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Searching for monochromatic signals in the ALLEGRO gravitational wave detector data

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Abstract. The detection of continuous gravitational wave (GW) signals is investigated using on a method developed for the detection of monochromatic signals in the middle of strong noise which makes power spectrum estimates using averaged modified periodograms. With this method it is possible to obtain a power spectrum for the data which preserves peaks due to monochromatic signals. In GW detection two kinds of Doppler shifts are expected, with annual and daily periods. Using the method an analysis is performed on persistent peaks, searching for frequency drifts that might present a pattern similar to the one due to Doppler shifts. For the chosen data set of the ALLEGRO gravitational wave detector it was found that none of the strongest, persistent peaks investigated presented a frequency drift with a Doppler shift pattern, thus excluding them as GW signal candidates.

1. Introduction

At the moment a large amount of data from gravitational wave (GW) detectors is available for analysis, including those from the ALLEGRO detector [1].

This detector was originally designed for the detection of burst signals [2] but the large amount of data taken continuously allows the search for monochromatic signals as well, like the

continuous emission of a non-axisymmetric neutron star. In one approach [3] the Doppler shift due to the Earth's motion was compensated and the intensity of the signals was the main parameter used for the identification of candidate signals. Using the same approach, a search for continuous signals coming from any direction in the sky was also performed [4].

In the present work a new approach will be tried. It is based on a method developed for the detection of monochromatic signals in the middle of strong noise by P. D. Welch [5, 6].

The results will be presented in Section 4. But first a theoretical introduction to the GW Doppler shift will be given in Section 2. The ALLEGRO detector data acquisition system will be briefly described in Section 3. The final Section is devoted to conclusions.

2. The Doppler shift of monochromatic gravitational wave signals

In GW detection one can assume that there will be a relative motion between an astrophysical source and a detector on Earth. This assumption is important when one analyzes long time series looking for periodic signals. A relative motion between source and detector changes the signal frequency by the Doppler effect. For galactic sources there are two major Doppler shifts: one due to the Earth's rotation and the other due to the Earth's translation.

Here one is interested on searching for signals that change in frequency in the ALLEGRO antenna time series. Those signals would be, in principle, gravitational wave signal candidates. From Doppler shift calculations one obtains the minimum frequency shift for an entire year.

3. The ALLEGRO gravitational wave detector and its data

The ALLEGRO bar detector is located at the Louisiana State University (latitude: 30.412577° N; longitude: 91.178627° W) in Baton Rouge (USA). The bar axis is directed along a line 40°24' west of North. When in operation the system was cooled down to 4.2 K and had two modes in which the sensitivity reached maxima: ~ 895 Hz (minus mode) and ~ 919 Hz (plus mode).

ALLEGRO's data was sampled at a rate of 125 Hz. Twenty seconds worth of data (2500 samples) were assembled by software into a data block (a raw data record) and written to disk.

4. Applying averaged modified periodograms to ALLEGRO data

Several days of ALLEGRO's data from the year 1997 were analyzed in the search for frequency drifts.

One day with particularly low noise is day 8, Figure 1 shows the temperatures of the two modes of this day. Figure 2 presents ALLEGRO's power spectral density for day 8, 1997, obtained applying the Welch method. Some peaks have well known origin, like the minus mode of the antenna, near 895 Hz, the plus mode, near 919 Hz, and the peak near 900 Hz, which comes from a harmonic of the electric 60 Hz network. There are other peaks of unknown origin. One of them was called "Mystery Mode" by the ALLEGRO group, with frequency near 887.5 Hz, identified as X mode in that figure, the peak identified as Y has a frequency near 907.5 Hz and the peak identified as Z has a frequency of 957.6 Hz.

In order to apply Welch's method looking for an annual Doppler shift, 500 records were selected each day, among the total 4320, what gives a integration time of 2.77 hours. Their data concerning the x and the y outputs of the lock-in were stored in a MATLAB [7] file, totalizing 1,250,000 (x, y) pairs.

A MATLAB software was then developed to manipulate this data conveniently. The routine groups data as powers of 2. A $32768 (= 2^{15})$ sample group needed collected, thus yielding a frequency resolution $\Delta f \sim 3.7$ mHz. This value is much smaller than the annual GW Doppler shift. Therefore, this frequency resolution is applicable to a data analysis searching for an annual period Doppler shift.

