Le prince, l'arpenteur & la mesure
350 ans d'astronomie sans frontières

Colloque organisé par l'Observatoire de Paris et le Centre de recherche du château de Versailles

Colloque international
21 & 22 juin 2017
Observatoire de Paris, salle de la Méridienne – Château de Versailles, auditorium

Illustrations

Couverture

- A. Coquart (graveur), *L'observatoire royal de Paris* (détail), estampe, 1705. Versailles, châteaux de Versailles et de Trianon, GR 54.1 (C) RMN-Grand Palais (château de Versailles) / Gérard Blot

Dos

- H. Testelin, *Colbert présente à Louis XIV les membres de l'Académie Royale des Sciences créée en 1667* (détail), huile sur toile, XVIIe siècle. Versailles, châteaux de Versailles et de Trianon, MV 2074 (C) RMN-Grand Palais (Château de Versailles) / Gérard Blot
- A. Coquart (graveur), *L'observatoire royal de Paris* (détail), estampe, 1705. Versailles, château de Versailles et de Trianon, GR 54.1 (C) RMN-Grand Palais (château de Versailles) / Gérard Blot
- N.-A. Monsiau, *Louis XVI donnant ses instructions au capitaine de vaisseau La Pérouse* (détail), huile sur toile, 1817. Versailles, châteaux de Versailles et de Trianon, MV 220 (C) RMN-Grand Palais (Château de Versailles) / Gérard Blot

Le prince, l'arpenteur et la mesure

À l'occasion du 350e anniversaire de l'Observatoire de Paris et du tracé de sa ligne méridienne le 21 juin 1667 – jour du solstice d'été - un colloque international, interdisciplinaire se tiendra les 21 et 22 juin 2017 à l'Observatoire de Paris et au Château de Versailles. Il se propose d'examiner le contexte politique et curial de l'événement et la dissémination d'un certain modèle parisien d'académie et d'observatoire en Europe au cours des deux siècles suivants.

À la croisée de l'histoire des cours européennes, l'histoire des sciences et l'histoire de l'architecture, *le bâtiment tout savant* de Claude Perrault participe à la mise en scène du pouvoir royal et attire de nombreux savants et visiteurs prestigieux. Colbert le compare à un autre projet de monument qui lui, ne verra jamais le jour, l'« *Arc de triomphe pour les conquêtes de terre - Observatoire pour les cieux* ».

L'Observatoire est le lieu d'avancées considérables en astronomie mathématique. Pour illustrer ces avancées, les interventions du colloque s'appuient sur des travaux récents basés sur la correspondance entre Leibniz, qui séjourna à Paris de 1672 à 1676, et Huygens ; le fonctionnement de l'Observatoire sous J.-D. Cassini ; la visite du tsar Pierre-le-Grand à Versailles et à l'Observatoire en 1717 ; les travaux de Lagrange, savant turinois devenu académicien prussien puis français ; les calculs de Le Verrier ayant permis la découverte de la planète Neptune, enfin l'amitié de près de quarante années entre Arago et Humboldt.

En contrepoint, le colloque présente une sélection des grands projets internationaux qui structurent la vie scientifique de l'Observatoire aujourd'hui, tels la conception des futurs télescopes du XXIe siècle, les révolutions en métrologie avec les horloges atomiques, les missions spatiales dans le système solaire lointain ou l'exploration de la matière noire et de l'univers à très grande échelle.

The Prince, the Surveyor, and the Measure

An international interdisciplinary colloquium will be held on 21-22 June 2017 in the Observatoire de Paris and in the Centre de Recherche du château de Versailles, to commemorate the 350th anniversary of the founding of the Observatoire — as well as of the drawing of its Meridian Line on solstice day, 21 June 1667. The event furnishes an opportunity to examine the political and courtly context of the foundation, and the dissemination of a Parisian model of academies and observatories throughout Europe in the following two centuries.

At the crossword of the history of European courts, the history of science, and the history of architecture, Claude Perrault's design of the building intended to stage royal power while attracting many scholars and famous visitors. In addition to drawing the Meridian line for determining the longitudes, the Observatory was intended to serve as a storehouse of scientific artifacts and a monument to Louis XIV's glory — likened by Colbert to another monumental project by Perrault that was never completed, "Triumphal Arch for the conquest of the earth. Observatory for the heavens."

