光計測の見方

A view of photo-spectro-polarimetry in astronomy

多バンド＝⊂多モード

I ([撮像：θ]⊗[分光：λ=>色]⊗[偏光：σ]) with *t*

1 『Measure intensities on properties of photon along with time』

Properties of photon are (1) direction(θ_{xy}), (2) wavelength（λ）, (3) polarization（σ） and (4) photon number ***I*** (θ λ σ : *t*).

2 As example of this view by using *TRIPOL*:

“*Triple-Range Imager and POLarimeter*”.

View of photometry ： 光計測の見方

単一フォトン
: single photon

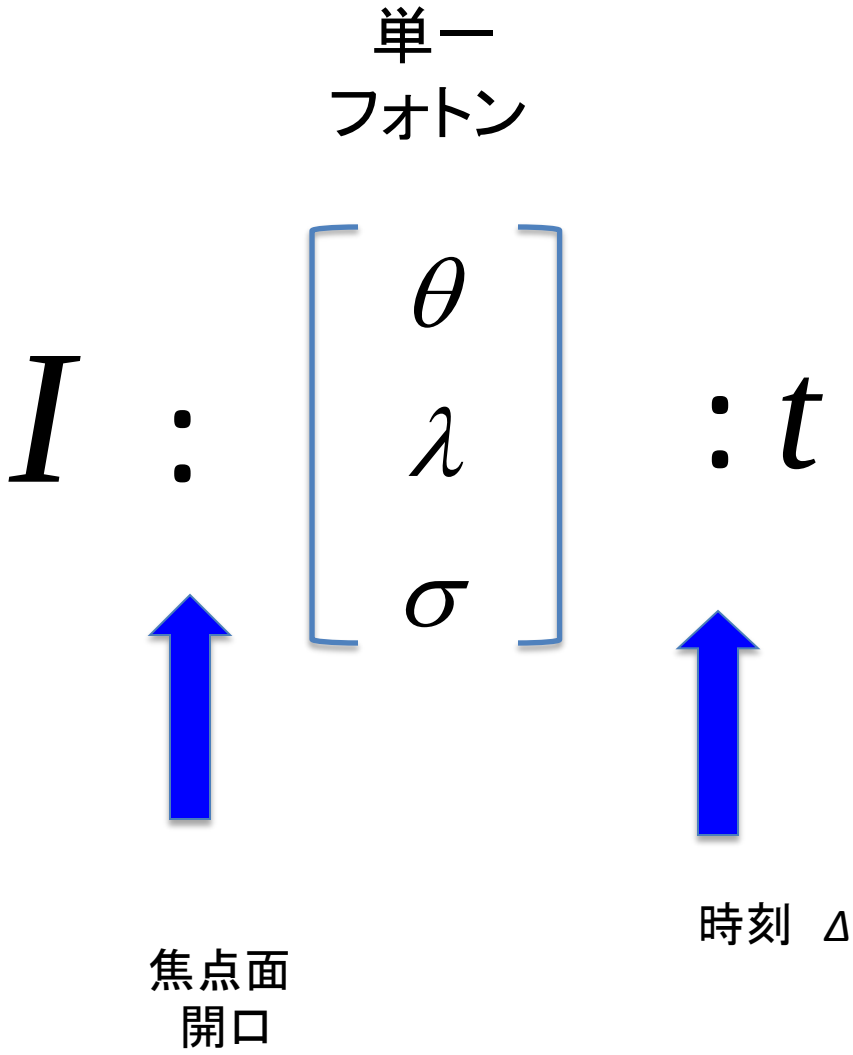
$$\begin{bmatrix} \theta \\ \lambda \\ \sigma \end{bmatrix}$$

方向=direction

スペクトル =specrum
（エネルギー／運動量）

かたより=polarization

View of photometry ： 光計測の見方



$$I : \begin{bmatrix} \theta \\ \lambda \\ \sigma \end{bmatrix} : t$$

Focal plane

Aperture synthesis
Coronagraph

Image slicer
IFS integral field
spectrometer
tiger-spectrograph

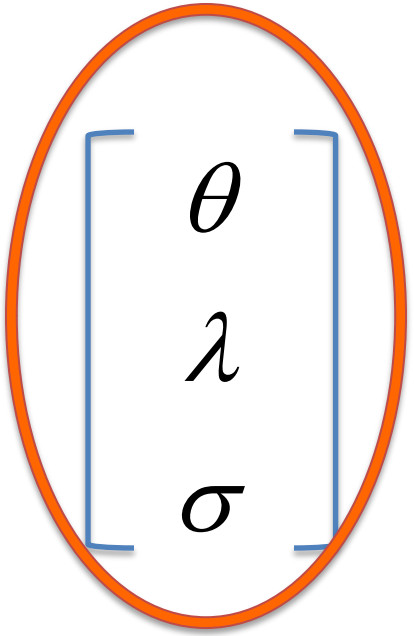
Time : Δt

pulsar
Intensity-interferometer
高速測光計

光計測の見方

Measure of properties
(direction, wavelength and polarization)
of “ensemble” of single photon

