Research Assessment 2016-2021

NETHERLANDS RESEARCH SCHOOL FOR ASTRONOMY (NOVA)

and

the University Astronomical Institutes

ANTON PANNEKOEK INSTITUTE, UNIVERSITY OF AMSTERDAM
KAPTEYN ASTRONOMICAL INSTITUTE, UNIVERSITY OF GRONINGEN
LEIDEN OBSERVATORY, LEIDEN UNIVERSITY
DEPARTMENT OF ASTROPHYSICS, RADBOUD UNIVERSITY NIJMEGEN

April 2023

Executive summary - Netherlands School of Astronomy (NOVA)

An external committee of peers (henceforth the 'Committee') evaluated the research quality of the Netherlands Research School for Astronomy (NOVA) and the university astronomical institutes of the Netherlands during a site visit in January 2023. This executive summary contains a brief overview of the Committee's main findings on NOVA, and its conclusions that apply to all four astronomical institutes. More detailed findings and recommendations can be found in the relevant sections of the report.

The Committee certifies that **astronomy in the Netherlands is world leading in many research areas**, with several globally impactful results achieved in the review period to illustrate this. The **outstanding science** being carried out by NOVA is reflected in the large number of international prizes and awards gained by NOVA astronomers which continues to be impressive. The results and the recognition they bring are good indicators of the **wisdom of past investment choices and the management of the NOVA program**.

One of the great strengths of NOVA has been its role in marshaling the community to commit to, and successfully deliver, **instruments from which the whole community benefits** through the sharing of guaranteed time. Furthermore, the NOVA **involvement in the control and data-pipeline software for instruments** means that Dutch astronomers have been familiar with these systems from the start, enabling them to exploit early data effectively.

The NOVA program has an **impressive record of educating and inspiring people,** of all ages, about astronomy, **training world-class talent and collaborating with industry**. Overall, the **PhD programs** at the NOVA institutes appear to be **excellent** and benefit from being part of NOVA.

To the Committee, there is no doubt that **NOVA is critical to the outstanding success of astronomy in the Netherlands**. Its coordination and funding role make the whole astronomy enterprise in the Netherlands much greater than the sum of the efforts of the four universities separately.

Regardless of this enthusiastic overall assessment, **the Committee has also identified challenges.** It has formulated **specific recommendations** relating to these challenges**:**

(1) This review period included the long intervals where normal working practices were suspended (COVID-19). These affected everyone in NOVA and highlighted some challenges that were already present but perhaps less apparently so. **Some revisions in the management structure of the larger institutes need to be implemented** so that those in leadership roles have a reasonable number of direct reports and can effectively manage the parts of the program for which they are responsible. **NOVA should consider what role it can play in the creation of such structures and the sharing of best practice among partners.**

(2) Despite the best efforts of many faculty, the limitations of the current management arrangements combined with COVID-19 restrictions, meant that junior staff, postdocs and PhD students do not have confidence in the informal and formal grievance procedures in place to handle allegations of inappropriate behavior. **NOVA and the partner institutes need to take prompt measures to rectify this situation.** Recommended measures by the Committee include **driving cultural change by example** and ensuring that **any grievance** that works its way up to the director level will be **responded to promptly** in a compassionate and thoughtful way; providing **NOVA-wide horizontal structures** to improve communications and share experiences; and sharing best social safety practices. Importantly, NOVA could play a role in **implementing the use of regular climate surveys/cultural audits across institutes**, as they can produce "closed loops" where policies can respond to needs and solutions can be assessed.

(3) The Sectorplan has secured continuing funding for the NOVA instrumentation and NOVA Information Center (NIC) programs, which is a welcome development. Now that funding for instrumentation is secured, it is time to **develop a strategic plan for instrumentation**, including consideration of, among other things, whether the NOVA instrumentation program is optimally organized and includes a sufficient diversity of projects. This would include exploring options for moving the group at Dwingeloo to a university campus, the most obvious candidate being Groningen.

(4) With the funding for the instrumentation program secured, a further challenge arises: how to ensure the continuation of the added value of close collaboration between the Institutes? The Committee recommends **moving from a loose collaboration of institutions towards a strategic decision for NOVA scientists to address key problems with the instrumentation resources acquired through NOVA**. Since all institutes have an interest in exoplanet science, the discovery and characterization of exoplanets might be one possibility.

(5) **The greatest threat to future success is the need to secure future funding for the network and fellowships programs.** This will need to be done through the SUMMIT initiative. It seems unlikely that a bid for `more of the same' is the best way forward. **The committee suggests that a greater degree of top-down planning is in order so that the SUMMIT bid gives a clear picture of the major questions in astrophysics, and beyond, that NOVA intends to address with these resources.** It may be helpful to **develop partnerships with other disciplines**, for example data science or engineering, and perhaps also **with industry**, to increase its chances of success. **Crafting the SUMMIT bid should be the highest short-term priority of the NOVA MT, the NOVA Board, and the University leadership.**

(6) There is considerable potential for Dutch astronomy to lead an interdisciplinary effort in the application of data science to large datasets. The Committee recommends NOVA to **develop a program for strengthening training in machine learning for astronomers, connect the astronomy community to the computer science community and help facilitate access to astronomical data for applications in data science**. As mentioned above, using astronomy as a model for the application of data science is perhaps something that could be stressed in a SUMMIT proposal. These stronger connections will not only benefit astronomy but also computer science. Astronomical data sets are rich, have important and understood underlying symmetries, can be fully simulated and are free from the bias and ethical issues that pervade many other large data sets.

(7) While current **societal impact** is considerable, it **does not reach the scale one might expect**. **The Committee sees room to accelerate the impact on society through a more structured program which would include clear objectives.** For NOVA's **outreach activity**, the Committee recommends NOVA to **assess the effectiveness of the NIC outreach program** and to **play a stronger orchestrating role between the four institutes**, so that the best initiatives get maximum scale. Also, there is an opportunity to **consider significantly expanding the activity**. By attracting substantial third-party funding e.g. from a charitable foundation or industrial partner, such an expansion could transform the impact of the programme. Regarding **valorization**, the Committee advises NOVA to explore how it and the four partners can have a dramatically higher impact on industry and valorization.

Reader's guide

The report of the assessment of NOVA and the university astronomical institutes of the Netherlands contains the following sections.

1. A preamble, containing:
   - the foreword of the chair
   - an elaboration of the procedures followed

2. Assessment report of Netherlands Research School for Astronomy (NOVA)

3. Assessment reports of each of the University Astronomical Institutes
   - Anton Pannekoek Institute
   - Kapteyn Astronomical Institute
   - Leiden Observatory
   - Radboud Department of Astrophysics

4. Appendices

Sections 1 and 4 are overarching and are to be considered as the preamble to and the appendix of each of the separate reports.

The Committee strongly advises to first read the NOVA assessment report, before reading any individual institute reports, as the NOVA report provides the necessary context for the individual reports. Some sections and recommendations of the NOVA report apply to the broad academic astronomical community in the Netherlands, and are therefore also important for the individual institutes.

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Preamble

Preface

On behalf of the review Committee, I would like to thank the Dutch astronomy community, the NOVA leadership and particularly the Groningen department for their hospitality during our visit. We are particularly grateful to Jetje De Groof for her essential role in enabling this report.

While the report outlines a number of opportunities for growth and improvement, the Dutch astronomy community remains an important part of the world community and many of its practices are inspirational and excellent models for other national communities. The Dutch Astronomy community is a vital part of the European and World astronomical community.

- David Spergel
- New York, NY USA
- April 15, 2023

The review committee and the review procedures

1. The System of Quality Assessment of Research in The Netherlands

An external committee of peers (henceforth the 'Committee') evaluated the research quality of the Netherlands Research School for Astronomy (NOVA) and the university astronomical institutes of the Netherlands during a site visit in January 2023 and reports its findings in this document.

This quality assessment (peer review) is part of the assessment system for all publicly funded Dutch research organizations, as organized by the Association of Universities in the Netherlands (VSNU), the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Netherlands Organization for Scientific Research (NWO).

In accordance with the Strategy Evaluation Protocol 2021-2027 for Research Assessment in the Netherlands (SEP), the committee's tasks were to assess the quality of NOVA and the four university astronomical institutes on the basis of the information provided by the institutes and interviews with management, the research leaders, staff members, PhD program management and PhD students, and to advise on how it might be improved.

2. The Members of the Peer Review Committee

The Committee consisted of:

- Prof. Dr. D.N. Spergel, Princeton University (Emeritus) and Simons Foundation, USA (Chair)
- Prof. Dr. W. Benz, Universität Bern, Switzerland
- Prof. Dr. R.L. Davies, University of Oxford, UK
- Prof. Dr. V.M. Kaspi, McGill University, Canada
- Prof. Dr. B.P. Schmidt, Australian National University, Aus
- Dr. L.J. Tacconi, Max Planck Institute for Extraterrestrial Physics, Germany
- Dr. E. Choquet, Laboratoire d'Astrophysique de Marseille, France
- Ms. C. Stindt, University of Groningen, NL (Chemistry PhD student member)
- Dr. Marc de Jong, McKinsey & Company, NL (industry member)

Dr. Jetje De Groof (Antwerp, Belgium), independent higher education quality assurance project manager, was appointed as secretary to the Committee.

All members of the Committee signed a statement of impartiality to ensure that they would judge without bias, personal preference or personal interest, and that their judgment is made without undue influence from persons or parties committed to the institute or programs under review, or from other stakeholders.

3. Scope of the Assessment

The following four university institutes are centers for astronomical research and education in the Netherlands: Anton Pannekoek Institute (University of Amsterdam), Kapteyn Astronomical Institute (University of Groningen), Leiden Observatory (Leiden University), and the Department of Astrophysics (Radboud University Nijmegen). NOVA, the Netherlands Research School in Astronomy, is the alliance of these four university institutes.

The current assessment includes the evaluation of NOVA as well as each of the individual university institutes. It covers the period 2016-2021.

The scope of the assessment was set by the Terms of Reference (TOR). In the TOR, the Committee was requested to assess the quality of the astronomical institutes and of NOVA, as

well as to offer recommendations in order to improve the quality of their research and their strategy.

The committee was requested to carry out the assessment according to the guidelines specified in the Strategy Evaluation Protocol (SEP). The evaluation includes a backward-looking and a forward-looking component. Specifically, the committee was asked to judge the performance of the unit on the main assessment criteria and offer its written conclusions as well as recommendations based on considerations and arguments. The main assessment criteria are:
1. Research Quality
2. Societal Relevance
3. Viability

During the evaluation of these criteria, the Committee was asked to incorporate four specific aspects. These aspects are as follows:
1. Open Science: availability of research output, reuse of data, involvement of societal stakeholders.
2. PhD Policy and Training: supervision and instruction of PhD candidates.
3. Academic Culture: openness, (social) safety and inclusivity; and research integrity.
4. Human Resources Policy: diversity and talent management.

4. Data provided to the Committee

The Committee members received a documentation package well in advance of the site visit. This contained the self-evaluations of NOVA and the individual institutes, with a description of the mission, objectives and results achieved by each institute in the reporting period, as well as developments anticipated in the future. The documentation included quantitative data about staff composition, PhDs, publications, and financial resources. Additional information was provided on a secure website. The Committee also received the SEP and TOR for the assessment.

5. Procedures followed by the Committee

Committee members were asked to read the complete information package and provide their preliminary appraisal of both NOVA and the individual institutes prior to the site visit. This was used as input for a preparatory teleconference that was held a week prior to the site visit.

The Chair of the Committee assigned specific institutes and/or focus areas to each Committee member, based on their expertise. At least two Committee members teamed up for each institute. This enabled EB members to pay particular attention to their designated task areas during preparation and take the lead in interviews and discussions during the site visit as well as in the subsequent reporting.

Appendix 1 shows the program of the site visit. Presentations, interviews, and discussions on both the NOVA level and with the individual institutes were held in Groningen. Between the interviews, time was available for the Committee to discuss the various findings. During the last day of the site visit, a closed Committee session was held so that all members could come to a consensus on the final assessments of NOVA and each of the four individual institutes. At the conclusion of the visit, the Committee orally presented its main preliminary conclusions in a series of briefings to institute directors, university Deans, Groningen University Board and NOVA management, as documented in Appendix 1.

After the site visit, the evaluation report was prepared, with each Committee member taking the lead in composing the sections they had focused on. An integrated version of the report was then circulated to the Committee for comment. A final version, that took these comments into

account, was then drawn up and sent to NOVA and the four astronomical institutes for a check on possible factual errors. Finally, the report was delivered to the Executive Board of Groningen University.

Assessment of Netherlands Research School for Astronomy (NOVA)

1. Aims, strategy, organization

Through the preparatory documents and the site visit, the Committee received a clear view of the mission, strategy, and organization of NOVA. A summary is given below.

NOVA was founded in 1992 as the alliance of the four university astronomy institutes in the Netherlands - in Amsterdam (UvA), Groningen (RUG), Leiden (UL) and Utrecht (UU). Nijmegen (Radboud, RU) joined the alliance in 2001; the Utrecht astronomy institute closed in 2012. NOVA's mission is to carry out front-line astronomical research, to train young astronomers at the highest international levels, and to share its knowledge with society. In line with its mission, NOVA coordinates the Dutch university astronomy research, optical/IR and sub-mm instrumentation and the national aspects of PhD education, outreach and valorization activities in a coherent and collaborative national program called "The lifecycle of stars and galaxies". Its main strategic aims for the reporting period have been to (1) foster an attractive, intellectually rich, vibrant and inclusive scientific atmosphere which allows astronomers to pursue their ideas and push scientific boundaries, both disciplinary and interdisciplinary and in which young scientists can develop and safely grow; (2) to design and build advanced instrumentation for state-of-the-art observing facilities, in particular for ESO, and which provide priority access to observations of particular importance for Dutch astronomy; and (3) to enable significant societal impact of astronomical research in the broadest sense.

NOVA's research program is organized along three interrelated thematic programs or "networks": "Origin and evolution of galaxies from high redshift to the present" (NW1); "Formation and evolution of stars and planetary systems" (NW2); and "Astrophysics in extreme conditions" (NW3). The research program is coordinated by the NOVA scientific director and deputy director, together with two coordinators for each of the three interuniversity networks.

As regards instrumentation, NOVA runs and funds two instrumentation groups. All instrumentation projects have a principal investigator (PI) based at one of the universities. The Optical-IR (Op-IR) instrumentation group is located at the ASTRON Institute in Dwingeloo. The ALMA submillimeter (submm) instrumentation group is located at the SRON Institute in Groningen.

Science communication and education are coordinated through the NOVA Information Centre. Valorization efforts, including industry liaison, are coordinated by the NOVA Office. The Dutch Astronomy Education Committee (LOCNOC) oversees the university education at the BSc, MSc and PhD level, including the organization of the NOVA first year PhD school and the third year PhD weekend together with the NOVA office.

The NOVA community, which consists of all researchers with an affiliation to one of the four participating institutions, or the two NOVA instrumentation groups consisted of 372.7 FTE researchers (on reference date 1st of September 2021) comprising 74.9 FTE permanent and tenure-track staff, 4.6 FTE affiliated staff, 100 FTE postdocs, 171.5 FTE PhD students and 39.5 FTE instrumentalists. Of the latter, 24,7 FTE are members of the NOVA instrumentation groups and 14,8 FTE work on projects at the university institutes.

The NOVA Board, NOVA Directorate and NOVA Supervisory Board are the main components of NOVA's governance structure. The NOVA Board consists of the directors of the participating university astronomy institutes. It reports to the Supervisory Board and has the overall responsibility for the program, sets the overall strategy and decides on the distribution of funds administered through NOVA. The NOVA Directorate is responsible for the day-to-day running of NOVA and its scientific coherence and is supported by the NOVA Office. NOVA's Supervisory Board (Raad van Toezicht) consists of the deans of the science faculties of the participating universities.

NOVA collaborates with a variety of partners. Nationally, NOVA works closely with the NWO institutes ASTRON and SRON. Together with these, it forms the Astronomy Council (Raad voor de Astronomie, RvdA). Importantly, NOVA astronomers have scientific partnerships with Physics, also via NWO particle physics institute Nikhef, Computer Science, Mathematics, Chemistry, Biology and Earth Sciences. Other partners include the Dutch Technical Universities of Delft, Twente and Eindhoven, ESA-ESTEC, TNO-SPACE, and industrial partners such as VDL-ETG.

All of NOVA's research, instrumentation and outreach program is highly international, with collaborations across the globe. NOVA has positioned itself as the Dutch homebase of ESO, particularly through its instrumentation program. NOVA researchers are moreover very visible in international projects associated with the roadmap for Astronomy and Particle Physics large scale research infrastructure (NWO), for example as project scientists (e.g., WEAVE, MICADO) or PIs (e.g., METIS).

2. Qualitative assessment of NOVA

In this section, the Committee assesses the performance of NOVA against the three criteria of research quality, societal relevance, and viability. It also weighs the results and reflections of the research unit on the four specific aspects of how it organizes and conducts its research with particular reference to Open Science, PhD policy and training, academic culture and human resources policy.

An overview of the Committee's recommendations is given in section 3 of this report.

2.1. Research quality

Scientific quality

Astronomy in the Netherlands is world leading in many research areas. Several globally impactful results achieved in the review period illustrate this: the first image of the shadow of a black hole, and the first detection of gravitational waves, are perhaps the most prominent. The identification of the first neutron star merger, GW170817, was a major discovery with NOVA scientists playing a key role in the astrophysical interpretation.

The results from the GAIA satellite are transforming our view of how the Milky Way was assembled with a new view of the Galactic halo emerging where roughly 50% of the halo stars near the Sun are thought to have formed elsewhere in the Universe. The low frequency radio survey of the northern sky carried out by NOVA researchers using LOFAR is detecting thousands of heretofore undiscovered radio sources and generating new insights into black hole physics. The MUSE spectrograph on the VLT has been used by NOVA scientists to detect faint Lyα and CIII emission lines leading to the suggestion that the reionization of the early Universe is caused by the light from stars in low mass galaxies.

