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MAGNETIC COORDINATES FOR THE PIONEER 10 JUPITER ENCOUNTER

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ABSTRACT

The magnetic coordinates of the Pioneer 10 spacecraft and the five innermost satellites are given around the time of Jupiter encounter, December 1-8, 1973. The D_2 offset dipole model of Smith et al. (1974, this issue) is used to made the calculations. Magnetic coordinates are needed for the interpretation of the trapped-particle measurements, including the absorption effects of the satellites, reported on elsewhere in this issue. Contours of constant field magnitude and magnetic latitude are given at the surface of Jupiter for the D_2 model. The System III longitude of a spacecraft at Jupiter is derived, and formulas given for the relationships between System I, II, and III longitudes. The longitude of the magnetic dipole increases by about 3° per year, due to the inaccurate rotation rate used to define System III longitude.

INTRODUCTION

On December 4, 1973, at 0225 UT, the Pioneer 10 spacecraft reached its closest approach of 2.84 R_J from the center of the planet Jupiter (by mutual agreement among the experimenters, the unit of distance 1 $R_J \equiv 71372$ Km). During a period of about a week prior to and subsequent to this time, the spacecraft traveled within Jupiter's magnetosphere and measured its magnetic field and trapped radiation belt particles. A very preliminary report from each of the Pioneer 10 experiment teams, based upon analyses made up to approximately December 21, 1973, was published in Science (January 25, 1974). Much more complete and detailed analyses of the trapped particle encounter results are contained elsewhere in this issue (Fillius and McIlwain, 1974; Simpson et al., 1974; Trainor et al., 1974; Van Allen et al., 1974).

The purpose of this paper is to present calculations of the magnetic coordinates of the spacecraft during its traversal through Jupiter's magnetosphere, particularly the inner portion, and to give the magnetic coordinates of Jupiter's four innermost satellites when the spacecraft passed through the L-shells of each of these satellites. Such information should serve as a general background for the detailed interpretation of the trapped-particle results given in the accompanying papers, and should eliminate the need for basic data on magnetic coordinates to be duplicated in each of those papers.

The ability to calculate magnetic coordinates presupposes the existence of a model of the planetary magnetic field arising from internal sources. Calculations of dipole latitude and longitude, solar magnetic coordinates, and solar magnetospheric coordinates at Earth assume knowledge of the (centered) dipole field, which is usually derived from the three dipole coefficients of an appropriate spherical harmonic expansion. Quadrupole and higher-order coefficients are ignored in these calculations.

Preliminary calculations of the expected magnetic coordinates of Pioneer 10 made prior to the encounter (Mead, unpublished manuscript, April, 1973) used what seemed at that time to be the best-known values of the dipole parameters determined from radio observations of Jupiter (dipole strength $B_o = 10$ Gauss-R_J^3, dipole tilt with respect to the rotation axis = 10°, System III longitude of the pole of the dipole = 224° in 1973.9; see Appendix for a discussion of System III coordinates). A centered dipole was assumed, since at that time there was no convincing evidence for a significant dipole offset (McCulloch and Komesaroff, 1973; Berge, 1974). Smith et al. (1974a) published a preliminary offset dipole model fit to the Pioneer 10 data from perijove out to $6R_J$, covering a System III longitude range from 180° to 320°. In this model (subsequently labeled the D_1 model) the dipole was offset by 0.23 R_J and tilted by 14°.7 with respect to the rotation axis. Recognizing the possible existence of a roll attitude error, the experiment team subsequently reanalyzed the data with the introduction of an arbitrary roll error. They found that the residuals exhibited a well-defined minimum for a roll error of -5.4° (Smith et al., 1974b, this issue), and that the spherical harmonic fit corresponding to this roll error could be extended to significantly greater jovicentric distances ($10R_J$) than for the preliminary data. They concluded that there is a significant roll error in the preliminary data and that a model derived from the adjusted data (labeled D_2) would be superior to one based on the preliminary data. They plan to use D_2, or its equivalent, in their subsequent interim analysis and encourage others to use it in place of D_1. (A centered dipole model similar to D_2 was deduced independently by Van Allen et al. (1974), based on their analysis of the trapped-particle data.) The calculations in this paper are therefore based on the D_2 model (Smith et al., 1974b). The parameters of that model in a System III coordinate system are as follows:

Cartesian coordinates of the vector dipole moment (right-hand coordinates):

$M_x = -0.547$ Gauss-R_J^3

$M_y = 0.494$ Gauss-R_J^3

$M_z = 3.932$ Gauss-R_J^3

$M \simeq 4.000$ Gauss-R_J^3

Cartesian coordinates of the source location:

$x = -0.105\ R_J$

$y = -0.008\ R_J$

$z = 0.030\ R_J$

$r \simeq 0.110\ R_J$

The dipole is tilted towards $\ell_{III} \simeq 222°$ at an angle of 10°6 with respect to the rotation axis; the offset is in the direction of jovigraphic latitude 16°, longitude 176°. (Note that by I.A.U. convention Jupiter's System III longitude is defined in a left-handed sense, with longitudes increasing westward from 0° to 360°.) The dipole field is opposite in direction to that of the Earth.

COORDINATES OF PIONEER 10

The Pioneer 10 trajectory within 10 R_J of the planet, as viewed from the north ecliptic pole, is shown in Figure 1. Also shown is the position of the two innermost Galilean satellites, Io and Europa, within 8 hours of the closest approach (perijove). The satellite positions are important to an understanding of the trapped particle results, since effects were observed which appear to be related to the effects of satellite absorption predicted prior to the encounter (Mead and Hess, 1973; Hess et al., 1973, 1974). A larger-scale view, showing the trajectory out to 250 R_J, is shown in Figure 3 of the paper by Wolfe et al. (1974). The spacecraft approached Jupiter from a direction approximately 30° west of the Sun, circled the planet in a counter-clockwise direction, then exited towards the dawn meridian. The solar magnetic longitude of Pioneer 10 and Sun-Jupiter-probe angle are shown as a function of time in Figure 2. Within ± 60 hours of perijove, the solar magnetic longitude increased from -30° to approximately 255°; the S-J-P angle decreased from 30° to a minimum of 12° and then reached a maximum of 168° two hours after perijove, before decreasing to its asymptotic value of about 105° on the outbound passage.

During the two-week period that Pioneer 10 spent inside Jupiter's magnetosphere, the planet underwent over

30 full rotations. As viewed from a fixed planet, therefore, the spacecraft appeared to revolve clockwise, as is indicated in Figure 3, showing the System III longitude and distance of the spacecraft as a function of time. To the degree that trapped particles and low-energy plasma corotate with the planet, this Figure also represents the path of Pioneer 10 through the corotating magnetosphere.

