Chapter 2
Studies in Utrecht

Mathematics is the door and key to the sciences.
Roger Bacon (ca.1214–1294).[1]

In theory, there is no difference between theory and practice.
But, in practice, there is.
Jan L. A. van de Snepscheut (1953–1994).[2]

2.1 Universities in the Netherlands

At the time when Kapteyn was preparing to start his studies at a university, there were only three such institutions in the Netherlands. The oldest, the University of Leiden, had been founded in 1575, the one in Groningen in 1614 and the university of Utrecht in 1636. In Amsterdam an *Athenaeum Illustre* had been established in 1632, but this had not been given the status of university. The 'illustrious school' had no authority to bestow degrees upon students, although it was recognized as an institution for higher education. Amsterdam has only had a university since 1877, when the Athenaeum was finally given that status.

There had been two more universities in the Netherlands, the one of Franeker in Friesland, which had been founded in 1585, and the university of Harderwijk, not far from Barneveld, founded in 1648. During the French occupation (1795–1813) all universities, except those in Leiden and Groningen, were closed, in 1811, by decree

[1]Roger Bacon, British Franciscan friar and philosopher.

[2]Johannes Lambertus Adriana van de Snepscheut, computer scientist, originally at the University of Groningen, later California Institute of Technology (Cal Tech). He died in a fire in his Pasadena home under circumstances that remain unclear. Some people attribute the quote to Yogi (Lawrence Peter) Berra (b. 1925).

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of the Napoleonic government. Eventually those at Franeker and Harderwijk continued as athenea, but did not prosper and were closed in 1818 and 1843 respectively (see G. Jensma & H. de Vries, *Veranderingen in het hoger onderwijs in Nederland tussen 1815 en 1940* [1].). The university of Franeker had originally thrived, but during the eighteenth century had suffered from strongly decreasing student numbers. The university of Harderwijk had never been much more than a cheap place to graduate, its reputation as a learned institution being very limited. Indeed, most students only went there for a short period to take advantage of the low tuition fees, obtained their doctor's degree and left. The most prominent among these were the physician and botanist Herman Boerhaave (1668–1738), who graduated in 1693 and Carl Nilsson Linnæus (1708–1778), founder of the scheme of binomial nomenclature for living species. He graduated in 1735, reputedly since it was not possible to obtain such a degree in Sweden at the time. Linnæus only stayed in Harderwijk for a week to get his thesis printed.

After the University of Utrecht had been closed by the Napoleonic occupation, it was actually downgraded to a secondary school (école secundaire). After the defeat of Napoleon, when the Netherlands re-emerged as an independent state, the University of Utrecht, unlike those of Franeker and Harderwijk, was reinstated as a university. This was part of the resolution of August 2, 1815, in which the Dutch government created a new system of the 'higher education in the northern provinces' (the current Netherlands). At the 'Congress of Vienna' in 1815, the United Kingdom of the Netherlands was created, encompassing the area covered today by the Netherlands and Belgium. The latter country gained independence again in 1830. The fact that it would have been very expensive to support the two universities of Groningen and Franeker, located so near to one another in the sparsely populated North of the country, must have played a role in the fact that the University of Franeker was not re-instituted. In the so-called *Organiek Besluit* – 'organizational resolution' – (see e.g., G. Jensma & H. de Vries; M. Groen, *op. cit.* or H.A.M. Snelders, *De schei- en natuurkunde aan de Utrechtse universeit in de negentiende eeuw* [2]), the universities at Leiden, Groningen and Utrecht were instituted with five Faculties, including a separate one for mathematics and physics. In this Faculty, four professors taught the subjects of mathematics, physics, astronomy, chemistry, biology and agriculture. It was separate from the faculties of philosophy and literature, medical sciences, theology and law.

2.2 Kapteyn and His Academic Lineage

In Appendix A, I have traced the academic lineage of Kapteyn. It goes all the way back to persons associated with Johannes Kepler, which is very gratifying as Kapteyn's genealogy applies to a large number of Dutch astronomers, including myself, and I am a great admirer of Kepler. In this Academic Genealogy the first person in the Netherlands was Johann Samuel König (1712–1257), who had studied under Johann (1667–1748) and Daniel Bernoulli (1700–1782) in Basel. König had been a professor in Franeker. His student Antonius Brugmans (1732–1789) had been a professor in Franeker and in Groningen and was the supervisor of Johannes Theodorus Rossijn (1744–1817). Rossijn had written a thesis *De tonitru et fulmine ex nova electricitatis theoria deducendis* (On thunder and lightning according to the new theory of electricity), which he defended at Franeker in 1762. Subsequently he was appointed professor in philosophy, mathematics and astronomy in Utrecht in 1775, after a period as professor in Harderwijk. Under Rossijn, mathematics and physics obtained an excellent reputation in Utrecht.

Gerard (also Gerrit) Moll (1795–1838) received his doctoral degree *honoris causa* in Utrecht in 1815 under Rossijn. Moll had also studied extensively in Amsterdam under physicist Jean Henri (also Jan Hendrik) van Swinden (1746–1823), and after having obtained a 'Candidaats' (Bachelor degree) in Leiden, he went to study in Paris under the mathematician and astronomer Jean-Baptiste Joseph Delambre (1749–1822), among others. Moll was appointed professor of mathematics, astronomy and physics in Utrecht in 1815. When he received a tempting offer to come to Leiden in 1826, he decided to stay in Utrecht, however. The city of Utrecht expressed its gratitude by awarding him the sum of 10,000 Guilders (equivalent to about 230,000€ today), to buy instruments for his scientific research. He was primarily famous for his work on the speed of sound and electromagnetic experiments, but also well-known as a practitioner of applied sciences such as mechanical and civil engineering, architecture, etc.

This tradition of mathematics, astronomy and physics, established by Moll, was continued by his student Richard van Rees (1797–1875), who obtained his PhD under Moll on a thesis entitled *De celeritate soni per fluida elastica propagati* (On the speed of sound in an elastic fluid) in 1819. Van Rees was a professor of mathematics and experimental philosophy in Utrecht from 1831 to 1867. He was a very active professor and he had 22 students, including the famous physicist and meteorologist Christophorus Henricus Didericus Buys Ballot (1818–1890) and the mathematician Cornelis Hubertus Carolus Grinwis (1831–1899) (see Fig. 2.1). Buys Ballot had obtained his doctorate in 1844 on a thesis *De synaphia et prosaphia* (On cohesion and adhesion) and Grinwis defended a thesis *De distributione fluidi electrici in superficie conductoris* (On the distribution of electricity over the surface of a conductor) in 1858. Buys Ballot was appointed professor of mathematics in 1847 and professor of physics in 1867; Grinwis became a professor of mathematics and physics in 1867. Kapteyn was to become a student under Buys Ballot as well as Grinwis.

Physics had been practiced extensively in Utrecht for quite some time. This was much facilitated by the existence of the 'Natuurkundig Gezelschap' (the Physics Association) in Utrecht [3]. It has been founded in 1777 as an initiative of Rossijn. The original full name was 'Gezelschap ter Beoefening en Bevordering van de proef-ondervindelijke Natuurkunde': Association for the practice and promotion of experimental physics. Originally, its primary aim was to collect funds to buy instruments for scientific research. The Association is still active today as one of the oldest of such societies in the Netherlands. It was an important reason why physics in Utrecht was a prominent field of study when Kapteyn entered its university.

Fig. 2.1 Christophorus Henricus Didericus Buys Ballot (1818–1890) and Cornelis Hubertus Carolus Grinwis (1831–1899) (Universiteitsmuseum Utrecht [14])

2.3 Kapteyn Entering Utrecht University

Kapteyn's choice for Utrecht was probably the obvious one; his two older brothers Nicolaas Pieter (1845–1916) and Willem (1849–1927) had studied there as well. Utrecht was the university closest to Barneveld, and the mathematics and natural sciences faculty as indeed the University of Utrecht as a whole, had an excellent name. In Dutch the faculty was designated 'wis- en natuurkunde', which currently would be translated 'mathematics and physics'. However, the faculty also comprised chemistry, biology and pharmacy. 'Natuurkunde' here refers to studies of Nature in a broad scene, so the appropriate translation of 'natuurkunde' here is 'natural sciences'.

