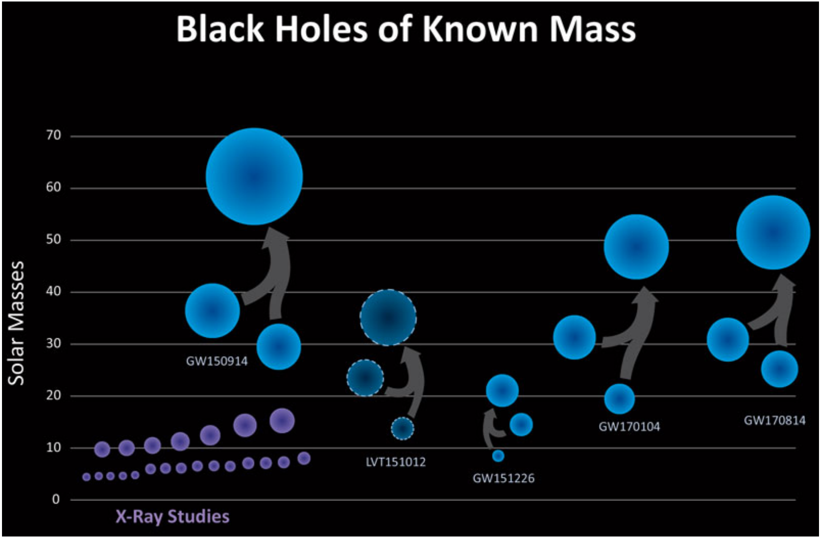
Poszukiwanie fal grawitacyjnych emitowanych przez rotujące gwiazdy neutronowe

NCBJ, Świerk, 5 grudnia 2017

1. J. Aasi et el. *"Implementation of an $\mathcal{F}$–statistic all-sky search for continuous gravitational waves in Virgo VSR1 data"* Class. Quantum Grav. **31** (2014) 165014.
2. S. Walsh, M. Pitkin, M. Oliver, S. D'Antonio, V. Dergachev, A. Królak, P. Astone, M. Bejger, M. Di Giovanni, O. Dorosh, S. Frasca, P. Leaci, S. Mastrogiovanni, A. Miller, C. Palomba, M. A. Papa, O. J. Piccinni, K. Riles, O. Sauter, and A. M. Sintes *"Comparison of methods for the detection of gravitational waves from unknown neutron stars"* Phys. Rev. D **94** (2016) 124010.
3. B.P. Abbott et al. *"All-sky search for periodic gravitational waves in the O1 LIGO data"* Phys. Rev. D **96** (2017) 062002.


Black Holes of Known Mass
Solar Masses
70
60
50
40
30
20
10
0
GW150914
LVT151012
GW151226
GW170104
GW170814
X-Ray Studies

LIGO/VIRGO

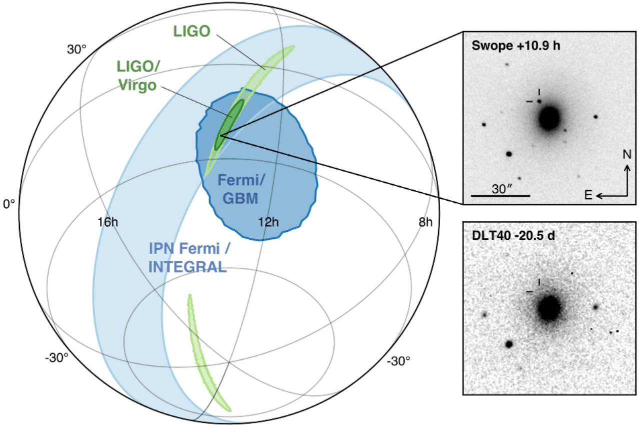
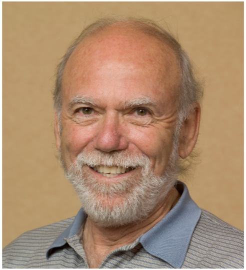


Figure 1. Localization of the gravitational-wave, gamma-ray, and optical signals. The left panel shows an orthographic projection of the 90% credible regions from LIGO (190 deg^2; light green), the initial LIGO-Virgo localization (31 deg^2; dark green), IPN triangulation from the time delay between *Fermi* and *INTEGRAL* (light blue), and *Fermi*-GBM (dark blue). The inset shows the location of the apparent host galaxy NGC 4993 in the Swope optical discovery image at 10.9 hr after the merger (top right) and the DLT40 pre-discovery image from 20.5 days prior to merger (bottom right). The reticle marks the position of the transient in both images.

