# Vacuum technology allows deepest glimpses into the universe

The VLT (Very Large Telescope) in action
Credit: ESO/S. Brunier

ESO, the "European Organization for Astronomical Research in the Southern Hemisphere" is a research community supported by fifteen member countries. ESO operates some of the world's most advanced ground-based astronomical observatories. ESO utilizes turbopumps to operate its infrared instruments. This report describes the test of an ATH 500 M for use with the VLT (Very Large Telescope) and the E-ELT (European Extremely Large Telescope), ready for operation in 2018.

Founded in 1962, ESO (European Southern Observatory) is an intergovernmental organization with the following member states: Belgium, Denmark, Germany, France, Finland, Italy, Netherlands, Austria, Portugal, Sweden, Switzerland, Spain, Czech Republic, United Kingdom, and Brazil. Located in the Chilean Atacama desert, this region's 350 clear night skies during the year and extreme dry conditions enable the observatories of ESO to provide exceptional conditions for astronomical research.

ESO utilizes turbopumps (type ATH 400 M) to operate its infrared instruments. Since their commissioning more than ten years ago, this type of pump did not fail once during its entire operation. Their proven dependability, long-term structural stability, and robustness made its successor, the ATH 500 M, a natural first choice for the future application in ESO's observatories on the Cerro Paranal site — the new home of E-ELT, the Cerro Armazones. This report describes preliminary laboratory tests of the ATH 500 M.

The investigations were conducted by Jean-Louis Lizon, Vacuum Manager at ESO Headquarters in Garching near Munich, Germany. Jean-Louis Lizon and Rudolf Konwitschny (Technical Support, Pfeiffer Vacuum) met for a final meeting to discuss the results.

**Konwitschny:** "Why does an astronomical instrument such as a telescope need vacuum"?

**Lizon:** "The core of our instruments is of course the high-performance optical equipment. Our Very Large Telescope consists of an array of four telescopes. The mirrors of these individual telescopes have a diameter of 8.2 m and are 17.5 cm thick. In order to take advantage of the power of these 20-ton giants, the discs are designed as active optics and rest on 150 bearing points each, which can be optimized with the control of a computer. We currently have the world's most powerful ground-based telescope. If the telescopes are connected to an interferometer, we achieve an optical performance equivalent to a telescope with a diameter of about 200 m. The base installed at the VLT is 13 years old. In fact, the detector technology in particular should have been modernized by technical advances made in recent years. That's why we are planning to install new instruments.

The E-ELT is a quantum leap in optical astronomy. The telescope's primary mirror is about 38 m in diameter and consists of approximately 1,000 individual segments with a diameter of about 2 m.

On the one hand, we require vacuum technology for the repeated coating of the reflective surfaces and on the other hand, we require analytical devices that we use for signal detection. One example is infrared instruments that consist of large CCD detector fields. According to the nature of the instrument, these detectors are operated at low temperatures between 4 K and 60 K.
They must be evacuated prior to cooling the instruments. To do this, pressure levels in the high vacuum range are required to act as an insulating vacuum. Moreover, the vacuum acts as protection against contamination of our highly sensitive detectors. The pumping process is continued during the first hours of the cooling process. The instruments are operated for several months at the low temperatures mentioned above. During this period, the vacuum is monitored periodically. If necessary, the instrument is reevacuated."

**Konwitschny:** "Why do you need turbopumps like the ATH 500 M with active control of the magnetic bearing?"

**Lizon:** "The pumping process of a cryogenic instrument is very critical. It is imperative to use completely oil-free pumping systems for these types of processes. Reverse diffusion of hydrocarbons from the oil-sealed pump systems would lead to condensation on the instruments and to enormous loss of the telescope's power. Reflection already occurs in monolayers of water vapor or hydrocarbons.

