Lowering the Swift threshold:

Proposal for an expanded search for GW bursts in association with GRBs during LIGO's 5th science run

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Lowering the Swift threshold

Overview

- Using GRBs as external triggers for LIGO GW search
- Swift GRB triggers and the BAT (Burst Alert Telescope)
- Two types of ‘subprime’ triggers
- Motivation for lowering the Swift threshold
- Getting the Swift data
- Setting a threshold
- Summary & Next steps

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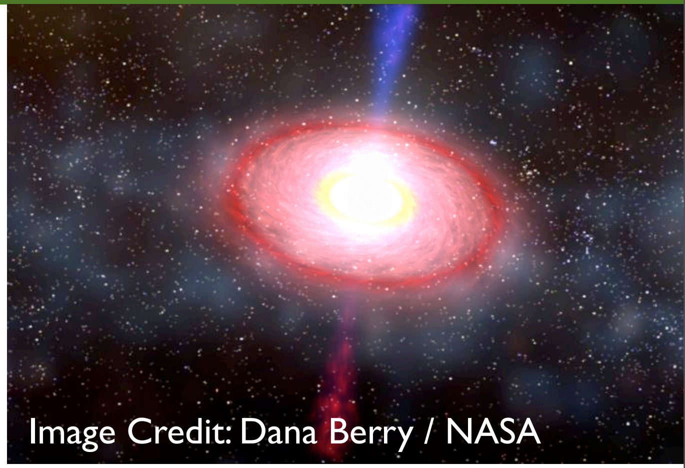
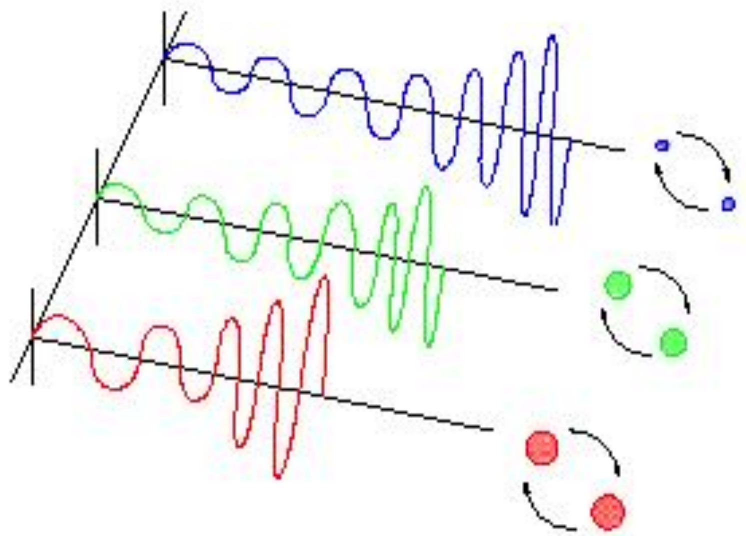
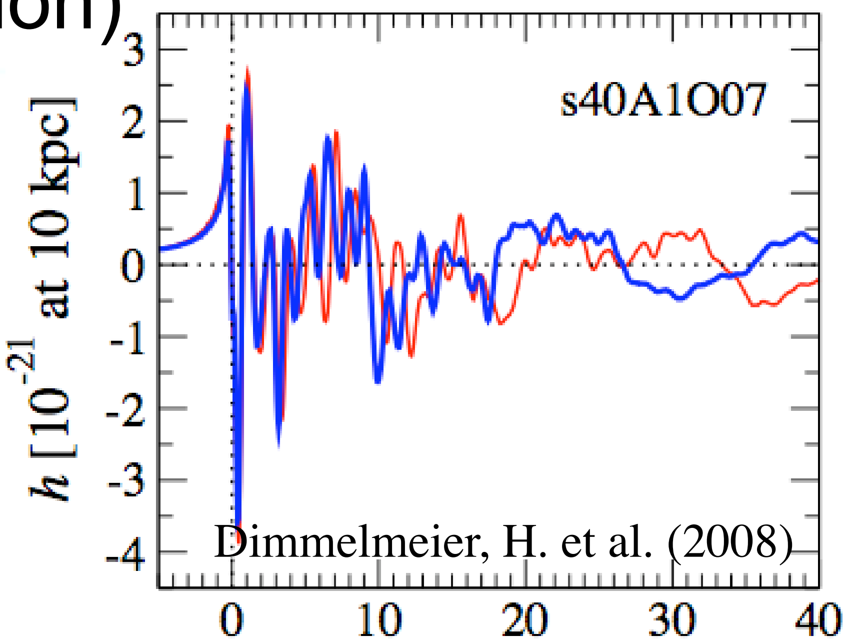
Using GRBs as triggers for GW search



