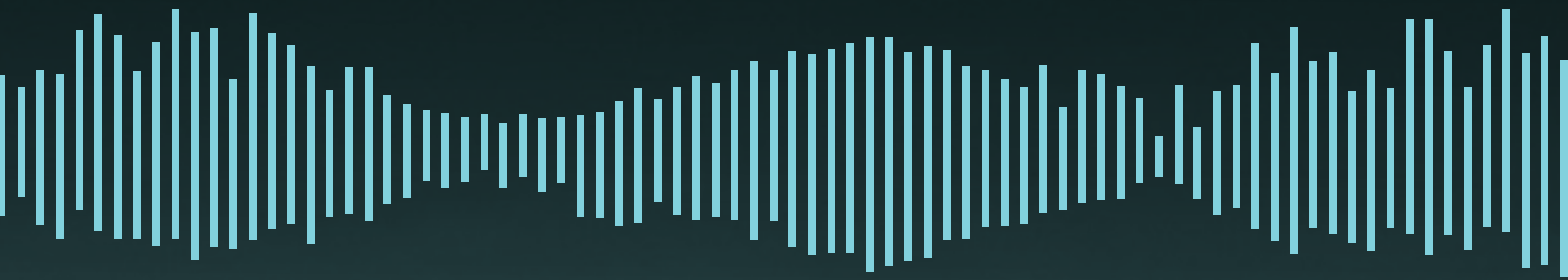

ASTRONOMY, RADIO SOURCES AND SOCIETY

THE WONDERFUL CENTURY

A SYMPOSIUM CELEBRATING GEORGE MILEY'S ACHIEVEMENTS

LEIDEN, THE NETHERLANDS 10-13 JUNE 2013

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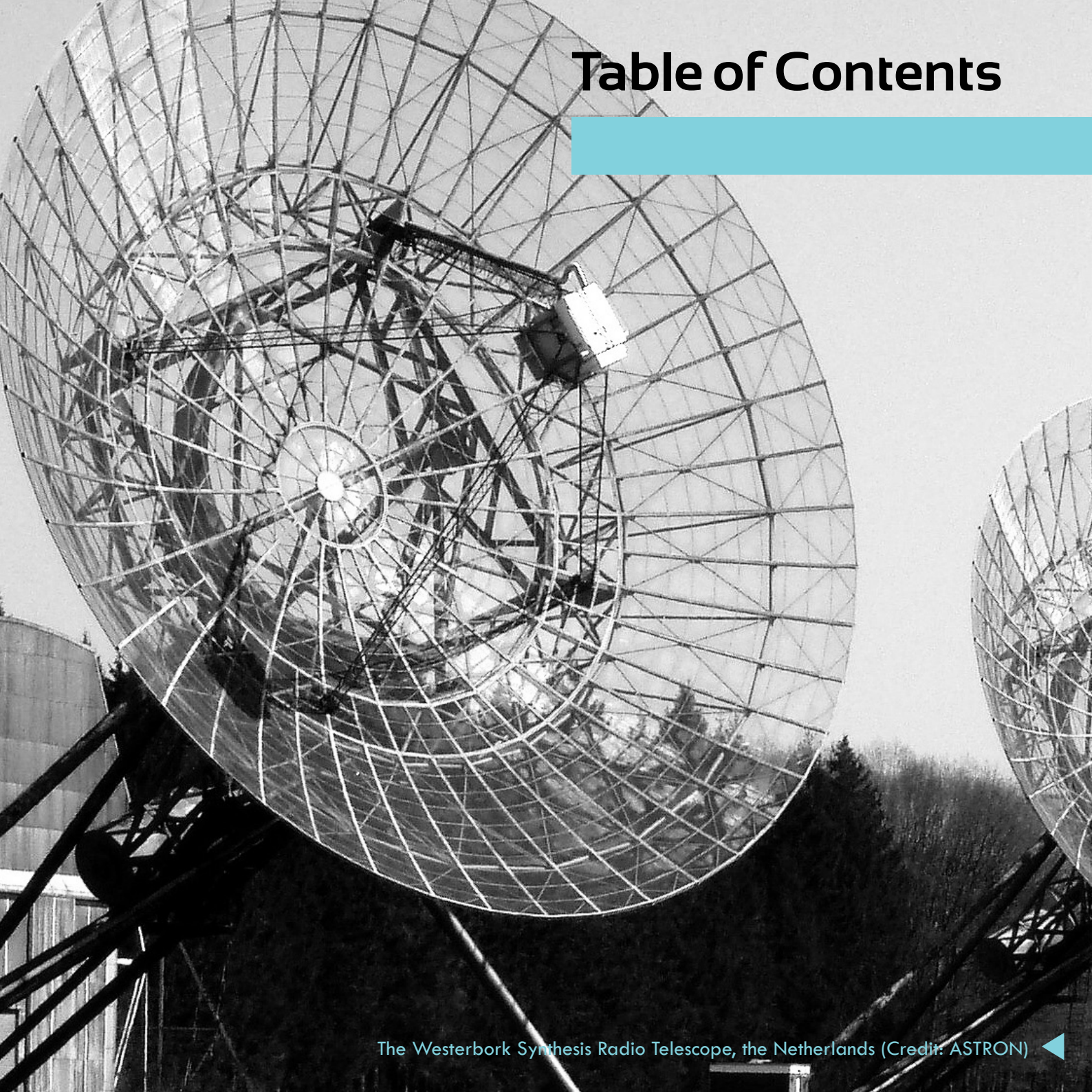


The Westerbork Synthesis Radio Telescope, the Netherlands (Credit: ASTRON)

WELCOME

By Huub Röttgering

Welcome to this 4 day celebration of George Miley's continued resistance against retirement. Now 71 years young, George still lives the life of an active scientist who has a vivid interest in all that is happening around him.

George still actively contributes to the scientific love of his live: radio astronomy. One of the current Leiden PhD students, Leah Morabito, is working on LOFAR observations of one of George Miley's (and Wil van Breugel's, see his contribution) favourite radio galaxies: 4C41.17. During the last few months George was almost constantly peering over Leah's shoulder, extremely excited about the fantastic progress she was making. The only reason that Leah is still getting a lot of work done is that George is away a lot. These days, he travels more than ever and at least one day a week George and Hanneke look, very happily, after their grandchildren. To review the status of the scientific fields George has worked in, the scientific organising committee has scheduled excellent review talks from many young-at-heart astronomers as well as talks presenting exciting new results from young astronomers.

George has always had a broad view of astronomy and one of his interests is the understanding of, and if possible helping in, the process of ensuring that the next generations of astronomers can explore the universe in novel ways. His proposal for the LOFAR telescope is a good example of this. In a workshop held in honour of Ron Eker's Oort-professorship in Leiden, George and Ron noticed that the lowest frequency part of the electromagnetic spectrum was the only part that had not yet been explored with a modern observing facility. George's enthusiasm and excellent writing skills started the LOFAR adventure. And with credit to ASTRON's hard and capable work, LOFAR is now a world class instrument that is in full operation. For the first day of this week, Richard Schilizzi has put together a wonderful program with speakers that will highlight the importance of large scale observing facilities not only as tools for astronomers, but also as important technical testbeds and training vehicles for young and talented people.

Using the beauty of the Universe to inspire young children was the main aim of the Universe Awareness (UNAWE) programme that George started when he was appointed as KNAW professor. Amazingly, UNAWE is now active in 56 countries. One of the UNAWE activities during the symposium will be a Teacher Training workshop for nursery and primary school educators.

With several personal contributions including one from George, a book presentation and musical performances, the programme for Monday evening will be entertaining for all. We hope that many of George's family, friends and colleagues will be able to come and enjoy the evening.

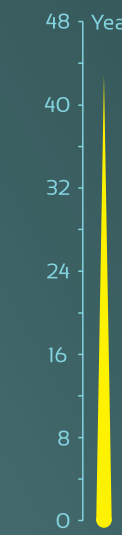
In 1988 the economic situation in the Netherlands was similar to today's: grim. The unemployment rate was on an extremely steep rise and many of my fellow students were struggling to get decent jobs. I was therefore extremely happy when George offered me one of the few PhD positions that were available that year. Knowing George's usual enthusiasm, I was rather surprised by his initial reaction when I instantly said yes: "Do you realise how uncertain your future will be? Are you really sure that you want to do this?" This was one of the first times I noticed how honest George can be when he is putting things into a greater context. Now, some years later, I can say with more certainty than ever to the last of his questions: yes! George, it was great to witness your many adventures. May you enjoy the adventures in the many years to come!