Apart from Buys Ballot and Grinwis, the university had among its professors a group of prominent scientists (the 'School of Utrecht'). They included the physiologist Franciscus Cornelis Donders (1818–1889), an authority on eye-diseases, biologist Pieter Harting (1812–1885), who devised improved microscopes and is seen as the earliest supporter of Charles Darwin's evolution theory in the Netherlands, and chemist Gerardus Johannes Mulder (1803–1880), an expert on the chemical composition of proteins. In his study on the development of natural science in the Netherlands, *In het voetspoor van Stevin; Geschiedenis van de natuurwetenschap in Nederland 1580–1940* [4], Klaas van Berkel writes: 'With Mulder, Buys Ballot, Donders and Harting, Utrecht had become the most important university of the country halfway through the nineteenth century, as far as the natural sciences were concerned.' Before I turn to Kapteyn's studies, I reproduce part of the *HHK biography* first, which deals with Kapteyn's choice to study mathematics and physics in Utrecht.

'His parents wanted him to study theology. None of the other sons had wanted to do that and they hoped that this quiet, devote son would fulfill their deepest wish and become a preacher. They had no idea of the boy's inner thoughts, or indeed of the changes that had taken place in him. They had no idea that he had in fact chosen to follow his own beliefs long before and would not be able to follow the path that they had wished him to choose. He knew that, like his brothers, he was more suited for a study in exact sciences. However, he did not have the courage to tell his very stern father, and together with another boy from the school who had the same problem, he agreed that they would present their wishes to their respective fathers at roughly the same moment. Taking heart from the fact that someone else was faced with the same difficult task, he found the courage. It turned out to be not difficult at all, since the old man Kapteyn was a wise man, who, although being thoroughly disappointed in his greatest wish, realized very well that he should not force his children to do a thing they did not want to do. And he agreed that this son would likewise study mathematics and physics. As a result he was enrolled at the University of Utrecht in 1868, where two of his brothers were students already.

The brothers did not see too much of each other and lived their lives as independently as they used to at home. Like all previous Kapteyns he was given the nickname 'Dux' [Latin for leader/captain and origin of the later 'Duke'], which was a name they were very much attached to. He studied under Professor Buys Ballot, the renowned meteorologist, and the mathematician Prof. Grinwis. He had little difficulty with his studies, since, as has already mentioned, he had done a lot of work at home in the previous year. So he spent little time studying and enjoyed life. Being the only student enrolled in the Faculty of philosophy (mathematics and physics), he joined a social club (society) of students in law, where he had great fun and enjoyed a free life, which brought him much happiness after his life of duty and obedience. This sudden, big change did little harm; it was common in those days that students did not take everything too seriously and Kapteyn went along with that. As soon as he noticed that the leisurely life was getting too much of a grip on him, he would find the strength to stop.'

There are two comments to make in relation to what is mentioned in these paragraphs. The first has to do with the interaction with his brothers. When Henriette Hertzsprung-Kapteyn tells us that the contacts with his brothers were very infrequent, this is not because they lived in different quarters. At least not where it concerned Willem. Van Berkel and Noordhof-Hoorn in the *Love Letters* note that in Utrecht Kapteyn moved into a room in the same house as his brother Willem, i.e., with the Huisman family at the address Predikherenkerkhof. If they were leading separate and different lives, this would be no more than continuing the way they grew up. A fact that may serve to illustrate this is that according to the *Love Letters*, Kapteyn, unlike his brother, became a member of the Utrechts Studenten Corps, the oldest student corporation (fraternity) in Utrecht, founded in 1816.

The second point concerns the remark that Kapteyn was the only student enrolled in his faculty. Indeed, the number of students in those years was small. Kapteyn was enrolled in the Faculty of mathematics and natural sciences, but it is incorrect to assume that he was the only student there. Maybe Kapteyn was the only *first year* student in that faculty; however, the total number of students that academic year (1868/69) was actually 63 and it is not likely that Kapteyn was the only one who had enrolled in his Faculty that year [5]. With regard to student numbers I note that these 63 compare to a total of 147 students for the three Dutch universities together in the mathematics and natural sciences faculties, and a total of 501 students for Utrecht university as a whole. By the time Kapteyn obtained his PhD degree during the academic year 1874/75, the first number had decreased to 52, while the national total in mathematics and natural sciences had grown to 175 and Utrecht as a whole to 527. The total number of students at the three universities of Leiden, Groningen and Utrecht grew from 1319 to 1684 [6]. The student numbers were small, but it is highly unlikely that Kapteyn was the only student in his cohort in his faculty.

> 'A great joy in those days was his friendship with 'Willy' Andree Wiltens. This young man was immediately charmed by the character and greatness of the Kapteyn boy and showed this with great warmheartedness. The heart of the lonely boy was warmed with joy and he basked in the ensuing love and friendship, which was new to him, but which he had longed for all his life. Wiltens was a son of a civil servant from the East Indies, whose three sons all studied in Utrecht and were members of prominent clubs. [...] He was a noble and good person and he had a rare characteristic, namely that he could admire and love with all the warmth of his heart. [...] Wiltens had a very special place in Kapteyn's life as the one who for the first time showed him what was most important in life, namely love.'

The combination Andrée Wiltens is the full double-barreled last name, sometimes written with the acute accent. The father, Henry Maximiliaan Andrée Wiltens (1823–1889), was a civil servant in the East Indies, in Padang on the island of Sumatra. With his second wife Euphemia Clementina Towsend (1822–1857) he had four sons. The study of the fourth and youngest, Jacob Willem Gerard Hendrik (1858–1923), would hardly have overlapped with Kapteyns, if he went to study in Utrecht in the first place, so the three must have been the older ones. The person referred to by Henriette Hertzsprung-Kapteyn is almost certainly the oldest, Henry William Andrée Wiltens (1851–1917), who had the same age as Kapteyn. In the *Love Letters* Kapteyn refers to him as 'Willie Wiltens'. The other two were Albert John (1853–1915) and Maximiliaan Leonard (1856–1935). 'Willie' Wiltens studied law and became a lawyer or attorney in his birthplace Padang, where he married Johanna Josephine van Hulsteijn (1855–1929) in 1880. He died in the Hague, so he must have returned to the Netherlands at some time. Kapteyn kept in close touch with the Andrée Wiltens family; Willie's brother-in-law was in fact a witness at Kapteyn's wedding (see page 109).

2.4 Kapteyn as a Student

'Kapteyn did not study too hard, as there was so much socializing and joy to have with friends as student life in the Netherlands was offering then, and his inherently joyful, social character enjoyed all this happily. His sense of humor and sociability, the happy side of his character, now started to come forward. He could be very sharp, which hurt others where his criticisms were wrapped in strict logic. He made enemies this way, which bothered him much, since he could not bear animosity and preferred to be on good terms with everybody. [...]

His first exam [Candidate (Bachelor), I presume] was only average. In those days exams were public and the audience had come in large numbers, so that the room was almost full. His father had come as well and was sitting close to him. He did not perform brilliantly and people started to become restless. The examiner kept going on about the same subject, although it was clear there was not much to gain from that. Kapteyn became irritated by that lack of logic and he said loud and clear: 'Professor, I don't know anything about this subject!'. It was absolutely quiet for a short moment and he saw his father turn pale. The professor, however, changed the subject to one Kapteyn knew a great deal about and in this manner he was enabled to save the day and obtain his degree.

After the exam the father and his sons went to the room where Kapteyn lived. The atmosphere was happy and lively and the largest surprise happened to the sons when they saw their very formal father taking an easy chair, propping his feet on the window sill and tipping the ashes from his cigar through the window. Was that really their formal, always correct father? 'Yes, boys, the upbringing has been completed and I no longer have to set an example', he said, laughing when he saw their surprise. In the evening the father went along with the friend to the student pub to celebrate the event. He was the center of attention and those present said unanimously: 'The old Dux will have to tell a story.' Everyone knew his talent, and the old Dux started telling stories so that everyone lost all sense of time.

