JHA, xxx (1999)

A CAREER OF CONTROVERSY: THE ANOMALY OF T. J. J. SEE

THOMAS J. SHERRILL, Los Altos, California

Few historical figures of early twentieth-century science inspire a degree of rancour comparable to that evoked by the American astronomer Thomas Jefferson Jackson See (Figure 1). At a time when the revolutionary developments of Einstein's theory of relativity and quantum mechanics were overturning the old physics, when new discoveries on the nature of the atom were astonishing the world, and when technological breakthroughs were occurring almost weekly, public interest in science grew to unprecedented levels. It seems perhaps odd that during this productive period there should emerge as a major "spokesman" for science — consulted by newspapers and other media to interpret scientific discoveries or worldly events such as eclipses, earthquakes, or volcanic eruptions — a scientist whose own theories ran counter to the revolution.

Although he had a solid background in celestial mechanics and was a respected telescopic observer early in his career, when he turned to theoretical work T. J. J. See began diverging from his astronomical colleagues in striking ways. He developed his own hypothesis of solar system evolution, as well as theories that explained the many diverse phenomena in the universe. In public lectures, numerous books, and dozens of articles in popular science magazines he frequently managed to convince a significant segment of the public that his unorthodox astronomical views were to be preferred over more accepted contemporary theories. From astronomy he ventured into other scientific fields, notably geology and physics, generating controversy after controversy. He helped lead scientific attacks on relativity, sought classical explanations for atomic and electromagnetic forces, and challenged Hubble's concept of an expanding universe. With each controversy he alienated himself further from the scientific establishment.

Despite his limited support among astronomers, See had a devoted public following who hailed him as "the American Herschel" and "the greatest astronomer in the world". This following was looked upon with embarrassment in the scientific community, and it served as a constant reminder of the difficulty of explaining science to the world at large. Once See had achieved some credibility with the public, it was hard to counter his influence with reasoned arguments that might be too technical for mass consumption.

Although his work is little known to today's younger astronomers, it is perhaps worthwhile to review See's career, if only as a counterexample to the case for strict application of the scientific method. While attempts have been made over the years to 'rehabilitate' his reputation, or to suggest that some of his ideas were indeed visionary for his time, the fact remains that many of his methods were deplorable and eventually detrimental to science.

0021-8286/99/3001-0025/$2.50 © 1999 Science History Publications Ltd

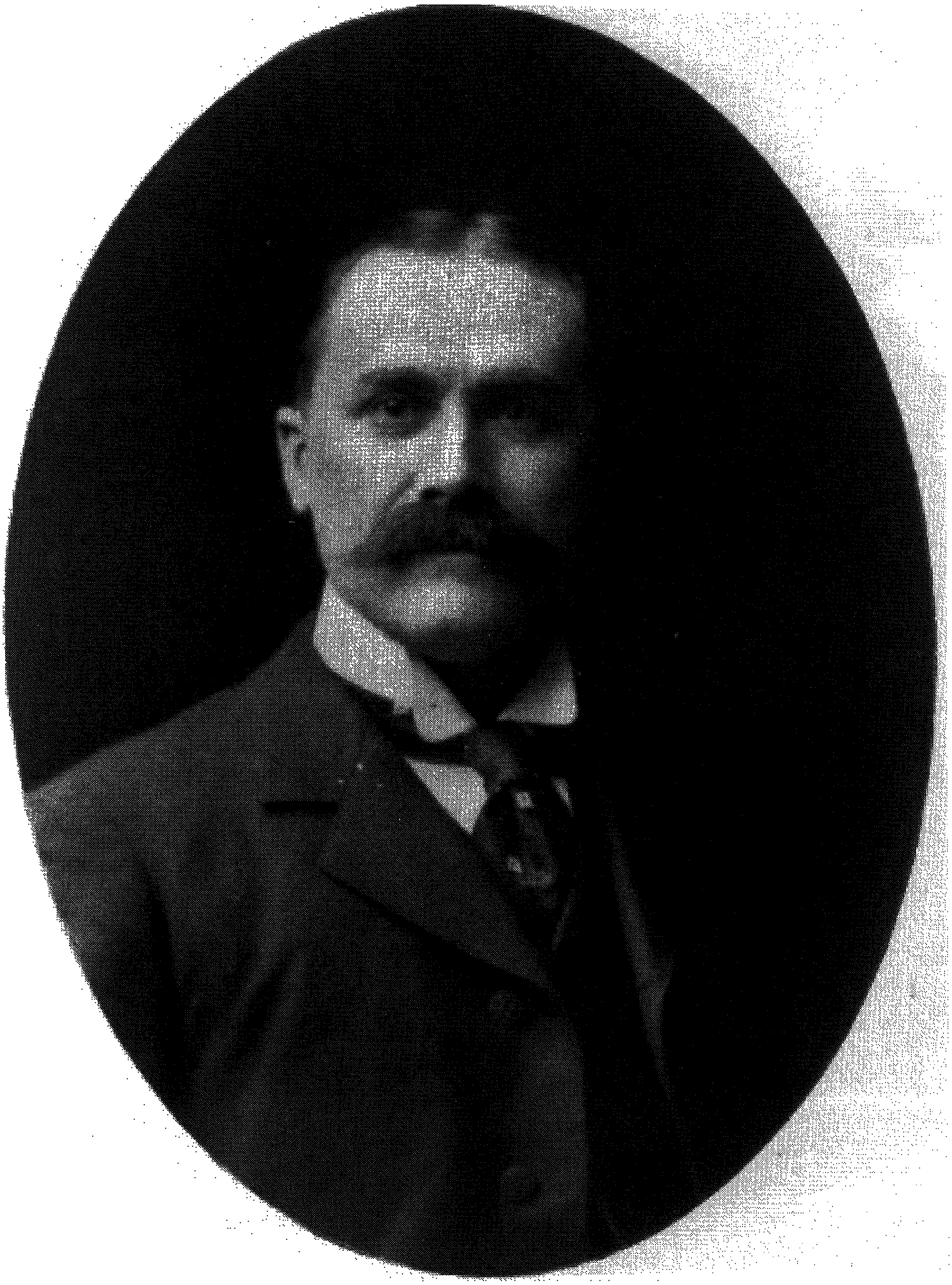

FIG. 1. T. J. J. See, from the frontispiece of W. L. Webb's *Brief biography* (ref. 1).

Background and Education

Born near Montgomery City, Missouri, on 19 February 1866, Thomas Jefferson Jackson was the sixth of nine children of Noah See, a well-to-do farmer. His early education was typical for a farmer's son in the post-Civil War era, consisting of no more than four winter months a year in a country schoolhouse. Despite his obvious brightness, it was only when he was seventeen years old that he was allowed to attend a proper high school in the county seat, where he so distinguished himself in science and mathematics that his father was persuaded to send him on to college.

At the State University of Missouri, in Columbia less than fifty miles from his home, See continued to excel in all the sciences, but it was astronomy that drew him most strongly. He was allowed to use the $7\frac{1}{2}$-inch equatorial telescope at the university's small observatory to study the planets, comets, and stars; he took a particular early interest in double stars. He graduated in 1889 as class valedictorian.

See was sent abroad for his graduate education, to the University of Berlin, which had one of the world's most respected faculties in the sciences, presided over by Hermann von Helmholtz. The astronomy professors allowed the hard-working student to observe and measure double stars with the Royal Observatory's 9-inch refractor. He learned the most modern techniques for calculating double star orbits, and was to write his dissertation on the subject of the origin of such multiple systems. He received his Doctor of Philosophy and Master of Arts degrees *magna cum laude* in December 1892.[1]

At the University of Chicago

Upon graduation, See was offered an instructorship with the astronomy department of the new University of Chicago by its president, William R. Harper, whom he had met in Berlin. At the time the University's astronomy department consisted solely of the astrophysicist George Ellery Hale and a celestial mechanics specialist, Kurt Laves. The department had considerable promise for the future, however, for Hale and Harper had recently persuaded Charles T. Yerkes, a Chicago streetcar tycoon, to purchase the 40-inch glass lenses then lying unground at the Massachusetts shop of Alvan Clark and Sons. They were intended for the largest refracting telescope in the world, to be the centrepiece of the planned Yerkes Observatory, a facility costing around $250,000.

