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EMIR: USING GRBS TO PROBE THE HIGH REDSHIFT UNIVERSE

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The recent detection of the optical counterpart of a Gamma-Ray Burst (GRB) at $z = 4.5$ has opened a new era in the GRB field (Andersen et al. 2001). In the present study we show the potential of using GRBs as a tool to trace the star formation rate of the high redshift Universe. In the present paper it is argued that prompt near-infrared observations carried out with GTC +EMIR could detect extremely high redshift GRBs ($z \lesssim 17$). We discuss the role that GTC +EMIR could play studying the primitive Universe, especially in the context of the GRBs detected by the *INTEGRAL* mission.

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1. INTRODUCTION

Gamma-ray burst (GRB) optical afterglows are fast-decaying sources. Their fluxes decay approximately as power laws, $F_\nu \sim t^b$. Their spectra are reasonably well described by power laws at any time: $F_\nu \sim \nu^a$. The positional coincidences between GRB OAs and the bright blue regions of the host galaxies support models in which GRBs are related to star formation (Djorgovski et al. 2001). The discovery of supernova components in the light-curves of OAs (Bloom et al. 1999; Castro-Tirado & Gorosabel 1999) suggest that at least some GRBs are related to the death of massive stars (MacFadyen & Woosley 1999).

The GRB detection rate (N_{GRB}) would then be proportional to the star formation rate in the Universe ($SFR(z)$).

$$N_{\rm GRB}(P) \sim \int_0^{\rm inf} \frac{SFR(z)}{(1+z)} \frac{dV(z)}{dz} \frac{dz}{dp} S(L) dL,$$

where $S(L)$ is an assumed luminosity function, V is the comoving volume, and P is the peak photon flux at the detector (cm^{-2} s^{-1}). Therefore, constructing the GRB detection distribution as a function of P ($N_{\rm GRB}(P)$) we could invert the previous integral and determine $SFR(z)$.

2. WHY USE EMIR TO OBSERVE GRBS IN THE NEAR INFRARED?

The large field of view (FOV) of EMIR ($6' \times 6'$) would allow us to cover with a single frame most of the GRB error boxes provided by *INTEGRAL*, SWIFT (and a large fraction of those provided by HETE-II and the IPN).

At least ∼25% of the GRBs detected by *INTEGRAL* would be carried out during guaranteed time programs, third of them being beyond $z > 5$ (Gorosabel et al. 2001). These programs will be mainly devoted to observe sources in the Galactic plane, so it would be necessary to mitigate the effect of Galactic plane extinction. This goal can be achieved observing in the near-infrared (NIR) bands.

The greatest drawback in finding extremely high redshift GRBs comes for the Lyman α blanketing effect, which strongly attenuates the radiation observed at $\lambda < 1216(1+z)$ Å. The only way to avoid this problem is to observe at longer than visible wavelengths. So among the planned instrumentation for GTC, EMIR is by far the best option.

The effect of redshift tends to reduce the spectral flux ($F_\nu(\nu,t)$) in GRB afterglows at a given frequency, but time dilation tends to increase it at a fixed time of observation after the GRB, since afterglow intensities decrease with time. The measured flux is related to the Luminosity $L_\nu(\nu,t)$ and the comoving distance $D(z)$ as follows:

$$F_\nu(\nu,t) = \frac{L_\nu(\nu,t)}{4\pi D^2(z)(1+z)^{(1-a+b)}} \exp^{-\tau},$$

where $\exp^{-\tau}$ is the Lyman α blanketing dimming factor; $1-a+b \sim 0$ implies no decrease in the spectral

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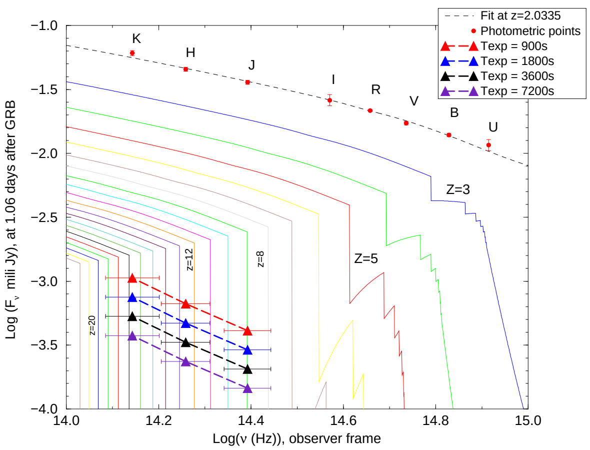

Fig. 1. Evolution of the observed flux of a typical GRB afterglow (GRB 000301c) shifted in redshift from $z = 2.0335$ (spectroscopic redshift) up to $z = 22$. The points show the photometric measurements of the afterglow from the U to the K band, taken 1.06 days after the GRB. The dashed line represents the SED fitted to the photometric points. The triangles show the JHK band sensitivity given by EMIR for a 5σ detection, for several exposure times (from 7200 s to 900 s, starting from the bottom). As can be seen, afterglows can be detected in the three JHK bands up to $z = 9$, even with a single exposure time of 900 s. K band counterparts would be detectable up to $z = 17$. As is shown here, in the case of EMIR the detectability of afterglows is dominated by the effect of the Lyman α blanketing and is basically independent of exposure time. The Lyman α blanketing absorption has been modeled following the literature (Madau 1995).

flux (except for the effect of $D(z)$, which increases slowly beyond $z \sim 3$). Thus, there is little decrease in the spectral flux of GRB afterglows with increasing redshift beyond $z \sim 3$.

Figure 1 shows the spectral energy distribution of a typical GRB afterglow (GRB 000301c, observed ∼1 day after the gamma-ray event) at different redshifts, compared to the sensitivity of EMIR (estimated for different exposure times and represented by triangles). As can be seen, EMIR would be able to detect GRB afterglows up to redshifts $z \sim 9$ simultaneously in the J, H, and K bands. If only a K band detection is required, then GRBs could be detected up to $z \sim 17$.

On the other hand, NIR observations allow color–color selection techniques, enabling fast identifications and hence avoiding second-epoch observations (Gorosabel et al. 2002).

3. CONCLUSIONS

The large FOV and high sensitivity of EMIR are especially useful for detecting high redshift GRBs. The combination of EMIR and the GRBs detected by *INTEGRAL* (especially in the guaranteed-time programs) provides a unique opportunity to study the unknown Universe beyond $z > 6$. Among many other open questions, GRBs detected with EMIR would provide us with unprecedented information on the reionization era, Population III stars and the chemical evolution of the primitive Universe.

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