7. J. D. Mulholland, *JPL Space Programs Summary No. 37-45* (1967), p. 17.
8. Solving for the semimajor axis of the orbits of both planets simultaneously leads, in the pure radar solution, to a near-singular normal matrix. The dominant signature in the time delay observable, resulting from adjusting the semimajor axis, is due to the change in the mean motion of the planet rather than to the direct effect of the change in the semimajor axis itself. The orbits of Venus and Earth are nearly coplanar and circular; so a change in the mean motion of Venus is almost indistinguishable from a corresponding negative change in the mean motion of Earth. The choice of either semimajor axis accommodates the relative mean motion correction and gives essentially the same results for the other parameters. In this solution, the semimajor axis of the Earth-Moon barycenter was used because it gave a slightly better fit in the least-squares sense.
9. The Mariner V spacecraft ranging and counted Doppler data taken during the Venus encounter phase provide an important and independent determination of the position of the center of gravity of Venus. The preliminary residual from Mariner V data analysis is shown on this figure at the epoch of closest approach to Venus, 19 October 1967 (private communications from J. D. Anderson, JPL).
10. This report presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under NASA contract NAS 7-100.

1 April 1968

Old Faithful: A Physical Model

Abstract. *The recent confirmation of a prediction that relates the duration of eruption to time between eruptions suggests a physical model of the internal cavity of Old Faithful.*

Rinehart (*1*) has proposed that Old Faithful exhibits two modes of eruption. One mode (a long interval between eruptions) consists of a 20- to 30-minute quiet period and is concluded by a brief series of long-period ground movements that are followed by general seismic activity (weak tremors and strong pulses) that continue up to the time of eruption. The second mode (a short interval between eruptions) is characterized by immediate seismic activity, consisting of both weak tremors and strong pulses and occasionally including the introductory long-duration movements. This activity continues up to eruption. There is no observable relationship between long and short intervals between eruptions. Old Faithful has also been observed to exhibit a range of from 1.5 to 4.5 minutes in the duration of water play.

On the basis of these data (*1*), I proposed (*2*) that Old Faithful consists of a single cavity that occasionally was incompletely emptied in an eruption. If we make the assumption that seismic activity is related to the boiling activity in the geyser cavity, we can explain (i) the immediate onset of seismic activity (in cases of a short interval between eruptions) and (ii) the existence of short-interval eruptions, by hypothesizing that this mode of eruption results when the prior eruption incompletely evacuates the cavity, and hence the cavity remains partially full of hot liquid. Therefore, there would be immediate boiling activity, and less time would be necessary to reach the critical point for a second eruption.

In cases of complete eruption, the cavity is left essentially empty, and there would follow a longer interval preceding the next eruption. The first part of this period would be quiet because there would not already be a mass of hot boiling liquid in the cavity. On the basis of the above rationale, I proposed that the relation between duration of water play (this should provide an estimate of how completely the cavity is emptied) and the length of the interval to the subsequent eruption should be examined, and I hypothesized that a brief duration of water play (incomplete emptying) would be associated with a brief interval to the following eruption.

This hypothesis was tested by Rinehart and confirmed (*3*); its confirmation suggests that there is a physical model for the geyser cavity (Fig. 1). During the quiet portion of a long interval between eruptions, the lower U part of the cavity would slowly fill and come to a boil. Seismic activity would result when the mass of boiling water was great enough to seal off the U portion of the cavity. This would mean that venting steam from the back half of the cavity would have to blow out through the water mass, producing detectable vibrations. An eruption would take place when the U portion of the cavity was sufficiently full to splash a quantity of water over into the hot, dry, back half of the cavity. The water would immediately flash boil to steam, forcing the water out of the U section of the cavity. The extent of the eruption would depend on the quantity of water splashed into the back half of the cavity. A large splash would generate a large volume of steam and blow the cavity clean. A smaller splash would result in a partial evacuation of the cavity. If, in the latter event, sufficient water remained in the cavity to seal off the U portion of the cavity, new seismic activity would start immediately.

