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A LIST OF SOME BRIGHT OBJECTS WHICH S-052 CAN OBSERVE

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16. ABSTRACT

To know the precise orientation of the photographs obtained by the High Altitude Observatory's ATM White Light Coronagraph, celestial objects must appear on each roll of film. A list of such bright objects and the times during which they can be observed is presented.

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A LIST OF SOME BRIGHT OBJECTS WHICH S-052 CAN OBSERVE

The Apollo Telescope Mount is a collection of five solar instruments which will be an integral part of the first United States space station, Skylab. One of these instruments is S-052, which is under the control of the High Altitude Observatory in Boulder, Colorado. Figure 1 shows an overall view of the instrument. At the solar end there are three apodized occulting disks on the external occulting disk assembly. These disks are located infinitely far away from the optics when compared to the focal length of the optics. This is done to block out the sun and its inner corona; that is, to occult from 0 to 1.5 solar radii. The optics housing is shown in Figure 2. Here one sees an internal occulting disk located behind the primary objective lens. Its purpose is to reduce the amount of stray light created by the external occulting disks. Using such an occulting system, S-052 will be able to observe the brightness, form, and polarization of the outer corona from about 1.5 to 6 solar radii from the center of the sun. An optics ray trace is presented in Figure 3. As is indicated by Figures 2 and 3, the data about the corona are primarily obtained photographically. However, when a flip-flop mirror is lowered into the light path, the data will appear on an SEC TV system.

The information obtained from this experiment will be combined with data obtained from the other ATM solar instruments and from ground-based observatories to give meaningful results on the solar corona. To do this, one needs to know the precise orientation of the corona data so that the various pieces of data can be correlated. The ATM does give precise orientation measurements for its main support structure, but this structure can be misaligned with S-052 during launch. This would destroy the kind of orientation measurements needed for S-052. Also, there could be a slight misalignment of the film in the various cameras and a slight misalignment of the cameras to S-052 during their replacement on the EVA's.

To determine the precise orientation of the data, one needs to include on each roll of film at least two known points of reference which cannot be superimposed. The best method is to have two celestial bodies appear on at least one picture in each roll of film. A second possibility is to have a celestial body appear in two different locations on each roll of film. In the latter case, it would be best to have the pictures separated in time by about 12 hours.

In the "ATM-WLCE Technique Memorandum #7" by the High Altitude Observatory, it was shown that S-052 could be expected to see at least 9^{th} magnitude stars. Later, the prototype of S-052 was flown on a balloon which reached a high altitude. Pictures taken by S-052 during this flight did not readily show any stars. Therefore, Dr. Newkirk of the High Altitude Observatory thought it best to develop a list of objects whose magnitude is brighter than 3.5 which S-052 might be able to observe for possible use in determining data orientation. The purpose of this paper is to present such a list. Originally the list was to include only stars, but since there were so few bright stars, it was decided to look at the planets as well. The moon was not included because its position relative to the spacecraft and the sun would be determined by the orbital parameters of the spacecraft and its time of launch. A program has been prepared which would yield the relative position of the moon once the above factors are known. A lesser but significant advantage of looking at the moon with S-052 would be that it could be used as a secondary intensity calibration source. The primary intensity calibration source for S-052 is the disc of the sun.

A possible side benefit of using the planets to determine the exact orientation of the sun is that one would be able to get some apparent magnitudes of some of the planets which have not yet been observed near the sun. The apparent magnitude of a planet is a function of the planet's distance from the sun, r, the planet's distance from the earth, d, and the solar phase angle, α, which is the angular distance at the planet between the earth and the sun. For Mercury, Venus, and the Moon, the solar phase angle varies from 0 to 180 degrees; for Mars the angle can attain a value of about 47 degrees, while for the more distant planets the angle reaches only a few degrees.

Neglecting possible variations in brightness due to rotation or intrinsic causes, the observed magnitude of a planet is given by

$$V = V(1, 0) + 5 \log rd + \Delta m(\alpha) \quad ,$$

where $V(1, 0)$ is the magnitude of the planet reduced to unit distance from the sun and earth and phase angle zero, and $\Delta m(\alpha)$ is the correction for the variation in magnitude of the planet with phase angle. The quantity $\Delta m(\alpha)$ is composed of two parts; the first arises from the fact that the fraction of the illuminated disk visible from the earth varies with α, while the second, and much larger, effect is due to the properties of diffuse reflection from the planet's surface or atmosphere. From the observational point of view, it is sufficient to express $\Delta m(\alpha)$ as a power series in α, retaining as many terms as are required to adequately represent the observations. For the outer planets it is generally sufficient to consider only the first term, and the coefficient of α so found is often referred to as the phase coefficient.

The magnitude, V(1, 0), corresponds to the quantity g introduced by earlier investigators; the new symbol is used here to specify the spectral region to which the observations refer. For some purposes it is convenient to use the mean opposition magnitude, V_o, which is related to V(1, 0) by

$$V_o = V(1, 0) + 5 \log \alpha (a - 1) \quad ,$$

where a is the semimajor axis of the planet's orbit. If the brightness of the planet is variable, the problem of predicting the apparent magnitude at a given time is considerably more complicated. The variability may arise from the following causes: (a) the planet's surface is spotted, giving rise to a brightness variation with the rotation period; (b) changes in the planet's atmosphere or surface features, giving rise to variations of an irregular character. These may be short-lived or persist for considerable periods of time. For planets exhibiting intrinsic variability, one tries to determine mean values of V(1, 0) and $\Delta m(\alpha)$ and indicate graphically the variations from these mean values. In particular, it is noted that the variation with rotational phase is a function of solar phase angle as well. This follows not only from geometrical considerations, but also because the properties of diffuse reflection must depend on the surface features.[1]

S-052 is an instrument which is to be operated only in a sun-centered mode. Its field of view goes from 1.5 to 6.0 solar radii; i.e., from 0.°4 to 1.°6 from the center of the sun. The list of bright objects should include the time during which the objects would be in that field of view. Becvar's "Atlas of the Heavens" and the Smithsonian "Star Catalogue" were used in the selection of the stars to be included in the list of bright objects, their apparent visual magnitude, and their positions. A computer printout of the Jet Propulsion Laboratory's Ephemeris was used to determine the position of the sun. The position of the sun was then plotted against the position of the stars to determine the time during which the stars would be in the field of view of S-052 (Figs. 4, 5, 6, 7, 8, 9, 10). The Jet Propulsion Laboratory's Ephemeris was used to determine the position of the planets relative to the sun and the time during which they would be in the field of view of S-052. A vectorial computer program was used to do this

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1. Kuiper and Middlehurst, ed.: Planets and Satellites. Chicago, 1961, p. 272.

