Follow-up Observations of the Various Transients with OISTER

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Yasuyuki Tanaka (Hiroshima Univ. -> MATSUDA)

Tomoki Morokuma (U. of Tokyo), Kouji Ohta (Kyoto Univ.), Ryosuke Itoh (TIT), Yousuke Utsumi (Hiroshima Univ. -> Stanford) Koji S. Kawabata, Hiroki Mori (Hiroshima Univ.) ,

On the behalf of OISTER collaboration

Topics (related to IceCube event) from Optical & NIR groups in this WS

1. OISTER (introducing the telescope/instrument properties, multi –band and –mode ToO follow ups, future prospects) by MY

2. Kanata (`How to read' optical data, polarization?) by Kawabata-san

3. Subaru HSC + FOCAS (Exploring the IceCube event based on the BROS catalog, and constraint on the redshift) by Ohta-san

Topics from MY

1. Introducing the OISTER

2. Exploring the IceCube event using Kanata (detailed matters will be talked by Kawabata-san)

3. Future prospects (Finding & Follow ups w/ Tomo-e Gozen/3.8-m/OISTER)

What’s OISTER ?

Optical and Infrared Telescopes of Synergetics for Education and Research (OISTER)

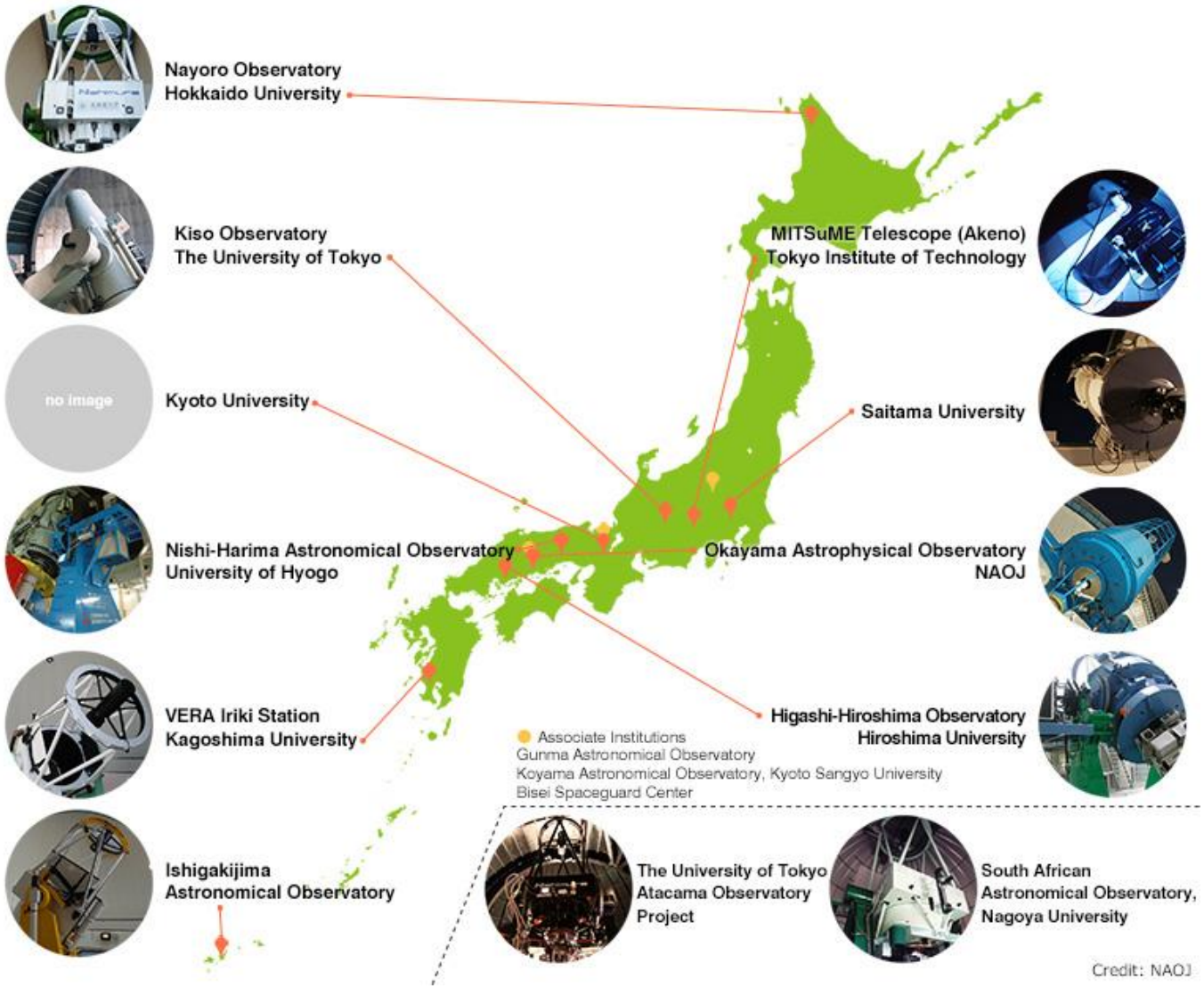
Overalls

- Cooperation among Universities having optical and near-infrared small/intermeridate (0.4 – 2.0m) telescopes
- Seven positions (Postdocs/Assistant prof.) were employed in each University. (MY, on May, 2017)
- An associate prof. (H. Maehara@Kyoto) was employed to summarize the overall among Universities
- First period finished and second began in 2017 (for 5 years)

Scientific goals

- Flexible and immediate follow-ups of transients and variables including the gravitational wave and neutrino events.
- Multi –band and –mode observations using the various instruments
- Participants have right to propose observations (External researchers can join as Co-I)
- 6 ToOs were triggered in 2017-2018 (ongoing for 2 of 6)
- Flexible operation is applied to the current observations

Telescopes


Nayoro Observatory
Hokkaido University
Kiso Observatory
The University of Tokyo
MITSuME Telescope (Akeno)
Tokyo Institute of Technology
no image
Kyoto University
Saitama University
Nishi-Harima Astronomical Observatory
University of Hyogo
Okayama Astrophysical Observatory
NAOJ
VERA Iriki Station
Kagoshima University
Higashi-Hiroshima Observatory
Hiroshima University
Associate Institutions
Gunma Astronomical Observatory
Koyama Astronomical Observatory, Kyoto Sangyo University
Bisei Spaceguard Center
Ishigakijima
Astronomical Observatory
The University of Tokyo
Atacama Observatory
Project
South African
Astronomical Observatory,
Nagoya University
Credit: NAOJ

Telescope/Instrument lists (from North)

Univ.	Observatories	Telescopes	Instruments	Imaging	Spectroscopy	Polarimetry
Hokkaido	Nayoro	1.6-m Pirka	MSI	UBVRI	R=150	Imaging pol.
			NaCS	BVgriz	R=300	
	Gunma	1.5-m	GLOWS	BVRI	R=400-500	
			GAEOS		R=100000	
			GIRCS	JHKs	R=1000	
Saitama		0.55-m SaCRA	MuSASHI	riz		
U. Tokyo	Kiso	1.0-m	KWFC	ugriz		
			Tomo-e Gozen	no (gri, Ha)		
Tokyo tech	Akeno	50cm	MITSuME	g'RI		
	Okayama	50cm	MITSuME	g'RI		
Nagoya	SAAO	1.4-m IRSF	SIRIUS/SIRPOL	JHKs		Imaging pol.
Kyoto		40cm		BVRI		
		3.8-m	KOOLS-IFU		R=600-2000	
U. of Hyogo	Nishi-harima	2.0-m Nayuta	MALLS		R=600-7500	
			MINT	BVRI		
			NIC	JHKs		