The Observatory contributed greatly to the Advancement of mathematical astronomy. Papers illustrating such contribution will present new insights on Parisian science during the 1670s, based on the correspondence between Leibniz, who lived in Paris from 1672 up to 1676, and Huygens; the role of J.-D. Cassini; the 1717 visit of tsar Peter the Great to Versailles and to the Observatory; the mathematical works of Lagrange, native of Turin who turned Prussian and then French academician; Le Verrier's calculations that led to the discovery of the planet Neptune; and the forty-year long friendship of between Arago and Humboldt.

As a contemporary counterpoint, the colloquium will highlight several large scale international projects involving the Observatory's community today, including the design of future telescopes, revolutionizing metrology with atomic clocks, space missions deep into the solar system, and exploration of dark matter and the large-scale structure of the universe.

Comité scientifique international du colloque

- Thomas Widemann, Observatoire de Paris - LESIA, université de Versailles-Saint-Quentin (Président)
- Eberhard Knobloch, Technische Universität Berlin, Berlin-Brandenburgische Akademie der Wissenschaften
- Mordechai Feingold, Division of the Humanities and Social Sciences, Caltech
- Françoise Combes, Observatoire de Paris - LERMA, Académie des Sciences
- Mathieu da Vinha, Centre de recherche du château de Versailles

Programme

Mercredi 21 juin 2017 - Observatoire de Paris, salle de la Méridienne

09:15 Accueil

09:30 Introduction par Thomas Widemann, Observatoire de Paris

Session 1 : L'astronomie mathématique

Présidente de séance : Michela Malpangotto, Observatoire de Paris/SYRTE

09:45 - *The Age of Academies*, Mordechai Feingold, Division of the Humanities and Social Sciences, Caltech

10:15 - *Leibniz: Arithmetical quadrature of the circle*, Eberhard Knobloch, Technische Universität Berlin, Berlin-Brandenburgische Akademie der Wissenschaften

10:45 - Pause

11:15 - *Lagrange and the Progress of Astronomy*, Maria Teresa Borgato & Luigi Pepe, Università di Ferrara

11:45 - *From Le Verrier's calculations for the discovery of Neptune to the search of Planet 9*, Jacques Laskar, Observatoire de Paris/IMCCE, Académie des Sciences

12:15 - Discussion

13:53 - Passage du soleil sur la ligne méridienne / Solar transit on the Meridian Line

Session 2 : Un bâtiment pour les savants

Président de séance : Eberhard Knobloch, Technische Universität Berlin, Berlin-Brandenburgische Akademie der Wissenschaften

14:00 - *Une nuit à l'Observatoire en galante compagnie vers 1740*, David Aubin, Institut de Mathématiques de Jussieu-Paris Rive-Gauche, université Pierre-et-Marie-Curie

14:30 - *Alexander von Humboldt and François Arago – A Prusso-French Connection*, Ulrich Päßler, Berlin-Brandenburgische Akademie der Wissenschaften

15:00 - Pause

15:30 - *L'Observatoire de Louis XIV au prisme des visites*, Dalia Deias, Centre Alexandre-Koyré – EHESS

[Abstract only] - *The Paris Observatory and Claude Perrault's theory of materials*, Lucia Allais, Princeton University School of Architecture

16:00 - Discussion

16:30 - Table ronde I : *The observatory from Louis XIV to Louis XVI (1667-1789)*

Moderator : Eberhard Knobloch, Technische Universität Berlin, Berlin-Brandenburgische Akademie der Wissenschaften

17:15 - Conclusions

Jeudi 22 Juin 2017 – Château de Versailles – auditorium

09:15 - Accueil

09:30 - Introduction par Mathieu DA VINHA, Centre de recherche du château de Versailles

Session 3 : Le Prince, l'observatoire et l'Europe

Président de séance : Mordechai FEINGOLD, Division of the Humanities and Social Sciences, Caltech

09:45 - *La visite de Pierre le Grand en 1717*, Dimitri BAYUK, Russian Academy of Sciences, Institute for the History of Science and Technology

10:15 - *Lagrange et la fondation de l'Observatoire de Turin*, Alberto CONTE, Accademia delle scienze di Torino

