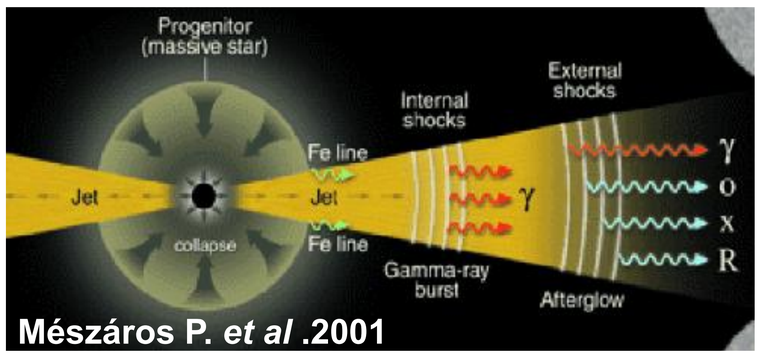
KaGErOFU: Observing Gamma-Ray Burst Optical Flashes with an Optical Star Camera System

Yusuke Munakata, Tatsuya Sawano , Kanaho Okamoto, Atsushi Takada [A], Yoshitaka Mizumura [B]
Kanazawa University , Kyoto University [A], ISAS/JAXA [B] **mail address: yusuke.munakata@astro.s.kanazawa-u.ac.jp**

1. Gamma-ray Bursts

Properties

- Extremely high-energy explosion ~10^{52} erg
- Transient event
- Observable across multi wavelength



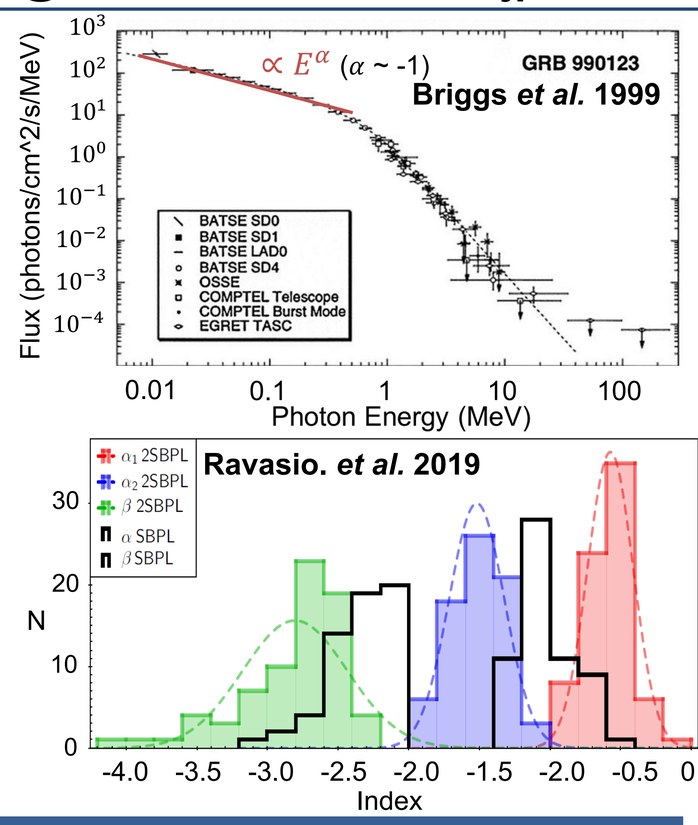
Mészáros P. *et al* .2001

Optical flash

- Rarely observed during the prompt emission.
- GRBs with optical flashes attributed to **internal shock (GRB 080319B)** [1] and **the external reverse shock (GRB 990123)** [2,3] have been previously observed.
- **The emission mechanism of the early optical flash can be identified by analyzing its correlation with the gamma-ray band.**

The key to elucidating the jet emission mechanism is accurately determining the Lorentz factor Γ of GRBs.

