MASTER’S PROGRAMME ASTRONOMY

FACULTY OF SCIENCE AND ENGINEERING

UNIVERSITY OF GRONINGEN

QANU
Catharijnesingel 56
PO Box 8035
3503 RA Utrecht
The Netherlands

Phone: +31 (0) 30 230 3100
E-mail: support@qanu.nl
Internet: www.qanu.nl

Project number: Q0727

CONTENTS

This report was finalised on 1 October 2019

REPORT ON THE MASTER'S PROGRAMME ASTRONOMY OF UNIVERSITY OF GRONINGEN

This report takes the NVAO's Assessment Framework for the Higher Education Accreditation System of the Netherlands for limited programme assessments as a starting point (September 2018).

ADMINISTRATIVE DATA REGARDING THE PROGRAMME

Master's programme Astronomy

Name of the programme:	Astronomy
CROHO number:	60200
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specialisations or tracks:	Quantum Universe Science, Business and Policy
Location:	Groningen
Mode of study:	full time
Language of instruction:	English
Submission deadline NVAO:	01/11/2019

The visit of the assessment panel Physics and Astronomy to the Faculty of Science and Engineering of University of Groningen took place on 13, 14 and 15 May 2019.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	University of Groningen
Status of the institution:	publicly funded institution
Result institutional quality assurance assessment:	positive

COMPOSITION OF THE ASSESSMENT PANEL

The NVAO has approved the composition of the panel on 1 February 2019. The panel that assessed the master's programme Astronomy consisted of:

- Prof. dr. R. (Reinder) Coehoorn, full professor at the Eindhoven University of Technology, on the Physics and Application of Nanosystems. He is affiliated to the research group Molecular Materials and Nanosystems, in the Department of Applied Physics [chair];
- Prof. dr. M.J. (Margriet) Van Bael, professor at the Department of Physics and Astronomy of the Faculty of Science of the KU Leuven (Belgium);
- Prof. dr. G. (Garrelt) Mellema, professor at the Department of Astronomy of Stockholm University (Sweden);
- Prof. dr. S. (Sjoerd) Stallinga, professor and head of the Department Imaging Physics of Delft University of Technology;
- J. (Jeffrey) van der Gucht BSc, master's student Physics and Astronomy at Radboud University [student member].

The panel was supported by dr. B.M. (Barbara) van Balen, who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

The master's programme Astronomy at the Faculty of Science and Engineering of University of Groningen was part of the cluster assessment Physics and Astronomy. Between April 2019 and June 2019 the panel assessed 17 programmes at 5 universities.

Panel members
The panel consisted of the following members:

- Prof. dr. R. (Reinder) Coehoorn, full professor at the Eindhoven University of Technology, on the Physics and Application of Nanosystems. He is affiliated to the research group Molecular Materials and Nanosystems, in the Department of Applied Physics [chair];
- Prof. dr. M.J. (Margriet) Van Bael, professor at the Department of Physics and Astronomy of the Faculty of Science of the KU Leuven (Belgium);
- Prof. dr. H. A.J. (Harro) Meijer, professor of Isotope Physics, chairman of the Centrum voor Isotopen Onderzoek (CIO) and director of the Energy and Sustainability Research Institute Groningen at University of Groningen;
- Prof. dr. G. (Garrelt) Mellema, professor at the Department of Astronomy of Stockholm University (Sweden);
- Prof. dr. S. (Sjoerd) Stallinga, professor and head of the Department Imaging Physics of Delft University of Technology;
- Prof. dr. G. (Geert) Vanpaemel, professor for History of Science and Science Communication at KU Leuven Belgium);
- J. (Jeffrey) van der Gucht BSc, master's student Physics and Astronomy at Radboud University [student member];
- B. N. R. (Bram) Lap BSc, master's student Astronomy at University of Groningen [student member];
- L. (Laura) Scheffer BSc, master's student Physics at Utrecht University [student member].

For each site visit, assessment panel members were selected based on their expertise, availability and independence.

The QANU project manager for the cluster assessment was Peter Hildering MSc. He acted as secretary in the site visit of Leiden University and Utrecht University. In order to assure the consistency of assessment within the cluster, the project manager was present at the panel discussion leading to the preliminary findings at all site visits and reviewed all draft reports. Dr. Barbara van Balen acted as secretary in the site visits of University of Groningen and the University of Amsterdam/Vrije Universiteit Amsterdam, and drs. Mariëtte Huisjes was secretary at Radboud University. The project manager and the secretaries regularly discussed the assessment process and outcomes.

Preparation
On March 15 2019, the panel chair was briefed by the project manager on the tasks and working method of the assessment panel and more specifically its role, as well as use of the assessment framework.

A preparatory panel meeting was organised on May 12 2019. During this meeting, the panel members received instruction on the tasks and working method and the use of the assessment framework. The panel also discussed their working method and the domain specific framework.

A schedule for the site visit was composed. Prior to the site visit, representative partners for the various interviews were selected. See Appendix 4 for the final schedule.

Before the site visit, the programmes wrote self-evaluation reports of the programmes and sent these to the project manager. He checked these on quality and completeness, and sent them to the panel members. The panel members studied the self-evaluation reports and formulated initial questions and remarks, as well as positive aspects of the programmes.

The panel also studied a selection of theses. The panel studied the work and the assessment forms of 10 students, based on a provided list of graduates between 2017-2018. For this selection, the panel used the opportunity to select a lower number of theses as described in the NVAO framework when there is significant overlap between the assessed programmes in a single site visit. In the case of the master's programme Astronomy, this overlap consists of a shared Board of Examiners with the bachelor's programme Astronomy, as well as alignment of assessment procedures with the (Applied) Physics Board of Examiners and an overlap in teaching staff between all six programmes. A variety of topics and tracks and a diversity of examiners were included in the selection. The project manager and panel chair assured that the distribution of grades in the selection matched the distribution of grades of all available theses.