10:45 - Pause

11:00 - *350 ans d'observation et d'étude des satellites de Jupiter*, Jean-Eudes ARLOT, Observatoire de Paris/IMCCE

11:30 - Table ronde II : *The observatory from Louis XVI to the Second Empire (1774-1870)*

Moderator : Mordechai FEINGOLD, Division of the Humanities and Social Sciences, Caltech

12:15 - Discussion

Session 4 – L'arpenteur et la mesure

Président de séance : Thomas WIDEMANN, Observatoire de Paris/LESIA & université de Versailles-Saint-Quentin

14:00 - *L'Observatoire de Paris dans les projets de grands télescopes au sol*, Daniel ROUAN, Observatoire de Paris/LESIA, Académie des Sciences

14:30 - *Métrologie : la révolution des horloges atomiques*, Noël DIMARCQ, Observatoire de Paris/SYRTE

15:00 - Pause

15:15 - *L'exploration du système de Saturne par la mission Cassini-Huygens*, Athena COUSTENIS, Observatoire de Paris/LESIA

15:45 - *Du soleil à la matière noire : l'univers à grande échelle*, Françoise COMBES, Observatoire de Paris/LERMA, Académie des Sciences

16:15 - Discussion

16:45 - Table ronde III : *L'Observatoire a 350 ans, et maintenant ?*

17:15 - Conclusions et synthèse

Résumés des interventions / Summaries of the lectures

Session 1 : L'astronomie mathématique

Présidente de séance : Michela Malpangotto
Observatoire de Paris/SYRTE

The Age of Academies

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The foundation of the Académie des Sciences on 22 December 1666, and the laying of the groundwork for the Observatoire de Paris six months later, marked the culmination of a remarkable movement of intellectual sociability. Italy, where the movement had originated two centuries earlier, saw the foundation of more than six hundred academies in the course of the sixteenth and seventeenth centuries; in France, some seventy academies were set up during the first half of the seventeenth century alone. With few exceptions, such private gatherings in the residences of esteemed scholars or influential patrons proved to be short-lived. Collectively, however, these meetings reveal not just a widespread yearning for learned conviviality on the part of the educated elite, but a growing realization that collaborative efforts are indispensable for the advancement — as well as for the validation — of scholarship, especially in the sciences.

My paper will examine key elements in the emergence of scientific sociability after 1600, and reflect on the symbolic significance of the events that took place 350 years ago for the promotion and institutionalization of natural knowledge.

Leibniz: Arithmetical quadrature of the circle

Eberhard Knobloch, Eberhard Knobloch, Technische Universität Berlin, Berlin-Brandenburgische Akademie der Wissenschaften
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I am interested in the history and philosophy of mathematical sciences from ancient times up to the 20th century. Hence I studied especially the main works of Archimedes, J. Kepler, L. W. Leibniz, L. Euler, A. von Humboldt, and E. Borel. In 1976 , I established series 7 *Mathematical writings*, in 2001 series 8 *Scientific, medical, technical writings* of the Leibniz edition.

I am especially interested in the history of mathematical analysis and in the mathematical handling of the infinite. My article on Euler and d'Alembert appeared in 2015, the article on Leibniz's conception of a general characteristic art and volume 2 of series 8 of the Leibniz edition appeared in 2016. I have just finished a long article on A. v. Humboldt and the natural sciences. The Latin-English edition of Kepler's *New solid geometry of wine barrels* has been sent to press.

In 1647, the Flemish Jesuit Grégoire de St. Vincent published his *Quadratura circuli* showing a curious optical solution of the problem. Leibniz studied the book during his sojourn in Paris (1672-1676). In 1672 he made the acquaintance of Christiaan Huygens. In 1673 Leibniz found his *arithmetical quadrature of the circle*, that is, the infinite, alternating, convergent series for $\pi/4$. In October 1674 he sent a short treatise about this subject to Huygens who reacted very positively. In 1676 Leibniz elaborated a long treatise *De quadratura arithmetica circuli*, *ellipseos et hyperbolae* and hoped to become a member of the French academy especially by means of this treatise. Yet, it was never published during his lifetime. Only in 1993, the first complete edition of the Latin text appeared in Gottingen. In 2016 an improved, bilingual Latin-German edition appeared in Heidelberg.

