This photograph, which dates from the 1930s, shows construction work for the University of Texas's McDonald Observatory on Mount Locke. The skeletal dome shown here eventually housed an eighty-two-inch reflecting telescope, which was officially dedicated on May 5, 1939, and was at that time the second largest telescope in the world. A picture of the telescope appears on page 519 of this issue. The construction of the McDonald Observatory brought to a close the early period of Texas astronomy described in the following article and ushered in the state's modern astronomical era. *Courtesy McDonald Observatory, University of Texas at Austin.*

Early Astronomy in Texas

David S. Evans and Donald W. Olson*

Modern Texans are quite used to the idea that the state is home to important activities in astronomy, whether at observatories such as McDonald in West Texas, or space science at the Lyndon B. Johnson Space Center near Houston, or in academia at Austin, Houston, and elsewhere. But it was not always so. Indeed, apart from Harvard, which had some astronomy since its foundation, there was essentially no astronomy of any significance in the United States until well into the nineteenth century.

As far as human effort is concerned, the same is true of Texas, and it is only recently that any paid professional jobs in academia have carried the explicit title of astronomer. All over the civilized world, however, there always have been amateur astronomers, that is, unpaid workers who have pursued the science out of intellectual curiosity and devotion. In fact, a large proportion of the best-known names in astronomy have begun as amateurs, and not all of them succeeded in obtaining later paid employment. The best of them produced work rivaling, especially in the early days when equipment was still uncomplicated, the efforts of the small band of professionals, whom they often outnumbered. The fields of activities especially suited to amateur effort included observation of phenomena, such as eclipses, and more frequently the timing of

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occultations, events when the Moon passed in front of a star or later revealed it. Such observations were important for the derivation of the lunar "ephemeris," the word describing the formula or calculations from it that permit the prediction of future lunar positions at any time. The word is also used to describe predictions of planetary positions or indeed, also, of the brightness of variable stars.

These last are the happy hunting ground of large numbers of amateurs who report their magnitudes to a central organization in Cambridge, Massachusetts—the American Association of Variable Star Observers, founded three quarters of a century ago. There are dozens of different kinds of variable stars, some of which repeat with clockwork regularity in minutes or months, others far less regularly, and some with explosive irregularity in violent outbursts changing brightness manyfold in times of seconds or days according to type. Chief among the latter are novae and the rare supernovae, the latter increasing in brightness by tens of thousands of times in a few days before fading slowly over several months.

Astronomy came to Texas with a bang some fifty million years ago when a large meteorite struck the Earth twenty miles south of Fort Stockton and made a crater eight miles across. The crater edges have long since been eroded and the depression filled in, but the central uplift still remains as a prominent isolated hill, the Sierra Madera, just north of the Glass Mountains.[1]

Events such as this present a problem to the chronicler of astronomical history. Meteorites in flight are astronomy; when they land they turn into geology. Even so we must mention a much more recent impact site ten miles southwest of the present site of Odessa, where there is a principal crater ninety feet deep and ten acres in extent. From this, now almost filled with debris, and two smaller craters, numerous meteorite fragments consisting of 91 percent iron and 7 percent nickel have been recovered by geologists.[2]

In 1772, Athanase de Mézières made what is probably the first written reference to meteoritic iron in Texas. On an expedition near the Brazos River, de Mézières visited an Indian village that was

> only a short distance from a mass of metal which the Indians say is hard, thick, heavy, and composed of iron. They venerate it as an extraordinary manifesta-

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[1] K. A. Howard, T. W. Offield, and H. G. Wilshire, "Structure of Sierra Madera, Texas," *Geological Society of America Bulletin,* LXXXIII (Sept., 1972), 2795–2808.

[2] E. H. Sellards, "Meteor Crater at Odessa," in Walter Prescott Webb, H. Bailey Carroll, and Eldon Stephen Branda (eds.), *The Handbook of Texas* (3 vols.; Austin: Texas State Historical Association, 1952, 1976), II, 180.

tion of nature. It is some twenty leagues to the north. I did not have an opportunity to go to examine it, but there is not a person in the village who does not tell of it.

The Indians believed that meteoritic irons had extraordinary curative powers, called them "medicine rocks," and left offerings of beads, arrowheads, and other tokens next to the meteorites.[3]

In 1808, the 1,635-pound meteorite known as the Red River, Texas, iron was visited and described by Indian trader Anthony Glass (ca. 1773–1819). The mass was recovered and brought down the Red River to Natchitoches, Louisiana, in 1810 and was exhibited in several different cities before reaching its current resting place in the Yale University collection in 1835. For many years this Texas iron was the largest meteorite in any collection.[4]

Another meteorite with a colorful history is the 320-pound octahedrite known as the Wichita County iron. In the spring of 1856, Indian agent Robert Simpson Neighbors (1815–1859) had the meteorite brought into Fort Belknap. The iron traveled to San Antonio and then to Austin by the summer of 1859. The meteorite survived the fire that destroyed the Capitol building on November 9, 1881. Recovered from the debris, the meteorite was eventually presented to the University of Texas. John William Mallet (1832–1912), professor of chemistry and physics and chairman of the faculty during the first session (1883–1884) of the University of Texas, published a chemical analysis of this meteorite in 1884. The iron is now displayed in the Texas Memorial Museum at the University of Texas at Austin.[5]

Meteorite discoveries and falls still occur, and, by 1984, a total of 210 meteorites had been catalogued in Texas.[6] Some had even been seen to fall, including one that went into Peña Blanca Spring in 1946 and two that landed in northeast Texas in 1961. A leading authority on Texas meteorites is Oscar E. Monnig of Fort Worth, an enthusiastic amateur

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[3] Herbert E. Bolton (ed.), *Athanase de Mézières and the Louisiana-Texas Frontier, 1768–1780* (2 vols.; Cleveland, Ohio: Arthur H. Clark Co., 1913–1914), I, 296.

[4] "Mass of Malleable Iron," *Bruce's American Mineralogical Journal,* I, No. 2 (1814), 124; B. Silliman, Jr., and T. S. Hunt, "On the Meteoric Iron of Texas and Lockport," *American Journal of Science,* 2nd ser., II (Nov., 1846), 370–376. See also Dan L. Flores, *Journal of an Indian Trader, Anthony Glass and the Texas Trading Frontier, 1790–1810* (College Station: Texas A&M University Press, 1985), for additional early references to the Red River iron.

[5] B. F. Shumard, "Notice of Meteoric Iron from Texas," *Transactions of the Academy of Science of St. Louis,* I, No. 4 (1860), 622–624; J. W. Mallet, "On a Mass of Meteoric Iron from Wichita County, Texas," *American Journal of Science,* 3rd ser., XXVIII (Oct., 1884), 285–288; W. F. Cummins, "The Texas Meteorites," *Transactions of the Texas Academy of Science,* I, No. 1 (1892), 14–18.

[6] A. L. Graham, A. W. R. Bevan, and R. Hutchison, *Catalogue of Meteorites* (Tucson: University of Arizona Press, 1985).

astronomer whose notable collection of meteorites has been donated to Texas Christian University. Several meteorites from the Monnig collection have been loaned to the W. L. Moody Visitors' Center of McDonald Observatory, where they are on display along with a 1,530-pound giant found in 1903 near Balmorhea.[7]

During the 1910 apparition of Halley's Comet, journalists sought out old people who might have witnessed the previous apparition in 1835. In Austin, one elderly black woman, Aunt Lavinia Forehand, recalled seeing the comet, and dated it as "two years after the stars fell."[8] This is a reference to the great Leonid meteor shower of November 13, 1833, possibly a more dramatic spectacle farther east than in Texas, when the sky seemed to be snowing meteors, so numerous were they. Many witnesses were so terrified that they fell to their knees in prayer, but a significant effect of the display was the interest in astronomy it stimulated in various parts of the United States where little or no interest existed previously.

