Time domain astronomy with `Kanata' and `HinOTORI' telescopes

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On behalf of Kanata team

And aided by Y. Utsumi and T. Morokuma

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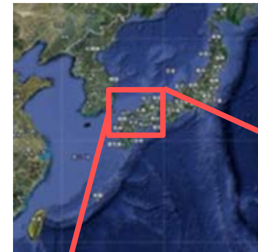
Index

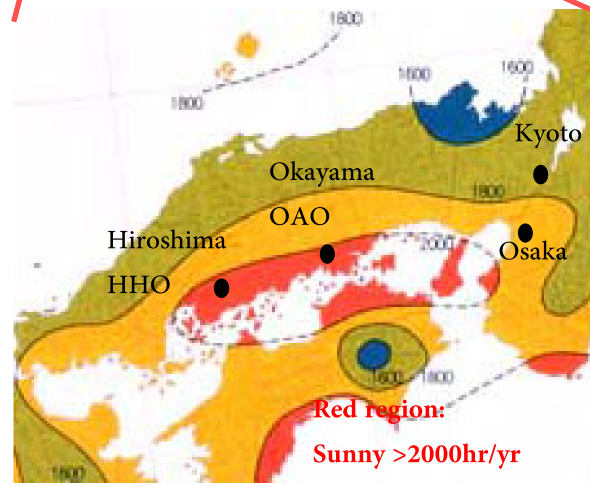
- `Kanata’1.5-m Optical Telescope
- Strategy of Kanata Telescope
  - Multi-wavelength, Multi-mode
- Representative Results
  - Blazars and related objects
  - IceCube events
  - Others
- New HinOTORI 0.5-m telescope inTibet, China
- Summary

Kanata'1.5-m Optical Telescope

Higashi-Hiroshima Observatory

- Found in 2006; operated by Hiroshima University
- Only 25 min by car from campus (503m above sea level)
- ~40% observable nights
- Better seeing condition (median FWHM ~1.2 arcsec)
- Sky brightness R=19-20 mag/arcsec^2 in dark nights





HE & Opt/NIR Obs. Astronomy group in Hiroshima

HE (X-ray and gamma-ray) Astronomy Group
- Fukazawa, Yasushi (Prof)
- Mizuno, Tsunefumi (Assoc. Prof)
- Takahashi, Hiromitsu (Assist. Prof)
- Poon, Helen (Postdoc)

Optical and Near-Infrared Astronomy Group
- Kawabata, Koji (Prof)
- Uemura, Makoto (Assoc. Prof)
- Inami, Hanae (Assist. Prof.) 2018.2-
- Mahito Sasada (S.-A. Assist. Prof)
- Akitaya, Hiroshi (Postdoc) 2018.1-

Theoretical Astronomy group
- Kojima, Okabe

Specially Appointed Professor
- Miyama Shoken (Past NAOJ dir.)

Yoshida →NAOJ | Y.Tanaka →Company | Utsumi →SLAC | Ohno →Hungary | Ohsugi →Retire | Yamanaka →Kyoto U

Several persons moved out from our group within recent 2 years

`Kanata' Telescope and Instruments

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Nasmyth focus#2

High Speed-readout camera and spectrograph

FoV: 2.3' × 2.3'

Wavelength res.: R = λ/Δλ =

9-70（400-800nm）、

150（430-690nm）

~30 frames/sec

Nasmyth focus#1

HOWPol 2009- (KSK+ 2008)

Opt Imaging： FoV 15′ Φ

Opt ImagPol： One-shot type

Spec： R~400(400-1050nm)

We-Do-Wo type Wollaston

`One-shot polarimetry' available-- Unique potential for quickly-variable object like GRB afterglows

`Kanata' 1.5-m Telescope

- Successor of IR simulator of Subaru telescope
- 1.5mΦ main mirror
- Azimuth rotation speed : 5°/sec, 2-4 times faster than normal 1-m size telescopes. (merit in high-response observation (e.g. GRBs)

Cassegrain focus

HONIR： 2012- （Akitaya+ 2014 SPIE）

1 Optical band + 1 （future 2) NIR band (simultaneous)

Opt+NIR Imaging： FoV 10′ × 10′

Opt+NIR Spec： R~400-500

Opt+NIR ImagPol/SpecPol

Maximizing information by single observation

One-shot polarimetry now available

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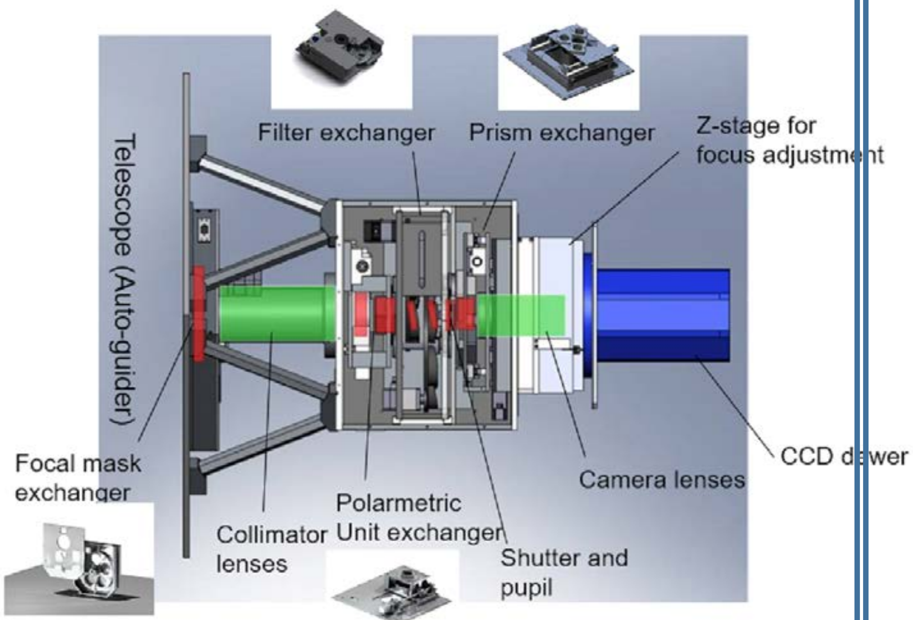
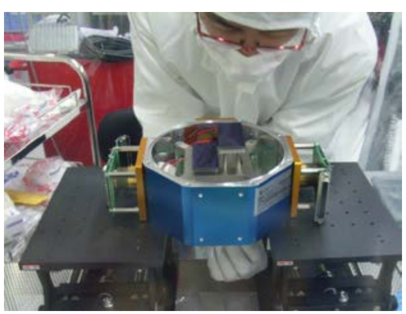
Instruments developed in-house

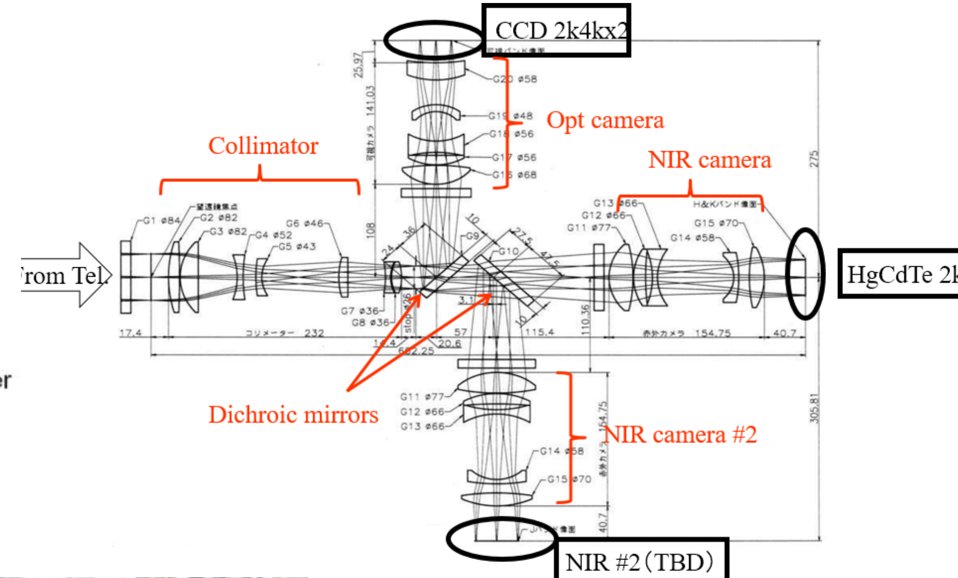
HOWPol: One-shot polarimeter, imager and low-res. spectrograph

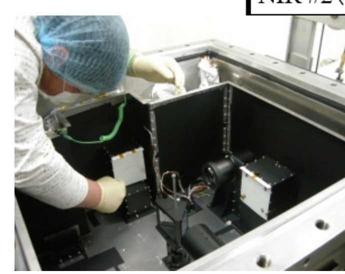


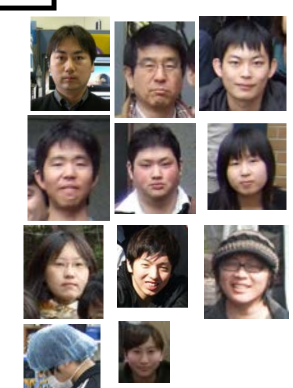


Chiyonobu+ 2007; KSK+ 2008

HONIR: Simultaneous optical and NIR 2 band imager, spectrograph and polarimeter







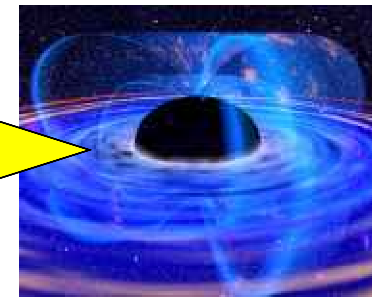
Akitaya+ 2014; Sakimoto+ 2012; Ui+ 2014

Strategy of Kanata Telescope

Higashi-Hiroshima Observatory: Aim

Multi-wavelength and/or Multi-band study for variable, transient objects

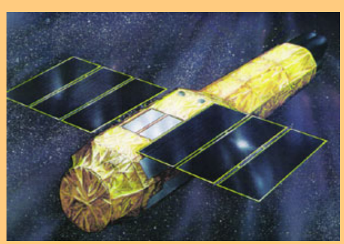
Gamma-ray, X-ray and Optical/NIR Observations



GRB, XRB, AGN, etc

1.5m Optical/NIR telescope, Kanata (2006-)
Gamma-ray satellite (Fermi 2008-)
X-ray satellite (Suzaku 2005-, Hitomi 2016)

