

MITSuME(爆発変動天体の多色撮像観測) プロジェクト

明野観測所に設置した3色同時撮像ロボット望遠鏡
による γ 線バースト残光と活動銀河核の観測

宇宙線研共同利用査定額：10万円
用途： 旅費（東工大→明野）

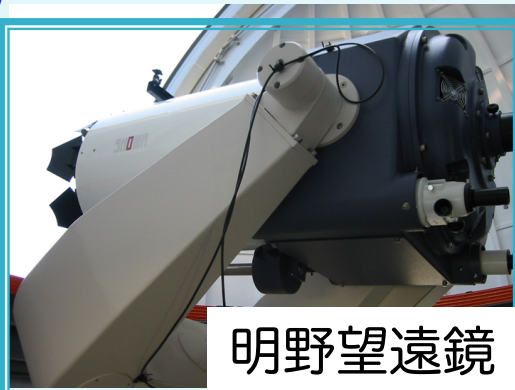
河合誠之、谷津陽一、森由希、中嶋英也、遠藤瑛紀（東工大）
福島正己（ICRR）、森正樹（立命館大）、
柳澤顕史、吉田道利、黒田大介、渡部潤一（国立天文台）ほか



MITSuME

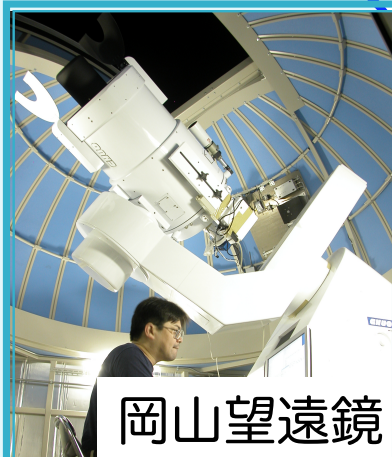
Multi-color Imaging Telescopes for Surveys and Monstrous Explosions

