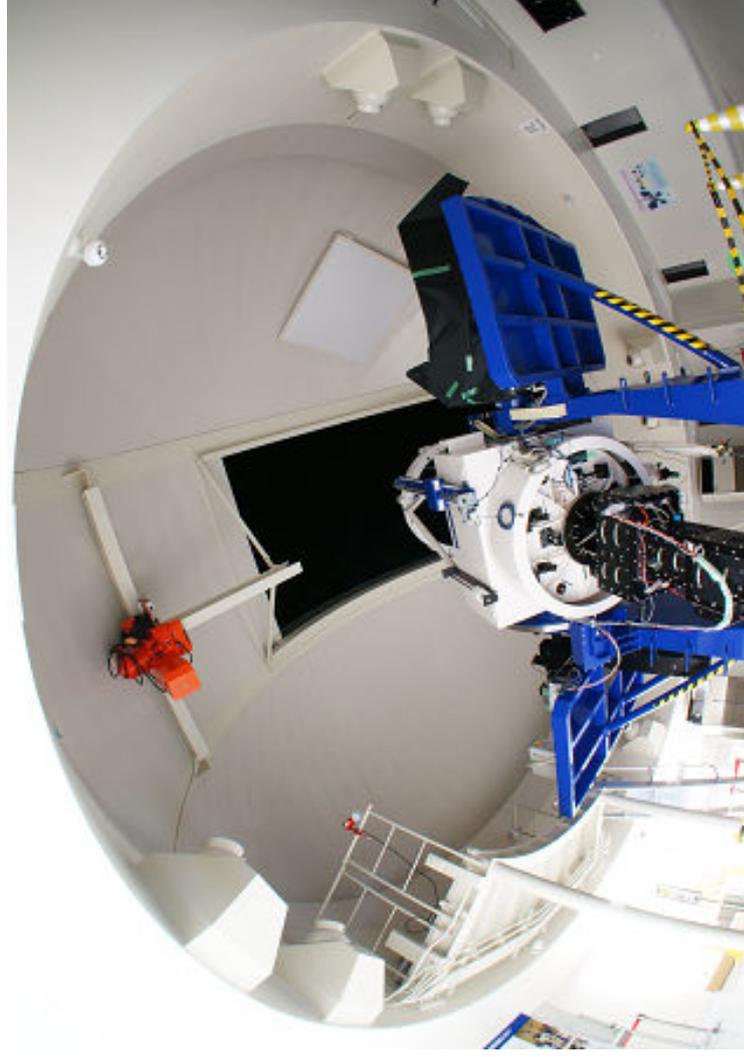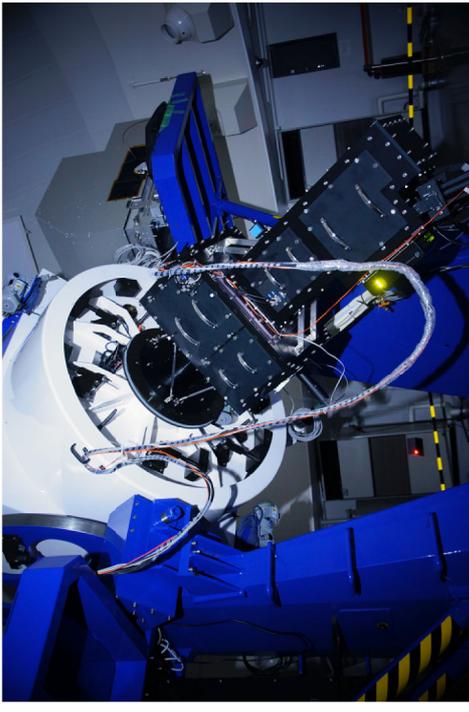# 高分散偏光分光観測装置
VESPolAの開発と初期観測結果

2013/12/17
第3回 可視赤外線観測装置技術ワークショップ
京都産業大学　新崎貴之

1.Introduction

VESPolA : Very precious Echelle Spectro-Polarimeter on Araki-telescope

- LIPS(Ikeda+ 2004)の後継機
- 神山天文台1.3m望遠鏡カセグレン専用機

VESPolA on Araki-telescope

VESPolAとは？

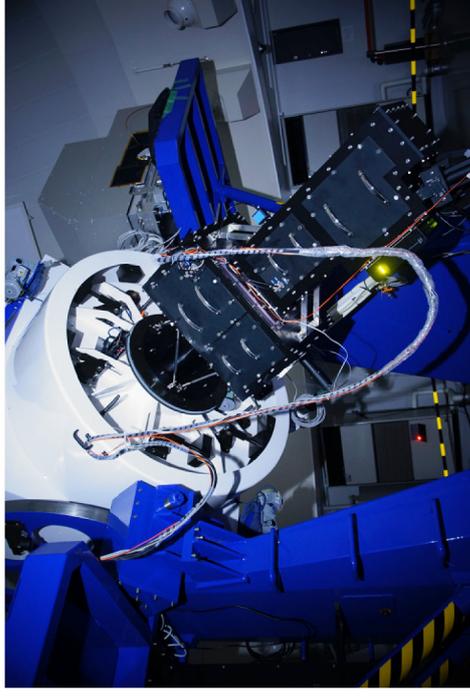突発天体や変光星等の時間変動天体の特に星周ガスの幾何学的構造及び速度場情報を高分散偏光分光観測により解明する事を目指した観測装置

2010年 4月 ： 京都産業大学にてVESPolAの開発がスタート

2012年11月 ： Engineering Firstlight による性能評価

2013年 8月 ： Science Firstlight (P Cyg, β Lry, Nova, etc)

LIPS on UH88

1.Introduction

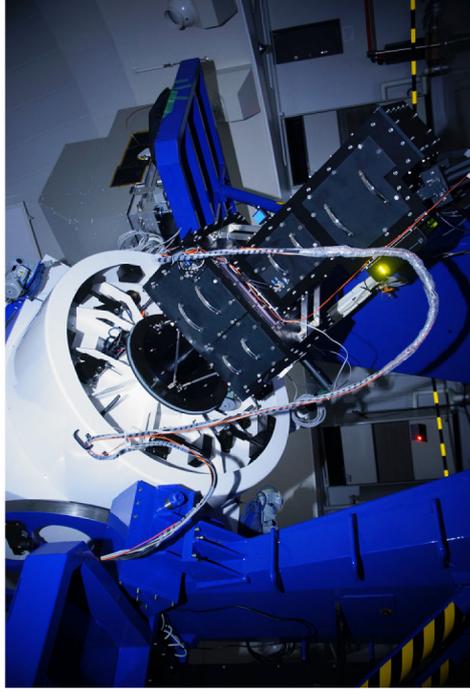## VESPolA : Very precious Echelle Spectro-Polarimeter on Araki-telescope

VESPolA on Araki-telescope

VESPolA仕様

Instrumentation	Specifications
Polarization mode	Liner and Circular
Spectral resolution	R~8,000 and 20,000
Spectral coverage	400 - 850nm
Spectral coverage for single exposure	Δλ=150-300nm
Detector	E2V 2K×2K
Polarimetric accuracy	ΔP<0.1%

1.Introduction

VESPolA : Very precious Echelle Spectro-Polarimeter on Araki-telescope
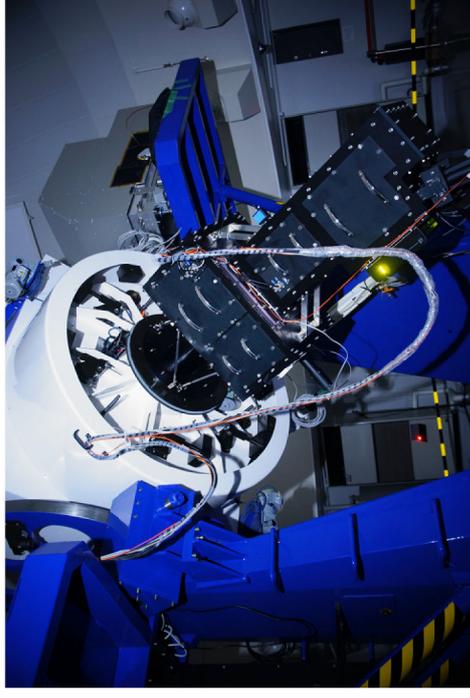

VESPolA on Araki-telescope

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＊現在までにR~8,000の直線偏光分光モードの開発が完了

1.Introduction

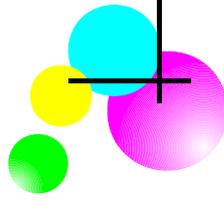## VESPolA : Very precious Echelle Spectro-Polarimeter on Araki-telescope

VESPolA on Araki-telescope

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＊現在までにR~8,000の直線偏光分光モードの開発が完了