© NASA



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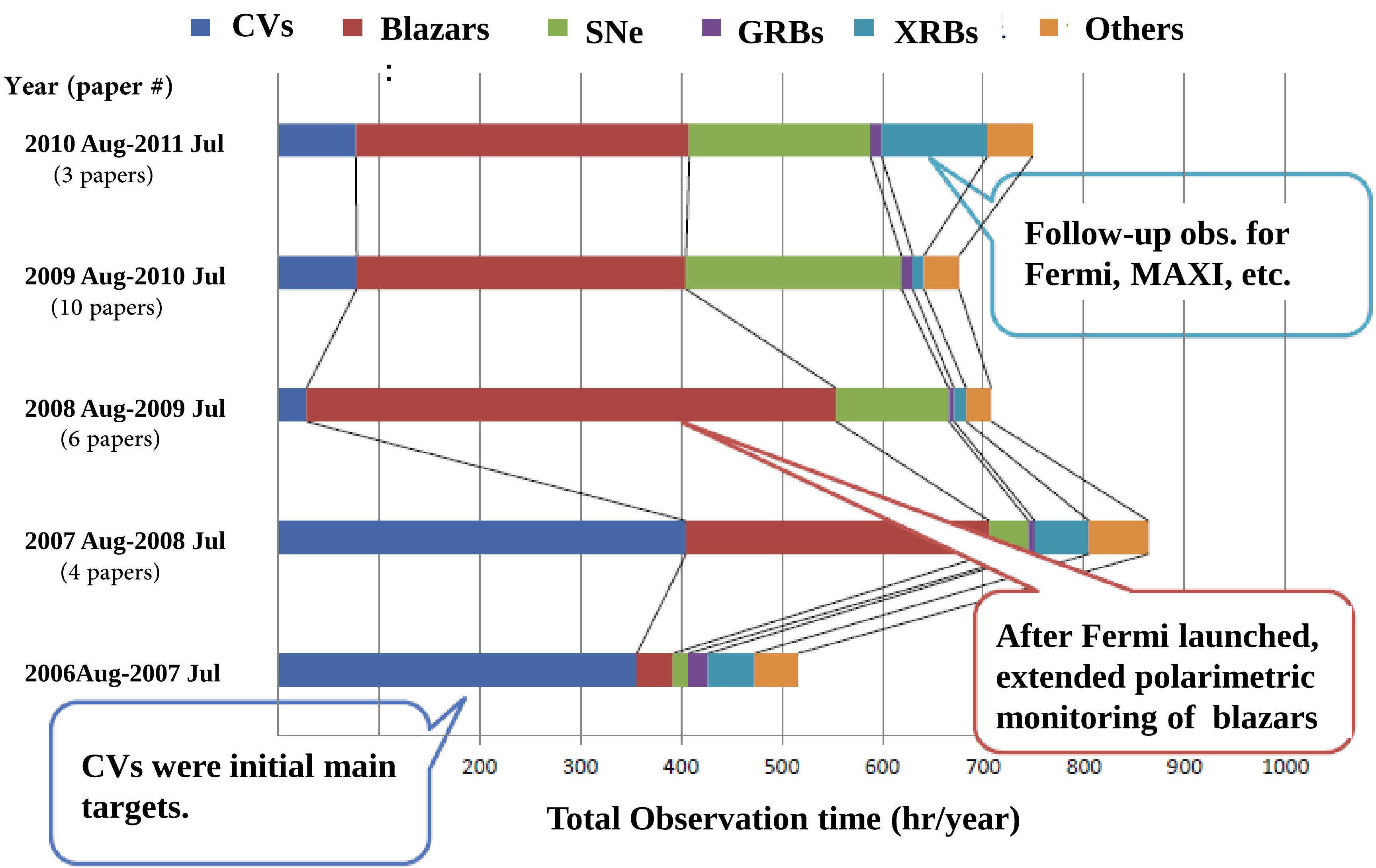
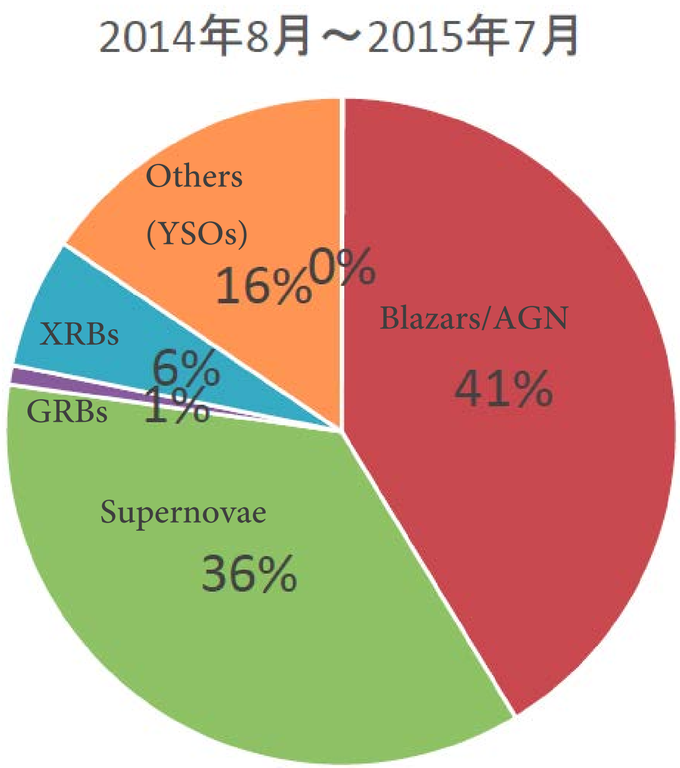
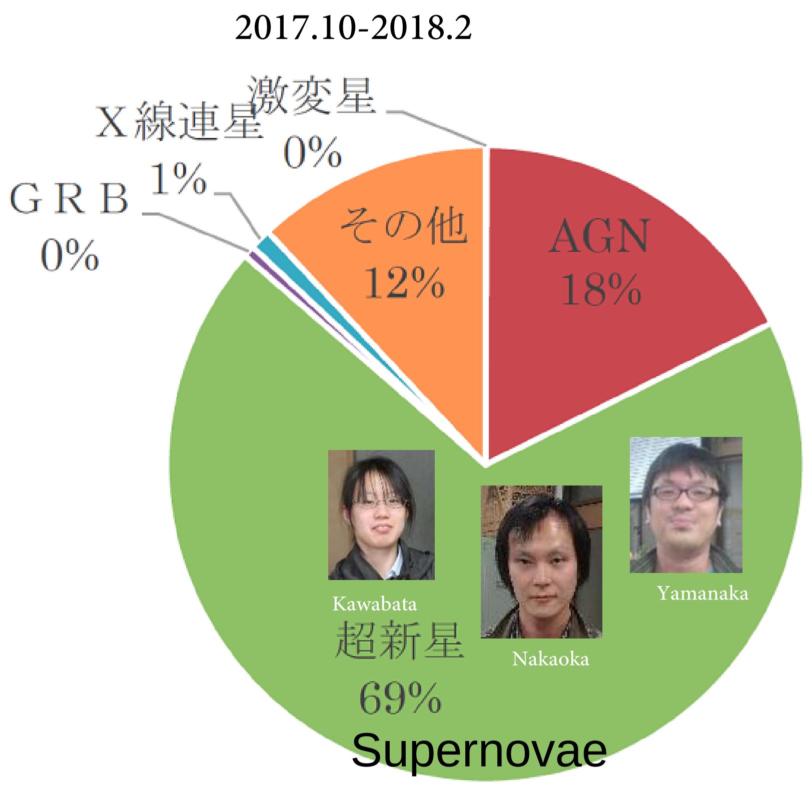
Targets with Kanata telescope 1/2



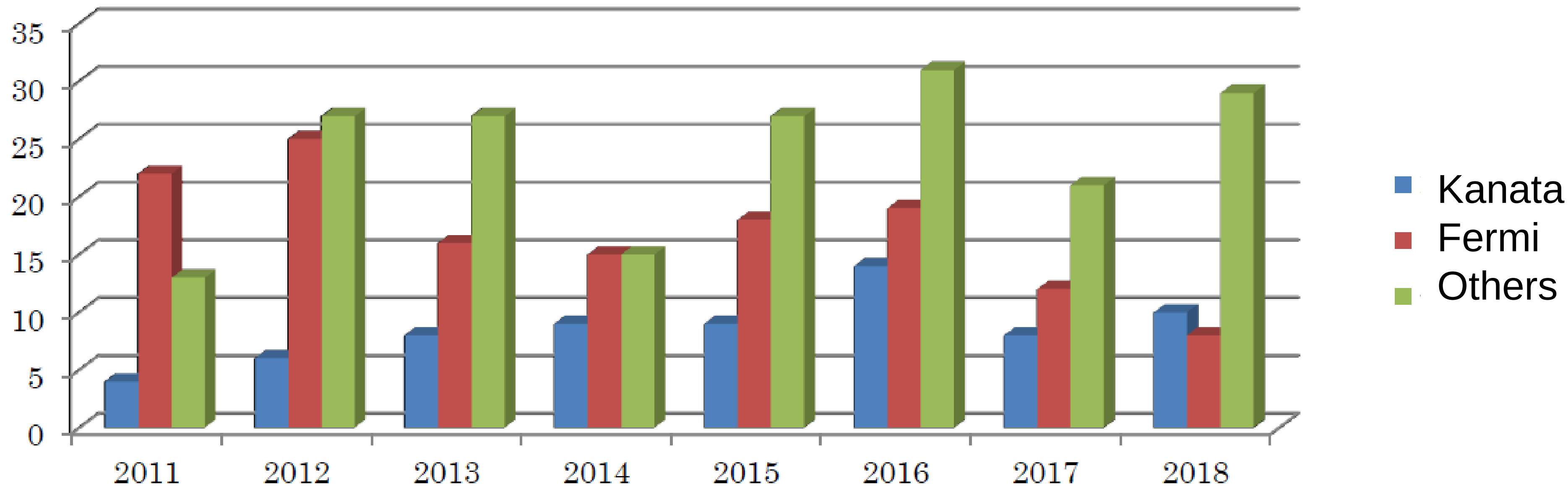
Targets with Kanata telescope 1/2





Number of published papers

~90 papers with Kanata observation since 2007



Kanata(Opt&NIR)

Fermi (Gamma-ray)

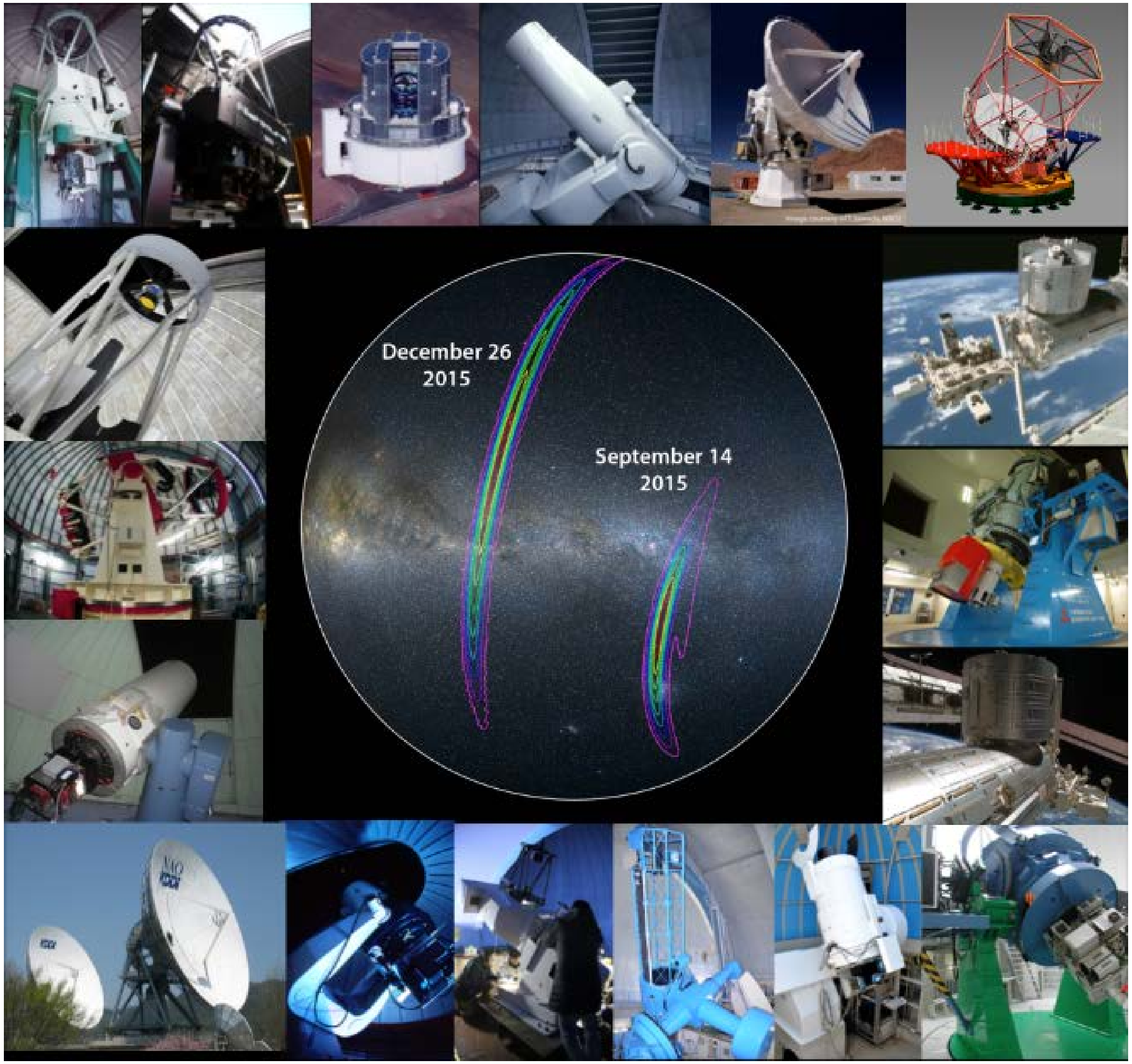
Part of OISTER 光赤外大学間連携

Optical & NIR Astronomy Inter-University Collaborative Programs in Japan 2011-

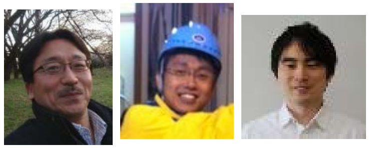
In Japan 14+3 tel's. (0.5-3.8m)
In Chile 1 tel (1m)
In South Africa 1 tel (1.4m)
Other supporting ~1 tel's

Extended observations for Supernovae, X-ray binaries in outburst, and other transient objects.

Part of GW-EM follow-up team, J-GEM

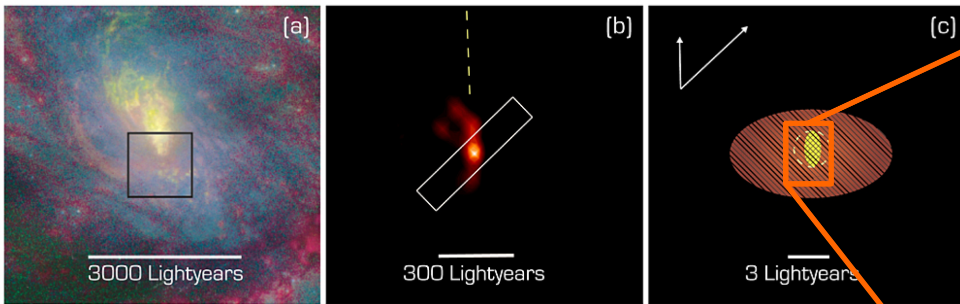


Telescopes in J-GEM collaboration (Morokuma+ 2017)



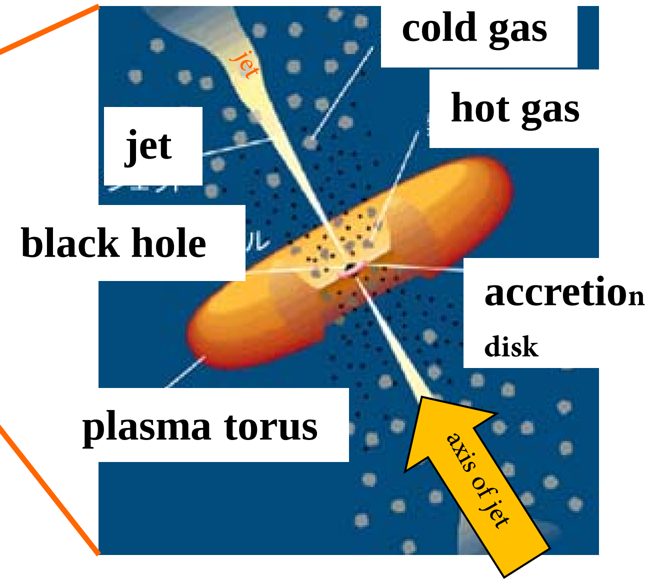
Representative results:
1. Blazars and related objects

Blazars and related objects



The Innermost Region of the Active Galaxy NGC 1068
(VLTI + MIDI)

ESO PR Photo 13/04 (5 May 2004)



Blazars： AGN seen from jet axis

Beamed synchrotron radiation from jet dominates (thus bright)

Kanata Blazar Photo-Polarimetry Campaign

2008-2014: 42 (13 FSRQs, 8 LSPs, 9 ISPs, and 12 HSPs) + 3 blazars have been monitored