フォトンの集合



方向=direction

スペクトル =specrum
（エネルギー／運動量）

かたより=polarization

Measurements of Light/Photon

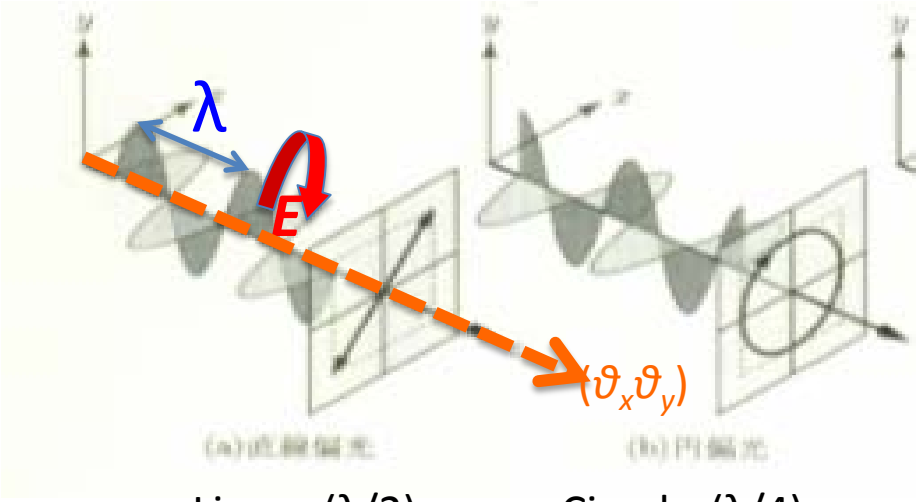
Photon number : *N*, *direction* ϑ: , *momentum* : λ , *spin* : σ *with time*

1) $N(\vartheta_x \vartheta_y)$ vs. direction ($\vartheta_x \vartheta_y \Rightarrow$x,y)
2) $N(\vartheta_y : \underline{\lambda})$ vs. wavelength λ
3) $N(\vartheta_x \vartheta_y : \underline{\sigma})$ vs. Electric Field

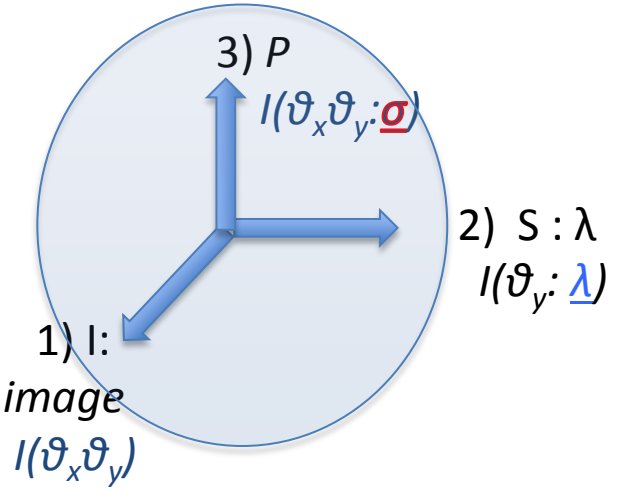
⇒Imaging
⇒Spectroscopy
⇒Polarimetry

$$TRIPOL \equiv I(\theta_x \theta_y : \underline{\lambda} : \underline{\sigma} \,//\, t)$$

Color {g' r' ...}



Linear (λ/2) Circular(λ/4)



方向 θ ⇔ 焦点f: ϑ =>(x : y)

Spectrum λ ⇔ 色-分解

分光 “band”

格子回折 多層膜干涉

sin θ

cos θ

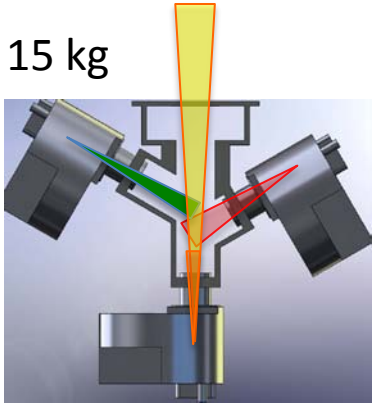
$m\lambda = d\sin\theta$ $\quad m = \dfrac{2d}{\lambda\cos\vartheta}$

