

THERMONUCLEAR EXPLOSIONS OF NEUTRON STARS INDUCED BY THEIR STORMS

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Abstract

The present paper deals with the computer simulation of nonstationary radiative plasma magnetohydrodynamics (MHD) processes under blow-up regime in the vicinity of neutron star crust which are accompanied by thermonuclear detonation and explosions.

1. Introduction

The formation and accumulation of deuterium is possible in the crust of neutron stars (NS) due to inverse beta-decay and following neutrons capture by protons [1]. Up to day the following 3 possible mechanisms of ignition of the observed thermonuclear explosions on NS have been considered in result of [1]: 1) accretion; 2) internal processes of NS heating; 3) residual radioactivity of external shell produce after previous explosions. In this paper it is shown that ignition of thermonuclear detonation and explosion can be in result of electro-discharge processes near the neutron stars surface in preference to mentioned above three mechanisms. Earlier in [2], a new hypothesis of the nature and mechanism of charge particle jets generation from the neutron stars (pulsars and from nuclear of quasi stellar radio source-QSS 3C273) was proposed, which is based on the nonlinear electro-discharge phenomena (current self-focusing and defocusing, generation of "shooting solitons") and recently have been confirmed by direct computer simulation [3-7]. These processes are accompanied by generation of strong shock waves and crater formation in crust on the surface of NS. This work is further continuation of [2-7] and deals with the direct computer simulation of the processes of thermonuclear detonation and explosions on the NS by using 2D MHD code [8,9] with some modifications for accounting of the specific of NS conditions.

2. Mathematical model

For simplicity the peculiarities of space-time near the NS calculations are disregarded as well as in calculations which was produced by Oppenheimer and Snider, Zel'dovich and his group [10]. The numerical simulations are performed by using the mathematical model which is based on system of the 2-D axisymmetrical magnetohydrodynamic (MHD), radiative and heat transfer equations. Thermal and electrical conductivity were calculated by using the simplified method [11] as well as the original model which earlier have been used in [3-7]. The system of MHD equations was completed by wide-range two-temperature equation of state which includes effects of an electron degeneration [12].

The discrete model is implemented on the base of implicit full conservative finite-difference scheme corresponding the difference system of MHD equations and used the

technique of adaptive grid. The algorithm for solution the system of finite-difference equations derive a few groups of equations depending on physical processes. There are motion, energy, field groups. Every group of equations is solved by means of Newton-like iteration procedure [12,13]. The energy balance calculation was carried out for the convergence control during the solving of the discrete MHD equations. The non-equidistant difference moving grid (see Fig. 1a) and two-temperature approximation have been used.

3. Results

Let us consider the following computer simulations: we propose that on the surface of NS crust (iron with density 10^5 g/cc) there exist a hot spot with initial (at $t=0$) temperature (of ions T_i and electrons T_e) distributions, which are described by the relationship:

$$T_i=T_e=T(R,Z)=T_0 \exp\{-[R/R_0]^2 - [(Z_s-Z)/Z_0]^2\},$$

where $T_0=25$ eV, $R_0=20$ m, $Z_0=6$ m. The dimensions of calculated area are : $0 \leq R \leq 200$ m, $0 \leq Z \leq 200$ m. The considered part of iron crust (with D+D cavity) is arranged between $0 \leq Z \leq Z_s = 100$ m and $0 \leq R \leq 200$ μ m (Fig.1b). The length of vacuum gap (between crust of NS and its magnetosphere) equals to 100 m. We assume that the temperature of NS crust is about of 1 eV, the tension of electric fields near the surface of neutron stars equals to 100 MV/cm and work function to 200 eV (as well as in [3-7, 14]).

Now we consider some results of direct computer simulation of such exotic electrical discharge (see Fig.1-4). It is interesting that up to $t=122$ ns the results of computer simulation are very similar to the mentioned above both means of calculations of thermal and electrical conductivity (including effects of strongly coupled plasma and without them, see Fig.1). After this time in a first case the ignition of thermonuclear detonation starts at the more short time. Already at the time $t= 137$ ns, we have the beginning of the fast heating of NS crust under so called „blow-up regime“ [15] (Fig.2-3).

The mass velocities are increased up to relativistic values (Fig.4), and for describing this later stages of thermonuclear explosions of NS we are needed to use the relativistic MHD code.

