Gianantonio Tadini and falling bodies

A new documentary source for the reconstruction of the history of experimental proofs on Earth rotation

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Abstract

Gianantonio Tadini (1754-1830) is the little known protagonist in an important experiment carried out in Bergamo between 1794 and 1795. Based on the measurement of the deviation of a falling body, the experiment owes much to the one that was conducted by Giambattista Guglielmini (1760-1817) in Bologna in 1791, and aimed at demonstrating Earth's rotation. Tadini's work experimentally represents the most successful attempt carried out before the 19th Century, and it led to the first correct formulation of deviation's measurement. In spite of this, it does not find enough place in the general literature on the history of experiments intended to show diurnal Earth's motion[1].

The discovery of Tadini's experiment diary as well as of some notes and a part of his correspondence – preserved as manuscripts in the municipal library "Angelo Mai" in Bergamo– allows now to reconstruct the history of Tadini's experiment and of his reasoning about Guglielmini's work. In this paper, I describe the genesis and the development of Tadini's experiment, I clarify the role played by the different personalities involved and set these trials against the background of the widest history of proofs on diurnal Earth's rotation carried out in Europe in those years.

Introduction: falling bodies *in hypothesi terrae motae*

The sensitive issue of Earth's rotation and its proofs has been of the main problems in the history of science since at least the Hellenistic period. Even if we go back to Aristotle's works, it was moreover closely related to the question of falling bodies. When he opposed Pythagorean doctrine on Earth's motion in the *De Caelo*, Aristotle affirmed that when a body is thrown upward into the air, it falls down perpendicularly at the same place[2].

Yet it was in the Modern Age that the connection between the Earth's rotation and the deviation of freely falling bodies gone on the stage in a new way due to the appearance of Copernicus' doctrine.

Copernicus himself needed to account for the absence of any appreciable westward deviation of falling bodies notwithstanding the rotation of the Earth which he postulated[3]. The same problem was drawn on again by Copernicans such as Thomas Digges (1546-1595)[4] and Giordano Bruno (1548-1600)[5] among others. The main solution was founded in the fact that the body, being a part of the Earth, is necessarily involved in his circular motion. Therefore, it is dragged eastward by the Earth's rotation.

From the 17th Century onwards, some early experiments were also carried out on the basis of the motion of projectiles thrown upward. The question was so crucial that when Robert Hooke (1635-1703) –who had succeeded (October 25, 1677) Henry Oldenburg (1619-1677) as Secretary of the *Royal Society*– wrote to Isaac Newton (1642-1727) on November 24, 1679 in order to know more about his new philosophical speculations, the latter suggested him he should determine the trajectory of a heavy body falling from a high tower[6]. In his words, it was "a fancy […] about discovering the Earth's diurnal motion"[7]. According to him, a falling body would have in fact suffered an eastward deviation from the vertical due to the Earth's rotation. The rich debate that arose from this early correspondence didn't cause a great stir. Indeed, not only Guglielmini completely ignored it at all but also Joseph-Jérôme de Lalande (1732-1807) didn't even mention it in the first edition (1764) of his *Astronomie*[8] and, in the second one (1771)[9], he incorrectly ascribed to Newton the suggestion of trying vertical throw with a cannon.

So, around the 17th Century the rotation of the Earth was still a controversial matter and the problem of its demonstration was at the core of many debates[10] which involved, among others, Tycho Brahe (1546-1601), Galileo Galilei (1564-1642), René Descartes (1596-1650), Marin Mersenne (1588-1648), Giovanni Battista Riccioli (1598-1671), Alfonso Borelli (1608-1679) and Stefano Degli Angeli (1623-1697). Although the rotation of the earth was already universally accepted as a mathematical and physical truth, in the latter part of 18th Century the question of its proof wasn't settled. Indeed, even if Jean le Ronde d'Alembert (1717-1783) claimed in his entry "Terre" of the *Encyclopédie* (1751-1772) that astronomers' work of his Century have dispelled any doubt regarding Earth's motion, he considered necessary to refute the "feeble and frivolous" arguments against it that had been adduced until then[11]. Since the beginning of the 18th Century, physical proofs of Earth's motion were sought by means of meridian grade measurements at the poles and at the equator in the search of a confirmation of Earth's flattening expected by Newton. Despite this, no argument turned out to be irrefutable. Theoretical objections against the alleged "immobility of the earth", like the fact that for "saving the appearances" the farthest stars should have presented a very high speed, were not satisfactory. From a kinetic point of view, the motion that implies that the stars in movement around the Earth and its opposite are in fact completely equivalent. As far as physical measurements of terrestrial globe goes, they were accounted for in terms of the centrifugal effect of rotation. However they could have been explained as easily as due to the physical structure of Earth.

Furthermore, in his *Index* of 1758 Pope Benedict XIV withdrew for the first time after 1616 the decree which prohibited «all books teaching the earth's rotation and the sun's immobility». This omission soon appeared to the catholic scientists as a sign of a new atmosphere of openness. Nevertheless, at the end of the 18th century the works of Copernicus, Galileo, Kepler, Foscarini and others continued to be explicitly included[12].

Although this problem was not new, the context in which the issue reemerged at the end of the 18th century was very different not only from an astronomical and religious point of view. As it will be shown below, the recurrence of the topic at this time involved complex and precise experimental techniques as well as accurate calculations. Actually, when the problem resurfaced the question had shifted from understanding the arrival point of a falling body to that of calculating its exact deviation in order to compare theoretical expectation with experimental outcomes.

In particular, as for it resurfaced at the end of the eighteenth century, the problem of the demonstration of the Earth's rotation is one of the most notable examples of how theoretical research and experiments are complementary. Theoretical calculation of the deviation of a falling body developed by successive approximations, also as a consequence of the progressive refinement of experimental techniques.

Giambattista Guglielmini's (1763-1817) experiment

The first real attempt to demonstrate experimentally once and for all the rotation with modern methodology was planned and performed by Giambattista Guglielmini between 1789 and 1792. Guglielmini was a young abbé that studied mathematics in Bologna with Sebastiano Canterzani (1734-1818). Since the end of 1788 he was in Rome at the service of the Cardinal Ignazio Boncompagni Ludovisi (1743-1799), at that time Secretary of State to Pius VI. From the very beginning of his permanence in Rome, Guglielmini started considering the possibility to drop balls from a considerable height to verify where they fell with respect to the vertical plumb line below their point of release. His aim was to demonstrate the rotation of the earth in order to establish «the right place for the Copernican system among the system of Sciences»[13]. Indeed, the velocity of a falling body grows together with the height from which it falls. This is due to the fact that it describes a greater arc in the same time. Thus a falling body moves with greater eastward velocity than the foot of the tower.

