Chaos and Light: Modernity in Paris in 1890

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Abstract

The late 1800s was a time of great innovation and transformation in Paris. This essay explored the modernization of Paris by following two parallel developments: the widespread adoption of electric light and the flourishing scientific revolution epitomized by the work of Henri Poincaré. The objective of the study was to identify the significant historical figures, events, and policy decisions that helped Paris become a beacon of light for Europe and the rest of the world by the time of the Exposition Universelle in 1889. The research also considered what can be learned about the process of modernization more generally by studying this moment in the history of Paris—from Haussmann and his urban developments, to Poincaré's scientific achievements, to the cultural impacts of modernity. The paper concludes that the 1889 Exposition Universelle was a turning point in history that marked the beginning of a radical transformation from Medieval Europe to our modern world—opening a pathway that has led to the technology and conveniences that society has today. Meanwhile, physics moved from a clock-work assumption of the way things work, to one with richer and more elaborate dynamics.

Keywords: Paris, Physics, Modernization, Electricity

1. Introduction

April 1890 was a most exciting time to be a scientist or an engineer in Paris. A year earlier Paris hosted the Exposition Universelle (world's fair), the fourth and most magnificent Exposition Universelle (Turner, 1889), with over 32 million visitors (Jones, 2005). After a series of dramatic power changes, from Napoleon III being defeated in the Franco-Prussian War, to the revolt of the Commune of Paris and the turmoil that followed these events, France set out to display its greatness on an international scale (McPhee, 2015). The event took place on the centenary of the storming of the Bastille and the Eiffel Tower, created for the Exposition, was the centerpiece (Harriss, 2004).

Like previous events, the 1889 Exposition Universelle took place on the Champ de Mars in the newly constructed Galerie de Machines and the Trocadero but was also expanded along the Seine to include the Colonial Exhibition in the Esplanade des Invalides (Harriss, 2004). The exhibition site took up 237 acres, was housed in eighty buildings and it included 61,722 exhibitors (Jeffery, 1889).

The exhibition was brightly lit with electric lights, with some on fountains that changed color (Picard, 1892). It showcased a future of technology with a phonograph, a telephone, the first gas powered car—made by Daimler, and Thomas Edison demonstrating what was possible with electricity (de Varigny, 1889). Nikola Tesla, the inventor of the AC Motor also attended, but did not demonstrate his inventions (O'Neill, 2007). Presiding over all these marvels was the 300 meter tall iron lattice Eiffel Tower (Figure 1), at that time the tallest building in the world (Harriss, 2004). It was a symbol of what was possible. Engraved on the four sides of the tower there are the names of seventy two engineers, scientists, and mathematicians whose work led to modernity, discoveries, and inventions, on display at the Exposition, and to a future that would change the lives of Parisiennes and the world (Harriss, 2004).

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In contrast, the daily lives of Parisiennes in 1890 were worlds away from that promised future. In the 19th Century, Paris was the largest city on the European continent. Only London was larger, but Paris was twice as dense. From 1800 to 1850, the population living in the 13 square miles of the city doubled to around 1.1 million, and the average population density also doubled. In the center of Paris there was one person for every eight square meters (Soppelsa, 2009). As one observer remarked, "the inner streets were narrow, crooked, crowded, ill built, and very unsavoury" (Schwartz, 1998). As another traveler said, disappointed by the muddy, narrow streets, "So this is Paris… the city that seemed so magnificent to me afar" (Jordan, 1995). Far from healthy, vibrant societal growth, this population explosion created an acute urban crisis. As Paris expanded to make more room for new inhabitants and packed more people into the city, the result was what David P. Jordan (1995) has vividly described as "a congested, chaotic, incoherent jumble" (p. 93).

For much of the 1800s there were few dwellings in Paris with running water, meaning that poor hygiene and sanitation, sprawling slums and periods of uncontrolled spread of disease were the norm (Jones, 2005). In fact, in 1888, only 697 buildings in Paris—less than 1% of all residential buildings—had direct-to-sewer drainage for toilets (Soppelsa, 2009). Other than those at the Exposition, there were very few electric lights (Holcombe, 1911). The most common form of transportation was walking, with human powered and horse powered carts of diverse shapes and sizes filling the streets (Osterhammel, 2014). However the process of providing electricity and plumbing to Paris had started (Holcombe, 1911), and there was public planning underway for the construction of the metro (Evenson, 1979). Paris would soon prove itself worthy of the name "the City of Lights".

