A first test of a Sine-Hough method for detection of pulsars in binary systems using the E4 Virgo test run data

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On behalf of the Virgo Collaboration

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- Motivations
- Principle
- The data set
- Preliminary results
- Conclusion

Why a search for pulsars in binary systems ?

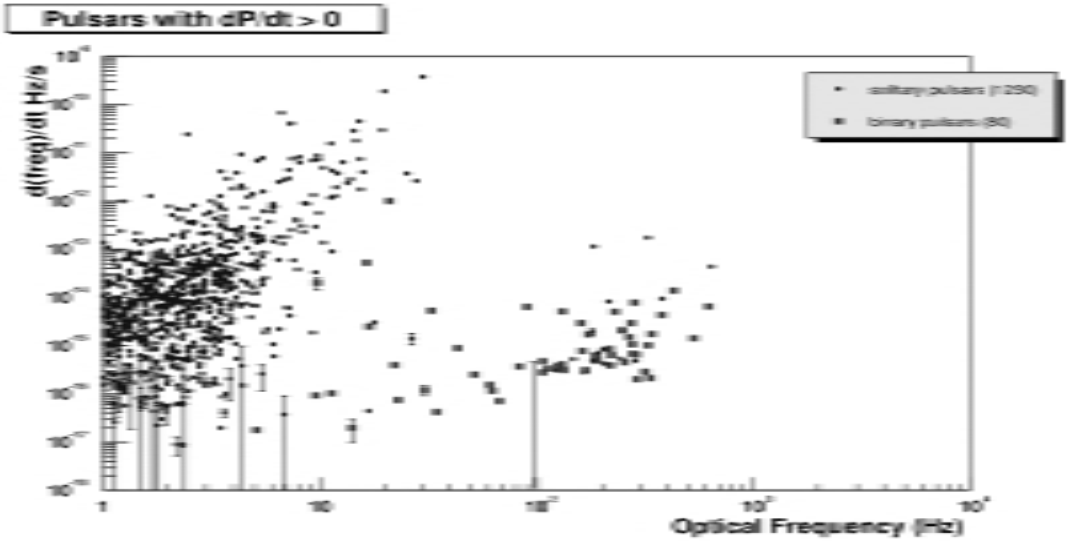
Observation:

1) In the Virgo detection range we are dominated by pulsars in binary systems
2) Pulsars in binary systems seem to belong to a different family of objects
3) Only a small number of binary systems have a significant eccentricity

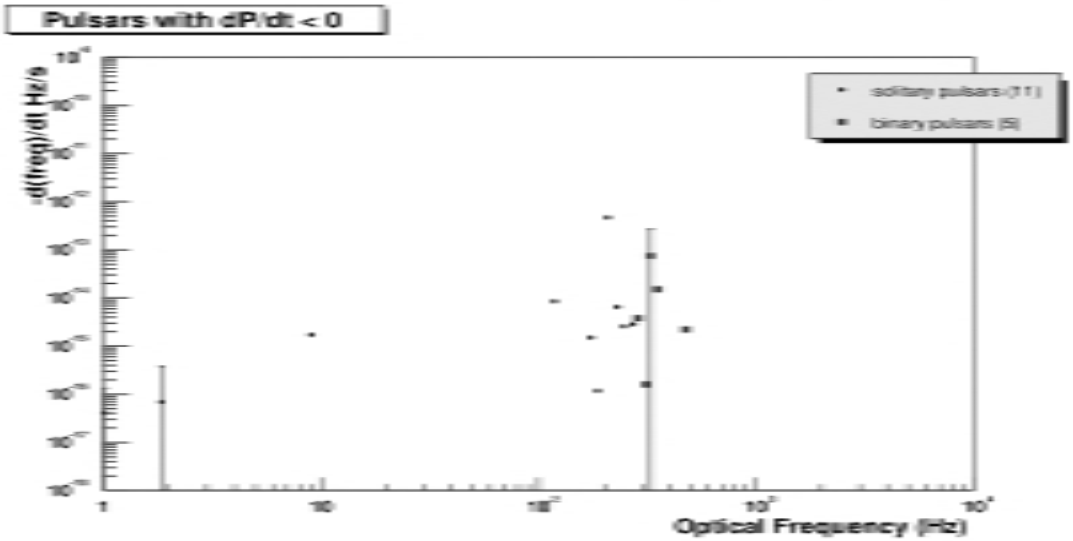
All pulsars from ATNF Catalog

(1326 pulsars)