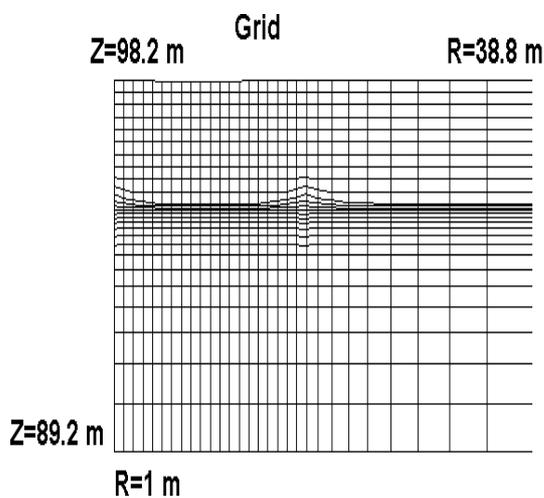


Fig. 1. a)

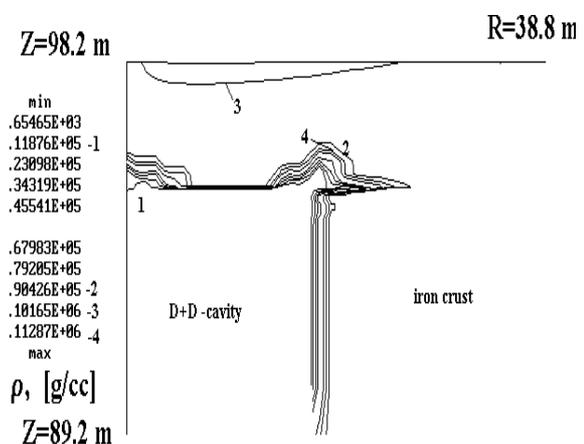


Fig. 1. b)

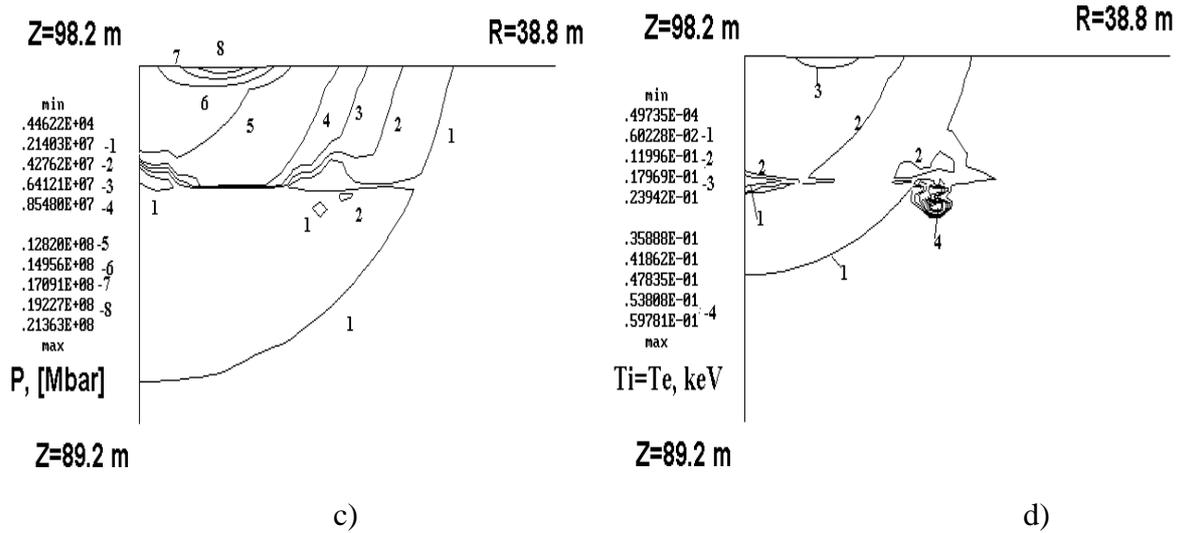


Fig. 1. (contd.) The spatial distribution in fragment of calculational area (a), of the main physical parameters of matter: density (b), pressure (c), and electron and ion temperatures (d) at $t=122$ ns.

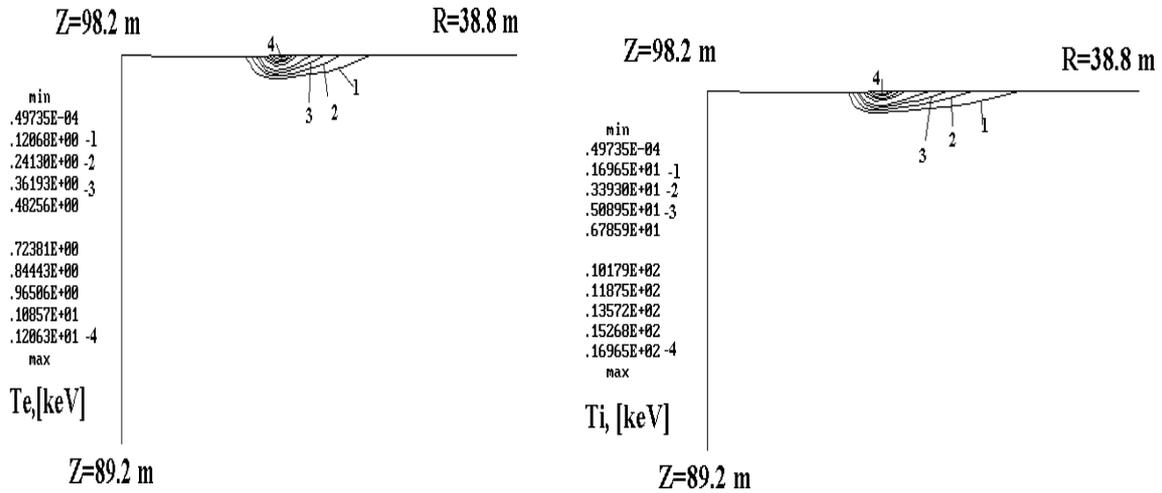


Fig. 2. The spatial distribution of electron (a) and ion (b) temperatures at $t=137$ ns.