The necessity to read out texts aloud in public proved a major difficulty for the young Kapteyn. He had a rather high-pitched, somewhat shrill voice, his intonation was not perfect and his reciting restless. One day he recited *Der Taucher* by Schiller, in a meeting of a students' reciting society, when someone in the audience remarked: 'I thought it impossible for anybody to recite so poorly.' He did not take this strong criticism as an insult, but as an inspiration to practice. A few years later, when a young professor in Groningen, he had to deliver his inaugural lecture, and he did all he could to be well prepared. He recited his lecture up to thirty times in front of two of his sisters, who were patiently sitting in the two farthest corners of the room as his audience and made comments. [...]'

OVER DE THEORIE

TRILLENDE PLATEN,

EN HAAR VERBAND MET DE EXPERIMENTEN.

ACADEMISCH PROEFSCHRIFT,

DOCTOR IN DE WIS- EN NATUURKUNDE,

AAN DE HOOGESCHOOL TE UTRECHT,

Dr. T. HALBERTSMA,

MET TOESTEMMING VAN DEN ACADEMISCHEN SENAAT

VOLGENS BESLUIT VAN DE FACULTEIT DER WIS- EN NATUURKUNDE,

TE VERDEDIGEN

op Vrijdag, 14 Junij, 1872, des namiddags ten 3 ure,

WILLEM KAPTEYN,

GEBOREN TE BARNEVELD.

BARNEVELD,
P. ANDREÆ MENGER,
1872.

ONDERZOEK

TRILLENDE PLATTE VLIEZEN.

Akademisch Proefschrift

DOCTOR IN DE WIS- EN NATUURKUNDE,

AAN DE HOOGESCHOOL TE UTRECHT,

Dr. C. H. C. GRINWIS,

MET TOESTEMMING VAN DEN ACADEMISCHEN SENAAT

TE VERDEDIGEN

JACOBUS CORNELIUS KAPTEYN,

BARNEVELD,
P. ANDREÆ MENGER,
1875.

Fig. 2.2 Title page of the PhD theses *On the theory of vibrating slabs and their relation to experiments* by Willem Kapteyn, submitted to the University of Utrecht to defend at 3 o'clock in the afternoon (15:00) on Friday, June 14, 1872 and *Study of vibrating flat membranes* by Jacobus Cornelius Kapteyn, submitted to the University of Utrecht to defend at 3 o'clock in the afternoon (15:00) on Thursday June 24, 1875 (Both theses were printed in Barneveld by P. Andreæ Menger)

2.5 Kapteyn's Supervisor and Astronomy in Utrecht

In the 1870s, the decade in which Kapteyn and two of his brothers obtained a doctor's degree, a number of persons in this country who were later to become famous scientists, wrote their PhD theses in natural sciences. Chief among these were the contemporaries of Kapteyn, and later Nobel Prize winners Johannes Diderik van der Waals (1837–1923) of Leiden University (*On the continuity of the gaseous and the liquid state*; 1873), Jacobus Henricus van 't Hoff (1852–1911) of Utrecht University (*Contribution to the understanding of cyanoacetic acid and Malonic acid*; 1874), Hendrik Antoon Lorentz (1853–1928), also of Leiden (*On the theory of reflection and refraction of light*; 1875), and Heike Kamerlingh Onnes (1853–1926) of the University of Groningen (*New proofs of the rotation of the Earth*; 1879).

In Utrecht, Kapteyn and two of his older brothers all obtained their doctorates with Grinwis as their supervisor. Willem Kapteyn (1849–1927) and Nicolaas Pieter Kapteyn (1845–1916) obtained their doctorates on the same date, June 14, 1872. The titles of their theses were *Over de theorie van trillende platen en haar verband met experimenten* (On the theory of vibrating slabs and the relation to experiments) and *Over de rekening met symbolen en de toepassing daarvan op de integratie van differentiaal-vergelijkingen* ((On the calculus with symbols and the application thereof on the integration of differential equations). Nicolaas Pieter received the judicium *magna cum laude* and Willem *cum laude*. Kapteyn followed three years later (June 24, 1875), also *magna cum laude*, with the thesis *Onderzoek der trillende platte vliezen* (Study of vibrating flat membranes).

Theses are being accompanied by propositions ('stellingen'). Such propositions (which have survived in Dutch universities to this day, except – as it turns out – in the University of Utrecht!) are a set of statements of a scientific nature, the first few of which may be related to the subject of the thesis itself and the rest is usually of a more general nature. The candidate should be prepared to defend these at the promotion ceremony. In the days of the Kapteyn brothers it was also possible to obtain a doctor's degree solely on presenting and defending a set of propositions. We find these identified as such in the *Album Promotorum Utrecht* [7], which lists all PhD theses, and shows that this happened almost exclusively in the Faculty of law and not at all in the natural sciences.

In the year 1872, a total of thirty doctor's degrees were awarded by the University of Utrecht. Seven were on propositions only (in the Faculty of law), eleven *cum laude* and another eleven *magna cum laude* (and one without a judicium). Of these thirty, six were in the Faculty of mathematics and natural sciences, three *cum laude* and three *magna cum laude*. In 1875 the university awarded 51 doctor's degrees. In this year 18 were on propositions only and one *honoris causa*, 16 *cum laude* and 16 *magna cum laude* (and, once again, one without a judicium). Of these, six were in the Faculty of mathematics and natural sciences again, albeit only one *cum laude* and five *magna cum laude*. It appears that the judicium *magna cum laude* was an honorable but not exceptional distinction.

Grinwis had 18 PhD students, according to the *Mathematics Genealogy Project* [8]. When we look at the titles we see that only five theses were in the field of pure mathematics (the one by Nicolaas Pieter Kapteyn being one of them), but most of them were in what we would now call applied mathematics. The ones by Willem and Jacobus Kapteyn are closely related. As we will see, the further lives of these two brothers show more parallels; they both became university professors, for example. Willem and Jacobus would later collaborate on some research projects in mathematics and publish a few joint papers. They even wrote one on an astronomical subject (*On the distribution of cosmic velocities*; Kapteyn & Kapteyn (1900), see appendix A.). The question arises why Willem was awarded the 'judicium' *cum laude* and Kapteyn *magna cum laude*. I will therefore discuss and compare the two theses.

But before looking into them in more detail, I will first address the question as to what could possibly have been the reason that Kapteyn did not produce a thesis in astronomy. Astronomy has a long tradition and history in Utrecht, as documented in detail by astronomers C. (Cees) de Jager, H.G. (Henk) van Bueren and M. (Max) Kuperus: *Bolwerk van de sterren* [10]. This book was written on the occasion of the celebration of 350 years of astronomy in Utrecht, in 1993. It is the basis of most of the contents of the next few paragraphs.

The first observatory was installed on a tower (the 'Smeetoren') on the walls of Utrecht in 1642, not long after the university had been founded. This tower was used by the guild of blacksmiths (the name Smee-tower comes from the Dutch word

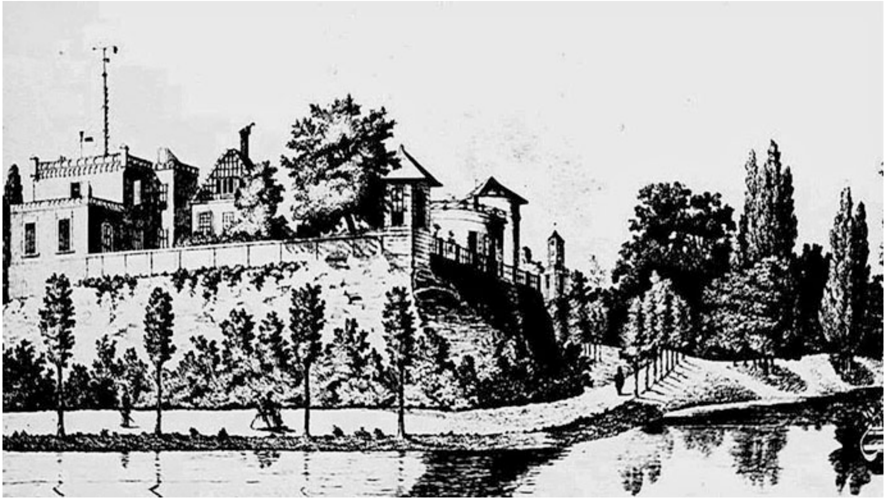

Fig. 2.3 Sonnenborgh not long after the Observatory and the Meteorological Institute were established here. The two towers were built to enable observing (Koninklijk Nederlands Meteorologisch Instituut [9])

'smeden' or forging); it had been built in 1145 and the sharp steeple was removed to leave an eight-sided platform fitted with a roof to enable astronomical observing. It was torn down in 1855; the observatory and the associated meteorological institute had been moved to a new location in 1854, on top of the old Sonnenborgh bastion or bulwark, which dates from 1552 and was built as part of the city fortification walls to provide cannon emplacements. Buys Ballot was very much involved in this, establishing the first meteorological institute there in 1854, together with the astronomical observatory (see Fig. 2.3). It has been a museum since the Utrecht astronomy department moved to the Uithof campus outside and to the east of Utrecht in the 1970s. Sonnenborgh is the oldest cupola (dome) observatory in the Netherlands. Eventually there were four large telescopes to study the Universe. Until 2002, the Merz Telescope from 1863 was one of the larger (night) telescope of its kind in the world [11]. Sadly, Utrecht University decided in 2011 to close its astronomy department, abruptly ending a tradition of 370 years of excellence and recognized first-class research (see the symposium *370 Years of Astronomy in Utrecht* [13]).

