Stellarium Gornergrat

Timm-Emanuel Riesen[1], Stéphane Gschwind[2], Andreas Müller[2], Simon Ruffieux[3], Jesse Weder[1], Jonas Frey[1], Miriam Missura[1], Heinrich Summermatter[1], Peter Schlatter[1], Michael Franz[1], Sascha Hohmann[5], Thomas Schildknecht[4], Susanne Wampfler[1], Yann Alibert[1]

[1]University of Bern, Center for Space & Habitability (CSH), Bern, Switzerland
[2]University of Geneva, Geneva, Switzerland
[3]Haute école d'ingénierie et d'architecture Fribourg, Fribourg, Switzerland
[4]University of Bern, Astronomical Institute (AIUB), Bern, Switzerland
[5]Leibniz Institute for Science and Mathematics Education (IPN), Didaktik der Physik, Kiel, Germany

timm.riesen@unibe.ch

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1. Project description

The Stellarium Gornergrat is a long-term project carried out by an on-going collaboration between the Center for Space and Habitability (CSH), the Astronomical Institute (AIUB), the University of Geneva (UoG), and the International Foundation High Altitude Research Stations Jungfraujoch and Gornergrat (HFSJG). Its major focus lies with public outreach and education. The project's main goals are:

- To build bridges between science and society.
- To spark and foster the public's interest in space, space sciences, and astronomy.
- Attract young people to the field and illustrate potential careers in astronomy and space sciences.
- Help people recognize and understand different observable phenomena in the day and night sky and let them appreciate the beauty and delicacy of nature.

To achieve these goals, the partners installed and operate an observatory at the Kulmhotel Gornergrat with different instruments and hardware (see Figure 2). The instrumentation in the south dome has to survive challenging meteorological conditions and is under constant maintenance. Our instrument park currently consists of these 5 different instruments:

1. The Allsky Camera (OMEA 8M) takes around the clock exposures of the day and night sky. This instrument replaces the previous Allsky Camera that was destroyed in the lightning incident. The camera is currently being commissioned in Bern.

2. The RiFast 600mm telescope with a huge Field of View (FOV) is ideal for deep sky objects.

3. The Planet Camera (Takahashi Mewlon-250) is ideal for planetary objects and small targets that require a smaller FOV.

4. The Constellation Camera is ideal to depict complete constellations, asterisms, and group of constellations. It has a customized housing that was developed and built in Bern.

5. The Look-through Telescope (Takahashi TAO-150) for local guests and guided tours at the observatory.

A major way to use the Stellarium Gornergrat is by scheduling observations remotely through a web portal that triggers robotic observing. Teachers, students, and the broad public can browse and pick among different astronomical activities and schedule observations. The Stellarium automatically works through the different scheduled observations and allows a registered user to access the obtained data or status information upon completion of an observation task.

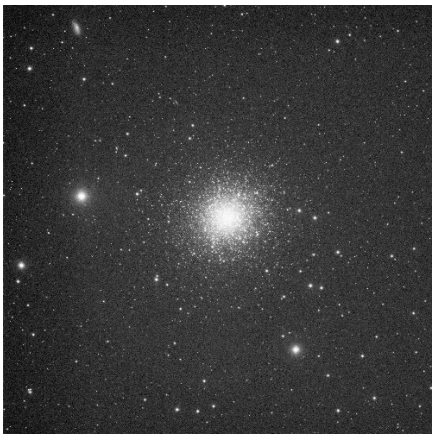

Figure 1. Messier 13, a great globular cluster in Hercules containing several hundred thousand stars. Stellarium Gornergrat 60cm Deep Sky Telescope, 280s, Red filter, 10.03.22. Observer: Michael Franz.

