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Gamma-ray Burst conference @ RIKEN

Optical Polarimetry of GRB Afterglows

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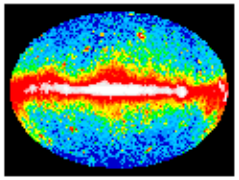
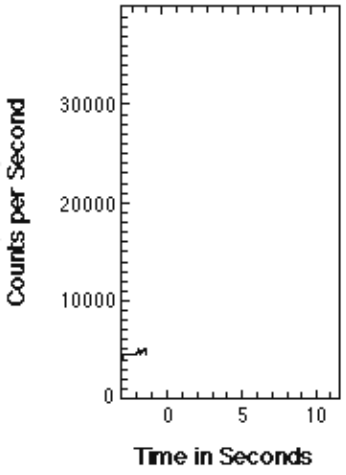
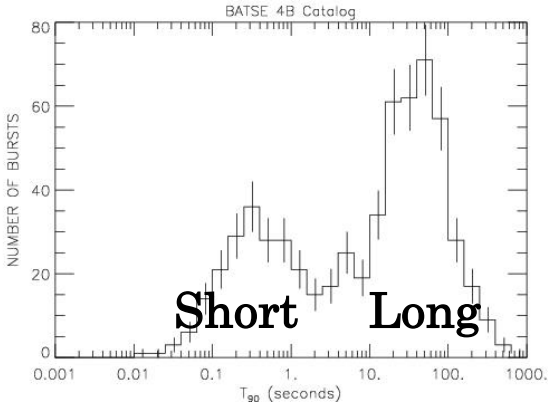
What is GRB (Gamma-ray Burst)

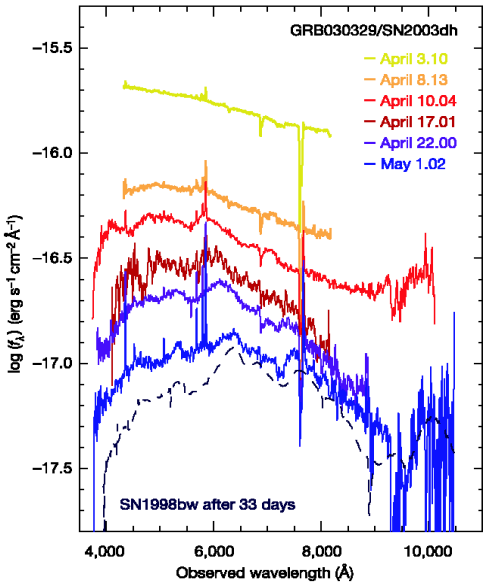
- Most energetic explosion in the universe (~ 10^{52} erg)
- Occurring at cosmological distance
- Gamma-ray arises in the form of relativistic jet.
  We observe it along the axis of the jet.
- Long GRB (> 2s) and short GRB (< 2s)
- A part of long GRBs associate with SNe Ic

Spectral evolution becoming SNe Ic









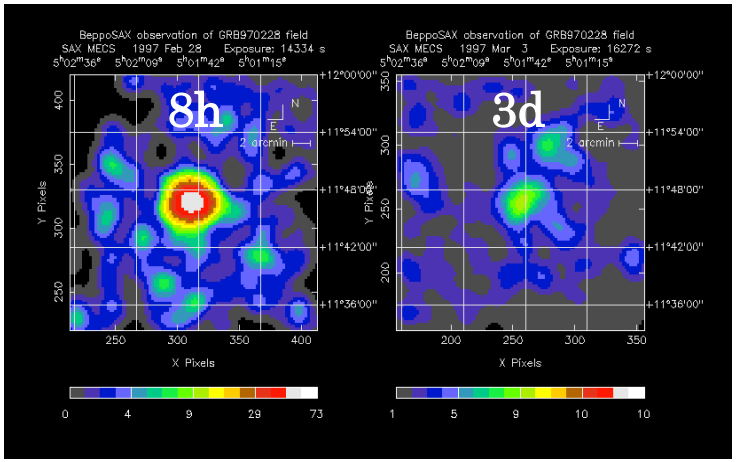
(Hjorth+ 03)

http://www.batse.msfc.nasa.gov/batse/grb/duration/

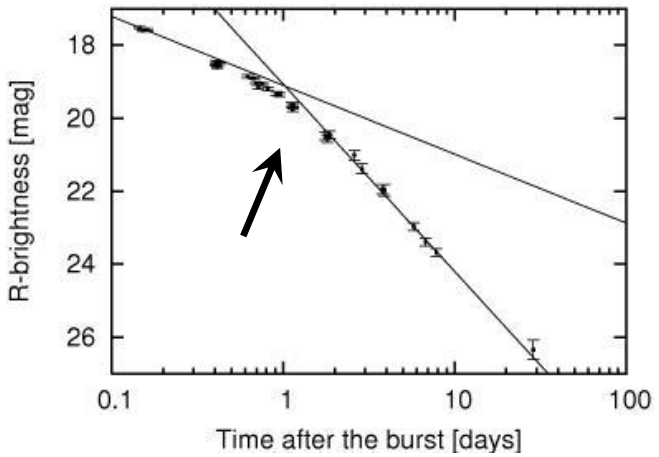
GRB afterglow

- A considerable fraction of GRBs show **afterglows**, in X-ray, optical, NIR, and radio wavelength.

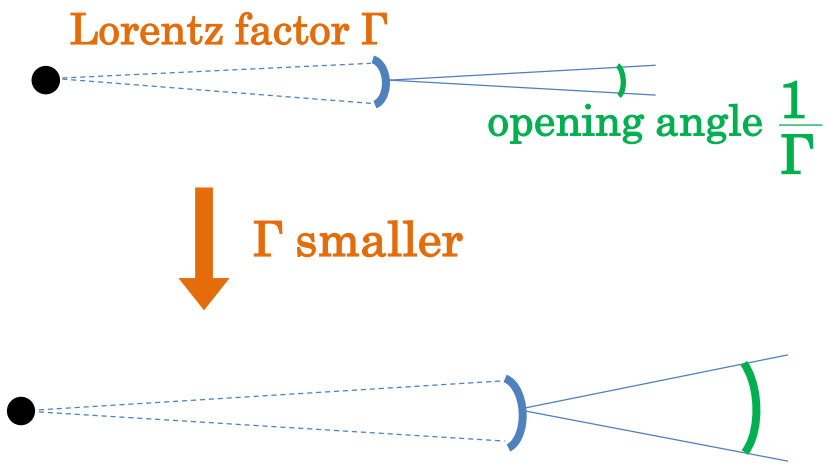
- GRBs are relativistic events.
  " jetbreak " ~1d after the burst.



