A directed Einstein@Home search for continuous gravitational-wave emission from Cassiopeia A

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on behalf of the Einstein@Home team

Motivation

Isolated, spinning neutron star with asymmetry
=> continuous gravitational waves (CWs)

CasA is **young** (~300 years old) and **close** (3.4 kpc);

compact central object is most likely a **neutron star**;
[e.g., Ho & Heinke 2009]

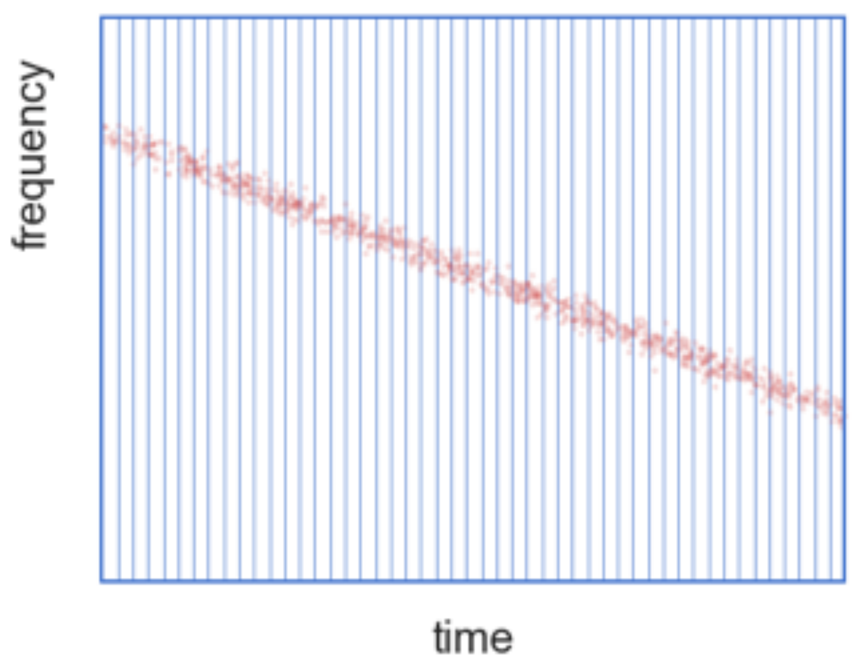
no electromagnetic pulsations detected, so spin period is unknown

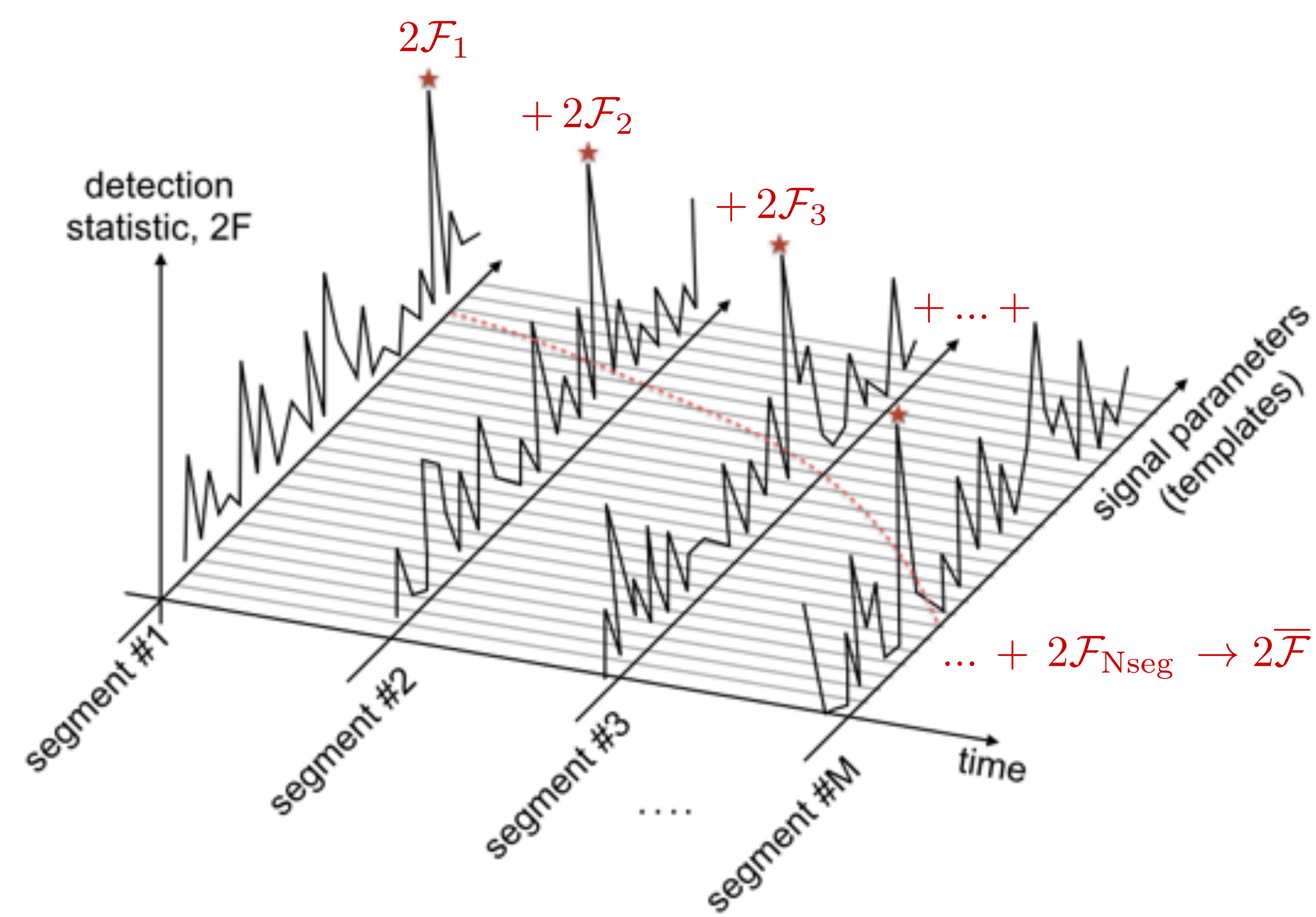
=> We performed a (directed) search for CWs from CasA using LIGO S6 data with Einstein@Home