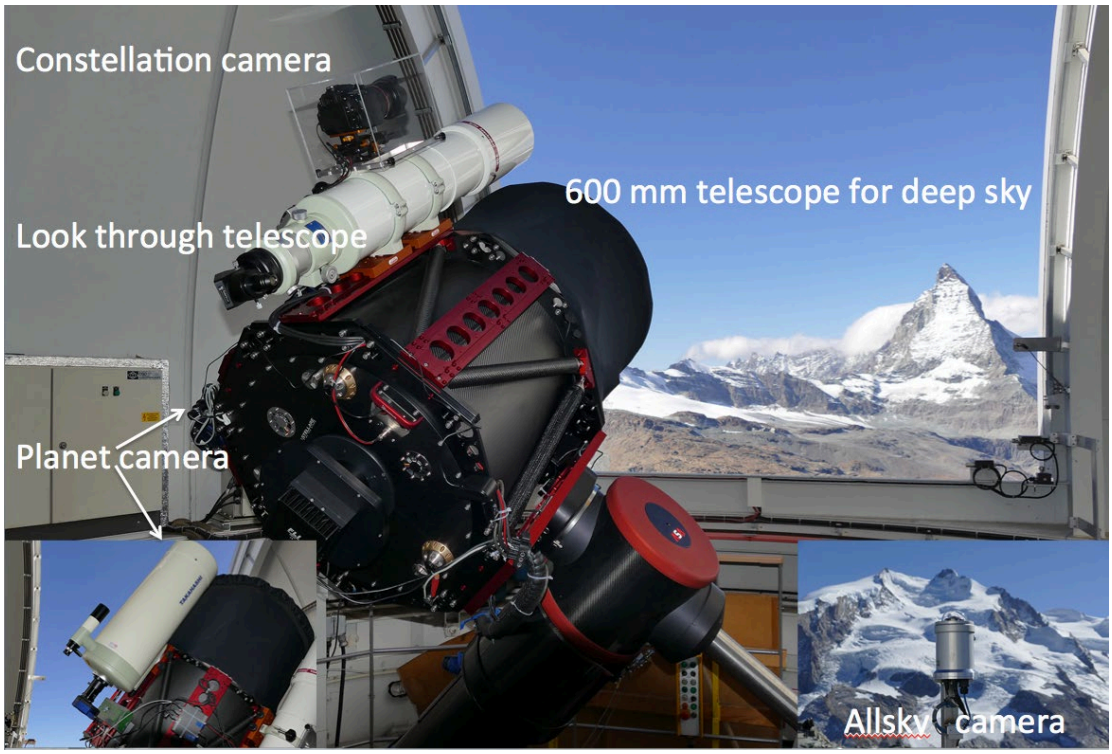

Figure 2. Available instruments at the Stellarium Gornergrat: On the ASA DDM 160 mount (with absolute encoders) inside the south dome are the Officina Stellare RiFast 600mm "Deep sky telescope", the Canon 60Da "Constellation camera", the Takahashi TAO-150 "Look-through telescope", and the Takahashi Mewlon-250 "Planet Camera"(see image inset in the lower left). Mounted on a boom outside the north dome is the Alcor systems "Allsky camera" with a DMK51AG02.AS CCD sensor (see image inset in the lower right).

2. Status of hardware and instruments

Table 1. Instrument/hardware status and performance.

Instrument	Status / Performance
Officina Stellare RiFast 60cm (DeepSky telescope)	Instrument image quality remained excellent in the reporting period. Mirror cleaning was not necessary but will be a topic in the next 2 years.
FLI Proline PL16803 (Main CCD detector)	The on-spec performance of the CCD was unchanged in 2022.
Takahashi Mewlon 250 (Planet camera will transform to Spectra camera in 2023)	Work has started in Q3 to use this instrument as SpectraCam, i.e. we plan to enable the taking of star spectra via portal. Tests with the full setup are expected for Q2/23.
Takahashi TOA 150 (Looking through telescope)	Telescope and eyepieces are in very good condition and regularly used in local events.
Canon 60Da (Constellation camera)	The camera is in very good condition and working as expected.
ALCOR OMEA 8M (Allsky camera)	The instrument was repaired but not yet re-deployed. We wait until work to improve the electrical grounding and internal overcurrent protection of the Kulmhotel has been finished (Expected in Q2/23).
SAIA and weather sensors	The Lambrecht sensor was repaired in Q2 and has been remounted. A hot spare has been bought and made ready. The clarity cloud sensor was damaged in a storm and was repaired in Bern and has been redeployed. The sensor can no longer detect raindrops but is otherwise fine. It will be replaced once the next generation is out. The regular and dedicated precipitation sensors work on spec.