可視50cm望遠鏡



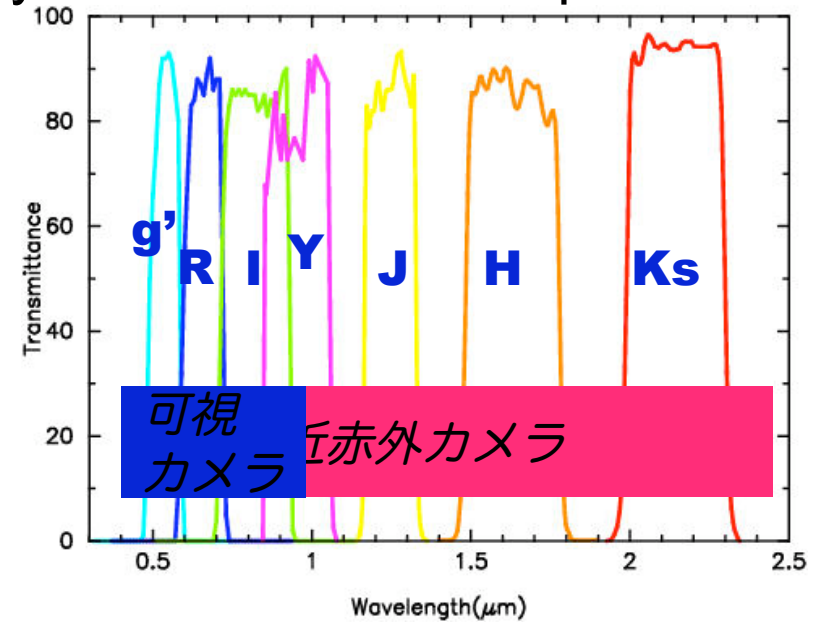
明野望遠鏡

東大宇宙線研明野観測所



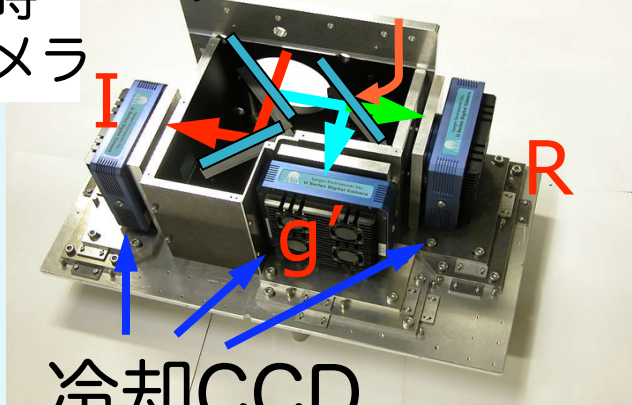
岡山望遠鏡

岡山天体物理観測所



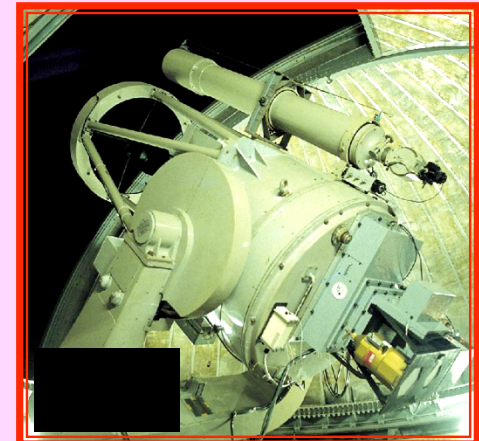
三色同時
撮像カメラ

ダイクロイックミラー

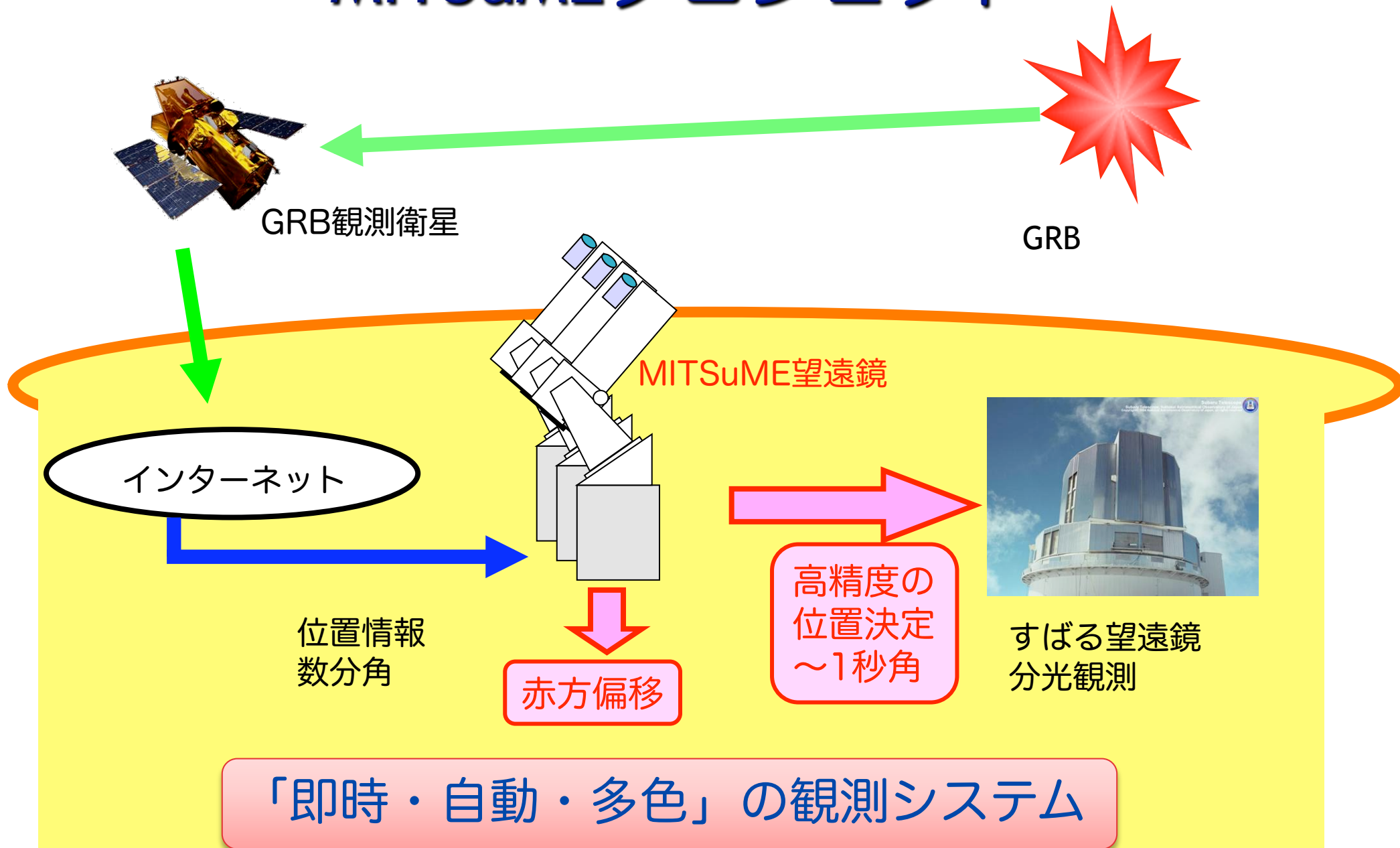


冷却CCD

近赤外91cm
望遠鏡



MITSuMEプロジェクト



明野50cmΦ望遠鏡の開発と運用

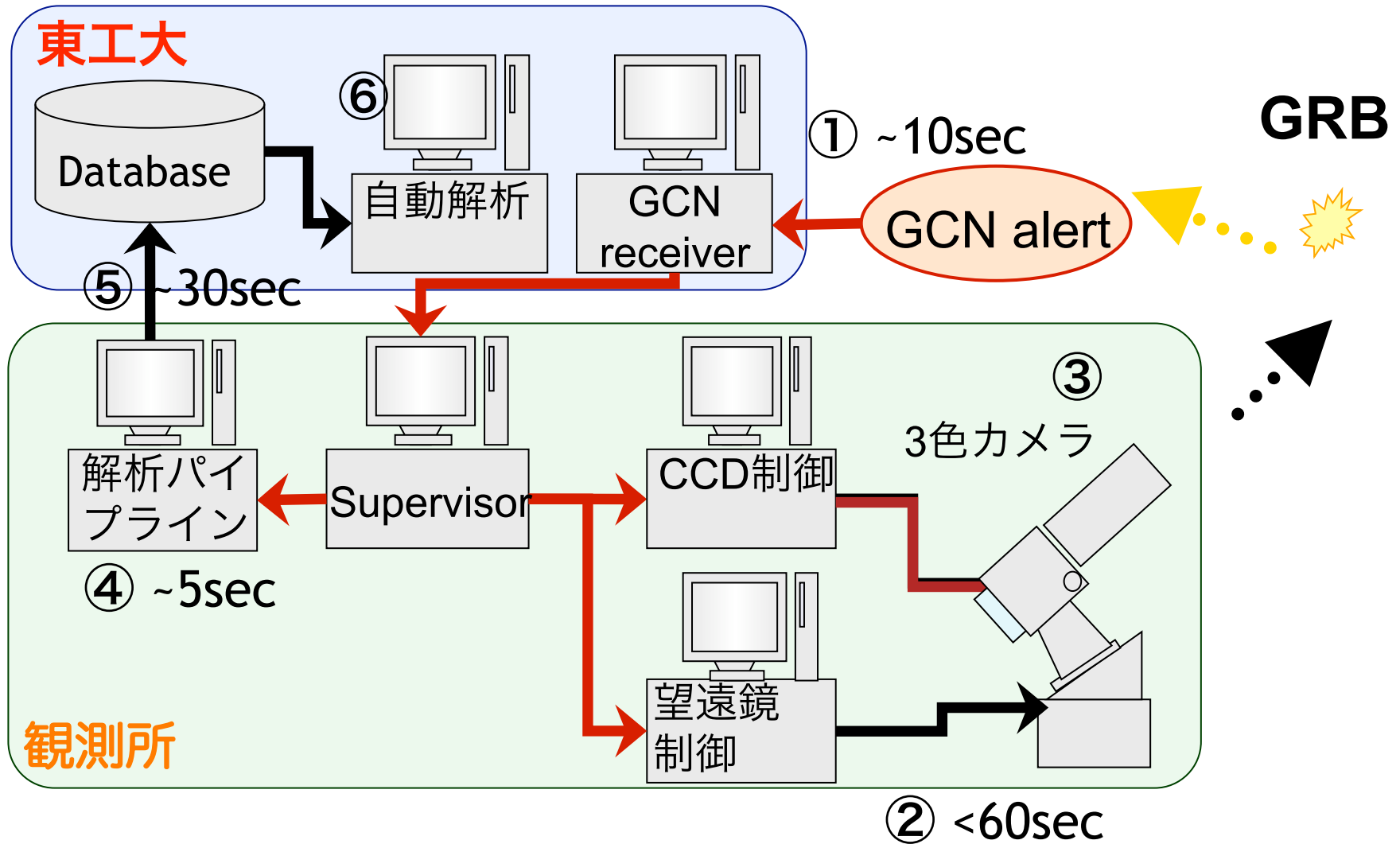
▶ 開発

- ほぼ終了。夏期のfocusに問題
- 自動観測（GRB、パトロール観測）
- 自動解析

▶ 運用

- ほぼ定常運用（PC, ドームのトラブルを除く）
- ドーム・スリット不具合（11月）→雨+停電、2週間観測中断
- GRB観測：通報から30秒以内に観測開始可能
 - 即時観測開始は、年間3件程度
 - 1日以内（発生時間帯、天候）は、年間10–15件程度
 - $\text{Swift } 100 \text{ GRB/yr} \times 0.3(\text{天候}) \times 0.5(\text{北天}) = 15/\text{yr}$
- AGN（GRB観測時以外）

MITSuME-Akeno Operation

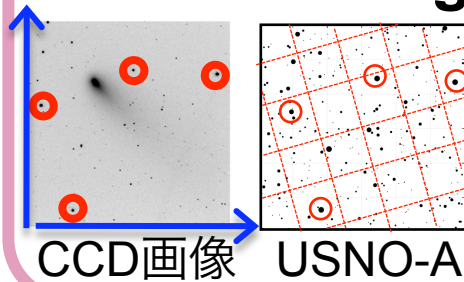


解析パイプライン



Source finding

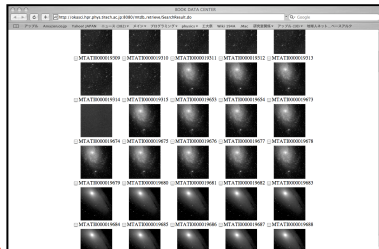
Catalog matching



- 明るい50天体を選択し、これらから画像の天球座標を決定

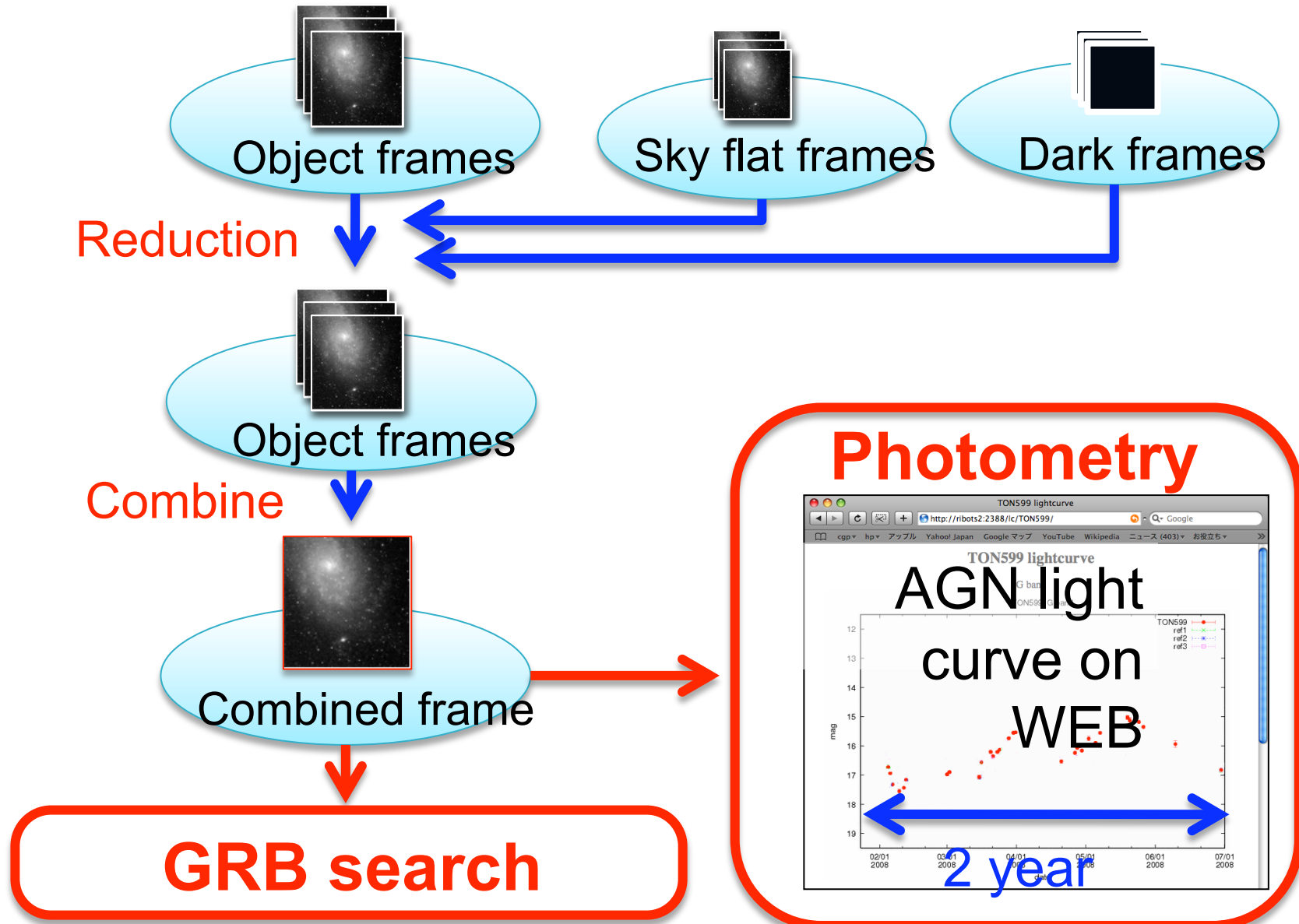
Photometry

Database



- 解析結果と画像が登録される
- WEBを通してアクセス可能
- QL画像も作成

自動解析



2009年のGRB観測実績

GRB	g' [mag]	Rc [mag]	lc [mag]	観測所	発生から観測開始までの時間
090404	>21.0	>20.5	>19.5	明野	59秒
090417B	>16.3	>16.3	>15.4	明野	456秒
090426	>20.2	19.4±0.3	19.0±0.4	明野	78分
090618	>17.6	18.8±1.0	>16.7	明野	3.4時間
090705	>17.8	>17.9	>17.0	明野	3時間
090709A	>15.0	>14.8	>13.9	明野	8.5時間
090814A	>19.3	>18.8	>18.1	明野	10時間
090916	>19.9	>19.8	>18.9	明野	10時間
091208A	>16.9	>16.6	>15.8	明野	49秒
091208B	17.2±0.2	16.0±0.1	15.5±0.1	明野	47秒

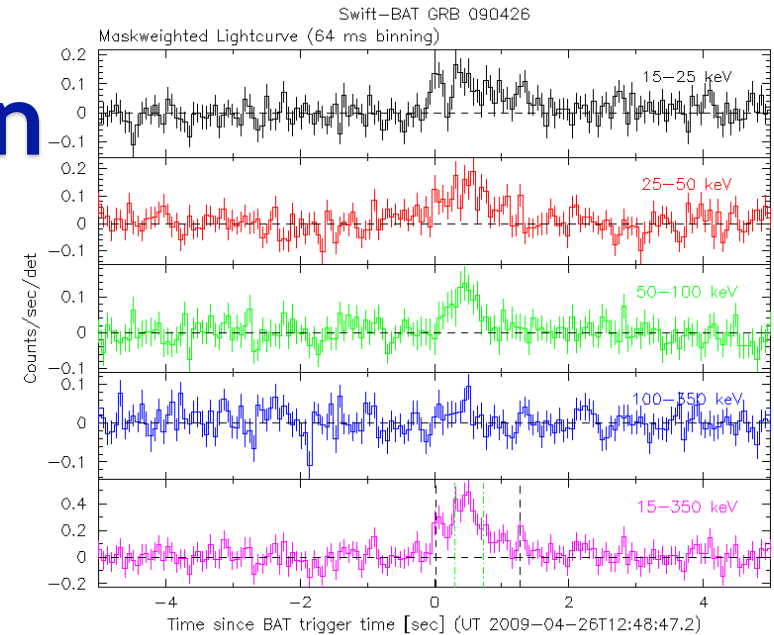
- ▶ 10件観測、3件検出 (2008: 2/15, 2007: 4/15)
- ▶ 他に、岡山で2件検出

