On the coincidence excess observed by the Explorer and Nautilus gravitational wave detectors in the year 2001

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Abstract
We recently published an analysis of the coincidences of the Explorer and Nautilus gravitational wave detectors in the year 2001 [1]. This has drawn attention and criticism by dr. S. Finn [2]. We discuss here why we do not agree with his arguments and conclusions, taking the opportunity to make some further considerations on our data.

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1. Introduction

When we analysed the data collected in 2001 by our gravitational wave (GW) detectors Explorer and Nautilus [1], we became convinced of the importance of communicating two issues:

1. unprecedented sensitivities were reached by our detectors
2. the use of powerful tools in the analysis of the data (energy consistency of the events and sidereal time analysis) led to an interesting indication, suggestive of possible signals from galactic sources.

Our paper also established a procedure on how we will search for galactic signals with the upcoming data, making future confirmation or denial somewhat easier. The indication we reported was not strong enough to claim a detection and, accordingly, no claim was made in our paper.

We find the criticisms of Finn [2] inappropriate and wrong; here we discuss why, considering in detail the points he criticized:

- the statistical significance of the coincidence excess and of the difference between its solar and sidereal distribution;
- the comparison of the observed sidereal hour distribution of the coincidences with the antenna pattern and possible galactic source distribution.

2. Statistical significance of the excess

Finn's paper hinges on his reasoning about "a priori" and "a posteriori" choices. In particular he states that the potential significance of a peak centered at sidereal hour 4 (which *must* be expected from galactic

Table 1: Number of coincidences n_c and corresponding number of accidentals $\bar{n}$ for various sidereal time intervals around hour 4. The last column gives the Poisson probability that the observed counts are due to a background fluctuation.

Sidereal time period (h)	n_c	$\bar{n}$	P
hour 4	4	0.92	$1.5 \cdot 10^{-2}$
3 - 5	7	1.69	$1.8 \cdot 10^{-3}$
2 - 6	8	3.45	$2.5 \cdot 10^{-2}$
1 - 7	10	5.01	$3.2 \cdot 10^{-2}$
0 - 8	13	6.2	$1.1 \cdot 10^{-2}$

sources), is diluted because we did not declare before the analysis (i.e. “a priori”) that we were searching for these sources. In other words he states that the significance of the peak was recognized “a posteriori”. As a consequence, the probability should be decreased by a factor of roughly 24 because “a priori” the peak could have been found in any of the 24 sidereal hours.

We remark that the experiment described in the paper [1] is inherently based on the “a priori” hypothesis of signals originating in the Galaxy. This was already clearly indicated in our previous paper [3] (page 248), *“No extragalactic GW signals should be detected with the present detectors. Therefore we shall focus our attention on possible sources located in the Galaxy.”*, and again repeated in paper [1] (page 5456), *“We had reasoned that, since extragalactic GW signals should not be detected with the present detectors, possible sources should be located in our Galaxy”*. And this is exactly the hypothesis that was tested in paper [1] by reporting the coincidences as a function of the sidereal time. It was Joseph Weber, over 40 years ago [4], who first applied the sidereal time analysis to GW data, searching for peaks corresponding to the hours of most favourable orientation of the detectors to galactic sources.

Recent work by Paturel and Baryshev [5] quantitatively indicates the signature expected from galactic sources in bar detectors of different sensitivity, and in particular the presence of a peak centered at sidereal hour 4. We therefore maintain that the experimental peak centered at around hour 4 found in our data, being consistent with the hypothesis of galactic sources, is physically significant and deserves consideration. We remark that this peak is consistent with sources anywhere in the Galactic Disc. In the case of a source density enhancement at the Center, an additional peak should show up at sidereal hour 14, which would have the same height as the peak at sidereal hour 4 if all the sources were located right in the Galactic Center.

Coming to evaluation of the statistical significance of the excess, Finn imputes us with a line of reasoning we never followed. In particular, we never claimed that the excess in a single bin was significant, in quantitative terms. In sec. 6 of our paper [1] we wrote: *“One notes a coincidence excess from sidereal hour 3 to sidereal hour 5 which appears to have some statistical significance”*. We remind the reader that we gave no overall probability figures in our paper, according to our clearly stated program of using the word “probability” as little as possible as *“we are well aware that its significance might be jeopardized by any possible data selection”* [1]. In spite of this attitude, the statement in ref. [2] (*“the “cluster” of events at sidereal hour 3 is an illusion: noise alone would produce this outcome more frequently than one in four observations”)* compels us to report (see 1) the Poisson probabilities of the observed number of coincidences with respect to the corresponding number of accidentals in intervals of increasing duration centered at sidereal time 4 (a well known special time, as recalled above).

