## MAIN RESULTS OF THE EXPERIMENTAL AND THEORETICAL RESEARCH COMPLETED IN 2012

### Discovery of hard X-ray emission lines from the decay of 44Ti in the remnant of Supernova 1987A

*(Grebenev S.A., Lutovinov A.A., Tsygankov S.S., Winkler C. “Hard X-ray emission lines from the decay of $^{44}$Ti in the remnant of Supernova 1987A'', Nature, 2012, v. 490, n. 7420, pp. 373-375).*

The first direct evidence for the synthesis of radioactive 44Ti during the explosion of Supernova 1987A was obtained. The total initial mass of 44Ti was estimated to be 0.03% of the Solar mass or approximately 100 masses of the Earth.

It is assumed that elements heavier than carbon and oxygen can not be produced by steady thermonuclear burning in stellar interiors but are synthesized during stellar explosions (supernova outbursts). Exactly the supernovae that have enriched interstellar medium by silicium, calcium, iron, made possible the formation of planets in the Solar system and creation of life at the Earth. Among the most convincing confirmations of this concept there was the detection of optical, X- and gamma-ray emission from the radioactive decay of 56Co (to 56Fe - ordinary iron) inside the ejecta of Supernova 1987A. This supernova flared up in the Large Magellanic Cloud 25 years ago and became the only local (160 thousand light years) and bright event of this type observed for the last ~400 years.

After the decay of 56Co (and 57Co), responsible for the energy budget of the remnant of SN 1987A during the first 3 years since the explosion, energy for its observed infrared, optical and ultraviolet emission could give the radioactive decay of the long-living isotope 44Ti. But the other possibilities still existed.

In the paper by the Space Research Institute's scientists S.A. Grebenev, A.A. Lutovinov and S.S. Tsygankov published in Nature issue on October 18, 2012, the detection from this remnant of hard X-ray emission in two direct-escape lines of 44Ti (at energies 67.9 and 78.4 keV) is reported. This result is based on very long observations of the Large Magellanic Cloud by the orbital gamma-ray astrophysics laboratory INTEGRAL in 2003-2011 with a total exposure of 6 Ms. The amount of synthesized 44Ti measured from the line fluxes was quite sufficient for the explanation of the optical and ultraviolet emission of the remnant. The large yield of 44Ti, near the upper bound of the theoretical predictions, may imply that the explosion was more complex than it was assumed in simulations, e.g. it could be strongly asymmetric. The indications for such an asymmetry has been obtained earlier from the data of ultraviolet and gamma-ray observations of SN 1987A.