NOVA scientists continue at the forefront of astrochemistry in proto-planetary disks. Using ALMA to probe disks on solar system scales (~50 AU) they found the prebiotic gas methyl isocyanate (CH_3NCO) and demonstrated the formation of such peptide bonds under cold conditions in the laboratory. NOVA scientists also produced some remarkable images of proto-planetary disks. The exoplanet imager SPHERE was used to discover changes in the features in a planet-forming disk on timescales of less than a year. The remarkable images show a circumstellar disk with spiral arms and dark patches caused by the inner disk casting long shadows on the outer part.

New insights into binarity in young stars emerged from X-shooter spectra of massive stars in 30-Doradus, a region of very high star formation in the Large Magellanic Cloud. Most of the very young stars are single, or only weakly bound to another star. As most stars are found in binaries this suggests that these stars will capture a companion before they age.

The outstanding science being carried out by NOVA is reflected in the large number of international prizes and awards gained by NOVA astronomers which continues to be impressive. The success with ERC grants is also exemplary. The results and the recognition they bring are good indicators of the wisdom of past investment choices and the management of the NOVA program.

One of NOVA's goals is to encourage collaboration across institutes. The Committee noted that only 15% of publication output included authors from two or more of the NOVA partners which seems rather low given the quality and volume of published output. With the resumption of in-person meetings, NOVA should explore how it can increase inter-institution collaborations.

Quality of instrumentation

One of the strengths of NOVA has been its role in marshaling the community to commit to, and successfully deliver, instruments from which the whole community benefits through the sharing of guaranteed time. The instrumentation program has thus provided a focus for collaboration amongst the institutions. By targeting its investment in the early stages of an instrumentation project to bring the work to a stage where feasibility is demonstrated, the funds used have been successfully leveraged into large contracts. Furthermore, the NOVA involvement in the control and data-pipeline software for instruments means that NL astronomers have been familiar with these systems from the start, enabling them to exploit early data effectively. This is a successful aspect of NOVA and the foundations are here for more success in the future. The NOVA management team (MT) should ensure that the program remains appropriately structured to achieve this success and, where possible, mitigate the risk that inflation diminishes what can be achieved in the future.

Looking to the future, large ESO instruments are likely to become increasingly dominant in the NOVA portfolio and the ability to innovate on short timescales and pursue instrumentation R&D could be compromised. The long timescales involved in increasingly large instruments also make it harder, but not impossible, for students to make a significant contribution during their PhD. The NOVA MT should consider ways of retaining some nimble short-term aspects to the instrumentation program that will increase its attractiveness to creative staff and students alike.

NOVA seeks to always have one ESO instrument PI-ship and currently that instrument is METIS. METIS is by far the largest instrumentation investment by NOVA and has advanced well over the review period, passing its PDR in 2020.

WEAVE is the next largest investment (in €) and the delivery of the instrument to the WHT in La Palma in 2020 is a major milestone in this review period. It is a complex multi-object spectrograph capable of simultaneously observing 1000 objects at intermediate resolution. It will provide a powerful facility to follow-up the GAIA results on the assembly of the Milky Way and offers the opportunity to pursue a range of other surveys.

Several other smaller instrumentation efforts were either completed or passed major milestones during the review period. These quality smaller projects are an important part of NOVA's portfolio. All Band 5 receivers for the ALMA array were delivered, and a new contract to deliver Band 2 receivers with international partners was signed. The MATISSE instrument for the VLT-interferometer was delivered. Three BlackGem telescopes were installed at La Silla. NOVA is providing the main filter wheel assembly and the atmospheric dispersion compensator (ADC) as well as major stake in the science and data reduction work packages for the ESO ELT imager, MICADO, which passed its PDR. Finally the NOVA contributions to JWST instrumentation, in MIRI and NIRSpec started to operate in orbit with spectacular results.

This is an extensive and multi-scaled instrument program. It will take careful planning to retain this range of activities in the next phase. The Committee learned from the interviews with instrumentation staff from the different centers that they rarely get the chance to interact with each other. There is a clear need for cross-network and cross-institute structures to improve interaction amongst the groups and to increase the cohesion of the instrumentation program.

Now that the Sectorplan has secured continuing funding for the NOVA instrumentation program, there are several issues the MT can consider. It is time to ask `is the NOVA instrumentation program organized optimally? Is the number and size of the individual groups correct? Do they each have a critical mass of staff and activity able to attract and retain staff with the necessary range of skills? Is the infrastructure of laboratories and equipment sufficient to keep the instrument program competitive into the future as larger, more ambitious instruments are

needed'? The Committee's view is that radical changes are not necessarily essential. However, it is timely for the NOVA MT to reflect on these questions and plan appropriately for the future.

When visiting the Dwingeloo instrumentation team, the Committee concluded that the group was isolated and has outgrown the infrastructure at the site. The Committee also learned that there had recently been some issues of social safety. The Committee recommends that options for moving this group to a university campus be explored, the most obvious candidate being Groningen. Recruitment of skilled instrumentation specialists is highly competitive internationally and the Committee believes that a move to a university environment will be advantageous for retaining a competitive offer to new recruits. The Committee also believes such a move will improve the working culture and likely improve social safety.

The connection between NOVA and the national laboratories, SRON and ASTRON, is a potential strength that could be built on to expand both space and radio instrumentation activities. The Committee sounds a note of caution with regard to the employment formalities for NOVA-run instrumentation groups embedded in these two organizations. NOVA feels responsible for personnel at Dwingeloo and Groningen and organizes HR aspects such as training and promotion. However, formally the staff are employed by NWO or RUG. While there are considerable advantages to embedding the NOVA activities at Dwingeloo and RUG arising from synergies in the work, there are also risks when personnel issues emerge. The formal responsibility sits with the employer, and not NOVA, and this arrangement has not always worked as effectively as it could.

NOVA's added value

The Committee is of the opinion that the NOVA program contributes pivotally to the success of NL astronomy by:

(i) encouraging complementary research programs in the four partner universities which produces a broad-based national program with much less competition and duplication than otherwise,

(ii) providing, through its networks, a conduit for communication across institutions that facilitates the sharing of techniques and expertise. Through this, new Early Career Researchers (ECRs) from abroad can identify local collaborators within the Netherlands, as a positive alternative to persisting with the partnerships they established previously elsewhere.

(iii) providing the seed funding for research programs to be developed to the stage of being competitive for external funding, for example from the European Research Council.

(iv) enabling junior researchers access to large collaborations, often international, that they would not be able to join from outside NOVA.

(v) funding instrumentation initiatives that enable Dutch astronomers to gain early access to the most advanced data across a wide range of astronomical sub-disciplines.

There is no doubt that NOVA is critical to the outstanding success of astronomy in the Netherlands. Its coordination and funding role make the whole astronomy enterprise in the Netherlands much greater than the sum of the efforts of the four universities separately.

This is evidenced most spectacularly by the success at all levels in the competition for ERC grants. The Netherlands has the highest per capita success rate of all nations in the European Union. This success reflects the sustained support provided by NOVA over decade timescales. Writing competitive grant applications in astronomy benefits hugely from an in-depth knowledge of instrumentation and facilities. That flows most naturally from the leadership roles that have been secured by Dutch astronomers through NOVA support for PI and other leadership positions.

The Committee recognizes that the NOVA program contributes pivotally to a highly successful Dutch astronomy activity. Many of the suggestions and recommendations made in this report arise from the challenge of managing that success and the increased scale of activity that comes along with it.

2.2. Relevance to society

The NOVA program has an impressive record of educating and inspiring people, of all ages, about astronomy, training world-class talent for a career in science or elsewhere and collaborating with industry. The value of the NOVA programme to Dutch society is high. The challenge for the future is whether this aspect of the programme could make an even greater positive impact on society.

In recent years, there has been a growing expectation that publicly funded scientific research should not only demonstrate excellence, but also have a clear positive impact on society. The astronomy research by NOVA and the four institutes occupies a flagship role in Dutch basic science. The Committee recognizes that this is fully warranted by the world-class level of scientific excellence, and brings with it an urgency to demonstrate a proportionately positive impact on society. Whilst the Committee recognizes that this high share is fully warranted by the world-class level of scientific excellence, they do see that with this large funding comes urgency to have demonstrable and scaled positive impact on society.

As will be detailed in separate sections below, the Committee is of the opinion that NOVA and the four institutes have generated substantial societal impact in all three pillars of the NOVA impact on society strategy: (a) outreach and public awareness; (b) strengthening the innovation landscape through industrial collaborations and start-ups (valorization); and (c) human capital generation. However, the Committee has observed that, while current impact is considerable, it does not reach the scale that could be achieved by a more focused and ambitious effort. One of the main reasons is that the expectations are not explicitly formulated, nor are they embedded in a professional and structured way in the daily activities of staff members. The Committee sees room to accelerate the impact on society through a more structured program which would include (a) clear and measurable targets, well aligned across NOVA and the four institutes; (b) solid plans detailing who does what; and professional discussions on how all this can be commensurate to the scientific and educational tasks of staff members; (3) a well-oiled mechanism to scale successful initiatives across NOVA Institutes or the university; and (4) professional program management, and sufficient support for, e.g., events and media. The Committee recognizes that these ambitions cannot be achieved in the context of the current funding. However, it encourages NOVA to seek additional funding sources to grow efforts in the three areas outlined below.

2.2.1. Outreach

The NOVA outreach program is extensive and multi-faceted, reaching a wide audience with some imaginative material. The current activities of school visits and planetarium shows are vibrant and well received. A recent success was centered on the first images from JWST, where the NOVA Information Center (NIC) co-ordinated a National Press Day that resulted in comprehensive media coverage. In parallel, NIC organized an event at the Omniversum Dome Theatre in The Hague. After switching much of the content online during the period of covid restrictions, the mobile planetarium program has been revamped. The program was re-focused to change the emphasis from 80:20 secondary/primary to 50:50 with the result that the demand from schools is now double that before COVID-19. The biggest challenge now is the limited capacity of the planetarium.

Through the spectacular images of astronomical objects and the natural fascination with questions of our origins, astronomy is one of the scientific subjects that most easily captures the imagination of school pupils. As such it can be used as a gateway into STEM and thus play a crucial part in the development of scientific talent. The committee learned during the interviews that NOVA's current outreach program reaches an estimated 15-25% of Dutch school pupils once in their school career.

While there is much evidence that these activities are enjoyed by all who participate, an assessment of the effectiveness of them is missing. This will make it harder for the NOVA management to plan how the program could evolve in the future. With core funding for the NOVA Information Centre (NIC) having recently been secured into the future, it is timely for NOVA management to consider whether it is optimally organized and how it might contribute most effectively in the future. The Committee feels there is an opportunity to consider significantly expanding the activity. By attracting substantial third-party funding e.g. from a charitable foundation or industrial partner such an expansion could be substantial. Given the success of much larger programs elsewhere, most notably in the United States, there is now the potential for NOVA to explore the idea of a vastly increased program, independently funded, based on the core activities of NIC. This idea is the subject of a Committee recommendation (see below, Section 3).

Outreach is an area where NOVA can be a catalyst for sharing best practice. It is natural that each institute will have its own regional focus: the needs of each area will be different, and sharing best practice does not mean uniformity of approach. Nevertheless, NOVA could play a greater role in developing outreach initiatives that reach under-served communities, be they the rural communities in the north, or immigrant communities in Amsterdam.

2.2.2. Valorization

There have been some notable successes in translating NOVA-funded activities into increasing industrial capability. Through NOVA's ESO Industry Liaison, contacts have been built and maintained between NOVA and industry. This resulted in improved skills at several companies. For example, the requirements of the work-package to control the ELT primary mirror have resulted in augmenting the technical capacity of the high-tech contractor VDL making it more competitive. There are many interesting examples of such outcomes which are likely to be beyond the resources of an individual university group and suggest that the NOVA team is effective in this area.

There are some areas where the potential for synergy/cross-fertilization have yet to be taken. The increasingly complex demands of astronomical instrumentation are not only technical but to a large degree also organizational. Each of the sub-systems of a modern instrument, mechanical, electronic, thermal performance, optics, control, and reduction software has major technical hurdles to overcome, however the challenge of bringing all these systems together to create a single system at the telescope is at least as great. The systems engineering approach required to keep track of all these sub-systems and impose an orderly route to progress is also needed, and perhaps available, in high tech companies that face similar challenges. This suggests that a forum for drawing up a roadmap together that shows the potential impact for industry could not only identify a means of filling skills gaps but also help to secure government funding for future projects. In general, the Committee feels that structural collaboration with one or more of the technical Universities on System Engineering might be a highly valuable avenue to explore.

In addition, the Committee was a bit underwhelmed by the limited start-up activity. Next to two clear start-ups from Groningen and some (not entirely clear) links provided by Nijmegen and Leiden, it feels that NOVA and the institutes are punching below their weight. With so much

talent and efforts in highly innovative fields such as data science, high-performance computing, radio and optical technologies, lightweight materials, etc., one wonders why the spin-off is not an order of magnitude more. The Committee recommends exploring this deeper and identify potential root causes (which could be in the mindset, culture, PhD curriculums, support mechanisms, relationships to industry and VCs etc. etc.).

2.2.3. Human Capital & training

This is a crucial area for the health of the subject. The Committee found that the talent pipeline from undergraduate specialization, through PhD training, to Early Career Researcher (ECR) is overall healthy with some areas that could be improved. The Committee focuses on NOVAs role in developing, mentoring, and training Early Career Researchers further in this report (see below, 2.4. 'Special Aspects').

The Committee recommends that NOVA continue to invest in its database on the career paths of the astronomy alumni of all institutes, so that NOVA can regularly carry out an impact study on this important benefit of astronomy to society.

2.3. Viability

NOVA has played a crucial role in enabling the Dutch astronomical community to plan on long timescales. The Sectorplan has now secured continuing funding for the NOVA instrumentation program and for NIC. This welcome development makes it timely for NOVA to review these two aspects to ensure they are properly organized for the long-term and on the correct scale.

NOVA has encouraged the separate institutions to focus on, and develop, their own strengths to avoid too much duplication and unhelpful competition amongst the partners. This differentiation is breaking down somewhat with the aspiration to build exoplanet groups in each partner institution. The NOVA program has been both the glue that, for example, provides coherence in the national PhD program, and the grease that facilitates collaboration between institutes centered around instrumentation projects. Now that the instrumentation program has long-term funding, how will NOVA ensure that the imperative to collaborate sustains?

The NOVA Board may wish to consider whether plans should be more top down. This would involve moving from a loose collaboration of institutions towards identifying strategic directions for NOVA scientists to address key problems with the instrumentation resources acquired through NOVA. Since all institutes have an interest in exoplanet science, the discovery and characterization of exoplanets might be one possibility.
NOVA has the potential to play an important role in strengthening Dutch data science. As emphasized in the US decadal survey on astronomy, astronomy is well positioned to play an essential role in driving data science. First, the data is open access, has no commercial value, and is free of the many ethical issues associated with other kinds of image data. In contrast, images of faces scraped from the Internet often do not have permissions, are used for photo surveillance, and are often racially biased samples. Second, astronomical data is rich and ranges from images, tables, graphs, and uneven time series to multidimensional grids. Third, data in the physical sciences is structured with individual particles, planets, and stars interacting in particular ways and with well-understood symmetries- data structures that differ from the widely studied images and sequences in other areas. This rich structure has already inspired early work in graph neural networks and geometric deep learning. Fourth, astrophysicists have high-fidelity simulators that capture mechanistic causal models that describe both the astronomical phenomenon (e.g., the evolution of large-scale structure) and the astronomical processes (e.g., observations of gravitationally lensed galaxies by the Euclid telescope). In recent years, astrophysicists and data scientists have developed numerous new techniques for

likelihood-free inference, advances in density estimation, implicit generative models, and probabilistic programming. These techniques are now being used across a wide range of fields (e.g., particle physics, chemistry, and neuroscience) and are part of an emerging new area spanning machine learning and the physical sciences. Fifth, because it is possible to simulate data, it is possible to query whether a model is overfitting the data. Since the underlying physics is known for many astrophysical data sets, it is possible to learn whether artificial intelligence (AI) is learning the true underlying rules. This is a much more significant test of a model than cross-validation and is important for making models safe and improving the understanding of science. Sixth, building theories for the physical world is a potentially less ethically fraught implementation of AI on classifying text or images. During the period of this evaluation, several major AI companies have expanded their efforts in the Netherlands. These companies can be both a source of technical expertise for data analyses and partners for validation.

At present the success of Dutch astronomy, achieved through the support of the NOVA program, is highly leveraged. Grant success, particularly in the ERC competitions, has been outstanding. This, however, has led to a significant fraction of the Dutch enterprise relying on such short-term funding. Is there a fallback plan if Dutch scientists grant success experiences a significant fall for a few consecutive years?

The missing ingredient from the Sectorplan is funding for the networks and fellows. These are central to the success of NOVA. The SUMMIT program offers the possibility of gaining this funding through a new route. **The Committee sees the successful outcome of a SUMMIT bid to be essential for the future health of NOVA and Dutch astronomy**. This will require the NOVA Board and management to work together to mobilize all their influence in the highest levels of their host universities. The Committee recommends that NOVA management explore new ways of presenting the program in a SUMMIT bid to emphasize a more coherent approach, one possibility might be to showcase the cross-disciplinary advantages an advanced program in data science could have for astronomy and beyond. Further yet, NOVA could offer itself as a model for multi-institutional collaboration in other subjects.

2.4. Special aspects

2.4.1. Open Science

Astronomy is a global leader in the area of Open Science, and Dutch Astronomy is a strong part of this global community. By and large astronomical publications can be obtained freely and astronomical data is curated professionally and made available to any interested user. The international astronomy community stores most of its research data according to the FAIR4 principles or is moving towards doing so. The Dutch astronomical community sits within a context where open-source publication and free access to archived data is the norm.

To the extent that NOVA is a partnership of four universities it involves its major stakeholders centrally in all its plans and their implementation. The staff of the four universities are centrally involved in setting the direction taken in the NOVA networks and the instrumentation program. The early career researchers and PhD students have a less clear path for involvement and have requested more input into the decision making that affects them. The Committee recommends that NOVA explore ways of achieving this.