Adolf Stephanus Rueb (1806–1854) had been appointed lecturer in astronomy in 1843, relieving Buys Ballot from his astronomy teaching. Rueb was also in charge of the astronomical observations at the observatory. His appointment was an upgrade of the position of observator, which had been instituted under Moll. This means that in 1843 astronomy was actively practiced in Utrecht as a discipline for the first time. Rueb had supervised the construction of the building of the observatory on the Sonnenborgh, but died in 1854 before it was completed. Again Buys Ballot had to take over the teaching of astronomy until in 1856 Jean Abraham Chrétien Oudemans (1827–1906) was appointed Rueb's successor, but now as an extraordinary profes-

Fig. 2.4 Jean Abraham Chrétien Oudemans (1827–1906) and Martinus Hoek (1834–1873) (Universiteismuseum Utrecht [12])

sor. Oudemans had been a student of Frederik Kaiser (1808–1878) in Leiden, who regarded Oudemans as his best student. However, Oudemans accepted in 1857 a position as senior engineer for the Geographical Service of the Dutch East Indies, and after a period in which Buys Ballot was once again forced to take over the teaching of astronomy, Martinus Hoek (1834–1873) was appointed in 1859. Figure 2.4 shows Oudemans and Hoek.

The first doctor's degree that was awarded in Utrecht on an astronomical subject or under a supervisor who was professor of astronomy dates from 1880, according to *Bolwerk van de sterren*. The title of the thesis was *Planeet 182 (Elsbeth)*, the candidate J. Robbers and the supervisor Oudemans. Minor planet 182 was discovered on February 7, and is now designated 'Elsa' 1878 [15] (see Box 2.1 for objects in the Solar System known in 1870). Oudemans must have taken up this PhD thesis project after he returned from the Indies. Buys Ballot had PhD theses written under his supervision when Kapteyn was a student in Utrecht; the nearest in time to Kapteyn's were those by Abraham Johan Verweij, 1874, *De waarnemingen der bevolkingsstatistiek* (Observations of population statistics) and Eiso Henricus Groenman, 1877, *Iets over den invloed van de temperatuur op het magnetisme van ijzer en staal* (On the influence of temperature on the magnetic properties of iron and steel). The only astronomical one under Buys Ballot had been much earlier, in 1871, by Adrianus Jacobus Sandberg *De orbita Undinae* (On the orbit of Undina). Undina is a minor planet, no 92, discovered on July 7, 1867. The list of astronomical theses in Utrecht in *Bolwerk van de sterren* has overlooked this one.

So we see that Hoek was the professor of astronomy during most of the time that Kapteyn was a student of Utrecht University. But Hoek was in poor health and

Box 2.1 The Solar System in 1870
As far as people around 1870, when Kapteyn entered university, were aware of, the **Solar System** looked as follows:
Apart from the Sun in the center, all eight **planets** were known; in addition to Mercury, Venus, Earth, Mars, Jupiter and Saturn, which could be seen with the naked eye, another two that could only be seen with telescopes, had been discovered: Uranus (accent on first syllable) in 1781, by Sir William Herschel (1738–1822), and Neptune in 1846, by Johann Gottfried Galle (1812–1910), after its position had been predicted by Urbain le Verrier (1811–1877) on the basis of perturbations of Uranus' orbit.
Apart from the Moon, the only known **moons** or **natural satellites** of other planets in 1870 were four for Jupiter, eight for Saturn (in addition, its ring had been known since Christiaan Huygens (1629–1685) recognized it as such in 1655), two for Uranus and three for Neptune.
Comets had been known to be objects on highly eccentric orbits ever since Edmond Halley (1656–1742) realized that the comets of 1531, 1607 and 1682 had very similar orbits and actually involved the same object, which subsequently became known as Halley's comet. His prediction in 1705 that it would reappear in 1758/59 was confirmed.
Minor Planets or **asteroids** reside in the large gap between the orbits of Mars and Jupiter. The first one, Ceres, was accidentally discovered on the first day of the eighteenth century, January 1, 1801, by Giuseppe Piazzi (1746–1826). By 1870, about 200 were known.

did little observing, concentrating on experiments and theory, not only in astronomy but also in physics. He is widely known for his interferometric work, published in 1868 (for a description of his experiment see *The Hoek Experiment (1868)* by Doug Marett [16]), in which he looked for the effect of a dragging by the Earth of the ether that was supposed to propagate light; he found no such effect, but his results were not sufficiently convincing to take it as proof of the non-existence of ether. As is well-known, this issue was settled in the end by the famous experiment of Albert Abraham Michelson (1852–1931) and Edward Williams Morley (1838–1923) in 1887. Hoek also advanced the concept of groups of comets (comets that have very similar orbits resulting from the breaking up a single 'mother-comet') and on this basis worked out a theory for the origin of comets. Hoek's last publication listed in the Astrophysics Data System (ADS) is a paper on this subject of 1868, *On the phenomena which a very extended swarm of meteors coming from space presents after its entry into the Solar System* [17], and it is very likely that he did little astronomical research after that; in fact he never had a PhD thesis written under his supervision. Hoek died in 1873 at the very young age of 39 years and Oudemans, who was wrapping up his work in Java, was asked to return to Utrecht. He did not arrive until 1875, around the time Kapteyn was *completing* his PhD thesis. Buys Ballot had once more taken over the responsibility for astronomy in Utrecht. If Kapteyn had been interested in doing a PhD thesis on an astronomical subject in addition to the astronomical courses he had followed, it would have been very difficult to do so. Hoek had died in 1873, Buys Ballot had little interest in astronomical research and

Oudemans had not returned from his work in the East Indies yet. A mathematical thesis under Grinwis seemed the only realistic option.

We know from the *Utrechtse Studenten Almanak* [18] that astronomical subjects were taught extensively in Kapteyn's (undergraduate) student days (I consulted the Almanak for the years 1868 through 1874). There is very little variation from year to year. Buys Ballot gave lectures on 'experimental physics', 'analytical engineering', 'meteorology', 'analytical geometry and higher algebra' and sometimes selected topics in physics, while he also gave practical courses in experimentation. Grinwis taught 'mathematical physics', 'fundamentals of mathematics', 'integral and differential calculus' and 'spherical geometry'. During the majority of Kapteyn's years in Utrecht, Hoek offered courses in 'general astronomy' (described as 'popular astronomy', but not in the current meaning of the word popular), 'theoretical astronomy' and 'practical astronomy', while he usually offered (daily!) 'exercise in observational astronomy' as well. During most of Kapteyn's years, van Rees offered 'to assist students with their studies' even after he had retired. After Hoek's death in 1873, Buys Ballot again took over astronomy and in 1974 he gave three series of astronomical lectures, viz. 'popular astronomy', 'theoretical astronomy' and 'practical astronomy', in addition to four courses on physics-related subjects.

So, astronomy was definitely not neglected in the curriculum. Kapteyn had a wide choice and ample opportunity to be taught astronomy. There is no record of which students followed which courses, but it is very likely that Kapteyn made use of this broad range of subjects to choose from and consequently received extensive training in astronomical subjects as well as in mathematics, physics and possibly meteorology. His interest in astronomy, which was obvious even before he entered university – as is evident from the facts that as a teenager he made a map of the stellar sky and that his father made him a present of a telescope when he was a boy – must have developed to the extent that he formulated a relatively large number of propositions on astronomical matters in his thesis (as we will see below).

