Most of our knowledge about the universe has been gained by observing photons. These light quanta are produced in large quantities, are stable and are easily traced in a wide range of energy. Their spectrum also supplies detailed information about the chemical and physical composition of the source. Unfortunately, the extremely hot, dense areas that form the center of stars, active galactic centers and other astrophysical energy sources are completely impermeable to photons. There is only one type of particle capable of helping scientists obtain more information about these highly interesting objects: the neutrino.

Neutrinos are electrically neutral elementary particles that belong to the lepton family. For every electrically charged lepton (electron, myon and tau), there is a neutrino counterpart (electron neutrino, myon neutrino and tau neutrino). These family members can tell us a lot about the universe, which is why their observation is so important to astronomers. Since they can cover enormous distances in matter without reciprocal action, they are helpful in investigating energy-generating processes, for example in suns, where they form during the fusion of hydrogen atoms. Veritable neutrino outbreaks occur when a neutron star develops in the heart of a supernova, a celestial phenomenon that also interests astrophysicists.

Deep-sea glass spheres help detect neutrinos

Several large-scale experiments have already been conducted to detect neutrinos. One way to achieve this is to perform experiments in large areas of water, such as lakes or ocean regions, since neutrinos can interact with an electron in a water molecule. If a neutrino with enough high energy is scattered by an electron, the electron emits a blue light, which experts call Cerenkov radiation, on its way through the water. This blue light can be detected by very sensitive photomultipliers, but they must be correctly
placed in the water. Deep-sea spheres made with special glass play an indispensable role in properly positioning these highly sensitive instruments for the job.

Take, for example, the French project ANTARES, which after years of preparatory work is now entering its decisive phase. Some 900 of these glass instrument housings are in operation off the coast of Toulon. They are positioned at a depth of 2.5 kilometers in ten lines each 300 meters long to detect neutrinos from distant outer space.

The spheres consist of two half shells that are produced from “Duran” borosilicate glass in a 40-metric ton press mold at SCHOTT in Mainz. This process results in the fewest differences in wall thickness – a major prerequisite to ensure that the hollow object can withstand the extreme pressure of 900 bar – or 360 times the pressure of a car tire – at depths of 9,000 meters. The high optical quality of the glass is also important. Even when the glass wall of the spheres is 18 millimeters thick, the exceptional optical quality enables cameras inside the sphere to take excellent photographs, for instance, of the sea floor.

The unfinished glass shells are further processed at SCHOTT Medica in Wertheim, where the edges are cut and rough-ground with a milling machine. The exclusive customer is Nautilus Marine Service GmbH in Bremen, which sells an average of 2,000 glass spheres per year throughout the world. “We perform the final processing steps according to customer specifications. This work includes precision grinding of the sealing surfaces, in addition to coating, drilling for the cabling of instruments and assembling vacuum valves to produce a partial vacuum inside the spheres,” explains Gerald Abich, Managing Director of Nautilus. The absolutely perfect fit of the half shells ensures a uniform load transmission – a decisive factor for the stability of the fully assembled sphere, which is closed with a sealant band.

Another area of application: seismology

In addition to their application in neutrino detection, glass spheres are also used for instruments that register seismic action. For example, the location of seaquakes can be determined by timing the intervals between the tremors. Such data are also required for extreme precision is a prerequisite throughout the production of the spheres, for example, to guarantee a uniform wall thickness. This is the secret behind their stability – even at sea depths of 9,000 meters where the water pressure is 900 bar.
In oceanographic applications, the deep-sea spheres are used as buoyancy floats or as housings for electronic instruments and batteries.

research into underwater volcanoes as well as for commercial purposes such as in oil and natural gas exploration. The method applied is called refraction seismology in which acoustic waves are passed through solid bodies. Depending on the composition of the underground, the sound waves have different intervals until they reach the surface again. If these signals are recorded with the suitable devices, it is possible to gain valuable geological information. The geophones are placed near the floor of the ocean in order not to disturb the measurements through the water column and to obtain as accurate results as possible.

GEO PRO GmbH in Hamburg works in this field. “The glass modules are extremely versatile, can be used at depths between two and several thousand meters and are compact and light,” says Jannis Makris, retired professor of geophysics at the University of Hamburg and Managing Director of GEO PRO. The company not only sells spheres equipped with measuring systems, but also uses them to collect their own data. “From this information, we are able to develop geological models of, for instance, tectonic disturbances for our customers,” explains Makris.

There is also considerable interest in such results in Japan, which is frequently struck by earthquakes and seaquakes. For this reason, scientists regularly compile seismic profiles. More than 100 measuring instruments in glass housings are used for the campaigns that are organized and conducted by the Japan Marine Science and Technology Center (JAMSTEC). As a technical service provider, JAMSTEC then furnishes complete sets of data for evaluation by the participating Japanese universities. JAMSTEC obtains its deep-sea spheres from the city of Bremen in distant Germany.

There are good reasons for this choice of supplier. “The spheres from SCHOTT may have their price, but they are also top quality,” stresses Abich. Generally speaking, glass offers the best ratio between buoyancy and price. Possible alternatives such as titanium or plastic foams are more expensive by a factor of 50 and 10, respectively, while steel is too heavy. Due to the high quality of the glass, it is also possible to save costs. “Each operation with a ship results in considerable costs of up to 20,000 euros per day, which is why it is so important that the instruments and their protective shells function without fail. That is the key to the success of every measuring campaign,” says the Managing Director of Nautilus. For this reason, oceanographers and marine biologists also use versatile buoyancy floats to measure pressure, temperature and conductivity or to determine the turbidity or flow rate. In addition, they bring so-called landing systems back to the surface. These devices are used to observe sediments, marine life on the ocean floor and fish populations.

A dive into the Mariana Trench

After 2003 the glass spheres from Germany will play a special role in another particularly interesting project. The renowned Scripps Research Institute in La Jolla, California, the largest private and non-commercial organization in the United States, will celebrate the 100th anniversary of its founding with a diving operation into the Mariana Trench. Here in the western Pacific is where Scripps’ legendary diving expedition with Jacques Piccard from Switzerland and Donald Walsh from the United States took place in 1960. They dived to a depth of 11,521 meters, the deepest point of the Earth’s oceans. This descent is supposed to be repeated, but this time a camera enclosed in a “Duran” glass sphere will deliver photographs of the deepest part, called the Challenger Deep.

With great expectations the specialists at Nautilus are also waiting for the NEMO project to be realized. Off the coast of Sicily the biggest neutrino experiment of all times is scheduled to take place under this name. A gigantic neutrino array could be set up over an area of ten square kilometers. Some 10,000 glass spheres would be required to hunt down the elusive particles from outer space over such an area – a commission that CEO Abich would be more than pleased to secure for Nautilus.