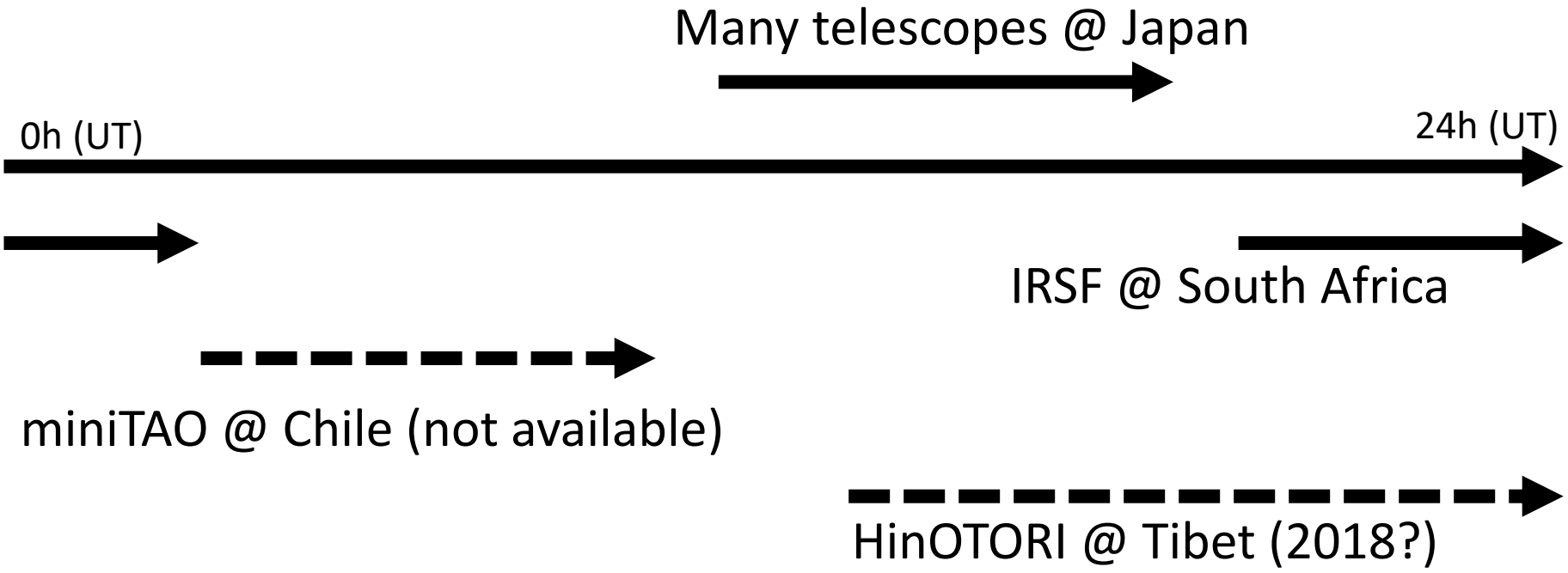
Telescope/Instrument lists

Univ.	Observatories	Telescopes	Instruments	Imaging	Spectra	Polarimetry
Hiroshima	HHAO	1.5m Kanata	HOWPol	BVRIz'+Y	R=400	Imaging pol.
			HONIR	VRI+JHKs	R=600?	Imag/specpol
			HSCAM	BVRI	R=20-150	
Kagoshima	Iriki	1.0m	NIR Cam	JHKs		
NAOJ	Ishigakijima	1.05m Murikabushi	MITSuME	g'RI		

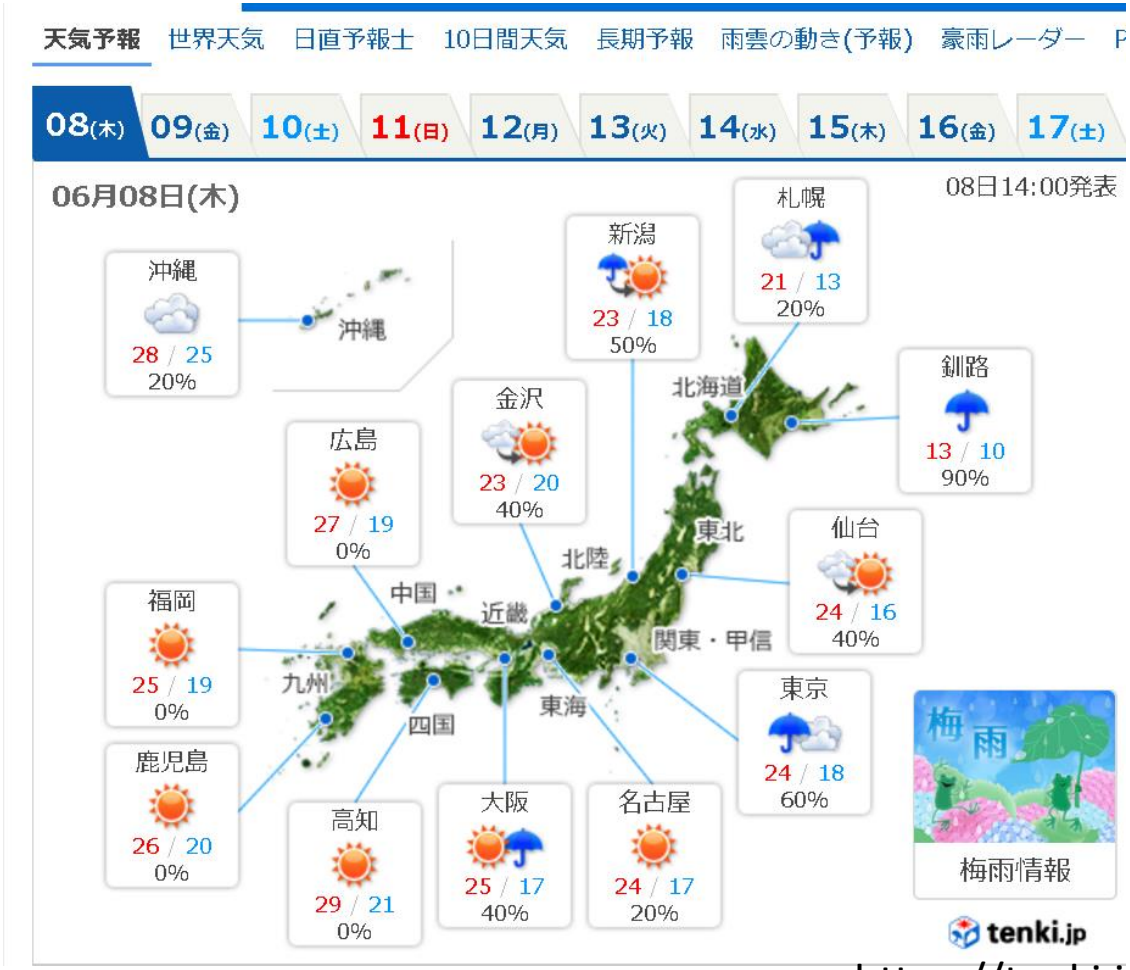
※ 1.0m miniTAO (Tokyo) is not available
※ 3.8m telescope (Kyoto) will have HSCAM on 2019?
※ Kyoto Sangyo Univ (1.3m)., Bisei Space Gard Center also participates.

We can always perform photometry, spectroscopy, and polarimetry in optical and NIR

Timescale (intra-day)



