N76-24126

LATITUDINAL PROPERTIES OF THE SOLAR WIND FROM STUDIES OF IONIC COMET TAILS

John C. Brandt
Laboratory for Solar Physics and Astrophysics
NASA-Goddard Space Flight Center
Greenbelt, Maryland 20771

Abstract - Analysis of the orientations of ionic comet tails gives no support for the suggestion that the radial solar wind speed is higher near the solar poles than near the equator. These results refer to a long-term, global flow pattern and do not refer to short-term variations.

Evidence from comets concerning the latitudinal variation of solar wind parameters has been discussed previously by Pflug (1966), Brandt (1967), and by Bertaux, Blamont and Festou (1973). In this short report, I summarize the evidence based on ionic comet-tail orientations as recently analyzed by Brandt, Harrington, and Roosen (1975), and show the distribution of the sample in latitude, time, and phase of the solar cycle.

The basic observation is the position angle of the tail axis on the plane of the sky (Belton and Brandt 1966). The position angle Θ is interpreted in terms of a tail vector $\underset{\sim}{T}$ whose direction in space is determined by dynamical aberration, viz.,

$$\underset{\sim}{T} = \underset{\sim}{w} - \underset{\sim}{V} \tag{1}$$

where $\underset{\sim}{w}$ is the solar wind velocity vector and V is the vector velocity of the comet. The astrometric technique developed by Brandt, Roosen, and Harrington (1972) does not assume that the comet tail lies in the plane of the comet's orbit. Each observation determines essentially a half plane in velocity space. A preferred solar wind velocity vector (w_r, w_θ, w_ϕ) is determined as the one which minimizes the sum of the squares of the residuals between the computed and observed position angles.

At present, a sample of 678 observations are available and these are spread over approximately 75 years in time and between roughly 0.5 to 1.5 a.u. in heliocentric distance. The basic results are a radial velocity, $< w_r > \approx 400$ km/sec, an azimuthal velocity $< w_\phi > \approx 6$-7 km/sec (varying with solar latitude b and distance r as $\cos^{2.315} |b|/r$), and a

RMS dispersion of $3\overset{\circ}{.}7$. An additional result from comet tail orientations, but not from the astrometric technique, is that $w_r \geqslant 225$ km/sec (Brandt and Heise 1970). These values are in good agreement with results from spacecraft and provide confirmation of the basic approach.

This technique has been previously used to search for a meridional flow pattern in the solar wind. A value $w_m \approx 2.5$ km/sec (at $\theta = 45^{\circ}$, varying as $\sin 2\theta$) has been found in the sense of a flow diverging from the plane of the solar equator by Brandt, Harrington, and Roosen (1973). This result implies a radial variation in the equatorial density of the solar wind of $N \propto r^{-2.013}$. If this law held from the sun to earth, the density would be 7% smaller than on spherically symmetric models.

The basic technique can be used to search for a latitudinal variation of the radial solar wind speed by assuming that it varies as

$$w_r = w_o + \frac{dw_r}{d|b|} |b| \tag{2}$$

where w_o and $dw_r/d|b|$ are constants to be determined. The results are given in Table 1.

Table 1.

Solar-Wind Speeds With and Without a Latitudinal Variation in Radial Speed

w_r or w_o (km sec^{-1})	$dw_r/d\lvert b\rvert$ (km sec^{-1} deg^{-1})	w_m (km sec^{-1})	w_ϕ (km sec^{-1})	RMS Dispersion in $(\Theta - \Theta_c)$
402.5±11.9	≡0	+2.6±1.2	7.0±1.8	$3.^{\circ}749$
418.5±27.3	-(0.9±0.7)	+2.9±1.3	5.3±2.2	$3.^{\circ}750$

The latitudinal variation found in our sample, if any, is in the sense of decreasing radial speed with increasing latitude. However, the error in $[dw_r/d|b|]$ is almost as large as the value of -0.9 km sec^{-1} deg^{-1} found, and there is clearly no trend. In addition, the best solution as judged by RMS dispersion is still the solution with $[dw_r/d|b|] \equiv 0$. When an additional significant parameter is included in the model, the dispersion must decrease even if only marginally. The lack of a decrease is a definite flag that the additional parameter has no significance. The slight increase in RMS dispersion is simply due to round-off error. The errors in the components of the solar wind speed increase with a latitudinal variation included because then all components are functions of heliographic latitude and can be correlated. Possible correlations between components are calculated and are used to assign the probable errors. This is the explanation for the increase in errors while the RMS residuals remained essentially constant.

