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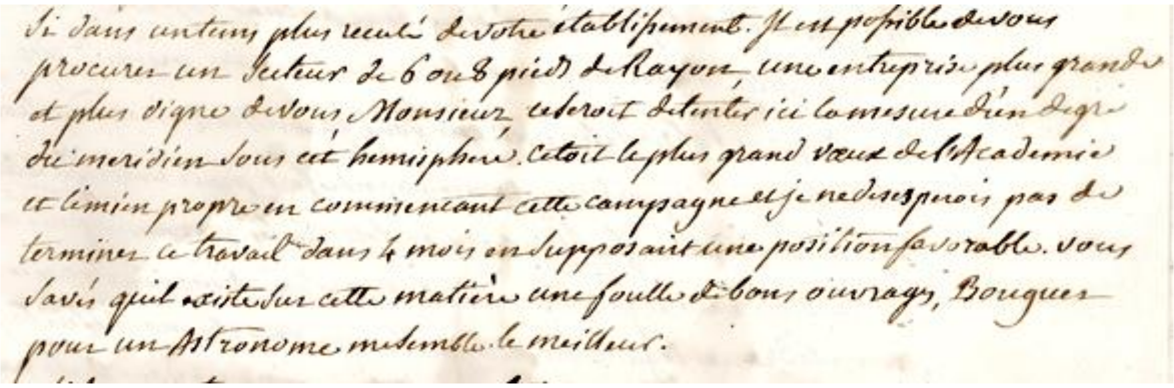
# Joseph Lepaute Dagelet and his pendulum experiments at Botany Bay, 1788

When they met at Botany Bay in February-March 1788, Joseph Lepaute Dagelet, the astronomer on the Lapérouse expedition, urged William Dawes, the new English colony's astronomer, to attempt "la mesure d'un degré du meridien sous cet hemisphere [the measurement of a degree of the meridian in this hemisphere]".[1]

Dawes was unable to act on this recommendation, but as he would have known, measurement of a degree of the meridian had been an aim of the Académie Royale des Sciences for over a century. In 1670, Gabriel Mouton, one of the first members of the Académie after its foundation in 1666, was concerned to preserve an accurate and verifiable measure of the then current unit of length, the Parisian *toise*.[2] He proposed a decimal system of measurement based on the circumference of the Earth. Explaining the advantages of a system based on nature, he proposed a unit, the *milliare*, defined as the length of a minute of arc along a meridian of longitude. Conscious of the effort required to do this, he suggested that the actual standard be based on pendulum movement, which was easier to verify. A pendulum located in Lyons, his native city, of length 1/10.000 of a minute of arc, would beat a definite number of times during a fixed period. He estimated there should be 3,959.2 oscillations every half hour, which would verify the pendulum was the correct length.