2.6 The Thesis of Willem Kapteyn

I will discuss the thesis by Willem Kapteyn first. His subject was the theory of vibrating slabs (see Fig. 2.2) and concerned the observation by the German physicist Ernst Florens Friedrich Chladni (1756–1827) that when a flat plate is covered with a powder and then made to vibrate by a violin bow, for example, the powder forms regular, symmetric patterns. Various famous scientists, such as Jacob (II) Bernoulli (1759–1789), Joseph-Louis Lagrange (1736–1813), Siméon Denis Poisson (1781–1840), Augustin Louis Cauchy (1789–1857) and Gustav Robert Kirchhoff (1824–1887), had worked on a theory for this. A prize competition on the subject of vibrating slabs, organized by the French Academy of Paris in 1810, had been won by the French female mathematician Marie-Sophie Germain (1776–1831). Germain, being a woman, met with great opposition on the part of her parents when she wanted to enter the field of mathematics (later on, she was likewise frustrated in her plans by the Paris École Polytechnique) and she never came to hold a formal position. She learned mathematics from her father's library and corresponded with Lagrange.

Willem's thesis started with a presentation of the basic theory behind the physics of vibrating slabs. He considered the mechanical work expended by the internal elastic forces when each infinitely small element is displaced by an infinitely small amount and equating that to the work exercised by the external forces. This had to do with behavior characteristic of the (elastic) properties of the material involved. The resulting equations were then treated first for a situation where the slab is infinitely thin and subsequently for the general case, but reduced to the mid-plane of the slab. This was valid as long as one limits oneself to transverse vibrations. Since the slabs were finite in extent, the results depended on the shape of the slab through a different set of equations that were applicable to the elements at the outer edges.

Willem Kapteyn compared his results to those of earlier studies. He concluded that the theory of Germain started from an incorrect assumption (viz., that the slab is in equilibrium), but in spite of that she 'accidentally' arrived at the correct equation of motion. In his book *Vibrations of Shells and Plates* [19], Werner Soedel agreed: 'Germain (1821) gave an almost correct form of the plate equation. The bending stiffness and density constants were not defined. Neither were the boundary conditions stated correctly. These errors were the reason that her name is not associated today with the equation, despite the brilliance or her approach'. (The book by Soedel has a excellent introductory chapter on the history of vibration analysis.) Willem Kapteyn then criticized a theory proposed by Jacob (II) Bernoulli as a generalization of work by his uncle Daniel Bernoulli (1700–1782), who had put forward a theory of transverse vibrations of flexible thin beams in 1735. Jacob had taken the important step to extend this by treating a slab as a collection of connected beams (incidentally, Willem Kapteyn invariably spelled the name Bernoulli incorrectly as Bernouilli). Without detailed discussion Willem Kapteyn discarded this theory, claiming it disagreed with observations. Soedel simply stated that Bernoulli's equation was incorrect. Willem Kapteyn mentioned the theories of Poisson and Cauchy omitting to discuss them in detail and demonstrated that these gave correct results for the case of a circular slab, for which the theory was the same as that developed by Kirchhoff. The conclusions of Willem Kapteyn corresponded to the historical section in Soedel's extensive and definitive book on the subject of vibrations.

Willem then went on to review experiments (performed by others) to which solutions of the equations given in his first chapter should be compared. Prominent are the observations by Chladni on rectangular and elliptical slabs (including square and circular ones as special cases) and by the British physicist Charles Wheatstone (1802–1875). The results of the experiments were classified according to patterns of the (lines of) nodes. Nodes are the positions on the slab where vibration is absent. An example of a node is the stationary point halfway along a string that vibrates in the first overtone. Nodes are observable by 'strewing sand on vibrating surfaces, commonly called acoustic figures' (taken from the title of Wheatstone's publication). Chladni used metal plates, those employed by Wheatstone were wooden.

On the final eleven pages Willem presents solutions to the (differential) equations for the case of circular slabs. These solutions had been given earlier by Poisson and in a different form by Kirchhoff. After comparing them to the experiments, he concludes that the analogy is 'good enough to assume that the actual differences can be ascribed to unavoidable measuring errors.'

The work in this thesis displays a good understanding of the issues, but does not really provide a great deal of new and original material; it is a re-discussion, occasionally presenting newly formulated results that have been obtained earlier. In addition, the comparison between theory and observation is very limited.

I conclude by considering the set of propositions accompanying Willem Kapteyn's thesis. He presents fourteen such propositions, the first four being directly related to the content of the thesis itself. Nos 5 through 9 are statements of a mathematical nature. The final five are of a diverse nature. No 10 is astronomical; it reads: *The explanation for the colors of stars as given by Christian Andreas Doppler is improbable*. Doppler (1803–1853) had discovered the effect named after him that light is shifted to shorter wavelengths when the object is approaching the observer and vice versa. He surmised that all stars are white and that their colors derive from different motions with respect to us. This was also criticized by Buys Ballot, among others, who noted that for a significant shift in color the radial velocity of the star would need to be a significant fraction of the speed of light and that this was highly improbable. Evidently, Willem Kapteyn agrees. His further propositions concerned matters such as calorimeters, explanations for the Ice Ages, the origin of life and the division of humankind into species rather than races.

Neither the propositions nor the thesis itself present much original work, as far as I can tell. However, it should be remembered that this was by no means uncommon in these days.

2.7 Kapteyn's PhD Thesis

The thesis of Jacobus Kapteyn is much along the lines of Willem's. Kapteyn begins by pointing out that studying membranes rather than slabs or plates is more straightforward, the reason being that experiments with slabs are less conclusive due to the variations in thickness, lack of homogeneity of the material and difficulty to support them. Membranes are supported along the edges and less vulnerable to inhomogeneities. Because of their relative simplicity, membrane vibrations are useful to study for the development of a theory of elasticity and in particular for a better understanding of hearing and sound.

The theory Kapteyn elaborates on is to a large extent a re-discussion of that of Poisson, who concentrated on the general rectangular case and the special case of a circular membrane. But Kapteyn had also available to him the work of Gabriel Léon Jean Baptiste Lamé (1795–1870), in particular on triangular membranes, Georg Friedrich Bernard Riemann (1826–1866) and Émile Léonard Mathieu (1835–1890), the latter for treating elliptical membranes.

Kapteyn's exposition is easier to follow than Willem's. This is no surprise, as the membrane analysis is a two-dimensional problem, whereas that of Willem Kapteyn's slabs is not (although it is not fully three-dimensional, since the slab is assumed to be of constant thickness and Willem mostly restricted himself to transverse vibrations in the central plane). In order to understand the import and purpose of the thesis, I discuss his approach in some detail. Kapteyn noted a simple equation of motion for a membrane, in which the co-ordinates of an infinite element are x,y, which experiences an infinitely small displacement w in the perpendicular direction. The equation is no more than Isaac Newton's law in the vertical direction, which says that the force equals the mass times the acceleration. For a more detailed treatment see Box 2.2 (and also chapters 2 and 6 of M.H. Sadd: *Wave Motion and Vibration of Continuous Media* [20]). Kapteyn showed how upon integrating this (differential) equation, one obtained an expression containing a superposition of waves of various frequencies. There are different ways of the membrane to vibrate. In Box 2.3 the mathematical details are given for a rectangular membrane. Figure 2.5 shows modern illustrations of some of the simplest modes in which a square membrane can vibrate. Note that (except in the first fundamental mode) there are straight lines which are stationary; these are the lines of nodes and they depend on the shape of the membrane. They can be used (as they are by Kapteyn) to classify the various modes. Generally speaking, these lines of nodes need not be straight.

