

Early solar eclipse images and tests of relativity

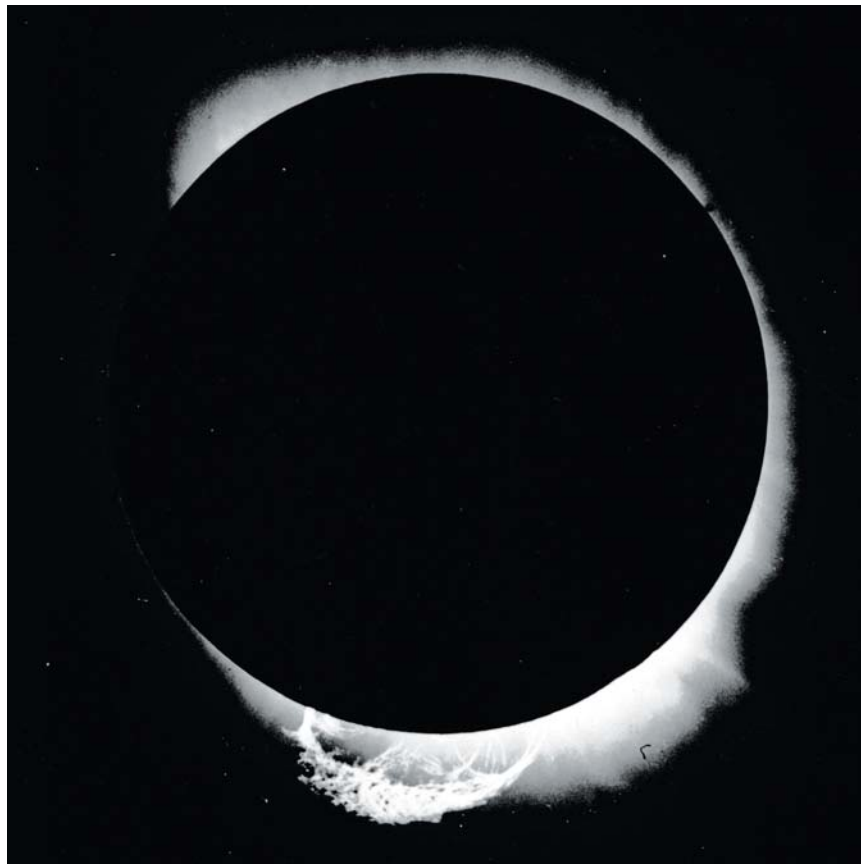
In a letter in the June 2020 issue of *PHYSICS TODAY* (page 12), Robert McAdory posed the question of whether photographic plates taken at earlier solar eclipses might have been of use to the famous British eclipse expeditions of 1919. Those expeditions tested Albert Einstein's prediction that the positions of stars seen near the Sun are affected by the gravitational deflection of light. Deborah Kent's article about the solar eclipse of 1869 (*PHYSICS TODAY*, August 2019, page 46) discussed very early photographic plates of the Sun. Because we have both written about astronomers' testing of Einstein's theory of general relativity, we wanted to expand on that interesting discussion.

Stars almost certainly did not appear on plates taken in 1869, because the wet-plate photography in use then was not very sensitive. Generally, only bright objects like the Sun or Moon appeared on photographs of the sky. Not until the development and popularization of dry-plate photography in the 1880s did stellar photography become possible.

Some star images were obtained during eclipses before 1919, and efforts were made to use those plates to retroactively test Einstein's light-deflection prediction. However, none of the images were clear enough for measuring the small light-deflection effect, essentially because of the following confounding factors.

► **Too few stars were imaged.** Frank Dyson and Charles Davidson, the two astronomers mainly responsible for data analysis of the plates taken in Sobral, Brazil, in 1919, had examined plates from a 1905 eclipse taken with one of the lenses that would be used in 1919. They had found only two stellar images. But they anticipated that the same setup would work in 1919, since the star field was much richer in bright stars. For subsequent eclipses, astronomers took very long exposures in order to image enough stars. The 1922 eclipse exposures, for example, were about one minute long.

