Light Phenomena over the ESO Observatories II: Red Sprites

Petr Horálek[1]
Lars Lindberg Christensen[1]
József Bór[2]
Martin Setvák[3]

[1] ESO
[2] Research Centre of Astronomy and Earth Sciences, GGI, Hungarian Academy of Sciences, Budapest, Hungary
[3] Czech Hydrometeorological Institute, Prague, Czech Republic

A rare atmospheric phenomenon, known as red sprites, was observed and captured on camera from the La Silla Observatory. This event signalled the first time that these extremely short-lived flashes of red light, originating in the Earth's upper atmosphere, were photographed from a major astronomical observatory. Further images of red sprites from the La Silla Paranal Observatory sites are presented and the nature of red sprites is discussed.

Petr Horálek/ESO

Figure 1. (Above) Red sprites caught on extremely deep digital camera images from the La Silla Observatory on 20 January 2015. The time of each exposure is indicated.

EUMETSAT; Martin Setvák/CHMI; Petr Horálek/ESO

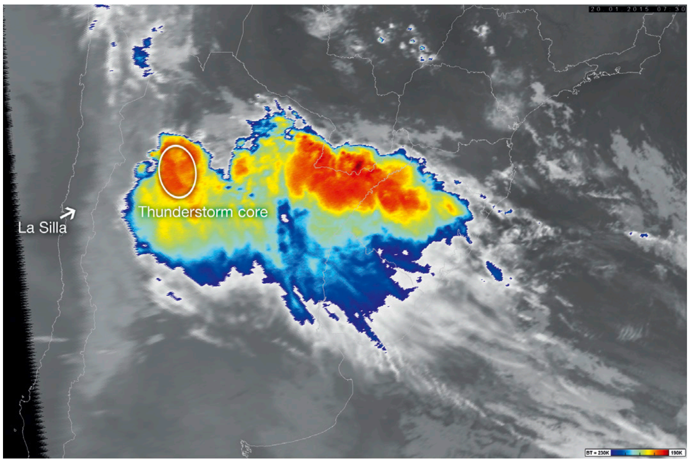

Figure 2. This image from the EUMETSAT's Meteosat-10 (Meteosat Second Generation, MSG-3) satellite was taken on 20 January 2015 at 7:30 UTC. The storm cell above which the sprites were observed (Figure 1) is marked.

On 20 January 2015, ESO Photo Ambassador Petr Horálek was photographing the Milky Way at the La Silla Observatory, when a series of short-lived flashes of red light appeared above the horizon and caught his eye. Using a digital camera, adapted for better near-infrared performance by removing the infrared blocking filter, a series of features known as red sprites was successfully photographed (see Figure 1). Red sprites have not been extensively imaged, and the image in Figure 1 marked the first time that they had been captured from a major astronomical observatory.

Subsequent investigation revealed the origin of the sprites to be a cluster of massive thunderstorms over northern Argentina on the eastern foothills of the Andes. Figure 2 shows the Meteosat-10 satellite image of this thunderstorm; the storm's activity reached its maximum at the time this image was recorded. The red sprites were photographed from La Silla around the same time. The core of the thunderstorm is marked in Figure 2 and was located about 560 kilometres from La Silla.

A week later at Paranal, just a few hours before daybreak on 27 January 2015, the first author once again spotted the unmistakable tendrils of red sprites, and this time photographed several over an almost two-hour period (see Figure 3). From the camera's perspective, they appeared to come from the direction of the rising Galactic Bulge of the Milky Way. In reality they originated from another huge complex of storms over the Andes at approximately the same location in Argentina, this time about 620 kilometres away. Figure 4 shows the Meteosat-10 image of this storm. The most spectacular red sprites were photographed from Paranal from 8:30 to 9:10 UTC. The core of the thunderstorm is marked in Figure 4 and is located about 550 kilometres from the Paranal Observatory.

The storms were so strong that another display of their activity was observed and documented. High in the atmosphere, gravity waves generated by these storms (Siefring et al., 2010) formed ripples in the greenish layer of airglow about four hours before the red sprites appeared (Figure 5).

The first observations of red sprites

The existence of transient luminous events, or TLEs, was predicted by the Scottish physicist Charles Wilson (1869–1959) in 1920. He was the inventor of the

P. Horálek/ESO

Figure 3. The unmistakable tendrils of multiple red sprites imaged by ESO Photo Ambassador Petr Horálek from ESO's Paranal Observatory on 27 January 2015. Two exposures were combined, with the upper sprite occurring at 7:46:43 UTC and the lower at 8:07:25 UTC. In the foreground is one of the 1.8 metre VLT Auxiliary Telescopes.

