Interview with Prof. Bernhard Brandl, Leiden University, The Netherlands

⇒ **Prof. Brandl, let's begin with your current work. Could you briefly tell us about your main research areas, and what particularly draws you to infrared astronomy and starburst galaxies?**

Actually, I entered astronomy somewhat through the back door. During my university days I was a high-energy physicist, but I did not like the idea of working within very large research consortia. I was looking for something more practical, something that could be done in smaller groups.

At that time there was an opportunity to pursue a PhD at the Max Planck Institute for Extraterrestrial Physics. The project involved building a near-infrared camera designed to work together with one of the first astronomical adaptive optics systems. In the late 1990s this system was deployed on the 3.6-meter telescope at the La Silla Observatory in Chile.

I really enjoyed the process of building an instrument and then using it on the sky to make discoveries. That experience shaped my scientific path—learning by doing. The instrument itself essentially determined the scientific direction: it was designed for the near-infrared, which was where adaptive optics worked best at the time. That is how I became involved in astronomical instrumentation, while in parallel I was learning astronomy itself.

Prof. Bernhard Brandl in Leinden University
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Later I received an interesting job offer to move to Cornell University. That was also where I first came into contact with Armenian astronomers. At the time Yervant Terzian was the chair of the department, and Areg Mickaelian was visiting Cornell. After some work on instrumentation, I had the opportunity to work with data from the **Spitzer Space Telescope**, one of NASA's Great Observatories operating in the infrared.

Spitzer was ideally suited for studying starburst galaxies. There I could combine my earlier work on high-angular-resolution observations of massive star clusters with integrated spectra of starburst complexes. That became the central theme of my scientific work: instrumentation combined with studies of the infrared universe.

Later I moved to Leiden and worked on the spectrograph for the **James Webb Space Telescope**. And today I am the Principal Investigator of the **METIS instrument**, the thermal mid-infrared instrument for the **Extremely Large Telescope (ELT)**. Throughout my career I have alternated between ground-based and space-based instrumentation, but instrumentation has always been the central theme.

⇒ **You are leading the METIS project for the European Extremely Large Telescope (ELT). What makes METIS unique, and how will it contribute to the next generation of astronomical discoveries?**

The Extremely Large Telescope represents a huge leap forward—from today's 8–10 meter telescopes to a telescope with a primary mirror of about 40 meters. This means the angular resolution will improve by roughly a factor of five.

Such an improvement is particularly important for observations that require very high angular resolution or very high contrast. A prime example is the search for exoplanets. In protoplanetary disks, for instance, we need to study very small angular separations from the central star—regions that are currently extremely difficult to observe.

Another key advantage is the enormous collecting area. In the mid-infrared we are often limited by thermal background radiation, which produces significant photon noise. A much larger telescope aperture increases the signal-to-noise ratio, allowing us to detect objects that were previously beyond reach.

METIS will be one of the first instruments installed on the ELT. It operates at longer wavelengths and is optimized for studying dusty, warm, or cool environments—objects that are not the hottest in the universe but are rich in infrared emission. Key science drivers include **exoplanets and protoplanetary disks**.

The instrument includes a relatively small field of view but very advanced spectroscopic capabilities. In particular, it features an integral-field spectrograph with extremely high spectral resolution—around **R ≈ 100,000**. At the same time, it will achieve angular resolutions on the order of **20 milliarcseconds**.

To put that into perspective: typical atmospheric seeing at a good observatory site might be around one arcsecond. METIS will provide roughly **50 times better angular resolution**. Combined with the high spectral resolution, this will allow detailed studies of kinematics and chemical composition in environments such as protoplanetary disks. These capabilities make METIS a truly unique instrument.

⇒ **You are also one of the co-principal investigators of the MIRI instrument onboard the James Webb Space Telescope. Could you share any exciting updates from MIRI's recent observations?**

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In very simple terms, the most remarkable result is that everything works so well. The telescope and its instruments are producing an extraordinary amount of high-quality data. Considering how complex the mission is, the fact that it operates so efficiently and without major problems is already a major success.

Of course, this success reflects the work of thousands of scientists and engineers who contributed to the mission over many years. It also explains why the project required such a significant investment.

It is difficult to single out one specific scientific discovery. Modern astronomy often advances through the accumulation of evidence rather than a single dramatic observation. Nevertheless, one particularly exciting area is the study of the **early universe**.

For the first time we are able to observe very young galaxies and resolve their spatial structure. This allows astronomers to compare observations directly with theoretical models of early galaxy formation. Some of the results have been surprising and are helping refine our understanding of how galaxies formed shortly after the Big Bang.

There is a great deal of exciting science emerging from these observations, and undoubtedly much more to come.