In consultation with S. W. Burnham, the noted double star observer who was awaiting a faculty appointment, it was decided that virtually all published double star orbits — some of them decades old — required revision based on more recent observations. See was assigned the task of leading a few graduate students in collecting old and new observations, adding some of their own made at cooperating nearby observatories, and systematically recalculating the orbits of the forty best-observed binary systems. With such an ambitious project some shortcuts had to be taken, so new graphical methods worked out with Burnham were utilized to speed up the process of reducing the orbits.

See quickly realized that the project provided a fertile source of recognition, and he began submitting papers almost monthly to the *Astronomical journal* in America and the *Astronomische Nachrichten* in Germany, as the binary orbits were analysed one by one.[2] This was the start of a prolific career as an astronomical writer and popularizer, as he also began publishing articles in non-professional scientific monthlies such as *Popular astronomy*.[3]

In the meantime, the University of Chicago's efforts to get the Yerkes Observatory out of the planning stage had bogged down. After an observing session in Europe, Hale was preoccupied with establishing the *Astrophysical journal*, and Harper became increasingly worried about a projected estimate of $30,000 a year which might be required to run the Observatory once it was built. At a meeting with Harper, See offered to draw up a plan for running Yerkes on a much reduced budget, and this offer was accepted. Supposedly this budget reduction earned the young astronomer Hale's animosity; among other things, See felt that this animosity was behind the University's reneging on a promise to publish his investigation of the forty binary orbits in book form.[4] Thus See had to arrange to publish this work, entitled *Researches on the evolution of the stellar systems*: *Volume 1* (for he had further plans for the subject), at his own expense.[5]

In the spring of 1896, in consequence of See's growing reputation as an observer, Percival Lowell invited him to undertake a survey of the southern sky using the 24-inch Clark refractor at Flagstaff, Arizona, for the discovery and measurement of double stars. See accepted, and Harper offered him leave of absence to do this work, with the rank of assistant professor. See, however, insisted on the position of associate professor as his price to remain connected with Chicago. Since this was the rank of the much more prominent Hale, Harper could not grant the request, and See simply left.[6] Thus he lost the opportunity to work with the Yerkes 40-inch, which was completed and the Observatory opened in September 1897.

At the Lowell Observatory

The work for Lowell was another major undertaking for See, as many southern doubles had not been measured since their discovery by Sir John Herschel during his expedition to the Cape of Good Hope from 1834 to 1838. Because observations of Mars had top priority at Flagstaff, the binary survey with the 24-inch (Figure 2) had to be done when the planet was least accessible. During the winter of 1896–97 the telescope was transported to a site near Mexico City, where the low latitude enabled the survey to reach as far south as declination –65° (again vying for time with Lowell's Mars work). The results, which included the discovery of 600 new doubles and the re-measurement of 1400 previously recognized by Herschel, were catalogued in the March 1898 issue of the *Astronomical journal*.[7]

Although this work was generally well-received, there were some astronomers who began to accuse See privately of carelessness as an observer.[8] In addition, they felt that the young man's overconfidence frequently led him to mischaracterize

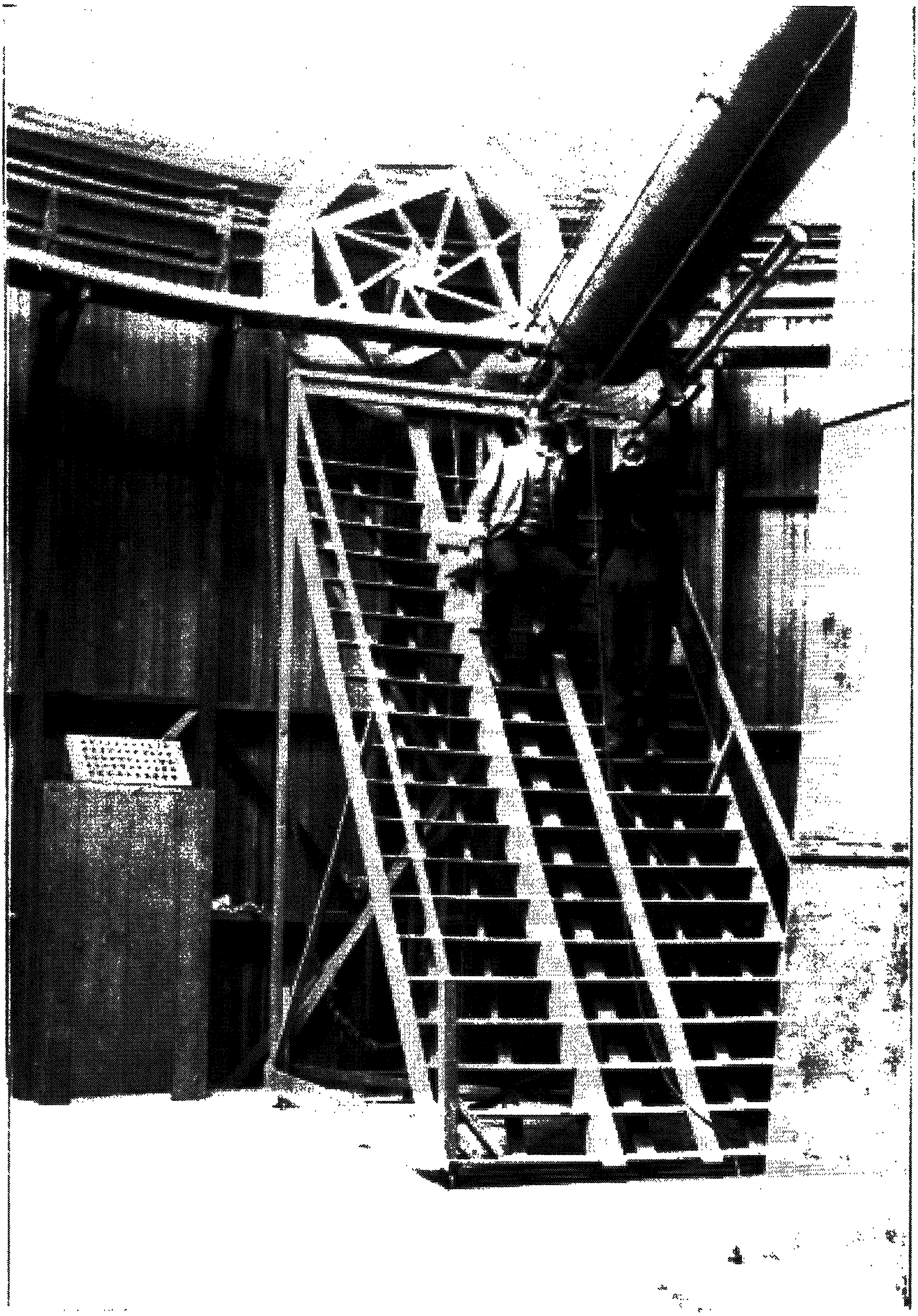

FIG. 2. T. J. J. See (right) and his assistant, W. G. Cogshall, sweeping for double stars with the Lowell Observatory's 24-inch Clark refractor in Mexico City during the winter of 1896–97. Their positions were normally reversed, with See at the main telescope's eyepiece and his assistant recording the micrometer measurements and sketching the finder's field. From Webb's *Brief biography* (ref. 1), plate following p. 66.

results, and sometimes to engage in rank speculation in his writings. For example, while reducing the forty binary orbits at Chicago he had written about one of them in an October 1895 letter to the *Astronomical journal*:

> Since August 20, when I first announced to you the existence of peculiar anomalies in the motion of the companion of [70 Ophiuchi], I have succeeded in showing conclusively that the system is perturbed by an unseen body.... I find that the dark body has a period of approximately forty years.... The sudden deviation of the companion from Schur's ephemeris proves the existence of the dark body here assumed.[9]

Elsewhere, writing of his Lowell double star survey, he claimed that

> Among these obscure objects about a half a dozen are truly wonderful, in that they seem to be dark, almost black in color, and apparently are shining by a dull reflecting light. It is unlikely that they will prove to be self-luminous.[10]

See stopped just short of declaring these dark bodies to be "... the first case of planets ... noticed among the fixed stars".

In October 1897 See published his first article for a non-scientific national magazine, *Atlantic monthly* — a nine-page dissertation highlighting his work on double stars.[10] Apparently he wanted to ensure that his accomplishments received due notice in the world at large, as well as in the scientific community.