Compared with gamma-ray with Fermi observation

Itoh et al. 2016; Ikejiri et al. 2011

Target Blazars

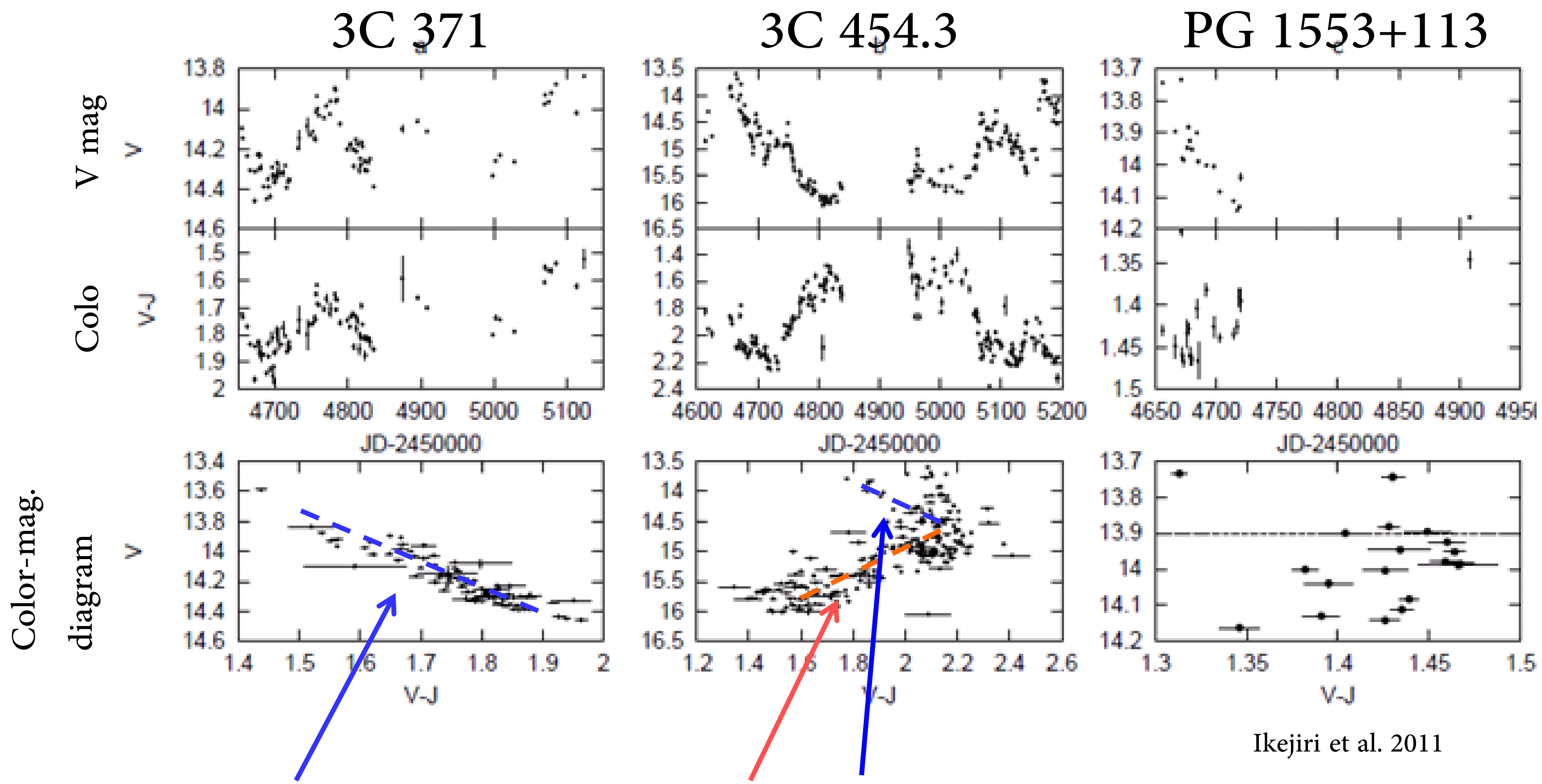
PKS 0048	PKS 0754	3C279
S2 0109	1ES 0806	OQ 530
MisV1436	OJ 49	PKS 1502
PKS 0215	OJ 287	PKS 1510
3C66A	S4 0954	PG 1553
AO 0235	3EG 1052	Mrk 501
SO 0324	Mrk 421	H1722+119
1ES 0323	RGB 1136	PKS 1749
PKS 0422	ON 325	S5 1803
QSO 0454Q	ON 231	3C371
1ES 0647	3C 273	1ES 1959
S5 0716	QSO1239	PKS 2155
BL Lac	1ES 2344	3C454.3

TABLE 2
LIST OF OUR TARGETS WITH MORE THAN 10 DATA POINTS.

Object Name (1)	3FGL name (2)	$\log(\nu_{\rm peak})$ (3)	Type (4)	z (5)	$N_{\rm opt.}$ (6)	N_γ (7)
S2 0109+22	3FGL J0112.1+2245	14.6	ISP	0.265	44	24
Mis V1436	3FGL J0136.9+4751	13.6	LSP (FSRQ)	0.859	52	18
3C 66A	3FGL J0222.6+4302	15.1	ISP	0.444	462	164
AO 0235+164	3FGL J0238.7+1637	13.5	LSP	0.94	72	26
PKS 0454-234	3FGL J0457.0-2325	13.1	LSP (FSRQ)	1.003	27	20
S5 0716+714	3FGL J0721.9+7120	14.6	ISP	0.3	556	198
OJ 49	3FGL J0831.9+0429	13.5	LSP	0.1737	27	16
OJ 287	3FGL J0854.8+2005	13.4	LSP	0.306	174	75
Mrk 421	3FGL J1104.4+3812	16.6	HSP	0.031	85	46
ON 325	3FGL J1217.8+3006	15.5	HSP	0.13	38	17
3C 273	3FGL J1229.1+0202	13.5	LSP (FSRQ)	0.15834	224	91
3C 279	3FGL J1256.1-0547	12.6	LSP (FSRQ)	0.5362	140	72
PKS 1502+106	3FGL J1504.3+1029	13.6	LSP (FSRQ)	1.839	71	27
PKS 1510-089	3FGL J1512.8-0906	13.1	LSP (FSRQ)	0.36	108	51
RX J1542.8+612	3FGL J1542.9+6129	14.1	LSP (FSRQ)	0.117	69	38
PG 1553+113	3FGL J1555.7+1111	15.4	HSP	0.36	196	90
Mrk 501	3FGL J1653.9+3945	17.1	HSP	0.033663	170	80
PKS 1749+096	3FGL J1751.5+0938	13.1	LSP (FSRQ)	0.322	47	16
3C 371	3FGL J1806.7+6948	14.7	ISP (FSRQ)	0.051	21	16
1ES 1959+650	3FGL J2000.0+6509	16.6	ISP	0.047	82	42
PKS 2155-304	3FGL J2158.8-3013	16.0	HSP	0.116	146	60
BL Lac	3FGL J2202.8+4216	13.6	LSP	0.0686	340	137
CTA 102	3FGL J2232.4+1143	13.6	LSP (FSRQ)	1.07	76	33
3C 454.3	3FGL J2253.9+1609	13.6	LSP (FSRQ)	0.859	442	143




Flux-color correlation



Ikejiri et al. 2011

72% blazars

`Bluer when brighter'

trend in the whole data

16% blazars

`Bluer when brighter' in brighter phase

In faint phase, `bluer when fainter' - hot disk component is dominant

Multi-wavelength study in 3C 279

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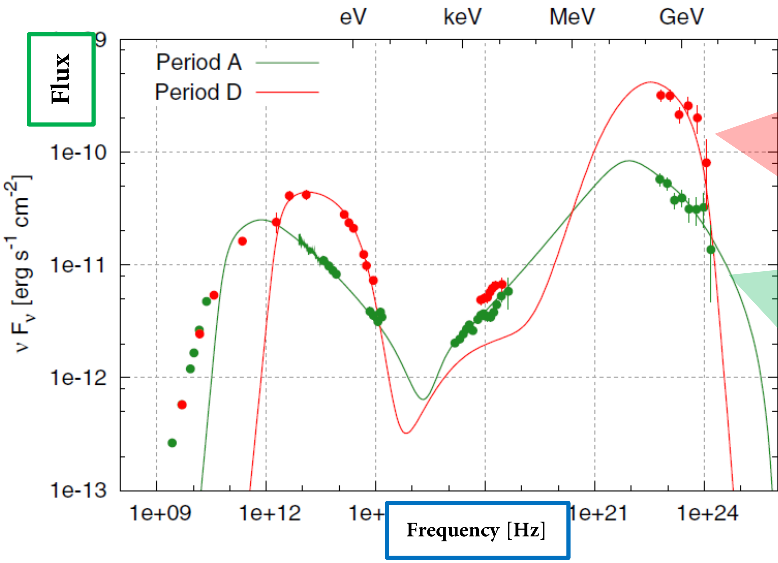
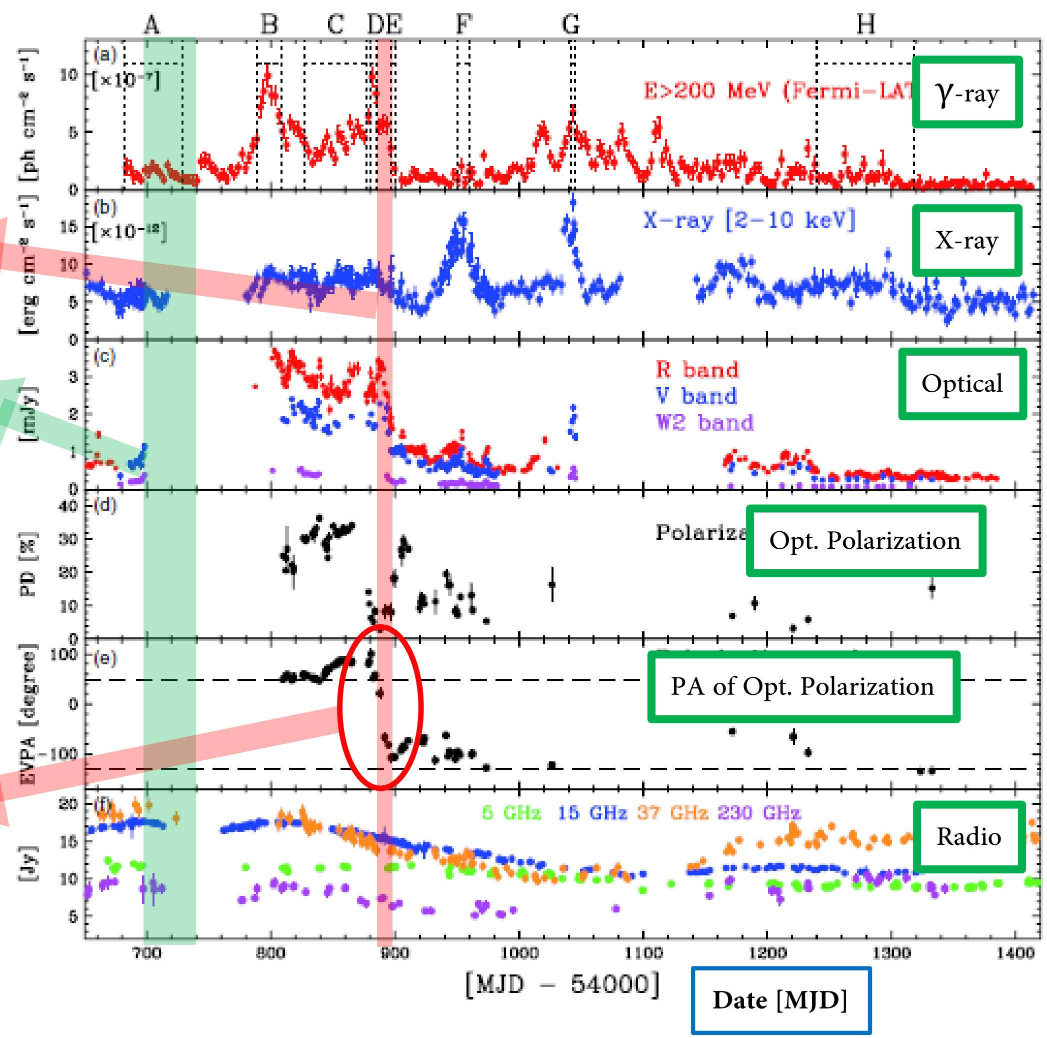
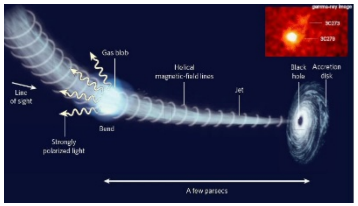




Abdo+10, Hayashida+12

Optical polarization angle rotated at the end of the flare in 2009
→ Bent jet (?)