Since the jovicentric angular velocity of the spacecraft in an inertial frame was nearly the same as that of Jupiter at perijove, the System III longitude of the spacecraft varied relatively slowly near perijove and the path of the spacecraft appears cusp-like in Figure 3. (See Figure 3 of Smith et al. (1974b) for a closer view of the cusp.) Pioneer 10 sampled the planet-produced magnetic field within 6 R_J only over a range of about 130° in longitude, thus limiting the accuracy of the magnetic field model derived from the measurements. It is worthwhile noting that the Pioneer 11 spacecraft, in addition to approaching much closer to the planet over a wider latitude range, will circle the planet in a clockwise direction instead of counter-clockwise; thus a comparable plot of the System III longitude of Pioneer 11 would show the spacecraft circling the planet nearly twice within a distance of 6 R_J. The magnetic field model derived from this data should therefore be much more representative of the planetary field.

The inclination of the Pioneer 10 trajectory with respect to Jupiter's rotational equator was 14°; thus the spacecraft remained at relatively low jovigraphic latitudes throughout the encounter. However, due to the tilt of the dipole with respect to the rotational axis, the jovimagnetic latitude of the spacecraft appeared to oscillate with about a 10-hour period, as shown in Figure 2. The maximum magnetic latitude reached by the spacecraft was -23° before perijove and +23° after. During each planetary rotation, the spacecraft nearly approached or just passed through the magnetic equator. The times during which the spacecraft was near the magnetic equator corresponded closely to the times when most of the trapped-particle detectors reached their maximum counting rates during each rotation period, indicating that trapped-particle fluxes depend strongly on magnetic latitude.

Figure 4 shows the distance of the spacecraft to the center of the offset dipole, R, plus the dipolar L-value of the spacecraft, given by

$$L = R/\cos^2\lambda_m$$

where λ_m is its jovimagnetic latitude. Since Pioneer 10 moves rather slowly through Jupiter's magnetosphere, the spacecraft bobs in and out of L-shells during each rotation period.

In Figure 5 the path of the spacecraft is shown as it would appear in a magnetic meridian moving around in longitude with the spacecraft. This is a $R-\lambda_m$ polar coordinate plot, affectionately known to the particle experimenters as a "wiggle diagram". From it one can get a good idea of the path of Pioneer 10 through Jupiter's radiation belt. The asterisks show the position of the spacecraft at two-hour intervals. Note that the spacecraft passed through the magnetic equator about one hour prior to perijove, at a distance of about 3.1 R_J. Most of the particle detectors reached their peak at about the same time, indicating that particle fluxes depend more strongly on magnetic latitude than on jovicentric distance in this portion of Jupiter's magnetosphere.

COORDINATES OF JUPITER'S SATELLITES

Also shown in Figure 5 is the path of each of Jupiter's four innermost satellites. (The outer Galilean satellite, Callisto, is outside the diagram.) Pioneer 10 passed through the L-shells of each of the four Galilean satellites twice, once inbound and once outbound, and nearly reached the L-shell of the tiny innermost satellite Amalthea. It was fortuitous that for Io ($L \approx 6.0$), Europa ($L \approx 9.5$), and Ganymede ($L \approx 15.0$) one L-shell crossing was near the magnetic equator and one crossing was at relatively high latitudes. Thus it should be possible to compare the observed absorption effects with the theoretical predictions that the effects of absorption should be greater at higher latitudes (Mead and Hess, 1973; Hess et al., 1974).

The satellites appear to trace out clockwise crescent-like paths as calculated with the offset dipole model; with a centered dipole their paths would appear as arcs of a circle, since their eccentricity is essentially zero. Since their inclination is also nearly zero, the maximum magnetic latitude reached by each satellite is about equal to the dipole tilt, i.e., 11° in these calculations. The maximum positive latitude is reached when each satellite is at a System III longitude of 222°, i.e., when the dipole appears to be tilted towards the satellite; maximum negative latitudes are at ℓ_{III}=42°. The closest point is at ℓ_{III}=176°, i.e., when the dipole offset is in the direction of the satellite. Each satellite completes one full crescent during one corotation period, i.e., the time for its System III longitude to increase by 360°; this corotation period varies from 2.4 days for Amalthea to 10.2 hours for Callisto (Mead and Hess, 1973, Table 2).

Any analysis of the effect of lunar absorption on trapped particles should be carried out in a corotating system, i.e., using System III longitude. The coordinates of the five inner satellites near the time of the Pioneer 10 encounter can be calculated by first determing from the ephemeris (American Ephemeris, 1973) the mid-time of the transit of the shadow across the planet. After correcting for the Earth-Jupiter light-time, and using the value of the mean synodic period of each satellite, their east solar longitudes ϕ are given by

$$\phi\ (\text{Amalthea}) = 49° + 722.55\ \Delta t$$
$$\phi\ (\text{Io}) = 348° + 203.41\ \Delta t$$
$$\phi\ (\text{Europa}) = 52° + 101.29\ \Delta t$$
$$\phi\ (\text{Ganymede}) = 351° + 50.23\ \Delta t$$
$$\phi\ (\text{Callisto}) = 47° + 21.49\ \Delta t$$

where Δt is the time at Jupiter in days after 0^h on December 4, 1973 (circular orbits are assumed). The System III longitude is then given by $V_{III} - A_s - \phi$, where V_{III} is the hour angle of Jupiter's vernal equinox from the System

III zero meridian (see Appendix), and A_s is the jovicentric right ascension of the sun, obtained from the ephemeris. This yields

$$\ell_{III} \text{ (Amalthea)} = 223° + 147.91 \; \Delta t$$
$$\ell_{III} \text{ (Io)} = 284° + 667.05 \; \Delta t$$
$$\ell_{III} \text{ (Europa)} = 220° + 769.16 \; \Delta t$$
$$\ell_{III} \text{ (Ganymede)} = 281° + 820.22 \; \Delta t$$
$$\ell_{III} \text{ (Callisto)} = 225° + 848.96 \; \Delta t$$

Ignoring a small correction due to the dipole offset, the magnetic latitude of each satellite is then given by

$$\sin \lambda_m = \sin 10.^\circ 6 \cos(\ell_{III} - 222°).$$

Absorption of trapped particles by a satellite can occur over a band of L-shells, due to 1) the excursion of the satellite in magnetic latitude, 2) the offset of the dipole, 3) the finite diameter of the satellite, 4) the finite gyroradius of the trapped particles, and 5) distortion of the L-shells due to external currents or higher-order internal multipoles. The effect of the first three factors is to produce a region of interaction whose width ranges from about 0.4 R_J at Io to 1.1 R_J at Callisto (see Figure 21 of Simpson et al., 1974, for the path of Io through L-space). The times when Pioneer 10 passed through the inner and outer edges of each of these regions are given in Table 1, together with the magnetic latitude and System III longitude of the spacecraft and the corresponding satellite. These times can be compared with the times when various detectors appeared to measure a satellite absorption effect, in order to determine the detailed nature of the absorption process.

