

Synergy with SGMAP and current and future high-energy missions

広島大学宇宙科学センター

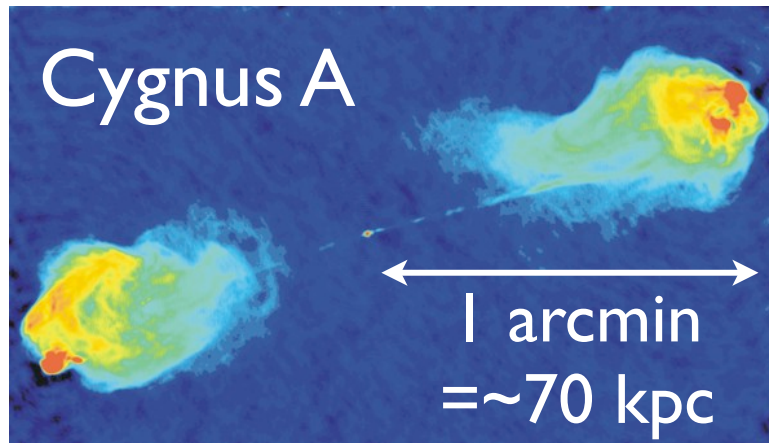
田中康之

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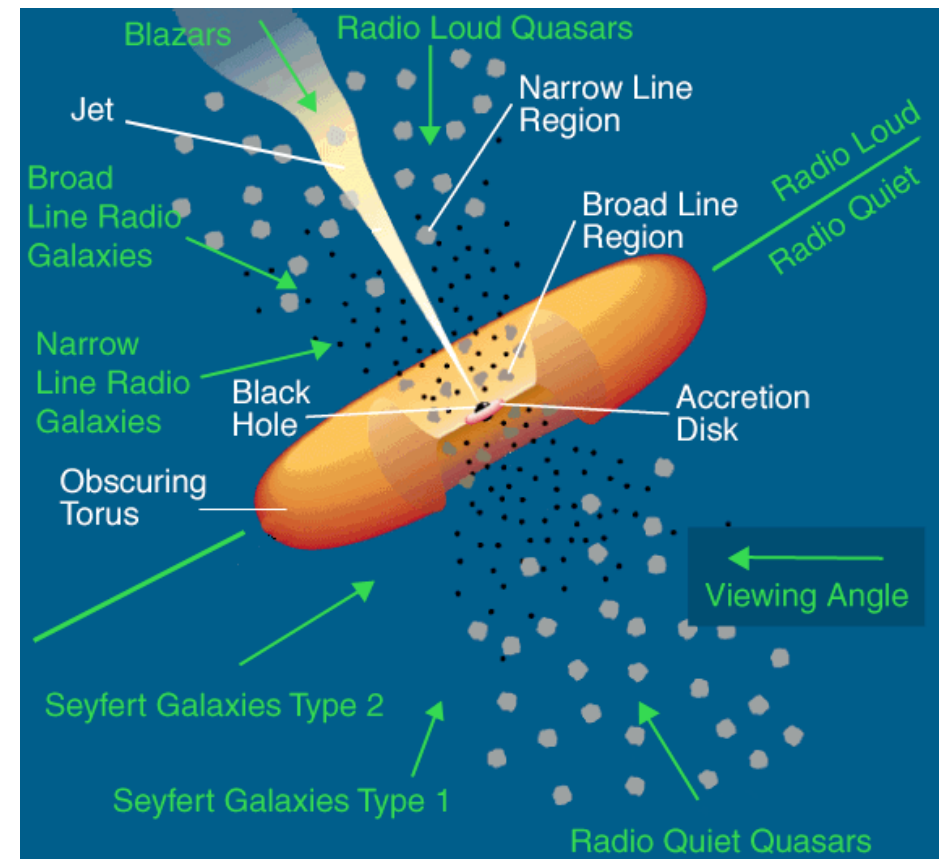
1. Fermi Gamma-ray Space Telescope
2. Recent Kanata results of “Fermi” flaring blazars
3. SGMAPとhigh-energy missionで切り拓くサイエンス
4. 硬X線サーベイカタログを用いた最近の系統的研究
5. Summary

ブレーザー天体

ジェットが我々の方向を向いているAGN

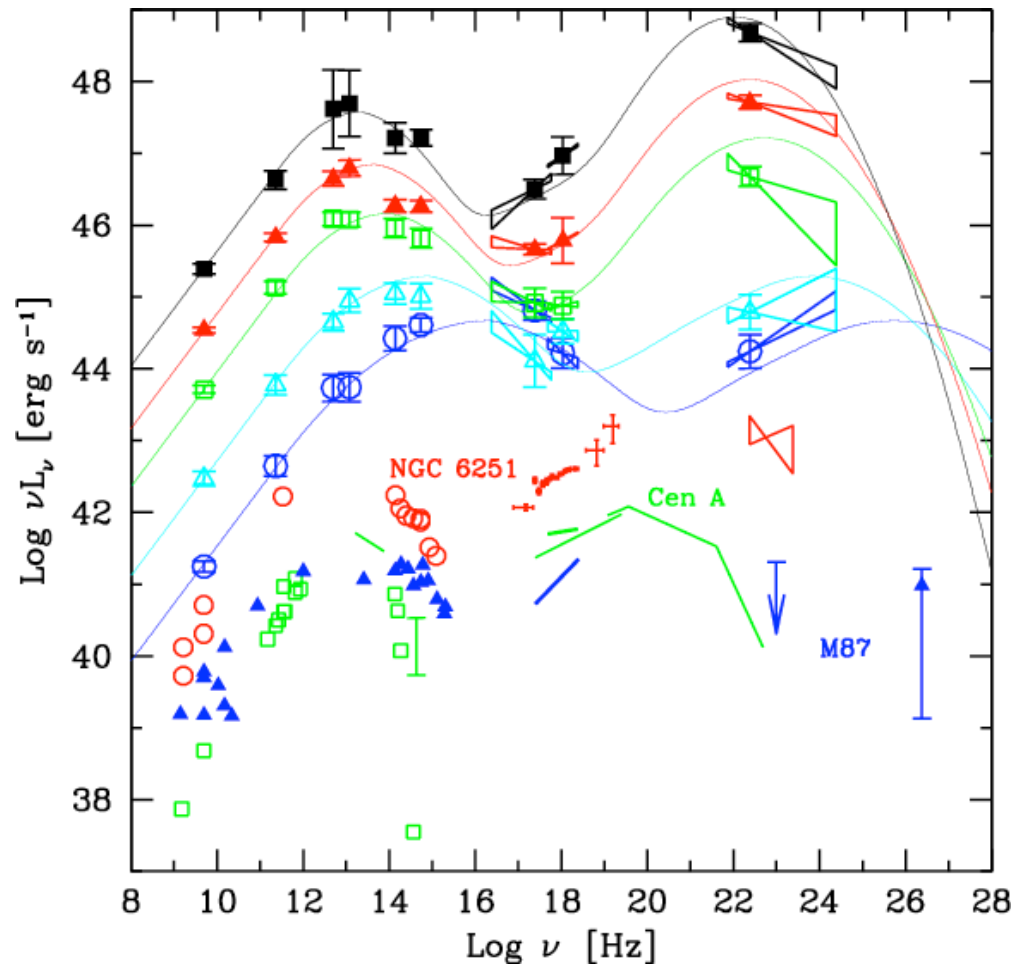


- **Quasi-Stellar Objects aka Quasars** ($\sim 10^{-7} \text{ Mpc}^{-3}$)
Radio-quiet or radio-loud quasars
- **BL Lacertae Objects** ($\sim 10^{-7} \text{ Mpc}^{-3}$)
- **Radio Galaxies** ($\sim 10^{-6} \text{ Mpc}^{-3}$)
Broad or narrow line radio galaxies
Fanaroff-Riley class I or II
...any many more...
- **Seyfert Galaxies** ($\sim 10^{-4} \text{ Mpc}^{-3}$)
Seyferts type 1 - 2
Narrow-Line Seyferts

