OPTICAL VARIABILITY OF BLAZARS IN THE TOMO-E GOZEN NORTHERN SKY TRANSIENT SURVEY

Zhang TianFang (D1)

Institute of Astronomy
The University of Tokyo

5/10/2021

Contents

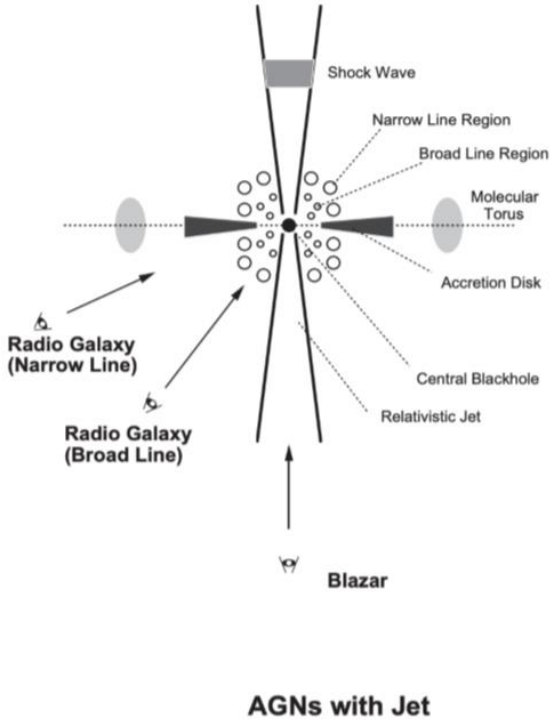
Data source: Tomo-e Gozen, SDSS, Pan-STARRS, Fermi/LAT

Contents

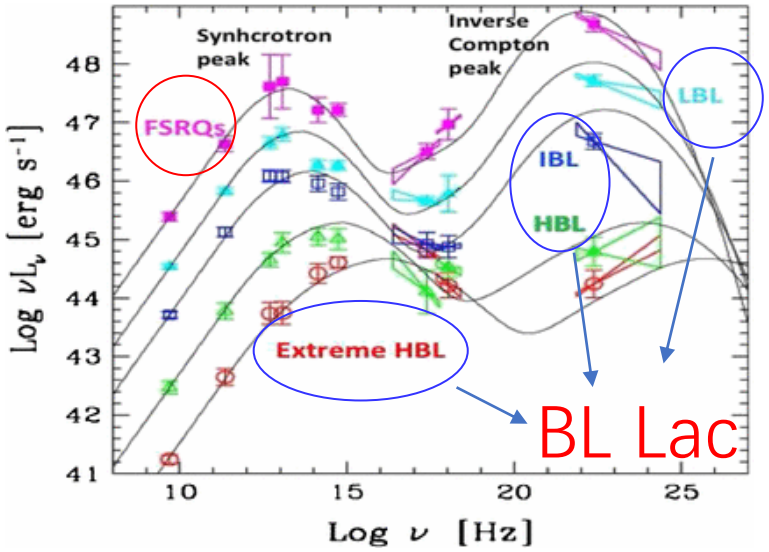
Blazars

A blazar is an active galactic nucleus (AGN) with a relativistic jet directed closely towards an observer.

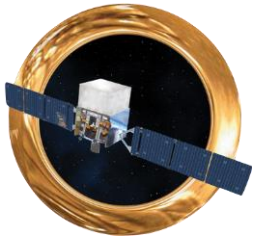
Blazar type	Synchrotron peak frequency	Accretion disk emission line
BL Lac	High(some >10^{16}Hz)	faint
Flat-spectrum radio quasar (FSRQ)	Low(<10^{15}Hz)	strong



Kataoka Ph.D. thesis (2001)

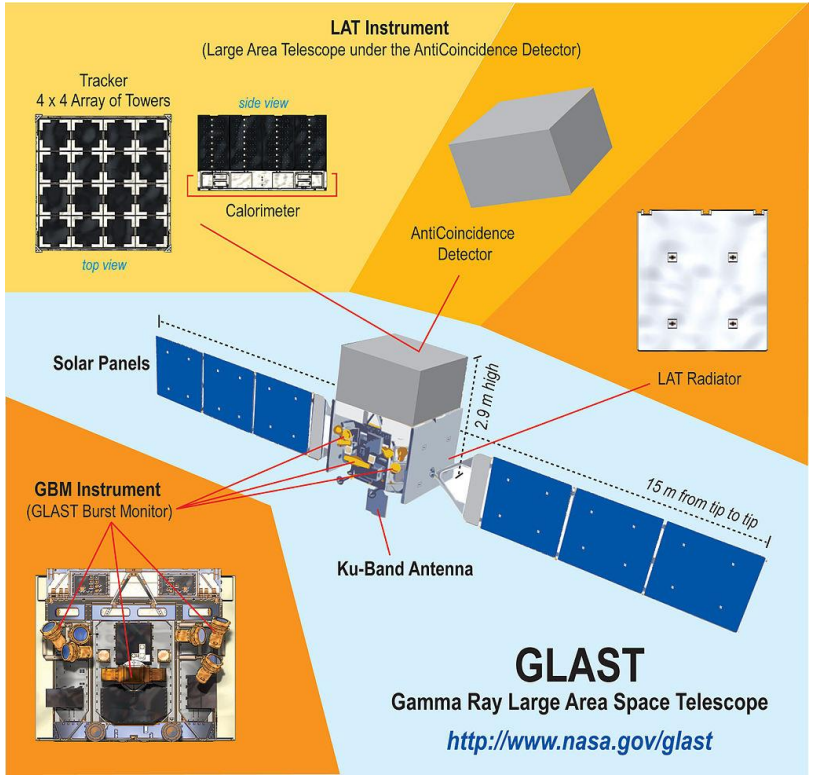


Fossati et al. 1998



Blazar Source – 4FGL Catalog

- The Large Area Telescope (LAT) on board NASA's Fermi Gamma-ray (50 MeV to 1 TeV energy range) Space Telescope.
- Produce LAT 8-year (August 4, 2008, to August 2, 2016) Source All sky survey Catalog (4FGL).