The *pwelch* routine yielded a function in the time domain, and it was transformed into the frequency domain using the MATLAB *fftshift* routine. Figure 1 shows the result obtained for day 8. The identified peaks were found to be persistent throughout the year. However, none of them showed a modulated pattern as a Doppler shifted signal would show. In contrast, the peaks

at the antenna modes (plus and minus) were monitored as well and they did not change bins at all during the observed days.

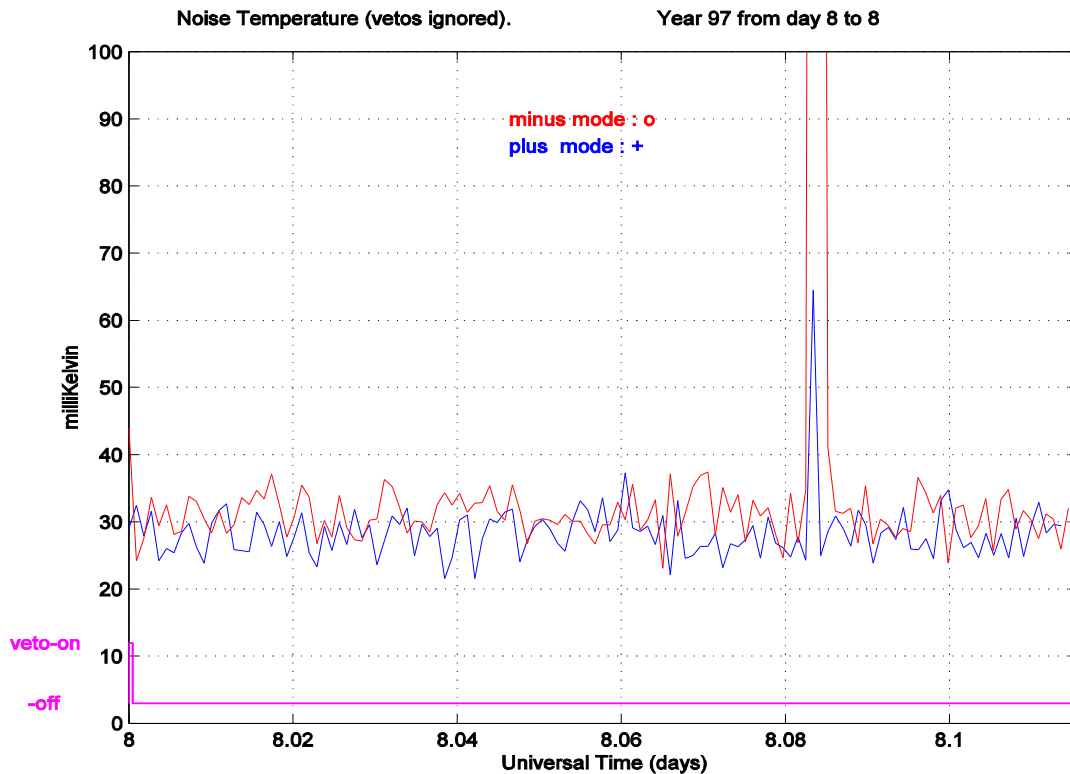


Figure. 1: Temperatures of modes plus and minus along day 8, 1997.

5. Conclusions

In this work a new method was applied to the search for monochromatic GW signals within data collected from the gravitational wave detector ALLEGRO. The method, due to Welch, is known in the literature but had not been applied to GW searches, as far as the authors know.

Three peaks in the data spectrum (X, Y and Z) were investigated in order to verify whether they had GW origin or not. This analysis indicates that none of the investigated peaks had GW origin, because they don't present a behavior compatible with Doppler variations. The analysis is versatile enough to allow for future more detailed searches (in frequency resolution).

The natural continuation of this work is the investigation of frequency drifts in other peaks in the data spectrum, including those with small amplitudes.

In fact, in order to improve the investigation it is planned to analyze more days of the year 1997, as well as including days from the years 1999 and 2000, increasing the sensitivity by averaging the periodograms in a longer period of time taking in account the change in frequency due to relative motion of the source and its direction in the sky. Figure 3 shows the periods of time that can be used, where the days when the detector was very noisy have been removed. When increasing the integration new peaks could appear, and these will be a very good candidate a gravitational wave signal.

