The capabilities for AGN monitoring in polarized light

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Scientific justification

1. Polarization in continuum → MF in AD $B(R)$ and BH spin
   Silant'ev+07, Afanasiev+11, Piotrovich+17; Afanasiev+18 etc.

2. Spectropolarimetry in lines → gas kinematics and M_{SMBH} independent from the inclination angle
   Smith+05; Afanasiev&Popovic+15; Afanasiev+19; Savic+19 etc.

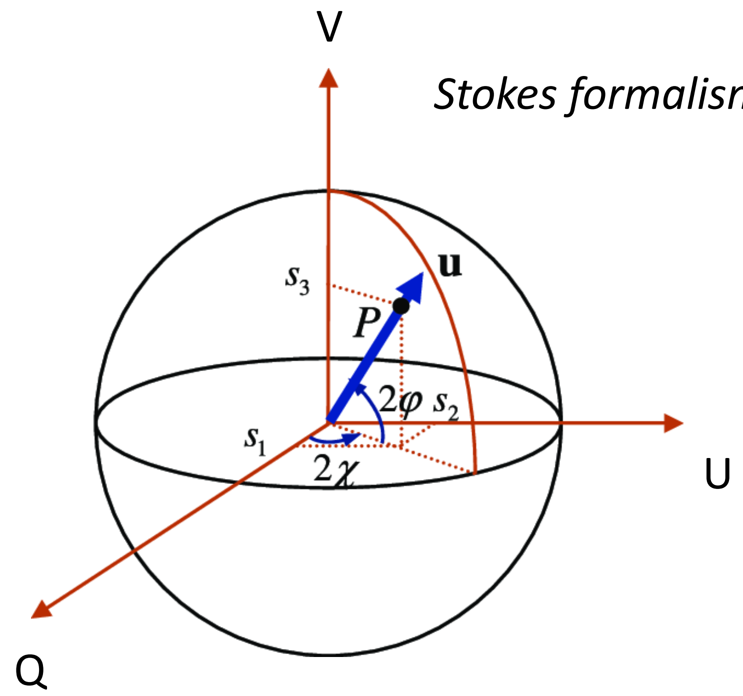
3. RM in polarized light → inner radius of the scattering region R_{sc}
   Shablovinskaya+19 (in print)

4. Rapid polarization variability in BL Lac objects → jet MF configuration and size
   Shablovinskaya&Afanasiev19 etc.

I. Polarimetric methods

Type of analyzers

1. Savart plate
2. Dichroic polaroid
3. Wollaston prism
4. Double Wollaston prism + quadrupole Wollaston prism

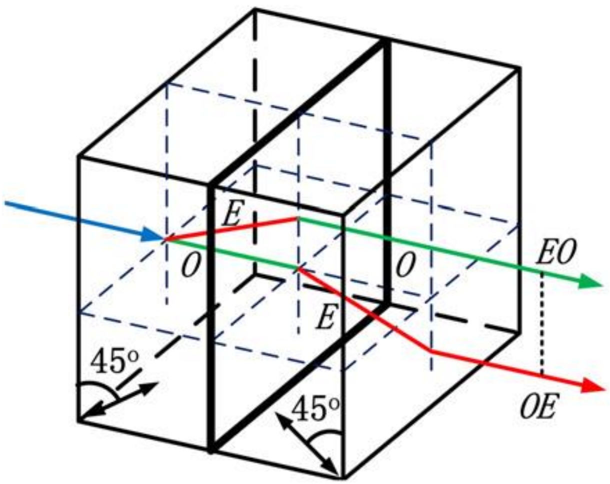


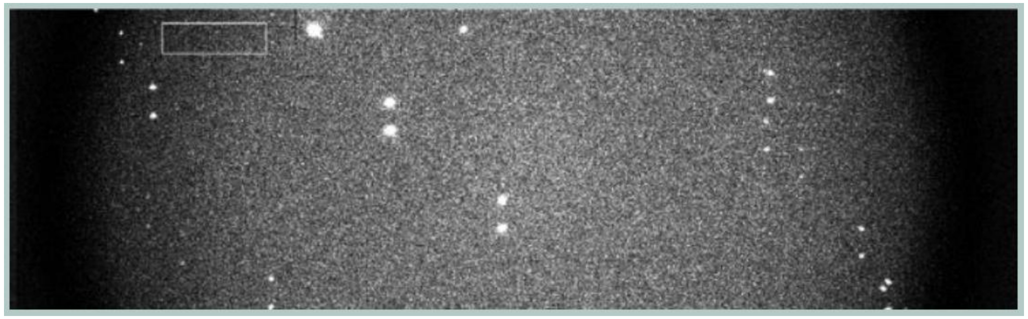
Polarization is a vector value!

$$P(\lambda) = \sqrt{Q(\lambda)^2 + U(\lambda)^2} \qquad \varphi(\lambda) = \frac{1}{2}\mathrm{arctg}[U(\lambda)/Q(\lambda)]$$

Type of analyzers

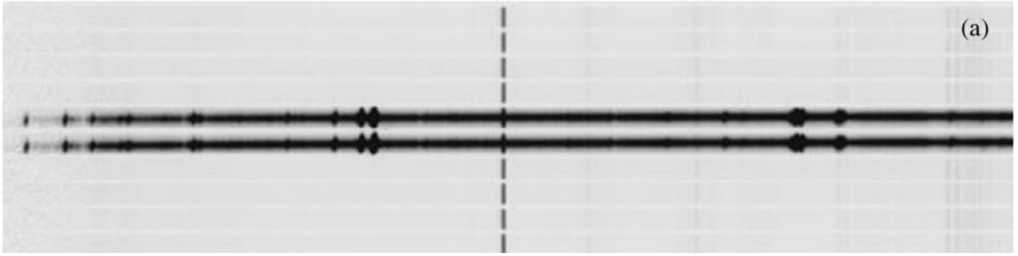
1. Savart plate





One need to observe at 2 positions of Savart plate (or 2 positions of λ/2 plate + SP)

