

フェルミ衛星による MeV/GeVトランジェント天体 の観測

田中康之 (広島大学)

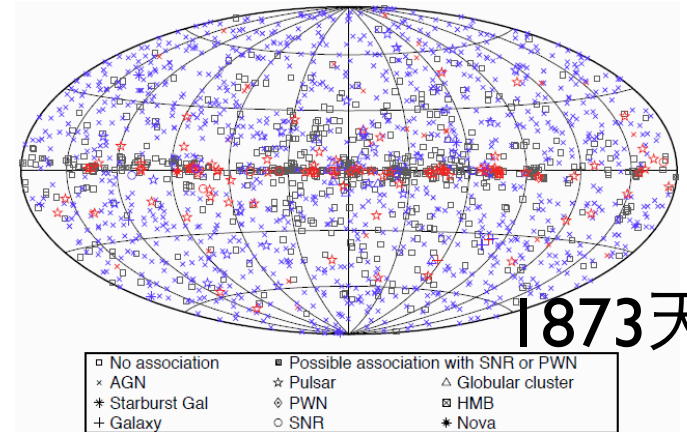
on behalf of Fermi-LAT collaboration

目次

- フェルミガンマ線望遠鏡について
- トランジェント天体の検出体制、情報発信
- 系内トランジェント
- 系外トランジェントと太陽
- Fermi TOO観測について
- Summary

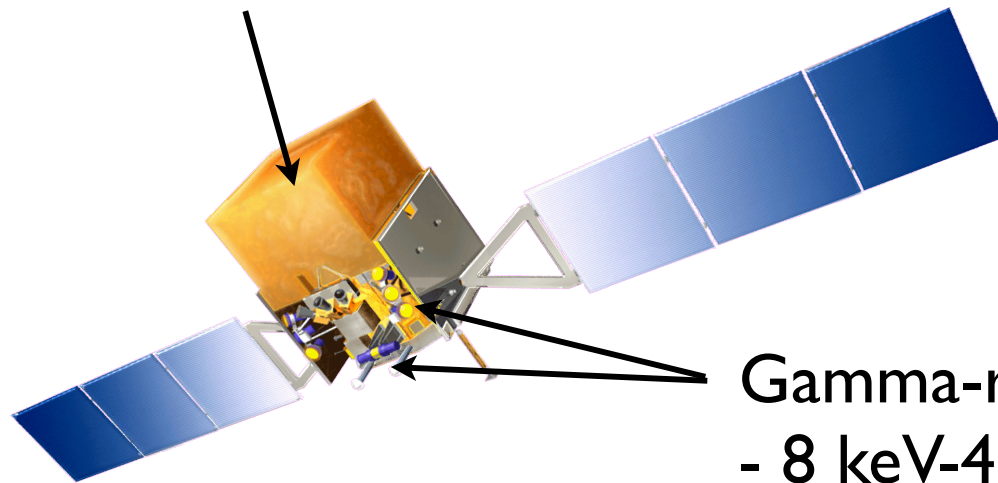
フェルミガンマ線宇宙望遠鏡

- 2008年6月11日打ち上げ
- 現在も順調に観測を継続中 (全天サーベイモード)



Large Area Telescope (LAT)

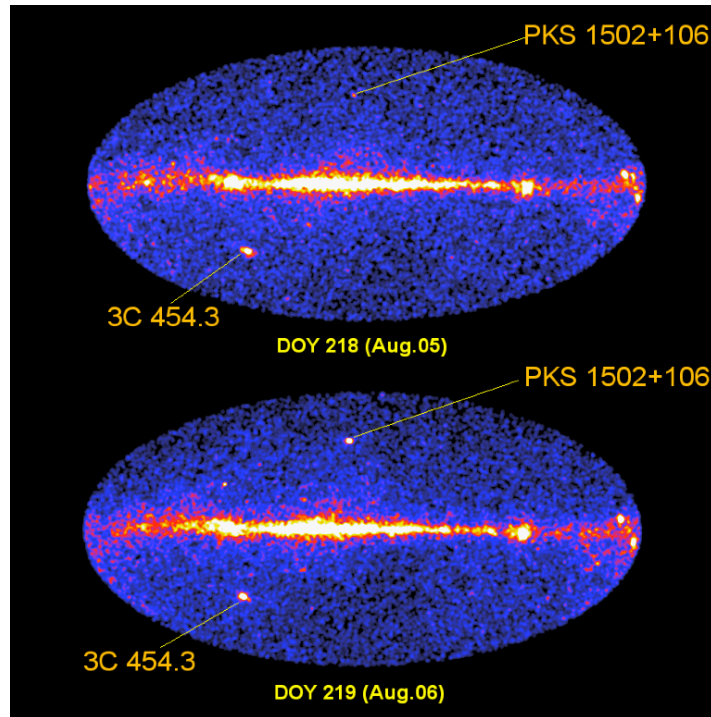
- 20 MeV-300 GeV
- 2.4 strの広い視野を生かして、3時間毎に全天をスキャン



Gamma-ray Burst Monitor (GBM)

- 8 keV-40 MeV
- 全天を監視

トランジェント天体の検出体制



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GLAST LAT detection of a possible new gamma-ray flaring blazar: PKS 1502+106

ATel #1650; [S. Ciprini \(Univ./INFN Perugia\) on behalf of the GLAST Large Area Telescope Collaboration on 8 Aug 2008; 00:02 UT](#)
Credentia Certification: [Stelano Ciprini \(stelano.ciprini@pg.infn.it\)](mailto:Stelano.Ciprini@pg.infn.it)

Subjects: Gamma Ray, >GeV, AGN, Quasar

Referred to by ATel #: [1661](#), [1905](#)

The Large Area Telescope (LAT), one of two instruments on the Gamma-ray Large Area Space Telescope (GLAST) (launched June 11, 2008), which is still in its post-launch commissioning and checkout phase, has been monitoring high flux from a source positionally consistent with the blazar PKS 1502+106 (R.A.:15h04m24.9797s; Dec.:+10d29m39.198s, also known as OR 103 and S3 1502+10) since August 6, 2008.

Preliminary analysis indicates that the source is in a high state with a gamma-ray flux ($E>100\text{MeV}$) well above pre-defined LAT flaring source reporting threshold of 2×10^{-6} photons $\text{cm}^{-2} \text{s}^{-1}$.

This is a well-known radio source classified as a Flat Spectrum Radio Quasar (FSRQ), observed by several X-ray instruments. This is the first time that it has been reported to have gamma-ray emission.

Please note that PKS 1502+106 has two possible redshifts listed in the literature: $z=0.56$ and 1.83 ; the former seems preferred (A.E. Wright et al. 1979 ApJ 229,73; B.J. Wilkes 1986, MNRAS, 218, 331).

Because GLAST has just started its scientific standard operations, regular gamma-ray monitoring of this source will be pursued. In consideration of the ongoing activity of this source we strongly encourage multiwavelength observations of PKS 1502+106.

The GLAST LAT is a pair conversion telescope designed to cover the energy band from 20 MeV to greater than 300 GeV. It is the product of an international collaboration between NASA and DOE in the U.S. and many scientific institutions across France, Italy, Japan and Sweden.

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Related	
1905	Fermi-LAT detection of renewed activity from the blazar PKS 1502+106
1661	Archival light curve for the flaring GLAST blazar: PKS 1502+106
1650	GLAST LAT detection of a possible new gamma-ray flaring blazar: PKS 1502+106

- 毎日、フレア当番 (Flare Advocate) が、6時間積分、1日積分のデータを解析 (半自動)
- トランジェント天体が検出されれば、すぐにAstronomers Telegramに報告 ($\text{Flux} > 1.0 \times 10^{-6}$ photons/cm²/s, $E > 100$ MeV)

Atel 以外での情報発信

Fermi monitored source list light curve

Weekly Fermi sky blog

The screenshot shows the Fermi Science Support Center website. The main heading is "Monitored Source List Light Curves". Below the heading, there is a paragraph explaining that the LAT team monitors flux values for bright sources and transient sources. A "PLEASE NOTE" section follows, stating that tabulated fluxes are derived from an automated analysis. Below the text, there is a table with two columns: "Source" and "Light Curve". The table lists two sources: 4C 31.03 and 0208-512. For each source, there are links to "Daily Light Curve", "Daily Light Curve Fits File", "Weekly Light Curve", and "Weekly Light Curve Fits File".

Source	Daily LC	Weekly LC
4C 31.03 (RA = 18.2100, Dec = 32.1380) • Daily Light Curve • Daily Light Curve Fits File • Weekly Light Curve • Weekly Light Curve Fits File		
0208-512 (RA = 32.6930, Dec = -51.0170) • Daily Light Curve • Daily Light Curve Fits File • Weekly Light Curve • Weekly Light Curve Fits File		

FERMI GAMMA-RAY SKY

WEDNESDAY, SEPTEMBER 12, 2012

Fermi LAT weekly report N.221

Covered period: 2012.Aug.27 - 2012.Sep.02

LAT Mission week: 221.57 - 222.57

- Mkn 421 and B3 1343+451 were detected almost all week long with flux in the range $0.4\text{--}0.7 \times 10^{-6}$ and $0.5\text{--}1.0 \times 10^{-6}$, respectively.
- Four other sources were detected at least in 3 days of the week with some trend in brightness. The flux decreased from 2.1 to 0.5×10^{-6} for PKS 2233-148. On the contrary, the flux increased from 0.4 to 0.7×10^{-6} for 4C +38.41 and from 0.6 to 0.9×10^{-6} for PKS B1424-418.
- Sporadic activity (fluxes above 1.0×10^{-6}) was observed from S4 0218+35 (1.7 on Aug. 27) and 3C 273 (1.9 on Aug. 31).
- Sporadic activity (fluxes below 1.0×10^{-6}) was observed from BL Lacertae (0.5 and 0.8 on Aug. 27 and 28), PKS 2326-502 (0.4 and 0.7 on Aug. 28 and 30), PKS 0250-225 (0.4 on Aug. 30), PKS 0405-385 (0.4 on Aug. 31), PKS 0537-441 (0.2 on Sep. 02), B2 0716+33 (0.3 on Sep. 01), and 1H 1013+498 (0.1 on Sep. 01).

LAT DATA

- [LAT First Catalog](#)
- [LAT Monitored Source List Light Curves](#)
- [LAT Bright Source List](#)
- [Browse interface to monitored source data](#)
- [Contact Information by Individual Sources](#)

BLOG ARCHIVE

- ▼ 2012 (35)
 - ▼ September (1)
 - [Fermi LAT weekly report N.221](#)
 - ▶ August (5)
 - ▶ July (4)
 - ▶ June (5)
 - ▶ May (4)
 - ▶ April (4)
 - ▶ March (4)

過去にAtelが出された天体の
daily, weekly light curveが並ぶ

週1回、weekly digestが
アップされる

Fermi MeV/GeV transients

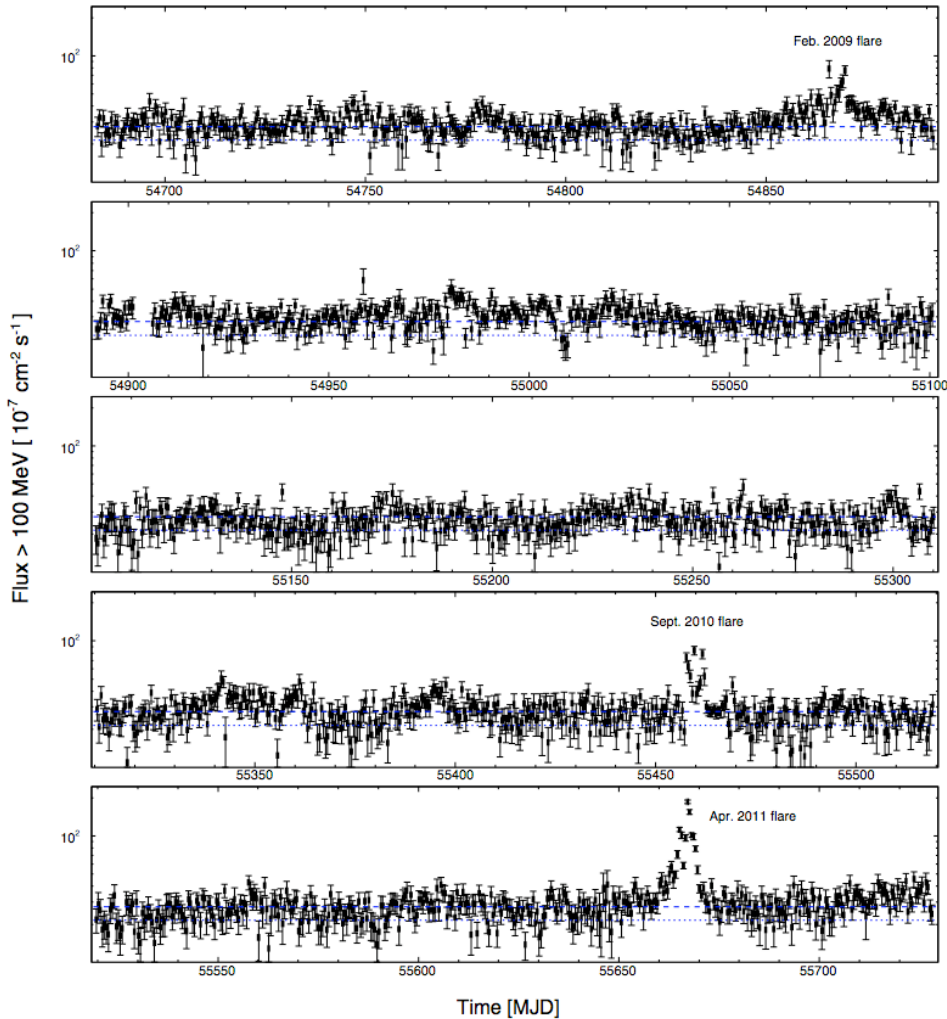
大まかな継続時間	系内	系外
数秒~数分	Impulsive solar flare	GRB
数時間~数10時間	long-lasting solar event	
数日~数10日	Crab nebula flare, Nova, Cyg X-3, PSR B1259-63	AGN flare
未検出	Microquasar, Stellar/Protostellar flare	Tidal disruption event

