Searches for inspiral gravitational waves associated with short gamma-ray bursts in LIGO's fifth and Virgo's first science run

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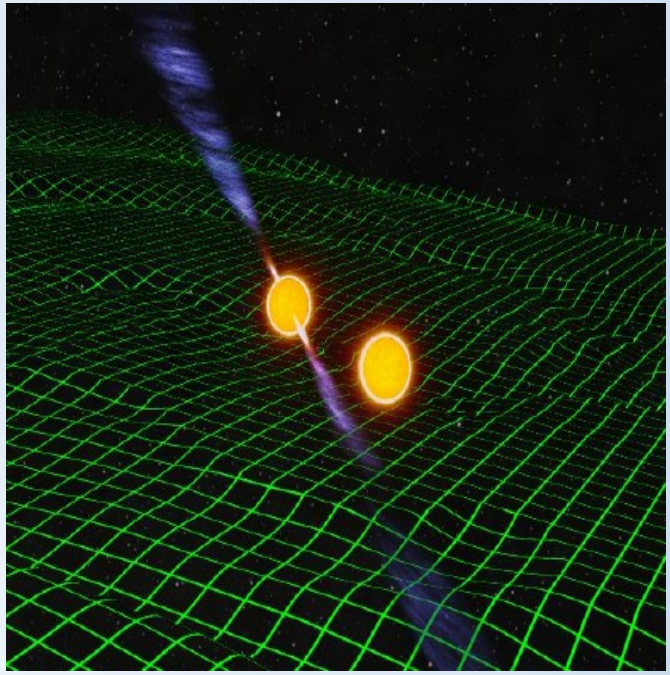
and the Virgo collaboration

Contents

- Motivation for SGRB triggered inspiral search
- Some details of this search
- ***Results from S5/VSR1***
- Outlook

Science with short GRB's

- The merger of two compact objects is a likely scenario to generate a short GRB
- Search for burst signals from long and short GRB: see talk by Marka
  burst search: Abbot et. al. arXiv:0908.3824
- The scientific payoff of coincident observation can be great:
  - Determination masses and spins
    L. Finn, & D. Chernoff, PRD 47, 2198 (1993)
    E. Poisson& C. Will, PRD 52, 848, (1995)
  - NS equation of state
    E. Flanagan, PRD, 77, 021502 (2008)
    J. Read *et.al*, PRD 79, 124033, (2009)
  - Luminosity distance
    S. Nissanke *et. al.*, arXiv:0904.1017 (2009)
  - Test of strong-field GR, Graviton mass, LIV,...
    C. Will, Living Rev. Rel., 9, 3, gr-qc/0510072 (2005)
    A. Stavridis *et. al.*, PRD 80, 044002 (2009)
    J. Ellis *et. al.*, Astropart. Phys. 25, 402 (2006)

