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POLARIZATION OF VENUS: OBSERVATIONS OF SHORT-TERM QUASI-PERIODIC VARIATIONS*

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DR. BOWELL: Short-term variations have been noted in CO_2 line strengths, and of course morphological variations in the cloud deck have been well documented. But up to now, no one has, to my knowledge, discovered any short-term variations in polarization. There are seasonal variations which have been discussed by Coffeen.

Figure 1 is a composite, as it were, showing both variations in polarization and in CO_2 line strengths. The CO_2 measurements are by Barker, who will talk about them later. The interval concerned is August to September 1973. The polarization observations were made in September, and the CO_2 measurements in August.

The sine curve should simply be interpreted as a reference curve. It doesn't purport to fit the observations. What it does purport to do is to show that both the CO_2 and polarization variations are in phase and have a common period of something like 5.5 to 6 days.

Let me explain the CO_2 and polarization scales. The peak-to-peak variation in CO_2 line strengths, in August 1973, is about 20%. The semi-amplitude of the variation in the polarization is something like 2-1/2 thousandths (0.25 percent). This is a fairly small number in polarimetric parlance. Observations of the whole disk, as these are, can be made to an accuracy of something like half a thousandth. Therefore, looking for a 1 or 2 thousandths variation is quite a difficult job.

What's causing the variation in polarization? Is it variation in particle size? Is it variation in the variance of the particle size

size distribution? Is it variation in the thickness of an overlying Rayleigh atmosphere?

Figure 2 is an attempt to show that the variation in the ultraviolet polarization is not coming from changes in refractive index of the particles. The phase angle at the time of the observations was in the range 60 to 80 degrees, and this diagram, from a paper by Hansen and Hovenier, indicates that quite radical changes in refractive index would not change polarization very greatly. One should note that this doesn't preclude very large changes in refractive index causing a variation in polarization. Yet, in all other previous observations no great variation in polarization has been observed at small phase angles where there would be enormous differences in the observed polarization if the refractive index were to change on a short time scale.

Here is another polarization-phase curve (Figure 3) which this time is intended to show that the parameter known as f_R, the contribution of Rayleigh scattering to the phase matrix, could indeed change the polarization drastically over the relevant range of phase angles (60 to 80 degrees). In fact, a change of 0.001 in f_R corresponds to a change of about 0.001 in the polarization at phase angle 70 degrees.

I would suggest that the observed variations in polarization are indicative of changes in the height of the absorbing layer in the cloud and that this is reflected in changes in thickness of the Rayleigh scattering layer above the cloud. To give you some figures: assuming that the top of the absorbing cloud is at the 50-millibar level, which everyone else has done, then a change of 2-1/2 thousandths in the polarization would result from a change of pressure at the level of the cloud top of something like 3 millibars. So this is a change of 3 millibars in 50 millibars occurring planetwide on a time scale of days.

~~(Slide.)~~

Figure 4 shows the amplitude of variation in polarization (units are thousandths) versus wavelength. It bears a resemblance to a figure by Coffeen (see Figure 5) in an article about contrast of ultraviolet features on Venus. The drop from the ultraviolet down into the blue here is fairly steep. In green I can't readily attach any variation in polarization; the spot marks the analytical position.

~~(Slide.)~~

Figure 5 is Coffeen's diagram of contrast versus wavelength. There is a steeper slope, but it can't readily be compared with the previous slide of polarization variation as a function of wavelength because Coffeen's contrast data were derived from a series of scans taken instantaneously, as it were, and refer to different regions over the planet, whereas the variation in polarization is a temporal phenomenon which is integrated over the whole planetary disk.

There seems, therefore, to be a tie-up between variation in polarization, between CO_2 line strengths, and if this bad comparison between contrast and polarization variation is to be believed, between ultraviolet features and variation in polarization.

I think this goes back to what Andy Young was saying earlier, that all these different parameters we're measuring, probably referring to the same 50-millibar level, just have to correlate. The next step will be to refine all the measurements: to link in the polarization and the CO_2 observations with greater certainty, to link those in turn with the visual aspect of clouds in the ultraviolet, and eventually to move from a global to a localized appraisal of these parameters. This is certainly technically feasible with regard to polarimetry. One can make pretty accurate local polarization measurements and, with luck, observe changes in weather on Venus over a time scale of hours (this has already been done to a limited extent).

DR. KURIYAN: Could you tell us how you measure the polarization to this accuracy?