decelerating pulsars



accelerating pulsars



All pulsars from ATNF Catalog

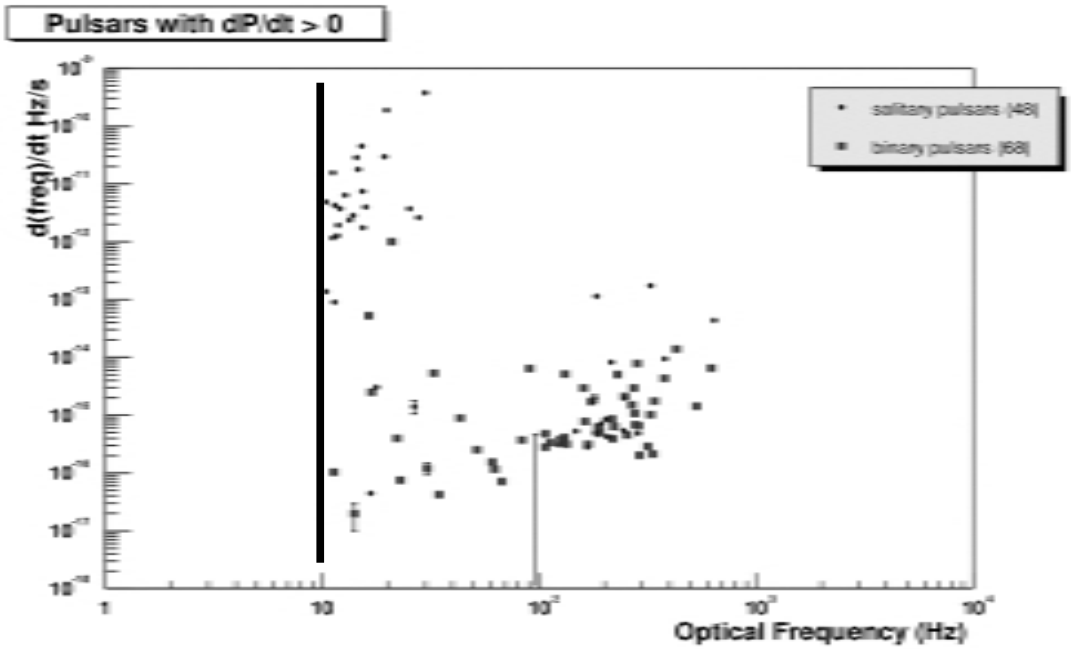
(1326 pulsars)

Pulsars with dP/dt > 0

ν_{opt}>10Hz

Singles : 48

In binary syst: 68



1) above 10 Hz we are dominated by pulsars in binary systems

2) Single pulsars and binaries do not belong to the same category of objects

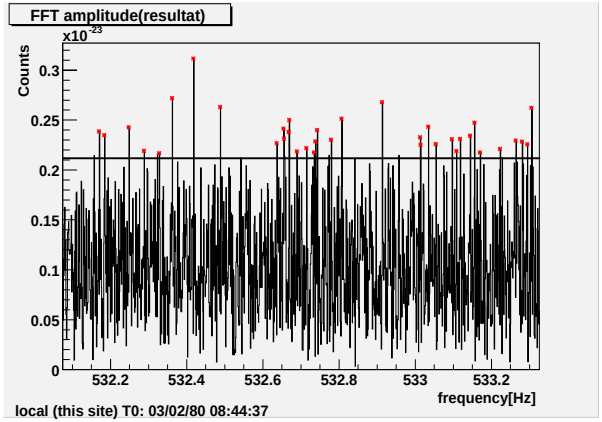
Principle:

