# Solargraphs of ESO

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**The recently developed technique of simple pinhole camera "solargraphy" enables images of the path of the Sun to be recorded over long periods. Solargraphy cameras have been installed at the three ESO observatory sites in Chile and at ESO Headquarters in Garching. These intriguing images are presented and described. They illustrate, in a very direct way, the clear skies at the observatories.**

## Introduction

The origin of the technique of "solargraphy" can be traced deep into the history of the photographic process when the first attempts were made to record sunlit scenes on a photosensitive surface (e.g., William Henry Fox Talbot, 1800–1877). The astronomer Edward Emerson Barnard (1857–1923) acquired his interest in photography by using sunlight through a negative to produce an image on print-out paper in a commercial studio. This contact process was the normal way of making prints in the 1870s. The technique that has recently been re-invented under the name of solarigraphy was, however, only born when images were published on the internet in November 2000 by the project Solaris[1], led by the inventors of this unique photographic technique, Slawomir Decyk, Pawel Kula and Diego Lopez Calvin. They called these images "solarigraphics", and they are created with pinhole cameras (without lenses) and light-sensitive material exposed in such a way that the image is revealed directly, without the use of further chemical development processes.

These pinhole cameras, which have come to be called "cans", are extremely simple and cheap to construct and have a sensitivity low enough to enable images to be taken of the path of the Sun across the sky with exposures lasting many months. One of us (TT) was an early pioneer of this process, renaming it "solargraphy" and starting a project to collect exposures from interesting locations all around the world[2].

During 2009, we had the idea of placing cans at the three ESO observing sites in Chile: La Silla, Paranal and Chajnantor and exposing them for several months. Apart from the wish to obtain images from what are undoubtedly interesting locations, our thought was that this would be a graphic visual record of the clarity and largely cloud-free properties of the observatories.

Here we present the images from Garching and the three observatory sites and explain what they show[3].

## Process

The cans are constructed from small black plastic canisters used for storing 35 mm film cassettes (see Figure 1). A pinhole in a sheet of aluminium foil is placed over a small aperture drilled into the side of the can, normally at half-height. A rectangle of black and white photographic printing paper (not film) is curled and placed snugly around the inside of the can with sufficient gap to leave the inside of the pinhole unobscured. The can is then sealed with plastic tape to make it watertight (except for the pinhole!).

In order to capture the scene with an exposure of several months, the cans are mounted securely with tape and/or cable-ties in a position that can record a good fraction of the path of the Sun across the sky. At the end of the exposure, the camera is recovered and, in a dimly lit room, the undeveloped photographic paper is scanned on a colour scanner. The resulting image is transformed to a "positive" by having its intensity scale inverted, followed by some appropriate adjustment of levels and colour balance.

The colours in black and white photographic paper exposed to light come from finely divided metallic silver growing on the silver halide grains. The latent image, which is typically ~ 10 silver atoms per billion-atom grain is invisible, but on continued exposure the latent image clumps grow so that the first visible signs of a print-out image are yellowish, darkening to sepia than a maroonish-brown as the particle size increases. Eventually the maximum exposure produces a slate-grey shade. Reversing an image with this natural range of variations will produce interesting colours, which are of course unrelated to the real colour of the scene. However, lightly exposed parts will be bluish and shades of green/cyan will likely appear in the mid-tones, both of which will lend the positive images a natural look.

Figure 1. A mounted solargaphy can with the "shutter" open.

## The solargraphs

We have obtained multi-month exposure solargraphs in Garching, La Silla, Paranal and Chajnantor (APEX) with the help of a number of very willing ESO staff who are listed in the acknowledgements.

*ESO Headquarters in Garching.* This camera was exposed from 21 July–15 December 2009 from outside the entrance floor offices on the south side of the building looking southwest and pointing up at an altitude of 20 degrees (see Figure 2). The obscuration at the top left is the back of a small satellite dish on whose support the camera was mounted. Those familiar with the location will recognise the large, now unused, satellite dish at the left and the glass pyramid roof just left of centre. The ST-ECF offices can be seen to the right. The white solar trails reveal what we all know: there is a lot of cloud cover in Bavaria! The summer period was not bad, but the autumn and winter months are well broken up.