GRB090426 detection

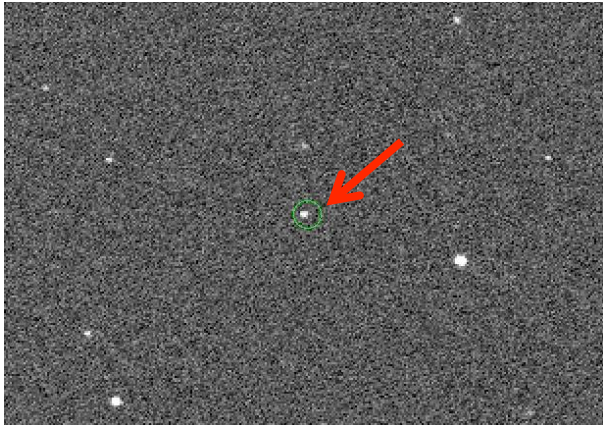
2009-04-26 12:48:47(UT)
triggered by Swift BAT

RA= 12h 36m 19.7s

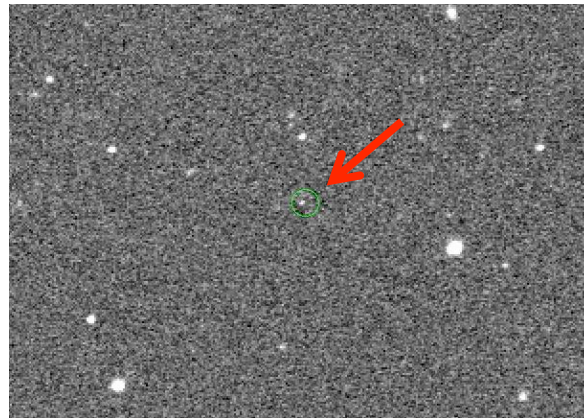
Dec= +32°58' 40.6"



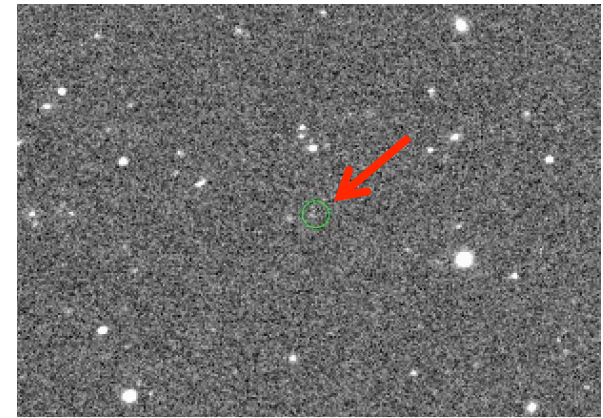
トリガーから2分後～6時間後の間観測 (岡山+明野)



トリガーから3分後
Mag=16.7±0.1

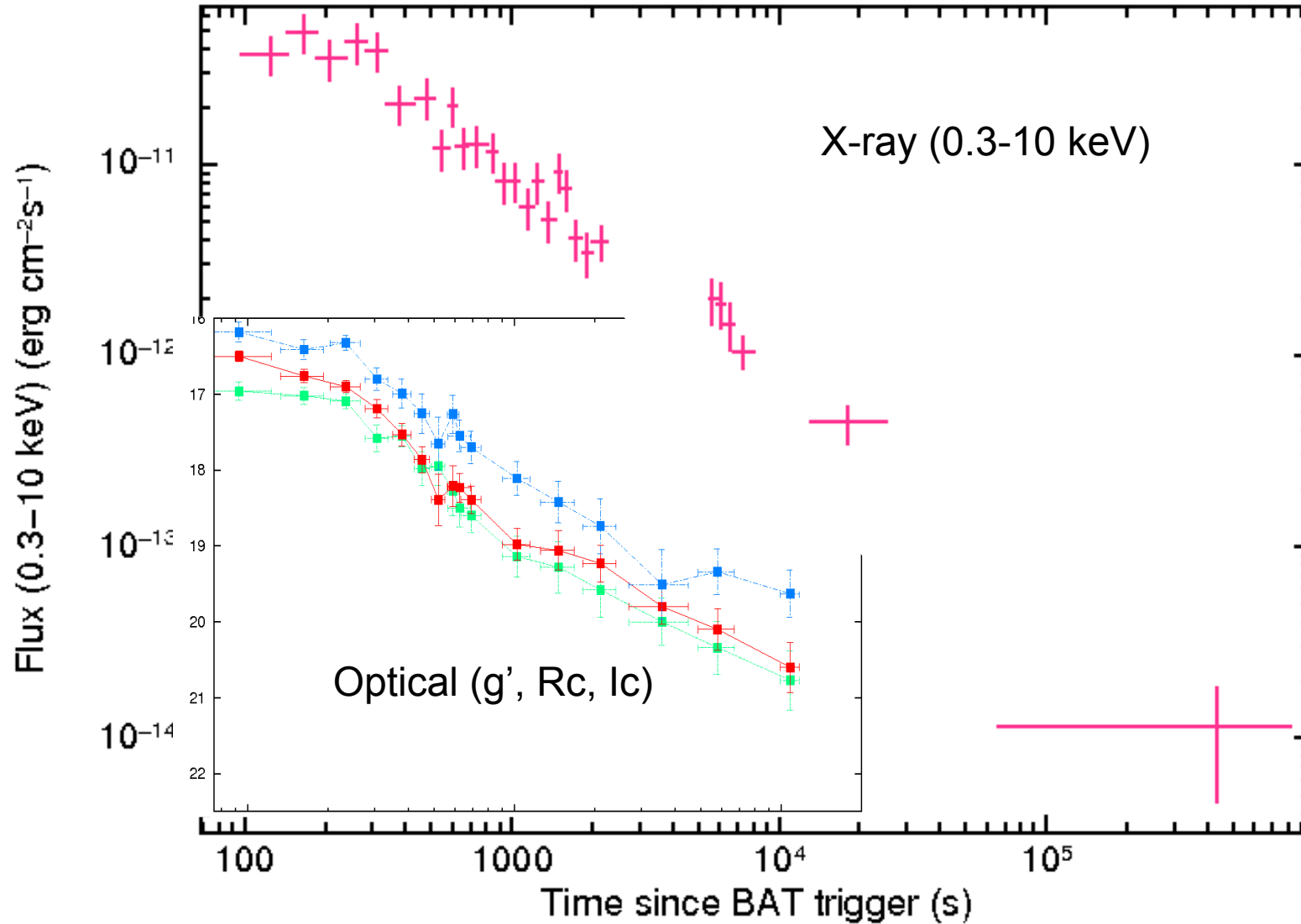
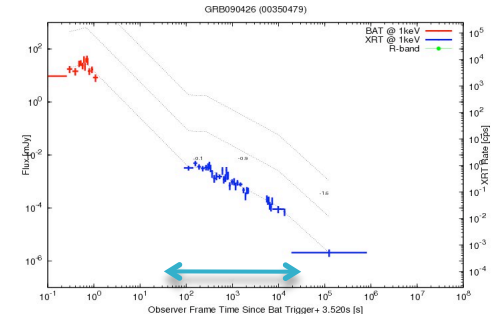


トリガーから10分後
Mag=18.2±0.2



トリガーから96分後
Mag=20.1±0.3

GRB090426 light curve

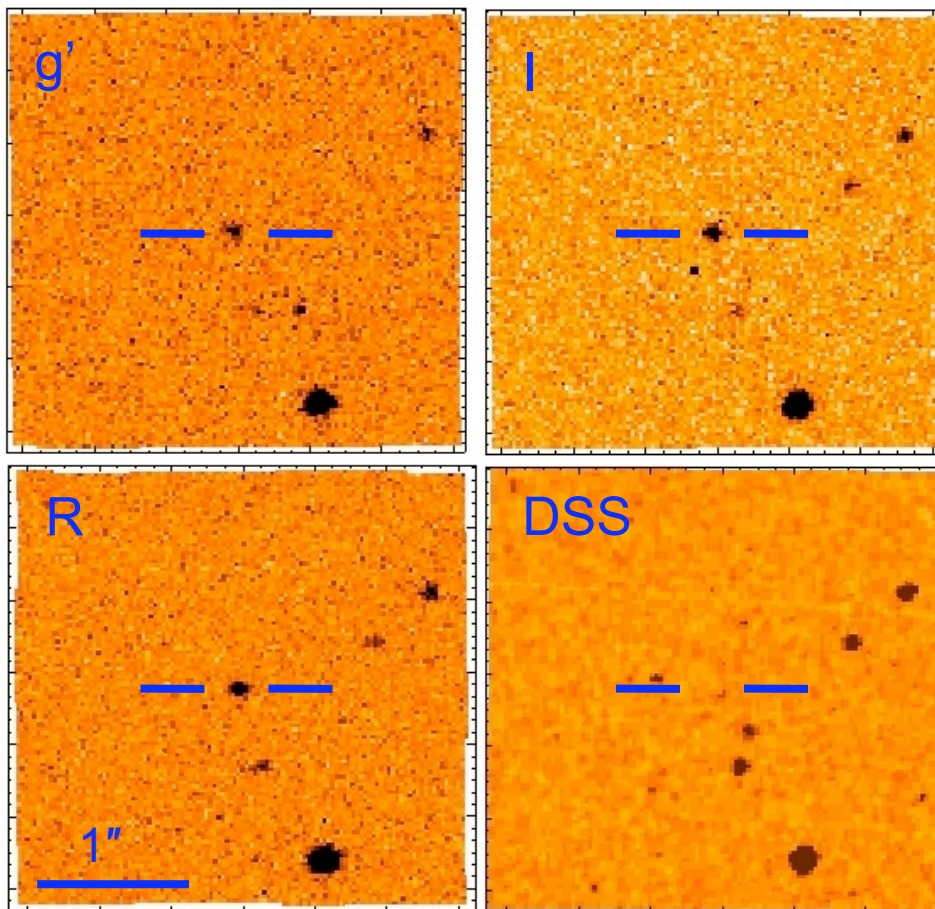


GRB 091208B detection

BAT trigger: 09:49:58 (UT)

GCN notice: 09:50:22 (UT)

明野 start : 09:50:45 (UT) (通報後 23 s, 発生後 47 s)