At the moment of the site visit, no recent theses for students in the SBP track were available to the panel, as no Astronomy students participated in this faculty-wide track in the past years. For the realised learning outcomes for this track, the panel refers to the reports of other panels that considered this track at the Faculty of Science and Engineering, for instance Chemistry and Mathematics.

Site visit
The site visit to University of Groningen took place on 13, 14 and 15 May 2019.

At the start of the site visit, the panel discussed its initial findings on the self-evaluation reports and the theses, as well as the division of tasks during the site visit.

During the site visit, the panel studied additional materials about the programmes and exams, as well as minutes of the Programme Committee and the Board of Examiners. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni and representatives of the Board of Examiners. It also offered students and staff members an opportunity for confidential discussion during a consultation hour. No requests for private consultation were received.

The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel chair publicly presented the panel's preliminary findings and general observations.

Report
After the site visit, the secretary wrote a draft report based on the panel's findings and submitted it to the project manager for peer assessment. Subsequently, the secretary sent the report to the panel. After processing the panel members' feedback, the project manager sent the draft reports to the faculty in order to have these checked for factual irregularities. The project manager discussed the ensuing comments with the panel's chair and changes were implemented accordingly. The report was then finalised and sent to the Faculty of Science and Engineering and University Board.

Definition of judgements standards
In accordance with the NVAO's Assessment framework for limited programme assessments, the panel used the following definitions for the assessment of the standards:

Generic quality
The quality that, from an international perspective, may reasonably be expected from a higher education Associate Degree, Bachelor's or Master's programme.

Meets the standard
The programme meets the generic quality standard.

Partially meets the standard
The programme meets the generic quality standard to a significant extent, but improvements are required in order to fully meet the standard.

Does not meet the standard
The programme does not meet the generic quality standard.

The panel used the following definitions for the assessment of the programme as a whole:

Positive
The programme meets all the standards.

Conditionally positive
The programme meets standard 1 and partially meets a maximum of two standards, with the imposition of conditions being recommended by the panel.

Negative
In the following situations:
- The programme fails to meet one or more standards;
- The programme partially meets standard 1;
- The programme partially meets one or two standards, without the imposition of conditions being recommended by the panel;
- The programme partially meets three or more standards.

SUMMARY JUDGEMENT

Standard 1
Astronomy as a discipline deals with the fundamental understanding of the universe, which involves quantitative observations, data processing and analysis, mathematical, physical and/or numerical modelling of the phenomena observed and putting them together to expand our understanding of the universe at small and large scales. The master's degree programme Astronomy aims to produce astrophysicists with the skills, knowledge and insight in a specialised and advanced area of the field of physics, i.e. advanced materials and the quantum universe, with a focus on insights and approaches to complex scientific problems. The programme translated this vision into intended learning outcomes (ILOs) within the framework of the Dublin Descriptors and the domain-specific reference frame. The panel established that the ILOs are formulated in line with the mission and sufficiently indicate what could be expected from students at a master's level. The ILOs reflect the content, level and orientation of the master's programme and match the professional field.

Standard 2
Students can choose between two tracks: Quantum Universe and Science, Business and Policy. The curriculum of the master's degree programme in Astronomy consists of an astronomy core, comprising advanced courses in basic astronomy topics (20 EC), a Quantum Universe core consisting of four advanced courses in Physics and Astronomy (20 EC), and 20 EC in electives. The students choose electives belonging to one of three specialisations: Theoretical and Observational Astronomy, Instrumentation and Informatics, and Data Science in Astronomy. The second year of the master's programme is dedicated to the master's research project of 60 EC. The specialisation Quantum Universe – Instrumentation and Informatics deviates slightly from this setup. This specialisation is more technically oriented. Students follow 30 EC of Astronomy and Instrumentation and Informatics courses, 20 EC of Quantum Universe core courses, an Information Technology project of 10 EC, an industrial internship of 20 EC and perform a research project of 40 EC.

The master's programme has a solid curriculum. There is a good alignment between it and the intended learning outcomes. The teaching forms used in the master's programme are in line with the level and the content of the curriculum.

The quality of the teaching staff is good. The panel noticed a strong improvement in the percentage of staff that is UTQ qualified. The university has an adequate policy and good intensive training programmes to enhance the didactic quality of the teaching.

The facilities of the Astronomy programmes are excellent and add to the quality of the programme in the panel's opinion. The panel encourages the management of the Faculty to keep these facilities on the same high level.

Standard 3
The programme director drafts an assessment plan annually at the programme level. In addition, a Course Unit Assessment Overview (CUAO) is available for each course.

The panel finds the assessment system and policy adequately developed and implemented. The courses use a variety of assessment methods, which are aligned with the ILOs and the curriculum. The procedures are transparent for teachers and students.
The panel is positive about the way the Board of Examiners is performing its tasks. Its role has obviously been extended and improved in the assessment period. The panel concluded that the examinations, tests and thesis assessment are transparent, valid and reliable. It particularly values the Course Unit Assessment Overviews (CUAOs) for all courses.

Standard 4
The panel verified the alignment between the ILOs of the programme and the courses and exams in the curriculum. It concluded that this alignment ensures that graduates have achieved the ILOs. It

studied a selection of ten master's theses and their assessments. The theses demonstrated that the minimum level required for a master's programme in Astronomy had been reached and had been exceeded in many cases.