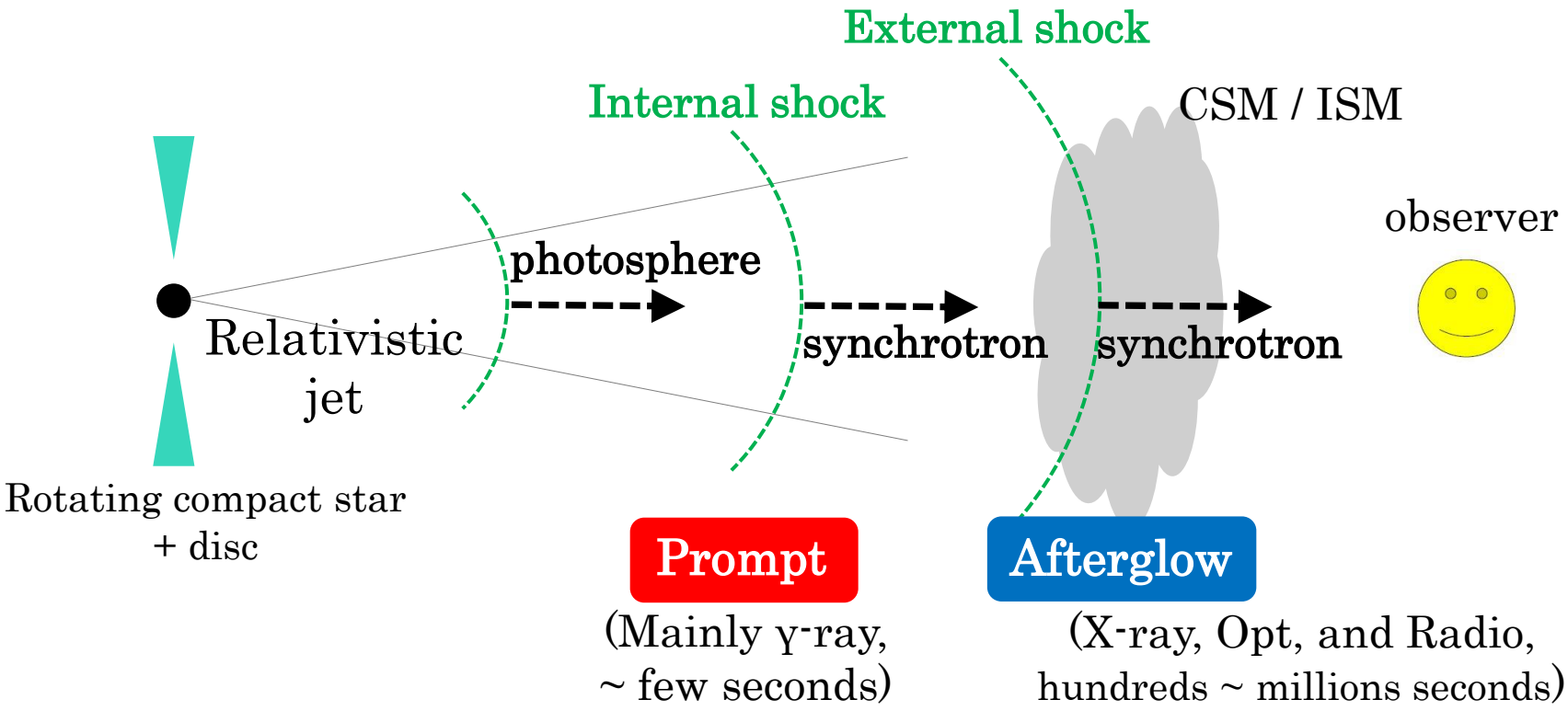
http://spiff.rit.edu/classes/phys240/lectures/grb_pres/grb_pres.html



(Wei+ 02)



Standard emission model



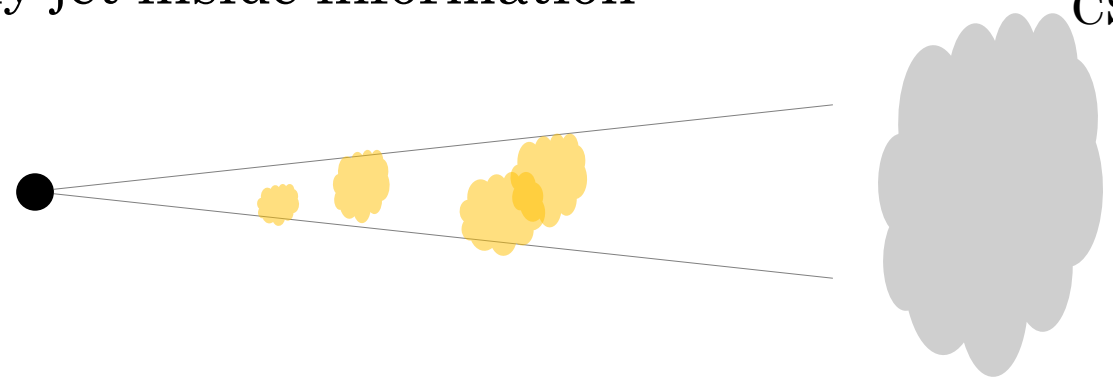
Synchrotron Radiation is most likely

→ A key to *B*-field and Jet structure

Ever polarimetry 1

Prompt

Mainly jet inside information



GRB	Π (68% c.l.)	Peak energy (keV)	Fluence and Energy Range (erg cm^{-2})	z	Instrument
041291A	65±26%	201^{+80}_{-41}	2.5×10^{-4} in 20–200 keV	$0.31^{+0.54}_{-0.26}$	IBIS
06122	>60%	188±17	2.0×10^{-5} in 20–200 keV	$1.33^{+0.77}_{-0.76}$	IBIS
100826A	25±15%	606^{+134}_{-109}	3.0×10^{-4} in 20 keV–10 MeV	0.71–6.84[1]	GAP
110301A	70±22%	107±2	3.6×10^{-5} in 10 keV–1 MeV	0.21–1.09[1]	GAP
110721	84^{+16}_{-28}%	393^{+199}_{-104}	3.5×10^{-4} in 10 keV–1 MeV	0.45–3.12[1]	GAP
140206A	>48%	98±17	2.0×10^{-5} in 15–350 keV	2.739±0.001	IBIS

