Research Assessment 2010-2015

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

March 2017

Executive summary - Netherlands Research School for Astronomy (NOVA)

An external committee of senior scientists (henceforth the 'Evaluation Board' or EB) 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 November 2016. This executive summary contains a brief overview of the EB's main findings on NOVA. Findings on the separate university institutes can be found in the relevant sections of the report.

First and foremost, the EB can certify that NOVA has performed at an exemplary level in all the key areas of its mission: research, instrumentation, PhD education, and education and outreach. These exemplary standards hold across all of the institutes, with NOVA greatly enhancing existing institutional strengths.

The very high degree of integration between research and instrumentation strategies is a key element in NOVA's ability to `punch well above its weight' in astronomy within Europe and the world. The EB emphasizes that the NOVA-led PhD program in astronomy and astrophysics is of the world-wide highest quality in all respects. The NOVA coordinated outreach activities set a standard that is exemplary for comparable astronomy and education outreach programs world-wide.

Notwithstanding this enthusiastic overall assessment, the EB has also produced recommendations, in line with its role as a peer review panel. The EB recommends that NOVA continues to review its scientific strategy on a regular basis, in order to be able to exploit rapidly emerging scientific opportunities. Secondly, NOVA and its partner universities should continue to exercise tight managerial and financial oversight of the METIS project, with particular attention to management of externally subcontracted work packages, in order to mitigate the considerable risks associated with a project of this scale. Thirdly, the EB is of the opinion that NOVA and its partner universities should continue to take proactive steps to address the pronounced imbalances in the age and gender distributions among its tenured and tenure-track faculty. Fourthly, the NOVA Board should continue its preparations to identify, recruit, and appoint successors to the current Academic and Executive Directors of NOVA, both of whom will step down in 2-4 years. Fifthly, elements of NOVA's excellent coordination of supervision and mentoring of PhD students should be extended and adapted to improve the mentoring of its ~90 postdoctoral research associates. And finally, NOVA should produce a comprehensive long-term education and outreach strategy, which would consider the balance between different elements (in the context of existing activities across STEM subjects in the Netherlands), and prioritize future activities accordingly. The EB trusts that its recommendations will prove helpful to NOVA and the Netherlands scientific establishment as they develop strategic plans for the coming decade.

The Board's work was greatly aided by the excellent set of materials that were provided and the open discussions during the site visit. The Board's ability to quickly reach consensus on virtually all key findings and conclusions was due in no small part to the extremely high quality of the background information presented.

Preface

This review evaluates the research quality, relevance to society, and viability of astronomy in the Netherlands over the past six years (2010 – 2015), at four university-based institutes (Anton Pannekoek Institute at the University of Amsterdam, Kapteyn Astronomical Institute at the University of Groningen, Leiden Observatory at Leiden University, Department of Astrophysics at Radboud University Nijmegen) as well as at the Netherlands Research School for Astronomy (NOVA), an independently funded organization linking activities across these institutes.

The Evaluation Board consisted of seven professors from leading universities and research institutes in Europe, the USA, and Australia, with expertise spanning the range of subfields and activities undertaken in Dutch astronomy. I am indebted to all of these Board members for their hard work and cooperative spirit throughout the evaluation process.

The Board's work was greatly aided by the excellent set of materials that were provided to us by NOVA and each of the four institutes in advance of the review visit. During the visit itself, we benefited from impressive presentations and frank discussions with the directors, staff, PhD students, and postdoctoral researchers. Together, these provided the Evaluation Board with the documentation and information needed for its work, and enabled it to optimize use of the relatively limited contact time available. The Board's ability to quickly reach consensus on virtually all key findings and conclusions was due in no small part to the extremely high quality of the background information presented. We would like to extend a special thanks to the institute directors, professors Ralph Wijers, Reynier Peletier, Huub Rottgering, and Paul Groot, and Ewine van Dishoeck and Wilfried Boland, the Academic and Executive Directors of NOVA, respectively, for their support and assistance in the review process.

For this review, all presentations and deliberations took place at Leiden University, rather than having subgroups of the Board visit each institute. On the one hand, this arrangement maximized the time available for full Board discussion and also ensured consistent evaluations of the institutes. On the other hand, the arrangement placed a heavy burden of organization on the staff of the NOVA office, and we would like to acknowledge in particular Jacqueline Quist for her excellent logistical support leading up to and during the course of the review. We would also like to record a special thanks to the Secretary of the review, Jetje De Groof. Dr. De Groof provided unflagging and exemplary support to the Evaluation Board, and in particular to its Chair, as well as maintaining a superb set of minutes, which were invaluable in the preparation of this report.

The goal of this review was to offer an objective external evaluation of the research, societal relevance, and viability of the Dutch astronomical institutes and organizations. As will become apparent, our assessment of activities in all of these areas is very positive. Astrophysics is a strong discipline in the Netherlands, with an established tradition for excellence, and a good record for being involved in front line topics. The role played by the Netherlands in astrophysics is clearly much above what could be expected from a country of its size, and accordingly many of its researchers and results enjoy high recognition. At the same time, the Dutch astronomical institutes have a major impact on a broad range of national societal issues. These exemplary standards hold across all of the institutes, aided greatly by the success of NOVA in enhancing and building on existing institutional strengths. Notwithstanding this overall enthusiastic assessment, the Evaluation Board has taken its role as a panel of 'critical colleagues' very seriously and trusts that its findings and recommendations will prove helpful to the astronomy institutes, their host universities, NOVA, and the Netherlands scientific establishment as they develop strategic plans for the coming decade.

January 2017
Prof. dr. R.C. Kennicutt, Chair

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The Evaluation Board and the review procedures

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

An external committee of peers (henceforth the 'Evaluation Board' or EB) 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 November 2016, and reports its findings in this document.

This peer review is part of the assessment system for all publicly funded Dutch research organizations. In accordance with the Standard Evaluation Protocol 2015-2021 for Research Assessment in the Netherlands (SEP), the EB's task was to assess the quality of NOVA and the four university astronomical institutes on the basis of the information provided by the institutes and by interviews with management, the research leaders, staff members, PhD program management and PhD students, as well as to advise on possible improvements.

2. Criteria and Assessment Scale

The SEP requires the EB to assess the research according to three main criteria:

- Research quality (the level of the research conducted);
- Societal relevance (social, economic and cultural relevance of the research);
- Viability (strategy, governance and leadership).

The qualitative assessments are supplemented by assigning discrete categories (1-4): Excellent (1); Very good (2); Good (3); Unsatisfactory (4). Appendix 2 provides a complete description of each of the categories on this four-point scale.

Astronomy in the Netherlands is very strong, as detailed in the remainder of this report. Each of the four institutes contains individual research groups carrying out world-leading work in their specialties, and the strength of the departments is evidenced by the high Category scores assigned by the EB, none lower than Very Good (2) across all three SEP criteria. The EB wishes to emphasize that it has implemented the Category scores in Table 1 of the SEP guidance quite literally, with scores of 1.0 only assigned for performance (at the institute-wide level) among the leading few astronomical research departments or institutes in the world. No grade inflation whatsoever has been applied, and the EB has included scores of 1.5 where appropriate to provide some additional differentiation. Moreover the EB interpreted the Viability criterion in terms of maintaining the current high levels of performance, including external factors such as the funding horizon. Finally the EB notes that although no SEP Category scores were requested for NOVA, its performance in research and societal relevance is exemplary, and considerably greater than the sum of the individual institutional contributions.

3. The Members of the Evaluation Board

The Evaluation Board consisted of:
Prof. dr. R.C. Kennicutt, University of Cambridge (chair);
Prof. dr. C.J. Cesarsky, CEA Saclay;
Prof. dr. H.-W. Rix, Max Planck Institut für Astronomie, Heidelberg;
Prof. dr. A.I. Sargent, California Institute of Technology;
Prof. dr. B.P. Schmidt, Australian National University;
Prof. dr. D.N. Spergel, Princeton University;
Prof. dr. W.J. van der Zande, ASML.

Dr. Jetje De Groof (Belgium) was appointed as secretary to the Evaluation Board (EB).

A short curriculum vitae of each of the members is included in Appendix 1.

All members of the EB signed a statement of independence 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.

4. Scope of the Assessment

Astronomical research and education in the Netherlands takes place at the following four university institutes: 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 and funded as a top-research school by the Ministry of Education, Culture and Science (OCW). NOVA is legally represented by Leiden University.

The current assessment includes the evaluation of NOVA as a whole as well as each of the individual university institutes. It covers the period 2010-2015. It was organized and coordinated by Leiden University.

The scope of the assessment is set by the Terms of Reference (TOR). Two separate sets of TOR were provided to the EB: one for the assessment of NOVA and its institutes as a whole; and one for the evaluation of the individual university institutes.

For the assessment of NOVA as a whole, the TOR stipulate that the aggregation level is NOVA, its university institutes and its two instrumentation groups. The EB is asked to assess the quality, relevance to society, and viability of the research, instrumentation and outreach programs conducted by NOVA and its four university institutes as a whole in the international context. Specifically, the EB should assess how NOVA is complying with its mission 'to carry out front-line astronomical research and to train young astronomers at the highest international level'. The EB is expected do this by judging performance against the three SEP-criteria of 'research quality', 'relevance to society', and 'viability'. The EB is requested to provide a written assessment of NOVA and its institutes as a whole based on each of these three criteria, and to compare performance with leading institutes worldwide. SEP guidelines for grading do not apply here. In addition, the EB is asked to pay special attention to five specific questions regarding NOVA as a whole. These questions are listed in the section of the report containing the NOVA assessment.

For the individual institutes, the TOR states that each should be evaluated at the level of institute as a whole. The EB is asked to assess the quality, relevance to society and viability of the research conducted by each of the four university institutes, as well as their strategic targets and the extent to which they are equipped to achieve them. The TOR states that the EB should do so by judging the unit's performance against the three SEP assessment criteria of 'research quality', 'relevance to society', and 'viability'. Current international trends and developments in science and society should be taken into account in the analysis. In the SEP, indicators of research quality explicitly include areas such as instrumentation and infrastructure developed by the research unit. In addition, the EB is asked to (1) provide a qualitative assessment of each institute as a whole in relation to its strategic targets and to the governance and leadership skills of its management; (2) make recommendations, in accordance with the SEP, on the PhD programs at each institute; (3) reflect on the research integrity at each institute. The TOR lists three additional questions the EB is asked to pay special attention to in the context of the Department of Astrophysics of Radboud University, Nijmegen. These questions are listed in the section of this report containing the assessment of the Radboud department. In addition to providing its written assessments and category scores, the EB is also asked to provide recommendations for improvement.

4. Data provided to the EB

The EB 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, PhD's, publications, and financial resources. Additional information was provided on a secure website and included a bibliometric analysis to quantify the numbers of citations to publications in refereed journals with at least one author affiliated to an institute subject to this evaluation. The EB also received the SEP and TOR for the assessment.

5. Procedures followed by the EB

EB 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 two weeks prior to the site visit.

Following this teleconference, the Chair of the EB assigned specific institutes and/or focus areas to each EB member, taking into account their expertise. At least two EB members teamed up for each institute or focus area. 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 3 shows the program of the site visit. Presentations, interviews and discussions on both the NOVA level and with the individual institutes were held in Leiden. Between the interviews, time was available for the EB to discuss the various findings. During the last day of the site visit, a closed EB session was held so that all members could come to consensus on the final qualitative and quantitative assessments of NOVA and each of the four individual institutes. At the conclusion of the visit, the EB orally presented its main preliminary conclusions in a series of briefings to institute directors, university Deans, and NOVA management, as documented in Appendix 3.

After the site visit, the evaluation report was prepared, with each EB member taking the lead in composing the sections they had focused on. An integrated version of the report was then circulated to the EB 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 Leiden University.

Netherlands Research School for Astronomy (NOVA)

1. Description of NOVA

The preparatory documents and the site visit gave the EB a clear view of the mission, structure and organization of NOVA. A summary is given below.

1.1. Mission and research activities

NOVA is the alliance of the current four university astronomy institutes in the Netherlands. The aim of NOVA is to coordinate Dutch university astronomy research, instrumentation, PhD education and outreach activities in a coherent and collaborative national program, called 'The lifecycle of stars and galaxies'. Its mission is to carry out front-line astronomical research, to train young astronomers at the highest international levels, and to share discoveries with society.

The NOVA research program is organized along three interrelated thematic programs or 'networks', chosen to address the major questions in modern astronomy:

- Network 1: Origin and evolution of galaxies from high redshift to the present;
- Network 2: Formation and evolution of stars and planetary systems;
- Network 3: Astrophysics in extreme conditions.

The networks are highly dynamic and open so as to enable NOVA to quickly adapt its research programs to new ideas and developments. As these ideas often require new observations, instruments and technology, NOVA strategy includes designing and building advanced instrumentation for state-of-the-art observing facilities. This allows NOVA astronomers to be among the first to use the new facilities and thus reap the cutting-edge early science harvest. Indeed, research and instrumentation are strongly linked in the NOVA program, with the choice of instruments being driven by the science questions from the networks.

Although the NOVA instrumentation program focuses largely on ESO projects, there are also investments in smaller-scale instrument and technical R&D projects. At the moment, the two priority areas for technical R&D are (i) high contrast imaging; and (ii) multi-pixel submillimeter instrumentation. NOVA also makes an effort to stimulate development of specialized data reduction software, numerical modelling and laboratory astrophysics.

1.2. Management and organization

The NOVA Board consists of the directors of the participating university astronomy institutes. Oversight is provided by the NOVA Raad van Toezicht (RvT, Supervisory Board), consisting of the deans of the science faculties of the participating universities. The day-to-day running of NOVA is the responsibility of the NOVA Directorate and Office.

The NOVA research program is coordinated by the NOVA scientific director and the coordinator of each of the three inter-university networks, using a bottom-up process. NOVA-funded PhD student positions may have a second supervisor or mentor from another NOVA university, or (especially when new technologies are involved) from the Netherlands Institute for Space Research (SRON) or the Netherlands Institute for Radio Astronomy (ASTRON), stimulating collaboration and establishing relationships between the institutes. Cross-network research projects are also encouraged and several staff members participate in the activities of more than one network.

All NOVA instrumentation projects have a principal investigator (PI) based at one of the universities. The optical and infrared (OIR) instrumentation group is located at ASTRON in

Dwingeloo. The submillimeter instrumentation group is hosted at the Kapteyn Astronomical Institute in Groningen, and is co-located with the SRON Institute. NOVA has full responsibility for both groups, although it does not itself employ the staff. Since the last IB review an instrumentation coordinator has been added to the team to support the NOVA executive director in overseeing the NOVA instrumentation program. NOVA reports that, with the Instrument Steering Committee, it now has a good process in place to monitor progress and identify where additional effort is needed.

NOVA Outreach is coordinated through the NOVA Information Centre (NIC).

1.3. Resources

1.3.1. Human Resources

The NOVA astronomical community consists of 365 FTE researchers. Table 1 in Appendix 4 gives a complete overview of different categories of NOVA research staff and lists the distribution of staff of the NOVA institutes. It shows the growth from 311 FTE in 2010 to 365 in 2015. Possible negative effects of the closure of the Utrecht astronomy department have been alleviated by the successful transfer of most faculty to other NOVA institutes, particularly Radboud.

NOVA reports that the overall gender balance of the permanent and tenure-track staff has improved from 11% female in 2010 to 19% in 2015 (Appendix 4, Table 3). Since 2010, 57% of the new staff appointments have been women. In 2015, 32% of postdocs and 40% of PhD students were female.

The age distribution of permanent and tenure-track staff (Appendix 4, Table 1) shows 5.4 (10%) staff members younger than 40, 31.5 (57%) with ages in the range 41-50, 12.2 (22%) 51-55, and 6.4 (11%) older than 55. NOVA often helps retain faculty numbers in a given department by funding 'overlap' positions so that young tenure track staff can be attracted and hired a few years before a senior faculty member actually retires. Nevertheless, NOVA investments in new staff positions remain a priority.

1.3.2. Financial resources

NOVA receives baseline funding from the Ministry of Education, Culture and Science (OCW). This currently amounts to 5.2 M€ per year and is called the 'NOVA grant' and, since 1999, has been renewed every five years. In addition, funding is acquired from other grants, usually awarded through competition and resulting in a total annual budget administered by NOVA of ~8.4 M€. The joint budget of the university astronomical institutes and NOVA is 33 M€ (2015).

Sources of funding are analyzed in Appendix 4 (Tables 4 and 5). Funding for the combined NOVA and university research programs has increased annually from 17.1 M€ in 2010 to 21.5 M€ in 2015. This increase of almost 26% is largely due to continuing and expanding success in winning grants through national (e.g. NWO and KNAW) and international (e.g. ERC) competitions (Appendix 4, figure 2). Total funding for the NOVA instrumentation program amounted to 30.2 M€ over the 2010-2015 period, with large annual fluctuations. The funding sources are the NOVA grant (38%), ESO (35%), NWO (17%) and other resources (10%).

In February 2016, OCW extended the NOVA grant for a subsequent five years up to the end of 2023. The NOVA grant is a unique financial instrument in the Dutch scientific landscape. The closest alternative program in the Netherlands is the NWO Zwaartekracht-program ('Gravitation'-program), with a lower budget cap than the present NOVA grant.

2. Qualitative assessment of NOVA

In this section, the EB evaluates the performance of NOVA as a whole based on the three SEP criteria of research quality, relevance to society and viability. In addition, the EB gives its evaluation of PhD supervision and education, as stipulated in the TOR for NOVA. An overview of the EB's recommendations is given in section 3 of this report.

