

Stellarium Gornergrat – A Swiss Robotic Observatory for Education and Citizen Science

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Abstract

Stellarium Gornergrat is the first remote controlled observatory in Switzerland dedicated to public and educational use. Five professional instruments are available, each with a specific use. Four of them (deep sky telescope, planet hunter, constellation camera, all sky camera) can be manipulated via the online platform, a fifth is for making visual observations during tours.

Students and amateur astronomers can make their own observations and take their own pictures using four different professional instruments. Learning units are available, complete with observation activities, worksheets and background information. Activities cover target audiences from primary school to students looking for a matura thesis in astronomy, from near space, through the solar system and the milky way, to far-away galaxies.

1 Introduction

From the 1960s to 2010, the picturesque Gornergrat (see Fig. 1) played host to advanced astronomy research [1]. The site stands 3100 metres above sea-level near Zermatt in Switzerland, with a view on the Matterhorn. The isolation, altitude and low light pollution make the location one of the best for astronomical observation in all of central Europe. However, over the last few decades, the scientific requirements for telescope locations have become more stringent. Thus, large telescopes now tend to be built in extremely dry and remote regions such as the Atacama desert in Chile [2]. Nonetheless, the Gornergrat remains a prime location for astronomical observations. The universities of Bern and Ge-

neva and the Foundation High Altitude Research Stations Jungfrauoch and Gornergrat HFSJG desired to continue using the site. Their discussions eventually led to the installation of the first remote controlled observatory in Switzerland dedicated exclusively to public and educational use, called Stellarium Gornergrat and installed in one of the domes of the Gornergrat Kulm hotel (see Fig 1).

The Stellarium is dedicated in particular to use by pupils. Observations can be ordered via a website (<https://stellarium-gornergrat.ch>). They are then carried out automatically by the telescope. In addition, fully developed learning units are available. These contain information for teachers and students, worksheets, exercises, observation tasks, and themes for various school levels. For particularly interested students, there is the option to develop high-school theses (matura) projects.

2 The concept – practical and educational aspects

The particularly motivating effects of treating astronomical themes in natural sciences teaching have been established in previous research [3]. They can be intensified by working with one's own astronomical data. A field trip to an observatory with a group the size of a school class is most often impossible. This is especially true for locations that, while ideal for observations, are geographically remote, such as the Gornergrat. Therefore, a robotic telescope is the solution of choice, as is now the standard in science [4], e.g. for the search for extrasolar planets [5].

An educational framework is also required, however, to give meaning to the work carried out on the observations



Fig. 1: Stellarium Gornergrat (in the dome on the left) with the Gornergrat Kulm hotel and the view on the Matterhorn. The project of a remote controlled observatory for educational purposes was initiated and supported by Kathrin Altwegg*, Hans Balsiger*,***, Willy Benz*, Erwin Flückiger*,***, Kevin Heng*, Didier Queloz*** and Stephane Udry*** (*University of Bern, **University of Geneva, ***High Altitude Research Stations Jungfrauoch and Gornergrat HFSJG. Financial support was provided in the framework of the Agora Science Communication Program of the Swiss National Foundation (PI Didier Queloz).

made and images taken. Such a context has therefore been provided via the growing number of activities available in French and German, comprising all the documents and background information necessary for teachers and students to use them “straight-out-of-the-box”.

Efforts have also been made to ensure that activities are available for a variety of ages. This ranges from the basics for pupils aged about 8, to complex topics with advanced conceptual and mathematical requirements for students at the end of the high school (see sect. 5 for details). In case of poor weather or technical problems, archive images are available for all activities.

3 The online portal

The online platform for download of learning material and for booking observations is available in French and German (Fig. 2, [6]). Registration is free of charge. The platform displays a list of bookable activities, split into three types: “teaching and learning activities”, “free observations”, and materials and suggestions for “high school diploma-level” work.

