Course number: 3345.320

Astronomical Polarimetry

Practice session:
Data reduction of the SQUIDPOL's data

2024 Nov 5, 14:00~15:15

Lecturer: Jooyeon GEEM (KIM)

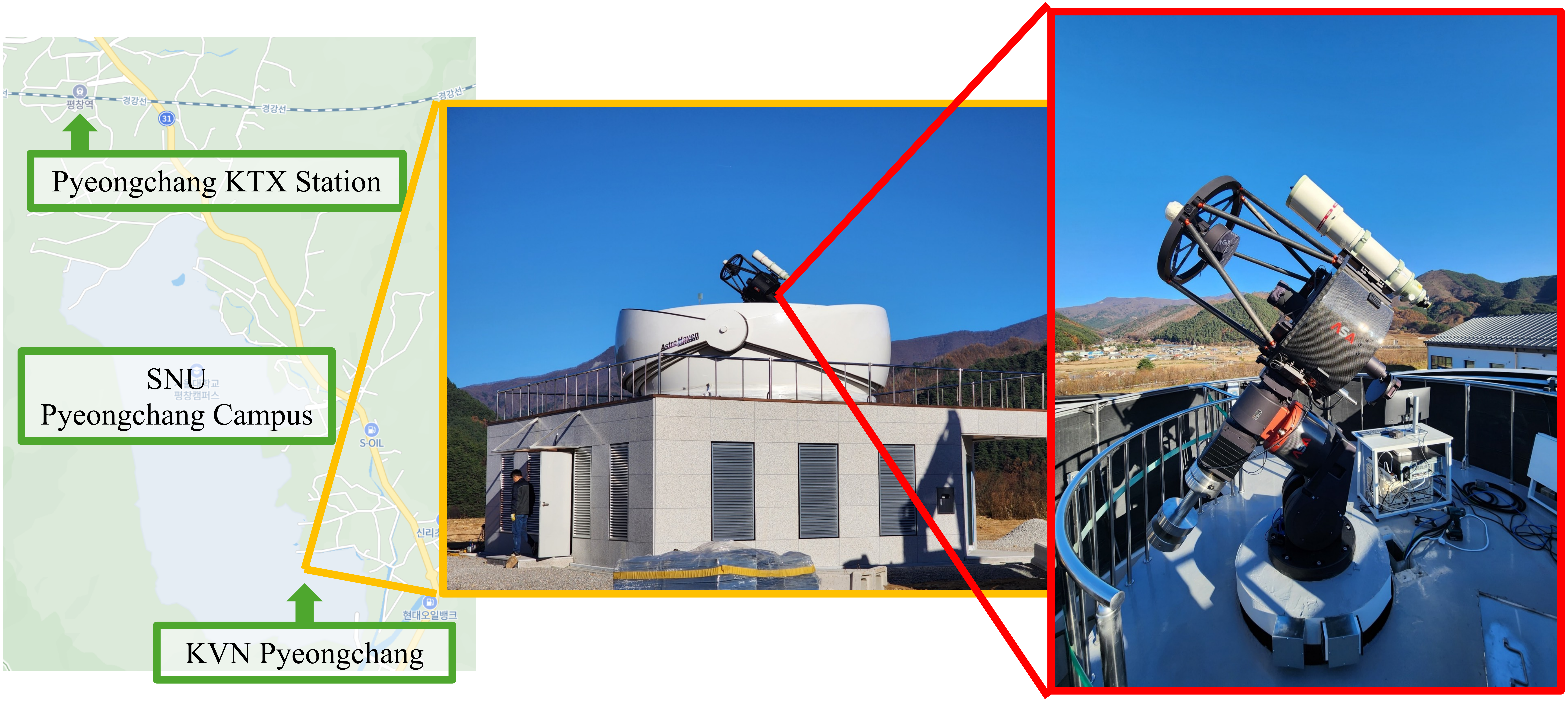
Today’s goal

- Understanding the polarimetric instrument, SQUIDPOL
- Deriving the linear polarization (Q/I and U/I) by using the SQUIDPOL images

Design of SQUIDPOL (SNU QUadruple Imager for POLarimetry) for the SNU Pyeongchang 60-cm Telescope

From the 2024 추계 천문학회 presentation made by Sun Jin

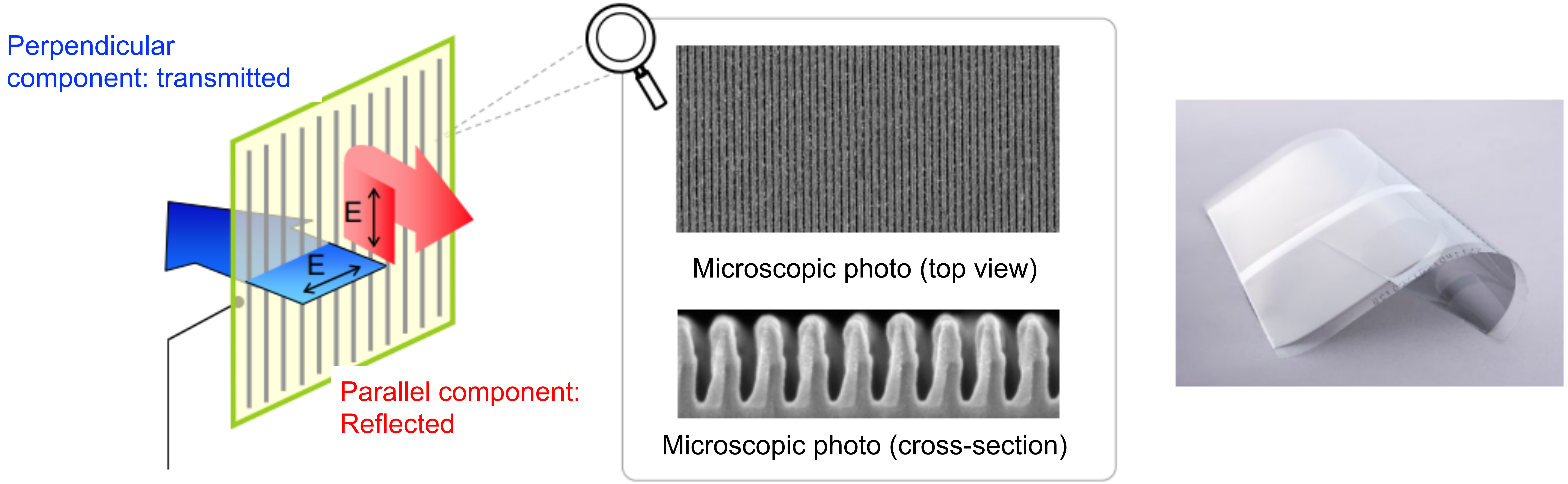
SNU Pyeongchang 60-cm telescope



For helping your remind…

3. Polarimetric device (2) Polarizing filter

- Wiregrid filter
  - This type of polarizing filter consists of ‘an array of parallel metallic wires’.
  - It is sandwiched between glass substrates.
  - Wire grid polarizers transmit light with an electric field perpendicular to the wire and reflect light with the electric field parallel to the wire (see the figure below) because



Substrate: ：COP(Cyclo Olefin Polymer)