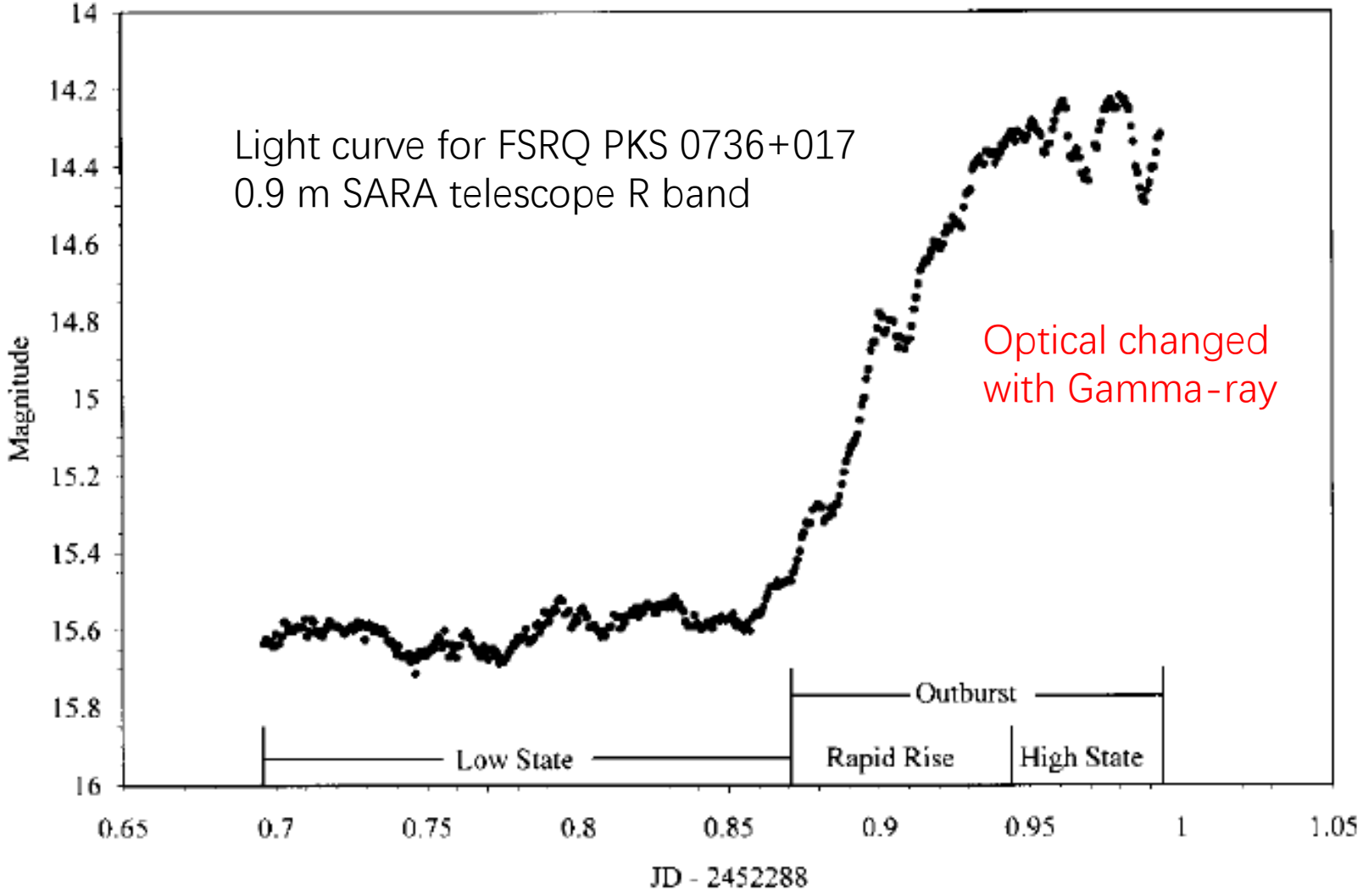


Variable source

Description	Identified		Associated	
	Designator	Number	Designator	Number
Pulsar, identified by pulsations	PSR	232	...	...
Pulsar, no pulsations seen in LAT yet	...	...	psr	7
Pulsar wind nebula	PWN	11	pwn	6
Supernova remnant	SNR	24	snr	16
Supernova remnant / Pulsar wind nebula	SPP	0	spp	78
Globular cluster	GLC	0	glc	30
Star-forming region	SFR	3	sfr	0
High-mass binary	HMB	5	hmb	3
Low-mass binary	LMB	1	lmb	1
Binary	BIN	1	bin	0
Nova	NOV	1	nov	0
BL Lac type of blazar	BLL	22	bll	1109
FSRQ type of blazar	FSRQ	43	fsrq	651
Radio galaxy	RDG	6	rdg	36
Non-blazar active galaxy	AGN	1	agn	10
Steep spectrum radio quasar	SSRQ	0	ssrq	2
Compact Steep Spectrum radio source	CSS	0	css	5
Blazar candidate of uncertain type	BCU	2	bcu	1310
Narrow-line Seyfert 1	NLSY1	4	nlsy1	5
Seyfert galaxy	SEY	0	sey	1
Starburst galaxy	SBG	0	sbg	7
Normal galaxy (or part)	GAL	2	gal	1
Unknown	UNK	0	unk	92
Total	...	358	...	3370
Unassociated	...	...	...	1336

S. Abdollahi (2020)

Blazar Optical Variability



Clements et al. 2002

Blazar Optical Variability

https://en.wikipedia.org/wiki/Samuel_Oschin_telescope

Previous Survey: Palomar-QUEST Survey

Telescope: Samuel Oschin telescope

Diameter: 48-inch

Sensor type: CCD camera

Field of view: 16.6 degree^2

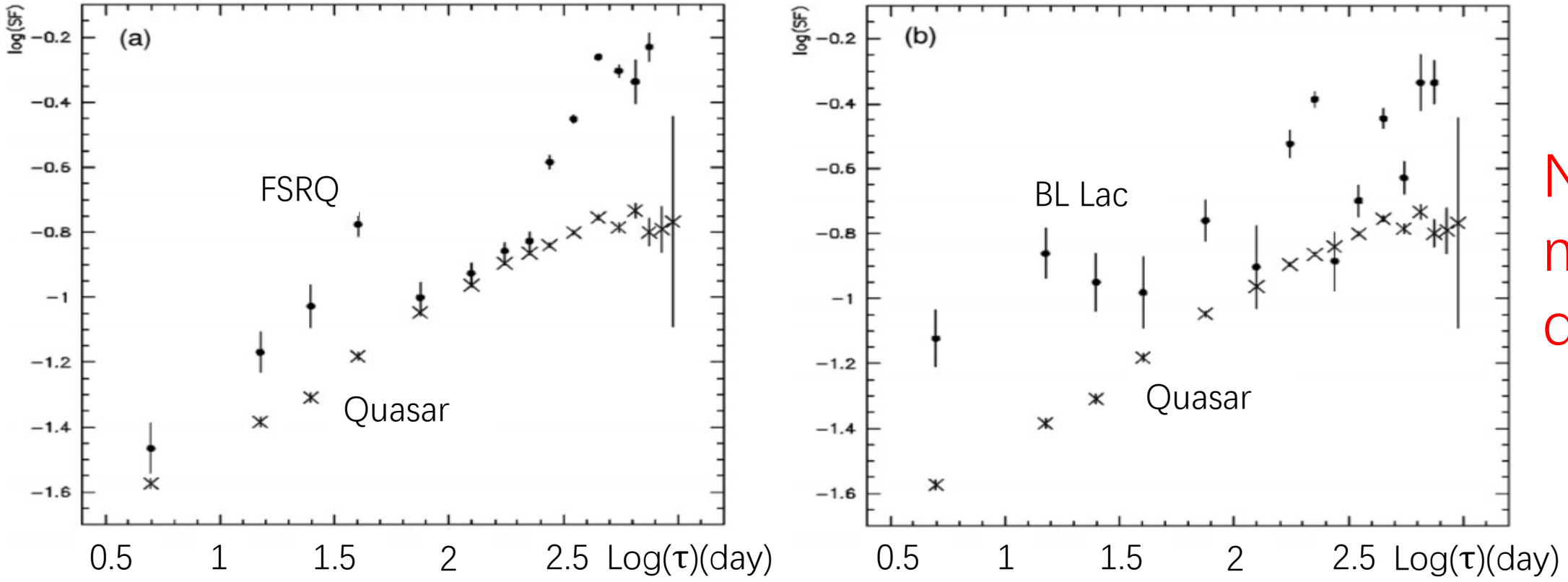
Filters: Johnson UBRI and SDSS *r'I'z'*

Observation period: 2007-2009

Blazar Optical Variability - Structure Function

To determine the temporal characteristics of the luminosity variability!