Galactic Transients

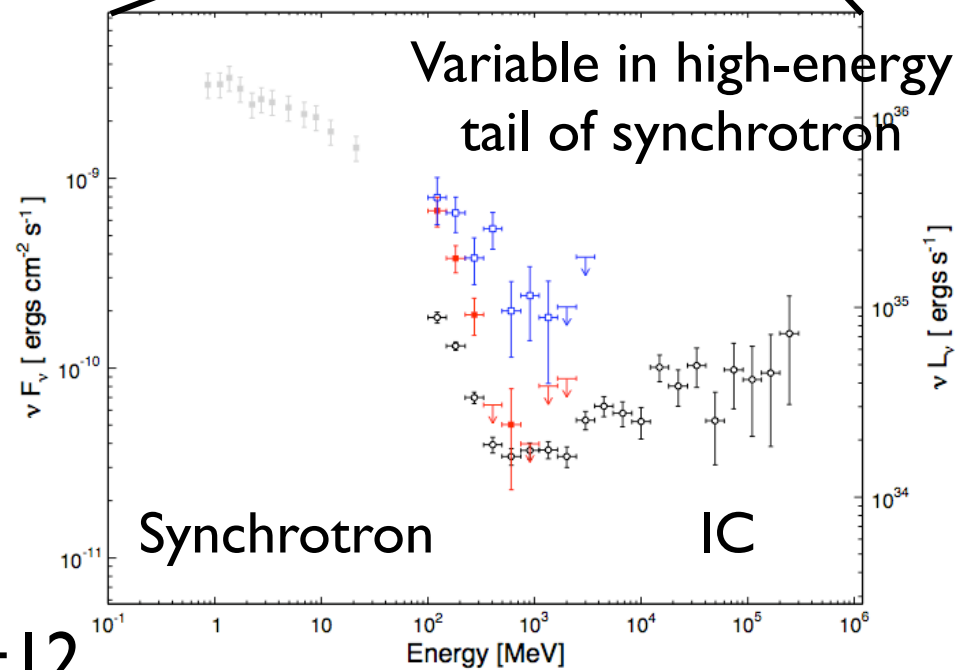
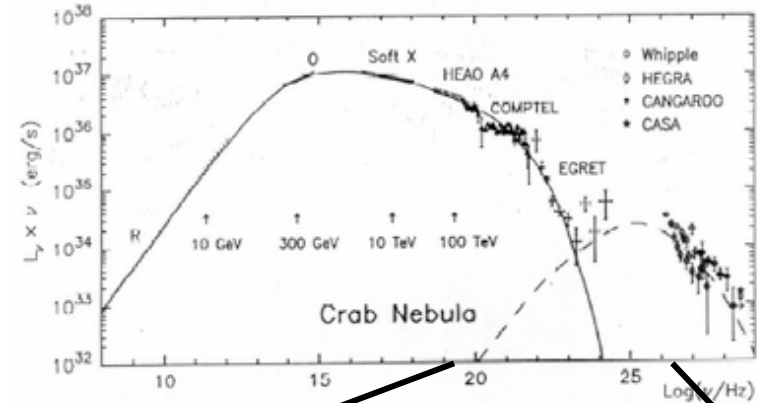
- ✓ Crab nebula flare
- ✓ Nova
- ✓ Cygnus X-3
- ✓ PSR B1259-63 (Periastron Passage in 2010 Dec.)

Crab nebula flare

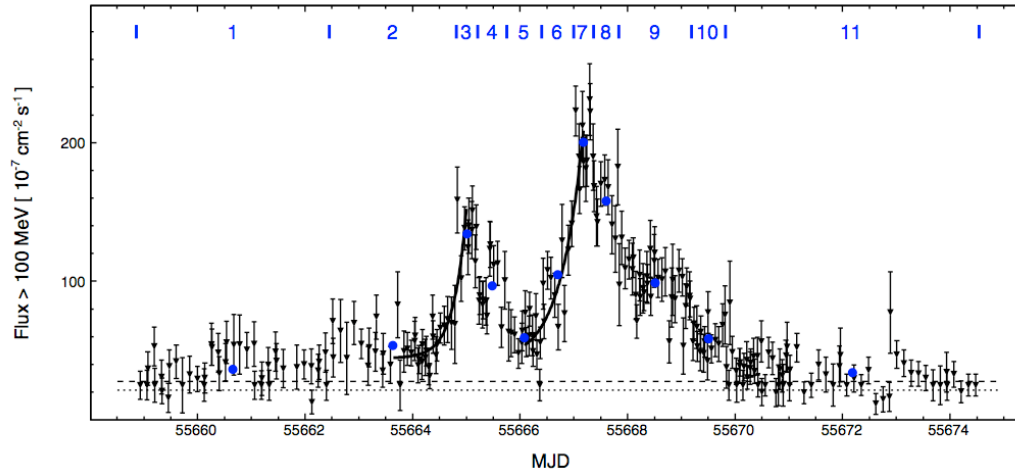
LAT light curve ($E > 100$ MeV)



Abdo+11, Buehler+12

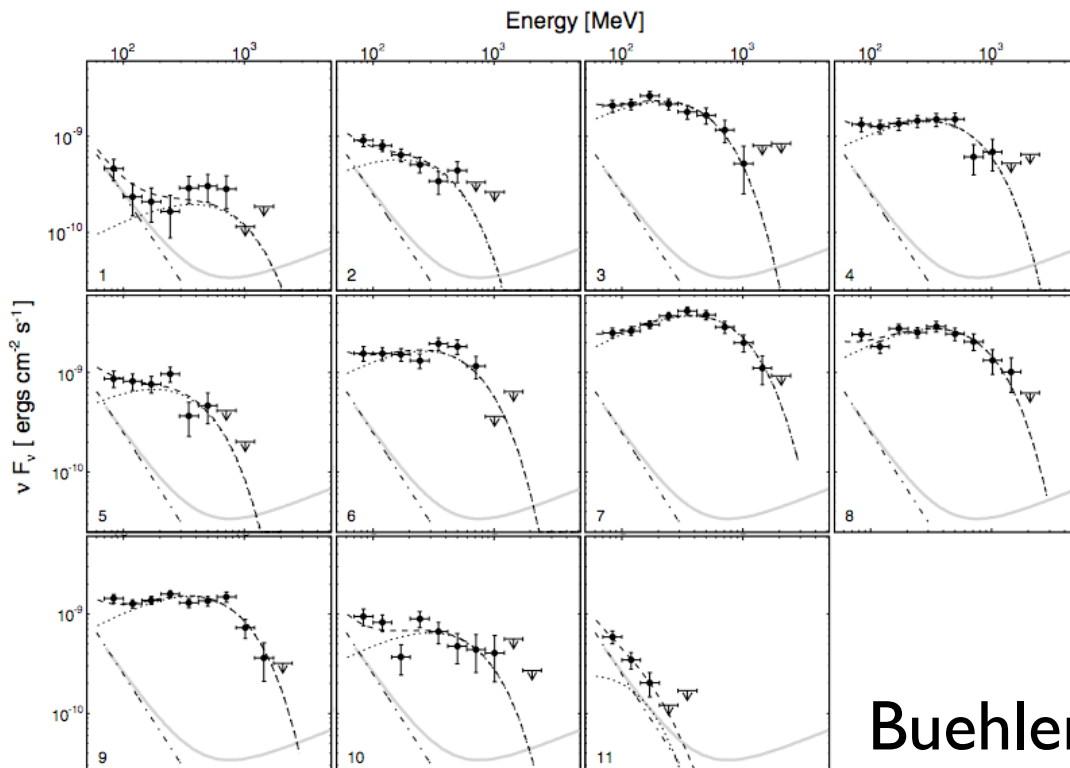


Giant flare in 2011 April



Doubling timescale of ~ 8 hour
(Compact emission region of $L < ct_d \sim 2.8 \times 10^4$ pc)

Isotropic peak luminosity is 4×10^{36} erg/s ($\sim 1\%$ of total spin-down power)

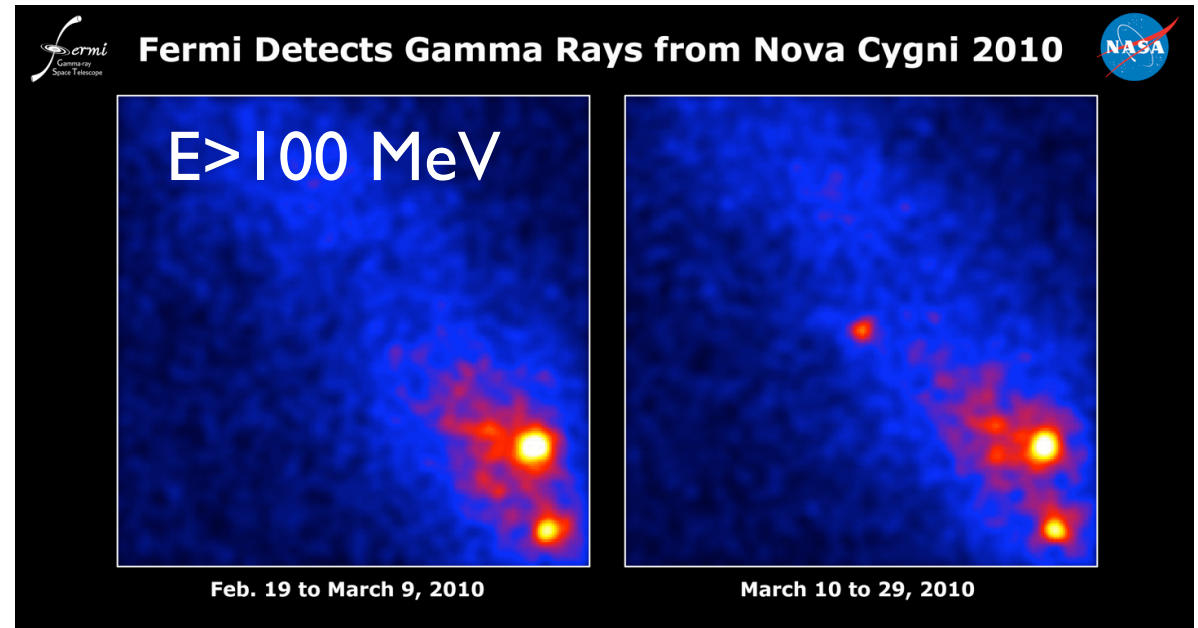
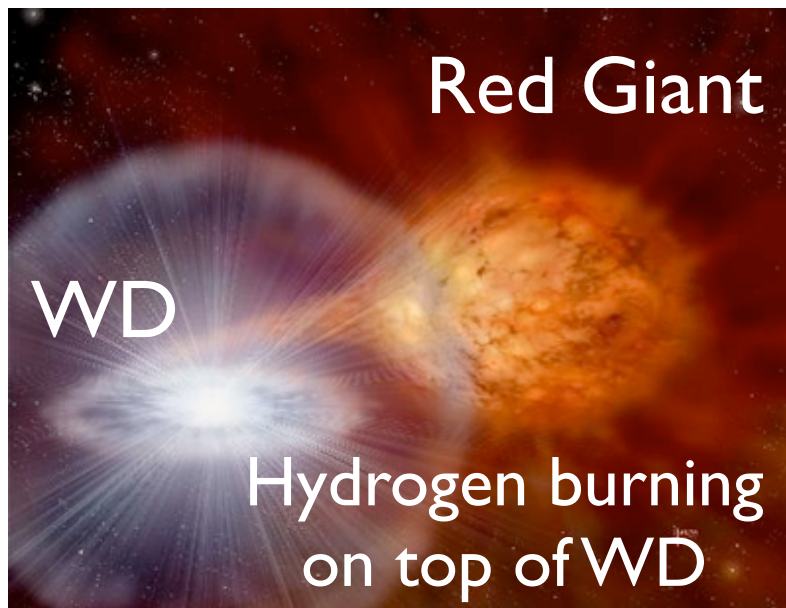


Cutoff Energy is above 400 MeV
(this is above theoretical upper limit of cutoff energy of ~ 200 MeV)

Buehler+12, 田中孝+12(物理学会誌)

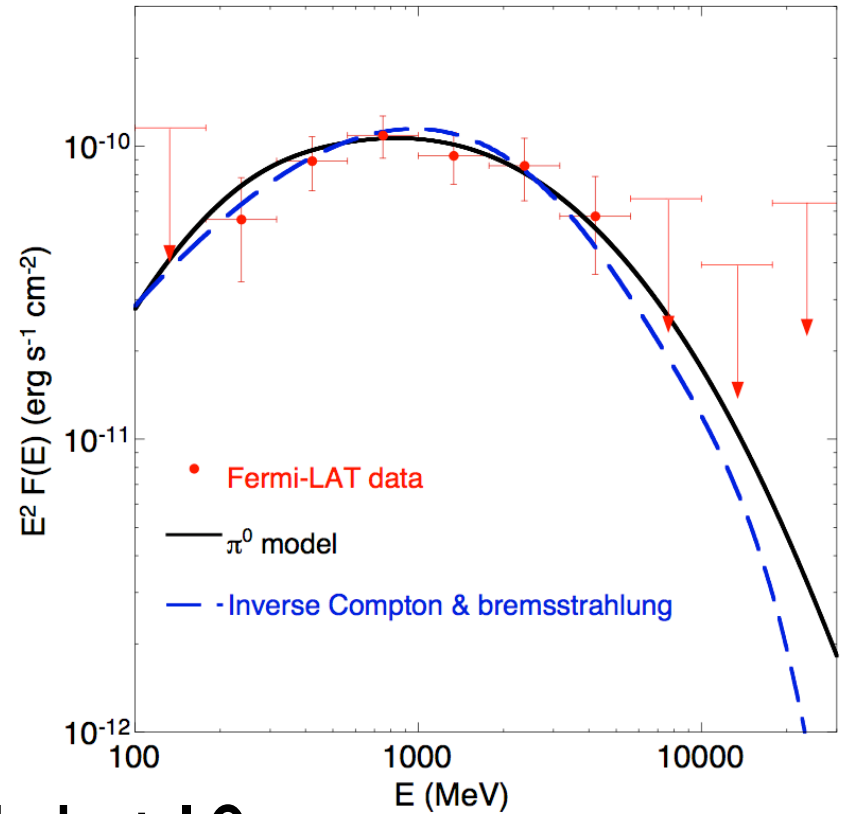
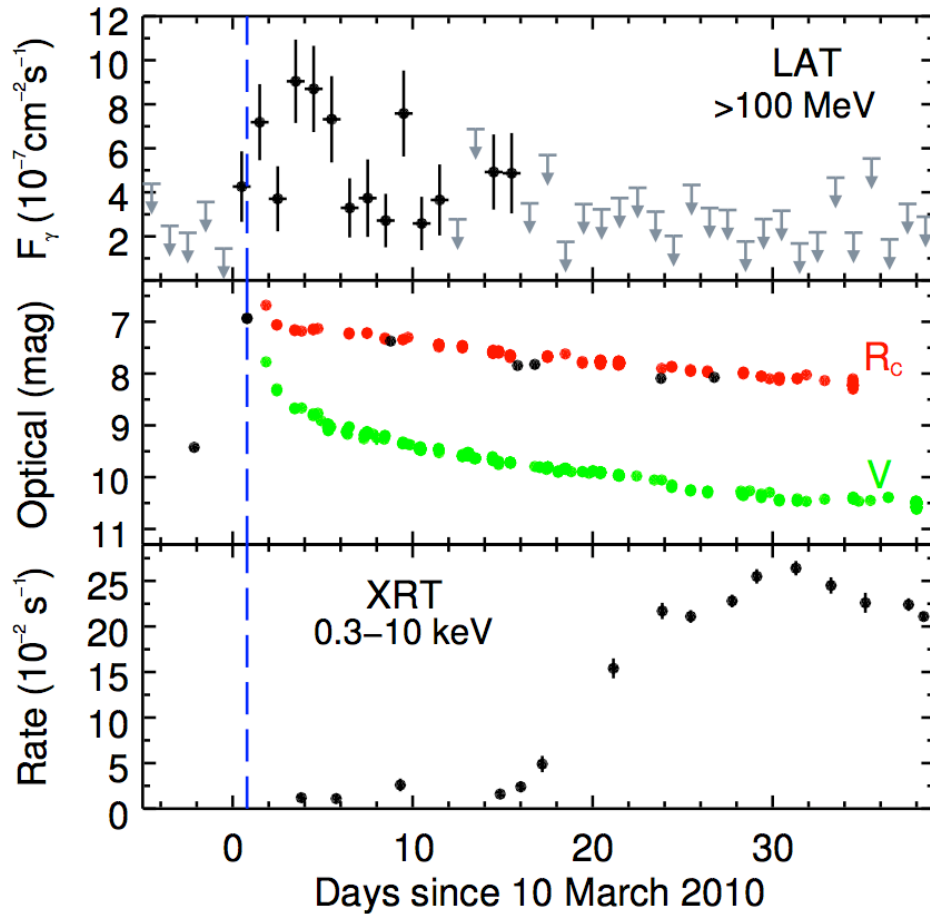
Nova is also GeV emitter