SUMMARY AND DISCUSSION

The D_2 offset dipole model of Smith et al. (1974b) has been used to calculate the magnetic coordinates of the Pioneer 10 spacecraft and the five inner Jovian satellites near the time of the Jupiter encounter. These coordinates can be used to interpret the close-in trapped-particle results presented elsewhere in this issue. Beyond about 10-15 R_J, however, external perturbations distort the field significantly, and a simple dipole model is insufficient to interpret the results.

By publishing a variety of models of Jupiter's internally produced field, Smith et al. (1974b) caution the reader not to take any one model too literally. Such advice is well-taken, particularly since Pioneer 11, due to fly by Jupiter in only a few months, will very likely provide a much more definitive model. As with the Earth, probably the best long-range model will be a jovicentric expansion in spherical harmonics to as many terms as the data seem to warrant. However, until such models become available, the D_2 model published by Smith et al. appears to be the simplest and most reliable model to use at distances less than 10 R_J.

Since theories of Jupiter's decametric emission depend heavily on knowledge of the field strength at Jupiter's surface, the D_2 model has been used to construct a contour plot of $|B|$ as a function of jovigraphic latitude and System III longitude. The results are shown in Figure 6. In these calculations the equatorial radius was assumed to be 71372 Km and a flattening of $1/15.4 \simeq 0.065$ was used (the flattening increases the values near the poles by 22% over those for a spherical planet). The field magnitude at Jupiter ranges from 3.0 Gauss near the equator to 11.5 Gauss near the north magnetic pole. Also shown are contours of constant magnetic latitude, including those at $\pm 66°$, which connect to the satellite Io. Along these two contours the field magnitude ranges from 7 Gauss in the southern hemisphere to a maximum of 11 Gauss in the northern hemisphere, corresponding to cyclotron frequencies of 19 to 31 MHz, respectively. This upper frequency is somewhat less than the maximum cutoff frequency of 39 MHz observed for the decametric emission, indicating that at least a portion of the decametric noise cannot be cyclotron emission at the foot of the field line passing through Io, or that the quadrupole and higher harmonics increase the field magnitude sufficiently over localized regions.

APPENDIX: SYSTEM III LONGITUDE AT JUPITER

Three different longitude systems have been used at Jupiter, corresponding to three differently-defined sidereal rotation rates. The defined rotation periods and associated daily motions are given in Table 2. The System III (1957.0) rate (I.A.U. Information Bulletin No. 8, March 1962) is based on measurements of periodicities in the decametric and decimetric radio emissions, and is supposedly related to the magnetic field rotation. The period was defined in 1962, soon after the discovery of Jupiter's radio emission. In the meantime the period has been measured with much greater precision. Recent values obtained by Carr (1971), Duncan (1971), and Kaiser and Alexander (1972) are listed in Table 1. These differ by about 0.35 sec from the 1962 adopted period, leading to cumulative longitude drifts of about 3° per year. Although Carr (1971) has suggested that a new system be adopted based on a more accurate rotation rate, no action has yet been taken by the I.A.U.

The complete definition of a longitude system requires knowledge of the position of the zero meridian at some epoch, in addition to the pole position and the rotation rate. Systems I and II are defined by specifying the longitudes of the central meridian as seen at the Earth at a specified epoch (Explanatory Supplement, 1961, p. 338). After applying a light-time correction of about 25° (the amount of rotation during the time the light signal traveled from Jupiter to Earth), this definition can be reduced to an adopted value of V, the hour angle of Jupiter's vernal equinox (the ascending node of the orbit of Jupiter on its equator) as would be measured at Jupiter from its zero meridian at that reference epoch. For Systems I and II,

$$V_I = 281^\circ\!.001 + 877^\circ\!.90\ (J - 2414120.0) \tag{A1}$$

$$V_{II} = 330^\circ\!.002 + 870^\circ\!.27\ (J - 2414120.0) \tag{A2}$$

(Explanatory Supplement, 1961; Supplement to the A.E. 1968, 1966; Melbourne et al., 1968, p. 29), where J is the Julian Date. The definition of V is equivalent to the definition of Greenwich Sidereal Time at Earth.

System III (1957.0) was defined to coincide with System II at 0^h U.T. on January 1, 1957 (J.D. 2435839.5). Thus, substituting this date into A1 and A2,

$$V_I = 70^\circ\!.06 + 877^\circ\!.90\ (J - 2435839.5) \tag{A3}$$

$$V_{II} = 359^\circ\!.28 + 870^\circ\!.27\ (J - 2435839.5) \tag{A4}$$

$$V_{III}\ (1957.0) = 359^\circ\!.28 + 870^\circ\!.54432\ (J - 2435839.5) \tag{A5}$$

By I.A.U. convention, the planetographic longitude of the central meridian, as observed from a fixed direction, increases with time. Thus, since Jupiter rotates counter-clockwise when viewed from above, longitudes increase westward from 0° to 360°. This is a left-hand system and is opposite to the convention usually adopted at Earth. Thus if the jovicentric right ascension (measured with respect to Jupiter's vernal equinox) of a planetary probe such as Pioneer 10 is given by A_p, the west longitude of the probe ℓ_p in a jovicentric rotating system is given by

$$\ell_p = V - A_p \tag{A6}$$

This is the same as the relationship between Greenwich Sidereal Time and the longitude and right ascension of a spacecraft at Earth.

Taking differences between A3, A4, and A5 and using A6 (A_p is the same in all systems), we have the following relationships between longitude systems at Jupiter:

$$\ell_{III}(1957.0) = \ell_{II} + 0.27432\ (J - 2435839.5) \tag{A7}$$

$$\ell_{II} = \ell_I - 7.63\ (J - 2435839.5) - 70.78 \tag{A8}$$

$$\ell_{III}(1957.0) = \ell_I - 7.35568\ (J - 2435839.5) - 70.78 \tag{A9}$$

The corresponding relationships at Earth can be obtained by reducing the value of J by the Earth-Jupiter light time (≈0.03 days), yielding a correction of about 0°.2 in A8 and A9.

If the true daily motion of some object fixed on Jupiter, such as the north pole of Jupiter's magnetic dipole, were d_{true}, its apparent System III longitude would gradually increase by an amount equal to (d_{true} - 870.54432) degrees per day. For the recent determinations of the rotation rate of Jupiter's magnetic field given in Table 1, this ranges from 2.9 to 3.4 degrees per year. Thus Jupiter's magnetic field drifts westward by about 3° per year relative to the System III (1957.0) coordinate system, and any determination of the dipole longitude will depend on the date of the relevant measurements. The results of a number of such determinations are shown in Figure A1, plotted as a function of the date of the measurements. Included are the values corresponding to the D_1 (231°) and D_2 (222°) models of Smith et al. (1974a, b), as well as a recent radio astronomy result 228° ± 2° (M. Klein, B. Gary, private communication). The drift is clearly seen. The straight-line fit is given by

$$\ell_{III}(1957.) = 175° + 3° \quad (T - 1957.0) \tag{A1}$$

These determinations, made over a period of 10 years, are consistent with a true magnetic rotation period of $9^h55^m29^s.7$. This rotation period is now sufficiently well known that it would seem desirable for the I.A.U. to define a new system of longitude, based on a more accurate rotation rate, which would be free of the longitude drift characteristic of the present system.

