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New Worlds

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Dies Lecture given by
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during the 434th Dies Natalis
on Monday 9 February 2009 in the Pieterskerk.

NEW WORLDS

Rector Magnificus, most esteemed guests,

It is 20 October 1995: a headline on the front page of the New York Times reads: 'Two sightings of planet orbiting a Sun-like star challenge notions that Earth is unique.' Exactly two weeks earlier, Swiss astronomers had announced at a conference in Italy the discovery of the first so-called exoplanet around the 51 Pegasi.[1] This is a star not unlike our Sun, but at 50 light years distance from the Earth instead of 8 light minutes. The discovery spread like wildfire throughout the whole world and a week later American astronomers were able to confirm the discovery of the Jupiter-like planet with new, independent observations. They were able to do this so quickly because they had direct access to a private telescope in California, unlike most astronomers who have to submit an application to use a telescope a year in advance. The confirmation of the discovery of the first planet around another star was revolutionary news, with far-reaching implications for science and even for humanity as a whole. Although people had speculated on planets outside our solar system for centuries, the illusion that our solar system is unique in the Universe was now shattered in one fell swoop.

Exoplanets

The discovery of this 'new world' overturned other aspects of our cosmic world view: the planet, which is half the mass of Jupiter, turned out not to be at a respectable distance from the star, but instead orbits very close to the star. Jupiter takes some twelve years to orbit our Sun; this exoplanet circles 51 Pegasi in just four days! Theoreticians had for decades come up with wonderful explanations why Jupiter is at precisely 5.5 astronomical units from the Sun in our solar system, that is at 5.5 times the distance from the Earth to the Sun (some 5.5 x 825 million km). But now all these conventional theories had to be abandoned and one untested scenario after another was put forward to try to explain the new world. This is an important lesson for every researcher: don't just look for what you or your colleagues expect to see, but remain open to new and surprising findings. Heraclitus of Ephesus said some five centuries before Christ: ' If you don't expect the unexpected, you will never find it.' In this case, the discovery was ---with hindsight--- not difficult, because there was a strong signal. The American group indeed also had information for some time which revealed the existence of exoplanets; they had just never analysed the information with such rapid orbits in mind. Students and PhD researchers, take note: sometimes it is easier to become famous than you think! Or, as physicist Leo Szilard said: 'If you want to succeed in this world, you don't have to be much cleverer than other people, you just have to be one day earlier.' These are just the kinds of new and unexpected discoveries that make the natural sciences so exciting and so fascinating.

The discovery of the planet around 51 Pegasi resulted in a flood of new exoplanet detections. Now, a decade later, some 300 exoplanets have been discovered and it is one of the fastest growing branches of astronomy. One of these 300 exoplanets has just been discovered by a group of Leiden's bachelor's students[2]; they were invited to tell their story on Dutch television in the programme '*De wereld draait door'* and last month they were awarded the annual research prize of the Faculty of Science for their discovery. Exoplanets are found in all types and sizes. Some, like the planet around 51 Pegasi, orbit in a circular orbit close to the star, others follow an elliptical orbit at a greater distance from the star. For some stars, astronomers have even managed to locate a system of three or more planets at varying distances. The majority of the planets have been observed indirectly via the periodic movement that they induce in the parent star. In analogy, our Sun is not completely motionless either; it oscillates a little around the midpoint of our solar system because Jupiter in particular – the heaviest planet in our solar system – exercises a weak pulling force on it. The sensitivity of this technique is equal to the mass of the planet: large movements are easier to measure than small movements. So far, the limit of what we can just detect is some 5 – 10 times the mass of the Earth. In other words: gas-rich planets such as Jupiter, Saturn, Neptune and Uranus can be observed; rock-like planets such as the Earth, Mars and Venus which are some 500 times lighter, so far cannot. The orbital period also plays a role: following a complete orbit of a planet at the same distance with respect to its parent star as that of Jupiter with respect to the Sun takes almost 12 years, at the distance of Neptune it takes 165 years. Very accurate instruments to measure the movements of stars have only existed for about 15 years, so we are only now becoming aware of planets which are located at some 5 astronomical units from their star. All in all, it is clear that our inventory of exoplanetary worlds is still incomplete. One of the main motivations for building future telescopes is to make this inventory more complete. A direct photo of a twin of the Earth is the eventual goal. This aim came closer two months ago with the publication of the first direct images of two exoplanetary systems.