In terms of partnerships in wider society the outreach program has built a network of connections within the educational community and amongst other community science groups. The committee commented above on the success of NOVA's outreach effort. As said, it has the potential to serve as the model for a much larger effort.

In terms of collaboration with other disciplines these are healthy at individual institutes where connections with engineering, computer science and other disciplines have been forged. There is considerable potential for Dutch astronomy to lead an interdisciplinary effort in the application of data science to large datasets. Using astronomy as a model for the application of data science is perhaps something that could be stressed in a SUMMIT proposal.

Going further, to develop centers of excellence in artificial intelligence and machine learning among clusters of university departments will require a long-term vision and reaching out to other departments and networks to find projects of common interest. This is a natural step for a collaboration like NOVA to take but there is much to do and the international competition is fierce so it will take a sustained effort.

2.4.2. PhD policy and training

Overall, the PhD programs at the NOVA institutes appear to be excellent and benefit from being part of NOVA. The overall success rate (93% over the years 2013-2017), and mean duration of only 4.3 years, are very good and the high quality of the programs is evidenced by the number of prestigious postdoctoral fellowships awarded to PhD graduates from the Netherlands. Although COVID-19 significantly impacted graduate students' work and social life, most felt closer to their contemporaries than the ECRs and more part of a local student community, so they were not as badly affected.

The interviews revealed that the PhD students are very appreciative of the role that NOVA plays in their PhD trajectory and career preparation. They appreciated NOVA bringing together students from the different institutes for training and career development, in particular the NOVA PhD school for first-year PhD students, the third-year PhD weekend, and the SKIES program.

The first-year PhD school provides students with a broad overview of the Dutch astronomical research landscape, which was regarded as being very useful. The late-stage PhD students whom the Committee spoke to were very enthusiastic about the third-year PhD weekend, which focuses on employability. The Committee considers this as particularly relevant considering that the fraction of PhD graduates that obtained their first job in astronomy after completing their PhD dropped from 80% in the previous evaluation period to 67% in 2020-2021. Moreover, the number of PhD students across NOVA is such that the majority will not spend the greater part of their working life in astronomy. This has important implications for PhD training and for NOVA's part in it, as there is room for NOVA to play a more intensive role in preparing PhD students broadly for career opportunities both inside and outside astronomy and both inside and outside academia. The Committee recommends providing information about the range of careers outside astronomy as part of a sustained effort to establish a culture in which taking a job beyond academia is not considered `failure' but instead a different kind of success. These events would ideally involve, for example, industry partners, local hospitals, space science contractors, software companies and high-tech manufacturing companies.

The EU-funded SKIES program was set up to provide training to PhD students as well as first-year postdoctoral researchers integrating open science, innovation and entrepreneurship. This successful program was perceived as a welcome addition to the other NOVA activities. The committee strongly encourages the continuation of such initiatives.

Regardless of the success of the current NOVA events, students expressed a desire for more opportunities to link with the broader astronomical community. They feel that networking opportunities, especially during multiday events, are very beneficial to them, and see an opportunity for NOVA to play a leading role in organizing such events. This view was shared by the postdocs. The Committee recommends that NOVA considers expanding provision of

mentoring and training for PhD students to include more regular student multi-day events to provide graduate students with the opportunity to interact across institutions and networks.

The Committee noted that the practice of students having one of their PhD committee members from another NOVA institute seems to have been discontinued. The Committee recommends that NOVA consider reinstating this arrangement as part of a review of expanded provision of PhD student mentoring and training, as this practice has the advantage of making connections to other members of their network easier, encouraging joint projects and publications and generally sharing best practice.

Like the postdocs (see below) PhD students would like some direct interaction with NOVA management, either through representation in the Board or some other mechanism. The Committee recommends that NOVA explore ways of hearing from PhD students and feeding back information to them. In this way the Committee expects further suggestions for developing the PhD training and mentoring aspect of NOVA to emerge.

2.4.3. Academic Culture

Academic culture was a particular focus at this meeting because of the recent episode with a senior professor at Leiden. The Committee looked widely across the NOVA program at the issue of social safety. Formal responsibility often sits with the individual institutions within NOVA, or with partners such as SRON and ASTON, who employ staff so the sections of the Committee's report on individual institutions will also cover the topic. NOVA can however play an important role in generating a healthy academic culture across the program. In this section the Committee summarizes what it found in its discussions with staff and students regarding social safety and makes recommendations for NOVA to ensure all those involved in the program feel safe and secure in the workplace.

The Committee recommends that NOVA leadership should drive cultural change by example and make it clear that this is a primary goal. The aim should be to create an atmosphere of openness and transparency where people are kind to each other and feel confident in raising matters of concern. All staff and students need to see that any grievance that works its way up to the director level will be responded to promptly in a compassionate and thoughtful way. NOVA should organize proactive monitoring of the work culture to ensure that new measures that are adopted are working. NOVA should seek to ensure that the highest standards and most effective procedures are in place across all the institutes. Through its networks NOVA can lead discussion of how to improve the working environment across the program. NOVA can ensure that social safety is discussed at every meeting both at the NOVA level, and at the institute level.

Across NOVA and the individual institutes, the Committee found that the emphasis for ensuring a healthy work environment relies on the formal procedures in place at the University level for dealing with alleged inappropriate behavior and in parallel on the informal routes for raising problems that are expected to resolve issues at an early stage before formal procedures are invoked. Amongst the academic staff there was confidence in these formal and informal routes for raising and resolving issues. More junior staff and PhD students did not always share this confidence. We learned from them that they were often reluctant to come forward with a grievance because of concerns about confidentiality, the seriousness of such a move, and because of the potential consequences for their future career.

The Committee concludes that the formal reporting procedures that are in place are not working adequately. It notes that, with the exception of Radboud University, there was no attempt to 'close the loop' by surveying the community to establish how staff and students perceived the working environment and the procedures in place to express and rectify any concerns. NOVA should survey the community regularly to monitor progress in improving the working

environment. As practices for encouraging social safety vary across the institutes, NOVA can play a role in sharing best practice. Several groups expressed a desire to have structures in place to improve communications and share experience. NOVA should consider setting up `horizontal' structures for such groups, examples include, women, young researchers, members of the LGBT+ community, and instrumentalists. Other groupings are likely to emerge.

The senior academic staff have not generally been trained in managing issues of social safety. Most senior staff feel that they are sufficiently approachable that the informal mechanisms for handling complaints about inappropriate behavior would work. Academic leaders, particularly those in positions of responsibility, need training and access to regular coaching from experienced individuals. Could NOVA facilitate this training and coaching? This will help senior staff feel confident in their leadership roles, enable them to lead by example, and help them to recover from what, for some, has been a traumatic experience.

The success of NOVA and its partners has led to considerable growth in the size of the institutes concerned with a consequence that the close interactions that characterized the groups at earlier times, the `family feeling', has been lost. In consequence many staff and students do not feel comfortable engaging either the informal or formal routes to resolve problems. Leiden is already of sufficient size that reform of the management structure is needed. Groningen and Amsterdam are approaching this size. Such reform might involve establishing a structure that has a Director with a number of deputies responsible for specific parts of the activity so that each person in the structure can realistically manage their direct reports. Some horizontal structures will need to be established to avoid the groups becoming siloed. NOVA should consider what role it can play in the creation of such structures and the sharing of best practice among partners.

There is no doubt that the isolation implicit in the restrictions on working habits caused by COVID-19 has contributed to the poor functioning of some of these processes. As the institutes start to be reoccupied the Committee expects there is a chance to bring about an improvement in the work environment. If some parts of the program are struggling to attract people back to the office, measures should be taken to improve in-person attendance.

The Astronomy Council's NAEIC offers a potentially helpful vehicle for communication and sharing good practice on issues of inclusivity and social safety. It organizes a successful series of talks that are reasonably well attended. However, it does not reach the whole community, for example PhD students do not seem to be aware of the NAEIC's existence. Also, the Committee noted that the NAEIC has not been given a clear mission, nor means to act on these topics, and its actions are currently limited in scope. NOVA MT should consider whether expanding the program of NAEIC would be a helpful tool in addressing issues of social safety across the program. If so, it needs to have an increased profile and expanded set of activities.

2.4.4. Human Resources Policy

Formal responsibility for Human Resources often sits with the individual institutions within NOVA, or with partners such as SRON and ASTRON, as they are the employers of staff working on NOVA programs. NOVA organizes training and promotion and plays an important role in generating a healthy academic culture. However, the Committee found that when a problem arose with a sustained inappropriate behavior towards female staff, the host HR team did not act promptly and on one occasion mistakenly concluded they had addressed and rectified the problem. The committee recommends that the interface between NOVA funded staff and the HR processes in their host institutes are reviewed with a view to making them more effective.

NOVA's recruitment policies and the training and development offered to staff appear to be working well. NOVA MT should consider intensifying its actions aimed at postdoctoral staff.

Most of these staff are not from the Netherlands. This presents a challenge of how to integrate new arrivals, make them feel at home and part of the local endeavor. After almost three years of COVID-19-related restrictions the committee found this group to be the most disadvantaged and least integrated in local university and NOVA life. Efforts were made to ease their path but nevertheless many postdocs felt and still feel detached. NOVA and the MT should consider how this can be mitigated, and put in place formal and informal processes to address this problem. One measure to consider is appointing a mentor at a different university for each postdoctoral or ECR hire. This would help spread best practice and provide an outside voice should issues of social safety arise. The postdocs the Committee spoke to expressed a desire to have some representation directly to NOVA. Providing more opportunities to network would be of great value enabling them to identify where they might build new collaborations and partnerships within NOVA rather than fall back on the collaborations they forged during their PhD training. Helping this group to feel less detached is an urgent priority for NOVA. Cross network groups would be helpful to get them integrated and socialized, possibilities would be an instrumentation group, high performance computing group, a women's group, LGBTI group etc. Undoubtedly a structure that provides them direct access to NOVA would come up with further ideas. Without wishing to be prescriptive the committee recommends that ways of doing this are worth exploring.

Many of the issues associated with the scale of postdoc activity in NOVA that apply to PhD students also apply to postdocs and many of the same solutions apply. Most notably postdocs need (i) more education about the positive range of careers outside astronomy that are available in NL and (ii) a change in the postdoc culture so that taking a job beyond academia is not considered `failure'. Such changes offer the Dutch economy huge opportunities as highly trained talent at postdoctoral level are sought after.

2.5. Conclusion

The Committee finds the NOVA program to be highly productive, internationally recognized and world leading in many areas. This success, achieved over twenty years, has resulted in considerable growth in each of the partner institutes. Many of the recommendations arise from the need to address problems that have their origins in this growth. However, the challenges faced by NOVA should not be over-emphasized, they can be successfully addressed and the Committee makes specific recommendations relating to this.

The success in securing continuing funding for the instrumentation and NIC programs provides a great opportunity to look closely at those activities to ensure they are appropriately organized for a long, bright future. This is the subject of several specific recommendations.

The greatest threat to future success is the need to secure future funding for the network and fellowships programs. This will need to be done through the SUMMIT initiative. It seems unlikely that a bid for `more of the same' is the best way forward. The committee suggests that a greater degree of top-down planning is in order so that the SUMMIT bid gives a clear picture of the major questions in astrophysics, and beyond, that NOVA intends to address with these resources. It may be helpful to develop partnerships with other disciplines, for example data science or engineering, and perhaps also with industry, to increase its chances of success. Crafting the SUMMIT bid should be NOVA MT & Boards highest short-term priority.

This review period included the long intervals where normal working practices were suspended by restrictions necessary to avoid the spread of COVID-19. These affected everyone in NOVA and highlighted some challenges that were already present but perhaps less apparent than we found today. The growth in numbers of people at the larger partners meant that the informal management arrangements in place when NOVA first started are failing. It is no longer possible

to rely on the `family atmosphere' of institutes for problems to be identified and addressed. Some revisions in the management structure of the larger institutes need to be implemented so that those in leadership roles have a reasonable number of direct reports and can effectively manage the parts of the program for which they are responsible.

The challenges faced by the current management structures, combined with COVID-19 restrictions, resulted, despite the best efforts of many faculty, in inadequate communications. Among other things this led to a loss of confidence among junior staff, postdocs and PhD students in the informal and formal grievance procedures in place to handle allegations of inappropriate behavior. NOVA and the partner institutes need to take prompt measures to rectify this situation and they are the subject of several recommendations. The aim should be to create an atmosphere of transparency and openness where people are kind to each other, and staff and students feel confident in raising matters of concern. All staff and students need to see that any grievance that works its way up to the director level will be responded to promptly in a compassionate and thoughtful way.

The NOVA program is of great value to Dutch astronomy but also to wider Dutch society from training excellent PhD students to inspiring Dutch school pupils and building synergistic partnerships with industry. The Committee is confident that NOVA can address the recommendations and be even more productive in the coming years.

3. Recommendations

1. Instrumentation

The Committee recommends NOVA to develop a strategic plan for instrumentation that addresses the following:

(a) consider ways of retaining some nimble short-term aspects to the instrumentation program that will increase its attractiveness to creative staff and students alike.

(b) consider establishing a cross-network and cross-institute structure to improve interaction amongst the instrumentation groups and to increase the cohesion of the program.

(c) consider whether the NOVA instrumentation program is organized optimally, now that funding for instrumentation is secured.

(d) take measures at the Dwingeloo instrumentation team to train staff appropriately and to ensure that all staff can be confident in both informal and formal channels of communication for raising grievances.

(e) explore options for moving the group at Dwingeloo to a university campus, the most obvious candidate being Groningen.

2. Relevance to society

Overall the Committee recommends NOVA to

(a) accelerate the impact on society through a more structured program with clear objectives.

(b) develop a simple, clear, and compelling narrative, so that all NOVA participants "sing from the same songbook" to build conviction in Dutch society how valuable the Dutch preeminence in astronomy is.

(c) (recognizing that the ambitions mentioned below cannot be achieved in the context of the current funding) obtain additional funding to enable the enhancement of its programs.

2.2.1. Outreach

The Committee recommends NOVA to

(a) assess the effectiveness of the NIC outreach program. This could perhaps best be achieved using a consultancy to avoid disrupting the current program which is limited by the level staff and other resources.

(b) (now that future funding for this activity is secure) explore the idea of a vastly increased program, based on the core activities of NIC.

(c) play a stronger orchestrating role between the four institutes, so that the best initiatives get maximum scale.

2.2.2. Valorization

The Committee recommends NOVA to

(a) (as the complexity of integrating complex subsystems into a single astronomical instrument in a remote site requires exceptional systems engineering skills) consider setting up a forum with industry to draw up a roadmap that shows what will be needed in future, identifies skills gaps and the potential for industry to contribute.

(a) explore how NOVA and its institutes can have a dramatically higher impact on industry and valorization.

2.2.3. Talent attraction, training, and retention

The Committee recommends NOVA to

(b) develop a more clearly articulated talent strategy, towards Dutch society and industry, with clear objectives and targets, and a much more focused program to realize this, collaborating with the biggest "demand pools" (i.e., high-tech industry, banking and tech (e.g., for AI), government).

(c) set up a dedicated System-Engineering program in close collaboration with one or more of the Technical Universities (e.g., TU Delft Aerospace), ensuring that state-of-the-art SE methodologies are applied and providing unique training opportunities for talented students and staff.

(d) continue investing in a database on the career paths of its astronomy alumni (potentially in close collaboration with overall university alumni support), so that the department and NOVA can carry out an impact study on this important benefit of astronomy to society, regularly.

3. Viability

The Committee recommends NOVA to

(a) consider moving from a loose collaboration of institutions towards a strategic decision for NOVA scientists to address key problems with the instrumentation resources acquired through NOVA. Since all departments have an interest in exoplanet science, the discovery and characterization of exoplanets might be one possibility.

(b) develop a program for strengthening training in machine learning for astronomers, connect the astronomy community to the computer science community and help facilitate access to astronomical data for applications in data science.

(c) consider how the program would be managed in the event that Dutch scientists grant success falls significantly for a few years in a row, as a significant fraction of the Dutch enterprise relies on such short-term funding.

(d) work together as a Board and management to mobilize all influence in the highest levels of the respective host universities to ensure a successful outcome of a SUMMIT bid, as success is absolutely essential for the future health of NOVA and Dutch astronomy.

(e) against this background, explore new ways of presenting the program in a SUMMIT bid to emphasize a more coherent approach. One possibility might be to showcase the cross-

disciplinary advantages an advanced program in data science could have for astronomy and beyond. Further yet, NOVA could offer itself as a model for multi-institutional collaboration in other subjects.

4. PhD policy and training

The Committee recommends NOVA to

(a) expand provision of PhD student mentoring and training to include more regular student overnight events to provide graduate students with the opportunity to interact across institutions and networks.

(b) reinstate the practice of students having one of their committee members from another NOVA institute.

(c) provide more education, both to PhD students and postdocs, about the positive range of careers outside astronomy that are available in the Netherlands.

5. Postdocs

The Committee recommends NOVA to

(a) find ways to integrate postdocs more effectively into the program.

(b) ensure that parts of its excellent training and mentoring of PhD students are extended to its postdoctoral researchers, especially now that the SKIES program has ended.

(c) establish ways that the NOVA MT can hear directly from PhD students and postdocs.

(d) explore ways to extend one-day network meetings to two days, as this would greatly enhance the opportunities for networking for PhDs and postdocs.

(e) establish cross network groups that help the integration of new people, perhaps ease the sharing of best practice, and identification of suitable mentors.

6. Academic culture

The Committee recommends NOVA leadership to

(a) drive cultural change by example and make it clear that this is one of their prime goals, e.g. by involving MT in EDI committees (e.g. NAEIC) or including EDI officers in the management team. All staff and students need to see that any grievance that works its way up to the director level will be responded to promptly in a compassionate and thoughtful way.

(b) ensure that the highest standards and most effective procedures are in place across all the institutes.

(c) facilitate regular climate surveys/cultural audits to community surveys across the program to establish a baseline and monitor progress in improving the working environment. As practices for encouraging social safety vary, NOVA can play a role in sharing best practice. The aim should be to create an atmosphere of transparency and openness where people are kind to each other, and staff and students feel confident in raising matters of concern.