Capt. Abner H. Cook at the Confederate home had no recollection of Halley's Comet, "for I would have you to understand that I am a comparatively young man," but he did have a vivid recollection of the comet seen "just before the war":

> Our family was living up here just back of where the Governor's mansion stands, and the comet shone splendid and beautiful half way between the horizon and the zenith in the northeastern heavens. The tail was long and majestic, and the comet itself like a great red illumination, lighted the Earth more than a full Moon would have done.[9]

Captain Cook was more perceptive than many amateur observers for whom any comet must be Halley's. The comet he observed was probably Comet 1861 II (1861 b), which was bright enough to be easily seen in sunlight by one observer, and which moved through the northern constellations Lynx and Ursa Major.[10] The Earth passed through the tail of this comet, as it did with Halley's in 1910, the tail thus spanning the whole sky for a while. As for old Jack Gray, also at the Confederate Home, he saw the stars fall in Georgia (what a pity not in Alabama), but "I didn't see any comet, and I don't much believe in 'em."[11]

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[7] Virgil E. Barnes, "Meteorites in Texas," in Webb, Carroll, and Branda (eds.), *Handbook of Texas,* II, 180; Oscar E. Monnig, "Meteorites in Texas," ibid., III, 593.

[8] Austin *Statesman,* May 18, 1910.

[9] Ibid.

[10] S. K. Vsekhsvyatskii, *Physical Characteristics of Comets,* trans. from the Russian (Jerusalem: Israel Program for Scientific Translations, 1964), 210–213.

[11] Austin *Statesman,* May 18, 1910.

Before Texas independence there was no astronomically based survey of the territory, and land grants were issued based on prominent landmarks and compass traverses. The honor of being the first professional astronomical observer in Texas probably goes to Thomas Freeman, who led an expedition up the Red River in the summer of 1806. Freeman, assisted by Lt. Enoch Humphreys, used a chronometer, nautical almanac, sextants, and an achromatic telescope to make accurate determinations of the latitudes and longitudes of prominent landmarks along the river.[12] Col. James Duncan Graham (1799–1865) made astronomical observations as a young lieutenant in the U.S. Army expedition that crossed the Panhandle in 1820. Graham later surveyed on the Sabine River to determine the U.S.-Texas border, and in 1850–1851 was the principal astronomer and head of the Scientific Corps demarcating the U.S.-Mexican border. His counterpart on the Mexican side was José Salazar y Larrequi, who even surveyed well inside Texas at Comanche Springs near the present site of Fort Stockton.[13]

The serious business of survey work by the (then) U.S. Coast Survey came after statehood and involved so many people that it is not practicable to name them all, especially since their astronomical work was essentially routine. For a long time the observers were dependent on instruments manufactured in Britain and Germany and almost entirely on catalogues of star positions produced in Europe and even in Australia and South Africa.[14]

The oldest of these pioneers seem to have been R. H. Fauntleroy and J. E. Hilgard, who established a survey marker (now lost) at Dollar Point near Galveston in 1848, and George Washington Dean (1825–1897), who established one on the eastern end of Galveston Island in 1853. Dean continued work with the Coast Survey until 1885 and, like many other early men of science in Texas, had a wide range of interests, including, in his case, the study of reptiles.[15]

Some of the early survey stations, such as the one established in Galveston in 1868, were marked only by a stone crock with a bottle in the center, buried almost a foot below the surface of the ground, with two

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[12] Dan L. Flores, *Jefferson and Southwestern Exploration, the Freeman and Custis Accounts of the Red River Expedition of 1806* (Norman: University of Oklahoma Press, 1984), 62–65.

[13] Samuel W. Geiser, "Men of Science in Texas, 1820–1880," *Field and Laboratory,* XXVI (July–Oct., 1958), 86–139, and XXVII (Jan., 1959), 20–48; (Apr., 1959), 81–96; (July, 1959), 111–160; and (Oct., 1959), 163–256, lists 1,060 biographical entries. In Geiser, "Men of Science in Texas," see "Col. James Duncan Graham," XXVII (Jan., 1959), 24, and "José Salazar y Larrequi," XXVII (Oct., 1959), 193.

[14] U.S. Coast and Geodetic Survey, Special Publication No. 110, *Astronomic Determinations* (Washington, D.C.: Government Printing Office, 1925).

[15] Ibid., 248; "George Washington Dean," in Geiser, "Men of Science in Texas," XXVI (July–Oct., 1958), 119.

adjacent witness posts. Even as late as 1905, stations such as the one at Alice were marked by "a 60d. nail [presumably six times the size of a tenpenny nail] in the center of a 2-inch iron pipe 2 feet long, filled with concrete and surrounded by a block of concrete 12 inches in diameter." Since then markers have become standardized and far more numerous and their claim to rank as part of Texas astronomical history less conspicuous by comparison with more extraterrestrial researches. In taking our leave of the survey work we may mention Hugh Campbell, who was an assistant astronomer on Lt. Amiel Weeks Whipple's Pacific Railroad Survey of 1855, which crossed the Panhandle of Texas.[16]

There was little or no academic interest in astronomy in Texas in the early days of the state, but there were a few pioneers. Oscar Hopestill Leland (1826–1914) was professor of mathematics and astronomy at Baylor University (1856–1861) and at Waco University (1861–1865). After retiring from Waco he took to the law, was called to the bar, and became a county judge and large landowner.[17]

J. H. S. Stanley gave a well-attended series of astronomical lectures in Houston in November 1850. Stanley was a photographer by profession but was much interested in astronomy. At his death, probably in the early 1870s, he left behind a large collection of high-quality astronomical instruments, including a fine Dollond glass of 4½-inches aperture, a large solar microscope, and an astronomical transit instrument. The presence in the collection of this last instrument, used in determinations of time and longitude, especially indicates that the owner must have had a serious interest in astronomy.[18] In addition to Stanley's lectures in Houston, Matthew Hopkins (1808–1883) lectured on physical astronomy to the Austin Library Association on November 25, 1873.[19]

Franklin L. Yoakum (1819–1891) was a physician who in 1855 became president of Larissa College in Cherokee County. For the 1859–1860 collegiate year, $700 was spent to purchase a telescope and equatorial mounting from the New York firm of Henry Fitz (1808–1863), the premier telescope maker in the United States during the decade before the Civil War. The telescope, of six-inch aperture and eight-foot

[16] U.S. Coast and Geodetic Survey, Special Publication No. 110, *Astronomic Determinations*, 244, 245 (quotation), 246–249; "Hugh Campbell," in Geiser, "Men of Science in Texas," XXVI (July–Oct., 1958), 109.

[17] "Oscar Hopestill Leland," in Geiser, "Men of Science in Texas," XXVII (July, 1959), 124.

[18] "J. H. S. Stanley," in Geiser, "Men of Science in Texas," XXVII (Oct., 1959), 211–212.