DR. BOWELL: Dr. Dollfüs could best answer that. It was his polarimeter. A half-wave plate rotates in front of an analyzer, usually. One measures the modulation of the output signal, and this is a measure of the polarization. You must have a fairly instantaneous method of measuring the change of the polarized signal.

DR. KURIYAN: And you could get it to an accuracy of .01 percent?

DR. BOWELL: I reckon it's on the order of .05 percent. This is a common accuracy astronomically. However, Venus is a different object because it has to be observed during the day. The sky is equal in intensity to Venus and is usually many times more polarized. So that's the real problem.

DR. SAGAN: You are proposing a pressure modulation of a few millibars to explain the polarization variations?

DR. BOWELL: Yes.

DR. SAGAN: What variation in ultraviolet contrast would result from the same pressure modulation?

DR. BOWELL: I haven't calculated that.

DR. SAGAN: I am wondering if these are compatible numbers. Jim Hansen thinks the answer is no.

DR. HANSEN: The magnitude of the changes in the Rayleigh optical thickness that you're talking about would have a negligible effect on the contrast, on the brightness.

DR. BOWELL: Therefore, you don't think the polarimetry would necessarily be correlated with the ultraviolet markings?

DR. HANSEN: That's right, not necessarily. I suspect that it may be correlated, but I think that explanation for the contrast variation is wrong. I think your data are very impressive. The magnitude of the effect that you see is clearly much larger than the non-systematic errors. But it would be easy to construct half a dozen different models which could give you that type of variation, and I don't think you can choose between those models until you have local polarization measurements of bright and dark areas. But you need to have these as a function of phase angle, and since things are changing on a short time scale, you can't wait for the phase angle of Venus to change as seen from the earth. So far as I can see, the only way to solve the problem is with measurements from an orbiting spacecraft.

DR. BOWELL: Oh, yes, indeed.

DR. YOUNG: I would point out that essentially we have this kind of observation from the ground. It's easy to see the CO_2 variations. We made a special effort to try to match up the CO_2 variations with ultraviolet features. We just don't see any variation at all between bright and dark ultraviolet features on the same day. I mean what we see is quite like what Ted Bowell sees, namely something like 5 or 10 percent variation in the apparent amount of gas. He sees it in Rayleigh scattering and we see it in CO_2 absorption, but it's the apparent amount of gas in the line of sight. But when you look at a bright area and a dark area in the ultraviolet photographs and ask if there is any difference between them, my answer is that the average difference is 1 ± 3 percent. It's very mysterious as to why the difference is so small. I surely expected I would see some difference and nothing came out.

FIGURE CAPTIONS

Figure 1. Short-period variations in ultraviolet polarization (3540 and 3790 Å) and CO_2 line intensity. Ordinate units represent about 0.002 change in polarization and 10% change in CO_2 line intensity.

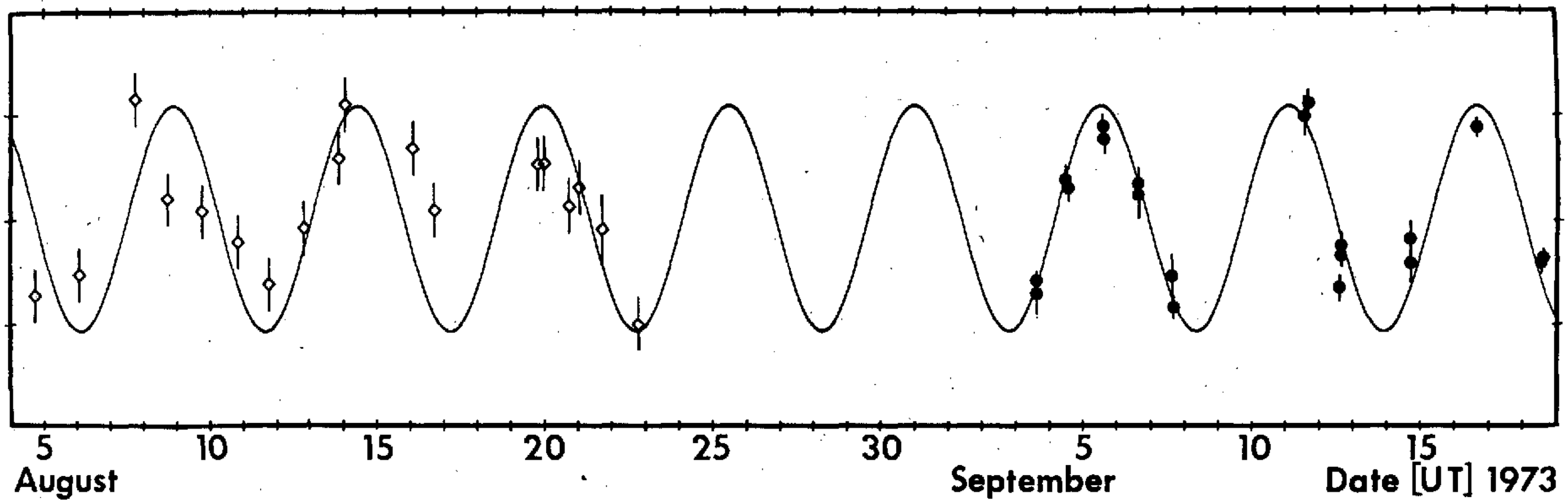
Figure 2. Observations and theoretical polarization-phase curves for the integrated disk of Venus. The effect of varying particle refractive index is shown. [J. E. Hansen and J. W. Hovenier, J. Atmos. Sci. **31**, 1137, 1974]