Correlation between gamma-ray and optical light

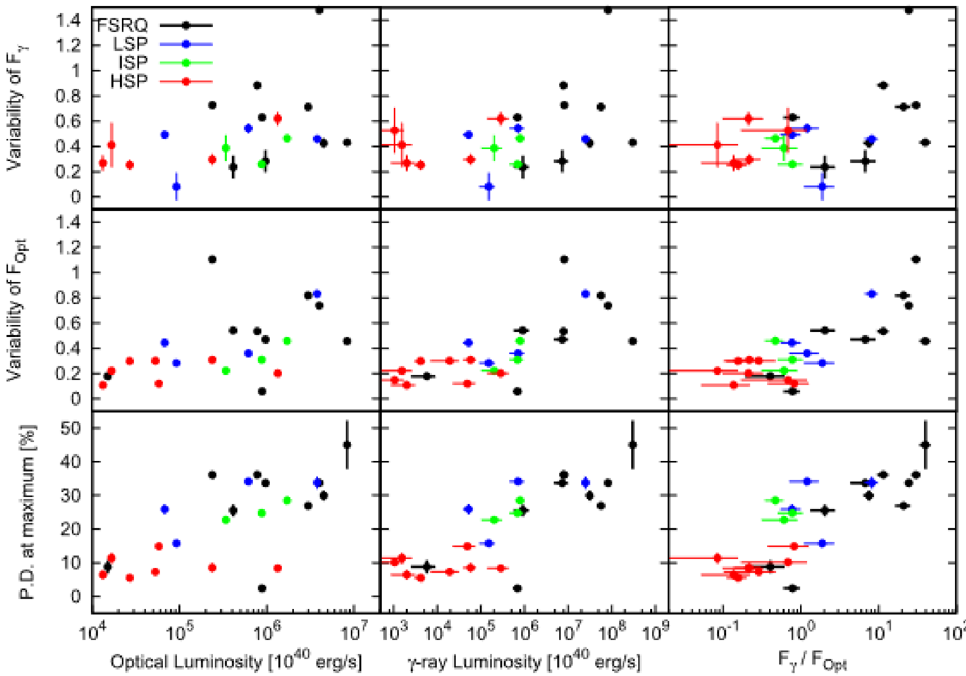


TABLE 4
SUMMARY OF CORRELATION TIME LAGS BETWEEN GAMMA-RAY FLUX AND OPTICAL FLUX

Source Name	time lag (days)	DCF peak value
AO 0235+164	0^{+4}_{-14}	0.67 ± 0.08
S5 0716+714	0 ±7	0.47 ± 0.05
OJ 287	-134^{+4}_{-28}	1.0 ± 0.5
3C 273	-145^{+7}_{-21}	-0.97 ± 0.18
3C 279	-28 ±14	0.67 ± 0.15
3C 279	77^{+7}_{-14}	-0.6 ± 0.1
PG 1553+113	21^{+14}_{-28}	0.4 ± 0.1
PKS 2155-304	-28^{+28}_{-7}	0.9 ± 0.2
BL Lac	0^{+28}_{-77}	1.0 ± 0.1
CTA 102	0 ±7	0.8 ± 0.2
3C 454.3	0^{+49}_{-49}	0.84 ± 0.13

Itoh et al. 2016

Alignment of magnetic field is likely to depend on blazar type

Active phase monitoring in CTA 102

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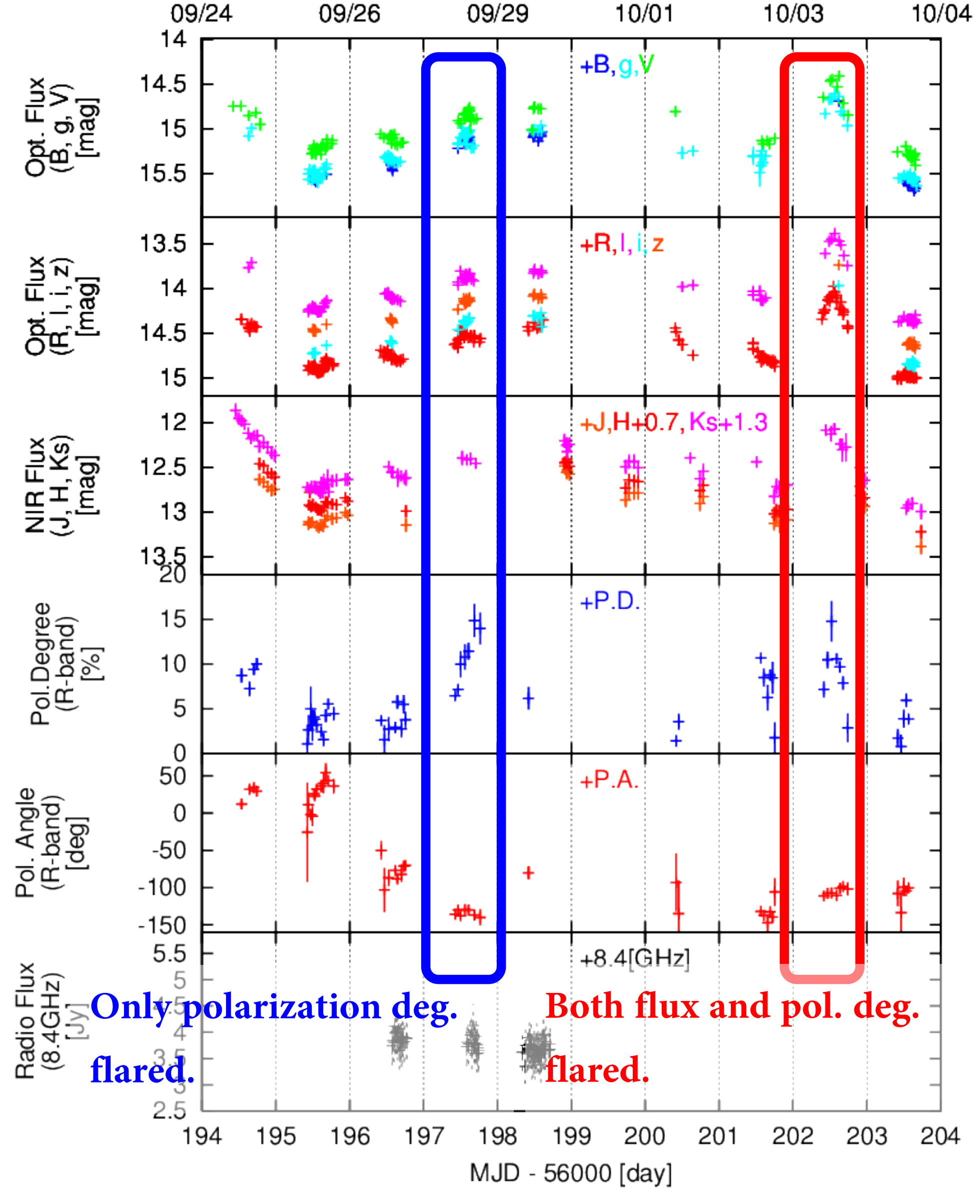
FSRQ (z = 1.037)

Flare observed on
19 Sep 2012 Optical report (ATel #4397)
21 Sep 2012 GeV report (ATel #4409)

Started dense monitoring with Kanata + OISTER

Different types of violent variation in optical polarization observed.

Itoh, Fukazawa, Tanaka+13



Itoh Y. Tanaka

Representative results:
2. Neutrino sources


Y. Tanaka

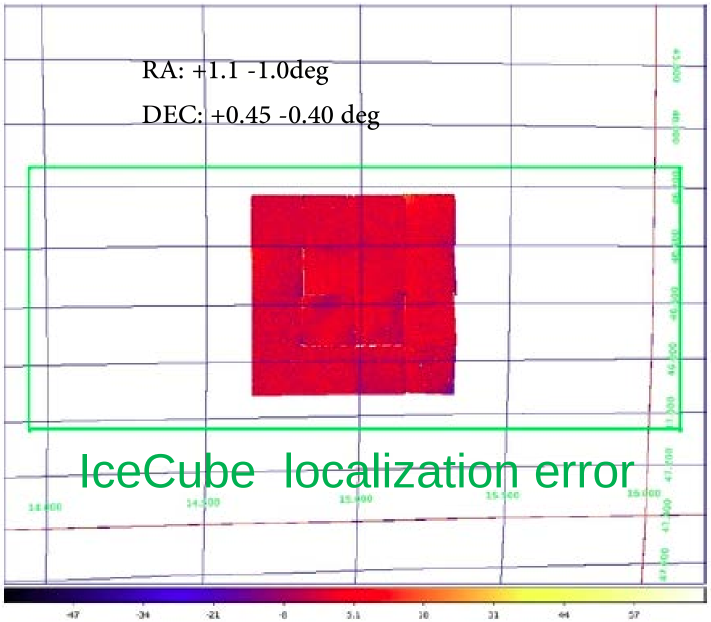

Utsumi


H. Mori


Yamanaka

IceCube-161210A

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



2016-12-11 9:30-17:30 (UT)

J-band imaging (tiling)

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)

- Tiling observation with simultaneous Opt/NIR bands (10’x10’ FoV)
  → No new object

Lessons learned:

Requires much time to cover the error region

Strategy modified for counterpart search

- Tiling observation covering error circle

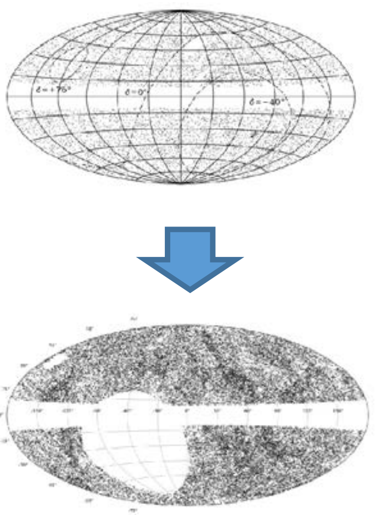
↓

- Targeted observation for blazars within error circle

Focusing to blazars

- ➢ Applying methods for GW event follow-up
- ➢ Constructing new blazar catalogue, BROS
  (Y. T. Tanaka+, Itoh+ in prep.)

  5 times more blazars than in CRATES catalog （Healey+ 2007）

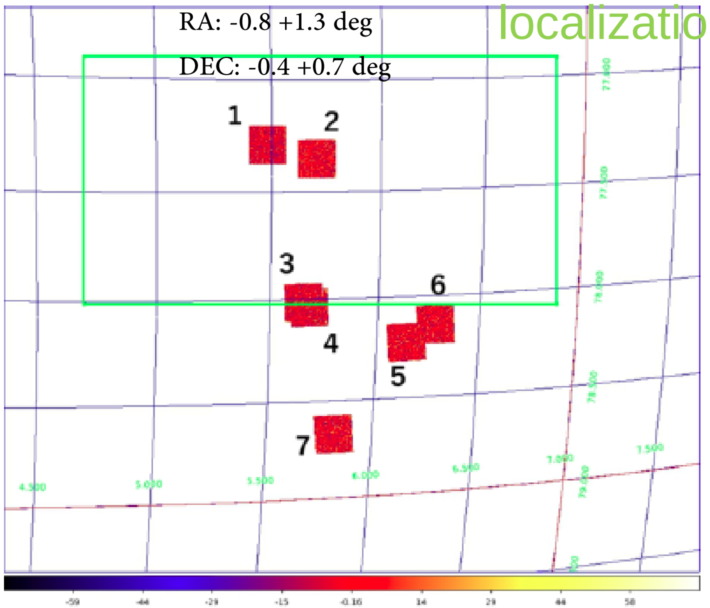


Blazar candidates

IceCube-170922A

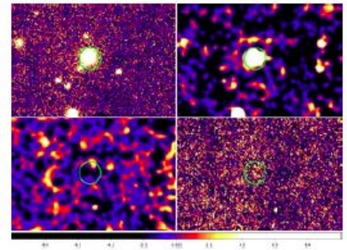
Alert: 2017-09-22 20:54(UT)

IceCube localization error

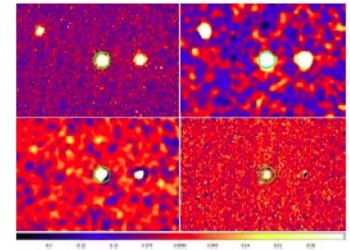


2017-09-23 16:10-20:20 (UT)

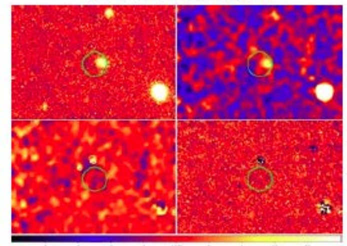
J-band imaging



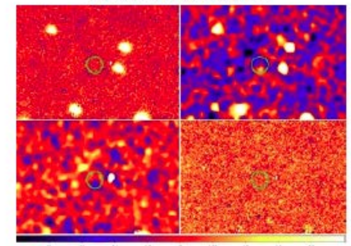
ID:1-J050912 の拡大図



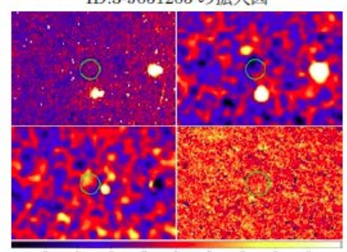
ID:2-J050926 の拡大図



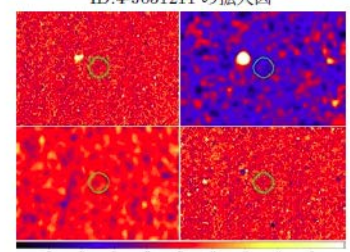
ID:3-J051205 の拡大図



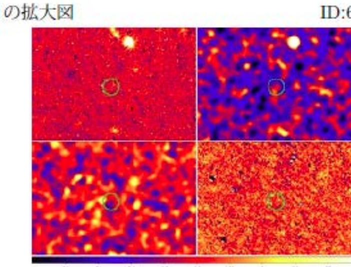
ID:4-J051211 の拡大図



ID:5-J051256 の拡大図



ID:6-J051236 の拡大図

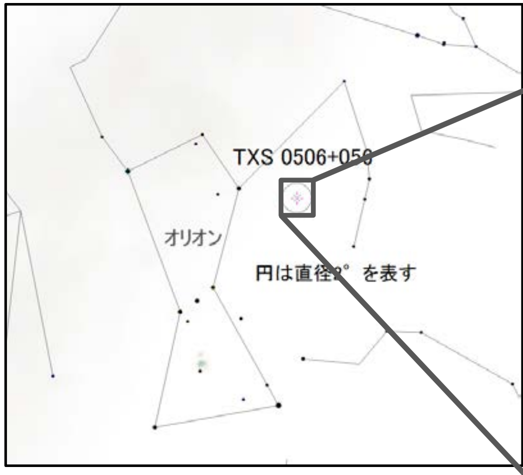


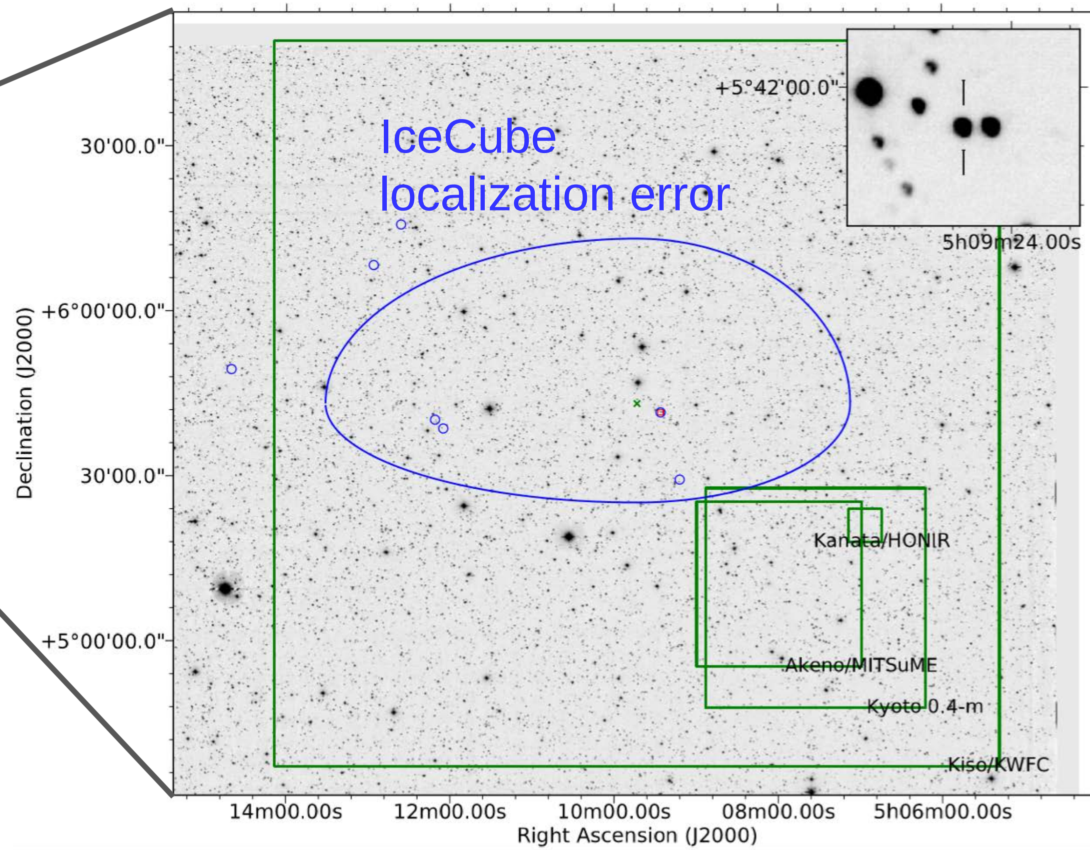
ID:7-J051440 の拡大図

In #2, we found possible variability!

