Main results of the experimental and theoretical research completed in 2013

Search for galaxy clusters in Planck all-sky survey using Sunyaev-Zeldovitch effect, data interpretatin and optical identifications with Russian-Turkish 1.5-m telescope.

Burenin R. A., Gilfanov M. R., Sunyaev R. A., Churazov E. M.

Using the observations of Sunyaev-Zeldovitch effect in Planck all-sky survey, galaxy clusters were detected and the catalogue of these objects was constructed. The measurements of cluster mass function were done, cosmological constraints were obtained. Also various investigations of the physics of hot gas in clusters were carried out.

For the works on optical identification of galaxy clusters from Planck survey the observations made with Russian-Turkish 1.5-m telescope (RTT150) were successfully used. Durung the last two years for the observations of Planck clusters over 100 dark and grey nights were allocated at RTT150, i.e. approximately 25% of all dark and grey observing time available at the telescope. Very significant amount of observations was done also at 6-m telescope of SAO RAN (BTA). In result, observations at RTT and BTA constitute now a very significant part of all observations needed to provide the optical support of Planck survey.

These results were obtained by large international collaboration with active participation of R. A. Burenin, M. R. Gilfanov, R. A. Sunyaev, E. M. Churazov.

Antigravity of a dark energy as an accelerator of a gas outflow from clusters of galaxies.

G.S. Bisnovatyi-Kogan

The solution is obtained for the outflow of a gas, with a polytropic equation of state, in a spherically symmetric gravitational field, in presence of a dark energy (DE), represented by Einstein cosmological constant creating antigravity. DE antigravity may accelerate galactic cluster wind to velocities much larger than virial velocities of galaxies in the cluster. Collisions of two accelerating winds, in presence of a magnetic field, may create extreme energy cosmic rays near GZK energy limit. It could happen only when peculiar velocities of two clusters are directed towards each other.

Application to the Coma cluster.
Radius = 15 Mpc, Mass = 5 $*10^{15}$ Solar mass
Dark energy density (from WMAP observations) 0.71 $10^{\{-29\}}$ g/cm^3

Sound velocity in the critical point is ~1200 km/s, corresponding to kT ~ 5 keV.
At the distance 75 Mpc from the center the wind velocity is ~ 2500 km/s in presence of DE, and would drop to ~ 600 km/s without DE, and adiabatic power 5/3, which is present due to very small outflowing gas density.

The distances to the galactic clusters are equal to: 17 Mpc for Virgo cluster, 100 Mpc for Coma cluster, 170 Mpc for Hercules cluster.

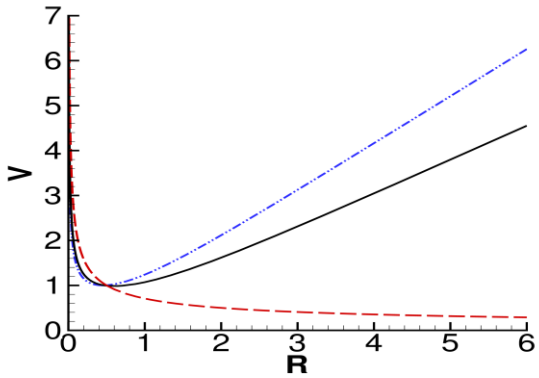

Fig.1. Wind acceleration from the Coma cluster.
Full line corresponds to the wind in presence of a dark energy(DE). Dashed line corresponds to the wind without DE. Dot-dashed line corresponds to the wind with a doubled DE density.

Galactic cluster winds in presence of a dark energy
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Kinetic mechanism of the enhancement of magnetic field chirality in plasma configurations.

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On the basis of the analysis of multipoint CLUSTER observations the mechanism of the enhancement of magnetic field chirality (the strength of a guide field) in plasmoid-like configurations was revealed. The enhancement of chirality is caused by the electric currents, which, in turn, are generated due to the asymmetry of the reflection/refraction of nonadiabatic ions from the current sheet in the central plane of a plasmoid. The current system, which is formed due to these kinetic effects, generates a guide magnetic field, which could continue to increase until the entire ion population becomes magnetized and the kinetic effects decay [1]. This mechanism demonstrates how "fine" kinetic plasma effects operating at micro-scales affect the large-scale plasma configurations.