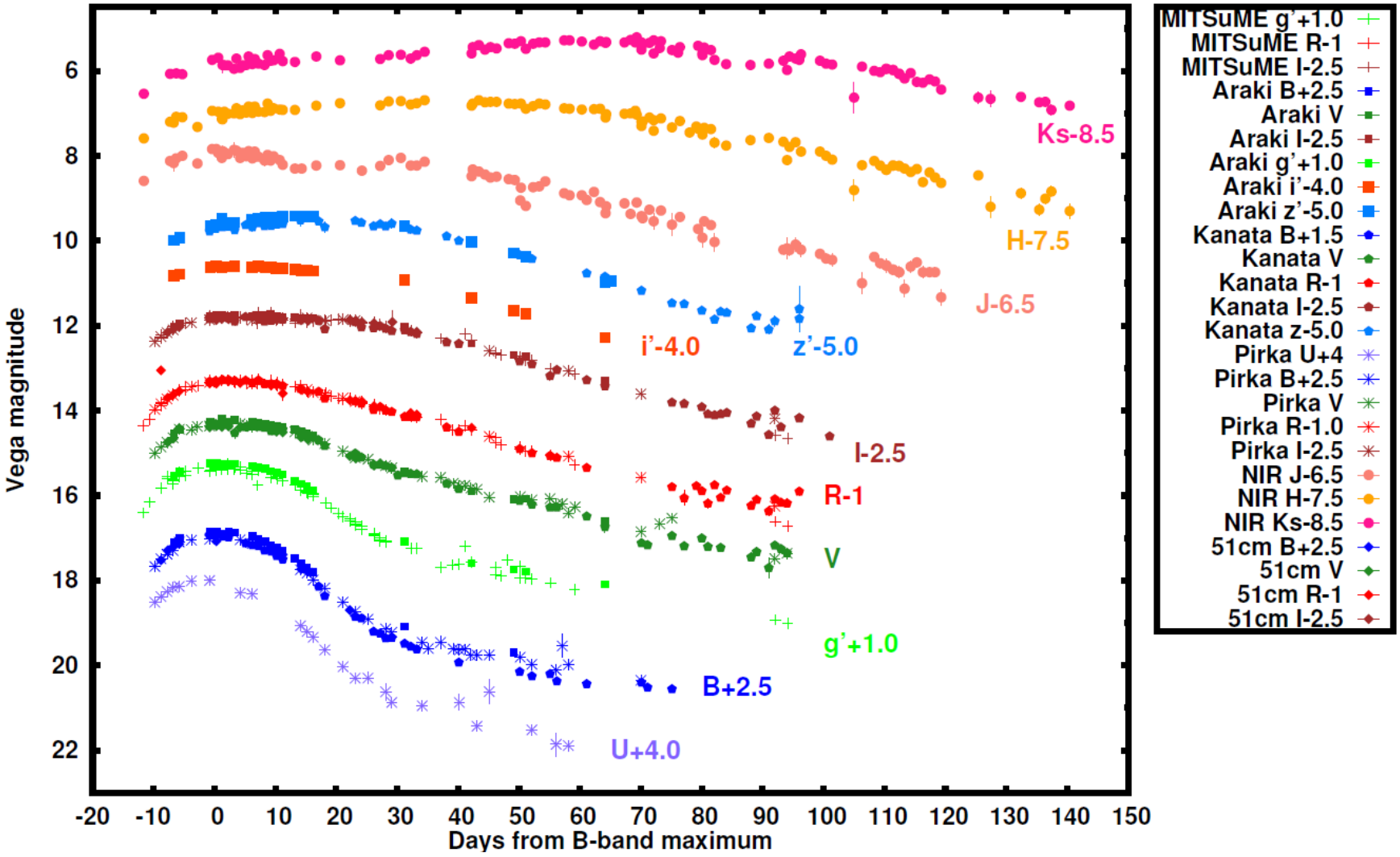
Timescale (inter-day)



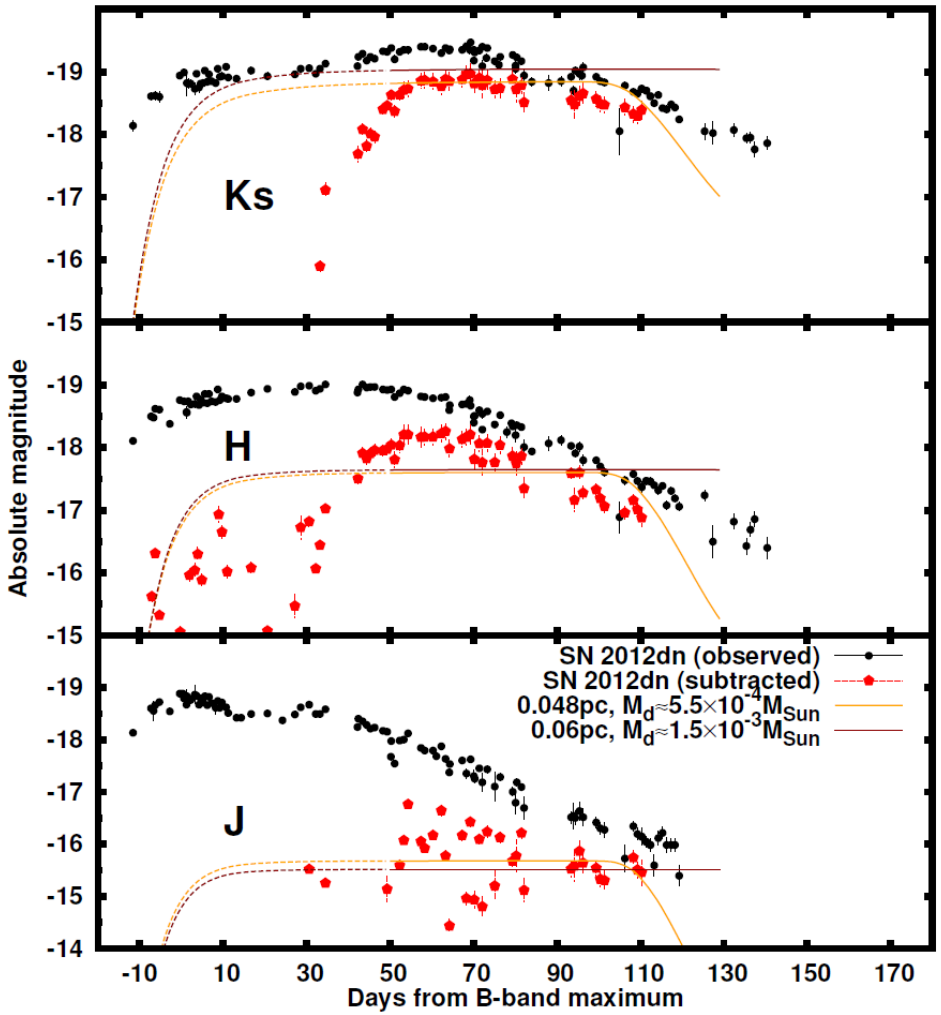
https://tenki.jp

We can avoid the weather risk! (typically shows ~ 1 day delay between Hiroshima and Tokyo)

A science case: Dust emission in peculiar Type Ia SN



A science case: Dust emission in peculiar Type Ia SN



JHKs-band flux of SN 2012dn was subtracted using the SN 2009dc (prototype SC).

We found the **`NIR echo'** (flat evolution of NIR flux), by comparing to the model (Maeda et al. 2015, Nagao et al. 2017, 2018)

Dust locates on **0.48pc** to the SN ejecta. The total dust mass was **$5.5\times10^{-4} M_{Sun}$** assuming the carbon dust

Results from OISTER ToO observations

"Broad-lined Supernova 2016coi with a Helium Envelope", **YM**; Nakaoka, Tatsuya; Tanaka, Masaomi et al., 2017, ApJ, 837, 1

"Measurement of Interstellar Polarization and Estimation of Galactic Extinction for the Direction of X-ray Black Hole Binary V404 Cygni", Itoh, R., Tanaka, Y. T., Kawabata, K. S., et al. 2016, PASJ accepted,

"OISTER optical and near-infrared observations of the super-Chandrasekhar supernova candidate SN 2012dn: Dust emission from the circumstellar shell", **YM**., Maeda, K., Tanaka, M., Tominaga, N., Kawabata, K. S., et al. 2016, PASJ, 68, 68.

"No Evidence of Intrinsic Optical/Near-infrared Linear Polarization for V404 Cygni during Its Bright Outburst in 2015: Broadband Modeling and Constraint on Jet Parameters"
Tanaka, Y. T., Itoh, R., Uemura, M., Inoue, Y., et al.,2016, ApJ, 823, 35.

"Optical and Near-infrared Polarimetry for a Highly Dormant Comet 209P/LINEAR"
Kuroda, D., Ishiguro, M., Watanabe, M., et al. 2015, ApJ, 814, 156.

"OISTER Optical and Near-Infrared Observations of Type Iax Supernova 2012Z"
YM., Maeda, K., Kawabata, K. S., Tanaka, M., Tominaga, N., et al. 2015, ApJ, 806, 191.

"Multi-wavelength Observations of the Black Widow Pulsar 2FGL J2339.6-0532 with OISTER and Suzaku" Yatsu, Y., Kataoka, J., Takahashi, Y., Tachibana, Y., Kawai, N. et al. and OISTER Team,2015, ApJ, 802, 84.

"Dust from Comet 209P/LINEAR during its 2014 Return: Parent Body of a New Meteor Shower, the May Camelopardalids", Ishiguro, M., Kuroda, D., et al.2015, ApJL, 798, L34.

"Variable optical polarization during high state in $¥gamma$-ray loud, narrow-line Seyfert 1 galaxy 1H 0323+342", Itoh, R., Tanaka, Y. T. et al. 2014, PASJ, 66, 108.

