INTERNATIONAL
SPACE
SCIENCE
INSTITUTE

SPATIUM

Published by the Association Pro ISSI

No. 50, October 2022

Cosmographia Bernensis

ISSI's place in the history of Bernese cosmography

50

Editorial

Omnium rerum principia parva sunt.

Marcus Tullius Cicero, philosopher and politician in ancient Rome, knew that the beginning of all things is inconspicuous. This is also true for *Spatium,* whose 50th issue we are proud and pleased to present to you today. This anniversary gives us an opportunity to pause a little and remember with gratitude the personalities whose visions laid the foundation for the exact sciences in Bern and thus also for the ISSI. With their exciting "Cosmographia Bernensis", Anuschka Pauluhn and Andreas Verdun present this history on the following pages.

The beginning of our *Spatium* is also inconspicuous. We find this beginning in a brief remark made by Peter Creola at the meeting of the ISSI Foundation Board in autumn 1997, pointing out that although the Institute's scientific publications have gained a great deal of resonance in the international research community, this does not give ordinary citizens access to the Institute's programmes. With a popular science publication, ISSI should give the interested layperson an insight into the fascination of space research. Johannes Geiss immediately took up this idea, appointed Hansjörg Schlaepfer as editor and also offered him to write the content for the first issue. The name *Spatium* was to be the programme, a name that would briefly stand for the broad horizon intended of the new publication.

With his report "Entstehung des Universums", Johannes Geiss had provided *Spatium* with momentum and appeal, and so it was easy for the editor to invite other prominent scientists to give lectures for Pro ISSI and thus guarantee the further success of *Spatium*. The first issues appeared in German because the Swiss audience was the main focus at the time; however, it soon became apparent that the publication could also appeal to the growing number of scientists from all over the world who visited ISSI. Therefore, *Spatium* soon switched to English. A largely unnoticed moment in the history of *Spatium* came when ISSI Beijing launched the first issue of *Taikong*, a sister publication, so to speak, with similar objectives as *Spatium*. Furthermore, issue 41 in May 2018 marked a significant milestone when a newly assembled editorial team of three presented their first *Spatium*.

Spatium has now become an integral part of ISSI's publications, and one can note with satisfaction that it successfully brings the allure of space research to a wider audience and hopefully also helps facilitating the entry of a younger generation of researchers into this scientific field, which is so important for Switzerland. My heartfelt thanks go to all those who contribute to the success of *Spatium,* to the speakers presenting their fields of activity with great enthusiasm and to the many readers around the world, whose interest is the raison d'être of *Spatium*.

Hansjörg Schlaepfer
Brissago, October 2022

Impressum

ISSN 2297–5888 (Print)
ISSN 2297–590X (Online)

Spatium
Published by the
Association Pro ISSI

Association Pro ISSI
Hallerstrasse 6, CH-3012 Bern
Phone +41 (0)31 684 48 96
see
www.issibern.ch/pro-issi.html
for the whole *Spatium* series

President
Prof. Dr. Christoph Mordasini
University of Bern

Editors
PD Dr. Andreas Verdun
CH-3086 Zimmerwald

Dr. Anuschka Pauluhn
CH-5237 Mönthal

Printing
Stämpfli AG
CH-3001 Bern

Title Caption
Comet Donati at its 1859 appearance observed in the evening sky over Bern. Drawing by R. Kiener, 1859. (Credit: AIUB)

Cosmographia Bernensis

ISSI's place in the history of Bernese cosmography

Anuschka Pauluhn and Andreas Verdun

The term cosmography was coined during the 16th century, particularly by the works of Peter Apian (1495–1552) and Sebastian Münster (1488–1552). It has two distinct meanings: traditionally it has been the protoscience of mapping the general features of the Cosmos, i. e., Heaven and Earth; more recently, it has been used to describe the ongoing effort to determine the large-scale features of the observable Universe. Similarly, the research at the International Space Science Institute (ISSI) is interdisciplinary including all fields of research to describe the "Cosmos" observed from Earth and from space. ISSI is situated in Bern since its foundation in 1995. This happened not by chance. Bernese cosmography has a long-lasting tradition. The goal of this 50th issue of *Spatium* is to outline ISSI's place in the history of Bernese cosmography.

1. Early modern science in Bern

The disciplines of early modern exact science associated with cosmography, e. g., astronomy, geodesy, and mathematics, were not yet established on a sophisticated level in Bern from the 16th to the middle of the 18th century. Astronomy was still intertwined with astrology, "geodesy" was limited to surveying, and mathematics did not exceed fundamentals in arithmetic, algebra, and geometry. Scientific activity consisted, if at all, of adopting established main stream knowledge. Writings printed in Bern or published by Bernese authors comprised almanacs and calendars, mostly mixed with astrological prognostics, broadsheets on celestial phenomena as rainbows, halos, comets, and bright meteors, as well as arithmetic school books and treatises on commercial computing. There are, however, some few outstanding works relevant for the history of Bernese cosmography. In 1556, Benedicht Marti (1522–1574), also named "Aretius", published his "Brevis cometarum explicatio" **(Figure 1)**. He studied theology, botany, mathematics, and astronomy, and was a student of Johannes Dryander (1500–1560), a famous manufacturer of astronomical instruments. His library, containing works by Nicomachus, Sacrobosco, Regiomontanus, Peter Apian, and Orontius Fineus, is still preserved in the University Library of Bern. The "Brevis cometarum explicatio" is one of the first catalogues of comets ever published. Therein, Marti describes 72 appearances of comets as well as his own observations of comets, sometimes recorded in his own hand.

Fig. 1: Title page of "Brevis cometarum explicatio", published in 1556 by Benedicht Marti (Aretius) in Bern. (Credit: UB Bern, MUE H XXVII 332)

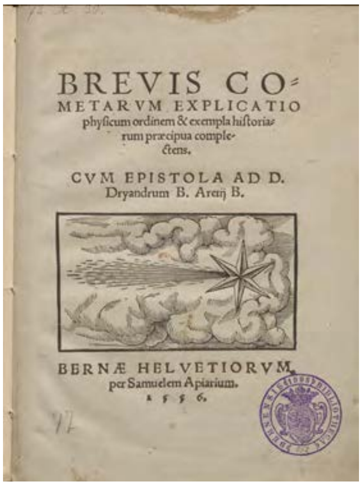


Fig. 2: Engraved large copper plate added to the treatise "Der bedenckliche Janus", published in 1665 by the Bernese printer and publisher Georg Sonnleitner. It shows the path of the comet of 1664/65 through the constellations as well as a halo phenomenon. (Credit: UB Bern, MUE Rar alt 4452:2)

Figur
der
Erden,
beſtimmet durch die
Beobachtungen
der Herren von Maupertuis, Clairaut, Camus,
le Monnier, von der Academie der Wiſſenſchaften,
und des Hrn. Abts Outhiers, Correſpondents
der gleichen Academie,
In Begleitung des Herrn Celſius,
Profeſſor in der Aſtronomie zu Upſal,
Auf Ordre des Königs beym
Polar-Zirkel
angeſtellet.
Durch Hrn. von Maupertuis.
Aus dem Franzöſiſchen überſetzt, und mit Hrn.
Celſius Unterſuchung der Caſſiniſchen Meſſungen vermehret.

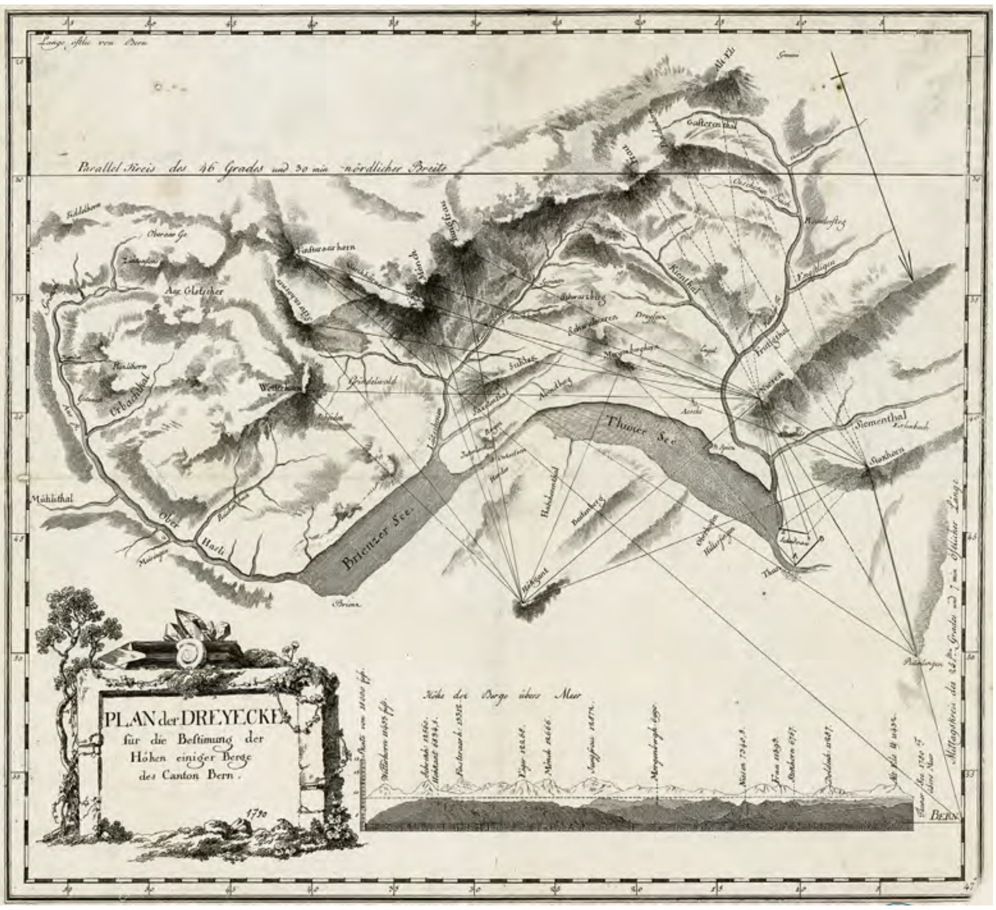
Zürich, bey Heidegger und Compagnie. 1741.

Fig. 3: Title page of the 1741 German edition of Maupertuis's "Figure of the Earth", translated by König. (Credit: Library of A. Verdun)

Fig. 4: Theodolite used by Tralles for measuring the mountains of the canton of Bern. (Credit: UB Bern, MUE H I 147)

Even in the 17th century, comets were still considered as scary phenomena often described with bad connotations and astrological interpretations. Also the comet of 1664/65, as described in the book titled "Der bedenckliche Janus" and published in 1665 by the Bernese printer and publisher Georg Sonnleitner, was attributed with such kind of meanings. Attached to this book is a large engraved copper plate showing the path of this comet through the constellations along with a halo phenomenon **(Figure 2)**. All these works on comets are closely related to observational astronomy. Theoretical or mathematical astronomy was represented by the works of Johann Rudolf von Graffenried (1584–1648) and Jakob Rosius (1598–1676). Both authors became widely known beyond the borders of the canton of Bern, the former by his books on arithmetic and particularly by his treatise "Compendium Sciotericorum" published in 1617 and (heavily enlarged) in 1629 on the construction of sundials and astronomical instruments, the latter by his numerous calendars and almanacs published yearly on a regular basis.

Fig. 5: Tralles' triangulation network for measuring the canton of Bern. Note the baseline at Thun. South is up. (Credit: UB Bern, MUE H I 147)



These works did not hide the fact that "science" was dominated by dilettantes at that time. The situation changed drastically during the 18th century, when mathematics and natural philosophy became more and more institutional disciplines at the University of Bern, and when scientific work went over to professionals. Moreover, the driving force which pushed the exact sciences in Bern to a high level of research was an emerging discipline joining both mathematics and astronomy to a new field, namely geodesy. Triggered by the empirical findings on the flattened shape of the Earth resulting from the expeditions sent to Lapland and South America, Pierre Louis Moreau de Maupertuis's (1698–1759) famous report published in 1738 in French was immediately translated into several languages, among others into German **(Figure 3)** by the son of the Bernese theologian and mathematician Samuel König Sr. (1661–1750). He was the first full professor for mathematics at the University of Bern and became well known in history of science by his son Samuel König Jr. (1712–1757), who ignited the famous quarrel on the discovery of the principle of least action, involving among others Maupertuis and Leonhard Euler (1707–1783). In 1785, Johann Georg Tralles (1763–1822) was appointed professor for "Matheseos et Physicae Experimentalis" at the University of Bern. Four years later, in 1789, he started with his works for surveying the Bernese Alps and the canton of Bern with the goal to extend these measurements for whole Switzerland. He published his projects and first results for a geodetic and topographic national survey in 1790 and the following years **(Figures 4 and 5)**.

Johann Friedrich Trechsel (1776–1849), student and successor of Tralles, continued these projects in the framework of the "Carte de France" initialized by the Académie des sciences. Trechsel decided to establish a fundamental place (a former ammunition depot) in Bern used as origin for setting up and establishing a triangulation network which enabled visual connections to sights situated on Jurassic mountains. Along with the French engineering geographers Henry and Delcros he founded in 1812 a primary station ("Station primaire") on the top of the bastion "Hohliebi", which was part of the fortification of Bern **(Figures 6 and 7)**. The cottage may already be identified on a city map of Bern published in 1807 **(Figure 8)**.

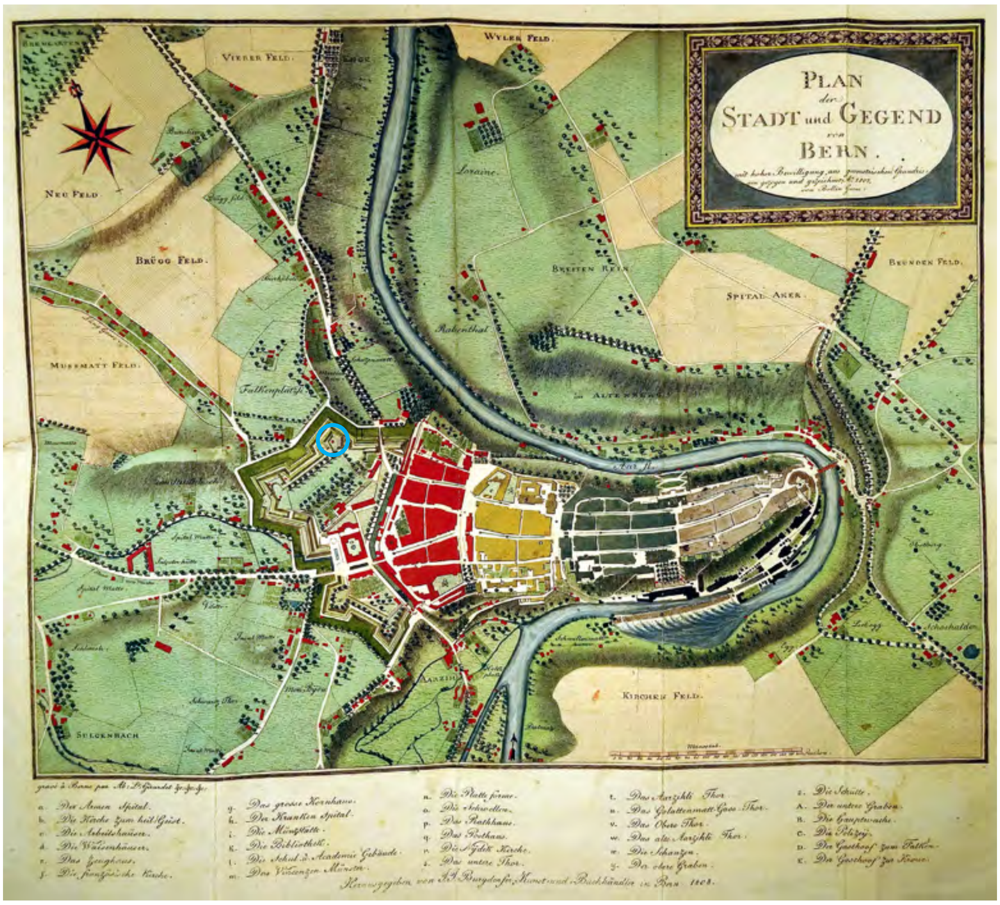

46

Station primaire
de
l'Observatoire de Bern
Campagne de 1812

Fig. 6: Geodetic measurement report documenting the foundation of the primary station in 1812. (Credit: IGN, cai48 paq2 car46)

Fig. 7: The bastion "Hohliebi" (on the right hand side of the image) as part of the fortification of Bern. (Credit: SNB, GS-GUGE-SCHIEL-B-2)

Fig. 8: City map of Bern drawn by Bollin in 1807 showing the cottage (encircled) which became the primary station of the geodetic national survey. (Credit: Library of A. Verdun)



2. Bern's "Uraniae"

"Uraniae" was the name of the first Bernese astronomical observatory founded by Trechsel in 1822, devoted to the goddess "Urania", who was, in Greek mythology, the daughter of Zeus by Mnemosyne and also a great granddaughter of Uranus, as well as the muse of astronomy. The octagonal stone house contained, among other astronomical instruments and clocks, a meridian circle mounted exactly at the fundamental point defined in 1812 by the "Station primaire" which became the origin of the national coordinate system used for the Dufour map **(Figure 9)**. The whole western fortification was successively removed during the 1830s so that only the observatory remained on a hill that resulted from the dismantling of the bastion "Hohliebi" **(Figures 10 and 11)**.