偏光 σ ⇔ [内部]自由度 3: *q-, u-, v-*

“bi-refringence” can degenerate

TRIPOL

15 kg



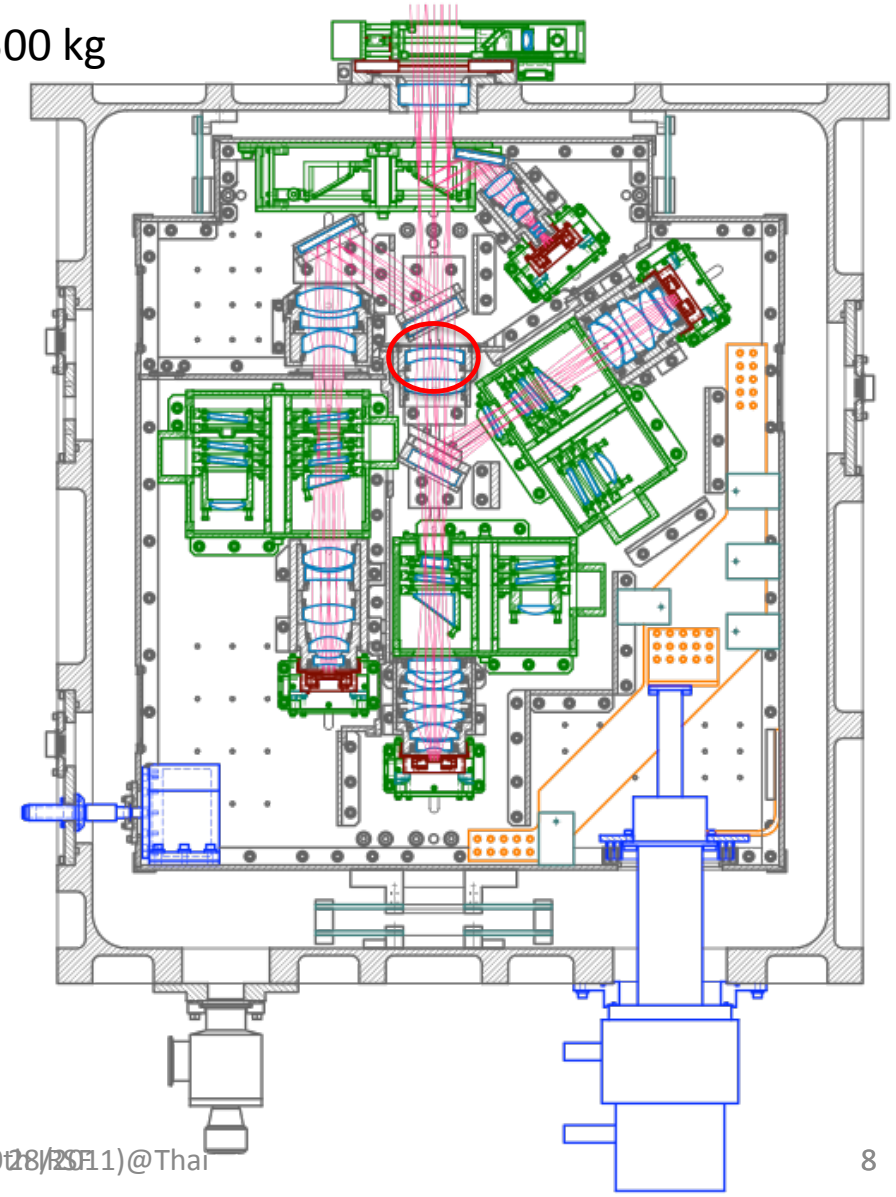
34 cm