Huub Röttgering
Director Leiden Observatory

GEORGE K. MILEY

AWARDS AND DISTINCTIONS

- Honorary Fellow of the Royal Astronomical Society, UK: 2013
- Ridder in de Orde van de Nederlandse Leeuw (Knight in the Order of the Netherlands Lion) 2012
- Vice President, International Astronomical Union 2006–2012
- Royal Netherlands Academy of Arts and Sciences (KNAW) Professor 2003–2008
- Member of the Royal Netherlands Academy of Arts and Sciences since 1999
- Koninklijke Shell Oeuvre Prize 1996



George K. Miley
15 March 1942

1942

1959-1963
BSc Physics, University College Dublin, Ireland

1959

1963

1963-1968 PhD Radio astronomy, University of Manchester, UK

1968-1970 Research Associate and Assistant Scientist, National Radio Astronomy Observatory, USA

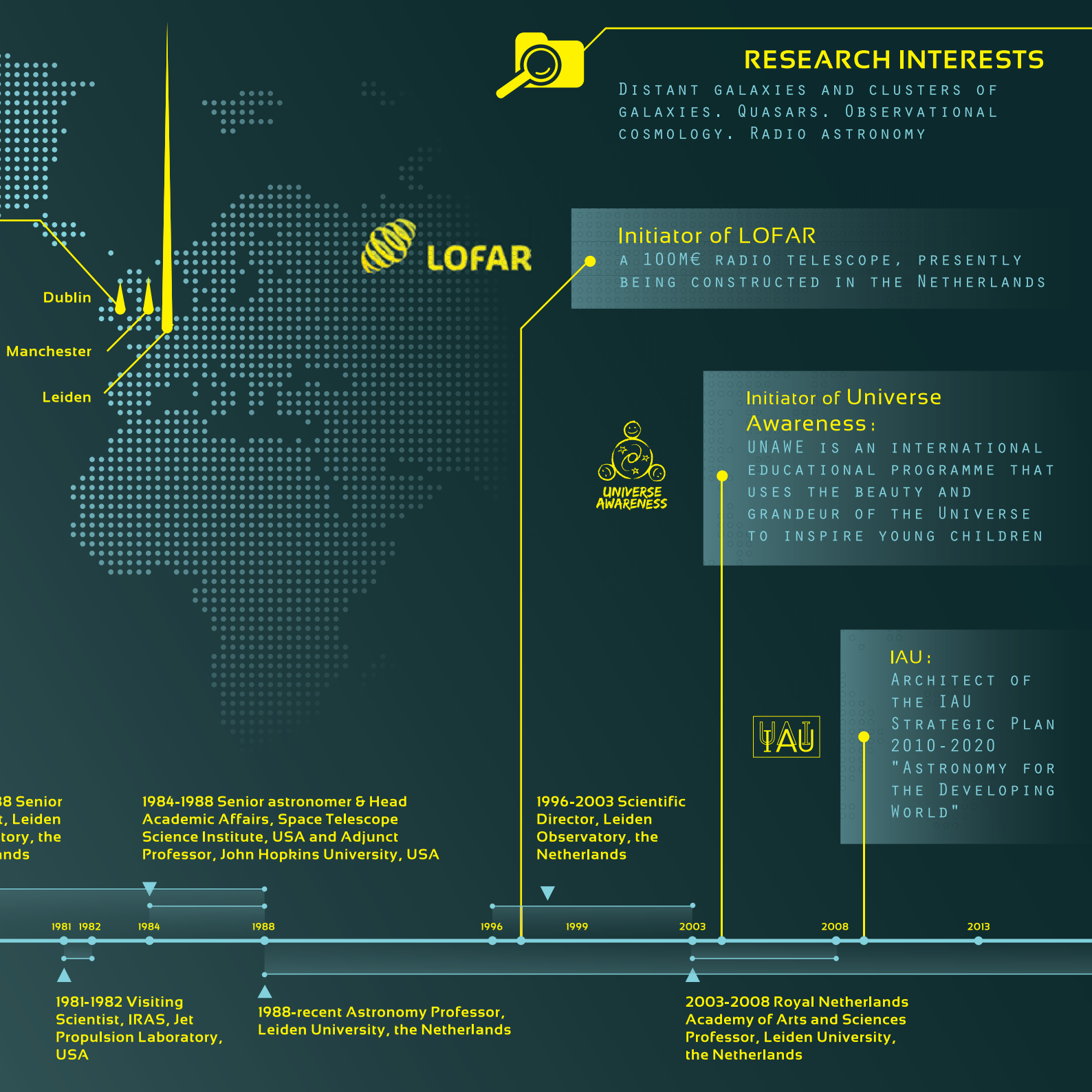
1968

1970

1970-198
Scientist
Observa
Netherla

1977 1978

1977-1978 Visiting Professor, Lick Observatory, USA


RESEARCH INTERESTS
Distant galaxies and clusters of galaxies. Quasars. Observational cosmology. Radio astronomy
LOFAR
Initiator of LOFAR
a 100M€ radio telescope, presently being constructed in the Netherlands
Dublin
Manchester
Leiden
UNIVERSE AWARENESS
Initiator of Universe Awareness:
UNAWE is an international educational programme that uses the beauty and grandeur of the Universe to inspire young children
IAU
IAU:
Architect of the IAU Strategic Plan 2010-2020 "Astronomy for the Developing World"
88 Senior
t, Leiden
tory, the
nds
1984-1988 Senior astronomer & Head Academic Affairs, Space Telescope Science Institute, USA and Adjunct Professor, John Hopkins University, USA
1996-2003 Scientific Director, Leiden Observatory, the Netherlands
1981
1982
1984
1988
1996
1999
2003
2008
2013
1981-1982 Visiting Scientist, IRAS, Jet Propulsion Laboratory, USA
1988-recent Astronomy Professor, Leiden University, the Netherlands
2003-2008 Royal Netherlands Academy of Arts and Sciences Professor, Leiden University, the Netherlands

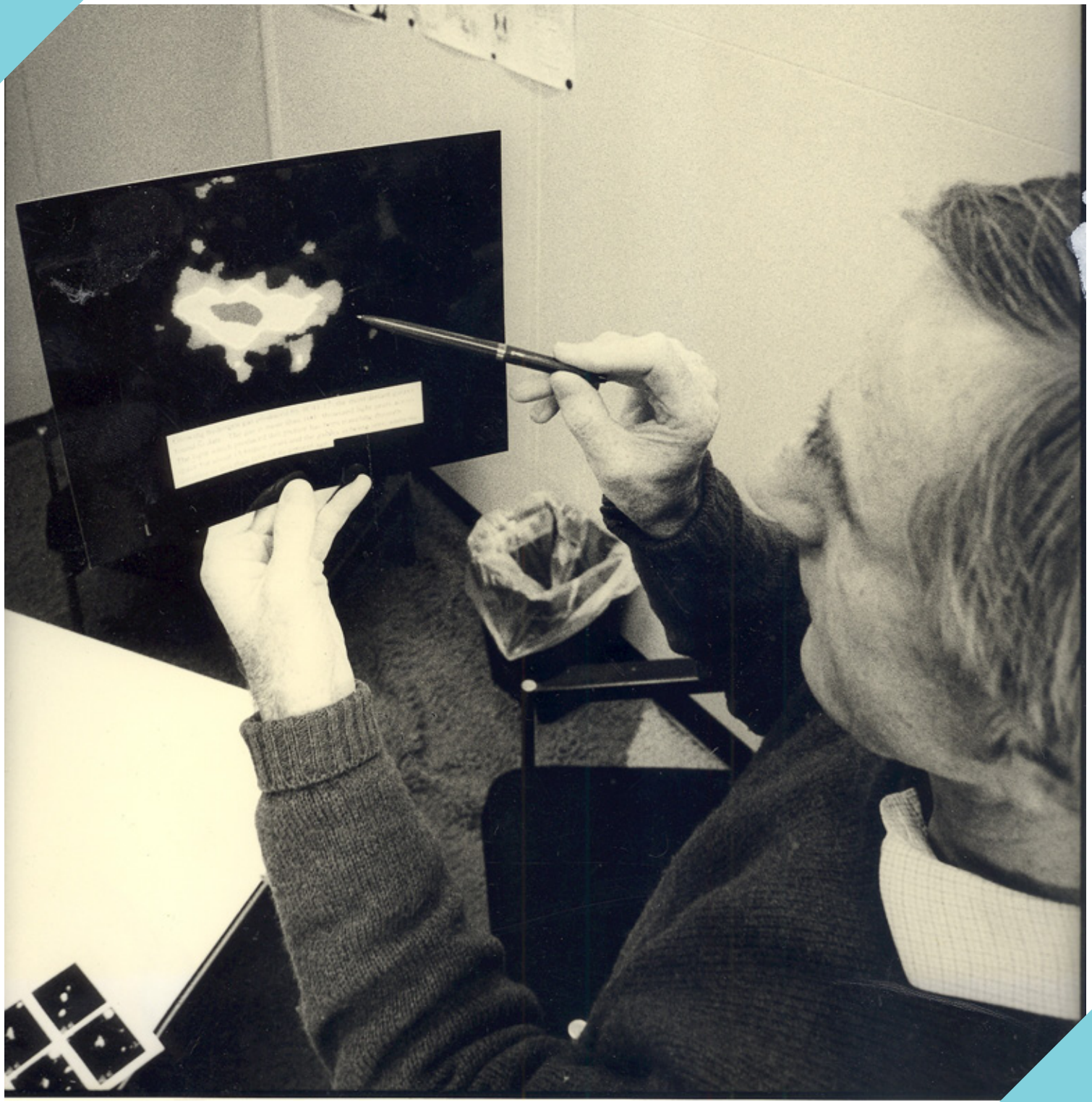
ALWAYS LOOKING FURTHER

By Iris Nijman

Biography of George Miley

What defines the life of the Irish-Dutch astronomer, George Kildare Miley? According to his colleagues, he's always been in the right place at the right time, doing the right thing – and it's true. From his discovery of the most distant object in the universe and his proposal for the new radio telescope, LOFAR, to his fight against the budget cuts as Director of Leiden Observatory and his newest educational programme, Universe Awareness, Miley has always pioneered groundbreaking projects. But not because he wanted to make a career, he says: "I was just working on fun, exciting things. For me, that's the most important part."

