The Multinational History of Strasbourg Astronomical Observatory
Ed. A. Heck, (c) Springer 2005

STRASBOURG GREEN RAYS

A. HECK
Observatoire Astronomique
11, rue de l'Université
F-67000 Strasbourg, France
heck@astro.u-strasbg.fr

Abstract. The literature dealing with the Cathedral of Strasbourg has known a recent boom thanks to a green-beam phenomenology taking place around the equinoxes within the building itself. After discussing this now fashionable popular attraction (without real significance), we detail Danjon & Rougier's first spectrographic observations of the solar green-ray phenomenon carried out in 1920 on the platform of the Cathedral. They confirmed the rôle of selective atmospheric absorption and explained the sometimes abnormal duration of the "flashes" as resulting from a combination between dispersion, turbulence and terrain irregularities at the horizon.

1. Strasbourg Cathedral Green Beam

Acknowledged as one of the most beautiful and most original achievements of gothic art, Strasbourg Cathedral is actually mixing several styles that have been masterfully integrated over the centuries. Initiated in 1015 along the roman style, its construction resumed in 1176 after a fire destroyed the first building.

The current facade displays triumphally the purest gothic of the 13^{th} and 14^{th} centuries, while the unique spire is from the 15^{th} century (Fig. 1). Gigantic masterpiece of virtuosity, that building has been used diversely over time (as a church, a temple, a storage area, ...) and has been left almost untouched by the various conflicts in the region.

Since a few years, more and more tourists are attracted by a remarkable luminous phenomenon inside the Cathedral: at the equinoxes, around local Noon, a green beam scans the pulpit from West to East and passes over the head of Christ on the cross. Glossy volumes featuring the effect on colorful covers can be found in virtually all the city bookshops.

That exceptional green light is generated by sunrays passing through a piece of transparent green glass within one of the stained-glass windows. Intentional phenomenon ou pure coincidence? And what could be its interpretations?

It is easy to formulate these:
• an *astronomical* interpretation seeing in the green piece of glass and the vertical axis of the cross that it illuminates the elements of a equinoxial sundial signalling the season changes;
• an *artistic* interpretation since the pulpit, a jewel of flamboyant gothic, is singled out through that green light scan;
• a *religious* and *mystical* interpretation since the Spring equinox is close to Easter, Christ on the cross being then illuminated near his resurrection.

Is this then a demonstration of the genius of artists on stained glass, expressing their ability, their mystical and religious feelings while leaving a testimony to posterity? Such examples are available, generally centered on the solstices, as at the Chartres Cathedral. But nothing is less sure in Strasbourg. A detailed and well-documented sudy by Louis Tschaen (1986) tempers indeed the most imaginative enthusiasms.

An astronomical analysis of the phenomenon shows that the green beam passes over the head of Christ about one hour before true Noon (most elevated position locally of the Sun during the day) and this, one or two days after the Spring and the Fall equinoxes. Moreover, because of screening obstacles, the green light is visible from the pulpit axis only during approximately one month around the equinoxes. In terms of precision, much better results were already achievable at the time of the building construction.

If the stained-glass window from which the green beam originates dates back to 1875, the first mention of the phenomenon is much more recent, apparently from 1972 only. It is however another announcement in 1984 that had a real echo in the media and that caused the current touristic interest.

Other indications and detailed crosschecks by Tschaen (1986) converge towards a recent repair of the window (likely one of those carried out around 1950) that would have introduced a piece of glass of a different composition, allowing a well-contrasted beam to reach the pulpit.

Tschaen (1986) concludes to a high probability of an accidental nature of that equinoxial illumination, even if the various documents that would definitely prove it have not been found and might never be found.

Figure 1. Strasbourg Cathedral on an early 20^{th}-century postcard. The platform level (66m elevation to ground) from which Danjon and Rougier carried out their observations in 1920 is clearly visible.

2. The Solar Green Rays

The solar green-light effects (rims, segments, rays or "flashes") are now widely known and extensive documentation can be found on them (see for instance Andrew T. Young's web site[1]). They can be observed at sunset (or just before sunrise) in favorable conditions of visibility: clear sky and far, unobstructed horizon.

