Retirement of Lothar Noethe

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Lothar Noethe retired in April after 33 years at ESO. An appreciation of his contributions is presented, in particular his pioneering work in active optics and his role in the commissioning of the NTT and VLT.

Lothar Noethe joined ESO in January 1983 to work in the Telescope Group led by Ray Wilson. Lothar had studied physics at Bochum University and theoretical physics at Liverpool University and worked for Siemens. In this period Ray was developing active optics and a thin (19 mm) 1-metre test mirror with 78 actuators was the experimental testbed (Noethe et al., 1986; Madsen, 2012, p. 121).

Active optics

Controlling the shape of telescope mirrors and their relative position has been a challenge for telescope builders since the earliest times. Passive control (for example, by mechanical astatic supports and Serrurier trusses), as well as semi-active operations (for example, by pneumatic or vacuum mirror supports) had been in use at telescopes for many years before the advent of what we now call active optics. The breakthrough for active optics was to build a system that would operate in closed loop on short enough timescales that the engineering of the telescope could be simplified, making for cheaper and better telescopes. Active optics, in contrast to adaptive optics, corrects the fine alignment and optical figure of a telescope under temperature and gravity vector variations, typically on a timescale of minutes (Noethe, 2002). The enabling technology was the digital detectors that could be used to sense the wavefront; the enabling thinking was the partnership between Ray Wilson and Lothar Noethe.

In today's environment it is difficult to contemplate an era when digital imaging was at the cutting edge of telescope technology. A charge-coupled device (CCD) was first deployed at La Silla on the Danish 1.54-metre telescope in 1982. The CCDs were tiny, had poor quantum efficiency and high readout noise. Computing resources were limited and efficiency in the algorithms was paramount. The New Technology Telescope (NTT) project was audaciously launched at approximately the same time. It is worth noting that as late as the early 1990s there were highly respectable voices in the field who held that the thin meniscus mirror would never be able to deliver images of the same quality as stiffer mirrors. Lothar's keen mathematical mind excelled in this environment and he solved the problem of quickly processing the data from the wavefront sensors into mirror positioning and shaping commands.

While optical engineers had long worked in Zernike space when dealing with aberrations, Lothar revolutionised the field by shifting the control of the optics to natural modes. These, in effect, are the mechanical modes in which the mirror bends most naturally, whose deformations are significantly simpler to realise and require less force and therefore are easier to control. As Ray commented, this "is one of the great contributions of Lothar Noethe" (Wilson, 2003). The shift in thinking that this brought about is profound, not only in the control of the optics and the cost of the mirror cell and actuators through the use of lightweight substrates, but also, very critically, in the polishing requirements for the mirrors.

NTT to VLT

Lothar was a key player in the commissioning of the NTT, and later for the Very Large Telescope (VLT), and present for all first stars (the first time the telescope sees a star). Lothar's work was critical in making it appear to the outside world that a smooth and elegant transition from the assembly of the telescopes to their first lights was taking place. Without Lothar it would have been neither smooth nor elegant, but there was also an element of luck involved. The initial success of the NTT, with the spectacular appearance of astronomical images with an image quality of 0.33 arcseconds during the commissioning night of 22–23 March 1989 (Wilson, 1989), was astounding; a value difficult to believe at the time. This was of course more than a year before the launch of the Hubble Space Telescope. As observations with the Differential Image Motion Monitor (DIMM) showed, this was a night with exceptionally good seeing (Sarazin, 1989). But not much later, long-term atmospheric variations substantially increased the mean seeing at La Silla for a period of several years — the great success of the NTT first light would have had less impact under less favourable seeing conditions.

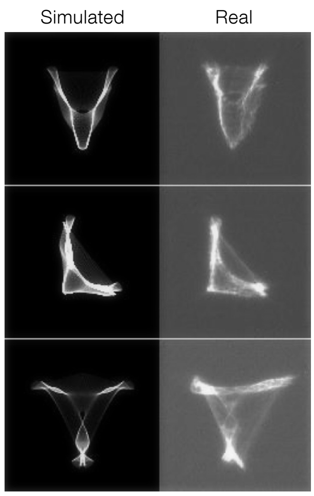

Figure 1. Simulated and real letters "written" in the sky, produced by creating aberrations with the VLT active primary mirror.

Lothar continued as a pioneer of active optics, which was also the foundation for the primary mirror of the Very Large Telescope (VLT). First star for Unit Telescope 1 (UT1) was achieved three weeks prior to the official first light (25 May 1998). Using just the guide probe wavefront sensor Lothar, supported by Stephane Guisard and Roberto Abuter, was able to work with the active optics system to give the commissioning team the confidence to communicate within ESO that the telescope was likely to work. Semi-cryptic public releases of information advised those in the know that all was going well. Some first stars were truly ugly and Lothar would compute manually the commands to transform stars that were 30 arcseconds in size and stretched out like strings of beads, into small roundish images that the active optics could deal with.