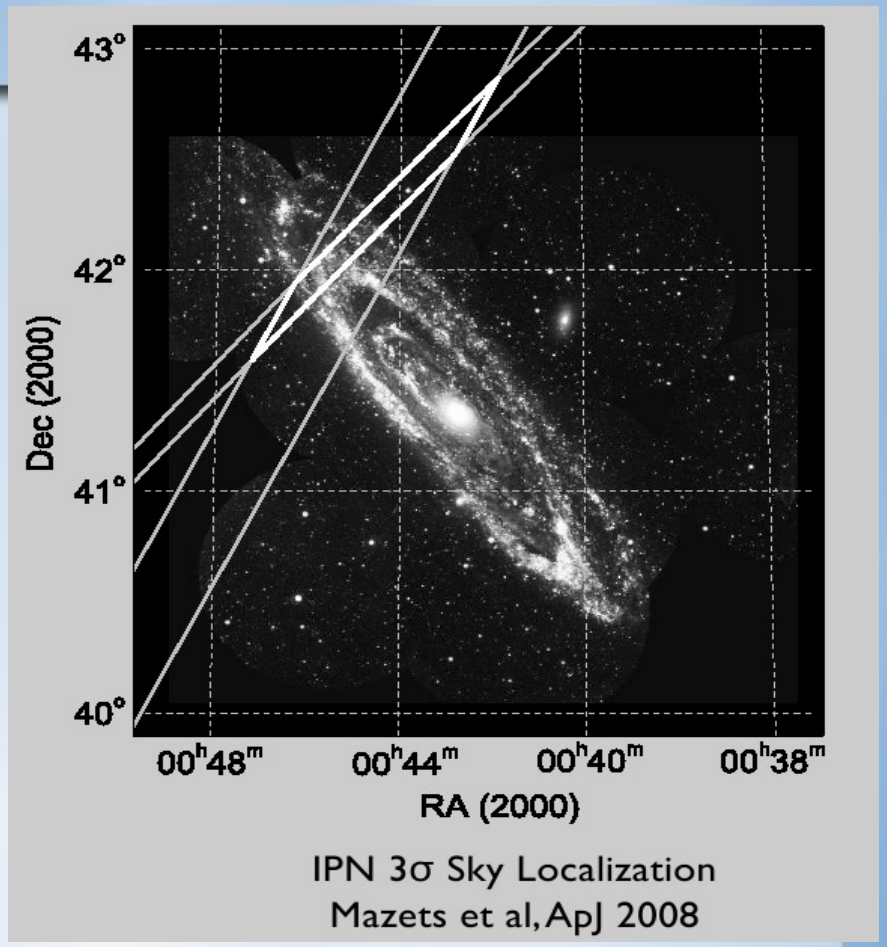


GRB-triggered search

- Satellite-based gamma/X-ray detection of a GRB gives the time and sky location
  - SWIFT, Integral, IPN, ...
- (Almost) Standard LIGO/Virgo analysis pipeline used with lower detection threshold and known sky position
  - Matched filtering with inspiral templates
  - Coincidence criteria from 2 or more detectors
- New more sensitive Likelihood-based analysis used
  - To determine the significance of the candidates
- Previously published: Search for a GW from M31 (GRB 070201) [Abbott et.al., ApJ 681, 1419 (2008)]
  - Reanalyzed in this work with lower threshold

GRB 070201

- A short GRB observed in direction of M31.
- Merger in M31 excluded at >99% C.L. [1]
- GRB probably merger farther away or a SGR in M31 [2,3]



[1] Abbott et.al., ApJ 681, 1419 (2008)
[2] Mazets et.al., ApJ 680, 545 (2008)
[3] Ofek et.al., ApJ, 681, 1464 (2008)

GRBs during S5/VSR1

- Analyzed data: S5/VSR1 Nov 2005-Nov 2007
- 212 GRBs in total
- 33 short GRB
- 22 short GRB with enough data from at least two interferometers
  - H1, H2: Hanford, WA
  - L1: Livingston, LA
  - V1: Cascina, Italy

analyzed GRBs

051114	070209
051210	070429B
051211	070512
060121	070707
060313	070714
060427B	070714B
060429	070724
061006	070729
061201	070809
061217	070810B
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Previously published: No GW detected, inspiral merger excluded in M31 at >99% level.

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This GRB was analyzed with data from all three sites (L1, H1, V1).