Symbiotic system



- V407 Cyg is symbiotic nova, not classical nova ($D \sim 1 \text{ kpc}$)
- LAT detected high-energy gamma-rays from Nova V407 Cyg in 2010 (Abdo+10)

LAT observation



Abdo+10

- Gamma-ray emission lated for ~ 10 days
- Pizero decay is favored, but leptonic origin cannot be ruled out

Recent LAT detection of Classical Novae

Atel #4284

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Fermi LAT Detection of a New Galactic Bulge Gamma-ray Transient in the Scorpius Region: Fermi J1750-3243, and its Possible Association with Nova Sco 2012

ATel #4284; *C. C. Cheung (NRC/NRL), T. Glanzman, A. B. Hill (SLAC); on behalf of the Fermi Large Area Telescope Collaboration*
on 28 Jul 2012; 18:01 UT

Credential Certification: *Teddy Cheung (ccheung@milkyway.gsfc.nasa.gov)*

Subjects: Gamma Ray, >GeV, Nova, Transient

Referred to by ATel #: [4287](#), [4288](#), [4310](#)

The Large Area Telescope (LAT), on board the Fermi Gamma-ray Space Telescope, has detected a transient gamma-ray source in the Galactic Bulge: Fermi J1750-3243. Preliminary analysis of the Fermi-LAT data indicates that from 2012 June 18-24, the source was detected with a >100 MeV flux of $(0.8 \pm 0.1) \times 10^{-6}$ ph cm⁻² s⁻¹ (statistical only; a systematic uncertainty of 30% should be added to this number) with >10 sigma significance. The source was detected with >3 sigma significance on a daily basis as early as June 16 and up to June 30. There is no previously reported gamma-ray source at this location.

Atel #4310

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Possible Association of the Gamma-ray Transient Fermi J0639+0548 with Nova Mon 2012

ATel #4310; *C. C. Cheung (NRC/NRL), S. N. Shore (U. Pisa and INFN), I. De Gennaro Aquino (U. Pisa), S. Charbonnel (Durtal Observatory, France), J. Edlin (Idaho Falls, Idaho), E. Hays (NASA/GSFC), R. H.D. Corbet (UMBC, NASA/GSFC), D. L. Wood (NRL); on behalf of the Fermi Large Area Telescope Collaboration*

on 17 Aug 2012; 18:30 UT

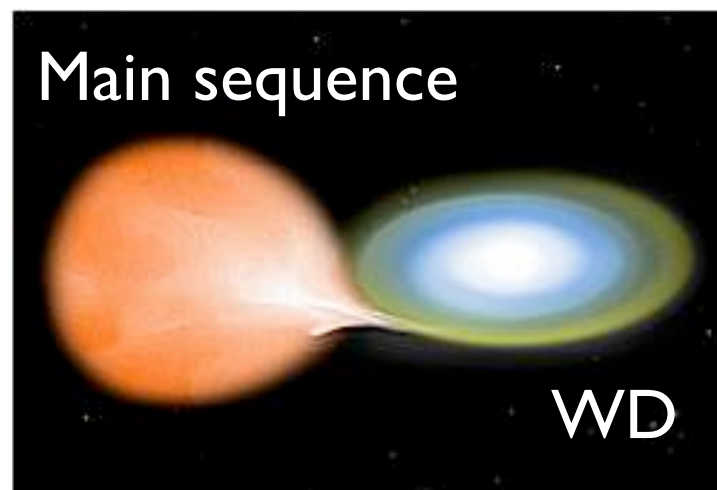
Credential Certification: *Teddy Cheung (ccheung@milkyway.gsfc.nasa.gov)*

Subjects: Gamma Ray, >GeV, Nova, Transient

Referred to by ATel #: [4320](#), [4321](#), [4352](#), [4365](#), [4376](#)

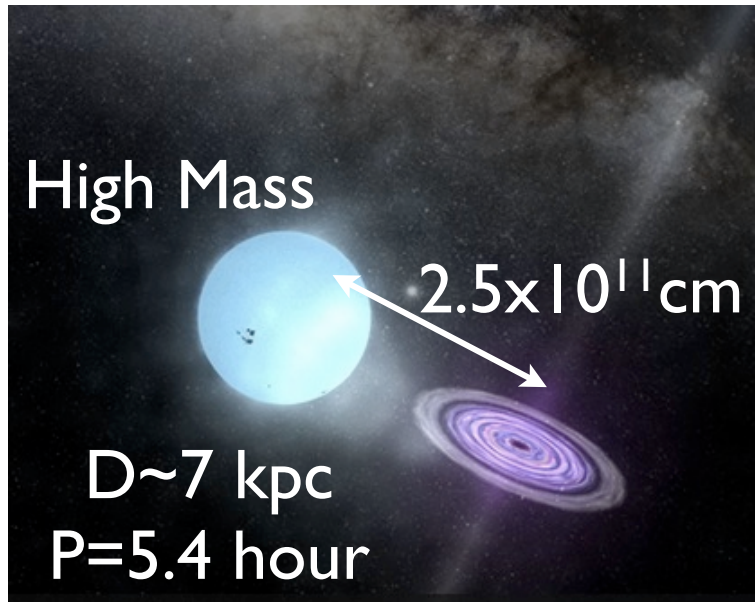
In ATel #4224, we reported the detection by the Fermi Large Area Telescope of Fermi J0639+0548, a new gamma-ray transient in the Galactic plane, beginning on 2012 June 22. The transient was seen through the Monoceros region of our Galaxy with Galactic coordinates, (l, b) = (206.42 deg, 0.03 deg). We noted the gamma-ray source was close to the Sun at the time of detection, thus precluding prompt follow-up with Swift (and also ground-based optical observers).

Classical Nova

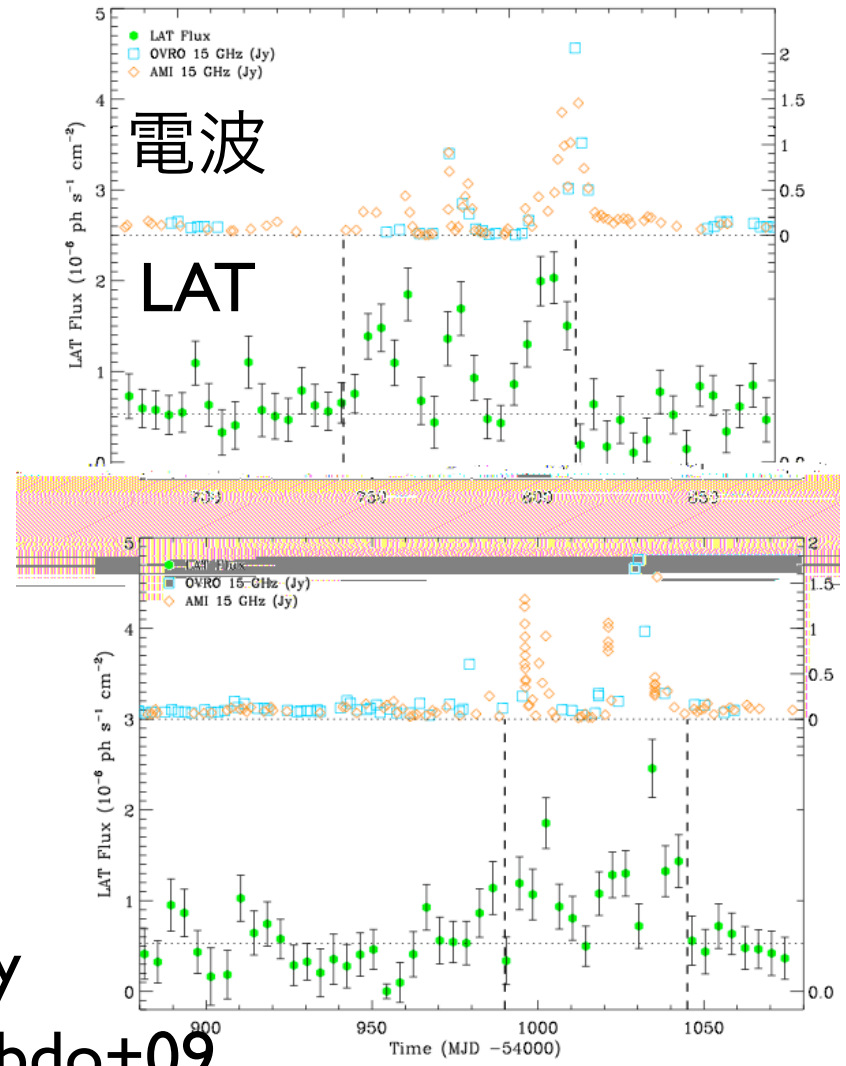


- Event rate is ~10/yr for classical nova
- Why only these 2 events are detected by LAT?

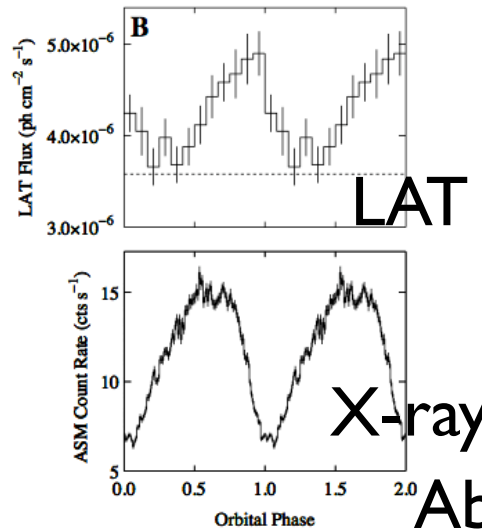
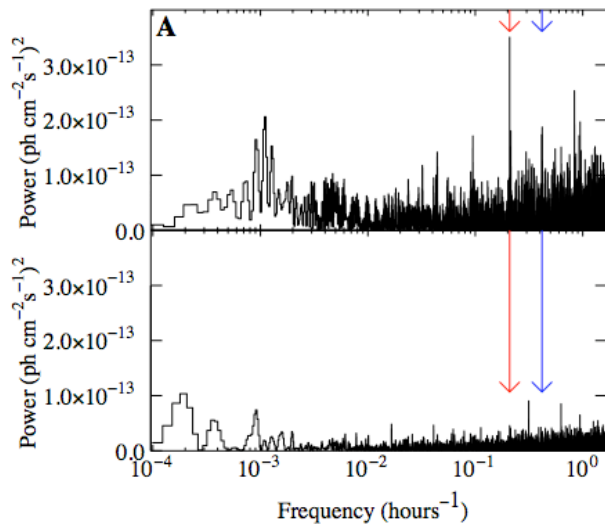
Transient modulated gamma-rays from Cygnus X-3



