Development of Simultaneous Imaging Polarimeter for Asteroids

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Abstract

We are currently developing a polarimeter to interpret the surface physical properties (e.g., dust size, dust composition) of asteroids. To enhance the polarimetric accuracy and observational efficiency, we newly constructed a polarimeter which can measure the two linear Stokes parameters Q and U, simultaneously.

Test-observations using a prototype polarimeter have been carried out on December 12, 2003, January 10 and 24, 2004, mounted on the 101cm telescope at the Bisei Astronomical Observatory , Okayama, Japan. In the observations, four unpolarized standard stars and six polarized standard stars were observed to estimate the instrumental polarization and the accuracy of the measurements. The results show that the instrumental polarization is about 5%, and the accuracy of the measurements to be ±0.18%

1.Introduction

☆What can we study about the asteroids from polarimetric observations?

•Relation between the polarization degree and phase angle

>Estimation of "albedo" from P_{min}

>Estimation of "dust size" from P_{max} and albedo

•Asteroids typically have a few or less percent of linear polarization at optical wavelengths. **Therefore, an accuracy of better than 0.1% is needed.**

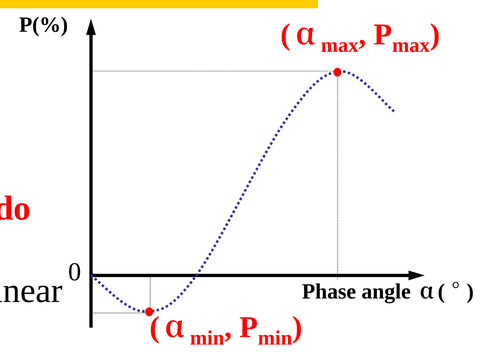

Figure 1. Relation between the polarization degree and phase angle

☆Popular configurations of current polarimeters

>Wollaston prism with a rotating λ/2 plate

→Simultaneous measurements of orthogonally polarized beams

→High accuracy for Q or U parameter

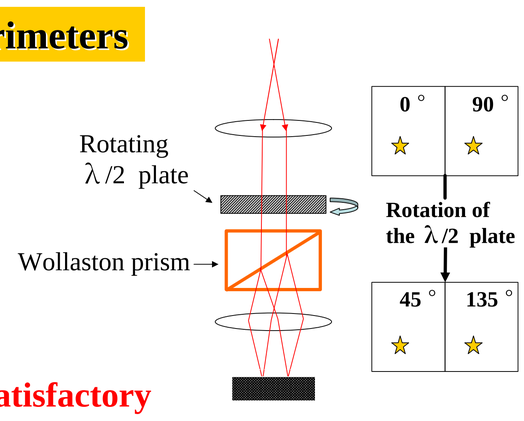

Figure 2. Polarimeter

>**However**, **the resultant accuracy was not satisfactory (>0.1%) for faint objects (>10mag),** due to the tracking error of athetelescope, and changes in atmospheric conditions.

We are developing a polarimeter which can take 0 °, 45 °, 90 °, and 135 ° simultaneously, to enhance observational efficiency and polarimetric accuracy.