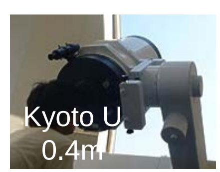
森 修論(2018)

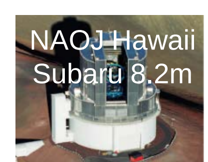
OISTER obs. For IceCube-170922A

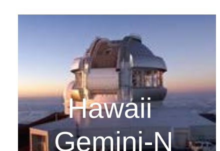




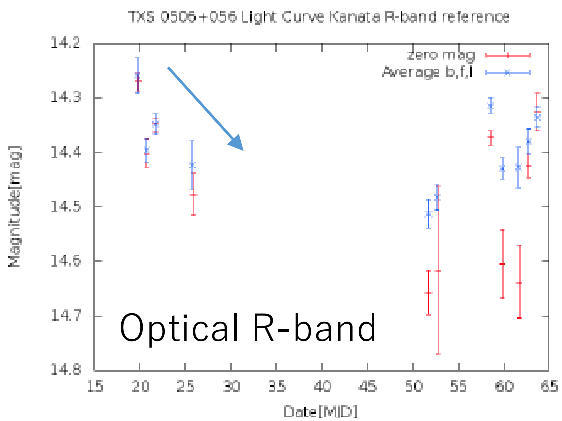
Morokuma, T. et al., in prep.
Tanaka, Y. T. et al. ATel 10791; Yamanaka, M. et al. Atel 11489

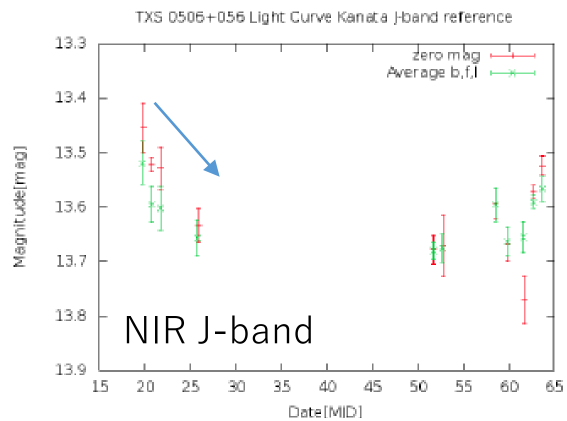






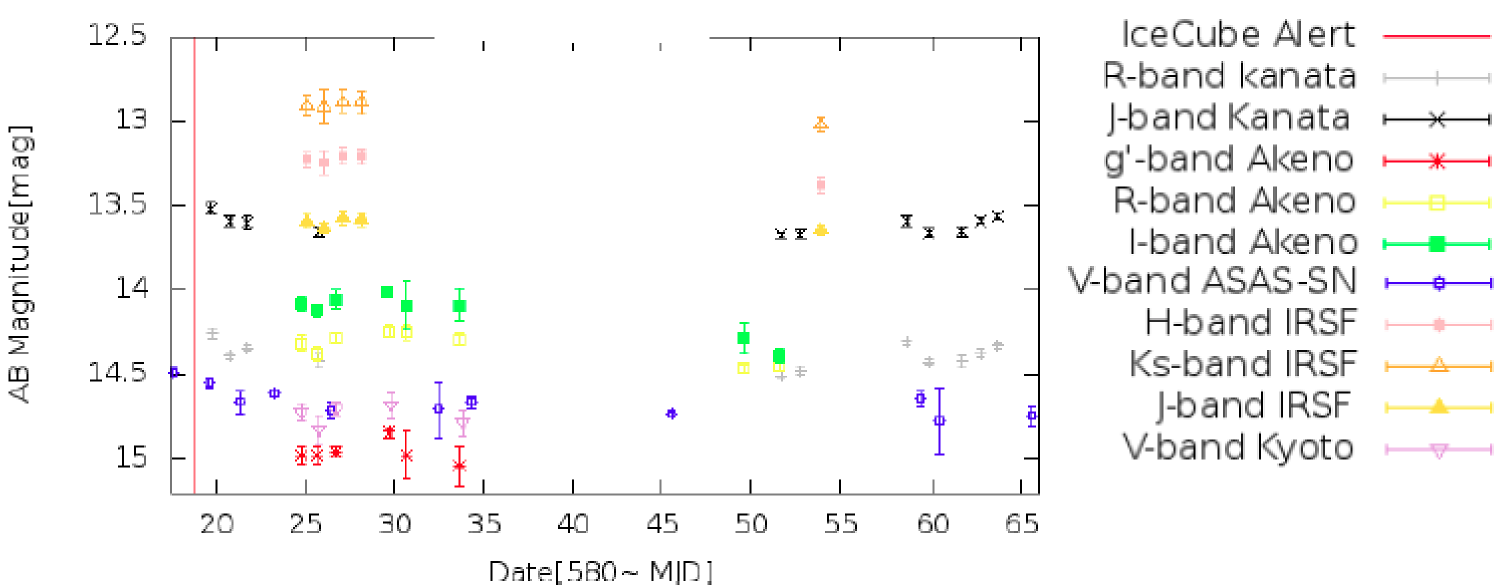
IceCube-170922A: Light curve



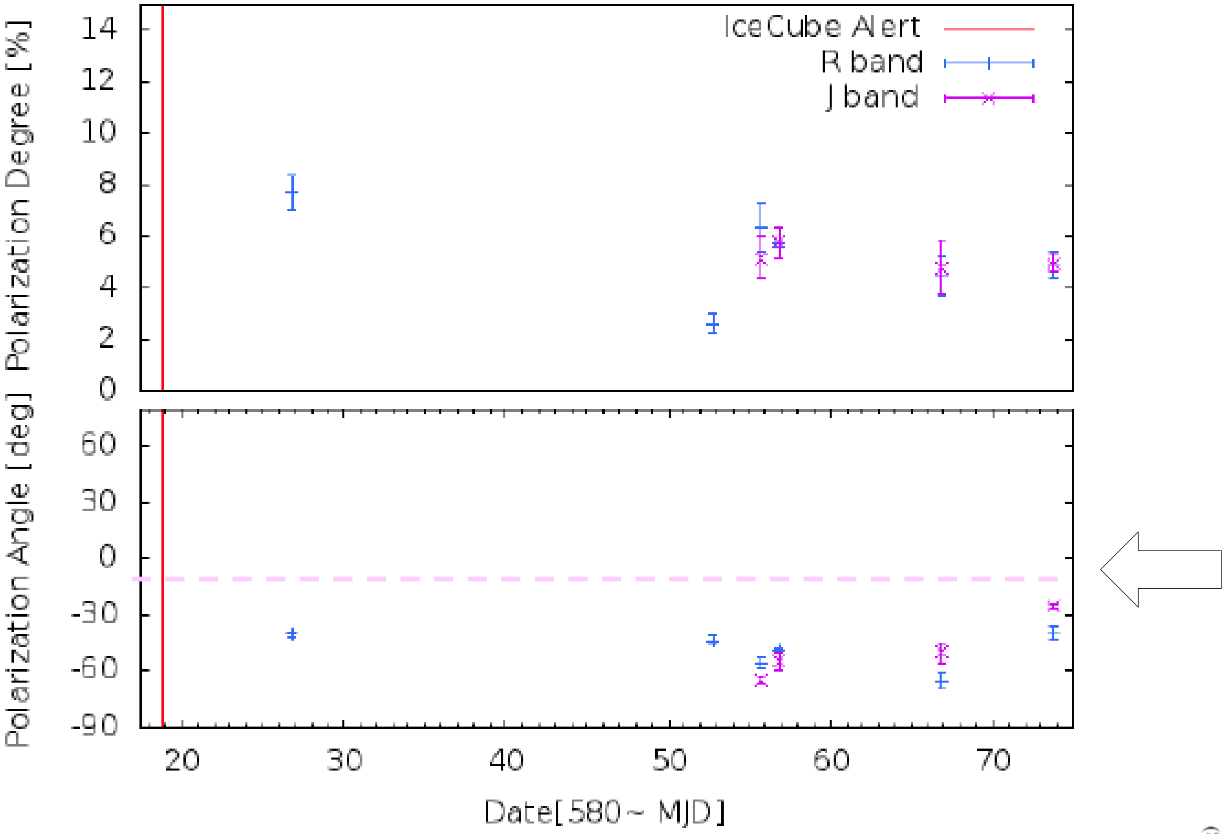


森 修論(2018)

Faded by 20% within first 2 days after IceCube alert

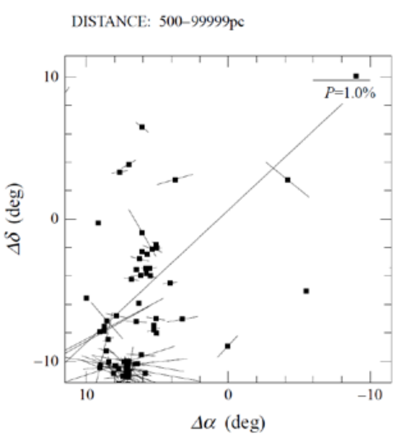


IceCube-170922A: Polarization



Radio jet axis

Misalignment with jet axis?



Polarization map of nearby stars

→ Intrinsic polarization

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Summary of Hiroshima's activity

- Obs. started ~20 hours after the IceCube alert
- Found a blazar (TXS 0506) which is brightened by 3 times than past record (SDSS DR4).
- From day 0 to day 1, TX 0506 faded by 15%
- Found brightening in gamma-ray in Fermi LAT data

Certainly active phase
→ ATel report (Y. T. Tanaka), triggering OISTER obs.

- Found optical polarization of ~7%; time variable
  - Consistent with typical blazars
  - Variability continues even 0.5 year after the IceCube alert


Y. Tanaka


Utsumi


Yamanaka

→ Further observation and study in Morokuma-san's talk

Integration: Orchestrating observatories

- A system for typical, small field-of-view observatories for GW-EM search
  - Japan's active GW-EM searchers joining (J-GEM; Morokuma et al. 2016)
  - Making use of heritages from J-GEM — no additional development
    - Same format, easy to participate for OptNIR observers
- Blazar candidates will be suggested automatically according to a GCN notice
  - Based on BROS catalog (Itoh et al. in prep.)
    - Same idea for finding TXS 0506+056
  - Possible to include other catalog sources (Any idea)
- First observation with this system has been made on May 2019
  - Not yet fully commissioned. Need to get consensus in J-GEM.

candidate : IC42419327_132508

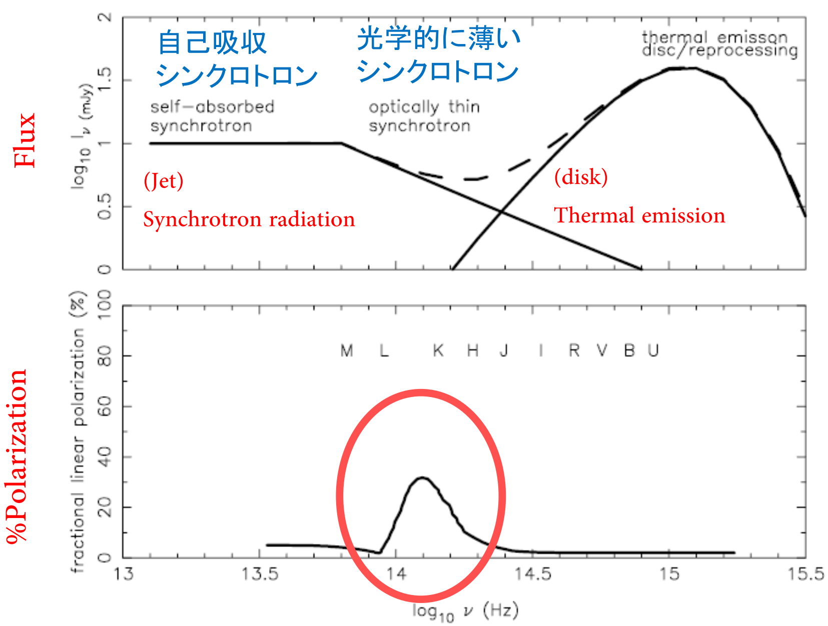
galid	eventid	prob	inserted	ra	dec	d
BROS_J0801.0+0626	IC42419327_132508	0.2876742	2019-05-03 17:25:01.983909	120.267315	6.441576	9
BROS_J0801.2+0628	IC42419327_132508	0.2740911	2019-05-03 17:25:01.983909	120.318049	6.476643	9
BROS_J0801.5+0611	IC42419327_132508	0.2411585	2019-05-03 17:25:01.983909	120.375726	6.197231	9

Utsumi 2019

Multi-wavelength Observation Sample 3: Others (X-ray binaries, GRBs, SNe)

