Gamma Ray Bursts: Theoretical Search
for Enigmatic Flow of Energy

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Abstract

In this article gamma ray bursts are explained over the new theoretical consequence of electromagnetic radiation from accelerated mass, here it is deceleration due to bounce at the end of gravitational collapse in on self for massive stealer objects or at their merger. Implication of this theory with typical values of the parameters in case of gravitational collapse of star core at the end of supernova when mass of the star encounter a huge bounce within few seconds results very high energy out blown in the magnitude of gamma ray burst which resolves ultimately the enigmatic energy flow \( \sim 10^{47}\text{Joules} \) in a matter of seconds.

Keywords: Electromagnetic radiation, decelerated mass, gravitational collapse, merger of stealer objects, gamma ray bursts

1. Introduction

Since the discovery of gamma ray burst (GRB) in 1960 numerous theories [1, 4, 5, 7, 8] have been prescribed to resolve the enduring mystery but the true nature of GRBs remains unsolved. So far in comparisons of observed properties [1, 5, 12] GRBs represent extremely high explosions even too much greater than a supernova makes its precedence to astrophysics and astrophysicists are still overwhelming to theorize the whole. Usually for the most cases the emission of photons energy from the GRB’s ranges over 20Mev to100Gev [4, 8] tells that the
underlying process is not alike to the known most powerful fusion process where maximum photon energy is less than 20Mev. The synchrotron radiation, synchrotron self Compton emission and latter inverse Compton emission theories have made some significant contributions regarding the creation of high energy photons from 200Mev to 20Gev from the gamma ray burst [7, 8]. But regarding energy outcome the theories are not even unquestionable [1, 4, 6, 13] for the essential features why

(a) The duration of the bursts are short just 30ms to 1000s [4].

(b) High energy flow in a single burst almost a solar mass vaporized in to pure energy of $10^{47}$ Joules within few seconds [5, 6, 11, 12]

(c) Almost isotropic [1, 4]

In the following sections all these above scenarios will be encountered over new theoretical [3] point of view without any empirical considerations.

2. The process during the GRB

From the astrophysical observation the gamma ray burst comes from the massive star at the end of supernova [5, 6, 9, 11, 12, 13] when the massive star core with mass greater than Chandrasekhar limit 1.44 solar mass just undergoes into gravitational collapse into itself [5, 6, 11, 12]. The collapse is so powerful that electrons are captured by protons to form stable neutron star or perhaps a black hole [5] as a whole. After attaining maximum collapse velocity it ceased to zero (compared to initial magnitude) with a bounce [5] in very short time of few seconds results extremely high deceleration. In other way the evidence of generation very short duration gamma ray bursts of two seconds by the merger of two small, super-dense stellar objects called kilonova[13] has been reported by NASA’s Hubble Space Telescope recently.

3. Radiative energy at the star core collapsing

From above scenarios in Sec.-2 there is the scope to have large amount of radiation as the implications of very recent theory about generations of electromagnetic radiations from accelerated mass. The theory in the article “Accelerated Mass as the Source of Electromagnetic Radiation” [3] presents the equations of radiation fields at distance $r$ and present time $t$ for the mass($m$) with acceleration ($\dot{u}$) and velocity ($u$) are

$$E_{rad} = \frac{Gm\gamma^3}{rc^2} \left[ u \times (u \times \dot{u}) + \frac{c^2 u - \dot{r}(u, \dot{u})}{c^2} \right]$$  (1)
\[ B_{\text{rad}} = \hat{r} \times \frac{E_{\text{rad}}}{c} \]  \hspace{1cm} (2)

\[ G \sim 6.674 \times 10^{-11} \text{ S. I. and } c = 3 \times 10^8 \text{ m/s} \]

Now the power radiative Poynting flux \( S = E \times H \), the directional rate of loss of energy at retarded time \( t' \) from the source in an elementary solid angle \( d\Omega \) gives [2]

\[-\frac{dU(\theta)}{dt'} d\Omega = (E \times H) \cdot \hat{r} \frac{d}{dt'} r^2 d\Omega \]  \hspace{1cm} (3)

Where, \( H = \varepsilon_0 c^2 B \)

Here \( \varepsilon_0 = 8.856 \times 10^{-12} \text{ F/m} \)

To ease the calculation let the star is considered into two hemispherical lobes during the deceleration each of the centers of the masses (CM) of the lobes undergo equal and opposite deceleration.

![Diagram](image)

**Fig-1**

Radiation through an elementary surface for deceleration of the lobes of star core

Then from the Fig-1 at point ‘P’ the energy outflow through the elementary surface \( r^2 d\Omega \sin \theta \) of the sphere for flux of radiation \( (E \times H) \cdot \hat{r} \sin \theta \) following equation (3)
\[-\frac{dU(\theta)}{dt'} \sin \theta d\Omega = (\mathbf{E} \times \mathbf{H}).\hat{r} \frac{dt}{dt'} r^2 d\Omega \sin \theta \quad (4)\]

The usual non-relativistic case when proper velocity of CM \( u \ll c \) and considering the major contribution of the deceleration of the CM of the lobes come from the outer layer of the collapsing star then general relativistic time dilation can be ignored leads \( \frac{dt}{dt'} \rightarrow 1 \)

