PHOTOMETRIC AXIS MEASUREMENTS OF THE ZODIACAL LIGHT AT LARGE ELONGATIONS

H. Tanabe, A. Takechi and A. Miyashita
Tokyo Astronomical Observatory, Mitaka, Tokyo 181, Japan

1. INTRODUCTION

Measurement of the position of the photometric axis of the zodiacal light at large elongations ($90° < \lambda - \lambda_\odot < 270°$; λ:ecliptic longitude, $\lambda_\odot$: ecliptic longitude of the sun) provides information about the spatial distribution of the interplanetary dust outside the orbit of the Earth. However, modern photoelectric measurements in this part are scarce, except for the Gegenschein region, because of the observational difficulty due to faintness of this part of the zodiacal light.

This paper is a report of our photoelectric measurements of the photometric axis at $90° < \lambda - \lambda_\odot < 270°$ made at the Kiso Station (geographic longitude = $9^h 10^m.5$E, latitude = 35°48'N, elevation = 1130m) of the Tokyo Astronomical Observatory on nine clear nights in 1978.

2. INSTRUMENT AND OBSERVATION

Automatic scans of the sky along the meridian between 60°N and 65°S zenith distance were performed with a photoelectric photometer furnished with an objective lens of 80mm aperture and 180mm focal length, and a rectangular field of view of 2°(meridian direction) $\times$ 3°. Six interference filters for 5300A, 5577A and other airglow radiations were successively exchanged every scan, hence the scans of a particular color were made every 13 minutes.

Combining these meridional scans with the diurnal motion of the celestial sphere, the 5300A brightness distributions across the ecliptic at various elongations were measured.

3. REDUCTION AND RESULT

Reduction of the data has been made with the following method.
(1) Deflections on the recorder chart were read with 0°.56 step in decli-

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Table 1. Ecliptic coordinates of the photometric axis
(λ : longitude, $\lambda_\odot$: longitude of the sun, β : latitude)

$\lambda - \lambda_\odot$	β
Feb.6/7,	$\lambda_\odot$=317°
216°	+3°.8*
220	+4.8*
242	-0.1*
250	+0.8
253	+3.3
256	+3.7*
261	+2.8
264	+3.1
Feb.7/8,	$\lambda_\odot$=318°
212°	+5°.3
244	+4.5*
249	+1.6
252	+3.5
256	+3.2
Mar.8/9,	$\lambda_\odot$=347°
233°	+2°.6
237	+3.0
241	+2.1

$\lambda - \lambda_\odot$	β
Sept.1/2,	$\lambda_\odot$=158°
186°	-5°.2
190	-3.8*
195	-0.4
200	+2.5*
204	-3.0*
212	-0.4
220	+0.2
226	-1.7
233	-0.4
235	-5.0*
Oct30/31,	$\lambda_\odot$=216°
110°	-1°.8
114	-1.9
117	-1.3
121	-1.9*
128	-0.6
131	-2.1
136	+0.1*
142	-2.6
145	-2.2

$\lambda - \lambda_\odot$	β
148°	-4°.2
155	+1.7*
156	-4.2*
161	-0.4*
168	-1.3*
171	-1.4
175	-0.4
178	-1.0
181	-2.7*
Oct.31/1,	$\lambda_\odot$=217°
99°	+0°.5*
105	-1.4*
109	-1.7
112	-1.1
115	-2.3
128	-0.6
135	-0.5
141	-2.9*
147	+1.1
150	-0.6
154	+0.6

$\lambda - \lambda_\odot$	β
157°	+0°.1
169	+0.7
171	-1.7
Nov.29/30,	$\lambda_\odot$=246°
237°	-0°.2
244	0.0
247	+0.8
250	+1.4
Nov.30/1,	$\lambda_\odot$=247°
97°	-2°.1
100	-2.6*
104	-1.3*
111	-2.5*
116	-0.6*
120	+0.2
123	-1.1
126	-2.9*
130	-0.7
137	-1.8

$\lambda - \lambda_\odot$	β
141°	-2°.0
148	-1.0
151	-3.6
156	+0.7
159	0.0*
245	+1.0
249	+0.8
253	-2.5
256	-0.8*
260	-1.4
Dec.28/29,	$\lambda_\odot$=276°
215°	+0°.3
218	+0.6
222	-0.1*
226	-0.1
229	+0.8*
237	+1.0
239	+3.2
243	+4.2
254	+4.2*

nation (1mm step on the chart) by an Automatic Curve Reader and punched on computer cards. (2) Airglow component included in each 5300A reading was removed by using the 5577A reading for the same sky direction with a 5300A-5577A relation found at the celestial pole for each night. (3) Corrections for the extinction and the atmospheric scattered light were made with an extinction coefficient obtained from star-crossing data for each night, and the table of scattered light given by Ashburn [1954], respectively. (4) A standard lamp calibrated by α Aur(G8) was used for conversion to the absolute brightness, $S_{10}(V)$. (5) We used the table of Roach and Megill [1961] for subtraction of the star background(≥ 6 mag.), and Atlas Coeli [Bečvář, 1962] and Catalogue of Bright Stars[Hoffleit, 1964] for elimination of the bright stars(<6 mag.). (6) From the 5300A brightness curves near the ecliptic obtained by the above process, we determined the declinations of the positions of the maximum brightness referring to the star positions, and converted to ecliptic coordinates.

Final results are listed in Table 1. These are all in the region of $|b|>30°$ of the galactic latitude, and the data having large contamination by bright stars near the ecliptic have been omitted. Accuracy of the positions is approximately within ±0°.5, but ±1°.0 for marked *.

