

CONTENTS

- Prologue: May 29, 1919 1
- 1 The Experiment That Weighed Light 6
- 2 Eclipses 19
- 3 Two Pacifists, Einstein and Eddington 31
- 4 Europe in Its Madness 56
- 5 Preparations in Time of War 92
- 6 The Opportunity of the Century? 105
- 7 Tools of the Trade 125
- 8 The Improvised Expedition 142
- 9 Outward Bound 152
- 10 Through Cloud, Hopefully 172
- 11 Not Only Because of Theory 181
- 12 Lights All Askew in the Heavens 226
- 13 Theories and Experiments 252
- 14 The Unbearable Heaviness of Light 288
- 15 The Problem of Scientific Bias 328
- Epilogue: Where Are They Now? 341

Acknowledgments 353

Appendix 357

Notes 367

Bibliography 375

Index 387

1

The Experiment That Weighed Light

Although Eddington and Dyson collaborated closely in organizing the expeditions of 1919, the two expeditions remained quite separate. Two different English observatories were involved, Dyson being director of one and Eddington of the other. Conscious of the vagaries of the weather, they chose different locations and hoped that the results from each site would confirm each other. Eddington, who was then one of England's most famous astrophysicists, personally led one expedition. He took with him a Northamptonshire clockmaker named Edwin Turner Cottingham to keep their instruments in working order while Eddington himself conducted the experiment. The Royal Observatory at Greenwich mounted the second expedition. As director of that observatory, Frank Dyson sent two of his assistants, Andrew Claude de la Cherois Crommelin and Charles Rundle Davidson. They would each operate a different instrument, for some further redundancy. Dyson would oversee their data analysis after their return to England. Dyson and Eddington, working together, had hatched the plan and raised the funds, and together they would reveal the results later that year at a packed

meeting of two of Britain's leading scientific societies. If May 29 is an important date in the history of science, then November 6, 1919, is also famous. The atmosphere that day was like that of a Greek drama, in the words of one participant. As one might expect in a Greek drama, some people greeted the news of the eclipse results with excitement and others with despair. The arguments as to the interpretation of the data still continue.

Just as the expeditions were mounted by two different observatories working closely in concert, two different societies collaborated in sponsoring them. The Royal Society of London, founded in 1660 at Gresham College in London, is England's premier scientific society. For centuries it has brought scientists of all fields together to discuss their work. In the nineteenth century, science diversified, and the number of scientists greatly increased. As different scientific disciplines grew, the scientists formed various professional societies. One of the oldest is the Royal Astronomical Society (usually known as the RAS), which was founded as the Astronomical Society of London in 1820 and took its current name in 1831. Both societies are still very active today, publishing scholarly journals and meeting regularly to hear talks by distinguished scientists.

Throughout their history, these societies have played an important role in sponsoring scientific research, especially where considerable expense is involved. Expeditions for the purpose of scientific discovery are a classic example of where such sponsorship is necessary. The late nineteenth century saw a revolution in astronomy that gave birth to the field of astrophysics. The experimental techniques of physics, including the use of spectroscopy and photography, began to be applied to astronomy, transforming how astronomers did their work. These new techniques increased interest in eclipses of the Sun, and in 1884 the RAS founded the Permanent Eclipse Committee to oversee planning for expeditions to observe solar eclipses.¹

It was found helpful for the RAS committee to collaborate with a similar eclipse committee organized by the Royal Society to plan an expedition to West Africa in 1893 (Pang 1993). In the wake of that expedition, and so the two societies could collaborate in the future, the Permanent Eclipse Committee became, in 1894, the Joint

Permanent Eclipse Committee, or JPEC. By 1919 JPEC therefore already had a quarter century of experience in organizing eclipse expeditions. Its chair at that time was Dyson, and it was he who played the leading role in mobilizing resources on behalf of the two expeditions that year. The famous joint meeting of the Royal Society and the RAS was held specifically to hear JPEC's report on the expeditions of 1919.

The astronomers of 1919 thus were blessed to control an institutional framework with the power to mount such expeditions. They would need all the help they could get. They were beset with troubles, most importantly those of war. World War I ended just barely in time (in November 1918) for the expeditions to travel at all. The measurements to be made were much more challenging than those typically attempted during an eclipse. They would attempt to measure the shifts in position of the stars close to the Sun due to the Sun's gravitational pull on the starlight as it passed close by the Sun on its way to Earth. This was what Einstein had predicted. But the amount of the deflection of starlight he had predicted was such that the shift of a star's position, as measured on a photographic plate, would be less than the width of the star's image on the plate. Thus, the effect was quite tiny and would only be measurable with the most sensitive handling of the instruments during the eclipse and the most careful measurements afterward. Even then it would be possible to distinguish the true deflection of starlight from effects caused by changes in optical magnification of the telescope only with long and tedious calculations. These calculations would be performed at Greenwich by *computers*, a word that at that time referred to humans whose job was to crunch numbers using pen and paper only, without the aid of electronic calculating machines.

Fortunately, the science of astrometry, as the measurement of stellar positions is called, had greatly advanced in the decades before 1919. During this era, the distances to a large number of nearby stars were measured for the first time. This was done by very carefully determining tiny shifts in the positions of stars (their *parallax*) between different seasons of the year, due to the Earth's motion. Both Dyson and Eddington had carried out such work when they

began their careers in astronomy. They had the experience, but they had previously always performed such exacting measurements in optimal conditions. They had used telescopes permanently and appropriately mounted in an observatory, with the equipment needed for data analysis all readily on hand and on-site. Most important, if there was a problem with any of their work, they could simply take a new image on a suitable night and begin again. In 1919, they would have no second opportunities to get things right. They would have no chance to profit by any mistakes they would make—only to regret them.

Some events in astronomy can be missed in the blink of an eye. A transit of Venus occurs only twice in every century or so. But anyone on one whole hemisphere of the globe can observe such a transit, so even if one observer is clouded out or suffers an equipment malfunction, others will witness it. The implacability of scientific advance is enabled by repeatability. Scientists tinker and modify with each new trial, and the expectation is that over time the precision of measurement will relentlessly improve. Take away the ability of scientists to demonstrate their persistence and they become more mortal. They are prone to the vagaries of fate that bedevil most human endeavors. The caprice of weather or of human fallibility may ruin any amount of careful preparation.

Given everything they had to contend with and the limitations imposed by scarce equipment and limited preparation time, the men of 1919 seem to have been very fortunate to get the results they did. Whether they really achieved the measurement precision they claimed has often been doubted. Whether they really overthrew Newton and vindicated Einstein has been questioned. One even sometimes hears the word *fraud* spoken in connection with their work. This is partly because their experiment was repeated many times over the succeeding decades without the level of precision ever noticeably improving. Surely, this suggests something suspicious. Can it be that nothing was learned from one expedition to another? We have to remember that few people were fortunate enough to repeat the experiment. When it comes to eclipse experiments, persistence is frequently rewarded with disappointment. Einstein's closest colleague in astronomy, Erwin Finlay Freundlich, went on at least six expeditions to

test his mentor's theory and was able to observe totality only once. There is plenty of reason to call Dyson and Eddington lucky, but why should they also be called frauds? The answer is that Eddington was a renowned champion of Einstein's theory. He was quite frank in admitting his expectation, or at least his hope, that the theory would be confirmed. Many people have accused him of bias and have even claimed that he had ulterior motives that went beyond the science of the case. Could it be that this most famous of experiments was decided by someone who had made up his mind beforehand? What does this tell us about the way science is conducted? Are the expense and painstaking care of complex experimentation simply wasted efforts in which scientists merely contrive to confirm their expectations? The expeditions of 1919, it turns out, have something to tell us not only about the history of physics but also about the way science itself works.

Two Astronomers: Eddington and Dyson

Arthur Stanley Eddington was born in 1888 into a Quaker family in a scenic part of the North of England, the Lake District. His father was a school headmaster who died when Eddington was still an infant. His mother moved to the West of England, to Weston-super-Mare, and brought up Eddington and his sister in genteel poverty. Eddington remained very close to his mother and his sister, to whom he was known as Stanley, throughout his life. He was a brilliant student and availed himself of a series of scholarships to attend Owens College (now the University of Manchester) and then Trinity College, Cambridge. In 1904 he became the first student to become Senior Wrangler in only his second year at Cambridge. The title of Senior Wrangler is awarded annually to the student achieving the best mark in the mathematics degree exams, which is typically of three years' duration.

After briefly working at the famous Cavendish laboratory in Cambridge, Eddington went to the Greenwich observatory as chief assistant to the director, who is known as England's Astronomer Royal. His work there resulted in a paper that received Cambridge's Smith's



FIGURE 1. Frank Watson Dyson and Arthur Stanley Eddington, in a photograph probably taken at an International Astronomical Union meeting in Cambridge, Massachusetts, in 1932. Dyson and Eddington had much in common, including their religious and educational backgrounds, career paths, and passion for astronomy. They cooperated brilliantly in the planning, execution, and subsequent presentation of the eclipse expedition and its results. This photograph appears to have been taken just after a more formal one by the same photographer. Here, Dyson has turned animatedly toward Eddington, who smiles in response. (Courtesy of the Meggers collection of the Emilio-Segrè Visual Archive.)

prize in 1907, and this led to him being elected a fellow of his old Cambridge college, Trinity. In 1913 he succeeded Charles Darwin's son George as the Plumian Professor of Astronomy and the next year was made director of the Cambridge Observatory. His rapid ascent to the heights of British science is very reminiscent of the path followed more than a decade previously by his colleague Dyson.

Frank Dyson's background and career were very similar to Eddington's. It is not hard to see why the two men should have gotten along well. Like Eddington, Dyson was religiously nonconformist. His father was a Baptist minister. Although born in Leicestershire in 1868, he mostly grew up in Yorkshire, from where the Dysons had originally hailed. Like Eddington, he was a Trinity student at Cambridge. He was Second Wrangler in 1889, compared to Eddington's achievement of Senior Wrangler fifteen years later. Both men won the Smith's prize (Barrow-Green 1999) and were awarded fellowships at Trinity as a result. Both began their astronomy careers in the important position of chief assistant at the Royal Observatory at Greenwich. In fact, Eddington succeeded Dyson in this position when the latter went off to Edinburgh as Astronomer Royal for Scotland. Of course, the odd similarity of his résumé with Eddington's mostly reflects the well-trodden path of the best and brightest coming up through the Cambridge system. Here were two talented and highly intelligent men who went to the forefront of their profession at each step on the ladder.

Because of the difficulties posed by wartime conditions, there is a mildly improvised air about the 1919 eclipse expeditions. Compromises were made in equipment and personnel since many instruments and people were simply not available because of the war. But in its two leaders, the expedition was blessed with men who were superbly qualified for the task at hand. If they were self-selected, it was because they were among the few who clearly saw the need for such a test at the time. As we shall see, it would have been hard to find two people with more experience of differential astrometry to undertake the experiment, especially since this was a very new field in which Dyson and Eddington were pioneers.

Although their backgrounds were similar, their careers diverged in one sense. Dyson reached the heights of astronomy as England's Astronomer Royal and immersed himself in observational work and in the organizational tasks of the leader of England's astronomical community. Eddington, though also an observatory director, was a Cambridge professor continuing the Cambridge tradition of theoretical physics. Even if he applied that physics training primarily to astronomical problems, he remained at the forefront of European theoretical physics, so he brought a unique double perspective to bear on the problem of testing Einstein's theory of general relativity. On the one hand, he understood the theory as well as anyone did; on the other hand, he had the observational skills to go out and test it, since this could only be done through high-precision astronomy.