A first pamphlet was published by Guglielmini at the end of 1789. These early *Riflessioni sopra un nuovo esperimento in prova del diurno moto della Terra*[14], dedicated to the Cardinal Boncompagni Ludovisi –with the support of which he had hoped to execute his experiment in the St Peter's Dome in Rome– contain the theoretical calculus of expected deviations.

In spite of the news introduced by Benedict's Index, when Guglielmini planned and executed his experiment, the question was still controversial, so much so that he did not obtain the permission to carry out his drops from St. Peter's Dome[15]. That also probably depends on the worsening of the political position of Cardinal Boncompagni that in September 1789 was obliged to resign. Guglielmini was forced to move to Bologna, his hometown, where he had the support of the *Accademia delle Scienze*. In Bologna, he executed a first series of attempts in the Asinelli's tower in August 1790, and then he moved in the Specola's tower where he carried out 6 drops between September 12th and 14th with the assistance of Luigi Zanotti, Petronio Matteucci and Francesco Sacchetti. The inconclusiveness of these trials led Guglielmini to reiterate his experiment in Asinelli's tower with Alamanno Isolani, Alfonso Bonfioli Malvezzi and Petronio Colliva. The news of the attempts made in Rome by Giuseppe Calandrelli (1749-1827) and in Turin and Novara by Felix de Saint Martin de la Motte (1762-1818) and Ignazio Michelotti (1764-1846) convinced Guglielmini not to give up even after the failure of this third series of drops.

At the base of the *De diurno Terrae-motu experimentis phisico-mathematicis confirmato opusculum*[16], published in Bologna at the end of 1792, there is in fact a last series of trials executed by Guglielmini between July and September 1791. After some drops carried out from a reduced height, 16 bodies were dropped by Guglielmini, Isolani, Bonfioli Malvezzi and Tagliavini from the whole height of the Asinelli's tower. The results, reported in the book, proved a mean eastern deviation of 8,375'''(about 0.75 inch.) and a mean southern deviation of 5,272''' (about 0.5 inch), whereas theoretical calculations gave 7.6''' and 6.2'''. The smallness of these effects involved sophisticated experimental techniques such as the use of microscope or the elimination of any possible cause of perturbation of the body's fall and explains why no one detected them before the end of the 18th Century. As a matter of fact, the experiment consisted in dropping some lead balls of one-inch diameter from the highest point and in registering their landing point on a wax plate. The most delicate aspect was the release moment because the thread from which the balls were hanging had to be burnt only when they looked perfectly immobile. For this reason Guglielmini commissioned to Francesco Comelli a special device built to hang the spheres and drop them by a simple pressure on a lever. This was supposed to cancel out the vibrations caused by ball's release.

At first Guglielmini determined the measure of the deviation with respect to a conventional point. The actual foot of the plumb line was set only six months later because of the atmospheric conditions. As it will be shown below, this was considered the greatest weakness in Guglielmini's experimental procedure.

With regard to expected results and theoretical calculations, Guglielmini did a rough approximation. The small eastward deviation of the falling body depends upon the difference between the velocity of the top and the foot of the tower. Its trajectory is given by the composition of the rectilinear motion due to this difference and its gravitational fall. According to Guglielmini, on small scales, gravity can be considered to act along parallel lines and the round landing surface of the earth can be considered flat. Then he approximated the trajectory of the falling body with a parabola. So, he found an eastward deviation equal to

$$\frac{a \times u}{r} \times t$$

where t is the falling time, a is the falling height, r the earth radius and u the tangential velocity of the earth surface at the point of release.

As it is shown by the studies on the history of falling bodies[17], Guglielmini's experiment immediately roused a great interest in the Italian and in the European scientific world. In some Italian towns similar experiments were planned or executed and the theoretical problem of deviations involved a large number of *savants* both in Italy and, some years later, in France and in Germany. In spite of the rise and the diffusion of many experimental replications, only Guglielmini's experiment was considered really successful.

The history of Guglielmini's experiment as well as of its background and of the discussions it gave rise to has been widely discussed in many respects. A large number of documents and letters of Guglielmini have been published and analyzed and several studies have been carried out on the origins and the historical, scientific and cultural relevance of this debate over the last years.

So, to retrace the steps that led Guglielmini to conceive and carry out his experiment would be a largely superfluous work, as well as to hark back to the important historical precedents or to the theoretical results afterwards achieved by Laplace and Gauss in France and in Germany.

Nevertheless, the analysis of the documents preserved in the archive of the "Angelo Mai" library in Bergamo brought to light new unedited sources that allow us to reconstruct –from a local, particular but also privileged point of view– the atmosphere, the tensions and the theoretical reflections that followed one of the most important and less known replications of Guglielmini's experiment.

If the different trials carried out in Italy in those years don't seem to improve on Guglielmini's work, the experiment executed by Tadini in Bergamo shows interesting peculiarities both from the experimental point of view and from the theoretical one. Because of its weights both on theoretical and on experimental corrections of Guglielmini's work, it also represents in such a context a key example of the deep interaction between physical theories and experimental practice in 18th century Physics. As it will be shown below, Tadini corrects Guglielmini's theoretical calculations by considering the gravity directed towards the center of the Earth and by taking into account the horizontal component of the resistance of the air. He also got over Guglielmini's merely geometrical method by using differential calculus. But the relevance of Tadini's intervention in this debate cannot be restricted to his theoretical achievement. The attempts carried out in Bergamo provide a very expressive portrait of the deep interaction between experimental and mathematical techniques at the end of 18th century. As it emerges from his journal, Tadini's theoretical remarks and calculations constantly went with improving experimental observations.

The experiment in Bergamo

In September 1794, the abbé Gianantonio Tadini (1754-1830) happened to know that Lorenzo Mascheroni (1750-1800) was setting a series of drops in the Dome of the Basilica of Santa Maria Maggiore in Bergamo. Tadini, probably educated in Medicine (and then in Physics and Mathematics) at the University of Padua[18], in 1783 became "lettore di Filosofia" in the *Collegio Mariano*, a counter-reformation institution founded in Bergamo in opposition to the Seminar. However, when the experiment began in Bergamo Tadini didn't have any institutional appointments. Actually, in 1792 he was forced to resign from the *Collegio*. This was the result of a controversy about the dissertation of one of Tadini's student. Directly supported and sustained by Tadini, that research aimed to explain scientifically a phenomenon which was considered to be miraculous. The dissertation was accused of heresy. Although the accusation was dropped the polemic originated by it led Tadini to leave the *Collegio Mariano*. From then on, Tadini no longer had any kind of institutional appointments. This is probably one of the main reasons why he was almost unknown until now. It is through the discovery of its correspondence and its journal about the experiment that it is now possible to reconstruct his education, his actual involvement in the political and institutional life of his time as well as to retrace his real contribution to the experiment on the rotation of the earth.