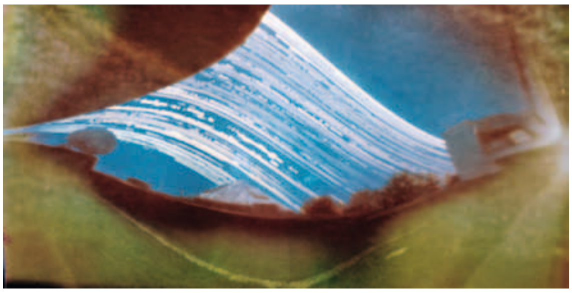

Figure 2. A five-month solargraph exposure at ESO Headquarters in Garching showing foreground objects, a satellite dish to the left and a pyramid roof left of centre.

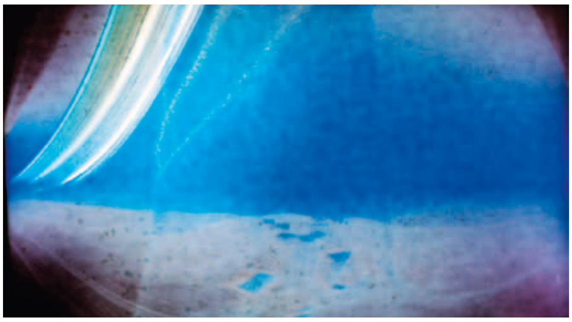

Figure 3. Solargraph taken at La Silla looking northwest from the CAT telescope dome and showing three months of sunsets over the Pacific.

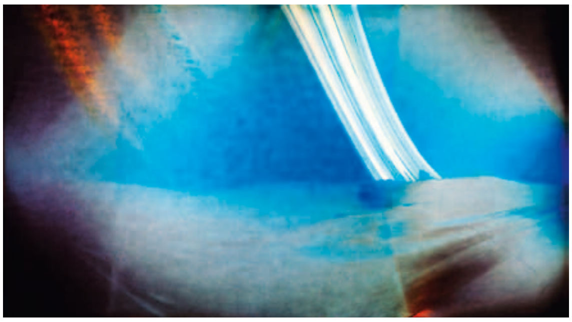

Figure 4. Sunrise behind the NTT at La Silla, exposed from the Danish 1.54-metre telescope catwalk, is shown on this solargraph.

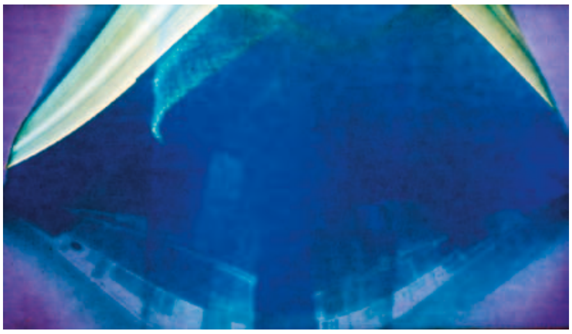

Figure 5. Solargraph taken at the VLT at Paranal, exposed for three months from the roof of the VLTI building, pointing north between UT2 and UT3.

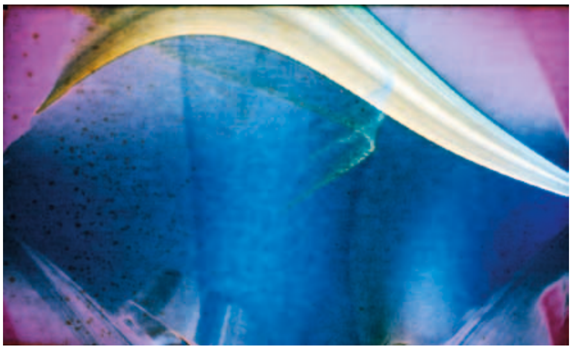

Figure 6. Solargraph taken from the control room roof of the VLT at Paranal looking north towards UT1.

