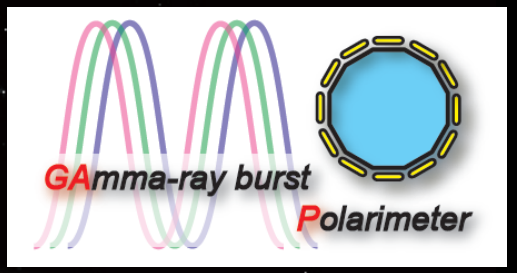
Study of emission mechanism of Gamma-Ray Bursts by the gamma-ray polarization with IKAROS-GAP



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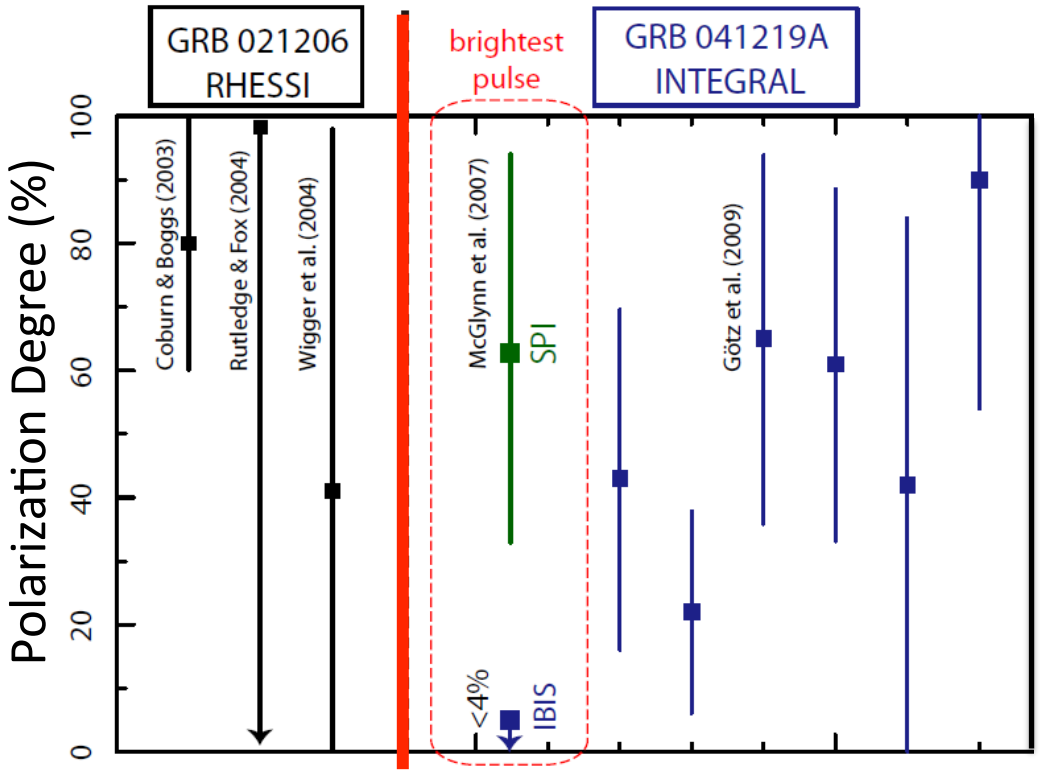
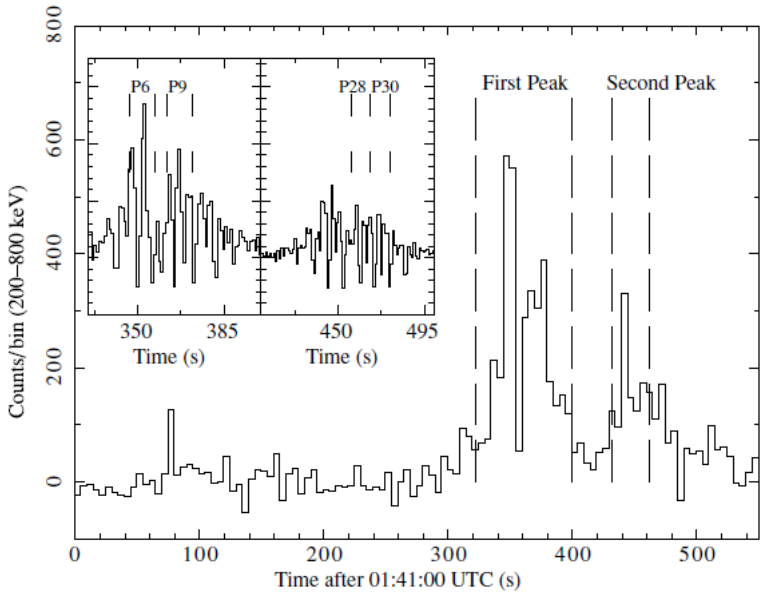
The Fermi/Swift GRB Conference 2012
Munich, Germany (7-11, May, 2012)

GRB polarimetry

How to release the huge amount of energy of $10^{52\text{-}54}$ erg in gamma-ray band in short time duration.

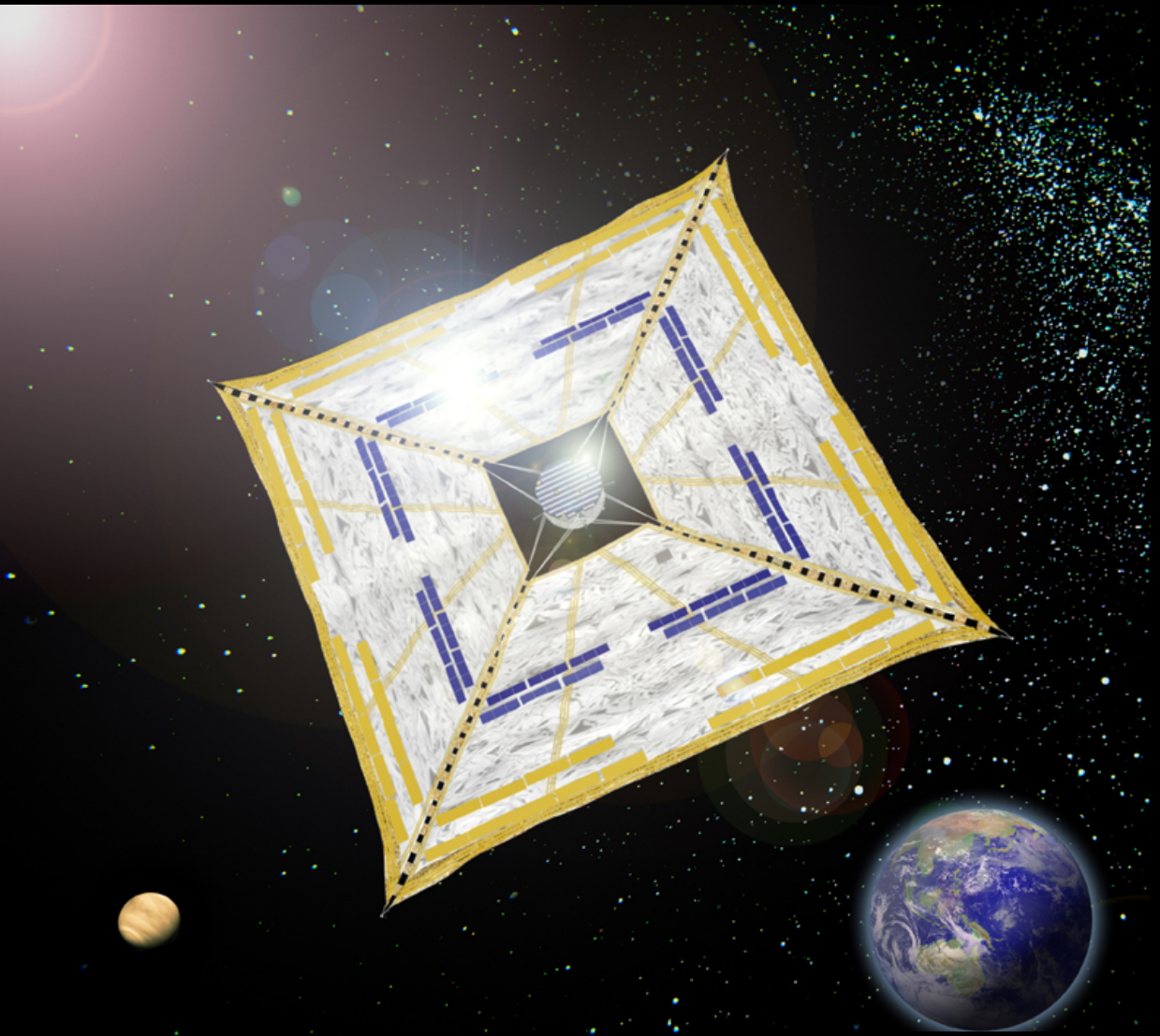
Direction (spatial distribution), Time Variability, Spectrum, The another information of E-M Wave "Polarization".

