LIGO - GBM Sub-threshold Search for the 1st Advanced LIGO Science Run

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Fermi-LIGO Workshop

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Search Team

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History of this Proposed Search

- 2009 Camp proposes LIGO S6 follow-up search with RXTE (ASM) and Fermi (GBM)
  - Approved by LSC
  - 2010 Lindy Blackburn joins Goddard to develop method

- 2014 Blackburn (with Camp, Christensen, Veitch, Briggs and Connaughton) publish search method , Ap J S 217 8 (2015)
  - Includes coherent detection in GBM
  - Coincidence requirement rejects large majority of LIGO triggers, and allows sub-threshold GBM search

- 2015 Organizing for O1 follow-up search
  - LB, JC, NC, JV, MB, VC + Peter Shawhan and Leo Singer
  - Coherent GBM detection and on-line alerts
  - Search plan: LIGO-T1500082

LIGO – GBM Coincident Search

- GBM coincidence in time and space will help verify the GW event

- Possible interesting astrophysics of EM/GW association
    - Jet geometry and energetics
    - Precursor to sGRB → NS resonant crust cracking → NS EOS
    - Followup of GBM detection with PTF (Singer, Cenko, VC)

<u>Optimistic</u> Advanced LIGO and sGRB Rates

aLIGO BNS Detections

Epoch	Estimated Run Duration	Burst Range (Mpc) LIGO	Burst Range (Mpc) Virgo	BNS Range (Mpc) LIGO	BNS Range (Mpc) Virgo	Number of BNS Detections	% BNS Localized within 5 deg^2	% BNS Localized within 20 deg^2
2015	3 months	40 – 60	—	40 – 80	—	0.0004 - 3	-	-
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 - 20	2	5-12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 - 100	1-2	10-12
2019+	(per year)	105	40 – 70	200	65 – 115	0.2 - 200	3-7	8-24
2022+ (India)	(per year)	105	80	200	130	0.4 - 400	17	48

sGRB Detections

Typical jet angle ~ 8 degree → beaming factor ~ 100

Thus 3 LIGO BNS detections → ~ 0.03 coincident sGRB detection
→ ~ 0.3 (subthreshold/GW on jet axis)

Realistic rates likely to be factor 10 lower…

Swift has seen 2 sGRBs within 500 Mpc (NS-BH range) → 0.2/yr
Redshift obtained 1/3 of the time so rate → 0.6/yr → 2/yr (Fermi)

Coherent Analysis of GBM Detectors
(L. Blackburn)

data

signal

$$\Lambda(d) = \frac{P(d|H_1)}{P(d|H_0)}$$

noise

Instrument response

Source amplitude,
position

$$P(d_i|H_1) = \prod_i \frac{1}{\sqrt{2\pi}\sigma_{d_i}} \exp\left(-\frac{(\tilde{d}_i - r_i s)^2}{2\sigma_{d_i}^2}\right)$$