(Fig. 11). The computer printout (Table 1) gives the time according to the Julian calendar to the nearest hour. Also, the right ascension and declinations are given for the planets and the moon. Differences between the right ascension and declinations of the sun with respect to the planets and the moon are given. Finally, the angles between the center of the sun and the planets and the moon, as viewed from the center of the earth, are given in degrees. Since only the planets, and not the moon, can be considered infinitely far away with respect to the distance between the center of the earth and Skylab, the only relevant data of concern is the angular separation for the planets. Table 2, the result of this work, gives the object, the object's apparent stellar magnitude, and the time during which the object could be in the field of view of S-052. The apparent stellar magnitudes of the planets were estimated by using the "American Ephemeris and Nautical Almanac" in conjunction with the appropriate computer printouts. The Principal Investigator of the High Altitude Observatory's ATM White Light Coronagraph will determine whether or not these objects are to be observed.

TABLE 1. OBJECT ORIENTATION PRINTOUT

DAY		SUN	MERCUR	VENUS	MARS	JUPITE	SATURN	MOON
2442364.00	RA	226.92	209.29	228.59	217.66	339.95	109.89	206.68
	DEC	-17.57	-9.56	-17.43	-14.53	-9.88	21.72	-14.63
	DRA		-17.63	1.67	-9.26	113.03	-117.03	-20.24
	DDEC		8.01	.14	3.05	7.69	39.29	2.95
	ANGL		18.90	1.60	9.41	108.39	120.95	19.65
2442364.04	RA	226.96	209.34	228.65	217.68	339.95	109.89	207.25
	DEC	-17.59	-9.58	-17.45	-14.54	-9.88	21.72	-14.79
	DRA		-17.63	1.68	-9.28	112.99	-117.08	-19.71
	DDEC		8.00	.14	3.05	7.70	39.30	2.79
	ANGL		18.89	1.61	9.42	108.35	120.99	19.12
2442364.08	RA	227.01	209.38	228.70	217.71	339.95	109.89	207.82
	DEC	-17.60	-9.60	-17.46	-14.54	-9.88	21.72	-14.96
	DRA		-17.62	1.69	-9.29	112.95	-117.12	-19.18
	DDEC		8.00	.14	3.05	7.71	39.31	2.64
	ANGL		18.89	1.62	9.44	108.31	121.03	18.59
2442364.12	RA	227.05	209.43	228.75	217.74	339.95	109.88	208.39
	DEC	-17.61	-9.62	-17.48	-14.55	-9.88	21.72	-15.12
	DRA		-17.62	1.70	-9.31	112.90	-117.16	-18.65
	DDEC		7.99	.13	3.05	7.73	39.32	2.49
	ANGL		18.88	1.63	9.45	108.27	121.08	18.06
2442364.17	RA	227.09	209.47	228.80	217.77	339.95	109.88	208.97
	DEC	-17.62	-9.64	-17.49	-14.56	-9.88	21.72	-15.28
	DRA		-17.62	1.71	-9.32	112.86	-117.21	-18.13
	DDEC		7.98	.13	3.06	7.74	39.34	2.34
	ANGL		18.87	1.64	9.46	108.23	121.12	17.53
2442364.21	RA	227.13	209.52	228.86	217.80	339.96	109.88	209.54
	DEC	-17.63	-9.65	-17.51	-14.57	-9.88	21.72	-15.44
	DRA		-17.61	1.72	-9.34	112.82	-117.25	-17.60
	DDEC		7.98	.13	3.06	7.75	39.35	2.19
	ANGL		18.86	1.65	9.48	108.19	121.16	17.00
2442364.25	RA	227.18	209.57	228.91	217.82	339.96	109.88	210.11
	DEC	-17.64	-9.67	-17.52	-14.58	-9.88	21.72	-15.60
	DRA		-17.61	1.73	-9.35	112.78	-117.29	-17.07
	DDEC		7.97	.12	3.06	7.76	39.36	2.04
	ANGL		18.86	1.66	9.49	108.15	121.21	16.47

TABLE 2. LIST OF BRIGHT CELESTIAL OBJECTS

Object	m_V	Universal Time for Possible Acquisition by S-052
Mercury	-1.3	1^h May 19, 1973 to 2^h May 20, 1973
Mercury	-1.3	12^h May 20, 1973 to 13^h May 21, 1973
Saturn	0.4	23^h June 13, 1973 to 19^h June 16, 1973
η Gemini	3-4	12^h June 23, 1973 to 0^h June 26, 1973[a]
μ Gemini	3.2	9^h June 25, 1973 to 0^h June 28, 1973[a]
δ Gemini	3.5	1^h July 9, 1973 to 5^h July 10, 1973
δ Gemini	3.5	23^h July 10, 1973 to 3^h July 12, 1973
α Leo	1.3	5^h August 21, 1973 to 6^h August 24, 1973
α^2 Libra	2.9	20^h November 5, 1973 to 1^h November 7, 1973
α^2 Libra	2.9	14^h November 7, 1973 to 18^h November 8, 1973
Mercury	-1.3	19^h November 9, 1973 to 6^h November 10, 1973
Mercury	-1.3	15^h November 10, 1973 to 2^h November 11, 1973
β Scorpio	2.9	4^h November 24, 1973 to 9^h November 26, 1973
π Sagittarius	3.0	23^h January 5, 1974 to 3^h January 7, 1974
Jupiter	-1.3	20^h February 11, 1974 to 11^h February 15, 1974
Mercury	-1.3	9^h May 3, 1974 to 9^h May 4, 1974
Mercury	-1.3	1^h May 5, 1974 to 0^h May 6, 1974
η Gemini	3-4	18^h June 23, 1974 to 6^h June 26, 1974[a]
μ Gemini	3.2	15^h June 25, 1974 to 6^h June 28, 1974[a]
Saturn	0.4	17^h June 28, 1974 to 7^h July 2, 1974
δ Gemini	3.5	7^h July 9, 1974 to 11^h July 10, 1974
δ Gemini	3.5	5^h July 11, 1974 to 9^h July 12, 1974
α Leo	1.3	11^h August 21, 1974 to 12^h August 24, 1974

TABLE 2. (Concluded)

Object	m_V	Universal Time for Possible Acquisition by S-052
Mars	+2.0	0^h October 10, 1974 to 5^h October 19, 1974
Mercury	-1.3	2^h October 25, 1974 to 4^h October 26, 1974
Venus	-3.5	10^h November 1, 1974 to 12^h November 12, 1974[a]
α^2 Libra	2.9	2^h November 6, 1974 to 7^h November 7, 1974
α^2 Libra	2.9	20^h November 7, 1974 to 0^h November 9, 1974
β Scorpio	2.9	10^h November 24, 1974 to 15^h November 26, 1974
Mercury	-1.3	3^h December 18, 1974 to 6^h December 20, 1974
π Sagittarius	3.0	6^h January 6, 1975 to 10^h January 7, 1975
Jupiter	-1.3	12^h March 20, 1975 to 15^h March 23, 1975
Mercury	-1.3	15^h April 17, 1975 to 5^h April 20, 1975
η Gemini	3-4	0^h June 24, 1975 to 13^h June 26, 1975[a]
μ Gemini	3.2	22^h June 25, 1975 to 12^h June 28, 1975[a]
δ Gemini	3.5	13^h July 9, 1975 to 17^h July 10, 1975
δ Gemini	3.5	11^h July 11, 1975 to 15^h July 12, 1975
Saturn	0.4	17^h July 13, 1975 to 3^h July 15, 1975
Saturn	0.4	3^h July 16, 1975 to 13^h July 17, 1975
α Leo	1.3	17^h August 21, 1975 to 18^h August 24, 1975
α^2 Libra	2.9	8^h November 6, 1975 to 13^h November 7, 1975
α^2 Libra	2.9	2^h November 8, 1975 to 6^h November 9, 1975
β Scorpio	2.9	16^h November 24, 1975 to 21^h November 26, 1975[a]
Mercury	-1.3	3^h November 26, 1975 to 5^h December 1, 1975[a]

a. These are bright objects which are in the field of view of S-052 with another bright object, other than the sun and the moon.