[LVC [arXiv:1606.09619]]
[Singh et al. [arXiv:1607.00745]]

stack-slide search

[e.g., Brady and Creighton 2000]
[e.g., Pletsch 2010]

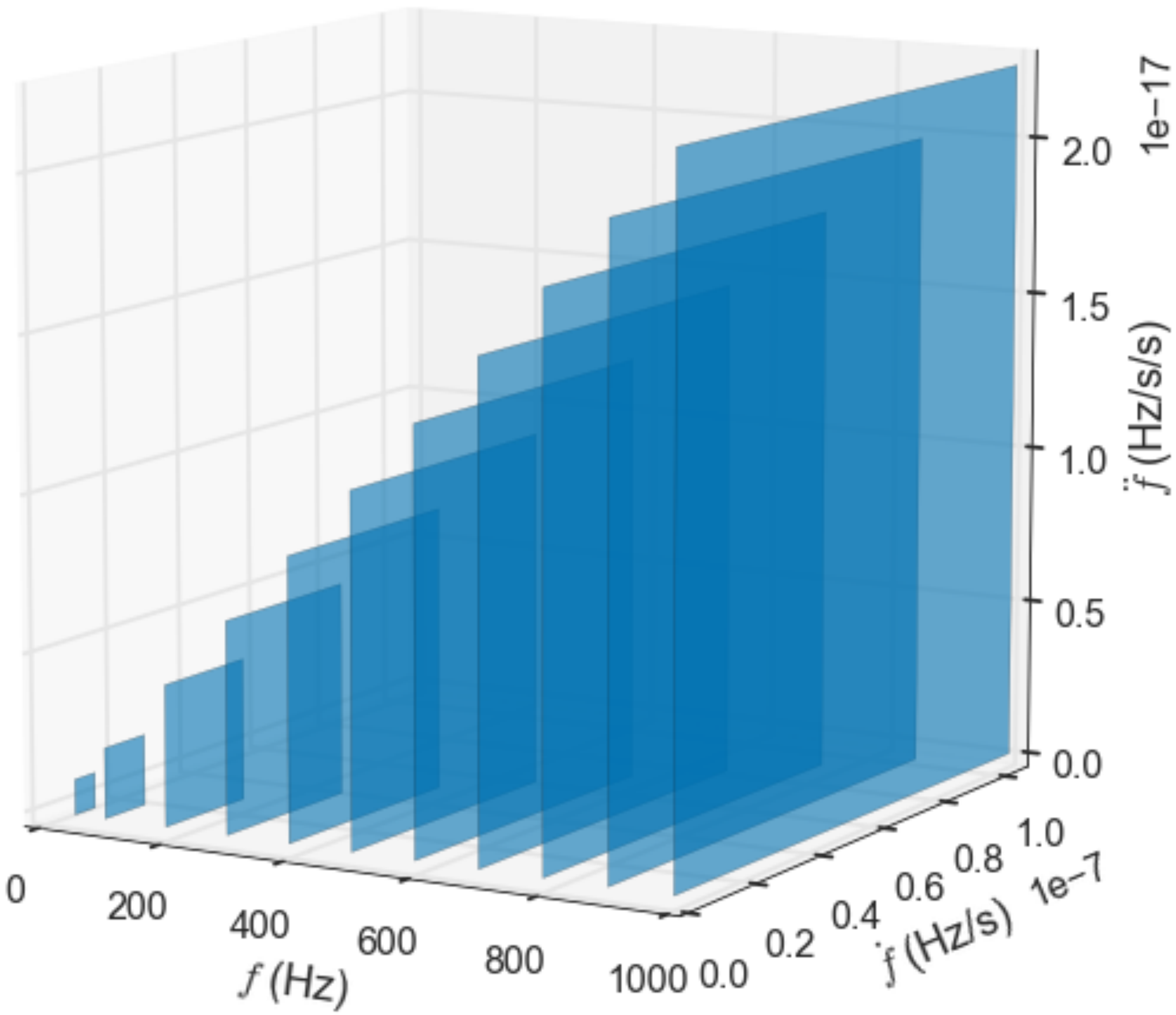


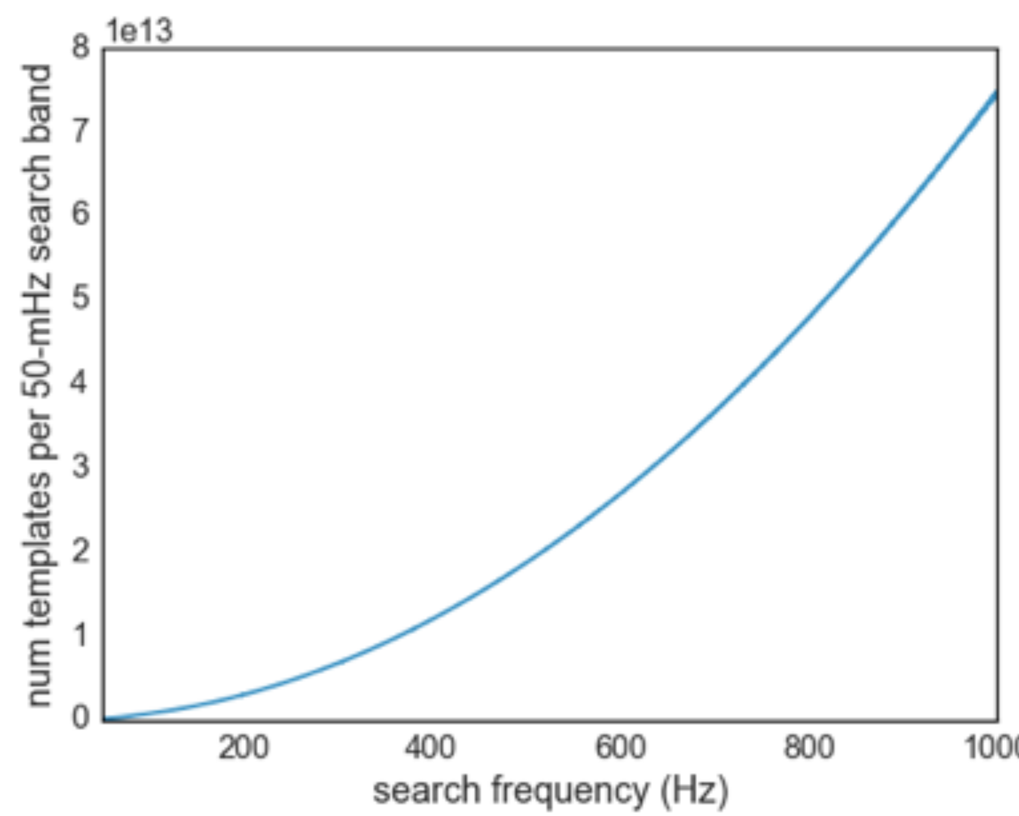


[credit: M. A. Papa]

