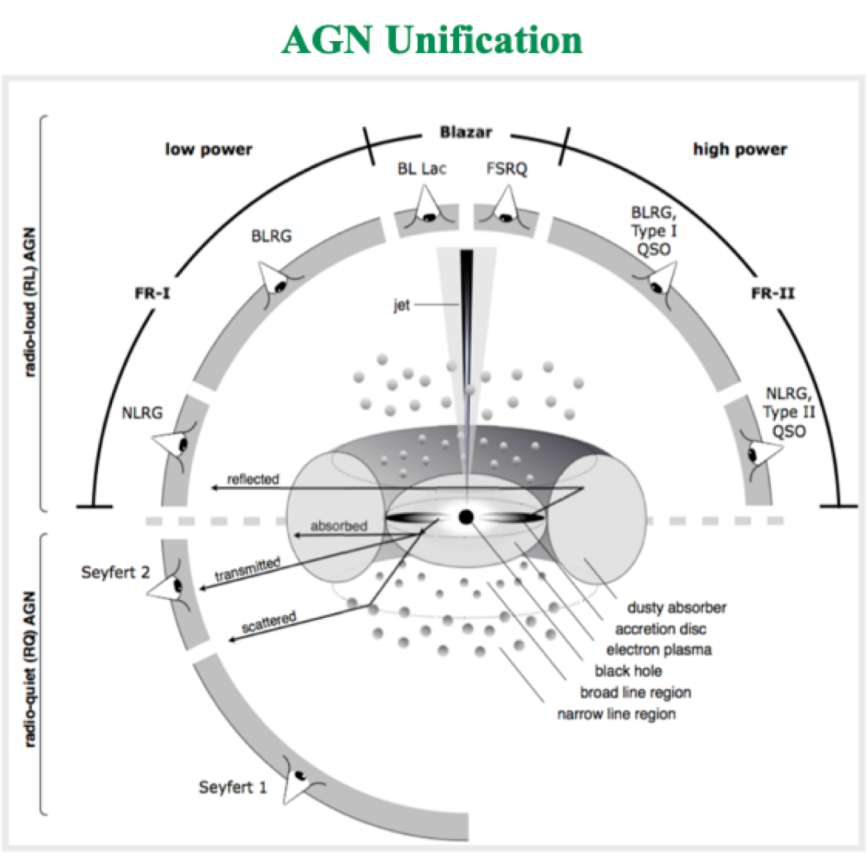
GRB Jet energetics and structure

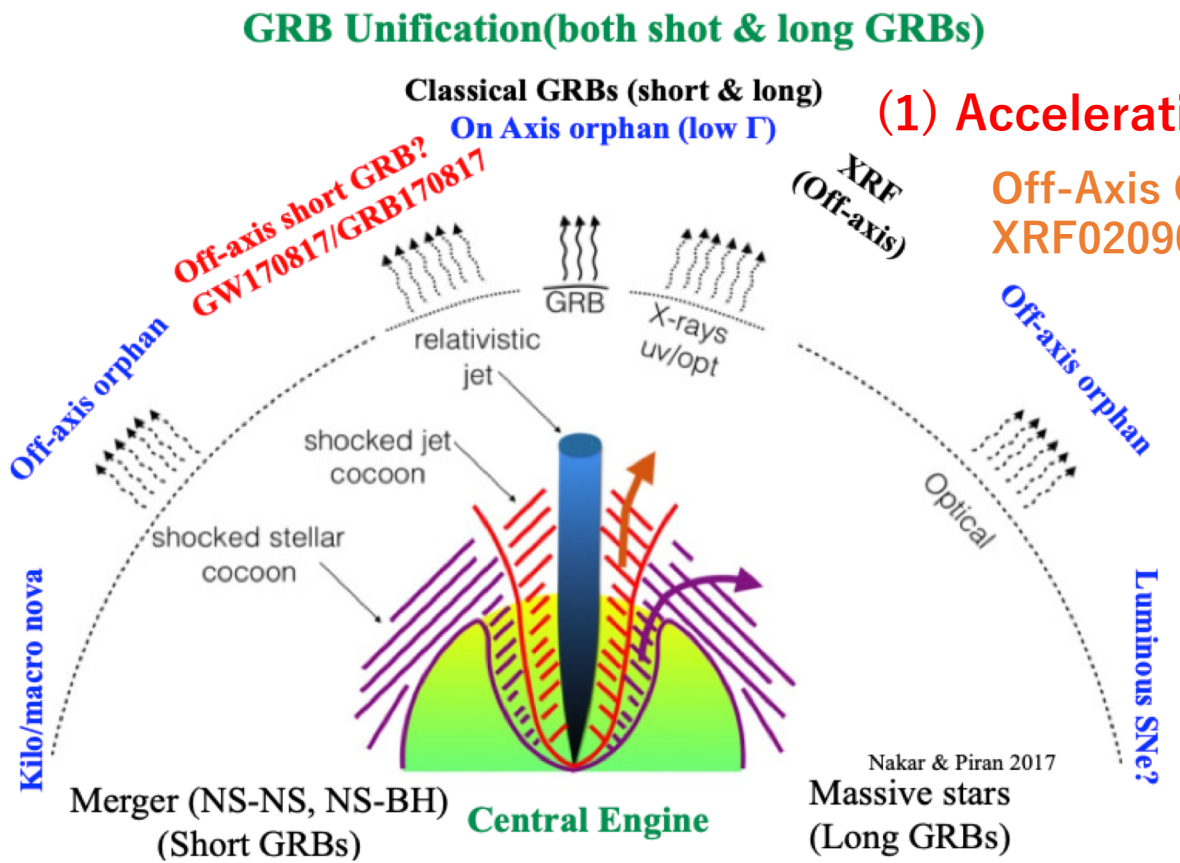
Yuji Urata (NCU)