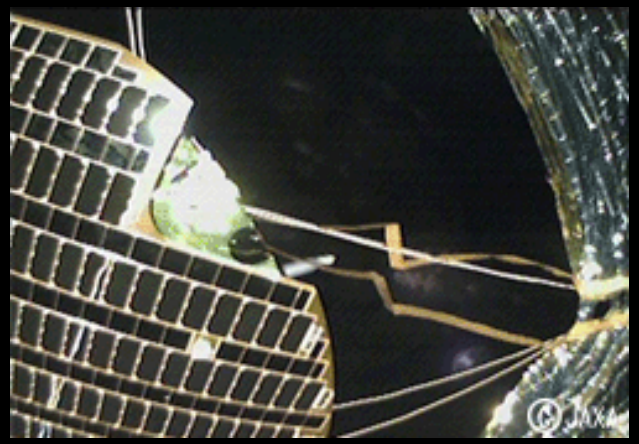




RHESSI
Coburn & Boggs (2003)
Rutledge & Fox (2004)
Wigger et al. (2004)

INTEGRAL
McGlynn et al. (2007)
Kalemci et al. (2007)
Gotz et al. (2009)





IKAROS

Launched
May 21, 2010

Interplanetary Kite-craft Accelerated by Radiation Of the Sun

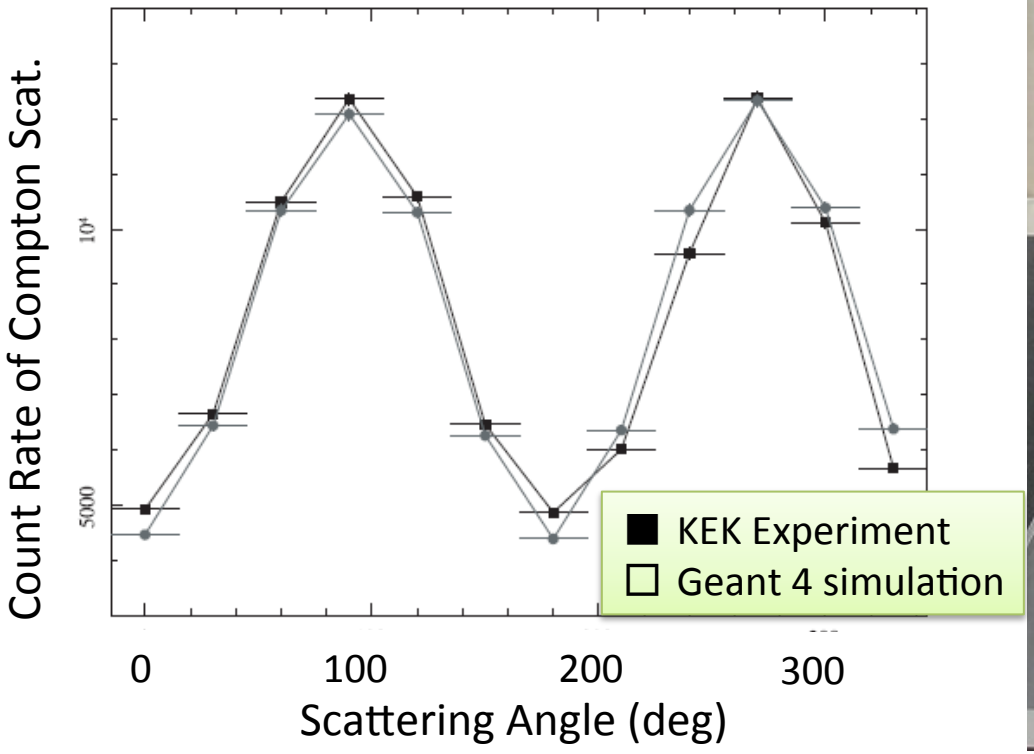
GAmma-ray burst Polarimeter

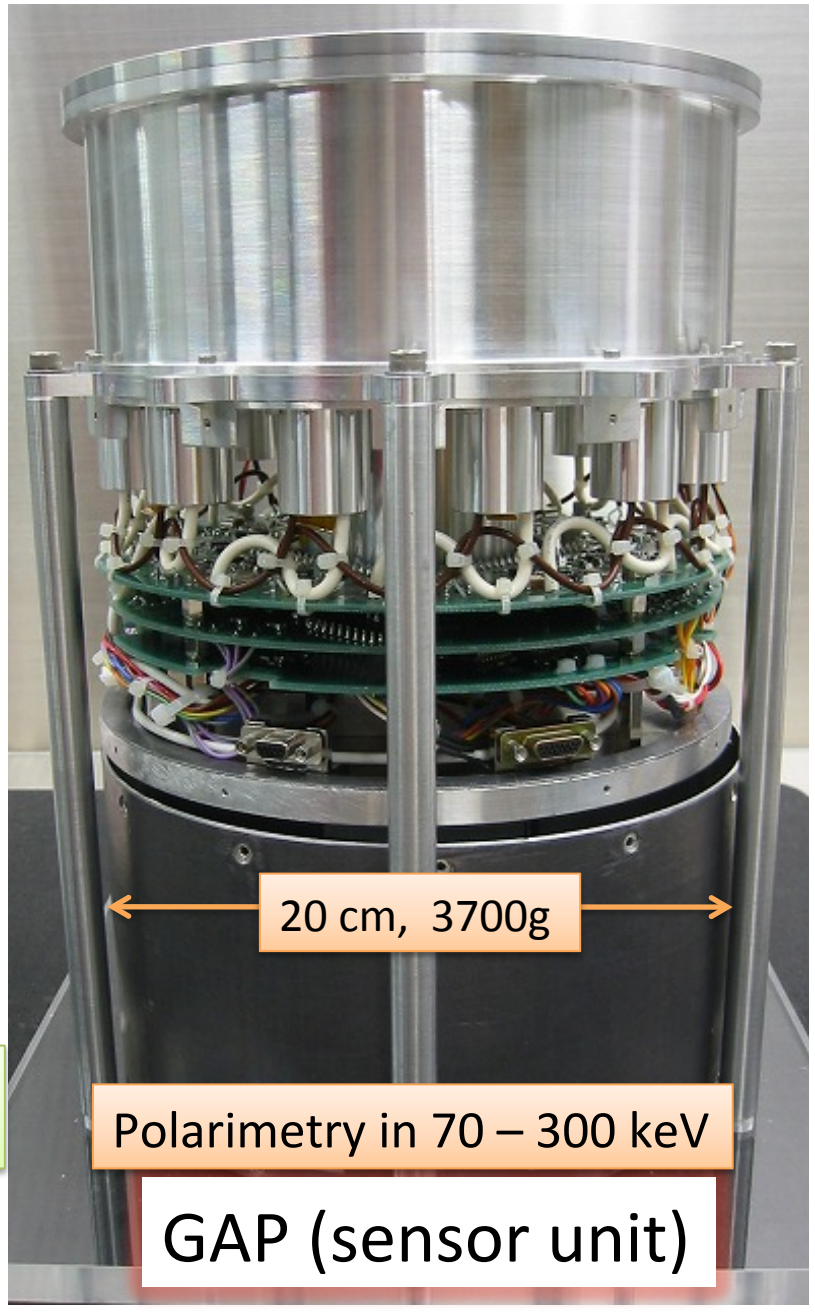
Yonetoku et al. (2011)

- Angular distribution of Compton Scat.
- Geometrical symmetry

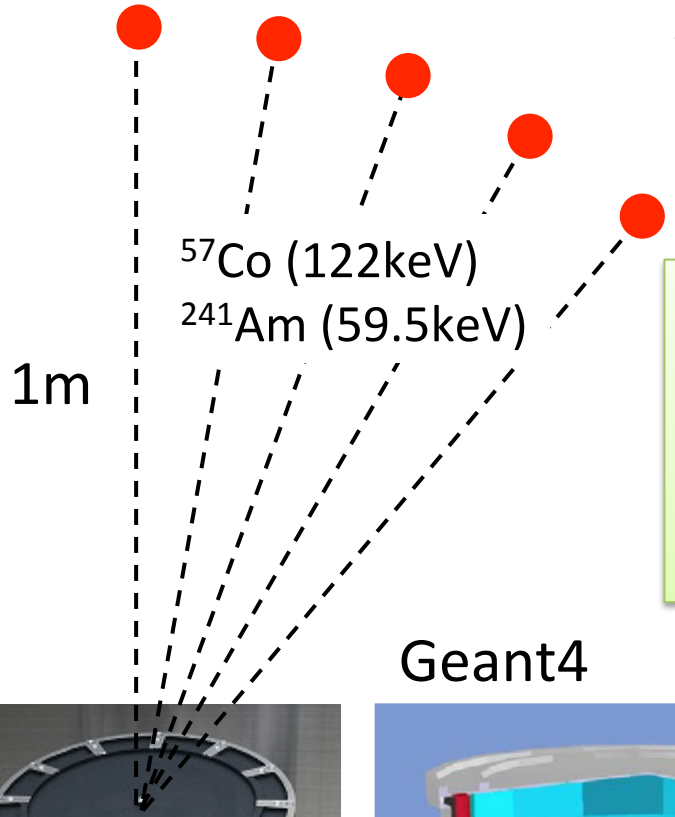