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FIGURE CAPTIONS

Figure 1 - Pioneer 10 encounter trajectory as viewed from the north ecliptic pole. The positions of Io and Europa are shown within ±8 hours of perijove. The Pioneer 10 orbital plane is inclined 14° with respect to Jupiter's rotational equator.

Figure 2 - The Sun-Jupiter-probe angle, solar magnetic longitude, and magnetic latitude according the the D_2 model of Smith et al. (1974b). (Solar magnetic longitude is the difference in magnetic longitudes of Pioneer 10 and the Sun.)

Figure 3 - Pioneer 10 trajectory in a Jupiter-Fixed coordinate system, as viewed from the north rotational pole. See Appendix for discussion of System III longitude.

Figure 4 - Jovicentric distance from the offset dipole, and L-value, assuming a dipole field.

Figure 5 - Pioneer 10 trajectory in an offset dipole meridian plane. Positions are indicated at two-hour intervals (spacecraft time is about 45 minutes earlier than ground received time, GRT). Magnetic coordinates are also shown for the four inner satellites, over one complete cycle of System III longitude. The satellite Callisto, at 26.4 R_J, is outside the diagram.

Figure 6 - Field magnitude contours (solid lines) and contours of magnetic latitude (dashed lines) at the surface of Jupiter, according to the D_2 model. The $\pm 66°$ latitude contours are at the foot of the field line connected with the satellite Io. A flattening of 1/15.4 was assumed for Jupiter.

Figure A1 -System III longitude of the north pole of the magnetic dipole as determined by a number of different investigators. The drift (3° per year) is due to the inaccurate rotation rate used in the definition of System III longitude.

Table 1. Position of Pioneer 10 and each satellite as the Spacecraft passes through the outer (O) and inner (I) edge of the band of L-shells over which the satellite travels during one corotation period.

		L	Date (1973)	Spacecraft Time	Pioneer 10			Satellite	
					r	λ_m	ℓ_{III}	λ_m	ℓ_{III}
Inbound									
Callisto	O	27.4	12/2	2230	25.3	-16.2	88	-10.6	43
	I	26.3	12/2	2300	24.8	-13.5	106	-10.2	59
Ganymede	O	15.6	12/3	1110	15.6	- 2.9	178	9.8	202
	I	14.9	12/3	1205	14.9	- 0.5	207	10.2	234
Europa	O	9.8	12/3	1915	8.7	-19.4	93	- 9.7	68
	I	9.3	12/3	1935	8.4	-17.8	104	- 8.7	78
Io	O	6.2	12/3	2155	6.1	- 6.7	175	10.3	226
	I	5.8	12/3	2220	5.7	- 5.4	187	9.9	238
Outbound									
Io	I	5.8	12/4	0605	5.4	15.4	296	- 7.0	93
	O	6.2	12/4	0635	5.9	13.2	309	- 5.0	107
Europa	I	9.3	12/4	1010	9.3	3.0	59	8.4	186
	O	9.8	12/4	1045	9.7	4.4	78	9.9	205
Ganymede	I	14.9	12/4	1415	12.7	22.2	197	-10.6	48
	O	15.6	12/4	1450	13.2	23.1	217	- 9.6	68
Callisto	I	26.3	12/5	0745	26.2	4.5	96	7.5	266
	O	27.4	12/5	0835	26.7	9.4	126	2.8	296

Table 2. Jupiter rotation rates.

Determination	Sidereal Rotation Period	Daily Motion
System I	$9^h50^m30\overset{s}{.}003$	877.90 deg/day
System II	$9^h55^m40\overset{s}{.}632$	870.27
System III (1957.0)	$9^h55^m29\overset{s}{.}37$	870.54432
Carr (1971)	$9^h55^m29\overset{s}{.}75 \pm 0.04$	870.53506
Duncan (1971)	$9^h55^m29\overset{s}{.}70 \pm 0.05$	870.53628
Kaiser and Alexander (1972)	$9^h55^m29\overset{s}{.}70 \pm 0.02$	870.53628