Maria Teresa Borgato and Alessandra Fiocca recently stressed for the first time the importance of Tadini's contribution to the debate on the history of the proofs on Earth's rotation. Nevertheless, their studies only took the published writings into account and completely ignored Tadini's manuscripts.

If they have the merit of mentioning for the first time the experiment carried out by Tadini, they just exposed it through the articles and the book he published in 1796 and 1815. Furthermore they analyzed thoroughly neither the genesis of Tadini's work nor its connections to Guglielmini, Laplace and Benzenberg ones. An analysis of the manuscripts preserved in Bergamo[19] allows now to study in depth the reasons that have induced Tadini to start his experiment as well as to reconstruct the genesis of his theory, the climate in which he operates and his relations with Guglielmini and Laplace.

Indeed the journal of the experiment is very accurate and it describes Tadini's reflections on a daily basis and his change in the experimental procedure as well as Mascheroni's contribution. It also covers different reactions that experiment gave rise to. The correspondence[20] allows to clarify the relations between Tadini and Guglielimini, the delay in the publication of Tadini's book (20 years after the end of the experiment) and their connections to Laplace and Benzemberg.

As Tadini explains in the first lines of his journal, Mascheroni learned of the experiment carried out by Guglielmini in 1791. So, having noticed a hole in the Dome during a visit to the Basilica, he decided to repeat the experiment there.

It was through Mascheroni that Tadini became acquainted with Guglielmini's experiment. How much Mascheroni knew at that time about the experiment carried out in Bologna is substantially unclear. The information we can find in the opening of Tadini's journal[21] as well as the fact that Mascheroni immediately ordered a reproduction of the instrument that Guglielmini used in the next series of his drops leads to suppose that Mascheroni had read the *De Diurno Terrae Motu* before September 1794. In 1792, some reviews of Guglielmini's work was also published in the *Effemeridi letterarie di Roma*[22] and in the *Giornale de' letterati di Pisa*[23], but no description of Comelli's instrument appeared in it.

Nevertheless, the ignorance of Mascheroni about some of the main aspects of the *De Diurno Terrae Motu* seems to exclude that he really read the text before he climbed the top of the Dome. In any case, even if he had come into contact with the book, Mascheroni did not have it in hand any more in October 1794 when he tried to get a hold on it by Giuseppe Beltramelli (1734-1816). The latter was a friend and preceptor of the countess Paolina Secco Suardi Grismondi (1746-1801). He had been a student at Jesuit College in Bologna where he met several men of letters, Giuseppe Lucchesini (1739-1820) was among them. It was through Lucchesini, an erudite Bolognese bookseller with whom he maintained a prolific correspondence[24], that Beltramelli got two copies of *De diurno terrae motu* for Mascheroni[25]. Mascheroni received the books in January 1795[26]. In April he sent one of the two copies to Tadini[27]. At that time, Tadini did not know much about Guglielmini's experiment[28].

At first, Tadini started to carry out the experiment with Mascheroni. When he found out about Mascheroni's drops in Santa Maria Maggiore, he thought that their failure depended on a luck of accuracy in the execution. So, in September 19th, he went into the Basilica asking for the permission to make some attempts himself. Since then, not only had Tadini been involved in the experiment, but he also took the main part in it: he dropped the bodies himself, he improved on the instruments and he spent a lot of time determining the plumb-line and calculating the southern deviation. In the years following Guglielmini's first publication (1789), the question of the southern deviation caused quite a stir in the debate on the deviation of falling bodies. The dispute, that involved Teodoro Bonati (1724-1820) and Giuseppe Calandrelli (1749-1827)[29], found a place in the *De diurno terrae motu* but seemed totally unknown in Bergamo before 1795, when Tadini received his copy from Mascheroni.

In his first *Riflessioni sopra un nuovo esperimento in prova del diurno moto della Terra* Guglielmini only mentioned the possibility of a southern deviation of the body. The controversy originated from Bonati's intervention led Guglielmini to identify in an analogous declination of the plumb-line the cause of the impossibility to detect any southern body's deviation. A minimal southern deviation was nevertheless registered in several experiments carried out until then. In the *Diurno terrae motu*, Guglielmini reached the conclusion that the presence of the air, irrelevant on the plumb-line declination, slightly increased the southern deviation of the body. Therefore, the difference between the two, that was null in the vacuum, became for him minimal in the presence of air.

The first part of Tadini's journal is full of reflections on that matter. He wrote about his disagreement with Mascheroni that was convinced of the need to detect a southern deviation. He did not find any, and he performed a number of experiments to ensure that this absence was not accidental. So, it is first and foremost through experimental verifications that Tadini thought to solve his doubts about the southern deviation. Simultaneously he also face theoretical calculation and in October 30th, he concluded that the plumb line deflects in the same way as the falling body. Contrary to what was claimed by Guglielmini, in Tadini's opinion, the only effect of the air on the deviation of the body's motion concerns its horizontal component which is negligible in regard to southern gap[30]. Thus, in freely falling bodies, the southern deviation is imperceptible both in the vacuum and in the air.

Once he had reached a conclusion about the southern deviation, Tadini rapidly encountered different kinds of problems. In Bergamo the experiment on falling bodies soon suffered the hostility of the part of the clergy from the *Collegio Apostolico*[31]. As reported by Tadini in his journal, the priests of the Basilica affirmed that the doctrines on the Earth's motion he sustained with his experiment were against the Scripture[32]. Three days later he added that Mascheroni told him that people in Bergamo called him "insane" for his trials[33]. The situation precipitated shortly afterward. On October 6th Tadini wrote about a conversation with Mascheroni and the necessity for him to give up his experiment in the basilica[34]. While Tadini was forced to leave the church, Mascheroni could easily continue with the drops there. This was probably due to the accusation of heresy Tadini had suffered two years before. Actually the *Collegio Mariano*, the institution in which Tadini worked at that time, was founded by the same congregation managing the Basilica since 1449.

Few days after his expulsion from S. Maria Maggiore, Tadini moved to the Franciscan convent where he started a new series of experiment in the bell tower. His drops and his calculations became even finickier. He commissioned new instruments, more appropriate to the tower's structure, and he started to note down every drop in worksheet. Besides the date and the deviations, he also mentioned the meteorological conditions, the length of the thread used to suspend the body, the side of the thread that he burnt and so on.

