

# Blind Injection Studies in LVC

重力波の初検出に向けたトレーニング

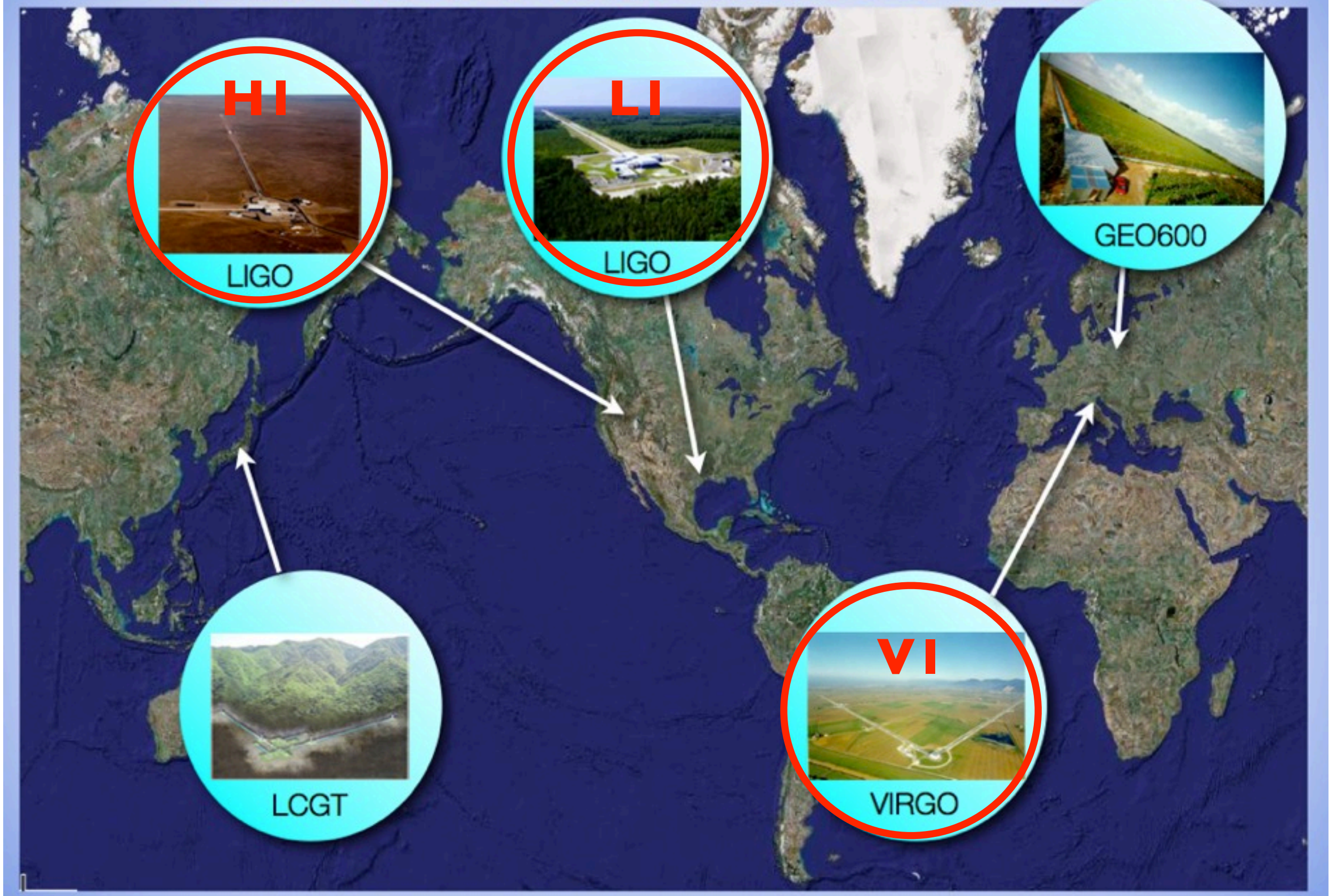


端山和大

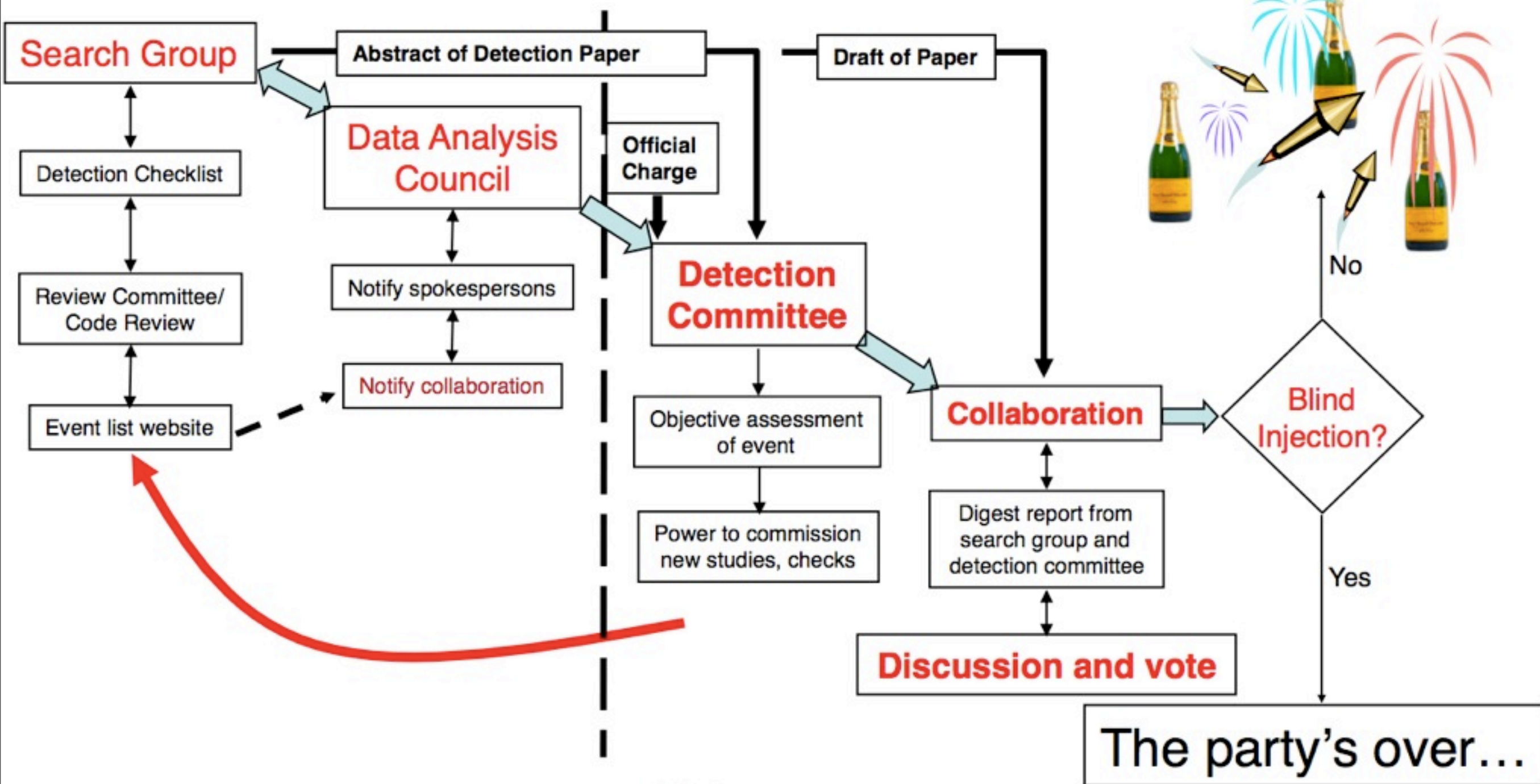
*National Astronomical Observatory of Japan*



