Attempts to prove Einstein`s Theory of Relativity

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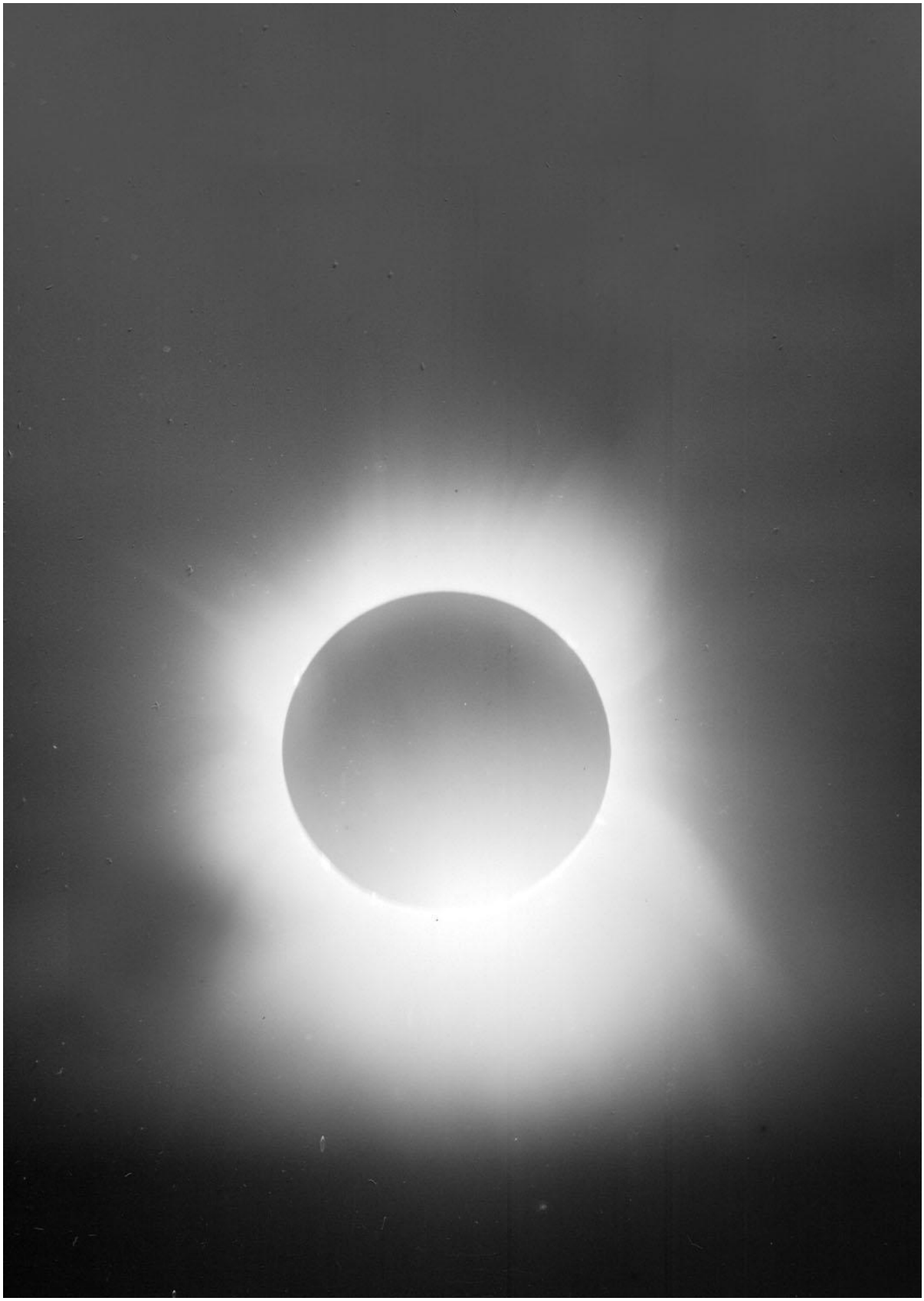
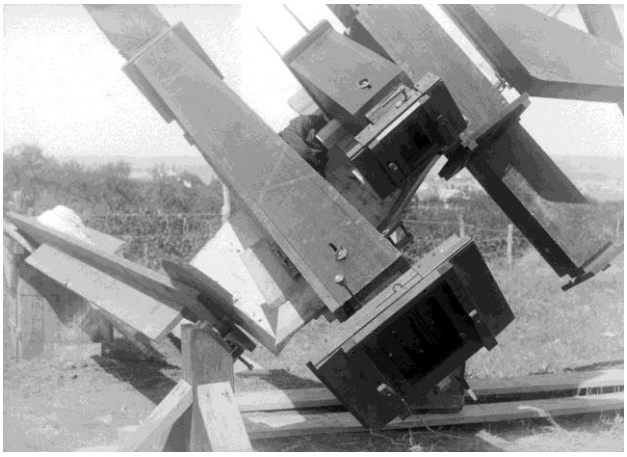
la traducción al inglés del capítulo 20 "Intentos para probar la Teoría de la Relatividad de Einstein".

3er Workshop de Difusión y Enseñanza de la Astronomía



Total Solar Eclipse photograph taken on February 3rd, 1916, by Enrique Chaudet in Tucacas, Venezuela (Archive of Plates. OAC Library)

Attempts to prove Einstein`s Theory of Relativity



Photographic camera, designed and built in Cordoba National Observatory for the observation of the Total Solar Eclipse in 1914 (Archive of Plates. OAC Library)

A few years before Charles D. Perrine was appointed Director of the Argentine National Observatory, Einstein had formulated his famous Theory of Special Relativity. This revolutionary and controversial proposal, which questioned the authority of Newton´s well-established theory, produced an intense debate in the scientific world, generating adhesions and rejections.