An example of a 100 nm pitch wiregrid filter

Modified: (Original https://www.osc-japan.com/mirror-corp/film/)

From Prof. Ishiguro's lecture slide

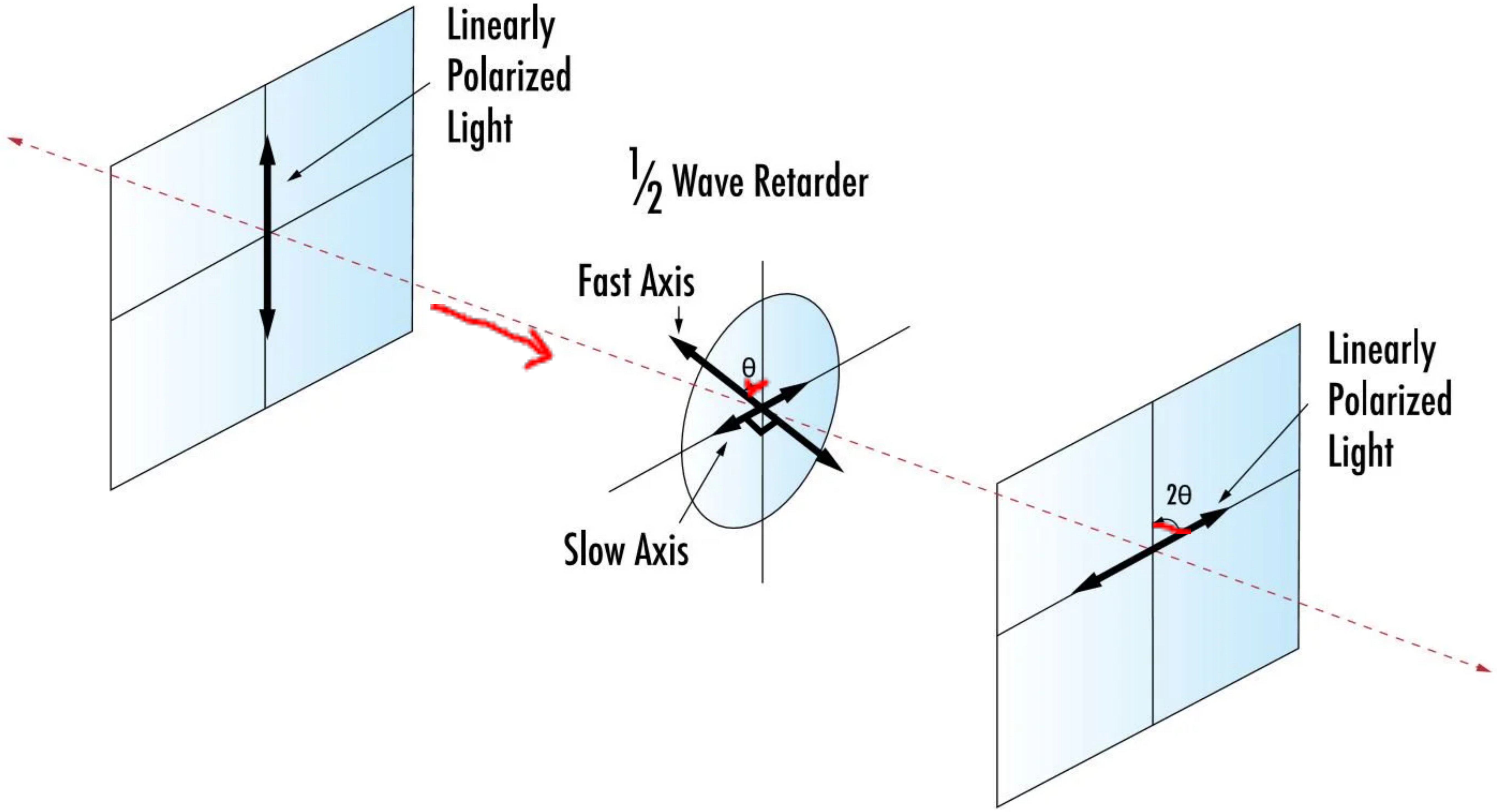
For helping your remind…

3. Polarimetric device (4) λ/2 Waveplates [2]

- λ/2 waveplates:

- It converts linearly polarized light in the direction of angle θ into linearly polarized light with angle 2θ.

- It also acts to reverse the direction of rotation of circularly polarized light.



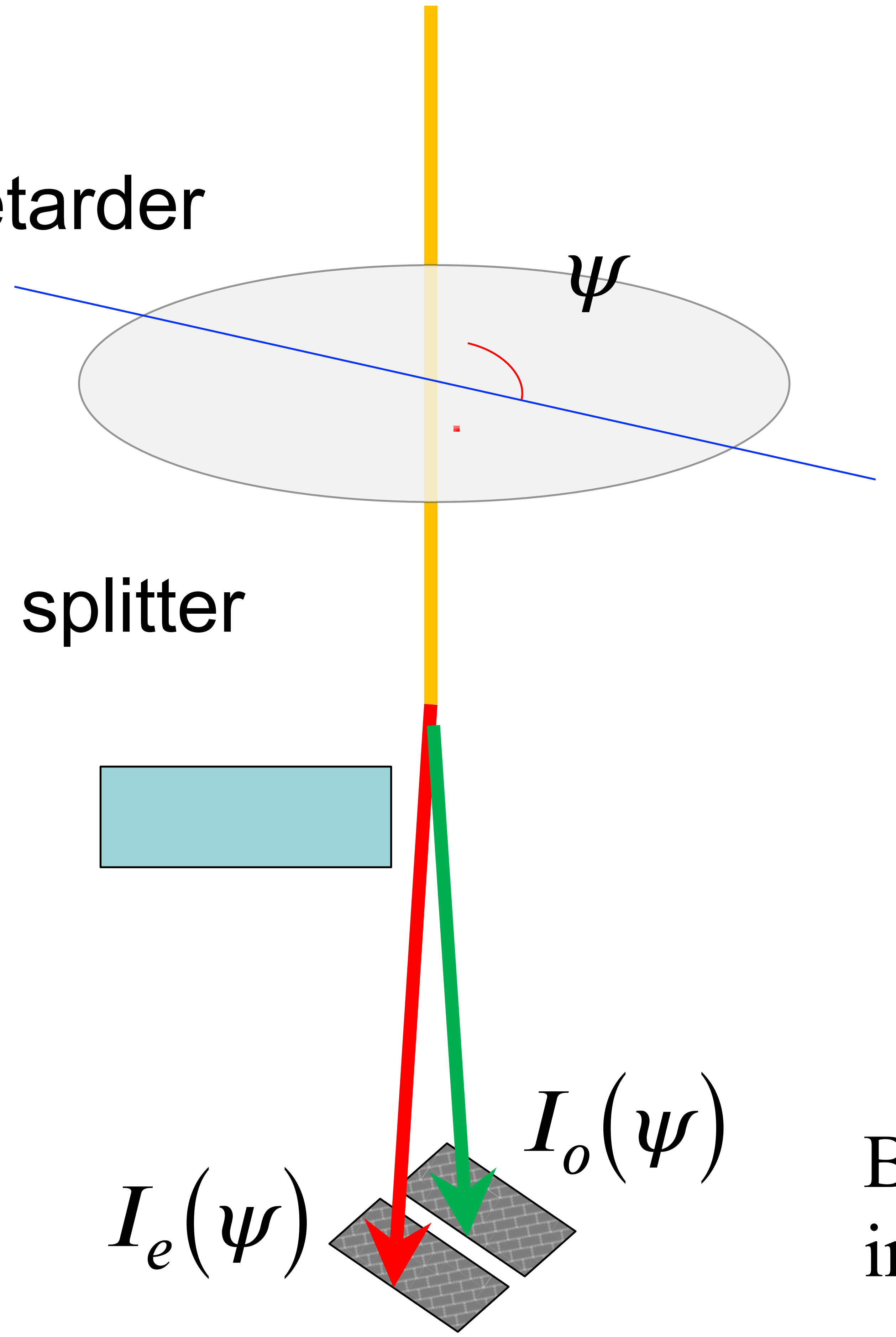
https://www.edmundoptics.com/knowledge-center/application-notes/optics/understanding-waveplates/