The TOR also identify five specific questions for the EB. To avoid repetition, these questions have been grouped under the broader headings of the SEP criteria and are addressed in turn.

2.1. Research quality

Overall Assessment

The quality of astronomy research in the Netherlands continues to maintain an excellent standard, and is world-leading in a number of subfields including astrochemistry, laboratory astrophysics, the astrophysics of compact stellar remnants, and data science. Objective evidence for this high quality and international standing include publication and citation metrics, as well as success rates in international competitions for grants and top-rank postdoctoral fellowships. When these metrics are compared on a per GDP basis Dutch astronomy overall ranks on a par with the other world leaders in astronomical research (US, UK, Germany, France), and when considered as a 'virtual institute' NOVA is competitive with the leading astronomy and astrophysics institutes in Europe and the US.

The same degree of excellence is being achieved across all three of the NOVA research networks. Prime examples include recent papers on the identification and properties of the highest redshift galaxies yet discovered, state-of-the art simulations of galaxy formation and evolution, and new insights into the structure and evolution of the Milky Way from the RAVE and Gaia projects (NW1); new revelations on the dominant role of binary evolution for massive stars, observations of the structure and chemical composition of protoplanetary disks, and the detection of molecular features and the rotation of exoplanets (NW2); and new constraints on the equation of state of matter in neutron stars, relativistic frame dragging from oscillations of neutron stars, cosmic ray science with the LOFAR array, and the spectacular first detection of gravitational waves from merging black holes (NW3). Areas of excellence are present in each of the four research institutes, as detailed later in this report. In summary, *"NOVA and its four constituent university institutes continue to conduct astrophysical research and instrumentation development consistent with the highest international standards"* (NOVA Mid-Term Review, 2014, p. 1).

EB's answers to specific questions formulated by NOVA

What is the impact of the NOVA grant funding on the integrated research and instrumentation program? Assess the vision and strategy of NOVA in this respect.

NOVA funding is about evenly divided between support for astronomical research and for optical, infrared (OIR) and submillimeter instrumentation. The strategies for and benefits from these investments are closely coupled, because leadership and partnership in instrumentation projects often carries with it guaranteed access to telescope time. This in turn enables Dutch astronomers to carry out ground-breaking 'first light'-research projects on new facilities. The involvement in instrumentation and its associated software development also allows Dutch researchers to make the most effective use of the new facilities, and compete more successfully for open telescope time. This degree of integration between research and instrumentation strategies, where choices of instrument projects are driven by institutional and national scientific priorities, is unmatched anywhere, and is a key element in NOVA's ability to 'punch well above its weight' in astronomy within Europe and the world.

The impact of NOVA in OIR and submillimeter instrumentation has been transformational. Most notably, it provides leadership and critical seed funding for an internationally competitive instrumentation effort, as well as serving as the coordinating body for realizing the integrated research and instrumentation strategy. In particular it has led to the Netherlands participating as significant partners in a large number of instruments within the European Southern Observatory (ESO), including the Very Large Telescope (VLT) (pre-NOVA: VISIR; more recently SINFONI, X-Shooter, MUSE, SPHERE), the VLT Interferometer (MIDI, MATISSE), and the the European Extremely Large Telescope (E-ELT) (MICADO). They are now playing a leading role with their most ambitious project, METIS, a mid-infrared imager and spectrometer for the 39m E-ELT telescope, which when completed will be the most powerful ground-based mid-infrared instrument ever built, on the largest telescope ever built. For the Atacama Large Millimeter Array (ALMA), NOVA played a big role in the construction and delivery of Band-9 receivers and is now continuing with Band-5 receivers; NOVA runs the ALMA regional data centre, ALLEGRO, for the Dutch community. NOVA is also coordinating Dutch participation in instruments for major space projects such as the James Webb Space Telescope (JWST) and ground-based facilities such as the WEAVE multi-fibre spectrograph for the William Herschel Telescope in the Canary Islands. It has also facilitated Netherlands' launching of BlackGEM, and its possible future involvement in the large international project CTA. These project partnerships place Dutch researchers in a position to take optimal advantage of the scientific exploitation of the resulting facilities.

NOVA participation in these instrumentation projects has brought other, broader benefits. Apart from enhancing the effectiveness of the research program as mentioned earlier, it has created a lean but expert team of instrument scientists and engineers that complements the expertise already resident within ASTRON and SRON and has strengthened links with industry. A number of the advances in technology and data handling have led to highly successful spinoff projects, which are evaluated later under 'Relevance to Society'. As with the funding for research, the NOVA investment in instrumentation is highly leveraged, ,with the majority of the total funding coming from external sources.

Another 45% of NOVA funding supports research through a combination of 'overlap positions' (bridge funding for new faculty), PhD studentships, postdoctoral positions, and seed money for new initiatives. NOVA awards are allocated through a combination of bottom-up proposals for collaborative projects (the source for most of the studentships and postdoc appointments) and strategically targeted support such as contributions to new hires (salary bridging, startup funding, or both) and exploiting opportunities for participation in international projects. The decision processes within NOVA combine the stability of periodically updated long-range strategies and roadmaps (in which the entire Dutch research community participates), with sufficient flexibility to respond to new opportunities as they arise. In the view of the EB, this balance of long-range and short-term planning has been very effectively managed.

The NOVA investments in research support are also highly leveraged. Perhaps the best example is in the support for junior faculty and researchers through overlap positions, startup, and seed funding. The faculty hired by the four universities in recent years have been especially successful in competitions for ERC, EC, VICI, VIDI, and VENI grants, which in aggregate easily exceed the initial seed funding investments.

What is the quality of NOVA's optical/infrared and submillimeter instrumentation groups?

The current astronomical instrumentation program in the Netherlands relies on close collaboration between research and technical experts managed by ASTRON, SRON, and NOVA. By exploiting these collaborations it has been possible to conduct a diverse program and leverage a modest financial investment. Both the OIR and submillimeter groups have a strong track record for designing and delivering instrument packages on time and on budget, highly important measures of program quality. A prime example was the delivery of the large number of Band 9 receivers for ALMA, eight months early and €2.4M under budget (out of a total budget of €17.5M). This effort was led by the NOVA's ALMA technical group, in collaboration with the SIS detector technology group at the TU Delft.

Are the available resources, personnel and infrastructure sufficient to carry out NOVA's instrumentation program?

NOVA's leadership of the METIS project presents a qualitatively new level of challenge in terms of project leadership, total project costs, duration, technical complexity, and reliance on subcontracts for major components of the instrument with all of their attendant financial risks. In its 2014 review the IB recommended that NOVA should bolster its expertise in project management and systems engineering to meet the challenges of METIS as well as those of its growing suite of other commitments. The EB is pleased to note that this advice has been taken and that financial management has also been strengthened. Steps have been taken by the NOVA partner universities to underwrite the Netherlands share of the costs of METIS so as to mitigate against any shortfalls in NOVA funding through the construction period. An external advisory board has also been established to provide independent oversight of the project.

The METIS program is at a scale well beyond projects undertaken by NOVA in the past. While NOVA and its partners have an exceptional record at delivering instruments on-time and on-budget, this is the first project where NOVA is the lead institution. While the instrument group is well aware of the additional risks, and the scale of these risks, the EB has not heard the same concern from the NOVA faculty or institutions. METIS is a very high profile project and the NOVA universities need to be aware of the scale and nature of the risks, and to ensure that they manage them with extreme diligence. This should include oversight of partnerships and subcontractors where NOVA does not have direct managerial control.

Comment on the balance between NOVA funding for research (staff, networks) and instrumentation. Is it optimal to achieve maximum impact?

The EB views the present balance of funding for research, instrumentation, and administration/outreach (45:45:10) as close to optimal, given the currently available €5M per year. This has provided sufficient critical mass in funding to realise a highly effective instrumentation program, while at the same time enabling impressive scientific exploitation of these instruments and of the facilities thus available to Dutch astronomers, and supporting the theoretical research needed to ensure maximum scientific impact.

During its review the EB considered whether it would be appropriate to maintain this roughly equal balance between research and instrumentation funding in the event of a significant reduction in total funding for NOVA, either through changes in the base support or from a significant project cost overrun (e.g., with METIS). In the EB's view the most critical elements for the continuing success of the NOVA program are the funding for instrumentation, the support for new faculty (bridge positions and start-up), and the seed funding for new research initiatives. In tight financial circumstances the EB argues that those elements of the program should receive the highest priority, even if it means less support for other elements.

2.2. Relevance to society

The EB's assessment of this criterion coincides with its answer to the following request that it was asked to pay special attention to:

Assess the NOVA efforts on outreach and other relevance for society in comparison to other top-institutes worldwide.

For astronomical research the most relevant activities for society fall into three categories: public education and outreach; valorization of new technologies and software systems; and human capital generation. Significant contributions in all three of these areas are being made by the four institutes as well as by NOVA itself. In order to avoid repetition the EB focuses in this section on those elements of the outreach program that are coordinated and administered centrally by NOVA. Valorization activities with NOVA involvement are discussed in the sections for individual institutes. Comments on NOVA's role in human capital development are also contained in Section 2.4.

NOVA coordinates public education and outreach activities on the national level through the NIC, and its achievements are notable for both their quality and reach. Activities have spanned the full spectrum including school visits (650 schools) and mobile planetarium programs (200,000 students), teacher training (150), production of educational materials (e.g., 50,000 spectrometers distributed), media appearances (>1000 per year), press releases (80 per year), national television programs (4,500,000 viewers in 2015), and social media platforms (>1,000,000 views per year). A citizen science project enlisting 4000 participants to monitor air quality via a simple smartphone attachment is but the start of a wider array of such planned efforts. The program already attained national recognition (e.g. a NOT Innovatieprijs in 2011). This broad and diverse program was enabled with minimal NOVA resources (1.7 FTE), thanks to an effective coordination and free sharing of best practices across the network of institute-based outreach groups and the enthusiastic support of the Dutch astronomy community.

The awareness of the importance of public education and outreach is traditionally very strong in astrophysics, a field with a significant appeal to many. This awareness has resulted in activities that can be considered best practices in comparison to most if not all other scientific fields. To be more specific, these activities set an exemplary standard unmatched by any comparable sized astronomy education and outreach program in the world, which is undoubtedly connected to the coordinating role of NOVA within the Netherlands astrophysics community. The EB can offer only one suggestion for improvement. The EB recommends that NOVA produce a more comprehensive longer-term education and outreach strategy, which would consider the balance between different elements (in the context of existing activities across STEM subjects in the Netherlands), and prioritize future activities accordingly. As part of the development of the plan NOVA should learn from best practice not only within the Netherlands but from other successful programs around the world. Ideally such a plan would also expand current efforts to measure the quality and longer-term impact as well as the reach of the activities within the limits of what is practical and achievable.

2.3. Viability

The assessment of this criterion coincides with the answer to the two following questions the EB was asked to pay special attention to (questions in bold and italic):

What are the prospects of the research fields in which NOVA is active? Is NOVA embarking on new scientific ideas and fields with high potential for the future? Are the research fields well chosen, given the available expertise and facilities of NOVA?

The NOVA research networks build on existing strengths in Dutch astronomy, and represent three of the most important research areas in global astrophysics, as documented in the most recent decadal surveys for Europe and the US. All are likely to remain at the cutting edge of astrophysics over the coming decade. The formation and evolution of galaxies (NW1) is poised for major advances driven by ALMA, LOFAR, the E-ELT, and SKA on the ground, and by space missions such as JWST, Gaia and Euclid, as well as by advances in theory and numerical simulations. The study of the formation of stars and planets (NW2) is experiencing a scientific revolution, with the discovery of new extrasolar planets nearly every week and new observational capabilities for characterizing forming stars and solar systems and the exoplanets themselves (e.g., ALMA, VLT, HST, JWST, E-ELT, PLATO, SPICA). The study of astrophysics in extreme conditions (NW3) is on the verge of its own revolution, with the detection of gravitational waves opening an entirely new observational frontier (e.g., LIGO, VIRGO, LISA) and new facilities designed to observe the electromagnetic and cosmic ray signatures of high-energy phenomena, some in the strong-field relativistic regime (e.g., LOFAR, CTA, BlackGEM, Event Horizon Telescope, LSST). Dutch groups are playing important roles in many of these areas, including several involvements in key instrumentation projects.

Nevertheless, all of these fields are very dynamic, and if NOVA is to maintain its leadership role it will need to adapt its priorities with some agility in the coming years to take most advantage of future opportunities. This agility will need to come in several forms: a willingness to redirect research funding towards emerging areas and away from others; a steady renewal of its research staff (even within current staffing numbers); and the financial discipline to avoid overinvestment in current commitments (in research and instrumentation) at the expense of future opportunities.

Over its sixteen-year history NOVA has already demonstrated its ability to re-align its priorities in response to new opportunities. Perhaps the best example is the reworking of NW2 to exploit the rapidly growing subject of extrasolar planets. NOVA has supported the growth of the subject through overlap positions, studentships and postdocs, and other seed funding.

Looking forward, the EB identified a few areas where the Netherlands is especially well positioned to exploit emerging opportunities, and where additional investment could prove especially effective. These include an expansion of its activities in exoplanetary research including atmospheric characterization; the study of gravitational wave sources and other high-energy transient phenomena; and large-scale data mining and data science.

As already noted, exoplanet and related research is already strong in the Netherlands, and the EB only suggests that the subfield of atmospheric characterization of exoplanets may benefit from modest growth so that the relevant groups in the Netherlands can remain internationally competitive.

The recent direct detection of gravitational waves from a system of merging massive stellar black holes (by a team including seven members of NOVA) and the rapid growth of transient science, place Dutch astronomers in an almost unmatched position to take a leading role in the astrophysical interpretation of the data from future experiments in these fields. The EB is aware of no communities other than NOVA which contain a similar combination of world-leading expertise in massive and binary stellar evolution, supernovae and core collapse phenomena, compact stellar remnants, electromagnetic transients, and gravitational radiation astrophysics. A modest investment to fill any gaps and to facilitate collaborative research across the institutes could pay major scientific dividends over the coming decade and beyond.

A third promising area identified by the EB is in data mining, survey science, and other applications of large-scale computing. Considerable expertise already exists within the NOVA institutes, in both empirical data handling and theoretical simulations, but with Dutch participation already in projects such as Gaia and Euclid and the growing importance of 'Big Data' science internationally the NOVA consortium is well positioned to build on its current strong position.

In highlighting these opportunities the EB has no wish to be prescriptive. Clearly the future shape of NOVA should be determined by the members of NOVA, but the EB hopes that its observations may be useful inputs to that planning process.

Identify obstacles or problems regarding the pursuance of the highest quality in research, instrumentation and training of PhD students.

Future Funding: In its 2014 review the NOVA IB identified the uncertain future funding of NOVA as the most important (and at the time urgent) obstacle in the path of future success. Since that time NOVA funding has been renewed until 2023. At the same time the member universities of NOVA have committed funds to ensure that the METIS instrument can be completed independent of the future government funding for NOVA. These are welcome developments which provide several years of stable funding for the entire program and assured funding for its largest long-term international commitment.

Nevertheless, uncertainty in the funding for NOVA beyond 2023 remains as the most important threat reported in the self-evaluations (SWOT analyses) both for NOVA and the four university institutes. The EB discussed the issue with the NOVA scientists, its Board, and with each of the Deans of the relevant universities. Attitudes within this community varied, ranging from a strong commitment to maintaining NOVA at its current levels of activities and support indefinitely, to a more cautious outlook that counselled looking at backup options which would continue some of NOVA's activities at a reduced level of support, with a broader range of funding sources, or both.

As an external international committee the EB lacks the expertise and authority to offer advice on these complex internal issues, but it can offer its independent expert perspective. First and foremost, the EB can certify that NOVA has performed at an exemplary level in all the key areas of its mission: research, instrumentation, PhD education, and education and outreach. The resources spent on the network to date have been spent very effectively, and with impressive financial leveraging which have returned excellent value for money. The program has elevated Dutch astronomy, especially if regarded as a single virtual institute, to among the leading astronomy research groups in the world.

In view of this strong assessment, the EB encourages the NOVA management to continue to aim high and seek to maintain as much of its current portfolio of activities as possible. At the same time, however, the EB emphasizes that it would be imprudent for NOVA to predicate its future planning and strategy on the presumption that current levels of funding can be sustained (or increased) indefinitely. Any future internal planning ought to consider a range of funding scenarios (e.g., the NWO *Zwaartekracht* program). Ideally this would include discussions among the universities of whether additional forms of matching funding would be helpful in negotiating an optimal outcome. Within NOVA it would be wise to weigh the relative importance of the various activities in its portfolio, in case difficult decisions are required in the future.

Faculty Demographics and Diversity: Beyond the uncertainties surrounding funding, the greatest obstacle identified by the EB is the age profile of the tenured and tenure-track faculty in the four NOVA universities. Currently more than three quarters of the staff are in the age range

40-55, with only 5 individuals (10%) under the age of 41, and 11% above 55. This implies that, barring unexpected faculty departures or new positions, only 5 new tenure-track positions will open up over the next decade, *over all 4 universities combined*. It is expected that over the same period approximately 400 PhD degrees in astronomy will be awarded. The demographic challenge is exacerbated by current funding policies for NWO and ERC grants, which favour early-career researchers. When these factors are considered together, there is inevitable risk of intellectual stagnation until the current mid-career cohort retires in 2025-2040. Such limited hiring opportunities will also perpetuate the current gender imbalance in the faculty. Although some commendable efforts to diversify the faculty are under way (notably it's the Rosalind Franklin initiative in Groningen and the MacGillavry program in Amsterdam), future improvements will certainly be slowed if there is only one faculty hire every two years across the entire country.

