Explanation of GRB and Early Afterglows as Quark-Nova Phenomenon

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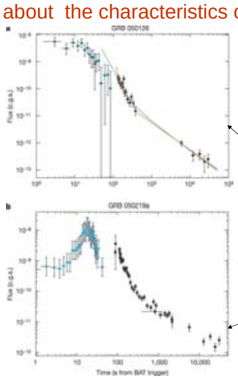
Gamma-Ray Bursts (**GRB**s) are the most luminous physical phenomenon known in the universe and are flashes of gamma rays that last from seconds to hours, the longer ones being followed by several days of X-ray afterglow. GRBs occur at apparently random positions in the sky once per day on average.

There are different models for GRB. Long GRBs are commonly accepted to originate during some explosive phenomena in massive stars giving rise to a highly relativistic jet. Internal inhomogeneities in the expanding flow give rise to internal shock waves that are believed to produce gamma rays. AS the jet travels further outward into the surrounding circum-stellar medium " external shocks " give rise to after glow emission seen in the X - ray , optical and radio bands.

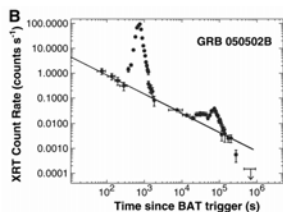
Because of the time needed to determine the GRB position, most afterglow measurements had been made hours after the bursts. So little was known about the characteristics of afterglows in the minutes following a burst.

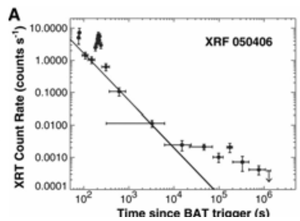
Swift changes the scenario after its launch in November 2004.

Swift observations reveals discontinuities in afterglow lightcurves which can not be explained with standard model predicting smooth light curve as the relativistic blast wave expanding into ambient medium with spherically smooth density distribution should emit homogeneous and spherical shock fronts. This implies that the mechanism behind afterglow is different from that of GRB. Moreover, for some GRBs, giant X-ray flares are seen which whose source must be different from from that of afterglows – may be the same as the original GRB.



GRB afterglow with discontinuity [1]





GRB afterglow with giant X ray flares [2]

So may the Strange Star hypothesis Through Quark Nova phenomenon be an alternative ??

How do a Strange Star form ?

- Due to separation of baryonic phase from deconfined quark phase in the early universe [3]
- Through a supernova
- By conversion of a neutron star to a strange star.

Mean Field Model for Strange Star :-

- A modified Richardson potential is taken as interquark interaction.
- The potential is screened due to medium effect and the screening depends on both density and temperature of the matter.
- The quark masses are taken to be density dependent so that with increasing density quark masses falls from their current to constituent values.
- The quark matter is charge neutral and beta equilibrated
- Effect of temperature is incorporated through Fermi function.
- A relativistic Hartree Fock formalism is done to obtain EOSs
- Solving TOV equations, Mass-Radius relations have been obtained [4], [5].

Strange Stars are compact stars entirely made of deconfined u, d, s quark matter. The possible existence of strange star is a direct consequence of the hypothesis (proposed by Witten) that strange quark matter may be the absolute ground state of strongly interacting matter rather than Fe^{56} . Several compact stars like Her X-1, 4U 1820-30, IE1207- are now established to be Strange Stars [3], [4].

Conversion of Neutron Star to Strange Star :-

If the density of neutron star matter becomes too large, nuclear matter converts to deconfined u,d quark matter. Then by weak interaction u + d -> u + s , some s quark generates and an almost inhomogeneous u, d, s quark matter form.

Quark Nova Scenario : -

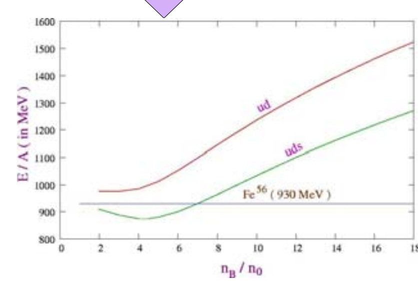
1) The quark nova, where the core of the neutron star is converted to quark matter and some matter is ejected. Then gradually the entire star becomes a strange star. This is the " ***Quark Nova*** " phenomenon.

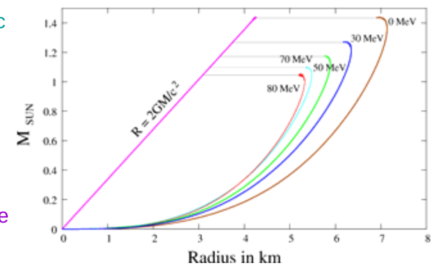
2) Some of the matter ejected in the Quark Nova will fall back and form an accretion disk. This launches a jet that will overtake the shell ejected by the quark nova. This is a possible location for the prompt x-ray afterglow. Moreover, the strange star contains charge neutral, beta equilibrated strange quark matter and is surrounded by a thin electron cloud. The remaining normal matter envelope material in the supernova remnant falls freely to form a crust for the strange star. The collision of infalling particles with the electrons of the cloud may also produce X-ray. The presence of these two different mechanisms for production of X-ray are revealed in the discontinuous nature of the X-ray afterglow. Internal shocks in the jet produce the GRB.

3) If enough matter is accreted onto the quark star, it will collapse and form a black hole. Continued accretion onto the black hole can lead to an ultrarelativistic jet with internal shocks and may produce giant X-ray flares.

But why a strange star will convert to a black hole ? From the mass-radius relation of the strange star, it is clear that there is a maximum value of mass where the star becomes unstable and if more matter fall on this star, it will collapse to a black hole.

We found that at lower temperature, the value of maximum allowable mass for the strange star is greater. This result amazingly point out to the well know relation from black hole thermodynamics $M \propto \frac{1}{T}$





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