MULTI-WAVELENGTH OBSERVATIONS OF THE MERCURY TRANSIT OF NOVEMBER 1999. B. M. Cudnik[1], [1]Department of Physics, Prairie View A&M University, New Science Building, Room 330AE, L.W. Minor Street, Prairie View, Texas 77446. Brian_Cudnik@pvamu.edu

Introduction and Historical Background: The Mercury transit of the Sun, 15 November 1999, was observed at the Prairie View Solar Observatory (PVSO) and with three channels of the TRACE satellite. These CCD observations enabled an objective study of the historic Black Drop under different conditions and with different filters. The Black Drop phenomenon has a much subtler counterpart referred to as the "Gray Drop phenomenon", of which the former is a more prominent component of the latter. The optical causes of both effects are very similar and appear to require a sharp, uniform boundary of sufficient contrast (e.g. the solar limb against a sky at least as dark as the center of Mercury's disk), coupled with a blurring agent. Without all these conditions in place, the visibility of the Black Drop is greatly reduced or eliminated. Such was the case of the transit as observed with Hα at line center, the TRACE UV (1600Å) channel, and the EUV (171Å) channel. This suppression of visibility in these cases was due to the contrast-lowering background of the chromosphere or corona.

For over 300 years, astronomers have been using the transits of Mercury and Venus as tools for their studies of the inner solar system. Such observations have been made as early as 1639 December 4, by Jeremiah Horrocks for Venus [1] and since at least 1667 for Mercury [2]. Prior to the turn of the 20th century, the main use for transit observations have been to gauge the size of the inner solar system and the Sun itself. More recently, these events have provided astronomers with a means of calibrating their data and their instruments (including establishing correction functions for scattered light), gauging changes in the physical size of the sun, and studying the optical physics behind the famous Black Drop phenomenon. At the beginning of the 21st century, in the age of spacecraft and satellites, observations of planetary transits (of Mercury and Venus) are of little scientific value, with perhaps the exception of the optical effects these events produce.

Circumstances of the 1999 November 15 Transit: The unique characteristic of the 15 November 1999 Transit of Mercury was its grazing nature. The planet was present, at least partially, for less than one hour on the solar disk as observed at the PVSO, with maximum limb-to-limb separation of 5.8". Further south and west, this separation decreased to zero, with observers in most of Australia observing only a partial transit. These circumstances allowed for an extended observation of the Black Drop phenomenon at the PVSO and enabled one to observationally test the results of numerical simulations, such as that of [3]. It was also possible to watch for anomalies similar to the limb deformation anomaly observed photographically by [4], where, at third contact, a concave deformation as great as 2.2 arc-seconds was observed beginning 97 seconds before third contact.

Circumstances were similar for the TRACE satellite, which observed the transit through three of its channels. The satellite provided observations unblurred by the Earth's atmosphere and an excellent opportunity to study the optical effects of the transit produced only by diffraction and the TRACE instrument's Point Spread Function (PSF) [5]. Thus, a total of four wavelengths were available for studying the Mercury Transit and comparing the visibility of, or lack of visibility of, the black drop effect. Images taken near mid-transit are presented in Figure 1.

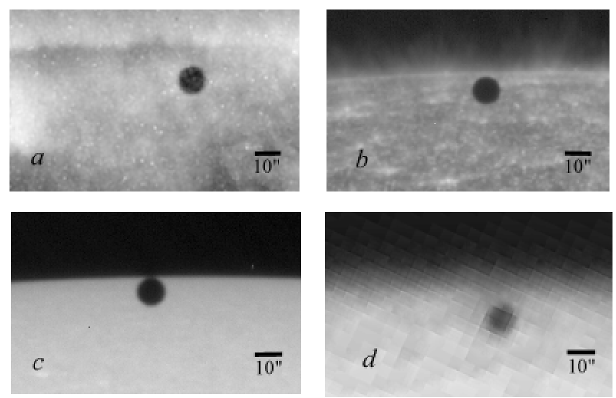

Figure 1. Appearance of Mercury's Disk at four wavelengths. Each image was obtained at the following UT on 15 November 1999: (a) 171A Far UV, 21:45:55, (b.) 1600A UV, 21:40:59, (c.) 5000A White Light, 21:41:38, (d.) 6563A Hydrogen-Alpha (PVSO), 21:44. The PVSO Ha image was rotated to match the others, hence the striations.