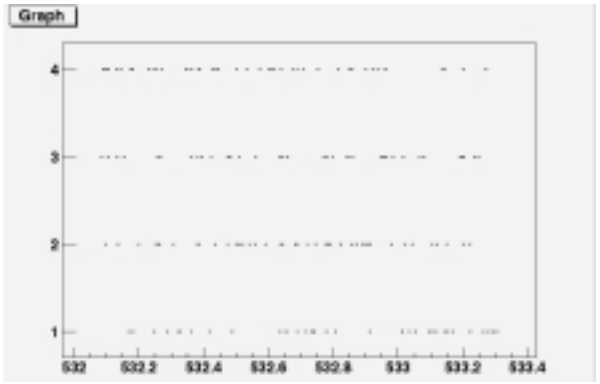
If the system has a null eccentricity (large majority of binary systems) the evolution of the Doppler shift as a function of time is a sine function(*).
In a time frequency diagram the problem becomes the identification of a sine shape in a noisy environment

(*)The Doppler shift due to the relative motion of the binaries dominates the Earth motion effect for the large majority of the systems

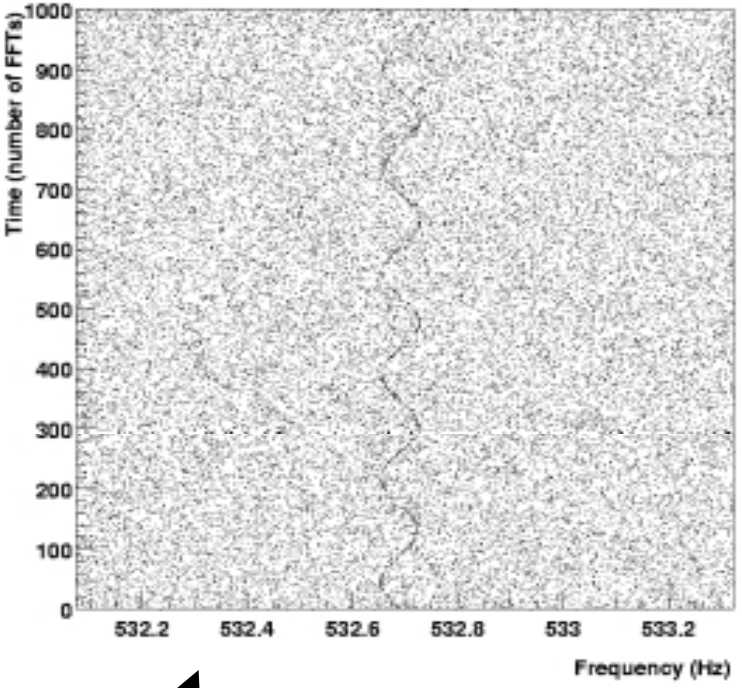
Build up a time-frequency diagram:

- take from the Fourier transform the points above a threshold
- use the so-constructed lines to build up a time frequency diagram





~ 10 days



Hough Sine method

Problem:
Find a sine shape among a set of points (4 parameters)

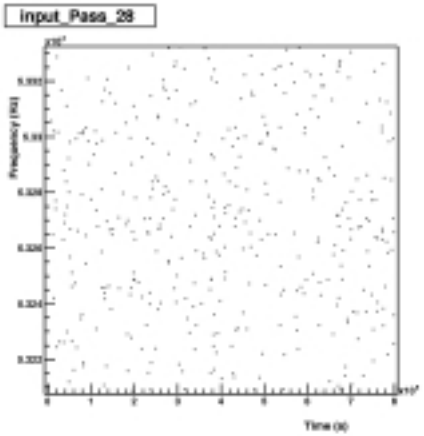
$$y = y_0 + a.\sin(2\pi\nu t + \varphi)$$