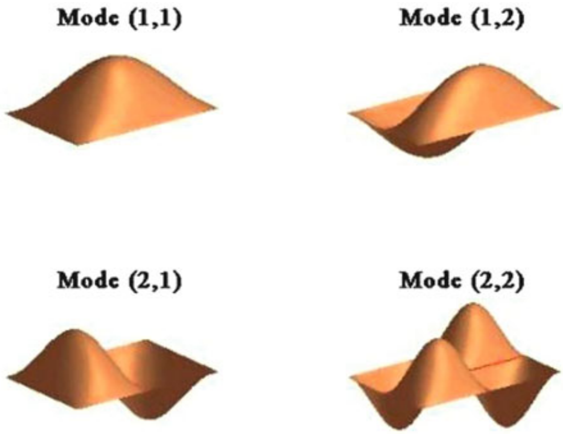

Fig. 2.5 Vibrations in some simple modes of a square membrane. This is a still from a movie animation (Institute of Sound and Vibration Research (ISVR) [22])

Kapteyn treated the square membrane in detail. In Fig. 2.6 I have collected some of Kapteyn's illustrations of nodes. The interesting conclusion is the occurrence of nodal *points*. This seems new and appears to be an original contribution to the theory. In addition, he supplied a detailed treatment of the theory of unilateral triangular and circular membranes, and a less in-depth treatment of elliptical membranes.

Box 2.2 The equation of motion in Kapteyn's vibrating membrane study
Take an infinitely small area of size ∂x and ∂y. Then we have

$$Fdy\frac{\partial^2 w}{\partial x^2}dx + Fdx\frac{\partial^2 w}{\partial y^2}dy = \rho dxdy\frac{\partial^2 w}{\partial t^2}.$$

Left is the force and right is mass times acceleration, both in the (vertical) *w-direction*. Start with the right-hand side. Here ρ is the mass surface density (mass per unit area) and this is multiplied by the area (so we get the mass of the element), and $\partial^2 w/\partial t^2$ is the w-acceleration. If w is the position, the first derivative $\partial w/\partial t$ is the change in w per unit time t and thus the velocity; the second derivative $\partial^2 w/\partial t^2$ is the acceleration (the change per unit time of the velocity).
Now look at the left, where we have two very similar terms. It is the total force *in the vertical direction*, one term comes from the x-direction, one from y. The first one shows the force arising from the stretching of the membrane in the x-direction, where F is the tension per unit length in the membrane (assumed the same everywhere in both x and y directions). The force in the x-direction on the area equals Fdy and is multiplied by a factor that projects it onto the w-direction (it equals the differences between the sinuses of the projection angles onto the w-direction at either end of the area). This then gives the component of the force in the w-direction arising from the stretching of the membrane in the x-direction. The second term is the same in the y-direction. This equation Kapteyn rewrites as

$$\frac{\partial^2 w}{\partial t^2} = c^2\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2}\right) \text{ with } c^2 = \frac{F}{\rho}.$$

The fundamental equation was first derived in this form by Poisson. It must be complemented with the conditions that the displacements w are zero at the edges only and the initial conditions that all w and dw/dt are zero at the start (time $t = 0$).

Kapteyn finally compared his theoretical results extensively to experiments in the relevant literature, in particular a comprehensive set of experiments by Justin Bourget and Félix Bernard ('Professeurs à la Faculté des Sciences de Clermont-Ferrand'), *Sur les vibrations de membranes carrées* [21], published in 1860. On the whole, these observations compared reasonably well to the theory, but no more than that, and he attributed this to problems with imperfections in the experiments, particularly inhomogeneities in the thickness and tension across the membranes used. It was the basis of his first proposition: *I. The agreement between theory and observation concerning vibrating membranes is not completely satisfactory.* Concerning the nodal *points*, Kapteyn noted that Bourget and Bernard observed them although, as far as I can see, only with respect to tones $N(p,1)$–, but provided an incorrect interpretation. In Kapteyn's own words: 'Bourget and Bernard, who

Box 2.3 Kapteyn's solutions for the rectangular membrane
Assume a rectangle with sides a and b.

$$w = \sum_{i=0}^{\infty}\sum_{j=0}^{\infty}(A_{ij}\cos\gamma t + B_{ij}\sin\gamma t)\sin i\pi\frac{x}{a}\sin j\pi\frac{y}{b}.$$

The constants A_{ij} and B_{ij} are found by applying the boundary and initial conditions. Each term ij then represents a vibration with frequency

$$N(i,j) = \gamma/2\pi = \frac{c}{2}\sqrt{\frac{i^2}{a^2}+\frac{j^2}{b^2}}.$$

Restricting to *square* membranes ($a = b$) gives the following results. The tones allowed have frequencies in the ratio $\sqrt{2}:\sqrt{5}:\sqrt{8}:\sqrt{10}:\ldots$, which equals $1 : 1.58 : 2 : 2.24 :\ldots$. The system of lines of nodes for tone $N(p,q)$ is determined by the equations

$$A_{p,q}\sin\frac{p\pi x}{a}\sin\frac{q\pi y}{a} + A_{q,p}\sin\frac{w\pi x}{a}\sin\frac{p\pi y}{a} = 0,$$

$$B_{p,q}\sin\frac{p\pi x}{a}\sin\frac{q\pi y}{a} + B_{q,p}\sin\frac{w\pi x}{a}\sin\frac{p\pi y}{a} = 0.$$

restricted themselves to Lamé's theory, have, just like him, overlooked the theoretical necessity of nodal points.' Kapteyn's second proposition expressed this: *II. the theory of the membrane can be pronounced complete only with the theoretical derivation, given in this thesis, of nodal points of the square membrane*. Here we have something in his thesis that appears original. He also remarked that such nodal points could only be seen in experiments when the tension across the membrane was extremely uniform. In modern textbooks, such as those by Soedel or by Sadd (but see also He & Fu [23]), little attention is paid to these nodal points. These may be formal solutions, whose usefulness or applicability in practice is limited.

2.8 Propositions

I look at Kapteyn's propositions in some detail. He had 18 of them. As we have seen, the first two were on his thesis subject. Nos 3 through 9 were concerned with mathematics or mathematical physics. But his propositions 10 through 16 were on astronomy, and the last two had a biological scope.

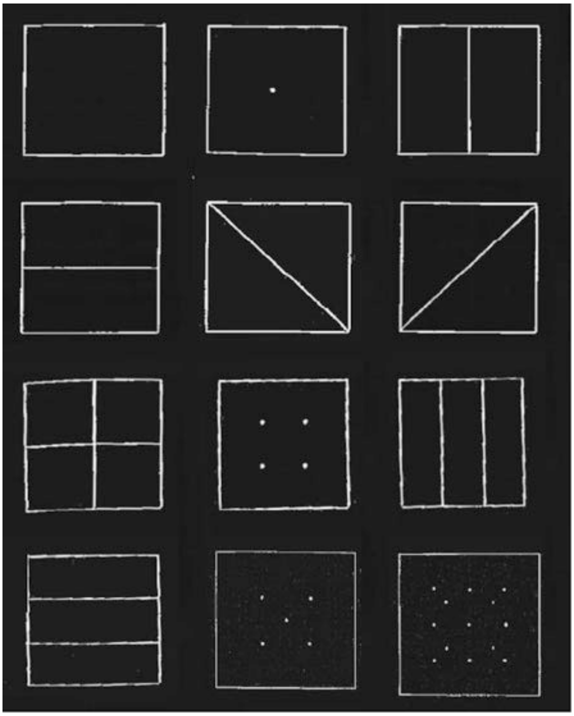

Fig. 2.6 Lines of nodes and nodal points for a square vibrating membrane from Kapteyn's thesis. In the top-left the wavelength is twice the sides of the square, so that the only nodes are the edges. This mode is designated as $N(1,1)$, according to a classification scheme of Lamé. The next five (the next two in the top row and the three in the second row) are the cases $N(2,1)$. The third and fourth rows have $N(2,2)$, three cases for $N(3,1)$, $N(3,2)$ and $N(4,3)$

No VII merits a closer look, not so much for reasons of the content but rather because of the person he was referring to. It reads: *VII. The assertion by Multatuli that the profit of the casino is not a result of the advantage of the presence of a zero which, according to him 'can for my part be completely abolished', is incorrect.* Eduard Douwes Dekker (1820–1887), who used the pen name Multatuli (literally: 'I have suffered much'), was a 19th century Dutch novelist and essayist and had been a major source of inspiration to Kapteyn (see page 110). He was quickly drawn to the non-conformist views upon society and religion promoted by Multatuli, in particular those protesting the exploitation of the indigenous population of the Dutch East Indies (the current Indonesia) by the Dutch administrators, in his most famous book *Max Havelaar*. Reading Multatuli (and also Jean-Jacques Rousseau) must have played a major role in Kapteyn's rejection of the dogmatic religion of his parents. We know from the HHK biography that Kapteyn had read almost all of Multatuli's works and may have stumbled on this remark, which was probably meant by Multatuli as a protest against a suspected unfairness of the operators of casinos.

