Observation and multi-wavelength modeling of GRB 190829A and GRB 201015A by the MAGIC telescopes

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on behalf of the MAGIC Collaboration

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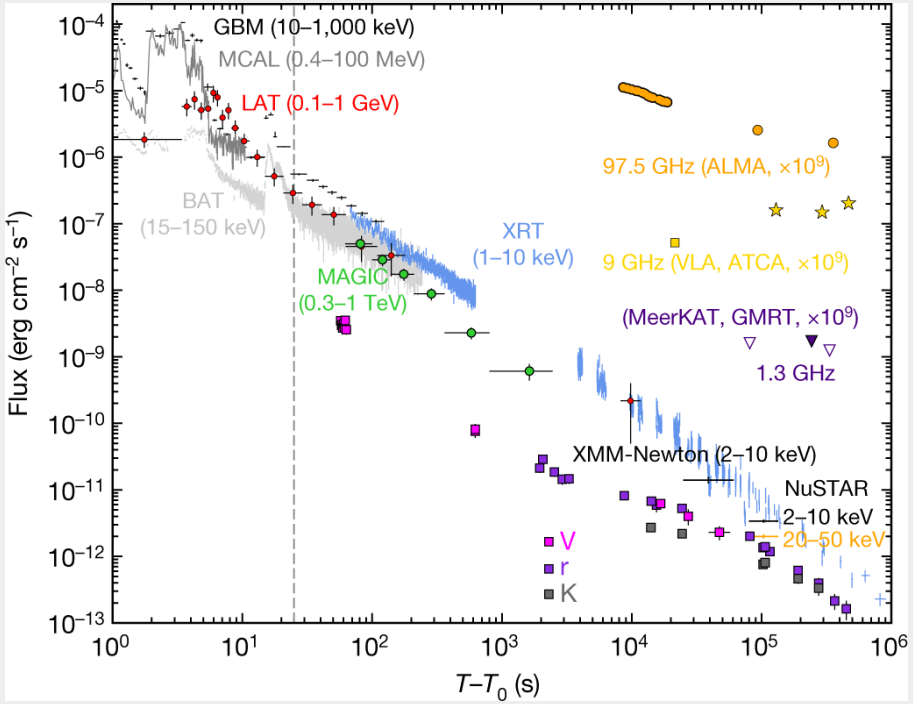
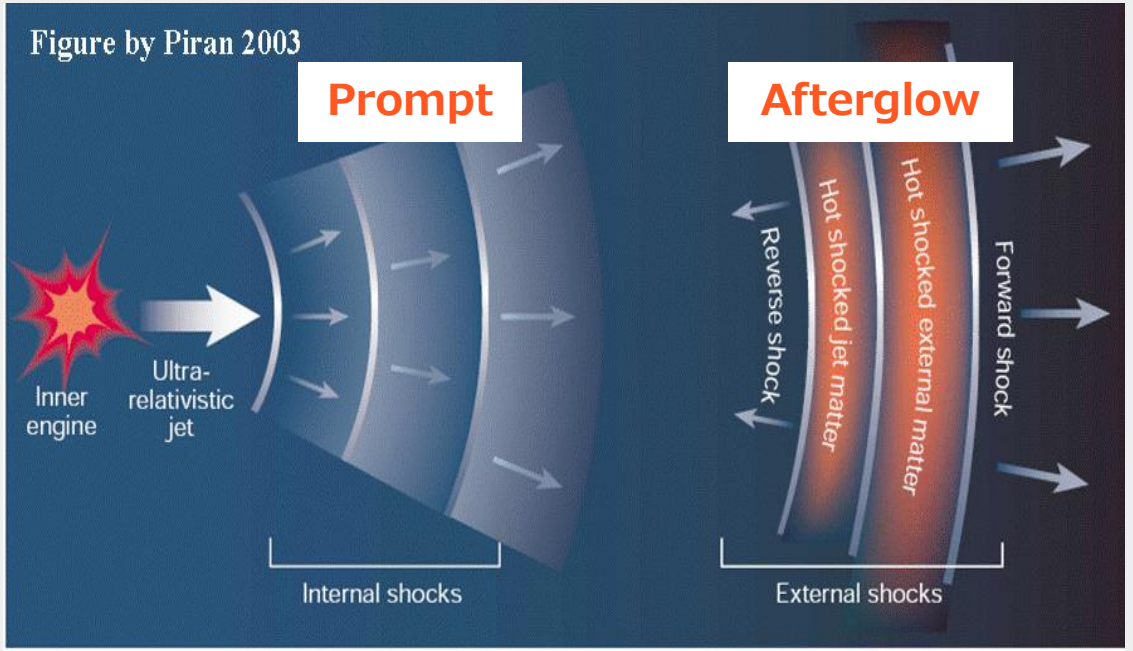
Gamma-ray Burst (GRB)

- Extremely energetic emission from relativistic jet
- Isotropic gamma-ray energy release: typically, $10^{51} \sim 10^{53}$ erg
- Prompt: series of short pulses (long: duration > 2 s; short: duration < 2 s)
- Afterglow: power-law decay with duration of days to weeks



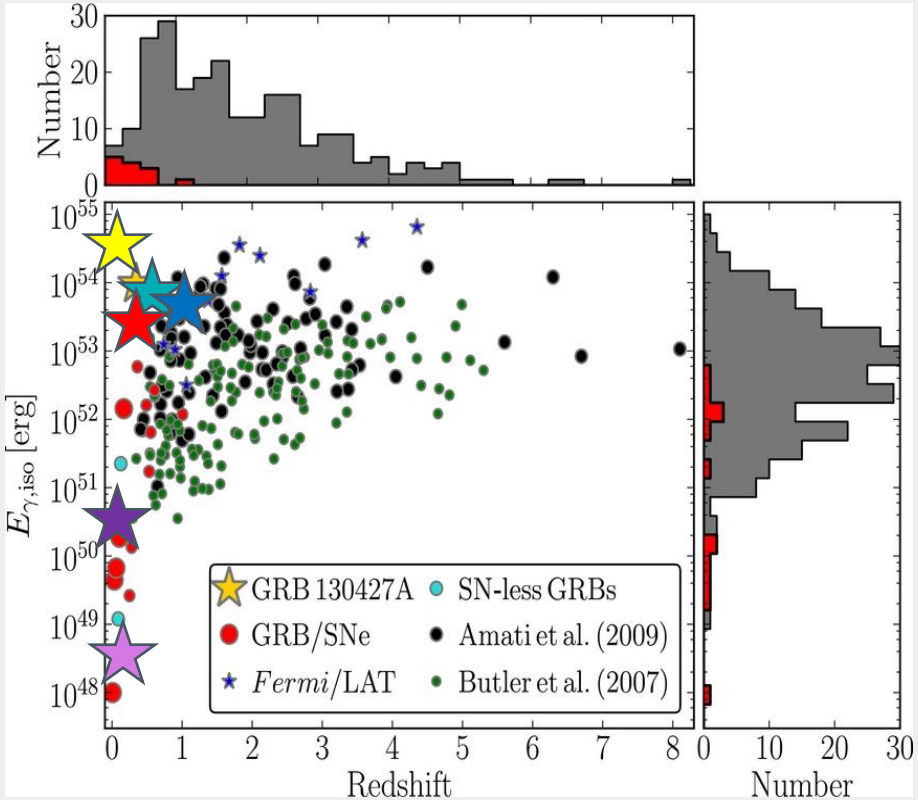
MAGIC Collaboration (2019)