In its 2014 report the IB called attention to this issue, and it is frankly surprised that it was not addressed more fully by NOVA in its self-evaluation or in its presentations. While the problem could be alleviated by creating new faculty positions in astronomy (and this point is addressed specifically in the evaluation of the Radboud Institute), this is probably an unrealistic expectation and other approaches are certainly required. Options that might be considered could include increased use of NOVA funding to underwrite new hires, mortgaged if necessary against a few posts in the 40-55 year old peak of current faculty; expansion of university-level initiatives such as the Franklin program; and/or increased flexibility to pursue targets of opportunity out of the normal hiring cycle in appropriate instances.

METIS: In Section 2.1 the EB called attention to the unprecedented scale, technical and managerial complexity, and financial risk of the METIS project, and while applauding NOVA for taking on the project the EB reiterates that very close monitoring and management of this project will be critical to mitigate its inherent risks.

Leadership and Succession Planning: The success of NOVA is owed in large part to its Academic Director, Ewine van Dishoeck, and its Executive Director, Wilfried Boland (as well as the founder of NOVA Tim de Zeeuw). The performance and dedication of both individuals has been exemplary in its own right, and both have become indispensable to the smooth running and success of the network. Both individuals, however, are approaching the dates when they will step down from their current roles. Replacing two such talented and experienced people will be very challenging, and their successors should be identified and appointed in sufficient time to allow for generous overlap periods. The EB discussed this matter privately with Prof. van Dishoeck and Dr. Boland and with the NOVA Board, and all parties apparently are fully aware of the need to move forward with succession planning. This may have to include consideration of whether the current job descriptions and levels of delegation, etc are still optimal for the respective roles.

PhD Program: As detailed in Section 2.4 below, the overall effect of NOVA on the Astronomy PhD programs in the Netherlands is remarkable and its success is acknowledged worldwide. Nevertheless, the EB found some suggestion that there is room for improvement in the way individual universities, and even individual staff members in these universities respond to NOVA policy. From conversations with a broad sample of students and staff, it is clear that NOVA's ideal, that each student have two advisors, the lead from their own institution and a second, usually from another NOVA university, can be extremely helpful in rectifying potential inequities in student support/treatment in their home institutions. This can only be truly effective if individual Deans as well as faculty and staff are enthusiastic participants. The EB recommends that its strong endorsement of NOVA's policy in this regard be made very clear to university staff and administrations.

That said, the EB is so impressed by the NOVA PhD program and its general influence that it suggests that a similar program for the ~90 post-doctoral researchers be introduced**.** It is widely and internationally acknowledged that post-docs are frequently not well-supported academically, personally, or in terms of career development. Their welfare is at best dependent on the interest and goodwill of their individual university staff supervisors, if indeed such are identified. NOVA is well placed to make available support mechanisms that cross university boundaries.

2.4. PhD program

The current PhD programs at the four NOVA universities are remarkably successful. It is noteworthy that the overall retention rate for the NOVA universities is over 90% and that almost 80% of the 40 PhD's being produced each year move immediately into positions in astronomy and astrophysics. The high quality of these Dutch PhDs is recognized in elite institutions worldwide, and often leads to prestigious fellowships or appointments. The EB is convinced that the role of NOVA in these successes is critical and contributes significantly to the observed satisfaction of the students. That satisfaction is overall much higher than the EB has encountered outside the Netherlands!

Most notably, the PhD students praise the camaraderie and broad view of astronomy and astrophysics that NOVA provides for them in joint conferences. In addition to increasing their science and instrumentation awareness, NOVA sponsors meetings dedicated to preparing them for the graduate school experience, to advising, often at the hands-on level, on presenting research results, and to considering careers outside astronomy *per se*. More senior students, in particular, appreciated the attention given to this last matter. The third year NOVA meeting is carefully planned and enables students closer to completing their PhD to learn not only about possible career options but also how to craft their resumés for the appropriate audiences, and even how to network in a more industry-focused environment. The EB also has high praise for these programs. This is especially important, as the large numbers of Dutch PhDs being produced in astronomy and astrophysics lead to a concomitantly lower likelihood of a permanent professorial appointment in the Netherlands. NOVA's recognition and response is exemplary.

Initially, the EB had some concerns about the efficacy of the NOVA PhD Program, given its unusually large size, and the relatively high ratios of students to staff. In particular, members were concerned that individual students might be short-changed in terms of interaction with staff advisors, introducing questions about the levels of training in high quality research and instrumentation. As a result, the EB probed this area extensively. It found that the support of PhD students at the individual universities is strongly reliant on the NOVA-led PhD programs and strategies and tailored around them, consistent with the larger university policies. Students from all the universities consistently speak highly of the NOVA influence on their professional lives. These issues are discussed in a little more detail in the sections on the individual universities. Here, the EB emphasizes that the NOVA-led PhD program in astronomy and astrophysics is of the highest quality in all respects and could well provide a model for the rest of the world.

3. Recommendations

NOVA should continue to review its scientific strategy on a regular basis, in order to be able to exploit rapidly emerging scientific opportunities. Promising areas include (but are not necessarily limited to) exoplanetary research including atmospheric characterization, the study of gravitational wave sources (and their electromagnetic counterparts), other high-energy transient phenomena, and astronomical applications of large-scale data mining and data science.

NOVA and its partner universities should continue to exercise tight managerial and financial oversight of the METIS project, with particular attention to management of externally subcontracted work packages, in order to mitigate the considerable risks associated with a project of this scale.

NOVA should produce a long-term education and outreach strategy, which would consider the balance between different elements (in the context of existing activities across STEM subjects in the Netherlands), and prioritize future activities accordingly. As part of the development of the plan NOVA should learn from best practice not only within the Netherlands but from other successful programs around the world. Ideally such a plan would also expand current efforts to measure the quality and longer-term impact as well as the reach of the activities within the limits of what is practical and achievable. This strategy will further increase the consistency and efficiency of an already exceptional program.

NOVA and its partner universities should take proactive steps to address the pronounced imbalances in the age and gender distributions among its tenured and tenure-track faculty. This might include the increased use of NOVA funds to support overlap positions and other mechanisms to create junior faculty positions, either as new posts or mortgages against currently held positions.

The NOVA Board should continue its preparations to identify, recruit, and appoint successors to the current Academic and Executive Directors of NOVA, both of whom will step down in 2-4 years. It is important to fill these positions early enough to ensure a smooth transition and effective relaying of knowledge, experience, and contacts with NOVA's institutional, university, and government partners.

Elements of NOVA's excellent coordination of supervision and mentoring of PhD students should be extended and adapted to improve the mentoring of its ~90 postdoctoral research associates.

Anton Pannekoek Institute, University of Amsterdam

1. Description of Anton Pannekoek Institute

Through the preparatory documents and the site visit, the EB gained a clear view of the mission, structure and organization of the Anton Pannekoek Institute (API). A summary is given below.

1.1. Mission and research activities

API conducts astronomical research and trains astronomers from the bachelor to postdoctoral level, aiming at world-leading levels in all its activities. It has two main research divisions. First, X-ray astronomy, which has broadened into high-energy astrophysics (HEA), focuses on the study of relativistic compact objects and the energetic phenomena and space-time physics around them. This work aligns well with NOVA Network 3. Second, stellar astrophysics remains a strong focus but as part of a broader Origins program (ORI) that includes investigations of the formation and evolution of stars and stellar populations, and the study of planet formation and, in particular, planetary atmospheres. This aligns with NOVA Network 2.

Within the two divisions, API's research can be broadly grouped into five themes: (1) Relativistic accretion flows; (2) Dense matter; (3) Jets, extreme explosions and particles; (4) Stars and stellar populations; (5) Exoplanets and planet formation. A number of overarching issues cut across the themes: strong gravity is crucial for (1), (2) and (3); (M)HD is relevant in all five; strong magnetic field physics applies in (2) and (3); stellar astrophysics plays a role in all except (3); while accretion and/or the role of transients must be considered in all. Overall, this motivates significant cross-pollination between the themes and fosters common interests among the themes.

API's primary strategy to achieve its ambitions is encapsulated in the concept 'Top astronomy = top people + top instrumentation'. Involvement in the instrumentation that is key to API priority science is central to this strategy. Broadly speaking, that involvement has been in scientific definition, software development, and the calibration and commissioning of instruments with applications across the electromagnetic spectrum. API has consciously chosen to leave the actual hardware construction of the instruments to the NOVA optical/infrared group, and to ASTRON and SRON.

Another essential element of API's strategy for success in research that has much expanded in the past six years is interdisciplinary work. For example, during this reporting period, two API interdisciplinary programs have formally become collaboration structures as a result of university-wide competitions for (permanent) funding. Gravitation and Astroparticle Physics Amsterdam (GRAPPA) is a collaboration between API and UvA Physics, with particular relevance to the API programs in relativistic astrophysics, compact stellar remnants, and energetic phenomena. The other interdisciplinary program 'Are We Alone?', is a collaboration with VUA Earth Sciences and SRON to create a centre of physics and astronomy at the API campus with particular emphasis on exoplanetary research and star and planet formation. In addition, there is increasing collaboration with computer scientists, most notably in time domain radio astronomy.

1.2. Management and organization

API is the astronomical institute of the Faculty of Science (FNWI) of the University of Amsterdam (UvA). It is responsible for the research and teaching in astronomy and astrophysics in Amsterdam. Its management structure includes a director, institute manager, and management team. Monthly staff meetings engage all staff in the running of API affairs. In addition, API has installed the API PhD student/Postdoc Council that provides input from the non-tenured researchers.

On the national level API coordinates its science program through NOVA. Further coordination is done through the NCA. Specific actions by API in the past five years that further strengthen these national ties include several shared appointments of faculty with ASTRON and SRON. API's international involvement is largely coordinated at a national level: ESA missions via SRON, ESO instrumentation via NOVA, and radio astronomy via ASTRON/JIVE. API reports that it scientists play key roles in missions and projects appropriate to their expertise and interest. All API astronomers are members of international consortia, boards and advisory panels.

1.3. Resources

1.3.1. Human Resources

Appendix 4, Table 1, gives an overview of the number of research staff at API. The institute has experienced a steady growth during the review period, by 50% in tenured faculty to 13.5 FTE and 70% in postdocs and PhD candidates to 50 FTE. API regards this as indicating strong support by UvA, as well as convincing power in earning external funding. API also reports that due to its significant growth in the review period, the faculty age-profile has rejuvenated, laying to rest one of the concerns of the midterm review. The Institute has also improved its proportion of female staff: in 2015 26% of its faculty were female, compared to 13% in 2010, due in considerable part to the help of a University-wide MacGillavry program for the recruitment of outstanding women to the faculty.

1.3.2. Financial resources

An overview of API's funding sources is given in Appendix 4 (Tables 4 and 5). The institute's university funding consists of a small base budget. Other important sources of funding are the 'NOVA-grant' and national and international research grants.

Also, the university has created special incentive programs for research focus areas. As already noted, API participates in two of these, GRAPPA and AWA; this has contributed to a rise in university funding compared to the previous review period. As a result of the increasing university funding base, API reports having been able to hire about one new faculty member per year over the past period. This, in turn, has led to a relatively high number of faculty eligible for early-career grants from NWO and the ERC. Success in these programs and in various senior grant-funding schemes has assured strong external funding for API's research. It is reported that this external funding, and especially the NOVA funding, is crucial to API's research impact. Since half of API's university funding is also contingent on obtaining this external funding, 75% of API funding is due to external grant funding directly or indirectly.

2. Qualitative and quantitative assessment of Anton Pannekoek Institute

In this section, the EB evaluates the performance of API as a whole based on the three criteria of research quality, relevance to society and viability. In addition, the EB provides its evaluation of of academic integrity, and of PhD supervision and education, as stipulated in the TOR. An overview of the EB's recommendations for API is given in section 3.

2.1. Research quality

Over the past decade API has stepped up its efforts in its traditionally strong field: the study of high-energy astrophysics focused within the realm of stellar astronomy, including the underpinning areas of X-ray binaries, neutron stars, black holes, and high mass binaries. Within the 15 faculty, 20 postdocs, and 45 PhD students that make up the API, exists arguably the world-leading group in this vibrant area of astronomy, combining a rich range of theory, observation, and instrumentation. Objective evidence for this assessment comes from statistics of high-impact publications, success in grants competitions, frequency of invited talks, and participation in major international projects. Instances of remarkable results are the continued work on quasi-periodic oscillations in accreting black holes and pulsars; the semi analytic MHD relativistic models for black-hole jets; the statistical work on the importance of binarity in massive star evolution, based on a sample of binaries in nearby Galactic open clusters, showing that the occurrence and effect of mass exchange between the two stars is much greater than had previously been assumed; a survey with VLT-FLAMES in Tarantula, in the Large Magellanic Cloud yields a flurry of important results on the evolution of massive stars, and finds a somewhat lower ratio of close binaries, but with similar over all characteristics; and the work with Herschel on the protoplanetary disk around Fomalhaut, showing that to maintain the dust disk requires 2000 comets to collide with it every day. The increased effort of the department in recent years has been realized thanks to a clever use of all available avenues to create critical mass of faculty, through the recruitment of 9 new members, of which 6 are in HEA and 3 in ORI (with only 2 retirements). Of these new faculty members, 3 are shared with Physics and 2 with ASTRON. API has had very good grants success with some 23M Euro worth of grant income, that is a tribute to the strong research strategy in place.

Through the AWA initiative, API has brought together a small, but excellent team working in planet formation and exo-planetary atmospheres. This is one of the most rapidly growing subfields in all of astronomy, but it is also a very highly competitive field worldwide, and thus there is potential risk in not achieving critical mass, or trying to bring together too disparate groups with insufficiently overlapping research interests. The EB raised questions, for example, about whether earth observation expertise can be effectively combined with the exo-planet expertise. At the same time, the EB notes there are real opportunities here to better bring together the work that is happening across all of NOVA and help achieve the critical mass that is required in this area.

Within the GRAPPA initiative, the EB was happy to see the pivot to activities that more naturally fit within the collective expertise/interests of both API and Physics, including activities around the Cherenkov Telescope Array (CTA) and in the area of particle acceleration. GRAPPA is especially good at enhancing the experience of PhD students, providing a set of highly appreciated coursework within the domain of theoretical physics. While the research collaborations within GRAPPA continue to develop, the involved staff must be careful to continue to focus on areas where they can be truly excellent. The EB notes specific opportunities in the area of predicting and interpreting the EM signatures of Gravitational Wave events, especially if API and the Department of Astrophysics at Radboud University Nijmegen are able to constructively work together, and/or make additional appointments with Physics. In combination with Nijmegen, API and GRAPPA could play a leading role in building the coalition needed for leadership in the Einstein Telescope project. However, such efforts will be challenging in the current national context, due to the difficulty in simultaneously funding what is both a physics and astronomy project.

API has identified a significant benefit that would accrue from hiring a theorist with expertise in fluid dynamics and the ability to work on problems in accretion physics that range from proto-disks to X-ray binaries. The EB agrees that such a hire is well targeted and would bring great value for the department.

Score: 1.5

2.2. Relevance to society

For astronomical research the relevant activities for society fall into three categories: public education and outreach, valorization of new technologies and software systems, and human capital generation. Traditionally, astrophysics has been extremely active in public education and outreach. The EB has established that API staff, both at the junior and at the senior level, is continuously active in public education and outreach. The NOVA office that is geared at public education and outreach is located at API (NIC), which leads to the boundaries between 'pure' API activities and initiatives at the NOVA level being sometimes blurred. An example is the involvement of API staff in shaping the curriculum and developing educational books for the last stage of high school education, the impact of which cannot be underestimated. Due to its location, API profits from short communication lines with the National Science Museum (NEMO) and national broadcasting organizations and has commendably used these links to leverage its societal impact. Although API staff is enthusiastically active in outreach and public education, the EB also took note of the fact that no central strategy has been established connected to these activities.

The valorization of new technologies and software systems requires extra effort for the research field of astrophysics, which concentrates primarily on acquiring a fundamental understanding of the universe. Compared to the other nodes of NOVA, API has a less developed program at translating research into new technologies and software systems. The EB perceives this situation as largely attributable to the Institute's strategic decision not to host the kind of instrumentation or software groups, where most such activities originate as part of its portfolio.

Score: 2.0

2.3. Viability

Overall, API has benefitted from strong leadership, with its graduate program close to best practice, and the very strong department has benefited from a number of excellent recent hires in targeted areas. These hires, and the world-leading expertise they bring together, have created a critical mass, which can thrive in the years ahead. API has also done an excellent job at improving gender diversity within the department. Indeed, API is more diverse than most comparable institutions worldwide. However, the hiring of such a youthful faculty has led to an issue of demography, where there are essentially no permanent positions available for many years. While departments have some natural attrition, API may need to take steps to ensure that the current energy within the department is maintained even during a period of low staff turnover.

API has a strong sense of the opportunities for achievement presented by its choice Amsterdam location, coupled with the scale of bringing together more than 600 researchers in Astronomy and Physics. However, from the EB perspective, the overall view of the University with respect to relocation of, for example, SRON, to the science campus remains unclear. The EB sees very real opportunities for API if it is co-located with SRON, but a strong vision and corresponding strategy needs to be developed by management if the benefits are to be realised. While an overarching strategy is essential, keeping a significant level of autonomy within API will be equally important for it to continue to maintain its international leadership in its core areas of strength.