These numbers represent the Poisson probability that the measured number of counts be due to a background fluctuation. They are, at most, at the level of a few percent. Instead, going up to the entire 24 hour period, the overall number of coincidences (31) with respect to the accidentals (25) gives a Poisson probability of 0.14. Finally, a point emerging from 1 is the difficulty of making a statement about the width of the coincidence excess peak.

We remark, however, that a correct statistical approach should allow us to put together any piece of experimental evidence for increasing or decreasing our degree of belief for the evidence of a given hypothesis based on a specific model. This also means that the data analyst should be free to discuss and evaluate against the data any model, regardless of whether a priori, as in the case of our paper [1], or a posteriori. A quantitative analysis of this kind applied to our 2001 data is to be reported [6].

As for comparison of the solar and sidereal hour distributions, we note that Finn read the background values from fig. 5 of our paper [1]. In doing so he obtained a total number of accidental coincidences amounting to 25.3 for the sidereal time distribution, and 24.4 for the solar one, while the two total numbers must, obviously, be identical. We also note in table 1 of ref. [2] that several individual values have large deviations from those plotted in fig. 5 of [1]. These errors affect the following analysis and flaw the conclusion: *"the event distribution in solar hour and sidereal hour are statistically indistinguishable"*. Using the right numbers, our conclusion is that the sidereal time distribution is about seven times less likely to derive from a fluctuation of its background than the solar one. This result tends to favour the hypothesis that the two distributions are different.

3. Comparison of the observed and expected sidereal hour distribution of the coincidences

Another criticism raised by Finn is that, since bar detectors have rather broad antenna patterns, one should expect a correspondingly broad peak in the distribution of the coincidences, instead of the relatively narrow peak reported in [1]. Again his argument is incorrect, for the following reason.

One must realize that the expected probability of detecting events in a single detector is a function of its antenna pattern, its detector noise, the threshold used in the analysis and the amplitudes of the expected signals. The number and distribution of coincidences in a two-detector experiment then depends on the product of the two detectors' efficiencies. Therefore, fig. 2 of ref. [2], which only shows the geometrical antenna pattern of a single detector, has little to do with our data. To illustrate this we may mention the following two cases:

a) the expected GW signals are significantly larger than the threshold, in which case the expected response becomes flat;
b) the expected GW signals are of the order of the threshold or less; then the efficiency of each of the detectors is relevant to the calculations, significantly changing the shape of the sidereal time response and providing a notably narrow peak.

As a consequence, the expected response of a coincidence experiment to GW signals is different from the antenna pattern of a single detector. This conclusion is also illustrated in ref. [5]: in general, the peak width depends on the source strength and on the spatial distribution and wave polarization.

It can safely be stated that, because of the small number of candidate events, we consider our data physically compatible with practically any distribution of sources in the Galaxy, whether spread in the Disc or strongly enhanced in the Center.

4. Conclusions

We have discussed the experimental results obtained by our detectors Explorer and Nautilus in the year 2001, subsequent to criticisms of Finn. We believe we have shown that his criticisms are unfounded and that an interesting coincidence excess is indeed present in our data in a physically significant sidereal time interval.

A point that has impressed many readers but that was completely ignored by Finn is the strong energy correlation of the 8 coincidence events during the sidereal hours interval 3 to 5 (see figs 8, 9 and 10 of ref. [1]). Those events have a correlation coefficient of 0.96, which is compatible with the null hypothesis with a probability of $5.6 \cdot 10^{-3}$. The slope of the linear regression line for Nautilus energy vs Explorer energy is 1.2, which, within the accuracy of the absolute detector calibrations, is in agreement with the hypothesis of having equal signals on the two detectors. By contrast, the events at the other sidereal hours exhibit a correlation coefficient of -0.19, compatible with the mode of distribution of the correlation coefficient in the case of a null hypothesis.

We conclude by reaffirming what we stated in our previous paper: new data are necessary to complement our previous observations and possibly to reach strong statistical significance. Only if this significance is reached, can a meaningful comparison with astrophysical models be undertaken. We believe that our paper [1] helps in setting the frame for any new experimental data analysis in GW burst search.

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