Outburst of blackhole binary V404 Cyg

Conceptual SED and polarization vs frequency for X-ray binary in active phase

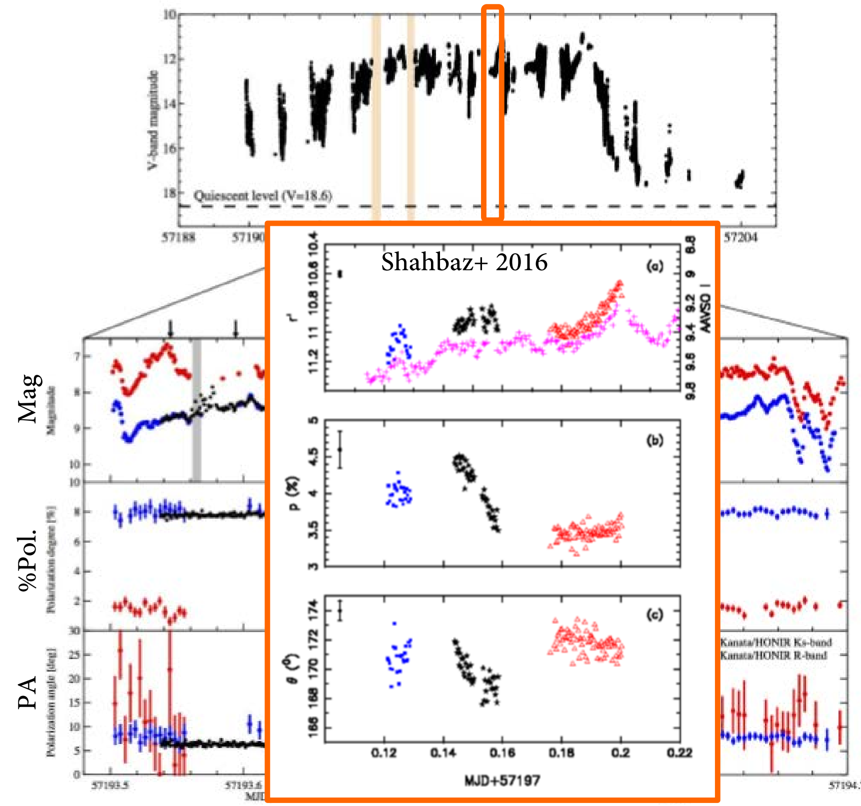


Shahbaz+ (2008)

>a few % polarization is expected in NIR bands

V404 Cyg in outburst phase

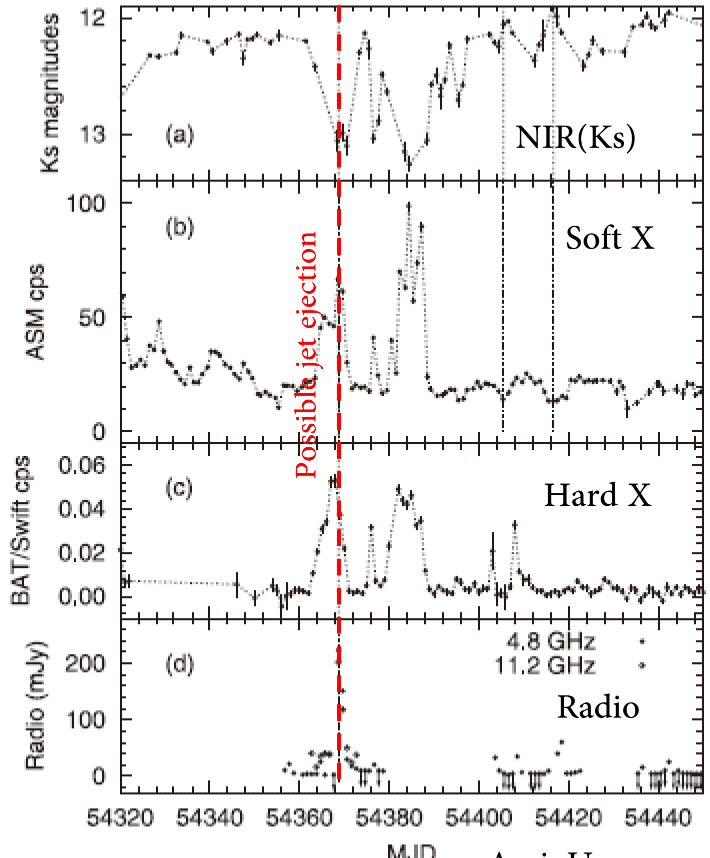
(Kanata/HONIR, Pirka; Tanaka+ 2016)



Delayied optical synchrotron activity


Y. Tanaka Itoh

GRS 1915+015: NIR and X-ray monitoring



Arai, Uemura et al (2009)

NIR photometric monitoring.

X-ray hardness ratio suggests this binary is in soft state at MJD 54320-54570.

Around MJD 54370, X-ray and radio flare appeared

→ jet ejection

In contrast, NIR flux decreased.

(Time lag < 1d)

This NIR – X/radio anti-correlation continued during its soft state (~250 d).

Arai

Uemura

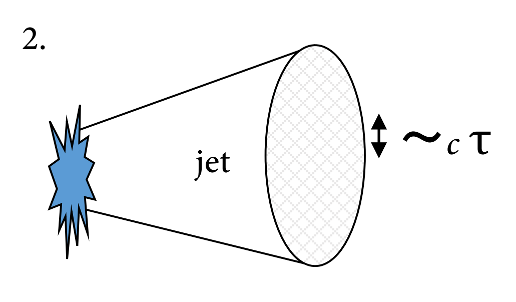
List of Kanata optical polarimetry for GRBs

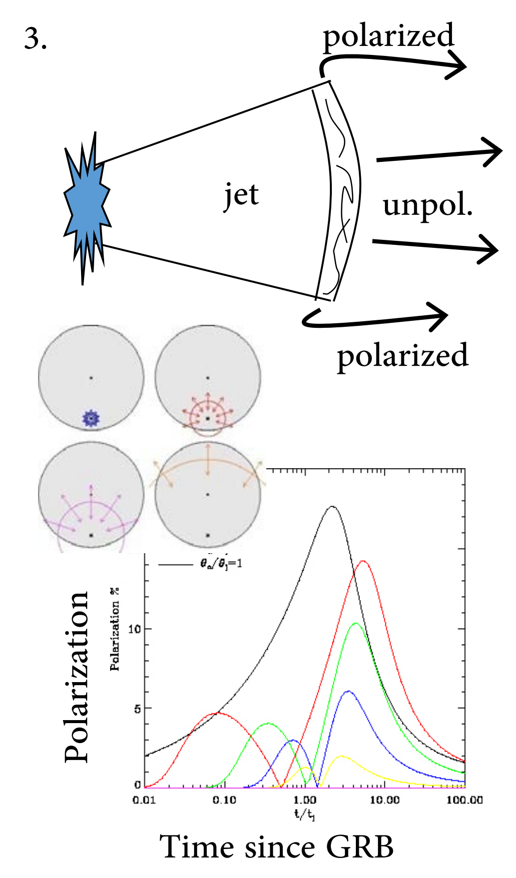
	GRB trigger t1	GCN receive t2	Expos. start t3	t3−t1 (s)	t3−t2 (s)	Polarized?
GRB 091208B	9:49:58	9:50:24	9:52:27	149	123	Yes
GRB 111228A	15:44:43	15:45:33	15:47:25	162	112	Yes
GRB 121011A	11:15:30	11:16:09	11:17:02	92	53	No
GRB 130427A	7:47:57	7:49:15	11:40:26	14027	13949	No
GRB 130505A	8:22:28	8:22:51	10:46:08	8643	8620	No
GRB 140629A	14:17:30	14:17:46	14:18:43	73	57	No
GRB 180720B	14:21:44	14:21:59	14:22:57	74	53	Yes

Capability of quickly starting polarimetry with >1m telescope is unique.

GRB afterglow polarization: Geometry of magnetism

1. **Totally random orientation of magnetism.**
   → Null polarization
2. **Combination of coherent patches (scale length ~ $c\tau$). Within each patch, the magnetic field is ordered. Normal jet may have ~50 patches.**
   → Constant polarization of ~10% (=70%/√N)
   (e.g., Gruzinov & Waxman 1999)
3. **Axi-symmetric polarization pattern due to compressed, tangled magnetic field, coupled with relativistic `beaming' and `occultation' of emitting region.**
   → Variable polarization of p=0-10% from oblique line of sight (e.g, Sari+ 1999; Rossi+ 2004)
4. **Large scale ordered-magnetic field in (not hydrodynamic jet, but) Poynting-flux dominated jet** (e.g, Lyutikov+ 2003)
   → Large polarization (up to ~50%)





Rossi+ 04

GRB 111228A (z=0.714)

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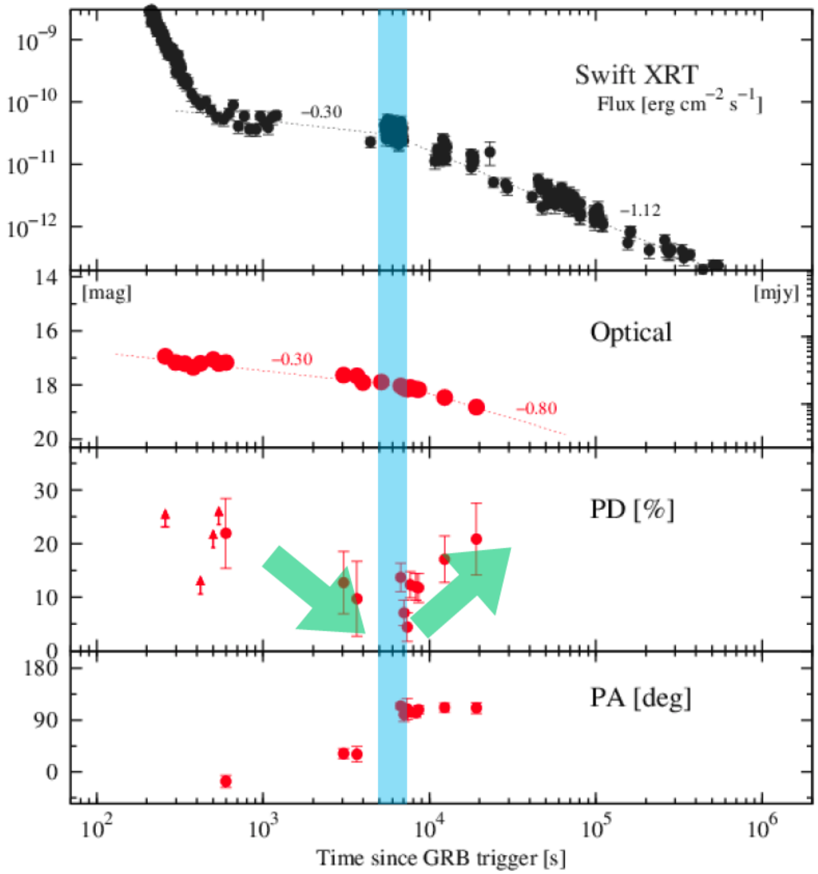

Takaki, Toma, KSK+, submitted

Optical afterglow shows significant temporal polarization change.

<u>GRB 111228A: Strongly polarized</u>

GRB 180720B (z=0.714)

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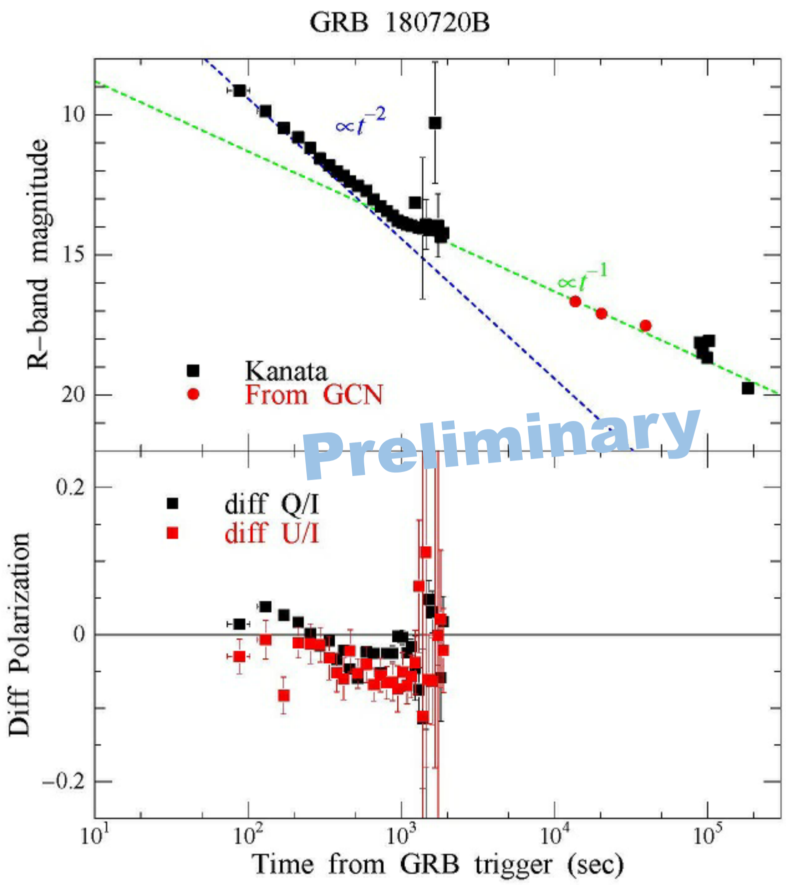