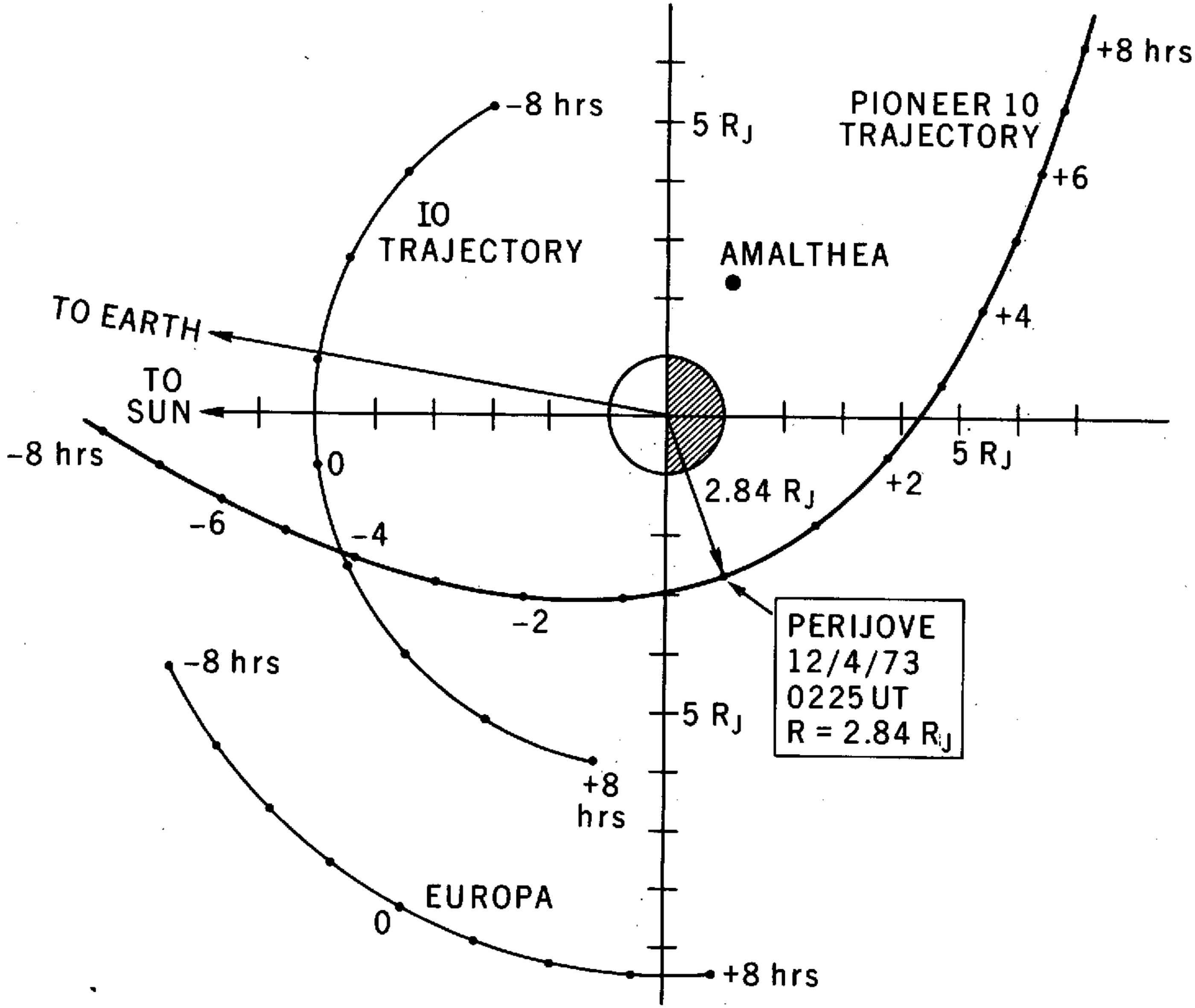

-8 hrs
5 R_J
PIONEER 10
TRAJECTORY
+8 hrs
+6
IO
TRAJECTORY
AMALTHEA
TO EARTH
+4
TO
SUN
-8 hrs
0
5 R_J
2.84 R_J
+2
-6
-4
-2
PERIJOVE
12/4/73
0225 UT
R = 2.84 R_J
-8 hrs
5 R_J
+8
hrs
EUROPA
0
+8 hrs

Figure 1

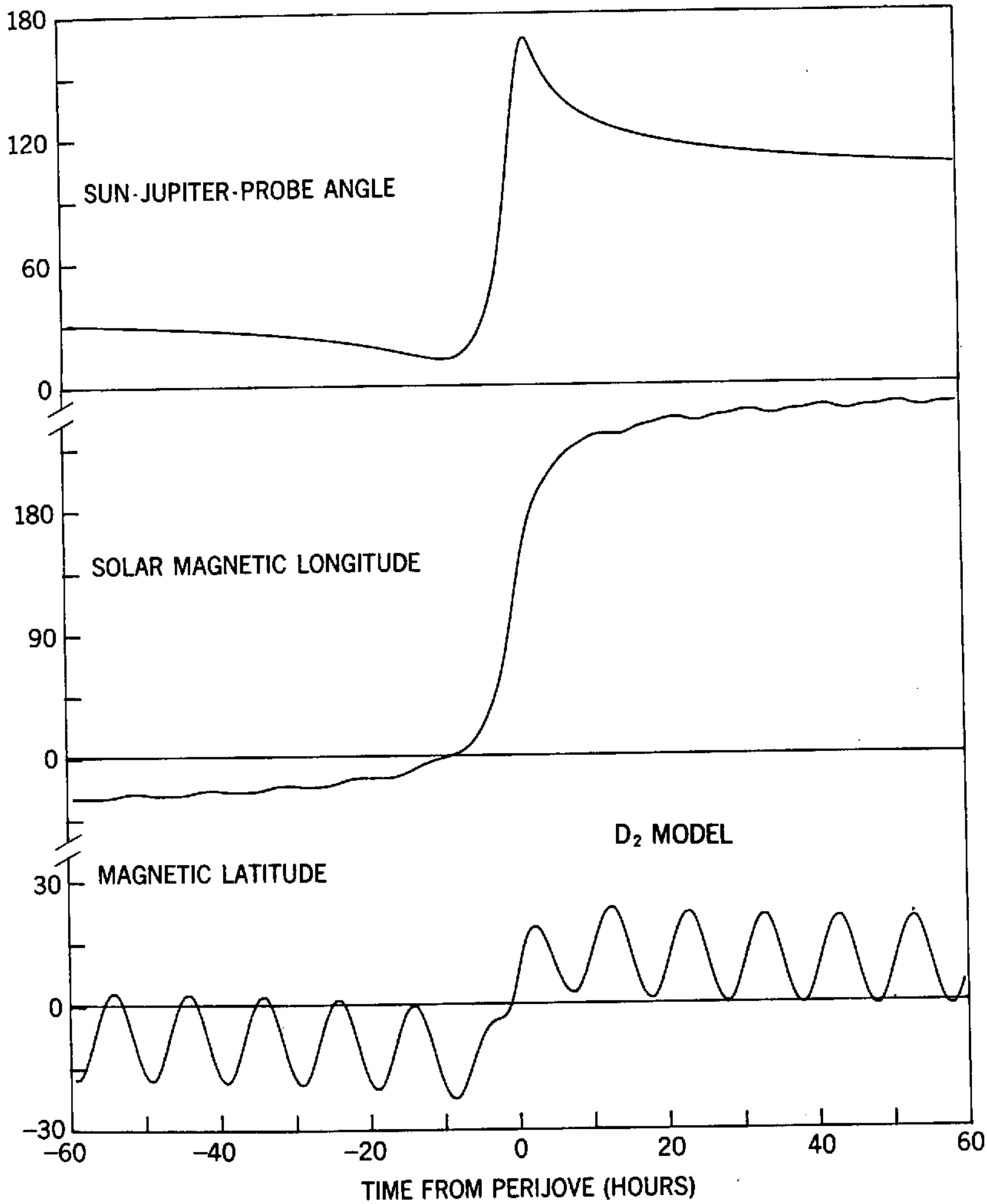

180
120
SUN-JUPITER-PROBE ANGLE
60
0
180
SOLAR MAGNETIC LONGITUDE
90
0
D_2 MODEL
30
MAGNETIC LATITUDE
0
-30
-60
-40
-20
0
20
40
60
TIME FROM PERIJOVE (HOURS)