[1] `http://mintaka.sdsu.edu/GF/`

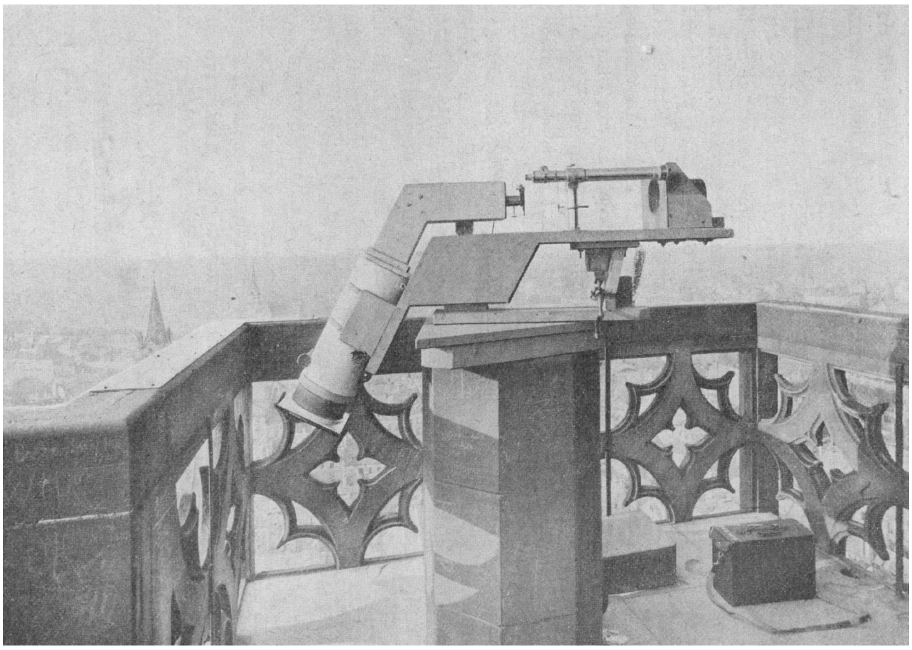

Figure 2. Spectrograph installed in 1920 by Danjon and Rougier on the platform of Strasbourg Cathedral to study the green flash. The spire visible on the left of the picture is the *Temple Neuf* one while the faint structure perceptible to its right is *St Pierre le Jeune* spire. (© Obs. Astron. Strasbourg)

Physics easily explains the phenomenon through decomposition of sunlight by atmospheric refraction. Because of it, objects near the horizon appear higher in the sky than they actually are. Additionally, the refraction is more important for the short wavelengths (green, blue) than for the longer ones (yellow, orange, red). Thus near the horizon the green image (disk in the case of the Sun) is very slightly higher on the horizon than the red image (disk).

One must also take into account another phenomenon: the general absorption and dispersion of sunlight by the atmosphere, much more effective on the blue rays and *de facto* causing the blue background of the sky during the day. For the same reason, and because of the much thicker atmospheric layer crossed by the rays at sunset or sunrise (tangentially to Earth surface) than at Noon, the images of the Sun are then more reddish. Apart from local peculiarities, the sunset images are also generally redder than the sunrise ones because of an increased atmospheric absorption at the end of the day (water evaporation and increased aerosol turbulence during the day, etc.). All in all, this clarifies why the shortest solar wavelengths of interest here come from the green region of the spectrum.

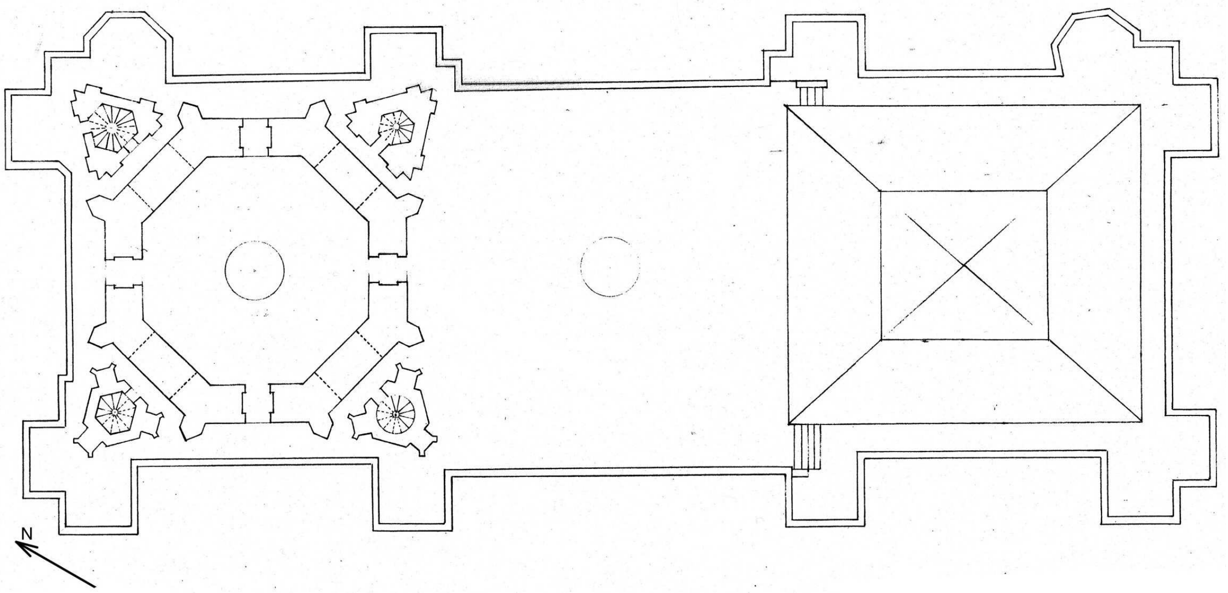

Figure 3. Sketch of Strasbourg Cathedral platform. To study the green flash in 1920, Danjon & Rougier's put their spectrograph on the Northwest corner (just above the arrow) identified thanks to the spires discernible in the far on Fig. 2. (Courtesy and © Oeuvre Notre-Dame)