$$\frac{d\sigma}{d\Omega} = \frac{r_0^2}{2}\frac{E^2}{E_0^2}\left(\frac{E_0}{E} + \frac{E}{E_0} - 2\sin^2\theta\cos^2\phi\right)$$

r_0 : classical electron radius
E_0 : energy of incident photon
E : energy of scattered photon



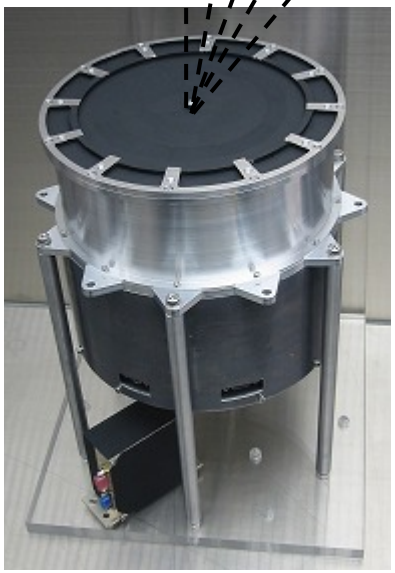


Systematic Uncertainty for Off-Axis Incident Photon

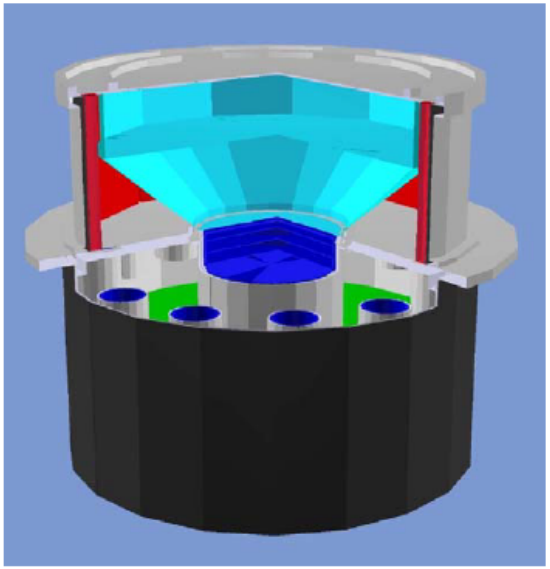


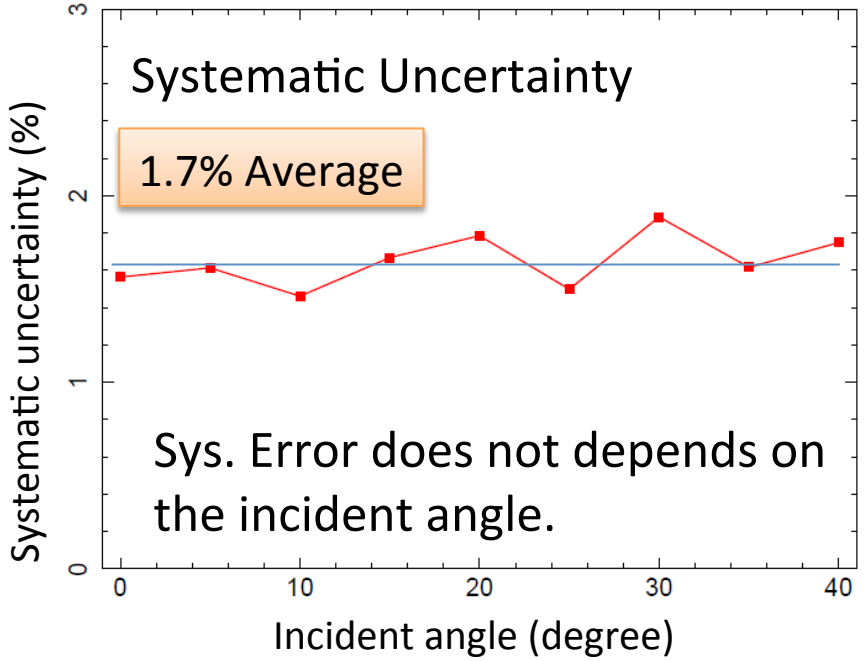
The systematics caused by imperfect tunings of parameters in the ground and in-orbit calibrations for the **off-axis radiation**.

