Piezonuclear reactions and DST-reactions

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Over the past two decades a great deal of evidence has been gathered about the existence and the possible energetic exploitation of a new type of reactions predicted by the Deformed Special Relativity, which is an extension of Special Relativity. According to that theory, the energy of every physical phenomenon determines, by deforming it, the space-time in which the same phenomenon evolves. The practical consequences of this theoretical prediction are that mechanical machines, such as ultrasound generators or other compressing equipments, can also induce nuclear reactions on systems consisting of stable atoms such as iron, if they are able to trigger some particular physical effects able to concentrate an adequate amount of energy in an adequate space-time region. The experimental research aims at converting those predictions into experimental results and, in perspective, into industrial prototypes for a following commercial use. The evidence of nuclear transmutation of elements is among the most interesting possible results. Neutron and alpha particles emission are also reported.

Keywords: piezonuclear reactions; deformed space-time; neutron emission; alpha emission; transmutation

1. Introduction

Some experiments will be reported which all are not easy to be interpreted, according to the theories commonly accepted nowadays. However, they can find an explanation at the light of a recently proposed conjecture of Deformed Space-Time [1, 2]. The validity of this theory and its predictions need to be more deeply checked and other corroborating experimental evidence needs to be gathered. However, some consequences are verified to occur and the implications for future applications are forecast. They make these theoretical and experimental results worthy to be presented inside this overview of the current state of research on materials and processes for energy.

Non conventional cases of neutron emission will be first presented: from liquid solutions irradiated by ultrasounds, in the next paragraph; from rocks at fracture, in paragraph 3; from iron and steel bars under ultrasound irradiation, in paragraph 4. The first evidences of alpha emission will be reported in the following §5.

Paragraph 6 is dedicated to a short presentation of the Deformed Space-Time theory. Finally, some of the possible applications and possible future developments will be depicted in the last paragraphs.

2. Liquid solutions

2.1 Cavitation

Acoustic cavitation is a characteristic phenomenon that takes place in liquids when they get stuck, for instance, by ultrasound waves with suitable frequency and intensity: the micro-bubbles dispersed in the liquid can collapse giving rise to quite complex chemical and physical effects, that are not yet fully clarified [3,4]. Notwithstanding this ignorance, a simple computation can demonstrate that a very high energy concentration can be achieved in a short time. If we consider, for instance, a bubble having a radius of the order of the micron, which is struck by a spherical symmetric compression and collapses down to the atom size, which is of the order of 10^{-4} micron, then the surface power density is expected to increase by a factor 10^8. Due to this high amplification factor, some authors considered cavitation a candidate mechanism to overcome the Coulomb barrier of the nuclei and thus to obtain nuclear reactions.

In the 1990s the first attempts to obtain cavitation-induced nuclear fusion effects were performed in USSR [5]. A Titanium vibrator was used to cavitate heavy water and induce the formation of titanium deuteride (TiD) or to induce nuclear reactions by dispersing intermetallic LaNi5D6 powder. In the latter case a neutron flux about 30 times higher than the background was obtained.

The works in Russia went on with studies of focused shockwaves, created by the explosion of a semicircular wire in heavy water with high bubble content [6]: a neutron flux was measured corresponding to a yield of 10^8-10^{10} neutrons per explosion. Also very large (some millimetres) deuterium bubbles in glycerine were crushed [7] with high impact forces obtaining a neutron flux 9 times higher than the background level.
Much of the work performed in Russia was not widely known in the rest of the world as it was published in Russian journals and in Russian language.

Also the work performed in USA was misrecognized. After an initial success, the results obtained in this field at the beginning of the new millennium [8, 9, 10] were afterwards pushed aside, due to a presumed misconduct of the main author. In fact, the independent verifications of the results [11-13] were considered not independent from the first author, while a further verification was unsuccessful [14], maybe because the proper experimental conditions were not realised [15]. Without further taking into account that a neutron emission was observed above the background in correspondence of the cluster collapse and that the neutron spectrum was consistent with Tritium production after Deuterium/Deuterium fusion, any other research in the field was locked, under the threat of jeopardizing the career.

