光学近赤外線における高エネルギーニュートリノ対応天体の追観測

山中雅之 (広島大学)

Collaborators

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Kouji Ohta (Kyoto Univ.),
Ryosuke Itoh (TIT),
Yousuke Utsumi (Hiroshima Univ. -> Stanford),
Masayuki Yamanaka (Hiroshima Univ.)
Koji S. Kawabata, Hiroki Mori (Hiroshima Univ.) ,
on the behalf of OISTER collaboration

Outlines

- かなた望遠鏡におけるフォローアップ戦略
- これまでのフォローアップの実際
- IceCube-170922A アラートにおける追観測：
    -TXS 0506+056の変動発見
    -光赤外線大学連携・すばる望遠鏡による追観測
        -- Light curve
        -- Spectra (redshift)
        -- Polarization (Current observations)

- Future prospect
        -- ブレーザー・超新星
        -- Tomo-e Gozen サーベイ
        -- 3.8m 分光フォローアップ

AAAS Science journal

RESEARCH ARTICLE SUMMARY

NEUTRINO ASTROPHYSICS

Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A

The IceCube Collaboration, *Fermi*-LAT, MAGIC, *AGILE*, ASAS-SN, HAWC, H.E.S.S., *INTEGRAL*, Kanata, Kiso, Kapteyn, Liverpool Telescope, Subaru, *Swift/NuSTAR*, VERITAS, and VLA/17B-403 teams*†

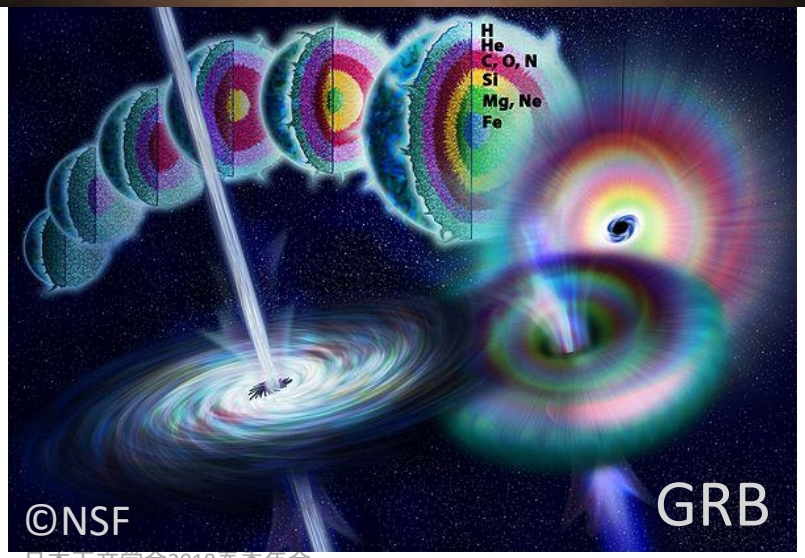
The IceCube Collaboration et al.,
Science 361, 146 (2018) 13 July 2018

Briefing for press in the MEXT
文科省記者会見 on Jul 20

9月16日付 読売新聞

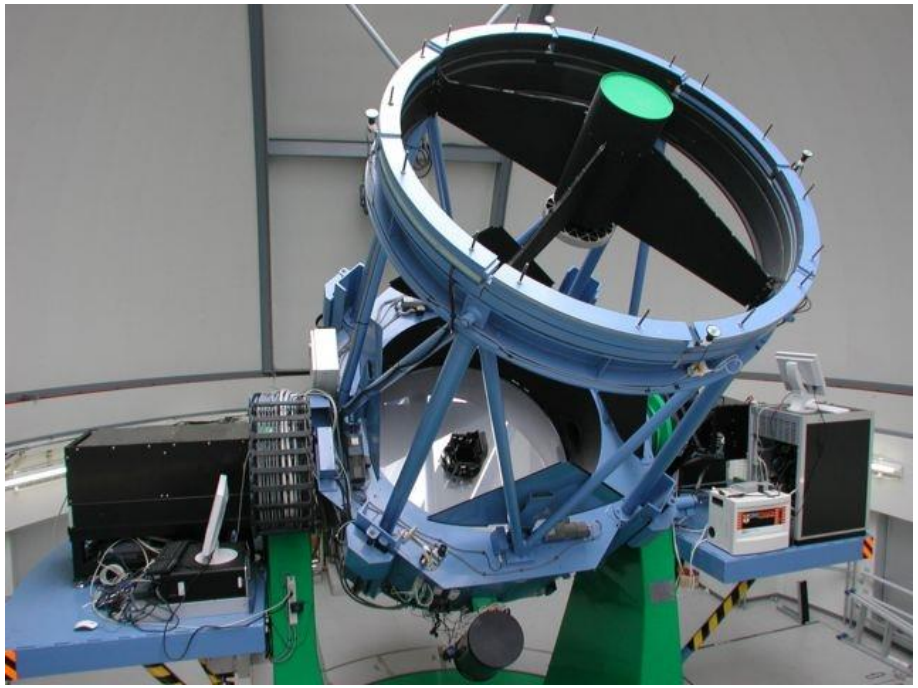

15 くらしサイエンス 13版
2018年(平成30年)9月16日(日曜日)
観測に参加した望遠鏡
すばる望遠鏡(米ハワイ島)
シュミット望遠鏡(東京大木曽観測所)
かなた望遠鏡(広島大東広島天文台)
人工衛星「フェルミ宇宙望遠鏡」
世界の「目」で一斉観測
1 南極のアイスキューブが特殊な光を検知。千葉大が開発したシステムで高エネルギーのニュートリノと判断
2 世界各地の望遠鏡に追加観測を呼びかける
3 40億光年先の「ブレーザー天体」が放出源と特定
ハワイ
南極
日本
ブレーザー天体
・中心のブラックホールをガスが取り囲み、プラズマを噴き出す
・プラズマ内で宇宙線が光とぶつかり、ニュートリノが発生
「アイスキューブ」国際観測施設
地上
深さ1450m
2450m
5160個の光センサー
地上施設
光センサー
ニュートリノが凍った水の分子と反応する際に出る特殊な光を検知する
日本のニュートリノ研究の歴史
1987年 小柴昌俊・東京大特別栄誉教授が岐阜県の観測装置「カミオカンデ」で、超新星爆発によって放出されたニュートリノを観測する
1998年 梶田隆章・東京大宇宙線研究所長が「スーパーカミオカンデ」によって、ニュートリノに質量があることを証明する
2012年 千葉大などの国際チームが、アイスキューブを使って高エネルギーのニュートリノを観測する
2018年 千葉大などの国際チームが、高エネルギーのニュートリノの放出源を特定する
アイスキューブや東京大、広島大、国立天文台、米航空宇宙局などの資料を基に作成
サイエンスView
ニュートリノ 放出源探せ

Possible Origin of high-energy (TeV) neutrinos



From Morokuma san's slide

1.5m Kanata+HONIR



HONIR (Hiroshima Optical and Near-InfraRed camera; Akitaya et al. 2014)
可視近赤外線２バンド同時観測
視野10’ x 10’
限界等級 ~20mag (可視)

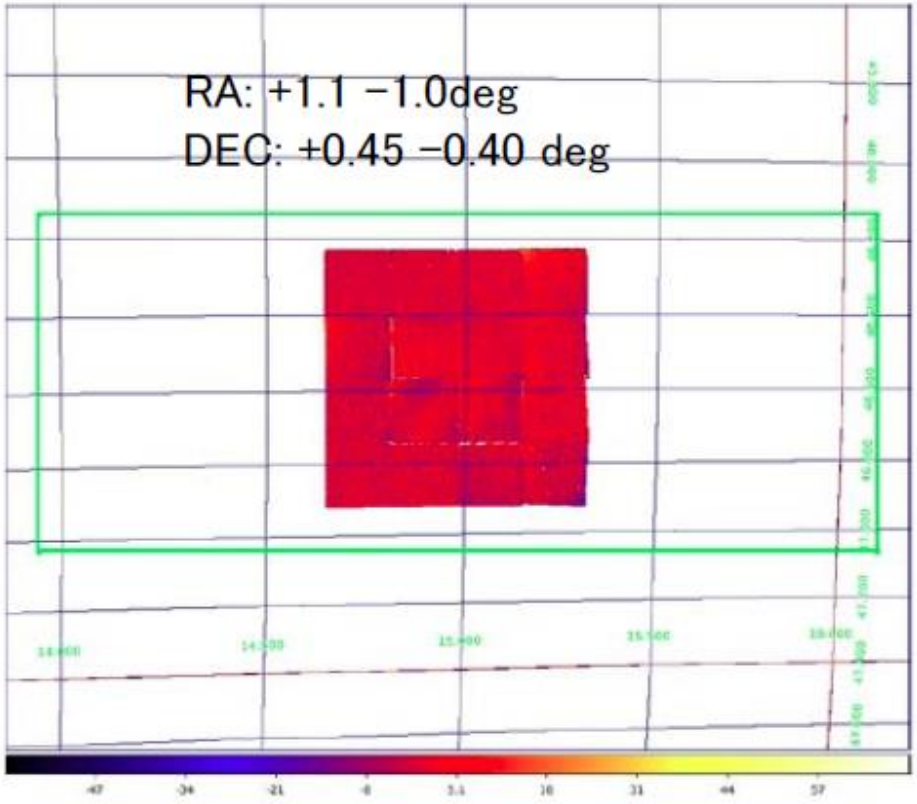
Casts related to the Kanata follow-up

Y. Tanaka　Mori　Utsumi　MY

Itoh　M. Kawabata　Nakaoka　K. S. Kawabata

IceCube-161210A

Alert: 2016-12-10 20:07(UT)