Now using equation (2) with above consideration with \( u \) and \( -\dot{u} \) are in the same direction making an angle \( \theta \) to the position vector \( r \) reduces equation (4) for a single lobe

\[-\frac{dU(\theta)}{dt'} \sin \theta d\Omega = \epsilon_0 c E_{rad}^2 \sin^3 \theta r^2 d\Omega \quad (5)\]

For the two identical opposite lobes from Fig-1 total energy out flow will be doubled so (5) need to be presented as

\[-\frac{dU(\theta)}{dt'} \sin \theta d\Omega = \frac{\epsilon_0 G^2}{2c} M^2 u^2 \dot{u}^2 \cos^2 \theta \sin^3 \theta d\Omega \quad (6)\]

Where non relativistic case \( u \ll c \),

\[E_{rad} = \frac{GMu}{2rc} \cos \theta \dot{u}, \quad (7)\]

For the non rotating homologous collapse the arbitrary choice of point ‘P’ one can set an identical configuration as Fig-1 with another two lobes such that equation (6) remains unchanged. Thus the flux density through any point on the surface of the sphere is same. This fulfills the condition (c) in Sec.-1 and allows measuring the total out flow rate of radiation energy through the entire surface of the star

\[-\frac{dU(\theta)}{dt'} \sin \theta \mathbf{f} d\Omega = -\frac{dU}{dt'} = \frac{\epsilon_0 G^2}{2c} M^2 u^2 \dot{u}^2 \cos^2 \theta \sin^3 \theta \mathbf{f} d\Omega \quad (8)\]

If the mass distribution is isotropic then angle(\( \theta \)) remains unchanged independent to the size of the sphere during the deceleration of CM of the hemispherical lobes, thus angle \( \theta \) is independent of time \( t' \). Further considering deceleration—\( \dot{u} \) is constant over the short period of time \( \Delta t' \). Now at any instant \( t' \) putting velocity \( u = u_0 - \dot{u}t' \) the total energy out flow during the deceleration process

\[-U = -\int_0^{\Delta t'} \frac{dU}{dt'} dt' = \frac{2\epsilon_0 G^2}{c} M^2 \dot{u}^2 \cos^2 \theta \sin^3 \theta \int_0^{\Delta t'} (u_0 - \dot{u}t')^2 dt' \quad (9)\]

The decelerated CMs of the lobes are ceased its velocity (compared to initial maximum velocity) \( u_0 \) after time \( \Delta t' \) as the condition in Sec.-2, then implying

\[u_0 = \dot{u} \Delta t' \quad (10)\]
\[ -U = \frac{2\pi\epsilon_0 G^2}{3c} M^2 \cos^2 \theta \sin^3 \theta \dot{u} \Delta t^\beta \] (11)

Further expressing \( \dot{u} = \frac{u_0}{\Delta t'} \) and replacing \( \cos^2 \theta \sin^3 \theta = \left[ \frac{\Delta R}{\sqrt{R^2 + \Delta R^2}} \right]^2 \left[ \frac{R}{\sqrt{R^2 + \Delta R^2}} \right]^3 \)

ultimately equation comes to

\[ -U = \frac{2\pi\epsilon_0 G^2}{3c} \left[ \frac{\Delta R}{\sqrt{R^2 + \Delta R^2}} \right]^2 \left[ \frac{R}{\sqrt{R^2 + \Delta R^2}} \right]^3 M^2 \frac{u_0^4}{\Delta t'} \] (12)

Taking the density as the linear function of R, considerable choice allows \( \Delta R = 0.34R[2] \) and putting all the values of constants in equation (12)

\[ -U = 2.4 \times 10^{-41} M^2 \frac{u_0^4}{\Delta t'} \text{ Joules} \] (13)

Equation (13) is the required form to estimate the total energy out come as electromagnetic radiation for a collapsing star core after supernova. It also tells keeping the other parameters unchanged shorter the deceleration period higher the energy out come in GRBs.

Typically supernova generates for a massive star of mass around \( M \geq 25M_\odot \), and mass of the collapsing core is \( 2M_\odot \) (solar mass \( M_\odot = 1.988 \times 10^{30} k\text{g.} \)) with maximum outer layer of core velocity \( 70000 \text{ km/sec}[5] \) but inner core will not have like high velocity so for the sake of simplicity considering average momentum density the initial maximum velocities of each CMs are now \( u_0 \sim 10000 \text{ km/sec} \), with this taking collapsing duration at the bounce is \( \Delta t' \sim 10 \text{ secs} \) equation (13) results a gravity induced radiation of electromagnetic energy \( \sim 10^{47} \text{ Joules} \), agrees with conditions(a &b) in Sec.-1.

**Conclusion**

Throughout the above sections the GRB regarding energy flow in a matter of seconds as the deceleration period is obvious with the observed measurement and ultimately enigma is resolved by equation (13). Unlike non rotating homologous gravitational collapse for the mergers of stealer objects [13] could make a burst as the consequence but the burst will be no more isotropic. Although GRBs have some another properties like simple continuum spectrum [1, 4] which is possible as the natural deceleration [3] radiation from the mass as like as the bremsstrahlung [9] of charged particles. Besides this some GRBs with photon energy at the highest level of 10 Tev[12] need further theoretical search.
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References


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