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Title: All-sky search of EXPLORER data: methods and results

Abstract:

Methods of matched-filtering of data for multiparameter signals are outlined. Results of the recently completed all-sky search for gravitational waves from spinning neutron stars in the data from the resonant bar detector EXPLORER are presented. Statistics of the candidate events are given and the upper bound for the amplitude of the gravitational wave is set. It is shown how the methods and the techniques applied to the case of the bar data can be used in the analysis of the data from laser interferometric detectors. Both to the ground based interferometers that recently started to collect data and to the planned interferometers in space. The main limitation of the matched-filtering method is the computational power available. The need for large scale computational facilities to analyse gravitational wave data is emphasized.

All-sky search of EXPLORER data for continuous sources: methods and results

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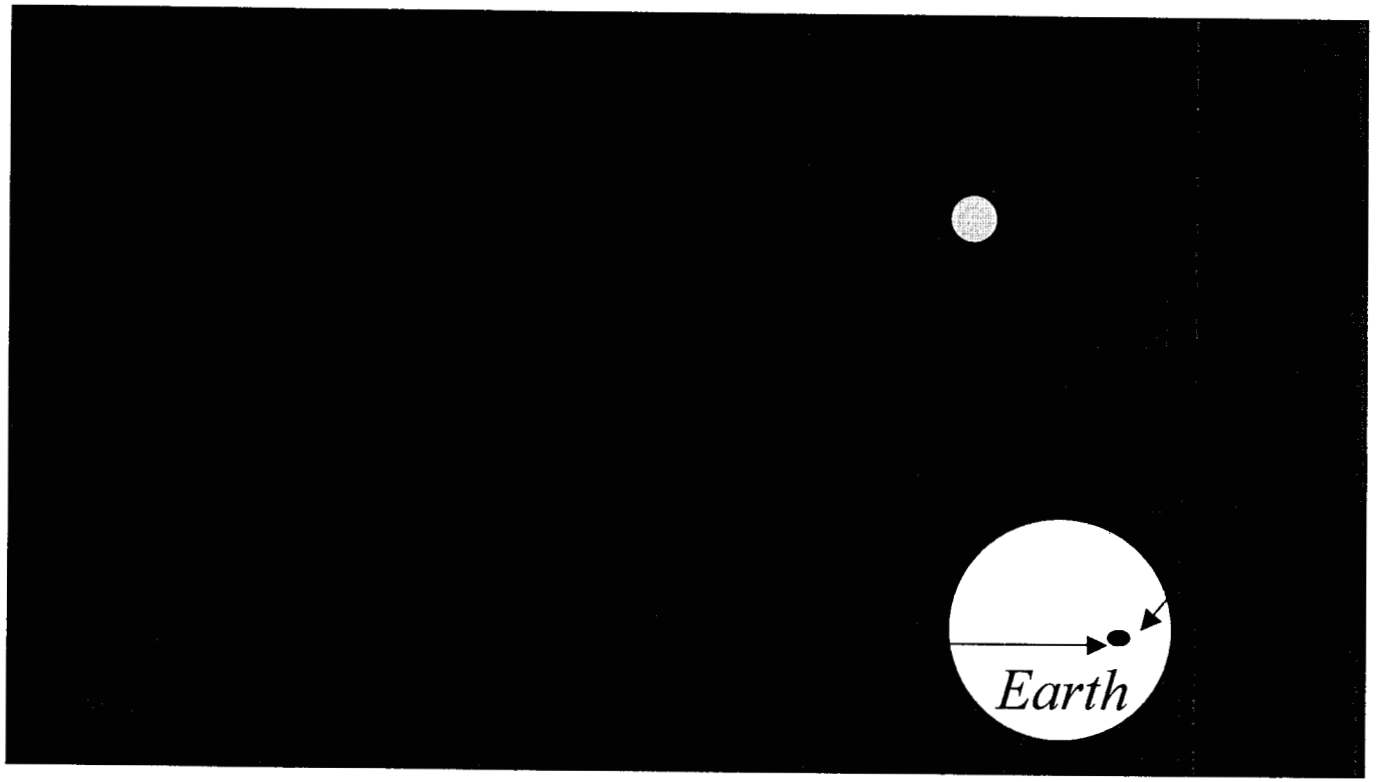
Introduction

- Detection of gravitational radiation is considered as a great challenge. Once detected it will provide a wealth of astrophysical information complementing observations through electromagnetic radiation.