template signal parameters: $f, \dot{f}, \ddot{f}, \alpha, \delta, \ldots$

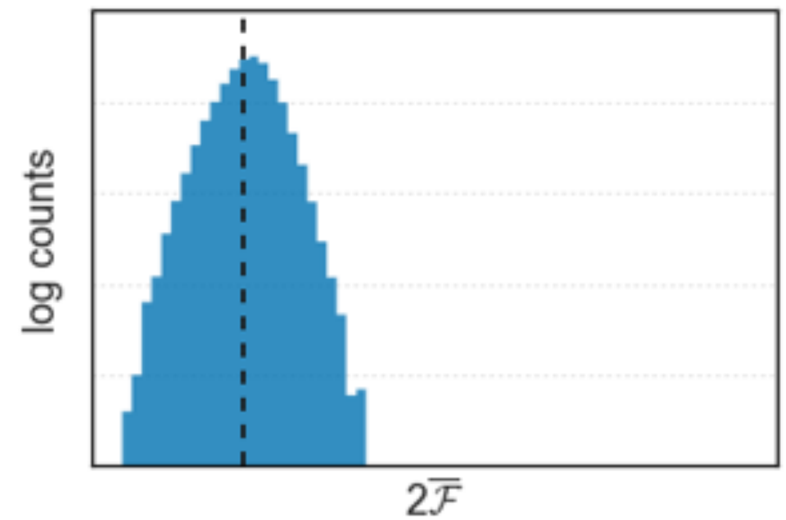
Search setup



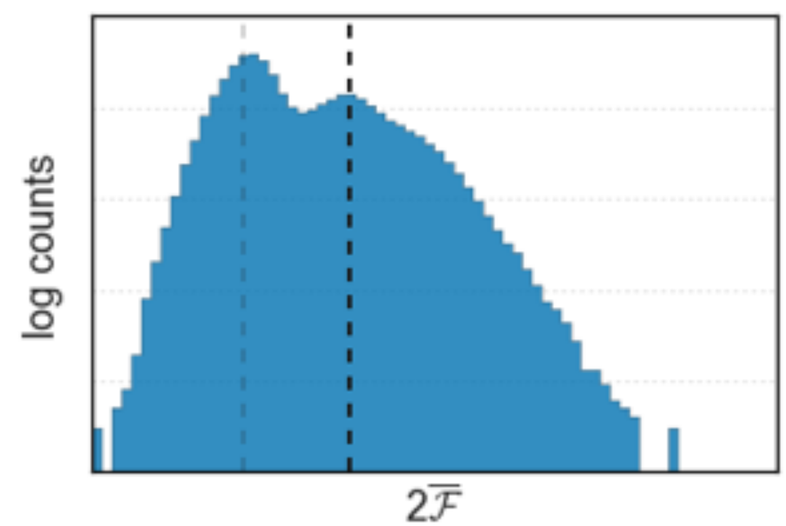


$2\overline{\mathcal{F}}$

$2\overline{\mathcal{F}}$ in Gaussian noise has a well-defined distribution;
only parameter: (effective) number of templates [Wette 2012]



undisturbed
(Gaussian noise)



disturbed

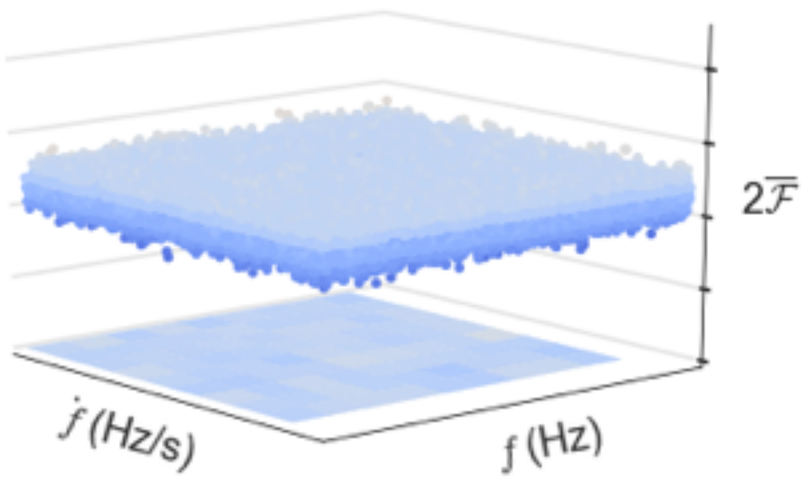
SystDistId (working name)

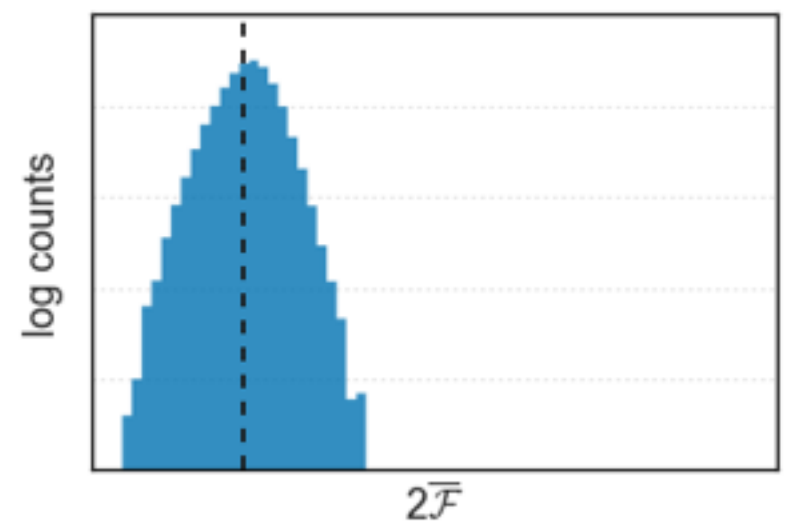
New statistic $\hat{O}_{\mathrm{SGL}}$ performs as well as $2\overline{\mathcal{F}}$ in Gaussian noise
and better than $2\overline{\mathcal{F}}$ in the presence of stationary disturbances [Keitel, et al., 2014]
=> use $\hat{O}_{\mathrm{SGL}}$ to find loudest candidates, and
use $2\overline{\mathcal{F}}$ to characterise candidates' significances

