



# Profileringsplan VU Beta 15 May 2019

# Application Form 'profileringsplan'

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## 1. Title

Profileringsplan Bèta, Vrije Universiteit Amsterdam (VU)

## 2. Main applicant

**Name, initials, title and position:** prof. dr. A. Th. (Guus) Schreiber, Dean Faculty of Science

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## 3. Requested funding

*Table 1 Overview VU Bèta*

Vrije Universiteit - Faculty of Science	Number of proposed positions	Requested funding
Computer Science	7	960k
Physics	8	1,270k
Chemistry	8	1,270k
Mathematics	7	900K
Regional outreach (with UvA, see Sec. 5)		100K
<b>Total</b>	<b>30</b>	<b>4,500K</b>

#### **4. Executive Summary**

##### **VU Computer Science**

VU Computer Science has a long and internationally recognized tradition of computer science that has contributed significant achievements in both fundamental and applied areas of our discipline. Historically, our focus has been on research in theoretical computer science, databases, networked/distributed systems, software systems and artificial intelligence. We also have well-regarded groups in information systems and information analytics. Throughout our history we have built strong relationships with the Institute for Informatics at the UvA and with CWI, as well as with other universities nationally and across Europe.

VU Computer Science prides itself on its strong interdisciplinarity character. Through our Network Institute and in individual programs, we have established deep relationships with colleagues in Law, Linguistics, Mathematics, Social Sciences, Philosophy and Psychology. We participate in ACBA (the Amsterdam Center for Business Analytics) with Mathematics, business studies and economics. We are a founding member of Amsterdam Data Science, the Amsterdam Cyber Security Centre, and the Innovation Centre for Artificial Intelligence (ICAI). Our research has led to numerous personal and group awards (including 2 ERC grants, 4 VENI, 2 VIDI and 1 VICI) and has formed the basis for international standards that have been widely adopted world-wide. The department provides research and teaching that cover a broad range of topics within Computer Science. Our 'zwaartekracht' focus for this proposal, which has been coordinated nationally via the IPN, addresses the areas of Data Modelling and Analysis, Security and Privacy, Machine Reasoning and Interaction and Networked Computer Systems & Embedded Systems. Our proposed research areas cover five distinct topics that address fundamental issues for the future development of our field.

Number of positions applied for: 7

## VU Physics

The research activities of VU physics have a long-standing focus on physics of life and health, physics of energy and fundamentals of physics. This focus has resulted in a substantial growth of VU physics, thanks to the previous 'Sectorplan' and numerous (personal) grants. Most research efforts are embedded in the Amsterdam Institute of Lasers, Life Sciences and Biophotonics (LaserLaB), the research in subatomic physics is an integral part of the national collaboration Nikhef. Research quality has been evaluated in 2018 as world leading / excellent. A particular strength of physics VU is its strong connection to society: research addresses societal challenges (health, energy transition), has resulted in several very successful start-up companies, close connections with companies and is actively translated to the clinic. Furthermore, VU physics is strongly connected to its Amsterdam neighbours: it is partner in Nikhef and ARCNL and has strong ties with AMOLF, Amsterdam UMC, and UvA Physics and Astronomy. Research is strongly connected to education. VU Physics is not only involved in the Physics and Astronomy programs (joint degree BSc and MSc programs with UvA) but also in Medical Natural Sciences (BSc and MSc, with VU Chemistry), Science Business and Innovation (BSc and MSc, with VU Chemistry) and starting next year, Mechanical Engineering (BSc, with UT).

VU Physics research can be divided in four 'zwaartepunten', all connecting to the national 'focusgebieden': (1) Particle & Gravitational Physics, (2) Quantum Metrology and Laser Applications, (3) Photonics for Life and Health, and (4) Photosynthesis and Energy. Research in all these four 'Zwaartepunten' is excellent, resulting in world-class publications and PhD theses, receives substantial competitive funding, in particular in personal grants (ERC, VIDI/VICI). To strengthen and modernize these 'zwaartepunten' in research and education, VU physics requests funding for up to eight new positions (up to M€1.27). The highest priority is for a gender (female) junior tenure-track position in any of the four 'zwaartepunten', in order to highlight the emphasis of VU physics in improving gender balance. The second highest priority is for a full professor in the field of gravitational wave detection, a booming field in which VU physics has played a national pioneering role. The other positions requested are distributed over the four 'Zwaartepunten' and comprise of junior tenure-track positions, which is a deliberate choice given the age distribution in VU physics. With this new impulse as part of the 'Sectorplan', the foundations of VU physics will be substantially strengthened, which will allow VU physics to keep on excelling in research, education and valorization in the future.

Number of positions applied for: 8



## VU Chemistry

VU Chemistry is world leading in fundamental and societally relevant fields of the molecular sciences that are arranged in the national focus areas 'Chemistry of Life' and 'Fundamentals of chemistry and chemical methods'. Historically, we have a very strong, internationally recognized reputation in *pharmacochemistry* and theoretical chemistry as well as in organic synthesis and analytical chemistry (5 VICI + 1 Pionier laureates). Our expertise is organized in four 'zwaartepunten': 1. Medicinal Chemistry & Chemical Biology, 2. Computational Chemistry, 3. Synthesis, and 4. Analytical Chemistry & Spectroscopy. In research, education and outreach, VU Chemistry (focusing more on life) works in a complementary manner yet synergistically with its partners at UvA (focusing more on sustainability). VU Chemistry, together with partners at UvA, participates in internationally highly esteemed centers: Amsterdam Center for Multiscale Modeling (ACMM), recognized by CECAM as a European top center, and Center for Analytical Sciences Amsterdam (CASA). VU Chemistry has successfully developed its research along the translational chain from molecule to medicine, amongst others by establishing the successful Amsterdam Institute for Molecules, Medicines & Systems (AIMMS) with close contacts to the VU academic hospital. We participate in national initiatives and alliances such as the National Science Agenda (NWA: e.g. Personalized medicines, Origins of life) and, as associated partner, the Advanced Research Center Chemical Building Blocks Consortium (ARC CBBC).

VU chemistry has been very successful in valorisation of its state-of-the-art expertise through three different spin-offs (SCM, Griffin Discovery, IOTA Pharmaceuticals). Within the context of AIMMS valorization strategies have been developed that aim at economic target groups such as pharmaceutical companies which resulted in the above-mentioned spin-offs and various patents. There are industrial collaborations with Nouryon (former AkzoNobel Polymer Chemistry), DSM and others.

Our educational programs are modern and highly relevant and offer a very broad range of subdisciplines at the bachelor and master's level: Chemistry (JDs with UvA Chemistry), Pharmaceutical Sciences, Medical Natural Sciences (with VU Physics), Science Business & Innovation (with VU Physics), and participation in the Amsterdam University College (AUC) as well as the new BSc Mechanical Engineering (with our sister departments and Twente). Recently, very positive reviews were obtained in national context (SEP review committee for research; NVAO accreditation for BSc & MSc Chemistry JD with UvA; BSc Pharm. Sci. & MSc DDS). Outreach towards schools is organised via Bètapartners. VU chemistry is determined to increase female staff. Recently, we have quadrupled the number of female chairs to 4 (29% of chairs).

Here, we apply for 8 new positions (1 Sr. HL, 7 Jr. TT f/m) to reinforce VU Chemistry, hiring at least 35%, preferably 50% female new staff. The positions cover all four 'zwaartepunten' and serve to start novel research lines that connect internally, and also towards Computer Science, and Physics. The positions also play an important role in our plans to modernise our educational programs, such as, the joint initiative with UvA to innovate our JD master Chemistry by introducing a track addressing AI and other aspects of computer science in chemical modeling and chemistry in general. Last but not least, we also wish to rejuvenate our staff and to increase diversity; in particular, we wish to further increase the ratio of female staff.

Number of positions applied for:

## VU Mathematics

The Department of Mathematics aims to strengthen and enrich its principal research lines in *Dynamical Systems* and *Stochastics*. These two fields form the backbone of the research effort of the department, complemented by valuable smaller groups in differential topology and number theory. The sustained strategy to create critical mass in the areas of *Dynamical Systems* and *Stochastics* has resulted in excellent international visibility and world class research. All seven requested positions are destined to enhance this focus, by attracting talented young researchers, by capitalizing on current developments, and by broadening the scope of collaborations and application areas.

The requested positions are all situated in the focus areas at the interface between the NDNS+ and STAR clusters, as outlined in the nationally coordinated plan laid down in the 'sectorbeeld'. On the one hand, the internal connections between dynamical systems and stochastics will be reinforced through requested positions in the 'focusgebieden' *Statistical Learning* and *Dynamic Data*. On the other hand, the links with adjoining areas will be enhanced through requested positions in the 'focusgebieden' *Geometric and Stochastic Evolution* (connection to the GQT cluster) and *Networks* (connection to the DIAMANT cluster). Networks have both important stochastic and dynamic features and the proposed positions will thus also generate natural opportunities for uniting the two viewpoints. By bolstering the distinct and coherent profile of the department, these positions will lead to a quality stimulus which will further boost the position of the department within the international mathematical landscape.

The Department of Mathematics has a very good scientific reputation. In the 2015 national research assessment, research quality in the department was rated as very good (and even excellent in dynamical systems), and the relevance to society was assessed as excellent. While maintaining a strong research profile, the department also offers a broad palette of courses. Besides the Mathematics program and courses for other disciplines in the Sciences and at the Amsterdam University College, the department runs a very successful Business Analytics program (bachelor and master), the sole academic business mathematics program in the Netherlands (nationally accredited in conjunction with the regular Mathematics programmes). The requested positions will, in addition to boosting research quality, help alleviate the strain of our extremely low staff-student ratio.

