Coherent searches for periodic gravitational waves from unknown isolated sources and Scorpius X-1: Results from the second LIGO science run

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on behalf of LIGO Scientific Collaboration

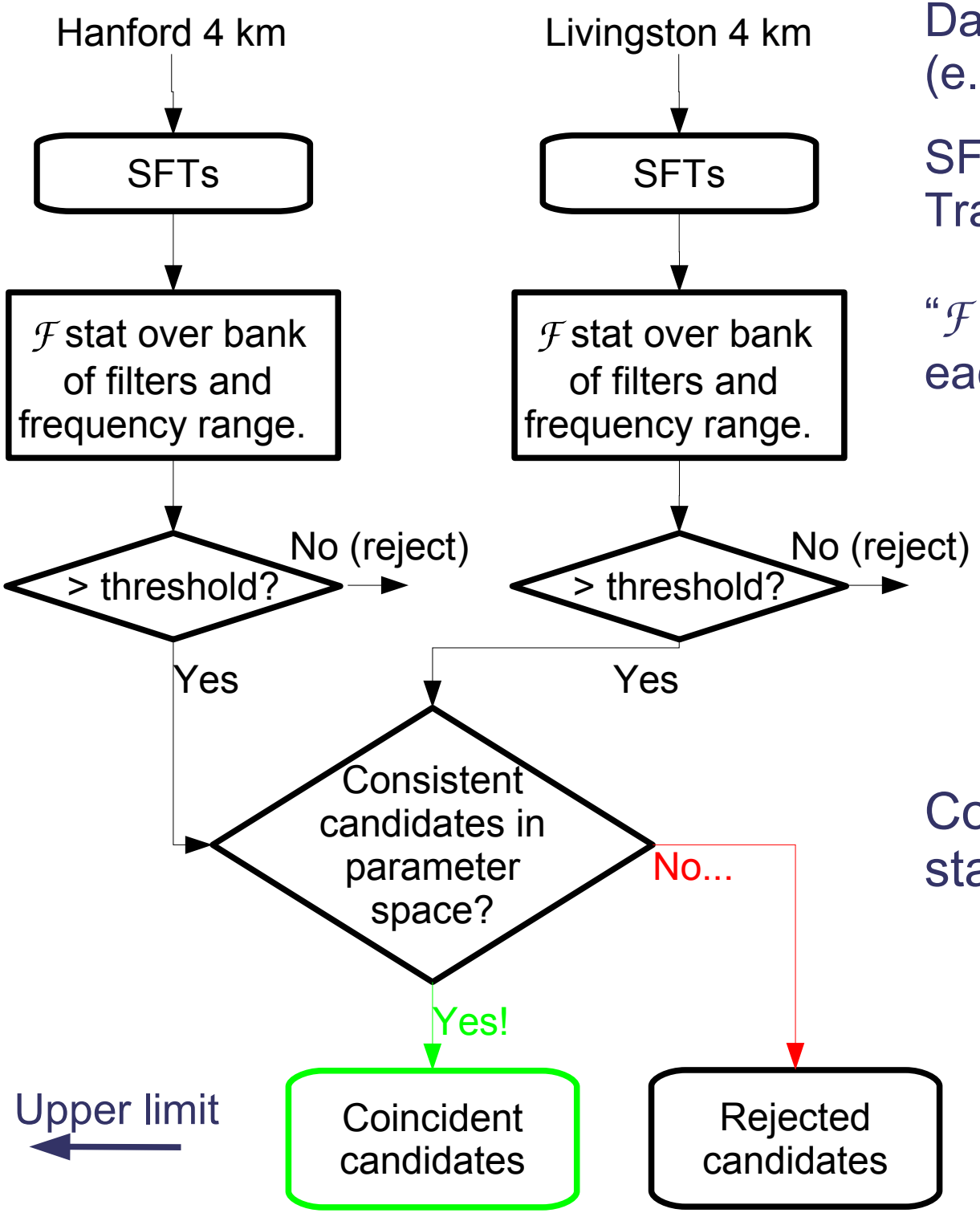
Introduction: Pulsar search method

- Semi-coherent stage, such as:
  - Hough transform
  - Stackslide (Talk by G. Mendell, W11)
  - PowerFlux (Talk by V. Dergachev, W11)
- Fully-coherent stage, such as:
  - Targeted searches; time-domain method (Talk by M. Pitkin, C7, Saturday)
  - Maximum-likelihood method ("$\mathcal{F}$ statistic") (this talk, W11)
    - matched filter based frequency-domain analysis
    - basis of Einstein@Home (Talk by R. Prix, C7, Saturday)
- CW search scheme: Hierarchical search
  - comprises semi-coherent & fully-coherent stage
  - optimal sensitivity for fixed comp. resource