Systematic **Dist**urbance **Id**entification:
a semi-automated method of identifying potentially disturbed bands

SystDistId (working name)

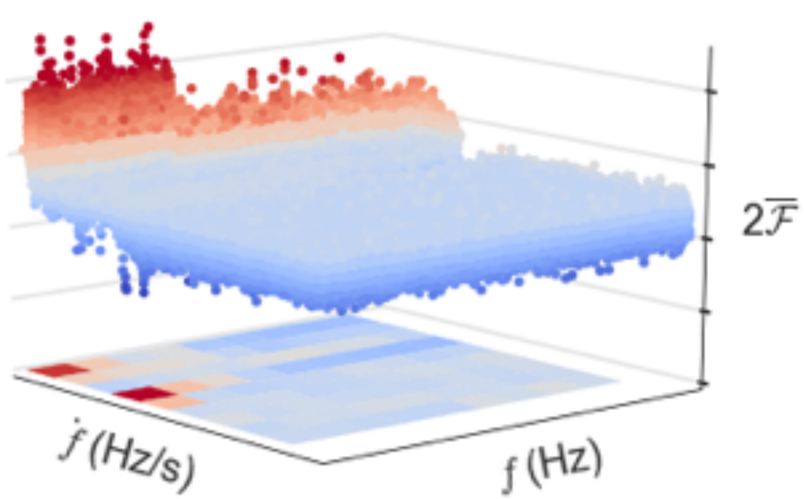
undisturbed
(Gaussian noise)

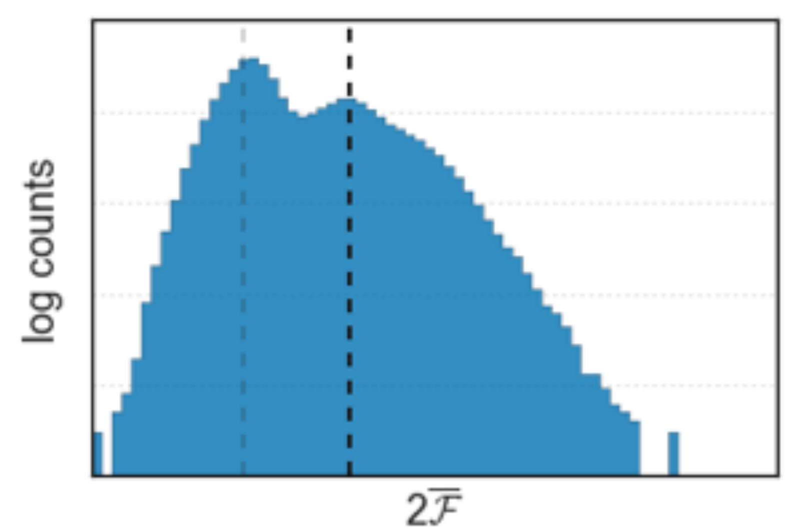




undisturbed
(Gaussian noise)