The negative result for significant latitudinal variation in w_r refers only to a long-term, global situation. It does not rule out shorter term results such as the one presented by Rickett (1975; preceeding paper). It does appear to imply that such short-term variations average out over the long term.

The sample is concentrated in the range $0 \leq |b| \leq 50^{\circ}$ as shown in Figure 1a where the solid line represents the present sample of 678 observations and the dashed line represents the same number distributed at random; only 60 observations lie in the range $50^{\circ} \leq |b| \leq 90^{\circ}$. If we plot the distribution against latitude instead of the absolute value of latitude as shown in Figure 1b, we find a strong concentration of observations in the northern hemisphere. There is no obvious reason to expect an adverse effect from this observational bias. The sample by year of observation is shown in Figure 1c which reflects the irregular nature of cometary apparitions and the reduction of observations. Figure 1d shows the distribution of the sample with phase in the solar cycle; the observations are concentrated toward solar maximum.

Because the astrometric technique can be applied only to fairly large groups of observations, results on short-term variations in the solar wind speed cannot be obtained directly. Work on an indirect technique is currently in progress.

Nevertheless, there is ample direct evidence for large, short-term variations in solar wind properties. The time required to establish a meaningful measurement of an average property at a particular latitude is probably at least one solar rotation. This was found to be the case for spacecraft observations of w_ϕ as reported by Lazarus and Goldstein (1971). Hence, direct out-of-the-ecliptic observations of the solar wind should utilize an orbit with a slowly changing latitude. Several passes through all solar latitudes and possibly several spacecraft will be required to map out the basic structure of the solar wind in three dimensions.

REFERENCES

Belton, M. J. S., and J. C. Brandt, Interplanetary Gas. XII. A catalog of comet-tail orientations, Ap. J. Suppl., 13, 125 (No. 117), 1966.

Bertaux, J. L., J. E. Blamont, and M. Festou, Interpretation of hydrogen Lyman-alpha observations of Comets Bennett and Encke, Astr. and Ap., 25, 415, 1973.

Brandt, J. C., Interplanetary Gas. XIII. Gross plasma velocities from the orientations of ionic comet tails, Ap. J., 147, 201, 1967.

Brandt, J. C., R. S. Harrington, and R. G. Roosen, Interplanetary Gas. XIX. Observational evidence for a meridional solar-wind flow diverging from the plane of the solar equator, Ap. J., 184, 27, 1973.

Brandt, J. C., R. S. Harrington, and R. G. Roosen, Interplanetary Gas. XX. Does the radial solar wind speed increase with latitude?, Ap. J., 196, 877, 1975.

Brandt, J. C., and J. Heise, Interplanetary Gas. XV. Nonradial plasma motions from the orientations of ionic comet tails, Ap. J., 159, 1057, 1970.

Brandt, J. C., R. G. Roosen, and R. S. Harrington, Interplanetary Gas. XVII. An astrometric determination of solar-wind velocities from orientations of ionic comet tails, Ap. J., 177, 277, 1972.