"Dense Optical and Near-infrared Monitoring of CTA 102 during High State in 2012 with OISTER: Detection of Intra-night "Orphan Polarized Flux Flare"", Itoh, Ryosuke; Fukazawa, Yasushi; Tanaka, Yasuyuki T. et al. 2013, ApJ, 768L, 24

Follow ups of IceCube transients

Researchers related to IceCube transient follow-ups

Y. Tanaka (Hiroshima U. -> MATSUDA)

-> Fermi, BROS, Subaru, Blazars

T. Morokuma (Tokyo Univ.)

-> OISTER, Kiso(Tomo-e Gozen, KWFC), Subaru/(HSC, FOCAS), AGN, J-GEM

R. Itoh (Tokyo In. of Tech.)

-> Fermi, OISTER, BROS, MITSUME A/O, GROWTH, J-GEM, Blazars

K. Ohta (Kyoto Univ.) talk (tomorrow)

-> OISTER, Blazars, Subaru/(HSC, FOCAS), 3.8m@Okayama, 40cm@Kyoto, J-GEM, Galaxies

Y. Utsumi (Hiroshima U. -> Stanford U.)

-> Subar/HSC, J-GEM, HinOTORI, 1.5-m Kanata

K. S. Kawabata (Hiroshima Univ.) talk (tomorrow)

-> OISTER, 1.5-m Kanata, Subaru/HSC, Supernovae, J-GEM

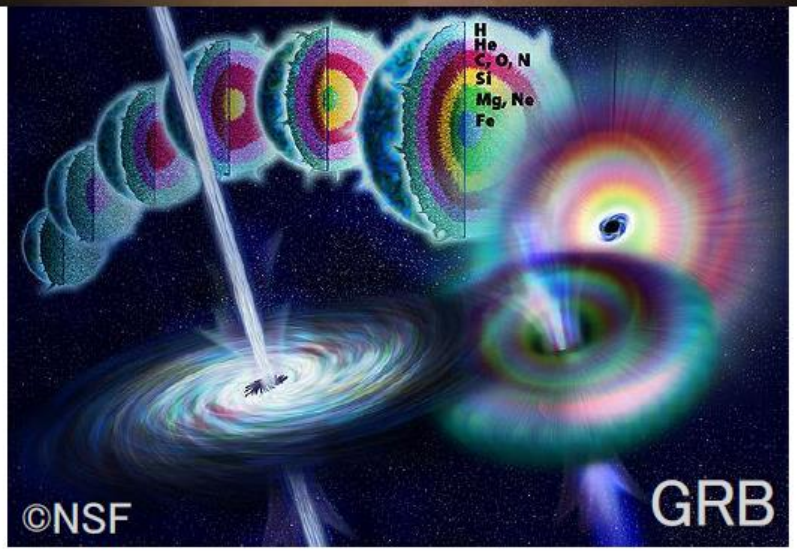
M. Yamanaka (Hiroshima Univ.) this talk

-> OISTER, 1.5m Kanata, Supernovae

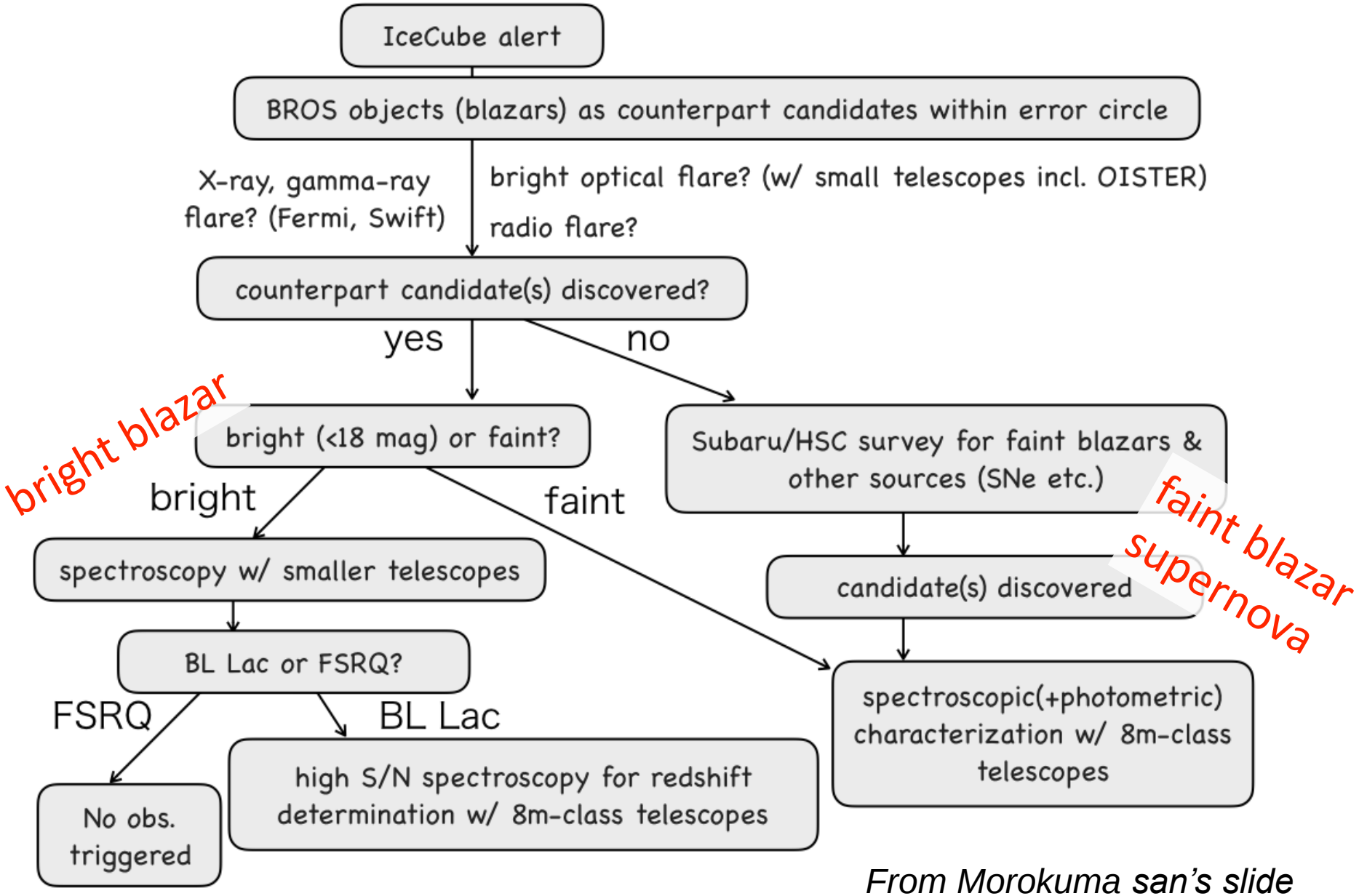
On the behalf of OISTER collaboration

From Morokuma san's slide

Origin of high-energy (T-PeV) neutrinos (high-energy cosmic ray)



Counterpart Search Strategy@optical (see also *Ohta-san's talk*)