George looking at image of 4C41.47 in 1989



Miley's interest in physics and astronomy started early in his life, when his father, a lawyer, told him all about the theory of relativity and read to him the science fiction story, 'War of the Worlds' by H.G. Wells. After high school, where he was taught no science, he decided to study physics at University College Dublin. After graduating with a BSc in Physics in 1963, he decided that astronomy would be an intriguing field of research. "Radio astronomy was a hot topic at the time, because it offered a new window on the Universe," Miley says.

Miley therefore chose to do a PhD in radio astronomy in the UK at the University of Manchester, Nuffield Radio Astronomy Laboratories, Jodrell Bank (NRAL). At NRAL a new radio telescope had been completed and was being used to follow the first Russian spacecrafts on their way to the Moon. "These space probes were constantly in the news," Miley enthuses. "Jodrell Bank was a very exciting environment. We developed long baseline interferometry, an important technique used to measure tiny radio sources at enormous distances, like quasars."

In the late sixties, Miley worked as a research associate for a couple of years at the National Radio Astronomy Observatory in Charlottesville, USA, where he continued his research on quasars and other radio sources in the Universe. Miley found a relation between the size of quasars and their distance: the smaller the quasar, the further away it is. "We were working with extremely distant objects, billions of light years away that had just been discovered and were helping us to probe the early Universe and its origin," he says.

WESTERBORK

While Miley was in USA, the world's newest radio telescope was being built in Westerbork in the Netherlands. Miley, who wanted to use this very important facility, wrote a letter to Jan Oort, a famous Dutch astronomer. Oort was the Director of Leiden Observatory at the time and architect of the Westerbork Synthesis Radio Telescope (WSRT). Miley was hired immediately in a permanent position, without ever meeting Oort. "I had never even been to the Netherlands!" says Miley, still surprised. "This should never have happened, but I'm so happy that I got this chance."

In the seventies, Miley married his Dutch wife, Hanneke, and made his home in Leiden, which was then the headquarters of ASTRON, the Netherlands Institute for Radio Astronomy, previously known as the Stichting Radiostraling van Zon en Melkweg (SRZM). Together with Professor Harry van der Laan's research group, Miley used the WSRT extensively to study the sizes and structures of many classes of radio sources, such as radio galaxies — extremely active galaxies that emit large amounts of radio energy. Miley's observations demonstrated that a black hole often rotates in the centre of these galaxies, working like a nuclear powerhouse that emits energy along jets. Miley expected to not only find interesting radio sources at large distances, but also within our own Milky Way, and he was right. Together with Luc Braes he pinpointed the position of Cygnus X-1, a radio source that was found to be the first observed black hole.

COSMIC EVOLUTION

In 1977, Miley took a sabbatical year at the American Lick Observatory in California. There he moved beyond his own field of work and began exploring optical astronomy. He evolved from a radio astronomer into a 'multi-wavelength' astronomer, which was very uncommon at this time. "Until then you usually were a radio astronomer or an optical astronomer," Miley explains. "But I wanted to combine these different techniques to discover more about the same objects. The invention of digital cameras in the seventies made it easier for radio astronomers to do optical astronomy." Using the new generation of optical detectors Miley helped develop a new diagnostic tool that used extended optical emission lines for studying the physics of radio galaxies. He discovered that "redder" radio galaxies were extremely faint optical sources, which meant that they were very distant. Later in his career Miley focused on these sources with 'ultra-steep radio spectra' to find more and more distant galaxies. For several years Miley and his colleagues held the record for the most distant galaxy discovered.

Miley's multi-wavelength skills were further expanded in the 80s, when he joined the international science team responsible for IRAS, the Infrared Astronomical Satellite. IRAS was used to complete the first deep infrared map of the sky. Miley then spent six months, at NASA's Jet Propulsion Laboratory in Pasadena, USA, working on these pioneering IRAS surveys.

Back in Leiden, he used his new knowledge of optical and infrared astronomy to study the physical conditions within radio galaxies and the gas that surrounds them. He did this together with Tim Heckman, then a dynamic young Leiden postdoc and Wil van Breugel, a creative PhD student. Another of his first students was Peter Barthel, now working as an astronomy professor at the University of Groningen in the Netherlands. Barthel and Miley studied radio structures in the early and late Universe, discovered that radio sources in the early universe were more bent than expected and suggested that this was due to interaction with dense gas in the galaxies that hosted the quasars "Those were exciting times in Leiden, when we were working on cosmic evolution," Barthel explains. According to Barthel, Miley was a very independent researcher and he also wanted his students to become independent. "He wanted you to discover things for yourself. I found that difficult at first, but it made me a better researcher. I now do the same to my students!"

THRILL-SEEKER

During Barthel's PhD, Miley wasn't around all the time. "Miley is a thrill-seeker," says Barthel. "He always wants to be in the place where it all happens, where the exciting things are discovered." That's why Miley moved to Baltimore (USA) in 1984 with his wife Hanneke and two daughters, Helen and Anna. There he worked at the Space Science Telescope Institute, where he hoped to observe with Hubble, but that was delayed due to the Challenger disaster in 1986. Regardless, he continued working in Baltimore for four years, as the Head of Academic Affairs and began his optical research on high redshift radio galaxies.

In 1988, Miley returned to Leiden permanently and was appointed a professorship. His research on distant radio galaxies continued and Miley remains very excited talking about this time. "Radio galaxies are fantastic objects. I worked with a lot

of excellent people, including Huub Röttgering, the current scientific director of Leiden Observatory." They showed that luminous radio galaxies can lead the way to finding the first galaxy clusters, 'cosmic cities of galaxies' that formed in the Early Universe. "Miley's multi-spectral knowledge and enthusiasm was again appreciated," says Röttgering, who completed his PhD in 1993 under Miley's supervision. "Miley had so many ideas and always had a good overview of what had to be done and where we had to go with our research," Röttgering says. "He thought about new opportunities like no-one else, which always brought us to the right place at the right moment."

LOFAR

Miley was the Scientific Director of Leiden Observatory from 1995 to 2003. While he was still only acting Director, he fought fiercely against the faculty plans that were based purely on education without taking any account of research. In his words, "Astronomy was an outstanding research department, but because it had relatively few undergraduates, it was very vulnerable for cuts." Miley therefore wrote a letter to the Faculty Board, questioning the assumptions of the Faculty Plan. He pointed out that the department had already been cut drastically over the previous decades. "I stated that it would be better to close the Observatory completely than make it any smaller. They didn't, because the Dean of the Faculty was replaced and the new Dean, Kees Libbenga was extremely supportive," says Miley. Since then, Leiden Observatory has grown to become one of the largest and most productive astronomy departments in Europe.

But Miley was always looking further. While he was a member of the board of the ASTRON foundation, he was looking for a way to boost radio astronomy in the Netherlands and Europe. In 1997, he wrote a proposal for a new radio telescope that would look even further into the early Universe, which he called the Low Frequency Array (LOFAR) — it succeeded. In 2006, ASTRON started to build LOFAR, which consists of 7000 small antennas, situated in the north of the Netherlands and four more European countries. "It's fantastic that it has become a reality now and that it is actually being built. The project has become much more ambitious than my original plan. I'm a bit proud, I have to confess," says Miley joyfully. He is now part of various LOFAR observation programmes.

In 2003, Miley was awarded one of the first distinguished academy professorships by the Royal Netherlands Academy of Arts and Sciences (KNAW). He used this time to work further on his research on protoclusters, groups of galaxies that begin to form clusters around distant radio galaxies. He has also supervised more than 25 PhD theses since 1978.

ASTRONOMY FOR DEVELOPMENT

Besides research, Miley used his time as a KNAW-professor to 'stick his neck out' in developing a new education programme for young, disadvantaged children, called Universe Awareness (UNAWE). The idea — to inspire very young kids with astronomy — had already occurred to him much earlier, when he went to his daughters' primary school to tell kids about the Universe. "I saw how excited kids become when you tell them about the Universe," Miley says. "But astronomy is not only suitable to show them the fun parts of science, it also gives them perspective and it stimulates global citizenship and tolerance.

Fanaticism and nationalism are put into perspective when you show young children how small our world is compared to the Universe." UNAWE has grown into a worldwide programme, funded by the European Union and is now active in more than 50 countries, where it inspires children from 4 to 10 years old with the wonders of our Universe.

Since the foundation of UNAWE, Miley's career has taken a turn. As UNAWE was starting up in 2006, he was appointed Vice-President of the International Astronomical Union (IAU). As vice-president, he designed the IAU strategic plan 'Astronomy for Development', which advocates the use of the technological and educational aspects of astronomy to stimulate technological and human capacity building throughout the world. Miley is responsible for overseeing the implementation of this strategic plan until 2015 and he talks about this with a lot of passion. "During my youth I was a political left-winger. I'm therefore particularly happy that I can now, in addition to doing pure research, help contribute more directly to society. Astronomy is linked to cutting-edge technologies, fundamental science and the most profound culture, so it can be a unique tool for development throughout the world. Several countries, such as South Africa and China, have acknowledged this during the last few years."

DREAM

Miley now travels all around the world for projects such as UNAWE and the IAU, to get in contact with people and give talks. He also wants to continue working with LOFAR, to find more distant radio galaxies that can give us insight in to the history of the Universe. "Astronomers are actually super historians," he says. "We write the history of the Universe all the way back to the Big Bang. The most fascinating aspect of astronomy for me is that it provides us with perspective and wonder."