2. Optical Configuration

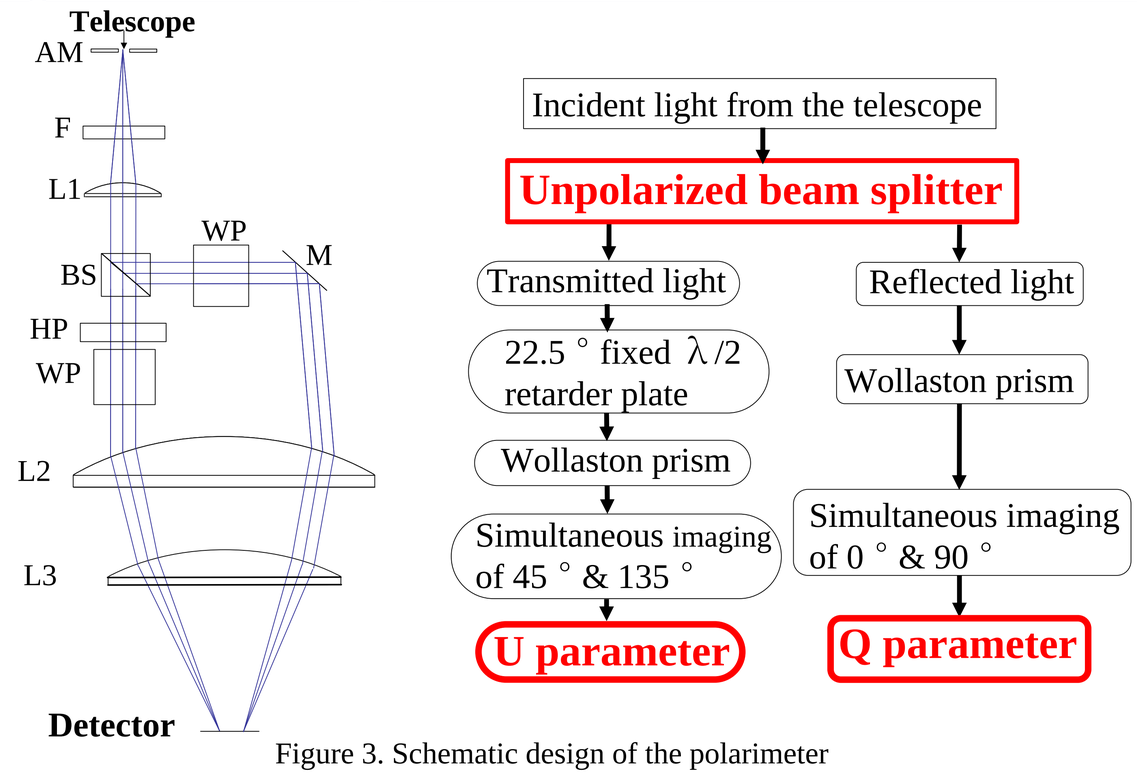

Figure 3. Schematic design of the polarimeter

- AM: Aperture mask
- F: Bessell R-band filter
- L1: Achromatic collimator lens
- BS: Non-polarized beam splitter
- HP: Mica λ/2 retarder plate
- WP: Calcite Wollaston prism
- M: Folding mirror
- L2,L3: Camera lenses

※The Wollaston prisms separate the incident light perpendicular to the paper

- CCD camera : Apogee, Ap7p
- Pixel number : 512×512 pixels
- Pixel scale : 0."3 / pixel
- Field of view : 1.'13×1.'13 / polarized image
- Size : 200×500×225 mm
- Weight : ～3 kg

>The polarimeter can measure the linear Stokes parameters Q and U simultaneously, with no-moving parts
>This can be applied on-board an astronomical satellite

3. Test-Observations and Results

☆Test-Observations

- Date : December 12,2003, January 10, 24, 2004
- Telescope : Bisei 101cm telescope, Okayama, Japan
- Seeing size : ～3″
- Observational method : 9 positions of dithering

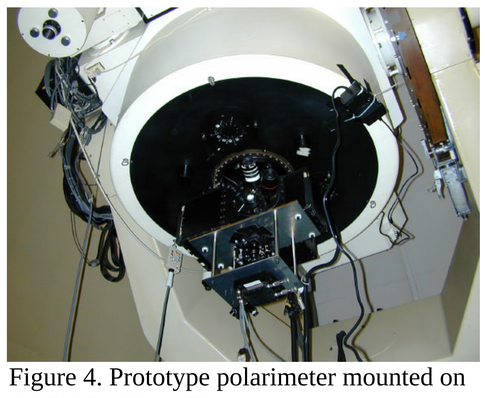

Figure 4. Prototype polarimeter mounted on the BAO 101cm Telescope.

☆Results of test-observations

(1) Obtained image

> We confirmed that the four polarized images were taken simultaneously.

> In the Figure 5, the spots at the bottom of 45 ° and 135 ° are ghosts.

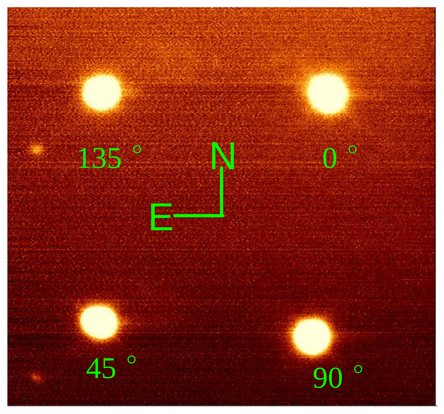

Figure 5. The obtained image of β Uma.

(2) Unpolarized standard stars

Objects	V magnitude (mag)	P_{obs}(%)	θ_{obs}(°)	Exposure time (sec)
HD21447	5.10	5.03(±0.16)	6.51(±0.99)	10×9
HD94851	9.10	5.08(±0.18)	7.31(±1.21)	60×9
θ Uma	3.18	5.04(±0.17)	6.12(±0.69)	1×9
β Uma	2.37	5.09(±0.20)	6.63(±0.68)	0.5×9

Table 1. Results of unpolarized standard stars

> Instrumental polarization : P_{inst} ～5 (%), α_{inst}～6.6 °
> Accuracy of measurements : ±0.18 (%)

(3) Polarized standard stars

Objects	V magnitude (mag)	P(%)[a] (published)	θ(°)[a] (published)	P_{obs}(%)	θ_{obs}(°)	Exposure time (sec)
HD21291	4.21	3.49 (±0.02)	116.6	3.13(±0.40)	113.4(±1.8)	5×9
HD19820	7.11	4.81 (±0.05)	114.9	4.44(±0.37)	110.4(±3.7)	20×9
HD25443	6.78	5.13 (±0.06)	134.2	4.63(±0.28)	131.2(±1.5)	20×9
HD43384	6.27	2.94 (±0.04)	169.8	2.83(±0.27)	164.9(±1.0)	30×9
HD251204	10.28	4.06 (±0.07)	147	4.09(±0.65)	137.0(±1.0)	60×9
BD25+727	9.5	4.27 (±0.01)	33.8	5.76(±0.40)	28.7(±1.2)	60×9

Table 2. Results of polarized standard stars a:Turnshek et al. (1990), Hsu & Berger (1982)

•Possible causes of the difference

> Misalignment of the principal plane between the λ/2 retarder and the Wollaston prisms.

> Mismatching in the wavelength of the λ/2 retarder plate

4. Conclusions

A new imaging polarimeter designed for the observation of asteroids has been developed and tested, mounted on 101cm telescope of the Bisei Astronomical Observatory, Okayama, Japan. The main results are as below:

(1) We confirmed that four polarized images were taken simultaneously by the polarimeter. This can be applied on-board an astronomical satellite.

(2) An instrumental polarization about 5% has been measured. The accuracy of the measurements is estimated to be about ±0.18%.