EUMETSAT; Martin Setvák/CHMI; Petr Horálek/ESO

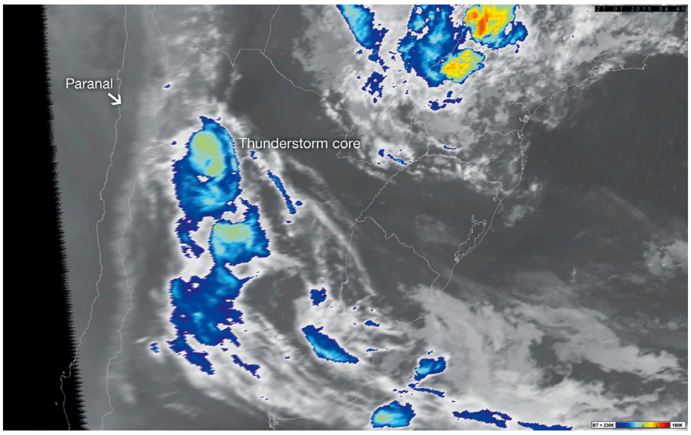

Figure 4. Image taken by the Meteosat-10 satellite on 27 January 2015 at 8:45 UTC as the thunderstorm's activity decreased. The weakening storm cell, above which the sprites in Figure 3 were observed, is indicated.

Wilson cloud chamber for the detection of elementary particles, and he was awarded the Nobel Prize in 1927 for his development of a method of visualising electrical particle tracks in condensed vapours. Unfortunately, Wilson did not live to witness the experimental confirmation of his theory.

The interest in TLEs has grown since 1989, when they were first detected with auroral cameras in Minnesota, USA (Franz et al., 1990), and interest has increased following imaging from the NASA Space Shuttle and the International Space Station (ISS); see Jehl et al. (2013) and Yair et al. (2013). Astronauts on the ISS have a particularly good vantage point and have recorded red sprites with digital cameras (Figure 6). The appearance of red sprites shortly follows the occurrence of the corresponding lightning stroke; both kinds of flashes are often captured on the same image that is taken from space.

A few years after the discovery of red sprites, the NASA Compton Gamma Ray Observatory managed to observe gamma bursts originating above thunderstorms — another consequence of tropospheric lightning activity (Fishman et al., 1994).

What causes red sprites to appear?

In thunderstorms, most cloud-to-ground discharges are called negative lightning, as they transfer negative charge to the ground. However, up to 5% of all discharges are positive cloud-to-ground

Petr Horálek/ESO

Figure 5. Gravity waves in the airglow above Paranal, just a few hours before the red sprites shown in Figure 3 were photographed over the distant storm.

ISS/NASA

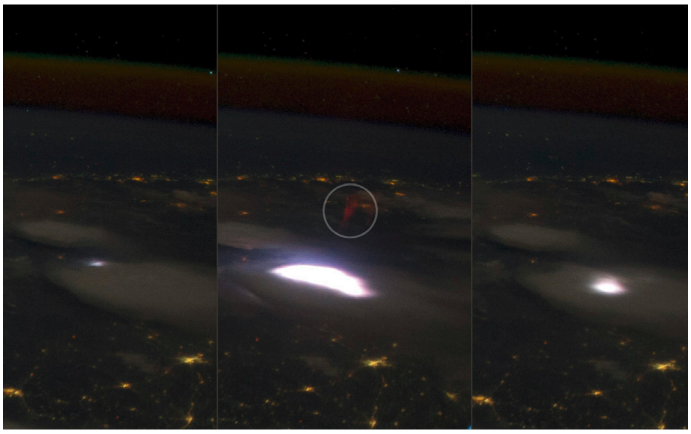

Figure 6. Red sprite photographed from the International Space Station above Southeast Asia in April 2012.