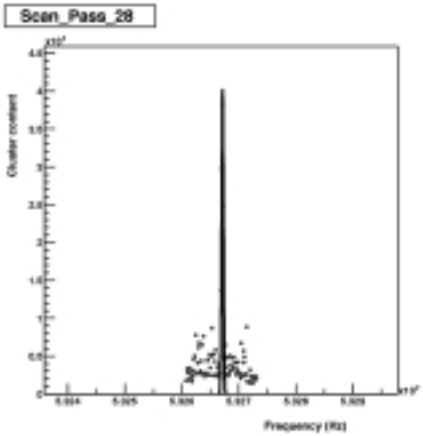
Idea:

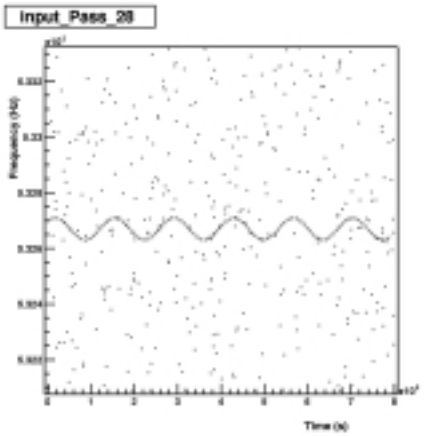
1) Fix the value of y_0
2) Take 3 points to compute a , ν , φ
3) From the obtained values increment a cell in a 3d volume with axis a ν φ
4) Loop over all combinations of points 3 by 3
5) Search for accumulations in this 3d volume
6) Scan the possible values of y_0

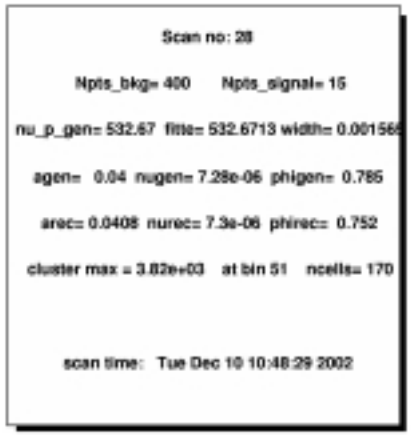
Hough Sine method Test on simple Monte-Carlo