# Gravitational wave detector network







**R. Weiss (MIT)**



 **S5 blind injection**

 **Transient**

 **CBC**

 **Burst**

 **S6 blind injection**

 **Transient**

 **Continuous**

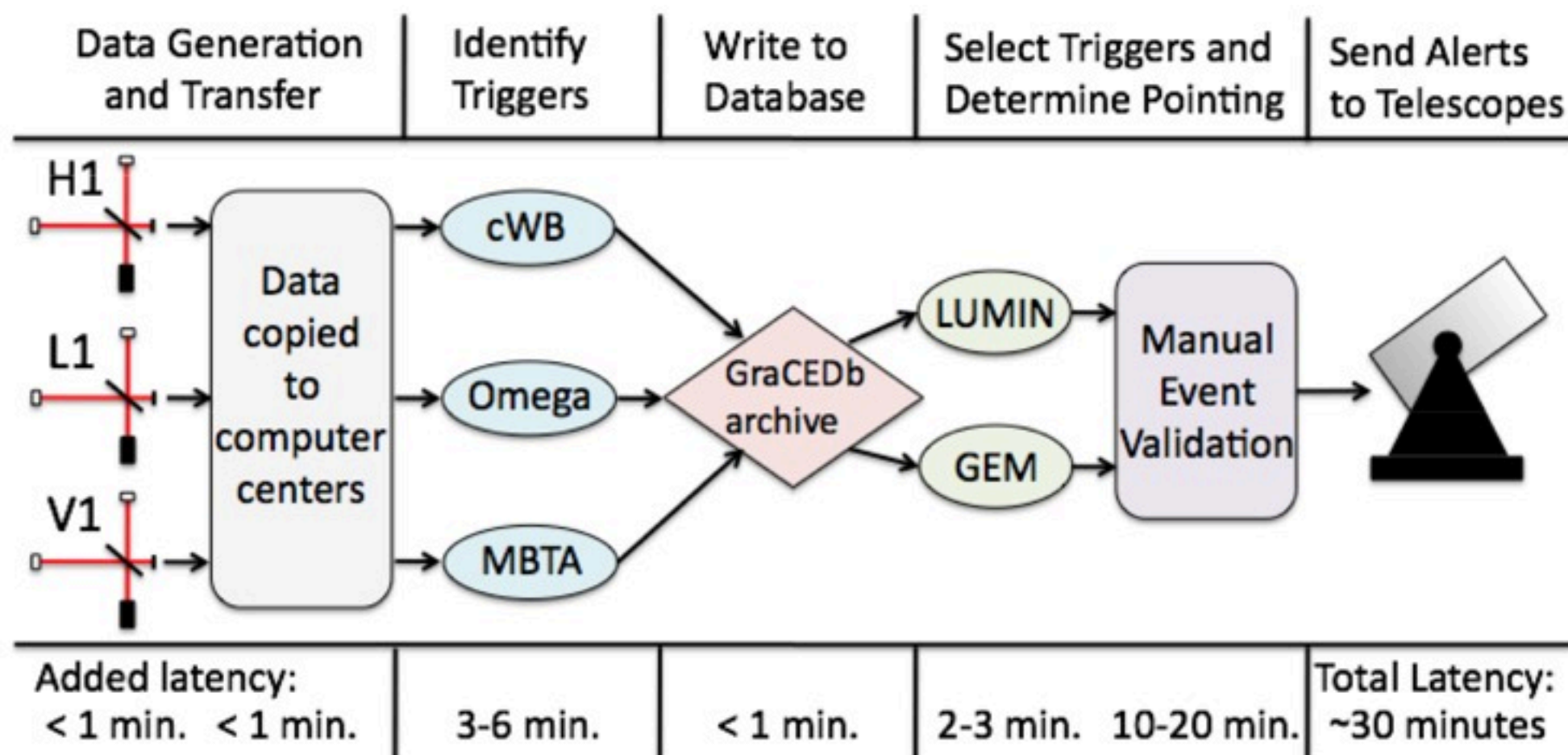
● S6ではフォローアップ観測のテストが重要視されていたので

● Low-latency on-line data analysis

● Off-line data analysis

が行われた。

## Flowchart of Low-latency on-line data analysis



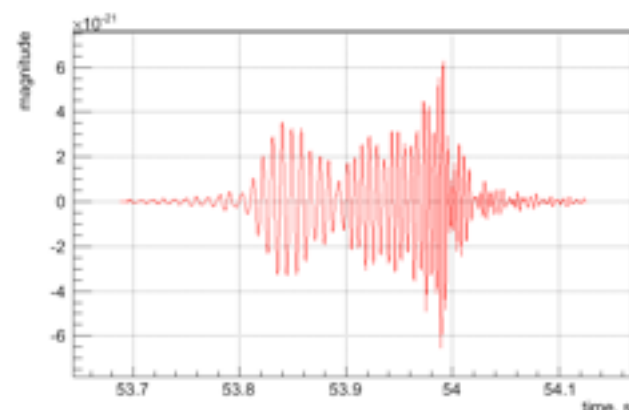
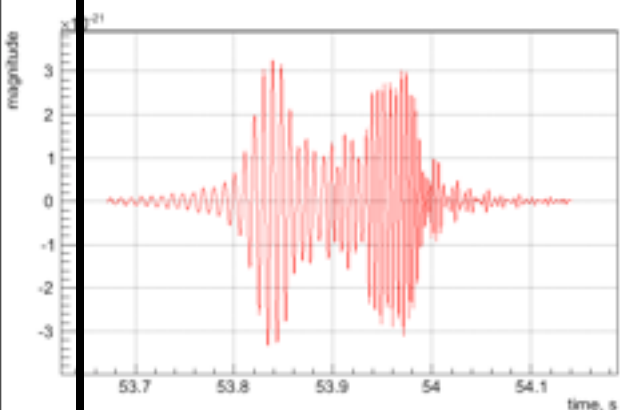
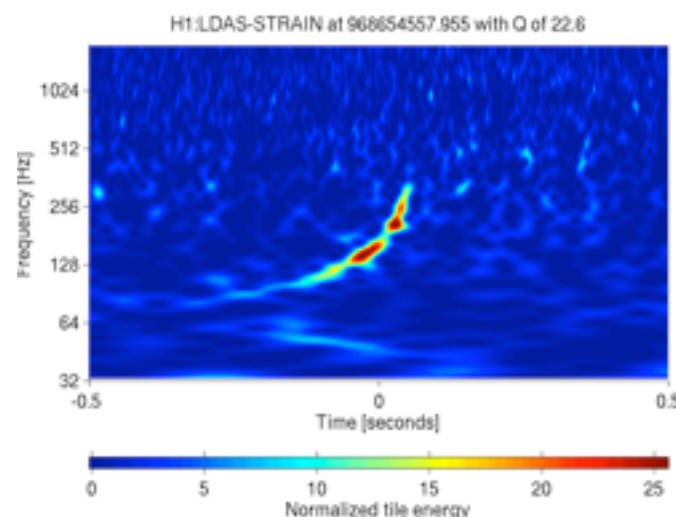
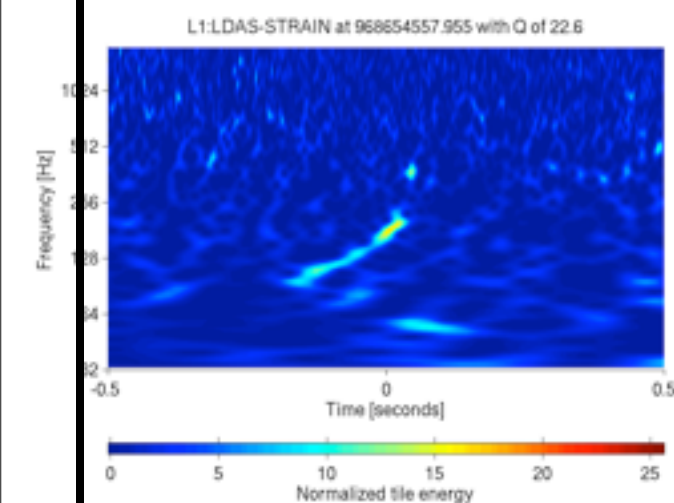


## Burst pipeline (cWB)

## Human Check

L1

H1



‘gold plated inspiral at first glance’ (Igor)

### Undefined flags

- Are there any undefined CAT 1 or CAT 2 flags? : No
- If Yes, please include the names of the flags here:
- GO/NOGO: **GO**
- Checked by: Christian Ott
- Comments:

### Sanity Checks Script

See sanity check script output - '+' means **GO** / '!' or '-' means **NOGO**

- Within detector locks: GO
- DQ Flags: GO
- KleineWelle trigger rate: GO
- GO/NOGO: **GO**
- Checked by: Christian Ott, Peter Shawhan, LLO [SciMon](#)
- Comments: Confusion about error messages concerning Virgo (script says 'ignore')

### Control Room Sign-off - Include any notes on Omega grams or FOM here

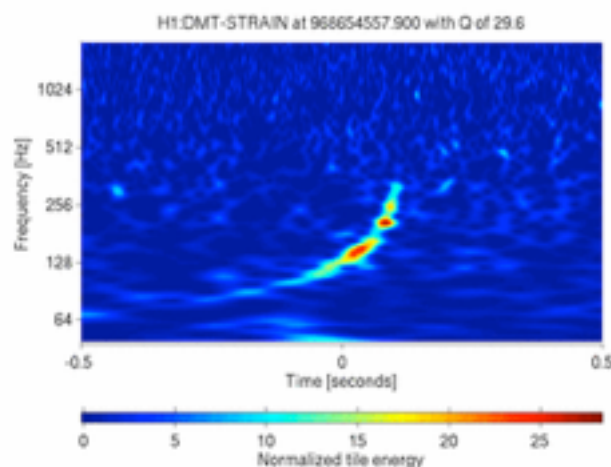
- H1:
  - Scimon Name: Kiwamu Izumi
  - GO
- L1:
  - Scimon Name: Rahul Kumar
  - GO
- V1:
  - Scimon Name: K.Borkowski
  - GO
- GO/NOGO: **GO**
- Comments:

$t_{\text{dog}}+8[\text{m}]$

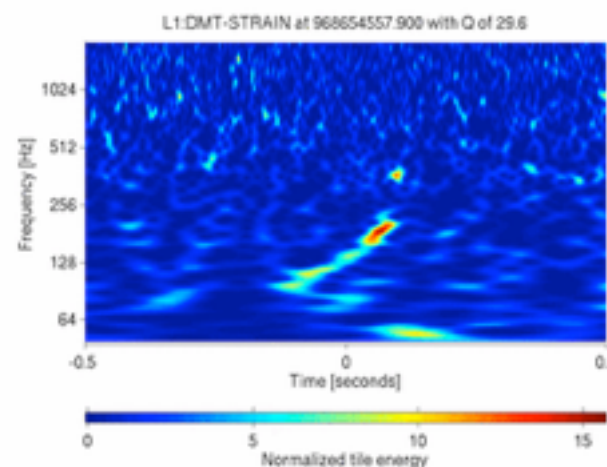
$t_{\text{dog}}+42[\text{m}]$

- **HI-LI cross-correlation analysis**ではスペクトルの見積もりが9秒前にLIに出現したグリッチのせいで正しく行われず、信号は見えなかった。→スペクトルの見積もりはstationarityを調べてから！
- もう一つのバーストパイプライン**Omega** は9秒前のグリッチもフォーカスしてしまい、信号をミスした。(その時間を指定して解析させると、はっきりとチャープが見える)→一つのセグメントの中に複数の信号が入っていても対処できるアルゴリズムでないとダメ