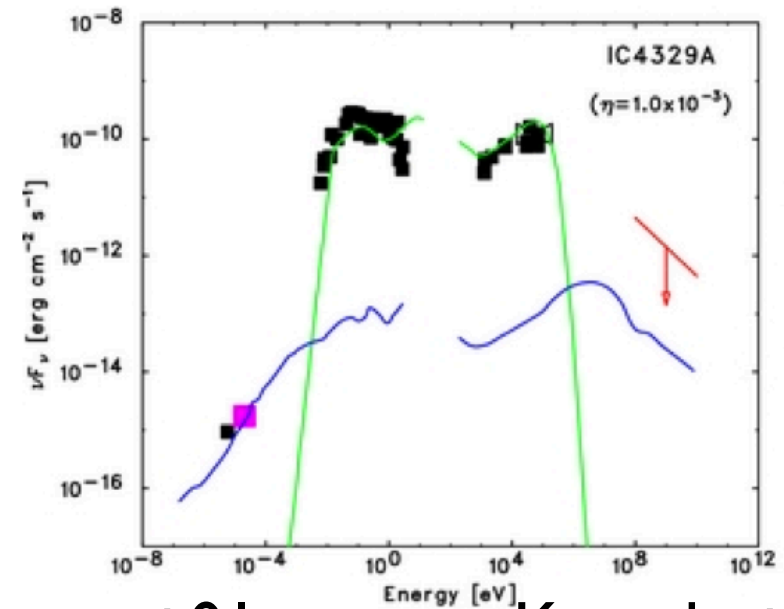


Unified model of AGN

Broadband spectrum of blazar



c.f. typical Seyfert SED

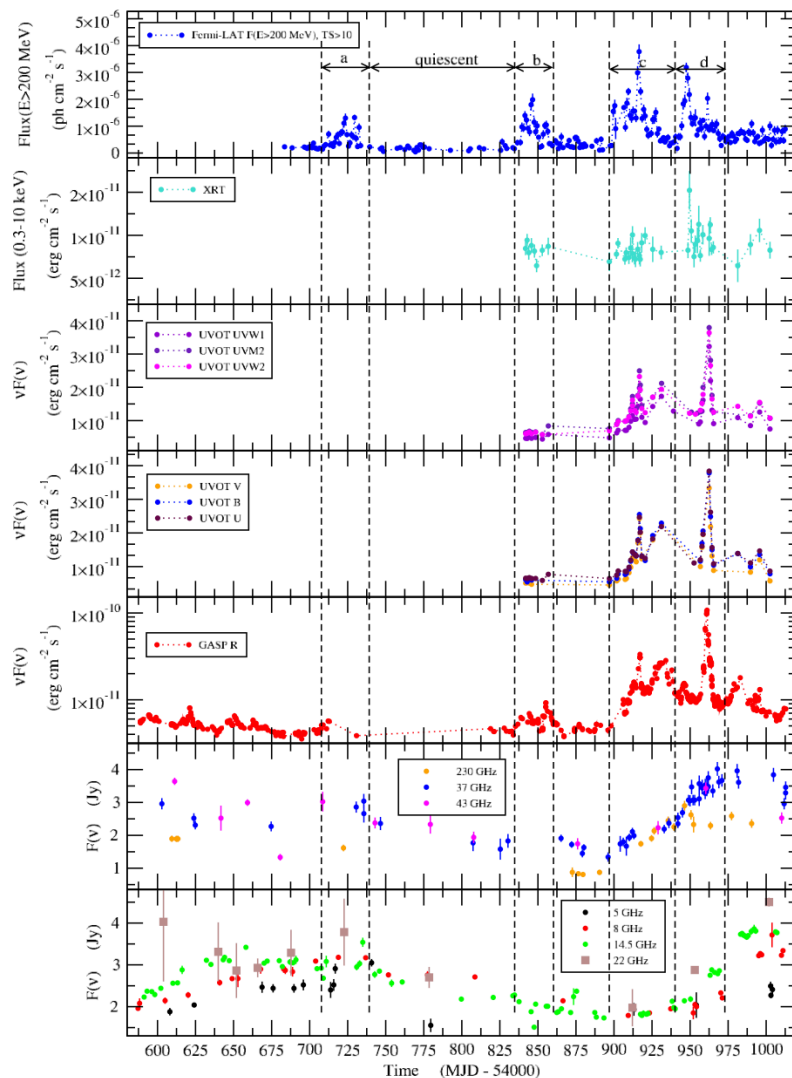


Donato+01

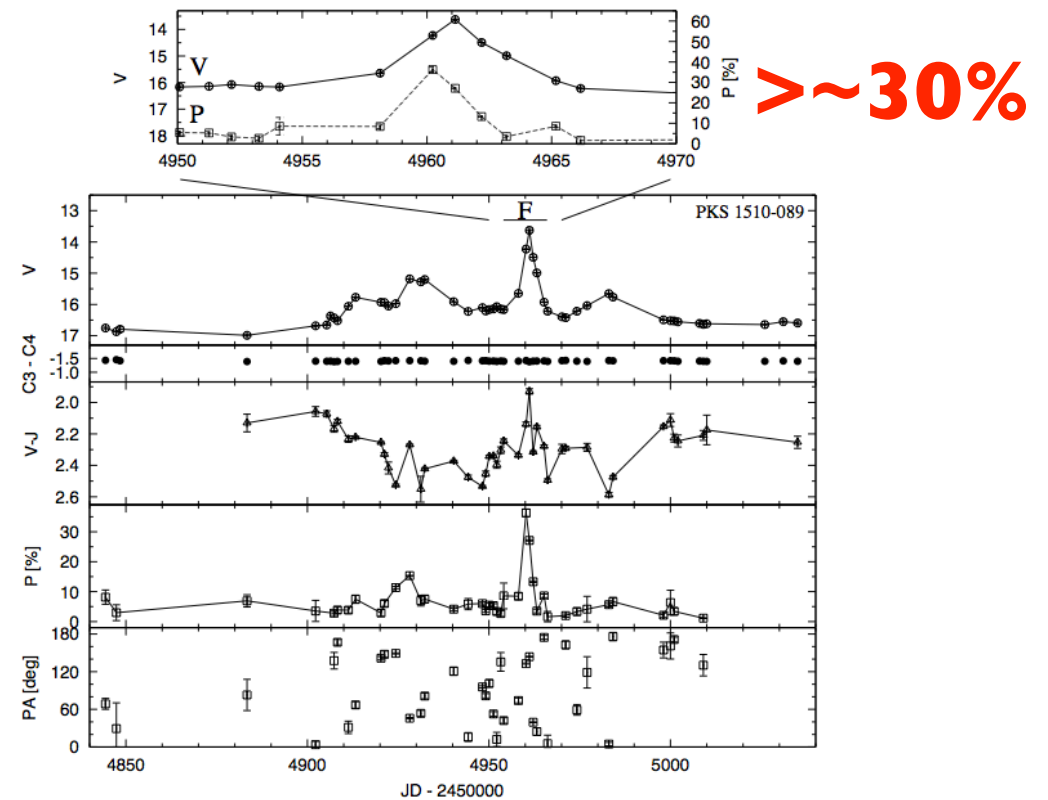
Kataoka+11

- Non-thermal emission dominates over the whole bands due to relativistic beaming effect
- One zone synchrotron and inverse compton model

Highly variable in all bands and strongly polarized optical emission



Famous blazar PKS 1510-089



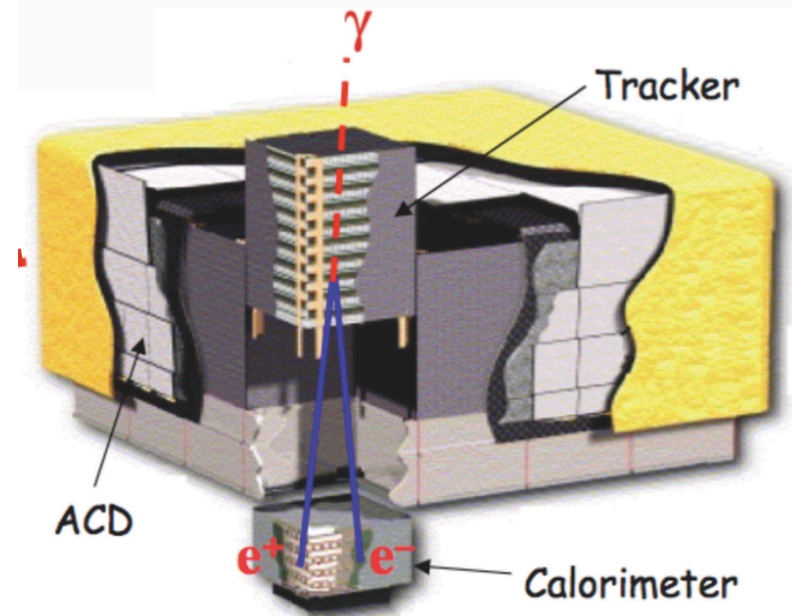
Abdo+10

Sasada+11

Fermi Gamma-ray Space Telescope



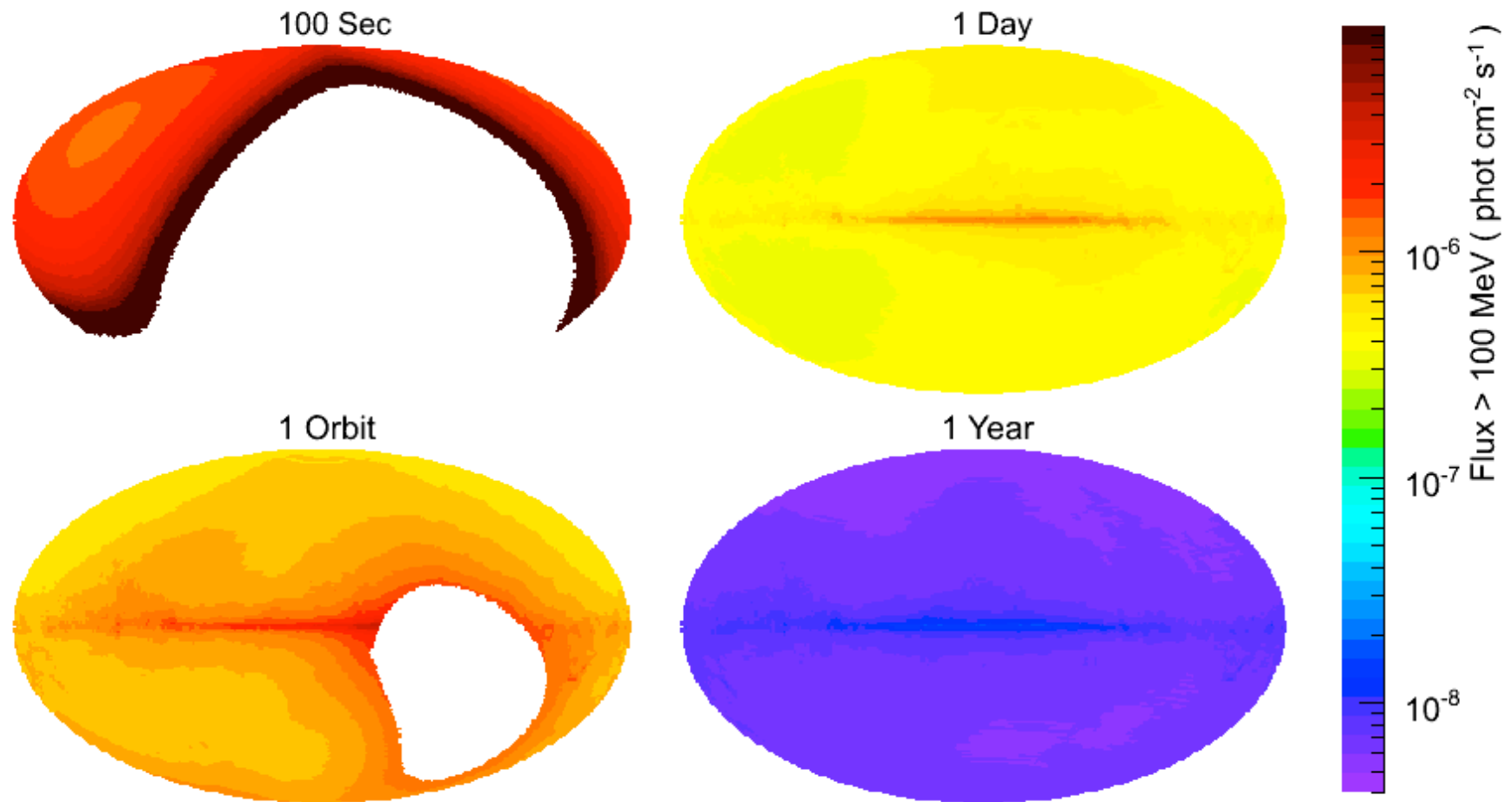
Large Area Telescope (LAT)
20 MeV-300 GeV



