ent system[4]. But I am not aware of any evidence of field-aligned currents in the ionospheric holes observed at Venus.

Finally, the dispersive properties of the ionospheres at the Earth and Venus are not similar, as Maeda and Grebowsky imply. At the Earth, the sub-auroral ionosphere is characterized by relatively low electron densities and large magnetic fields, such that $f_p/f_g \sim 0.1$ (where f_p and f_g are the electron plasma frequency and gyrofrequency respectively). From cold plasma theory, the phase speed for whistler-mode waves, v, is less than $0.3c$, where c is the speed of light. In the Venus nightside ionosphere the magnetic field is weak, even within holes, whereas the density is high, so that $f_p/f_g \gg 1$, typically about 500. In this case, theory shows that $v < 10^{-3}c$. If VLF saucers were to be generated in the nightside ionosphere at Venus, their phase speeds would be even lower because VLF saucers are generated on the resonance cone, as evidenced by the V-shaped pattern in dynamic spectra[4]. The phase speed would be comparable to electron thermal speeds, and the waves would be subject to electron Landau damping rather than growth.

In conclusion, there are marked differences between the observed properties of VLF saucers and VLF emissions in the nightside ionosphere of Venus. Furthermore, the ionospheres at Earth and Venus are sufficiently different that instabilities applicable at the Earth are not applicable on Venus. The saucer mechanism is therefore not as plausible an explanation for the OEFD emissions as Maeda and Grebowsky suggest.

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SIR—Maeda and Grebowsky[1] misstate the conclusions of earlier work on the source of VLF (very low-frequency) bursts in the ionosphere of Venus, ignoring the many reported properties of these bursts which may not agree with their hypothesis. It is true that, in our initial studies[2,3], we speculated that volcanic plumes on Venus might produce electric discharges as they do on Earth, but in the last of the three papers[4] cited by Maeda and Grebowsky, we clearly state that "the fact that some active regions are close to, but not right over, highlands implies that volcanoes or tall mountains are probably not the immediate cause of the lightning." We tested our hypothesis, found it wanting and rejected it.

But there are many properties of the VLF signals that are consistent with discharges in the clouds. The rise and decay time of many of the signals seem to be smaller than the rise and decay time of the instrument[5]. These signals last for much less than 1 second, and decrease in occurrence rate with altitude at all frequencies[6,7]. (An exception to this trend below about 150 kilometres seems to be due to refractive index changes[8].) The signals have a strong local time asymmetry suggesting a late afternoon or early evening source[6,7] and the Poynting flux of the waves is consistent with the expected strength of a planetary lightning source[8].

To postulate a reasonable source for the VLF waves, one must provide a plausible energy source for the waves, explain why the energy is released in the form observed and explain the properties of the observed waves, their local time and altitude distribution, for example. The proposed plasma wave source does not yet do this. The proposed lightning source does.

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MAEDA AND GREBOWSKY REPLY—We now accept that the volcanic lightning source for the Venus VLF bursts had been discarded by its advocates in a paper[1] of which we were not aware. The statement in the paper we did cite[2], singled out in Russell's comment, we wrongly interpreted as leaving open the possibility of such a source. For this we are in error.

But our paper was not concerned with refuting a volcanic, meteorological or any other source for lightning. Rather, we were trying to show that there are natural ionospheric emission sources which can produce whistler waves with the features seen at Venus.

We consider that the issue is still open, and offer as proof the following slight rewording of a section of Russell's comment: "There are many properties of the VLF signals which are consistent with an aurora-like emission source. The rise and decay time of many of the signals seem to be smaller than the rise and decay time of the instrument. These signals last for much less than 1 second, as would be expected for the OEFD detection of some saucer signals or other fine-scaled discrete auroral emissions. The signals decrease in occurrence rate with altitude as would be expected for a lower ionosphere source. (The exception to this trend below 150 kilometres might be due to going beneath the source.) The signals have a strong local time asymmetry suggesting that conditions for ionospheric signal production are more favourable on the dusk side of midnight. The electric field energy density in the 100-Hz waves is the same order as the **E** field energy density in typical terrestrial saucer emissions."

Strangeway's comment focuses on evaluating the VLF saucer production hypothesis within the Venusian environment and has some merit. The discussion of the potential importance of Landau damping may indeed rule out one of the two mechanisms for saucer production cited in our paper. But the point that discrete saucer-like emissions can produce emissions of less than 1-second duration as observed from the Pioneer Venus OEFD is still valid. Although our densitometer analysis of terrestrial DE-1 data used a narrower bandwidth than the Pioneer instrument, one cannot simply scale the durations as Strangeway has done — the scaling depends on the aperture angle of the saucer ray in the frequency–time spectrum. If the source region, for example, is traversed, the duration is the same regardless of the detector bandwidth.

The most telling argument against an ionospheric plasma source would be an analysis of the VLF Venus bursts that showed that the bursts were all consistent with durations less than the instrument resolution time. Unfortunately, the presence or absence of whistler bursts of duration longer than the instrument sample time has yet to be determined. In addition, Strangeway points out that there is, as yet, no evidence for field-aligned currents in the Venus holes but at the base of the nightside ionosphere the high-resolution **B**-field measurements show extreme variability[1], thus providing evidence for the existence of plasma current sheets.

Within the framework of the information known or surmised about VLF bursts and the local plasma environment, we therefore hold that a local ionospheric source is still a viable hypothesis. To resolve these issues, proper observational data of the Venusian nightside VLF emissions, such as the broadband frequency–time spectrograms, must be obtained instead of repeating speculative arguments based on the fragmentary monochromatic data.

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