Comparing the experimental and simulated modulation curves, we estimated the systematic uncertainty is ~ **1.7%** of the total coincidence gamma-rays.



Geant4





Data Samples

Konus, Fermi, Swift,
WAM, Integral, Mess.

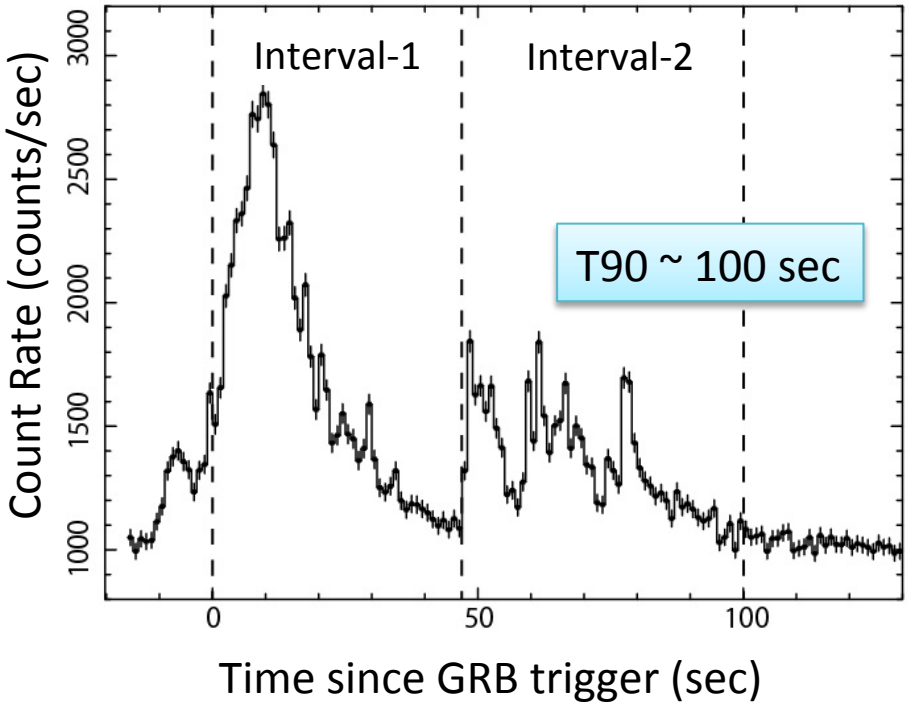
a : 10-1000 keV c : 20-5000 keV
b : 20-10000 keV d : 20-200 keV

No.	GRB	Fluence (erg/cm^2)	incident angle	Other Obs.	No.	GRB	Fluence (erg/cm^2)	incident angle	Other Obs.
1	100707A	[a] 8.8×10^{-5}	93	K,F,W, M	16	110124A		-	K,W
2	100715A		19	K,I,W,M	17	110301A	[a] 3.7×10^{-5}	48	K,F,W
3	100719B		145	K,F	18	110406A	[b] 4.8×10^{-5}	133	K,W,I,Sw
4	100722A		34	K,F	19	110423A		-	K
5	100804A		63	K,F	20	110428A	[a] 2.3×10^{-5}	109	K,F,W,Sw
6	100809A		-	K	21	110505?		-	?
7	100820A		34	K,F	22	110510?		-	?
8	100826A	[b] 3.0×10^{-4}	20	K,F,W, M	23	110514		-	K
9	101014A	[a] 2.0×10^{-4}	54	K,F	24	110604A	[c] 3.1×10^{-5}	43	K,W,Sw
10	101021A		41	K,F	25	110625A	[b] 6.1×10^{-5}	41	K,F,Sw
11	101113A		26	K,F	26	110708A	[d] 2×10^{-6}	67	K,F,Sw
12	101123A	[a] 1.3×10^{-4}	74	K,F,I,Sw	27	110715A	[b] 2.3×10^{-5}	88	K,W,Sw
13	101126A		62	K,F	28	110717B		25	F,K
14	101219A	[b] 3.0×10^{-6}	52	K,Sw	29	110721A	[a] 3.5×10^{-5}	30	K,F,I,M

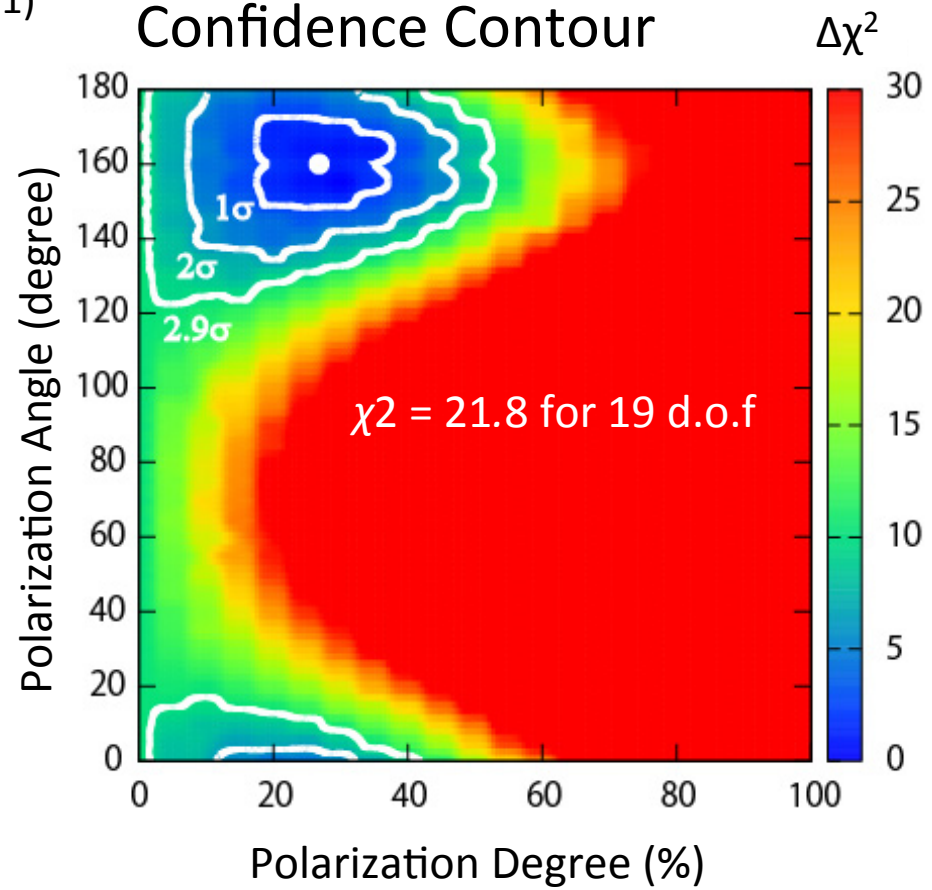
GRB100826A

Yonetoku et al. (2011)