Gamma-ray Burst Monitor (GBM)
8 keV-40 MeV

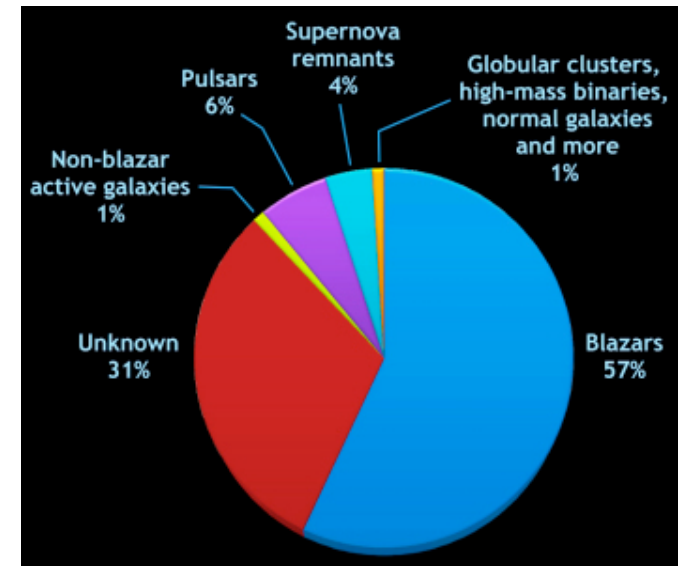
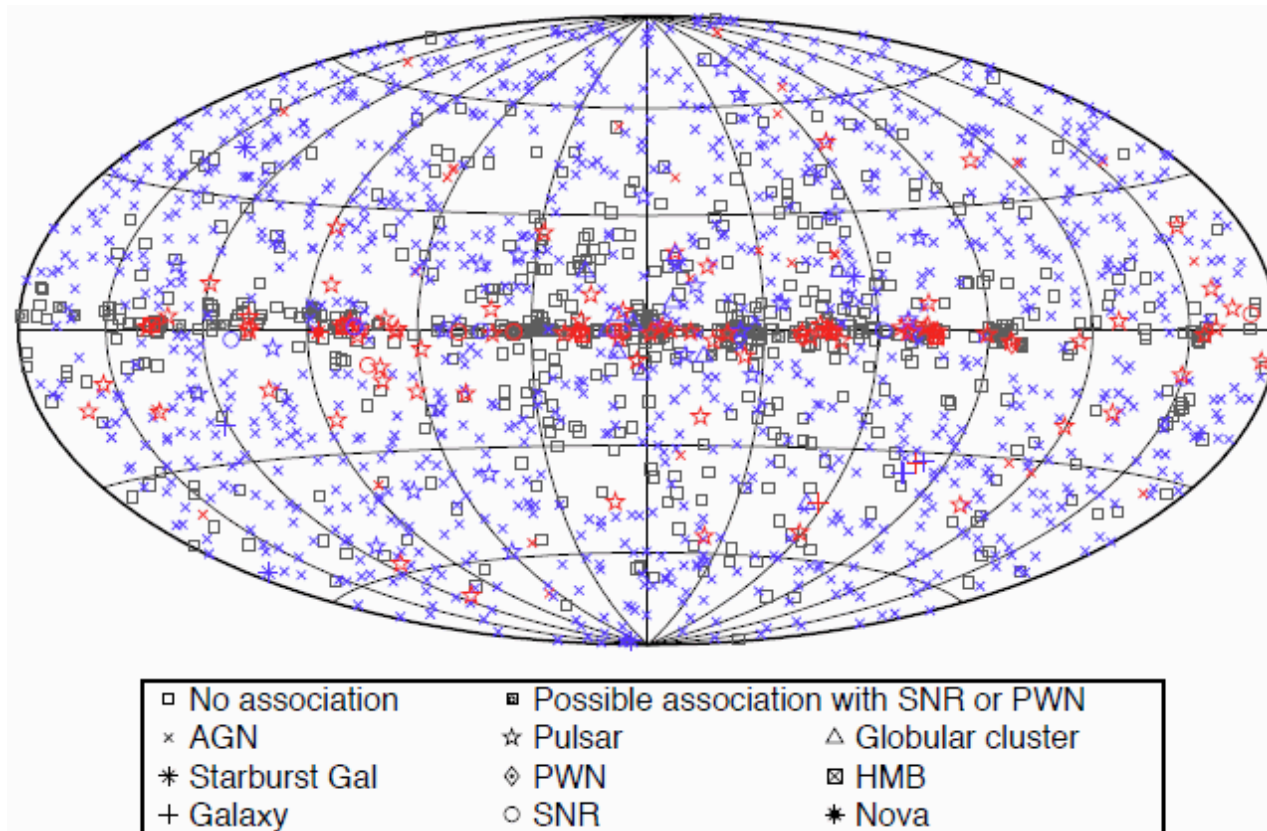
- 2008年6月打ち上げ
- 先代のCGRO/EGRETに比べて~30倍の感度向上

Survey instrument LAT



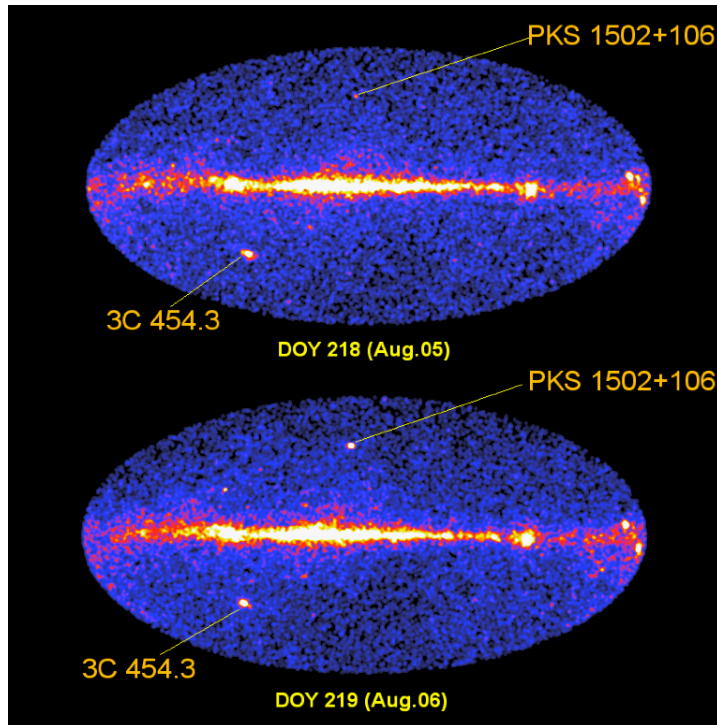
- 全天サーベイ観測を継続中 (約3時間で全天をスキャン)

LAT 2-year sources



- 2年積分のデータから1873天体が検出 (観測は5年目)
- 系外天体 ($b > 10$ deg)の多くはブレーザー
- 30% (約600天体)が未同定天体 (unID)

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
Credential Certification: Stefano Ciprini (stefano.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 $2 \times 10^{-6} \text{ photons cm}^{-2} \text{ s}^{-1}$.

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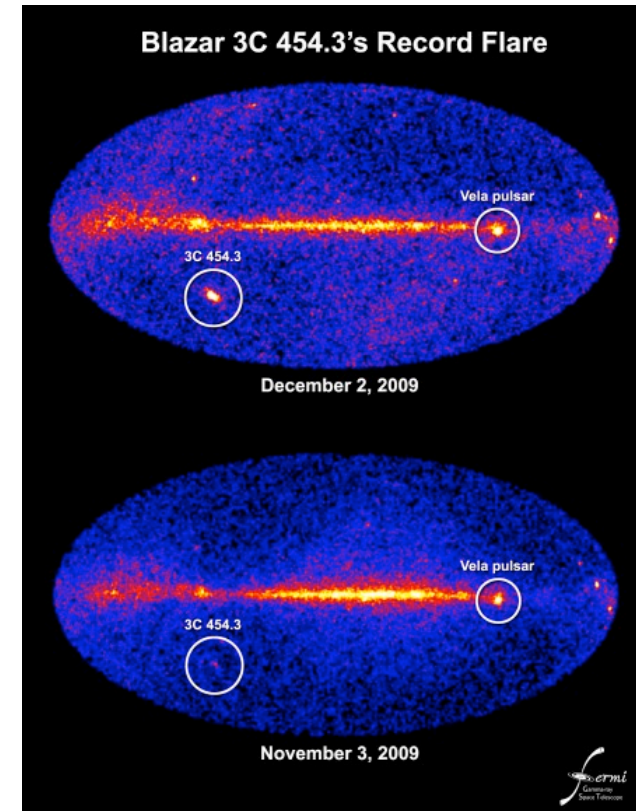
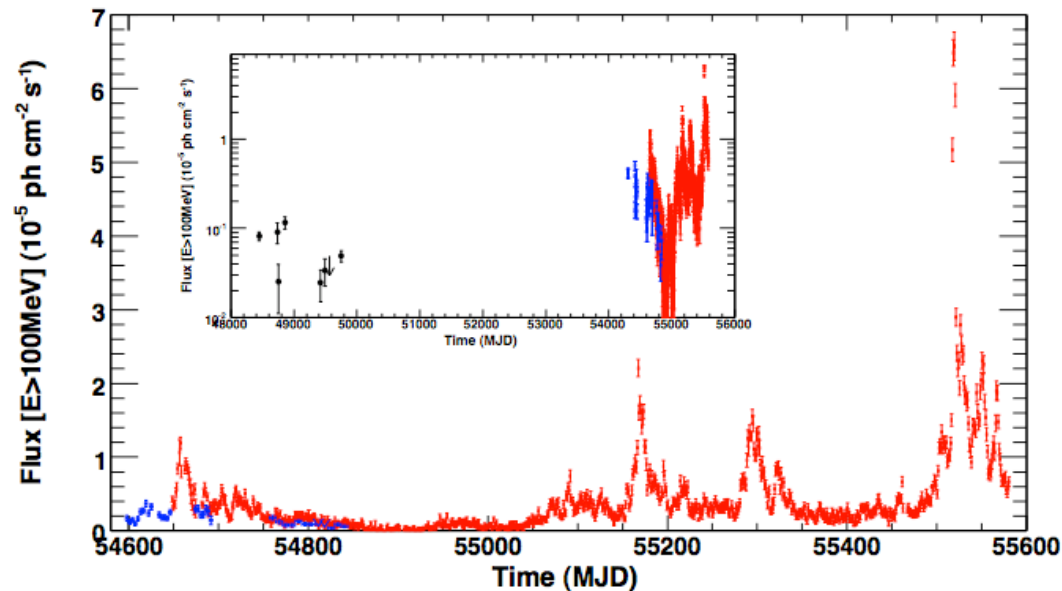
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Related	
1905	Fermi-LAT detection of renewed activity from the blazar PKS 1502+106
1661	Archival light curve for the flaring GLAST blazar PKS 1502+106
1650	GLAST LAT detection of a possible new gamma-ray flaring blazar: PKS 1502+106

- 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 ($\text{Flux} > 1.0 \times 10^{-6} \text{ photons/cm}^2/\text{s}$, $E > 100 \text{ MeV}$)

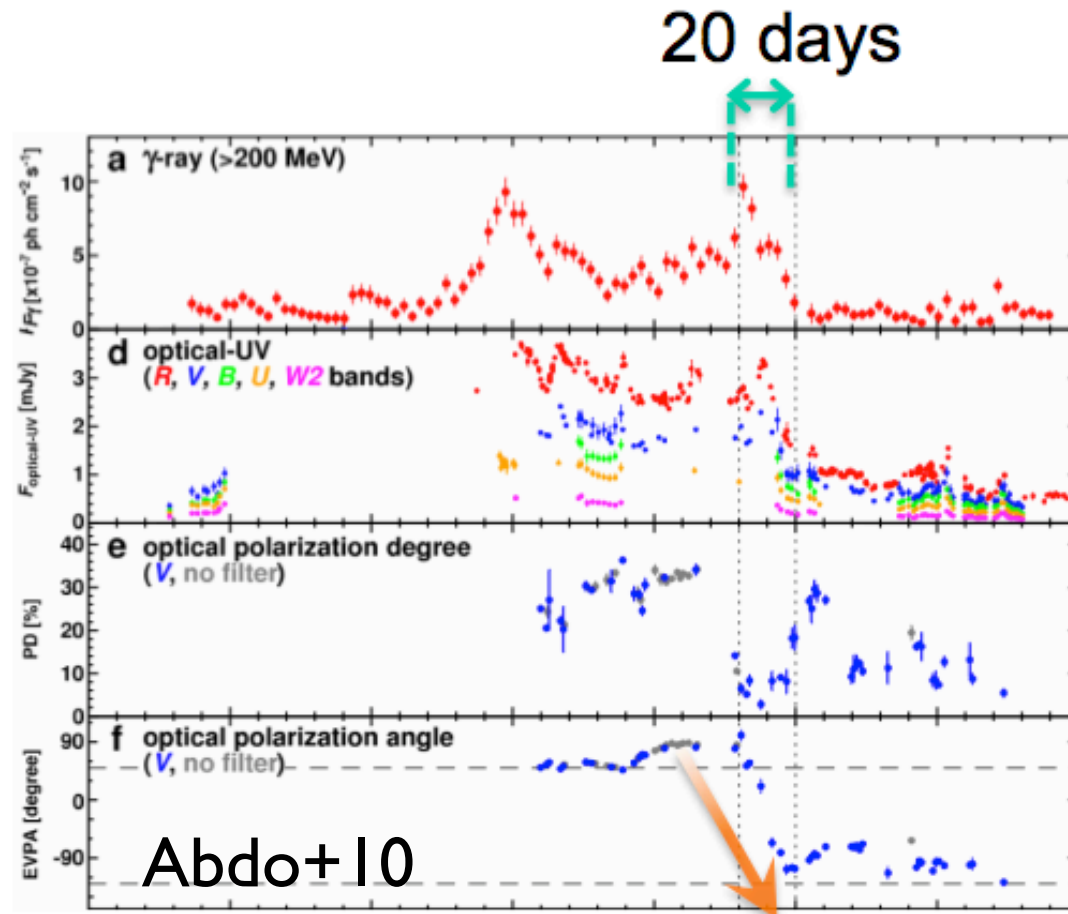
Blazar flare

3C 454.3 (Abdo+11)