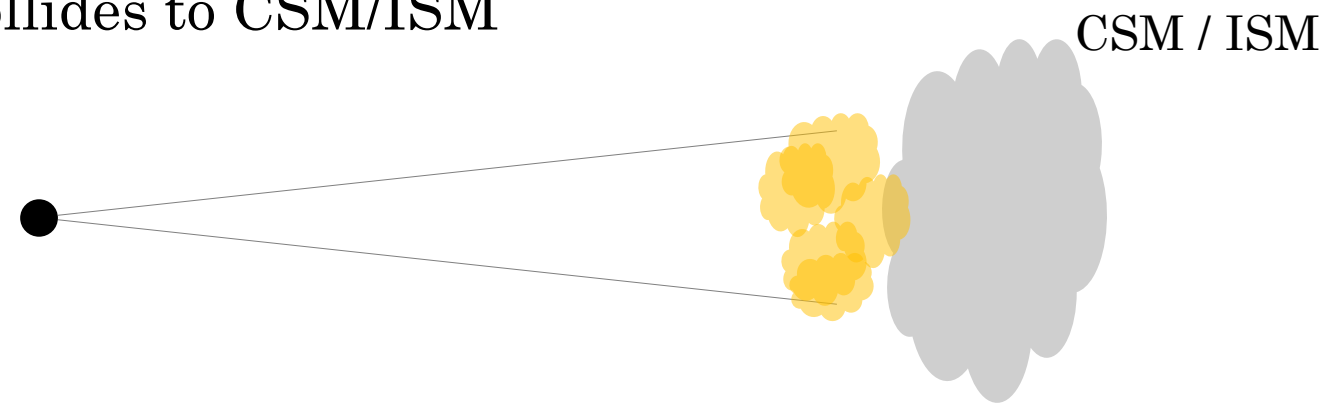
All high PD!

(Gotz+ 14)

Ever polarimetry 2

Afterglow

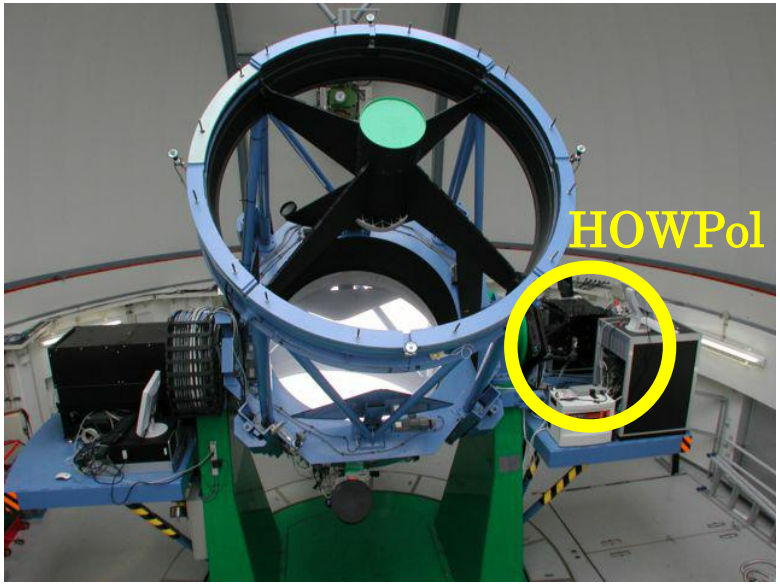
Jet collides to CSM/ISM



GRB	z	t_{obs} [s]	PD	Note	Ref.
060418	1.490	203 ~	< 8%		Mundell +07
090102	1.547	161 ~	10.2 ±1.3 %		Steel+ 09
110205A			< 16 %		Cucchiara+ 11
120308A	~3.2	240 ~ 827	28 → 16 %	PA const.	Mundell+ 13
131030A	1.294		< 2 %		King+ 14

Various…

Kanata telescope + HOWPol



Kanata telescope

- HHAO
  (Higashi-Hiroshima Astronomical Observatory)
- Effective aperture 1.5 m
- Fair weather ratio ~50%
- Moving speed
  Azimuth axis 5 degree / s
  Altitude axis 2 degree / s
  Extremely fast as 1m-class

HOWPol

(Hiroshima One-shot Wide-field Polarimeter)

- Polarimetry **with only one exposure**
- Mechanical pol. due to nasmith focus (P_{inst} ~3.5 ± 0.5%)

GRB auto-observation system

Relay satellite

at earliest

~20s

Kanata Telescope

- high moving speed
- auto system

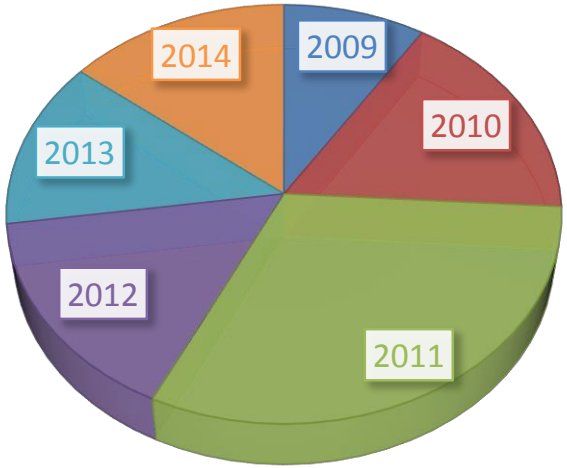
HOWPol

- only one exposure

Start exposure at earliest ~1m

Dedicated system to GRB polarimetry

Ever polarimetry at HHAO



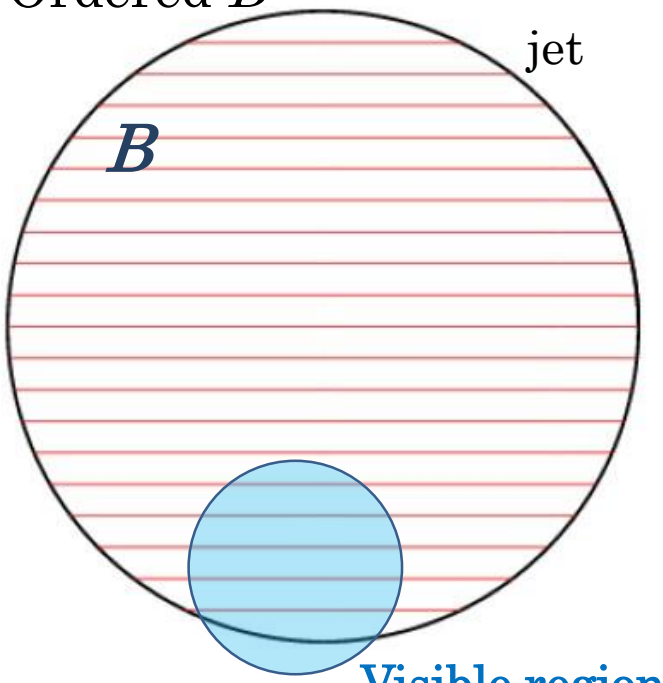
All observed GRB 129

Auto-observed GRB 77

	ID	Time [s]	Publication
1	GRB 091208B	149 ~ 1286	Uehara+ 12, ApJL
2	GRB 111228A	163 ~ 19000	KT+ in prep.
3	GRB 121011A	92 ~ 5241	
4	GRB 130427A	10000 ~ 30000	
5	GRB 130505A	~10000	
6	GRB 140629A	73 ~ 12000	KT+ in prep.
7	GRB 140907A	622 ~ 10000	