Radio flareに同期した
 ガンマ線の検出

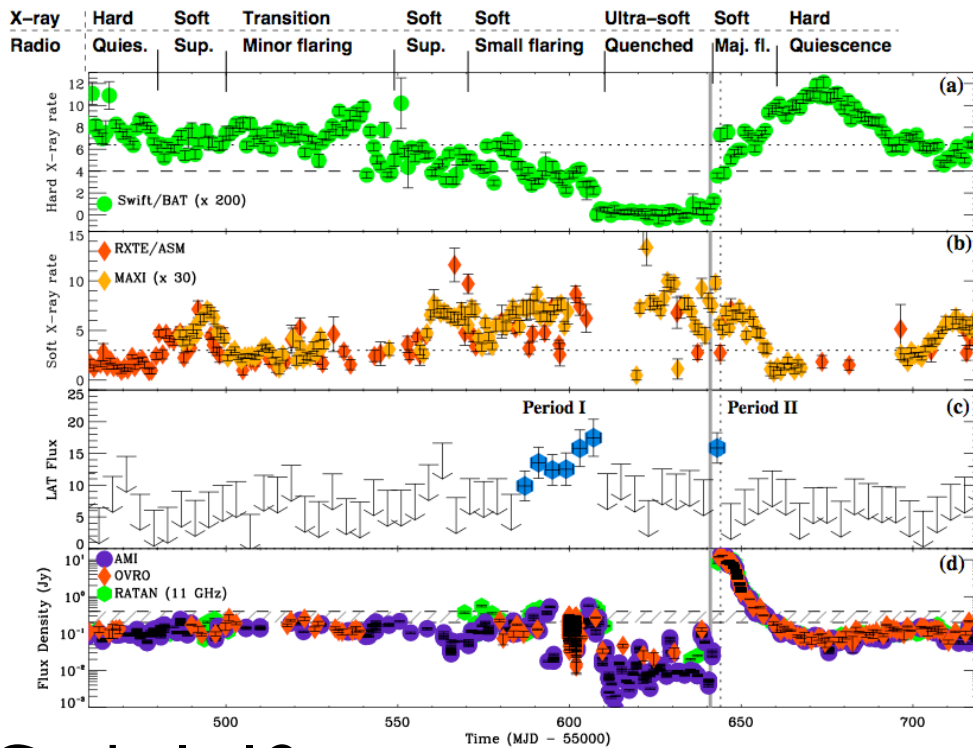


Clear modulation

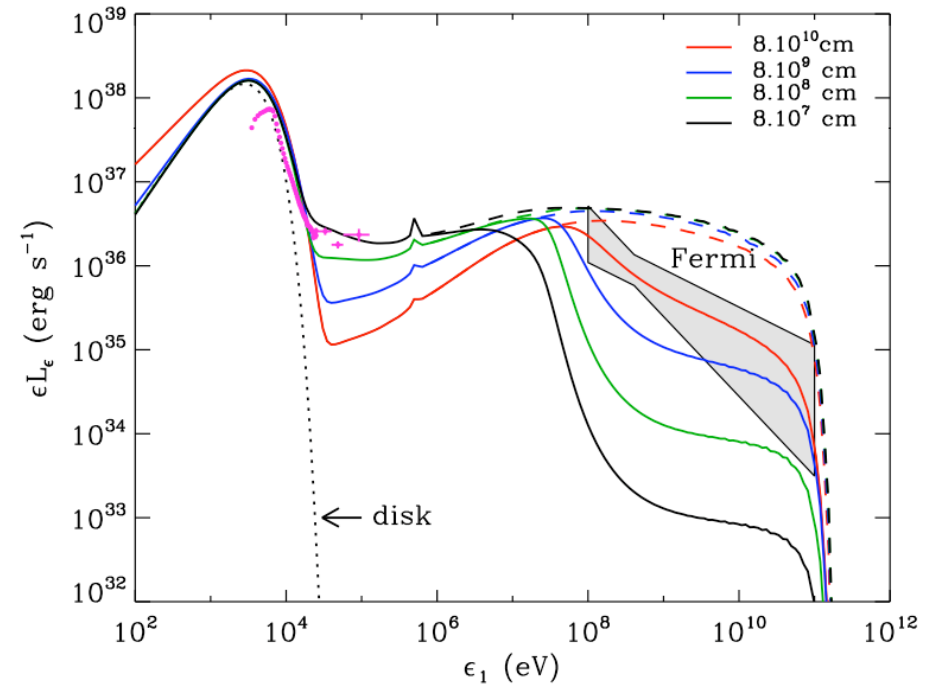


Abdo+09

Gamma-ray emission before and after ultra-soft state



Corbel+12

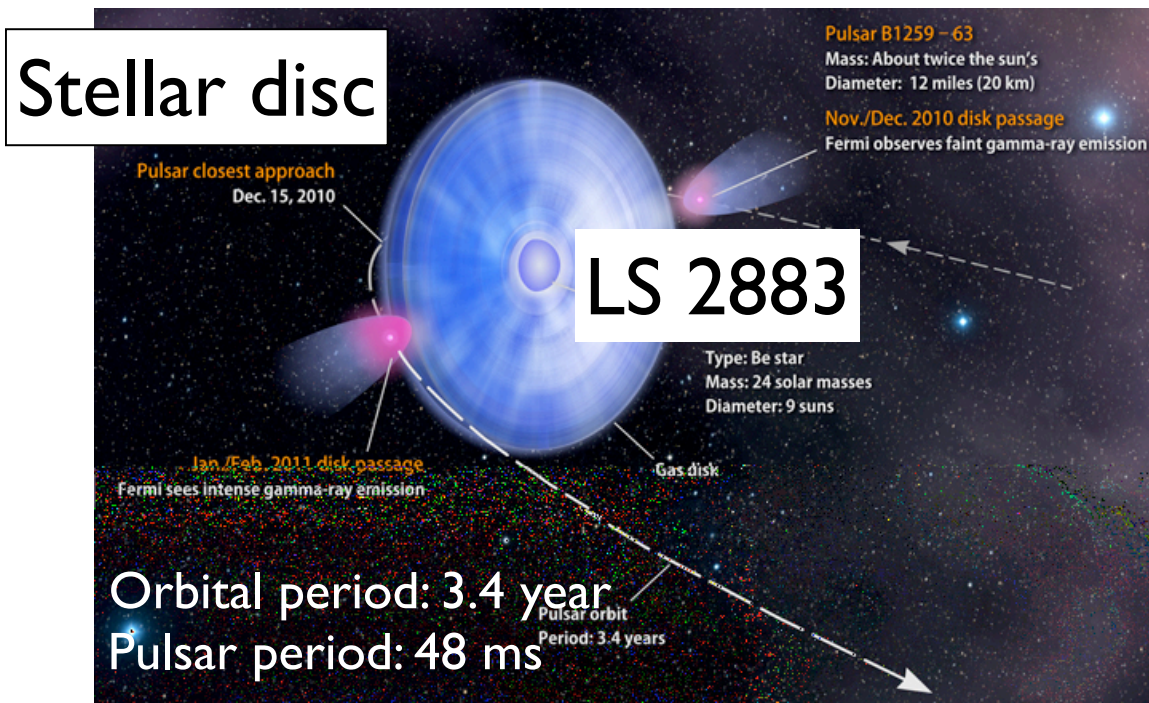


Cerutti+11

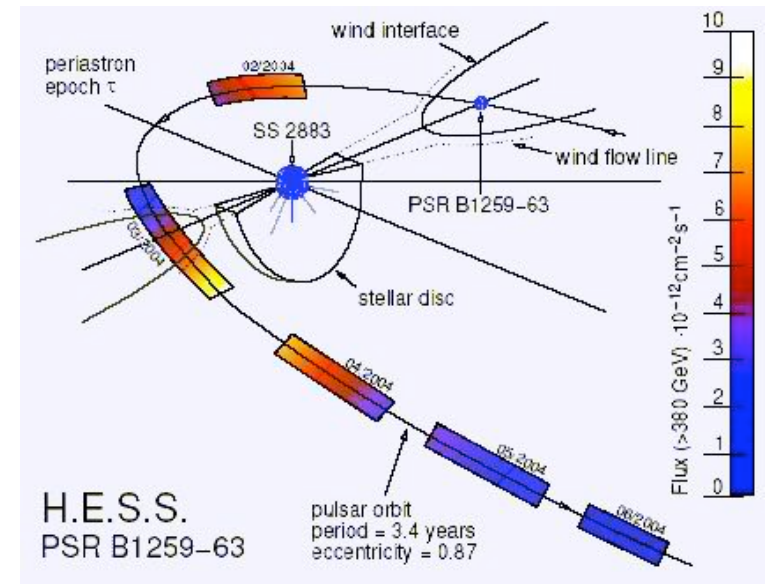
- Leptonic origin (IC) is favored, but pion decay cannot be ruled out

PSR B1259-63 (Periastron passage in 2010 Dec.)

Pulsar + Be star system

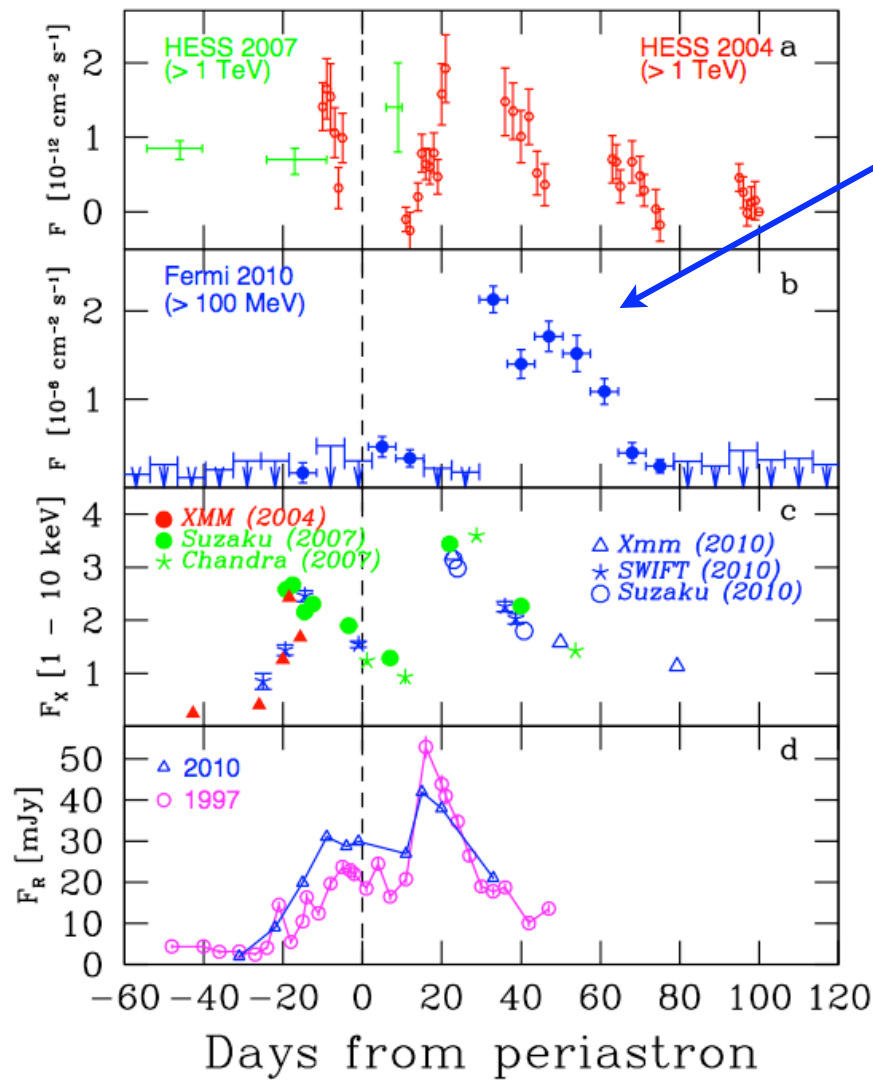


HESS detection
in previous passage

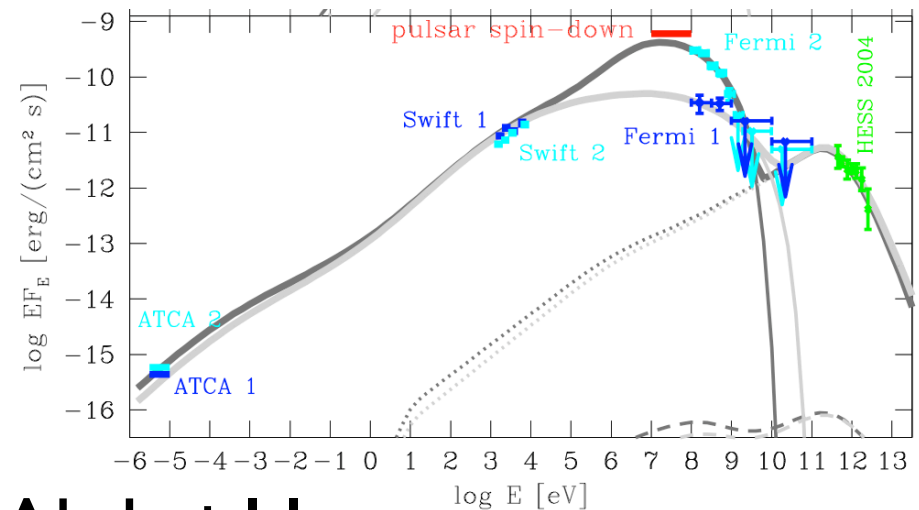


- 過去のperiastron passageで、HESSがTeV放射を検出
- 2010年12月の近星点通過でも、LATで検出されると期待されていた

Delayed LAT emission



Strong GeV flare
delayed by ~ 30 days



Abdo+11

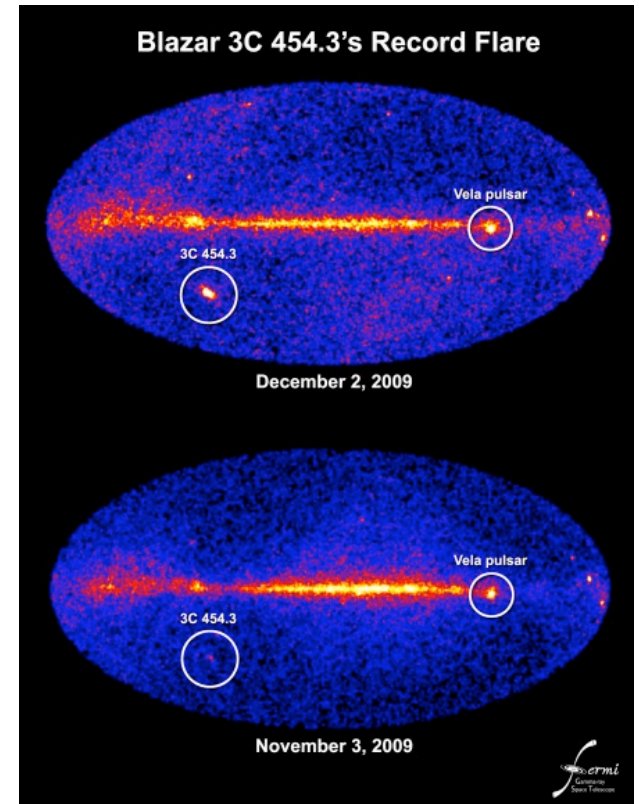
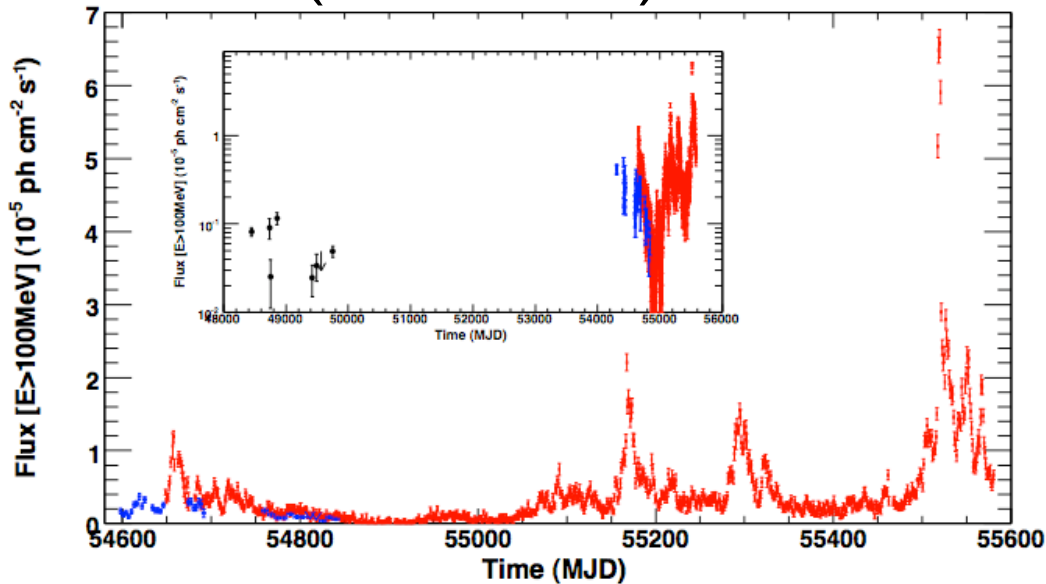
GeV photons would be
synchrotron origin