400 points of noise,
15 points of a sine signal







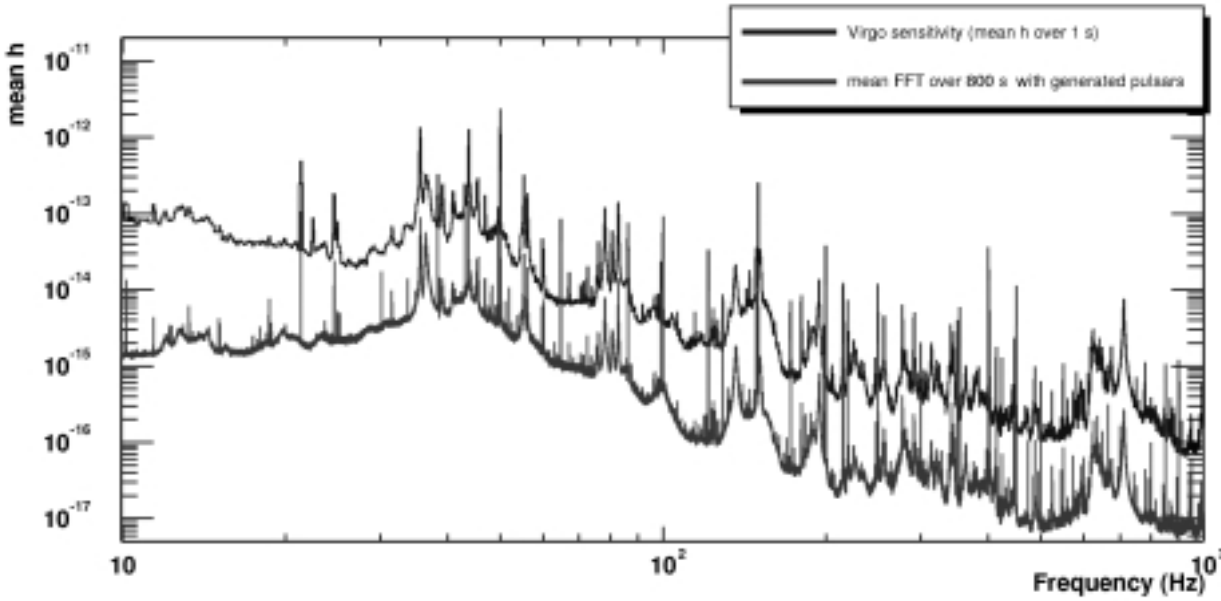


Input data:

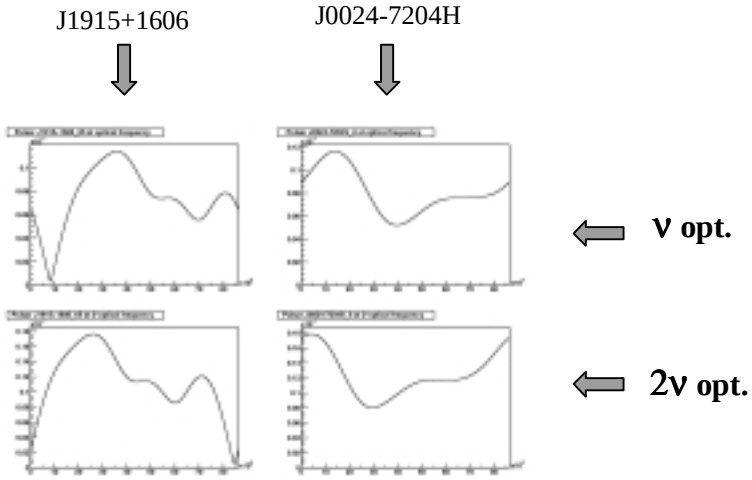
Select the "good time zones"

Add to the data, in the time domain, 66 pulsars in binary systems with the ATNF catalog data parameters, generated with ν_{opt} + 1Hz (the double freq. will have +2Hz), 132 lines.

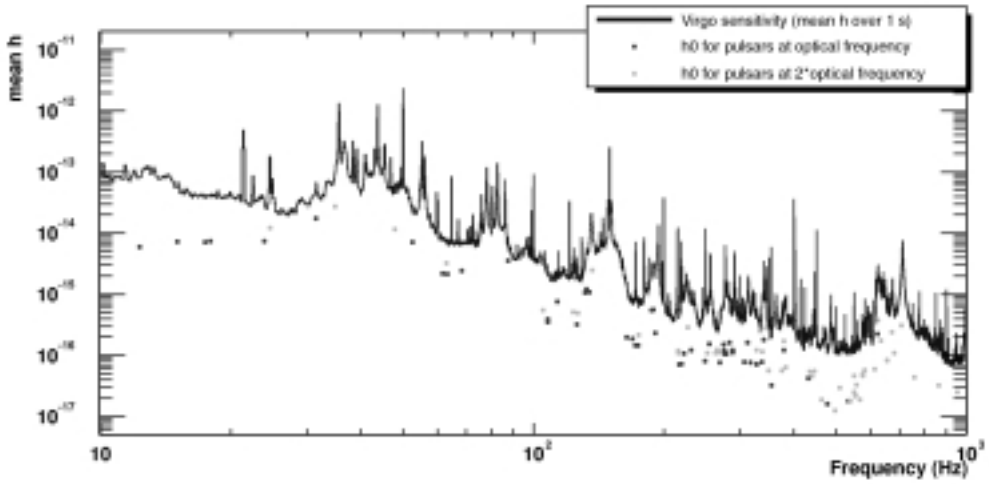
4KHz sampling, Fft 800s, with Hanning window and time shift of 400s total of 276 lines in time and 792000 bins in frequency from 10 to 1000 Hz