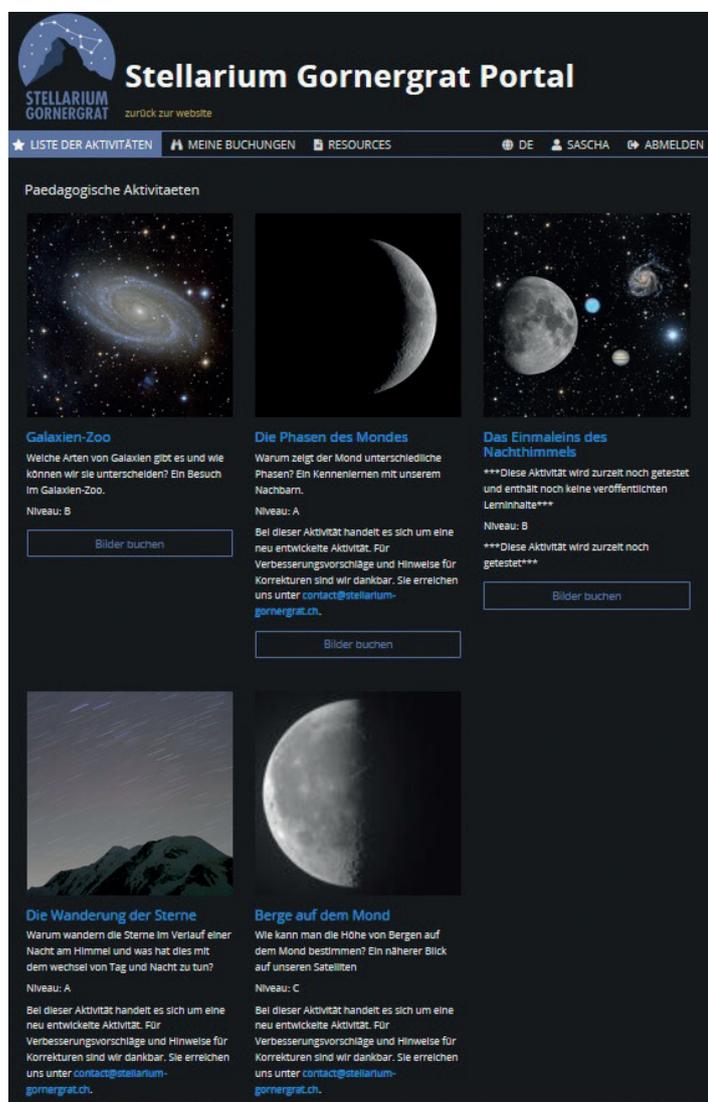


Fig. 2: Stellarium Gernergrat’s educational platform.

Within the “activities” (“Aktivitäten”) section complete observation projects (teaching sequences) are provided, including all the necessary documentation for students and teachers. “Free observations” include only the observation options, with no additional information. The section “Matura-Arbeiten” (high school theses) for students at the end of

their school careers generally deal with more complex topics, selected at in discussion with Stellarium staff.

Observations are booked on the platform via the *Bilder buchen* (“book images”) button (see Fig. 3). In addition, the following settings must be specified: an identifying number for the object to be observed must be chosen, and the telescope settings must be set to either automatic or manual mode. In most cases, automatic mode is recommended. It can nonetheless be interesting in a classroom context to look at the manual settings available. Finally, a time for the observation must be chosen. The options are the next available time at which the object is visible (above a certain elevation), the time at which the object will be best in the best position for an observation, or a manually-selected time (see Fig. 3).

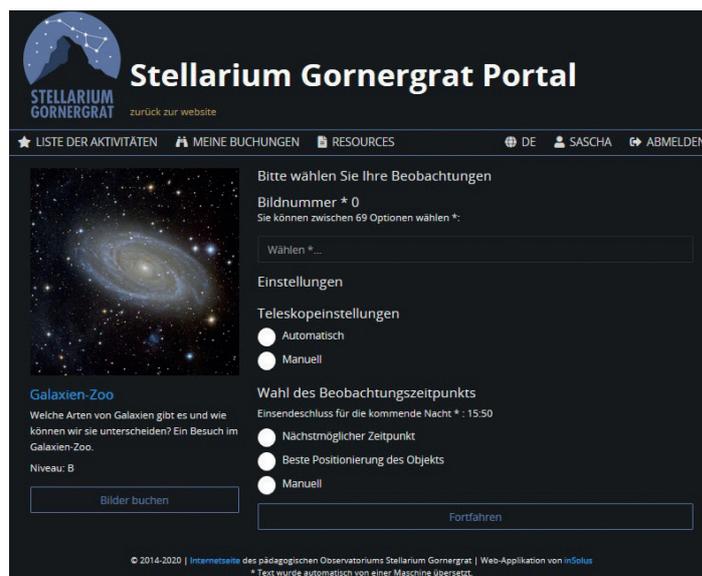


Fig. 3: The booking process.