＊2014年度にR~20,000 及び 円偏光モードを導入予定

2.Optics

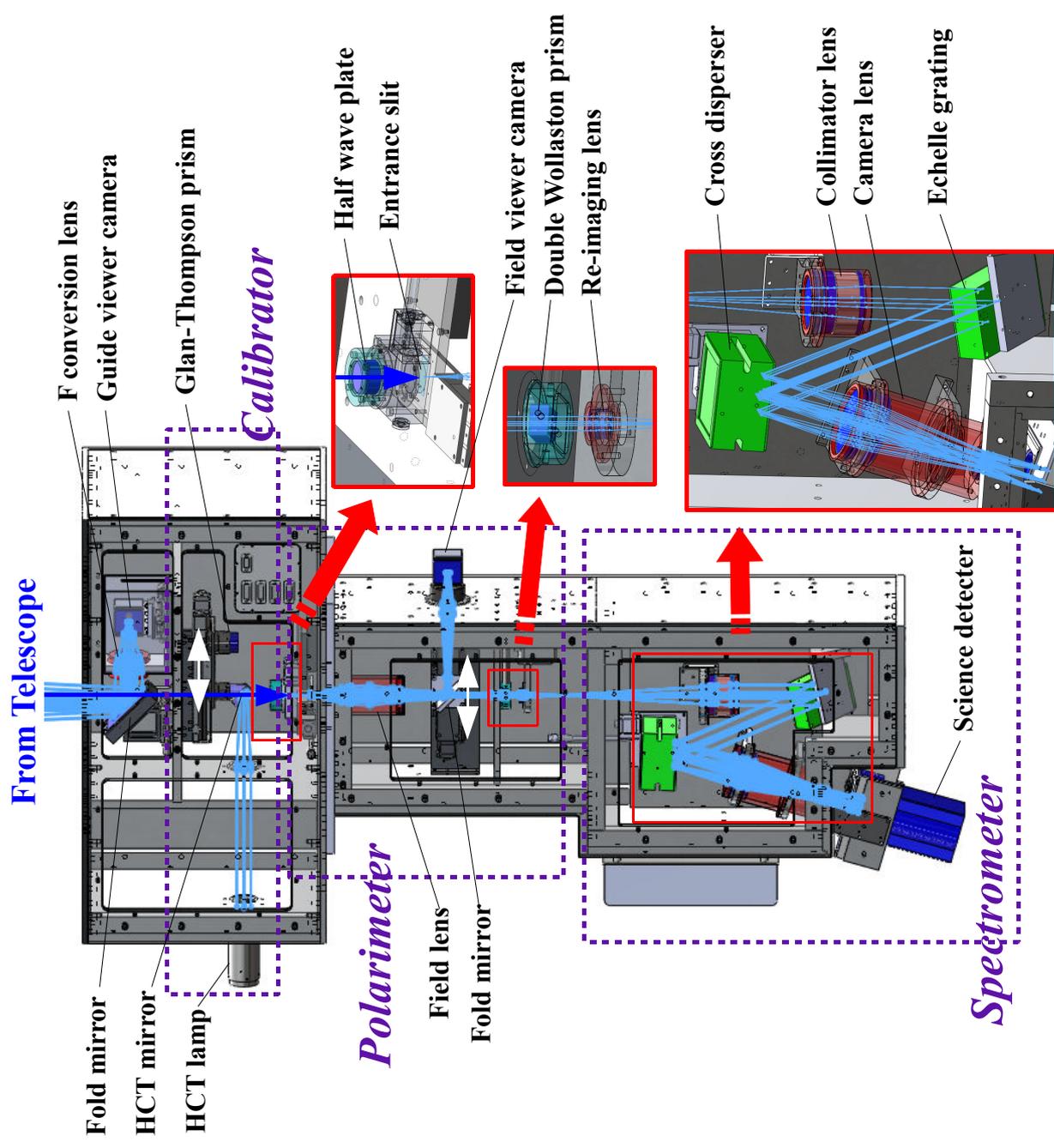- **Calibrator**
- **Polarimeter**
- **Spectrometer**
- ◇ **Auto guider**
- ◇ **Field viewer**

From Telescope

F conversion lens
Guide viewer camera
Glan–Thompson prism
Calibrator

Fold mirror
HCT mirror
HCT lamp

Polarimeter

Field lens
Fold mirror

Half wave plate
Entrance slit

Field viewer camera
Double Wollaston prism
Re-imaging lens

Spectrometer

Science detecter

Cross disperser
Collimator lens
Camera lens
Echelle grating

2.Optics

- **Calibrator** ●
- **Polarimeter** ●
- **Spectrometer** ●
- **Auto guider** ◇
- **Field viewer** ◇

From Telescope

F conversion lens
Guide viewer camera
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Field viewer camera
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Field lens
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Collimator lens
Camera lens
Echelle grating