Figure 3. Observations and theoretical polarization-phase curves for the integrated disk of Venus, showing the effect of varying f_R, the Rayleigh contribution to the phase matrix. [J. E. Hansen and J. W. Hovenier, J. Atmos. Sci. **31**, 1137, 1974]

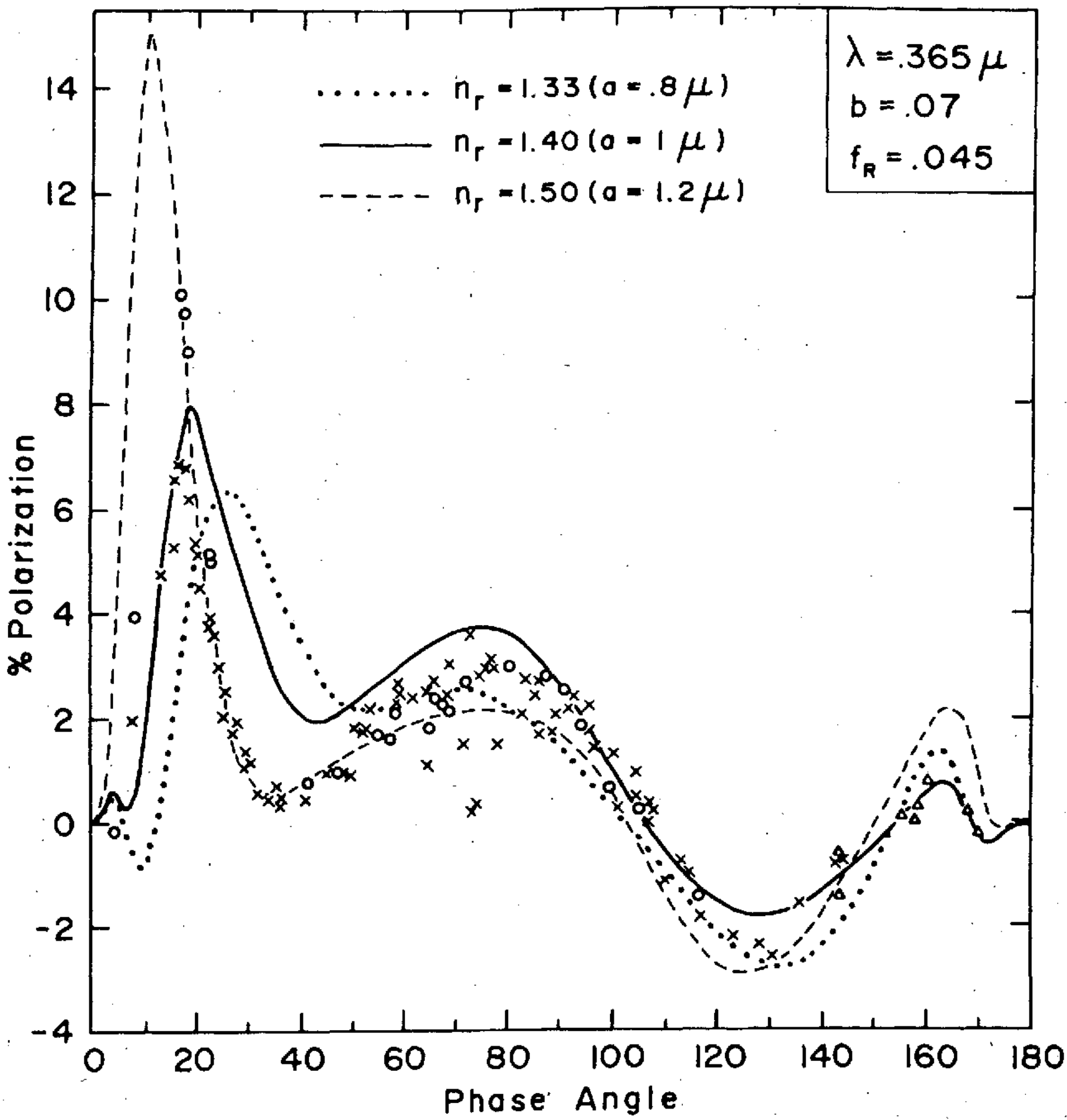
Figure 4. Amplitude of the short-term variation in the polarization of Venus as a function of wavelength. Observations of September 1973.