Extragalactic transients and Sun

- AGN flare (mostly blazars)
- Tidal disruption event (Swift J1644+57)
- Long-lasting solar gamma-ray emission

AGN flare

3C 454.3 (Abdo+11)



- 毎日のようにフレアが検出されている (FSRQ, BL lac, NLSy1)
- ここ最近は、(i) フレアが初めて検出された天体、(ii) フレアが既に検出されている天体については、フラックスが極めて高いなど特異なフレアの場合、にのみAtelが出される
- LAT monitored source list light curve, Fermi sky blogも参照下さい

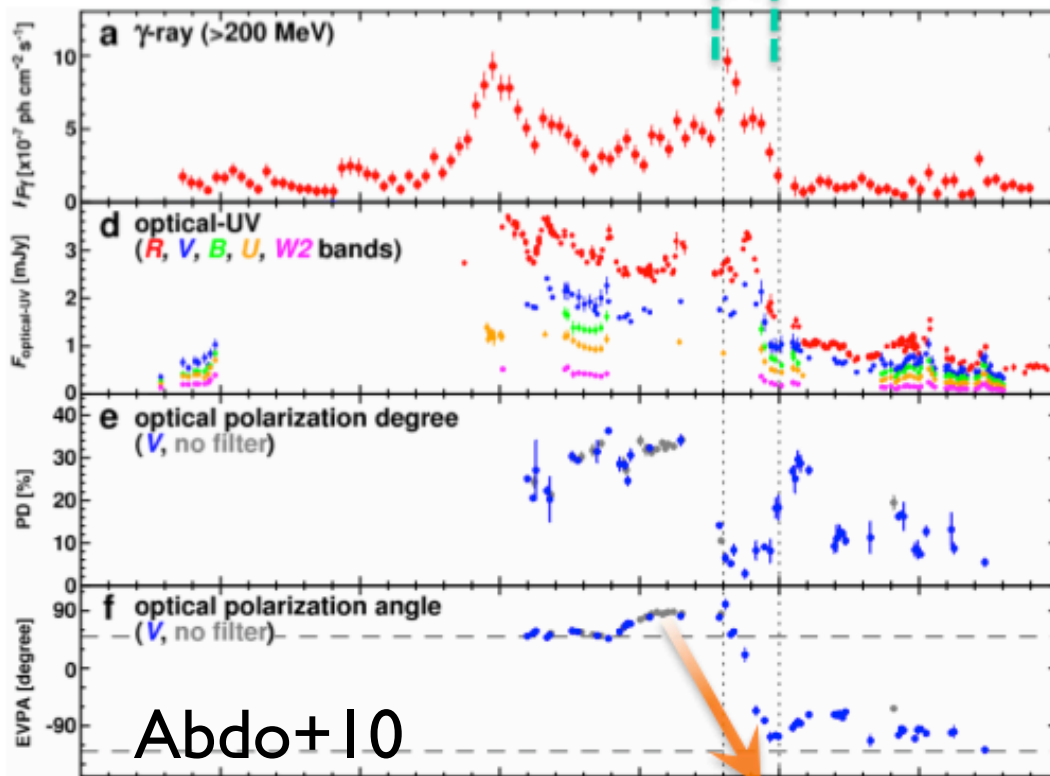
多波長フォローアップ観測の戦略

どのブレーザーを何でフォローアップするか

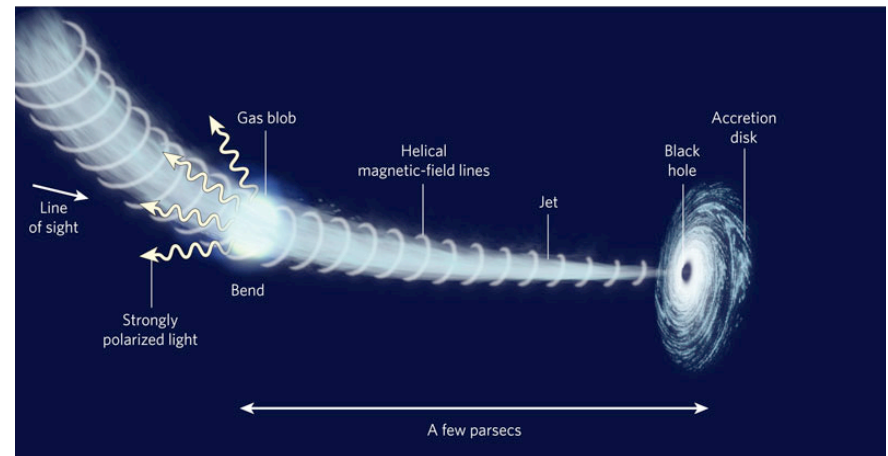
- Fermi flaring blazarをとにかくフォローアップする
 - ✓ 3C 279 with かなた望遠鏡 (optical polarization measurement)
- 1日積分のデータで、GeV indexが0.2程度のエラーで決まるので spectral hardeningしたブレーザー(数は多くない)を抽出し、素早く TeVコミュニティに通報
 - ✓ 4C 21.35 ($z=0.432$): MAGIC detection in 2010 June
 - ✓ PKS 1510-089 ($z=0.360$): MAGIC detection in 2012 Feb.

3C 279 flare in 2009

20 days



Gamma-ray flare with optical polarization angle swing
 -> Co-spatiality of optical and gamma-ray emissions



$$r_{\text{event}} \geq \Delta r_{\text{event}} \sim 10^{19} \left(\frac{\Delta t_{\text{event}}}{20 \text{ days}} \right) \left(\frac{\Gamma_{\text{jet}}}{15} \right)^2 \text{ cm}$$

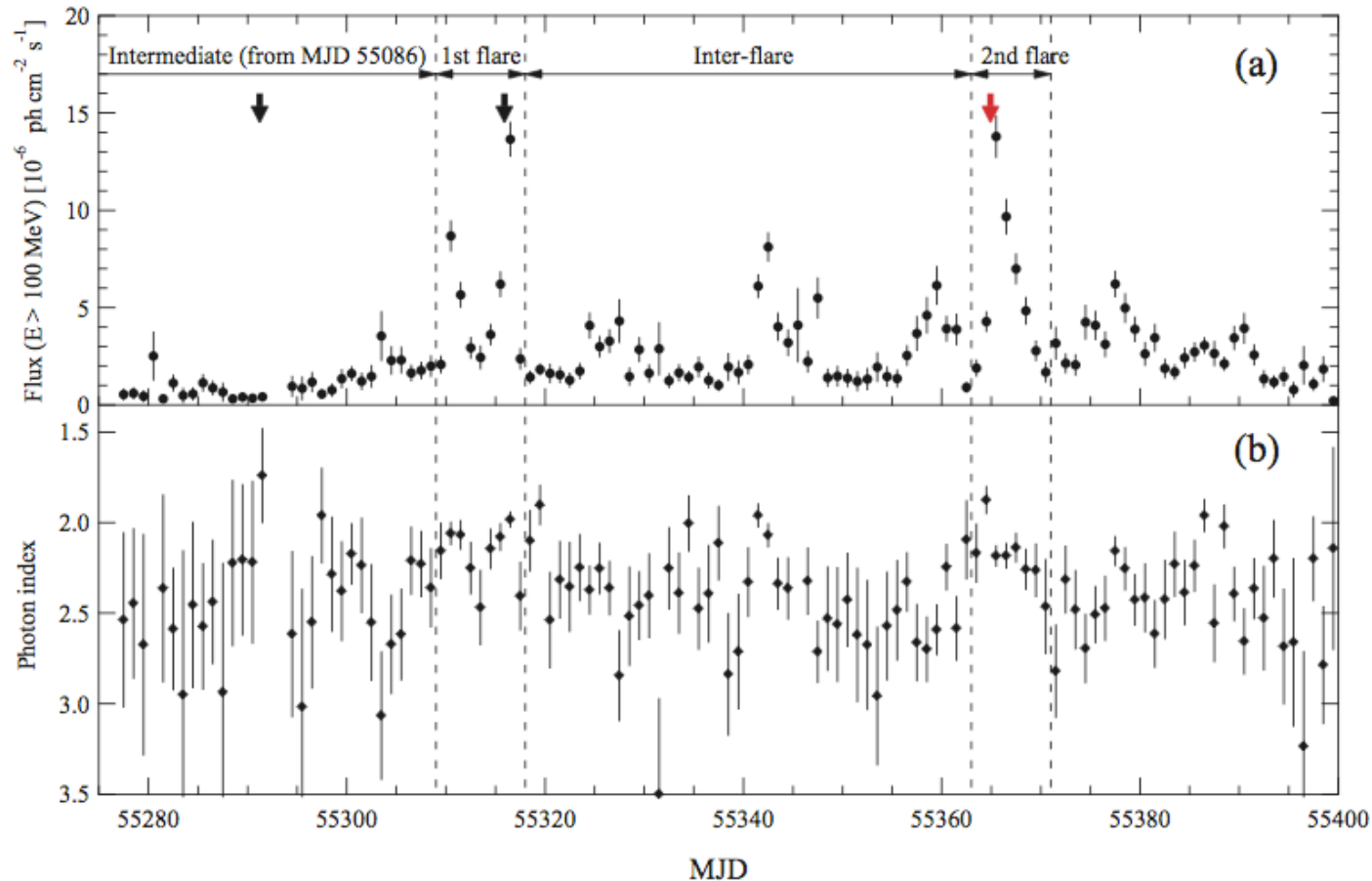
Location of emission zone from BH Propagation distance of emitting blob

Emission zone locates pc scale from BH

LAT observation of 4C 21.35

1 day bin light curve

MAGIC detection

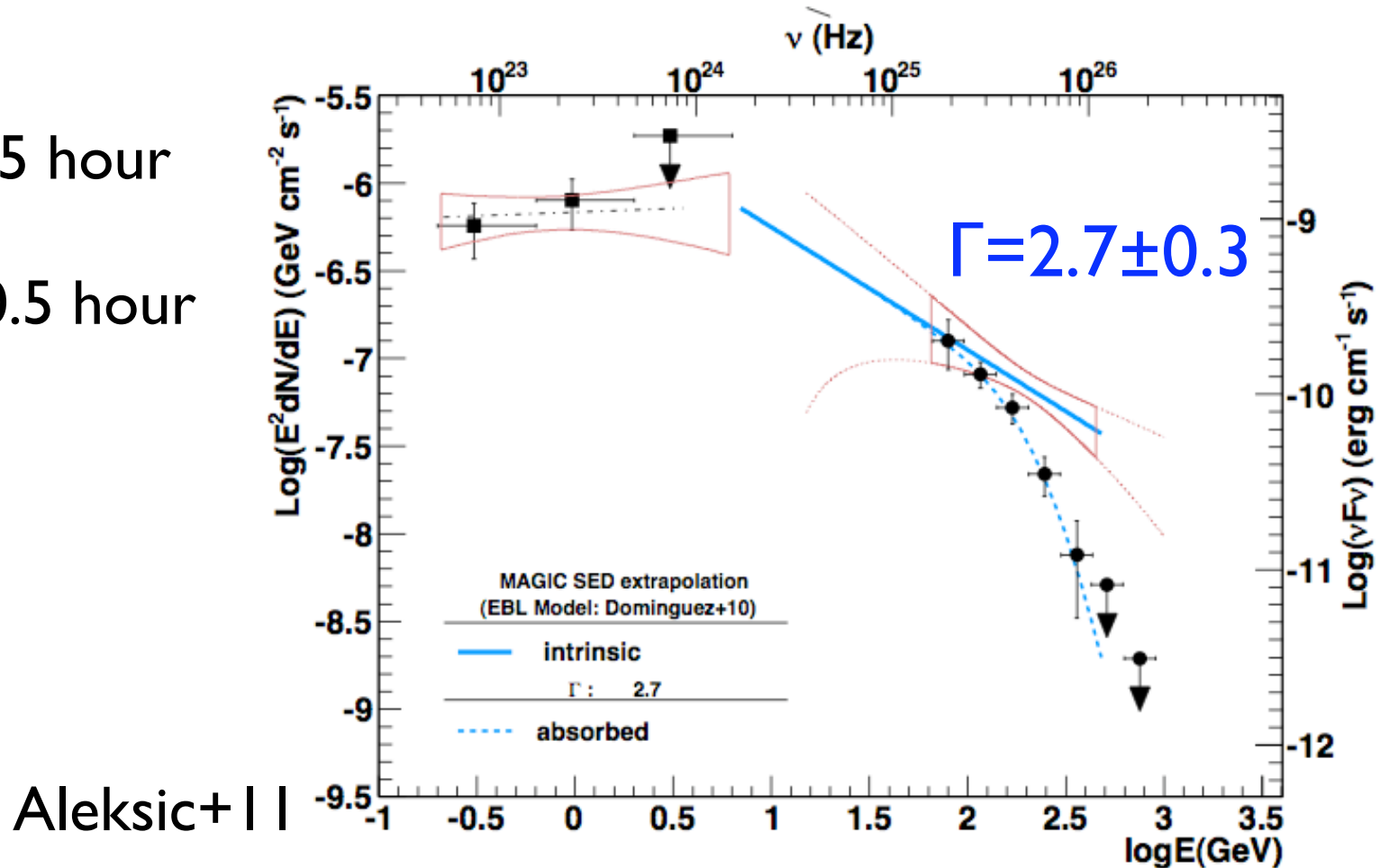


Tanaka+11

- Hard index is indeed a good indicator to hunt for TeV FSRQ

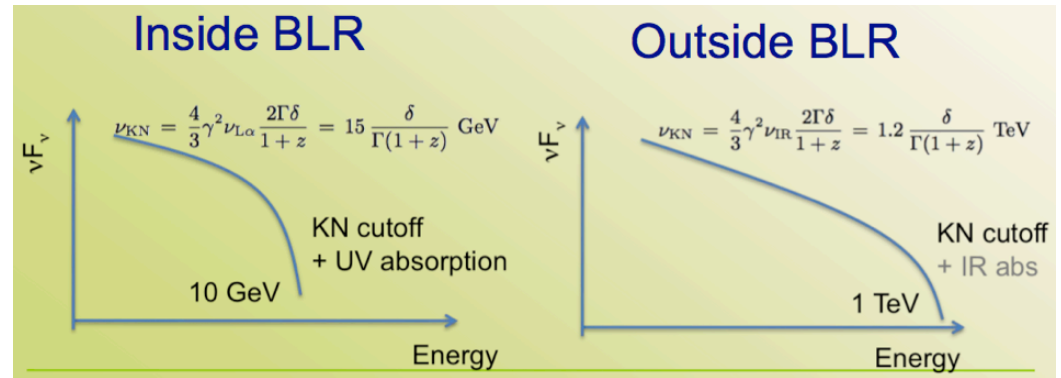
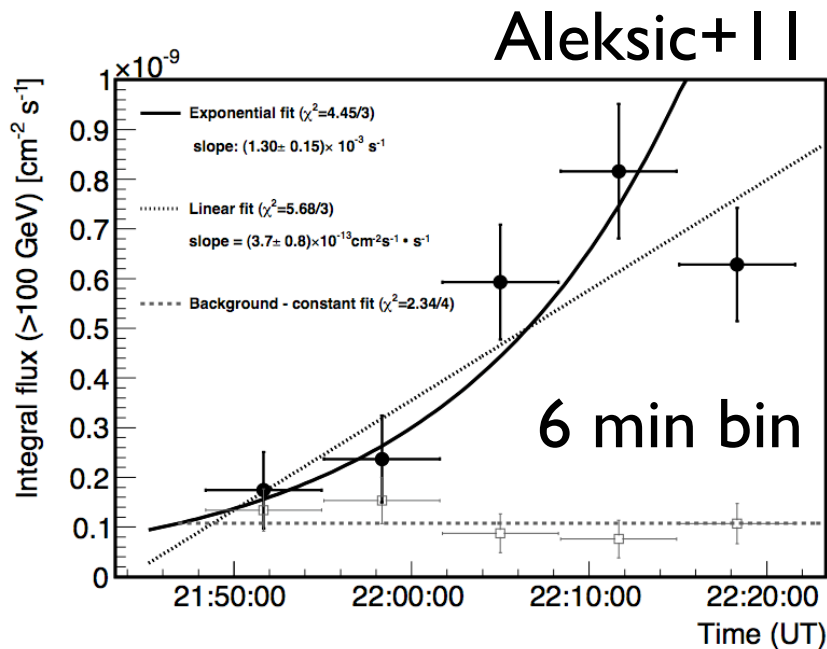
Fermi-MAGIC simultaneous spectrum