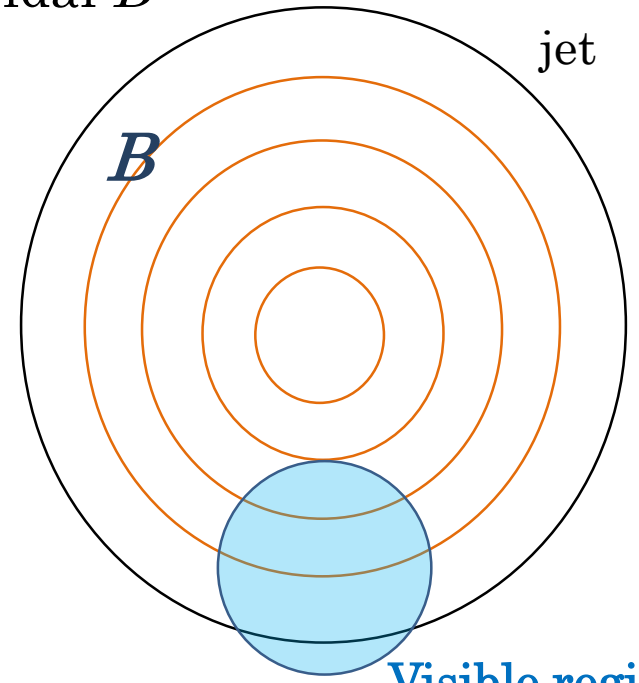
Basic ideas of GRB polarization

Ordered B



Visible region～1/Γ

Troidal B



Visible region～1/Γ
Same as ordered B

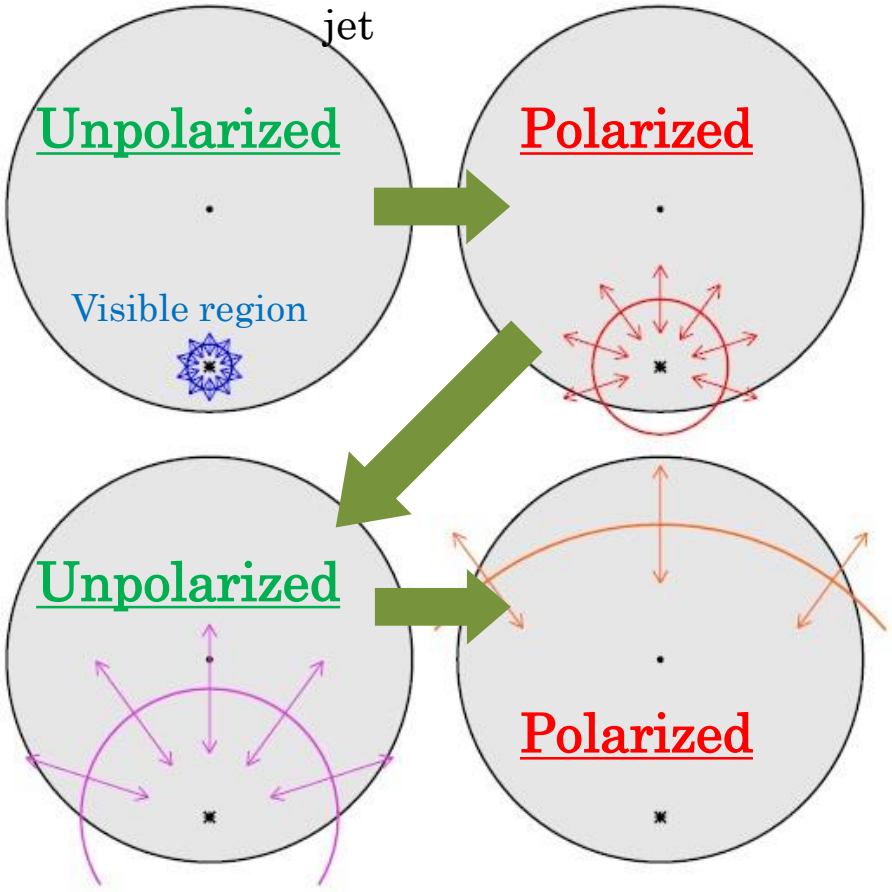
- P.D. ~ max 70%
- no time variability

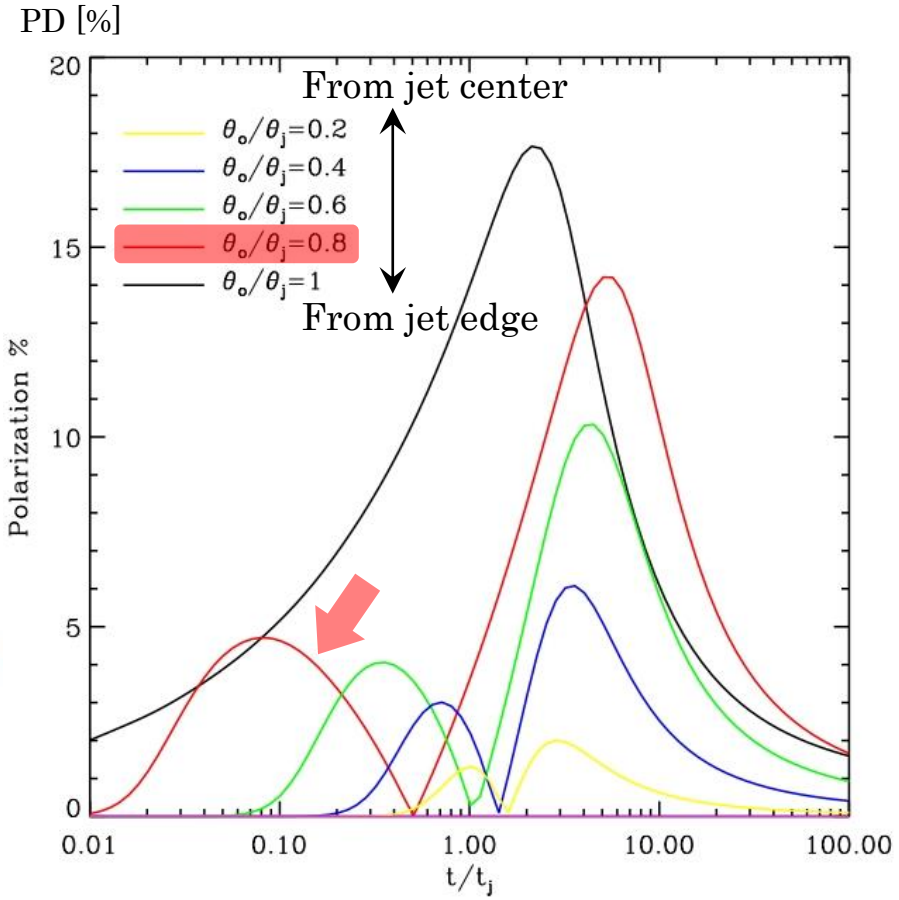
- local P.D. ~ max 70%
- P.D. become smaller with time

Important model 1

Random B-field in micro-scale + off-axis jet beaming effect

(Sari +99 ; Rossi +04 ; Granot +99 etc.)