Data on the volume of water erupted would provide an additional test of the model. Because the geyser opening is a constant, a measure of the velocity of the escaping liquid in addition to the duration of water play would provide a good estimate of the volume ejected. On the basis of the above model, one would predict that eruptions which precede a long interval (complete emptying) would involve longer water play, a greater total volume ejected, and also a greater water eruption velocity. (It has been hypothesized above that a greater volume of steam is generated in these cases.) Therefore the internal pressure should be greater, and

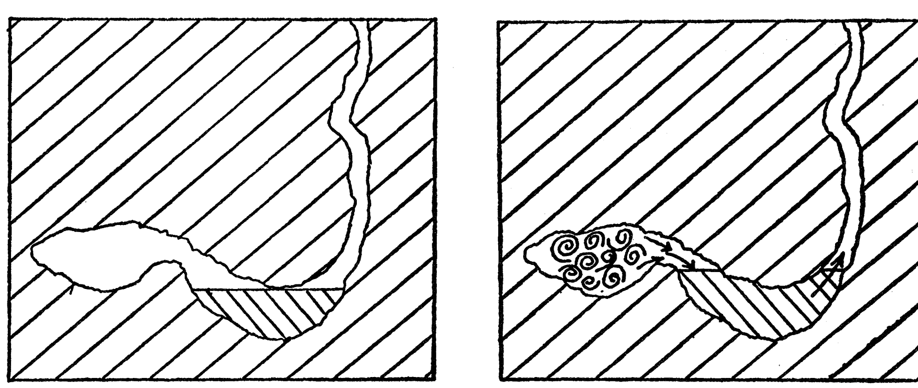

Fig. 1. (Left) Cavity filled to point at which the surging motion of the water in the U portion of the cavity (which results from the venting of steam from the back portion) would produce noticeable ground tremors and pulses. (Right) Water splashing over into the hot, dry, back portion of the cavity flashes into steam and blows the liquid up and out of the U portion of the cavity.

the eruption velocity greater. Although an additional test should be made, the present data seem to lend adequate support to the proposed model to warrant its temporary adoption.

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14 April 1968

Detection of Lyman-β and Helium Resonance Radiation in the Night Sky

Abstract. *A rocket-borne photometer has detected far ultraviolet night glow radiations that are identified as Lyman-β (HI 1026 angstroms), and the helium lines at 304 or 584 angstroms, or at both. At an altitude of 227 kilometers the measured intensity for Lyman-β was about 10 rayleighs. The discrimination characteristics of the broad-band helium radiation filter give helium line intensities, at 227 kilometers, of 4.8 and 12 rayleighs, respectively, pending identification of the wavelength of the radiation as 304 or 584 angstroms. These ultraviolet radiations appear sufficient to maintain the night E and F_1 regions of the ionosphere.*

The existence of an ultraviolet night glow at Lyman-β (HI 1026 Å) and the two helium resonance lines, HeI 584 Å and HeII 304 Å, has been postulated on the basis of resonant scattering theory (*1*). It has been suggested that this radiation may explain the behavior of the nighttime E and F_1 regions of the ionosphere (*2*). In 1960, Byram, Chubb, and Friedman (*3*) flew an open-window, lithium fluoride photocell and set an upper limit of 230 rayleighs for the resonant helium glow.

At 2330 Mountain Standard Time on 10 August 1967, a photometer experiment designed to detect far ultraviolet radiation in the night sky was flown aboard an Aerobee 150 rocket, NC 3.187, launched from the White Sands Missile Range, New Mexico. Two of the photometers that were flown were detectors of the thin film-scintillating phosphor-photomultiplier type described by Lincke and Palumbo (*4*), while the third was an ionization chamber with a lithium fluoride window filled with nitric oxide (*5*). One thin-film filter was an indium window (band pass, 770- to 1080-Å) and was designed for the detection of Lyman-β; the second employed an aluminum window (band pass, 150- to 750-Å) and was utilized for the detection of the combined helium resonance radiations at 304 and 584 Å (*6*). The ionization chamber was used to detect the Lyman-α (HI 1216 Å) airglow.