Science detecter

Spectrometer

2.Optics

● **Polarimeter**

アクリル製無色波長板 + ダブルウォラストンプリズム

Slit width =94um
Half wave plate
S-LAM66
S-FPL53
S-PHM52
S-LAM66
Field lens (f = 84.4mm)
S-NPH1
S-PHM52
S-LAM66
Order sort filter
Double Wollaston prism
Pupil image
Re-imaging lens (f = 65.3mm)
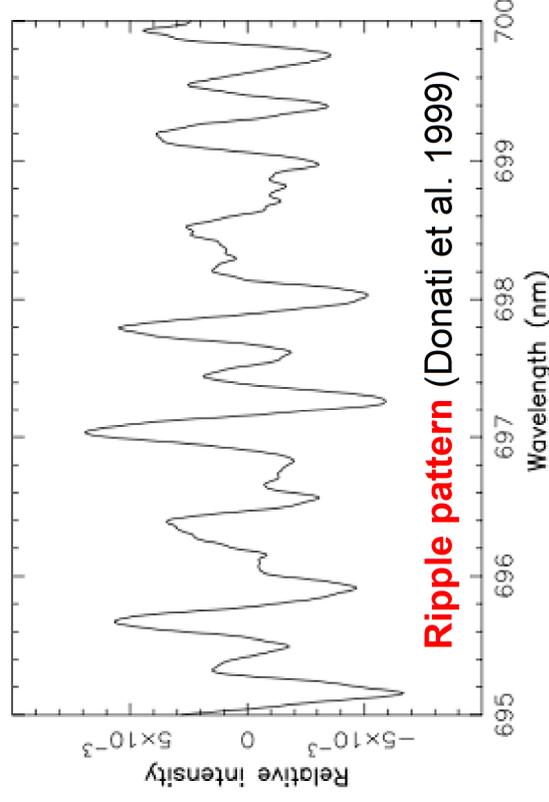S-FPL53
S-LAL18
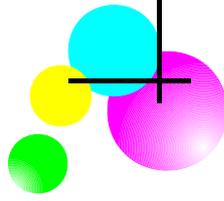S-FPL53
Slit images
e-ray
o-ray
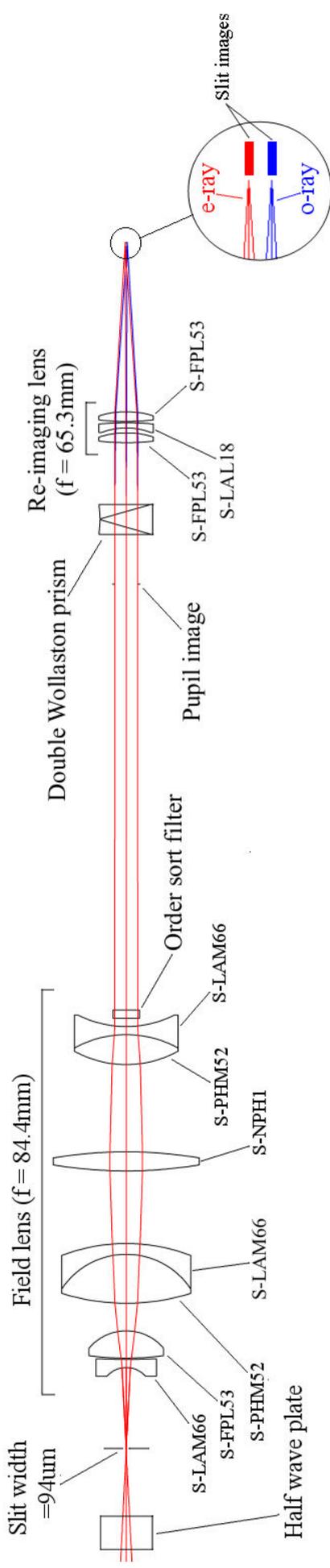
アクリル製無色波長板(Ikeda+ 2004)
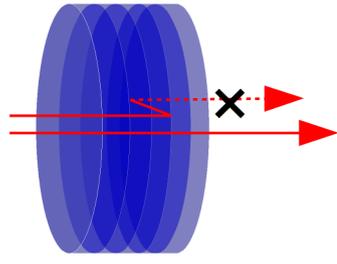
- PMMA(アクリル n=1.49)
  のの5層構造
- アクリルに最適な屈折率
  の接着剤を選択
  (屈折率差: 0.02-0.03)
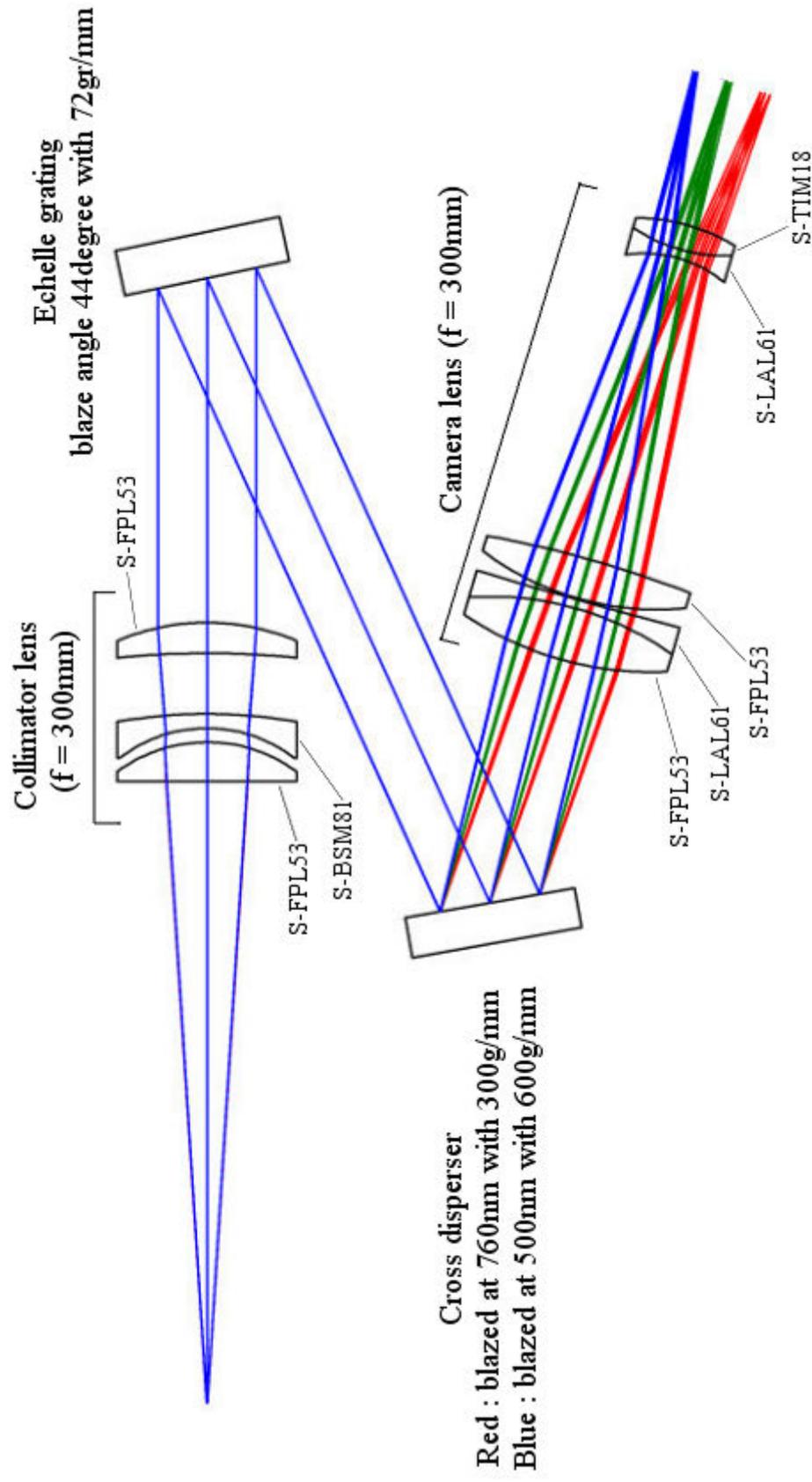
境界面で生じる反射光が無視でき
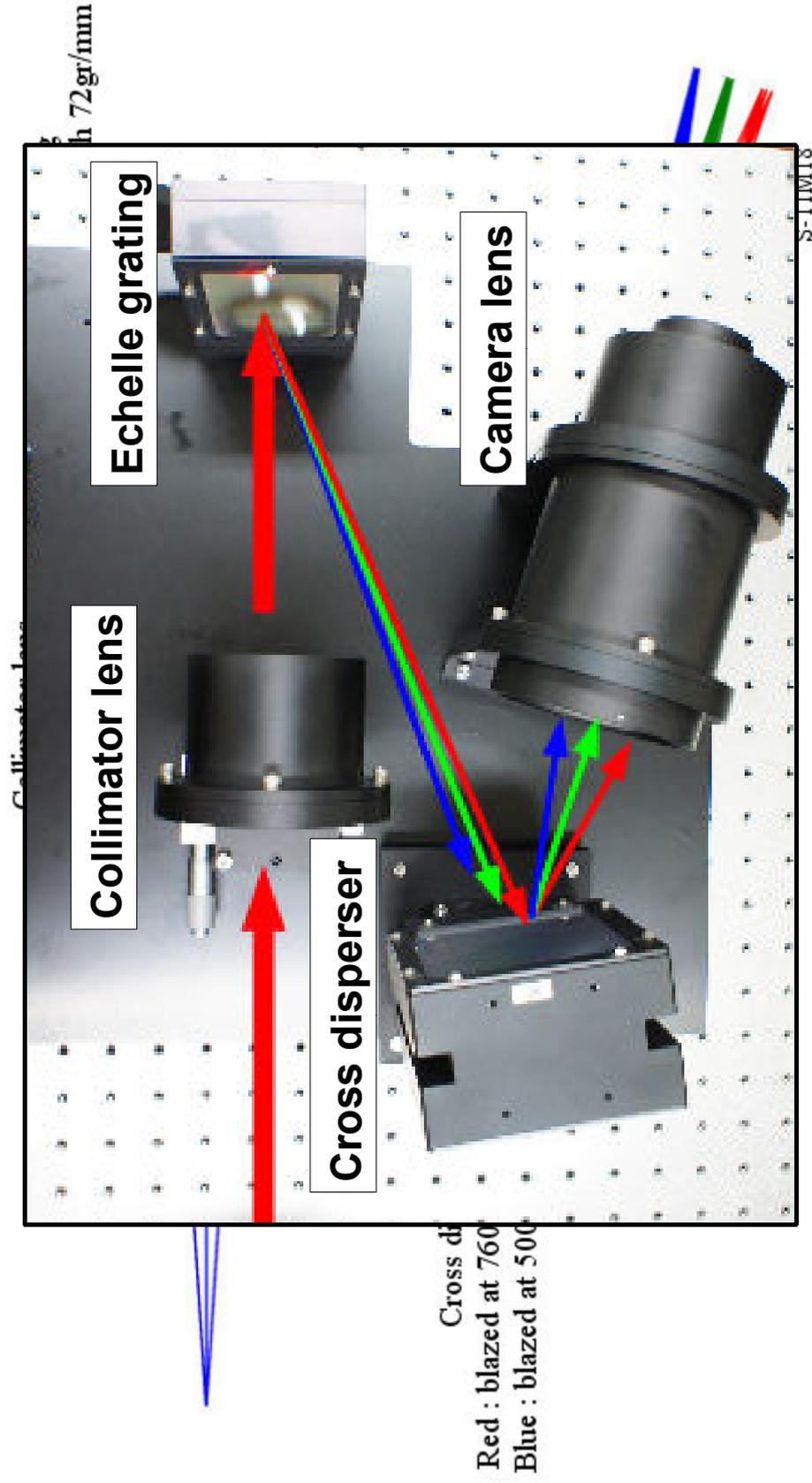Ripple pattern (Donati et al. 1999)の発生を防ぐ

Ripple pattern (Donati et al. 1999)

2.Optics

Spectrometer

Echelle grating + Cross disperser

Echelle grating
blaze angle 44degree with 72gr/mm

Collimator lens
(f = 300mm)

S-FPL53

S-FPL53

S-BSM81

Camera lens (f = 300mm)

S-TIM18

S-LAL61

S-FPL53

S-LAL61

S-FPL53

Cross disperser
Red : blazed at 760nm with 300g/mm
Blue : blazed at 500nm with 600g/mm

2.Optics

● **Spectrometer**

Echelle grating + Cross disperser

2.Optics

● Spectrometer

RED

m = 23	16.8 μm	11.9 μm	13.6 μm
	838.46nm	820.62nm	802.78nm
m = 28	6.1 μm	10.8 μm	5.2 μm
	686.12nm	674.08nm	662.04nm
m = 35	10.5 μm	12.5 μm	15.4 μm
	546.97nm	539.26nm	531.56nm

BLUE

青：常光線
赤：異常光線

m = 36	14.3 μm	12.6 μm	13.5 μm
	531.57nm	524.28nm	517.01nm
m = 42	11.8 μm	4.6 μm	10.1 μm
	454.74nm	449.39nm	444.04nm
m = 48	15.8 μm	8.5 μm	11.9 μm
	397.31nm	393.21nm	389.12nm