2016-12-11 9:30-17:30 (UT)
J-band imaging

Tiling observation

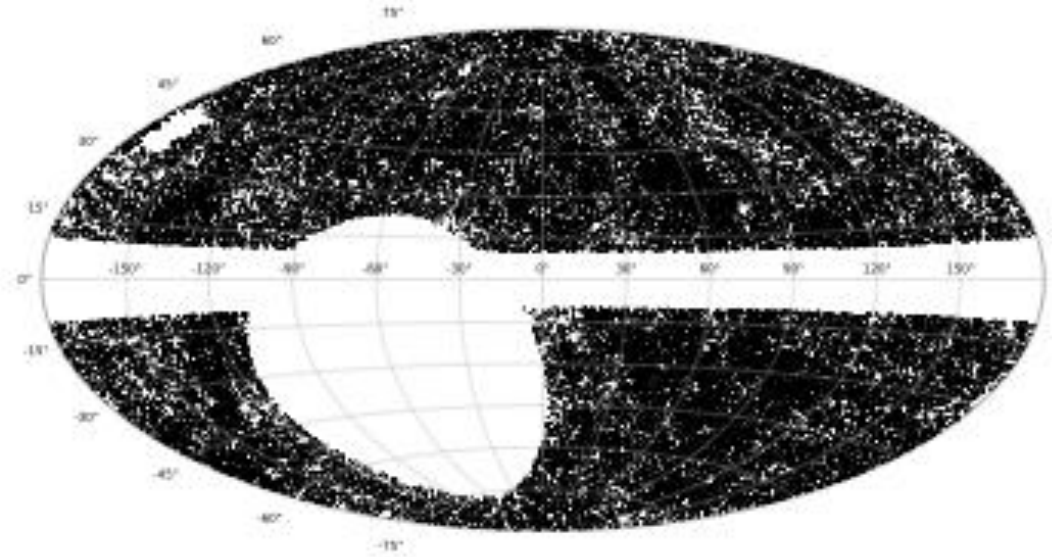
とても大変

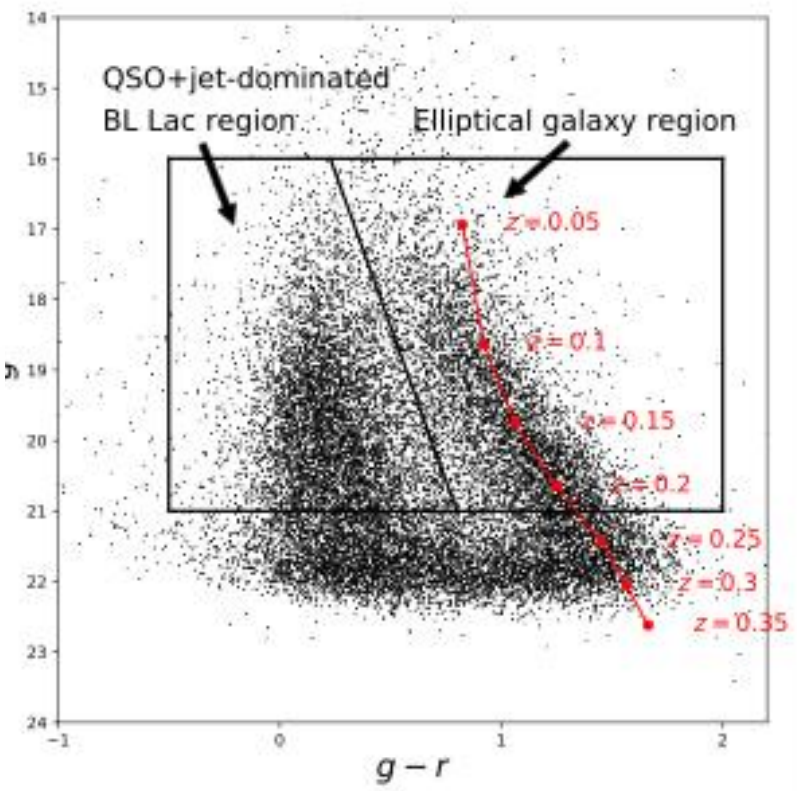
ID	1	2	3	4	5	6	7	8
積分時間 [sec]	300	300	300	300	300	900	1200	300
5sigma 限界等級 [AB mag]	19.29	19.39	19.27	18.64	18.58	18.07	18.50	18.32
変動天体 (目視)	なし	なし	なし	なし	なし	なし	なし	なし
ID	9	10	11	12	13	14	15	16
積分時間 [sec]	300	900	1020	300	300	300	300	300
5sigma 限界等級 [AB mag]	18.97	19.02	18.54	19.21	19.20	18.82	18.77	19.12
変動天体 (目視)	なし	なし	なし	なし	なし	なし	なし	なし

森修論(2018)

New Blazar Catalog (BROS)

- Blazar Radio and Optical Survey (BROS; Itoh et al. in prep.)
- ~50000 sources at Dec.>-40 deg
  - BZCAT: ~4000 sources
- flat-spectrum@radio: NVSS (1.4 GHz) + TGSS (151 MHz)
- Pan-STARSS(PS1)@optical
  - ~40% not detected in PS1 (r>23)

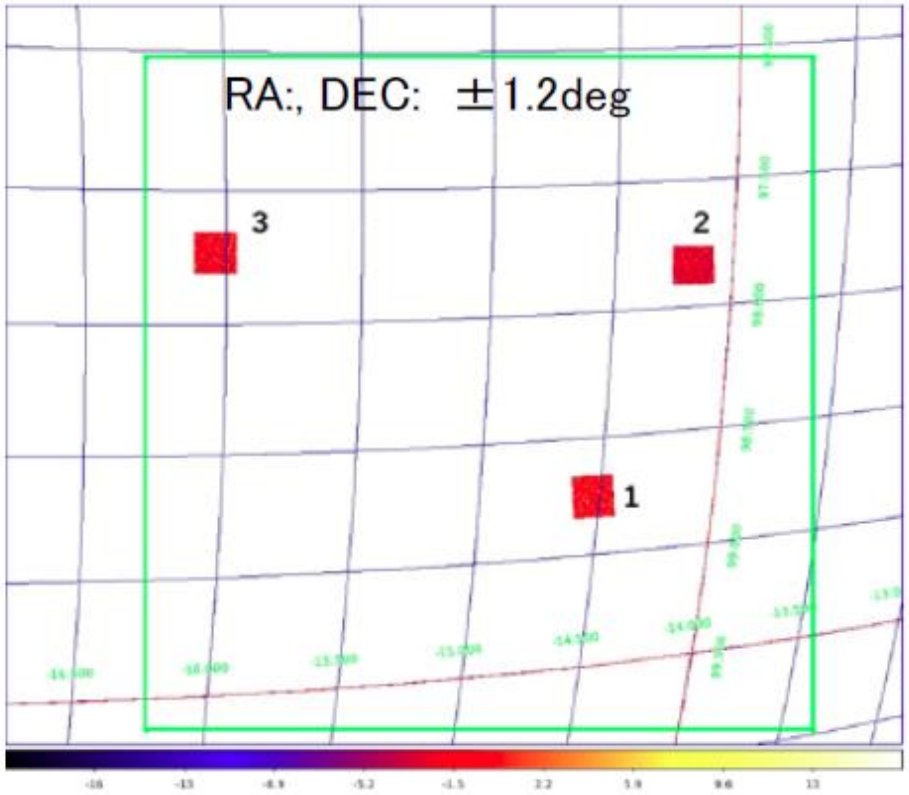


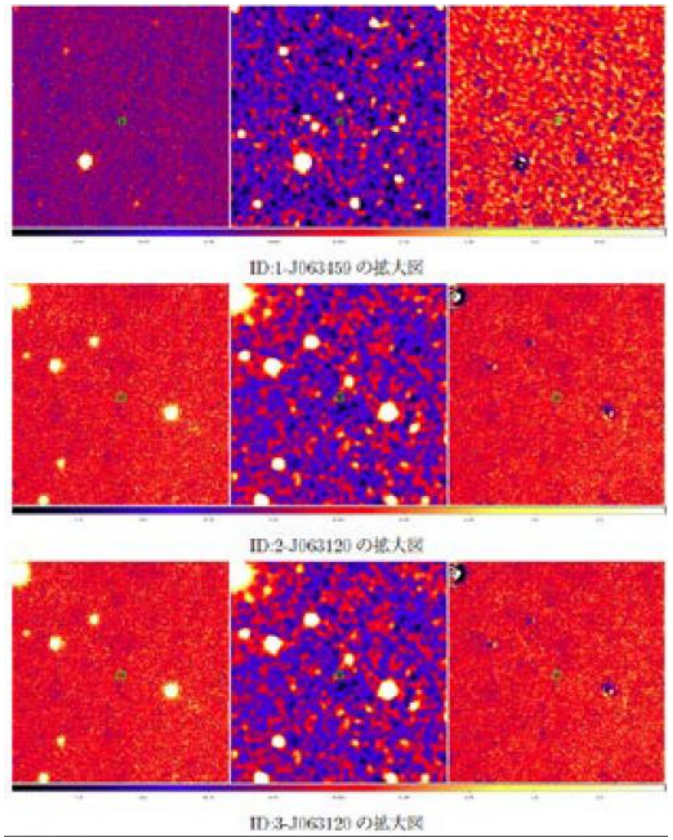


IceCube-170321A

BROS blazar catalog

Alert: 2017-03-21 07:32(UT)