At 80.5 km on the ascent of the rocket flight, a protective door covering the two thin-film window detectors was released. Upon door ejection, each detector recorded signals that varied as a function of altitude and attitude of the system throughout flight.

Data taken when the two thin-film detectors were looking at a fixed direction in space were first plotted as a function of altitude and were then corrected for signals due to Lyman-α radiation (as measured by the ionization chamber), background noise (determined before ejection of the protective door), and background visible light (detected by an optical star sensor). The corrected signals from each detector increased with increasing altitude, indicating the presence of far ultraviolet radiations that are absorbed high in the earth's atmosphere.

Analysis of the corrected signal from the 770- to 1080-Å detector indicated a radiation that is absorbed principally in the 100-km region of the atmosphere and has an extinction coefficient (*7*) of $\mu \simeq 10^{-6}$ cm^{-1} in this altitude range. Both of these characteristics are exhibited by Lyman-β as it is absorbed by O_2 in the earth's high atmosphere (*8, 9*).

Analysis of the corrected signal from the 150- to 750-Å band-pass detector indicated a radiation that is absorbed mainly in the 140- to 160-km altitude range and has an extinction coefficient that varies from 2.8 to 6.5×10^{-7} cm^{-1} in this region. These characteristics agree quite well with the behavior of HeII 304 Å as it is absorbed by the upper atmosphere (*8*). We cannot, however, eliminate the possibility that a certain percentage of the radiation detected by the 150- to 750-Å detector was the 584-Å line of HeI. Rather than estimate the contribution from each wavelength, we shall give values of intensities and absorption rates, assuming it is either one line or the other.

If the ultraviolet radiations detected were Lyman-β, HeII 304 Å, and/or HeI 584 Å, we find the following intensities and absorption rates. At peak of flight (227 km), the intensity of Lyman-β was 9.6 rayleighs and the absorption rate per unit volume in the 100-km region was about 0.75 photon per cubic centimeter per second. The use of 58 percent (*9*) as the ionization efficiency of Lyman-β when absorbed by O_2 leads to a nighttime production rate of 0.43 O_2^+ ion cm^{-3} sec^{-1} in this altitude range. If all the radiation detected by the 150- to 750-Å band-pass photometer was HeII 304 Å, then its intensity at peak of flight was 4.8 rayleighs, and the absorption rate per unit volume in the 140- to 160-km altitude range was about 0.29 photon cm^{-3} sec^{-1}. If, on the other hand, all the radiation detected by this photometer is to be ascribed to the 584-Å line of HeI, then the above values of intensity and absorption rate per unit volume must be multiplied by a factor of 2.5, the relative efficiency of the aluminum filter at these two wavelengths.

Resonant scattering theory predicts a night glow at those wavelengths measured in our experiment. We shall now examine what conclusions, if any, we can draw on the nature of the scattering medium—whether most of the resonant scattering takes place within the earth's high atmosphere or whether scattering by the gases in interplanetary space makes an appreciable contribution to the measured night glow radiations. In regard to Lyman-β, Meier (*10*) of this laboratory has calculated that the observed intensities can be explained reasonably well by the resonant scattering of solar Lyman-β photons within the earth's hydrogen geocorona. This does not, of course, exclude the possibility that some of the night sky Lyman-β is due to the scattering of solar radiation by atomic hydrogen in the interplanetary medium, but it does not seem necessary to invoke this mechanism in order to explain the bulk of the observational results. The case for the helium resonance radiations is less clear-cut, since exact calculations dealing with the resonant scattering of the solar 584- and 304-Å lines by the neutral and ionized helium within the earth's atmosphere are lacking. Qualitative estimates lead to predicted intensities that are roughly within an order of magnitude of those quoted above for these two wavelengths, but it appears that future experiments are necessary before definitive statements can be made concerning the role of the interplanetary