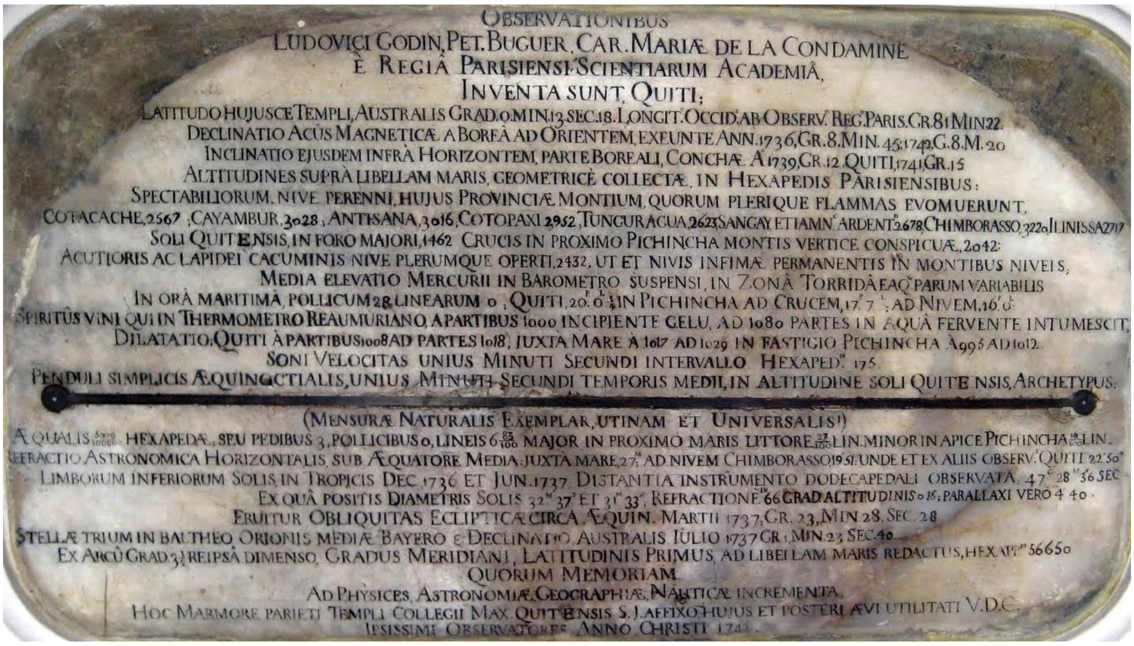

Si dans un tems plus reculé de votre établissement il est possible de vous procurer un Secteur de 6 ou 8 pieds de Rayon, une entreprise plus grande et plus digne de vous Monsieur ce seroit de tenter ici la mesure d'un degré du meridien sous cet hemisphere. c'etoit le plus grand voeux de l'Academie et le mien propre en commencant cette campagne et je ne desesperois pas de terminer ce travail dans 4 mois en supposant une position favorable. vous savés qu'il existe sur cette matière une foulle de bons ouvrages, Bouguer pour un Astronome me semble le meilleur.

Dagelet à Dawes, à la Baye Botanique, 3 Mars 1788, suggesting he measure "a degree of the meridian in this hemisphere".
State Library of New South Wales (Sydney), Mitchell Ad 49/6-7

The Abbé Jean Picard, also a member of the Académie Royale des Sciences, measured an arc of the Meridian of Paris between Malvoisine, south of Paris, and Sourdon near Amiens, in 1669 and established the length of a degree of longitude as 57,060 *toises* (111,209 metres).[3] His unit of measurement, the *toise*, did not have a perfectly preserved standard, as it varied from time to time and from place to place throughout France. Christiaan Huygens, Picard's and Mouton's colleague at the Académie des Sciences and the inventor of the pendulum clock, had been approached by Mouton and at his suggestion proposed in 1673 the length of a pendulum beating at seconds as the basic unit for a universal measure which, "once agreed upon, could not only be established by people everywhere, but also in times to come be reconstituted".[4] Picard supported this proposal, acknowledging the virtue of a standard that could be recovered if necessary by making it referable to an invariable feature of nature, and the length of a pendulum beating at seconds seemed to fit this criterion.[5]

The difficulty of using the length of a seconds pendulum as the standard unit of measure was that it was found to be not, in fact, an invariable feature of nature, but varied with the latitude where it was measured. This was discovered by another member of the Académie, the astronomer Jean Richer. Between 1671 and 1673 he performed experiments and carried out celestial observations at Cayenne, French Guiana. Richer had one of Huygens' pendulum clocks for this purpose which, though it had kept perfect time in Paris, had to be adjusted by shortening its pendulum by 1.25 *lignes* (2.8 millimetres) to make it beat faster in Cayenne to compensate for the weaker strength of gravity there. The English mathematician Isaac Newton subsequently commented that if, as he had proposed, the force of gravity decreases with the inverse square of the distance between objects, the obvious conclusion to be drawn from Richer's work was that near-equatorial Cayenne was further from the centre of the earth than Paris, where the first such measurements had been taken. Thus the earth could not be spherical, as had been presumed by Mouton and his colleagues, but rather bulged at and near the Equator, forming an oblate spheroid.[6]

In 1742, during the course of a scientific expedition to what is now Ecuador, then Peru, to ascertain the shape of the Earth, Charles-Marie de la Condamine established the length of a pendulum beating seconds on the Equator near Quito, and he proposed this for the universal unit of measure: "mensurae naturalis exemplar, utinam et universalis [a natural and, may it be, an universal model of measure]".[7]




Bronze exemplar (*varilla metalica*) of the length of the pendulum on a marble plaque with inscription on observations on the pendulum's motion which La Condamine placed on one of the walls of the Jesuit Collegio Maximo de Quito, now in the Observatório Astronómico in the Parque Alameda, Quito, Ecuador. Photograph, Conrad Woldringh.