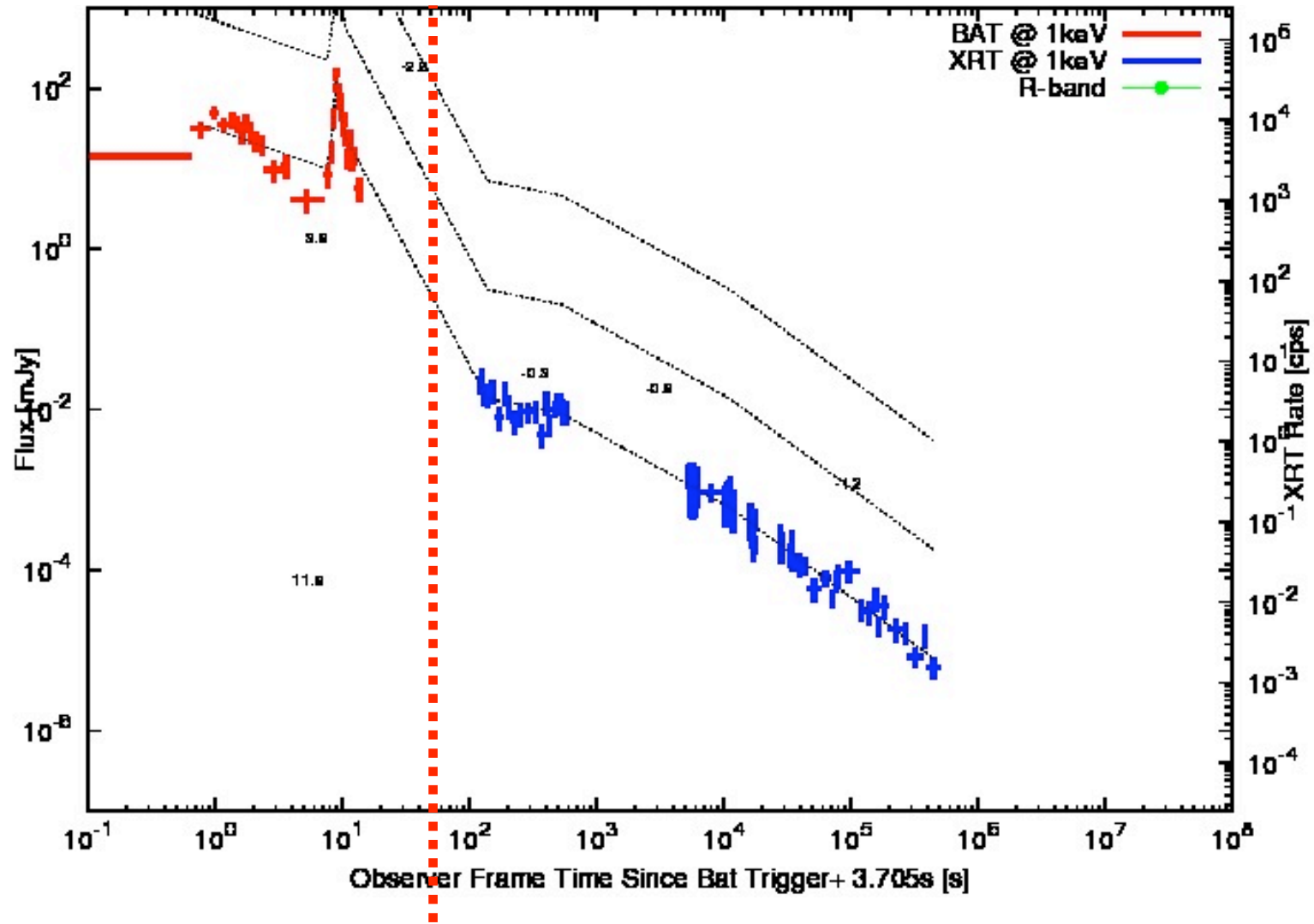
MITSuME 明野画像

mag at 09:51:15

$g' = 17.2$

$R = 16.1$ $I = 15.5$

GRB 091208B



明野観測開始 $T=47$ s

BAT·XRT (http://astro.berkeley.edu/~nat/swift/00378559/bat_xrt.jpg)

パトロール観測

- ▶ GRB待機中にAGN観測
- ▶ Fermi/MAXI との他波長同時観測へ

starList search

name

ra[deg]

dec[deg]

kind

AGN

order by

name

ra[deg]

priority

only observe

search

reset

[Today's Schedule](#)

[create Schedule file](#)

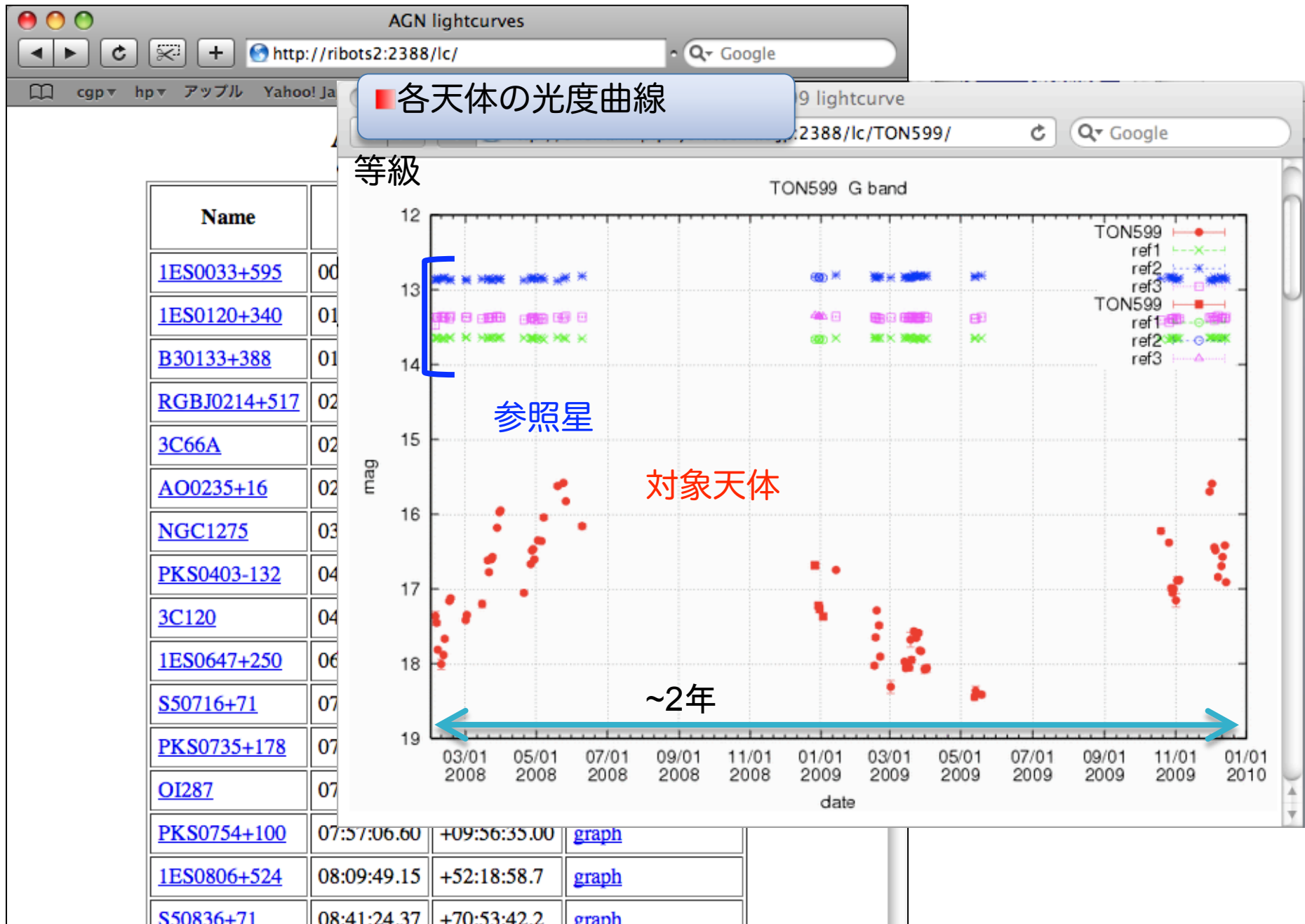
name	ra	dec	ra [deg]	dec [deg]	priority	m_no	m_se
1E0317.0+1835	03:19:51.80	+18:45:34.20	49.965833	18.7595	1.0	1	3
1E1415.6+2557	14:17:56.68	+25:43:26.24	214.486167	25.723956	2.0	1	3
1ES0033+595	00:35:52.64	+59:50:04.6	8.96935	59.834608	1.5	1	3
1ES0120+340	01:23:08.55	+34:20:47.50	20.785625	34.346528	1.5	1	3
1ES0229+200	02:32:48.62	+20:17:17.45	38.202567	20.288181	1.0	1	3
1ES0414+009	04:16:53.81	+01:04:57.00	64.2242	1.0825	2.0	1	3
1ES0502+675	05:07:56.25	+67:37:24.40	76.984375	67.6234444	2.0	1	3
1ES0647+250	06:50:46.52	+25:03:00.3	102.693833	25.050083	3.0	1	3
1ES0806+524	08:09:49.15	+52:18:58.7	122.454792	52.316306	3.0	1	3
1ES1011+496	10:15:04.14	+49:26:00.7	153.767249	49.433529	3.0	1	3
1ES1028+511	10:31:18.51	+50:53:35.9	157.827125	50.893306	3.0	1	3
1ES1101-232	11:03:37.57	-23:29:30.18	165.90655	-23.491718	2.0	1	3
1ES1218+304	12:21:21.94	+30:10:37.1	185.341421	30.176975	5.0	1	3
1ES1219+044	12:22:22.55	+04:13:15.78	185.5939567	4.2210489	2.0	1	3
1ES1517+656	15:17:47.60	+65:25:23.90	229.448333	65.423306	2.0	1	3
1ES1544+820	15:40:16.01	+81:55:05.50	235.066708	81.918194	3.0	1	3
1ES1553+113	15:55:43.04	+11:11:24.37	238.92935	11.1901014	2.0	1	3
1ES1959+650	19:59:59.85	+65:08:54.65	299.999384	65.148514	10.0	1	6
1ES2344+514	23:47:04.84	+51:42:17.88	356.770158	51.704966	5.0	1	3
1H0323+022	03:26:13.97	+02:25:14.66	51.558213	2.420738	1.0	1	3
1H0658+595	07:10:30.05	+59:08:19.60	107.6252083	59.1387778	2.0	1	3
1H1720+117	17:25:04.36	+11:52:15.20	261.2681667	11.8708889	2.0	1	3
3C111	04:18:21.28	+38:01:35.80	64.588655	38.0266111	5.0	1	3