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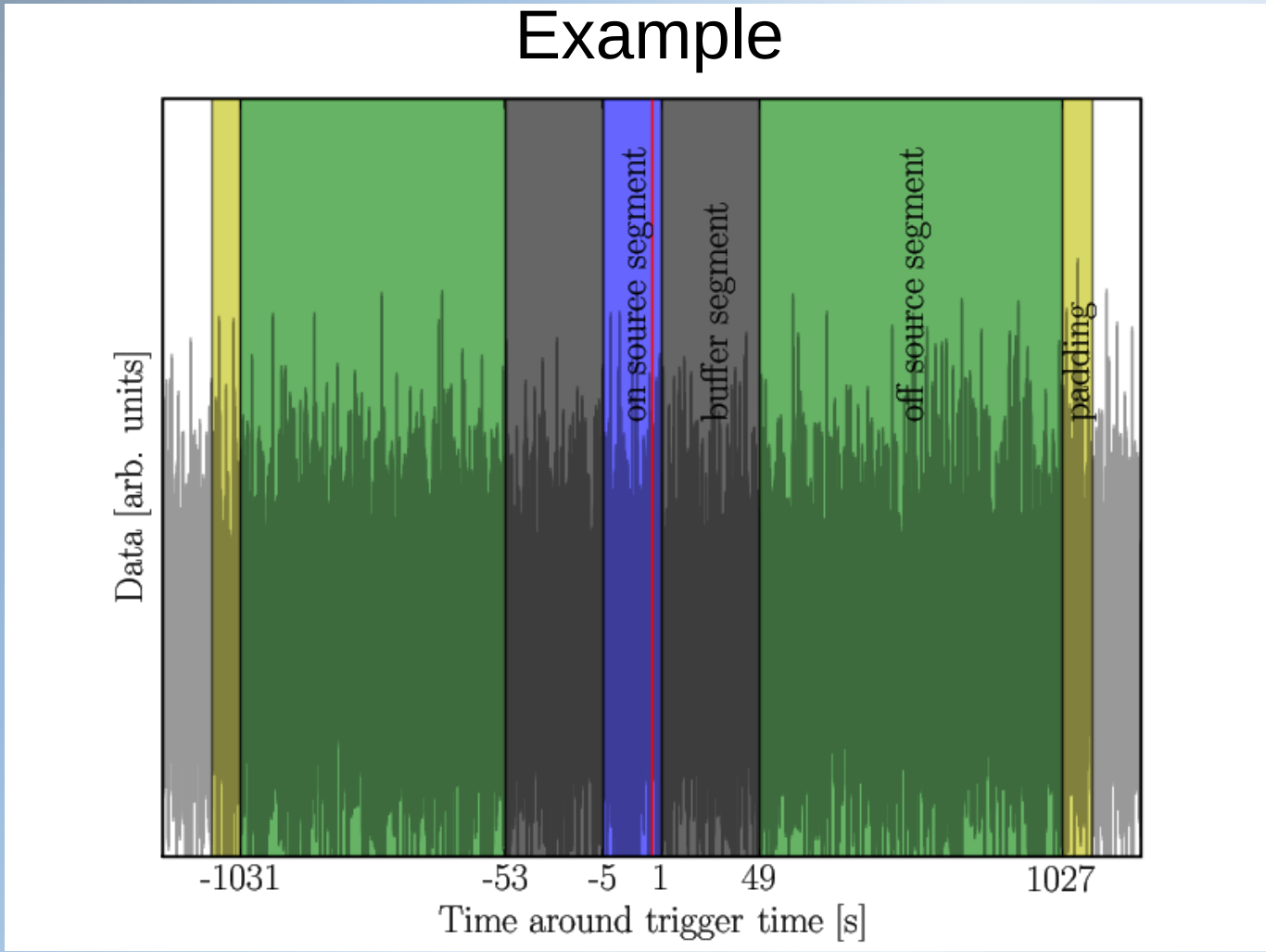
Technically *long* GRB, but spectral features suggest belonging to short GRB class.