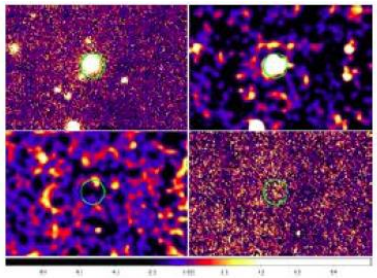


2017-03-22 10:30-11:10 (UT)

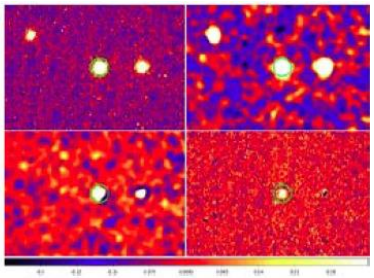
J-band imaging

森修論(2018)

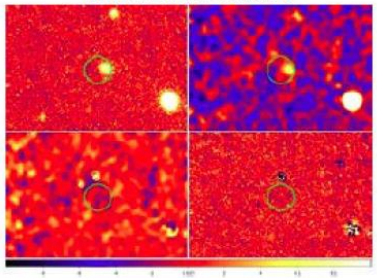
IceCube-170922A



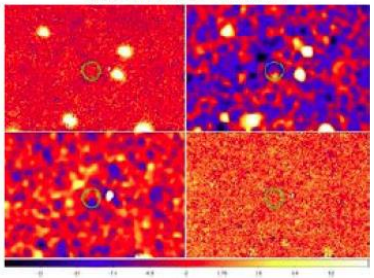
ID:1-J050912 の拡大図



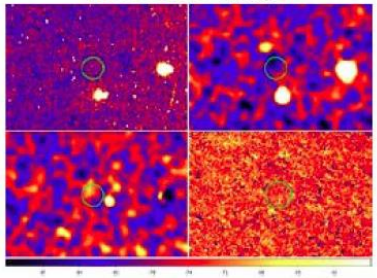
ID:2-J050926 の拡大図



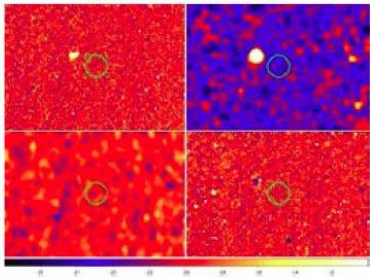
ID:3-J051205 の拡大図



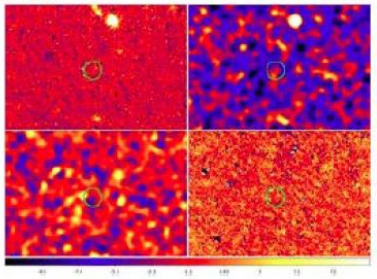
ID:4-J051211 の拡大図



ID:5-J051256 の拡大図



ID:6-J051236 の拡大図

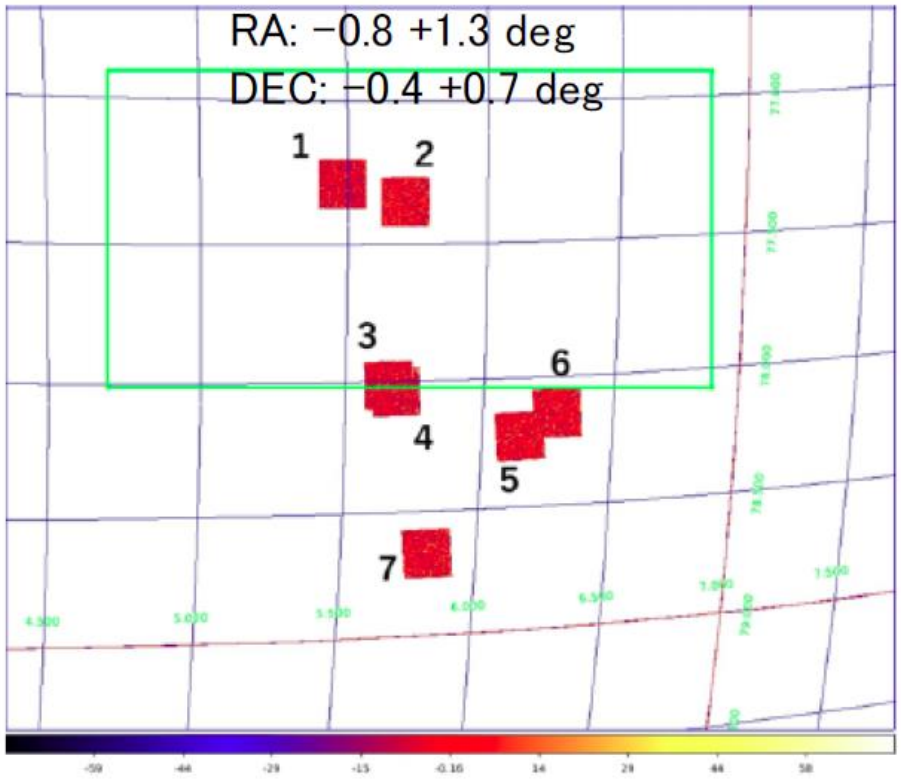


ID:7-J051440 の拡大図

J band

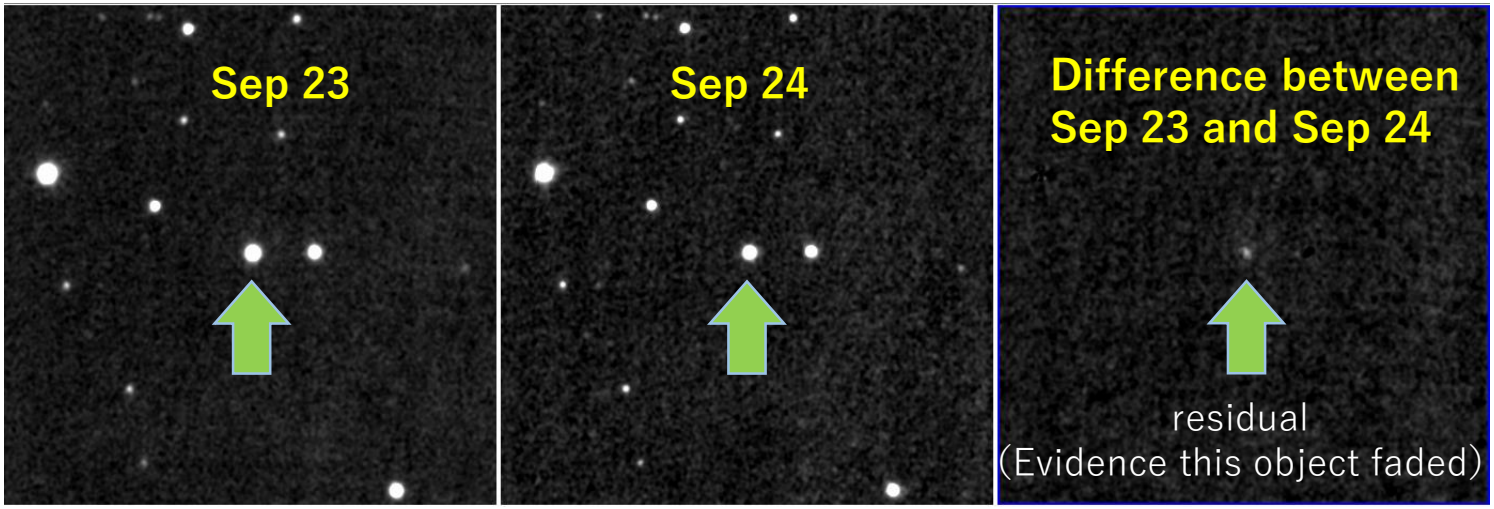
Follow-up observations of seven candidates within the error circle region were performed with Kanata

2夜の観測で7つのうち
1天体のみ変動を検出



森修論
(2018)