The Talk

- Methods and tools of gravitational wave data analysis – significance of the cell concept.
- Analysis of the EXPLORER bar detector data.

Response of the detector to a continuous GW signals.



$$h_o \approx 4.2\times10^{-23}\left(\frac{\varepsilon}{10^{-6}}\right)\left(\frac{I}{10^{45}\mathrm{gcm}^2}\right)\left(\frac{1\mathrm{kpc}}{r}\right)\left(\frac{f}{1\mathrm{kHz}}\right)^2$$

$$\Phi(t) = \sum_{k=0}^{s_1} \omega_k \frac{t^{k+1}}{(k+1)!} + \frac{\vec{n}_o \cdot \vec{r}_{SSB}(t)}{c} \sum_{k=0}^{s_2} \omega_k \frac{t^k}{k!}$$

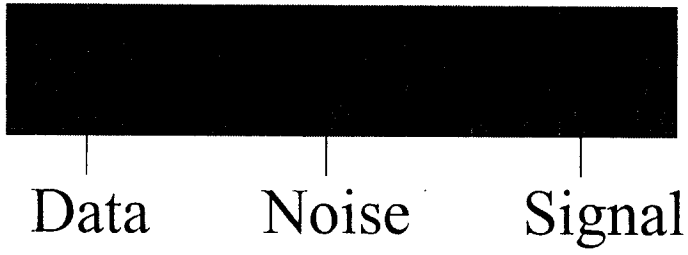
Linear parameterization of the response

- For observation time of few days and a few Hz bandwidth linear representation is an adequate approximation.

$$\Phi_s = p_o t + \sum_{k=1}^{s} p_k t^{k+1} + A\cos(\Omega t) + B\sin(\Omega t)$$

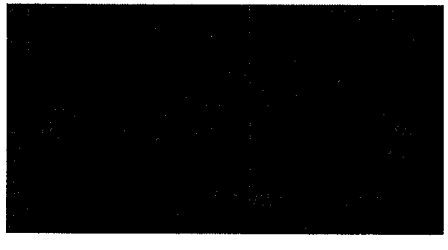
Matched filtering

additive noise



likelihood ratio

signal-to-noise ratio



Maximum likelihood detection

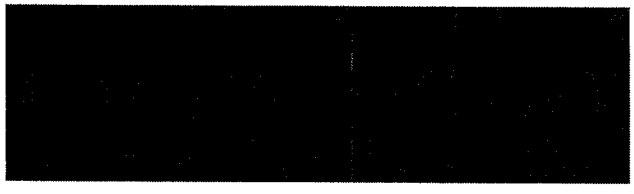
[redacted]

$$T_j = \int_0^{T_o} x(t)\, a_j(t) \exp[-i\Phi_{NS}(t)] \exp[-i p_0 t]\, dt$$

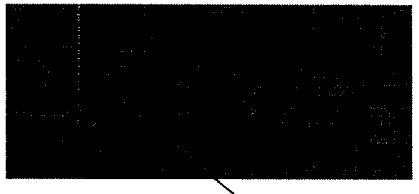
[redacted]

In the case of a linear phase model F is a homogeneous random field.

Characteristic correlation hyperellipse



Taylor expansion



Fisher information matrix

Number of cells in the parameter space:

False alarm probability

Grid of templates in the parameter space

Expectation value of the statistics when the signal is present in the data

[redacted]

[redacted]