Tadini's published writings

In 1796 Gianantonio Tadini published three articles[35] on the *Avanzamenti della medicina e fisica,* the Journal founded by Luigi Valentino Brugnatelli (1761-1818). In these writings, Tadini presents his calculations of the expected deviations of a body dropped from a great altitude. In particular, he shows that eastern deviation had to be reduced by a third in comparison with the deviation calculated by Guglielmini. He furthermore shows that there is no southern deviation.

In contrast with Guglielmini, according to which on a small scale the force of gravity acted along parallel lines, Tadini assumed that gravity points towards the centre of the Earth in accordance with Newton's theory. Consequently, the trajectory of a falling body –that Guglielmini presupposed to be parabolic– becomes elliptical. In fact, the force of gravity has not only a vertical component but also a horizontal one that reduces the eastern deviation of a freely falling body. Moreover, as Tadini underlines in these articles, the eastern deviation is also reduced by the air resistance. According to him, there is a component of the air resistance – which was supposed to be proportional to the square of the body's velocity– that opposes the body's deviation towards east.

In particular, by using series expansions and by taking into account both parabolic trajectory of the falling body and the air resistance, Tadini obtained the following expression for the eastern deviation:

$$\frac{2}{3}\frac{x}{R}s - 0{,}1mu^2\frac{x}{R}s - 0{,}0248m^2u^4\frac{x}{R}s \ldots$$

where *x* is the horizontal space covered by the body in the vacuum because of the Earth's rotation in the time *t*, *R* is Earth's radius extended to the top of a tower *s*, *m* is an unknown constant depending on air resistance and *u* is the velocity of the body falling in the vacuum from a height *s*.

The first term of the series represents the eastern deviation in the vacuum. The second one –of which Tadini approximates the whole series– describes the difference due to the horizontal component of the air resistance.

Guglielmini only considered the vertical component of the air. In his opinion, that component would have given rise to an increase of the falling time and thus to a greater eastern deviation. According to Tadini, the vertical component of the air «takes from and returns to the deviation the same quantity»[36]. Therefore, in contrast to Guglielmini, in his 1796's writings Tadini shows not only that the horizontal component of the air has to reduce the eastern deviation of the body, but also that the vertical one is irrelevant[37]. As Tadini underlines, in his theory Guglielmini ignored both the direction of the gravitational force towards the center of the Earth and the restraining effect of the resistance of the air.

Tadini started his experiment in September 1794. As I already pointed out, he published his theoretical reflections in 1796, immediately after the end of his trials. Conversely, his experimental results did not become public until 1815. In fact, the deviations he obtained in dropping heavy bodies in Bergamo were published only in 1815, in a Latin book edited by Vincenzo Ferrario (1768-1844)[38].

The reasons of such a delay in the publication of the experimental data become clear once his correspondence with Guglielmini, preserved in the municipal library of Bergamo, is taken into account. Such a correspondence also allows to determine the relations between Tadini and Guglielmini and to clarify their exchanges with Laplace and Lalande. More generally, the documents preserved in the library –among which the journal of the experiment and a description of the instruments he utilized– enable us to reconstruct the history of the experiment in Bergamo, its roots as well as its debts to the Guglielmini's one.

Tadini's response to Guglielmini's book

When Tadini received the *De diurno terrae motu* (April 28th, 1795) he had been at the Franciscan convent for almost six months and he was already clear about the theoretical aspects of the experiment. Two days after receiving the book, Tadini wrote to Mascheroni informing him about his astonishment[39]. He was bewildered both by the slender number of Guglielmini's drops (16) and by the methods employed in the experiment[40]. One of the first problems Tadini focused on was the determination of the plumb-line. Since his first attempts in the Basilica Tadini dedicated all of his efforts to detect the point perpendicularly below the place of release. It was for him the most important and trickiest operation. He repeated it many times, dedicating to it several hours every day, even just for a test.

On the contrary, as noted in the *De diurno terrae motu*, Guglielmini measured it just once and only a few months after the conclusion of his experiment. But then, he later admitted that his operation had its own limits. It was carried out after the conclusion of the drops over a windy period[41].

Nevertheless Tadini did not restrict his remarks to Guglielmini's experimental procedure. Since his first glance at the book in April 1795, he pointed out the theoretical problems concerning Guglielmini's calculation of the deviations. Even if Tadini published his own theory only in 1796, by 1795 he had already made up his mind about Guglielmini's mistakes. His journal shows that in October 1794, still unaware of Guglielmini results, he reached a conclusion not only about the southern deviation but also about the eastern one. The letters he sent to Mascheroni in the days following him receiving of the *De diurno terrae motu* demonstrate his immediate astonishment and they end with a lapidary judgment: «[…] in conclusion, Bologna's experiments are 16 very bad works [ribalderie] as I thought immediately»[42].

Tadini was probably the first to highlight the inaccuracy of Guglielmini's experiment and theory, but the *De diurno terrae motu* rapidly spread also in France and Germany and in the early years of the 19th Century new experiments and theories arose in both countries. In 1802 Johann Fiedrich Benzenberg (1777-1846) carried out a new series of drops trying to get around the reasons of Bolognese inaccuracies[43]. Wilhelm Olbers (1758-1840)[44] and Carl Friedrich Gauss (1777- 1855)[45] were involved for the theoretical aspects concerning the experiment. Moreover, between 1802 and 1805 Pierre-Simon Laplace (1749-1827) gave the correct formula for the calculation of falling bodies' deviations. Benzenberg's experiment as well as Laplace and Gauss' theories concerning the motion of freely falling bodies are largely studied and discussed. For this reason, they will not be discussed here apart for their connections to Tadini's work only. With regard to that matter, it is important to underline that despite the fact that calculations of the deviation by Tadini and Laplace agreed, Laplace's theory is formally different: Tadini used geometrical reasoning, series expansion and approximations, whereas Laplace's theory is based on different reference frames, changes of coordinates and on D'Alembert's principle[46].

According to a speech delivered by Guglielmini in November 18th, 1802, in 1796 Lalande informed him about some calculation performed by Laplace according to which the expected eastern deviation had to be reduced by a third and the southern one became null[47]. If we cling on to the note added by Sylvestre François de Lacroix (1765-1843) to Laplace's paper of 1803, Guglielmini would reply to Laplace's objection in 1797 admitting the inexistence of any southern deviation and announcing new experiments. However, in a letter sent to Tadini some years later, Guglielmini affirms to have also included in his answer to Lalande that Tadini had reached the same results[48].