From Morokuma san's slide

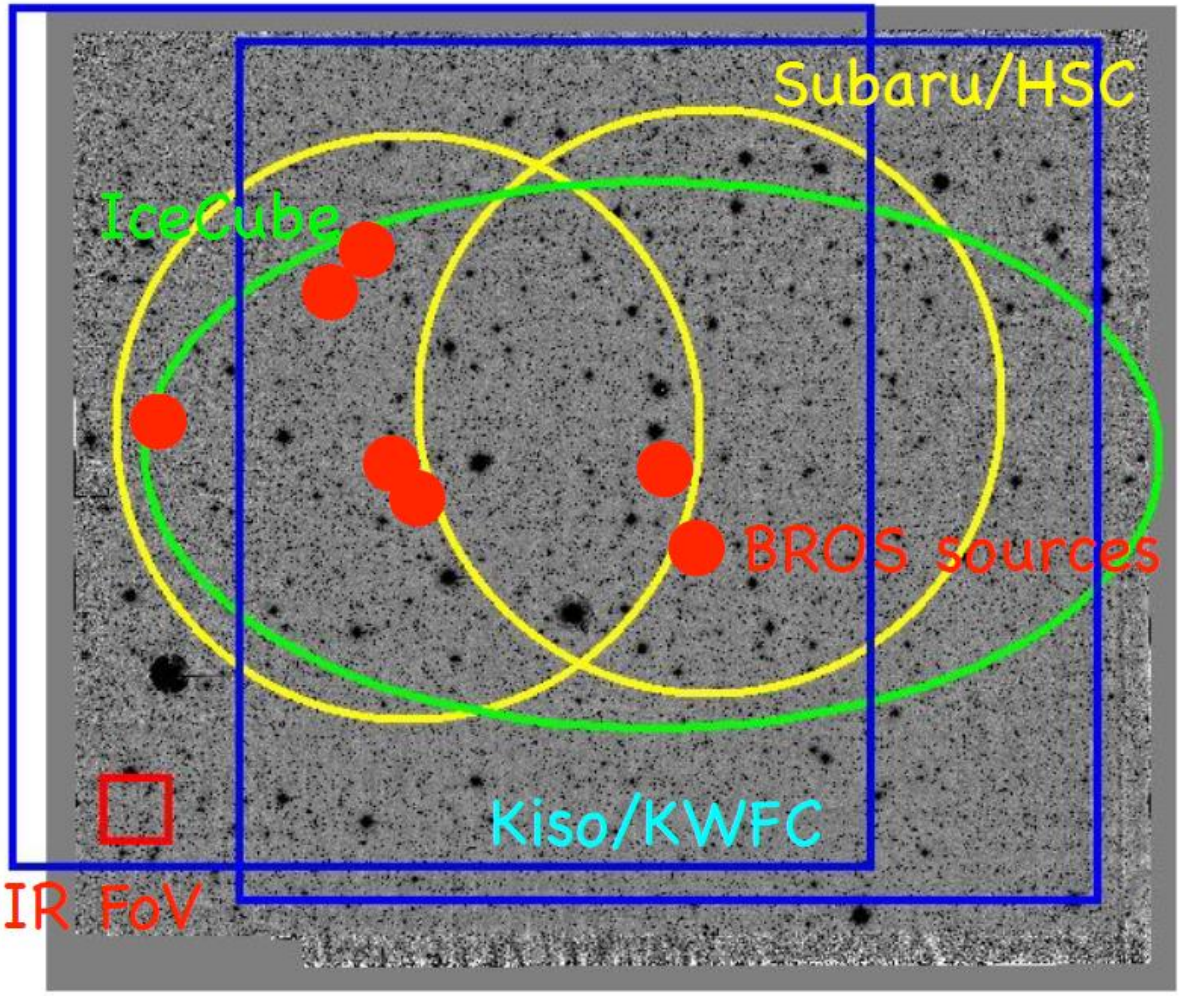
IceCube-170922A case

From Morokuma san's slide

- 7 BROS sources (blazar candidates) incl. 1 Fermi blazar.
- We observed all these blazars w/ Subaru/Hyper Suprime-Cam (HSC) & Kiso/KWFC.
  - covered almost the entire error region.

3 objects was observed by Kanata, but the variation was not detected

BROS catalog will be introduced by Ohta-san



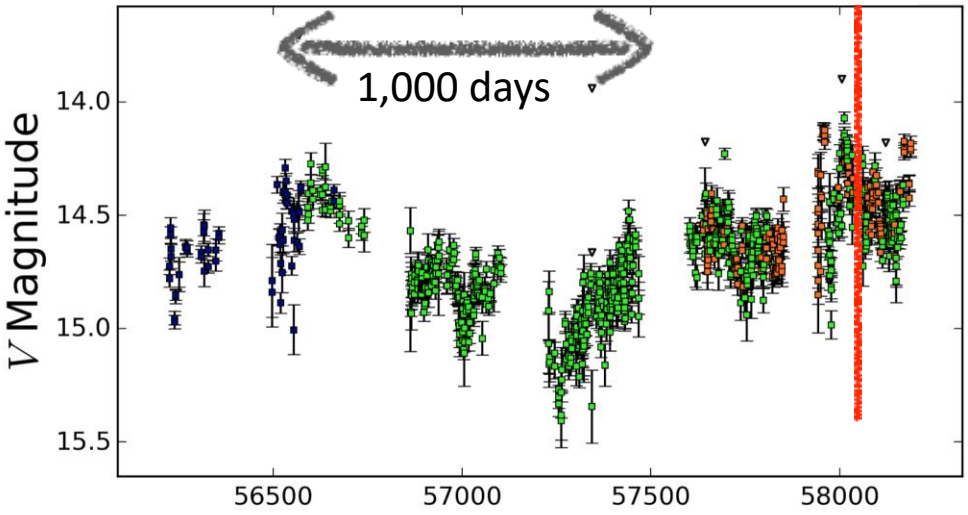
Road to EM Counterpart Discovery of IceCube-170922A

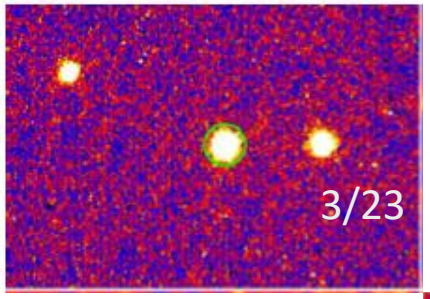
From Morokuma-san's slide

- IceCube alert (GCN 21916): 2017/09/22, 20:54:30 (UT)
- 7 BROS sources within IceCube-170922A error region
  - TXS 0506+056 variability detected with Kanata/HONIR on 2017/09/24
  - Y. Tanaka & TM talked during Subaru ToO observations at remote observing room and noticed LAT variability…(no special care about Subaru…)
- found Fermi/LAT (gamma, ATel #10791, Tanaka+), ASAS-SN (opt) variabilities
  ==> multi-wavelength follow-up
  optical/NIR imaging, spectroscopy, polarization: incl. MITSuME, Kiso, Nayuta, Kanata, IRSF (OISTER) + Subaru (TM+ in prep.)
- blue-when-brighter trend: not special
- no detailed studies yet about variability behavior

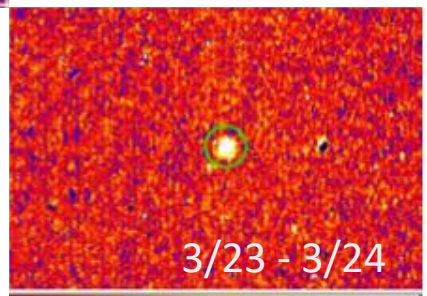
R.A. 05 09 25.964
Decl. +05 41 35.33

ASAS-SN long-term light curve (V-band, 0.5um)





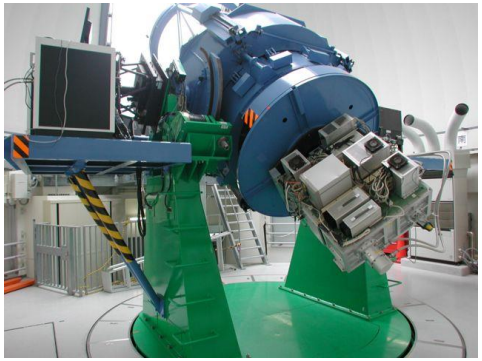
Kanata/HONIR
J-band



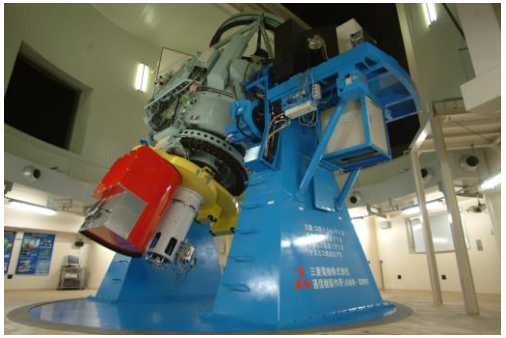
Telescopes we used through the OISTER framework

40cm@Kyoto

1.5-m Kanata
@Hiroshima



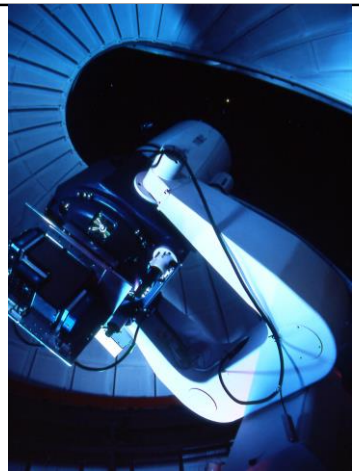
2.0-m Nayuta
@Hyogo



1.0-m schmidt
@Kiso (U. of Tokyo)
Optical Photometry

1.4-m IRSF
@SAAO (Nagoya U.)
NIR photometry

0.5-m MITSuME
@Akeno (TIT)
Optical Photometry



OISTER Multi –band and –mode follow up results

RJ w/ polarimetry (Kanata/HONIR@Hiroshima)

g'RI(0.5m MITSuME@Akeno)