□ = 27μm : 2pix×2pix size
右数値：スポットのRMS直径

2.Optics

● Spectrometer
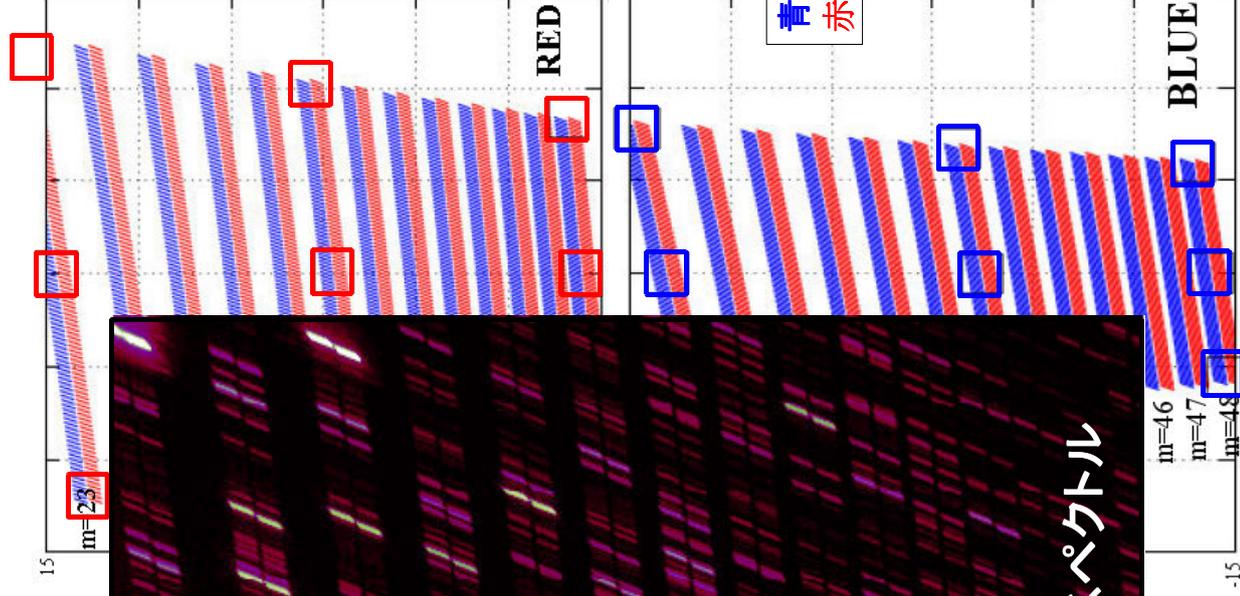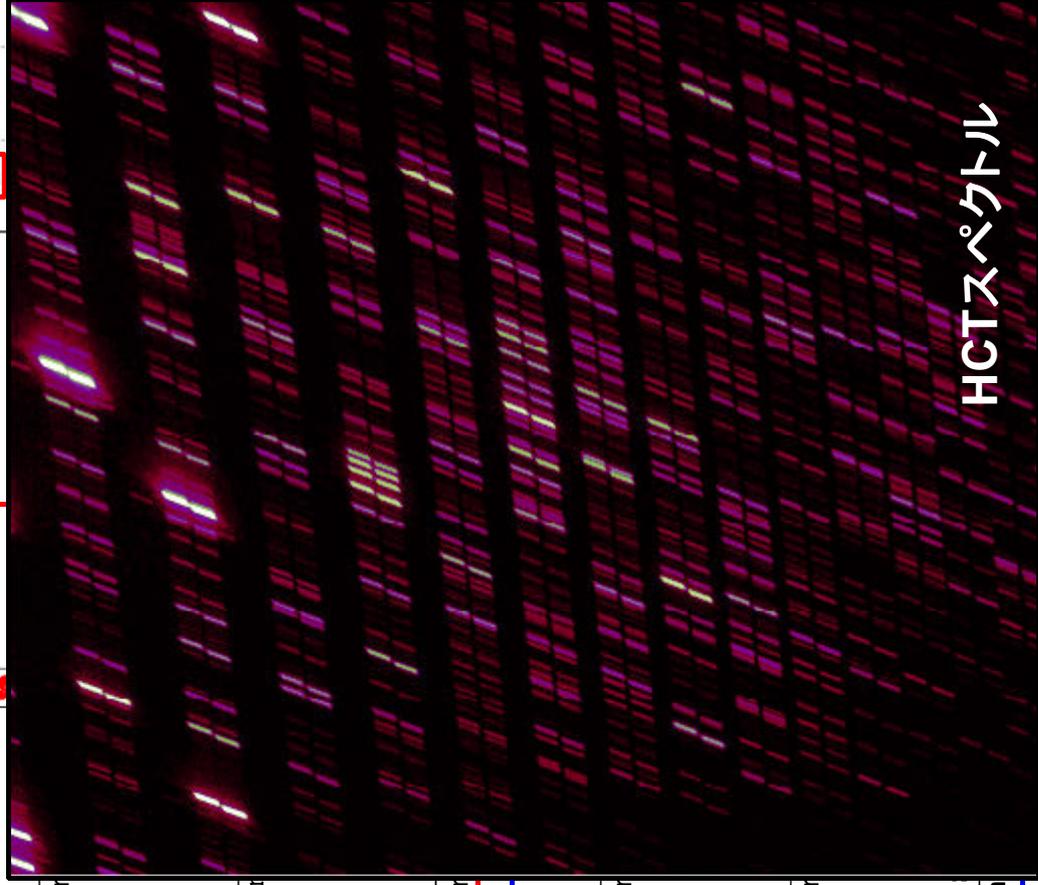

RED

BLUE

青：常光光線
赤：異常光線

HCTスペクトル

m=23

m=46
m=47
m=48

m = 23	16.8 μm	820.62m
	838.46nm	
m = 28	6.1 μm	674. 08m
	686. 12nm	
m = 35	10.5 μm	539.26m
	546.97nm	

m = 36	14.3 μm	524.28m
	531.57nm	
m = 42	11.8 μm	449.39m
	454.74nm	
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	397.31nm	

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右数値：スポットのRMS直径

3.Performance evaluation

- Resolution
- Polarimetric accuracy
- Position angle accuracy
- Equipment efficiency
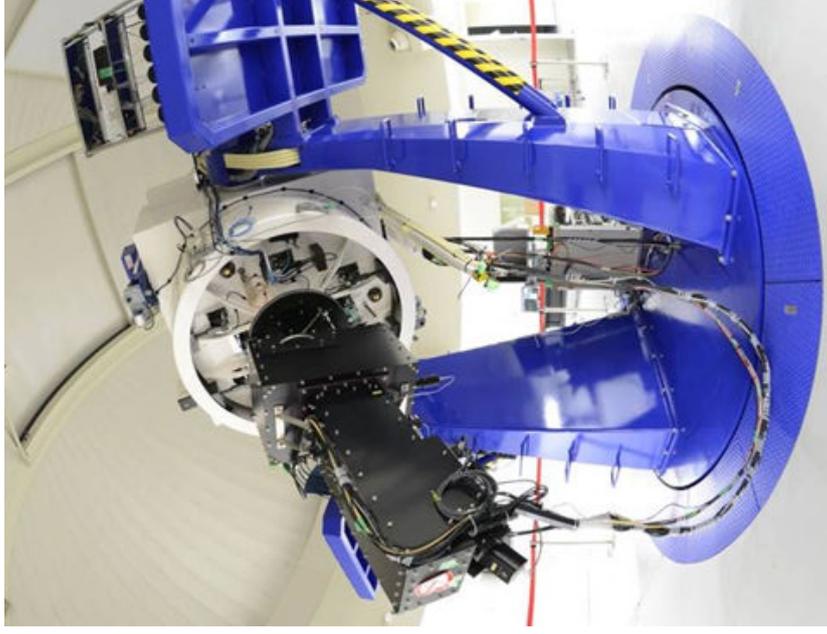
3.Performance evaluation
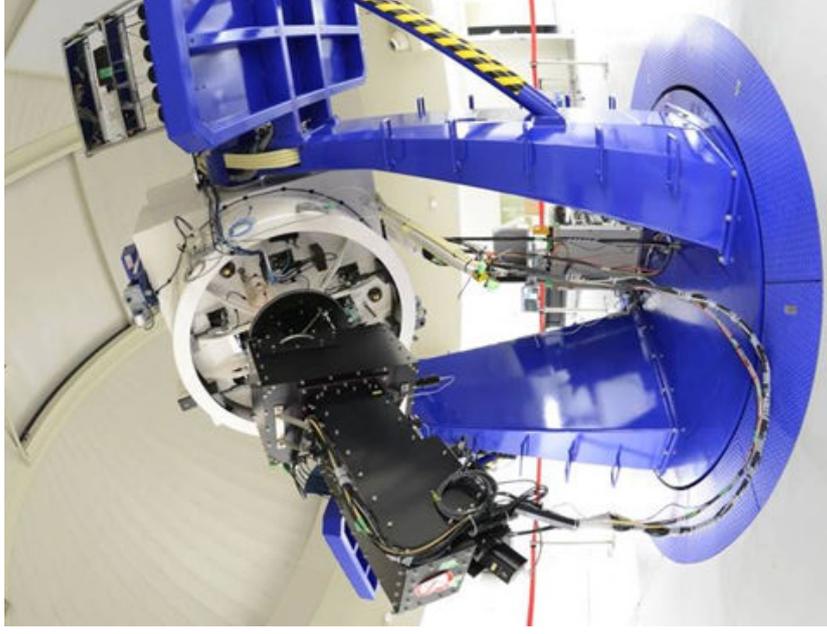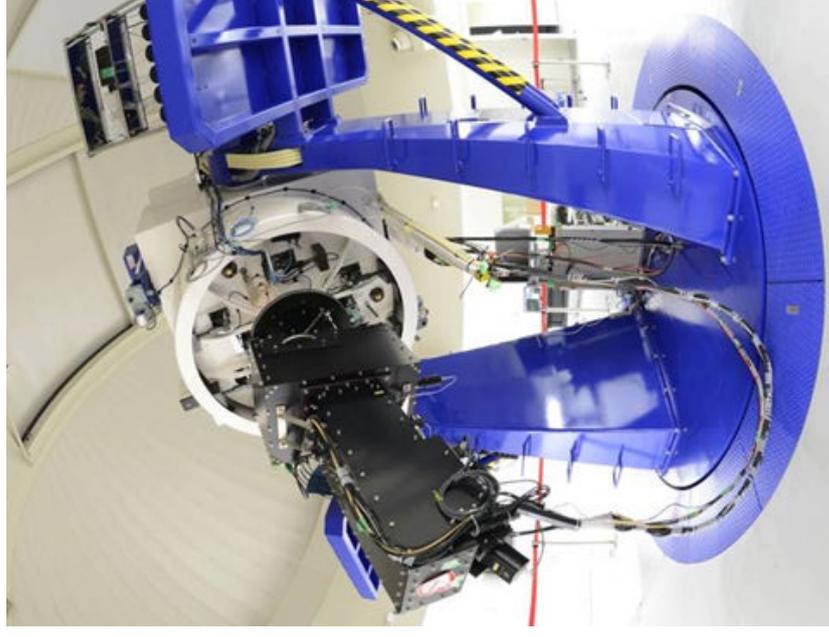