The panel assesses the standards from the *Assessment framework for limited programme assessments* in the following way:

Master's programme Astronomy

Standard 1: Intended learning outcomes	meets the standard
Standard 2: Teaching-learning environment	meets the standard
Standard 3: Student assessment	meets the standard
Standard 4: Achieved learning outcomes	meets the standard
General conclusion	positive

The chair of the panel, prof. dr. Reinder Coehoorn, and the secretary, dr. Barbara van Balen, hereby declare that all panel members have studied this report and that they agree with the judgements laid down in it. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 1 October 2019

DESCRIPTION OF THE STANDARDS FROM THE ASSESSMENT FRAMEWORK FOR LIMITED FRAMEWORK ASSESSMENTS

The master's degree programme Astronomy is provided by the Faculty of Science and Engineering of the University of Groningen. This Faculty also offers the bachelor's degree programmes Physics, Applied Physics and Astronomy and the master's programmes Physics and Applied Physics which are also being assessed in this cluster assessment. This report concerns the assessment of the master's degree programme in Astronomy; the assessments of the other master's and bachelor's degree programmes are described in separate reports.

The Faculty of Science and Engineering (FSE) is a large faculty, its programmes in research and education range from nanomaterials and bio-machinery to astronomy and also include mathematics, pharmacy, neurosciences, computer science and biology. Research at FSE is carried out in a number of institutes. The master's degree programme Astronomy is strongly connected to the Kapteyn Astronomical Institute (Kapteyn).

Within the FSE, the master's as well as the PhD programmes are organised within the Graduate School of Science (GSSE). The master's programmes are managed by the director of the GSSE together with the programme directors of the respective programmes. The management of the daily affairs of the master's degree programmes in physics, applied physics and astronomy is in the hands of the programme director, programme coordinator and academic advisor. The master's degree programmes in Physics, Applied Physics and Astronomy are taught in English in an international environment.

Standard 1: Intended learning outcomes
The intended learning outcomes tie in with the level and orientation of the programme; they are geared to the expectations of the professional field, the discipline, and international requirements.

Findings
Astronomy as a discipline deals with the fundamental understanding of the universe, which involves quantitative observations, data processing and analysis, mathematical, physical and/or numerical modelling of the phenomena observed and putting them together to expand our understanding of the universe at small and large scales.

The University of Groningen offers one of the two master's programmes Astronomy in the Netherlands; the other one is offered by Leiden University. Other universities (University of Utrecht, the universities of Amsterdam, Radboud University Nijmegen) offer astronomy in combination with physics. The University of Groningen, together with the space scientists of SRON, located in the same building, has one of the largest concentration of astronomers in the Netherlands. In the panel's view, this gives the programme a good position.

The master's programme in Astronomy has the following objectives:
- To acquire skills, knowledge and insight in a specialised and advanced area of the field of physics, i.e. advanced materials and the quantum universe, with a focus on insights and approaches to complex scientific problems;
- To develop the ability to communicate the acquired knowledge clearly and concisely to others;
- To prepare students for a professional career; this means being able to carry out fundamental or applied scientific research in physics, as well as applying state-of-the-art scientific knowledge and mathematical, computational and experimental skills in physics in a wide variety of new practical situations.

All students follow the Quantum Universe track, a common track with the master's programme Physics, except for a very small minority that follows the faculty-wide Science, Business and Policy track.

The programme translated this vision into intended learning outcomes (ILOs) within the framework of the Dublin Descriptors (see Appendix 2) and the domain-specific reference framework (Appendix 1). This framework is used by all Physics and Astronomy programmes in the Netherlands. It was developed in a joint process at the European level (Tuning Physics) to align the Physics and Astronomy programmes at an international level. The panel established that the ILOs are formulated in line with the mission and sufficiently indicate what could be expected from students at a master's level. The ILOs reflect the content, level and orientation of the master's programme and match the professional field. The distinction between the ILOs of the bachelor's and the master's programme is clear.

The panel appreciates that since the last programme assessment, several improvements have been implemented. One of them concerns the establishment of an external advisory panel. This panel provides the programme management with feedback about the connection of the degree programme to developments in the field. Several mechanisms are in place to regularly update the ILOs and ensure that they keep pace with changes in society and the scientific discipline. The programme Master director keeps an overall eye on the programme to make sure that the various aspects of the curriculum remain balanced. The lecturers are involved in research at an internationally competitive level and are therefore aware of the latest developments in their field and incorporate them, where appropriate, into the courses they teach. Furthermore, regular staff meetings of the Kapteyn Institute are dedicated to teaching. The discussions in these meetings sometimes lead a curriculum committee being instated about a certain topic. The panel appreciates the improvements that the programme has taken in the last period and the mechanisms to ensure the regular evaluation and updating of the learning outcomes. It encourages the programme to continue in this line.

Considerations
The panel concluded that the intended learning outcomes of the master's degree programme Astronomy meet the Dutch qualification framework and the international standards. They sufficiently indicate the academic master's level.

The panel appreciates the strong research-oriented tracks offered in the master's programme. It values the improvements that the programme has taken in the last period and appreciates the mechanisms to ensure the regular evaluation and updating of the learning outcomes. It encourages the programme to continue in this line.

Conclusion
Master's programme Astronomy: the panel assesses Standard 1 as 'meets the standard'.

Standard 2: Teaching-learning environment
The curriculum, the teaching-learning environment and the quality of the teaching staff enable the incoming students to achieve the intended learning outcomes.

Findings

Curriculum
Students can choose between two tracks in the master's programme: Quantum Universe and Science Business and Policy. The curriculum of the master's degree programme Astronomy consists of an astronomy core comprising advanced courses in basic astronomy topics (20 EC), a Quantum Universe core consisting of four advanced courses in Physics and Astronomy (20 EC), and 20 EC in electives. The students choose electives belonging to one of three specialisations: Theoretical and Observational Astronomy, Instrumentation and Informatics, and Data Science in Astronomy. The

second year of the master's programme is dedicated to the master's research project of 60 EC performed at the Kapteyn Astronomical Institute, the Bernoulli Institute (Computer Science), ASTRON or, in special cases, elsewhere. The Quantum Universe – Instrumentation and Informatics specialisation deviates slightly from this setup. This specialisation is more technically oriented. Students follow 30 EC of Astronomy and Instrumentation and Informatics courses, 20 EC of Quantum Universe core courses, a project Information Technology of 10 EC, an industrial internship of 20 EC and perform a research project of 40 EC. The master's degree programme is taught in English in an international environment.

