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GRBs from the First Stars

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Abstract. We present an estimate of the Gamma Ray Bursts which should be expected from metal–free, elusive first generation of stars known as PopulationIII (PopIII). We derive the GRB rate from these stars from the the Stellar Formation Rate obtained in several Reionization scenarios available in the literature. In all of the analyzed models we find that GRBs from PopIII are subdominant with respect to the "standard" (PopII) ones up to $z \approx 10$.

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INTRODUCTION

The First Stars, formed from the collapse of the very first structures in the Universe at very high redhift ($z < 30$), are commonly thought to be very massive ($\approx 100\ M_\odot$) and end their lives with powerful explosions, after the peculiar properties of the metal–free environment in which they form, [1] and [2]. Due to their high masses their contribution to the Reionization is relevant and constraints on their Stellar Formation Rates (SFR) can be obtained in Epoch of Reionizatioin (EoR) models by evaluating the mutual feedback between the two different Populations of stars. However some parameters, such as the stellar mass and relative electromagnetic spectra or the ionizing efficiency (related to the photon escape fraction from the halo) of the stellar populations, have not been totally determined by theory thus allowing for different scenarios. In the following we estimate the GRB rate expected from PopII and PopIII from different EoR models. Given the nature of our analysis it is worth stressing that SFRs of the two populations we use are mutually consistent within the analyzed EoR, which in turn have been tuned in order to fit observational data relevant to Reionization history such as temperature and density of the Inter–Galactic–Medium and Gunn Peterson optical depth.

THE MODELS

In order to calculate the rate of GRBs expected at redshift $z > 5$ from the two populations of stars we have used different models of the EoR available in literature, each of them calculating in a self–consistent scenario the interplay among the two generations and the mutual feedback effects, namely we adopt models presented in [3] and [4], which implement the new cosmological parameters from WMAP3 [5]. Following the assumption that for PopII the GRB rate follows the stellar formation rate, modulo the corrections reported below, we have converted the PopII SFR (SFR $_{II}$) given in each model in order to obtain the ratio of massive stars that explode as Core Collapse SuperNovae (CC SNe); we have then introduced another factor to account for the ratio of such stars that will explode as GRBs. Namely $GRB_{II} = SFR_{II} \times f_{SN} \times f^{II}_{G/S}$, being:

$$f_{SN} = \frac{\int_{20}^{125} S(m)dm}{\int_{0.1}^{125} mS(m)dm}, \tag{1}$$

where "S(m)" is the Salpeter mass function assumed to be the IMF for PopII according to the EoR models, and by imposing that only stars with mass $20 < M < 125$ will explode as CC SNe. The fraction of SN that will give birth to a GRB "$f^{II}_{G/S}$" is chosen accordingly to [6], and it includes a correcting factor which takes into account the GRB–metallicity anticorrelation, thus enhancing the production of GRBa from Population II stars at high redshifts: $f^{II}_{G/S} = \frac{(1+z)^{1.4}}{1250}$. For the PopIII the SFR$_{III}$ has been normalized by the average stellar mass of each model thus obtaining the number of stellar events belonging to that population; we chose the maximal ratio f$^{III}_{G/S}$=1 given the lack of direct knowledge on the matter. Readers can easily convert the rate of PopIII "events" we present in PopIII GRB by simply

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TABLE 1. GRB rates integrated over the whole sky (yr^{-1}) for PopII and PopIII for the CF05–a (upper) and CF05–b (lower) model

	5 < z < 8	**8 < z < 10**	**z > 10**
PopII	8.3×10^5	8.9×10^4	3.7×10^4
PopIII	4.1×10^3	4.7×10^4	1.4×10^5
PopII	9.3×10^5	1.4×10^5	7.4×10^3
PopIII	0	1.7×10^4	6.9×10^4

TABLE 2. GRB rates integrated over the whole sky (yr^{-1}) for PopII and PopIII for the CF06 model

	5 < z < 8	**8 < z < 10**	**z > 10**
PopII	7.5×10^5	1.0×10^5	4.9×10^4
PopIII	5.4×10^4	7.4×10^4	2.7×10^5

multiplying by the value of the mentioned parameter they may feel more confortable with. In Table 1 we show results obtained following the described method using the models in [3] at page 9 (their "fiducial" model) and 13 (CF05–a and CF05–b, respectively); they both assume an average stellar mass for PopIII of M_{III}=300$M_{\odot}$, cosmological parameters as in WMAP1 [7] and differ only in the ionizing efficiency of PopIII, chosen to be bigger in CF05–b by a factor 4. We stress once again that the numbers shown for these models mean an actual rate of GRBs for PopII, whereas for PopIII they represent an **absolute** upper limit to the rate of GRBs, being the rate of stellar objects belonging to the population. In Table 2 we present results from the model in [4] (CF06): it implements the same astrophysical parameters as CF05–a using the cosmological parameters from WMAP3 instead that the ones in WMAP1, and assuming a Salpeter mass function for PopIII. In this case the results presented in Table 3 for PopIII represent a GRB rate, obtained by converting the SFR according to the same prescriptions adopted for PopII, consistently with the nature of the IMF.

CONCLUSIONS

We present an estimate of the GRB rates expected from the First Stars, by using SFRs for PopII and PopIII mutually consistent within different Reionization models. We find that the PopII GRB rate dominates over the number of PopIII stellar events up to redshift z$\approx$ 10 in the models (CF05–a and CF05–b) with very massive stars, thus implying that even assuming a GRB/SN ratio equal to one among PopIII stars, PopII GRB events will still be dominating up to very high redshifts. If we choose a $f^{III}_{G/S}$=10$\times$ $f^{II}_{G/S}$, the maximal value adopted in literature, [9], the rates from the two populations will be comparable even at z$>$ 10. In another scenario, assuming a Salpeter mass function for the PopIII, we have assumed the same GRB/SN ratio among PopII and PopIII stars: also in this case PopII GRBs are dominating up to z$\approx$ 10, although the rates of the two populations become of the same order of magnitude at z$\approx$ 8.

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