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Distributions of the Signals from Gravitational Antennas versus Nautilus Local Sidereal Hours (NaLSh) and Correlations between the Signals and X-ray Signatures in Close Binary Systems and SGR

Gian Paolo Murtas ⋆

Laboratori Nazionali dell'INFN, Frascati, Italia

Abstract I have considered coincidences between signals detected by resonant detectors of Gravitational Wave NAUTILUS and EXPLORER located in LNF Frascati and CERN Geneva SW. Time coincidences acceptance is ± 10 s. In this way the coincidences are accidentals and have a physical meaning if they are due to projectiles hitting independently the two distant detectors. In order to understand the phenomena I have performed correlations with X-ray detected by satellites and found that 4U1820–30, XTEJ1550–564, SGR1627–41, SGR1900+14, SGR1806–20, during the 1997, 1998 ware the responsible Sources. Studying the energy distribution of the projectiles versus NAUTILUS Local Sidereal hours I found that these projectiles have a quadrupolar structure, transport polarization, and the simplest interpretation is that they are GRAVITONS.

Key words: neutron star — SGR — black hole — gravitational wave — gravitons

1 PART – CORRELATIONS BETWEEN THE SIGNALS AND X-RAY SIGNATURES IN CLOSE BINARY SYSTEMS AND SGR

At the Vulcano workshop in May 2005 I presented a talk titled: **Correlations between Coincidences of Gravitational Waves Nautilus and Explorer and X-ray Emission of 4U1820–30 and XTE J1550–564.** The work has been published last year in the Chinese Journal of Astronomy and Astrophysics (Murtas 2006).

I will present today the results obtained in the last two years of analysis of the coincidences collected by NAUTILUS and EXPLORER antennas (Astone et al. 1993; 1997) in the years 1997 and 1998 having changed the coincidence acceptance interval up to $\pm$10s improving the total number of coincidences up to 4500, collected in a total number of 250 days. In this way our coincidences are mainly accidental and can have a physical meaning only if we are detecting projectiles hitting each detector independently. We can improve our understanding by looking not only EXP+NA coincidences, but also X-rays collected by satellites from many sources. In other words this is a Multifrequency behaviour work. We found data in the archive of NASA where it is possible to find X-ray light curves, periodicities, ephemeredes, and quasi periodical oscillations QPO. I found also selected data in many Doctorate Theses (Guidorzi 2003). By studying the behaviour of the coincidences with X-ray emission we have found sources such as:

1) The Black Hole candidate XTE J1550–564, that have emitted projectiles detected by NA+EXP, and a strong X-RAY flare detected by satellites in Sept 1998.
2) Also we find 4U 1820–30 that has been emitting projectiles detected by NA+EXP with periodicity of 171 days. The 4U1820–30 is a binary system of a neutron star and a white dwarf orbiting with a period $P_{\rm inner} = 11.4169$ min. It is believed that the presence of a third companion rotating with a period

⋆ E-mail: Gian.Paolo.Murtas@lnf.infn.it

$P_{\rm outer} = 1.1$ days, induces an eccentricity variation with period $P_{\rm long} = KP^2_{\rm outer} / P_{\rm inner}$ that is to say (Mazeh 1979) with a close approach every 171 days, and a negative and very small derivative of the period P'. The ephemeredes of 4U1820–30 are RA=18.20 Sh, Dec = –30 deg, $P_o = 171.033 \pm 0.326$ d, $P' = -7.54e-13$, $T_o = 2450738.867(\pm 11.66)$ JD (Chou et al. 2001; Stella et al. 1997).

3) And finally SGR1900+14, SGR1806–20, and SGR1627–41.

Figures 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 show the results of this analysis.

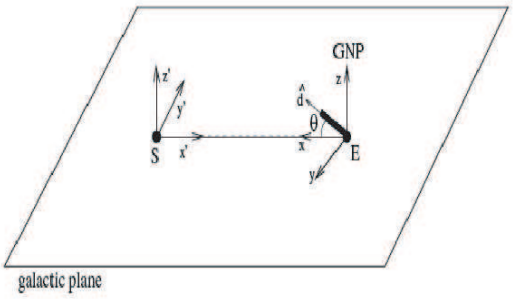

Fig. 1 Show the position of the antennas respect to the Galactic plane. S=source, E=Earth, $\underline{d}$ is the antenna bar, θ is the angle between the $\underline{d}$ and the direction of the source $\underline{x}$. φ is the angle between $\underline{y}$ and the d projection in the $\underline{y}$, $\underline{z}$ plane, being $\underline{y}$ in the galactic plane.