Eddington's fame was based upon the study of light and gravity. It was he who showed that the radiation pressure of sunlight trying to escape the interior of the Sun is what keeps the Sun from collapsing under its own gravitational force. This remarkable insight defies ordinary intuition, since the most incredible weight in the solar system, that of the Sun, is held up by literally the "lightest" support imaginable, light itself. So intense is the power of sunlight emerging from the core of the Sun that it can accomplish this Herculean task of supporting the weight of the Sun on its shoulders. This aspect of Eddington's work certainly prepared him for the eclipse experiment of 1919. Einstein had argued that if gravity was a universal force, it ought to affect light. Eddington was well prepared to think of light as a thing having weight and heft. Indeed, it was he himself who presented the eclipse test as an attempt to weigh light. Physicists of the nineteenth century had naively presumed that light was weightless. Now Eddington and Dyson would prove them wrong.

Eddington's ideas about the interior structure of the Sun ultimately led to the modern study of gravitational collapse and the discovery of collapsed stars like neutron stars and black holes. Ironically, Eddington rejected the idea that such ultradense objects could exist, disappointing a young student, Subramanian Chandrasekhar, known as Chandra, who imagined that he was building upon his

mentor's groundbreaking work. In a similar way, the inventors of quantum mechanics were shocked that Einstein rejected their ideas. Instead, both men engaged in the quest for a unified field theory (nowadays, sometimes called a "theory of everything") in their later years. Neither received any kudos for this later work. It was viewed as eccentric and outside the mainstream of physics. Eddington was obsessed with numbers and tried to calculate how many fundamental particles are in the universe based on what most physicists regarded as a kind of numerology. Later, the philosopher Bertrand Russell recalled "enjoy[ing] asking him questions to which nobody else would have given a definite answer," such as "How many electrons are there in the Universe? . . . He would give me an answer, not in round numbers, but exact to the last digit." Russell also recalled Eddington's satisfied response to the discovery of the expansion of the universe: "He told me once, with evident pleasure, that the expanding universe would shortly become too large for a dictator, since messages sent with the velocity of light would never reach its more distant portions."²

Two Observatories: Greenwich and Cambridge

The eclipse expeditions of 1919 were organized on behalf of two learned societies by the Joint Permanent Eclipse Committee, but they were carried out by personnel from two different English observatories. Typically, this was how such expeditions were mounted at the time. The English system of coordination through the learned societies was used primarily to facilitate government funding and arrange for the sharing of equipment between observatories. Crucially, the data analysis was carried out separately at the two observatories, and the expeditions took their own data quite independently of each other at two different sites. This is important to keep in mind because Eddington's subsequent fame has overshadowed everyone else who participated, and some modern commentators talk almost as if Eddington was solely responsible for every decision taken. At the time, no one in England would have made this mistake. Dyson was a well-respected and widely known public figure. As Eddington

himself took pains to point out, it was Dyson's expertise and influence that made the whole enterprise possible.

The Principe team was led by Eddington, in his capacity as director of the Cambridge Observatory. Eddington's role was largely personal. He understood the theory being tested and was experienced in the type of astrometry required to measure the predicted effect. But his observatory was not known for its expertise in eclipses, and the equipment he used was largely borrowed from the Oxford Observatory. He was accompanied not by one of his own staff but by Cottingham, who was familiar with the equipment to be used, as he counted both the Oxford and Cambridge Observatories among his clients. Cottingham's role was largely to maintain the equipment in working order at the site. It is probable that Eddington alone handled the data analysis of the Principe expedition. We cannot determine how this was done because none of the data analysis sheets or photographic plates have survived. We do know that Eddington began the data analysis on Principe by himself, so it is almost certain that he continued on his own when back in England.

The expedition to Sobral in Brazil was under the direction of Dyson, the Astronomer Royal. He sent two members of his own staff, and some of the equipment was from his own observatory. Although he did not go himself, he directed the data analysis after the expedition returned to England. Key points in the data analysis sheets are in his handwriting, and he cowrote the report on the expeditions with Eddington. He took the lead in publicizing the results among the astronomy community and was coequal with Eddington in communicating them to the general public. They were both important public scientific figures who had a gift for popularization.³

The Royal Observatory at Greenwich opened in 1676, having been commissioned by King Charles II the previous year. He created the position of Astronomer Royal at the same time. Until recently, the Astronomer Royal also served as the director of the observatory. In the eighteenth century, the observatory played a leading role in solving the problem of longitude. As a result, the prime meridian, the reference longitude for most of the world, runs through the old observatory at Greenwich to this day. Since the best-known method



FIGURE 2. A view of the Royal Observatory at Greenwich in the 1920s. The dome in the foreground at right is where the astrographic telescope was housed. Frank Dyson and Charles Davidson spent many years working on this instrument, and its lens accompanied Davidson to Sobral in 1919. In 1894 high winds blew the shutter off the dome, and the headpiece fell into the room below, narrowly missing Davidson as he and Dyson were at work. The Royal Observatory is now a museum. (Image courtesy of Graham Dolan.)

of finding longitude at sea involved the use of precision timekeeping, the observatory was placed in charge of timekeeping for the British navy. This involved, among other things, dropping a ball down a spire at the top of the observatory at 1:00 p.m. each day by which ships in the Thames below could set their timepieces. By the early twentieth century, timekeeping had become important in civilian life, following the growth of the railways. Previously, towns had kept their own local time, but now it became desirable for everyone in England to follow Greenwich time. In order to facilitate this, Dyson developed the pips system with the BBC (British Broadcasting Corporation). This involved sending out a radio signal broadcasting the sound of six pips marking the seconds leading up to each hour. This permitted everyone with a radio set capable of receiving the BBC to set their clocks against master clocks at Greenwich, which controlled the time signal.

The early twentieth century was a golden age for astronomy. The subject had great prestige after the dramatic discoveries of the previous 150 years, including the addition of two new planets to the solar system. As new universities were founded in the late nineteenth century, many of them built observatories. Even the observatories of the older universities are not as old as one might think. Eddington's observatory in Cambridge was built in 1823, for instance. In the nineteenth century, British eclipse expeditions were dominated by London observatories—not only Greenwich but also newer facilities like Kew Observatory and the Solar Physics Observatory at the Royal College of Science in Kensington (now part of Imperial College, London). The Kew Observatory had been built for King George III in the eighteenth century (it is often known as the King's Observatory) to allow him to observe the transit of Venus in 1769. In the nineteenth century, the British Association for the Advancement of Science took over the building. Its director in the mid-nineteenth century, Warren de la Rue, was a pioneer of the use of photography in astronomy and focused particularly on solar physics. Because of his interest in astronomical photography, he donated the astrographic telescope to the Oxford Observatory for use in the *Carte du Ciel* project.⁴ The lens from this telescope would be taken by Eddington to Principe. The Solar Physics Observatory in Kensington was built for Sir Norman Lockyer, a key member of JPEC for decades and the founder of the journal *Nature*.

By 1919 the Kew Observatory had become the home of the Met Office, Britain's national weather forecasting service, and Lockyer's Kensington observatory had been closed down. Lockyer had moved to Sidmouth in southwestern England, where he had a new observatory called the Hill Observatory (now known as the Norman Lockyer Observatory). Most of the equipment from his London observatory went to Cambridge to the new Solar Physics Observatory, a near neighbor to Eddington at the Cambridge Observatory. As an illustration of how common and influential amateur observatories were at this time, Sidmouth played host to not one but two observatories in 1917. The other was the personal observatory of a wealthy

German engineer, Adolph Friedrich Lindemann. Lindemann had been involved in the laying of one of the first successful transatlantic cables for telegraphic communication between Europe and America. He and his son, a promising young physicist named Frederick Alexander Lindemann, were interested in astronomy and in Einstein's theory. Since they both spoke German and spent time in Germany, they were more familiar with his work than most astronomers in Britain and were interested in joining the effort to test the theory. Not being eclipse specialists, they wondered if the light deflection experiment might be accomplished during the daytime, using filters to try to pick out the light of particularly bright stars against the glare of the sky. After some experiments carried out at Sidmouth, they wrote a paper proposing that a bigger observatory should try the observation at the conjunction of the Sun with Regulus on August 21, 1917. Regulus, also known as Alpha Leonis, since it is the brightest star in the constellation Leo, is the brightest star close to the ecliptic and thus the brightest star that the Sun comes close to in the sky. John Evershed, at the Kodaikanal observatory in India, a solar astronomer already used to testing Einstein's theory, took up the challenge and tried the observation on that date. We can argue that this was the first attempt to test Einstein's full theory of general relativity (before 1915 he had a different prediction for light deflection, as we shall see). As such it had a very fitting centenary because on August 21, 2017, Regulus was once again close to the Sun, but on this occasion the Sun was in total eclipse across a swath of land through the middle of the United States. This made the 2017 eclipse easily accessible by professional and amateur astronomers who cared to attempt the Einstein test.

But back in 1917, the attempt failed. Regulus could not be imaged in full daylight near the Sun. So it seemed that if the measurement was to be accomplished at all, it would have to be at an eclipse. In the wake of World War I, with astronomers of many countries still on war duty or struggling to survive amid revolution and upheaval, the field was wide open for Cambridge and Greenwich to make the running in 1919.

INDEX

Page numbers in *italics* refer to figures and tables.

- V^2V Club, Cambridge, 266–267
 κ_1 and κ_2 Tauri, double star in the Hyades cluster, 191, 269
- Aberdeen, Scotland, 77
aberration. *See* stellar aberration
Adams, John Couch, 83, 234
Adams, Walter, 184, 300–301, 304
Adler, Friedrich (Fritz), 122–123
Adler, Victor (father of Friedrich Adler), 122–123
Admiralty, British, 64, 84, 137, 153, 154
Advisory Committee on Uranium, forerunner to the Manhattan Project, 309
aerial bombardment. *See* zeppelin raids (and other forms of aerial bombardment)
aeronautics, highest ascent records, 302–303
aether. *See* ether, luminiferous
Africa, 1, 3, 7, 23, 24, 35, 107, 108, 126, 126–127, 134, 157, 187, 214, 241, 245, 305, 312, 340, 355, 371n6 (ch. 10)
Airy, George, 234
Allied countries of World War I. *See* Triple Entente
almanacs, 21
Almaty (formerly Alma-Ata), Kazakhstan, 310
aluminizing process of telescope mirrors, 179, 342
amateur astronomers (and physicists), 17, 18, 26, 27, 32, 66, 99, 123, 125–126, 127, 132, 136, 141, 157, 222, 237, 305, 319, 347, 373n1 (epilogue)
Amazon.com, online retailer, 187, 371n4 (ch. 11)
Amazon River, rainforest and basin, 108, 157, 164, 347
America, North, 23, 116
America, South, 23, 108, 156
American Astronomical Society, Eclipse Committee of, 281–283
American Physical Society (APS), 225
Anatolia, 172
Anderson, Alexander, 237–238
Anderson, Millicent Mary (known as “Nant”), 29–30
Anglesey, Wales, 156
Anglo-German relations, 213
Anglo-Irish, the, 135, 136, 140, 345
Annulus Mirabilis of 1905 (Einstein), 31, 33, 44, 56
Anomie, 316
SS Anselm, 108, 154–157, 156, 160, 164–165, 347
SS Anselm (successor ship), 370n2 (ch. 9)
Antarctica, 175, 279
Antikythera mechanism, 174
anti-Relativity (or Anti-Einstein) company, GmbH, 86, 120–123, 330
anti-Semitism, 32, 121, 298
antiwar movement, 34–35, 74–75, 90, 122, 143, 336
ants, leaf-cutter, 164
Araujo, Leocadio, 165
Archangelsk, Russia, 30
Arcturus, 169, 171, 196
Argentina, 58, 113, 347
Argentine National Observatory (now Astronomical Observatory of Córdoba), 29, 58, 113
Aristarchus of Samos, 218
RMS Arlanza, 29–30, 157
Armagh Observatory, Ireland, 136
Ascorecard plate measuring machine (Zeiss), 242–243
Asia, 23