Intermezzo 1. Astronomy in art

One of my hobbies is astronomy in art. At home I have an engraving from 1798 entitled 'Universal Solar System' (Figure 1). This print illustrates what many scientists at that time suspected: other planetary systems do not necessarily have to resemble our solar system. Some have more and others fewer planets; some are closer to the star, others further away. Only now, more than two centuries later, has this suspicion actually been proven. It is therefore very appropriate that this engraving appeared on the front cover of the special edition of the authoritative journal Physics Today on exoplanets. During this lecture I will give a few other examples of how astronomy and art go hand in hand, and how artists have been inspired by the night sky. Urania, one of the nine Muses in Greek mythology, is the muse of astronomy, which emphasizes the fact that this science is also a classical art.

Figure 1: English engraving from 1798 entitled 'Universal Solar System'. Our own solar system is displayed in the centre panel, and shows the seven planets which were known at the time, plus a small number of comets. In the other panels the artist speculates how other planetary systems could look. Collection: E.F. van Dishoeck and P.T. de Zeeuw.

Formation of stars and planets

Characterising new worlds is naturally an important branch of research. But the present exoplanetary systems are actually quite boring. Nothing has happened for billions of years – these planets simply follow their orbits – and also in the coming billion years little will change. Equally interesting is the question of how this great variety of planets came about and whether all stars can have a planetary system around them. The answer lies in the history of how the planets formed and developed, a question which touches directly on my own research.[3]

Stars and planets are born in the tenuous clouds found everywhere between the stars in our solar system. Stars are not eternal: they are born, exist and disappear again when the fuel for nuclear fusion is exhausted. In our Milky Way – a middle-aged stellar system – some three Suns are born every year. My colleagues at the Leiden Observatory study much younger galaxies in the early Universe which underwent a baby boom of some 1000 Suns per year a long time ago.

The interstellar clouds consist of gas (99% in terms of mass, mainly hydrogen and helium) and small dust particles (1% in terms of mass, primarily silicates and carbonaceous compounds) of around one-ten thousandth of a millimetre in size, more than a thousand times smaller than a grain of sand on the beach. The dust particles absorb and disperse the light from surrounding stars so that their radiation can barely penetrate the clouds, or is not able to do so at all, in the same way as smoke particles restrict our vision in a smoky café. The clouds are therefore dark on photos made in visible light, that is the light we see with our own eyes.

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The clouds of gas and dust between the stars are only able to maintain their fragile balance for some 10 million years, and collapse at a given moment under their own weight. This gives rise to a protostar in the centre of the cloud. In the first hundred thousand years, material from the cloud continues to rain onto the young star, which continues to grow. At a given point in time this rain of material stops because the cloud has been driven apart by the wind from the young star. The Spanish artist Joan Miró made many paintings of astronomical objects, and paints an interesting image in his 'Birth of the World'. Although dark interstellar clouds had not yet been discovered at the time of the painting, 1925, Miró's new world emerges from a black cocoon, which, with some foresight on his part, is not round. The young Sun in this painting is also – rightly – red: we can observe a young star which is still in its cosmic cradle only with infrared telescopes.

Because the cloud always has a little angular momentum (rotation), the material cannot continue to fall straight onto the star, but the majority forms a rotating flat disc around it. The existence of such circumstellar discs had already been posited by Emmanuel Kant, among others, in 1755 because all the planets in our solar system lie in one plane and rotate in the same direction. For a long time scientists were unable to progress beyond this view of our primordial solar nebula. It was only some 40 years ago that more detailed theories about planet formation were developed. In the most common scenario, the dust particles in the disc stick together, forming larger and larger blocks of rock, which eventually form planets. How exactly this happens is still a mystery: two blocks of rock do not just to stick together when they collide. The most massive protoplanets attract the gas in the disc, and form gas-rich planets such as Jupiter.

In an alternative theory, Jupiter-like planets are formed through instabilities in the disc, which cause fragmentation. Like every good theory, this one also makes predictions which can be tested to confirm or falsify the theory, a process which is at the heart of scientific research. The first theory predicts that planets are formed quite late in the evolutionary process, while the second theory indicates the exact opposite. Together with our colleagues, we have recently presented new measurements of young planets which can test these theories (Figure 2).[4]

Figure 2: Sketch of a disc with gas and dust around a young star.[4] New astronomical observations show that some discs have a hole in their dust disc where new Jupiter-like planets are already being formed. The sizes of these discs are comparable with those of our own solar system. Credit: European Southern Observatory.