Very bright events with F = 3.0×10^{-4} erg/cm2



Confidence Contour



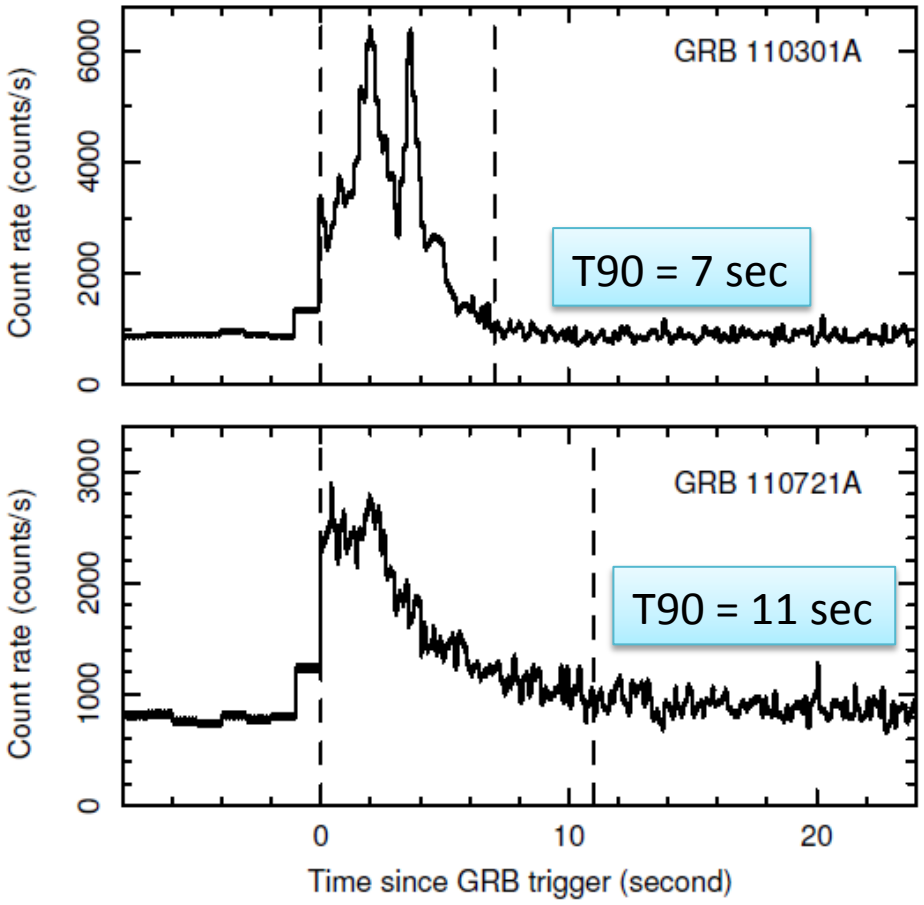
	Polarization Degree (including sys. uncertainty)	**Polarization Angle**
Interval-1	P = 25±15% (95.4% C.L.)	PA = 159±18 deg
Interval-2	P = 31±21% (89.0% C.L.)	PA = 75±20 deg
Combined Fit	P = 27±11% (99.4% C.L.)	

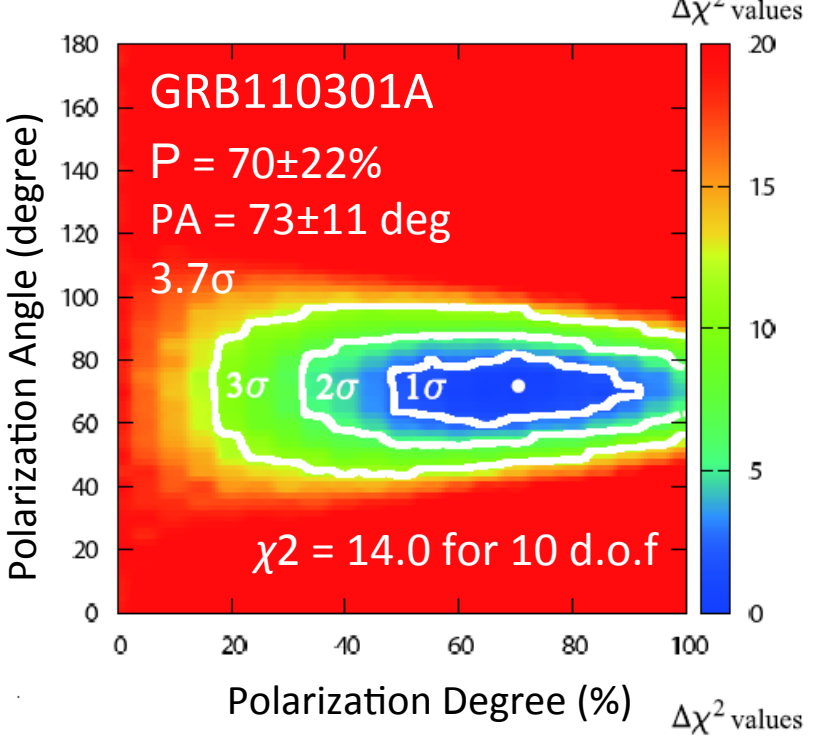
3.5σ Confidence Level

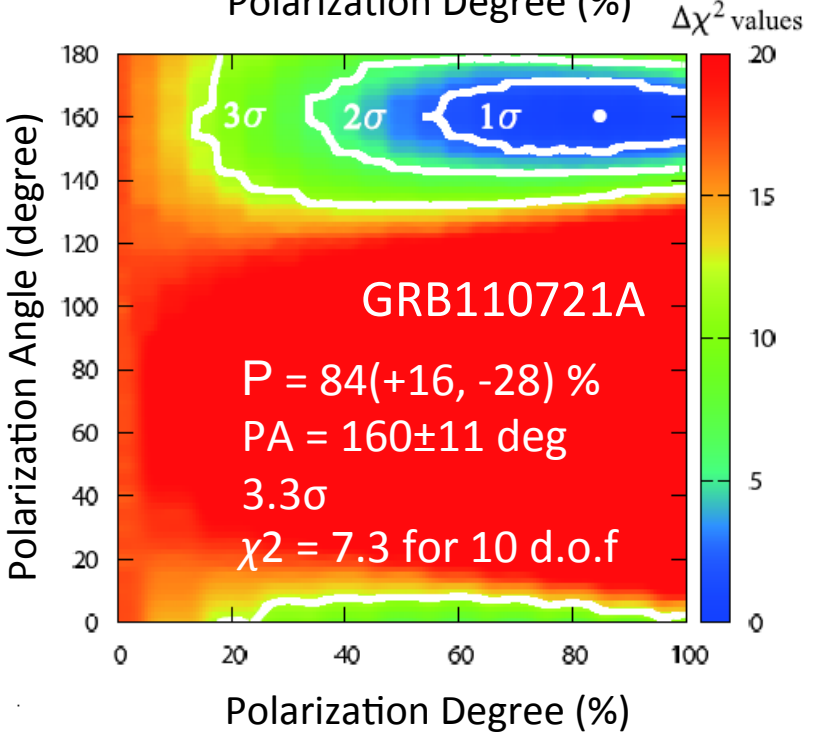
GRB110301A & GRB110721A

We detected the polarization from two bright GRBs with high significance.

