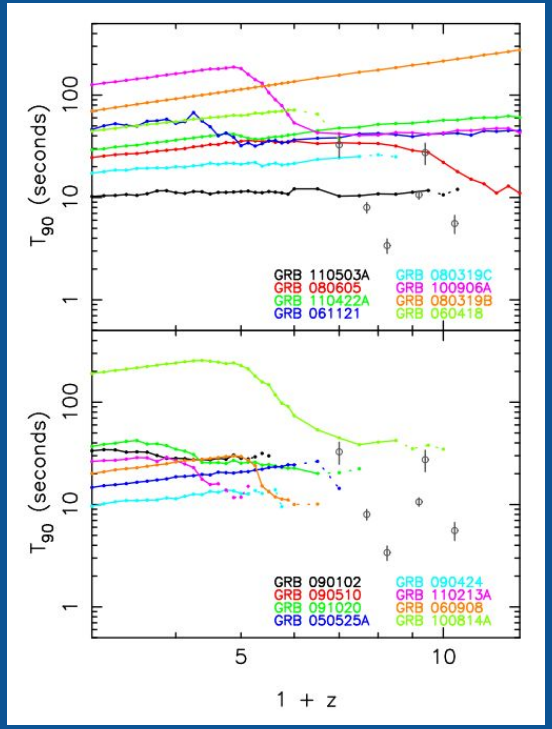

Littlejohns et al., 2013

# Distance Considerations



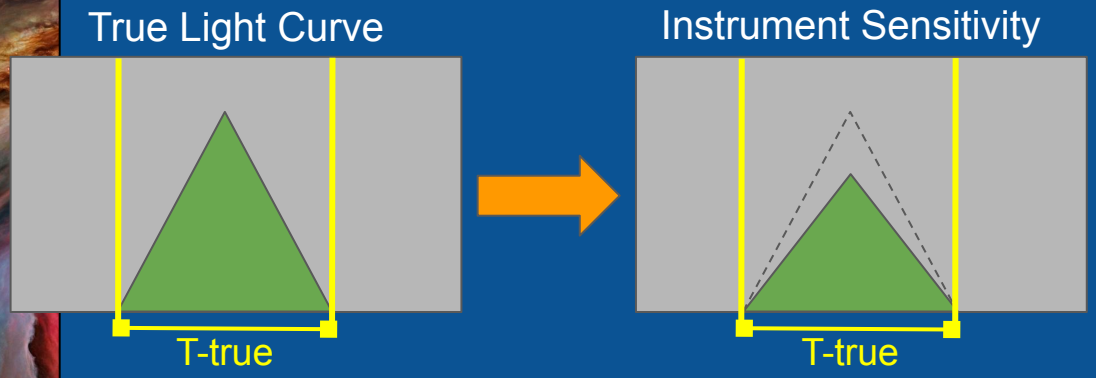

Kocevski and Petrosian, 2013



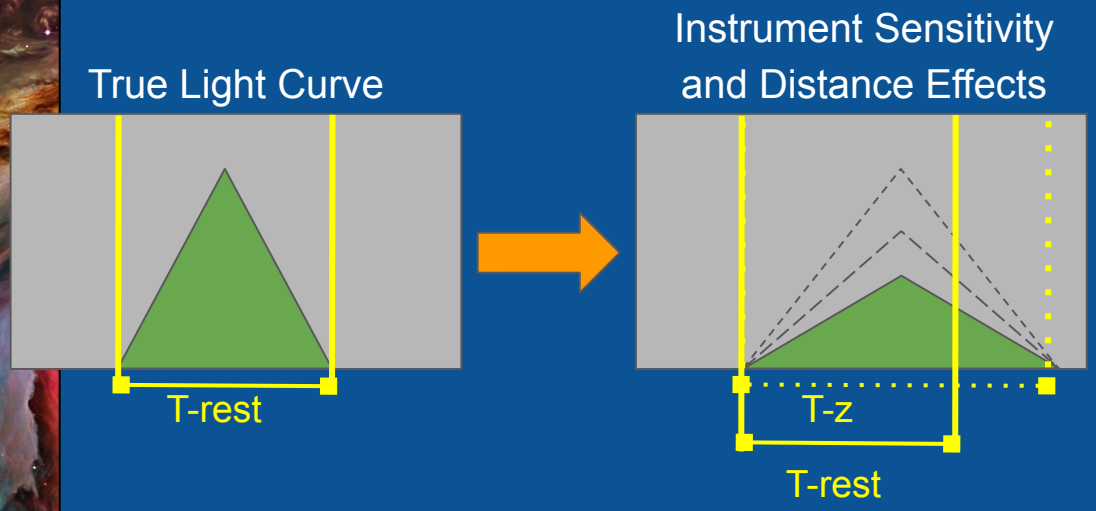