BLLAC

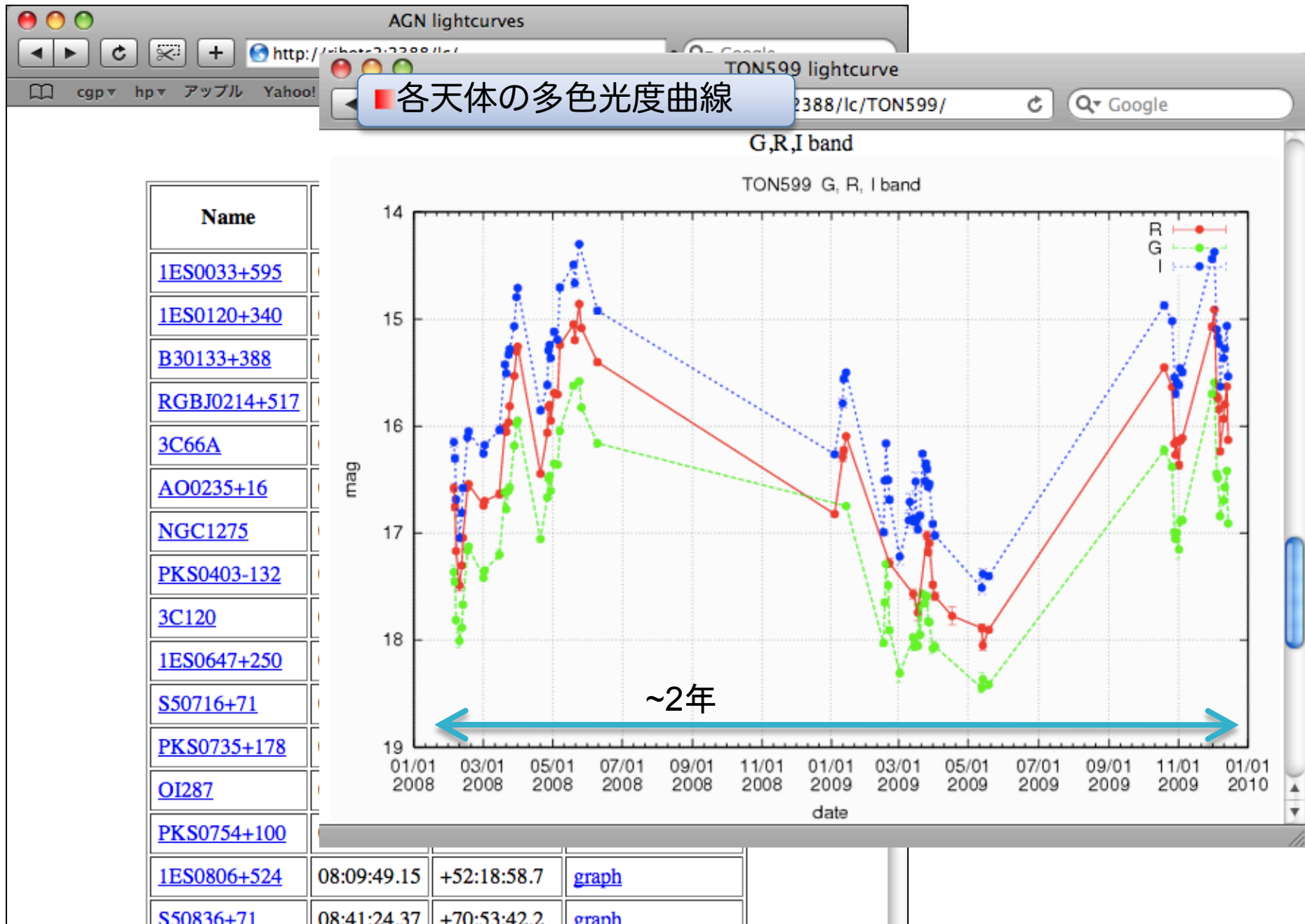
Name	BLLAC
epoch	2000
Ra[hms]	22:02:43.30
Dec[hms]	+42:16:40.00
Ra[deg]	330.6804
Dec[deg]	42.2778
priority	5.0
exp time	60
m_no	1
m_set	4
d_pat	1 (9 points)
observe	Yes
kind	AGN
Site	AKENO

DSS 5'x 5'

AGN光度変動の長期的監視



AGN光度変動の長期的監視



Blazars

- direction from observer $\sim 1/\Gamma_{\text{BLK}} \sim 5^\circ$
- relativistic beaming effect
- superluminal motion, extreme variability
- Luminosity $L_{\text{obs}} \propto \nu t^{-1} d\Omega^{-1}$
 $\propto \delta^4 \sim 10,000!$

Flat Spectrum Radio Quasar (FSRQ)

Low-freq peak BL Lac (LBL)

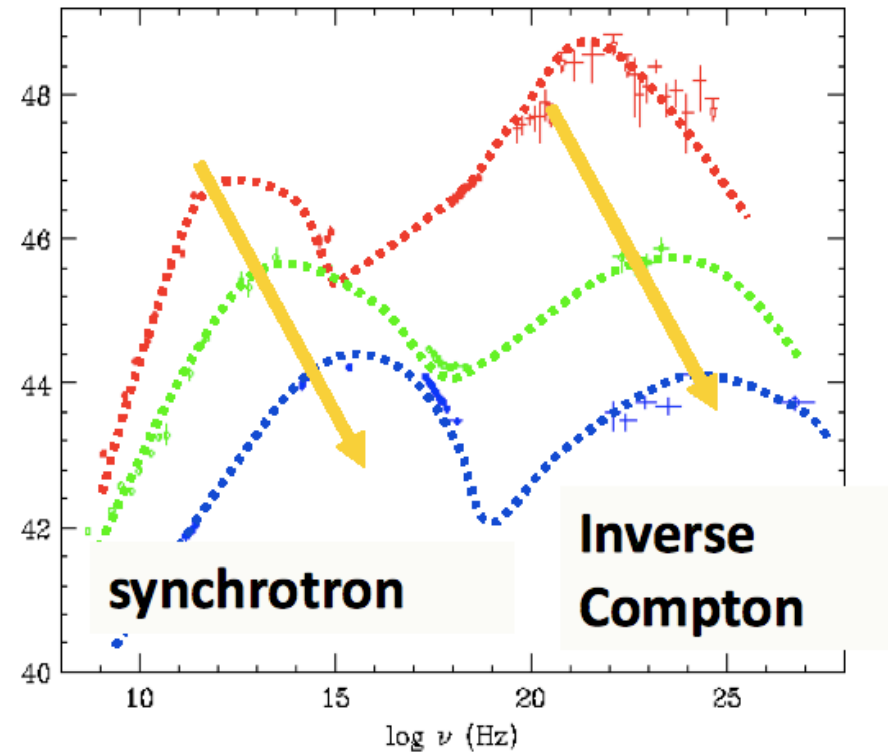
High-freq peak BL Lac (HBL)

Radiation process

- Synchrotron Radiation
 + Inverse Compton Scattering
- Blazar Sequence
- Synchrotron Self Compton,
 External Compton
- Thermal emission from accretion disk

Questions

- Correlation between luminosity, variability, beaming?
- Time lags between flares?
- Variability vs. spectral properties?



Kubo+ 98, Fossati+ 98, Kataoka 02

Optical Variability

- ▶ F_{var} : the fractional root mean square (rms) variability amplitude of optical fluxes (Vaughan et al. 2003)

$$F_{\text{var}} = \sqrt{\frac{S^2 - \overline{\sigma_{\text{err}}^2}}{\bar{x}^2}}$$

$$\overline{\sigma_{\text{err}}^2} = \frac{1}{N} \sum_{i=1}^N \sigma_{\text{err},i}^2$$

- ▶ Monitor list (2008.3~)

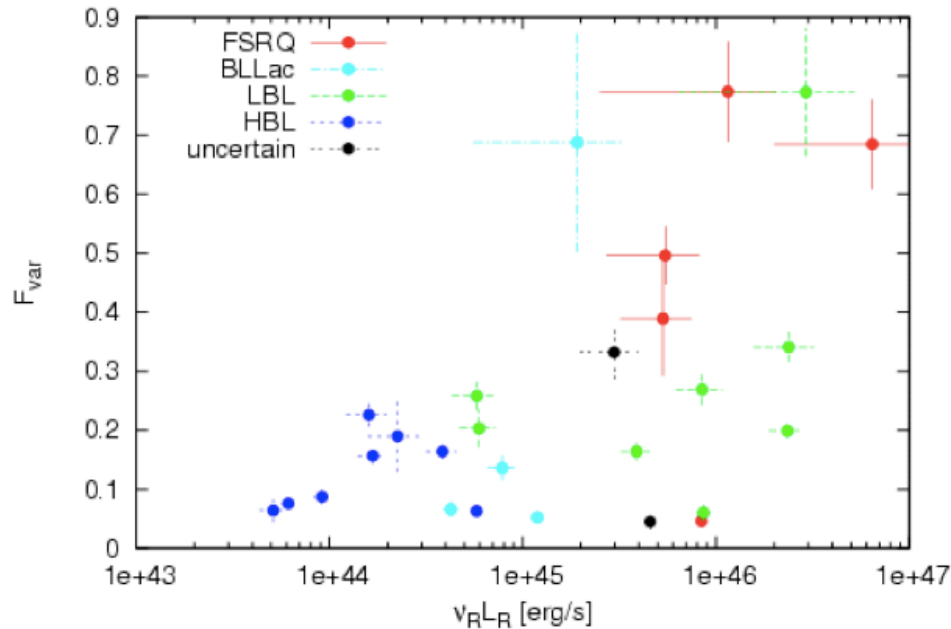
1ES 0033+595
GC 0109+224
3C 66A
AO 0235+16
S5 0716+71
PKS 0735+17
1ES0806+524
Q 0827+243
OJ 287
1ES 1011+496

1ES 1028+511
Mrk 421
4C 29.45
B2 1215+30
1ES 1218+304
W Com
PG 1222+216
3C 273
3C 279
PG 1424+240