From Prof. Ishiguro's lecture slide

For helping your remind…

4. Usage for Astronomical Linear Polarimetry (2)

- More common case*ref:



$$I_o(\psi) = \frac{I}{2}\left\{1 + \frac{Q}{I}\cos 4\psi + \frac{U}{I}\sin 4\psi\right\} k_o \kappa(t)$$

$$I_e(\psi) = \frac{I}{2}\left\{1 - \frac{Q}{I}\cos 4\psi - \frac{U}{I}\sin 4\psi\right\} k_e \kappa(t)$$

different throughput for o- and e-rays within the instruments

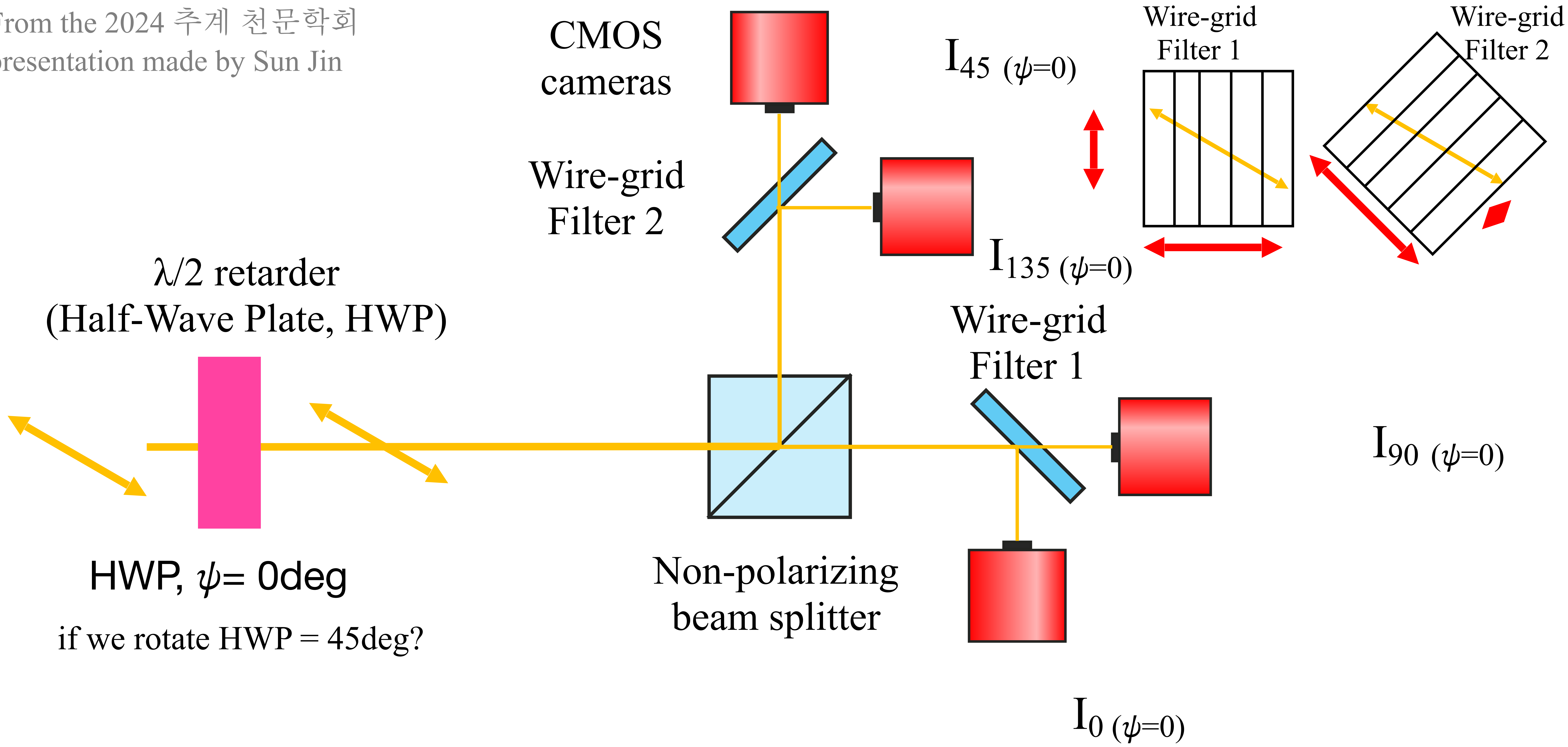
Time-dependent atmospheric transparency

$$a_1 = \sqrt{\frac{I_e(0^\mathrm{o})}{I_o(0^\mathrm{o})} \Big/ \frac{I_e(45^\mathrm{o})}{I_o(45^\mathrm{o})}}, \quad a_2 = \sqrt{\frac{I_e(22.5^\mathrm{o})}{I_o(22.5^\mathrm{o})} \Big/ \frac{I_e(67.5^\mathrm{o})}{I_o(67.5^\mathrm{o})}}$$

$$\frac{Q}{I} = \frac{1 - a_1}{1 + a_1}, \quad \frac{U}{I} = \frac{1 - a_2}{1 + a_2}$$