- assistant, chief at Greenwich, 10, 12, 28,
29, 31, 125, 192, 282, 348, 368n2 (ch. 4),
371n3 (ch. 11)
- assistant astronomers, 3, 4, 6, 57, 66, 79,
106, 109, 114, 118, 132, 133, 134, 144, 147,
149–150, 235, 240, 257, 280, 343
- astigmatism, optical, 189, 193, 311, 313, 321
- Astrographic Catalogue*, 111, 112, 125, Fig. 8
(126), 128–129, 131, 133, 134, 136, 179,
192, 341
- Astrographic Catalogue* 2000, 129
- astrophysical telescopes and lenses, 16, 17,
107, 111, 128, 134, 136, 138, 141, 145, 146,
150, 154, 167, 167–168, 170, 178, 179, 181,
189, 192, 193, 194, 195, 197, 201, 203,
204, 206–207, 209, 211, 215, 223, 232,
241–245, 248–251, 258–259, 282, 311, 318,
322, 341–342, 344, 346, 355, 357, 358,
358–365, 359, 363, 368n2 (ch. 4)
- astrometry, 8, 12, 15, 58, 104, 108, 112, 126,
127–128, 129, 133, 137, 138, 149, 166, 168,
169, 193, 242, 280, 290, 314, 316, 317;
data-reduction software used in, 241–242,
245, 251; team at the RGO, Herstmon-
ceux, 242
- Astronomer Royal, 2, 10, 13, 15, 84, 106, 129,
185, 203, 223, 234, 348, 369n1 (ch. 6)
- Astronomer Royal for Ireland, 343
- Astronomer Royal for Scotland, 12, 346,
373n3 (epilogue)
- astronomical day, 106
- Astronomical Society of the Pacific, 116
- astronomical tables, 21
- Astronomical Unit, 23, 109
- asymptotic flatness, 53
- Atlantic Ocean, 23, 71, 106, 107, 108, 108,
158
- Atlee, Clement, 78
- atoms and atomic number, 43–44, 68, 72,
112, 333
- Austria and Austrians, 122
- axioms, 50–51, 95
- Babelsburg Observatory. *See* Berlin, Royal
Observatory of
- Babylonian astronomy, 192–193, 371n5
(ch. 11)
- Ball, Robert Stawell, 83
- ballooning, scientific, 302–303
- Baltimore, Maryland, 118
- Baptists, 12
- HMS Baralong*, Royal Navy Q-Ship, 368n5
(ch. 4)
- Battle of Halys. *See* eclipse (dates): May 28,
585 BC (Thale's eclipse)
- Bauer, Louis Agricola, 109, 205, 221, 239–
241, 255
- Beer Hall Putsch, 369n9
- Belém, state of Pará, Brazil, 108, 164, 165
- Belfast, Ireland, 30, 348
- Belgium and Belgians, 66, 69, 70, 74, 309
- Berkeley, California, 326
- Berlin, Germany (and Berliners), 32, 36, 56,
57, 58, 59, 61, 62, 70, 71, 74, 86, 87, 88–91,
113, 121, 206, 229, 254, 274, 275, 277, 349,
369n9 (ch. 4)
- Berlin, Royal Observatory of, 57, 59, 113
- Berliner Tageblatt*, 64
- Berlin Wall, fall of, 369n9 (ch. 4)
- Bern, Switzerland, 31, 42
- Besso, Michele, 46, 89
- Bible Society, 157
- big bang theory, 321
- binary stars, 40, 317, 350
- black holes, 13, 306, 321–322, 340, 349,
350–351, 369n2 (ch. 5)
- Black Sea, 142
- Blandy, Frances, 160
- Bluecoat School. *See* Christ's Hospital
school, England
- Bolsheviks. *See* Communism and
Communists
- Bolyai, János, 51
- Booth Line, shipping company, 154, 156,
347
- Born, Hedwig, 295
- Born, Max, 89, 91, 294–295, 349
- Bourdin, Martial, 368n2 (ch. 4)
- Bournemouth, England, 205–206
- Boyle, Robert, 4
- Bradley, James, 129, 131, 132, 133
- Brans, Carl, 308
- Brans-Dicke theory of gravity, 308, 314
- Brazil and Brazilians, 2, 15, 21, 29, 97, 107,
112, 114, 148, 154, 155, 156, 157, 164, 165,
167, 167, 170, 178, 180, 189, 220, 241, 309,
310, 311, 313, 321, 347, 370n3 (ch. 6)
- Brazilian National Observatory, Rio de
Janeiro, 164
- Brazil nuts, 165
- Brest-Litovsk, treaty of, 79, 143
- Brief History of Time, A* (Hawking),
245–246
- Briggs, Lyman, 309
- Britain and British science, 4, 7, 17, 18, 22,
25, 30, 31, 35, 66, 71, 72, 76, 84, 93, 111,

- 113, 114, 135, 136, 158, 222, 237, 327, 345, 346, 371n1 (ch. 12)
- British Association for the Advancement of Science (BAAS), 17, 94, 145, 205, 263
- British Broadcasting Corporation (BBC), 16
- British consul, Madeira, 160
- British Empire, 79, 119
- British Expeditionary Force (BEF) of World War I, 79, 157
- British Grand Fleet, World War I, 369n6 (ch. 4)
- British Navy (the Royal Navy), 16, 23, 71, 105, 135, 151, 153, 154
- Broome, Western Australia, 283
- Brück, Hermann, 343, 373n3 (epilogue)
- Brussels, Belgium, 63, 180, 256, 302, 303
- bull-fighting, 162
- Burlington House, Piccadilly, London, 105, 152, 222, 346, 369n2 (ch. 6)
- calculus, 218, 223. *For the cartoon character, see Professor Calculus*
- California, 25, 27, 113, 119, 256, 286, 292, 324, 347, 372n7 (ch. 13)
- California Institute of Technology (Caltech), 295, 302, 373n2 (ch. 14)
- Callanan, Paul, 346
- Cambridge, England, 17, 78, 83, 153, 220, 241, 275, 341, 346, 369
- Cambridge, Massachusetts, *II*
- Cambridge Observatory, 1, 6, 12, 13, 14, 15, 17, 18, 38, 77, 79, 109, 144, 155, 161, 181, 189, 209, 220, 234, 235, 242, 244, 274, 346, 369n7 (ch. 4)
- Cambridge University, 10, 12, 13, 17, 18, 32, 35, 77, 78, 80, 83, 94, 95, 98, 106, 109, 149, 215, 220, 235, 266, 267, 268, 273, 274
- Cambridge University Library, 204, 241, 357
- Camocim, Brazil, 165
- Campbell, Douglas, 372n10 (ch. 13)
- Campbell, Elizabeth, 25, 281, 335, 372n10 (ch. 13)
- Campbell, William Wallace, 25, 57, 58, 59, 60, 63, 109, 110, 112, 113–116, 124, 180, 226, 239, 241, 252, 255, 256–257, 260, 262, 280–281, 283–287, 290–291, 304, 321, 324, 330, 333, 335, 337, 348, 372n10 (ch. 13)
- Canary Islands, 157
- Cape Observatory. *See* Royal Observatory at the Cape of Good Hope, South Africa
- Cape Palmas, Liberia, 108
- Cape Verde Islands, 160
- Captain Persius, war correspondent for *Berliner Tageblatt*, 64–65
- Carlton House Terrace, London, 346
- Carl Zeiss Optics, 62, 135, 242, 243
- Carnegie Institute of Washington, 220, 221, 239, 347
- Carneiro, Jeronymo, 162–163
- Carroll, Lewis (pen name of Charles Dodgson), 203, 324
- Carte du Ciel project, 17, 111. *See also Astrographic Catalogue*
- cartography, 21, 109
- Case School of Applied Science. *See* Case Western Reserve University
- Case Western Reserve University, Cleveland, Ohio, 292
- casino in Funchal, Madeira, 159, 163
- Catholics, Roman, 144, 147
- Cavendish Laboratory, Cambridge, 10
- Ceará, Brazilian state, 165
- RMS Celtic*, 278, 372n5 (ch. 13)
- Central Organization for a Durable Peace, 74
- Central Powers, alliance of Germany and other nations during World War I, 276
- Challis, James, 234
- Chandrasekhar, Subramanian (known as “Chandra”), 13, 35, 82, 306, 328, 329, 371n8 (ch. 11)
- Chapel Hill, North Carolina, meeting of 1957, 306
- charge-coupled device (CCD), 305, 320
- Charles II, 15
- Charles University, Prague, 56, 349
- check plates, for independently measuring plate scale change, 153, 169, 171, 175, 196, 199, 200, 201, 203, 284, 286, 312, 318, 319
- Cheltenham, England, 58
- Chicago, University of, 308
- Chief of Police, Funchal, Madeira, 159, 160
- Chile, 71, 347
- Christmas, 70, 326, 368n2 (ch. 4)
- Christmas Island, 210, 250, 281, 282, 283, 284
- Christoffel, Elwin, 66
- Christopher Columbus, 4, 21
- Christ’s Hospital school, England, 149
- chromosphere, 26, 304
- Churchill, Winston, 237
- Church of England, 32
- citizen-scientists, 305, 355. *See also* amateur astronomers (and physicists)
- citizenship, question of Einstein’s, 36, 74, 76, 277

- civil day, 106
Clements, E. D. "Clem," 242
Cleveland, Ohio, 292–293, 302
clocks: for driving telescopes, 116, 176; in relativity theory, 39, 40, 43, 96, 324, 368n4 (ch. 3); masters kept at Greenwich, 16. *See also* "pips" for synchronizing clocks via radio from Greenwich
clockwork drivers for telescopes and coelostat mirrors, 111–112, 127, 135–138, 145, 146, 148, 169, 283, 284, 310, 311, 321
cocoa, 162–163
coelostat mirrors, 110, 111, 112, 135, 137–138, 139, 141, 144–147, 166, 167, 168, 169, 178, 179, 189, 201–203, 225, 282, 283–284, 311, 323, 343, 344, 346, 354
Cold War, 321, 369n8 (ch. 4)
Collins, Harry, 186, 232–233, 260, 270, 313
Colombia, 113, 164
Columbia University, 123
comet of 1882, 125, 126, 126, 127
comets, generally, 84, 147, 237
Communism and Communists, 34–35, 75, 79, 91, 114, 143
comparison plates, 2, 107, 115–116, 118, 130, 170, 180, 181, 188–190, 191, 192, 193, 196
computers: ancient (*see* Antikythera mechanism); electronic, 27, 241, 242, 320; human, 3, 8, 149–150, 189, 241, 349
Congolesse rainforest and basin, 108
congruent lines, 50–52, 54, 367n2 (ch. 3)
conjunction of Regulus with the Sun, August 21, 1917, 237, 305
Conrad, Joseph, 368n2 (ch. 4)
conscientious objector (also "Conchie" or c.o.), 35, 76–82, 84
conscription, military, 35, 36, 37, 72, 76, 77, 79, 82, 140, 149. *See also* military service
Cook, James, 23, 24
Cook, Thomas, 24
Copernicus, 21, 218
Cordillo Downs, South Australia, 250, 372n9 (ch. 13)
Cork, Ireland: city and harbor, 29–30, 135, 141, 278, 345–346, 368n5 (ch. 4), 372n5 (ch. 13); Crawford Observatory, 135, 141, 345–346; University College, 135, 346
corona. *See* solar corona (and coronagraphs)
Cortie, Father Aloysius, 105, 112, 144–145, 146–147, 149, 152, 155, 165, 166, 167, 168, 178, 201, 206–207, 318, 322, 343, 244
Cosmic Microwave Background, 297, 321
cosmology, 47, 53, 88, 93, 218, 321, 340.
See also Great Debate on galaxies and the universe
Cottingham, Edwin Turner, 6, 15, 112, 144, 146, 154, 155–157, 159, 163, 168, 169, 182, 205, 215, 220, 233, 262, 267, 287, 322, 348
cotton, 165
Cowell, Phillip, 66, 123
Crawford Observatory, Ireland, 135, 141, 345–346
Crelinsten, Jeffrey, 116, 226, 257, 258, 280, 285, 296, 304, 372n1 (ch. 13)
Crimea, during eclipse of 1914, 62, 113, 231, 235
Crommelin, Andrew Claude de la Cherois, 6, 105, 106, 108, 109, 145–148, 148, 152, 153, 154–157, 164–166, 168, 176, 180, 181, 195, 202, 222, 252, 322, 324, 343, 344, 348
Cunningham, Ebenezer, 80, 82, 94, 215, 266, 268
Curtis, Heber, 114–117, 122–124, 180, 209, 211–212, 239, 256–258, 260, 279, 280–281, 294, 304, 329–330, 332, 337
curvature of spacetime, 42, 47–55, 54, 95, 117, 183, 340, 367n1 (ch. 3), 368n3 (ch. 4), 373n6 (ch. 14)
Cushenden, co. Antrim, Ireland, 147
Czechoslovakia, German occupation in 1938, 349
Daily Telegraph, 64
Dallmeyer optical firm, 127
Daramona House Observatory, Westmeath, Ireland, 345
Dardenelles, 76. *See also* Gallipoli
dark energy, 351
Darwin, Charles, 12
Darwin, George, 12, 83
data analysis, especially of Sobral plates from 1919, 2, 3, 6, 9, 14, 15, 116, 134, 153, 182, 190, 204, 213, 239, 246, 248, 251, 260, 262, 279, 285, 290, 329, 354, 357–365
Davidson, Charles Rundle, 6, 16, 107, 112, 134, 146, 147, 148, 149–151, 153, 154–157, 164, 168, 176, 178–179, 180, 181, 189, 199, 200, 202, 203, 204–205, 209, 221, 234, 240, 241, 249, 250–251, 283, 316, 322, 323, 348–349, 357–364, 368n2 (ch. 4), 372n9 (ch. 13); diary of, 179
declination (celestial coordinate), 193–194, 243, 244
Defense of the Realm Act, British, 78