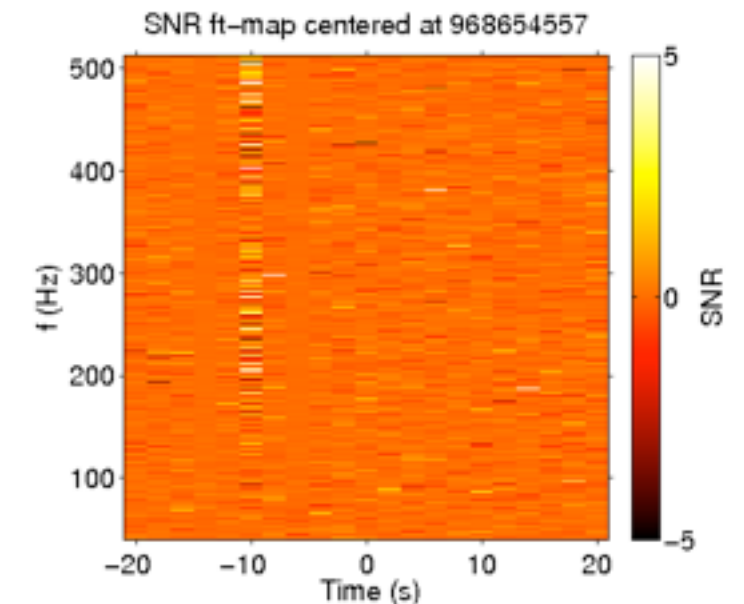
**HI**



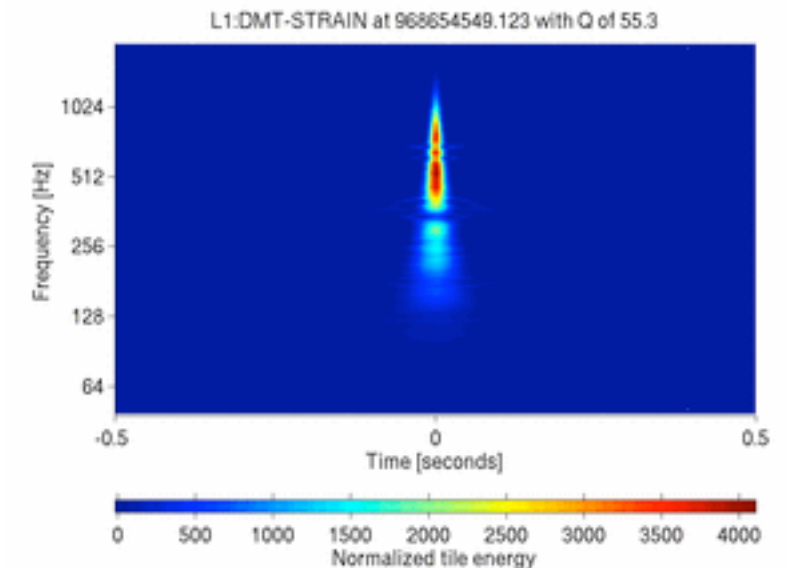
**LI**



## CCアウトプット

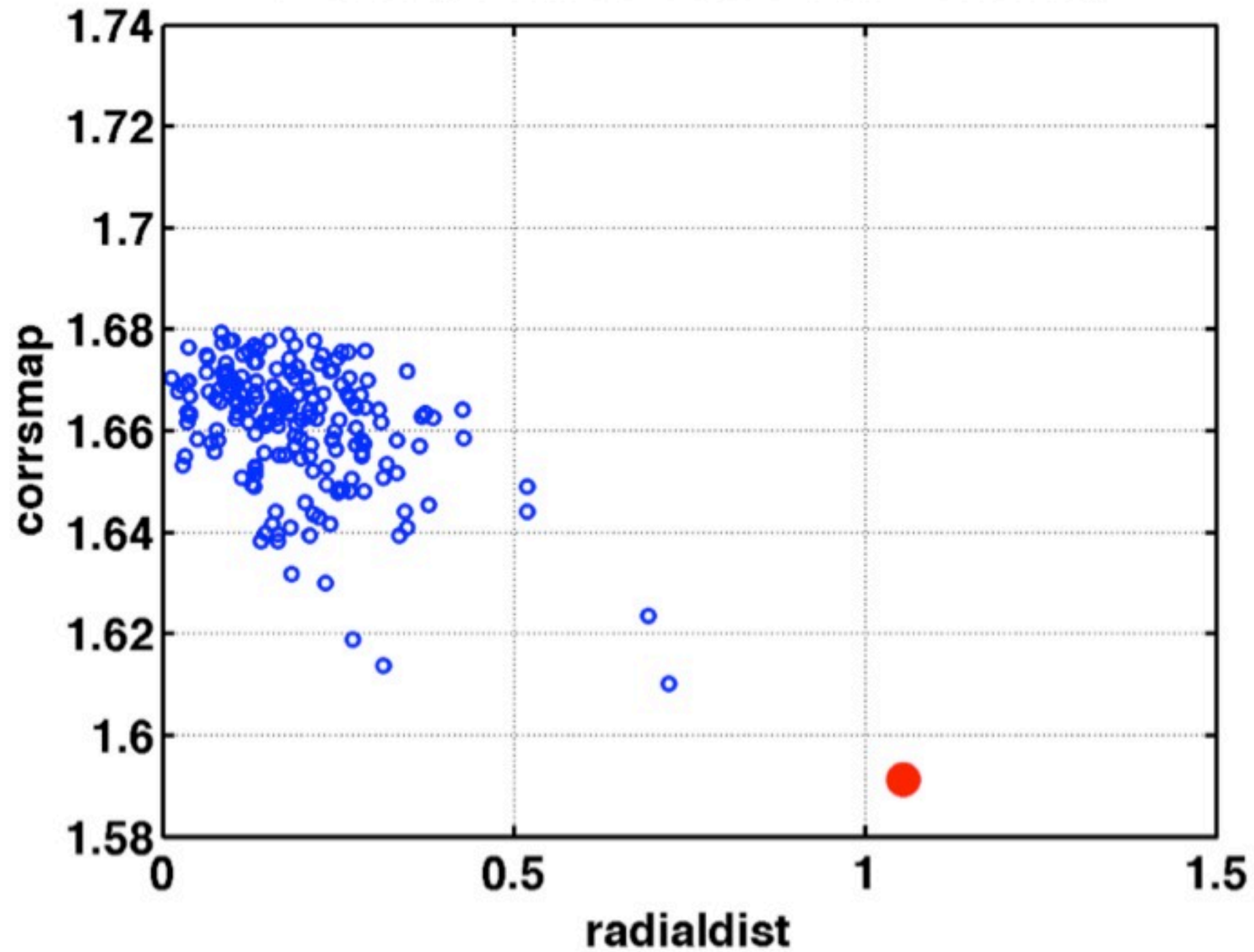


## LIグリッチ

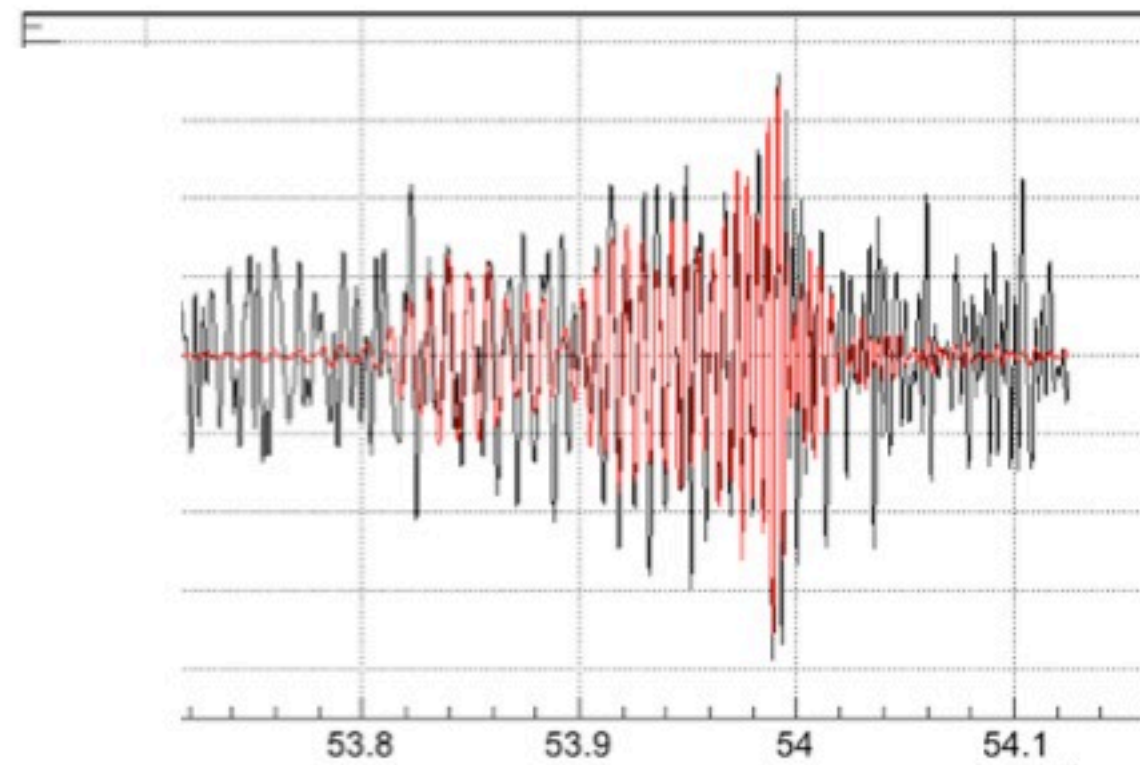
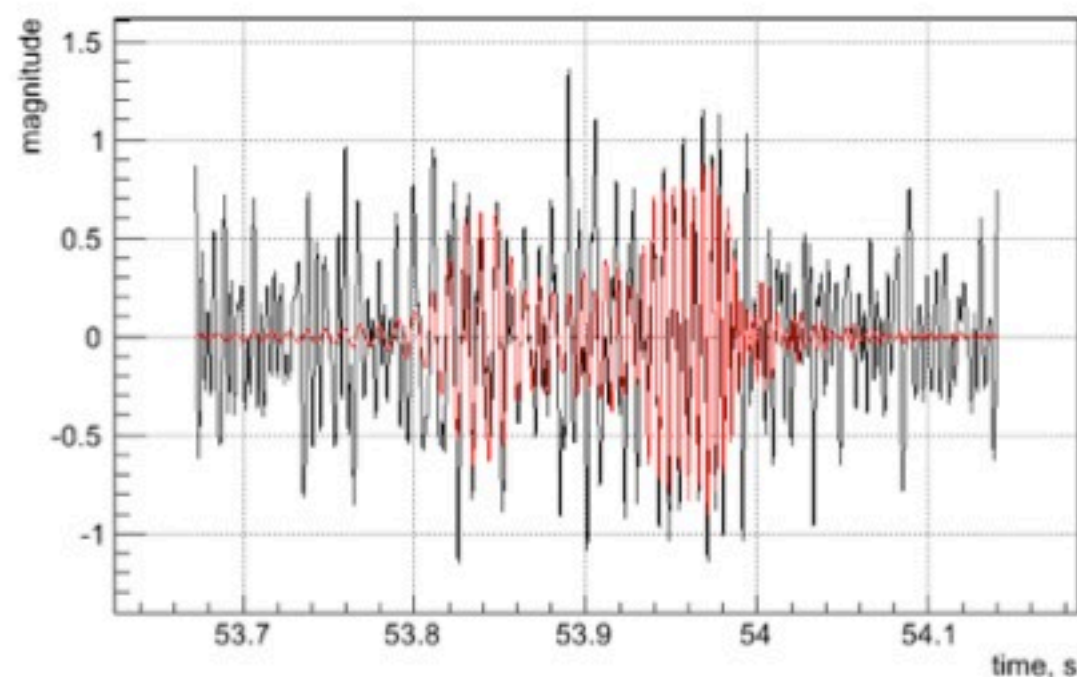
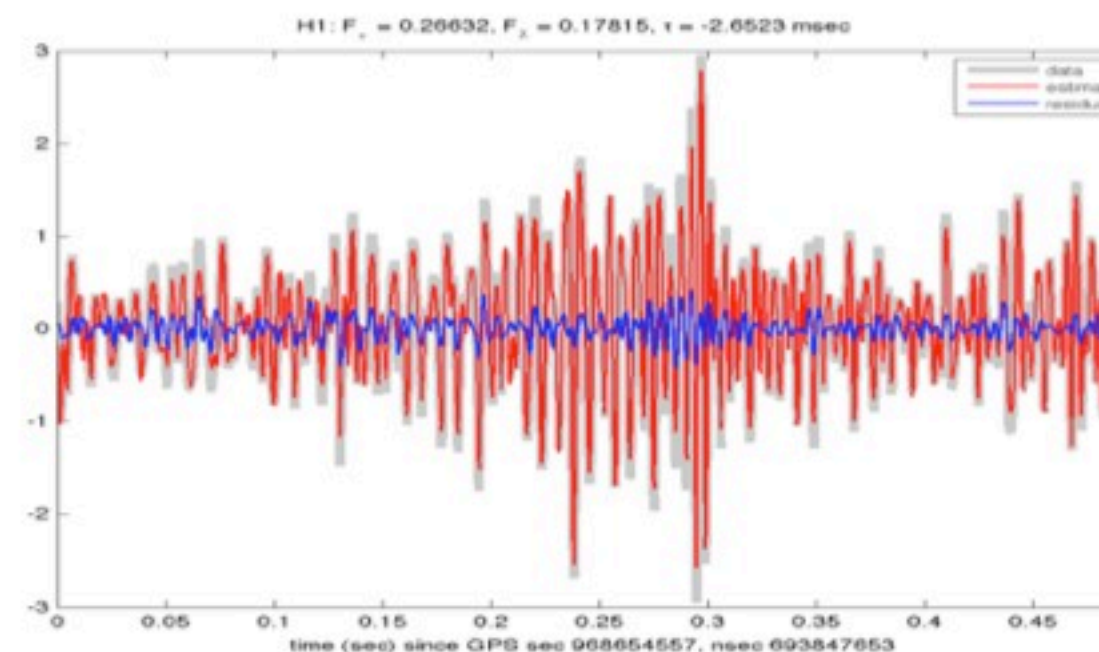
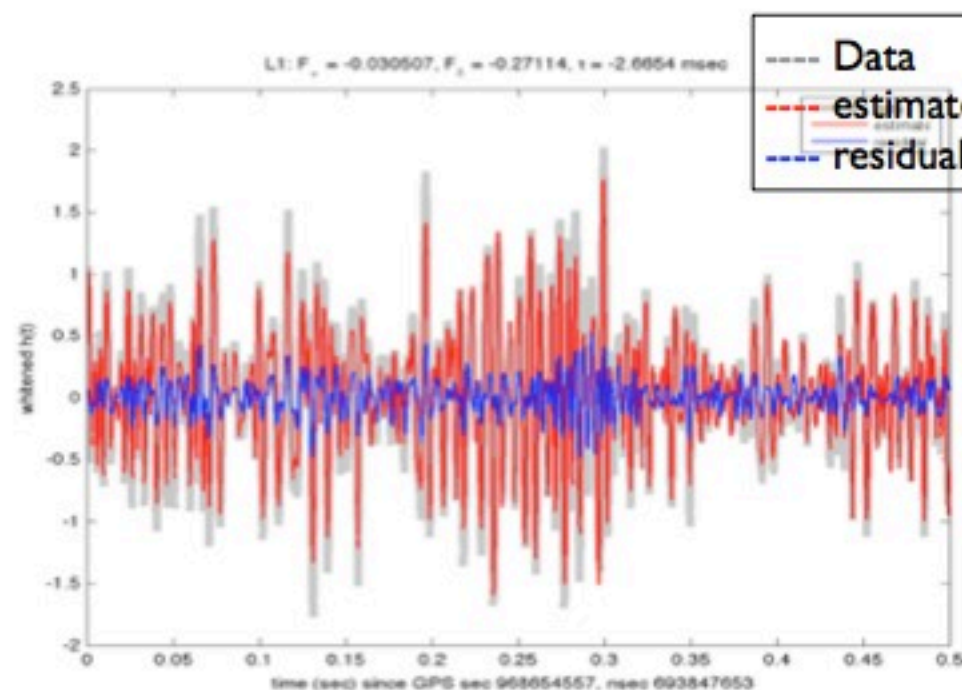




