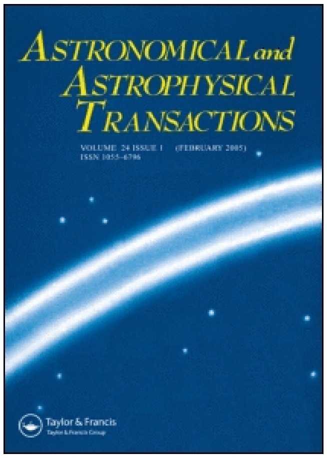

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The similarity of the processes in comets and in the interstellar medium: Production of multicharged ions

S. Ibadov [a]

[a] Institute of Astrophysics, Dushanbe, Tajikistan

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THE SIMILARITY OF THE PROCESSES IN COMETS AND IN THE INTERSTELLAR MEDIUM: PRODUCTION OF MULTICHARGED IONS

S. IBADOV

Institute of Astrophysics, Dushanbe 734670. Tajikistan

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The production of the multicharged ions of heavy elements (Fe, Si, O, etc.) in comets, as well as in the insterstellar medium, is possibly due to high-velocity ($\gtrsim$20 km/s) grain-grain collisions. The role of such processes is essential in the production of the ions of refractory elements in the comae of dusty Halley type comets at large heliocentric distances and, possibly, in the production of the heavy component of cosmic rays by colliding high-velocity interstellar gas-dust clouds due to the action of the Fermi mechanism and the betatron effect.

KEY WORDS Interstellar medium, comets, multicharged ions.

Multicharged ions (C VI, O VI, Fe XIV, Fe XXVII, etc.) are observed in cosmic rays, the solar corona, solar wind, and in the interstellar medium. The problem of the mechanisms of ionization of the interstellar medium and production of cosmic rays remains open. The abnormally high abundance of the ions of heavy elements has been detected in cosmic rays, while in the interstellar medium a strong depletion of heavy elements is observed. The anomaly of the chemical composition of cosmic rays is connected with the injection problem, and the depletion of heavy elements in the interstellar medium, including interstellar clouds, is explained by the consumption of heavy elements for production of dust grains (see, e.g., Ginzburg and Syrovatsky, 1963; Grinberg, 1970; Kaplan and Pikelner, 1979; Sunyaev, 1986; McKee, 1989).

In situ measurements by VEGA and GIOTTO spacecrafts during their encounters with comet Halley in March 1986 at heliocentric distance $R \simeq 0.8$ Au has led unexpectedly to the discovery of the Fe^+ type ions in the cometary coma (Balsiger *et al.*, 1986; Gringauz *et al.*, 1986; Krankowsky *et al.*, 1986). Calculations show that the interaction of the electromagnetic and corpuscular radiations of the Sun with the cometary matter, i.e., the sputtering of cometary dust by solar protons and the photoionization of the metallic atoms produced cannot explain the observed concentration of Fe^+ (Ibadov, 1980; Ip and Axford, 1986). Thus, the production of the ions of refractory elements in cometary comae at large distances from the Sun remains a problem.

In connection with the above problems, it is reasonable to consider dust grain collisions at high relative velocities, e.g., the expansion velocities of gas-dust envelopes of eruptive stars ($V = 100$–1000 km/s), the downward velocities of high-latitude gas-dust clouds above the disk of the Galaxy ($V = 50$–300 km/s), the impact velocities between cometary and zodical dust particles ($V = 20$–700 km/s at $R = 0.01$–10 AU). In each case, a high-temperature phase is produced (Ibadov, 1981, 1989, 1990a; Hirth *et al.*, 1985; Tenorio-Tagle *et al.*, 1987).

Calculations show that the mean ion charge z in the expanding plasma cluster, produced by high-velocity grain-grain collisions, non-linearly depends on the velocity. For iron ions, $z = 2$–26 at $V = 20$–2000 km/s. In the region of a cometary coma where interplanetary dust is transformed into the plasma, the mean concentration of Fe^+ ions is about 100 ion/cm^3, which allows to explain naturally the abundance of Fe^+ in the coma of comet Halley found by in situ measurements of VEGA and GIOTO spacecrafts. Hence, the ions of the refractory elements of the Fe^+ type can serve as indicators of the passage of comets through interplanetary dust clouds. Furthermore, emission of multi-charged ions in the cometary atmospheres, if detected, can allow to determine the chemical composition of cometary and interplanetary dust particles as well as to reveal interplanetary and circumsolar dust bands (Ibadov 1988, 1990b).

The impact of high-velocity gas-dust clouds onto the galactic disk result in plasma production with the power $\sim 10^{40}$ erg/s per collision (that is, of the order of the mean power of cosmic ray generation by supernovae) and the initial kinetic energies of multicharged ions in expanding plasma clusters resulting from grain-grain collisions are of the order of 1–10 keV. Such ions probably can be accelerated by the electromagnetic fields of colliding clouds by the Fermi mechanism and by the betatron effect.

Thus, collisions of high-velocity cosmic dust grains can, in certain situations, play an important role in the production of the ion component of both comets and interstellar medium.

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