Taylor expansion

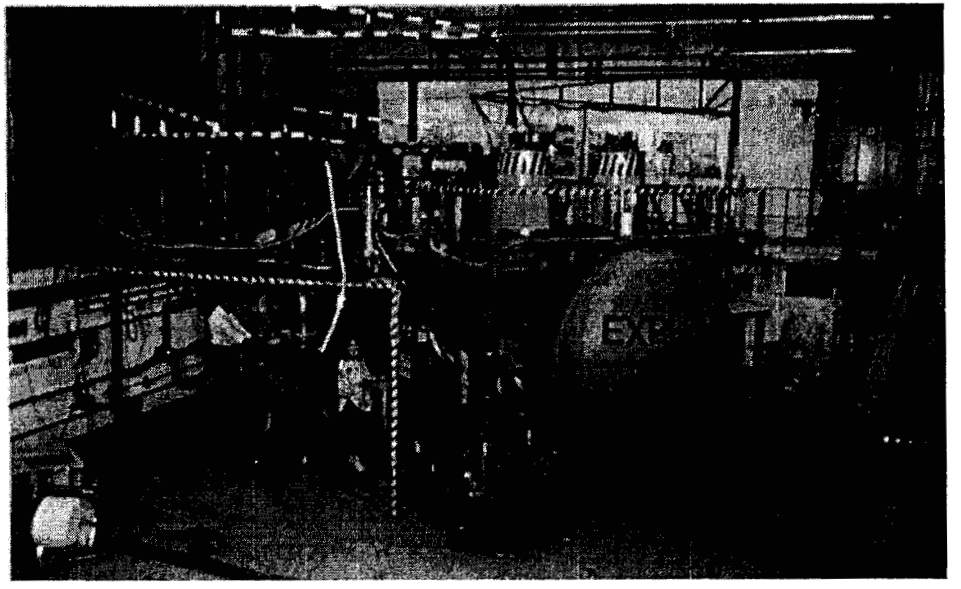
[redacted]

Find a regular grid so that each elements of the grid is inscribed into hyperellipsoid

[redacted]

All-sky Search of the EXPLORER Data

EXPLORER resonant bar detector



The EXPLORER detector is operated by Italian group called ROG currently led by Eugenio Coccia. The analysis is performed by a team consisting of Pia Astone, Kazik Borkowski, Piotr Jaranowski i Andrzej Królak and is carried out on the basis of Memorandum of Understanding between the ROG group and Institute of Mathematics of Polish Academy of Sciences.

Parameters of the search

- Parameters of the data:
- The Modified Julian Date of the first sample: 48580.7908507
- Length of observation time: 2 days
- Bandwidth of the search: 920.9992 -- 921.7598 Hz
- Parameters of the search:
- Spin down range: $-9.1762\ 10^{-8}$ -- $+9.1762\ 10^{-8}$ Hz s^{-1}
- No. of spin downs 2868
- Sky positions: All sky, no. of pointings 31915
- No. of filters = 183064440
- No. of cells = 1.6×10^{12}
- Sensitivity of the search
- Spectral density (two-sided) = $10^{-21}/\sqrt{Hz}$
- Amplitude

  d =1 h = 3.4×10^{-24}

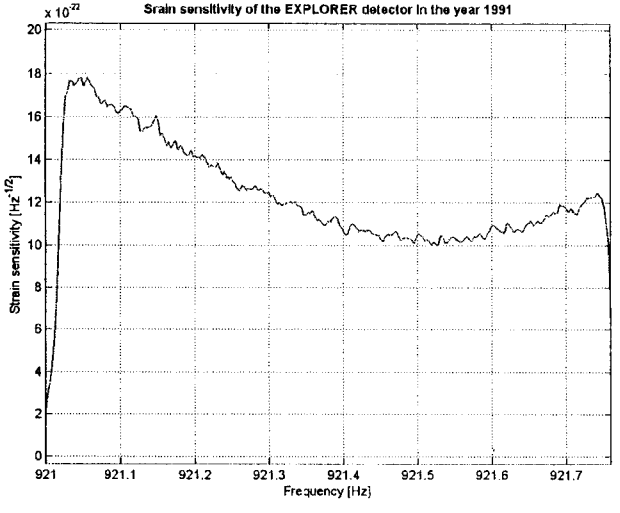
  d = 8.3 h = 2.8×10^{-23} (e=10^{-5}, P = 2ms, r = 1kpc)