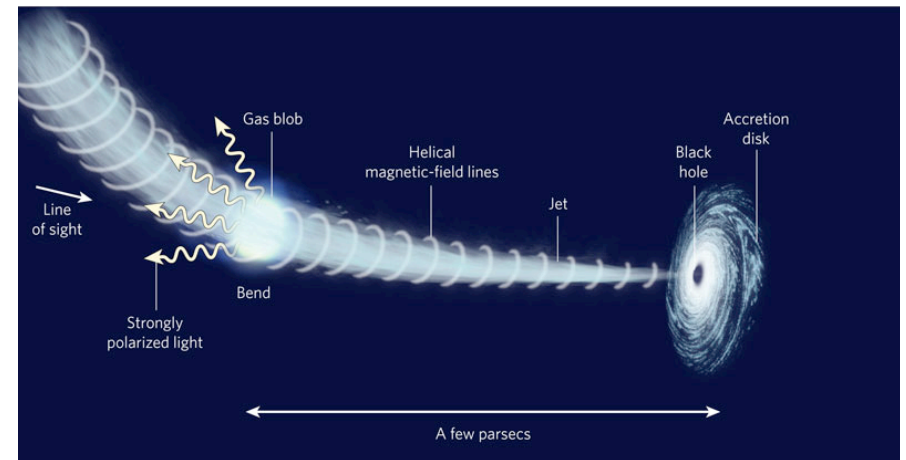


- Fermi-LATの全天無バイアスサーベイ観測により、flaring blazarが毎日のように検出されている
- かなたのquick polarimetric follow-upなど多波長フォローアップにより、ジェットの磁場構造の解明や放射位置の特定などが進んできた

3C 279 flare in 2009



Gamma-ray flare with optical polarization angle swing
 $\rightarrow$ Co-spatiality of optical and gamma-ray emissions



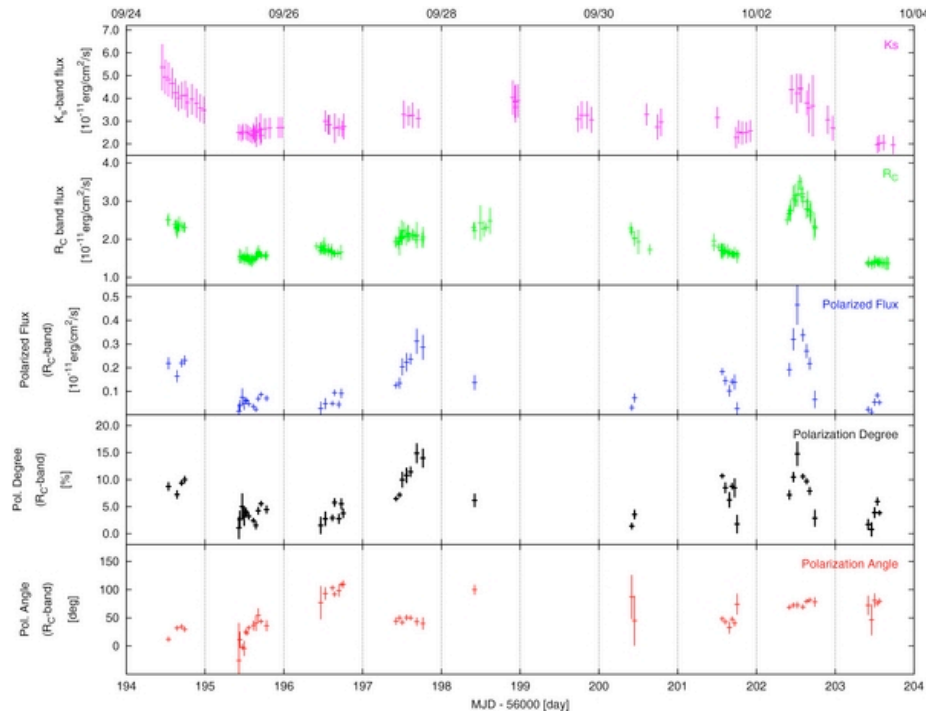
$$r_{\text{event}} \geq \Delta r_{\text{event}} \sim 10^{19} (\Delta t_{\text{event}} / 20 \text{ days}) (\Gamma_{\text{jet}} / 15)^2 \text{ cm}$$

Location of emission zone from BH

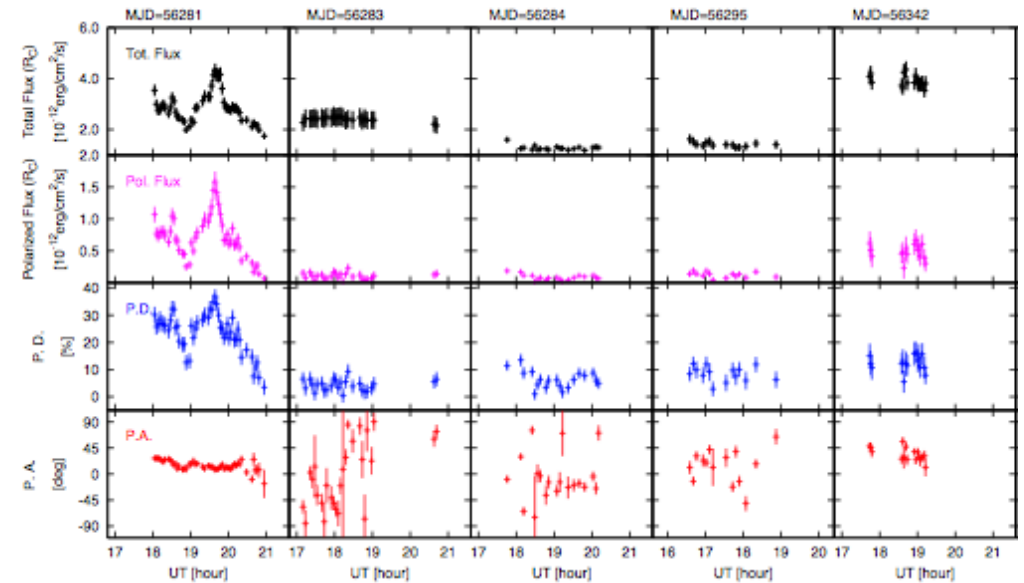
Propagation distance of emitting blob

Emission zone locates pc scale from BH

Emergence of a compact emission region with highly-ordered magnetic field



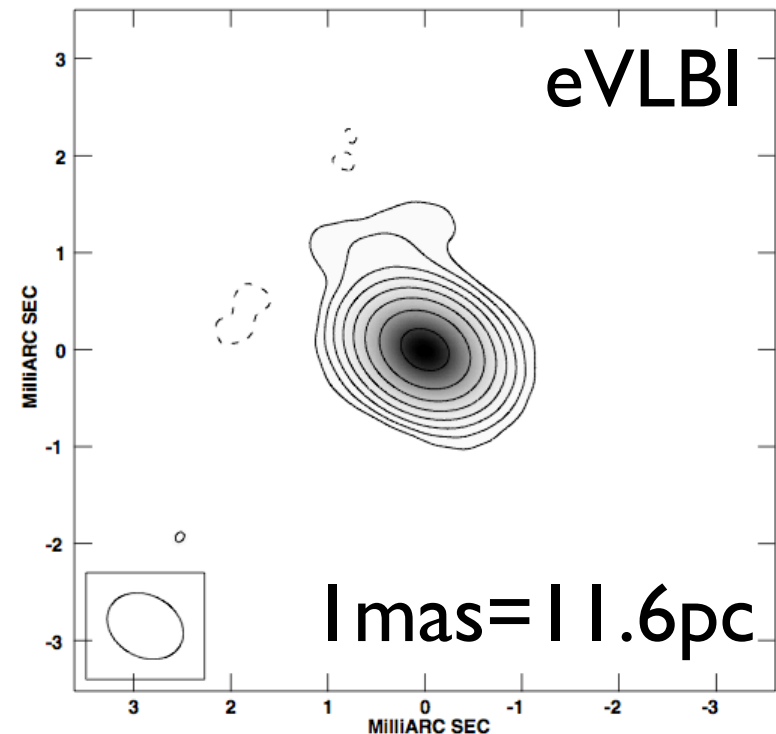
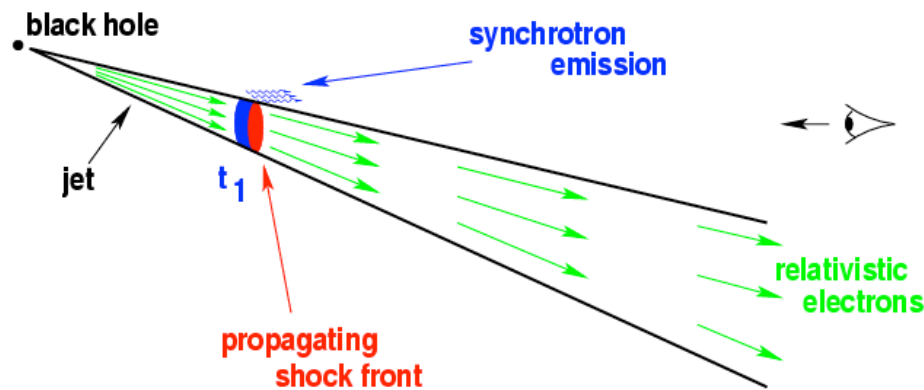
Itoh+13



Itoh+submitted

- Fermi flaring blazarをかなたでフォローアップ
- Total fluxとPDが良く相関して変動

Shock-in-jet model can reasonably account for the observed PA direction etc



Giroletti+12

Fig. 2. Total intensity contours for J0948+0022 at epoch 2, with levels traced at $(-1, 1, 2, 4, \dots) \times 1.5 \text{ mJy beam}^{-1}$. The central pixel corresponds to RA = $09^{\text{h}}48^{\text{m}}57.320^{\text{s}}$, Dec = $+0^{\circ}22'25.560''$.