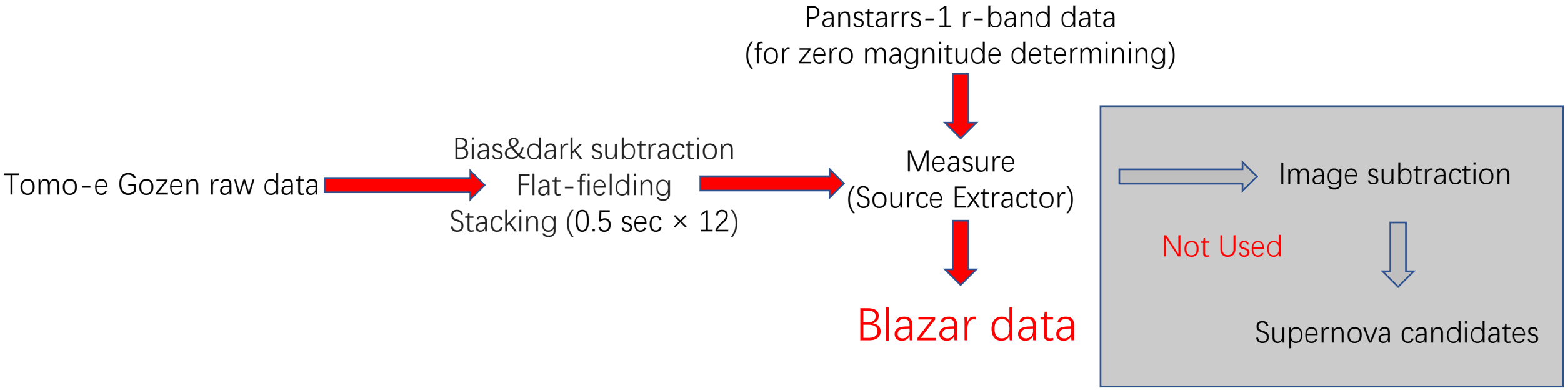
$$\mathrm{SF}(\tau) = \sqrt{\langle [m(t) - m(t-\tau)]^2 \rangle - \langle \sigma_{sn}^2 \rangle} \quad \sigma_{sn} = \sqrt{\{magerr(t)^2 + magerr(t-\tau)^2\}}$$



Need more data!

Bauer et al. 2009 (with Palomar-QUEST Survey)

Tomo-e Gozen Pipeline



Not specially designed for measurement optical variability.

Need to verify its photometry!

Developed by Osawa et al. for data reduction and Morokuma et al. for supernova search.

Contents

Standard Star Catalog

Standard Star Catalog from Ivezic et al. 2007

From STRIPE 82 (RA from 20:00h to 4:00h, DEC from -1.26° to +1.26°), a 300 deg^2 equatorial field of the sky that was scanned multiple times by the Sloan Digital Sky Survey from 2000 to 2008

Magnitude range : 14~22 in 5 bands (ugriz)

Total number : 991472 stars

Used in this research : 302740 stars

Tomo-e Gozen Used Data

Parameter	Range
Observation Date	31/8/2019~28/5/2021
Magnitude (based on SExtractor MAG_AUTO)	14~19 mag
Limiting magnitude (5 sigma)	16~19 mag
Zero magnitude (the magnitude for 1-count signal with 1 second of exposure. depending on weather etc.)	24~25.6 mag
Position in fits	Edge 10 pixel excluded