- De Haas, Wander, 261
- De la Rue, Warren, 17, 367n4 (ch. 1)
- demarcation, problem of, 228, 272, 315
- Department of Terrestrial Magnetism of the Carnegie Institute of Washington, 239
- Deptford, London, 65
- depth of field, photographic, 170
- depth of focus, photographic, 171
- DeWitt, Bryce, 312
- DeWitt-Morette, Cecile, 312, 314
- Dicke, Robert, 306–308
- differential refraction, 108, 115, 170, 190, 204
- dimensions of spacetime, 33, 41, 42, 50, 52, 53, 95, 325
- dissenters (English Protestants dissenting from the Church of England), 32, 144
- Distinguished Service Order, 371n1 (ch. 12)
- Dodson, George Frederick, 372n9 (ch. 13)
- Doppler shift, 44, 118–120, 271
- Douglas, Allie Vibert, 38, 370n4 (ch. 9)
- HMS Dreadnought*, 345
- drought, in Brazilian state of Ceará, 165, 175
- Dunkirk, France, 79
- Dunsink Observatory, Ireland, 141, 145, 246, 343, 344, 345, 373n3 (epilogue)
- Dutch people and the Netherlands (Holland), 47, 66, 74, 88, 93, 127, 205, 229, 238, 261, 263, 273, 275, 296
- Dyce work camp near Aberdeen, Scotland, 77
- Dyson, Frank Watson, 2–4, 6, 8, 10, 11, 12–15, 16, 20, 27–29, 35, 63, 65–67, 83–85, 92, 97, 105–107, 109–112, 117, 120, 124, 125, 131–134, 138, 141, 142, 147, 149–154, 158, 166–168, 170, 173, 176, 178–183, 185–186, 189, 192–196, 198–203, 205–211, 208, 213–215, 221–222, 225–226, 232–236, 239–241, 243–245, 248–253, 255, 258–259, 261–271, 275–276, 279–281, 283, 285–287, 290–291, 297, 305, 307, 311, 316, 318, 321–323, 327, 329, 331–333, 336, 338, 341, 346, 348, 254, 357–365, 367n3 (ch. 1), 368n2 (ch. 4), 369n1 (ch. 6), 371n1 (ch. 11); luck with eclipse weather, 2, 144, 234, 235, 314, 323
- Dyson, Freeman, 367n3 (ch. 1)
- $E = mc^2$, 45, 102, 326
- Earman, John, and Clark Glymour, 119–120, 186, 197, 209, 214, 215, 219, 231, 232, 233, 236, 270
- Earth, the, 2, 5, 8, 19, 20, 23, 24, 27, 28, 39, 43, 44, 54, 54, 58, 95, 100, 101, 103, 106, 108, 109, 111, 114, 115, 119, 123–126, 129–131, 130, 137, 170, 173, 173, 190, 193, 218, 237, 238, 261, 271, 292–293, 295, 298–299, 300, 303, 305, 308, 332, 367n1 (ch. 1), 370n6 (ch. 6)
- Easter, 326
- Easter Rising, 1916 (Dublin), 135
- Eastman Kodak Company, 240
- eclipse, 15, 19, 29; annular, 20, 23, 279; change of temperature associated with totality of, 146, 167, 169, 192, 199, 290, 312, 321; lunar, 19, 21, 367n1 (ch. 1); partial (or partial phase of total eclipse), 20, 176, 279; solar, 4, 5, 7, 19, 20, 21, 172, 173, 114, 174, 175, 319; total, 4, 5, 20, 21, 45, 247, 22, 45
- eclipse (dates): May 28, 585 BC (Thale's eclipse), 172–174; March 1, 1504, lunar (Columbus' eclipse), 4, 21; May 3, 1715 (Halley's eclipse), 21, 22, 323; May 22, 1724, 22, 323; August 18, 1868 (King of Siam's eclipse), 27, 370n5 (ch. 6); April 16, 1893, 7; May 28, 1900, 28, 29, 116, 141, 146, 174, 343, 344, 373n1 (epilogue); May 18, 1901, 173; August 30, 1905, 107, 146; April 28, 1911, 146; April 17, 1912, 23; October 10, 1912, 21, 28, 29, 58, 114; August 21, 1914, 20, 21, 59, 146, 230; February 3, 1916, 67, 113; June 8, 1918, 58, 106, 112–117, 180, 226, 239, 280, 304, 329–330, 337; May 29, 1919, 1–4, 7, 9, 18, 26, 28, 106, 142, 146, 172–180, 177, 191, 220, 222, 227, 279, 351; October 1, 1921, 279; September 21, 1922, 58, 199, 200, 203, 210, 241, 250, 257, 279–284, 287, 281, 282, 330; September 10, 1923, 116, 285–286; May 9, 1929, 252–255; April 28, 1930, 372n7 (ch. 13); June 19, 1936, 309–310, 311; May 29, 1938, 175; September 21, 1941, 310; May 20, 1947, 308–309, 313; February 25, 1952, 309, 311; June 30, 1954, 349; June 20, 1955, 174, 349; March 7, 1970, 373n4 (ch. 14); June 30, 1973, 3, 168, 214, 246, 316, 335; July 31, 1981, 311; August 21, 2017, 18, 304–305, 320; April 8, 2024 (predicted), 320; May 29, 2310 (predicted), 175
- eclipse expeditions, 23–30; of Crocker, 1918 (Goldendale, Washington), 112–117, 180, 239, 257, 80, 304, 329–330; of 1868 (India), 370n5 (ch. 6); of 1893 (West Africa, 7; of 1900 (Spain, Portugal, and Georgia, 116, 141, 343, 344, 373n1

- eclipse expeditions (*continued*)
(epilogue); of 1905 (Tunisia), 107; of 1912 (Brazil), 21, 29–30, 58, 97, 114, 164, 370n3 (ch. 6); of 1914 (Sweden and Russia), 20, 21; of 1919 (Brazil and Principe), 1–4, 7, 8, 10, 12, 14–17, 20, 24, 25, 30, 34, 36, 42, 79, 106–109, 108, 112, 115, 142–182, 148, 156, 167, 189, 191, 191, 194–208, 208, 213, 220–223, 228, 232, 238, 243, 268, 313, 317, 322, 328, 344, 370n3 (ch. 6), 371n7 (ch. 11); of 1922 (Christmas Island and Australia), 58, 199, 203, 210, 250–251, 280–287, 282, 289–290, 316, 324, 330, 372n9 (ch. 13); of 1929 (Sumatra), 252–255, 287, 289–290, 333, 349; of 1936 (Soviet Far East), 309–310, 311; of 1941 (Kazakhstan), 310; of 1947 (Brazil), 309, 313, 321; of 1952 (Sudan), 311; of 1954 (Sweden), 349; of 1955 (Southeast Asia), 349; of 1973 (Texas Mauretanian Eclipse Team), 3, 168, 214, 246, 305, 307, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 335
- eclipse plates of 1919, whereabouts of, 221, 242
- ecliptic, plane of, 18, 19, 58, 131, 173, 173, 200
- Eddington, Arthur Stanley, 1–3, 6, 8, 10, 11, 12–15, 17, 20–21, 24–27, 29–38, 38, 45, 60, 66, 68, 72–85, 91, 93–101, 104, 106, 109–110, 112, 114–115, 117, 120, 122, 124, 125, 132, 134, 136, 138, 142–171, 161, 174–217, 208, 219–224, 226, 228–236, 238–245, 247–253, 256–279, 283–285, 287, 290–291, 294–295, 297, 300–301, 305, 307, 309–310, 312, 314–316, 318, 322, 324, 326–333, 335–340, 345–346, 348, 367n1 (ch. 2), 368n3 (ch. 4), 369n7 (ch. 4), 369n3 (ch. 6), 370n2 (ch. 9), 370n4 (ch. 9), 371n6 (ch. 10), 371n1 (ch. 11), 371n3 (ch. 11), 371n7 (ch. 11), 371n8 (ch. 11), 372n6 (ch. 13); bias of, 3, 10, 134, 183, 185–186, 201, 207, 209–211, 214–215, 231, 245, 259, 271, 290–291, 307, 314, 328–340; critics of, 183–184, 186, 194, 201, 211, 215, 219, 235–241, 253, 259, 261, 279, 329, 335, 348
- Eddington, Sarah Ann, 10, 25, 29, 35, 155, 158, 160–163, 161, 165, 170, 175–176, 182
- Eddington, Winifred, 10, 25, 35, 38, 155, 161, 163, 220, 348
- Edinburgh, 12, 346, 373n3 (epilogue)
- Edward VII, 159, 370n3 (ch. 9)
- Ehrenfest, Paul, 48, 73, 93, 205, 229, 301–302
- Eighty Mile Beach (or Ninety Mile Beach), Western Australia, 281, 283, 372n8 (ch. 13)
- Einstein, Albert, 2–4, 8–10, 13, 14, 18, 20, 25, 28–64, 38, 54, 60, 66, 70–78, 80, 84–104, 107, 112–124, 129, 133, 141–144, 150–151, 174, 178–188, 190, 192, 194, 197, 198, 200–201, 203, 205–206, 208–215, 217, 219, 221–226, 228–232, 236–243, 245, 247–248, 250, 252–257, 259–271, 273–281, 285–287, 289–296, 299–303, 305–310, 312, 320, 322, 324–334, 336–340, 343, 346, 348–350, 362, 364, 365, 369n9 (ch. 4), 371n3 (ch. 12), 372n7 (ch. 13), 372n9 (ch. 13), 373n3 (ch. 14); centenary in 1979, 242; first news of the 1919 eclipse results, by telegram, 229, 263
- Einstein, Elsa, 36, 87, 88, 90–91
- Einstein, Pauline, 229, 262, 263
- Einstein-De Hass experiment, 261
- Einstein effect. *See* redshift: solar
- Einstein equations, 47, 53, 267, 325, 373n6 (ch. 14)
- Einstein's Jury* (Crelinsten), 280
- Einstein's prediction of light deflection effect. *See* light deflection: "full" prediction of general relativity
- Einstein tensor, 267, 325, 373n6 (ch. 14)
- Einstein Tower at Potsdam Observatory, 62, 254, 343
- electromagnetic field, 47, 98, 214
- England and Englishmen, 1–3, 6, 7, 10, 13–17, 21, 22, 29, 32, 35, 36, 58, 61, 62, 64–65, 67, 76, 84, 88, 91, 93, 94, 96, 97, 105, 106, 109, 112, 115, 117, 119, 121, 129, 136, 137, 140, 142, 144, 146–149, 159, 160, 162, 163, 168, 169, 170, 181, 182, 204, 205, 206, 213, 226, 229, 232, 235, 256, 273, 275, 276, 278, 285, 286, 323, 328, 336, 345, 346, 347
- Entwurf theory, 46, 50, 87, 97
- ephemerides, 21, 109
- Equator, 1, 52, 107, 157, 219, 308, 367n2 (ch. 3)
- equatorially mounted telescope, 126, 127, 135–138, 203, 225, 320, 342
- equivalence principle, 29, 43, 44, 46, 47, 49, 50, 55, 92, 96, 115, 117, 185, 212, 213, 306
- ether, Earth's velocity through, 39, 102–103, 183, 216, 292, 293, 295, 296, 297, 299, 332
- ether, luminiferous, 39, 44, 47–48, 98, 102–103, 120, 183, 216, 224, 238, 256, 257,