Littlejohns et al., 2013

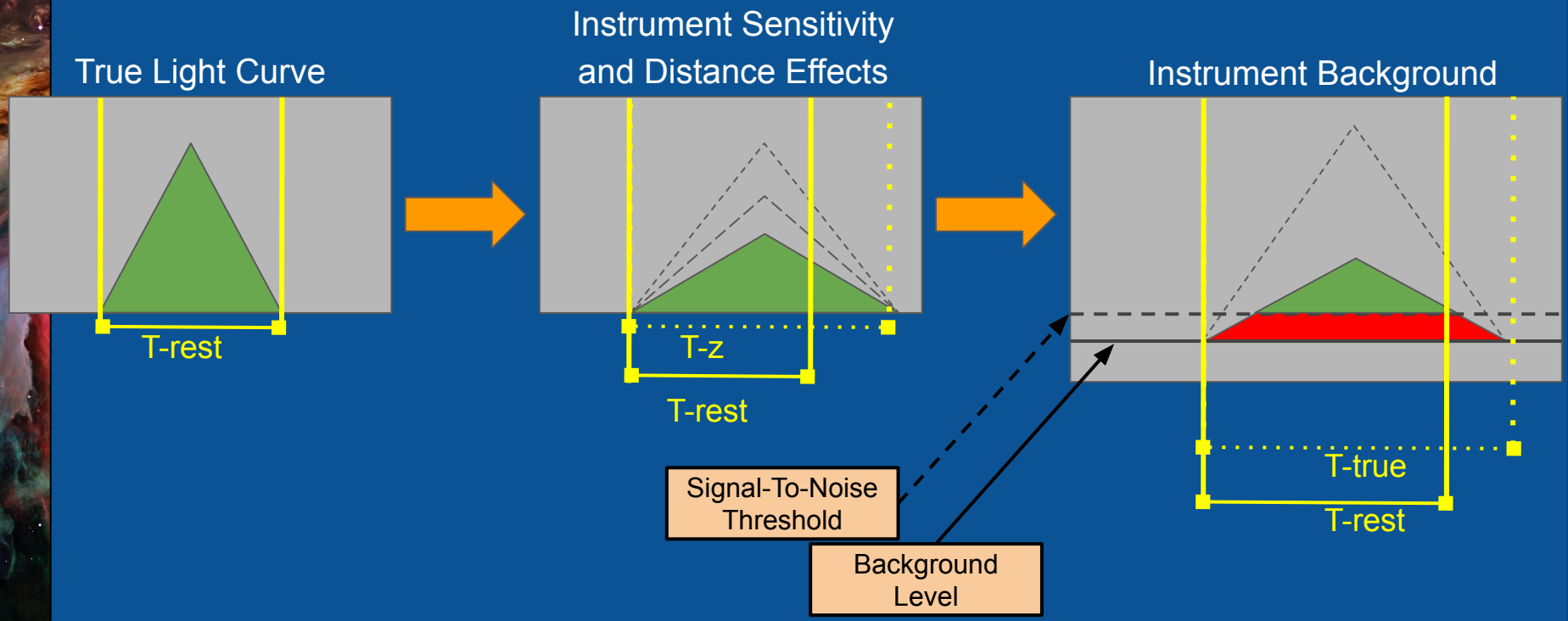
# Distance Effects on GRB Light Curves



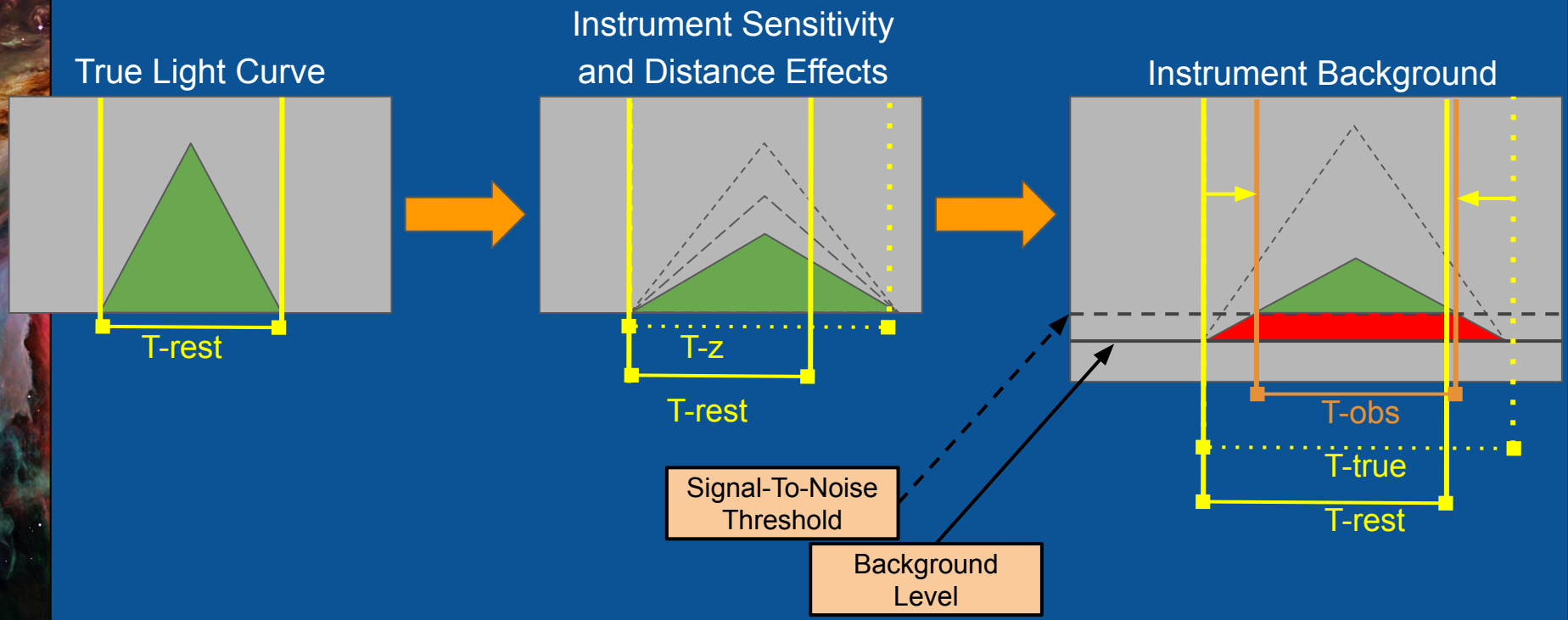
# Distance Effects on GRB Light Curves



# Distance Effects on GRB Light Curves