Next, a summary is shown, including the observation date. If the “best position” time option is chosen, this can be up to a couple of weeks in the future. Typically, the images taken are made available to download via the platform on the afternoon following the observation date, in JPG and FIT formats.

4 The instruments

Stellarium Gernergrat is equipped with five professional instruments, each with a specific use. Four of them can be manipulated via the online platform. The fifth is for making visual observations during tours.

The **DeepSky Telescope** is a 60 cm Riccardi Fast Astrograph from Officina Stellare (RiFast), with a focal length of 2280 millimetres (Fig. 4). It is ideally designed to take images of faint objects, such as galaxies and various nebulae, also capable of producing colour images because of its CCD camera and changeable filters such as Red, Green, Blue, Transparent, H-alpha or Johnson filters (BVR: Blue, Visual, Red). Thanks to its large field of view (roughly 1 degree by 1 degree), images can easily be taken of larger objects such as the full moon or the Andromeda galaxy. Fig. 9 gives an impressive example of the observations possible.

The **Planet Camera** is a Takahashi Mewlon 250 Reflektor with an opening of 250 millimetres and a focal length of 3000 millimetres (Fig. 5). It is ideally designed to observe planets in our Solar System and their moons, or individual craters on our own Moon – the smaller field of view, (22



Fig. 4: The RiFast deep sky telescope.



Fig. 5: The Takahashi Mewlon 250 Planet Camera with a picture of Jupiter (inset).

arcminutes by 15 arcminutes), is particularly helpful for this. The attached camera can take colour pictures and videos: this feature adds great value, especially when observing planets (Fig. 5, inset).

During guided tours at the Stellarium, visitors can make visual observations using the **Look Through Telescope**, a Takahashi TAO 150 with an opening of 150 millimetres and a focal length of 1100 millimetres (Fig. 6). With a wide range of eyepieces, this allrounder is suitable for observing the most interesting objects in the night sky.

The **ConstellationCam** (Fig. 6, with a picture of Orion on the right) can be used to take pictures of very large structures, such as asterism constellations. It is an ordinary Canon 60Da reflex camera with a Canon 24-105 millimetre lens,

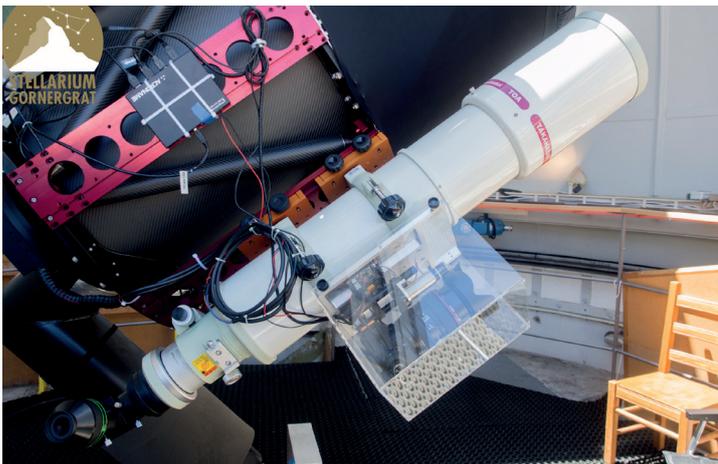


Fig. 6: The lookthrough telescope and the ConstellationCam with a picture of the great Orion nebula.

protected by a custom-fitted case that was developed and built by the University of Bern.

The final instrument is the **AllSky Camera** (Fig. 7), which is outside the observatory dome. This camera has a field of view of 180°, so it can see the whole sky. Because it is out-



Fig. 7: The AllSky Camera.

doors, it can take pictures 24 hours per day. It can be used for example to observe the movement of stars in the night sky (Fig. 8).

5 Educational Activities

5.1 OVERVIEW

Because new activities are constantly being uploaded to the online platform, only a snapshot of the current offer can be given. A complete list is available at <https://stellarium-gornergrat.ch/portal/>.