It had been intended to extend the Lowell survey even farther south by temporarily relocating the 24-inch refractor in Peru, but Percival Lowell suffered an unexpected nervous breakdown in 1898, so that most of his observatory projects had to be suspended for over two years. In February 1899, on the recommendation of the Secretary of the Navy, President William McKinley appointed See to a professorship of mathematics in the Navy, on assignment to the U.S. Naval Observatory in Washington D.C. In fairly short order he was put in charge of the Observatory's biggest telescope, the 26-inch Clark refractor.[11] This instrument was as excellent as the Lowell 24-inch, although its achievements were limited by the unsteady skies of Washington, which could seldom match the seeing at Flagstaff.

Thus, in 1899 the 33-year-old See had one of the most promising futures of any young astronomer in the country.

The Dark Star

A comedown was in store. See had followed up his 1895 letter to the *Astronomical journal* on the orbit of 70 Ophiuchi with a paper analysing the apparent systematic departures of the 88-year-period binary from the orbit given earlier by Schur and from one recalculated by See which included more recent observations. He confirmed that the most likely explanation was an unseen satellite of the companion, whose period he revised to approximately 36 years. He confidently stated that the nature of the residuals between observed and computed positions "... would be a necessary consequence of the orbital motion of the visible companion about the common center of gravity, and may be said to establish completely the reality of that phenomenon".[12]

In the 15 May 1899 issue of the *Astronomical journal* Forest Ray Moulton, who had been a graduate student of See's at the University of Chicago (and had not yet been awarded his Ph.D.), published a paper which showed that the postulated dark satellite could not exist. On the basis of the solution of the restricted three-body problem, Moulton proved that the orbit of such a satellite would be highly unstable.[13] He pointed out that Eric Doolittle, another former student who had performed most of the calculations for See's paper, had in the meantime calculated a new orbit for 70 Ophiuchi which represented the observations reasonably well without assuming the existence of a third body.[14]

See could have considered this disclosure just a temporary setback, as double star work is replete with examples of misidentifications of single stars or false conjectures of additional components.[15] However, he attempted to evade the charge of coming to an erroneous conclusion. "Those who will examine my original papers in *A. J.* 358, 363", he wrote to the journal in response, "will see that I foresaw from the first the difficulty of securing stability, and that while I assigned the unseen body to the companion, ... I never entertained any very decided view as to which star the dark body attended".[16]

The *Astronomical journal* did not print the bulk of See's letter, so it is unknown what additional claims he made on his behalf. But from their appended note it is clear that the *Journal*'s editors felt that See was obscuring the issues:

> Dr. See's remarks were transmitted to Mr. Moulton to afford him the opportunity, if he desired, to reply; but he declines, on perfectly correct and dignified grounds, to do so; his essential and sufficient reason being that the statements are not in accordance with the facts....
>
> The present is as fitting an opportunity as any to observe that heretofore Dr. See has been permitted, in the presentation of his views in this journal, the widest latitude that even a forced interpretation of the rules of catholicity would allow; but that hereafter he must not be surprised if these rules, whether as to soundness, pertinency, discreetness or propriety, are construed within what may appear to him unduly restricted limits.[17]

The *Journal*'s note, with its implicit threat to censor future contributions by See, was interpreted as banishing him from the publication. Such an outright act was almost unprecedented for a scientific journal, and represented a severe reverse for someone in the process of making a name for himself as an astronomer. See continued to use the *Astronomische Nachrichten* as a vehicle for publishing detailed technical papers (mostly in English), and *Popular astronomy* and other, wider-circulation magazines for more popular articles on his work. If the articles he wrote were sometimes self-serving, they were also widely read by a public anxious for information on the latest developments in science.

FIG. 3. Captain See in his office at the small U.S. Naval Observatory at Mare Island, California. He is shown examining the plans of William Herschel's 40-ft reflector. Working up to eighteen hours a day, in this room the indefatigable See wrote thousands of pages expanding upon his scientific theories. From Webb's *Brief biography* (ref. 1), third plate following p. 82.

With the Navy

See was able to take full advantage of the 26-inch refractor at the Naval Observatory, making micrometrical measurements of asteroids, faint satellites, and planetary diameters. Although he did not publicly state so at the time, he later claimed that he observed faint belts on Neptune and glimpsed crater-like markings on Mercury during this period.[18] He also participated in the international effort to redetermine the solar parallax by observing the asteroid Eros at its close approach to the Earth in 1901.[19]

However, See did not take well to the highly organized program of work at the Naval Observatory, and the tension and overwork he experienced there contributed to a "breakdown" in 1902.[20] See himself described symptoms of stomach trouble and insomnia, due to "a severe internal catarrhal condition approaching a mild form of appendicitis".[21] He was to suffer similar bouts off and on for several years.

Following a six-month leave of absence to recuperate, See was transferred to the U.S. Naval Academy at Annapolis, where he was an instructor in mathematics for one semester. He did not fully recover from his illness there, and so was transferred once more in November 1903, this time to be placed in charge of the Naval Observatory at Mare Island, near Vallejo, California. The more healthful west coast climate agreed with him, and he was to remain there for the rest of his life.

The Observatory, however, was little more than a chronometer and time station attached to the huge naval shipyard, and had no telescope larger than a 5-inch refractor. It became clear to See that if he was to make further discoveries, it would not be as an observational astronomer. Instead, he was to turn to theoretical work (Figure 3), with a view toward making the work the core of vol. ii of his *Researches on the evolution of the stellar systems.*

The work proceeded only slowly. See's Navy superiors at Mare Island, apparently pleased to have an astronomer of some stature at their little observatory, allowed him much leeway in what he chose to investigate. Working up to eighteen hours a day, he was often sidetracked when some area captured his interest — particularly if he thought his work on the subject would likewise capture *public* interest.

Thus, after the great San Francisco earthquake of 1906, See embarked on a two-year study to attempt to shed light on the origin of such events. He concluded that the main cause of earthquakes was leakage of the ocean floor. Coming into contact with lava beneath the sea bed, the leaking water generated steam, which expelled the lava landward to produce the upheaving of the Earth's crust during a coastal earthquake. See also alleged that many repetitions of this process over time had been responsible for the formation of mountain ranges. He expounded these views most thoroughly in hundreds of pages in the *Proceedings* of the American Philosophical Society of Philadelphia.[22]

Professional geologists in the main were not impressed by See's incursion into their field, and except for a few European investigators tended to ignore his work.

In a letter to *Science*, See proclaimed that "I have proved that mountains are formed by the sea, ... and ... that the oceans are gradually drying up and the land increasing".[23] He furthermore stated that his arguments had been so convincing that "... geologists have discreetly kept silent". In response, a noted Yale geologist, Joseph Barrell, wrote to *Science* that ocean leakage was an old idea, and that See's work was merely

> ... a dressing out of this old and, to say the least, doubtful hypothesis with many speculative additions, with much repetition of well-known facts and theories, and with specific applications in such frequent discord with modern teaching of the principles of physiography and known details of geologic structure and history, that no geologist has felt called upon to comment.[24]

But See was not deterred by attacks, and continued to explore other fields while working on plans for his *Researches*. He travelled and lectured widely, and spent most summers at his childhood home in Missouri. On one such visit, in June 1907, he married Frances Graves, a physician's daughter, in Montgomery City. See was 41. The couple were to have one surviving son, Ernest, although another son died in infancy.

The Capture Theory of Cosmical Evolution

When See returned to astronomical subjects, he took up the popular topic of solar system evolution. He had for years doubted the long-held eighteenth-century Laplacian hypothesis that the gravitationally contracting solar nebula had deposited gaseous rings at the orbital radii of the planets, and that these rings subsequently had condensed to form the planets themselves. Forest Ray Moulton had shown in 1900 that this idea was not consistent with the Sun's current rotation rate, on the basis of the laws of conservation of angular momentum.[25] By the close of the first decade of this century, most astronomers had come to reject Laplace's hypothesis, but there was no consensus in favour of a theory to replace it.

In 1904 Moulton and T. C. Chamberlin, a geologist at the University of Chicago, developed the *planetesimal hypothesis*, which proposed that nebulous matter surrounding the early Sun condensed into small solid bodies called planetesimals, which eventually aggregated through collisions to form the planets.[26] Although they claimed it was not required by the theory, they favoured as the origin of the solar nebula tidal disruption of the Sun by an encounter with a passing star. Along with many astronomers of the day, Moulton and Chamberlin came to believe that the stunning time exposure photographs of spiral nebulae coming out of Lick Observatory and other places represented direct evidence of forming solar systems. (The Shapley–Curtis debate touching on whether the spirals were nearby nebulae or distant galaxies was still sixteen years in the future.) It was thought that the spiral's nucleus was condensing into a star like our Sun, while the knots and clumps of gaseous matter arrayed along the spiral arms were the infant planets and satellites.