"for decisive contributions to the LIGO detector and the observation of gravitational waves"

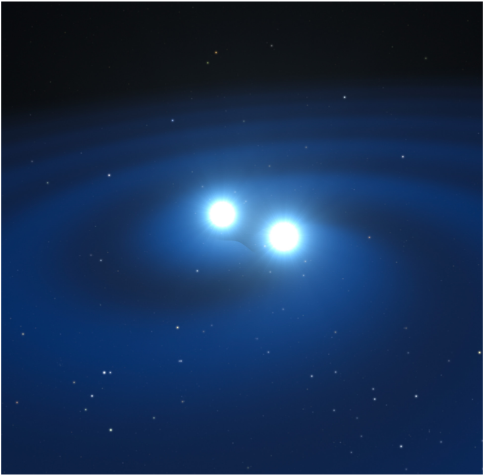
Kip Thorne



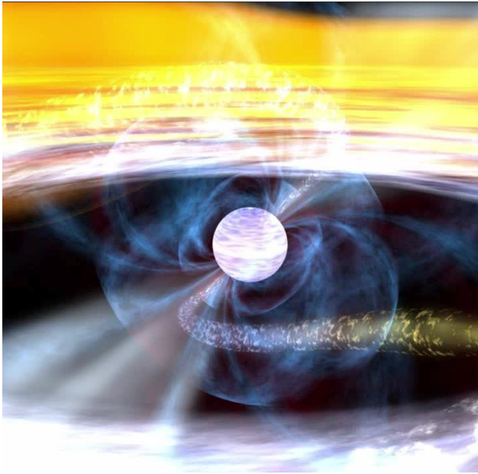
Barry Barish

Rainer Weiss

Źródła promieniowania fal grawitacyjnych



Wikipedia



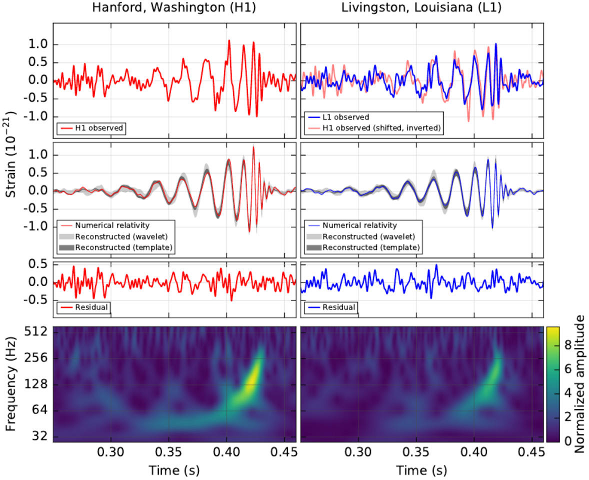
Emisja fal grawitacyjnych przez rotujące gwiazdy neutronowe

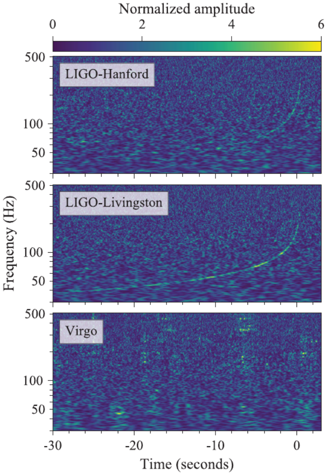
$$h_0 = \frac{4\pi^2 G}{c^4} \frac{I_{zz} f^2 \epsilon}{d} \tag{1}$$

f — częstotliwość fal grawitacyjnych,
G — stała Newtona,
c — prędkość światła,
d — odległość do gwiazdy neutronowej.

$$\epsilon = \frac{|I_{xx} - I_{yy}|}{I_{zz}} \tag{2}$$

GW150914 **GW1708017**





B. P. Abbott et al. *"Observation of Gravitational Waves from a Binary Black Hole Merger"* Physical Review Letters **116** (2016) 061102.

B. P. Abbott et al. *"GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral"* Physical Review Letters **119** (2017) 161101.

