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Impact of the interstellar medium on processes on the Earth

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Abstract. The paper discusses possible impacts of the interstellar medium (ISM) on processes on Earth, first of all those, which may affect the Earth biosphere.

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ISM is a multicomponent dynamic matter. Cosmic rays (CR) is what most strongly affects processes on Earth and its biosphere. Brief reviews of physical processes due to the CR impact on life on Earth is given by Medvedev & Melott (2007) and Atri & Melott (2014). Here we consider mainly the astronomical aspects and influence of long time variations of ISM parameters near and inside Solar system (SS).

SS moves through the interstellar (IS) matter (ISM) around the center of the Galaxy along a quasi-circular orbit distorted by the spiral arms gravitational fields (Gies & Helsel 2005), and rises a little (70 pc) above or sinks under the galactic plane. Presently the Sun is located in the ISM region known as Local ISM (LISM), not far from the edge of the superbubble (Bochkarev, 1990) formed by the Sco-Cen stellar association, from which stellar winds and supernova explosions, in a cumulative effort, have blown away most of ISM to a distance of about 170 pc. Inside the blown away gas remain fragments of structures (small clouds, filaments, etc).

ISM in the Sun close vicinity, but outside heliosphere has a temperature 8000 K, a number density of a few tenths particle per cubic centimeter, ionization degree 50%. That is, the SS is located in the warm HI region but very close to the hot gas. Once inside heliosphere, ISM neutral atoms gradually get ionized by the Sun UV radiation and charge exchange reactions with solar wind ions take place. Once electrically charged, the particles are carried back by the solar wind forming the “pickup ion” flow. Approaching the two-layer shock wave inner edge, those ions accelerate at the wave front forming the anomalous CR component. Unlike galactic CR the anomalous CR are sub-relativistic. They interact more intensively with atoms and molecules, in particular with those in planetary atmosphere outer layers (if manage to reach them).

Statistics of ISM cloud size and density distribution show that the Sun in its 4.5 billion year long travel along the Galaxy have about 130 times (7-8 time per galactic year) crossed ISM clouds with number density $n > 100\ cm^{-3}$ and about 16 times those with $n > 1000\ cm^{-3}$ (Talbot & Newman 1977; Pavlov *et al.* 2005a).

CR effect on the ozone amount in the Earth atmosphere. The present-day heliosphere radius is ~ 100 a.u. When the SS enters an ISM cloud, heliosphere contracts down to $1-2$ a.u., which practically does not change the parameters of the CR penetrating it. But the energy of the anomalous CR accelerating at the heliosphere outer border increases by hundreds of times. As a result, the Earth upper atmosphere (at least at the polar regions) is irradiated by the anomalous CR hundreds of times more intensively, leading, in the now-a-day nitrogen-oxygen Earth atmosphere, to formation of ozone disrupting nitrogen oxide molecules and subsequent significant ozone layer thinning. The characteristic time for ozone concentration to achieve a new stationary state is about 5-10 years (Pavlov *et al.* 2005a). Results of computation of ozone model distribution over the Earth globe surface for today heliosphere size, and for the case of heliosphere being strongly compressed by the surrounding IS gas of a concentration of 100 cm^{-3} are given in Pavlov *et al.* (2005a). The ozone mass is shown to diminish by 2-4 times in sub-polar regions but only by 40% in the equatorial ones. Reversals of the Earth magnetic field polarity and magnetic excursions, when the magnetic field dipole component weakens drastically for 1-10 kyr, approaching zero, are well documented. They occur, in the average, once in 200 kyr, though tens of millions of years long periods of stable polarity are known to have taken place. The typical time of the SS remaining inside a giant molecular cloud is of the order of 1 Myr. Over this time-interval the Earth magnetic field polarity may suffer several alternations, the ozone protection of the biosphere weakening for several kyrs all over the Earth surface, including the equatorial regions, which, naturally, undermines the biosphere and may lead to a massive extinction of species.

Galactic CR flux variations. Low energetic galactic CR (GCR) are distributed unevenly in the Galaxy. This is seen even from the fact that a significant part of gamma radiation comes from molecular clouds. CR being very dense there produce gamma rays that interact with ISM. Molecular clouds are located mainly in the Galaxy spiral arms. That is why the content of low energy CR is higher there.

The SS in its orbital motion, passes through areas with different CR density. Comparison of such phenomena on Earth as successive cooling and warming epochs, great glaciations, mass extinction of species with the periods when the Sun crosses the spiral arms and with galactic CR flow variations, suggests our planet climate dependence on these phenomena (Shaviv 2003). It should be reminded that as the Sun evolves, solar wind and solar CR parameters change, which affects, in particular, the size of the heliosphere and, consequently, the penetration of GCR into the SS.

The role of the Galaxy evolution. The SS age makes a significant part of our Galaxy age (~13 Gyr). During that time, the physical conditions in the ISM that surrounds the SS and through which it moves could have experienced considerable changes.

IS dust influence. IS dust can also influence the biosphere through various processes. First, if dense enough it would on the way down to the planet surface absorb sunlight. This mechanism was first proposed By F.Hoyle in his science-fiction novel "The Black Cloud" and described quantitatively in Pavlov *et al.* (2005b). Besides, if a planet upper atmosphere is dusty enough, electromagnetic radiation absorption by the dust leads to this layer heating, also affecting the planet's climate. For the biosphere of planets with a scarce stock of nutrients, organic molecules frozen in the dust particles and carried by them down to the planet surface could make an important additional source of nutrients.

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