Feasibility studies of commercial reactors based on cavitation-induced nuclear fusion were performed at Los Alamos National Laboratory (USA) since 1995 [16]. A recent paper [15] reports the design of a reactor, after considering that restarting the active research in the field is a critical issue, also pointing out that private companies dedicated to the problem already exist which are also working under military contract.

Beside the just reported studies on nuclear fusion in USSR and USA, a separate branch of research was developed in Italy aiming at exploiting the amplification effect of energy density created by the sonication. Despite the same exploitation of pressure and cavitation to concentrate energy and hence to bring about nuclear reactions, the Italian vision differs from the previous ones from the theoretical, phenomenological and experimental points of view. On the theoretical side, it considers the high concentration of energy, reachable in cavitation, not as the mean to overcome the Coulomb barrier and hence induce d-d fusion, but rather as the mean to produce a deformation of the local (nuclear) space-time (according to the theory of Deformed Special Relativity [1,2]) and hence to induce a new type of nuclear reactions. On the phenomenological side, the Italians do not consider the collapsing bubble as an impermeable piston whose content, the reactants, is subjected to increasing pressure and temperature, but rather they consider the bubble as surrounded by a permeable surface from which the content of the bubble can escape while the reactants are entrapped in this collapsing surface. From the experimental point of view the reactant used in the experiments is not deuterium, but rather a medium weight stable nuclide. In the first campaign of Italian experiments the pressure was induced in liquids by ultrasonic cavitation, however in the following experimental campaigns, pressure was also applied to solids by mechanical presses. Since the induced nuclear reactions in these experiments are of a new type, they were named piezo-nuclear reactions, where the prefix “piezo” comes from the Greek word “piezein” (πιεζειν), which means “exerting a pressure”. Besides, a further term, “DST-reaction”, will be also used in order to put in evidence that a reaction is considered a consequence of a locally Deformed Space-Time. A more detailed description of these reactions is given in the following parts.

2.2 Water experiments

Starting from 1998, three main experiments of cavitated water were performed in Italy: two in Perugia [17,18], the last one in Rome [19].

In the first experiment [17] a sample of bidistilled and deionized water was cavitated for 210 minutes by using 20 kHz ultrasounds with a power of 630 W and then it was compared with a similar sample made of non-cavitated water. Techniques of mass atomic absorption (Inductively Coupled Plasma, ICP), Cyclotron spectrometry (ICR) and Mass spectrometry (MS) were used. A precision of 1 part per billion was achieved and the standard deviation on concentration values was $10^{-5}$ μg/litre.

Fig. 1 (after ref. 1,18,19.)

ICP mass spectrometry results. Number of particles with mass 137.93±0.01 a.m.u. recorded as a function of the time. The five sonication sessions correspond to the black regions.
The analysis was restricted to the stable elements with atomic number from \( Z = 1 \) to \( Z = 92 \) with the aim of searching for concentration variations of stable nuclei induced by ultrasound stimulation, without using nuclear-active substances. In the sonicated sample, the concentration of 10 elements was found increased while that of 19 elements decreased with respect to the non-sonicated one. In particular, a high concentration of Uranium was found. It is worthy to note that the total number of protons is conserved after these changes while that of the neutrons is not. Besides, the decrease of stable elements having low mass numbers is worthy of being noticed, as well.

After the analysis of the Titanium tip of the cavitator and the flint glass of the vessel, a contribution from impurities coming from these parts was excluded.

The atomic masses between 210 and 271 were investigated in the second experiment [18]. Cooling intervals of 15 minutes separated four sonication sessions, ten minutes each, with ultrasound power of 0.3 kW and frequency of 20 kHz. In order to avoid systematic perturbations due to the local background, a different location of the experiment was chosen. A sample was taken from the cavitated water and analysed by a spectrometer after each of the four runs. An increase of some nuclear species within the atomic mass range 238 < M < 264 was observed, thus including transuranic elements. This last result is in agreement with the significant increase of uranium found in the first experiment. In fact transuranic elements can form and then decay. A decreased concentration of stable elements having light-medium mass was recorded in both of the experiments, while an increased concentration was observed in the case of heavier ones.