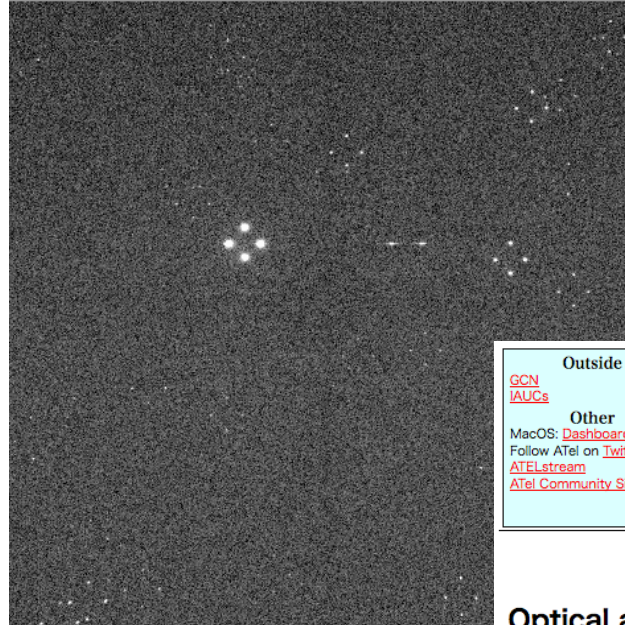
- 数10GHzの偏波観測が可能になりKanataや新しい望遠鏡で共同研究を。

Kanata+new 2m-telescope

	Kanata	2m-telescope
Relatively bright blazars	Optical spectroscopy, Fast photometry	B, V, R, I polarimetry
Galactic sources Faint blazars	J, H, K polarimetry	B, V, R, I polarimetry

- 多様な観測モードで新しいサイエンスを切り拓くチャンスが大きく広がる
- フェルミが稼働中の今がまさにチャンス

Robopol



First light image

Outside
GCN
IAUCs
Other
MacOS: [Dashboard Widget](#)
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Present Time: 17 Jul 2013; 13:33 UT

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Optical and gamma-ray brightening of blazar OC 457

ATel #4779; [D. Blinov](#) (*St. Petersburg Univ.*), [I. Myserlis](#), [E. Angelakis](#) (*MPIfR*),
[O. King](#) (*Caltech*), [V. Pavlidou](#) (*Univ. of Crete*) for the *RoboPol* Collaboration
on 2 Feb 2013; 16:08 UT

Credential Certification: [Oliver King](#) ([ogk@astro.caltech.edu](#))

Subjects: Optical, Gamma Ray, AGN, Black Hole, Blazar

The RoboPol Collaboration is currently performing a preliminary photopolarimetric survey of gamma-ray bright blazars in the frame of the RoboPol project. We report that blazar OC 457 (a.k.a. S4 0133+47) is now in a flaring state. Preliminary estimated R magnitude was 14.9 on 2013 Jan. 24.70 UT and R=15.0 on Jan. 26.77 UT, which is significantly brighter than previously reported R=19.25 (Healey et al., 2008). R-band polarization is also high PD=16.4 $\pm$ 0.6%. Analysis of publicly available data of the LAT onboard of the Fermi gamma-ray observatory also reveals a brightening at gamma-ray wavelengths. Weekly averaged gamma-ray flux reached 2.5E-7 ph cm⁻²s⁻¹ (E>100MeV) on Jan. 24, about 6 times greater than the average flux reported in the second Fermi LAT catalog (2FGL). Multifrequency observations of the blazar are encouraged.

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- 1.3 m telescope in Greece (Crete)
- First light on May 16, 2013

Synergy with SGD onboard Astro-H (2015年打ち上げ予定)



SGD Concept



- ❖ 狭視野Compton Camera技術により、60-600keVでバックグラウンドを極限まで下げて感度を上げる

- 狭視野 Compton camera

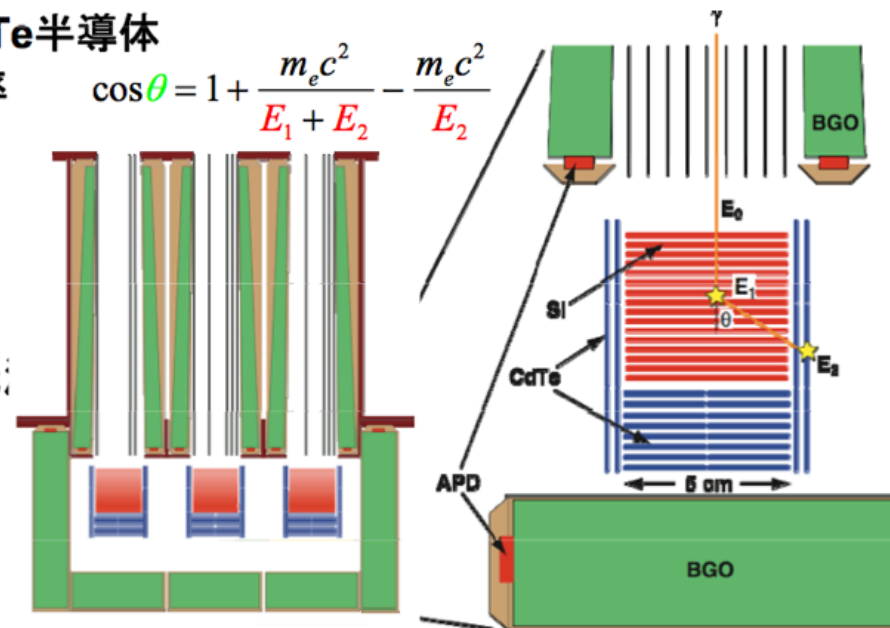
- ◆ Compton 再構成によるイベント選別により、バックグラウンド低減
- ◆ BGO Active shieldで囲んで、バックグラウンド低減(すざくHXDで実証)

- 多層半導体 Compton camera

- ◆ 散乱体のSi、吸収体のCdTe半導体
- ◆ 多層化により高い検出効率
- ◆ 角度分解能向上

- ❖ Extra success

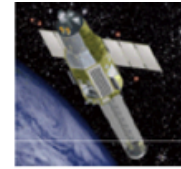
- 明るい天体のガンマ線偏光



Taken from
Fukazawa's slide



観測性能、偏光観測



Crab

スペクトル

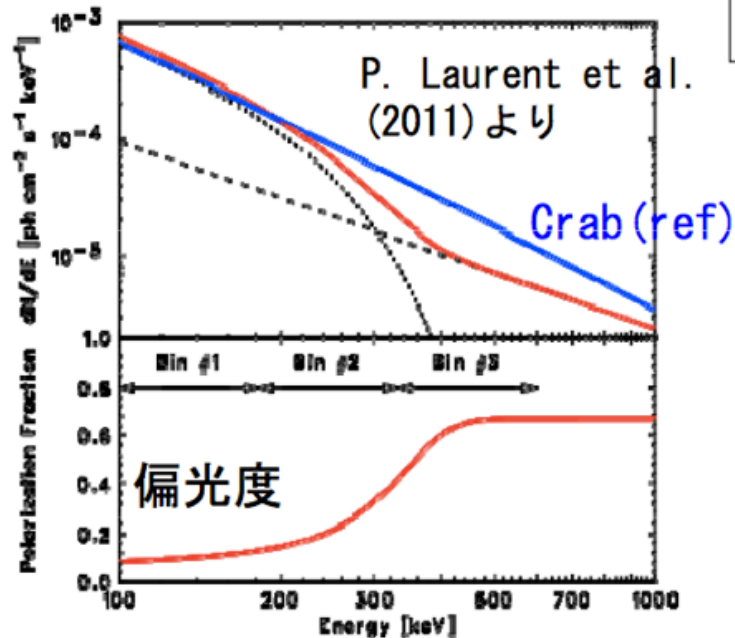
$$\frac{dN}{dE} = 3.87 \left(\frac{E}{1 \text{ keV}} \right)^{-[1.79+0.134 \ln(E/20 \text{ keV})]}$$

Jourdain & Roques (2009)

偏光度: 50% in all energy

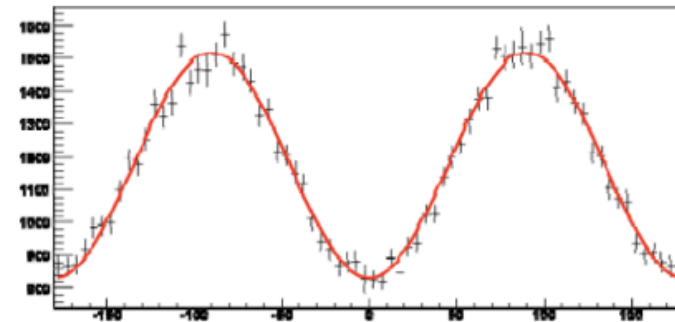
観測simulation

Cygnus X-1



Crab, 80-300 keV, 100 ks

Azimuth Distribution (Si-CdTe, FI Cut)

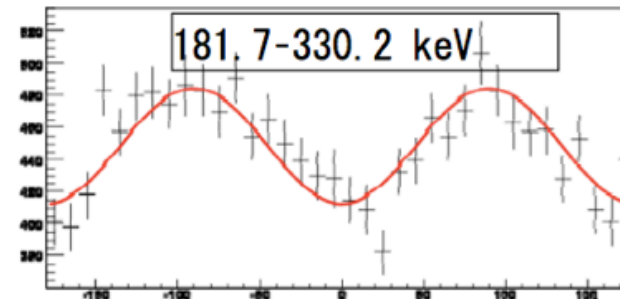


significance: 58 σ

観測される Modulation Profile

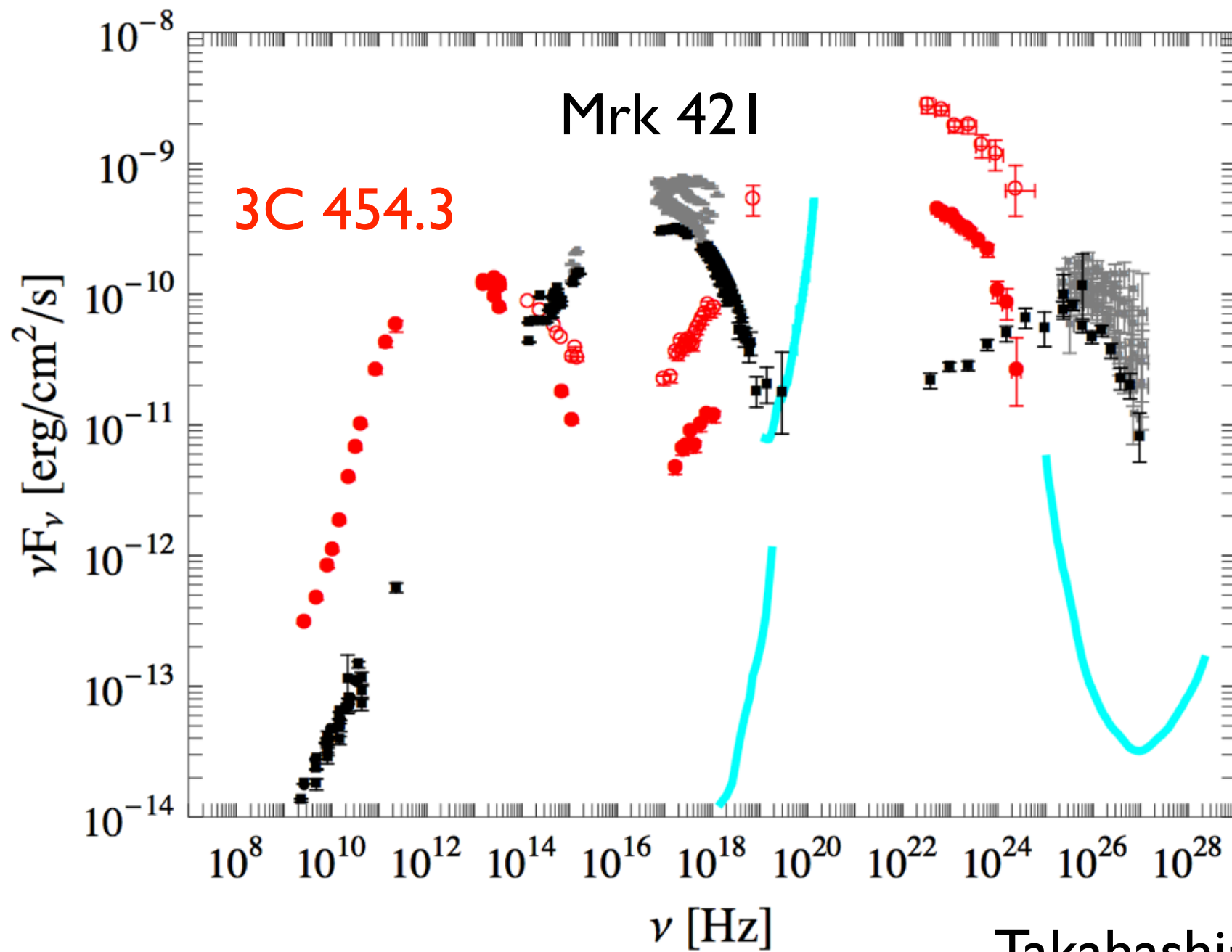
300 ksec観測

Azimuth Distribution (Si-CdTe, FI Cut)