Johann Rudolf Wolf (1816–1893) took over the observatory from Trechsel as its new director in 1847. Trechsel gave him a Daguerrotype of the observatory taken in 1845 by the Bernese veterinary physician Friedrich Andreas Gerber (1797–1872), a pioneer of photography. It is probably the oldest photograph ever taken of an astronomical observatory building **(Figure 12)**. The observatory was in a bad condition and equipped with out-of-date instruments **(Figures 13 and 14)**. Until his appointment to Zurich in 1855, Wolf successfully managed to enlarge the observatory in two steps. In 1848, the observatory building was extended along the south-west and north-east direction, and in 1853/54, the cupola was removed and a cylindrical tower supporting a rotatable dome was added close to the west side of the main building **(Figure 15)**. This second rebuilding

Fig. 10: Map of the western part of Bern drawn by Piseux in 1838 showing the remaining fortification with the bastion "Hohliebi" and the observatory. (Credit: StABE, AA IV 1651,1)

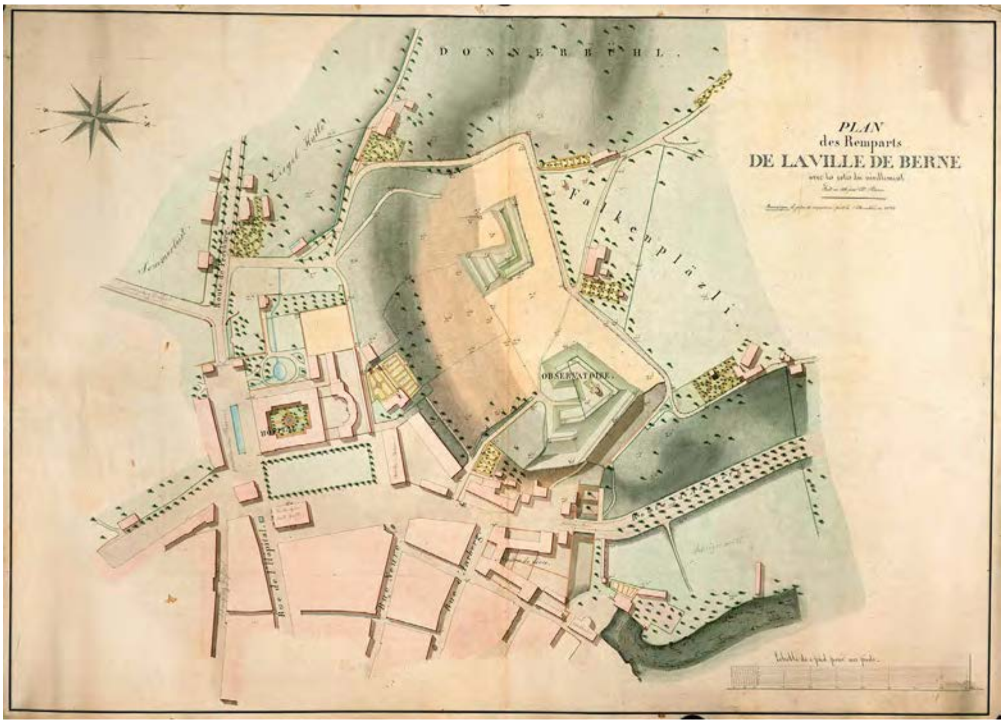


Fig. 9: The observatory "Uraniae" shown on a lithography by Burgdorffer published in 1822. (Credit: UB Bern, J1 BeM ZB Nat XI 68:1)

Fig. 11: The observatory "Uraniae" on the top of the hill which resulted from the dismantling of the bastion "Hohliebi" (part of the Bernese fortification) in 1844. (Credit: StABE, AA IV 1661 [cutout from the right hand side marginal drawing])

was caused by the need of regular time determinations required for the newly installed telegraph system introduced in Bern by Steinheil as well as for the regulation of the clocks mounted in the then newly built railway station of Bern. For that end a new meridian circle made by Ertel in Munich was installed in the meridian hall of the observatory. The dome housed a refractor made by Fraunhofer and Utzschneider in Munich. Using this telescope Wolf observed the sunspots systematically. In combination with the analysis of historic observations of the Sun, he discovered the 11-year solar cycle in 1853 **(Figure 16)**.

Heinrich von Wild (1833–1902) became appointed professor for physics and astronomy of the University of Bern in 1858.

Fig. 12: Daguerrotype of the observatory “Uraniae” made by F. A. Gerber in autumn/winter 1845. The view is from the west side, so that the meridian slit is not visible. The cupola was used as planetarium. (Credit: Library of the ETHZ, KGS-454-0)

Fig. 15: Ground plan of the observatory hill and the building “Uraniae” in 1848. The two quadratic extensions to the hexagonal building can clearly be identified on the cutout image. West is up. (Credit: StABE, AA VIII II 67a)

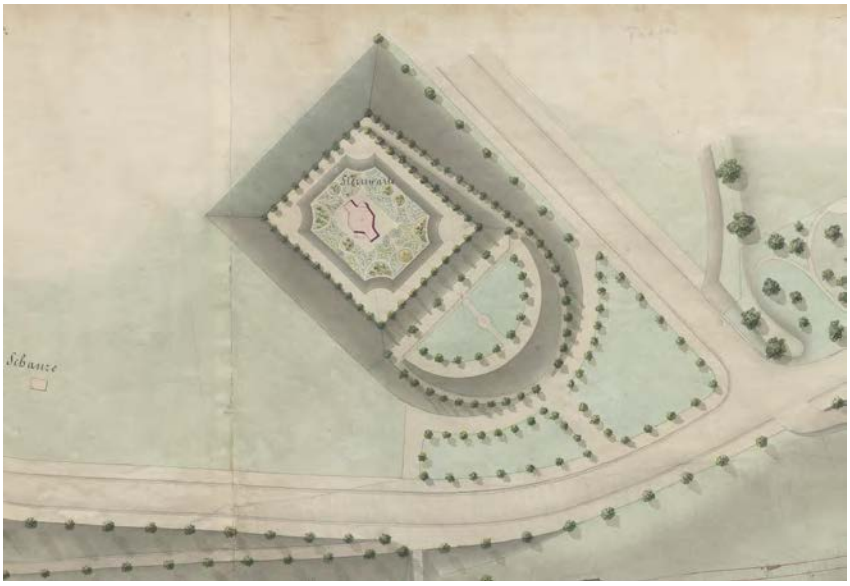


Fig. 13: Gregorian reflector made by Short, London, 1764. This telescope was used at the observatory “Uraniae”. It is well preserved and archived at the Physics Institute of the University of Bern. (Credit: PIUB, Photo A. Verdun)

Fig. 14: Keplerian refractor made by Dollond, London, about 1780. This telescope was used at the observatory “Uraniae”. The objective lens is broken but still in its original lens mount. This telescope is archived at the Physics Institute of the University of Bern. (Credit: PIUB, Photo A. Verdun)

Fig. 16: Sunspot observations published by Rudolf Wolf. He discovered the 11-year solar cycle in 1853. (Credit: Library of A. Verdun)

He was director of the observatory from 1862 to 1868, when he left Bern and accepted a position in Russia, where he built up and established the Russian meteorological central station. He transformed the astronomical observatory of Bern into a meteorological central station. For that end he constructed and manufactured self-recording meteorological instruments (a novelty at the time) which he installed on the platform of a new extension of the observatory which was built in 1861 according to his own plan **(Figure 17)**. As a consequence, the astronomical observations were reduced to a minimum, as the observation journal, started in 1859 by Wild, proves **(Figure 18)**. The observatory and its meteorological instruments installed on the new platform may be identified on photographs taken between 1864 and 1868 **(Figures 19, 20 and 21)**.

Fig. 17: Wild's plan for the extension of the observatory and its transformation into a meteorological central station. This enlargement was built in 1861. (Credit: StABE, BB IIIb 652)

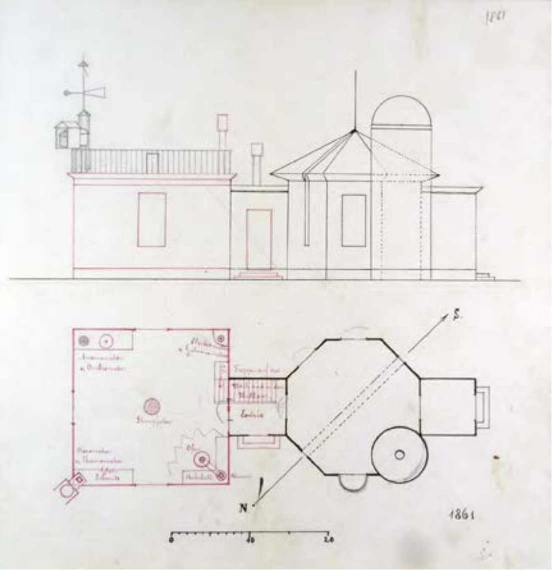
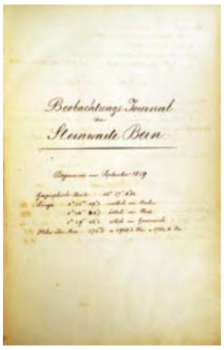


Fig. 18: Title page of the observation journal started by Wild in September 1859. (Credit: AIUB)



Beobachtungs Journal
der
Sternwarte Bern

Fig. 20: The observatory of Bern at the top of the remaining hill of the bastion "Hohliebi" viewed from a building in the south of the railway station taken in 1865. The roofs of the "Burger" hospital (left corner) and of the railway station (bottom right) are also displayed. (Credit: EAD, EAD-144661)

Fig. 21: The observatory of Bern viewed from the northern side taken by the Bernese photographer Vollenweider in 1868. In front of the observatory is a new small building, and on the left hand side there is a small wooden meteorological station. (Credit: Library of A. Verdun)

Fig. 19: The observatory of Bern viewed from a building in the south of the railway station taken in 1864. This image is a very small cutout of a photograph documenting the demolition of the Christoffel Tower (part of the fortification of Bern) in 1864. (Credit: BBB, FP.E.78)

3. The "Telluric Observatory"

The successor of Heinrich von Wild was Aimé Forster (1843–1926). He was appointed professor for physics and meteorology at the University of Bern in 1869 and became director of the observatory in 1871. His field of research was geophysics, which is why he proposed the transformation of the astronomical/meteorological observatory into a "Telluric Observatory" in 1874. Already in 1876, the old observatory of Bern was demolished and the much larger Telluric Observatory was built exactly at its place as first geophysics and physics institute in Bern **(Figure 22)**. To enlarge the ground area, the height of the observatory hill was reduced by the half. The new building contained laboratory rooms, a workshop, a lecture room, a meridian hall, an astronomical tower bearing the dome and a meteorological tower for the meteorological and geophysical instruments, and – last but not least – the official residence for the director **(Figure 23)**. The total costs for building this Telluric Observatory were tremendous, but finally accepted by the political institutions. The dome housed the Fraunhofer refractor, which actually belonged to the Realschule Bern. However, this telescope was never used at its new dome. It existed there in a very bad shape until at least 1935, afterwards its tracks covered. The Telluric Observatory never reached the expected status of a scientific beacon. As a geophysical observatory situated in the center of the city of Bern, the sensitivity of the instruments could not be exhausted to their limits due to small terrestrial vibrations (caused by railway traffic), due to atmospheric and magnetic turbulences, and due to thermal effects. Only heavy earth-quakes were registered from time to time. The most important scientific output of this observatory consisted in the meteorological observations recorded on a regular (subdaily) basis comprising all relevant meteorological parameters.