- ✳ GRB models predict the most likely gamma-ray burst progenitors are:
  - ✦ NS-NS and NS-BH inspiral / coalescence (short: <2sec duration)
  - ✦ Core-collapse supernovae (long: >2sec duration)
- ✳ Both sources also produce gravitational waves at frequencies accessible to LIGO detectors.



inspiral waveforms



simulated core collapse waveform

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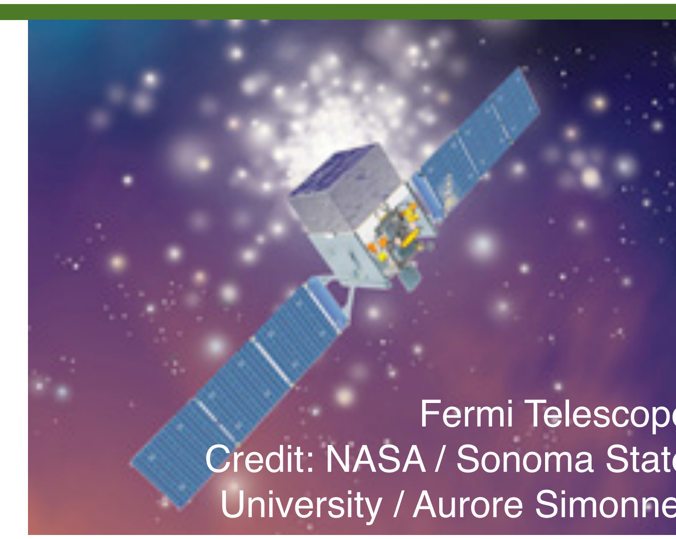
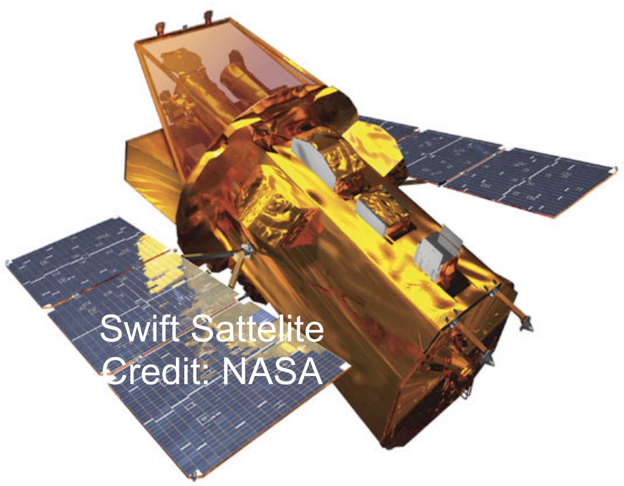
Using GRBs as triggers for GW search



GRBs are currently being detected by Swift and other IPN satellites at a rate of ~1/day. Events are distributed to the GRB research community via GCN circulars.



The LIGO GRB-triggered GW burst search uses source location and arrival time of electromagnetically detected GRBs to increase the sensitivity of a search for associated GWs. (Talk by Isabel Leonor later today).

Currently developed search pipelines allow for both:

- ✳Coherent network analysis (combining data from a network of detectors to improve search sensitivity - known source location), and...
- ✳Time coincidence analysis (non-coherent - unknown source location)