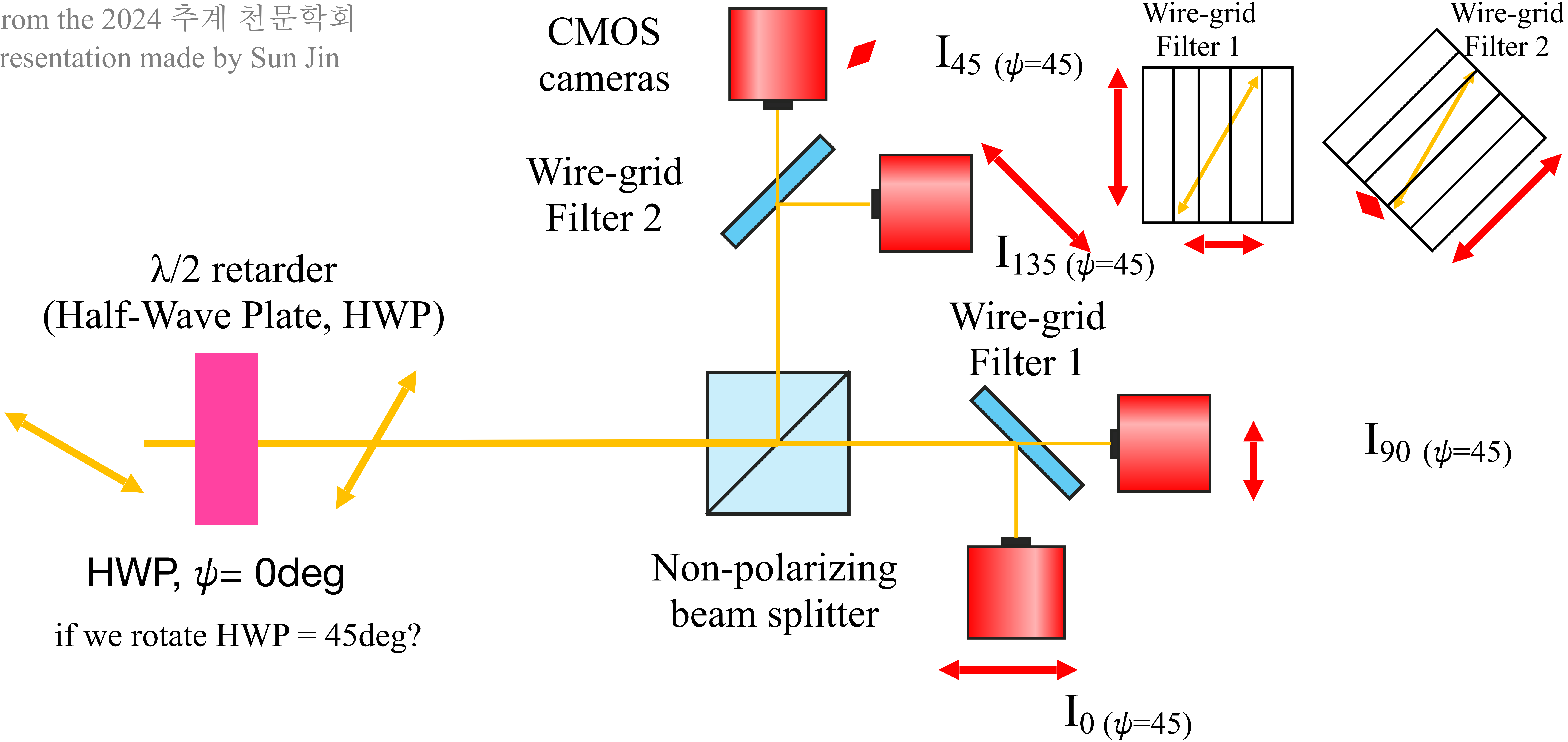
Because these kinds of polarimetric instruments are immune to atmospheric influence and system throughput, allowing for extremely accurate measurements.

[*ref] Referred to Lecture note by Prof. Kawabata (Hiroshima Univ) https://sci.nao.ac.jp/MEMBER/kataoka/kagoshima2016/kawabata.pdf


CMOS
cameras
I_{45} (ψ=0)
Wire-grid
Filter 1
Wire-grid
Filter 2
Wire-grid
Filter 2
I_{135} (ψ=0)
λ/2 retarder
(Half-Wave Plate, HWP)
Wire-grid
Filter 1
I_{90} (ψ=0)
HWP, ψ= 0deg
if we rotate HWP = 45deg?
Non-polarizing
beam splitter
I_{0} (ψ=0)

Concept

From the 2024 추계 천문학회
presentation made by Sun Jin

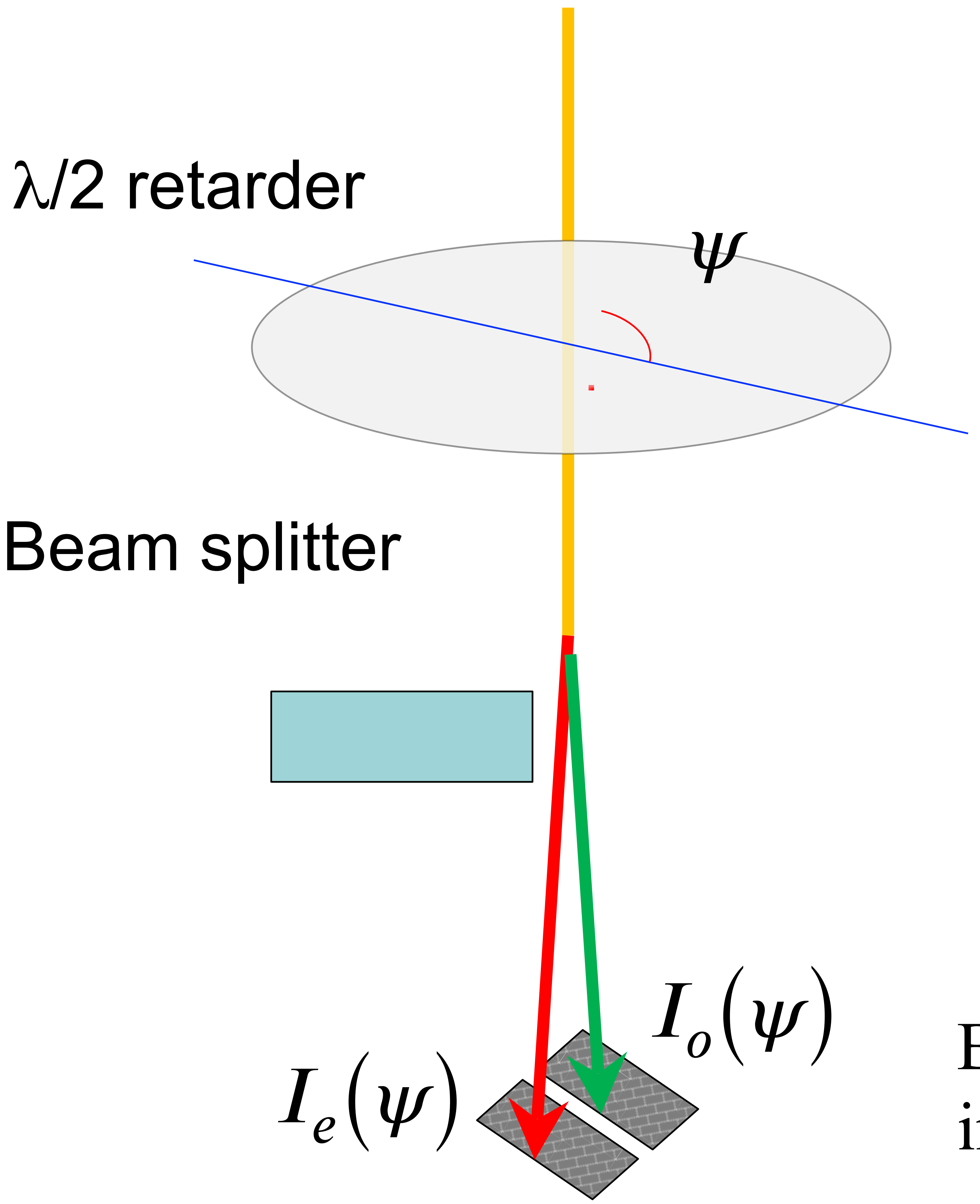


Concept

From Prof. Ishiguro's lecture slide

4. Usage for Astronomical Linear Polarimetry (2)

- More common case*ref:



$$I_o(\psi) = \frac{I}{2}\left\{1 + \frac{Q}{I}\cos 4\psi + \frac{U}{I}\sin 4\psi\right\} k_o \kappa(t)$$

$$I_e(\psi) = \frac{I}{2}\left\{1 - \frac{Q}{I}\cos 4\psi - \frac{U}{I}\sin 4\psi\right\} k_e \kappa(t)$$

different throughput for o- and e-rays within the instruments

Time-dependent atmospheric transparency

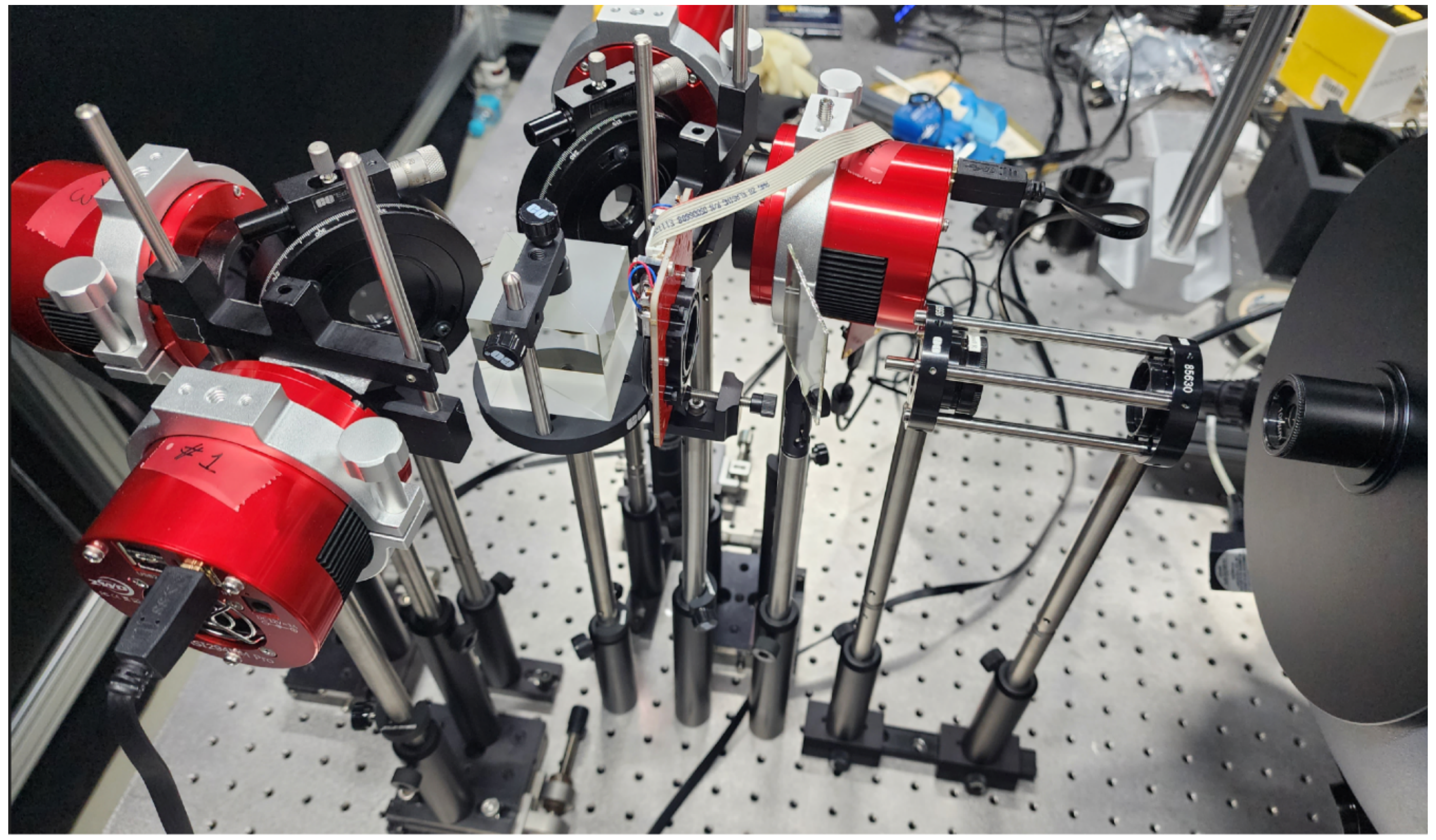
$$a_1 = \sqrt{\frac{I_e(0^\circ)}{I_o(0^\circ)} \Big/ \frac{I_e(45^\circ)}{I_o(45^\circ)}}, \quad a_2 = \sqrt{\frac{I_e(22.5^\circ)}{I_o(22.5^\circ)} \Big/ \frac{I_e(67.5^\circ)}{I_o(67.5^\circ)}}$$

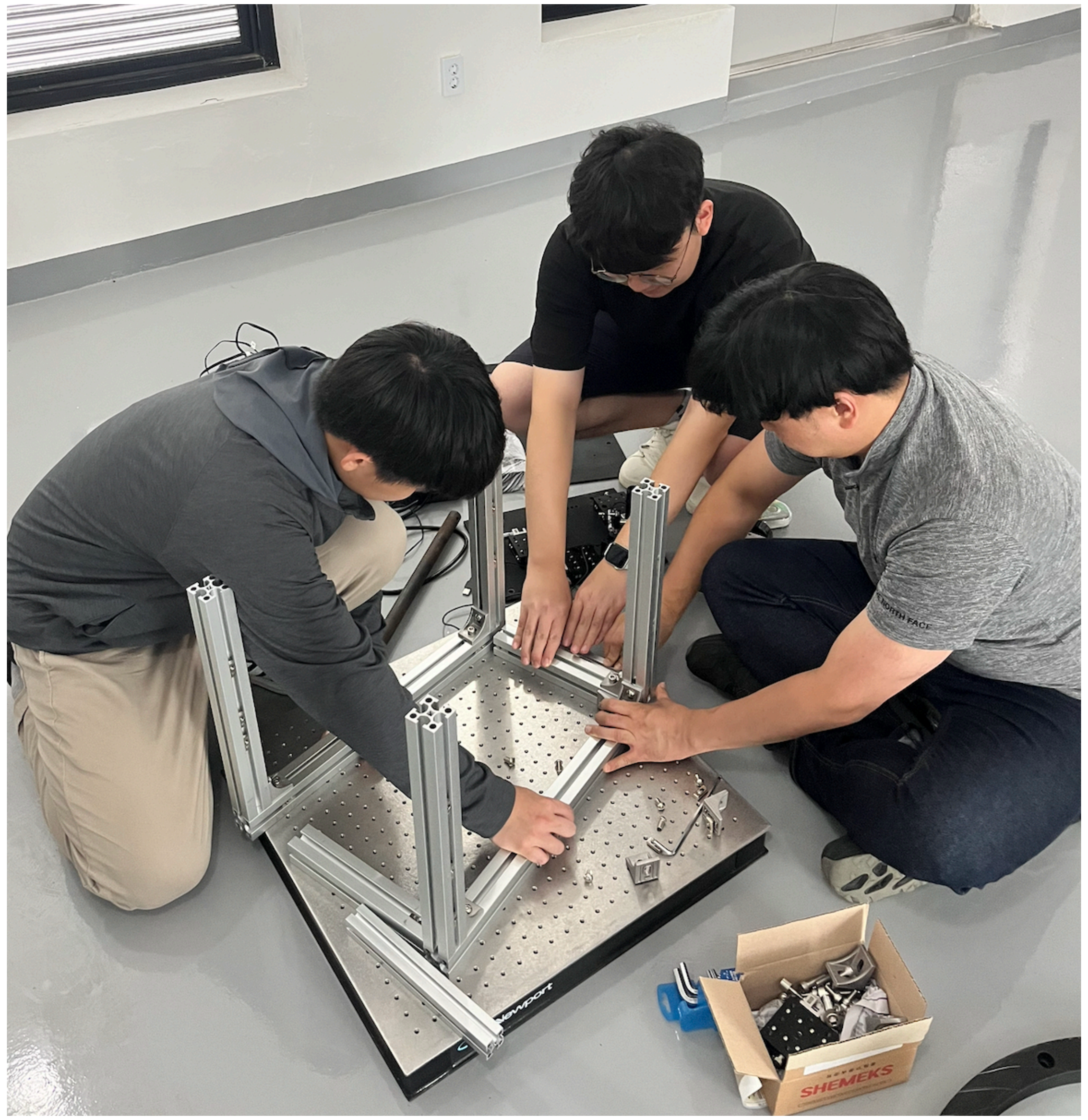
$$\frac{Q}{I} = \frac{1 - a_1}{1 + a_1}, \quad \frac{U}{I} = \frac{1 - a_2}{1 + a_2}$$