As we can infer from his speech *Sulla deviazione meridionale* (1802), Guglielmini met Tadini in 1797 in Milan on the occasion of a session of the Cisalpine Republic[49]. There, he acquainted himself with Tadini's articles on Brugnatelli's journal. In spite of his objections to the type of calculation method used, his opinion on Tadini's work remains very positive. Nevertheless, the extract in which Guglielmini underlines Tadini's contribution[50] completely disappears in the version of the speech sent to Benzenberg in March 23rd, 1803 and then published in Benzenberg's work in 1804[51]. Besides, reference to Tadini appears neither in Lalande's articles nor in Laplace's works may be found on the subject[52].

According to Giuseppe Bravi –the author, in 1835, of the most extensive printed work on Tadini– Tadini's calculations and articles were sent to Laplace[53]. Unfortunately, there is no documentary evidence of this alleged mailing. As a matter of fact, no correspondence from Tadini to Lalande or Laplace was found. No letter referring to the experiment in Bergamo in the correspondence between the two French astronomers was ever found either[54]. In addition, Tadini's publication does not appear in the list of documents and works sent to the *Académie Royale des Sciences* of Paris[55].

Even if it is impossible to demonstrate a direct influence of Tadini's work on Laplace –that proceeded with a different mathematical method– it is interesting to notice that the well-known Laplace's results were reached also by Tadini. As it was shown earlier, in May 1795 Tadini already exposed his deviations' calculations to Mascheroni coming to the conclusion that the southern deviation is null and the eastern one has to be reduced by a third. The first information about Laplace's corrections was only published in 1803 and dates back to the letter that Guglielmini reported to have received in 1796. It was the same year in which Tadini's articles on the falling bodies problem was printed by Brugnatelli.

Moreover, in a letter to Tadini, Guglielmini begins by saying that he was the first to demonstrate that the southern deviation had to be null:

> You were the first to demonstrate in 1796 that southern deviation had to be nil: after you the famous astronomer Lalande wrote to me that the illustrious Geometer Laplace asked him to write me the same. [56]

However, except for his 1802 speech and his letters to Tadini, Guglielmini always omitted Tadini's name and it appears neither in Benzenberg's works nor in Laplace's and Lalande's writings.

The relation between Guglielmini and Tadini is controversial and it also involved the publication of Tadini's experimental results. As it was mentioned above, these data were edited only in 1815. The four letters from Guglielmini to Tadini preserved in *Angelo Mai* Library in Bergamo testified that in 1806 Tadini had sent to Guglielmini the table of his experiments of March and April 1975[57] and that Guglielmini's position regarding the publication of Tadini's work appears ambiguous. In the first letter, Guglielmini suggests Tadini to wait before publishing his results so that the former could add his own reflections[58]. That position is confirmed in a following letter[59] but Guglielmini's reflections about Tadini's experiment never came out. The results of the experiment carried out in the Franciscan tower were published in Latin by the Milanese editor Vincenzo Ferrario only in 1815[60].

Conclusion

Tadini's work did not cause the stir occasioned by Guglielmini's one and it was followed mainly by the circle of the Bergamo's intellectuals, with a few exceptions due to the personal contacts of these intellectuals with some scientists or academics working in other places in Italy. The publication of the theoretical results on the Brugnatelli's *Giornale chimico-fisico* did not give prominence to Tadini's work. In spite of the importance of the publishing initiative of Brugnatelli regarding the Italian scientific periodical scene in the late 18th Century, the *Giornale* was short-lived (1792-1796) and his circulation was not comparable to his principal European equivalents[61].

As far as the book printed in Milan by Ferrario is concerned, not only the publication came after several years of both Tadini's experiment and following works of Laplace, Benzenberg and Gauss, but no such review was published in scientific journals at that time. About the circulation of the *Quotidiana terrae conversio* we only know that Tadini originally ordered 150 copies which Ferrario considered too little an amount[62].

The inadequate circulation of Tadini's works was probably also caused by the particular political circumstances in which they got into print. At the time of the publications on the Brugnateli's journal, French troops were invading northern Italy occupying the territories of the Duchy of Milan, Mantua, Modena, Reggio and a part of Papal States altering the political Italian equilibrium of the 18th Century. Also the *Quotidiana terrae conversio* was published in a critical period for the history of northern Italy. The Kingdom of Italy, the last institutional form of the French occupancy, did not survive the fall of its monarch and collapsed in 1814. The Congress of Vienna created then the Kingdom of Lombardy–Venetia completely modifying again the Italian political shape. Thus, in almost twenty years Bergamo passed from the Venetian control to the French rule and, then, to the Austrian domination. These deep and continual political mutations inevitably made scientific exchanges between these territories and much more difficult. In this context, Tadini –that did not work at a University and did not have many personal scientific contacts – could not have the same visibility as Guglielmini or Laplace.

Moreover, at the time of the publication of the experimental results, the debate on the freely falling bodies almost faded. The works of Benzenberg, Olbers, Laplace, Lalande and Gauss were well-known and their answers to the questions raised by the *De diurno Terrae motu* were considered as exhaustive.

Nevertheless, Tadini's experiment represents a very significant step in this debate. As I underlined Tadini was the first to correct Guglielmini's calculations and to repeat Bolognese trials with the needed accuracy.

The history of the demonstration of the Earth's rotation was around 1800 characterized by a succession of theoretical and experimental approximations. As it was shown, the first theoretical analysis carried out by Guglielmini in 1789 was rather rough. He considered gravitation as acting along parallel lines and the surface of the Earth as flat. The path that led from the first Guglielmini's formulation to Laplace and Gauss' theories was marked by an increasing accuracy both in experimental and in theoretical techniques. The hypothesis formulated by Guglielmini in 1789 was progressively corrected and integrated by taking into account some neglected variable like the sphericity of the Earth's surface, the convergence of gravity at the center of the Earth and the horizontal component of the resistance of the air.

In this sense, the case of Bergamo's experiment shows better than any other the deep interaction between observation and theoretical analysis that characterized physics at the end of 18th century. Guglielmini presented his calculations of the expected deviations two years before the begin of his experimental trials and he revised them just owing to Tadini and Laplace criticism. When Benzemberg carried out his new experimental attempts, he completely entrusted mathematical calculations to Olbers. As far as Laplace goes, his refined theoretical study of the expected deviations never had an experimental counterpart.

In contrast, Tadini's journal shows a continuous interaction between theoretical prediction and observations from the very beginning of his trials in the Basilica of Santa Maria Maggiore. Moreover the agreement between his theoretical expectation and his experimental results is the best in the history of this kind of attempts.

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Manuscripts

Manuscripts citations are listed here according to the name and location of repository, the title of the collection, folio reference and date (as applicable). They are cited in the footnotes according to the name of repository, the author's name or the manuscript title.

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Beltramelli, G., *Zibaldone di varie sue memorie*, R. 68 (4), cc. 136, 137, 138.