Following Condamine's death, Turgot, Comptroller-General of Finances, was urged by Jean-Antoine de Condorcet, Permanent Secretary of the Académie and ardent advocate for reform of the system of measures, to carry out the project of establishing a universal unit of measure. In October 1775, Turgot wrote to the astronomer Charles Messier: "M. Condorcet must have advised you, Sir, of the project that I have to ascertain by exact experiments the precise length of a pendulum, which it seems to me should serve as a common standard and term of comparison for all measures that will be easy to reduce to it". [8] He asked Messier to measure the seconds pendulum at sea level at Bordeaux, a city on latitude 45º North, half-way between the Equator and the North Pole.[9] Messier, however, was unable to fulfill his mission before Turgot had been dismissed from office. Turgot's successor, Jacques Necker, was unconvinced that Condorcet's vision could be realised and dropped the proposals for reform.[10]

When Louis XVI in 1785 took up the project for a round the world voyage of discovery, his Minister of the Household, Breteuil, who was a member of the Académie des Sciences, made sure an astronomer was included among the expedition's savants. Joseph Lepaute Dagelet was chosen for this appointment. Born in the village of Thonne-la-Long, Lorraine, on 25 November 1751, he went to Paris in 1767 to live with his uncle and aunt, Jean-André and Nicole-Reine Lepaute. Jean-André and his brother, Jean-Baptiste, held the appointment of clockmakers to the King. His aunt, Nicole-Reine, was an astronomer of note and assistant to the eminent astronomer Jérôme Lalande. She encouraged Joseph’s aptitude for astronomy, and from his arrival in Paris until 1772 he studied in the observatory of the Collège Mazarin, where he was guided by Lalande. In 1773, he was appointed to the expedition commanded Kerguelen de Trémarec to the southern Indian Ocean. As a result of his work on this expedition, he was when he returned made professor of mathematics at the École Militaire, Paris, where he was able to continue his astronomical researches. In recognition of his observations of the planets and stars he was named astronomer to the Académie des Sciences in 1785. Although the hardships he had experienced during the Kerguelen expedition had extinguished any enthusiasm he might have had for oceanic voyages, he was appointed the same the year to the expedition commanded by Lapérouse. One of Dagelet's pupils at the École Militaire, the sixteen-year old Napoleon Bonaparte, applied to be his assistant but was rejected in favour of another, Roux d'Arbaud. A set of recommendation drawn up by the Académie for the savants of the expedition stated:

> One of the most interesting objects for research is that concerning the determination of the length of a pendulum at seconds at different latitudes. The conclusions which up to now has been drawn from this instrument to determine variations of gravity, have been based on a small number of experiments done by different observers, with different instruments, and this lack of uniformity in the experiments has necessarily influenced the accuracy of the conclusions deduced from the comparison of results. It will be appreciated how valuable would be a set of experiments of this kind made with care by the same persons and with the same instruments.[11]

In a journal article on the current state of astronomy, Lalande described Dagelet’s appointment and the work he was expected to carry out with the pendulum:

