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

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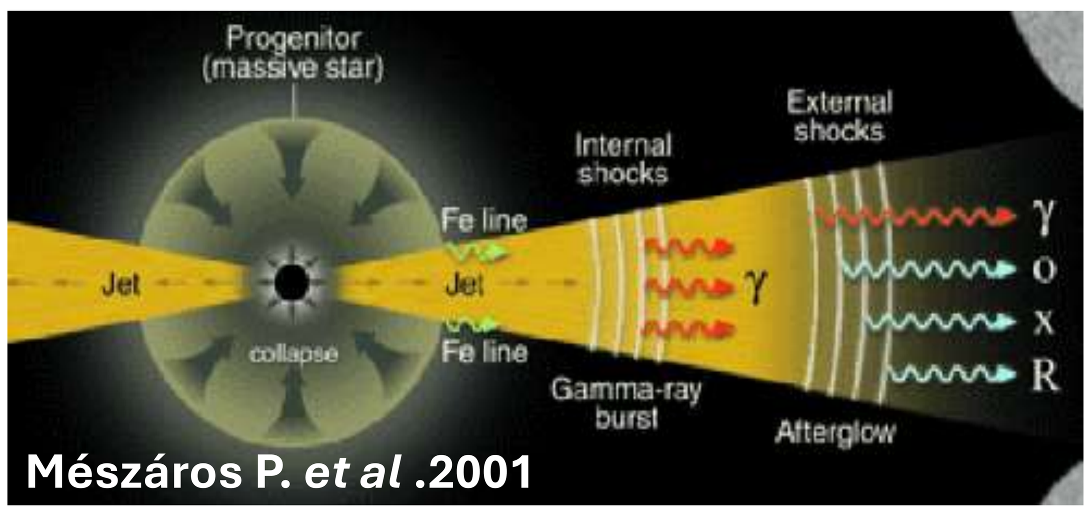
1. background

➢ **Gamma-ray burst GRB**

○ properties
- Extremely high-energy explosion ~10^{52}erg
- Transient event
- Observable across multiple wavelengths



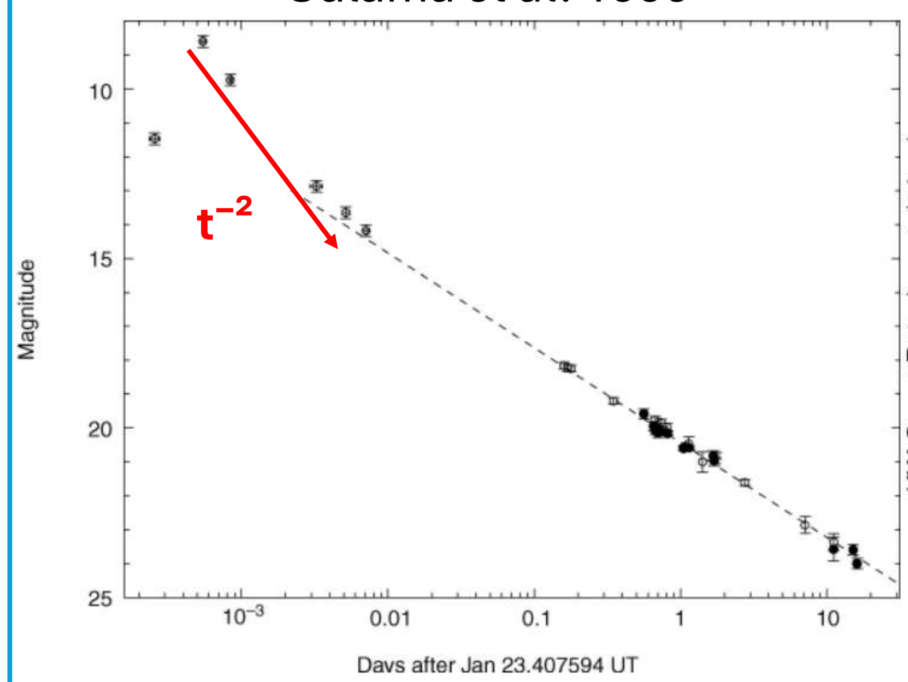
Mészáros P. *et al* .2001

○ Radiation mechanism of prompt emission
- Internal shock model
- Photospheric model