Students find the programme excellent and challenging, although they have some recommendations for adjusting the content of the core courses. They particularly recommend providing more dedicated core courses for the astronomy students. They indicated two courses, which are also part of the master's programme Physics: Electrodynamics of Radiation and Particle Physics Phenomenology. Both courses are crucial for Astronomy master's students in their opinion, but are too theoretical and too difficult because of the combination with Physics master's students. The panel learnt during the site visit that these suggestions, certainly with respect to the Particle Physics Phenomenology course, are being considered and encourages the management team to adjust the content of these courses to the needs of the Astronomy students.

Teaching forms

The programme is research-oriented but also takes the application-oriented approach. In the first part of the programme, the students take courses that are designed to deepen their knowledge and technical/observational skills in astrophysics. These courses prepare them for the research work that follows.

Teaching is hands-on; the lecture classes are small and most often contain tutorials and modes of instruction that require active participation by the students through assignments, presentations and reports. The teaching methods require an independent attitude of the student.
Training of research skills, academic skills as well as scientific integrity occurs throughout the programme. In the master's research project, students learn advanced research skills and acquire increasing autonomy in research as well as the capability to communicate research results to others.

During the research project, the students are embedded in a research group. This means that they meet on a frequent basis and discuss astrophysics with senior staff members, PhD candidates and fellow students.

The panel finds the teaching forms appropriate for the programme.

Feasibility

The academic year is divided into two semesters, each divided in two periods of eight instruction weeks followed by two exam weeks. In every period three course components of 5 EC are taught. The nominal workload for students is 40 hours per week. Students experiencing any problems that hinder his or her progress can contact the academic advisor to discuss them. The programme states that with the growing numbers of students (the enrolment increased from 4 in 2013 to 18 in 2017), it has started to monitor the students more closely. Relatively recently, a planning form for the master's research project has been provided in which deadlines are given for critical parts of the project and intermediate meetings. The students did not indicate any specific obstacles in the master's programme. They confirmed to the panel that the programme is feasible within two years.

Staff

The tenured staff members contributing to the programme all have a PhD degree and are actively involved in research. Some 82% of the active teaching staff has acquired a University Teaching Qualification (UTQ). The panel established that the master's programme is taught by experts strongly connected to the Kapteyn Institute and that tenured staff has sufficient didactical training The students are positive about the teachers. Since the number of students is small, the contact between the scientific staff and the students is intensive. This close contact is one of the most attractive aspects of the master's degree programme Astronomy according to the panel. The staff is aware that the student numbers will grow because of the increased number of bachelor students and will pay attention to this aspect.

The master's degree programme is taught in English in an international environment. This is necessary in the panel's view to achieve the level that is required for a master's degree in astronomy. An international academic environment community adds to the quality of the programme and prepares the students for their future career. The level of English proficiency of the teachers is sufficient.

The panel finds the quality of the teaching staff to be good.

Facilities
The Kapteyn Astronomical Institute is located in its own building called Kapteynborg. It has its own well-equipped lecture room for lectures and scientific meetings of the staff. It has two computer clusters with a total of 40 computer systems. These computers are equipped with general astronomical software and data reduction packages. The computers are used for computer practicals or assignments from other courses, and are available to Astronomy students for self-study. During the bachelor's and master's research project, the students have a flexible workplace (including computer and user account) in the institute.

Students find these working spaces to be excellent. However, with the expected increase in student numbers, working space for students could become a problem. The students think that more flex computer spaces are needed.

The University of Groningen has a modest astronomical observatory on the Zernike complex. This is one of the largest optical telescopes in the Netherlands. During the site visit the panel visited the Kapteyn Institute, saw the work spaces and the lecture rooms, got an introduction to the use of the dedicated computer facilities and had a tour of the observatory. It confirmed that the Astronomy degree programmes have excellent facilities. The facilities for the students enable them to be part of the scientific community. The housing of the Kapteyn Institute and the dedicated facilities add to the quality of the programme, in the panel's opinion.

Considerations
The curriculum of the master's programme Astronomy enables the students to achieve the intended learning outcomes. According to the panel, the master's programme offers a solid curriculum that gives students the opportunity to specialise and deepen their knowledge and skills. The students are thoroughly trained in research. The panel found the curriculum to be well developed, managed and implemented, and there is a good alignment between it and the intended learning outcomes. It appreciated that the programme contains a course on scientific integrity as part of the master's thesis project. The teaching forms used in the master's programme are in line with the level and the content of the curriculum.

The quality of the teaching staff is good. The panel noticed a strong improvement in the percentage of staff that is UTQ qualified. The university has an adequate UTQ policy and good intensive training programmes to enhance the didactic quality of the teaching.

The facilities of the Astronomy programmes are excellent and add to the quality of the programme in the panel's opinion. The panel encourages the management of the Faculty to keep these facilities on the same high level.

Conclusion
Master's programme Astronomy: the panel assesses Standard 2 as 'meets the standard'.

Standard 3: Student assessment The programme has an adequate system of student assessment in place.