- Observed GRB spectra display two breaks, strongly supporting synchrotron emission originating from a marginally fast cooling regime.
- Analysis using **the 2SBPL model** by Ravasio *et al.* (2019) revealed evidence of two power-law segments with α_1= -2/3 and α_2= -3/2, separated by the cooling frequency $\boldsymbol{\nu_c}$. [4]



Simultaneous optical observation of the GRB prompt emission allows us to constrain the jet's energy distribution

2.KaGErOFU Kanazawa University Gamma-ray Burst Explorer for Optical Flash Understanding

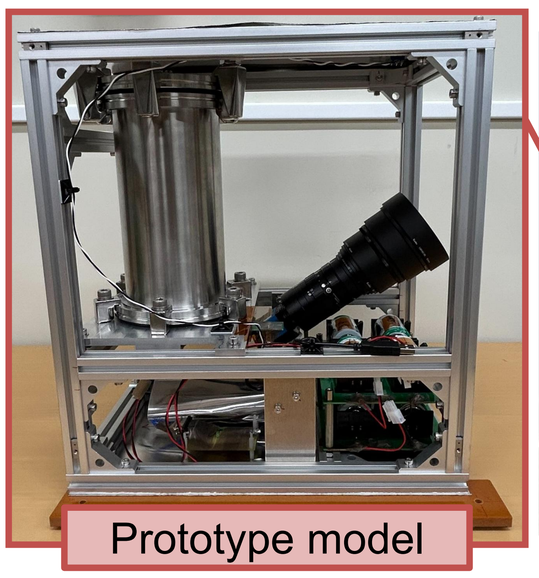
Our mission is to observe the early optical flashes from GRBs

- **Overview**
  - Experiment using **a ground-based wide-field optical camera** (§4) and **a scientific balloon**.
- **Advantages of Scientific Balloon Experiments**
  - Enables experiments at a **lower cost** than satellites
  - Allows observations **unaffected by weather conditions** and reduces atmospheric effects.
- **Target Imaging Performance on Balloon experiment**

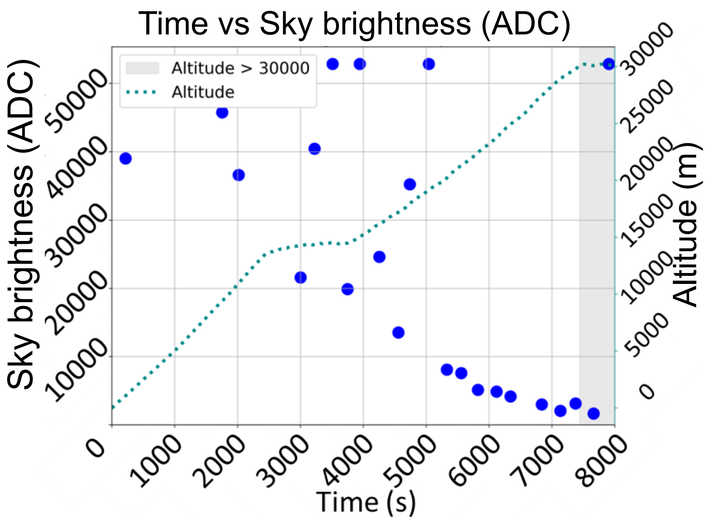
Daytime imaging of stars ($mag \leq 7$) at balloon altitude.

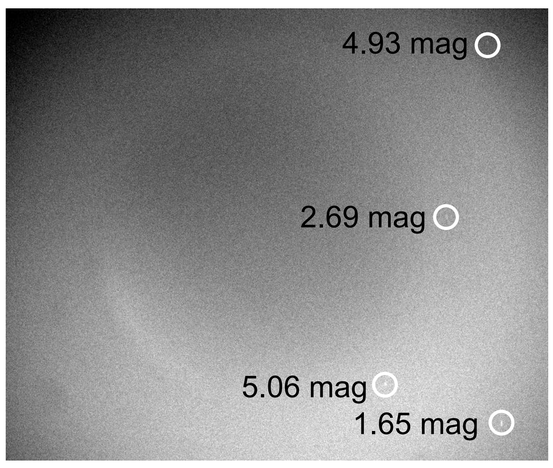
3. Piggyback Balloon Experiment

The proof-of-concept experiment for this project conducted the JAXA 2025 Domestic Scientific Balloon Program at the JAXA Taiki Aerospace Research Field.
(Taiki-cho, Hokkaido, 2025.6.20 B25-03)


Prototype model

The prototype model is equipped with an optical camera (**The Imaging Source DFK33UX264**) and a lens (**FUJINON HF25SA-1**) as its main instrument, providing a Field of View of ~300 deg^2.