The main ambitions of the proposed expansion of the department are to fortify the excellence of the dynamics group with a special eye towards computational facets, to strengthen the fundamental research in the area of data science and mathematical statistics, to ameliorate our exceptionally adverse staff-student ratio, and to improve the gender balance in the department. To this end at least three female colleagues will be hired on the new positions, with one position specifically earmarked for a strong female mathematician in the very broad area of *Applied and computational mathematics*, allowing for the broadest possible search for candidates. In the 'Zwaartepunt' *Dynamical Systems – Computational Mathematics*, we aim to create a position *Data assimilation and data driven dynamics* to complement the existing expertise of the dynamics group and strengthen the bonds with the applied analysis groups at UU, TUE and UT. The requested position in *Dynamics on large networks* links naturally to existing research strengths in bifurcations and symmetry, computational dynamics and partial differential equations, as well as to the proposed *Statistics for network data* position, research in the VU systems biology group, and the applied analysis group at TUE. Another position is envisaged in *Geometric partial differential equations*, which will give renewed impetus to the traditionally strong research in this area in the department and has ample connections to work done at TUD, UL, and RU. In the 'Zwaartepunt' *Stochastics – Mathematical Data Science*, we aim for a senior position in *Fundamentals of data science* to further expand the department's research on learning from big data, which has a huge potential for connections to other research groups (local, national and international), as well as to our educational programmes. The desire to establish a new position in *Computational statistics* is driven by the rapid developments in stochastic algorithms, and connects to research in the statistics groups of UL, TUD, and TU. Finally, the requested position in *Statistics for network data* has a natural complementary relation to the 'zwaartekrachtprogramma' NETWORKS and to research performed at the UvA, with which the department already has strong bonds, as well as to the proposed position in *Dynamics on large networks*.

Number of positions applied for: 7

## 5. Preamble: concise description of the academic ambitions for the disciplines

The VU combines curiosity-driven research on fundamental questions with applications that tackle important issues in society. The VU campus harbours a diverse and inclusive community of staff and students. The VU, historically rooted in protestant values, has transformed itself in this century into a modern place where everybody is welcome and where open debate, respect and tolerance are the norm.

**VU Faculty of Science:** The four disciplines Computer Science, Physics, Chemistry and Mathematics are all departments of the VU Faculty of Science (which includes other disciplines such as biology, earth sciences and environmental sciences). All disciplines have focus areas with internationally recognized top research, such as dynamical systems and statistical data analysis (mathematics), laser technology and gravitational waves (physics), pharmaceutical chemistry and theoretical chemistry (chemistry), and security and AI (computer science). Recent research evaluations confirm this. The educational portfolio constitutes of a mix of mono- and multidisciplinary programs; currently, the four disciplines are involved in 10 bachelor and 13 master curricula, including the joint degrees with UvA. The faculty also offers qualifications for secondary school teachers (as part of the regular curricula).

The Faculty of Science is by far the largest faculty of the VU, with 1250 employees and 7000 students. For historical reasons (dating back to the eighties) the VU receives, compared to other general universities with a science faculty, a relatively low fixed part of the government budget. As a consequence, the VU Faculty of Science is in particular keen to increase its staff-student ratio. Research in the faculty is characterised by a combination of theoretical and experimental research. Examples of the experimental side of the faculty are the laser-lab facilities, in which a large part of VU Physics is involved, the drug-discovery research of VU Chemistry and the many popular open-source products originating from VU Computer Science. Experimental facilities are for the major part funded by external grants. The VU University supports the experimental side of the faculty through a housing program that meets the needs of the faculty (see below).

**Valorisation:** Traditionally, the VU has focused on societal valorisation. In recent years this has been complemented by a successful economic valorisation strategy, resulting in a range of spin-off companies (see the descriptions of the disciplines). A key enabler for new economic activities is the Demonstrator Lab, which acts as greenhouse to make the steps from initial business idea via concrete business plan and proof of concept, to actual start-up. Students participate actively in the Demonstrator Lab alongside academic staff. The Demonstrator Lab and many of the spin-off companies are currently housed in the old building of the faculty. The VU Executive Board intends to create new start-up facilities on university grounds close to the 'Zuidas'.

**VU Research and Education:** The VU has four profile themes for research and education. The Faculty of Science plays a central role in three of these: (i) Human Health & Life Sciences, (ii) Sustainability and (iii) Connected World, and has one additional profile theme, (iv) Fundamentals of Science. Research in these themes is fostered through intra- and inter-faculty research institutes, that typically provide seed budget for new collaborations and act as a cross-disciplinary research community. Examples of such research institutes are the Amsterdam Center for Business Analytics (mathematics, computer science, economics), the LaserLaB (physics, Amsterdam UMC), the Amsterdam Institute for Molecules, Medicines and Systems (chemistry, biology, bioinformatics), and the Network Institute (computer science, humanities, social sciences, economics). These collaborations are also visible in the educational portfolio, e.g., the bachelor programs Medical Natural Sciences (physics, chemistry, medical school), Business Analytics (mathematics, computer science, economics) and Science Business & Innovation (chemistry, physics, economics). The faculty is housed next to the VU Medical Centre (VUmc, recently merged with AMC into the Amsterdam UMC), resulting in long-standing relations. The link is also apparent in the nature of the spin-off companies, many of which apply results obtained from fundamental research to technology for and applications in the medical/health domain. The move of the European Medicines Agency to Amsterdam Zuidas adds further strength to this link, in particular for the drug-discovery research of Chemistry.

**Collaboration with UvA:** The faculty has a strong link with its sister faculty at UvA. The link is anchored in collaboration and complementarity. The two faculties had comprehensive joint housing plans, in which the two Physics departments would be housed at the UvA Science Park and the two Computer Science departments at the VU campus. The VU and UvA Executive Boards were strong supporters of these plans, but in April 2017 failed to get the consent from the central participatory council of UvA ('centrale medezeggenschap'). This was a big blow, but the staff of the two faculties handled this setback extremely well and continues to collaborate in many ways across the Amstel river. The joint bachelor programs in Physics & Astronomy and Chemistry continue with the same intensity as before, with staff teaching on both locations. Staff of both faculties offers a wide range of courses at the Amsterdam University College. The four disciplines have agreed on complementary research profiles (see also the "Sectorbeeld") and work together in joint research institutes (e.g. Amsterdam Data Science, Innovation Center for Artificial Intelligence) and in NWO institutes (e.g., ARCNL, Nikhef, CWI). The two universities have a joint valorisation office IXA.

**National collaboration:** The VU disciplines work with many partners in other Dutch science faculties. Examples of this are the cooperation within Nikhef (UvA, Groningen, Utrecht, Nijmegen, Maastricht) and ARC CBBC (Eindhoven, Utrecht, Groningen). In response to the public appeal of a number of key technical companies (such as ASML) to offer a technical degree program in the North Holland region (high-school students select such a degree significantly less in this region) we have started a cooperation with University of Twente to host the UT bachelor Mechanical Engineering on the VU campus as a second location. The Ministry of Education has agreed to this and the program will start in the upcoming academic year. The program will be taught by staff from both universities; the VU Executive Board and the disciplines themselves are investing for this purpose in new staff in physics, chemistry and mathematics.

**Housing:** The VU is also investing heavily in new buildings for the faculty. Effectively, all new buildings on the VU Campus are for the Faculty of Science. VU Chemistry moved to the O|2 building in 2016, together with colleagues from life sciences and the medical school, further strengthening research collaborations. In the fall of this year, VU Mathematics and Computer Science will move to the New University building, which will also house extensive teaching facilities. Finally, a third building is being designed (planned to be ready in 2022), which will house (amongst others) VU Physics, including LaserLaB, teaching labs and extensive technology centres (electronics and engineering support).

**Gender diversity:** In 2017 the Faculty agreed on an action plan<sup>1</sup> to achieve a better gender balance. This includes measures such as gender-bias training and reformulating selection criteria that could introduce such bias (e.g. experience abroad as criterion for tenure track). The current percentage of female full professors is 21% (Yearly Report 2018). While we consider it essential to increase this percentage significantly, we view the early/mid-career phase as the major stumbling block. This is also the focus of the action plan.

**Regional outreach:** The Science faculties of UvA and VU are proud of their regional outreach platform [Bètapartners](#), in which we collaborate with 44 secondary schools. Also, industry is involved via the collaboration with Jet-Net, which is the Dutch network for schools & technology. Bètapartners is the platform for intensive contacts with science teachers, to help them maintain their enthusiasm and to guide their pupils to our Bachelor's programmes. Our goals are: enrolment of more strongly motivated students, lowering the dropout rates in the first year of the Bachelor's programmes, and increasing diversity in the individual programmes, with the aim of obtaining a student population that is a better reflection of the composition of the Dutch population, be it in gender or socio-economic/cultural background. To further strengthen the future of Bètapartners, the UvA and VU Science faculties propose to each allocate an extra 100K/y from 'sectorplan' funding. The other half of the Bètapartners' total budget (400K/y) consists of contributions from schools and funds for outreach from the central UvA and VU budget. Goals and ambitions for the next five years are: a closer collaboration between Bètapartners and the UvA/VU teacher training programmes, a larger coverage of member schools, and more attention for diversity and an equal-opportunity educational chain in the region. Importantly, we will also invest in generating more attention among teachers and their pupils for our joint-degree Bachelor's programs (Physics & Astronomy and Chemistry) and our Mathematics programs in order to increase the student influx. To this end, we will invest more in life-long learning courses for teachers and step up the activity of the highly successful Physics Fair at secondary schools; start up a Chemistry Fair and a similar Mathematics school programme. We will do this by engaging our students to take part in these activities. Finally, we will support the introduction of the new Computer Science high-school (VWO) program via the 'Bètapartners Steunpunt Informatica' for teachers.