The third experiment aimed at detecting a range of masses including the rare-earth elements [19]. Five sonication sessions, 15 minutes each, separated by 15 minutes intervals were realised by using 0.1 kW power and 20 kHz frequency ultrasounds. The main result of ICP (Inductively Coupled Plasma) mass spectrometry is reported in fig.1. By focusing the attention on the counts of atoms with mass \( M = 137.93 \pm 0.01 \) a.m.u as a function of the time, two peaks were obtained. They were attributed to two subsequent cycles of production and decay of an element with that mass.

The half-life was evaluated to be \( T_{1/2} = 12 \pm 1 \) sec, which is characteristic of the \(^{138}\text{Eu}\) Europium isotope. Such isotope does not exist in nature; it is an artificial radionuclide discovered in 1995–1997 [20]. Nowadays it can be only produced in nuclear reactors or by synchrotrons. It can be produced by nuclear fission or by nuclear fusion, the former process requiring less energy. However, from the results of the first two experiments, the concentration of heavy nuclei able to produce \(^{138}\text{Eu}\) by nuclear fission is two/three orders of magnitude smaller with respect to the intermediate nuclei that can produce it by fusion. Such a fusion reaction to form \(^{138}\text{Eu}\) from intermediate weight nuclei would be in agreement with the decrease of stable element observed in the first experiment.

### 2.3 Water solution experiments

Following the results of the cavitation experiments of water, with hints of non-conservation of the neutron number, a detailed investigation aiming at detecting the possible emitted neutrons was performed. Water solutions of Lithium Chloride, Aluminium Chloride, Iron Chloride and Iron Nitrate (1 ppm, in deionized and bidistilled water) and a reference sample of pure water were sonicated at a frequency of 20 kHz, with an amplitude of 30 \( \mu \)m at tip, [21]. The \( \alpha \), \( \beta \), \( \gamma \) and neutron intensities were measured during the ultrasound irradiation. At the same time in a suitable separated room, detectors of the same type measured the background intensities.

The experimental conditions were the same for the three types of ions, Lithium, Aluminium and Iron, but neutron emissions clearly distinguished from the background were only recorded in the two solutions containing Iron. In both cases, the first detections were recorder after 40 - 50 minutes from the beginning of the ultrasound irradiation. In no case, however, the gamma radiation was higher than the background level.

\(^{1}\) Fission and fusion must be understood in the sense of the deformed space-time theory.

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771
Since this first investigation of water solutions put in evidence the basic role of iron in these nuclear reactions, a second set of measurements was devoted to a systematic study of solutions only containing iron nitrate.

Six cavitation sessions, 90 min each, were carried out on the same quantity (250ml) of deionized and bidistilled water, containing different concentrations of Fe(NO₃)₃. Ultrasounds of different power, 100 and 130 W, were used, corresponding to 50% and 70% oscillation amplitude of the sonicator respectively. The characteristics of the six sessions are:

(a) water – 100 W
(b) water – 130 W
(c) water solution of 1 ppm Fe(NO₃)₃ – 100W
(d) water solution of 10 ppm Fe(NO₃)₃ – 100W
(e) water solution of 1 ppm Fe(NO₃)₃ – 130W
(f) water solution of 10 ppm Fe(NO₃)₃ – 130W

The energy delivered to the solutions during the cavitation time was therefore 0.54 MJ for (a), (c) and (d) and 0.70 MJ for (b), (e) and (f).

Two Geiger counters measured alpha, beta and gamma radiation while five Defender detectors of the XL type were used for neutron radiation measurements. The background neutron level was measured at the beginning of the whole set of cavitation experiments.