[19] Webb, Carroll, and Branda (eds.), *Handbook of Texas*, I, 835. Copies of Matthew Hopkins, "Lectures on Physical Astronomy," Nov. 25, 1873, are in the General Collection, Austin History Center, and in the Texas Collection Library, Eugene C. Barker Texas History Center, University of Texas at Austin (cited hereafter as BTHC).

focal length, was the pride and joy of the school, was featured prominently in the annual catalogues and announcements, and was used in astronomy classes taught by Yoakum. Later, Yoakum was cofounder of that version of the Texas Academy of Sciences that operated from 1880 until about 1890.[20]

Caleb G. Forshey (1812–1881) founded the Texas Military Institute at Galveston in 1854 and relocated the institution to Rutersville, in Fayette County, for 1856–1861.[21] During the spring of 1858 and again in 1859, Forshey made detailed observations of the zodiacal light and zodiacal band, the boundaries of which he traced onto star charts. These faint and elusive glows are so named because they extend along the ecliptic, which passes through the familiar zodiacal constellations.[22] On the dark moonless nights of March 2 and April 4, 1859, Forshey and four of his cadets at Rutersville were able to trace the zodiacal band as it "reached entirely across the sky" from the western horizon, through Gemini and Leo, all the way to the foot of Virgo near the eastern horizon. Such an observation is possible only under excellent conditions, but it was noted that the "atmosphere in Texas has a remarkable transparency, particularly after 'northers' . . . the skies seem to be nearer to them in Texas than in any other part of the world. . . . observations in Texas are very satisfactory."[23]

A great auroral display, of almost unprecedented magnificence, was seen in Texas later in 1859, on the nights of August 28–29 and September 1–2. Caleb Forshey made sketches and described how "the whole sky, from Ursa Major to the zodiac in the east, was occupied by the streams or spiral columns. . . . over the same extent, was an exquisite roseate tint which faded and returned" and that "a stupendous pyramid of white light" was surrounded on either side by "a pyramid of rosy light." His observations were published in the *American Journal of Science,* along with accounts by Lt. Albert Miller Lea at Corpus Christi,

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[20] "Dr. Franklin L. Yoakum," in Geiser, "Men of Science in Texas," XXVII (Oct., 1959), 253–254; Nellie Jean Evans, "A History of Larissa College" (M.A. thesis, University of Texas at Austin, 1941), 64–66; Fred Hugo Ford and John Lemuel Brown, *Larissa* (Jacksonville, Tex.: McFarland Publishing Co., 1951), 43, 57, 74–75; John Lankford, "In Search of Henry Fitz," *Sky & Telescope,* LXVIII (Sept., 1984), 214–218.

[21] "Caleb G. Forshey," in Geiser, "Men of Science in Texas," XXVI (July–Oct., 1958), 133–134.

[22] The zodiacal light, the zodiacal band, and the gegenschein (a brightening in the zodiacal band at the point exactly opposite the Sun) are caused by sunlight reflecting from interplanetary dust particles orbiting the Sun near the ecliptic plane (the plane of the Earth's orbit around the Sun).

[23] Forshey's account was included in a compilation by George Jones, "Recent Observations, by Various Persons, on the Gegenschein, or Completed Arch of the Zodiacal Light," *Proceedings of the American Association for the Advancement of Science,* XIII (1860), 172–177, 178 (2nd quotation), 179 (1st quotation), 180–181.

Maj. Benjamin Franklin Rucker at Washington-on-the-Brazos, Francis Kellogg at Wheelock, and Dr. William Henry Gantt at Union Hill, and a report from Dallas by John McClannahan Crockett, then mayor of Dallas and later (1861–1863) lieutenant governor of Texas.[24] Although any sighting of an aurora from Texas is of some interest, the display of September 1–2, 1859, has special significance because of its relation to a historic observation made in England. While timing the drift of sunspots on a projected image of the Sun at 11:18 A.M. Greenwich mean time on September 1, 1859, the English astronomer Richard C. Carrington (1826–1875) witnessed a "singular appearance" as "two patches of intensely bright and white light broke out" only to fade from view five minutes later. Carrington's observation is now famed as the first report of a solar flare, and furthermore, of the rare type known as a white-light flare.[25]

In November 1866, William Henry Gantt, professor of physiology at Galveston Medical College, observed the Leonid meteor shower at Chappell Hill. His written description was later sent to the Smithsonian Institution.[26]

Most of the early professional astronomical activity in Texas was conducted by visitors from out of state. On May 6, 1878, there occurred a transit of Mercury; that is, Mercury was seen to cross the disk of the Sun. On most occasions when Mercury passes between the Sun and the Earth, it does so north or south of the Sun, but on moderately rare occasions, always in May or November, it is seen silhouetted against the solar disk during the space of some hours. November transits are the more frequent, while May transits are rarer, occurring singly or in pairs at intervals of forty-six years.[27]

The interest of these phenomena a century ago was to determine the precise instants at which Mercury was seen to impinge on, and depart from, the solar disk, in order to improve the ephemeris of the planet, and to measure its angular size and so determine its linear dimensions.

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[24] The accounts from Texas are included in a compilation by Elias Loomis, "The Great Auroral Exhibition of Aug. 28th to Sept. 4th, 1859," *American Journal of Science*, 2nd ser., XXIX (Mar., 1860), 263 (quotations), 264, and XXX (Nov., 1860), 347–360; see also "John McClannahan Crockett," in Geiser, "Men of Science in Texas," XXVI (July–Oct., 1958), 118.

[25] Richard C. Carrington, "Description of a Singular Appearance seen in the Sun on September 1, 1859," *Monthly Notices of the Royal Astronomical Society*, XX (Nov. 11, 1859), 13 (quotations), 14–15. A modern account of Carrington's observation has been given by Joseph Ashbrook, *The Astronomical Scrapbook* (Cambridge, Mass.: Sky Publishing Corp., 1984), 340–344.

[26] "Dr. William Henry Gantt," in Geiser, "Men of Science in Texas," XXVI (July–Oct., 1958), 137.

[27] May transits of Mercury have occurred in 1661 and 1674, 1707, 1740 and 1753, 1786 and 1799, 1832 and 1845, 1878 and 1891, 1924 and 1937, 1957 and 1970, with the next to occur in 2003 and 2016; see Jean Meeus, *Astronomical Tables of the Sun, Moon, and Planets* (Richmond, Va.: Willmann-Bell, 1983), Table XI.

For the 1878 event, William Harkness (1837–1903), a well-known astronomer from the U.S. Naval Observatory in Washington, D.C., accompanied by Lt. George E. Ide, U.S. Navy, came to Austin on April 29. Harkness engaged R. C. Lambie to build a hut ten feet square erected at the Old Coast Survey station on the grounds of the Land Office near the Capitol. Preliminary observations of the Sun were made to rate their chronometers which kept Greenwich mean time (fig. 1).[28]

In the matter of weather, they were unfortunate.

> For about fifty-five hours previous to the transit the sky was perfectly clear, but, at sunrise on May 6, there was a heavy bank of clouds in the east which increased so rapidly that by 7 A.M. there was every indication of impending rain. At 8 A.M. we went to our station. At 8:45 A.M., which was the time of first contact, the sky was completely and densely overcast. . . .

How often the soul of the astronomer has been harrowed by such circumstances! The sky partially cleared, however, and measurements of the angular diameter of Mercury (11.92 arcseconds in the mean) were made, starting at 10:25 A.M. and continuing until last contact at 4:14 P.M.[29]

Harkness, in his report, remarks that he observed some of the anomalous effects that show up at the transit of an inferior planet just as it touches the limb (edge) of the solar disk as a bulge on the disk or as a sort of stalk of the planet's image, and which make exact timings of the contacts uncertain.[30]

Later that same year on July 29, 1878, a total eclipse of the Sun was visible from parts of Texas, including Forth Worth and Dallas. Several expeditions were sent both to Texas and to northwest parts of the U.S., including one from Princeton to Denver, Colorado, and another to Wyoming, which included Thomas Alva Edison.[31]

The expedition to Fort Worth was organized by Leonard Waldo (1853–1929) from the Harvard College Observatory, who published his findings in a book issued from Cambridge, Massachusetts, in the following year.[32] After graduating from Marietta College in 1873, Waldo was an assistant at Columbia (1873–1875), at Harvard (1875–

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[28] William Harkness, "Report of Professor William Harkness," in *Reports on Telescopic Observations of the Transit of Mercury, May 5–6, 1878* (Washington, D.C.: Government Printing Office, 1879), 9–20.

[29] Ibid., 16–17.

[30] Ibid., 19.

[31] John Eddy, "The Great Eclipse of 1878," *Sky & Telescope,* XLV (June, 1973), 340–346.

[32] Leonard Waldo, *Report of the Observations of the Total Solar Eclipse, July 29, 1878, Made at Fort Worth, Texas* (Cambridge, Mass.: John Wilson and Son, 1879); see also "The Fort-Worth Eclipse Expedition, 1878," *Observatory,* III (Oct., 1879), 182–184.

