#sic2020london

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Online

SCIENCE MUSEUM

ROYAL MUSEUMS GREENWICH

Abstracts and Biographies

Theme 1 - Instruments in Education Today
Monday 14 September

A special session, organised by Elizabeth Cavicchi and Peter Heering, exploring the uses of scientific instruments in educational contexts (including schools, universities and museums) today. How do historical instruments of science engage learners, whether through authentic historical instruments, or with models, reproductions, or constructions of their own?

Session 1

Zheran Wang
Making Instruments as a Way to Understand History: An Experimental Course in the University

This presentation will give an introduction to an experimental course that was first offered in the fall of 2019 at Tsinghua University in Beijing, China. The course aims to combine the theoretical teaching of the history of science with the making of scientific instruments. Students made two instruments during the course: one imaginary, that is Leonardo da Vinci's aerial screw, or "the helicopter," and one real, an ancient Chinese armillary sphere, based on a collection in the Forbidden City. The two teachers offer a series of lectures around the two instruments, including the life and the manuscript of Leonardo da Vinci, a history of flying machines, a brief history of machinery, the ancient concepts of heaven and astronomy in both China and the West, a history of astronomical instruments, etc. In the practical section, students learn to build the devices by mastering usual woodworking tools, ranging from traditional ones such as a file, saw, and plane to the new computerized numerical control carved machines. Now Tsinghua University is planning to build its science museum, for which the two lecturers are in charge of construction or reconstruction of exhibits. This experimental course is the result of their endeavours in translating research into teaching. The presentation will share their ideas on how to link the mind to the hand in college and museum education.

Zheran Wang is an assistant professor in the Department of History of Science, Tsinghua University (Beijing, China). He is interested in the history of mathematics and natural philosophy in Europe before Newton, especially in the history of optics and perspective theory, the relations between science and arts during the Renaissance. He currently works on the scientific and technological manuscripts of Leonardo da Vinci, making reconstructions of some of his mechanical inventions for the future Science Museum of Tsinghua University.

Frédérique Plantevin
Historical machines, education and DIY in the Cabinet of Curiosity of Brest, France

At the beginning of 2016, the Cabinet of Curiosity of the Faculty of Science and Technology of Brest opened its doors with a double aim: to be an exhibition center and a permanent workshop for scientific instruments. An unusual feature of the Cabinet is that in addition to manipulating some instruments (original samples, reconstructions or prototypes) users can also attempt to create their own by means of the tools available in the Cabinet (mainly for carton and wood crafts) or via collaboration with a local FabLab (Brest Open Factory). Instruments from the Cabinet collection have been used in several educational contexts with teachers, students and pupils. Activities include object classification (comparing with classification in naturalist collections), description of artefacts, analysis of unknown instruments, reconstruction of historical machines (by direct observation when present in the collection, or from other sources when not physically present) and invention of new ones. In this paper we will discuss the example of a course we have been trialing for three years with future teachers of mathematics. Students work in small groups on a historical machine

and present their results, with demonstrations of the chosen instruments. We focus on two groups who chose to study and also build by themselves their own machines: one to draw parabolas with a string (quite well known, although not to the students at first) and the other (much less common) for an exponential curve thanks to tractional motion. This experiment leads us to a certain understanding of the 'why' and the 'how' of working on instruments.

Frédérique Plantevin is lecturer in mathematics at the University of Brest – France; she is involved in initial and continuing teacher training, in particular through her implication in the Institute of Research in Mathematics Teaching network (IREM network, since 2006), and the Houses for Sciences for Teachers (MPLS, since 2016). She developed an axis of work with primary and secondary teachers on historical instruments in the classes. She organized exhibitions on instruments (integral and differential calculus, navigation, arithmetic calculus) with workshops for classes animated by students, teachers and researchers. In 2016, she founded the Cabinet of Curiosity in the Faculty of Science and Technology which collects outdated scientific instruments and objects of the Faculty, and also copies or reconstructions of ancient mathematical and physical instruments. She is keeper of this collection and convenes a group gathering some Faculty teachers, researchers, technicians and engineers for its enhancement. She took part in the publication "Passerelles – Enseigner les mathématiques par leur histoire au cycle 3", coordinated by M. Moyon and D. Tournès for the chapter on calculus mechanization, which was awarded the "Académie des Sciences" prize of best scientific teaching book in 2019.

Marta Rinaudo and Matteo Leone

Underexplored places: the old school physics cabinets as effective physics learning environments

The aim of this talk is to provide details on a physics education project which is conducted since 2017 at the University of Turin, Italy. The project's goal is studying the educational significance of the history of physics. During the project we discovered that the old – and usually neglected – collections of physics instruments preserved by the oldest public and private secondary schools in the Turin and Cuneo provinces (North-western Italy), if appropriately studied and re-designed, could again serve an educational function. Furthermore, we collected evidence that this historical approach might provide us a better insight into student's prior knowledge and promote a better understanding of physical sciences.

The core of this project is a two-step collaborative effort between the schools and the University of Turin. The first step takes place at the Museum of Physics of the University. The Museum of Physics offers to teachers and students a one-day programme for a guided visit to the collections and a workshop to make scientific instruments inspired to the collection using inexpensive materials, with a focus on the instruments about electricity, optics, and vacuum. Each work session begins with a semi-structured questionnaire designed to detect student's prior knowledge about the physics contents later addressed in the workshop and to explore if the possible difficulties experienced by students are historically rooted.

The second step is conducted in schools that, besides hosting large collections of physics instruments of historical-scientific interest, are also staffed by teachers actively engaged in training seminars in physics education and, in particular, interested in this historical approach. The aim is to help the teachers to exploit the local collections of old physics instruments for educational purposes. So far, interesting results have been obtained in two public and one private classical lyceums in the towns of Turin and Mondovì.

Marta Rinaudo is Ph.D. in physics and astrophysics at the University of Turin, Italy. Her main research deals with the didactics and the history of physics, with a focus on the educational potential of the old collections of physics instruments in schools and universities.
Matteo Leone is full professor of didactics and history of physics and President of the Master Degree in Primary Education at the University of Turin, Italy. His research focuses on the 19th and 20th centuries history of physics, on the educational power of the history of physics and on children's ideas in science.

Janet Laidla
Making it about objects: a reboot of a history of science course

The recent curriculum reform in Estonian higher education concentrates on the practical implementation of theoretical knowledge. It is no longer deemed sufficient to provide the students with theoretical knowledge through lectures, seminars, and papers but to further their practical and soft skills through projects, practical workshops, and work placements. This places pressure on teaching staff to come up with new teaching methods in order to attract the interests of the students, their future employers, and the university government. The paper introduces a case study that was a collaboration project between the Institute of History and Archaeology and the University Museum at the University of Tartu through which a new elective course in general history of science was created that not only introduces to (humanities) students the scientific instruments, their use, and history but also gives basic knowledge in object handling, photography, and graphic design. The students could choose one object to work with and had to create a poster about their object and this were exhibited publicly in the staircase of the University Museum. Feedback was gathered from the students afterwards and analysed for possible improvements for the next time the course will be offered (in spring 2021).

Janet Laidla works as a curator at the University of Tartu Museum and as a lecturer of Estonian history at the University of Tartu Institute of History and Archaeology. She has a PhD in history, with interests in modern history of culture and history of science.

Dominique Bernard and Julie Priser
Collections of scientific instruments: a tool for the education of children and for the training of students and teachers

The University of Rennes 1 (France) has a large scientific instrument collection from the 19th century (around 1,000 pieces) and the 20th century (around 3,000 objects). We will show the great interest of the use of these collections in training and education.
We will cover examples for different audiences: school children (from 6 to 18 years old), students, teachers, scientists or not, with four different approaches:
* Concrete experiments on a range of devices such as Heron's fountain, electrostatic machine, tuning forks, spectroscopes, Jules Violle's actinometer, gramophones or calculating instruments.
* Demonstration and reconstruction of historical apparatus (including radioactivity experiments of Pierre and Marie Curie, Cloud chamber, Turing machine).
* Student internships' supervision (License or Master) and teacher training (Maison pour la Science en Bretagne).
* Historical and bibliographic studies on researchers or laboratories.
We will also give some examples which demonstrate the interest of such devices to explain in a simple and sensitive way scientific concepts which are not always very accessible to people such as energy conservation, heat, sound, radiation, signal recording and data storage.

Julie Priser is assistant of collections of ancient and contemporary scientific instruments from the University of Rennes 1 - in charge of the Brittany Scientific and Technical Heritage mission (PATSTEC-CNAM). She is also responsible for welcoming schools, colleges and high schools, scientific students and intervening in teacher training organized by "La Maison pour la Science de Bretagne".

Dominique Bernard was Maître de Conférences of physics at the University of Rennes 1 (France). In 2004, he decided, with his colleague J.P. Taché, to gather all the old scientific instruments existing at the University (4000 objects). He is also working on the history of old physics instruments by focusing and developing an experimental approach. With B. Pigelet, they restored and operated the collections of Curie apparatus and reconstructed the historical experience of measuring the radioactivity. He is also a Rennes en Sciences association's member and has recently published a book on the scientific instrument collection (winner of the 2019 Academy of Sciences Prize).

Thomas McCloughlin
The Nooth Apparatus: Today's Teaching Aid, Yesterday's Health Gimmick and Medical Device

This paper outlines how an example of the Nooth apparatus, a water-carbonating apparatus manufactured between 1774 and 1831, is used as a historical teaching apparatus in science education courses in Dublin City University. Teaching with the apparatus is done within the frame of 'experimental history of science' whereby science experiments are carried out as near their historical and original protocol as possible, and for discussion on the nature of scientific discovery. The Nooth apparatus is used within workshops on topics whereby historical apparatus is employed as the working stimulus for discussion on scientific discovery.

The Nooth apparatus provides a snapshot of late 18th-century theorising and experimentation concerning air, its constituents and what gases are, connecting the stories of Priestley, Lavoisier and Hales (familiar to students from high school) with broader stories about health fads and commercial production by Nooth and the better-known Schweppes. The apparatus is currently used in teaching Bachelor of Education students who have a greater experience of the humanities than the sciences. A historical approach to science, and in particular a historical-scientific approach where the narrative of discovery is told, has proven beneficial to them.

Dr. Thomas McCloughlin is the director of the DCU Herbarium (HUUD) and curator of the science equipment archive at Dublin City University. He has taught biology at all levels, and he is currently an assistant professor in biology and education. He is particularly interested in the innovative process driving the production of biological apparatus in the 17th - 20th centuries. Dr. McCloughlin is a fellow of the Linnean Society and Royal Society of Biology.

Flora Paparou
"What is happening in the lab?" Transforming the School Lab into a Contextual Science Teaching Environment

Science teaching and experimentation are nowadays unbreakably linked. The use of experiments, as a means to confirm scientific theories or to explore scientific notions, is common practice in today's science textbooks. However, the research of the last decades on the history and philosophy of experimentation offers new perspectives in laboratory

training, by providing tools to transform utilitarian practices into contextual teaching experiences.

In this paper we will present examples of teaching scenarios woven within both curricular activities and extracurricular projects. With their help a secondary school lab has been transformed into a place to discover history of science and experimental techniques. 17th century experiments on pneumatics, 18th century electricity shows and 19th century research on electric discharges in rarified gases have been part of our laboratory life during the last eight years.

The basic principle for the above transformation was the fact that all machines in the laboratory and all experiments performed with their help refer to specific episodes in the history of science. Knowledge of the history of scientific instruments and the philosophy of experiment enabled us to link particular forms of instruments to historical episodes, as well as to introduce experiments as processes. Failed attempts, improvements of experimental set-ups, modifications of devices and unpredictable events were utilized as valuable pieces of evidence, in order to portray experiments as scientific adventures.
We will present various outcomes from our projects, including theater performances, experimental studies of specific episodes, paper writing on selected experimental issues and museum visits.

Flora Paparou is a Chemical Engineer. She holds a Ph.D. in science education in the field of the integration of the history of science in science teaching. Her research focuses on the material culture of science as well as on science and culture issues. She has been working as a science teacher in secondary education since 1997. She currently works at the upper secondary school of Vrilissia, Athens. She also has long experience as museum educator. During the period 2003-2008 she led the introduction of a science education programme in the Science Museum of Chios, an important historical school-museum in Greece. During the period 2013-2015 she collaborated with the Athens University History Museum and worked on the identification of its historical scientific instrument collection and on the creation of educational activities for the exploration of this collection.

Stéphane Fischer
The fall of bodies according to Galileo

As part of a recent temporary exhibition devoted to mechanics, The Musée d'histoire des sciences of Geneva has designed several experimental devices inspired by Galileo to demonstrate to the public the fundamental principles of falling bodies.
The centerpiece of these reconstitutions is undoubtedly a 660cm long inclined wood plane, fitted with removable bells (ringing at the pass of the balls), designed by the Tuscan scientist, to study falling bodies and to demonstrate that the movement of falling balls along the inclined plane is a uniformly accelerated movement.
Galileo also developed a clever device for the study of falling bodies: the pendulum which makes it possible to renew at each oscillation the fall of an object suspended at the end of a wire. The Musée d'histoire des sciences presents several models of pendulums. Some have identical lengths of wire with different suspended bodies (balls of steel, wood and paper). Others are made up of identical bodies suspended at the end of wires of different length. Their observation allows a demonstration that the period of oscillation of a pendulum does not depend on the weight of the suspended bodies, but only on the length of the wires.
These historical reconstructions are not left freely accessible to the public: a mediator or a curator is present to put these experiments in their historical context (Aristotle, Galileo, Newton). But the public is invited to participate in the measurements of falling times of the inclined plane. If they have Galileo's musicial ear, they can also practice moving the different bells along the inclined plane so as to obtain identical time intervals between two bells. By

measuring the distances between the bells , they will notice that after the first time interval, the ball travels one unit of distance, after two time intervals, 4 units of distance, after three, 9 units of distance, etc. Then, they will arrive at the conclusion stated by Galileo more than 400 years ago, namely that the distances traveled by a falling body are proportional to the square of time.

Assistant curator at the Musée d'histoire des sciences of Geneva, Stéphane Fischer is in charge of the collection of the Museum. As part of his activities, he carries out numerous projects (exhibitions, publications, replications) in connection with the museum's collection.

