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Some results from a continuous wave search using the ALLEGRO antenna

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Abstract

We have analysed the ALLEGRO data for the years 1999 and 2000 looking for continuous wave signals coming from some specific directions in the sky. No signal was found for these directions in long time integrations. However, we found a 'signal' at 919.535 Hz in a 50 min time integration search, which appeared on 13 August 1999 and disappeared on 12 December 1999. We present here the results of these searches and the reasons why we believe this 'signal' is probably noise.

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1. Introduction

Evan Mauceli was the first to analyse ALLEGRO data looking for continuous wave (CW) sources [1]. Pulsars with periods near 2 ms could emit gravitational radiation in the two most sensitive bands of the ALLEGRO antenna, which are at the minus and plus mode frequencies[4] both around 900 Hz. In the analyses made by Mauceli two directions were chosen: the galactic centre and the 47 Tucanae cluster. The final result of each analysis was a 'source spectrum' of strain amplitude versus signal frequency. No significant enough deviations were found to warrant any claim of discovery [2].

In this paper we show the results of a CW search using the same well-established Mauceli's method, which was applied to a more recent Allegro data, covering the years 1999 and 2000. For the explanation of this method of analysis see [1].

[4] The ALLEGRO antenna together with the transducer resonator forms a two-mode mechanical system with resonant frequencies at $f-$ and $f+$, the so-called minus mode and plus mode, which is the jargon used by experimentalists operating resonant-mass detectors. The noise curve for the 1999–2000 data had minimum values exactly around these mode frequencies. So, in other words, the maximum sensitivities were around the minus and the plus mode frequencies.

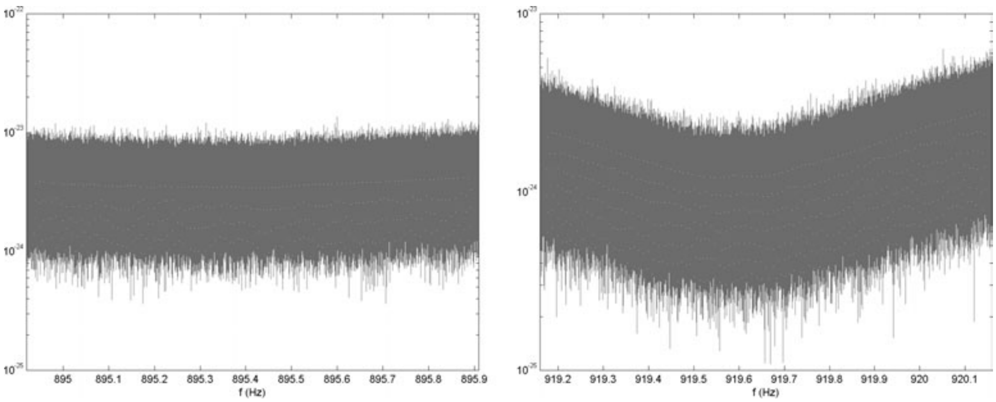

Figure 1. Strain amplitude versus frequency for the galactic spiral arm direction analyses: minus mode (left) and plus mode (right).

2. The spiral arm search

We repeated a similar set of analyses made by Mauceli now looking for CWs coming from a particular direction with the following coordinates: 55° galactic longitude (l) and 0° galactic latitude (b). This direction is aligned with one of the Milky Way spiral arms and for this reason a large number of the closest pulsars are located in that direction.

Another important change was that our continuous wave filter had a length of 20 days instead of the short 28 h length used by Mauceli. This is because the clock used by the ALLEGRO antenna in the 1999–2000 run was much more reliable than the previous one used for the data run analysed by Mauceli.

Figure 1 shows the results of our filtering analysis for the spiral arm direction in the two most sensitive bands of the ALLEGRO antenna, which are around the minus and plus modes, respectively. In this analysis we used three 20 day continuous data intervals. No relevant signal was found for this direction above 6σ. The mean and standard deviation were, respectively, 3.56×10^{-24} and 1.26×10^{-24} for the minus mode frequency (895.415 Hz) and 9.94×10^{-25} and 3.13×10^{-25} for the plus mode frequency (919.66 Hz).

3. Looking for strong CW signals coming from any direction in the sky

After the spiral arm search, we decided to turn off the Doppler correction[5] (removing it from the program), looking for strong signals coming from any direction in the sky. In order to accomplish this, we 'opened' the bandwidth of our filter, analysing 50 min intervals, instead of 20 day intervals. We chose this time interval duration (Δt_i) to keep an extraterrestrial signal in the same frequency bin even with the maximum Doppler shift variation possible due to the earth's rotation and translation.