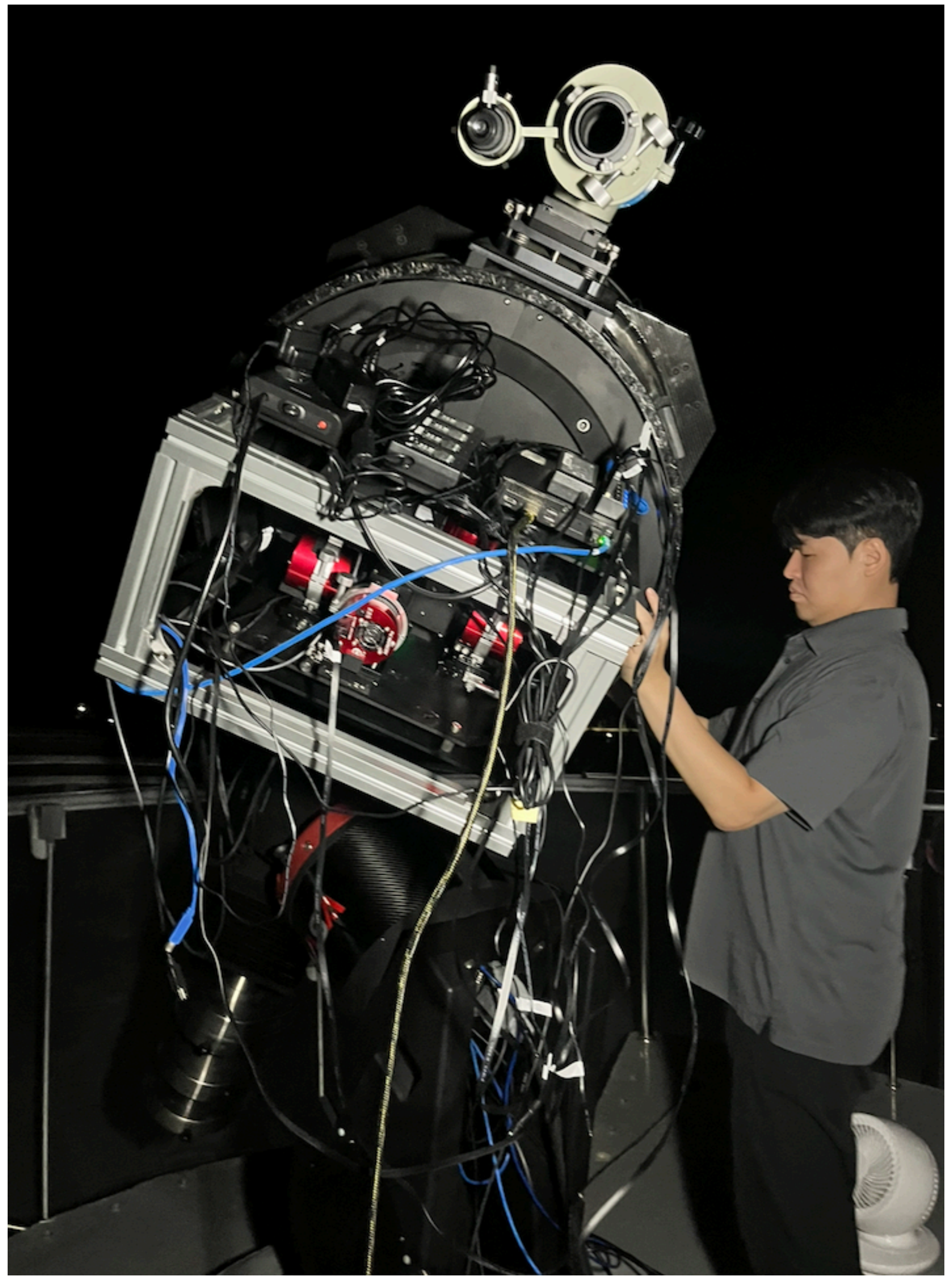
Because these kinds of polarimetric instruments are immune to atmospheric influence and system throughput, allowing for extremely accurate measurements.

[*ref] Referred to Lecture note by Prof. Kawabata (Hiroshima Univ) https://sci.nao.ac.jp/MEMBER/kataoka/kagoshima2016/kawabata.pdf