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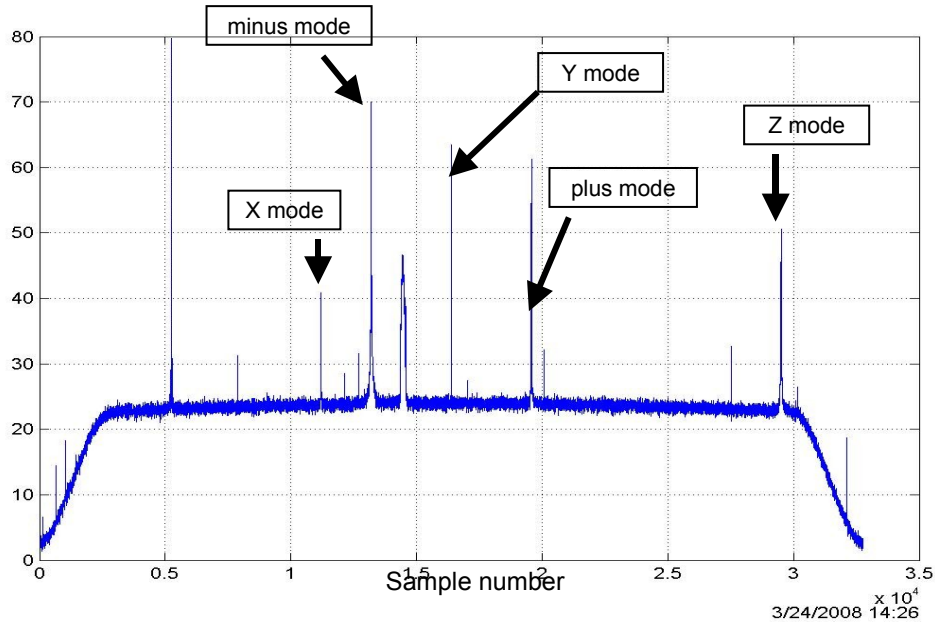


Figure 2: Averaged power spectrum for day 8.
The first sample starts at 844.810853 Hz, and the bin width is 3.824 mHz.

References

- [1] The ALLEGRO detector homepage is “sam.phys.lsu.edu”.
- [2] Mauceli, E. et al., *Phys. Rev. D* **54**, 1264 (1996).
- [3] Mauceli, E., McHugh, M.P., Hamilton, W. O., Johnson, W. W. and Morse, ArXiv:gr-qc/0007023v1, July 11, 2000.
- [4] E. S. Matos, O. D. Aguiar, R. M. Marinho Jr., W. O. Hamilton, W. W. Johnson and I. S. Heng, *Class. Quantum Grav.* **21**, S787 (2004).
- [5] A. V. Oppenheim and R.W. Schaffer. *Discrete-Time Signal Processing*. Prentice Hall International, 1989.
- [6] P. D. Welch. The Use of the Fast Fourier Transform for the Estimation of Power Spectra. *IEEE Transactions on Audio Electroacoustics* AU-15, 70-73 (June 1970).
- [7] MATLAB. Version 7.0.4.365 (R14). The MathWorks, Inc., 2005. See also at “www.mathworks.com”.

ON Times para ALLEGRO Detector 1997-2000

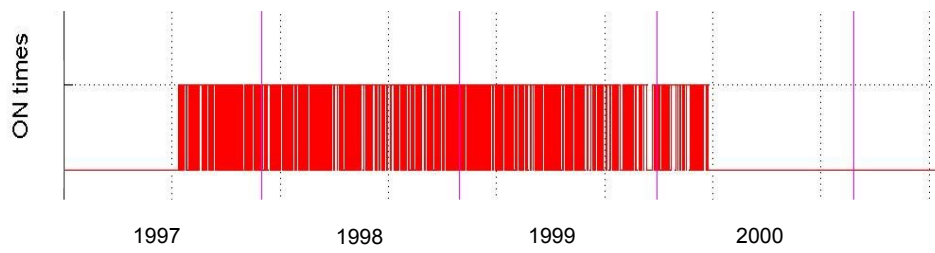


Figure 3. Periods of times when the ALLEGRO's data can be used.