- Chen, Urata et al. 2020 ApJL, 891, L15
  "Two Component Jets of GRB160623A as Shocked Jet cocoon afterglow"
- Huang, Urata et al. 2020 ApJ, 897, 69
  "Orphan GRB afterglow searches with the Pan-STARRS1 COSMOS survey"
- Urata et al. 2019 ApJL, 884, L58
  "First Detection of Radio Linear Polarization in a Gamma-Ray Burst Afterglow"
- Urata et al. 2015 ApJ 806, 222
  "Extremely Soft X-Ray Flash as the Indicator of Off-axis Orphan GRB Afterglow"

GRB as Jet

- Establishment of unification of pictures as identical to AGN is critical
- **Massive stellar explosion (long GRBs)** / NS-NS merger (short GRBs)
  (1) Efficiency of acceleration (true energetics related with progenitors)
  (2) Jet structures (cocoon, head of jet)





(1) Acceleration efficiency

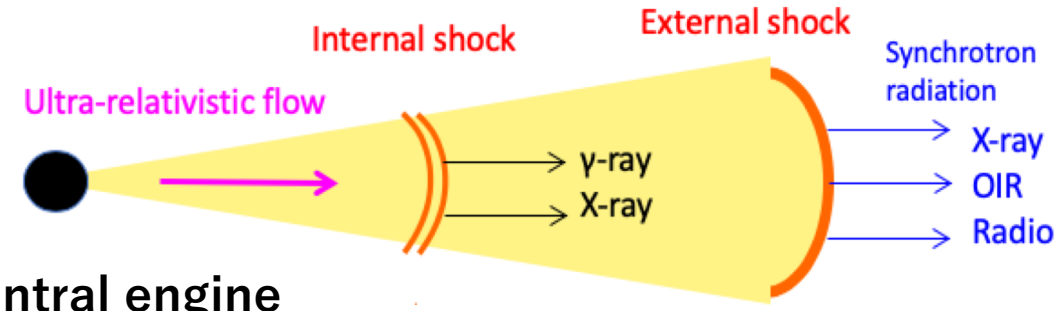
Off-Axis GRB,
XRF020903 (Urata+15)

(2) Jet structures
Cocoon
Jet head

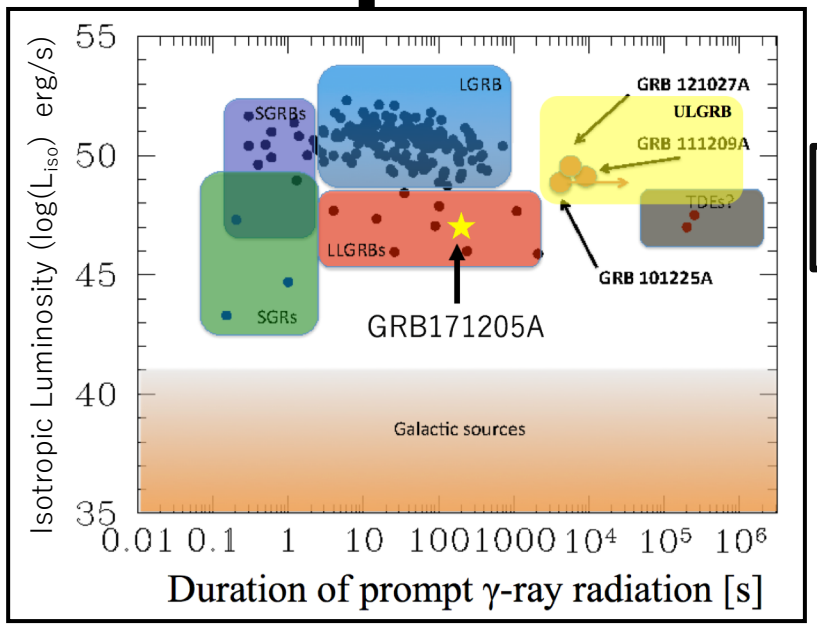
(1) Efficiency of electron acceleration at external shock

Faraday depolarization is only the method.