⇒ **Being involved in both ground-based and Space instrumentation, how do you see the balance between these platforms evolving in the coming decade?**

Many of the technologies involved are actually very similar. Whether in Space or on the ground, we build instruments with similar materials, optics, and opto-mechanical systems.

However, ground-based instruments allow more flexibility. You can adopt newer technologies and take greater risks. If something fails, it can often be repaired or replaced. For example, ground-based instruments can use the very latest detector technologies.

Space missions, on the other hand, must use extremely reliable and thoroughly tested technology. Instruments must pass many qualification procedures and demonstrate that they can survive the harsh conditions of space, including radiation. This means the technology used in Space missions is often several years older by the time the instrument is launched.

Ground-based observations also face practical limitations such as weather and atmospheric turbulence. Adaptive optics helps correct for atmospheric distortion, but it is not a perfect solution and works only under certain conditions.

Space telescopes offer incredibly stable observing conditions with very low background noise. This allows astronomers to integrate observations for many hours and detect extremely faint objects, something that is very difficult from the ground.

However, Space missions are extremely expensive and cannot easily be repaired once deployed. In the past, the Hubble Space Telescope could be serviced because it was in Earth orbit, but modern missions like the James Webb Space Telescope are far beyond that reach.

In short, both platforms are essential and complementary. Ground-based telescopes allow flexibility and technological innovation, while Space telescopes provide stability and access to wavelengths that are difficult or impossible to observe from Earth.

⇒ **You are also a member of the Armenian Astronomical Society (ArAS). How did your connection with Armenia and its astronomical community begin?**

It started through a fortunate coincidence when I was a postdoctoral researcher at Cornell University. Areg Mickaelian came to visit Cornell, where he had connections with the Department.

At that time I was working on starburst galaxies and infrared spectroscopy, and there was clear scientific overlap with the **First Byurakan Survey**, which identified many emission-line galaxies.

We had many discussions with colleagues such as Dan Weedman and Jim Houck. The approaches were quite complementary. The Byurakan surveys provided large datasets and catalogs containing many interesting objects, while our work often focused on detailed observations of individual targets using large telescopes.

Through the **Spitzer Guaranteed Time Observing program**, we were able to observe some of the galaxies identified in those catalogs. That collaboration began in the early 2000s.

Since then we have remained in contact, exchanging ideas and visits. I also find it personally interesting to see what is happening in Armenia. There are many enthusiastic young astronomers there, and it also reminds us how fortunate we are in Central Europe, where access to large observing facilities is relatively straightforward. Not everyone has that privilege.

⇒ **Based on your experience, where do you see potential for cooperation between METIS-related research and BAO?**

Astronomy as a field is currently going through a period of transition. For a long time we had a relatively stable situation with 8-meter-class telescopes as the largest facilities. Now we are building 30- and 40-meter telescopes and planning new large space missions.

Prof. Bernhard Brandl in Leinden University Academy Building
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At the same time, many smaller observatories with telescopes in the 2–4 meter range continue to produce excellent science. No one wants to abandon these facilities, but funding is always limited.

The global community is therefore rethinking how to best use telescopes of different sizes. Large telescopes are essential for the most challenging observations, but smaller telescopes remain extremely important for follow-up observations, surveys, and student training.

In fact, we cannot train students exclusively on the largest telescopes. Students also need hands-on experience with observations and instrumentation.

For collaboration with BAO, one promising direction would be **instrumentation development**. Building unique instruments at medium-sized observatories could provide valuable opportunities for students and enable follow-up observations for large international projects.

Exactly what form this collaboration might take is something that would require further discussion.

⇒ **What advice would you give to students and early-career researchers in Armenia who want to enter fields such as infrared instrumentation or Space missions?**

First of all, working in astronomy is a privilege. It allows you to pursue your curiosity about the Universe.

However, the field has become increasingly competitive. Finding a permanent position is more difficult today than it was twenty or thirty years ago. Because of that, it is important to be driven by genuine curiosity and passion for the subject.

At the same time, astronomy is evolving. Many modern projects involve large surveys that produce enormous volumes of data—terabytes every night. No one can examine this data

manually anymore. Instead, we rely on advanced data analysis techniques, including artificial intelligence.

For young scientists, it is therefore important not only to understand astronomy but also to develop skills in programming, data analysis, and machine learning.

Another important change is that data are becoming more accessible. A hundred years ago you had to be physically present at an observatory to access observations. Today many datasets from large surveys are publicly available worldwide.

This means that students in Armenia can work with the same data as students at major research institutions. With the right tools and ideas, they can make significant discoveries even without direct access to large observatories.

Interview conducted by Lilit Darbinyan
Press Secretary of Byurakan Astrophysical Observatory (BAO)
Newsletter Editor of Armenian Astronomical Society (ArAS)