**Teacher outreach:** The Amsterdam Science faculties of UvA and VU see the shortage of high school teachers as an urgent problem for society and also as a direct long-term threat to their enrolment and thus also to our partners upstream who rely on our graduates as a high-skills, scientifically-trained workforce. Our strategy to increase the number of secondary science teachers is based on three lines of action: For the short term, we focus on side-entrants by contributing to beta4all and by helping to spark of the VSNU 'Aan de Slag voor de Klas' program in Amsterdam. Secondly, we are exploring innovative options for our own students to obtain a teacher qualification. We aim to train at least 50 teachers per year across the four disciplines. Thirdly, we intend to increase the retention rate in teaching by making the profession of high-school teacher more attractive, for example to engage teachers in ongoing research through part-time internships (see the national plan for details).



## 6. 'Facultaire zwaartepunten' per discipline

### VU Computer Science

The VU 'Zwaartepunten' in Computer Science are all aligned with the VU's mission to address responsible and socially engaged research questions. Computer security, energy-efficient computing, hybrid and human-centred intelligence (artificial intelligence with humans at the centre), ethical computing and quantitative data analytics all address major questions in today's and tomorrow's society, as well as raising deep questions into the nature of information and computing. Each of these 'zwaartepunten' is directly related to the university-wide research theme "the Connected World", under the umbrella of the VU-wide Network Institute.

As one of the few compact campus universities in The Netherlands, the VU prides itself on its strong interdisciplinarity character, and our 'Zwaartepunten' selection stands in that tradition. Ethical computing forges links with the law, social sciences and philosophy. Hybrid intelligence forges links with linguistics, social science and psychology. Computer security forges links with law. Quantitative data science builds on links with chemistry, mathematics and applications in bioinformatics, life sciences and business studies and economics. We have tight links with the UvA and operate in a complementary way with UvA colleagues on research. We further participate as founding partners in Amsterdam Data Science (ADS), the Amsterdam Cyber Security Centre (AMSec) and the Innovation Centre for Artificial Intelligence (ICAI).

VU Computer Science has a large number of successful multi-track education programmes, offering a broad range of directions at the master's level. Although we have seen student numbers rise sharply in the last few years, we have managed to sustain educational quality. This is demonstrated by the fact that two of our master programs have received the accolade "Top Master" in the National Student Survey (NSE): Parallel Distributed Computer Systems and Bioinformatics & Systems Biology. We closely collaborate with the UvA regarding education and offer joint-degree master programs together.

During the last few years, significant attention has been devoted to training of high-school teachers in Informatics, where we have run course modules and special days. In September 2019 we will start a teacher-training program in Informatics, which will include an Educational BSc Minor open to all our BSc programmes, leading to a second-degree teaching qualification. We will also offer a 1-year Educational master programme, which will lead to a first-degree teaching qualification for students with an MSc in AI, CS or IS. This initiative is supported by the central VU 'lerarenopleiding'. We are currently recruiting an embedded didactic expert with expertise in Informatics to support these efforts.

Our 'zwaartepunten' are strongly interrelated and there is considerable cross-fertilisation between them: ethical computing will address issues raised in data analytics, hybrid intelligence and security, security will use techniques from data analytics, and data analytics will be an essential tool for energy efficient computing. All the requested positions have been nationally coordinated under the umbrella of the Informatics Platform Netherlands (IPN), as well as the special interest groups on AI (SIGAI) and Data Science within IPN. We are and will be actively striving to increase female staff, and have managed to attract a number of female colleagues in the last few years.

**VU Computer Science 'zwaartepunt' 1, Quantitative Data Analytics** connects to 'focusgebied' Data modeling & analysis. VU has a unique angle in data modelling and analysis based on knowledge representation and reasoning, as well as semantic web approaches. The 'Sectorbeeld' document underlines the importance of empirical methods in data science and AI, arguing that these have led to fundamental questions about the explainability of digital systems. The 'Zwaartepunt' is also in line with the Special Interest Group on AI (SIGAI) strategic plan for the future (with all universities represented). In the NWA, many different routes are mentioned to which the research done in this position can contribute (e.g. health care, smart cities). Another fundamental link lies in the route "value creation through responsible access to and usage of big data". Central themes of the Vrije Universiteit include Governance for society; Human health and life sciences; Connected World, and Science for Sustainability. Clearly, this 'Zwaartepunt' seamlessly fits the latter three as these are natural application areas. Other societally significant application areas include Creative Industry; Energy; High-tech Systems and Materials, and Life Sciences and Health. Specifically concerning the latter area, a strategic alignment with health focus is already in place with the Amsterdam Municipality. Research within the 'Zwaartepunt' on computational methods for scientific discovery will be done in collaboration with VU Chemistry ('Zwaartepunt' *Computational Chemistry*), while activities will also be closely aligned with *Fundamentals of Data Science*, which is a core theme of VU Mathematics. Together, research efforts will span the entire Data Analytics spectrum from mathematical foundations to practical computational algorithms.

**VU Computer Science 'zwaartepunt' 2, Assessing and Evaluating Security** connects to 'focusgebied' Security and Privacy. The 'Sectorbeeld' explicitly mentions the lack of understanding of the principles for the development of secure systems as one of the key challenges in the 'focusgebied' security and privacy. The foundations of building secure systems is also one of the five themes of the national cyber security research agenda, which is used as the basis for security funding by NWO. Given its explicit

positioning as a university deeply involved with society, VU opted to play a leading role in safety, security & privacy — issues that concern all citizens. For this very reason, the university adopted the leadership of the VSNU Safety and Security program line in the Digital Society. Security is a cross-cutting concern that is explicitly mentioned in NWA routes such as Sustainable production of safe and healthy food, Energy transition, Health care research, Sickness prevention and treatment, Logistics and transport in an energetic, Innovative and sustainable society, Towards resilient societies, Smart Industry, Smart Liveable Cities, and Creating value through responsible access to and use of big data. Likewise, for top sectors HTSM, Life Sciences and Health, and Energy. Looking into the future, the principled design and evaluation of security in these areas will not just be a promising research topic, but a *conditio sine qua non* for all these areas.

**VU Computer Science 'zwaartepunt' 3, Ethical Computing** connects to 'focusgebied' Machine reasoning & Interaction. It does so since it is concerned with how interaction between humans and machines can be used to address ethical requirements. Besides this main focus area, it is also related to other 'focusgebieden' for VU computer science (i.e. "data-modelling & analysis" and "security & privacy") because of the ethical dilemmas which typically occur in those areas. In a national context, this 'Zwaartepunt' is a direct contribution to the VSNU Research Agenda on The Digital Society, aiming at ROBUST systems (Resilient, Open Beneficial, User-oriented, Secure and Trustworthy), and FACT algorithms (Fair, Accurate, Confidential and Transparent), and lies at the heart of the VSNU's agenda chapter on Responsible Data Science, as well as ethical aspects of Safety & Security. As to the NWA, Ethical Computing is directly related to the route on 'Waardecreatie door verantwoorde toegang tot en gebruik van big data' and 'Op weg naar veerkrachtige samenlevingen'. Finally, the VU has a strong tradition of collaboration between computer science and the humanities, and ethical computing is directly related to the focus area on digitisation in the social sciences and humanities ('Domeinbreed plan digitale SSH'). Ethical Computing will leverage and extend existing, multidisciplinary collaboration on NWO-funded computational infrastructure projects in the digital humanities (CLARIAH/plus) and social sciences (ODISSEI) where ethics of algorithms and data-use are key questions. On a European scale, it contributes to the EU long term mission on Responsible Research and Innovation (RRI) and the "Inclusive and Secure Society" cluster in the Horizon Europe framework. It is intentionally aligned with the EU-wide CLAIRE initiative (Confederation of Laboratories for AI research in Europe), with its "human-centred focus". Finally, the 'Zwaartepunt' will contribute to the EU's vision of a trustworthy and FAIR European Open Science Cloud (EOSC).

**VU Computer Science 'zwaartepunt' 4, Energy Efficient Computing** connects to 'focusgebied' Networked Computer Systems & Embedded Systems. It does so particularly on the three topics sensor networks, Internet of Things, and energy consumption. The 'zwaartepunt' fits in the "Big Data" NWA route - we already participate in the NWA program 'Verantwoorde Waardecreatie met Big Data (VWData)'. The work is relevant for several top sectors, especially Life Sciences and Health (see our NWO EPI project), High-Tech Systems and Materials (see our TATA steel project), and Logistics (see our EDL project with Schiphol airport and our NWO COMMIT2DATA project on logistics). The "Roadmap for large-scale infrastructures" covers several sensor-based facilities. The SKA (like LOFAR) is an extremely data-intensive example from radio astronomy; we have an external PhD student at ASTRON who studies data processing for both SKA and LOFAR, including energy aspects. Finally, we foresee strong collaborations with the new 'Zwaartepunt' "Quantitative Data Analytics", which will provide use cases and applications for our research, especially around computationally expensive processing like Machine Learning.