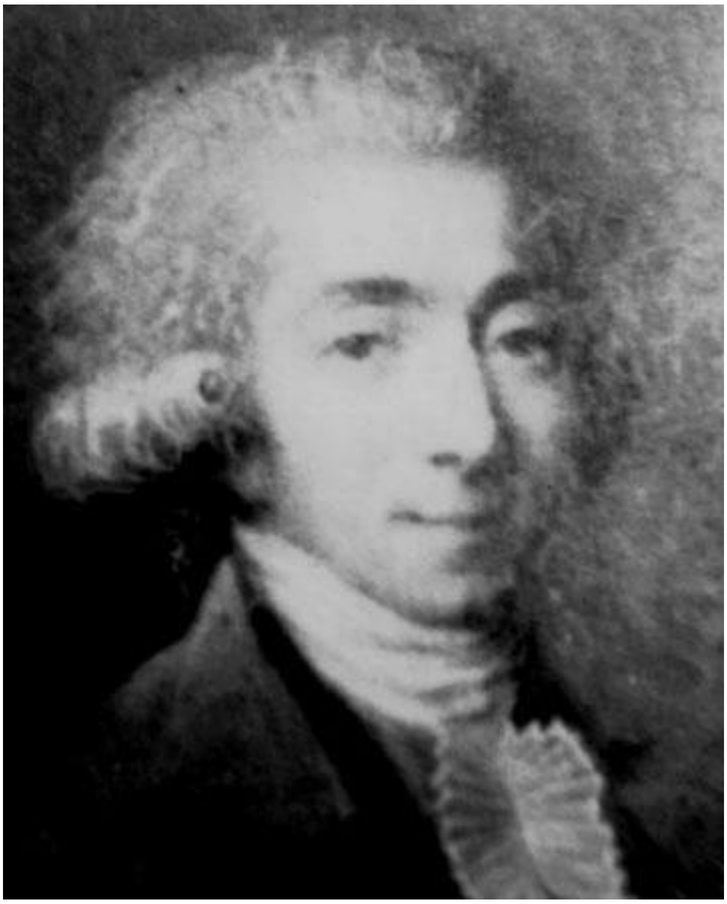
> I myself presented to Mr. Dagelet an invariable pendulum, which Mr. Condamine had carried in America, M. de la Caille in Africa, Mr. Mallet in Lapland, & M. Dagelet to the austral lands. When this pendulum has gone around the world, we will have for all parts of the globe, the true gravity which should be indicated, & the flattening of the earth, & its heterogeneity, as well as the equality or inequality of its two hemispheres.[12]

Dagelet’s tasks were referred to in another article describing the Lapérouse expedition:

> This voyage cannot fail to gain new discoveries for geography, be it in the north or the south; marine watches will serve to determine longitudes. Mr. Dagelet must specifically occupy himself with observations on tides, and observations with the pendulum that should shed light on the variations of gravity in different parts of the earth, on the difference there may be between the two hemispheres, and on the exact amount of the flattening of the earth. For this, M. Dagelet has taken the invariable

> pendulum of M. de la Condamine, which had already done service in America, Africa & Lapland.[13]

The London *Times* of 7 May 1788 reported that “M. Dagelet”, of the Academy of Sciences, who went with the Lapérouse expedition as its astronomer, “was particularly directed to make observations with the pendulum, to determine the differences in gravity, and to ascertain the true proportion of the equatorial to the polar diameter of the earth”. A later article published after reports from Lapérouse had been received from Petropavlovsk in Kamchatka said that, “Mr. Lepaute d’Agelet, astronomer of the expedition, has made observations on the length of the simple pendulum, to determine the force of gravitation, in climates where none such were made before”.[14]



Portrait of Joseph Lepaute Dagelet on a snuffbox which was exhibited in 1927 at the Château de Malmaison; current owner unknown. Photograph, Josiane Dennaud. http://genealis01.mutu.firstheberg.net/lepaute/presentation.php?page=documents

Dagelet is presumed to have died in the wreck of the expedition’s ships at Vanikoro in May 1788, or if he survived the wreck, some time thereafter. Lalande subsequently wrote:

> He wrote to me from all the ports they called at, but did not send me any observations. La Perouse so demanded it, and the great confidence he showed in d’Agelet did not allow the latter to say the least word against the wishes of his captain. This fatal precaution of jealousy or vanity deprived us of the fruits of that labour. The Academy did not receive from him any the slightest information on any position.[15]

The loss of all of Dagelet's observations underlines the scale of the disaster entailed in the tragedy that befell the expedition.