In the years following the formulation of the theory, the urgent need for its experimental confirmation was raised. To such end, Einstein suggested to carry out an astronomical observation to prove the discrepancy between his predictions and that of the Newtonian theory on the deflection of light due to gravity.

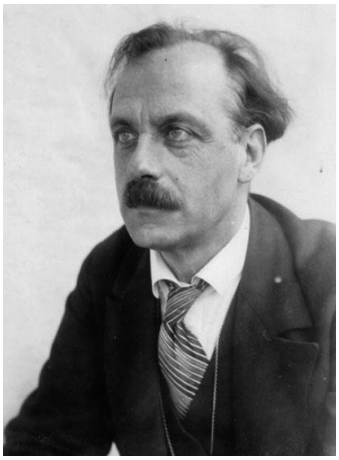
Both the English Henry Cavendish at the end of the 18th century and the German physicist Johann von Soldner at the beginning of the next, calculated, from Newtonian physics, the deflection of light caused by gravitational action. According to the new theory, taking into account the space curvature, the calculated value turned out to be twice the value based on the classical theory.

Einstein's idea, apparently simple, consisted in measuring the change in the position of stars near the solar limb, an object massive enough to make the slight effect measurable. This measurement was only possible during a total eclipse, at which time the light coming from the Sun would not impede observation.

A totally eclipsed photograph of the Sun had to be taken, in which a good number of background stars could be observed, to later compare it with another of the same sky area obtained during the night, a few months before the eclipse. The exact measurement of the stellar positions in both plates would allow to compare them and obtain the deflection of a light ray grazing the sun. This value was initially calculated by Einstein to be 0.87 arcseconds, but later corrected taking it to 1.75 arcseconds. These are very small angles as a second of arc corresponds approximately to 1,800th part of the apparent diameter of the Sun or the Moon seen in the sky.

The conditions that had to be met were numerous. The eclipse would have to occur in a region of the sky with plenty of bright stars; besides, it would have to be long lasting so that a good number of exposures could be obtained and occur high over the horizon to minimize the effects of atmospheric refraction.

Erwin Freundich



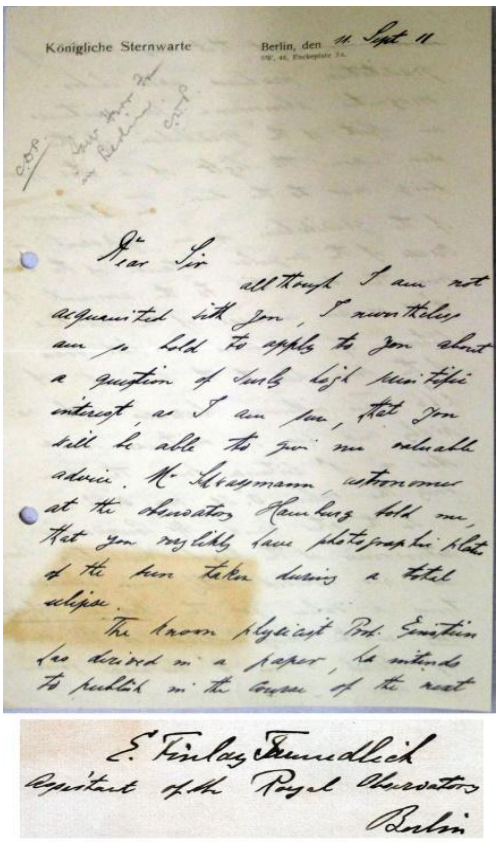
Einstein made young Dr. Erwin Freundlich [1], from the Observatory of Berlin, take an interest in helping him carry out the work. As expected, Freundlich initially tried to use photographs of previous solar eclipses; therefore, he contacted different observatories.

The proposal

As may be recalled, on September 29, 1911, Dr. Perrine had departed from Buenos Aires to Europe on the R.M.S. "Asturias" to attend the meeting of the Carte du Ciel Committee in Paris, which was held in October that year.

From the City of Light, he travelled by train to the Imperial Observatory of Pulkovo, located a few kilometres south of Saint Petersburg, with Dr. O. Backlund, Director of this well-known institution, with stopovers in Bonn and Berlin for a few hours. During the latter, he was contacted by Leopold Courvoisier and Erwin Freundlich, who updated him about the attempts to prove Einstein's theory.

Freundlich asked Perrine if it would be possible to use the photographs that he had taken during the expeditions he had made while he worked for Lick Observatory. The Director dismissed this possibility since the Sun was not located in the centre of the plates, the field was reduced, and the exposures were short, which implied scarce recorded stars.



Königliche Sternwarte

Berlin, den 11. Sept. 11

Dear Sir

although I am not acquainted with you, I nevertheless am so bold to apply to you about a question of such high scientific interest, as I am sure, that you will be able to give me valuable advice. Mr. Hartmann, astronomer at the observatory Hamburg told me, that you possibly have photographic plates of the sun taken during a total eclipse.

The known physicist Prof. Einstein has devised in a paper, he intends to publish in the course of the next

E. Finlay Freundlich
Assistant of the Royal Observatory
Berlin

On the previous September 11, Freundlich had written to Perrine raising that query but the letter arrived when the Director had already departed. The missive was only replied by Dr. ***Sabastian Albercht*** on October 6.