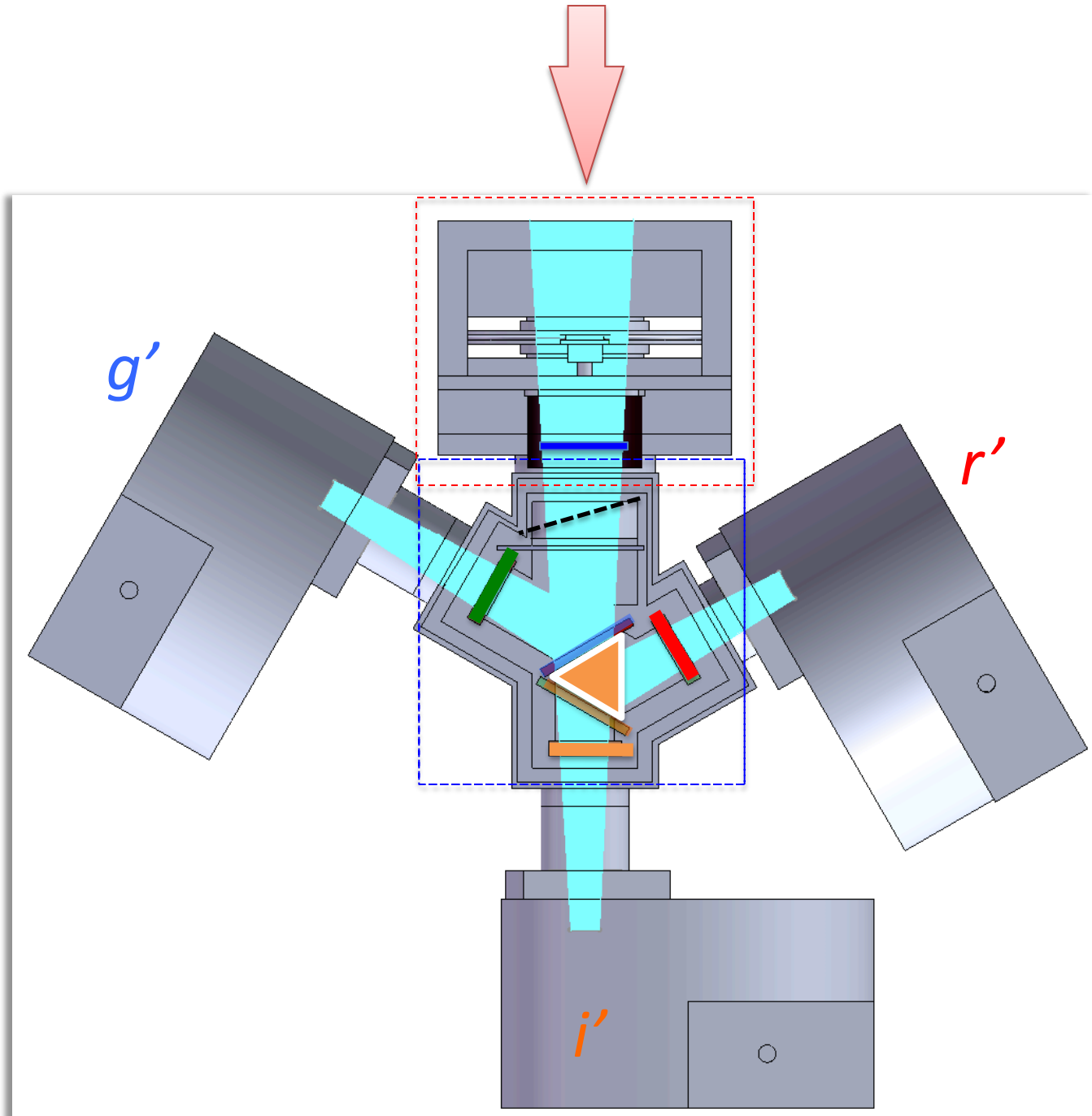
~10 cm

TRISPEC

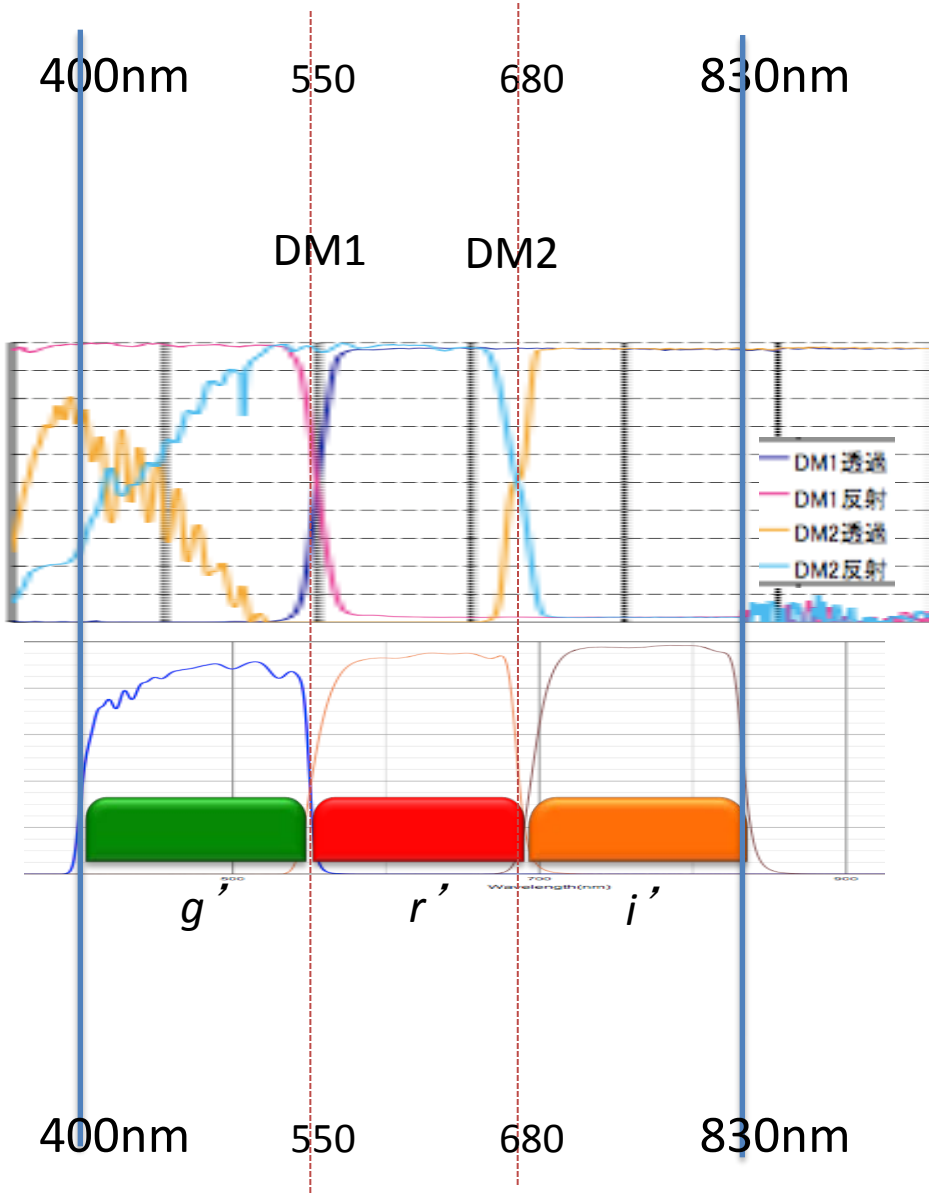
500 kg

1m




g’
r’
i’