The polarization angles did not change during the prompt GRBs.







Results of Polarization Analyses

GRB

Polarization Degree (%)

Duration T90 (sec)

Incident Angle (deg)

前半と後半の継続時間をたして平均をとった 101/2 sec

って得られた偏光度との相関がどのようなものになっ

のようなパラメ　100　関連付けし見ていく。偏光解析に用いたコインシデンスヒットパター

際に積分した観測時間 T、偏光解析に用いたコインシデンスカウント、他衛星の解析により

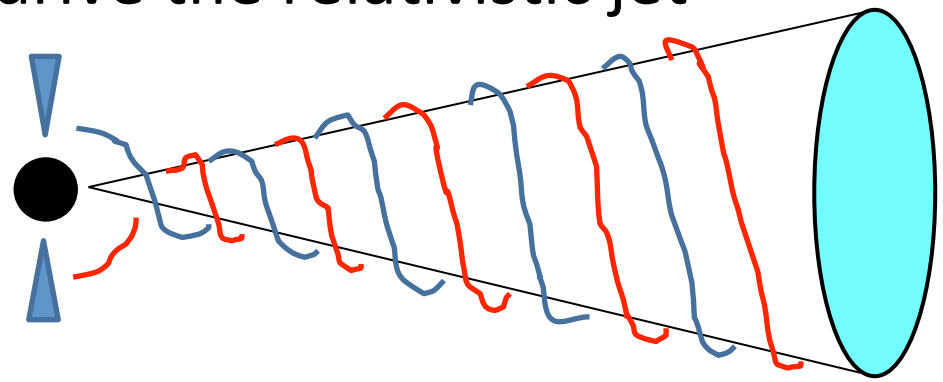
及び GAP のエネルギー帯域に換算した Fluence などの各種パラメータと解析によって示し

90% upper-limit

- Significant Polarization was detected from 3 GRBs.
- GRB100826A : Polarization angle changed (3.5s confidence level.)
- GRB110721A & GRB110301A : Polarization angle was stable.

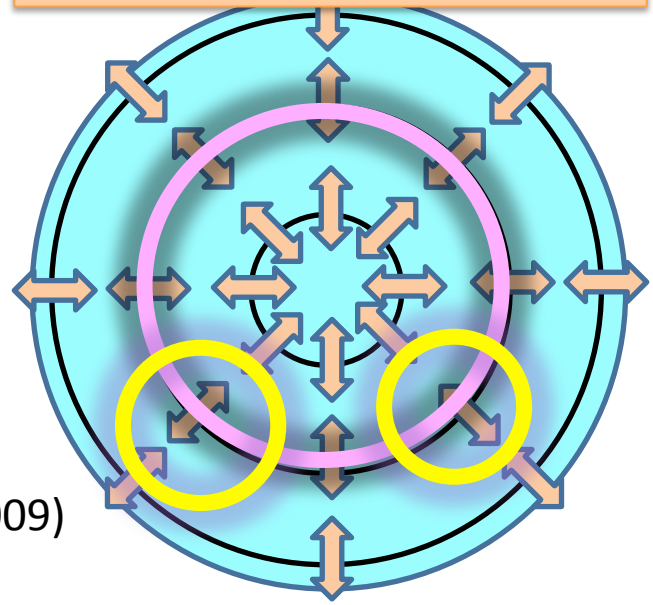
We need the emission model to explain both cases of change and no-change of polarization angle.

Helical Magnetic Fields to drive the relativistic jet



Jet opening angle : θj
Relativistic beaming effect : $1/\Gamma$

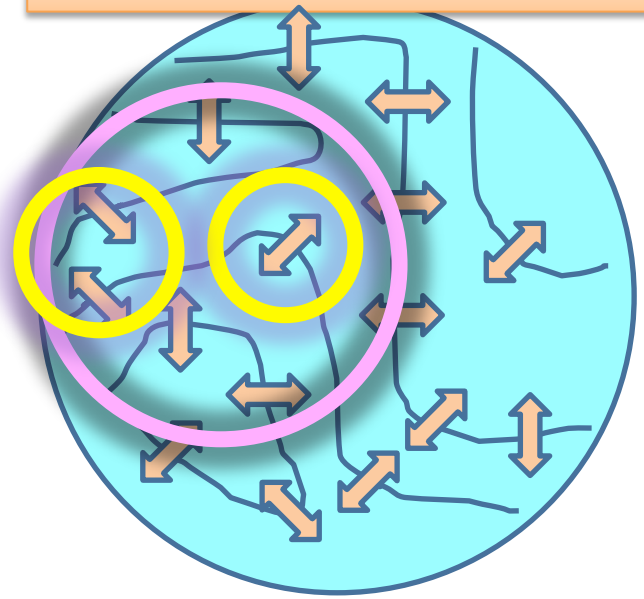
Distribution of polarization



Lazzati et al. (2003–2009)
Toma et al. (2009)