See at first strongly opposed this interpretation of the nebula photographs, writing in a 1906 *Popular astronomy* article with characteristic assertiveness: "The speculations on spiral nebulae have been decidedly overdone, and it is time to call a halt. There is not the slightest probability that our solar system was ever a part of a spiral nebula, and such a suggestion is simply misleading and mischievous."[27]

But See changed his mind, apparently feeling that he needed the evidence of the suggestive photographs to make a case for his own developing theory. He was to call his picture of solar system formation the *capture theory* after its central tenet: that instead of being separated off from the Sun the planets had been captured gravitationally from where they had formed farther out in the solar nebula. Their initially eccentric orbits had been reduced in size and circularized by the resisting action of the nebular gas surrounding the Sun. In a similar way, the planetary satellites originally rotated about the Sun but were captured by the larger planets.[28]

See developed these ideas, some of which originated with earlier investigators, over a period of several years (Figure 4), and planned to showcase them in his follow-up volume of the *Researches*. He decided to give a preview of this portion of the work at a January 1909 meeting of the Astronomical Society of the Pacific at Chabot Observatory in Oakland, California. However, he developed full-blown appendicitis about three weeks prior to the meeting, and lay in the hospital for sixteen days before his doctors felt it was safe to operate.

Thus, T. J. J. See was not even present at the event he was to later characterize as one of his life's greatest triumphs. His paper was read before the open meeting by Russell T. Crawford of the University of California at Berkeley, the Society's secretary. The front page of one section of the Sunday *San Francisco Call* on the following day declared "Prof. See's Paper Creates Sensation at Meeting of Astronomical Society",[29] while an article in the *San Francisco Examiner* was headlined "Scientists in Furore over Nebulae".[30] Over the next few days the opinions of astronomers who were present at the meeting, as well as those of others who were not, were solicited by the San Francisco newspapers. Charles Burckhalter of Chabot Observatory was quoted as saying, "Professor See's theory seems to me more reasonable than any other that has yet been advanced.... I believe that See has not solved the whole mystery of the universe, but he is enthusiastic in his discovery, which is a great one."[31] Crawford himself thought See's theory was plausible, but was basically undecided "until I am able to give a closer examination to the facts that Professor See has compiled".[32] John Brashear, the well-known astronomical instrument maker, issued a signed statement from Pittsburgh that he could not tell from newspaper accounts exactly what See was proposing, but that "there is little doubt Dr. See's paper ... should be given much weight, because he is a man whose researches and mathematical studies entitle him to a hearing among his scientific colleagues".[33]

Interviewed in his sick bed at Mare Island's naval hospital, See asserted with little modesty, "I am fairly convinced that I have solved the problem and that no astronomer in the future will be able to disturb the chain of reasoning and

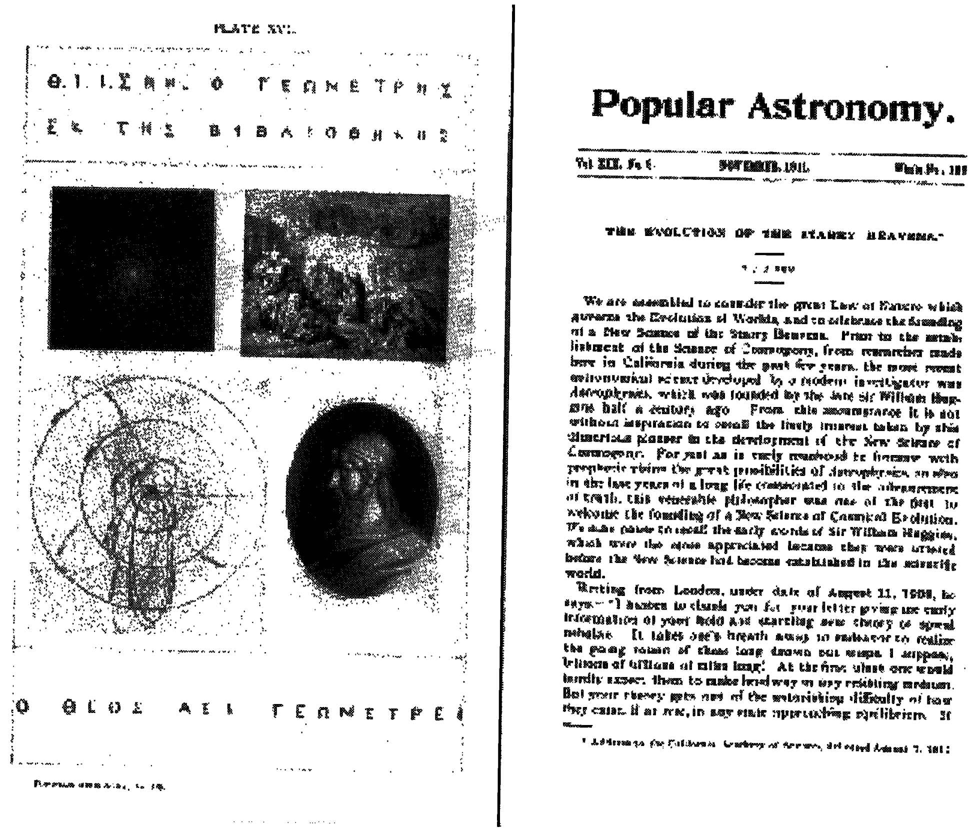

FIG. 4. One of the sixty or so articles in *Popular astronomy* by which See established his firm reputation with the public. The frontispiece is a copy of a bookplate presented to him by California admirers, and depicts (clockwise from upper left): M74; Kaulbach's painting of Homer and the Greeks; Plato; and the solar system. The Greek caption at the top reads: "T. J. J. See, the geometer outside the library", while that at the foot quotes the Platonic aphorism, "The Deity always geometrizes". From *Popular astronomy*, xix (1911), 528–9.

mathematics that I have worked out".[30] A five-page paper summarizing his theory appeared in the *Astronomische Nachrichten* on 24 February 1909, but it contained no such mathematical chain.[34] This must have been a disappointment to those in the astronomical community who seemed willing to listen, but it appears to have mattered little to See. Rather, he seemed to relish the attention he was getting, whether his peers embraced his hypotheses or not.

While his summary papers were at least serious and reasoned, See apparently could not resist a desire to be recognized as a prophet: in a postscript submitted to the *Astronomische Nachrichten* nine days after his summary paper, he predicted "... that there is certainly one, most likely two, and probably three unknown planets beyond Neptune".[35] On the basis of unpublished work he had done in 1904, he placed the nearest of the new bodies at a radius of 42.25 AU from the Sun, and the others at 56 and 72 AU. He recommended a photographic search of a specific region of the ecliptic for the first body, which he tentatively named "Oceanus". See never revealed how he arrived at his predictions, but it seems most likely that he applied some graphical technique to observed perturbations of Neptune. There is no evidence that anyone seriously sought his postulated new planets.

In addition to his local exposure, See sought a wider audience for his latest ideas. In a letter of 28 May 1909 to *Science* he attacked "... the inconsistent and purely destructive criticisms recently put forth at Chicago by Chamberlin and Moulton.... Most of the recent speculations on cosmogony are not worth the paper they are written on; and yet some of them have been published by the *Astrophysical journal* and the Carnegie Institution." He went on to promote his own competing theory:

> It is only fair to say that no constructive results of consistent character had been reached on this subject till my own investigation was completed last year, of which an account is given in Astronomische Nachrichten.... As I have worked on this subject uninterruptedly for twenty-five years, I am prepared to speak with some degree of authority.[23]

Forest Ray Moulton had been silent during the earlier debate over See's theory, but the *Science* letter represented direct and personal criticism. In a response published in the 23 July issue of *Science*, he accused See of "extravagant pretensions" regarding his (See's) background in cosmogony (as cosmology was then called), pointing out that See's "alleged twenty-five years of uninterrupted work" in the field had apparently resulted in only two published papers. He also castigated See's claim of consistency, contrasting his 1906 claim that there was "not the slightest probability that our solar system was ever part of a spiral nebula" with his latest paper's statement that "The solar system was formed from a spiral nebula". In fact, Moulton averred that

> In See's paper there are only two points of divergence from the ideas fully developed by Professor Chamberlin and myself. The first is that spiral nebulas have their origin in "the meeting of two or more streams of cosmical dust". The second is that satellites are captured bodies.[36]

Moulton strongly implied that See had deliberately adapted portions of the planetesimal hypothesis to his own purposes without giving credit to its authors.