Despite what had been indicated by Perrine, the German astronomer requested the photographs from W. W. Campbell, Director of Lick Observatory and former Perrine's boss, and examined them without any positive results, as had been anticipated.

Letter from Freundlich to Perrine, 9/11/1911, preserved at the Museum of the Astronomical Observatory of the National University of Córdoba, Argentina.

[1] Erwin Finlay Freundlich was born on May 29, 1885 in Biebrich and died on July 24, 1964 in Wiesbaden, Germany. He graduated from the University of Göttingen in 1910, a few years before the above-mentioned events. He started out in the Observatory of Berlin.

As this attempt failed, at the beginning of 1912 Freundlich sent a new letter to Perrine seeking cooperation to make appropriate observations during the eclipse that would occur on October 10 that year in Brazil, a proposal which was immediately accepted. The communication between both men of science would last long[2].

Perrine and the study of solar eclipses

Dr. Perrine had studied numerous total eclipses in Georgia, Spain and Flint Island, among others, since the mid-1890s and had been in charge of the expedition carried out by the Lick Observatory to Sumatra to study the eclipse in 1901. In 1894, he also observed the transit of Mercury in front of the Sun. Therefore, he was an experienced observer of these phenomena.

The attempt to detect a planet in Mercury's inner orbit was one of the aims of these observations, which were part of the study of the anomalies found in its orbit.

Like all the planets of the Solar System, Mercury moves around the Sun describing an ellipse. Consequently, its distance to the central star varies between a maximum and a minimum, this closest point being called perihelion.

The gravitational disturbances caused by the other planets of the system cause the position of Mercury's perihelion to change, moving around the Sun in a period of several thousand years.

Around the middle of the 19th century, the French mathematician Urbain Jean Joseph Le Verrier made the calculations of the displacement of Mercury's perihelion and proved that the resulting values differed from those observed by 43 arcseconds per century. Despite being small, that difference showed an inconsistency.

Le Verrier then formulated the hypothesis that there existed a planet situated between Mercury and the Sun, whose gravity would account for the discrepancy. Its possible orbit and mass were calculated, estimating that its diameter should have been roughly one quarter of Mercury's.

A few years earlier, Le Verrier had predicted the existence of a planet beyond Uranus from the irregularities of its orbit. Based on his calculations, the German astronomer Johann Gottfried Galle found it in September 1846. The discovery of Neptune was a major breakthrough that brought the French mathematician fame and boosted even more confidence on the gravitational theory[3].

Given these facts, the possibility of the existence of this planet was considered very seriously, to such an extent that it was given a name: Vulcan.

Since then, it had been actively searched for. Due to its closeness to the Sun, which hindered direct observation, there had been attempts to detect it by observing the planet's transit in front of the Sun or during the total eclipses.

The apparent discovery was announced on several occasions. One of them was in 1860, in Volume 131 (page 88) of *The Astronomical Journal*, where its editor, Dr. Gould, communicated the observation of a transit that had been made by the French astronomer Lescarbault in 1858. He was

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[2] Perrine Charles D. 1923, *Contribution to the history of attempts to test the theory of the relativity by means of astronomical observations*, Astronomische Nachrichten, 219, pp. 281-284.

[3] As mentioned in another chapter, Benjamin Gould was in Europe at this historical moment. Being a friend of Galle's, the future director of the National Observatory wrote about the discovery and the dispute over it between Le Verrier and John Adams, in the Smithsonian Report, 1859, p. 56, 8th, "Report on the history of the discovery of Neptune."

visited by LeVerrier himself, who confirmed the possibility of the finding. The studies carried out by Perrine led to the publication of four articles in which negative results of the Vulcan search were presented. The anomaly was later explained using the theory of relativity[4].

For the Director of the observatory, the solar eclipses were a subjugating celestial phenomenon, as expressed in his words:

> *"A total eclipse of the Sun, seen in a clean sky and especially from a height, is a phenomenon that thrills the observer. The gradual but inexorable decline of the light of our King of the Day, its utter helplessness to stop the march of the great Dragon of Darkness, its useless efforts to avoid the lethargy that overwhelms it and then, at the end, despair; and when only a narrow and biting contour of light, like the jaws of a hellish and livid monster, is left, in a last and eager expire an almost spiritual culmination is announced. And what a culmination! The corona! Hanging between the sky and the Earth, that circle of pearly light reveals a spectacle without equal in the terrestrial experience. "*

The first attempt

Among the research proposals that Dr. Perrine submitted to the Minister, after having taken office at the National Observatory, he included the observation of the total solar eclipse of 1912. In the report of 1910 to the Minister, the director highlighted the importance of studying this event and insisted on it the following year. As this occurred before Dr. Freundlich´s request, the observation to prove Einstein's theory only had to be added to what was being planned.

Dr. Campbell was extremely interested in this undertaking. On March 13, 1912, he sent a letter to Perrine commenting on Freundlich's work. Faced with the impossibility of sending an expedition himself, he offered to the National Observatory the lenses used by the Lick Observatory in the search for Vulcan. They arrived in Córdoba directly from the United States in August 1912, while two other lenses of 345.5 centimetres (11 feet and 4 inches) of focal distance were sent with Professor William Hussey, who was the director of the Observatory of La Plata at that time[5].

Cristina, state of Mina Gerais, Brazil. To the right at the church back side, it is the big photographic camera (1912) (Archive of Plates. OAC Library)

[4] It was Dr. Freundlich who demonstrated this in 1913, being at Berlin Observatory, at the request of Albert Einstein.