- 265, 268, 289, 291, 292, 294, 295, 296, 300, 338
- ether drag, theory of, 292, 293, 300, 303
- ether wind, or drift, 47–48, 257, 292, 293, 294, 300, 301, 302, 332, 338
- Euclid and Euclid's *Elements*, 50–52, 95
- Euclidean geometry (flat or plane geometry), 42, 52–53, 95, 127, 174, 325, 327, 340
- Euclid's fifth postulate. *See* axioms
- Europe and Europeans, 13, 18, 21, 23, 24, 25, 32, 36, 37, 56–91, 105, 135, 159, 162, 164, 166, 226, 256, 257, 277, 298, 309
- Euston station, London, 155
- Everitt, Francis, 261–262
- Evershed, John, 18, 119, 184, 233, 237, 270, 271, 283, 284, 305
- exemplars (research tools), 217, 218, 219, 294
- exemption from conscription, for Eddington, 35, 72, 76–80, 82, 84
- experimental art, 4, 318
- Experimenters' Malaise, 315–320, 335
- Experimenters' Progress, 315–317, 332, 335
- Experimenters' Regress, 232, 260, 315
- experimentum crucis*, 279
- expertise, 4, 15, 94, 121, 135, 136, 145, 233, 241, 280, 318, 319, 333, 334
- falsification of theories, 100, 186, 215, 228–230, 236, 238, 241, 248, 252–255, 269, 279, 287, 294, 295, 301, 307, 308, 314, 332, 334, 338
- Fascism, 34–35
- Fenians. *See* Irish republicanism
- Feynman, Richard, 373n6 (ch. 14)
- Finland and Finns, 213, 263
- first contact, during eclipse, 176
- Fitzgerald, George, 47
- Flamsteed, John, 129, 130
- flatness. *See* Euclidean geometry (flat or plane geometry)
- Flores, Brazil, 164
- focusing scale, 179
- folktales and oral narratives, 248, 264, 328
- football (probably association), 158
- SS Fortaleza*, 165
- four-inch lens used in Sobral, 112, 141, 145, 146, 148, 166, 167, 167, 168, 179, 191, 194, 200, 206, 207, 208, 209, 221, 232, 240–243, 246, 248–249, 289, 218, 322, 343, 344, 358, 359, 360, 364
- Fowler, Alfred, 105, 110, 154, 234, 237, 267, 276
- frame dragging (Lense-Thirring precession), 261–262
- France and the French, 22, 25, 30, 67, 79, 101, 111, 128, 135, 139, 143, 157, 158, 164, 300, 312, 371n1 (ch. 12)
- fraud, scientific, 9–10, 187, 231, 316, 332
- free fall, in general relativity, 42, 43
- Freikorps troops, 75, 90
- Freud, Sigmund and Freudians, 228
- Freundlich, Erwin Finlay, 9, 56–59, 61–63, 87, 92, 94, 97, 103, 113, 142–144, 231, 252–255, 260, 261, 273, 280, 281, 283, 287–290, 307, 310, 319, 324, 335, 337, 343, 348–349
- Fuller, Buckminster, 225
- Funchal, Madeira, 154, 157, 158, 160
- Furner, Herbert Henry, 149, 150, 189, 205, 241, 357
- GALAXY plate measuring machine, 242
- Galileo Galilei, 42, 304
- Galison, Peter, 231, 232, 261, 331
- Gallipoli, Allied landings and campaign at, 72, 76. *See also* Dardenelles
- Galway, Ireland, 237
- gamma rays, 326
- Gauss, Carl Friedrich, 51
- Gaussian error, 258
- Gaussian geometry. *See* geometry, differential
- general relativity (GR), theory of, 2–4, 10, 13, 18, 20, 25, 28, 29, 33, 42–44, 53, 54, 55, 57, 59, 66, 72, 80, 86–87, 92–94, 96–98, 113, 115, 117–120, 123, 180, 183, 186, 188, 194, 206, 207, 210–216, 220, 224, 228, 230, 233, 241, 245, 247–248, 252–253, 255–256, 258–259, 261, 264, 267, 269–272, 279, 287, 300, 301, 304–309, 311, 321–322, 336, 339, 340, 344, 348, 350–351, 369n3 (ch. 5), 372n1 (ch. 13), 373n6 (ch. 14); renaissance and golden age of, 321, 348–349
- Geodesics, 52–55, 54, 253, 367n2 (ch. 3), 368n3 (ch. 3)
- geography and geographers, 71, 107, 109, 309
- geologists and geophysicists, 109, 148, 205, 220, 239
- geometry, differential, 42, 47–53, 57, 66, 94, 95, 185, 219, 368n3 (ch. 3)
- geometry, of spacetime. *See* curvature of spacetime
- George III, 17
- Georgia, United States, 116

- German Army, 64, 65, 68, 69, 72, 91, 143, 151, 368n4 (ch. 4)
- German Navy, 151, 367n2 (ch. 2)
- “German Physics,” 121–122
- German University, Prague. *See* Charles University, Prague
- Germany and Germans, 18, 20, 25, 30–34, 36, 37, 56, 57, 59, 61–77, 79–80, 83–86, 88–91, 93, 121–122, 135–136, 142–143, 151, 158, 184, 205, 210, 212, 213, 237, 246, 262, 263, 264, 273, 275–279, 280, 294, 298, 310, 319, 321, 336, 343, 345, 349, 367n2 (ch. 2), 368n1 (ch. 4), 368n4 (ch. 4), 368n5 (ch. 5), 369n8 (ch. 4), 369n9 (ch. 4), 373n5 (ch. 14)
- Giggleswick, Yorkshire, 323
- Gill, David, 126–128, 126, 134, 138–140
- Glass, Ian, 141
- globular clusters, 296
- Glymour, Clark. *See* Earman, John, and Clark Glymour
- God, subtlety of, combined with absence of malice, 302, 373n3 (ch. 14)
- God, sympathy for, on his disagreements with theoretical physics, 229
- Goldendale, Washington, 113–116, 257, 280, 304, 329
- gold medal award of the Royal Astronomical Society, 273–275, 278, 329, 346
- Golem, The* (Collins and Pinch), 186, 232
- Göttingen, University of, 57, 280
- Government Grant Committee, British, 24, 110
- Governor Musgrave*, Steamer, 283
- gravana weather pattern on Principe, 175, 199
- gravitational collapse, 13, 306, 321
- gravitational lenses and lensing, 54, 322, 350
- gravitational waves, 47, 88, 322, 340, 351
- gravity, relativistic theories of, 92, 184–185, 213, 238, 263–265, 308, 340, 351
- gravity and gravitational fields, 2–4, 13, 29, 33–34, 42, 43–47, 49–50, 53–56, 54, 87, 92, 95–103, 117–118, 121, 184–185, 188, 203, 205, 206, 211–213, 215, 218–219, 236, 238, 248, 261–263, 279, 287, 291, 300–201, 306–307, 318, 322, 324, 326, 330, 331, 334, 340, 349, 350, 351, 373n6 (ch. 14)
- Gravity Probe B, 261–262
- Great Debate on galaxies and the universe, 124, 281
- Greece and Greeks, 7, 50, 103, 143, 172, 174, 222, 264
- Greenwich Observatory, Royal (and RGO in later locations), 2, 6, 8, 10, 12, 14, 15–18, 16, 28, 29, 31, 64–65, 66, 105–106, 111–112, 125, 128–129, 131–133, 138, 141, 144, 147–149, 153, 166, 168, 179, 182, 185, 189, 192–194, 196, 197, 199, 203, 204, 207, 209, 221, 234, 235, 241, 244, 245, 250, 280, 282, 283, 285, 316, 323, 333, 341, 342, 346–347, 354, 371n3 (ch. 11), 372n4 (ch. 12), 372n9 (ch. 13)
- Greenwich time, 1, 16, 106
- Gresham College, 7
- Groombridge, Stephen, 132
- Grossman, Marcel, 46, 50, 52, 87
- Grubb, Howard, 111, 127, 128, 134–141, 139, 145, 146, 154, 166, 167, 203, 283, 342, 343, 344, 345–346, 373n1 (epilogue)
- Grubb, Thomas, 134–136, 138, 343
- Grubb-Parsons, optical firm, 342–343
- guano, 71
- Guillaume, Edouard, 123, 230, 269
- Gwendolen* (schooner), 283
- Haber, Fritz, 36, 61, 70–72
- Haber-Bosch process, 71
- Habicht, Conrad, 46
- Hale, George Ellery, 59, 60, 292, 299, 300, 308, 373n2 (ch. 14)
- Halley, Edmund, 21–23, 22, 323
- halo stars, 296, 297
- Hampton Roads, Virginia, 372n5 (ch. 13)
- Harland and Wolff shipyards, Belfast, 30
- Harvey, Geoffrey M., 242–244, 251
- Hawking, Stephen, 245–247
- Hawking radiation, 322
- Hebrew University of Jerusalem, 277
- Heidelberg, Germany, 369n8 (ch. 4)
- Helium, 27, 370n5 (ch. 6)
- Henry, Paul and Prosper, 127–128, 134, 139
- Henschel, Klaus, 271
- Hergé (pen name of Georges Remi), 303
- Her Majesty’s Astronomer at the Cape of Good Hope, 126
- Herodotus, 172
- Herschel, William, 103, 130–133, 224, 281, 296
- Herstmonceux Castle, England (also the Observatory Science Center), 242–243, 316, 341–342, 346, 372n4 (ch. 12)
- Hertfordshire, England, 65
- Hinks, Arthur Robert, 107–110, 330