Figure 1. William Harkness. *Courtesy U.S. Naval Observatory.*

1880), and at Yale (1880–1887), and later went to New York.[33] For his observations at Fort Worth, Waldo organized a considerable team comprising, besides himself, R. W. Wilson, also from Harvard, J. K. Rees and W. H. Pulsifer from Washington University, St. Louis, and F. E. Seagrave of Providence, Rhode Island. They established themselves at

[33]"Leonard Waldo," in Geiser, "Men of Science in Texas," XXVII (Oct., 1959), 231.

the house of Spotswood W. Lomax, about a half mile south of the city limits.[34] The observational program was most ambitious: "It was determined that the corona should be examined with the naked eye, the telescope, the spectroscope, the polariscope, and that an effort should be made to photograph the corona, and also to take such photographs as might indicate polarization, by placing between the two lenses of cameras double refracting prisms."[35] The visual observations were to be made by eight volunteer sketchers installed on the flat roof of the Lomax house alongside A. M. Britton, who could see the Moon's shadow advancing and had the task of calling out the number of seconds of totality remaining from the expected total of two minutes and twenty-nine seconds. Waldo published some of the photographs and sketches in his book, together with a report by Pulsifer on his spectroscopic observations of the "reversion layer" (the solar chromosphere) from which he deduced the interesting result that it must have a vertical extent of at least 524 miles (a decided underestimate of the modern value) (figs. 2 and 3).[36] Waldo's preliminary observations to determine the precise geographical situation of the observing site led, after a little local surveying, to a determination of the coordinates of the courthouse square in Fort Worth, and some funds were even raised to erect a tablet there, giving these data and recording the occasion for their determination, but apparently this project never came to fruition.[37] Waldo quotes naked-eye observations supplied by other observers in Allen, Bremond, Dallas, and McKinney, all visual timings.[38]

David P. Todd (1855–1939) from the U.S. Naval Observatory led an expedition that observed the July 29, 1878, solar eclipse from Dallas.[39]

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[34] Spotswood W. Lomax is listed in the *General Directory of the City of Fort Worth for 1878–79* (Houston: C. D. Morrison & Co., 1878), with a residence on Adams, southwest of the Texas and Pacific railroad line. Waldo, *Report of the Observations of the Total Solar Eclipse,* 27, gives coordinates of his transit pier, 5,454 feet south and 982 feet west of a point in the courthouse square, from which we conclude independently that the solar eclipse observing station was about two blocks south of the railroad, probably on Adams in the block between Jarvis and West Daggett.

[35] Waldo, *Report of the Observations of the Total Solar Eclipse,* 7. The corona is a permanent, faint white, high-temperature (millions of degrees), tenuous luminous cloud surrounding the Sun, extending many solar diameters. Its light is partially polarized. Its structure varies with the sunspot cycle. A century ago it could be detected only when the disk of the Sun was hidden at a total eclipse.

[36] Waldo, *Report of the Observations of the Total Solar Eclipse,* 48–50, 51 (quotation). The solar chromosphere is a gaseous layer immediately above the solar surface. The chromosphere has the red color that gives it its name because its spectrum is quite different from that of the solar surface. It can now be detected to a height of some 7,000 kilometers above that level.

[37] No such monument in courthouse square could be located in 1978, according to Donna Darovich, "Eclipse caught in FW," *Fort Worth Star-Telegram,* July 29, 1978.

[38] Waldo, *Report of the Observations of the Total Solar Eclipse,* 57–60.

[39] David P. Todd, "Observations at Dallas, Texas" in *Reports on the Total Solar Eclipses of July 29, 1878, and January 11, 1880. Issued by the United States Naval Observatory* (Washington, D.C.: Government Printing Office, 1880), 327–366, Sketches No. 14–25, Plate 18.

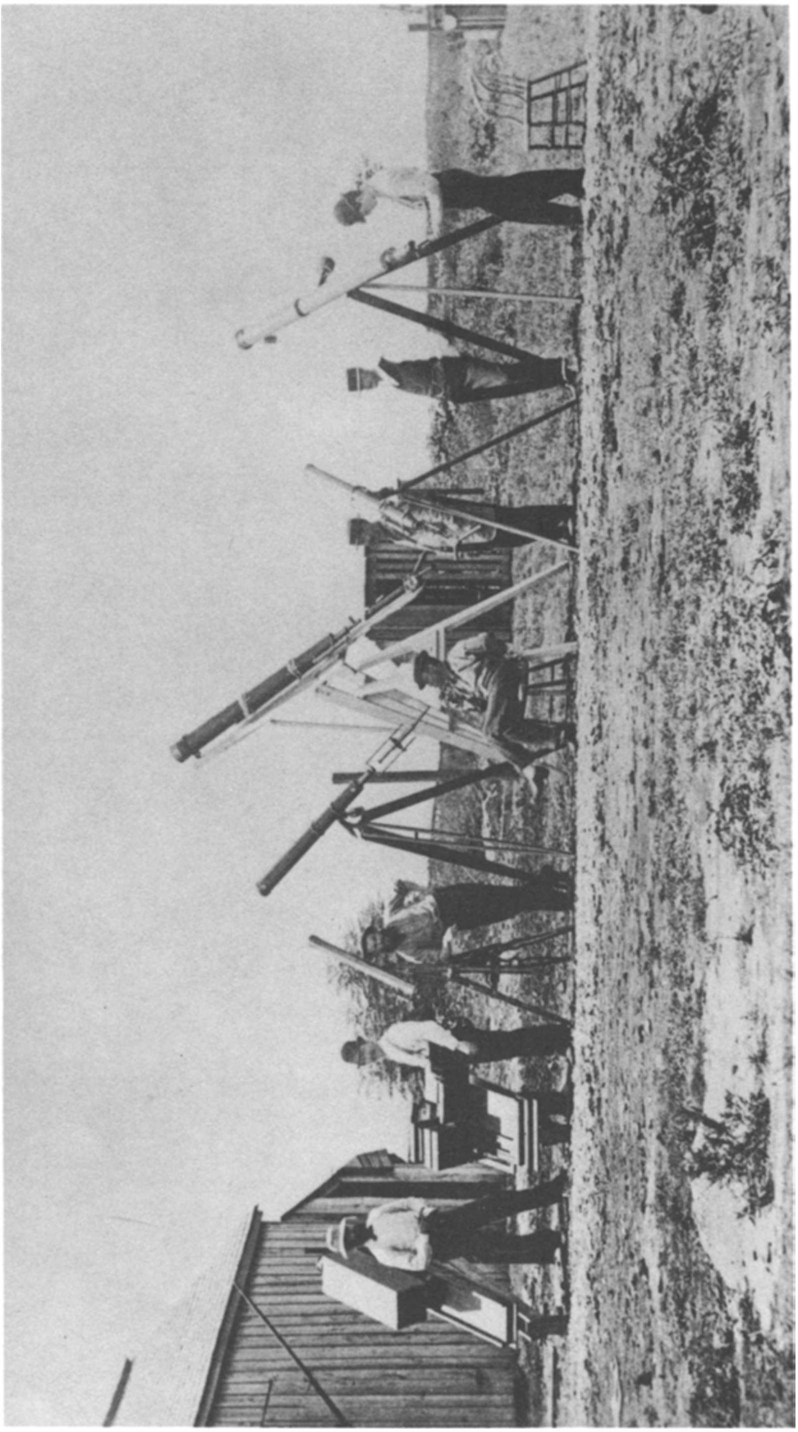

Figure 2. Solar eclipse expedition at Forth Worth, July, 1878. *Courtesy Donald W. Olson.*