Theme 2 – Private Spaces: Court
Monday 14 September

Samuel Gessner

Probing the fitness of instruments: materializing the movement of the 8th sphere for the lecture hall, court, and library

The paper scrutinizes some early modern armillary spheres that represent the complex movement of the 8th sphere, a movement also called the precession of the equinoxes. This movement has haunted the minds of calendar reformers and of astrologers of the age. So these rare spheres – held today in Schweinfurt, Kassel, Augsburg, Greenwich and many other places – tell a story about how this technical topic reverberated among early modern society. The sphere in Kassel even echoes controversy: after on-site examination it became apparent that it is an armillary representation (perhaps the only one extant) of Johann Werner's alternative theory of the 8th sphere. The astronomer's publication in 1522 had drawn harsh criticism, by Copernicus immediately (1524) and by Tycho later (1590). Of four other lavishly produced spheres in the workshop of Arsenius the one from 1568 is held in Greenwich. Its accurate description by Dekker points to several open points in its interpretation. While scholarly debates constitute the intellectual context, we don't know the specific spaces for which each instrument was produced. To a certain extent, we can reconstruct the original immediate environment of such a spheres, if we apply a concept of "specific fitness". To clarify the concept of "instrument fitness" I will show its use. For historians, not only the theory implicit in the spheres serves as a cultural marker, but also their material and stylistic characteristics. Such evidence then forms the basis for concluding that one sphere fitted well into a teaching environment; another one into a court context; while Ch. Schissler the Elder visibly designed his sphere (1605) for display to the town patricians of Augsburg.

A historian of mathematics and astronomy, Samuel Gessner focuses on the diverse scientific cultures in medieval and early modern Europe and on how they interacted by studying the role of mathematical instruments as conceived by both theoreticians and practitioners. Using preserved artifacts of material culture as primary sources alongside textual documents has become his favorite approach. As a post-doc he did research at the Center of History of Science (CIUHCT) in Portugal and at the State Museums Dresden (SKD) in Germany. Currently (2019-2021) he is at the Observatoire de Paris in France where he is a post-doc of ERC research project ALFA CoG 723085, on Alfonsine astronomy lead by M. Husson. A medium term goal is to understand the material and mechanical realizations of Ptolemaic theory in models, equatoria and planetary clocks and their role in history of astronomy. Gessner was a co-organizer with Dominique Tournès, Jeanne Peiffer and Ulf Hashagen of the Oberwolfach Workshop "Mathematical Instruments Between Material Artifacts and Ideal Machines", December 2017.

Michael Korey
Locked Away, Tested, Failed, Walled Up … and Celebrated: the Contested Biography of the Planetary Clock of Philipp Imser

Only four clocks aiming to show, in real time, the true positions of the planets according to the geometrical models of Ptolemaic theory survive from the 16th century. Of these, the 'Imser Clock', commissioned by Count Ottheinrich of the Palatinate from the Tübingen mathematician Philipp Imser, with assistance from the clockmaker Georg Emmoser, has a particularly checkered history. The tale of its construction features repeated delays, a nervous breakdown, and a physical brawl over priority. Under state pressure it was tested, found wanting, later sold, walled in, forgotten, rediscovered, misattributed, and ultimately celebrated. The paper presents an account of the clock's biography in its various settings, with special emphasis on recently recovered raw data from the original trial runs for the clock and an analysis of the conditions which led it initially to be considered a failure as a mathematical instrument.

Michael Korey is the senior curator of mathematical and philosophical instruments at the Mathematisch-Physikalischer Salon in Dresden. His current research projects address Renaissance planetary automata and early-modern optical instruments.

Giorgio Strano
Italian Planetary Clocks between the Fourteenth and Sixteenth Centuries: A Preliminary Overview

Since Antiquity, mathematicians, astronomers and technicians have cultivated the idea of combining a clock and the cosmos as a machine. Despite this interest, the ability to build a functioning and reliable planetary clock remained extremely rare.

Until the sixteenth century, very few complete planetary clocks — i.e. including pointers for all planets — were built in the Italian area. They belong to two categories: private and public. Their number is less than the fingers of one hand.

There are historical records of three remarkable Italian planetary clocks intended for private use: the celebrated "astrarium" of Giovanni Dondi, presented to the Duke Gian Galeazzo Visconti in 1381, and two "orologi dei pianeti" of Lorenzo della Volpaia, one bought in 1488 by the King Matthias Corvinus of Hungary, and another completed in 1510, placed in the Florentine Palazzo Vecchio. Such extremely complex and completely lost planetary clocks were very likely intended to answer astrological questions for the exclusive benefit of their owners.

Astronomical clocks placed in public places usually offered limited information on the positions of the Sun and Moon along the Zodiac, and the lunar phases. They were primarily intended for civilian astrological and medical use. Only one complete planetary clock was built between 1570 and 1571 by the three brothers Giulio, Ippolito Maria and Ippolito Ranieri for the tower of the town hall of Macerata. Fragments of the original clock remain, while its present reconstruction is essentially a reinterpretation of the original device and its functions.

Giorgio Strano is curator of the collections at the Museo Galileo of Florence. He is actively involved in research studies and the popularization of the history of astronomy and has published in numerous international journals. He has also collaborated on exhibitions on the history of astronomy and science. He is general editor of the series Scientific Instruments and Collections (Brill).

Theme 3 – Private Spaces: Knowledge and Instruments
Tuesday 15 September

Gaye Danişan

An Ottoman volvelle found in Rūznāma-i Shaikh Wafāʾ

Muṣṭafā ibn Aḥmad al-Qunawī, known as Shaikh Wafāʾ (d. 1491), prepared the *Rūznāma-i Shaikh Wafāʾ* which was treatise that consists of a perpetual calendar for long-term usage and instructions on its use. The *Rūznāma* remained popular throughout the Ottoman era for several centuries and was copied extensively. Among these, the version copied in 1676, is one of the most significant *Rūznāma* which is currently kept in the Bibliothèque Nationale de France with the archive number: *supplément turc* 537. This version is different from the other copies because it contains a paper instrument with two moving circles (volvelle). The volvelle represents the positions of the Moon and Sun to calculate the phase of the Moon, lunar mansions, and eclipses (both lunar and solar) which in turn makes it an attractive source to work on. This paper aims to focus on the volvelle found in the *Rūznāma-i Shaikh Wafā* and discuss its significance among the paper instruments in the history of Ottoman Astronomy.

Gaye Danışan is a graduate Astronomer who holds B.Sc. and Masters Degrees in Astronomy and Space Sciences from Istanbul University. She received her PhD at 2016 with a thesis entitled 'The sixteenth-century Ottoman nautical astronomy and astronomical instruments' at the Department of the History of Science, Istanbul University. She pursued a post-doctoral research project on Ottoman portable astronomical instruments at the Museum of the History of Science, Oxford, from 2017 to 2018 and currently is an Assistant Professor at the Department of the History of Science, Istanbul University. Her current research focuses on two projects, Scientific Instrument Society funds one on the Paper Instruments in the History of Ottoman astronomy, and the other is entitled A Comparative Study on Theoretical and Practical Aspects of Scientific Activity in the Ottoman Empire: Annual and Perpetual Calendars (1550-1710) funded by the Scientific and Technological Research Council of Turkey (TUBITAK-1003).

John Davis

Fourteenth-century Latin Astrolabes – Their journeys in location, time and function

The corpus of medieval Latin astrolabes is not large but has been under-researched because their provenances are often totally unknown – academics have preferred to study the scientific manuscripts of the period. A detailed reading of the actual instruments, however, can generally recover much more information than is generally realized, particularly in relation to the changing spaces of production and use of the astrolabe as will be demonstrated by a case study of a group of 14th-century astrolabes shown to be from an unknown northern European workshop.

The members of this group are now distributed in museums across a number of European countries having arrived there either soon after manufacture or much more recently. Astrolabes, with their multiple latitude plates, are intended to be used in different locations

and although they are sometimes arranged to cover wide geographical regions, they also can have specific locations which give clues either to where they were made or to whom they were given – the end-users were often 'foreigners'. Plates could also be replaced and, where this can be recognised by means of their palaeography or metallurgy, this gives information on their later journeys. Statistical methods of analysing X-ray fluorescence measurements of the 'brass' compositions are beginning to provide important new evidence of instrument workshops.

Medieval astrolabes had long lives and were sometimes re-purposed in the Renaissance period for a different use by additional engraving to the plates. The function of the instruments moved from astrology – followed by the most leading medieval courts – to timekeeping.

In the late 18th century, medieval astrolabes became collectors' pieces; their beautiful designs saved some of them from being recycled for their brass. After their neglect for several centuries, they found their way into modern museums by routes only just being uncovered.

John Davis trained in physics and engineering and spent his career in telecommunications research. Having taken early retirement in 1999, he has spent his time researching, and making replicas of, 17th and 18th century sundials and, for the last decade, investigating medieval Latin astrolabes, mainly from northern Europe. He is particularly interested in discovering the medieval workshops that made them and the techniques and materials that were used. In particular, he is exploring whether the metallurgy of the instruments can give added clues to their origins. As well as reverse-engineering a number of individual astrolabes, he has found that studies of the political and social histories of the countries where they were both made and used can help to fill in the details of these beautiful but enigmatic instruments. These methods have resulted in the publication of several articles on individual instruments, revising their accepted histories.

Pouyan Rezvani

Al-Bīrūnī's Treatise on the Applications of Standard and Some Non-Standard Astrolabes

Abū Rayḥān Muḥammad ibn Aḥmad al-Bīrūnī (973–1048 A.D.) was one of the leading mathematicians and astronomers in the 11th century Islamic scientific tradition. In his Treatise on Opening the Way towards Using the Different Kinds of Astrolabes (Maqāla fī al-Taṭrīq bi-Istiʿmāl Funūn al-Usṭurlābāt; hereafter Taṭrīq), Bīrūnī elaborates instructions for standard and some (but by no means at all) non-standard astrolabes. Some of the information on technical and historical aspects of these non-standard astrolabes in the Taṭrīq cannot be found in any other astrolabe treatise. As an advanced-level user manual, the Taṭrīq contains a comprehensive introduction and 20 chapters. It is a late work, written in all likelihood after 1036 A.D. when Bīrūnī was in Afghanistan. The only extant manuscript of this work, preserved in the Bibliothèque nationale de France in Paris, was carelessly written with a large amount of unclear and incorrectly spelled words, and has left empty spaces for the geometrical figures. To make matters more complicated, the treatise was written in very flowery prose.

In my talk I will pay particular attention to the construction and use of the non-standard astrolabes which are discussed by Bīrūnī in this treatise. I will also clarify the place of these kinds of astrolabes in the history of astronomical instruments, as scientific gifts to be presented at the courts of kings besides some didactic applications. Thus I will discuss that the Taṭrīq was most likely written in the context of the scientific traditions at courts.

Pouyan Rezvani is an Iranian postdoctoral researcher at the project Ptolemaeus Arabus et Latinus (PAL). In his PhD dissertation he worked on two hitherto unpublished astrolabe texts by Abū Rayḥān al-Bīrūnī under the supervision of Prof. Dr. Jan P. Hogendijk at Utrecht University. He was an academic member of the department of the history of science at the Encyclopaedia Islamica Foundation (Tehran, Iran) from 2013 to 2018. His special interest is history of astronomical instruments in Medieval Islam.

Petra G. Schmidl and Convin M. Splettsen
Instruments and prognostication

During the XXXIV Scientific Instrument Symposium in Turin in 2015 a panel investigated "instruments in astrological contexts" whose results were published two years later in the volume "Heaven and Earth United". Besides astronomy and astrology, there are, however, other prognostic practices that induce or aim at learning more about the future or the arcane. Most of them make use of different kinds of objects, a few also of more elaborated instruments, most prominent the geomantic device preserved in the British Museum.

This talk will provide a first overview of pre-modern material traditions of prognostication in Islamicate societies with an outlook for medieval and early modern Europe. Based on this, it will pursue questions concerning locations where these instruments and objects were made and where they are found today, but also where practitioners used them to perform these practices.

Petra G. Schmidl received her doctoral degree from Frankfurt University in 2005 for her work on three folk astronomical treatises from 11th-century Hijaz and 13th-century Yemen. She worked as research assistant at the universities of Frankfurt, Bonn and Erlangen. Her research interests lie in the field of pre-modern astronomy and astrology in Islamicate societies, prognostic, in particular mantic, practices and astronomical instruments, mainly the astrolabe, in both the orient and the occident.

Convin Splettsen is studying history, history of science and ethnology in Frankfurt at the Goethe University. Apart from astrolabes, he is interested in magic and its science, and of course in material culture. Some of his research has been presented at SIC 2018 and SIC 2019 Symposia.

Theme 4 – Public spaces: museums and popular science
Tuesday 15 September

Raphael Beuing
Space within museum's space. The restoration of a grand orrery by George Adams

A grand orrery with a diameter of 3 ½ feet, made by the London instrument maker George Adams between 1748 and 1759, is one of the most significant scientific instruments in the collections of the Bayerisches Nationalmuseum in Munich and the only piece of its kind in a German museum. Throughout the centuries several features of this planetarium got lost, and during an undocumented restoration in the 1970s the metal discs were partly replaced with acrylic glass in order to allow a view of the hidden mechanism. A recent loan request and subsequently available funds lead to the re-restoration of this magnificent piece in 2019, returning it as much as possible to its original appearance. To enhance visitor experience after the mechanism was closed up again by the original metal discs, a video showing the functioning of the gear trains and the movement of planets and satellites was to be produced. The process of the restoration as well as the running of the orrery for the video required a deeper understanding of the mechanism and the comparison with other orreries. This revealed how little research has been done on these complex models throughout recent decades. After being set up in the space of a princely library in the 18th century where it was driven by a clockwork, curators and conservators continue to be faced with explaining the orrery to a museum's audience, aided today by the video which will also be shown during the talk.

Raphael Beuing is curator for arms and armour, timepieces, scientific instruments and base metal at the Bayerisches Nationalmuseum in Munich. Prior to taking up his post in 2012 he worked on silver and other examples of the decorative arts as well as on collecting art during the early modern period. He is keen on explaining the functioning of scientific instruments to a wider museum's audience.