There are four different difficulty levels for the activities:

- General public and children aged 8-15 (in Switzerland: primary level and secondary level I): no physics/astronomy or mathematical knowledge required.
- Children and young people aged 13-16 (Swiss secondary level II): basic knowledge in mathematics, physics and astronomy required.
- Young people aged 16-19 (end of Swiss secondary level I to secondary level II): more complex topics are covered, requiring particularly high levels of mathematical knowledge, as well as fundamental concepts in physics and astronomy.
- Especially highly-motivated young people following specific astronomy courses or carrying out matura thesis work (Swiss secondary level II) or undergraduate



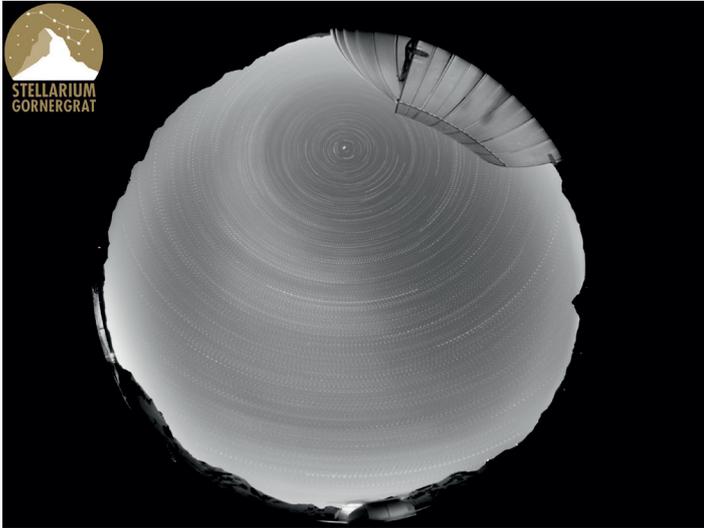


Fig. 8: Circumpolar motion of stars.



Fig. 9: Galaxy Zoo (M81 and M82).

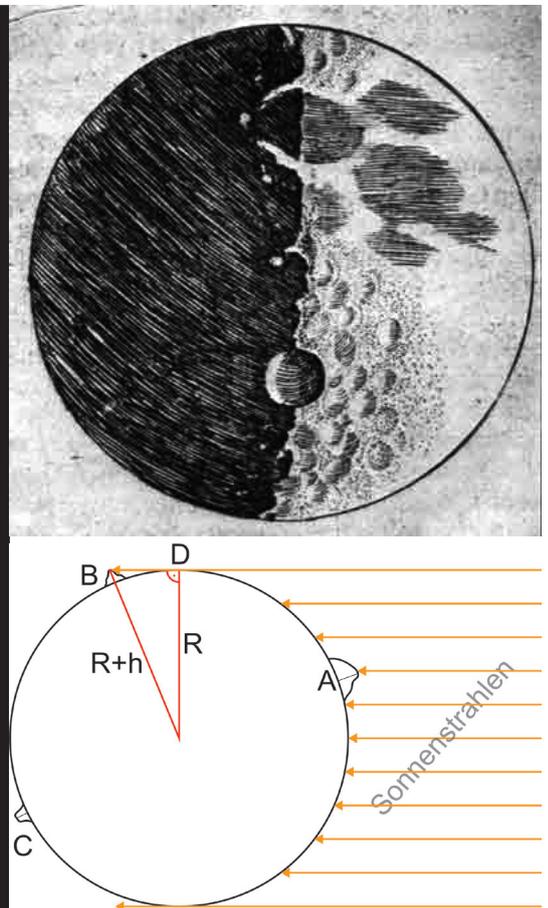


Fig. 10: Mountains on the Moon: Stellarium image, a drawing by Galileo, and the geometry of his method of determination of the lunar mountain heights.

students projects: more complex and open problems are treated, requiring broad mathematical capabilities and advanced knowledge in physics and astronomy.

Pre-requisites, learning objectives and learning stages are specified for each activity. In addition, documents for students, teachers and further information are available. These can be downloaded as both PDF and DOCX files, enabling users (if they so desire) to adapt the content to their own context. A selection of the activities are briefly presented below.

The **phases of the Moon** (level A) is an introductory activity designed to allow users to get to know the equipment. Students learn why the Moon is visible at all, how the phases of the Moon come about, and what they are called. The difference between phases of the Moon and a lunar eclipse is also addressed. No prior subject knowledge is required here. In addition to the usual documentation, files are available so users can play a little game, whereby they must correctly place the various phases of the Moon as it orbits the Earth.

The **Wandering of the Stars** (level A, Fig. 8) is another introductory activity. Here, users select and obtain pictures of the night sky with the AllSky camera at regular intervals, such that the movement of the stars becomes apparent. The students learn that this movement is a consequence of the Earth's rotation and how day and night come about. In addition, particular attention is paid to near-polar stars, especially the North Star.