The Doppler shift is given by $\Delta \nu \sim \nu(\Delta v/c)$, where c is the speed of light. On the other hand, $\Delta v = \Delta t_i(\mathrm{d}v/\mathrm{d}t)$ and the bin width is $\Delta \nu = 1/\Delta t_i$. Therefore, $(\Delta t_i)^2 = c/[\nu(\mathrm{d}v/\mathrm{d}t)]$

[5] The frequency of the signal received from the pulsar is shifted by the relative movement between the laboratory and the pulsar. This effect is due to the Doppler shift. For galactic sources there are two major Doppler shifts: one due to the Earth's rotation around itself and the other due to the Earth's translation about the Sun. Therefore, in order to search for the pulsar signal the digital filter used should take into account this frequency shift or 'Doppler correction'.

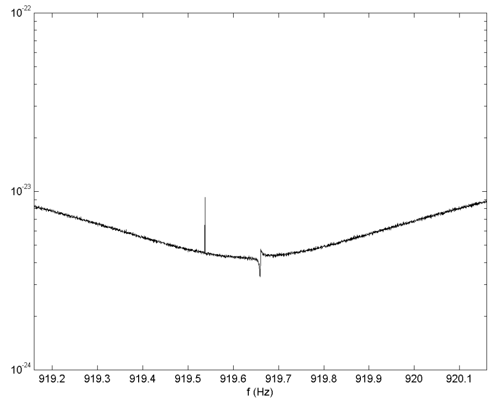

Figure 2. Strain amplitude versus frequency for the 'any direction' analysis (sum of all 50 min time intervals from day 225 to day 346 of 1999).

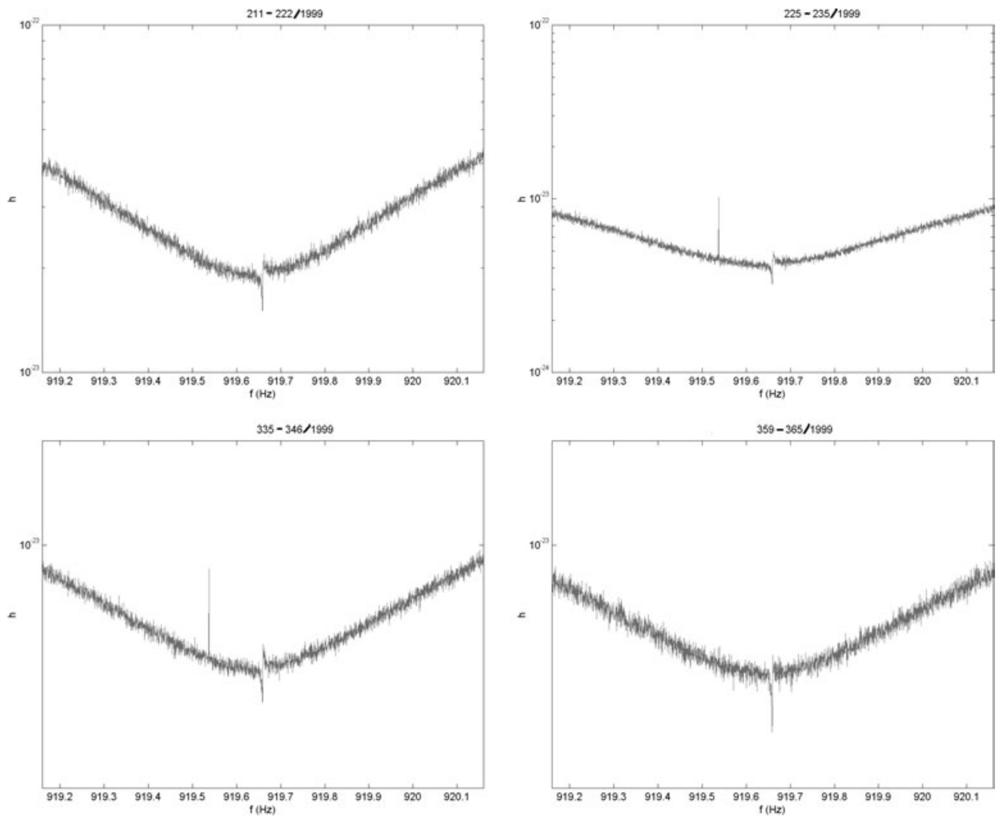

Figure 3. Strain amplitude versus frequency for the 'any direction' analyses: day 211 to day 222 of 1999 (top left), day 225 to day 235 of 1999 (top right), day 335 to day 346 of 1999 (bottom left), day 359 to day 365 of 1999 (bottom right).

