Systematic Observation of Long GRB Host Galaxies in the Subaru/Gemini Time Exchange Program

Subaru Users’ Meeting FY2015
Yuu NIINO (NAOJ)
collaborators:
Introduction
Long Gamma–Ray Bursts (GRBs)

- Transient events in soft γ-ray/hard X-ray
  - accompanied by afterglows in X-ray—radio
- duration ~ 2–1000 sec
- afterglows last hrs—days
- very bright
- highest GRB spec–z: 8.2
- associated with core-collapse events of massive stars
  - relativistic jets erupted from newly born BH accretion disk/magnetars.
Long GRB Occurrence & Metallicity

- GRB/core-collapse ~ 1/1000
- 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 (core-collapse) & $R_{GRB}$.
  - Quantitative constraint is poor.
Previous Studies of GRB Hosts (1)

- pre-Swift era (< 2004)
  - small number of GRBs with redshift measurements
  - the host galaxies were intensely studied once the redshift is known to be low (≤ 0.3)

- Swift era
  - many GRB redshifts
    - but still < 50%
    - maybe biased against dusty event
  - various groups independently observe their target of interest.
  - more spectra but with uncontrolled sampling
Previous Studies of GRB Hosts (2)

• 2010’s: unbiased surveys
  • selection only by γ-ray/X-ray properties & observing condition
  • observe all objects that fulfill the selection criteria
• difficulties in studying progenitor properties with these samples
  • spanning wide range of redshift (~ 0–6)
  • mainly photometric
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 ≲ 0.3).
• Low redshift sub–samples in the unbiased surveys are too small (2–3 long GRBs @ z ≲ 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 ≤ 0.41 (telescope time limited) until Mar. 2014
  • 12 GRBs (excluding XRFs)
    • 7 with known metallicity
    • 5 without sufficient spectroscopy
      • we observe 3 of them (z < 0.35)
      • 2 spectra were published recently (Krühler+ 2015)
Gemini/GMOS Spectroscopy

- The targets are widely spread over RA & DEC.
  - Queue mode capability in the northern & southern hemisphere is essential.
- The Subaru–Gemini time exchange.
  - queue mode with GMOS–N/S
- Theoretical metallicity calibration by Kobulnicky & Kewley (2004, KK04), using [OII], Hβ, [OIII], Hα & [NII]
Comparison to General Star Forming Galaxies
**M★, SFR, Metallicity of Galaxies**

- SFR weighted log(O/H) dist. of general star forming galaxies of local galaxies
  - assuming M★ function, M★–Z relation, & M★–SFR (main sequence) relation
- inconsistent with the GRB host galaxies
  - in agreement with the previous results with smaller/incomplete sample
GRB Efficiency Model

- GRB efficiency
  - \( \varepsilon_{GRB} = \frac{R_{GRB}}{SFR} \)
- assumptions:
  - a step function of “progenitor” metallicity
  - ≠ “host” metallicity
- 2 parameters:
  - \( 12 + \log(O/H) \) cut
  - \( f_{\text{high-Z}} \)
**Internal O/H Variation**

- what we observe: host galaxy metallicity
- $12 + \log(O/H)_{\text{cut}}$: progenitor metallicity
- We need to know metallicity distribution of young stars in each galaxy.
  - Not well understood

Results & Discussion

• Preliminary results suggest:
  • $12 + \log(O/H)_{\text{cut}} = 8.1 - 8.4$
    • $\sim 0.3 - 0.5Z_\odot$
  • $f_{\text{high-Z}} < 3\%$ (0 is the best)
• The power-law $\varepsilon_{\text{GRB}}$ also prefer steep slope index $< -4$.
• There might be sub-populations among the low-z long GRBs.
  • The sample is too small to discuss the sub-populations.
    • wider redshift range, more recent objects, XRFs
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 with sharp cut at ~ 0.3—0.5Z⊙ & no high-metallicity GRB production.