Intermezzo 2: What is a planet?

An increasingly important element of lecturing is interactive communication with the students. This public lecture in such a large lecture hall is not exactly suitable for this purpose, but I would nonetheless like to ask who of you can explain the difference between a star and a planet? The answer is that a star is a sphere of hot gas which itself produces energy through nuclear fusion of hydrogen and other elements in its nucleus, and a planet does not. The process of formation is also different, as discussed above.

The next question is not so easy: what is the difference between a planet and a large rock like an asteroid? This question can give rise to heated discussions, as became apparent in 2006 when astronomers decided that Pluto was not a 'real' planet but only a dwarf planet. I was present at the world congress in Prague where this decision was made, and I can assure you that there were few people who had realized at the start of the discussions what a commotion this would cause.

The reason for dethroning Pluto was, scientifically speaking, crystal clear: new observations showed that there were more large rocks in the outermost part of the solar system, comparable in size with Pluto (some 2,300 km in diameter) or even larger. This belt of objects, large and small, was predicted as early as some fifty years ago by Dutch astronomer Gerard Kuiper, and an additional cloud which lies further outside, by Jan Hendrik Oort. Are all of these large rocks planets? Could our solar system contain some 200 planets? After a great deal of discussion, the scientists present in Prague reached agreement on a definition: a planet not only has to revolve around a star and be spherical, it also has to have enough mass to sweep its orbit around the star clean of other objects. Pluto does not meet this last criterion, which caused it to loose its status as a planet. Most astronomers supported this decision, but explaining to a wider audience that scientists are sometimes forced by new insights to retract earlier claims, proved much more difficult than expected. But this is at the core of doing science. The new definition also has the advantage that school children now only have to remember the name of 8 planets, rather than 200.

Building blocks for planets

The discs around young stars where planets are formed were first imaged around 15 years ago, roughly at the same time as the first exoplanets were discovered. It took so long because these discs are much smaller and less massive than the clouds from which the stars are formed, and they can easily be outshone by the light from stars. Detecting discs has in the meantime become a routine task and we now know that almost all the stars in our Milky Way are born with such a disc. They generally comprise enough material to form a solar system like our own, which requires ten times the mass of Jupiter. Mapping the structure of the disc is much more difficult and requires a new generation of telescopes which I will describe later. The discs do not need to be regular, but can be like the painting 'The red disc' by Joan Miró, which in terms of structure is remarkably similar to a recent astronomical image of a young disc with asymmetric spiral arms (Figure 3).

Figure 3: Left: The painting 'The Red Disc' by Joan Miró (1960). Credit: Famous Artist Gallery.Com and the painter. Right: Infrared image of a dusty disc around the young star AB Aurigae, made with the Subaru Telescope (2004). The light from the star itself is blocked by a coronograph. The diameter of the dust disc is some 500 astronomic units, the distance to the star is 470 light years. Credit: Subaru Telescope, National Astronomical Observatory of Japan.

What raw materials are available to build planets in the discs? Unlike physicists or chemists, astronomers cannot study the object in situ. We can't just hop into the 'Starship USS Enterprise' and fly off at Warp 9 to a distant dust cloud and then raise the temperature or add a few chemical compounds and see what effect this has. All our knowledge is obtained indirectly from the radiation which the objects themselves emit.

According to the laws of quantum mechanics, each atom or molecule can only emit at a limited number of specific wavelengths. As a result, it has a unique fingerprint with which we can identify it in space as well as on Earth. The main bands are in the infrared and microwave region, so astrochemists 'listen' at longer wavelengths than those of visible light. A big advantage is that the dusty regions at these long wavelengths are transparent, so that we can study all the processes deep inside the cloud or disc. The shape of the band gives information on the movements in the cloud (inward and outward flows, rotation) and the relative strength is an indication of temperature and pressure. By scanning a wide bandwidth range we can make an inventory of which molecules are present and which are not.