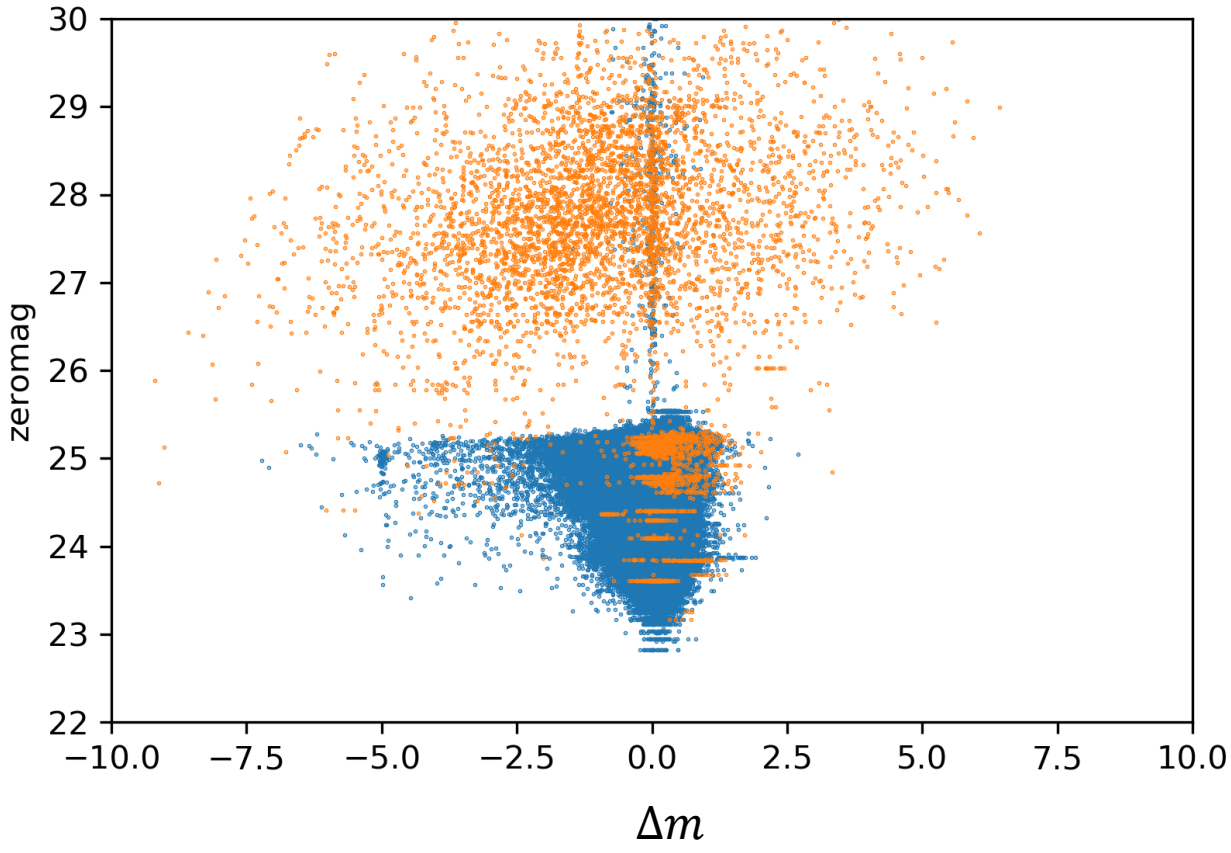
Data Selection

$$\Delta m = m_t - m_s$$

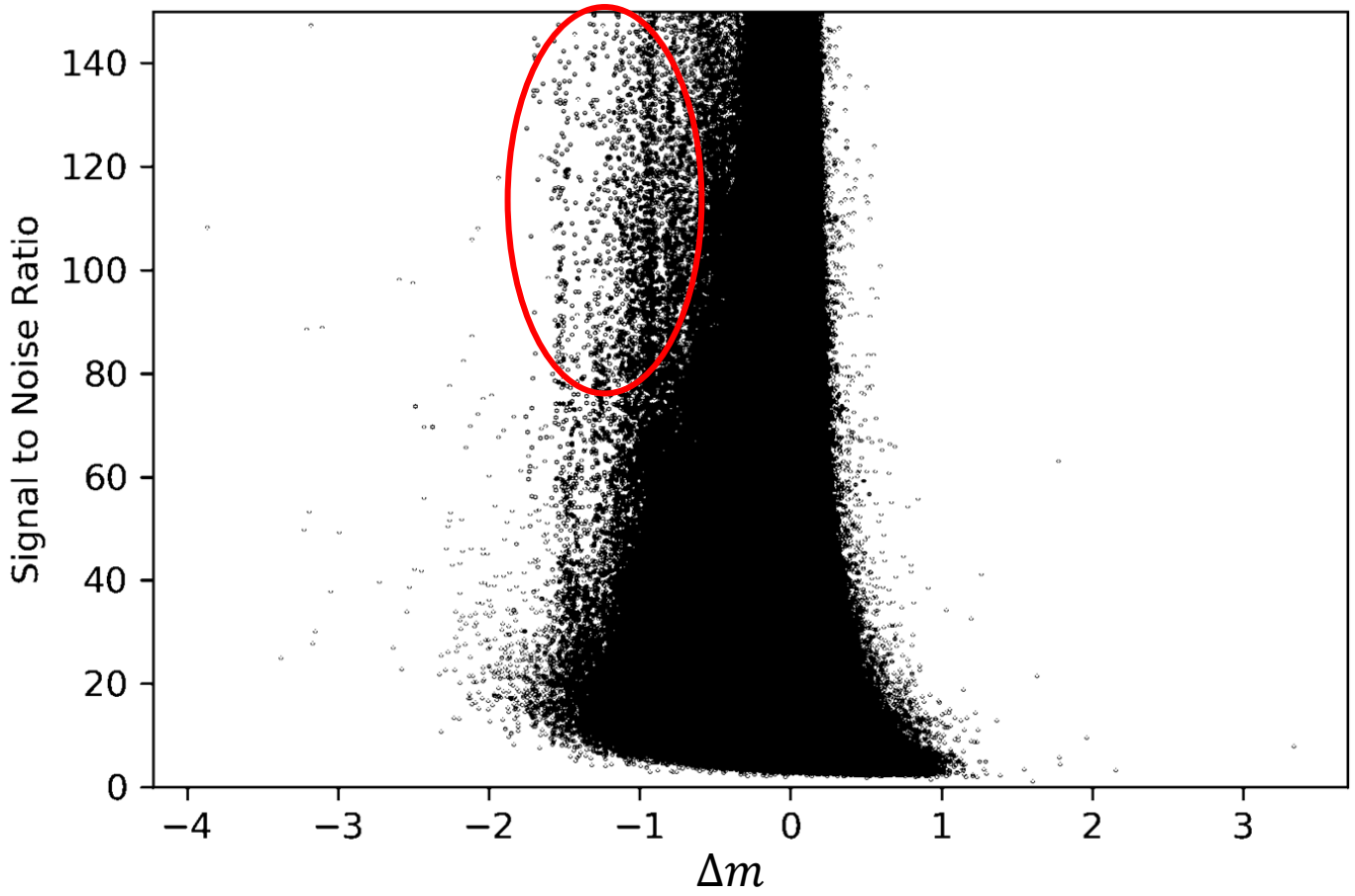
m_t: magnitude from Tomo-e Gozen

m_s: standard star catalog magnitude

If the average Δm of all SDSS standard stars in the same frame is greater than ± 0.3 mag, mark that frame as "Error Frame".



Data Quality -Signal to Noise Ratio (SNR)

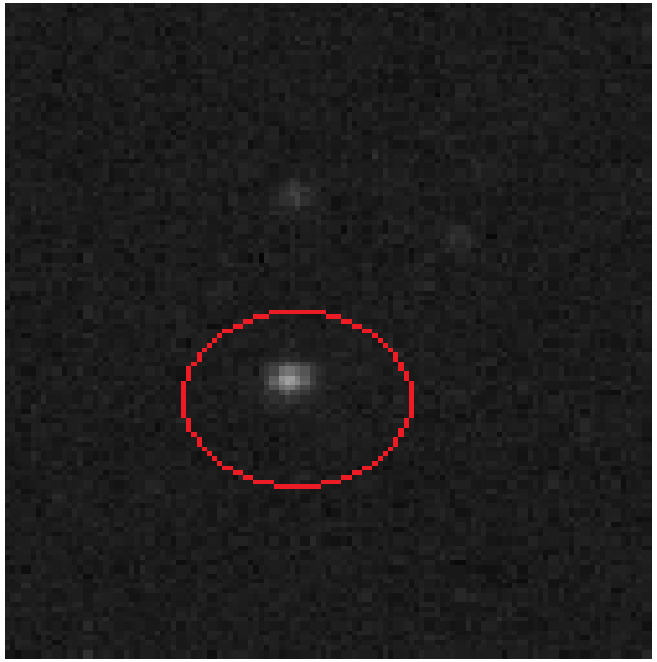


Tomo-e Gozen sometimes incorrectly gives a brighter result.