**VU Computer Science 'Zwaartepunt' 5, Hybrid Intelligence** connects to 'focusgebied' Machine reasoning & Interaction. Hybrid Intelligence is linked to the NWA route on 'Creating value through responsible access to and use of big data', with the Europe-wide AI initiative CLAIRE with its focus on a focus on human-centred AI, "designed to complement rather than replace human intelligence". The VU is leading a recently formed national consortium on Hybrid Intelligence, and other proposals under this program (e.g. from Delft) reflect the strong national collaboration on this topic. There is strong mutual reinforcement between the 'zwaartepunten' on ethical computing, hybrid intelligence and quantitative data-science: data-science is in strong need of responsible, ethical and explainable methods; hybrid intelligent systems, can be enablers for ethical computing, using humans as "sensors on ethics"; and ethical computing can use data-science and HI systems as excellent use-cases.

## VU Physics

More than 15 years ago, VU physics made a strategic choice to focus on three areas: fundamentals of physics, physics of life, and physics of energy, with theoretical and experimental research lines interwoven. This strategy was adopted to create critical mass in these areas and to connect to the strengths of VU (societal orientation of VU, with focus on health and sustainability, VUmc on the same campus). This choice of focus is complementary to UvA physics, our close partner. The strategy furthermore included to give the freedom to junior scientists to develop themselves independently within a larger group working on similar topics. This led to extraordinary success in NWO and ERC personal grants. The research focus is mirrored in education: VU physics is co-owner of the BSc and MSc programs Physics and Astronomy (joint degree with UvA), Medical Natural Sciences (with VU Chemistry), Science Business and Innovation (with VU Chemistry) and is involved in the Mechanical Engineering bachelor program (with UT) that will start 2019/20.

VU Physics concentrates on four of the national 'focusgebieden': Particle and Gravitational Physics, Physics of Life & Health, Energy & Sustainability, and Precision Measurement & Fabrication. The majority of VU physics research efforts are the basis of LaserLaB Amsterdam, a research institute, unique within the Netherlands, that bundles research in the realm of Lasers, Life sciences and Biophotonics. LaserLaB is founding member of LASERLAB-Europe, a consortium of 30 major laser laboratories jointly providing access to researchers and performing research, financed by EU. In the 2018 SEP evaluation, LaserLaB was evaluated world leading / excellent in research quality and relevance to society. VU research in subatomic physics, which is an integral part of the national collaboration Nikhef, has been evaluated as world leading / excellent with respect to research quality and viability (SEP evaluation 2018, with UvA High-Energy Physics). Physics VU has strong ties with AMOLF and Amsterdam UMC and actively links to society, via successful valorization activities (exemplified by 3 recent NWO Physics valorization prizes) such as successful spin-off companies (employing in total >100 people), the unique Demonstrator Lab, involvement in ARCNL and translational research bringing physics inventions to the clinic.

**VU Physics 'zwaartepunt' 1, Particle & Gravitational Physics** (connects to the 'focusgebied' with the same name) concentrates on two major contributions to international collaborative efforts, coordinated nationally within Nikhef. VU is involved in (a) efforts of the Large Hadron Collider at CERN to study matter-antimatter differences, and the search for new particles and physics beyond the Standard Model, in particular with its contribution to the LHCb experiment (Raven, Merk) and efforts in phenomenology (Rojo, Mulders, Fleischer), and in (b) the Advanced VIRGO gravitational wave interferometer (Italy), part of the LIGO-VIRGO collaboration (vd Brand, Bulten). VU physics researchers have taken part in the first detection of gravitational waves, one of the most important recent fundamental physics discoveries. Scientific excellence is evident from publication, citations and from prestigious positions within the international collaborations: Spokesperson of VIRGO (vd Brand), High-Level-Trigger Project Leader in LHCb (Raven). VU researchers have been leading major successful funding initiatives (FOM program, NWO Groot investment grants) and personal grants (1 ERC Adv and 1 ERC Start). vd Brand obtained several notable awards: Physica prize, NWO Physics Valorization prize, Gruber Cosmology prize and Breakthrough Prize in Fundamental Physics. Although of its highly fundamental character, this research has led to important connections with industry (VDL, ASML) and to spin-off company Innoseis, which develops seismic sensors.

**VU Physics 'zwaartepunt' 2, Quantum Metrology and Laser Applications** connects to 'focusgebieden' Particle and Gravitational Physics, and Precision Measurement & Fabrication. VU has unique expertise and equipment in precision laser metrology and control over quantum state of matter (Bethlem, Eikema, Ubachs, Vassen). Scientific goals are to investigate fundamental physics, including ultraprecise measurements of the electric dipole moment of the electron, searches for variations in natural constants, tests of quantum electrodynamics, measurements of finite nuclear size effects in atoms ( $\text{He}^+$ , He) and molecules ( $\text{H}_2$ , HD,  $\text{HD}^+$ ), and searches for physics beyond the Standard Model. Scientific highlights include the world's first molecular fountain, excitation of the doubly-forbidden  $\text{He}^*$  transition, Ramsey-comb excitation, precision VUV two-photon excitation of  $\text{H}_2$ , and overtone excitation of HD. These discoveries have been published in leading journals (Science, Nature, Physical Review Letters, Nature Physics). The group has been highly successful in attracting individual (2 ERC Adv, 1 ERC Start, 1 VICI and 2 VIDI's) and collaborative grants (3 FOM Programs, 1 NWO Groot investment). The unique knowledge of lasers and precision techniques is used for applications in lithography within ARCNL (Ubachs, Eikema, Witte, Den Boef, Frenken), and remote sensing and space exploration (ESA, SRON, Aben). Spin-off company OPNT develops technology for telecom network synchronization.

**VU Physics 'zwaartepunt' 3, Photonics for Life and Health** connects to 'focusgebied' Physics of Life & Health. Research concentrates on the development of optical instrumentation and its application to biomedical problems. Research includes the development of (i) single-molecule and -cell imaging and manipulation tools for biophysical studies (DNA transactions, mechanics of cells and biomolecules, and intracellular transport (Heller, Wuite, Peterman)), (ii) Raman spectroscopy (Ariese), (iii) nonlinear microscopy for instant pathology (Groot), (iv) Optical Coherence Tomography for endoscopic imaging (de Boer); (v) optomechanical instruments for cell and tissue stiffness measurements (Iannuzzi), (vi) integrated photonics for cost-effective, miniaturized devices (Avci), and (vii) image analysis tools for small-animal behavior (Stephens). Research is tightly connected to AMOLF (Koenderink, Shimizu, ten Wolde), Amsterdam UMC (e.g. VUmc Imaging Center). Excellence is evident from publication records and success in personal grants (1 ERC Adv, 1 ERC Cons, 2 ERC Start, 3 VICI, 4 VIDI). VU is involved in the Gravitation Program 'Building a Synthetic Cell'. Unique is the expertise in valorization, including translational research towards the clinic, highly successful spin-off companies (Optics11, LUMICKS, Tritos Diagnostics), and strong involvement in Demonstrator Lab. In the National Agenda Photonics, Amsterdam is center of gravity for medical photonics. Research is connected to topsectors High Tech Systems and Materials, Life Sciences & Health, and NWA themes Personalized Medicine and Origin of Life.

**VU Physics 'zwaartepunt' 4, Photosynthesis and Energy** connects to 'focusgebieden' Physics of Life & Health, and Energy & Sustainability. VU has a long-standing tradition in research of natural and artificial photosynthesis using advanced laser spectroscopy embedded in LaserLaB Amsterdam (Croce, Kennis, van Stokkum). In the last years, research has broadened with expertise in biochemistry and genetics of plants and algae (Croce), and photovoltaics (hybrid (Frese) and organic (von Hauff)). This has resulted in a multidisciplinary research group unique in the world, with an extensive portfolio of technical knowhow and equipment, equipped to tackle modern problems in energy research. For example, photosynthesis is studied at different levels of complexity from single molecule to whole organism, from artificial system, to bacterium or plant. This is timely, given the general consensus that improving photosynthesis is a must for increasing food and biomass production for the growing population on our planet. Efforts are ongoing to create EU flagship consortia focusing on both artificial and natural photosynthesis, with the Dutch and VU photosynthesis community playing leading roles. "Turbosynthesis", the improvement of photosynthesis, is part of NWA. Excellence of research is evident from the publication record and personal grants (1 ERC Adv, 1 ERC Cons, 2 VICI, 3 VIDI, 2 CW TOP).