ASA DDM160 (Equatorial mount)	The mount continuously works as expected and had no thermal issues for more than 3 years, so we regard these problems solved. We found some software errors that can lead to a forbidden slew with the telescope down instead of up. There is no solution to this problem so far (by the manufacturer ASA).
EATON USV (Large UPS in the cellar)	Yearly maintenance showed no problems. Performed as expected.
USB hubs, and active repeaters	One of the two Acroname USB hubs was damaged by overcurrent and will need to be replaced in 2023. It protected the connected equipment well (FLI camera, telescope, etc).
Dome, azimuth and shutter motors, encoder, hydraulic system	There was a hydraulic oil spill in late summer with no obvious cause. Later in winter, the oil level, caused by temperature, was then detected too low by the electrical system and dome shutter operations were inhibited. Topping off the oil solved the problem; however we need to keep an eye on spilling and some older parts of the hydraulic system.

Table 1 summarizes the instrument status throughout the reporting period. Overall, the operations were stable, and the facility was at a high rate available to our remote users. The only significant downtime occurred in the last third of November when suddenly the dome could not be opened anymore. Locating the error was time consuming: At first, the hydraulic system seemed to be fine as the indicated oil level was higher than the hand markings for safe operations. A lengthy investigation and inspection of the electrical system followed and revealed that the actual oil level proved to be too low for an integrated level switch to close. The cause was indeed a too low oil level leading this switch to interrupt the electrical power flow to the shutter motor. After filling enough oil to close the switch, the shutter operations turned back to nominal. Full operations were restored in early December.

3. Milestones & Achievements regarding robotic abilities and software on site

The automated observing procedure requires constant monitoring and the generated error reporting output needs to be reviewed regularly. In addition to these recurring tasks, our collaborators in Fribourg also worked on significant improvements summarized below.

Multiple observations per plan: the possibility to request multiple observations per plan has been implemented. The whole communication pipeline (transfer, databases, website, etc.) has been updated to handle the possibility to take several images within a single observation plan.

Automatic DARKS generation: the option for the system to automatically generate DARK before specific plans has been monitored and improved. The DARK seemed to have an undesired effect on focusing processes, which has required an extensive investigation on the whole system.

Automatic BIAS generation: the option for the system to automatically generate BIAS at the beginning and at the end of an observing night has been monitored and improved. The maintaining of a correct focus has been guaranteed through the better focus control. BIASES are automatically taken by the system and stored in a specific folder.

Automatic observation clean interrupt: the possibility to perform a clean abortion of the automatic observation procedure after it started has been improved to guarantee a quick interruption in case a manual override is needed unforeseen.

Pointing model real-time update: the update of the pointing model in real-time according to the physical tilt of the tower has been implemented. This update corrects and improves the precision of the pointing model and results in better pointing for all instruments with a small field of view (both Takahashis).

Automatic observation resuming: the resuming of observations allows to interrupt and then resume operations in case of bad weather. This functionality has been live since early 2020 and constantly monitored and improved. Additional functionalities have been added and constant validation has been kept up after each deployment of new feature.

Error Management: the error management of the automatic observation system has been monitored and improved. We notably corrected some critical issues after a telescope was physically disconnected and triggered critical crashes.

4. Local events, remote usage, and statistical quantities

4.1 Local events and visitors

In 2022, a total of 674 persons (previous year 531) visited the Stellarium and got a tour of the facility and/or night-time observing on site. Further key numbers: Total number of day crew: 37 (previous year 23). Total number of night crew: 21 (previous year 19). The “Dining with the stars events” in winter as the “Space week” in fall were very successful and often booked out.

4.2 Remote usage via web portal

Remote usage increased to a new all-time high of 6364 submitted observing plans in the reporting period (4190 plans in 2021 and 2735 plans in 2020). This translates to an average of 32 observing plans for each of the 201 nights last year, where the weather allowed observations for more than 70% of the night (see Fig. 9). This is near saturation when considering the length of the nights and the high alpine weather.