(d) to provide horizontal structures to improve communications and share experience (affinity groups, e.g. Women in NOVA, LGBT+ in NOVA, Internationals in NOVA…).

(e) facilitate this training and coaching for academic leaders, particularly those in positions of responsibility. This will help senior staff feel confident in their leadership roles, enable them to lead by example, and help them to recover from what, for some, has been a traumatic experience.

(f) consider how it might aid the partner institutes to reform their management structures to take account of their substantially increased size and the problems of internal communication that arise as a result. If partner institutes adopt management models with a nested structure, so that each person in the structure can realistically manage their direct reports, it will be necessary to establish some horizontal structures to avoid the groups becoming siloed. NOVA should consider what role it can play in the creation of such structures and the sharing of best practice among partners.

(g) give a clear goal and mission to NAEIC and increase its visibility within NOVA.

Assessment of Anton Pannekoek Institute, University of Amsterdam

1. Aims, strategy, organization

Through the preparatory documents and the site visit, the Committee received a clear view of the aims, strategy, and organization of Anton Pannekoek Institute (API). A summary is given below.

In 2021, the API celebrated its 100th anniversary. During the current review period, the API has grown to 14.3 faculty FTE, representing a 20% increase from the previous review period. The current 17.3 faculty FTE are held by a total of 20 individuals, 9 of whom are female and 13 of whom are of international origin. The number of full professors has also increased from 3 to 8, with all promotions coming from within the API. Additionally, the number of postdocs and PhD students at the API has increased by approximately 30% over the previous review period and has been consistently between 50 and 60 individuals. The API is located within the Faculty of Science (FNWI) at the University of Amsterdam (UvA). The API's management structure is led by a scientific director appointed by the dean after collecting input from API staff. The director is ultimately responsible for all decisions concerning the API and is supported by an institute manager and a management team, which currently consists of 4 staff members in addition to the institute manager. API's management culture is informal and flat, emphasizing short and informal lines of communication between the director and the faculty, staff, and PhD students.

The Institute's mission is to further research, teaching, and public understanding of astronomy. API conducts astronomical research and trains astronomers from bachelor to postdoctoral level, aiming at world-leading level in its activities. Historically the research of API is rooted in stars and stellar evolution. Over time, this opened two main domains: High-Energy Astrophysics (HEA), and Origins (ORI), and within these API currently has five research themes: (1) relativistic accretion, inflows and outflows, (2) dense matter, (3) transients, explosions and particles, (4) massive stars and stellar populations, and (5) exoplanets and planet formation. For its research, API uses world-class facilities in space and on the ground.

In addition to conducting its own research and education programs, API collaborates with local, national, and international partners. In collaboration with local partners, API has established two interdisciplinary research focus areas because of university-wide competitions for funding. These include GRavitation and AstroParticle Physics Amsterdam (GRAPPA), which is already structurally funded and involves the Free University (VU) and UvA physics, and Origins of Life (ORI), which is being established at the time of the report and involves VU earth sciences, UvA chemistry, and SRON. At the national level, API coordinates its research and instrumentation through NOVA and its strategy with the national funding agency NWO and its institutes SRON and ASTRON through the Astronomy Council (RvdA). Collaboration and coordination with other astronomy institutes are organized through shared supervision (NOVA institutes, SRON and ASTRON) and shared staff positions (ASTRON). API's international involvement is nationally coordinated through SRON, NOVA and ASTRON/JIVE. API faculty members also contribute significantly to the development of international agendas by serving on influential boards and advisory panels such as ESA, ESO, SKA, NWO, and ASTRONET.

2. Assessment of Anton Pannekoek Institute

In this section, the committee assesses the performance of API against the three criteria of research quality, societal relevance, and viability. It also weighs the results and reflections of the research unit on the four specific aspects of how it organizes and conducts its research with reference to Open Science, PhD policy and training, academic culture and human resources policy.

An overview of the committee's recommendations is given in section 3 of this report.

2.1. Research quality

The students and researchers at API have been highly productive scientists during the assessment period. They have been doing world-leading research in several areas. Overall, they have a strong, focused research program with high impact in forefront areas that are also well integrated within NOVA. API scientists are leading high-quality research work across a balanced portfolio: observation, theory, instrumentation and simulation. API scientists are leaders in open science through their work with the arXiv and their efforts at developing and supporting software both for simulations and for instrumentation. API scientists have played an important role in several very high-profile results in high energy astrophysics: the first image of a black hole, the measurement of the general relativistic precision of accretion disks, the discovery of jets emanating from neutron stars with strong magnetic fields, and NICER observations of plasma flows close to black holes. They have been at the forefront of the study of the puzzling Fast Radio Bursts and are leading efforts in the detection of low-frequency radio transients. API researchers are at the forefront of the most challenging and important problems in computational astrophysics: fully relativistic MHD simulations of the environment around black holes. API has a growing program in the exciting areas of planet formation and exoplanets. Also, the Institute is well integrated into the overall NOVA/Dutch astronomy framework.

Several standard performance indicators support API's impressive achievements over the reporting period. API staff produced 40% more refereed publication compared with the previous reporting period, some of them in highly prestigious journals such as Nature, Science, and PRL. Approximately 6% of API papers rank in the top 1% of highly cited papers, while 25% reach the top 10% category. Compared with the previous review period, API now has 20% more faculty, structurally. It has performed very well in attracting large personal grants (ERC and NWO). API's quality and impact are also evident through other indicators, such as prizes, memberships in academies, editorships, and other leadership roles, which remain at high levels.

API has done an excellent job in creating local collaborations. Established 10 years ago, GRAPPA (Gravitation and Astroparticle Physics Amsterdam) has become an outstanding and internationally recognized center connecting particle physics and astronomy. This exemplary interdisciplinary effort is now playing a key role in some of API's research highlights. Based on this example, API has also built strong connections with the chemistry and biology departments (Origins of Life). Further collaborations include instrumentation (ESO, ASTRON, SRON) and software development.

API continues to attract high quality PhD students from around the world and also has a strong cohort of postdoctoral researchers.

2.2. Relevance to society

General remark
As detailed in separate sections below, the Committee is of the opinion that API has generated substantial societal impact in all three pillars of the NOVA impact on society strategy: (a) outreach and public awareness; (b) strengthening the innovation landscape through industrial collaborations and start-ups (valorization); and (c) human capital generation. However, the Committee has observed that, while current impact is considerable, an organized focus could significantly enhance its impact. The Committee sees room to accelerate the impact on society through a more structured program. As explained in the NOVA section of the report (page 19-22), there is room for NOVA to play a stronger orchestrating role between the four institutes, so that the best initiatives get maximum scale, and that initiatives are supported by means of professional program management. At a local level, the Committee suggests to pair up with groups across the sciences to generate maximal impact.

Public engagement and education
The API has a solid education and outreach program. The Institute has been successful in engaging the local public. Notably, API has an exemplary outreach and education program aimed at young girls and local under-privileged children and foreign MSc students, with the ALTAIR and ASPIRE programs. These are critical activities to raise awareness of STEM in under-represented communities and may serve as a model that other NOVA institutions may want to emulate in the future. In addition, the Committee was impressed with API's creative new approaches, like collaboration with artists, drawing upon a long historical tradition of astronomy and art's mutual inspiration.

API's outreach program is strong when it comes to the media presence of its faculty. API members have played central roles in some of the most significant, and visible, astronomical discoveries of the past decade (e.g., gravitational wave discovery, colliding neutron stars, and black hole imaging). This work has earned significant recognition with international awards such as the Fame Lab and invitations to the Royal Society of Sciences and Humanities. Nevertheless, the Committee also observed that API's social media presence is modest. The level of reach reported in the self-assessment does not compare well with that of international institutes. API should make a decision to either invest more heavily in this area to increase the reach of their social media or not view this as an important part of their program.

The API has been actively engaged in building bridges between academia and society. Within the university, they teach broad courses such as "How to build an alien?", which the committee feels is an excellent way to engage a broader group of students (and encourage bachelor students from related areas to choose for astronomy as a master). More broadly, they work with artists to generate visual representations of black holes.

The Anton Pannekoek Observatory is highly valued by the API community as part of its outreach program. Nonetheless, with 1000 visitors per year, the usage for outreach is relatively modest. With the threat of construction blocking access to the site, API should consider alternative plans for remote observing facilities that could potentially engage a larger number of community members in astronomy.

Overall, API's outreach program has large potential for expansion, and is particularly promising given Amsterdam's multicultural nature. The program would benefit from a more strategic roadmap and plan, with specific goals and key performance indicators identified.

Valorization and interactions with policymakers
API has opportunities to strengthen its program of valorization. The Committee has noted very little impact in this area and feels that API has opportunities to step up: the focus on innovative

technology areas, in particular related to data science, the international and talented group of students and scientists, and the location on Amsterdam Science Park should allow for a more vibrant valorization program. The Committee would also think that NOVA can play a role here – for example by assisting in sharing of data science expertise across the different institutes, where it appears Groningen has already had a few notable valorization successes.

Human capital generation
With its strong undergraduate program, its engagement in data science, and its ability to attract outstanding international talent to Amsterdam, API contributes significantly to human capital generation for the Netherlands. Its plans to strengthen the connections with the strong data science program in Amsterdam will provide further opportunities to enhance its role in human capital generation. The new program in science, technology and innovation should provide pathways for students to careers in high tech fields.

The Committee recommends that API establish a database on the career paths of its astronomy alumni (potentially in close collaboration with overall university alumni support), so that the department and NOVA can carry out an impact study on this important benefit of astronomy to society, regularly.

2.3. Viability

With its strong research faculty, its excellent ability to recruit postdocs and graduate students from around the world, and its open, safe, and inclusive academic environment (see also below), API is well positioned to continue to lead in its targeted fields. The API faculty has grown to a size to create a vibrant institute. The Sectorplan will likely provide an additional significant growth in staff size.

Going forward, API's location on the Science Campus provides opportunities for strengthening connections with geographically and intellectually adjacent neighbors. GRAPPA has been a great success and is a model for future API partnerships. Amsterdam is ideally situated to build collaborations across science and data science. In this respect, the growing "Science and AI" program in the faculty of Science at UVA is an opportunity for future growth. UvA has a strong computer science department with interests in machine learning applications to physics. Microsoft's growing presence in Amsterdam offers additional opportunities for collaboration and interaction.

The "Science and AI" program has already been fertile ground for collaborations and could provide a route for Amsterdam to follow models such as MILA (Montreal Institute for Learning Algorithms). MILA has played an influential role in machine learning and has helped make Montreal a leading destination for the burgeoning data science industry. NYU's Center for Data Science offers another potential model for the "Science and AI" program with "capstone" projects that involve students working on a project with a faculty member: the model both encourages strong teamwork and code development skills that are highly valued by industry but also make more efficient use of faculty time in mentorship. However, the Committee is concerned that the current data science program will be too focused on narrow fields such as metamaterials. This will lead Amsterdam to miss out on opportunities to play an important role in the fast-growing field.

Amsterdam is also well positioned to play an important role in the interactions between data scientists and instrument builders. Data simulation is an important part of the Sector plan proposal and projects such as MOSAIC will be very data intensive. The API has significant strength in generating high performance simulation data. This simulation data can be very valuable training data for machine learning and the potential seed for growing stronger links between astronomy and data science at Amsterdam.

All these elements bode well for API's viability. However, the Institute has reached the size that requires the transition from the smaller "family" feel to a more sophisticated structure to ensure that people at all levels continue to feel they have a channel for communication, are valued and supported. Improved management structure and a larger support staff would alleviate some of the burdens on the members of the faculty. This could include a structure of a director with deputies, together with some matrix elements to avoid people working in silos. Moreover, a program of coaching and learning can enhance the skills of the management team. As is true in many academic environments, they are outstanding scientists that lack any formal leadership, mentorship and management training.

Another point of concern is that over the past six years, the number of postdocs and PhD students has shrunk modestly. There has been limited success in grants for PhD student and postdoc support. While not a presently critical situation, this is a potential area of concern.

2.4. Special aspects

2.4.1. Open Science

API has implemented best practices in open science. The Institute has made its data, codes, and scientific papers available. For example, API researchers have developed what is currently the fastest (ideal) GRMHD code available, H-AMR and the BHAC code, the primary open source European GRMHD code. They have implemented a formal Research Data Management policy and use Zenodo as the platform for data dissemination.

API has among its staff a world leader in supporting open access, serving as chair of the Science Advisory Board of the "arXiv". With over 2,000,000 papers and over 2,000,000 downloads per month, arXiv.org is the most important open-source site not only for astronomy, but also for mathematics, physics, and computer science.

2.4.2. PhD Policy and Training

The API offers an excellent and highly competitive PhD program. It has a strong interdisciplinary focus in its research and teaching, both through strong local connections, e.g., the GRAPPA and Origins of Life programs, and through national connections, e.g., SRON and ASTRON. This interdisciplinarity is one of the assets of the PhD program at the API. Another key asset, according to the Committee, is API's strong focus on equity, diversity and inclusion (see also below).

Generally, the PhD students appear to greatly enjoy their program at the API as part of the NOVA PhD school. PhD recruitment, procedures, and outcomes seem very good and in line with most NOVA institutes. Still, the interviews revealed that the PhD students do experience some confusion regarding their graduation requirements. In particular, they indicated that there is a worrisome perception among part of the PhD students that the graduation requirements are rather rigid and too demanding in terms of the number of papers to be published or submitted for publication. Evaluation of the graduation requirements and improved communication towards the PhD students could resolve this issue.

Besides the training and mentoring of PhD students, the Committee is happy to see that the API now also has a system in place for the training, supervision and mentoring of its postdocs. In particular, the Committee commends the establishment of a PhD/Postdoc council and the new initiatives to support the career development of postdocs. It encourages the Institute to keep up their laudable efforts to develop and maintain their supervision and mentoring system for both PhD students and postdocs. The committee believes that there is an opportunity to step up, and

more structurally create programs to connect PhD students with companies, where they can continue their career, as well as to stimulate entrepreneurship.

2.4.3. Academic Culture

Based on the Committee's meetings with the staff and the students, the research environment at API appears to be open, safe and inclusive. Students and staff alike pinpointed the safe, inclusive culture as one of API's strengths. API has been proactive in increasing social safety, as is evidenced by the wide array of actions taken to further improve academic culture. Sophisticated social safety procedures are in place and the information on these procedures is easily available. For example, API has formulated a well-thought-out Code of Conduct and has developed a Social Safety leaflet, which appears to be well-known among API's community. Equity, Diversity, and Inclusion (EDI) seminars and training are offered to staff to raise awareness on equity and diversity and to reduce biases in the API community. Importantly, an EDI committee to coordinate these activities has been established.

While fully appreciating the wide array of actions taken, the Committee sees room for improvement in better assessing the actual effectiveness of social safety and inclusion policy measures, and to further refine them where necessary, e.g. by means of a cultural audit or a recurrent survey. Also, the Committee suggests that the management team be more closely involved in the EDI committee to show leadership engagement. This would allow the management team to further enforce social safety measures and to promptly implement recommendations identified by the EDI committee. Furthermore, although the Committee values that PhD-students and post-docs can voice concerns through the PhD/postdoc Councils, it also learned that this structure is not always suited to report sensitive issues or concerns. Against this background, the Committee advises to look into the option to install spokespersons and advisors to detect social safety issues and provide alternative routes for young researchers to report issues and grievances as part of a confidential structure.

During the site visit, API management identified the Institute's flat management structure as a key element contributing to the warm academic culture. As mentioned above, the Committee is of the opinion that the Institute current scale requires a scale-up of its flat structure to a more sophisticated structure. This is also important in view of safety and inclusion. When scaling up, consideration of strategies for maintaining the positive culture within the institute is recommended.

The self-assessment and the Committee's meetings with the students, postdoctoral research and members of the faculty suggest that API has not fully recovered from the effects of COVID-19. There are too few people in the office and the pre-COVID-19 interactive culture has not been fully restored. It should be a high priority to get the entire staff, including the support staff, fully back into the office. The Committee notes, however, that this issue is common worldwide and not obviously specific to API.

The University's policy on research integrity appears fit for purpose, and there is no evidence of any issues of research integrity within the Institute.

2.4.4. Human Resources Policy

API has made significant strides in the past decade toward gender equity. The Institute has also attracted a diverse community of international scholars. As noted in its self-assessment, however, the representation of local minorities is lacking. The Altair program implemented by API staff is promising for improving this situation.

The Committee was pleased to learn that API provides dedicated management training to all

new employees, as well as coaching and additional courses to all career stages. Still, as noted by the management team, API needs to improve its on-boarding process. This weakness was most significant during COVID.

API has lost several outstanding staff members over the past few years. One of the risks associated with attracting outstanding international faculty is that they often get offers to play significant roles closer to home or leadership roles in other institutions. API has succeeded at retaining several people who had very attractive external offers.

Several members of the faculty noted growing work pressures due to mentorship, teaching, grant writing and research pressures. API's situation seems typical of many faculties worldwide recovering from the effects of the pandemic and its aftershocks. The management team noted that opportunities for sabbaticals are underutilized and could be helpful. Additionally, an improved management structure including additional support staff, as discussed above, are likely to relieve some of the research staff's stress.

2.5. Conclusion

API faculty members are conducting high quality research in extremely topical areas of astrophysics that have great potential for continued high impact going forward. API is also recruiting and training outstanding PhD students and postdocs. The API community seems healthy, with strong management, and a very open, diverse and inclusive culture. Amsterdam has become an important center, particularly for the study of compact objects and seems poised to continue to thrive. API has enjoyed significant growth which, if well managed, could bring it to even higher levels in the global astrophysics landscape. Going forward, API's location on the Science Campus and its experience in building interdisciplinary partnerships put it in an ideal position to build collaborations across science and data science. This should also provide a good platform for more valorization.