► **The field of view was too narrow.** Most eclipse plates are framed tightly on the Sun and its corona and do not include other stars at all. Plates taken in search of



THE GREAT PROMINENCE VISIBLE HERE is from the famous 1919 eclipse. The photo was taken by Arthur Stanley Eddington using an Astrographic lens on the island of Principe. This image was worthless for testing Einstein's light deflection effect. Clouds occluded the stars near the Sun but prevented overexposure of the bright prominence. (Courtesy of Charlie Johnson.)

the nonexistent planet Vulcan were different, but they tended to place the Sun in the corner of a plate, when its being in the center is optimum for the light-deflection experiment.

► **Tracking was inappropriate.** Because the Sun is typically the center of attention during eclipses, astronomers naturally tracked with their telescopes to keep the Sun fixed on the plate. Star images would not be so fixed, so any that appeared would sustain some streaking, which would compromise the measurement of position shifts.

► **No comparison plates were available.** Before 1919 there was no reason to make comparison plates of the same star field

with the same equipment months before or after an eclipse. But without them, any small shift of position would be difficult to notice, let alone measure. In the early 20th century, positions for the vast majority of stars were not accurately known. In fact, Dyson and Davidson were beaver-ing away on the first all-sky photographic survey, the Carte du Ciel project. Even their routine measurements were not necessarily accurate enough to notice Einstein's predicted effect.

American astronomer Heber Curtis (who attempted the Einstein experiment during a 1918 eclipse) did try to analyze plates from the 1900 eclipse, using plates taken in 1919 for comparison. He mea-

sured the positions of six stars visible on the plates, but with the 19-year time lapse, he could not rule out proper motion (the projected motion of the stars in the Milky Way) as an explanation of any shift in position. That would be especially true of the particular star field, since the Hyades stars—in which the Sun is located on 28 and 29 May, the dates of the 1900 and 1919 eclipses—are close to our solar system and exhibit large proper motions.

For his six stars, Curtis did use rectangular coordinates from the Paris zone of the Carte du Ciel project, and he believed they supported his contention that the predicted light-deflection effect was not real. But his data were of poor quality, and William Wallace Campbell, his collaborator and employer at the Lick Observatory, declined to publish the results.

In his letter, McAdory asked whether any astronomers, independent of Einstein, suspected the existence of a shift of star positions near the Sun. One who did believe was Leopold Courvoisier, a Swiss astronomer at the Babelsberg Observatory in Berlin and a colleague of Einstein collaborator Erwin Finlay Freundlich. However, Courvoisier thought the effect extended much farther from the Sun and could be observed without the need for eclipse expeditions. The shift was essentially a seasonal one, he believed, bigger than the one Einstein called for, with the Sun at its center. He was a staunch antirelativist who hated Einstein's theory, and he attributed the effect to the solar system's motion through the ether.

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Eliminating the GRE

A musician would not take a multiple-choice test to join a band. Yet such tests are how many physics and astronomy graduate programs select students. As a result, departments unintentionally limit the talent that enters the field.

With testing centers closed because of the coronavirus and with concerns about the fairness or the lack¹ of online alternatives, physics and astronomy graduate programs have temporarily stopped using entrance exams to make admissions decisions. I suggest that become a permanent change.

Many faculty members and students believe that the physics Graduate Record Examination (GRE) is one of the most important aspects of graduate admissions.² Many programs require a certain score for admission. In theory, a standardized test provides an objective measure for comparing applicants. Everyone takes the same test, so it allows candidates the ability to distinguish themselves by scoring well, or so the argument goes.

But that's not exactly right. With Marcos Caballero, I conducted a study³ of more than 2500 applicants to five physics programs; we found that doing well on the physics GRE did not result in a higher chance of admission than earning high grades did. In fact, nine times as many applicants are likely to be hurt by a poor physics GRE score despite high grades as are likely to benefit from a high score despite low grades. That discrepancy is in addition to the known test disparities based on gender and race: Women and people of color score lower on the GREs than their white male peers. The differences in scores are because of circumstances, not ability.

Take, for example, stereotype threat. Imagine a Black student hearing her peers say people like her are not good at physics or don't belong in it. If she does poorly on the test, her peers might take it as evidence that they were correct. Now, besides worrying about the test, she worries about proving herself. As a result, she cannot concentrate on the test, and she scores worse than students who didn't worry about stereotypes. The test is hardly a fair method of comparing applicants.

Then there is the expense. While it affects all students, it particularly hurts

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