Insight and Wonder

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0. Vooraf

Mijnheer de Rector, Mijnheer de voorzitter van het College van Bestuur, Mijnheer de dekaan, familie, vrienden, collegas en allen die bent gekomen naar de laatste toespraak van iemand die meer dan dertig jaar aan de Leidse universiteit verbonden is geweest en die deze universiteit erkentelijk is voor wat zij hem heeft geboden.

Vader, de rest van deze rede zal ik in het Engels uitspreken- een taal die vanzelfsprekend door iedereen wordt gekend en verstaan. Maar een van de weinigen hier voor wie dat niet opgaat ben jij: je hebt geen middelbare school opleiding gehad, hoewel die bijzonder goed aan jou besteed zou zijn geweest: toen jij twaalf jaar was dwongen de economische omstandigheden je vader, die graag anders had gewild, jou mee te nemen naar zijn werk om zo bij te dragen aan het gezinsinkomen. Hetzelfde is moeder overkomen. Toen jullie elkaar hadden gevonden wisten jullie één ding heel zeker: dit overkomt onze kinderen niet; zij zullen het beste onderwijs krijgen dat zij aan kunnen. Leren, en dan graag je leven lang, is een ideaal dat moeder en jij op jullie drie kinderen hebt overgedragen. We hebben er alle drie van geprofiteerd, en ik wel het meest. Maandag a.s. wordt je 99 jaar oud- een materieel cadeau wil je nooit; 'kinderen, ik heb alles al' zeg je dan. Daarom een verjaarscadeau dat je nog nooit eerder hebt gehad: dat ik in het openbaar en tegen al deze mensen hier, zeg hoe belangrijk voor mijn leven die ruimhartige visie van jou en van moeder is geweest.

INSIGHT and WONDER

1. Preamble

Dear Friends and Colleagues, I will begin by obeying to a tradition, namely to tell an anecdote before I begin to teach. As you and I know full-well, all students of today are lazy, sloppy and unmotivated and to get their attention you have to amuse them first. That is what I will try to do.

1.1. Mr Ebels

I entered Groningen University in 1955 as a student in chemistry; a subject that I had carefully chosen. Unfortunately (or fortunately) during my first experiments I broke so many glass instruments that in order not to go bankrupt I switched to theoretical physics, a subject that offered less risk of breaking hardware. This switch required that I follow courses in astronomy, a subject not totally strange to me, but certainly not my first choice. The astronomy classes were given in the 'laboratory' that Kapteyn had founded some 60 years earlier and that carried his name. The astronomy course was given by Professor van Rhijn, who had succeeded Kapteyn more than 30 years before. Everything in the classroom seemed to be the same as when Kapteyn had been the director. While outside Groningen astronomy had already the character of a fast running river the Kapteyn laboratory was like a puddle on the river bank — a deep puddle, but still water. About twelve students from mathematics and theoretical physics (not a single astronomy student) sat on wooden chairs behind long wooden tables covered with a green cloth. The woodwork was of high quality. The Professor, already in his seventies and in poor health for many years, sat on a chair and read his course from a clearly very old notebook. He recommended especially Dryer´s fifty years old book on the history of astronomy - a classic text, but not a source of inspiration for a first year student.

When the Professor wanted to show some illustrations ('lichtbeelden', 'illuminated images') he pushed a button. Then, somewhere in the building a bell rang, you could hear someone coming down the stairs and Mr. Ebels, one of the senior computers, a human person and not a machine, entered in his khaki dustcoat. First he closed the thick curtains and this produced so much dust that several of us students began to sneeze heavily. While we were sneezing Mr. Ebels had climbed on to a small platform in the back where he opened a big, black machine. By running an electric current through two carbon sticks he started an electric arch that gave a beautiful bright light. The machine was closed again and Mr. Ebels put the first piece of coloured glass in a container, shoved the container between the lamp and lens and a high quality projection appeared on the whitewashed wall behind the Professor. The Professor, who remained seated, had now a long pointer in his hand to draw our attention to relevant details. When he decided that it was time for the next slide, he stamped on the floor with his pointer and at this sign Mr. Ebels dutifully slid in the next piece of coloured glass. After going through a number of slides the Professor said 'Ebels, zo is het wel genoeg' ('This is enough, Ebels') and Mr. Ebels left, keeping us in the room with the curtains closed. I must have been a lazy and unmotivated student of that day, who did not listen because the old Professor did not begin with an anecdote: I must admit, I do not remember anything that was taught or projected on the screen. I do, however, remember in great detail the smell of the wax on chairs and tables, the dust in the curtains, the touch of the faded green table cloth and I see again van Rhijn´s face that showed no emotion except that it seemed to express great fatigue.