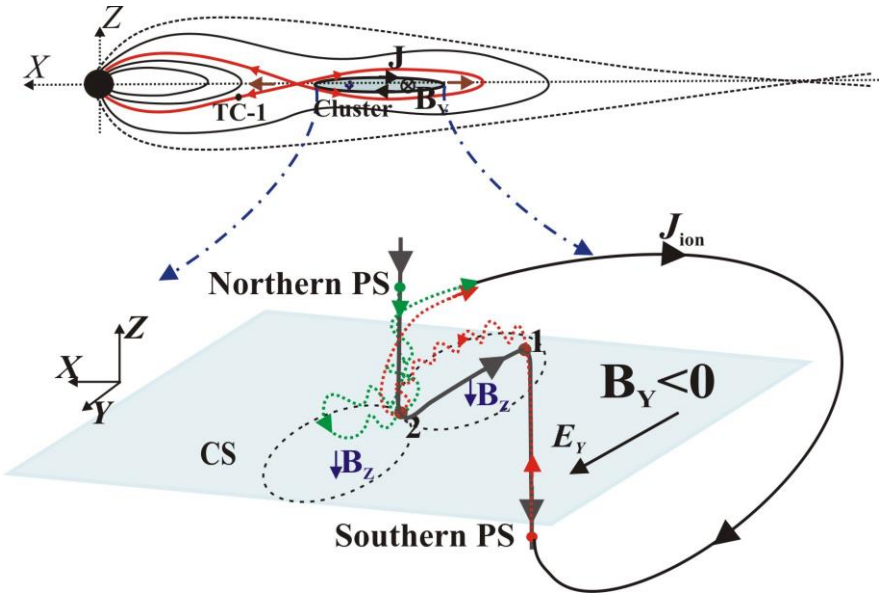

Figure. The enhancement of a guide B_Y field in the Current Sheet (CS, is shown by blue) of the Earth magnetotail due to the electric current loop J_{ion} around a plasmoid-like configuration (the blue-shaded region in the top plot). In such magnetic configuration the majority of nonadiabatic ions coming to the CS from the northern Plasma Sheet (PS) are ejected back after the interaction with the CS (the ion trajectory is shown by the green dotted line in the bottom plot). Nonadiabatic ions coming to the CS from the southern PS are also ejected to the northern PS after the interaction with the CS (such ion trajectory is shown by the red dotted line). Due to such north-south asymmetry in ion ejection the system of

oppositely directed electric currents (the current loop J_{ion} is shown by the solid black line in the bottom plot) is formed in the northern and southern PS. As a result, in the center plane of this loop a guide B_Y field is increased.

Russian experiment DAN onboard Curiosity rover

Laboratory for Space Gamma Spectroscopy

We continued the DAN experiment onboard NASA's Curiosity rover in 2013. The instrument is operating on Martian surface for more than 15 months, total number of neutron pulses performed is now 1.9 million, the instrument is operating properly. 270 measurements of Martian soil composition were taken along the rover path (fig. 1) with active neutron generator pulses, as well as constant monitoring of natural radiation from galactic cosmic rays in passive mode (fig. 2).

