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1. Observation of a fireball

Researchers from Northwest Normal University (Lanzhou, China), J Cen, P Yuan, and S Xue, have become the first to make a high-speed survey and to measure the radiation spectrum of a fireball (FB) which occasionally came into the field of vision of the apparatus during a study of ordinary lightning. The observations were carried out on the Qinghai plateau at an altitude of 2530 m above sea level in the northwest of China using two slitless spectrographs equipped with a video camera and a high-speed photo camera operating in the range of 0.4 to 1 μm. A fireball that emerged upon the lightning discharge between a cloud and Earth's surface near the lower base of the discharge channel was observed from a distance of nearly 900 meters for 1.64 s. The FB had an almost spherical shape with the luminosity profile intensifying towards the center and moved with a transverse velocity of 8.6 m s^{-1}. Along with the continuum, the FB spectrum also showed the lines of silicon, iron, and calcium — that is, elements normally present in soil. This testifies in favor of the FB model proposed by J Abrahamson and J Dinniss in 2000. According to their theory, the FB glow is due to oxidation of silicon nanoparticles produced in a $SiO_2 + 2C \rightarrow Si + 2CO$ reaction in the soil substance under the action of a fibrous electric discharge. Glowing silicon balls resembling FBs were actually obtained in lab experiments [see *Phys. Usp.* **53** 209 (2010)]. Three stages may be singled out in the FB evolution: first, the luminosity and the size decrease rapidly; at the extensive second stage, the FB characteristics are almost stable and the visible diameter of luminosity is nearly 5 m; at the last stage, the color changes from white to red and the luminosity and the size slowly diminish to the absolute FB disappearance. It is of interest that at the second stage the FB luminosity oscillated with a frequency of 99.4 Hz, with the Si I, Fe I, and Ca I lines being seen constantly, and the lines of N I and O I periodically vanishing and appearing with the above-indicated frequency. The researchers suspect that since a high-voltage (35 kV) line lay at a distance of ≈ 20 m from the FB, the oscillations could be caused by the second harmonic of the alternating current in the line. Possibly, different phenomena exist under the name 'fireball', and in this case only one type was observed. The FB is probably the only macroscopic physical phenomenon on Earth which has not yet been explained, and hence the performed detailed observations are very important for clarifying its nature. FB properties were also discussed in the reviews published in *Sov. Phys. Usp.* **33** (4) 261 (1990), *Sov. Phys. Usp.* **35** (8) 650 (1992), and in the papers: *Phys. Usp.* **39** (11) 1189 (1996); *Phys. Usp.* **47** 99 (2004); *Phys. Usp.* **53** 209, 215 (2010).

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2. Parity violation in electron scattering by quarks

The violation of parity (invariance under mirror reflection) in deep inelastic scattering of electrons by quarks entering into the composition of nuclei has been studied by the PVDIS Collaboration at the Thomas Jefferson Laboratory (USA). A beam of linearly polarized electrons with energies of 6.067 GeV was sent to a deuterium target, and a small contribution from the quark spin was singled out from the data on scattering. The combination $2C_{2u} - C_{2d} = -0.145 \pm 0.068$ of effective constants of the electron–quark weak coupling was determined for the first time. The two-chirality electron scattering asymmetry depends on this combination. Good agreement with the Standard Model prediction of $2C_{2u} - C_{2d} = -0.0950 \pm 0.0004$ was obtained, and the possible contribution from new parity-violating interactions beyond the Standard Model was constrained. Analogous higher-energy measurements cannot now be performed, and therefore the PVDIS results supplement the experiments carried out on the Large Hadron Collider.

Source: *Nature* **506** 67 (2014)
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3. Dirac fermions in a 3D material

Z K Liu (Stanford Institute for Materials and Energy Sciences, USA) and his co-workers have discovered that in the semimetal compound Na_3Bi electrons have a Dirac type dispersion curve in the 3D sample volume — that is, they behave effectively as massless particles. This property had only been observed before in two-dimensional systems: in graphene, and on the topological insulator surface. The electronic structure of the crystalline sample was studied by the angle-resolved photoemission spectroscopy. As was theoretically predicted by C L Kane (University of Pennsylvania, USA) and his colleagues, electrons in Na_3Bi have a Dirac-cone dispersion curve in a 3D space, the cone being anisotropic: Fermi velocities $V_x \approx V_y$ and $V_z \approx 0.25 V_x$. Such substances are 3D analogues of graphene and can find useful applications in microelectronics and spintronics.

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4. Inertially confined thermonuclear fusion: a positive energy balance is reached

In an inertially confined nuclear fusion experiment, performed at Lawrence Livermore National Laboratory (USA), a fusion energy yield exceeding by 1.2 to 1.4 times the energy absorbed by a deuterium–tritium target pressed in a capsule has been obtained for the first time. The light of 192 lasers with 1.9 MJ in the resultant pulse was reemitted by gold capsule walls in the X-ray band, inducing evaporation of the plastic target shell and its compression at a rate of nearly 300 km s^{-1}, which led to an abrupt heating and thermonuclear reactions. Laser pulses somewhat extended in time, not short ones, were exploited (the 'high-foot' technique). This made it possible to stabilize the compression front and to lessen the mixing of the shell substance and the frozen deuterium–tritium charge, which were serious restricting factors in previous experiments. As a result, the relative energy release was approximately an order of magnitude larger than before. The experiment showed that a noticeable role in the target heating was played by the alpha-particles produced in the nuclear fusion reactions. These alpha-particles were then scattered by nuclei and transferred additional energy to them.

Source: *Nature* **506** 343 (2014)
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5. Neutrino mass from cosmological data

Ya B Zeldovich and S S Gershtern were the first to obtain in 1966 a restriction from above on the neutrino mass from cosmological data. Having combined the data on the fluctuations of cosmic background radiation and the calculations of galactic clusters based on the Sunyaev–Zeldovich effect, the Plank Collaboration has presented an estimate of the sum of masses of three types of neutrinos: $\sum m_{\nu} = (0.22 \pm 0.09)$ eV. R A Battye (University of Manchester, UK) and A Moss (University of Nottingham, UK) refined this estimate by allowing for the effects of weak gravitational lensing of galaxies and CRB. All the sets of cosmological data turned out to agree well among themselves, provided that $\sum m_{\nu} = (0.320 \pm 0.081)$ eV. In the presence of sterile neutrinos, the estimate becomes somewhat different. Because of the high neutrino velocities, the formation of large-scale structures in their medium is obstructed, which makes it possible to relate the neutrino mass to the evaluated results for galaxy clusters and other cosmological data.

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