Developing SQUIDPOL





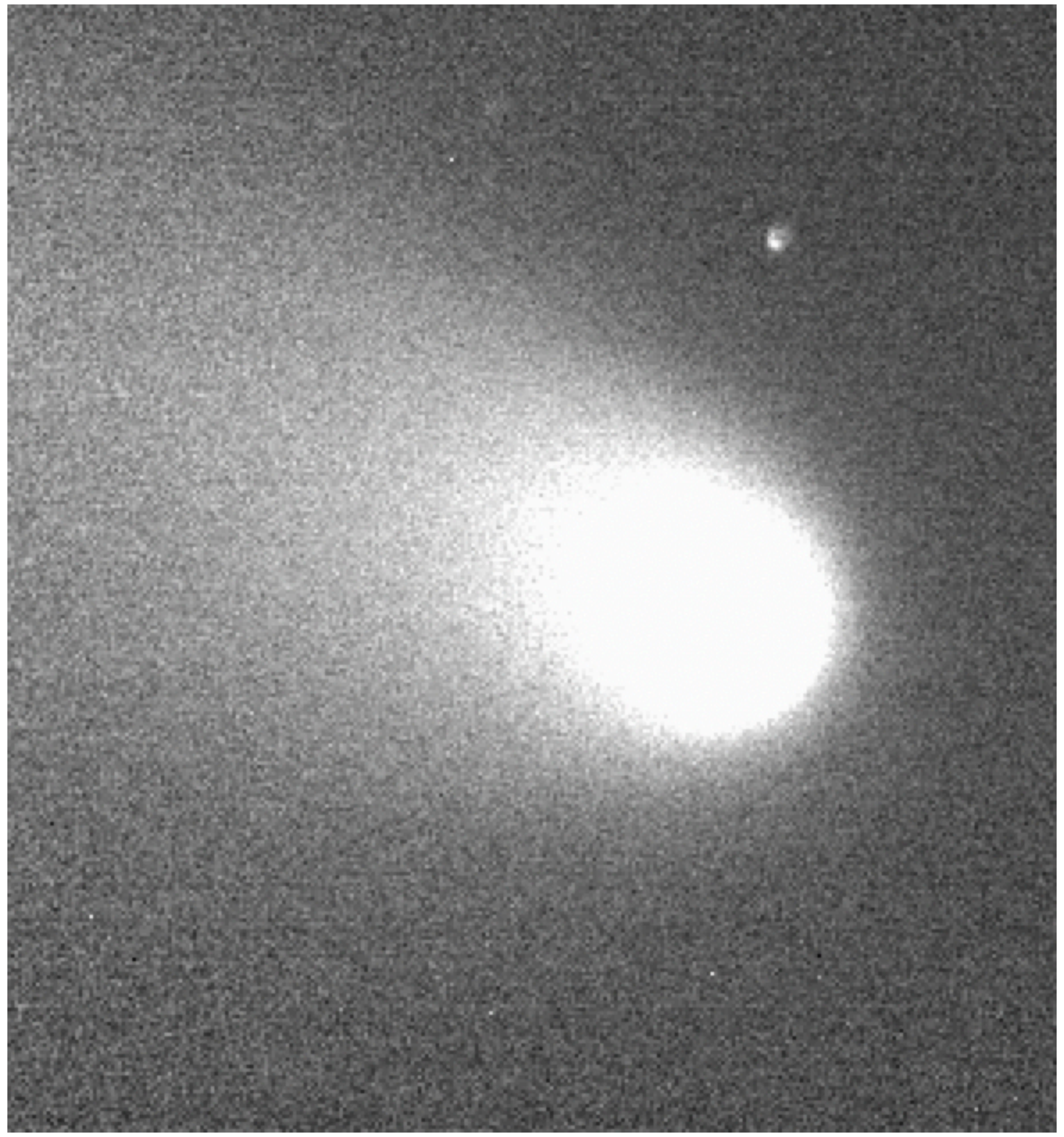


@Laboratory

@ Pyeongchang Campus

What we will do: Deriving Q/I and U/I values of the C/2023 A3

2024 Oct 16, @ Pyeonchang Campus
Exp=3s, taken by Prof.Ishiguro, iPhone



Example image of C2023A3
Exp=30s, taken by Lim & Geem,
SQUIDPOL, R-band

Method

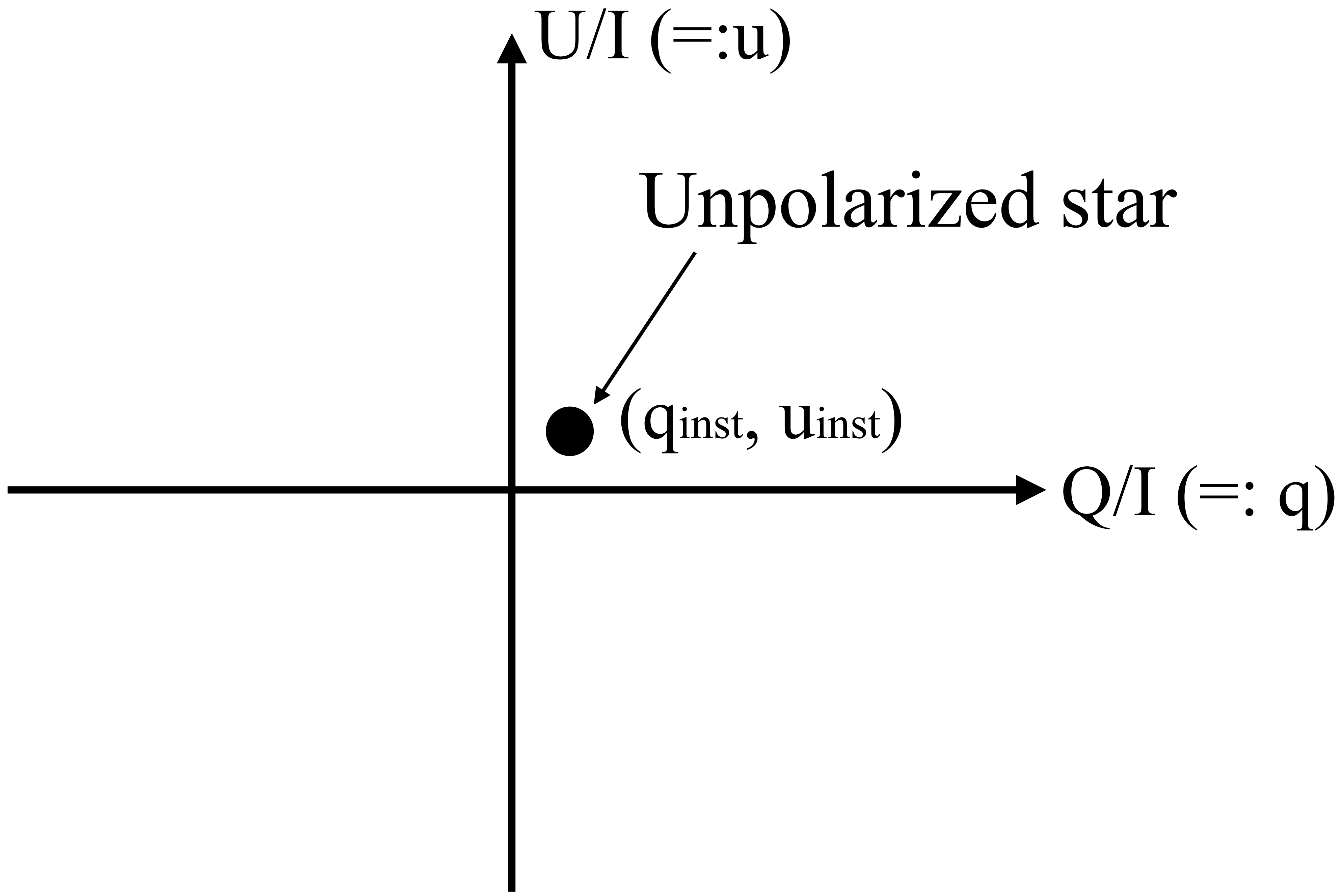
1. Aperture photometry to derive I_0, I_{45}, I_{90}, and I_{135}
   -I will distribute the python code