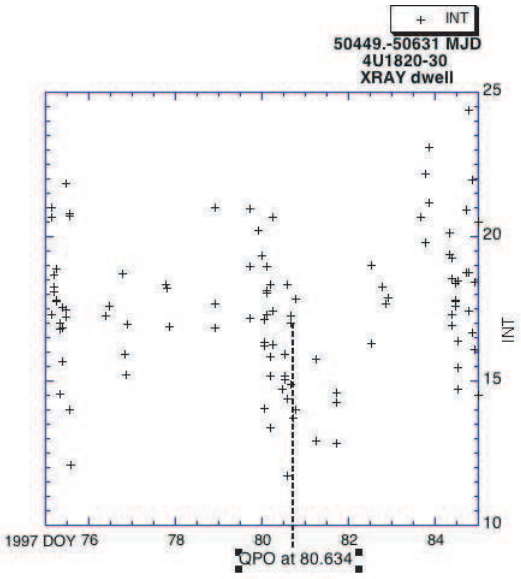

Fig. 2 Show the results of the analysis of the data collected during the year 1997 from NA+EXP. The data are compared with the X-ray light curve dwell by dwell from the system 4U1820–30. The positions of the QPO and relative frequencies are reported F. Murtas (2004): red Square are of 710 and 760 Hertz and green triangle are of 1050 Hertz. To be note that the emission of projectiles hitting the antennas happens when there is a decreasing of the X-ray intensity, i.e. when there is a temperature decrease of the accreting disk. The bursts detected by the antennas are emitted when material fall in the Neutron Star. At the end there is QPO. The burst at Doy 44–47 is due to SGR 1806–20.

Both θ and φ depends on sidereal time due to the Earth rotation. $(\sin\theta)^4 \times (\cos 2\varphi)^2$ and $(\sin\theta)^4 \times (\sin 2\varphi)^2$ represents the two detector pattern function for quadrupolar gravitational wave with + and $\times$ polarization respect to the Galactic plane, $(\sin\theta)^4$ is the intensity function for unpolarized wave. Greater intensity detection happens when the wave is orthogonal to the antenna bar. For the computation of θ(t) and φ(t) see Coccia, Dubath & Maggiore (2004).

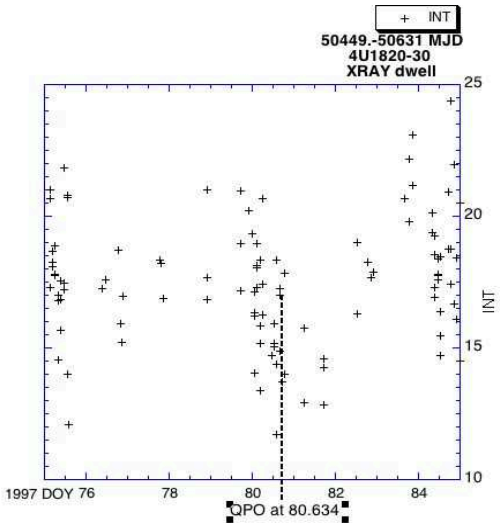

Fig. 3 Show a detail of the X-ray light curve between Doy 75 to 85. It appears evident the sharp decrease of the X-ray emission just before the QPO initiate. Unfortunately during that time NA+EXP was shut down.

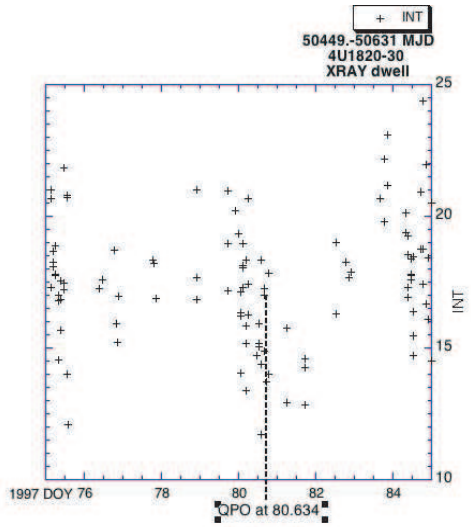

Fig. 4 Show the light curve expanded around the DOY 100, Fig. 3. To be noted the time of the events (X-ray black dot and Energy of NA+EXP red circle) and the position of the QPO. Between Doy 101 and 105 there are no QPO because there was no measurements.