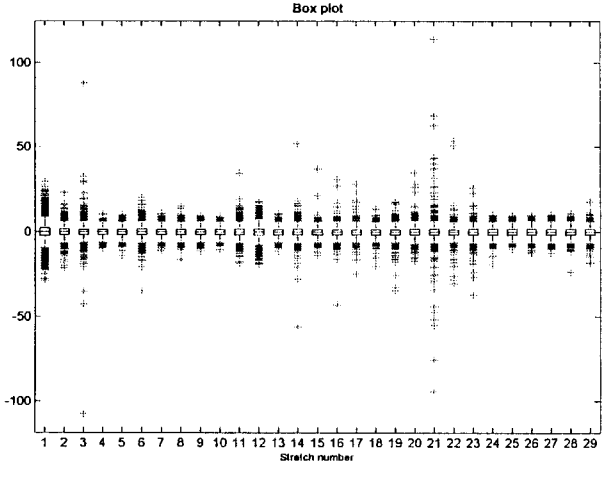
Search progress

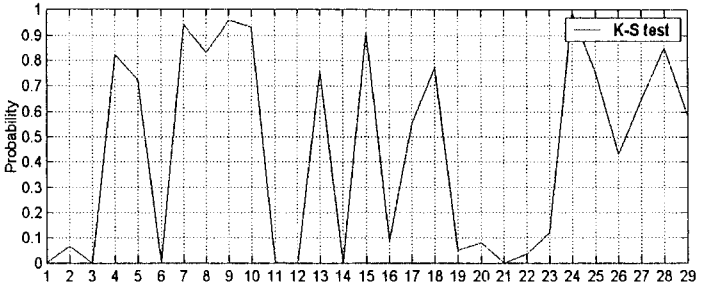
- Our website:

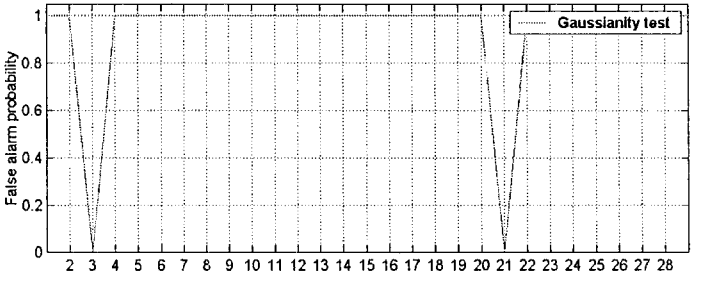
http://www.astro.uni.torun.pl/~kb/AllSky/AllSky.html