3. Recommendations

The Committee recommends the API to

1. improve the current management structure to accommodate the growing size of the Institute. Provide a program of coaching and learning to Institute leadership.
2. continue to proactively improve API's social safety net, particularly supporting diversity along multiple axes. The use of regular climate surveys/cultural audits can produce "closed loops" where policies can respond to needs and solutions can be assessed.
3. continue efforts to improve the academic culture: e.g. involve the management team in the EDI committee to show leadership on this aspect; e.g. install spokespersons and advisors to detect social safety issues.
4. seize the opportunities to build collaborations across science and data science, and to play a leading role in this fast-growing field.
5. seize the opportunities to play an important role in the interactions between data scientists and instrument builders.
6. evaluate the graduation requirements for PhD students and to improve its communication towards the students to remove existing unclarity regarding these requirements.
7. maintain effective gender balance over time and continue efforts to preserve/increase diversity.
8. accelerate the impact on society through a more structured program with clear objectives and professional support, where relevant supported by NOVA.

Assessment of Kapteyn Astronomical Institute, University of Groningen

1. Aims, strategy, organization

Through the preparatory documents and the site visit, the Committee received a clear view of the aims, strategy and organization of Kapteyn Institute. A summary is given below.

The Kapteyn Astronomical Institute, founded over a century ago, has grown from a single-professor institute to one that currently has 15.8 FTE research faculty members, about fifty PhD students, twenty postdocs, and a dozen research support staff. In addition, there are ten general support staff members, with some in the NOVA sub-mm lab and others in the Omega-Cen group that operates the Dutch Euclid Science Data Centre. The Kapteyn Institute is located within the Faculty of Science and Engineering (FSE) of the University of Groningen, and it is led by a Scientific (General) Director and an Education Director. The Institute is supported by a management team that includes the Education Director, Scientific Coordinator, and two senior staff members.

The Institute's mission is to conduct leading-edge research in astronomy, advance cutting-edge instrumentation, and prepare the next generation of exceptional researchers. During the current evaluation period of 2016-2021, the Institute has placed greater emphasis on interdisciplinary and multidisciplinary research, as well as on data science, and has also given importance to the research and instrumentation development environment. The latter involves improving policies, procedures, and practices that ensure a successful mission, including enhancing the work environment, providing training for non-academic jobs, promoting a better work-life balance, advocating for open science and FAIR research practices, supporting diversity within the institute's population, and beginning the process of achieving long-term sustainability for their research.

The Institute's research portfolio is centered around two large domains: (i) the formation, structure, and evolution of galaxies, and (ii) the formation and evolution of stars and planets, each connected to one of NOVA's main research networks. Some of the staff members also work on astrophysics in extreme conditions, but this remains limited in scope. Data science, particularly related to "Big-Data" processing and machine learning applied to astronomical data, has increased significantly in prominence in recent years.

Besides conducting its own research and education program, the Institute carries out joint interdisciplinary and cross-disciplinary research, instrumentation programs and educational activities with other FSE institutes. Kapteyn's data and compute-intense operations are done jointly with the Centre for Information Technology (CIT) at the University of Groningen, but also make use of other national and international facilities. Nationally, the Institute is part of the Netherlands Research School for Astronomy (NOVA) with the Kapteyn Institute and SRON-Groningen hosting the NOVA sub-mm lab. Instrumentation design and development are done jointly with SRON, ASTRON, JIVE and the two NOVA instrumentation labs, but also with the Groningen institute of engineering, ENTEG, and indirectly with ESO, ESA, SKAO and CTAO, and the ING on La Palma.

2. Assessment of Kapteyn Institute

In this section, the Committee assesses the performance of Kapteyn Institute against the three criteria of research quality, societal relevance and viability. It also weighs the results and reflections of the research unit on the four specific aspects of how it organizes and conducts its research with particular reference to Open Science, PhD policy and training, academic culture and human resources policy.

An overview of the Committee's recommendations is given in section 3 of this report.

2.1. Research quality

From every perspective, the Kapteyn Institute at the University of Groningen has been extraordinarily successful during this assessment cycle, despite the fact that the COVID-19 pandemic has had a profound impact on the traditional ways of doing business. This success is partially based on the ability of Kapteyn researchers to achieve a high return on past investments. The strategy of focusing research on two specific but key domains of modern astrophysics, (1) Structure, formation, and evolution of galaxies in their cosmic environment and 2) Structure, formation, and evolution of stars and planets in their Galactic environment, has undeniably been a great success.

One example of a success story resulting from this targeted approach can be found in the domain of Galactic archaeology. The long tradition at Kapteyn Institute in this field of astrophysics has led to very active participation in ESA's GAIA mission including in-depth analysis of the data releases. Tracing back the collision history of our Milky Way galaxy, this research has succeeded in identifying the last big collision in its history ten billion years ago. Additional ground-based spectroscopic observations of extremely low metallicity stars have further enlarged the picture of these early times of our Galaxy. These efforts have definitively positioned Kapteyn as a global leader in this highly competitive area of research.

Kapteyn's research achievements include several significant highlights covering both domains of research and obtained by observations ranging from optical/infrared to sub-millimeter and radio as well as a variety of investigating techniques. The focusing of Kapteyn Institute's research and the collaborations within NOVA in both science and instrumentation have definitively led to a significant further increase in the quality and impact of the research.

Several other indicators can be used to measure the quality of astronomical research carried out at the Kapteyn Institute. The research findings have been widely disseminated in the open literature, enjoy a high citation index, and have been influential in shaping future research in the field. Researchers at Kapteyn Institute have won prestigious prizes (e.g. Spinoza) and highly competitive external grants, all of which acknowledge the innovative, impactful, and valuable work being carried out. Finally, representatives from Kapteyn are members of important strategic committees thereby participating in shaping the future of astronomy in Europe and in the world (e.g. ESO Council).

Kapteyn Institute has been involved in the design/development of a number of instruments (e.g., ALMA receivers, Gaia, APERTIF, 4MOST, Euclid, WEAVE, LOFAR, SKA and ELT) and their associated data processing. In particular, the preparations for hosting the Dutch Euclid Data Center charged with processing petabytes of data into science-ready products have brought a new perspective to evolve the hosting of astronomical data by involving data science and computer science. This is an exciting development, based on strong local expertise and strategically integrated into NOVA's plans for developing synergistic collaborations with data and computer sciences. Kapetyn offers a number of best practices in these areas that should be

part of the effort of NOVA creating a new Dutch landscape where astronomical data enables developments in data and computer sciences.

2.2. Relevance to society

General remark
As detailed in separate sections below, the Committee is of the opinion that Kapteyn has generated substantial societal impact in all three pillars of the NOVA impact on society strategy: (a) outreach and public awareness; (b) strengthening the innovation landscape through industrial collaborations and start-ups (valorization); and (c) human capital generation. However, the Committee has observed that, while current impact is considerable, an organized focus could significantly enhance its impact. The Committee sees room to accelerate the impact on society through a more structured program. As explained in the NOVA section of the report (page 19-22), there is room for NOVA to play a stronger orchestrating role between the four institutes, so that the best initiatives get maximum scale, and that initiatives are supported by means of professional program management. At a local level, the Committee suggests to pair up with groups across the sciences to generate maximal impact.

Public engagement and education
Over the past funding period, the Kapteyn Institute has made remarkable progress in its outreach efforts. Their DOT Live planetarium shows in Groningen have captivated audiences, while the mobile planetariums have brought the wonders of astronomy to countless school children in northern Netherlands. The Dark Sky Program is a collaborative effort between the Forestry Service, the Wadden Foundation, and the Northern Provinces to raise awareness of the significance of dark skies for both humans and wildlife. This effort has culminated with the installation of a state-of-the-art robotic telescope, which serves for outreach purposes. The success of this project has led to its expansion into Germany, furthering its reach and impact.

Looking ahead, Kapteyn aims to further solidify its impact by honing in on a select few, highly impactful initiatives. The Committee encourages this strategy and encourages Kapteyn to be as ambitious as possible, including considering the sun as a subject allowing daytime activities. For this, a more structured approach is recommended defining target groups and corresponding goals to reach (e.g. how many school children should be reached per year) as well as a clear metric to measure the activities' impact.

Outreach activities require significant manpower. While some of it can be carried out on a voluntary basis by staff, postdocs and graduate students, proceeding with the hire of the outreach officer is seen as essential to ensure a professional and coherent approach. Finally, a close collaboration with the other NOVA institutions is seen as essential especially since the remote telescope approach may provide new synergies.

Valorization and interactions with policymakers
With a wealth of expertise in hosting astronomical data, the institute was well-positioned to launch VAEX.IO, a start-up dedicated to visualizing large data sets. With the mission "Big data made simple", they offer a full range of consultancy and training services to meet the data needs of their clients.

The second start-up, TiLT, is focused on empowering people to resist online manipulation by providing innovative and engaging products and services. In an era where misinformation and disinformation are becoming increasingly prevalent, this exciting development is a nice example of the impact astronomical research can have on society at large.

The Committee found that while very good, a more aggressive valorization in the private sector of the expertise developed at the Kapteyn Institute could be possible. It encourages a more

aggressive culture of entrepreneurship in which staff is actively encouraged to think about potential and rewarded in consequence.

In addition, the Committee is of the opinion that (also through NOVA), Groningen can play a strong role in encouraging the other institutes in their data science aspiration, where NOVA could play a role in ensuring economies of scale and scope.

Human capital generation
A large influx of international Bachelor students is evidence of an attractive academic program. With many of them dispersing over Europe for their Masters, this represents a significant contribution towards educating the young generation.

The Committee recommends that Groningen continue to invest in its database on the career paths of its astronomy alumni (potentially in close collaboration with overall university alumni support) , so that the department and NOVA can carry out an impact study on this important benefit of astronomy to society, regularly.

2.3. Viability

The Committee agrees with the Kapteyn Institute that it is well-positioned for the future, thanks in part to the substantial efforts made since last assessment. By including the committee's recommendations when crafting their strategic plan, the Institute has effectively improved in nearly all areas. However, new challenges have arisen because of their success, which have been acknowledged and addressed through measures already in place today or planned for implementation in the near future.

Building on past efforts, the Institute has made significant investments in securing its future through involvement in some of the largest astronomical initiatives, such as ESA's Euclid mission and ESO's ELT, both in instrument development and hosting data, such as the Dutch Euclid Science Data Center. In collaboration with data scientists at the University of Groningen, they aim to further evolve the Euclid Science Data Center into a more comprehensive and ambitious Astronomical Data Science Center, which will make a meaningful contribution to the field and secure a strategic position for the Institute.

With the instrumentation program within NOVA now secured by the Sectorplan, it is a suitable moment to evaluate the geographical distribution of the various instrumental groups, particularly the Opt/IR group at Dwingeloo. As ELT instrumentation becomes a major priority, the availability of large facilities for development, assembly integration, and verification becomes increasingly crucial. Simultaneously, maintaining a smaller, fast-track instrumentation program is equally important for testing future technologies and training the next generation of instrumentalists. A strategic positioning of the Kapteyn Institute within NOVA, integrating the possibility to host the Opt/IR group currently at Dwingeloo and the plans for developing a Dutch Astronomical Data Center would be beneficial.

All these elements bode well for Kapteyn's viability. However, the Institute has reached the size that requires the transition from the smaller "family" feel to a more sophisticated structure to ensure that people at all levels continue to feel they have a channel for communication, are valued and supported. An improved management structure and a larger support staff would alleviate some of the burdens on the members of the faculty. This could include a structure of a director with deputies, together with some matrix elements to avoid people working in silos. Moreover, a program of coaching and learning can enhance the skills of the management team. As is true in many academic environments, they are outstanding scientists that lack any formal leadership, mentorship and management training. Importantly, when scaling up, consideration of strategies for maintaining the positive culture within the Institute is recommended.

Another point of concern for Kapteyn is the high workload of staff, which can in part be traced back to the funding system in the Netherlands. The base funding of the system relies on the number of ECTS earned through teaching students and the number of PhD degrees awarded annually. For the latter, securing external grants is crucial. This puts the system under considerable pressure (especially junior staff) and creates a potential instability if success in securing large external grants decreases, especially considering that the recent years have been quite exceptional. Furthermore, the requirement that every undergraduate student carries out her/his own research project translates into an additional heavy burden on staff to supervise. As a potential approach to mitigate the risk of overload and potential burnout, Kapteyn could consider whether the involvement of postdocs and PhD students would be helpful.

2.4. Special aspects

2.4.1. Open Science

The Kapteyn Institute has a proactive policy that fosters open access publications, including financial support if necessary. As an example of proactive measures, a Digital Competence Center has been created at the University of Groningen with two research data management officers in charge of training early-career scientists and staff in open-data and software policies.

Currently, 95% of the Institute's publications appear to be open access. A similar policy for data (FAIR) is implemented.

2.4.2. PhD Policy and Training

The PhD students who were interviewed expressed high levels of satisfaction with their situation. They reported receiving adequate mentorship and resources necessary to conduct their research effectively. A visible system of formal and informal support for PhD students appears to be in place as well as adequate mentoring and supervision during their trajectory. A personalized Training and Support Plan, agreed by all parties, outlines the expectations for both the student and supervisors. Throughout their studies, PhD students receive constant feedback from the committee and have access to an independent mentor, confidential advisors, and psychological support if needed. The Committee commends the excellent onboarding of PhD students which includes clear communication about expectations and requirements.

PhD students experience a positive culture and appreciate the institute-wide interactions through lectures and colloquia, although the recovery from COVID-19 was still underway at the time of writing of this report. They spoke highly of the collaboration and interdisciplinarity in their research at the institute.

The Committee is pleased to see that during the evaluation period, the Kapteyn institute has moreover made considerable progress to advance the training, mentoring and support of its postdocs, which includes an initiative to introduce a training and support plan for postdocs similarly to the one for PhD students. However, thus far, support has been on a voluntary basis. This can sometimes lead to a perception that they receive less guidance and mentorship compared to the PhD students. Nevertheless, the postdocs interviewed expressed much satisfaction about the possibilities for career development at the Kapteyn Institute.

In conclusion, the Kapteyn institute appears to have a very happy PhD and postdoc community, and the large growth in undergraduate, graduate and PhD students attests that the Kapteyn institute offers a very attractive program indeed.

One point of concern is that the ratio of PhD students to staff remains very high at the Kapteyn institute. Over the evaluation period, this ratio has increased even further and it is now

significantly higher than at the other NOVA institutes. In combination with the high teaching load originating from the large number of BSc and MSc students, the Committee worries about the strain this might put on the tenured staff and the effects it could have on the quality of the program. The Committee encourages the Kapteyn institute to continue to evaluate the PhD student/staff ratio in view of both the quality of the PhD program and the high workload of the staff.

2.4.3. Academic Culture

The Academic culture within Kapteyn, through the Committee's interviews, appears to be very good. The recent challenging situation at Leiden has heightened awareness within the Institution of the importance of promoting a culture of openness, safety, and inclusiveness. The panel values that Kapteyn has an Equity, Diversity, and Inclusion (EDI) officer and provides EDI training for staff members, yet also learned from its discussions with the staff that they feel that they could use more training classes to help them with social safety and EDI aspects.

Kapteyn has a range of policies in place to support and protect their staff and students, including a code of conduct, independent mentors for all PhD students and postdocs, access to confidential advisors, psychological support, and an ombudsperson. Female staff hired through the Rosalind Franklin program also have a dedicated mentor network. Since the Covid pandemic, Kapteyn has set up a well-being committee, the KREC, which advises the director on all matters related to well-being in the Kapteyn community. These measures provide multiple ways for students and staff to raise flags in case of issues. Also, efforts are being made to raise awareness of the channels available to get help if needed.

All these measures ensure that Kapteyn's PhD student and postdoc communities feel happy and supported by their staff and management team. The PhD students and postdocs interviewed expressed satisfaction about the local culture and support they get. They indicated that they would trust their organization in handling a difficult personal situation should they experience one. Despite these very positive aspects, the Committee felt that while the appropriate policies are in place, there is no mechanism to effectively "close the loop", i.e. to verify that the measures taken are effective and are reaching their goal. The Committee sees room for improvement in better assessing the actual effectiveness of social safety and inclusion policy measures, and to further refine them where necessary, e.g. by means of a cultural audit or a recurrent survey. In this respect, NOVA could play a central role in ensuring that the different institutions exchange their experiences and, together, define best practices. Also, even though adequate policies are in place, the Committee observed that there is a noticeable level of stress in the staff due to overload and tenure-track pressure (see above).

The University's policy on research integrity appears fit for purpose, and there is no evidence of any issues of research integrity within the Institute.

2.4.4. Human Resources Policy

The Human Resources Policy at Kapteyn is excellent. The recommendation of the previous peer review committee to improve gender and demographic balance was taken very seriously, resulting today in a well-balanced and diverse staff in terms of both gender and age. The Committee extends its commendations to the Institute for this remarkable accomplishment. It remarks that the University's Rosalind Franklin program, that stimulates hiring female faculty and supports them once hired, has also been key in realizing this achievement.

The Institute has demonstrated that it takes the growth and success of early career staff during the tenure process very seriously. To this end, the organization offers several valuable support systems, such as a comprehensive mentoring program as well as a comfortable financial start-

up. New staff have regular progress meetings with the HR and management teams to help them for the tenure process. Additionally, a dedicated financial officer is available to assist with grants and interviews. The Institute also finances external consultancies when necessary. Learning the Dutch language is a requirement in the tenure track. An immersion course is offered, which staff has found useful.

The Committee learned that several research support staff, particularly in instrumentation, are funded through temporary project grants. This creates a challenging situation for an institution striving to establish long-term technical excellence. Although the positions obtained from the new Sectorplan will provide increased stability, some fragility will remain.

Training support is offered at all career stages. All students have a training budget and courses and have access to a special career perspective series. Postdocs also have access to these on a voluntary basis.

2.5. Conclusion

The Kapteyn Institute has progressed remarkably well since the last evaluation in all areas being assessed. The Institute has been able to produce a number of outstanding research results based on previous investments, which were acknowledged worldwide and which translated into increased external grant support, distinguished prizes, and an increase in overall reputation. They have a strategy in place for capitalizing further on their expertise by moving decisively more towards data science benefitting from local expertise on campus. The Sectorplan offers the Kapteyn Institute as well as all of NOVA an opportunity to reflect upon the geographical distribution of the Dutch instrumentation efforts in view of an increased priority given to the building of ELT instruments. An efficient recruiting approach has allowed the Kapteyn Institute not only to rejuvenate its staff but also to achieve gender parity, which is quite remarkable. The Committee would like to commend the Kapteyn Institute for their achievements.