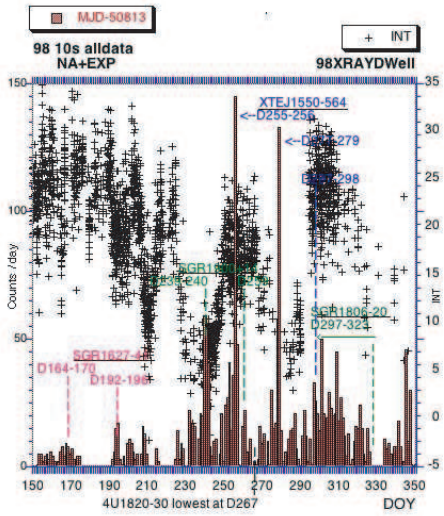

Fig. 5 Show the coincidences between Nautilus and Explorer, function of the Day of the Year (DOY). The data are referred to the Year 1998 and range from DOY 150 to DOY 350.The systems responsible of the signals are over imposed on the graph. These information are recoverable on the web at the site: http:// science. msfc. nasa. gov/ newhome/ headlines/sgr _slides/4-up.jpg.

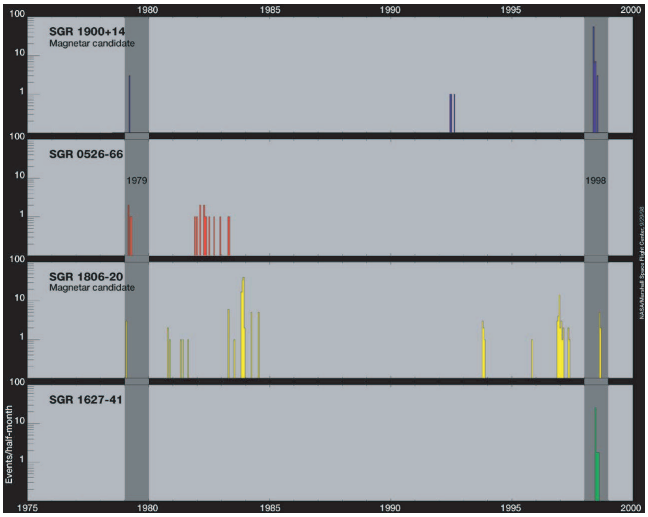

Fig. 6 Show the data of Fig. 4 with the light curve of 4U1820–30 over imposed. Around the phase zero of the period of 171 days, there is the emission of a burst of X-rays due to nuclear reactions (He-H burning to C). Must be noted near the minimum of the 4U1820–30 at DOY 267 the presence of relevant bursts from XTEJ1550–564, SGR1900+14, SGR1806–20. SGR1627–41. The existence of that burst was suggested by the following graph, Fig. 7.

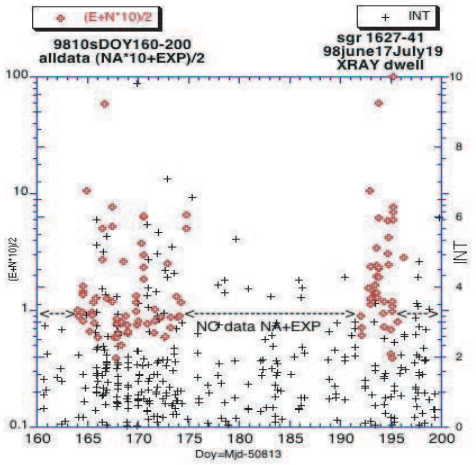

Fig. 7 Show SGR Flares versus time (year) from http://science. msfc.nasa. gov/ newhome/ headlines/sgr_slides/4-up.jpg