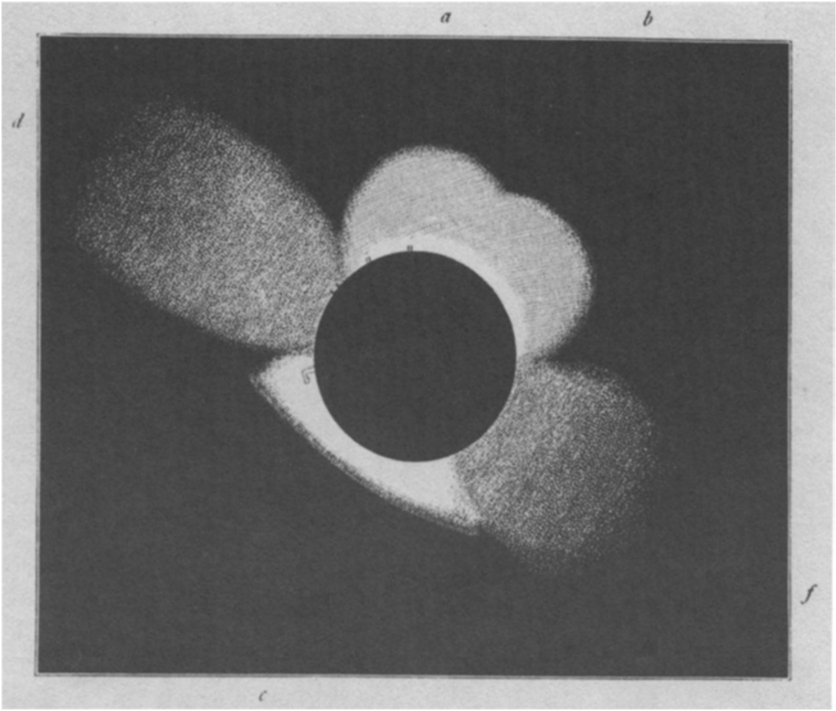

Figure 3. Drawing of the corona at the total solar eclipse of July 29, 1878. *Courtesy Donald W. Olson.*

His observing station was established on the north side of the city at the residence of John M. Oram, a local jeweler and watchmaker. Only after his arrival in Dallas was Todd directed to make an accurate determination of his longitude. Since he had not brought a transit telescope from Washington, Todd made a special railway trip on July 26 to Houston, where he was given permission to appropriate the instruments left behind after the death of J. H. S. Stanley. Todd described this collection of telescopes, now covered with dust and grime, as his "Discovery of a 'Fossil Observatory.'" Of special interest was a good transit instrument, made by Troughton and Simms in London in 1837. Todd telegraphed the news of this find to Dallas, and, in one day's time, under the direction of Oram, local masons built a transit pier of fire-brick, Portland cement, and a slab of dark slate.[40] Todd, aided by a gunsmith and by

[40] The U.S.N.O. solar eclipse station, with Todd's transit pier, was located on the north side of Dallas at the residence of John M. Oram, 103 Cottage Lane, at the intersection of Cottage Lane (now called Federal Street) and Bullington. Oram's residence is described by Todd, "Observa-

Col. G. Jordan of the Houston and Texas Central Railway, quickly returned the transit instrument to working order and used it in Dallas to determine the coordinates of the pier, latitude 32°46′36″ north and longitude 96°47′52″ west. After the eclipse, Todd left instructions with S. W. S. Duncan, city engineer of Dallas, so that meridian markers for permanent reference could be made on city landmarks, including the old City Hall.[41]

Along with his own observations of the eclipse, Todd's report includes thirteen drawings of the corona as seen by various observers in Dallas, Tyler, and Palestine. Todd had traveled during July to enlist volunteer observers, especially at towns selected near the northeastern and southwestern limits of total obscuration of the Sun, and he published written records from eighteen of these stations. Only a few of the observing groups did more than simple visual timings of the duration of totality. Photography was attempted at Waco by W. M. Ragland and J. C. Walker, and three positive photographs were sent to Todd by C. B. Pollock and A. W. Swanitz of Palestine. At a point six miles north of McKinney, a group of five observers, H. S. Moore, C. B. Moore, A. M. Wilson, T. M. Wilson, and T. B. Wilson, used a 35-power field glass and a good surveyor's transit. Moore reported that during totality the latter instrument revealed several "protuberances" around the Moon. This observation by the amateur at McKinney was accurate, since prominences can be seen on the drawings made by professional astronomers (see fig. 3).[42]

Cleveland Abbe (1838–1916), the astronomer and meteorologist often called the "father of the weather bureau," published a volume collecting observations of the July 29, 1878, solar eclipse as reported to the Signal Service. Abbe himself viewed the eclipse from Pike's Peak, Colorado, but his book includes written descriptions from twenty-six observers at eleven different points in Texas and reproduces eight of the drawings that had accompanied the reports from Texas.[43]

Another significant astronomical event occurred on December 6, 1882. This was a transit of Venus. These are very rare events, pairs of

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tions at Dallas, Texas," 331 (quotation), 332–333, is listed in the *General Directory of the City of Dallas, 1886–87* (Galveston: Morrison & Fourmy, 1886), and is shown on the map, *Dallas, Texas* (New York: Sanborn Map & Publishing Co., 1888), sheet no. 19, in the Sanborn Map Collection (BTHC).

[41] Todd, "Observations at Dallas, Texas," 327–366.

[42] Todd, "Observations at Dallas, Texas," 327–356, 357 (quotation), 358–366, Sketches No. 14–25, Plate 18.

[43] Cleveland Abbe, *Professional Papers of the Signal Service, No. 1: Report on the Solar Eclipse of July, 1878* (Washington, D.C.: Government Printing Office, 1881), 90–95, Sketches 20–27.

transits having occurred most recently in 1761 and 1769, and in 1874 and 1882, with the next to occur in 2004 and 2012.[44] The interest of these events a century ago is that when they occur, the distance of Venus from the Earth is only about 26 million miles, so that from different stations on the Earth the tracks of the planet across the solar disk are significantly different. From precise measurement of the times of contacts, and/or angular measures of the position of the planet on the disk at various times, it is, in principle, possible to deduce the linear distance of the planet from the Earth and from this to derive the distance of the Earth from the Sun. A hundred years ago this was not known with any precision. In view of the recent return of Halley's Comet, it is interesting to recall that this method was proposed by Edmond Halley, after he had observed a transit of Mercury in 1677 from the island of St. Helena in the south Atlantic, where he had gone to make observations of the southern stars. Transits of Venus can be used for the purpose, but not the transits of Mercury, since at such times it is much farther away from the Earth than Venus is.

During the eighteenth century, Venus transit expeditions from many countries were sent all over the world to suitable observing sites, and all encountered the phenomena already mentioned in connection with the Mercury transit, namely peculiar image distortions at the moments when the planets were in contact with the edge of the Sun.

The U.S. Naval Observatory sent eight expeditions to (different) suitable observing sites for both the 1874 and 1882 events, using photographic methods, and taking elaborate precautions to try to overcome the problems encountered by previous observers. The best-placed station in North America in 1882 was San Antonio, and in that same year not only an American expedition but a Belgian one as well traveled there.[45]

The latter was led by the director of the Royal Observatory at Brussels, Jean-Charles-Hippolyte-Joseph Houzeau de Lehaie (1820–1888) (fig. 4), whose extraordinary personal history included a previous association with Texas.[46] In 1882 he returned to Texas to observe the transit of Venus at San Antonio, after which he returned to Belgium. In 1883

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[44] Jean Meeus, *Astronomical Tables of the Sun, Moon, and Planets* (Richmond, Va.: Willmann-Bell, 1983), Table XII.

[45] Memorandum, May 27, 1922, for Superintendent Concerning Origin and Operation of the US Transit of Venus Commission, typescript initialed "WDH," U.S. Naval Observatory Library; J-C. Houzeau, "Passage de Vénus du 6 décembre 1882," *Annales de l'Observatoire Royal de Bruxelles*, V, Pt. 1 (1884), 1–29, and V, Pt. 2 (1884), 1–79.