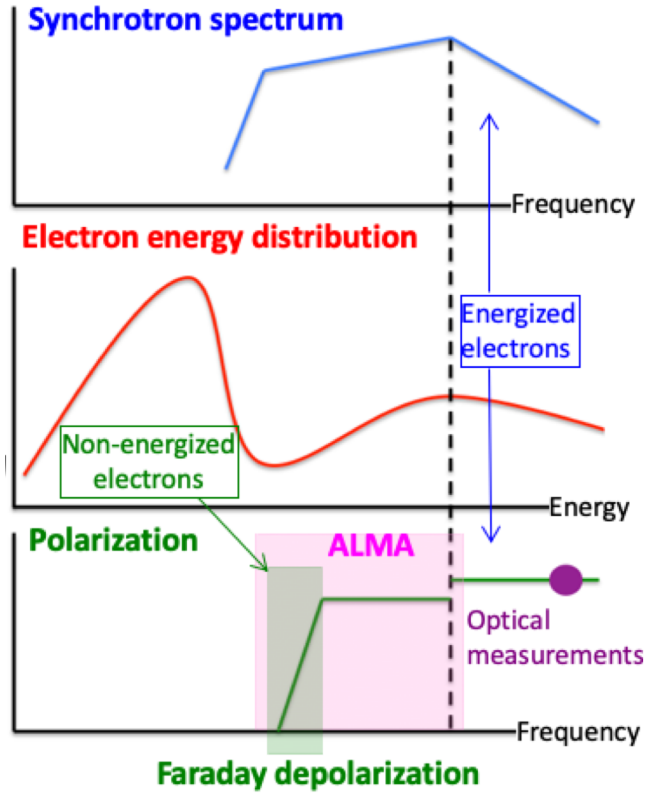
Urata+19 ApJL



$E_{tot} = E\gamma$ (prompt emission) + [E_{AG} (afterglow radiation), $E_{AG,h}$ (Faraday depolarization)]



Various GRB types classified by gamma-ray properties



ALMA established identifying the non-energized electrons of various types of GRBs and their afterglows

(1) Energetics (Indicator of mass of progenitors) and Unification

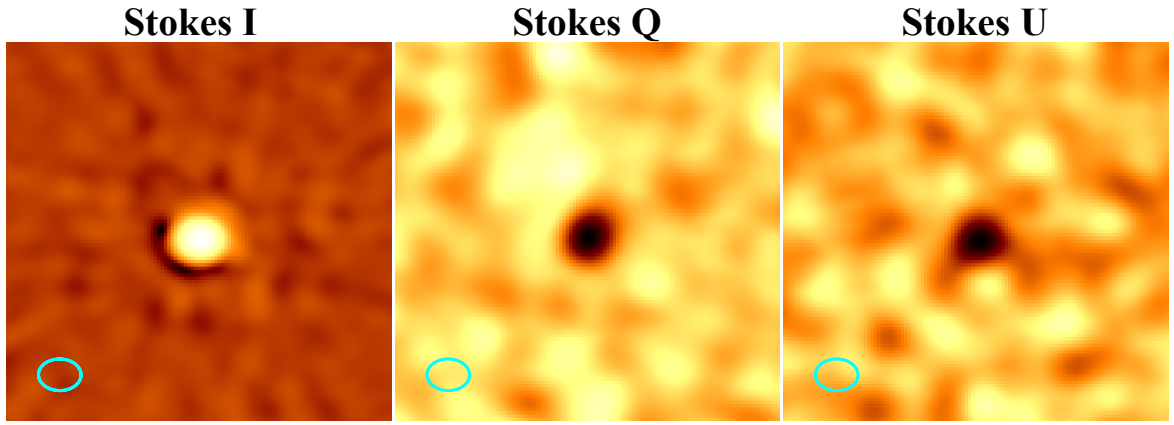
First Detection of Radio Linear in a GRB afterglow