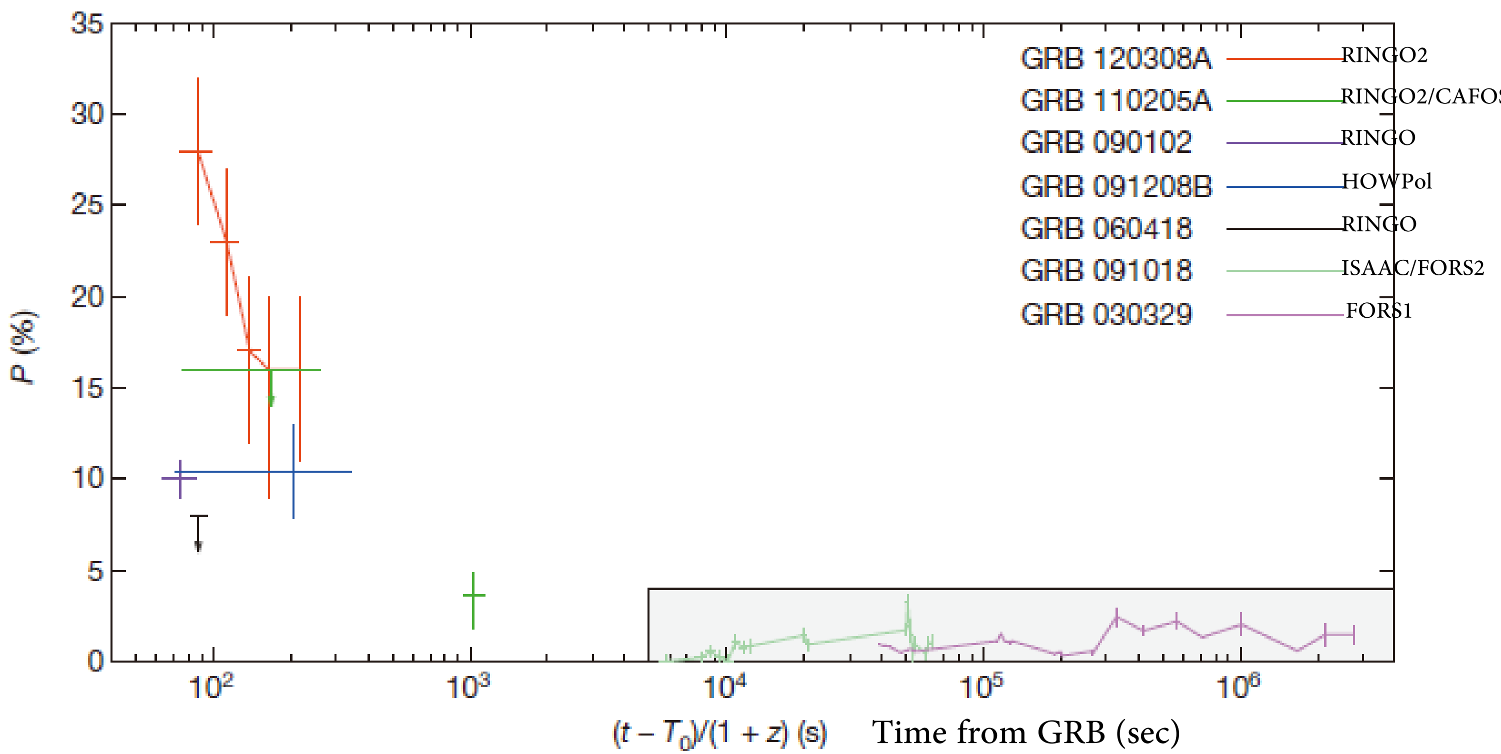
KSK, Takagi+ in prep.

Small, but clear change/rotation of optical polarization in steep decline phase (reverse-shock).

GRB 180720B: Mildly polarized

Other early afterglow polarimetry

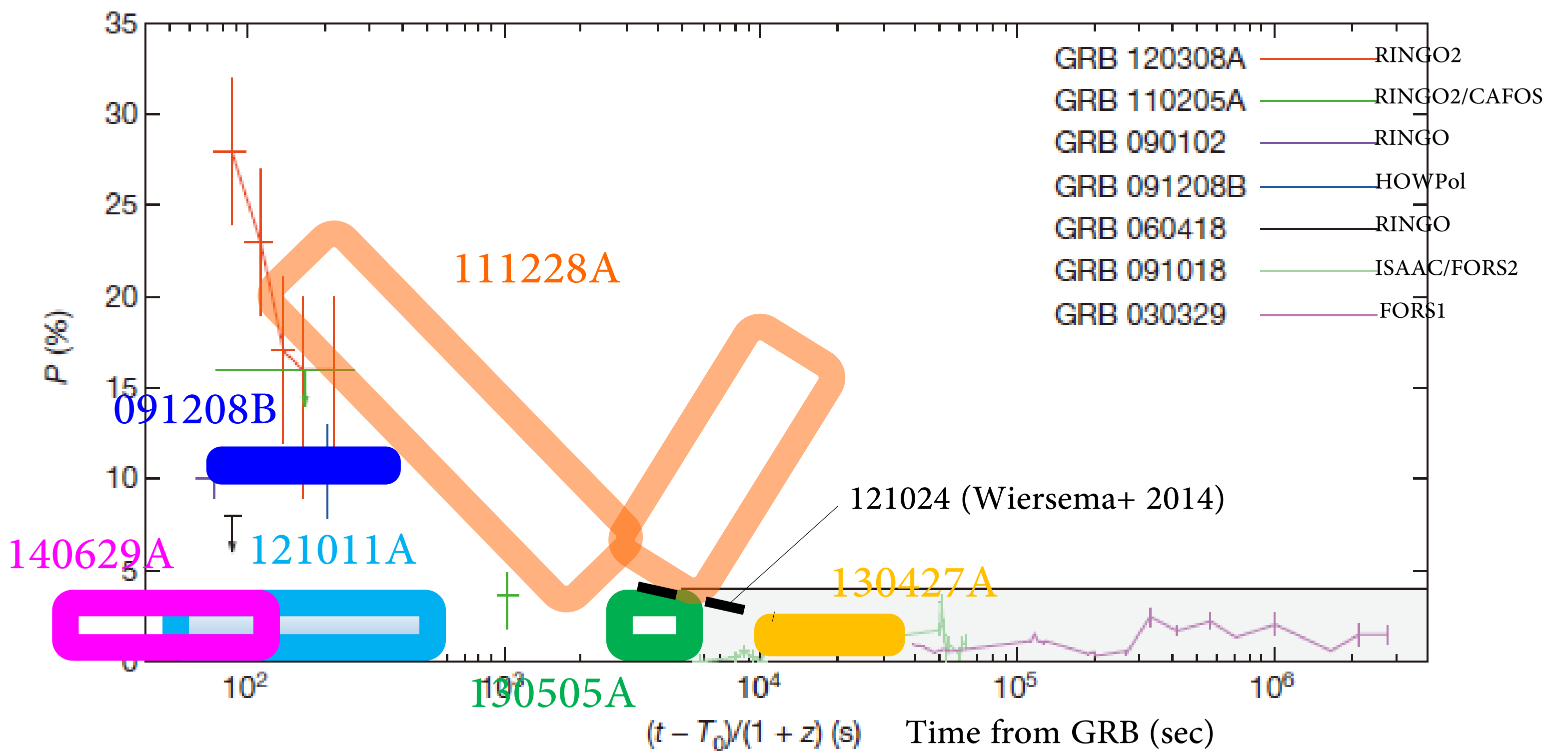
Mundell+ (2013), Nature



Earliest afterglow is generally strongly polarized?

Other early afterglow polarimetry w/ HOWPol data

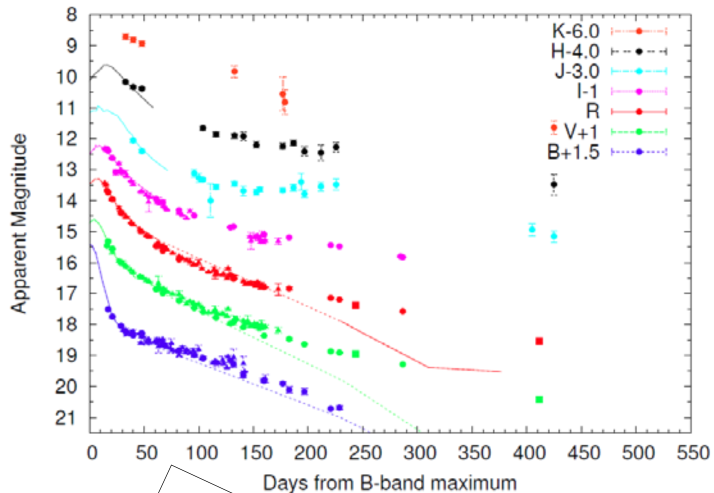
Mundell+ (2013), Nature

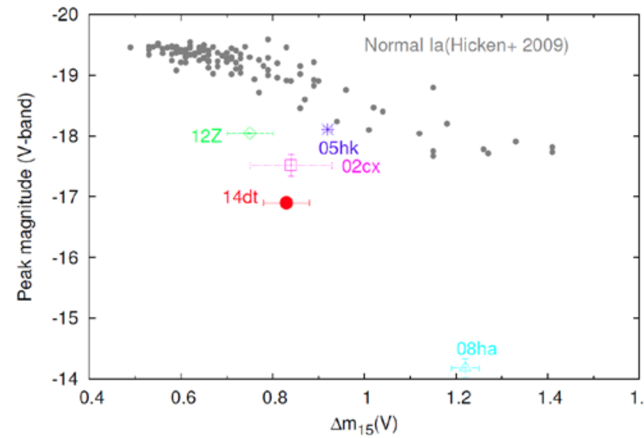


Earliest afterglow is generally strongly polarized?

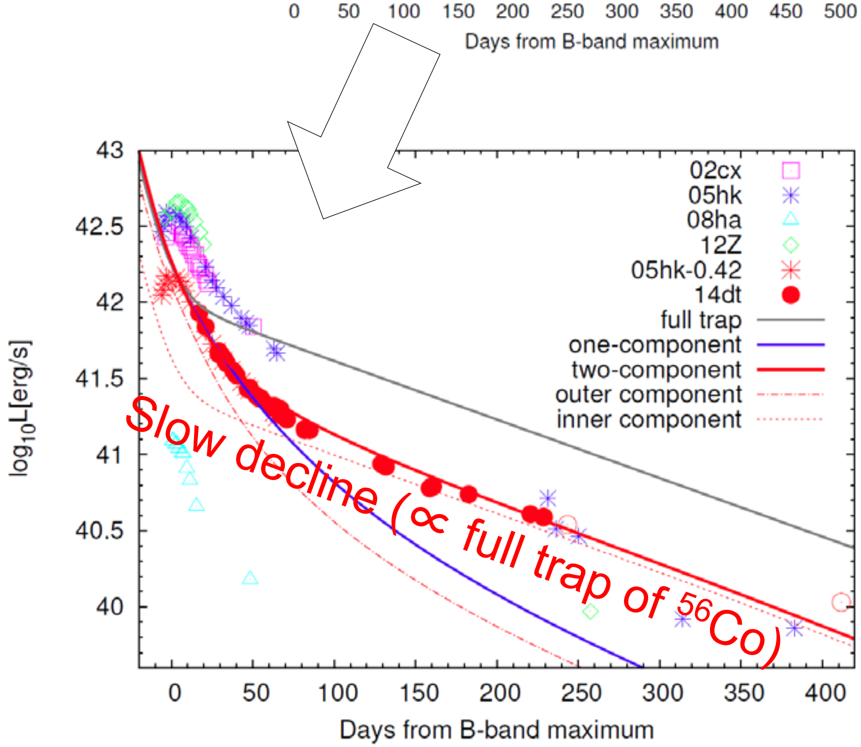
– No.

SN 2014dt: Faint Type Ia (Iax) supernova





Miho Kawabata et al. (2018)



Peculiar (faint, low explosion velocity, hot photosphere) Type Ia
→ Type Iax

We monitored a SN Iax densely.

Slow decline → suggesting hot dense core even in late phase (possibly a bound white dwarf remnant).

HinOTORI 0.5m telescope in Tibet, China



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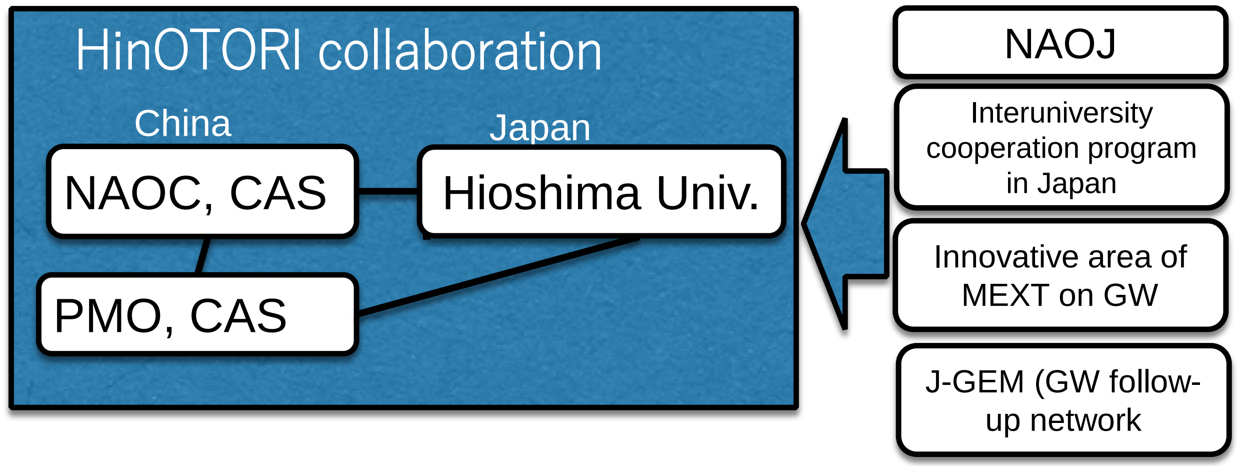
HinOTORI Project