PKS 1510-089
3C 345
Mrk 501
IZW 187
OT 081
1ES 1959+650
BL Lac
CTA 102
3C 454.3
1ES 2344+514

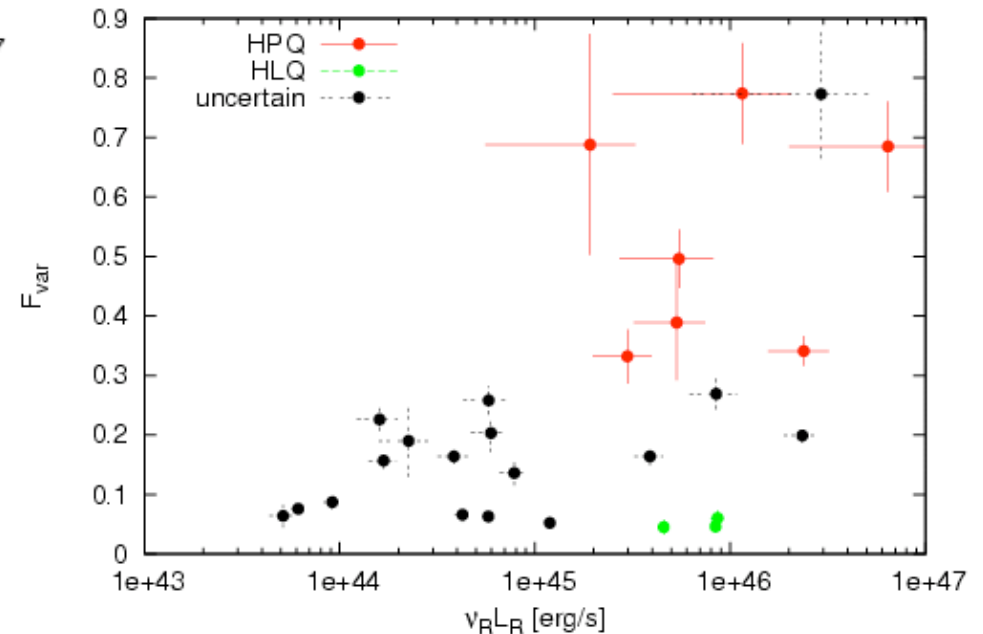
Fermi-detected
not detected

Optical Variability and Fluxes



- ▶ The variability of HPQs are larger than LPQs

- ▶ The variability of HBLs tends to be small (<0.3), on the other hand, three FSRQs have large variability that are all HPQs
- ▶ The only FSRQ that has small variability is LPQ



MULTIWAVELENGTH OBSERVATIONS OF 3C 454.3. II. THE *AGILE* 2007 DECEMBER CAMPAIGN

I. DONNARUMMA^{1,25}, G. PUCELLA¹, V. VITTORINI¹, F. D'AMMANDO^{1,2}, S. VERCELLONE³, C. M. RAITERI⁴, M. VILLATA⁴,
M. PERRI⁵, W. P. CHEN⁶, R. L. SMART⁴, J. KATAOKA⁷, N. KAWAI⁷, Y. MORI⁷, G. TOSTI⁸, D. IMPIOMBATO⁸, T. TAKAHASHI⁹,

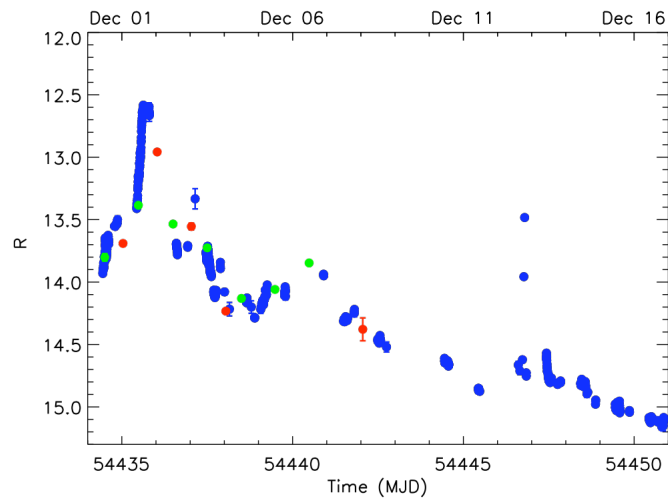
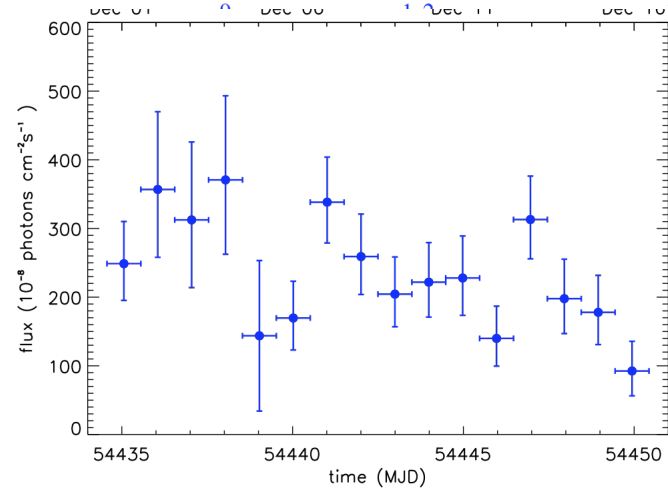
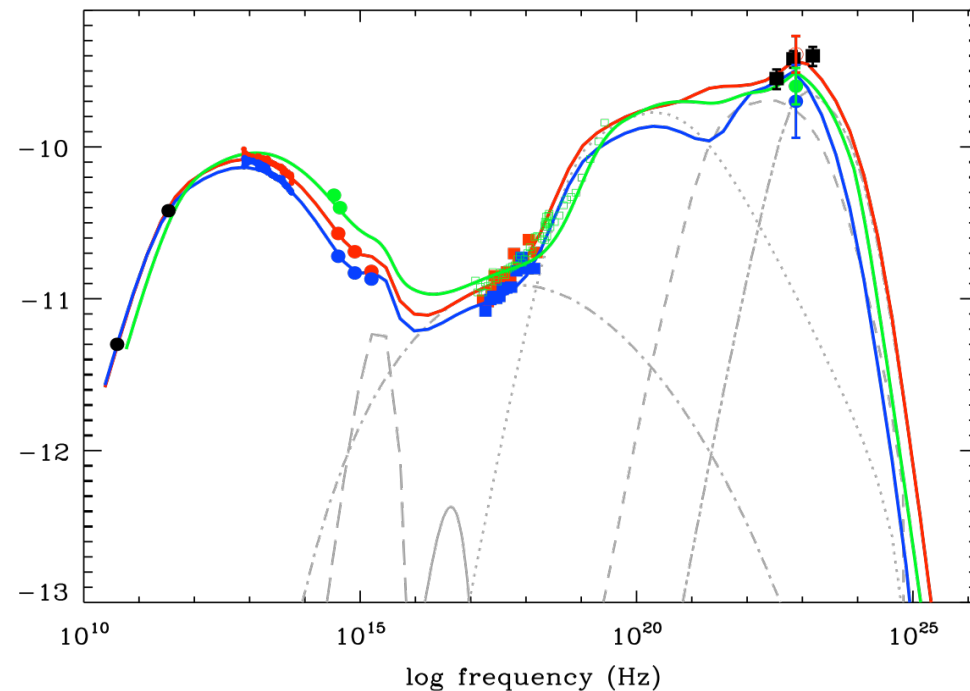


Figure 1. Top panel: *AGILE*-GRID γ -ray light curve of 3C 454.3 at one-day resolution for $E > 100$ MeV in units of 10^{-8} photons $\text{cm}^{-2} \text{s}^{-1}$ during the period from 2007 November 30 to December 16; bottom panel: R -band light curve obtained by WEBT (blue circles), REM (red circles), and MITSuME

A. W. CHEN¹¹, A. GIULIANI¹¹, F. LONGO¹², L. PACCIANI¹, A. ARGAN¹,
. W. CATTANEO¹³, V. COCCO¹, T. CONTESSI¹¹, E. COSTA¹, E. DEL MONTE¹,
M. FEROCI¹, A. FERRARI^{14,15}, M. FIORINI¹¹, T. FROYSLAND¹⁴, M. FRUTTI¹,
ABANTI¹⁰, I. LAPSHOV¹, F. LAZZAROTTO¹, P. LIPARI¹⁷, M. MARISALDI¹⁰,
RELLI¹⁰, E. MORETTI¹², A. MORSELLI¹⁹, A. PELLIZZONI²⁰, F. PEROTTI¹¹,
PROVECCHIO¹, M. PREST²¹, M. RAPISARDA²², A. RAPPOLDI¹³, A. RUBINI¹,
.2 M. TRIFOGLIO¹⁰, A. TROIS¹, E. VALIAZZA¹², A. ZAMBRA¹¹, D. ZANELLO¹⁷,
DONNARUMMA ET AL.

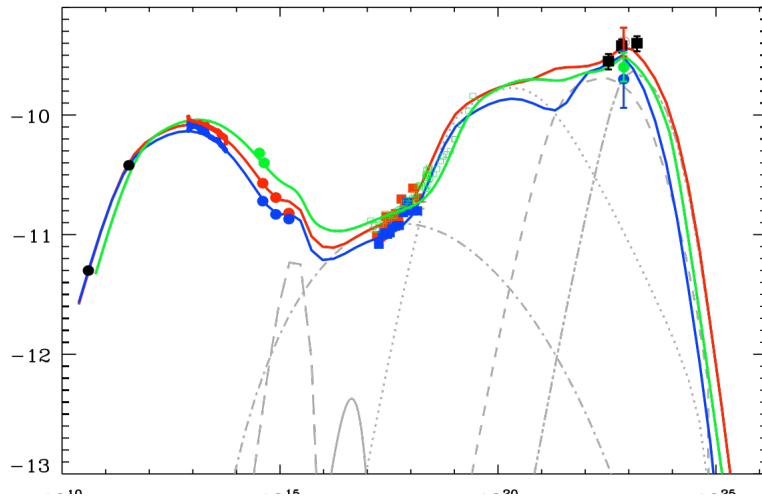


December 5, 13, and 15 (green, red, and blue solid lines, respectively). The γ -ray spectrum for $E >$

