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Explosive evolution of young stars

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Impacts of comet-like objects, "falling evaporating bodies" (FEBs), with stars (at velocities around 600 km/s) will be accompanied, due to intense aerodynamic effects in stellar atmosphere/chromosphere, by FEB "explosions" and generation of strong "blast" shock waves: FEB-generated stellar flares. Multi-wavelength monitoring of young stars with dense protoplanetary disks (rich in FEBs) are of interest for physics/evolution of young stars, including revealing and identification of mechanisms for young stars variability.

Keywords: Young stars, falling evaporating bodies, FEB-generated explosions, stellar flares

1 Introduction

High-resolution spectral observations of young stars with dense protoplanetary disks like Beta Pictoris led to the discovery of variable emission lines of metal atoms, Na, Fe, etc. that indicate the presence of fluxes of comet-like objects, so called falling evaporating bodies (FEBs) (see, e.g., Lagrange et al. 1987; Beust et al. 1996; Grinin et al. 1996; Teets et al. 2011).

Besides, more than 2000 sungrazing comets were discovered during the last three decades by coronagraphic observations of the Sun with solar observatories like SOHO (MacQueen et al. 1991; http://sungrazer.nrl.navy.mil/).

At FEBs velocities around 600 km/s the specific kinetic energy of the bodies essentially exceeds the sublimation heat of their material, 10^{10} erg/g. Hence, there is possibility of the appearance of high-temperature phenomena (cf. Ibadov 1987; Ibadov 1990; Ibadov 1996; Ibadov et al. 2007; Ibodov et al. 2010; Ibodov et al. 2011; Ibodov et al. 2014).

An analytic approach to the problem of explosion of large meteoroids (bolides and superbolides/fireballs) in planetary atmospheres was presented by Prof. Grigorian during 1976–1979. This approach was further developed in connection with the 100th

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anniversary of the 1908, June 30, Tunguska phenomenon (Ibadov et al. 2008). The complete analytic theory of explosive evolution of falling bodies in planetary atmospheres was created and used/tested to explain the 15 February 2013 Chelyabinsk event (Grigorian et al. 2013).

We present some results, derived by using the theory above mentioned, on the flare activity of young stars due to falling evaporating bodies.

2 Aerodynamic heating and crushing of FEBs in stellar atmospheres

Calculations show that within the stellar chromosphere intense aerodynamic crushing of FEBs occur, as well as their transversal expansion due to aerodynamic pressure gradient. Hence, physical evolution of FEBs in the field of solar thermal radiation may be considered in a vacuum approximation (see, e.g., Weissman 1983) only above the solar chromosphere: disintegration of FEBs within the chromosphere will have meteor-like character and can cause production of anomalously high abundances of atoms of refractory elements like Fe, Si, etc.

Moreover, additional line emissions of such metal atoms may be detected in the background of solar coronal radiation, if FEBs have radii around or more than 100 meters (Grigorian et al. 1997; Grigorian et al. 1998; Ibadov et al. 1999; Ibadov et al. 2007).

3 Aerodynamic "explosion" of FEBs in stellar atmosphere: FEBs-generated stellar flares

Using modified form of basic equations of the physical theory of meteors (see, e.g., Levin 1956) an equation for the loss/dissipation of the kinetic energy of aerodynamically completely crushed and transversally expanding/flattening FEBs in stellar atmosphere/near-photosphere can be obtained. This equation allows us to find all parameters related to the place of maximum energy release, i.e., FEB atmospheric "explosion".

The characteristic time for thermalization of the FEBs kinetic energy within decelerating/"exploding" layer is around 0.3 sec, at thickness of the layer about $0.7H = 140$ km, H is height scale of the photosphere.

The FEBs, for example the comet Halley 1986 III, will release explosive energy close to the energy of large solar flares, 10^{32} erg, while FEBs such as comet Hale–Bopp 1995 OI or larger (corresponding FEBs radii will be close or more 30 km) will lead to stellar super-flares (cf. Grigorian et al. 2000; Ibadov et al. 2009; Eichler & Mordecai 2012).

4 Conclusions

The impacts of falling evaporating bodies, FEBs, with young stars like Beta Pictoris will be accompanied by high-temperature explosive phenomena: impulse production

of hot, around 10^7 K, plasma within a relatively very thin layer near stellar photosphere, strong "blast" shock wave, eruption of a hot photospheric-cometary matter plasma into space above stellar chromosphere, emissions of metal atoms like Fe, Si, Na, etc.

Variable anomalously intense emissions of metal atoms/ions produced during FEB "explosions" may be indicators of FEB-generated stellar flares.

Multi-wavelength observations/monitoring of young stars by space observatories like SDO having high spatio-temporal resolutions, are of interest for studying mechanisms of their flare activity.

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