Light Phenomena over the ESO Observatories I: Airglow

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Airglow, the faint light emitted by the Earth's atmosphere, has in recent years been frequently photographed in large field images taken at ESO's observatories. The nature of the airglow is briefly described and example images are shown, capturing the variety of the displays.

On a moonless night at the La Silla Observatory, in the Atacama Desert of northern Chile, it should be very dark, but at times, strange green and red colours can be seen shimmering in the night sky. Although visible, albeit faintly, to the unaided eye, these unusual lights are very prominent in long exposures captured by commercial digital single-lens reflex (SLR) cameras. An example is shown in Figure 1. To the untrained eye, these lights may appear to be some kind of peculiar low-latitude auroral phenomenon, but they are actually the emission of airglow — light emitted by the Earth's atmosphere. This optical phenomenon prevents the night sky from ever becoming completely dark (Roach & Gordon, 1973; Patat, 2004, 2008; Noll et al., 2012), even in the absence of astronomical sources.

The formation of airglow

The first airglow emission line was identified in 1868 by the Swedish scientist Anders Ångström, but it took until the 1920s to understand that airglow differs from aurorae (Mc Lennan, 1928; Roach & Gordon, 1973). Since the 1950s airglow has been extensively studied by ground-based instruments (photometric and spectroscopic), by instruments aboard rockets and satellites and by laboratory experiments (Khomich et al., 2008).

These research efforts have revealed that the Sun is constantly showering the Earth's atmosphere with ultraviolet light, which photodissociates molecular oxygen (O_2) into individual atoms during the daytime and triggers a chain of complex chemical reactions after sunset. Atomic oxygen (O) cannot efficiently recombine and therefore has a long lifetime in the upper atmosphere. It represents a store of chemical energy that is also available at night. O_2, O, sodium (Na), and the hydroxyl radical OH can then be produced and excited by further reactions and collisions, causing them to emit radiation by chemiluminescence (Roach & Gordon, 1973; Khomich et al., 2008; Noll et al., 2012, 2015a, 2015b).

Astronomers are used to subtracting airglow emission lines from ground-based spectra. The airglow lines extend from the near-ultraviolet to the near-infrared regime (Rousselot et al., 2000; Hanuschik, 2003; Noll et al., 2012), and are characterised by clusters of numerous narrow emission lines. This structure is especially common in the near-infrared, where the strongest airglow lines are found (OH bands) and give rise to background patterns that present interesting challenges if they have to be removed (Noll et al., 2014). An example is presented by exposures from the VLT Infrared Survey Telescope for Astronomy (VISTA), in which the OH airglow structures move between the dithered exposures of the widely spaced array of CCD chips. This effect is especially visible until about two hours after twilight[1].

Observations of airglow

Airglow is very faint, but the strongest appearances of the phenomenon can be visible to the naked eye as an unexpected faint structure on the stellar background. To the naked eye, the colours of this airglow are invisible, but sensitive wide-angle photographs reveal the fine green and reddish shades of the phenomenon. Sometimes airglow presents itself as just a faint tinge of colour on the horizon, but it can also appear as a melange of changing colourful shapes (Figure 1).

The green layer of airglow lies about 100 kilometres above the ground and can easily be observed from the International Space Station (Figure 2). A much fainter reddish tint of luminescent atmosphere resides above the green layer, at altitudes between 150 and 350 kilometres. Both layers are related to atomic oxygen, but their different altitudes cause the green emission to peak much closer to the horizon (Noll et al., 2012).

The extent, colour and brightness of airglow is influenced by many different factors, including the time and location of the observation (Roach & Gordon, 1973; Khomich et al., 2008; Patat, 2008; Noll et al., 2012). The red oxygen glow, for example, tends to be brightest at the start of the night, but after midnight, it can be very weak. However sporadic bursts of airglow emission can occur at any time.

