Recent measurements of IGEC2 GW observatory

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OUTLINES OF THE TALK

• IGEC2 collaboration detectors

• First data exchange May – Nov 2005
  - Introduction to data analysis methods
  - Characteristics of exchanged data
  - False alarm estimation
  - Statistical data analysis & follow up

• Results  NO CANDIDATE FOUND
IGEC 2

International Gravitational Events Collaboration

ALLEGRO– AURIGA – ROG (EXPLORER-NAUTILUS)
The “oldest” among the resonant detectors, EXPLORER started operations about 16 years ago.

Detectors of this kind reached, since several years, a high level of reliability.

The present duty factor is higher than 90%.

In the past the data of the different experiments, alone or in coincidence, have been used in searches for different kind of sources: continuous, stochastic background and burst signals.
IGEC – search for burst signals

- **IGEC1 1997-2000** – First experience using the data of 5 bar detectors: ALLEGRO, AURIGA, EXPLORER NAUTILUS and NIOBE. In four years 29 days of four-fold coincidences-178 days of three-fold coincidences - 713 days of two-fold coincidences

- After the last upgrades the resonant detectors have resumed the operations at different time: EXPLORER in 2000, AURIGA in 2003, NAUTILUS in 2003, ALLEGRO in 2004. NIOBE no more in operation.

- **IGEC2 2005-….. -**. First exchanged period May-November 2005 when no other observatory was operating. A larger amount of data is available for further analysis.
• The four antennas receive an identical signal, independently from the source and time.
SENSITIVITY OF IGEC DETECTORS

IGEC 1
1997-2000

IGEC 2
2004 - ....
FIRST DATA EXCHANGE OF IGEC2

• The first exchanged data set goes from Friday May 20 through Tuesday Nov 15, 2005.
  • **AURIGA-EXPLORER-NAUTILUS** data exchanged
  • **ALLEGRO** data available only for follow-up investigation
  • IGEC2 was the only GW observatory in operation
  • The analysis results were public at the end of September 2006
DATA ANALYSIS METHODS

• Each group produces a list of candidate events using filters matched for δ signals

• The data are exchanged after adding a “secret time shift” (within ± 10s) to the time of the candidate events.

• A statistical distribution of the accidental time coincidences number is calculated using many different lists of candidate events obtained from the original ones simply adding different time shifts.

• The search parameters (search threshold, coincidence window) are fixed “a priori” using the accidental coincidences analysis. An upper limit at the present sensitivity of the bar detectors is not an interesting scientific result therefore the analysis was tuned to a possible detection requiring an identification of possible candidates with high confidence fixing the false alarm to 1 coincidence over 100 years

• Finally the groups exchange the secret times and the search for real coincidences is performed.

• If any candidate is found, follow-up investigation would be performed.
OPERATION TIME – MAY 20 – NOV 15, 2005
(AURIGA- EXPLORER- NAUTILUS)

- no detector 0.6 days
- Single 3.6 days
- Double 45.0 days
- Triple 130.8 days

Data from ALLEGRO to be added

96 %
87 %
86 %

days of operation

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AMPLITUDE OF THE EXCHANGED DATA
In terms of Fourier component \( H \)

- \( \text{SNR} \geq 4.5 \) for AURIGA
- \( \text{SNR} \geq 4.0 \) for EXPLORER and NAUTILUS
DATA QUALITY: DISTRIBUTIONS OF EVENTS

- Few events/day with SNR>6
- Few very large events (SNR>30) on the whole period
• The sensitivity is stationary

• Due to the improvement in the noise of the detectors the search threshold is about a factor 3 lower than in IGEC 1

Percentage of time with the search threshold smaller than H
TIME COINCIDENCE WINDOW

• Coincidence window \( |t_1 - t_2| < 4.47 \sqrt{\sigma^2(t_1) + \sigma^2(t_2)} \)
using Byenaimé-Tchebychev false dismissal < 5% (<15% for triple coincidences)

For EXPLORER and NAUTILUS the \( \sigma t \) was fixed at 10 ms
The coincidence distribution is poissonian
THREE-FOLD COINCIDENCES BACKGROUND

Total number of time shifts

Mean number of accidental triples on 131 days

ALL THE EXCHANGED DATA $\text{SNR} \geq 4.5$ AU $\text{SNR} \geq 4.0$ EX-NA

$\pm 2200$ Time Shift (5 sec) EX-AU & NA-AU

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CHOICES IN THE ANALYSIS
main target 1 false alarm/century