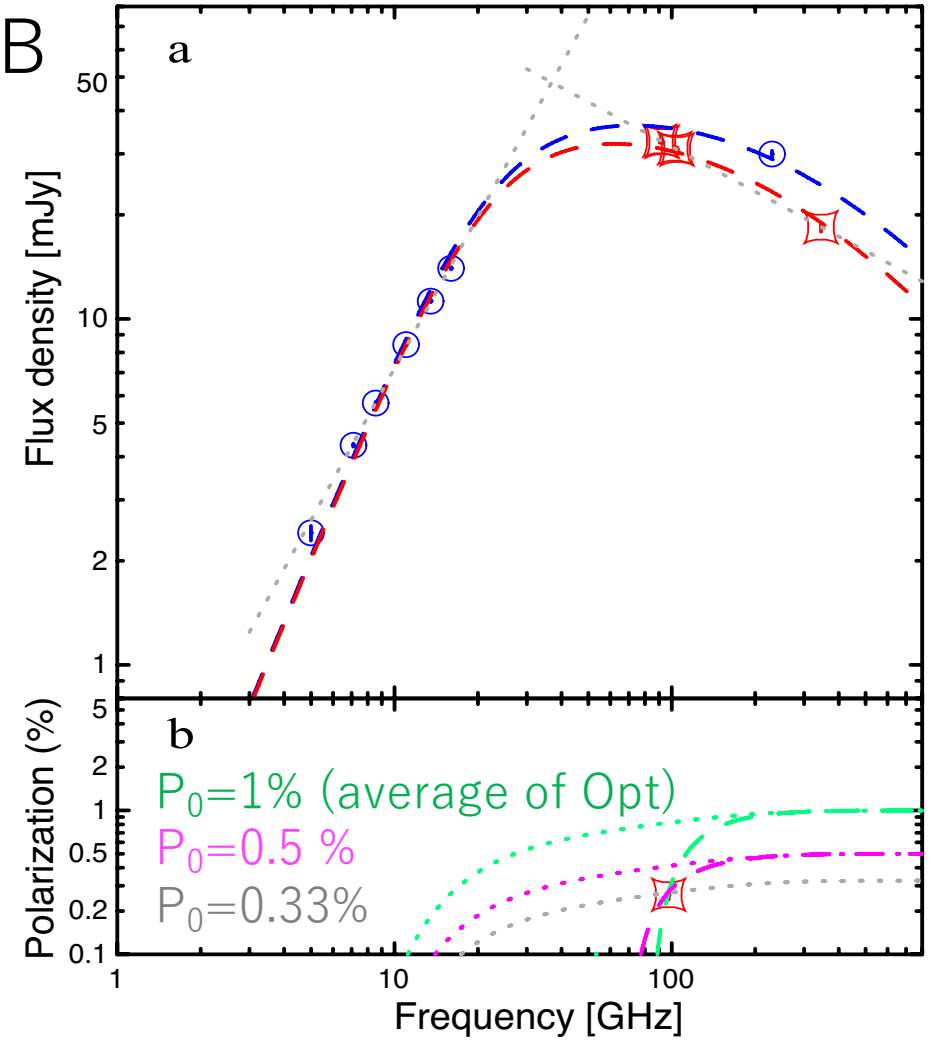
Urata+19 ApJL

ALMA polarimetry for low-luminosity GRB

0.27 ± 0.04 % @ 5.2 days

(including systematic error)





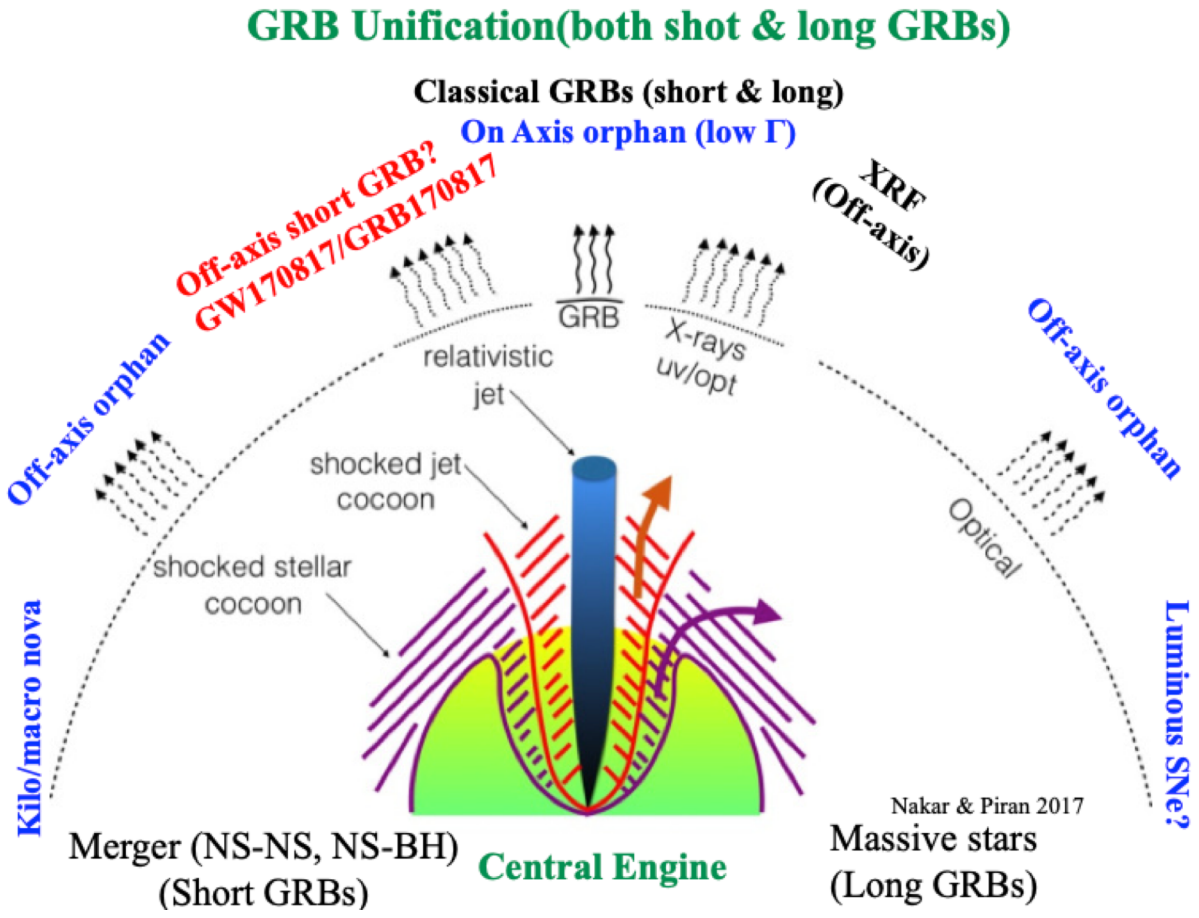
Only ~ 10% of electrons are accelerated!