API is wisely involved in interdisciplinary research, which can give the Institute access to new knowledge and extra funds, and also helps to increase the work force in its topics of interest.

Score: 1.5

2.4. PhD program

Like all the partner universities, API has seen a steady growth in PhD candidates since the last review. The program quality is comparable to the world's best, judging from the immediate placement of it graduates. In common with the other NOVA universities, the students seem amazingly happy with their situation. The API as a whole seems particularly encouraged by the NOVA policy of having external as well as in-university advisors for each student. Areas of expertise at API align well with European and international key areas for astronomical research. The anticipated relocation of SRON would add to opportunities for research projects involving technical and instrumental development programs. The EB concurs with student views that the physics component of GRAPPA enhances their research perspective.

The EB views the current program as excellent and highly successful, with no significant weaknesses. The only suggestions going forward come from the students, who view visiting scholars as an important asset and would like the program to be extended and expanded.

2.5. Research integrity

The EB has no specific concerns about the department's data management practices, the level of internal research integrity and the transparency of the department's research culture. The EB looks forward to the further development of the data management plan.

3. Recommendations

API should look to continue to scientifically diversify its faculty, especially taking into account demographics when choosing new hires, to avoid future stagnation. The EB strongly supports the hiring of a theorist with expertise in fluid dynamics with the ability to work on problems in accretion physics that span proto-disks to X-ray binaries.

API should continue to monitor the development of its AWA activities, with the aim of refining its scientific focus as needed and building strong ties to the other NOVA nodes to further enhance the research base in this area. The EB also notes growing opportunities, both within and outside of GRAPPA, for success in the emerging field of the astrophysical interpretation of possible high-energy counterparts of Gravitational Wave detection. In addition to its own efforts in this area, API should seek to work constructively with the Department of Astrophysics at Radboud University to their mutual benefit.

A strong vision for harvesting the potential benefits of co-locating SRON into the science park needs to be developed by the University in consultation with API.

The API, with NOVA, should extend a career development set of activities to its postdocs; this should be similar to but separate from its PhD student programs.

API should develop a more systematic strategy for public education, outreach, and valorization and should consider carefully how to improve their valorization commitment.

Kapteyn Astronomical Institute, University of Groningen

1. Description of Kapteyn Astronomical Institute

Through the preparatory documents and the site visit, the EB gained a clear view of the mission, structure and organization of the Kapteyn Astronomical Institute (hereafter 'Kapteyn'). A summary is given below.

1.1. Mission and research activities

Kapteyn focuses on a number of research domains and themes to ensure diversity in a rapidly changing scientific environment. Current critical-mass focus areas are galaxy dynamics, strong lensing, cosmology and reionization, galaxy structure and evolution, stellar populations, and the formation of stars and planetary systems. Kapteyn is active in all three NOVA networks. Beyond these domains/themes, substantial staff effort is being put into advanced instrumentation and software as well as data science and virtual observatories.

Kapteyn illustrated that most of its successful research programs are directly related to its involvement in the development of state-of-the-art instrumentation and data science. The Institute is aiming to harvest its investment in a large number of international programs (e.g., related to LOFAR, Gaia, VST, WEAVE, APERTIF, JWST, Euclid) and to build new research directions based on this harvest. Increasingly, Kapteyn's efforts are concentrated on instrumentation and data science, making optimal use of the proximity of SRON and ASTRON, and the NOVA-funded ALMA and Optical/IR groups (with the highly successful ALMA instrumentation work being a prime example).

An overall goal is to establish Groningen as an astronomical instrumentation centre in the Netherlands. In data science, the aim is to establish a data science centre, where expertise in astronomical data analysis is combined with expertise in areas such as computer science and artificial intelligence. In particular, it plans to continue handling and analyzing Big Data from large instruments. These efforts are expected to flourish further in the future with a new building for Exact Sciences expected in 5–8 years.

1.2. Management and organization

Kapteyn is part of the Faculty of Mathematics and Natural Sciences (FMNS) of the University of Groningen (RUG). The Institute is led by a scientific director, who is supported by a management team, which includes an adjunct director for astronomy education and three other staff. Kapteyn is embedded in the interdisciplinary Data Sciences and Systems Complexity (DSSC) theme of the faculty together with the departments of mathematics and computer science (JBI), artificial intelligence (ALICE), and engineering (ENTEG). It is moreover developing a new research focus, Fundamentals of the Universe, with the institutes of mathematics and computer science and theoretical physics. Kapteyn is a founding member of the Quantum Universe Masters program with theoretical physics and KVI-CART.

Relations with the other Dutch astronomy institutes are coordinated via the NCA and the NOVA Board. Kapteyn reports that it has traditionally forged strong ties with the nearby NWO-funded SRON and ASTRON institutes. In its report, Kapteyn also mentions its strong international connections, some of which are through NOVA and national representation in ESO and ESA related to e.g., E-ELT, Euclid, and Gaia. There are also strong ties with the SKA project through membership in various working groups and via ASTRON. Instrumentation/software development at Kapteyn (e.g. radio, sub-mm, Euclid) is often embedded in international consortia via or together with SRON, ASTRON and NOVA.

1.3. Resources

1.4.1. Human Resources

Appendix 4 Table 1 gives an overview of the number of research staff at Kapteyn. Kapteyn has maintained a steady level of research staff members with ~13.5 FTE scientific staff, including 0.5 FTE joint staff with ASTRON plus ~11 adjunct ('zero-appointment') staff with ASTRON and SRON. Scientific staff are hired and promoted via a tenure-track system. Kapteyn has been successful in attracting world-class female researchers (30% of the scientific staff in the period) via active searches and also with the help of the University-wide Rosalind Franklin Fellowship program.

The institute has significantly boosted its number of postdocs and has stabilized the number of PhD students at about three per staff member. These both represent marked improvements since the research evaluation of 2010.

1.3.2. Financial resources

An overview of Kapteyn's funding sources is given in Appendix 4 (Tables 4 and 5). Currently 12 of the 13.5 FTE of the scientific staff are funded from the base budget of FMNS, and the remaining 1.5 FTE are funded temporarily by NOVA and the University Board through the Rosalind Franklin Fellowship program. The latter positions overlap with positions that will cease to exist through retirements in the coming decade and are financially secure until then.

Most funding is acquired by Kapteyn staff members in peer-reviewed external competitions, and other more-infrequent opportunities like local initiatives such as the DSSC theme and funding from the Northern Provinces.

The level of external funding in 2010–2015 was on average 2.6 M€ per year, a factor of three increase over 2004–2009. The fraction of personnel funded by the base budget therefore decreased from 43% to 32%. In this period Kapteyn staff obtained a large number of major (career) grants.

2. Qualitative and quantitative assessment of Kapteyn Astronomical Institute

In this section, the EB evaluates the performance of Kapteyn as a whole based on the three criteria of research quality, relevance to society and viability. In addition, the EB provides its evaluation of PhD supervision and education, and of academic integrity, as stipulated in the TOR. An overview of the EB's recommendations for Kapteyn is given in section 3 of this report.

2.1. Research quality

The Kapteyn Institute has significantly improved its research strength and quality, compared to the situation in the last review. It has succeeded in attracting three new talented and dynamic staff members (one male, two females, raising the staff ratio females/males even higher), has obtained numerous grants (including six ERCs) and thus raised its income, while the number of undergraduate students has grown by a factor of three in six years. The result of all of these positive changes has been a rejuvenation of the department that was very obvious to the EB during its review.

Since the last review, the productivity of the institute in terms of number of papers has remained level. Most interesting results are spread over the various fields of research, with emphasis on 'the local universe of galaxies'. Examples of results obtained are, for studies in stellar populations and galaxy evolution, a recalibration of an important abundance indicator enabled progress in our understanding of classical dwarf galaxy evolution, revealing the existence of tails of extremely low-metallicity stars. Other studies provide the first detailed late-stage chemical evolution history of a small nearby dwarf spheroidal galaxy in the Local Group. In galaxy dynamics, we may quote results on the distribution of luminous and dark matter in spiral galaxies.

The strategy of the Institute is to have strong involvement at the hardware and/or the software level in the development of a large number of ground and space instruments. Once the instruments are in operation, they can be put to use to fulfil staff science goals in their various areas of interest. The proximity to SRON, ASTRON and LOFAR is of course an asset. The Institute was involved in HIFI, on the Herschel satellite, which has yielded many of the publications on their list, e.g. on water in protoplanetary disks and the interstellar medium. Indeed, many of Kapteyn's most important results are related to milestones in the projects. Some more recent projects are already being exploited and promise to further enhance the quality of the science output. Another example is Gaia, which has released its first batch of data. A. Helmi and her group have already completed several papers on the history of the formation of the Milky Way. There is also strong involvement in the LOFAR key science program, 'Galaxy formation during the Epoch of Recombination and Cosmic Dawn' which is pushing the facility to its limit. A first upper limit on the power spectrum of neutral hydrogen at $z \sim 10$ has been obtained in one night. Improvements by two to three orders of magnitude are possible in the next two years, leading hopefully to a detection.

Staff members of the Kapteyn Institute often play the role of PI for the Dutch participation in international projects. This is the case for optical instrumentation for several ESO telescopes, including one instrument (MICADO) on the ELT, and for a spectrometer (WEAVE) in construction for the William Herschel Telescope in the Canary Islands. In space projects, there is equally strong participation in future projects, Euclid and ATHENA in particular, and SPICA if it is selected.

A particular strength of the Institute is the ability to deal with large amounts of data, with the OmegaCen group, closely linked to the Target valorization project. Thus, they can deal with LOFAR, or with the ESO VST KiDS survey, among others. Even more ambitious, they are planning to establish there the Dutch data centre for Euclid.

Score: 1.5

2.2. Relevance to society

The EB considered in this context public education and outreach, as well as valorization activities, including interactions with industry and data science.

Based on the documentation and a presentation, the EB judged the whole range of Kapteyn's activities to bring science and an understanding of the Universe to the public to be excellent. The EB found the wide range of first-rate outreach activities impressive, and the particular focus on serving the north of the Netherlands laudable. The fact that the program aspires to near complete coverage of schools in the north is remarkable. The first travelling planetarium and the online classes are examples that stand out. These activities appear to be resulting from a well thought-out overall strategy. Even stronger integration of these activities into NOVA as a whole would be advisable. Inspired by Kapteyn's best practice, the Faculty Board now finances a part-time staff member who introduces examples of the astrophysics outreach to the other sciences.

In the strategic planning of their valorization and in the interfacing with the broader data science community Kapteyn is exemplary, and leading within the Netherlands. The EB sees the Institute's use of Astrowise expertise to become a big player in the larger TARGET data science initiative as a brilliant move. It has put Kapteyn into a leading position in the Netherlands (and in a globally prominent position) in astronomical data science. The potential effect of improving data science in other disciplines is significant and forms an intrinsic strength of the Astrowise initiative. The EB noted that the dominant portion of this important activity is focussed on one faculty member, which may pose a long-term risk. To safeguard these activities in the future may require actions in staffing.

Kapteyn trains a large number of PhD students, in a broad diversity of focus areas, including instrumentation and data science, often in co-operation with ASTRON, SRON Groningen and LOFAR. This broad training of PhD students in a societally relevant set of competences and skills further emphasizes Kapteyn's relevance to society.

Score: 1.5

2.3. Viability

The Institute has high quality staff and a wide portfolio of projects. Its strategic plan is at the same time sound and ambitious, and thus the future looks bright. With more and more of the projects starting to yield data (Gaia, VST, LOFAR now, soon APERTIF, the ground telescope instruments, JWST…), the EB expects that the productivity of Kapteyn and, even more, the visibility of the research being carried out, will increase.

The EB has, however, also identified a number of potential risks. First, there is the generic risk of a decline in research funds in the future, once the present grants are spent. This is especially relevant if there are fewer opportunities e.g. with the ERC or with Dutch or regional grants, and if NOVA is not renewed beyond 2023. The EB also sees a risk of overextending the number of projects and of research fields to the point of having sub-critical mass in each of them. This overextension could lead to the overburdening the staff with project responsibilities, thereby curtailing their scientific productivity.

Another issue is the present age distribution in the staff, and the fact that some of senior faculty slots have already been allocated to the most recent hires. As a result there may be challenges ahead in continuous staff renewal over the next 5-10 years (a problem across NOVA discussed earlier).

The EB noted that the Institute has a strong investment in SKA, which may take longer to materialize than planned; the same holds true for SPICA, which may not be selected by ESA/JAXA. On the positive side, it has a large number of secure projects, extending over a very long time, and could redeploy its staff and students if need be. Finally, although there is a risk that LOFAR may fall short of some of its ambitious goals in detecting and characterizing the HI power spectrum at the Epoch of Reionization, the EB also thinks it is worth trying and pushing the system to its limit.

While calling attention to these potential risks, the EB was reassured to find that the staff and the Kapteyn management team are aware of all the issues, and hopefully will be equipped to deal with them if and when they arise. In combination with the wide range of projects in its portfolio and the excellent prospects for its data initiatives, the EB is of the overall opinion that Kapteyn is very well positioned for the future.

Score: 1.5

2.4. PhD program

Like the PhD students at the other NOVA universities, those at Kapteyn are very happy with its program, especially as it is augmented by the NOVA joint activities described in the main report. In EB conversations with the students, the various joint NOVA meetings were frequently described as enormously helpful in terms of their professional development as researchers, as well as in providing support and connections if they chose non-academic career paths. Being able to get to know students from other groups who were working in similar research areas was also much appreciated and diminished any sense of isolation that might have come from being located in the northern part of the country.

The EB was pleased to see the degree to which the PhD program at Kapteyn has grown since the last evaluation, both in size and in quality. Changes that have led to a more vibrant research-oriented department (discussed elsewhere in this report) have also had an effect on the student body; Kapteyn is now much more attractive and produces very good and outstanding students. The development of links between the Kapteyn Institute and Groningen's Computer Science department was noted as one example of forward thinking that enables students to pursue innovative research. As already noted, the EB was particularly impressed by the Institute's broad training of PhD students in societally relevant skill sets.

On the other hand, the ratio of PhD students to staff is greatest in Groningen, although this may be slightly inflated, since ASTRON and SRON staff also supervise PhD theses. The EB notes with approval that the department appears to be taking steps to stabilize the situation but some kind of monitoring to ensure that the quality of the Kapteyn program is not compromised by taking on too many students would seem to be in order. Since the EB perceives high student/staff ratios as something of a NOVA-wide issue, it might advisable for NOVA to lead some strategic planning in this area. This is obviously a concern for the future. At this time, the EB finds that Kapteyn has an excellent and steadily improving PhD program. There are no substantive weaknesses.

2.5. Research integrity

The EB judged the research integrity of Kapteyn/RUG on the basis of the provided information, the presentations, individual conversations and the broader community perception. All research activities appear to live up to current international standards of research integrity and transparency; there is no evidence for any breaches. The EB commends RUG on its efforts, in particular in the context of Astrowise on the creation and proliferation of an open code open data culture, which was deemed exemplary.

3. Recommendations

In connection with the risks listed above, the EB advises the Kapteyn Institute be prepared to invest further in emerging fields where it already has programmatic strengths, and to avoid overextending the number of projects and fields of study, and spreading its expertise too thinly.

Given the fact that Groningen is relatively far from The Hague and government officials, the EB advises that the experienced and possibly emeritus Dutch scientists of the Institute mentor the younger, mostly foreign staff members, to help them play influential roles in policy, strategy, and decision making at the national level.

The Kapteyn Institute is advised to continue its strong efforts in outreach and valorization, and to transmit lessons from best practice to other nodes in the NOVA network (especially in valorization).

The Kapteyn Institute is advised to carefully monitor grant funding activity, and be prepared to work to diversify funding streams should the normal channels dry up due to demographic and other factors.

The Kapteyn Institute is advised to continue current efforts to diversify its faculty in age and gender

The Kapteyn Institute, with NOVA, should extend a separate career development set of activities to its postdocs, building on its highly successful program for its PhD students.

The Kapteyn Institute is advised to continue to monitor the ratio of PhD students to supervisory staff to ensure the quality of graduate education remains high.

Leiden Observatory, Leiden University

1. Description of Leiden Observatory

Through the preparatory documents and the site visit, the EB gained a clear view of the mission, structure and organization of Leiden Observatory (Sterrewacht Leiden). A summary is given below.

1.1. Mission and research activities

The astrophysics research program of Leiden Observatory is wide-ranging, with emphasis on observational and theoretical studies of galaxies and the structures in which they are embedded, of star and planet formation, and of exoplanets. These investigations involve a wide range of research approaches from the design and construction of novel instrumentation, to state-of-the-art observational campaigns and the development of theoretical frameworks, often with the help of large-scale numerical simulations.

The independent research programs of individual Leiden staff members fall readily into the themes of the NOVA science networks: Large-scale Structure and Cosmology (NW1); Galaxies and AGN (NW1); Star and planet formation (NW2); Exoplanets (NW2/NWO); Planetary and Exoplanetary Science Program (PEPSci)); Computational astrophysics (NW1/NW2/NW3); Laboratory astrophysics and astrochemistry (NW2, NWO Dutch astrochemistry network); Instrumentation; History of Science.