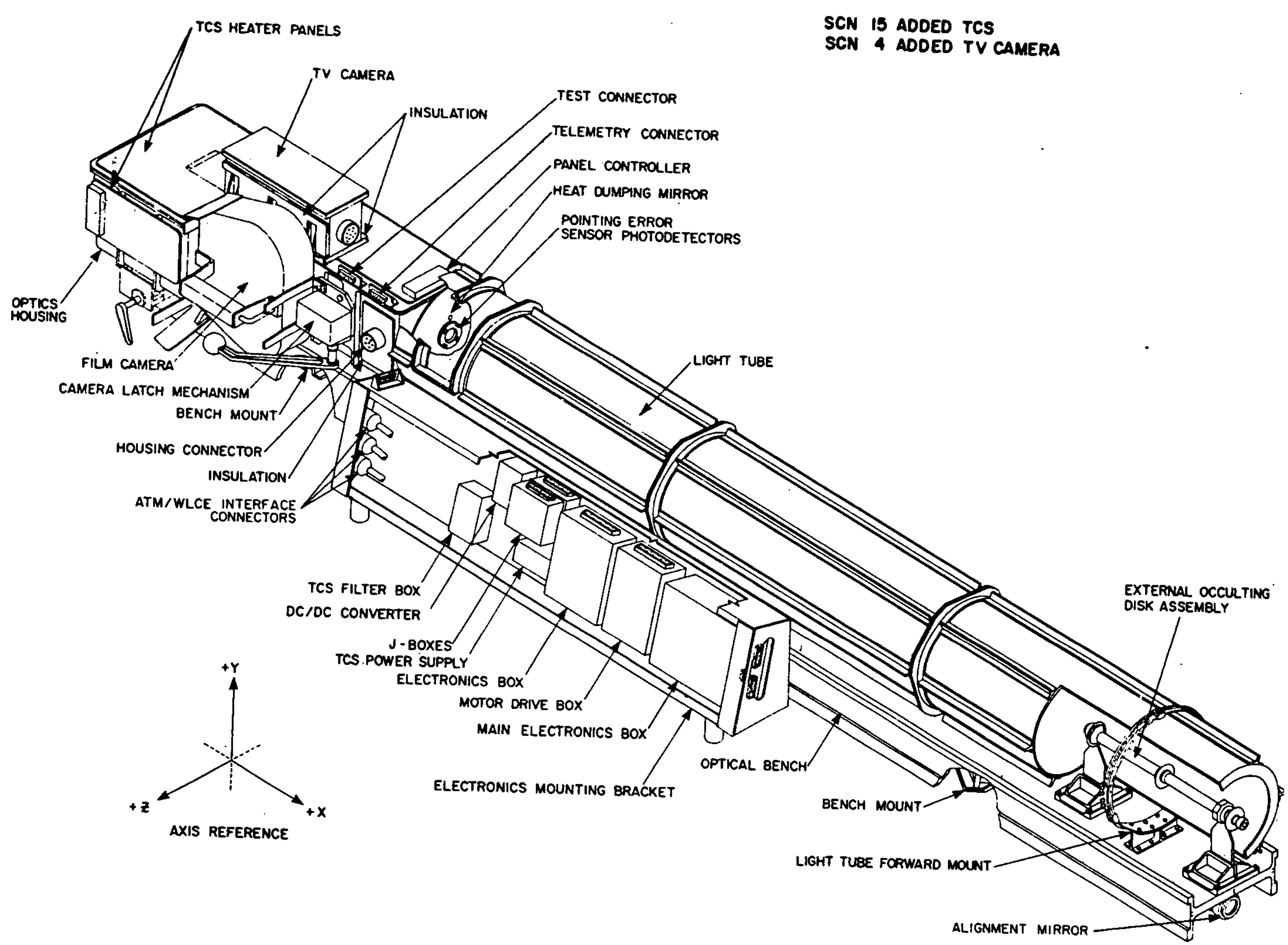


Figure 1. ATM-WLCE configuration.