Experimental design



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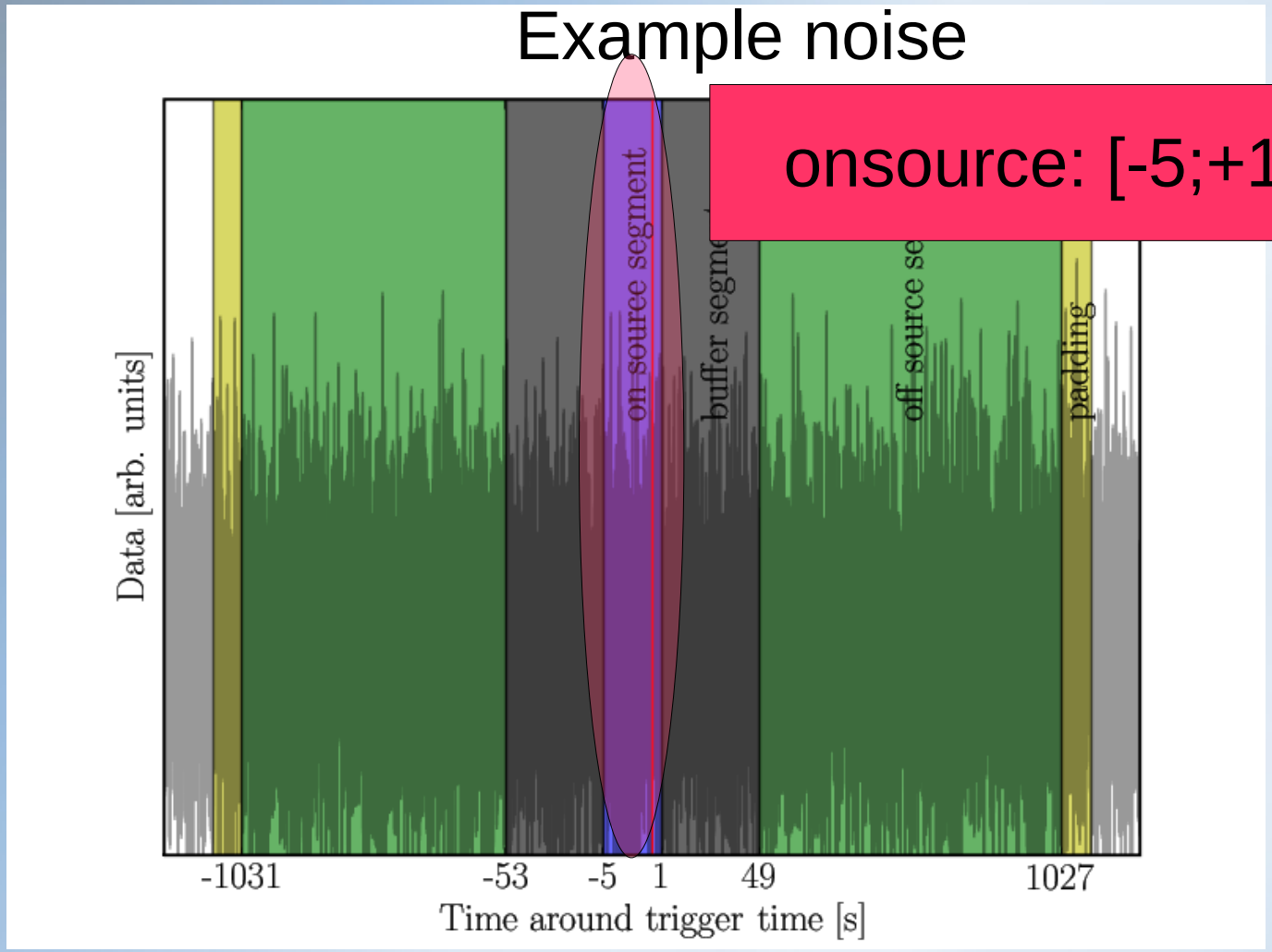
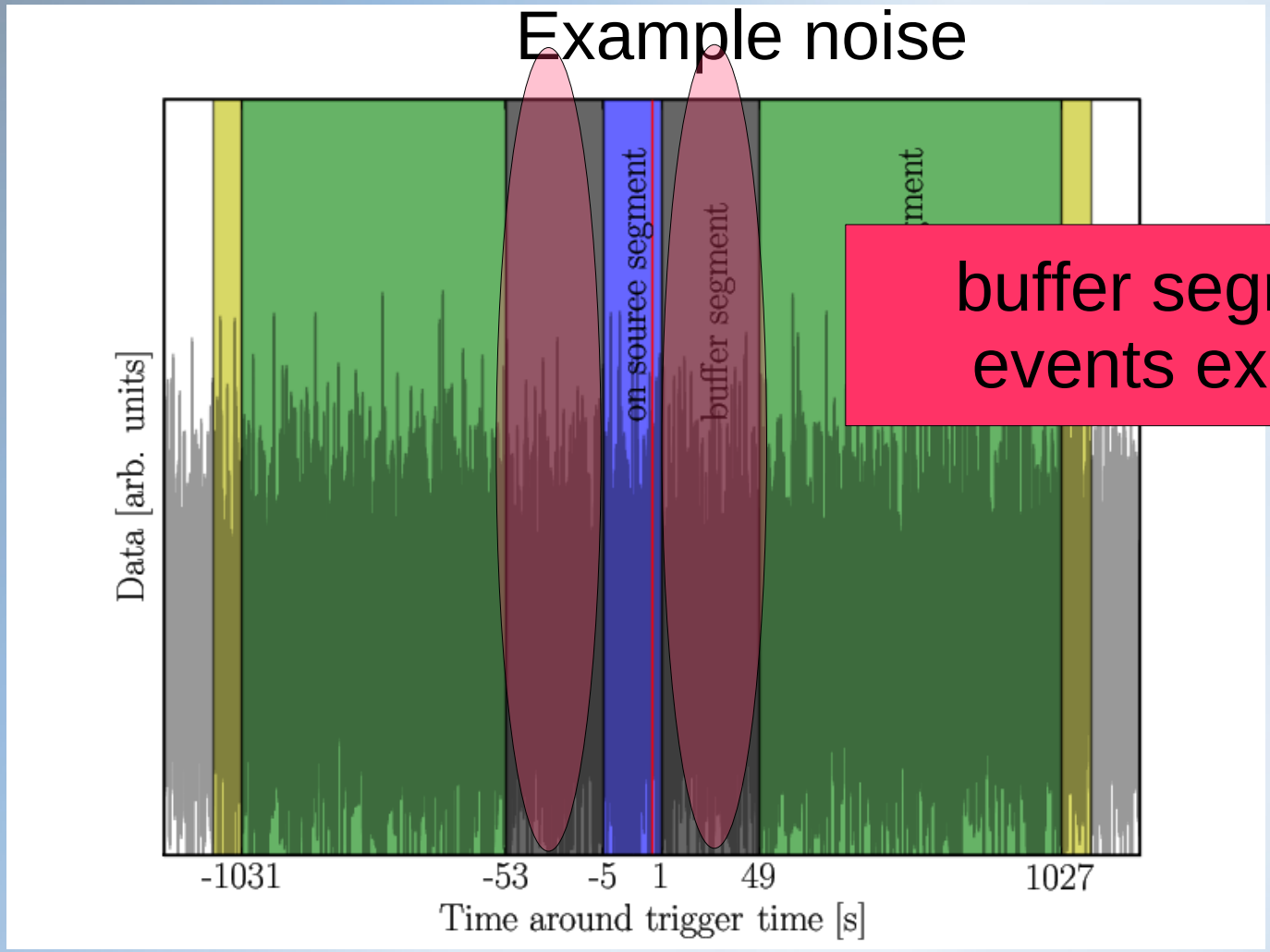