GRBs in VHE Regime

- Most of GRBs detected in VHE regime are bright and luminous events (E_iso > 10^{53} erg)
- There are only few events with relatively small energy release
  - 1 detection (GRB190829A) and 1 hint (GRB160821B)
- Less luminous GRBs give us an insight on sub-energetic explosion
  - Potential connection to Low-Luminosity GRBs

D. Xu et al. ApJ 776 98 (2013)



★ GRB180720B (z = 0.65)
★ GRB190114C (z = 0.42)
★ GRB201216C (z = 1.1)
★ GRB221009A (z = 0.15)
★ GRB190829A (z = 0.078)
★ GRB160821B (z = 0.16; short)

Less Luminous VHE GRBs

★GRB190829A
- Triggered by Fermi-GBM
- T_{90} = 59.4 ± 0.6 s (50 - 300 keV)
- E_{iso} = 1.8×10^{50} erg
- z = 0.078
- H.E.S.S. detected VHE emission

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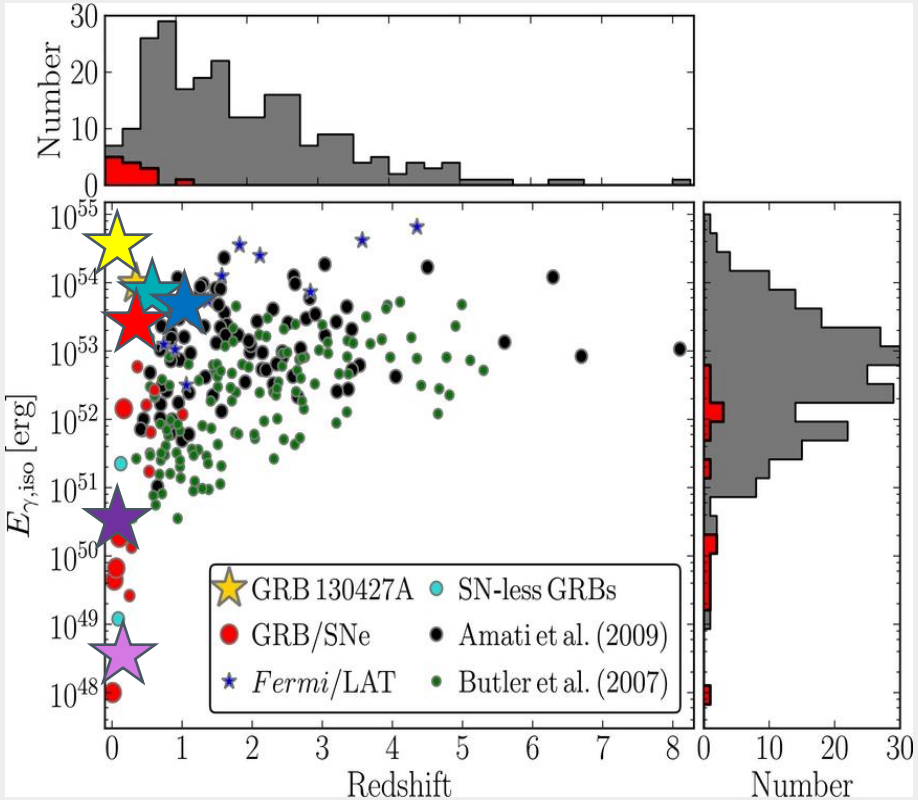

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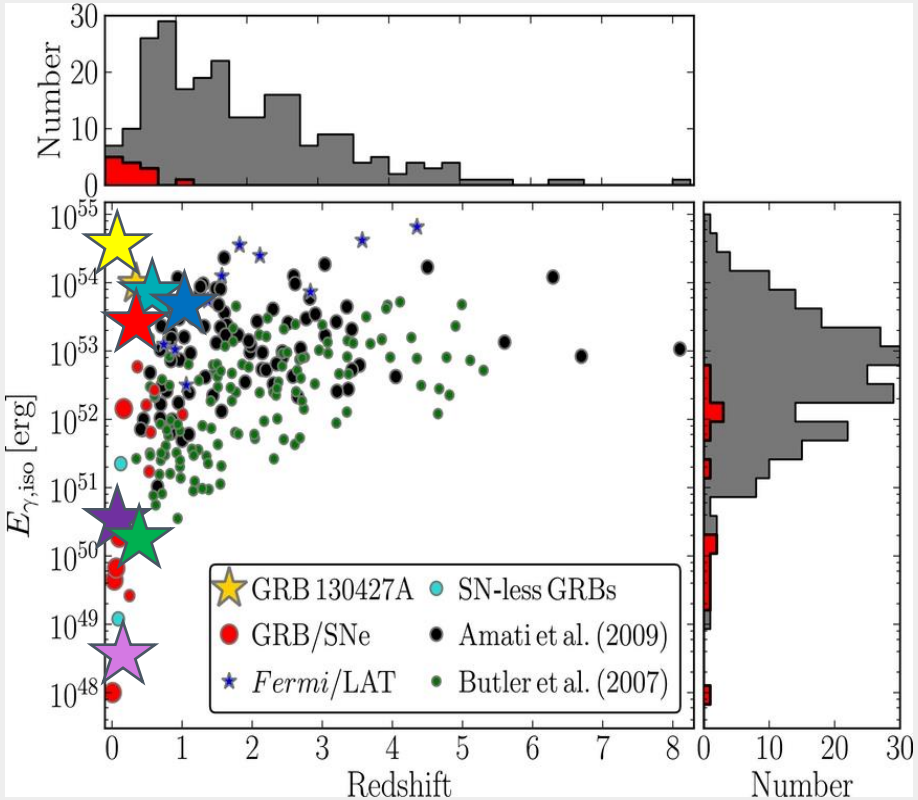
★GRB201015A (This talk's main topic)
- Triggered by Swift-BAT
- T_{90} = 9.8 ± 3.5 s (15 - 350 keV)
- E_{iso} = 1.1×10^{50} erg
- z = 0.426
- Supernova (Ic-BL) signature detected (GCN29033)