③Dichroic mirrors
Transmission/Relection

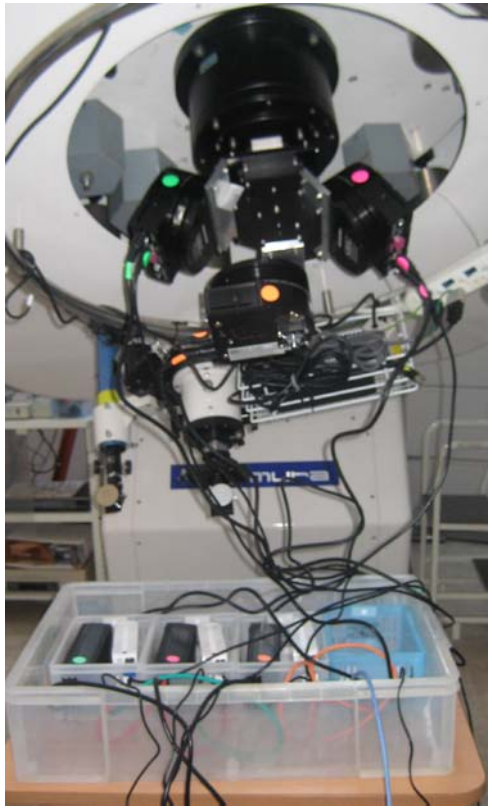


東海光学

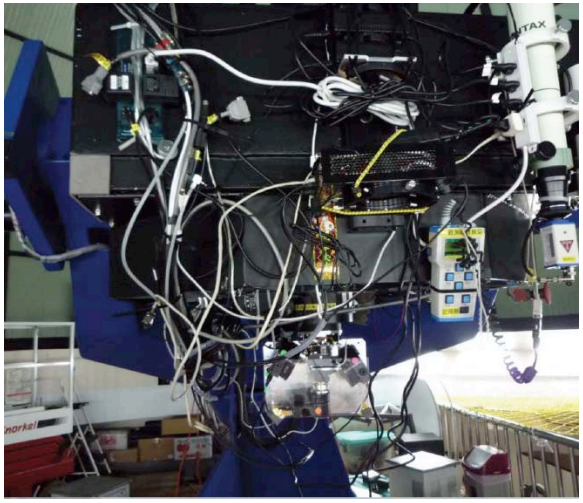
④Bandpass filters
Transmission

朝日分光

*TRIPOL*の写真



2011/01/02
岐阜・安八
70cm望遠鏡



2011/08
台湾・鹿林
100cm望遠鏡

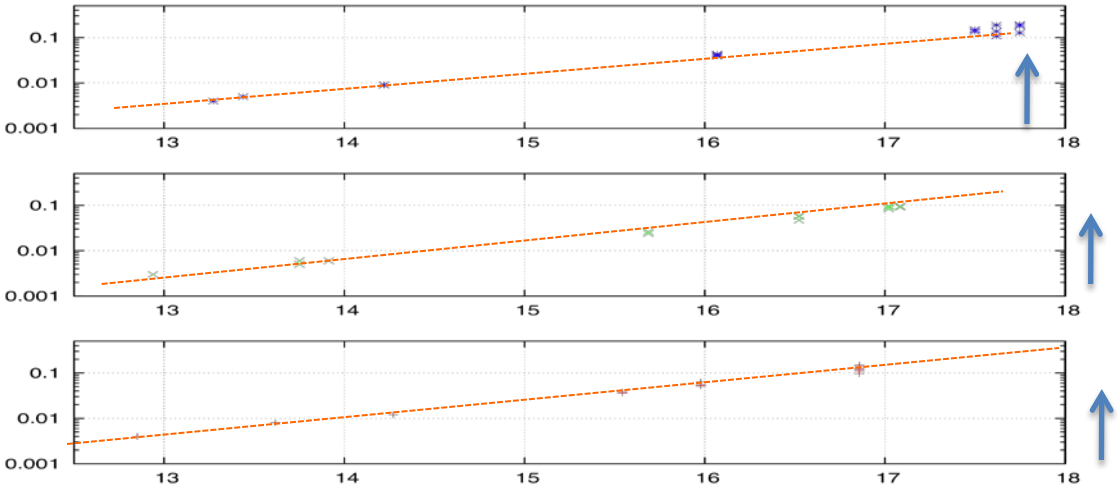