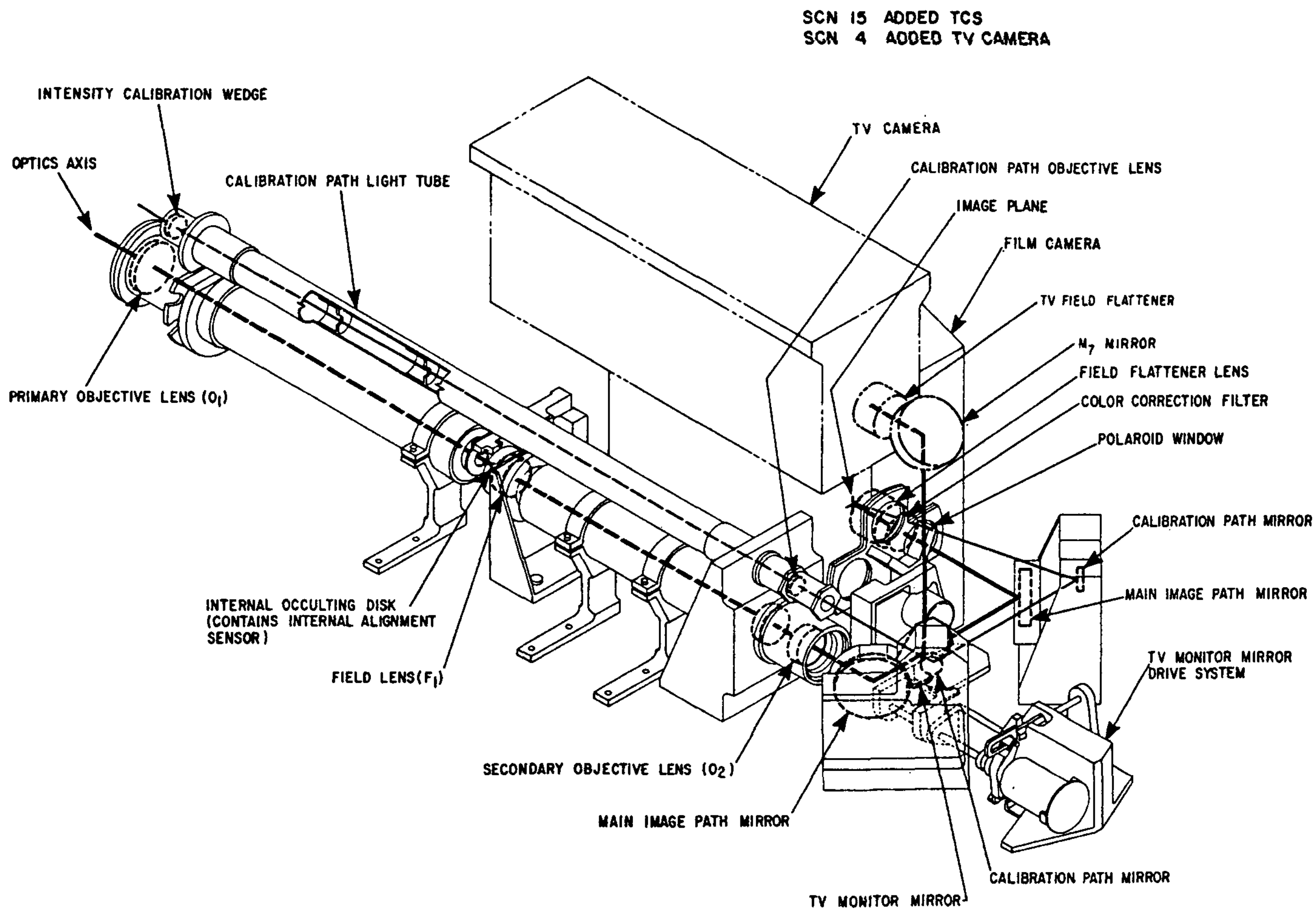


Figure 2. Optics housing detail.

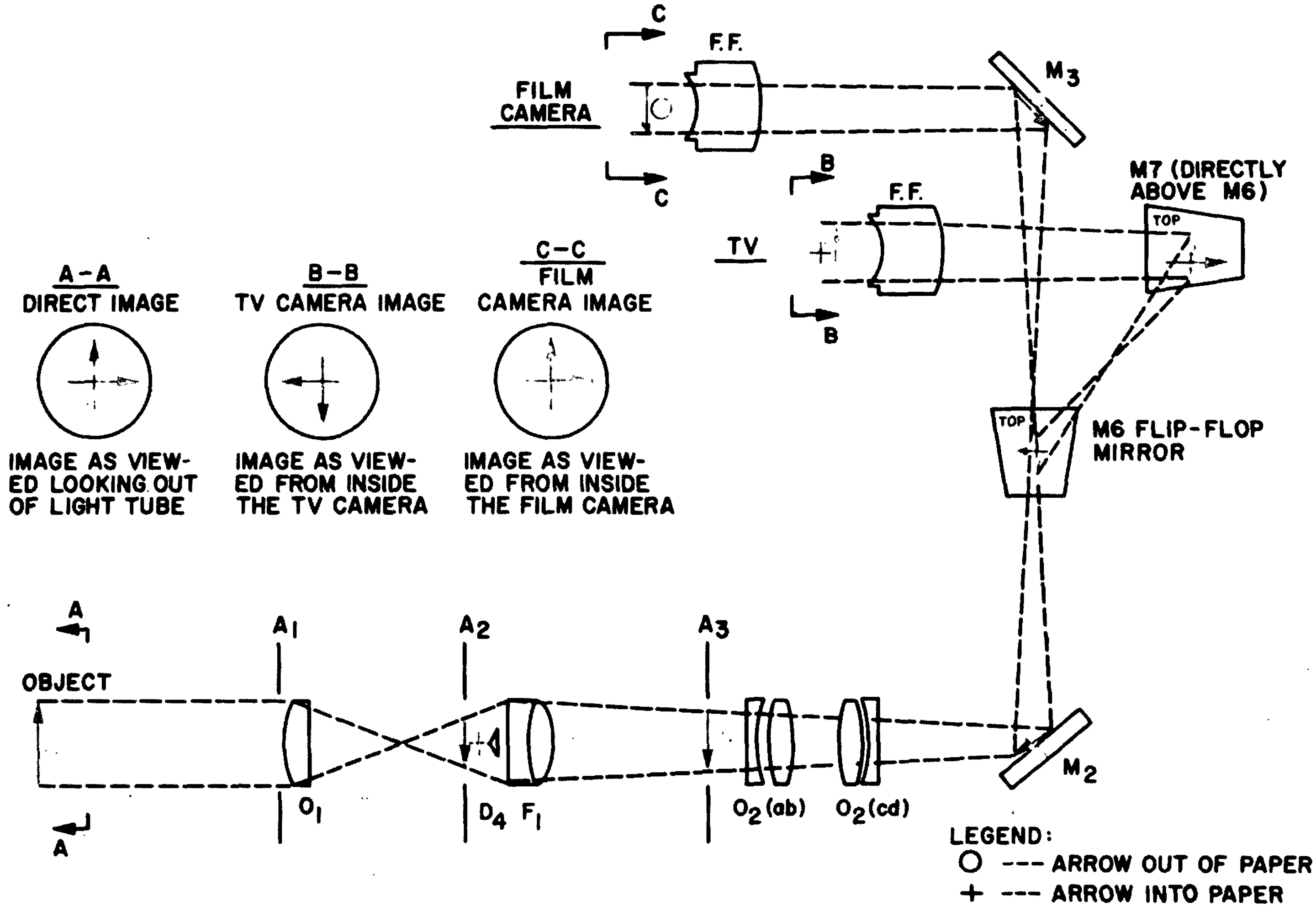


Figure 3. ATM-WLCE optics — ray trace.

