X-ray and Gamma Ray Bursts from Collapsing Stars

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Abstract

When the stellar magnetosphere compreses under the collapse it's magnetic field considerably increases. Charged particles will be accelerated in this field. These particles will generate radiation when moving in the magnetic field. The collapsing stars can by powerful sources of non-thermal radiation produced by the interaction of charged particles with the magnetic field. The effect can be observed by means of modern instruments. The radiation flux grows during stellar collapse by millions and can be observed as bursts of the electromagnetic radiation in wide band (from gamma ray to radio waves) with duration equal to the stellar collapse time. This flux depends on the distance to the star, its magnetic field, and the particle spectrum in the magnetosphere. The radiation fluxes are calculated for various collapsing stars with initial dipole magnetic fields and initial power- law, relativistic Maxwell and Boltzmann particle energy distributions in the magnetosphere.

1. Introduction

Collapse begins when the mass of stellar core exceeds the Chandrasekhar bound, and the star become dynamically unstable. The star will Compress and its radius decrease. After that, the star can evolve by several ways. The first way is that a star explodes and loses its mass. The collapse of a massive star ($M_o \leq 3 \div 6M_o$) may results in the formation of a neutron star or a black hole. The neutron star formation can accompany by the explosion and loss of mass. This phenomenon is observed as a supernova star. The star with smaller mass collapse to white dwarf [10, 11], the process may be accompanied by the formation of planetary nebula. The second way is realised when star collapse without the loss of mass. In this case it is very difficult to observe the collapse and hitherto there are not strong astronomical date conforming the evidence of this stage. The star emits electromagnetic radiation under the collapse. In this paper the non-thermal radiation from the collapsing stars with the initial dipole magnetic field at the non-relativistic stage is studied and the method for the observation of collapse using the data on this radiation are proposed.

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2. Non-thermal radiation from collapsing stars

The ratio between the radiation flux $I_{\nu i}$ from collapsing stars on a frequency ν and its initial radiation flux $I_{\nu P0}$ on a frequency ν_0 for the power-series, relativistic Maxwell, and Boltzmann distributions, can be written respectively, [7]

$$I_{\nu P}/I_{\nu P0} = (\nu/\nu_0)^{(1-\gamma)/2} R_*^{\gamma-2} \int (R_*)^{-a_1(\gamma-2)} \sin\theta d\theta, \tag{1}$$

$$I_{\nu M}/I_{\nu M0} = R_*^{-3}(\nu/\nu_0)(1/kT) \int R_*^{-\beta_2} \exp(-E/kT) \sin\theta dE d\theta, \tag{2}$$

$$I_{\nu B}/I_{\nu B0} = R_*^{-3}(kT)(\nu/\nu_0) \int R_*^{-\beta_3} E^{-2} \exp(-E/kT) \sin\theta dE d\theta \tag{3}$$

Here K_C, K_M, K_B are the spectral coefficients; k is the Boltzmann constant; E is the particles energy and T is the temperature in the magnetosphere; γ is the power spectrum; $\beta_1 = a_1(\gamma-1)$; $\beta_2 = a_1(E/kT \ln E - 3)$; $\beta_3 = a_1(E/kT \ln E - 1)$; $a_1 = (5k_1/3)(3\cos^4\theta + 1.2\cos^2\theta - 1)(1+3\cos^2\theta)^{-2}$; $R_* = R_o/R$; R is a radius of collapsing stars having a initial radius R_o.

Using Eqs. (1) - (3) the radiation flux from the collapsing stars can be calculated. The ratio between the radiation flux from collapsing stars and its initial flux by $\nu/\nu_0 = 1$ are in the ranges:

$1 \leq I_{\nu P}/I_{\nu P0} \leq 1.34 \times 10^{10}$
for $2.4 \leq \gamma \leq 3.4$, $10 \leq R_* \leq 1000$;

$1 \leq J_{\nu M}/J_{\nu M0} \leq 4.86 \times 10^5$
for $1\ eV \leq kT \leq 9\ eV$, $145 \leq R_* \leq 850$;

$1 \leq J_{\nu B}/J_{\nu B0} \leq 2.23 \times 10^{11}$
for $1\ eV \leq kT \leq 9\ eV$, $145 \leq R_* \leq 850$.

These values obtained by the numerical integration of the equations for the ratio between the radiation flux in the range $2\ eV \leq E \leq 10^9\ eV$, $0 \leq \theta \leq \pi/2$ for the different radius R_* , temperature kT and index γ.

3. Conclusions

We can see from obtaining results that the radiation flux grows during the collapse very rapidly (in millions times and more compare with the initial flux). The radiation flux grows the most rapidly for the collapsing stars with the cool magnetospheres ($kTleq1\ eV$). For these stars the flux increases in million times when the stellar radius decreases in ten times. For the magnetospheres with middle temperature ($1\ eV \leq kT \leq 3\ eV$) the flux grows at the more late stage of collapse. By collapse of the stars with the high-temperature magnetospheres the radiation flux grows at the still more the stage collapse, when the stellar radius decreases in a hundreds times. The radiation flux from stars with Boltzmann distributions grows more rapidly in comparison with the stars having relativistic Maxwell distribution. The general conclusions from the obtained results are next. The stellar magnetic field will increased considerable during the collapse. The charged particles can be accelerated in this magnetic field, which will emitted the electromagnetic waves in the wide frequency range from radio waves to gamma rays. The radiation flux grows during collapse and reaches the maximum at the final stage of collapse. We can observed this radiation as the radiation impulses in the wide frequency range. The pulse duration completes with the collapse time defining the initial mass and initial radius of collapsing star. The intensity of these pulses are very strong, and the radiation flux from collapsing stars at the final stage of collapse exceed the initial flux in millions times. We can see (Tables 1-2) that the radiation fluxes for stars with the initial fluxes in range [1-6, 8, 9] $10^{-22} erg/cm^2 s\ Hz \ \leq I_{\nu o} \leq 10^{-30} erg/cm^2 s\ Hz$ can increase to $10^{-16} erg/cm^2 s\ Hz \ \leq I_{\nu o} \leq 10^{-24} erg/cm^2 s\ Hz$ and more. Thus the collapsing stars can be the powerful sources of the non-thermal radiation impulse. Where this impulse can be observed? First of all in the middle of powerful gamma bursts and X bursts which are not periodical and can be connected with the precollapse stars and the stars which are at the stages of evolution those preceeds of the neutron star formation and supernova explosion. The impulse non-thermal radiation can observe also before explosion of nova and from the white dwarfs in double systems on the stage accretion induced collapse. Periodical impulse of the non-thermal radiation can be generated by the pulsation of the stars with magnetic field as since in this case the charged particles can be accelerated and they can emit of the radiation.

4. References

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