My lecture consists of three parts. The first part deals with the correspondence between Leibniz and Huygens regarding this treatise. The second part explains its fundamental theorem 6: It is the core of Leibniz's integration theory using well defined notions of infinitely small and of infinite, establishing Riemann's integral for continuous functions and giving an absolutely rigorous demonstration. The last part explains Leibniz's crucial distinction between *infinite* and *unbounded*.

Lagrange and the Progress of Astronomy

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In Lagrange's production, the works of astronomy constitute the major part of his scientific activity and testify to the success of the application of calculus as well as to the invention of new mathematical methods arising from astronomic problems in the field of mathematical analysis and of probabilities.

In agreement with the historian of mathematics, Gino Loria (1913), out of a total of 4642 pages of the memoirs contained in the *Oeuvres de Lagrange* (14 vol., Paris 1867-1892), about 1650 can be classified as concerning astronomy: more than double of those dedicated to questions of analysis (714 p.) or mathematical physics (553 p.). In 1764, when Lagrange was still in Turin, his *Recherches sur la libration de la Lune* received an award in Paris (prix de l'Académie des Sciences), and were perfected in Berlin (*Théorie de la libration de la Lune*). When he was in Berlin as director of the class of mathematics at the Academy of Frederic II, he composed his fundamental memoirs *Sur les inégalités des satellites de Jupiter* (1766), *Sur le problème des trois corps* (1772), *Sur les équations séculaires des mouvements des nœuds et des inclinations des orbites des planètes* (1774), *Sur la théorie des perturbations des comètes* (1778). During 1808-09, when Lagrange was senator and count of the Napoleonic Empire, he presented his last great memoirs *Variations des éléments des planètes* to the Institut de France.

In the conference attention will be focused on the following: a comparison between the progress of astronomy and hydrodynamics, another field left open by Newton; the increase of mathematical methods favoured by astronomical research (the variation of arbitrary constants, the principle of virtual velocity etc.); works concerning probability and finite difference equations which Lagrange and Laplace undertook particularly regarding astronomical problems. References to numerous questions regarding Lagrange's memoirs on astronomy are to be found in his correspondence with d'Alembert, Euler and Laplace.

From Le Verrier's calculations for the discovery of Neptune to the search of Planet 9

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Jusqu'en 1781, date de la découverte d'Uranus par Hershell, les seules planètes connues étaient celles du système solaire observables à l'oeil nu : Mercure, Vénus, Terre, Mars, Jupiter et Saturne. La découverte de Neptune par Le Verrier et Galle en 1846 a particulièrement frappé les esprits car Le Verrier a réussi à prédire la position de Neptune par la seule force du calcul.

Ces calculs constituent un véritable exploit qu'il est possible d'apprécier en se plongeant dans les manuscrits laissés par Le Verrier à la bibliothèque de l'Observatoire de Paris. Ceux ci sont rassemblés en sept cahiers et totalisent près de mille pages de calculs denses dont la complexité n'a pas sans doute pas permis jusqu'à présent une relecture critique approfondie. C'est ce travail que nous avons entrepris avec Guy Bertrand pour tenter de retracer toutes les étapes qui ont permis cette fabuleuse découverte. Ce travail ne fait que démarrer, mais j'en ferai l'esquisse pendant cet exposé car Le Verrier est l'une des figures emblématiques de l'histoire de l'Observatoire de Paris.

Après cette découverte, beaucoup ont cherché à en renouveler l'exploit, mais la découverte de Pluton n'a été que le fruit du hasard, et comble de malchance pour les découvreurs, ce corps s'est vu rétrograder de son statut de planète à celui de planète naine par l'Union Astronomique Internationale en 2006. En revanche, depuis 1995 et la découverte de 51 Peg b par Michel Mayor et Didier Queloz, les planètes sont découvertes par milliers autour des étoiles proches de notre galaxie.

Tout aurait pu en rester là, mais la découverte en 2014 de l'objet 2012VP113 de la ceinture de Kuiper par Trujillo et Sheppard a relancé la question d'une planète additionnelle dans le système solaire, une possible planète 9. En effet, la similarité des orbites de Sedna et de 2012VP113 a conduit à supposer l'existence d'une planète additionnelle, hypothèse renforcée par la parution le 20 janvier 2016 de l'étude de Batygin et Brown rendant le scénario plausible. Depuis, une partie de la communauté astronomique s'est lancée dans la chasse à la planète 9.