Revising total energy ~10 times larger

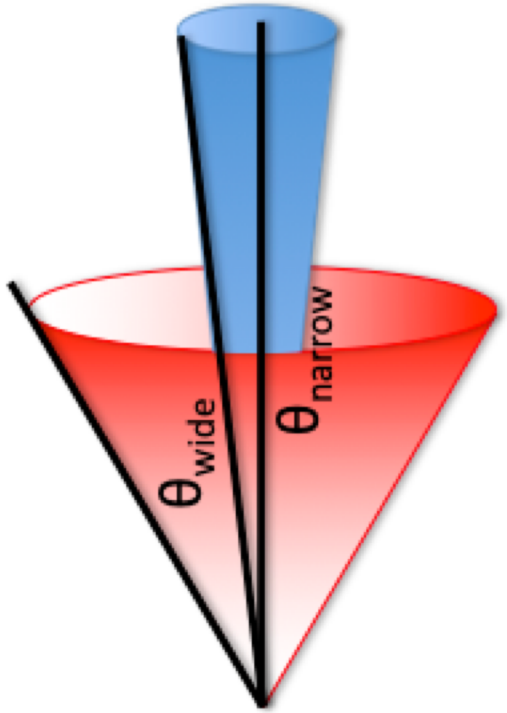
Further systematic measurements for various type of GRB is essential for unification picture.

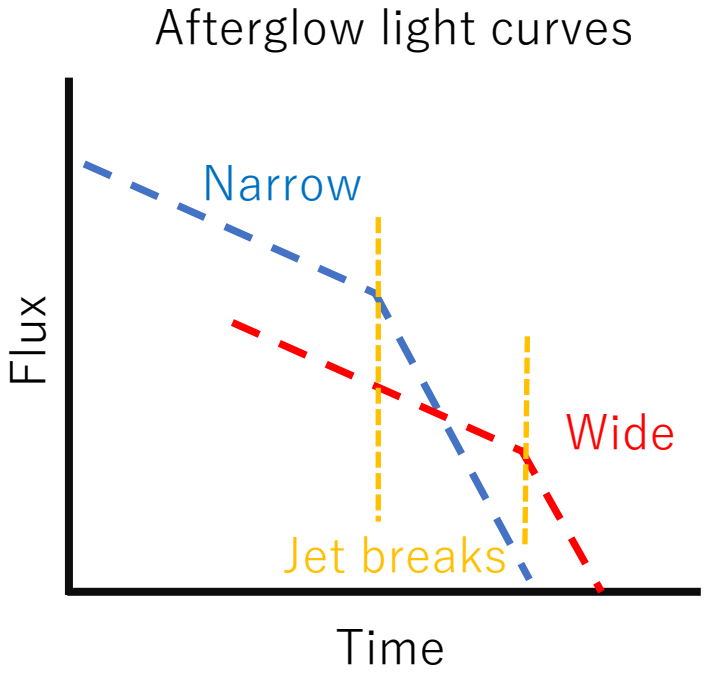
(2-1) GRB Jet structure and unification

- Under standing of jet and surrounding structures of GRBs
- As same as AGN, existence of cocoon was expected