TXS 0506+056 ：活動的な時期



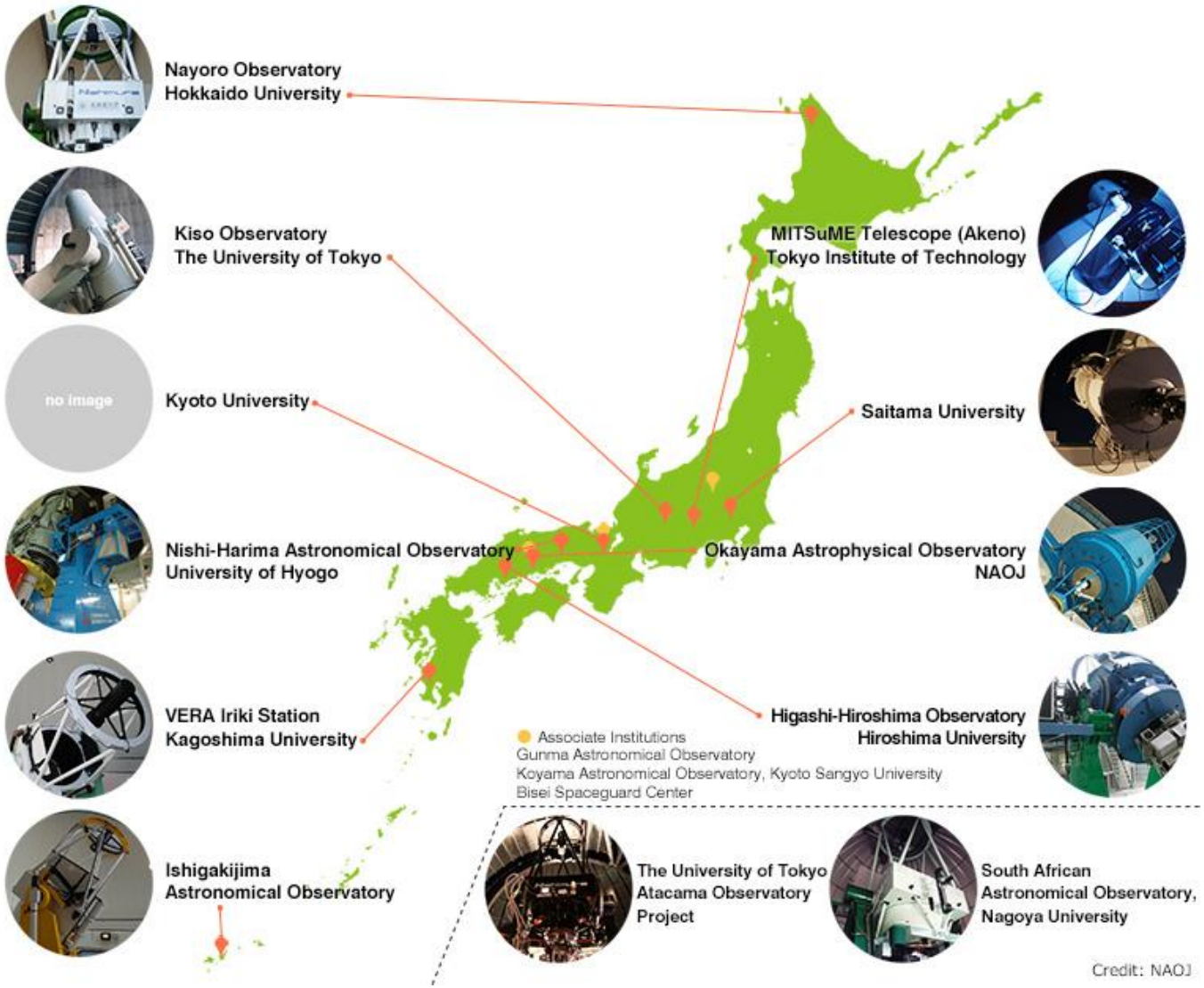
Observed in R band using Kanata/HONIR

We found that TXS 0506 was much luminous on Sep 23 comparing to the previous observations. We observed the slow decline part of the optical flux.

The brightening the gamma-ray emission is observed, and Tanaka+ reported this observational fact. （Tanaka, Y. T. et al. ATel #10791）