Scatter plot of radialdist and corrsmap



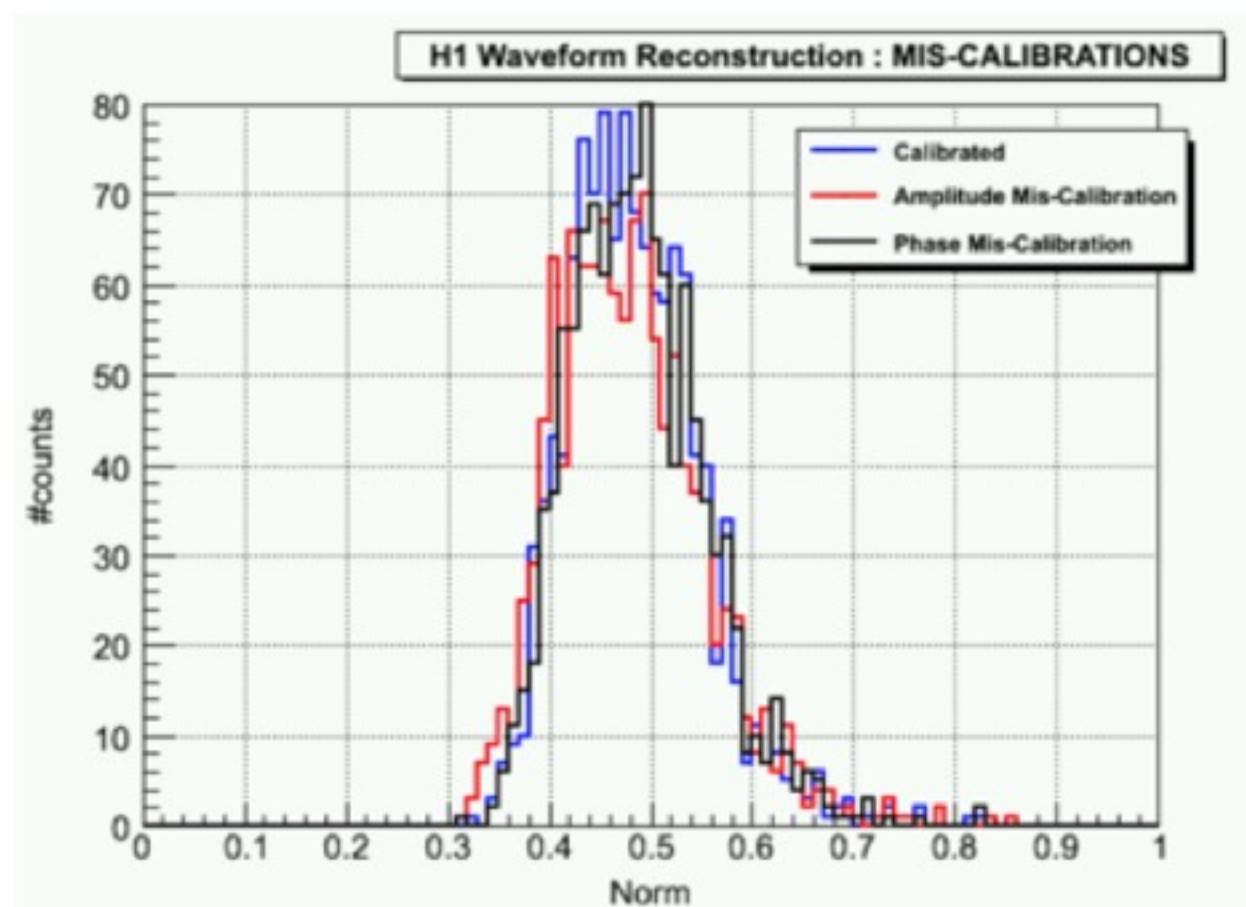




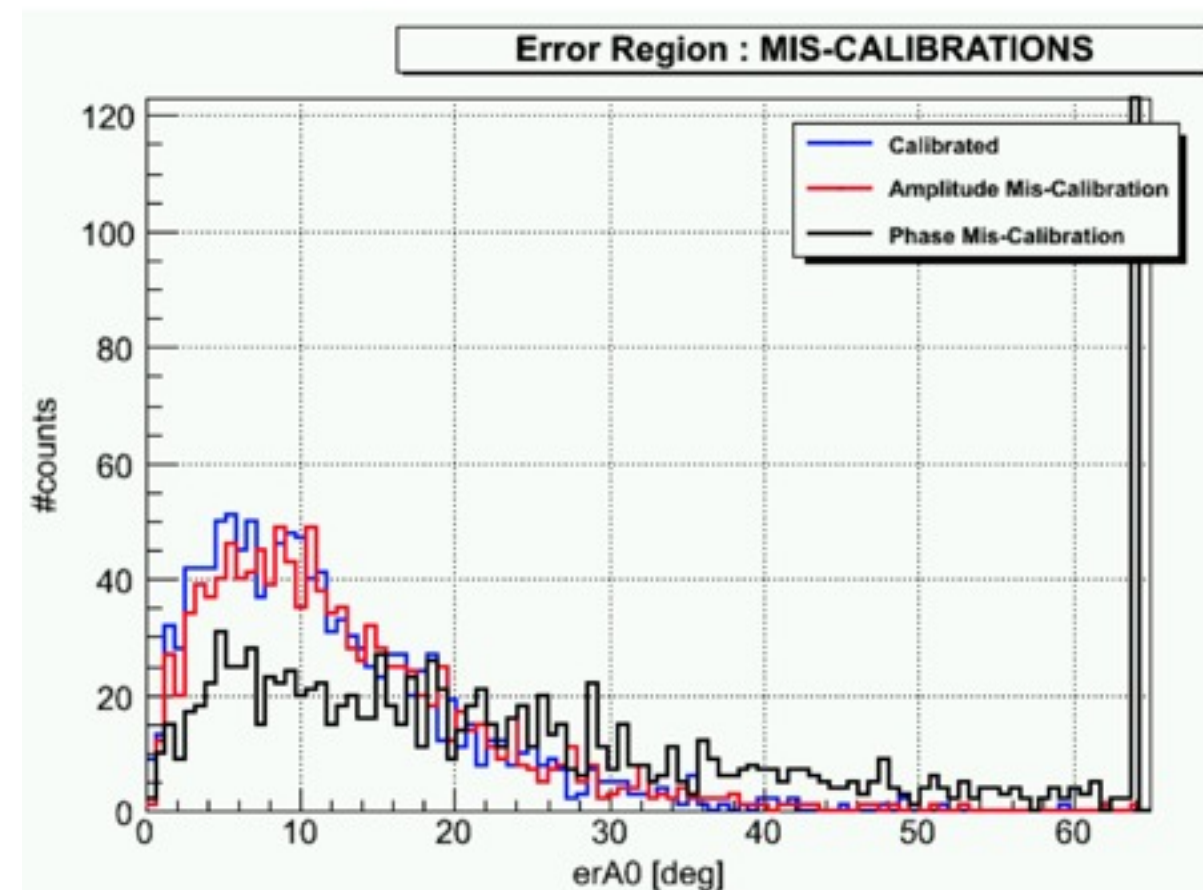


- キャリブレーションエラーの影響は結果を変えるほど大きなものではないことが分かった。

## Waveform reconstruction

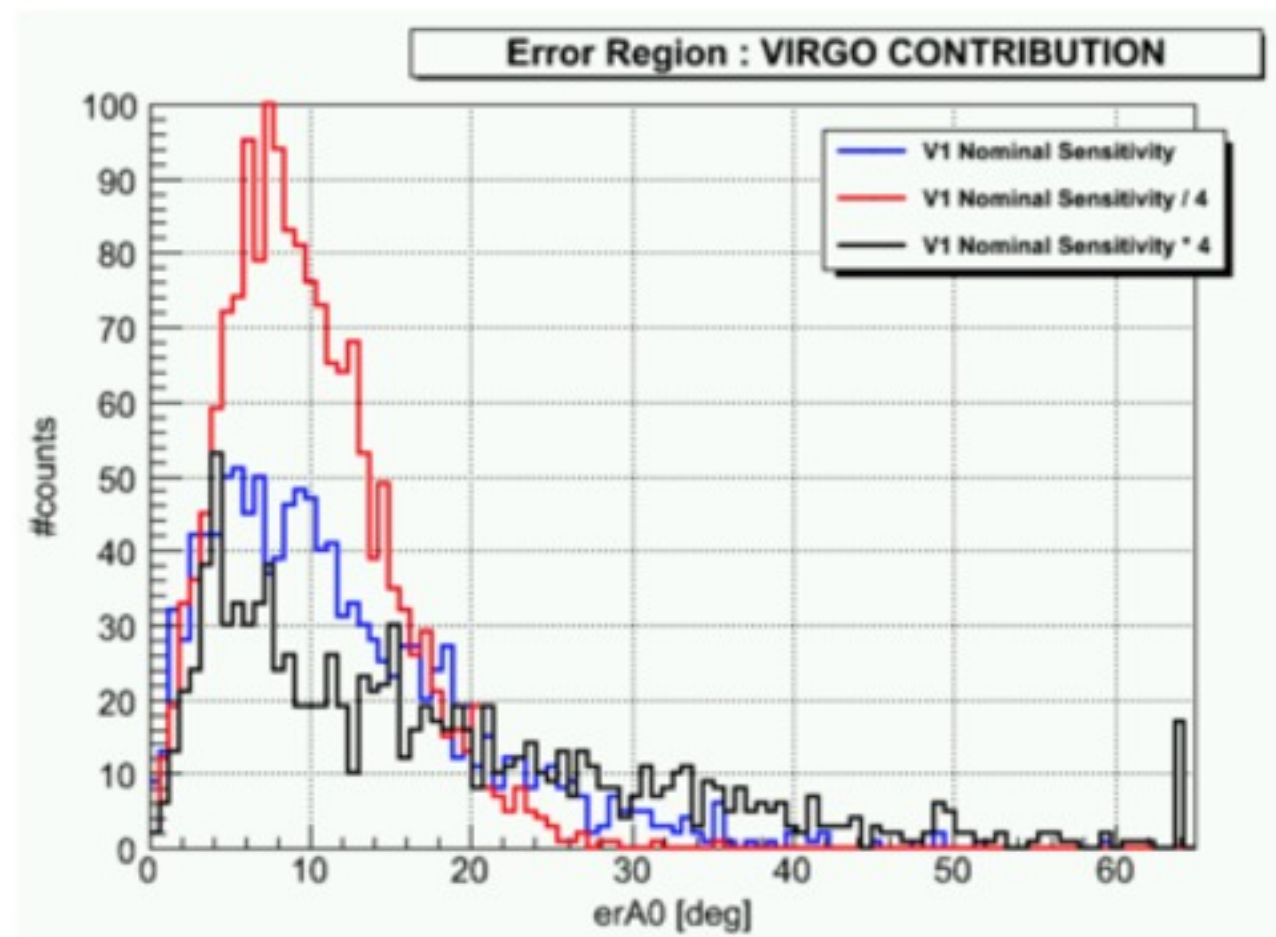


## Sky location





- **Virgo**の感度を4倍にすると、重力波の到来方向推定は著しく改善される。







## Audio recordings of this candidate.

Caution: adjust volume before putting on headphones.

1. [H1\\_G19377.wav](#): audio file containing whitened and bandpassed  $h(t)$  from H1, courtesy of gstlal. With a decent pair of earbuds or headphones, the chirp can be clearly heard around 17 seconds into the recording.
  2. [L1\\_G19377.wav](#): audio file containing whitened and bandpassed  $h(t)$  from L1, courtesy of gstlal. With a decent pair of earbuds or headphones, the spike glitch can be heard around 8 seconds and the chirp can be heard around 17 seconds into the recording.
  3. [V1\\_G19377.wav](#): audio file containing whitened and bandpassed  $h(t)$  from V1, courtesy of gstlal.
  4. [L1.wav](#): Audio file of reconstructed L1 strain from cWB.
  5. [H1.wav](#): Audio file of reconstructed H1 strain from cWB.
- [stereo\\_H1L1\\_hoft.wav](#): Stereo recording of whitened  $h(t)$ ; channel 1 is H1 and channel 2 is L1.