Double Star

$$\Delta m < \text{-}0.5 \text{ mag}$$
$$\&$$
$$\frac{Standard\ deviation}{\sqrt{(number\ of\ detection)}} < 0.03\ mag$$

⟶ 1274 stars

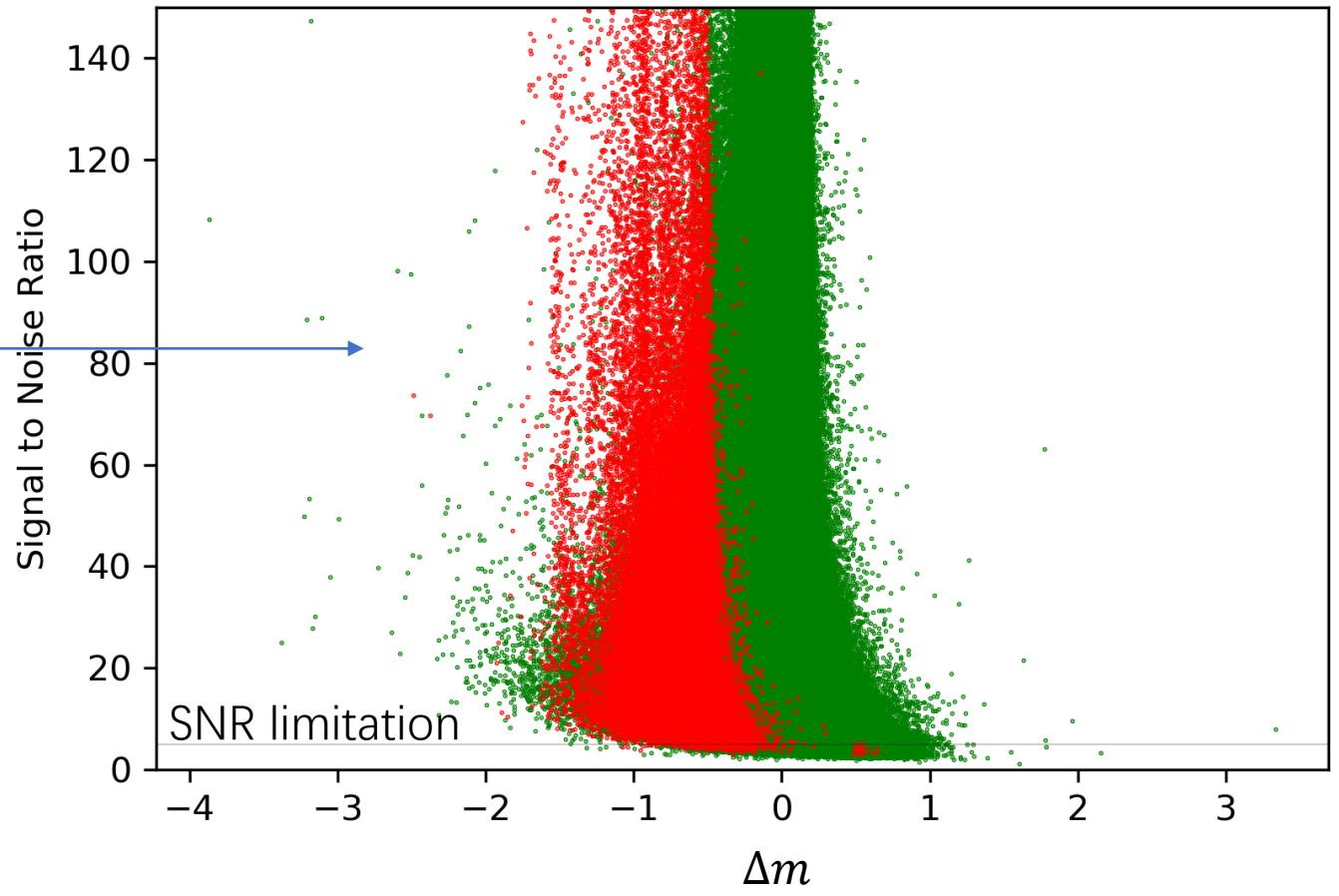


Tomo-e Gozen

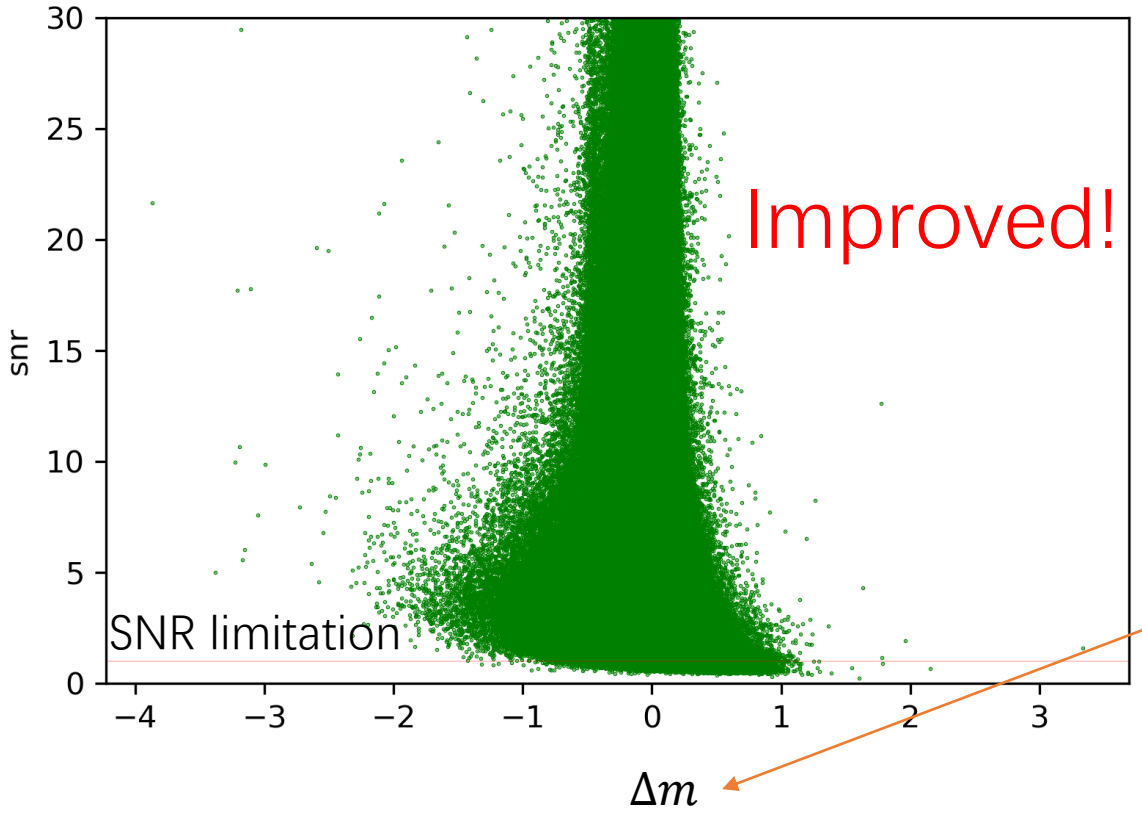
PanSTARRS-1

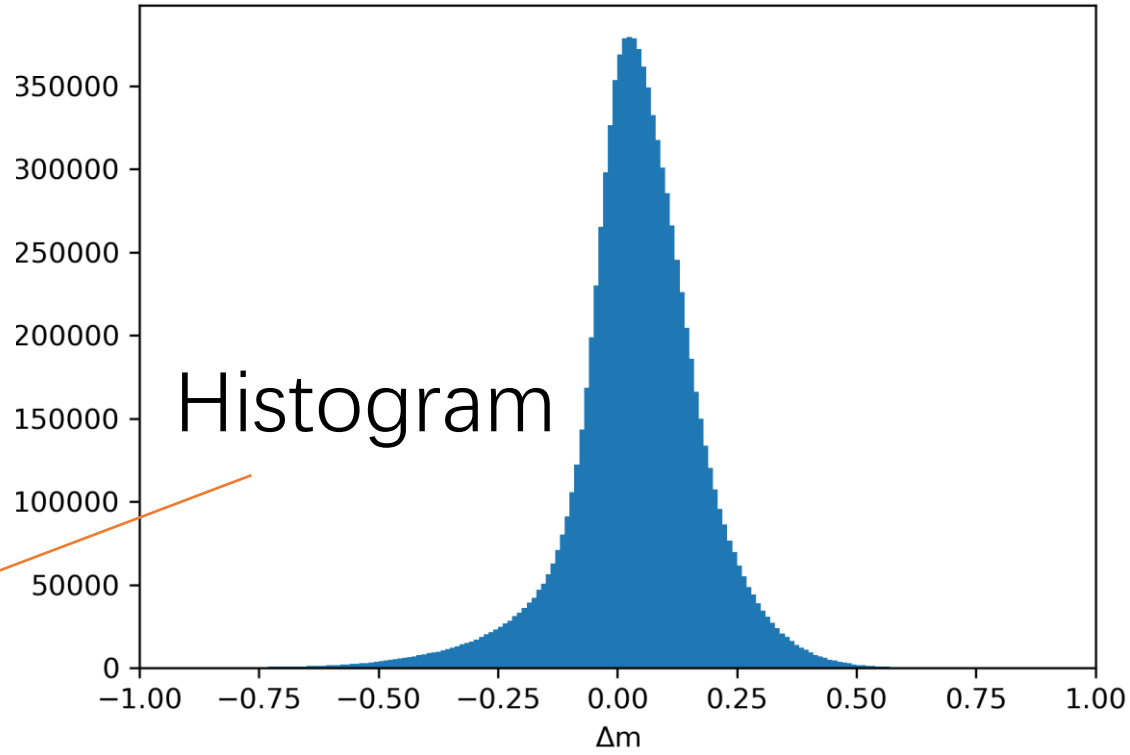
Data Quality -Signal to Noise Ratio

Red points are measured with offsets for double stars. Removed from the sample.