Findings

Assessment policy
An assessment plan is drafted by the programme director annually and approved by the Faculty Board. This assessment plan consists of a list of examiners, modes of assessment of all course units, a list of individual Research Project supervisors, and a matrix clarifying the relationship between the learning outcomes of the course units and the final learning outcomes of the degree programme.. In addition to this assessment plan at the programme level, a Course Unit Assessment Overview (CUAO) is available for each course. This overview is a systematic description of the links between the learning outcomes, modes of instruction and modes of assessment and grading, and the position of the course in the curriculum. These overviews are updated annually. A summary of the CUAO is made available to the students. The panel studied several CUAOs during the site visit and was very positive about these dossiers in regard to quality assurance.

Most courses have written exams. There are often also homework exercises, written reports of larger projects, including programming in Python, written essays, and/or oral exams. As a rule, exams and assignments of course units are always drafted or checked by two lecturers (peer review). The Master Research Project is assessed using a standard assessment form based on four categories: scientific quality of research, management of research, colloquium/final presentation; report/thesis. At least two examiners are involved: the supervisor and a second examiner from a different research group, who is not directly involved in the research project under consideration. The process is guided and monitored by the Master's project coordinator, who also takes care of the calibration of the grades with respect to the whole cohort and those of previous years. The panel reviewed the assessment forms used for the research project and discussed the use of this form as well as the procedure followed by the examiners with the teachers and the Board of Examiners during the site visit. It noticed that there is no grading rubric included in the form and that some of the completed forms lacked written motivation for the grades. The panel recommends formalising motivation of the grading on paper.

Board of Examiners
Since the last programme assessment several actions were taken to strengthen the role and the task performance of the Board of Examiners (BoE). The BoE is responsible for ensuring the quality of examinations and final assessments. The BoE for the bachelor's and master's degree programmes in Astronomy consists of four members, chosen among the teaching staff, and one external member. It checks whether the Assessment Plan is appropriate for the intended learning outcomes of the programme, whether the suggested examiners are qualified for their role, whether there is sufficient variety in the modes of assessment, and whether they are appropriate for the specific learning outcomes.

To check the assessment of the master research projects, the BoE annually checks all theses with grades <7 or >8.5, as well as a few randomly selected theses. In the assessment period the BoE generally agreed with the grades awarded by the supervisors. One aspect of improvement identified by the BoE was that the supervisors could elaborate more on the justification of grades of the assessment form. This aspect was also noted by the panel, as described above.

The CUAO is an important instrument for the BoE to check the quality of the assessments of the course unit. To ensure the quality of examinations, the BoE annually checks the assessments of about eight course units. The panel is positive about the way the BoE is performing its tasks. Its role has obviously been extended and improved in the assessment period. The panel concluded that the examinations, tests and thesis assessment are transparent, valid and reliable.

Considerations
The panel finds the assessment system and policy adequately developed and implemented. The courses use a variety of assessment methods, which are aligned with the learning outcomes and the curriculum. The procedures are transparent for teachers and students.

The panel is positive about the way the Board of Examiners is performing its tasks. Its role has obviously been extended and improved in the assessment period. The panel concluded that the examinations, tests and thesis assessment are transparent, valid and reliable.

The panel particularly values the Course Unit Assessment Overviews (CUAOs) for all courses.

Conclusion
Master's programme Astronomy: the panel assesses Standard 3 as 'meets the standard'.

Standard 4: Achieved learning outcomes The programme demonstrates that the intended learning outcomes are achieved.

Findings
The BoE checks whether the content and depth of the exams reflect the requirements of the master's degree programme Astronomy as outlined in the ILOs. It uses the master's degree programme assessment plan for this check. This plan was also included in the self-evaluation report. According to the panel, the plan indicates that the master's programme Astronomy guarantees that students are educated regarding knowledge, skills, and attitude as specified in the learning outcomes of the programme, and it concluded that the curriculum ensures that graduates have achieved the ILOs. It studied a selection of ten master's theses and their assessments. The theses showed that the minimum level required for a master's programme in Astronomy had been exceeded. They demonstrated that the graduates are capable of carrying out research aimed at understanding physical phenomena and their description in scientific terms. The theses also indicate that the graduates can analyse a new complex physical problem and use modelling skills to develop a structured and well-planned research approach. The panel has seen that the graduates are capable of obtaining relevant information and drawing conclusions on the basis of limited or incomplete information, and are able to realise and formulate the limitations of such conclusions.

The self-evaluation report presented the results of a survey conducted among alumni. The majority of alumni is working in academia in data science or in institutes related to astronomy (such as NWO institutes SRON and ASTRON, and TNO). The panel concludes that the graduates are sufficiently prepared for a career either in academia or in industry.

Considerations
The panel concludes that graduates of the master's programme Astronomy have achieved the intended learning outcomes. The minimum level had been reached and often exceeded. It found the level of the master's theses to be good and generally agrees with the grading of the theses. It would have graded some theses a bit higher and others a bit lower. The graduates are well prepared for continuing in a PhD trajectory or a job in industry.

Conclusion
Master's programme Astronomy: the panel assesses Standard 4 as 'meets the standard'.

GENERAL CONCLUSION

The panel judged that the master's programme Astronomy offered by the University of Groningen meets all standards of the NVAO assessment framework for a limited programme assessment. The panel therefore recommends accreditation of the programme.

Conclusion
The panel assesses the *master's programme Astronomy* as 'positive.

APPENDICES

APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

Introduction

The goal of a university programme is to prepare students for an independent practice of the profession of the relevant discipline, and to give them the ability to apply the knowledge and skills they have acquired. Dutch university programmes in the domain of (applied) physics and astronomy are required to reach a level which allows the graduate to be competitive in the international research or in the job market, in particular with respect to countries which have a high profile in these areas. The domain specific reference frame is meant to be a gauge for reaching this goal.