H1

L1

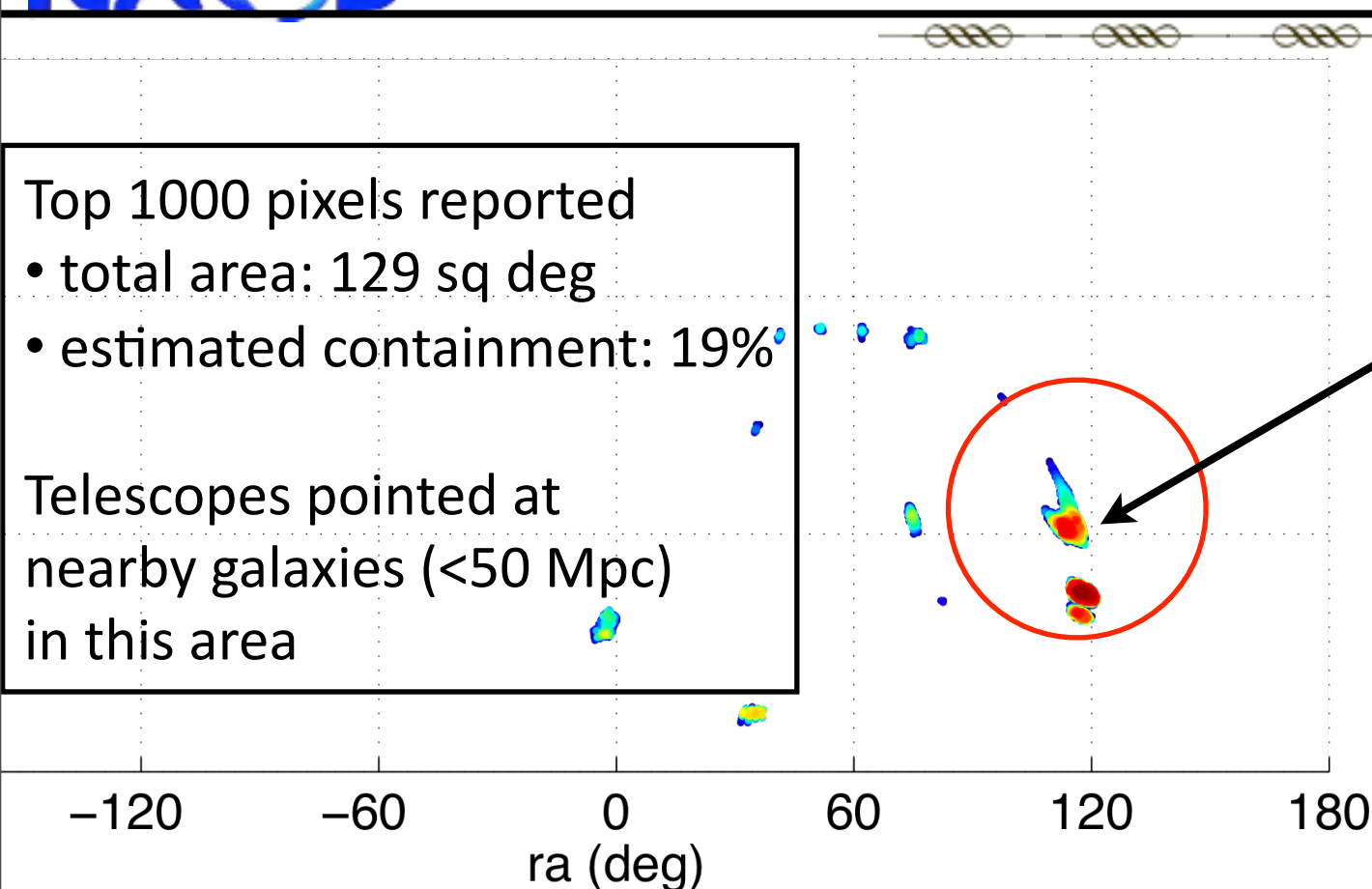
生データ

再構成

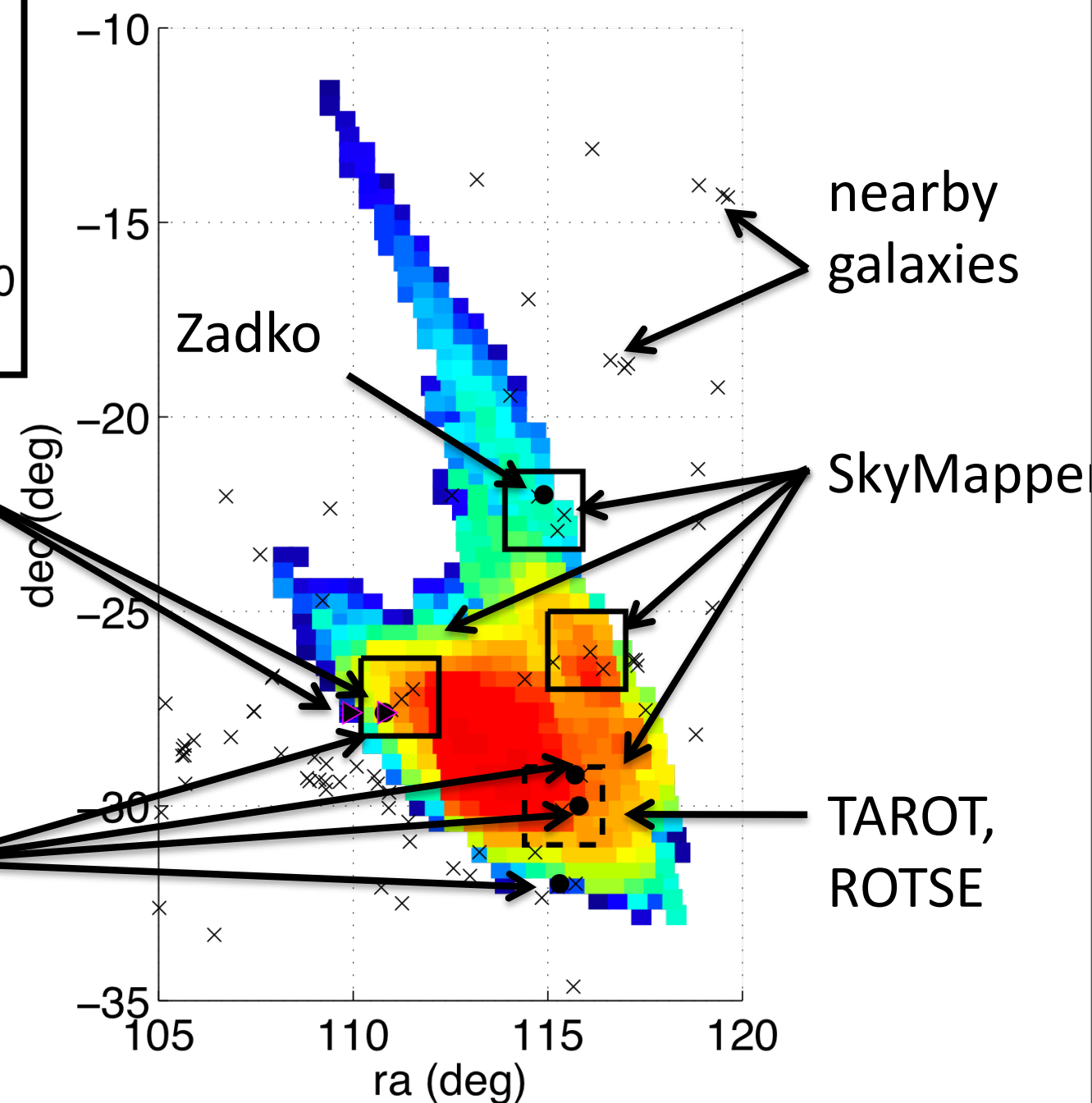
Top 1000 pixels reported

- total area: 129 sq deg
- estimated containment: 19%

Telescopes pointed at nearby galaxies (<50 Mpc) in this area



**LUMIN pipeline**  
銀河カタログを参照して  
これらの島が選ばれた

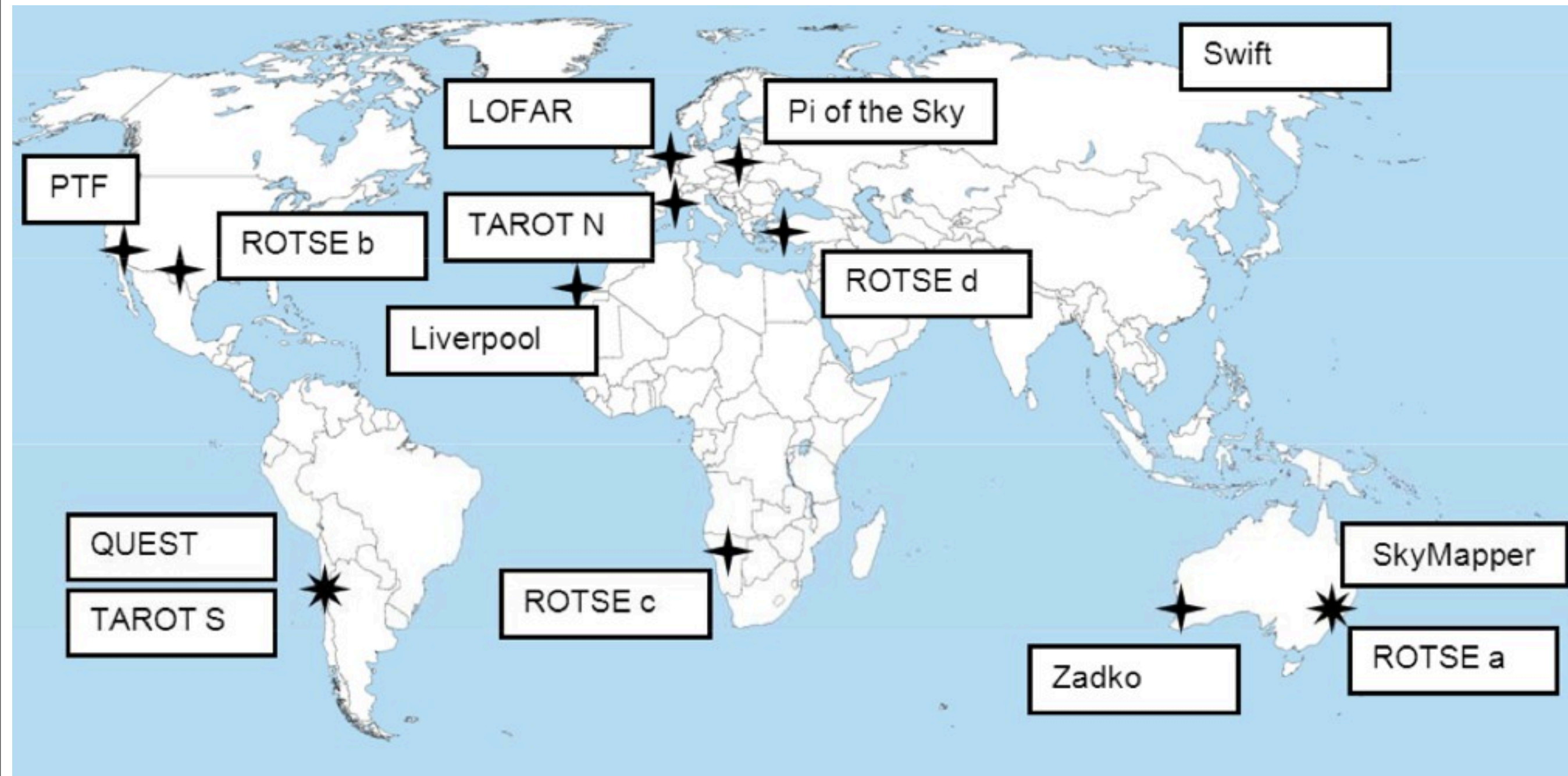


## Usable images:

- TAROT: 20, + [44 min - 4 day]
- ROTSE: 102, + [0.5 - 29] day
- Zadko: 63, + [1, 160] day
- SkyMapper: 21, + 8 day
- *Swift*: 4, + [0.5, 105] day

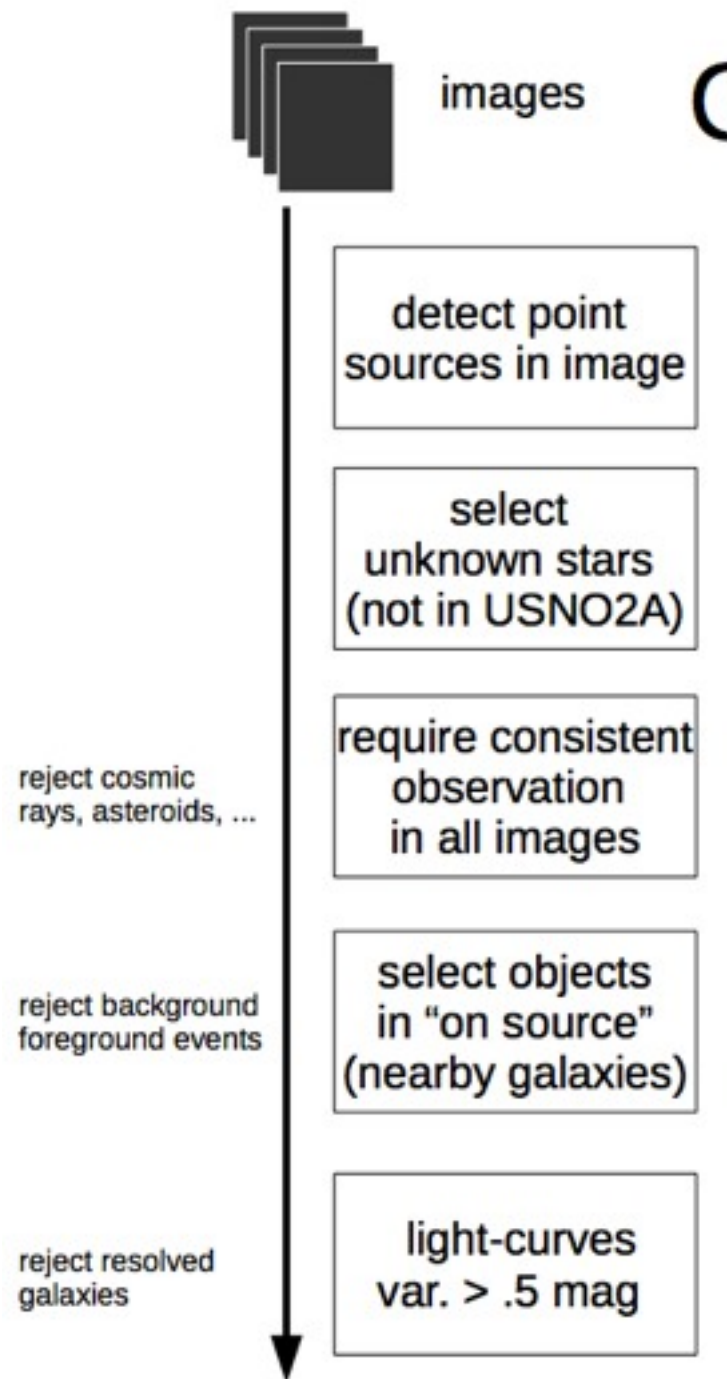
*Swift*

Zadko



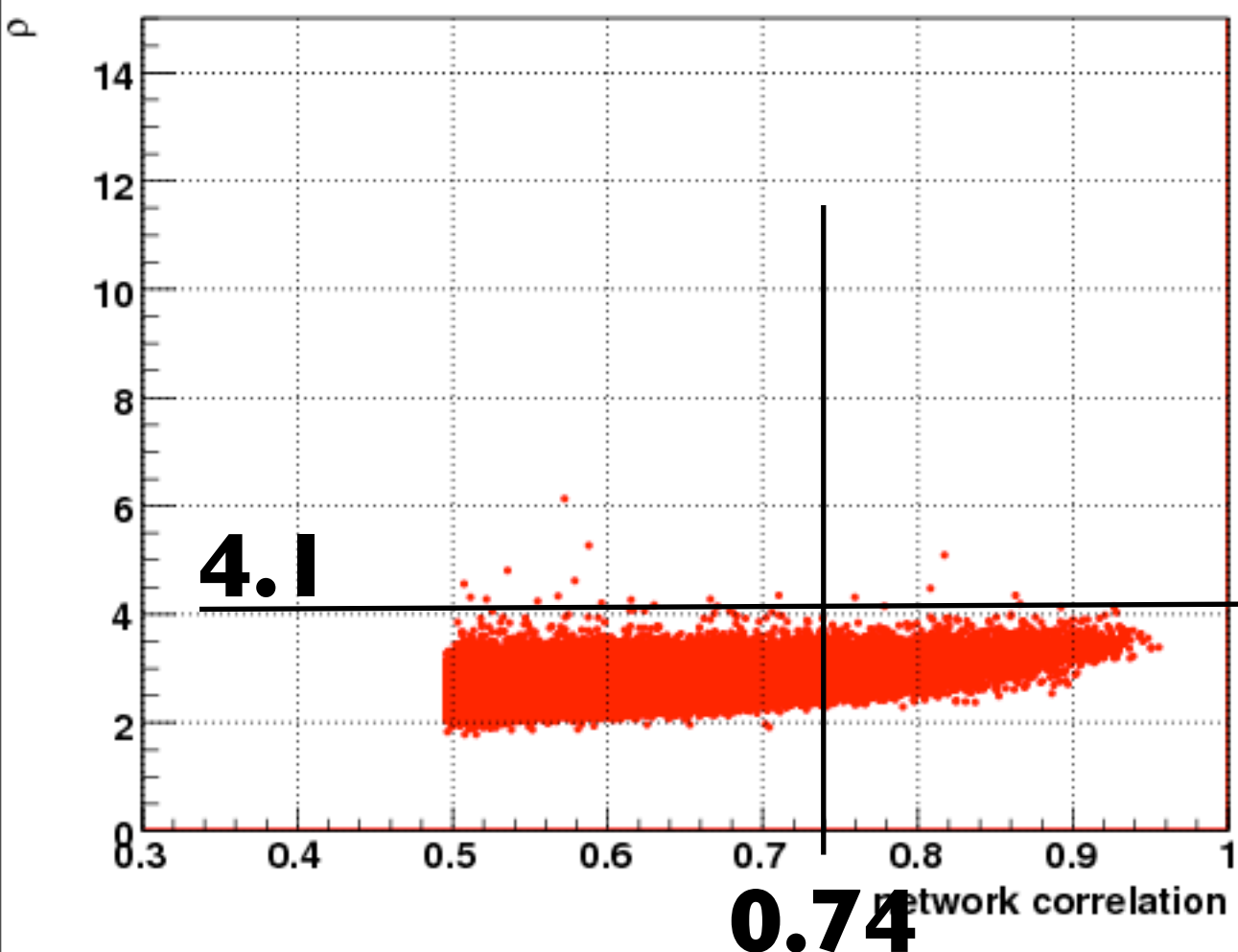


- After image analysis, all EM telescopes did not find any transient events in their images.