4. DISCUSSION

Misconi [1977] predicted the position of the photometric axis of the zodiacal light at any elongation for any time of the year assuming various possible symmetry planes of the dust distribution, after estimating the geocentric distance of the dust that contributes most of the brightness at each elongation. However, the general trend of our results listed in Table 1, though they show a scatter, does not agree with his two prediction curves for large elongations obtained by considering Mars' orbital plane and the invariable plane as symmetry planes.

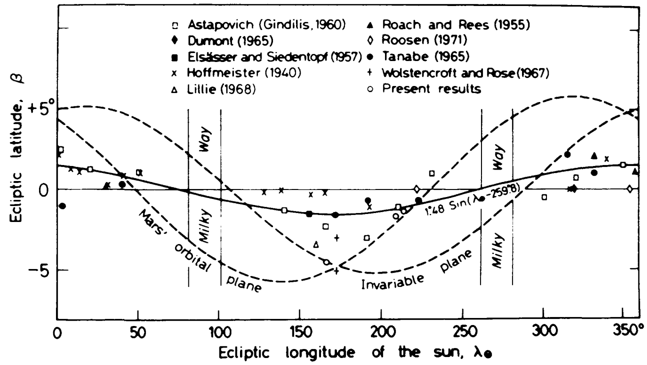

Fig. 1. Predicted and observed positions of the photometric center of the Gegenschein. Dashed curves are predictions [Misconi, 1977] obtained by considering Mars' orbital plane and the invariable plane as symmetry planes. Solid curve is the best fit sine-curve to observed positions.

Figure 1 shows Misconi's prediction curves for the Gegenschein(taken from Figure 5 of his paper), and a plot of the observed positions of the photometric center of the Gegenschein reported by various observers including present results at $170° \lesssim \lambda - \lambda_\odot \lesssim 190°$. Some of the points represent the average of individual measurements. As Misconi has pointed out, the observed positions are scattered between his two predicted curves. Furthermore, from Figure 1 it is seen that the amplitudes of the predicted curves are larger than that of the observed points.

Accordingly, we calculated the best fit sine-curve by the least squares method from all the observed values plotted in the figure. The resulting curve, whose amplitude is 1°48 and phase angle 259°8 of $\lambda_\odot$, is also shown in Figure 1. Using the value of 0.5AU as the geocentric distance of the dust for the Gegenschein(following Misconi), a symmetry plane corresponding to the best fit curve was obtained. The new symmetry plane has ascending node Ω=79°8, inclination i=0°49 to the ecliptic plane.

In order to confirm the symmetry plane obtained above, we calculated the position of the photometric axis at each elongation for this plane for each night of our observation by using the geocentric distances of the dust (read from Figure 2 of Misconi's paper). Two examples of our calculated positions of the photometric axis for the new symmetry plane are shown in Figure 2. In addition to our observational results, Hoffmeister's results [1940], which were observed in the same time of the year, are plotted in the figure. In spite of their scatter, both observations agree with each other in their general trend, and the curves of our calculated positions seem to be in accord with their central line except in the Milky Way region of October. The observed positions in the Milky Way might have large errors due to the bright background star-light.

The inclination of the new symmetry plane is smaller than that of the invariable plane and the ascending node is close to that of Venus (76°5), which means that the symmetry plane is close to both the orbital planes of the Earth and Venus. On the other hand, Misconi and Weinberg [1978] concluded that the symmetry plane inside the Earth's orbit is close to the orbital plane of Venus from their examination of the photometric axis at small elongations. Since the masses of the Earth and

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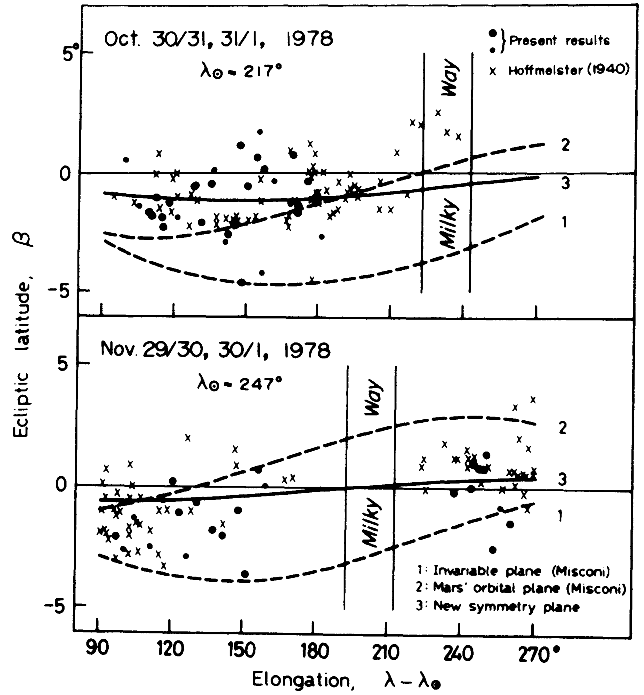

Fig. 2. Calculated and observed positions of the photometric axis of the zodiacal light at each elongation. Curves 1 and 2 are Misconi's predictions[1977], and curve 3 is our calculation for the new symmetry plane. Size of dots indicates weight of measurement.

Venus are much greater than those of other inner planets (Mars and Mercury), the gravitational effects of the Earth and Venus might control the dust distribution in the inner part of the solar system.

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