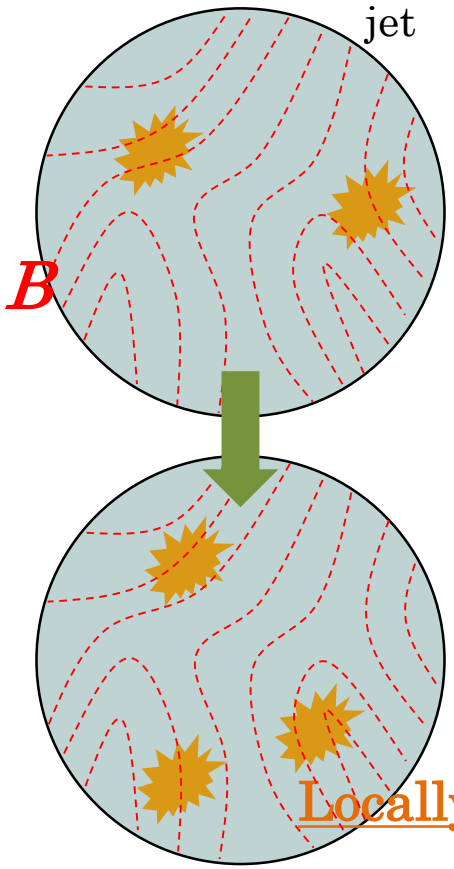




Important model 2

Group of independent patches having coherent B-field

(Gruzinov & Waxman +99)



Many coherent patches (N~50)

$$P = \frac{70\%}{\sqrt{N}} \sim 10\%$$

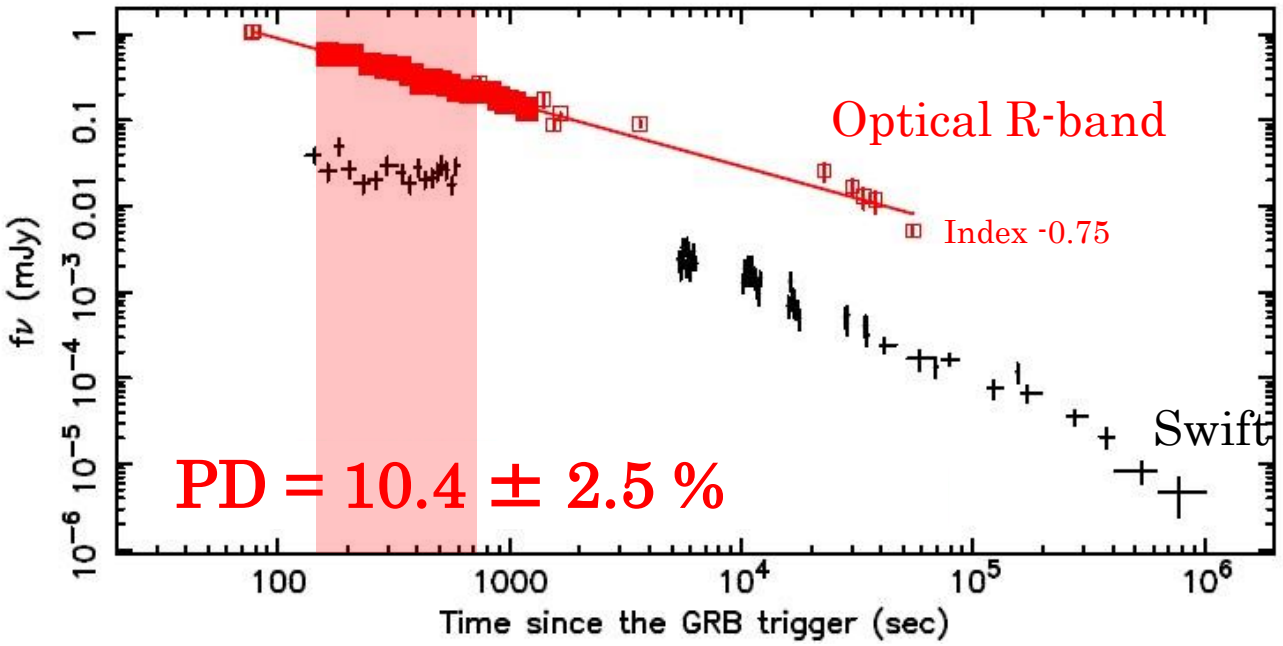
not canceled out completely

Possible to produce complicated P.D.

Independent from jetbreak
→ high P.D. at early epoch ?

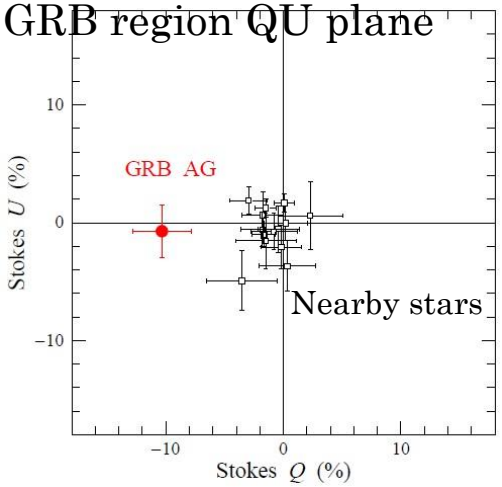
GRB 091208B

$z = 1.063$, $T_{90} = 14.9 \pm 3.7$ s



(Uehara+ 12)