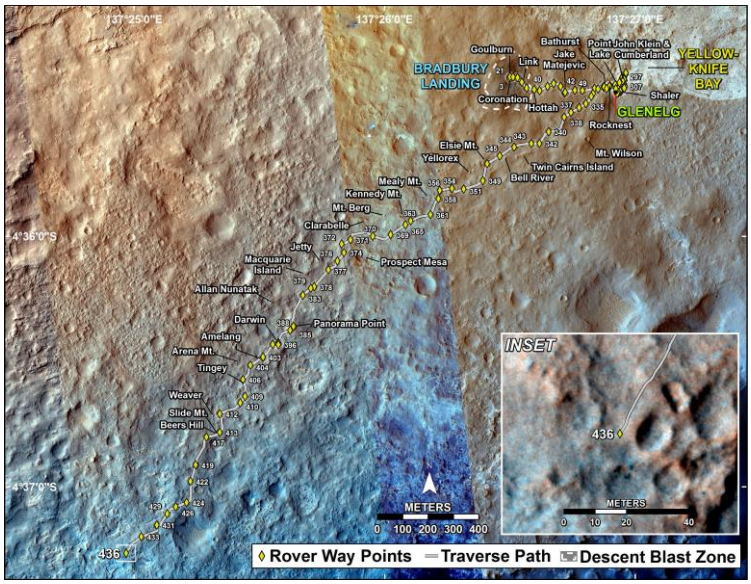

Fig 1. Path of Curiosity rover with Russian instrument DAN onboard during the 436 sols in Gale crater.

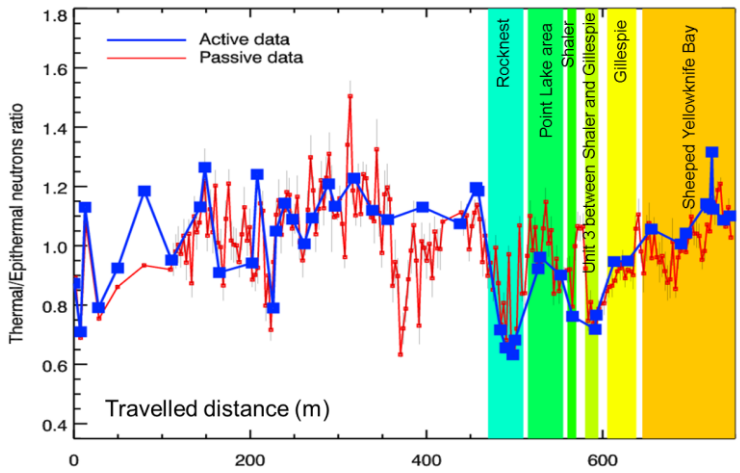

Fig 2. Measurements of the neutron flux from the planet's surface along the rover path. Colors show measurements performed with active neutron generator usage (in blue) and in passive mode with the use of natural galactic cosmic rays flux (in red).

Cross-correlation analysis between data of active neutron measurements of Gale crater soil with DAN instrument onboard mars rover and orbital data measured with another Russian instrument HEND onboard "Mars Odyssey" using only natural radiation. It is shown, that soils in Gale crater have generally lower water content of around 1-3% and generally higher chlorine content of around 1% compared to soils surrounding Gale crater with water content of more than 5% and chlorine 0.5%. It is known, that Gale crater was filled with water

a number of times during the evolution of Mars. It was earlier assumed that the substance brought with water flows and accumulated on the bottom of the crater as stratified deposits must contain a higher percent of absorbed and chemically bound water compared to substance surrounding the crater. Data obtained with DAN and HEND experiments will require to revisit these former opinions on water circulation in ancient and modern eras of Martian history.

Russian DAN experiment's first results will be published promptly in the Proceedings of Russian Academy of Sciences journal. These results were reported a number of times in 2013 at different scientific conferences in Russia and internationally. Russian members of the experiment are co-authors of seven articles in the Science journal dealing with the first results of Curiosity's investigations.

Space flight dynamics problems of constructing planetary defense system

R. R. Nazirov, N. A. Eismont, M. N. Boyarskii, A. A. Ledkov, K.S. Fedyaev

Results of research:

1. The method of changing the trajectories of hazardous asteroids with orbits known for some years to be on a possible collision course with the Earth was developed. The method relies on the use of small asteroids (asteroid-projectiles) directed at hazardous celestial bodies by giving the projectile a sufficiently small velocity impulse ensuring the Earth gravity assist. As a result, the asteroid - projectile vector can be controllably changed over a wide range. Apophis is considered as an example of the target asteroid. The technical feasibility of this method is discussed.