Figure 2

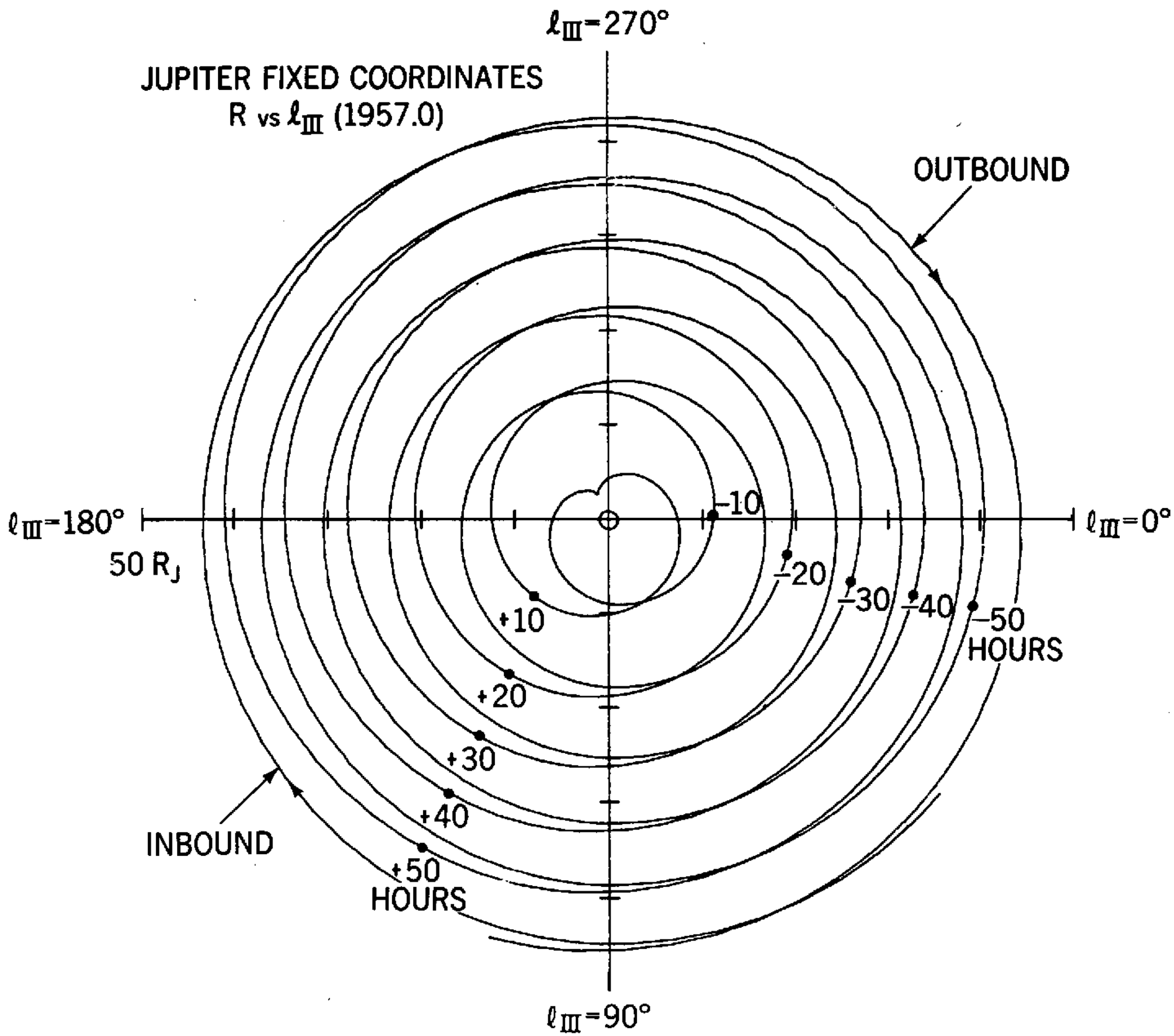