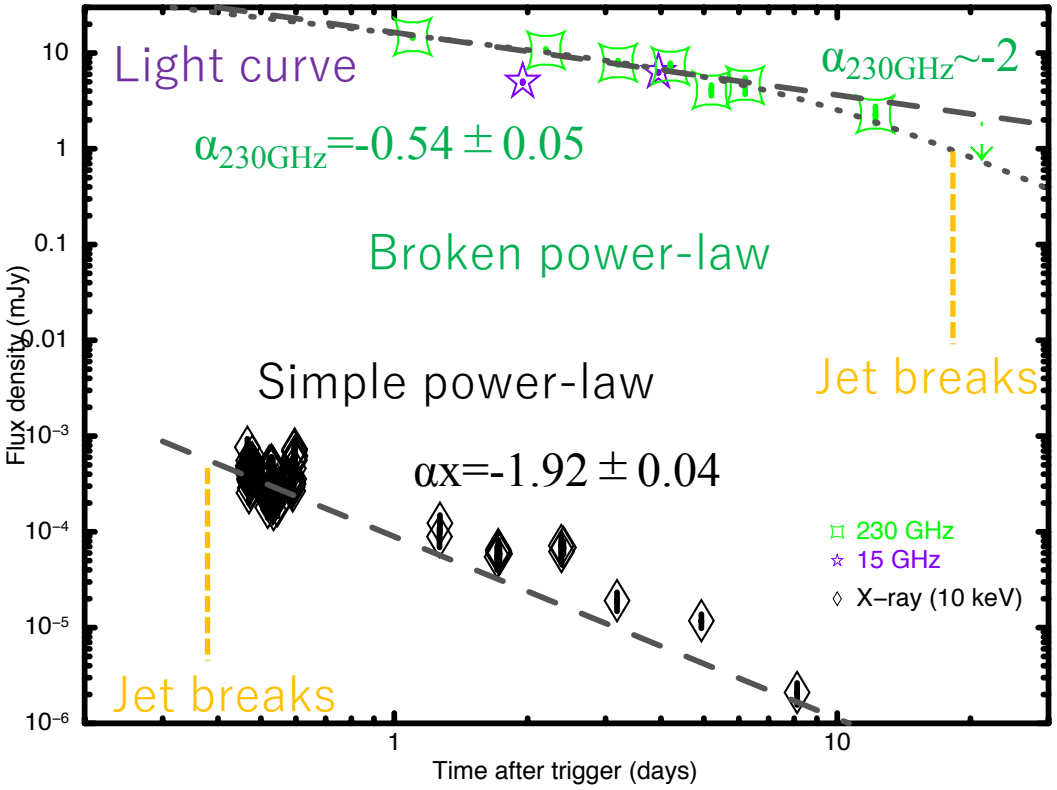
Observed as two component jet (narrow and wide)

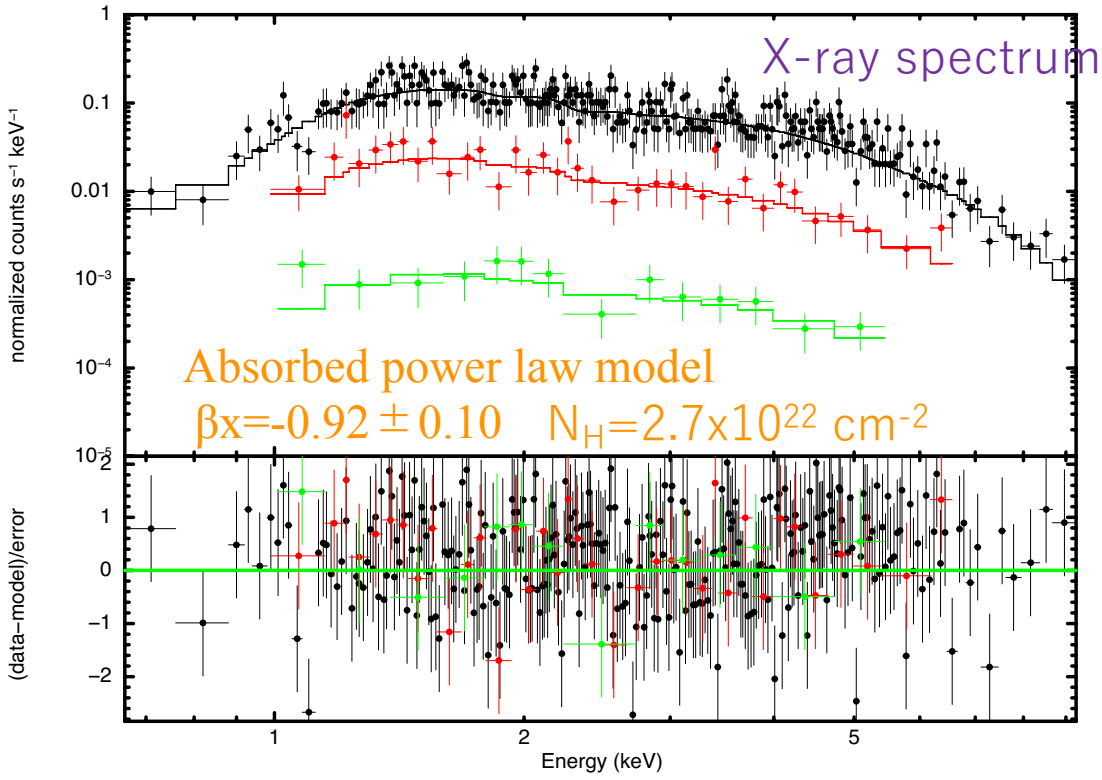




(2-1) First confirmation of Shocked Jet Cocoon Chen, YU et al. 2020 ApJL

Fermi/LAT detected GRB160623A (i.e. energetic event, 3.4 GeV)