Kate Bowell
Navigating Narratives: The Lighthouse Instruments and Labels of National Museums Scotland

For 154 years, National Museums Scotland has displayed lighthouse instruments and models. Throughout their time on the exhibition floor, these pieces, ranging from examples of construction joineries to full-scale Fresnel lenses, have been presented to educate the public and highlight the ground-breaking engineering achievements associated with the science of these structures.

But that's only one part of the stories they tell. Within the history of lighthouses at the museum, narratives of people have also been present. From Robert Stevenson, the famed civil engineer who designed 16 British lighthouses, to Henry Hall, the valiant lightkeeper who attempted to extinguish the Eddystone Lighthouse fire and died as a result, human stories have stood alongside, and at times in contrast to, industrial ones. The result is a history of objects within the museum that repeatedly negotiates tensions between the highly technical and the deeply personal.

This paper will examine the lighthouse objects and labels on display from 1866 to today, tracing a story that regularly interweaves accounts of science and society. By analyzing the scope of themes told about the objects, it becomes clear that, within the museum space, there has never been one single story for these instruments. Instead, they have stood at the

intersections between people, places, and progress, navigating continually evolving narratives.

Kate Bowell is a doctoral researcher at the University of Edinburgh working in collaboration with National Museums Scotland. Her work focuses on ways historical science and technology exhibition labels can be used as primary resources for exploring histories of scientific narratives and public engagement within museums. Previously, Kate worked as a museum curator and developer in the United States and Germany. Her work included the design and launch of three new museums and the development of the cultural and natural interpretation of the Lindenmeier National Historic Landmark, the largest PaleoIndian archaeological site in North America. Writing about museums, Kate has maintained the website Museums Askew since 2011 and is a contributing author to multiple books. The most recent, Active Collections, won the 2020 National Council on Public History Book Award.

Tim Lücke and Martin Weiss
The Restoration of the 1915 German Tide Predicting Machine

With the outbreak of World War I in 1914, German oceanographers had a problem: Overnight, they were cut out of the international network they relied on to obtain the data required to calculate and draw up the annual tide tables mariners on German vessel needed to navigate the seas.

Just days later, the German Hydrographic Office requested funding for an analogue computer to perform the task of calculating the tides: in other countries several such tide predicting machines had already been built since Lord Kelvin devised a basic principle for the mechanical calculation of the tides in the 1870s. Each one of them constituted a masterpiece of precision engineering. Within a year the first German tide predicting machine had been constructed in Potsdam and was in use in Wilhelmshaven.

For the past decades, this machine has been on display at the German Maritime Museum in Bremerhaven, alongside a later machine which was built in East Germany after World War II. Archival material does not reveal when exactly the first machine was reassembled before it was brought to Bremerhaven in the 1970s, but it is clear that it was in use throughout the 1920s and 1930s and that (almost) all parts have been preserved in their original state.

Through generous donations the German Maritime Museum has been able to provide the funds to clean the tide predicting machine, with the aim of restoring it to working order. This paper presents both some historical background to the machine and a summary of the restoration work, which commenced in May 2019 and is scheduled to be completed by October 2020. Besides focusing on the challenges of the restoration work itself, it will also reflect on how this is undertaken in an exhibition setting.

Tim Lücke is head of restoration at the Saxon Museum of Industry in Chemnitz, Germany. He studied precision engineering and restoration in Berlin and has taken on the restoration of the tide predicting machine in Bremerhaven as a freelance project.

Martin Weiss is a postdoctoral researcher at the German Maritime Museum / Leibniz Institute of Maritime History in Bremerhaven. He studied physics and history of science in Aachen and Utrecht and received his PhD from the University of Leiden in 2013.

Tom Bennett
World's Tallest Barometer and Inverted Aquarium as Demonstration and Laboratory Apparatuses

Designing and constructing the Tall Barometer involved many interesting challenges including funding, component design, permit process, footprint location, part sourcing. staging of components, assembly technique and testing. The Tall Barometer has been in continuous use since it was built in 2013 as both a demonstration and laboratory apparatus. The Tall Barometer is located in the public atrium of Portland State University's Engineering Building, which regularly has tours, hosts STEM events and many visitors. The Civil and Environmental Engineering Department offers the junior level Fluids class and laboratory twice each year and the Tall Barometer is used for half of one lab exercise and for the following 5 weeks for atmospheric pressure data collection. It was constructed using recycled straight chemistry lab drain pipes.

The Inverted Aquarium is a combination regular aquarium and partial water barometer that allows fish to swim above the free surface of the water exposed to the atmosphere. It demonstrates principles of atmospheric and water head pressure. The Inverted Aquarium is a regular tour group destination and is also used as a laboratory demonstration apparatus for Fluids Laboratory students. It is located in the reception area of the PSU Civil and Environmental Engineering Department - a semi-public space. The suspended pipe for the Inverted Aquarium is also made from mostly curved sections of recycled chemistry lab drain pipes.

Tom Bennett is an experimental physicist with experience in condensed matter, optics, atmospheric, and space physics along with electronics, materials science, structural engineering, machining and general construction.

Ben Russell
A process of ventriloquism: The manufactured meanings of James Watt's Micrometer

A significant item among the Science Museum's holdings pertaining to the Scottish engineer James Watt is a micrometer, alleged to have been constructed by him in c. 1776. Although the micrometer has been described as possibly having been the first used for industrial purposes, its associated paper trail only stretches back as far as 1876, when it was displayed at the Special Loan Exhibition held in South Kensington. Thus, although the instrument is known to have come from the firm James Watt & Co., its exact origin is unclear.

This paper will briefly explore the places which might in theory be associated with the micrometer: Watt's workshop at his home 'Heathfield' outside Birmingham; the Watt Museum operated by James Watt & Co. close by; the Special Loan Exhibition; and the Science Museum. The nature of each association differs, from providing comparator items against which the physical instrument can be compared, to contextualising the instrument as part of the myth-making around Watt as a heroic figure in the nineteenth century.

Each place represents a step in what we might call a process of ventriloquism concerning the instrument. This process has been explored by Tom Ritchie in his PhD thesis about Douglas Hartree's Differential Analyser, also part of the Science museum's collections, and about how description and interpretation of the machine subtly changed over time.

We see a similar process occurring with Watt's micrometer. The instrument has been described and reinterpreted in ways which do not always entirely match what we actually know of the instrument. I will discuss the nuances of its use and value within the context of a collection of three-dimensional artefacts regarding a major figure from the history of Britain's industrial revolution.

Ben Russell is Curator of Mechanical Engineering at the Science Museum, London. He has curated five permanent galleries and temporary exhibitions at the museum, including Robots (2017) and James Watt's Workshop (2011), as well as Cosmonauts (2015). Watt's Workshop led to the writing and publication of his book, James Watt: Making the World Anew (Reaktion Books, 2014). Most recently, Ben edited Robots (Scala, 2017). Ben's research interests are based around study of the history of manufacture in the UK, the application of motive power, and particularly the evolution of engineering practice in London in 1780-1820.

Emily Hayes

Light Space: Popular Geography and Halford Mackinder's Photosphere

Thanks to his appointment as Reader in the 'new' Geography at the University of Oxford in 1887 Halford Mackinder (1861-1947) has been perceived as a central protagonist in the professionalization of the discipline of Geography in nineteenth-century Britain (Gilbert 1947; Blouet 1987). The imbrication of geographical institutions and visual technologies such as the camera and photographs has been explored (Ryan 1997 & 2005). In his own life time Mackinder's charisma, rhetorical powers of exposition and attentiveness to cultivating a geographical imagination were also much celebrated. Recent scholarship has uncovered Mackinder's early exposure to metropolitan 'popular science' and the scientific demonstration practices of John Tyndall at the Royal Institution (Hayes 2019) as well as his commitment to popularising knowledge via the University of Oxford Junior Scientific Club and the university's Extension Lectures (Hayes 2018 & 2019). Yet, his interest in space was more than conceptual. In 1890 he conceived of an optical device designed to improve the teaching of geography in schools and lectures. Believing that the use of globes comprised the optimal method of doing so, Mackinder described and sketched a device designed to overcome the difficulties posed by existing models of the earth. The epidiascope he described hybridized a magic lantern with a framework capable of rotating a series of small interchangeable globes upon which were depicted a range of geographical features. The paper draws from histories of science and technology and studies of atmospheric and elemental spaces (Serres, 2018 & 2019; Engelmann and McCormack, 2018). In arguing for the enmeshment of Mackinder's popularising activities and his overlooked role as a historian and philosopher of human and social sciences, the paper considers the connections between fin de siècle geographical ways of knowing and political idealism.

I grew up and was educated in both the U.K. and in France. I hold an undergraduate degree in Archaeology and Anthropology (University of Cambridge) and an M.Sc in Archaeology and Environmental Science from Paris 1 and 10. Before undertaking postdoctoral research my professional background was in the art world. My AHRC-funded CDA PhD in Historical Geography, 'Geographical projections: lantern-slides and the making of geographical knowledge at the Royal Geographical Society c.1885 – 1924,' was undertaken in collaboration with the University of Exeter and the Royal Geographical Society, London (awarded 2016). I have held postdoctoral researcher positions at the University of Exeter and now at Oxford Brookes University where I am a Research Associate and Associate Lecturer. I am interested in interdisciplinary research in historical geography, history of anthropology, comparative global histories and philosophies of science and science and technology studies, and knowledge popularisation.

Celeste Ottaviani

A Temple in a Science Museum: Object Biography of Gerzabeck's Zündmaschine

The Zündmaschine developed and manufactured by Johannes Gerzabeck in 1817, at first glance, does not look much more than a decorative object with its temple-like appearance. However, after a more careful examination, it reveals to be a perfect combination of nineteenth century technology and of early '800s culture and social expectations. This machine is part of the permanent exhibition of the "Academy Collection" at the Deutsches Museum in Munich (inventory no. 1271). The starting point for the object analysis is the Fleming's model (1974) characterized by the following steps: identification, evaluation, cultural analysis, interpretation. However, this protocol lacks "a confrontation with the object's materiality". Therefore, a material culture approach is used in order to include a scientific and technical point of view. Thanks to this "corrected" and "adjusted" model, the Zündmaschine is discovered to be a table lighter that exploits an electric spark to ignite hydrogen produced inside the lighter itself. This proves the innovative nature of this object that, differently for the previous lighters, does not require an external source of hydrogen since this is produced inside the object itself through the reaction between sulphuric acid and zinc. Another advantage of the process of writing the object biography is that of discovering information about the "users" of the machine. The Zündmaschine reveals its nature as a status symbol of wealth, comfort and elegance. It represents the advancements of technology that allow few elected to take control of the power of electricity, "the purest celestial fire", and "guide it" at one's own convenience.

I am Celeste Ottaviani and I am a student of the second year of the Master Degree in Physics at the University of Bologna (Italy). During my Bachelor and Master studies, I have attended courses focusing on the Didactics of Physics, on the history and the discoveries 2 of Nuclear Physics, on communication in Science and on the History of Physics. In March 2020 I had the opportunity to take part in the "IV International Seminar funded by the Wilhelm und Else Heraeus Foundation on Material Culture in the History of Physics" that took place at the Deutsches Museum in Munich. The focus of this seminar was on object oriented research, material culture studies and experimental history of science. I have a strong interest on the historical side of Physics and on the material culture approach to the study of scientific objects. I am also keen on science museology.

Theme 5 – Trading spaces

Alexi Baker
Bones from Bedlam: supplying the instrument trade in early modern London

The instrument trade in early modern London inhabited and was shaped by a framework of interconnected socioeconomic networks embedded in physical geographies. This presentation will focus on the networks and geographies which brought raw materials and worked components into the production of finished optical, mathematical, and philosophical instruments – both within the metropolis and from distant lands. Examples of the materials include raw and worked wood, metal, glass, shagreen, tortoiseshell, and bone and ivory. These fed into the production of everything from small and fashionable vision aids and mathematical instruments, to navigational and surveying tools such as sextants and theodolites, to research and demonstration apparatus such as air pumps and observatory instruments.

Two primary case studies will be the known suppliers of raw and worked materials to the prolific optician George Willdey who died in 1737, and the generations of the Clitherow family who supplied Willdey and other instrument makers with turned bone and ivory components. These interconnected stories are illuminated by a combination of archival, geographical, and material culture research. This includes extraordinary new discoveries made by Museum of

London archaeologists in the waste materials which the Clitherow family dumped at the "Bedlam" or New Churchyard cemetery

Alexi Baker oversees the History of Science and Technology collection at Yale University's Peabody Museum of Natural History. This nationally-important collection consists of more than 10,000 scientific instruments, other scientific artefacts, and diverse technologies from across more than 500 years. Dr. Baker completed an M.Sc. at the Oxford Museum of the History of Science and a D.Phil. in History of Science at Oxford, with a dissertation on the socioeconomics and geography of the instrument trade in 18th-century London. In 2010-2013, she was a post-doc at Cambridge on the project "The Board of Longitude 1714–1828: Science, Innovation and Empire in the Georgian World", helmed by Professor Simon Schaffer at Cambridge and by Drs. Richard Dunn and Rebekah Higgitt then at the National Maritime Museum at Greenwich. Dr. Baker also wrote numerous contextual essays and volume summaries for a digitization project at the Cambridge University Library, "Navigating 18th Century Science and Technology: the Board of Longitude". In 2013-2015, she was a Mellon-Newton Postdoctoral Interdisciplinary Research Fellow at the Centre for Research in the Arts, Social Sciences and Humanities at Cambridge. This included convening and organizing an international interdisciplinary conference, "Objects in Motion: Material Culture in Transition" in June 2015.

Kristin Halverson
Medical Devices and Social Networks: Two Nordic Examples, 1870 - 1900

During the nineteenth century, at least a few instrument makers in Sweden and Denmark were in active dialogue with physicians regarding instruments. There has been historical research outside of these countries which has highlighted the importance of social networks in the proliferation of medical devices. However, there have been few studies which have looked at specific cases in the Swedish and Danish contexts. This paper aims to analyse two cases that highlight the social strategies of instrument makers in navigating nineteenth-

century medicine. The first case will examine the discussions of a hernia truss by Danish instrument maker Camillus Nyrop. The second case studies an operating table made by Swedish instrument maker Max Stille. Both of these cases illustrate the social element of introducing new innovations and the importance of social networks in the proliferation of medical devices in nineteenth-century Nordic medicine.