After the loss of the Lapérouse expedition, the project of establishing a universal system of measures remained a priority of for the savants of the Académie, and their opportunity came in 1789 with the Revolution. A report was presented to the French National Assembly by Charles de Talleyrand on 9 March 1790. Recommending reform and reduction to uniformity of the immense confusion of weights and measures traditionally used in France, Talleyrand emphasized that it was necessary for a perfect solution to the problem that the basic standard to be adopted should be referrable to an invariable model taken from nature, which could be returned to in case the standard needed to be checked or altered at some future time. Having reviewed the several alternatives put forward by leading savants Talleyrand, on the advice of Condorcet, gave preference to that which consisted of taking "for the elemental measure, the length of the pendulum at seconds in the latitude of 45º," as "the numerous partisans of that method have preferred this point, as being the mid-term between the Equator and the Pole". The National Assembly debated Talleyrand's report on 8 May 1790, and adopted his recommendation. The resolution of the Assembly was reported in *Le Moniteur Universel*, and subsequently in the English press:

> 8 May 1790. It was this evening decreed — "That the President do wait on the King, and request him to write to his Brittannic Majesty for his concurrence in the project of establishing an universal standard of weights and measures; and that an equal number of the Royal Society of London, and of the Academy of Sciences in Paris may be appointed, by authority of Parliament and of the National Assembly, to ascertain the length of the pendulum, at 45 degrees latitude, or elsewhere".[16]

The Spanish naval officer and astronomer, José Mendoza y Ríos, was at that time working closely with the French savants, having been sent to France and several other European countries as leader of a delegation of Spanish officers charged with obtaining information on advances in astronomy and navigation. He recommended that the task of measuring the figure of the earth be added to the mission of the Spanish expedition of discovery commanded by Alexandro Malaspina.[17] When the expedition reached Acapulco on the Pacific coast of Mexico, Malaspina received a letter from Antonio Valdéz, Minister for the Marine and the Indies, dated 22 December 1790, accompanied by a specially made pendulum that Mendoza had procured in London. The letter from Valdéz said:

> As it is being endeavoured in France to set up a new system of weights and measures derived from the length of a pendulum that oscillates at seconds at the latitude of 45º, the King has judged it appropriate to take advantage of this opportunity to promote the progress of Geography and resolved that as the course of your voyage enables you to obtain information on this interesting point, you are to do so at convenient locations, so that it may be compared with that which has been verified in that Kingdom, and that knowledge concerning the actual figure of the Earth may be perfected by determining, if the southern hemisphere is more flattened, what may be this difference and others in the exterior shape of our globe, supposing its surface not to be as symmetrical as commonly imagined. As these points must be resolved by measurements of various degrees in different regions or by the observation of the pendulum in a certain number of locations, one that has been purposely constructed with the greatest care is being sent to you with Naval Lieutenants Don José Espinosa and Don Ciriaco de Cevallos. As in order to form an idea of the meridian the best way is to observe the pendulum in

> two locations proper for deducing the difference between them, His Majesty has resolved that the observations done at 45º South are to repeat those already carried out at the same latitude North, to link our investigations with those of the French academicians.[18]

Observations of gravity were made during the course of the Malaspina expedition at fifteen locations in the northern and southern hemispheres, including Port Jackson (Sydney). Malaspina referred to Joseph Dagelet several times in his journal, and while at Manila in March 1792 noted: “Now, as on many other occasions, we regretted that we did not have the results of M. Dagelet’s calculations on the ill-fated expedition of Count de la Peyrouse, although we had no doubt that they would have been similar to our own”.[19] Ciriaco de Cevallos was able to correlate these when the expedition arrived at Montevideo in February 1794. They confirmed that the figure of the earth was not symmetrical in both hemispheres, as it was possible to detect with the pendulum a stronger gravitational pull in the South.[20] In the press report on the results of the expedition, the gravitational experiments and their anticipated contribution to the establishment of a new metric system were given particular mention:

> In both hemispheres, and in a variety of different latitudes, many experiments were made relative to the weight of bodies, which will tend to important discoveries connected with the irregular form of our globe; these will also be highly useful, so far as respects a fixed and general measure.[21]