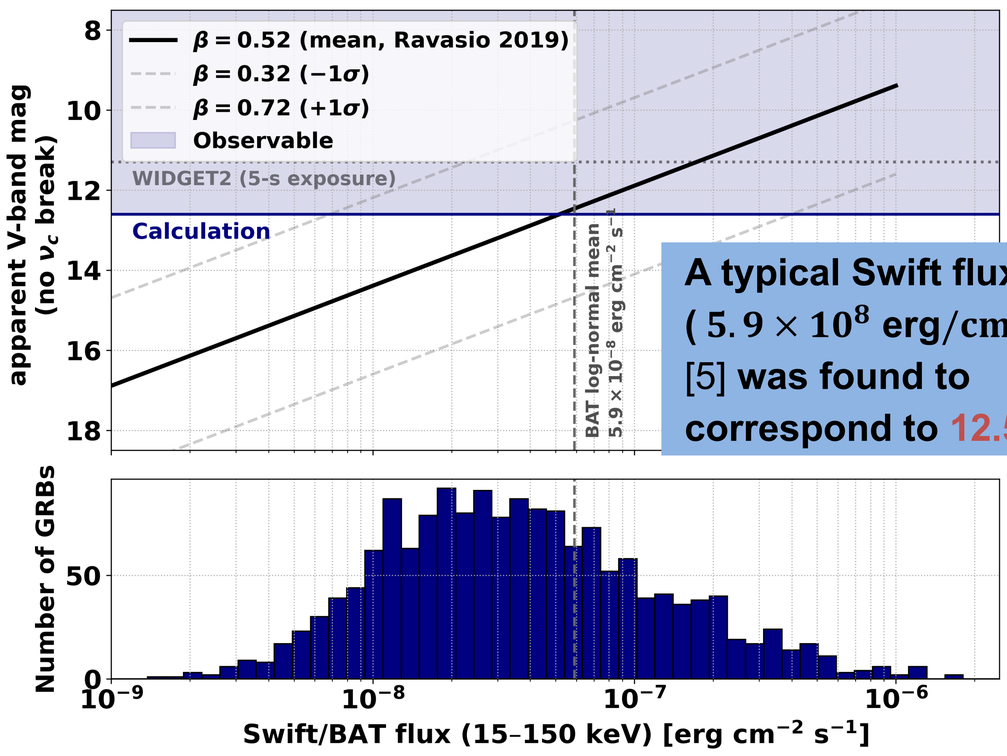


This image captured at an altitude of ~30 km

The balloon reached an altitude of **about 30 km** and successfully captured **over 500 images**. We successfully detected stars as faint as **magnitude 5.06**.

4. Ground-based Sensitivity and Expected Performance

Calculation of Required Sensitivity



A typical Swift flux (5.9×10^{8} erg/cm^2/s) [5] was found to correspond to 12.5 mag.

Design of the Ground-based Instrument

	WIDGET2 [6]	KaGErOFU
Observation Strategy	Fixed Wide-field	**Pre-follow-up Einstein Probe, Fermi etc.**
Limiting Mag	11.3	**12.6**
Field of view	3600 deg^2	**~ 3000 deg^2 (Our goal)**

We aim to elucidate GRB emission mechanisms via simultaneous X-ray, gamma-ray, and optical observations.

5. Summery & Prospects

- The KaGErOFU project aims to observe rare optical flashes during the prompt emission phase of GRBs using both **balloon experiments** and **ground-based instruments**.
- The balloon experiment was conducted as a proof-of-concept.
  It ascended to an altitude of approximately **30 km** and detected stars as faint as **magnitude 5.06**.
- Using the spectral index α_2= 1.52 from Ravasio *et al.* (2019), we calculated that **a typical GRB flux corresponds to an optical magnitude of 12.5**.
- We aim to elucidate GRB emission mechanisms by constraining jet parameters through simultaneous ground-based optical and satellite observations of typical GRBs.

<References>
[1] Racusin *et al*., 2008, *Nature*, 455, pp183−188. [2] Sari & Piran, 1999, *ApJ*, 519, pp17−20. [3] Akerlof *et al.,* 2000, *The Astrophysical Journal*, 532, pp 25-28. [4] Ravasio *et al*., 2019, *Astronomy & Astrophysics*, 625, A60. [5] Lien *et al.,* 2016, *ApJ,* 829, 7. [6] Urata *et al.,* 2010, *PASJ,* 63, pp137-146.