Five of the seven astronomical propositions concerned matters such as the theory and orbits of comets, apparent size of the Sun and the Moon on the sky and sunspots (which he thinks are cyclones). It demonstrated an active interest in astronomy and astronomical publications, for it seems unlikely that he would have chosen propositions without it. Clearly, these subjects must have been close to his heart and it

Box 2.4 Brightness and magnitudes in astronomy
For historical reasons, astronomers express the **apparent brightness** of a star in **magnitudes**. This concept has come down to us from antiquity, which is why the scale was not rigorously defined at first. Eventually the scale became accurately established keeping the historic values roughly conserved as a logarithmic one, such that 5 magnitudes corresponds to exactly a factor 100 (and thus one magnitude to a factor $10^{0.4} = 2.512$). This definition was established by the British astronomer Norman Robert Pogson (1829–1891), who proposed this scale in 1856.
To the naked eye the brightest star is Sirius at a magnitude of -1.5; the faintest that can be seen are about magnitude 6. This represents a factor of 1000 or so in brightness. To give an idea, the Pole-star (Polaris) is of magnitude 2.0. The majority of the visible stars in the well-known constellations Ursa Major (Big Dipper), Cassiopeia or the belt of Orion (accent on the second syllable 'ri') have magnitudes between roughly 1.7 and 2.4 or differ by only a factor two or so. But their distances range from 65 to 1300 lightyears, or by a factor 20.
In order to correct the apparent magnitude of a star for its separation from us the **absolute magnitude** is defined by calculating the magnitude of a star if its distance were 10 parsecs or about 32.6 lightyears (see Box 5.6 for the definition of the parsec). This definition of absolute magnitude was introduced by Kapteyn.

seems he was actively pursuing and extending his knowledge and understanding of this discipline. In this context, there are two propositions that I have examined in more detail, viz., nos 10 and 15.

X. The best photometer is that of Zöllner. For a good understanding of this, we need to go into the practice of astronomical photometry in some more detail. Johann Karl Friedrich Zöllner (1834–1882) developed a photometer to accurately determine the brightness of stars in 1858. Originally the assignment of stellar magnitudes (see Box 2.4) was done by a visual estimate when comparing two stars in the telescope. However, in the early nineteenth century this started to change. For example, Sir John Frederick William Herschel (1792–1871), son of Sir William Herschel, used a device that he called an 'astrometer', in which he compared the particular star to a reduced image of the Moon, reflected by a prism and focused into the field of view with a lens. Carl August von Steinheil (1801–1870), of Munich, had developed a device in which out-of-focus images of stars were compared to estimate brightness ratios. His device was a telescope with an objective lens (at the front of the telescope) cut into two parts which could be moved independently. He brought two star images into the same field of view and then, with both stellar images out of focus, he adjusted one of the half-objectives until both images had the same surface brightness.

Zöllner's photometer (see Fig. 2.7) made use of a suggestion by François Jean Dominique Arago (1796–1853) to use polarization of light , which he had discovered together with Augustin-Jean Fresnel (1788–1827). This is the property of light, when regarded as a wave, that the wave can oscillate in different planes. Sometimes

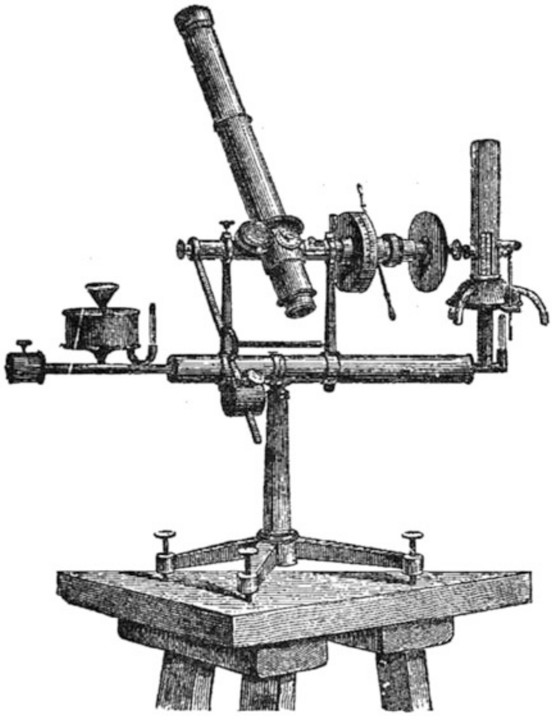

Fig. 2.7 In the Zöllner photometer, the light of a flame (in the tube on the right) is focused into the field of the telescope through a diaphragm. Between the flame and telescope a rotating polarizer was used to decrease the brightness of the resulting artificial star. The structure on the left acts as a counterweight (Efron Encyclopedic Dictionary [24])

the discovery is credited to Christiaan Huygens (1629–1685), who discovered the double refraction that occurs when light passes a crystal such as Iceland spar. This effect, in which the different polarizations of light have different refractive indices depending on how they are aligned with the crystal, indeed results from polarization, but Huygens proposed a different explanation. By using a transparent plate that transmits light of only a particular polarization, one selects a limited range of planes of vibration. Using another such plate (or prism), the light can be fully extinguished if the two polarizations are perpendicular or completely transmitted when the two are parallel. In intermediate cases a certain percentage of the light is transmitted. Zöllner, in his photometer used a controllable flame (in a Bunsen burner so that it is very stable) and diaphragms to produce an artificial star image that was projected into the field of view. Using a fixed and a rotating polarizing element, the apparent brightness of the artificial star could then be adapted until it was the same as that of the 'real' star. The amount of rotation of the polarizer can be calibrated using stars of known brightness and this way the magnitude of stars can be determined quite accurately. A detailed and interesting discussion of the instrument, including the construction of a replica, can be found in two papers by Klaus B. Staubermann: *The trouble with the instrument: Zöllner's photometer* and *Making stars: Projection culture in nineteenth-century German astronomy* [25].

The Zöllner photometer revolutionized stellar photometry and remained in use for many decades. In 1922, J. van der Bilt in *Note on the photometric scales of Pickering and Parkhurst* [26] reports on the use of the Utrecht Zöllner photometer (at some point in time Utrecht apparently owned such a photometer) mounted on a Leiden telescope to compare the inconsistent magnitude scales as given by Yerkes and Harvard observatories. These photometers were complemented and gradually replaced by photographic techniques and modern photo-electronic devices. An excellent review of *the development of astronomical photometry* was written by Harold F. Weaver in 1946 [27].

This proposition demonstrates Kapteyn's early interest in astronomical instrumentation and the measurement of stellar properties. Zöllner photometers were extremely popular at the time when Kapteyn was working on his thesis and they were used on a large scale; Utrecht Observatory almost certainly possessed one. In spite of the kind help of the staff of the Utrecht University Museum, it has not been possible to find an inventory that proves that Utrecht actually possessed a photometer as early as the 1870s. It cannot be denied that the proposition is hardly original, since there were no other accurate photometers to compete with Zöllner's. In that sense Kapteyn's proposition was the equivalent of forcing an open door. However, knowledge of the existence and purpose of such instruments was limited to a very specialist circle and it is unclear how Kapteyn would have known about them, let alone be acquainted with their use, had he not had a lively interest in astronomy and been aware of the instruments at the observatory, their operation and pitfalls.