可視との同時偏光観測が実現

Taken from
Fukazawa's slide



Takahashi+12

Synergy with soft gamma-ray survey “CAST” mission

SGD is focused on the lower energy band around 100 keV.
On the other hand,

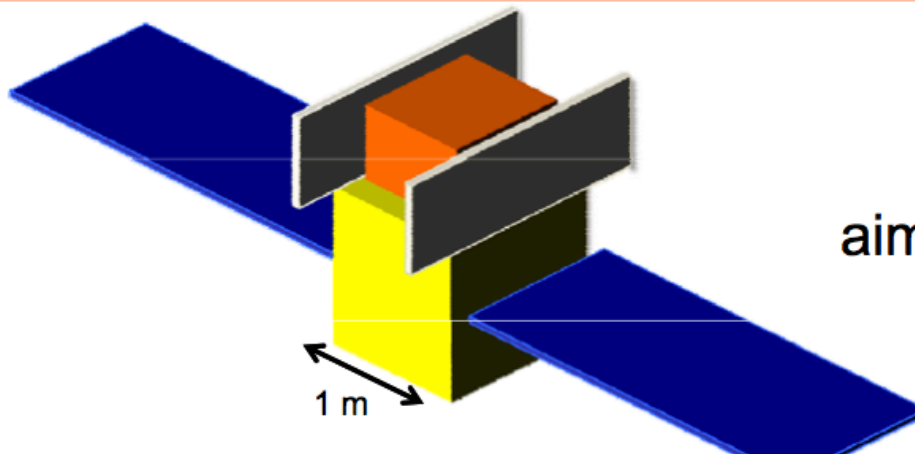
sub-MeV & MeV all-sky survey with:

Si/CdTe larger Compton Camera arrays

Enhance the sensitivity above 200 keV

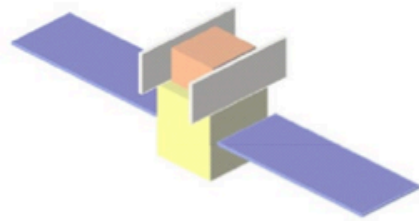
Focus to 0.2-2 MeV wide FOV (e.g. COMPTEL 1-30 MeV)]

Dedicated small satellite or ISS (500 kg against CGRO 15 t)



aim launch 2018-2020

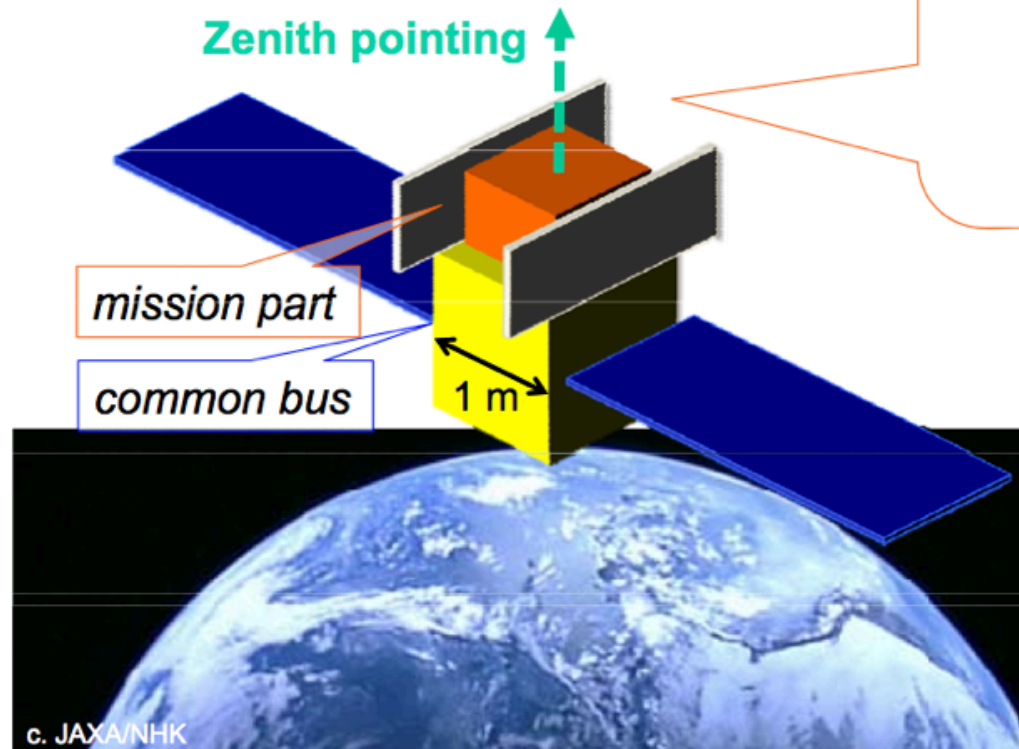
Taken from Fukazawa's slide



CAST satellite design

- Orbit: 500 km LEO, incl. 5-30 deg
- total mass = 500 kg

3x3 Compton Cameras (CCs)
One CC is larger than SGD-CC.



Wide-FOV
>1/10 of all sky
Localization
< 0.5 deg

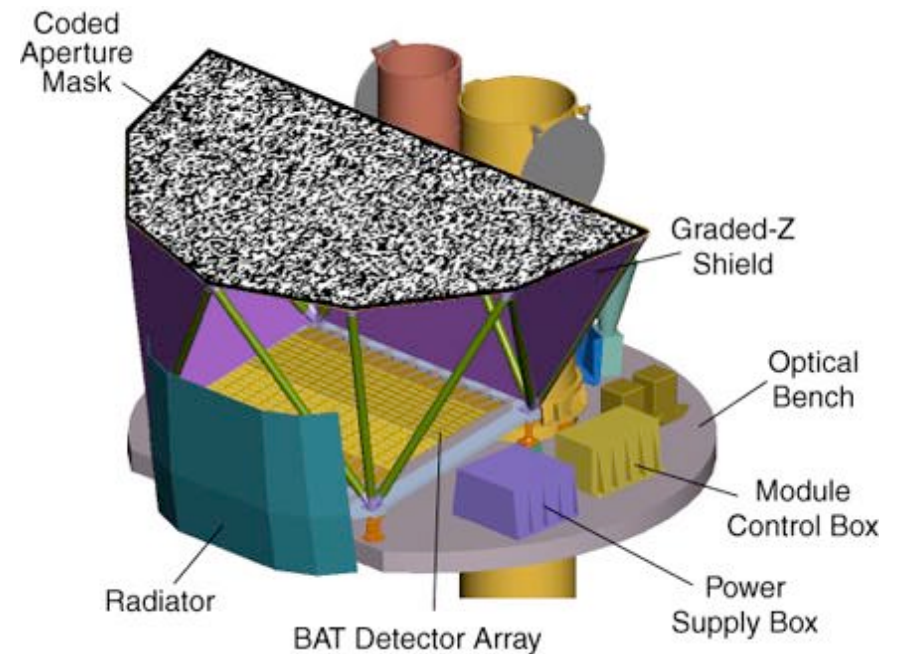
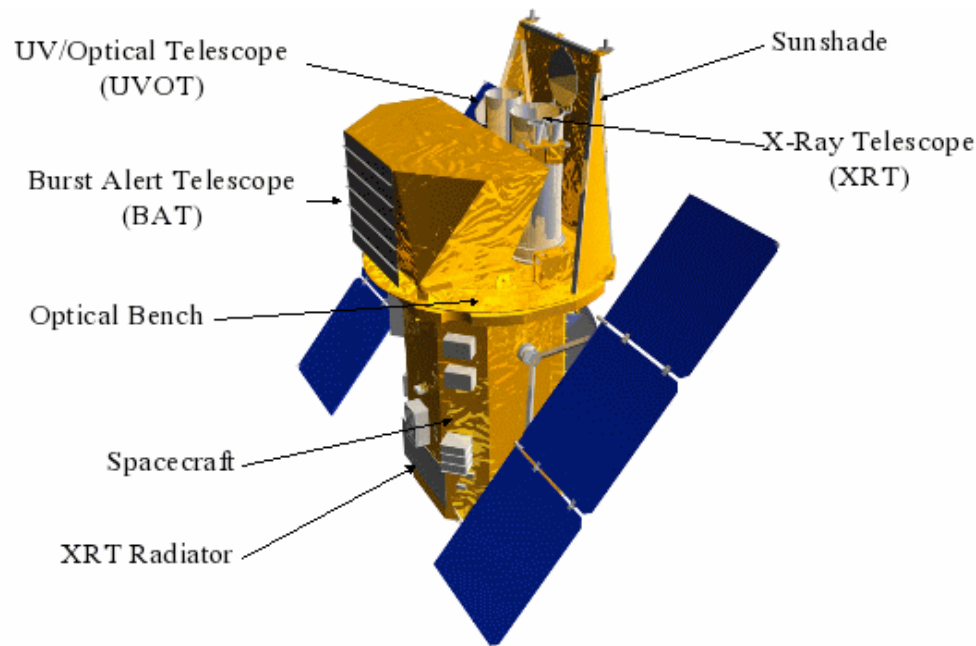
Taken from Fukazawa's slide

全天サーベイ衛星

- Fermi-LAT survey in MeV/GeV band
- Swift-BAT hard X-ray survey
- MAXI (all-sky X-ray monitor)
- eROSITA (2014~? by MPI and Russia)