The framework is based on that used in the Teaching Programme Assessment (Onderwijsvisitatie) of 2013. This in its turn was derived from the qualifications as formulated in the document 'Reference points for the design and delivery of degree programmes in physics', which was a product of the so-called Tuning Project63[1] and, to a lesser extent, the document 'A European Specification for Physics Master Studies' of the European Physical Society (2009). The 2013 framework has been modified and updated in three ways: (1) the programme descriptors are now divided over the usual five Dublin indicators, instead of over the original three categories: cognitive competences, practical skills, and generic competences, (2) several competences have been rephrased, (3) the competence 'Estimation skills' has been added.

The descriptors for the programmes have been formulated in terms of competences acquired by the graduating student, which leads to specific requirements for the curriculum. Programmes with the same name at different (Dutch) universities will in general not be identical. Different specialisations in the research staff or focus on particular subjects leads to differences in the eligible part of the programmes, and there is a structural difference between (the goals of) general universities and universities of technology. As a consequence, there are different ways to comply with the requirements of the reference frame. Essential is that the local choices for, and focus of the programme fit the internationally accepted standards.

Programme descriptors

Similarly to the Bachelor's degree programmes, the descriptors for the Master's degree programmes are divided over the five Dublin descriptors, where the highest or most relevant descriptor is used for this division. The number in the second column is the 'Rating of importance' at the Master's level mentioned in the Tuning Physics document. The competence 'Estimation skills' and the related competence 'Problem solving skills' are combined (ratings 2 and 9). The three colors indicate the type of competence: light color = core curriculum, medium color = familiarity with physics research, dark color = general skills.

The basic difference with respect to the descriptors for the Bachelor's programmes is the different emphasis. Where a Bachelor's programme aims at including some aspects of the forefront of knowledge, a Master's programme aims at providing a basis (or opportunity) for originality.

[1] In May 2018 a new version of the Tuning document was published, as output of the CALOHEE project (https://www.calohee.eu/). In this document, a different structure of competences is proposed (nine 'disciplines', each divided into 'knowledge', 'skills' and 'wider competences'). The compilers of the present framework have decided to follow the simpler, yet elegant structure of the Tuning 2008 document. Where relevant, aspects of the Tuning (2018) have been incorporated.

(A) Knowledge and understanding

	Rating of importance	Specific competence	Description. On completion of the degree course, the student should
A1	5	Knowledge and understanding of physics	have a good understanding of the important physical theories (logical and mathematical structure, experimental support, physical phenomena described).
A2	14	Understanding of the physics culture	be familiar with the most important areas of physics and with the common approaches, which span many areas in physics.
A3	8	Frontier research (MSc only)	have a good knowledge of the state of the art in (at least) one of the presently active topics in physics research.

(B) Applying knowledge and understanding

		Specific competence	Description. On completion of the degree course, the student should
B1	2, 9	Problem solving skills, Estimation skills	be able to frame, analyse and break down a problem in phases defining a suitable algorithmic procedure; be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems.

B2	1	Modelling skills	be able to identify the essentials of a process/situation and to set up a working model of the same; be able to perform the required approximations; *i.e.* critically think about how to construct physical models.
B3	7	Mathematical skills	be able to understand and master the use of the most commonly used mathematical and numerical methods.
B4	10	Experimental skills	have become familiar with most important experimental methods and be able to perform experiments independently, as well as to describe, analyse and critically evaluate experimental data; and to be able to scientifically report the findings.
B5		Computer skills	be able to use appropriate software, programming language, computational tools and methods in physical and mathematical investigations.
B6	6	Familiarity with basic and applied research	acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, *e.g.* engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.

(C) Judgement

C1	13	Human / professional skills	be able to develop a personal sense of responsibility; be able to gain professional flexibility through the wide spectrum of scientific techniques offered in the curriculum; be able to organize the personal learning process, evaluate personal work, consult experts for information (*e.g.* about career opportunities) and support when

			appropriate; have had the opportunity to take courses that prepare for teaching physics at secondary school, as well as the opportunity to gain in-depth interdisciplinary skills.
C2	18	Absolute standards	have become familiar with highly regarded research in the field, thus developing an awareness of the highest standards.
C3	17	Ethical awareness (relevant for physics)	be able to understand the socially related problems related to the profession, and to comprehend the ethical characteristics of research and of the professional activity in physics and its responsibility to society; be able to conduct processes of decision making and inspect the consequences of actions taking into account principles, norms, values and standards both from a personal and a professional standpoint.
C4	12	Management skills (MSc only)	be able to work with a high degree of autonomy, even accepting responsibility in (project) planning, and in the managing of structures.

(D) Communication

D1	11	Communication skills	be able to listen carefully and to present difficult ideas and complex information in a clear and concise manner to a professional as well as to lay audiences; be able to work in a multidisciplinary or in an interdisciplinary team.
D2	16	Language skills	be able to read, speak, and write in technical English.

(E) Learning

E1	3	Literature search	be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development.
E2	4	Learning ability	be able to enter new fields through independent study; have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy (lifelong learning).
E3	15	Updating skills (MSc only)	enjoy the facility to remain informed of new developments and methods, and be able to provide professional advice on their possible impact or range of applications.

APPENDIX 2: INTENDED LEARNING OUTCOMES

1. Knowledge, skills, and insight

The Master graduate in Astronomy:

1.1. masters the fundamental astronomical and astrophysical concepts as well as the necessary tools from physics, mathematics and computer science including modelling skills. The level of these skills permits admission to PhD studies;

1.2. is familiar with the quantitative character of astronomy and astrophysics, and with the relevant research methods;

1.3. [Theoretical and Observational specialisation] has operational knowledge in an observational or theoretical astronomical or astrophysical subarea and knowledge of the state-of the art in at least one specific research area;

1.4. [Instrumentation and Informatics specialisation] has operational knowledge in the area of instrumentation and information technology in astronomy, physics, and/or space research and knowledge of the state-of the art in at least one specific research area;

1.5. [Data Science specialisation] has operational knowledge in the area of data science technology in astronomy, and knowledge of the state-of-the-art in at least one specific research area;

1.6. [Business and Policy track] has operational knowledge of and insight into the functioning of companies and administrations, as well as the relevant legislation and knowledge of the state-of the art in at least one specific research area.