D. Xu et al. ApJ 776 98 (2013)



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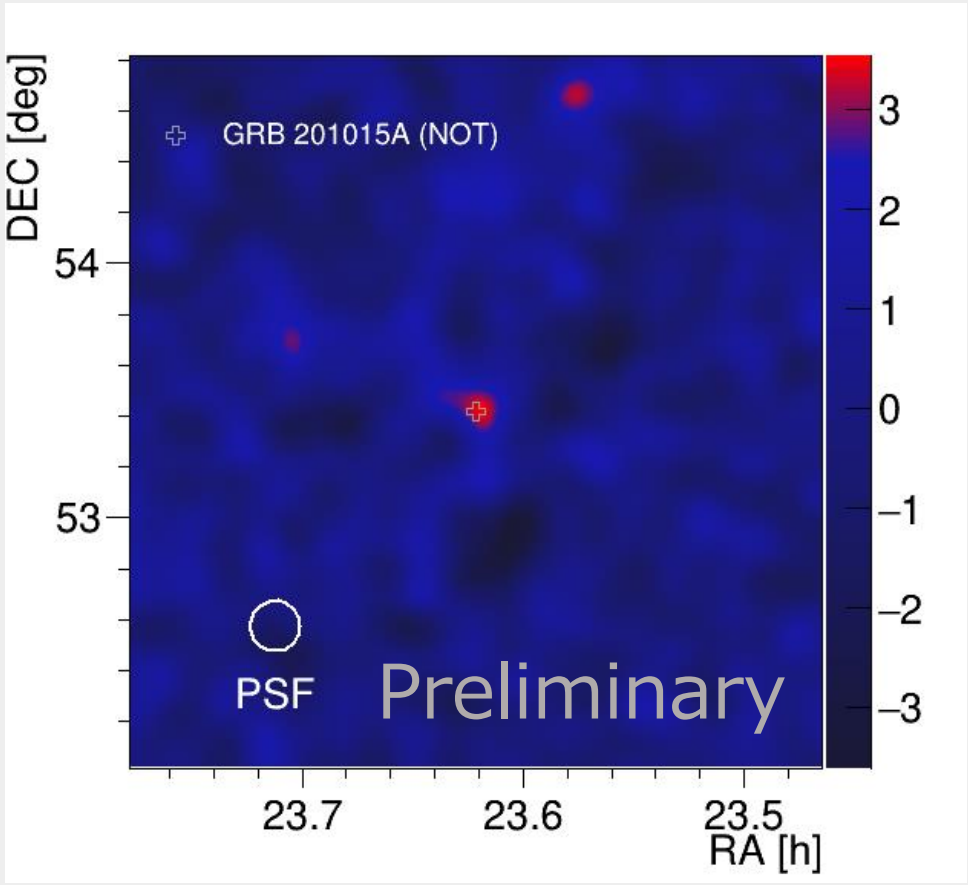
GRB201015A: MAGIC Observation

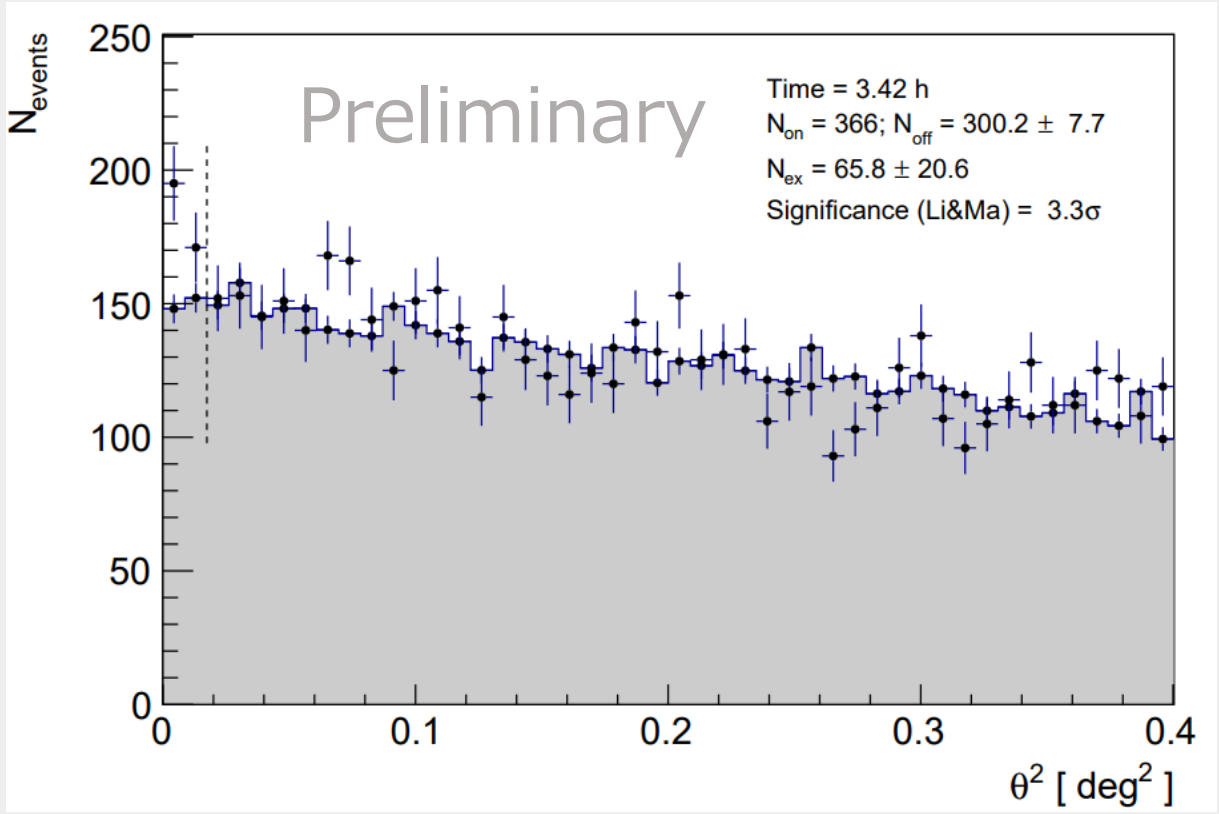
MAGIC telescopes

- Observed from 33 s after the burst trigger
- Total observation time of 3.42 hr
- Zd range: 24 -> 48
- Observation under good dark condition but no LIDAR measurement
  (it was misaligned)
- Background rate study was performed to evaluate energy shift due to unknown transmission
  - According to the study, the energy shift is evaluated to be ~1%