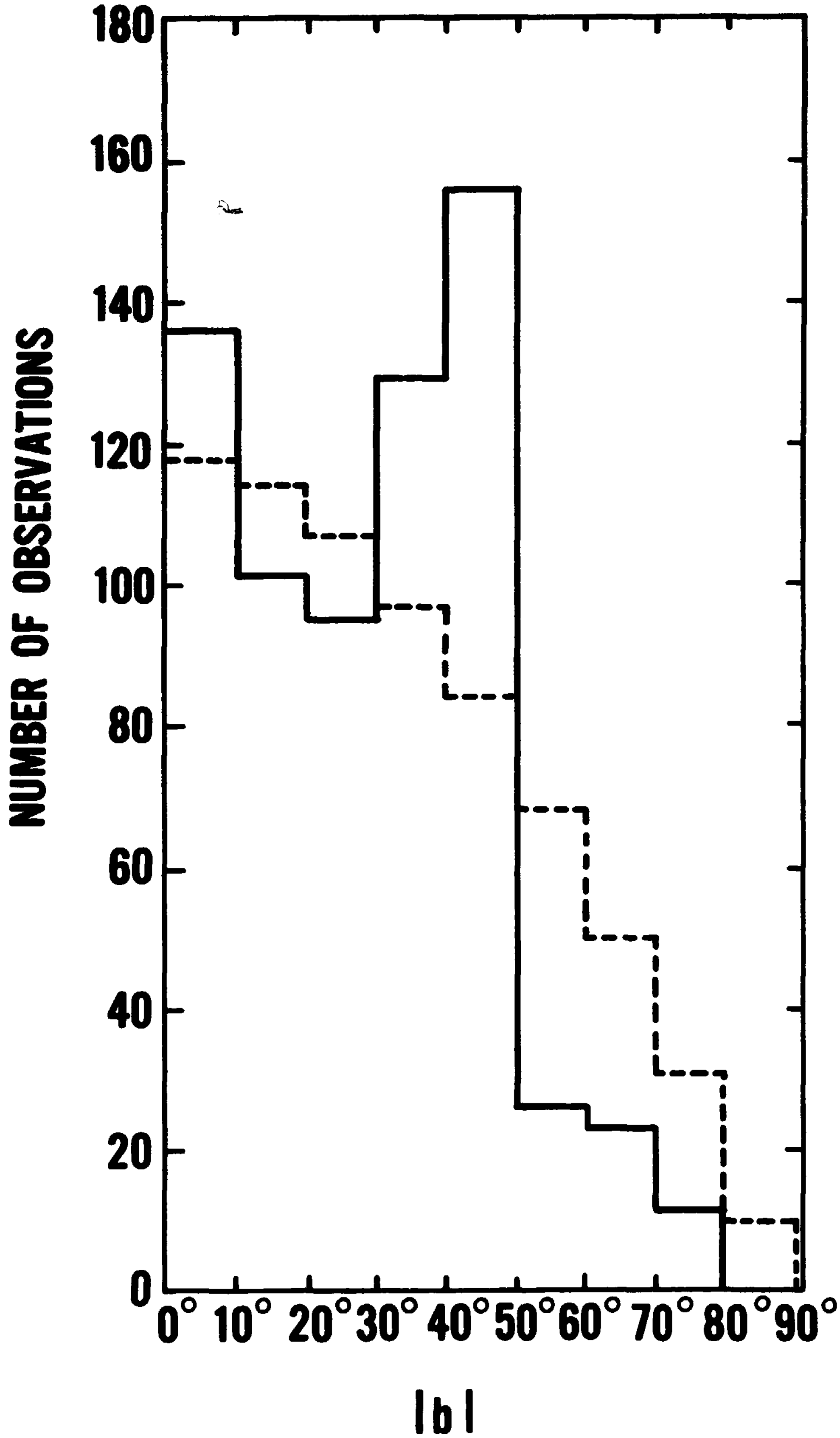
Lazarus, A. J., and B. E. Goldstein, Observation of the angular-momentum flux carried by the solar wind, Ap. J., 168, 571, 1971.