Miley, now 71 years old, is not thinking about retiring. "As long as I can make myself useful, I will continue working," he says. "There is so much work yet to be done, I can't picture myself just sitting at home!" One of his dreams is that UNAWE will continue to expand and will obtain structural funding."Working on development can never be finished. There are so many children in the world whose talents and potential are currently being wasted," he says. "We must try to motivate these children and give them the idea that there's more to the world than their own village or ghetto."

George at 60

OBSERVATIONS OF GEORGE MILEY

By Wil van Breugel

George set me off on my astronomy career, which paralleled his own for quite a while, and in many ways.

This started out when he fired his very first graduate student so he could hire me! How generous and prescient that was! This first student was going to work on quasi-stellar radio sources ('quasars') but he wasn't up to George's standards, and those of Harry van der Laan, who was the boss then, because George wasn't a 'real' professor yet. That was still going to take many more years.

These quasar studies now fell to George himself for a while, and he would mutter occasionally that it was a nuisance to have to do his own graduate student's work. Four years later quasars were going to be properly taken care of by Peter Barthel, George's second (successful) graduate student.

But I grant it to George that at the time he didn't hand to me these chewed-on quasars for further digestion. Instead my task – I should really say my opportunity – was to study the other luminous branch of the radio loud universe: Radio galaxies i.e. luminous radio sources of non-thermal synchrotron emission with usually two extended blobs ('radio lobes') straddling a large elliptical galaxy. With hindsight that was my second lucky break.

To be frank, before I go on, I should say that I had some serious doubts that this was astronomy, what 'they' were doing; those radio guys. Biased as it may be, and I was aware of this, I thought astronomy was something you should do with your own eyes peering through a real telescope. This skeptical view was seriously reinforced after I learned that a large fraction of radio sources, especially those with ultra-steep radio synchrotron spectra, could not even be seen on the deepest optical survey plates at the time from the Palomar Observatory.

I will never forget the sensation, after peering at the radio position of an Ultra Steep Spectrum (USS) source through a microscope hovering above a printed piece of sky, that there was nothing to be seen! It brought home to me that there were 'things out there' that we would never know what they were! But I will come back to that.

At the time there were more urgent questions: Why did some galaxies have luminous radio lobes? Where did these come from, and how were they energized? Strange, linear optical features ('optical jets') were known to be directed away from the center of a wimpy radio galaxy, M87, and from a quasar, 3C273, but nothing of the kind was yet seen in the growing zoo of other radio galaxies and quasars which had even more powerful radio emission.

When I started as a graduate student with George the Westerbork Synthesis Radio Telescope (WSRT) had just been upgraded, to be more sensitive, more stable, and also capable of observing at short wavelengths and hence with better resolution. This allowed us to get more detailed radio images of radio galaxies than our competitors at Cambridge in the United Kingdom, especially if you also allowed 'cleaning' using computer image enhancement techniques. That works well with stable, high dynamic range telescopes and was something our colleagues at Cambridge weren't allowed to do at the time!

The first data from WSRT was already in hand, or in George's and Harry van der Laan's hands, I should say. In fact, the WSRT itself remained as invisible to me as the waves it collected for the first 1½ year of my thesis research! My task was to 'reduce' these radio data to a nice plot on a large piece of paper. These sources included B2 0844+31 with a very prominent one-sided radio jet, 3C129 with its two swept-back radio jets ('tails'), and the nearby, ultra-steep spectrum source 3C310 with its bubbly radio structure.

Together these three sources were the first step in revealing Radio 'jets' in radio galaxies, the title of our first paper together (in Nature 1977) and the first chapter in my later Ph.D. thesis in 1980 on the Structure of Radio Galaxies with George and Harry van der Laan. These high quality WSRT radio observations suggested that radio jets were the paths along which radio lobes were energized by some powerful processes taking place at the centers of their parent galaxies. Even though this was a straightforward result I remember my struggle with writing this well, as I had trouble getting started on it, and it only got going after George wrote the first section.

3C310 was actually also a source of contention with our Cambridge colleagues, which was only ameliorated when I went on a pilgrimage there together with Xander Tielens, to convince them that its structure was not due to cleaning artifacts.

Xander by the way is famous, at least to Imke and me, for his 'klein onderzoek' (small research) with George and Tony Willis, which involved staring at blank fields associated with USS's on Palomar survey plates! I remember that Xander actually asked us for advice at the time – him being a budding interstellar medium theorist with not much use for extra-galactic radio sources – on whether this project was worth doing!

I don't recall what we said, especially since we would typically discuss such things while drinking a plentitude of trappist beers, but I suspect that we thought that this was the perfect project for him! Xander did tell me recently that these blank fields were not at all what George had expected, and that he checked the Palomar prints for himself to see that there really was nothing there.

After the arrival of Tim Heckman at Leiden Observatory it became clear that radio galaxies had interesting ways of interacting with their environment. Tim, and also Andrew Wilson in Leiden at the time, introduced us to the wonderful world of optical emission lines and the physics that could be pried from them, with real, optical telescopes. I will always credit Leiden with this multi-spectral astronomical approach to understanding the universe. This also stimulated the great and sustained quest that George undertook, and which so well resonated with my own curiosity.

And indeed, George had already seen the future, and soon went on sabbatical to an optical observatory at UC Santa Cruz in California. With that he left me with a multitude of data but also with capable mentors, like Tony Willis and Richard Strom, who enlightened me in the more practical ways of working with radio data.

Starting around that time the three of us, George, Tim and I embarked on many great discovery adventures using the WSRT and the Very Large Array (VLA) in New Mexico, in conjunction with optical telescopes at the Kitt Peak National Observatory (KPNO) and Steward Observatory in Tucson, Arizona.

At KPNO we had a valuable collaborator in Harvey Butcher, who had developed a novel instrument: a vidicon video camera, which recorded data in digital format. I remember Harvey once complaining that 'real' optical astronomers at the time did not take his instrument very seriously. But of course this was great for us radio guys, since it gave us an opportunity to study radio galaxies in the optical with little competition. Messing around with optical plates and riding at the prime focus did not seem very attractive to us and I don't think that George or I would have been very good at that.

Some of the first observations with Harvey's instrument were used to search for optical synchrotron jets, suspected counter parts of the radio jets that were now showing up in VLA maps of many radio galaxies. These discoveries subsequently made it into my thesis with George, and they may have motivated Geoffrey Burbidge, the director of KPNO at the time, to offer me later a postdoctoral position after my Ph.D.

Harvey Butcher himself was also so excited about these combined radio and optical studies that he became a radio astronomer for a while, at Groningen University and the WSRT, where he helped LOFAR come off the ground so to speak.

After my Ph.D. thesis, with Tim and me being both in Tucson, George became a regular visitor and helped us put together our observing programs and proposals.

The combination of detailed radio maps with narrowband images and long-slit spectroscopy was a great new venue for studying radio galaxies. For the first time we could now see the interaction of radio jets and lobes with their ambient medium! We could actually measure some physical parameters – the densities, pressures and velocities – of gas that was swept up by the radio sources.

An interesting point is that initially we used radio polarization observations, one of the strengths of the WSRT, to select sources with un-polarized jets or lobes, since we thought that those features might have been depolarized by the entrainment of ionized ambient gas. We indeed found a number of sources that way that had lots of emission-line gas associated with them, such as Coma A and 4C29.30.

But one of the most interesting discoveries, towards the end of my time in Tucson, and after I had succeeded Tim as the Bok Fellow at Steward Observatory, was that radio jets could even trigger star formation when they interact with dense enough gas! We discovered some amazing cases, including the low red shift 'Minkowski's Object' in a companion galaxy of 3C40.

Shortly after my move to UC Berkeley, where I had become a research astronomer in the radio lab of Jack Welch, new telescopes and instruments provided very good optical images – initially mainly from the Canada-France-Hawaii Telescope (CFHT) in Hawaii. These showed that distant radio galaxies had often multiple components that were thought to be the merging components of younger, bigger galaxies in the making.

George and I, independently, with graduate students in Leiden (Ken Chambers) and Berkeley (Pat McCarthy) then discovered that these optical continuum structures were actually aligned with their radio sources! That suggested that these were not simply merging galaxies. When I mentioned this once to Mark Davis at UC Berkeley I vividly remember that he exclaimed 'but gravity rules!' This may be, but radio jets do make their mark too, at least for a while.

In fact it suggested that these optical structures might be due to induced star formation like we had seen in Minkowski's Object, and which was also known to occur in Centaurus A in the southern hemisphere. Within one year after the discovery of this 'radio / optical alignment effect' several theoretical papers were written seeking to explain this phenomenon.

One of the most spectacular radio/optical aligned sources, at very high red shift, was 4C41.17, a USS at $z = 3.8$. This became an object of intense study by us with several Leiden and Berkeley graduate students, for many years and at many wavelengths. Ultimately deep long-slit spectro-polarimetry observations at the world's largest, Keck twin 10m telescopes by UC Berkeley graduate student Arjun Dey proved decisively that the radio-aligned optical emission was indeed due to star formation.

Meanwhile infrared detectors had also become available on the Keck 10m telescopes. It was my good fortune to have access to these telescopes, first through UC Berkeley, often in collaboration with Hy Spinrad and James Graham and their graduate students, and later when I was a research astronomer at the UC Lawrence Livermore National Laboratory (LLNL).