International electromagnetic observations were promoted by this report

OISTER


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

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

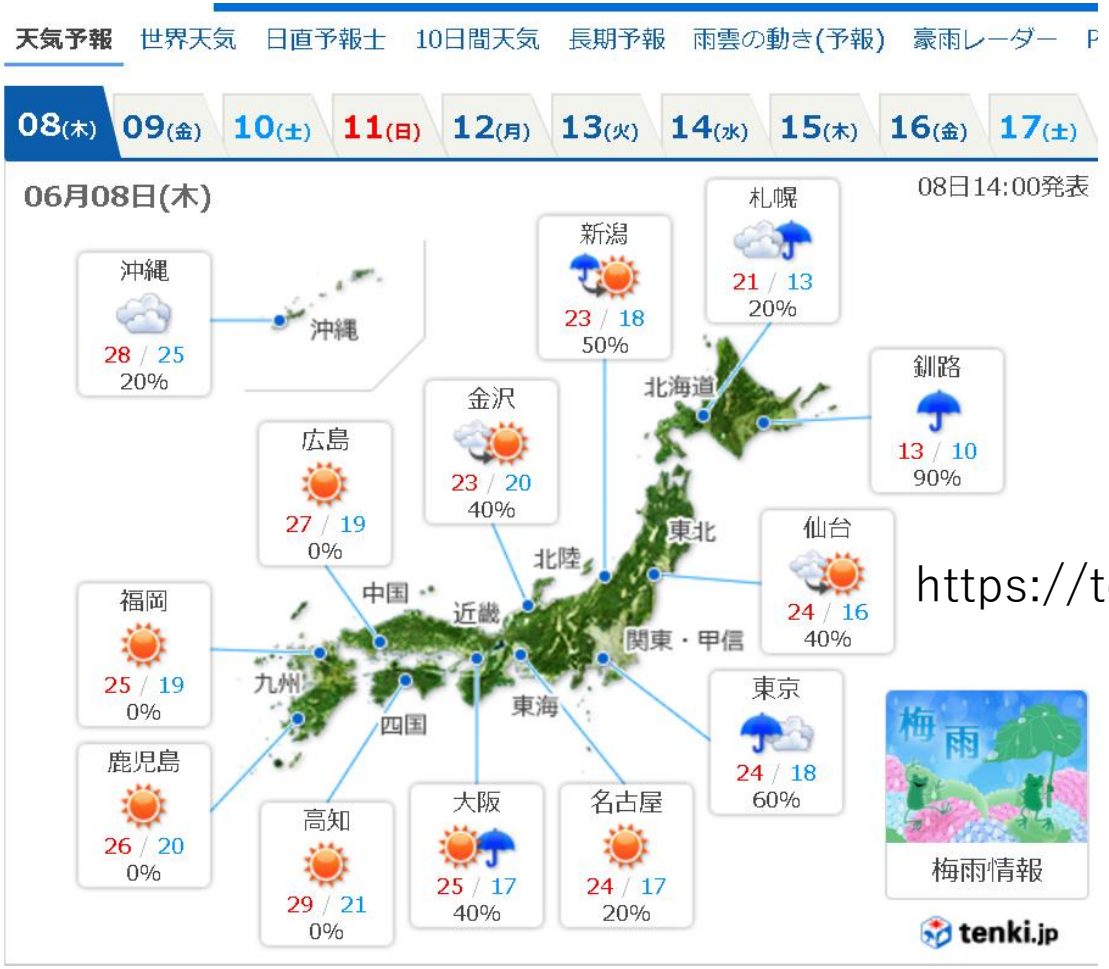
Overalls

- 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

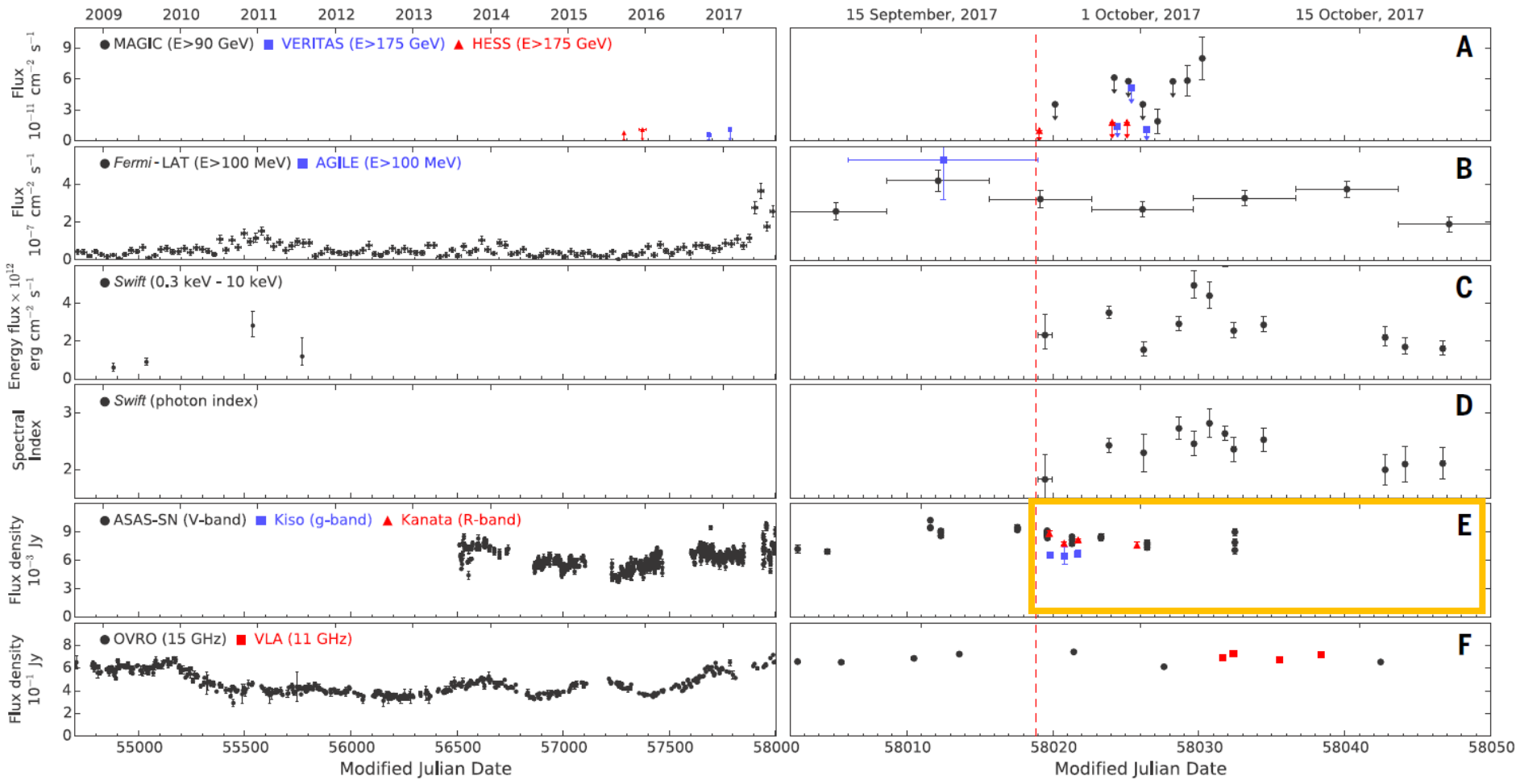
Canceling the weather risk



https://tenki.jp

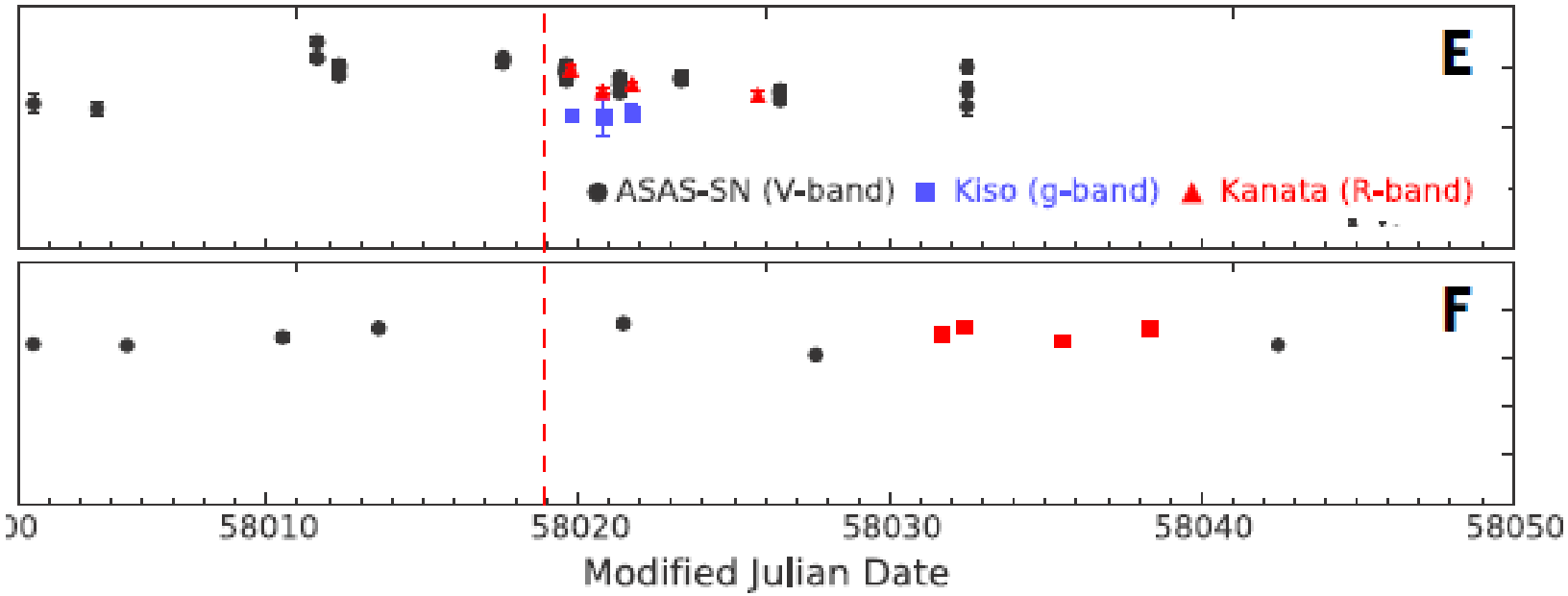
We can avoid the weather risk! (typically shows ~ 1 day delay between Hiroshima and Tokyo)

TXS 0506+056: Multiwavelength light curves



The IceCube Collaboration et al., Science 361, 146 (2018)

Optical and NIR light curves



- We started the observations using Kanata/HONIR since 20 hours after the neutrino alert.
- We found that the luminosity is three times more luminous than the previous data, and the flux decreased by 15% on Sep 24.
- When the neutrino was emitted, this blazar would be more luminous, indicating that this object is in the active phase.