$\sim$50.7 min, for $\nu \sim 920$ Hz and the maximum $\mathrm{d}v/\mathrm{d}t$ possible, which is 0.035 m s^{-2} for Baton Rouge latitude.

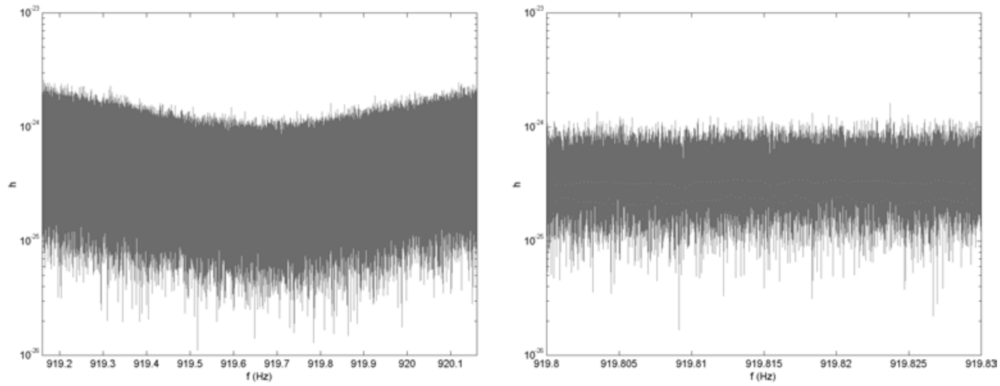

Figure 4. Strain amplitude versus frequency for the spiral arm direction analysis with the addition of a pure 919.81 Hz sinusoidal signal (the graph on the right is the zoom of the curve on the left).

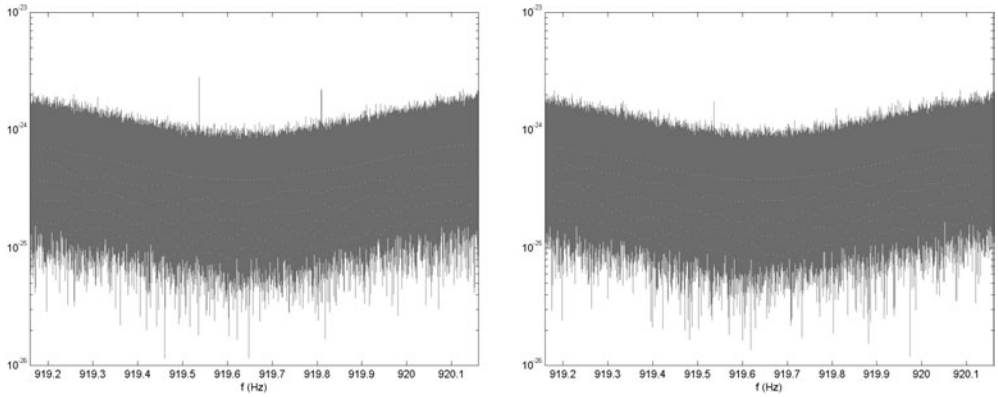

Figure 5. Strain amplitude versus frequency for the ecliptic 'north pole' (left) and 'south pole' (right) analyses with the addition of a pure 919.81 Hz sinusoidal signal.

An 80σ 'signal' was then found at 919.535 Hz, which is inside the plus mode band, in all $\sim$3k intervals during the period from day 225 to day 346 of 1999 (figure 2). We did not find it above 3 s, which was $h = 4.62 \times 10^{-24}$ at 919.535 Hz, in any of the 50 min intervals we had before or after that period (figure 3).

In order to test if this 'signal' was from a real source or just a local noise, we added a pure 919.81 Hz sinusoidal signal with 2×10^{-23} amplitude to our previous analysis for the spiral arm direction. Even though the amplitude of this added 'noise' was high, nothing was found above 6σ, which was $h \sim 2.8 \times 10^{-24}$ at that particular frequency in the strain amplitude curve (figure 4).