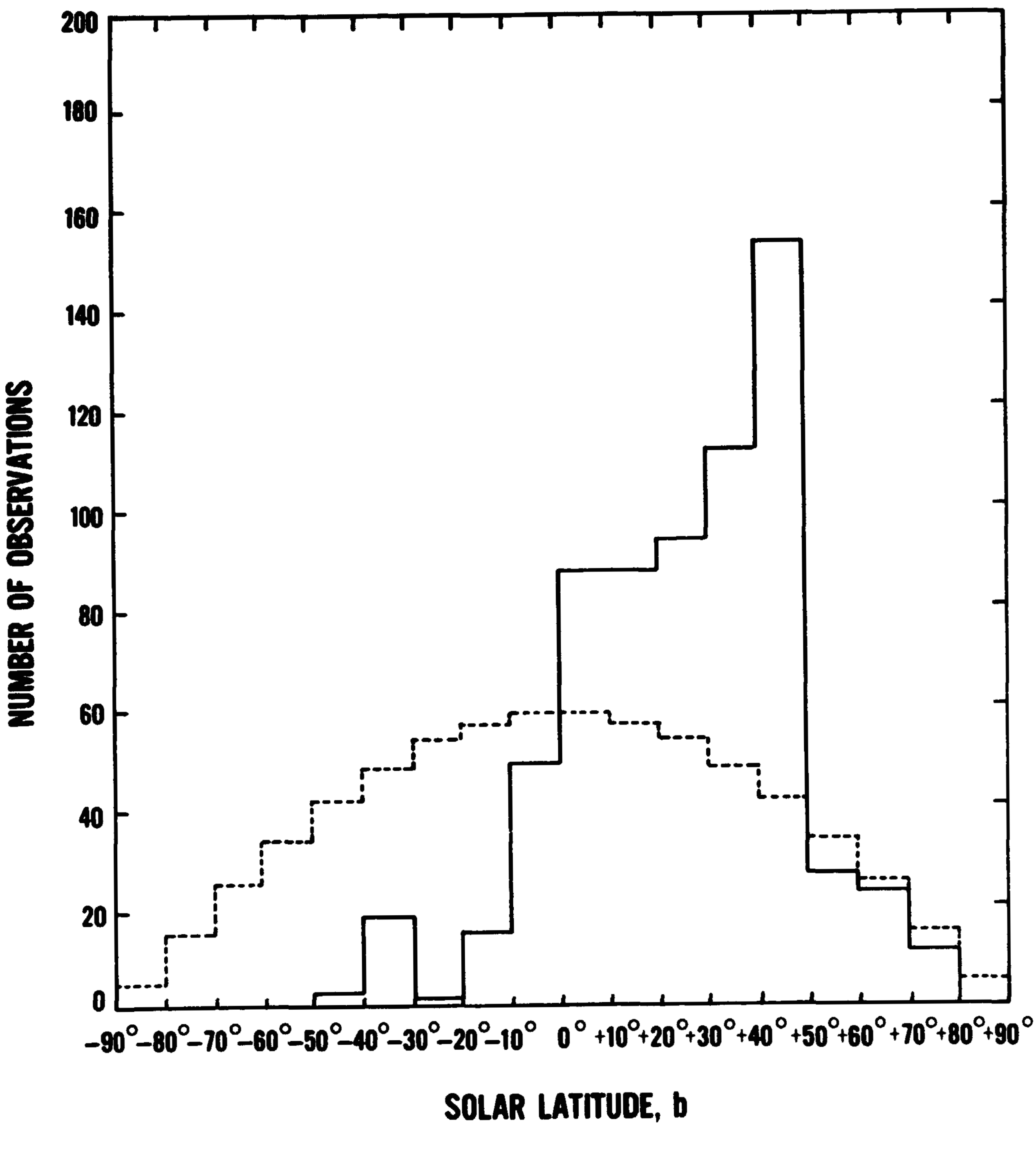
Pflug, K., Die bestimmung der ausbreitungsgeschwindigkeit und anderer eigenschaften des interplanetaren plasmas aus der richtung der gasschweife der kometen, Pub. Ap. Obs. Potsdam, No. 106, 1966.