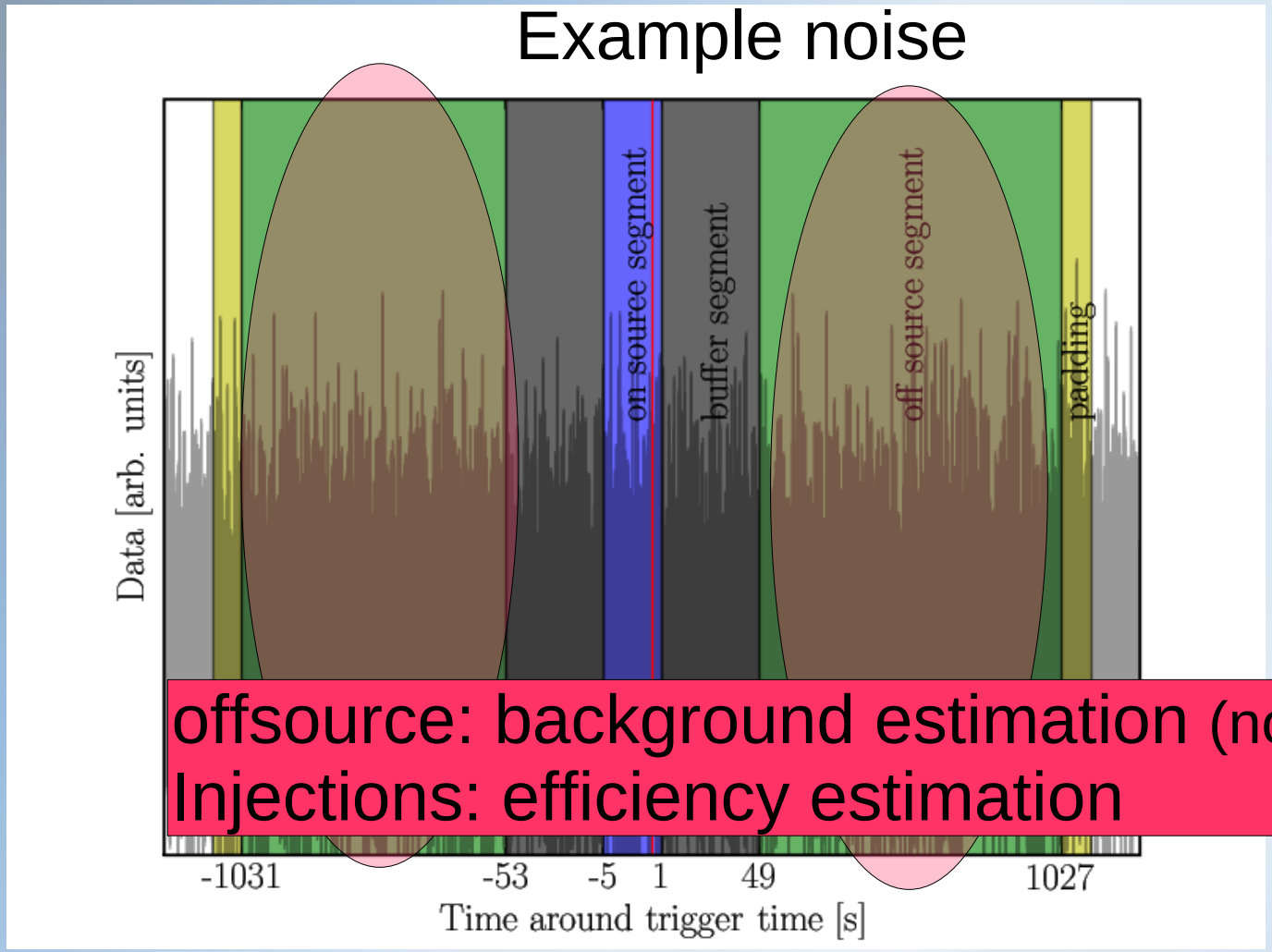
onsource: [-5;+1] seconds

Experimental design



buffer segments: events excluded

Experimental design



offsource: background estimation (no time slides)