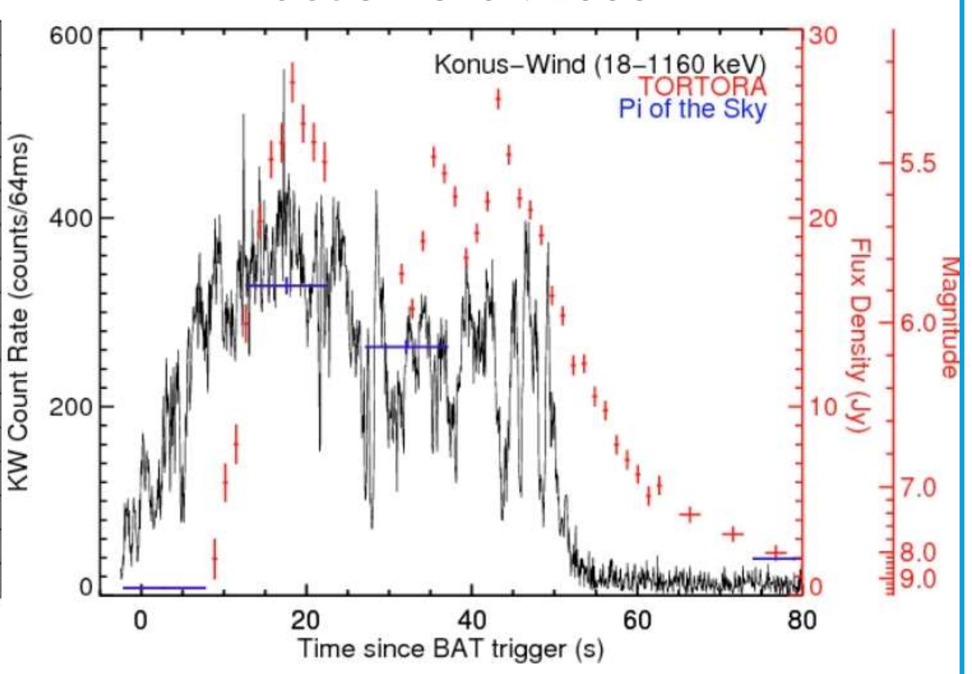
polarization observations of gamma rays ⇒ the internal shock model ?
certain spectra remain unexplained ⇒ investigate with multi-wavelength

➢ **Optical flash**
- Rare optical event during the prompt emission
- The origin theory is competed
  Synchrotron emission or Reverse shock during initial afterglow

GRB 990123 Light Curve
Galama *et al*. 1999



GRB 080319B Light Curve
Racusin *et al*. 2008



- $\propto t^{-2}$
- reverse shock during initial afterglow

- Strong correlation with gamma ray
- Synchrotron emission during prompt emission

Constraints on theoretical models from early optical emission

2.KaGErOFU

Kanazawa University Gamma-ray Burst Explorer for Optical Flash Understanding

➢ **Spin-off from the MeV gamma-ray galactic plane survey project SMILE-3**
⇒ Application from subsystems to mission equipment

➢ **Mission goal**

Multiple star camera systems are mounted on a super-pressure balloon, and aim to observe several examples of optical flash

○advantage

Compared to ground observations:
- Ascends to altitudes of 20 to 50 km
- Atmospheric effects reduced to less than 5%
- Not affected by ground weather conditions

Compared to satellite observations:
- Reduced cost and operational resources
- Capable of long-duration observations

○Objective of development

⇒Poster 97 : Study on Piggyback Balloon Experiment of Star Camera System for SMILE-3 Project