## VU Chemistry

VU Chemistry is world leading in fundamental and societally relevant fields of the molecular sciences and has the ambition to strengthen and further develop this position in the coming time. We focus on Chemistry of Life, with a long and internationally recognized reputation in *pharmacochemistry*, theoretical chemistry, organic synthesis, and analytical chemistry (i.a. 5 VICI + 1 Pionier laureates). In the past period, VU Chemistry has successfully developed its research along the translational chain from molecule to medicine, amongst others by establishing the successful Amsterdam Institute for Molecules, Medicines & Systems (AIMMS) with close connections to the VU academic hospital. We work intensively and synergistically with our partners at UvA in research, education and outreach. Both UvA and VU are connected via a strong component in the focus on Fundamentals of Chemistry and chemical methods, and both sides participate in internationally highly esteemed centers: Amsterdam Center for Multiscale Modeling (ACMM) and Center for Analytical Sciences Amsterdam (CASA). The life theme is represented by our four 'zwaartepunten' (see below) that we will reinforce by starting novel research lines that connect internally, and also towards Computer Science, and Physics. Our educational programs are modern and highly relevant and offer a very broad range of subdisciplines at the bachelor and master's level: Chemistry (JDs with UvA Chemistry), Pharmaceutical Sciences, Medical Natural Sciences (with i.a. Physics), Science Business & Innovation (with i.a. Physics), and participation in the Amsterdam University College (AUC) as well as the new BSc Mechanical Engineering (with our sister departments and Twente). We have established a division devoted to innovation of teaching, headed by a newly appointed female professor (van Muijlwijk). Recently, very positive reviews were obtained in national context (SEP review committee for research; NVAO accreditation for BSc & MSc Chemistry JD with UvA; BSc Pharm. Sci. & MSc DDS). Outreach towards schools is organised via Bètapartners. Valorisation led to three spin offs: SCM, Griffin Discoveries, IOTA Pharmaceuticals. VU chemistry is determined to increase female staff. Recently, we have quadrupled the number of female chairs to 4 (29% of chairs). Next, we aim at hiring at least 35%, preferably 50% female new staff.

**VU Chemistry 'zwaartepunt' 1, Medicinal Chemistry and Chemical Biology** (Leurs, de Esch, Smit, Jennings) is a stronghold in the national focus area Chemistry of Life. Moreover, it augments UvA and is also nationally relatively unique. Naturally, the research perfectly aligns with the National Science Agenda (NWA) on e.g. personalized medicines. Research is centred around the main molecular disciplines in early discovery and systems-based biochemistry, molecular toxicology, fragment-based design and synthesis, and medicinal chemistry of GPCR ligands and drugs for Neglected Tropical Diseases. Indicators of excellence include highly-cited publications in top international journals, presence at international (invited/keynote) conferences as invited or keynote lecturers, several competitive grants (including 1 VICI and 1 Pionier laureate), committees of trust (NWO) and elected membership of the KNAW. This 'Zwaartepunt' is also successful in setting up public-private partnerships, e.g., with Dutch Top institute Pharma and a series of EU-funded Innovative Medicines Initiative (IMI) projects and has spawned two spin-off companies, Griffin Discoveries and IOTA Pharmaceuticals, that valorise the fundamental drug discovery knowledge of VU. We aim at investing into new research lines in: (i) novel biochemical approaches to personalized drug responses; (ii) the study of the role of the microbiome in e.g. individual differences in drug metabolism and generation of bio-active molecules; (iii) new computational approaches in fragment-based drug discovery using machine learning; and (iv) biophysics of drug-target interactions.

**VU Chemistry 'zwaartepunt' 2, Computational Chemistry** (Bickelhaupt, Visscher, Fonseca Guerra, Gori-Giorgi) unites with UvA colleagues in the Amsterdam Center of Multiscale Modeling (ACMM) which is officially recognized as a top European center by the "Centre Européen de Calcul Atomique et Moléculaire" (CECAM). ACMM covers a broad range of topics, from mathematical developments via quantum chemistry and software development to conceptual chemical theory and simulation. The VU group is oriented more (but not exclusively) towards quantum chemistry with research centred around the physics and conceptual models of chemical bonding and reactivity, relativistic effects and sub-system methods, density functional (matrix) theory, and supramolecular quantum biochemistry. The group is main developer of the ADF computational chemistry program package. Research connects with the NWA, e.g. in the topic Origin of life, and has collected various prestigious prizes and grants (i.a., 3 VICI laureates). Excellence is also demonstrated by very high-impact publications in top international journals, presence (invited/keynote) at conferences, and memberships in boards and committees of trust. We aim at initiating a new research line in the novel area of theory-driven organic synthesis that links Computational Chemistry and Synthesis with Physics and in particular Computer Science (AI). This also serves to innovate our BSc and MSc Chemistry (JD with UvA) by introducing modern machine learning and AI concepts into chemistry and modeling. We recently achieved 100% gender balance (2 f + 2 m HL).



**VU Chemistry 'zwaartepunt' 3, Synthesis** (Orru, Grossmann) is an essential pillar for the focus areas Fundamentals of chemistry and chemical methods as well as for Chemistry of Life. Top level research focuses on new synthetic methodologies in order to access building blocks and high-added value end-products to develop molecular probes and drugs in the *Life & Health* domain as well as in the context of sustainable production processes for medicines of the 21st century. The research aligns with several topics of the National Science Agenda (NWA), e.g., bio-based building blocks. Indicators of excellence include publications in top international journals, good citation impact of a relatively young staff, continuous presence at international conferences, competitive grants (1 VICI, several TOP, ERC Starting and ERC proof of concept) and two Innovative Medicines Initiative grants (public-private partnerships: CHEM21 and ELF). To further strengthen in the focus area Chemistry of Life, we plan to invest in a TT-UD position on *Sustainable Manufacturing of Therapeutics*. Synthesis also participate jointly with Computational Chemistry in a junior TT position Theory-Driven Organic Synthesis which creates a link with Computer Science and paves the way for the innovation of our JD master program Chemistry (with UvA).

**VU Chemistry 'zwaartepunt' 4, Analytical Chemistry & Spectroscopy** (Somsen, Takats) cooperates with UvA colleagues in the Centre for Analytical Sciences Amsterdam (CASA) which is the national focal point for Analytical Chemistry and the leading party in TI-COAST, the Dutch initiative on analytical science and technology comprising over 80 companies and institutes. VU research centres around novel multidimensional analytics addressing critical queries pertaining to the focus areas Chemistry of Life as well as Chemical Methods. The VU group focuses on analytical hyphenation, integration and miniaturization for in-depth macromolecular characterization, high-resolution bioactivity screening, and cutting-edge *in situ* medical diagnostics. Through the route "Measuring and detecting", the research perfectly aligns with several other NWA topics, such as personalised medicine. Indicators of excellence include publications in top international journals, high citation impact, continuous presence at international conferences as invited or keynote lecturers, highly competitive grants (e.g. ERC Consolidator, VENI, CHIPP, TTW), editorships, and committees of trust (NWO). This 'Zwaartepunt' is particularly successful in engaging public-private partnerships (amongst others with DSM, AkzoNobel, BASF, Roche, Bruker, Sciex) and involved in several EU-ITN programs. Innovations are valorised in high-end analytical instruments, such as the GC fractionator and the Fractiomate™ (marketed by Da Vinci Lab Solutions and Spark Holland). We plan to invest in new research lines encompassing (i) bioanalysis of complex natural products aiming to discover new chemistries with relevant biological and potential pharmacological activities, and (ii) novel analytical strategies for studying the role of protein heterogeneity in biological and pharmacological function.

## VU Mathematics

VU Mathematics has a strong tradition in building bridges between fundamental mathematics and novel applications of mathematical methods, both in its research and its teaching. In the past decade, the department has developed a distinct profile with two principal research lines: dynamical systems and stochastics. These are complemented by smaller research groups in number theory and differential topology. The main application areas are in the life sciences and in (business) analytics and optimization. This profiling aligns with the Faculty's themes Connected World, Fundamentals of Science, and Health and Life Sciences, reflects the societal orientation of the VU, as well as the department's strong links to the VUmc, VU Computer Science, VU School of Business and Economics, and the CWI, and is complementary to that of UvA Mathematics. The societal impact of our research is internationally recognized as excellent, and the research of the dynamical systems group is considered world leading (SEP evaluation 2015). More recently, VU Mathematics has made the further strategic choice to strengthen and extend its research in dynamical systems/number theory/differential topology into the direction of computational mathematics—including modeling—in order to intensify the societal relevance of its research, to reinforce the links between the three groups, and to increase the teaching capacity in this area. For the stochastics research line the strategic aim is two-fold: to put particular emphasis on excellent fundamental research, and to strengthen its data science research, as there are many scientific, educational and societal opportunities in this field, and because of the rapidly increasing demand both internally and externally for expertise in this area. This demand is amply illustrated by the need for statistical collaboration from the side of business analytics, research challenges posed by our collaborators in the life sciences, the increasing demand for statistics teaching, supervision and course development due to the rapidly growing numbers of students that are interested in this field. VU Mathematics is involved in a broad range of teaching activities. In addition to providing the BSc and MSc Mathematics programmes, the MSc Stochastics and Financial Mathematics program (with UvA), and a broad palette of courses for other disciplines in the VU-Sciences, Data Science UvA, and for the Amsterdam University College, the department runs the BSc and MSc Business Analytics programmes—the sole academic business mathematics program in the Netherlands (nationally accredited in conjunction with the regular Mathematics programmes)—and participates in the BSc Mechanical Engineering (with UT) that will start 2019/20. In the past couple of years, the number of students in our Business Analytics programs has increased dramatically, and we expect a continuing growth in student number due to the change to English in the BSc Mathematics, and the new BSc Mechanical Engineering. During the past two years the department has started to implement its strategic choice by 2 new positions in computational mathematics (topological data analysis, computer algebra) and 3 in mathematical data science (fundamentals of survival analysis, statistics for neuroscience, business analytics). The requested positions will further substantiate the chosen research directions, help alleviate the strain of our extremely low staff-student ratio and improve the gender balance.