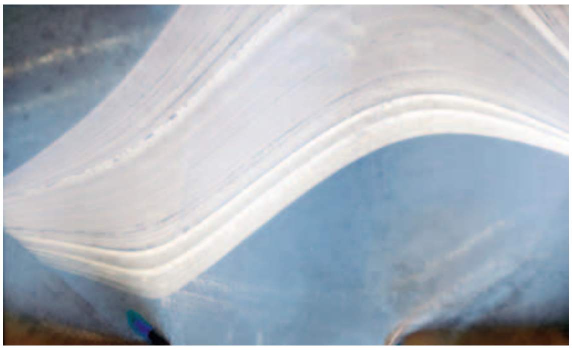

Figure 7. Six months of exposure from the APEX enclosure gate-post looking west of north is shown on this solargraph. The moving antenna has created bright reflections that appear as a mottled white haze in the lower right of the image.

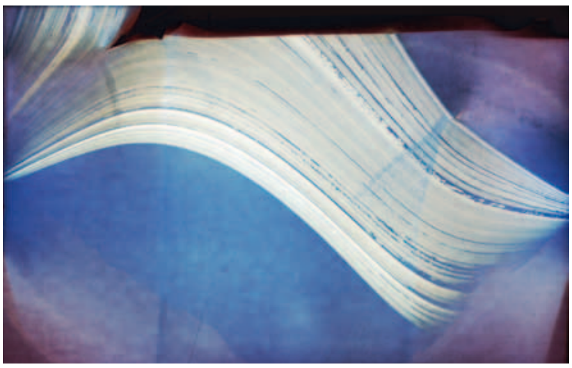

Figure 8. Looking east of north from the roof of the APEX generator building, this solargraph image shows sunrise over Cerro Chajnantor.

*La Silla.* Two cans were mounted at La Silla by Peter Sinclaire and exposed from 6 October–28 December 2009. The first points northwest from the Coudé Auxiliary Telescope (CAT) dome and shows the New Technology Telescope (NTT), the Swiss 1.2-metre Leonhard Euler telescope and a number of other buildings and domes (Figure 3). The Pacific Ocean is on the horizon. The buildings appear blue because of the bright solar reflections from their white or metallic exteriors. The second can was mounted between the same dates and is looking east from the catwalk of the Danish 1.54-metre telescope and shows the NTT

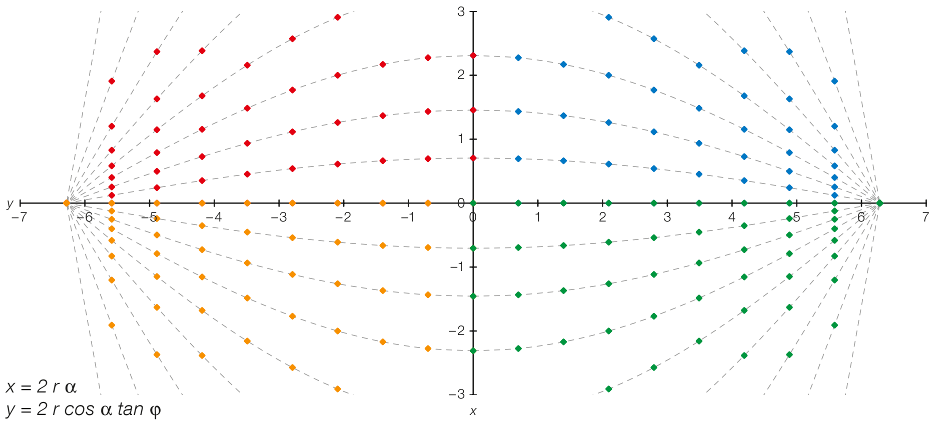


Figure 9. A representation of the projection of altitude and azimuth in a cylindrical pinhole camera is shown. The coloured points are separated by 10 degrees and the *x* and *y* scales are in units of cm for the solargraph cans used here. *x* and *y* are the horizontal and vertical coordinates, *r* is the radius of the can, and φ and α are the altitude and azimuth angles respectively.

