

THE CHANGE IN NEAR-ECLIPTIC ZODIACAL LIGHT BRIGHTNESS WITH
HELIOCENTRIC DISTANCE

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ABSTRACT. Background starlight observed by the Pioneer 10 Imaging Photopolarimeter from beyond the asteroid belt is used to isolate zodiacal light in Pioneer observations at heliocentric distances R between 1 and 3 AU. Near-ecliptic zodiacal light brightness data in the range 65° to 180° elongation ϵ are used to depict changes in the shape of the zodiacal light with ϵ and R and are compared to the corresponding views seen from the Earth and from the Helios 1 and 2 spacecraft.

The heliocentric dependence of zodiacal light can only be observed directly by a space probe, the first such probe measurement being made by Pioneer 10. During the cruise phase of this outer solar system mission, sky brightness and polarization were mapped using a photopolarimeter (Weinberg, et al.; 1973, 1974). At elongations greater than 90° , the contribution of zodiacal light decreased to negligible levels beyond 3 AU (Hanner, et al.; 1974, 1976). As part of an analysis of additional Pioneer 10 data, Schuerman, et al. (1977) pointed out that there is no evidence for the zodiacal light being absent beyond 3 AU - only that it becomes vanishingly small compared to the background starlight (integrated starlight, diffuse galactic light, extragalactic background light). These studies are extended to smaller elongations and, for the first time, zodiacal light brightnesses are tabulated as a function of ϵ , β , and R (Table 1).

Since zodiacal light is negligible at large R , observations in these regions have been used to derive maps of background starlight over the sky (Toller, 1981; Weinberg, 1981). These data and brightnesses due to discrete ($m_v < 6.5$) stars are subtracted from Pioneer 10 observations between 1 and 3 AU to derive the 4400\AA ϵ, β, R zodiacal light topology given in Table 1. The three entries in each ϵ, R box correspond to data at ecliptic latitudes $\beta = +10^\circ, 0^\circ, -10^\circ$ from top to bottom, respectively. Empty boxes indicate regions not yet analyzed. Blank areas within a box denote regions where the data was either not analyzed or is uncertain due to the presence of a bright star in the field of view. Additional Pioneer 10 blue data and the corresponding Pioneer 10 red (6400\AA) data will be similarly analyzed and published elsewhere.

Figure 1a illustrates the change in zodiacal light brightness, I , with R for $\beta = 0^\circ$. It confirms the falloff of zodiacal light to undetected levels at $R > 2.8$ AU for outward-looking directions, as noted by Schuerman, et al. (1977). $R^{-2.6}$ is the best fit to the run of relative brightness with R (Figure 1b), a steeper decline than the $R^{-2.3}$ found by Link, et al. (1976) and Leinert, et al. (1981) from Helios 1/2 observations between 0.31 and 1.0 AU. Weinberg and Sparrow (1978) suggested that this difference is probably the result of different viewing directions and spacecraft positions for Pioneer 10 and Helios 1/2. Figure 2 depicts zodiacal light brightness versus elongation for several values of R and β . Pioneer 10 observations from $R = 1.011$ AU, at .01 AU below the ecliptic, and in a plane parallel to the ecliptic are 20% below the ground-based, in-ecliptic observations taken by Dumont (Levasseur-Regourd and Dumont, 1980). 3% of this can be attributed to the .011 AU difference in R between the Pioneer and ground data, with approximately 10% more due to Pioneer's position below the plane of symmetry of the dust (Hanner, et al., 1976). Helios data at 0.984 AU normalized to 1 AU (Leinert, et al., 1981) also falls below the ground data in the range $\epsilon > 90^\circ$. There is brightness "structure" in the Pioneer data (Figure 2) that appears to reproduce at the same elongations above and below the ecliptic *and at different heliocentric distances* (i.e., seen through different parts of the zodiacal cloud). Similar ϵ, β structures were discovered by Hong in Pioneer 10 Gegen-schein data and in ground observations from Mt. Haleakala, Hawaii (Hong, et al., this volume).

This research was supported by U.S. Air Force Office of Scientific Research grant 83-0107.