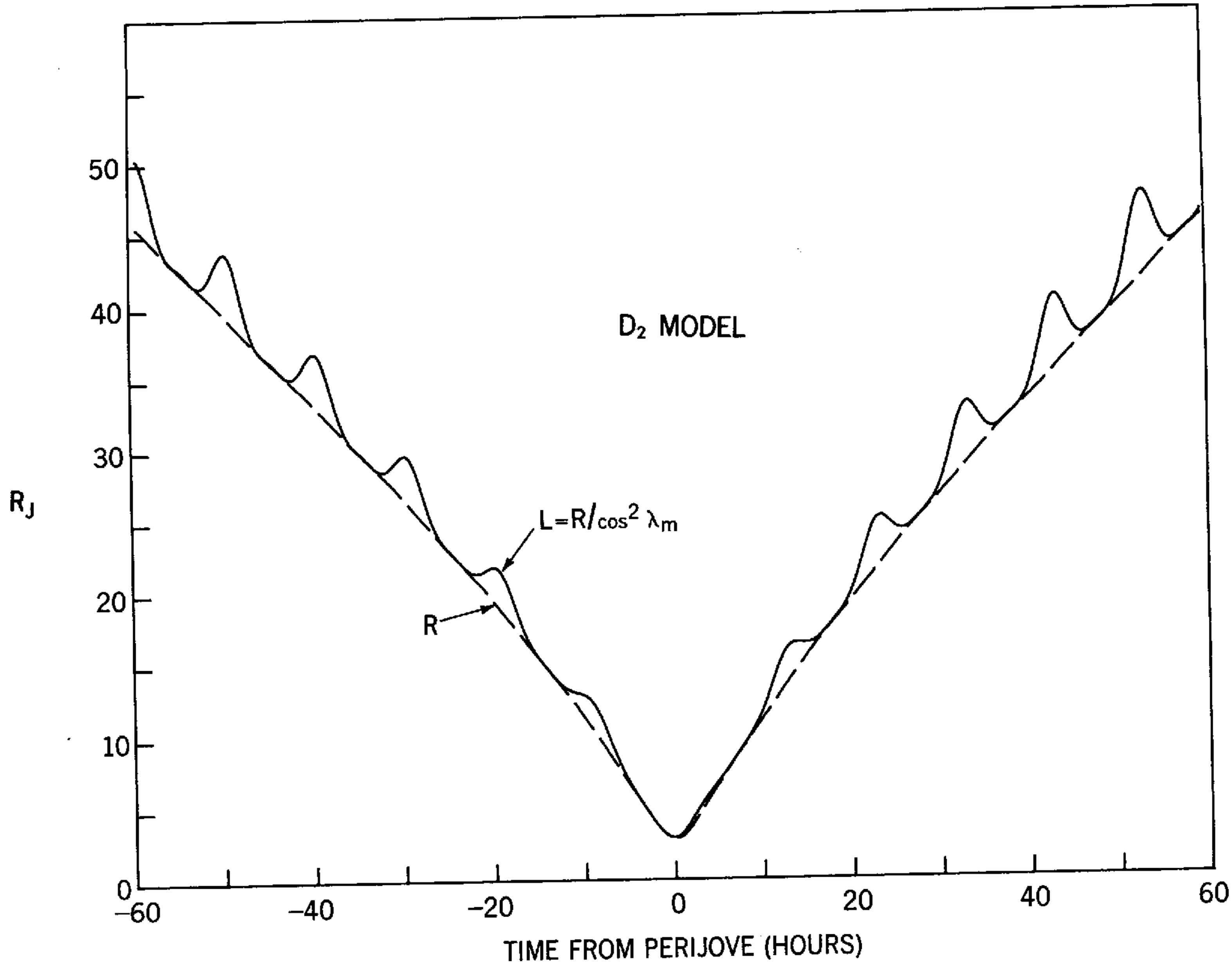
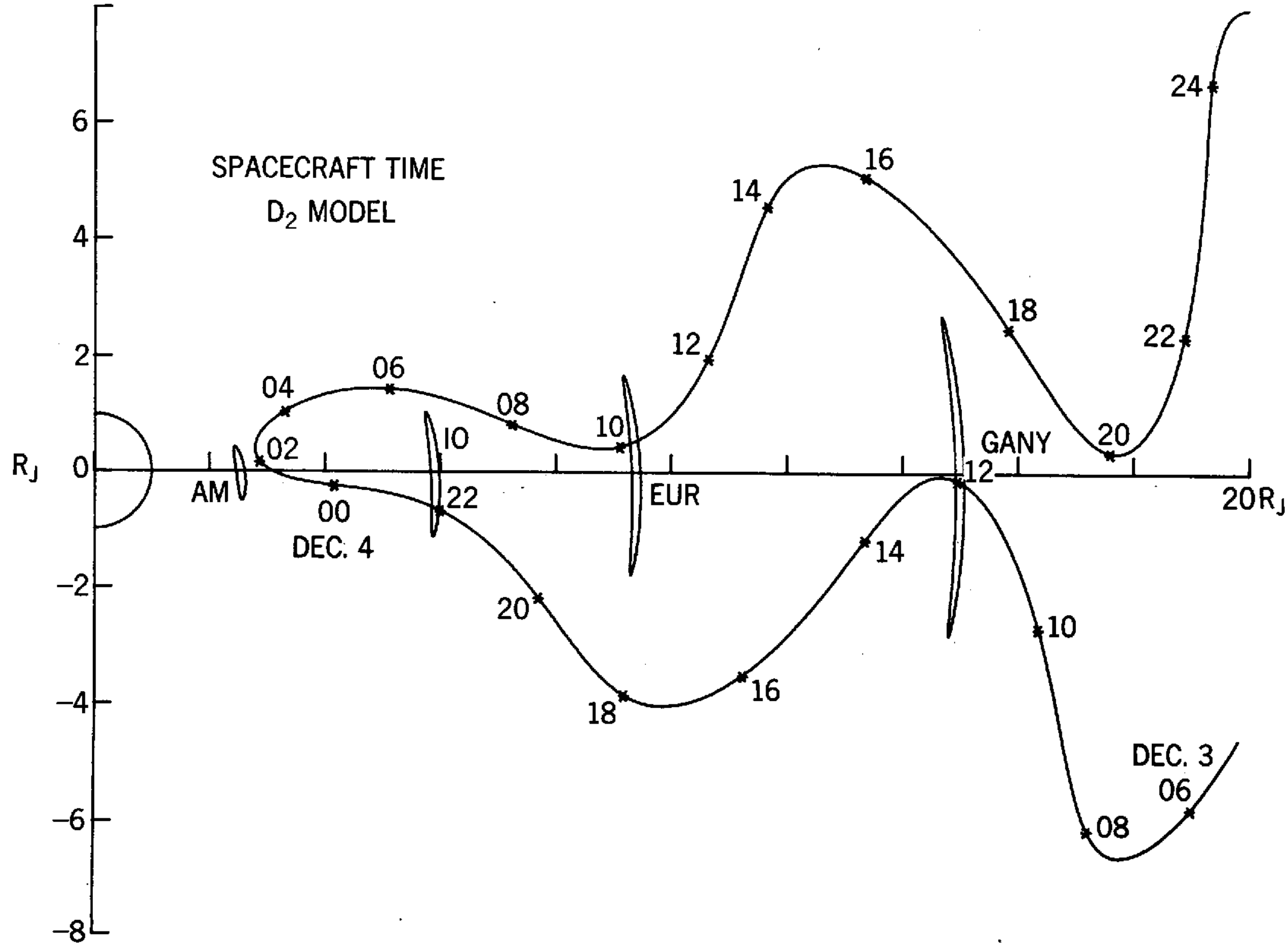