Moulton's accusations were printed on the front page of the *San Francisco Call*, under the headline "Astronomers Warring — Moulton Exposes See" and the subheading "Chicago Professor Says Mare Island Observer Stole Discarded Theories".[37] See responded the following day that the Chicago professors were "exercised" because See's researches had been accepted by the scientific world and had completely upset several years' worth of their work.[38] He also maintained in a letter of reply to *Science* that "I have since developed a rigorous proof ... of just how the capture of satellites comes about".[39] The proof was not forthcoming, and Moulton's conflict with See continued to smoulder for nearly three more years.

Vol. ii of See's *Researches*, subtitled *The capture theory of cosmical evolution*, appeared late in 1910, running to some 735 oversize quarto pages. Beautifully printed (again at his own expense) and profusely illustrated, it presented a review of many topics in celestial mechanics and drew together much of See's work since vol. i, but it also contained much that was new. In See's world view, most of the phenomena of nature could be explained by suitable application of his capture theory and attendant hypotheses. Besides his treatment of solar system evolution, some of his key points were as follows:[40]

The Moon's craters were caused by the impact of other, smaller satellites of the solar system, rather than by volcanic action.

The Earth and other planets once had craters like the Moon's, but these have since been obliterated by water and atmospheric erosion.

Direct (west to east) planetary rotation resulted from the cumulative effect of collisions with smaller bodies, as did the tendency of a planet's equatorial plane to coincide with its orbital plane about the Sun.

Comets originate in the outer reaches of the remnant solar nebula, and periodic comets are those that have been gathered in by the gravitational action of Jupiter.

In addition to gravitational attraction, repulsive forces are at work in the universe, in the form of gas and dust continuously being expelled from stars.

The matter expelled from stars tends to aggregate in vacant regions toward the poles of the Milky Way, which explains why spiral nebulae are more numerous in these directions.

After stars form out of the spiral nebulae, they eventually drift back into the plane of the Milky Way.

Diffuse nebulosity results when the gas expelled from stars is too tenuous to condense into more compact form.

Collisions of smaller bodies are the cause of most of the light of nebulae.

All single stars have planetary systems revolving about them.

Double and multiple stars are formed when a large spiral nebula divides into two or more parts, which condense separately.

Star clusters evolve from incredibly vast nebulae, and from the gathering in of neighbouring stars under the clustering power of gravitation.

Variable stars occur when the orbits of attending dark companions cause them to eclipse the light of the primary star, or occasionally when a companion gives off light due to nebular resistance encountered when closest to the primary.

Novae result from the conflagration produced when a planetary body collides with its central star.

The Milky Way is much more extensive than previously thought; extinction of light by cosmic dust is so great that starlight from the farthest distances is cut off.

Life is a general phenomenon of the physical universe, and almost as universal as matter itself.

Some of See's ideas in the book were quite original and even prescient of more modern theories, but many more were speculations presented with little justification, and others were borrowed from his contemporaries. Still, he could fairly claim that he had unified many of these concepts for the first time.

The astronomical community's reaction to See's tome was reasonably polite, although some continued to be disappointed by the lack of sufficient evidence for many of the author's conjectures. His publisher issued a circular quoting about two dozen scientists' comments on the work, some of which must be taken with a grain of salt (since they were undoubtedly solicited in exchange for a free copy). A few were possibly left-handed compliments, such as that of the celestial mechanics specialist, E. W. Brown of Yale: "The beautiful printing and magnificent illustrations are a very unusual feature, and make the book a welcome addition to any library, quite apart from the contents."[41]

If some astronomers were equivocal in expressing their support, See himself apparently had no qualms about claiming it. To *Popular astronomy* and elsewhere he submitted an article asserting that E. W. Brown had verified his ideas of the capture of satellites,[42] and in other articles he stated that the French mathematician Henri Poincaré had adopted some material from See's book into a course of lectures in Paris.[43]

Forest Ray Moulton, however, was in no way equivocal in his reaction to See's book. In an article in the February 1912 *Popular astronomy* entitled "Capture theory and capture practice", Moulton demonstrated that an important section of the work had been "captured" from Moulton's 1902 book *Introduction to celestial mechanics* without credit.[44] The article reprinted three pages of See's book and the corresponding parts of Moulton's text face-to-face to show that except for changes of notation the equations involved were identical. The failure to give specific credit might have been attributed to oversight — the chapter was after all a review of the three-body problem and not claimed to be original, and See had referenced Moulton's book in the second chapter previous (his only such mention of it in the *Researches*) — but Moulton also asserted that See's discussion of the equations showed a serious lack of understanding of the fundamentals of celestial mechanics. Moulton claimed that equations were misused, illustrations misdrawn, and important concepts played havoc with. The critique made numerous sarcastic references to See's immodest claims on behalf of the capture theory, especially the claims that Brown and Poincaré supported it, emphasizing that "these astronomers have not announced in their publications that they have taken such a position". As in some of his earlier attacks, Moulton appeared galled by the fact that See was garnering wide attention for a theory which he had developed largely from the efforts of others, without having mathematically derived a significant number of his own results. Moulton expressed contempt for "those who make books with shears".

See never again wrote for *Popular astronomy* (except for an obituary piece on a close astronomer friend in 1920[45]), although he had previously written some sixty articles and letters over twenty years. It does not seem likely that the magazine's editors "banished" him as had the editors of the *Astronomical journal*, for he was a popular contributor and the Moulton affair was just one black mark. Rather, See was probably incensed and hurt that the editors would print such a scathing and personal attack upon him.

A Growing Dichotomy

This crushing blow to his self-esteem served only to widen the gap between T. J. J. See's position within the professional astronomy community and his stature as perceived by the public at large. On the one hand, except for a modest core of supporters, astronomers remained cool toward the *Researches*; the work was seldom cited in professional papers. The public, on the other hand, was largely unaware of Moulton's highly technical critique, and knew little of See's humiliation within the scientific world. They saw his theories discussed in the *New York Times* and national magazines, as well as presented as the subject of editorials. In an era of expanding scientific discovery, scientists who could expound impressively on their ideas were held up to public adulation, and See was a grand example. In his naval captain's uniform (he was commissioned an officer in 1913), the six-foot four-inch, athletically built professor must have been an imposing figure on the lecture platform. At the time the public lecture was both a popular form of entertainment and an educational experience, and a riveting speaker could transfix an audience with the help of a lantern slide projector and never-before-seen astronomical photographs. If the speaker was not quite accepted by the scientific establishment, his listeners could probably convince themselves that they were witnessing the revelation of a startling new view of the cosmos.

In 1913 a longtime admirer and amateur astronomer from Independence, Missouri, William Larkin Webb, published the 300-page *Brief biography and popular account of the unparalleled discoveries of T. J. J. See*. The introduction declares:

> Professor See is universally recognized as the most intrepid and indefatigable of the explorers of Nature; and since the death of Poincaré and Sir George Darwin, in 1912, occupies easily the front place among living natural philosophers.[46]

Chapter after chapter cites See's numerous accomplishments, leading up to "the triumph of the Capture Theory". Of the acceptance of the latter the book is blithely optimistic:

> Considering the extremely revolutionary character of See's discoveries, it must be held that they have had a very favorable reception from the scientific world.... [As] time has elapsed it is noticed that acceptance of the results is general, and that acquiescence in See's conclusions becomes more and more universal.[47]

Considering the sometimes fawning prose in the biography, most reviews of the book were not overly unkind, although *The nation*'s review noted that it abounded in "parlous surfeit of superlatives". Less than one-half of the book actually describes events in See's life (the remainder reprints several of his papers and lectures), and *The nation* took the opportunity to poke fun at the hyperbole in the scientist's portrayal:

> The infant See, we are told, first saw the light on the 393d anniversary of Copernicus's birth, ... [and] showed himself "every inch a natural philosopher" by speculating on the origins of sun, moon, and stars at the tender age of two, never so much as dreaming that he should grow into a "little boy with methodical methods", and one day become "the greatest astronomer in the world".[48]

With considerable insight, the reviewer presented a more balanced view of the scientific world's actual reception of See's theories:

> During the past twelve years he [See] has pursued researches in universe building to which has not as yet been accorded that full acceptance which their author and his biographer seem to believe has been the case.... So far his revolutionary theories seem only in small part acceptable to his scientific contemporaries.