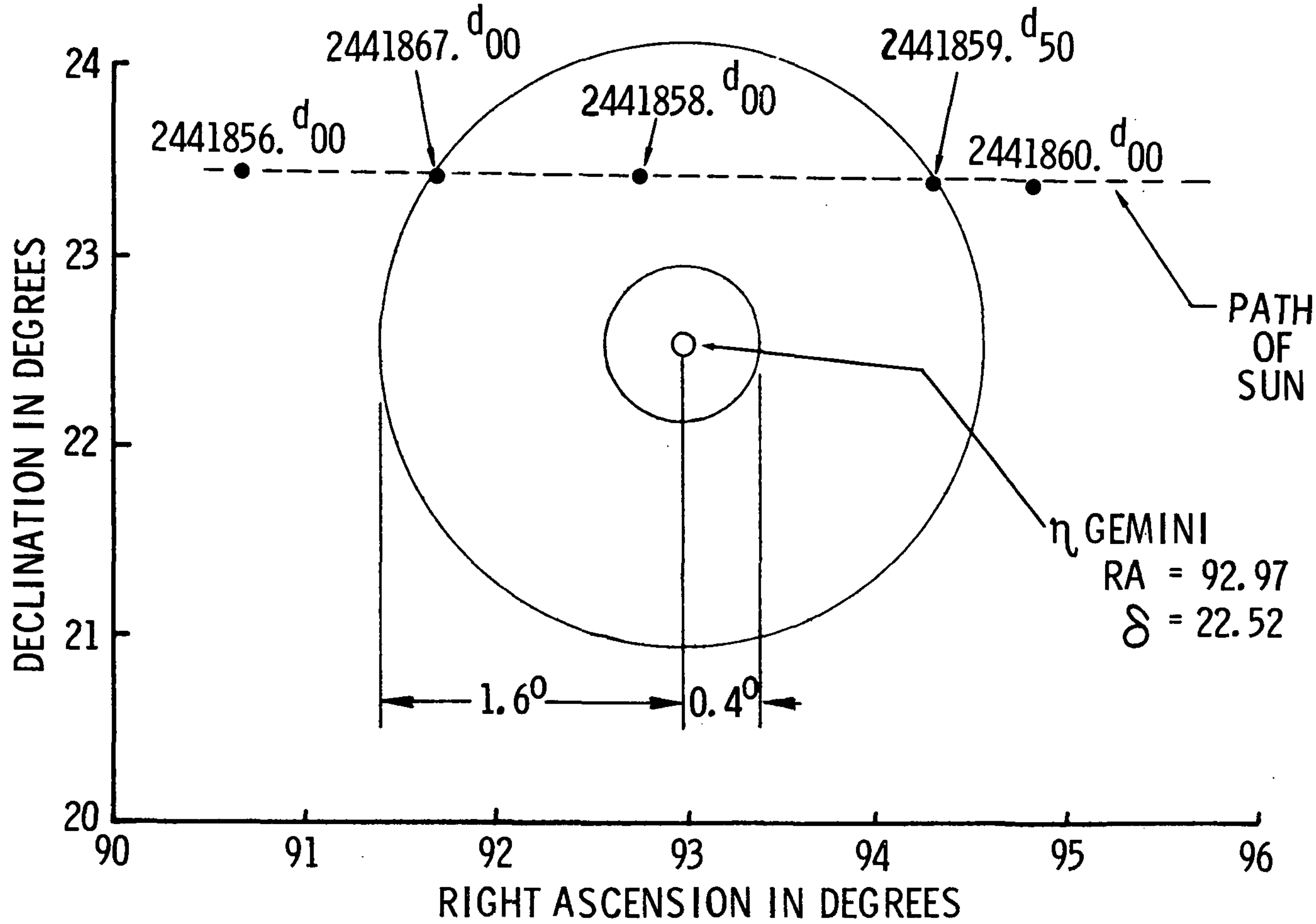


Figure 4. Plot of sun versus η Gemini.

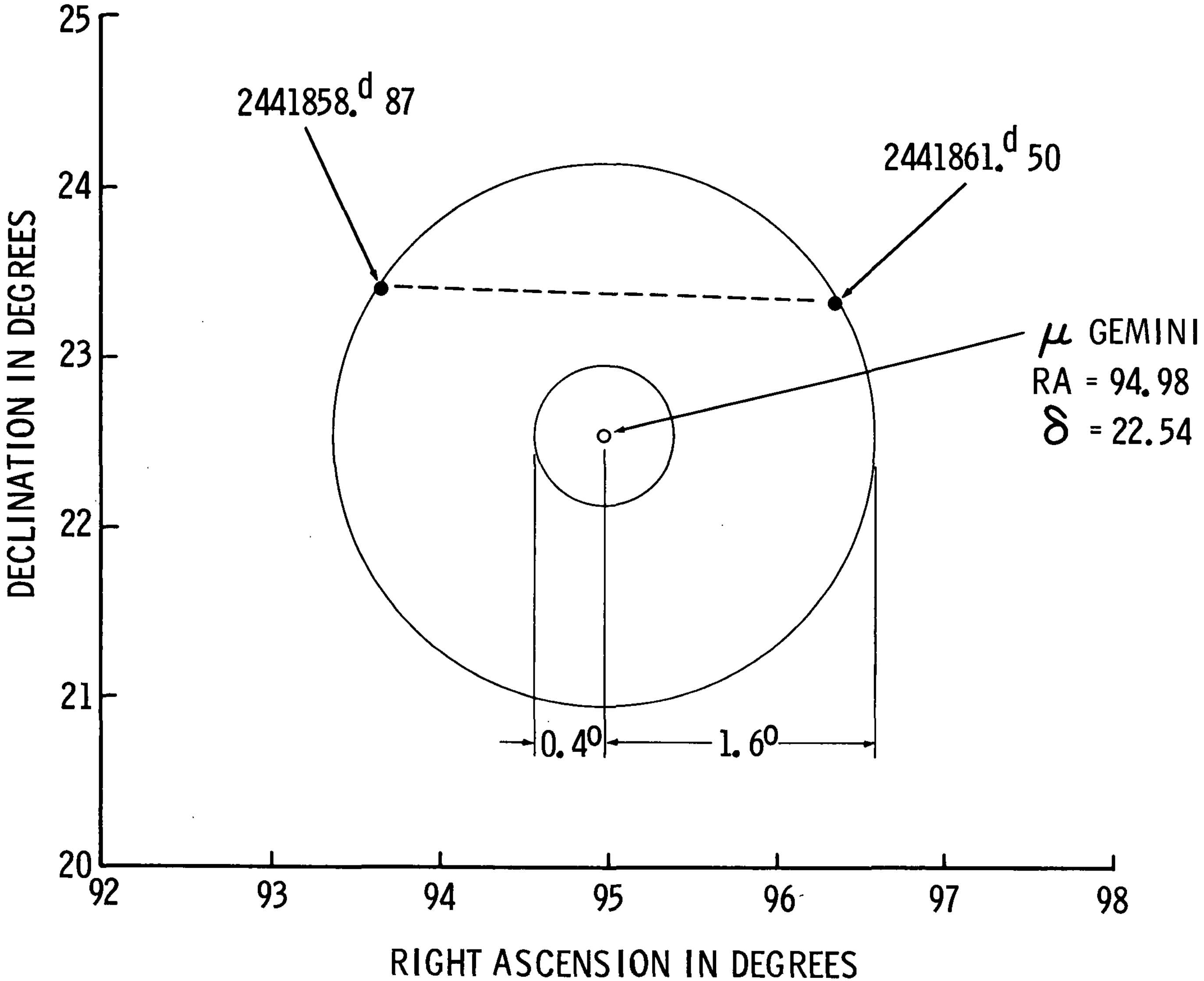


Figure 5. Plot of sun versus μ Gemini.