3. Recommendations

The Committee recommends the Kapteyn Institute to

1. continue to evaluate the student/staff ratio in view of both the quality of the PhD program and the high workload of the staff.
2. continue to work towards a more stable funding situation for its research support staff.
3. improve the current management structure to accommodate the growing size of the Institute. Provide a program of coaching and learning to Institute leadership.
4. position itself strategically within NOVA, integrating the possibility to host the Opt/IR group currently at Dwingeloo and the plans for developing a Dutch Astronomical Data Center.
5. accelerate the impact on society through a more structured program with clear objectives and professional support, where relevant supported by NOVA.
6. proceed with the hire of an outreach officer.
7. develop a more aggressive culture of entrepreneurship.
8. organize regular surveys to assess the well-being of the community and confidence in the system in an anonymous way.
9. maintain its excellent gender balance and broad cultural basis.

Assessment of Leiden Observatory,
Leiden University

1. Aims, strategy, organization

Through the preparatory documents and the site visit, the Committee gained a clear picture of the aims, strategies and organization of the Leiden Observatory. A summary is given below.

Leiden Observatory, the astronomical institute of the Faculty of Science of Leiden University, was established in 1633. Over the reporting period, its permanent scientific staff grew from 22 people/19.9 FTE in 2016 to 41 people/33.6 FTE at the beginning of 2022. It now consists of around 40 faculty and adjunct faculty, 55 postdoctoral researchers, 130 MSc students and 100 PhD students, and 30 support staff. Its management structure consists of a day-to-day Management Team, a Scientific Management Team, and a Scientific Council. The aim is to give staff full freedom to develop their own scientific ideas and directions. The Observatory has a flat management structure.

The mission of Leiden Observatory is (1) to conduct world-class astronomical research, to maintain a strong PhD program, to contribute to the design of future major international observing facilities and to develop key technologies for groundbreaking astronomical discoveries; (2) to provide excellent education at Bachelor and Master level, not only to prepare students for PhD projects, but also for society at large; and (3) to engage the general public with exciting results and the beauty of the Universe. It places particular emphasis on studies of the characterization, formation and evolution of (1) galaxies and the structures in which they are embedded, and (2) exoplanets and their host stars.

The methods used range from numerical simulations on huge parallel computer systems, to observations with large ground and space-based observatories. The Institute has its own optical and astrochemical laboratories and has built its own dedicated large-scale multi-processing computing facilities. It also has access to world-class ground- and space-based observatories around the world. An important resource is the observational facilities that are provided by the European Southern Observatory (ESO). The Leiden Observatory is also home to the METIS project office. The main objective of its instrumentation program is to develop novel optical techniques and state-of-the-art instrumentation for the detection and characterization of exoplanets.

The Observatory works closely together with the Physics, Chemistry, Mathematics and Computer Science Institutes within the Faculty of Science, with a focus on cosmology, astrochemistry, advanced statistics, big data, large-scale computing, and machine learning. Nationally, the Observatory is well connected to the science networks of the National Research School NOVA. Recently the NWO national institute SRON moved to the premises of the Leiden University Science Campus. This has provided an opportunity to strengthen the links between the Observatory and SRON and thus ESA's space projects, and has led to joint appointments.

2. Assessment of Leiden Observatory

In this section, the Committee assesses the performance of Leiden Observatory against the three criteria of research quality, societal relevance and viability. It also weighs the results and reflections of the research unit on the four specific aspects of how it organizes and conducts its research with particular reference to Open Science, PhD policy and training, academic culture and human resources policy.

An overview of the Committee's recommendations is given in section 3 of this report.

2.1. Research quality

The research quality and scientific output of the Leiden Observatory is undeniably outstanding, covering a wide range of topics in contemporary astrophysics. The Observatory has a strong international reputation, and is one of the leading astronomy departments in the world. The large number of prizes and grants awarded to the Observatory's top faculty is testament to this research excellence. The group centered around Prof Ewine van Dishoeck is the world leader in astrochemistry research. Also, the exoplanet and planet formation research effort has grown substantially in the last six years, and enjoys a strong international reputation. The galaxy evolution effort has maintained its excellent international reputation with the recruitment of several new faculty members. The Observatory's performance in these fields is illustrative of the Institute's excellence, yet the examples are neither exhaustive nor do they do justice to the Institute as a whole.

The Observatory's researchers are active at the world's best facilities, including participation in the early science and GTO programs with JWST. They are also highly successful in winning competitive observing time at ALMA and ESO facilities. METIS has made excellent progress, and is on track to be one of the first three instruments to be commissioned on the ESO ELT later this decade. The guaranteed time programs for this instrument will allow research efforts in Leiden and elsewhere in NOVA to follow up on the results from JWST, particularly in the fields of astrochemistry and exoplanets. The Leiden-based ALLEGRO Arc-node is an extremely valuable resource in the Netherlands, providing excellent support to the Dutch ALMA users. Led and managed by top researchers themselves, the node provides the expertise needed to write successful proposals and to make the most of ALMA data.

The excellent and broad research profile of the Leiden Observatory has enabled it to attract top students and young researchers. Several standard performance indicators further support the Institute's impressive achievements over the reporting period. The Observatory has been very active and productive, with the number of published papers at an all-time high. Representatives of the Leiden Observatory are members of important strategic committees helping to shape the future of astronomy in Europe and in the world. The prestigious grants and prizes obtained are a testimony of the quality of the research at the Observatory, with the Kavli Prize in 2018 and the NWO Spinoza in 2022 as absolute highlights. The Observatory's success in obtaining these grants and prizes has led to a strong growth in the Institute over the last funding period. This growth is one of the two main challenges now facing the continued success of the Department, as discussed in the sections below.

2.2. Relevance to society

General remark
As detailed in separate sections below, the Committee is of the opinion that Leiden Observatory has generated substantial societal impact in all three pillars of the NOVA impact on society strategy: (a) outreach and public awareness; (b) strengthening the innovation landscape

through industrial collaborations and start-ups (valorization); and (c) human capital generation. However, the Committee has observed that, while current impact is considerable, an organized focus could significantly enhance its impact. The Committee sees room to accelerate the impact on society through a more structured program. As explained in the NOVA section of the report (page 19-22), there is room for NOVA to play a stronger orchestrating role between the four institutes, so that the best initiatives get maximum scale, and that initiatives are supported by means of professional program management. At a local level, the Committee suggests to pair up with groups across the sciences to generate maximal impact.

Public engagement and education
The outreach effort at Leiden has been extensive, and involves members of the Institute at all levels, from undergraduates to senior professors and everyone in between. It has benefited from the fact that the IAU regional office for Astronomy is located in Leiden, together with the coordination of the international celebration of the IAU's 100th anniversary. This celebration has included over 4000 events in 135 countries, reaching over 10 million people worldwide, which the Committee finds very impressive.

The dedicated Astronomy & Society Group reaches over 800.000 people every year, and organized in the review period a wide range of local and international activities, including a wide range of educational programs and a citizen science lab. Also, the regular collaborations with artists are noteworthy, drawing upon a long historical tradition of mutual inspiration.

The Committee is however uncertain about the ultimate goals of these efforts, and suggests that more specific objectives be formulated, helping to define targeted actions to maximize the impact of the efforts. The Committee also wonders whether a tighter collaboration with the three other astronomy institutes and NOVA could leverage this dedicated effort to create societal impact at scale and help to address the current fragmentation.

Valorization and interactions with policymakers
Another way in which the Institute in Leiden gives back to society is through its R&D in instrumentation and software development. A number of PhD students are also involved in these efforts, gaining valuable experience for their post-graduate careers.

The Committee noted several technology spin-offs that felt quite exciting, such as the cryogenic, fast tip-tilt mirror, SPEX, However, the overall valorization feels relatively low in comparison to the size of the group, and the Committee feels there is room for a much higher valorization impact.

Human capital generation
Leiden University trains a large number of Masters and PhD students every year. Many of these students go on to lead successful academic and research careers. However, many also take up very important positions in industry, schools, science journalism, software companies, etc.

The Committee recommends that Leiden continue to invest in its database on the career paths of its astronomy alumni (potentially in close collaboration with overall university alumni support) , so that the department and NOVA can carry out an impact study on this important benefit of astronomy to society, regularly.

2.3. Viability

The Leiden Observatory is a world leader in research, in the training of young students and postdoctoral researchers, and in the development and support of major instrumentation and observational efforts. It has grown to become one of the largest astronomy departments in the world. Its plans for the next six years remain ambitious, and the Committee has no doubt that

the research will remain strong. There are exciting research opportunities with JWST, ALMA, the ESO VLT and in the future the ELT. METIS is making good progress and now has a final design and a sustainable budget. The ALLEGRO ARC is providing excellent support and service to the Dutch ALMA community.

However, this growth and success has had some negative consequences for the Observatory as well. The Observatory is at a point where this long-standing center of excellence is at risk. This high-performing group has grown to a level that poses new challenges for management in terms of communication and coherence. Input to the Committee from all levels was that the size of the Observatory made it difficult to communicate regularly with colleagues outside of their own research groups. For example, the Committee heard that the current common room is not large enough to accommodate the entire Observatory. The move to a new building should help alleviate some of the size issues, but further measures are needed to improve the interaction and communication within the department.

The ratio of faculty to PhD students has not changed with the growth of the Observatory, which is excellent news for the mentoring of PhD students. However, the increased number of bachelor and masters students has placed an additional burden of supervision on the postdoctoral fellows, PhD students and scientific staff. Measures need to be taken to compensate those who take on additional burdens, especially for PhD students and researchers on non-permanent contracts.

The higher-level support for Allegro (senior postdocs, etc.) and (presumably) Metis is largely fixed term appointments, not tenure track. This means that there is always a risk of loss of expertise, as key people move on to other positions. There is some frustration among the senior project staff, who are consistently referred to as postdocs, even though they are leaders. There does not seem to be a role in the university system for this type of position. The Committee recognizes that it is not possible to change the employment laws, but urges the University and the Observatory to ensure that these critical staff are properly recognized for the immense value they bring to Leiden.

The flat management structure is not effective for the current size of the department. The recent harassment case has highlighted the need for smaller structures where people at all levels can feel they have a channel for communication, are valued and supported. The Director and senior management recognize this need. The Committee recommends that the Observatory seek advice on how best to restructure. This could include a structure of a director with deputies, together with some matrix elements to avoid people working in silos.

2.4. Special aspects

2.4.1. Open Science

Astronomy is a global leader in the area of Open Science, and Dutch Astronomy is a strong part of this global community. Within this context, Leiden Observatory adheres to the FAIR principles. The Observatory has a policy that fosters open publications and data. An example of Leiden's policies concerning open access is that all PhD candidates, before their defense, are required to disclose the location of all research data and their accessibility. It is now common practice at the Leiden Observatory to also make software open access and even required by many journals upon publication, even though making software available (such as AMUSE at Leiden Observatory) often requires significant investment in documentation, training, and maintenance. Currently, 95% of publications from Leiden Observatory are openly accessible via ADS (Astrophysical Data System).

2.4.2. PhD Policy and Training

The Leiden Observatory offers a very competitive PhD program unique in its size. In addition, the university offers attractive BSc and MSc training programs, which have also grown significantly in size and provide a pool of excellent potential candidates for its own PhD program. PhD students at Leiden have expressed their appreciation of the NOVA structure and the benefits they derive from it, such as the training they receive in career development and the interaction with students from other NOVA institutes.

However, it was clear from discussions with students and staff that the size of the Institute had a negative impact on aspects of their well-being and the social cohesion within the Institute. They felt that there was less interaction between the different groups within the Institute, and that the large number of undergraduate and graduate students put a considerable strain on the staff, PhD students and postdoctoral researchers. In particular, the latter group seemed to feel significantly more pressure from their supervisory responsibilities than their counterparts in the other institutes. A major source of anxiety identified by PhD students are the degree requirements in terms of the required number of published and/or submitted (first-author) papers, which they perceive as being disproportionately harsh and rigid. The Committee recommends that these requirements and their rigidity be evaluated and that communication to students be improved, as these requirements and their strict implementation may no longer be appropriate.

Recent events have shown that a strong focus on improving the social safety and (mental) well-being of PhD students and postdocs will be essential in the coming years to ensure a healthy and inclusive working environment in which they can thrive. NOVA may have a role to play here, and the Committee encourages the sharing of best practice between institutes. Several issues that became apparent to the Committee were the lack of a visible formal support structure for PhD students and postdocs, a perceived lack of confidentiality in the handling of feedback through the available channels, lack of clarity regarding the role of the second PhD supervisor, and the lack of adequate tools (e.g., surveys) to monitor the well-being of students and staff and to assess the impact of protocols and policies implemented. The Committee recommends that these and other issues be (further) addressed to ensure that Leiden Observatory can continue to run its world-class astronomy program with confidence.

2.4.3. Academic Culture

Leiden Observatory is still recovering from the harassment case that led to the exclusion of one of its staff members. The management team is working on new policies to improve the safety and academic culture at the observatory, with high expectations both internally and from the wider astronomy community. For example, at the time of the site visit a Social Safety Action Plan for Leiden Observatory was being unfolded. These policies will enable better practices for Leiden in the long term. To achieve this goal, the management team would benefit from external, independent support (coaches for the management team, inputs from the other NOVA institutes on their policies, etc.). In particular, this case revealed that the reporting system was flawed, and that victims did not trust the reporting mechanisms. This highlights the need for multiple avenues for raising concerns or issues. Regular climate surveys closely monitor the well-being of students and postdocs and, as importantly, their confidence in the reporting system. Such surveys have been organized by the management team in the past, but not on a regular basis. The Committee sees room for improvement in better assessing the actual effectiveness of social safety and inclusion policy measures, and to further refine them where necessary, e.g. by means of a cultural audit or a recurrent survey. The recently established Equality, Diversity, and Inclusion (EDI) committee is a promising step towards building a sense of belonging for the Leiden astronomy community and improving social safety.

2.4.4. Human Resources Policy

The gender balance at Leiden has improved significantly over the past period, with ten new female hires since 2016. Recommendations from the new EDI committee have contributed to this goal. There is still room for improvement, as the gender balance at all career levels has reached an average level of 30-35%.

Young staff have access to some training (teaching) and some degree of mentoring, as well as support in applying for grants. There is currently no mandatory training for HR /active by-stander. The management team would benefit from executive coaching and perhaps training in specific areas related to staff management and support.

The Committee was pleased to learn that the Observatory has been forward looking in preparing for the continuity of the research area of star/planet formation and astrochemistry, in view of the expected retirement of Prof. van Dishoeck, who is a world-renowned leader in this field. This is an important step for the future. The Institute is encouraged to look at ways to further support retiring faculty, who may wish to continue with their research after retirement.

2.5. Conclusion

Astronomy at Leiden University is one of the world's leading departments. The panel was impressed by the breadth and impact of the research and instrumentation programs, by the impressive number of publications, prizes and grants by the faculty and research staff, and by the quality of the postdoctoral and doctoral students attracted to Leiden. It was also impressed by the commitment of the staff, through their interactions with the department at all levels. Faculty, staff, postdocs and students alike are proud of the department and are recovering well from the recent incident, but mention that they would like to see more communication and structure in the institute. The Committee notes that the continued success of the Institute is at risk if management does not find a way to restructure it.

3. Recommendations

The Committee recommends the Leiden Observatory

1. to seek advice on how best to restructure in order to move away from the flat structure, which is not optimal for such a large department. This may involve establishing a Director + Deputies structure together with some matrix elements to avoid people working in silos.
2. to be vigilant in maintaining the world-class reputation of the top research groups in the event of retirement or departure of key faculty.
3. that the requirements for the award of a PhD degree and their rigidity be re-evaluated, as it considers that these requirements and their strict implementation may no longer be appropriate.
4. to continue to be vigilant in addressing the social safety issues at the Institute in order to ensure a healthy and inclusive working environment in which students and staff can thrive. Measures such as executive management coaching, harassment awareness and bystander training, and regular climate surveys could be useful to achieve the desired environment.
5. accelerate the impact on society through a more structured program with clear objectives and professional support, where relevant supported by NOVA.
6. to provide support to both junior and senior members of the Leiden astronomy community. The combination of COVID-19 and the recent harassment case has stressed the entire staff including its leadership. Now is the time to first recover and then rebuild.

Assessment of Department of Astrophysics, Radboud University

1. Aims, strategy, organization

Through the preparatory documents and the site visit, the Committee received a clear view of the mission, strategy and organization of the Department of Astrophysics. A summary is given below.

The Department of Astrophysics was founded in 2001 with two FTE academic staff and two PhD positions. Over time, it has grown significantly, and now includes 14 academic staff members (13 FTEs), three associated staff members, approximately 15 postdoctoral scientists, and almost 30 PhD students. The Department focuses on research and education in astrophysics, with particular emphasis on compact object physics, astroparticle physics, and the building blocks of galaxies, stellar evolution, populations, star clusters, interstellar matter, supermassive black holes, and magnetic fields. The Department also includes the Radboud Radio Lab (RRL), which employs approximately 10 FTE scientists and engineers to work on instrument development projects within the Department, as well as initiating and developing their own technological and innovation projects.

The Department is embedded in the Institute for Mathematics, Astrophysics, and Particle Physics (IMAPP) at Radboud University, which is part of the Faculty of Science (FNWI). It operates under a flat hierarchical structure. The Department head is supported by a deputy, secretariat, the IMAPP managing director, two liaison officers in the financial department, and one in the human resources department. The Department is also part of the Netherlands Research School for Astronomy (NOVA) at the national level. It is heavily involved in international scientific collaborations, including those with the European Southern Observatory (ESO), the European Space Agency (ESA) for projects such as LISA and Athena, the Event Horizon Telescope (EHT) collaboration, the Pierre Auger collaboration, and the VIRGO/LIGO/KAGRA collaborations. Additionally, the Department leads the BlackGEM/MeerLICHT consortia.