It was found that very small delta-V (2.38 m/s) may be required to transfer small asteroid to the trajectory, what includes gravity assist maneuver near Earth, followed by collision of this asteroid with the hazardous object like Apophis. Proposed method allows to change velocity of dangerous object by the value unachievable by any other contemporary technologies. For practical implementation of the proposed approach some further progress in broadening the catalogue of candidate asteroid-projectile in needed especially as it is related to small asteroids. Five the best asteroids, satisfying described demands were chosen by our studies.

Scenario of mission for deflecting hazardous near Earth object from trajectory with Earth collision consists from the following phases is illustrated by Figure 1:

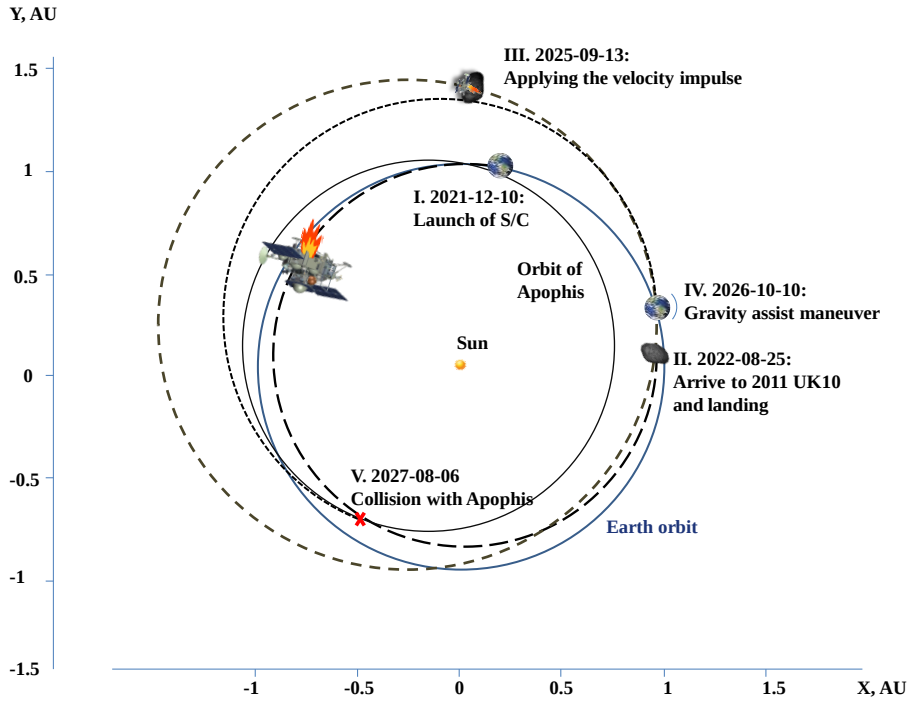

Fig. 1 Trajectories of Earth, Apophis, asteroid-projectile 2011 UK and spacecraft transfer trajectory from Earth to 2011 UK

The mission scenario of the deflection of hazardous near-Earth objects and the prevention of collisions with the Earth consists of the following steps:

- The launch of the spacecraft from the Earth and the trip to the asteroid which is to be used as a controlled device directed to the hazardous object.
- The landing of the spacecraft on the asteroid and its fixation on the surface by cancellation of the relative velocity of the spacecraft and "docking" with the asteroid.
- A relatively small velocity impulse to the asteroid delivered by the rocket engines of the docked spacecraft sets the asteroid on the trajectory to the Earth in order to undergo the gravity assist.
- The Earth gravity assist takes the controlled asteroid on the collision path with a hazardous object. In our case, with the asteroid Apophis.
- The trip to Apophis followed by a collision.

2. The proposed concept of using small asteroids to deflect the hazardous objects from the trajectory of collision with Earth may be developed further. The idea is to transfer small asteroids onto Earth resonance orbits, for example with period of one year, using described above method of gravity assist maneuver. Our preliminary studies have confirmed that it is possible to find 11 asteroids which are possible to transfer on such orbits by apply the delta-V not exceeding 20 m/s. Thus a system is constructed which allows sending asteroid-projectile to the hazardous object approximately each month during year.

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