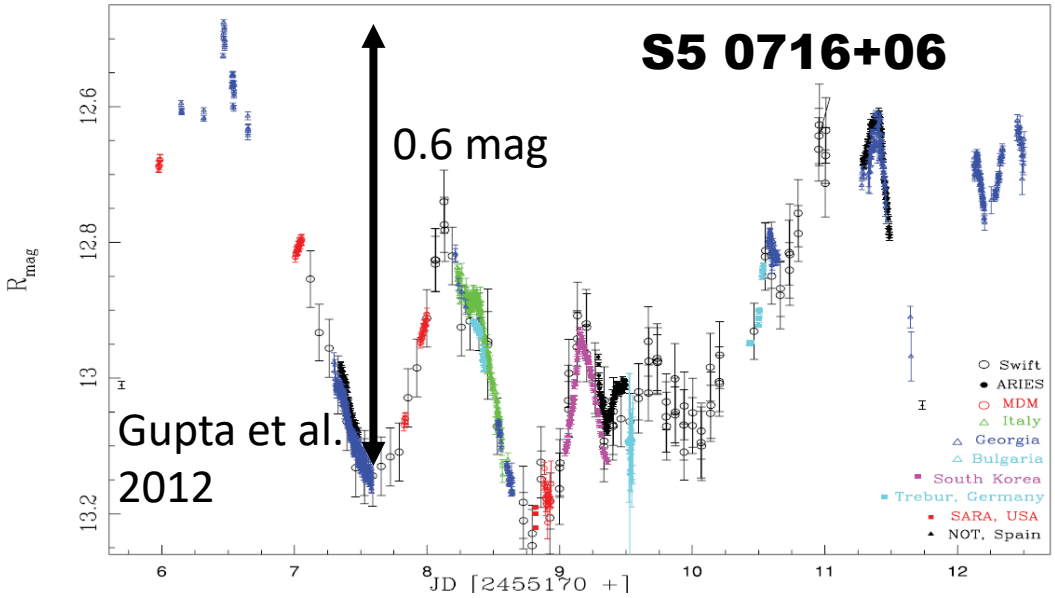
JHKs (IRSF@SAAO)

V (40cm@Kyoto)

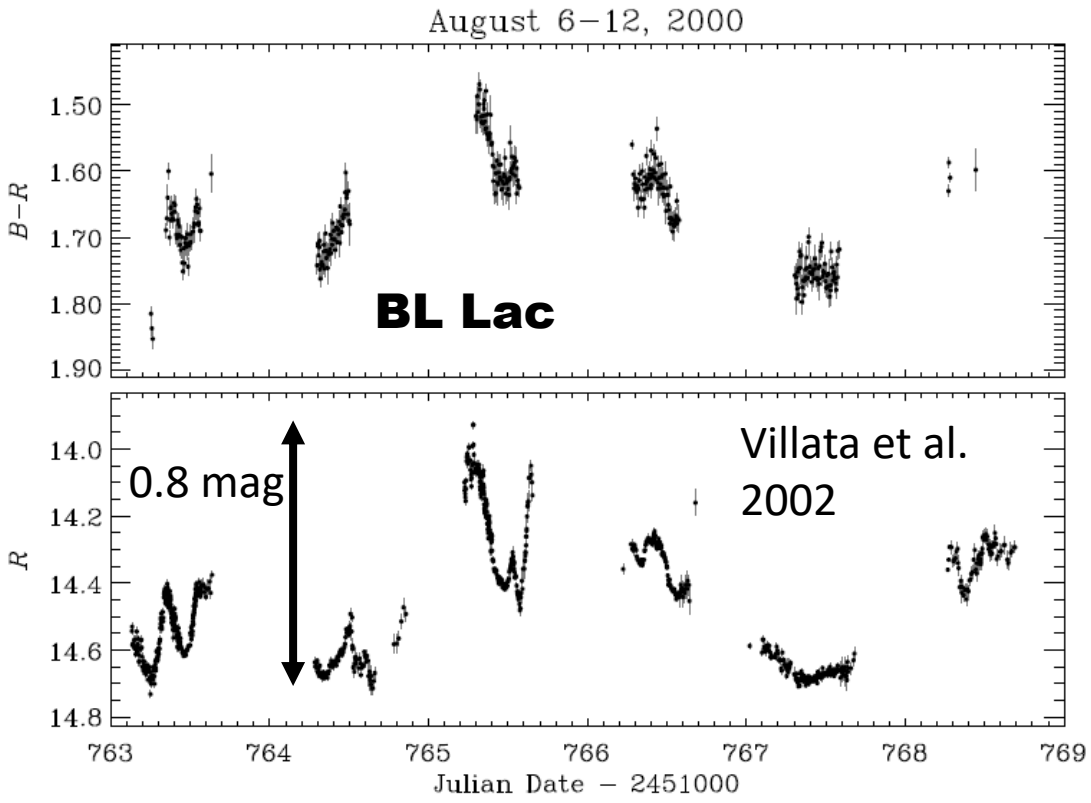
Flux, color ~"almost constant"

Polarization degree decreases (will be talked by Kawabata-san)

Short-term and large-amplitude variatior of BL Lac objects



We do not find `significantly' Large-amplitude brigtening



Spectra = redshift (see Ohta san's talk)

Featureless..

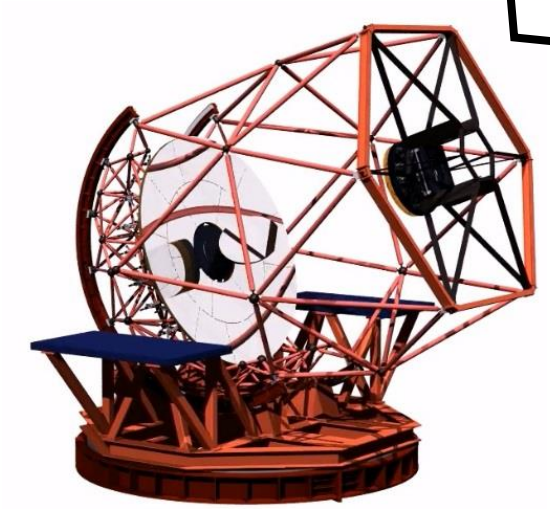
1.5m Kanata/HOWPol

Future prospects

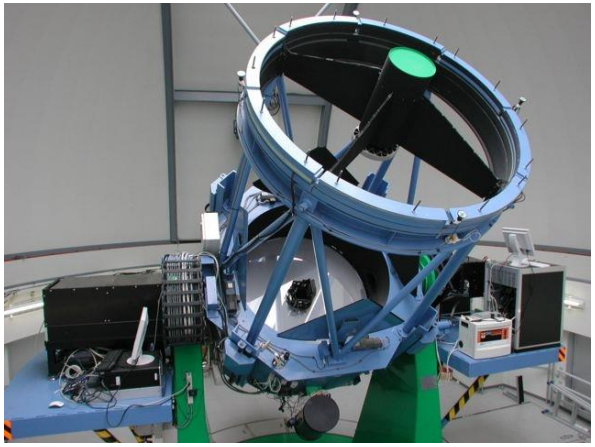
Follow-up of transient discovered by “Tomo-e Gozen”