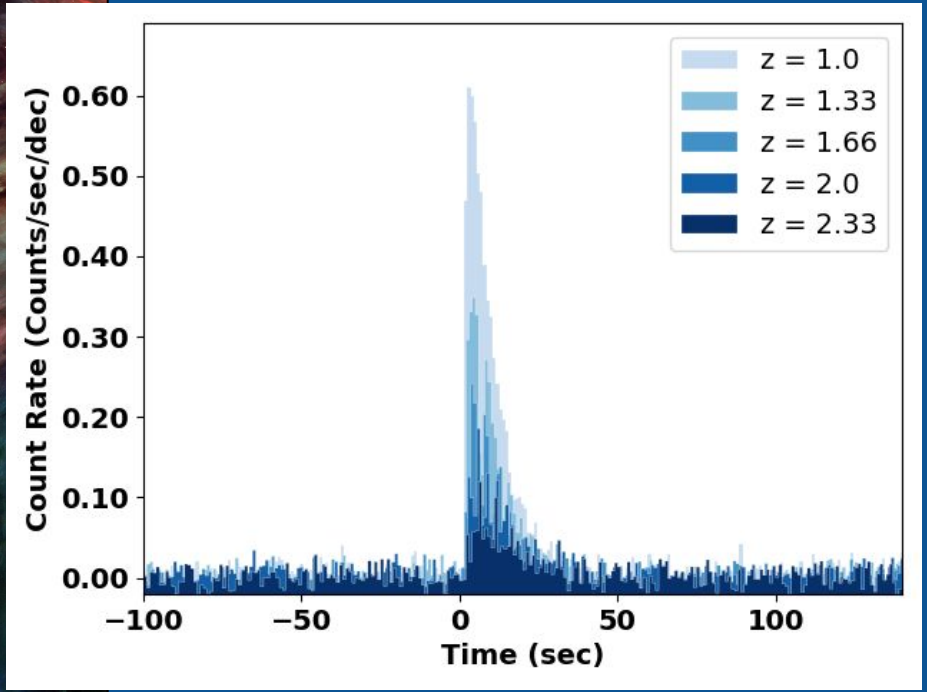


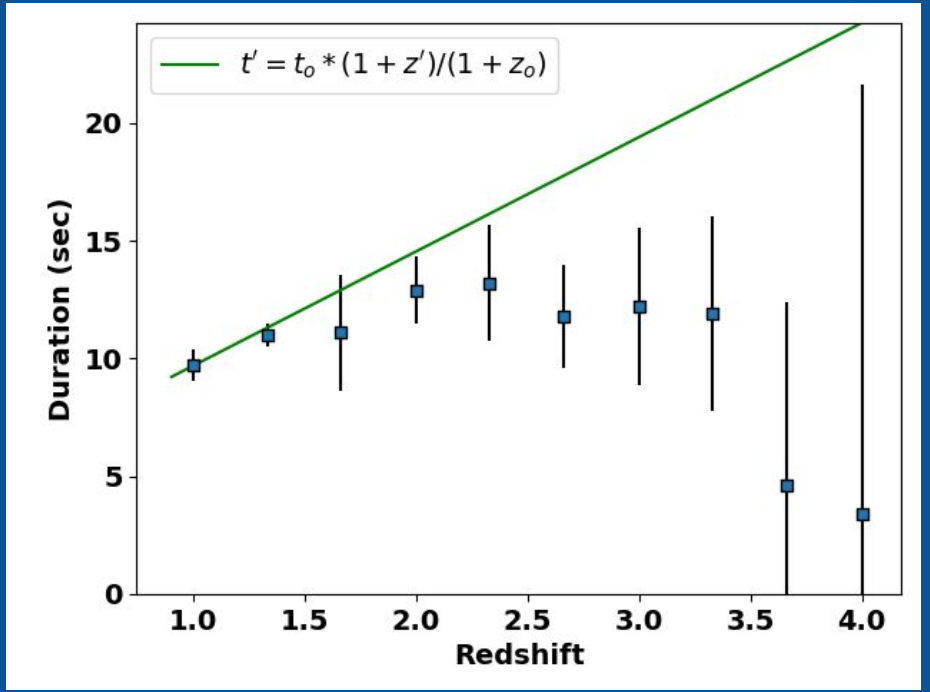
# Distance Effects on GRB Light Curves



# Distance Considerations - Results

This is preliminary, to be further investigated at a later time.