Fermi 2.5 hour
&
MAGIC 0.5 hour



- **Single component from 3 to 400 GeV**
- **Cutoff excluded at $E < \sim 130$ GeV (95%CL)**

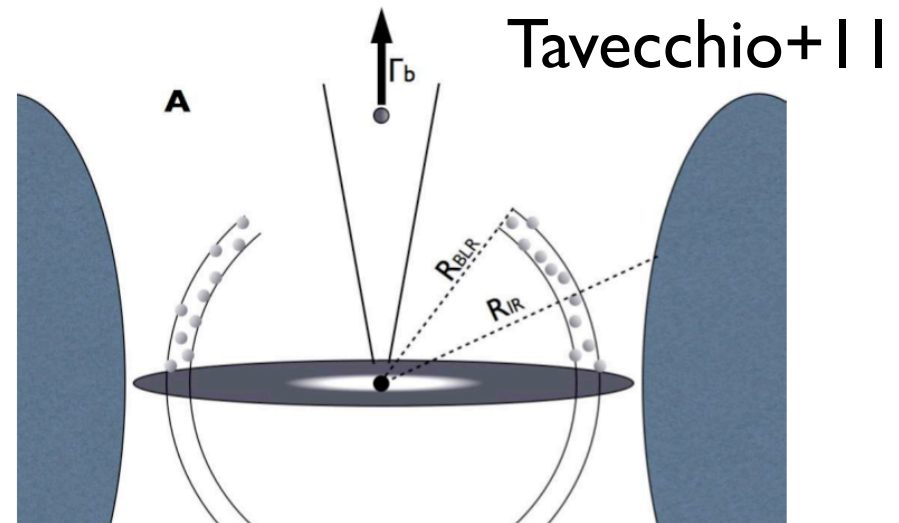
Rapid variability and implications



Taken from Stamerra's slide at Fermi sympo 2011

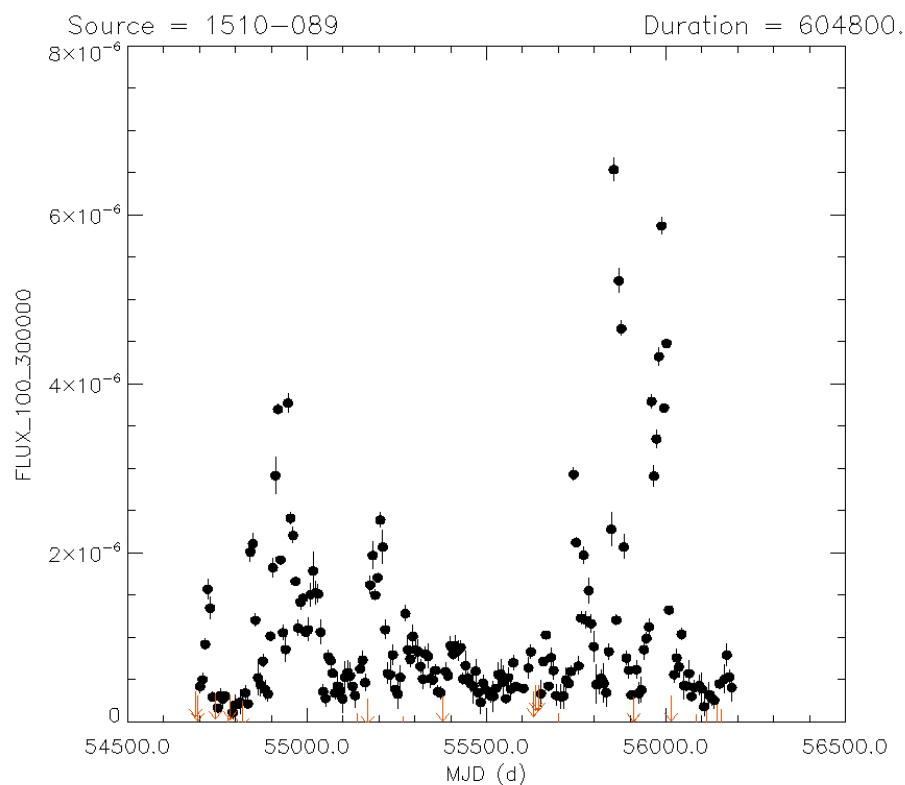
**Doubling time of ~10 min
(very compact emission region of $R \sim 10^{14} \text{ cm}$)**

$$R = \frac{\delta c t_{\text{var}}}{1+z} = 1.3 \times 10^{14} \text{ cm} \left(\frac{\delta}{10} \right) \left(\frac{t_{\text{var}}}{10 \text{ min}} \right)$$



PKS 1510-089 flare in 2012 Feb.

LAT weekly light curve



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MAGIC detects very high energy gamma-ray emission from the FSRQ PKS 1510-089

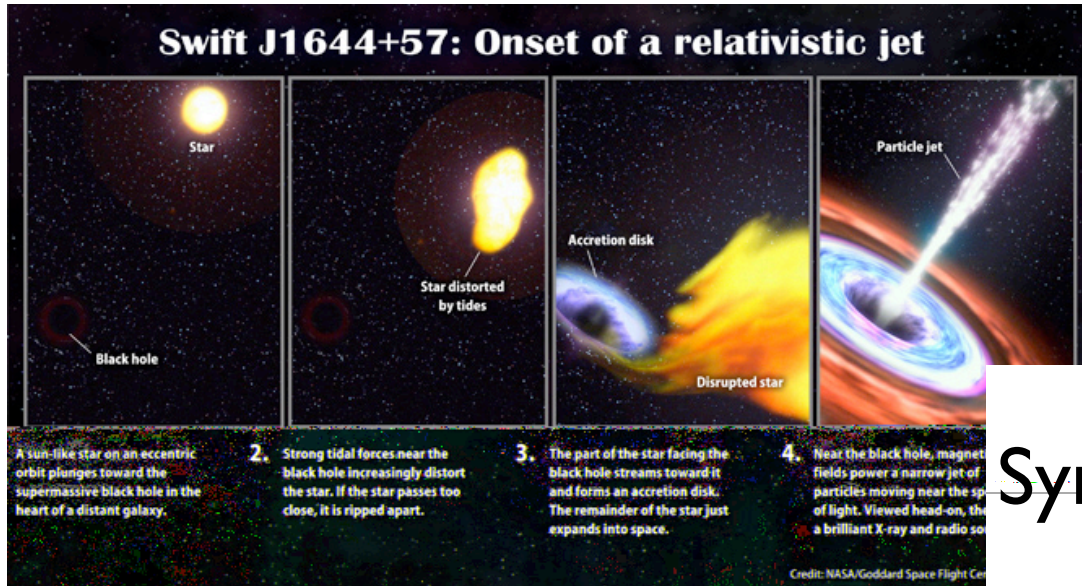
ATel #3965; [Juan Cortina \(IFAE Barcelona\) on behalf of the MAGIC Collaboration on 13 Mar 2012; 20:19 UT](#)
Credential Certification: [Juan Cortina \(cortina@ifae.es\)](mailto:cortina@ifae.es)

Subjects: Gamma Ray, >GeV, TeV, VHE, AGN, Quasar

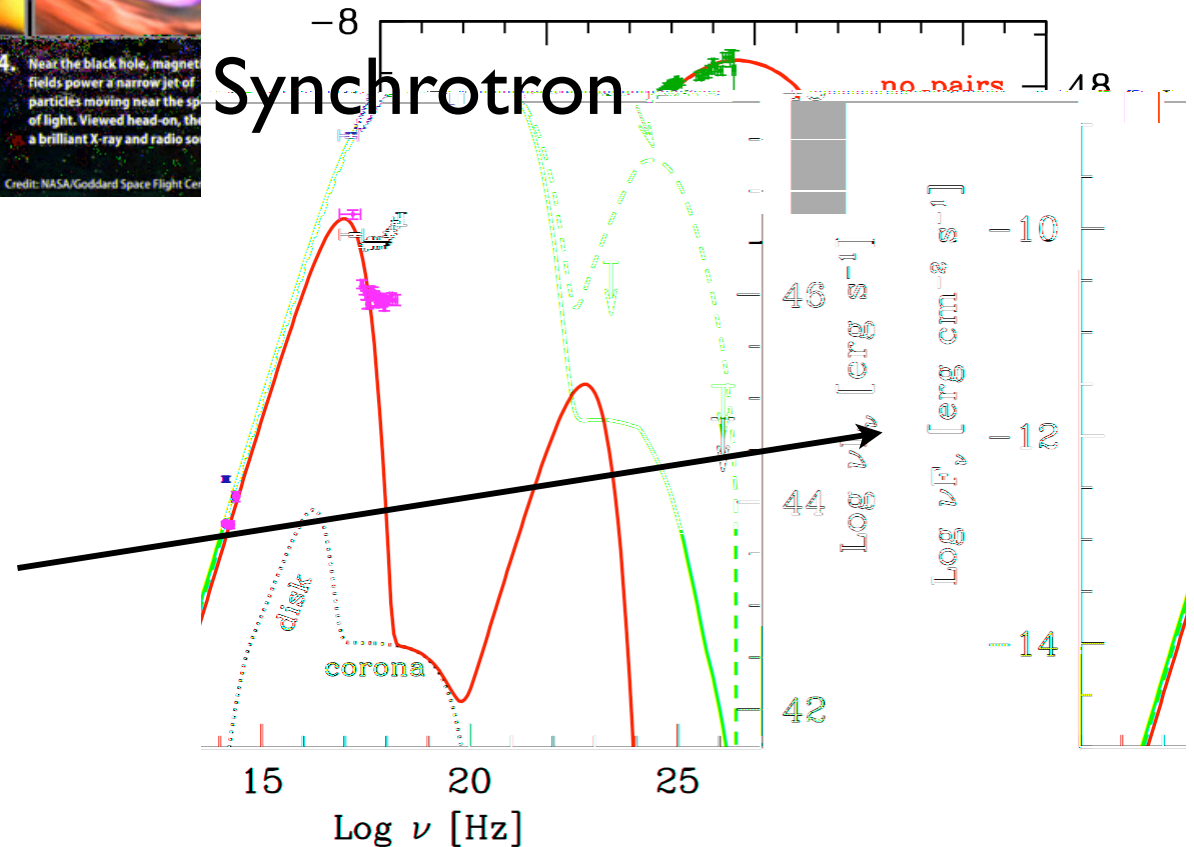
Following the communication from the Fermi-LAT collaboration on February 1st that PKS 1510-089 ($z=0.36$, R.A.= 15h 12m 50.5s, Dec.=09d 05m 59.8s, J2000) underwent spectral hardening in MeV-GeV range (Dave Thompson, priv. comm. to TeV facilities) and ATel #3907 announcing enhanced gamma-ray emission observed by AGILE on February 2nd, the source was observed by MAGIC starting on February 3rd, just before the full moon shut down. The observations were resumed on February 19th and in total ~10 hours of data have been collected. The preliminary analysis of the data reveals a clear signal with a statistical significance of >5 sigma.