• We decided to use only three-fold coincidences
• We decided to perform one composite search made by the OR among 3 different data selections:
  • **Selection A** - SNR > 4.95 for AU, EX e NA
    0.396 false alarm/century
    target signals centered in the EX-NA peaks
  • **Selection B** - SNR > 7.00 for AU, SNR>4.25 per EX e NA
    0.572 false alarm/century
    target δ-like signals
  • **Selection C** - common thresholds IGEC1-style:
    thresholds a 1.3, 1.4, 1.5, ..., 3.0 x 10^{-21}/Hz
    0.134 false alarm/century
    targets δ-like signals
Data Selection A – Same SNR Thresholds

SNR > 4.95 for AU, EX & NA

- Equal data quality
- Target signals: centered in the NA-EX band
- 0.396 false alarm/century
Data Selection B – Different SNR Thresholds

AU-SNR > 7.00 : EX-SNR & NA-SNR > 4.25

- Target signals: δ-like
- 0.572 false alarm/century

![Graph showing Amplitude H vs. # events with different SNR thresholds: AU (SNR > 7.00), NA (SNR > 4.25), and EX (SNR > 4.25).]
Data Selection C – Common Thresholds IGEC1-style

search thresholds @ H=1.2, 1.3, 1.4, 1.5, ..., 2.4, ..., 3.0*10^{-21}/Hz

- target δ-like signals
- 0.134 false alarm/century

Common Threshold = 2.4e-21
The total false alarm is calculated taking into account the accidental coincidences common to more than one data selection is 1 false alarm/century.
CUMULATIVE FALSE ALARM DISTRIBUTION of the 3 data selections

- The accidental coincidences are the union of the accidental coincidences for each data selection counting only once the repeated accidental coincidences.

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- Systematic errors \( \sim 0.1 \times 10^{-3} \)

- With no selection it was 2.16 over 130 days

- 3.63 \times 10^{-3} over 130 days

- 1.0 false alarm/century

- 1\(\sigma\) \sim 0.02 \times 10^{-3}
A confidence interval on the mean number of coincidences due to any signal or correlated noise was set using Feldman&Cousins construction, assuming a Poisson model, fitting the empirical distribution of the accidental coincidences.

Measured Background = 0.00364 ± 0.00006 (±3σ) events
TEST THE NULL HYPOTHESIS

• The null hypothesis will be rejected if at least one coincidence is found.

• If null hypothesis is not confirmed:
  
  • the coincidence is not explained by accidental coincidences with 99.637% ± 0.006% (±3σ);
  
  • the coincidence can be due to correlated signal/noise in the three detectors
  
  • a follow-up a posteriori analysis is necessary to characterize the coincidences
FOLLOW-UP PLANNED ANALYSIS

• Additional checks for mistakes in the network analysis;
• The follow-up results will not affect the confidence of the rejection of the null, they will be interpreted in terms of “degree of belief” (subjective confidence) by the collaboration;
• Investigation on $h(t)$ data will try to discriminate among known possible sources (gravitational waves, electromagnetic or seismic disturbances, …). The $h(t)$ data will be filtered to implement network searches based on cross-correlation and wavelet transform;
• Data from ALLEGRO will be added: $h(t)$ and list of candidates.
• IGEC2 will investigate on simultaneous observations by other kind of detectors (neutrinos, gamma, x …).
ANALYSIS RESULTS

- Once defined all the analysis parameters, the secret time shifts were exchanged
- **No candidate event was found and the null hypothesis was not rejected**
- One of the data subset can be used to calculate an upper limit to be compared with the previous one of IGEC 1
An observatory made of 3 resonant detectors is presently capable of high duty cycle and low false alarm.

A low false alarm rate can be obtained also at low values of SNR threshold.

The blind analysis used made the statistical interpretation non-controversial.
The collaboration is going to exchange a new set of data relative to a longer time period (whole 2006).

This time the data from ALLEGRO will be included in the coincidences analysis.

If four-fold coincidences will be possible on long periods, the same false alarm level (1 event/century) will be reachable with less severe data selection.

IGEC2 is starting a collaboration with LIGO to exchange data gathered during its present S5 run.