3.Star camera BBM

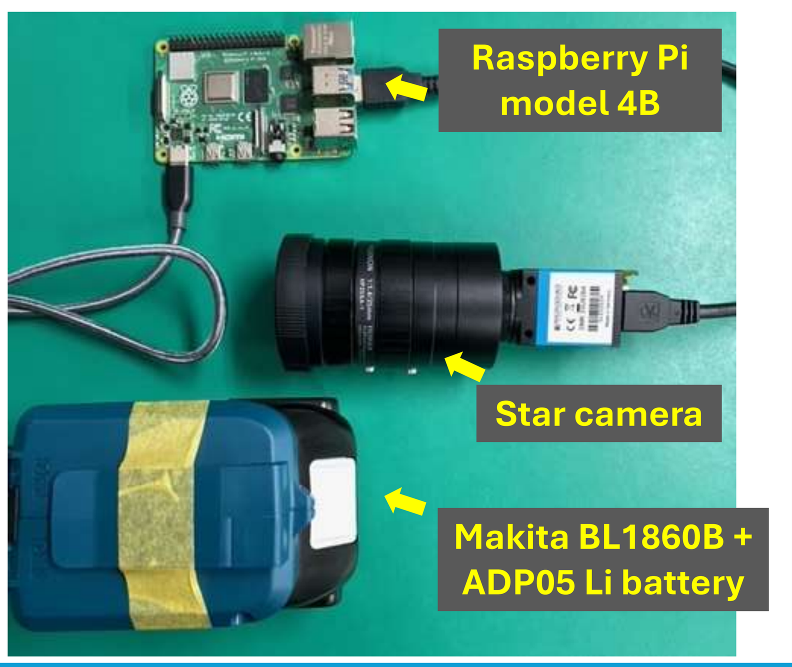
➢ **Sencer and lense**


- 2/3" Sony CMOS Pregius IMX264sencer
  The Imaging Source DFK33UX264
- sencer size：8.4456mm×7.0656mm
  (2448pix×2048pix)

https://www.argocorp.com/cam/usb3/tis/DxK33UX264.html


- FUJINON HF25SA-1
- aperture：50mm
- focal length：25mm

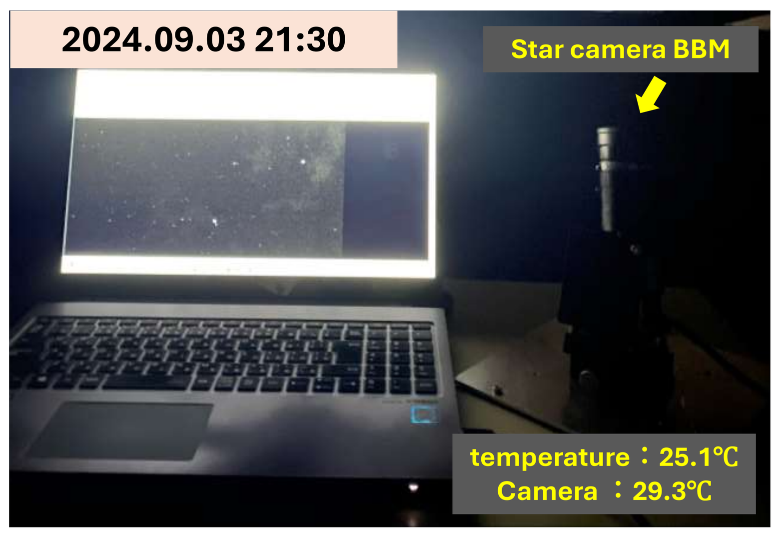
https://www.fujifilm.com/jp/ja/business/optical-devices/mvlens/hfsa#model02



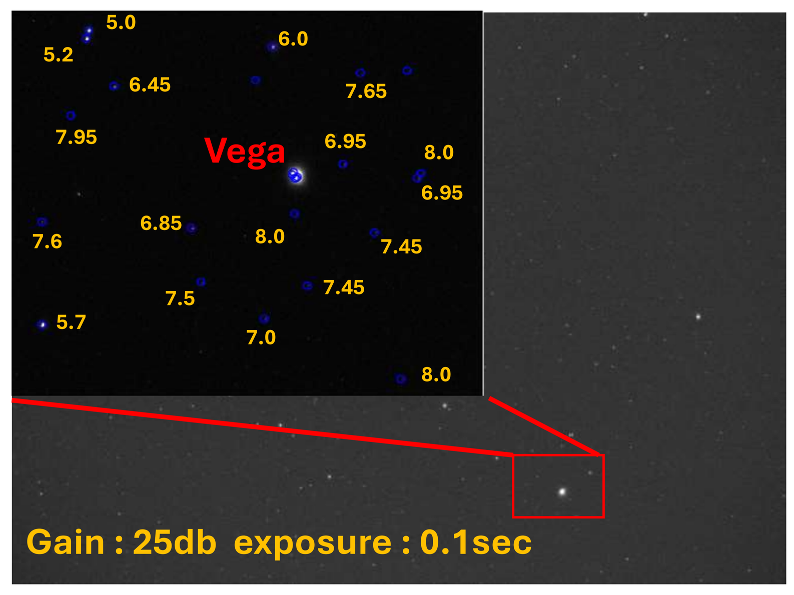
4.Gound test for evaluating imaging performance