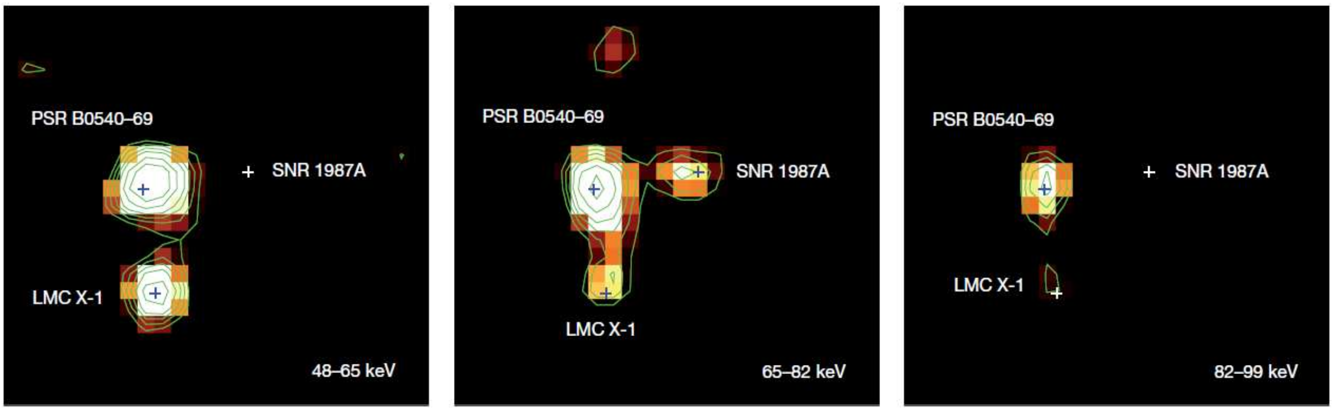


*Figure 1: X-ray images of the SN 1987A region in three subsequent energy bands. Emission from the remnant of SN 1987A is detected only in the central image, in the band containing two lines of the radioactive decay of $^{44}$Ti (67.9 and 78.4 keV). Two other sources in the field (the pulsar PSR B0540-69 and the black-hole LMC X-1) are present in all the images.*

## Dynamics of the atmosphere of Venus at cloud tops according to Venus Express data.

According to observations of the apparent motions of the clouds in the UV range (VMC on board Venus Express) at first time during a long period of time - 10 Venusian years (2006-2012) - studied the dynamics of the atmosphere at the cloud tops level. Approximately 450 000 velocity vectors were obtained from UV images made on 600 orbits around the planet. The zonal wind speed at low latitudes is in the range 85-110 m/s. It is consistent with measurements obtained from other missions. The zonal wind velocity in the low latitudes gradually increased from 85±2 m/s in 2006 to 110±2.5 m/s in 2012 (Fig. 1). The observed long term trend of the zonal wind speed may be caused by variations of the cloud top level in UV, variations of the optical depth of the haze above the clouds, possible impact of changes in solar activity and the long term variations of the climate of Venus.

Paper assigned in Icarus, presentation made on EPSC2012.