[5] William Joseph Hussey (1862, Ohio, USA - 1926, London, England). He was an observational astronomer, director of the Observatories of Detroit and Michigan. He worked at the Lick Observatory between 1896 and 1905 with Aitken, with whom he discovered more than a thousand double stars. At that time he also worked with Perrine on comet 1896d. He was director of the Observatory of La Plata between 1911 and 1915, a period in which the observatory began its collaboration in international projects and edited the third series of the Publications of the Astronomical Observatory. He returned to his homeland in 1915 due to his wife's ill health.

James Mulvey and Robert Winter, Brasil (Caras y Caretas, 1912)

For this occasion, several instruments were prepared in Córdoba. They were designed and manufactured by James Oliver Mulvey, mechanic, and were made completely of wood so that they would be more stable than the metallic ones considering the rapid changes of temperature they would be exposed to during the observation. These devices were similar to those used in the expeditions of the Lick Observatory, in which Perrine had participated.

The narrow strip of land from which the Sun would be observed completely covered stretched from west to east in South America. It would begin in Ecuador near Quito, cross only northern Peru and the entire Brazilian territory, and finally leave the Pacific between Sao Paulo and Rio de Janeiro. In the rest of the continent, it would be seen as partial. In this rare phenomenon, the time in which the totality occurs is very small, not exceeding 5 or 6 minutes; in this case, it was less than 2 minutes, which limited the observations that could be made.

The expedition sent by the Observatory was widely announced in the local press and in Buenos Aires, with data of the eclipse, highlighting its importance and the request from Berlin Observatory.

The committee, composed of the Director, Third Astronomer Enrique Chaudet, mechanic Mulvey and photographer Robert Winter, departed from Buenos Aires on September 13, 1912, on the Aragon ship.

Six days later they were in Rio de Janeiro. Perrine and his assistants arrival was registered by the local press. As with the other expeditions that had arrived there, they were welcomed by members of the local Observatory, who handled the baggage by taking it through Customs without any delay. All the scientists were very nicely looked after by the local authorities and accommodated in the best hotels, especially the Argentinian Committee in Hotel Avenida.

The instruments and other baggage were sent by railway for free and with the highest priority. Perrine praised the organization.

Several expeditions were organized by different institutes. The Brazilians established stations, including a meteorological one, in different parts of their territory. The largest Brazilian committee, two English[6] and a French one were located in Passa Quatro, Muniera do Sul. The committee from the Observatory of La Plata and the one from Córdoba, which were numerous, were established in Alfeira, the most distant place from the coast. The National Observatory of Chile, whose director was F. W. Ristenpart[7], made some observations with a selenium photometer, and the meteorological office of that country was in charge of the physical measurements of the air.

[6] Arthur Eddington, who could later successfully prove the effect foreseen by Einstein's theory, took part in one of them.

[7] On his way back to Chile, Ristenpart stopped in Buenos Aires. On October 29, 1912 he delivered a lecture at the Argentine Scientific Society and dazzled the audience with "bright" projections of sharp photographs. On that occasion, a particular event occurred. The chronicler of the newspaper La Tarde criticized the presentation made by the "wise man", pointing out that the measurements he had taken with the "selenium sheet" could not be precise due to the presence of clouds, and called him "blunderer". This fact deserved the publication of several articles. The writer said that he had been supported by "the directors of the national observatories", while the Ministry of the Interior requested the published texts. On November 12 Perrine commented: "This man's statement on this eclipse issue is inexplicable because it is incorrect at its base" (referring to the German astronomer). In the same article, it was stated that on March 12, 1918, the Chilean government had cancelled Ristenpart's contract, as a result of

The ONA delegation consisted of Charles D. Perrine as manager and the photographer Roberto Winter, the mechanic James O. Mulvey and one assistant astronomer, Enrique Chaudet (detail on the left). (Archive of Plates. OAC Library)

The Carnegie Institution of Washington worked in magnetic measurements along with this expedition. However, the Argentinian expedition was the only one concerned with proving the relativist theory.

The group from the National Observatory was the first to depart. They settled in the backyard of a church, on the outskirts of the small town of Cristina, state of Minas Gerais, located about 200 kilometres northeast of San Pablo and about 1,000 meters above sea level. From this position, the mountains in the surroundings as well as the tower of the main church could be seen.

The instruments were placed in three groups. Two of these groups, supported by mounts with polar axes, consisted of several square box cameras. The third group was a large photographic telescope. The two 7.5 centimetre diameter and 335.3 focal length lenses were installed next to each other with a common black cloth diaphragm. The photographs intended to prove Einstein's theory would be made with these instruments.

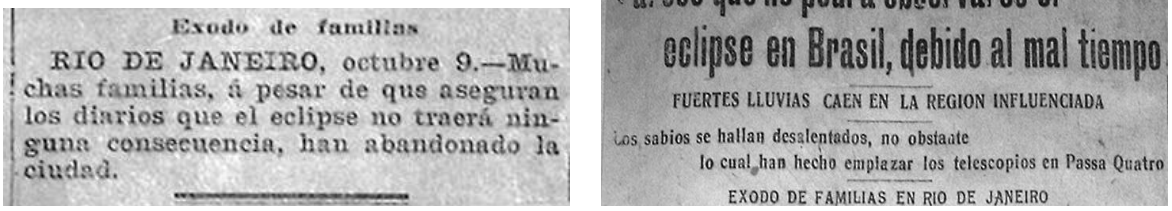
Other similar cameras were aimed at studying the polarized light of the corona. Two prisms were also included, mounted on two 5-inch diameter lenses (12.5 centimetres) with focal lengths of 183 and 70 cm, designed to obtain spectra from the photosphere and the solar corona. They would, thus, determine their structure and composition. Images would also be taken to establish the total light received from the corona from the different parts of the spectrum.