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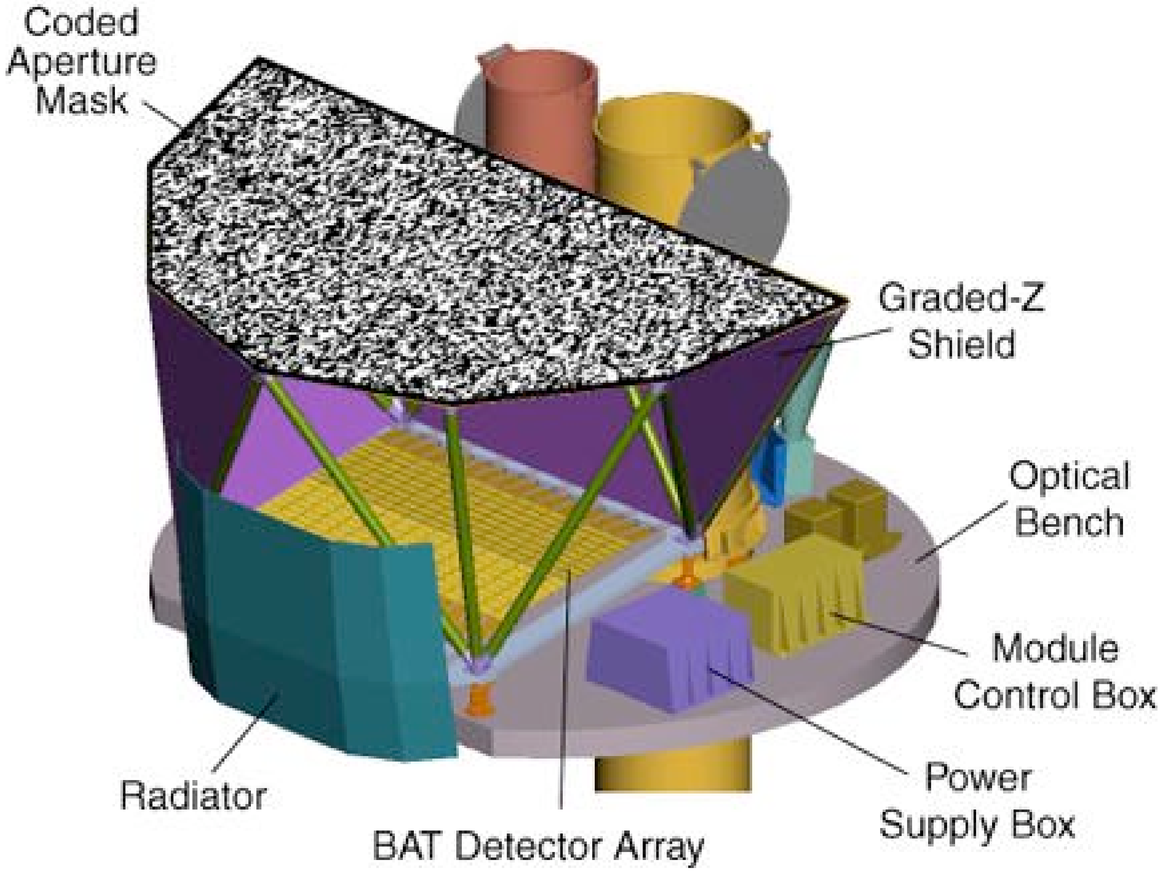
BAT imaging

Two imaging processes:

1) Increased count rate in detector plane → 'rate trigger'
   - If possible, FFT image produced from corresponding time and energy interval
2) Images are also produced at various intervals when there is no rate trigger → 'image trigger'

The images produced by both processes are searched for peaks. Image peaks above 6.5 sigma are classified as 'provisional bursts' and are followed-up with additional observations, spacecraft slew, etc.



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BAT imaging

But what if a rate trigger doesn't result in an image??

