What causes the Black Drop Effect?

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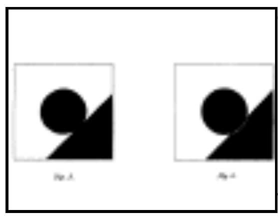

The black drop effect is the apparent smearing of the edge of Venus against the edge of the sun during a transit of Venus. The ligament joining the two objects makes it harder to time the exact second when the edges appear to make contact, thus diminishing the value of using a transit of Venus to measure the size of the solar system as Edmond Halley and others had proposed. While there have been many proposed theories over the years, the true cause of the effect was revealed during a transit of Mercury, which was observed by the TRACE spacecraft. The cause of the black drop effect is limb darkening and point-spread function. Astronomer Jay Pasachoff explains:

Glenn Schneider and I worked out the cause of the black-drop effect using spacecraft observations of the 1999 transit of Mercury across the face of the Sun. Given that our telescope was in space (NASA's Transition Region and Coronal Explorer, known as TRACE) and that Mercury has no atmosphere, the fact that we detected a black-effect meant that an atmosphere was not necessary to cause it.

Our analysis showed that the black-drop effect for Mercury (and, by extension, for Venus, whose atmosphere is too thin in the physical "up" dimension to cause the effect that lasts about a minute after second contact and before third contact) was caused by two effects conjoined. First, each optical system has an inherent blurriness, and the early telescope used for the transits of 1761 and 1769 were blurrier than today's telescopes, even amateur ones. (Technically, that blurriness is known as the "point-spread function"; that simply means how much an image of a point is spread out.)

Second, the Sun is a ball of gas, without a solid edge. So why does the Sun look as though it has a sharp edge? Actually, any gas (think of a foggy day) has a certain "opacity," the percentage (actually an inverse factor of the fundamental number e) by which light is dimmed. At opacity 1, the light is dimmed by 1/e, approximately 1/3; at opacity 2, the light is dimmed by 1/e squared, or approximately 8; at opacity 3, the light is dimmed by 1/3 cubed, or approximately 20, with very little light getting through (only 5%). The angle over which the Sun's gas is transparent to opaque is less than the angle that the eye can resolve (about 1 arc minute). Further, at the extreme edge of the Sun, we are looking through the solar gas at a great angle. Since the opacity totals up at a slant, we reach high opacity at a relatively high level in the solar atmosphere, Since the sun gets cooler as you go outward, that higher level is cooler, and therefore darker.

So now we know that at the extreme edge--and it turns out to be in that last little angle over which we see the black-drop effect--the Sun's gas is relatively dark. Combined with the inherent blurriness of the telescope, that darkness seems to extend from Venus's dark silhouette out to past the solar edge. And that is what we call the black-drop effect.

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www.solarcorona.com
I discuss solar astronomy in:
Leon Golub and Jay M. Pasachoff, Nearest Star: The Surprising Science of Our Sun (Harvard U. Press)
Jay M. Pasachoff, The Complete Idiot's Guide to the Sun (available free online through ***www.williams.edu/sun****)*

More historic images and suggested explanations are at **http://www.transitofvenus.org/history/black-drop**.
See also **http://transitofvenus.nl/wp/observing/black-drop/**.

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