Fig.3 shows the setting of the neutron detectors around the samples. The horizontal detectors (2) and (4) were positioned next to the bottle close to the tip of the sonotrode, in order to capture the particles horizontally emitted and crossing a 1.5 cm thick layer of water in the bottle. The horizontal detector (3) was placed underneath the bottle in order to collect the vertically emitted neutrons. The water layer thickness in that direction was 7 cm. The vertical detectors (1) and (5) were screened by carbon powder (neutron moderator) and by boron powder (thermal neutron absorber), respectively.

In all of the six experiments, evidence of neutron emission was obtained by the unscreened Defenders (2), (3) and (4) while the screened Defenders (1) and (5) always detected a reduced neutron dose, comparable with the background, thus indicating that the particles came from the solution.

The ionizing radiation measured by the Geiger counters was always comparable to the background level.

The Defender detectors contain minute droplets of a superheated liquid inside an elastic polymer gel. If a neutron beam hit these droplets, a small gas bubble is created, which remains trapped in the polymer. Thus, the deposited energy of the particles can be evaluated by counting the number of these bubbles, which show different features and distribution in the case they are produced by neutrons rather than by ionising particles.

A detailed description of the number of bubbles in the Defenders, i.e. of the total accumulated energy of the neutrons, as a function of the time during the six experiments is reported in fig.4.

The higher amount of accumulated energy in the solutions with higher Iron concentration is a further evidence of Iron effectiveness in generating the DST-reactions. This evidence is also a negative answer to a possible doubt that the ultrasounds instead of the neutrons could be directly responsible of the bubble formation inside the Defenders.

In addition, the neutron emission by sonicated pure water, which was deduced in the previous experiments from the non-conservation of neutron number, is experimentally confirmed in this case, thanks to the higher sensitivity of the used detectors, as reported in the two lower images of figure 4.
Neutron dose (nSv) as a function of the sonication time, with time steps of ten minutes. The ultrasound power was 100 W (first column, corresponding to a total energy of 0.54 MJ) or 130 W (second column, energy of 0.70 MJ).

The Fe(NO₃)₃ concentration was 10 ppm (first row), 1 ppm (second row) or 0 (last row).

The neutron background level of 3.5 nSv in 90' (horizontal line in all the images) is also related to the thermodynamic behaviour of the detectors.

### 3. Fractured rocks

In the wake of the piezonuclear reactions, a relevant position is also occupied by those experiments making use of mechanical presses to induce a pressure in solid materials. Both natural rocks and commercial materials were used as investigated samples.

Studies of rocks subjected to fracture were performed in Torino (Italy) [22-26]. Four samples, two made of green Luserna granite (gneiss) and two of Carrara marble (calcite), were compressed at a controlled displacement rate of the piston (10 μm/s). A helium-3 detector for neutrons was enclosed in a polystyrene case and was placed 10 cm from the samples, in order to prevent the results from being altered by acoustical-mechanical stresses. The average neutron background was $3.8 \times 10^{-2} \pm 0.2 \times 10^{-2}$ cps, corresponding to $5.8 \times 10^{-4} \pm 0.3 \times 10^{-4}$ thermal neutron/(s cm²).

The upper part of figure 5 shows the neutron intensities emitted from one of the granite samples at brittle failure to be about one order of magnitude higher than the background level. The lower part of figure 5 shows that such effect is not present in the case of marble samples of the same sizes and shape. A lower Iron content and a ductile failure are characteristic of the latter. Similar results were obtained in the case of the other two twin samples.

The features of the neutron emission were also studied by using bubble detectors of the Defender type. Sets of measurements performed on these two types of rocks confirmed that those neutrons are emitted during the crush of granite and not of marble specimens. The bubbles inside the detector resulted localised in a limited zone of the sensitive volume, thus supporting an impulsive and anisotropic nature of the neutron emission. In fact a continuous and isotropic neutron emission would be uniformly spread in all the directions and the corresponding bubbles diffused along the entire sensitive volume of the detectors.
The abrupt energy release, that in the case of water solutions is caused by cavitation, in this case is determined by the brittle failure, that corresponds to an instantaneous catastrophic release of the load (upper part of figure 5), in contraposition to the ductile one, where the stress release is not abrupt and a considerable load is retained after the rupture (lower part of figure 5).