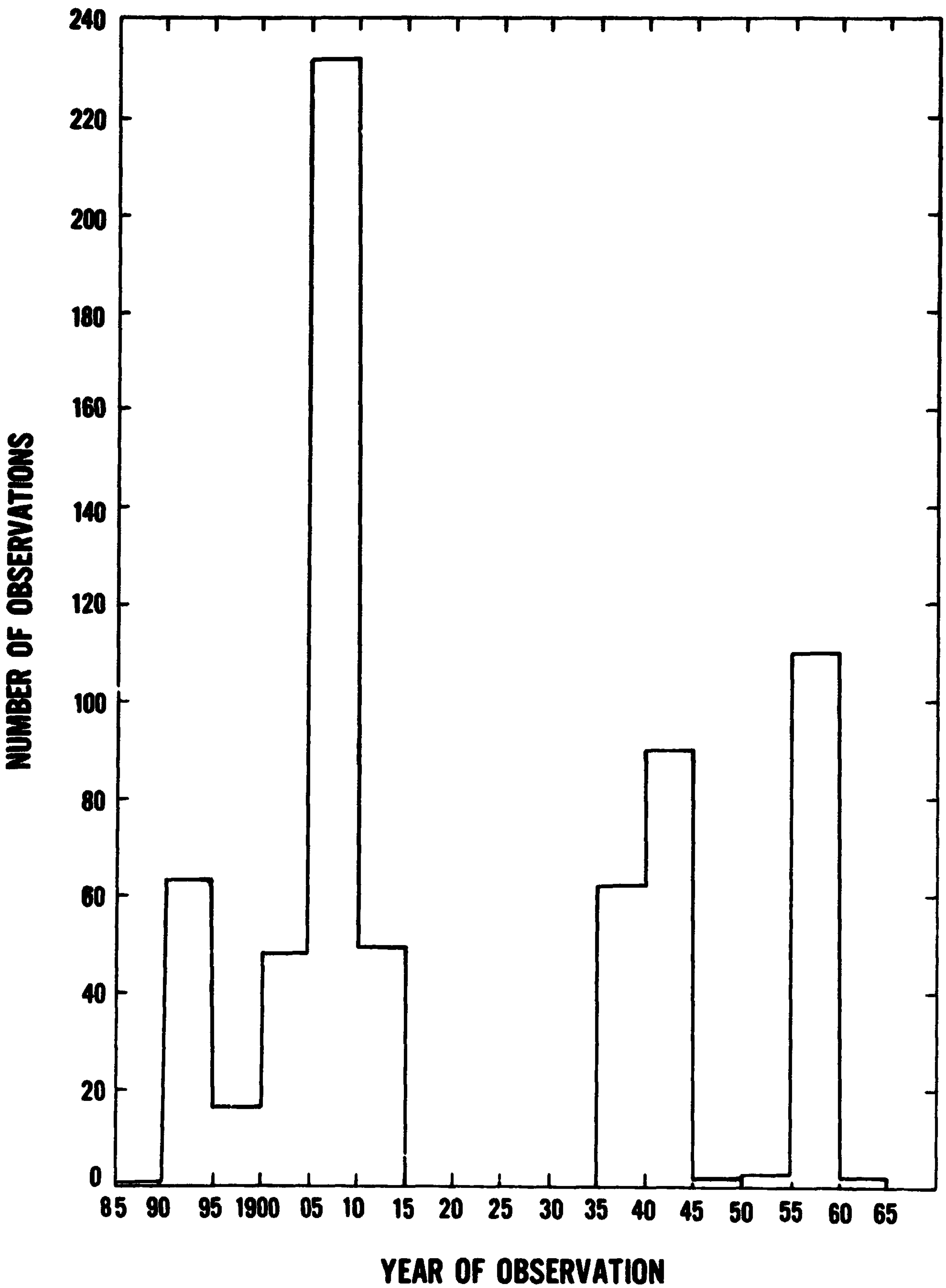
Rickett, B. J. The solar wind velocity in 1972-1974 as measured by radio scintillations, preceding paper, 1975.