$$Q/I = \frac{I_o - I_e}{I_o + I_e} \quad \text{at } 0^\circ$$



$$U/I = \frac{I_o - I_e}{I_o + I_e} \quad \text{at } 45^\circ$$

Type of analyzers

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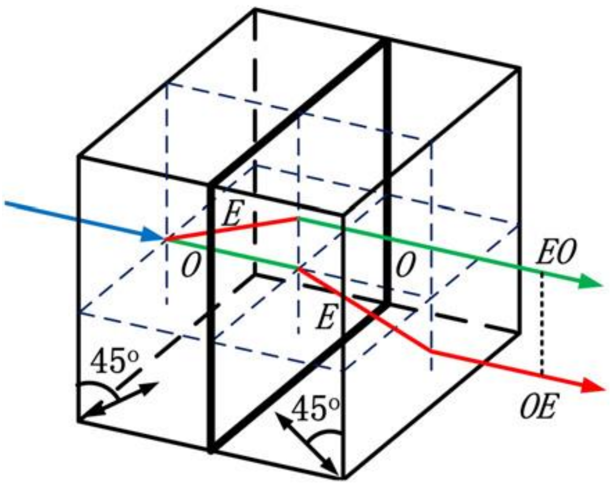
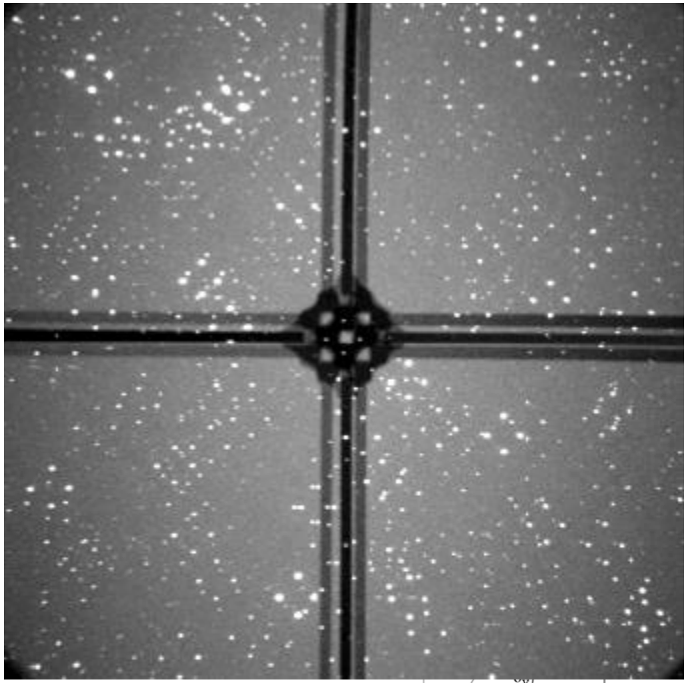


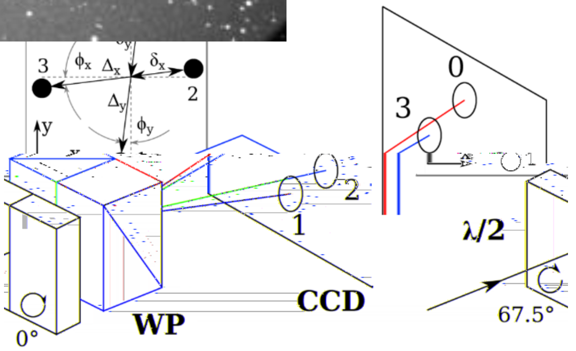
$$Q/I = \frac{I_o - I_e}{I_o + I_e} \quad \text{at } 0^\circ$$

$$U/I = \frac{I_o - I_e}{I_o + I_e} \quad \text{at } 45^\circ$$

robopol



King+04



Type of analyzers

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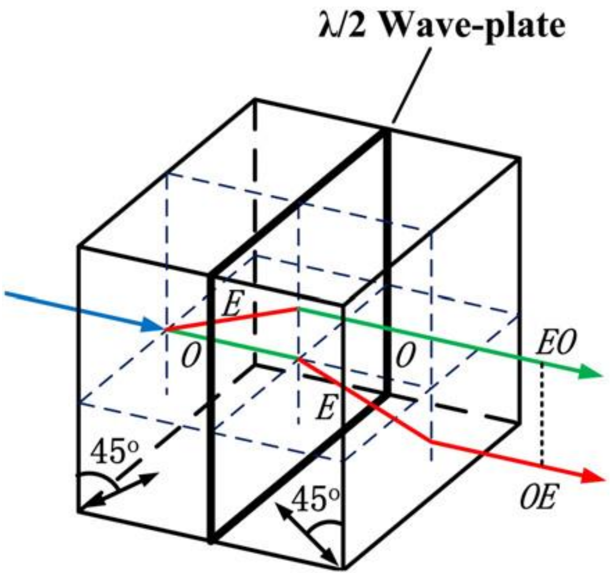


$$Q/I = \frac{I_o \cdot R(\lambda) - I_e}{I_o \cdot R(\lambda) + I_e} \quad \text{at } 0^\circ$$

$$U/I = \frac{I_o - I_e \cdot R(\lambda)}{I_o + I_e \cdot R(\lambda)} \quad \text{at } 45^\circ$$

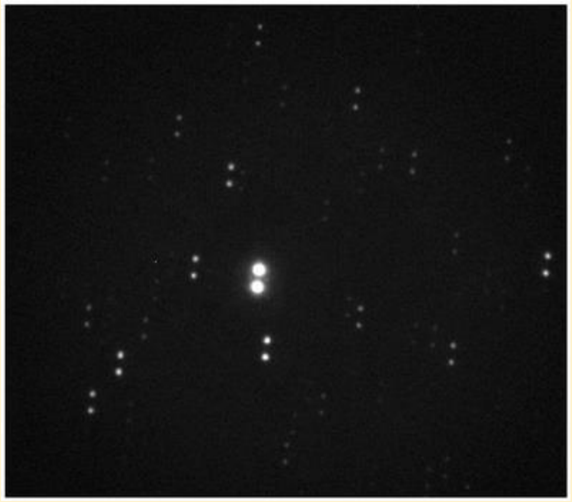
$$R(\lambda) = I_o/I_e$$

+

- easy to construct
- no optical path difference for the e and o – rays

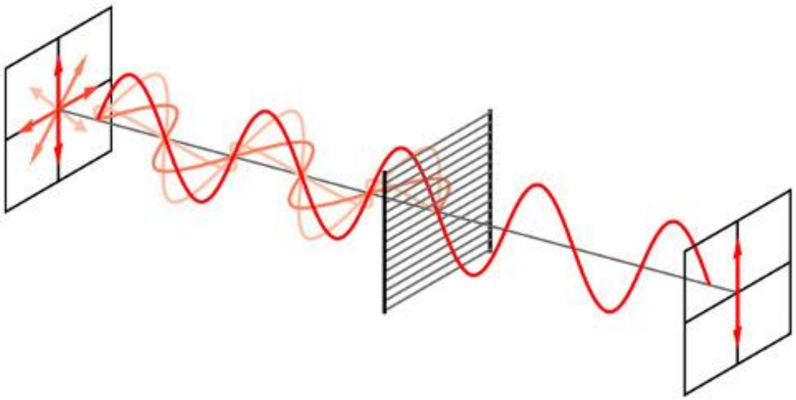
-

- only star-like objects
- bad for crowded regions



Type of analyzers

2. Dichroic polaroid



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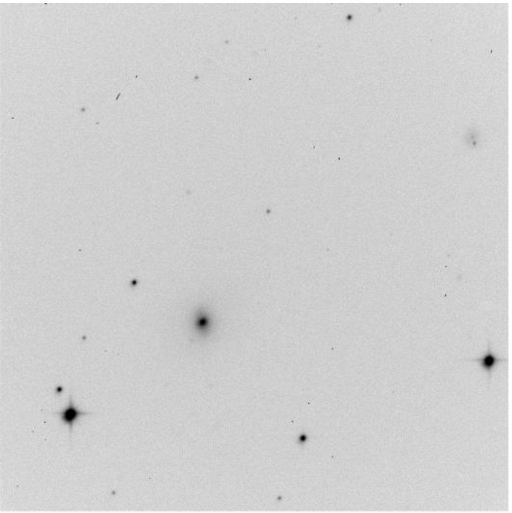
- imapol of extended objects