Figure 5. Venus cloud contrasts as a function of wavelength [from an article by D. L. Coffeen, in "Planetary Atmospheres," eds. C. Sagan *et al.*, Reidel, 1971].

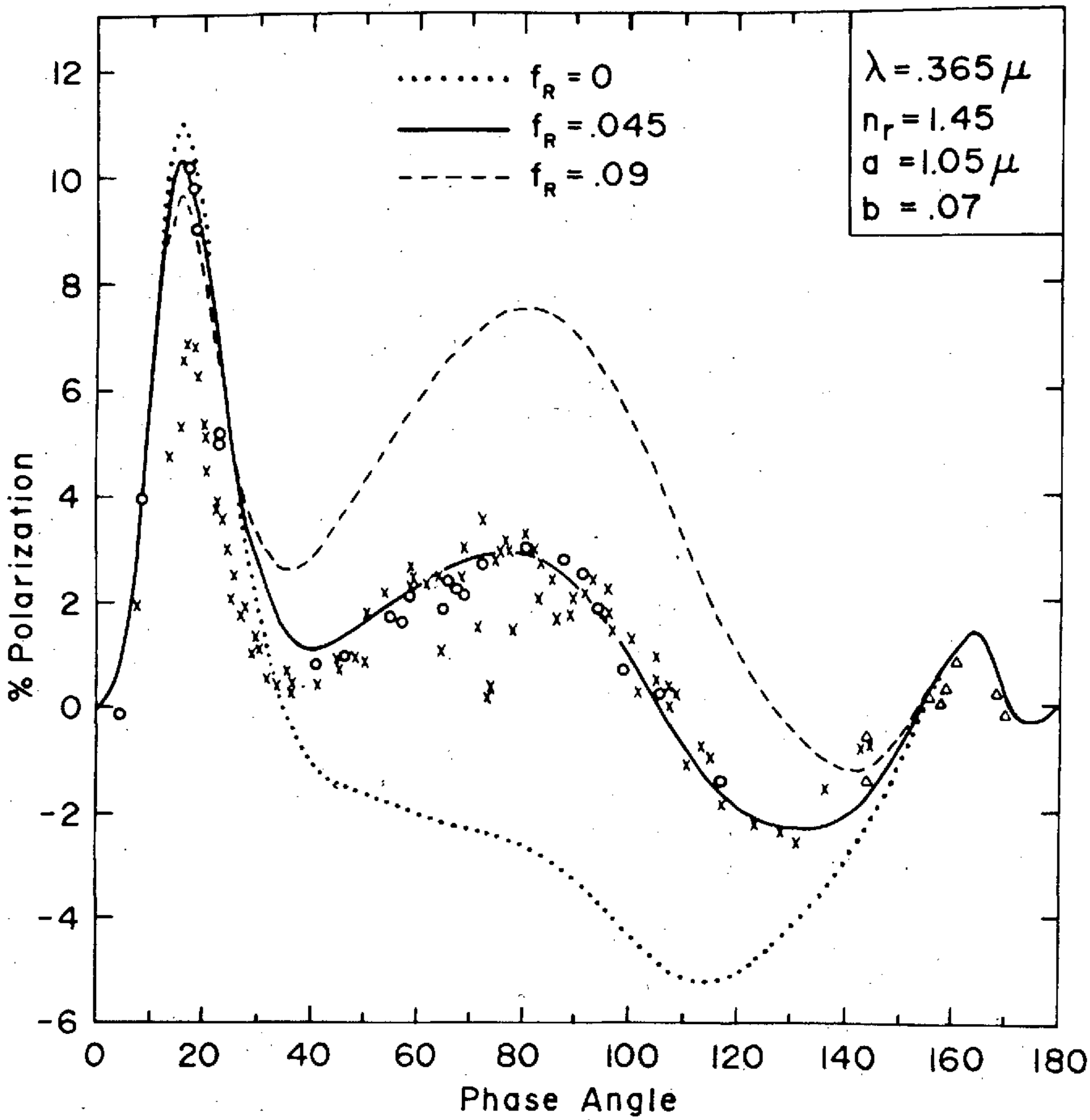
Normalized relative CO_2 line intensity [◇] and u.v. polarization [•] of Venus