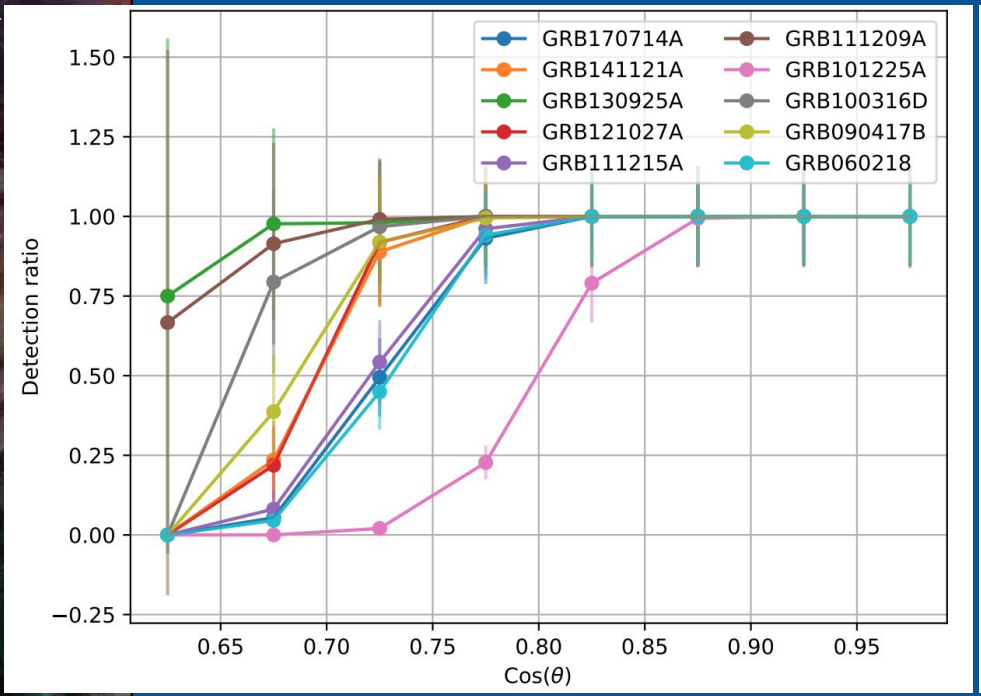



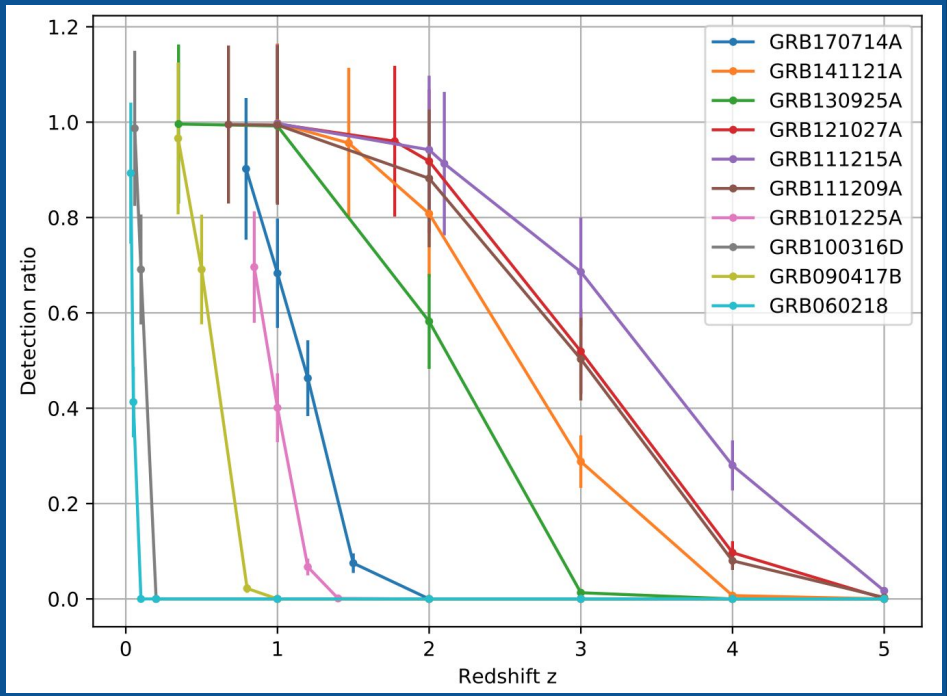
# Conclusions

1. **Swift/BAT GRB duration measurements are highly impacted by observing conditions**
2. **As instrument sensitivity decreases**
   - **Average T90 becomes shorter and**
   - **T90 uncertainty becomes larger**