Globally Random Magnetic Fields, But Locally Ordered

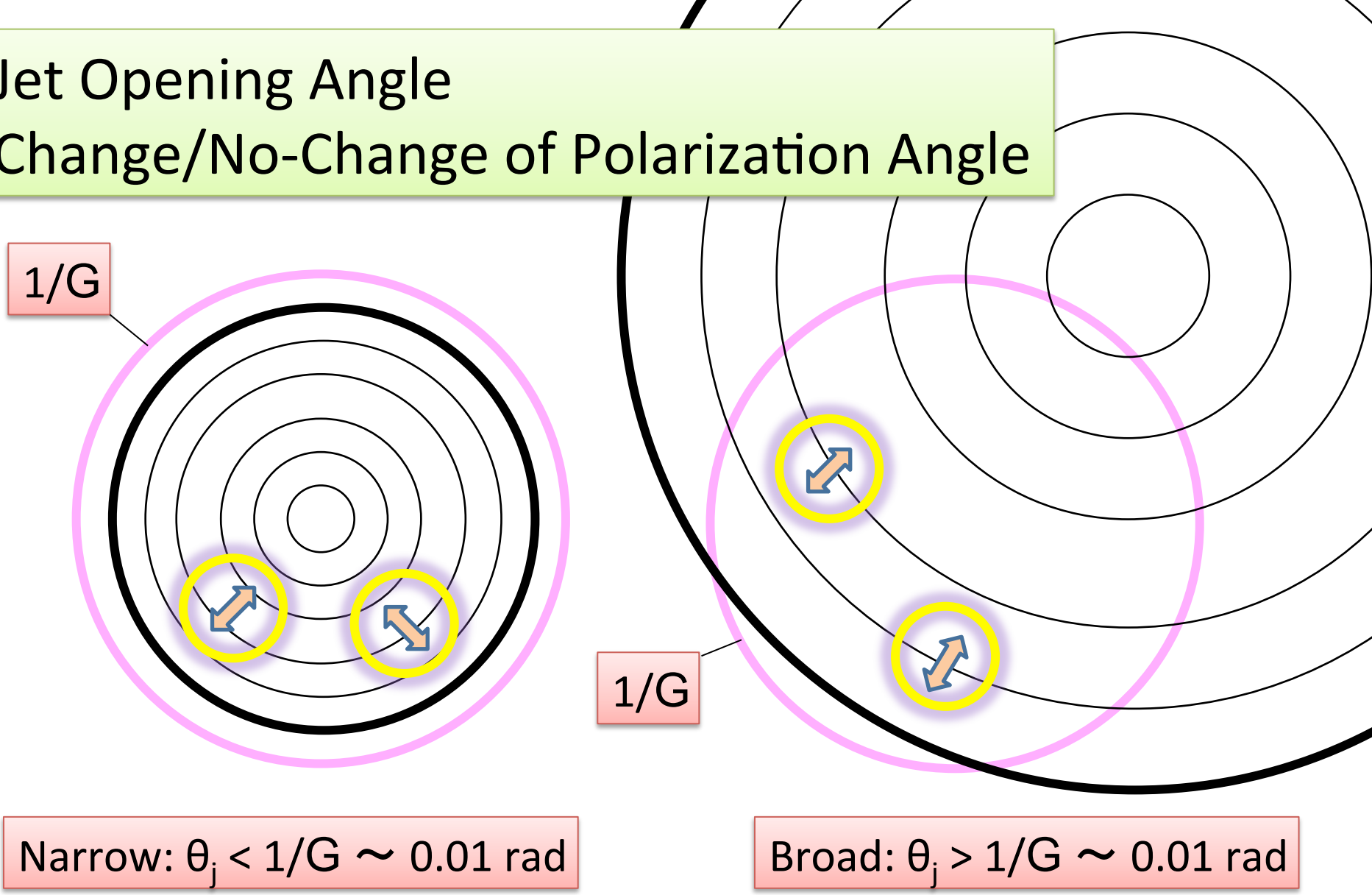
Distribution of polarization



The change of polarization angle can be explained with patchy structures of smaller than $1/\Gamma$.

Inner Structures may exist in the Jet.

Jet Opening Angle
Change/No-Change of Polarization Angle



Narrow: $\theta_j < 1/G \sim 0.01$ rad

Broad: $\theta_j > 1/G \sim 0.01$ rad

We can explain both cases of change/no-change of pol. angle

Summary

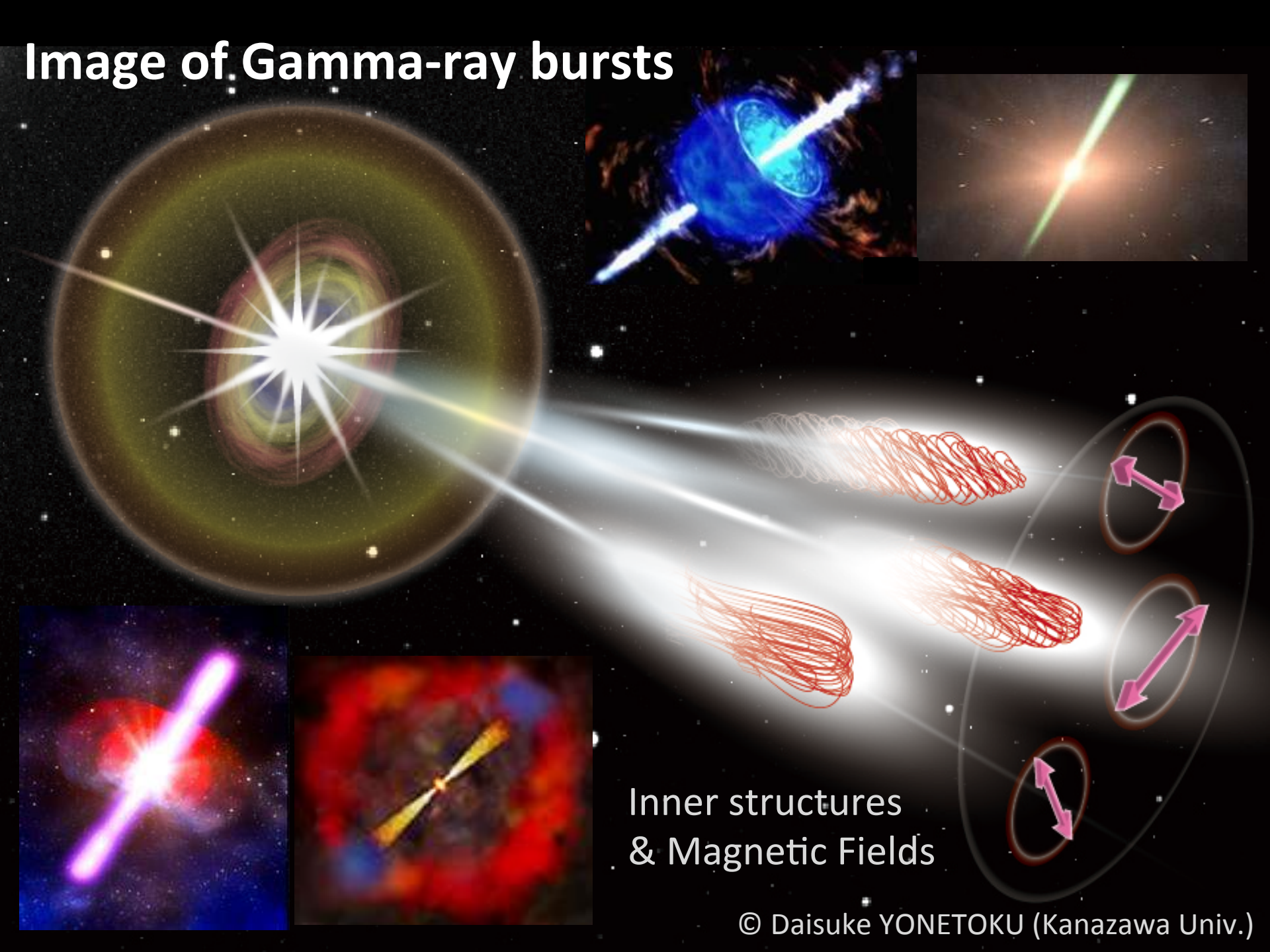
- We successfully launched the GRB polarimeter "GAP".
- We detected the gamma-ray polarization from 3 GRBs, and set upper-limit for 4 GRBs.
- The emission mechanism of prompt GRBs are probably the synchrotron radiation in the magnetic fields.