-
- half-intensity lost
- need stable weather conditions



NGC 3516, Zeiss1000+ MMPP

Fessenkov's formula (1935):

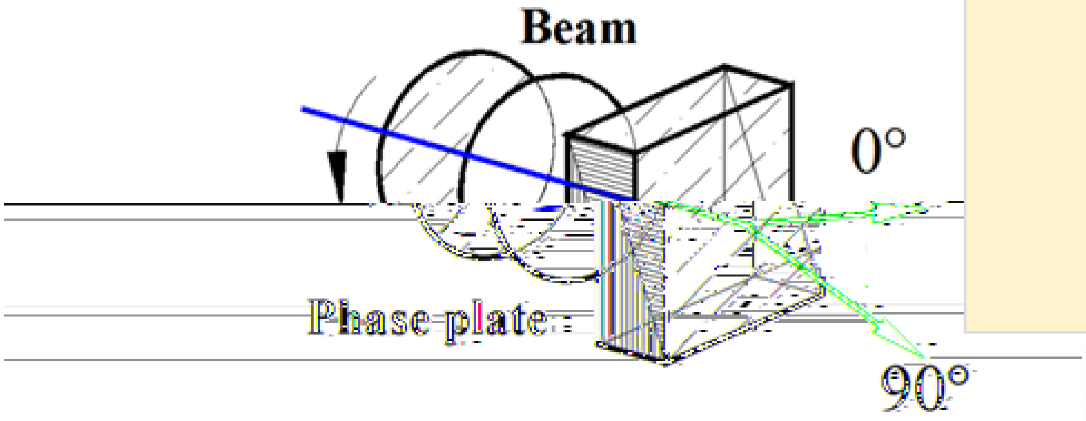
$$P = 2\frac{\sqrt{(I_1 - I_2) I_1 + (I_2 - I_3) I_2 + (I_3 - I_1) I_3}}{I_1 + I_2 + I_3},$$

$$\operatorname{tg} 2(\varphi_0 - \varphi_1) = \sqrt{3}\frac{I_2 - I_3}{2I_1 - I_2 - I_3}.$$

$$Q = \frac{1}{2}\frac{2I_0 - I_{+60} - I_{-60}}{I_0 + I_{+60} + I_{-60}} \qquad U = \frac{\sqrt{3}}{2}\frac{I_{+60} - I_{-60}}{I_0 + I_{+60} + I_{-60}}$$

Type of analyzers

3. Wollaston prism



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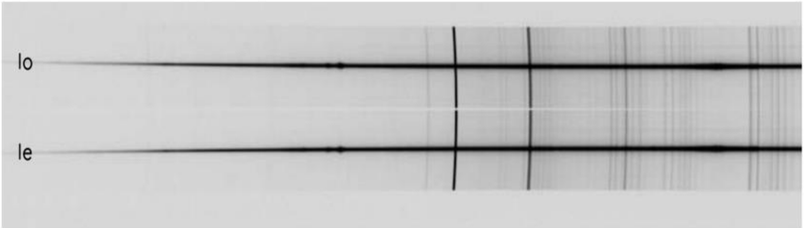
- imapol of extended objects

-

- need λ/2 plate
- non-simultaneous Q and U



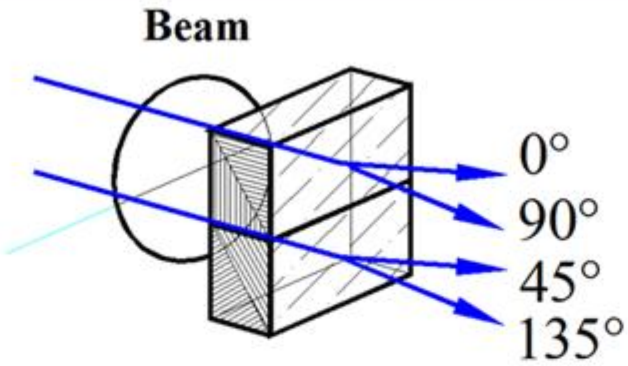
$$Q(\lambda) = \frac{1}{2}\left(\frac{I_0(\lambda) - I_{90}(\lambda)}{I_0(\lambda) + I_{90}(\lambda)}\right)_{\phi=0} - \frac{1}{2}\left(\frac{I_0(\lambda) - I_{90}(\lambda)}{I_0(\lambda) + I_{90}(\lambda)}\right)_{\phi=22.5}$$

$$U(\lambda) = \frac{1}{2}\left(\frac{I_0(\lambda) - I_{90}(\lambda)}{I_0(\lambda) + I_{90}(\lambda)}\right)_{\phi=0} - \frac{1}{2}\left(\frac{I_0(\lambda) - I_{90}(\lambda)}{I_0(\lambda) + I_{90}(\lambda)}\right)_{\phi=67.5}$$

$$I(\lambda) = \sum_{\phi}[I_0(\lambda) + I_{90}(\lambda)]_{\phi}, \qquad \phi = 0, 45, 22.5, 67.5$$

Type of analyzers

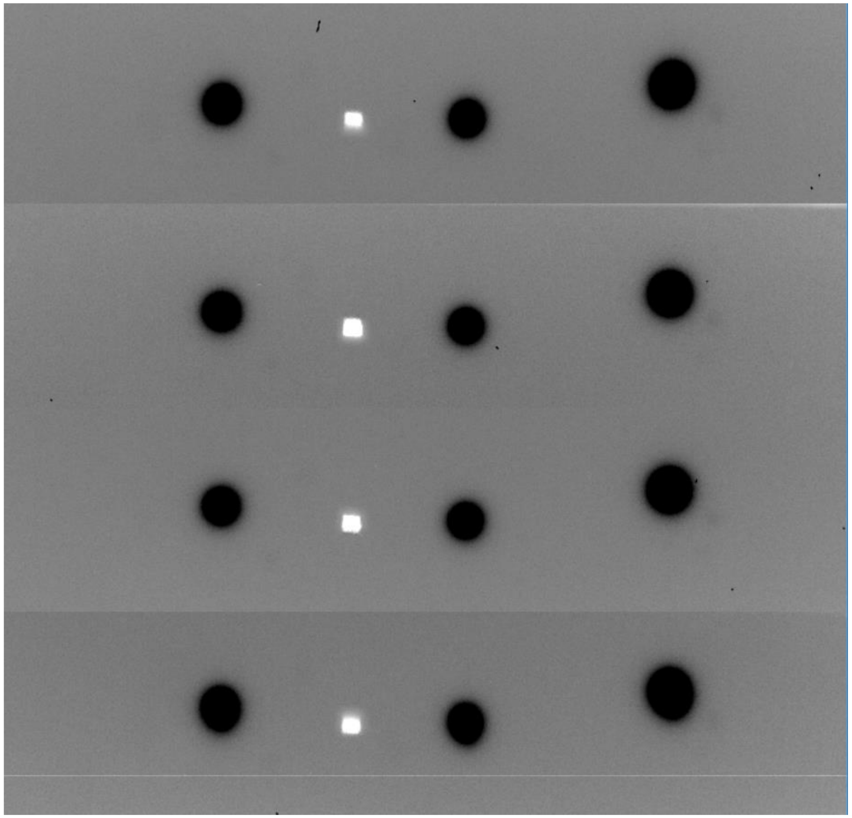
4. Double Wollaston prism



$$Q(\lambda) = \frac{I_0(\lambda) - I_{90}(\lambda)}{I_0(\lambda) + I_{90}(\lambda)},$$

$$U(\lambda) = \frac{I_{45}(\lambda) - I_{135}(\lambda)}{I_{45}(\lambda) + I_{135}(\lambda)},$$

$$I(\lambda) = I_0(\lambda) + I_{90}(\lambda) + I_{45}(\lambda) + I_{135}(\lambda)$$