When Rudolf Wolf in Zurich was informed about the demolishment of the old observatory, he successfully advocated for preserving the reference point as origin of the national cartographic coordinate system represented by the meridian circle installed in the old observa-

Fig. 22: Plan of the front side of the Telluric Observatory or Physics Institute, dated 25 November, 1875. Note that there were slight differences between this plan and the realized building, e.g., the extension on the right hand side of the main building does not correspond to the meridian hall as displayed on the photograph of Figure 23. (Credit: StABE, AA III 907, 1)

Fig. 23: Photograph of the new Observatory or Physics Institute of the University of Bern taken before 1880, showing the large lecture room on the left hand side of the two-story main building, the meridian hall at its right hand side, and the two towers, the squared one used for meteorological/geophysical observations and the round one carrying the dome used for astronomical observations. (Credit: BBB, FPa.10 Nr. 46)

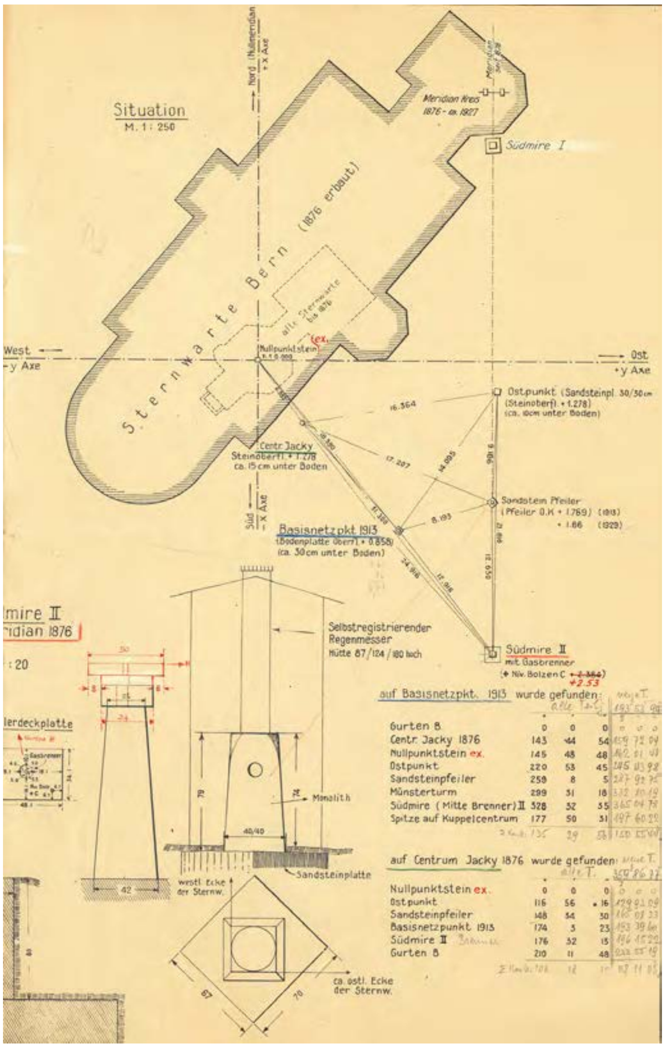
tory. Before the beginning of the demolishment, the exact place of this origin was trigonometrically measured against auxiliary reference marks outside the structure of the building. The meridian circle was then revised and mounted in the meridian hall of the Telluric Observatory in 1877/78 **(Figures 24 and 25)**, so that its displacement was very precisely known. In order to calibrate its position, three targets (so-called mires) were installed, one of them as collimator placed directly in front of the meridian hall, two others in distances up to about 50 metres in southern direction **(Figures 26 and 27)**. However, no systematic observations of any scientific value were performed with this instrument. The meridian circle was lent to the Bernese Historical Museum in 1927, where it is preserved until now. In the 1930s, the slit of the meridian hall was walled up.

Fig. 24: The meridian circle by Ertel remounted in the meridian hall of the Telluric Observatory in 1878. (Credit: AIUB)

Fig. 25: The two pillar mount of the meridian circle by Ertel in the meridian hall of the Telluric Observatory in 1878. (Credit: AIUB)

Fig. 27: The collimator mire in front of the meridian hall of the Telluric Observatory in 1931. (Credit: swisstopo)

Fig. 26: Ground plots of the old and the telluric observatory (top). The origin of the national coordinate system defined by the "Station primaire" was trigonometrically measured against reference points set outside the observatory structures by special targets (so-called mires) which also were used to calibrate the alignment and position of the meridian circle. The small cottage housing a lighting device is displayed at the right hand side of Figure 27. (Credit: swisstopo)



Forster was very interested in the emerging astrophysics, particularly in the new techniques, such as spectroscopy and astrophotography. He also held many public lectures on these topics, one of them, entitled "The beginning and end of the world", was published in 1874 **(Figure 28)**. One of his "hobbies" was the application of the newly discovered color photography to meteorology. A couple of his color photographies on clouds and the sky survived **(Figure 29)**. In this respect, he belonged most likely to one of the pioneers in this métier. Forster continued the meteorological observations started by Wild. Moreover, he extended the measurements by using newly developed instruments, e. g., to record the sunshine duration by a coelostat **(Figure 30)**. However, the detection and registration of all relevant meteorological parameters on a regular basis, e. g., each hour, from 5 a.m. until 10 p.m., including weekends and holidays, was very hard and not his business. For that purpose he employed women, called "weather fairies", thus playing down the extremely hard work they had to overcome. Thousands of handwritten measurements and records in dozens of folios are still preserved in the archive of the Astronomical Institute of the University of Bern **(Figure 31)**. Today, these records are relevant for climate research, in particular for the reconstruction of the local climate of Bern. Only a small part of these measurements were regularly published as "Yearbooks" **(Figures 32 and 33)**.

Fig. 28: Forster's public talk on the beginning and end of the world published in 1874, with his handwritten dedication. (Credit: Library of A. Verdun)

DER WELT ANFANG UND ENDE.

Oeffentlicher Vortrag

Berner Naturforschenden Gesellschaft

Prof. Dr. A. FORSTER

BERN.

Fig. 29: Color photograph showing the sky and clouds (and the main building of the University of Bern) taken by Forster in 1907.
(Credit: StABE, FN Forster D.6)

Fig. 30: Coelostat for the registration of the sunshine duration used at the Telluric Observatory of Bern.
(Credit: PIUB, Photo A. Verdun)

Fig. 31: A couple of meteorological journals bound in large folios containing thousands of meteorological measurements and observations written by female assistances. Dozens of such records are preserved in the archive of the Astronomical Institute of the University of Bern. These data comprising time series back to the 1850s are relevant today for climate research. (Credit: AIUB)

Fig. 32: First volume of the "Results of meteorological observations" published by the observatory of Bern in 1874. (Credit: AIUB)

RESULTATE

METEOROLOGISCHEN BEOBACHTUNGEN

STERNWARTE ZU BERN

FÜR DAS JAHR 1874

Fig. 33: First volume of the "Yearbooks" published by the Telluric Observatory of Bern in 1879.
(Credit: AIUB)

JAHRBÜCHER

tellurischen Observatoriums zu Bern

Prof. Dr. A. FORSTER

1878

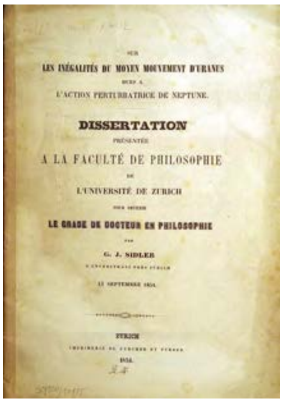
INHALT:

4. Theoretical astronomy

Already during the last decade of the "old" observatory of Bern, practical astronomy was reduced to regular determination of time using the Ertel meridian circle. Observational astronomy was no longer existent during Forster's era in the Telluric Observatory. Astronomy became part of mathematics and was taught and studied as "new" academic discipline, called theoretical astronomy, including celestial mechanics. During 1876 to 1922, theoretical astronomy was a domain of the Bernese mathematicians Georg Sidler (1831–1907), Gottlieb Huber (1847–1923) and Christian Moser (1861–1931).

Sidler studied mathematics at the University of Zurich and continued his studies from 1852 to 1854 in Paris at the famous Sorbonne. There, he attended the lectures on celestial mechanics given by Urbain Leverrier (1811–1877) and Victor Alexandre Puiseux (1820–1883). In September 1854, he became a "doctor philosophiae summa cum laude" with his PhD thesis "Sur les inégalités du moyen movement d'Uranus dues à l'action perturbatrice de Neptune" at the University of Zurich **(Figure 34)**. After having received his "venia docendi" due to a lecture on the method of least squares, he moved to Berlin in November 1854 to extend his studies in mathematics, physics, and theoretical astronomy by attending the lectures given (among others) by Dirichlet, Encke, Steiner, and Clausius. In autumn 1856, he moved to Bern, where he started his research and teaching in celestial mechanics at the University of Bern in the summer semester 1857 as "Privatdozent" **(Figure 35)**. He became Professor for astronomy and mathematics in 1866. After his death, he left over 50 000 manuscript sheets, mainly on mathematics and theoretical astronomy, which are still preserved at the Burgerbibliothek Bern **(Figure 36)**. It was Sidler who introduced the long-lasting tradition of celestial mechanics at the University of Bern, thus laying the foundations of space science in Bern.

Fig. 34: Title page of Sidler's PhD thesis on the motion of Uranus perturbed by Neptune published in 1854 in Zurich. (Credit: Library of A. Verdun)



LES INÉGALITÉS DU MOYEN MOUVEMENT D'URANUS
L'ACTION PERTURBATRICE DE NEPTUNE.
DISSERTATION
A LA FACULTÉ DE PHILOSOPHIE
L'UNIVERSITÉ DE ZURICH
LE GRADE DE DOCTEUR EN PHILOSOPHIE
G. J. SIDLER
ZURICH

Fig. 36: Lecture notes by Sidler from the lecture on "Astronomie physique" given by Leverrier in Winter 1852/53 at the Sorbonne. (Credit: BBB)

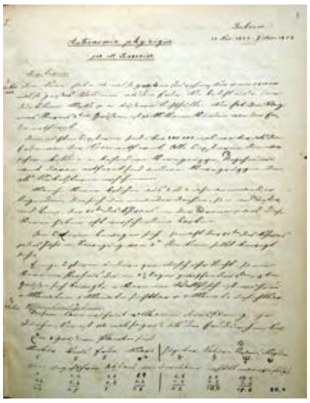
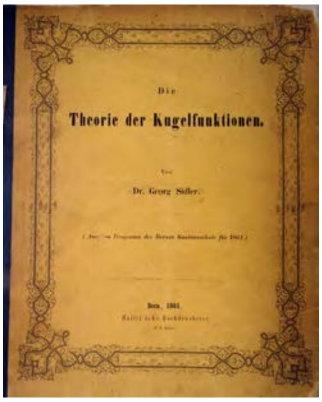


Fig. 35: Title page of Sidler's "Theorie der Kugelfunktionen" (Theory on spherical functions) published in 1861 in Bern, when he was "Privatdozent" at the University of Bern. (Credit: Library of A. Verdun)



Die
Theorie der Kugelfunktionen.
Von
Dr. Georg Sidler.

Fig. 37: Title page of Huber's "Die Kegelfokalen" (The conic foci) published in 1893 in Bern. (Credit: Library of A. Verdun)

Die Kegelfokalen.
Prof. Dr. G. Huber.

Gottlieb Huber and Christian Moser continued the lectures on celestial mechanics at the University of Bern since the beginning of the 20th century. Huber was, however, much more engaged in this matter **(Figure 37)** and on a higher level than Moser, who eventually focused his research activity on mathematical statistics and insurance. The lectures on celestial mechanics given by Huber are still preserved as manuscripts written by Huber himself in the archive of the Astronomical Institute of the University of Bern **(Figures 38 and 39)**. They reveal that almost all relevant topics in celestial mechanics were covered at the time, including perturbation theory and orbit determination, however only as theoretical disciplines without the processing of real astronomical observations for, e. g., the determination orbits of minor planets and comets, since no astrometric observations were performed at the Telluric Observatory.

It was the goal of Sigmund Mauderli (1876–1962) to change this situation and revive observational astronomy in Bern by combining it with theoretical astronomy, which was established by the beginning of the 20th century. He studied mathematics, astronomy, and physics at the University of Lausanne from 1898 and continued his studies at the University of Zurich in 1900, where he achieved his PhD thesis on the stability of dynamical systems in celestial mechanics in 1909 **(Figure 40)**. This thesis was supervised by Alfred Wolfer, a student, assistant, and successor of Rudolf Wolf in Zurich. Mauderli became "Privatdozent" at the University of Bern in 1910 after having returned from the Berlin-Babelsberg Observatory. While living as teacher in Solothurn, he planned a new astronomical observatory in Bern, which later should become the Astronomical Institute of the University of Bern, particularly when he became associated Professor in 1918 and ordinary Professor for astronomy in 1921 there. He knew that the Telluric Observatory was still in the hands of the geophysicist Forster and that no cooperation was possible with him, so that a new observatory had to be built as solution of this problem.

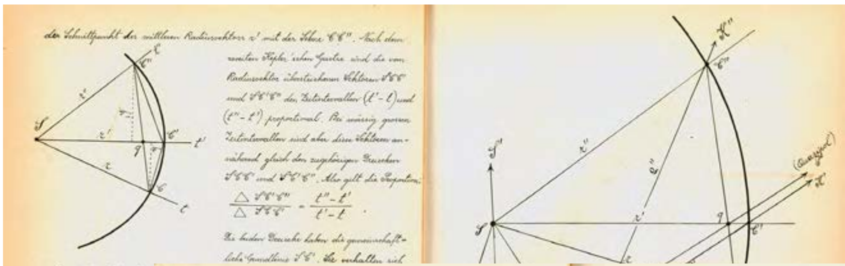


Fig. 38: A double page out of Huber's manuscript of his lecture on orbit determination. (Credit: AIUB)

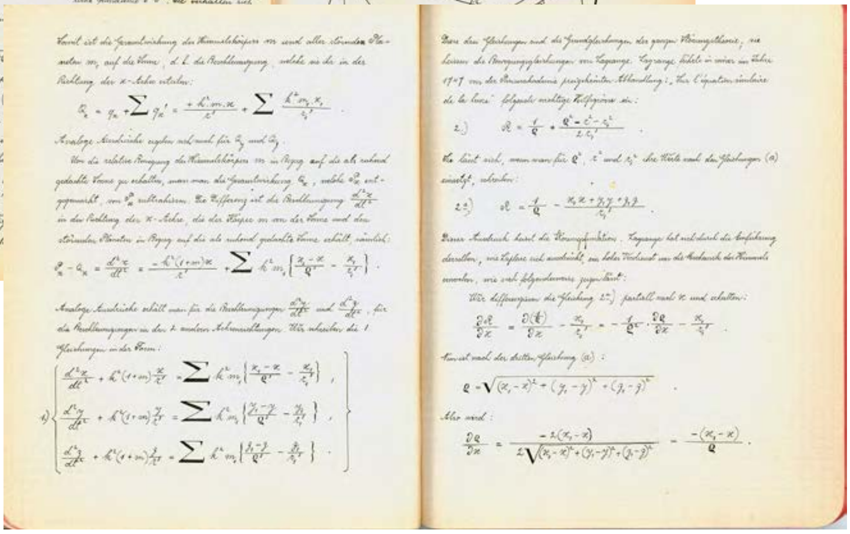
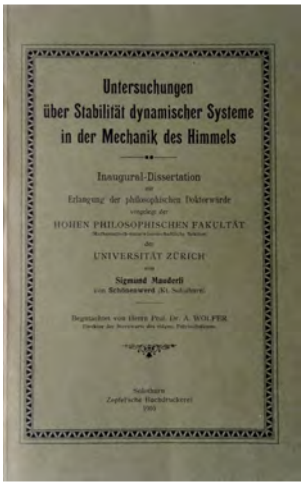


Fig. 39: A double page out of Huber's manuscript of his lecture on celestial mechanics and perturbation theory. (Credit: AIUB)

Fig. 40: Title page of Mauderli's PhD thesis published in Solothurn in 1910. (Credit: Library of A. Verdun)



Untersuchungen
über Stabilität dynamischer Systeme
in der Mechanik des Himmels

Inaugural-Dissertation
Erlangung der philosophischen Doktorwürde
HOHEN PHILOSOPHISCHEN FAKULTÄT
UNIVERSITÄT ZÜRICH
Sigmund Mauderli
von Schönenwerd (Kt. Solothurn)

Begutachtet von Herrn Prof. Dr. A. WOLFER

Solothurn
Zepfel'sche Buchdruckerei

5. Observational astronomy

Observational astronomy, astrophysics, and experimental physics were established in Bern during the years 1922 to 1961 by Mauderli and Heinrich Greinacher (1880–1974), the successor of Forster and first professor for experimental physics in Bern. Greinacher became famous by the invention of what today is called the "Greinacher circuit", a device for electric power amplification. Mauderli had been able to successfully acquire enough money from "crowdfunding" and major sponsors to build an astronomical observatory at the Muesmattstrasse in Bern **(Figure 41)**. On 25 November, 1922, this observatory was officially inaugurated and committed to the University of Bern as new Astronomical Institute **(Figure 42)** with Mauderli as its first director. It was equipped by a 175 mm refractor manufactured by Georg Merz in Munich **(Figure 43)**. Mauderli was forced to focus his activities mainly on astronomical education due to the limited observation conditions caused by the location of the observatory within the near environment of the city and due to the small aperture of the telescope.