F-statystyka

$$
\begin{aligned}
\ln\Lambda &= (x|h) - \frac{1}{2}(h|h)\\
x(t) &= n(t) + h(t)\\
h(t) &= h_1(t) + h_2(t)\\
h_1(t) &= F_+(t)h_{1+}(t) + F_\times(t)h_{1\times}\\
h_2(t) &= F_+(t)h_{2+}(t) + F_\times(t)h_{2\times}
\end{aligned}
$$

$$(f, \dot{f}, \alpha, \delta)$$

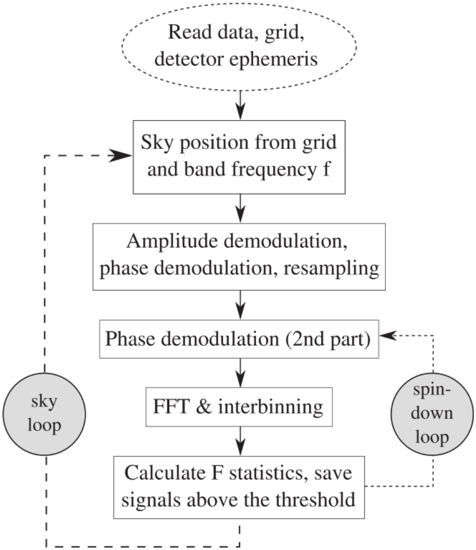
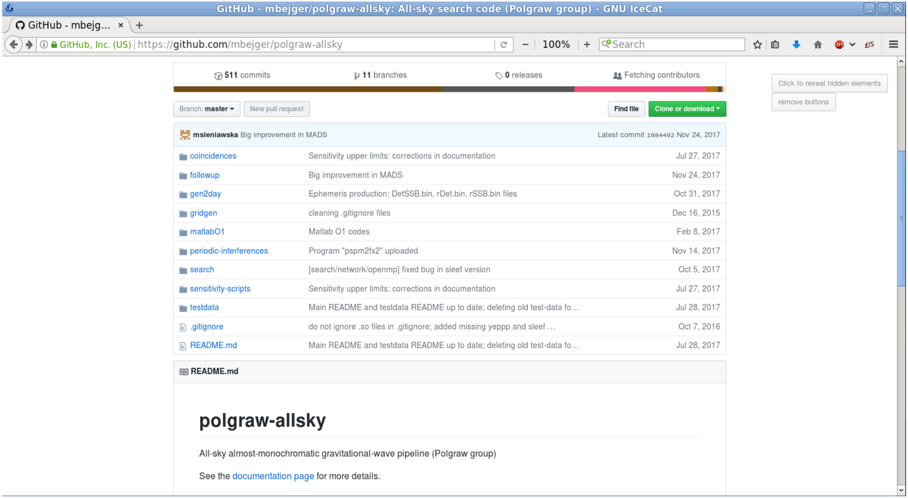


Figure 6. Workflow of the $\mathcal{F}$-statistic search pipeline.


GitHub - mbejger/polgraw-allsky: All-sky search code (Polgraw group) - GNU IceCat
GitHub - mbejg...
GitHub, Inc. (US) https://github.com/mbejger/polgraw-allsky
100%
Search
511 commits
11 branches
0 releases
Fetching contributors
Click to reveal hidden elements
remove buttons
Branch: master
New pull request
Find file
Clone or download
msieniawska Big improvement in MADS
Latest commit 1984492 Nov 24, 2017
coincidences Sensitivity upper limits: corrections in documentation Jul 27, 2017
followup Big improvement in MADS Nov 24, 2017
gen2day Ephemeris production: DetSSB.bin, rDet.bin, rSSB.bin files Oct 31, 2017
gridgen cleaning .gitignore files Dec 16, 2015
matlabO1 Matlab O1 codes Feb 8, 2017
periodic-interferences Program "pspm2fx2" uploaded Nov 14, 2017
search [search/network/openmp] fixed bug in sleef version Oct 5, 2017
sensitivity-scripts Sensitivity upper limits: corrections in documentation Jul 27, 2017
testdata Main README and testdata README up to date; deleting old test-data fo… Jul 28, 2017
.gitignore do not ignore .so files in .gitignore; added missing yeppp and sleef … Oct 7, 2016
README.md Main README and testdata README up to date; deleting old test-data fo… Jul 28, 2017
README.md
polgraw-allsky
All-sky almost-monochromatic gravitational-wave pipeline (Polgraw group)
See the documentation page for more details.

Class. Quantum Grav. **31** (2014) 165014.

- Zakres częstotliwości 100 – 1000 Hz.
- "Coherent searck" dla dwódniowych odcinków (dwie doby gwiazdowe). Po czym szukanie koincydencji dla poszczególnych odcinków dwudniowych.
- Zakres śpindown": $-1.6(\frac{f_0}{100\mathrm{Hz}}) \times 10^{-9}$ Hz/s do zera.