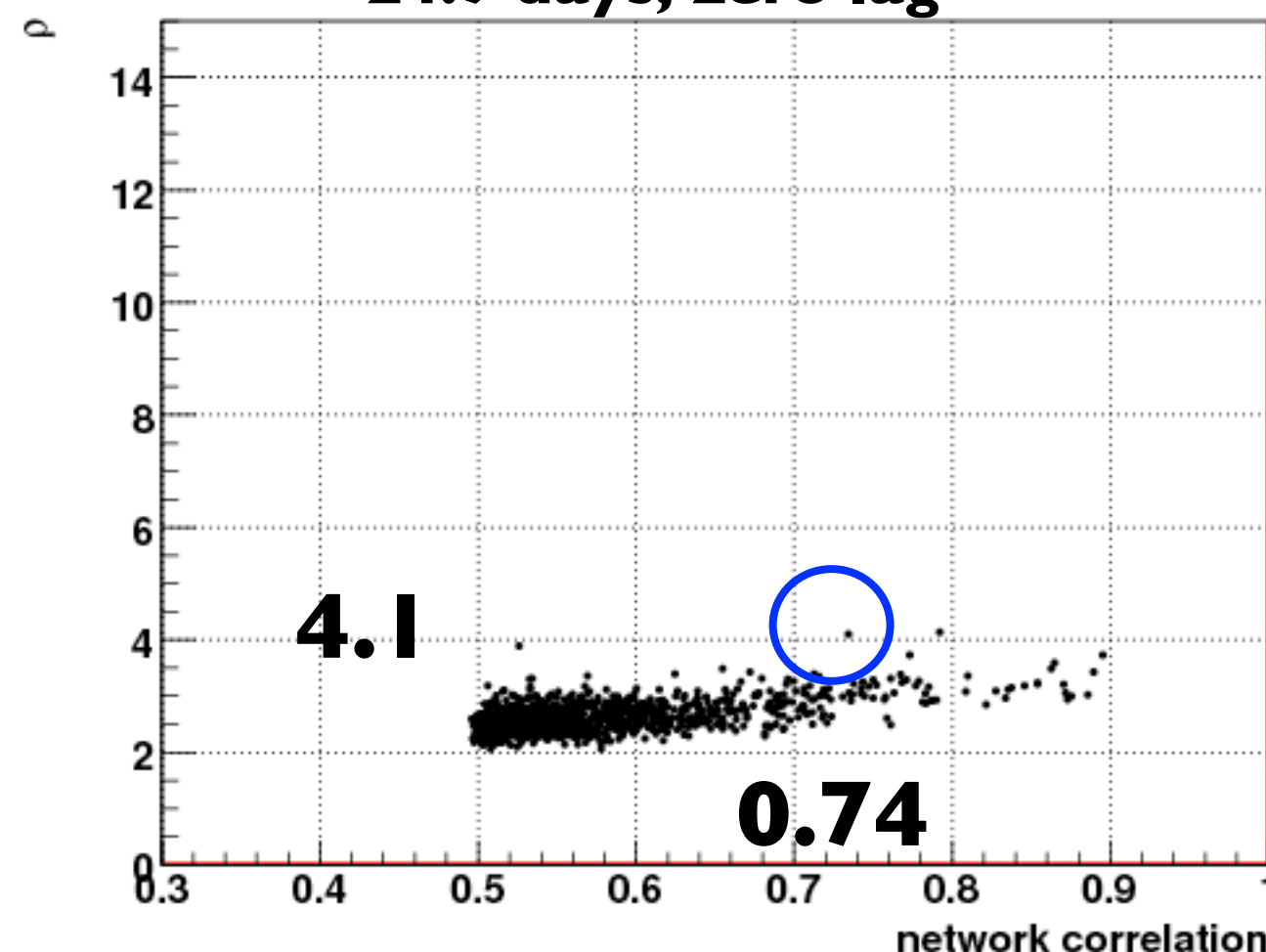


- **LI-HI-VI network**
- **SNR of LI:9.2, HI:13.8, VI:4.9**
- **network correlation: 7.4, rho: 4.1**
- **IFAR:3.27years ( < 8 years, our threshold)**
- **No detection from burst search**

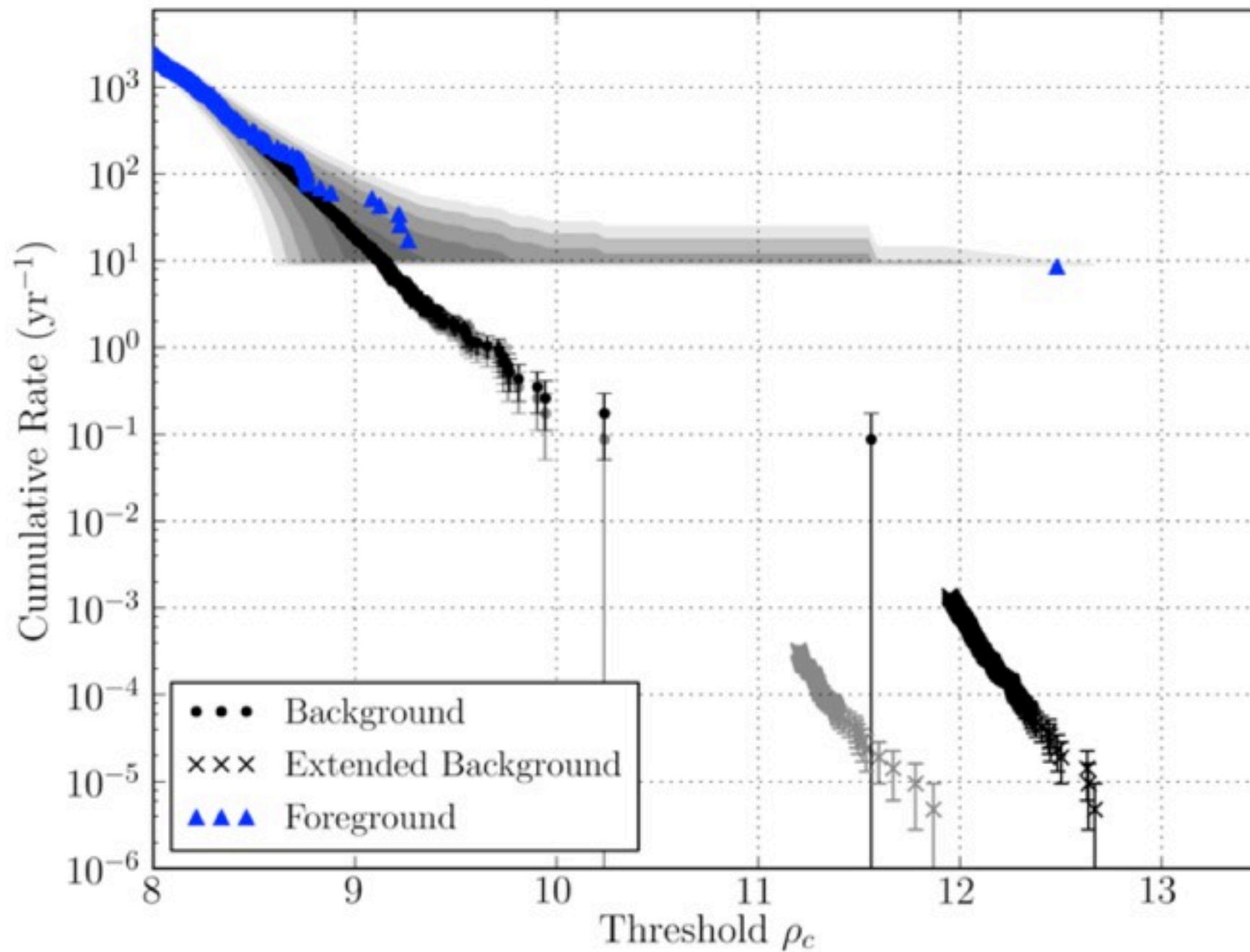
**13.1 years, 200 non-zero lags**



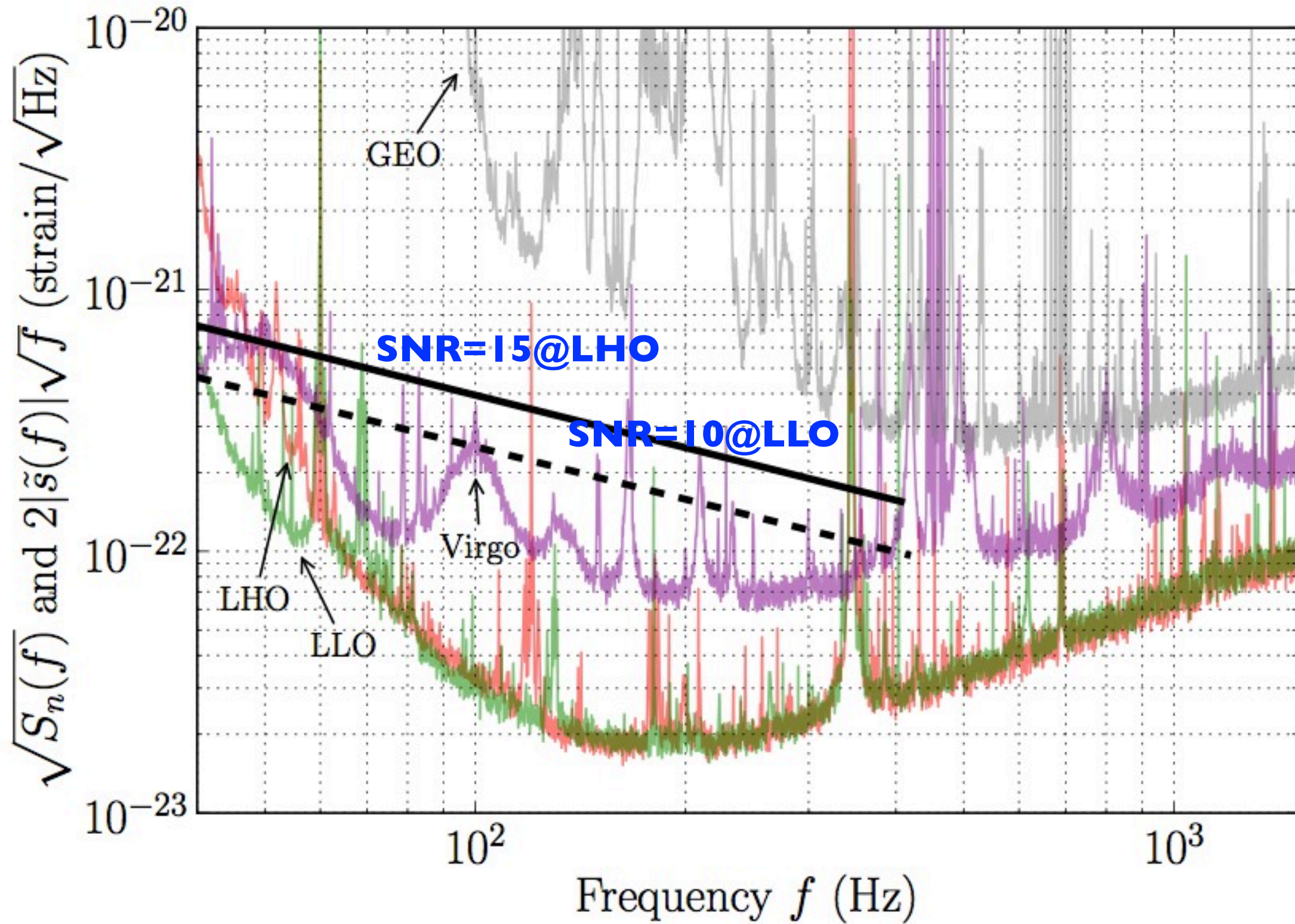
**24.9 days, zero lag**



● False alarm rate is 1/7000 years, significant enough!