**VU Mathematics 'zwaartepunt' 1, *Dynamical Systems – Computational Mathematics*** connects to 'focusgebieden' *Dynamic Data*, *Geometric and Stochastic Evolution*, and *Networks*. Research concentrates on developing novel mathematical theory for finite and infinite dimensional dynamical systems and applying state-of-the-art dynamics techniques to solve problems originating from other disciplines and in society at large. It is inspired both by the central role of dynamical systems in modern mathematics and by the fact that they arise throughout the sciences. There are many prolific internal and international collaborations. The group has unique expertise in network dynamics (Rink) and computational dynamics (van den Berg). Other areas in which the group is making seminal contributions include dynamics and data (Botnan), topological methods (van der Vorst) and emergence of patterns (Rink, van den Berg). A particularly fruitful application area is in systems biology, where a strong alliance (Hulshof, Planqué) has been shaped with the VU-Systems Bioinformatics group of Teusink and Bruggeman. The dynamical systems group has a well-established leading role in the national NDNS+ research cluster, and participates in the NWA project "Gravity — a new voyage of discovery", which is part of the route 'Bouwstenen van materie en fundamentele van ruimte en tijd'. Other NWA routes that relate to the research in this 'Zwaartepunt' are 'Oorsprong van het leven op aarde en in het heelal' and 'Waardecreatie door verantwoorde toegang tot en gebruik van big data'.

**VU Mathematics 'zwaartepunt' 2, *Stochastics – Mathematical Data Science*** connects to 'focusgebieden' *Networks* and *Statistical Learning*. The research concerns statistics, probability and stochastic operations research for data science, and encompasses a broad spectrum, from novel foundational contributions to genuinely applied research in data science. The group is especially strong in statistical data analysis, from theory to applications in business processes. Its research covers areas such as high-dimensional and nonparametric Bayesian inference, uncertainty quantification (Belitser), analytics and stochastic optimization with applications to business, health care logistics, queueing networks (Bekker, Bhulai, Van der Mei, Koole), non- and semiparametric inference for survival analysis (Dobler), statistics for life sciences and neuroscience (De Gunst, Hindriks, Van Wieringen), statistics and probability for forensic genetics (Meester, Slooten). The group plays an important role in the national STAR research cluster, participates in the Amsterdam Neuroscience and Amsterdam Data

Science initiatives, and it is one of the founders of the Amsterdam Center for Business Analytics. It also has intensive research collaborations within the VUmc and many companies. The group participates in projects financed by the 'Topsector' 'Logistiek'. NWA routes that relate to the research in this 'zwaartepunt' are 'Waardecreatie door verantwoorde toegang tot en gebruik van big data' and 'Logistiek en transport in een energieke en duurzame samenleving'.

## 7. Characteristics of 'zwaartepunten' for which funding is requested

<b>VU Computer Science</b>
<b>'Zwaartepunt' 1:</b> Quantitative Data Analytics (Focusgebied: Data modeling & analysis)
<p><b>Scientific content:</b> The applicability of modern methods for data analytics is often limited to the ideal scenario: an abundance of data, no intrinsic understanding of underlying information models, no huge consequences in case of faulty or biased predictions, and nearly unlimited computational resources. While this approach has served a first generation of applications, future needs will demand a more grounded approach. This chair will focus on making data analytics algorithms more applicable for societally important domains. Based on previous and current activities in the Department, we will study applications of data analytics in areas including bioinformatics (with our bioinformatics group), healthcare (working with the City of Amsterdam in its plan to become a center of excellence for data science in health, building on our collaborations with the Amsterdam UMC), finance (building on our participation in ACBA, the Amsterdam Center for Business Analytics), IoT (with our research group on computer systems), computer security (with our research group on computer security), robotics (with the Computational Intelligence group and the Social AI group), and computational methods for scientific discovery. Regarding the latter topic, we will collaborate closely with the Chemistry department on integrating experimental and computational approaches to chemical design and synthesis, as a particular case of using data-analytic methods to accelerate scientific progress. For this, the Chemistry department requests a tenure track position.</p> <p><i>Alignment with VU Chemistry:</i> On computational methods for scientific discovery, members of this new group will closely collaborate with VU Chemistry ('Zwaartepunt' Computational Chemistry) on integrating experimental and computational approaches to chemical design and synthesis, as a particular case of using data-analytic methods to accelerate scientific progress.</p> <p><i>Alignment with VU Mathematics:</i> This chair is closely aligned with the positions on <i>Fundamentals of Data Science</i> as requested by our colleagues from the Department of Mathematics. Together these appointments will span the entire Data Analytics spectrum from mathematical foundations to practical computational algorithms.</p>
<p><b>Quality:</b> The <i>Computational Intelligence group</i> with whom this new group will be closely aligned, has attracted worldwide attention with its evolutionary approach to robotics, and has a number of publications in both Nature and Science, which is extremely rare for Computer Science research. Gusztai Eiben has received a lifetime achievement award from the main European conference in his field, and ranks in the world wide top 20 of the field of Evolutionary Computing (Google Scholar data).</p> <p><b>Impact:</b> This new group on Quantitative Data Analytics will be a contribute significantly to the already substantial impact of the thriving Amsterdam Data Science network, of which the VU is one of the founding members, in areas such finance (with colleagues at the VU Business School in the Amsterdam Center for Business Analytics) and healthcare (collaboration with the joint VU/UvA Amsterdam University Medical Center). It will complement groups at the University of Amsterdam (on Deep Learning, and learning from text, image and video) with whom we collaborate closely. It is well aligned with the NWA route on "Verantwoorde Waardecreatie met Big Data". Methods from Quantitative Data Analytics are required in large scale data-sharing platforms funded under the NWO infrastructure roadmap, with the VU actively involved in the funded platform CLARIAH (humanities) and the proposed platforms ODISSEI (social sciences) and ELIXIR (life sciences; Jaap Heringa is Head-of-Node of ELIXIR-NL).</p>
<p><b>Master programs or -tracks associated with 'Zwaartepunt'</b></p> <ul style="list-style-type: none"> <li>• M Computer Science 60300</li> <li>• M Computer Science (joint degree) 65014</li> <li>• M Artificial Intelligence 66981</li> <li>• M Business Analytics 66856</li> <li>• M Information Sciences 60255</li> <li>• M Bioinformatics and Systems Biology (joint degree) 65020</li> </ul>
<p><b>Size and intended expansion of the permanent scientific staff</b>  Current Computer Science staff on data analytics: 0.5 fte full professor, 1.0 fte UHD, 2.0 fte UD  Requested extension: 1.0 fte full professor, 1.0 fte TT</p>

## VU Computer Science

### 'Zwaartepunt' 2: Assessing and Evaluating Security (Focusgebied: Security and Privacy)

**Scientific content:** As system complexity increases and the need for trusted software grows, a seeming simple question arises: "How secure is the system?" Today, this question is *impossible* to answer in anything approaching a general case. Providing insights into software integrity requires a deep understanding of the foundations of software and system security. Given its world class systems security group, VU is in a unique position to establish an expanded research cluster that links the system perspective to foundational theory—providing a cluster that is largely absent in Europe, but pioneered very successfully by MIT in the US and NICTA/Data61 in Australia.

The goals for this "Zwaartepunt" is to develop knowledge:

- to design and assess the security of tomorrow's systems (e.g., in AI, IoT, data science),
- to verify adherence to fundamental security principles,
- to develop practical systems that are secure from the outset (much like seL4),
- to complement and link existing security research to other groups in the department.

The proposed unit complements existing foundational security groups in NL in its focus on the security of real system software and in working side by side with the systems researchers. Marrying systems and theory, it will take on what may be *the* main research challenge in the years to come: the ability to fundamentally prove/disprove the security of a system and to provide guarantees of security at the systems level.

**Quality:** The VU security group is one of the most successful such groups in the world—ranked #13 worldwide for no. of publications in the traditional "Top-4" venues in computer security over the past 3 years and #1 per faculty (see <http://csrankings.org>). All faculty have won NWO Innovation impulse grants. Herbert Bos has won an ERC StG and a VICI and currently ranks 19th worldwide in the all-time list of number of top publications (<https://bit.ly/2TGzsV6>). Cristiano Giuffrida and Kaveh Razavi each won a VENI grant. VUsec has won 3 of the 4 PWNIE Awards ever awarded to researchers in the Netherlands, and the only CSAW Award. The group regularly receives best paper awards at the top venues of our field. Five of our students have received the Roger Needham Ph.D. Award for best thesis in computer systems in Europe. In addition, we received the Dennis M. Ritchie Ph.D. Award and ACM SIGSAC Ph.D. Award for best theses worldwide in computer systems and security, respectively. We also won 3 of the 4 Dutch Cyber Security Research Paper Award (for best research paper in security from the Netherlands). At the policy level, Bos has co-authored all 3 editions of the National Cyber Security Research Agenda (the basis for NWO research funding since 2012). He leads the VSNU Digital Society "Safety and Security" line and regularly advises the government on security. In addition, Bos initiated the foundation of AMSec, a center that brings together computer scientists, lawyers and criminologist at VU, UvA, CWI and NSCR in an Amsterdam Center for Cyber Security.

**Impact:** Our research results were adopted by Microsoft, Apple, Google and every major browser and operating system. Our takedown of the Zeus malware, with the FBI and law enforcement agencies around the world, made headlines from Australia to the US.