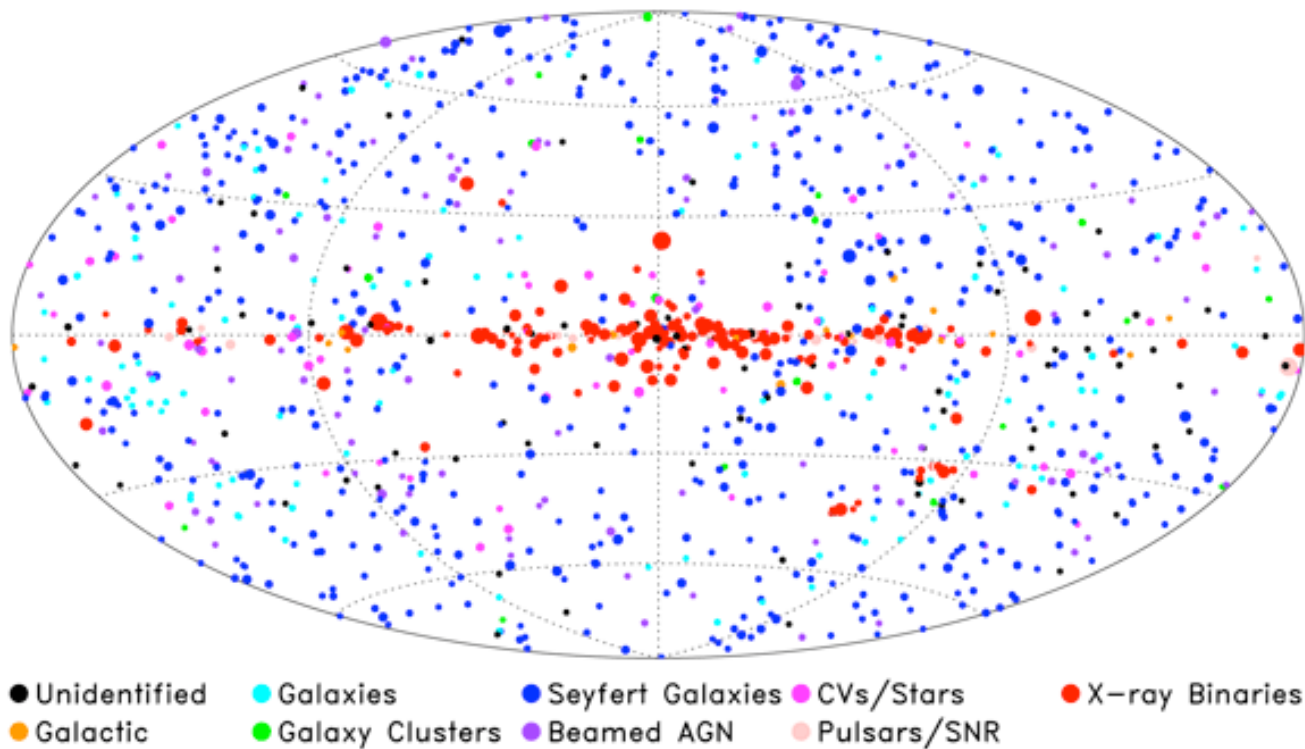
Swift-BAT hard X-ray survey since 2005

FoV: 2 str



- Unbiased hard X-ray survey; 14-195 keV range
- Down to $\sim 10^{-11}$ erg/cm²/s over 90% of the sky

70-months hard X-ray catalog



Class	Source Type	# in Catalog
0	Unknown	65
1	Galactic	23
2	Galax	111
3	Galaxy Cluster	19
4	Seyfert I (Sy 1.0-1.5)	292
5	Seyfert II (Sy 1.7-2.0)	261
6	Other AGN	23
7	Blazar/BI Lac	49
8	QSO	86
9	Cataclysmic Variable Star (CV)	55
10	Pulsar	20
11	Supernova Remnant (SNR)	6
12	Star	14
13	High Mass X-ray Binary (HMXB)	85
14	Low Mass X-ray Binary (LMXB)	84
15	Other X-ray Binary (XRB)	17
Total		1210

- 全部で1210天体
- 近傍セイファート銀河が90%を占める

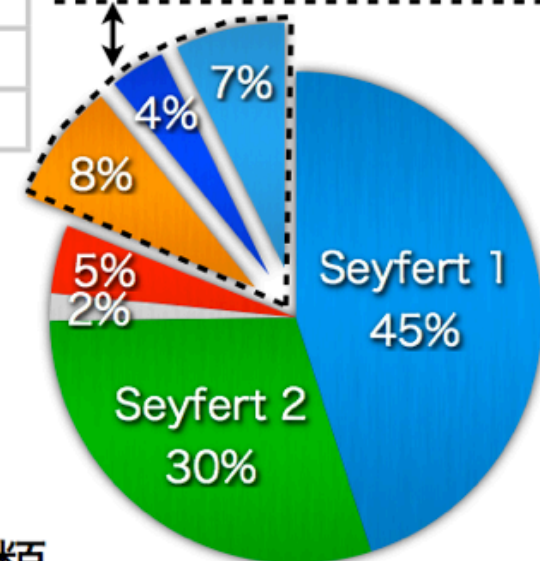
(1) 硬X線-赤外線光度相関

・カタログ概要

	Swift/BAT 22-month Catalog (Tueller et al. 2010)	AKARI Point Source Catalog (PSC) (Ishihara et al. 2010, Yamamura et al. 2010) Infrared Camera (IRC)
観測帯域	14 - 195 keV	9 / 18 μm
検出限界	$2.3 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$	0.05 / 0.09 Jy
総天体数	461 (AGN : 268)	870,973
観測時期	2004/12 - 2006/10	2006/5 - 2007/8
角分解能	1'	7"

IRC 9 μm (111天体)

- Seyfert 1
- Seyfert 2
- LINER
- Blazar
- 1型電波銀河
- 2型電波銀河
- Compton-thick AGN



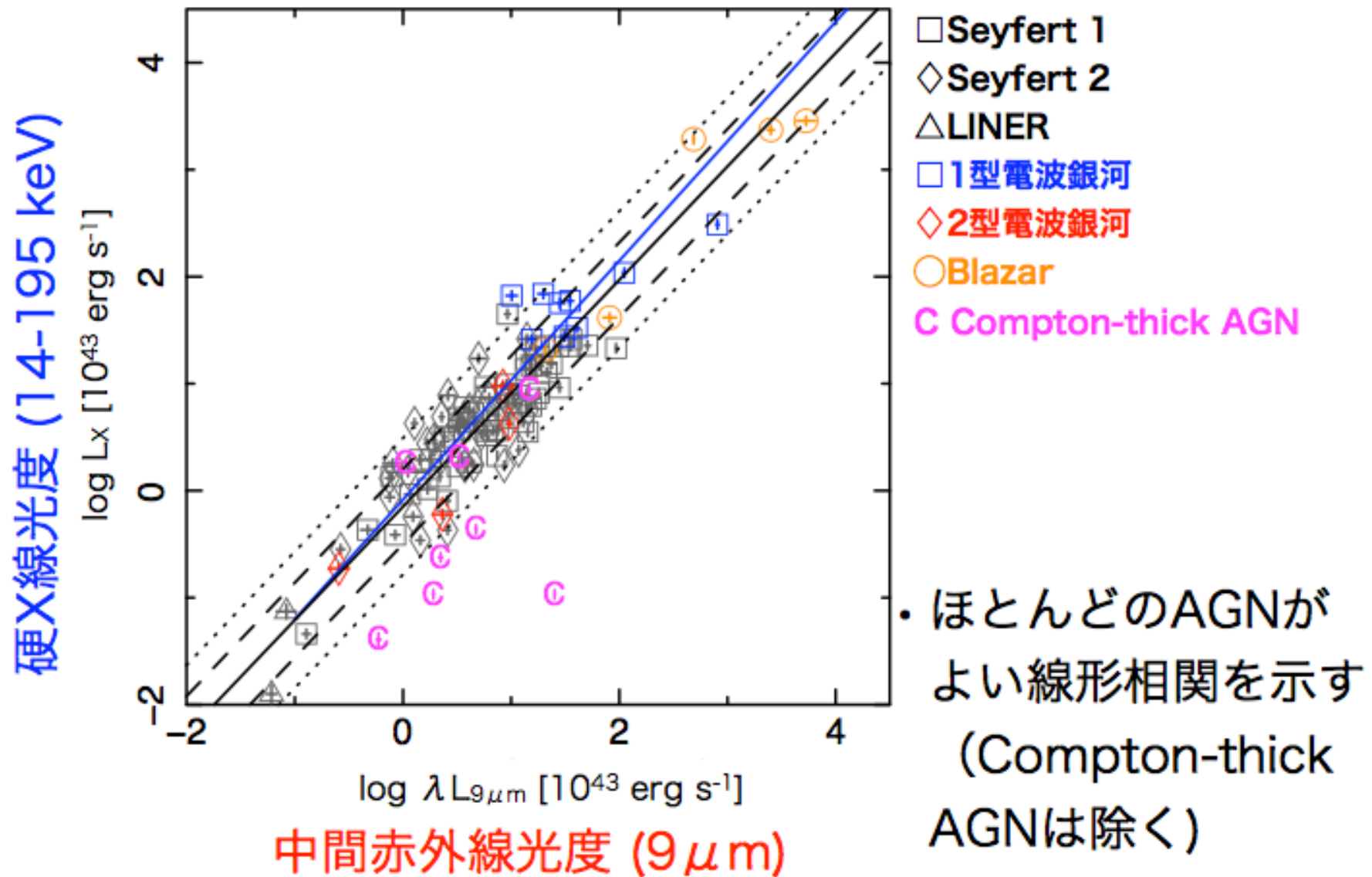
・AKARI/PSC

- ・ 半径10"以内 (位置不定性 3σ)
- ・ フラックス決定精度：高

→ 158 (61.2%、 $z_{\text{med}} = 0.022$)