3. The PCODE has the strongest influence
4. Strong dependence on light curve
5. Most of our sample, consistent with intrinsic durations in only ~20% - 40% of simulations.
6. Light curves with a intrinsic T90 > 2 sec may be observed with T90 < 2 sec

# Instrumental Considerations - SVOM/ECLAIRs



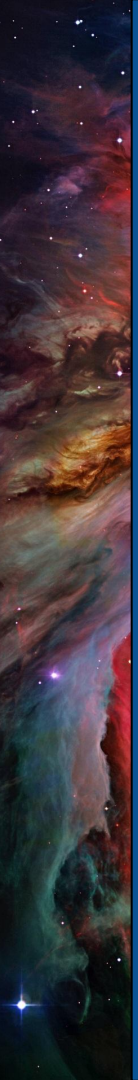




Dagoneau, Schanne, Atteia, Götz, and Cordier (2020)

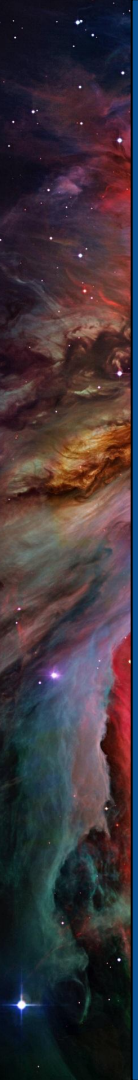
See also B. Arcier, et al. 2021 for SVOM/ECLAIRs detection capability of short high-energy transients

# Next Steps

- Include complex light curves
- Cosmological distance effects
- Investigate bias in the observed luminosity and T90 distributions
- Apply to other instruments

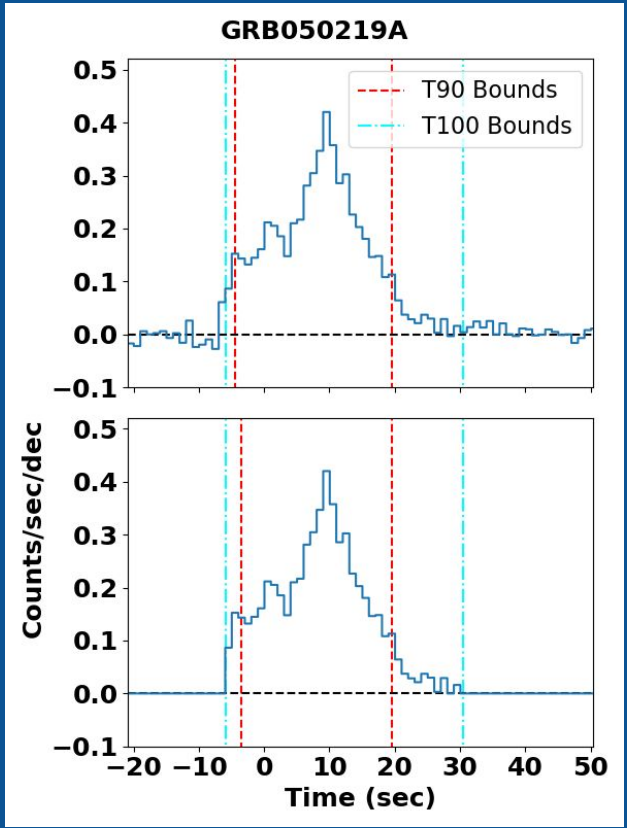



Thank you!