Building blocks for life

Star-forming regions have a surprisingly rich chemistry, varying from simple compounds such as carbon monoxide (CO) to rather complex organic compounds such as methyl formate

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($HCOOCH_3$) and ethylene glycol ($HOCH_2CH_2OH$), better known as anti-freeze.[3] Some of these compounds are pre-biotic, that is they play a role in the origin of life. Good examples are molecules such as acetamide (CH_3CONH_2), the biggest interstellar molecule with a peptide bond, and acetonitrile (NH_2CH_2CN), a direct precursor of the most simple amino acid glycine. Glycine itself has not yet been identified convincingly, although it has already been reported in the literature and the press. A few years ago, our group identified enormous quantities of prussic acid and acetylene in the innermost parts of the discs where planets are formed.[5] Prussic acid, HCN, is a very toxic substance on Earth, but just 6 HCN molecules are enough to form the amino acid adenine.

Astrochemists now think that the majority of the complex molecules are formed on the surfaces of the cold dust particles. During the collapse of a cloud, the density is so high that almost all the gases (except hydrogen itself) collide with a cold dust particle and freeze to it, just as water from the air forms a layer of ice on a car windscreen during a frosty night. The temperatures are only just above absolute zero, -250° C. These chemical networks were proposed more than 20 years ago by my Leiden colleague Tielens, but the reactions have only just been measured in the Raymond and Beverly Sackler laboratory in Leiden, under the supervision of colleague Linnartz. Last year, we successfully managed to distil alcohol (ethanol, C_2H_5OH) from a cocktail of hydrogen atoms and simulated cosmic ice. Ethanol is observed in large quantities in star-forming regions: the Orion nebula contains enough ethanol to make as many as 10^{26} bottles of whisky! Nonetheless, the concentration in relation to water is not high, just 2%. Ice in space is ‘ice light’.[6]

Water

Water (H_2O) is undoubtedly one of the most important molecules in the origin of life.[7] Life on Earth – and probably also on Earth-like planets elsewhere in the Universe – is not possible without water. As Thales of Miletus wrote in the sixth century before Christ: ‘Water is the basis, the raw material of all things.’ All life’s chemical reactions take place in water. Both the geology and the climate of our planet are determined by water. Leonardo da Vinci was enormously fascinated by water and illustrated this with his sketch: ‘Water is the lifeblood of the planet.’

On Earth, we know water in three forms: gas (vapour), liquid (water) and solid (ice). Liquid water in is not found in interstellar space because the ambient pressure is too low. We think that water in space is primarily formed on the dust particles in cold clouds by reactions of oxygen and hydrogen atoms. Once formed, a young star gradually heats its surrounding dust so strongly that the ice layers start to evaporate. Under the low pressures in space, this evaporation temperature is much lower than on Earth, around -160° C instead of 0° C. You can compare this to the boiling point of water in the mountains as opposed to at sea level: at the top of Mont Blanc, the boiling point is 85° C, whereas at the top of Mount Everest it is 73° C. With the Infrared Space Observatory (ISO), a satellite which operated from 1995-1998, we were able for the first time to observe clearly both the water freeze-out and its subsequent evaporation near the most massive young stars in our Milky Way Galaxy such as, for example, those in the Orion nebula. One such cloud contains just as many water molecules as a million oceans on Earth! With the Herschel Space Observatory, which will be launched later this year, we will be able to follow the formation and evolution of water in low-mass stars comparable to our young Sun, and into the discs where planets are formed. Using the Spitzer Space Telescope, we recently found surprisingly hot water (steam at 500° C) in the innermost parts of discs. This suggests that there is plenty of water present in the disc regions where planets are formed.

Origin of water on Earth and exoplanets

How does all this water from a disc come onto a new world? In its early stages, the young Earth was so hot that virtually all the original water vaporized and escaped. Thus, the water must have been replenished at a later stage when the Earth had cooled down. Collisions with comets are one possibility. Comets are blocks of rock and ice, a couple of km in size, which have remained as left-over building material from the planet formation process. They have spent most of their 4.5 billion years in the most distant (>50 astronomical units) and coldest part of our solar system and are thus messengers from that earlier period. Comets have been represented in art for centuries, as in the famous Bayeux tapestry and in a more modern painting by Kandinsky.