GRB201015A: MAGIC Observation

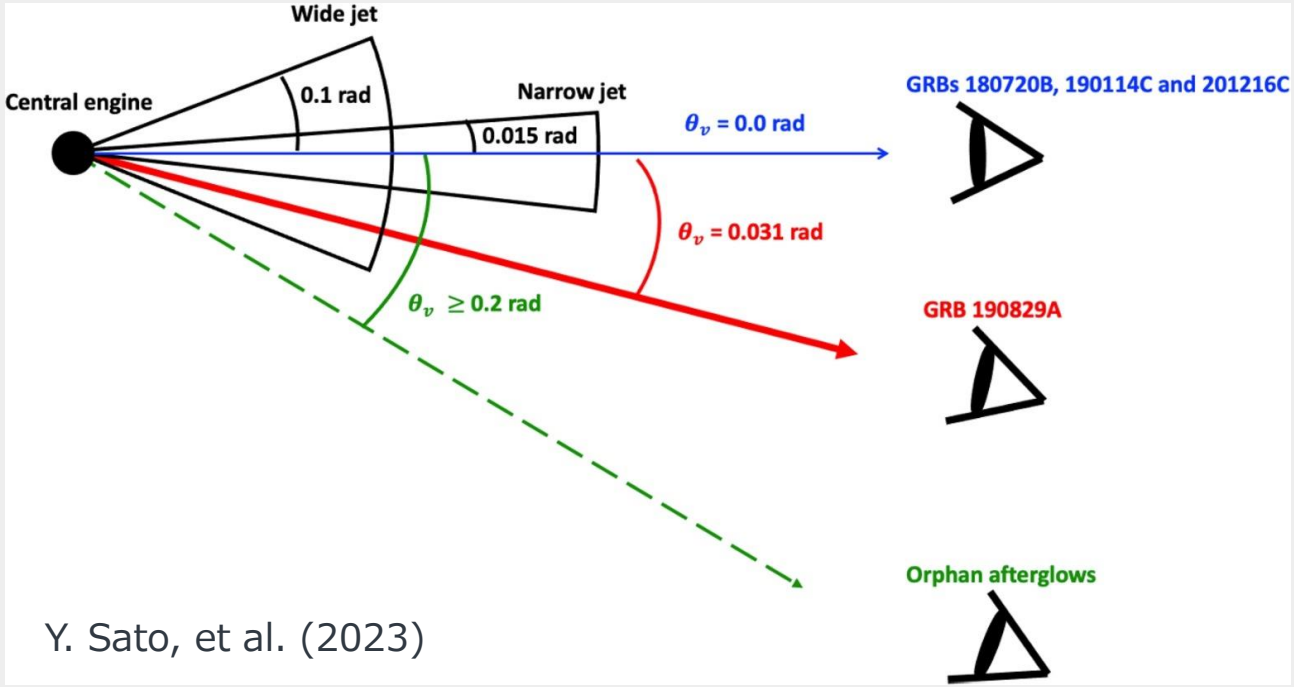
- Obtained a hint of gamma-ray signal from position consistent with optical detection
  - 3.3 σ (pre-trial) → 3.0 σ (post-trial)





Modeling Scheme

- We performed modeling of the two (relatively) low luminous GRBs with following configuration
  - ✓ The model considers narrow and wide jets
  - ✓ Allows different viewing angles (on-axis: typically bright; off-axis: typically faint)
  - ✓ Regarding GRB201015A, only the narrow jet is considered since the MAGIC data are in early phase of afterglow and supernova arises from the late phase



Y. Sato, et al. (2023)

GRB190829A: MWL Light Curve

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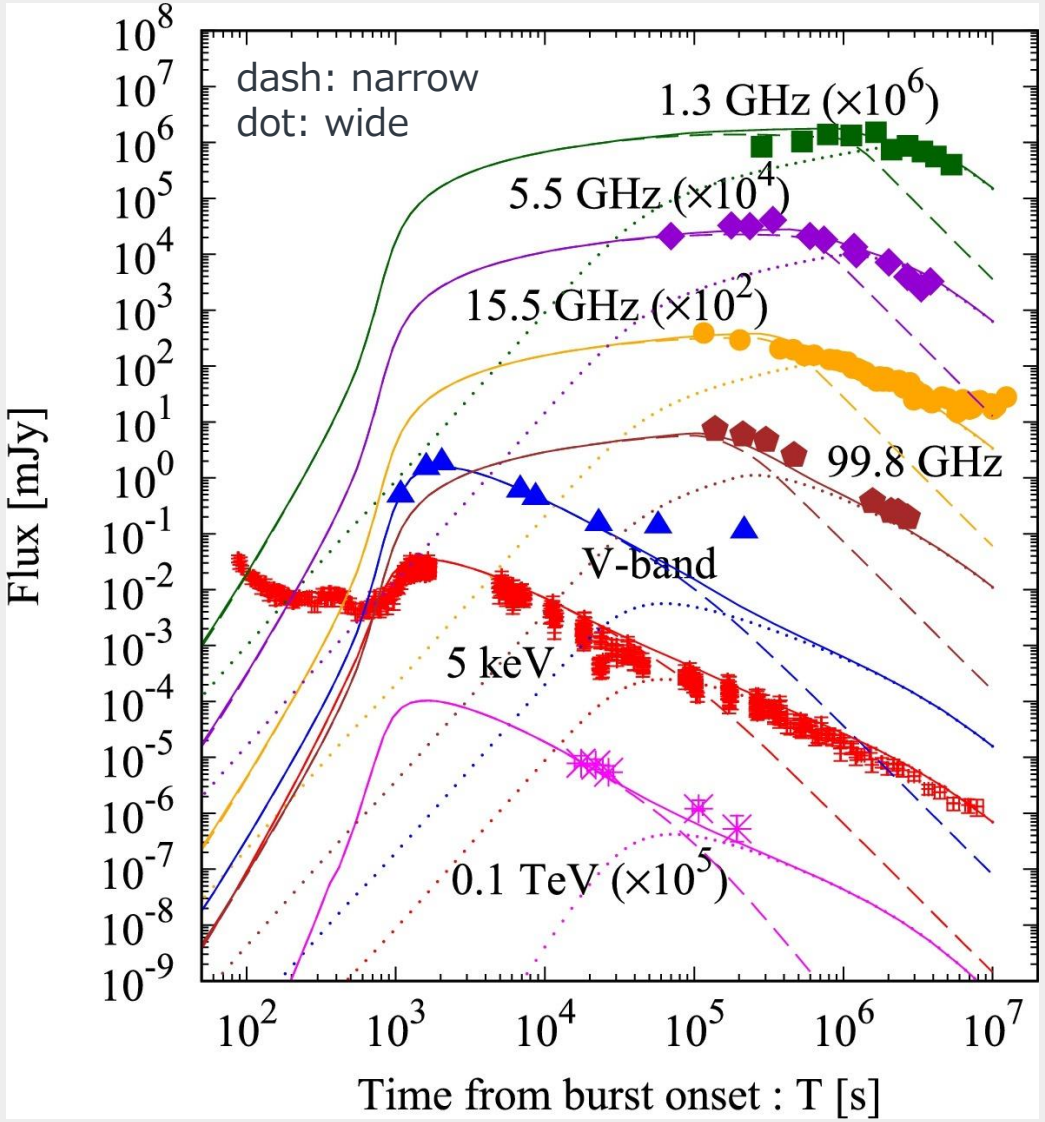