- LAT and MAGIC spectra are smoothly connected with broken power-law of $\Gamma_{\text{low}} \sim 2.2$, $\Gamma_{\text{high}} \sim 2.7$, and $E_{\text{break}} \sim 1$ GeV (Yesterday's Saito-san's talk)
- Emission region is outside BLR

LAT non-detection of Tidal disruption event

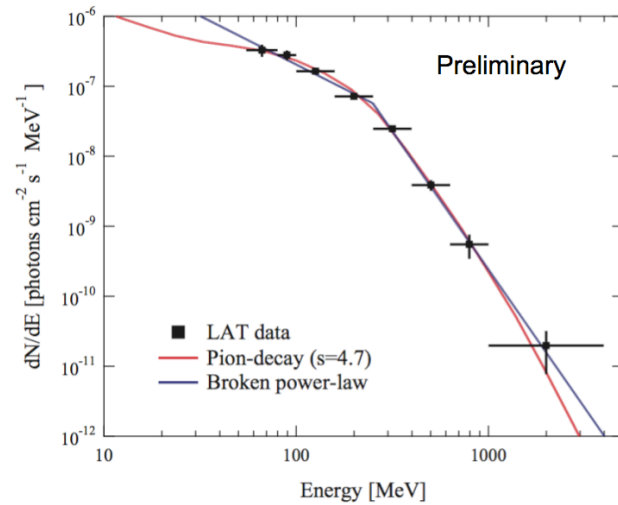
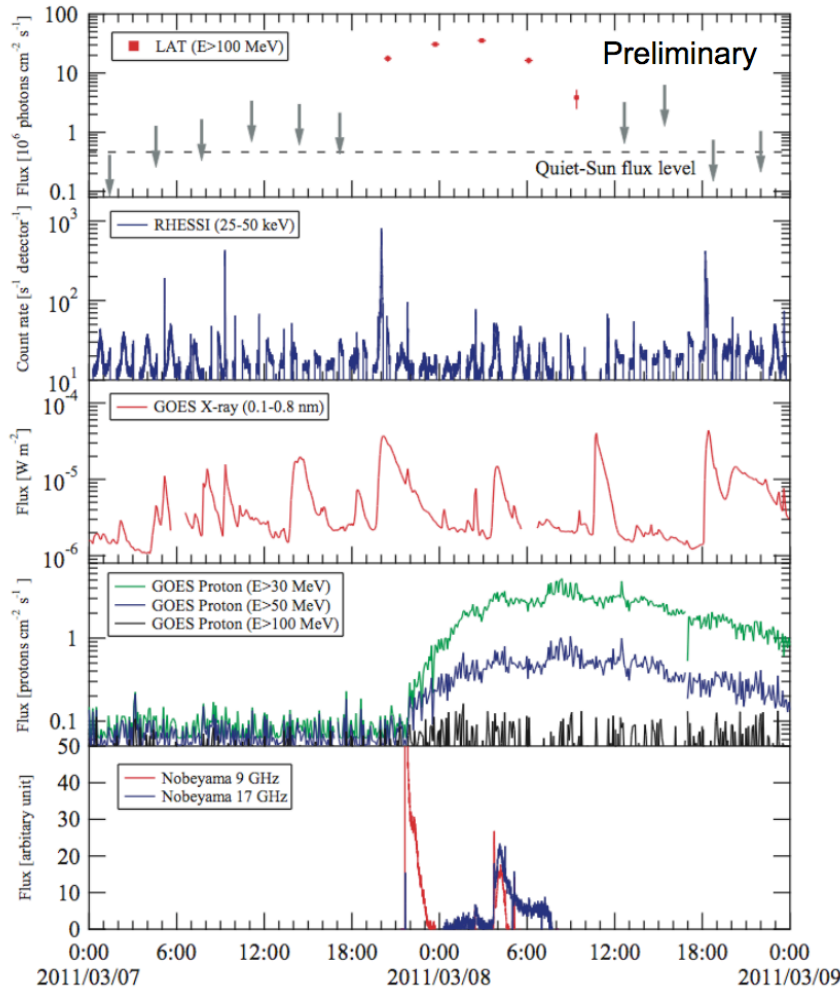


SSC component is suppressed by γ - γ pair production (Burrows+11)



Long-lasting gamma-ray emission associated with solar flares

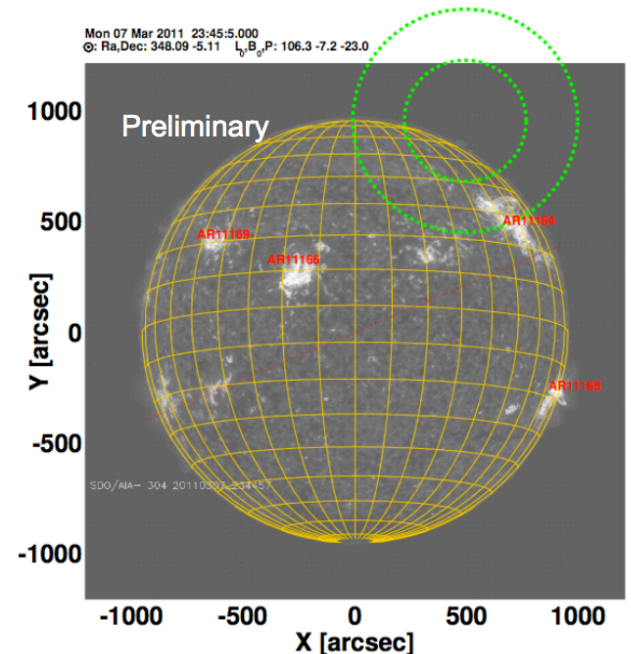
M3.7 flare on 2011 March 7



Pion-decay bump is clearly seen

Gamma-ray emission region is associated with Active Region

Tanaka+Gamma2012 conference



LAT detection of the Sun

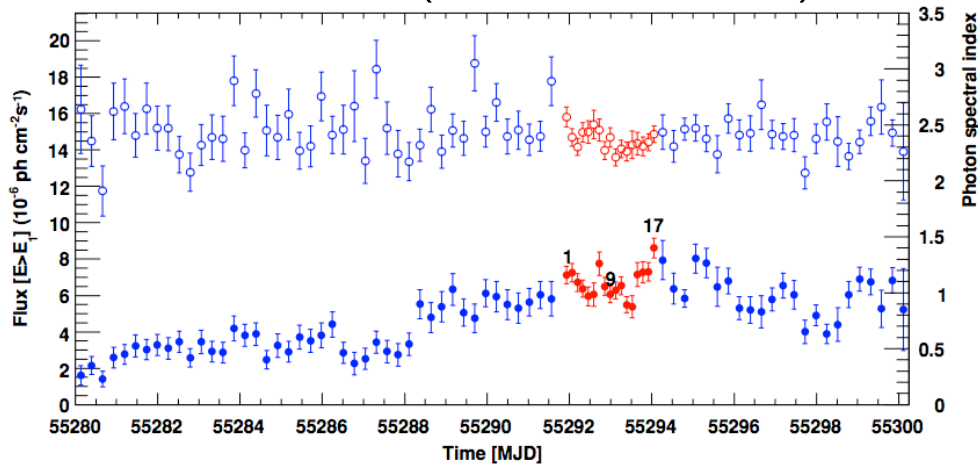
Preliminary

Date	Type	GOES Class	CME speed
2010-06-12	Impulsive	M-class	<500 km/s
2011-03-07	~15h	M-class	~2000 km/s
2011-06-07	~3h	M-class	~1200 km/s
2011-08-04	~3h	X-Class	~1000 km/s
2011-08-09	Impulsive	X-Class	~1700 km/s
2011-09-06	Impulsive + 3h	X-Class	~1000 km/s
2011-09-07	~6h	X-Class	~700 km/s
2011-09-24	Impulsive	X-Class	<500 km/s+1500 km/s (delayed)
2012-01-23	~9h	M-class	~1500 km/s
2012-01-27	~3h	X-Class	MULTIPLE >1500 km/s
2012-03-05	~6h	X-Class	~1700 km/s
2012-03-07	Impulsive + ~20 h	X-Class	MULTIPLE >1700 km/s
2012-03-09	~6h	M-class	~1000 km/s
2012-03-10	~3h	M-class	~1700 km/s
2012-05-17	~3h	M-class	~1700 km/s

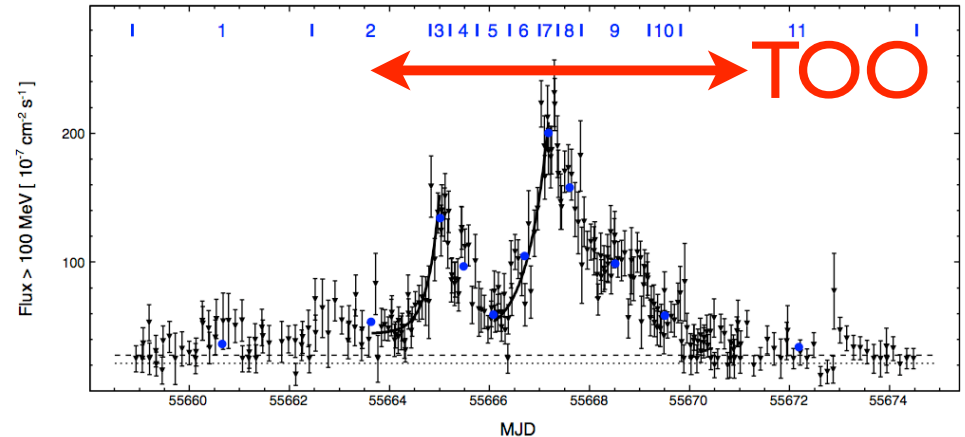
ISS太陽中性子, RHESSI, Nobeyama, ALMAによる観測で加速機構を解明へ

TOO Pointed observation

3C 454.3 (Ackermann+10)



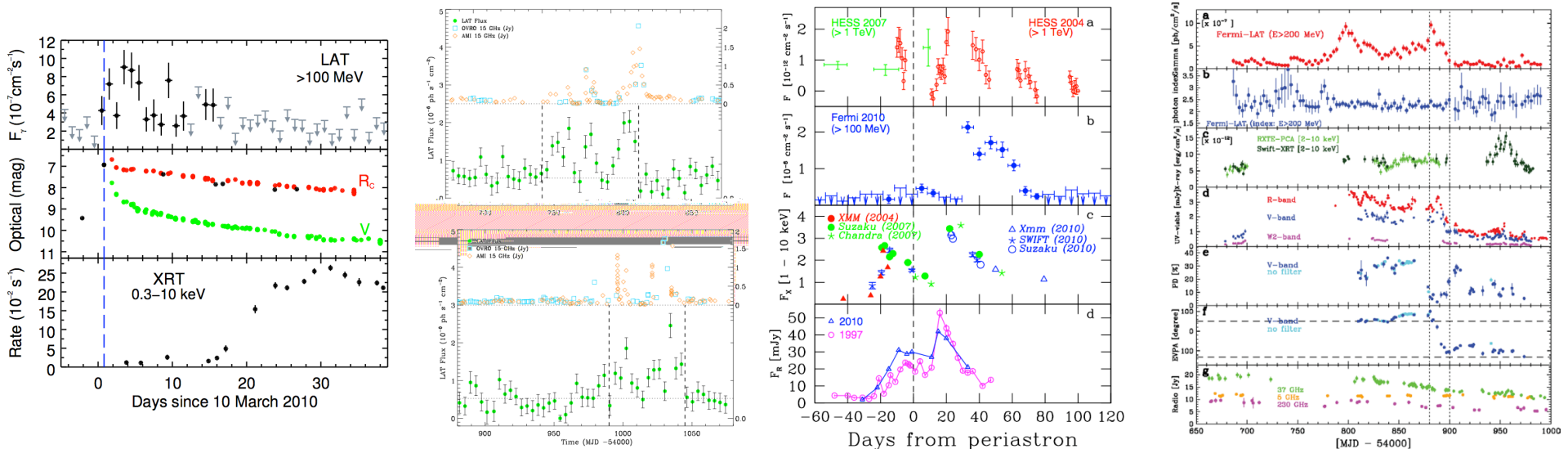
Crab nebula flare (Buehler+12)



- 興味深い現象が起これば (またはあらかじめ予想できれば)、TOO観測が提案でき、望遠鏡を向けることが可能 (3C 454.3, Crab, PSR B1259-63, Cygnus X-3, Sun) **Sgr A*のTOO??**
- Survey modeと比較してexposureが~4倍増加する
- Modified survey modeというオプションもある (one orbit for northern sky and following 2 orbits for southern sky)

Summary

- Fermi-LATは、2008年6月以降、太陽から系外天体まで、興味深いトランジェント現象を続々と検出している
- 未検出でも重要な上限値を与えている
- 通常はsurvey modeでの運用だが、TOO pointed modeも申請できる (数100 ksec程度、modified survey modeなら1000 ksec程度)



Appendix

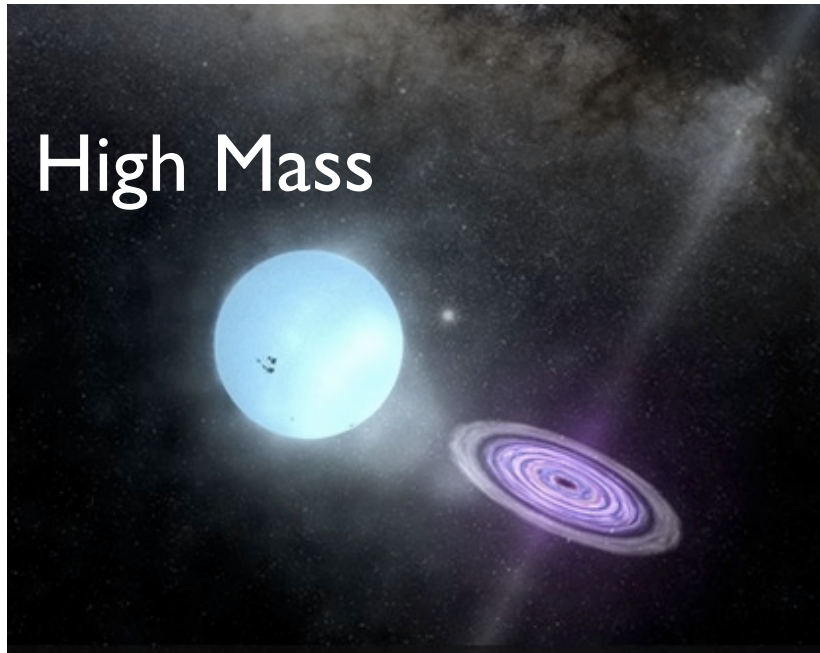
恒星フレアの検出の可能性

- 2012 March 7 太陽フレアのピークフラックス ($\sim 10^{-3}$ photons cm^{-2} s^{-1} , $E > 100$ MeV)を用いて、
- 太陽フレアの 10^4 倍強い (フラックスの大きい)フレアを仮定し、
- フェルミの1日積分データの検出限界を $\sim 5 \times 10^{-7}$ photons cm^{-2} s^{-1} ($E > 100$ MeV) とする
- $D_{\text{star}} < \sim (2 \times 10^5) (F/10^4)^{0.5} D_{\text{sun}} = 3 \times 10^{18} (F/10^4)^{0.5} \text{ cm} = 1 (F/10^4)^{0.5} \text{ pc}$
- 数pc程度のごく近傍の星が、太陽フレアよりも 10^4 倍明るいフレアを起こせば、LATで検出できる

