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Technical Comments

Detecting Potassium on Mercury

A. L. Sprague *et al.* (*1*) attribute an enhanced emission in the potassium (K) D lines on 14 October 1987 in the equatorial region of Mercury to a diffusion source centered on Caloris Basin. We believe that Sprague *et al.* misinterpreted the data.

The single observation of enhanced emission of K in the equatorial bin was followed 50 minutes later by a second observation that showed no enhancement (Table 1). The equatorial column abundance derived from the second observation was smaller by a factor of 3.6 and was similar to abundances observed before and after the enhanced emission. The average column abundance from the two is 2.3×10^9 K atoms cm^{-2}. This is similar to normal K abundances (0.5 to 1.0×10^9 K atoms cm^{-2}). The ratio of equatorial to polar column abundance appears to decrease by a factor of 2.5 in 50 minutes. This suggests the presence of noise in the measurement of enhanced emission.

If the source of the volatiles was primarily in the Caloris Basin region, then an enhanced emission should be correlated with the position of Caloris Basin for the entire body of observations. The illumination and viewing geometry of the 14 October observations closely match the discovery observation of 16 November 1985 (*2*). We resampled our data to match the binning of the 14 October data. The average zenith column abundance along the slit for the discovery observation was within 30% of the second observation from 14 October (Table 1). However, when we compared the discovery observation with the first observation from 14 October, we found a difference of a factor of 5. Similarly, the equator to pole ratio from the discovery observation matched the second observation from 14 October, but was a factor of 3.5 smaller than the first observation. In short, the discovery observation did not confirm the high K abundance reported by Sprague *et al.* over Caloris.

Table 1. Potassium observations (uncorrected for atmospheric turbulence).

Reference	Date	Time	Longitude of sub-Earth point	Longitude of sub-solar point	Phase	Disk average column abundance ($\times 10^9$)	Equator to pole ratio of column abundance
(*2*)	16 Nov. 1985	21:48	279	174	109	0.72	1.2
(*1*)	14 Oct. 1987	21:32	269	161	107	3.60	4.2
(*1*)	14 Oct. 1987	22:22	269	161	107	1.00	1.7

Table 2. Sodium observations (corrected for atmospheric turbulence).

Reference	Date	Longitude of sub-Earth point	Longitude of sub-solar point	Phase	Disk average column abundance ($\times 10^{11}$)	Equator to pole ratio of column abundance
(*3*)	2 Apr. 1987	24.5	102.1	77.6	1.78	1.0
(*3*)	3 Apr. 1987	29.4	105.5	76.1	2.42	1.0
(*3*)	6 Apr. 1987	43.9	115.4	71.6	0.68	1.3
(*3*)	13 Feb. 1987	92.7	0.08	92.6	2.60	1.0
(*3*)	3 Dec. 1986	127.2	188.7	63.2	0.80	1.0

The emission intensity for the north polar region should be larger than that for the south polar region if there is a Caloris Basin source. The center of Caloris Basin is near 30° north latitude and extends roughly from the equator to about 60° north latitude. Atmospheric turbulence, usually affecting spatial resolution by 2 to 3 arc seconds, can smear the light from a source at 30° well up to northern latitudes. Sprague *et al.* grouped their observations into three bins, with the equatorial bin spanning the mid-half of the disk. Even with this wide bin, one would expect an asymmetric distribution (with the northern bin significantly larger than the southern bin), but the data do not show this. The discovery observations also do not show any significant north-to-south asymmetry.

Sprague *et al.* note that the behavior of sodium (Na) and K are expected to be similar. Consequently, another place to search for evidence of a Caloris Basin source would be in the published Na data for Mercury. R. M. Killen *et al.* (*3*) and A. E. Potter and T. H. Morgan (*4*) cite several instances of Na observation on Mercury. In the observations of 16 November (*4*) and 3 December 1986 (*3*), Caloris Basin was in view. The subsolar column abundances on these dates were the lowest that we have recorded. The equator-to-pole ratios are all near unity for the observations of Na in the paper by Killen *et al.* (Table 2), for the discovery observation of K, and for the second K observation of Sprague *et al.* These data do not support the conclusion of Sprague *et al.* that there is a significant vapor source at Caloris Basin.

Sprague *et al.* also point out that some of the Na images reported by Potter and Morgan (*5*) showed enhancements that approximately matched the location of Caloris Basin or its antipode. This is only part of the story, because most of the images that showed strong local enhancements showed *two* regions of high Na concentration. These appeared on the same side of the planet, centered at about 60° north and 50° south latitude. A single diffusion source at Caloris Basin could not account for north-to-south pairs of Na images on the same side of the planet. One could evoke multiple, time-variable, geologic sources to explain the emission peaks, but such explanations would not be convincing.

Finally, Sprague (*6*) postulates that the diffusion source at Caloris is at a mean depth of 10 km. Such a source could not produce a variable atmosphere in less than a day. Nor could tidal forces influence the release of gas from a diffusion source. The average column abundance is found to increase with Mercury's distance from the sun, so that it is at a maximum at aphelion and at a minimum at perihelion. This is exactly the opposite behavior from that expected from tidal forces. These forces are proportional to the inverse cube of the radius vector between Mercury and the sun, so they are greatest at perihelion.