[46] At a very early age Houzeau became a prodigious writer on scientific and social topics. For a while he lived and studied in Paris, but in 1843, Adolphe Quételet, founder of the Royal

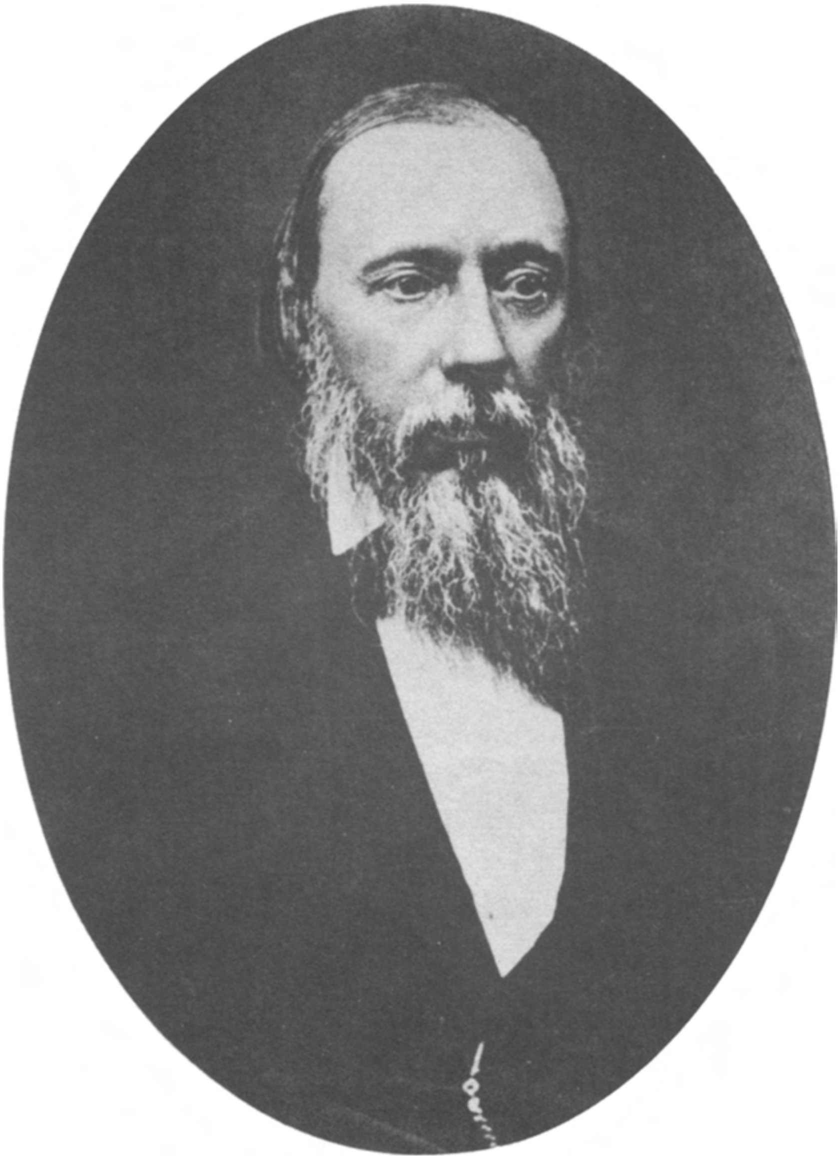

Figure 4. Jean-Charles Houzeau, published in *Ciel et Terre,* ix (1888–1889). *Courtesy* Sky & Telescope.

Observatory of Belgium, took him on, first as a volunteer and later as a paid assistant. During the social upheavals of 1848 Houzeau took a firm republican stand and was chased out of Belgium by a royalist mob to range about Europe writing books on geography. In 1854 he was recalled to Belgium to do survey work, but in 1857 he left for New Orleans on an old sailing tub, a voyage that took seven weeks. He then left for Texas on an ox cart, reaching San Antonio in May of 1858, where he supported himself with survey work, incidentally observing the fahe relinquished the directorship and, besides the usual flood of articles, completed—with the librarian of the observatory, Albert-Benoit Lancaster—his monumental general bibliography of astronomy.[47]

A long account of the proceedings at San Antonio was written by Lancaster for the journal *Ciel et Terre* in 1883.[48] The Venus expeditions to Chile and Texas were the first international expeditions ever sent from Belgium, the one to San Antonio comprising Houzeau, Lancaster, then described as a meteorological inspector, and E. Stuyvaert, assistant astronomer. San Antonio was chosen in preference to Uvalde, then regarded as the limit of Texas civilization. Both Belgian expeditions were provided with heliometers, described in detail below, and some other optical instruments and chronometers. Houzeau and Stuyvaert went to San Antonio directly, where Houzeau rented a house facing Fort Sam Houston on Government Hill, about two miles out of town, and hoisted the Belgian flag.[49]

Lancaster followed a circuitous route, with some astronomical visits, via New York, Niagara, Philadelphia, Washington, D.C., Denver, and Pueblo. The train on which he crossed Kansas was held up by bandits a few days later, prompting Lancaster to the prim remark, "You see that one should take certain precautions in the less well inhabited parts of the U.S.A."[50]

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mous comet, Donati, of that year. When the civil war broke out he was hounded for his anti-slavery views, but, taking the name of Carlos Uso and disguised as a Mexican wagoneer, he took a load of cotton over the Mexican border. He supported himself as an architect until he could get ship to New Orleans, where, with an interval in New York and Philadelphia, he edited a Negro newspaper. By a miracle he escaped a mob of southern bigots in 1866, and went to Panama and later to Jamaica. Quételet died in 1874, and King Leopold II overrode the objections of his ministers and appointed Houzeau director of the observatory. See J-C. Houzeau, *My Passage at the New Orleans* Tribune, *A Memoir of the Civil War Era*, ed. David C. Rankin, trans. from the French by Gerard F. Denault (Baton Rouge: Louisiana State University Press, 1984).

[47] J-C. Houzeau and A-B. Lancaster, *Bibliographie Générale de l'Astronomie* (2 vols.; Bruxelles: X. Havermans, F. Hayes, 1880–1889). The original edition contains a biography of Houzeau by Lancaster (pp. i–cxix) not included in the new edition by David W. Dewhirst (London: Holland Press, 1964).

[48] A-B. Lancaster, "Nos Missions en Amérique," *Ciel et Terre*, 3rd yr. (1883), 361–365, 386–396, 483–488, 503–504, 516–522.

[49] The Belgian observatory was located in the back garden of a rented house that faced the Staff Post and the Quadrangle of Fort Sam Houston. The house, which no longer exists, was probably on the south side of Grayson Street, in the block between the streets now called North Palmetto Avenue and Pierce Street. The telescope piers were approximately 640 feet south and 950 feet west of the clock tower in the Quadrangle. To establish this location, we have relied on the account by J-C. Houzeau, "Passage de Vénus du 6 décembre 1882," V, Pt. 2, 78–79, which we compared to the map, *San Antonio, Texas* (New York: Sanborn Map Company, 1904), sheet no. 179, in the Sanborn Map Collection (BTHC), and to various other earlier maps in the collection at the Fort Sam Houston Museum, San Antonio. Lancaster, "Nos Missions en Amérique," 392.

[50] Lancaster, "Nos Missions en Amérique," 363–365, 386–391, 392 (quotation).

The Venus transit expedition from the U.S. Naval Observatory was led by Asaph Hall (1829–1907) (fig. 5), a distinguished astronomer best known to a wider public as the discoverer of the two tiny satellites of Mars. By the local journalists understandably unfamiliar with Welsh hagiography, he was invariably printed as "Asa P. Hall." Hall was assisted by D. R. Holmes of Milford, Delaware, George H. Hurlbut from Illinois, and R. S. Woodward of Detroit, all specialist photographers. They camped in tents supplied by the army about 500 yards east of the Belgians.[51] The Americans used a heliostat, a moving mirror to feed the Sun's light into a lens of forty-feet focal length, and then to photographic plates preceded by a ruled grid of fine lines and a plumb bob of which the line was to mark the true vertical.[52]

Both of these sites, the Belgian observatory and the U.S.N.O. station, may be deserving of historical markers, to commemorate these early attempts to determine the scale of the solar system.