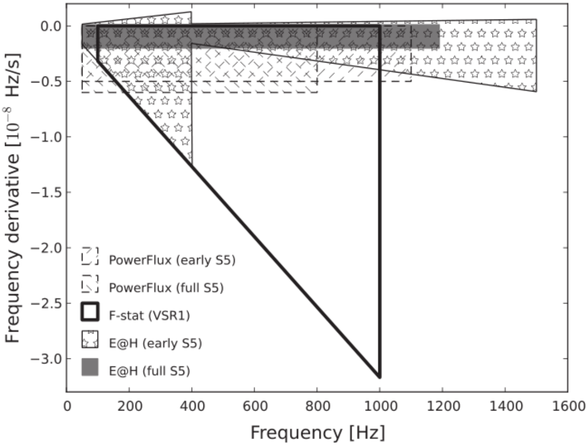


Figure 5. Comparison of the parameter space in $f-\dot{f}$ plane searched in VSR1 analysis presented in this paper (area enclosed by a thick black line) and recently published PowerFlux and E@H searches of the LIGO S5 data.

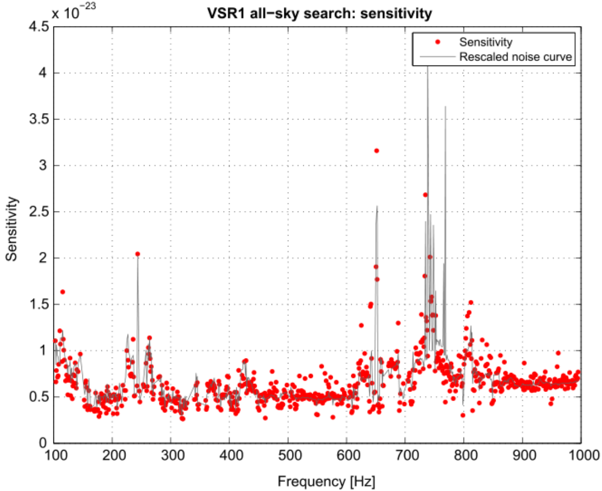


Figure 10. The 90% confidence sensitivity of the all-sky search of Virgo VSR1 data in the band from 100 Hz to 1 kHz. The dots show the source strain amplitude h_0 for which 90% of sources are confidently detected by this pipeline. The thin line is the rescaled instrumental noise curve, see equation (28).

Phys. Rev. D **94** (2016) 124010.
The Mock Data Chalenge (MDC)
Użyto danych S6. Wykonano 3110 "injection" sygnałów.
Zakres 40–2000 Hz

- F-statistics
- PowerFlax
- Sky Hough
- Frequency Hough
- Einstein@Home

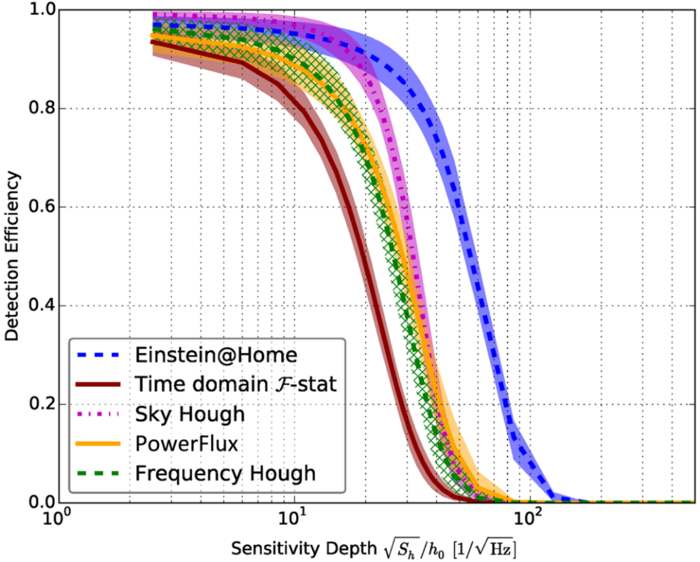
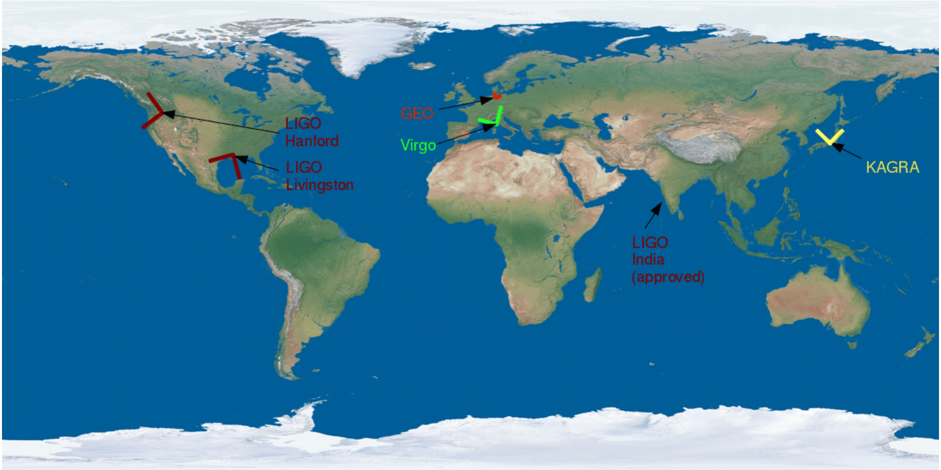


FIG. 1. Detection efficiency measured for all 3110 injections.