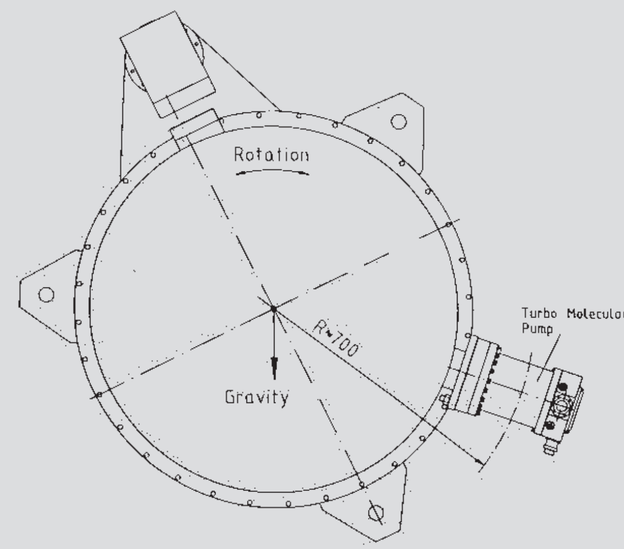


Illustration of the test bench for turbopump at ESO, Garching near Munich, Germany

Each single layer formed on the detectors reduces the light sensitivity of our instruments. The turbopump´s concept of magnetic bearings and oil-free emergency bearings meets the requirements of this process perfectly."

**Konwitschny:** "Are there other requirements for the pumping system?"

**Lizon:** "In order to continue the pumping process at the telescope during the on-going operation, we need a pumping system that can withstand the fastest angular velocities of the telescope. We have verified that on our test bench.

The test bench is a replica of the instrument support unit used in the observatories in Chile. The instrument allows detailed simulations in terms of vibration characteristics and radial acceleration of the tested pumps. For the test, the pump is installed with its rotational axis perpendicular to the main axis of the test container. Then, the container is installed on the telescope simulator, which allows rotations around the horizontal axis."

**Lizon:** "The pumps are mounted on the very top of the telescope creating a giant lever. Any vibrations occurring on the ground will be considerably amplified across the approximately 15-meter long telescope. Our simulated vibration tests show that the ATH 500 M, just like its tested and proven predecessor ATH 400 M, produces very little vibrations in our test rig. The vibration spectrum shows only a few high frequencies. Thus, the pump is ideally suited for our application. The natural frequency of our instruments is 14 hertz, and we can control the auxiliary mirror by controlling the accelerometers on the main mirrors. In interferometric applications, a so-called “delay line“ compensates for all vibrations. Vibrations of vacuum pumps no longer present a problem for us. Oil pressure pumps for the bearings of the telescopes are much more critical.

What we also like about the pump is its operational stability and reliability. To understand this, you must consider our operating conditions. We sit on a 2635-meter high mountain in the Atacama Desert, 130 km from the nearest city of Antofagasta. In addition, several times during the year, we experience earthquakes, and magnitudes of more than 5.4 on the Richter scale are not uncommon. We were largely spared from the big quake further south in Chile in February 2010; however, as a consequence of the aftershocks we had to fine-tune our optical equipment again.“

**Konwitschny:** “Previously, you mentioned tests on moving telescope support beams. What experience have you gained with regard to these conditions?“

**Lizon:** “These tests were conducted with different angular velocities, ranging between 0.1 deg/min and 5 deg/sec. Typically, we move our telescopes very slowly if we follow an object that we are currently interested in. We only switch to high speeds when we skip from one object to another. The maximum angular acceleration tested so far was 1 deg/$s^2$. This corresponds to about twice the speed reached in practice. We repeated these tests ten times applying the most difficult parameters. The pump has coped with this ordeal without an adverse incident.
Simply put, what we want from each component of our telescopes is optimal temperature stability. Any temperature gradient produces a minute amount of convection, which may of course interfere with our optical observation. Therefore, we use only components in our applications that meet our specification of a temperature stability of +1°C to -3°C. We achieve this perfectly with water-cooled pumps.
Once, an accidental water leakage caused a two-week plant shutdown. That's why we prefer convectional cooling whenever possible. When using this type of cooling, the electronics in particular stay a bit warmer. However, we are responsible for the connection of the cooling water supply. Basically, when compared to the previous version, the compact design of the ATH 500 M helps us with its integrated electronics and low surface temperatures.“

**Konwitschny:** “Mr. Lizon, thank you for this interview.“


The ATH 500 M is a turbopump with active control of the magnetic bearing that acts upon five axes in the inertial axis of the pump.

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Pfeiffer Vacuum stands for innovative and custom vacuum solutions worldwide, for German engineering art, competent advice and reliable service.

Ever since the invention of the turbopump, we have been setting standards in our industry and this claim to leadership will continue to drive us in the future.

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