1.2 The choice for astronomy

Three years later I was about to get my bachelors degree and I had to choose between theoretical physics or astronomy as my major for the masters degree. During these years the scene had changed completely. A successor had been found for van Rhijn, and the old man could retire and begin to enjoy his peace and quiet. The successor was Adriaan Blaauw who had been lured back from Yerkes observatory with the promise that he could reorganize and expand the institute. When I heard the news I asked for a meeting with Blaauw. My mind had been opened for astronomy: by chance I had seen the Dwingeloo 25m radio telescope under construction and it inspired the feeling of a new future. I remember also having read enthusiastic reports in the newspapers on spiral structure in our Galaxy and about the polarization of the light of the Crab nebula; clearly, there was more in astronomy than looking at the stars. In his interview it took Blaauw at most ten minutes to get me on his side. Especially important to me was his casual remark that to get the best observations astronomers should travel even if that carried them as far as the United States! Strange as it may seem now I had never thought that I would ever visit the United States. Another piece of news also affected me greatly, the announcement that a radio astronomer from Leiden, a Mr. Van Woerden, would come to Groningen to begin radio astronomical studies with the Dwingeloo telescope. I had never been to Leiden, but I was fully convinced that it was the Mecca of astronomy and that it would be a privilege to work under the supervision of someone from such a famous institute. And so I entered astronomy as an undergraduate student. I was the second who was attracted by Blaauw, the first being Tjeerd van Albada.

A. INSIGHTS

2.1 Technical limitations and achievements, 1960-2000

Let me summarize the most impressive additions to our scientific knowledge in the years that I was one of the many players in the field of astronomy, 1960-2003. Others might make a different selection; this is mine.

Astronomy is a science based on what one sees. It is not a science in which the Universe is built up mechanistically from fundamental principles- in this astronomy differs from physics. The Universe is as it is and we try to understand how it came about. We depend on the light to discover the nature of the objects in the sky and so we want as much light as we can obtain. The best way to collect more light is to make telescopes with larger mirrors because these pick up more light than smaller mirrors. By collecting more light we can also look deeper into the Universe. For a long time a Soviet telescope with a mirror 6 meter in diameter was the largest in the world, but its handling was rather difficult. The problem was an engineering one: the glass mirror was so large, thick and heavy that it could not be pointed very well. From 1948 until about 1990 the largest all-round telescope was one in California with a diameter of 5 meter. It was then clear that this mastodon was the biggest telescope that ever could be built – mirrors larger than 5 meter in diameter were too heavy to handle with the subtility that was needed. Then in the 1980s engineers began to realize that you could make telescope mirrors much thinner, if you used a flexible support for the mirrors, a support that could be bent in the right shape under computer control. The European organization ESO built a 3.5 meter telescope according to these principles and it was an immediate success. Today there are some 10 telescopes in the world with diameters between 8 and 10 meter and these can see objects that are 100 or more times fainter - reaching distances about 10 times farther away. Plans are being developed in Europe and in the USA to build telescopes with a diameter of 50 m or more.

There is a second reason to study the faintest objects and that has to do with the speed of light. When a picture is taken of the Sun, we see the Sun as it was 8 minutes ago, not as it is now. When we look at the nearest star we see it as it was 3 years ago. The faintest objects detected by the new telescopes emitted the light that we receive NOW about 15 billion years ago: we see this object as it was then, 15 billion years ago. By looking far away we also look back in time; history is observed directly. An interesting result of these new telescopes is that so long ago the universe looked different. Not only were the galaxies then much closer to one another (because the universe was then smaller), but the galaxies themselves were different.