Sterrewacht Leiden's objectives for the next decade are to maintain a broad and dynamic research program and to be among the first to exploit science returns from new observing facilities, particularly ESO's. The Observatory reports that over the years this has been an effective strategy. By contributing to the design and construction of key instruments, the staff gain prized opportunities for early exploitation of these new technical facilities. Current scientific and instrumentation expertise rests on a solid foundation of careful investment in these areas and helps Leiden to claim similarly important roles in future facilities.

1.2. Management and organization

Leiden Observatory is one of the eight research institutes of the Leiden University Faculty of Science. As the research and teaching institute for astronomy, it offers comprehensive bachelor and master programs in close collaboration with the physics and mathematics institutes of the University. Research at Leiden University is divided over eleven research focus areas covering the sciences and humanities. One of these focus areas is '*Fundamentals of Science*', combining topics from (bio-)physics, mathematics, and astronomy. Astronomy is a very prominent part of this particular research focus area.

The Observatory's overall responsibility rests with the scientific director, supported by a day-to-day management team and other management teams with specific tasks and responsibilities. Other committees (Scientific Council, Institute Council, Advisory Board) also advise the observatory management on longer-term strategic issues. In addition, a focused supervisory committee and, in particular, its chair monitor the well-being and progress of the PhD students. Informal activities supplement these formal structures to ensure a good flow of information and assist in signalling any potential problems.

At the national level, Leiden Observatory is an integral part of NOVA and reports excellent relations with SRON and ASTRON. Internationally, the Observatory has numerous close collaborations with the ESO, ESA and SKA. Contacts are also actively maintained with nearby industry and institutes (Airbus, ESTEC, high-tech industry on the science campus, TNO-SPACE) that focus on collaborative projects for all major ESA astronomy missions and ESO instruments.

1.3. Resources

1.4.1. Human Resources

Appendix 4 Table 1 gives an overview of number of research staff at Leiden Observatory. At the end of 2015, the Sterrewacht comprised 19.3 FTE faculty, 7.3 FTE scientists working on instrument development, 46.2 FTE postdoctoral fellows and 67.6 FTE PhD students, as well as 5 active emeritus faculty. Permanent research staff members are appointed on a US-style tenure-track system. The number has been stable over the last five years.

1.4.2. Financial resources

An overview of Leiden Observatory's funding sources is given in Appendix 4 (Tables 4 and 5). The annual budget of Sterrewacht Leiden was 8.3 M€ in 2010, steadily increasing to 12.5 M€ in 2015. Leiden University contributes to the Observatory's budget according to the university funding model. In 2015 the contribution was 3.9 M€, approximately 31% of the current total budget for the Observatory. The remainder was due largely to the success of staff in securing funds from European and national sources. In fact, during the entire reporting period the Observatory was awarded 39 M€ through national and international research grants. Major funding agencies included the Netherlands Science Foundation (NWO) and the EU European Research Council (ERC).

2. Qualitative and quantitative assessment of Leiden Observatory

In this section, the EB evaluates the performance of Leiden Observatory as a whole, based on the three criteria of research quality, relevance to society and viability. In addition, the EB provides an evaluation of PhD supervision and education, and of academic integrity, as stipulated in the TOR. An overview of the EB's recommendations for Leiden Observatory is given in section 3 of this report.

2.1. Research quality

Overall, the quality, impact, breadth and innovation of research at the Sterrewacht Leiden is exemplary. It is one of the leading astronomy research programs in the world. This is reflected in a large number of very high impact publications across widely distributed fields. The EB was very impressed by the quality, depth and breadth of the research presented, and believes that it would not do justice to the staff to select only one or two pieces of work for special mention here. Suffice it to say that the concentration of Spinoza prizes, ERC-advanced grants, and Dutch '*Vernieuwingsimpuls*' awarded to individual Observatory staff members over the years is exceptional, and evidences the strength and standing of the staff. It also shows the depth of excellent of early-, mid- and late-career researchers; this is not just a large department with a few senior stars. From the EB's perspective, the Observatory's hiring strategy to date has contributed significantly to this strength. Briefly, Leiden has adhered to the practice of identifying 'targets of opportunity' – candidates of very high scientific standing who may be happy to join the department – and has been remarkably successful; the first person offered the position usually accepts. At the same time, the Observatory has carried out broader searches, putting emphasis on recruiting the best scientists who come forward. However, there is an element of risk in this strategy in that younger candidates may look less attractive while both younger candidates and women are less likely to apply if they are not encouraged personally. The age and gender profile of the Observatory permanent staff suggests that this may indeed be happening. In addition, the EB is concerned that there are now few options to recruit new permanent staff of world-class calibre and that this may lead to foregoing or postponing expansion into new and promising directions.

NOVA has been an effective enabling force in the continued success and scientific excellence of the Sterrewacht Leiden, as it has been for all of the partner institutes. The instrumentation program has benefitted particularly from the easy collaborations among the universities, ASTRON and SRON. Junior level hires and the PhD program have also benefitted tremendously. The most recent and perhaps most dramatic success has been the award of the PI-ship for the construction of METIS to Sterrewacht Leiden. Nevertheless, this success brings with it considerable risk and an imperative to be continuously alert to damage control (as discussed already in the evaluation of NOVA). Leiden prides itself on having always brought projects in "on budget and on schedule". However, it must be acknowledged that the projects to date contributed to major instruments rather than led their development at the PI level. The EB strongly recommends that the METIS project takes every step necessary, making use of the wider resources available through NOVA, to monitor progress on METIS and minimize risk at every level. Schedule failures by even one contractor could have severe repercussions budget-wise on NOVA as a whole.

Score: 1.0

2.2. Relevance to society

The EB considered both outreach and interactions with industry in this context. Based on the documentation and a presentation, the EB judged the whole range of Leiden's activities to bring science and an understanding of the Universe to the public to be excellent.

The Leiden outreach program has a set of well-defined target groups, and the Sterrewacht's faculty and students together provide an impressive personnel pool for this ambitious program. Two aspects stood out: first, The Universe Awareness (UNAWE) activity was initiated in Leiden and has now matured into one of the most important educational outreach activities in astronomy with scope to act on a worldwide level especially in underdeveloped countries. Second, the EB felt that Leiden's decision to support outreach at the department level with a full, long-term position was an important move that reflects the Sterrewacht's sense of responsibilityfor these areas. . This new hire will allow a systematic assessment of the impact of outreach activities, which the EB deemed an excellent development in this area. The EB particularly notes the strong increase in undergraduate students in astronomy, which is plausibly linked to past outreach activities.

Sterrewacht Leiden's valorization activities in collaboration with industry and the subsequent knowledge transfer were found to be outstanding. Among a number of examples, the most striking was to include the public in an experimental project via an add-on on a mobile phone, allowing measurements of aerosol content in our Earth atmosphere. The methodology was derived from satellite-based instrumentation. Other examples are the extension of instrument development for astrophysics instruments to societal and industrial applications. The fact that this resulted in several 1M€ collaborations, grants and contracts was deemed exemplary in the context of a university department. However, for the most part, valorization seems to be opportunity driven, rather than to derive from a pre-determined strategy.

Score: 1.5

2.3. Viability

The EB found that the Sterrewacht Leiden is in a very strong and robust position, boding well for its long-term viability; in terms of research, there are only a few discernable important risks or single-point failures, including those associated with the METIS project as discussed earlier. For a faculty of its size and prominence, its cohesion and team spirit are exemplary.

There are a number of issues that will require managerial attention, which the EB lists here. Overall the EB was left with the impression that the Institute's management is well aware of them.

The Sterrewacht's enormous success in grant raising (ERC, VVV, Spinoza, etc.) has allowed it to grow considerably. If the overall funding climate in the Netherlands and Europe remains stable, the faculty's strength should be sufficient to sustain both size and status. The lack of base funding for the Institute makes it, however, rather vulnerable to external funding 'shocks'. In the view of the EB, this risk, which argues against growing the department significantly, even if near-term funding opportunities would permit, must be carefully balanced against the imperative to improve the age and gender profiles of the faculty (as discussed below).

The enormous growth of undergraduates in astronomy is a testament to the Institute's strength and attractiveness, but will require a serious increase in supervisory efforts. The EB simply notes this as a likely source of strain in the coming years.

The PI-ship for the ELT instrument METIS is at Sterrewacht Leiden; this is a project of unprecedented scale and responsibility within NOVA and Leiden. On the one hand, this offers a great opportunity, but on the other hand it also implies a considerable risk, especially as factors well beyond the PI's control can lead to delays. The instrument team seems to be acutely (and correctly) aware of these risks, but it important that the scale of METIS is broadly perceived. The METIS team has taken important steps to risk mitigation. But close monitoring of the METIS developments also by the university is advised.

Sterrewacht Leiden has achieved an impressive staff with its past hiring strategy. However, the EB notes that currently only one permanent scientific staff member is younger than 42 years of age. By contrast, over the same five years, the number of postdocs and PhD students increased by 83% and 50%, respectively. The EB is concerned by this age profile and also by the slow progress in achieving gender balance among the permanent staff. Although 50% of the staff hires have been female in the reporting period, the gender balance at Leiden remains disappointing when compared to other NOVA universities. It is clear that this needs continued attention.

Score: 1.5

2.4. PhD program

The PhD program at the Sterrewacht Leiden is exceptional in that it is presumably the largest world-class PhD program in astrophysics across the globe. Each year, the program attracts a large group of well-prepared, strong students; nearly all of these graduate within a reasonable time-frame, with strong research and career skills, as well as a published record of innovative research results. As already noted in this report, the EB was initially concerned that student interaction with their advisors and overall support for individual student welfare, both academic and personal, might suffer due to the large group size. However, the students appeared – and self-reported as being – well-mentored and trained, with sufficient access to their advisors. Overall, some credit must go to NOVA since the NOVA-sponsored meetings of students at various key points of their careers and the inter-university camaraderie play a large part in ensuring the satisfaction of most students

The Observatory is evidently aware of the risks of insufficient or inconsistent mentoring resulting from the large number of students and has put in place mechanisms to ensure their progress is monitored carefully. Indeed one senior staff member takes responsibility for overseeing graduate student progress and seems a key figure in maintaining stability. A large program necessarily means a range in student excellence, but the department is rightly proud of producing more students who go on to top US postdoctoral fellowships than any other European institution. Leiden's best students are among the very best in the world.

Nevertheless, as noted by the IB in 2014, the large number of PhD students who graduate, and the continuing growth of the program, seem to be driven more by the awards of successful grants than by deliberate strategy. The EB once again suggests that the university partners, in concert with, or perhaps even led by, NOVA should consider the optimum size for the PhD program, and strive to work towards attaining that equilibrium. In every other way, the program is exemplary with no significant weaknesses.

2.5. Research integrity

The EB judged the research integrity of Leiden Observatory on the basis of the information provided, the presentations, individual conversations and the broader community perception. All research activities appear to live up to current international standards of research integrity and transparency. The EB sees it as a positive that Leiden has both an integrity policy and a responsible person for these matters. This is not only laudable but beyond common best practices at the departmental level.

3. Recommendations

The excellent research program at the Observatory relies so heavily on funding from sources external to the university that careful and continuing monitoring of the availability of such funds in the future is essential to ensure the vitality of the program. Since independent national funding appears to be preferentially directed at younger faculty members, the current age imbalance in Leiden staff could pose a serious funding risk in the future.

The age and gender profiles for the Sterrewacht faculty are, as already noted, distinctly out of balance. These issues should be addressed proactively, since they will inevitably affect the long-term success of the Observatory. Current hiring strategies should be reviewed with this in mind.

The Sterrewacht appears to be justifiably proud of attracting the leadership role in the construction of METIS. The EB is concerned that the staff as a whole should recognize the very serious concerns regarding the level of risk in this venture and should support NOVA and the project administration in the wide-ranging monitoring that is required

At the moment, the Observatory appears to be managing its remarkably large PhD program effectively. However, the EB cautions that this too requires careful monitoring. The NOVA policy of having an external advisor for each student seems to be less important to Leiden but could provide an avenue to instances where the program is not properly serving students. Since the apparently open-ended approach to PhD program size applies to all the universities, NOVA is perhaps best placed to lead them in the development of strategies for the future. In a similar vein, the Observatory should work to ensure that sufficient resources are allocated to manage the rapidly increasing numbers of undergraduate students.

The Observatory is encouraged to continue and extend its current efforts in education, outreach, and valorization, and whenever possible to share its expertise and best practice with the other NOVA partners.

Department of Astrophysics, Radboud University

1. Description of the Department of Astrophysics

Through the preparatory documents and the site visit, the EB received a clear view of the mission, structure and organization of Radboud University's Department of Astrophysics (henceforth 'the Department'). A summary is given below.

1.1. Mission and research activities

The Radboud Department of Astrophysics, founded in 2001, is by far the "youngest" of NOVA's astronomical institutes and is relatively small. Its research concentrates on astronomy, astrophysics, and astroparticle physics and can be roughly divided in three interlinked broad topics, with overlapping interests and staff involvement: (1) The physics of compact objects, including accretion and jets; (2) Astroparticle physics: gravitational waves, high-energy cosmic rays and dark matter; (3) Galactic ecology: stellar/binary evolution and populations, galactic structure and evolution. Its research projects span the range of observational, theoretical and numerical astrophysics. Observations are multi-wavelength and multi-messenger. From its inception, the aim of the Department has been to straddle the boundary between astronomy and physics. As an anchor point for this goal, the Department is part of IMAPP, the Institute for Mathematics, Astronomy, and Particle Physics at Radboud. The research is at the centre of the NOVA Network 3.

Being relatively small, the Department aims to broaden its scope through collaborations. Thus, it is developing the Radboud Radio Lab (RRL) as a small-scale 'proto-typing' facility, in close collaboration with ASTRON, the TechnoCenter of the Faculty of Sciences, the NOVA Optical-Infrared and ALMA groups and local industry. Future goals include growing stronger bonds with the Radboud Stochastics group and the Computer Sciences in the area of data analysis and machine learning, as well as with the physics community, in particular as they investigate the possibility of bringing the Einstein Telescope to the Netherlands.

1.2. Management and organization

Astrophysics is one of three departments within the Institute for Mathematics, Astrophysics and Particle Physics and (IMAPP), which is one of the research institutes of the Faculty of Science of Radboud University. The Department has a flat hierarchical structure with no subdivisions and a single head, supported by the secretariat, the IMAPP managing director, two liaison officers in the financial department, and one in the human resource department. Within IMAPP the Department strongly interacts with the Experimental High Energy Physics group on research into cosmic-rays and dark matter. Members also interact with the Stochastics group within IMAPP and the Machine Learning group of Heskes within the ICIS Computer Science institute.

At a national level, the staff is strongly involved in the coordination of astronomy and has strong ties withSRON and ASTRON. Several members of the Department are also part of the NWO institute Nikhef for subatomic physics, strengthening the bonds with astroparticle physics. The Department reports strong international ties, some through NOVA and national representation in ESO and ESA. In addition, there are multi-person bonds with several international institutes, as well as many links at the level of individual staff members.

Astrophysics is one of the ten focal points in research at Radboud University. In 2015 the Governing Board of the university allocated five-year funding for the Radboud Radio Lab (RRL), a research and prototyping oriented group for new (radio-based) instrumentation projects, with a clear objective to cultivate and exploit ties with (local) industry and ASTRON. The current RRL portfolio is significant and includes SKA-studies, BlackGEM/MeerLICHT, HIPERSENSE, the African millimetre Telescope (AMT), and the payloads for the Stratos-II and Chang'e 4 satellite missions. The RRL is a conduit for (technological) knowledge transfer between the University and industry and links local industry to the University.

1.3. Resources

1.3.1. Human Resources

Appendix 4 Table 1 gives an overview of number of research staff at the Department of Astrophysics. The department was founded in 2001 with 2 FTE academic staff and 2 PhD positions. The 2015 size of the Department was 10.6 FTE scientific staff, 2-3 FTE temporary science-support staff, 15 FTE postdocs, 25 FTE PhD students, 0.5 FTE technical support, 1.9 FTE secretarial support and 7-12 MSc students. The department is composed of 68% men and 32% women, with a strong gradient across academic seniority, ranging from 11 % (1.1 FTE) female scientific staff to 42% women among the PhD students. Of the current 10.6 FTE scientific staff, 8.2 FTE are on long-term permanent contracts, as are another 2 FTE until retirements (in 2019) and 0.4 FTE are 5-year extraordinary professorship positions. Additionally, 3 FTE non-permanent staff are in science management positions.

1.3.2. Financial resources

A major part of the Radboud Department's funding comes from external grants (80%). An overview of the total volume of funding is given in Appendix 4 (Tables 4 and 5). Of the scientific staff (10.6 FTE), 6.6 FTEs are dependent on temporary grants. External funding is therefore a life-line for the Department and continuing reliance on this funding source is rightly reported as a concern in an (inter)national landscape where funding is allocated in ever-larger chunks to an ever-smaller number of groups. The Department considers this to be a significant threat, especially to its research diversity, which is essential to provide students and postdocs with a broad view on the Universe as well as to keep staff scientifically motivated through lively interactions and developments.

The Department has a 100-120 kEuro annual operating budget. This is intended to be used for travel not supported from individual grants; for investments to start new projects, to co-invest, or to match obligations; for contingency for (instrumentation) projects; and for consumables (office supplies coffee/tea, ICT infrastructure, etc.). The total volume of the Department's portfolio including instrumentation projects is 5 M€/yr (2012-2015).