Detektory fal grawitacyjnych

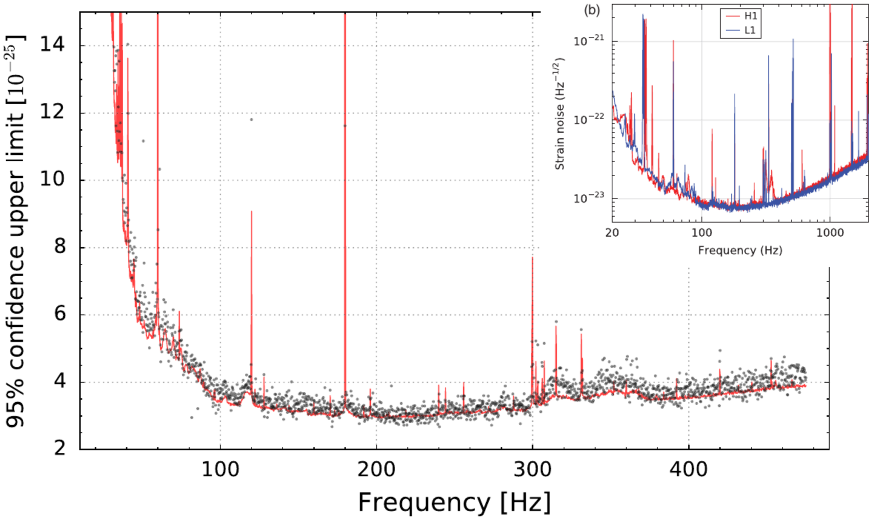


Pokolenia detektorów

Initial LIGO	2011–2014 (S1–S6)
Advanced LIGO	O1 (09.2015–01.2016)
Advanced LIGO	O2 (11.2016 08.2017)
Initial Virgo	VSR1 (18.05.2007 – 1.10.2007)
Virgo+	VSR2 (7.07.2009 – 8.01.2010)
Virgo+(monolitic suspention)	VSR3 (11.08.2010 – 19.10.2010)
Advanced Virgo	sierpień 2017

Phys. Rev. D **96** (2017) 620020.
"All-sky search"
Użyto danych O1. Zakres 20–475 Hz Spin-down
$[-1{,}0, +1{,}] \times 10^{-8}$ Hz/s.

- F-statistics
- PowerFlax
- Sky Hough
- Frequency Hough



B.P. Abbott et al. *"All-sky search for periodic gravitational waves in the O1 LIGO data"* Phys. Rev. D **96** (2017) 062002.
B. P. Abbott et al. *"Observation of Gravitational Waves from a Binary Black Hole Merger"* Physical Review Letters **116** (2016) 061102.

Are Gravitational Waves Spinning Down PSR J1023 + 0038?

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The pulsar J1023 + 0038 rotates with a frequency $\nu \approx 592$ Hz and has been observed to transition between a radio state, during which it is visible as a millisecond radio pulsar, and a low-mass x-ray binary (LMXB) state, during which accretion powered x-ray pulsations are visible. Timing during the two phases reveals that during the LMXB phase the neutron star is spinning down at a rate of $\dot{\nu} \approx -3 \times 10^{-15}$ Hz/s, which is approximately 27% faster than the rate measured during the radio phase, $\dot{\nu} \approx -2.4 \times 10^{-15}$ Hz/s, and is at odds with the predictions of accretion models. We suggest that the increase in spin-down rate is compatible with gravitational wave emission, particularly with the creation of a "mountain" during the accretion phase. We show that asymmetries in pycnonuclear reaction rates in the crust can lead to a large enough mass quadrupole to explain the observed spin-down rate, which thus far has no other self-consistent explanation. We also suggest two observational tests of this scenario, involving radio timing at the onset of the next millisecond radio pulsar phase, when the mountain should dissipate, and accurate timing during the next LMXB phase to track the increase in torque as the mountain builds up. Another possibility is that an unstable r mode with an amplitude $\alpha \approx 5 \times 10^{-8}$ may be present in the system.

DOI: 10.1103/PhysRevLett.119.161103

Dziękuję za uwagę.