Figure 1. *The Eiffel Tower is on fire*, color engraving by Georges Garen, 1889, Musée d'Orsay. This image was chosen as one of the representative images of the Exposition.

After being elected president of the Second Republic in 1848, Louis-Napoleon Bonaparte (a nephew of Napoleon Bonaparte), became France's last monarch in the coup d'état of 1851 (McPhee, 2015). In 1853, as Emperor Napoleon III, he commissioned his prefect of the Seine, Georges-Eugène Haussmann, to address the overcrowded conditions and to modernize Paris (Jordan, 1995). Haussmann demolished medieval neighborhoods, expanded the city to include the sprawling areas that surrounded the city, and built wide avenues giving Paris its distinctive modern appearance (Jones, 2005). Many of his projects, including new parks, public squares, sewers, fountains, and aqueducts continued for over fifty five years after he was dismissed by Napoleon III in 1870 (Jordan, 1995). For example, Colin Jones (2005) reports that "more than three times as many buildings were erected between 1878 and 1888 as between 1860 and 1869" (p. 334).

Haussmann's plan for a modern Paris took massive funding that France could hardly afford. In response to criticisms about a misappropriation of public funds, Haussmann asserted that debt-financed expenditure did not add any burden to the French treasury: quoting Louis XIV, he remarked, "Build, always build. We will go ahead, others will pay for it" (Jordan, 1995). Due to both economic concerns and social impacts, the implications of haussmannization were contentiously debated at the time. On one hand, his ambitions for Paris were interpreted as an effort that would rid of the destitution in the daily lives of Parisians, and on the other, critics saw it as a measure of gentrification. Philosopher Freidrich Engels, for example, saw haussmannization as "a practice which has now become general of making breaches in the working class quarters of our big towns" (Paccoud, 2015).

By 1889, as Jones describes in "Paris: Biography of a City" (2005), the view from the top of the newly constructed Eiffel Tower showed a city in the throes of modernization. There were boulevards and chic department stores in the western neighborhoods, contrasted with the factories and workers dwellings of the outer arrondissements. At this time

Paris was a center of spectacular consumption, but also an industrial city with contrasting regions of the old Paris and the new Paris. Haussmann, and the process that followed him, installed thousands of gas lights in the streets of Paris, which lit up some of the wealthier areas of the city, but most of the city remained dark (Jordan, 1995).

This paper shall examine the beginning of a new era in technological advancement through the lens of two different meanings of the word "chaos": in one sense, the disorder of an un-industrialized society, in another, the discovery of a new form of mathematics. These connections have implications for modern scientists, policy-makers, and city planners who wish to promote innovation while minimizing the risk of harm from large societal changes.

2. Light and Modernity

The first electric lighting in Paris was in the 1878 Exposition Universelle (Jones, 2005), but no further progress in providing electric light occurred until the Electrical Exposition in 1881 (Holcombe, 1911). Sir William Henry Preece, a Welsh electrical engineer and inventor who ran Britain's nationalized telegraph network (Morus, 2009) wrote an account of that event that included: "It was, however, as an exhibition of electric lighting that it was principally attractive, and those who saw it for the first time will never forget the vivid impression that the great blaze of splendor produced upon their minds" (Preece, 1882, p. 151).

The 1881 Electrical Exposition revived interest in the electric light and a commission was set up by the prefect of the Seine to consider the feasibility of introducing electricity into the public lighting system (Carré, 1983). Then in 1887 the destruction of the Opéra Comique by fire provided new proof of the dangers of gas and led to the study of electricity as a substitute for gas in public places. It was however not until 1888 that the city government of Paris adopted a plan which gradually supplied the city with electric current both for lighting and power. To study different electric lighting systems and to advance further electric-lighting policy, the government divided the city into seven sections, assigning each section to one of six different operating companies (Holcombe, 1911).