2. Qualitative and quantitative assessment of the Department of Astrophysics

In this section, the EB evaluates the performance of the Department of Astrophysics as a whole on the three criteria of research quality, relevance to society and viability. In addition, the EB gives its evaluation of PhD supervision and education, and of academic integrity, as stipulated in the TOR. An overview of the EB's recommendations for the Radboud Department of Astrophysics is given in section 3 of this report.

The TOR for the Nijmegen Department of Astrophysics also identified three specific questions the EB was asked to address. In order to avoid repetition these questions have been grouped under the broader headings of research quality, relevance to society, and viability, and have been addressed in turn under the relevant SEP criterion.

2.1. Research quality

Over the past six years, Radboud University had had a remarkable period of intellectual and physical growth. The Department has now increased to ten faculty members, the critical size advocated in the 2014 IB report. Some of this growth can be attributed to the successful absorption of some of the Utrecht faculty, while the rest is due to adding new lines and several new young faculty members. In keeping with its goal straddling research boundaries, the Department is particularly strong in particle astrophysics and gravitational wave astrophysics, two areas that have deep links with the physics department.

The Department's publication record and citation rate has also grown at a remarkable pace over the past five years. While outside of the official window for the evaluation, the two most impressive papers from the department appeared in 2016: the first detection of gravitational waves, a discovery that is very likely to earn Nobel Prizes for the LIGO team leaders, and the radio detection of the correlation of cosmic rays with LOFAR and AUGER.

Nijmegen scientists led the Nature paper reporting the detection of high energy (1017 eV) cosmic rays with LOFAR, and co-led the LIGO astrophysics interpretation paper. Also, one of the 'featured' scientists in the LIGO press releases, was hired on a new tenure track position at the Nijmegen Department in 2016. Overall, the diverse and innovative suite of projects being undertaken is an impressive portfolio for a department of modest size.

Radboud is now positioned to play a leading role in gravitational astrophysics. The decision to focus on gravitational wave astronomy appears to have been a terrific bet as the field is poised to take off. The Department is the only astronomy group in the Netherlands in the VIRGO-LIGO collaboration. In addition, the BlackGEM telescope is an integral part of the VIRGO-LIGO follow-up network and is scheduled to begin operation in the near future. Nijmegen researchers are also playing a leading role in BlackHoleCam through the synergy grant that was obtained. BlackholeCam is designed to make the first accurate image of a black hole.

The department currently has a unique opportunity to develop as a leading center for gravitational wave astrophysics. In terms of understanding the EM counterparts, collaborations with the Amsterdam program with its complementary strength in binary evolution is encouraged. At the same time, IMAPP offers potential for growth in areas such as computational general relativity. A new staff hire in this area could effectively link the gravitational astronomy program with both physics and mathematics.

In the TOR, the EB was asked to address the following specific question, that links to 'research quality': *How does the EB see the Department's research agenda within the NOVA/NL context, and on an international scale? Also on its links with the Physics community.* The EB is of the opinion that Nijmegen's research agenda complements the efforts of the other NOVA universities in critical ways. The departmental strength in particle astrophysics and gravitational wave astronomy ensures that NOVA scientists will have a strong presence in the emerging new discoveries and links the Radboud astronomy group strongly with the physics community. Through its involvement in AUGER and VIRGO, the Radboud department is deeply embedded in the broader international particle astrophysics community and the growing gravitational astrophysics community. The EB perceives Radboud's scientific interests and strong external links as very important to NOVA's future.

Score: 1.5

2.2. Relevance to society

The EB considered in this context the aspects of public education and outreach, as well as valorization activities including interactions with industry. Based on the documentation and a presentation, the EB judged the outreach and public education activities of the Radboud University to be very good, certainly in comparison to what is the norm in other sciences. There appears to be a lower degree of central coordination of activities than in the larger NOVA institutes, but this can be readily attributed to the small size of the department. The project of outreach and public education targeting religious groups was remarkable and noteworthy in targeting an often ignored group.

The EB took note of the fact that at the Department, valorization and interface activities are largely opportunity driven. Nevertheless, the positive attitude of staff to make connections to industry in view of potential valorization was clearly present. Examples were the generation of a cleaner form of green energy around observational infrastructure (HIPERSENSE) and the construction of special lightweight stable platforms with special mechanical stability.

Score: 2.0

2.3. Viability

The Nijmegen faculty has now reached critical size. The effect, in terms of productivity and morale compared with earlier reviews, was clear to the EB. It strongly encourages the university to maintain the department at this size and perhaps to allow modest growth to twelve faculty members in the coming years. If the department shrinks below ten faculty members, there are risks of not having the breadth to support their multiple cutting-edge projects, mentor their graduate students, and be active participants in Dutch astronomy. As noted above, IMAPP could be a mechanism to grow critical mass in the astrophysics group through co-funding of positions with maths and high-energy physics.

The leadership is successfully managing the department's growth. The only identified governance issue was a university level problem of slow promotion of Assistant Professors. The expectations for promotion seem to be poorly understood and vague. With a young faculty, this problem could threaten the viability of the program.

If the Netherlands were to play a leading role in the Einstein telescope, this would be a tremendous opportunity for the Nijmegen department. However, the relative lack of interactions between NOVA and NIKHEF makes it more challenging to build this telescope in the Netherlands. Nevertheless, because of the department's close ties to the physics community, it could play a leading role in building the coalition needed for leadership in this major project.

In the TOR, the EB was asked to address the following specific question that links into the viability of the department: *Given the relative young age of the Department what actions does the EB see that would further strengthen the long-term perspective of the Department? In particular, the relation between the breadth of research topics and the staff size.* The EB is of the opinion that the department has grown to critical mass and seems to have an adequate size to support the current range of research topics. The department has built strengths in transient science and gravitational wave astrophysics. Given the enormous international investment in projects such as LIGO/VIRGO and the Large Synoptic Survey Telescope (LSST), the EB is convinced that the department has invested its hires wisely in research areas that are likely to have significant intellectual activity and enormous scientific impact in the coming years.

Another question the EB was asked to address is: *How does the EB see the balance between research and instrumentation efforts in the Department?* The EB views the Radboud instrumentation efforts as high quality, strategic, and creatively very interesting. It believes that they are appropriate for the size and research directions of the department. The radio lab is certainly reviving the traditional Dutch spirit of innovation in radio astronomy by undertaking small technology experiments that can grow into larger missions.

The Department's small instrumentation group is developing novel experiments that are integrally tied to its broader scientific strategy. RU is the PI/scientific lead in a Chinese space radio mission, Chang'e-4. They are designing the digital electronics on this joint project with ASTRON and the Delft company ISIS. The ultimate goal of this innovative instrument is the detection the 21 cm hydrogen line. At the same time, considerable instrumental and collaborative effort has been focused on the BlackGem project. The EB sees the Radboud radio lab and BlackGem as examples of strategic instrument projects that are well matched to the department's research portfolio.

Score: 2.0

2.4. PhD program

Overall the students at Radboud are happy with the PhD program and appreciate the benefits that derive from being part of NOVA. Like their fellow students from other NOVA universities they enjoy the enhanced opportunities for professional interaction with their peers as well as the career-help meetings that are such as an important part of the NOVA program. However, these interactions have also made them more aware of some issues that appear to be associated only with the Radboud program.

Students reported a lack of clarity in Radboud PhD requirements, an issue that did not arise in discussions with other NOVA universities. The number of papers to be published or submitted for publication was a particular point of uncertainty. They also perceived a structure in the PhD supervisory panels that was less supportive of students than elsewhere. A worrisome perception was that their teaching load seemed to be much higher than at other universities.

The EB was advised that some of these issues derived from an unusual situation within the Radboud University structure that has now been changed for the better. Making the PhD requirements clearer is a small matter but the EB suggests it would be to the advantage of the Department to continue to work with the students on these matters. It will be important to demonstrate that such issues are dealt with in a timely manner so as to ensure that the environment in Nijmegen will continue to attract the best students. In this regard, the NOVA policy of having an external supervisor could be used to good effect. Radboud students spoke most highly about (internal) second supervisors and believed that having a second supervisor had already helped when difficult supervisor–student relations arose.

That said, the EB found that, overall, the students enjoyed the Radboud PhD program. It appears to be very successful with no significant weaknesses. The EB was inclined to believe that some of the issues raised in fact reflect the marginal criticality of the Radboud group size, that is, the number of faculty in the department. This concern about faculty numbers is raised elsewhere in the report.

2.5. Research integrity

The EB has no concerns about the department's data management practices, the level of internal research integrity and the transparency of the department's research culture.

3. Recommendations

The Radboud department should maintain its size of ten faculty members as it has just reached the critical size needed for a vibrant department. While additional modest growth would be beneficial, consolidating the department at its current size is essential. When the former Utrecht faculty members retire, the department may consider making appointments in areas such as numerical relativity. These appointments could be cross-appointments with physics and/or mathematics.

The department should make every effort to exploit its potential to play a leading role in gravitational astrophysics. Given the complementary research interests, collaboration with the API on the interpretation of high energy astrophysical counterparts of gravitational wave detections may be of mutual benefit.

In consultation with the university administration, and perhaps with NOVA support, the department should continue to try to improve the processes involved in staff advancement at Radboud. Otherwise, the department risks losing some of its promising junior members.

The department should ensure that the steps in the path to a PhD are clear for students. There seems to be a perception among the students of a lack of parity with the other universities both in terms of graduation requirements and teaching requirements, and regardless of its reality improved communications may be beneficial .

While the current efforts in public education, outreach, and valorization are certainly satisfactory for a department of this size, the development of a more systematic NOVA strategy in these areas could be especially beneficial for this institute.

Appendices

1. Appendix 1: Curricula vitae of the EB members

Robert Kennicutt (chair) is the Plumian Professor of Astronomy and Experimental Philosophy at the University of Cambridge, where he has also served as Director of the Institute of Astronomy and Dean of the School of the Physical Sciences. He is an expert in observational extragalactic astronomy, and has authored more than 400 papers on the structure and evolution of galaxies, star formation, and observational cosmology. He took up his position in Cambridge in 2005, and prior to that held faculty positions at the University of Arizona and the University of Minnesota, as well as the editorship of The Astrophysical Journal, the leading North American research journal in astronomy. He won the Dannie Heineman Prize of the American Astronomical Society and the American Institute of Physics in 2007 for his research on star formation in galaxies, and shared the 2009 Gruber Cosmology Prize (with Wendy Freedman and Jeremy Mould) for their work on calibrating the extragalactic distance scale. He is a member of the US National Academy of Sciences and a Fellow of the Royal Society, and has participated in numerous policy-making activities including the most recent decadal surveys of astronomy for Europe and the USA.

Born in France, **Catherine Cesarsky** graduated with a PhD in Astronomy in 1971 from Harvard University. She then worked at the California Institute of Technology. In 1974, she moved to France, becoming a staff member of the Service d'Astrophysique (SAp), Direction des Sciences de la Matière (DSM), Commissariat à l'Energie Atomique (CEA). From 1985 to 1993, she was the Head of SAp, and from 1994 to 1999 she was Director of DSM. From 1999 to 2007, she was Director General of the European Southern Observatory. From 2009 to 2012, she was High Commissioner for Atomic Energy in France, advisor to the French government for science and energy issues. Now, she is High level Science Advisor at CEA. From August 2006 to August 2009, she was President of the International Astronomical Union. Her research activities include studies of the propagation and composition of galactic cosmic rays, and of the acceleration of particles in astrophysical shocks, as well as of the evolution of galaxies, in particular through their infrared emission. She is recipient of the 1998 COSPAR (Committee on Space Research) Space Science Award, and member or Foreign member of various Academies (French Académie des Sciences, Academia Europaea, International Academy of Astronautics, National Academy of Sciences USA, Royal Swedish Academy of Sciences, Royal Society of London, Argentina Academy of Natural Sciences).

Hans-Walter Rix stumbled into astronomy research as a Fulbright Scholar at the University of Arizona in Tucson, where he stayed another four years to get his PhD. In his thesis work with Simon White he figured out that most large elliptical galaxies also have sizable stellar disks, and hence must have a different formation history than thought at the time. He then went on to the Institute for Advanced Studies in Princeton, working on some of the very first HST data on gravitational lensing. After a year at MPA, Garching and three years on the faculty at the University of Arizona, he came to MPIA, Heidelberg late 1998. In the first five years, his focus was on galaxy evolution, helping to draw up a comprehensive picture of what the population of galaxies looked like when the Universe was half its age. In recent years he has focussed his research on our very own galaxy, the Milky Way, because the intricate detail in which it can be studied, should lead us to a better understanding of galaxy formation as a whole. As of 2016, the Gaia space mission along with other vast spectroscopic surveys of stars, and then Hubble's successor JWST are the next beacons on his science path.

A native of Scotland, **Anneila Sargent** earned her B.Sc. (Hons Physics) at the University of Edinburgh and her Ph.D. from the California Institute of Technology (Caltech) in 1977. She has spent her career at Caltech where she is currently the Ira S. Bowen Professor of Astronomy. Her research largely concentrates on understanding how stars and other planetary systems are created and evolve. As Benjamin Rosen Professor of Astronomy, she was Director of Caltech's Owens Valley Radio Observatory (OVRO) from 1996 until 2007 and founding Director of the

Combined Array for Millimeter-wave Astronomy (CARMA), the U.S. precursor to ALMA. Between 2007 and 2015, she was Caltech's Vice President for Student Affairs. Sargent has been President of the American Astronomical Society and is a Fellow of the American Academy of Arts and Sciences. She has chaired the NASA Space Science Advisory Committee and the U.S. National Research Council (NRC) Board of Physics and Astronomy, and served on the U.K. Science and Technology Facilities Council. She was named Jan H. Oort Professor at the University of Leiden for 2005 and is currently a member of the U.S. National Science Board, a presidential appointment.

Brian Schmidt was appointed Vice-Chancellor of The Australian National University (ANU) in January 2016. Winner of the 2011 Nobel Prize in Physics, Professor Schmidt was an astrophysicist at the ANU Mount Stromlo Observatory and Research School of Astronomy and Astrophysics before becoming Vice-Chancellor. Professor Schmidt received undergraduate degrees in Astronomy and Physics from the University of Arizona in 1989, and completed his Astronomy Master's degree (1992) and PhD (1993) from Harvard University. Under his leadership, in 1998, the High-Z Supernova Search team made the startling discovery that the expansion rate of the Universe is accelerating. Fellow of the Australian Academy of Science, The United States Academy of Science, and the Royal Society, he was made a Companion of the Order of Australia in 2013.

David Spergel is the Charles Young Professor of Astronomy on the Class of 1897 Foundation and just completed 10 years of service as the Chair of the Department of Astrophysical Sciences at Princeton University. He is the Founding Director of the The Flatiron Institute's Center for Computational Astrophysics. Spergel was a member of the WMAP science team and the lead author of the most cited paper in physics in the new Millennium which described the cosmology based on its results. Spergel is a MacArthur Fellow, a Fellow of the APS, and a member of both the National Academy of Sciences and the American Academy of Arts and Sciences. Spergel shared the Gruber Prize, the Heinemann Prize, and the Shaw Prize for his work on cosmology. Spergel is currently chair of the NAS Space Studies Board, a member of the NASA Advisory Council, and co-chair of the WFIRST science team.

Wim Van der Zande gained his PhD in chemical physics at the University of Amsterdam in 1988. He has been Director of Research at ASML since 2014. The themes of his research team encompass physics and chemistry processes in the LPP Source and the scanner, including material science for future pellicle materials and possible resist developments. Prior to 2014, he worked in academics at the Radboud University Nijmegen and the FOM Institute AMLF in Amsterdam. He has been a member of the Board of SRON since 2004 and was Chairman of its Scientific Advisory Board between 2002 and 2004. Between 2003 and 2009 he was the edidor in chief of the Nederlands Tijdschrift voor Natuurkunde.

Appendix 2: Explanation of the SEP criteria and categories

Extended description of the 4-point scale for categorizing the quality along three criteria

Category	Meaning	Research quality	Relevance to society	Viability
1	World leading/ excellent	The research unit has been shown to be one of the few most influential research groups in the world in its particular field.	The research unit makes an outstanding contribution to society.	The research unit is excellently equipped for the future.
2	Very good	The research unit conducts very good, internationally recognized research.	The research unit makes a very good contribution to society.	The research unit is very well equipped for the future.
3	Good	The research unit conducts good research.	The research unit makes a good contribution to society.	The research unit makes responsible strategic decisions and is therefore well equipped for the future.
4	Unsatisfactory	The research unit does not achieve satisfactory results in its field.	The research unit does not make a satisfactory contribution to society.	The research unit is not adequately equipped for the future.