The Department's mission is to conduct world-class research, provide exceptional education and training to students and department members, and engage the general public in astronomy. To achieve this mission, the department aims to create an open and inclusive environment that enables researchers to freely pursue their research and educational goals and provides access to excellent facilities and training.

During the reporting period, the Department consolidated its existing main scientific research lines, which include black holes and accretion onto compact objects, gravitational waves and transients, cosmic rays, stellar physics, stellar populations, the Milky Way, and nearby galaxies, as well as instrumentation. Additionally, a new scientific research line on planet formation and exoplanets was established. These research lines have strong connections with partners within IMAPP, the Faculty of Science, NOVA, national research institutes, Astron, Nikhef, and SRON, as well as on an international level. The research lines also involve significant interdisciplinary activities.

2. Assessment of the Department of Astrophysics

In this section, the Committee assesses the performance of the Department of Astrophysics against the three criteria of research quality, societal relevance and viability. It also weighs the results and reflections of the research unit on the four specific aspects of how it organizes and conducts its research with particular reference to Open Science, PhD policy and training, academic culture and human resources policy.

An overview of the Committee's recommendations is given in section 3 of this report.

2.1. Research quality

Over the past six years, two of Astronomy's most iconic scientific results, the discovery and analysis of gravitational waves and associated electromagnetic signature from a merging neutron star binary, and the direct imaging of a supermassive black hole, had major participation from members of the Department of Astrophysics of Radboud University. The fact that these path-breaking discoveries involving large international teams had significant leadership from a single relatively small department is remarkable. It is a direct result of highly strategic focus and investment by Radboud University over the past decade. These results are so impressive, it is hard to imagine that such groundbreaking accomplishment will be repeated any time soon. Nonetheless, the Department remains well set to continue international leadership in its main areas for the decade to come.

Astrophysics at Radboud University has grown to reach a critical mass, which has been associated with a dramatic improvement of the research quality of the Department. The Department has decided to focus on specific research lines:

1. Black holes and accretion onto compact objects;
2. Gravitational waves and transients;
3. Cosmic rays;
4. Stellar physics, stellar populations, the Milky Way and nearby galaxies
5. Planet formation and exoplanets (recently added)

These efforts are enabled by work in Data Science and instrumentation.

The Department's research in black holes and compact object accretion, and in gravitational waves and transients (items 1. and 2. above) are very well supported by the instrumentation program, are world-leading, and highly complementary to each other. Leadership of the EHT, as well as development of the BlackGem and MeerLicht telescopes, and strong involvement in eLISA, will deliver high impact results into the future. In total, Radboud has established itself as a world leader in this highly topical area of Astronomy. It remains small but is outstanding.

In the cosmic ray arena (item 3. above) the Department participates in the Pierre Auger Observatory upgrade and has been part of the broader consortium results on the energy spectrum, mass composition, and arrival directions of cosmic rays. The Department is taking a leading role in the installation of the Radio Detector as part of the Pierre Auger Observatory upgrade. This has interesting synergy with the instrumentation/observing techniques relevant to their work in compact objects. Because of the large consortium nature of much of the cosmic ray work, it is harder to define the research impact of Radboud itself within the larger consortium.

Radboud's research in stellar populations and Galactic astrophysics (item 4. above) has significant scientific overlap with the compact object, gravitational waves and transients (items 1. and 2. above), which helps bring a coherence and critical scale to the Department in what might be seen as a fairly diffuse line of research inquiry. ISM and magnetic field work overlaps

with the cosmic ray work (item 3.) and bolsters these two areas which are relatively small. The work is of overall high quality.

The work on planet formation (item 5. above) is relatively new and comprises a single staff member who joined in 2020. It is not yet possible to assess this area of enquiry, though it has tremendous potential. The work on data science is proposed for the future, but is highly relevant in astrophysics broadly and a growth area.

Overall, Radboud's success as a department has been to create a series of highly topical overlapping research themes with well-supported researchers whose interests overlap. All of this is supported with an equally focused and well supported instrumentation program. This combination is laudable. One risk is diffusion away from collective themes. The new initiative in exoplanets (item 5.) is an area of intense global interest and does not obviously connect to other lines within the Department yet. It will be imperative to have a deliberate strategy to ensure this succeeds over the coming six years, especially as the single senior staff member is scheduled to soon retire. The plans for data science will be highly relevant to all other areas, but suffers from a global shortage of expertise, and connecting it to research strengths (and possibly other places) will be essential for success.

Within the context of metrics, the publication rate has grown and is strong, with average citations per paper off the charts due to major discoveries discussed above. The Department has done exceptionally well in extending its 1.3MEuro base funding, with an additional 500KEuro NOVA money, to secure 2.5-3MEuro grant funding per annum. This includes a series of highly competitive ERC grants. This is comfortably the highest grant return on investment (ROI) of all of the NOVA institutions, which, as a set, sits at the top of the ERC program with respect to ROI. In short, it is hard to imagine better research performance from a Department with less than 2MEuro of recurrent funding.

2.2. Relevance to society

General remark
As detailed in separate sections below, the Committee is of the opinion that the Radboud Department of Astrophysics has generated substantial societal impact in all three pillars of the NOVA impact on society strategy: (a) outreach and public awareness; (b) strengthening the innovation landscape through industrial collaborations and start-ups (valorization); and (c) human capital generation. However, the Committee has observed that, while current impact is considerable, an organized focus could significantly enhance its impact. The Committee sees room to accelerate the impact on society through a more structured program. As explained in the NOVA section of the report (page 19-22), there is room for NOVA to play a stronger orchestrating role between the four institutes, so that the best initiatives get maximum scale, and that initiatives are supported by means of professional program management. At a local level, the Committee suggests to pair up with groups across the sciences to generate maximal impact.

Public engagement and education
The iconic discoveries made over the past six years at Radboud have made a global impact with respect to telling the world about astronomical advances. These discoveries, which include Nobel-class achievements in gravitational wave astrophysics, and EHT black hole imaging, are literally in the top-10 best known scientific advances (from any area of study) in the world over this period. These are outstanding discoveries, and they were amplified to the public and in the press very effectively, and this is to be commended.

The Astronomy Department at Radboud puts in significant effort to connect to its local community, including stargazing evenings in the winter, public lectures, and other media

activity. This is important for the local community and appears to be of high quality. What might be of great benefit is a larger strategy to undertake this type of outreach at a national and global scale with specific objectives and quantified targets, in terms of school pupils reached and public reached. It would not be expected that Radboud could or should do this on its own. Certainly, integrating some of its activities and considerable effort into a NOVA-wide set of activities would seem to be worth considering. There are individual activities that are in this area – for example, StarGazing Live, and the impressive work in Southern Africa.

Valorization and interactions with policymakers
The instrumentation program through Radiolab seems to connect to local industry through direct interaction, and the creation of multiple spinoff companies. There would seem to be some green shoots here that indicate that a strategy informed and supported by a broader University technology transfer program would bear fruit and is worth considering. This might include targets for contracts, capital raised in associated spinoffs, and PhDs that have included work with an external partner. This effort also should be strengthened by NOVA wide alignment and orchestration.

Human capital generation
The Astronomy Department of Radboud has an excellent PhD program with a large majority of its graduates going into positions that clearly benefit from the PhD experience. It is pleasing to see 57% of its PhD students going into academic positions (indication of high academic quality); it is equally pleasing that a majority of students not going into the academy are undertaking work elsewhere that benefits directly from their PhD skillset.

The Committee recommends that Nijmegen establish a database on the career paths of its astronomy alumni (potentially in close collaboration with overall university alumni support), so that the Department and NOVA can carry out an impact study on this important benefit of astronomy to society, regularly.

2.3. Viability

The Astronomy Department at Radboud has come a long way over the past six years with respect to long-term viability. The Department has shown a coherent scientific program of great vitality, and has grown above a critical size needed for this excellence. It has a strong education program, and has shown the ability to bring benefit to society in multiple ways. It has substantially grown its income particularly effectively from external sources. However, it still remains the most fragile of the four Astronomy institutes in the Netherlands, ultimately due to having fewer base resources than the other three. From the quantitative data provided, the Committee learned that Radboud is the smallest of the four institutes, attracts over 50% of its total funding from external research grants and contracts, and receives the smallest fraction of its support from NOVA. The departmental budget, listed as 70 k € in 2021, is not large enough to be impactful.

Therefore, while Radboud's goals for the coming six-year period are appropriate, they are fragile. To be achieved, retention of key members of staff will be essential, as will be a continuing high level of success in acquiring external research grants and contracts. It seems likely that shocks to the current near-optimum state will occur over the next six years, and the resilience of the Department to such shocks should be of concern. When such shocks occur at other departments around the world, it typically results in loss of key staff, a full or partial retreat from novel research, outreach and instrumentation programs, and a contraction of activity away from excellence towards the basic activities required of the department around teaching and administration.

Given the outstanding state that the Department finds itself in currently, it is worthwhile to build in some resilience now, when things are good. The Department needs to ask itself if it can truly support seven research lines, sustainably, even with the new Sectorplan funding. Radboud University and NOVA (through the new Sectorplan) need to ask if they can increase, even if by a small amount, the underlying funding that supports the highly successful program, but in a way that does not stretch the Department to do too many new things, at the expense of the overall support of its current core of excellence.

2.4. Special aspects

2.4.1. Open Science

Astronomy is a global leader in the area of Open Science, and Dutch Astronomy is a strong part of this global community. While there is no clear stand-out activity at Radboud University in this area, given its relatively small size, it seems appropriate for it to work with other Dutch institutions as part of national and international initiatives, as it currently does. The upcoming investment in Data Science, via the Sectorplan, has the potential to add value in this area, but again, given the Department's size, any engagement should be part of a highly collaborative effort with partners outside the Department.

2.4.2. PhD Policy and Training

The Committee was pleased to observe that the PhD program has improved over the past six years with respect to the support of students. The interviews revealed that students show a high level of happiness with the program compared to six years ago. This is likely due to the systematic program put in place for each student, including having two supervisors, an on-boarding process that sets out clear expectations, and the creation of a PhD Advisory Committee (PAC) that monitors the progress of all students, which consists of two staff members that are not involved in the supervision.

Notably, PhD students and postdocs experience the atmosphere at Radboud as very positive. The relatively small size of the Department, also compared to the other NOVA institutes, leads to a strong feeling of social cohesion, and a culture of trust. For example, the Radboud PhD students and postdocs greatly value the weekly meetings that take place with the entire Department. The flat hierarchical structure also seems to work well. PhD students and postdocs appreciate that they have a representative to communicate information, requests and concerns to the Chair(s).

Wellbeing is high on the agenda of the Department, and the processes and structures that are in place seem to be working well. After the 2019 well-being survey revealed a number of (mental) wellbeing issues, monitoring of PhD students' mental health by supervisors and the PhD coordinator was strengthened, peer meetings were organized, and the accessibility to confidential advisors and mental health professionals was increased. These measures seem to be effective, and PhD students and postdocs confirmed that the support system is available and visible.

The bi-annual well-being surveys for the PhD students and postdocs look highly effective, and the PhD students view it as an adequate tool to flag any issues. It might serve as a template for the whole NOVA consortium to monitor the academic culture and the well-being of PhD students and postdocs, and as a means of evaluating the effect of implemented policies.

Similarly to students from the other NOVA institutes, Radboud students appreciate the opportunities that come with the embedding of their program in the NOVA framework, in particular participation in the events that are organized by NOVA, such as the third-year PhD weekend.

The program has also become substantially more gender-diverse over this period, and is consistently producing graduates with good employment outcomes, both within academia, and outside.

The future path looks appropriate, and the Committee encourages the Department to remain on course to continue with the current new innovations of its PhD students. It is likely to see even better completion times and graduate outcomes into the future.

2.4.3. Academic Culture

The academic culture within the Astronomy Department, through the Committee's interviews, appears to be uniformly good. This is perhaps not surprising given the high-level of performance over the past six years. The PhD, ECRs, and senior staff have identified as feeling part of a coherent community that is supportive. This includes members of the community who span a range of cultural backgrounds, as well as different genders, and sexual orientations. The flat management structure, appropriate for the Department's size, was repeatedly mentioned as allowing for openness in discussions and decisions.

Adequate policy measures have been implemented to support and improve social safety and inclusion. Commendably, the academic staff has access to various activities that raise awareness about equity, diversity and inclusion (EDI) and to improve social safety in their community. The Department's leadership, the academic staff including the co-chairs followed a two-day masterclass in Diversity & Inclusion organized by the Dutch Expertise Centre for Diversity Policy ECHO. The broader community participates in discussions, EDI sessions and active-bystander training at the weekly Department meetings. In case of any issues, the Department relies on University's Code of Conduct. The Committee notes that a Departmental Code of Conduct might further improve its visibility and generate more engagement of staff and management.

The policy measures mentioned above to address PhD students' and postdocs' mental wellbeing seem to further support the Department's engagement to constantly improve social safety and inclusion.

The University's policy on research integrity appears fit for purpose, and there is no evidence of any issues of research integrity within the department.

2.4.4. Human Resources Policy

Gender diversity, while much improved within the PhD cohort, remains challenging within the senior ranks. The proportion of women remains low at all career levels, and the issue is particularly relevant within the RRL. This situation puts additional loads to the Department's few female staff members, who are overly solicited in committees. . The issue needs unrelenting attention, most notably within the instrumentation program, if progress is to be made. This is even more pressing given the prospects of limited growth of the group. A specific strategy at improving diversity might help speed the journey.

The Department has done a good job of attracting and retaining its talent. By interview, members of the community feel supported in their careers, with clear pathways to advancement. The Department abandoned its tenure track system to "reduce the stress on young faculty members". It is unclear to the Committee how Radboud will mitigate any performance issues that might arise, that used to be managed through the tenure process. The Department needs to develop clear policies for evaluation and communicate them effectively.

2.5. Conclusion

The Department of Astronomy at Radboud University has had an absolutely outstanding past six years. It has grown in size to reach a critical mass, and retained almost all of its outstanding faculty. Its leadership in two of the most important discoveries within astronomy during the six-year period (and indeed the last fifty years), will be almost impossible to repeat, but it places it in a position of leadership within these areas for the coming decades. Also, the other areas of research within the Department are strong as well.

During the past six years, the Department has grown an instrumentation group that has had significant impact in empowering the scientific endeavor, as well as creating direct and indirect value for the people of the Netherlands. The program's current success has been facilitated by extraordinary success in research funding – with over half of its total income coming from external grants and contracts. The PhD Program has been greatly improved, and overall the whole community is happier and higher performing than six years ago. There are opportunities to further improve the diversity of the tenured academic staff, mirroring the success within the PhD program over the past period.

Over the coming six years, the Department has an appropriate plan to continue to foster a strong positive academic culture that underpins its excellent education program at the undergraduate and postgraduate level. It intends to pursue, with the help of investment from the new Sectorplan, a seven-strand research program, that includes new areas of exoplanets and data science. There are risks to further increasing the research horizons that this relatively small department with a very small recurrent budget undertakes, and we encourage the Department, NOVA, and the University to reflect on what is genuinely sustainable over the coming decade.

3. Recommendations

The Committee recommends the Department of Astrophysics to

1. celebrate what has been an extraordinary positive period in the Department's history.
2. continue with the changes made to the PhD program over the past year, and share these with other NOVA members. This includes approaches to improve gender balance, the PAC, inclusivity within the Department, and the wellness survey.
3. not lose focus on the support and retention of staff. Develop a plan for supporting and developing the performance of young staff in lieu of a tenure track process.
4. work with NOVA and the University to develop a sustainable budget and set of research themes that is resilient over a decade-long period.
5. accelerate the impact on society through a more structured program with clear objectives and professional support, where relevant supported by NOVA.
6. have a specific strategy to improve diversity within the Department over the coming decade. Radboud Astronomy should pay particular attention to increasing the gender ratio in their group for the next hires. This holds particularly for the next hires at the RRL, for which Radboud Astronomy should be proactively searching for female candidates and offer specific terms to attract them.
7. maintain the current friendly and supportive work environment.

Appendices

1. Appendix 1: Program site visit

Day 1	Day 2	Day 3	Day 4
Sunday Jan 22nd	Monday Jan 23rd	Tuesday Jan 24th	Wednesday Jan 25th
Dwingeloo – Groninger Museum	*Forum*	*Forum*	*Prinsenhof*
• PRC members arrive @Schiphol • Transfer north	9:00-9:30 Closed session PRC 9:30-10:00 Closed session PRC + NOVA Board & Directorate **• NOVA Plenary Session •** 10:00-10:20 NOVA Overview 10:20-10:40 Network 1 highlights 10:40-11:00 Network 2 highlights 11:00-11:20 Network 3 highlights *11:20-11:40 Coffee* 11:40-12:15 Instrumentation 12:15-12:30 Outreach 12:30-12:45 Valorisation	8:45-9:15 Closed session PRC **• PRC meets groups •** 9:15-9:45 PRC splits in 2 and meets: - PhDs (2 from each institute) - Postdocs (idem) 9:45-10:15 PRC splits in 2 and meets: - Junior staff - Senior staff *10:15-10:30 Coffee* 10:30-11:00 PRC splits in 3 and meets: - Representatives NOVA Instr groups - Representatives NOVA data science technical staff - NIC & Office 11:00-11:30 PRC & Directors HR session	9:00-12:00 Closed session PRC - Writing report (preliminary)
• *Lunch in transit*	*12:45-13:30 Lunch*	11:30-12:30 PRC Closed session (*lunch*)	*12:00-13:00 Lunch*
13:30-15:00 Visit to Op-IR instrumentation group in Dwingeloo Includes discussion with female/junior members 15:00-16:00 Transfer to Groningen 16:00-16:45 PRC members check in to hotel 16:45 Pickup by taxi, transfer to museum 17:00-19:00 Closed sessions: 17:00 PRC 18:00 NOVA Board & Directorate 18:30 NOVA RvT and penvoerder	**• Nijmegen session •** 13:30-13:50 Presentation by Director 13:50-14:35 Various cross sections 14:35-14:55 Societal relevance 14:55-15:25 Director & MT 15:25-15:45 Closed session PRC 15:45-16:00 *Coffee* **• Leiden session •** 16:00-16:20 Presentation by Director 16:20-17:05 Various cross sections 17:05-17:25 Societal relevance 17:25-17:55 Director & MT 17:55-18:15 Closed session PRC	**• Amsterdam session •** 12:30-12:50 Presentation by Director 12:50-13:35 Various cross sections 13:25-13:55 Societal relevance / Data sci. 13:55-14:25 Director & MT 14:25-14:45 Closed session PRC 14:45-15:00 *Coffee* **• Groningen session •** 15:00-15:20 Presentation by Director 15:20-16:05 Various cross sections 16:05-16:25 Societal relevance 16:25-16:55 Director & MT 16:55-17:15 Closed session PRC	13:00-13:45 Preliminary feedback to RvT on NOVA 13:45-15:00 Feedback to individual institutes and their deans: 13:45 Amsterdam 14:03 Groningen 14:20 Leiden 14:38 Nijmegen 15:00-15:30 Feedback to NOVA 15:30-16:00 Meeting with CvB's (at minimum from RUG) and OCW (remotely via Zoom)
19:00-21:00 Dinner PRC, NOVA Board & Directorate, RvT	18:45-20:45 Drinks & walking dinner Posters & exhibition	17:30-20:00 Closed working dinner PRC	

Appendix 2: Quantitative data on composition and funding

1. Staff

The staff overview tables are provided first for the individual NOVA institutes and the Optical-Infrared instrumentation group, and then for NOVA as a whole.