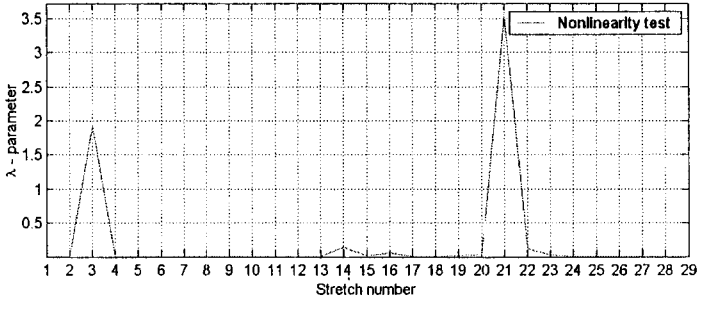
Data characteristics



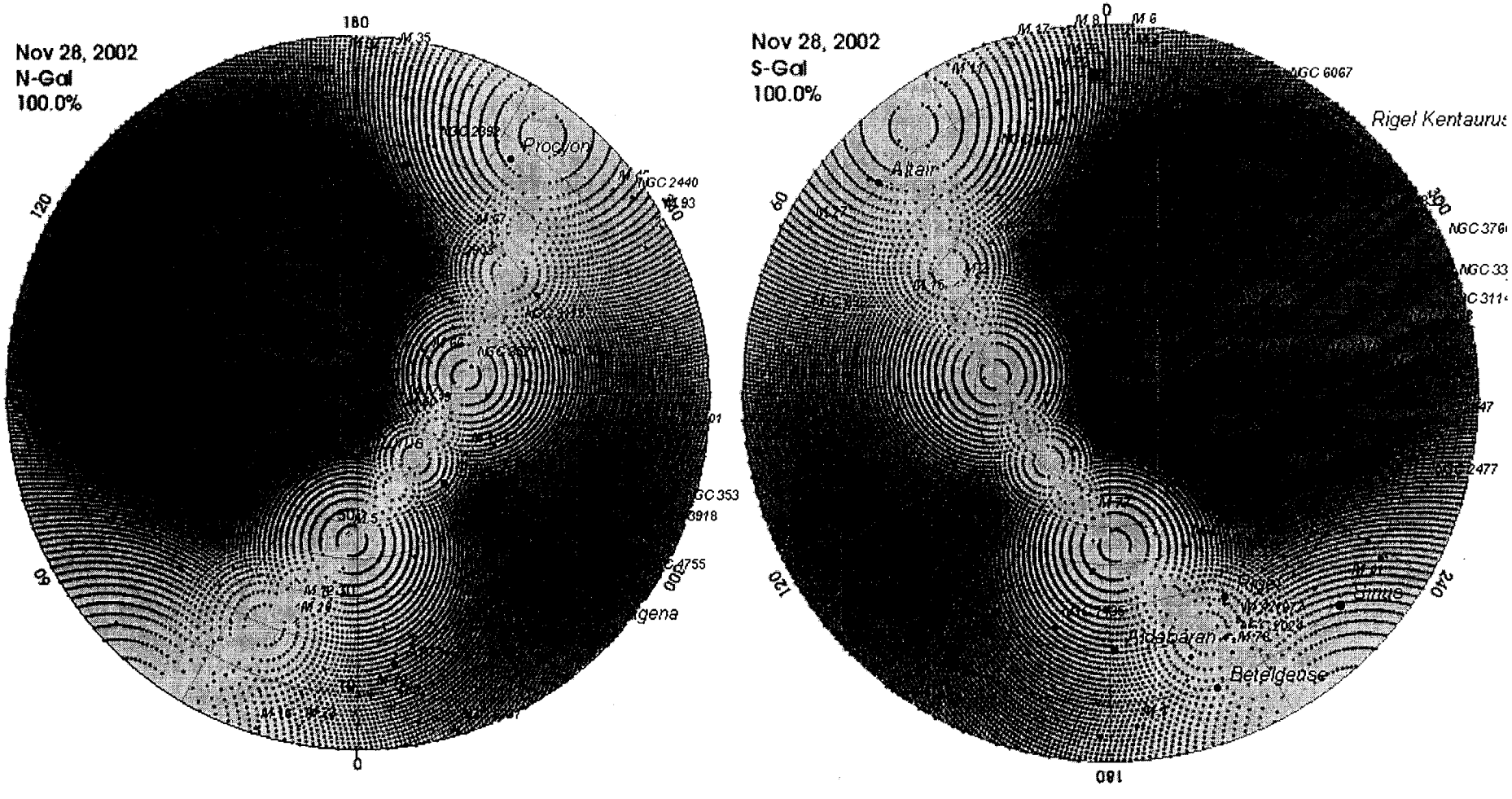






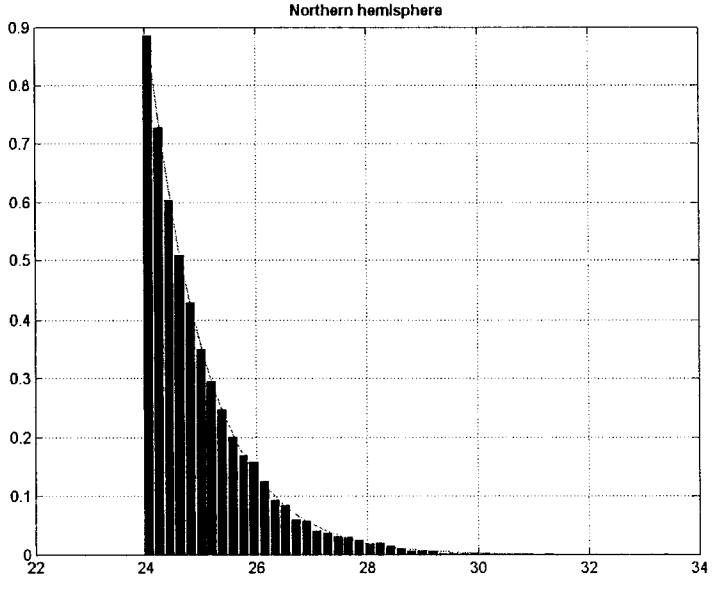


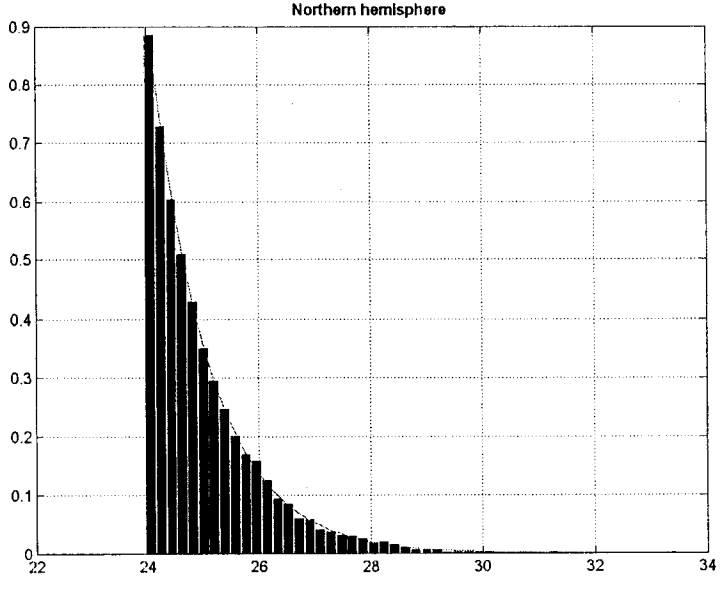
Search progress



Candidate statistics

If there is no noise F has χ^2distribution with 4 degrees of freedom.

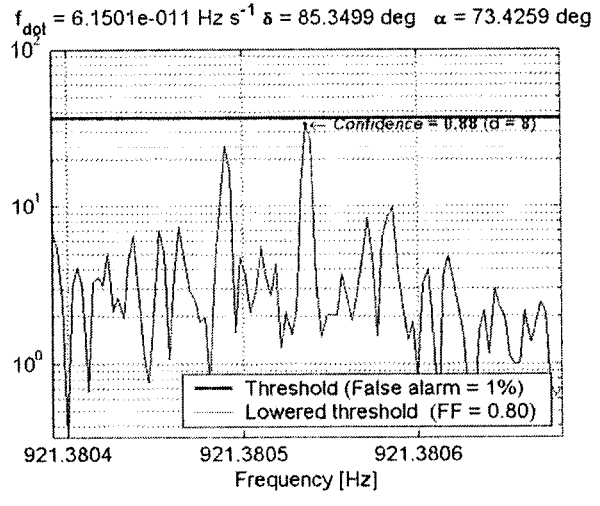


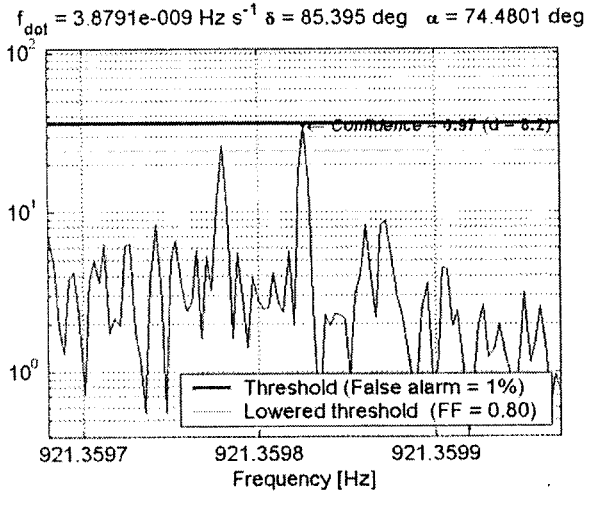


Candidate verification

1. Transformation from parameters (p_0,p_1,A,B) to astrophysical parameters (f, f_1, α, β) .
2. Search on a small grid around astrophysical parameters.
3. Search in a different 2-day stretch of data.
4. Search in a 4-day stretch of data containing the original 2-day stretch.

Candidate verification: an example





NO SIGNAL FOR DIFFERENT OBSERVATION TIME