➢ **Night observation**

○Investigation of the feasibility of imaging a 7th magnitude star
- Captured with varying exposure
- targeting Vega in the field of view on the rooftop of Kanazawa University.



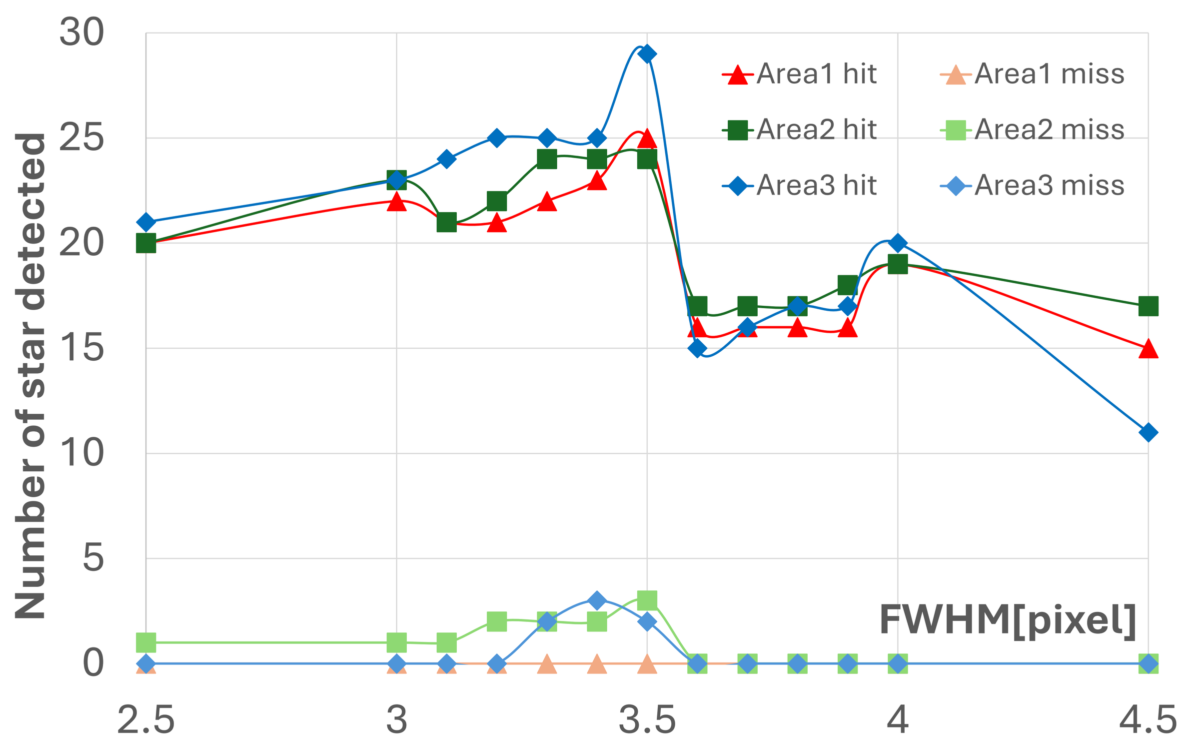
After confirming the position of Vega using the Windows camera viewer software, the image was captured using BBM



➢ **Star extraction**

○Using DAOStarFinder from photutils
Set the threshold for identifying stars and the Full Width at Half Maximum (FWHM) to define the spread of pixels considered as a star.