This talk is about: Made it, tested it, and saw it working

- (Development of) $\mathcal{F}$-stat method/code
  - for very wide parameter space pulsar search
  - indispensable building block for LIGO
- S2 coincident analysis: Livingston 4 km - Hanford 4 km
  - Small subset (6-10 hrs) of entire S2 data (59 days)
  - Two kinds of searches conducted:
    - All-sky blind search for isolated NS (10 hrs)
    - Scorpius X-1 (6 hrs)
  - More a demonstration of the pipeline with real-world data (no detection expected)
  - Set upper limits for both

Fully-coherent stage pipeline



Data divided into chunks (e.g. 10hrs each)

SFT=Short (30 min) Fourier Transform

"$\mathcal{F}$ stat" (likelihood function) for each IFO

Coincident analysis stage

Two different systems

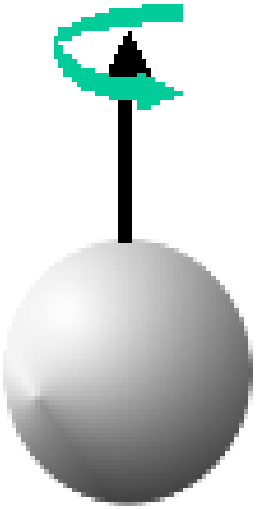


Image by
J.Creighton

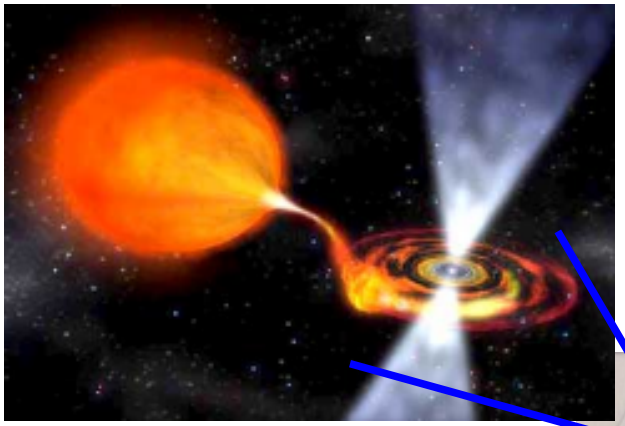
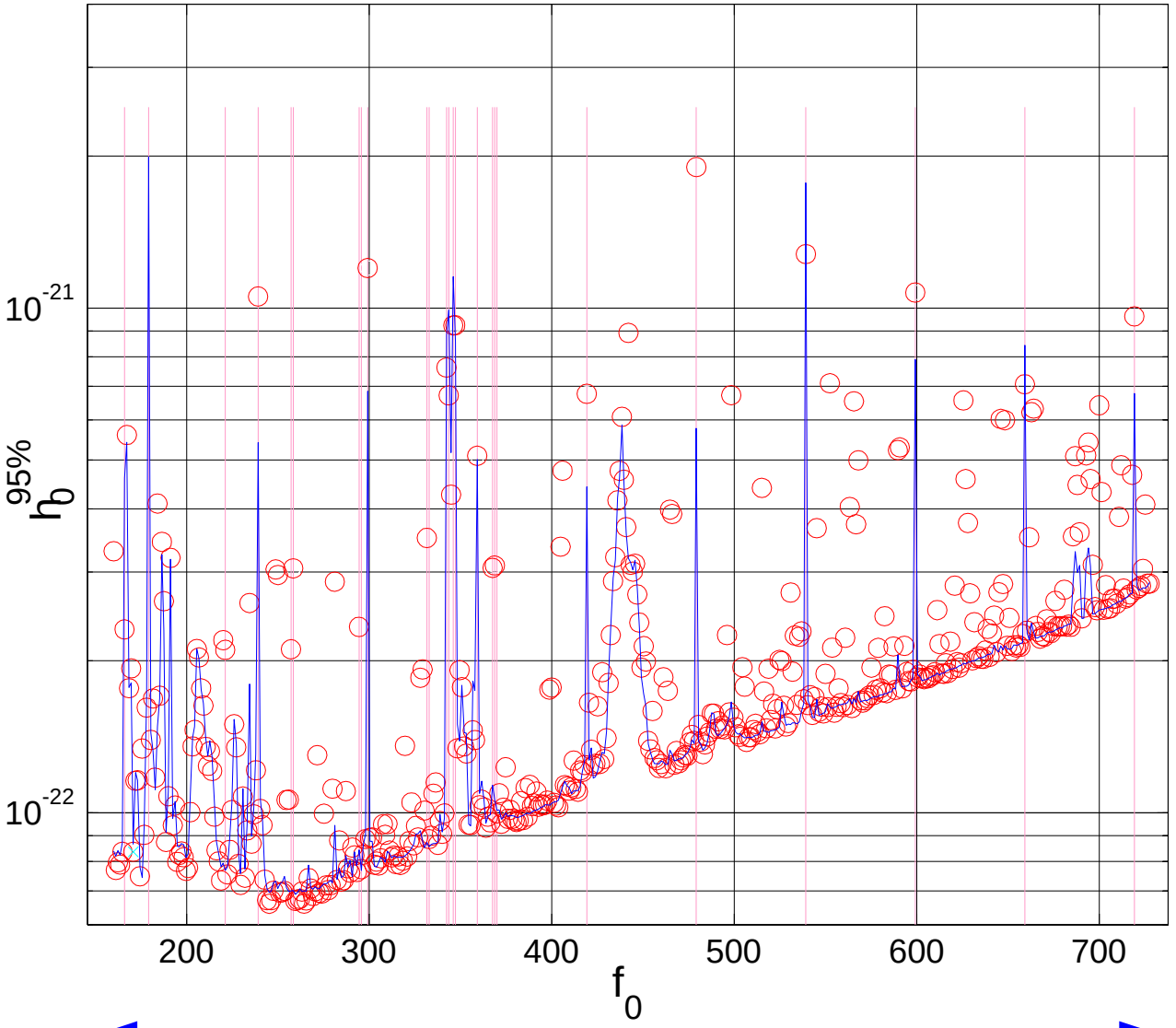