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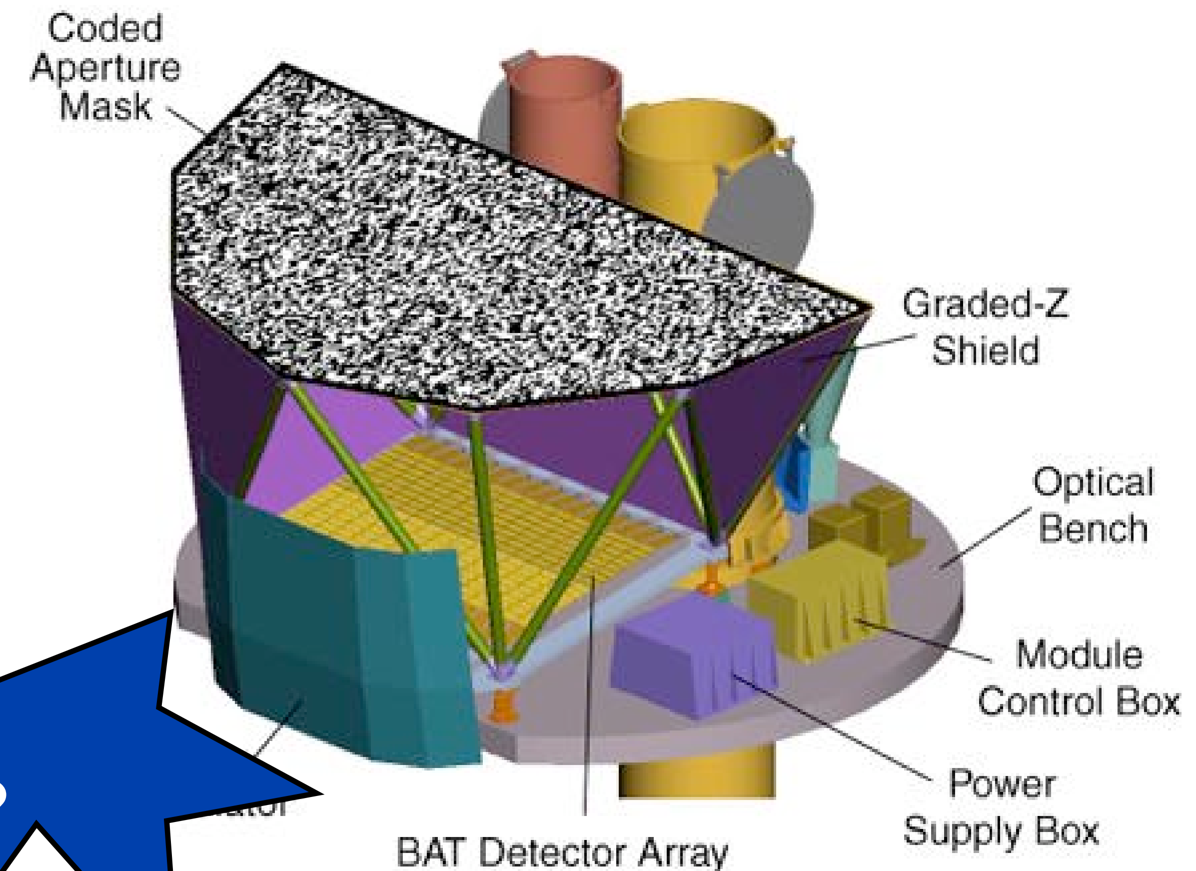

And what happens to the peaks below 6.5 sigma??

Two types of subprime triggers

1) Strong rate trigger that does not produce an image. Events are outside BAT FOV and spacecraft cannot slew for whatever reason. *Sometimes* these events are flagged by hand and follow-up observations are made by other telescopes. We want to look at the events that have been passed over.

   → unknown sky position
   time-coincidence search

2) Events that produce image peaks below 6.5 sigma in the BAT (either from rate trigger or image trigger). Most below-threshold peaks are noise, but not all.

   → known sky position
   coherent network analysis

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Motivation

Why are below-threshold image peaks potentially interesting triggers for a GW search?

GRB brightness is not always correlated with GW signal strength.

- ✴ Beaming (BAT position in beam can affect detected brightness - or BAT can lie outside of beam completely.)
- ✴ Model predictions (short GRBs dimmer, but stronger GW emitters than long GRBs)

Swift data

- Swift data is public and easy to download.
- Files are 'fits' formatted.
- FTOOLS software packages available for viewing and manipulating fits files.
- Swift collaborators extremely helpful in pointing me to the relevant files and helping me understand what's in them.
- 'Image files' contain results of every image produced by the BAT.
- Have parsed 1 month worth of image files during S5 (Nov. 2005) and dug out the significance of every image peak found.