Hiroshima University Operated Tibet Optical Robotic Imager

HinOTORI
Hiroshima University Operated Tibet Optical Robotic Imager

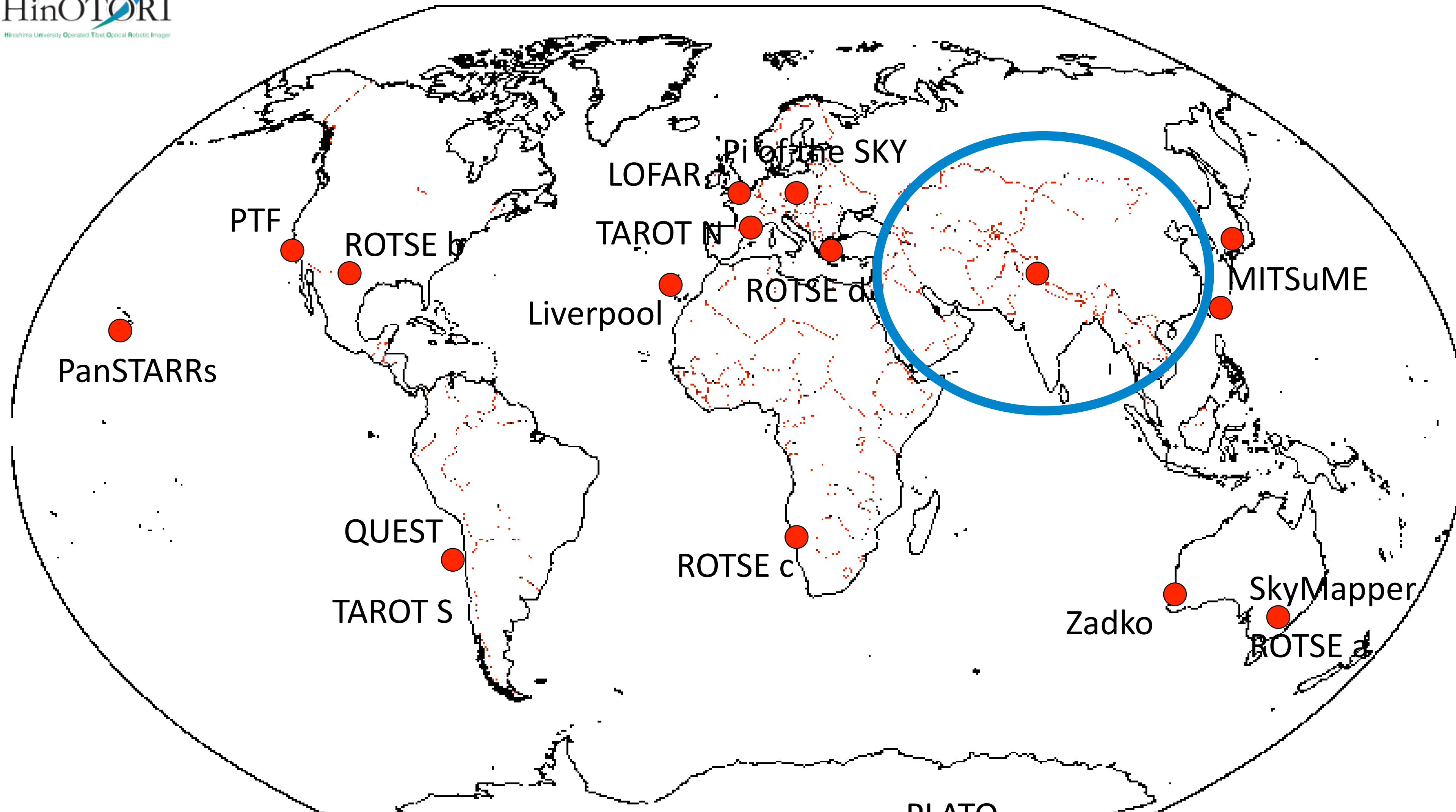


- Supported by Grant-in-Aid for Scientific Research on Innovative Areas of MEXT,
- “New development of astrophysics through multi-messenger observations of gravitational wave sources”. This project is a collaborative project between Hiroshima Univ., National Astronomical Observatory of China, and Purple Mountain Observatory.

科研費 KAKENHI

重力波対応天体探索用広視野三色同時撮像カメラ

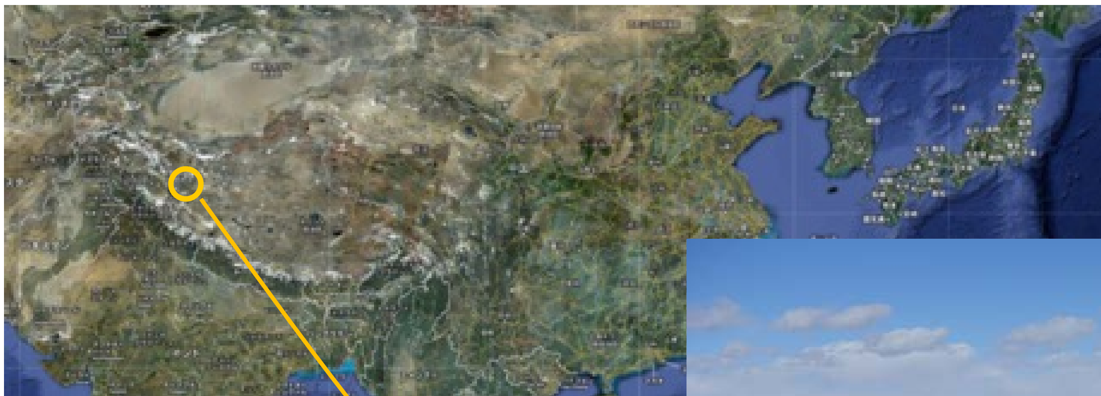
Robotic telescopes for transient objects



No robotic tel. around middle Asia.

Gar site in Tibet Ali area

Longitude : 60 degree apart from Japan
Altitude = 5100m→ Good for U-band observations

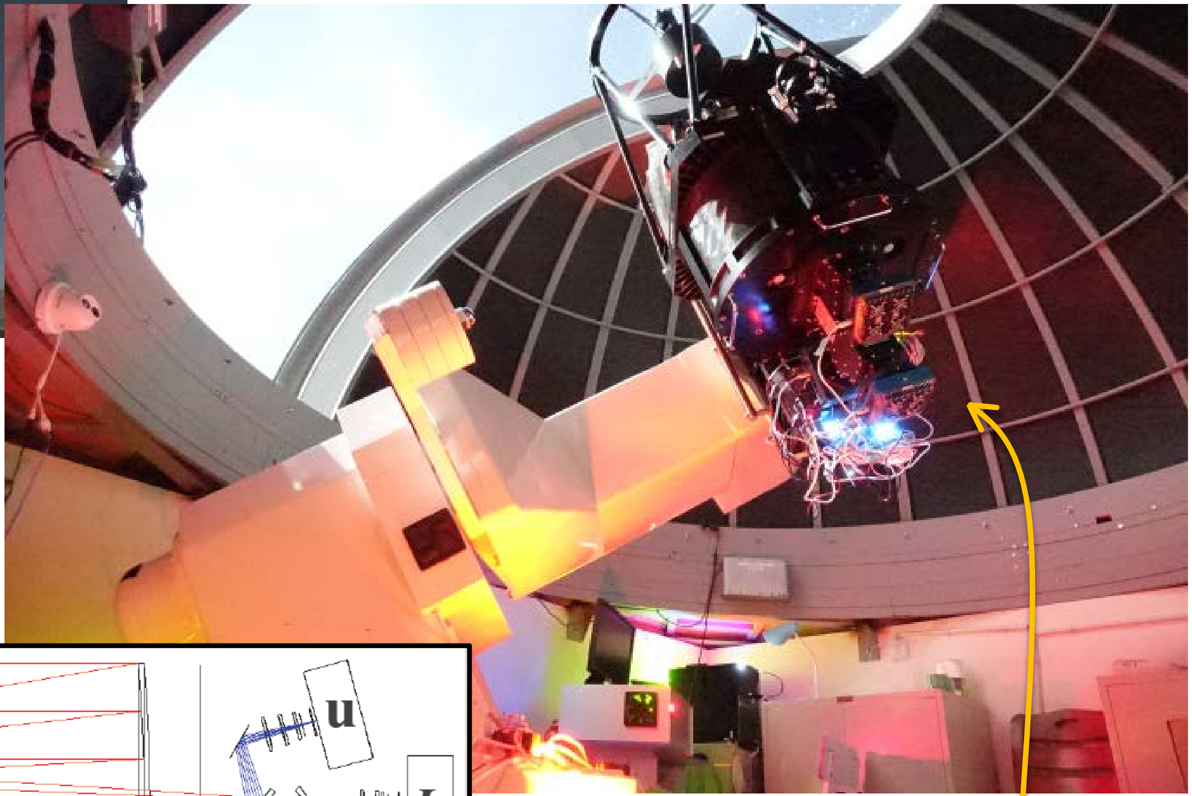


One of the world highest astronomical observatoris

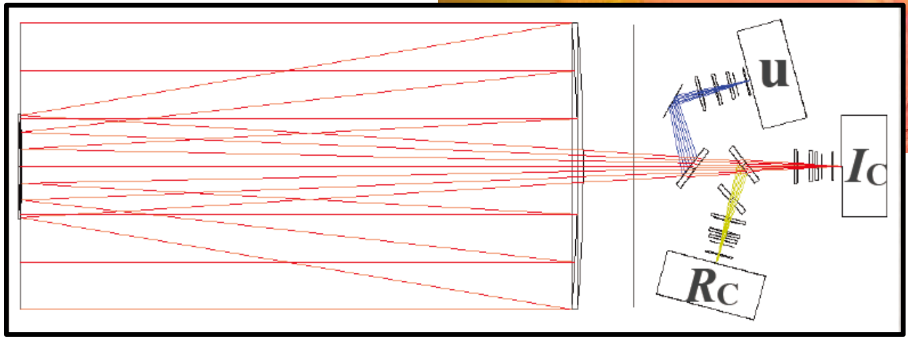
Telescope and Instruments

Dome of HinOTORI telescope 2017.10

50cm Robotic Telescope

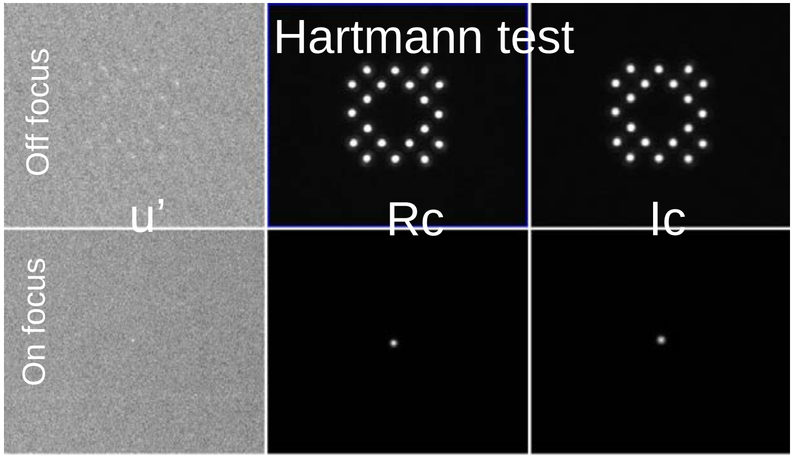


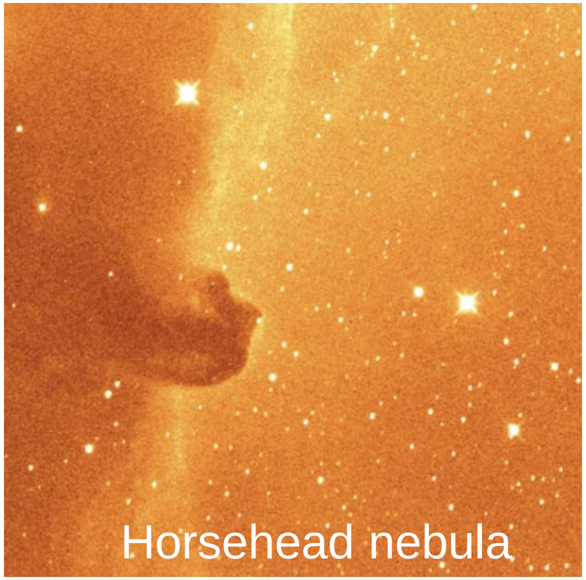
3 Color Camera

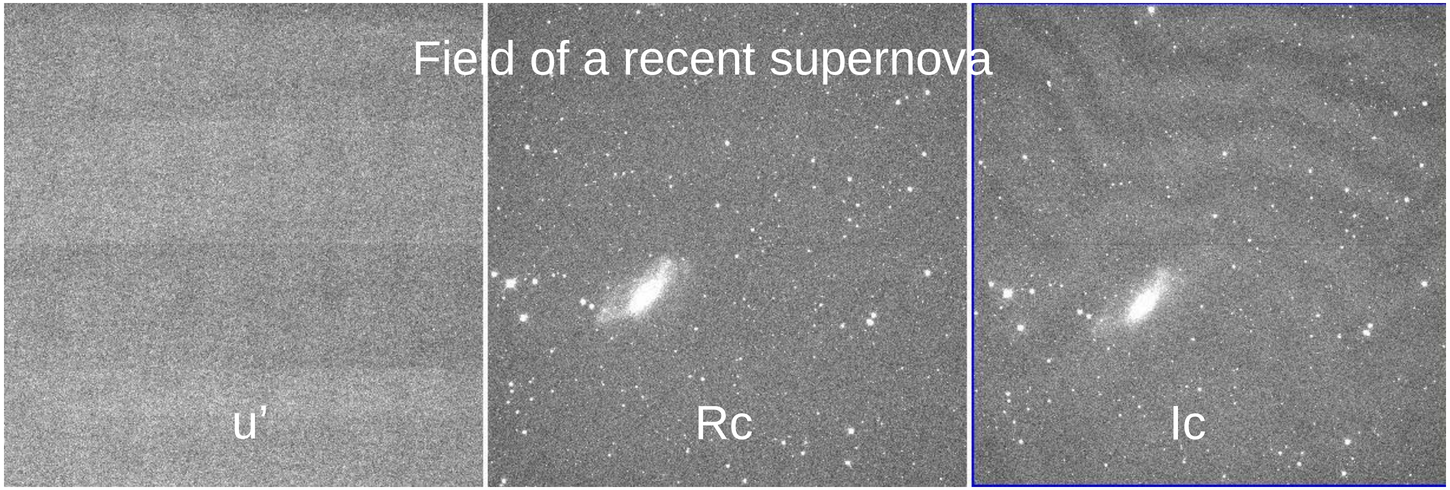


Utsumi+ 2015

Scientific First Light in 2018 Oct.







Summary

- Kanata 1.5m telescope
  - Dedicated for transient objects/phenomana
  - Simultaneous optical and NIR observation (imaging, spectroscopy, polarimetry)
  - Supernova, Blazars, GRBs, IceCube events, GW events,..
- HinOTORI 0.5m telescope
  - Construction almost finished.
  - Preparing remote/robotic observation system.