At a higher level comes the **Galaxy Zoo**, see Fig. 9 (level B). In this activity, students learn about the basic types of galaxies. By the end, they know how to classify real galaxies

by their basic type and can name the differences between the types, and they can also classify them according to the Hubble sequence. However, this requires a basic understanding of galaxies and their components. A list of suitable galaxies is included in the learning materials.

Older students can measure **Mountains on the Moon** (level C), for which some details are given in the next section.

5.2 TWO EXAMPLES: FROM GALILEO TO THE NOBEL PRIZE 2019

Below, we will present some details of two examples which, beyond its physics content as such, are of complementary interest for science education: the first for historical reasons, being a milestone in the development of the modern “Weltbild” of physics; the second for providing insight to contemporary research of far-reaching importance.

In the end of 1609 Galileo aimed his telescope to the moon and soon discovered, among other things, something highly surprising at the time: the Moon’s mountains. This was one of the discoveries contradicting the profound distinction between the terrestrial and celestial realm which had been part of the established world-view since the antiquity [7]. Celestial objects should be perfect spheres, whereas Galileo’s observations made evident that Moon’s surface was uneven with mountains (and craters) very similarly to Earth’s surface. He also observed also that some mountain peaks were still illuminated by sunshine when the valleys were already in the dark like in “alpine glow” (a very Swiss form of the similarity between celestial and terrestrial phenomena).

Galileo went on, and this is another major component of his legacy to the development of physics, to analyse his observation in a quantitative way. Indeed, the heights of mountains (depths of craters) on the Moon can be estimated using geometric and trigonometric methods, leading to

$$h = \sqrt{R^2 + (DB)^2} - R$$

(Galileis method, at half moon and with mountains near terminator)

$$= l \cdot \tan\left(\frac{d}{R}\right) \approx l \cdot \frac{d}{R} \text{ (general method)}$$

where R is Moon’s radius, the distance DB as in Fig. 10, and l , d are the length of the shadow and the distance to the terminator of a mountain, respectively. Fig. 10 gives an impression of the activity. Finally, students put together a map of the Moon with their own mountain and crater measurements.

As for an example related to very recent research, consider Fig. 11, based on transit observations with the DeepSky Telescope and analysis by the software *AstrolmageJ* [8]: basically also nothing but a shadow, but of an extrasolar planet 800 ly away! As you can see, the Stellarium allows high school students (and amateurs) to make their own observation and analysis of an extrasolar planet, topic of the Nobel prize for Physics in 2019 [9].

With the use of the transit-method one needs some luck to get a whole transit without any clouds, even with the good conditions at the Gornergrat, but there is a really good chance to get at least the ingress or the egress (as it is shown in the figure) of the planet. In the given case, the duration of the exit is roughly 0.02 days \approx 30 minutes (25 minutes with a more precise analysis of the data), fitting quite well to other observations [10].

With a whole transit, it is also possible to get an rough estimate of the radius of the planet if the radius of the star is known. We know the time from the begin of the ingress until the begin of the egress (2 hours and 25 minutes) and the duration of the ingress (and egress, each 25 minutes). With this, we know that the planet passes its own diameter in 25 minutes and that of the of the star in 2 hours and 25 minutes, therefore, its radius is roughly 15% of the radius of the star. The star (WASP3) has a radius of 1.3 solar radii, leading to a planetary radius of \approx 2 radii of Jupiter – about 1/3 larger than in the literature (in fact this estimate can even be improved with the means of the Stellarium, e.g. by a better time resolution, which was 5 min. in this case).

We think this example is especially remarkable, if one considers that just 25 years have passed since the first extra-solar planet surrounding a main-sequence star (51 Pegasi b) was detected by Michael Mayor and Didier Queloz from the University of Geneva [9] – and now it is possible to do so in school.

6 By way of conclusion...

This contribution is only a short overview of the Stellarium, its concept, purpose, and activities. In the future, further activities will be developed. Meanwhile, the reader is invited to register online and try them out for herself!

We are always grateful to hear about completed activities. What worked well, what needs improvement? Were there difficulties or misunderstandings? All types of feedback are highly welcome!