- HIPPARCOS satellite, 112, 129, 305, 320, 341
Holland. *See* Dutch people and the Netherlands (Holland)
Holyhead, Wales, 156
home counties, England, 65
House of Commons, British, 139
House of Lords, British, 286
How Experiments End (Galison), 231
Huggins, William, 26
huguenots, 147
“Huns” and other derogatory words for Germans, 68
“Hunting of the Snark, The” (Carroll), 203
Hyades star cluster, 2, 28, 106, 116, 170
hypersphere, 53
- iceberg, 23
Indian Ocean, 281
Indonesia, 281
inertial observers and frames of reference, 39–41, 43–44, 48, 299, 300, 369n2 (ch. 5)
influenza, 145
Institute of Astronomy, Cambridge, 235, 242, 346
International Astronomical News Service, 84–85
International Astronomical Union (IAU), *II*, 63, 85
International Council of Scientific Unions (formally now the International Council for Science, formerly the International Research Council), 210
interpretive flexibility, 228, 232, 239
invariant quantities and theories, 41, 42, 100, 102, 185, 213, 223
Iranians, 172
Ireland and the Irish, 4, 22, 29, 47, 76, 79, 86, 111, 112, 135–137, 138, 140, 141, 145, 147, 148, 150, 166, 237, 278, 323, 343, 344, 345–346, 368n5 (ch. 4), 370n6 (ch. 6), 373n1 (epilogue)
Irish republicanism, 76, 137, 140, 345
Irish War of Independence, 278
Islands of the Blessed (or Fortunate Islands), 158
Istanbul, Turkey, 349
Italy and Italians, 31, 42
- jail, 35, 74, 77, 79, 82, 83, 122, 140
Jamaica, 21
Janssen, Jules, 26, 304
Jena, Germany, 135
Jesuits (members of the Society of Jesus), 105, 144–145, 155
Jewell, Lewis, 118
“Jewish physics,” 32
Jews and Judaism, 31–32, 35, 63, 72, 120–122, 276–277, 279, 298, 349, 369n9 (ch. 4), 372n4 (ch. 13)
Johns Hopkins University, 118
joint meeting of the Royal Society and the RAS, November 6, 1919, 7, 8, 195, 220–225, 226, 234, 237, 266–267, 268, 273, 276, 279, 346, 371n3 (ch. 12)
Joint Permanent Eclipse Committee (JPEC), 7, 8, 14, 17, 20, 24–27, 61, 92, 97, 105, 107, 110, 113, 145, 152, 178, 222, 234, 235, 267, 318, 369n1 (ch. 5), 371n3 (ch. 11)
Jonckheere, Robert, 66, 238
Jones, Harold Spencer, 105, 147, 185, 203, 282, 283, 369n1 (ch. 6), 371n3 (ch. 11)
JPEC planning sub-committee for the eclipse of 1919, 67, 110, 112, 145, 152–155, 369n2 (ch. 6)
Jupiter, 59
- Kaiserslacht, German spring offensive of 1918, 79–80, 143
Kaiser Wilhelm Institute for Physics (now part of the Max Planck Institutes), 88
Kapteyn, Jacobus, 66, 127, 131–132, 297, 298, 368n3 (ch. 4)
Keele University, Staffordshire, 342
Kelvin, 1st Baron (William Thomson), 160
Kennedy, Roy, 295, 302, 303
Kennefick, Julia, 27, 241
Kepler, Johannes, 21
Kerensky, Alexander, 114
Kessel (military encirclement) near Kiev in World War II, 310, 373n5 (ch. 14)
Kew Observatory, 17
Khartoum, Sudan, 311
Khayyam, Omar. *See* Omar Khayyam
Kiev, Ukraine, 310
Klein, Felix, 57
Kobe, Japan, 114
Kodaikanal Observatory, India, 18, 119, 283
Kola peninsula, 30
Koppel, Leopold, 61
Kouybshevka, Russia, 309
Krasnoyarsk, Russia, 311
Kristallnacht, 369n9 (ch. 4)
Krupp, Gustav, 62
Kuhn, Thomas, 217, 231, 269, 270, 294

- Labour Party, British, 78
Lake Baikal, Russia, 311
Lake District (of England), 10, 147
Lake Tanganyika, Africa, 107–108, 108, 110, 369n3 (ch. 6), 370n4 (ch. 6)
Lambert, Michael, 140
Lancashire, England, 145
Land War, Irish, 140, 373n2 (epilogue)
La Paz, Bolivia, 108, 370n4 (ch. 6)
Laplace, Pierre-Simon de, 101, 267, 369n3 (ch. 5)
Larmor, Joseph, 68, 80, 82, 239, 373n2 (ch. 14)
Latin, 40
Legion d’Honneur, 371n1 (ch. 12)
Leicestershire, England, 12
Lenard, Phillip, 121–122
length contraction, in relativity, 40–41, 47–49, 367n1 (ch. 3)
Lenin (Vladimir Ilyich Ulyanov), 34, 91
Leningrad, Soviet Union, 321
Lewis (cable station operator, Principe), 163
liberalism, 72, 121
Liberia, 109, 221, 239
Lick Observatory, California, 25, 57, 113–116, 180, 257, 280, 285, 289, 347, 372n7 (ch. 13)
Liebknecht, Karl, 75
light, speed of. *See* speed of light (in vacuum)
light deflection: “double” deflection proposed by Cottingham, 182, 215; “full” prediction of general relativity (1.75 at the limb of the Sun), 46, 54, 55, 63, 113, 117, 182, 185, 186, 198, 206–207, 211, 213, 252, 253, 255, 256, 263, 285–286, 287, 307, 310, 311, 337, 372n9 (ch. 13); “half” or “Newtonian” prediction of (0.87 at the limb of the Sun), 46, 54, 54, 63, 117, 121, 182, 185, 186, 198, 206–207, 211, 213, 214, 215, 245, 248, 252, 253, 256, 263, 264, 285, 324, 331, 364, 372n9 (ch. 13); “null” or zero deflection prediction, 116–117, 122, 182, 183, 186, 211, 212, 213, 215, 216, 220, 254, 256, 257, 263, 264, 265, 361
light deflection test and prediction, 2, 8, 9, 12, 13, 18, 20, 21, 25, 28, 29, 42, 44, 45, 46, 54, 55, 57, 58, 59, 63, 86, 92, 93, 95, 97, 107, 114, 115, 117, 180, 183, 184, 190, 191, 191–192, 195–198, 200, 203, 204, 207, 212, 214, 229, 237, 238, 239, 244, 245, 246, 248–250, 252, 253, 255, 258, 263, 275, 279, 280, 284, 286, 288, 289, 291, 304–305, 307–310, 314, 316, 322, 323, 324, 331, 349, 350, 357–364
Lille Observatory, Belgium, 66
Lindblad, Bertil, 296–297
Lindemann, Adolph Friedrich, 18, 305
Lindemann, Frederick Alexander, 18, 237, 278, 305, 372n6 (ch. 13)
Lisbon, Portugal, 108, 154, 155, 157, 162
Lisbon Observatory, Portugal, 154
Liverpool, 154–155, 278, 347
Lloyd’s of London underwriters, 202
Lobachevsky, Nikolai, 51
Lockyer, Norman, 17, 26–27, 235, 304
Lodge, Oliver, 80–81
London, 2, 7, 17, 26, 64, 65, 66, 105, 127, 136, 147, 149, 152, 155, 180, 226, 266, 267, 276, 278, 341, 346, 369n1 (ch. 5), 269n2 (ch. 6)
London Illustrated News, 227
longitude, measurement of, 15, 16, 21, 24, 52, 68, 129, 166, 185, 367n2 (ch. 3), 370n3 (ch. 6), 371n3 (ch. 11)
Lorentz, Hendrik Antoon, 47, 48, 74–75, 96, 229, 263
Lorentz transforms, 99–100
Louvain, Belgium, burning of, 66, 69–70, 75
Ludlam, Ernest, 274–275
luminiferous ether. *See* ether, luminiferous
RMS Lusitania, sinking of, 66, 69, 368n5 (ch. 4)
Luton, England, 278
Luxembourg, Rosa, 75
Lydians (ancient people of Anatolia), 172
Lynden-Bell, Donald, 242, 371n2 (ch. 12)

Madeira, island of, 108, 154–155, 156, 157–163
Madingley Road, Cambridge, 161, 235, 346
magnification, optical. *See* scale of photographic images (magnification)
Maldives Islands, 210, 283
Manaus, Brazil (formerly Manaós), 164–165
Manchester, England, 79, 278
Manchester, University of (formerly Owens College), 10
Manhattan Project, 309
Manifesto of the Ninety-Three, 69, 75
Manifesto to the Europeans, 70, 73–74, 84
Maric, Mileva, 86–88
Markree Observatory, Ireland, 136
Marxism, 122, 228, 255
Maunder, Annie, 370n6 (ch. 6)
Mauretania, 168, 214, 305, 307, 311–312, 315
Maxwell, James Clerk, 44–45, 99–100, 101
McDonald Observatory, Texas, 312

- Medes (ancient Iranian people), 172
Melbourne Observatory, Australia, 128, 136, 141
Mercury (planet) 28; anomalous perihelion advance of, 45, 46, 53, 61, 87, 93, 103, 115, 117, 212, 216, 223, 263, 308, 317, 325
meridian line, 166, 371. *See also* prime meridian
Mersey River, Liverpool, 156
meteorology, 24, 64–65, 237. *See also* weather
Met Office of Britain, 17
metric of spacetime, and metric theories, 41–42, 263, 339
Michelson, Albert Abraham, 183, 184, 257, 299, 300, 303, 304
Michelson-Gale experiment (on the Sagnac effect), 300
Michelson-Morley experiment (and similar experiments), 39, 47, 291, 292, 294, 295, 298, 300, 303
micrometer screw, for measuring star positions on plates, 2, 133, 153, 181, 189, 195, 204, 207, 221, 359, 360
Middle Ages, 174, 349
Mikhailov, Aleksandr Aleksandrovich, 309–313, 315, 319, 321
militarism, 34–35, 36, 70, 76
military service, 36, 76–77, 78
Military Service Tribunal, 77, 78
Milky Way Galaxy, 124, 132, 296, 297, 341
Miller, Dayton, 123, 292–303, 320, 332, 338, 372n1 (ch. 14)
Millikan, Robert, 187, 257, 295, 301–302, 303
mimosa (plant), 164
mine, naval, 30, 367n2 (ch. 2), 370n1 (ch. 8)
Ministry of Shipping, British government, 153
Minkowski, Hermann, 41, 96
Minsk, Belarus, 147
modernism, 121
monarchism, 35, 155, 157
Moon, 19, 20, 21, 23, 26, 28, 45, 100, 101, 126, 129, 131, 169, 173, 173, 176, 193, 201, 245; full, 19, 28, 173, 192, 284; new, 23, 173, 173, 175
Moon shadow, 19–20, 169, 237. *See also* totality, path or track of; umbra of a total eclipse
Moritz, Rudolf, 66, 123
Morize, Henry, 164, 165, 220
Moscow, Russia, 310
Moseley, Henry, 72
Mouchez, Admiral Amédée, 128, 134
Mount Hamilton, California, 115, 347.
See also Lick Observatory, California
Mount Palomar Observatory, California, 27
Mount Wilson Observatory, California, 119, 292, 293, 294, 295, 296, 299, 300, 302, 308, 347
Mumbles, Wales, 159
Munich, 31
Murmansk convoy, 30
Murray, Andrew, 242–244, 246, 251, 372n4 (ch. 12)
myths, about eclipse of 1919, 188, 248
myths, analogy with the fecundity of science, 339–340
Napoleon Bonaparte, 314
National Academy of Sciences meeting, April 1925, 294, 296, 300
National Geographic Society, 309
Nature magazine, 17, 106, 108, 195, 237, 250
Die Naturwissenschaften, 263
naval arms race, before World War I, 136
naval blockade of Germany, 30, 67, 71, 88, 275
Nazi Party, 32, 62, 73, 91, 122, 277, 278, 310, 319, 349, 369n9 (ch. 4)
Neptune, 28, 99, 234
Nernst, Walther, 36, 71
Netherlands, the. *See* Dutch people and the Netherlands (Holland)
neutron stars, 13, 321, 340. *See also* pulsars
Newall, Hugh, 80, 82, 235–237, 275–276, 369n7 (ch. 4), 371n3 (ch. 12)
Newcastle upon Tyne, England, 343, 345
New Fatherland League, 73
Newton, Isaac, 4, 9, 26, 33, 34, 36, 39, 42, 45, 46, 55, 98, 101, 102, 117, 121, 182, 211–212, 213, 214, 215, 216, 218, 219, 223, 224, 232, 248, 251–252, 253, 255, 256, 264, 265, 267, 268, 274, 279, 289, 291, 337, 362, 365
Newtonian limit of General Relativity, 220
“Newtonian” prediction of light deflection. *See* light deflection: “half” or “Newtonian” prediction of
Newtonian theory of gravity, 4, 42, 45, 46, 98, 99–100, 101, 102, 121, 182, 186, 188, 213, 215, 216, 218, 219, 226, 240, 252, 253, 263, 267, 268, 269, 287, 318, 337, 338, 344, 350
Newton’s laws of motion, 45, 99, 121

