Complete Metallicity Measurements of Long GRB Host Galaxies at Low-Redshifts

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Introduction
Long GRB Occurrence & Metallicity

- Stellar evolution theory:
  - Only a low-metallicity star can maintain rotation to form a GRB central engine.

- Host galaxy observations:
  - Long GRBs preferentially occur in low-metallicity galaxies.
  - A few host galaxies have high-metallicity.

- Metallicity determines the relation between SFR & $R_{GRB}$.
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Possible Bias & the Unbiased Surveys

• 2000’s: many groups independently observe their target of interest.
  • possible bias:
    • redshift & host galaxy identification
    • human interest
• 2010’s: unbiased surveys
  • selection only by γ-ray properties & observing condition
  • unbiased population of GRB host galaxies
  • maybe not the best for constraining the progenitors
    • spanning wide range of redshift (~ 0-6)
    • without complete spectroscopy
How can we constrain the metallicity effect?

• Low redshift GRBs are the clue.
  • The metallicity effect would appear most significantly.
  • A wealth of control sample (e.g. SDSS @ $z \lesssim 0.3$).
• Low redshift sub-samples in the unbiased surveys are too small (2–3 long GRBs @ $z \approx 0.3$).
• Complete spectroscopy of low redshifts long GRB host galaxies is needed.
  • possible bias: redshift identification
    • less strong at lower redshifts
Observations
Target Selection

- all long GRBs known @ $z \leq 0.345$ (telescope time limited) until Mar. 2014
  - 11 GRBs
    - 7 with significant limit on metallicity
    - 3 without sufficient spectroscopy
      - GRB 060614, 090417B, 130427A
    - 1 with archival spectra obtained irrelevantly to the GRB
Redshift Determination Bias

- The SHOALS unbiased sample
  - Swift GRBs between 041217 & 120308A
  - spec. redshift 103/119
  - 2 @ \( z \leq 0.345 \)
- All GRBs in the same epoch
  - 587 (204 known redshifts)
  - assuming the SHOALS z-dist.:
    - 11.4 @ \( z \leq 0.345 \)
  - 8 known @ \( z \leq 0.345 \)
  - \( \sim 70\% \) success?
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Gemini/GMOS Spectroscopy

- The targets are widely spread over the sky.
  - Queue mode capability in the northern & southern hemisphere is essential.
- S15A Subaru-Gemini time exchange:
  - 7.5 hrs in total
  - Metallicity indicator: \([\text{NII}]/\text{H}\alpha\)
    - analysis of oxygen lines underway
Comparison to General Star Forming Galaxies
SFR weighted log(O/H) dist. of general star forming galaxies

- assuming M_\odot function, M_\odot-Z relation, & M_\odot-SFR (main sequence) relation of local galaxies
- inconsistent with the GRB host galaxies
- in agreement with the previous results with smaller sample
Internal O/H Variation

- what we observe: host galaxy metallicity
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- can be different

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GRB Efficiency Model

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  - $\varepsilon_{\text{GRB}} = \frac{R_{\text{GRB}}}{SFR}$
- assumptions:
  - a step function of progenitor metallicity
  - not host galaxy metallicity
- 2 parameters:
  - $12 + \log(O/H)_{\text{cut}}$
  - $f_{\text{const}}$
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Results & Discussion

- $\log(O/H)_{\text{cut}}$ and $f_{\text{const}}$ are determined almost independently.
- Preliminary results suggest:
  - $12+\log(O/H)_{\text{cut}} = 8.1–8.4$
  - $f_{\text{const}} < 3\%$ (0.0 is the best)
- The host galaxy metallicity distribution prefers single low-metallicity channel.
Summary

• Unbiased and redshift selected studies of GRB host galaxies works complementarily to unveil the nature of long GRB progenitors.
  • Redshift selected: constrain progenitor models
  • Unbiased: clarify sampling the bias effects
• Current data prefer progenitor models without high-metallicity GRB production.
• Internal metallicity variation within each galaxy maybe a major source of uncertainties.