The large 40-foot focal length telescope, just over 12 meters and 12.5 centimetres in diameter, was made up of a square tube of canvas. The end with the plate holder was covered by a small tent. Given its huge size, it was supported by a wooden tower located against one of the walls. This instrument would be used to take photographs of the corona. The moments of contact would be determined visually.

Everything was ready. However, the weather played against it. A couple of days before Thursday, October 10, it had been cloudy and rainy, a condition that would remain for the next four days, frustrating this expedition as well as the others that had already been organized[8].

political problems, his bad relationship with the Observatory staff and the criticisms of his management voiced by the Chilean press. On the morning of April 9 of that year, Friedrich Wilhelm Ristenpart killed himself with a gunshot at his house in Quinta Normal.

[8] Not only were scientific studies frustrated. The president of Brazil, Mariscal Hermes da Fonseca, the Minister of Foreign Affairs, the English and American ambassadors, and their wives, were ready to observe the phenomenon in Passa Quatro.



Exodo de familias

RIO DE JANEIRO, octubre 9.—Muchas familias, á pesar de que aseguran los diarios que el eclipse no traerá ninguna consecuencia, han abandonado la ciudad.

Parece que no podrá observarse el eclipse en Brasil, debido al mal tiempo

FUERTES LLUVIAS CAEN EN LA REGION INFLUENCIADA

Los sabios se hallan desalentados, no obstante lo cual han hecho emplazar los telescopios en Passa Quatro

EXODO DE FAMILIAS EN RIO DE JANEIRO

(La Argentina, 9/10/1912)

The storm that had been slashing the area extended from the north of Brazil in Bahia to Argentina. The sun barely showed up for a few minutes when the eclipse was still partial, at 8.35; then it remained covered until 10, just when the phenomenon was over.

Campbell received a laconic telegram from E. C. Pickering: *"Perrine's wire from Brazil, rain."*

This was the first direct attempt to prove the then new theory of relativity by means of astronomical observations. It took place seven years before the successful expedition of 1919[9], which highlights its importance.

In Córdoba the eclipse was observed by Cherster W. Hawkins, who was in charge of the Observatory, and F. P. Symonds. They could obtain photographs although it was rather cloudy then.

The frustrated observers returned to Argentina on the ship called "Asturias". They arrived in Buenos Aires on October 21, together with the scientists from the Observatory of La Plata. In November of that year, the Director submitted a report on what had been done, to the Minister of the Interior. Perrine was not discouraged, though, and planned the next attempt for 1914.

The second expedition

The next opportunity would be on August 21, 1914, in the remote Ukraine. The path of totality would begin in the Arctic Circle in northern America, entering European territory through Norway, the Baltic countries, crossing Russia, the Middle East and barely touching India. The place that had been chosen by the National Observatory for the establishment of the committee was Feodosiya[10], located on the Crimean peninsula on the shores of the Black Sea, only 20 kilometres from the central line of totality. This site had been chosen because it was most likely that the weather would be clear there and because, during the event, the Sun would be at the highest possible height above the horizon.

However, it would be a costly expedition, plagued by difficulties of all kinds.

The instruments that were prepared for this expedition were the same as those taken to Cristina. As Dr. Freundlich could go to this eclipse with the expedition that had been organized by Berlin Observatory, he made instruments similar to those taken to Córdoba but in metal, since the German scientist doubted the stability of the wooden ones. However, Perrine, in various publications, insisted on the suitability of wooden instruments, based on his extensive experience.

[9] Jean Einsenstaedt and Antonio Augusto Passos Videira described all the attempts that had been made until the successful one in 1919 in the article "The South American Demonstration of Einstein's Theories" published in *Revista Ciencia Hoy*, 8, 44, in 1998.

[10] Founded in the 6th century BC, Feodosiya, Feodosia or Theodosia is today a city with more than 80,000 inhabitants and is located in the autonomous region of Crimea, Ukraine.

Set of instruments of the ONA, Feodosia, 1914. (Archive of Plates. OAC Library)

Despite the economic difficulties that almost ruined the project, the expedition of the Observatory, composed this time only by the Director and Mulvey, departed from Córdoba to Europe on June 16, embarking with destination to Genoa on the 20th. Then, the events that would trigger the First World War were already underway.

Perrine narrated the following about the initial stretch of the trip:

> *"Because of the headwinds, the steamer was delayed two days between Buenos Aires and Gibraltar. We passed near the Toulen gulf where several French warships were rehearsing ... We did not have the slightest suspicion then, or after we received through the wireless telegraph the news of the assassination of the crown prince of Austria, which would result in a European conflagration (the largest that history had recorded), and that these same ships would be fighting within a month"* (Los Principios, 11/10/1914)

Given the slowness of the ships that made the crossing between Genoa and Odessa, the instruments were sent by sea, while the observers made the journey by train, transporting the optical parts with them. On July 15, they went past Vienna, where large checkpoints were carried out. They continued the journey through Galicia, Krakow, Przemsyl and Lamber, among others, with the railway line being guarded in its entirety. In some of these areas, battles were later fought. Upon entering Russia, after a couple of hours of passport and baggage control, where *"All books and newspapers are very carefully examined"* according to the Director, they were able to eat at the station, changing trains before leaving. In the large and comfortable Russian sleepers they crossed the steppe (in which the Cossacks practiced), until they reached Odessa. They stayed in this city some days, during which they received the instruments and arranged their shipment to the final destination, besides visiting the Argentine Consul and the headquarters of the Observatory of the city. In the meantime, the commissions of the Solar Observatories of Cambridge and Berlin arrived.