4.3 System

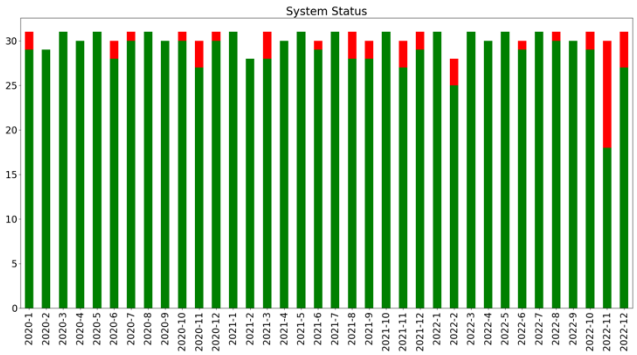

Figure 3. System availability over the last 3 years. Each month is represented with days online (green) and days offline (red).

4.4 Automatic Observations

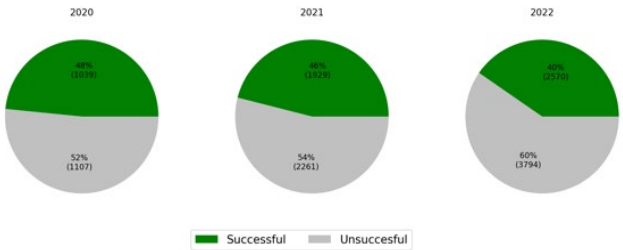

Figure 4. Success vs failure of automatic observations plans. The number of requested observations increased over the years (2146 in 2020, 4190 in 2021 and 6364 in 2022). The success rate roughly varies between 40 and 50% which is what can be expected considering the weather conditions on the Gornergrat. Most reported failures are due to unsafe weather conditions (estimated > 90%) whereas the rest is caused by network interruptions or other problems with hardware or software. Users can reschedule an observation that failed, until it is successful.

Figure 5. Whirlpool Galaxy observed with the 60cm Deep Sky Telescope of the Stellarium Gornergrat. The image was exposed 15min in Clear filter on 10.02.22. Observer: Portal User Lukas B.

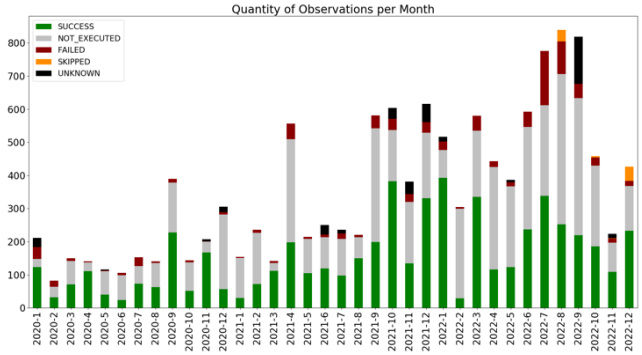

Figure 6. Histograms with observations in days/month over the last 3 years. The final status of the observation is colour coded. Green: SUCCESS, the observation was successfully performed. Gray: NOT_EXECUTED, the observation could not be executed because of weather conditions, or the observatory was used for manual observations. Dark red: FAILED, the observation failed because of a problem within the system, because the target was too low or because the weather conditions turned bad while performing the observation. Orange: SKIPPED, the observation was skipped because it was behind the scheduled time. Black: UNKNOWN, the information could not be retrieved from monitoring and log files. This can occur in case of a system crash or manual interruption of the automatic procedure (may also occur because of tests performed on the system).

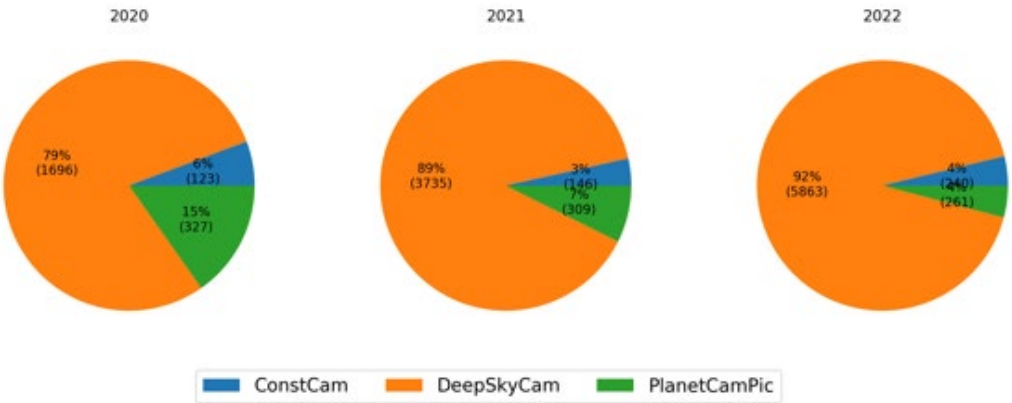

Figure 7. Instrument usage over the last 3 years. The trend of the last years is continued, the most popular instrument by far remains the RiFast 600mm / DeepSkyCam Telescope that was requested in 92% of all submitted observing plans in 2022. As the PlanetCam was demounted in Q4 for upgrades to turn it into an instrument for star spectra, we see a slight decrease of respective instrument use.