2011/10
南アフリカ
75cm望遠鏡

*TRIPOL*の評価

- 測光（撮像）

限界等級　*g'* ~17.8 等
r' ~18.2 等
i' ~18.3 等

[S/N~3] 60sec
SAAO口径75cm



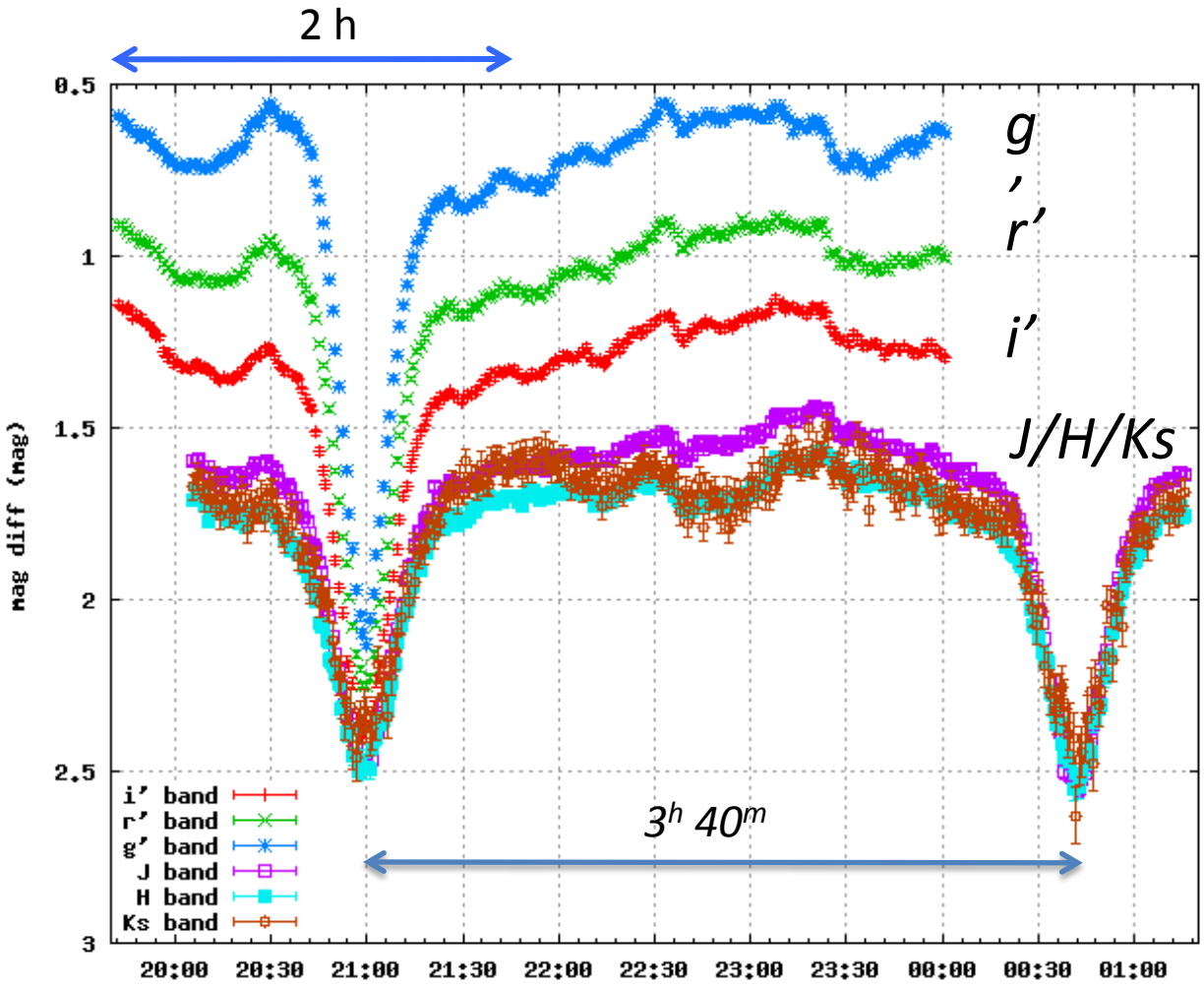
- 偏光

偏光標準星

High-偏光星	Hiltner 960	VI Cyg #12	HD204827	HD155197
Zero-偏光星	HD212311	BD+28_421	BD+32_373	