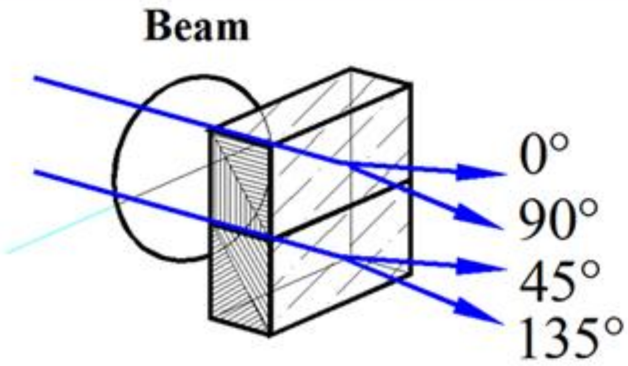


S5 0716+714, BTA+Sc2

Geyer+93; Oliva96

Type of analyzers

4. Double Wollaston prism



$$Q = \frac{I_0 - I_{90} D_Q}{I_0 + I_{90} D_Q}$$

$$U = \frac{I_{45} - I_{135} D_U}{I_{45} + I_{135} D_U}$$

where $D_{Q,U}$ are the coefficients of polarization channel transmission: $D_Q = 1.036 \pm 0.015$, $D_U = 0.985 \pm 0.015$.

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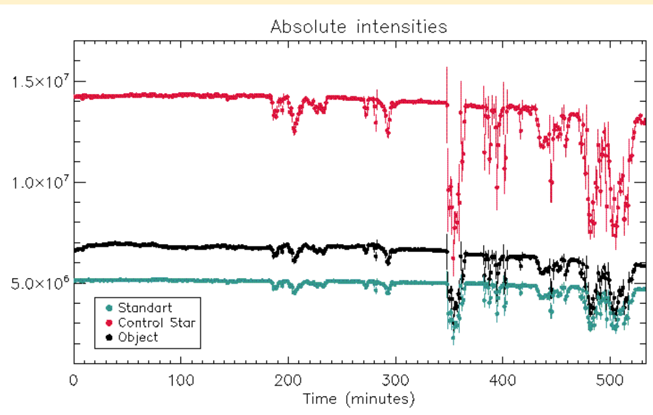
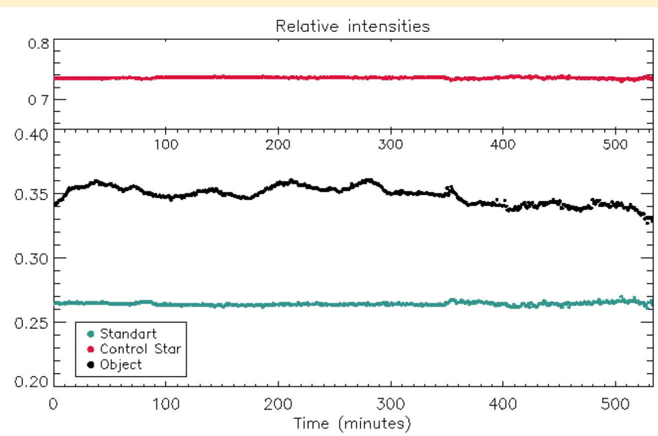
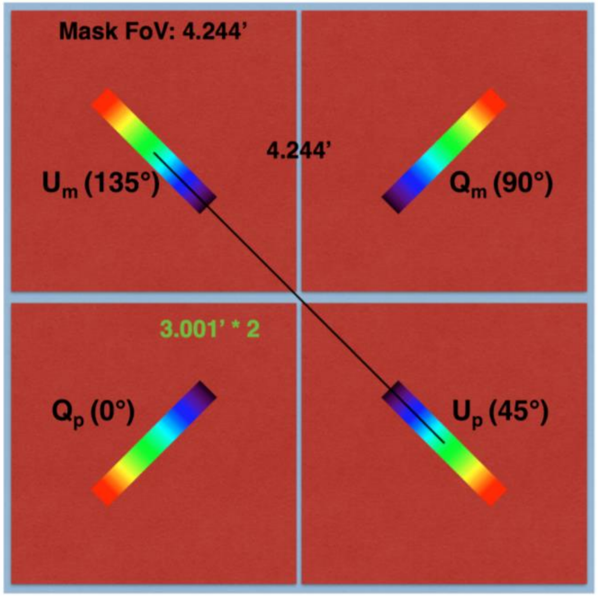
- simultaneous Q and U
- independent from weather