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Tadini, G., *Registro delle Sperienze*, Archivio Tadini.

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Lalande, J.J., Mss. 2396-7.

Bibliothèque de l'Observatoire, Paris (BOP)
Lalande, J.J. C 5-1/12
Lalande, J.J. C 5-28/29
Lalande, J.J. C 5bis 1/40
Lalande, J.J. *Correspondance reçue*, Ms. 1090

Bibliothèque Nationale de France, Paris (BNF)
Correspondance, nouvelles acquisitions françaises, 10 159
Correspondance, nouvelles acquisitions françaises, 15 984, ff. 178-179
Lettres reçues, nouvelles acquisitions françaises, 24 693, ff. 110-111

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[1] It has rarely mentioned and it was recently reported only by Mariateresa Borgato and Alessandra Fiocca showing for the first time the importance of Tadini's theoretical results (See: Bogato, "Tra teoria ed esperimenti: la deviazione dei gravi e la rotazione della Terra (1789-1805)", *Bollettino dell'Unione Matematica Italiana*, sez. A 10/A, (2007), 497-536; Borgato, "La prova fisica della rotazione della Terra e l'esperimento di Guglielmini" in: Pepe (Ed.), *Copernico e la questione copernicana in Italia dal XVI al XIX secolo*, (Ferrara, 1996), 201-261; Fiocca, "The southern deviation of freely falling bodies: from Robert Hooke's hypothesis to Edwin H. Hall's experiment (1679-1902)", *Physis*, XXXV, n.s., fasc. 1, (1998), 51-83). However, even in these studies, neither th experiment conducted in Bergamo nor the contacts which existed between Tadini, Guglielmini and Laplace find a great place. Furthermore, the role played by Lorenzo Mascheroni (1750-1800) –to which local literature normally attributes the whole credit in the event– remains often unclear (See: Savioli *Memorie appartenenti alla vita ed agli studj dell'abate Lorenzo Mascheroni* (Milan, 1801); Landi "Elogio di Lorenzo Mascheroni", *Memorie di Matematica e Fisica della Società Italiana di Scienze*, XI, (1804), XXXVIII-LI; Capaccioli, "Note biografiche su Lorenzo Mascheroni", *Bergomum*, a. 86, n. 2, (1991), 7-75, p. 39).

[2] Aristotle, *De Caelo*, II, 14, 296b, 22-26.

[3] See: Copernicus, *De Revolutionibus*, (Norimbergae, 1543), I, § 8.

[4] See: Digges, *A Perfit Description of the Caelestiall Orbes according to the most aunciente doctrine of the Pythagoreans, latelye revived by Copernicus and by Geometricall Demonstrations approved*, added as an appendix to Digges, L., *Prognostication everlasting*, (London, 1576). For further details see, among others: Johnson, "The influence of Thomas Digges on the Progress of modern astronomy in Sixteenth-Century England", *Osiris*, 1, (1936), 390-410; Johnson, *Astronomical Thought in Renaissance England*, (Baltimore, 1937); Johnson and Larkey, "Thomas Digges, the Copernican System and the Idea of Infinity of the Universe in 1576", *Huntington Library Bull,* 5, (1934) 69-117.

[5] See: Bruno, *La cena delle ceneri*, *Dialogo* III, (Milan 2004), pp. 72-74.

[6] On Correspondence between Hooke and Newton from November 1679 and January 1680, see: Turnbull, (ed.), *Correspondence of Isaac Newton* (Cambridge, 1960), Vol. 2 (1676–1687), pp. 297–314 and Ball, "Correspondence between Hooke and Newton, 1678-1680 and Memoranda relating thereto" in: Rouse Ball, (ed.). *An essay on Newton's "Principia"*, (London-New York, 1893), 139-153. It is possible to find an account of the experiments in the proceedings of the *Royal Society* (18 December 1679 and 22 January 1680). For further information about the topic see, among others: Lohne, "Hooke versus Newton", Centaurus, Volume 7, Issue 1, (September 1960), 6–52 and Whiteside, "Newton's early thoughts on planetary motion", *British Journal for the History of Science*, 2, (1964), 117-137.

[7] See: Rouse Ball, *op. cit.* (ref. 6), 142.

[8] See: Lalande, *Astronomie*, (Paris, 1764).

[9] Lalande, *Astronomie*, (Paris, 1771), vol. I, p. 519.

[10] For further information on the history of experiments on Earth's rotation before Guglielmini see, among others: Armitage, "The Deviation of Falling Bodies", *Annals of Science*, 5, (1947), 342-351; Gapaillard, "Le mouvement de la Terre. La détection de sa rotation par la chute des corps », *Cahiers d'Histoire et de Philosophie des Sciences*, 25, (1988), 1-179; Gilbert, "Les preuves mécaniques de la rotation de la Terre", *Bulletin des Sciences Mathématiques et Astronomiques*, 2ème série, 6, (1882), 189-223; Hagen, *La rotation de la terre. ses preuves mécaniques anciennes et nouvelles*, (Rome, 1991); Koyré, "A Documentary History of the Problem of Fall from Kepler to Newton", *Transactions of the American Mathematical Society*, New series, 45, (1955), 329-395. In particular, on the Riccioli-Borelli-Degli Angeli's controversy see: Galluzzi, "Galileo contro Copernico. Il dibattito sulla prova "galileiana" di G. B. Riccioli contro il moto della Terra", *Annali dell'Istituto e Museo di Storia della Scienza di Firenze*, Anno II, fasc. 2, (1977), 87-148.

[11] See: D'Alembert, "Terre", *Encyclopédie ou Dictionnaire raisonné des sciences, des arts et des métiers*, Tome XVI, (Paris, 1751-1765).

[12] The definitive revocation of this proscription would have to wait until 1835, even as a consequence of the "Settele's affair" (1820). The atmosphere of tolerance inaugurated by Benedict XIV indirectly encouraged in some way the reemergence of the problem of the demonstration of the earth's rotation.

[13] «l'annuo moto della Terra; affinché nella luce delle Scienze del Secol nostro il Copernicano Sistema trovi finalmente fra le filosofiche, ed astronomiche verità quel pacifico luogo, che alcuni tuttavia accremente gli contendono». Guglielmini, *Riflessioni sopra un nuovo esperimento in prova del diurno moto della Terra*, (Rome, 1789), p. 428. Translated by me.

[14] Guglielmini, *Riflessioni* (ref. 13).