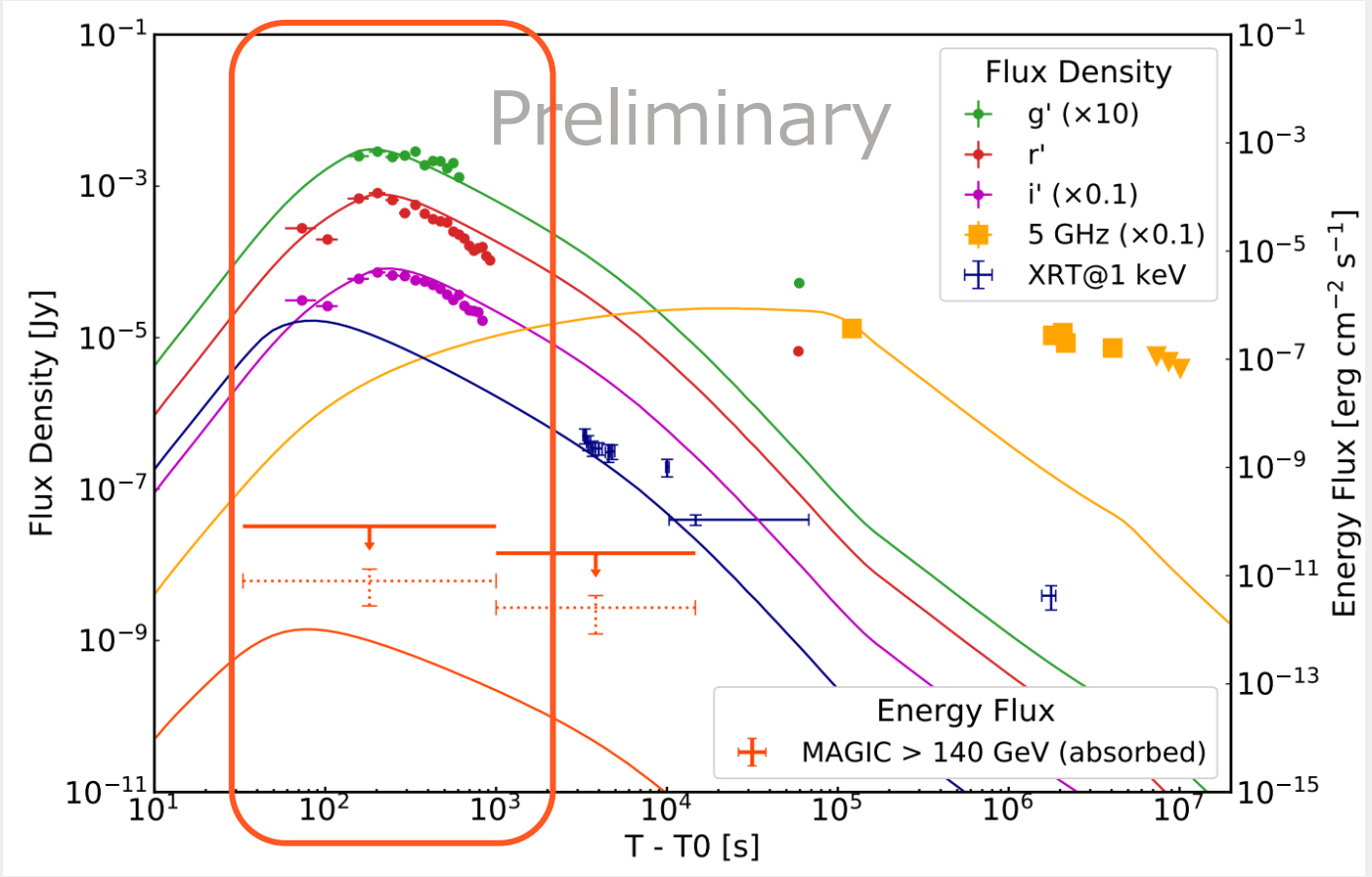
- MAGIC observed between H.E.S.S. 2nd and 3rd night
- Inferred MAGIC flux is consistent with H.E.S.S.
- Final result in prep.

<narrow jet>
$\Gamma_0 = 350$ small value
$\theta_0 = 0.015$ rad
$\theta_v = 0.0305$ rad
$E_{\rm iso,K} = 4 \times 10^{53}$ erg
$n_0 = 0.01$
$p = 2.44$
$\epsilon_e = 0.035$
$\epsilon_B = 6 \times 10^{-5}$
$f_e = 0.2$

<wide jet>
$\Gamma_0 = 20$
$\theta_0 = 0.15$ rad
$\theta_v = 0.0305$ rad
$E_{\rm iso,K} = 1 \times 10^{53}$ erg
$n_0 = 0.01$
$p = 2.2$
$\epsilon_e = 0.29$
$\epsilon_B = 1 \times 10^{-5}$
$f_e = 0.35$

GRB201015A: MWL Light Curve

- In order to reproduce the optical peak, it turned out that off-axis model is difficult to explain the observed data
  - Instead, on-axis model is used for this GRB
  - May indicate this GRB is intrinsically low luminous



$\Gamma_0 = 150$, $\theta_0 = 0.02$ rad, $\theta_v = 0.0$ rad, $E_{\mathrm{iso,K}} = 2 \times 10^{52}$ erg
$n_0 = 0.4$, $p = 2.5$, $\epsilon_e = 0.02$, $\epsilon_B = 4 \times 10^{-3}$, $f_e = 0.8$

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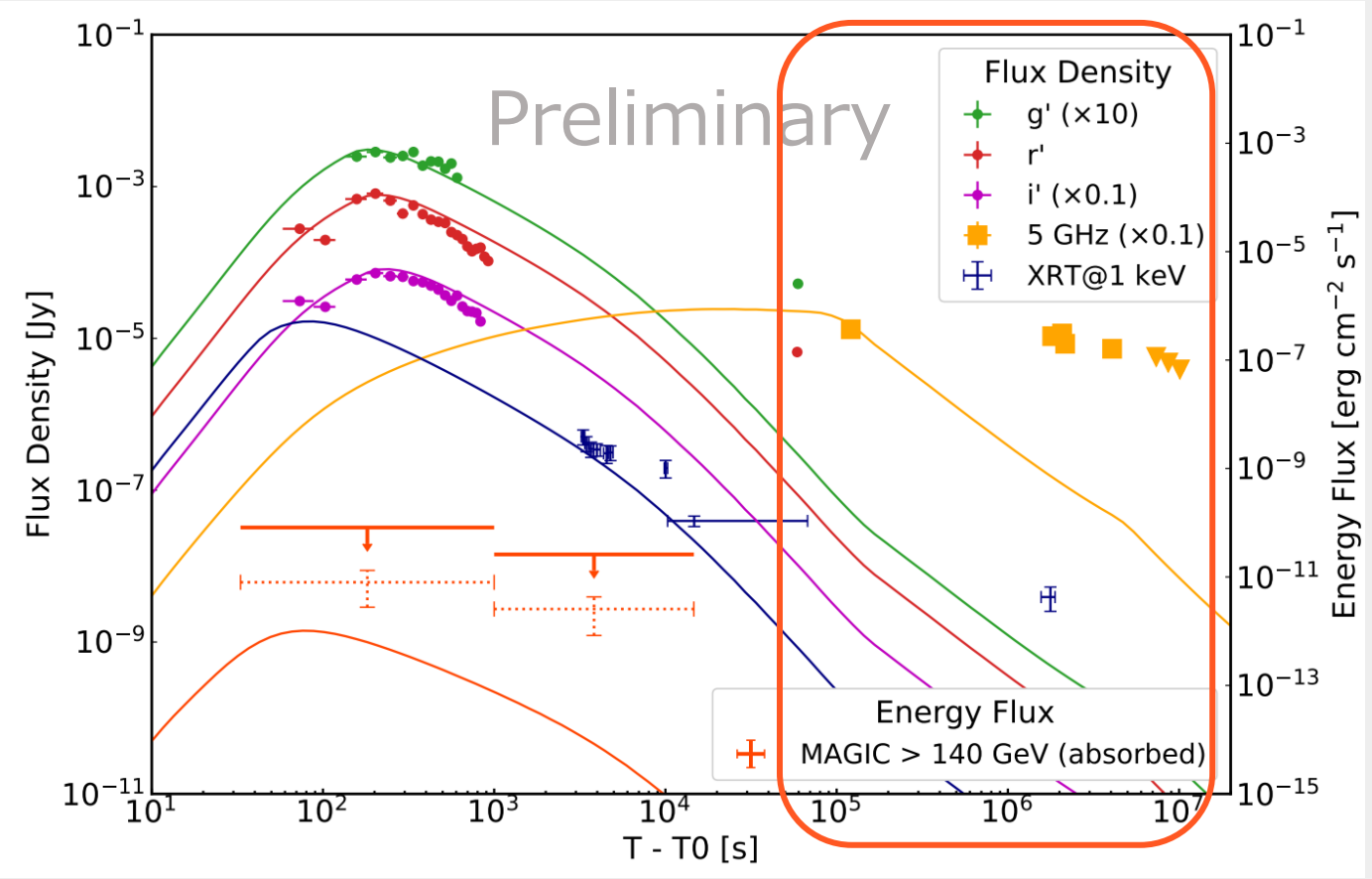
- Supernova emission is present after ~ 10^5 s
  - Modeling is complicated in this time range
  - Consider only narrow jet to focus on earlier time when MAGIC observed