REFERENCES

- Hanner, M.S., Sparrow, J.G., Weinberg, J.L., Beeson, D.E.: 1976, in Lecture Notes in Physics, No. 48, 29 (Springer-Verlag).
- Hanner, M.S., Weinberg, J.L., DeShields, L.M., Green, B.A., Toller, G.N.: 1974, J. Geophys. Res., 79, 3671.
- Leinert, C., Richter, I., Pitz, E., Planck, B.: 1981, Astron. Astrophys., 103, 177.
- Levasseur-Regourd, A.C., Dumont, R.: 1980, Astron. Astrophys., 84, 277.
- Link, H., Leinert, C., Pitz, E., Salm, N.: 1976, in Lecture Notes in Physics, No. 48, 24 (Springer-Verlag).
- Schuerman, D.W., Weinberg, J.L., Beeson, D.E.: 1977, B.A.A.S., 9, 313.
- Toller, G.N.: 1981, Dissertation, State Univ. of N.Y. at Stony Brook.
- Weinberg, J.L., Hanner, M.S., Mann, H.M., Hutchison, P.B., Fimmel, R.: 1973, Space Res. XIII, 1187.
- Weinberg, J.L., Hanner, M.S., Beeson, D.E., DeShields, L.M., Green, B.A.: 1974, J. Geophys. Res., 79, 3665.
- Weinberg, J.L., Sparrow, J.G.: 1978, in Cosmic Dust, 75 (Wiley-Interscience).
- Weinberg, J.L.: 1981, Sky and Tel., 61, 114.

		HELIOCENTRIC DISTANCE, R (AU)										
		1.011	1.150	1.171	1.349	1.453	1.652	1.861	2.294	2.413	2.641	2.939
ELONGATION, ϵ (DEGREES)	65											4
	70								55		25	2
									63			5
									71			
	75								40	33	19	4
									44		32	1
									50			5
	80							36	33	25	15	4
									29	23	22	3
								35	35		23	2
	85							25	26	20	7	1
								25	25	19	15	2
							33	22	15	12	3	
90						30	23	18	18	8	0	
						22	16	19	17	10	1	
						24	19	18	13		1	
95						27	21	15	16	4	0	
						23	17	19	14	8	0	
						27	21	19	13	9	0	
100					27	25	24	13	11	7	1	
						24	25	16	13	4	0	
						26	21	8	14	10	0	
105					40	31	25	10	9	5	0	
					37	27	20	10	12		0	
					36	27	20	12	13	6	0	
110				42	41	36	22	10	11	5	0	
					34	33	22		4	7	0	
					34	32	17	9	9	7	0	
115	122			45	49	32	22	8	10	5	0	
				42	37	33	26		11	6	0	
				49	36	27		10	10	4	0	
120	109			47	46	30	23	7	6	1	2	
	126			41	45	32	25	6	11	6	0	
				45	35	29	20	11	9	3		

Table 1 (part 1). Zodiacal light brightness at 4400\AA in $S_{10}(V)_{G2V}$ units as a function of elongation (angular distance from the sun) and heliocentric distance R. The three entries in each ϵ, R box correspond to ecliptic latitudes $\beta = +10^\circ, 0^\circ, -10^\circ$ from top to bottom, respectively.

		HELIOCENTRIC DISTANCE, R (AU)										
		1.011	1.150	1.171	1.349	1.453	1.652	1.861	2.294	2.413	2.641	2.939
125	108			69	48	47	32	24	11	13	3	0
			59	57	50	43	37	17	11	13	5	0
				44	40	31	19	12				
130	117	73	73	55	46	29	23	7	13	0	1	
		63	64	52	46	34	10	8	10	0	0	
		62	64	45	38	30	20	13				
135	113	68	68	53	45	29	20	15	5	1	0	
		68	64	52	43		23	8	0	0		
		68	60	43	37	26	20	8				
140	116	73	76	60	42	29	25	7	8			
	117	74	69	53	48		22	8	6			
		68	65	48	41	28	18	15				
145	118	73	78	56	47	34	23	9	5			
	120	73	79	56	45	35	26					
	101	68	67	46	41	29	17					
150	118	83	83	54	52	33	31	6				
	114	81	80	52	39	35						
	104	73	67	48	45	33						
155	117	82	80	59	52	41	23					
	118	83	80		51	33						
	103	72	72	50	43	28						
160	115	89	90	60	48	35	22					
	119	81	84	59	49							
		79		53	44							
165	119	91	86	60	55	43						
	130	98	90	61	56							
	111	79	78	51	43							
170	122											
	134	107	90	65	57							
	120	83	83	56								
175	138	109	100	70								
180	146	111	108	70								

Table 1 (part 2). Zodiacal light brightness at 4400\AA in $S_{10}(V)_{G2V}$ units as a function of elongation (angular distance from the sun) and heliocentric distance R. The three entries in each ϵ, R box correspond to ecliptic latitudes $\beta = +10^\circ, 0^\circ, -10^\circ$ from top to bottom, respectively.