Results: The available data provided the basis for a study of the Mercury Transit, specifically the black drop effect, in a number of environments, including hydrogen-alpha with less-than-favorable seeing, and white light in the airless environment of space. Evidence for the gray drop effect was found in two of the four wavelengths through mid transit; these images are shown in Figure 2. The white light channel of

TRACE provided a "near-perfect" environment to study the visibility of the black drop. While the visibility of the effect is greatly reduced due to the lack of blurring effects arising from the absence of an atmosphere, the black and gray drops did not disappear completely. Both were due to diffraction effects and the PSF of the instrument's detector.

Blurring attributed to atmospheric seeing along with defects in a collimating lens in the telescope system caused the gray drop noted in the Hα images. No definitive black drop was found, due to the presence of the chromosphere, rendering the solar limb less than sharp. No black- or gray-drop effects were observed in the TRACE UV and Far-UV channels, due to the presence of limb brightening, and/or a bright "sky" background. In both of these cases, the contrast between limb and sky needed as a starting point to reveal these optical effects were not present, and the same was true (to an extent) for the PVSO Hα images.

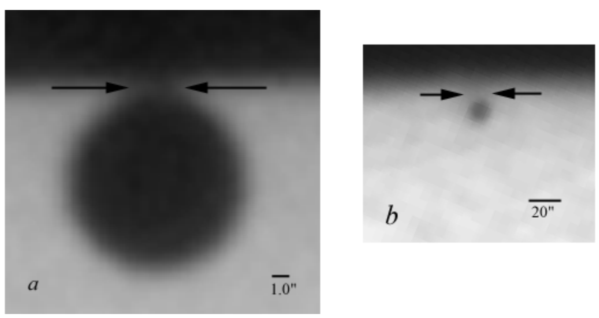

Figure 2. Images highlighting the Gray Drop effect as seen in H-α and WL. Arrows in each of the enlarged images draw attention to the shading of the effect. The scale of each image was optimized for maximum visual contrast of the gray drop.

Conclusions and Discussion: The gray drop effect appears to be related to the black drop in much the same way as the penumbral component of a shadow is related to the umbra. In both cases, the black (or darker) component is caused by a total (or near-total) obscuration of light from a source or region, whether this is reflected light due to the presence of an opaque object, or direct light diffracted or scattered away from an observer. Likewise, the gray part in both cases results from a partial blocking of light from reaching the detector or observer, resulting in a reduced intensity as compared with the surrounding, fully illuminated portion of the object. In the case of central transits, with greater maximum separation of the two limbs, the Gray Drop disappears. This phenomenon, like the Black Drop, can be simulated at any time, with the forefinger and thumb close to the eye. As one slowly separates the two, the Black Drop dissolves into the Gray Drop, which disappears completely with further separation.

There are many observing projects that are worth pursuing involving transits of both Mercury and Venus. Further study of the Gray Drop effect for both transits is strongly encouraged, especially in multiple wavelengths from earth- and space-based platforms. High-resolution studies, both spatially and temporally, of contacts II and III are strongly recommended as well. Such observations, achievable with high-speed CCD video and large solar telescopes equipped with adaptive optics, would show, in unprecedented detail, the evolution of the black drop effect. Such a setup could also improve measurements of small-scale solar features. The Gray Drop and the Black Drop are two manifestations of the same phenomena, with the term "black" and "gray" being somewhat relative given the continuous variation of the intensity of the umbilicus during and just after contact II and just before and during contact III. Further, more detailed studies of these effects may reveal more insight into their visibility in the past and provide a greater understanding into the factors that determine their appearances.

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