Then we tried the same kind of analysis for the direction perpendicular to the Earth–Sun orbital plane, for which the least Doppler correction is needed. The reasons for this are that for this direction there is no correction needed due to the orbit of the Earth about the Sun, and the Doppler correction due to the orbit of the Earth around itself is very small. The Earth's axis of rotation forms an angle of only $\sim 23.5^\circ$ with the direction perpendicular to the

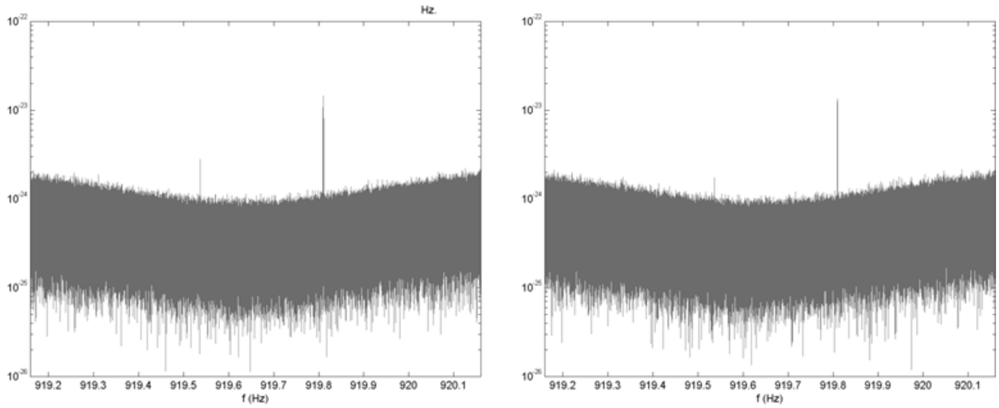

Figure 6. Strain amplitude versus frequency for the ecliptic 'north pole' (left) and 'south pole' (right) analyses with the addition of a 'real' 919.81 Hz signal at the 'north pole'.

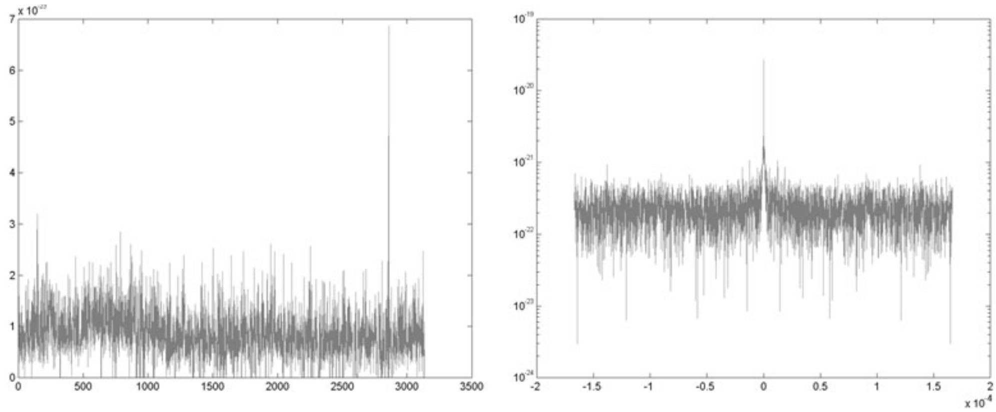

Figure 7. Strain amplitude versus 50 min interval for the 919.535 Hz 'signal' (a total of ∼3k 50 min intervals or ∼4 months was covered) (left), Fourier analysis (strain amplitude versus frequency (Hz)) of the previous graph (right).

Earth–Sun orbital plane. So, the relative velocity between the ALLEGRO antenna and sources placed in those directions would not exceed ∼0.16 km s^{-1}, which is negligible compared to ∼30 km s^{-1}, which is the maximum value of relative speed.

This 'signal' appeared for both 'north' and 'south' directions (figures 5 and 6). In figure 5 we compare it with a pure sinusoidal noise and in figure 6 with a simulated 'real' source at the 'north' pole. In both cases the analysis could not discard either possibility: real extraterrestrial signal or local noise.

Finally, we did a Fourier analysis for the full set of ∼3k (actually 2942) 50 min intervals which present the 'signal'. No significant sidereal day periodicity ($\sim 1.160 \times 10^{-5}$ Hz) was found in this analysis (figure 7). Therefore, we think that the most plausible conclusion is to suppose that this mysterious 'signal' was just a local laboratory noise. The data from the Nautilus antenna, which was also taking data in the period, may confirm this.

Acknowledgments

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