Appendix 3: Program of the site visit

Monday November 14: location Oude Sterrewacht

16:00 - 16:30: Tour Old Observatory (optional)
16:30 - 17:30: EB with NOVA Board + directorate
17:30 - 18:30: Closed session EB with chair NOVA RvT and penvoerder evaluations
18:30 – 19:00: Individual discussion with dean Groningen, dean Leiden
18:00 - 19:15: Closed session EB
19:15 - 21:15: Dinner with NOVA Board in Pieterskerk

Tuesday November 15: location Stadsgehoorzaal Leiden

9:00 - 9:25: Closed session EB
9:25 – 9:30: Welcome
9:30-10:00: NOVA overview and forward look, *Ewine van Dishoeck*
10:00-10:30: Formation and evolution of galaxies
  10.00-10.20: Overview NW1, *Amina Helmi*
  10.20-10.30: Recycled stellar ejecta as fuel for star formation in EAGLE simulations, *Marijke Segers* (UL, PhD)
10.30-11.00: Formation and evolution of stars and planetary system
  10.30-10.50: Overview NW2, *Carsten Dominik*
  10.50-11.00: Spinning worlds: The rotation of young gas giants and brown dwarf companions, *Henriette Schwartz* (UL, PhD)
11.00-11.10: Discussion
11:10-11:30: Coffee break
11:30-12:00: Astrophysics in extreme conditions
  11.30-11.50: Overview NW3, *Gijs Nelemans*
  11.50-12.00: Timing Observations of PSR J1023+0038 during a low-mass X-ray binary state, *Amruta Jaodand* (API, PhD):
12.00-12.10: Discussion
12:10-12:30: Outreach, *Marieke Baan* (NIC) and *Alex de Koter* (chair Minnaert committee)
12:30-13:45: Lunch + poster viewing
13:45-14:15: NOVA instrumentation overview and forward look, *Wilfried Boland*
14.15-14.30: Valorization, *Michiel Rodenhuis*
14.30-14.45: Discussion
14:45-16:00: Coffee break -EB closed session; including 15 min telecon with dean Nijmegen
16:00-16:30: Instrumentation: EB splits in two, meets with
  1. Op/IR and submm groups: *Navarro, Kroes, Pragt, Adema, Bekema, Baryshev*
  2. Instrumentation steering committee: *de Graauw (chair), Kaper, Désert, Verdoes Klein, Rodenhuis (secr)*
16:30-17:00: Young researchers: EB splits in two, meets with
  1. PhD students: *Leon Boschman (RUG), Cristiana Spignola (RUG), Samayra Straal (API), Amruta Jaodand (API), Payaswini Saikia (RU), Jordy Davelaar (RU), Merel van 't Hoff (UL), Marijke Segers (UL)*
  2. Postdocs: *Mariya Lyubenova (RUG), Manolis Papastergis (RUG), Patrick Crumley (API), Allona Vazan (API), Cornelia Muller (RU), Steven Bloemen (RU), Massimo Viola (UL), Francesco de Gasperin (UL)*
17:00-17:30: Young staff: EB splits in two, meets with
  1. Tenure Track staff: *Selma de Mink (API), Jean-Michel Désert (API), Antonia Rowlinson (API), Jacqueline Hodge (UL), Samaya Nissanke (RU), Pratika Dayal (RUG), John McKean (RUG)*
  2. Junior staff: *David Berge (API), Anna Watts (API), Jason Hessels (API), Karina Caputi (RUG), Elena Rossi (UL), Rychard Bouwens (UL), Matt Kenworthy (UL), Elmar Körding (RU)*
17:30-18:45: EB closed session, includes 15 min Skype/telecon with dean Amsterdam
18:45-20:30: Walking dinner - More poster viewing

Wednesday November 16: Location Kasteel Oud Poelgeest

8:45-10:45: **Institute 1: Amsterdam**

8:45 presentation Director, *Ralph Wijers*

9:00 meet with various cross sections institute

9:20 EB splits in two and meets with

A: Selection of staff: *Anna Watts, Jean-Michel Désert, Selma de Mink, Rudy Wijnands, Jacco Vink, Phil Uttley*

B: Selection PhD candidates & postdocs:

Postdocs: *Patrick Crumley, Allona Vazan*

PhD: *Ylva Gotberg, Amruta Jaodand, Samayra Straal, Tomas Stolker, Laura Ootes, Jacob Arcangeli, Mark Kuiack, Jacob van den Eijnden*

9:40 relevance to society discussion: *all API staff + Esther Hanko, Joeri van Leeuwen*

10:00 meet with Director + MT: *Ralph Wijers, Carsten Dominik, Michiel van der Klis, Alex de Koter, Sera Markoff, Annemarie van Groenestijn*

10:30 15 min EB closed session

11:15-13:15: **Institute 2: Groningen**

11:15 presentation Director, *Reynier Peletier*

11:30 meet with cross sections staff: *Amina Helmi, Pratika Dayal, Karina Caputi, Marc Verheijen, Mariano Mendez*

11:50 EB splits up in two:

A: non-academic staff: *Maarten Breddels, Gijs Verdoes Kleijn, Crescenzo Tortora, Kelly Hess, Lorenzo Posti*

B: PhD students: *Marisa Brienza, Matthijs Dries, Jorrit Hagen, Evandro Ribeiro, Anastasia Ponomareva*

12:10 EB splits up in two:

A: relevance to society discussion; connections to industry*: Edwin Valentijn, Gijs Verdoes Kleijn*

B: outreach: *Peter Barthel, Marlies van de Weijgaert*

12:30 meet with Director + MT: *Reynier Peletier, Leon Koopmans, Peter Barthel, Scott Trager, Lucia van der Voort*

13:00 15 min EB closed session

13:15-14:15: Closed working lunch EB

14:15-16:15: **Institute 3: Nijmegen**

14:15 presentation director, *Paul Groot*

14:30 meeting with staff: *Paul Groot, Gijs Nelemans, Heino Falcke, Samaya Nissanke, Frank Verbunt, Marijke Haverkorn*

14:50 relevance to society: *Marc Klein-Wolt, Roque Ruiz Carmona, Marijke Haverkorn, Paul Groot*

15:10 EB splits up in two:

A: Instrumentation: *Marc Klein-Wolt, Hamid Pourshaghaghi, Steven Bloemen, Christiaan Brinkerink*

B: PhDs: *Jordy Davelaar, Payaswini Saikia, Jan van Roestel, Roque Ruiz Carmona, Svea Hernandez, Martha Saladino and Kristhell Lopez*

15:30 meet with Director(s): *Paul Groot & Gijs Nelemans*

16:00 15 min EB closed session

16:45-18:45: **Institute 4**: **Leiden**

16:45 presentation Director, *Huub Röttgering*

17:00 meet with various cross sections institute (EB split in two):

A: Selection of staff: *Ignas Snellen, Henk Hoekstra, Jackie Hodge, Michiel Hogerheijde, Harold Linnartz, Anthony Brown, Bernhard Brandl*

B: Selection of PhDs: *Marijke Segers, Henriette Schwarz, Anna Miotello (TBC), Jorryt Matthee, Mason Carney, Merel van 't Hoff, Mieke Paalvast,* followed by 10 min: Chair PhD monitoring committee: Tielens

17:20 Presentation on relevance to society, industrial spinoff, and outreach *Christoph Keller*

17:40 meet with Director + MT*: Huub Röttgering, Evelijn Gerstel, Paul van der Werf, Joop Schaye, Marijn Franx, Koen Kuijken*

18:10 15 min EB closed session

19:00-21:00: Closed working dinner EB

Thursday November 17: Location Faculty Club University Rapenburg

9:00-12:30: Closed session EB: Writing report
12:30-13:00: Lunch
13:00-13:45: Feedback to deans/RvT on NOVA
13:45-15:00: Feedback to individual institutes: director + dean each institute
15:00-15:30: Feedback to NOVA Board + Directorate on NOVA
15:30-16:00: Meet with CvB Leiden
16.00-16.30: Delegation EB (Kennicutt, Sargent, Schmidt) meets with delegation Ministry OCW
16.45: end of meeting

Appendix 4: Quantitative data

1. Research staff numbers

Table 1: Numbers of research staff in fte's

API, UvA	2010	2011	2012	2013	2014	2015
Tenured Staff	9.0	10.1	11.1	11.5	11.6	12.7
Long-term postdocs	0.0	0.0	1.0	1.1	1.1	2.0
Co-workers	1.0	1.1	1.2	1.0	0.9	1.0
Postdocs	9.6	13.8	14.2	14.1	9.9	12.6
PhD students	19.7	24.3	30.9	26.6	30.7	35.8
Instrumentation	3.0	2.1	4.1	3.5	4.4	3.5
Total	**42.3**	**51.4**	**62.5**	**57.8**	**58.6**	**67.7**

Kapteyn Inst, RUG	2010	2011	2012	2013	2014	2015
Tenured Staff	14.1	13.3	14.2	13.2	13.5	13.5
Long-term postdocs	0.8	1.2	2.0	2.0	2.0	2.0
Co-workers	1.6	1.6	1.3	2.0	2.3	2.3
Postdocs	8.0	9.9	15.6	17.8	17.2	15.9
PhD students	43.2	42.5	40.2	40.8	38.4	43.2
Instrumentation	21.6	23.5	19.6	14.8	12.0	13.3
Total	**89.2**	**91.9**	**92.8**	**90.6**	**85.4**	**90.1**

Observatory, UL	2010	2011	2012	2013	2014	2015
Tenured Staff	21.3	21.6	20.1	19.5	19.5	19.3
Long-term postdocs	1.0	1.8	1.3	2.4	5.6	5.5
Co-workers	0.4	0.5	0.5	0.7	0.9	0.9
Postdocs	24.3	28.7	28.7	30.9	34.9	40.7
PhD students	45.3	55.1	64.3	68.4	69.4	67.6
Instrumentation	8.6	8.2	12.2	12.6	8.9	7.3
Total	**101.0**	**115.8**	**127.0**	**134.4**	**139.2**	**141.1**

Astrophysics, RU	2010	2011	2012	2013	2014	2015
Tenured Staff	5.6	6.4	10.1	10.2	10.0	10.0
Long-term postdocs	0.0	0.0	0.0	0.0	0.0	0.0
Co-workers	0.2	0.2	0.2	0.2	0.2	0.5
Postdocs	5.3	6.4	7.1	9.9	11.5	13.4
PhD students	10.8	14.6	24.2	25.2	27.0	24.7
Instrumentation	4.3	3.2	4.7	5.5	5.8	5.4
Total	**26.2**	**30.8**	**46.2**	**51.0**	**54.5**	**53.9**

Astronomy, UU	2010	2011				
Tenured Staff	7.0	7.0				
Long-term postdocs	1.0	1.0				
Co-workers	0.2	0.2				
Postdocs	4.9	3.4				
PhD students	23.5	18.8				
Instrumentation	5.0	4.2				
Total	**41.6**	**34.6**				

Op-IR group NOVA	2010	2011	2012	2013	2014	2015
Instrumentation	10.4	11.5	11.7	11.8	11.5	12.1

NOVA + Institutes	2010	2011	2012	2013	2014	2015
Tenured Staff	57.1	58.4	55.5	54.4	54.6	55.5
Long-term postdocs	2.8	3.9	4.3	5.5	8.7	9.5
Co-workers	3.5	3.6	3.2	3.9	4.3	4.8
Postdocs	52.1	62.1	65.5	72.6	73.6	82.6
PhD students	142.5	155.2	159.5	161.0	165.5	171.2
Instrumentation	52.8	52.6	52.3	48.2	42.5	41.4
Total	**310.7**	**335.9**	**340.3**	**345.6**	**349.2**	**364.9**

Table 2: Senior research staff at the university astronomical institutes and their research fields according the NOVA networks.

Senior researchers	NW1	NW2	NW3
Tenured + tenure-track staff	27	16	23
Long-term postdocs	5	2	3
Co-workers	10	13	7
Emeriti	8	0	3

2. Gender distribution for research staff

Table 3: Gender distribution for the four universities, and for NOVA and the institutes as a whole expressed as the fraction of women compared to the total number of researchers in that category.

UvA, API

	2010	2011	2012	2013	2014	2015
Tenured staff	0.13	0.22	0.20	0.19	0.21	0.26
Postdocs	0.26	0.30	0.27	0.28	0.28	0.19
PhDs	0.43	0.43	0.35	0.35	0.36	0.40

RUG, Kapteyn Institute

	2010	2011	2012	2013	2014	2015
Tenured staff	0.21	0.23	0.28	0.30	0.30	0.30
Postdocs	0.55	0.48	0.47	0.44	0.47	0.45
PhDs	0.31	0.33	0.40	0.39	0.36	0.38

UL, Observatory

	2010	2011	2012	2013	2014	2015
Tenured staff	0.05	0.09	0.10	0.10	0.10	0.12
Postdocs	0.31	0.34	0.29	0.31	0.34	0.31
PhDs	0.30	0.33	0.35	0.34	0.36	0.38

RU, Astrophysics

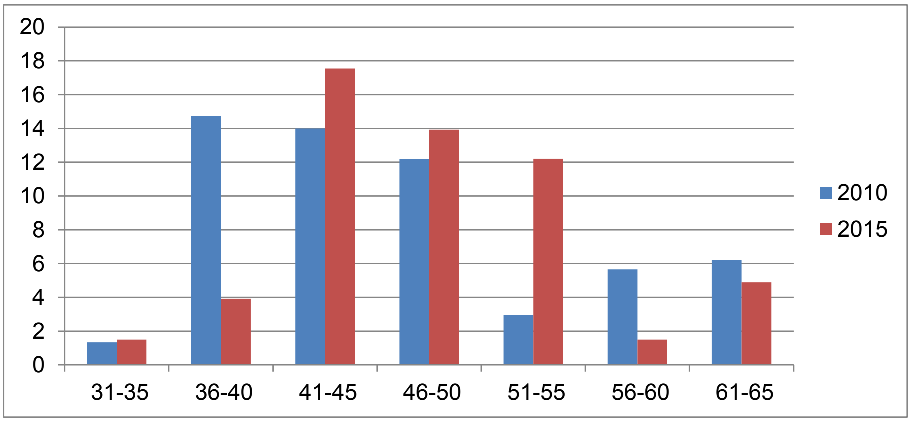
	2010	2011	2012	2013	2014	2015
Tenured staff	0.04	0.12	0.11	0.12	0.12	0.12
Postdocs	0.38	0.39	0.32	0.22	0.23	0.30
PhDs	0.23	0.33	0.41	0.39	0.42	0.45

NOVA+institutes

	2010	2011	2012	2013	2014	2015
Tenured staff	0.11	0.16	0.17	0.17	0.18	0.19
Postdocs	0.35	0.36	0.33	0.32	0.34	0.32
PhDs	0.32	0.35	0.37	0.36	0.37	0.40

3. Age distribution tenured research staff

Figure 1: The age distribution of tenured + tenure track research staff at the four university astronomical institutes, which is equivalent for NOVA as a whole, is shown in figure 1. Total numbers were 57.1 FTE in 2010 and 55.5



4. Revenues and expenditures

Table 4: Revenues and expenditures in k€ of each of the university institutes and for NOVA.

UvA, API	2010	2011	2012	2013	2014	2015
Revenues						
Direct University funding (1)	1,903	3,041	3,286	2,601	2,363	3,212
NOVA including NIC (7)	710	872	856	1,078	1,262	1,185
National research grants (2)	1,442	851	1,093	1,100	948	1,253
International grants and contract research (3)	516	623	1,089	892	634	449
Other (4)	-128	-629	-820	-8	297	61
Total revenues	**4,442**	**4,758**	**5,504**	**5,663**	**5,505**	**6,161**
Expenditure						
Personnel costs (5)	3,208	3,769	4,729	4,774	4,662	5,380
Instrumentation costs (6)	28	22	137	89	68	91
Other costs (4)	1,207	966	638	801	775	690
Total expenditure	**4,442**	**4,758**	**5,504**	**5,663**	**5,505**	**6,161**

RUG, Kapteyn Institute	2010	2011	2012	2013	2014	2015
Revenues						
Direct University funding (1)	2,785	2,615	2,843	2,661	2,565	2,469
NOVA (7)	1,634	1,563	1,408	1,154	1,213	1,515
National research grants (2)	1,306	901	767	1,183	964	1,256
International grants and contract research (3)	835	855	1,316	2,271	1,719	2,076
Other (4)						
Total revenues	**6,561**	**5,934**	**6,335**	**7,269**	**6,460**	**7,315**
Expenditure						
Personnel costs (5)	4,540	4,736	5,103	5,449	5,275	5,513
Instrumentation costs (6)						
Other costs (4)	2,022	1,198	1,233	1,820	1,185	1,803
Total expenditure	**6,561**	**5,934**	**6,335**	**7,269**	**6,460**	**7,315**

UL, Observatory	2010	2011	2012	2013	2014	2015
Revenues						
Direct University funding (1)	3,618	2,583	2,850	3,364	3,706	3,892
NOVA without NOVA Office (7)	1,712	2,063	1,939	1,321	1,120	1,096
National research grants (2)	2,282	2,608	3,109	4,147	3,789	4,524
International grants and contract research (3)	674	1,347	2,074	2,458	2,289	2,907
Other (4)	30	163	111	159	191	105
Total revenues	**8,316**	**8,764**	**10,084**	**11,449**	**11,094**	**12,524**
Expenditure						
Personnel costs (5) without NOVA Office	6,967	7,244	8,162	8,888	9,088	9,542
Instrumentation costs (6)	143	253	260	480	344	447
Other costs (4)	1,206	1,267	1,662	2,081	1,662	2,535
Total expenditure	**8,316**	**8,764**	**10,084**	**11,449**	**11,094**	**12,524**

RU, Astrophysics	2010	2011	2012	2013	2014	2015
Revenues						
Direct University funding (1)	390	557	918	1,025	1,232	1,522
NOVA (7)	304	403	486	688	905	944
National research grants (2)	121	1,003	4,485	913	2,188	30
International grants and contract research (3)	692	692	692	1,168	1,168	1,168
Other (4)						
Total revenues	**1,507**	**2,654**	**6,581**	**3,794**	**5,492**	**3,664**
Expenditure						
Personnel costs (5)	1,368	1,699	2,554	3,044	3,204	3,301
Instrumentation costs (6)	59	860	3,927	625	2,163	238
Other costs (4)	80	95	100	125	125	125
Total expenditure	**1,507**	**2,654**	**6,581**	**3,794**	**5,492**	**3,664**

Funding administrated by NOVA	2010	2011	2012	2013	2014	2015
Revenues						
OCW Grant (1)	5,151	5,039	5,058	5,184	5,197	5,227
University contributions (8)	77	55	248	219	73	205
National research grants (2)	940	430	671	2,509	850	30
International grants and contract research (3)	3,389	2,976	1,994	1,044	1,869	2,189
Other (4)	-1,006	-637	-301	263	-303	1,115
Total revenues	**8,552**	**7,863**	**7,671**	**9,219**	**7,685**	**8,767**
Expenditure						
Personnel costs (5)	5,837	5,810	5,598	5,026	4,488	5,468
Instrumentation costs (6)	1,770	1,083	1,178	3,459	2,315	2,357
Other costs (4)	945	971	896	734	882	942
Total expenditure	**8,552**	**7,863**	**7,671**	**9,219**	**7,685**	**8,767**

Institutes + NOVA	2010	2011	2012	2013	2014	2015
Revenues						
Sum of direct University funding (1)	8,696	8,795	9,898	9,651	9,866	11,095
Direct NOVA funding (1)	5,151	5,039	5,058	5,184	5,197	5,227
National research grants (2)	6,091	5,792	10,126	9,853	8,739	7,093
International grants and contract research (3)	6,106	6,494	7,165	7,832	7,678	8,788
Other (4)	-1,104	-1,103	-1,010	414	185	1,281
Total revenues	**24,941**	**25,017**	**31,237**	**32,934**	**31,665**	**33,485**
Expenditure						
Personnel costs (9)	17,559	18,357	21,455	22,939	22,219	24,463
Instrumentation costs (6)	1,922	2,163	5,254	4,434	4,818	2,928
Other costs (4)	5,460	4,498	4,529	5,561	4,629	6,095
Total expenditure	**24,941**	**25,017**	**31,237**	**32,934**	**31,665**	**33,485**

Table 5: Origin of funding for research positions at the university astronomical institutes for each year between 2010 and 2015, Funding figures are in k€.