Fig. 41: The building of the Observatory at its construction phase in 1922. (Credit: StaBE, BB IIIb 653, Akte 2)

Fig. 42: The newly built astronomical observatory and Astronomical Institute of the University of Bern in November 1922 after its inauguration. (Credit: AIUB)

Fig. 43: The 175 mm refractor made by Merz in Munich in its dome at the Astronomical Institute. (Credit: AIUB)

Fig. 44: The meridian circle made by Lerebours & Secrétan in Paris used at the Astronomical Institute for the observation of stellar occultations by the Moon. (Credit: StABE, FN Tschirren N 11.69, 8)

Fig. 45: The comet searcher and minor planet telescope at the Astronomical Observatory and Institute of the University of Bern. (Credit: StABE, FN Tschirren N 11.69, 2)

Fig. 46: Sigmund Mauderli working at the time transfer station in the Astronomical Institute of the University of Bern. (Credit: StABE, FN Tschirren N 11.70, 6)

However, the Institute's scientific program consisted in the observation of stellar occultations by the Moon on a regular basis since 1938 by using a Meridian circle manufactured by Lerebours & Secrétan in Paris **(Figure 44)**. These observations were used for the determination of the Earth's variable speed of rotation. The Muesmatt Observatory thus was listed as standard site in the "Explanatory Supplement to the Astronomical Almanac" since 1961. Other routine operations comprised the observations of minor planets and comets with a dedicated telescope **(Figure 45)**, the determination of their orbits, as well as of time determination and transfer by telegraph **(Figure 46)**.

Mauderli became elected member of the International Astronomical Union (IAU) at its second general assembly in Cambridge, UK, in 1925. He also participated to the assemblies of the IAU in 1928 in Leiden, in 1938 in Stockholm, and in 1948 in Zurich. On occasion of these conferences he got acquainted with such famous astronomers as Arthur Eddington, Harlow Shapley, Walter Baade, Edwin Hubble, Knut Lundmark, Willem de Sitter, George Lemaître, and Fred Hoyle, to mention but a few **(Figure 47)**.

Fig. 47: General assembly of the IAU 1928 in Leiden. Mauderli is sitting at the right front end in the governing board, along with Eddington and de Sitter. Shapley, Hubble, Baade, Lundmark, and Lemaître are sitting in the plenum. (Credit: Kapteyn Astronomical Institute Groningen)

Fig. 48: Small cutout of the group photograph taken at the general assembly of the IAU 1948 in Zurich showing Schürer (left in the back row), Mauderli (third from the left in the back row), Shapley (right), and Hubble (second from right). (Credit: AIUB)

Fig. 49: Backside of the solar camera during the total solar eclipse observed by Schürer in the year 1952 in Khartoum, Sudan. (Credit: AIUB)

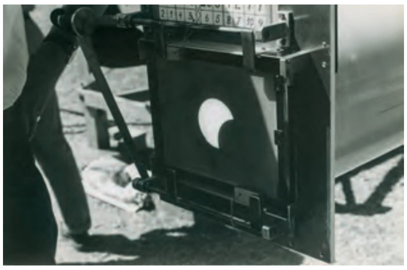


Fig. 50: Solar telescope mounted by Schürer in Oskarshamn, Sweden, in 1954 for confirming the "Einstein effect". (Credit: AIUB)

One of the highlights in the career of Mauderli was the organisation and realisation of the general assembly of the Astronomische Gesellschaft (AG) held in Bern in 1935. The AG was founded in 1863 and was a predecessor organisation of the IAU. Mauderli was member of the governing board of the AG from 1935 to 1945, along with Eddington and Lundmark.

Max Schürer (1910–1997) was PhD student of Mauderli and became his successor and second director of the Astronomical Institute of the University of Bern in 1946. His field of research was the structure and dynamics of the Milky Way. He collaborated with Emanuel von der Pahlen (the first PhD student of Karl Schwarzschild) and with Wilhelm Becker, von der Pahlen's successor and director of the Astronomical Institute of the University of Basel. Schürer was widely known for his much simpler derivation of a potential function first described by Subrahmanyan Chandrasekhar, which is now called the Chandrasekhar-Schürer transformation. Schürer organized the IAU general assembly of 1948 in Zurich **(Figure 48)**. He had a good feeling for telescope construction and was also interested in the observation of total solar eclipses for confirming the "Einstein effect", e.g., the tiny displacement of the star positions near the Sun due to spacetime curvature **(Figures 49 and 50)**.

Schürer was well aware that significant astronomical research was no longer possible at the Muesmatt Observatory. He therefore planned and realized an observatory in Zimmerwald, situated 15 km south of Bern at an altitude of almost 1000 m. It was finished in 1956 and equipped with a Schmidt-Cassegrain telescope in 1959 **(Figures 51 and 52)**. He employed Paul Wild (1925–2014) as observer, who was a student of Wolfgang Pauli, Hermann Weyl, and Emanuel von der Pahlen at the ETH in Zurich, and assistant and collaborator of Fritz Zwicky (1898–1974) on Palomar Mountain at that time. Zwicky and Wild published a catalogue of galaxies in seven volumes **(Figure 53)**. Wild discovered in 1953 an interacting group of galaxies called later on "Wild's triplet" **(Figure 54)**. Only 13 years later, Halton Arp published his famous catalogue of peculiar galaxies. At that time it was realized for the first time that galaxies are not

Fig. 51: The Zimmerwald Observatory after the installation of the Schmidt-Cassegrain telescope in 1959. (Credit: AIUB)

Fig. 54: Wild's triplet of interacting galaxies discovered by Paul Wild in 1953 on Mount Palomar. (Credit: AIUB)

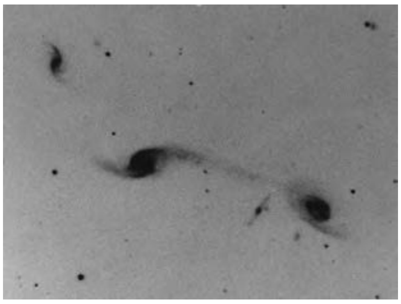
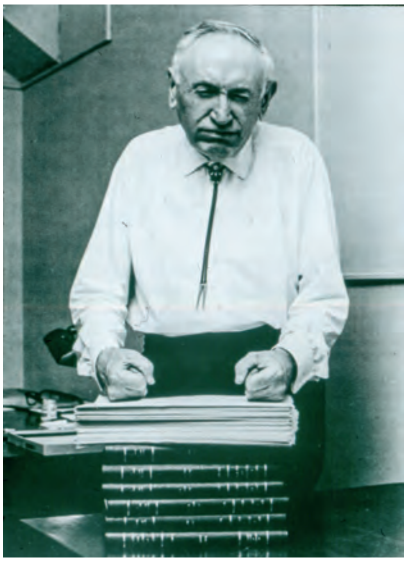


Fig. 52: The Schmidt-Cassegrain telescope in 1959. (Credit: AIUB)

Fig. 53: Fritz Zwicky in Pasadena with his fists on the seven volumes of his catalogue of galaxies. (Credit: AIUB)



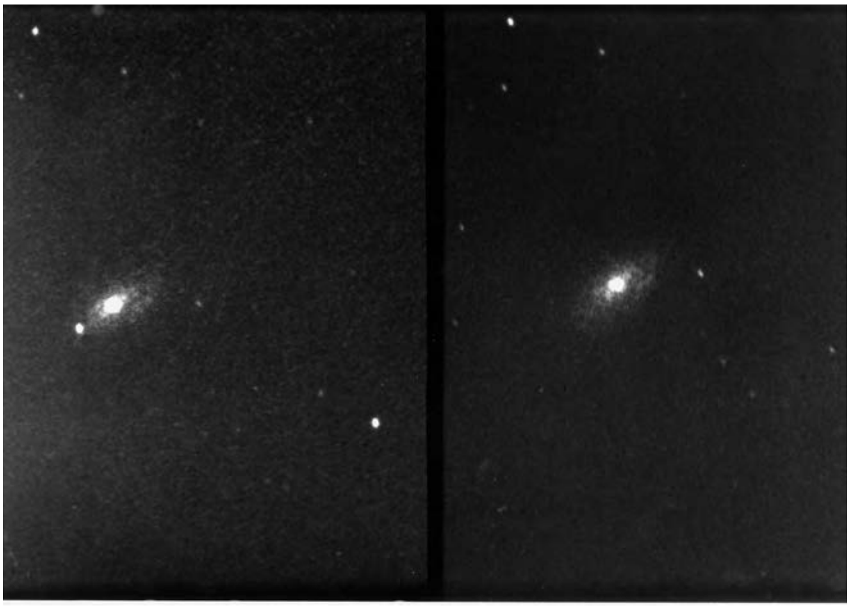


Fig. 55: One of the almost 50 supernovae discovered by Paul Wild at the Zimmerwald Observatory. The discovering image is on the left hand side, the comparison image on the right hand side. (Credit: AIUB)

Fig. 56: Comet Bennett 1968i taken on 16 April 1970 by Wild with the Schmidt camera at the Zimmerwald Observatory. Wild discovered six comets, among them Comet Wild-2, which was targeted by NASA's Stardust mission. (Credit: AIUB)

completely isolated "islands", but interact gravitationally with each other. Back in Zimmerwald, Wild continued the observation of galaxies in the framework of Zwicky's supernovae search programme. Wild discovered almost 50 supernovae and novae **(Figure 55)**, almost 100 minor planets and 6 comets **(Figure 56)**, among them Comet Wild-2, which was a target of NASA's Stardust mission.

When Zimmerwald Observatory started to operate the Schmidt-Cassegrain telescope for supernovae search on a regular basis, the era of the Telluric Observatory came to an end. As physics institute it had to harbour the facilities not only for physical experiments, but for lectures as well. There was only one "big" lecture room crammed with experiments for ed-

Fig. 57: The "big" lecture room in the shadow of the University's main building. (Credit: StABE, FN Nydegger 4292)

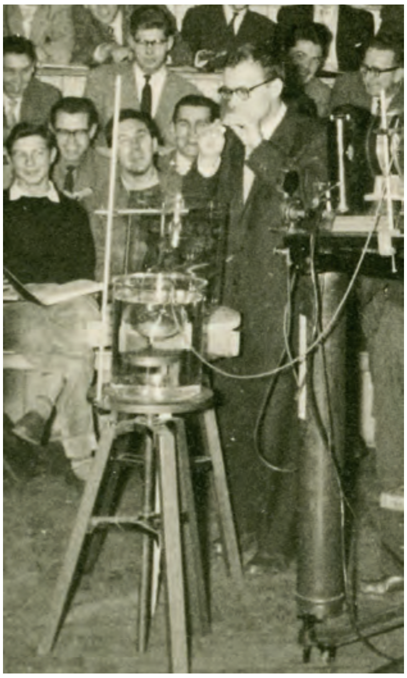
ucational purposes **(Figures 57 and 58)**. The lecture room was always crowded due to the increasing number of students **(Figure 59)**. The small "laboratories" were overfilled with instruments. Shortage of space was present everywhere. In this difficult environment, the first mass spectrometer, called "Susanne", was developed and calibrated in 1958 **(Figure 60)**. It was the beginning of a series of such devices, which later on were integrated into spacecrafts. During these years, a young physicist and "Privatdozent" gave his first lectures in experimental physics **(Figure 61)**: Johannes Geiss (1926–2020). Along with other physicists and astronomers of the University of Bern he transferred Bernese cosmography into the upcoming space age. It was more than a symbolic coincidence that with the beginning of the space sciences the Telluric Observatory or Physics Institute was demolished and a new center for exact science was built at its place, harbouring the Institutes for Astronomy, Physics, Mathematics, Statistics, and Climate and Environmental Physics.

Fig. 58: The blackboard and the physical experiments in the "big" lecture room of the Telluric Observatory around 1900. (Credit: PIUB)

Fig. 59: The "big" lecture room crowded with students during a lecture on experimental physics held in 1957. (Credit: PIUB)

Fig. 60: The first mass spectrometer called "Susanne" developed at the Telluric Observatory and Physics Institute. (Credit: PIUB)

Fig. 61: Johannes Geiss as "Privatdozent" during a lecture on experimental physics in the "big" lecture room of the Telluric Observatory and Physics Institute in 1957. (Credit: PIUB)



6. New branches of science in Bern

The sixties of the last century were the era when space-related research took off from the military to the university. In 1952, Friedrich "Fritz" Georg Houtermans (1903–1966) had joined the Physics Institute of the University of Bern (PIUB) and applied the methods he had been using as a nuclear physicist in Göttingen to astrophysics and geosciences.

In his research groups, which worked on nuclear physics, astrophysics and geophysics, Houtermans established methods for radiometric decay measurements for age determination of minerals and in meteorites. He was the driving force in what was later termed the "Berner Schule" (Bernese School).

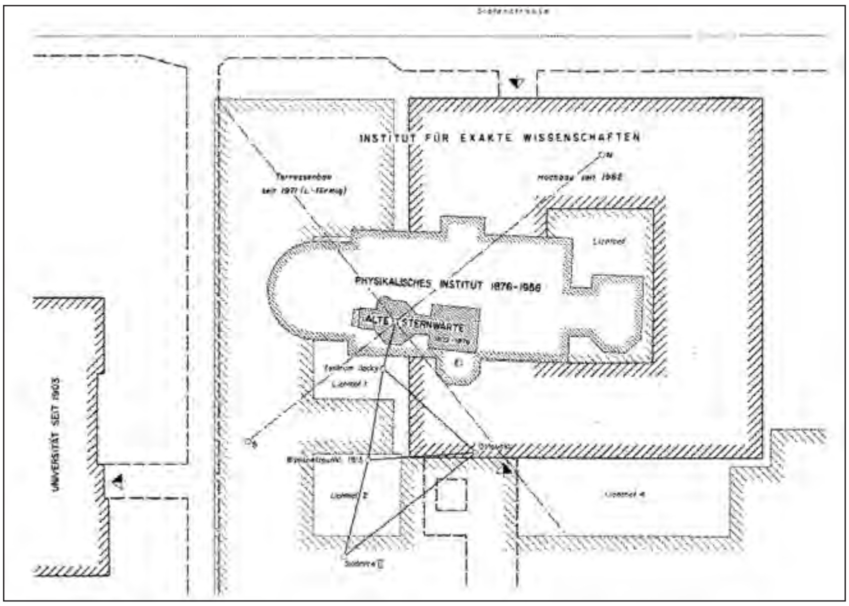
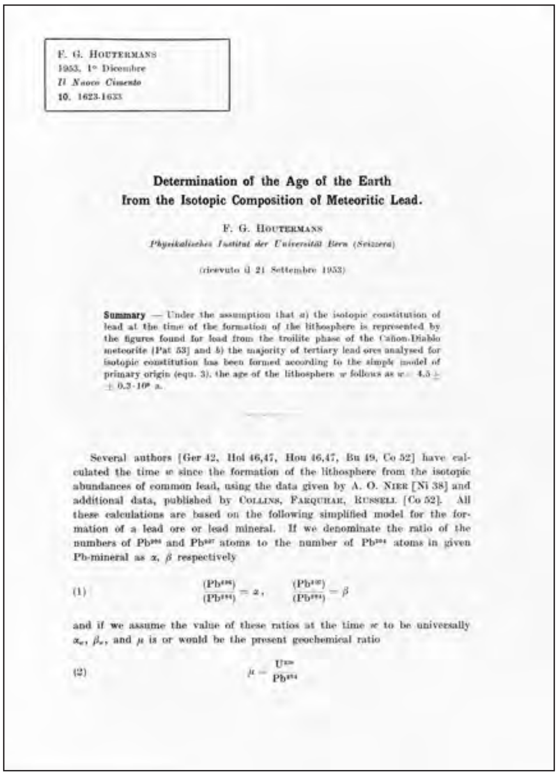


Fig. 62: The transformation from the old astronomical observatory "Uraniae" and the Telluric Observatory or Physics Institute (Credit: swisstopo) ….