- Resolution

- Polarimetric accuracy

- Position angle accuracy

- Equipment efficiency

3.Performance evaluation

● **Polarimetric accuracy**

・偏光度が小さい場合
→ランダム成分による影響が大きいため
無偏光標準星を用いた評価を行う

・偏光度が大きい場合
→偏光度に依存した成分が影響するため
強偏光標準星を用いた評価を行う

3.Performance evaluation

● **Polarimetric accuracy**

UP(UnPolarized standard star)を用いた評価

・ UPスペクトル例

Date	JD	Sec
UP: HD47105 (A0IV,mv=1.93,Pv=0.22%)		
2012 Nov 27 …	2456259.1819	60s×4
2012 Nov 28 …	2456260.1555	60s×4
2012 Nov 29 …	2456261.2791	60s×4
2012 Dec 14 …	2456276.2263	60s×4
2013 Jan 12 …	2456304.9923	60s×4
2013 Jan 18 …	2456311.0854	60s×4
2013 Jan 30 …	2456322.9666	60s×4
2013 Jan 31 …	2456323.9763	60s×4
UP: HD45418 (A1V,mv=2.37,Pv=0.18%)		
2012 Nov 27 …	2456259.2555	60s×4
2012 Nov 28 …	2456260.2333	180s×4
2012 Nov 29 …	2456261.2472	60s×4
2012 Dec 14 …	2456276.1895	60s×4
UP: HD39587 (G0V,mv=4.40,Pv=1.30%)		
2012 Nov 27 …	2456259.2875	180s×4
2012 Nov 28 …	2456260.2576	200s×4
2012 Nov 29 …	2456261.2604	120s×4
2012 Dec 14 …	2456276.2055	180s×4
2013 Jan 12 …	2456305.0375	100s×4
UP: HD61421 (F5IV,mv=0.37,Pv=0.50%)		
2012 Nov 29 …	2456261.2347	30s×4
2012 Dec 14 …	2456276.1791	30s×4
2013 Jan 11 …	2456304.1250	30s×4
2013 Jan 12 …	2456305.0527	15s×4
2013 Jan 18 …	2456311.1409	30s×4
2013 Jan 30 …	2456322.9888	30s×4

評価に用いたUPの観測ログ

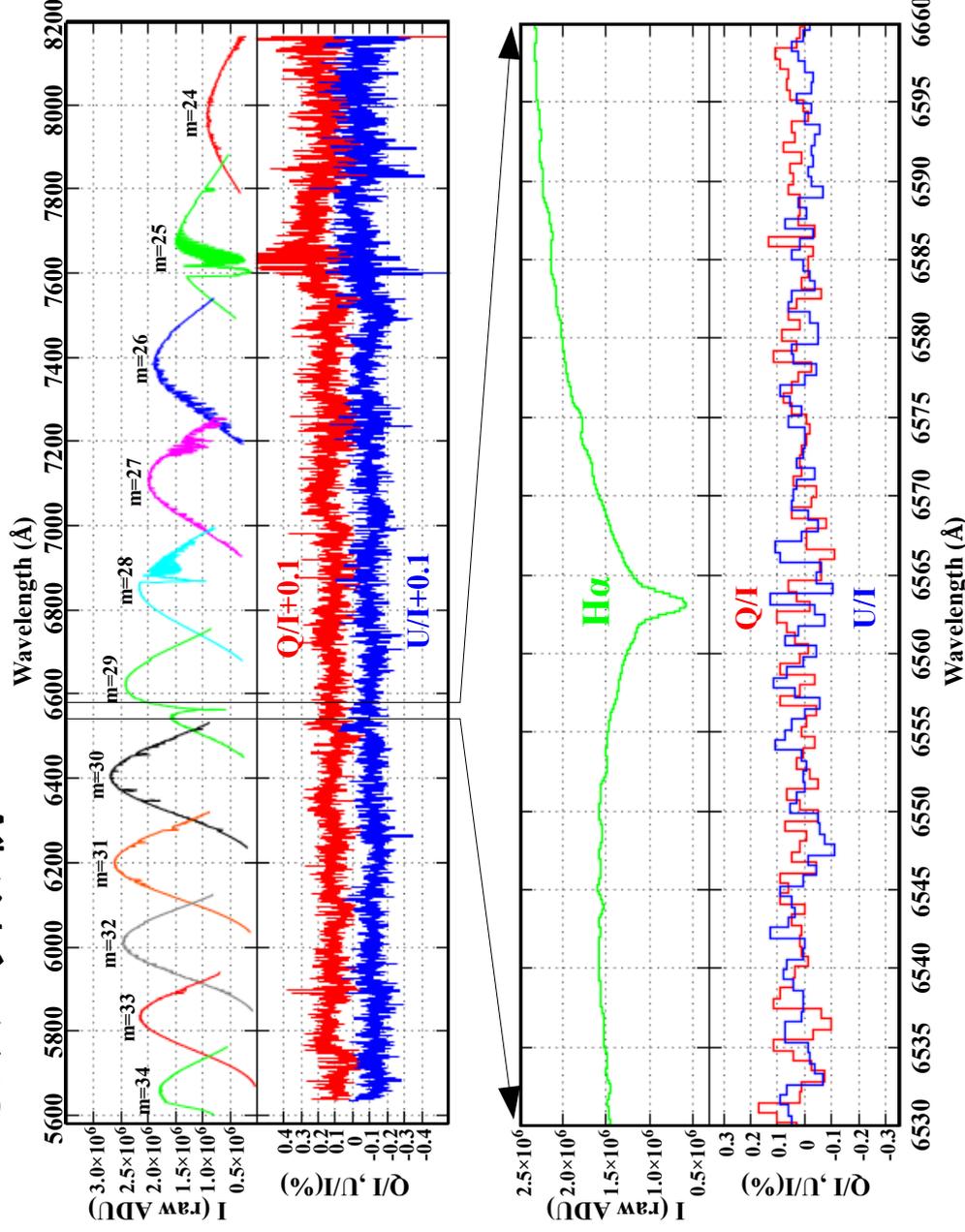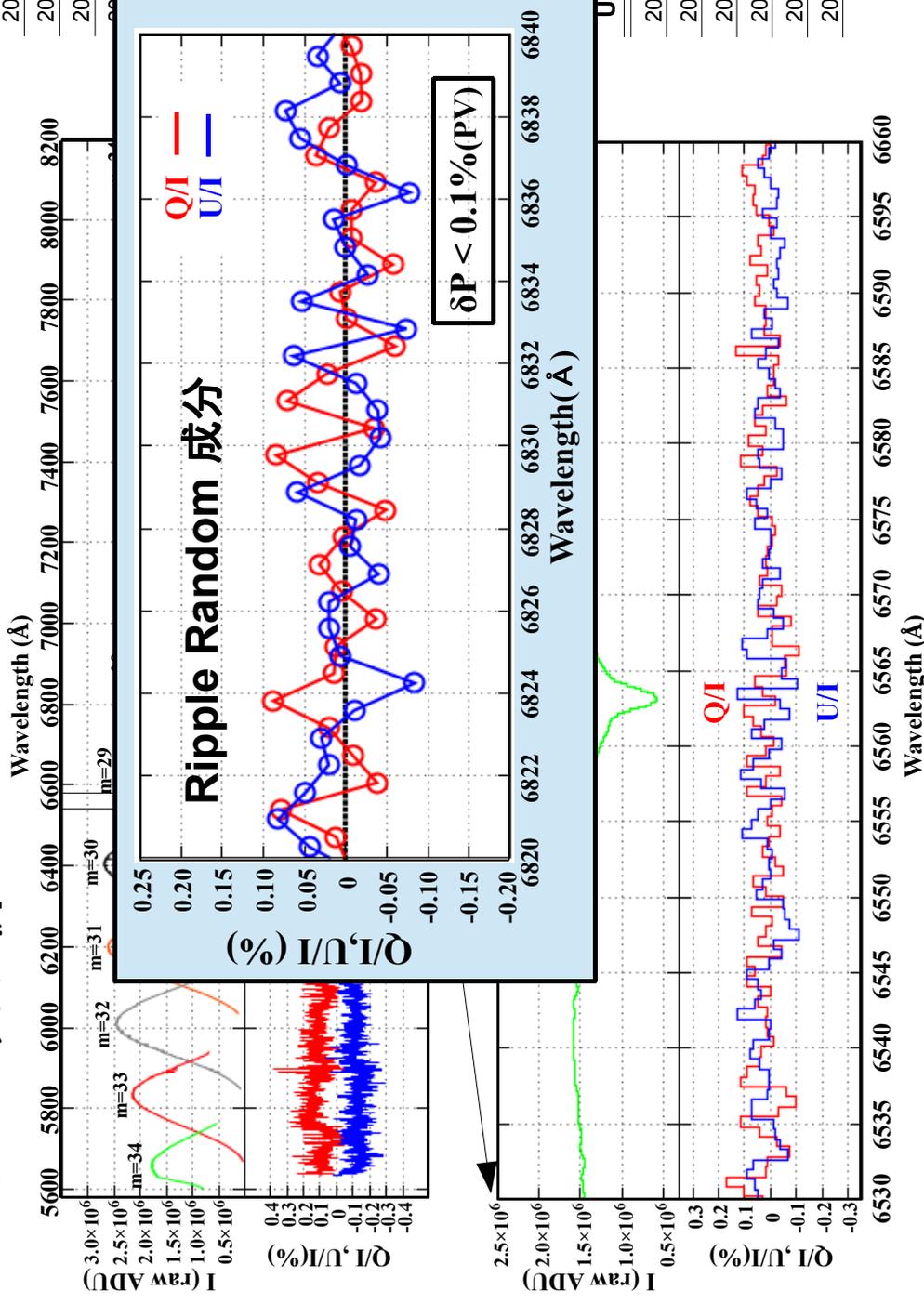# 3.Performance evaluation