Comparison of the amount of 'heavy' water (HDO) with that of normal water suggests that not all water on Earth originates from comets: asteroids in the innermost part of our primordial solar nebula probably also played a role. Our oceans are therefore literally 'cosmic oceans,' as is depicted in the powerful mosaic of Danish artist Carl-Henning Pedersen that adorns the great hall of the H.C. Ørsted institute in Copenhagen. Thus, the water molecules which we now see in the North Sea or which inhabit the cells of your body were made some 4.5 billion years ago on the small dust particles in the cloud from which our solar system formed.

Why are there still oceans on Earth, but no longer on Venus or Mars? The Earth is in the 'habitable zone', where it is neither too hot nor too cold for water to be liquid; Venus and Mars are just outside that area. Christiaan Huygens recognized the importance of liquid water for life in his *Kosmotheoros* in 1698, in which he argued that this was not possible for Jupiter and Saturn. Searches for exoplanets will in the future focus mainly on Earth-like planets in the habitable zone around their star, because these are the planets where the likelihood of life is greatest. Eventually we also hope to measure the composition of the atmosphere of such an Earth-like planet using the presence of so-called 'bio-markers' (ozone, oxygen, water). Similarly, the presence of methane gas in the atmosphere of Mars was recently proposed as a possible indication for micro-organisms which live below the Martian surface.

The chemical cycle

What can we now say about the probability of encountering life elsewhere in space? As mentioned above, we have known for some ten years that almost all young stars have a disc of gas and dust around them from which planets can be formed. We also find prebiotic molecules and water in almost all star-forming clouds. The material needed to form planets and life is therefore readily available. Our Milky Way Galaxy contains a few hundreds of billions of stars, and our Milky Way is just one of the hundreds of billions of stellar systems in the Universe. Opportunities enough, then.

More and more biologically important elements continue to be added: the nuclear reactor within a star makes heavy elements such as carbon and oxygen from hydrogen and helium. When a star runs out of fuel, it blows most of this material into space. This enriched gas is used to form the next generation of stars and planets. This is where Carl Sagan's famous comment 'We are all stardust' comes from. The first stars in the Universe had no organic material available, but the gas in our Milky Way now benefits from many generations of star death.

The question of how and when life is created from this raw material, is something for which we astrochemists have no answer. In fact, it is now up to the biochemists and biologists to investigate how life could originate from the ingredients that are found in space: the new discipline of astrobiology addresses this.

Future telescopes

Progress in astronomy is made possible primarily by technical advances. Thanks to bigger telescopes, more sensitive detectors and the development of cameras with millions of pixels, astronomers have been able to make enormous progress in recent decades. The coming 10 to 20 years also look promising thanks to a number of new facilities which are in the pipeline.

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First, the Herschel Space Observatory, which starting later this year will make observations in the far-infrared part of the spectrum that is completely obscured from the ground by water in our own atmosphere. The Netherlands has invested heavily in this satellite and the construction of the HIFI instrument is headed by colleague De Graauw from SRON (Netherlands Institute for Space Research), and who is also affiliated to Leiden University. I attended my first meeting on Herschel in 1982, as a PhD researcher, which clearly indicates the lengthy processes involved in developing such costly projects, typically worth a billion euro. This also means that the present generation of astronomers has the responsibility for putting the next generation of telescopes on the drawing board today, just as our predecessors did for us, so that our scientific children and grandchildren can perform observations with them.

Another top facility to which I personally have devoted a great deal of time and attention is the Atacama Large Millimetre/Submillimetre Array (ALMA), a worldwide project to link the signals of 66 radio dishes at a height of 5000m in Chile. The technology can be compared with that of the radio synthesis telescope in Westerbork or the LOFAR project here in the Netherlands, but then at a shorter wavelength of approximately 1 millimetre. Ten antennae have already arrived in Chile and the first observations will be made in late 2011.

A third facility under construction is the James Webb Space Telescope. This successor to the Hubble Space Telescope is a 6-metre telescope that will be launched at the end of 2013. The Netherlands is supplying the optics for the mid-infrared spectrometer, under the supervision of the Netherlands Research School for Astronomy (NOVA) and Leiden astronomers. NOVA and Leiden are also heading the design of a mid-infrared instrument for the European Extremely Large Telescope (E-ELT), a 42-metre optical telescope to be designed by the European Southern Observatory (ESO), which will hopefully be completed in the coming decade. ‘A telescope with James Bond allure,’ wrote the NRC Handelsblad last year following a visit to the present ESO facility in Chile, unaware that less than six months later the new James Bond Film, Quantum of Solace, would actually be filmed there. We are particularly pleased that the instrumentation branch of the NOVA programme has recently been strengthened with the commitment of 18.8 million euro by the Minister of Education, Culture and Science from the ESFRI round of subsidies. We can be justifiably proud of the fact that the Netherlands, and Leiden in particular, plays such a prominent role in the development of all these world-class facilities. The importance of Leiden astronomy is further illustrated by the fact that four of the seven Directors General of ESO have come from Leiden, the most recent one our colleague De Zeeuw. And that while the Netherlands contributes ~6% to the ESO finances.