Finally, they set out on a steamer from the Russian Shipping Company to Feodosiya, where they arrived after a two-day trip on July 25. They then moved to a point located 3 kilometres from the city, which was the site that the director of the National Observatory of Russia had reserved for the Argentine expedition, the same that the Russians would occupy, thus facilitating the issues related to language.

On July 28, the Austro-Hungarian Empire invaded Serbia, so Russia began to mobilize its troops. The German expeditions were forced to abandon their instruments and leave the country. Since they failed to do so before the declaration of war, they were taken prisoners and taken to

concentration camps. Dr. Freundlich was able to leave on time and return to Berlin[11]. Most of the English and French had to return to their countries to join the army. Only seven of the 27 expeditions were finally able to make the observations. Argentina was the only one in the southern hemisphere. On this occasion, W. W. Campbell organized a delegation that settled down without setbacks in Brovary in Crimea, as well as another English one.

The instruments only arrived on August 10. By then, the foundations had already been made[12]. After a great storm that delayed the assembly of the instruments, they could be mounted in a few hours, because they had already been prepared in Córdoba.

Some residents and officers of an English vessel without authorization to leave volunteered to help during the event. The exercises began three days before the eclipse, so as not to leave anything to chance.

On Friday, August 21, the sky dawned completely clear, but towards noon clouds began to appear, which partially covered the Sun during the entire duration of the phenomenon, whose centrality occurred at approximately 3:20 p.m. local time. Between the clouds, a few images of little use were obtained. However, these were the first ones taken especially for the purpose of proving the theory of relativity. The return of the expeditions was extremely complicated due to the war. The North American expedition had to store the instruments in Pulkovo Observatory[13]. On the other hand, Argentina lost the "eclipse fund" because of the impossibility of getting the gold, which amounted to one and a half salary of the director, who had to afford such expense on his own. This amount was never reimbursed, despite the many claims that were made.

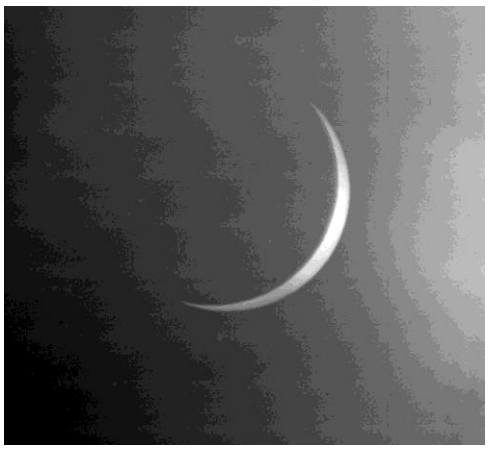
Because all the trains were used for the transportation of troops, Perrine and Mulvey could only depart on August 25. Without being certain of which way to take, they had to do part of the journey to Moscow and Saint Petersburg, for more than two days, in the corridors of the wagons.

Committee which helps with the “Observatorio Nacional Argentino” expedition in 1914 and some visitors. Standing, fourth from the left, James Mulvey; seated, second from the right, Charles D. Perrine (Archive of Plates. OAC Library)

11 In the letter sent by Perrine to G. Hale on 05/31/1915, he pointed out that Dr. Freundlich was lucky to leave Russia and arrive in Berlin. The war greatly hindered the attempts of the German astronomer to prove Einstein's theory.

12 Given the delay and the possibility that they would not arrive at their destination due to the war, Perrine and Mulvey began to elaborate some simple instruments.

13 As a consequence, they could not be used in the attempts made by the Lick Observatory during the eclipse of June 8, 1918, whose path of totality passed close to it. The clouds again prevented getting good plates. Some copies of them were later sent to Perrine for his examination and are today at the Observatory of Córdoba.



One of the Sun, in the middle of clouds, photographs, obtained by the "Observatorio Nacional Argentino" expedition in 1914 (Archive of Plates. OAC Library)

After having spent several days in Pulkovo with Dr. Backlund of the National Observatory, they left for Sweden. By rail they arrived in Rauma in the Gulf of Bothnia and then travelled to Stockholm by steam boat. Throughout the journey they suffered numerous arrests, delays and periodic document reviews. From Stockholm, again by train, they arrived in Bergen on the west coast of Norway and from there they began the dangerous journey to England, along with a lot of travellers who were desperate to get refuge. Finally, the journey to the Río de La Plata was made without any incidents.