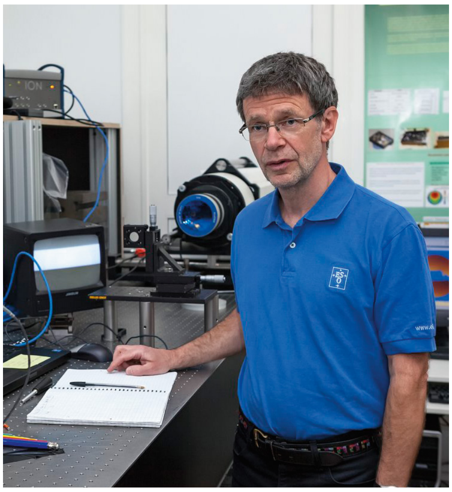

Figure 2. Lothar Noethe pictured in one of the optics laboratories at ESO Headquarters. The apparatus behind Lothar is a laser tracker, capable of measuring distances on the micrometre level.

A couple of anecdotes deserve recalling. After the first few million active optics corrections on UT1 (a couple of months into the commissioning of the telescope) the logging system that is an integral part of the VLT operational system could be used to provide beautiful statistics of the various aberrations. By this stage the telescope was providing exquisite imaging down to 0.26 arcseconds in the visible. The statistics were sent to Lothar as a recognition of his excellent work. Lothar immediately reacted, noting that the standard deviation of the focus term was too high and that something was not quite right. Some probing by him in the software resulted in a change in sign in the force setting for the outer ring of actuators for the primary mirror, and the almost perfect image quality became that little bit better.

One standard test of a telescope's performance is to make it write using starlight, by moving the telescope in particular patterns on the sky while exposing the detector. The NTT was made to write its own name. On the VLT Lothar decided that he could beat this: he created a mathematical description of the aberrations, converted them to forces on the primary mirror and movements of the secondary mirror as needed so that the stars would have the shapes of the letters V, L and T (see Figure 1). This was a strong demonstration that active optics had not only arrived, but was firmly under control.

New envelopes

After the commissioning of all the VLT UT's and the beginning of discussions about the next step to larger telescopes, Lothar became involved with control of segmented mirrors. In 2002, he went to the University of California at Irvine for six months to work with Gary Chanan and developed a long and fruitful collaboration on the challenges of active optics with segmented telescopes. Lothar also obtained a *Habilitation* (German higher degree) in 2001 at the Berlin Technische Universität, again on active optics. He was appointed head of the Optical Systems Department in 2003. When ESO embarked on the E-ELT project, Lothar was critical in pushing for novel systems engineering solutions (Karban et al., 2008) and for ESO to maintain its position as an innovation centre for telescopes. Lothar also had a clear vision for the needs of complex projects to be managed through requirements and structured thinking and contributed towards the adoption of a proper systems engineering culture at ESO.

Most recently Lothar looked at applying closed-loop active optics to wide-field telescopes. The correction procedure is more demanding in a wide-field telescope because of the tight alignment tolerances in fast optics. The field dependence of aberrations in misaligned wide-field systems also places tighter constraints on various system degrees of freedom than is the case with more conventional, narrow field-of-view telescopes, such as the VLT. On account of the higher sensitivity to aberrations and the large field of view, the science images can be used to derive the aberrations. This realisation laid the foundation for a novel method of active correction.

In the two wide-field telescopes operated by ESO, namely the 4-metre Visible Infrared Survey Telescope for Astronomy (VISTA) and the 2.6-metre VLT Survey Telescope (VST), curvature wavefront sensors are employed for the active optics control, in contrast to the more commonly used Shack–Hartmann (in the case of the NTT and VLT) or pyramid wavefront sensors. In a generalisation of curvature wavefront sensing, Lothar initiated an active optics control method based on an analytical model of small point spread function aberrations across the science image. The scheme has been implemented in *Mathematica* and successfully operated with OmegaCAM on the VST during several technical nights in 2015 (Holzlöhner et al., 2014). Development is still required to simplify the processing before this can become a standard technique for improving the image quality of the VST.

Lothar has advised many projects outside ESO and has selflessly supported the work of many junior engineers to advance the field. As Ray put it in his article (Wilson, 2003), "[Lothar's] application for the ESO job was one of the greatest pieces of good fortune in our whole active optics development". Telescope design and operation, and ground-based observational astronomy in general, have been profoundly affected by Lothar's work.

Retirement

Lothar retired at the end of April 2016 and a farewell lunch for the Optics Department was held on 29 April 2015 at ESO Headquarters (he had asked not to have a large farewell party organised). Besides excelling in optical engineering, Lothar has always been active in various sports, in particular table tennis, which he plays several times a week and coaches young players at the local sports club. Never ceasing to be curious and eager to learn, he has now enrolled in an advanced algebra course at the Technische Universität München. We wish him a very "active" retirement and look forward to more contributions in the field of telescope optics.

Acknowledgements

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