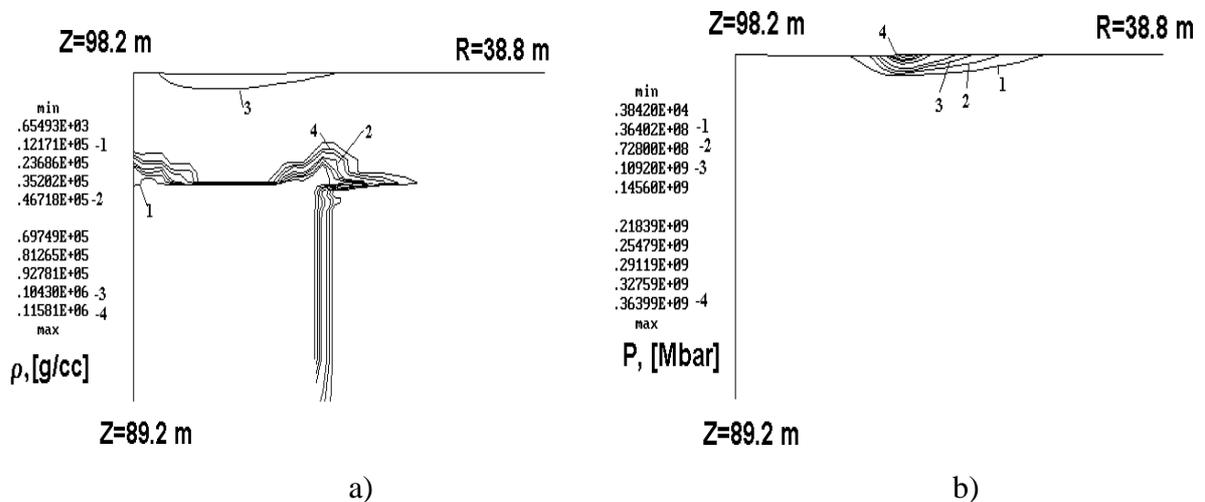


Fig. 3. The spatial distribution of matter density (a) and pressure (b) at $t=137$ ns.

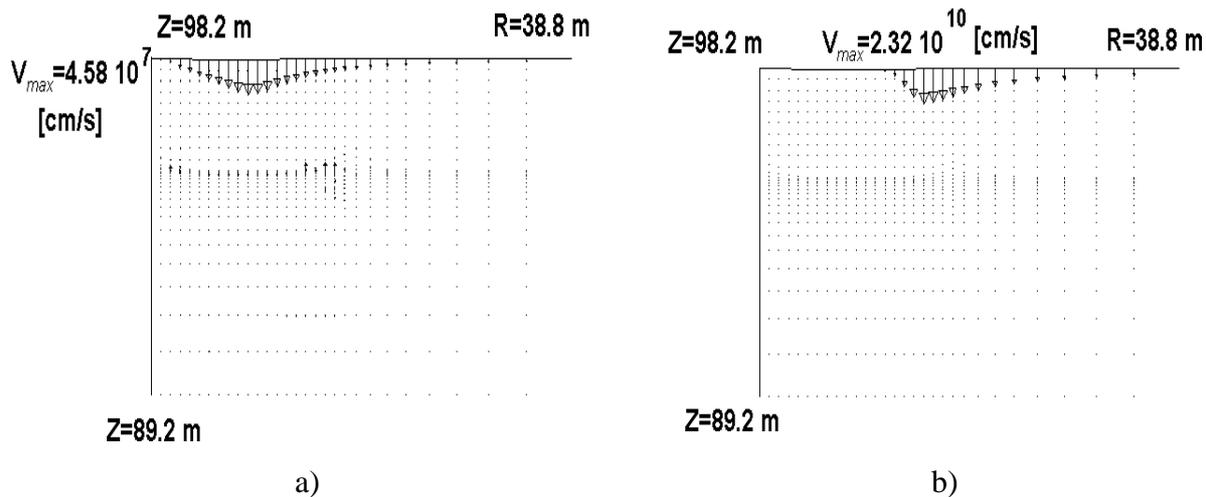


Fig. 4. Velocities of matter at $t=122$ ns and 137 ns accordingly.

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