[15] As Bezenberg underlined some years later: «It would be indeed a strong proof of the progress of the times if the trial for a system which the Church had banned were arranged in the holiest city of the entire Christendom, next to the grave of the holy Peter». Benzenberg, *Versuche über das Gesetz des Falls, über den Widerstand der Luft und über die Umdrehung der Erde, nebst der Geschichte aller früheren Versuche von Galiläi bis auf Guglielmini*, (Dortmund, 1804), p. 432. See also: Bertoloni Meli, "St. Peter and the Rotation of the Earth: The Problem of Fall around 1800", in: Shapiro, Harman, (Eds.), *The Investigation of Difficult Things*, (Cambridge, 1992), 421-47, p. 426.

[16] Guglielmini, *De diurno Terrae-motu experimentis phisico-mathematicis confirmato opusculum*, (Bononiae, 1792).

[17] In addition to the mentioned bibliography, see : Acloque, "Histoire des expériences pour la mise en évidence du mouvement de la terre", *Cahiers d'Histoire et de Philosophie des Sciences*, nouv. série, 4, (1982), 1-141 and Gianfranceschi, "La deviazione dei gravi in caduta", *Il Nuovo Cimento*, 6a serie, VI, (1913), 225-285.

[18] Biographical documentation on Tadini until 1778 and after 1783 is rather abundant. Instead, no reference to this middle period is detectable in the archives in Bergamo. Nevertheless the discovery of a degree certificate in Medicine and Arts obtained in Padua by a certain Giovanni Tadini from Bergamo let us to suppose that Tadini attended Padua's University in these years. Dated on May, 11th 1782 this degree certificate exactly coincides with the documentary void on Tadini's life. Furthermore it could explain Tadini's scientific competences. See: ASUPd, Archivio Storico dell'Università.

[19] Tadini's manuscripts were only recently published as appendix of my book on the experiment executed in Bergamo. See: Giannini, *Verso Oriente. Gianantonio Tadini e la prima prova fisica della rotazione terrestre*, (Florence, 2011). In the first part of the book it is possible to find also a Tadini's biography that was substantially lacking and that I outlined on the basis of documents preserved in different archives, in particular: the "Angelo Mai" Library in Bergamo, the

Archives of the Bergamo's Clergy, The Record Office of Milan, the Historical Archives of the University of Padua, the Archives of the Bergamo's Seminary and the Record Office of Venice.

[20] I also took in account Mascheroni's correspondence in order to elucidate his contribution to the experiment and his role in its design and carrying out.

[21] BCB, Tadini, *Registro delle sperienze*, Archivio Tadini, IV, 33, B, c. 1r, published in Giannini, *op. cit.*, (ref. 19), p. 57.

[22] See: *Effemeridi letterarie di Roma* (1792), pp. 329-333.

[23] See: *Giornale de' letterati di Pisa* (1792), pp. 274-275.

[24] See: BCB, Beltramelli, R. 68 (4), fols. 136, 137, 138; BCB, Beltramelli, MMB 416, fol. 34 (1-23). The first letter we found between Beltramelli and Lucchesini is addressed to Beltramelli and is dated September 28th, 1790. See also: Colombo, "Giuseppe Lucchesini stampatore libraio bolognese tra '700 e '800; inventario del carteggio e documenti", *L'Archiginnasio*, LXXIX, (1984), 287-311.

[25] See the letter from Giuseppe Lucchesini to Giuseppe Beltramelli of November 9th, 1794, BCB, Beltramelli, MMB 416, fol. 34/3.

[26] See, among the others, the letter from Beltramelli to Lorenzo Mascheroni of December 22nd, 1794, BCB, Mascheroni MMB 669, cc. 315-316 (from which we deduce that books are not still arrived) and the letter from Mascheroni to Barca of January 1795, BCB, Mascheroni R 68 3 10/42, photo 8 (in which Mascheroni says to have received the copies).

[27] See: BCB Tadini, *Registro delle sperienze*, fol. 7r; published in: Giannini (2011), pp. 57-103. See also the letter from Gianantonio Tadini to Lorenzo Mascheroni of April 30th, 1795, BCB, Mascheroni MMB 670, fols. 73-74, published in Giannini, *op. cit.*, (ref. 19), pp. 137-138.

[28] Ivi.

[29] See: Borgato, "La prova fisica della rotazione della Terra e l'esperimento di Guglielmini" (ref. 1), pp. 201-261; Bonati, *Carteggio scientifico: Lorgna, Canterzani, Frisi, Saladini, Calandrelli, Venturi*, Borgato, Fiocca, Pepe (Eds), (Florence, 1992); Guglielmini, *Carteggio De diurno terrae motu. Canterzani, Isolani, Matteucci, Bonfioli, Malvezzi, Caldani, Calandrelli, Bonati*, Borgato and Fiocca (Eds), (Florence, 1994).

[30] See: Tadini, "Della deviazione australe e d'altri minuti articoli di calcolo", *Avanzamenti della medicina e fisica*, IV, (1796), 146-72.

[31] The *Collegio Apostolico* was founded in Bergamo in 1717 by M. Antonia Grumelli (1741-1807) that set out to continue Jesuits' work after their suppression in 1773. It was in contrast with Jansenism and, afterwards, with the secularization process began by the French Revolution with the rise of the Napoleonic occupancy. For further details, see, among others: Zanchi, *Il Collegio Apostolico. Una esperienza singolare della Chiesa di Bergamo*", (Milan 2009).

[32] BCB Tadini, *Registro delle sperienze*, fol. 7v.

[33] Ivi, fol. 10v.

[34] Ivi, fol. 14v.

[35] Tadini, "Opuscolo intorno alla deviazione de' corpi cadenti dall'alto", *Avanzamenti della medicina e fisica*, I, (1796), 171-93; Id., "Volgarizzamento del calcolo della deviazione orientale", *Avanzamenti della medicina e fisica*, III, (1796), 123-42; Id., "Della deviazione australe e d'altri minuti articoli di calcolo" (ref. 30).

[36] "Toglie e restituisce alla deviazione la stessa quantità", Tadini, "Opuscolo intorno alla deviazione de' corpi cadenti dall'alto" (ref. 35), p. 188; translated by me.

[37] See: Ivi, p. 189.

[38] See: Tadini, *Quotidiana terrae conversio devio corporum casu demonstrata*, (Milan, 1815).

[39] See the letter from Tadini to Mascheroni of April 30th, 1795: BCB, Mascheroni, MMB 670, fols. 73-74, published in Giannini, *op. cit*, (ref. 19), p. 137.

[40] Ivi.

[41] See on this argument the speech given by him in November 18th, 1802 at the *Accademia delle Scienze* of Bologna (Guglielmini, 'Sulla deviazione meridionale', in Borgato, "Tra teoria ed esperimenti" (ref. 1), p. 234) and, above all, the letter he sent to Tadini in August 16th, 1809 (BCB, Tadini, *Archivio Tadini*, faldone VII, 88, fol. 2r; published in Giannini, *op. cit.* (ref. 19), p. 145).