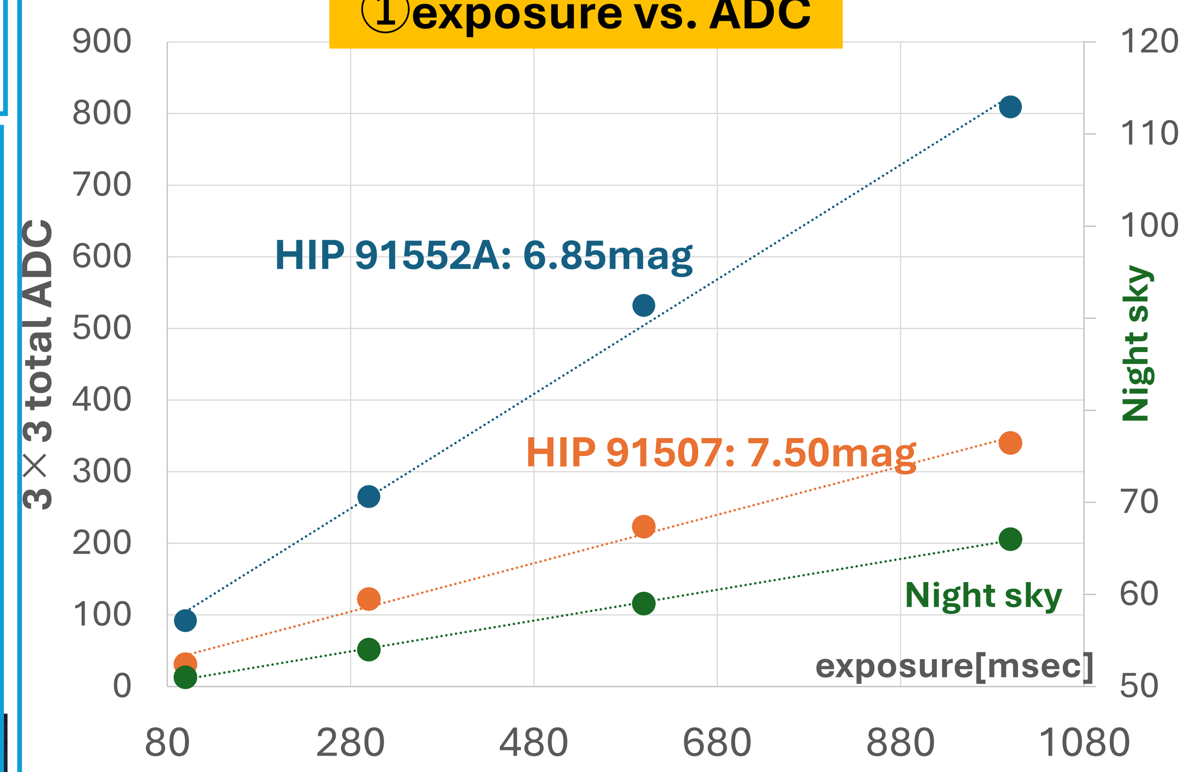
○Analysis flow
1. Calculate the median within 5σ of the ADC distribution to estimate night sky
2. Subtract night sky and use DAOStarFinder
3. Compare the extracted stars with the constellation software Stellarium