ℓ_{III}=270°
JUPITER FIXED COORDINATES
R vs ℓ_{III} (1957.0)
OUTBOUND
ℓ_{III}=180°
50 R_J
ℓ_{III}=0°
-10
-20
-30
-40
-50
HOURS
+10
+20
+30
+40
+50
HOURS
INBOUND
ℓ_{III}=90°

Figure 3



D2 MODEL
RJ
L=R/cos2 λm
R
50
40
30
20
10
0
-60
-40
-20
0
20
40
60
TIME FROM PERIJOVE (HOURS)

Figure 4



SPACECRAFT TIME
D_2 MODEL
6
4
2
0
−2
−4
−6
−8
R_J
AM
EUR
GANY
20 R_J
DEC. 4
DEC. 3
00
02
04
06
08
10
12
14
16
18
20
22
24

Figure 5

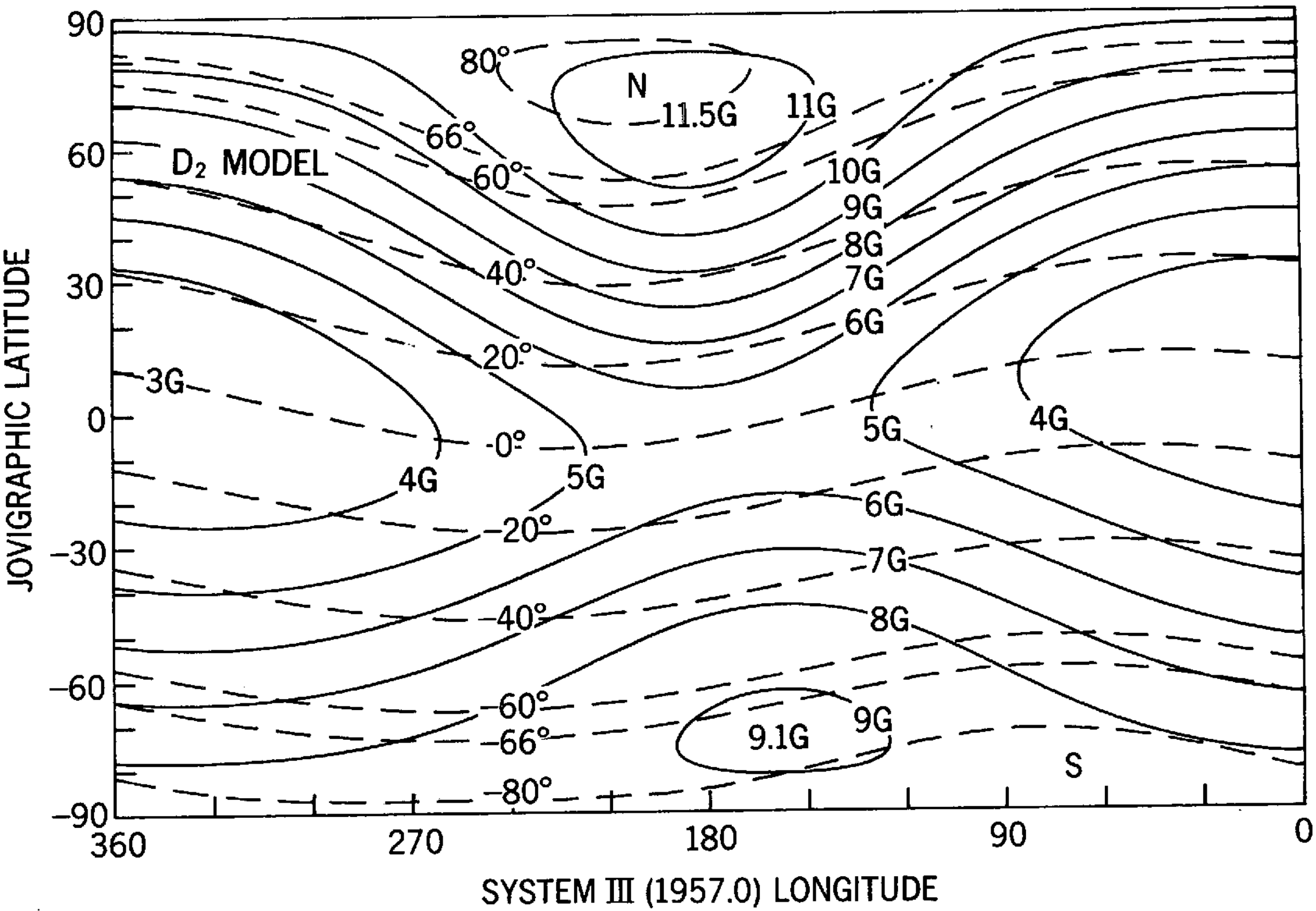
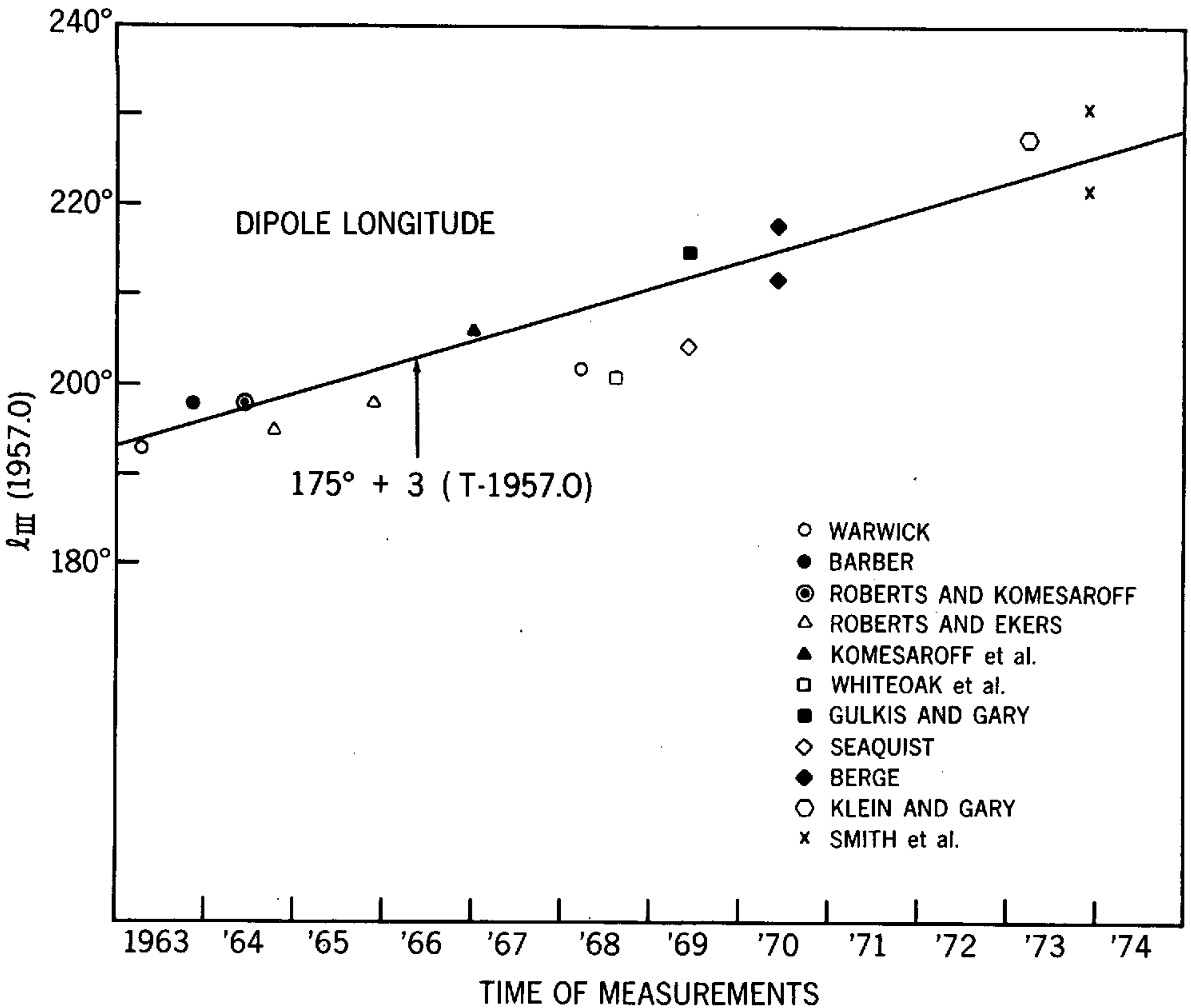

D2 MODEL
JOVIGRAPHIC LATITUDE
SYSTEM III (1957.0) LONGITUDE
N
S
11.5G
11G
10G
9G
8G
7G
6G
5G
4G
3G
9.1G
80°
66°
60°
40°
20°
-0°
-20°
-40°
-60°
-66°
-80°
90
60
30
0
-30
-60
-90
360
270
180
90
0

Figure 6



240°
220°
200°
180°
DIPOLE LONGITUDE
175° + 3 (T-1957.0)
ℓ_{III} (1957.0)
WARWICK
BARBER
ROBERTS AND KOMESAROFF
ROBERTS AND EKERS
KOMESAROFF et al.
WHITEOAK et al.
GULKIS AND GARY
SEAQUIST
BERGE
KLEIN AND GARY
SMITH et al.
1963
'64
'65
'66
'67
'68
'69
'70
'71
'72
'73
'74
TIME OF MEASUREMENTS

Figure A1