Airglow can also appear in formations called gravity waves (Taylor et al., 1997; Khomich et al., 2008), as illustrated by Figure 1, lower right. These propagating air pressure oscillations are mainly formed in the lower atmosphere (e.g., by air flows over mountains) and can then rise to high altitudes. Here, their amplitudes can increase to widths greater than those of the airglow layers due to very low air pressure and the conservation of wave energy and momentum. In turn, this affects the intensity of the airglow and characteristic moving ripples in the airglow can be formed (Figure 1).

Airglow increase

The origin of the airglow is now fairly well understood, but why are we seeing it more often in images taken at ESO sites in Chile over the past five years (see Figures 3, 4 and 5)? Has airglow become more common? Could it be caused by global changes in weather patterns? The answer is not yet clear, but the recent rapid development of digital cameras seems to play an important role as they allow for fainter details to be picked up in the night sky more frequently.

Identical cameras, however, have been found to capture dramatically different skies just weeks apart. Airglow changes with solar activity, so the 11-year solar cycle can have an impact on the brightness of the airglow. The current solar cycle (Cycle 24) peaked in 2014, although

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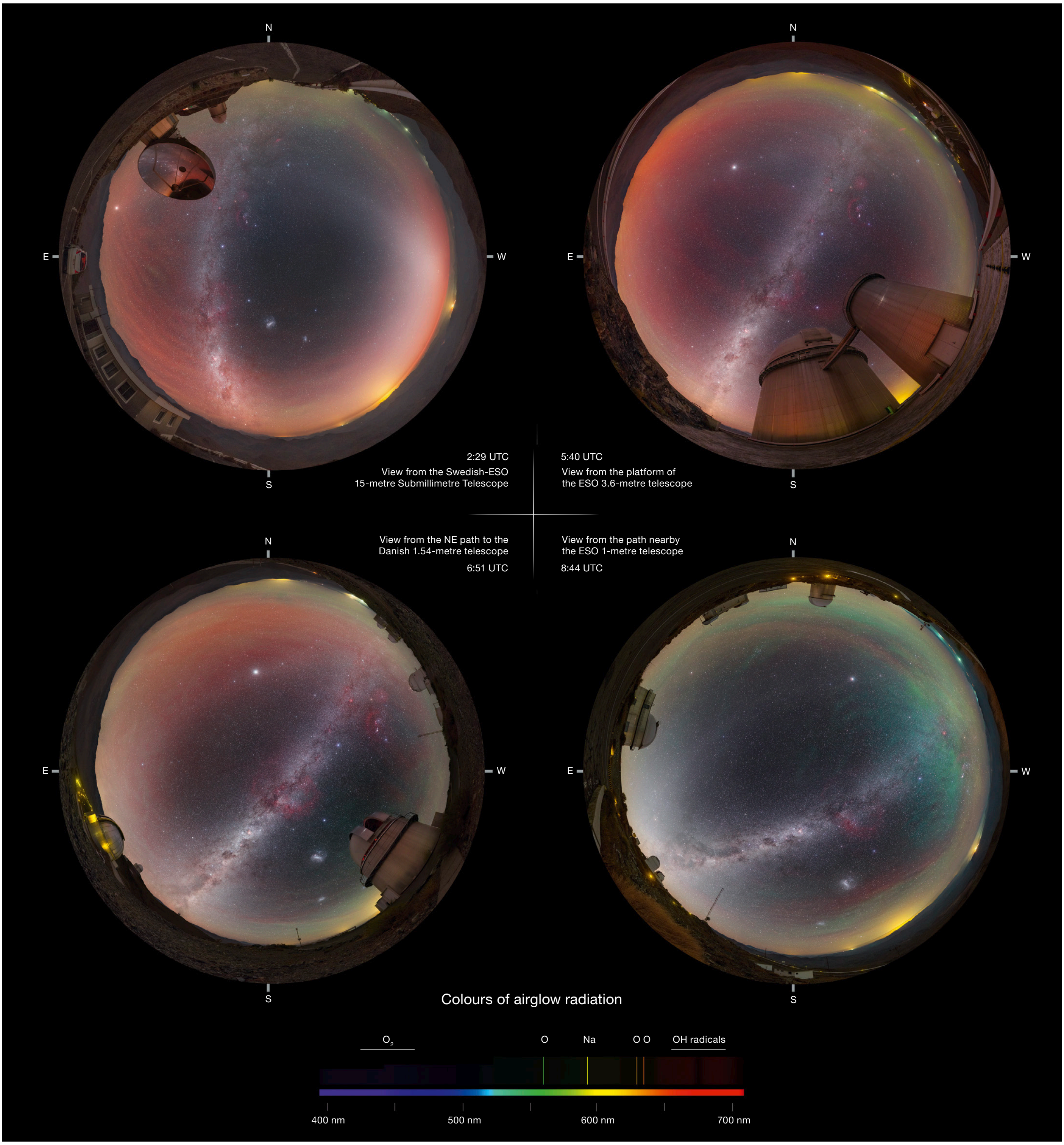