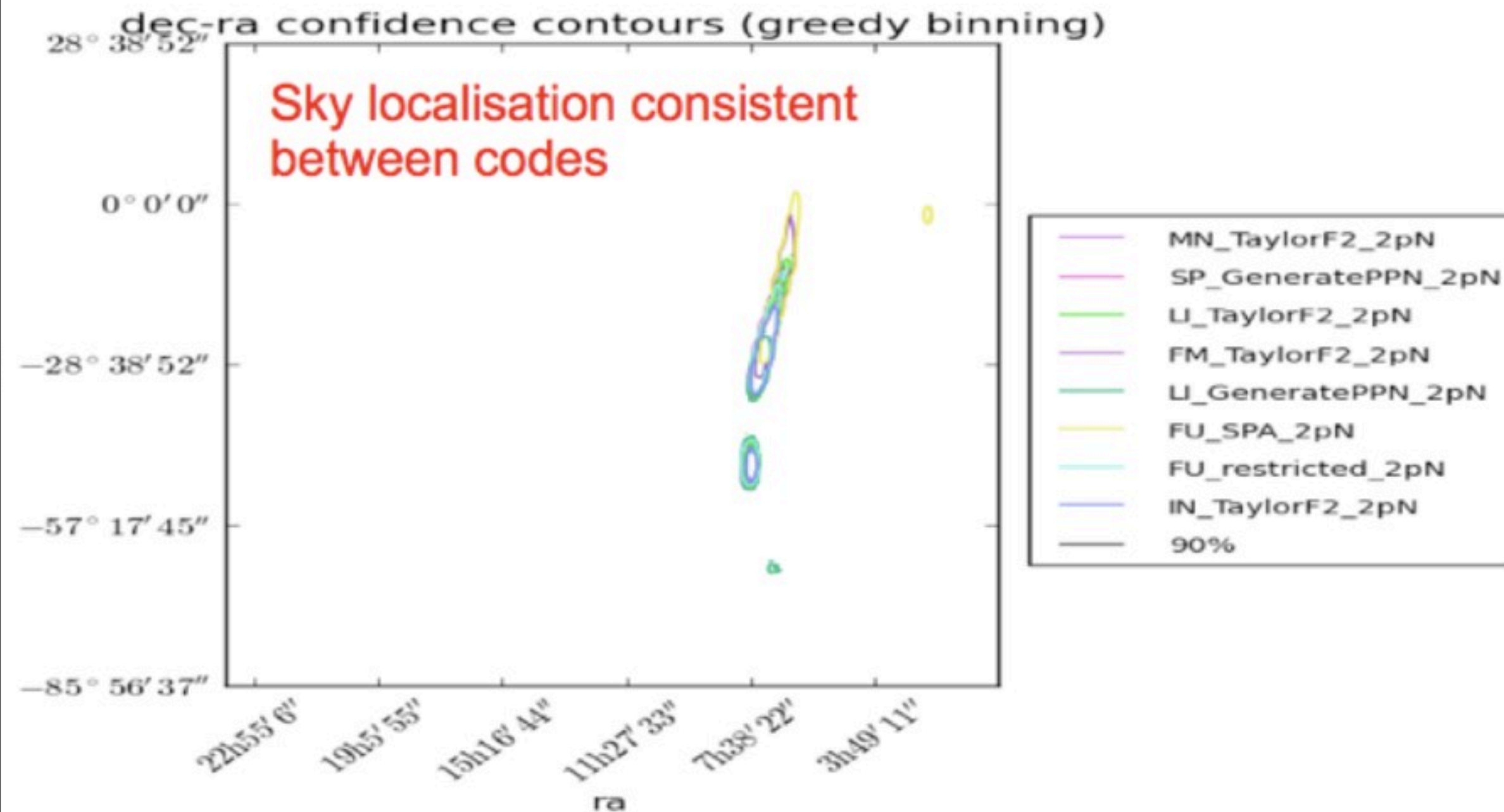




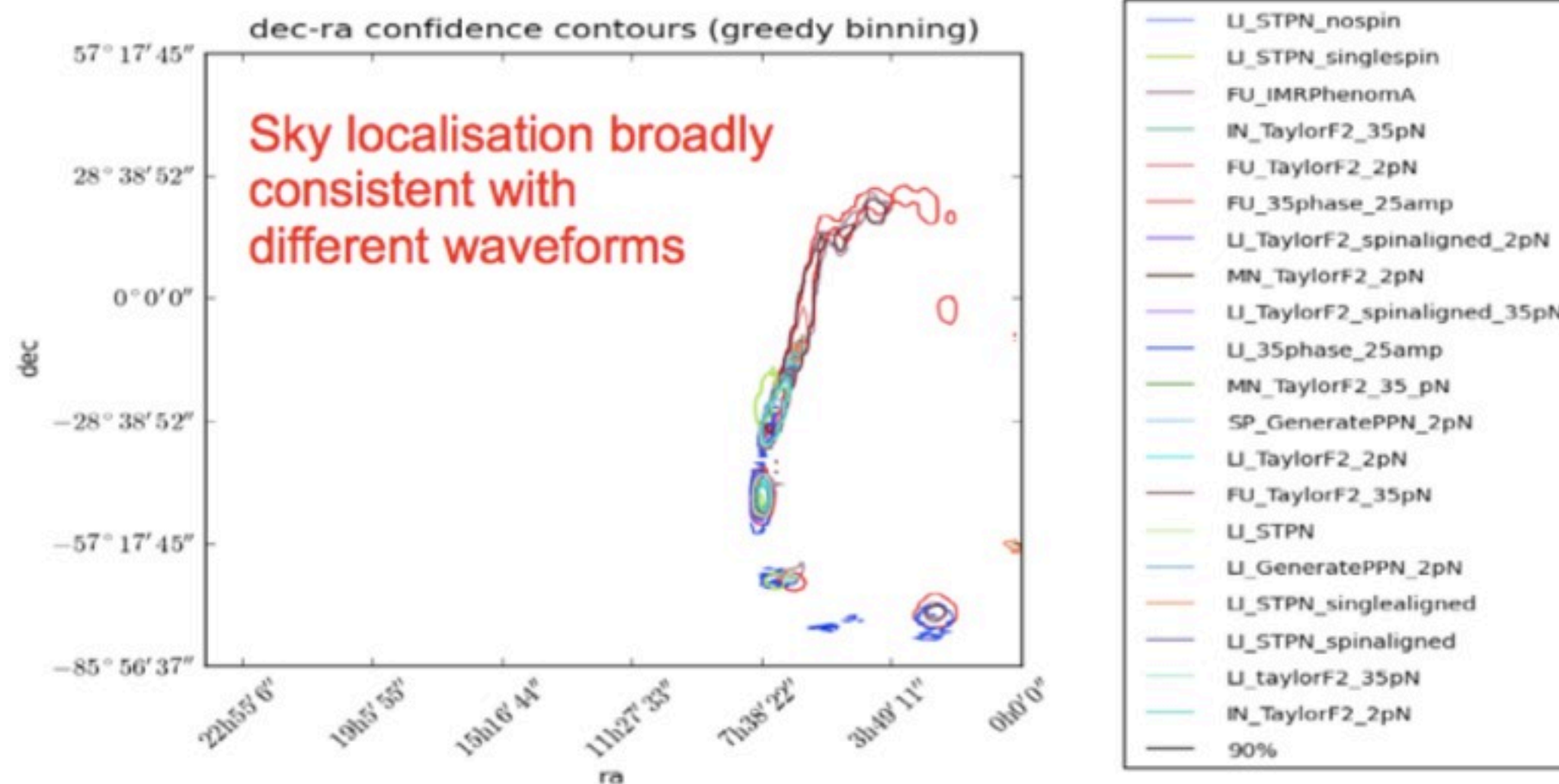


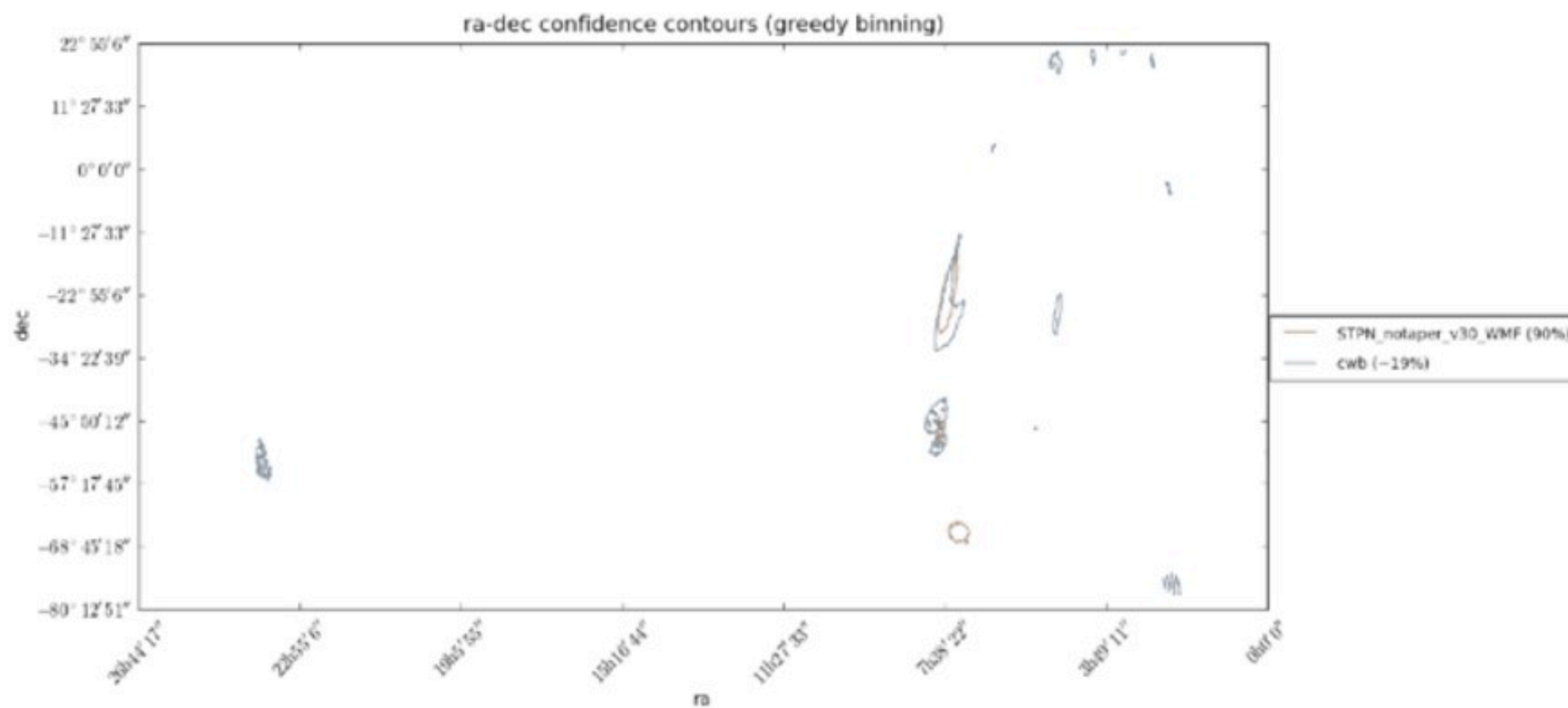
| Parameter                          | Lower (5%) | Upper (95%) |
|------------------------------------|------------|-------------|
| Chirp Mass ( $M_{\odot}$ )         | 4.38       | 5.18        |
| Symmetric mass ratio $\eta$        | 0.16       | 0.25        |
| Distance (Mpc)                     | 7          | 57          |
| Larger mass $m_1$ ( $M_{\odot}$ )  | 5.4        | 10.5        |
| Smaller mass $m_2$ ( $M_{\odot}$ ) | 2.7        | 5.5         |
| Spin on $m_1$                      | 0.67       | 1.0         |
| Spin Tilt on $m_1$ ( $^{\circ}$ )  | 84         | 111         |











1

## The envelop

2

The Blind injection team provided TWO triple coincident signals during S6—

One NS-BH inspiral (the big dog) and one short-lived pulsar signal.

In addition to the two coincident injections listed below, there were a few ultra-low SNR tests and a few single-detector transient injections when the other detectors were not in science mode.

3

Injected a blind inspiral around GPS 968654558 in L1, H1 and V1.