We now had the required tools to revisit the 'blank fields' associated with the USS's, and which we suspected might pin point massive forming galaxies (with massive active black holes) at very high red shifts. Indeed, our simple steep spectrum radio selection proved to be enormously effective when compared to pure optical / IR selection methods. In rapid succession we identified numerous high red shift radio galaxies, culminating in the discovery of the most distant powerful radio galaxy, TN J0924-2201 at z = 5.19 in 1999. This is still is the record holder, for 14 years now!

These USS's provided us with yet another great opportunity to use radio 'beacons' to study the formation of massive galaxies and their Active Galactic Nuclei (AGN) in the early universe. The identification and study of the most distant radio galaxies then became Ph.D. thesis topics for several Leiden graduate students with George, including Huub Röttgering, Carlos De Breuck and Michiel Reuland, the latter two on 'loan' from Leiden Observatory to work with me at LLNL.

Subsequent observations then centered on the search for the first forming galaxy clusters around them, spawning an entire cottage industry using multi-color imaging, deep spectroscopy and IR + millimeter observations, and once again providing several Leiden graduate students with Ph.D.'s and a shot at rewarding astronomy careers.

George had of course many other things going on. He was always close to the next frontier in observational astronomy, at observatories of any kind, and all over the world. But his great curiosity, driven by questions rather than telescopes, stands out the most. This also resonated so well with me, without knowing this at the time when he picked me as his first 'promovendus' who actually made it across the finish line.

The deep, and long lasting, mingling of radio and optical 'work' that was started and nurtured by George at Leiden Observatory, now some 40 years ago, resulted in happy and rewarding astronomy careers for himself and for many of us.

In closing I would like to note that George also developed a strong passion for education and outreach, an important part of this meeting here. As he himself stated this was triggered by the enthusiasm he saw in young children, including his own, when they were told about the wonders of our universe.

But perhaps the first seed for this was already planted when he himself was a young student at a Jesuit school, where he learned one lesson well: 'Give me a child for his first seven years and I will give you the man'. He now applies this same maxim, albeit with a rather different focus and motivation, to bring the wonder of science to children all over the world to further peace and understanding, with a zeal worthy of his own teachers.

Presentation of the 1997 Shell Oeuvre Prize to George by the then Chair of the Board of Royal Dutch Shell, Mr. Cor Herkströter

UNIVERSE AWARENESS

Inspiring Every Child with Our Wonderful Cosmos

In 2004, Leiden University professor George Miley first began exploring the idea of setting up an astronomy programme to educate and inspire young children, especially those from underprivileged backgrounds. He had been awarded an Academy Professorship by the Royal Netherlands Academy of Arts and Sciences and decided to use part of the associated funding to explore the feasibility of setting up such a programme. With considerable support and encouragement from the educational community, a successful workshop was held in Germany and it was agreed that the programme was worth pursuing. Universe Awareness (UNAWE) was born. Shortly afterwards, Carolina Ödman was appointed as the first UNAWE International Project Manager. In 2006, thanks to a grant provided by the Netherlands Minister of Education Culture and Science, Ms. van der Hoeven, the UNAWE International Office was founded at Leiden Observatory, the Netherlands. UNAWE grew into a thriving global project, with a network of about 400 experts from 40 countries.

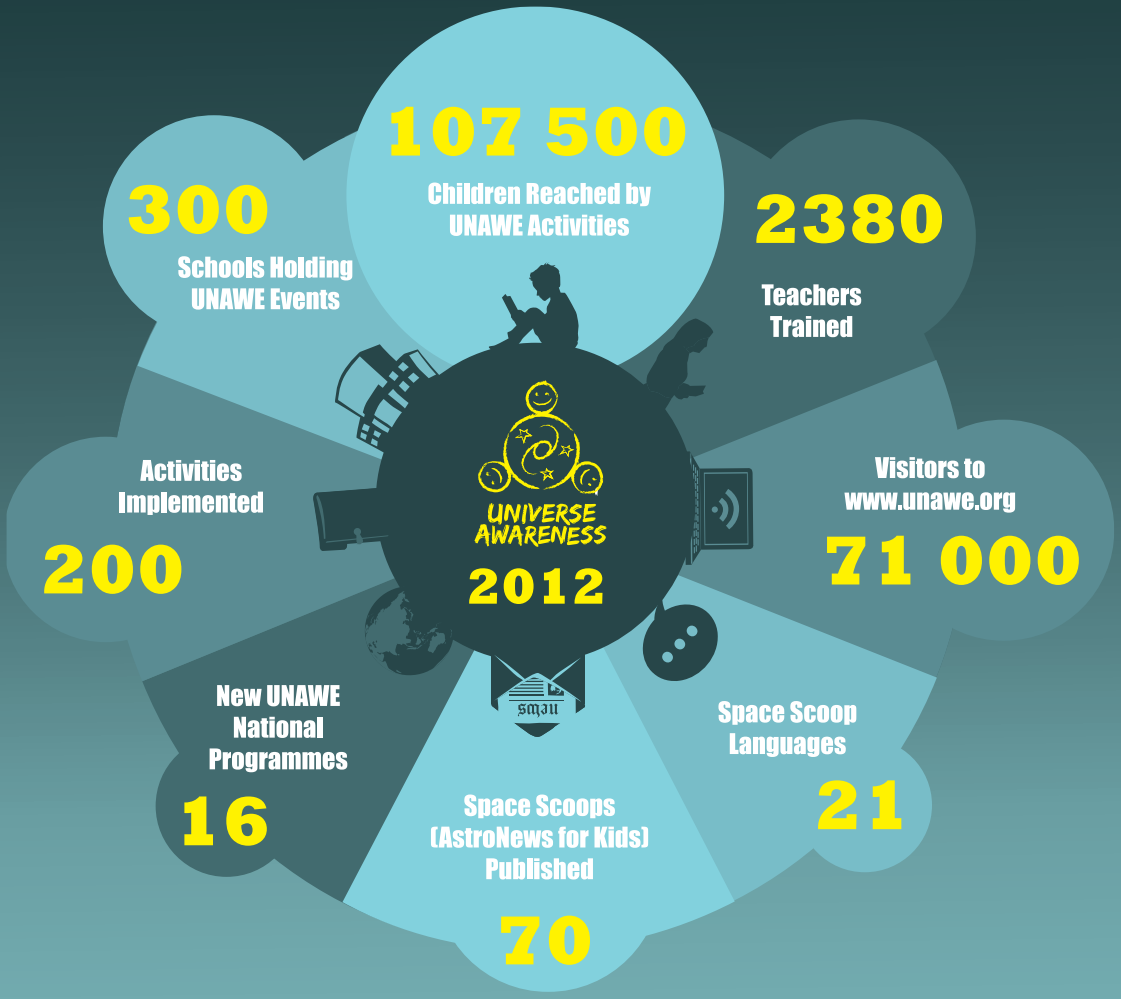
UNAWE became a Cornerstone project of the successful UN-ratified IAU/UNESCO International Year of Astronomy in 2009 (IYA2009). During IYA2009, thousands of UNAWE activities were organised in more than 45 countries. For example, in Venezuela, 43 teacher training sessions reached more than 1500 teachers and well over 60 000 children.

In 2011 the European Union awarded a grant of 1.9 million euros to fund a 3-year project called European Universe Awareness (EU-UNAWE), which builds on the work of Universe Awareness (UNAWE). With this grant, EU-UNAWE is now being further developed in six selected countries: the Netherlands, Germany, Spain, Italy, the United Kingdom and South Africa.

Last year was one of the UNAWE's most productive years yet. The UNAWE intentional network has expanded by more than 50 countries, bringing in a fresh crowd to enjoy the resources and news on our international and national websites. Educational activities and teacher training events have been

taking place non-stop throughout the year and behind the scenes the project coordinators have been busy designing an array of exciting new educational resources! In light of these achievements we'd like to say a huge thank you to our dedicated community, our motivated and creative network of educators, communicators and students; and of course, to all the enthusiastic children and teachers that have taken part in UNAWE activities throughout 2012.

UNAWE is endorsed by UNESCO and the International Astronomical Union (IAU) and it is now an integral part of the IAU Strategic Plan 2010–2020, which is called Astronomy for Development. This is an ambitious blueprint that aims to use astronomy to foster education and provide skills and competencies in science and technology throughout the world, particularly in developing countries.



More information: www.eu-unawe.org

THE IAU STRATEGIC PLAN 2010 2020

By Kevin Govender

"Astronomy for Development Building from the International Year of Astronomy 2009"

The International Astronomical Union (IAU) had for many years been conducting several education and development activities before George Miley arrived on the scene as IAU Vice President in 2006. However, it was only when he came on board that the task of establishing a strategy for these activities found a champion – it was a start that would see them grow to a whole new level. George Miley led the development of the IAU Strategic Plan, a visionary document that mapped out the use of astronomy as a tool for development.

The process of developing the IAU strategic plan was not easy due to the sometimes delicate discussions that were required to change the thinking of those who had always done things in a certain way, and who were comfortable doing so. There needed to be an extensive process of consultation which began with a meeting of stakeholders in Paris in January 2008. The final version presented to the IAU General Assembly in August 2009 included feedback from several people who made input into the various drafts of the Plan, especially members of IAU Commission 46 (which is the Commission in the IAU responsible for Astronomy Education and Development). It was adopted by the General Assembly of the IAU in Rio de Janeiro in August 2009, following an inspiring plenary talk by George. The objective of this Plan is to use astronomy to stimulate development in all regions of the world. Its adoption laid the foundation for the Office of Astronomy for Development – the structure that would see the plan into its implementation phase.