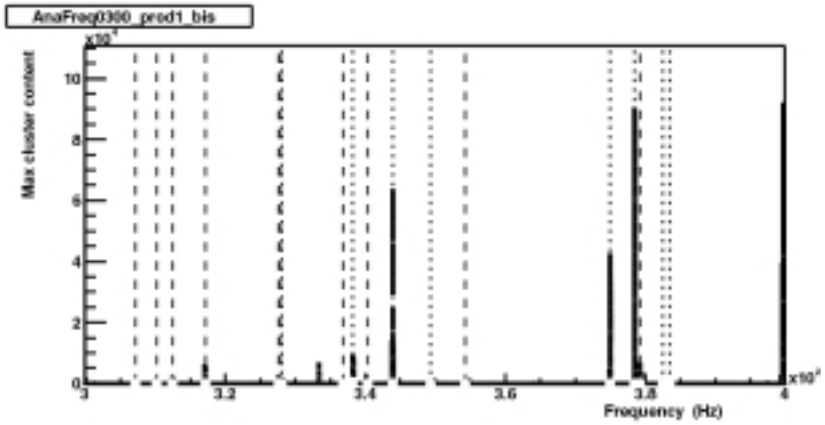


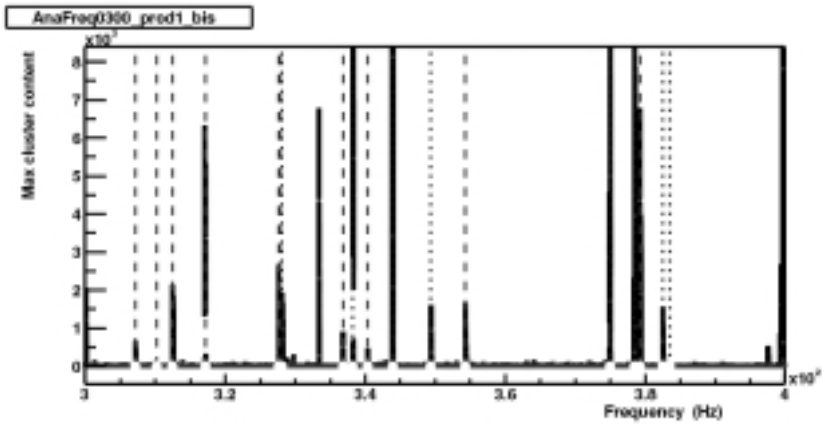
“antenna effect” evolution during 1 day for 2 pulsars