The IceCube et al. 2018

Polarization

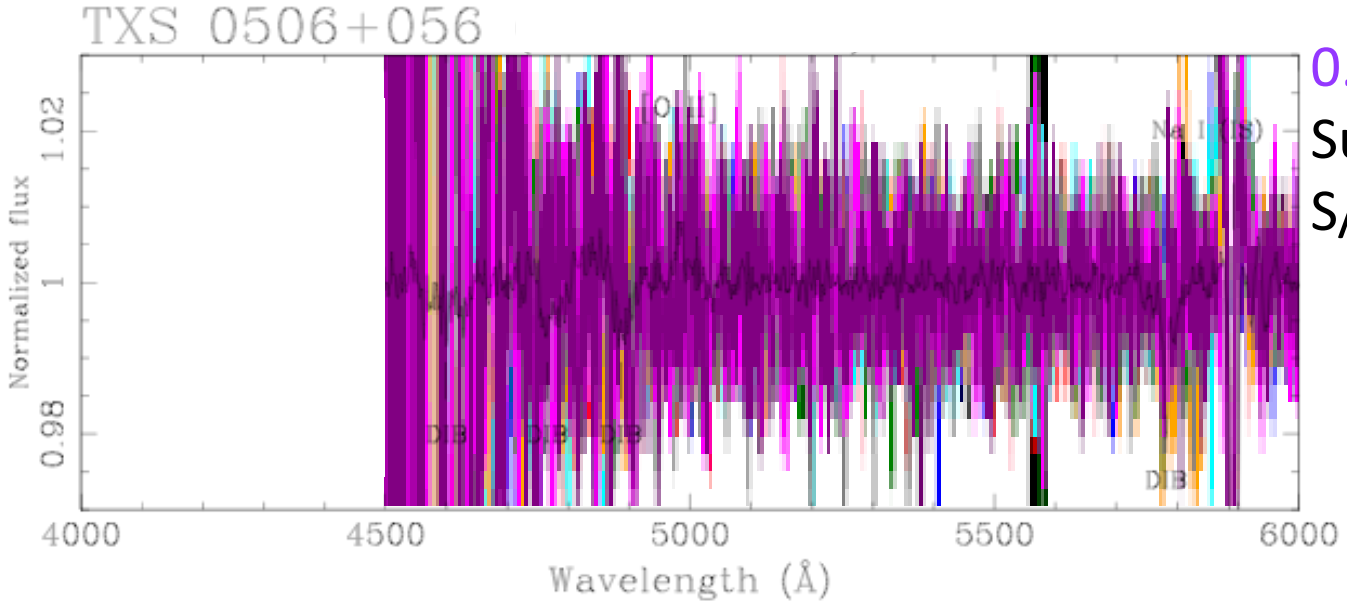
4月あたりの
観測

↓

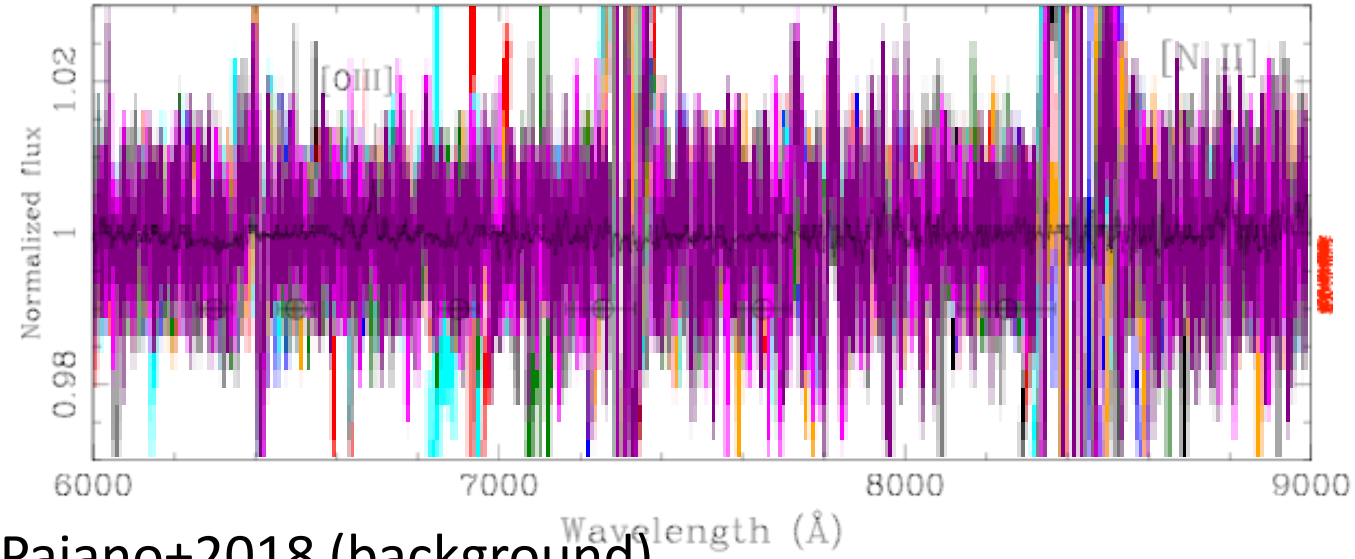
激しい偏光度の変化

サイエンスにて報告
された偏光度:7-8%
IceCube collaboration et al. 2018

Optical Spectroscopy: redshift determination



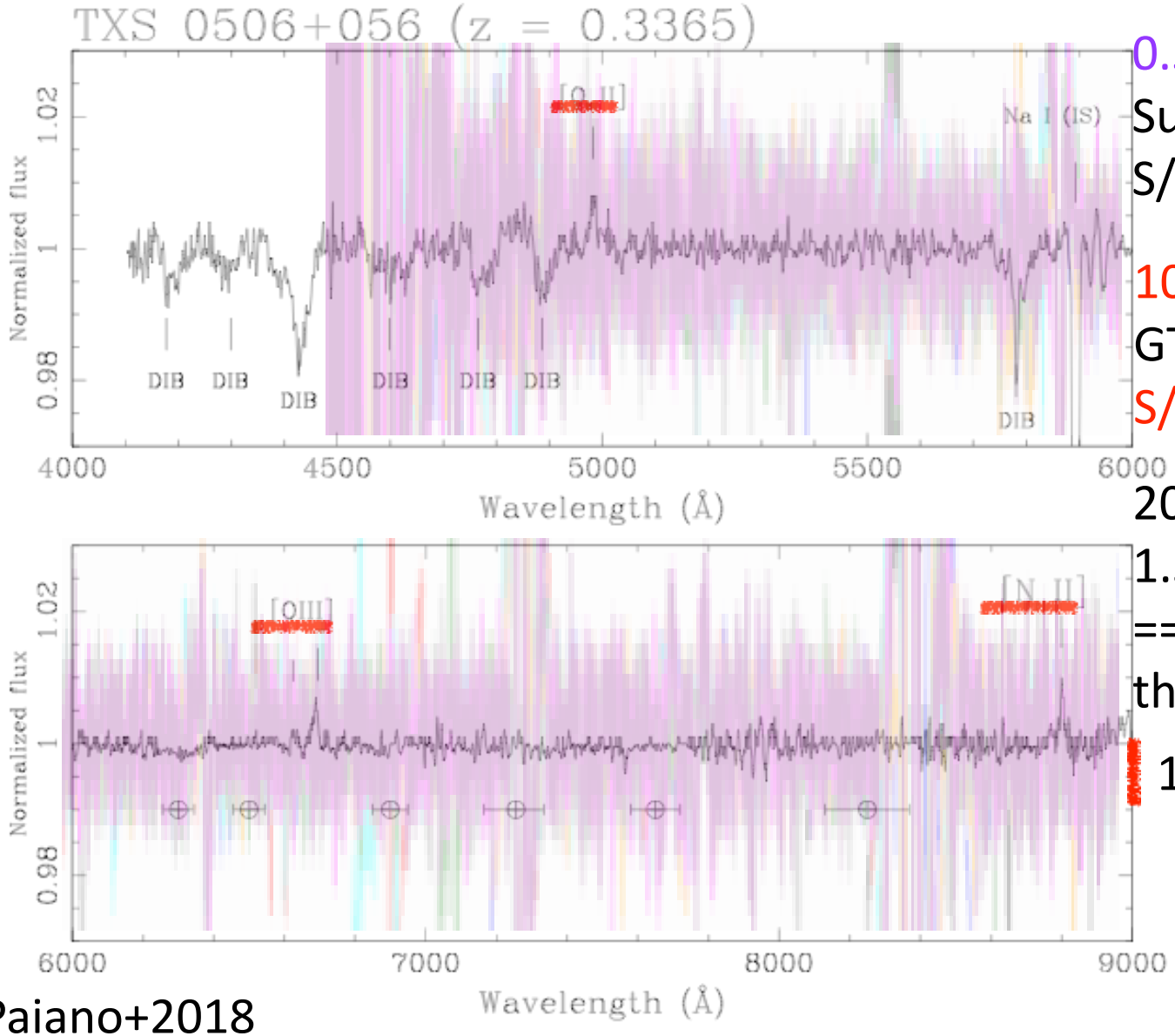
0.5-hour integration
Subaru(8.2m)/FOCAS
S/N~100



1% (S/N=100)

Paiano+2018 (background)

Optical Spectroscopy: redshift determination



0.5-hour integration
Subaru(8.2m)/FOCAS
S/N~100

10-hour integration
GTC(10m)/OSIRIS
S/N~500

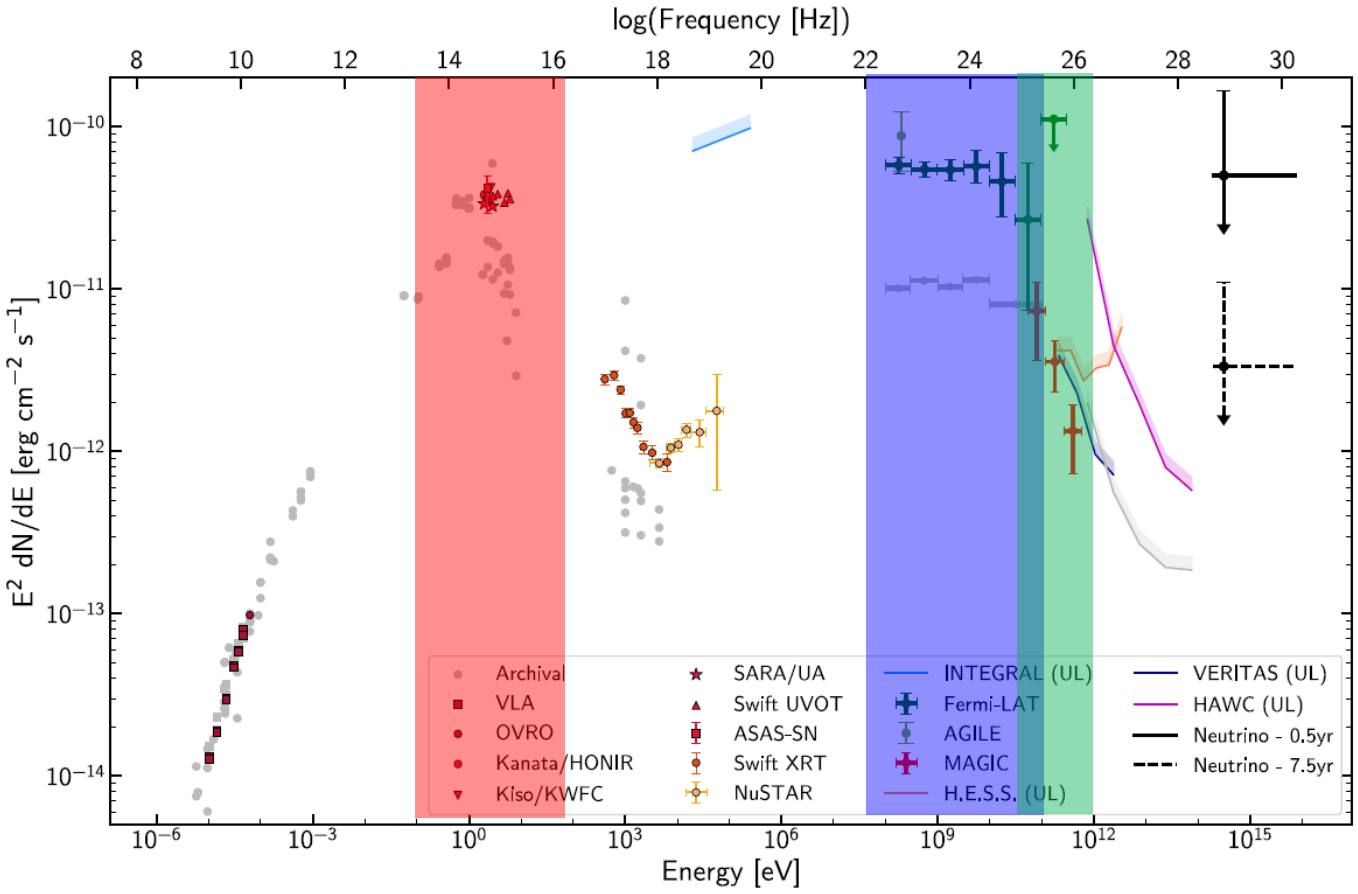
20 times longer
1.5 times larger
==> ~5 times better
than Subaru/FOCAS