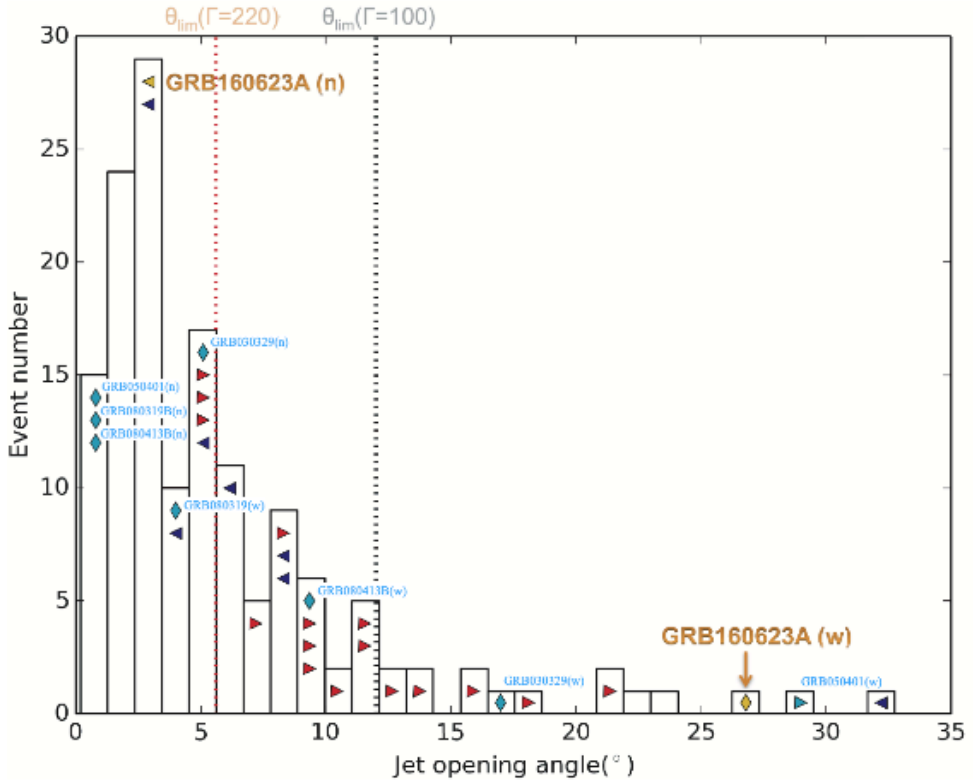


- X-ray and radio afterglows exhibited different temporal and spectral evolutions
- Both are explained by forward shock,
  but different jet collimation with θ_x <4.2° θ_{radio} = 27 °