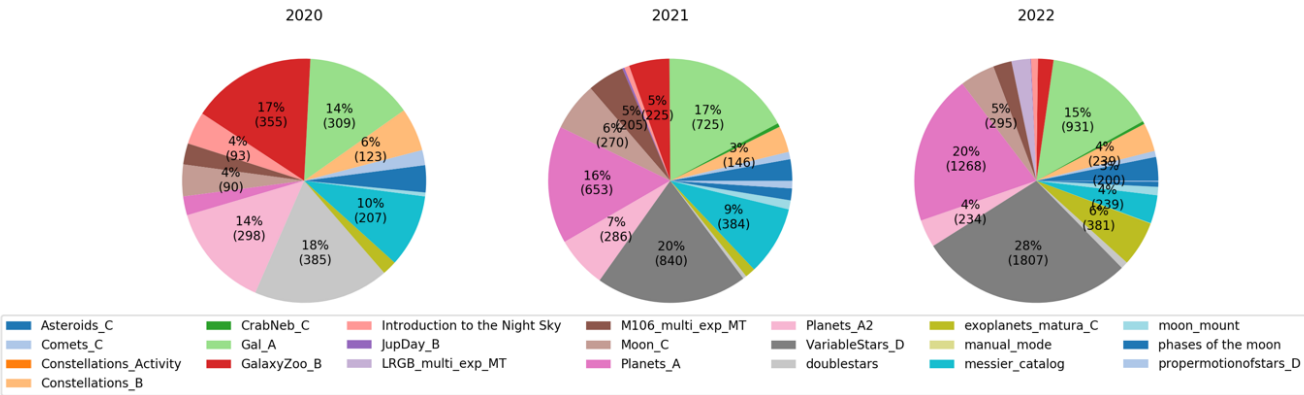

Figure 8. Type of activity requested by portal users over the last 3 years. Activities that were selected less than 3% are omitted in the graphical representation but can be found in Table 2 below. In 2022 the Galaxy Activity for level B (red) was selected significantly less compared to 2020, confirming a decrease that has been observed already in 2021.The level A equivalent is of stable interest to our user base. Over the last 3 years, we observe a sharp increase of interest to observe variable stars, driven by several matura theses with related topics.

Table 2. This table lists how often a certain activity was ordered via portal in the last 3 years.

Type of activity	2020	2021	2022
Asteroids_C	44	119	200
Comets_C	43	41	51
Constellations_Activity	0	0	1
Constellations_B	123	146	239
CrabNeb_C	0	21	25
Gal_A	309	725	931
GalaxyZoo_B	355	225	131
Introduction to the Night Sky	93	28	58
JupDay_B	0	12	5
LRGB_multi_exp_MT	0	0	159
M106_multi_exp_MT	60	205	156
Moon_C	90	270	295

Planets_A	54	653	1268
Planets_A2	298	286	234
VariableStars_D	0	840	1807
doublestars	385	20	60
exoplanets_matura_C	41	57	381
manual_mode	0	0	3
messier_catalog	207	384	239
moon_mount	11	50	70
phases of the moon	33	66	43
propermotionofstars_D	0	42	8

4.5 Observing Conditions

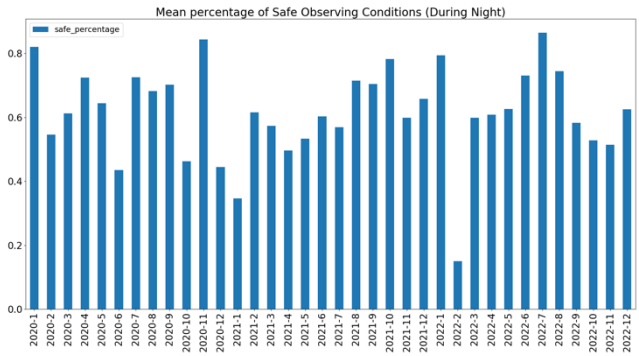

Figure 9. The robotic observatory always evaluates the weather conditions. The software fuses all sensor data and sets a Boolean flag to true when it is safe to observe. The histograms show the average percentage of time per/month when it was safe to observe.

