Enlightening cosmic dark ages with GRBs

by R. Salvaterra (INAF/IASF-MI)
why GRBs?

GRBs provide a complementary (sometime unique) tool to study the high-z Universe.

Pros:
- high-z events
- very bright
- inside normal galaxies
- power-law continuum
- fade away

Cons:
- fade away
- rare
- inside galaxies

high-z GRBs are 1% of the observed GRBs but ~10% of the entire population

Salvaterra et al. 2012, Ghirlanda et al. 2015
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Simulated population

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GRBs as a tool... an incomplete list

- ISM metals and dust
- reionization (Gallerani et al. 2008; McQuinn et al. 2008; Xu et al. 2011)
- escape fraction (Chen et al. 2007; Fynbo et al. 2009, Tanvir et al. 2018)
- identify and study high-z galaxies responsible for the reionization
- **constrain the high-z SFR slope and faint-end of the galaxy LF**
- **direct detection of PopIII stars** (Komissarov & Barkov 2009; Mezsaros & Rees 2010; Toma et al. 2011; Campisi et al. 2011; deSouza et al. 2011 …)
- **indirect PopIII detection** (Ma et al. 2015, 2017; Wang et al. 2012)
- probe the intergalactic radiation field (Inoue et al. 2010)
- constraints on DM (Mesinger et al. 2005, deSouza et al. 2013)
- primordial non-Gaussianity (Maio et al. 2012)
- …
Long GRBs are firmly associated with the death of a massive star by the detection of a type Ib,c SN in low-z events.

SN2013cq associated to GRB 130427A a low-z analogue to cosmological GRBs suggesting that GRBs can be used as tracers of SFR.
GRB host galaxy properties and population studies suggest a mild metallicity threshold implying that GRBs are good tracer of SF at high-z.
recovering the high-z SFR slope

A slope consistent with MD14 can be recovered with an error of ~0.1 (1 sigma)
searching for high-z hosts

the knowledge of position and redshift allows very deep search for the GRB host

for GRB 090423 at $z=8.2$ deep HST/WFC3 ($m_J>30.3$), Spitzer and ALMA observations provide a strong limit on host brightness and SFR

high-z host physical properties

we use the state-of-the art of numerical simulation of structure formation at high-z including all relevant physical process (e.g. chemical, mechanical and radiative feedback)

high-z hosts are expected to have low masses ($10^6$-$10^8$ $M_\odot$), high sSFRs and $Z \sim 0.05$ $Z_\odot$
constraining the galaxy LF faint-end
other high-z biases? IMF variation

High-z GRB population results can be compared with other high-z SFR measurements (e.g. JWST) to highlight the existence of other biases.
PopIII GRBs

shock breakout is possible even in a massive, metal-free PopIII stars with a large H envelope thanks to the long-lived powerful accretion onto the forming central BH see e.g. Fryer et al. (2001), Heger et al. 2003, Suwa et al. 2007, Komissarov & Barkow (2010), Meszaros & Rees (2010), Suwa & Ioka (2011), Toma et al. (2011), Nagakura et al. 2012, Piro et al. 2014 ...

\[ \text{Eiso} \sim 10^{55} \text{ erg} \]
\[ \text{T90} \sim 1000-10000 \text{ sec} \]
\[ \text{Liso} \sim 10^{52} \text{ erg/s} \]
PopIII GRB rate

given that none of Swift detected GRBs is likely to be associated to a PopIII progenitor we can set an upper limit to their rate (assuming that Swift is able to catch them!)

PopIII GRBs are rare (<10% of all detectable GRBs at z=6), i.e. <1 every 500 PopIII stars but they might dominate at z>10-12

[vs 1 PopII/I GRB every 300 SNIb/c (Ghirlanda et al. 2013a)]

Campisi et al. 2011, Kinugawa et al. 2018
indirect search for PopIII stars

we compute the expected rate of PopII GRB exploding in a gas enriched by PopIII stars

GRB_{II→III}(z>6)= 0.06 yr^{-1} sr^{-1}

~0.6 in 10 yrs of Swift

we expect GRB_{II→III} to be ~10% of z=10 PopII GRBs
GRB 050904 and 130606A abundance ratios are consistent with PopII SN enrichment
conclusions

the future of cosmic dark ages is bright