Before the great day, prayers were offered in all the "temples protestants" for fine weather, but to little avail. The first contacts between Venus and the Sun's disk were lost in cloud, but later on it cleared, and the Belgians made 124 heliometer measures of angles until the time of the last contact at 1:34 P.M. The Americans obtained 204 photographs, of which 121 were measurable, while the Reverend Dr. Richardson, an Episcopal clergyman, and Capt. W. R. Livermore, who had their own small telescopes, timed the third and fourth contacts (moments of last internal and external contact of the planetary disk with the solar disk). They had been of great help in showing streams of curious visitors celestial objects.[53]

One of these was the great comet of 1882, originally a southern hemisphere object, which, by December, had moved into Canis Major.[54]

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[51] The U.S.N.O. station was located near a point 700 feet south and 570 feet east of the clock tower in the Quadrangle of Fort Sam Houston. The U.S.N.O. heliostat was therefore in the field, now on the Infantry Post, immediately east of the present intersection of North New Braunfels Avenue and Quitman. To establish this location, we have inspected the site, with the assistance of the staff of the Fort Sam Houston Museum, and have relied primarily on Houzeau's coordinates of the American station relative to his own observatory and to the fort, as given in J-C. Houzeau, "Passage de Vénus du 6 décembre 1882," V, Pt. 2, 78–79. The U.S.N.O. position is given as west longitude 98°27'32".1, north latitude 29°26'32".9 in Asaph Hall's field notes (U.S. Transit of Venus Commission Records, U.S. Naval Observatory Library, Washington, D.C.).

Figure 5. Asaph Hall. *Courtesy U.S. Naval Observatory.*

Such was the local interest that the authorities in Waco rang the church bells at four in the morning to arouse hopeful viewers. This was the comet of which David Gill at the Cape of Good Hope obtained a photograph showing many star images; the success of this photograph played a pivotal role in the start of the international project to make a photographic map of the whole sky.[55] Lancaster cited an incident where the San Antonio correspondent of the New York *Herald* requested permission to view the comet on the following night, only to be shot dead two hours later in front of the Post Office by a fellow journalist.[56] As he remarked, "There is no scientific life here," a censorious judgment supported by the Austin paper, which jokingly reported that a "Prof. C. Sharp," assisted by "Prof. Phunnywhistler" and using two large clocks brought from Houston by ox cart, had determined the distance to the Sun accurate to a small fraction of an inch.[57]

Houzeau's observational technique showed considerable ingenuity, which merits a somewhat detailed description.

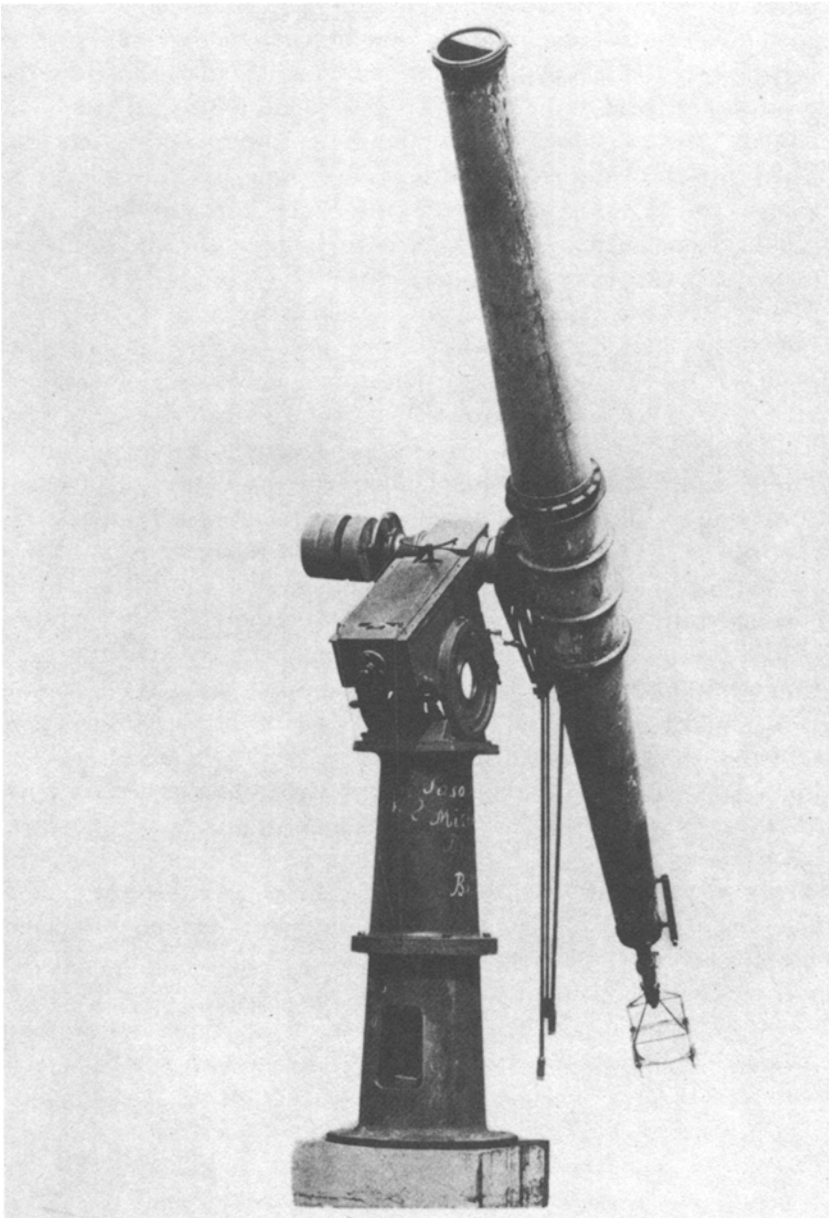
The heliometer, invented by the Bavarian optician Joseph von Fraunhofer, was a precision instrument for measuring small angular separations between astronomical objects and was employed in traditional form by a number of Venus expeditions. It consisted of a refracting telescope in which the objective lens was sawed in two halves diametrically, with one half fixed, and the other being capable of displacement on a micrometer stage operated by the observer. Each half produced an image of the objects in the field of view, and the separation between two of them could be measured by displacing the movable half lens until the two images coincided. In its usual application, the image of Venus was displaced until it touched the edge of the solar image, thus keeping track of the relative movement throughout the transit. Success usually required that both the ingress and egress of the planet from the disk of the Sun be observable, and this might not be so if there were clouds around.

Houzeau introduced a new wrinkle for his two Venus expeditions, one to San Antonio and one to Chile, from which he hoped to determine an all-Belgian value of the solar parallax. A photograph of his heliometer (fig. 6) shows only a single half lens at the top of the tube, and indeed, the museum of the Royal Observatory at Uccle has two half lenses both immovably secured on fixed brass mounts, one from each of the expeditions. The clue to what Houzeau called his "Héliomètre à Objectifs Inégaux" was provided to us by the presence of a much smaller, shorter focus, half lens in the same museum case. This was mounted on a micrometer stage inside the telescope tube, much nearer the focal plane, and could be moved by handles available to the ob-

[55] John Lankford, "Astronomical Photography," in Owen Gingerich (ed.), *The General History of Astronomy* (4 vols.; Cambridge: Cambridge University Press, 1984), IV, Pt. A, 16–39.

[56] Lancaster, "Nos Missions en Amérique," 517.