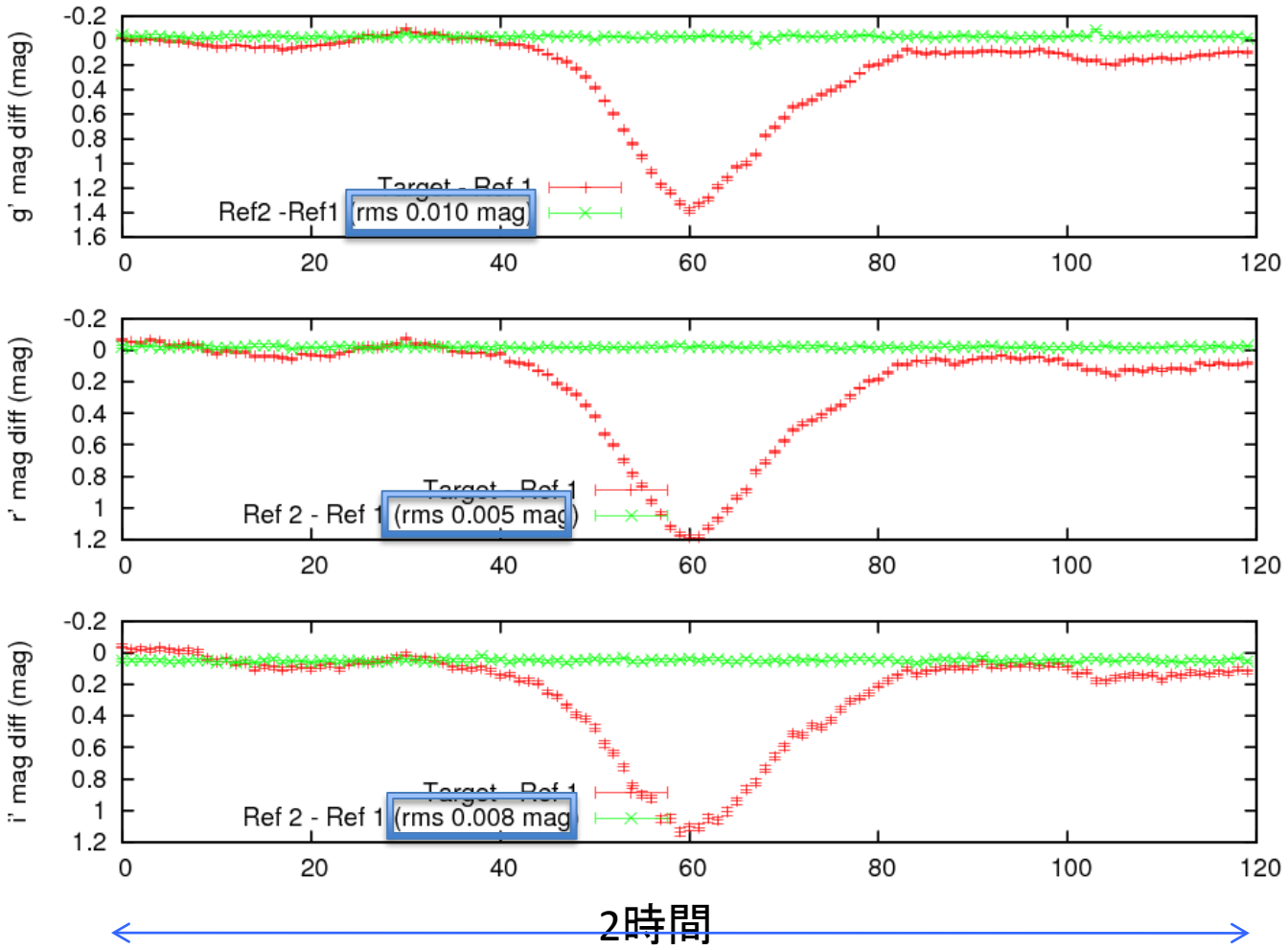
Simultaneous Six-color photometry of EC2117