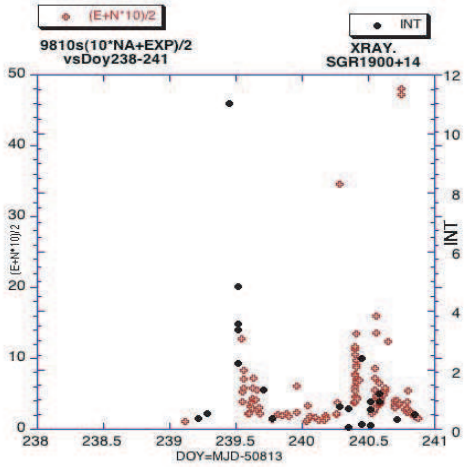

Fig. 8 Show in detail the distribution of the coincidences with the X-ray light curve dwell by dwell from SGR 1627–41 over imposed, from DOY160 to 200.

2 PART – DISTRIBUTIONS OF THE SIGNALS OF THE GRAVITATIONAL ANTENNAS VS. NAUTILUS LOCAL SIDEREAL HOURS (NALSH)

The most surprising results cam from the distribution of the signals versus NALSh. That analysis never was performed before, due to the pour number of events considered.

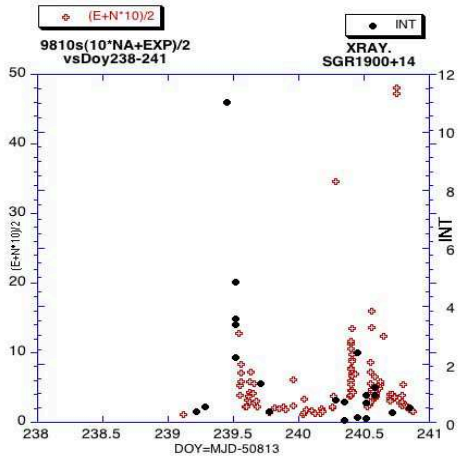

Fig. 9 Show details of the coincidences with the X-ray light curve dwell to dwell from SGR1900+14 from DOY 238 to 241.

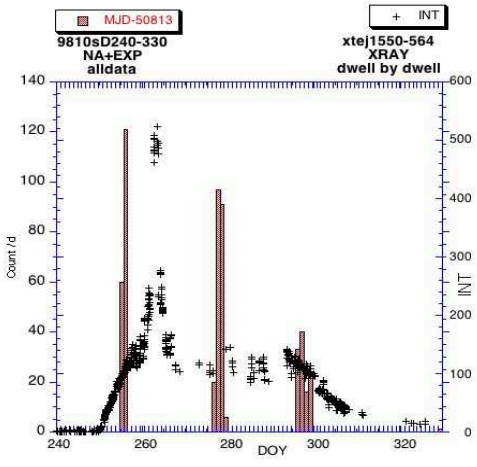

Fig. 10 Show the details of the coincidences with the X-ray light curve dwell by dwell from XTEJ1550–564 from DOY 239 to 325. A period of 13.98d has been found folding bumps in the X-rays light curve.

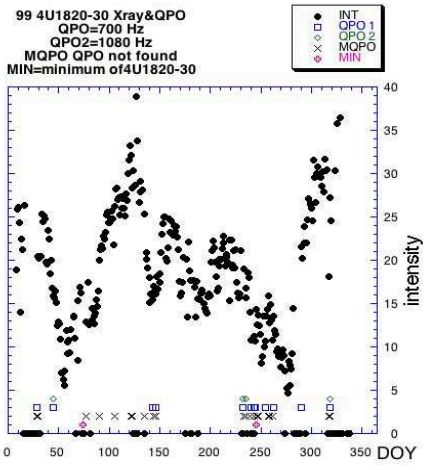

Fig. 11 Show X-ray light curves of 4U1820–30 and the QPO of the accreting disk. It can be noted the rise of the QPO. During the light curve intensity decreasing i.e. with the decreasing of the accreting disk temperature. Unfortunately for that year (1999) there are no data from booth antennas so it is impossible to show in the figure the coincidences NA+EXP.