Kristin Halverson is a doctoral student in the history of ideas at Södertörn University's Department of Historical Studies and is funded by the Baltic and East European Graduate School. Her primary research interests involve the history of medicine and science, especially approaches which examine devices, tools and instruments and their relationships with scientific knowledge and practices. Her dissertation studies medicine in Sweden and Denmark between 1850 and 1900, looking specifically at medical devices and the relationship(s) between device, knowledge and practice. Kristin favours multidisciplinary approaches in her research, drawing from the history of medicine, history of science, technology studies and economic history.

Rebekah Higgitt
Title: Instruments, Real and Imagined, at the Trinity House in London, 1660-1780

This paper will consider the several roles and meanings of scientific instruments in one of early modern London's many corporate spaces. This was the home of the maritime guild, Trinity House, which from 1661 was close to the river and to the Tower on the east side of the City. Within this space and its associated sites, which represented the interests of ships' masters, pilots, naval administrators and overseas traders, navigational instruments had both practical and symbolic meanings. It was a space in which maritime expertise was asserted, navigational knowledge tested, and innovation adjudicated. Instruments appeared within it as gifts, as decoration, as novelties, and occasionally even as tools. Tracing these instruments – whether present as material objects, as representations, or as ideas on paper – allows us to explore Trinity House's role in mediating the expertise represented by experienced mariners and that of mathematical practitioners and projectors.

Rebekah Higgitt completed her PhD on 19th-century biographies of Isaac Newton in 2004 at Imperial College London and then undertook postdoctoral research at the University of Edinburgh on the geographies of the British Association for the Advancement of Science. She was Curator of History of Science at the Royal Observatory Greenwich and National Maritime Museum 2008-2013, Co-Investigator on the AHRC project on the history of the Board of Longitude (2010-2015), and Co-Curator of Ships, Clocks and Stars: The Quest for Longitude (2014). Recently she has been was currently senior lecturer in history of science at the University of Kent and leader of a Leverhulme-funded project on knowledge and practice in London in 1600-1800, Metropolitan Science, in partnership with the Science Museum. In August 2020 she became Principal Curator of Science at National Museums Scotland.

Peggy Kidwell
Spaces for Mathematical Instruments – What Can one Learn from Instrument Cases?

Makers, vendors and users built and modified cases as spaces to hold and move about instruments. From the elegant cases covered with sharkskin or tortoise shell of the eighteenth century to the plastic and paper boxes of the late twentieth, cases reveal much about the use and nonuse of instruments; the role of instrument ownership as status symbol;

and the intentions of vendors, instructors, and users. This paper explores cases associated with drawing instruments, slide rules, and calculating machines made and used in the United States, particularly in the nineteenth and twentieth centuries. It draws especially on instruments from the Mathematics collections at the Smithsonian’s National Museum of American History.

Peggy Aldrich Kidwell is the curator of mathematics at the Smithsonian's National Museum of American History. Her research interests range from mathematical instruments to women in science to the history of mathematics education. Her undergraduate degree is in physics, and her graduate degrees in history of science.

Theme 6 – Technical spaces: observatories

Taha Yasin Arslan

The Timekeeper's Dilemma: Standard versus sophisticated Instruments in the 13th-16th century Islamic World

The office of timekeeper was a position for astronomers to be employed at important and/or central mosques. A timekeeper would be responsible for finding important dates and times for the religious practices such as the beginning of the fasting month Ramadan and the five daily prayers. Although the concept of timekeeper did emerge in Baghdad in the 9th century, the official post was created for the first time by Mamluks who ruled Egypt, Palestine, and Syria between the mid-13th and early 16th centuries. This practice was later adapted by Ottomans in the late 15th century only to be continued until 1952 in modern Turkey. House of timekeeper, dār al-muwaqqit in Arabic and muwaqqitkhāna in Ottoman Turkish, would usually be built in the mosque annexes. Standard instruments (i.e. astrolabes, quadrants…) for observation and calculation and a library, which ideally would contain numerous treatises on mathematical sciences, would be stored in these buildings. The textual evidences suggest that the Mamluk astronomers were not satisfied with using only standard instruments and worked on perfecting and simplifying instruments for accuracy and user friendliness. The works of two astronomers explicitly attest to this claim: ʿAlāʾ al-Dīn ʿAlī ibn Ibrāhīm (d. circa 1375), known as Ibn al-Shāṭir, and Shihāb al-Dīn Aḥmad ibn Abī Bakr (fl. 14th century), known as Ibn al-Sarrāj, were actively involved with instrument making as they designed and invented several sophisticated artefacts for observation and calculation. Type of projections, reference points for sets of markings and methods of their use were almost unique in the instruments such as hidden sine graph (jayb al-ghāʿib) or complete quadrant (rubʿ al-tāmm). Unfortunately, aiming for the stars did not make their instruments popular. This paper will briefly introduce the standard instruments at the house of timekeeper and discuss why the sophisticated ones never turned into standard assets.

Taha Yasin Arslan is an assistant professor at the Department of the History of Science of Istanbul Medeniyet University in Istanbul, Turkey. His research deals with the extant astronomical instruments and related manuscripts in the Islamic world. As part of his academic studies, he makes digital and physical reproductions of the instruments that were described in the historical texts. His recent focus is on the transition and transmission of practical astronomical knowledge in the Islamic world between the 13th and 16th centuries.

Daniel Belteki

Wiring the stars: the astronomical instruments and labour contributing to the production of Greenwich Time between 1850 and 1900

The distribution of Greenwich Time during the second half of the nineteenth century relied on wearisome astronomical labour taking place inside the Royal Observatory at Greenwich. This production chain involved several departments, multiple individuals, and various instruments situated within the Observatory grounds. While historians of science and technology have examined how Greenwich Time was distributed, they have paid relatively little attention to how it was produced. This paper follows how observations of celestial bodies were transformed at each stage of astronomical labour inside the Observatory into their final form of as Greenwich Time. The paper tracks how each transformation required a new assemblage of instruments and individuals, and how the rooms and spaces of the Observatory were modified after 1850 to accommodate this work.

The internal circulation of astronomical data highlights how the members of the Observatory staff actively contributed to the production of Greenwich Time. It brings forth the power of astronomical assistants to accelerate and slow down Greenwich Time, and the Observatory's reliance on their skills to use specialist equipment. In addition, by highlighting the difficulties in setting up and maintaining the materiality of time production, the paper contrasts the reliability of Greenwich Time with the messiness of its production.

The paper draws upon the internal documents of the Observatory preserved among the Airy papers at Cambridge University Library, on articles published by William Ellis and Thomas Lewis (two assistants of the Observatory supervising its Time Department), and on displays of Royal Museums Greenwich that are no longer exhibited.

I completed my PhD in History in 2019 on the history of the Airy Transit Circle. My specialist interest includes researching the life and work of George Airy. My work combines object biographies of scientific instruments with the analysis of how observatories were managed during the nineteenth century. From October 2020 I will be a Sackler Research Fellow at Royal Museums Greenwich, where I will be researching the contributions of the assistants of the Royal Observatory Greenwich during the nineteenth century.

Julien Gressot and Romain Jeanneret

The Ertel Meridian Circle (1858-1912) of the Neuchâtel Observatory: Material Analysis and Culture of Precision

When the Observatoire cantonal de Neuchâtel was founded in 1858-1859, the director Adolphe Hirsch (1830-1901) was in charge of setting up the entire instrumental system. He contacted well-known manufacturers like Ertel und Sohn to provide a meridian circle in order to determine time with accuracy. For over a year, frequent letter exchanges between Hirsch and Ertel created a paper trail of the negotiations between scientific needs, budgetary constraints and manufacturer's possibilities. During the realization of the Meridian circle, Hirsch decided to implement the recording of observations with a chronograph in order to increase the accuracy of time determination. This improvement had a consequence on the construction of the meridian circle and its accessories, leading to a close and fruitful collaboration with Mathäus Hipp (1813-1893). The Meridian circle was installed in September 1859, and, since then, the Observatory personnel have studied it continuously in order to determine its instrumental errors. Once operational, Hirsch used it for his research on the observer's physiological reaction time in order to minimize error. The quest to obtain the most accurate result possible continued until the replacement of the meridian circle in 1912.

In this paper we will introduce the Ertel Meridian Circle and the rich collection of associated correspondence and documents that enable us to study the establishment of a culture of 2 precision at the Neuchâtel Observatory. Which kind of strategies did the Observatory implement for acquiring its reputation of precision over time? What was the role of scientific instruments and of the Ertel & Son Meridian Circle in this process? How could a newly created Observatory manage to occupy a relevant place in the international network of scientific institutions? The aim of this talk is to answer these questions and to show the steps involved in obtaining a highly-accurate scientific instrument and keeping it operational for more than half a century.

Julien Gressot, PhD student, obtained a Master's degree at the University of Neuchâtel in historical sciences with honours summa cum laude and received the Werner Günter prize for a thesis subject in environmental history on the case of a company treating special waste that caused significant pollution. He then joined the SNF project L'Observatoire cantonal de Neuchâtel (1858-1948): cultures de la précision, économie de la qualité et «

marchandisation » de l'heure led by Professor Gianenrico Bernasconi. In this context, he is preparing a PhD about the astronomical culture of precision in the Observatory of Neuchâtel through the analysis of technical devices, actors, spatial configuration and scientific activities.

Romain Jeanneret obtained a Master of Arts in Conservation-Restoration at the Haute École Arc (HE-Arc CR) in Neuchâtel, Switzerland. He worked for 4 years as a research assistant at HE-Arc CR. Its activities are shared between several fields, including the "OBS" project on the interdisciplinary study of the collections of the Observatory of Neuchâtel. It is following this last research that he joined the team of the University of Neuchâtel, as a scientific collaborator on the present project.

Loïc Jeanson, Jean Davoigneau, Françoise Le Guet Tully
Dissimilar shelters for similar instruments

In 1853, Urbain Le Verrier, the recently-appointed director of the Paris Observatory, was disappointed by its instrumentation. Technologically, the meridian service equipment was outdated. With the support of successive governments to uphold French astronomy internationally, he ordered two meridian circles within a fifteen-year time span (1863 and 1877). The first, bigger than Airy's in Greenwich, proved to be disappointing. The second, smaller, produced excellent results and would serve as prototype and model for the meridian circles of the provincial observatories. In 13 years, between 1877 and 1891, all of the 8 French institutional observatories (Paris, Marseille, Lyon, Hendaye, Bordeaux, Toulouse, Besançon and Alger) were endowed with an exceptional meridian telescope built by Eichens-Gautier.

Le Verrier identified the Paris Observatory's meridian wing, built between 1828 and 1836, to be one of the major sources of the first circle's failure. In 1873, based upon Struve's principles from the Pulkovo Observatory, he analysed and documented the flaws of such an instrument-building pairing. The second meridian circle was installed in an autonomous wooden shelter in the garden of the Observatory, and from then on, autonomous shelters for meridian instruments were advocated by the Parisian institutions (Paris Observatory and the Bureau des longitudes). However, in France at the time, construction of public buildings remained the responsibility of local administration, and so every meridian shelter had a different architect, interpreting in various ways the precise construction rules for meridian shelters.

Starting from the description of the first meridian wing at the Paris Observatory, our paper will present the spatial specification of Le Verrier's meridian instruments. We will then present nine meridian buildings (the eight by Eichens-Gautier and the Brunner in Nice), their distinctiveness, and the implications of their spatial design on local activities and on the functioning of the instrument's network.

Loïc Jeanson is a Ph.D. candidate in mechanical engineering and in history of sciences and technology at the University of Nantes.

Jean Davoigneau, a historian with a scientific background, works for the Mission Inventaire général du patrimoine culturel at the French Ministry of Culture, where he is the specialist in scientific and technical heritage.

Françoise Le Guet Tully is honorary Astronomer (Observatoire de la Côte d'Azur)

Michael Burton

Armagh Observatory: the challenge of conserving historic telescopes within an active scientific research institution

Armagh Observatory was founded in 1790 and has been continuously used for astronomical research since. Modern science continues inside today, alongside historic telescopes that remain essentially in their original settings from when they were used for pioneering science in the 18th and 19th centuries. On deciding to build an Observatory, Primate Richard Robinson – the Archbishop of Armagh – sought advice from Revd. Nevil Maskelyne, Astronomer Royal at the Observatory in Greenwich. Armagh's initial instrument suite, in particular the pioneering Troughton Equatorial Telescope, the Earnshaw regulator (that shared in the Longitude Prize) and the design of the Observatory Dome around a central pier to isolate it from the building, came from Maskelyne's recommendations. The Troughton telescope today remains essentially as it was when installed in 1795.

Armagh developed a reputation for the accurate measurement of the positions of stars, notably through the publication by Directors Romney Robinson in 1859 of "Places of 5,345 Stars" and Dreyer in 1888 of the "New General Catalogue of Nebulae and Clusters of Stars" (still in use by professional astronomers today). The telescopes used to compile these catalogues remain in the Observatory. The Grubb 10-inch refractor, used for the NGC, is still a working instrument.

The great challenge in Armagh today, in running an active research and educational institution, is that there is limited resource for conserving the historic telescopes and instruments. No staff are tasked with this as part of their duties. That Armagh has survived as essentially a "living museum" is because the astronomers continue to work in the building, leaving the telescopes undisturbed, with the public being largely excluded. Armagh's future depends on finding a way to resolve this dichotomy, of opening and conserving the heritage, while remaining an active research institution. In this paper I will summarise the challenges and welcome your comments on how we might achieve success, particularly in comparison with observatories and similar collections elsewhere.

Michael Burton is the Director of the Armagh Observatory and Planetarium. He is an astronomer whose research takes in the molecular clouds of the interstellar medium of our Galaxy and the field of star formation. It has involved using radio and infrared telescopes sited on challenging environments such as the Atacama plateau of the Andes and the Antarctic plateau. He is also an educator with 25 years in university physics, most recently as Director of Teaching in the University of New South Wales in Sydney.

Armagh has both the oldest observatory (since 1790) continuously used for research in the British Isles, as well as the oldest planetarium (since 1968). It is a centre for education, with a programme spanning from pre-school to post-graduate, and a centre for astronomical research. It also maintains the longest daily meteorological record in these islands, extending back to 1795. The Observatory building is grade A listed heritage, originally also the home for the Director, but now providing offices for the astronomers, in addition to housing the original telescopes and their instruments. These are still mostly located in situ. Our great challenge is how to maintain these artefacts without staff resource for their care?