New Theory of the Aether

While See's astronomical views were at least treated with a modicum of respect, his ensuing researches into more fundamental physics provoked reactions approaching scorn. In April 1914 he announced to the press that he had discovered the cause of gravitation, thereby answering a question that had puzzled scientists since the days of Isaac Newton. He claimed that gravity results from particles being expelled at the speed of light on electrical streams from the millions of stars in the universe. The attractive force between two bodies is really only the apparent result of each body screening the other from the bombardment of these particles from all directions; since each body experiences fewer collisions from the direction of the other, they are forced together.[49]

Like many of See's earlier ideas, this one was essentially derivative, from hypotheses dating back two centuries. Natural philosophers in the time of Newton had developed the basic concept, but the scheme was most clearly spelled out in the "theory of ultramundane corpuscles" of George Louis Le Sage, published in 1818.[50]

See's alleged discovery was a secondary result of a discovery of the nature of light, which he announced at the same time. This hypothesis stated that light consists of egg-shaped particles of matter rotating about their shorter axes and bearing an electrical charge on the sharper ends. See claimed to have proved his theory, and overthrown the theory that light consists of waves transmitted through the ether.

Mainstream astronomers were quick to pronounce judgement on See's new theories. The *San Francisco Chronicle* submitted a summary of them to the University of California at Berkeley, where a committee of scientists that included the Lick

Observatory director, W. W. Campbell, met and issued a statement that "The whole thing is an unsubstantiated theory and as such cannot be dealt with by scientists. Until he shows proofs there can be no discussion. The scientific world will ignore the theory as it now stands."[51] See sent a 600-page account of his theory to the Royal Society of London in November 1914, but it was disregarded. In 1917 he privately published a revised version, which also received little serious attention.[52]

Between 1920 and 1926 the ever-indulgent *Astronomische Nachrichten* finally published See's re-revised theory as the "New theory of the aether" (which he apparently decided did exist after all), a series of eight papers comprising some 300 pages.[53] The theory asserted that gravity, electricity, and magnetism were all due to ether waves propagating at the speed of light. The ether was an extremely rarefied but enormously elastic gas, consisting of tiny particles called etherons, each one-billionth the size of an electron and travelling at a velocity 57% faster than light. Now, instead of his 1914 "screening" explanation, the attractive gravitational force between two bodies was explained in terms of helical electrodynamic waves emitted by each, as many rotating in a right-handed sense as in a left-handed sense. When the waves from one body encountered oppositely-rotating waves from the other, their interpenetration acted to undo the stress in the ether, so that the ether contracted and drew the bodies together.

In See's theory, virtually all of the phenomena of the universe — light, atomic forces, radioactivity, molecular forces, explosive forces, sunspots, lightning, auroras, magnetic storms, earth currents, etc., etc. — could be addressed in terms of waves in the ether. Thus, his was a "theory of everything" which could be called upon to explain physical happenings from the cosmic to the mundane.

Although See wrote hundreds of pages on these subjects, there was a serious lack of the substantive kind of proofs that the Berkeley committee had asked for. There were numerous historical anecdotes dating back to Laplace, Newton, or even the ancient Greeks; there were dozens of equations from Maxwell, Lord Kelvin, or Poisson, some of them irrelevant to the subject under discussion; there were trivial, hard-to-follow, or spurious arguments connecting the equations; but little was proved or even made to seem plausible. As an example of 'non-sequitur' reasoning, See deduced the velocity of etherons from a relationship he had worked out between the mean molecular velocity v and the velocity V of sound wave propagation in monatomic gases,

$$v = \pi/2V,$$

but he failed to justify why particles one-billionth the size of an electron should behave like a monatomic gas, or why electromagnetic waves should behave analogously to sound waves.[54]

In the last of the eight new papers See calculated the probability that his wave theory was a correct interpretation of nature to be as infinity to the 200th power to one ($\infty^{200} : 1$)![55] To his contemporaries the reasoning in the papers must have seemed to be only so much smoke and mirrors. As the Berkeley group had foretold, his new theory was not taken seriously, and went virtually undiscussed elsewhere in the scientific literature. (It may be speculated that the only reason the *Astronomische Nachrichten* continued to publish his papers is that its longtime editor, Hermann Kobold, was an old friend of See's.) Only in the popular press did his case for etherons get a hearing (Figure 5).[56]

Adversarial Physics

During this same period See began attacking Albert Einstein's theory of relativity, which he considered a "crazy vagary". Although many scientists of the day rejected relativity, See was especially vitriolic in his criticism. As most of the scientific world was applauding the confirmation of the theory's prediction for the bending of light rays passing near the Sun, based on solar eclipse observations in 1919 and 1922, See accused Einstein of having plagiarized the formula for this effect from the 1801 result of J. von Soldner, a German physicist, who had used Newton's corpuscular theory of light in his derivation.[57] See made much of the fact that Einstein had at first calculated a value for the magnitude of the deflection exactly one-half of his theory's final value, and accused Einstein of revising the theory in order to hide the error.[58]

Later on See claimed that Einstein had made more than eighty errors in his basic calculations on relativity theory. See entered into numerous debates on the theory with other scientists in articles and letters in the *New York Times* and elsewhere, and never missed an opportunity to attack Einstein or promote his own ether wave theory. The Cambridge astronomer Arthur S. Eddington branded See's criticism "all bosh and nothing to it",[59] but Einstein himself avoided the fracas. Einstein's only recorded comment regarding See came after his wife relayed a telegram to him in Holland containing the text of See's October 1924 claims to have demolished relativity: "Too bad about that long telegram from New York."[60]

See also rejected Edwin Hubble's idea of an expanding universe almost from the time it was first proposed in 1929. See contended that the observed increase in the red shift of extragalactic nebula spectral lines with distance was due not to motion away from the Milky Way galaxy but to physical changes of the light waves themselves. As interpreted by his theory, light waves lost energy in collisions with cosmic dust, and this loss produced a wavelength increase in proportion to the nebula's distance.[61]

See's many controversial ideas attracted substantial public attention and put him at odds with other scientists time and again. During this period he advanced a theory that sunspots were caused by meteors raining down upon the Sun's surface, directed by the gravitational influence of Jupiter and Saturn. He deduced that the eleven-year sunspot cycle period was a combination of the orbital periods of the two giant planets. He received considerable press coverage from his declarations that sunspots were responsible for climatic cycles of flood and drought on Earth.[62]

See also announced his interpretation of several intercontinental radio signal experiments which made news at the time. He claimed that radio waves travelled about 11% slower than light, bending around the Earth's surface during long-distance transmissions.[63] He also considered that radio waves travelled preferentially over the night


THE SAN FRANCISCO EXAMINER, SUNDAY, MARCH 11, 1928 K-5

HAS MYSTERY OF ETHER AT LAST BEEN SOLVED BY SCIENCE?

"I Have Calculated Its Density and Measured It s Velocity," Says Dr. See

Navy Astronomer Says That Ether Fills All Space and Calls It a "World Gas"

By GOBIND BEHARI LAL

Other Miracles

Fill All Space

Thinnest Gas

Move by Sound

By Calculation

Close to Electricity

SIR ISAAC NEWTON

JOHANN KEPLER

Gravitation and Lightning Among Miracles Attributed to Etherons by Scientist

Light Waves

Science Opposed

FIG. 5. A feature article on See's ether wave theory in the Sunday edition of the *San Francisco Examiner*, 11 March 1928, p. K-5. By this time See had largely stopped writing popular articles on his astronomical work, as there were numerous journalists only too willing to do this for him.

hemisphere rather than the day hemisphere because the ether is quieter at night.[64]

See retired from the Navy at age 64 in 1930, but he remained at Mare Island, now free to work on his theories full time. As he became increasingly strident in expressing eccentric views, scientific publications shunned his papers. Following the death of Hermann Kobold, even the *Astronomische Nachrichten* published no articles by him after 1938.

As the new physics gained acceptance by the scientific world and eventually by the public in the 1930s, See's views began to fall out of popular favour. Many scientists were especially relieved when controversy over relativity died down. Gradually, even the press stopped seeking out See's opinions on such topics.