Security is cross-cutting for the national Science Agenda, and explicitly mentioned in NWA routes such as Sustainable production of safe and healthy food, Energy transition, Health care research, sickness prevention and treatment, Logistics and transport in an energetic, innovative and sustainable society, Towards resilient societies, Smart Industry, Smart Liveable Cities, and Creating value through responsible access to and use of big data. Likewise, for top sectors HTSM, Life Sciences and Health, and Energy.

#### Master programs or -tracks associated with 'Zwaartepunt'

- Master track "Computer and System Security" in the Computer Science master (60300)

#### Size and intended expansion of the permanent scientific staff

The existing security group has 3 staff members: 1.0 fte full professor, 2.0 fte UD  
Requested extension: 1.0 fte full professor, 1.0 fte TT



<b>VU Computer Science</b>
<b>'Zwaartepunt' 3: Ethical Computing (Focusgebied: Machine reasoning &amp; Interaction)</b>
<p><b>Scientific content:</b> Ethical computing addresses the challenge of developing and evaluating ethical performance metrics for reasoning and interaction algorithms. Besides the regular metrics of correctness and efficiency, ethical characteristics of algorithms are becoming an additional focus of interest in computer science. Some examples are:</p> <ul style="list-style-type: none"> <li>• Operationalize high-level social values and norms (such as diversity, inclusion and privacy) into concrete tools that can be used to evaluate and improve socio-technical systems. Examples include metrics for bias in data sets used in training for machine learning, metrics for fairness of recommender systems deployed by public organisations, or warning systems that can flag or even prevent irresponsible use of sensitive data.</li> <li>• The development of ethical guidelines (ELSI), (semi)-formal computational models for systems with such social values and norms built-in, and (semi-) automatic ethical verification methods. Examples include formal methods for checking new models before deployment, tools to support designers in making complex trade-offs, such as those between transparency and privacy, between open data versus confidentiality, and between the guaranteed accuracy of a closed, controlled system and the interoperability of an open, community driven technical ecosystem.</li> <li>• Methods for conveying the results of complex reasoning to decision makers and users. This includes, for example, user interfaces that convey task-relevant inaccuracies or uncertainties in each step of a data science pipeline without overwhelming users with overly complex analyses, as well as dashboards with live visualisations of relevant ethical metrics on systems already in production.</li> </ul> <p>These topics stretch across different areas of computer science, such as transparency in data integration, privacy concerns in security, fairness in data analytics, to name just three. This position is in collaboration with the UvA TT on fair and transparent autonomous systems at UvA.</p>
<p><b>Quality:</b> The User-Centric Data Science group has been international leader in the development of the Semantic Web, and have co-authored the RDF 1.1 and OWL standards which are in widespread use in industry, government and healthcare worldwide. It has made essential contributions to the FAIR standards for scientific data publishing, leading to a Nature publication, and which are now adopted by the EU (EOSC) and many national research organisations. Members of the group have won 3 of the Semantic Web Challenge awards in the past decade. Over the past decade, the group has been responsible for the SWI Prolog system (150.000 downloads per year). The group on Social AI under the leadership of Koen Hindriks has attracted national attention with his applications of social robotics in primary schools and paediatric hospitals.</p> <p><b>Impact:</b> Ethical Computing appeals directly to the VU's core values of responsible, open and socially engaged research. On a national scale, Ethical Computing fits with the NWA route 'Verantwoorde Waardecreatie met Big Data', and lies at the core of VSNU's Digital Society Research Agenda, where we are leading the research line on Responsible Data Science. Internationally, the topic addresses the focus of the Europe-wide CLAIRE initiative on "AI with the human at the centre", as well as the call of the EU's High-Level Expert Group on Artificial Intelligence to build trustworthy AI through human-centric technology with that is designed and deployed with an ethical purpose. A recent motion adopted by the European parliament explicitly calls for the integration of ethics in the development of new computational frameworks. In life sciences and health, large ESFRI programs such as BBMRI and ELIXIR have an increasing focus on ethical/privacy issues (ELSI) and software to address these.</p>
<p><b>Master programs or -tracks associated with 'Zwaartepunt'</b></p> <ul style="list-style-type: none"> <li>• M Computer Science 60300</li> <li>• M Computer Science (joint degree) 65014</li> <li>• M Artificial Intelligence 66981</li> <li>• M Business Analytics 66856</li> <li>• M Information Sciences 60255</li> </ul>
<p><b>Size and intended expansion of the permanent scientific staff</b></p> <p>Size of the current permanent scientific staff: 1.5 fte full professor, 0.9 fte UHD</p> <p>Requested extension: 1.0 fte TT on "Ethical Computing"</p>

**VU Computer Science**

**'Zwaartepunt' 4:** Energy-efficient computing (Focusgebied: Networked Computer Systems & Embedded Systems)

**Scientific content:** There currently is an explosion of sensor data that can be collected from smartphones and Internet-of-Things (IoT) devices. Such sensor data is crucial for applications like eHealth, smart cities, smart maintenance, and smart traffic. Processing sensor data, however, is a major challenge: the scale of the data is enormous and applications need to perform increasingly complex local computations, such as Deep Learning and stream reasoning. Sensor processing differs from traditional supercomputing: the data is highly dynamic and comes from many, widely distributed sources. It often must be processed in real-time. In addition to traditional processing issues, the field introduces multiple requirements for energy-efficiency: the sensing devices have very limited battery power, but offloading all computations to remote clouds would further escalate the energy footprint with both the data centers and the networks. As a solution, we will study energy-efficient programming and scheduling methods that exploit new infrastructural developments, such as edge-computing (i.e. processing close to the data sources) and 5G networks. This topic comes with many scientific challenges. Foremost, new infrastructures are arising where processing can be done more (energy)efficiently on computers closer to the data, called Edge or Fog resources. As an example, an eHealth application may process data on a person's smart watch, a connected smartphone, an in-house server, or a remote cloud. It thus is very important that applications can run anywhere on such heterogeneous systems and that schedulers are developed that take good, energy-efficient decisions of which computations to execute where. This task is highly challenging, as the energy and performance properties of all infrastructure components and their interconnection networks must be taken into account. In summary, new programming paradigms for heterogeneous IoT systems are needed, together with new resource management and scheduling techniques.

We foresee strong collaborations with the requested positions on "Quantitative Data Analytics", which will provide use cases and applications for our research, especially around computationally expensive processing in Machine Learning.

**Quality:** The High Performance Distributed Computing group has been an international leader on programming environments for large-scale distributed systems for many years. Henri Bal received the Euro-Par 2014 Achievement Award, he is a member of the Academia Europaea, the Scientific director of the ASCI research school, and the Associate Editor of IEEE Transactions on Parallel and Distributed Systems, with an h-index of 57.

**Grants:** currently participating in NWO-TTW Perspectief program Efficient Deep Learning (EDL), NWO-DATA2PERSON project Enabling Personalized Interventions (EPI), NWO COMMIT2DATA Big Data: real time ICT for logistics project Secure scalable policy-enforced distributed data processing, NWO/NLeSC DTEC project A methodology and ecosystem for many-core programming ; NWO/M grants for 6 generations of Distributed ASCI Supercomputer (currently DAS-6); numerous earlier NWO projects, including NWO-PIONIER (1993)

**Impact:** currently participating in EFRO project with TATA steel consortium: Lab JIT Maintenance Techport; NWA Startimpulsprogramma VWData (Verantwoorde Waardecreatie met Big Data); Smart city testbed in Alkmaar.

The work fits in the "Big Data" NWA route and we already participate in the NWA program 'Verantwoorde Waardecreatie met Big Data (VWData)'. The work is further relevant for several top sectors, especially Life Sciences and Health (see our NWO EPI project), High-Tech Systems and Materials (see our TATA steel project), and Logistics (see our EDL project with Schiphol airport and our NWO COMMIT2DATA project on logistics).

The "roadmap for large-scale infrastructures" covers several sensor-based facilities. The SKA (like LOFAR) is an extremely data-intensive example from radio astronomy; we have an external PhD student at ASTRON who studies data processing for both SKA and LOFAR, including energy aspects.

**Master programs or -tracks associated with 'Zwaartepunt'**

- M Computer Science (tracks Parallel Computing Systems and Big Data Engineering) (60300)
- M Parallel and Distributed Computer Systems (Top-master, 60802)

**Size and intended expansion of the permanent scientific staff**

Size of the current staff: 1.0 fte full professor, 1.0 fte UD, 3.0 fte TT

Requested extension: 1.0 fte TT in energy-efficiency and distributed sensor processing.