There is more than making telescopes bigger. Think about an old-fashioned light bulb: it produces not only light, but also lots of heat radiation and that you cannot see, but you can easily feel it: it is called infrared radiation. What is true for light bulbs is true for stars and for galaxies. They radiate lots of energy that our eyes cannot see, but special detectors can: radio waves, infrared light, ultraviolet light, X-rays and gamma rays. Detection of these radiations is difficult: for one thing, the Earth´ atmosphere absorbs all radiations except light and radio waves. To detect those radiations that are absorbed by the atmosphere you need a telescope in space. The first machine in space was the Sputnik in 1957 and that was about the time that I chose to study astronomy. In my forty years in astronomy I have seen the launch of many satellites to measure radiation that cannot reach the surface of the Earth. These measurements have had a great impact.

Finally astronomical research has been changed fundamentally and often made easier by electronic computers: they play a basic role in planning the observations, in carrying out these observations, in correcting the signals for irrelevant effects, in interpreting the data and in developing theories to explain it all. How this changed our attitude? I shall relate my own experience. My first research assignment dealt with observations made with the Dwingeloo radio telescope. The radio signals were written by a ‘pen recorder’ on paper, and the radio astronomer later read the numbers to someone else, who wrote it all down. Thereafter the ‘reduction calculations’ could begin: all manual labour. Soon after I started my observations a drastic improvement was made: a new receiver in Dwingeloo produced not one but eight(!) different signals and suddenly we could observe eight times as fast as before. This was fantastic, but it multiplied the amount of subsequent human work also by a factor eight. It was clear to me that with this eight-channel recorder we had reached the end of our possibilities: further progress would require expanding our staff of assistants eight times and that was impossible. It thus followed that it would be useless to built faster recorders. I had no foresight that a few years later all radio signals would be recorded by (electronic) computers and we would be able to even decrease the number of assistants.

2.2 What we learned.

Let me go quickly through some of the enormous changes in our insight that happened between 1960 and 2000. My summary will not be complete.

I begin with the *stars*. When I started my studies the stars were already well understood: how the energy that a star radiates is produced deep inside the star, how this radiation is transported outwards and how long a star can continue to radiate this energy. We also knew that always new stars are being assembled and also there are always stars that die. But examples of stars under construction and of dying stars had not yet been detected. Thanks to radio astronomy and infrared astronomy hundreds of half-ready and of dying stars have been found and are being studied in various ways. A spectacular discovery, one of the most important discoveries in astronomy over the last fourty years, was made in about 1995 by Queloz and Mayor, two astronomers from Switzerland: they detected the first planet that moves around another star than the Sun. Hundreds more planets have since been found.

Almost all stars leave a remnant behind after they die. In the fifties we knew only one type of such a remnant: ‘white dwarfs’- they are objects as small as the Earth, but with the mass of the Sun; 1 cubic centimeter contains about 2000 kg of matter. During the 1960s two new types of dead stars were discovered: neutron stars and black holes. From a physics point of view these two new types of stellar remnants are more extreme than the white dwarfs and have very interesting properties. Perhaps you will ask: is a black hole a dead star? The answer is yes, but I will not go into detail here. Neutron stars and black holes are believed to be left over after a star explodes as a supernova. This very powerful explosion happens only in the heaviest stars. In recent years super-supernovae or hyper novae have been detected.

A development that has interested me concerns black clouds, things you see in large numbers on photographs of the Milky Way: in a small area there are no stars visible: a cloud with light absorbing material absorbs the light of all the stars behind the cloud. In 1960 we hardly knew more than that such clouds existed, but from 1969 onward more and more radio signals were detected from molecules in these clouds and suddenly the clouds came to life. Measurements of infrared radiation began to show that the clouds often contain unborn stars and we now know that these clouds are the maternity ward for stars.