Luis Calçada/ESO

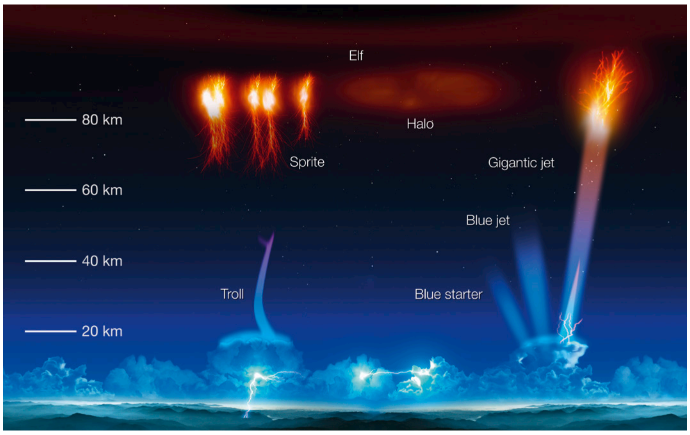

Figure 7. The family of TLE phenomena is depicted. Adapted from an illustration by Frankie Lucena.

lightning that transfer positive charge from the thundercloud to the ground. Up to ten times more energetic than negative lightning, positive lightning seems to be what makes the Earth's atmosphere produce red sprites and some of the other TLE phenomena, commonly known as upper-atmospheric lightning (Boccippio et al., 1995).

Red sprites are a manifestation of complex high-altitude electrical discharge processes (Pasko et al., 2012; Siingh et al., 2012). They typically show up over large and powerful thunderstorms that are strong enough to trigger gravity waves in the upper atmosphere. These unusual flashes are formed at altitudes up to 90 kilometres and get their distinct red hue from the excited nitrogen molecules in the atmosphere. They show up as figures composed of channels, beads and puffs (Bór, 2013). Red sprites are caused by electrical discharge fronts that move rapidly in the high-altitude electric field generated by tropospheric lightning[1].

There are many different species of TLEs (see Figure 7). The nomenclature of TLE phenomena is usually based on their shape and colour in the sky: blue jets, which occur at heights of 15–45 kilometres above the ground; red sprites at heights 50–85 kilometres; and elves at around 90–100 kilometres altitude (Pasko et al., 2012; Marshall & Inan, 2007). The vertically longest TLE phenomenon is the gigantic jet, which starts from the cloud tops and ends around 90 kilometres above the ground (Siingh et al., 2012). It has been speculated that similar phenomena could occur on other planets in the Solar System (Yair et al., 2009).

Red sprites are the most frequently photographed type of upper-atmospheric lightning phenomena on Earth. In photographs, they appear rather dim and the exact time and location of their appearance in the sky is unpredictable. They show up for only a fraction of a second, making them difficult to document and study. However with a wide-aperture lens and a clear view to the horizon in the direction of a powerful thunderstorm, together with low light pollution, they can be imaged with commercial cameras.

The La Silla and Paranal Observarory sites provide ideal conditions for photographing TLE phenomena. The observatories are located at more than 2000 metres above sea level and the dry and transparent air allows the phenomena to be observed at great distances and very low above the horizon. During midsummer (January–February), South America is rich in strong thunderstorm systems, especially above Brazil and Argentina. Due to the extremely low levels of light pollution above the ESO sites and the unimpeded view to the east, there is a good chance of capturing such phenomena with digital cameras, despite the very large distances to the thunderstorms. Recording the same red sprites from La Silla and Paranal simultaneously would enable the determination of their height and size by triangulation.

Red sprites are not yet completely understood and any new image showing them is valuable to atmospheric scientists studying these phenomena. Now ESO has been able to contribute to this intriguing puzzle of the Earth's atmosphere.

Acknowledgements

The contribution of József Bór was supported by the National Research, Development and Innovation Office, Hungary (NKFIH), K115836, and by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences. We are grateful to Bob Fosbury for comments.

References

Boccippio, D. J. et al. 1995, Science, 269, 1088
Bór, J. 2013, J. Atmospheric & Solar-Terrestrial Physics, 92, 151
Fishman, G. J. et al. 1994, Science, 264, 1313
Franz, R. C., Nemzek, R. J. & Winckler, J. R. 1990, Science, 249, 4964, 48
Jehl, A., Farges, T. & Blanc, E. 2013, J. Geophysical Research: Space Phys., 116, 454
Marshall, R. A. & Inan, U. S. 2007, Geophysical Research Letters, 34, L05806
Pasko, V. P., Yair, Y. & Kuo, C.-L. 2012, Space Sci. Rev., 168, 475
Siefring, C. L. et al. 2010, J. Geophysical Research, 115, A00E57
Siingh, D. et al. 2012, Space Sci. Rev., 169, 73
Yair, Y. et al. 2009, J. Geophysical Research, 114, E09002
Yair, Y. et al. 2013, J. Atmospheric & Solar-Terrestrial Physics, 102, 140

Links

[1] The BBC documentary *Exploring the Edge of Space* features spectacular footage of red sprites: http://www.youtube.com/watch?v=lqeqWOQQe2Y