- Mass 1 = 24.8140793 Msun
- Mass 2 = 1.73517299 Msun
- Distance = 9.74132919 Mpc
- Right Ascension = 0.241240293 rads
- Declination = -1.28577304 rads
- TC at Geocentre = 968654558.0
- TC at Hanford = 968654558.011451630
- TC at Livingston = 968654558.005227478
- TC at Virgo = 968654558.014196834
- Network SNR = 18

4

Inserted a pulsar signal during the last part of the run, starting at:

- H1 - 968637280
- L1 - 968637880
- V1 - 968680000
- refTime = 752680033.1 pulse reference time in MB frame
- aPlus = 3.62930e-24 plus-polarization signal amplitude
- aCross = 3.02728e-26 cross-polarization signal amplitude
- psi = 0.13821761 polarization angle psi
- phi0 = 4.29 phase at tRef
- f0 = 683.3517213 GW frequency at tRef
- latitude = 0.881018031 latitude (in radians) in radians
- longitude = 2.453662475 longitude (in radians) in radians
- fdot = -8.811-11 spin-down parameters d/dt
- fddot = 8.0

5

All of the files that were created when lalapps\_makeblindinj was invoked to create the big dog are available in a zip file at the following:

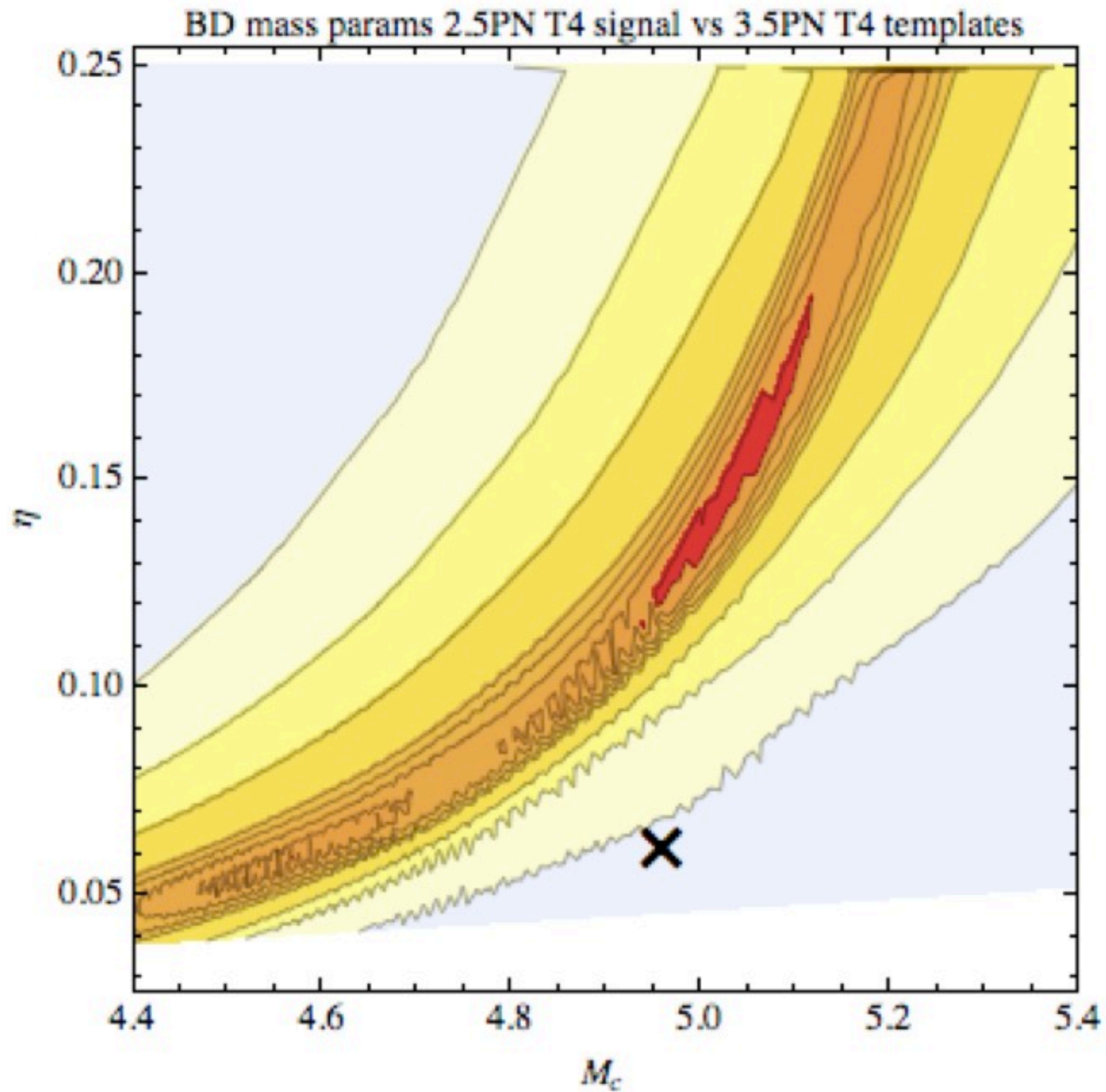
temporary location (and will go the the DCC soon):  
[http://ligo.phys.lsu.edu/pickup/LSC\\_files/BigDog.zip](http://ligo.phys.lsu.edu/pickup/LSC_files/BigDog.zip)

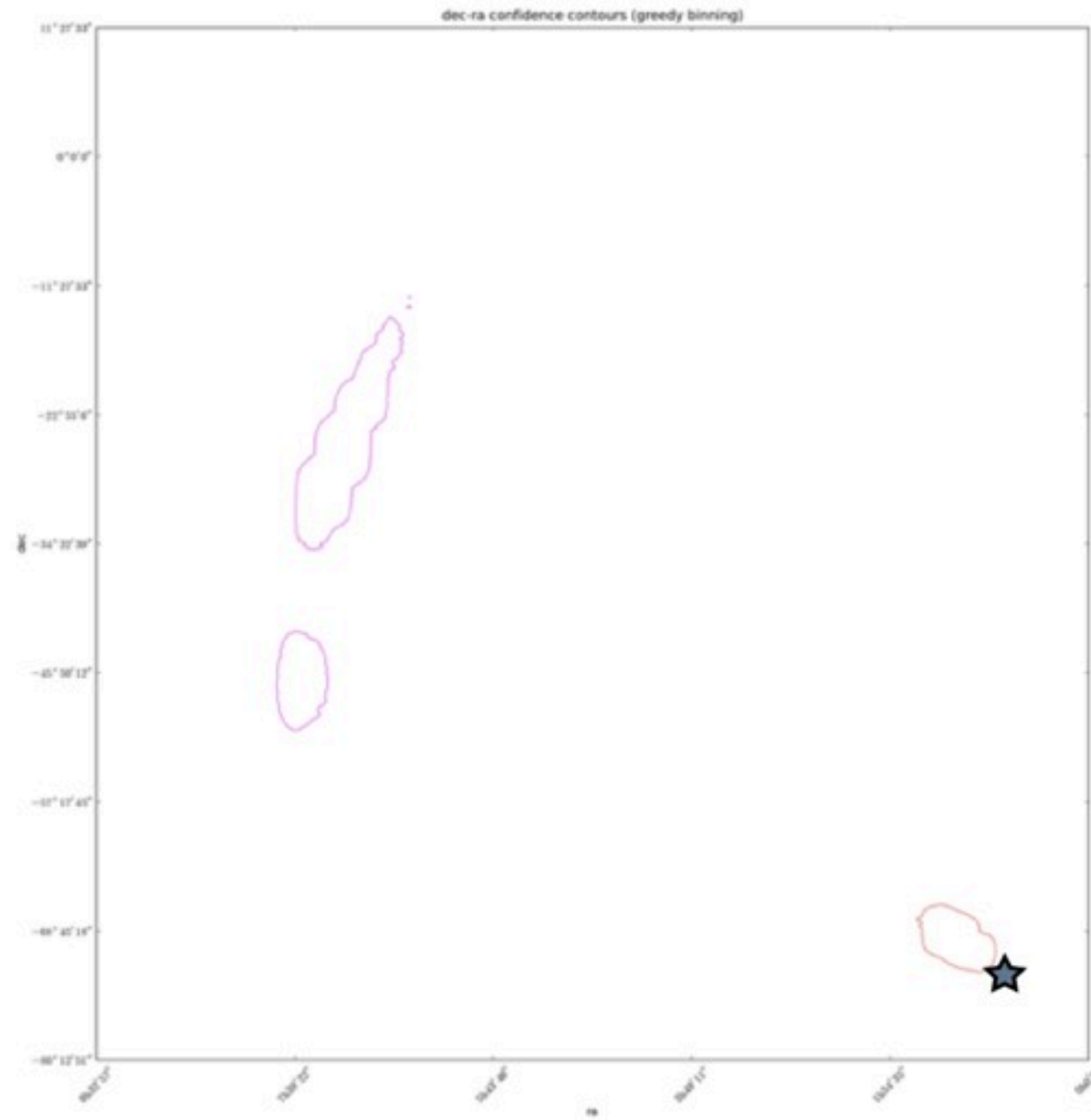


- **Big Dog**はblind injectionだった。
- **signal generation**に古いコードを使っていたため、一つのデータストリームの符号が逆になっていた。
- **Post-Newton 2.5次**を使っていた。(解析では3.5次を用いている。)

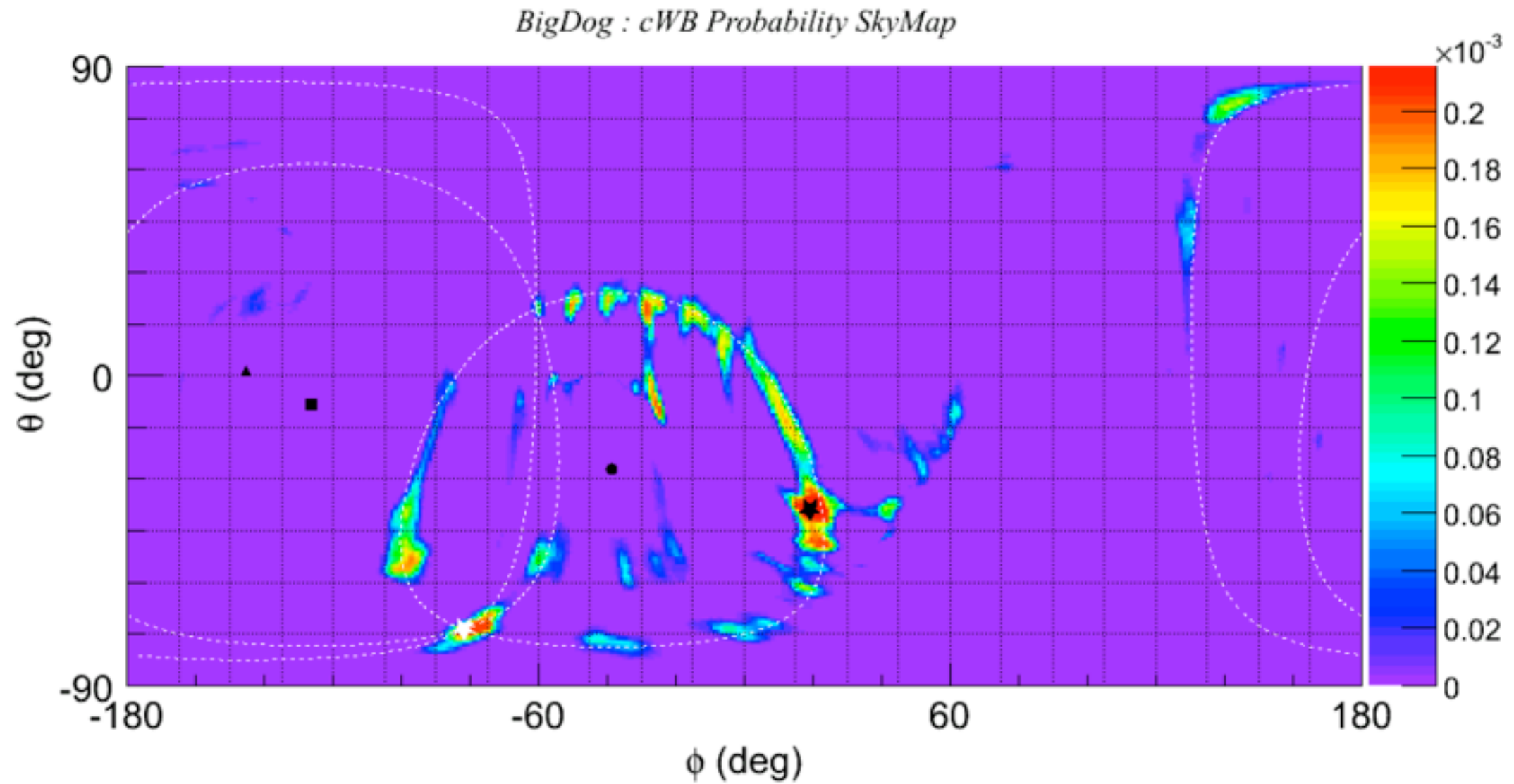
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- Right Ascension = 0.241240293 rads
- Declination = -1.28577304 rads
- tC at Geocentre = 968654558.0
- tC at Hanford = 968654558.011451630
- tC at Livingston = 968654558.005227478
- tC at Virgo = 968654558.014196834
- Network SNR = 18









- S6dの解析が終わる前にオープンにされてしまった。
- 20日のようなshort-lived 信号はobservation intervalを変えずに現パイプラインを走らせても検出できない。
- Narrow band searchでfollow-upしたら検出できた。
- Estimated SNRs are: H1 47, L1 39, V1 17

Inserted a pulsar signal during the last part of the run, starting at:

- H1 - 969837280
- L1 - 969837694
- V1 - 969869000
- refTime = 751680013      pulsar reference time in SSB frame
- aPlus = 3.02930e-24      plus-polarization signal amplitude
- aCross = 3.01724e-24      cross-polarization signal amplitude
- psi = 0.15823742      polarization angle psi
- phi0 = 4.29      phase at tRef
- f0 = 643.3517213      GW frequency at tRef
- latitude = 0.465456321      latitude (delta, declination) in radians
- longitude = 2.453682475      longitude (alpha, right ascension) in radians
- f1dot = -8.84E-11      spindown parameters d/dt f0
- f2dot = 0.0
- f3dot = 0.0