In the 2009 to 2012 triennium of the IAU, George Miley enjoyed the immense and unending support from the IAU President Robert Williams and IAU General Secretary Ian Corbett to move forward with the Strategic Plan. Almost immediately after the 2009 General Assembly an Announcement of Opportunity was issued to find a host country for the Office of Astronomy for Development (OAD). After a lengthy international selection process, the IAU chose South Africa as the host country for the OAD and the South African Astronomical Observatory (SAAO), a facility of the National Research Foundation (NRF), as the host institution. In a strong partnership between the IAU and the South African government, the OAD began its work on 1st March 2011. Funding for the OAD operations was provided for an initial period of 5 years from the South African Department of Science and Technology (ZAR1,500,000 per annum) and the IAU (€50,000 per annum), all administered within the NRF financial system. In addition the IAU generally provides project funding of the order of €100,000 per annum for the annual Call for Proposals which is administered by the OAD.

All this was put into place under George's chairmanship of the OAD Steering Committee which carried out general oversight of the OAD. The Steering Committee comprises 3 nominees from the IAU (George Miley, Kaz Sekiguchi and Megan Donahue) and 3 nominees from the NRF (Khotso Mokhele, Patricia Whitelock and Claude Carignan). All major decisions involving IAU finances or the IAU endorsement are taken by the Extended Development Oversight Committee (EDOC) which comprises the OAD Steering Committee plus the IAU President, General Secretary and President of Division C (Education, Outreach and Heritage). Such decisions include appointment of Task Force members, selection of Regional Nodes and Language Expertise Centres and final approval of OAD-funded projects.

The OAD began operations in March 2011 under the Directorship of Kevin Govender. By June 2011 Nuhaah Solomon had joined the OAD as the Administration Assistant. After a lengthy period of searching, the third and final full time staff member (OAD Project Officer, Jean-Christophe Mauduit) joined the OAD in February 2013. This saw the start of an era of "normal" operations, as envisaged in the original plan for the OAD staffing.

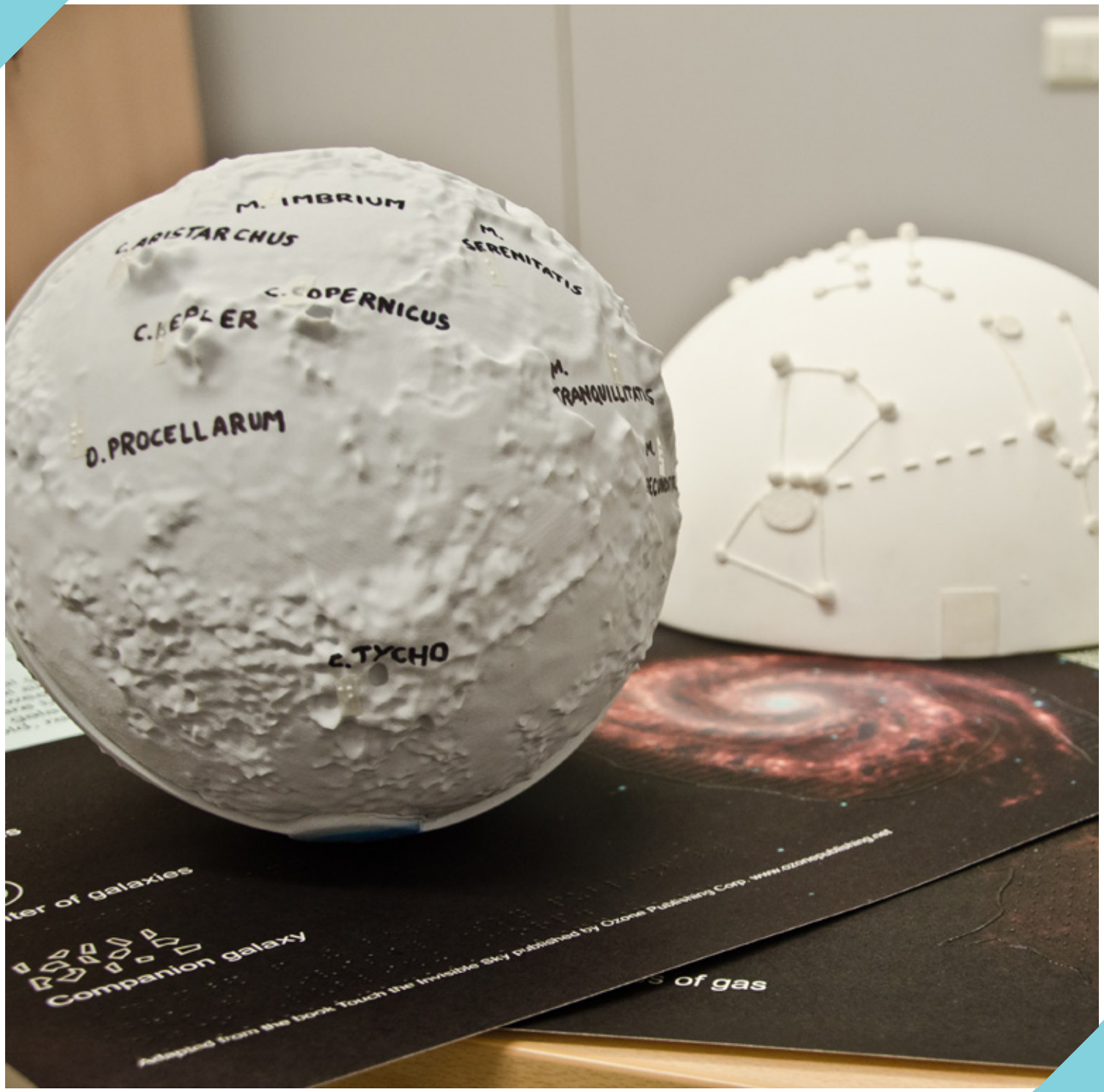
The first year of operation of the OAD was mainly about setting up the office, building the necessary networks and promoting its existence in various

fora. It culminated in an international workshop of stakeholders in December 2011 followed by an announcement of opportunity for the establishment of regional nodes, and a call for nominations for the Task Forces. The second year saw the launch of the three Task Forces (Universities and Research; Children and Schools; and Public Outreach), the establishment of two regional nodes in China and Thailand respectively (the China node also serving as a language expertise centre), and the first release of annual OAD open call for proposals. This Call for Proposals was completely oversubscribed by a factor of 10 and really emphasized the need for more funds in this area as well as the success of what had been achieved so far in the conceptualisation that George had led. At the IAU General Assembly in August 2012 the OAD highlighted its existence to the IAU membership through an exhibition area and a Special Session to discuss the current opportunities and the way forward. The OAD also completed agreements with several partners such as the International Centre of Theoretical Physics (ICTP) who serves as a Global Partner to the OAD; the Royal Astronomical Society; the Netherlands Organisation for Scientific Research; the University of Central Lancashire and the Inter-University Centre for Astronomy and Astrophysics.

At the 2012 General Assembly it was also the end of George's tenure as IAU Vice President. However, his impact had been so great with the work of the Strategic Plan and the OAD that he was asked by the IAU to stay on in an Emeritus position on the Executive Committee in order to sustain the OAD's momentum for one more triennium. He currently chairs the EDOC and will do so until another member of the Executive Committee takes over from him at the next General Assembly in 2015. In March 2013 George Miley handed over the chair of the OAD Steering Committee to Khotso Mokhele, as per the agreement. Khotso Mokhele is the former president of the NRF and the person who many consider to be the "father" of both the Southern African Large Telescope and the South African bid to host the Square Kilometre Array. Khotso stated clearly upon his taking over as chair that he would still need George to work very closely with him to keep the excellent momentum going for at least a few more years. All these high level requests for George to remain involved with the OAD and the oversight of the Strategic Plan shows what an incredible amount he has brought to this area. There are truly few people who could have managed to bring a vision that started in 2006 to where it is now. It was a process that required the utmost sensitivity, professionalism, scientific stature, inspiring leadership, kindness of heart and good sense of humour that only George Miley could have brought to the table.

> The success of the IAU Strategic Plan and the OAD thus far is very much due to George Miley, a person whose far reaching vision is only matched by his passion and drive to achieve it.

A tactile moon and tactile celestial sphere from the "A Touch of The Universe" project aimed at the visually impaired, funded by the IAU OAD in 2013


M. IMBRIUM
C. ARISTARCHUS
M. SERENITATIS
C. COPERNICUS
C. KEPLER
M. TRANQUILLITATIS
O. PROCELLARUM
C. TYCHO
Companion galaxy
of gas

EU-UNAWE activity in Heidelberg, Germany (April 2013).
Credit: EU-UNAWE/W. Schrier

Symposium Venue: Leidse Schouwburg in Leiden, The Netherlands
(Credit: B. Migulski)


LEIDSE SCHOUWBURG

CONFERENCE PROGRAMME

Local Organising Committee: Deul, Gerstel, Lub, Röttgering, Russo, Stroe (Chair), vd Veld & Williams

Astronomy, Radio Sources and Society

The Wonderful Century

Leiden, The Netherlands 10-13 June 2013

PART 1 (10 June) from 09h00 through to 18h00 will be a detailed scientific/ technical meeting with talks focussing on the lessons learned from past projects in securing funding for large astronomical facilities around the world and on astronomy as an engine for stimulating global capacity building. This part will conclude with a light dinner and drinks.