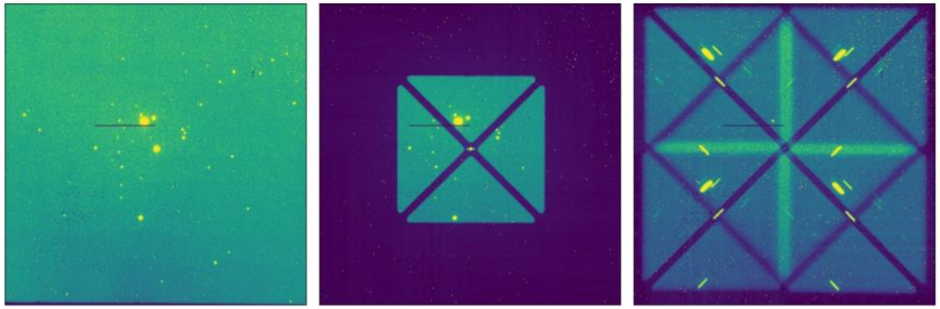




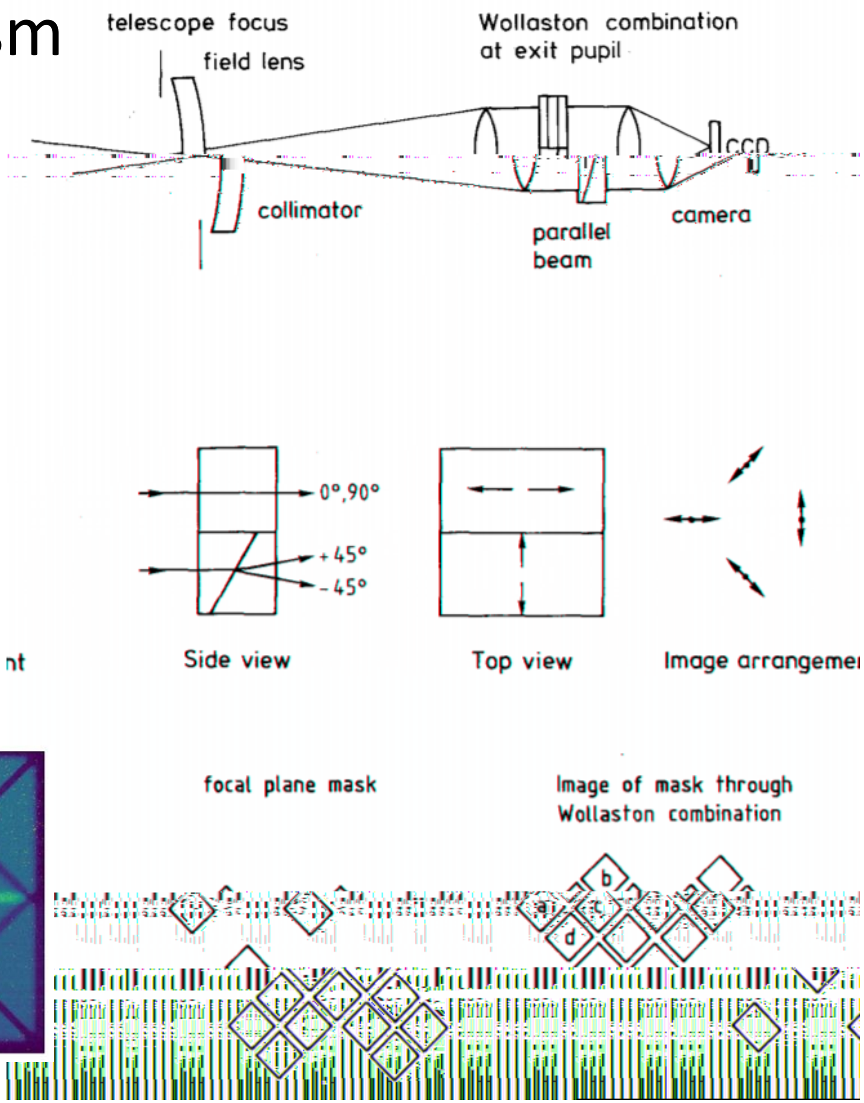
Type of analyzers

4. Quadrupole Wollaston prism





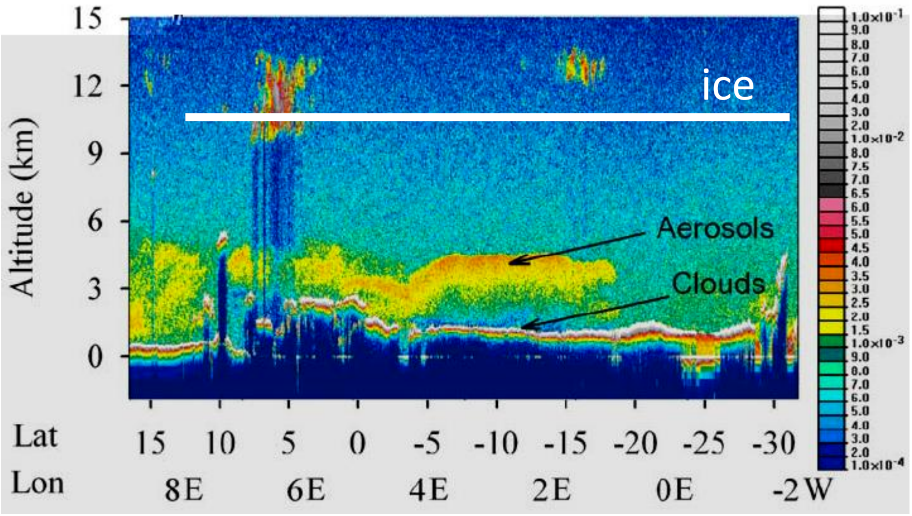
Tinyanont+18



Geyer+96

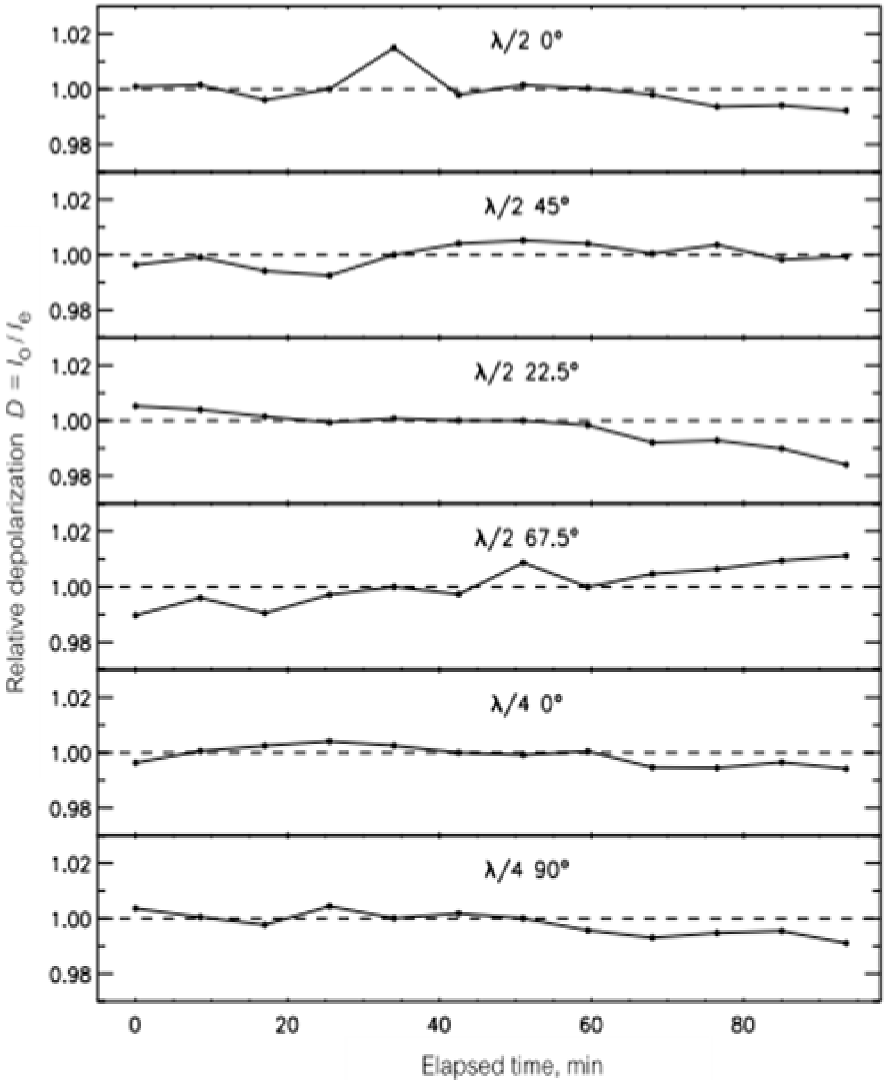
Observational techniques

1. Depolarization in atmosphere



Rayleigh – $p = \frac{\sin^2\theta}{1+\cos^2\theta}$