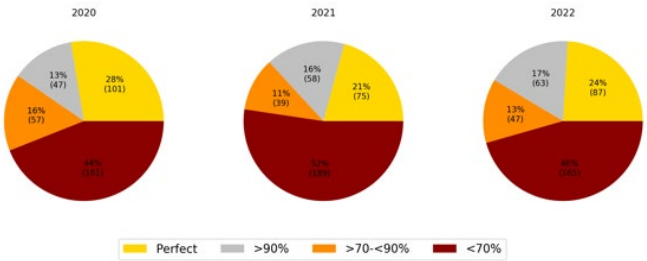

Figure 10. Analysis of night quality over the last 3 years. The indicated percentage describes the proportional amount of time for a given night, for which the fused sensor data indicated that it was safe to observe. Example: In 2022, 46% of all nights had at least bad weather for 30% of the night-time or more.

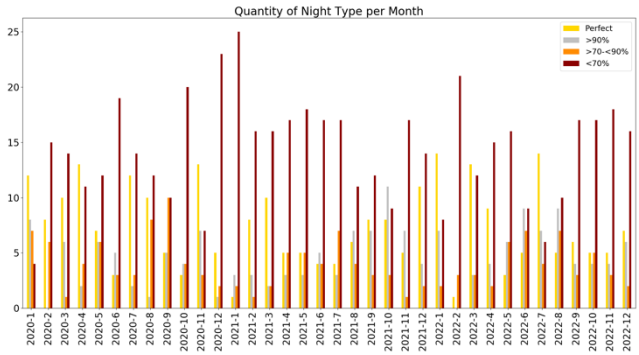

Figure 11. Per month analysis of the night quality as explained in Figure 9.

5. Development of website and pedagogical portal

The Stellarium Gornergrat requires a high amount of recurring maintenance and surveillance tasks of the involved IT infrastructure in Bern and on the Gornergrat. Regarding the website and portal, new features are also being developed continuously; the most important milestones for 2022 are summarized below:

Manual mode: A major effort went into the development of a completely new mode of ordering images, that allows the direct scheduling of observations using repetitions, sets, filter groups, etc. for more seasoned observers. Updates were required on server and client side, where the API was generalized and native Javascript ES6 modules were introduced respectively. This feature also involves the implementation of some quota, as a user can potentially schedule large amount of telescope time, with little effort. The development is already in testing phase with the goal to release the manual mode to the public in Q2/23.

Facilitating overrides by controlling slot availabilities: Instead of cancelling observing plans, whenever the telescope is used for local events, we can now block dates and times beforehand, so users can't schedule observations at the respective hours. This feature was sorely wanted but missing from the start and needed a fair bit of reverse engineering the web portal to be able to implement it.

6. Educational Activities

6.1 Overview

Several activities were completed in 2022. The activity "Size of the moon" was completed and put online. The "Exoplanet" activity was also finished and put online. An extension is currently being prepared for this activity. The "Constellations activity" has undergone a major overhaul and has been put online. A new activity on asteroids is underway with data acquisition.

Several activities have been translated from German into French and vice versa and new translations are in progress.

There have been several matura theses in both language region, for an overview of present and past topics and a selection of completed matura theses in full text, please visit our website.

Very fruitful contacts with the teacher community went on as in the last years, both within teacher education (see below) and with in-service teachers. As an illustrative case for the latter, a teacher from Collège Calvin in Geneva had contacted us to ask for a presentation of the project and the opportunities offered to high-school students to carry out a matura thesis with the instruments of the Gornergrat Observatory.

This teacher had already supervised students for matura theses made in collaboration with the Stellarium Gornergrat in the past. This is another example of the high interest of teachers and students in this kind of collaboration and underlines the importance of an extensive contact with the community and justifies the continuing and support and development of the Stellarium project including the further implementation and development (see next section).