4. Iron and steel bars

A step forward in the study of ultrasound effects on solid materials was moved when commercial materials at high iron content were considered. Cylindrical bars having 1 cm of radius and 20 cm of height and made of sintered Ferrite ($\alpha$-iron) or of steel, surface hardened by carbon steel, were treated by ultrasounds of 19W and 20 kHz [27]. The purpose of these experiments was firstly to check whether neutrons are emitted also in this case as in the case of fractured rocks; secondly if their emission is in bursts; thirdly if it exists a delay time before their emission, as in the case of water solutions, thus indicating that a sufficient amount of energy has to be stored before the piezonuclear reactions take place. The answer was positive to all the questions, as a delay of five minutes was necessary before bursts of neutrons began to be detected. Their intensity was 25% higher than the background. Also in this case, as in the previous experiments, no gamma rays higher than the background level were detected in correspondence of the neutron bursts. An unexpected effect, however, was the appearance of circular, macroscopic and regular damage spots on the lateral surface of all the treated samples. In the case of the carbon steel bars they were brownish in the peripheral zones, whitish in the centre and had a diameter of 2-3 mm. A picture of one of the steel bars is reported in figure 6. Such effect is really puzzling from a metallurgic point of view, due to the low power of the ultrasounds, which is considered insufficient to affect the hardened surfaces of the steel bars.
A semi-quantitative microanalysis of some damaged regions was performed by using a Zeiss Supra 40 FESEM with a 20 KeV electron beam and equipped with an Oxford INCA energy dispersive X-ray detector Si(Li). The results were compared with those obtained from apparently not damaged zones. Elements lighter than Iron, which were not present in the latter, were found in the former, as shown in Tab.1. In addition, the decreased concentration of iron is balanced by the increased amount of carbon and oxygen atoms.

\[
\begin{array}{|c|c|} \hline
\text{Matrix} & \text{Damage spot} \\
\hline
\text{Element} & \text{Weight \%} & \text{Element} & \text{Weight \%} \\
\hline
C & Carbon & 2.37 & C & Carbon & 19.80 \\
- & - & - & O & Oxygen & 29.27 \\
- & - & - & Na & Sodium & 1.20 \\
- & - & - & Mg & Magnesium & 0.19 \\
- & - & - & Al & Aluminum & 0.53 \\
Si & Silicon & 0.21 & Si & Silicon & 0.49 \\
- & - & - & S & Sulfur & 0.27 \\
- & - & - & Cl & Chlorine & 1.61 \\
- & - & - & K & Potassium & 0.54 \\
- & - & - & Ca & Calcium & 0.68 \\
Mn & Manganese & 0.66 & Mn & Manganese & 0.47 \\
Fe & Iron & 96.04 & Fe & Iron & 44.45 \\
W & Tungsten & 0.53 & W & Tungsten & 0.50 \\
Cr & Chromium & 0.18 & - & - & - \\
\hline
\end{array}
\]

In the same experiment [27] the first energy spectra of neutrons produced in piezonuclear reactions were obtained and are reported in figure 7 together with a reference background. The anisotropic and not continuous distribution of the strongly damaged brownish zones (fig.6) is more compatible with a production of isolated neutron bursts of short time duration and high total energy rather than a continuous isotropic emission of separated neutrons. Thus the registered number of neutrons reported in figure 7 a and b is probably underestimated, as the detectors and their electronics are optimised to register standard fluxes of neutrons rather than bursts of many particles in a very short time interval. Furthermore, the emissions appear to be highly directional: if so, they preclude any detection by instruments that are not perfectly aligned with respect to their directions. The reported data, however, are useful for a rough estimate of the produced particles.