Bowell Figure 1

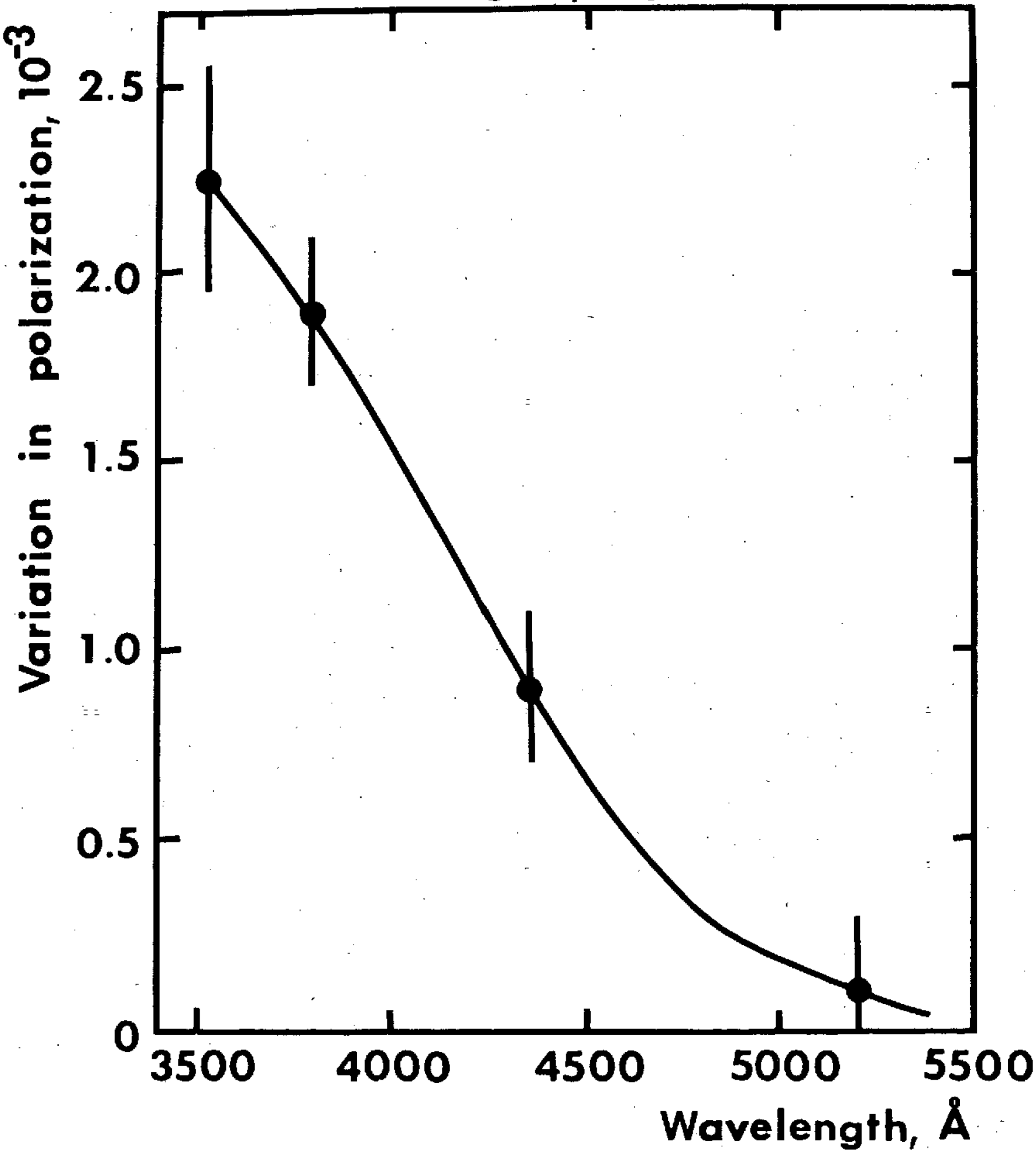


Bowell Figure 2

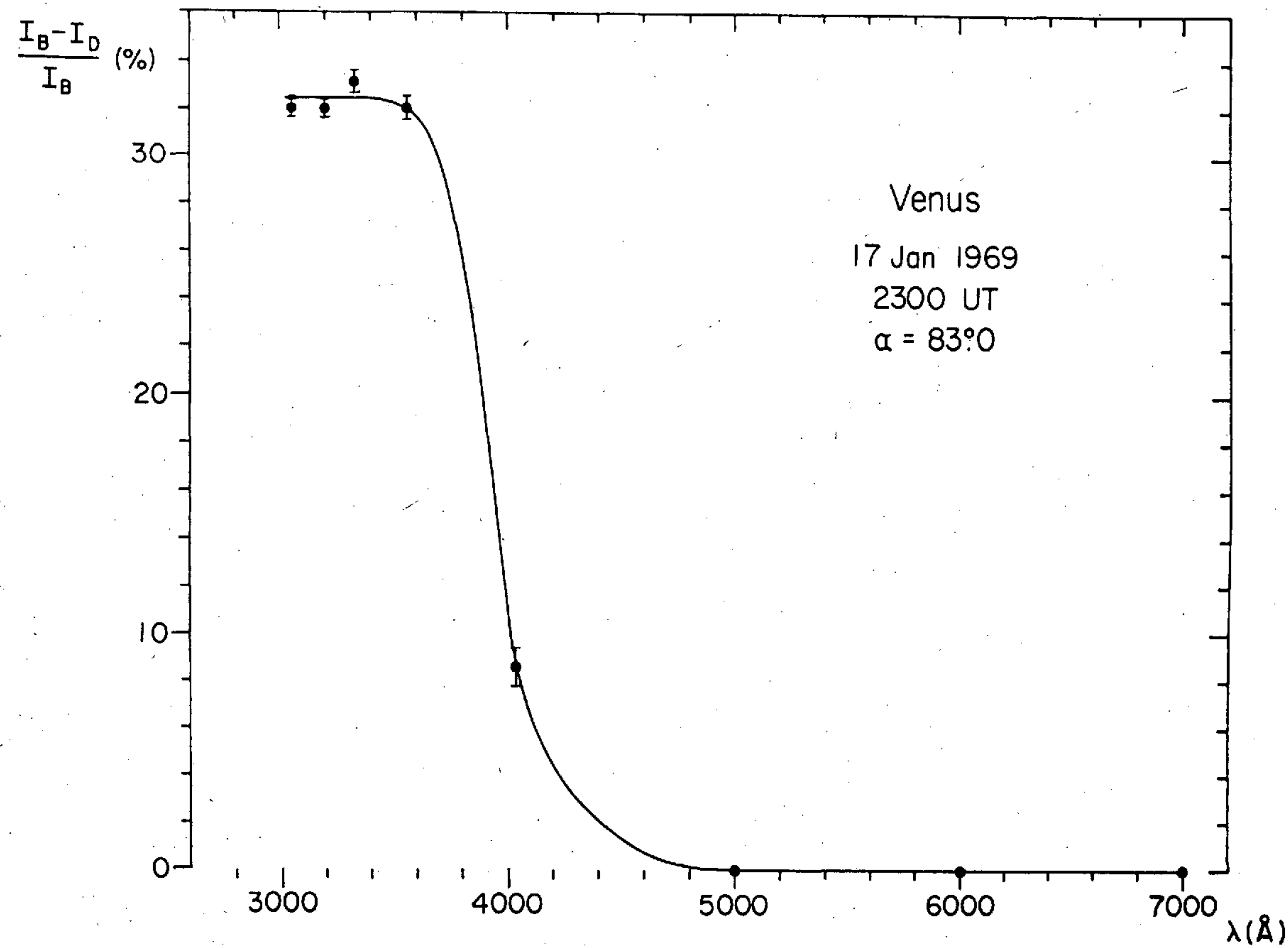


Bowell Figure 3

Amplitude of the short-term variation in polarization of Venus as a function of wavelength. Observations of August, September 1973



Bowell Figure 4



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