Figure 1. One night at the La Silla Observatory (20 January 2015) exhibiting different displays of green and red airglow seen in deep fisheye images spanning 360 degrees azimuth and 120 degrees altitude. In the lower right image, gravity waves can be seen forming ripples in the greenish layer of airglow.

Figure 2. This unique photograph, taken from the International Space Station, shows the airglow layers above the city lights of Brisbane, Australia.

Figure 3. Red and green airglow dances above ESO Photo Ambassador Babak Tafreshi as he prepares his camera to capture the night sky.

Figure 4. An example of airglow display at Cerro Paranal with the VLT in the foreground.

Figure 5. Flaming red airglow photographed over the Paranal Observatory. The three 1.8-metre Auxiliary Telescopes, part of the Very Large Telescope Interferometer, can be seen in the foreground.

it was amongst the weakest maxima on record (Hathaway, 2015). It seems that the solar maximum could be partly responsible for the increase in airglow captured in images from ESO's observatories in recent years (Noll et al., 2012).

It is also worth mentioning that ESO's observatories in Chile are located below the South Atlantic Anomaly (Heirtzler, 2002). Here, the Earth's magnetic field — which prevents charged particles from reaching the surface — is reduced and thus more particles from the Sun penetrate the atmosphere. This anomaly can affect the red airglow, which originates in the Earth's ionosphere (see Figure 5), although the geomagnetic latitude is more crucial for the observed variability.

One way or another, airglow has become a regular feature in the magnificent celestial displays witnessed over the ESO sites. Even at one of the darkest places on the planet, the sky never becomes completely dark.

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References

Hanuschik, R. W. 2003, A&A, 407, 1157
Hathaway, D. H. 2015, Living Rev. Solar Phys., 12, 4
Heirtzler, J. R. 2002, JASTP, 64, 1701
Khomich, V. Y. et al. 2008, *Airglow as an Indicator of Upper Atmospheric Structure and Dynamics*, (Berlin: Springer)
McLennan, 1928, *Bakerian Lecture. The Aurora and Its Spectrum*, Royal Society Proc. A, 120, 785
Noll, S. et al. 2012, A&A, 543, A92
Noll, S. et al. 2014, A&A, 567, A25
Noll, S. et al. 2015a, *Atmospheric Chemistry and Physics*, 15, 3647
Noll, S. et al. 2015b, ACPD, 15, 30793
Patat, F. 2004, The Messenger, 115, 18
Patat, F. 2008, A&A, 481, 575
Roach, F. E. & Gordon, J. L. 1973, *The Light of the Night Sky*, (Dordrecht: Reidel)
Rousselot, P. et al. 2000, A&A, 354, 1134
Taylor, M. J. et al. 1997, JGR, 102, 26283

Links

[1] Sky brightness record from VISTA VIRCAM imaging: http://casu.ast.cam.ac.uk/surveys-projects/vista/technical/sky-brightness-variation