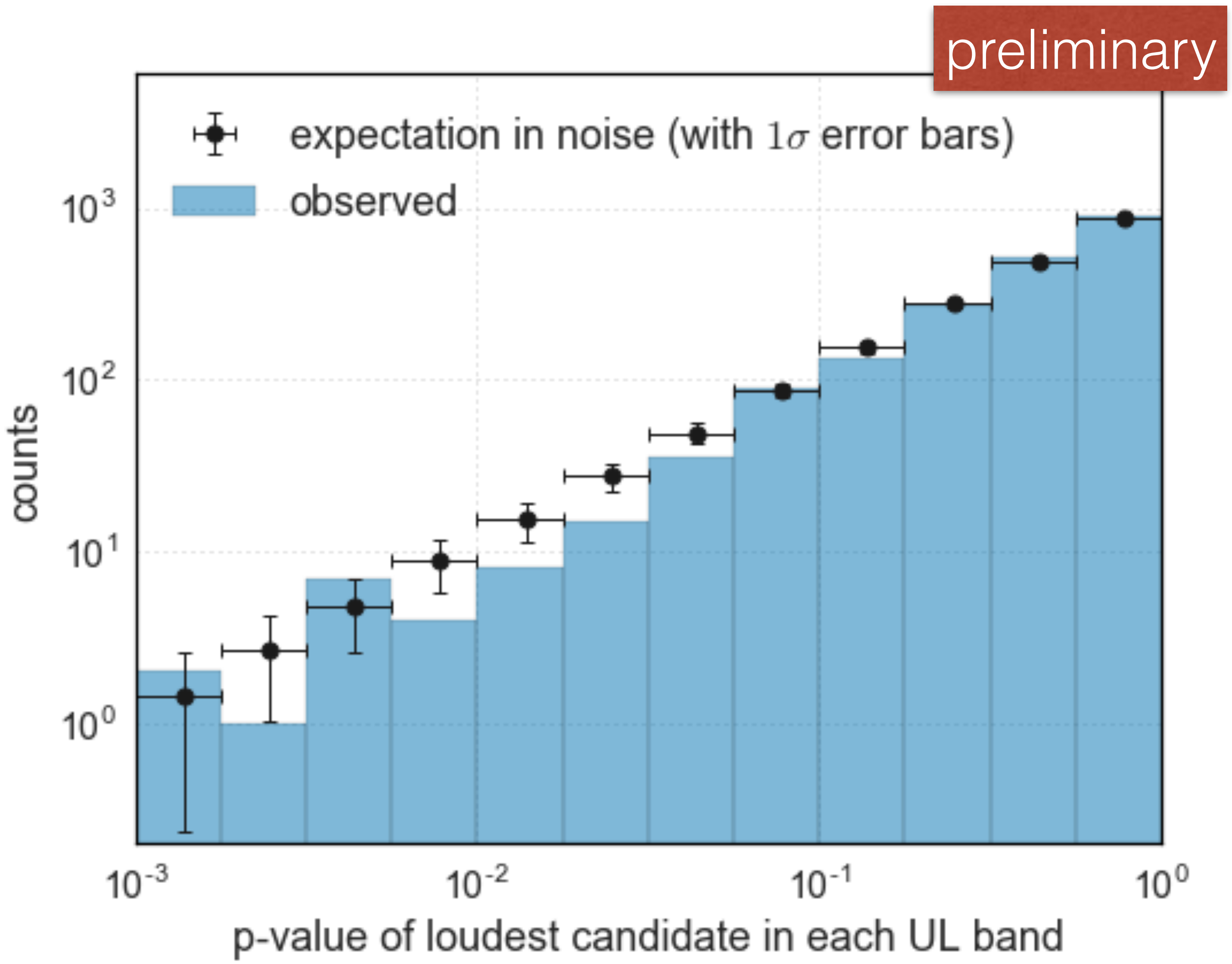
disturbed



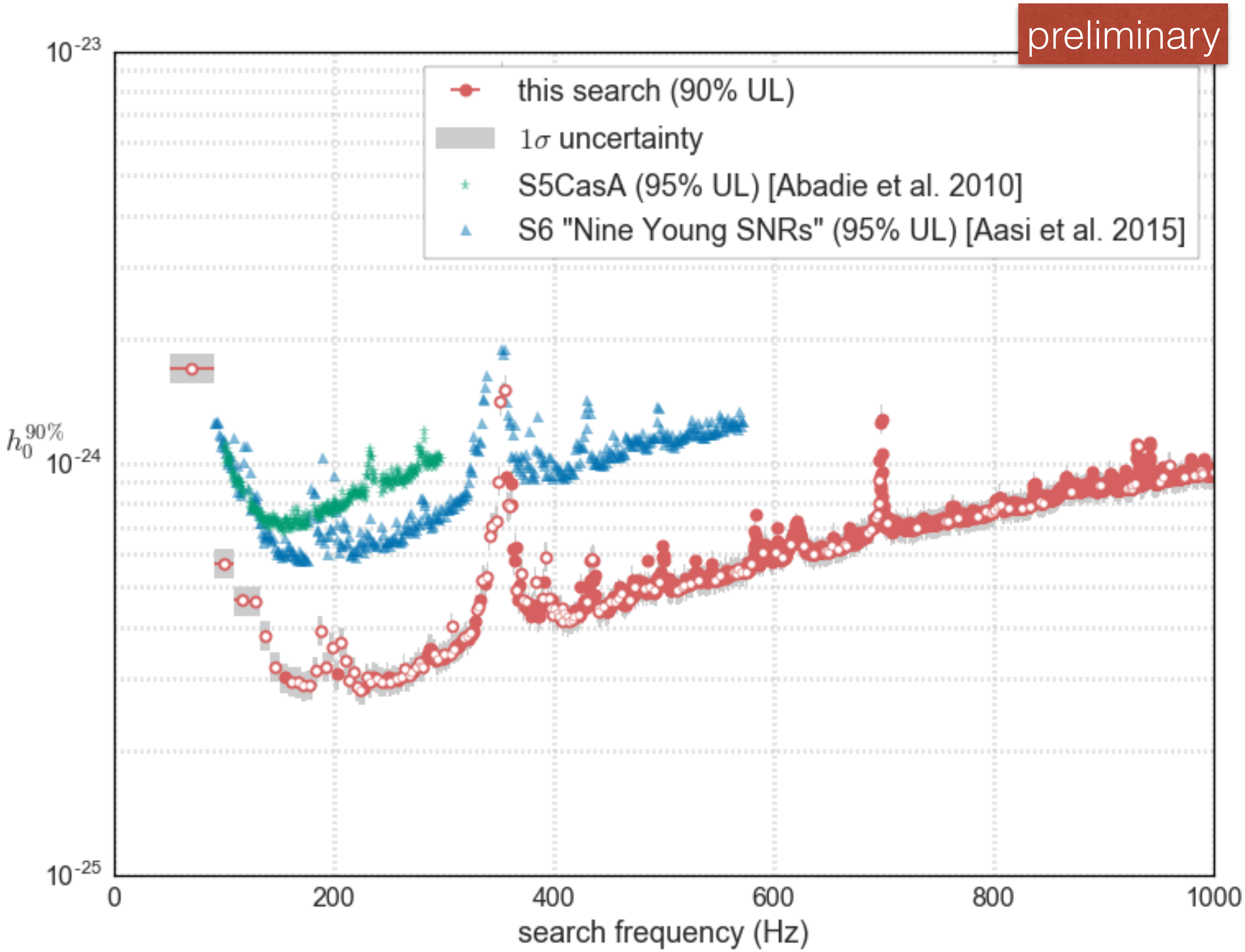


disturbed

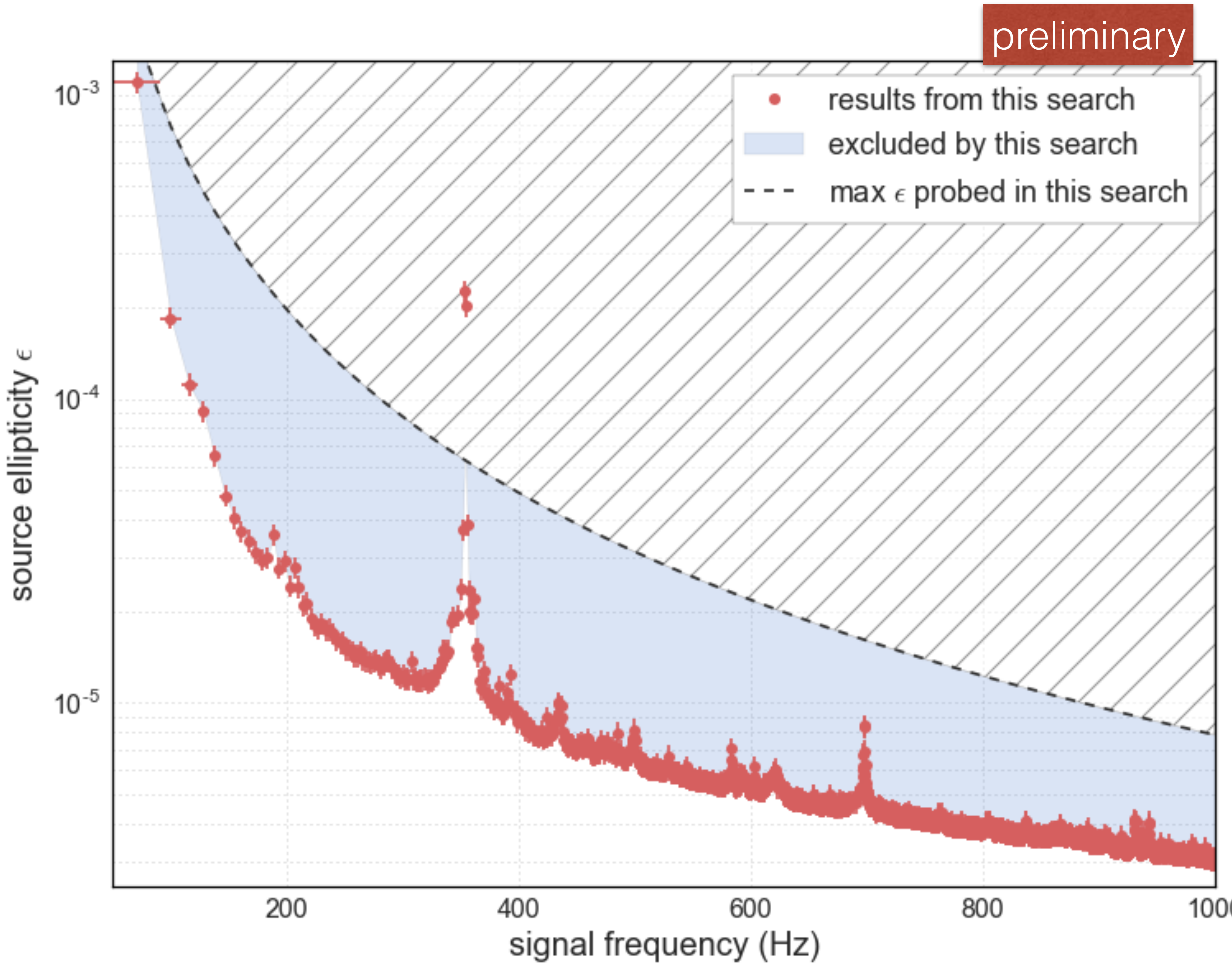
observed vs expectation in noise



Upper limits



Source ellipticity constraints



Citations

Ho, W. C. G. and Heinke, C. O., “A neutron star with a carbon atmosphere in the Cassiopeia A supernova remnant,” Nature 462 (2009)

LIGO and Virgo Collaborations, “Results of the deepest all-sky survey for continuous gravitational waves on LIGO S6 data running on the Einstein@Home volunteer distributed computing project,” submitted to Physical Review D, arXiv:1606.09619

Singh., A., et al., “Results of an all-sky high-frequency Einstein@Home search for continuous gravitational waves in the LIGO 5th Science Run,” LIGO document P1600196

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Pletsch, H. J., “Parameter-space metric of semicoherent searches for continuous gravitational waves,” Physical Review D 82 (2010)

Wette, K., “Estimating the sensitivity of wide-parameter-space searches for gravitational-wave pulsars,” Physical Review D 85 (2012)

Keitel, D., et al., “Search for continuous gravitational waves: Improving robustness versus instrumental artifacts,” Physical Review D 89 (2014)

Abadie, J., et al., “First Search for Gravitational Waves from the Youngest Known Neutron Star,” ApJ 722 (2010)

Aasi, J., et al., “Searches for Continuous Gravitational Waves from Nine Young Supernova Remnants,” ApJ 813 (2015)