Ice crystals – 20-30%



Observational techniques

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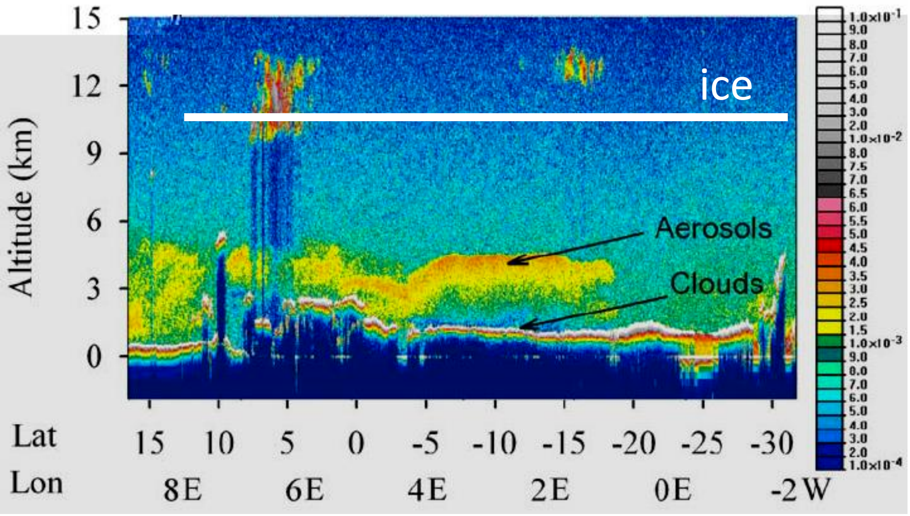

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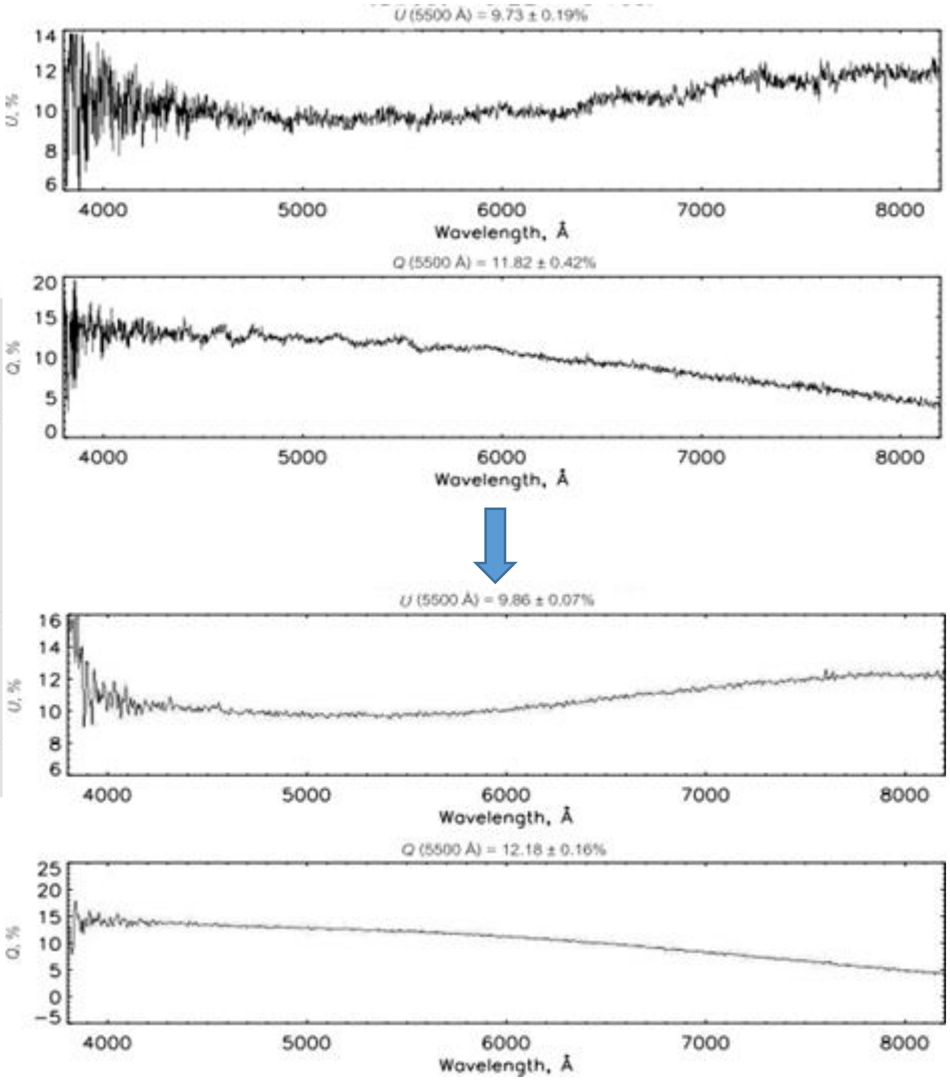
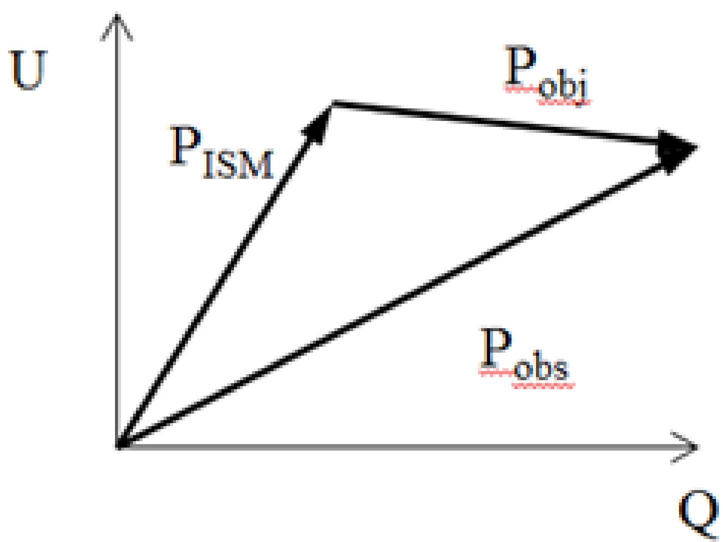
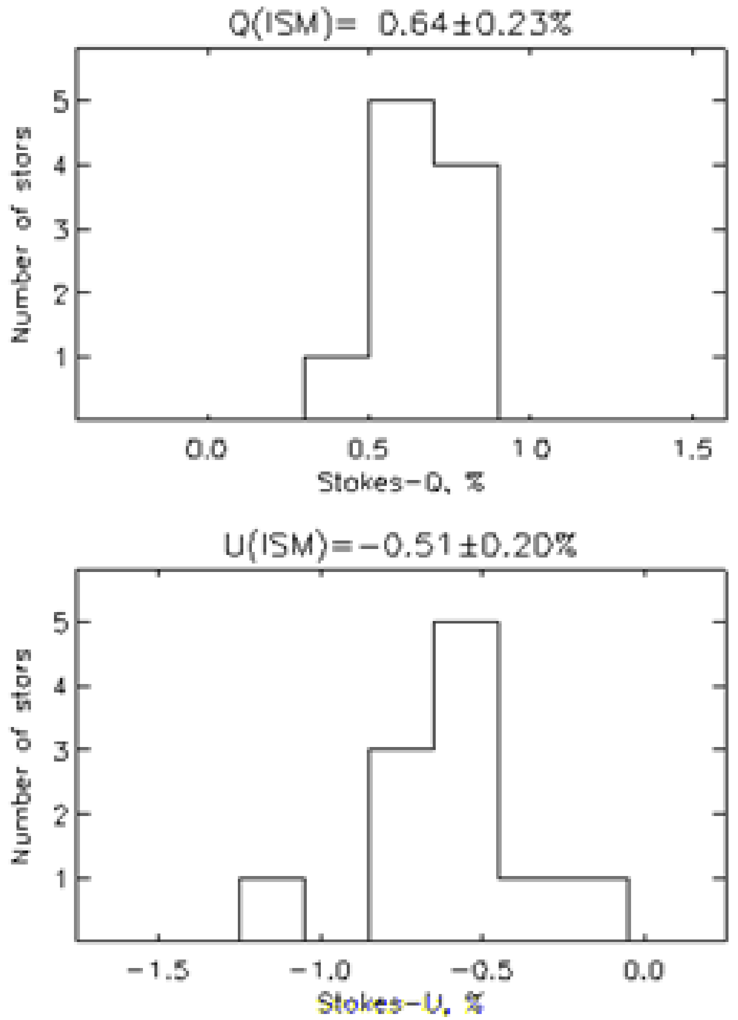