	2010 Funding	***2010*** *Fraction*	**2011** Funding	***2011*** *Fraction*	**2012** Funding	***2012*** *Fraction*	**2013** Funding	***2013*** *Fraction*	**2014** Funding	***2014*** *Fraction*	**2015** Funding	***2015*** *Fraction*
Univ	6,830	*0.40*	6,364	*0.33*	5,355	*0.29*	5,716	*0.29*	6,288	*0.31*	6,601	*0.31*
NOVA	3,423	*0.20*	4,402	*0.23*	3,780	*0.20*	3,132	*0.16*	3,055	*0.15*	3,444	*0.16*
NWO+KNAW	4,395	*0.26*	4,587	*0.24*	5,047	*0.27*	5,754	*0.29*	6,345	*0.31*	6,667	*0.31*
ASTRON+SRON	503	*0.03*	542	*0.03*	584	*0.03*	554	*0.03*	693	*0.03*	667	*0.03*
EC	1,207	*0.07*	2,548	*0.13*	3,184	*0.17*	3,649	*0.18*	3,243	*0.16*	3,453	*0.16*
Contracts	255	*0.01*	454	*0.02*	67	*0.00*	387	*0.02*	148	*0.01*	110	*0.01*
Foreign	511	*0.03*	550	*0.03*	624	*0.03*	630	*0.03*	618	*0.03*	583	*0.03*
Total	**17,125**	***1.00***	**19,448**	***1.00***	**18,641**	***1.00***	**19,821**	***1.00***	**20,391**	***1.00***	**21,527**	***1.00***

Figure 2: Origin of funding in fractions for the research positions at the university astronomical institutes for 2010 (blue) and 2015 (red).

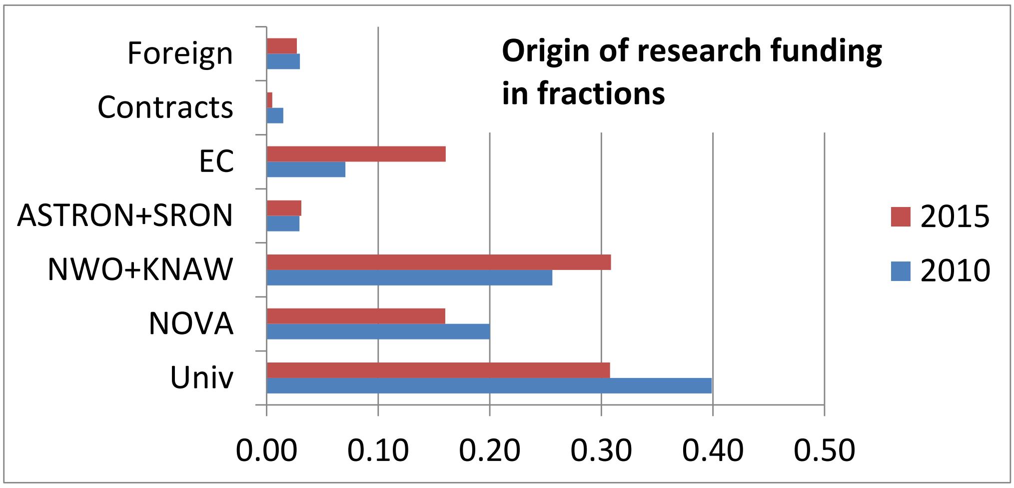
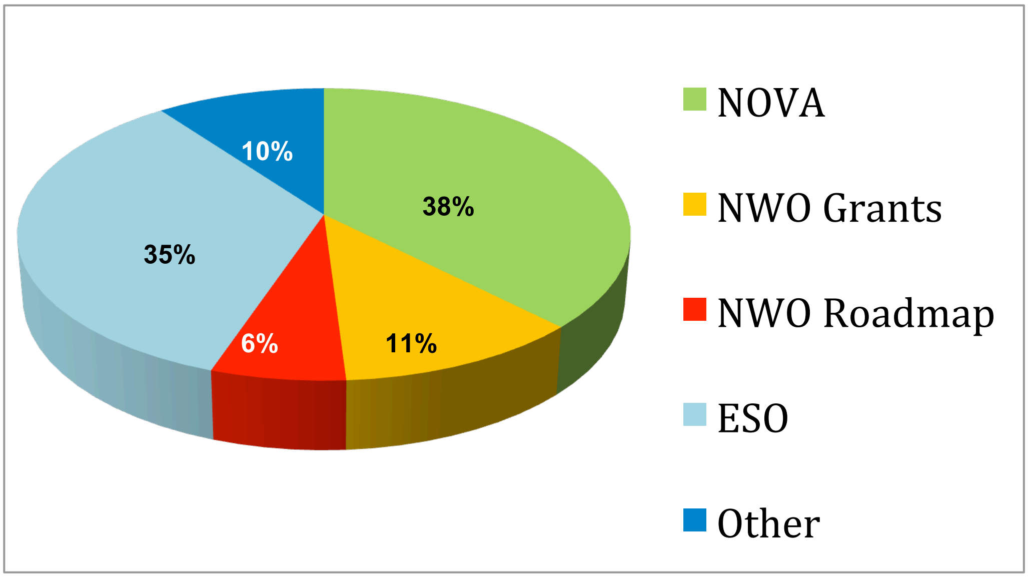


Figure 3: Origin of funding for the NOVA instrumentation program for the 2010-2015 period. Total funding amounts to 30.2 M€ for the period 2010-2015.



5. Research output and quality indicators

Table 6: Numbers of publications for the period 2010-2015 for each institute and for NOVA and the institutes as a whole.

UvA, Anton Pannekoek Institute	2010	2011	2012	2013	2014	2015	Total
Refereed articles (1)	138	148	173	174	166	166	**965**
Non-refereed articles (2)	105	117	96	90	65	63	**536**
Books (3)	0	0	0	0	2	0	**2**
Book chapters (3)	3	0	0	2	1	2	**8**
PhD theses (4)	10	4	0	12	8	6	**40**
Professional publications (5)	1	0	0	0	0	0	**1**
Publications aimed at the general public (6)	108	108	108	108	107	108	**647**
Other research output (7)	90	89	89	102	103	72	**545**
Total publications	**455**	**466**	**466**	**488**	**452**	**417**	**2744**

RUG, Kapteyn Institute	2010	2011	2012	2013	2014	2015	Total
Refereed articles (1)	191	167	139	184	176	191	**1048**
Non-refereed articles (2)	83	83	76	44	70	66	**422**
Books (3)	0	0	0	1	0	2	**3**
Book chapters (3)	1	0	0	1	2	1	**5**
PhD theses (4)	11	10	9	12	6	9	**57**
Professional publications (5)	0	0	0	0	0	0	**0**
Publications aimed at the general public (6)	5	5	5	5	5	5	**30**
Other research output (7)	90	90	90	90	100	100	**560**
Total publications	**381**	**355**	**319**	**337**	**359**	**374**	**2125**

UL, Observatory	2010	2011	2012	2013	2014	2015	Total
Refereed articles (1)	288	303	345	376	316	376	**2004**
Non-refereed articles (2)	107	157	169	295	172	191	**1091**
Books (3)	0	0	0	0	0	2	**2**
Book chapters (3)	0	0	0	0	0	0	**0**
PhD theses (4)	10	9	9	14	16	23	**81**
Professional publications (5)	0	0	0	0	0	0	**0**
Publications aimed at the general public (6)	29	25	34	22	21	33	**164**
Other research output (7)	161	168	181	183	231	234	**1158**
Total publications	**161**	**168**	**181**	**183**	**231**	**234**	**4500**

RU, Astronomy & Astrophysics	2010	2011	2012	2013	2014	2015	Total
Refereed articles (1)	128	104	130	149	188	137	**836**
Non-refereed articles (2)	75	81	91	164	76	137	**624**
Books (3)	0	0	0	0	1	0	**1**
Book chapters (3)	0	0	1	0	1	0	**2**
PhD theses (4)	0	1	1	6	5	5	**18**
Professional publications (5)	0	0	0	0	0	0	**0**
Publications aimed at the general public (6)	14	44	25	37	46	65	**231**
Other research output (7)	0	0	0	0	0	0	**0**
Total publications	**217**	**230**	**248**	**356**	**317**	**344**	**1712**

NOVA + institutes as a whole	2010	2011	2012	2013	2014	2015	Total
Refereed articles (1)	583	626	698	743	738	741	**4129**
Non-refereed articles (2)	362	433	442	608	384	264	**2493**
Books (3)	0	0	0	1	3	4	**8**
Book chapters (3)	4	0	1	3	4	3	**15**
PhD theses (4)	31	24	19	44	35	43	**196**
Professional publications (5)	1	0	0	0	0	0	**1**
Publications aimed at the general public (6)	156	182	172	172	179	211	**1072**
Other research output (7)	341	347	360	375	434	406	**2263**
Total publications	**1478**	**1612**	**1692**	**1946**	**1777**	**1672**	**10177**

6. PhD program

Table 7: Numbers of PhDs in astronomy and astrophysics awarded between 2010 and 2015 and their distribution over the universities participating in NOVA. The astronomy program in Utrecht was terminated at the end of 2011.

	2010	2011	2012	2013	2014	2015	Total
UvA	10	4	0	12	8	6	**40**
RUG	11	10	9	12	6	9	**57**
UL	10	9	9	14	16	23	**81**
UU	4	10	0	0	0	0	**14**
RU	0	1	1	6	5	5	**18**
Total	**35**	**34**	**19**	**44**	**35**	**43**	**210**

Table 8: Median duration of research projects that resulted in a PhD award in the period 2010-2015.

Statistics on PhDs	NOVA	UvA	RUG	RU	UL	UU
Number PhDs	210	40	57	18	81	14
Included in statistics	179	35	54	13	77	0
Median Duration (yrs)	4.4	4.3	4.4	4.4	4.4	

Table 9: Statistics for the PhD program according the instructions in the SEP protocol.

UvA-API				**Graduation in # years**						
Start	Male	Female	Total (M+F)	≤ 4 yrs	in 5 yrs or earlier	in 6 yrs or earlier	in 7 yrs or earlier	Total graduated	Not yet finished	Stopped without PhD
2006	5	3	8	1 (12%)	7 (88%)			7 (88%)		1 (12%)
2007	1	0	1		1 (100%)			1 (100%)		
2008	3	1	4		3 (75%)	4 (100%)		4 (100%)		
2009	4	5	9	1 (11%)	9(100%)			9 (100%)		
2010	4	4	8	4 (50%)	8 (100%)			8 (100%)		
2011	8	1	9	1 (11%)	5 (56%)			5 (56%)	4 (44%)	
2012	0	0	0							
2013	6	6	12						11 (92%)	1 (8%)
2014	6	7	13						12 (92%)	1 (8%)
2015	9	6	15						15 (100%)	
Total	**46**	**33**	**79**							

RUG - Kapteyn Institutes				**Graduation in # years**						
Start	Male	Female	Total (M+F)	≤ 4 yrs	in 5 yrs or earlier	in 6 yrs or earlier	in 7 yrs or earlier	Total graduated	Not yet finished	Stopped without PhD
2006	7	3	10		9 (90%)	10 (100%)				
2007	7	2	9	1 (11%)	7 (78%)					2 (22%)
2008	8	4	12	1 (8%)	10 (83%)	11 (92)				1 (8%)
2009	8	5	13	5 38%)	9 (70%)	10 (77%)	12 (92%)		1 (8%)	
2010	7	3	10	5 (50%)	6 (50%)	8 (80%)			1 (10%)	1 (10%)
2011	2	5	7	1 (14%)	5 (71%)				1 (14%)	
2012	11	3	14	3 (21%)					9 (64%)	2 (14%)
2013	7	3	10	1 (10%)					9 (90%)	
2014	12	6	18						17 (94%)	1 (6%)
2015	5	2	7						7 (100%)	
Total	**74**	**36**	**110**							

UL-Observatory				**Graduation in # years**						
Start	Male	Female	Total (M+F)	≤ 4 yrs	in 5 yrs or earlier	in 6 yrs or earlier	in 7 yrs or earlier	Total graduated	Not yet finished	Stopped without PhD
2006	6	2	8		5 (63%)	7 (88%)		7 (88%)	1 (12%)	
2007	11	6	17	1 (6%)	15 (88%)	16 (94%)		16 (94%)		1 (6%)
2008	2	1	3	1 (33%)	3 (100%)			3 (100%)		
2009	11	5	16	1 (6%)	14 (88%)	15 (94%)	16 (100%)	16 (100%)		
2010	15	4	19	4 (21%)	14 (74%)	17 (89%)		17 (89%)	1 (5%)	1 (5%)
2011	13	12	25	4 (16%)	18 (72%)			18 (72%)	4 (16%)	3 (12%)
2012	10	4	14	1 (7%)	2 (14%)			2 (14%)	11 (79%)	1 (7%)
2013	9	6	15						14 (93%)	1 (7%)
2014	15	9	24						24 (100%)	
2015	13	6	19						19 (100%)	
Total	**105**	**55**	**160**							

RU, Astrophysics (excl. UU started)				**Graduation in # years**						
Start	Male	Female	Total (M+F)	≤ 4 yrs	in 5 yrs or earlier	in 6 yrs or earlier	in 7 yrs or earlier	Total graduated	Not yet finished	Stopped without PhD
2006	1		1	1				1 (100%)		
2007										
2008	3	2	5	1	2	1	1	5 (100%)		
2009	4		4	1	1		1	3 (75%)	1	
2010	3	2	5		4	1		5 (100%)		
2011	1	4	5		3			3 (60%)	2	
2012	4	1	5	1				1 (25%)	4	
2013	7	3	10						10	
2014	1	2	3						3	
2015	1	3	4						4	
Total	**24**	**17**	**41**							

Appendix 5: Glossary

ALMA	Atacama Large Millimeter Array
ASTRON	Netherlands Institute for Radio Astronomy
UvA	University of Amsterdam
CTA	Cherenkov Telescope Array
EB	Evaluation Board
E-ELT	European Extremely Large Telescope
ERC	European Research Council
ESO	European Southern Observatory
HST	Hubble Space Telescope
IMAPP	Institute for Mathematics, Astrophysics and Particle Physics
IB	International Board
JWST	James Webb Space Telescope
LIGO	Laser Interferometer Gravitational-Wave Observatory
LISA	Laser Interferometer Space Antenna
LOFAR	Low Frequency Array radio telescope
LSST	Large Synoptic Survey Telescope
METIS	Mid-infrared imager and spectrometer for the 39m E-ELT Telescope
NIC	NOVA Information Centre
NIKHEF	National Institute for Nuclear Physics and High Energy Physics
NOVA	Netherlands Research School for Astronomy
NWO	Netherlands Organisation for Scientific Research
OCW	Ministry of Education, Culture and Science
PI	Principal investigator
OIR	Optical and infrared
RAVE	Radial Velocity Experiment
RRL	Radboud Radio Lab
RU	Radboud University Nijmegen
RUG	University of Groningen
SEP	Standard Evaluation Protocol
SKA	Square Kilometre Array Telescope
SPICA	Infrared Telescope
SRON	Netherlands Institute for Space Research
TOR	Terms of Reference
UL	Leiden University
UNAWE	Universe Awareness
VLT	Very Large Telescope
VIRGO	Gravitational Wave Detector
VUA	Vrije Universiteit Amsterdam