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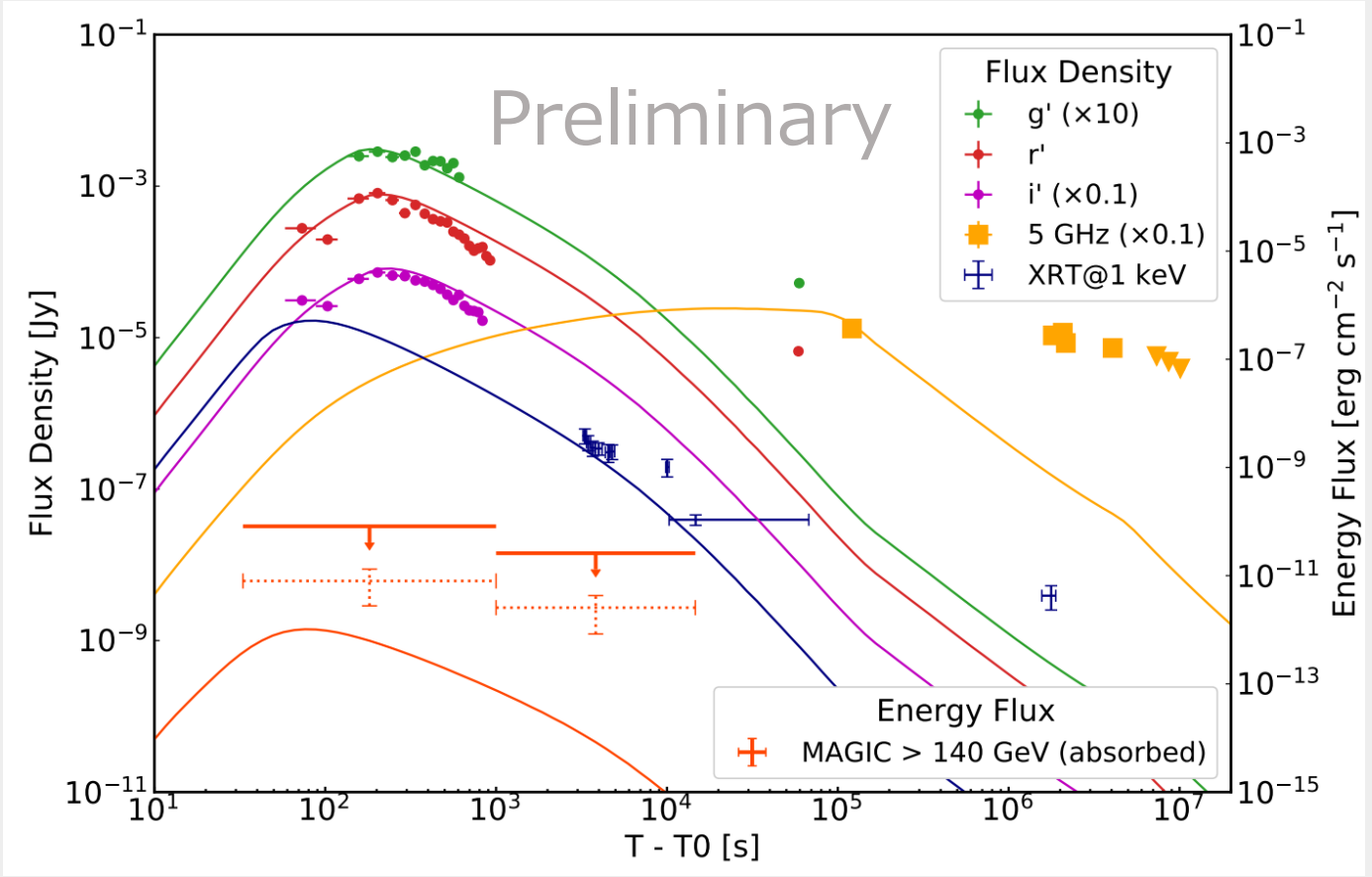
  - Small opening angle leads to early jet break