See was to write eleven more volumes expanding on his ether wave theory. Issued under the collective title *Wave-theory!* between 1938 and 1952, these volumes were published as rotographic prints of typewritten copy, with equations written in and illustrations (Figure 6) drawn by hand.[65] In the preface to the first volume See compared his struggles to get the definitive version of his theory published to the Royal Society of London's hedging on the publication of Newton's *Principia*, which Halley eventually printed at his own expense.

Wave-theory! re-covered much of the ground gone over in the eight *Astronomische Nachrichten* papers, then went on to extend See's ideas to further physical phenomena and to scientific discoveries made since 1926. The arcane illustrations, most drawn by the author himself, bore more of a resemblance to those seen in metaphysical treatises of the period than to those in scientific works. Perhaps in an effort to appear modern, See "proved" in vol. v that the developing quantum theory was really just a branch of his wave theory, and "derived" the value of Planck's constant from his theory's basic principles. Never reluctant to go out on a limb, in vol. ix he calculated the age of the solar system as at least 10.44 trillion years, 3000 times the age estimated by other astronomers at the time.

Conclusion

But by the time of the last *Wave-theory!* volume See was 86 years old, and most of the scientific community had long ceased to take him seriously. For over thirty years few scientists bothered to criticize his work in a public forum, as if to do so would dignify it. See was debated mainly when he publicly attacked other scientists such as Einstein, and in their responses others would seldom mention See's own new theories.

An unhappy aspect of See's becoming virtually a pariah to the scientific world is the deterrent that this might present to later investigators with unorthodox or otherwise unpopular views. Fortunately, most scientists are willing to grant a degree of respect to those with opposing opinions, as long as these opinions have some rational basis. They are all too aware that today's unpopular theory can become tomorrow's fundamental truth. In addition, there is no permanent stigma attached to being wrong on some issue: Albert Einstein himself could not accept some of the basic principles of quantum mechanics, as evidenced by his famous quote, "God does not play

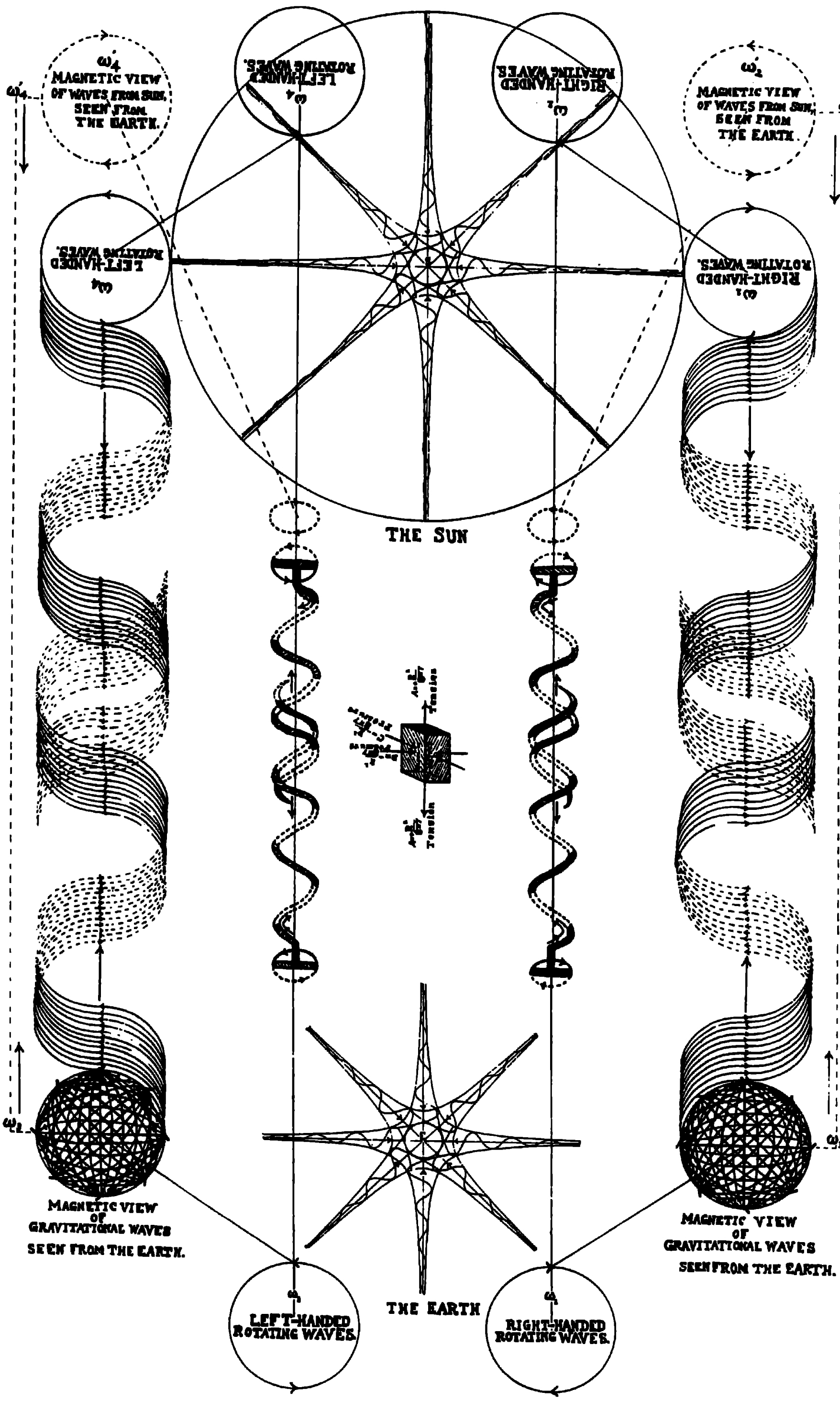

FIG. 6. Diagram illustrating See's theory of gravitation, from p. 27 of vol. i (1938) of his *Wave theory!* He saw the attraction between the Sun and Earth as arising from helical electrodynamic waves emitted by each. Interpenetration of waves rotating in opposite directions acts to undo the stress in the ether, so that the ether contracts and draws the bodies together.

dice". See became anathema because he insisted on taking his case to the public at large when he was unable to convince his peers. It was also considered questionable in an age of growing specialization to venture outside of one's field of training — as See did into geology, climatology, and numerous branches of physics.

Nevertheless, See's excesses should not be allowed completely to overshadow his accomplishments. His early double star work was in large part sound, and his observational skills were generally to be trusted. He was basically on the right track in promoting — although in many cases he did not originate — the ideas that the solar nebula was initially very cold, that stars constantly expel gaseous matter, that cosmic dust gives rise to extinction of distant starlight, that comets originate in the remnant outer regions of the solar nebula, and that the Moon's surface gives evidence of bombardment by small planetoids. In addition, capture phenomena, the central feature of See's ill-starred theory of solar system evolution, are today held by many astronomers to be responsible for a large proportion of planetary satellites (as well as for events such as the crash of Comet Shoemaker-Levy 9 into Jupiter in 1994). Finally, See deserves credit for pressing British scientific societies to publish Sir William Herschel's collected works; this resulted in the release of a beautiful two-volume edition in 1912.[66]

See died at Oak Knoll Naval Hospital in Oakland, California, on 4 July 1962, at the age of 96. Although he merited only a four-line obituary in *Science*,[67] the *New York Times* saw fit to print almost an entire column of biographical material.[68] It is sad that a promising astronomical career was sacrificed to See's need for public attention. Other than the controversy that he generated during his heyday, little is remembered today of his astronomical work. But it cannot be denied that he played a part in an exciting time for American science, when the man on the street was beginning to develop a real passion for the subject, and to assign hero status to some of its practitioners.

History has taken a divided view on Thomas Jefferson Jackson See. Much the majority opinion is expressed by the *Encyclopedia Americana*: "Although he had an unremarkable career and made no important contributions to science, See is remembered for his numerous controversial papers on astronomical subjects and his unfailing knack for espousing the discredited side of scientific theories."[69] Nonetheless, a revisionistic dissent is registered by the *Dictionary of scientific biography:* "See's numerous publications were considered unorthodox and were dismissed by scientists of his time. Many of his ideas, however, are in striking agreement with current theories."[70] While it is desirable that See's career be judged dispassionately, it is to be hoped that one day his more eccentric theories are not 'rediscovered' and made a part of the pseudo-science revolution!