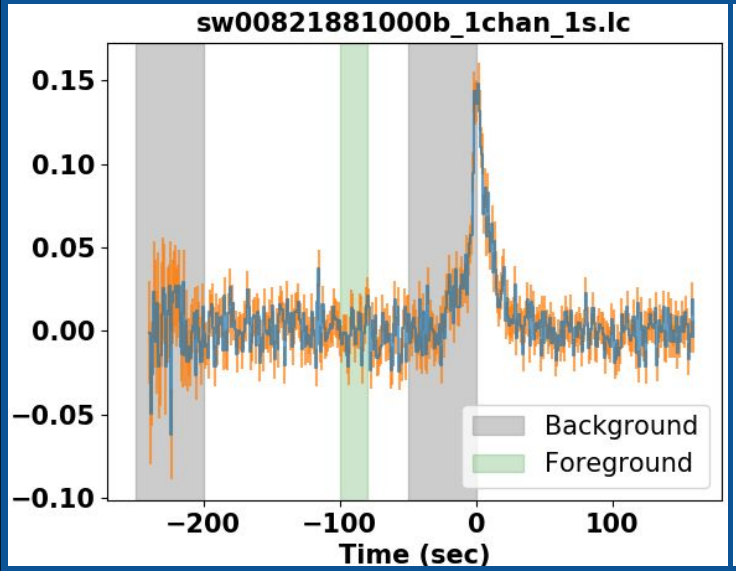
# Backup Slides

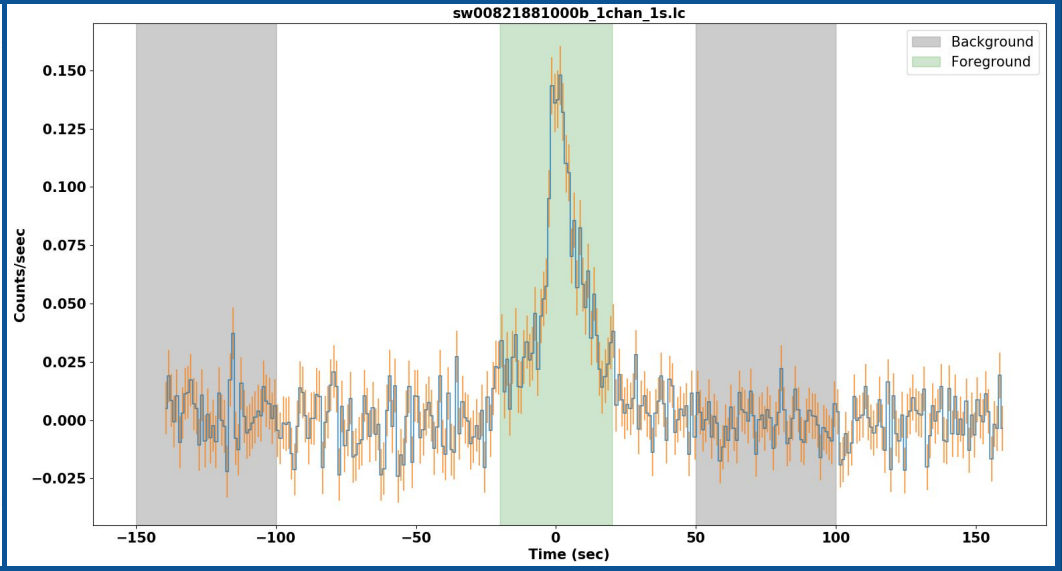
Template Light Curve → Simulate Source Light Curve → Simulate Observed Light Curve → GRB Durations