Discovery

spectroscopy

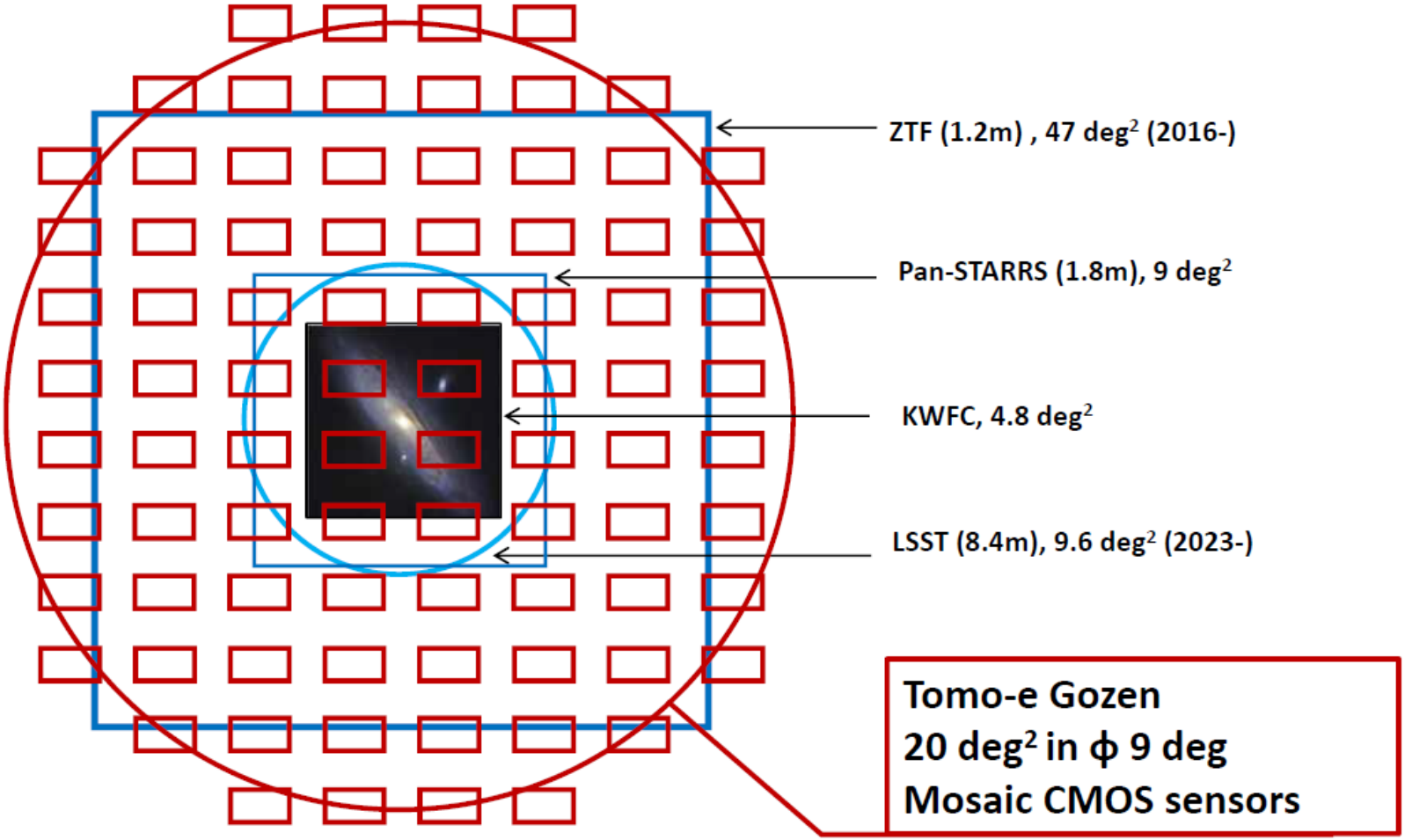


Photometry (polarization)



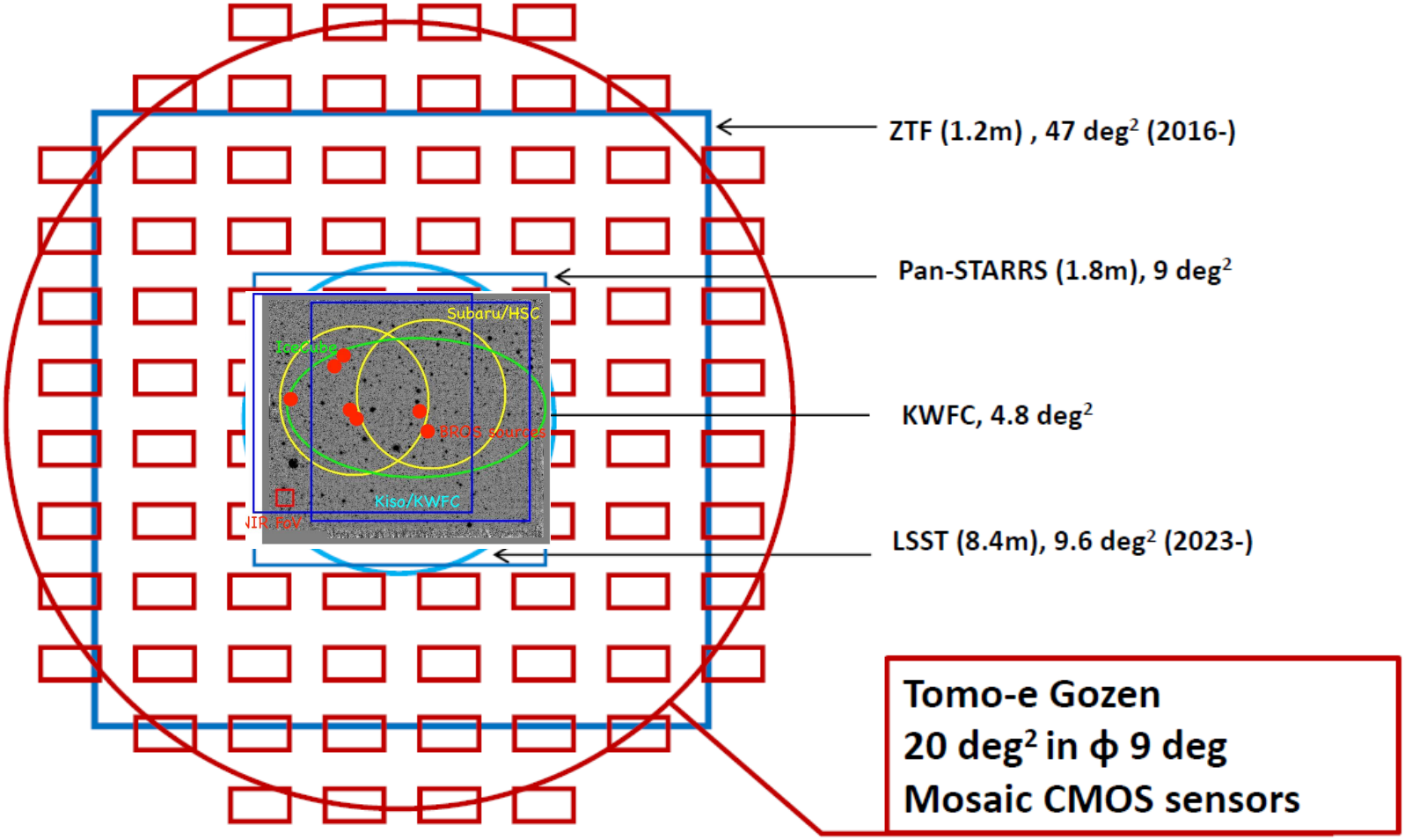
Wide-field transient survey w/ Tomo-e Gozen