Galaxies are large collections of stars held together by gravitation. I single out one major discovery: Most of the matter (90% or more) of a galaxy we do not see: we do not know how it looks like, or in what form it could be. But we know that it is there because it produces gravitational attraction. What is it? Many guesses have been made but nobody knows and its presence is a great mystery.
Finally, a brief word about cosmology. Since 1927 it has been known that our universe expands, becomes bigger- the conclusion followed when one measured the spectra of galaxies and saw that the fainter the galaxy looks, the faster it moves away from us as the Doppler effect shows. (If you do not know what the Doppler Effect is, forget that I mentioned it.) Around 1967 the most important recent discovery in the field of cosmology occurred and it happened unexpectedly: radio astronomers from the laboratories of Bell Telephone Company in the USA discovered that the whole universe is uniformly filled with radio radiation. Cosmologists from the nearby Princeton University came immediately with an explanation: long ago, when the universe was small the energy in the universe was divided between matter and radiation. But when the universe expanded matter and radiation were separated. The radiation found by these radio astronomers is radiation left over from that moment of separation. This radiation, now called the Cosmic Background Radiation is taken as one of the strongest pieces of evidence that the Universe was much smaller in the distant past.

Astronomy has had a golden age over the last fifty years. And there is more to come. There are many plans to build larger and better telescopes- the techniques are being developed and the political climate appears to be favorable. I will not name these new projects. But it might be kept in mind that in the race for new science there are also a few dark horses that may either make a fatal fall or result in a sensational new development. One example is the attempt to measure gravitational waves: When somewhere in the universe a supernova explodes, the tea cup on the table will tinkle. To hear it tinkle you need a very sensitive instrument, for example the detector MiniGRAIL that has been built in Leiden by Arlette de Waard and Giorgio Frossati.

2.3 Why are we here? Cosmic evolution

Some fifteen billion years ago the Universe was very small, perhaps infinitely small and then it began to expand: the words to describe this are `expansion of the universe´ or `cosmic evolution´. This concept is the basis for *all* present day astronomical research; similarly biologists assure me that the idea of evolution is at the base of all biological research. For those who have not heard this statement made before: there is much information in favor of cosmic evolution and there are no convincing scientific facts against; opponents to the idea of cosmic evolution have to be found in fundamentalist religious groups.

Accepting the idea of cosmic evolution has some important consequences: life on Earth is a natural phenomenon that happened because by chance the conditions were right. Life is probably temporary and it will disappear when the conditions become bad for us. Life on this Earth has survived so far because of a number of special conditions: (1) there is a steady source of energy, the Sun, that (2) is located in a sufficiently isolated place in the Universe so that no nearby supernova or gamma ray burster went off and destroyed all life by its energetic radiations. In addition (3) there is at least one planet in a stable, circular orbit around this Sun with an atmosphere in which we can breath and (4) this planet has not (yet) been hit by a large asteroid- a thing that may easily happen in the next few million years and destroy all the life on our planet; some 150 million years ago the dynosaurs were all killed in the wake of the impact of a rock from outside the Earth.

PART B: WONDER

I have been working in astronomical research and in university teaching for more than forty years; I was fascinated when I started and I still am fascinated. I am a lucky man. Let me reflect on my life long fascination for scientific research and education.

3.1 Emotion and motivation

My origins are in a world far way from the academic world - I did not know that this world existed when, at the age of ten I was asked by my good friend Tjerk to visit the Museum of Mineralogy in Groningen. The museum was normally closed and only visitors with a special permission from the Professor of Geology were admitted. Through relations Tjerk's father got this permission and so Tjerk and I walked through the large room of the museum and saw all the minerals transmitting and reflecting beautiful colors. We looked at the minerals and we both got very excited. We realized that these beautiful gems had not been made by craftsmen but that they were natural. Nature had made these things with their perfect shape and their beautiful colors! And you could find out how nature had done this. It was possible to *know* these things.

I recently read a biography of Newton. Now I always identify myself to some extent with the subject of a biography. That has its dangers, certainly in this case. For one thing, Newton was a genius of the kind only born once every 500 years. Another reason not to associate yourself with Newton is that he was quite a neurotic person, difficult and unpleasant to others and probably also to himself. But there is at least one aspect of Newton that I recognize in myself: Newton's desire to *know*. In his case this was so strong that he isolated himself from the outside work and virtually locked himself up for many years. I have never done that (my wife would have prevented it) but it is easy to feel some compassion for this trait of Newton's character.