Table 3. Overview on the development of teaching materials in 2022.

Name	Level	Status	Comment
Jupiter's Great Red Spot	B/C	French version translated and online	
Parallax Method	C	Advanced	Additional Data collected
The Size of the Moon	B	Finished and online	French version translated and online
Constellations	A	Finished and online	French translation in planning
Exoplanets	C	Finished and online	Additional version in planning
Cepheids	C	Basic conception	Proof of concept
The Solar System	B	Finished	French translation in progress
Asteroid	B	Started	Collecting data

6.2 Talks and Teacher Education / Professional Development Offers

Table 4 gives an overview on conference and outreach talks held in 2022, from which we select two illustrative examples.

Spring Meeting German Physical Society (DPG): Unfortunately, COVID restrictions did not allow the Spring Meeting (Frühjahrstagung der Deutschen Physikalischen Gesellschaft) in Heidelberg to be held in person as originally planned, but the online conference still allowed us to present our project. From the content of the questions asked after the presentation, it seems to have been a great success: many of the participants had visited our website during the session and had several questions, including their immediate registration. Incidentally, the talk held just before ours was entitled: "Fern, ferner, am fernsten - warum es sinnvoll ist, auch im Mathematikunterricht über Exoplaneten und Kosmologie zu sprechen (Eleen Hammer und Holger Cartarius, Friedrich-Schiller-Universität Jena). What a beautiful coincidence. This illustrates that we can indeed respond to current demands and that we offer exactly what is missing from desirable and requested opportunities.

250 the anniversary of the Geneva Observatory: This occasion was celebrated by the observatory by "Journées Portes Ouvertes" on the weekend of June, 18th and 19th.

The two open days were a great success with many people who attended. The Stellarium Gornergrat had the opportunity to set up a stand. We were able to present our project and show visitors how they could book images at the Gornergrat Observatory using three computers at our booth. The people who visited our stand really appreciated our initiative. They were not only pleasantly surprised by the technical capabilities (e.g. the possibility to book images remotely) offered by our project, but they were also enthusiastic about the fact that such a project is aimed at schools and the general public. We were even thanked by the visitors for making such a project available to the educational world and the general public.

Table 4. Teacher Education Courses and Conference Talks.

Event	Place	Date	Activity
DPG Spring Meeting	online	23.03.2022	Conference talk
Collège de la Gradelle ("Career days" at high school)	Collège de la Gradelle, Geneva	2.06.2022	Outreach talk
Journées portes ouvertes 250 ans de l'Observatoire de Genève	Observatoire de Genève	18 and 19.06.2022	Presentation stand
Collège Emilie-Gourd (Matura thesis)	Collège Emilie Gourd	30.8.2022	Presentation about Matura theses
Collège Calvin (Matura thesis)	Collège Calvin, Geneva	15.9.2022	Presentation about Matura theses
Physics teacher meeting in Geneva	Collège de Cayla	15.9.2022	Outreach talk

As for the teacher community, several in-house professional education courses were given, in particular regarding the possibility of matura theses (see above). Additionally, measures for integration of the Stellarium Gornergrat into initial teacher education were continued. An emerging opportunity of special interest for this are teacher education courses on the use of ICT in science teaching, a development of obvious interest, including specific requirements in the federal matura regulations, as well as cantonal study programs. The Stellarium offers a broad range of possibilities in that respect, from experience with a high-end robotic observation facility and open data infrastructures to the use of specific algorithms and programs for data analysis (image processing, fitting procedure, etc.).

6.3 Further Funding and Perspectives for 2023

500'000 EUR grant: A German Foundation for Physics Education within the "Stifterverband für die deutsche Wissenschaft" (https://www.stifterverband.org/english) has granted 500'000 EUR for further development of the Stellarium Gornergrat in collaboration of the University of Geneva and leading researchers in Germany. Specifically, the grant is for integration of "further topics of current astronomy and of its evidence-based potential for motivation and cognitive activation in physics education (exoplanets, cosmology...)" into the offer of the Stellarium.

Cosmology perspectives: Among the perspectives for 2023 we would like to mention also, among others, a founding request for cosmology within the Agora program of the Swiss National Science Foundation, where activities with the Stellarium are planned to have an integral part (cosmic distance ladder, Hubble law).