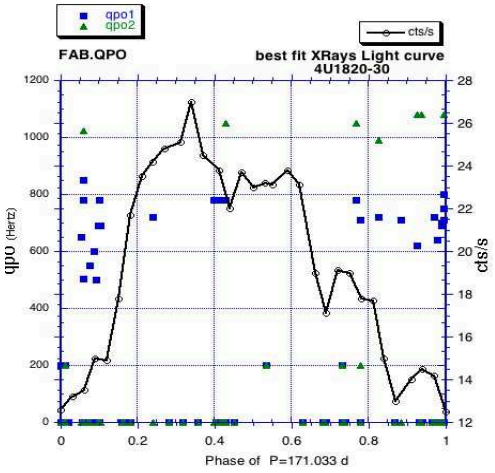

Fig. 12 Show a best fit of the X-ray light curve of the system 4U1820–30 (Chou & Grindlay 2001) with the position of the QPO versus Phase of $P = 171.033$ d. Murtas (2006). The presence of QPO mainly in the Phase interval 0–0.15, 0.4–0.45, 0.75–1 means that we must wait these Phase Interval for have coincidences in the Antennas due to 4U1820–30.

Figures 13, 14, 15, 16, 17, 18, 18 and 20 show the intensity respectively for Unpolarized waves i.e. $(\sin\theta)^4$ curve (Red). The polarization parallel to the galactic plane $(\cos 2\mathrm{FI})^2$ is the Blue curve and the polarization at 45° with the galactic plane $(\sin 2\mathrm{FI})^2$ is the Green curve.

Figures 21, 22, 23, 24 shown the angles (θ) TETA and (ϕ) FI versus NALSh for: XTEJ1550–564, 4U1820–30, SGR1900+14, SGR1806–20.

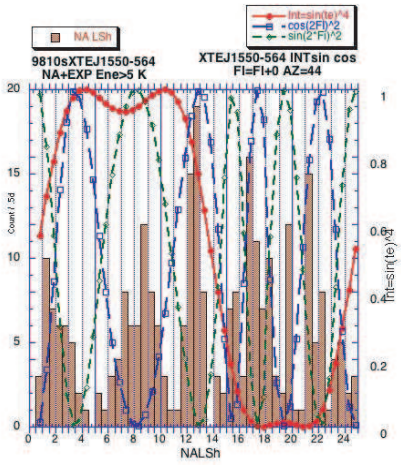

Fig. 13 Scatter plot of NA+EXP hits vs. NALSh (NAUTILIS Local Sideral hours) for XTEJ1550–564, in bins of half hour. In that case in order to see distinct distribution, energy >5 K filters have been applied. It is evident that the red curve (sin theta)^4 do not reproduce the distribution of the events. In fact many events appears between 15 and 23 NALSh. In the main time the events seems due to both + and × polarization.

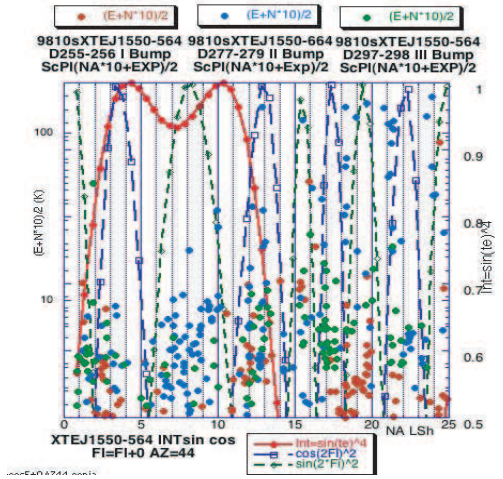

Fig. 14 Average energy of the NA+EXP hits vs. NALSh for XTEJ1550–564. All the energy of each hit of the 3 burst are represented. Red points are due to the first burst, the blue points are due the second burst, green points are due to the third burst. Points under the blue curve can be considered produced by a polarization + parallel to the Galactic plane and points under green curve can be considered produced by a polarization × i.e. 45° from the Galactic plane.

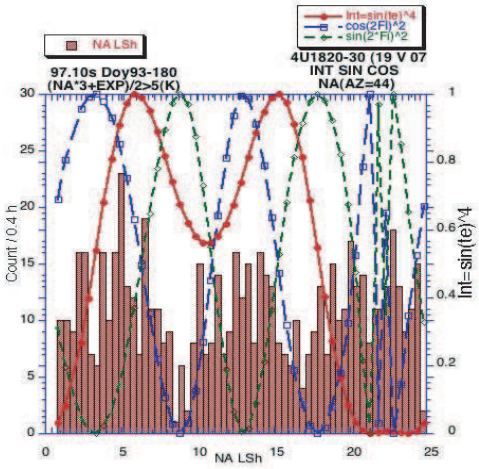

Fig. 15 Scatter plot of NA+EXP hits vs. NALSh for 4U1820–30, in bins of half hour. In order to see distinct distribution, energy >5K filters has been applied. It is evident that the red curve i.e. (sinθ)^4 do not reproduce the distribution of the events.