Some years ago I was asked for my motto in life. I wanted to answer that I did not have a motto when a memory of long ago passed my brain and I said: 'From chaos emerges the light'. I still like the answer, because it expresses the happiness and joy, any time I learn something new; for a short period my brain is lifted out of the emotional chaos that it is usually in and I feel relaxed and safe. It is this moment that is so wonderful and that has given me the motivation to continue. To my pleasant surprise two artists, a painter and a sculptor, later wrote to me and asked me whether they might use this phrase to decorate their workshop.

3.2 The unity of all sciences

When I started in astronomy forty years ago it was still considered possible to oversee the whole of astronomy. This is now an illusion: astronomical research has branched out in too many different fields. It should not surprise us; a similar expansion reached other fields, chemistry, physics, biology, medicine, much earlier: the branching out of astronomy has come late. This branching out has been bemoaned, but I think that we should not over-dramatize the situation. To the contrary, I have always felt much in common with students in other fields. When occasionally I talk to a colleague who is a historian of medieval Dutch poetry, I meet a related spirit and I feel at home. I have many more such experiences and I am firmly convinced that there is a basic attitude shared by scholars and scientists of all fields of research: to approach the world around us in a rational manner, to prefer doubt over mystic explanations. To me this attitude *is* the unity of the sciences. Universities are valuable to the society that supports them for a variety of reasons. One of these is that the universities maintain a large group of people with this critical and rational attitude.

The following statement is far from original, but it is a Grand Perspective, it has majesty. There is only one history, one continuous sequence of sciences- a linear chain: from cosmology to astronomy to geology to biology and paleontology to archeology to history. Each of these disciplines answers its own questions, and studies these questions with its own techniques, but the scientific attitude is the same. The complexity of the subject studied determines the technique that you use for your study. Astronomical questions are simple enough that you can get quantitative answers using mathematical equations based on the rigorous laws of physics. At the other end of the sequence there is history; it studies human behavior. Human beings are infinitely more complex than galaxies and all answers are qualitative instead of quantitative. Future behavior cannot be predicted. Be it as it is, I am convinced that the basic scientific attitudes of historians and astronomers are the same.

3.3 Physics and chemistry provide the basic knowledge

The laws of physics, measured in a small laboratory somewhere on Earth, turn out to be valid in far away regions billions of years ago. That is astounding. To me the most beautiful demonstration of the power of physics for astronomy is in the equation derived by Planck in 1900 when he wanted to explain the radiation coming from a hot oven- an oven as you might find in most kitchens. But it now appears that this same equation describes with unbelievable accuracy the radiation that fills the universe, the cosmic background radiation that I mentioned before.

Contemporary physics explains much of what we observe. There are however two important facts that physics does not (yet?) explain. It cannot explain to us what happened during the first seconds after the Big Bang. And it cannot explain the nature of about 90% of the matter in the Universe- the dark matter that surrounds galaxies. With so much not yet understood we must not be too confident that our world picture is definite.

We should also consider the fact that the whole of physics is not a unified theory. There are four basic interactions of matter and radiation and three of these are unified in quantum theory. Gravity, the 4th force, is described beautifully in Einstein's theory of general relativity. A basic problem is that general relativity and quantum theory cannot be unified into one theory. The drive to unify these theories is absolutely a valid scientific goal. In the 19th century there was a strong desire to bring thermodynamics, electricity, magnetism and gravity in to one basic self consistent frame and this was achieved around 1900. The unified theory, that has yet to come, has already been labeled 'The theory of everything' or TOE by what seems to me to be almost a sect around Stephen Hawking. Hawking appears to have said: ´If we have the TOE we know the mind of God´. To quote an even bigger name than Hawking's I use Einstein, who apparently has said that the theory of general relativity cannot explain the love between humans. I agree that, if God exists, God will contain more than only the `Theory of Everything'; love will certainly be part of him.

During my employment by Leiden University the departments of physics and astronomy have been together in one administrative structure for almost 15 years. This was a most unhappy marriage; several of us here have had a fair share of the sufferings it produced. Then, about ten years ago, physics and astronomy separated and since that time we are the best of friends and I am very happy about that. But this is all administration. How are the relations scientifically? Is astrophysics the same as physics? This question has interested me for a long time. My answer is that there *is* a fundamental difference between physics and astrophysics, but that in practice this does not matter. The ideal of physicists is, I think, to build all of our knowledge on a limited frame that will be there from now to eternity. Physics is forever. Newton's law, Maxwell's laws, Planck's law- they will always be valid: from the time when the universe began expanding until the time that the universe will be so old that nothing will happen anymore. In contrast time plays an essential role in astronomy: we want to see the differences between the universe as it is now, when it was young and when it will be old. The very different role of time in astronomy and physics makes the fundamental difference between the two.