Hans Hooijmaijers
The whereabouts of a large quadrant

In the first room of The Golden Age in Rijksmuseum Boerhaave, your eye is immediately caught by a large quadrant of c. 2 metres radius, standing in the centre.

In my paper I will tell the story of this quadrant, made by the famous cartographer, atlas and globe maker Willem Janszoon Blaeu. Why was it made by him? The man who ordered the quadrant was Willem Snel van Royen, better known as Snellius. Where did he want it for? After Snel's death the quadrant ended up in the Leiden Observatory. How did it come there and what did it do there? And how did it end up in Rijksmuseum Boerhaave?

In my paper I will answer these questions and sketch the lifecycle of this quadrant, its different functions and whereabouts.

Hans Hooijmaijers is Vice Director and Head of Collections of Rijksmuseum Boerhaave. He started his career as a curator of physics and astronomy, making exhibitions on amongst others weather, light, food, clocks and telescopes. His latest writing projects include Dutch orreries, observatories and navigation. After the refurbishment of the museum in 2017, he now prepares a new extension of the museum which will focus on present day research on life sciences.

Lee Macdonald
Proposals to move the Royal Observatory, Greenwich, 1836-1944

In 1939, the British Admiralty agreed to move the Royal Observatory from Greenwich to a darker, clearer site. The observatory's eventual removal to Herstmonceux Castle in Sussex was delayed due to the Second World War and was then slowed down further by the economic difficulties of post-war Britain, with the result that it was not fully re-established at Herstmonceux until well into the 1950s. Yet some historians have tantalizingly pointed to some much earlier debates about the suitability of the Greenwich site for Britain's national observatory. Indeed, given how by the 1930s observing conditions at Greenwich were severely compromised by air pollution and electric outside lighting, it might reasonably be asked why the observatory was not moved several decades earlier. In this paper I examine several proposals to remove the observatory that were put forward in a period spanning just over a century before 1939 and ask why none of these were taken up. In particular, I ask why the Royal Observatory's astronomers and its governing Board of Visitors did not seriously consider removal during the 1905-1912 period, when a large power station was built just half a mile from the observatory and the poor observing conditions at Greenwich were discussed in the press. I argue that the lateness of the move was due partly to astronomers' fears that the observatory would lose prestige – political as well as scientific – if moved away from the famous Greenwich meridian, and also to certain cultural aspects of professional astronomy in early twentieth-century Britain.

Lee Macdonald holds Master's and PhD degrees in History and Philosophy of Science from the Universities of Cambridge and Leeds respectively. He specialises in the history of astronomy and observatories and has published widely in this field. His article on the origins and early years of the Magnetic and Meteorological Department at Greenwich Observatory, published in Annals of Science in 2018, won that journal's US$1000 best paper prize. He is the author of a book, Kew Observatory and the Evolution of Victorian Science, 1840-1910, published by the University of Pittsburgh Press in 2018. From 2016 to 2020 he worked as Research Facilitator at the University of Oxford's History of Science Museum, managing the Museum's library and archives. In 2020, Royal Museums Greenwich awarded him a two-

year Sackler Research Fellowship, in which he will be researching the 1900-1950 history of the Royal Observatory, Greenwich. He will be exploring the history of the Royal Observatory in connection with the changing world of twentieth-century astronomy and the two World Wars, as well as the observatory's interaction with the wider public in this period.

Yolanda Muñoz Rey
Spaces for Instruments in ROA Collection

The Royal Navy Observatory of San Fernando has been one of the world's leading astronomical observatories and a leading research center since 18th century. Belonging to the Spanish Navy, it is located in the city of San Fernando (Cádiz), and due to its extensive and intense scientific and military history, it preserves almost the whole of the collection of scientific instruments that have been used there for more than 200 years. During this time, the institution has generated a multiplicity of spaces around its instruments, that today we can still see and recover: workshops, rooms, cabinets, astronomical observation outdoor spaces and external projections, such as the ships it served with instruments. To them are added now, museum rooms, warehouses, archives and libraries. They have been and are workspaces, technological innovation, development, study, conservation and prospective spaces.

Yolanda Muñoz Rey (Madrid, 1973), PhD on Arts and Humanities Master in Research and Innovation in Education and Master in Historical-Archaeological Heritage, Grade on Fine Arts and Grade on Art History. After 15 years of professional experience as a teacher and Manager of Educational Programs, nowadays she works as Lecturer in the University of Cádiz, PhD researcher in HUM726 Research Group University, Academician at the Royal Academy of San Romualdo of Sciences, Arts and Letters, and Manager of a Discussion Group about Defense of Heritage. Her research interest is museology and conservation of ancient scientific instruments. She has an extensive complementary education and training; she has several Research Awards, Grants and Fellowships; she has lectured in Conferences, Congresses and moderating Debates; she has several publications (books, articles, papers, conference proceedings, and articles and interviews in press); she has been Visiting Scholar in UK, Morocco, Portugal and Russia.

Theme 7 – School and university spaces
Thursday 17 September

Rosanna Evans

Problem solving: hand- and home-made instruments in the Science Museum's English school science teaching collections, 1944-1988

Despite a resurgence in interest, the impact of learning experiences on scientific culture remains underestimated. Historiographies of science education from the 1970s have considered policy change and educational structure, examining what ought to have happened at school rather than authentic classroom interactions.

There is a dearth of research exploring how educational occurrences were actually experienced by young people. A tentative resurgence of work on education has looked to university teaching collections and textbooks, frequently examining education systems forming during the 19th century. Yet what of modern schools and educational techniques? For in Britain, as well as in many other countries, compulsory school experiences now affect almost every citizen. If school is one of the first times a person is exposed to material manifestations of science, these experiences are likely to be hugely impactful on later engagement with science.

Here, material culture is a valuable asset. Scientific teaching instruments endure as material indicators of students' practical learning experiences. This paper will investigate genuine teacher behaviours by employing object biographies to elucidate information about relevant educational structures, networks, and regulations and gather authentic information. The Science Museum in London holds over 1200 teaching objects: many collected from schools or donated by teachers, many constructed by science teachers for specific purposes. By investigating hand-made instruments - the motivations for their construction, use, and donation to the museum; their design; the materials used in construction; and evidence of use prior to donation; authentic evidence can be gathered about formative experiences of science.

I am a part-time doctoral candidate in the School of Philosophy, Religion and History of Science (PRHS) at the University of Leeds. My thesis investigates the role and value of science equipment and apparatus at different types of schools between 1944 and 1988, and is co-supervised by the Science Museum as a part of an AHRC-funded Collaborative Doctoral Partnership. As a part of this research, I am constructing object biographies as well as recording oral histories of ex-pupils and teachers that recall using scientific apparatus and equipment as a part of their education, considering both the short- and long- term impact of practical science on learning and attitudes to science. Alongside my PhD, I am the Learning Associate: Schools and Teachers at the Fitzwilliam Museum, part of the University of Cambridge Museums. Previously, I was the Learning Co-ordinator at the Whipple Museum of the History of Science at the University of Cambridge.

I am particularly interested in understanding how people learn using objects, and whether the methods of using of objects in education can impact who accesses that learning. I am also interested in science communication and public understandings of science, as well as representation and inclusion of diverse audiences within museum collections, meaning making within museums, and gender and queer history.

Delphine Issenmann

The campus of the Imperial Univerity in Strasbourg: when scientific instruments influence architecture and town planning

Following the 1870 Franco-Prussian War, the French city of Strasbourg and its region were annexed to create the new Land Elsass-Lothringen (Alsace-Lorraine). In its new Alsatian capital, the German Empire almost immediately founded a new university, intended to disseminate German culture and science. The establishment of a new and prestigious type of institution, giving pride of place to experimental sciences and closely combining teaching and research, was too ambitious to be accommodated in the existing premises of the French university. Consequently, the building of a new campus was decided, which would take place at the heart of the city's expansion, planned at the same time. In 1875, a young architect from Berlin, Hermann Eggert, was charged with designing this university complex, bringing together physical sciences, natural sciences and humanities on a single site. Working in close cooperation with the directors of the future institutes, he designed for each discipline a building whose architecture was at the service of science.

This paper aims first to analyze, based on the examination of the various institutes which formed this new site inaugurated in 1884, the conditions of collaboration between the architect and the scientists. It will secondly determine how the latter, by choosing the instruments and their location in advance, were the bona fide designers of the architectural project. We will conclude by highlighting the technical solutions applied to meet the functional needs of each discipline and its equipment. We will discuss how the original design of what we identify as « instrument-buildings », resulting from this approach, not only defined the spatial layout of the new campus, but can also be considered alongside the extension of the city - the Neustadt - which the campus locally influenced.

Delphine Issenmann studied history and art history and holds an MA in Cultural Heritage management, as well as an MA in Science Studies. In charge of collections of the Jardin des Sciences (University of Strasbourg) since 2004, she has been coordinating the inventory of scientific instruments and the study of architectural heritage of the campus.

Sieger Vreeling

Groningen Under the Petrographic Microscope, 1877-1912

The first part of this paper intends to show how Prof. Friedrich Julius Peter van Calker (1841-1913) used new research methods and instruments to study the diluvial past of the city of Groningen, The Netherlands. Van Calker was appointed Professor of Mineralogy and Geology in Groningen in 1877, arriving in a city that was in the midst of dismantling its fortifications. He seized this opportunity to collect hundreds of erratic boulders from building sites across the city, to prove that Prof. Otto Torell's glacial theory (1875) also held true for the Netherlands. To establish their exact origin, thin sections of boulders from Groningen were compared to samples from Scandinavia under the petrographic microscope.

The second part of this paper will discuss the relation between the city and Van Calker's laboratory. Between 1892 and 1912 the city of Groningen experienced a building explosion of university laboratories. Van Calker's new Mineralogical-Geological Institute – built on a former rampart – opened its doors in 1901. It was purpose-built, with rooms designed around the intended research, i.e. around the instruments. What's more, between 1900 and 1902, Van Calker's budget was almost tripled to fit-up the new laboratory: the new building cost around 200.000 guilders, the new instruments around 16.000. In this state-of-the-art

laboratory, Van Calker was able to finish his research on the erratic boulders from Groningen in 1912.

Dr. Sieger Vreeling (1987) has a Bachelor's degree in Building Engineering and a Master's degree in Architectural History (cum laude). Last year, he defended his dissertation Geen stijl, or No Style, a plea for a richer architectural history, one that is not just restricted to architectural styles, but also incorporates the functionality and technology of buildings, and the organization of their building process. His dissertation looked behind the façade of several large, complex building types, including university laboratories. He was one of the co-organizers of the international conference The Laboratory Revolution. The Rise of the Modern Laboratory and the Changing Nature of the University, 1850-1950 (Groningen, 26-27 October 2017).

Grazia Zini
From production to obsolescence and beyond: stories of L.Golaz's scientific instruments acquired by the University of Ferrara (Italy) in the XIX century

This paper reports the results of our recent research work about some historical scientific instruments created and signed by L. Golaz, owner of the scientific-instrument manufacturing firm of the same name, active in Paris from 1830 until the beginning of XX century. In 1865, these instruments were acquired by Curzio Buzzetti (1815-1877), Professor of Physics and Meteorology of the University of Ferrara, who used them for didactic and research aims. They are now part of the CISFIS Collection of historical scientific instruments of the University of Ferrara (Italy). Among these instruments we can mention apparatuses for gas, an apparatus for thermometers calibration, a hygrometer, an essential oil distiller, a eudiometer used to determine the degree of purity of air and a vacuum pump. They all prove the interest of the Professors of Physics of the University of Ferrara in these areas of physics. The present research highlights the different uses and locations of Golaz's instruments, from their acquisition to obsolescence stage, which occured at a different time for each of them. Since 2003, these instruments have been used for expositions and science outreach project, as part of the CISFIS Collection.

Grazia Zini held the chair for Physics Education at the University of Ferrara (Italy) from 1985 until her retirement in 2006. Between 2003 and 2006 she supervised the recovery of long-forgotten historical scientific instruments stored in various rooms of the Physics Department of the University of Ferrara. These activities led to the establishment of the CISFIS Collection of historical scientific instruments of the University of Ferrara (Italy). 2 She headed several Physics research projects for the University of Ferrara and the Italian National Research Council (CNR). Many of them focused on scientific and historical analyses of some instruments of the CISFIS Collection. She authored and co-authored various academic articles published on both national and international journals. Since 2006 she has been researching in the field of History of Physics and Physics Education. She contributes to all the activities related to the CISFIS Collection.

Pietro Milici
Poleni's instruments to trace transcendental curves "by an astonishingly pure and simple method"

During the seventeenth century, mathematicians radically modified their idea of a curve, transitioning from the trace of a machine to the solution of an equation. With that in mind, Descartes and Leibniz introduced theoretical machines (i.e. sketches to be considered mentally but not practically realized) to legitimate the geometrical status of algebraic and

transcendental curves obtained as solutions of analytical equations. The general method to construct transcendental curves in particular was the solution of the inverse tangent problem by the so-called tractional motion. At the end of the nineteenth century, integraphs practically implemented such ideas in order to mechanically plot the integral of a graphically defined function.

We are interested in the intermediate 18th-century perspective. In particular, we analyse the geometric instruments designed by Giovanni Poleni, polymath and Professor at the University of Padua in Italy. These instruments, which were technically similar to posterior integraphs, had been described with an engineer's precision in a letter to Jacob Hermann who was Poleni's predecessor in the chair of Mathematics. The letter was included in the Epistolarum Mathematicarum Fasciculus published in 1729. From Poleni's foundational perspective, these machines had to prove the geometricity of the tractrix and logarithmic curves. While these curves were well known and generally accepted, for him a curve could only be considered geometrical if it could be constructed by the continuous trace of a simple instrument, guaranteeing adequate usability and accuracy. Despite initial enthusiastic feedback from contemporaries such as Leonard Euler, such machines were soon forgotten, probably because geometric constructions fell out of favor in mainstream mathematics. While Poleni listed these machines among the artefacts in his cabinet of Experimental Philosophy, they are no longer present in the Paduan University collection. Thus, in order to see them working in real life, we recreated Poleni's machines by following his descriptions. Such reconstructions help to explore Poleni's ideas and to share them with others through experimentation in various educational contexts.