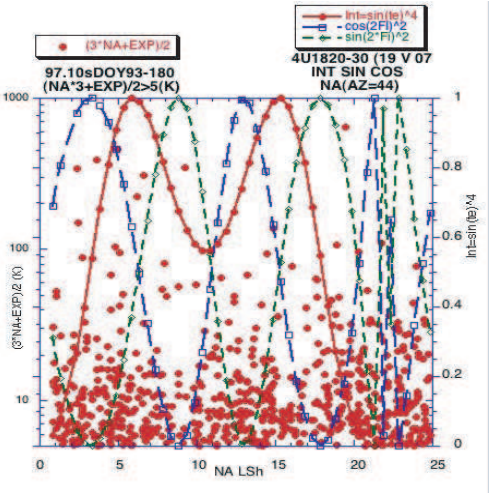

Fig. 16 Average energy of the NA+EXP hits vs. NALSh for 4U1820–30. Many events appears between 20 and 0.83 NALSh. The data are collected in 60 days. They seem to evidence a preference for the x blue curve polarization in the Galactic plane, at least until 16 NASLh.

3 CONCLUSIONS

In this talk I presented the results obtained from the analysis of the coincidences from NA+EXP and their correlations with the X-ray light curves of some binary systems and SGR, occurred in the years 1997 and 1998. The conclusion that can be deduced from this analysis are:

1) The coincidences within an acceptance window of $\pm$ 10s, shows the presence of burst during some days, due to the systems SGR1620–40, SGR 1806–20, 4U1820–30,SGR1900+14, and XTEJ1550–564.

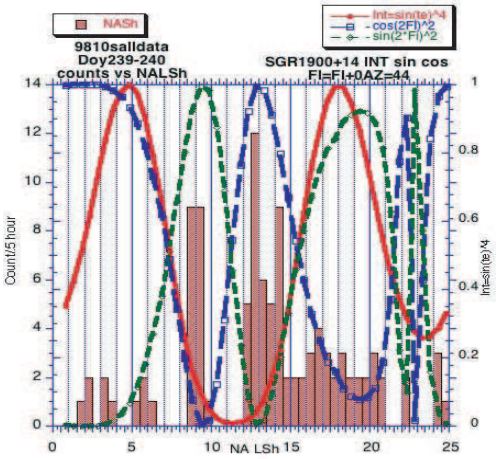

Fig. 17 Scatter plot of NA+EXP hits vs. NALSh for SGR1900+14. In bins of half hour. No energy filter has been applied.

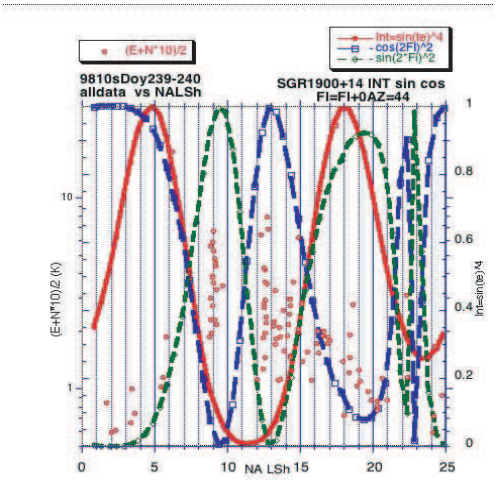

Fig. 18 Average energy of the NA+EXP hits vs. NALSh for SGR1900+14. It is evident that the red curve $(\sin\theta)^4$ do not reproduce the distribution of the events. In fact many events appears between 9 and 15 NALSh. Seems evident the presence of both + and $\times$ polarization.