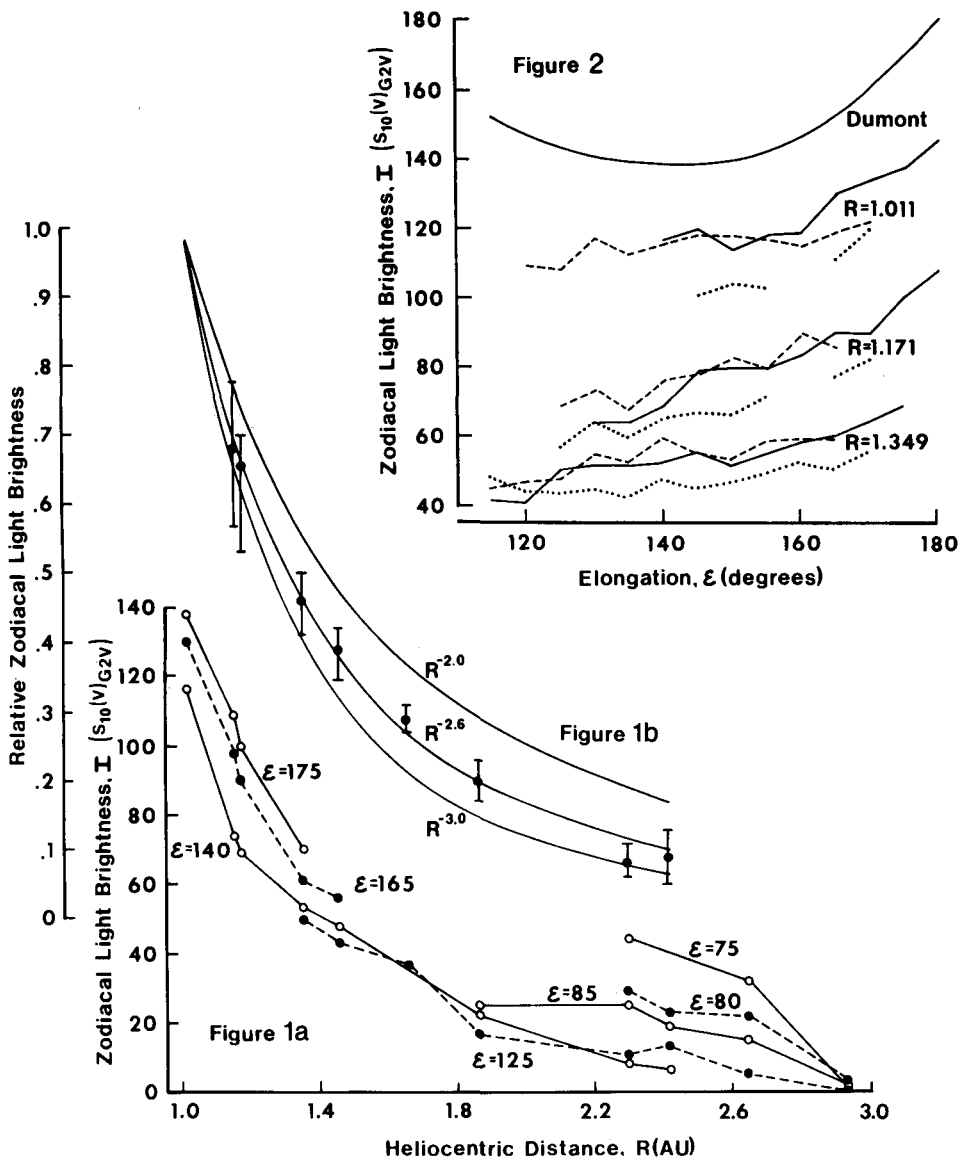


Figure 1a. Pioneer 10 zodiacal light brightness versus heliocentric distance for $\beta = 0^\circ$ and for several elongations.
 Figure 1b. Relative zodiacal light brightness versus heliocentric distance. Circles are an average over several elongations, and error bars denote the range of relative brightness for all elongation angles. Power law curves are included for comparison.
 Figure 2. Near-ecliptic zodiacal light brightness at large elongations for several heliocentric distances. Observations by Dumont at 1 AU are included for comparison. Solid lines indicate $\beta = 0^\circ$, dashed lines $\beta = +10^\circ$, and dotted lines $\beta = -10^\circ$.