\[
\text{Neutron spectra:}
\begin{align*}
\text{Ferrite bar} & : 
\begin{array}{c|c}
\text{Energy (MeV)} & \text{Counts} \\
0 & 5 \\
1 & 0 \\
2 & 0 \\
3 & 0 \\
\end{array} \\
\text{Steel bar} & : 
\begin{array}{c|c}
\text{Energy (MeV)} & \text{Counts} \\
0 & 5 \\
1 & 0 \\
2 & 0 \\
3 & 0 \\
\end{array} \\
\text{Background} & : 
\begin{array}{c|c}
\text{Energy (MeV)} & \text{Counts} \\
0 & 5 \\
1 & 0 \\
2 & 0 \\
3 & 0 \\
\end{array}
\end{align*}
\]

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A detailed investigation of one of the ferrite bars was then performed [28] at Urbino (I) and Ancona (I). Two parallelepipeds were extracted from the bar by using Electric Discharge Machining techniques (wire-EDM). The longest side of each parallelepiped was perpendicular to the lateral surface of the bar and corresponded to a bar diameter, 2 cm long (fig.8). The square surface (side: 2 mm) of one sample corresponded to a damage spot. The other sample was extracted from a region with no evident external sign of damage.

These cuts allowed investigating external and internal regions of the bar, in particular the zone under the surface damage. Optic microscope and an Environmental Scanning Electron Microscope (ESEM) were used. A cross sectional view of the external damage was also obtained by polishing the sample down to the centre of the external damage mark.

The damage marks are blackish, less regular and smaller (size not larger than about 1 mm) than those produced on the steel bars and are distinguishable from rust. They are characterised by a cratered morphology with cracked material made of elements having mass inferior to that of ferrite. The craters, ~20 μm deep, can be caused by sub-surface reactions creating local micro-explosions. In fact, a partial fusion of the ferrite and a rapid cooling and vetrification of the fused material are evident. A region with a high density of deformed microcavities having irregular walls and maximum dimensions of 10 μm has been observed inside the bar. The microcavities are partially filled with chaotic material with irregular morphology. The EDS (Energy Dispersive System) spectra for X-ray atomic analysis of the amorphous material of the surface damaged zone and of internal craters are shown in fig.9. As a reference, the spectrum of a zone without any evident damage is also reported in the same figure.

Several elements foreign to the ferrite are found in the former, in particular an anomalous enrichment of carbon is observed in the internal cavity.

Some analogies can be found between the unconventional reactions observed in water solutions (§2.2 and §2.3) and in solid bars (§4). In fact, in both the cases neutron emissions are recorded after ultrasound irradiation and no gamma emission is registered. Moreover in both cases the reactions originate inside a microvolume: the bubbles of the liquid and the microcavities of the solids. These micro-regions also seem to operate as active micro-reactors, as they take part to the creation of the abrupt energy condensation in space-time.

In fact, the spherical symmetry of the bubbles was considered of fundamental importance in the case of sonication-induced effects [1,2]. In a similar way, the almost spherical shape of the microcavities and their same dimensions, some microns as in the case of the bubbles, are supposed to play a fundamental role in causing the proper condition of space-time concentration of energy, necessary to sustain the reactions, after that the energy thresholds necessary to locally deform the space-time is crossed. In fact, the sudden collapse of inter-crystalline cavities under the influence of high pressure produced by the ultrasonic waves is supposed to create a similar effect to the bubble implosion [1,28].

5. Alpha particle emission

The previous paragraph reports the alterations of elemental composition observed in steel or iron bars after ultrasound irradiation. Together with the emission of neutrons and the absence of gamma radiation, these facts raise many questions on the theoretical field. In order to give a possible explanation of the observed changes, some non-conventional reactions were proposed [27].
These reactions are not to be read as fissions or fusions, as they are proposed in a theoretical framework different from the traditional one. They are based on the deformation of space-time induced by the right amount of energy and they are sustained by the right energy density in the space-time. We defined them as DST-reactions in §2.1.