Staff UvA, FTE	2016	2017	2018	2019	2020	2021
Tenured Staff: HL	3,0	4,0	4,6	5,5	6,1	6,6
Tenured Staff: UHD	3,0	3,0	3,0	3,3	2,5	2,1
Tenured Staff: UD	2,0	1,7	2,2	3,5	3,8	5,4
Tenured Staff: staff (UD/UHD)	5,5	5,2	4,5	3,3	2,0	0,4
Postdocs	19,5	23,5	23,0	23,7	18,5	14,1
Co-workers	1,0	1,2	1,4	1,6	1,6	0,5
PhD students	37,8	41,4	39,1	36,5	32,7	34,3
Instrumentation	4,4	3,1	1,4	0,8	0,8	0,0
Total	**76,2**	**83,1**	**79,1**	**78,1**	**67,9**	**63,4**

Staff RUG, FTE	2016	2017	2018	2019	2020	2021
Tenured Staff: HL	10,0	10,2	9,2	9,3	10,3	10,3
Tenured Staff: UHD	2,7	2,7	3,2	3,5	3,1	3,5
Tenured Staff: UD	1,8	1,5	1,5	1,0	1,1	2,0
Postdocs	20,3	19,2	20,7	16,9	13,4	20,7
Co-workers	2,5	2,5	2,2	2,4	2,4	2,0
PhD students	39,9	42,1	48,1	44,3	47,3	52,1
Instrumentation	15,0	16,2	16,8	16,1	13,9	11,6
Total	**92,2**	**94,4**	**101,7**	**93,4**	**91,5**	**102,1**

Staff UL, FTE	2016	2017	2018	2019	2020	2021
Tenured Staff: HL	13,3	13,7	14,3	14,3	14,8	16,0
Tenured Staff: UHD	4,4	5,6	4,2	4,1	4,9	5,7
Tenured Staff: UD	2,3	2,7	6,0	7,8	9,3	11,9
Postdocs	44,7	40,8	45,4	41,8	44,0	43,6
Co-workers	1,4	1,4	1,6	1,6	1,6	1,60
PhD students	63,5	63,9	66,8	61,8	60,7	67,1
Instrumentation	6,0	11,9	10,3	7,7	6,5	6,5
Total	**135,6**	**140,0**	**148,7**	**139,1**	**141,9**	**152,4**

Staff RU, FTE	2016	2017	2018	2019	2020	2021
Tenured Staff: HL	6,0	6,0	6,5	6,9	6,3	7,5
Tenured Staff: staff (UD/UHD)	5,0	5,3	5,3	5,5	5,0	4,9
Postdocs	12,3	11,7	8,5	9,6	13,5	16,7
Co-workers	0,8	0,8	0,6	0,6	0,6	0,6
PhD students	21,6	20,7	18,1	17,1	20,3	20,0
Instrumentation	5,2	4,5	5,0	6,4	7,3	6,7
Total	**50,9**	**49,0**	**44,0**	**46,1**	**53,2**	**56,4**

Staff NOVA Opt-IR Group, FTE	2016	2017	2018	2019	2020	2021
Instrumentation	13,1	13,1	11,4	12,6	18,8	17,9

Staff NOVA total, FTE	2016	2017	2018	2019	2020	2021
Tenured Staff: HL	32,3	33,9	34,6	36	37,5	40,4
Tenured Staff: UHD	10,1	11,3	10,4	10,9	10,5	11,3
Tenured Staff: UD	6,1	5,9	9,7	12,3	14,2	19,3
Tenured Staff: Staff (UD/UHD)	10,5	10,5	9,8	8,8	7	5,3
Postdocs	96,8	95,2	97,6	92	89,4	95,1
Co-workers	5,7	5,9	5,8	6,2	6,2	4,7
PhD students	162,8	168,1	172,1	159,7	161	173,5
Instrumentation	43,7	48,8	44,9	43,6	47,3	42,7
Total	**368**	**379,6**	**384,9**	**369,5**	**373,1**	**392,3**

2. Funding

NOVA

NOVA funding, per source (k€)	2016	2017	2018	2019	2020	2021	Total
NOVA grant (Ministry of OCW)	5.354	5.363	5.602	5.735	5.884	6.023	33.961
ESO	2.233	1.627	1.172	183	929	283	6.427
NWO, including Roadmap	892	1.045	935	4.758	2.862	1.140	11.632
SRON	0	3	0	0	0	0	3
ASTRON	0	67	0	0	0	0	67
External funding ESA & NSO	0	0	150	225	352	0	727
Other universities	14	1.406	0	51	0	6	1.477
Industry contracts	19	51	4	10	35	97	216
Miscellaneous	40	9	1	107	58	0	214
Funding, total	**8.553**	**9.569**	**7.865**	**11.068**	**10.121**	**7.550**	**54.726**
Expenditures:							
Research	2.785	2.277	1.998	2.396	2.662	2.673	14.791
Instrumentation	6.111	5.716	5.620	5.933	6.191	6.207	35.778
Office & NIC	674	554	689	798	847	791	4.353
Expenditures, total	**9.570**	**8.547**	**8.307**	9.127	9.700	9.671	54.922

Anton Pannekoek Institute, University of Amsterdam

UvA, API	2016	2017	2018	2019	2020	2021
Revenues						
Direct University funding	3.955	3.484	3.036	3.135	3.540	4.602
NOVA including NIC	1.367	1.346	962	1.224	1.377	1.057
National research grants	1.823	2.163	2.390	2.685	1.687	1.627
International grants and contract research	759	856	1.293	1.267	668	664
Other	73	30	19	30	29	19
Total revenues	**7.976**	**7.878**	**7.700**	**8.342**	**7.301**	**7.969**
Expenditure						
Personnel costs	6.347	6.990	6.948	7.720	6.637	7.175
Instrumentation costs	81	81	81	81	81	81
Other costs	1.085	1.190	1.168	1.236	843	395
Total expenditure	**7.513**	**8.262**	**8.197**	**9.036**	**7.561**	**7.651**

Kapteyn Astronomical Institute, University of Groningen

Funding Table	EU	sub	2016	2017	2018	2019	2020	2021
		Other	2.347.001	2.670.059	2.325.012	2.302.411	2.198.927	2.805.947
		Nova	1.929.841	1.885.634	1.500.498	1.580.210	1.457.797	1.582.055
		Total	4.276.842	4.555.693	3.825.510	3.882.621	3.656.724	4.388.002
Research Grants nat.		Other	1.389.601	1.594.039	1.949.618	1.956.972	1.254.031	992.949
Research Grants Inter.	EU	ERC	901.428	700.428	929.083	838.892	722.330	757.927
	EU	Other	14.104	5.777	157.115	191.355	456.349	525.133
	Non-EU	Other	43.695	127.636	265.502	311.111	605.362	607.934
Total Research Grants Inter.			959.228	833.842	1.351.700	1.341.358	1.784.041	1.890.994
Grand Total			**6.625.671**	**6.983.573**	**7.126.828**	**7.180.951**	**6.694.796**	**7.271.945**
Expenditure								
Personnel costs			5.732.123	5.913.214	5.871.768	5.837.046	5.646.296	6.523.650
Other costs			893.548	1.070.359	1.255.060	1.343.905	1.048.500	748.295
Total Costs			**6.625.671**	**6.983.573**	**7.126.828**	**7.180.951**	**6.694.796**	**7.271.945**

Leiden Observatory, Leiden University

Revenues	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Direct university funding [1)]	4.175	5.420	6.211	6.066	6.342	7.225
NOVA (without NOVA office)	1.131	1.164	1.085	1.220	1.314	1.770
National Research grants [2)]	4.455	4.747	4.543	3.957	3.680	4.113
International grants EU	2.775	2.803	2.329	2.134	2.508	2.412
Contract research / other [3)]	185	212	515	640	361	596
Total Revenues	**12.721**	**14.346**	**14.683**	**14.017**	**14.206**	**16.116**
Expenditure	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Personnel costs[4)] excl NOVA office	9.950	10.917	11.541	10.737	12.125	13.863
Instrumentation costs[5)]	741	583	476	342	295	234
Other costs	2.026	2.684	2.268	2.335	1.685	1.707
Total Expenditure	**12.717**	**14.184**	**14.285**	**13.414**	**14.105**	**15.804**

Department of Astrophysics, Radboud University

	2016	2017	2018	2019	2020	2021
Revenues						
Direct University Funding	947	995	926	1.061	1.215	1.312
NOVA	*1.058*	*490*	*269*	*425*	*242*	*488*
National research grants (NWO)	*1.095*	*1.309*	*1.316*	*1.310*	*1.425*	*1.309*
International Grants and contract research	*1.128*	*1.779*	*1.462*	*1.851*	*1.591*	*1.233*
Other Grants	235	-	188	-	-	-
Other revenue 1ste GS	817	972	909	1.024	734	775
Total Revenues	5.280	5.545	5.070	5.671	5.207	5.117
Expenditure						
Personnel costs 1ste GS	1.462	1.495	1.622	1.693	1.918	2.085
Personnel costs 2de GS	1.810	1.861	1.891	2.239	2.356	2.227
Instrumentation costs total	1.945	1.802	1.403	1.166	628	267
Other costs	22	29	33	18	30	47
Total Expenditure	5.239	5.187	4.949	5.116	4.932	4.626

3. PhD candidates

NOVA

Enrolment					Completion											
Year of enrolment	Total # enrolled	# Male	# Female	% Female	In year 4		In year 5		In year 6		In year > 6		Yet to graduate		Discontinued	
					#	%	#	%	#	%	#	%	#	%	#	%
2013	45	27	18	40,0%	32	71,1%	4	8,9%	2	4,4%	0	0,0%	2	4,4%	5	11,1%
2014	58	34	24	41,4%	45	77,6%	6	10,3%	3	5,2%	1	1,7%	0	0,0%	3	5,2%
2015	46	30	16	34,8%	34	73,9%	9	19,6%	0	0,0%	0	0,0%	0	0,0%	3	6,5%
2016	35	20	15	42,9%	21	60,0%	6	17,1%	1	2,9%	-	-	5	14,3%	2	5,7%
2017	51	31	20	39,2%	23	45,1%	0	0,0%	-	-	-	-	25	49,0%	3	5,9%
2018	45	28	17	37,8%	2	4,4%	-	-	-	-	-	-	42	93,3%	1	2,2%
Grand Total	**280**	**170**	**110**	**39,3%**	**157**	**56,1%**	**25**	**8,9%**	**6**	**2,1%**	**1**	**0,4%**	**74**	**26,4%**	**17**	**6,1%**

Anton Pannekoek Institute, University of Amsterdam

Enrolment					Duration interval											
Year of enrolment	Total # enrolled	# Male	# Female	% Female	t < 5 yr		5 ≤ t < 6 yr		6 ≤ t < 7 yr		t ≥ 7 yr		Not grad. before 12-31-2021		Disco nt.	
						%		%		%		%		%		%
2013	11	5	6	54,5%	7	63,6%	1	9,1%	0	0,0%	0	0,0%	0	0,0%	3	27,3%
2014	13	6	7	53,8%	10	76,9%	2	15,4%	0	0,0%	0	0,0%	0	0,0%	1	7,7%
2015	16	10	6	37,5%	15	93,8%	1	6,3%	0	0,0%	0	0,0%	0	0,0%	0	0,0%
2016	8	5	3	37,5%	5	62,5%	2	25,0%	0	0,0%	-	-	1	12,5%	0	0,0%
2017	7	3	4	57,1%	4	57,1%	0	0,0%	-	-	-	-	3	42,9%	0	0,0%
2018	10	7	3	30,0%	1	10,0%	-	-	-	-	-	-	9	90,0%	0	0,0%
Grand Tc	**65**	**36**	**29**	**44,6%**	**42**	**64,6%**	**6**	**9,2%**	**0**	**0,0%**	**0**	**0,0%**	**13**	**20,0%**	**4**	**6,2%**

Kapteyn Astronomical Institute, University of Groningen

Year of enrolment	Total enrolled	# M	# F	% F	< 5 yr		5 - 6 yr		6 – 7 yr		t ≥ 7 yr		Not graduated before 12-31-2021	%#	Discontinued
2013	9	6	3	33,3%	7	77,8%	0	0,0%	0	0,0%	0	0,0%	1	11,1%	1	%
2014	19	12	7	36,8%	14	73,7%	2	10,5%	1	5,3%	0	0,0%	0	0,0%	2	11,1%
2015	8	6	2	25,0%	3	37,5%	3	37,5%	0	0,0%	0	0,0%	0	0,0%	2	10,5%
2016	9	3	6	66,7%	4	44,4%	2	22,2%	1	11,1%	-	-	2	22,2%	0	25,0%
2017	18	9	9	50,0%	8	44,4%	0	0,0%	-	-	-	-	9	50,0%	1	0,0%
2018	16	11	5	31,3%	0	0,0%	-	-	-	-	-	-	15	93,8%	1	5,6%
Grand Total	79	47	32	40,5%	36	45,6%	7	8,9%	2	2,5%	0	0,0%	27	34,2%	7	6,3%

Leiden Observatory, Leiden University

Enrolment					Duration interval											
Year of enrolment	Total # enrolled	# Male	# Female	% Female	t < 5 yr	%	5 ≤ t < 6 y	%	6 ≤ t < 7 y	%	t ≥ 7 yr	%	Not grad. before 12-31-2021	%	Discont.	%
2013	15	9	6	40,0%	11	73,3%	2	13,3%	1	6,7%	0	0,0%	0	0,0%	1	6,7%
2014	24	15	9	37,5%	19	79,2%	2	8,3%	0	0,0%	1	4,2%	1	4,2%	1	4,2%
2015	20	13	7	35,0%	15	75,0%	4	20,0%	0	0,0%	0	0,0%	0	0,0%	1	5,0%
2016	15	9	6	40,0%	10	66,7%	3	20,0%	0	0,0%	-	-	0	0,0%	2	13,3%
2017	22	18	4	18,2%	6	27,3%	0	0,0%	-	-	-	-	13	59,1%	3	13,6%
2018	20	11	9	45,0%	3	15,0%	-	-	-	-	-	-	15	75,0%	2	10,0%
Grand Total	**116**	**75**	**41**	**35,3%**	**64**	**55,2%**	**11**	**9,5%**	**1**	**0,9%**	**1**	**0,9%**	**29**	**25,0%**	**10**	**8,6%**

Department of Astrophysics, Radboud University

Name	Start Date	End Date	Duration [yr]
Johannes Schulz	15/02/2012	11/02/2016	3.99
Serena Repetto - f	01/10/2011	28/09/2016	4.99
Sally MacFarlane - f	15/12/2011	28/09/2016	4.79
Deanne Coppejans - f	15/12/2011	03/10/2016	4.80
Rocco Coppejans	14/01/2013	23/03/2017	4.19
Pim van Oirschot	01/09/2011	17/04/2019	7.63 (*)
Emilio Enriquez Rascon	01/10/2011	29/09/2019	7.99
Christiaan Brinkerink	01/03/2012	22/09/2021	9.56 (*)
Cameron van Eck	14/01/2013	09/10/2017	4.74
Thomas Wijnen	01/03/2013	05/10/2017	4.59
Payaswini Saikia - f	15/07/2013	14/06/2018	4.91
Jan van Roestel	01/09/2013	27/11/2018	5.24
Thomas Wevers	01/09/2013	30/11/2017	4.25
Ester Aranzana Martinez - f	01/10/2013	07/09/2018	4.93
Andrei Igoshev	01/10/2013	21/12/2017	4.22
Roque Ruiz Carmona	01/10/2013	22/11/2019	6.14
Irene Polderman - f	01/10/2014	22/03/2021	6.48 (*)
Arthur Corstanje	15/01/2009	23/09/2019	10.69 (*)
Thomas Bronzwaer	01/10/2014	04/07/2018	3.76
Martha Saladino Rosas - f	01/10/2014	12/06/2019	4.70
Svea Hernandez Orta - f	01/01/2015	22/06/2018	3.48
Ala'a Al-Zetoun	01/06/2015	05/10/2020	5.34
Kristhell Lopez - f	01/10/2015	03/04/2020	4.51
Giacomo Cannizzaro	01/10/2015	24/06/2021	5.73
Freek Roelofs	01/11/2016	28/10/2020	3.99
Jordy Davelaar	15/09/2016	24/08/2020	3.94
Michael Janβen	01/10/2016	13/01/2021	4.28
Bjarni Pont	01/04/2017	28/06/2021	4.24
Sara Issaoun - f	01/09/2017	03/09/2021	4.01
Jakub Klencki	01/09/2017	28/09/2021	4.08
Martyna Chruslinska - f	01/09/2017	27/09/2021	4.07