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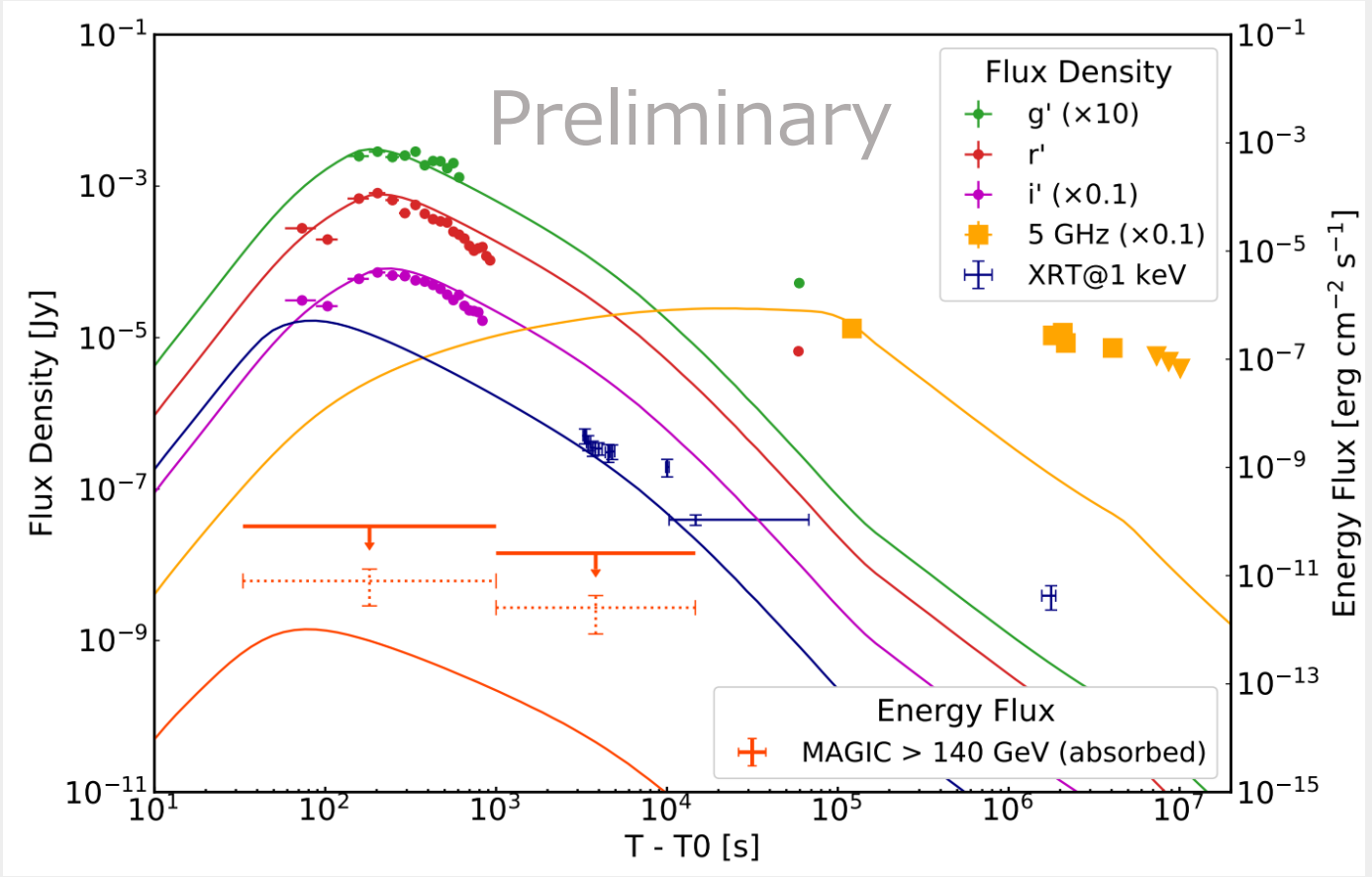
- Regardless of on/off axis, our modeling suggests that both GRBs have a jet with small opening angle (~ 1.1 deg)
  - Small opening angle leads to early jet break
- Suggest radiation efficiency of prompt emission is very low (η = 0.5 %)
  - Very low radiation efficiency is consistent with internal shock dissipation model



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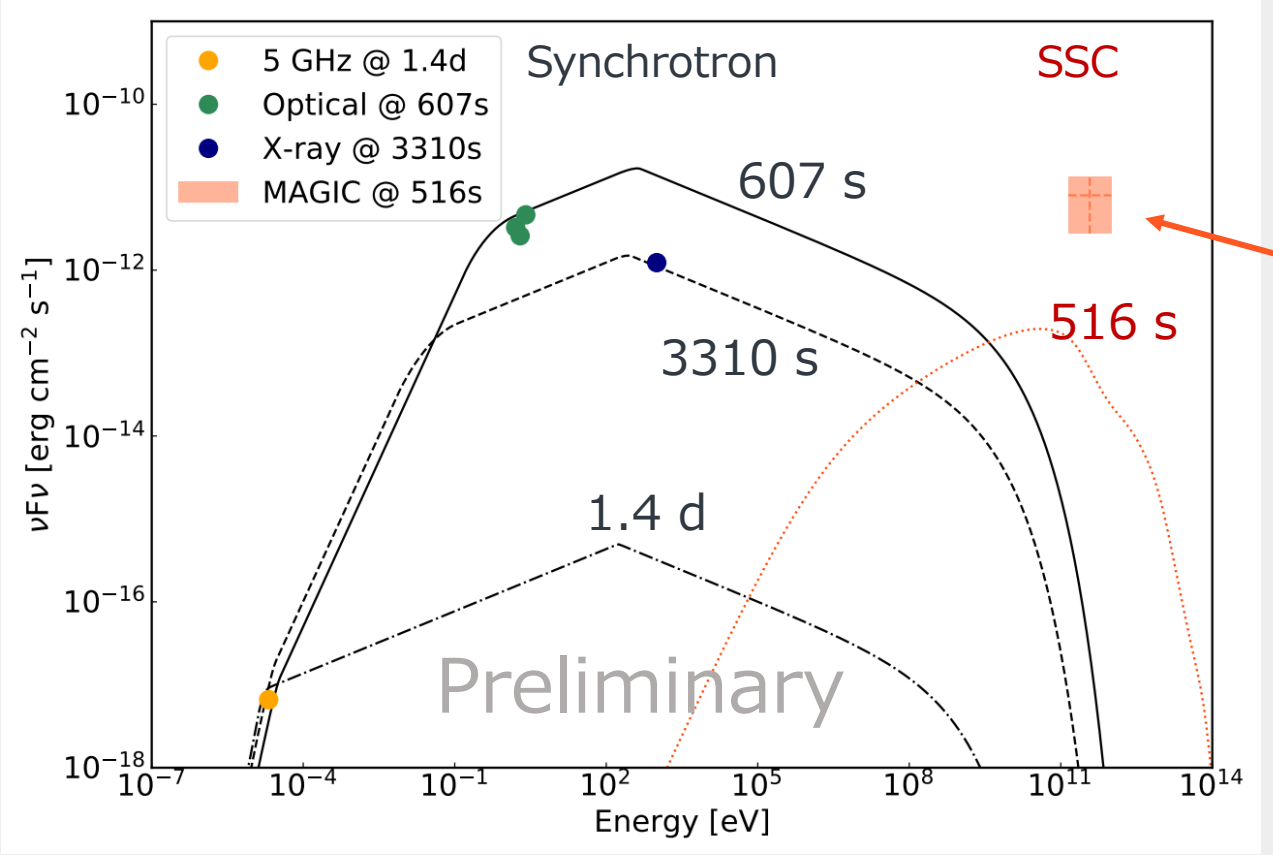
∗Prompt energy release $E_{\mathrm{iso},\gamma} = 1.1 \times 10^{50}$ erg

GRB201015A: MWL SED

- Note that MAGIC data is not EBL corrected
  - EBL model adopted for modeling: Franceschini et al. (2008)

- If MAGIC signal is real, inferred SSC flux level may be insufficient to explain the MAGIC data



Summary

- GRB201015A and GRB190829A are GRBs with relatively low luminosity
  - Different from other VHE-detected GRBs with high luminosity

- MAGIC obtained a hint of signal from both GRB201015A and GRB190829A

- Attempt to model the two GRBs with one component off-axis model
  - For now, GRB190829A is well explained by this model
  - As for GRB201015A, off-axis model is difficult to explain. On-axis model is adopted instead
  - Our modeling suggests both GRBs have a jet with small opening angle

- Paper describing the results of the two GRBs in preparation

Interested in proposing observations with MAGIC ?