GRB region QU plane

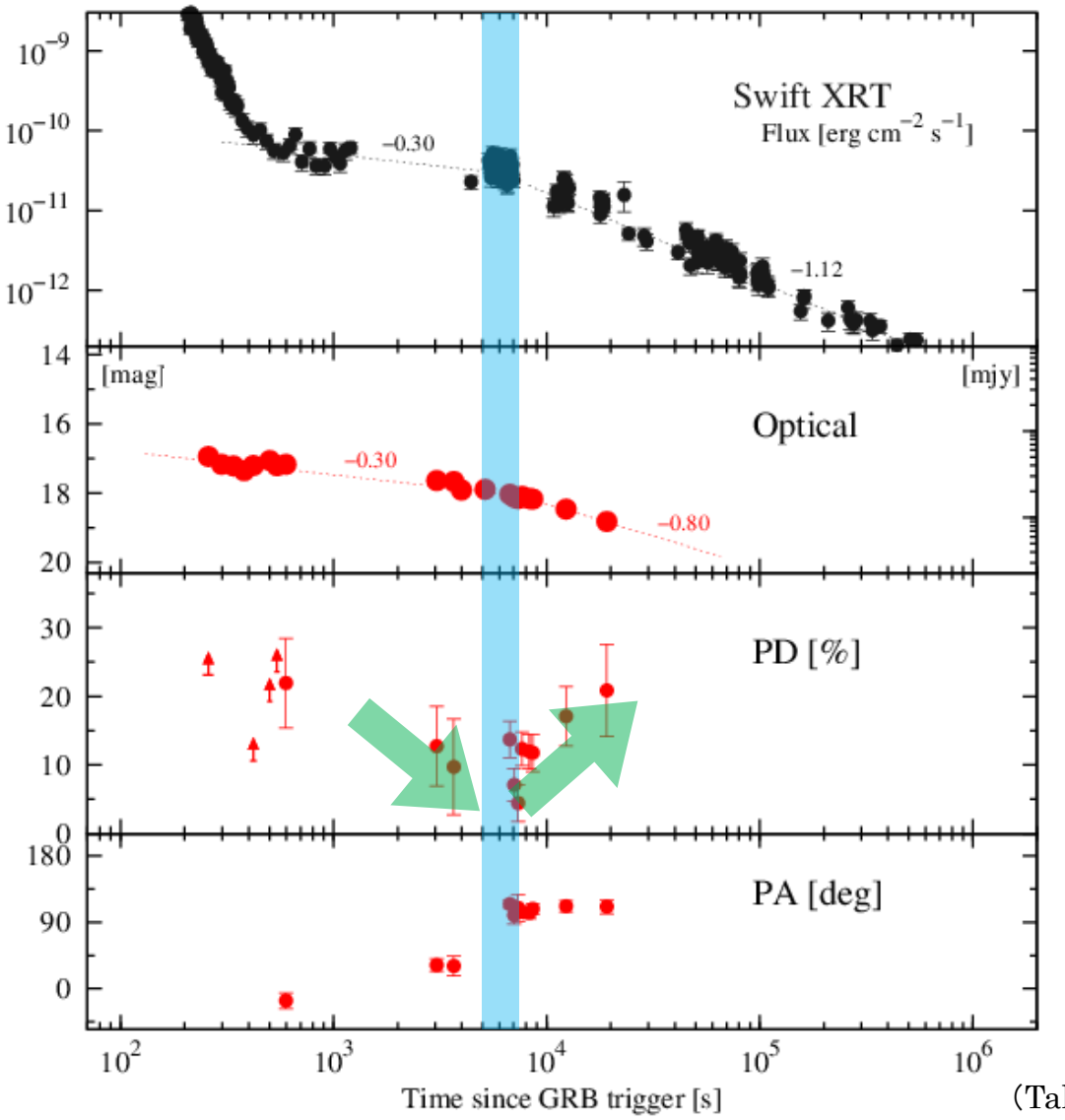


- Standard Afterglow
- Forward shock emission
- High PD is **inconsistent with model 1**

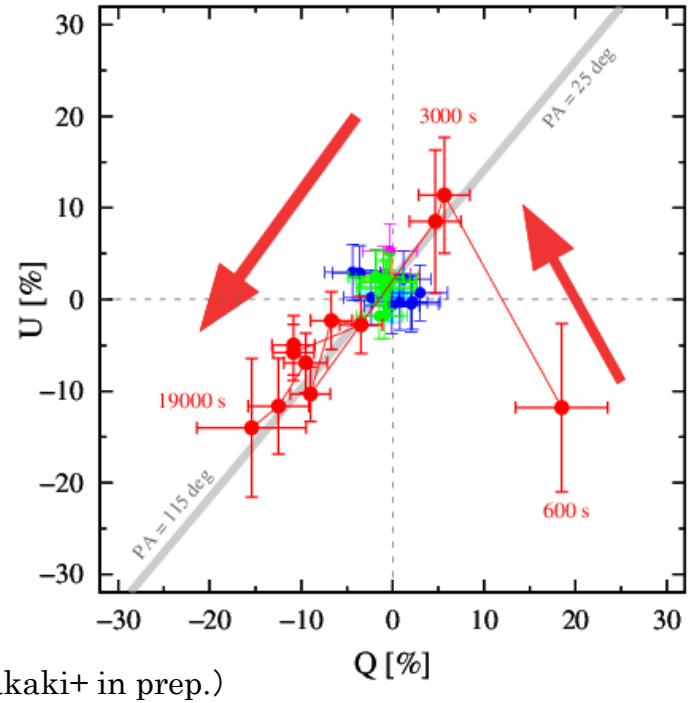
See Uehara et al. 2012 for detail.

GRB 111228A

$z = 0.714$, $T_{90} = 101.2 \pm 5.4$ s



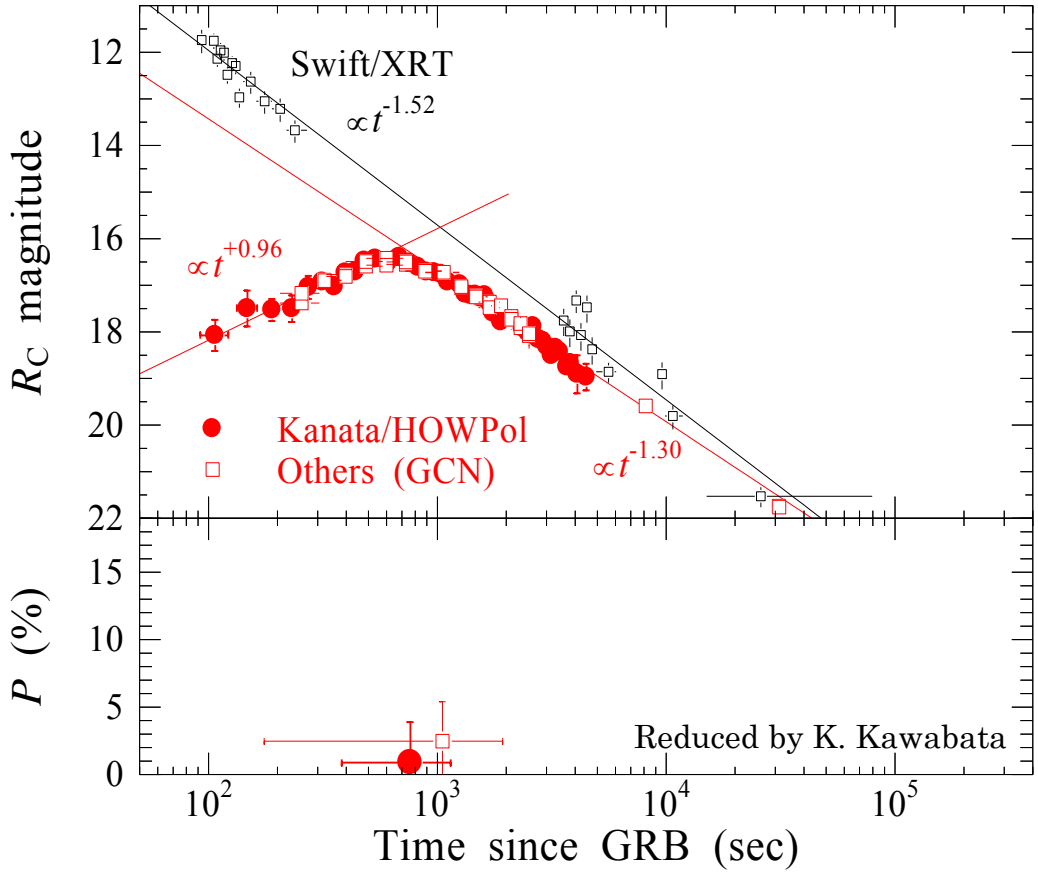
- Simultaneous LC break
- PD evolution
  ~10% → zero → ~20%
- PA rotated 90d
  (across origin in QU-plane)



(Takaki+ in prep.)