6.4 Redesign of existing teaching materials in the framework of the MINT promotion grant

Miriam Missura (lecturer in science didactics) and Heinrich Summermatter (lecturer in general didactics) have joined the Stellarium Gornergrat project in summer 2022 and been adapting the previously developed learning activities of the "Stellarium Gornergrat" to the new Swiss curriculum 21 for public schools. For this purpose, both published and planned learning units were analyzed, summarized in an overview and complemented by historical research. Existing activities were assessed page by page based on the competencies of the new curriculum 21 and the learning goals of the high school curriculum to assess necessary subject or language changes for the different school levels.

Table 5. Adaption of teaching materials to curriculum 21

Veröffentlichte Aktivitäten (DE)	Alte Klassifizierung	1.-2. Klasse	3.-4. Klasse	5.-6. Klasse	7.-9. Klasse	10.-12. Klasse
Galaxy Zoo	B	0	0	X	X	X
Das Einmaleins des Nachthimmels	B	X	X	X	X	X
Berge auf dem Mond	C	0	0	0	X	X
Die Phasen des Mondes	A	X	X	X	X	X
Die Wanderung der Sterne	C	0	X	X	X	X
Der Krebsnebel	C	0	0	0	X	X
Ein Tag auf Jupiter	B	0	0	X	X	X
Supermond	C	0	0	X	X	X
Neu: Das Sonnensystem	A	X	X	X	X	X
Grün: Bestehendes kann zum grösseren Teil verwendet werden, kleine Ergänzungen						
Orange: Bestehendes kann verwendet werden, es sind aber grundlegende Anpassungen nötig						
Rot: Bestehendes wird nur als Idee gebraucht, die Aktivität muss auf ein anderes Niveau transformiert oder umkonzipiert werden						
0: nicht relevant für diesen Zyklus						

Existing learning content was organized and recombined according to elementary and high school cycles: for the 3rd/4th and 5th/6th grades, lesson plans and teacher comments were outlined and build upon each other across subjects. Enriched learning tasks include the different previous knowledge and learning pace of students and furthermore facilitate their personal, social and methodological development. At the same time, the structure of the electronic self-learning environment for a high school astronomy curriculum was created, its first chapters filled with existing learning content and supplemented with historical facts and interactive exercises.

In the spring semester of 2023, the planning for the primary and high school will be completed and further learning units with various media will be created or linked into the self-learning environment. An important focus will focus on tasks that develop fundamental principles of scientific thinking based on historical advancements in astronomy.

Figure 12. Comet C/2022 E3 (ZTF), detected on January 25th 2023 using the 60cm Deep Sky telescope of the Stellarium Gornergrat. Total integration time is 1h 40min with sets of 5x300s in the filters R, G, B. The tracking speed was set according to the hourly rates of the comet. The comet coma with its green head section is clearly visible as is the newly forming dust tail after a recent disconnection event that is believed to be caused by high solar winds. Observer and image preparation: Timm Riesen.

Internet data bases
https://stellarium-gornergrat.ch
https://stellarium-gornergrat.ch/portal
https://akademien-schweiz.ch/de/themen/mint-forderung/mint-2021-2024/projekte-2021-2024/

Scientific publications and public outreach 2022

Refereed journal articles and their internet access
Gschwind, S., S. Hohmann, A. Müller, T. Riesen, Das Stellarium Gornergrat: Ein ferngesteuertes Observatorium für Bildungszwecke, Astronomie & Raumfahrt im Unterricht[1], **60**, 32-36, 2022.
https://elibrary.utb.de/doi/epdf/10.5555/ar-185-2022_08

Conference Papers
Gschwind, S., S. Hohmann, A. Müller, J. Nordine, T. Riesen (accepted for publication), The Stellarium Gornergrat: Astrophysics with your own Data, Proceedings of the 3rd World Conference on Physics Education, Hanoi, Vietnam, December 13-16, 2021.

Address
Stellarium Gornergrat
University of Bern
Center for Space and Habitability (CSH)
CH-3012 Bern
Switzerland

Contacts
Dr. Timm-Emanuel Riesen
Tel.: +41 31 684 3318
e-mail: timm.riesen@unibe.ch

[1] Leading journal for astronomy education and amateurs in German language.