Injections: efficiency estimation

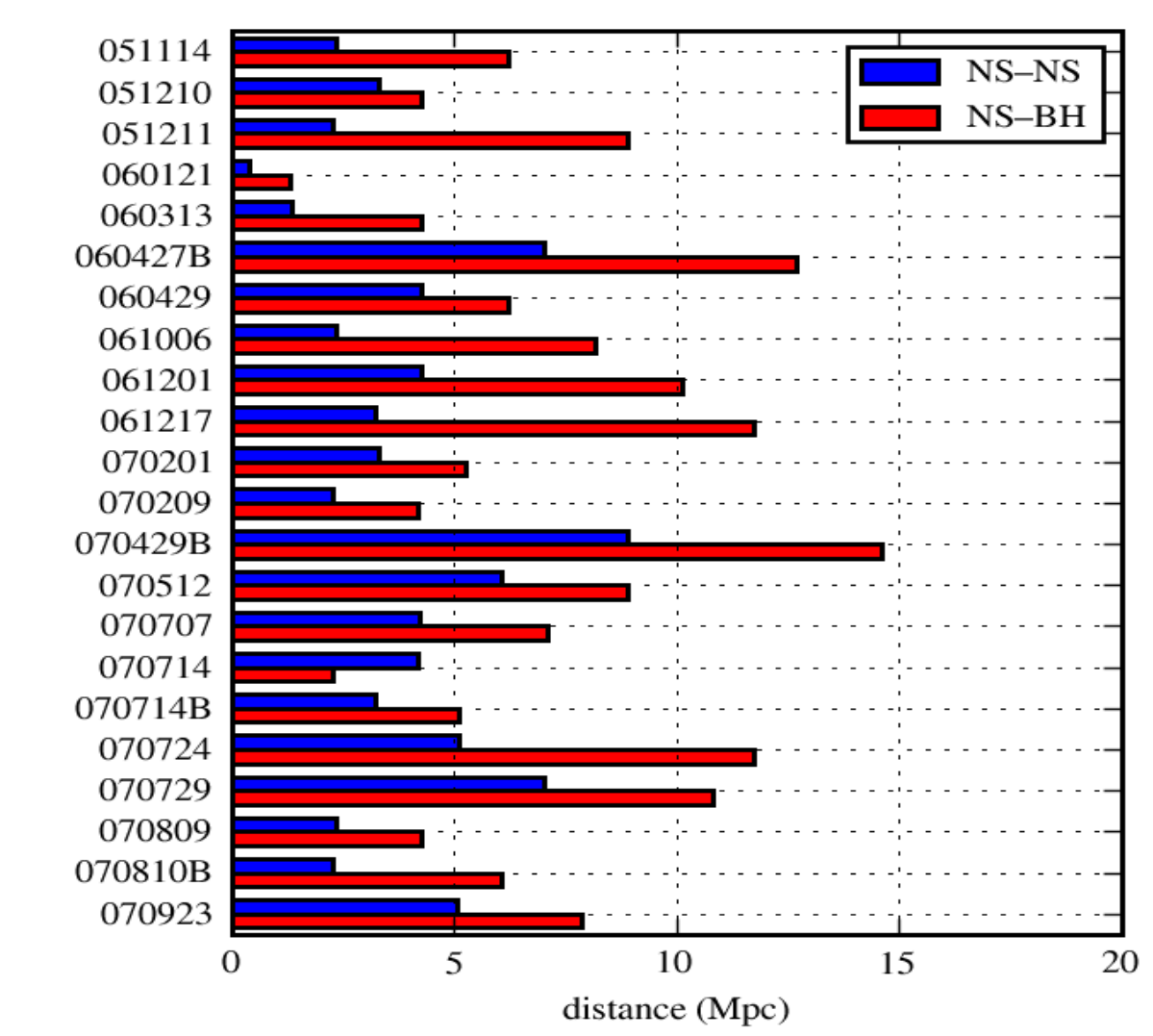
Search result

- Final search results after analysis of all data around the 22 short GRB:

No gravitational-wave signal detected

Abadie et.al (LIGO Scientific Collaboration and Virgo Collaboration), arXiv:1001.0165v1 (2010)

Exclusion distances

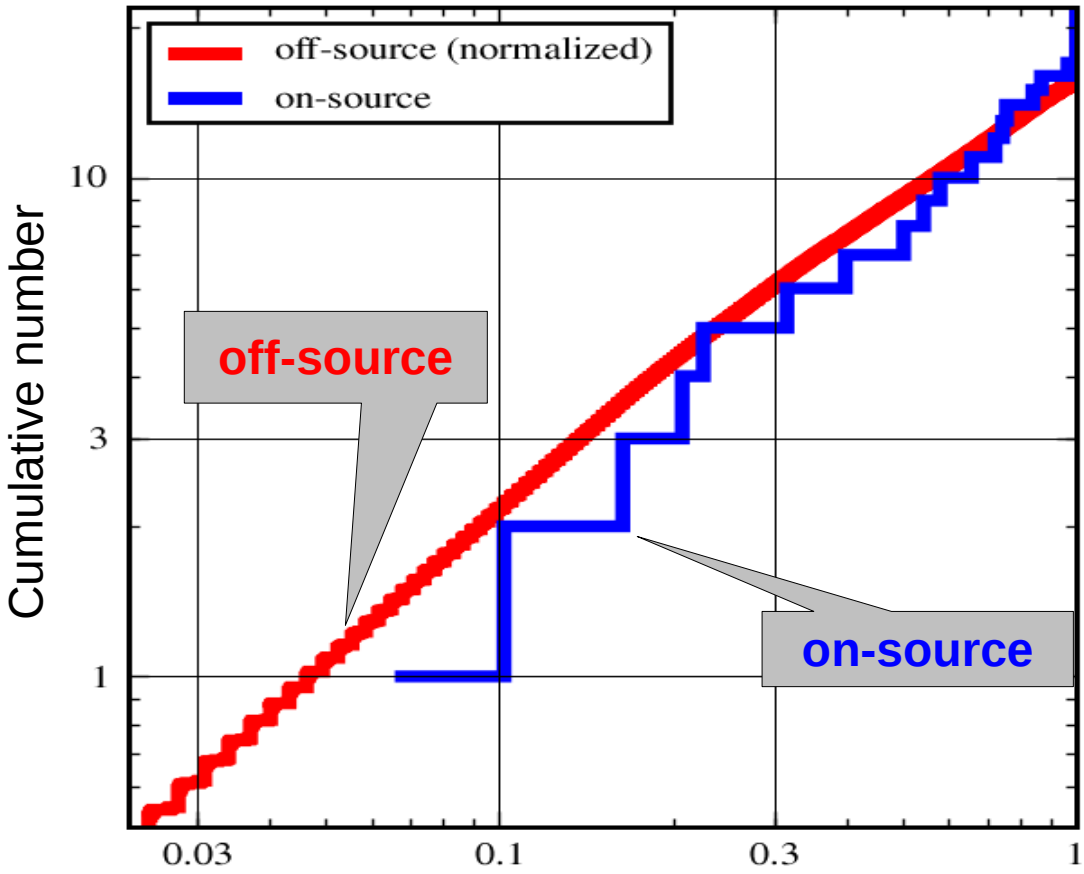


- Using Feldman-Cousins method
- 90% exclusion distances
  - Median NS-NS ($1.4/1.4\ M_\odot$)

    3.3 Mpc
  - Median NS-BH ($1.4/10\ M_\odot$)

    6.7 Mpc

False-alarm probabilities



- Plot of false-alarm probabilities
- Fraction of off-source candidates larger than the largest on-source candidate
- Most significant candidate: GRB 070201 with 6.8 % FAP (consistent with expectations)

Mann-Whitney Result

- Statistical method to decide if on-source and off-source samples are drawn from same population
- Used non-parametric test: Mann-Whitney U
- Based on ranking the significances of the candidates
  - High/low U-statistic (compared to U_0): on-source candidates more/less significant than off-source sample
  - If $U \simeq U_0$: Samples drawn from same population