At the Exposition Universelle of 1889 electric lighting transformed the natural world into a spectacular display by lighting it through the night with fireworks and streetlights (Turner, 1889). The grounds of the exhibition were illuminated by light shows and the Eiffel Tower was draped with 3,200 colored lights and was crowned with a rotating beam of light (Morus, 2009). Through the technological exhibitions, the world's opinion of what machinery could accomplish was permanently changed (Rydell, 1989). The modernity and technological breadth displayed in producing the Galeries des Machines implied France's economic and technical accomplishments (Jones, 2005).

In 1889 science was thriving in France, and in particular in Paris, shedding yet another kind of illumination on the modernizing city. By 1860, government funding of the sciences and engineering had begun to increase, and the funding doubled between 1877 and 1883 (Gray, 2012). Of the 726 PhD degrees awarded in France in Natural Science, Physics and Mathematics between 1810 and 1880, fifty six percent of these were from universities in Paris. This rate of 10.4 PhDs per year in France grew to 19.1 per year by 1910 (Phillips, 1983). In the 19th century France had the most spectacular set of scientists the world had ever seen, and many of them in physics.

The areas of physics that were particularly active at the end of the 19th century were the application of newly developed mathematics to electricity, light, and celestial mechanics (Morus, 2009). One of the names engraved on the Eiffel Tower is Urbain Le Verrier whose work in celestial mechanics, using only mathematics, predicted the existence and location of Neptune. Also engraved is the name of Charles-Eugéne Delaunay who worked on a special case of the three body problem—an analysis of the motion of the moon (Le Lay, 2021). The work of these two scientists leads us back to April of 1890 and to the research of Henri Poincaré.

3. Poincaré and the Birth of Chaos

As construction began on the Eiffel Tower on the Champ de Mars, four kilometers away at the Sorbonne, Henri Poincaré was writing the first volume of two volumes on Celestial Mechanics (Volterra, 1915). He was thirty five years old and held three professorships, including: Physical and Experimental Mechanics, Mathematical Physics and the Theory of Probability, and Celestial Mechanics and Astronomy. His strict habit was to conduct his research only from 10 am to noon and from 3 pm to 5 pm every day, and to let nothing disturb his sleep. He believed strongly that his unconscious mind continued working on the problems as ideas would arrive fully formed in his head at unpredictable times. According to his cousin, Paul Boutroux, “He waited for the truth to strike him like thunder, and counted on his excellent memory to remember it” (Gray, 2012, p. 21). He had just won an international mathematics prize for his work on the three body problem and was made a Knight of the Légion d’honneur.

The mathematics prize was from a competition that was announced in 1887 to honor the 60th birthday of King Oscar II of Sweden, arranged by the editor of a new journal called *Acta Mathematica* (Volterra, 1915). The challenge was to mathematically demonstrate the stability of the solar system. Since the publication of Newton’s theory of gravitation a hundred years earlier, the clockwork-like motion of planets was believed to be stable. Newton had used his newly developed mathematics to derive Kepler's Laws of planetary motion, which describes the stable elliptical orbits of two bodies. However the motion of three or more bodies could only be approximated (Gray, 2012).

There was also a problem with the stability expected from Newton’s work. From observations published in 1718 by a French astronomer, it was found that Jupiter’s orbit appeared to be shrinking, and Saturn’s appeared to be expanding. Joseph Louis Lagrange, who had made the largest contribution to celestial mechanics since Newton and is celebrated on the Eiffel Tower, had tried to solve this problem but without success (Leine, 2010). Lagrange had made approximations that ignored small values in the equations of motion of planets. Pierre-Simone Laplace, whose name is also engraved on the Eiffel Tower, developed an improved mathematics, and showed that when summed over time these small terms became significant. He showed that these two planets and the sun had a mutual equilibrium, which when corrected for, explained the observations and showed they were consistent with Newton’s theory and stability of the planets. This work launched Laplace’s research on the stability of the solar system (Pannekoek, 1948). Laplace proposed that all physical phenomena could be explained by knowing the location and momentum of all particles. In Laplace’s view everything was predictable, and everything was like the movement of a clock.