with TRIPOL on SAAO 75cm + *SIRIUS* on IRSF 1.4m



Long-term Stability

Relative to a reference star R_*-R_{ref}

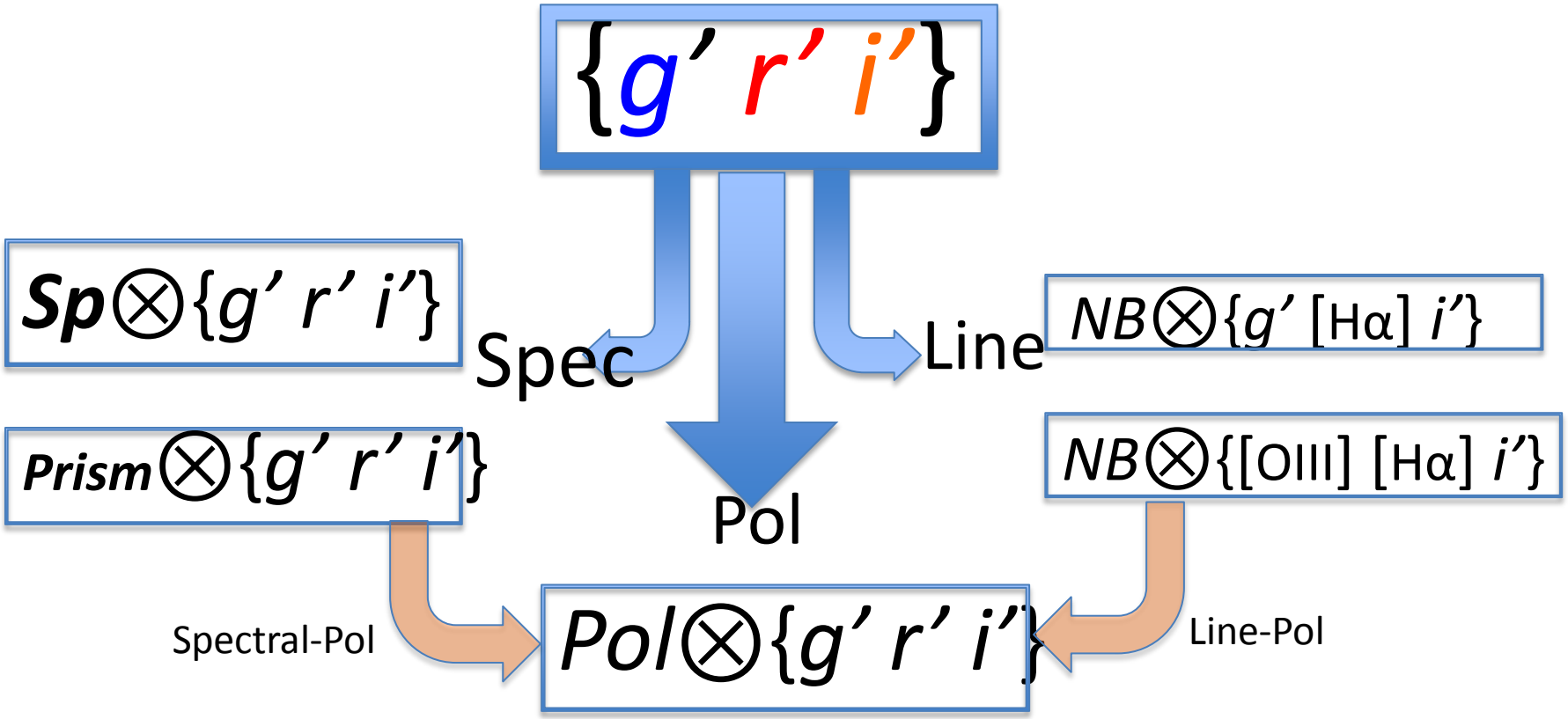


For calibration at Lulin 1m telescope, We measured

- four high polarized standard stars (Hiltner 960, VI Cyg#12, HD155197 , HD204827) and three zero polarized standard stars (BD+28 4211, BD+32373, HD 212311).
- DATA are from Bo-He (NCU)'s analysis;
- ---------- High-polarized ----------
- g' r' i'
- Hiltner 960 5.82±0.21% 6° 5.4±0.11% 6° 4.5±0.14% 11° * 2011.08.17
- VI Cyg#12 9.46±0.05% 8.98±0.06% 7.88±0.05% 2011.06.16
- HD155197 4.18±0.08% 102° 4.38±0.04% 103° 3.69±0.03% 103° # 2011.08.17
- HD204827 4.2% 102° 4.4% 103° 3.9% 103°
- For comparison with the Schmidt et al's. data (1992) at V, R, and I-bands,
- V R I
- Hiltner 960 5.663% 55° 5.210% 55° 4.55% 54° *
- HD 155197 4.320% 103° 4.274% 103° 3.906% 103° #
- ---------- Zero-polarized ----------
- As for instrumental polarization from measurements of non-polarized standard stars,
- on 11, 14, 15, 17 August
- g' r' i'
- HD 212311 q/ u => P±ΔP θ±Δθ q/ u => P±ΔP θ±Δθ q/ u => P±ΔP θ±Δθ
- BD+32373,
- BD+28 4211 as
- 0.3±0.2% 0.4±0.2% 0.3±0.2%

	Pg'	*Pr'*	*Pi'*	*2011.*
V374 Cep	4.79±0.04% (77°)	4.87±0.03% (81°)	4.72±0.05% (74°)	8.17
BD+55 2693	2.63±0.04% (-9°)	2.29±0.06% (-7°)	2.15±0.11% (-2°)	8.17
V1578 Cyg	0.67±0.05% (-1°)	0.35±0.04% (4°)	0.38±0.10% (7°)	8.17
BD+56 2626	2.35±0.02% (-33°)	2.46±0.01% (-27°)	2.70±0.02% (-26°)	8.17
BD+56 563	3.89±0.01% (66°)	3.80±0.01% (69°)	3.24±0.05% (74°)	8.17
V2028 Cyg	3.16±0.09% (3°)	2.85±0.04% (*°)	1.98±0.05% (11°)	8.17
PDS 581	14.01±0.26% (-4°)	15.28±0.14% (-4°)	15.97±0.27% (0°)	8.17
T Tau	0.70±0.14% (22°)	0.63±0.06% (28°)	0.78±0.06% (37°)	8.17
DG Tau	5.90±0.34% (17°)	5.07±0.13% (-87°)	5.45±0.14% (-84°)	8.17
GM Cep	5.61±0.19% (18°)	5.03±0.09% (*°)	4.10±0.10% (28°)	8.17
HL Tau	13.10±0.32% (81°)	13.78±0.14% (85°)	13.49±0.16% (*°)	8.17
BL Lac	9.02±0.13% (-23°)	7.77±0.04% (-19°)	7.81±0.04% (-15°)	8.18
BL Lac	11.93±0.59% (-45°)	10.60±0.25% (-42°)	11.16±0.21% (-37°)	8.18

Extension of TRIPOL



View of astronomical photometry

『光の属性の強度 *I* を、時刻 *t* 毎に測定する』こと
を考える。光の属性とは、①方向(θ_{xy})、②波長(λ)、③偏り(σ)、そして④個数(*I*)、である: *I* (θ_{xy} λσ: *t*)

➔ Intensities (or photon numbers) of properties of photons
(1) direction θ_{xy} , (2) energy=wavelength λ , (3) E-vector=polarization σ,
along with time t : Δt

➔ How to assign/to allocate CCD pixels
to which properties you want?

example
TRIPOL acquires data *I*
of ([撮像 : θ]⊗[分光 : λ]⊗[偏光 : σ])
along with *t*