Observational techniques

2. ISM

$$\vec{P}_{obs} = \vec{P}_{obj} + \vec{P}_{ISM}$$





II. Observational potential

SAO telescopes – 6-m

SCORPIO-2(1)

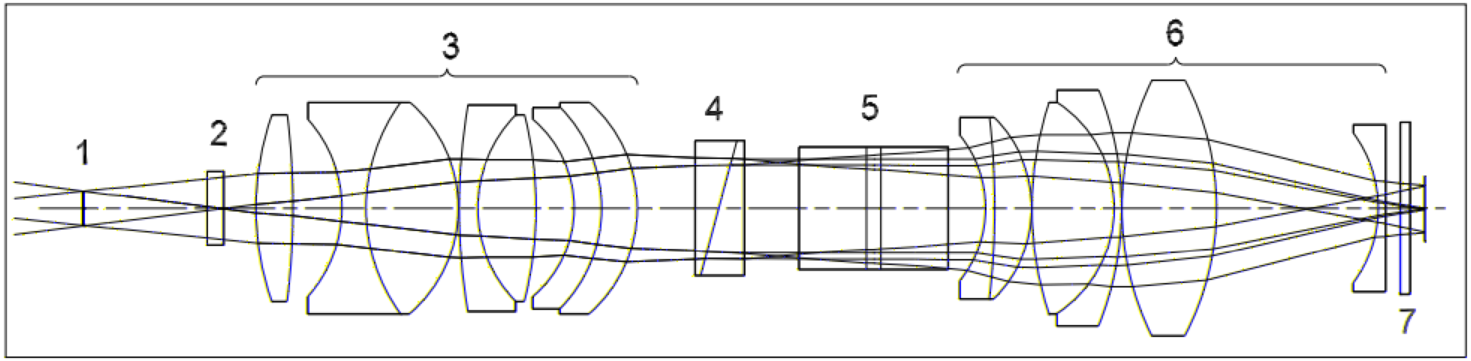


Fig. 1. The optical scheme of the polarimetric mode of the next generation focal reducer SCORPIO-2: 1—slit; 2—the phase plate; 3—the collimator, 4—the Wollaston prism; 5—the grism; 6—the spectrograph camera; 7—the entrance window of the CCD cryostat.

Wollaston prism + λ/2 plate

Double Wollaston prism (WeDoWo)

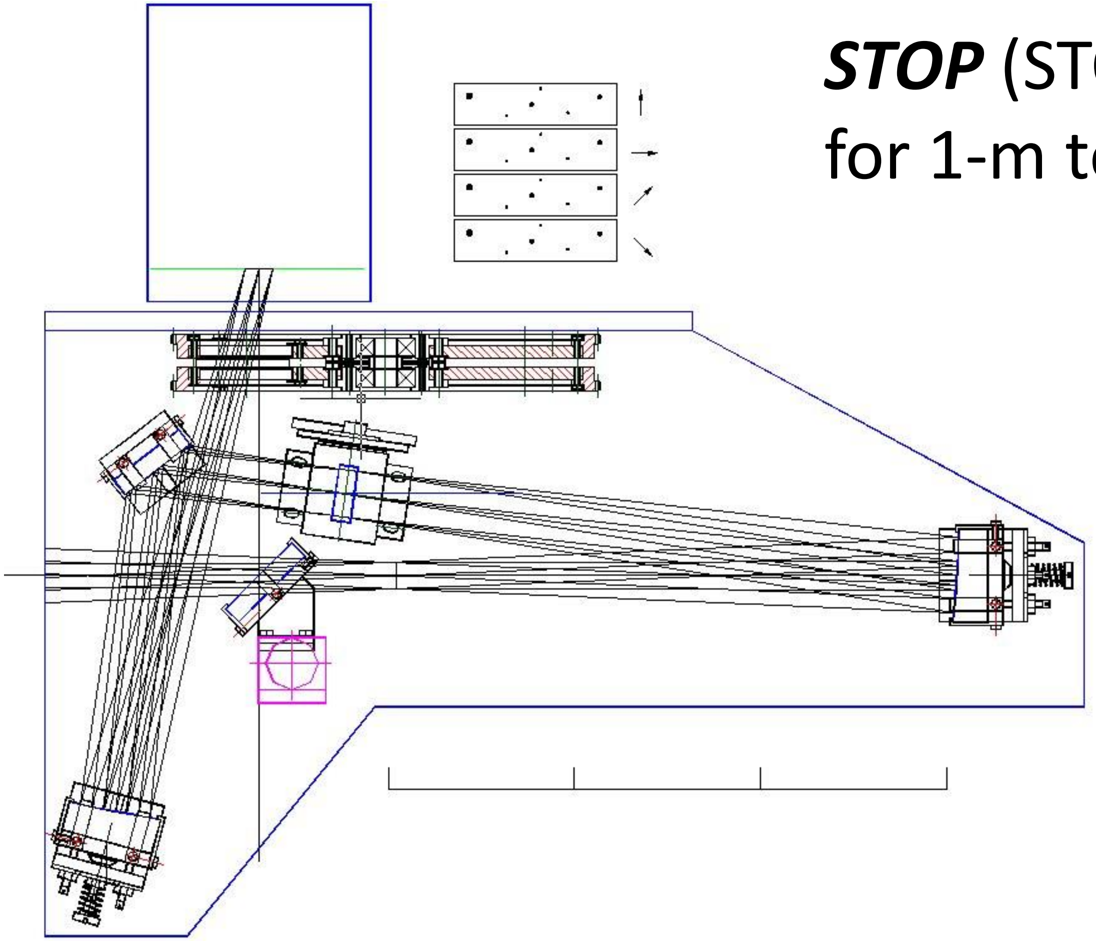
Dichroic Polarization Analyzer

Spectropolarimetry

Image polarimetry

Afanasiev+11,14,15,18,19; Savic+19; Shapovalova+19; Shablovinskaya+19…

SAO telescopes – 1-m (commission)