Session 2 : Un bâtiment pour les savants

Président de séance : Eberhard Knobloch

Technische Universität Berlin, Berlin-Brandenburgische Akademie der Wissenschaften

Une nuit à l'Observatoire en galante compagnie vers 1740

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Dans un manuscrit récemment découvert à l'Observatoire de Paris, César-François Cassini de Thury (le petit-fils du premier astronome de la famille appelé en France par Louis XIV) met en scène un dialogue entre une jeune femme et un astronome.

Ce texte est surtout remarquable pour la manière dont il cherche à vulgariser non pas tellement les théories astronomiques de l'époque (en particulier le copernicanisme ou le newtonianisme) mais bien les pratiques d'observation et de calcul qui en sont le fondement. Ce manuscrit nous offre à voir un volet méconnu de la vulgarisation des sciences au siècle des Lumières.

Alexander von Humboldt and François Arago – A Prusso-French connection

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For over forty years Alexander von Humboldt (1769-1859) and Dominique François Arago (1786-1853) maintained a close friendship, which was not only marked by a similar, almost encyclopedic approach to the physical sciences. Both researchers shared a common vision regarding the relevance of knowledge for social progress and the scientist's responsibility in disseminating a scientific world view to the general public.

Although the friendship between Humboldt and Arago began upon the latter's return from the meridian arc measurement expedition to Paris in 1809, it was Humboldt's move to Berlin in 1827 that initiated a specifically scientific partnership. Through correspondence, Humboldt kept Arago up-to-date with the scientific work done in Prussia. Arago, who had become secrétaire-perpétuel of the Academy of Sciences in 1830, presented these outlines during the Academy's weekly meetings, thereby reinforcing the European dimension of its activities. Humboldt used this platform to promote the research of young Prussian researchers in the scientific capital of Europe. Both Humboldt and Arago promoted the popularization of scientific knowledge. While Arago lectured on *Astronomie populaire* since 1813, Humboldt gave two popular lecture series on physical geography (*Kosmos2Vorträge*) in 1827/1828. As public speakers and authors, they paid special attention to the history of science, while being self » confidently aware of their own prominent position within it.

The presentation aims to locate this "Prusso-French connection" between Humboldt and Arago within a wider comparative context of transnational scientific relations during the first half of the 19th century. Besides pointing out the striking similarities in the life and work of both researchers, it will also address some remarkable differences, namely in social position and political mentality. Finally, it will explore contemporary perceptions of this extraordinary friendship from admirers and critics alike.

L'Observatoire de Louis XIV au prisme des visites

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My research in the field of history of cosmology and of Giovanni Domenico Cassini (a.k.a. Cassini I, 1625-1712) began in Italy during my studies in astrophysics and cosmology. Since then, with the Centre Alexandre,Koyré in Paris, I have come closer to the same subject through connection of history of astronomy with the political as well as social contexts in the production of such knowledge, especially scientific institutions like the observatories. I have been focusing particularly on the astronomer Cassini I and the various contexts of his work, in fact the Studio of Bologna, the Italian catholic environments and networks and the early Observatoire Royal de Paris during the Grand Siècle. Correspondences of the savants are my research's main source.

My PhD thesis focuses on what the Observatoire Royal de Paris was at the time of its invention (~1665-1672) and on how it was operated during its first decades (1672-1715). This research is the result of a questioning on the role of astronomical observatories in the framework of social history of science and global history. In my research I approached the Observatoire Royal through the case of Giovanni Domenico Cassini and his correspondence, the main corpus of the thesis, which an important contribution of Observatoire de Paris archives. Other correspondences, especially Italian ones, are integrated in other manuscripts and in the Royal Academy of sciences's publications. When analyzing the sources such as the letters, we can clearly see the work of the Observatoire Royal in co, dependency with other environments such as the royal courts or the diplomatic and religious networks.