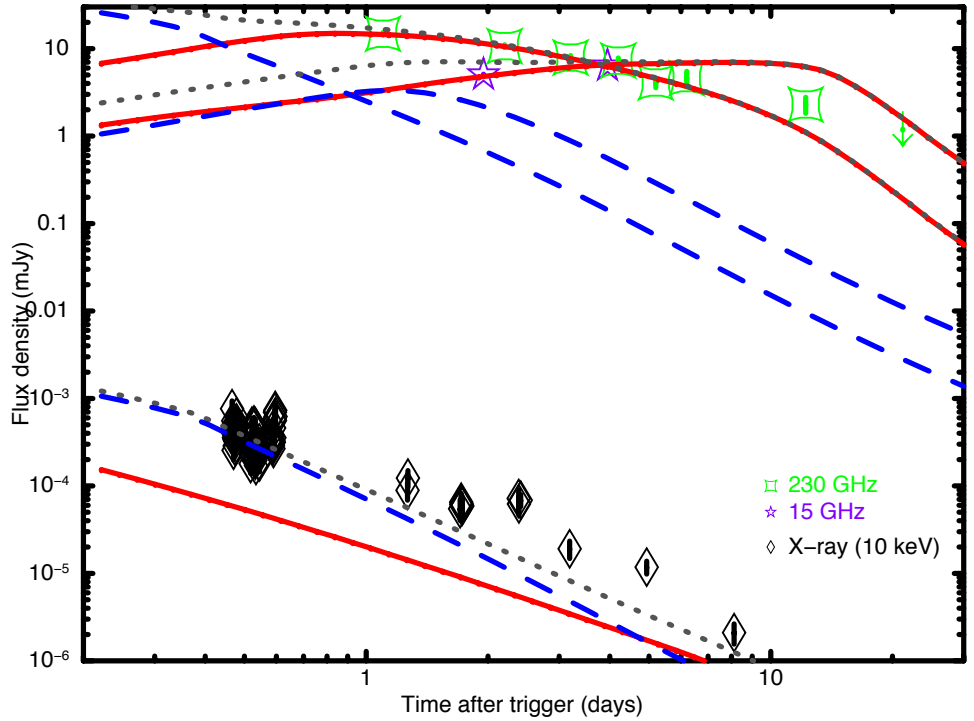
→ **Two component jet**

(2-1) First confirmation of Shocked Jet Cocoon Chen, YU et al. 2020 ApJL

Histogram of GRB jet opening angles:



Energetics based on 2D MHD modeling:



E_{narrow}: ~ 7 x 10^{53} erg E_{wide} : 7.7 x 10^{52} erg

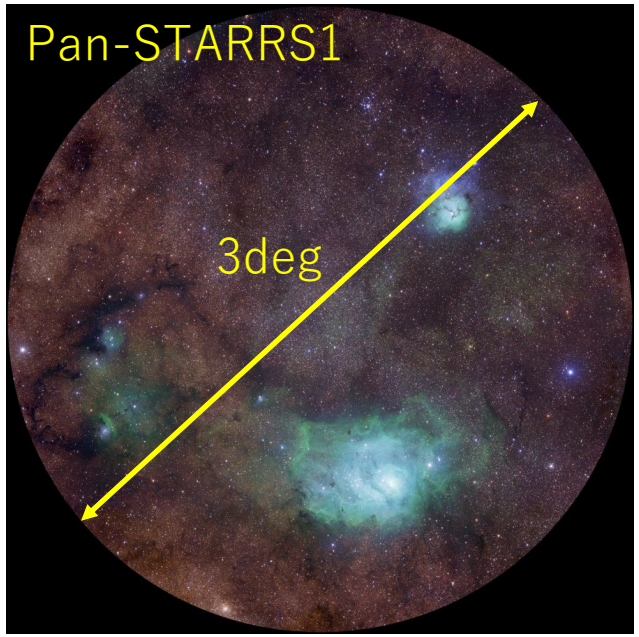
- Both are explained by forward shock, but different jet collimation with
  $\theta_x < 4.2°$ $\theta_{radio} = 27°$
  → **Two component jet**

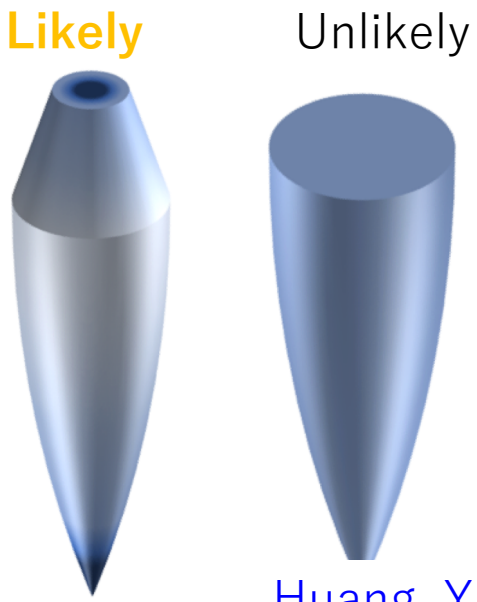
E_{wide} / E_{narrow} ~ 0.1 is consistent with the predicted value (Peng+05) for the collapsar jet

The radio afterglow with the wide jet angle originated from the shocked jet cocoon.

(2-2) Jet structure : Orphan GRB search

- Off-axis viewing of GRB jets produce “orphan GRB afterglow (OA)” (no prompt emission should be observed)
- Detectability of OA depends on the head structure of jet
- Pan-STARRS1 (+ SUBARU/HSC) made the first intensive (3.5 years with daily cadence) wide field optical time domain survey for OA
- Null detection indicates the “top hat” structure of jet is unlikely





Huang, YU et al. 2020 ApJ

Summary

- Toward establishment of unification pictures of massive stellar explosion and compact mergers, acceleration efficiency and jet structures are critical.

- Acceleration efficiency of electrons at external shock is ~10% for Low-luminosity GRB (GRB171205A)

  Urata et al. 2019 ApJL, 884, L58

- Jet structures related with GRBs
  - First detection of shocked jet cocoon

    Chen, Urata et al. 2020 ApJL, 891, L15

  - Top hat structure of jet head is unlikely.

    Huang, Urata et al. 2020 ApJ, 897, 69