2. Application of knowledge and skills

The Master graduate in Astronomy:

2.1. is capable to carry out research, aimed at understanding of astronomical phenomena, both observational and theoretical;

2.2. is capable to analyse a (new) complex astrophysical problem, and develop a structured and well-planned research/modelling approach;

2.3. is capable to apply his/her specific knowledge and skills in his/her own and related subject areas;

2.4. is capable to collaborate in a (multi-disciplinary) team and has basic skills to manage a (collaborative) project.

3. Judgment

The Master graduate in Astronomy:

3.1. is capable to obtain relevant information using modern information channels, and to interpret this information critically in the context of an absolute standard;

3.2. is capable to judge his/her and others' actions within a scientific context, taking societal and ethical aspects into account;

3.3. is able to draw conclusions on the basis of limited or incomplete information, and is able to realise and formulate the limitations of such conclusions;

3.4. is acting and conducting research according to the VSNU Code of Conduct for Academic Practice.

4. Communication skills

The Master graduate in Astronomy:

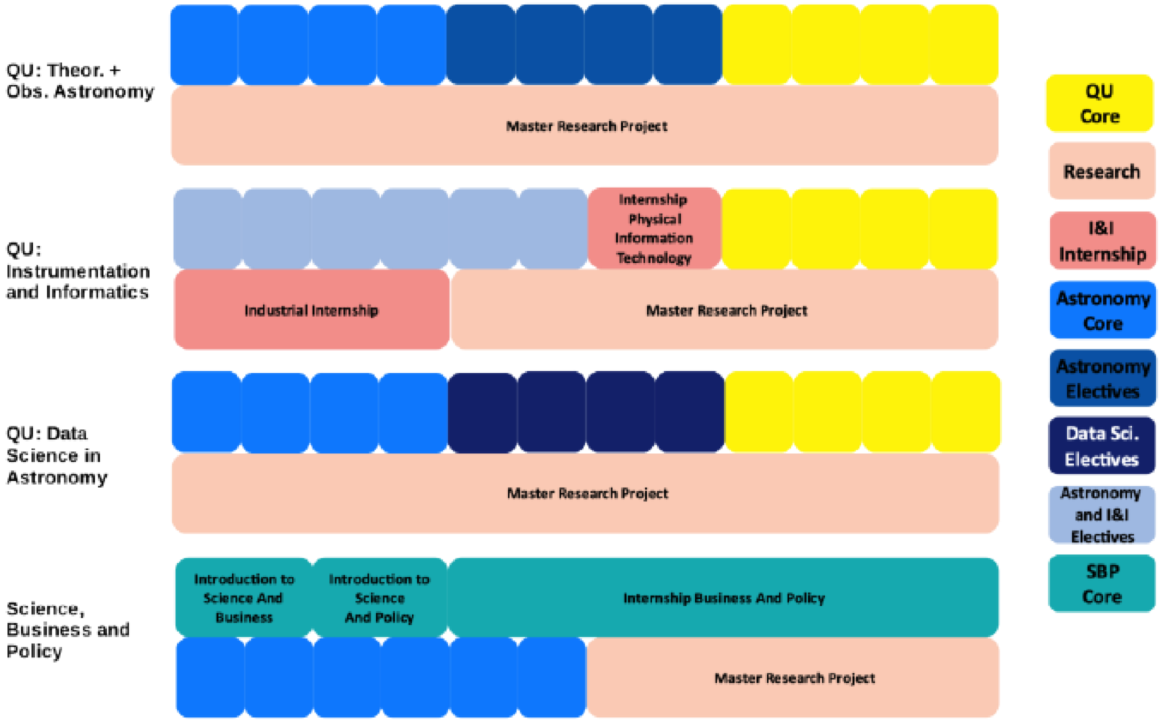
4.1. is capable to communicate clearly, verbally and in writing, on his/her subject and relevant applications, at a level which is understandable to experts and non-experts, and using modern communication tools.

5. Learning skills

The Master graduate in Astronomy:

5.1. is capable to also address issues outside his/her main subject area, therefore and thereby gaining new knowledge and skills.

APPENDIX 3: OVERVIEW OF THE CURRICULUM



In the first part of the programme the students take 60 EC of course work (except for the SBP track). The full second year is dedicated to research. The research project comprises 60 EC, performed at the Kapteyn Astronomical Institute, SRON or ASTRON, or in individual cases at a university abroad. For the Instrumentation and Informatics specialisation, this research is split in a 20 EC Industrial Internship and a 40 EC Master research project.

Specialisation Quantum Universe – Theoretical and Observational Astronomy
First of all, the students have to follow 20 EC in astrophysics core courses. On top of that, they take 20 EC Quantum Universe core courses and 20 EC optional courses.

The Astrophysics core courses such as ‘Stellar Structure and Evolution’, ‘Cosmic Structure Formation’, Statistical Signal Processing’, ‘Formation and Evolution of Galaxies’, ‘High Energy Astrophysics’, Dynamics of Galaxies’ and ‘Star and Planet Formation’ treat the theory, tools, and applications of advanced astronomy topics. The student chooses four courses from this category.