Fig. 63: …into the "ExWi" (short for "Gebäude Exakte Wissenschaften"), one of the rare university institutes harbouring a complete train station. (Credit: PIUB)

Fig. 64: Fritz Houtermans on his motor bike at the University of Bern 1952. (Credit: PIUB)



F. G. Houtermans
1953, 1° Dicembre
Il Nuovo Cimento
10, 1623-1633

Determination of the Age of the Earth from the Isotopic Composition of Meteoritic Lead.

F. G. Houtermans
Physikalisches Institut der Universität Bern (Svizzera)

(ricevuto il 21 Settembre 1953)

Summary — Under the assumption that *a*) the isotopic constitution of lead at the time of the formation of the lithosphere is represented by the figures found for lead from the troilite phase of the Cañon-Diablo meteorite [Pat 53] and *b*) the majority of tertiary lead ores analysed for isotopic constitution has been formed according to the simple model of primary origin (equ. 3), the age of the lithosphere w follows as $w = 4.5 \pm 0.2 \cdot 10^9$ a.

Several authors [Ger 42, Hol 46,47, Hou 46,47, Bu 49, Co 52] have calculated the time w since the formation of the lithosphere from the isotopic abundances of common lead, using the data given by A. O. Nier [Ni 38] and additional data, published by Collins, Farquhar, Russell [Co 52]. All these calculations are based on the following simplified model for the formation of a lead ore or lead mineral. If we denominate the ratio of the numbers of Pb^{206} and Pb^{207} atoms to the number of Pb^{204} atoms in given Pb-mineral as α, β respectively

$$\frac{(Pb^{206})}{(Pb^{204})} = \alpha\,, \qquad \frac{(Pb^{207})}{(Pb^{204})} = \beta \tag{1}$$

and if we assume the value of these ratios at the time w to be universally α_w, β_w, and μ is or would be the present geochemical ratio

$$\mu = \frac{U^{238}}{Pb^{204}} \tag{2}$$

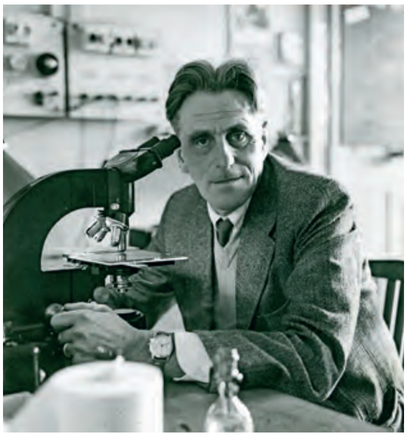


Fig. 66: Fritz Houtermans in the laboratory at the University of Bern, around 1952. (Credit: PIUB)

Fig. 65: Title page of a publication on isotopic composition in meteorites by Houtermans in 1953.
(Credit Library of A. Verdun)

For applying mass spectroscopy to determine the age of meteoritic matter, Houtermans employed Johannes Geiss, who had been using that technique in Göttingen to determine the isotopic composition of lead (*Spatium* 27 by H. Schlaepfer provides an overview of the life and work of J. Geiss). Geiss brought his mass spectrometer with him, and, as described before, this served as a starting point for the development of the prototype spectrometer "Susanne". These mass spectrometers and their further developments and successors became the base of numerous extremely successful Bernese projects and missions.

In particular, they served for the evaluation of the (as simple as ingenious) solar wind sail experiment, which propelled the physics department of the University of Bern to the forefront of research in extra-terrestrial experimental physics. The group of Johannes Geiss had developed a special ultra-pure aluminium foil in order to capture the particles of the solar wind during the Apollo-11 astronauts' stay on the moon, the solar wind collector (SWC). As the Moon lacks an atmosphere and a magnetic field, it had been identified a perfect location for collecting information about the solar wind's composition. It took Geiss a year of intense lobbying in Houston to have the experiment finally secured and the Bernese foil (including its engraved Swiss flag) planted into the lunar soil on 21 July 1969 by Edwin E. Aldrin even before the American flag.

Fig. 67: The follow-up version of the mass spectrometer "Susanne", called "Evelyne". (Credit: PIUB)

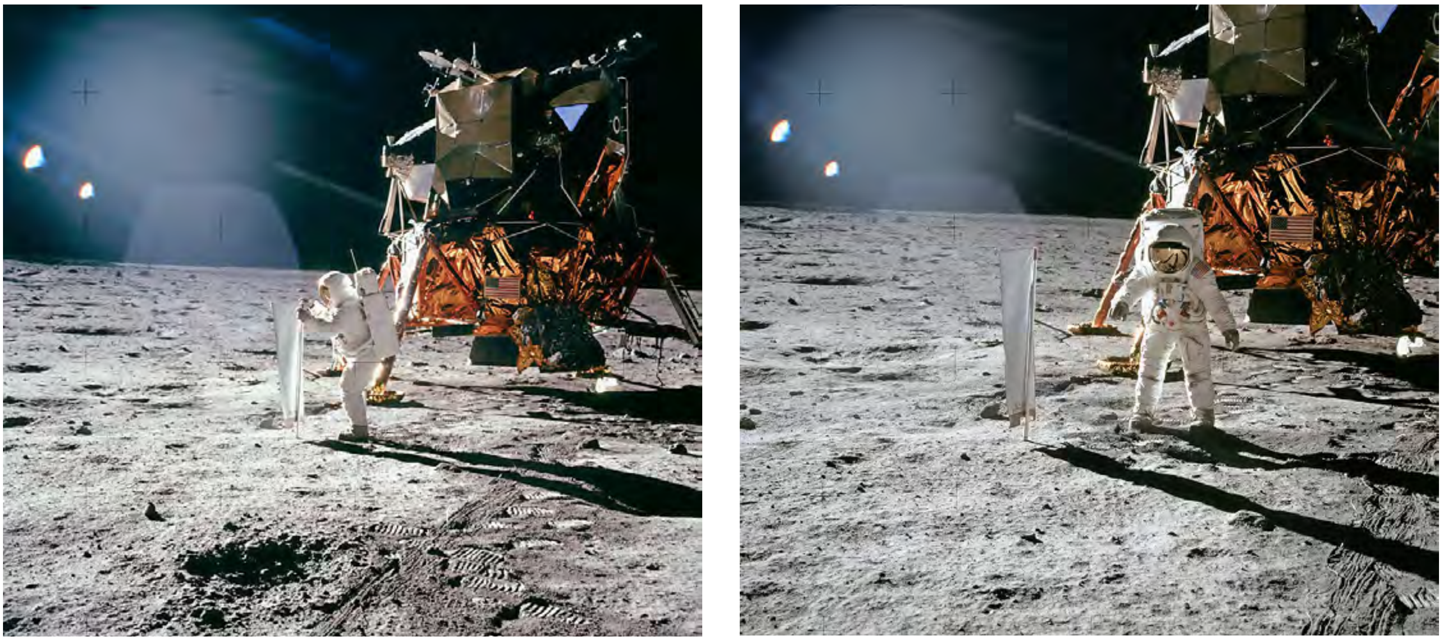
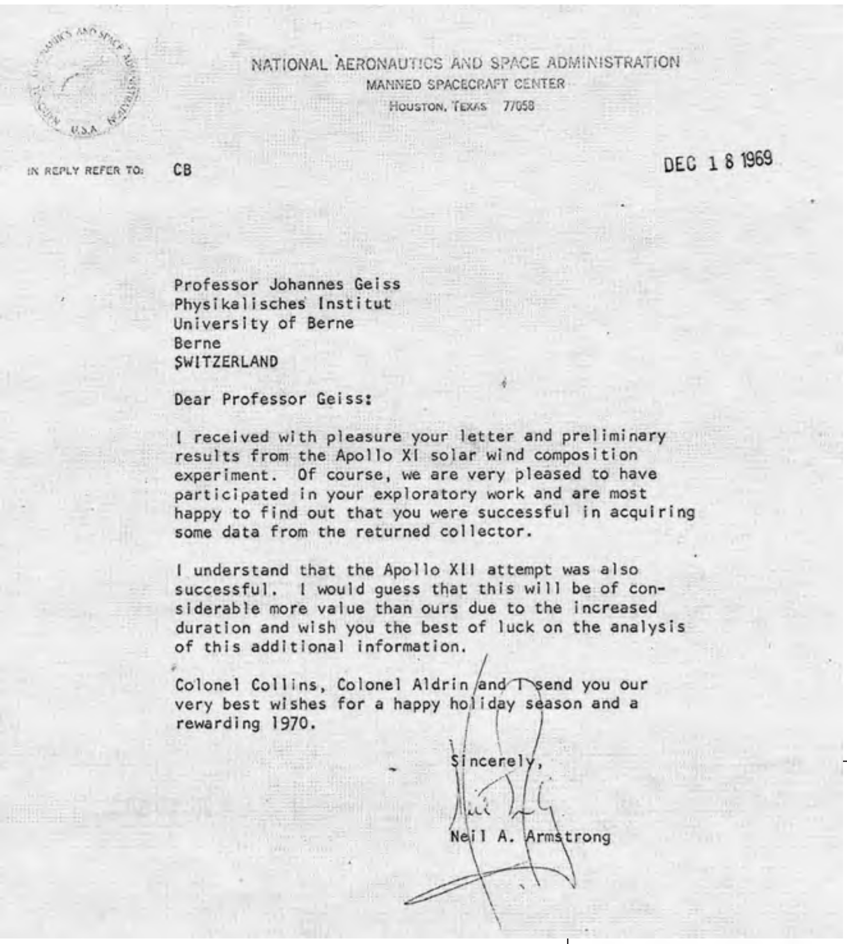


Fig. 68: Astronaut Edwin E. Aldrin Jr., Lunar Module pilot, is photographed during the Apollo-11 extravehicular activity (EVA) on the lunar surface while "planting the Swiss flag". In the right background is the Lunar Module "Eagle". On Aldrin's right is the Solar Wind Composition (SWC) experiment, already deployed. Neil A. Armstrong took these photographs on 21 July 1969 with a 70 mm lunar surface camera. (Credit: NASA, Neil A. Armstrong)

Similarly, the experiment was an integral part of the setup on four other Apollo missions. The time exposure to the solar wind particles was 77 minutes on Apollo 11, 18 hours and 42 minutes on Apollo 12, 21 hours on Apollo 14, 41 hours and 8 minutes on Apollo 15, and 45 hours and 5 minutes on Apollo 16. The subsequent analysis of the particles collected in the foil, especially the ratio of the helium isotopes, revealed the average baryonic density of the Universe as a whole to be 0.2 atoms per square metre. Moreover, after this success, the field of mass spectroscopy in combination with a significant experience in the design of space experiments should become a solid cornerstone of research at the University of Bern for decades to come.

Fig. 69: Herbert Cerutti explains the evaluation of the SWC experiment to the Apollo-13 crew (Jack Swigert, Fred Haise, Jim Lovell). The photo was taken at the ion accelerator of the spectrometer, October 1970. (Credit: PIUB)



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

IN REPLY REFER TO: CB

DEC 1 8 1969

Professor Johannes Geiss
Physikalisches Institut
University of Berne
Berne
SWITZERLAND

Dear Professor Geiss:

I received with pleasure your letter and preliminary results from the Apollo XI solar wind composition experiment. Of course, we are very pleased to have participated in your exploratory work and are most happy to find out that you were successful in acquiring some data from the returned collector.

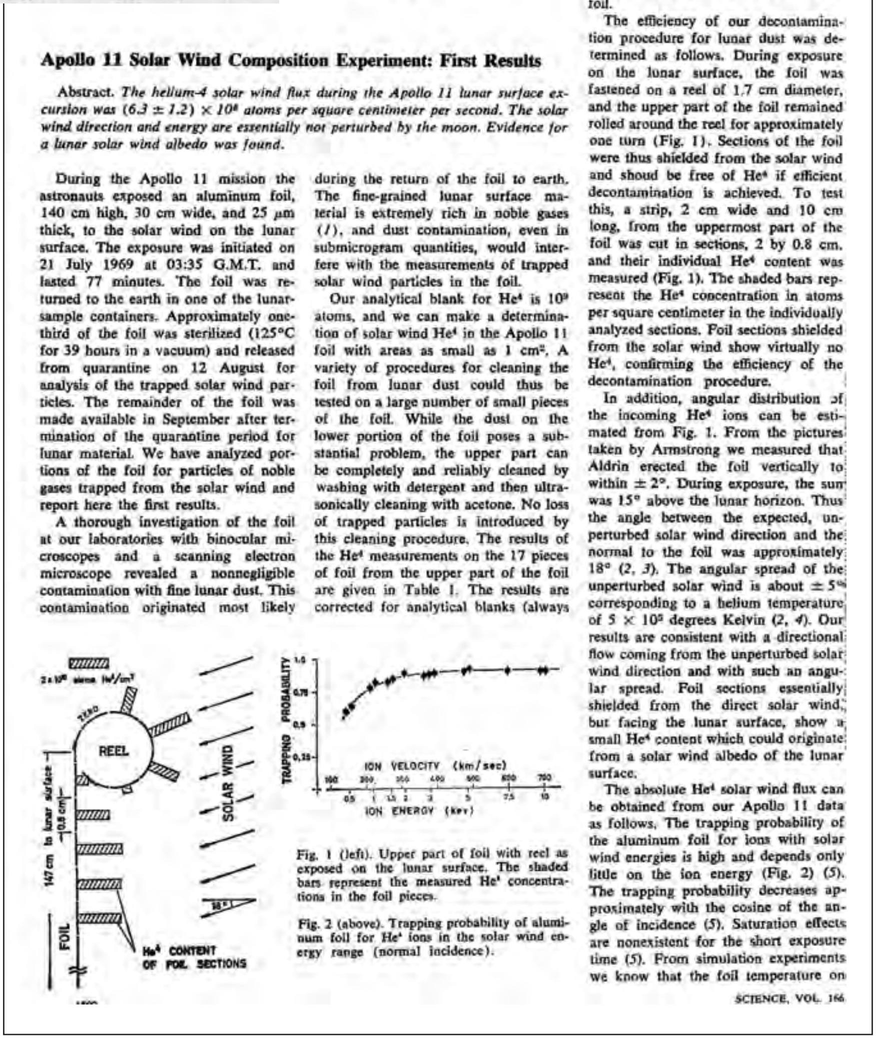
I understand that the Apollo XII attempt was also successful. I would guess that this will be of considerable more value than ours due to the increased duration and wish you the best of luck on the analysis of this additional information.

Colonel Collins, Colonel Aldrin and I send you our very best wishes for a happy holiday season and a rewarding 1970.

