

# Comments on the 2001 run of the EXPLORER/NAUTILUS gravitational wave experiment

P Astone<sup>†</sup>, D Babusci<sup>‡</sup>, M Bassan<sup>§</sup>, P Bonifazi<sup>||</sup>, P Carelli<sup>¶</sup>,  
G Cavallari<sup>+</sup>, E Coccia<sup>§</sup>, C Cosmelli<sup>\*</sup>, S D’Antonio<sup>§</sup>,  
V Fafone<sup>‡</sup>, S Frasca<sup>\*</sup>, G Giordano<sup>‡</sup>, A Marini<sup>‡</sup>, Y Minenkov<sup>§</sup>,  
I Modena<sup>§</sup>, G Modestino<sup>‡</sup>, A Moleti<sup>§</sup>, G V Pallottino<sup>\*</sup>,  
G Pizzella<sup>‡</sup>, L Quintieri<sup>‡</sup>, A Rocchi<sup>§</sup>, F Ronga<sup>‡</sup>, R Terenzi<sup>||</sup>,  
G Torrioli<sup>††</sup> and M. Visco<sup>||</sup>

<sup>†</sup> Istituto Nazionale di Fisica Nucleare INFN, Rome, Italy

<sup>‡</sup> Istituto Nazionale di Fisica Nucleare INFN, Frascati, Italy

<sup>§</sup> University of Rome “Tor Vergata” and INFN, Rome II, Italy

<sup>||</sup> IFSI-CNR and INFN, Rome, Italy

<sup>¶</sup> University of L’Aquila and INFN, Rome II, Italy

<sup>+</sup> CERN, Geneva, Switzerland

<sup>\*</sup> University of Rome “La Sapienza” and INFN, Rome, Italy

<sup>‡</sup> University of Rome “Tor Vergata” and INFN, Frascati, Italy

<sup>††</sup> IFN-CNR and INFN, Rome II, Italy

**Abstract.** The recently published analysis of the coincidences between the EXPLORER and NAUTILUS gravitational wave detectors in the year 2001 [1] has drawn some criticism [2]. We do not hold with these objections, even if we agree that no claim can be made with our data. The paper we published reports data of unprecedented quality and sets a new procedure for the coincidence search, which can be repeated again by us and by other groups in order to search for signature of possible signals. About the reported coincidence excess, we remark that it is not destined to remain an intriguing observation for long: it will be confirmed or denied soon by interferometers and bars operating at their expected sensitivity.

## 1. Comments on the experimental results

At present, the 2001 scientific run performed by our gravitational wave (GW) detectors EXPLORER and NAUTILUS [1] constitutes the most sensitive experiment for the detection of GW bursts ever carried out. When we analyzed the data collected, we became convinced of the importance of communicating that unprecedented sensitivities were reached by our detectors and that the use of powerful tools in analysis of the data (energy consistency of the events and sidereal time analysis) led to a coincidence excess centered at sidereal hour 4, which was defined in the paper “an interesting indication”.

**Table 1.** Number of observed coincidences  $n_c$  and integral number of accidentals  $\bar{n}$  for various sidereal time intervals around hour 4. The last column gives the Poisson probability that a background fluctuation produces  $n_c$  or more counts.

Sidereal time period (h)	$n_c$	$\bar{n}$	P
4	4	0.92	0.0145
3 - 5	7	1.69	0.0018
2 - 6	8	3.45	0.025
1 - 7	10	5.01	0.032
0 - 8	13	6.2	0.011

Criticisms to this analysis have been recently published [2]. A first criticism regards the mere existence of a coincidence excess. It is stated that the potential significance of the peak centered at sidereal hour 4 must be “diluted” because we did not declare before the analysis (i.e. “a priori”) that we were searching for sources giving excess in that sidereal hour (i.e. galactic sources). In other words, the significance of the peak was recognized “a posteriori”. As a consequence, the probability should be decreased of roughly a factor 24 because *a priori* the peak could have been found in any of the 24 sidereal hours.

To be quantitative about what we called an “interesting indication”, let us report (see Table 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.

These probabilities 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.