From Sako-san's slide



Wide-field transient survey w/ Tomo-e Gozen

From Sako-san's slide



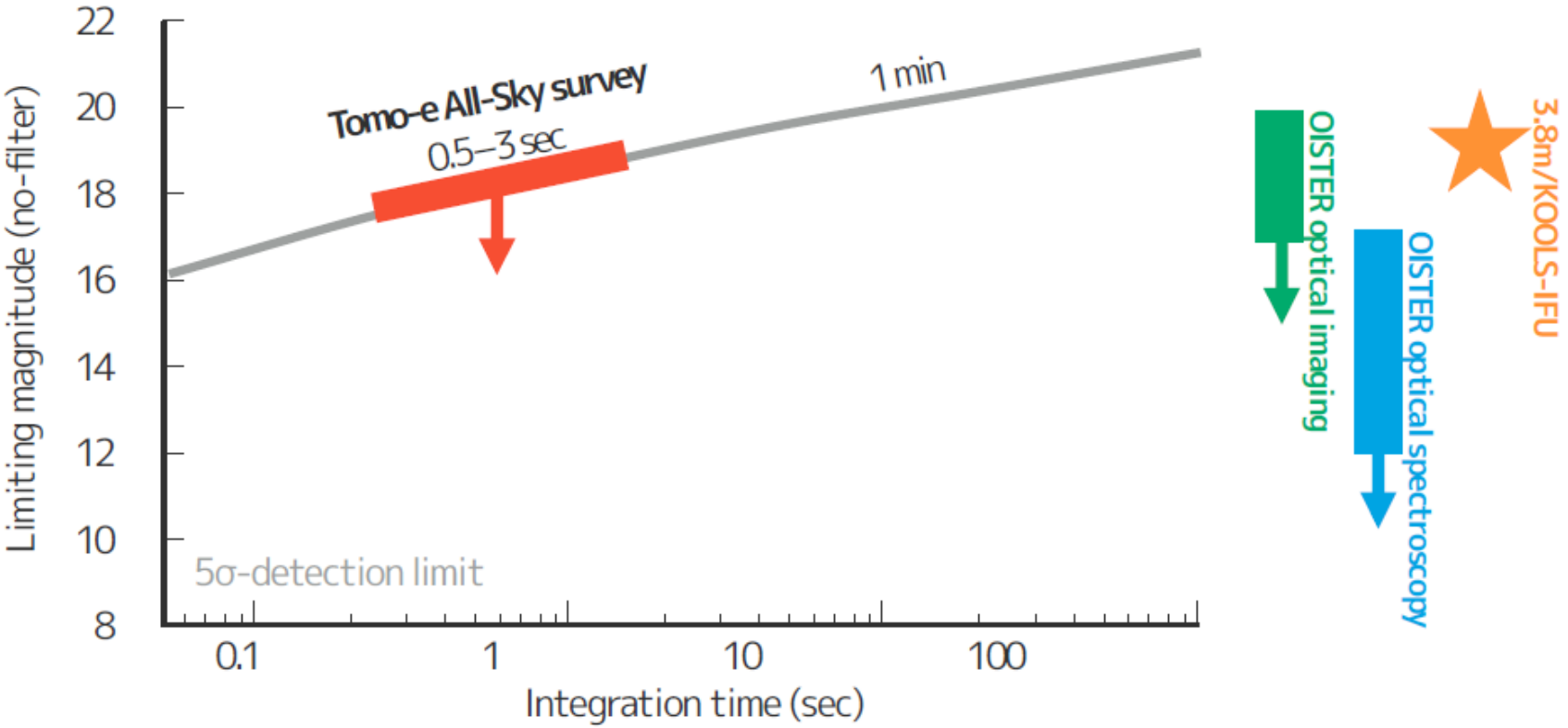
Wide-field transient survey w/ Tomo-e Gozen

All-sky survey (~10000 deg^2) will be performed @ <1 day cadence

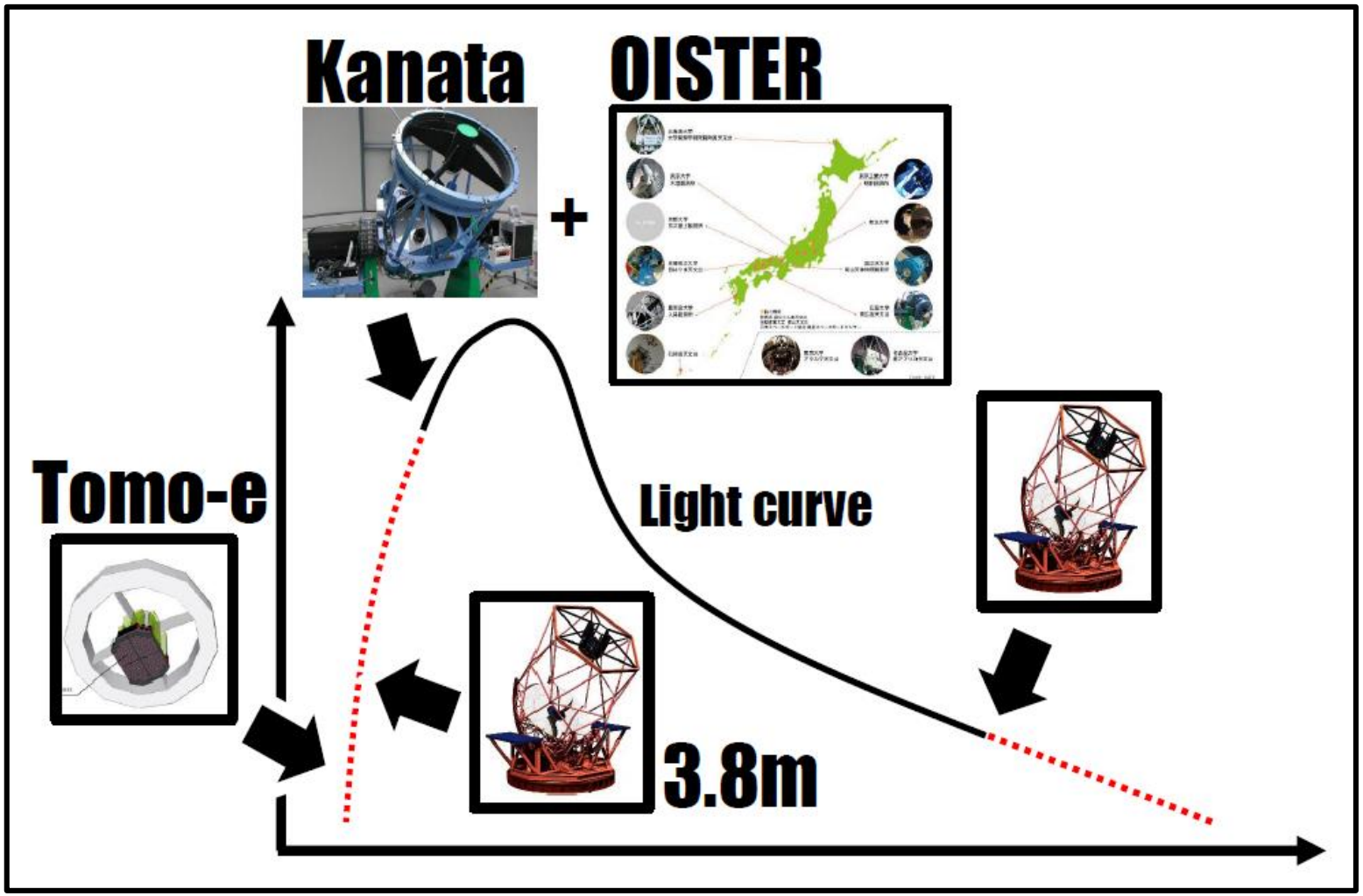
-> We can research all light curves of BROS catalog blazars…

Detection limit

from Osawa-san's slide



Synergy of follow ups
(for the case of supernovae…)



IceCube transients (BL Lac??)

Flux, color
~“almost constant”

Spectra
~no (weak) feature
-> difficult to give a constrainton the redshift

Polarization ??

No polarization observations for first 10 days

We focus on the `flux variation` in order to discover the `new transient'

However, BL Lac objects are known to exhibit the rapid polarization variation (see Itoh et al. 2016)

Currently, polarization shows large variation ??

Optical polarimetry of TXS 0506+056 (possible counterpart of IceCube-170922A)

ATel #11430; *I. A. Steele, H. Jermak, C. Copperwheat (Liverpool JMU)*
on 16 Mar 2018; 10:08 UT
Credential Certification: Iain Steele (iainsteele@mac.com)

Subjects: Optical, Gamma Ray, Neutrinos, Quasar

ATel #11419 reports enhanced Gamma Ray Activity of TXS 0506+056 detected by Fermi-LAT on 2018 March 13. A previous Fermi-LAT high state of this source in the period 2017 Sept 15-27 was potentially associated with the Ice Cube Neutrino detection 170922A (ATel #10791). TXS 0506+056 is a BL Lac object (e.g. ATel #10799) with redshift z=0.34 (Paiano et al, 2018, ApJ, 854, L32).

We obtained optical polarimetry of the BL Lac object on the night of 2018 March 14 using the RINGO3 polarimeter of the 2.0 metre Liverpool Telescope, La Palma. We find the polarisation is moderately strong (P~14%) at wavelengths roughly corresponding to the R and I bands. This is an increase from the R band polarisation P~8% reported in ATel #10844 from the Katana telescope at the time of the previous high state on 2017 Sept 30, although it is within the typical range of BL Lac optical polarisation values of 0-30% (see e.g. Figure 4 of Jermak et al, 2016, MNRAS, 462, 4267).

Summary

- We have performed the follow-up observations of various transients thourgh OISTER.
- We used various instruments to get the multi –band and –mode observational data.
- We performed the follow ups of IceCube 170922A through OISTER ToO program.
- The flux and color variation show almost constant..
- Current observations show the large variation of polarization ?? (preliminary)
- We will construct the new framework for `prompt' follow-ups of transients discovered by `Tomo-e Gozen'. The follow-up will also be done using Kyoto 3.8 m (KOOLS-IFU) and OISTER telescopes.