Sincerely,

Neil A. Armstrong

Fig. 70: Letter sent from the Apollo crew to Johannes Geiss. (Credit: Estate of Johannes Geiss)



Reports

Apollo 11 Solar Wind Composition Experiment: First Results

Abstract. *The helium-4 solar wind flux during the Apollo 11 lunar surface excursion was* $(6.3 \pm 1.2) \times 10^6$ *atoms per square centimeter per second. The solar wind direction and energy are essentially not perturbed by the moon. Evidence for a lunar solar wind albedo was found.*

During the Apollo 11 mission the astronauts exposed an aluminum foil, 140 cm high, 30 cm wide, and 25 μm thick, to the solar wind on the lunar surface. The exposure was initiated on 21 July 1969 at 03:35 G.M.T. and lasted 77 minutes. The foil was returned to the earth in one of the lunar-sample containers. Approximately one-third of the foil was sterilized (125°C for 39 hours in a vacuum) and released from quarantine on 12 August for analysis of the trapped solar wind particles. The remainder of the foil was made available in September after termination of the quarantine period for lunar material. We have analyzed portions of the foil for particles of noble gases trapped from the solar wind and report here the first results.

A thorough investigation of the foil at our laboratories with binocular microscopes and a scanning electron microscope revealed a nonnegligible contamination with fine lunar dust. This contamination originated most likely during the return of the foil to earth. The fine-grained lunar surface material is extremely rich in noble gases (*1*), and dust contamination, even in submicrogram quantities, would interfere with the measurements of trapped solar wind particles in the foil.

Our analytical blank for He^4 is 10^9 atoms, and we can make a determination of solar wind He^4 in the Apollo 11 foil with areas as small as 1 cm^2. A variety of procedures for cleaning the foil from lunar dust could thus be tested on a large number of small pieces of the foil. While the dust on the lower portion of the foil poses a substantial problem, the upper part can be completely and reliably cleaned by washing with detergent and then ultrasonically cleaning with acetone. No loss of trapped particles is introduced by this cleaning procedure. The results of the He^4 measurements on the 17 pieces of foil from the upper part of the foil are given in Table 1. The results are corrected for analytical blanks (always less than 5 percent) and for the blank He^4 content of the foil (approximately 10^8 atoms of He^4 per square centimeter). The average distance above lunar ground of these 17 pieces of foil was 135 cm. In addition to He^4 we have detected solar wind He^3 in the foil.

The efficiency of our decontamination procedure for lunar dust was determined as follows. During exposure on the lunar surface, the foil was fastened on a reel of 1.7 cm diameter, and the upper part of the foil remained rolled around the reel for approximately one turn (Fig. 1). Sections of the foil were thus shielded from the solar wind and shoud be free of He^4 if efficient decontamination is achieved. To test this, a strip, 2 cm wide and 10 cm long, from the uppermost part of the foil was cut in sections, 2 by 0.8 cm, and their individual He^4 content was measured (Fig. 1). The shaded bars represent the He^4 concentration in atoms per square centimeter in the individually analyzed sections. Foil sections shielded from the solar wind show virtually no He^4, confirming the efficiency of the decontamination procedure.

In addition, angular distribution of the incoming He^4 ions can be estimated from Fig. 1. From the pictures taken by Armstrong we measured that Aldrin erected the foil vertically to within ± 2°. During exposure, the sun was 15° above the lunar horizon. Thus the angle between the expected, unperturbed solar wind direction and the normal to the foil was approximately 18° (*2, 3*). The angular spread of the unperturbed solar wind is about ± 5°, corresponding to a helium temperature of 5×10^5 degrees Kelvin (*2, 4*). Our results are consistent with a directional flow coming from the unperturbed solar wind direction and with such an angular spread. Foil sections essentially shielded from the direct solar wind, but facing the lunar surface, show a small He^4 content which could originate from a solar wind albedo of the lunar surface.

The absolute He^4 solar wind flux can be obtained from our Apollo 11 data as follows. The trapping probability of the aluminum foil for ions with solar wind energies is high and depends only little on the ion energy (Fig. 2) (*5*). The trapping probability decreases approximately with the cosine of the angle of incidence (*5*). Saturation effects are nonexistent for the short exposure time (*5*). From simulation experiments we know that the foil temperature on

Fig. 1 (left). Upper part of foil with reel as exposed on the lunar surface. The shaded bars represent the measured He^4 concentrations in the foil pieces.

Fig. 2 (above). Trapping probability of aluminum foil for He^4 ions in the solar wind energy range (normal incidence).

SCIENCE, VOL. 166

Fig. 71: The article in Science 166, Nov. 1969, by Bühler, Eberhardt, Geiss, Meister and Signer, with the first reported results of the solar wind composition experiments. (www.science.org)

As director of the PIUB, Fritz Houtermans did not only foster astrophysics but also had Hans Oeschger (1927–1998) found a Laboratory of Low Level Counting in 1963, from which later the division of Climate and Environmental Physics emerged. In 1962, Oeschger had started to study firn and ice and to extract physical and chemical information of the environment from these samples **(Figure 72)**.

In addition to successfully using mass spectroscopy, Oeschger developed the proportional gas counter, a highly sensitive instrument that measured low levels of activity of natural radionuclides. The first nuclide was radiocarbon, ^{14}C, which was used to date old waters from the deep layers of the Pacific Ocean. The Bern radiocarbon measurement was known for its unprecedented sensitivity giving access to samples as old as 50 000 years. Low level counting soon extended to other nuclides (^{39}Ar, ^{37}Ar, ^{85}Kr, ^{3}H), through a series of PhD theses under Hans Oeschger's supervision. Measuring activities of a palette of radionuclides enabled a new and extended understanding of relevant physical and chemical processes in the Earth system. In 1971, the group started monitoring of water isotope composition via an oxygen isotope record of the precipitation in the city of Bern, which was extended to a Swiss network in the following years. Oeschger had the vision to apply the radiocarbon dating method to old ice from Greenland and Antarctica. Consequently, he and his team participated in numerous international expeditions to Greenland and Antarctica and collected dating and environmental information from isotopes within polar ice cores **(Figures 73 to 79)**.

Fig. 72: Hans Oeschger in the laboratory of the Physics Institute, controlling the evaluation of ^{14}C data (ca. 1960). (Credit: OCCR)

Oeschger and his team continued to push the limits of environmental analytics. They developed sophisticated extraction systems of gas enclosed in bubbles in the polar ice and coupled these devices to a series of available measurement techniques (laser absorption spectroscopy, electron capture and gas chromatography). This enabled the determination of trace gas concentrations in the enclosed bubbles, in

Fig. 73: Working in the ice tunnel of the US Army camp Tuto near Thule (now Qaanaaq) in Greenland. The vessel was used for the extraction of CO_2 from ice in order to determine the ^{14}C fraction (1965). (Credit: OCCR)

Fig. 74: Very basic fieldwork, snow shoveling for the water provision at Byrd Station, Antarctica (January 1968). (Credit: OCCR).

particular CO_2, CH_4 and N_2O. For CO_2, the ice sample is crushed to liberate the enclosed air; for CH_4 and N_2O, samples are melted and slowly refrozen to access the gas fraction.

In the mid 1980s, the pre-industrial levels of these greenhouse gases could be determined, and soon after, first measurements of ice age samples were carried out. With that, Hans Oeschger and his team were now in the position to address fundamental questions of climate science. The participation of the Bern team in international deep drilling projects in Greenland and Antarctica gave access to samples.

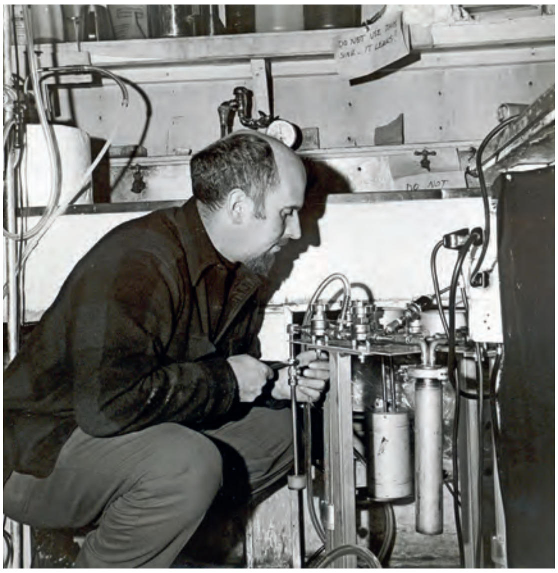


Fig. 75: Fieldwork at Byrd Station, Antarctica, retrieving CO_2 samples (30.11.1968).
(Credit: "Official US Navy Photograph")

Fig. 76: Fieldwork in Greenland for the International Glaciological Greenland Expedition (EGIG), together with Bernhard Stauffer from Bern (right) and Henrik Clausen from Denmark, 1967.
(Photo: Gianni della Valle)

Fig. 77: Ice core from a polar drilling site.
(Credit: OCCR)

Fig. 78: Not only space ships promised new insights and adventures: fieldwork in Greenland during the International Glaciological Expedition 1967 (Photo: Bernhard Stauffer)

Fig. 79: On the Danish research vessel Tycho Brahe: Oeschger (right) together with Willy Dansgaard (left) and Henrik Clausen (middle) in 1967. (Photo: Bernhard Stauffer)

To date, the oldest ice core was retrieved from Dome C (Antarctica) and a paleoclimatic record dating back 800 000 years could be constructed **(Figure 80)**.

Climate modelling, already recognised by Oeschger's team, held the key to a deeper understanding of the paleoclimatic records. This component of research was enhanced by Hans Oeschger's successor, Thomas Stocker (born 1959), and his team since 1993. The combination of analytical capabilities with climate models unleashed synergies that are a hallmark of physics-based climate research at the University of Bern.

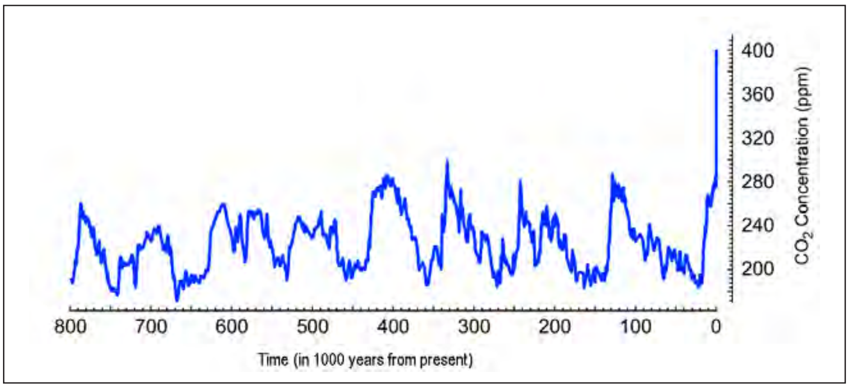


Fig. 80: Global atmospheric carbon dioxide (CO_2) concentration in parts per million (ppm) for the past 800 000 years. The peaks and valleys track ice ages (low CO_2) and warmer interglacials (higher CO_2). During these cycles, CO_2 was never higher than 300 ppm. The increase over the last 60 years is 100 times faster than previous natural increases. In fact, on the geologic time scale, the increase from the end of the last ice age to the present looks virtually instantaneous. (Credit: Th. Stocker)

Hans Oeschger was able to demonstrate, among other things, that the rising concentrations of greenhouse gases in the atmosphere are a result of the burning of fossil fuels. In 1978, Uli Siegenthaler and Hans Oeschger predicted levels of CO_2 for the turn of the millennium, based on their understanding of the global carbon cycle. In this paper, published in "Science", they declared that *"a maximum permissible level of atmospheric CO_2 might be found which should not be exceeded if the radiation balance is not to be disturbed in a dangerous way."* They estimated that a 50 % increase of the pre-industrial CO_2 concentration would lead to a man-made warming of 1°C to 2°C in the global mean. Today we are exactly at this concentration and measure a global mean surface warming of 1.1°C, including about 0.4°C cooling through anthropogenic aerosols. The Bern team's assessment was decades ahead of its time and remarkably precise. It is still relevant today, as expressed in Article 2 of the United Nations Framework Convention on Climate Change.

A further key insight from polar ice cores was the limited stability of the Earth System. Together with the Danish geophysicist Willi Dansgaard, Hans Oeschger was able to show that climate changes were taking place at an alarmingly rapid pace. A series of climatic swings, now referred to as "Dansgaard-Oeschger events", are evidence of a new potential risk of anthropogenic climate change, the risk of crossing thresholds that lead to large and irreversible climate change. The deep insight from the paleoclimatic record into mechanisms determining the global climate prompted Hans Oeschger to become actively involved. Consequently, he announced the results from his fundamental research to the public and warned early of the consequences of changes of the enhanced greenhouse effect through the burning of fossil fuels. In 1990/1992, he was one of the authors of the First Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Since then, team members of Climate and Environmental Physics have been involved in all six Assessments Reports of the IPCC in leading positions. Hans Oeschger was also a founding director of the Past Global Changes (PAGES) initiative of the International Geosphere-Biosphere Programme (IGBP). The international project office is still in Bern and engages a network of hundreds of scientist around the globe.

7. Global beacons of Bernese cosmography

With the tremendous success of the various projects of the physics and astronomy departments of the University of Bern, the need for extended activities became clear. The heirs of the "Berner Schule" were mature to further develop and at the same time specialise and broaden their research, as well as disseminate it.

The increased involvement in international geo-, astro- and general space missions lead to the foundation of dedicated research institutes and groups, some of them not only specialised in their particular research but also fostering interdisciplinarity and international cooperation.

Fig. 81: The Zimmerwald Observatory of the Astronomical Institute of the University of Bern (AIUB) specialised in satellite geodesy and precise orbit determination. In the sixties, it started using not only optical (photographic) astrometry but also lasers for tracking geodetic satellites, and meanwhile it operates a laser ranging station, a true "beacon". Recently, the tracking of space debris has become an increasingly important project and duty. (Credit: AIUB)

The Astronomical Institute of the University of Bern

The competence in optical astronomy, celestial mechanics, and satellite geodesy, including Satellite Laser Ranging (SLR) is strengthened in the 1980s. In particular, the synergies between geophysics and astronomy are advantageously used. For example, the analysis of data from the satellites of the Global Positioning System (GPS) is established. In the following decade, Gerhard Beutler (born 1946) promotes research in this field at the AIUB, particularly celestial mechanics and satellite geodesy, the research topics already started by Max Schürer around 1960. Bern consolidates as a centre of international importance for the study of satellite orbits and various data products for application and science.

In the late 1980s, the observatory at Zimmerwald **(Figure 81)** starts a cooperation with the Swiss Federal Office of Topography (swisstopo) and the geodesy group at the ETH Zürich, and a new 1 m telescope is taken into operation for astrometry and laser ranging. The latter is integrated as an observatory in the worldwide International Laser Ranging Service (ILRS) network of about 40 stations. This service from the International Association of Geodesy provides global satellite and lunar laser ranging data and their derived data products to support research in geodesy, geophysics, lunar science, and fundamental astronomy.