The Observatoire Royal was the place to visit during the Grand Siècle. Not only the Academy's astronomers came to work within its walls and in the gardens, but other distinguished visitors were welcomed: royals, diplomats, clerics, curious people or a combination of several of these categories at the same time. In my talk, I will give some examples about the nature and the work of this royal and scientific institution through some cases study touching the visits and the meetings orchestrated by the astronomers living inside the observatoire, especially Cassini and his family.

[Abstract only] - The Paris Observatory and Claude Perrault's theory of materials

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Claude Perrault's design for the building of the Paris Observatory has largely been interpreted through the lens of an analogy between architecture and astronomy. The expectation that the building would perform as a scientific instrument was established as soon as its first stone was laid upon a new meridian line in 1667, and it was declared "un bâtiment tout savant." The controversies that came to surround the commission in its early years only amplified the charge. In 1669, Jean Dominique Cassini complained that "j'aurai voulu que le bâtiment même eut été un grand instrument," while that same year Colbert praised the design by pairing it with another of Perrault's own - "Arc de triomphe pour les conquestes de terre L'Observatoire pour les cieux." In the three centuries since, architectural historians have thus been faced with a dual legacy, continuing to critique the building as a (failed) instrument, while evaluating its achievements as a monument.

Instead of revisiting this ongoing debate, my paper investigates how the architecture of the observatory constitutes a demonstration of a theory of materiality that can be found in Perrault's system of thought - a theory more concerned with earthly forces than celestial ones, and where architecture's relationship to science is discursive, not instrumental. In this interpretation, the building performs a set of material operations that can be related to sources in Perrault's written and graphic oeuvre.

Textual evidence will include Perrault's translation of Ten Books of Vitruvius (1684) notably the "modern" annotations to the chapter on materials; as well as plate engravings of the observatory scheme used to illustrate architectural conventions, and of other structures shown to be sitting on top of mounds. As for architectural evidence, I will move past the discussion of the geometry of the plan to focus on the issues posed by the building in section during its design (1667L1672) and first redesign (1780L1785), particularly: the establishment of the site on top of a "terrain creux par dessous par des grandes carrières"; the vaulting of the piano nobile; and the stereometry of the staircase.

Session 3 : Le Prince, l'observatoire et l'Europe

Président de séance : Mordechai Feingold
Division of the Humanities and Social Sciences, Caltech

La visite de Pierre le Grand en 1717

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Peter the Great visited Western Europe for the second time in the beginning of 1717, i.e. just few years before he declared the Russian Empire in 1721. His rule marked the start of imperial period in Russian history which included a rapid modernization, and a vast portion of European culture was to be transplanted on the Russian soil. The attention of many scholars in the world is now focused on various problems related to this transplantation and domestication of received knowledge. As far as the Italian Renaissance and the Scientific Revolution of the 17th century had provided the basis for new knowledge and further unprecedented technological growth, their propagation to other parts of the world was necessary both for economic growth and cultural development.

Since my doctoral studies in late 1980s -early 1990s, in my research I have also been focusing on the Scientific Revolution and its reception in non-European countries. Evidently, the establishing of the Imperial Academy in St. Petersburg was an important component of the process. Two embassies of Peter the Great to Europe in 1697-1698 and in 1717 served a prologue both to his Empire and to his Academy. Being a very practical mind he understood his imperial ambitions would never be realized without modern knowledges. And his interest to the astronomy was particularly manifest.

Peter the Great visited Versailles on 13 May and on 3 June, 1717. On 12 May he paid his first visit to the Paris Observatory, where he returned on 19 May. My hypothesis is that in both places he discovered important elements of his future empire — artistic in the first, scientific in the second. Versailles was seen by Peter the Great as a symbol, or rather as a constellation of symbols, of imperial power; the Observatory was understood by him as a necessary instrument of imperial expansion. His first Grand Embassy was preceded by decades of exploration into Siberia and the Far East region, and this caused a number of military conflicts on the banks of Amur River in its upper reaches, in the situation when geographical outlines of these vast regions were more than uncertain. Peter the Great was informed how much royal astronomers and the Paris Observatory had been effective in solving similar problems for French coastal lines and remote colonies just few decades earlier.