Acknowledgements

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References and Links

The Stellarium Gornergrat website:

<https://stellarium-gornergrat.ch/>

On Facebook:

<https://de-de.facebook.com/stellariumgornergrat/>

Statement by the HFSJG:

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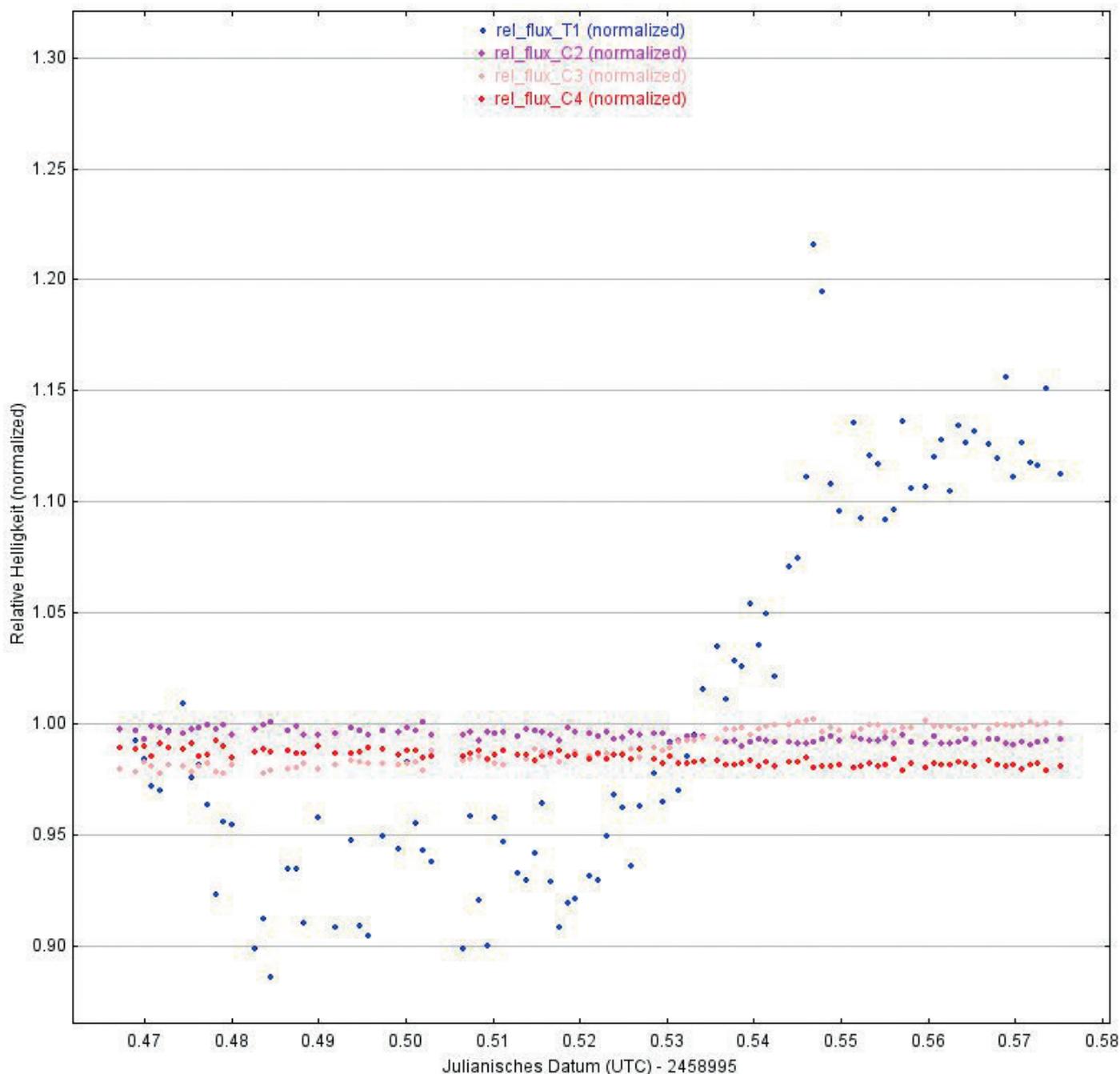
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Plot of Measurements

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WASP 3b



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Fig. 11: Light curve of WASP3b with some reference stars. One clearly sees the exit around 0.53 JD. x-axis: Coordinated Universal Time (UCT), units: (heliocentric) Julian date (JD). As usual in astronomy, dates given as Julian date, i.e. the days and fractions of days are counted that have passed since the first of January 4713 before Christ. y-axis: relative brightness, normalized to the average brightness of the WASP3.