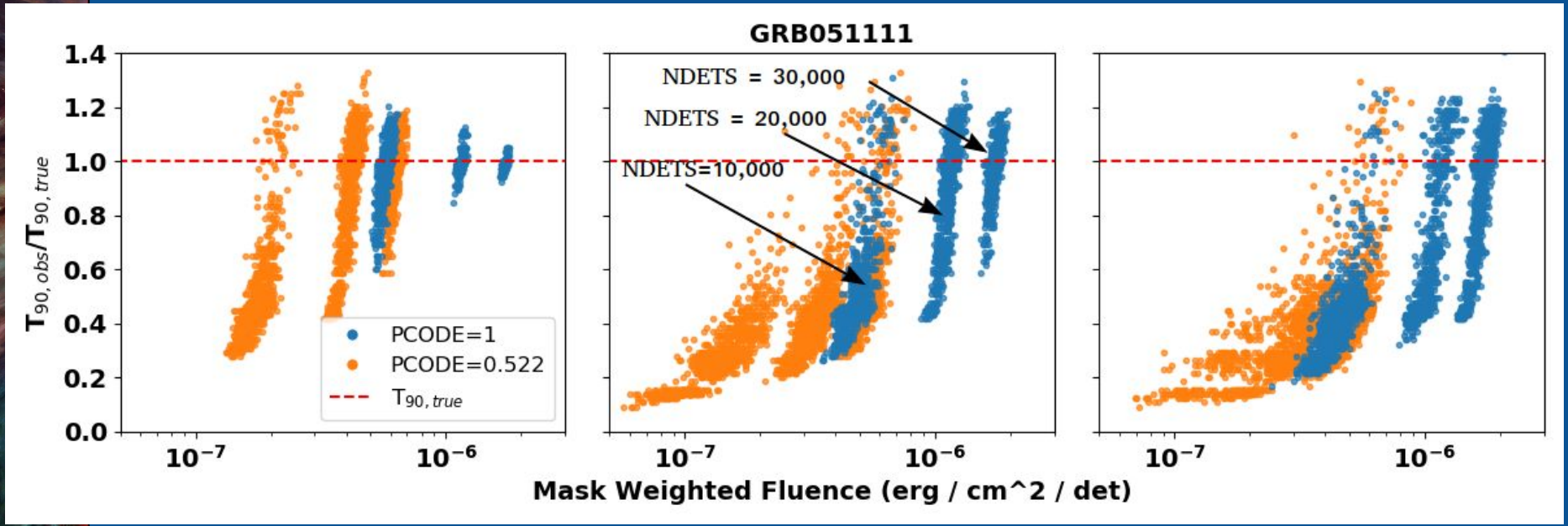
# Bayesian Blocks

Few hundred sliding Bayesian Blocks combinations



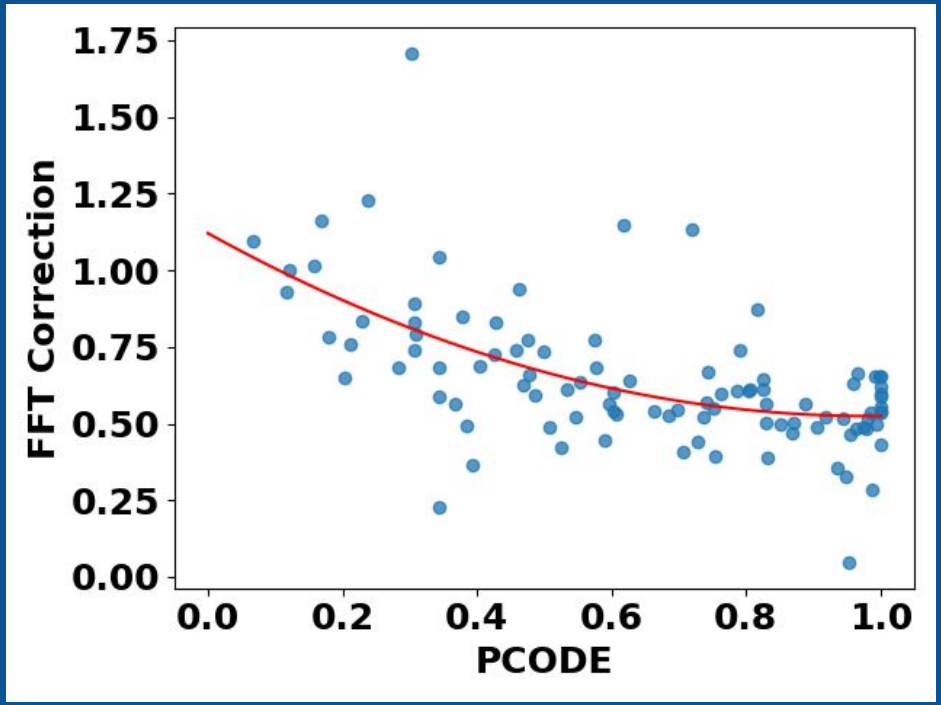
# Signal-to-Noise Ratio



# FFT Loss Factor

FFT causes additional loss of signal

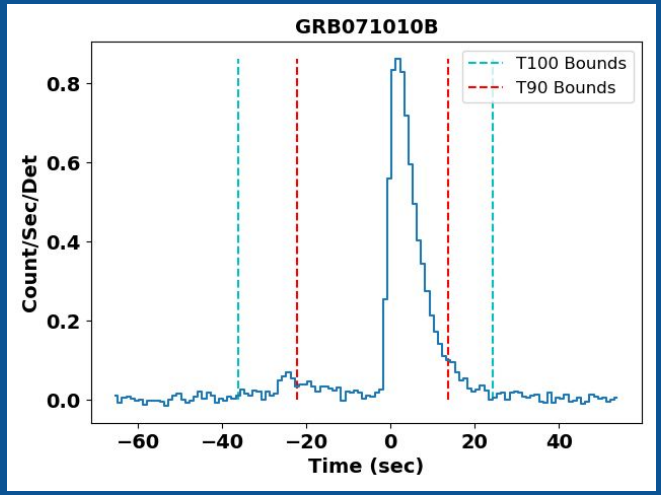
We calculated the loss for 100 GRBs and Fit a line as a function of PCODE.