[42] «[…] per conclusione di tutto le sperienze di Bologna sono 16 ribalderie, com'io erami presagito al primo vederle». See the letter from Tadini to Mascheroni of May 11th, 1795, BCB, Mascheroni, MMB 670, fols. 77-78 (published in Giannini, *op. cit.* (ref. 19), p. 138). Translated by me.

[43] Benzenberg, *Versuche über das Gesetz des Falls* (ref. 15).
[44] On Olbers' contribution and theory see in particular: Bertoloni Meli, "St. Peter and the Rotation of the Earth" (ref. 15), pp. 434-438; Gapaillard, "Le mouvement de la Terre" (ref. 10), pp. 81-90.
[45] Gauss was in fact involved by Olbers, see: Benzenberg, *Versuche über das Gesetz des Falls* (ref. 15), p. 346 and Olbers, *Sein Leben und seine Werke*, (Berlin, 1900), vol. 2, pp. 107-11.
[46] See: Fiocca, "The southern deviation of freely falling bodies (ref. 1).
[47] Guglielmini, "Sulla deviazione meridionale", in Borgato "Tra teoria ed esperimenti" (ref. 1), pp. 233-7.
[48] See the letter from Guglielmini to Tadini of August 16, 1809, BCB, Tadini, *Archivio Tadini*, faldone VII, 88, fols. 2r.-2v (published in Giannini *op. cit*, (ref. 19), pp. 145-6. To this letter Tadini probably refers when in his *Quotidianae terrae conversio devio corporum casu demonstrata* writes: 'et aliquot post annos Laplacius Gallorum Geometrarum facile princeps litteris Lalandi nuntiavit Guglielmino (is Bononiae plurimum in re versatus fuerat) exploratum sibi esse, nullam fieri posse decidentium corporum in australem plagam declinationem; cui statim responso declaratum est, id in Italia jamdudum a me demonstratum'. Tadini, *Quotidiana terrae conversio* (ref. 38).
[49] Following the occupancy of Italian northern territories by Napoleon Bonaparte and the institution of the Cisalpine Republic (1797, the capital being Milan) both Guglielmini and Tadini assumed important political office, the first as deputy of the Reno's Department (Bologna-based) and the second as a member of the Council of Junior of the Serio's Department (Bergamo-based).
[50] See: Guglielmini, 'Sulla deviazione meridionale', in Borgato, "Tra teoria ed esperimenti" (ref. 1), p. 235.
[51] See: Benzenberg *Versuche über das Gesetz des Falls* (ref. 15), pp. 384-7.
[52] In his *Traité de mécanique céleste* Laplace only mentions the several experiments carried out in Italy and in Germany: 'On a déjà fait, en Italie et en Allemagne, plusieurs expériences sur la chute des corps, qui s'accordent avec les résultats précédents. Mais ces expériences, qui exigent des attentions très délicates, ont besoin d'être répétées avec plus d'exactitude encore', Laplace, *Traité de mécanique céleste*, (Paris, 1805), p. 303.
[53] Bravi, *Analisi delle Opere di Antonio Tadini*, (Bergamo, 1835), p. 45.
[54] See: BCB, Tadini, Archivio Tadini, *Corrispondenza particolare*, fald. VII; BCB, Archivio Tadini, fald. IX/XX; BCB, Tadini, *Lettere a Carlo Marieni* (1789-1830), MMB 223; BCB, Tadini, *Collezione di autografi e notizie*, 65 R 10 and BCB, Tadini, *Specola epistolari* 487 and 779. On Lalande's correspondence see: AAS, *Dossier Lalande*; AAS, *Manuscrits isolés*, 1 j 4 Lalande; BIF, Mss. 2396-7; BOP, C 5-1/12; BOP C 5-28/29, C 5bis 1/40; BOP, *Correspondance reçue*, Ms. 1090; BNF, *Correspondance*, nouvelles acquisitions françaises, 10 159; BNF, *Correspondance*, nouvelles acquisitions françaises, 15 984, ff. 178-179; BNF, *Lettres reçues*, nouvelles acquisitions françaises, 24 693, ff. 110-111; AOB, *Oriani*, carte varie; AOB, *Corrispondenza scientifica*, 1797. For a compendium on Laplace's correspondence see: Hahn, *The new calendar of the correspondence of Pierre Simon Laplace*, Berkeley, 1994).
[55] See : AAS, Registres diverses, *Entrée de manuscrits et imprimés*, vol. 1 (an IV-1821); AAS, Registres diverses, *Mise à l'étude*, vol. 1 (an IV-1821).
[56] «Voi foste il primo a dimostrare nel 1796, che la meridionale deviazione de' Gravi cadenti doveva esser nulla: dopo voi il noto astronomo Lalande mi scrisse, che il celebre Geometra Laplace lo aveva incaricato di scrivermi lo stesso». Guglielmini to Tadini, August, 16 1809, BCB, Archivio Tadini, Faldone VII, 88, c. 2, published in Giannini, *op. cit.* (ref. 19), pp. 145-6. Translated by me.
[57] Guglielmini to Tadini, August 16, 1809, BCB, *Archivio Tadini*, Faldone VII, 88, c. 2; published in Giannini, *op. cit.* (ref. 19), pp. 145-6.
[58] Guglielmini to Tadini, April 23rd, 1806, BCB, Archivio Tadini, Faldone VII, 88, c. 2; published in Giannini, *op. cit.* (ref. 19), p. 144.
[59] See: Guglielmini to Tadini, September 16th, 1809, BCB, *Archivio Tadini*, Faldone VII, 88, c. 3; published in Giannini, *op. cit.* (ref. 19), p. 147.
[60] See: Tadini, *Quotidiana terrae conversio* (ref. 38).
[61] See: Berengo, *Intellettuali e librai nella Milano della Restaurazione*, (Turin, 1980); Beretta, "Luigi Valentino Brugnatelli e la chimica in Italia alla fine del Settecento", *Storia in Lombardia*, n. 2, (1988), 3-31, in part. pp. 27-31;

(1980), pp. 245-247; Beretta (1988), in part. pp. 27-31; Del Piano, “I periodici scientifici nel Nord Italia alla fine del Settecento: studi e ipotesi di ricerca”, *Studi storici*, XXX, (1989), 457-481 (1989); Seligardi, *Lavoisier in Italia: la comunità scientifica italiana e la rivoluzione chimica*, (Florence, 2002).

[62] See the letter from Ferrario to Tadini of May 20th, 1814, BCB, Archivio Tadini, fald. VII, c. 79.