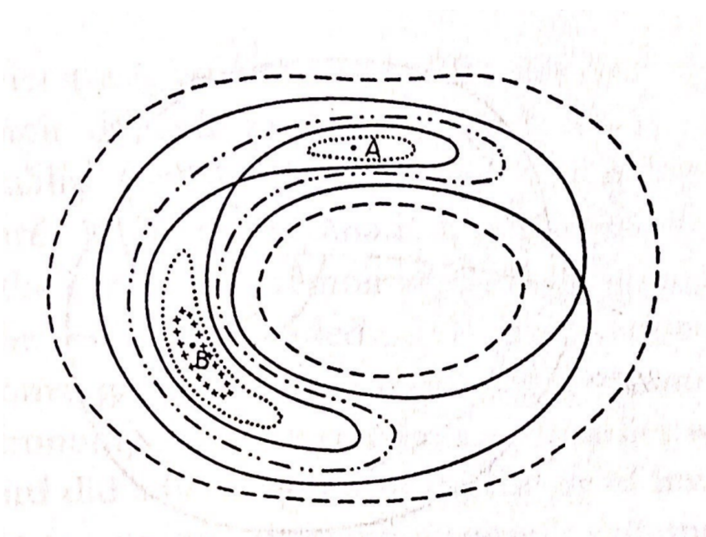

Figure 2. A cross-section, published by Poincare in *Oeuvres de Henri Poincaré* in 1890, illustrates the gravitational forces that are acting on a third planet that is moving in an orbit around two larger planets that are labeled A and B.

However there was still no sufficient mathematical treatment of the gravitational forces on the many bodies in the solar system to show that it was stable. Poincaré’s submission for the prize was a mathematical description of a simplified motion of the three bodies, in that all of the orbits were in a plane, and the third body was not massive enough to affect the orbits of the other two. Poincaré’s initial submission for the prize intended to prove stability rigorously, and to show that no planet escapes and where each one returns infinitely many times to places near where it began (Gray, 2012).

After submitting his answer Poincaré discovered an error, in that the trajectories the theory described for the hypothetical planet in the three body system did not converge, and that the orbits are not always stable and in fact the orbits were not periodic or predictable unless there was a way to very accurately measure them (Hadamard, 1922); (Galison, 2003). In January 1890, he submitted a ninety two page addendum to his answer and corrected the error that was included in his prior solution, as seen in Figure 2. This new version was even more ground breaking, but he had to spend one and a half times the prize money to publish the correction (Gray, 2012).

In his research on the three-body problem, Poincaré became the first person to discover chaos in a deterministic system (Galison, 2003). Starting with only the law of gravity and the initial positions and velocities of the three bodies in all of space, the subsequent positions and velocities are fixed—so the three-body system is deterministic. However, Poincaré found that the evolution of the system is often chaotic in the sense that a small change in the initial position

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or momentum of one of the bodies can lead to a completely different later set of positions and momentums (now sometimes called the butterfly effect) (Lorenz, 2000). Also if the slight change isn't detectable by our measuring instruments, then it is not possible to predict the final positions and momentums that occur (Galison, 2003). After the start of space exploration, NASA brought out an English translation of Poincaré's work on celestial mechanics (Poincaré, 1967) and it has been used by practitioners to model the movement of asteroids, and to optimize the energy use in the planned path for man-made satellites (Marsden & Ross, 2006).

4. Conclusion

The year 1890 in Paris was a time where science and engineering flourished. This blooming of modernity was enthusiastically supported by the government and by, in large part, the people. Electric lights, water, better hygiene and improved transportation were on the cusp of being made available to the population. Progress toward modernity was clearly underway. The Exposition Universelle of 1889 and the Eiffel Tower, were symbols of this support, and they drew millions of visitors, who then returned to spur modernity in other parts of the world.

Scientists, like Poincaré, certainly thrived in this environment, and while the discovery of chaos theory upset the simplicity of clockwork-like models of planetary motion, it illuminated the path to a deeper understanding of the physical world, and perhaps the technology of spaceflight.

Poincaré's model is also a useful metaphor for the process of modernity. The trajectory is not simple and direct like the periodic orbits of two bodies, described by Newton, but more like the chaotic orbits of three or more bodies. On one hand progress is made, which then reveals new chaos and which, in turn, then requires new progress.

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