Pietro Milici is a postdoc at the mathematics laboratory LMBA of the Université de Bretagne Occidentale (Brest, France), where he collaborates with the local Cabinet of Curiosity. His main research interests deal with mathematical machines (mainly for tractional motion) from multiple perspectives: history and philosophy of science, the foundation of mathematics and computer science, and STEM education. He has a PhD in mathematics (Palermo, Italy) and in epistemology (Sorbonne, France), and he is a member of the international project EuroPoleni on 18th-century Italian polymath Giovanni Poleni.

Jorge Luis Gálvez Soler
Theodolite: past and present in university education in Havana

Montané Anthropological Museum was the first university museum of its kind founded in the Republic of Cuba. There specialists from diverse careers have collaborated such as geographers, architects, engineers, biologists and anthropologists. This talk will explore how those scientists have often made use of the theodolite since the foundation of the museum, and how the instruments has been used in university education in Havana. Its past use is illustrated by various images and records kept in the archives of the museum, as well as by practical classes, which have taken place in the countryside and in the city. Currently its use continues, and it is wonderful how that same instrument has evolved over time in the university community. This includes educational activities with children and adolescents, using theodolites produced in the former Soviet Union and United States across the twentieth century. The instruments' restoration and maintenance is essential for their operation and preservation, and physical colleagues undertake this arduous task in the museum's laboratory. The restoration itself is also used to educate students. Museum, classroom, city and countryside are all spaces that have witnessed teaching with the theodolite, and this is where knowledge of it is still being transmitted to new generations. The theodolite is part of the university's instrumental heritage, and our ongoing activities contribute to its recognition and protection.

Lic. Jorge Luis Gálvez Soler graduated with a degree in biology from the School of Biology at the University of Havana in 2018. He currently works at the Montané Anthropological Museum at the University of Havana. He was a student at the winter school on university heritage at the UH (March 2018, University of Havana / University of Padua), was a member of the Anthropos 2020 Convention and was Secretary of the Honorific Chair Luis Montané, was Secretary in the Jury of the Student Scientific Forum (2018) in anthropology, and was a Researcher of the Local Development Network in the rural community (Picadora, Yaguajay, Sancti Spíritus, Cuba) and was an Assistant in the History of the Anthropology. He presented a poster at SIC 2019, "Instruments at Crossroads: Insertion of ancient instruments in the exhibition room of the Montané Anthropological Museum". He has been a speaker in archeology and paleontology workshops and has a diploma in management and preservation of cultural heritage from the San Geronimo school of the University of Havana (2018-2019). He has also authored publications on nutrition and obesity.

Emma Angelini, Margherita Bongiovanni, Annalisa Pessando

The collections of scientific instruments of Politecnico di Torino derived from the Regio Museo Industriale

Every institution must take care of the memory of his origin in order to gain awareness of his state and the reason for future developments. Politecnico di Torino followed this policy from the beginning. When in 1906 the Regia Scuola di Applicazione per gli Ingegneri and the Regio Museo Industriale merged in Politecnico, they both had precious collections of scientific instruments and artefacts, some used exclusively for didactics, others exhibited in museums open to the public. In 1911 the collections were reorganized and updated, due also to the acquisition of the Museum of Geology and Mineralogy that was hosted in Valentino Castle. In 1942 the building of the Museo Industriale, which hosted the School of electrical engineering founded by Galileo Ferraris, the Mineralogical Museum and other important collections, was destroyed by bombs and only parts of collections could be saved. Nowadays the collections are stored in different departments of Politecnico in respect of both the historical consistency and the didactic use.

In this paper we will make an illustration of the laboratories and of the artefacts of the Regio Museo Industriale of Torino, established with the Royal Decree of 23 November 1862, under the authority of the Ministry of Agriculture, Industry and Commerce, for the initiative of the

senator Giuseppe Devincenzi (1841-1903) who was the Regio Commissario at the London Exhibition of 1862. He wanted to reproduce in Italy an institution on model of the South Kensington Museum in London and of the Conservatoire des Arts et Métiers in Paris. The museum's aim was to "promote industrial education and the progress of industry and commerce". This institute had a very important role for the engineering teaching.

Attention will be paid to the crossing between spaces of the scientific instruments of the different laboratories, electrochemistry, chemistry, mechanics, physics and testing paper and other branches of engineering.

Emma Angelini is full professor of Applied Physical Chemistry in Politecnico di Torino and is vice-president of the ICC - International Corrosion Council. Her research areas are corrosion and protection of metallic materials, plasma chemistry, as well as the safeguarding of Cultural Heritage, from materials characterization to environmental monitoring. She is responsible of several research projects on Cultural Heritage protection. She is involved in

intercultural dialogue activities between different audiences carried out in the Arte della Lana Museum of Stia and in the Museo Galileo in Florence.

Margherita Bongiovanni is an architect, operating since 1998 within the Museum and Historical Documentation Centre of Politecnico di Torino. Since 2013, she is responsible for the Politecnico Museum, part of the University Library. Her activities range from projects to preserve, conserve and promote the historical heritage to the spread of scientific cultural programs. Her interests also involve gender studies with a focus on women who studied at Politecnico. She is member of A.I.D.I.A., Italian Association of Women Engineers and Architects.

Annalisa Barbara Pesando, Architect and PhD in History of Architecture and Urban Planning, is currently a research fellow at the Polytechnic of Turin. She is a contract lecturer in the courses of History of Contemporary Architecture and Design in the Degree in Design and Communication of the Polytechnic of Turin. The research field is mainly addressed to the themes of the nineteenth and the first half of the twentieth century.

Theme 8 – Technical spaces: in the field
Thursday 17 September

Marvin Bolt
Diverse uses of glass spheres: new instruments for new spaces

The earliest recorded use of glass floats comes from Norway in the 1840s, although they were likely in use in Scandinavia prior to then. A century later, fishing boats throughout Europe, North America, and Japan used glass floats rather than wood or cork ones. Glass floats soon became an effective tool for oceanography, enabling research in diverse disciplines: marine biology and ecology, fluid thermodynamics, meteorology, climatology, and more. Recently, those glass spheres became a vital part of the IceCube Neutrino Observatory, a research project using the Antarctica ice sheets as a means to detect extraordinarily elusive neutrinos. In telling what we hope is a compelling story about the history, variety, and trajectory of the uses of glass spheres (including at least two other examples not yet mentioned), we'll explore the ideas of materiality, the transfer of technologies across spaces, and the seemingly always subtle (or even changing) notion of what constitutes a scientific instrument.

Marvin Bolt is an historian of science, technology, and ideas, now serving as the Curator Emeritus of Science and Technology at the Corning Museum of Glass. After exploring the history of astronomy at Chicago's Adler Planetarium, he has more recently attended to the materiality and anthropology of glass, which includes his long-term pre-occupation / obsession with pre-1750 refracting telescopes. Other ongoing collaborative projects include interpreting representations of the Star of Bethlehem, exploring the translations of instruments into new contexts, developing graphical design techniques for communicating scientific and technical information with lay audiences, and encouraging the development of a new generation of cross-disciplinary scholars.

Francesco Guerra, Matteo Leone, Nadia Robotti
Witness to disaster: an electrometer and its journey to the North Pole and back

This talk explores the eventful history of a Wiechert electrometer that, after a few years of honourable service in a Laboratory in Rome, Italy, was brought to the North Pole by General Umberto Nobile in 1928. While on the way to a polar expedition, it survived the tragic crash of the Italia airship and was then brought back to Italy to be almost forgotten for about 90 years.

This apparatus, originally developed in 1909 by German physicist Emil Johann Wiechert, represented a notable improvement in the method of measurement compared with other electrometers. It accomplished this through a particular arrangement of its quartz fibers, whose displacement could be observed simultaneously by means of an ingenious optical device. An example of this apparatus was bought in 1924 by the Radium Office of the Italian National Institute of Health, with the goal of calibrating radioactive sources through the measurement of the ionization current produced by an ionization chamber.

In early 1928, Giulio Cesare Trabacchi, Director of the Radium Office, lent this Wiechert electrometer to General Nobile. He did so upon the recommendation of Aldo Pontremoli, Professor of Physics in Milan, who was charged with overseeing the scientific aspects of the polar expedition. With this electrometer, then very rare in physics laboratories, Pontremoli

was expected to carry out vital measurements of the electric gradient in the atmosphere at the polar latitudes.

Unfortunately, on 25 May 1928 the Italia airship which was carrying the people and supplies for the expedition crashed after a sudden loss of altitude. Ten crewmen were scattered across the ice, while Pontremoli and five other crew remained attached to the airship envelope, which regained altitude and drifted away to never be recovered. In the following months, the survivors were rescued, and the materials for the expedition were recovered. Among the latter was the Wiechert electrometer, a silent witness to the tragedy. The electrometer, which escaped the disaster because it was in the airship's cabin, was eventually fixed and stored at the Institute of Health.

Francesco Guerra is Professor of Theoretical Physics (Emeritus) at the Department of Physics of Sapienza University of Rome. His research interests include Quantum Field Theory, Elementary Particle Theory, Statistical Mechanics of Complex Systems, and History of Nuclear Physics.

Matteo Leone is Full Professor of Didactics and History of Physics at the Department of Philosophy and Educational Sciences of the University of Turin. His research activities focus on the 19th- and 20th-century history of physics.

Nadia Robotti is Full Professor of History of Physics at the Department of Physics of the University of Genova and a member of the Académie Internationale d'Histoire des Sciences. Her research activities focus on the history of atomic physics, nuclear physics and quantum mechanics.

Richard Kremer
Instruments moving in space: Mass spectrometry from Berkeley to Ethiopia to Mars

Like the microscope or the voltmeter, the mass spectrometer by the 1930s had become a 'universal instrument', widely used in many different scientific fields, in this case, to identify isotopes or to use isotopes for myriad purposes. This paper will trace the application of mass spectrometry to geochronology, i.e., to the dating of mineral samples by measuring isotopes that have undergone radioactive decay at known rates. In particular, I will analyse the K/Ar method of radiometric dating, developed in 1950 in Germany, elaborated at Berkeley into a standard geochronological tool that also could be elaborated for highly specialized tasks such as dating the Australopithecus specimen "Lucy" found in 1974 in Ethiopia, or Martian rocks on the NASA Rover "Curiosity" in 2013. A tool, created in physics to measure tiny variations in mass, moved widely through space to measure absolute time at scales reaching billions of years. The largest challenge, in these geological spaces, was not the adaptation of the mass spectrometer but rather the preparation of geological samples that could be measured with the physical instrument.

Rich Kremer curates the collection of historic scientific instruments at Dartmouth College, currently serves as President of the Scientific Instrument Commission, and researches and writes on scientific instruments in medieval Europe as well as in 19th and 20th-century North America. In 2014 he co-edited with Giorgio Strano, Silke Ackermann and Mara Miniati one of the SIC's Brill volumes, Scientific Instruments on Display.

Luisa Spairani
Michela: a piano for technical-scientific communication

The “Michela” is a shorthand machine (the word "stenotype" was not used for another 80 years or more) invented and built in 1863 by Antonio Michela Zucco, an Italian inventor and teacher active in Turin and Ivrea in the mid-1800s.

In 1878 the machine was patented in Italy and in 1879 in the US. In 1880 it was adopted for the shorthand reporting of the parliamentary works of the Italian Senate, an activity that has continued uninterruptedly until today (the current Michela machine is completely computerized and allows immediate and clear transcription of the debates).

Thanks to the "Michela" machine, the stenographers of the Italian Senate have achieved three world titles (1983, 1985 and 1995) at the world shorthand championships and, until 1996, all Italian titles.

After 1880 Antonio Michela Zucco devoted himself to the application of shorthand and in particular the "Michela Method” to the optimization of the telegraph. Numerous experiments were carried out in France between Paris (Ministère de Télégraphes), Orleans, Tour, Le Havre and various other cities at an ever greater distance with good results. The invention and the progressive use of the radio stopped this line of research.

Luisa Spairani is a Theoretical Physics graduate cum laude and Vice president of “Gruppo Astrofili Eporediesi”. Since April 82 Luisa works in the computer industry and she currently coordinates the R&D projects. She has 20 years’ experience in Asset Management and Maintenance, gained in a range of industries, including P.A., automotive, Oil & Gas, Utilities, Transport, food & beverage and Infrastructure. She continues to cultivates her interests in Physics, Astrophysics, and history of science.

Theme 9 – Technical spaces: laboratories and factories
Thursday 17 September

Sena Aydin
Microscopy in 19th Century Ottoman Science

This study aims to present a brief survey for the use of microscope in the 19th century Ottoman science by providing details on five treatises which were published in Istanbul as part of the introduction process of modern sciences to the Ottomans. First of these treatises is *Majmuʿa-i ʿulūm-i riyādhiya*, the very first encyclopaedia of positive sciences in the Ottoman Empire. It was compiled by Ishak Efendi (d.1836) who also introduced modern optics to the realm. This treatise contains information on the vision in microscopes as well as descriptions of compound and solar microscopes. Mahmud Celaleddin's article "Hurdebin or Microscope" ("Hurdebin yahud Mikroskop"), our second treatise, was published in 1881 and it explains the use of microscopes. This work, which also gives general information about lenses, describes the areas of use of the microscope and its benefits for various branches of science. While Mehmed Ali wrote an article about the history of the microscope in 1891, Salih Zeki devoted the section titled Instruments of Light (Ālāt-i Dhiyāʾiyya") in his compendium *Natural Sciences* (*Ḥikmat-i Ṭabīʿiyya*) to optical gadgets in 1896. *Ḥikmat-i Ṭabīʿiyya* was an important source in physics as it offered the terminology on general and experimental physics and used as a sourcebook for physics education in Ottoman Turkey in the late 19th and early 20th centuries. In the section Ālāt-i Dhiyāʾiyya, Salih Zeki provides information on the use of simple and compound microscopes. Our last source is an article titled "Microscope that is Hurdebin" ("Mikroskop yani Hurdebin"). It was published in 1905 by a teacher in the School of Agriculture of the Ottoman State named Ihsan. In this article, he mentions the invention of the microscope and introduces some parts of the device. He explains the benefits of the use of microscope in sericulture and the procedures to follow for the purification of the lenses. With this study, we aim to gain information about microscopy in 19th century Ottoman Science from different perspectives. We will learn what an Ottoman textbook and an Ottoman encyclopedia provide. Also we'll learn about the fields of application of microscopes for this period just as in the field of sericulture.