Beside the already observed neutron emissions, the presence of alpha particles among the reaction products is also forecast. In order to check this point, and in particular keeping in mind the second of the reactions above, a study was performed on steel bars subjected to pressure. The investigated material is AISI304 steel and its mechanical treatments are compression/relaxation cycles characterized by different strain rates [29]. The investigation is based on the parallelism between bubble collapse in liquids and the collapse of the gas inside pores or cavities, created during the production process of the solids.

Three ZnS detectors of alpha particles and a Geiger detector for alpha, beta and gamma particles registered signals higher than the maximum background intensity during the strain/stress cycles. After considering that the recorded intensity of the Geiger is similar to that of the ZnS detectors, the presence of alpha particles was deduced. A further support to this conclusion came from the analysis of CR39 polycarbonate detectors for alpha particles that were suitably put in contact with the surface of the bars.

6. Deformed Space-Time conjecture

The above-cited experimental results share the same apparent evidence: nuclear fragments are detected after the samples are supplied with a relatively small amount of energy, produced either by ultrasound irradiation or by a press.

Based on the commonly accepted theories of nuclear physics, the above given descriptions are unrealistic, as the furnished energy (about 0.1 meV per atom of iron, in average) is not enough to overcome the Coulomb energy barrier (some MeV for light nuclei, up to hundreds of MeV or some GeV for medium weight nuclei like iron), thus triggering nuclear fusions or nuclear fission of stable atoms like iron. Still more unrealistic is that no gamma emission has been detected associated to the neutron emissions.

However, these phenomena can be explained within the framework of the Deformed Special Relativity theory [1,2,30] that predicts the existence of a locally deformed space-time for the four fundamental interactions. The validity of this hypothesis and its predictions still needs to be assessed and more corroborating experimental evidences need to be gathered.

According to this theory, the energy of a physical phenomenon deforms the local space-time where it takes place. In the process, the deformed geometry of the local space-time takes part in the dynamics of the whole phenomenon by retaining some of the energy in the deformation. The theory also predicts the existence of an energy threshold for the deformation of the local space-time for each fundamental interaction. The value of these energy thresholds is different for each of the four fundamental interactions and, once overcome, the amount of deformation is energy dependent.

In the reported cases of water solutions and ferrite bars, a violent local collapse is a common phenomenological factor able to produce enough energy density and an abrupt mechanism to release it in order to overcome the deformation threshold for strong nuclear interaction. In fact, a bubble collapse in the case of liquids and a collapse inside the microcavities in the case of steel bars make possible that nuclear reactions take place in a deformed, i.e. non-Minkowskian, space-time. The outcome is that neutrons are emitted while the energy, which in the known nuclear reactions is released in the form of gamma particles, in these cases is used for and stored in the local deformation of space-time. This mechanism allows the deformation to continue and burst of particles, rather than separate ones, to be

![Ferrite not damaged surface](image1)

![Damaged surface](image2)

![Internal cavity](image3)


EDS spectra obtained from the apparently not damaged surface (up), from a surface damaged zone (centre) and from chaotic material of an internal cavity (bottom).
emitted. The presence of neutron bursts and the absence of gamma rays are thus considered as the signature of a locally non-Minkowskyan space-time.

Although the deformation of space-time seems to be a quite speculative problem, its effects appear to be this way relatively easy to detect experimentally and the consequences could be of great practical use, as discussed in the next paragraphs.

Beside the absence of gamma radiation a further feature of DST-reactions can be deduced from the experiments with water solutions of iron ions (§2.3). A latency time of 40-50 minutes was observed between the beginning of the ultrasound irradiation and the beginning of neutron emission. This delay can be attributed to the time necessary to accumulate energy up to the threshold for deforming space-time. This accumulated energy, however, is the same for the other solutions, where no emission was observed. The same nucleus of iron, thus, could play an important role in determining the deformation, together with the high concentration of energy.