Juan Ravenet, "Experiencia de la gravedad”, at Port Egmont, Falkland Islands, January 1794; Museo Naval 1726 (36)

The results of the gravity observations made by the Malaspina expedition were analysed by Gabriel Ciscar, who found the experiments revealed a different strength of gravity, a different length of pendulum and different flattening (eccentricity) of the Earth for the different locations. He attributed these irregularities to “the heterogeneity of the strata of our globe, to some slight errors in the observations and to some small, irregular alteration in the length of the supposedly invariable pendulum”.[22]

When Valdéz sent the pendulum to Malaspina in December 1790, it was expected, on the basis of the resolution of the French National Assembly of 8 May. that the gravity experiments would be the basis of the intended universal standard of measure. But the British Cabinet, when pressed by the French Ambassador to respond to the invitation from the National Assembly for collaboration, replied: “that the affair was very intricate, and they did not wish to engage in it at present”. [23] In view of this rebuff from the English, the French resolved to make the establishment of the new system of measurement a national project, and on 26 March 1791 the National Assembly adopted as the criterion for the universal measure one ten-millionth the distance from the Pole to the Equator as determined by extrapolation from the measurement of an arc of the Meridian of Paris between Dunkirk and Barcelona. [24] Eventually, an International Commission for Weights and Measures was convened in Paris to settle the true length of the metre, and Ciscar attended as a member of its sub-committee on the arc of the meridian.[25] On 22 June 1799 the Commission adopted a standard metre based on the length of a pendulum beating seconds on the Equator as established by La Condamine and his colleagues during the 1736-1742 expedition to Peru. This fell short of one-ten millionth the distance between the Equator and the North Pole: the actual distance was later found to be some 10,003,250 of the new metres. The 1799 metre was replaced in 1875 by a new metre based on it, the definition of which omitted any reference to the shape of the Earth.[26]

Dagelet's pendulum experiments at Botany Bay in February-March 1788 can be seen as part of an enterprise led by the Académie Royale des Sciences for over a century to ascertain the true shape or figure of the Earth and to establish a universal system of measure. His efforts qualify as the first systematic scientific experiments conducted in Australia.[27] The loss of his observations was certainly tragic, but his efforts inspired others, most immediately the officers of the Malaspina expedition, to complete his work.

Robert J. King

illustration 1. Dagelet à Dawes, à la Baye Botanique, 3 Mars 1788, suggesting he measure "a degree of the meridian in this hemisphere".
State Library of New South Wales (Sydney), Mitchell Ad 49/6-7

illustration 2. Portrait of Joseph Lepaute Dagelet on a snuffbox which was exhibited in 1927 at the Château de Malmaison; current owner unknown.
Photograph, Josiane Dennaud. Marie-Lise Rochoy, *De la Lorraine à Vanikoro: Sur les traces de Joseph Lepaute Dagelet,* Web site:
http://genealis01.mutu.firstheberg.net/lepaute/presentation.php?page=documents