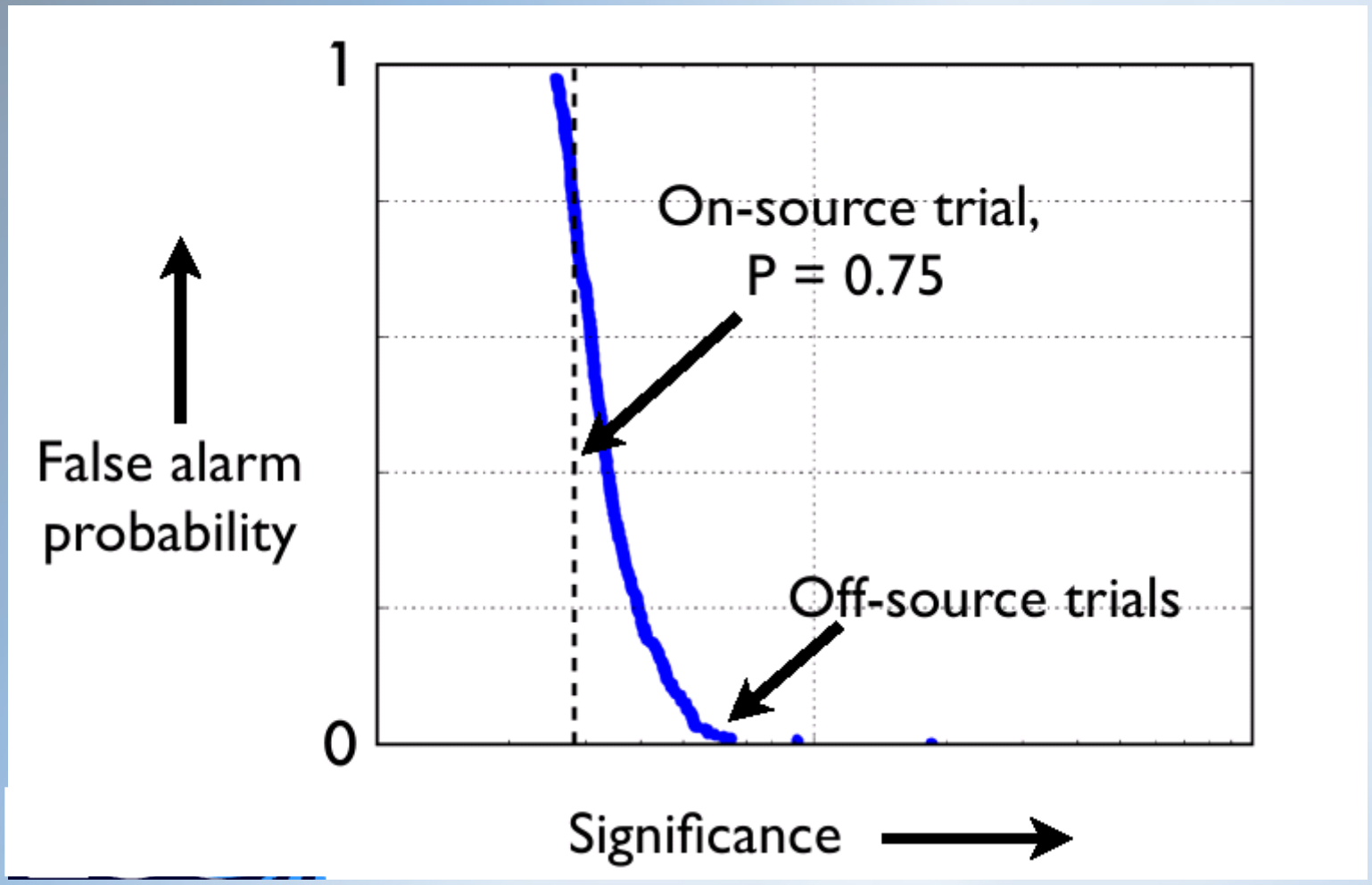
- Actual U-statistic consistent with on- and off-source samples being drawn from the same distribution
- *No evidence for excess*

Abadie et.al (LIGO Scientific Collaboration and Virgo Collaboration), arXiv:1001.0165v1 (2010)

Future work

- S5 analysis complete
- Analyzing data taken in S6/VSR2 (running since July 09)
- Online system running, automatic start of analysis
- Room for improvements:
  - Better background estimation
  - Faster turnaround
  - Better parameter estimation
  - Coherent searches
  - Bayesian methods
- *Prepare for advanced detectors (start ~2015)*

Example Noise



Example (fake) Signal