The last category is formed by the optional courses. This category gives the students the opportunity to broaden and/or deepen their knowledge and skills in the field of Astronomy or related fields. In this category, the student can choose from a list of Instrumentation and Informatics courses, Capita Selecta (which are 3 EC), and additional courses from the above listed Astrophysics core courses. The Instrumentation and Informatics courses provide a broadening into the more technical field and the Capita Selecta expose the students to potential Master research topics and more advanced literature studies. The topic of the Capita Selecta varies often, taking advantage of specialists who are available to teach these advanced, specialised courses.

Specialisation Quantum Universe – Data Science
The setup of the Data Science specialisation is similar to the one in Theoretical and Observational Astronomy. Here the students will have to follow the following blocks:

- Astrophysics core courses (20 EC);
- Quantum Universe core courses (20 EC);

- introduction to Data Science (5 EC);
- optional courses in Data Science or Capita Selecta (15 EC) The research project comprises 60 EC, performed at the Kapteyn Astronomical Institute, the Bernoulli Institute (Computer Science), ASTRON or, in special cases, elsewhere.

The category of optional courses gives the students the opportunity to broaden and/or deepen their knowledge and skills in the field of Data Science or related fields. In this category, the student can choose from a list of Data Science courses or, Capita Selecta courses (which are 3 EC).

Specialisation Quantum Universe – Instrumentation and Informatics
The specialisation Instrumentation and Information is more technically oriented. Here the students will have to follow:

- 30 EC of Astronomy and I&I courses;
- Quantum Universe core courses (20 EC);
- a project Information Technology (10 EC);
- an Industrial Internship (20 EC);
- a research project (40 EC).

The courses need to be selected from a collection of courses containing the astrophysics core courses, other astronomy courses, courses related to astronomical instrumentation, and capita selecta.

The objective of the Project Information Technology is to familiarise the students with information technical aspects as computer programming, design, construction and testing. This project takes place in a research group related to the Kapteyn Astronomical Institute, and possibly at SRON, ASTRON or at KVI-CART. The Industrial Internship takes place in a research laboratory of a company in industry and will be in a field where information technical aspects play an important role. Whereas for the Project Information Technology the project is fully defined in advanced and mostly takes place at the University, the Industrial Internship is conducted at an external party (also ASTRON, SRON or the NOVA group in Dwingeloo) requiring a more autonomous attitude of the students. The final research project is performed at the Kapteyn Astronomical Institute, SRON or ASTRON, together with a RUG examiner. The Astronomy and Instrumentation and Informatics courses are taken from a list consisting of Astronomy related courses and of Instrumentation and Informatics related courses in the field of Engineering, Physics, Mathematics, and Computing Science.

Track Science, Business and Policy
The faculty-wide track Science, Business and Policy, followed by very few astronomy students, consists of an Astronomy part consisting of 30 EC dedicated to course work and of 30 EC for an astronomy research project performed at the Kapteyn Astronomical Institute.

The other 60 EC are devoted to Business and Policy. A specific module Business and Policy (20 EC) introduces the students to interdisciplinary teamwork, economics, judicial issues, deadlines and the ethical and social context of science. The course Business and Policy is followed by an internship (40 EC) in which the student experiences how science can be applied to industrial goals, developing policies or social issues. The student learns to contribute his/her scientific expertise to a team achieving a common goal; the student works on solving a problem, either in business or government, with a relation to astronomy. The internship is complemented with lectures, training, sharing experiences and a report in two preparative weeks, a return week, and a concluding week. It should be noted that supervision for the Business and Policy part is largely provided by staff of the Science and Society group within the Faculty of Science and Engineering.

APPENDIX 4: PROGRAMME OF THE SITE VISIT

12 May 2019
17.00 – 19.00 Internal panel meeting

13 May 2019
09.00 – 09.15 Arrival and welcome
09.15 – 09.45 Internal panel meeting
09.45 – 10.45 Management bachelor + master Physics + Applied Physics
10.45 – 11.00 Break
11.00 – 11.45 Bachelor and master students Physics
11.45 – 12.00 Break
12.00 – 12.45 Teaching staff Physics
12.45 – 13.30 Lunch + internal panel meeting
13.30 – 14.15 Show cases, poster presentations by students
14.15 – 14.30 Break
14.30 – 15.15 Bachelor and master students Applied Physics
15.15 – 15.30 Break
15.30 - 16.15 Teaching staff Applied Physics
16.15 – 16.30 Break
16.30 – 17.15 Board of Examiners Physics and Applied Physics
17.15 – 17.30 Break
17.30 – 18.15 Alumni + External Advisory Panel (combined)
18.15 – 18.45 Visit to the observatory

14 May 2019
09.00 – 09.45 Internal panel meeting (overleg)
09.45 – 10.30 Management bachelor + master Astronomy
10.30 – 10.45 Break
10.45 – 11.30 Bachelor and master students Astronomy
11.30 – 11.45 Break
11.45 – 12.30 Teaching staff Astronomy
12.30 – 13.00 Lunch
13.00 – 13.30 Consultation hour
13.30 – 14.15 Tour of the facilities and poster presentation students
14.15 – 14.30 Break
14.30 – 15.15 Board of Examiners Astronomy
15.15 – 16.00 Internal panel meeting preparation meeting with formal management
16.00 – 17.00 Formeel management (combined)

15 May 2019
09.00 – 12.00 Concluding panel meeting, formulating judgements
12.00 – 12.15 Preliminary feedback
12.15 – 12.30 Break
12.30 – 13.30 Development Dialogue (combined) – including lunch

APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 10 theses of the master's programme Astronomy. Information on the selected theses is available from QANU upon request.

During the site visit, the panel studied, among other things, the following documents (partly as hard copies, partly via the institute's electronic learning environment):

- Course Unit Assessment Overviews of a sample of courses
- Study Handbooks
- Internship reports, including the assessment forms
- Exemplary journal articles used in the courses
- Year reports of the Boards of Examiners and the Programme Committees
- Quality Assurance Manuals