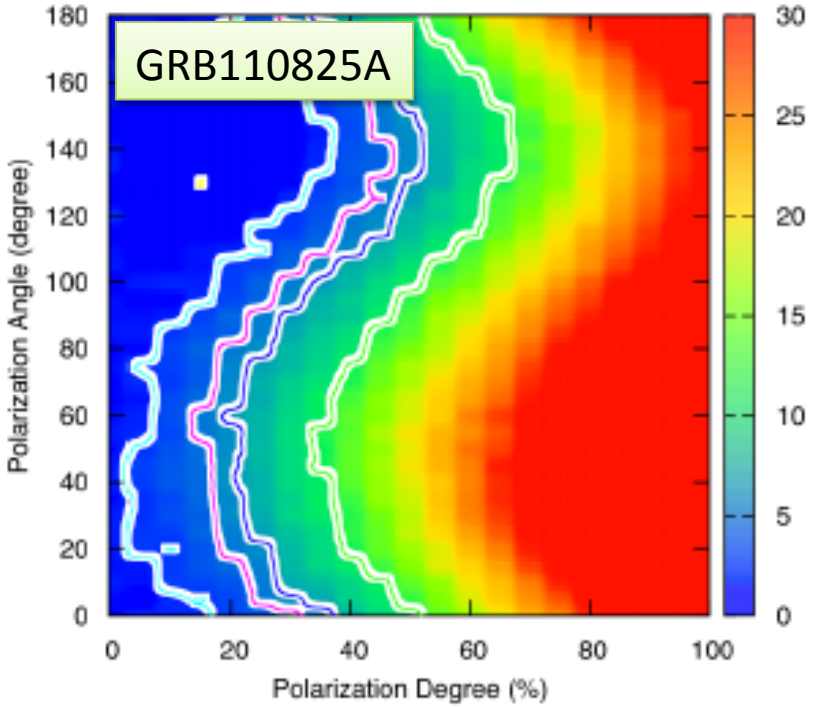
(we cannot exclude the photospheric and comptnized emission model)

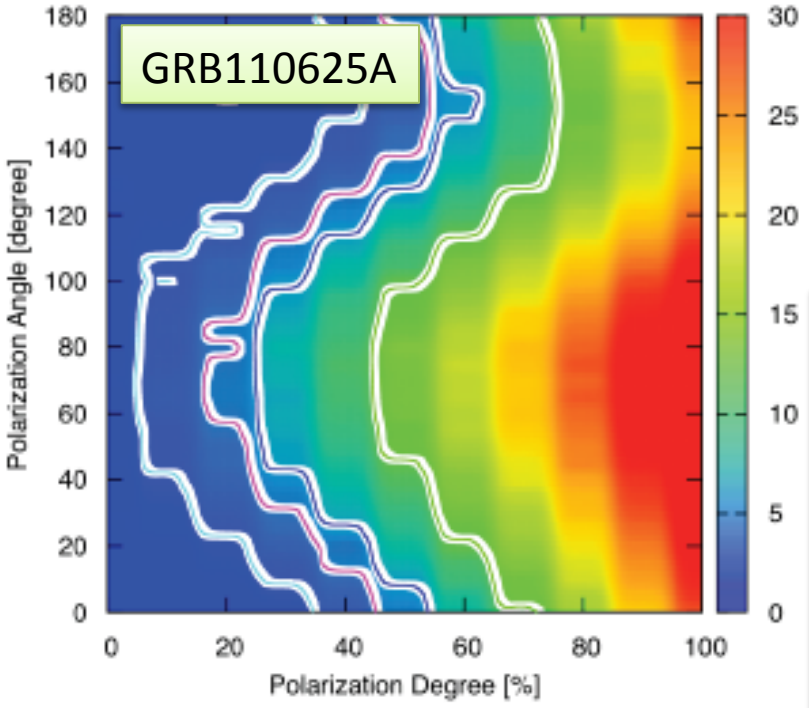
- Since the polarization angle rapidly changed, the multiple emission regions and/or the patchy structures with the scale of $< 1/\Gamma$ may exist in the relativistic jet.

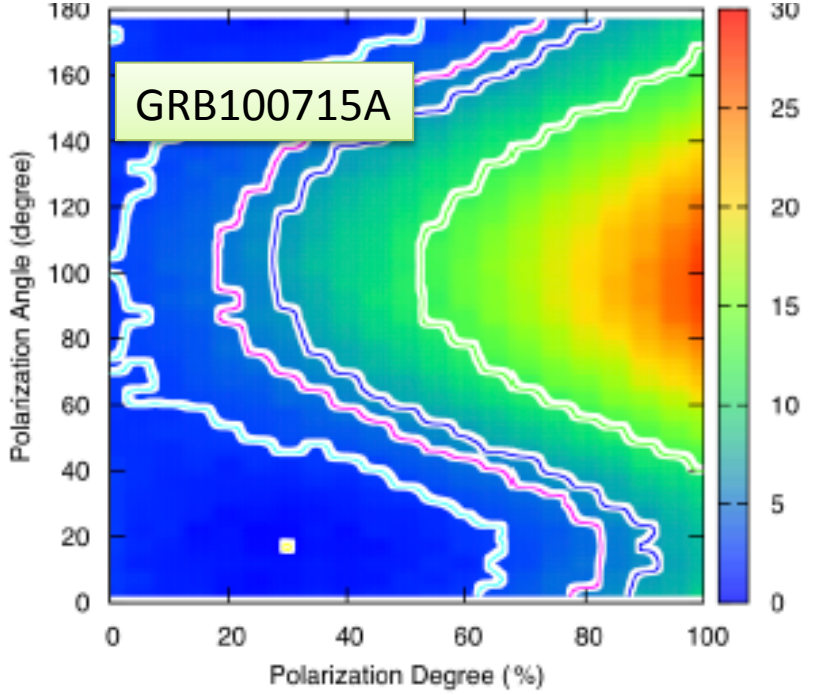
Next gamma-ray polarimeter aboard "TSUBAME" small satellite by the Tokyo-Tech team will be launched at the end of this year.

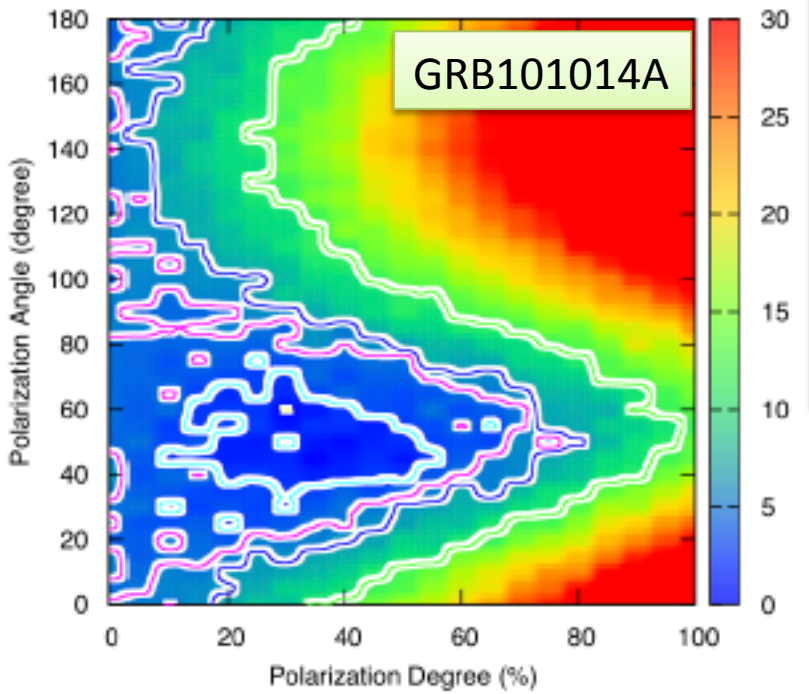
Image of Gamma-ray bursts











Preliminary Data