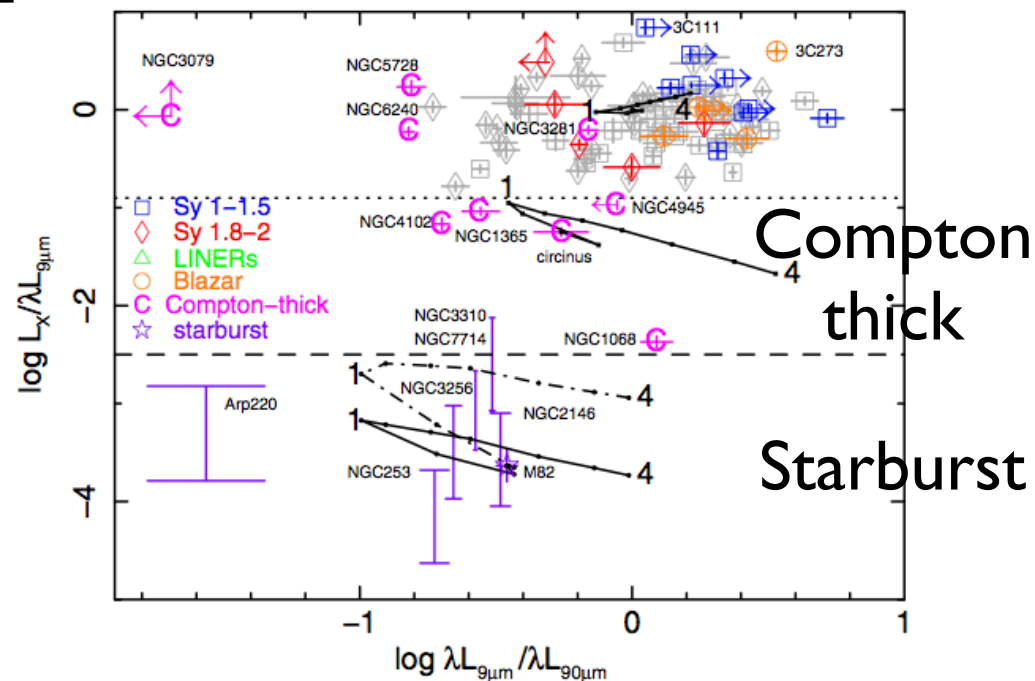
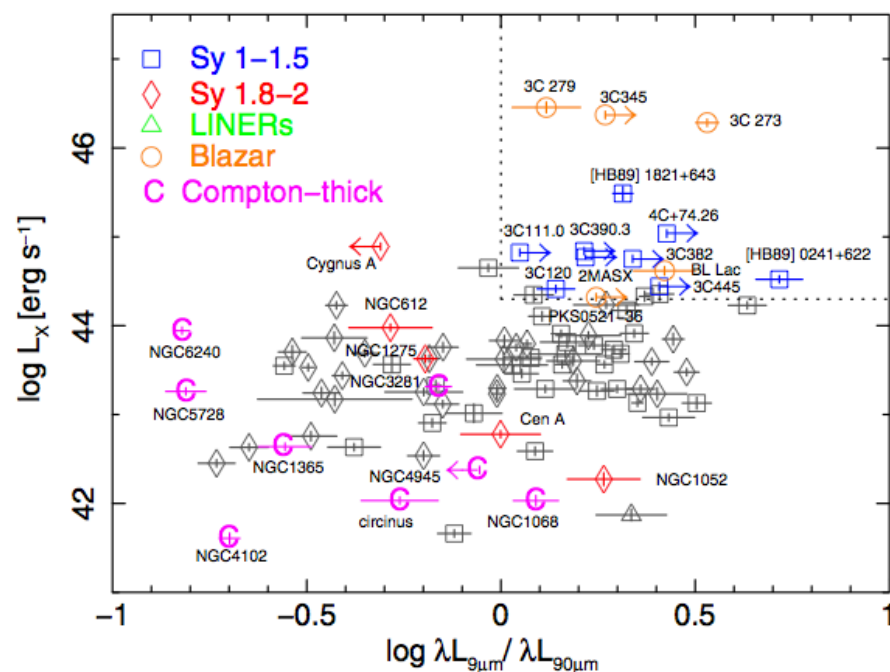
- ・ 電波銀河、Compton-thick AGNを再分類

(1) 硬X線-赤外線光度相関



New source classification scheme

Radio-loud

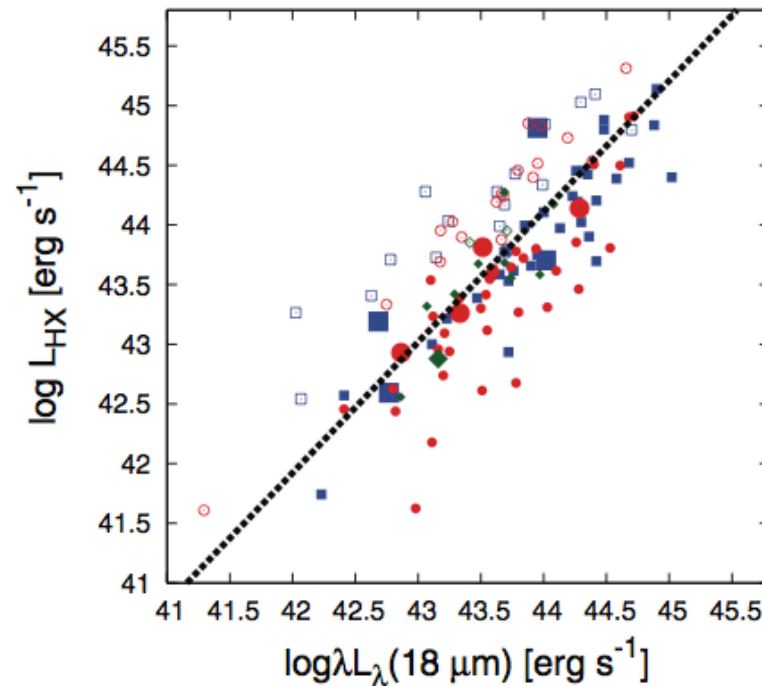
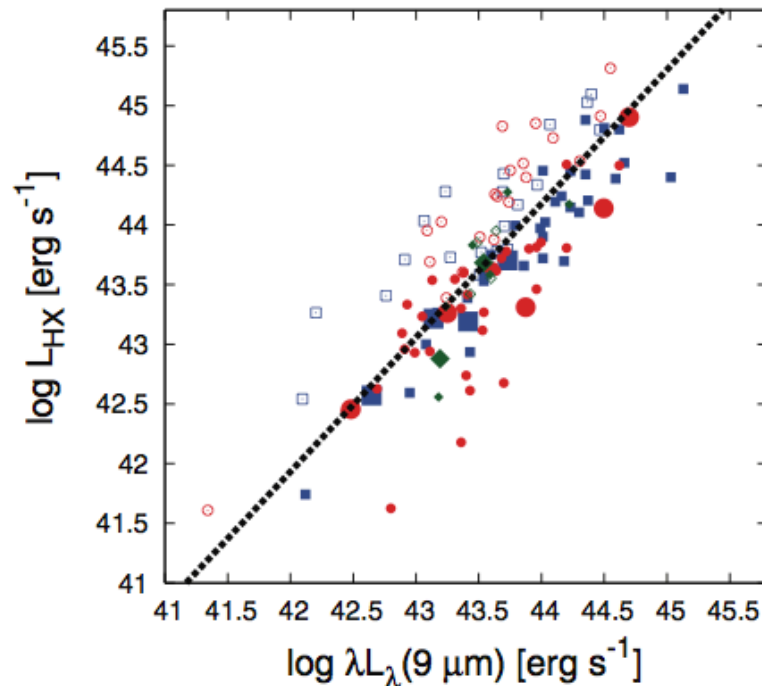


Matsuta+12

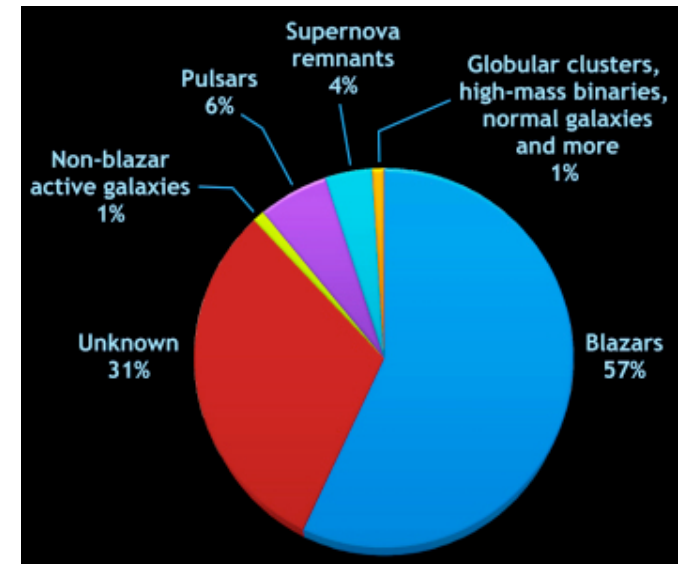
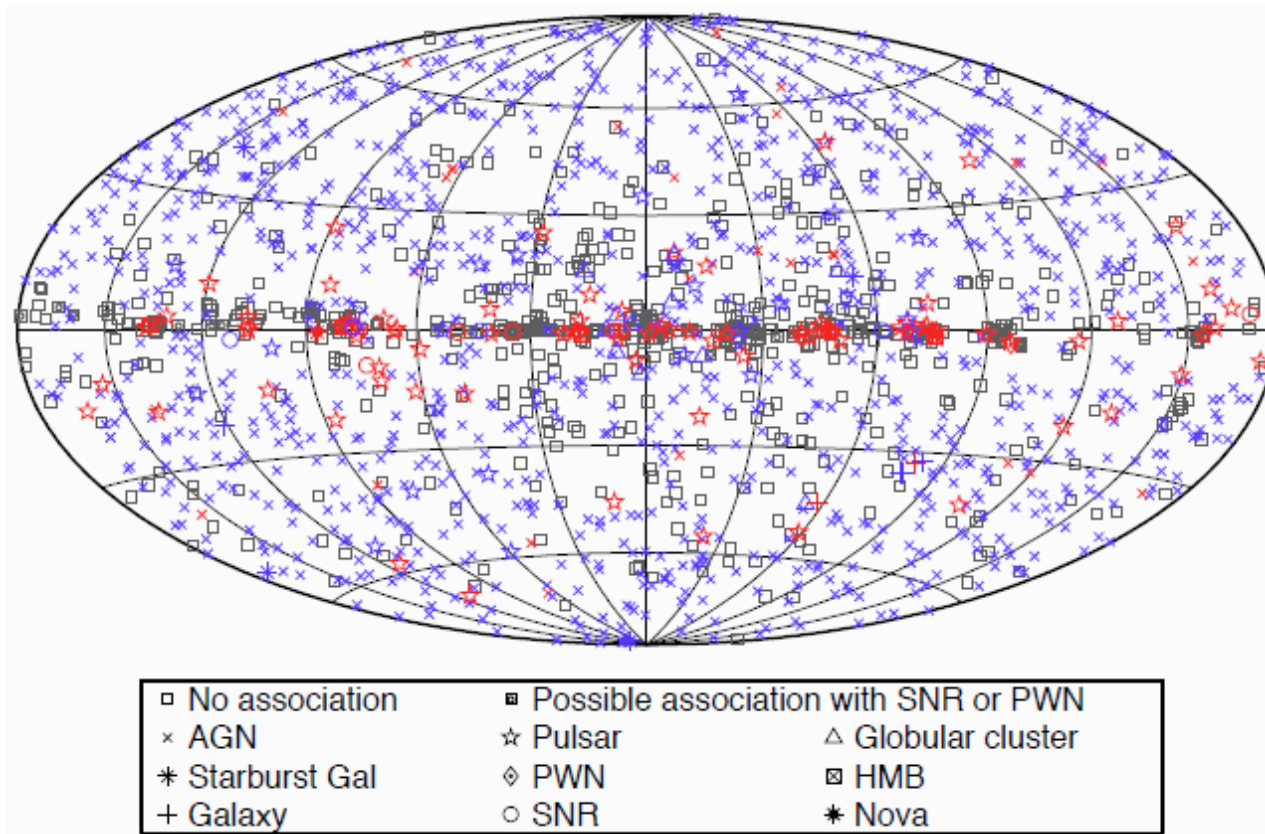
- 158 AGN including blazars
- New indicator to identify CT and starburst galaxies

Swift-BAT and Akari/IRAS/WISE

- BATカタログ (hard X-ray sources)に含まれる135 non-blazar AGNについて、Akari/IRAS/WISEカタログのMIR counterpartをサーチ



Revealing Fermi-LAT unIDs



- 30% (576天体)が未同定天体 (unID)
- 電波フォローアップによるidentificationが始まっている
- 偏光カタログデータが威力を発揮するだろう

Summary

- 現状では、フェルミ衛星がブレーザー研究をリードしており、Fermi flaring blazarの可視偏光フォローアップ観測はジェット構造、磁場構造、粒子加速機構の解明に重要な貢献をしている
- Kanataと新しい2m望遠鏡によって観測モードのオプションは大幅に増えるので、新しいサイエンスを切り拓くチャンスが大きく増えると期待している
- Astro-H/SGDやCAST missionによってX線偏光観測も可能になり、可視X線同時観測から新しいサイエンスが産まれるだろう