The Eclipse in Venezuela

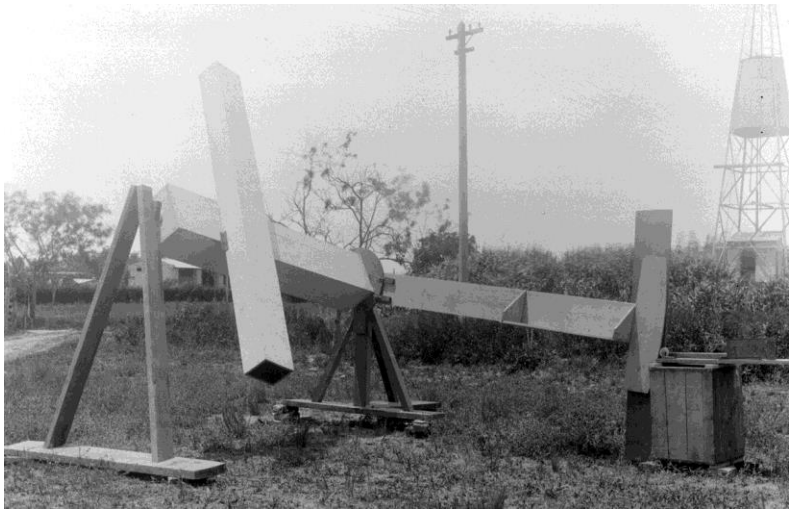
The Director kept in touch with Erwin Freundlich and they met in Theodesia. On that occasion the German astronomer told him about the great difficulties he was having at Berlin Observatory because of following new lines of work. He even stated his intention to leave Germany in search of a place where he would have greater freedom to investigate. Already in Córdoba, Perrine received a letter from Freundlich in which he asked him about the possibility of observing Jupiter, as an alternative to prove Einstein's theory. Since the 1.5 metre reflector that would be installed in Bosque Alegre was far from being completed, on May 31, 1915, the Director wrote to George Ellery Hale, to ask if it was feasible for Freundlich to make such observations at Wilson Mount Observatory and thus migrate to the US. He said that Freundlich's mother was English and qualified him as a bright, very sociable and hardworking person. Hale's answer was an outright refusal. He explained that it was impossible to hire investigators directly or indirectly related to the war; he added that he had already lost two members of his staff (A. Kohlschiitter and Capon), so the initiative was truncated[14].

The next expedition, which would become the last during Perrine's administration, was organized for the eclipse on February 3, 1916. Its path of totality started in the Pacific Ocean, crossed the northern part of South America, Colombia and Venezuela, and ended in the Atlantic.

In November, 1915 the authorization of the Ministry was received. Due to the shortage of funds, the only person in charge of the expedition was E. Chaudet, who left to go to Venezuela on December 2 of that year with the intention of settling in Tucacas, a port city of the state of Falcón, located on the western coast of the Gulf Sad in the Caribbean Sea. The lone traveller arrived in Caracas on January 14 of the following year, where he met the Argentinian ambassador Manuel Malbrán, who contacted him with the Civil Chief General Julio J. Farias, in charge of facilitating the stay. Some days later, Chaudet arrived at destination after overcoming great difficulties to obtain transportation from Barbados.

Tucacas was a small town of no more than 3,000 inhabitants, many of whom resided temporarily as they were in a French mining company. The main activity was the port. They

[14] Freundlich would soon leave Germany in the 1930s. The biography of this important German astronomer can be found in: Erwin Finlay-Freundlich (obituary) Quarterly Journal of the Royal Astronomical Society, Vol. 6, p.82, 1965 (in English) and Erwin Finlay-Freundlich Astronomische Nachrichten, 288, No. 5/6, 1965 (in German), both available on the Web.



Instruments built in Córdoba for testing of performance, previous to Venezuela mission (Archive of Plates. OAC Library)

shipped natural products that arrived from the south by rail from Barquisimeto. Chaudet highlighted the lack of the most basic and transport supplies, including carriages and horses.

In spite of these difficulties and the frequent rains, in a week Chaudet managed to assemble the instruments with very little help in the yard of the house that served as office and accommodation for the employees of the government. The collaboration came from government employees and people from the area who served as assistants. Such help was easily obtained thanks to the support of the residents and the Venezuelan Government.

As on previous occasions, the observations were planned by Perrine, although then they had to be slightly changed.

This time the equipment was much more limited than that used in the previous expeditions, given the serious economic restrictions resulting from the crisis caused by the war. For the same reasons, many observatories could not send their committees to cover the phenomenon, such as the case of Lick, whose director Campbell, very interested in the study of the theory of relativity, wished the Argentine expedition could carry out this task. However, among the missing instruments was the specific one for the proof.

Besides the expedition from Córdoba, there was a six-member Venezuelan expedition led by Dr. Luis Ugüeto, director of the Astronomical and Meteorological Observatory, which was also located in Tucacas, together with the Argentine committee.

The main missing instrument was the large 12-metre camera, as well as the elements for observing the solar corona with polarized light.

The devices were mounted on polar axes; one large and the other smaller. The major axis allowed the movement of an 11-foot focal length camera used for obtaining photographs of the corona in order to study its structure. In addition, it had a short focal length camera with a prism, which would obtain the "lightning" (flash) and corona spectra. There was a photometer designed to determine the total light coming from the corona, too. On the other polar axis, a 6-foot camera was placed, with which the corona would be photographed on a smaller scale, in order to have a wider view of it. There was also a second 6-foot focal length camera, with a large prism, with the same lenses as the smaller one. Finally, there was a slit spectrograph to record the general spectrum. The contact times would be determined visually.

A sextant with an artificial horizon was employed to determine the geographical position and time. However, its use was limited, since the information provided by the Venezuelan expedition was used, as well as the data on temperature and atmospheric pressure. The Observatory of La Plata provided a chronometer and barometer for this event.

Enrique Chaudet with the instruments in Tucacas (1916) (Archive of Plates. OAC Library)

During the morning of Thursday, February 3, it rained heavily, but at the time of the eclipse the sky was covered by light clouds.

Chaudet was in charge of the largest camera with a prism, while the rest of the instruments were looked after by locals[15]. All the plate holders were ready. At the signal, the person in charge of the chronometer began to count the seconds aloud and everybody started carrying out their work as had previously been rehearsed.

Through the thin cloud veil, 28 exposures of the corona, its spectrum and that of the reversing layer were taken during the two and a half minutes that the eclipse lasted.