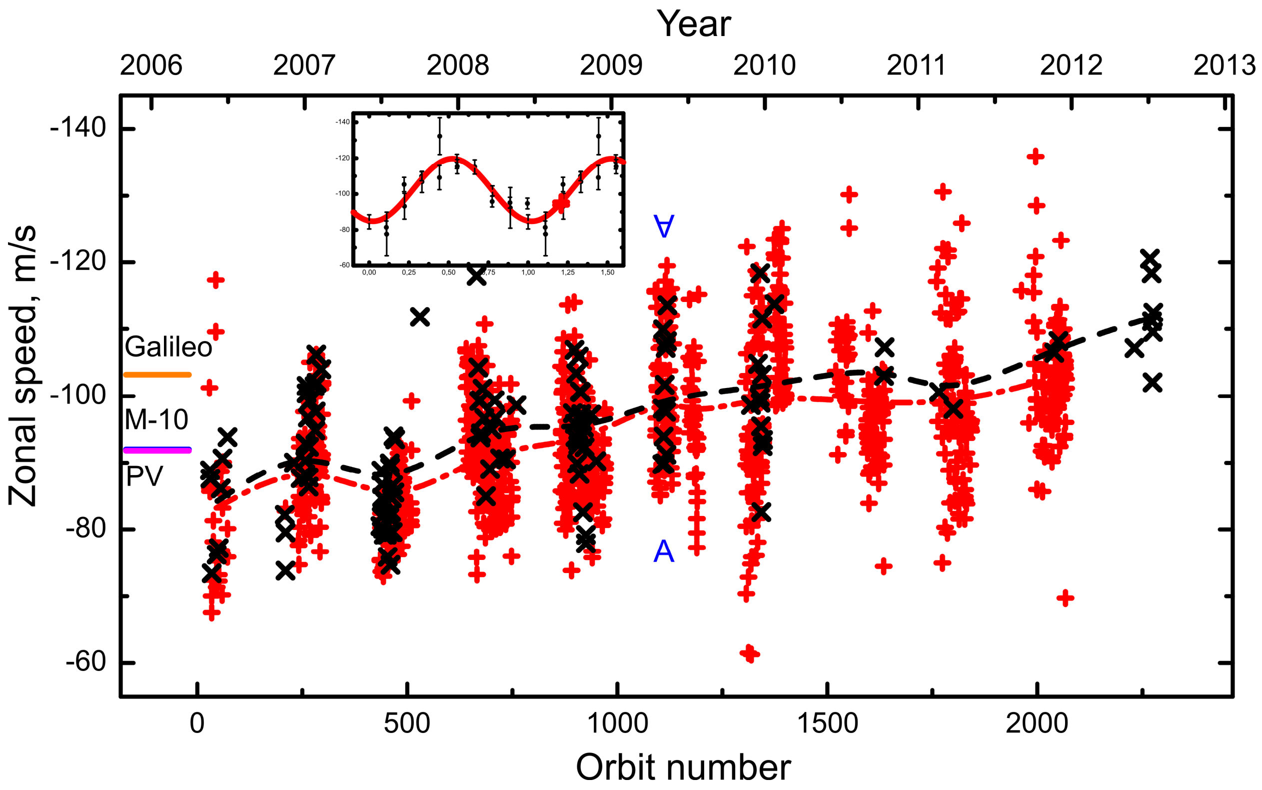



Fig. 1. Long term variations of the mean zonal winds at 20º±2.5º S at cloud top level (68±2 km) over the mission time. Symbols show orbital averages derived by manual ("x" and black dashed line) and digital ("+" and red dotted line) methods. The results from the Mariner-10 (~92 m/s), Pioneer-Venus (91.8±3 m/s) and Galileo (~103 m/s) missions for the same latitude zone are presented on the left edge of the plot. In window show the short term variations correspond to the period of superrotation (near 4.5 days), relate to A – ∀ section.

1. I.V. Khatuntsev, M.V. Patsaeva, D. V. Titov, A.V. Turin, S.S. Limaye, N.I. Ignatiev, W.J. Markiewicz, M. Almeida, Th. Roatsch, R. Moissl. Cloud level winds from the Venus Express Monitoring Camera imaging. Assigned to Icarus.

2. Khatuntsev, I.; Patsaeva, M.; Ignatiev, N.; Titov, D.; Markiewicz, W.; Temporal variations of zonal wind speed at Venus cloud tops from Venus Monitoring Camera UV images // European Planetary Science Congress 2012, held 23-28 Septembre in Madrid, Spain, EPSC Abstracts, Vol.7 EPSC2012-18 2012.

## Comets nuclei destruction.

Space vehicles are effective in previously inaccessible studies of cometary nuclei and allowed to observe the subsequent destruction of comet nuclei. The possibility of such observations seemed highly improbable. Recently the nucleus of comets Tempel 1, Borelli, Wild-2, Halley, Itokawa and Hartley 2 have been able to explore. Destruction of comet nuclei in certain circumstances, lead to the process in which a giant energy is produced. E.g., the energy produced in the collision of the largest fragment G of the Comet Shoemaker-Levy debris with Jupiter was estimated as 2.5·1022 J (the energy of the explosion of one megaton hydrogen bomb is 4·1015 J).

A special case is the destruction of the nucleus of the Hartley 2 comet - a rare case of the evidented destruction of the celestial body. The nucleus of comet Hartley 2 has the shape of a dumbbell with a smooth neck, free from meteorite impacts, which points to its "youth." The nucleus rotates, that’s why it was suggested that the smooth neck was formed by centrifugal force, which leads to the appearance of the neck of the nucleus. The detailed calculations were carried out, which showed that there is a slow elongation of the dumbbell’s neck and start destruction of the comet nuclei, which should be completed by mutual removing fragments of the nucleus. The destruction is hampered by the gravity forces. Analysis of the dynamic evolution of the comet's nucleus shows that in the narrow part the centrifugal forces are greater than gravity and that the nucleus is in the coming break indeed. The critical factor is the average density of the body. Mass of the nucleus of comet Hartley-2 is 3·1011 kg, and its average density is 320 kg·m-3. Having the angular velocity ω, centrifugal forces are the sum of F-= Σ MRω2, and the amount of forces determined by gravity is F+ = G Σ Mm / R2, where G is the gravitational constant. Thus, an interesting feature of the dynamics of cometary nuclei is that density for a centrifugal force is in the first degree, and for the centripetal is squared.