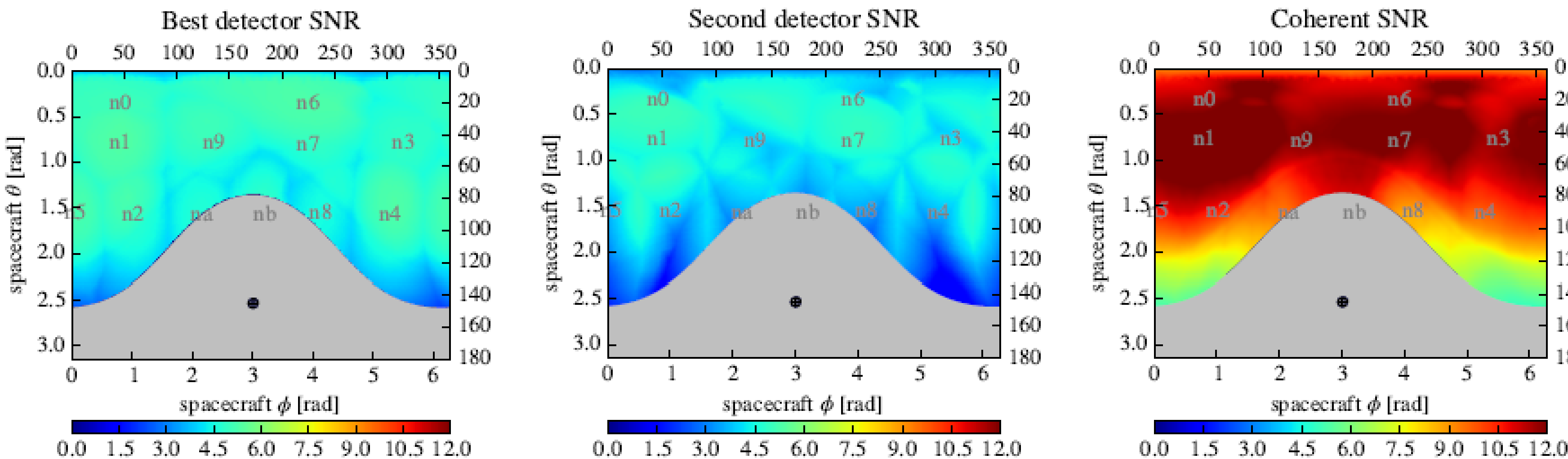
$$P(d_i|H_0) = \prod_i \frac{1}{\sqrt{2\pi}\sigma_{n_i}} \exp\left(-\frac{\tilde{d}_i{}^2}{2\sigma_{n_i}^2}\right)$$

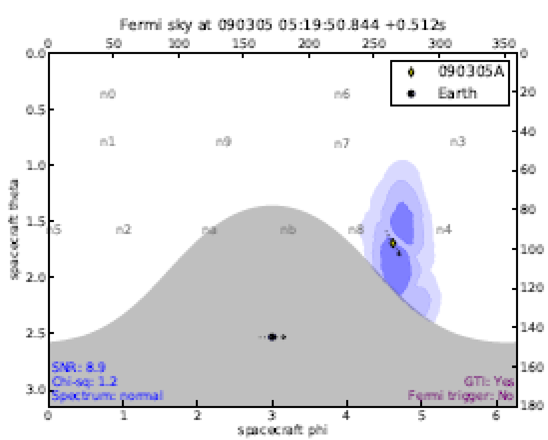
Evaluate Λ by marginalizing over amplitude, position

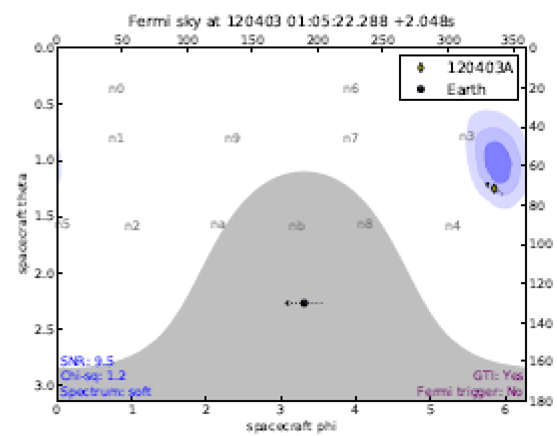
***r_i* provided by GBM detector model (Connaughton, UAH)**