[57] Lancaster, "Nos Missions en Amérique," 396 (1st quotation); Austin *Daily Statesman*, Dec. 7, 1882 (2nd and 3rd quotations).



HÉLIOMÈTRE A OBJECTIFS INÉGAUX.

Figure 6. Houzeau's heliometer with half lens objective. *Courtesy Royal Observatory of Belgium.*

server. The big half lens produced a large focused image of the Sun and of the disk of Venus projected on it. The small lens produced a tiny focused image of the Sun, actually smaller than that of Venus produced by the large lens. By superimposing the small Sun image on the large Venus image, so that a uniform ring of its darkness could be seen, the relative displacement of Venus with respect to the Sun's center could be measured throughout the transit. This meant that useful observations could be made, even if part of the transit might be covered by clouds. Moreover, since the results would not depend on precise timings of the moments of ingress and egress of the planet from the solar disk, it would be hoped that a phenomenon that bedeviled all the transit expeditions would not be of capital importance. This was the so-called "black drop effect," which made the exact contacts uncertain because of a kind of stalk appearing on the planet's image just as it came in contact with the edge of the Sun. This sort of optical effect proved fatal to the hopes of almost all the dozens of efforts made at Venus transits.

For all his ingenuity, Houzeau's result was not particularly good. The number sought is indirectly the value of the mean distance of the Earth from the Sun, but in practice is expressed as an angle, called the solar parallax, namely the angular size of the radius of the Earth as it would be seen from the Sun with the latter at its mean distance. The accurate value, now known from interplanetary radar, is 8.79418 seconds of arc. Houzeau came out with the high value of 8.907 arc seconds, and all other expeditions came out with comparable deviations from the true value.[58] The Americans, for whom San Antonio was only one of eight observing stations, published their result only much later, under the direction of Harkness, because the observatory director, Simon Newcomb, had grown tired of the subject when Congress failed to allocate sufficient funds.[59]

Precious little astronomy was undertaken in Texas during the latter part of the century, though there were isolated amateurs. One of them, H. S. Moore of McKinney, who had used a surveyor's transit to observe the solar eclipse on July 29, 1878, had acquired by 1885 a four-inch refractor. At 9 P.M. on August 30, 1885, Moore's observing notes indicate that he used this instrument to detect a remarkable "star in Andromeda nebula. Believe it to be new in this place. Nearly central in nebula." Moore forwarded his observing notes to astronomer Edward Emerson Barnard, who published them in both American and German

[58] "Cent-Cinquantième Anniversaire," *Bulletin Astronomique Observatoire Royale de Belgique,* X, No. 1 (1985), 64 (quotation), 65.

[59] R. W. Shufeldt, *Observations Made During the Year 1883 at the U.S. Naval Observatory* (Washington, D.C.: Government Printing Office, 1887), x–xiv.

journals and credited the amateur from McKinney as an independent discoverer of the bright supernova in the Andromeda galaxy in 1885.[60]

One exception to the lack of professional interest is the fact that, at the 1910 apparition of Halley's Comet, serious observations, which have apparently not been preserved, were made by Father John Joseph LeSage of the order of St. Vincent de Paul at Holy Trinity College in Dallas, where he was teaching science, including astronomy, during eleven of the years of his very long ministry and educational service.[61]

For the rest, public reaction to the comet in Texas was of the same fearful kind that occurred in other parts of the world, moderated, perhaps, by reassuring pronouncements by professional astronomers in other parts of the country. In recollections of the 1910 apparition of Halley's Comet, there is always some confusion, because two bright comets appeared in that year. In January 1910 a bright non-periodic comet appeared, attained a brightness several times that of Venus, and produced a tail that at one time was 40 degrees in length.[62] Halley's Comet was most prominent in May, when the Earth passed through the tail, arousing fears that its alleged poisonous gases would pollute the Earth's atmosphere. The press was full of drawings depicting the possible holocaust. One member of the lunatic fringe asserted that the tail was not composed of gases, but was the light rays of the Sun focused in a beam by the head of the comet. The "dreadful effect" of these "actinic rays" on society women caused them to flock to new religious cults.[63]

In the early years of the twentieth century, Texas astronomy was in the doldrums with the exception of such amateurs as S. H. Huntington of Kerrville, who sent 341 variable star observations to the American Association of Variable Star Observers between 1913 and 1915,[64] and, of course, Oscar Monnig of Fort Worth who has supplied a tape recording of his personal recollections. Monnig was born in Fort Worth in 1902, and recalls being stimulated by the sight of the opposition of Mars in 1909, and of both the January comet and Halley's in 1910. Monnig entered the University of Texas at Austin in 1920 and with two friends endeavored to register for an astronomy course to be taught by

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[60] E. E. Barnard, "The New Star in Andromeda Nebula," *Sidereal Messenger,* IV (1885), 247 (quotation); E. E. Barnard, "Ueber den neuen Stern im grossen Andromeda-Nebel," *Astronomische Nachrichten,* CXII (1885), col. 403; these references were called to our attention by Dr. Gerard de Vaucouleurs, University of Texas.

[61] *De Andrein* (Perryville, Missouri), XVI, No. 3 (1945), 1–5, provided to the authors with the assistance of Ruth Lang, secretary of Holy Trinity Church, Dallas.

[62] Vsekhsvyatskii, *Physical Characteristics of Comets,* 380–382.

[63] Austin *Statesman,* Sept. 13, 1910.

[64] Records of the American Association of Variable Star Observers, personal communication from Janet Mattei, secretary of the AAVSO.

Harry Yandell Benedict, astronomy graduate of Harvard, who was, successively, dean of the Faculty of Science and later university president. The course did not have sufficient enrollment, and, when they sought an interview with Benedict, he slapped his thighs and remarked that nobody had signed up for that course for twenty years.[65]

Though thwarted of an astronomical education, Monnig maintained his enthusiasm for the science. He had an interest in meteors and meteorites, of which he personally made several discoveries, and wrote a pamphlet of instructions on how meteorites could be recognized. He was a charter member of what became the Meteoritical Society and for some time was its president. As an observer who owned a five-inch telescope and a Schmidt camera, he communicated 1,284 observations to the American Association of Variable Star Observers between 1929 and 1945. As a publicist, he gave many lectures, and for fifteen years he distributed a monthly *Texas Observer's Bulletin.* With Sterling Bunch of Springtown, James H. Logan of Dallas, and Robert G. Brown (himself a variable star observer) and Blakeney Sanders of Fort Worth, he established a small observatory some nine miles south of the city. These praiseworthy efforts have been recognized by various awards, including the Texas Lonestargazer Award of the South West Region of the Astronomical League in 1984, and the designation of Minor Planet No. 2780 by the name "Monnig."[66]

The Great Depression must have severely curtailed opportunities for amateur astronomy between the wars, but the records of the AAVSO do include, as observers, H. H. Morse of Fort Worth, Graham D. Kendall of Houston, B. F. Grandstaff of Dallas, and A. Wade Mount during and immediately after the war.[67]

In spite of the hardships of the times, perhaps some of the stimulus to those who did take an interest in astronomy was the news, in 1926, that a wealthy northeast Texas rancher and banker, William Johnson McDonald, had bequeathed the greater part of his fortune of over a million dollars to the University of Texas, with which he had only the slenderest of connections, for the establishment of an astronomical observatory. With this development Texas moved into a modern astronomical era described in detail elsewhere.[68]

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[65] Oscar E. Monnig, tape recording and personal correspondence.

[66] Ibid.

[67] Personal communication from Thomas R. Williams, president of the AAVSO.

[68] David S. Evans, "Astronomy," in Leo J. Klosterman, Loyd S. Swenson, Jr., and Sylvia Rose (eds.), *100 Years of Science and Technology in Texas* (Houston: Rice University Press, 1986), 105–121; David S. Evans and J. Derral Mulholland, *Big and Bright: A History of the McDonald Observatory* (Austin: University of Texas Press, 1986).