With Adrian Jäggi (born 1976) as Beutler's successor, the latter studies are intensified and extended to gravity field determination and planetary geodesy. With the importance of Global Navigation Satellite Systems (GNSS), like the US-American GPS, the Russian GLONASS, the European Galileo and the Chinese BeiDou (BDS) ever increasing, the Bernese GNSS software (for GPS and GLONASS) provides a state-of-the-art software package for high-precision analysis of space geodetic data. Since 1992, the AIUB operates the

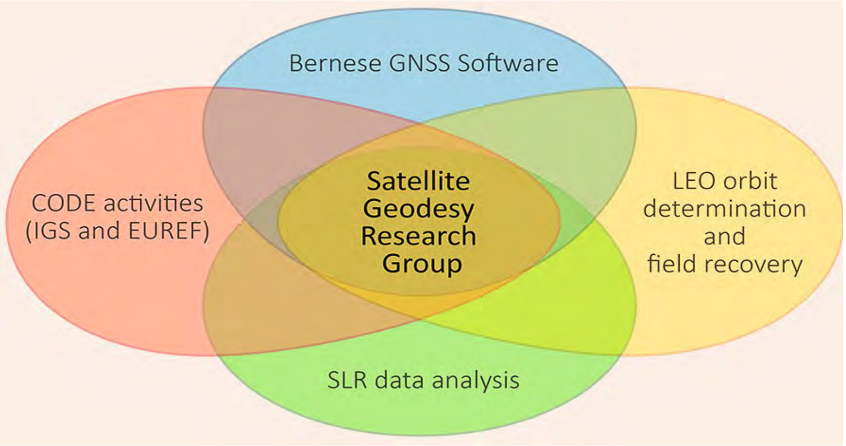
Center for Orbit Determination in Europe (CODE) global Analysis Center for the International GNSS Service (IGS) in a consortium with the Swiss Federal Office of Topography (swisstopo, Wabern, Switzerland), the Bundesamt für Kartographie und Geodäsie (BKG, Frankfurt a. M., Germany) and the Institut für Astronomische und Physikalische Geodäsie, Technische Universität München (IAPG/TUM, Germany).

The AIUB has thus, besides pure research, established a strong basis for providing important services for the geodetic and geophysical communities, namely positional and tracking information with observations and modelling, establishing and maintaining references and standards **(Figure 82)**.

In particular, the satellite laser ranging (SLR) with high accuracy as well as the GNSS measurements, i. e., the microwave-band measurements using the satellites from the global positioning systems, are used to determine precise satellite orbits, the terrestrial reference frame and the Earth's rotation parameters, the Earth's gravity field and for worldwide time synchronisation (see *Spatium* 10 by G. Beutler and *Spatium* 31 by R. Rummel).

The precise orbit determination (POD) of Low Earth Orbit (LEO) satellites, i. e., satellites flying at low altitudes of roughly 200 km to 2000 km is of fundamental importance. This holds especially for determining the Earth's time-variable gravity field by using precise orbits of the satellites (see *Spatium* 49 by A. Jäggi), as well as for altimetry missions (see *Spatium* 46 by A. Cazenave) that measure the sea surface height via the return time of a radar signal. For these kind of missions, any radial orbit error directly affects the sea-level height measurements.

Fig. 82: The activities of the Satellite Geodesy Group of the AIUB. EUREF is a European collaboration for maintaining a standard coordinate reference system. (Credit: AIUB)



Data from various satellite missions are employed, such as from Challenging Minisatellite Payload (CHAMP), Gravity Recovery and Climate Experiment (GRACE) and GRACE-FO (follow on), and Gravity Field and Steady-State Ocean Circulation Explorer (GOCE).

In addition, data from the NASA lunar gravity mission GRAIL (Gravity Recovery and Interior Laboratory) were studied and the Moon's gravity field has been modelled using the Bernese software.

In the SLR, a global network of observation stations measures the round trip time of flight of ultra-short laser pulses to satellites equipped with retroreflectors. This provides range measurements at a precision level of a few millimetres, which can be accumulated to provide accurate measurement of orbits. As the laser pulse can also be reflected by the surface of a satellite without a retroreflector, it can be used for tracking space debris, thus supporting the classic optical CCD astrometry in its detecting and cataloguing (see also *Spatium* 52 by T. Schildknecht).

The Oeschger Centre for Climate Change Research

In 2007, the Oeschger Centre for Climate Change Research (OCCR) was founded as an interdisciplinary institution to study the complex Earth System and its global response to perturbations in the past and the future. For this purpose, it brings together researchers from physics, geography, biology, chemistry, history, economy, political sciences and philosophy. The OCCR also offers training to young scientists in special graduate programmes and takes part in international assessment processes such as the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), for which members of the OCCR were elected as co-chairs.

The main scientific focus is on the climate system and its interactions with society. The core research topics are global and regional climate dynamics, consequences of climate change as well as climate risks and consequences of climate change for the economy and society as well as the adaptive and legal strategies that are derived from them.

In 2010, the chair in Climate Change Impacts in the Alpine Region was established through funds from the Mobiliar insurance association and in 2013, the Mobiliar Lab for Natural Risks has been founded, which serves as an important link between fundamental science and application. The Public Private Partnership is a key in better understanding risks of anthropogenic climate change and offer science-based solutions to mitigate and prevent adverse climate impacts, particularly through extreme climate and weather events. The most recent interdisciplinary addition to OCCR's portfolio is a cooperation with the Medical Faculty and the establishment of a senior research position on the topic of Climate and Health. The past few years have demonstrated that this topic will rapidly increase in importance, driven by the compound effect of demography and continuing climate change.


Fig. 83: Artist's impression of the CHEOPS spacecraft. (Credit: CSH)

The Albert Einstein Center for Fundamental Physics

The Albert Einstein Center for Fundamental Physics (AEC) has been founded within the Department of Physics and Astronomy in 2011. It comprises the Institute for Theoretical Physics (ITP) and the Laboratory for High Energy Physics (LHEP). The focus is on experimental and theoretical particle physics and its applications, as well as on the related spin-off and outreach activities (see *Spatium* 7 by K. Pretzl or *Spatium* 20 by U.J. Wiese). Its aim is to foster high-level research and teaching in fundamental physics at the University of Bern as well as interdisciplinary collaborations with other institutes such as the OCCR and the CSH. Collaborations with accelerator facilities in fundamental research as well as for medical applications are pursued.

The Division of Space Research and Planetary Science and the Center for Space and Habitability

The expertise of the Bernese Physics Institute in mass spectroscopy developed further at its Division of Space Research and Planetary Sciences (Weltraumforschung und Planetologie, WP): lunar rocks and samples of meteorites were studied to determine the ratios of noble gas isotopes and their variations. Mass spectrometers were developed not only for lunar missions, but also to fly on solar spacecraft, such as Ulysses, SOHO, ACE, WIND, STEREO, and Solar Orbiter. Importantly, research on comets and other minor bodies in the Solar System was done (see *Spatium* 4 by K. Altwegg), from Giotto to the ROSETTA mission. The latter, for example, ended very spectacularly in September 2016 with the landing on comet 67P/Churyumov-Gerasimenko. The on-board mass spectrometer ROSINA, developed at University of Bern by a team led by Kathrin Altwegg (born 1951), could monitor the composition of the volatiles surrounding the comet nucleus over a time span of two years. In 2012, ESA selected the Characterising Exoplanet Satellite (CHEOPS) mission, led by Willy Benz, as its first small-class mission **(Figure 83)**. CHEOPS carries a photometric space telescope observing extrasolar planets using the transit technique. It is the first ESA satellite led by Switzerland and was launched in 2019, determining with extremely high precision the radii of extrasolar planets (see *Spatium* 48 by A. Fortier).

Also in 2012, the Center for Space and Habitability (CSH) was founded by the University of Bern. Kathrin Altwegg served as its first director. The centre's goal is the investigation of all aspects of habitability and space research, theoretical and via space missions, in particular the origin and evolution of planets both in the Solar System and around other stars, their composition and atmospheres and their potential of hosting life (see, e. g., *Spatium* 6 by W. Benz and *Spatium* 29 by P. Wurz). Today, the Division of Space Research and Planetary Sciences is built upon two pillars. The first is experimental Solar System research by building and exploiting scientific instruments that fly on the most important international space missions to Solar System bodies. This is the backbone of the division and itself consists of two aspects: in-situ compositional measurements using mass spectroscopy (group of Peter Wurz, born 1961), which continues the heritage from the past, and as a new addition since 2003 remote sensing with optical imaging (group of N. Thomas). The latter has yielded stunning images of various Solar System bodies like comets (with the OSIRIS camera on ROSETTA) or of Mars with the CaSSIS (Colour and Stereo Surface Imaging System) camera on board the Trace Gas Orbiter, an ESA satellite currently orbiting the red planet (see *Spatium* 15 by N. Thomas). This camera was developed at University of Bern by a team led by Nicolas Thomas (born 1960). An impressive image taken by CaSSIS in 2019 is shown in **Figure 84**.

The second pillar are theoretical models of planet formation and

Fig. 84: Image of dune formations taken by CaSSIS in the north-pole region of Mars. Gas ejections during melting of CO_2 ice produce the dark regions. The shape of the dunes gives hints to the prevailing wind direction and sediment transport. (Credit: ESA/Roscosmos/CaSSIS)

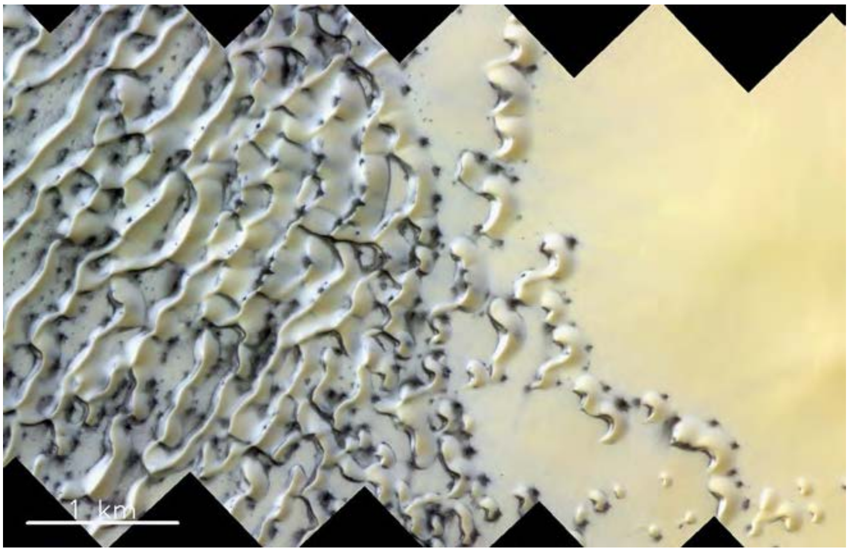


Fig. 85: The building Hallerstrasse 6, where ISSI has taken office, in walking distance to the Physics Institute of the university. (Credit: ISSI)

evolution that are used to interpret the observations and experimental results obtained both for the Solar System and for extrasolar planets. The study of these distant worlds has revolutionised our understanding of how planets form and is today one of the fastest growing fields in modern astronomy. The theory of planet formation and the study of extrasolar planets was brought to Bern by Willy Benz (born 1955), who served as the director of the Physics Institute and leader of the theory group for many years. With Christoph Mordasini (born 1978) as Benz's successor, these theoretical studies are intensified and extended to statistical comparisons between theoretical formation models and exoplanet observations (see *Spatium* 41 by Ch. Mordasini). Impact processes that have shaped many objects in the Solar System (like the comet 67P/Churyumov-Gerasimenko, but also Mars and Mercury) are also a main research line in the theoretical pillar. The next step will be the search for life on an extrasolar planet by finding biomarker gases in its atmospheric spectrum. The division is contributing to this exciting perspective by building parts of the high-resolution optical spectrograph ANDES, which will be an instrument of ESO's Extremely Large Telescope (ELT) that is currently being built in the Atacama Desert in Chile. The first light of this colossal telescope (diameter of the main mirror: 39 metres) is expected in 2027.

The International Space Science Institute

The International Space Science Institute (ISSI) in Bern is a non-profit organisation and foundation under Swiss law. Its mission to facilitate and support space-related research in international cooperation has in fact been a visionary idea of Johannes Geiss. International communication and cooperation and joint effort were already the basis for missions like Giotto to Halley's Comet in the mid-eighties, which required the common involvement of several space agencies.

Fig. 86 ISSI's founder Johannes Geiss at the entrance in 1995. (Credit: ISSI)

After Johannes Geiss' retirement from university, he fully pursued the realisation of an organisation that could proactively foster the exchange of scientific knowledge and ideas in an interdisciplinary and international way. During his time in Houston working for the SWC Apollo experiments, he had acquired enough experience in how to successfully lobby for his ideas and projects. He had the enthusiasm and eloquence not only to convince decision makers at the European Space Agency (ESA), the Swiss Confederation, the Swiss National Science Foundation (SNF) and the University of Bern to provide the financial resources, but also to secure a significant initial endowment by the leading Swiss space company Contraves Space AG, later Oerlikon Space AG and now a part of RUAG. Moreover, exponents of the main stakeholders as well as universitarian and private supporters had organised themselves in the association Pro ISSI to actively promote the creation of the International Space Science Institute, and it finally could be inaugurated in 1995. The location of the Institute and its founder at the entrance are shown in **Figures 85 and 86**, respectively. In 2013, the International Space Science Institute Beijing (ISSI-BJ) was founded, based on an agreement of cooperation in space science between ISSI Bern and China's National Space Science Center of the Chinese Academy of Sciences (NCCS, CAS).

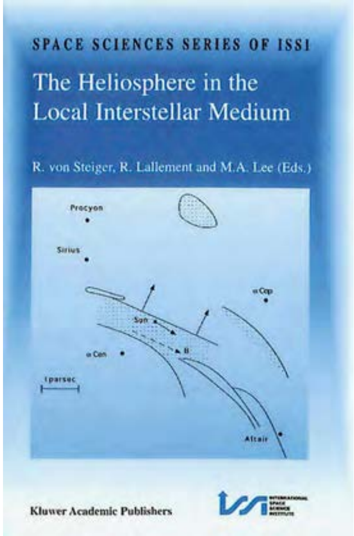
The "added value" that ISSI provides is a genuine environment for scientific discussion and exchange, in workshops, teams and dedicated working groups. Its "deliverables" are scientific publications of various formats to gain, secure, disseminate, and transfer knowledge. Starting from heliospheric research and Sun-Earth relations, space plasma physics and planetary physics, also research on Earth and climate science has been added to ISSI's portfolio.

Fig. 87: Half of the ISSI staff in 1996, left to right: Vittorio Manno, Rudolf von Steiger, Bengt Hultqvist. (Credit: ISSI)

Not only planning and organisation of missions in a global context but also calibration and maintenance of spacecraft needs a forum for international exchange, as well as the handling and evaluation of the growing number of data from the various missions and how to best make use of it. ISSI is exactly providing this kind of platform. **Figures 87 to 89** show impressions from the very first activities at ISSI.

Fig. 88: ISSI staff and the participants of the first ISSI workshop 1996 on "The Heliosphere in the Local Interstellar Medium". (Credit: ISSI, Photo Urs Lauterburg)

Fig. 89: The outcome of the first workshop, the first volume in the Space Science Series of ISSI, 1996. (Credit: ISSI)



SPACE SCIENCES SERIES OF ISSI

The Heliosphere in the Local Interstellar Medium

R. von Steiger, R. Lallement and M.A. Lee (Eds.)

Kluwer Academic Publishers

8. ISSI today

As of today, ISSI has been host to about 6500 visitors from nearly 60 countries in team meetings, workshops, working groups, fora, or as visiting scientists. It has been successfully seeding cooperation of agencies and laboratories, of individual scientists and groups. During the pandemic, an emphasis has been put to remote meetings and the organisation of video conferences and seminars, for example, the "Game Changer Series" of ISSI featuring various 45 min talks on a certain topic. So far, the featured subjects have been space missions that acted as "game changers", solar physics, and Earth and climate, a round on cosmology is about to start. All seminars can be followed in a live stream, as well as later on YouTube. In 2015, the Johannes Geiss Fellowship has been established to associate an internationally respected scientist to ISSI for several visits within one year.