Sena Aydın is a PhD candidate in Istanbul Medeniyet University in Turkey. She had her both bachelor and master degrees from the Physics Department in Boğaziçi Universiy, Istanbul. As an undergraduate she joined the Soft Condensed Matter Lab of Boğaziçi University and studied the dynamics of sand particles as a soft condensed matter and non-Newtonian fluid dynamics. She wrote her master thesis on "The Reception of Modern Optics in Ottoman Science". Currently she is writing her Phd thesis "A Set of Geometrical-Optical Problems in Ottoman Science between 1300-1600: Rainbow and Halo". Her research focuses on the history of optics in the Ottoman between the 14th and 19th centuries.

Ilknur Sahin
The Comparison of Chemistry Laboratory Equipment of Ottomans with Europe

The introduction of modern science to the Ottoman Empire was about the end of 18th century. Education was mainly done by the military schools of the Ottoman Empire, which became the center of translations from European science and technology to Ottoman Turkish books. There were many attempts to write lesson books for science classes for Darülfünun the first university known as İstanbul University, but these couldn't be continued for long periods. Therefore, translations from English and French were conducted by

individual effort. The beginning of 19th century, few books were translated to Ottoman Turkish from many foreign languages. The insertion of chemistry to the curriculum occurred around the 1860s. Başhoca İshak Efendi's book (1834) on modern science and technology can be thought as the milestone of modern technical education in the Ottoman Empire. After that, Dervish Pasha had written "Usûl-i Kimyâ" at 1848 at Ottoman Empire. Dervish Mehmet Emin Pasha was the pioneer of Ottoman chemistry, since he had written the first chemistry book and given courses at Darülfünun. In 1835, Dervish Pasha went to England and then to France to complete his education. After returning to İstanbul, he worked as physics and chemistry teacher at Mekteb-i Tıbbiye-i Şahane and Mekteb-i Harbiye. The treatise of Dervish Pasha's is the first chemistry lesson book written at 1848 at the Ottoman Empire. The book consists from 2 volumes and the book was used as course book at the Darülfünun. It mentioned about basic chemistry topics such as the acids, bases and many compounds used for ammunition. At the end of the book, there are some drawings about chemistry laboratory equipments such as allonge, bain-marie, ballon, capsule, cloche, cornue (retort), cictern pneumatic and drawings are similar to first hand sources' drawings. As a result, the book shows the scientific gap between east and west in the 19th century when compared with the first-hand sources written by Dr. Edward Turner "Elements of Chemistry'' (1842) and Louis Jacques Thénard "Traité élémentaire de chimie'' (5 vol. 1834-36).

I have graduated from METU chemistry education program and then start to doctorate program on math and science education at METU. At the same time, I studied on the history of science master program at Ankara University. I have studied on the Ottoman chemistry, especially on 19th century. I have transliterated the Ottoman chemistry book into Turkish. Because of the requirements of knowing Arabic, I start to learn Arabic simultaneously. I have compared the Ottoman chemistry laboratory equipments with the European laboratory equipments when I work on master thesis at history of science. I am working as lecturer at Kastamonu University. I would like to make research on the history of chemistry at later stages in my career life.

Tacye Phillipson
Pack them up carefully and dispatch to the Elaboratory in Edinburgh

In 1724, Dr Andrew Plummer (later Professor of Chemistry) and his colleagues the doctors John Rutherford, John Innes, and Andrew St Clair established an 'Elaboratory' in Edinburgh, to furnish apothecary shops with chemical medicines and to instruct students. They ordered chemical glassware, chemicals and some materia medica shipped by sea from London, rather than being able to source all of their materials locally, despite the existence of Scottish glassworks. A correspondence book with copies of their London orders and received invoices from suppliers from 1726 to 1743, has recently been fully transcribed by a Museum volunteer, Andrew Cronshaw. It is revealing about the magnitude of their industry, with orders for a considerable quantity of notable sizes of chemical glassware. It also offers insight into some considerable challenges involved in stocking a laboratory by mail order at the period. Comparison between the orders and invoices show differences between what was ordered and received, difficulty in identifying alternative suppliers, dilatory communication (and payment) and lack of availability. This paper will examine how the location of this laboratory and limitations imposed by written communication with distant suppliers were significant practical considerations for the chemists.

Later in the 18th century, Professor of Chemistry Joseph Black was involved with glassworks in Leith (Edinburgh's port) to establish a local source of chemical glassware. This volume highlights challenges posed by the previous lack of such a local source.

Tacye Phillipson is Senior Curator of Science at National Museums Scotland. She most recently curated the exhibition The Luxury of Time: Clocks from 1550-1750. She previously worked on the Enquire and Earth in Space galleries and curated exhibitions on prosthetic limbs, Sir James Black, Napier's rods, and the Higgs boson.

Ke Zhao, Quandong Ren, Deli Chen

Convergence across Space and Time: The Impact of British Multimeter on the Development of China's Electronics Industry

In the Electronic Science and Technology Museum in Chengdu, China, two multimeters with similar appearance are preserved. One is the Model 8 AVOmeter (MEGGER Company, the UK, 1950s), and the other is the Model 500 Multimeter (Shanghai No.4 Electronic Meter Factory, China, 1978). Electronic measuring instruments are the foundation of electronics industry. The convergence of these similar instruments from different spaces has witnessed the beginning of China's electronics industry.

This research aims at exploring the journey of Model 8 from the UK to China, as well as the development process of the Model 500. In the 1950s, Western countries launched an economic blockade policy on China. Therefore, China introduced instruments from the UK, including the Model 8, by setting Hong Kong as a free trade hub. The meters were allocated to the key research institutions and universities, among which was the University of Electronic Science and Technology of China. However, the number of Model 8 was far from the demand of research and industry. Based on the Model 8, the Shanghai No.4 Electronic Meter Factory developed the Model 500 in 1960s so that meter factories around the country were able to produce it. By 1980s, its production met millions, making it the most widely used multimeter in China. From a certain perspective, the introduction of Model 8 promoted the development of China's electronics industry at beginning.

Analogously, two other ammeters in the museum were similar. The M104 was directly provided to China in 1959 during the technology transfer assisted by the USSR. The C4 was produced in 1970 in a Chinese Harbin factory built in 1953 by the USSR.

In a word, focusing on the four instruments from different spaces, this research tracks the development path of China's measuring instruments, more generally, China's electronics industry, from space and time.

Ke Zhao is the director of the Electronic Science and Technology Museum in China. He earned his PhD in Microelectronics and Solid-state Electronics. He teaches History of Electronic Science and Technology in the University of Electronic Science and Technology of China. His research interests include history of technology and university museums.

Quandong Ren is the conservator of the Electronic Science and Technology Museum. He also teaches History of Electronic Science and Technology in the university. His interests include history of technology and museum education.

Deli Chen is the consultant of the Electronic Science and Technology Museum. He was the director of the library in the university. Now he continues his interests in museum education and history of technology.

Theme 10 – Failed Scientific Instruments
Friday 18 September

Introduction
A special session, organised by Sara J. Schechner, exploring instruments that were considered failures either at their time or later. Building on successful sessions on this theme at the SIC's Leiden and Havana symposia, the session will explore why some instruments fail or fall into oblivion, how failures may turn into success, what we can learn from such instruments, and how their study can enrich the history of science. Q&As about the presentations will be followed by a commentary and round-table discussion.

Johan Kärnfelt
On a failed mount: The Herschel telescope of the Royal Swedish academy of sciences

In the mid 1780s the Royal Swedish Academy of Sciences commissioned a speculum mirror for a six foot telescope from the workshop of William Herschel. The mirror, a secondary and some eyepieces arrived in mint condition in Stockholm 1790. However, due to an untried instruments maker, and rather confused instructions from the Academy, the construction of the telescope mount was delayed to the degree that the Academy forgot about it. Many years later, and after the Academy inspectors had made an inventory of the equipment at its observatory, the forgotten mirror resurfaced. After some negotiations the now half-finished mount was bought out to be finished by another instrument maker. In 1812, more than twenty years after the mirror was received, the telescope was delivered to the observatory. But what should have been a vital addition to the observatory's instrument collection turned out to be an utter disappointment. The mount, built after brief sketch in a book supplied by the Academy secretary, was clumsy, difficult to handle and extremely sensitive to vibration. According to the journals kept at the observatory it was used only once. In short it was a total disaster.

This paper details the biography of the Herschel telescope, from the late 18th century to the present era where it has been transformed from a scientific failure to an exhibition showpiece.

Johan Kärnfelt is associate professor in the History of Ideas and Science at Gothenburg university, Sweden. His research has previously been focused on the history of popular astronomy and of amateur astronomy. Recently he has moved into instrument studies and is preparing a research project on the telescopes used at the Royal Swedish Academy of Sciences' observatories

George N Vlahakis and Panagiotis Lazos
A telescope's lack of fortune: the Newall Telescope

Sometimes to be a success or a failure is nothing but the result of mere luck. This happens not only to people but to objects like scientific instruments as well. The Newall telescope is none of the most typical example of this argument as it "failed" to serve properly for its purpose for some decades before it found its appropriate setting. Newall refractor used to be the biggest telescope in the world, it was moved in three different locations in two different countries and it is operating almost continuously for 150 years. Nevertheless, the career of the Newall refractor is like that of a like a variable star that is sometimes dark and forgotten and when it shines and everyone turns their eyes to it.

R.S.Newall was a wealthy British entrepreneur and a keen astronomer who gave his name in one of the best and biggest telescopes of the 19th century. The telescope was initially built

by Thomas Cooke and finished by his sons. In 1871 it was placed in Newall's private observatory at Ferndene. No matter how much Newall tried to find a proper institution to donate the instrument, so it could be used as it deserved, the big refractor remained at Ferndene until his death. His son, H.F. Newall, donated the telescope to the Cambridge Observatory in 1891. He offered the money for the transportation and he proposed to work with it without a salary for 5 years. The telescope was the principal refractor in Cambridge observatory for more than 20 years and it was still used until the Second World War.

Then it fell into misuse and its destiny was vague, until the National Observatory of Athens expressed its interest to receive the telescope bearing the cost of transportation and accommodation in Athens. Finally, the donation was completed; the telescope arrived in Greece and was installed in 1957 in the area of Penteli Mountain, quite near Athens, and it was used for astronomical observations until the early 70's. Then the light pollution made it scientifically useless. During the 80's the refractor was almost abandoned but, fortunately, the last 25 years the telescope has been well maintained and it is now used to teach the public about astronomy and to inspire young pupils to look at the night sky.

George N. Vlahakis is assistant professor of History of Science and Philosophy at the Hellenic Open University and fellow Researcher at the Institute for Historical Research/ NHRF. He is president of the Commission on Science and Literature DHST/IUHST

Panagiotis Lazos works as physics teacher in secondary education and he is a PhD student. His main research interests are the recording of collections of scientific instruments of the 19th century in Greek schools, how they were used in the educational process and the experiments in physics.

Luis Tirapicos
Petrus Nonius, Tycho Brahe and Orazio Borgondio: Two failed schemes to read angular scales?

Two cases of apparently failed schemes to read angular scales with greater accuracy will be discussed. The first, proposed by mathematician and cosmographer Pedro Nunes (1502-1578) in his book De crepusculis (1542), was tested and used by Tycho Brahe (1546-1601) in four of his instruments at Uraniborg. Tycho argued that the device, later called 'nonius', was difficult to fabricate and use and abandoned Nunes' proposal replacing it by the diagonal scale. After the Danish astronomer only a couple of historical examples of the 'nonius' have been found raising serious doubts about the practical success of the invention. The second case refers to an intricate device to read angular scales conceived by Jesuit astronomer Orazio Borgondio (1675-1740), chair of mathematics in the Roman College. In 1720 Borgondio published his new technique in the 'Mémoires des Trévoux'. At least one 4-palm quadrant with Borgondio's reading device was produced by Domenico Lusverg, around 1724, and used by the Jesuits in Lisbon, but no later examples are known.

Luís Tirapicos studied astronomy in the University of Porto and history and philosophy of science in the University of Lisbon (MA, 2010; PhD, 2017). He is a researcher at the Interuniversity Centre for the History of Science and Technology in the Faculty of Sciences of the University of Lisbon. His main research interests are the history of astronomy in Portugal and Spain, Jesuit science, Iberian archaeoastronomy and the material culture of science. In early 2010 he was a research intern in the History of Science and Technology at the Royal Observatory – National Maritime Museum, Greenwich, and in the fall of 2013 a Resident Fellow of the Linda Hall Library in Kansas City (MO). As one of the authors of the Biographical Encyclopedia of Astronomers (Springer, 2014), edited by Thomas Hockey, he received the 2017 Donald E. Osterbrock Book Prize for Historical Astronomy, awarded by

the American Astronomical Society. He is also a Contributing Editor to Isis Current Bibliography.

Razieh S. Mousavi
Failure of the Complexity to Success of Simplicity: The Example of Qibla-Indicators

Following the establishment of the Safavid empire in Iran at the early sixteenth century, mathematicians found themselves in a threatened position. Religiously-oriented policy of the Safavids allowed Shiʿi legal scholars to undertake official positions at their courts. This new class of religious authority began to claim control over the Muslim community in many aspects under the court patronage. Finding the direction of Mecca (*qibla*) and timekeeping practices which were previously supervised by the mathematicians and astronomers, did not escape their notice. In the case of the qibla determination, they spread folk astronomical practices whose simplicity seemed to them more adaptable to the Islamic tradition. Moreover, the complex methods of the mathematicians came under attack and were condemned to be misleading and unapproachable to ordinary people. In response, the mathematicians, whose reputations were at risk in the Muslim community, appealed to the design and construction of new instruments for finding the holy direction.

The advantage of an instrument was the fact that the sophistication and abstraction of mathematical operations could be masked well behind the functionality and mechanism of a tangible object. On the way to reach this goal, generations of mathematicians devised and refined diverse qibla-indicators whose story of failure and success is the subject of this study. I will follow the thread of improvement along the history of evolution of qibla-indicators and see how instrument-makers analysed their faults and upgraded their products by offering attractive instruments in sizes, shapes, simplified functions, and multi-purpose applications. This study is also a window to observe how complex mathematical instruments for qibla-finding like astrolabes and quadrants shifted progressively towards today's user-friendly ad hoc tools which work literally as input-output calculators.