● **Polarimetric accuracy**

UP(UnPolarized standard star)を用いた評価

・UPスペクトル例

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UP: HD47105 (A0IV,mv=1.93,Pv=0.22%)		
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2013 Jan 18 …	2456311.0854	60s×4
2013 Jan 30 …	2456322.9666	60s×4
2013 Jan 31 …	2456323.9763	60s×4
P: HD45418 (A1V,mv=2.37,Pv=0.18%)		
2 Nov 27 …	2456259.2555	60s×4
2 Nov 28 …	2456260.2333	180s×4
2 Nov 29 …	2456261.2472	60s×4
2 Dec 14 …	2456276.1895	60s×4
P: HD39587 (G0V,mv=4.40,Pv=1.30%)		
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2 Nov 28 …	2456260.2576	200s×4
2 Nov 29 …	2456261.2604	120s×4
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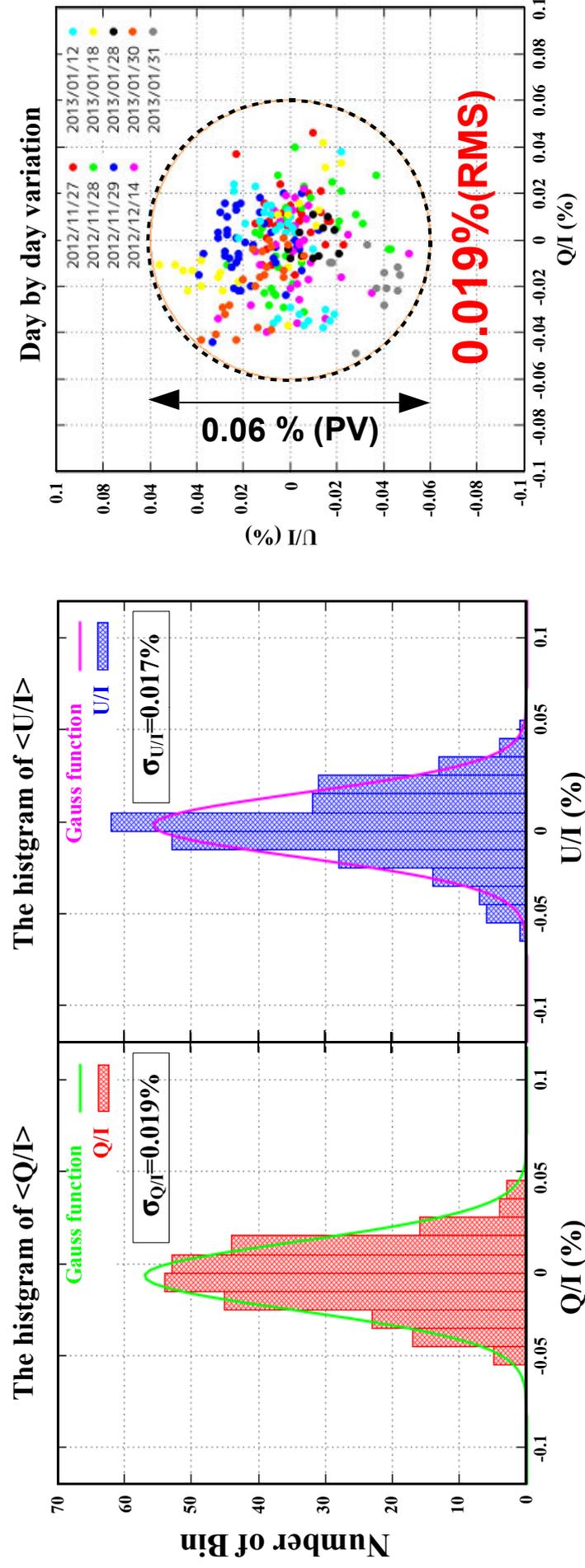評価に用いたUPの観測ログ

Ripple Random 成分

$\delta P < 0.1\%$(PV)

Q/I — (red)
U/I — (blue)

$Q/I, U/I$ (%)

Wavelength (Å)

I (raw ADU)

$m=29$, $m=30$, $m=31$, $m=32$, $m=33$, $m=34$

リップルはなにか。

3.Performance evaluation

● **Polarimetric accuracy**

UP(UnPolarized standard star)を用いた評価

The histgram of <Q/I>

The histgram of <U/I>

$\sigma_{Q/I}$=0.019%

Gauss function
Q/I

$\sigma_{U/I}$=0.017%

Gauss function
U/I

Number of Bin

Q/I (%)

U/I (%)

Day by day variation

2012/11/27　2013/01/12
2012/11/28　2013/01/18
2012/11/29　2013/01/28
2012/12/14　2013/01/30
　　　　　　　2013/01/31

0.06 % (PV)

0.019%(RMS)

U/I (%)

Q/I (%)

偏光度が小さい場合の

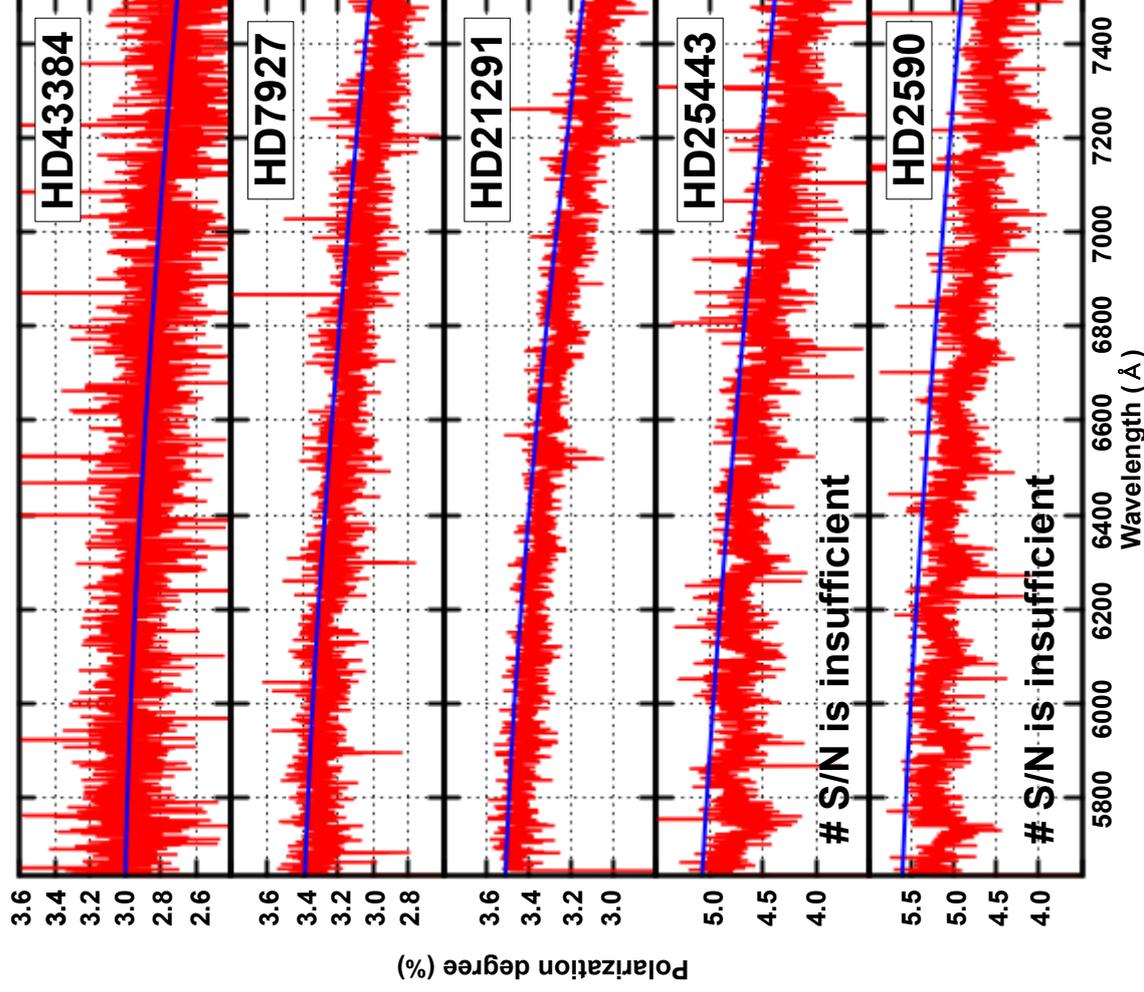　偏光測定精度評価結果 ： δP_{UP} = 0.019%(RMS)