The other proposition to consider in more detail is no 15. It reads: *XV. The average proper motions of stars of various magnitudes is not inversely proportional to their distance.* This is remarkable, as the matter of distances of stars as inferred by their proper motion would later become a major focus of his scientific efforts. It already shows that he foresees that deriving distances of stars in a statistical manner requires careful treatment; at least he must have looked into the possibility and maybe have tried it seriously on actual data in order to formulate this proposition. In addition, there was some literature on the subject that Kapteyn just may have seen which had been published in the major astronomical journal 'Monthly Notices of the Royal Astronomical Society', and which was present in the Utrecht University Library (the catalog shows ownership of a copy back to the first volume in 1827). Relevant papers that Kapteyn may have used to formulate this proposition include: George B. Airy: *On the movement of the Solar System in space*, Edwin Dunkin: *On the movement of the Solar System in space, deduced from the proper motions of 1167 stars* (1859) and Richard A. Proctor: *Note on the Sun's motion in space and on the relative distances of the fixed stars of various magnitudes* (1869) [28]. The last one in particular is relevant. Richard Anthony Proctor (1837–1888), a British writer and self-employed astronomer, concluded from a discussion of the fundamental data on proper motions of 1167 stars, that large proper motion is a better indication of a small distance ('argument for proximity') than apparent brightness. This study and this proposition were very much along the lines of Kapteyn's much later research, and his remarks in this proposition were a prelude to his extensive attempts to find a statistical method to derive stellar distances using their proper motions (see page 292). Once again, this proposition implies more than just a superficial knowledge of and interest in astronomy.

Kapteyn's thesis demonstrates some originality in both the work itself and the propositions, which may be the reason for his *magna cum laude*. He must have had an eye for experimental data, but above all it suggests that even at this early point in his career he was thinking much about astronomical matters. It is interesting to note that the Kapteyn Room in the Kapteyn Astronomical Institute (see Preface) does not contain a copy of the thesis, although Kapteyn collected reprints of all his publications and even had them bound in leather volumes. Maybe he simply did not feel this piece of work was special and worth keeping.

2.9 Catharina Elisabeth Kalshoven

While a student in Utrecht, Kapteyn became acquainted with his future wife, Catharina Elisabeth (Elise) Kalshoven. He was probably introduced into the Kalshoven family through Elise's half-sister Jacqueline (see Table 2.1.). The latter married Simon Brouwer (1833–1920) in 1873, who was a notary and, although Kapteyn's senior by almost twenty years, may still have been active in the student society of which Kapteyn was also a member (see page 31). Brouwer lived in Maarssen, in the same village close to Utrecht where the Kalshoven family lived. There is reason to believe that this is the way Kapteyn and Catharina Elisabeth Kalshoven met, for in one of the *Love Letters* (of November 22, 1878) Kapteyn expresses his concern with regard to Jacqueline being ill, noting that he 'owes much, probably the largest share in his life's happiness' to her. I again quote from the *HHK biography*, since this narrative must almost certainly be based on what Henriette Hertzsprung-Kapteyn was told by her mother.

> 'During his last year in Utrecht he made the acquaintance of the Kalshoven family, who turned out to be completely different from the Kapteyns. They could be described as antipodes. No heavy responsibilities were laid on the shoulders of the two young daughters, they did not study or have a job, the atmosphere was cheerful and cozy, life was enjoyed in a simple and relaxed manner. Gaiety, music and courtship, all those enchanting things in a young person filled the atmosphere. Mrs Kalshoven was a woman of fine, civilized manners and culture. As a young girl she had married the wood merchant Kalshoven, who was a widower with five children. Together they had another three, two girls and one boy. It had been a heavy task for the lively young girl, who came from a quiet, untroubled life in Harderwijk, where her father was the 'conrector' of the local Gymnasium, and now she had moved to a large old-fashioned house on the Singel in Amsterdam. Her husband's business was not flourishing and the family decided to move to Abcoude, where life was expected to be easier and less expensive.'

Table 2.1 Kapteyn's brothers and sisters-in-law. They were all born in Amsterdam. See Table 1.1 for their parents

Jacobus Wilhelmus Kalshoven and Catharina Elisabeth Brandt		
Willem Johan Christiaan	Sept. 13, 1839	Dec. 11, 1881 – Batavia
Elisabeth Wilhelmina	Oct. 17, 1840	June 4, 1860 – Amsterdam
Johan Christiaan	June 27, 1842	Sept. 10, 1842 – Amsterdam
Johannes Christiaan	Febr. 7, 1844	March 9, 1920 – London
Jan Anton	Jan. 31, 1845	April 17, 1928 – Amsterdam
Jacqueline Wilhelmine	June 4, 1846	April 2, 1926 – Den Haag
Jacobus Wilhelmus Kalshoven and Henriëtte Mariëtte Augustine Albertine Frieseman		
NN	March 5, 1854	(stillborn)
Catharina Elisabeth (Elise)	June 19, 1855	March 2, 1945 – Amsterdam
Marie Gabrielle (Marie)	June 7, 1857	Nov. 17, 1940 – Borger
Jacobus Wilhelmus (Jacques)	Dec. 30, 1859	Febr. 7, 1941 – Den Haag

A 'conrector' is the deputy of the rector or principal of a gymnasium (or grammar school). Harderwijk, which is also where the university was located mentioned in the beginning of this chapter, is a small town a little north of Barneveld, situated on what was then called the Zuiderzee. Most inhabitants made a living out of fishing and the related industry. Singel in Amsterdam is a canal that originally served as a protective moat that ran around the city in the Middle Ages, situated inside the system of canals that was dug in later centuries as Amsterdam expanded. Abcoude is a small municipality to the south-east not far from Amsterdam, in the province of Utrecht.

> 'Mrs Kalshoven was a strong woman, who accepted the circumstances and adjusted to them, and [she and her family] enjoyed happy years after the difficult times in Amsterdam. Her stepchildren grew up and left home, and after the death of her husband, Mrs Kalshoven and her own children moved to Utrecht [really Maarssen near Utrecht], where she had to live a simple and frugal life. As she became older, she had more and more difficulty walking and became restricted to her chair. She underwent these tribulations with resignation, but there were also days when she found it difficult to accept her handicap and hated having to rely on help and assistance. She would then complain and moan, but when she had visitors she became gay and happy, so that the two healthy daughters would look at each other and conclude it was not so serious after all. Being healthy youths they could not imagine what it meant to be an invalid.
>
> The mother was surrounded by a warm love, especially from her elder daughter Elise, who was the quieter and more serious of the two. She did her domestic duties without complaining, and the greatest joy was to sit at the piano and to play whatever came to her mind. She had a great talent for music and she further developed it by herself, since there was no money for music lessons in this simple family. Marie, the younger sister, had a beautiful singing voice and the two girls could spend hours playing and singing. Marie would think of a song and start singing, Elisa followed

Fig. 2.8 Kapteyn as a young man, probably sometime during the 1870s (Kapteyn Astronomical Institute [20])

on the piano, which went without much effort, since she was a very gifted musician. However, she failed to develop these talents by having lessons and much practice . And maybe that was not really necessary, as they were not persons given to serious study and work. They rather lived as the birds in a forest, singing and cheering when they wanted to, when the sun was shining and the sky was blue; and music brought them happiness throughout their lives. The mother had an impulsive character too and lived from one day to the next. She could not resist a beautiful summer's day and would then call out: 'Children, the Sun is shining, it is so lovely outside. We will have a carriage prepared and we will go on a tour.' The thrift and worries were forgotten for a moment and they went outside cheerfully.

Kapteyn enjoyed visiting the family and he became a regular guest. In this home he found the carefree way of living that he had never experienced at his home. There it had only been duty and work, here they did not immediately switch on the lamps to hover over books, but sat in the twilight as long as possible – with the voices of young girls singing and making fun in front of the open window, while all sorts of jokes were invented.

It was a lot of merriment, but Kapteyn did not fail to notice the more serious side of the character of the older girl. The small dark girl with the thick braids and the striking brown eyes possessed a dignified confidence, a caring soul and an absolute lack of self-awareness, so that she did not realize how beautiful she was. Since the girls had never gone to school and all they knew had been taught by a governess, they had never lost their authenticity, which gave them a certain noticeable charm.

One evening, when Kapteyn rang the doorbell of the Kalshoven house, the door was opened by Elise, who radiated happiness and joy. 'What happened?', he said, moved by her happiness. 'Oh, I am so happy, my brother [Jacques] has returned from the Indies.' Then he realized he wanted no other person to be his wife than this woman, who was the picture of happiness and, unlike many others, did not require to be made happy first. He had thought much about life, and made clear for himself what it was that constituted value and what not. His unique, genuine common sense had afforded him discernment and insight at an early age, when to others life was still a chaos of impulses and temptations. And he kept the picture of this young radiant girl in his heart, abiding his time.'

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