

Massive stars: flare activity due to infalls of comet-like bodies

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Abstract. Passages of comet-like bodies through the atmosphere/chromosphere of massive stars at velocities more than 600 km/s will be accompanied, due to aerodynamic effects as crushing and flattening, by impulse generation of hot plasma within a relatively very thin layer near the stellar surface/photosphere as well as “blast” shock wave, i.e., impact-generated photospheric stellar/solar flares. Observational manifestations of such high-temperature phenomena will be eruption of the explosive layer’s hot plasma, on materials of the star and “exploding” comet nuclei, into the circumstellar environment and variable anomalies in chemical abundances of metal atoms/ions like Fe, Si etc. Interferometric and spectroscopic observations/monitoring of young massive stars with dense protoplanetary discs are of interest for massive stars physics/evolution, including identification of mechanisms for massive stars variability.

Keywords. massive stars, impact-generated stellar flares, comet-like bodies

1. Introduction

High-resolution spectroscopic observations of young stars with dense protoplanetary discs like β Pictoris as well as coronagraphic observations by solar missions indicate the presence of fluxes of comet-like evaporating bodies (FEBs), falling onto Sun/stars (see, e.g. Lagrange *et al.* 1987; Beust *et al.* 1996, <http://sungrazer.nrl.navy.mil/>).

Disintegration of nuclei of sungrazing comets considered in a vacuum leads to a decrease in their radii to less than 10-20 m prior to impact (Weissman 1983).

Meanwhile, comet-like bodies fall onto massive stars with high orbital velocities $V_* \geq V_\odot$ ($V_\odot = 617$ km/s is the parabolic velocity for the Sun). This indicates the possibility of high energy processes in comets (cf. Ibadov 1990, 1996; Ibadov *et al.* 2009; Ibodov *et al.* 2010; Ibodov & Ibadov 2011, 2014). Impulse release of a large energy, up to 10^{32} erg, is possible due to the magnetic reconnection in the active Sun (cf. Somov 1992; Walder *et al.* 2012). We consider physical processes accompanying the passage of star-impacting comet nuclei through the stellar atmosphere, i.e., processes that are capable to lead to massive stars flare activity.

2. Massive stars comet-induced flares

To find, analytically, the law for the rate of the loss of kinetic energy of aerodynamically fully crushed and transversally expanding comet-like body along the height of the star atmosphere, h , we modify the basic equations of the physical theory of meteors (aerodynamic deceleration/evaporation) using the parameter $r = r(h) = \{\exp[(h_* - h)/H]\} - 1$. We use also the comet orbital velocity near the star surface, $V_* = V_\odot (M_* R_\odot / M_\odot R_*)^{1/2}$. Here M_* , M_\odot are the masses of the star and the Sun, R_* , R_\odot are their radii; h_* is the

onset height for aerodynamic crushing of comet nucleus, H is the atmosphere height scale.

The energy released around the height of $h = h_m$ (the height of the maximum rate of loss of kinetic energy of the crushed comet nucleus), manifesting as “explosion” in the atmosphere around $r = r_m = r_e$, and the initial temperature of plasma produced within the decelerating/exploding layer with the width, $\Delta h_d = \Delta h_e \approx 0.7H$, are

$$E_e = \frac{\pi \rho_n R_n^3 V_*^2}{3e}, \quad T_0 = \frac{Am_p V_*^2}{12ek(1+z+2x_1/3)}, \quad (2.1)$$

where ρ_n , R_n are the nucleus density and initial radius, A is the mean atomic number, m_p is the proton mass, k is the Boltzmann constant, z is the mean charge multiplicity of plasma ions, x_1 is the mean relative ionization potential; the theory was tested using for the 2013 Chelyabinsk superbolide explosion (cf. Ibadov *et al.* 2009; Ibadov 2012; Ibadov & Ibadov 2011; Grigoryan *et al.* 2013).

Using (2.1) with $\rho_n = 0.5 \text{ g/cm}^3$, $R_n = 10^5 \text{ cm}$, $V_* = V_0$, $A = 20$, $z = 5$, $x_1 = 3$ we have $\Delta h_e = 140 \text{ km}$, $E_e = 7 \cdot 10^{29} \text{ erg}$, $T_0 = 7 \cdot 10^6 \text{ K}$. Hence, “superflares” may be due to impacts with comets like comet Hale-Bopp 1995 OI (cf. Ibadov *et al.* 1999; Grigoryan *et al.* 2000; Ibadov *et al.* 2009; Eichler & Mordecai 2012; Ibadov & Ibadov 2014).

3. Conclusions

Impacts of sufficiently large, 100-meter or more, comet-like bodies with stars like the Sun and/or more massive ones will be accompanied by impulse production of a high-temperature plasma, strong “blast” shock wave, shock wave induced ejection of ionized photospheric and cometary matter.

Anomalously intense variable emissions of metal atoms and ions produced during the nucleus “explosion” near the stellar/solar surface may serve as possible indicators of comet impact-generated photospheric stellar/solar flares.

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