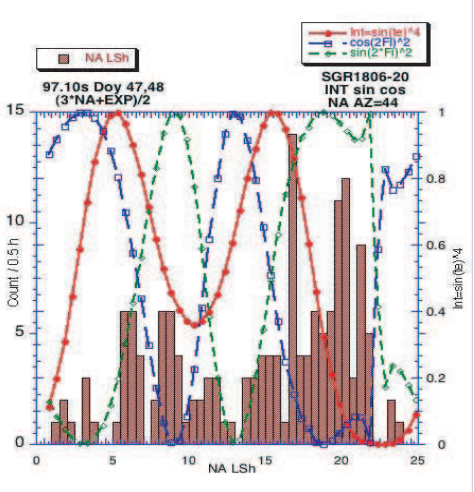

Fig. 19 Scatter plot of NA+EXP hits vs. NALSh fo SGR1806–20. In bins of half hour. No energy filter has been applied.

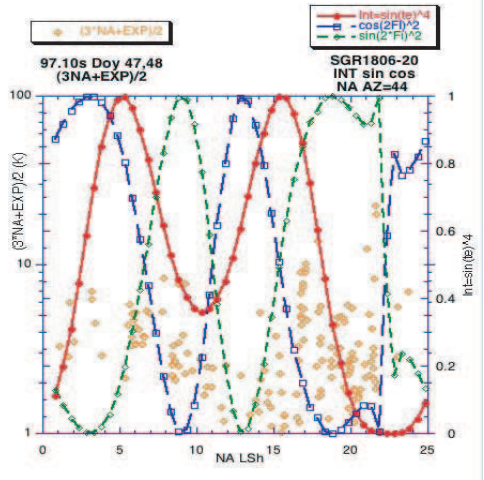

Fig. 20 Average energy of the NA+EXP hits vs. NALSh for SGR1806–20. It is evident that the red curve i.e. $(\sin\theta)^4$ do not reproduce the distribution of the events. In fact many events appears between 20and 24 NALSh. Seems evident the preference for the cross polarization $\times$ referred to the Galactic plane. $(\sin 2\phi)^2$ Green curve.

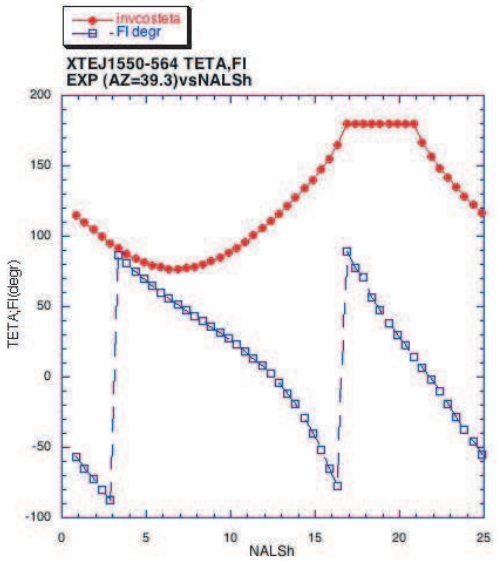

Fig. 21 Angles θ (red), ϕ (blue) vs. NALSh for XTEJ1550–564.

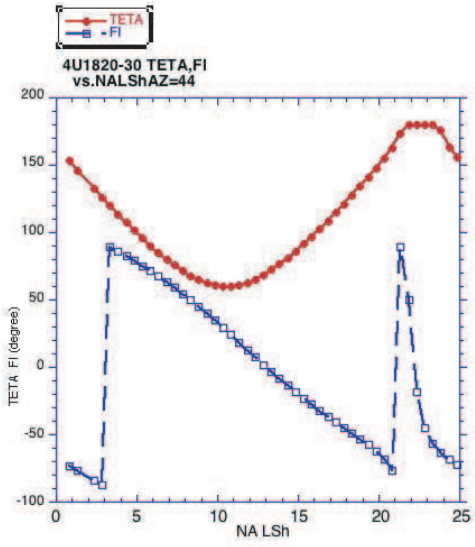

Fig. 22 Angles θ (red), ϕ (blue) vs. NALSh for 4U1820–30.

2) The coincidences NA+EXP appears correlated with the decreasing of the light curve intensity, and then of the temperature of the accreting disk; at its end appears the QPO.
3) Around the day 267 of the year 1998 instead of a minimum in the light curve of 4U1820–30 appears a big flare during about 60 days. In the same time interval flares are observed in SGR1806–20, SGR1900+14 and XTEJ1550–564. These facts suggest the occurring of a catastrophic event in the Galactic Centre, propagating to our region. Perhaps the Sun received something from this event with consequent emission of neutrinos with a periodicity of 13.75 days may be detected by Superkamiokande. See Milsztajn (2003).