REFERENCES

1. W. L. Webb, *Brief biography and popular account of the unparalleled discoveries of T. J. J. See* (Lynn, Mass., 1913).
2. See, for example, See's articles in *Astronomical journal*, xv (1895), 33, 54, 97, 101, 129, 155, 156, 161, 169, 171, 180, 188; xvi (1896), 17, 24, 41, 92, 125, 137; and in *Astronomische Nachrichten*, cxxxvii (1895), cols 159, 359; cxxxviii (1895), cols 25, 55, 149, 345, 369, 373; cxxxix (1896), cols 17, 63, 161, 163, 169, 341, 367; cxl (1896), cols 33, 35, 39; cxli (1896), col 7 (only first pages/columns here listed).
3. See, for example, See's articles in *Popular astronomy,* i (1893), 373; ii (1894), 103, 249, 289, 337, 385; iii (1895) 49, 178; iv (1896), 297, 533, 550 (only first pages here listed).
4. Webb, *op. cit.* (ref. 1), 59.
5. T. J. J. See, *Researches on the evolution of the stellar systems*: *Volume 1* (Lynn, Mass., 1896).
6. J. Ashbrook, "The sage of Mare Island", *Sky and telescope*, xxiv (1962), 193.
7. T. J. J. See, "Discoveries and measures of double and multiple stars in the Southern Hemisphere", *Astronomical journal*, xviii (1898), 181–7.
8. Ashbrook, *op. cit.* (ref. 6), states for example that W. H. van den Bos had pointed out that all of See's binary position angles for about a month had the same large systematic error, apparently due to a failure to check the micrometer's zero point each night.
9. T. J. J. See, "Perturbations in the motion of the double star F.70 Ophiuchi = Σ2272", *Astronomical journal*, xv (1895), 180.
10. T. J. J. See, "Recent discoveries respecting the origin of the universe", *Atlantic*, lxxx (1897), 484–92.
11. Ashbrook, *op. cit.* (ref. 6).
12. T. J. J. See, "Researches on the orbit of F.70 Ophiuchi, and on a periodic perturbation in the motion of the system arising from the action of an unseen body", *Astronomical journal*, xvi (1896), 17–23.
13. F. R. Moulton, "The limits of temporary stability of satellite motion, with an application to the question of the existence of an unseen body in the binary system F.70 Ophiuchi", *Astronomical journal*, xx (1899), 33–37.
14. E. Doolittle, "The orbit of F.70 Ophiuchi", *Astronomical journal*, xvii (1897), 121–2.
15. Subsequently, 6.5-year and 17-year perturbations were postulated by others for 70 Ophiuchi, but today these suggestions are discounted.
16. T. J. J. See, "Remarks on Mr. Moulton's paper", *Astronomical journal*, xx (1899), 56.
17. Editor's Note, *Astronomical journal*, xx (1899), 56.
18. Webb, *op. cit.* (ref. 1), 72, and the plate following p. 74.
19. Webb, *op. cit.* (ref. 1), 76.
20. Ashbrook, *op. cit.* (ref. 6).
21. Webb, *op. cit.* (ref. 1), 78.
22. T. J. J. See, articles in *Proceedings of the American Philosophical Society (Philadelphia)*, xlv (1906), 222–87; xlvi (1907), 191–299, 369–415; xlvii (1908), 157–275.
23. T. J. J. See, "Fair play and toleration in science", letter to editor of *Science*, xxix (1909), 858.
24. J. Barrell, "Fair play and toleration in criticism", letter to editor of *Science*, xxx (1909), 21.
25. F. R. Moulton, "An attempt to test the nebular hypothesis by an appeal to the laws of dynamics", *Astrophysical journal*, xi (1900), 103–30.
26. See, for example, T. C. Chamberlin and F. R. Moulton, "The development of the planetesimal hypothesis", *Science*, xxx (1909), 642–5.
27. T. J. J. See, "Significance of the spiral nebulae', *Popular astronomy*, xiv (1906), 614–16.
28. T. J. J. See, "On the cause of the remarkable circularity of the orbits of the planets and satellites and on the origin of the planetary system", *Popular astronomy*, xvii (1909), 263–72.

29. "Solar system was larger than now", *San Francisco Call*, 31 January 1909, p. 41.
30. "Scientists in furore over nebulae", *San Francisco Examiner*, 1 February 1909, p. 3.
31. "See's theory said to be reasonable", *San Francisco Call*, 1 February 1909, p. 12.
32. *Ibid.*
33. "Takes issue with See", *San Francisco Call*, 1 February 1909, p. 12.
34. T. J. J. See, "On the cause of the remarkable circularity of the orbits of the planets and satellites, and on the origin of the planetary system", *Astronomische Nachrichten*, clxxx (1909), cols 185–94.
35. T. J. J. See, Note to above paper, *Astronomische Nachrichten*, clxxx (1909), col. 194.
36. F. R. Moulton, "Remarks on recent contributions to cosmogony", letter to editor of *Science*, xxx (1909), 113–17.
37. "Astronomers warring — Moulton exposes See", *San Francisco Call*, 4 August 1909, p. 1.
38. "See says Moulton was only menial", *San Francisco Call*, 5 August 1909, p. 2.
39. T. J. J. See, "Geology and cosmogony", letter to editor of *Science*, xxx (1909), 479–80.
40. T. J. J. See, *Researches on the evolution of the stellar systems*: *Volume 2. The capture theory of cosmical evolution* (Lynn, Mass., 1910).
41. Webb, *op. cit.* (ref. 1), 246.
42. T. J. J. See, "Professor E. W. Brown's verification of the capture of satellites", *Popular astronomy*, xix (1911), 422–5.
43. T. J. J. See, "The evolution of the starry heavens", *Popular astronomy*, xix (1911), 529–47.
44. F. R. Moulton, "Capture theory and capture practice", *Popular astronomy*, xx (1912), 67–82.
45. T. J. J. See, "Historical notice of John Nelson Stockwell of Cleveland", *Popular astronomy*, xxviii (1920), 565–84.
46. Webb, *op. cit.* (ref. 1), p. viii.
47. *Ibid.*, 248.
48. "Professor See", review of *Brief biography and popular account of the unparalleled discoveries of T. J. J. See*, *The Nation*, xcviii (1914), 307–8.
49. "Dr. See solves gravity puzzle", *San Francisco Examiner*, 25 April 1914, p. 8.
50. *Traité physique mechanique par George Louis Le Sage*, ed. by P. Prévost (Paris, 1818).
51. "Want proofs before discussing discovery", *San Francisco Chronicle*, 25 April 1914, p. 13.
52. T. J. J. See, *Electrodynamic wave-theory of physical forces: Volume 1* (Lynn, Mass., 1917).
53. T. J. J. See, "New theory of the aether", *Astronomische Nachrichten*, ccxi (1920), cols 49–86, 137–90; ccxii (1920), cols 233–302, 385–454; ccxiv (1921), cols 281–359; ccxv (1922), cols 49–138; ccxvii (1922), cols 193–284; ccxxvi (1926), cols 401–97.
54. See, for example, the third of these papers (ref. 53), col. 233.
55. See the eighth of these papers, col. 493.
56. "Has mystery of ether at last been solved by science?", *San Francisco Examiner*, 11 March 1928, p. K-5.
57. T. J. J. See, "Capt. See scores Einstein", letter to editor of *New York Times*, 1 May 1923, p. 20.
58. "Prof. See declares Einstein in error", *New York Times*, 14 October 1924, p. 14.
59. "Denies error in relativity", *New York Times*, 16 October 1924, p. 12.
60. "Einstein ignores Capt. See", *New York Times*, 18 October 1924, p. 17.
61. T. J. J. See, *Wave-theory!*, v (Lynn, Mass., 1940).
62. "Meteoric rain on Sun blamed for heat wave", *San Francisco Chronicle*, 9 July 1921, p. 1.
63. "Finds the radio wave slower than light; around the globe at 165,000 miles a second", *New York Times*, 12 May 1924, p. 1.
64. T. J. J. See, "Radio waves by night", letter to editor of *New York Times*, 11 September 1924, p. 22.
65. T. J. J. See, *Wave-theory!*, i–xi (Lynn, Mass., 1938–52).
66. Webb, *op. cit.* (ref. 1), 268.

67. *Science*, cxxxvii (1962), 272.
68. "Capt. T. J. J. See, Astronomer, 96", *New York Times*, 5 July 1962, p. 23.
69. S. D. Gossner, "See, Thomas Jefferson Jackson", *Encyclopedia Americana* (New York, 1995), 515.
70. R. A. J. Schorn and L. D. G. Young, "See, Thomas Jefferson Jackson", *Dictionary of scientific biography*, xii, 280–1.