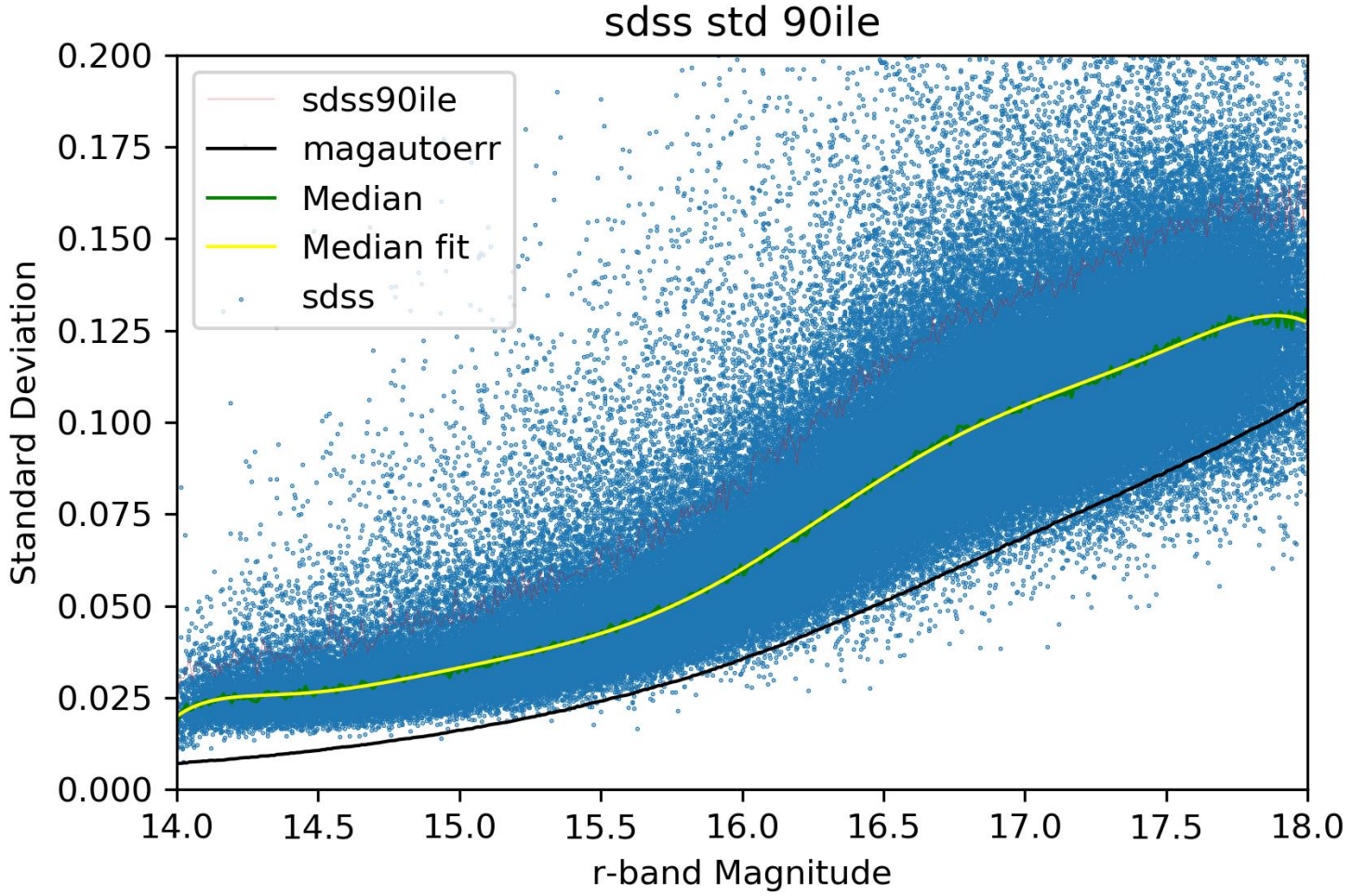
Data Quality – Signal to Noise Ratio





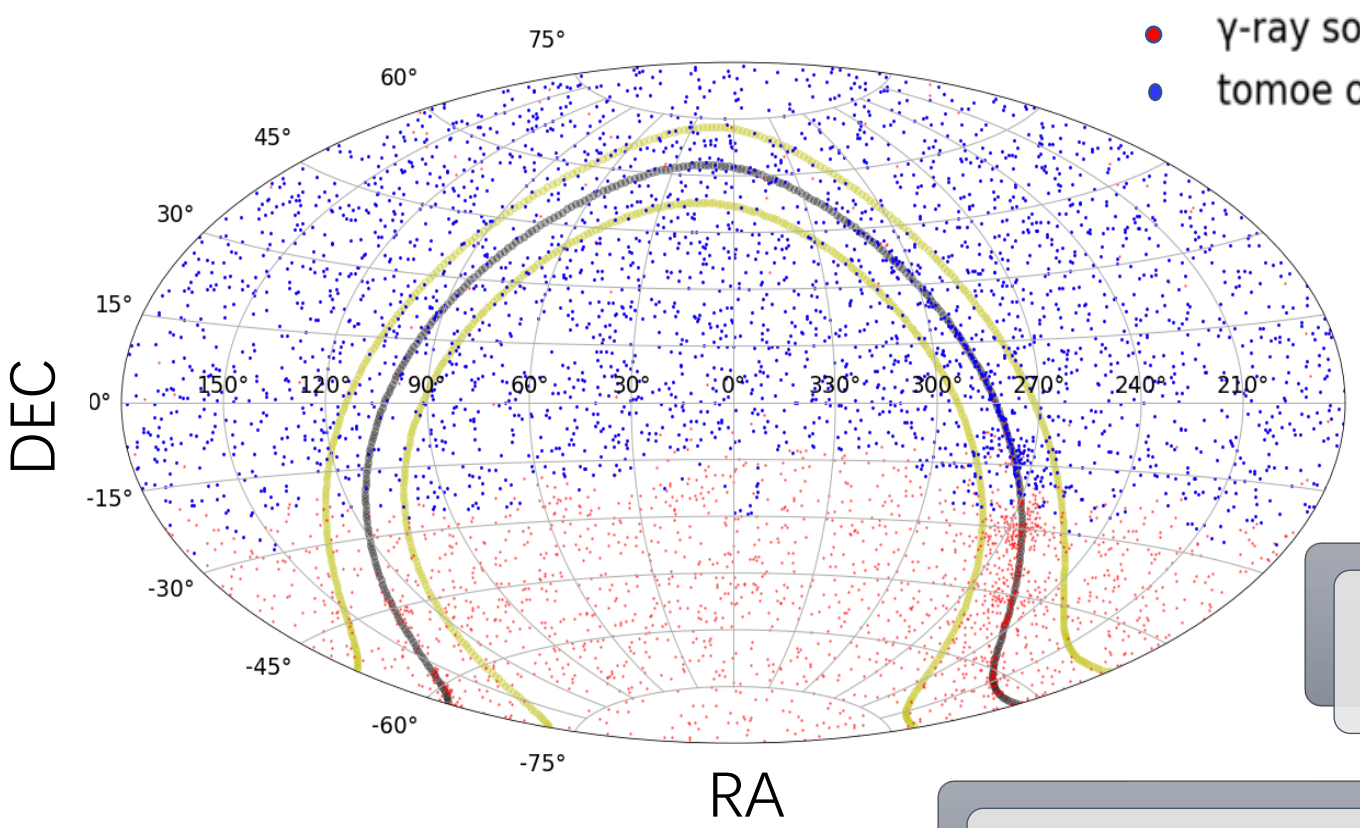
Photometric Errors

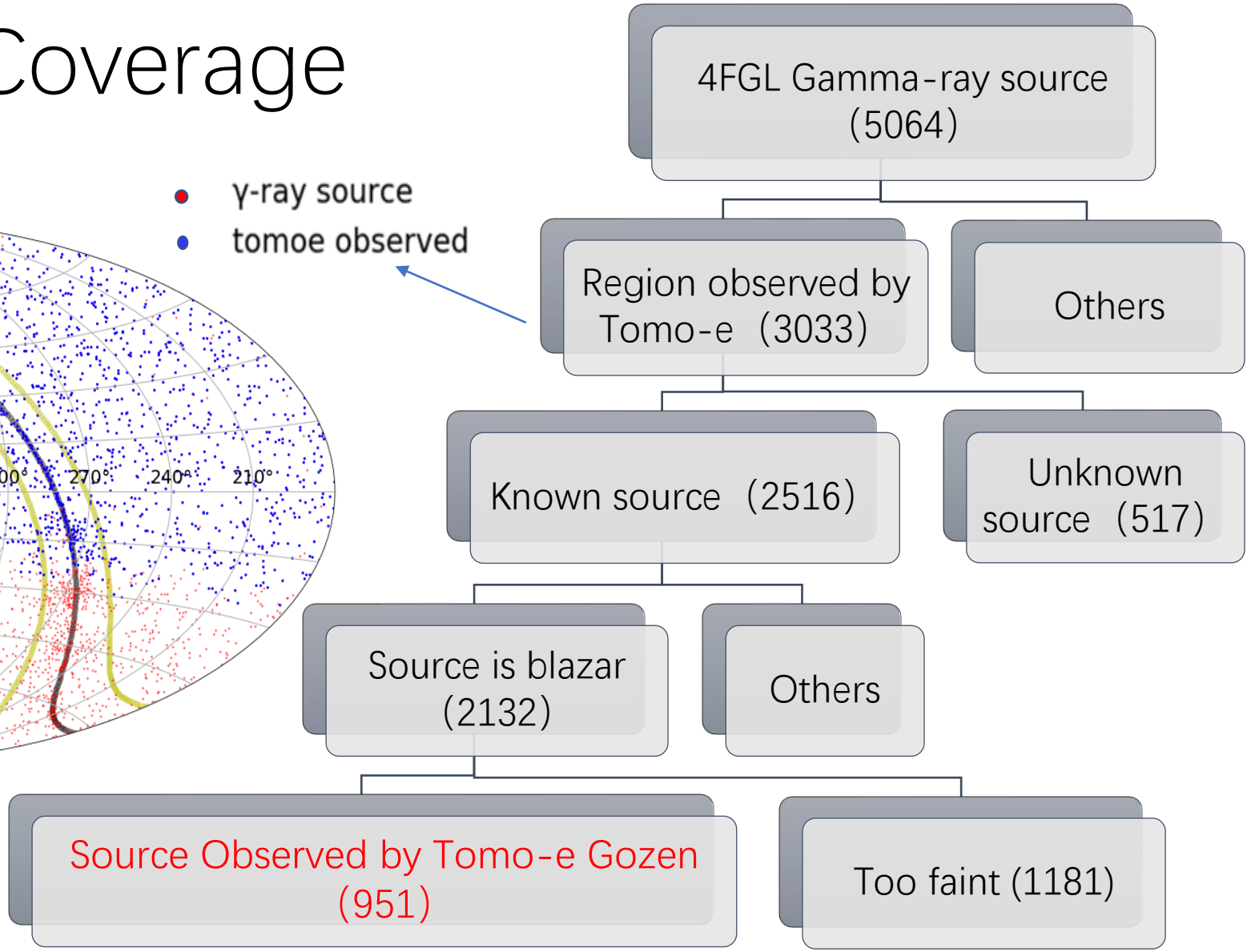
- Blue dots stand for SDSS standard stars (302740).
  - X: the averaged value of magnitude.
  - Y: standard deviation of each detection in magnitude.
- Yellow line is the median of the blue dots.
- Black line represents the average Sextractor magautoerr. Different from the Yellow line due to the zero point determination error and flat-field error?



