Bull. Astr. Soc. India (2000) **28**, 377-379

Limit on the average redshift of Gamma Ray Bursts from evolving galaxies

Deepak Jain[1,2], N. Panchapakesan[1], S. Mahajan[1] and V. B. Bhatia[1]

[1] *Department of Physics & Astrophysics, University of Delhi, Delhi 110 007, India*

[2] *Deen Dayal Upadhyaya College, Karam Pura, Delhi 110 015, India*

Abstract. Identification of gravitationally lensed Gamma Ray Bursts (GRBs) in the BATSE 4B catalog can be used to constrain the average redshift $<z>$ of the GRBs. Here we calculate an upper limit to $<z>$, independent of the physical model for GRBs, using a filled beam approximation to compute the lensing rate for GRBs at high z for a variety of cosmologies. The upper limit on $<z>$ depends directly on the cosmological parameters Ω and Λ. The other factor which can change the $<z>$ of GRBs is the evolution of the lensing galaxies. We find that merging of lensing galaxies puts the GRBs at higher redshift as compare to non evolving model of galaxies.

Key words : gravitational lensing, gamma ray bursts, evolution of galaxies

1. Introduction

The use of gravitational lensing as a tool for the determination of cosmological parameters (e.g. H_0, Ω_0, Λ_0) has frequently been discussed. To constrain these parameters either QSOs or galaxies have been used as sources. To use Gamma Ray Bursts (GRBs) as a source for gravitational lensing is not a new idea. If GRBs are cosmological then they should be gravitationally lensed just as quasars.

There is now overwhelming evidence that the majority of GRB sources lie at cosmological distances. The detection of GRB990123 which is believed to lie between redshift $1.6 \leq z < 2.14$, the identification of the host galaxy for GRB981214 at $z = 3.42$ and the detection of optical counterpart of GRB 970508 at redshift $z = 0.83$. Therefore it is expected that the GRBs must be gravitationally lensed as the probability of lensing increases with the source redshift.

All these obeservations have led researchers to explore scenarios in which the bursts are at much higher redshifts. One popular scenario is that the GRB rate should trace the star formation rate in the universe, consequently it places the very dim burst at $z \geq 6$.

Further the "no host galaxy problem" pushes the GRBs to be, either at very high redshift ($z > 6$) or not to be in normal host galaxies.

Another approach which has also put an upper limit on the average redshift of GRBs is the consideration of gravitational lensing of GRBs [Holz et al. 1999]. In this paper we have modified the above mentioned approach by making use of *evolution in the properties of lensing galaxies*. The whole calculation is completely independent of any physical model of GRBs.

2. Evolving galaxies, gravitational lensing and upper limit on < z > of GRBs

Normally the comoving number density of galaxies (lenses) is assumed to be constant while calculating lensing probability. But it is an oversimplification to assume that galaxies are formed at a single epoch. Evolution tells us how the number density or the mass of the lens changes over cosmic time scales. Merging between galaxies and the infall of the surrounding mass into galaxies are two possible processes that can change the comoving density of galaxies and/or their mass. We try three different models for evolving galaxies : fast merging, slow merging and mass accretion. We calculate the lensing probability in these three different models of evolving galaxies in different models of universe.

The differential probability $d\tau$ of a lensing event in evolutionary model can be written as :

$$d\tau = F(1+z_L)^3\left(\frac{D_{OL}D_{LS}}{R_o D_{OS}}\right)^2 f(\delta t)^{\left(1-\frac{4}{\gamma}\right)} \frac{1}{R_o}\frac{cdt}{dz_L}dz_L$$

Here we use the notation $D_{OL} = d(0,z_L)$, $D_{LS} = d(z_L, z_S)$, $D_{OS} = d(0,z_S)$, where $d(z_1, z_2)$ is the angular diameter distance between the redshift z_1 and z_2, $f(\delta t) = \exp(QH_0\delta t)$ for fast merging and $(f\delta t) = \left(1-\frac{\delta t}{t_0}\right)^{-2/3}$ for slow merging. In case of mass accretion $f(\delta t) = \left(1-\frac{\delta t}{t_0}\right)^{-2/3}$ but the exponent of $f(\delta t)$ for mass accretion model in above eq. becomes $(-1-\frac{4}{\gamma})$ as the total mass in galaxies increases with time. The value of γ is 3.3, R_o is Hubble distance and t stands for the look back time.

The lensing probability then depends directly on the parameter F, we take $F = 0.35$. We take a constant BATSE efficiency $\varepsilon = 0.34$ to see either image and ε^2 to see both. Let N_{tot} be the total number of observed bursts. So far total number of observed bursts in the BATSE 4B catalog are 1802. There are then approximately N_{tot}/ε actual burst sources above the BATSE threshold during this time. If these sources are all at a given redshift z, then the expected number of image pairs is :

$$N = (N_{tot}/\varepsilon).\varepsilon^2.\tau(z) = N_{tot}\varepsilon\tau(z)$$

For details of this whole calculation see (Jain et al. 1999)

3. Results

We have taken three representative values of (Ω, Λ) as (0.3, 0.7), (0.5, 0.5) and (0.2, 0). With these values we calculate the expected number of observable image pairs in the BATSE 4B as a function of average redshift for the mass accretion, fast merging, slow merging and no evolutionary models. We find that the best limit arises with a large cosmological constant where the lensing rate is quite high. At the 95% confidence level, we find an upper limit on $<z> <$ 6 for the non-evolutionary model and $<z> < 7$ for slow merging model, when $\Lambda = 0.7$ and $\Omega = 0.3$. At 68% confidence level, the slow merging model gives upper limit on $<z> < 3$, 4.6 or 5.5 for (Ω, Λ) values of (0.3, 0.7), (0.5, 0.5) or (0.2, 0) respectively. Similarly at 68% CL confidence level, fast merging model gives $<z> < 4.2$, 7.0 or 8.2 for (Ω, Λ) values of (0.3, 0.7), (0.5, 0.5) or (0.2, 0) respectively. The mass accretion model fails to give any upper limit on $<z>$ as it doesn't intersect the 68% confidence level limit line.

References

Holz D. E. et al., 1999, ApJ, 510, 54.

Jain D., et al., (in1999, IJMP, D8, No. 4 (in press).