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Merger Models of Gamma Ray Bursts: A Comparison

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Abstract

Two possible merger models of gamma ray bursts are considered. The merger of two white dwarfs leading to subsequent collapse to a rapidly spinning neutron star should give rise to a neutrino burst accompanying the gamma ray burst. However the merger of two neutron stars should give rise to only a gamma ray burst with a much smaller neutrino flux. Observable signatures to discriminate between these pictures is clarified.

1. Introduction:

The origin and mechanisms producing the isotropic burst of gamma rays still remain obscure. Although there is good evidence that enutron stars may be involved (perhaps even their merger or collisions), it is not yet clear whether the sources are of local (i.e. galactic origin) or are located at cosmological distance. Isotropic occurrence suggests they are at cosmological distances, but in that case to account for the observed gamma luminosity the burst energy should be $\sim 10^{51}$ ergs). Two neutron stars colliding or merging could in principle produce such high energies. So could perhaps two white dwarfs in close orbit merging and collapsing to form a fast spinning neutron star. We shall consider these two different scenarios and comment on their respective observable signatures.

2. WD Mergers

Two white dwarfs (radii $\approx 10^9 cm$) in close orbit would have a period $\approx 10^2$ sec. If they now merge exceeding the WD mass limit, the resulting object would collapse to form a neutron star. The large change in binding energy ($> 10^{53}$ ergs) would however be released mostly in the form of neutrinos over a period of a few seconds as the newly formed neutron star cools. Conservation of angular momentum and magnetic flux (assuming a WD mag.f. of $\sim 10^8 G$) would imply that the neutron star formed in this process would have a millisecond period and a magnetic field

$\approx 10^{15} G$. Subsequent to the binding energy being released in a preliminary neutrino burst, a gamma ray burst would follow after a few seconds as the NS loses its rotational K.E. We have:

$$\dot{E}_{rot} \approx \frac{2}{3} B^2 R^6 \omega^4/c^3 \approx 5 \times 10^{50} ergs \quad s^{-1}$$

$$(E_{rot} \approx \frac{1}{2} I \omega^2 \approx 5 \times 10^{52} \ ergs)$$

Thus the time scale over which the rotational K.E. is lost is $\approx 10^2 s$ (maximum). The max. parallel electric field is $\sim B(\frac{\omega R}{c})^{5/2}$. The γ factor is $\sim$ 10 - 100 giving a HE tail of $\sim$ 100 MeV. Thus in this scenario, the 10-50 s. $\gamma - ray$ burst is preceded by a neutriono burst of about ten seconds.

NS mergers

Two neutron stars in close orbit (period $\sim$ 1 ms), when merging can again form a NS with a millisecond rotation period. However, in this case, the binding energy change is much smaller (as no lepton number is lost as in the collapse of WD to NS) and not accompanied by a neutrino burst. However, the magnetic field and low period would again give rise to a gamma ray burst as in the previous case but without being preceded by a large neutrino burst.

Thus in principle observational signatures are very distinct in the two scenarios.