In practice, however, the difference is often very small or non-existent. There are many (most?) studies in astrophysics that would not have been done differently by a physicist. Several topics are thoroughly physics- for example the analysis of stellar vibrations: the recognition of different modes of vibrations and the interplay between these could be a physics textbook example. A fact is that more and more examples from astrophysics enter textbooks of physics. Fundamental differences appear, however in the more important role played in astronomy by intuition and speculation. Physicists and astronomers alike use intuition and speculation to get ideas on what they observe or measure. The difference is that for physicists this speculation is only the beginning of their research; from then on they will try to remove all speculations and to come to well established proofs of what they guessed. Astronomers have the same ideal, but often they get stuck because of the limited information they can collect. They accept that state of information as a part of life and they are not afraid to publish results that are still uncertain.

Here is an illustration about the role of intuition. Once, in a casual discussion with van de Hulst, I mentioned that I got stuck reading one of Oort's papers, because I could no longer follow the arguments. I found them contrived and very complex. Van de Hulst smiled and said: 'I understand. Sometimes I find his argumentation also rather poor. You see, usually Oort knows the answer intuitively before he has the arguments. To prove that he is right he has to find arguments and he is not always good at that'. I tell this story also, because I am an editor of a scientific journal and every week I read some twenty or so referee reports. Most referees do not like intuitive arguments and when they spot them they will express strong doubts about the scientific value of the manuscript. Nay, in their indignity they may even point out how inadequate, yes, how immoral such research methods are. I do not always agree with that part of the report.

3.4 Will astronomical knowledge ever reach completion? The Hogwart feeling.

Consider then the scientific progress over the last forty years. Will we make as much progress in the next, say, two decades or is our astronomical knowledge nearing some sort of completion? Will there be a time when the final text book on astronomy will have been written? Take for example the textbooks on physics by Landau and Lifshitz, six volumes originally written in Russian and translated in many languages (there is gossip that only one of the two authors wrote all the books; the other dictated them). Is all basic knowledge contained in these volumes and will they remain equally valid for all the time to come? This is not yet the case, but there might come a time when such books will have been written.

How much new science is in front of us, and how much new knowledge has not yet been discovered are questions that I believe no one can answer. To see why, take the following experience, which I know many of you have had: pose yourself a well defined scientific question and try to find the answer. You work on this problem for a long time; others, your colleagues and competitors are on the same track, it is a nervous hunt. And then, the answer is found, hopefully by you. From that moment on the question has lost all attraction to you; you might even find the answer now 'obvious' and 'boring'. But given this answer a new question comes up and at once there is a new perspective; and then you start again. There are scientists that never publish: when they have found the answer they are not interested any more in the question. The relevant question that I would like to pose here is: will this continue? Will each answer create more new and interesting questions? When Jan Oort died one of the major Dutch weekly magazines, Vrij Nederland, had an obituary with the title 'to die with a head full of questions'. I also hope to die with my head full of questions.

Because progress is unpredictable the way in which a subject evolves is often very complex. It is a well-known metaphor to compare scientific knowledge with a building. The phrase 'these are the fundaments of our understanding' is quite common. But how well is this building constructed? What is the architectural design? While watching the first Harry Potter movie I recognized the building of the sciences: it is the castle of Harry Potters boarding school, 'Hogwart' ('Zwijnstijn' in het Nederlands). With its hidden corridors, its invisible doors so that you can go from one place to another only if you belong to the right department and with dragons in its cellars Hogwart is the right metaphor for the building of astronomy.