Figure 10. An illustration of how stiff paper forms itself inside a cylindrical tube. The straightening of the ends produces caustic reflections in the image.

backed by the rising Sun (Figure 4). The dark blue structure to the lower left of the NTT is the combination of the Schmidt and the 2.2-metre telescopes. The 3.6-metre and the CAT telescope domes cannot be seen — probably because they exhibited a similar brightness to that of the clear sky against which they were silhouetted. The solar trails in these images show that the weather is considerably better than in Garching — as we might have hoped!

*Paranal.* Gerd Hüdepohl placed two cans on the VLT platform and exposed them from 5 October–26 December 2009. The first, placed on the roof of the Very Large Telescope Interferometer building, shows Unit Telescope 2 (Kueyen) on the left and UT 3 (Melipal) on the right with the VLT Survey Telescope on the far right (Figure 5). The second was placed on the control room extension roof facing north and shows UT1 (Antu) just left of centre (Figure 6). A remarkable feature of these two images from Paranal is that the solar trails are essentially unbroken. There was very little, if any, cloud cover during this period. Both of these solargraphs show a clear "ghostly" repeat of the solar trails, the origin of which is explained below.

*Chajnantor (APEX).* The cans at APEX were exposed for a full six months from mid-December 2009 until the winter solstice in June 2010. They were placed by David Rabanus and both were pointed at an elevation of about 45 degrees. One was mounted on the gatepost to the enclosure, close to the antenna, and pointed west of north (Figure 7). Reflections of light from the antenna can be seen as a whitish, mottled haze on the mid-right of this image. The second can was on the roof of the generator powerhouse to the east of the enclosure and pointed east of north (Figure 8). It includes the tilted profile of Cerro Chajnantor on the right silhouetted against the trails of the rising Sun (note that the paper at the top of this image was damaged and produces an artificial split in the solar trails). There were some clouds at the ALMA site during this six-month period — but not many!

## Some details

In order to interpret these images, it is necessary to understand the image geometry of cylindrical pinhole cameras. The projection of the altitude angle (ϕ) and the azimuth (α) onto the *x*,*y*-plane of the flattened photographic paper (with the angles in radians) is given by the formula in Figure 9. This figure shows a series of points, separated by ten degrees in altitude and azimuth, projected onto *x* and *y*. For a camera pointed horizontally with the cylinder axis vertical, this projection results in vertical lines remaining vertical. The *x*,*y* units in Figure 9 are in cm for a 35 mm film can camera.

An interesting feature of this kind of solargraph is noticeable in many published images, including especially the La Silla and Paranal examples shown here. The reflection of sunlight from the surface of the photographic paper (especially the glossy variety) results in a secondary image of the solar trails. For a perfect cylinder, this secondary image would appear at twice the distance of the primary image measured from the position of the pinhole just off the edge of the image. In reality, however, a rectangular sheet of stiff photographic paper curled inside a small cylindrical can does not form a perfect cylinder since the ends adopt a flatter form (see Figure 10). As can be shown by sketching the paths of light rays emerging from the position of the pinhole, reflections will describe a caustic along the lines where the paper makes a transition from a flat to a cylindrical profile. The position of this transition can be seen clearly in the Paranal images as approximately vertical dark blue lines.


### Acknowledgements

We should like to thank Andreas Kaufer for taking the cans to Chile and distributing them to the three observatory sites. Olivier Hainaut and Carlos de Breuck helped us interpret the images and Olivier quickly solved the problem of the caustics by understanding how the paper flattened at the ends! Peter Sinclaire, Gerd Hüdepohl and David Rabanus did a great job in placing the cameras and documenting the pointing. David Malin kindly supplied the paragraph explaining the formation of the latent image and the resulting colours.


### Links

[1] Solaris project: http://free.art.pl/solaris/solaris/Solaris.html
[2] Solargraphy project: http://www.solargraphy.com/
[3] Further images and descriptions: http://www.flickr.com/photos/bob_81667/