The new telescopes share the common characteristic that they are much sharper and more sensitive than their predecessors. For ALMA and the E-ELT, their angular resolution would allow them to read a traffic sign in Los Angeles from Leiden. This is sufficient to resolve the Sun-Earth distance in the nearest interstellar clouds. We can then finally chart planet formation.

The importance of fundamental research

In our new world, scientists, and therefore also astronomers, have to continuously justify fundamental research. Questions such as: ‘How does observing the stars benefit our society?’ keep being asked. And, to continue in terms of film classics: why does it always cost a “fistful of dollars” and why can it not be done “for a few dollars more?” The answer to these questions was provided very clearly in the Dies Lecture given in 1998 by colleague Miley, entitled: ‘The Alpha, Beta and Gamma of Astronomy.’[8]

Alpha: the Universe as the ultimate history book with the astronomer as archaeologist; because the speed of light is finite, we see very distant objects as they looked earlier. The Orion nebula some 1500 years ago; galaxies at the edge of the Universe some 12 billion years ago. Beta: astronomical research and technology, as I described above. This is not only significant for universities, but also for industry: the hundreds of millions of euros which are invested in new telescopes or satellites find their way almost 100% to European industry, thereby strengthening high-level technology in society. Gamma: the deeply felt desire of mankind to understand his origin and place in the Universe.

More generally, the usefulness of fundamental research can be divided into a number of classes[9]: (1) cultural value; (2) the opportunity to make discoveries of enormous economic and practical value; (3) spin-offs and incentives to industry; and (4) education. Present-day society seems to primarily emphasize aspects 2 and 3, partly because they are easier to measure, but this is a sign of short-term thinking. History teaches us that the opposite is the case: the transistor was not invented because people needed a radio or computer; it was invented by researchers who were investigating wave mechanics and quantum theory of solid materials. As has been proven time and again, the relationship between science and applied technology is by no means linear and is often characterised by a long time scale.

The importance of points 1 and 4 is at least as great, and scientists should be less afraid of highlighting the cultural aspects of fundamental research. This applies particularly to astronomy, as the following dialogue illustrates.[9]

“Person 1: Shall we set down astronomy among the subjects of study?
Person 2: I think so, to know something about the seasons, the months and the years is useful for military purposes, as well as for agriculture and for navigation.
Person 1: It amuses me to see how afraid you are, lest people could accuse you of recommending useless studies.’’

Few of you will realise that this is a literal citation from Plato’s Republic, written 380 BC, with Socrates as person 1 and Glaucon, Plato’s older brother, as person 2.

Point 4, the importance of a university education, is often underestimated today. In the end, it is not about being able to derive Planck’s law or to measure precisely the mass and age of the Andromeda galaxy. By no means every master’s student or PhD researcher will become a researcher at a university in our field: I know astronomers who now work on future strategy scenarios for Shell or who are head of the weather service at the KNMI. What is important for society is that universities continue to educate new generations of young people who can think critically, who know what fundamental research is, and who are able to develop new methods themselves in science or beyond. During his or her PhD research, the student’s ability for analytical thinking to resolve new problems independently is put to the ultimate test. This is what our complex new world really needs. Comments that educational programmes are only viable if they meet minimum enrolment criteria, miss this general importance of the programmes. The motto of research in physical sciences is ‘to measure is to know’, but policy-makers should not try to narrow-mindedly apply a policy of just ‘measuring knowledge’.

It is therefore no surprise that the main objective of NOVA is to conduct excellent research and to personally supervise and train PhD students at the highest international level. I am also delighted that Leiden University has designated ‘Fundamentals of Science’ as one of its research profile

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areas, and I hope that hereby the cuts on funding of PhD researchers by the university, which directly affect the scientific heart of the university, can be put to a halt.