1% (S/N=100)

z=0.336

Paiano+2018

Spectral Energy Distribution



かなた・木曽　　Fermi MAGIC

IceCube collaboration et al. 2018

Future prospect

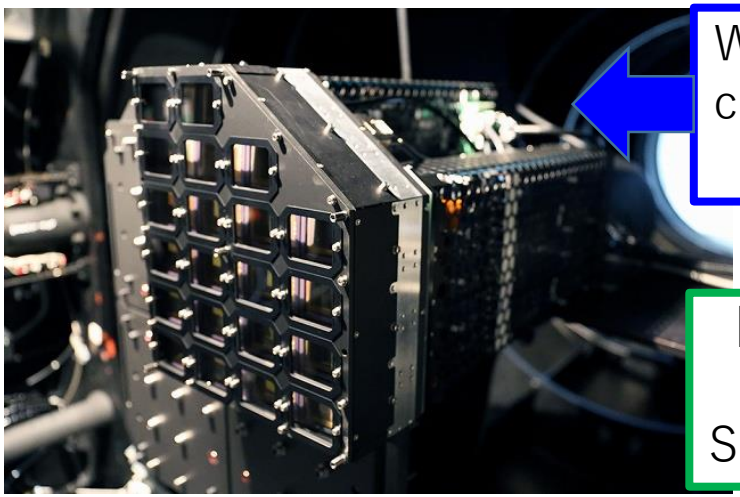
- **blazar（AGN）？**

  Similar procedure through the Kanata/OISTER will unveil another possible transient （2匹目のドジョウ）.

  Basical properties can be unveiled through multi-mode and –band observations

- **(IIn/Ibc) supernova?** **–still strong candidate**

  Prompt exploring the new transient in the galaxies using wide-field camera. Prompt follow-up would be performed by spectrograph.



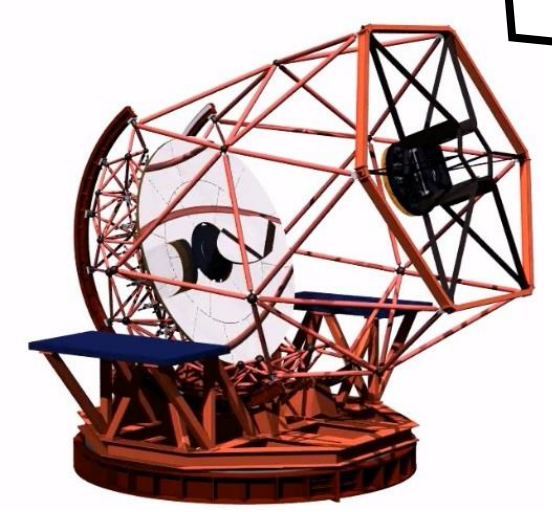
Wide-field camera:Tomo-e Gozen （Kiso, U of Tokyo）

「Seimei」3.8m telescope （Okayama, Kyoto U.） Spectroscopy

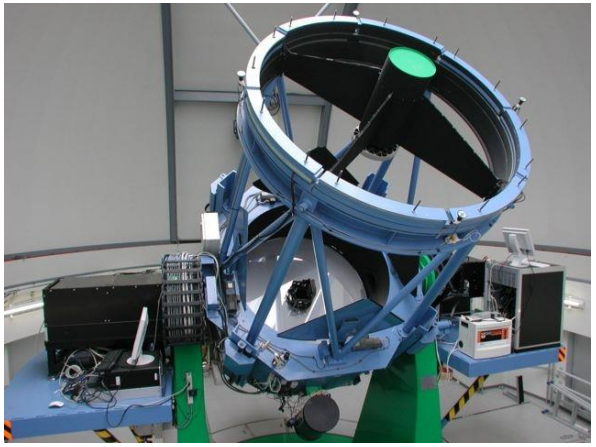
Follow-up of transients discovered by “Tomo-e Gozen”

Discovery

spectroscopy

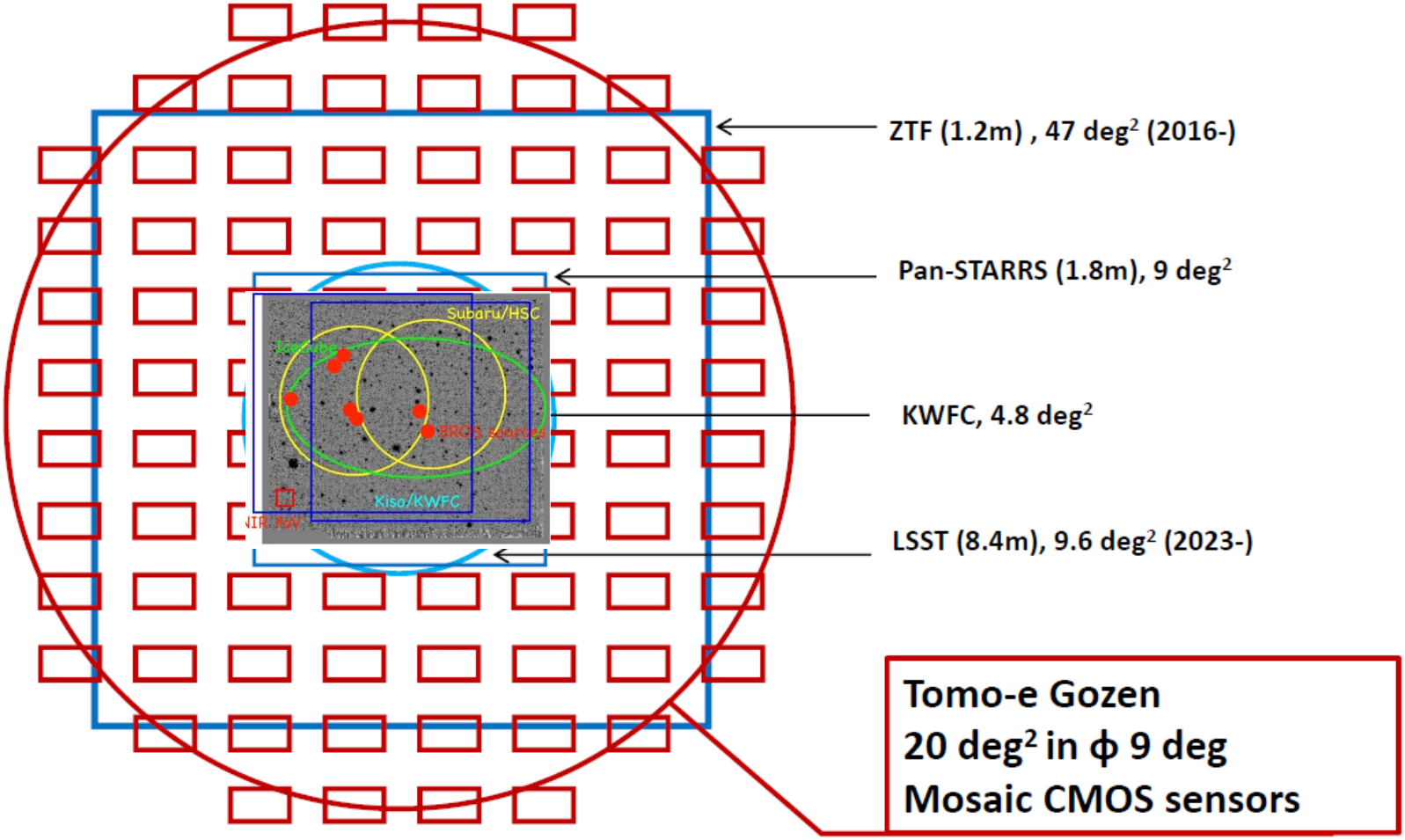


Photometry
(polarization)