- New York, 226, 277, 278, 372n5 (ch. 13)
New York Times, 226, 373n4 (epilogue)
New Zealand, 328
Nicolai, Georg, 73
Nobel Prize, 72, 76, 78, 121, 257, 277
node, of the lunar orbit, 19, 173, 173, 201
nonconformists. *See* dissenters (English Protestants dissenting from the Church of England)
non-Euclidean spacetime. *See* curvature of spacetime
Nordström, Gunnar, 213, 263, 264
Nordström's theory of gravity, 213, 263, 264, 265
Norman Lockyer Observatory, Sidmouth, Devon, 17
Northamptonshire, England 6, 112, 144
Norwegian Sea, 30
null geodesics, 54, 368n4 (ch. 3)
null result, of light deflection test. *See* light deflection: "null" or zero deflection prediction
null result of Michelson-Morley experiment, 183, 292, 293, 300
Observatory magazine, 67, 242, 286, 347
Odessa, Ukraine, 142–143
Ohio, 40
Omar Khayyam, 51, 52, 201, 367n2 (ch. 3)
Oort, Jan, 296–297
open clusters. *See* Hyades star cluster
Optics of Newton, 34, 223
oral transmission of stories about science, 248, 264, 299, 328
Organisation Consul, 75
Overbye, Dennis, 373n4 (epilogue)
Owens College. *See* Manchester, University of (formerly Owens College)
Oxford, England, and Oxford University, 110, 278, 342
Oxford University Observatory and the Oxford Astrographic telescope, 15, 17, 110, 111–112, 128, 141, 144, 146, 170, 171, 189, 196, 197, 199, 207, 342
pacifism and pacifists, 31, 32, 34, 35, 36, 37, 38, 73, 74, 76, 78, 79, 81, 84, 104, 121, 210, 215, 336
Pais, Abraham, 226, 302, 373n3 (ch. 14)
Pará (Brazilian state), 154, 164, 165
paradigms (research frameworks), 185, 217, 218, 219, 231, 269, 270, 294, 318, 339
paradigm shift, 231
parallax, 8, 23, 129, 131, 133, 240, 280
parallel lines, 51–54, 367n2 (ch. 3)
Paris, siege of (1870–71), 370n2 (ch. 7)
Paris Commune, 370n2 (ch. 7)
Paris Exposition Universelle (World's Fair) of 1900, 138
Paris Observatory, 128
Parliament, British. *See* House of Commons
parsec (parallax second, unit of distance), 131
Parsons, Charles, 343, 345
Parsons, William. *See* Rosse, 3rd Earl of (William Parsons)
Pasadena, California, 116, 211, 256
passports and visas, 79, 153, 156, 277, 278
patent office. *See* Swiss federal patent office
Pauli effect, adverse effect on experiments caused by presence of certain theorists, 185
Penrose process, 322
periscopes for submarines, 135, 137
Perkins, Adam, 242
Perrine, Charles, 29, 58, 97, 113–114
Persians (ancient Iranian people), 172
Perth Observatory, Australia, 128, 141
Phoenix Park, Dublin, 140
photography: dry plate method, 125; wet plate method, 126
photography and photographic plates, 1, 7, 8, 11, 15, 17, 25–29, 57, 58, 62, 92, 107, 111, 125, 126, 127–128, 132–133, 138, 140, 145, 149, 166–171, 176, 178, 182, 190, 194, 195, 196, 200, 205, 206, 214, 220, 240, 246, 269, 282, 284, 285, 290, 305, 311, 312, 315, 316, 319, 342, 371n7 (ch. 11)
photons, 33, 44, 45, 253, 334
Physical Foundations of General Relativity, *The* (Sciama), 247
Piccard, Auguste, 302–303
Piccard, Jean, 302–303
pilot, shipping, 156
Pinch, Trevor, 186
"pips" for synchronizing clocks via radio from Greenwich, 16
Planck, Max, 33, 36, 69, 229
plane geometry. *See* Euclidean geometry (flat or plane geometry)
plate measuring machines, 204, 241, 242, 245, 251, 257, 317, 360
Plumian Professor of Astronomy, Cambridge, 12, 109, 220, 234
Plutarch, 158
Pluto, 63

- poison gas warfare, 37
Poland and the Polish, 224
Pole, North Celestial, 128, 131, 166
Pole, South Celestial, 166
Pollak, Leo, 56–57
Poor, Charles Lane, 123, 308
Popper, Karl, 228–232, 236, 238, 254–255, 272, 295, 301, 315, 334, 338
SS Portugal, 158, 160, 162
Portugal, civil war over Monarchy of the North, 155, 157
Portugal and Portuguese, 23, 154, 155, 158, 162, 163, 221, 371n6 (ch. 10)
Potsdam Observatory, Germany, 62, 254, 319, 343
Pound-Rebka experiment, 306
Prague, 50, 349
prime meridian, 15, 166, 347, 372n4 (ch. 12)
Princeton University, 292, 306, 307
Principle, 1, 2, 15, 17, 24, 26, 79, 106, 107, 108, 109, 112, 115, 144, 146, 152–154, 157–163, 165, 168–171, 175–176, 177, 178, 180–182, 189, 191, 191, 194, 194, 195, 196–208, 213, 220–222, 233, 241–242, 250, 263, 315, 370n3 (ch. 6), 371n6 (ch. 10), 371n2 (ch. 11), 371n7 (ch. 11)
Principe, governor of, 160, 162
Principia of Newton, 279
principle of equivalence. *See* equivalence principle
principle of relativity. *See* relativity, principle of
principle of the constancy of the speed of light, 40
probability function or Ψ function, 278
Professor Calculus (character in Hergé's *Adventures of Tintin*), 303
proper motion of stars, 112, 129, 131–133, 280, 341, 342
Protestants, 147
Prussia and Prussians, 76, 121, 370n2 (ch. 7)
Prussian Academy of Sciences, 61, 88
Pulkovo Observatory, near St. Petersburg, Russia (also Poulkova), 114, 147, 321
pulsar, binary, 317, 350
pulsars, 306, 317, 321, 350. *See also* neutron stars
Punch magazine, 266, 278–279
Pythagorean theorem, 41, 42
quantum gravity, theory of, 322
quantum physics, 14, 33, 306
quasars, radio observations of occulting, 248, 304, 306, 321, 335
SS Quelimane, 159
Radcliffe Observatory, Oxford, 342
radiation pressure, 13, 45
radio astronomy, 246, 248, 304–306, 319, 321, 334
Rathenau, Walther, 75
Ray, Tom, 343
realism, scientific, 230, 232
re-analysis of 1919 plates in 1978, 241–248, 249, 317, 364
reception of 1919 results, 3, 235–241
Red Army, 143, 310
redshift: gravitational, 300–301, 306; solar, 44, 45, 57, 62, 115, 117–120, 184, 186, 230, 253, 269–272, 308, 317; transverse Doppler, 44
reflector sight, for rifles, 135
refraction, differential. *See* differential refraction
Regulus (Alpha Leonis), 18, 237, 305
relativity, general theory of. *See* general relativity (GR), theory of
relativity, principle of, 38–40, 42, 43, 96–97, 101, 103, 266, 299
relativity, special theory of. *See* special relativity
revolution, German (1919), 89–90, 143, 151
revolution in science, 7, 33, 183, 218, 226, 231, 296, 298, 341
revolutions, other: Austria, 122; Ireland, 140; Portugal, 154; Russia, 18, 34, 21, 114, 137
Riemann, Bernhard, 66
Riemannian geometry. *See* differential geometry
right ascension (celestial coordinate), 193, 243–244
Rio Negro, Brazil, 164
Robinson, Romney, 136
Robinson, W. B., 227
Roça Sundy, Principe, 161–165
Rome, Italy, 224
Rosenthal-Schneider, Ilse, 229, 263
Rosse, 3rd Earl of (William Parsons), 135–136, 343
Ross effect on gelatin films used in photography, 240
rotating disk thought experiment, 48–49, 367n1 (ch. 3)
Rotterdam, 64

- roulette, 159, 163
- Rowland, Henry, 118
- Royal Astronomical Society (RAS), 7, 8, 66, 105, 111, 145–146, 152, 178, 180, 193, 195, 221, 222, 234, 236, 237, 256, 268, 273–274, 280, 287, 329, 346, 347, 369n1 (ch. 5), 369n2 (ch. 6); dining club, 267; governing council, 274
- Royal Astronomical Society meetings: June 1919, 178, 280; July 1919, 180, 256, 280; November 1919, 180, 193, 234–236; December 1919, 180, 221, 268–269
- Royal Astronomical Society, Monthly Notices of the*, 93, 106
- Royal College of Science, Kensington, 17, 235
- Royal Dublin Society, 141, 343, 344
- Royal Greenwich Observatory (RGO). *See* Greenwich Observatory
- Royal Irish Academy, 112, 138, 141, 145, 323, 343, 344
- Royal Observatory, Edinburgh, 12, 346, 373n3 (epilogue)
- Royal Observatory at the Cape of Good Hope, South Africa, 126, 140
- Royal Society, 7, 8, 24, 105, 152, 195, 222–223, 246, 266, 346, 249
- Rubaiyat of Omar Khayyam* (translations by Edward Fitzgerald), 201
- rubber trade, 163, 164–165, 347
- Russell, Bertrand, 14, 78–79, 82, 367n2 (ch. 1)
- Russell, Henry Norris, 279, 372n3 (ch. 13)
- Russia, 20–21, 30, 34, 59, 62, 63, 67, 72, 79, 91, 105, 113–116, 137, 138, 142–143, 145–147, 162, 308–309, 322; civil war, 143; revolution, 21, 114, 137
- Rutherford, Ernest, 328–329
- Sagnac, George, 300
- Sagnac effect, 300
- Sahara desert, 157, 315
- San Gabriel Mountains, California, 293
- Santa Cruz, University of California at, 347
- Santo Antonio, Principe, 163
- São Tomé (formerly St. Thomé), 159, 163, 371n2 (ch. 11)
- saros cycle, 173, 174, 193. *See also* solar saros 136
- saru, Babylonian number word, 193, 371n5 (ch. 11)
- scale change, independent determination of, 197, 199, 200, 203–204, 250
- scale change between eclipse and comparison plates, 169, 171, 191, 195–197, 200–201, 204, 243–245, 249–251, 258, 284, 286, 290, 309–312, 318, 358, 359, 360–365, 363
- scale of photographic images (magnification), 8, 128, 148, 169–171, 190, 192, 194, 198–200, 203–204, 207, 243–245
- scale plate, 189
- Scandinavia, 59
- Scapa Flow, Orkney Islands, 369n6 (ch. 4)
- Schlesinger, Frank, 210
- Schrödinger, Erwin, 298
- Schütte-Lanz airships, 65
- Schwarzschild, Karl, 66–67, 72
- Sciama, Dennis, 247
- Science* magazine, 294
- science popularization, 15, 33, 37, 86, 186–188, 224, 228, 263–268, 273, 303, 351
- Scotland and the Scots, 12, 63, 77, 126, 132, 346, 349, 373n3 (epilogue)
- second contact, during eclipse, 176
- Secret Agent, The* (Conrad), 368n2 (ch. 4)
- See, Thomas Jefferson Jackson, 124
- seeing (astronomical term), 193, 284
- semireflecting mirror, 309
- Sfax, Tunisia, 107
- Shapin, Steven, 4
- Shapley, Harlow, 124
- Siberia, 309–310, 311
- Sidmouth, Devon, 17–18
- Silberstein, Ludwik, 123, 224–225, 240, 269, 293–294, 371n9 (ch. 11)
- silvering of coelostat mirrors, 178–179, 203
- Sirius B (white dwarf star), 300–301
- slave trade, 162, 371n6 (ch. 10)
- Sligo, Ireland, 136
- Slipher, Vesto, 114
- Smith, Harlan, 312
- Smith's Prize, 10–12
- Sobral, Brazil, 15, 16, 106, 108, 108, 112, 134, 138, 144–146, Fig. 11 (148), 148–150, 152–153, 155, 164–166, 167, 169–170, 175–179, 189–204, 191, 206–209, 208, 211, 213, 215, 220–221, 223, 232, 238, 240–244, 246, 248–251, 258–259, 282, 289, 311, 322, 329, 343, 344, 357, 358, 363, 364
- social constructivism, 232–233, 334
- socialism and socialists, 34, 35, 74–75, 78, 82, 89, 90, 121, 122
- solar astronomy, 1, 18, 45, 62, 117, 118, 120, 145
- solar atmosphere, 26, 27, 118, 119, 271, 275