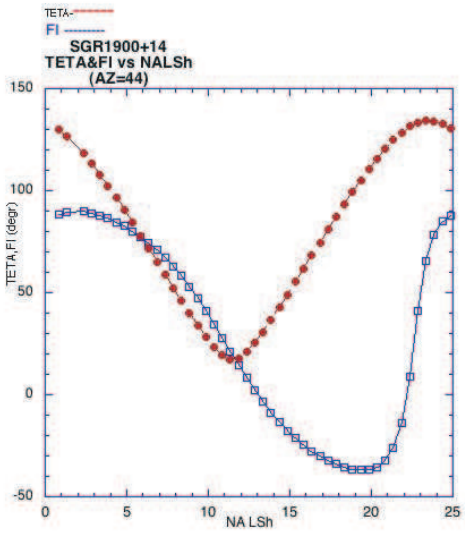

Fig. 23 Angles θ (red), ϕ (blue) vs. NALSh for SGR1900+14.

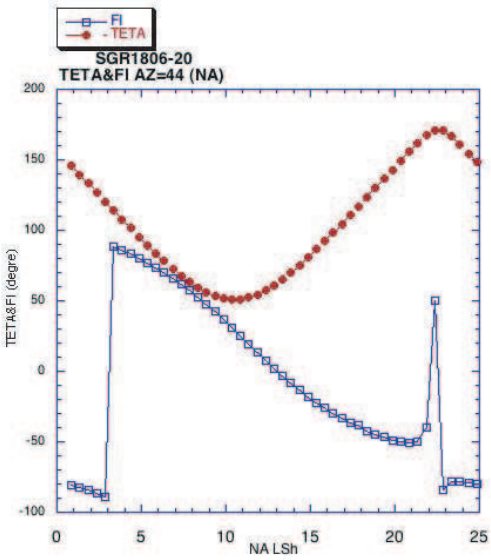

Fig. 24 Angles θ (red), ϕ (blue) vs. NALSh for SGR1806–20.

4) This suggestive hypothesis cannot be verified due to until now unavailability of the S-Kamiokande data with a bin time size of 1 day.
5) The projectiles hitting the antennas, including those who passed through the earth, shows a clear behaviour quadrupolar with + and or $\times$ polarization but not show a behaviour of a Wave so the most simple interpretation is that antennas NAUTILUS and EXPLORER have detected Gravitons.
6) Last I will reassume here these interesting results:

i= inclination angle of the orbital plane (at 90° the plane is edge on)

	Distance from us	Inclination angle	Polarization detected
SGR1806–20	14 kpc		×
4U1820–30	6.4 kpc	$i = 45°$	+
SGR1900+14	6 kpc	$i = 90°$	+ and ×
XTEJ1550–564	5.3 kpc	$i = 75°$	+ and ×

Acknowledgements This research has made use of data obtained from the High Energy Astrophysics Science Archive Research Centre (HEASARC), provided by NASA's Goddard Space Flight Centre. NA+EXP data are produced by the ROG collaboration after data quality cheeks realized by G.Giordano and Giuseppina Modestino of INFN of Frascati. Thanks must be given to Franco Giovannelli of IASF of Frascati and G. Barbiellini of Trieste University Dep. of physics and R. Habel of INFN of Frascati for helpful comments and suggestions, and to Mrs. L. Invidia for to translate in LateX this paper.

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DISCUSSION

JIM BEALL: What energy do You estimate in the Antenna and at the source for these waves?

GIAN PAOLO MURTAS: The energy detected by antennas are express in Kelvin . You see the range is between 1. and $5^{\star}10^{2}$ Kelvin. The energy in eV is K*T with K Boltzmann constant. That means that the energy range is 10^{-4}, 10^{-1} eV-for each graviton. A Calibration of the Antennas has been performed with cosmic rays and with a electron beam in a little antenna, RAP, in the Frascati Laboratori (2002). What energy at the source? Actually I know that all the particles are beamed in very collimated Jets starting from the sources.