The year of astronomy

2009 has been designated as 'The international Year of Astronomy', launched by the International Astronomical Union and the UN organisation Unesco under the motto: 'Space; discover it yourself!' Events have been organised throughout the country, for young and old, and I can heartily recommend the NOVA websites to you: www.astronomie.nl and www.jaarvandesterrenkunde.nl. One of these activities is the exhibition on 'Van Gogh and the colours of the night' which will move in mid-February from the Museum of Modern Art in New York to Amsterdam, and which includes the famous works 'The starry night' and 'The starry night above the Rhone.'[10] The direct impetus for this celebration is the fact that exactly 400 years ago Galileo Galilei first used a telescope for astronomical purposes. It was, in fact, the same telescope that was invented the year before in the Netherlands by optician Hans Lipperhey, from Zeeland, who applied for a patent for it. The cultural aspect of astronomy will be particularly emphasized in these activities, whereby citizens throughout the world will be encouraged to rediscover their place in the Universe and thereby engage a personal sense of wonder and discovery. If we can consciously place the present-day problems in our world beside the immense size and variety of the Universe, they take on a very different perspective.

Astronomy is also an excellent way of interesting young children in natural sciences in general. Topics such as life elsewhere in the Universe, black holes, gamma ray bursts (the most powerful explosions in the Universe), dark matter and dark energy (which together form 95% of the Universe but leave no observable trace behind) appeal strongly to the young. We try to stimulate this further from NOVA with reading material and advice to teachers, just as our colleague Miley does with his 'Universe awareness' programme to young children in underprivileged environments. Our aim is to further stress the image of natural sciences as an exciting and fun subject.

I would like to close with an appropriate painting from Australian aboriginal art: 'A Milky Way Dreaming' by Gabriella Possum Nungurrayi, daughter of the famous aboriginal painter Clifford Possum (figure 4). A 'dreaming' or 'dreamtime' forms the spiritual basis of the Aboriginals: it describes a time when the values, symbols and laws of society are defined and ordered, which are directly linked to the Aboriginals' cosmological vision of the Universe. In this image we see the Pleiades or 'Seven Sisters' which were hidden by their mother in the dusty heart of the Milky Way because an old man, Orion (at the top of the painting) is chasing them. In aboriginal culture an artist only gets to hear the whole story of a dreaming little by little from the tribal chief. Each time the theme is painted, more details and content can be seen.

Figure 4: Painting 'A Milky Way Dreaming' by Gabriella Possum Nungurrayi (2001). Collection: E.F. van Dishoeck and P.T. de Zeeuw.

This is how it is in astronomy: each time a new, more powerful telescope is constructed, we learn a little more about the Universe. Sometimes surprising discoveries are made with huge leaps forward, and sometimes with tiny steps. The value which we as society attach to these images of new worlds in the Universe eventually also determine the cultural heritage of our world.

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Achterflap

LINKS

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PHOTO

1980 - 1984:	PhD research, Universiteit Leiden
1984 - 1987:	Junior Fellow, Harvard Society of Fellows
1987 - 1988:	Visiting professor, Princeton University
1988 - 1990:	Assistant professor, California Institute of Technology
1990 - 1995:	Senior lecturer, Leiden Observatory
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RECHTS

Prof. Ewine F. van Dishoeck obtained her PhD in 1984 with distinction at Leiden University. She was junior fellow at Harvard University from 1984 – 1988, and was in 1987 – 1988 invited as visiting lecturer at Princeton University and the Institute for Advanced Study. In 1988 she was appointed Assistant Professor of Cosmochemistry at the California Institute of Technology. Since 1995 she has been working at the Leiden Observatory, initially as senior lecturer and since 1995 as professor. Here she continues to develop her interdisciplinary work between astronomy, chemistry and physics, supported by a SPINOZA subsidy from NWO. Her present research concentrates on the astrochemical evolution during star and planet formation. She holds many national and international functions, and since September 2007 has been Scientific Director the Netherlands Research School for Astronomy (NOVA). She is also an external scientific member of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany, since 2008. She is a member of the Royal Dutch Academy of Sciences , foreign associate of the US National Academy of Sciences and honorary member of the US Academy of Arts and Sciences. She has received numerous national and international awards for her research.