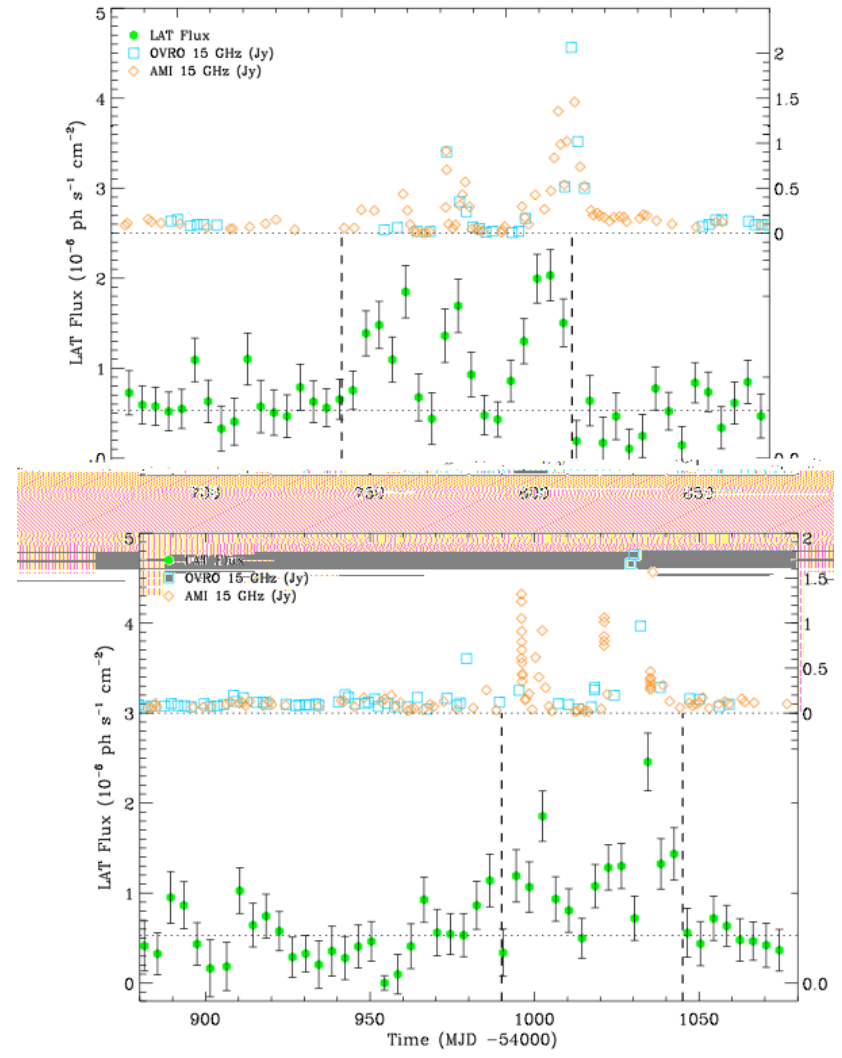
Gamma-ray Burst

- Nova
- Crab nebular flare
- Cyg X-3
- PSR B1259-63
- Blazar flare
- Radio galaxy
- GRB
- Solar flare
- Tidal disruption
- Microquasars (GRS 1915, SS433)
- Stellar/Protostellar flare
- Supernova shock breakout

Transient gamma-rays from Cygnus X-3



Distance	~7 kpc
Orbital period	5.4 hour
Binary separation	2.5×10^{11} cm

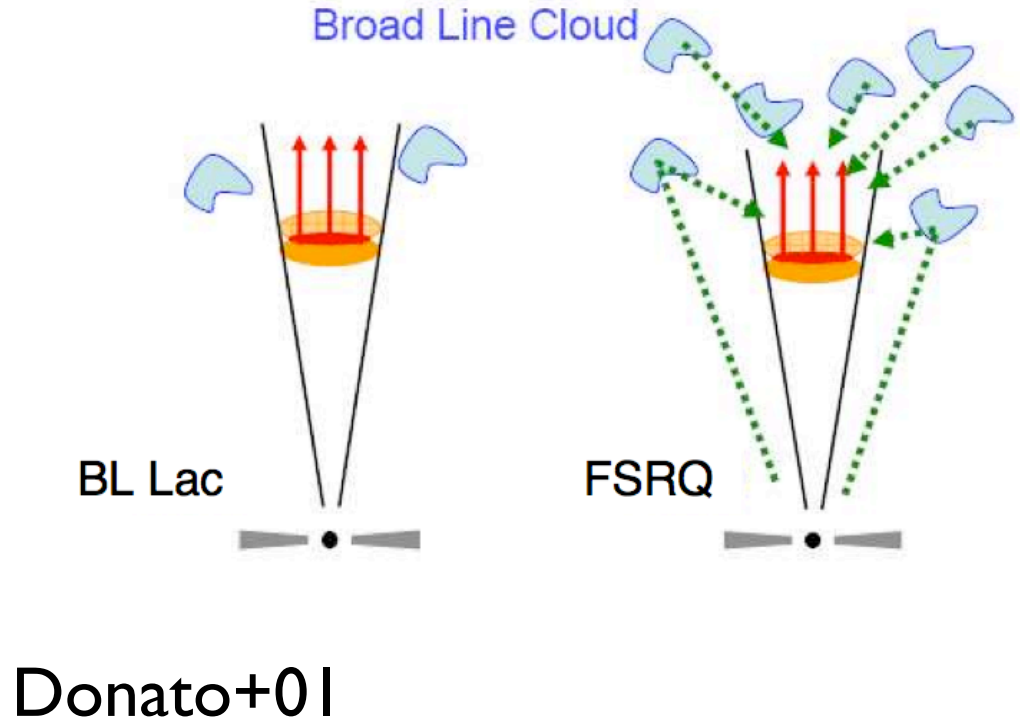
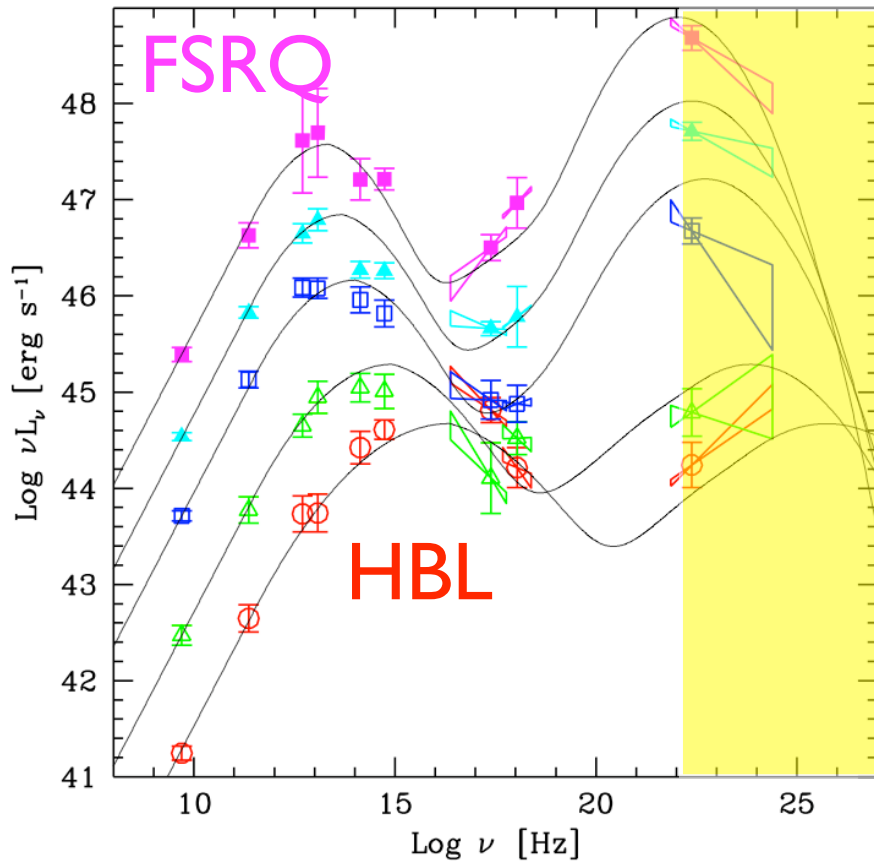


- LAT detection only at radio flares

〜し〜に〜毎〜日〜の〜あ〜ら〜わ〜る〜レ〜レ〜ノ〜大〜体〜が〜又〜か〜つ〜て〜い〜る

- 過去にAtelが流された天体はLAT monitored sourceとして、LAT ライトカーブがweb上に公開されている

Blazars



Flat spectrum radio quasars (FSRQs): Bright disk -> External compton dominant

BL Lac: Disk and BLR are faint (no optical emission line) -> SSC

No detection of other microquasars

- GRS 1915+105
- GRO J1655-40
- SS 433

Gamma-ray binary

Objects	orbital period	
LS I 61+303		
LS 5039		
PSR 1259-63		
HESS J0632		

Microquasars

	Distance	Orbital period	Binary separation	Companion	Radio intensity
Cyg X-3	7 kpc	5.4 hour	$2.50E+11$	VWR (high mass)	>0.5 Jy
Cyg X-1	2.5 kpc	5.6 day		O9.7Iab	
GRS 1915+105	~10 kpc	30.8 day			superluminal 0.01-0.1 Jy
GRO J1655-40	3.2 kpc	2.62 day		F3-6	superluminal
SS433	5.5 kpc	13.2 day			

Unidentified galactic transient

- So far, only one event
- Stellar flare? or blazar flare through Galactic plane? (boring)

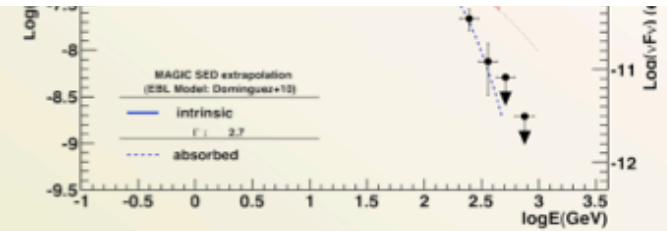
LS I 6 I +303

Solar flare

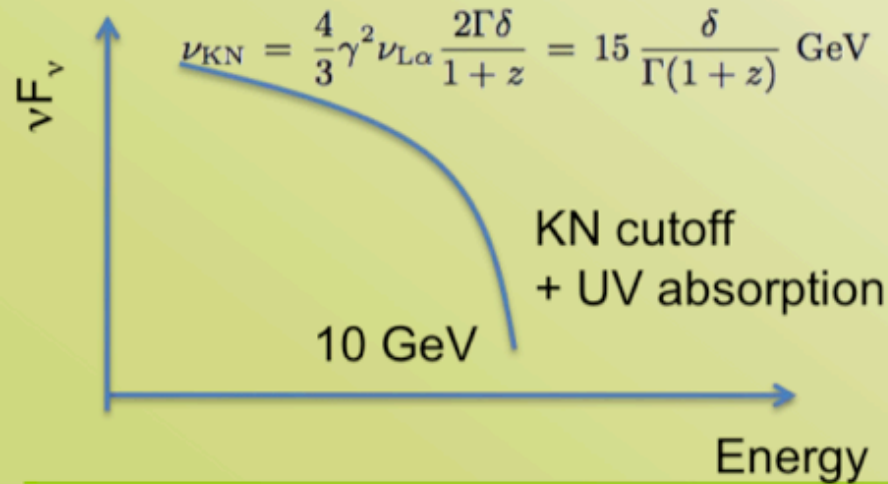
Internal absorption + Klein-Nishina break

Ghisellini & Tavecchio 2009

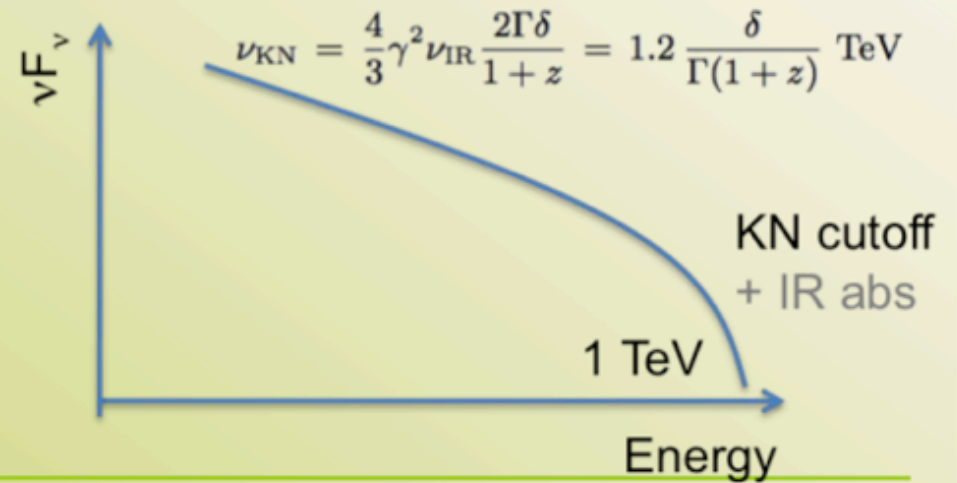
Liu & Bai 2006



Inside BLR



Outside BLR



ROM, 11 MAY 2011

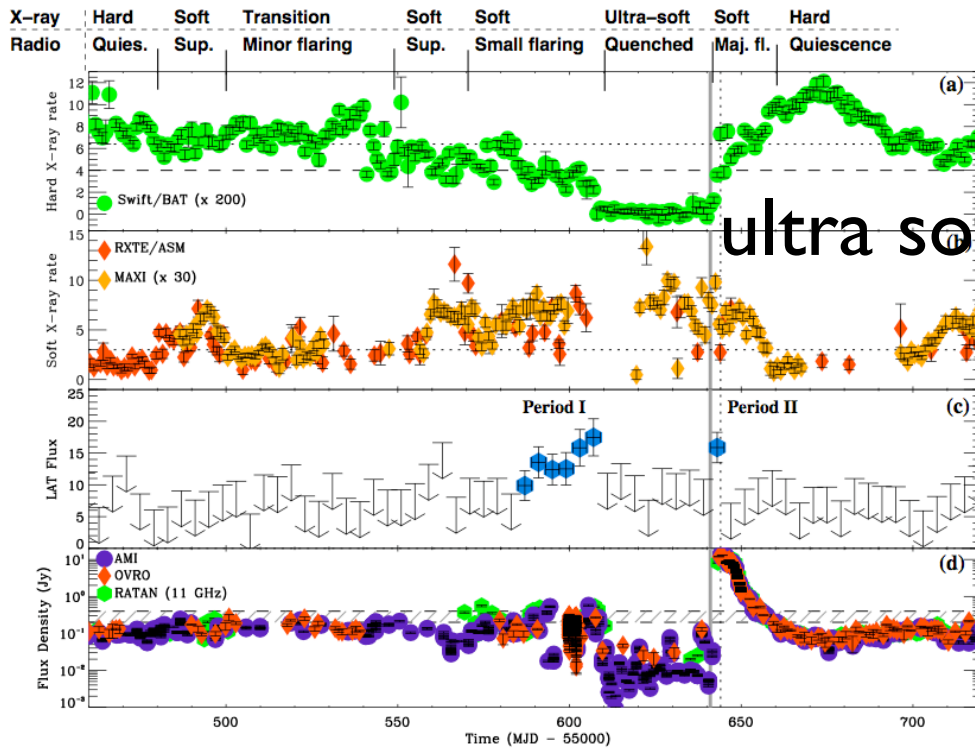
FERMI SYMPOSIUM

a. Stamerra

$$E_\gamma E_{BLR} = (m_e c^2)^2$$

$$E_{\text{break}} = 4.8 \text{ GeV} \left(\frac{54.4 \text{ eV}}{E_{BLR}} \right)$$

Gamma-ray emission before and after the ultra-soft state



ultra soft state

