STELLAR ACTIVITY FROM INFALLS OF COMET-LIKE BODIES.

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Infalls of cometary nuclei-like bodies onto stars with high orbital velocities, more than 100 km/s, are considered analytically taking into account the presence of an extended stellar atmosphere. It is found that due to aerodynamic fragmentation of the infalling body and transversal expansion of the fragmented mass under the action of pressure gradient on the frontal surface a thermalization of the kinetic energy of the body occurs by sharp stopping of the disk-like fragmented mass near the stellar surface within a relatively very thin layer and has, therefore, essentially impulsive and strongly explosive character. The specific energy release in the explosion region, erg/g, considerably, tens-hundreds thousands times, exceeds the sublimation/evaporation heat of the body so that the process is accompanied by production of a high-temperature plasma. Calculations show that energetics of such explosive high-temperature process corresponds to that of very large solar flares, for stars having masses of the order of solar mass and infalling bodies having masses equal to the mass of the nucleus of Comet Halley. Spectral observations of stars, especially young stars with high rate of mass influx, in wide spectral range, including X-rays with high time resolutions, of the order of 0.1–1 s, are important for revealing stellar activity in the form of impulsive, high-temperature plasma phenomena near the surface of stars connected with infalls of cometary-like bodies onto stars.

Coronagraphic observations by SOLWIND (Solar Wind), SMM (Solar Maximum Mission) and SOHO (Solar and Heliospheric Observatory) missions indicate the presence of a continuous comet flow passing close to the solar surface or colliding with the Sun (Bailey et al., 1992; COSPAR, 1998; MacQueen and St.Cyr, 1991).

Passages of comet-like bodies near stars are possible intensively in young stars with high rate of mass influx and are connected with changes in stellar spectra due to disintegration/evaporation of the bodies(see, e.g., Beust et al., 1998, and references therein).

At the same time the disintegration process of nuclei of sun/stargrazing comets, sungrazers, being considered in the framework of the traditional sublimation model, i.e. under the action of the solar thermal, photospheric, radiation, leads to insignificant decrease of the cometary nucleus radii, attaining no more than 20 meters (MacQueen and St.Cyr, 1991).

In the present report some results of the analytical approach developed to investigate the character of the stellar/solar activity as well as evolution of cometary nuclei at conditions of intense interaction between stellar atmosphere and infalling cometary nuclei-like bodies are presented.

We denote as $\rho_{\rm cr}$ the value of the stellar atmosphere density for which the energy flux on the surface of the nucleus of a comet approaching the star from the incident atoms of the star atmosphere, $J_{\rm a}$, is equal to that of the stellar photosphere emission, J_λ, namely the critical density of the stellar atmosphere is

$$\rho_{\rm cr} = L_0/2\pi R_0^2 V^3. \qquad (1)$$

Substituting into (1) the numerical value of the comet parabolic velocity $V = 6 \times 10^7$ cm/s, $L_* = L_0 = 4 \times 10^{33}$ erg/s, and $R_* = R_0 = 7 \times 10^{10}$ cm, we obtain $\rho_{\rm cr} = 5 \times 10^{-13}$ g/cm^3. This value corresponds to the density of the solar atmosphere near the upper boundary of the chromosphere.

During the passage through the stellar atmosphere the comet nucleus is subjected to aerodynamic loads which can cause its fragmentation (these loads substantially exceed the action of the tidal effect). From the equation for the aerodynamic deceleration of a constant-mass nucleus,

$$M dV/dt = (1/2) c_{\rm x} S \rho_{\rm a} V^2, \qquad (2)$$

and the condition of the fragmentation onset under the action of an aerodynamic load

$$P_{\rm a*} = \rho_{\rm a*} V^2 = \sigma_*, \qquad (3)$$

we find that the height corresponding to the onset of the nucleus aerodynamic fragmentation in the star atmosphere with the mass density distribution like to $\rho_{\rm a} = \rho_0 \exp(-h/H)$ (Ivanov-Kholodnyi and Nikol'skii, 1969) is

$$h_* = H \ln\left(\rho_0 V_0^2/\sigma_*\right). \qquad (4)$$

Substituting into (4) $H = 3 \times 10^8$ cm, $\rho_0 = 10^{-8}$ g/cm^3, and $\sigma_* = 10^4$ dyn/cm^2 (Greenberg et al., 1995), we obtain $h_* = 10^9$ cm.

It follows from equation (3) that $\rho_{\rm a*} = \sigma_*/V_0^2 = 3 \times 10^{-12}$ g/cm^3. Under these conditions we have $J_{\rm a} = \rho_{\rm a*} V_0^3/2 = 3 \times 10^6$ W/cm^2.

The comparison of the density of the energy fluxes under consideration incident onto the nucleus of a comet yields $J_{\rm a}/J_\lambda = 500$. This implies that not only the 10-meter-scale bodies, but the ones having any greater values are sublimated completely during their passage near the stellar surface, photosphere, due to preliminary mechanical, aerodynamic, disintegration and abrupt deceleration of crushed fragments.

The astrophysical manifestations of the process considered can be an excess of radiation in metal atoms lines, by the analogy with that observed as a result of the collision of the Shoemaker–Levy-9 comet with Jupiter (Fortov et al., 1996) and generation of X-rays (Grigoryan et al., 1997, 2000).

The passage of comet-like bodies near the stellar surface is accompanied by the fragmentation of their nuclei under the action of aerodynamic loading within the chromosphere and subsequent intense disintegration of fragments due to collisions with chromosphere particles.

The spectral monitoring of stellar radiation emission in bright lines of metal atoms and ions involving not only the visual range but also soft X-ray one is worthwhile.

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