1. Dagelet à Dawes, à la Baye Botanique, 3 Mars 1788, State Library of New South Wales (Sydney), Mitchell Ad 49/6-7; quoted in Doug Morrison and Ivan Barko, “Dagelet and Dawes: their meeting, their instruments and the first scientific experiments on Australian soil”, *Historical Records of Australian Science*, vol.20, no.1, June 2009, pp.1-40; Association Salomon (Nouméa, New Caledonia). *Le mystère Lapérouse, ou, le rêve inachevé d'un roi,* Paris, Conti, 2008, pp.58, 61, 106. Ivan Barko, “Lepaute Dagelet at Botany Bay (26 January-10 March 1788) and his encounter with William Dawes”, Explorations, no.44, Dec 2007pp. 21-40.
2. Gabriel Mouton *Observationes diametrorum solis et lunae, huic adjecta est brevis dissertatio de Nova Mensurarum Geometricarum Idea,* Paris, 1670, p.432.
3. Jean Picard, *Mesure de la Terre,* Paris, 1671, pp.8-11; cited in Edwin Danson, *Weighing the World: the Quest to measure the Earth,* New York, Oxford University Press, 2006, p.27.
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5. Aimé Richardt et Jean-Gérard Théobald, *Les savants du Roi-Soleil,* Paris, François-Xavier de Guibert, 2003, p.112.
6. J.W. Olmsted, "The scientific expedition of Jean Richer to Cayenne in 1672-73", *Isis,* vol.XXXIV, pt.2, no.94, 1942, pp.117-128.
7. From the inscription engraved on the commemorative marble plaque he presented to the Jesuits' Church of San Francisco in Quito in 1742: Charles-Marie de La Condamine, *Journal du Voyage fait par Ordre du Roi à l'Équateur,* Paris, Imprimerie Royale, 1751; and *idem,* "Nouveau Projet d'une Mesure invariable propre à servir de mesure commun à toutes les Nations", *Mémoires de l'Academie Royale des Sciences,* 1747, pp.489-514.
8. Turgot à Messier, 3 Octobre 1775, Turgot, *Oeuvres*, Paris, 1913, Tome V, pp.31-33.
9. Ronald Edward Zupko, *Revolution in Measurement: Western European Weights and Measures since the Age of Science*, Philadelphia, American Philosophical Society, 1990, pp.125-128, 136..
10. Ronald Edward Zupko, *Revolution in Measurement: Western European Weights and Measures since the Age of Science,* Philadelphia, American Philosophical Society, 1990, pp.125-128, 136; Robert Tavernor, *Smoot's Ear:the Measure of Humanity*, Yale University Press, 2007, p.59.
11. *Mémoire redigé par l'Académie Royale des Sciences pour servir aux Savans embarqués sous les ordres de M. de La Pérouse,* 1785.
12. Joseph-Jérome Lalande, "Considérations sur l'état actuel de l'Astronomie", *Mémoires de l'Académie des sciences, arts et belles lettres de Dijon,* 1785, pp.298-299.
13. *L'Esprit des Journaux,* Tome I, Janvier 1788, p.320.
14. Report from Paris of 1 March 1789 in *The Morning Post* and *The Whitehall Evening Post* (London), 7 March 1789; *The Pennsylvania Mercury* (Philadelphia), 14 May 1789.
15. Joseph Jérôme Le Français de Lalande, *Bibliographie Astronomique: avec l'Histoire de l'Astronomie depuis 1781 jusqu'à 1802,* Paris, Imprimerie de la République, 1803, p.711.
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17. Valdéz to Malaspina, 22 December 1790; cited in Porrua, p.453. Valdéz to Aranda, 15 April 1792, Museo Naval, Madrid, legajo 2294, doc.1; cited in António Ten, "El sistema métrico decimal y España", *Arbor,* no.134, 1989, pp.109-10.
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19. *The Malaspina Expedition, 1789-1794: the Journal of the Voyage by Alejandro Malaspina,* London and Madrid, Hakluyt Society in association with the Museo Naval, Volume II, 2003, p. 303.
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21. *The Britannic Magazine*, vol.3, issue 31, 1795, pp.91-92; this was a translation of the article published in the *Gazeta de Madrid*, 12 de Diciembre de 1794;
22. Josef Espinosa y Tello, *Memorias sobre las Obervaciones Astronomicas, hechas por los Navegantes Españoles en Distintos Lugares del Globo,* (Madrid, Imprenta Real, 1809, Tomo I, pp.190-212, "Experiencias sobre la gravedad hechas con un péndulo invariable en los puertos de Europa, América y Asia, mar Pacífico y Nueva Holanda en el viage de las corbetas Descubierta y Atrevida…calculadas por Don Gabriel de Ciscar".
23. *The Gazetteer,* 25 March 1791. See also Duke of Leeds to Luzerne, 3 December 1790, in Adrien Favre, *Les Origines du Systeme Metrique,* Paris, Presses Universitaires de France, 1931, pp.226-7.
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27. Ivan Barko, "Lepaute Dagelet at Botany Bay (26 January-10 March 1788) and his encounter with William Dawes", Explorations, no.43, December 2007, pp. 21-40, p.32.