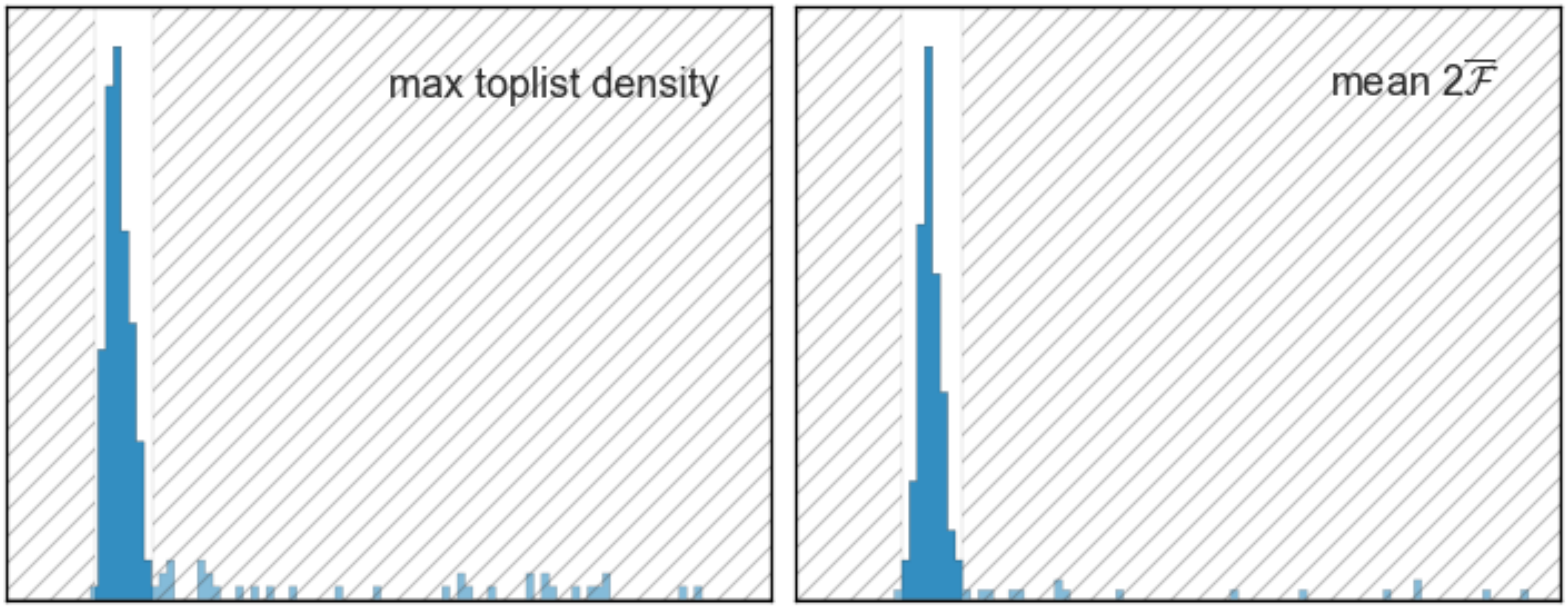
Back-up

Gory details

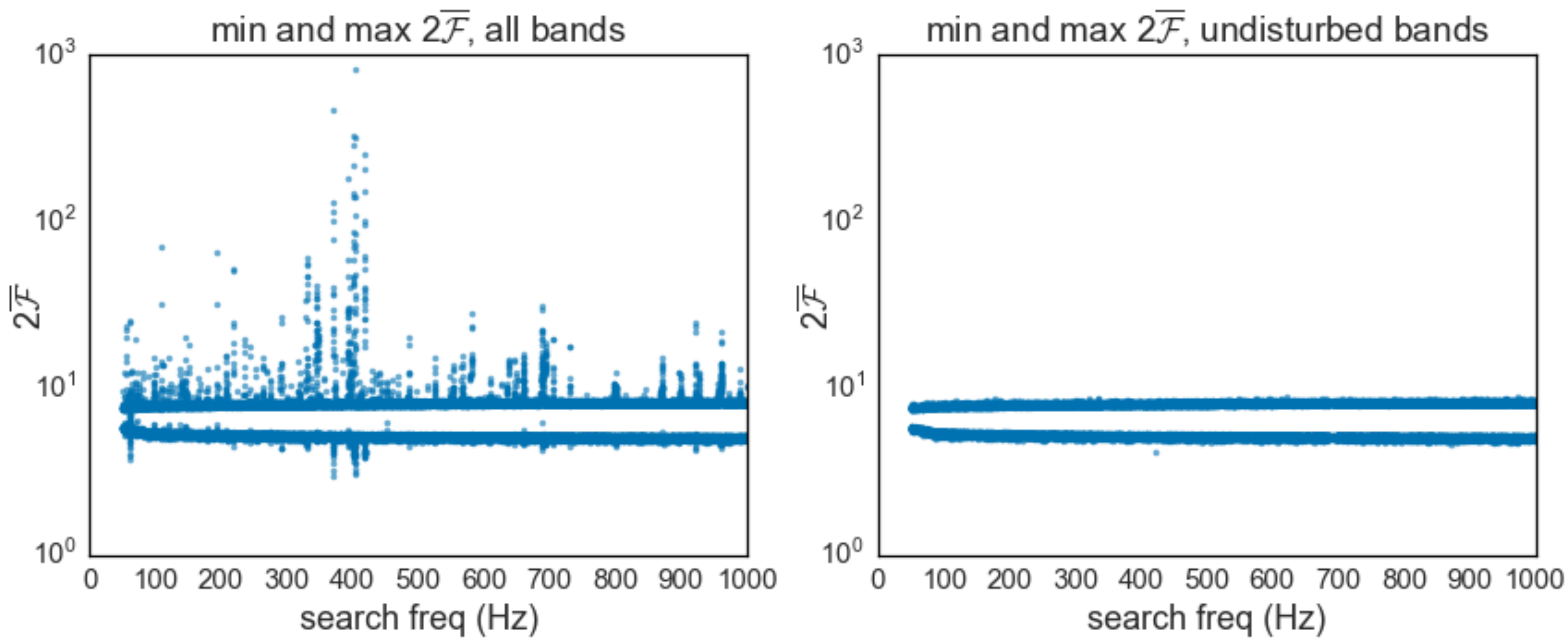
- Parameter space: “box-like”
  - alpha = 23:23:28, delta = 58^o 48’ 42”
  - Freq in [50, 1000] Hz
  - fdot in [-f/tau, 0] (tau = 300 yr)
  - f2dot in [0, $2f/tau^2$]
- Search set-up:
  - GPS = 949461068 to 971629632 (Feb to Oct 2010, 8.5 months)
  - Nseg = 44, Tcoh = 5.8 days (140 hrs)
  - dFreq = 5.3519e-7 | df1dot = 8.2281e-12 | df2dot = 1.9328e-18
  - gamma_1 = 90 | gamma_2 = 60
- No upfront cleaning of bands
- Identify disturbances using systematic method

SystDistId (working name)