Fig. 90: Johannes Geiss and Roger Bonnet, ISSI director since January 2003, during the handover statement. (Credit: ISSI)

Still, the organisation of ISSI has been kept lean, with a minimum of staff, and its directorate and scientists representing the various fields of space research. The infrastructure has undergone major upgrades and is optimised for hosting meetings; in particular, the equipment of the modern "Johannes Geiss Auditorium" features a highly developed video conferencing system.

The spectrum of ISSI's disciplines has broadened, covering the range from astrophysics and cosmology to Solar System physics and planetary sciences and from Earth sciences to astrobiology. Similarly, the objective of the association Pro ISSI has been changed – from founding organisation to supporting organisation. Special focus has been put to the public relation activities for ISSI, with hosting meetings and publication of the *Spatium*.

Fig. 91: Group photo at the celebration of 20 years of ISSI, 2015. (Credit: ISSI)

9. Review of ISSI's publication highlights since 1995

This selection has strongly been biased towards "local" research, and merely gives an overview over the broad variety of research topics. It is by no means fully representative, and it is highly recommended to visit https://www.issibern.ch/publications.

Selection from ISSI Space Sciences Series

The books from ISSI's Space Science Series present the results from Workshops held at ISSI. Thus, as the workshops, the volumes coherently cover well-defined topics from heliospheric research, general solar physics, plasma physics, planets, comets, Earth and planetary climates, astrobiology, galaxies, Black Holes, supernovae, Earth observation, and star formation. This fast-growing series of research papers by leading experts focuses on a special topic summarising latest research results. All papers are peer-reviewed and published in parallel as issues of Space Science Reviews or Surveys in Geophysics. Some journal papers are open access.

1 R. von Steiger, R. Lallement, M.A. Lee (Eds.),
The Heliosphere in the Local Interstellar Medium, October 1996

8 K. Altwegg, P. Ehrenfreund, J. Geiss, W. Huebner (Eds.),
Composition and Origin of Cometary Materials, 2000

9 W. Benz, R. Kallenbach, G.W. Lugmair (Eds.), From Dust to Terrestrial Planets, 2000

11 E. Friis-Christensen, C. Fröhlich, J.D. Haigh, M. Schüssler, R. von Steiger (Eds.),
Solar Variability and Climate, 2000

12 R. Kallenbach, J. Geiss, W.K. Hartmann (Eds.),
Chronology and Evolution of Mars, 2001

15 G. Paschmann, S. Haaland, R. Treumann (Eds.),
Auroral Plasma Physics, 2003, 2nd ed. 2005

17 G. Beutler, R. Rummel, M.R. Drinkwater, R. von Steiger (Eds.),
Earth Gravity Field from Space – from Sensors to Earth Sciences, 2003

25 O. Botta, J. Bada, J. Gómez Elvira, E. Javaux, F. Selsis, R. Summons (Eds.),
Strategies of Life Detection, 2008

28 H. Balsiger, K. Altwegg, W. Huebner, T. Owen, R. Schulz (Eds.),
Origin and Early Evolution of Comet Nuclei, 2008

47 A. Balogh, A. Bykov, P. Cargill, R. Dendy, T. Dudok de Wit, J. Raymond (Eds.),
Microphysics of Cosmic Plasmas, 2014

49 M. Falanga, T. Belloni, P. Casella, M. Gilfanov, P. Jonker, A. King (Eds.),
The Physics of Accretion onto Black Holes, 2016

58 A. Cazenave, N. Champollion, F. Paul, J. Benveniste (Eds.),
Integrative Study of the Mean Sea Level and its Components, 2017

66 R. de Grijs, M. Falanga (Eds.),
Astronomical Distance Determination in the Space Age, 2019

73 N. Thomas, B. Davidsson, L. Jorda, E. Kührt, R. Marschall, C. Snodgrass, R. Rodrigo
(Eds.), Cometary Science: Insights from 67P/Churyumov-Gerasimenko, 2021

Fig. 92: The first book of the ISSI Scientific Reports series. Two workshops in 1996 and 1997 resulted in the publication of the volume in 1998. (Credit: ISSI)

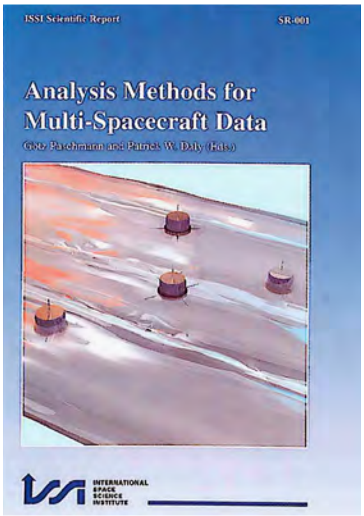


Fig. 93: The "Century of Space Science", a compendium on space-related research by leading experts, meticulously edited, in two volumes, of 2000 pages in total. (Credit: ISSI)

Selection from ISSI Scientific Reports

ISSI's Scientific Reports Series publish the results from Working Groups or Teams. In general, they deal with spacecraft or technical topics, as well as with research on methods and techniques.

1 G. Paschmann, P. W. Daly (Eds.), Analysis Methods for Multi-Spacecraft Data, 1998

2 A. Pauluhn, M. C. E. Huber, R. von Steiger (Eds.), The Radiometric Calibration of SOHO, 2002

3 J. Geiss, B. Hultqvist (Eds.), The Solar System and Beyond – Ten Years of ISSI, 2005

9 M. C. E. Huber, A. Pauluhn, J. L. Culhane, J. G. Timothy, K. Wilhelm, A. Zehnder (Eds.), Observing Photons in Space – A Guide to Experimental Space Astronomy, 2010; 2nd ed. 2013

10 N. Kämpfer (Ed.), Monitoring Atmospheric Water Vapour – Ground-based Remote Sensing and In-situ Methods, 2012

14 V. Minier, R. M. Bonnet, V. Bontems, T. de Graauw, M. Griffin, F. Helmich, G. Pilbratt, S. Volonte (Eds.), Inventing a Space Mission – The Story of the Herschel Space Observatory, 2017

ISSI's millennium monument and other special publications

Apart from its regular publications, ISSI has been supporting several books and volumes of special interest. A very prominent example is the "Century of Space Science" (eds. Bleeker, Geiss and Huber, 2 vols., 2001), which covers all important space-science related topics of the last century that have been enabling today's research. Another example of this kind is the book "Surviving 1000 Centuries" by Bonnet and Woltjer (2008), which gives a scientific assessment of a sustainable future life on Earth.

50 issues of Spatium in retrospect

In 1998, not too long after ISSI had been established, Hansjörg Schlaepfer, then Contraves Space, was convinced by Johannes Geiss to help disseminate and transfer the main research areas of ISSI beyond the circle of the research community (for more history see *Spatium* No. 27, 2011). He became the first editor and doyen of the *Spatium* series, documenting basics of research at ISSI and many of the ISSI seminars held for scientific audience and the interested public. The very first issue, of course by Johannes Geiss, titled "Entstehung des Universums", was published in April 1998, followed by "Das neue Bild der Sonne" by Ruedi von Steiger in November 1998. The first few issues had been published in German; however, with growing interest and audience on the speakers' as well as on the readers' side, the language was switched to English.

Fig. 94: "Surviving 1000 Centuries. Can we do it?" An assessment of the physical conditions and boundary conditions for sustainable future life on our planet, by R. M. Bonnet and L. Woltjer, 2008. (Credit: ISSI)

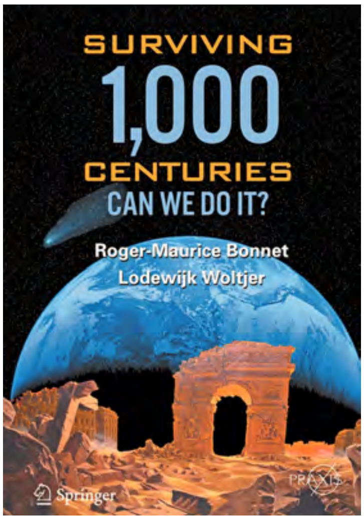


Fig. 95: The *Spatium* No. 1, 1998, by Johannes Geiss, edited by H. Schlaepfer. (Credit: ISSI)

Acknowledgements

The authors would like to express their gratitude for material generously provided by various institutions, archives, libraries, and colleagues, in particular Heinz Wanner, Thomas Stocker, Adrian Jäggi and Christoph Mordasini. Andrea Fischer was helpful in searching the ISSI archive for treasures, and so was Kaspar Meuli of the OCCR. Continuous support by all the ISSI colleagues, as well as by the Pro ISSI board and all members of the association is kindly acknowledged.

References

Webpages of the University of Bern and ISSI

Amaldi, E., "The Adventurous Life of Friedrich Georg Houtermans, Physicist 1903–1966"; ed. Saverio Braccini, Antonio Ereditato and Paola Scampoli, Springer Briefs in Physics 2013, pp. 152.

Bühler, F., Eberhardt, P., Geiss, J., Meister, J., and Signer, P., "Apollo 11 Solar Wind Composition Experiment: First Results", Science, vol. 166, no. 3912, pp. 1502–1503, 1969.

Geiss, J., Eberhardt, P., Bühler, F., Meister, J., and Signer, P., "Apollo 11 and 12 solar wind composition experiments: Fluxes of He and Ne isotopes", Journal of Geophysical Research, vol. 75, no. 31, p. 5972, 1970.

Lüthi, D., Le Floch, M., Bereiter, B., et al., "High-resolution carbon dioxide concentration record 650 000–800 000 years before present", Nature 453, pp. 379–382, 2008.

Siegenthaler, E., and Oeschger, H., "Predicting Future Atmospheric Carbon Dioxide Levels". Science 199, pp. 388–395, 1978.

Spatium No 1, Geiss, J., Entstehung des Universums, April 1998.

Spatium No 2, von Steiger, R., Das neue Bild der Sonne, November 1998.

Spatium No 4, Altwegg, K., Kometen, October 1999.

Spatium No 6, Benz, W., From Dust to Planets, October 2000.

Spatium No 7, Pretzl, K., In Search of the Dark Matter in the Universe, May 2001.

Spatium No 10, Beutler, G., Satellite Navigation Systems for Earth and Space Sciences, June 2003.

Spatium No 15, Thomas, N., Titan and the Huygens Mission, November 2005.

Spatium No 20, Wiese, U.-J., What the Universe consists of: From Luminous to Dark Matter and Quintessence, November 2007.

Spatium No 27, Schlaepfer, H., Science First, September 2011.

Spatium No 29, Wurz, P., Mysterious Mercury, May 2012.

Spatium No 31, Rummel, R., Earth Gravity From Space, May 2013.

Spatium No 41, Mordasini, Ch., Extrasolar Planets - Confronting the Theory of Planet Formation with Observations, May 2018.

Spatium No 46, Cazenave, A., Climate Change and Sea Level Rise, September 2020.

Spatium No 48, Fortier, A., CHEOPS, September 2021.

Spatium No 49, Jäggi, A., Exploring the Earth's Time-Variable Gravity Field using Satellite Observations, May 2022.

Spatium No 52, Schildknecht, Th., Space Debris, in preparation (due May 2023).

Abbreviations

AIUB	Astronomisches Institut der Universität Bern
BBB	Burgerbibliothek Bern
CSH	Center for Space and Habitability
EAD	Eidgenössisches Archiv für Denkmalpflege
ESA	European Space Agency
ETHZ	ETH Zürich
IGN	Institut Géographique Nationale Paris/Saint-Mandé
ISSI	International Space Science Institute
NASA	National Aeronautics and Space Administration
OCCR	Oeschger Centre for Climate Change Research
PIUB	Physikalisches Institut der Universität Bern
SNB	Schweizerische Nationalbibliothek, Bern
StABE	Staatsarchiv des Kantons Bern
swisstopo	Bundesamt für Landestopographie, Wabern
UB Bern	Universitätsbibliothek Bern

SPATIUM

In 1946, Harry Harper published the book "The Dawn of the Space Age", with which he not only announced a new era, but also coined the term "Space Age", which was used to describe this era from then on. It heralded both manned and, more importantly, unmanned exploration of near-Earth space and the Solar System. A rapid development began with the goal of sending humans into space and exploring the universe from space with satellites and space probes. In the 1940s and 1950s, this exploration was still limited to the upper atmosphere with so-called "sounding rockets". But with the first launch of an artificial Earth satellite in 1958, the technical conditions were in place to conduct astrophysics from space. The two central persons in this development were James A. van Allen and Homer E. Newell. They pushed forward that unmanned exploration of space with artificial satellites and space probes, which we today call "Space Science". The foundation was laid by van Allen with the publication of the conference volume "Scientific Uses of Earth Satellites" in 1956. In the same year, the Proceedings "Earth Satellites as Research Vehicles" contained an important contribution to the "International Geophysical Year" 1957/58 by Newell. In 1958, the Committee for Space Research (COSPAR) was founded. Already in 1961, the basic works by Lloyd V. Berkner and Hugh Odishaw "Science in Space" and by William Liller "Space Astrophysics" were published. The first comprehensive textbook entitled "Introduction to Space Science" was published by Wilmot N. Hess in 1965.

The physicists of the University of Bern were involved from the very beginning. The first international Space Science Symposium was held in Nice from 11 to 16 January, 1960 and its proceedings were published in the same year under the title "Space Research" by Hilde Kallmann Bijl. Two articles by Bernese physicists appeared in it, by the author duos Hans Debrunner and Friedrich Georg Houtermans and Johannes Geiss and Hans Oeschger. The further development of Space Sciences in Bern was mainly driven and shaped by the American Apollo programme and by various missions to comets. Missions like Cobe, WMAP, Planck, Chandra, Spitzer, Hipparcos, Gaia, SOHO, SDO, Parker, Kepler, CHEOPS, HST, JWST or Seasat, Geosat, ERS-1, ERS-2, Envisat, TOPEX/Poseidon, Jason and the Sentinel satellites or probes like Voyager 1 and 2, Cassini/Huygens, as well as all Mars rovers, to mention but a few, have revolutionised our knowledge in Earth sciences, planetology, astrophysics, and cosmology. This rapid development of space sciences led not least to the foundation of the International Space Science Institute (ISSI) in Bern by Johannes Geiss in 1995.

On the occasion of the 50th issue of *Spatium*, this development and especially the location of the ISSI in Bern have been put into a larger historical context and illustrated with pictures. In particular, it has been documented that in Bern the observation of the Earth and the cosmos, whether from the ground or from space, as well as their description can look back on a long tradition, starting with the "old" astronomical observatory "Uraniae" (founded in 1822), its successor, the so-called "Telluric Observatory" (founded in 1876 and predecessor of the Physics Institute), the outposts Muesmatt and Zimmerwald Observatories, up to the Building of Exact Sciences, harbouring the Institutes of Astronomy, Physics (theoretical and applied), Mathematics, and Climate and Environmental Physics including its diverse centres, i.e., Center for Space and Habitability (CSH), Albert Einstein Center for Fundamental Physics (AEC), and the Oeschger Centre for Climate Change Research (OCCR).