STOP (STOkes Polarimeter)
for 1-m telescope

Image polarimetry

Double Wollaston prism

SAO telescopes – 1-m

Dichroic Polaroid

MMPP

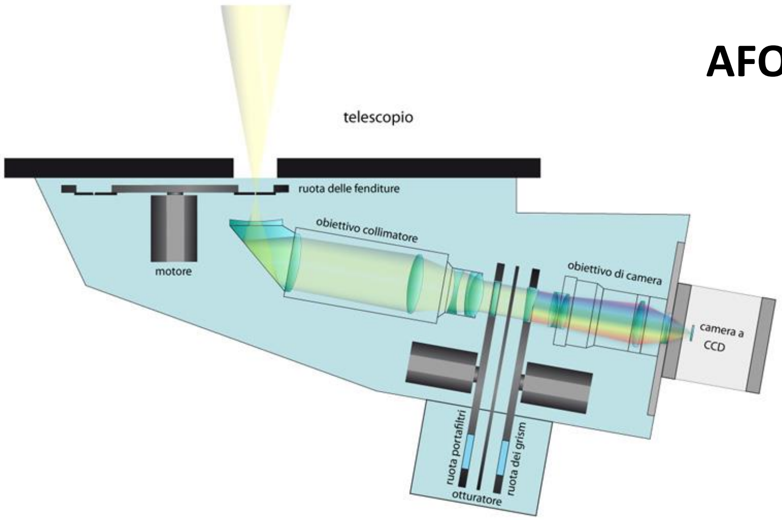
Multi-Mode Photometer-Polarimeter

Image polarimetry

Slow polaroid – strong dependency on weather

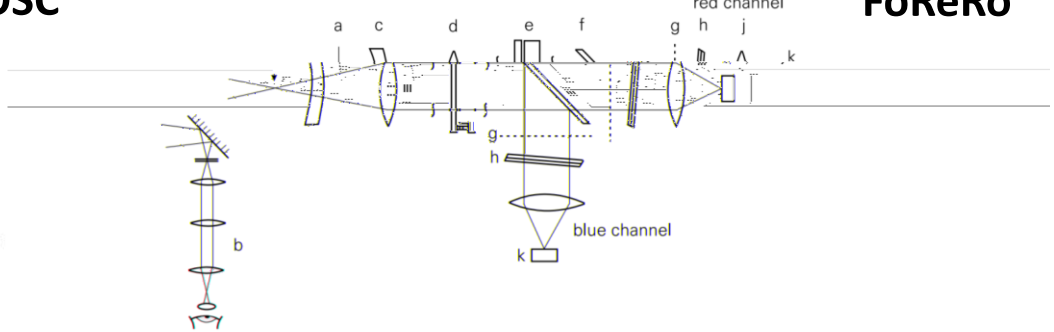
Others

Device	Telescope	Analyzer
AFOSC	1.82 m telescope at M. Ekar Observatory	double Wollaston (Oliva+97)
FoReRo	2m RCC-telescope at Rozhen Observatory	quadrupole Wollaston
TBA	1.4 m Milankovic telescope	Savart plate
TFOSC	1.5 m RTT	double Wollaston



AFOSC

FoReRo



: 1: Optical scheme of the Two-Channel Focal Reducer. (a) Cassegrain focal plane, (b) offset guider, (c) ens, (d) collimator, (e) Fabry-Perot etalon or four-beam Wollaston prism, (f) color divider, (g) Lyot stop lways present), (h) filter, (j) camera lens, (k) CCD detector. If position (e) is empty, the right part of the ment can be moved to the left toward Cassegrain focal plane in order to reduce vignetting.

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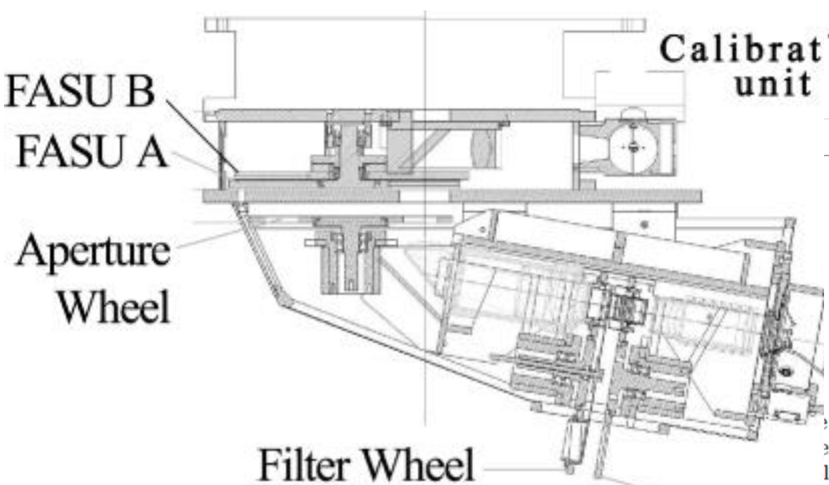
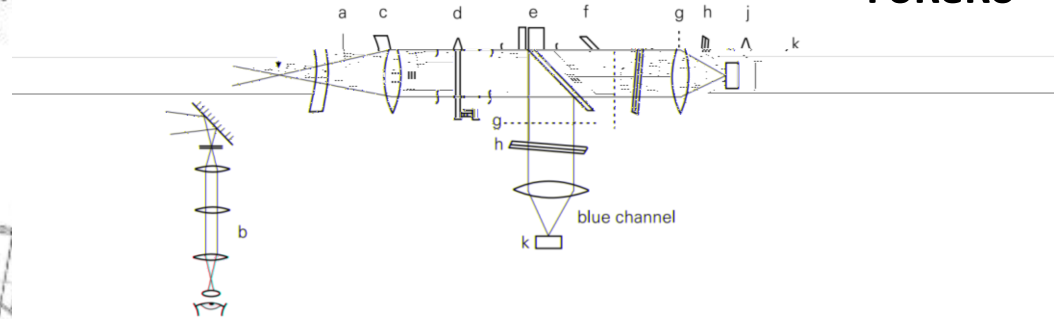


TFOSC

FoReRo



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