　　　　　　　　　　　　　　δP_{ripple} = 0.1%(PV)

$\delta P_{P\ll 0} \fallingdotseq \sqrt{(0.1)^2}$ %

3.Performance evaluation

● **Polarimetric accuracy**

SP(Strong Polarized standard star)を用いた評価

SPに現れる星間偏光スペクトル
→ Serkowski curve(Whittet+ 1992)で再現

$$p(\lambda) = P_{max} \exp\left[-K\ln^2\left(\frac{\lambda_{max}}{\lambda}\right)\right]$$

$$K = 1.66(\lambda_{max}/10^4 nm) + 0.01$$

偏光が大きくなるとSerkowski curveとのズレ
が0.数%レベルで発生する傾向が見られる

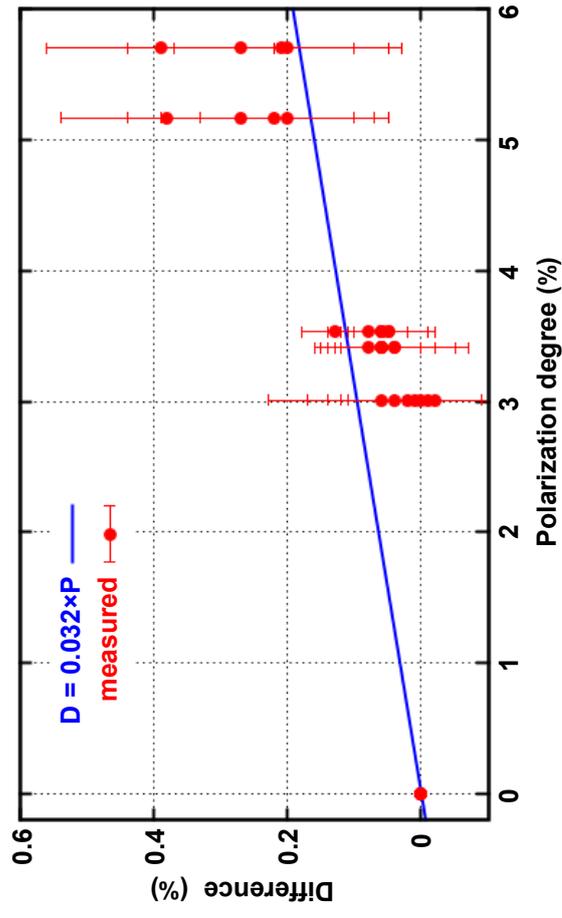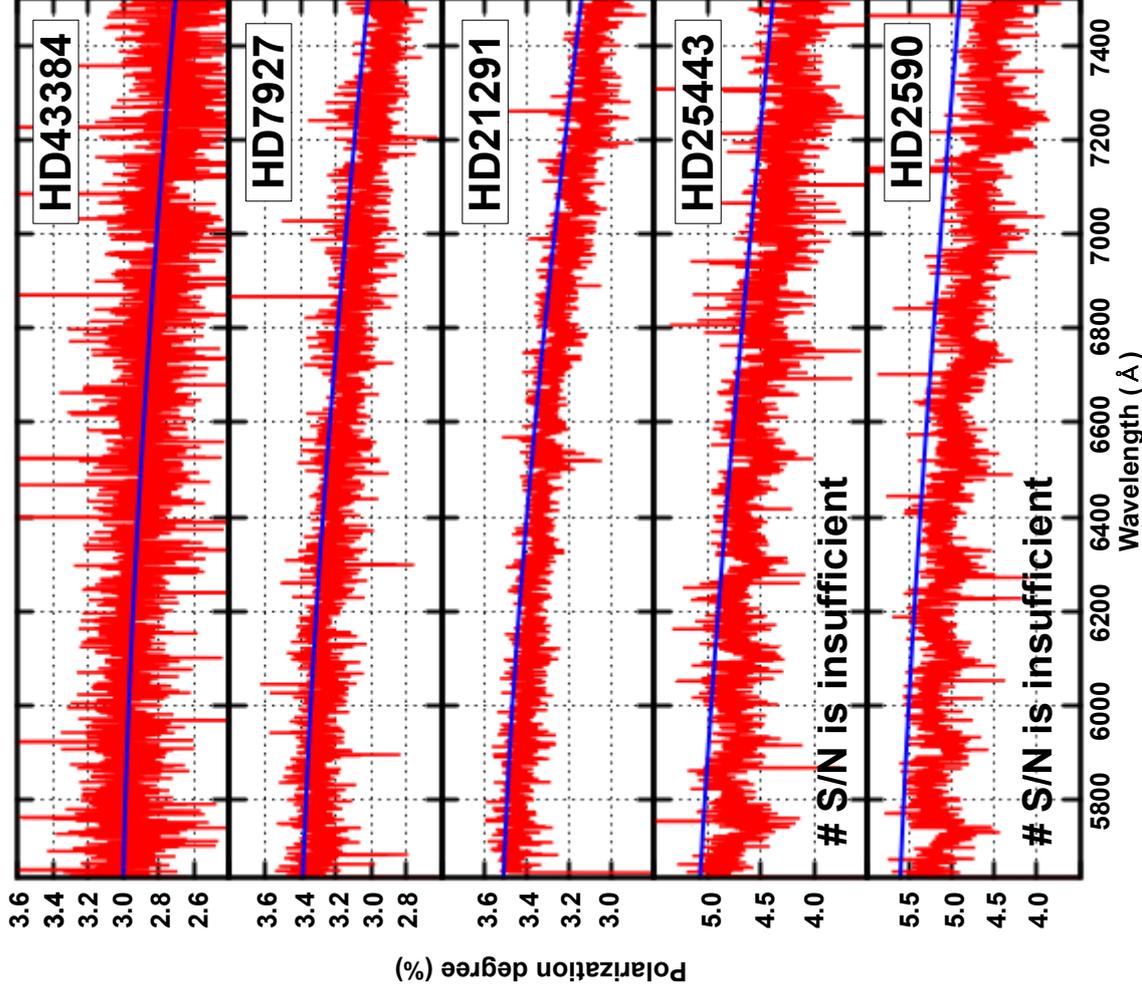➡ Pに依存した成分が存在

$$\delta P_{P\gg0} \fallingdotseq \sqrt{(\mathbf{a \times P})^2}\ \%$$

Star	Pmax	λmax	Date	JD	Sec
HD43384	3.01	531nm	2013 Jan 31 …	2456324.0520	60s×4
HD7927	3.29	510nm	2013 Nov 19 …	2456616.0520	60s×4
HD21291	3.53	521nm	2013 Nov 08 …	2456605.0625	60s×4
HD25443	5.20	471nm	2013 Nov 18 …	2456615.0937	60s×4
HD2590	5.70	490nm	2013 Nov 15 …	2456612.0625	60s×4

評価に用いたSP観測ログ

HD43384
HD7927
HD21291
HD25443
HD2590

S/N is insufficient
S/N is insufficient

Polarization degree (%)

Wavelength (Å)

3.Performance evaluation

● Polarimetric accuracy

SP(Strong Polarized standard star)を用いた評価

$$\delta P_{P\gg0} \doteqdot \sqrt{(0.03 \times P)^2}\ \%$$

より詳細な評価には6%以上の偏光の測定が必要

評価に用いたSP観測ログ

Star	Pmax	λmax	Date	JD	Sec
HD43384	3.01	531nm	2013 Jan 31 …	2456324.0520	60s×4
HD7927	3.29	510nm	2013 Nov 19 …	2456616.0520	60s×4
HD21291	3.53	521nm	2013 Nov 08 …	2456605.0625	60s×4
HD25443	5.20	471nm	2013 Nov 18 …	2456615.0937	60s×4
HD2590	5.70	490nm	2013 Nov 15 …	2456612.0625	60s×4

3.Performance evaluation

● **Polarimetric accuracy (Total)**

偏光度が小さい場合の
偏光測定精度評価結果 : $\delta P_{UP} = 0.019\%$ (RMS)
$\delta P_{ripple} = 0.1\%$ (PV)

→ $\delta P_{P \ll 0} \fallingdotseq \sqrt{(0.1)^2}$ %

偏光度が大きい場合の
偏光測定精度評価結果 : $\delta P_{SP} = \sqrt{(0.03P)^2}$ %

→ $\delta P_{P \gg 0} \fallingdotseq \sqrt{(0.03P)^2}$ %

⬆ $\delta P \fallingdotseq \sqrt{(0.1)^2 + (0.03P)^2}$ %

3.Performance evaluation

● **Summary**

VESPoIA性能評価値

Instrumentation	Specifications	Evaluation result
Polarization mode	Liner and Circular	Liner
Spectral resolution	R~8,000 and 20,000	R~8,000
Spectral coverage	400 - 850nm	550-810nm (Red mode)
Spectral coverage for single exposure	$\delta\lambda$=150-300nm	$\delta\lambda$=150-300nm
Position angle accuracy	$\delta\theta$<1deg	$\delta\theta$<1deg
Polarimetric accuracy	δP<0.1%	$\delta P \fallingdotseq \sqrt{(0.1)^2+(0.03P)^2}$ %
Efficiency (max)	18.0% (m=30)	20.0% (m=30)
Limiting magnitude : R=8,000	7.9mag (ΔP~0.1%)	8.0mag (ΔP~0.1%)
: R=20,000	6.5mag (ΔP~0.1%)	-