PART 2 (Evening 10 June) from 20h15 to 23h00 is a celebration of the work of George Miley and will feature a live astronomical-themed musical perfomance and a few short non-technical talks on Astronomy for a Better World.

PART 3 (11-13 June) is a scientific conference dedicated to extragalactic radio sources.

PART 4 (10 - 16 June) is a parallel event organised by EU Universe Awareness with several educational activities for children and educators.

Please note this programme is subject to change.

Image: View of the LOFAR site at Chilbolton, UK Credit: STFC/SEPnet

Astronomy and Society

Day # 1

10 June 2013

Organising committee: Schilizzi (Chair), Ekers, Fanaroff, Garrett, Righi-Steele, Schreier, van der Laan, Röttgering

09h00 Registration
09h30 Welcome

Session 1: 1950 - 2050: The wonderful century (Introduction to the scientific topic of the symposium)

09h40 Cosmology: past, present and next steps (Martin Rees)
10h20 Extragalactic radio sources and their importance for astronomy (Ron Ekers)
11h00 Tea/coffee Break

Session 2: Why should society fund big science projects and big astronomy projects in particular?

11h30 Benefits of science facilities (Cornelis van Bochove)
12h00 A government perspective on big science funding (John Womersley)
12h20 An astronomer's perspective on big science funding (Martha Haynes)
12h40 Lunch

Session 3.1: Why should society fund big science projects and big astronomy projects in particular? (cont.)

13h40 Big science projects in the developing world (Bernie Fanaroff)
14h00 An industry perspective on big science projects (Jim Crocker)
14h20 Public interest in big science projects (Bas Haring)
14h40 IAU Strategic Plan and the IAU Office of Astronomy for Development (Kevin Govender)
15h00 Tea/coffee Break

Session 3.2: Big astronomy projects: lessons learned

15h30 Panel discussion, first round: two or three initial points for six projects (5 mins each)
Tim de Zeeuw, Tony Beasley, Ethan Schreier, Marco de Vos, Michiel van Haarlem, Rogier Windhorst. (Moderator: Richard Schilizzi)
16h00 Panel discussion, second round: comments and discussion of initial points on lessons learned

Session 4.2: Conclusions

17h00 Conclusions (Peter Tindemans)
17h30 End
18h00 Drinks Reception
19h00 Buffet Dinner

EU Universe Awareness Activity in Timor-Leste on the occasion of the 2012 Transit of Venus. (Credit: EU-UNAWE)

Astronomy for a Better World

Evening

Organising committee: Barthel, P. and Russo, P.

Keys to stars: Peter Barthel collaborates with Grieg Pianoduo, Elles van der Heiden and Siebert Nix, in a project combining 4-hand piano music with astronomy.

20h15 Welcome + Mozart music (Sonata KV 521, 1st part)
20h25 Astronomy for Development/Capacity Building (George Miley)
20h55 Schubert Lebensstuerme Fantasie @ HUDF (Keys to the Stars)
21h05 Reflections (Wil van Breugel)
21h20 Intermission
21h40 Message from Africa
21h45 Universe Awareness: Inspiring every child with our wonderful cosmos (Carolina Ödman-Govender, Cecilia Scorza, Pedro Russo)
22h15 Book launch: "Spacey's Search for its Planet" (Govert Schilling, Jan Jutte)
22h20 Sisask Milky Way (Keys to the Stars)
22h30 Concluding Remarks
22h35 Drinks and bitterballen

Radio Sources: Emperors of the Early Universe

Day # 2

11 June 2013

Scientific organising committee: Carilli, Venemans, Barthel, Best, de Breuck (Co-Chair), Heckman, Hatch, Overzier, Jarvis, Kellermann, de Bruyn, Russo, Norman & Röttgering (Co-Chair)

09h00 Registration

09h30 Society, Government, and Radio Astronomy in America and Elsewhere (Bernard Burke)

09h55 Lessons learned from JWST: What is required to make Big Science projects? (Rogier Windhorst)

10h15 Tea/coffee Break

Session 3.1 Radio galaxies and quasars

10h45 Nature of radio sources - Particle acceleration (Roger Blandford)

11h10 Anatomy of extragalactic radio sources (Chris Carilli)

11h35 Nature of radio sources - Energy Source and collimation (Colin Norman)

12h00 Early results of AGN studies with the Space VLBI mission RadioAstron (Yuri Kovalev)

12h25 Lunch

13h30 Recurrent activity in radio galaxies (Marek Jamrozy)

13h50 Proper Motion and Relativistic Velocities in the Optical Synchrotron Jet of M87 (William Sparks)

14h10 LOFAR observations of M87 (Francesco de Gasperin)

14h30 The faint source population at 15 GHz (Imogen Whittam)

14h50 A Chandra Survey of 3C Radio Galaxies (Daniel Harris)

15h10 Tea/coffee Break

15h40 Links with galactic microquasars (Edward van den Heuvel)

16h05 Connection to the most distant quasars (Bram Venemans)

16h30 Duty cycles in quasars and microquasars: time-resolved studies of both classes of object (Katherine Blundell)

16h50 The influence of radio jets on their host galaxies: the subtle and not so subtle (Matt Lehnert)

17h10 End

19h00 Conference Dinner at Scheltema

Day # 3

12 June 2013

Session 3.2 Hosts galaxies of radio sources

09h00 Spectroscopy and outflows in radio sources (Timothy Heckman)
09h25 Brightest Cluster Galaxies: Spiders and flies (Nina Hatch)
09h50 Revelations in the infrared (Peter Barthel)
10h15 The interaction between radio sources and the interstellar medium of evolving galaxies and cooling flows (Geoffrey Bicknell)
10h35 Tea/coffee Break
11h05 Radio induced cavities (Michael Wise)
11h30 The properties of radio quiet radio galaxies at z=2 (Jesse van de Sande)
11h50 A diagnostic for different accretion modes in radio-loud AGN (Gulay Gurkan-uygun)
12h10 Radio sources as probes of molecules at high redshifts (Carlos De Breuck)
12h35 Lunch
13h30 HI gas in absorption towards central regions of radio galaxies (Yogesh Chandola)
13h50 Survey of CO(1-0) gas in high redshift protocluster radio galaxies (Bjorn Emonts)
14h10 Cold gas in the life of radio sources (Tom Oosterloo)
14h30 New insights from simulations of the jet-environment interaction (Martin Krause)

Session 3.3 Radio emission from clusters

14h50 Colliding clusters (Reinout van Weeren)
15h15 Tea/coffee Break
15h45 Simulating the impact of radio sources (Marcus Bruggen)
16h10 Shocking and Mysterious: new views of the radio relic in Abell 2256 (Lawrence Rudnick)
16h35 On the Physics of Radio Halos in Galaxy Clusters: Scaling Relations and Luminosity Functions (Fabio Zandanel)
16h55 End

Day # 4

13 June 2013

Session 3.3 Radio emission from clusters (cont.)

09h00 A correlation between radio halo power and Planck SZ measurements (Martin Sommer)

09h20 Intragroup gas density from bent-double radio sources (Emily Freeland)

Session 3.4 Radio selected protoclusters

09h40 Cluster Progenitors at High Redshift (Roderik Overzier)

10h05 Simulations of Cluster Formation (Stefano Borgani)

10h30 Tea/coffee Break

11h00 Galaxy cluster surveys with HST (Rychard Bouwens)

11h25 The different evolutionary paths of cluster and field ellipticals: comparing starburst fractions at high redshift (Elizabeth Cooke)

11h45 Spiders and webs (Jaron Kurk)

12h05 Searching for protoclusters in the far-infrared with Herschel/SPIRE (Emma Rigby)

12h25 Lunch

Session 3.5 Radio Sources and Cosmology

13h30 Radio source surveys and populations (Kenneth Kellermann)

13h55 From WSRT to LOFAR(-EoR) (Ger de Bruyn)

14h20 Chronology of formation: Black holes and galaxies (Joe Silk)

14h40 Towards the discovery of the first radio galaxies (Jose Afonso)

15h00 Cosmic radio dipole from NVSS and WENSS (Matthias Rubart)

15h20 Tea/coffee Break

15h50 Feeding the monsters: evolution of the dual accretion modes of Radio-loud AGN (Wendy Williams)

Session 3.6 The Future is Bright

16h10 Exploring the nature of jets and ultra-high energy cosmic rays with low-frequency radio telescopes (Heino Falcke)

16h30 Radio recombination lines and long baselines on 4C41.17 (Leah Morabito)

16h50 Radio Astronomy transformed: Aperture Arrays - past, present and future (Mike Garrett)

17h15 End

The beautiful radio galaxy Hercules imaged with NRAO's Very Large Array (radio) and the Hubble Space Telescope (optical)

Credit: NASA, ESA, S. Baum and C. O'Dea (RIT), R. Perley and W. Cotton (NRAO/AUI/NSF), and the Hubble Heritage Team (STScI/AURA)

UNAWE'S ACTIVITIES

Organising Committee: J vd Broek (co-chair), E. Arends, R. Kleian, C. Provot, S. Roberts, P. Russo (co-chair) and W. Schrier.

PART 4: PARALLEL EU UNIVERSE AWARENESS EVENTS

To celebrate the many UNAWE achievements, we will host a photographic exhibition during the Symposium, called 'UNAWE: Inspiring every child with our wonderful cosmos', and a UNAWE Teacher Training workshop for Kindergarten kindergarten and Primary primary School school educators and teachers. The photographic exhibit will feature UNAWE activities from around the world and it will be held on at Museum Boerhaave from 9th - 16th June. The UNAWE teacher Teacher training Training will take place in the afternoon of the 12 June in the Museum Boerhaave.