Coherent Analysis of GBM Detectors

multi-detector analysis provides increased SNR over single-detector







Localization of sub-threshold sGRBs, comparison with Swift

Test of Initial LIGO – GBM – ASM coincident analysis

HIGH-ENERGY ELECTROMAGNETIC OFFLINE FOLLOW-UP OF LIGO-VIRGO GRAVITATIONAL-WAVE BINARY COALESCENCE CANDIDATE EVENTS

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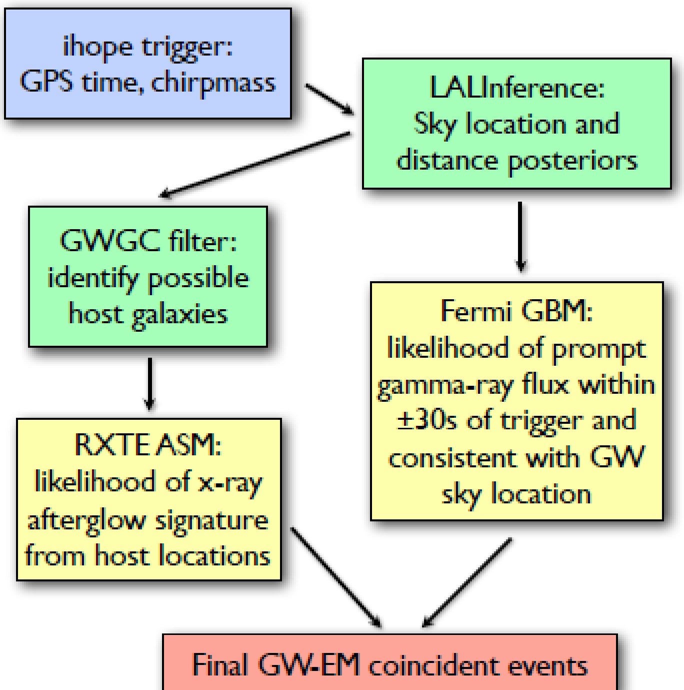
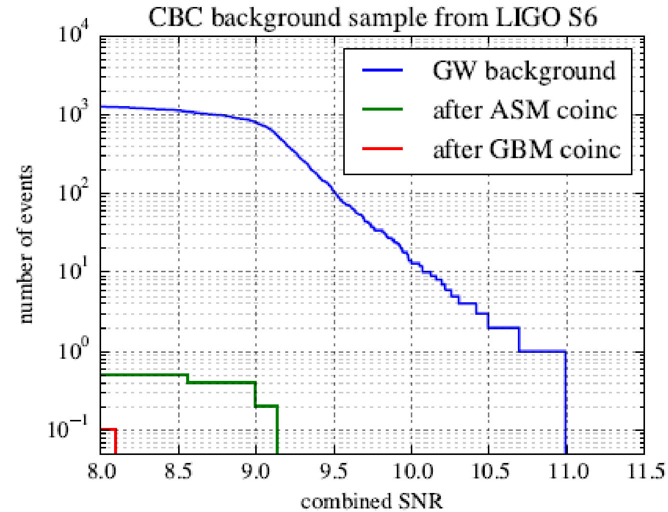
LIGO BNS trigger

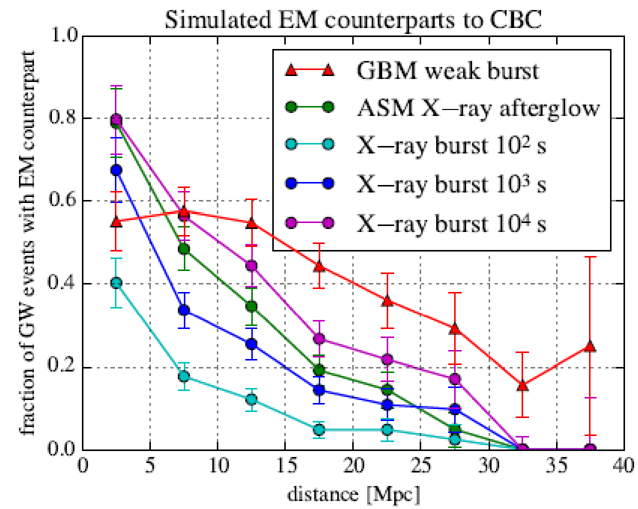
LIGO sky localization

ASM

GBM







O1 LIGO – GBM Search

- O1 run around fall 2015
  - 3 months
  - Hanford and Livingston detector range > 60 Mpc
- Pipeline development
  - Further tests of GBM coherent analysis
  - Use GBM continuous data from every downlink (CTTE)
  - LIGO sky localization: replace LAL inference with low-latency BAYESTAR to enable real-time alerts (Singer)
- Run pipeline
  - Analyze results and get ready for next year's run at > 100 Mpc
  - Continue development of GBM coherent analysis (UAH)