＊現在までにR~8,000の直線偏光分光モードの開発が完了

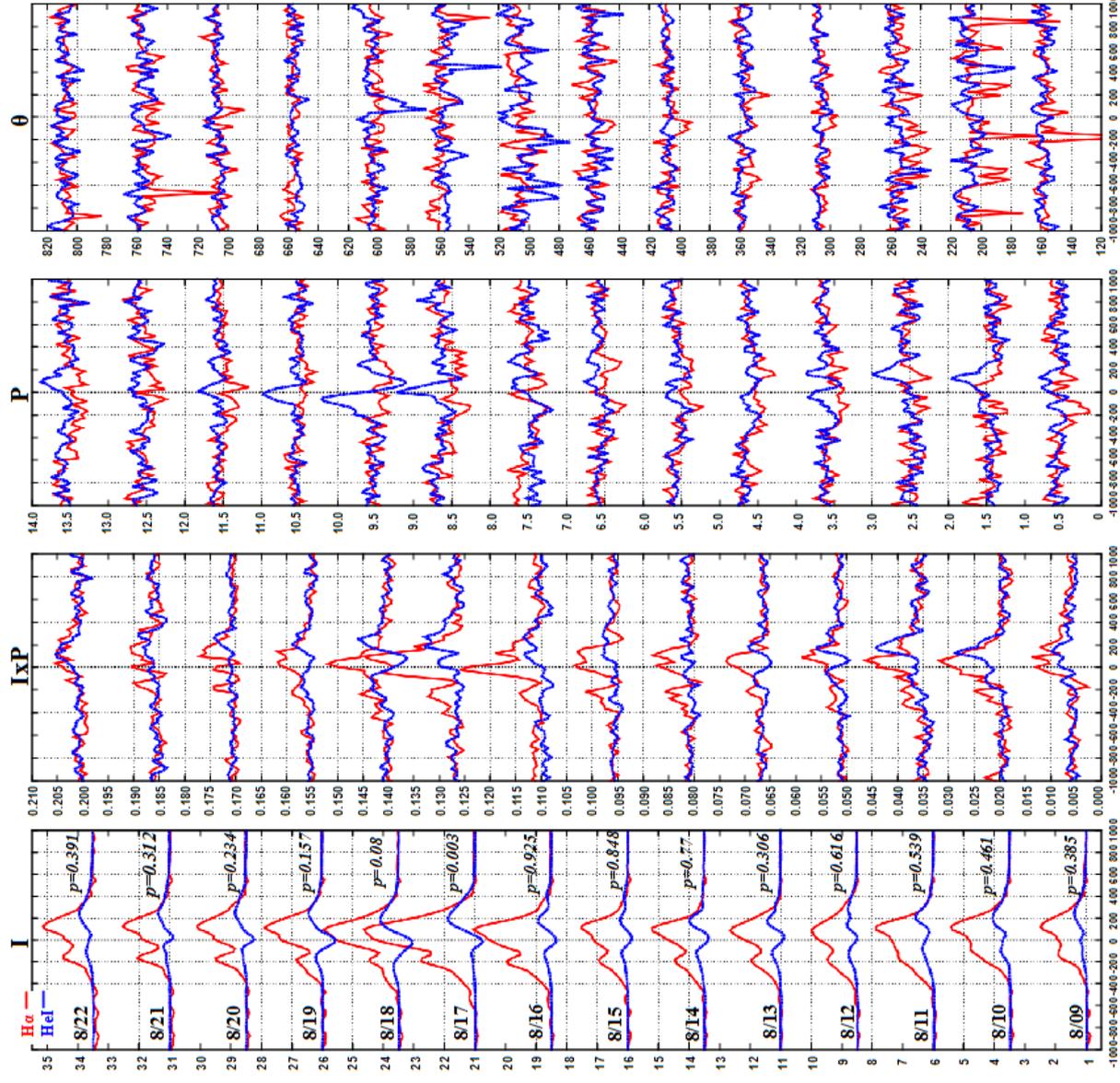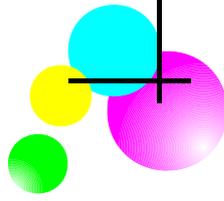＊2014年度にR~20,000 及び 円偏光モードを導入予定
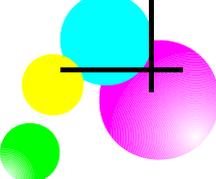
4.Preliminary results

- Beta Lyr (A8Vp + B6-8II , binary)

- P Cyg (B1lapeq)

- Nova V339 Del (classical nova)

4.Preliminary results

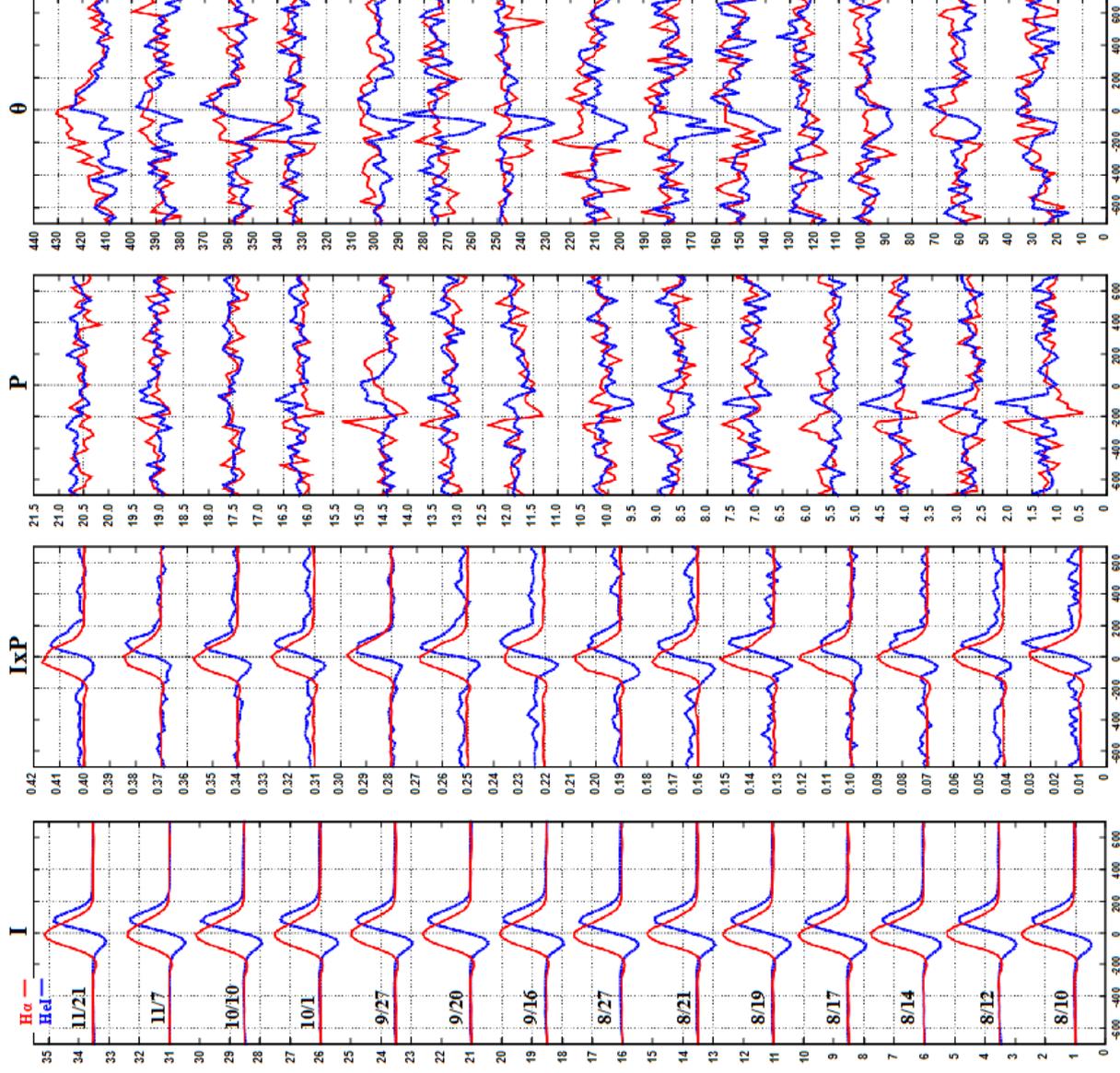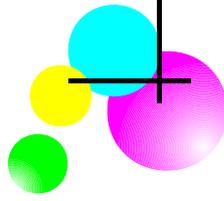● Beta Lyr (A8Vp + B6-8II , binary)

4.Preliminary results

● P Cyg (B1lapeq)

4.Preliminary results

● **Nova V339 Del (classical nova)**