Lagrange et la fondation de l'Observatoire de Turin

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The foundation of Torino astronomical Observatory goes back to 1761¸ when a small Specola(was built on the roof of the palace of the count Maurizio Orazio Fresia d'Oglianico, at the beginning of *Via Po.* It had been the scolopian father Giovanni Battista Beccaria (1716-1781), professor of *Fisica sperimentale* in Torino University who in 1759, on the occasion of the passage of the Halley's comet, had convinced the king Carlo Emanuele III of the importance of the astronomical observations and it was to him that the king, on the suggestion of the the jesuit father Ruggero Boscovich, committed the task of the measurement of the *Gradus Taurinensis*, the arc of the meridian going from Andrate to Mondovì in Piedmont.

It was Beccaria himself who discovered the outstanding mathematical talent of the young Lagrange (1736-1813), taught him the basics of Mathematics and Physics and raised his interest for Astronomy, which constitutes the major part of his scientific activity. In 1757 Lagrange, at the age of only 21, founded, together with his friends Cigna and Saluzzo, the S*ocietà privata torinese* which in 1783 the king Vittorio Amedeo III transformed into *Reale Accademia delle Scienze*. By that time Lagrange had already quitted Torino to move to the Prussian Academy in Berlin on the invitation of the king Frederik II, but he was appointed *Presidente onorario* of the new academy.

On sunday the 28th of june 1789 the king made his first visit to the Academy and on this occasion informed the academicians that he had decided to finance with 400 *lire piemontesi* the construction of an observatory on the roof of the *Collegio dei nobili*, the siege of the Academy. The architectural project was done by Francesco Feroggio, who visited also the specola of Brera in Milano for inspiration, and the building was completed in less than one and a half year on 30th November 1790. This observatory was used until 1822 when Giovanni Plana (1781-1864), who had been a student of Lagrange at the *Ecole polythéchnique* in Paris and appointed professor of astronomy in the University of Torino on his recommendation, decided to build a new an more efficient observatory over one of the roman towers of Palazzo Madama.

In the conference, with the help of the documentation kept in the archives of the Accademia delle scienze, of the Università di Torino and of the Comune di Torino, we will trace in details the history of these three historical observatories focusing on their architectural features and on the scientific instrumentation by which they were equipped.

350 ans d'observation et d'étude des satellites de Jupiter

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The satellites of Jupiter discovered by Galileo in 1610 are among the most interesting and difficult objects to study. These are complex worlds whose size is close to that of Mars. The four satellites are similar to a small solar system, their motions bringing together all the difficulties of celestial mechanics. These satellites also have the peculiarity of being regularly eclipsed by the planet Jupiter, which is very easily observed since the XVIIth century.

As soon as Paris Observatory was created, it soon became clear that these satellites were not only objects of study for astronomers, but also valuable auxiliaries for geographers and travelers, helping to define an universal time. Thus, they were used to perfect the cartography of France as desired by Louis XIV during the creation of the observatory. They also helped to demonstrate the finite speed of light.

The greatest astronomers were interested in these satellites, especially Pierre-Simon Laplace, who, first, understood and described the dynamics of the system. Delambre undertakes to observe and collect many observations of the eclipses of these satellites which are still useful today.

In the last 40 years, space exploration revived their studies. The Voyager probes sent us unprecedented images revealing their nature of ice. The continuous increase in the accuracy of the astrometric observations allowed to refine their dynamics, modeling and constraining their internal structure: the tides of Jupiter on its satellites are now observable from Earth They are still today subjects of study privileged at the observatory of Paris, 350 years after the beginning of a history that continues today.

Session 4 : L'Arpenteur et la mesure

Président de séance : Thomas Widemann

Observatoire de Paris/LESIA & université de Versailles-Saint-Quentin

L'Observatoire de Paris dans les projets de grands télescopes au sol

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Même si, comme dans tous les observatoires citadins historiques où la dégradation des conditions par la pollution lumineuse est devenue rédhibitoire, l'observation professionnelle n'est plus de mise à l'Observatoire de Paris, ses chercheurs ont cependant toujours maintenu une tradition vivace de recherche instrumentale et d'instrumentation pour les grands télescopes auxquels ses astronomes ont accès. Que ce soit dans le domaine du rayonnement visible, de la radio, de l'infrarouge ou même des hautes énergies, les laboratoires de l'Observatoire de Paris ont apporté des contributions essentielles en innovant sur les concepts optiques, en conduisant des recherches fondamentales sur les détecteurs ou en mettant au point des solutions sophistiquées pour corriger les effets de la turbulence atmosphérique, améliorer la résolution angulaire ou pour effectuer l'analyse spectroscopique de plusieurs sources simultanément. Un tour d'horizon de ces contributions et des télescopes qui en ont bénéficié dans le monde sera présenté.