Image by NASA

Scorpion by
Kawabe@LHO

- Unknown isolated lumpy NS
  - All-sky blind search
  - Wide frequency range
- Scorpius X-1
  - Known low mass X-ray binary (small star and accreting NS)
  - Position known
  - Two poorly known orbital parameters
  - Frequency loosely bound

Results: Upper limits for all-sky blind search



160 - 728.8 Hz range

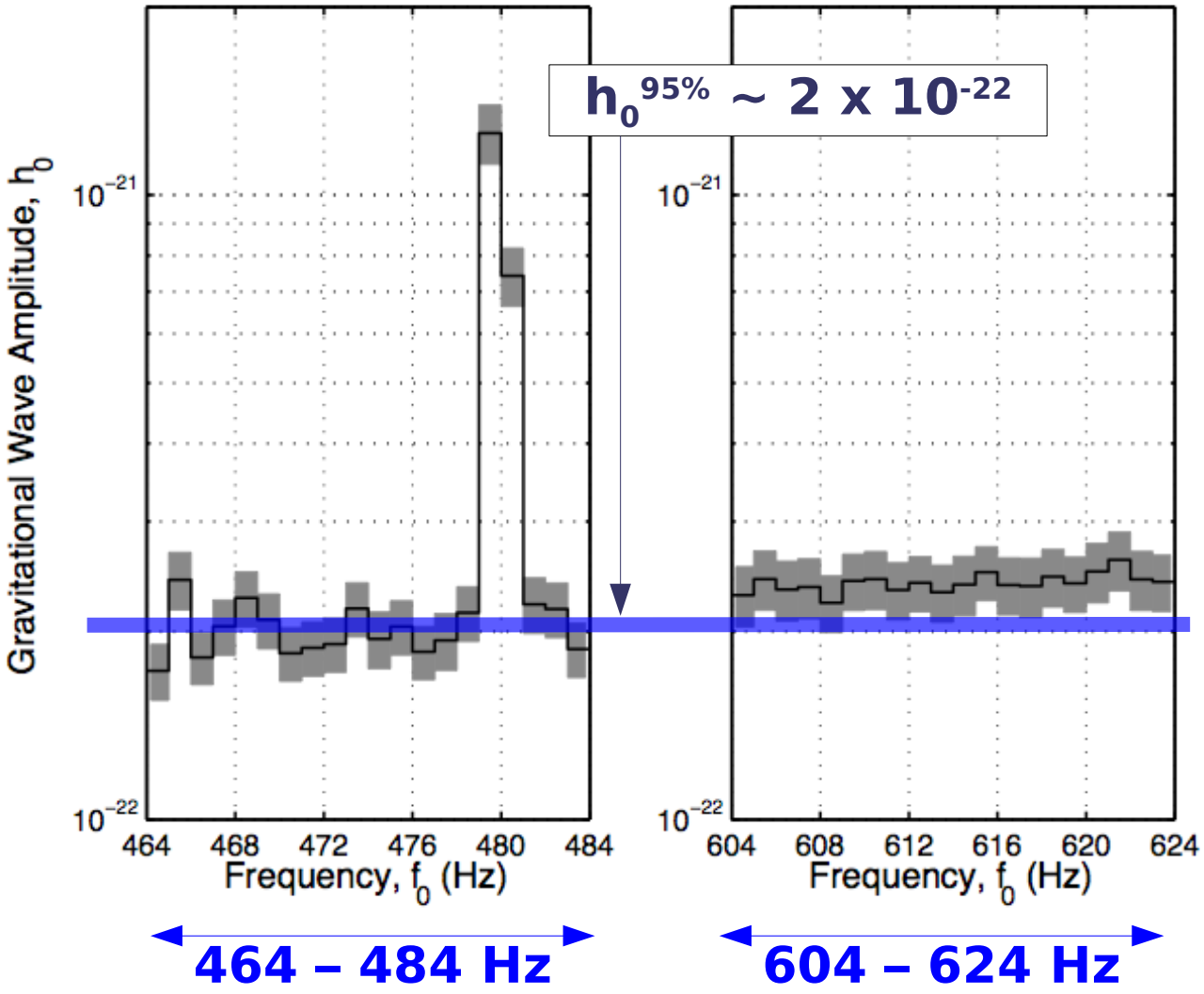
- Red: 95% confidence ULs per 1.2 Hz band
- Pink: position of known instrumental lines (power lines, wire violin resonances etc.)
- Blue: expected UL assuming the detector noise is stationary and Gaussian
- Outliers: Most of them understood instrumental
- Systematic uncertainty
  - MonteCarlo: < 3%
  - Calibration: 11%

Most constraining UL: 6.6 x 10^{-23} @ 245.2-246.4 & 264.4-265.6 Hz

Results: Upper limits for Scorpius X-1 search (orbital eccentricity $e = 0$)

- 95% confidence UL per 1Hz band
- Most constraining UL:

  $h_0^{95\%} = 1.7 \times 10^{-22}$
- Systematic uncertainty
  - MonteCarlo: < 3%
  - Calibration: 9%



- Upper limit on NS ellipticity (using Sco X-1 distance of 2.8 kpc):

$\varepsilon^{95\%} = 4.0 \times 10^{-4}$ to 3.6×10^{-3}

Conclusion: Made it, tested it, and saw it working

- Fully-coherent stage ($\mathcal{F}$-stat method/code) for wide parameter space developed for LIGO hierarchical scheme
- Demonstrated analysis of real-world data using (a subset of) S2 Livingston 4 km and Hanford 4 km
- No detection expected
- Upper limits for two kinds of sources
  - All-sky isolated NS: 6.6×10^{-23} to 1×10^{-21} across 160 to 728.8 Hz
  - Sco X-1: 1.7×10^{-22} to 1.3×10^{-21} across 464 to 484 & 604 to 624 Hz
  - First fully coherent search results for such a wide parameter space!

Future, or maybe present? Things already look better

- S3 analysis finished, improved version for S4 running,
  - in Einstein@Home (Talk by R. Prix, C7, Saturday)
    - http://einstein.phys.uwm.edu
    - http://www.einsteinathome.org
- Detectors already >~x10 quieter in S5 than S2 for frequency range of this talk
- T_{S5} (1 year) >> T_{S2} (59 days)
- Hierarchical scheme (fully-coherent + semi-coherent stages) will be implemented for S5

End.