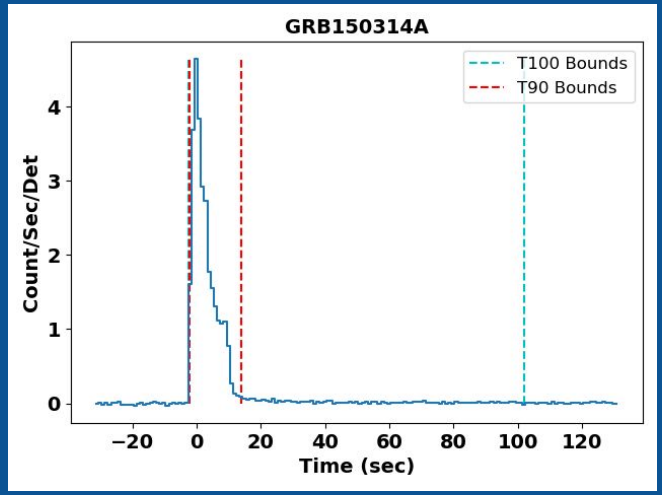


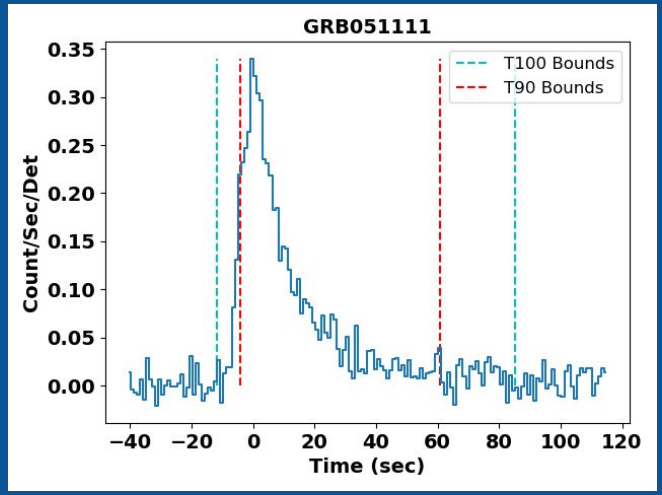
# Light Curve Sample

| GRB Name | $z$ | $T_{90}$ (sec) | Fluence (erg/cm$^2$)) | $\alpha$ | PCODE | $\theta_{inc}$ | SNR | Description |
|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| GRB160314A | 1.726 | 8.73 | $3.75 \times 10^{-07}$ | -1.53 | 0.75 | 19.69° | 14.18 | Short pulse |
| GRB150314A | 1.76 | 14.8 | $5.13 \times 10^{-05}$ | -1.08 | 0.344 | 35.1° | 256 | FRED-like with dim tail |
| GRB120119A | 1.73 | 68.0 | $3.17 \times 10^{-05}$ | -1.38 | 1.02 | 5.13° | 45.46 | Symmetric-like |
| GRB110422A | 1.77 | 25.8 | $5.56 \times 10^{-05}$ | -0.831 | 0.227 | 44.7° | 27.95 | Symmetric-like |
| GRB090510 | 0.903 | 5.664 | $1.46 \times 10^{-06}$ | -1.06 | 0.162 | 46.07° | 145.49 | Short-hard spike with soft tail |
| GRB071010B | 0.947 | 36.124 | $6.21 \times 10^{-06}$ | -1.97 | 0.8438 | 29.04° | 52.96 | FRED-like with dim pre-trigger emission |
| GRB051111 | 1.55 | 64.0 | $7.94 \times 10^{-06}$ | -1.32 | 0.594 | 27.2° | 37.09 | Broad FRED-like |
| GRB050219A | 0.211 | 23.8 | $4.53 \times 10^{-06}$ | -0.124 | 0.232 | 43.1° | 14.69 | Symmetric-like |

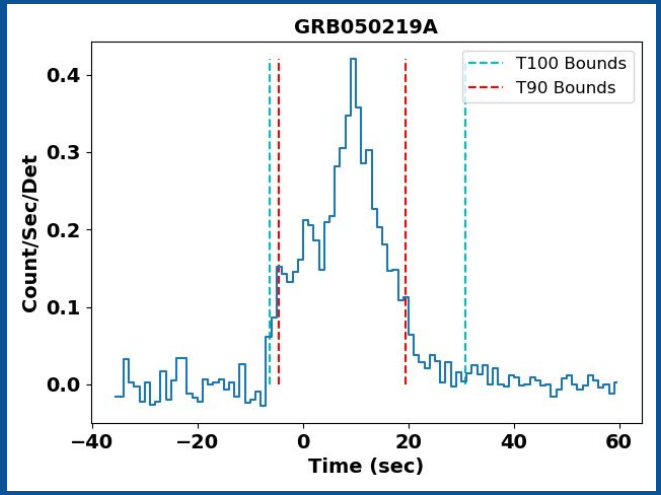
# GRB Light Curves
# FRED-like

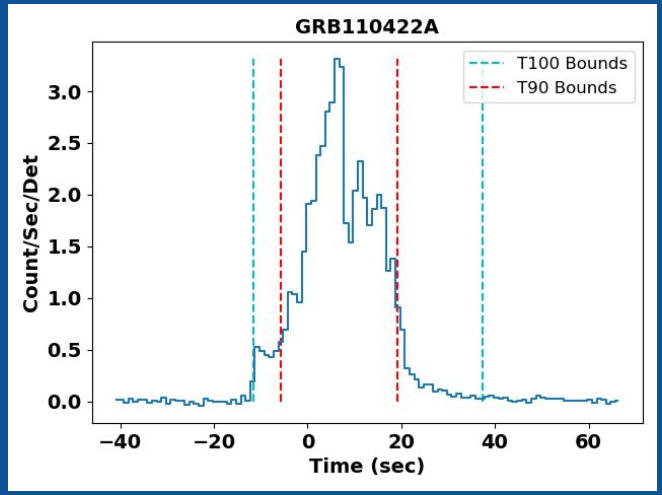


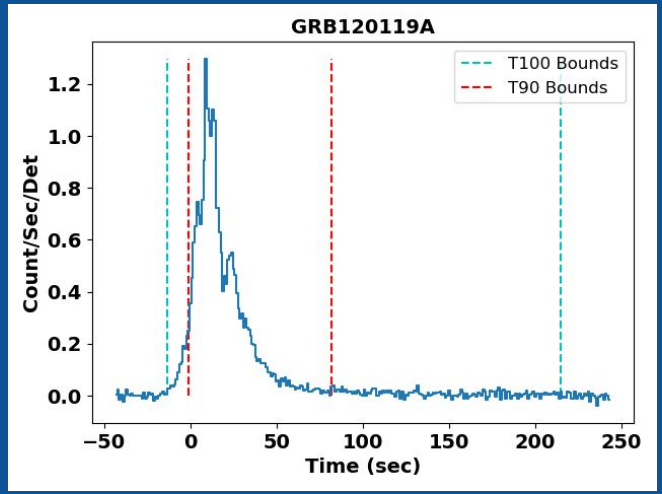



# GRB Light Curves Symmetric



# GRB Light Curves