Métrologie : la révolution des horloges atomiques

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L'exploration du système de Saturne par la mission Cassini-Huygens

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Recent discoveries in our solar system and in planetary systems around other suns (exoplanets) fascinate scientists, like the general public, with respect to the existence therein of habitable worlds. By exploring the outer solar system and beyond, scientists try to better understand the appearance and maintenance of life outside our own planet but also to explore icy satellites that offer habitable environments.

Mars was extensively explored by space missions in order to discover current or past traces of life, but In the outer solar system, around the giant planets, Jupiter and Saturn in particular, multiple natural satellites offer us the opportunity of a range of diverse and complex worlds to study. These satellites have been closely, albeit briefly, examined by space missions such as Voyager, Galileo and Pionneers. The Saturnian system itself has been thoroughly explored by Cassini-Huygens, still on site around Saturn since 2004 and until September 2017. This international mission has revealed to us not only the giant planet and its ring system, but also a large number of icy but active worlds, with water geysers, volcanic explosions, spongy or heavily-cratered surfaces with large canyons, oceans of liquid water inside, organic chemistry present in some, and more.

Among these worlds, Titan, Saturn's biggest satellite, is a fascinating large body with great astrobiological potential: although far away from the Sun, it resembles the Earth by its nitrogen4 dominated atmosphere, organic chemistry, hydrocarbon lakes, its ocean of liquid water inside, and seasonal variations. Quite different from Earth at the same time by its very low temperature (4180 °C), lack of oxygen, etc. Enceladus, another small satellite of Saturn that combines organics in its geysers and liquid water also under the surface... The satellites of Jupiter, Ganymede and Europe, will be explored from 2030 by the European probe JUICE that will study their possible oceans of liquid water beneath the surface, their magnetic fields and unique geological terrains. All these objects of the outer solar system may find counterparts around other suns. Indeed, exoplanets constitute a large breeding ground in which scientists will look for other worlds favorable to life... I will discuss the recent discoveries in the kronian system from current space missions and ground-based observations, as well as possible close encounters with them in the future.

Du soleil à la matière noire : l'univers à grande échelle

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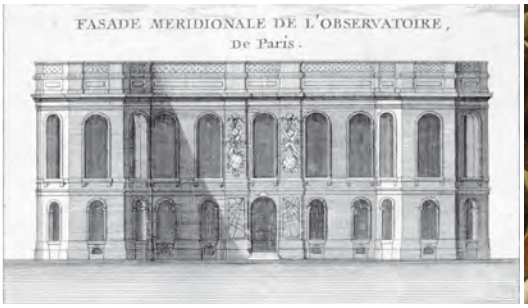
What is our Universe made of ? Thanks to the tremendous progress of modern cosmology, we know exactly that ordinary matter only represents 5% of the total, and 70% of the content of our Universe is dark energy.

As for matter, the major part (83%) is mysterious in nature, made of exotic particles whose mass remains unknown. These particles have escaped all detection, in astrophysical context as well as in powerful accelerators of particles. They are revealed only by their gravity.

It is therefore not easy for astrophysicists to reproduce our Universe and form galaxies in computers. The most widely used cosmological model today is that of Cold Dark Matter (CDM) which best represents the formation of large-scale structures in the Universe. Yet there are still many problems to explain the formation of galaxies, as they are now observed. In particular, numerical simulations predict galaxies like our Milky Way dominated by dark matter, and surrounded by a myriad of satellite galaxies, which are not observed. Are they dark galaxies dancing in the dark?

Large-scale structures in the Universe are traced now by the observation of millions of galaxies, and their dark matter content is mapped through gravitational lensing: their mass deviates the light coming from background galaxies. Our current state of knowledge will be reviewed, on the content and evolution of the universe, on galaxy formation, on the nature of dark matter, or on modified gravity.



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