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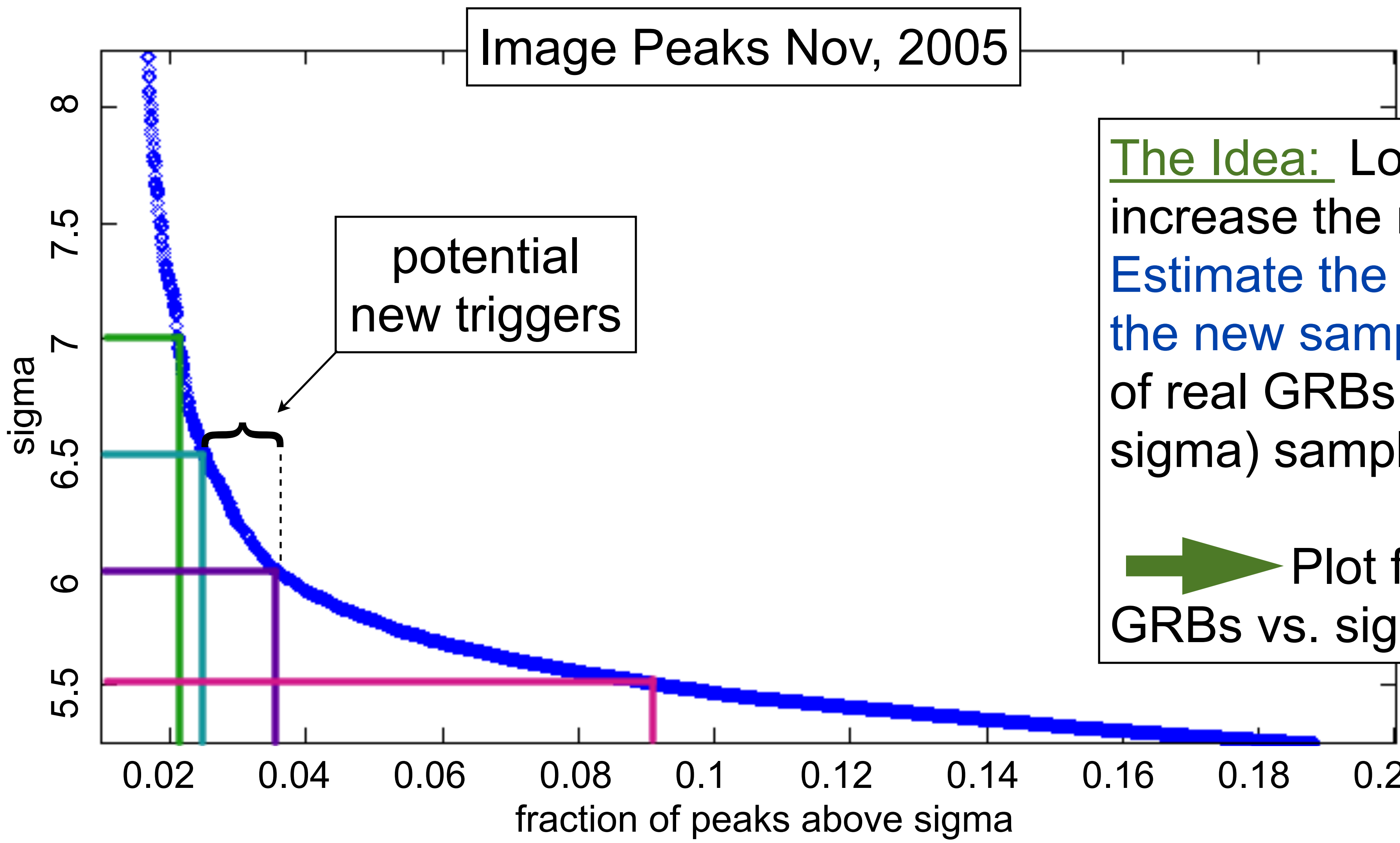
Image peak distribution (Nov. 2005)

- Distribution of image peaks found during November 2005 (first month of LIGO S5 run).
- Zoomed in to region near current threshold; includes some peaks from known sources.
- Sigma plotted is given in image file as ‘mStrength’ / ‘mLocalSigma’
- Peaks below 6.5 sigma are currently not followed-up by BAT



The Idea: Lower the threshold to increase the number of triggers. Estimate the number of *real* GRBs in the new sample based on the number of real GRBs in the adjacent (6.5-7.0 sigma) sample.

➡ Plot fraction of peaks that are GRBs vs. sigma (>6.5 sigma only)

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Next steps

- Download more data (only have one month so far)
- Choose a threshold (estimate false alarm rate in new trigger sample)
- Find the overlooked rate triggers (outside BAT FOV)
- Begin analysis!

Summary

- Approximately 200 GRBs were detected by Swift during LIGO's 5th science run. Choosing a different image detection threshold and examining all of the Swift rate triggers could potentially increase this number considerably at the cost of a small loss in purity (increased false alarm rate). We propose to analyze this new GRB set, thereby increasing the odds of finding within the sample a 'special event' detectable by LIGO.