Razieh Mousavi is a doctoral candidate in history of science at the Humboldt University of Berlin. Her dissertation focuses on an Arabic astronomical treatise titled the Elements of Astronomy by the renowned ninth-century scholar, al-Farghānī (Alfraganus). The overarching goal of her research is the investigation of textual forms as mobile carriers of different practices of historical epistemology. Her study is supported by SFB 980 Project in Germany entitled "Episteme in Motion, Transfer of Knowledge from the Ancient World to the Early Modern Period". Holding a BSc in pure mathematics and an MA in history of science from the University of Tehran, Ms. Mousavi is currently a predoctoral fellow at the Max Planck Institute for the History of Science in Berlin. In general, she is interested in the history of Mathematical and astronomical instruments in the Islamic tradition and exploring geometrical and graphical knowledge as employed by medieval scholars for modelling the configuration of the universe.

Jane Wess
Black and White Images Produce a Grey Area of Failure: The Photo-Theodolite at the Royal Geographical Society in the 1920s.

This talk argues that success or failure cannot be judged except in context, and only with the benefit of hindsight. Instruments are rarely totally successful or a total failure in the field. The constraints on their use depend on the logistical abilities of their users to manoeuvre them, obtain repairs if necessary, process results numerically or otherwise, and the instrument's

ability to function in various climates. This talk will look at the case of the Wild phototheodolite purchased at great cost by the RGS in 1925. It will demonstrate the particular requirements, not always satisfied, of new techniques which stretch the resources of expeditions sometimes to breaking point.

The photo-theodolite, a combination of a transit theodolite and camera, was an expensive instrument requiring back-up. While earlier versions of the instrument in principle are well-known, the Wild company is justified in seeing the development in the early 1920s of their universal theodolite to be a revolutionary step. Not until 1925 was the RGS able to examine the new instrument when it was decided that it should be purchased for £98 10s. It arrived in January 1926. A comprehensive technical description of it was given in the Journal as the instrument was thought not to be familiar to readers. While the photo-theodolite cost about £100, the stereo-cartograph, a necessary component of the process which reduced the results, cost £2400, so collaboration was required. The RGS had to request the use of the stereo- cartograph at Flums in an example of increasing reliance on international co-operation.

Steers was the first RGS-sponsored traveller to use the instrument for an expedition to Australia, specifically to survey the Great Barrier Reef in 1928, as previous to this the phototheodolite was lent to the War Office. Steers' diary reveals difficulties not recorded in the published account of the following year. The paper will look at these difficulties arguing that a new technology requires logistical support that was not available, and for this reason has to be regarded as a failure, although the ambition was a worthy one, and phototheodolites were made in increasing numbers in the following decade, and came into their own after WW2.

I was a curator at The Science Museum, London from 1979 until 2012. I looked after most of the physics collections, Weights and Measures, Mathematics, Science Teaching and the King George III Collection. I published a catalogue of the King George III Collection with Alan Morton in 1993. Since then I have written on many aspects of the history of science and mathematics with a particular focus on instruments. Recently I acquired a PhD studying the use of instruments by the Royal Geographical Society in the long nineteenth century. My major project now is a chapter on mathematics and technology in the eighteenth century for a collaborative multi-volume work on the social history of mathematics.

David Bryden

Finding Way at Sea – alternatives to the log-line and sandglass: conservative navigational practice or technological failure?

It is a measure of the perceived inadequacies of navigation by dead reckoning, that during the Hanoverian age, a significant number of instrumental designs were proposed for finding a ship's way. My study of English Patents of Invention includes a number of such designs – as do the papers of the Board of Longitude, the archives of the Society of Arts, and other sources. The paper will outline the range of design proposals, indicating those that were given sea trials, with various degrees of success reported at the time. Nevertheless the conventional navigational custom and practice of casting the log was not replaced. There was at best the odd, but limited short-term commercial success for the mechanical log during the age of sail. Were designs unsound in principle? Was the available technology inadequate? Were mariners inherently conservative?

David Bryden worked for four decades in various national and university museums in Edinburgh, London and Cambridge. In 'retirement' he is drawing to a close a detailed study of English patents as design evidence in the development of scientific instrument manufacture in the Georgian era. A comparative study of submissions to the Society for the Encouragement of Arts, Manufactures and Commerce was published in 2019 as a monograph by the William Shipley Group for RSA History (ISBN978-0-244-20311-5).

Paolo Brenni
The illusory forecast: the rise and fall of ceraunographs

At the end of the 19th century, several scientists and inventors proposed different apparatus for producing and detecting electromagnetic waves. These researches marked the birth and triggered the development of wireless telegraphy. However, it was also discovered that electric discharges produced by far thunderstorms could be detected by various type of coherer. In a few years several ceraunographs and electrographs, which were kind of wireless receivers for recording lightning, appeared in the scientific journals and in the catalogues of instrument makers. Optimistically it was believed that these apparatus could provide forecasts of the trajectory of thunderstorms by detecting and registering electric atmospheric discharges. These forecasts would have been extremely important for navigation and for agriculture.

However, after a few years of enthusiasm, it was possible to statistically study the data produces by ceraunographs and it was discovered that they were not at all precise. Coherers were temperamental and quite erratic devices: They did not always react to lightning but sometimes they reacted to much weaker electrical disturbances produced by local apparatus. By circa 1920, it was generally accepted that registrations produced by ceraunographs and similar apparatus were not trustworthy. Finally, these instruments, after having nourished great hope for a few years, were completely abandoned.

Paolo Brenni (born in 1954) studied experimental physics at the University of Zürich, where he graduated in 1981. He then specialised in the history of scientific instruments and of precision industry in the period from the beginning of 18th century to the mid-20th century. He is researcher for the Italian CNR (National Research Council) and collaborates for the Fondazione Scienza e Tecnica and the Museo Galileo in Florence and with several other European and American institutions. He studied, restored and catalogued several collections of historical instruments both in Italy and abroad. Between 2002 and 2013 he was president of the Scientific Instrument Commission of the IUHPS and since 2005 is president of the Scientific Instrument Society.

Michelle Mercier
Thomas Young's Eriometer: Wrong time, wrong inventor, wrong users…?

Thomas Young is widely known for the double-slit experiment. Almost unknown—even today—is an instrument that he invented and which was a practical application of his optical investigations on diffraction: the eriometer.

Young, a physician and physicist, claimed to be able to analyze the diameter of small fibres and particles with this instrument, and he offered several applications for it. The instrument was well suited for measuring the diameter of wool fibres – hence the name (*erios* is the Greek word for wool). He also advocated for the use of the eriometer in a medical context: The eriometer could tell whether there were blood cells included in pus or not, because the cells would produce a diffraction pattern due to their similar dimensions, whilst pus does not.

The instrument could be constructed with simple materials such as a card of paper and a piece of cord. Although practical experiments showed that Young's measurement method could, with experience, give precise enough results, this instrument did not become established at all. Young's poor reputation as a physicist was a handicap to his invention, which depended on his wave theory of light. He had failed in establishing the physical basis of this instrument a few years before. In addition, the users were only able to see diffraction patterns (not the samples themselves), and the physical reasons for their generation were hard to understand.

In London, I was able to identify two surviving eriometers by Young. One was part of a letter to Joseph Banks (1810). Another one is in the collection of the Royal Institution. In this paper, I will discuss those two objects and turn the attention to a failed instrument, which may have been unsuccessful primarily due to social reasons: wrong time, wrong status of its inventor, and wrong users.

I studied mathematics and physics at the Europa-Universitaet Flensburg. During my study, I dealt with the history of physics including Kundt's Tube from 1868 (about which I presented a paper at the SIC meeting in Havana) and the Thermoscope by Rumford. Now I am working as a postgraduate at the Europa-Universitaet Flensburg in the section of physics, its didactic and its history. In my dissertation, I analyze the experiment that is nowadays canonized as Young's double-slit experiment (1807). Young's account still leaves unanswered many questions about the experimental and theoretical significance - i.e. how this historical experiment had been performed, in which context and therefore the phenomenon itself. Hence, we do not know much about the historical role of the experiment, especially for Young. By using the replication method, I am analyzing the experimental and conceptual genesis of Young's double-slit experiment from 1807.

Jean-François Loude
The Diffusion Hygrometer: a commercial failure

The diffusion of gases, dry and moist, had been studied in 1874 by Louis Dufour (1832-1892), physics professor at the Academy of Lausanne (Switzerland). He observed a pressure difference across a porous wall separating moist air and a vessel containing either water or a desiccant. A long period of almost complete oblivion followed. Heinrich Greinacher (1880-1974) is best known for his Voltage Doubler (1914) and his Cascade Voltage Multiplier (1920), re-invented in 1932 by Cockroft and Walton. In 1944, then physics professor at the University of Bern (Switzerland) and Director of the Meteorological Observatory of this city, Greinacher became interested in instruments to measure the atmosphere moisture content. He re-rediscovered the Diffusion Hygrometers, claimed to have built the first one, proposed a theory and even got a patent for it. In the course of the 1950s, two different models were produced by young firms of Lausanne, Rüeger and TESA (in the UK, available from Rototherm). We found one exemplar of each maker in the collections of our Physics Museum. They are both very well made, with the TESA model

particularly attractive and convenient to use. We have tested them and compared their performances with the then currently available hygrometers. Eventually, the Diffusion Hygrometers were a commercial failure. Their drawbacks (periodic water refill, indoor use only while fastened to a wall, exaggerated claims of high accuracy, etc.) were too numerous. Actually, they were not better than good Hair Hygrometers. It's difficult to explain why Greinacher put so much energy promoting his device. And eventually, from 1965, progress in electronics made possible novel types of hygrometers, more convenient to use. Nowadays the Diffusion Hygrometer only deserves, at best, short mentions in books about hygrometry.

I studied Physics engineering at EPUL and got my Ph.D from the École polytechnique fédérale at Lausanne (EPFL) in 1969, specialising in nuclear physics. After two years at SIN (now PSI, Villigen), I returned to the Institute for High Energy Physics of the University of Lausanne (UNIL). I collaborated on high-energy physics experiments at SIN and CERN, developing particle detectors and associated electronics. I was also teaching electronics for physicists and lecturing about particle detectors. Associate professor from 1981, I retired in 2002, when physics was transferred from UNIL to EPFL. I authored or co-authored many papers about experimental aspects of nuclear and high-energy particle physics, high-Tc superconductivity and PET. Now, as an emeritus professor hosted at EPFL, I started a new career centred on the history of old physics instruments. I inventoried the instruments kept at UNIL, exhibiting the most interesting ones in a small museum (http://museephysique.epfl.ch). I have been assembling a large documentation, visiting many scientific and technical museums, attending several SIC Symposiums and presenting and writing papers. For a complete list, see my Web page: https://search.epfl.ch/?filter=publications&q=Loude .

Andreas Junk
The Transmission X-Ray Microscope - supermicroscope for biology or yet another niche instrument?

The concept of the transmission x-ray microscope (TXM) was inaugurated in the scientific community by Schmahl and Rudolph in 1967. They devised a microscopical setup based on Fresnel zone plates which would be able to make images even of biological specimens in the region of the water window between 2.5 and 4.5nm. Such a microscope would have overcome the paradigm of the "unfocusable X-rays" and also would have been a super microscope for biology, being able to convey 3D information of thick samples of a few micrometers.

The development allegedly started after a symposium on the use of holographic techniques as devised by Denes Gabor. Schmahl and Rudolph, then assistants at the university observatory Göttingen, fabricated the first zone plates in their spare time using laser light. A zone plate telescope carrying such zone plates was used as a test environment for the production procedure. After successfully making images of the sun's x-ray spectrum, the fabrication techniques were enhanced to make lenses for a microscope.

Although the setup of the TXM was completed and tested by the late seventies, the results from the images did not convince biologists to use the new instrument. Even after the completion of a series of images of malaria infected red cells, the instrument was not recognised as being necessary or paramount for research in the life sciences. Schmahl and Rudolph did receive quite a few prizes for the development, yet they were unable to get the life sciences to show considerable interest in the instrument. It seems, biologists rather stuck to their traditional methods of research because the information gained in addition by using

the TXM didn't seem to be worth while. Today the TXM is used at various synchrotron storage facilities in the field of material research.

I was trained as an experimental physicist and finished my studies at university in the field of laser-assisted catalytic research (University of Münster, Germany 1999). I switched my focus to history of physics for the subject presented, which was also the subject of my PhD thesis at the University of Oldenburg, Germany. The dissertation was finished in 2009, thesis advisor was Prof. Falk Riess. At present, I am a lecturer in the working group for Physics, its Teaching Methods and History at the University of Flensburg. My focus of research still lies in the field of optics with an emphasis on the development of instruments for stereoscopic imaging. In addition I am interested in unravelling the myths of nanotechnology and the alleged link to Richard Feynman and the historical approaches of John William Strutt to facilitate the construction process of fresnel zone plates in the late 19th century.

Nicolàs de Hilster
Failures, an instrument maker's perspective

In the past two SIC conferences discussions were held and papers presented on "scientific instruments that failed" or "failed instruments" in short. With this third SIC conference discussing the failures again it is about time to have a closer look at what a "failed instrument" actually is. The subject is approached from an instrument maker's point of view, using three examples: two instruments from my own workshop and the Hubble Space Telescope. The creative process is discussed and dissected into various stages, showing that never a single instrument is created, but that each stage results into an instrument, albeit a virtual one in most stages. And as the creative process is circular the concept "failed instrument" is hard to maintain. The "failed instrument" concept is further challenged by looking at it from a second point of view. Instead of looking at it from an instrument maker's point of view it is assessed by looking at it from an observational point. Finally, alternatives are given for what really failed on a "failed instrument".

Nicolàs de Hilster is a researcher of instruments and methods for navigation, hydrography and geodesy. PhD in the history, construction, development, use and accuracy of early modern instruments for celestial navigation at the Vrije Universiteit, Amsterdam, 2018. Amateur astronomer and Dutch representative of the Scientific Instrument Society (SIS). Member of the editorial board of De Hollandse Cirkel, the bulletin of the Dutch society for the awareness and preservation of Dutch geodetic heritage.