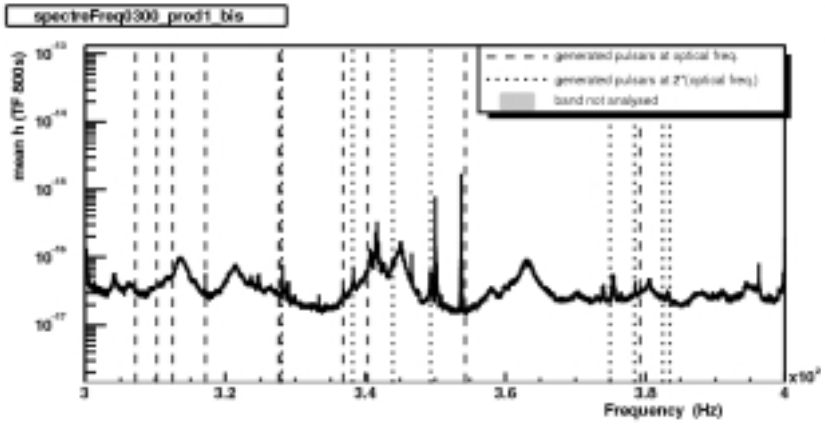


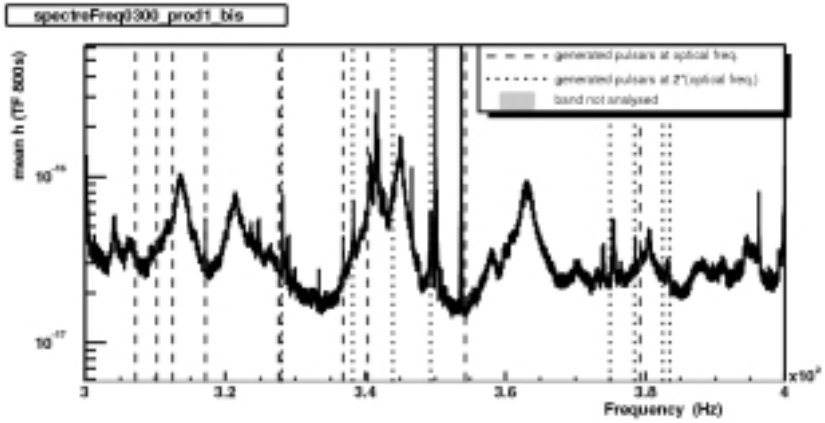
Generated h amplitude of the added pulsars




AnaFreq0300_prod1_bis
Max cluster content
Frequency (Hz)


AnaFreq0300_prod1_bis
Max cluster content
Frequency (Hz)


spectreFreq0300_prod1_bis
mean h (TF 800s)
generated pulsars at optical freq
generated pulsars at 2*(optical freq)
band not analysed
Frequency (Hz)


spectreFreq0300_prod1_bis
mean h (TF 800s)
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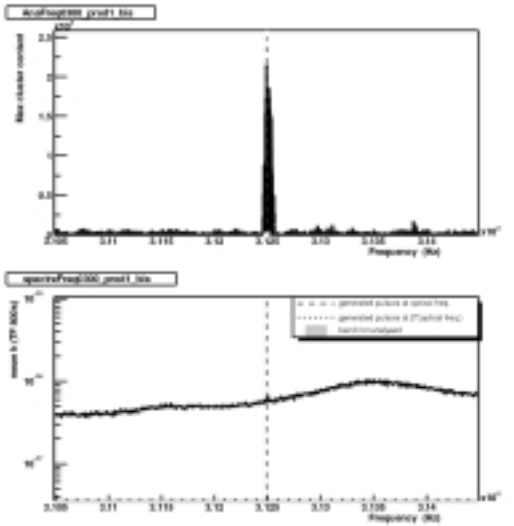
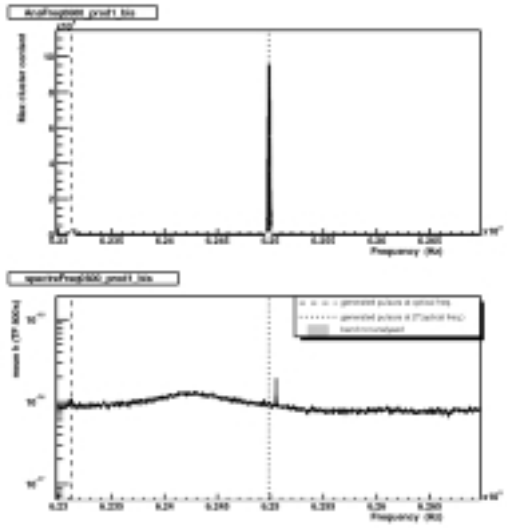
generated pulsars at 2*(optical freq)
band not analysed
Frequency (Hz)