3.5 Research is hard; the interesting answers are just outside reach

Often the most promising questions are those for which the answer is just behind the horizon, not the things well within reach: most likely these have already been explored. When a new instrument is made available quite often it is immediately used to measure the faintest signals it can reach, because one expects that the important new discoveries lie there. This, of course, is asking for difficulties, but then: it happens often. Scientific research is usually done there where you can no longer recognize sharply what is ahead; your vision is blurred. Opening new horizons requires hard work, much courage and ambition and the certainty that in a few years the results that you obtain now with hard work will be easily and quickly obtained by new instruments.

This ambition is shown by an anecdote about J.C. Kapteyn, the famous Groningen astronomer; Jet Katgert told it to me. At one time Kapteyn visited the Observatory at Bonn in Germany, where he discussed the structure of our Milky Way Galaxy. At one point his host said to him: 'You are so impatient. Why do you not wait for a few years when we will have taken, measured and analyzed all the data that you need?' At this point Kapteyn stamped with a foot on the floor and said, almost angrily: 'NO, I want to know it NOW'.

In the time I did most of my thesis research, 1963-1968, the group of undergraduate students of radio astronomy in Leiden and in Groningen felt a strong responsibility to exploit the advantages offered by the Dwingeloo telescope. At one time we discussed a bold plan: to make a map of the northern sky with the Dwingeloo telescope, a map that should be clean of an annoying effect, radiation that sneaked in from undesired directions, the so-called side lobe radiation. After considerable initial enthusiasm we abandoned the project; it would require computers that did not yet exist. I for one forgot the project, but it was not forgotten by my Leiden colleague Butler Burton. In 1990 even simple personal computers were fast enough and had sufficient memory to carry out the project. Dap Hartman did most of the work and the result was very impressive. The Leiden/Dwingeloo survey by Hartman and Burton is now a worldwide standard and its analysis is the subject of several PhDs in Leiden and elsewhere.

Sometimes you have luck and your progress is quick and relatively easy- instead of hard and slow. This happened to the American and Dutch/UK teams on the IRAS satellite in 1983. IRAS was the first astronomical satellite that surveyed the full sky. It detected infrared radiation from a few hundred thousand new stars and galaxies and this was such a big step forward that almost any of these stars and galaxies was new and interesting.

3.6 The organization of astronomy and Europe

The sky is large and astronomers are few, and international collaboration is an obvious goal. Collaboration between astronomers is common everywhere in the world. The International Astronomical Union was one of the first scientific unions (perhaps the first union) to include both mainland China and Taiwan as simultaneous members. Astronomy is a peaceful science and this helps, of course. In Europe we have two large and healthy organizations that allow us Europeans to be at the forefront of research. These are ESO, the European Southern Observatory, and ESA, the European Space Agency. ESO's Very large Telescope, four 8-m telescopes on a remote site in Chile, with a superior view of the sky has the same potential for research as the best observatories in the USA. Also in space research Europe is rather well-off although ESA has a budget that is only a small fraction of the NASA budget. Nevertheless in a number of cases ESA´s scientific programme competes succesfully with NASA´s space program. I believe that a major reason why we could compete well with a lower budget is that the ESA budget for scientific programmes has been stable: stability makes it possible to find compromises between different scientific communities: ‘I accept to let it be your turn this time, because the next will be mine’. One of my favorite satellites has been HIPPARCOS, a satellite to derive positions for half a million stars with a much higher precision than can be reached from the ground. The ESA technical establishment considered this satellite to be without glamorous prospects, but the consistent and insistent pressure of the astronomers in the ESA advisory boards led to the materialization of the satellite. After launch it became such a success that now three successors are being planned, one by Germany and two other large satellites, one each by ESA and by NASA.

Astronomical projects are very costly. Consequentially long-term planning is necessary and consensus has to be reached among the communities in all member states. In the course of the last fourty years European astronomy has been disciplined to achieve all this in interaction with the engineers of both ESA and ESO. I have participated often in committees and know that it is tiring, time consuming and often also frustrating; nevertheless I think that overall Europe is doing very well and by and large the plans have the support of the whole astronomical community- not a minor achievement.

One of the gradual and healthy developments has been an increasing openness about the results. Measurements made by for example a space telescope are made available to any one who would like to use them, where in the world he or she might be. This open policy often leads to unexpected and very interesting results. My first experience with this policy of openness was with the IRAS satellite in 1983. From the US side there was a strong push to make the data freely available, whereas in Europe we wanted to keep the data to ourselves. But later I became thoroughly convinced about the wisdom of the open policy and I have tried to contribute to it. I am quite happy that this open democratic attitude has become the standard of today.