- solar corona (and coronagraphs), 27, 28, 141, 147, 176, 191, 200, 202, 236, 237, 240, 284, 286, 304, 371n3 (ch. 12)
- solar oblateness, 307–308
- Solar Physics Observatory (first London, then Cambridge), 17, 235, 369n7 (ch. 4)
- solar prominence or solar flare, 26, 176–178, 177, 205–206, 221, 236
- solar redshift. *See* redshift, solar
- solar saros 136, 173, 349
- solar spectrum, 26, 27, 118, 270–272; absorption lines in (Fraunhofer lines), 184, 270
- solar system, 13, 17, 20, 28, 45, 46, 53, 102–103, 130, 130, 132, 218–219, 295–300, 297, 316–317; velocity of, 39, 295, 296, 297, 299, 332
- Soldner, Johann Georg von, 121, 220
- Solvay conference of 1921, 277
- Sommerfeld, Arnold, 61–63
- sound, speed of. *See* speed of sound
- South Africa, 126–127, 126, 134
- Southern Ocean, 175, 279
- South Georgia Island, 175
- Soviet Union, 122, 143, 309–310
- Space, Time and Gravitation* (Eddington), 216, 371n7 (ch. 11)
- spacetime, 33, 39, 41, 46, 47, 49–54, 54, 87, 101, 115, 117, 206, 211, 219, 261, 334, 351, 368n3 (ch. 3), 373n6 (ch. 14)
- spacetime, curvature. *See* curvature of spacetime
- Spain, 23, 141
- Spartacist uprising (or Spartacus week), 75, 90–91
- special relativity, theory of, 29, 33, 38, 39, 41, 43, 44, 47, 49, 88, 94–96, 100–102, 129, 294, 300, 337, 338
- spectroscopy, 7, 25, 26, 43–45
- speed of light (in vacuum), denoted c , 39, 40, 48, 95, 100, 102, 129, 238, 292, 325, 369n2 (ch. 5)
- speed of sound, 49
- spiral nebulae (other galaxies), 281, 296
- Sponsel, Alistair, 265–267
- spurious phenomena, such as the planet Vulcan, 316
- St. Albans, England, 136
- St. Andrews, Scotland, University of, 349
- Stanley, Matthew, 81
- star streams, 132, 297
- steam turbine, 345
- stellar aberration, 96, 129, 130, 131, 190, 194, 204, 241, 295, 362
- Stephens, James, founder of the IRB, 140
- St. John, Charles Everard, 119, 120, 184, 186, 230, 233, 269–272, 304
- Stonyhurst College, Lancashire, England, 144
- St. Petersburg (also Leningrad), Russia, 114, 321
- Straits of Magellan, 347
- Stratton, Frederick John Marrian “Chubby,” 221, 235–236, 371n1 (ch. 12)
- Streete, Co. Westmeath, Ireland, 345
- Strömberg, Gustaf, 296–300, 332, 297
- Struve, Hermann, 59, 61, 62
- Subtle Is the Lord* (Einstein biography by Pais), 302, 373n3 (ch. 14)
- Sudan, 311
- sugarcane production, on Madeira, 158
- Sumatra, 252
- Sun, 1–2, 4–5, 7–8, 13, 18–21, 23, 26–29, 33–34, 44–56, 53–55, 54, 57–60, 60, 83, 91, 92, 95, 96, 102, 103, 106, 108, 109, 113–116, 118–119, 121, 126, 129–131, 130, 141, 147, 166, 169–170, 173, 173–179, 177, 188–197, 191, 199–202, 205, 211, 216, 218–220, 223, 233, 236–238, 240, 243, 245–246, 249, 252, 257–258, 266, 270–271, 281, 284–286, 289, 293, 296, 297, 304–305, 307–312, 317, 323, 325, 327, 331, 332, 334, 349, 358, 359, 360, 361, 363, 364, 370n6 (ch. 6); internal structure of, 13, 28, 45; limb of, 26–27, 55, 96, 119, 197, 236, 249, 252, 270, 271, 289, 304, 358, 358–361, 359, 363, 364
- sunspots, 370n6 (ch. 6)
- supernovae of 1572 and 1604, 304
- Sussex, England, 242, 341, 346
- Swabia, Germany, 31
- Sweden, 20, 145–147, 162, 167, 349
- Swiss federal patent office, Bern, 31, 36, 42, 123, 230
- Swiss Federal Polytechnic Institute (ETH), Zurich, 31, 50, 184
- Switzerland, 31, 36, 42, 50, 56, 74, 87, 88, 90, 91, 123, 230, 257, 276–280, 285, 298, 302
- Sydney Observatory, Australia, 128, 141
- tacit knowledge, 150, 313–314, 317–318, 324
- Tacubaya Observatory, near Mexico City, 141
- Tahiti, 23, 284
- Taurus (constellation), 311
- Taylor, Joseph, 350
- telegrams. *See* Einstein, Albert: first news of the 1919 eclipse results, by telegram

- telegraph cables, 18, 85, 237
telegraph cable stations, 158, 163
telescopes: reflecting, 126, 135, 136, 169, 179, 342; refracting, 136, 138, 169, 342
telescope tracking. *See* clockwork drivers for telescopes and coelostat mirrors
tensors, 42, 267, 373n6 (ch. 14)
tests of relativity, classical, 43–44, 45, 47, 224, 228, 233, 300, 306
Texas, University of, 3, 214, 246, 305, 311
Thales of Miletus, 172–174; theorem of, 174
Thames River, 16
theoretical physics and theoretical physicists, 3, 13, 32–33, 38, 92, 99, 100, 101, 117, 121–122, 184, 206, 211, 215, 222, 230, 253, 257, 260, 261, 268, 281, 294, 295, 301, 306, 318, 320, 331, 336–339
Theoreticians' Art, 318, 339
theory testing, 57, 61, 211, 232, 252, 253, 255, 263, 270, 279, 331
third test. *See* redshift, solar
Thomson, Joseph John (J. J.), 223
thought experiments, 39, 43, 44, 48, 49, 96
three people who understand relativity theory (anecdote), 224–225
tidal friction, 20
Timbuctoo, 325
time dilation, in relativity, 40–41, 44, 368n4 (ch. 3)
timekeeping (6 pips), 16
Times of London (newspaper), 226, 276, 282
Tintin, the Adventures of (Hergé), 303
RMS Titanic, 23
Toronto, University of, 285
totality, path or track of, 5, 20, 21, 22, 23, 24, 59, 107, 108, 109, 162, 250, 279, 281, 323, 372n7 (ch. 13), 373n4 (ch. 14)
transit circle, 127
transit of Venus, 9, 17, 23
Trans-Siberian Railway, 309
Trimble, C. J. A., 149
Trimble, Virginia, 330
Trinity College, Cambridge (and library of), 10, 12, 221
Triple Entente, 64, 69, 88, 368n5 (ch. 4)
Trumpler, Robert, 252, 257, 260, 280, 281, 284–286, 289–291, 309, 348
Tunisia, 107
Turkey, 172
Turner, Geoffrey, 159, 161, 163
Turner, Herbert Hall, 67–69, 110, 111, 133, 192, 234–235, 267, 276, 277, 286
U-boats (submarines of Germany navy), 158, 367n2 (ch. 2), 368n5 (ch. 4), 370n2 (ch. 9)
Ukraine, 143
Ulm, Germany, 31
Ulster (province of Ireland), 147
umbra of a total eclipse, 237
unified field theories, 14, 184, 254, 321, 348
United States Air Force (formerly US Army Air Corps), 309
United States Naval Observatory, 129
United States of America and Americans, 18, 25, 59, 80, 85, 89, 106, 109, 112, 113, 114, 117, 118, 119, 123, 138, 142, 143, 148, 180, 205, 210, 220, 226, 239, 240, 256, 257, 277–278, 281, 286, 291, 292, 293, 295, 298, 304, 308, 309, 320, 369n9 (ch. 4), 373n4 (ch. 14)
universe. *See* cosmology
University Parks, Oxford, 342
Uranus, 28, 99
Van Biesbroeck, George, 308–313, 315, 319, 321
HMS Vanguard, 79, 369n6 (ch. 4), 370n1 (ch. 8)
vectors, 42
Venezuela, 113
Venus, 9, 17, 23, 312
Versailles Treaty (peace agreement after World War I), 152, 275
SS Vestris, 372n5 (ch. 13)
Vickers, Sons and Maxim (British engineering and shipbuilding firm), 137
Vladivostok, Russia, 114
Vulcan (hypothetical planet), 29, 45, 58, 113–114, 316
wager between Dicke and Wheeler on correctness of GR, 307
Wales, 156, 159
Walkley, missionary, 157
Wallal, Western Australian, 203, 283–285
Waller, John, 187
war crimes, 64, 66, 69, 74
war work, of various scientists, 35–36, 81, 82, 83, 112, 114, 115
Was Einstein Right? (Will), 247, 372n2 (ch. 13)
Washington, DC, 239
Washington state, 114, 304
Waterford, Ireland, 136

- wave nature of light, 3, 33, 34, 96, 121, 127, 268, 326
- wave nature of particles in general, 278
- Wayman, Patrick A., 246
- weather, 2, 5, 17, 24, 65, 109, 144, 145, 153, 162, 168, 181, 182, 183, 201, 204, 234, 235, 239, 261, 283, 284, 310, 320, 335, 349
- weighing light, 3, 13, 206, 212, 248, 326
- Weimar Republic, 75
- Weizmann, Chaim, 277
- Western Reserve University. *See* Case Western Reserve University
- Weston-super-Mare, Somerset, 10, 161
- Weyl, Hermann, 184, 210
- Wheeler, John Archibald, 306–307
- white dwarf star, 300–301
- white feather (symbol of cowardice), 35
- Whitehead, Alfred North, 222, 264
- White Sea, 30
- White Star Line, 278
- Wien, Wilhelm, 298
- Wilkinson, Norman (artist), 156
- Will, Clifford, 247, 372n2 (ch. 13)
- Williams, W. H., 326
- Wilson, Margaret (née Dyson), 348, 371n1 (ch. 11)
- Wilson, William Edward, 345, 373n1 (epilogue)
- Wobeser, Hauptmann Richard von, 65
- Workman and Clark shipyard, Belfast, Ireland, 348
- World War I (also the Great War), 2, 3, 8, 12, 18, 20, 30, 32, 34, 35, 36, 37, 62–64, 70, 71, 72, 76, 79, 84, 86, 93, 120, 135, 142, 152, 155, 158, 210, 277, 235, 369n6 (ch. 4), 370n1 (ch. 8), 372n10 (ch. 13)
- World War II, 72, 220, 235, 237, 304, 309, 321, 346, 348, 368n1 (ch. 4), 369n8 (ch. 4)
- wranglers, 10, 12, 94, 147, 149, 150, 235
- Wright (cable station operator, Principe), 163
- Yale Observatory, 210
- Yerkes Observatory of the University of Chicago, 308–309
- Yorkshire, 12, 323
- Yardsticks (or meter sticks), in relativity theory, 39, 40, 324
- SS Zaire*, 182
- Zeiss. *See* Carl Zeiss Optics
- zeppelin raids (and other forms of aerial bombardment), 37, 64–65, 368n4 (ch. 4)
- Zionism and Zionists, Einstein's work on behalf of, 120, 277
- Zurich, 50, 87, 90