We are well aware that extraordinary claims need extraordinary evidence. By simply looking at these Poisson probabilities, we see that the coincidence excess we reported was certainly not strong enough to claim a detection, and in fact no such claim was made in our paper. However, two remarkable facts need to be underlined and give sense to the words “interesting indication”:

- the peak is centered at a physically significant sidereal hour, corresponding to the most favorable orientation of the detectors with respect to sources in the Milky Way. The Galaxy is certainly the privileged place of the sources attainable by present GW detectors and we think that the experiment described in [1] should be considered as based on the “a priori” hypothesis of signals originating in the Galaxy. This was clearly indicated in our previous paper [3] (pag. 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.” Recent work by Paturel and Baryshev [4], quantitatively indicated 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 for EXPLORER and NAUTILUS. So

we don't think that the reported Poisson probabilities should be further "diluted" by a factor taking into account all the possible peak positions in sidereal time.

- there is a strong energy correlation for the coincidence events during the sidereal hours interval 3 to 5 (see figure 8 of reference [1]). For those events the output of the two detectors have a correlation coefficient of 0.96 and the slope of the linear regression line for NAUTILUS energy on EXPLORER energy is 1.18, which, within the accuracy of the detector calibration, is in agreement with the hypothesis of having equal signals on the two parallel bar detectors. On the contrary, the events at the other sidereal hours exhibit a correlation coefficient of -0.19 (a very poor correlation, as expected for random values).

Another criticism is that, since a bar detector has a rather broad antenna pattern, one should expect a correspondingly broad peak in the sidereal time distribution of the coincidences, instead of the relatively narrow peak reported in [1]. This argument is very weak, because, given a source distribution, the geometrical antenna pattern of a single detector is not representative of the distribution of the coincidences between two detectors. Each detector has its own detection efficiency, which depends on the detector noise, threshold, and on the signal level. The coincidence distribution depends on the product of the efficiencies of the two detectors, and may give a relatively narrow peak if, for instance, the signals are near the thresholds. The fact that the width of the peak depends on the signal level and detector threshold was already shown for a single detector in reference [4], where the case of EXPLORER was explicitly considered.

For these reasons, we disagree with the objections to our paper, even if we agree that no claim of detection can be made with our data.

Last comment: we were told that some statements in our paper about the possible contribution of real GW signals to our data led the reader to think that we were claiming a discovery. We admit that, in spite of our conservative attitude, in a couple of phrases the possible presence of gw signals in our data was considered. On the other hand it should be recognized by any experimentalist that it is difficult to take data with detectors of unprecedented sensitivity, containing the reported indication, without at least being open to this possibility.

## 2. The future

In order to calculate the probability, or the degree of belief, of having observed real GW signals (and not simply the Poisson probability that a background fluctuation produces  $n_c$  or more counts), one should introduce astrophysical models for the sources. We deliberately left out this step in our paper, for two reasons: because we wanted to keep separate the observations from the possible astrophysical interpretations and, moreover, because we thought that more data were needed to evaluate the (unexpected) possibility that many gw bursts at the level of  $h \simeq 2 \cdot 10^{-18}$  are bathing the Earth.

The exercise presented by Astone [5] at the workshop GWDAW 2002 outlines how we can proceed in the future: updating the degree of beliefs adding new pieces of

information as more data become available. That paper is an important contribution to the debate (now starting) on how to evaluate and compare the results reported by different gravitational wave experimental collaborations.

In conclusion, let us say that we are proud to have crossed the benchmark of “nihil obstat” upper limit on the strength of the wave: we find that the amplitudes and rate of our candidate events are not only compatible with existing experimental upper limits [6] but also they are permitted by theoretical upper limits on gravitational wave strengths based on cherished beliefs about the astrophysical structure of the Galaxy and about the physical laws governing gravitational radiation [7]. This was not the case of the events observed by Weber with its first generation bars at room temperatures, which amplitudes were at least two orders of magnitude larger and which can be explained only by invoking unconventional hypotheses, like strong beaming by sources near the galactic center, or today being a very special time in the evolution of the Galaxy [7].

We remark that the indication we reported is not destined to remain an intriguing observation (and source of trouble ...) for long: the existence of bursts bathing the Earth at the level of  $h \simeq 2 \cdot 10^{-18}$  and at a rate of many per year would be such an unexpected gift from nature that it will easily be confirmed or denied soon with interferometers and bars operating at their expected sensitivity.

## References

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