Currently parts of the nucleus of the comet Hartley-2 are kept together a by small friction forces in the neck only. Without them, the fragments would split up and removed. For the removal of parts to the distance S in the gravitational field of the nucleus the most part of the rotational energy of the nucleus E = Iω2 /2 will be used up/ The energy is determined by the angular velocity ω and the moment of inertia of the nucleus I, determined by the period of its rotation. In the absence of external perturbations both parts of the celestial body will disperse over a distance of about 900 meters. The conditions on the asteroid Itokawa, where there such a “neck” is observed too, the damage is not awaited due to a higher average density of the body.

*Literature:*

1. Ksanfomality L.V. On the dynamical evolution of comet Hartley-2 and the asteroid Itokawa // Solar System Research. 2011, Volume 45, № 6, p. 518-528.
2. Ksanfomality L.V. Destruction of comets nuclei. UFN. 2012, Volume 55, p. 137-146.

## Experimental observation of the break in frequency spectra of variations of solar wind plasma parameters that may be interpreted as the border between its inertial and dissipative branches.

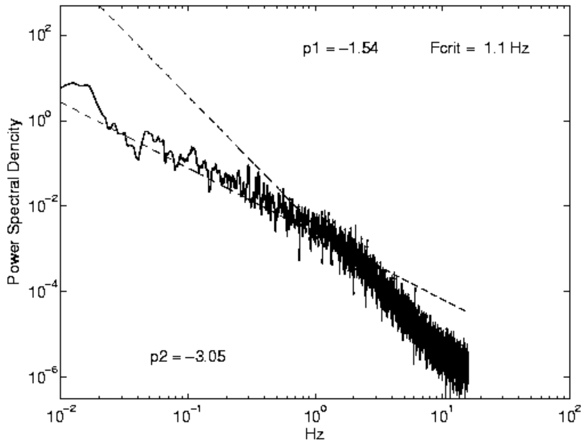
There was performed the investigations of the spectral features of the solar wind plasma in the range of rather high frequencies using the regular measurements with extremely high time resolution (up to 0.03 s) by plasma spectrometer BMSW onboard high elliptic spacecraft SPECTR-R.

These data allow us to find the frequency spectra of ion flux variations in the range 0.01 Hz till 10 Hz that was not obtained in previous experiments. Typical example of such spectrum is shown on the Fig. (below). It is seen (in the first time by plasma data) that this spectrum (according to the theoretical prediction) is separated on two branches – low frequency one ($10^{-2}$ Hz till up to about 1 Hz) and high frequency one (about 1 Hz up to 10 Hz).

The inclinations of these spectra were obtained by linear approximations (see the Fig) and it was shown that for low frequency range the spectral indices are near the Kolmogorov prediction (-5/3) and for high frequencies they are about two times larger. The frequency border between these two ranges is really the border between the inertial (for low frequencies) and dissipative (for high frequencies) ranges of plasma flux variations (mainly – the plasma density variations).

The average value of this break boundary is about 1.4+/-0.6 Hz that is about an order of value higher than girofrequency of protons. The spectral features of variations of other solar wind parameters (bulk speed, density, inclination of the flux vector) are similar to the described above.

So, we can conclude that in our experiment in the first time it was shown the existence of the two frequency branches (inertial one and dissipative one) of solar wind plasma variations with different indices and it was determined the border between them.




Scientific leader of this study G.N. Zastenker (SRI RAS)

- *Main results of the experimental and theoretical research completed in 2011*
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