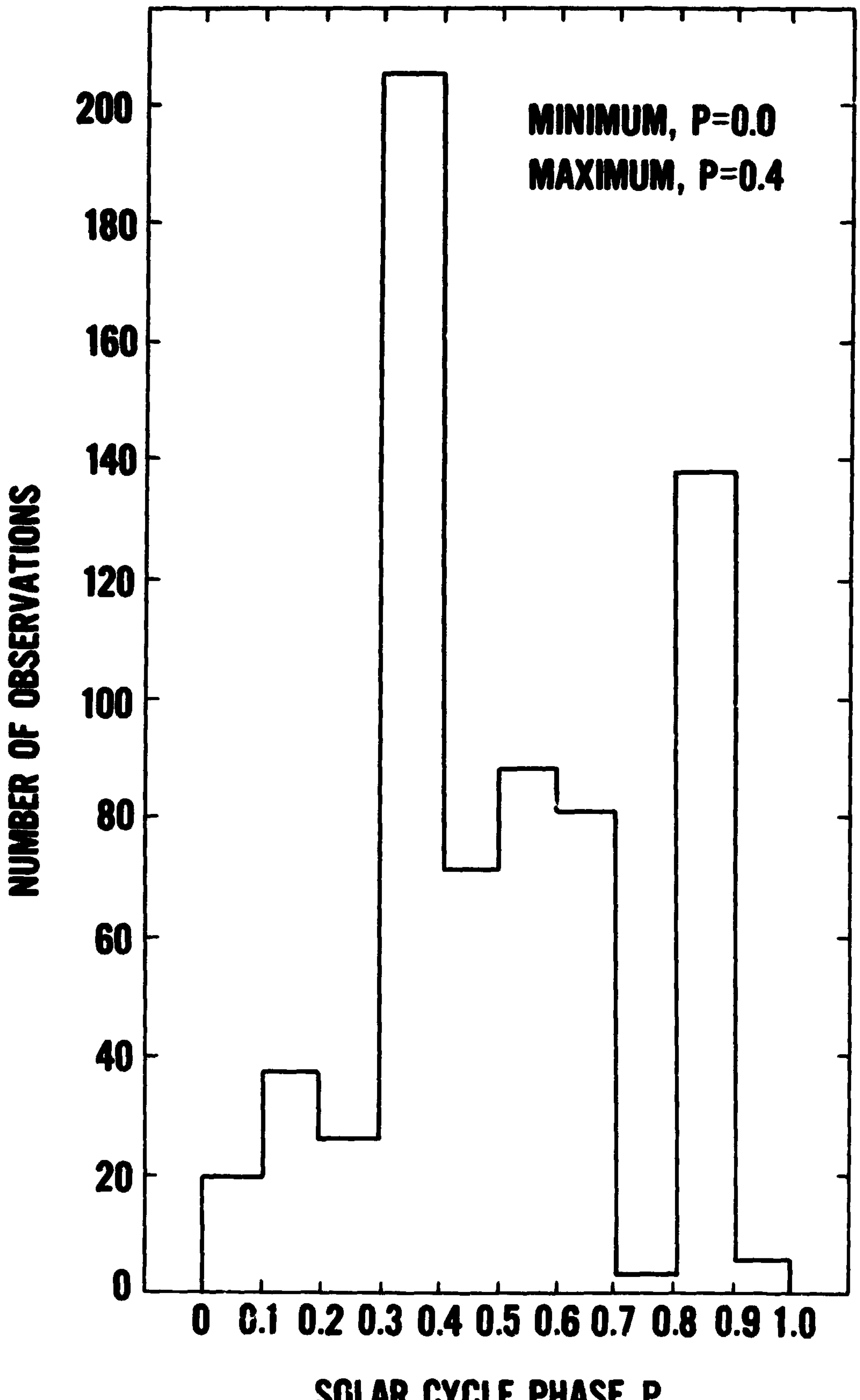
FIGURE CAPTION

Figure 1. The distribution of the sample of comet observations: (a) in absolute value of solar latitude; (b) in solar latitude; (c) in date of observation; and (d) in solar cycle phase. See text for discussion.


180
160
140
120
100
80
60
40
20
0
NUMBER OF OBSERVATIONS
0° 10° 20° 30° 40° 50° 60° 70° 80° 90°
|b|


200
180
160
140
120
100
80
60
40
20
0
NUMBER OF OBSERVATIONS
−90° −80° −70° −60° −50° −40° −30° −20° −10° 0° +10° +20° +30° +40° +50° +60° +70° +80° +90°
SOLAR LATITUDE, b


240
220
200
180
160
140
120
100
80
60
40
20
0
NUMBER OF OBSERVATIONS
85 90 95 1900 05 10 15 20 25 30 35 40 45 50 55 60 65
YEAR OF OBSERVATION


MINIMUM, P=0.0
MAXIMUM, P=0.4
NUMBER OF OBSERVATIONS
0
20
40
60
80
100
120
140
160
180
200
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
SOLAR CYCLE PHASE, P