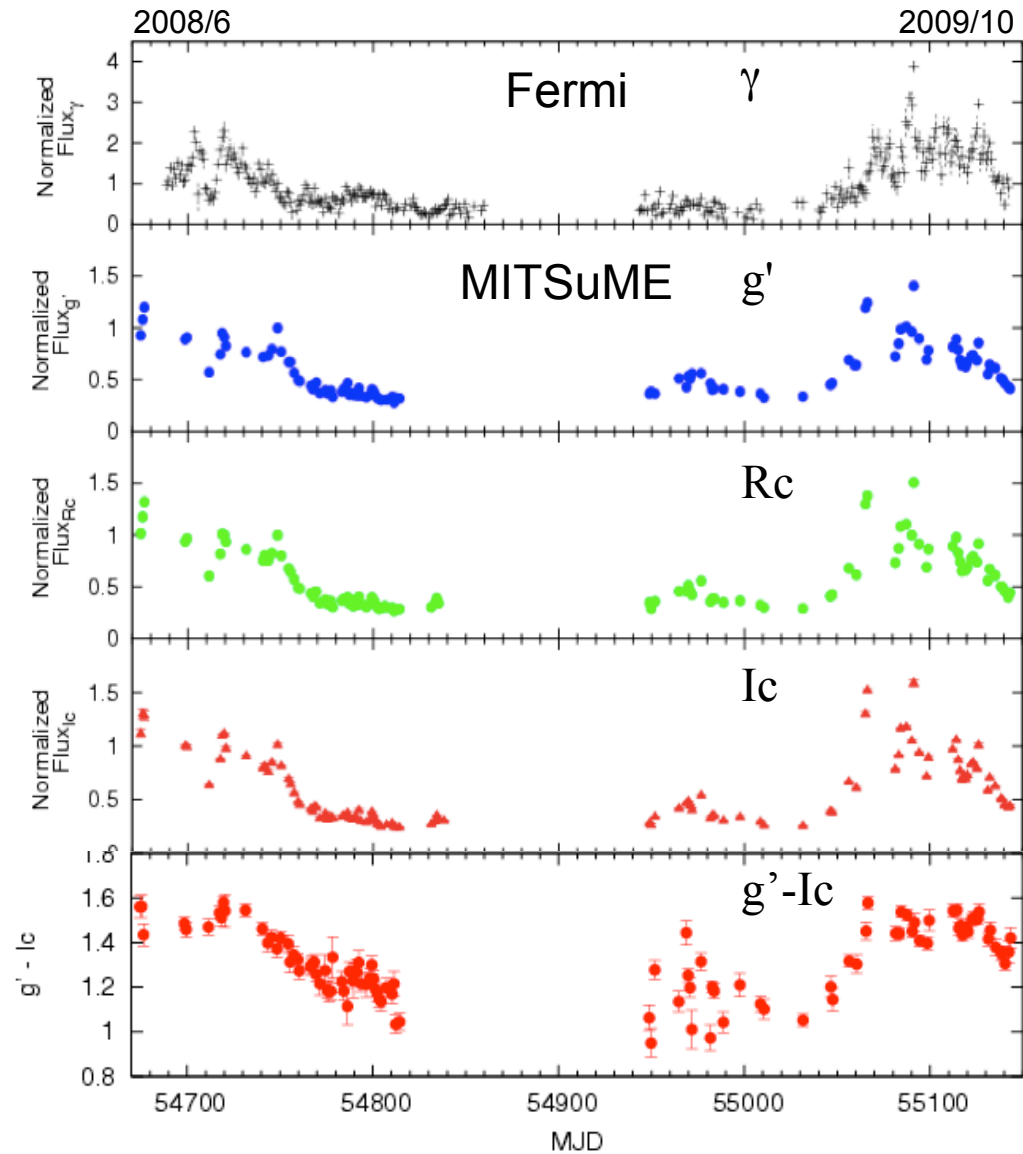
3C 454.3

- ▶ Detailed correlations
 - optical vs. gamma-ray
 - optical color
 - Thermal emission from the accretion disk comparable to synchrotron emission

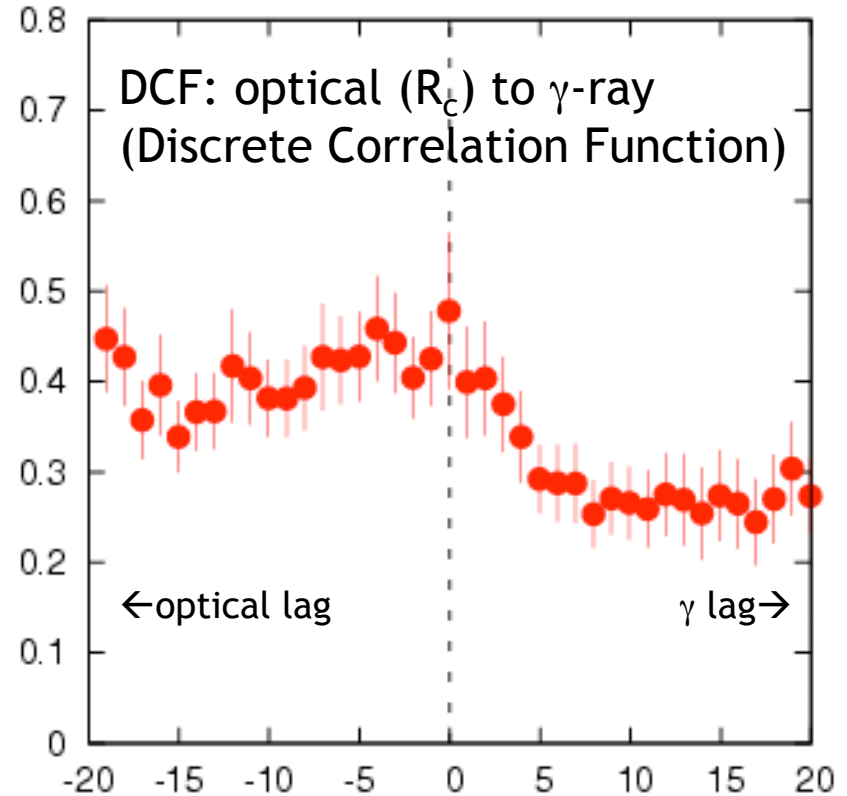
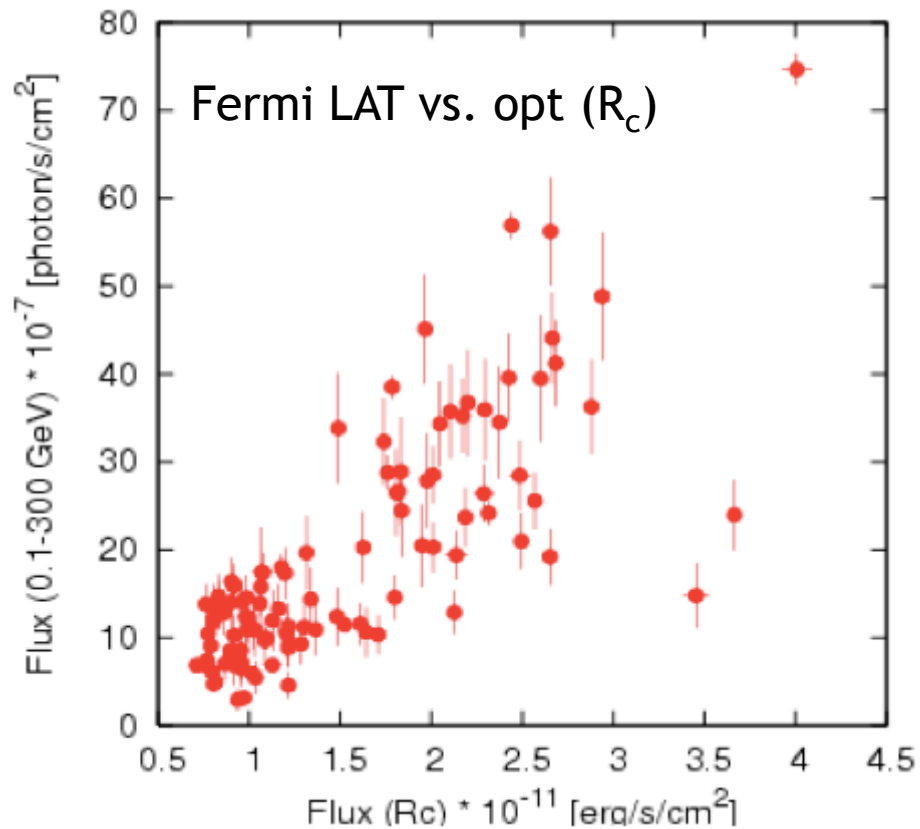
DONNARUMMA ET AL.



normalized in flux at MJD=54748

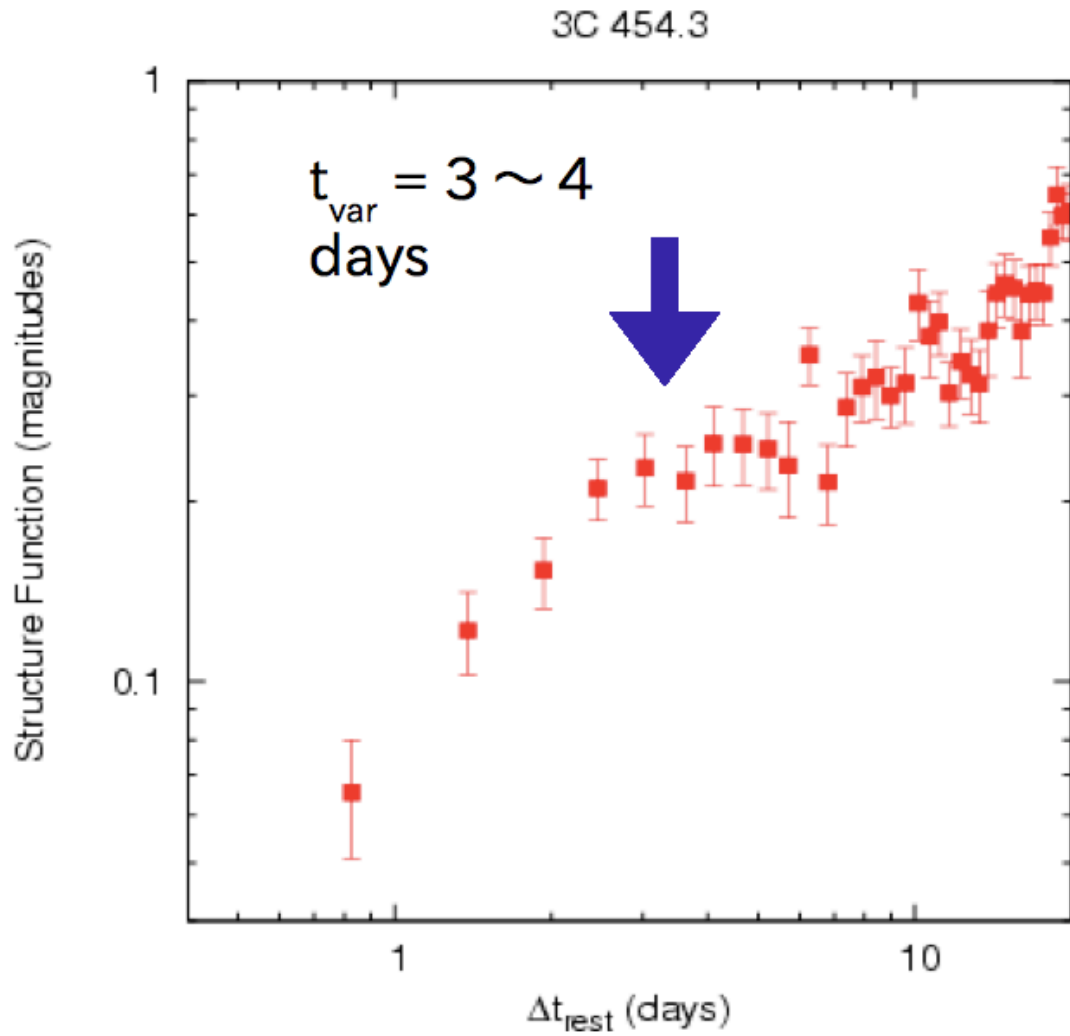


opt- γ Correlation/DCF



- ▶ peak of the DCF between 0 \sim -4
 - → Possibility of delay of the optical with respect to the gamma-ray