The development of the plates took four days and it was necessary to overcome various difficulties, including the need for ice, which was brought by rail from Arca, several hours away.

Perrine described the corona (which extended slightly more than a solar diameter) as typical of a period between maximum and minimum spots and similar to the eclipse of 1898. Chaudet highlighted the presence of numerous protuberances. The contact times and duration were also verified, which resulted in 2 minutes and 30 seconds against the 2 minutes 32 seconds calculated.

In the newspaper *Los Principios*, on June 25, 1916, a note was published with an extensive and detailed account of the expedition carried out by Chaudet. The first results were published that same year in the specialized magazines "Publications of the Astronomical Society of the Pacific", "Monthly Notices of the Royal Astronomical Society" and "The Observatory", all with the authorship of Perrine. In these articles and in the Report to the Minister of 1916 it was pointed out that definitive studies would be published in a specific volume. However, this has never happened.

The missed opportunity

In a letter that Perrine sent to the director of the National Observatory of Rio de Janeiro, Enrique Morize on April 20, 1919, he highlighted his intention to send an expedition to observe the total eclipse that would take place on May 29, 1919, and would be visible in the territory of Brazil, with an exceptional duration of almost seven minutes. He also asked Morize about the best location for the observation. Morize answered the letter on May 8, indicating that he was collecting the necessary information. On June 1, the director of the Observatory in Córdoba wrote to his colleague again, asking him to keep him informed about the advances in the subject and offering all the necessary help, which showed his special interest for the upcoming event.

[15] The 11-foot camera was in charge of Mr. F. Josué Leidenz (Secretary General of the Interior), who got 6 exposures (1, 2, 20, 10, 5 and 2 seconds). Mr. Carlos Cubillán Loretoin worked with the prismatic camera, obtaining 6 exposures (the first and last ones for the lightning spectrum and the others for the corona). The photometer was handled by the priest Luis M. Sucre, while the 6-foot camera was used by Mr. P. López Delgado (Revenue Manager), who obtained 5 exposures (2, 12, 10, 5 and 2 seconds). The slit spectrograph was handled by Mr. Pedro José Obediente, who made an exposure with the totality. Ernesto Aret was in charge of the chronometer, and the civil chief, General Julio J. Farías, took notes.

Despite these plans, the expedition was not authorized by the National Government and as a consequence, the Observatory was absent in Brazil.

In this eclipse the climatic conditions were finally adequate to obtain the images that would confirm the prediction of the famous theory of relativity[16].

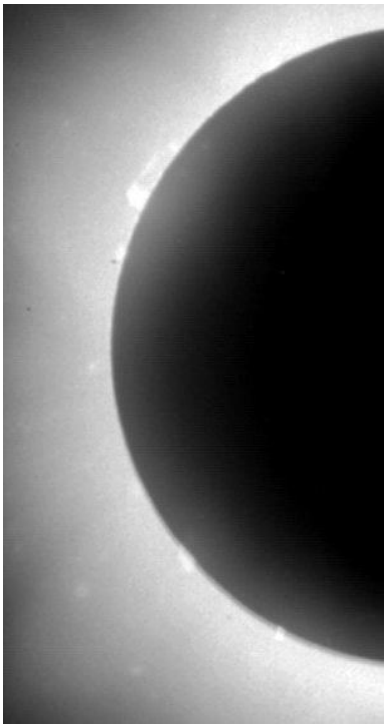
The national authorities may have refused to authorize the expedition for a number of reasons. The great expenses that the Observatory had to afford to carry out the three previous attempts, which failed to obtain good results, surely had a negative impact and represented a problem for the director. By 1919, several objections to his management had begun to appear; in fact, Deputy Ramon Loyarte cited especially the expeditions of Crimea and Venezuela in the criticisms he made to Perrine in 1932. On the other hand, relations between Argentina and Brazil were then not good enough for this type of undertaking[17].

Years later, in 1923, after the theory of relativity had been definitely proved, in an article published in the magazine Astronomische Nachrichten, Perrine claimed that the Argentine National Observatory be recognized as the first to attempt to prove the theory. The clouds prevented the Argentine observatory from getting the glory of this historical event.

After Perrine´s retirement, during the administration of Enrique Gaviola, studies of solar eclipses were carried out, the most notable was the one organized for the eclipse of May 20, 1947, with positive results. Two committees were located in Villa de Soto (province of Córdoba) and in Corrientes, where a film of the phenomenon was obtained.

Dr. Perrine's interest for the study of the Sun continued even after his retirement; from his home on the outskirts of the city of Córdoba, he observed the eclipse of 1947 and published a report.

The study of eclipses at the Argentine National Observatory, later referred to as the Astronomical Observatory of the National University of Córdoba, continued until the 1970s, particularly with those that occurred on November 12, 1966 and January 4, 1973. Dr. Gualterio Mario Iannini, head of the Department of Astrometry of the Observatory of Córdoba, made calculations on the most important solar eclipses. This task was carried out at least between the 1960s and 1980s, and the results were published by the institution.



Photograph obtained on February 3rd., 1916
(Archive of Plates. OAC Library)

16 Anyway, the results were not as satisfactory as expected, so proving the theory continued to be an objective of the expeditions, as happened with the 1922 eclipse of Australia and the one of 1929 seen in Sumatra and the Philippines, in which Dr. Freundlich was present.

17 Raquel dos Santos Oliveira carried out an analysis in this sense, stating that the deputy focused between the position of Brazil favorable to Pan-Americanism and that of Argentina to Latin Americanism.