Thus, as the Sun gradually descends under the horizon, the slightly shifted disks corresponding to the red, orange, yellow, green parts of the spectrum disappear one after the other. Whether the witnesses will perceive the last disappearance as a *rim*, a *segment*, a *ray*, a *flash* or something else will depend, beyond unavoidable subjectivity, of the atmospheric conditions of the moment (layers, turbulence, ...) and of terrain irregularities at the horizon that will determine the actual shape of the green-light source (as seen from the observer) as well as the duration of the phenomenon. If the meteorological conditions and the othe relements are helping, a last green dot could appear as dissociated from the solar disk and bathe the observer in a fugitive emerald light – a magic and moving moment.

Extensive travelling has now allowed people not living in propicious areas to witness green-ray phenomena at sunsets here or there. Documentation is also easily available. This was far from being the case at the end of the 19^{th} century or at the beginning of the 20^{th} one. Then novels such as Jules Verne's *"Le Rayon Vert"* (1882) were about the only popularizing outlets, in the typical style of the time and only towards a relatively educated readership.

3. Danjon & Rougier's study of the 'Rayon Vert'

In line with the fashion of the time, André Danjon (1890-1967) and Gilbert Rougier (1886-1947) – who had arrived in 1919 at Strasbourg Observatory after the return of Alsace-Moselle to France (see *e.g.* Heck 2005) – got interested in the solar green-ray phenomenon. As sunsets and sunrises are not visible from Strasbourg Observatory itself, they installed in 1920 a spectrograph (Fig. 2) on the platform of Strasbourg Cathedral (Fig. 3) which gave them an elevated position (66m) over the surrounding ground and the plain of Alsace. The sunset takes place in Alsace behind the Vosges, but the observing period was chosen for having the Sun disappearing behind a rather low line. The observations were stopped when the Sun started setting more to the South, behind higher and higher summits.

The spectrograph was articulated around a heavy flint 60° prism, a Tessar-Krauss objective (f = 26cm) and a photographic chamber with a Zeiss objective (f = 52cm). The photographic plate holder was movable, allowing to record six spectra on 9cm×12cm panchromatic Wratten plates. The whole structure was mobile, allowing to track the Sun and to maintain the spectrograph slit horizontal and tangent to the solar edge. The exposures lasted six seconds for the center of the disk, one to two minutes for the fringes.

In total 19 spectrographic plates were obtained between 17 July and 3 August 1920, among which three spectra of the red fringe, four of the green light and ten of the general disk.

Danjon & Rougier (1920, but mainly 1926) made a clear distinction between the rim or fringe (*frange*) and the flash or ray (*rayon*), confirming the conclusions of earlier observers that the flash is the top of the fringe emerging alone during a short while. After correctly explaining the phenomenon through the combined effects of refraction and molecular diffusion (cf. Sect. 2), they entered a long discussion on the duration of the green ray, concluding that it should theoretically last about one second and a half but noting that much longer durations had been observed. Their second interrogation was why, while theoretically the rim should progressively change from red to green via orange and yellow, the visual observer was receiving without any transition a flash of pure green light.

Their spectroscopic observations allowed them to answer the last question by concluding that the solar spectrum should not be considered as a continuum, since most of the light was concentrated near the horizon in red and green Brewster bands making the sunsets (or sunrises) discontinuous phenomena.

As to the controversy on the duration of the green-light phenomenon, they comment that the *theoretical* duration varies rapidly with the elevation

Figure 4. Were those Alsacians (on an early 20^{th}-century postcard) looking for the *green flash* from the Cathedral platform? Probably not since their shadows indicate they were turning their back to the Sun ...

of the horizon, the longest durations being observed from mountain sites since then the horizons are comparatively depressed. About actual durations of green phenomena reaching sometimes several seconds, they quite wisely conclude that nothing can be said without knowing the exact nature (slopes, obstacles, fragmentary horizon, etc.) of the terrain behind which the Sun is seen setting.

Acknowledgments

It is a real pleasure to acknowledge here the assistance of Ms. Sabine Bengel from *L'Oeuvre Notre-Dame.*

References

1. Danjon, A. & Rougier, G. 1920, Le spectre et la théorie du rayon vert, *C.R. Acad. Sciences Paris* **171**, 814-817.
2. Danjon, A. & Rougier, G. 1926, Le rayon vert – Étude spectroscopique et théorie, *Ann. Obs. Strasbourg* **I**, 105-115.
3. Heck, A. 2005, Strasbourg Astronomical Observatory and its Multinational History, this volume.
4. Tschaen, L. 1986, La lumière verte équinoxiale de la Cathédrale, *Bull. Cathédrale Strasbourg* **17**, 89-94.

5. Verne, J. 1882, Le rayon vert, Gauthier-Villars, Paris, 195 pp.