ARISTOTLE UNIVERSITY OF THESSALONIKI

Press Release

A NEW COSMIC ACCELERATOR

An important scientific discovery was made by the Aristotle University research team dealing with plasma astrophysics and High Energy Astrophysics, composed of the Professor at the Physics Department Loukas Vlahos, the researcher Dr. Heinz Isliker and the PhD candidate Theophilos Pisokas.

In particular, they propose that the heating and acceleration of particles, normally associated with explosive phenomena or astrophysical flows in space, are due to their interaction with turbulent magnetic and electric fields that are caused by astrophysical explosions.

The Universe is a very efficient charged particle accelerator. Most explosive phenomena in space (supernova, flares, and many others) are associated with high energy photons (X-rays and γ-rays), and cosmic rays and measurements from satellites crossing the Heliosphere witness the presence of cosmic accelerators. A new mechanism for particle acceleration has been suggested based on the abrupt release of magnetic energy that we encounter in unstable ionized gases (plasmas) and which is generated by explosive phenomena or astrophysical flows.

The new mechanism combines large amplitude magnetic disturbances and powerful electric fields concentrated in small structures within the ionized gases. Magnetic disturbances interact stochastically with the charged particles and heat them while strong electric fields accelerate electric charges, mainly contributing to the formation of a high energy tail in the energy distribution. The synergy of stochastic and systematic acceleration caused by the mixture of magnetic disturbances and electric fields heats and accelerates the particles.

The final energy distribution of the accelerated particles in the environment of turbulent electromagnetic fields is in agreement with the observations. Professor Loukas Vlahos argued that "turbulent strong electromagnetic fields are a very common state in space plasmas, when driven by astrophysical bursts or flows, and they combine two mechanisms for accelerating charged particles, originally proposed by the distinguished Italian astrophysicist Enrico Fermi in the early 1950s. We believe that strong turbulence is a new and very efficient mechanism for accelerating and heating astrophysical plasmas. An interesting part of this study is that the synergy of stochastic and systematic acceleration in turbulent electromagnetic fields has many similarities with astrophysical shock waves, the best known acceleration mechanism

till now in astrophysics, since large amplitude magnetic disturbances trap and force a fraction of the particles to return to the strong electric fields, which are randomly distributed within the unstable environment of astrophysical explosions or flows, thereby accelerating the particles systematically to very large energies".

The scientific discovery was published in the latest edition of the reputable international journal "The Astrophysical Journal" (https://doi.org/10.3847/1538-4357/aaa1e0).

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Figure 1: Tycho's Supernova Remnant, a major cosmic accelerator. [Credit: NASA/CXC/Chinese Academy of Sciences/F. Lu et al]

Figure 2: Solar Flares, a local cosmic accelerator. The sudden magnetic reconstruction of the unstable magnetic structure in the surface of the Sun, is behind the acceleration of the high energy particles [Solar Dynamic Observatory]

Figure 3: Spontaneous formation of coherent structures and large amplitude magnetic disturbances driven from the evolution of a turbulent plasma. The analysis is done with 3D Magnetohydrodynamic simulations [Isliker, Vlahos and Constadineskou, Physical Review Letters, 119, 51011, (2017)]

Figure 4: Acceleration and heating of typical electrons as a function of time inside a turbulent plasma. The synergy of the stochastic energization with the systematic energy gain by the coherent structures lead to high energy values [Pisokas, Vlahos and Isliker, The Astrophysical Journal, 852, 64, (2018)]of.