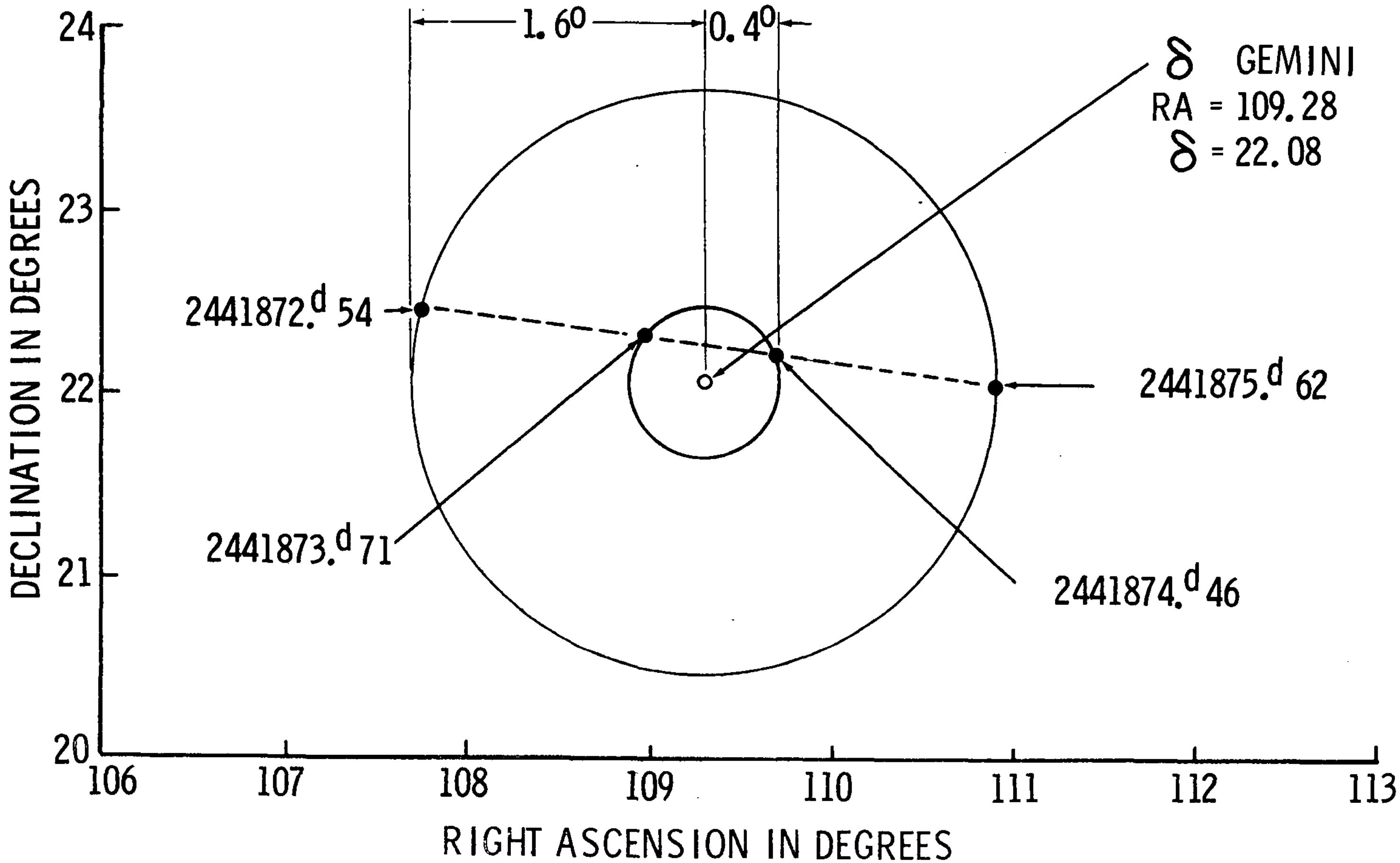


Figure 6. Plot of sun versus δ Gemini.

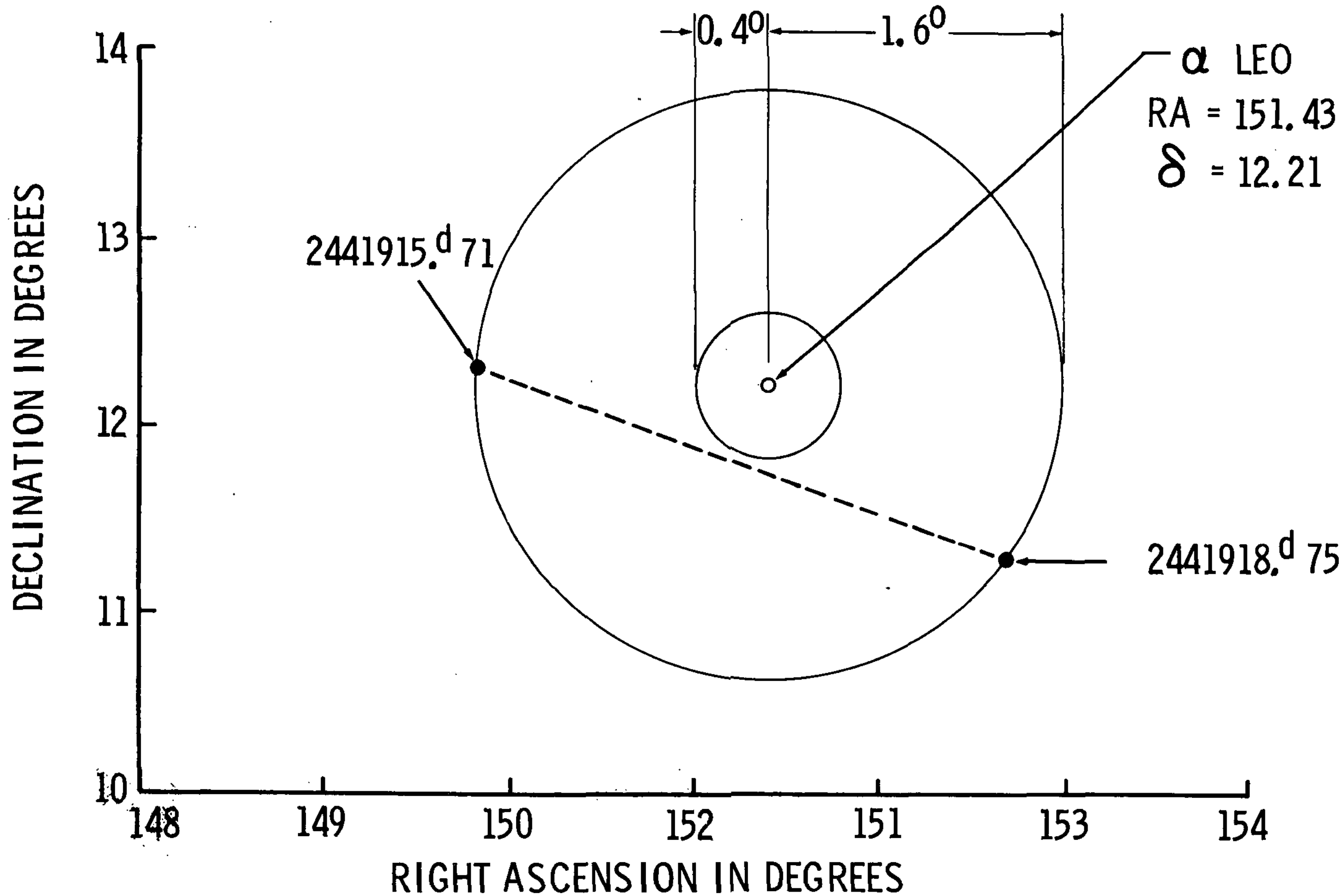


Figure 7. Plot of sun versus α Leo.