Next MAGIC observing call (Cycle-19) will come very soon. It will be posted here:

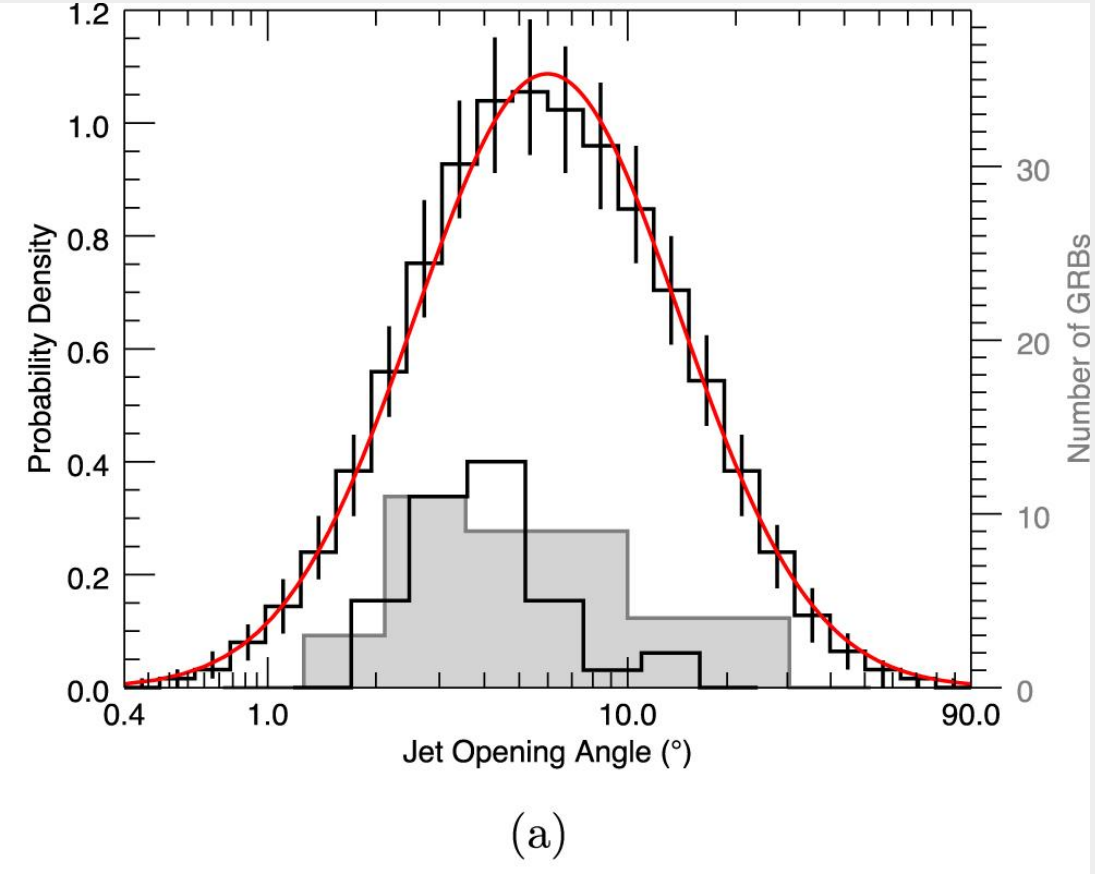
https://magic.mpp.mpg.de/public/magicop/

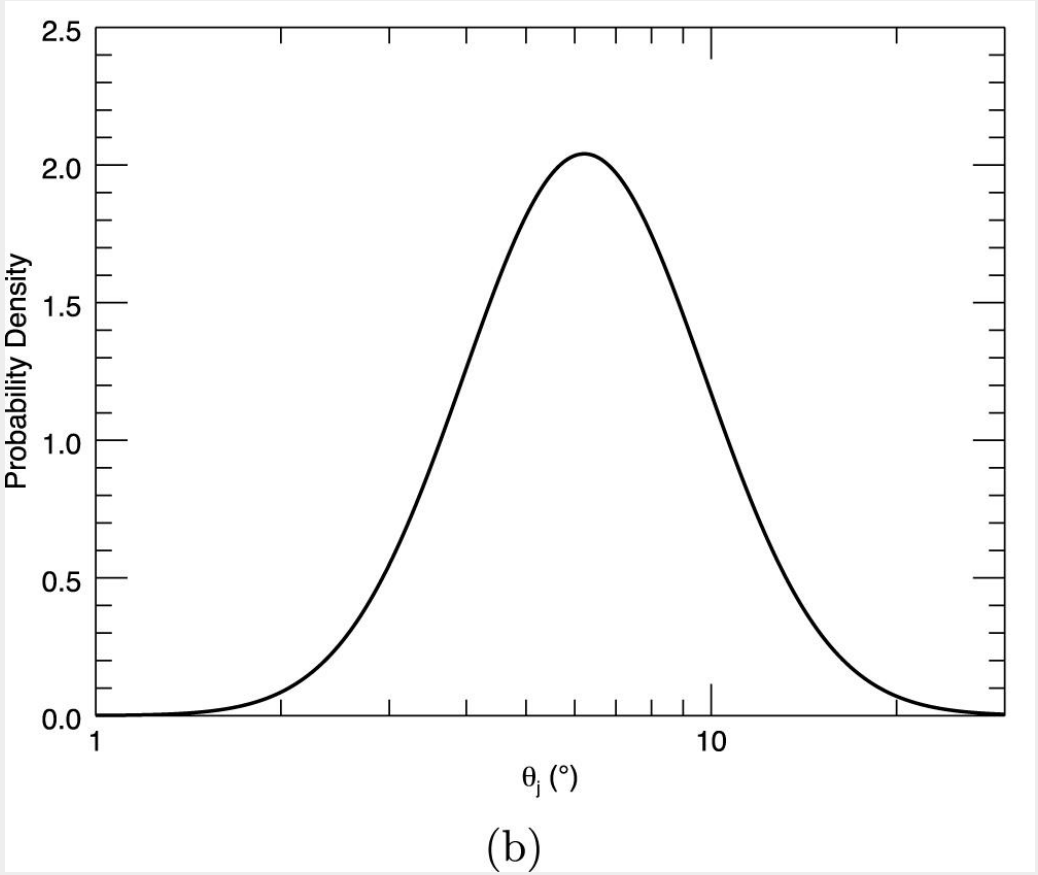
(Deadline for submitting proposals in the end of October or beginning of November)

Backup

Jet Opening Angle Distribution

A. Goldstein et al. (2016)





Supernova Associated with GRB201015A

GCN 29033