➢ **Imaging performance**

○3×3 photometry on the extracted stars

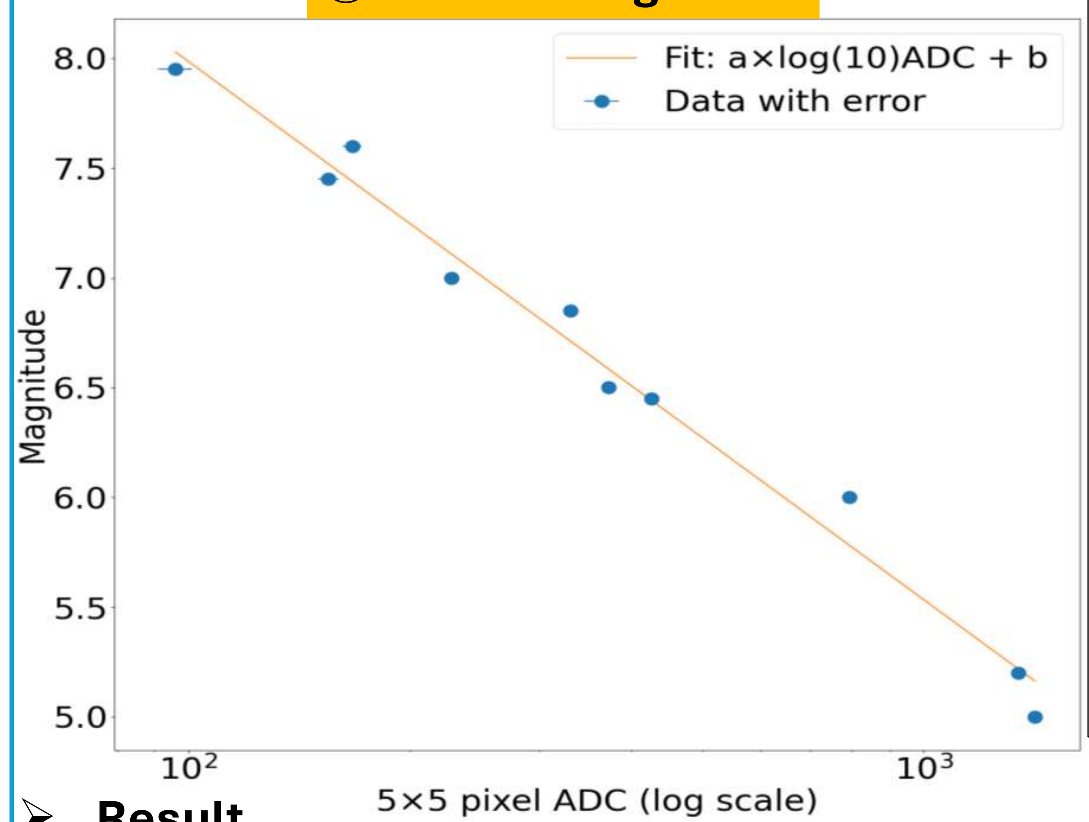
①exposure vs. ADC



- Radiant flux from the star
  fv = [erg / cm^2 / Hz / sec]
  ⇓
  Verify the linearity of the signal with exposure
- The star signal is sufficiently identified from the night sky
  ⇓
  Achieve the target sensitivity within the exposure limit

○5×5 photometry on the extracted stars

②ADC vs magnitude



- The relation between magnitude and Radiant flux

Magnitude = -2.5 $\log_{10}$ fv -48.6

fv and ADC are commutative

Magnitude = a × $\log_{10}$ADC + b

Fitting by this equation

a = -2.45 ± 0.115
b = 12.89 ± 0.298
⇓
The ADC dependence follows literature magnitudes

➢ **Result**
- Photometric performance of the star camera BBM is consistent with radiant flux determined by AB magnitude within 0.2 magnitude under room temperature and atmospheric pressure .
- Detection of stars up to approximately magnitude 9 has been confirmed. This suggests the possibility of detecting optical flashes, such as those observed in past GRBs (e.g., GRB 990123: ~10 mag, GRB 080319B: ~5.5 mag)

5.Summary and future

The KaGErOFU, developed as a scientific extension of the star camera subsystem from the SMILE-3 experiment, has been initiated. Ultimately, the goal is to mount multiple camera systems on a super-pressure balloon and observe several examples of optical flashes. For principle validation, a piggyback test using only the star camera system is planned for the next fiscal year. This test will investigate the overall system's operational performance at balloon altitude and evaluate the limiting magnitude due to scattered light from Earth. At present, it has been confirmed that, under room temperature and atmospheric pressure conditions, the photometric performance of the star camera BBM is consistent with radiant flux determined by AB magnitude within 0.2 magnitude, and cover the magnitudes of past optical flashes. In preparation for the piggyback test, we plan to fabricate an electronics board for the automated imaging system and conduct thermal-vacuum tests on the system. A matching script using the Hipparcos Catalogue is under development, with the goal of achieving direction determination accuracy of less than 0.5° for the camera's central field of view.