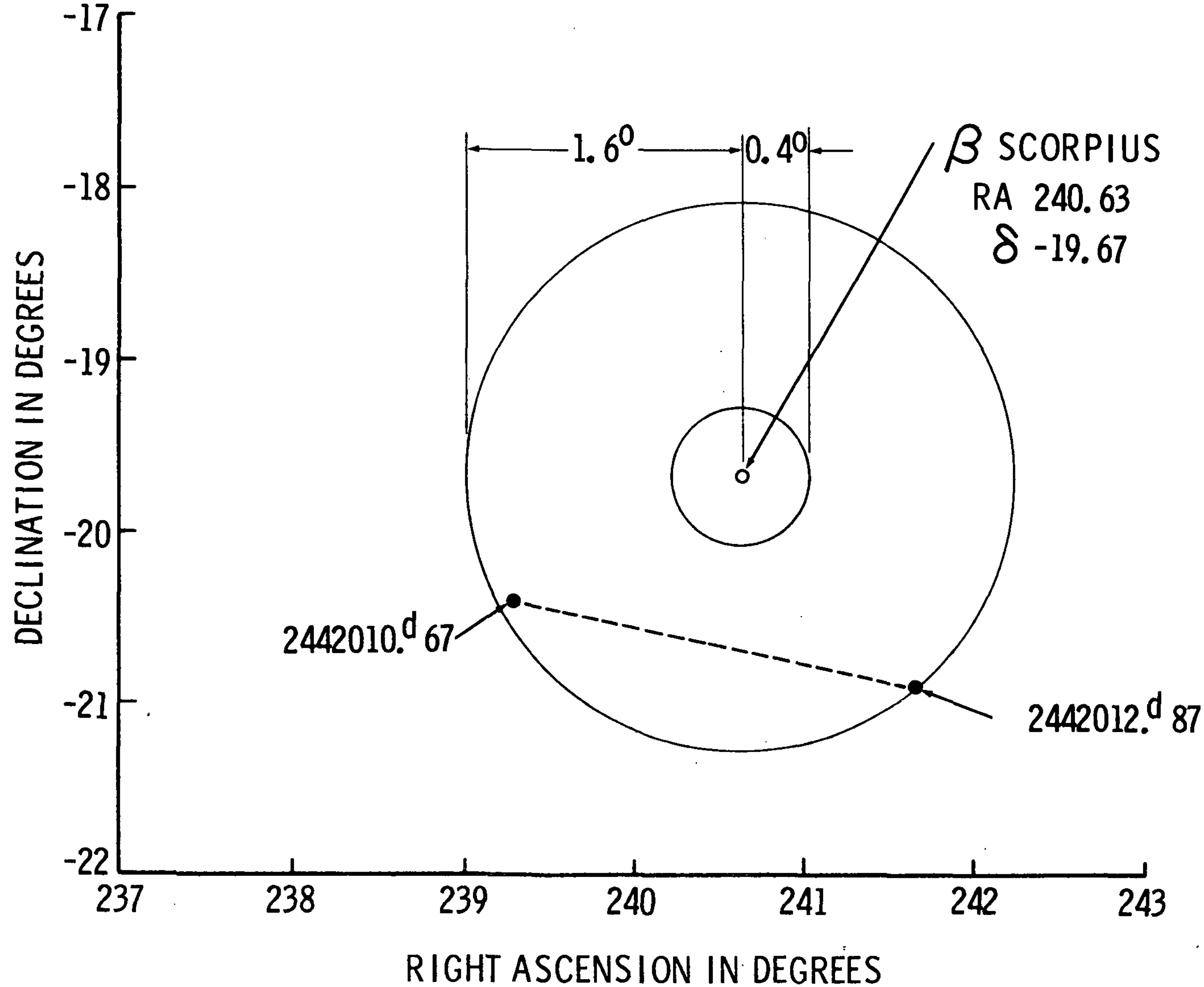


Figure 8. Plot of sun versus β Scorpius.

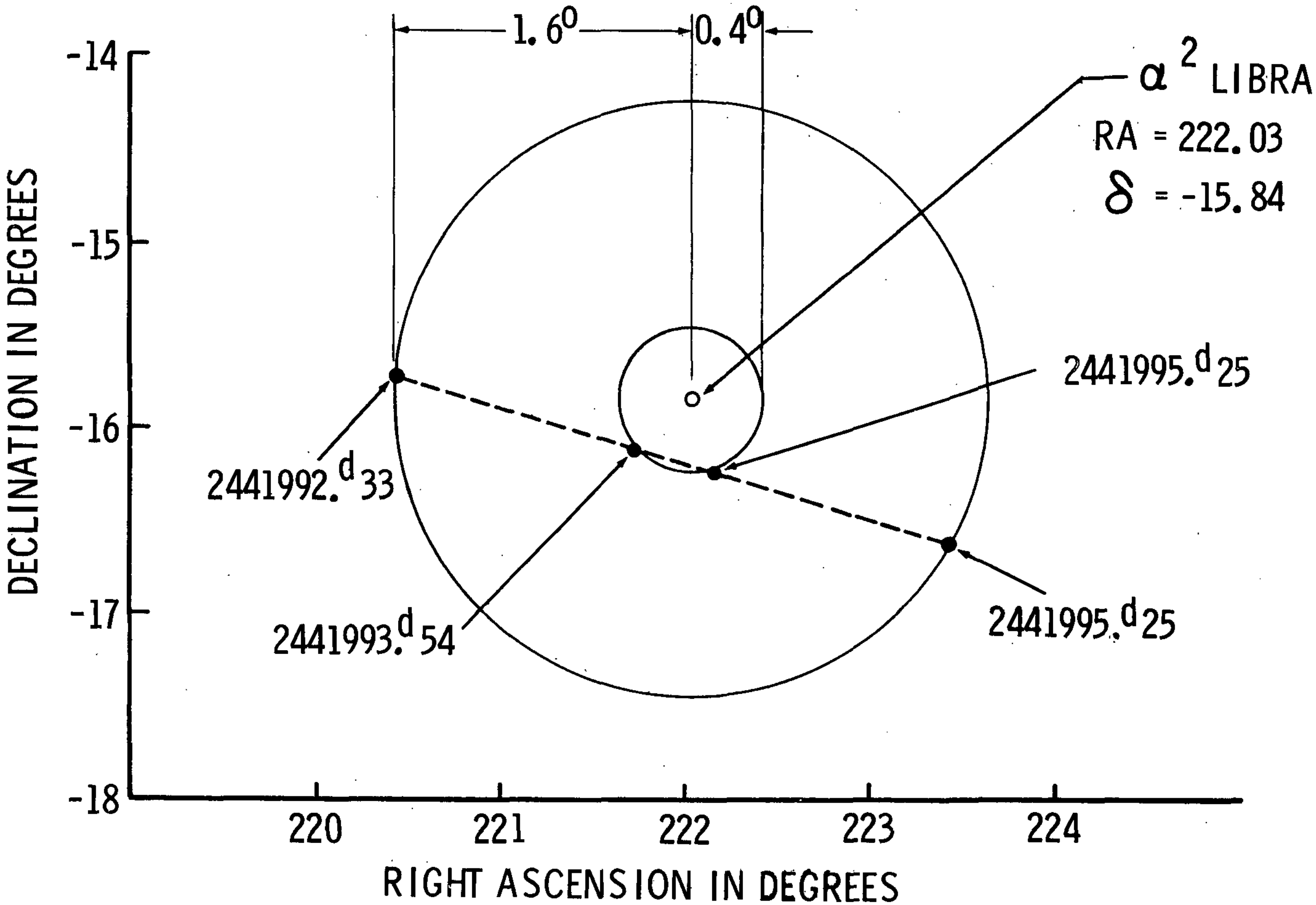


Figure 9. Plot of sun versus α^2 Libra.