During the symposium, Universe Awareness organised a EU- UNAWE Teacher Training workshop for nursery and primary school educators in the afternoon of 11 June, at Museum Boerhaave in Leiden.

Back in 2004, Professor George Miley first began exploring the idea of setting up an astronomy programme to educate and inspire young children, especially those from underprivileged backgrounds. This formed the foundation of the project Universe Awareness. Almost 10 years after the initial idea, Universe Awareness (UNAWE) is now active in 56 countries and comprises a global network of almost 700 astronomers, teachers and other educators. Just in 2012, UNAWE reached more than 124 000 children around the world. During the symposium, Universe Awareness will be organising a EU-UNAWE Teacher Training workshop for nursery and primary school educators in the afternoon of 11 June, at Museum Boerhaave in Leiden.

MORE INFORMATION:

http://www.unawe.nl/updates/UNAWE-updateNL-1325/

Universe Awareness activity in Zielona Góra, Poland (September 2012). (Credit: UNAWE Poland)


La Cloche

ASTRONOMY: THE NEXT 50 YEARS

By George Miley

Astronomy will continue to be one of the great triumphs of human civilization and more and more countries will participate in the exploration of the Universe is an activity that will be adopted by more and more countries.

George leading the precession of professors through Leiden in 1998, before delivering the annual ceremonial “Dies Lecture” in the Pieterskerk church.

When I hesitantly agreed to Huub's generous proposal to hold this conference, I had not envisaged that it would grow into such a huge marvellous event. I am immensely grateful to everyone that has contributed to its organisation, to all my friends and colleagues for coming and particularly to the magnificent speakers.

Pedro asked me to write about my vision on future developments in astronomy and its relation to society during the next century. I am neither brave enough nor arrogant enough to do this, and recall several previous scientific soothsayers who have blood on their faces. Three years before the proposal of special relativity Albert Michelson in 1902 stated that "The most important fundamental laws and facts of physical science have all been discovered, and these are now so firmly established that the possibility of their ever being supplanted is exceedingly remote". There is also the famous remark of Richard Woolley, on taking up the position of Astronomer Royal in 1956, one year before Sputnik, that "Space travel is utter bilge".

Although I am loath to make detailed predictions, I will jot down a few personal general remarks that are relevant to the theme.

1. Scientific progress occurs through interaction between observation, experiment and the development of fundamental theories. The process is driven by two main factors, on the one hand by technology, which facilitates the development of new instruments, and on the other hand by the willingness of society to support science. In this "Marxist" viewpoint individual scientists only produce a few small ripples on the ocean of scientific advance.

2. Astronomy is curiosity-driven research. It is fashionable among policy makers to state that the State cannot afford to spend taxpayers' money on fundamental research in an age ruled by global economic competitiveness. Utilitarianism is the fashion of the day. Research spending should be diverted to carefully planned programmes, designed to provide concrete measurable short-term benefits for society. There are countless studies that refute this viewpoint. I can do no better than quote the remarks of astronomer, Robert Hanbury Brown, "It is unlikely that many of the most important discoveries which underlie modern science such as the atomic nature of matter or the theory of relativity, would have been made by people trying to do socially relevant research; they were made by people who were seeking to know and to understand and to apply what they found..... To insist on relevance, in basic research is rather like insisting on naturalism in art.; if you are successful you end up with something not radically new, but comfortably familiar."

3. In my view the present focus within our profession on shaping research by means of well-justified proposals with possible results specified in advance, reduces the chances of making profound paradigm-changing discoveries. As Ron Ekers often points out, most of the important discoveries in radio astronomy happened by chance. Proposals to investigate such phenomena would never have been made, but if they had been, they would have been rejected as "fishing expeditions" both by science planners and scientific peers. To quote a remark of the British geneticist J. B. S. Haldane in 1927 "The Universe is not only queerer than we suppose, but queerer than we can suppose". Furthermore, many of the socially most beneficial results of basic research

such as the discoveries of X-rays and penicillin were made purely by accident.

4 . Radio galaxies, the main topic of this symposium, are wonderful objects. The radio emitting jets that they spew out produce some of the largest and most beautiful structures in the Universe. However, like dinosaurs the most luminous radio galaxies are creatures of the past and are now almost extinct. I often call these beautiful beasts the emperors of the early Universe. They include some of the most massive galaxies known and often dominate proto-clusters - giant mega-cities of galaxies that were forming when the Universe was 10 – 20% of its present age. Their nature has intrigued us for the last 60 years and they have been food for large astronomical facilities at all wavelengths on the ground and in space. Radio galaxies and their use as probes for tracing cosmic evolution will undoubtedly continue to excite astronomers for more than he next 60 years and provide our species with fundamental information about its origins.

5 . Although we cannot plan for profound astronomical discoveries, I suggest that there are two measures that we can take to cajole scientific progress in the right direction.

* The first, an obvious one, is to develop and exploit technical possibilities that explore new observing regimes. These include pushing into new wavelength regions, making substantial improvements in the sensitivity of our telescopes to reach further and fainter throughout the electromagnetic spectrum. During this conference we shall discuss several new facilities that are already operating or that will come on-line during the next 15 years. But there are other more intriguing developments on the longer term. During the next century it is likely that an observatory will be built on the far side of the moon. Because it will be shielded from the pollution of earth-light and radio interference and result in exciting new discoveries at long radio wavelengths. On a more exotic note, the potential of exploiting future astronomical observatories that probe the universe using gravitational waves and neutrinos are huge.

* My second suggestion, a more controversial one, is to encourage dissenting ideas both in peer review processes and in staff selection procedures. History shows that major breakthroughs are often made by scientists who are “difficult” people and who not afraid to stick their necks out. In the words of the physicist Jacob Bronowski, “From Luther in 1517 to Spinoza grinding lenses, from Huguenot weavers and Quaker ironmasters to the Puritans founding Harvard, and from Newton’s religious heresies to the calculating universe of Eddington, the profound movements in history have begun by nonconforming men. Dissent is the native activity of the scientist, and it has got him into a good deal of trouble in the last years. But if that is cut off, what is left will not be a scientist. And I doubt whether it will be a man.” Given the present pressure to favour people who can work effectively in large teams, dissenters find it more and more difficult to make a career in astronomy. But having a few nonconformist creative people in our midst may not necessarily optimise short-term research productivity, but on the long term such a policy can provide an important catalyst for scientific revolution.

6 . Although exploring the Universe is a profound and worthy activity in itself, it is unrealistic to expect

taxpayers to fund ever more expensive astronomical observing facilities without more substantial societal return. Are there additional benefits that modern astronomy can offer society to satisfy the practical needs of humankind? There are several.

The need to study the faintest celestial objects has driven advanced developments in electronics, optics and information technology and has been responsible for countless practical spin-off applications during the last 50 years. Astronomy will undoubtedly continue to drive technological development.

But astronomy can contribute to society on a much broader front. Because it combines science and technology with inspiration and excitement, astronomy can play a unique role in facilitating education and capacity building and in furthering sustainable development throughout the world.

* Large astronomical telescopes and satellites are high-tech cathedrals for exploring our deepest roots and are outstanding engines for fostering technological development. Many large international telescope facilities and astronomical archives are accessible to all astronomers throughout the world and provide an inexpensive entry to cutting-edge international research for developing countries.

* Astronomy is above all about inspiration and can play a unique role in furthering human capacity building and education at all levels “from the cradle to the grave”. It provides an exciting gateway into physics, chemistry, biology and mathematics. The quest to explore the Universe satisfies the deepest cultural and philosophical yearnings of our species. The perspective provided by learning about the Universe can help stimulate a sense of global citizenship. Astronomy has inspired countless teenagers to choose a career in science and technology and is a staple of adult education.

The above reasoning led the International Astronomical Union to develop a decadal strategic plan to exploit astronomy to stimulate development globally and to form a partnership with the South African government to implement it via the small but effective IAU Office of Astronomy for Development in Cape Town, under the outstanding leadership of Kevin Govender. This development activity is unique for a scientific union and has enormous potential. An important ingredient of the IAU plan is Universe Awareness (UNAWE), a project to inspire very young children from 4 to 10 years with astronomy, focusing on disadvantaged children. Goals of UNAWE are to develop a sense of world citizenship and introduce young children to the fascination of science. There is considerable evidence that educational interventions are economically more effective the earlier they are carried out. The excitement of astronomy can help motivate very young children and motivation begets motivation. Thanks to its dynamic international project managers (initially Carolina Ödman and presently Pedro Russo), UNAWE is now active in 56 countries and EU-UNAWE is a project that is receiving 2M€ funding from the European Commission.

Astronomy will continue to be one of the great triumphs of human civilization and more and more countries will participate in the exploration of the Universe is an activity that will be adopted by more and more countries.

To those that question this, I frequently reply with a quotation from the inspirational rationale given in a government white paper written in 1996 on the role of pure science within the new South Africa:

> "It is important to maintain a basic competence in 'flagship' sciences such as physics and astronomy for cultural reasons. Not to offer them would be to take a negative view of our future – the view that we are a second-class nation, chained forever to the treadmill of feeding and clothing ourselves"

George Miley June 2013

George at 8, with his scooter

CREDITS

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