Wide-field transient survey w/ Tomo-e Gozen

From Sako-san's slide



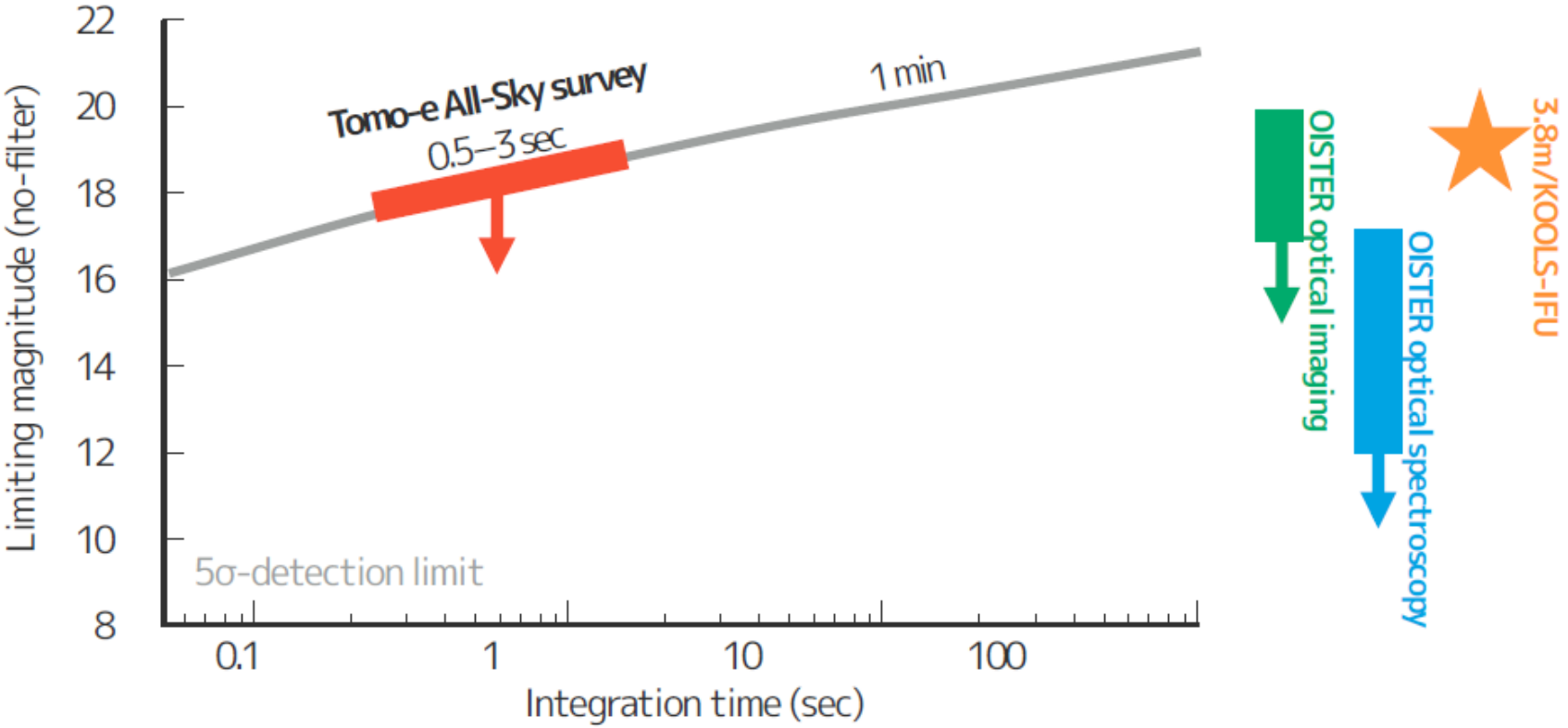
Wide-field transient survey w/ Tomo-e Gozen

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

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

Detection limit

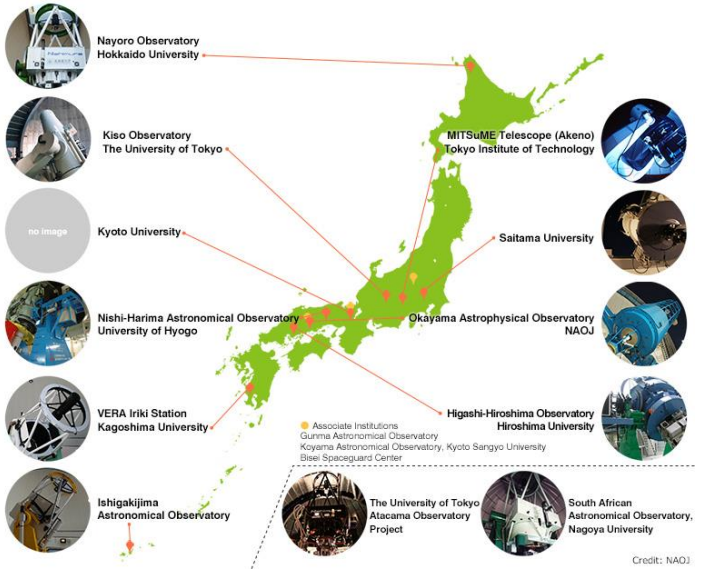
from Osawa-san's slide



3.8m + KOOLS/IFU

KOOLS-IFU (PI:松林)
ファイバー分光器
限界等級 **~20mag**

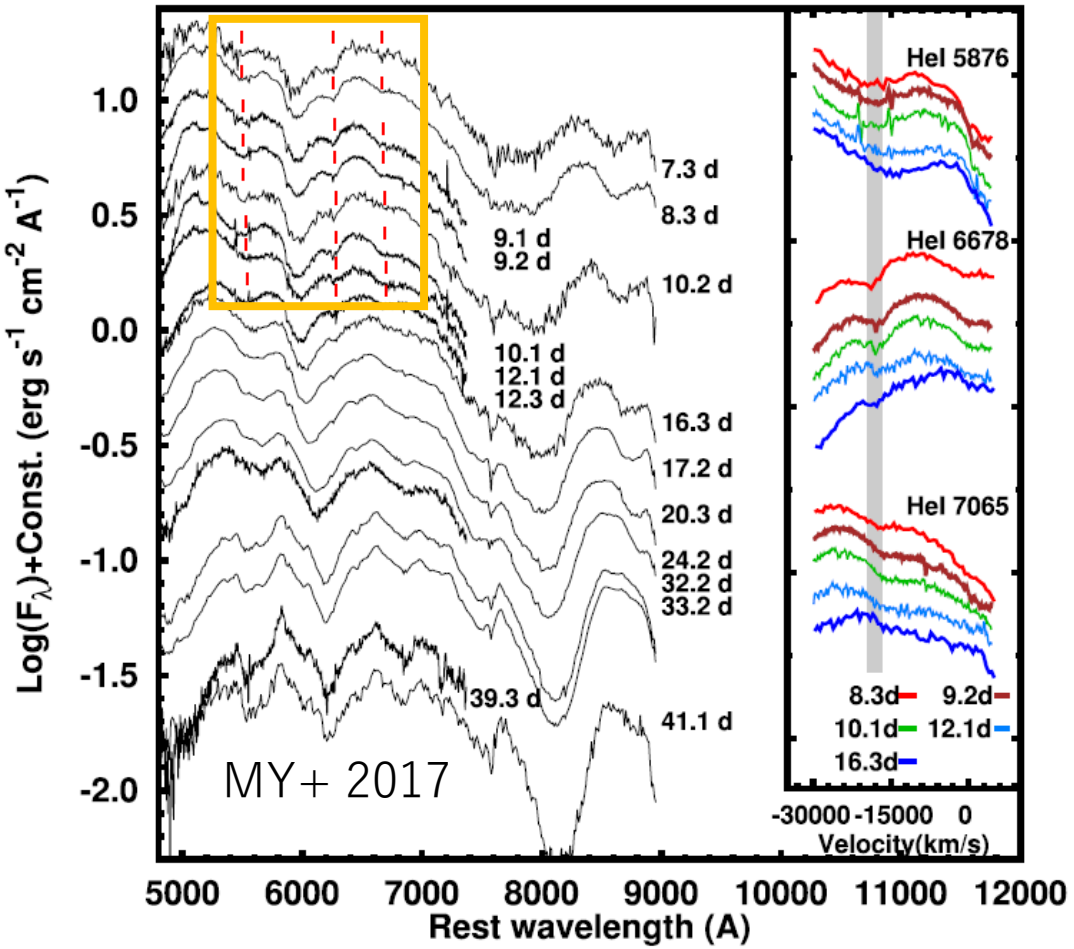
Early-phase spectroscopy



・**近傍であれば**超新星の性質を詳細に研究可能

・KOOLS-IFU **z~0.07程度までの**BL SNe分光可能？

Broad-lined `Type Ib' SN 2016coi



Summary

- 我々は、これまでIceCubeアラートに対して3度の即応的追観測を実施してきた。その結果、IceCube 170922Aにおいて, TXS 0506+056が明るい時期にあり、アラート後1日で減光過程にあることを見出した。

- Fermiの解析につながり(Tanaka 2017, ATEL)、国際的なマルチメッセンジャー追観測につながった

- TXS 0506+056はアラート直後 ~7%程度の偏光度、featurelessなスペクトル、BL Lacに一致

- 超新星シナリオを含めた制限を与えるべく、Tomo-e Gozen+3.8mのサーベイ・フォローアップ体制を構築中