Structure Function

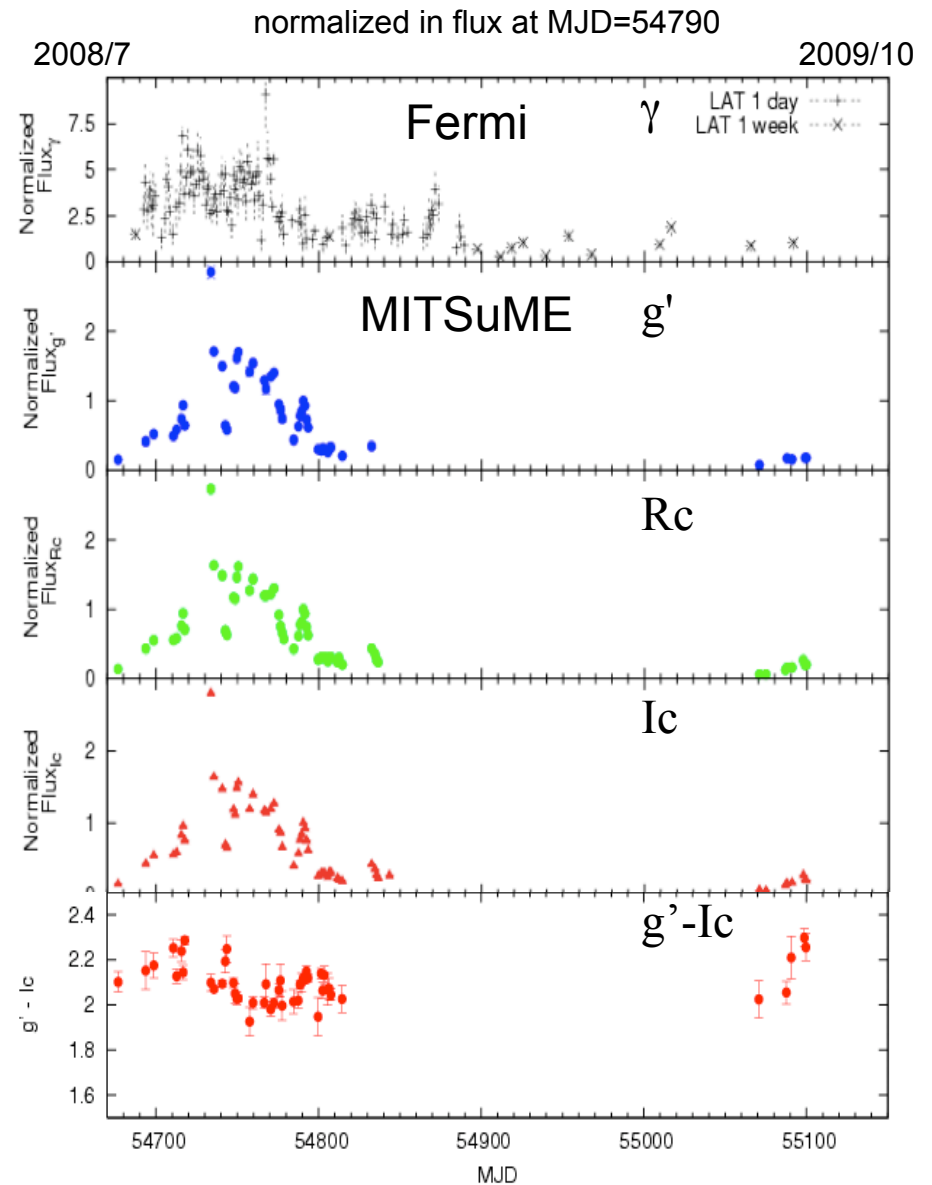


$$S_1 = \sqrt{\frac{\pi}{2} \langle |m(t + \Delta t) - m(t)| \rangle^2 - \sigma_n^2}$$

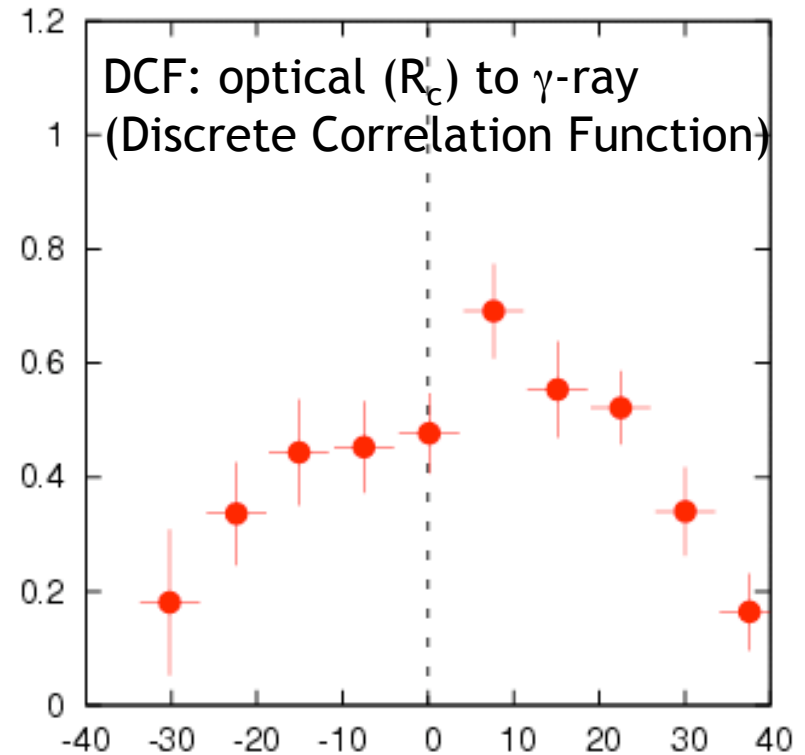
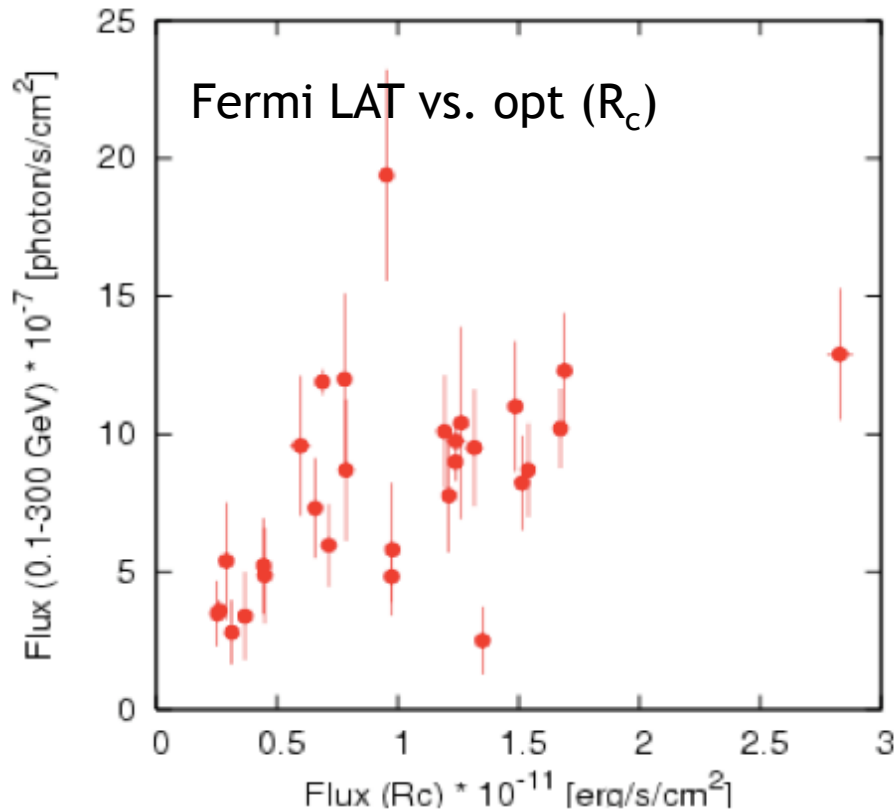
Di Clemente et al. 1996

AO 0235+16

- ▶ General correlation between optical and gamma-ray light curve
- ▶ The optical magnitude reached $R = 14.4$ at $MJD=54733$, however, there is no counterpart in gamma-ray light curve
- ▶ Weak color changes



opt- γ Correlation/DCF



- ▶ The relative peak of the DCF is around $\sim 7.5 \pm 3.5$
→ gamma-ray delayed compared to optical

Blazar Monitoring Findings

- ▶ Obtained 3-color optical light curves of ~ 50 blazars by MITSuME Telescope from January 2008
- ▶ Optical variability of HBLs smaller than that of FSRQs
- ▶ LPQs (among FSRQs) have small optical variability
- ▶ The gamma-ray luminosity of HBLs smaller than that of FSRQs and LBLs
- ▶ Color index ($g' - I_c$) of 3C 454.3 is low (i.e. bluer) when faint in optical
 - UV component (disk?) dominant if $F_R < 1.5 \cdot 10^{-11}$ (erg/cm²/s)
- ▶ The optical flare of AO 0235+16 at MJD=54733
 - however, no counterpart in the gamma-ray light curve
- ▶ Gamma-rays appear to be delayed with respect to the optical emission of AO 0235+16

まとめ

- ▶ 自動観測運用：ほぼ安定
- ▶ ガンマ線バースト追跡高速化：ほぼ限界
 - GRB 090426: X線残光と同期した減光を観測
 - GRB 091208B: 通報23秒後、Swift XRT に先行して観測
- ▶ パトロール観測
 - およそ30天体（主に Blazar型AGN)を2008年初めより約2年間
 - Fermi 衛星と (2008/6～)
 - MAXI と (2009/8～) (今後、BH連星なども etc.)
- ▶ 明野観測所での運用継続よろしくお願いします。