GRB 121011A

z = unknown, T_{90} = 75.6 ± 12.7 s

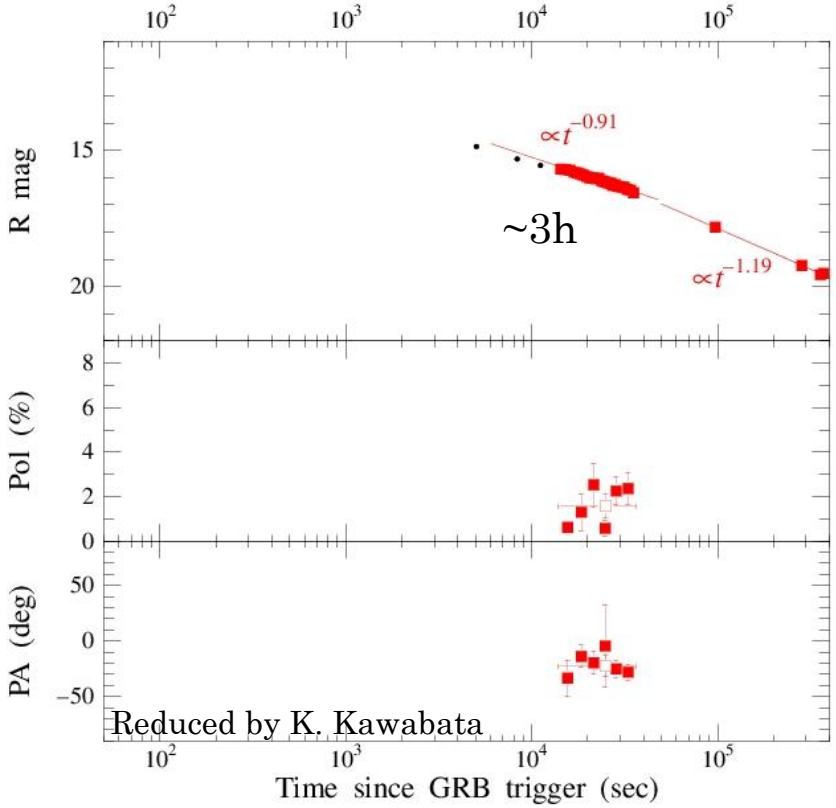


- Started observation from very early (t = 92 s)
- Standard Afterglow
- nearly zero PD (< 4%)