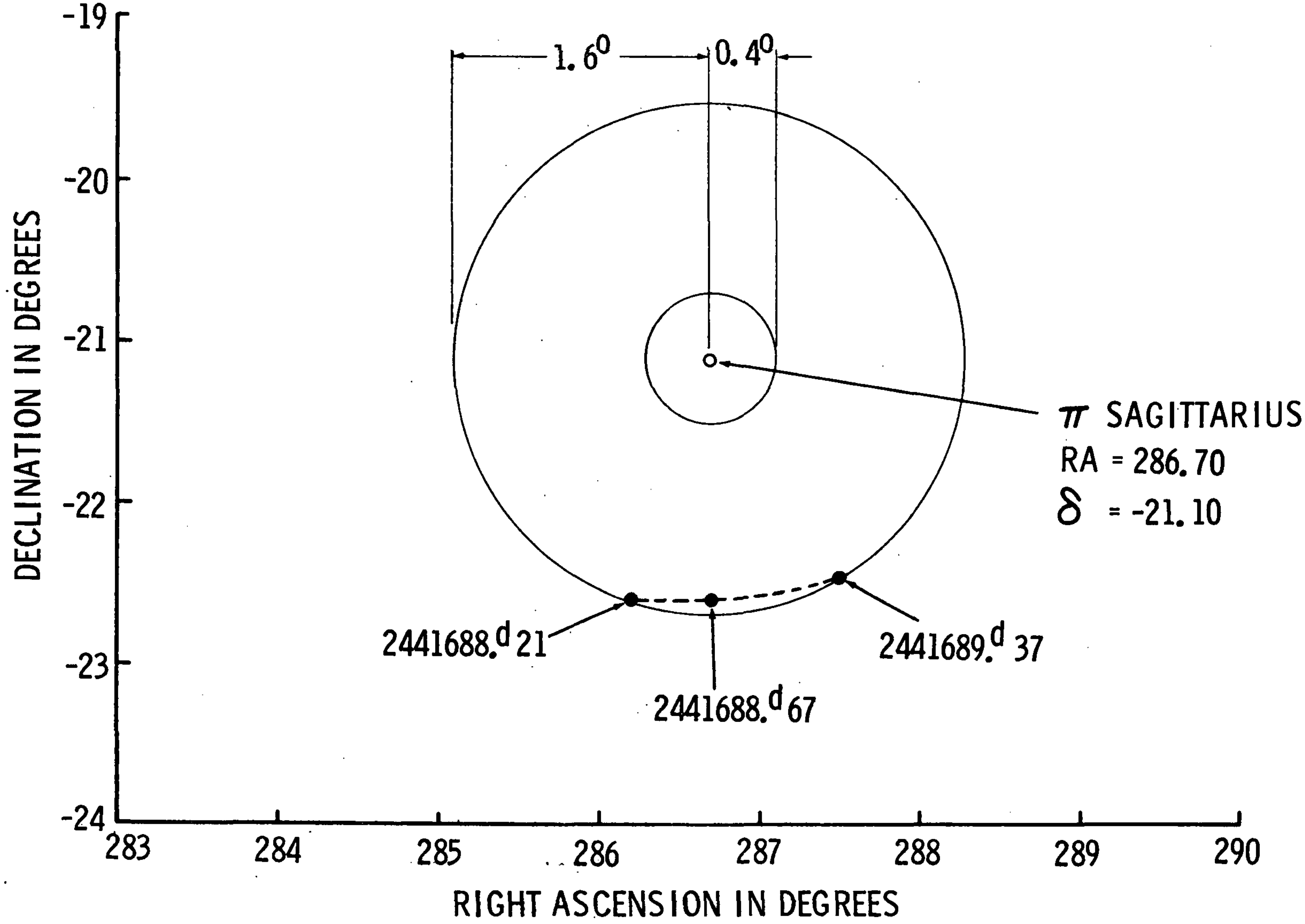
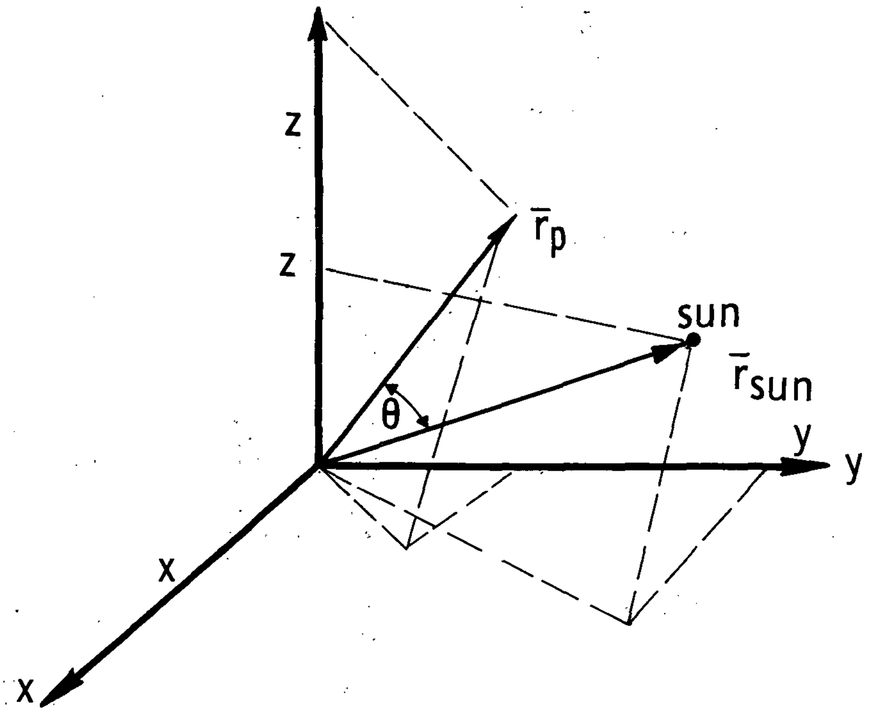


Figure 10. Plot of sun versus π Sagittarius.



$$\bar{r}_p \cdot \bar{r}_{sun} = |r_p|\,|r_{sun}| \cos\theta$$

$$\theta = \cos^{-1}\left(\frac{\bar{r}_p \cdot \bar{r}_{sun}}{|r_p|\,|r_{sun}|}\right)$$

Figure 11. Angular measurements between celestial objects from the earth's center.

APPROVAL

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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