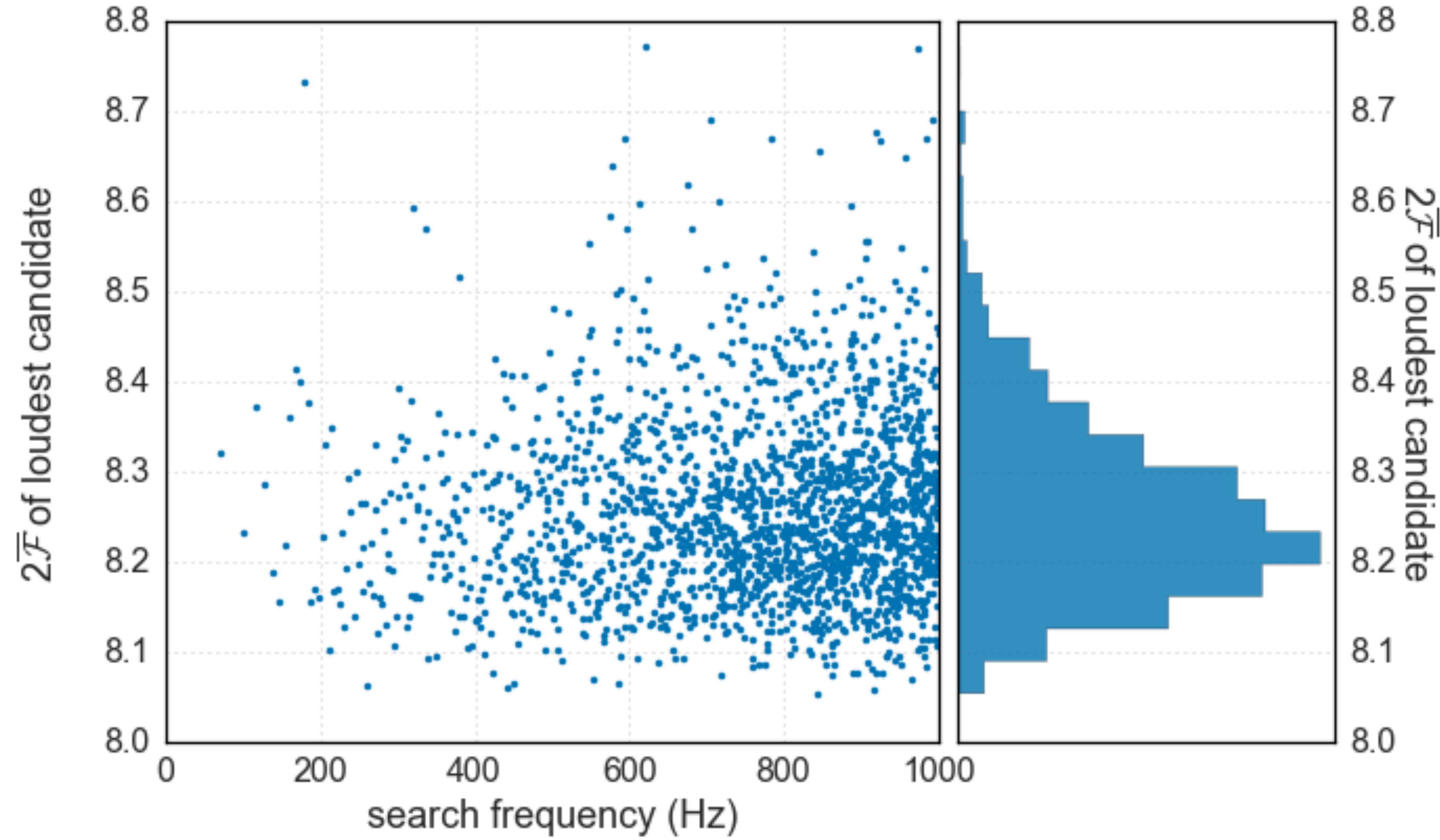
e.g., 90 to 100 Hz:



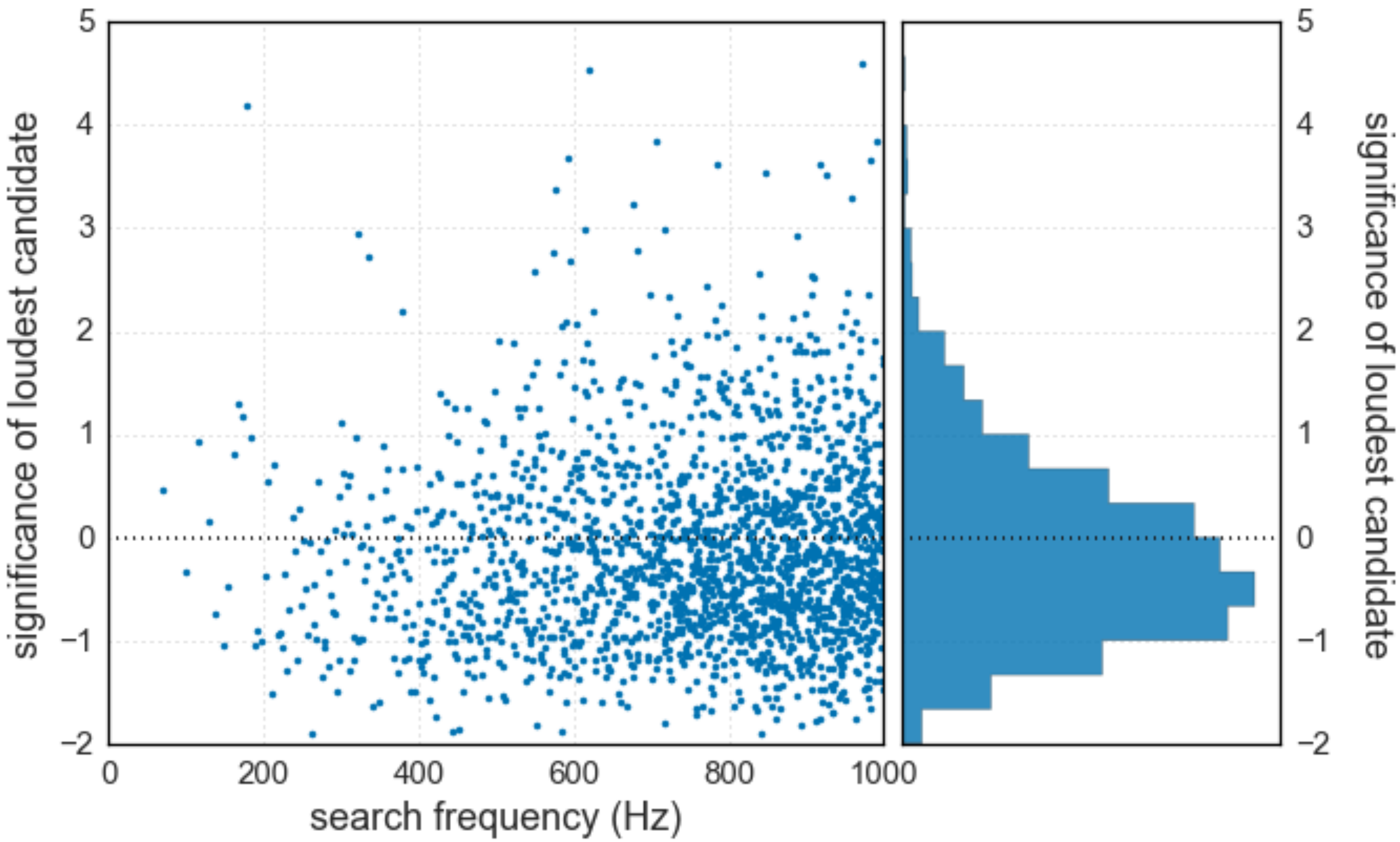
Removing disturbed bands



Loudest candidates



Loudest candidates



UL procedure

Sensitivity depth $D = \sqrt{(S_h)} / h_0 \approx$ constant

Calculate D for a set of representative freq bands, then use this ratio to obtain h_0 for the other bands