2. Deriving Q/I and U/I
   (What you have to do)

3. Polarimetric Calibration
   - Instrumental polarization
   - Position angle offset
   (What you have to do)

Polarimetric Calibration

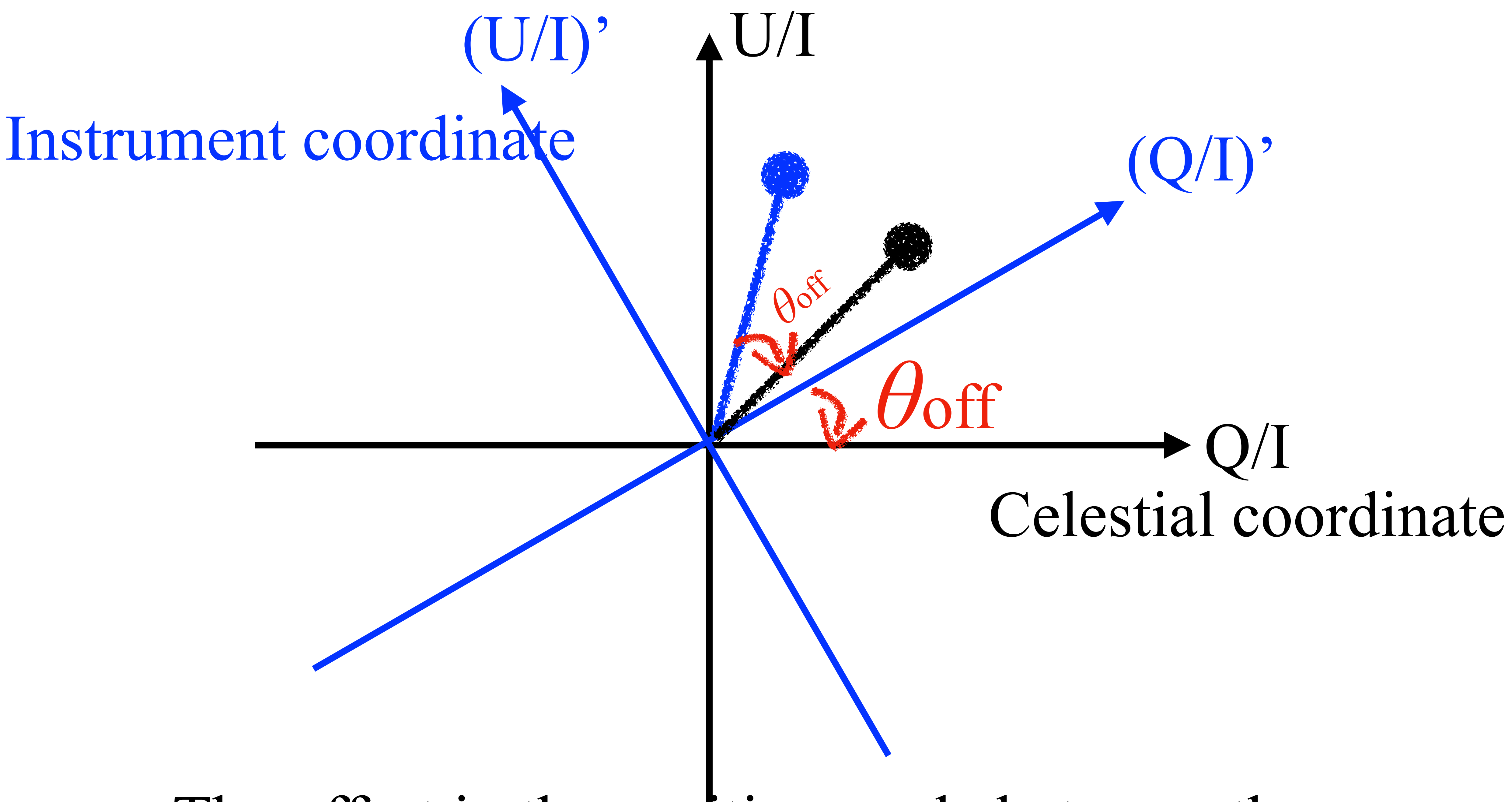
- **Instrumental polarization**



It is mainly produced by Fresnel reflection and refraction at the surfaces of telescope mirrors and lens elements located in front of HWP.
(Ikeda et al. 2007)

$$q' = q - q_{inst}, \quad u' = u - u_{inst}$$

- **Position angle offset**



The offset in the position angle between the celestial and instrumental coordinates should be corrected.

$$q'' = q' \cos(2\theta_{off}) + u' \sin(2\theta_{off})$$
$$u'' = - q' \sin(2\theta_{off}) + u' \mathrm{cose}(2\theta_{off})$$

Information you may need

1. Data
   - 2024 Oct 16, R-band, C2023 A3
   - After the preprocessing

2.

Component	Camera ID
I_0	Cam4
I_{90}	Cam3
I_{45}	Cam1
I_{135}	Cam3

3. Calibration parameters in R-band

Calibration parameters	Values
q_{inst}	-0.28 ± 0.16 %
u_{inst}	-0.45 ± 0.26 %
θ_{off}	-8.85 ± 0.2°

filename	Object	DATE	UT	EXPTIME	Cam	HWPANG	FIL
pSQ20241016_000036_Cam1.fits	C2023A3_r	2024-10-16	09:38:54.69	30.0	1	0.0	R
pSQ20241016_000036_Cam2.fits	C2023A3_r	2024-10-16	09:38:54.69	30.0	2	0.0	R
pSQ20241016_000036_Cam3.fits	C2023A3_r	2024-10-16	09:38:54.69	30.0	3	0.0	R
pSQ20241016_000036_Cam4.fits	C2023A3_r	2024-10-16	09:38:54.69	30.0	4	0.0	R
pSQ20241016_000037_Cam1.fits	C2023A3_r	2024-10-16	09:39:38.57	30.0	1	45.0	R
pSQ20241016_000037_Cam2.fits	C2023A3_r	2024-10-16	09:39:38.57	30.0	2	45.0	R
pSQ20241016_000037_Cam3.fits	C2023A3_r	2024-10-16	09:39:38.57	30.0	3	45.0	R
pSQ20241016_000037_Cam4.fits	C2023A3_r	2024-10-16	09:39:38.57	30.0	4	45.0	R
pSQ20241016_000038_Cam1.fits	C2023A3_r	2024-10-16	09:40:21.22	30.0	1	0.0	R
pSQ20241016_000038_Cam2.fits	C2023A3_r	2024-10-16	09:40:21.22	30.0	2	0.0	R
pSQ20241016_000038_Cam3.fits	C2023A3_r	2024-10-16	09:40:21.22	30.0	3	0.0	R
pSQ20241016_000038_Cam4.fits	C2023A3_r	2024-10-16	09:40:21.22	30.0	4	0.0	R
pSQ20241016_000039_Cam1.fits	C2023A3_r	2024-10-16	09:41:03.84	30.0	1	45.0	R
pSQ20241016_000039_Cam2.fits	C2023A3_r	2024-10-16	09:41:03.84	30.0	2	45.0	R
pSQ20241016_000039_Cam3.fits	C2023A3_r	2024-10-16	09:41:03.84	30.0	3	45.0	R
pSQ20241016_000039_Cam4.fits	C2023A3_r	2024-10-16	09:41:03.84	30.0	4	45.0	R