It is interesting to note that iron, the nuclide usually less indicated either for fusion or fission reactions due to its high (absolute value) bond energy per nucleon, resulted to be favourite for DST-reactions, due to a synergistic operation between the high 4D-density of energy and the high nuclear density of Iron.

7. Processes for energy

The DST-reactions seem to indicate that the interface between the well-known flat Minkowsky space-time and the supposed locally deformed non-Minkowsky space-time could be the way in the former space to obtain products of interactions occurring in the latter. Otherwise, obtaining these products directly from reaction occurring in the flat Minkowsky space-time should be energetically very costly or impossible.

Thus, in particular, the transmutation from an element into another could become viable at a low energetic cost.

A support to such possibility is the cavitation experiment of water solutions of the radioactive nuclide $^{228}_{90}$Th $^{138}_{90}$ [31].

Twelve identical solutions were divided into three groups of four elements. Two groups were sonicated for 90 minutes by 20kHz and 100W ultrasounds. The third group was kept as a reference. Inside of each of the twelve vessels containing the solution, one CR39 detector was stuck on the bottom. The figure 10 reports the alpha tracks obtained on the twelve detectors.

Three tracks in four solutions are visible in the reference group, while three tracks in eight solutions were obtained in the sonicated materials. Thus the tracks per solution are 0.75 ($\sigma = 0.43$) in not-cavitated solutions and 0.38 ($\sigma = 0.22$) in the cavitated solutions of thorium. This result hints at a halving of thorium alpha emission after sonication, although not definitely. In fact, they correspond to a 27% probability that the ratio between the first number and the second is not greater than one.

A more cogent indication came from a mass spectrometry analysis aiming at evaluating the thorium concentration in the six solutions, corresponding to the six observed alpha tracks.

The results, reported in tab.2, indicate a decrease of a factor greater than two after sonication. However, further studies on the subject are desirable as a Student's t-test with four degrees of freedom applied to these data indicates a 7% probability that the intensity average value of cavitated samples is not higher than not-cavitated.

The decrease of alpha emission intensity can be attributed to a decreased number of thorium nuclei due to ultrasound-induced transmutation.

In the previous paragraphs a strong analogy was reported between the piezonuclear reactions induced in liquids and those in solids. Thus, in analogy with the Thorium case, a decrease of activity can be conjectured in radioactive materials, either liquids or solids, after they undergo appropriate pressure treatments.

This possibility gives new perspectives for addressing the problem of radioactive waste.

The transmutation of elements, if confirmed, can also give a further contribution to the energetic problems.

In fact, elements lighter than Iron traditionally can give rise to fusion reaction, while those heavier can fission. Both the reactions find a limit in the Iron element. It was observed in §6, on the contrary, that Iron is the favourite nuclide for DST-reactions. Thus cycles can be envisaged, going toward Iron through traditional fission or fusion reactions and coming back through DST-reactions.
Tab. 2 (After ref.31)
Mass spectrometry data from the six solutions where alpha tracks were observed (fig.10).
The last column reports the thorium concentration (part per billion), as evaluated from the intensity (count per second) reported in the second column.

<table>
<thead>
<tr>
<th>Not sonicated Thorium solution</th>
<th>cps</th>
<th>ppb</th>
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<td><strong>.019</strong></td>
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8. Perspectives
All the above reported effects are mainly considered related to the strong nuclear interaction and the corresponding deformation of space-time. It is not to be excluded, however, that some of them may be connected to the weak nuclear interaction. This is one of the points to be focussed in the next investigations.

An important general aspect of the DST-reactions to be studied is their anisotropy and asymmetry. In fact, the mismatch between the flat and the deformed geometry is expected to create such effects. The emission angle of the produced particles is a parameter to be more deeply studied.

A further step is investigating the effects of Deformed Space-Time in the case of electro-magnetic interactions. In fact, in that case too a threshold was forecast [1]. In particular, anisotropy and asymmetry effects are expected, that could be of some interest for applications.


References

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