The high costs of research have intensified the contacts between astronomers and the organizations that provide the money. We are far past the time when as a young and rather naïve student I asked Mr. Piekaar, a high civil servant of the Ministry of Education and Science: ‘how do you decide what is worthwhile to fund’. He smiled and said: `funding astronomy is easy for us; we just give Oort the money that he asks for and we know that he will use it well´. This is all long ago. Nowadays one has to write proposals for getting almost anything. The interaction between those who write the proposals and those who distribute the money calls for strategies. We, the astronomers, want to get as much funds as we can, and the sponsor, in the Netherlands this usually is NWO, has an understandable desire to control the allocation of the money. Over the last three decades astronomers in the Netherlands have managed to reach a consensus in their choice of future projects, and one of the frustrations of the people from NWO has been that 'you astronomers always agree among yourselves so that we have no choice', by which, I think, they mean to say: `you take away from us our tool to play divide and rule´.

Proposing a research program is proposing to sail on the Ocean of the Unknown. You set out on a definite course, but while you are sailing you might be lured into changing this course. One of my fears has always been that NWO or the University will assign a controller on this ship to make sure that the ship continues sailing exactly in the direction specified in the original proposal even when another direction suddenly looks more promising.

An increasingly important development is the role of the so called citation index. I publish a scientific paper. How often will other astronomers refer to my paper? If they do this often, I have written a useful paper and my standing increases. If no body seems to notice my paper, my standing drops. Simple. As an example: if your paper receives more than 50 citations, you have done rather well; if the number is below 10, the paper had little impact. Thus: can we measure our colleagues by using this citation index? I have an example to show where the citation index fails. Compare the total number of citations of papers published by astronomer X with those published by astronomer Y. For astronomer X I have taken the average of three recent Presidents of the International Astronomical Union- clearly a position of very high international prestige. For astronomer Y I have taken the average of three scientific directors of an astronomical institute at a Dutch university. The result is significant: the Dutch directors have three times more citations per year than the presidents of the IAU. (If I were malicious, which I am not, I might suggest that the IAU Presidents have put more effort into networking than in writing papers.) But do I conclude that these three presidents have not earned their position? I do not! I know all three Presidents personally and I think that each is an important scientific leader. No, citation indices tell too little to make a full assessment.

4. Conclusion

The title of this lecture 'insight and wonder' hopefully characterizes how I have experienced my scientific work. The word 'wonder' has a positive sound: it expresses an unexpected and pleasant surprise. I like to plea that these words should be used more often to defend education on all levels. My wife and I have four grandchildren under the age of six. I am often impressed by their curiosity and by the pleasure they have when their curiosity is satisfied. I hope that they will not lose this and I make a plea that primary and secondary schools and universities help their students to develop this curiosity. One way to do that is to challenge them. During the last few months there has been much concern among Dutch scientists about a plan to teach much less physics at high schools. The main argument for this plan is: the present program is overloaded; we have to make it easier for the children. It is a wrong argument. In my secondary school I was taught difficult subjects: Latin, for example, and classical Greek. I am still happy at having been taught these subjects even though I have not used them ever since. Intellectual challenge is NOT a threat to education- it is a stimulus. Yes, physics is difficult- there is no free ride on the road to knowledge. But physics offers satisfaction when you finally understand. At university I was taught special relativity. When the light in my head turned on and I understood what it was about, I was so excited that I had to walk through Groningen for more than an hour before I could do anything else. I hope that our society will continue to make young people as happy as I have been.

I thank everyone with whom I have always (let me be more precise: most of the time) collaborated in a pleasant way: the University officials from low to high, the NWO staff, an organization for which I have a high regard, my colleagues in Leiden and elsewhere in the Netherlands, and, especially over the last years the staff in the A&A office in Leiden. The list could be made much longer but I stop. My last words of thanks are to my wife who has not only accepted my idiosyncrasies but also assured me that she loves me because of them.

Ik heb gezegd.