Contents

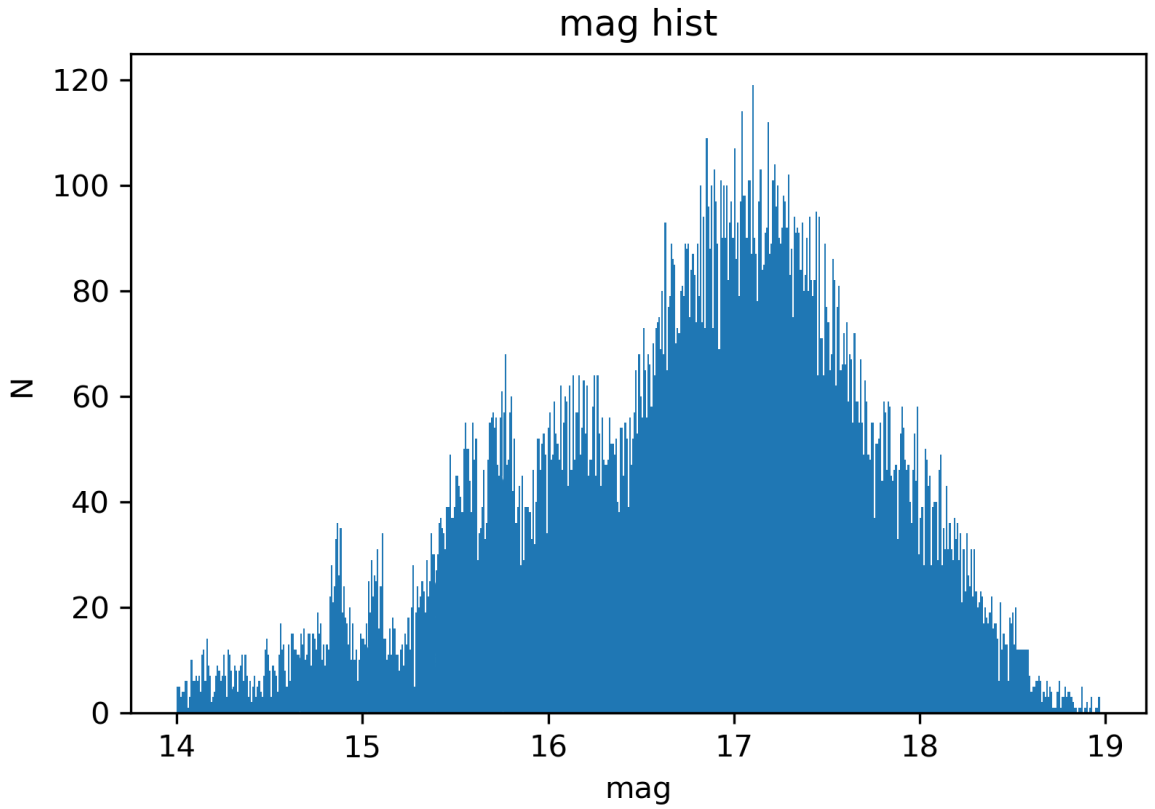
Tomo-e Gozen Coverage



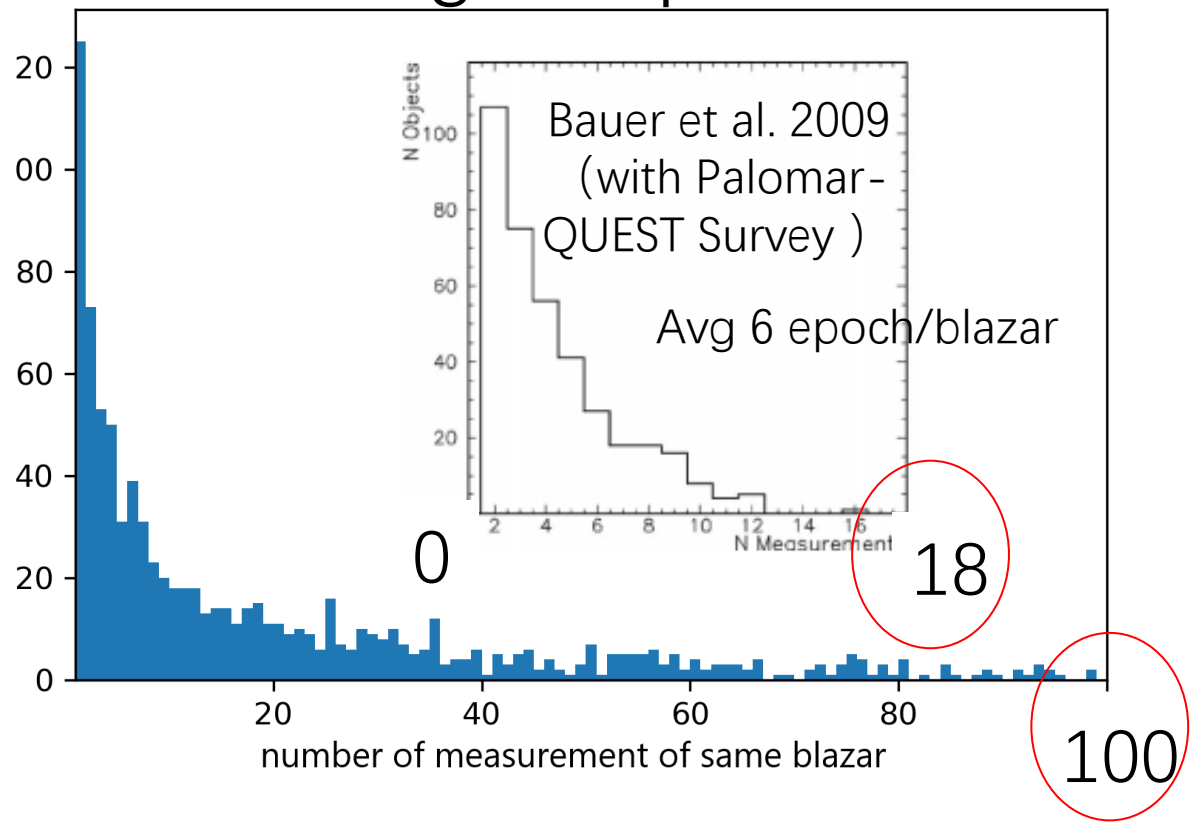


Observed Blazars

951 blazars
25917 epoch
Avg 26 epoch/blazar



Magnitude distribution of Tomo-e Gozen blazar data



More data!!

Contents

Summary

- We used SDSS standard stars (302740 stars with 10094423 epoch) to choose the proper data and pipeline parameters for Tomo-e Gozen.
- We measured optical variability of BL lacs and FSRQs recorded in the 4FGL catalog using Tomo-e Gozen Northern Sky Transient Survey (951 blazars with 25917 epoch).

Thank You