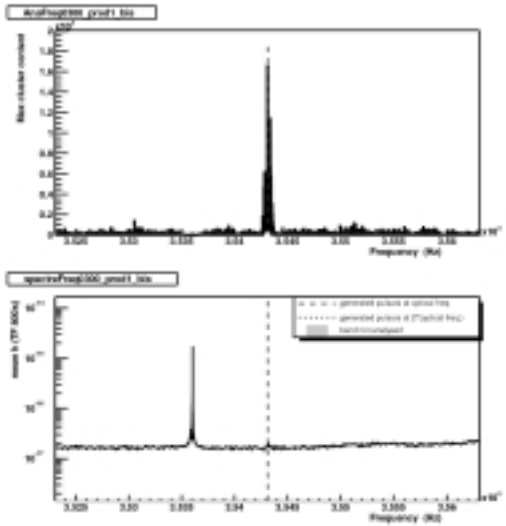
J0024-7204H
at optical freq.



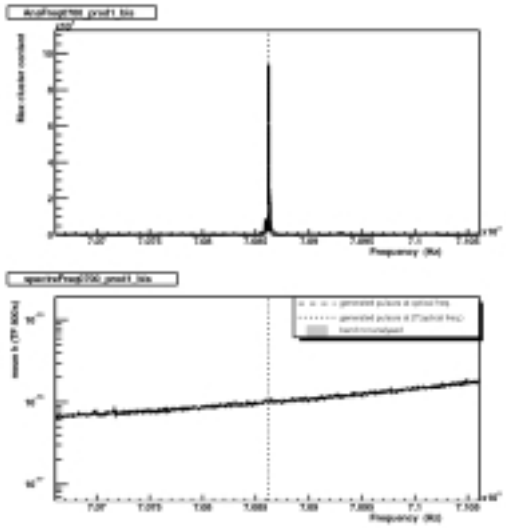
J0024-7204H
at 2*optical freq.



J0024-7204S
at optical freq.



J0024-7204S
at 2*optical freq.



Summary of results for J0024-7204H and J0024-7204S

J0024-7204H $\nu_{opt.}$ $h_0=1.61\ 10^{-16}$	Catalog	Generated	Reconstructed (peak)
pulsar frequency (Hz)	311.493	312.49	312.49
Frequency of binary system (Hz)	$4.909\ 10^{-6}$	$4.909\ 10^{-6}$	$4.78\ 10^{-6}$
Delta nu max (Hz)	0.02	0.02 (calculated)	0.022

J0024-7204H $2\nu_{opt.}$ $h_0=3.74\ 10^{-16}$	Catalog	Generated	Reconstructed (peak)
pulsar frequency (Hz)	622.698	624.98	624.98
Frequency of binary system (Hz)	$4.909\ 10^{-6}$	$4.909\ 10^{-6}$	$4.75\ 10^{-6}$
Delta nu max (Hz)	0.04	0.04 (calculated)	0.046

J0024-7204S $\nu_{opt.}$ $h_0=3.2\ 10^{-17}$	Catalog	Generated	Reconstructed (peak)
pulsar frequency (Hz)	353.306	354.31	354.31
Frequency of binary system (Hz)	9.63710^{-6}	$9.637\ 10^{-6}$	$9.71\ 10^{-6}$
Delta nu max (Hz)	0.016	0.016 (calculated)	0.016

J0024-7204S $2\nu_{opt.}$ $h_0=3.11\ 10^{-16}$	Catalog	Generated	Reconstructed (peak)
pulsar frequency (Hz)	706.612	708.61	708.61
Frequency of binary system (Hz)	$9.637\ 10^{-6}$	$9.637\ 10^{-6}$	$8.25\ 10^{-6}$
Delta nu max (Hz)	0.032	0.032 (calculated)	0.042

Conclusions

-Pulsars in binary systems are:
    -The majority (above 10Hz opt.)
    -Driven by non-standard mechanisms (non-standard h values?)

-This Sine-Hough method looks very promising to hunt them

-Without a fine tuning of some parameters (which have been "guessed") it allows to find pulsars in binary systems hidden in real data

-A lot of work remain to be done to understand the limits of the method