We have postulated that the source of the asymmetries and the temporal variability in Na and K emissions is rooted in an interaction of photoions with the magnetosphere (*3, 4*). A magnetospheric mechanism would produce enhancements at both poles and would be capable of producing rapid variations through enhanced sputtering by heavy ions impinging on the planet in the polar ovals, or through recycling of ions in a magnetic reconnection event, or both.

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Response: R. M. Killen *et al.* cite evidence that there are intermittent, local enhancements of K and Na abundances. They also suggest that the event we associated with Caloris Basin was caused by noise rather than by an unusually strong enhancement. As they point out, our enhancement decayed rapidly with a time constant that we estimate as about 30 minutes (for an assumed exponential decay and a rapid disappearance of source). This decay can be obtained from the numbers in our table 1 (*1*), but does not appear correctly in figure 1 (*1*) because of a regrettable plotting error. A spectrum taken from frame 291 (Fig. 1) shows an emission peak at the proper wavelength, of proper shape and width, and with a low noise level. We have no reason to think this emission peak might be spurious. The apparent column abundance decreased from a factor of 6 to a factor of 2 times the average value at all other longitudes (not including the antipodal terrain). We cannot prove that a single example is valid, but we think it cannot be readily dismissed.

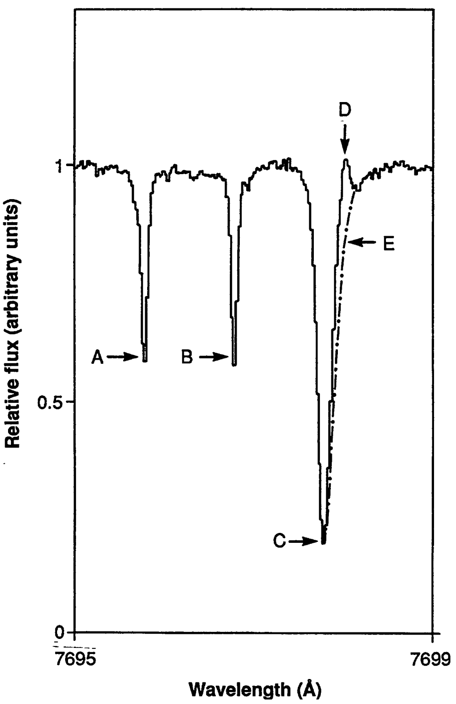

Fig. 1. A spectrum from part of the central latitude bin of image 291 (*2*). The zero level has been displaced upward by 8% of the continuum. This amount is typical of scattered light in the instrument. From left to right are two lines of O_2 (A and B) in Earth's atmosphere, the solar absorption line (C) reflected from Mercury's surface, and the atmospheric K emission line (D). Scattered light from Earth's atmosphere has been removed. The dashed line (E) indicates the estimated continuum. The signal-to-noise ratio of this line is high, and the shape is as expected for a narrow emission. The line appears at a shorter wavelength than 7699 Å because of a large Doppler shift.

The rapid decay pointed out by Killen *et al.* is surprising, but can be accounted for if K atoms colliding with the surface were adsorbed with a sticking efficiency of about 0.12 per collision. In 30 minutes the number of collisions with the surface was about eight, and the total probability is $(1 - 0.12)^8 = 0.36$ or approximately $1/e$ ($e \approx 2.718$). Alternatively, one collision out of eight could have been with a shadowed region at a temperature considerably lower than normal. The number eight was obtained from the hop time $(2/g)(kT/m)^{1/2}$, where g is the acceleration due to gravity, k is Boltzmann's constant, m is the mass of a potassium atom, and T is the temperature (taken as 2000 K or less).

Killen *et al.* also cite evidence that enhancements of sodium abundances appear in places other than Caloris Basin and suggest a tendency for them to appear in north-to-south pairs. This leads them to associate the enhancements with an auroral phenomenon, such as the one briefly described in (*2*). Although the morphological evidence is suggestive, we find that the mechanism is insufficient quantitatively, unless one were to assume that the surface being bombarded by auroral protons was essentially pure sodium. Killen *et al.* also found Na column abundances to be largest near aphelion. In contrast, we found K abundance to be enhanced by a factor of four near perihelion.

We prefer to associate the intermittent bright spots with localized sources of diffusion and degassing (*1, 3*), but it is now clear that the fractured terrain of Caloris Basin and of the antipode can be only two of several sources. There is good evidence for such a phenomenon on the moon, from observation of radioactive decay products by an orbiting gamma-ray spectrometer (*4*). We see nothing improbable about a variable degassing rate, in the presence of the strong thermal and tidal flexing of Mercury. Killen *et al.* assert that such forces would be a maximum at perihelion, but this ignores two important facts. First, there are two kinds of tidal distortion, one caused by varying distance from the sun and another caused by rotation of the planet with respect to the planet-sun line. Second, the radial stresses must be measured relative to those at the mean distance; this is why, for example, Earth has two high tides per day rather than one.

Both the auroral and degassing hypotheses require additional data and further quantitative elaboration before one can conclude which, if either, is correct. For the present, we still favor the diffusion and localized degassing hypothesis.

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