iv GRB 130427A & 130505A

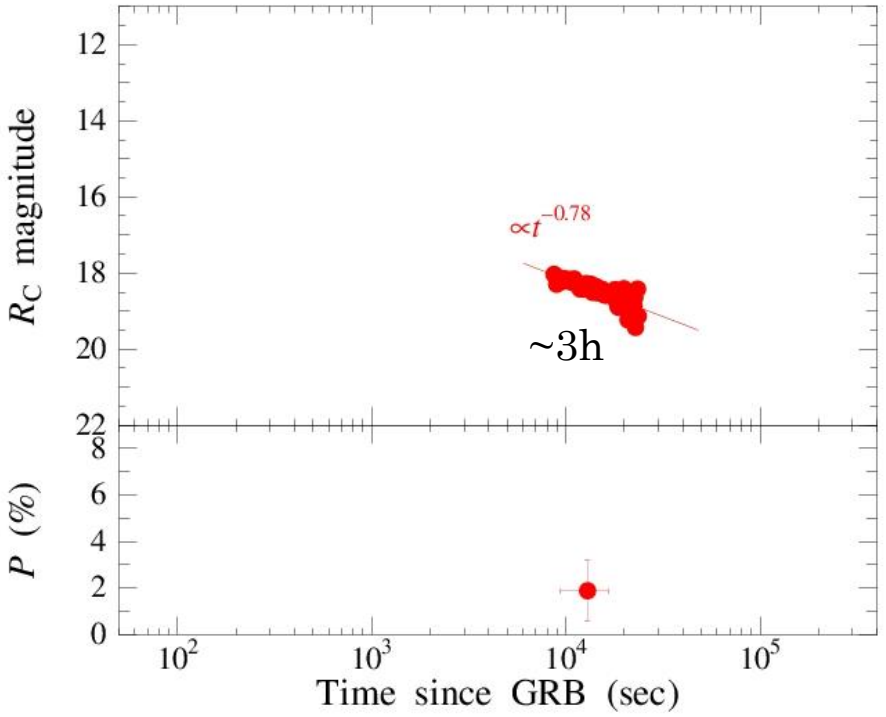
GRB 130427A

$z = 0.34$, $T_{90} = 162.8 \pm 1.4$ s



GRB 130505A

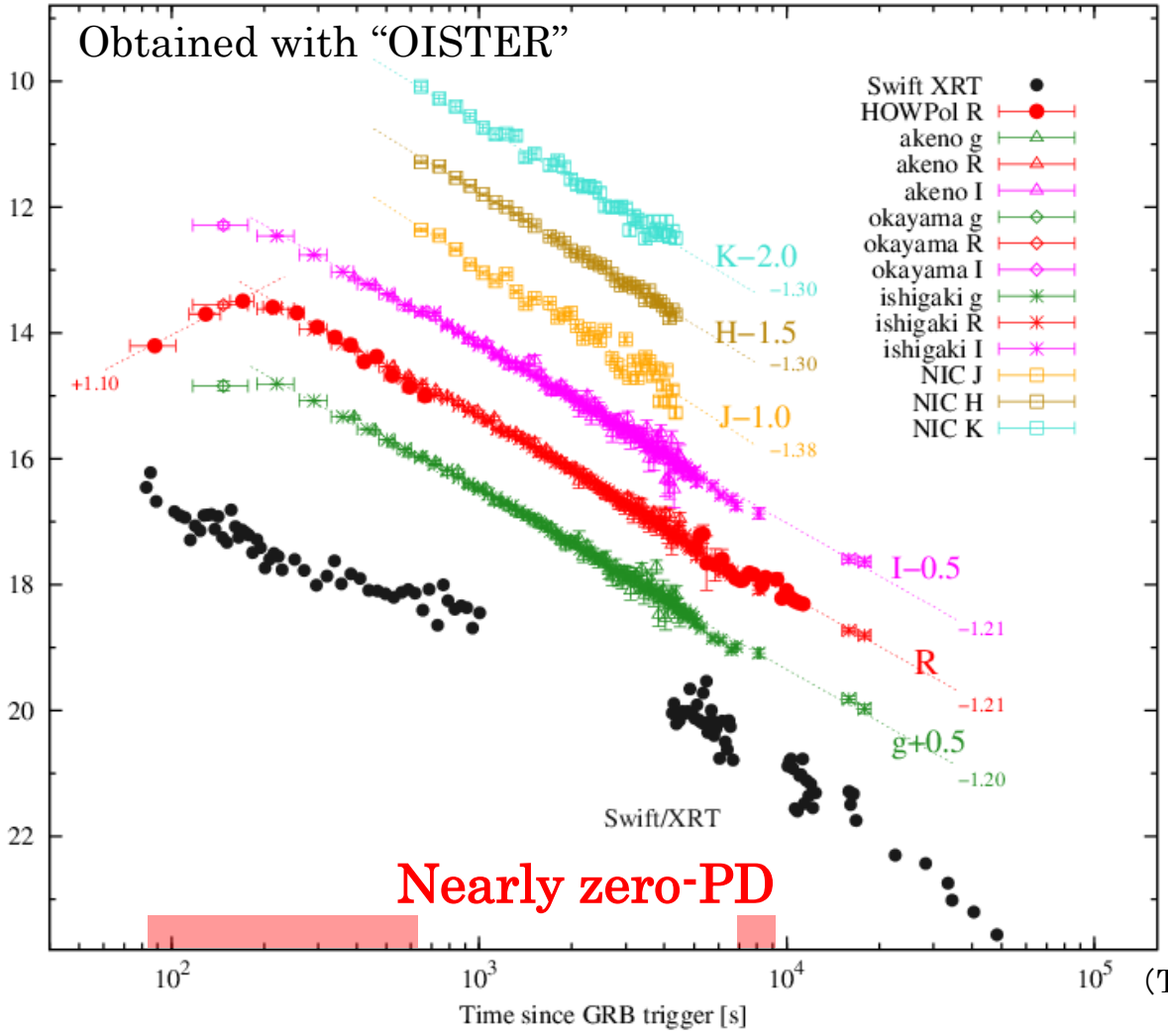
$z = 2.27$, $T_{90} = 88 \pm 10$ s



Both GRBs are small PD at ~10^4 s

V GRB 140629A

$z = \sim 2.28$, $T_{90} = 75.6 \pm 12.7$ s

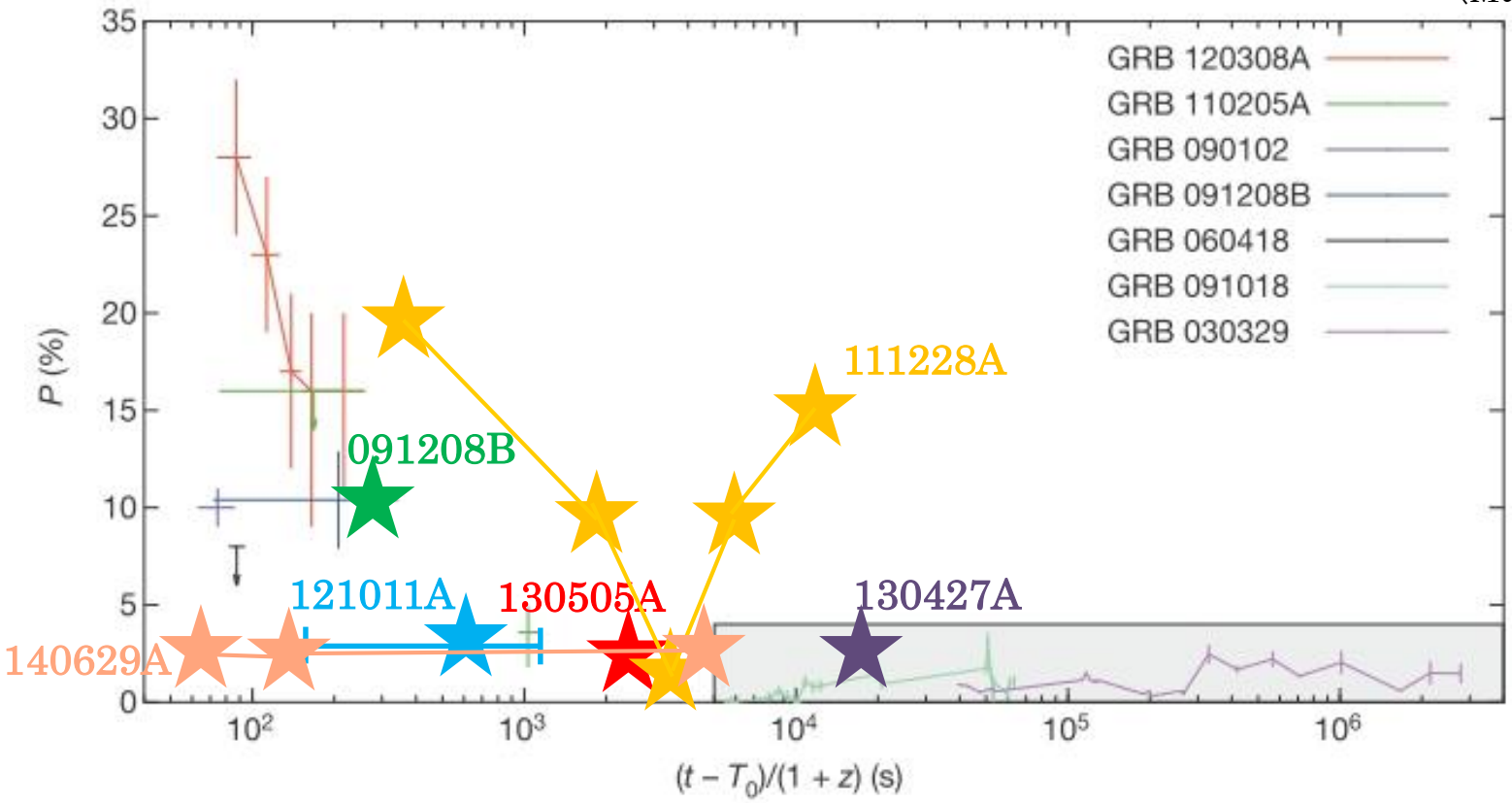


- Multi-band LC
- Very standard AG
- Small PD

(Takaki+ in prep.)

Summary

(Mundell+ 13)



- GRB polarization : 1 event / yr
- Still unclear, no uniformed picture
- More observation samples, especially early phase.