<b>VU Computer Science</b>
<b>'Zwaartepunt' 5:</b> Hybrid Intelligence (Focusgebied: Machine reasoning & Interaction)
<p><b>Scientific content:</b> Hybrid Intelligence (HI) is the study and design of methods, theories and algorithms that combine human and machine intelligence. The goal of HI research is to expand the human intellect instead of replacing it. By providing intelligent artificial collaborators that interact with people, HI systems amplify human capacity for learning, reasoning, decision making and problem solving.</p> <p>Successful Hybrid Intelligence requires meaningful interaction between intelligent agents and humans to negotiate and align goals, intentions and implications of actions. Developing HI will require fundamentally new solutions to core research problems such as general world knowledge (common sense), and the human capabilities of collaboration, adaptivity, explainability and awareness of norms and values.</p> <p>Technical challenges include:</p> <ul style="list-style-type: none"> <li>• collaboration, developing shared mental models between humans and machines, requiring computational forms of theory of mind and shared causal models, combining symbolic and statistical representations;</li> <li>• adaptivity when working in changing environments and in changing teams, requiring advances in reinforcement learning, auto ML, and the integration of learning and reasoning;</li> <li>• responsibility, requiring values such as transparency, accountability, trust, privacy and fairness to be the explicit subject of machine reasoning.</li> </ul> <p>The research plan for this area, which has been aligned with the national agendas within the special interest groups on AI (SIGAI) and Data Science within IPN, allows us to collaborate closely with our partners in Amsterdam and around the country, and provides foundational research opportunities in applied AI for a broad set of student research interests.</p>
<p><b>Quality:</b> The Knowledge Representation group has been an international leader in the development of the Semantic Web, and has co-authored the OWL standard which is now in widespread use in industry, government and healthcare worldwide.</p> <p><b>Awards:</b> conference awards at ISWC or ESWC in '08, '09, '10, '11, '12, '13, '15, '16 and '18; 10-year impact award of the International Semantic Web Conference; two of the 25 most cited papers in the AI and Medicine Journal, one of the 4 best papers in Medical AI in 2017, the most cited paper on formal methods in medical software systems; best paper award at AIME 2014 and at HealthInf '14, '15 and '16,</p> <p><b>Distinctions:</b> Van Harmelen is a fellow of the European Association for AI (EurAI), a member of the Royal Dutch Academy of Arts and Sciences (KNAW) and of the Academia Europea.</p> <p><b>Software:</b> the Sesame open source triple store (now RDF4J) with over 200.000 downloads to date;</p> <p><b>Impact:</b> AI will either empower our ability to make more informed choices or reduce human autonomy; expand the human experience or replace it; create new forms of human activity or make existing jobs redundant; expand democracy in our societies or put it in danger. Now that AI technologies affect our everyday lives at an ever-increasing pace, there is a greater need for AI systems to work synergistically with humans rather than simply replacing them. Thought leaders in AI increasingly share the conviction that in order for AI systems to help humans and humanity, we need a new understanding of AI that takes humans and humanity explicitly into account, arguing that AI systems should not be seen as autonomous thinking machines, but rather as cognitive prostheses that can help humans think better.</p> <p>TU Delft and VU are together leading a national consortium of 5 Universities on Hybrid Intelligence, and are both coordinating their requests for positions in this area.</p>
<p><b>Master programs or -tracks associated with 'Zwaartepunt'</b></p> <ul style="list-style-type: none"> <li>• M Artificial Intelligence 66981</li> </ul>
<p><b>Size and intended expansion of the permanent scientific staff</b></p> <p>Size of the current permanent scientific staff: 1.0 fte full professor, 1.0 fte UD</p> <p>Requested extension: 1.0 fte TT on "Hybrid Intelligence"</p>

<b>VU Physics</b>
<b>'Zwaartepunt' 1:</b> Particle and Gravitational Physics ('focusgebied' Particle and Gravitational Physics)
<p><b>Scientific content:</b> experimental and theoretical research in the fundamental understanding of the building blocks of the universe and matter, embedded in the national collaboration Nikhef. Two key research lines: (a) elementary particles &amp; physics beyond the Standard Model, with experimental contribution to the LHCb experiment at CERN and (b) the detection of gravitational waves at Advanced VIRGO.</p>
<p><b>Quality and Impact:</b>  <u>SEP evaluation:</u> World leading / excellent for research quality and viability; very good for relevance for society (2018, evaluation together with UvA Institute for High Energy Physics).  <u>Publications:</u> 122 / year (2016-2018 average).  <u>PhD defenses:</u> 12 (2016-2018).  <u>Spending on external grants:</u> M€1.05 / year (2016-2018 average).  <u>Embedding:</u> part of the national Nikhef collaboration; part of the international LHCb experiment; part of the international VIRGO experiment and the LIGO-VIRGO collaboration.  <u>Personal Grants:</u> 1 ERC Advanced, 1 ERC Starting.  <u>Prizes and Honors:</u> Physica prize (2017), NWO Physics Valorization prize (2015), Gruber Cosmology Prize (2016) and Breakthrough Prize in Fundamental Physics (2016).  <u>NWA route:</u> "Bouwstenen van materie en fundamentele van ruimte en tijd".  <u>Topsector:</u> High-Tech Systems and Materials.  <u>Spin-off company:</u> Innoseis (seismic sensing systems).  <u>Interactions with companies:</u> Shell (seismic sensing), VDL (precision machining), Zygo/ASML (mirror coatings).</p>
<p><b>Master programs or -tracks associated with 'Zwaartepunt'</b></p> <ul style="list-style-type: none"> <li>• MSc Physics and Astronomy (joint degree UvA &amp; VU; CROHO 65016), tracks: Gravitation, Astro- and Particle Physics, and Theoretical Physics.</li> </ul>
<p><b>Size and intended expansion of the permanent scientific staff</b>  Staff 31-12-2018: 5.0 fte VU staff (van den Brand, Bulten, Mulder, Raven, Rojo)  Requested extension: 2.0 fte (1 senior, 1 junior)</p>

<b>VU Physics</b>
<b>'Zwaartepunt' 2:</b> Quantum Metrology and Laser Applications ('focusgebieden' Particle & Gravitational Physics and Precision Measurement & Fabrication)
<p><b>Scientific content:</b> Fundamental experimental investigations at the atomic scale, searching for physics beyond the Standard Model; thereto developing advanced lasers, such as frequency-comb lasers, ultra-stable lasers, extreme-ultraviolet lasers and TeraWatt short-pulse lasers, and methods to cool, manipulate and trap atoms, molecules and ions, and performing precision measurements. Applied research into applications of lasers in EUV lithography (with ARCNL) and spectroscopy for remote sensing and space exploration.</p>
<p><b>Quality and Impact:</b>  <u>SEP evaluation:</u> World leading / excellent for research quality and relevance for society; very good for viability (2018, evaluation LaserLaB as a whole)  <u>Publications:</u> 43 / year (2016-2018 average)  <u>PhD defenses:</u> 11 (2016-2018)  <u>Spending on external grants:</u> M€3.3 / year (2016-2018 average)  <u>Embedding:</u> part of VU physics institute LaserLaB; 2 staff members are part-time working in ARCNL; intensive collaboration with van Swinderen Institute Groningen.  <u>Personal Grants:</u> 2 ERC Advanced, 1 ERC Starting, 1 VICI, 2 VIDI.  <u>NWA route:</u> "Bouwstenen van materie en fundamenteën van ruimte en tijd".  <u>Topsector:</u> High-Tech Systems and Materials.  <u>EU:</u> via LaserLaB member of Laserlab Europe (joint research &amp; access).  <u>Spin-off company:</u> OPNT (technology for network synchronization in telecom)  <u>Interactions with companies:</u> ASML (EUV source development, plasma spectroscopy and imaging metrology, lens-less and EUV).</p>
<p><b>Master programs or -tracks associated with 'Zwaartepunt'</b></p> <ul style="list-style-type: none"> <li>• MSc Physics and Astronomy (joint degree UvA &amp; VU; CROHO 65016), track: Advanced Matter and Energy Physics.</li> </ul>
<p><b>Size and intended expansion of the permanent scientific staff</b>  Staff 31-12-2018: 4.0 fte VU staff (Bethlem, Eikema, Ubachs, Vassen)  Requested extension: 2.0 fte (2 junior).</p>



<b>VU Physics</b>
<b>‘Zwaartepunt’ 3:</b> Photonics for Life and Health (‘focusgebied’ Physics of Life & Health)
<p><b>Scientific content:</b> Research in the development of optical tools (based on microscopy, optical tweezers, optical coherence tomography, Raman, fluorescence, mechanical measurements, integrated optics, image analysis, behaviour analysis) and their application to biological systems, from molecule, via cell, tissue to whole organisms, with as goals to unravel the physics of life and to provide new instrumentation for diagnosis and intervention in healthcare.</p>
<p><b>Quality and Impact:</b>  <u>SEP evaluation:</u> World leading / excellent for research quality and relevance for society; very good for viability (2018, evaluation LaserLaB as a whole)  <u>Publications:</u> 58 / year (2016-2018 average)  <u>PhD defenses:</u> 19 (2016-2018)  <u>Spending on external grants:</u> M€ 5.25 / year (2016-2018 average)  <u>Embedding:</u> part of VU physics institute LaserLaB; part of VUmc Imaging Center; close connections to AMOLF and Amsterdam UMC; center of gravity for medical photonics in the National Agenda Photonics; member of Gravitation research consortium “Building a Synthetic Cell”.  <u>Personal Grants:</u> 1 ERC Advanced, 1 ERC Consolidator, 2 ERC Starting, 3 VICI, 3 VIDI, 1 NWO CW Top, 1 ZonMW Top.  <u>Prizes and Honors:</u> 2 VU University Research Chairs; 2 NWO Physics Valorization Prizes; GG Stokes Award (SPIE).  <u>NWA themes:</u> Personalized Medicine and Origin of Life.  <u>Topsector:</u> High-Tech Systems and Materials, and Life Sciences &amp; Health, and NWA themes.  <u>EU:</u> via LaserLaB member of Laserlab Europe (joint research &amp; access). Co-ordinator of FET Open ‘Chromavision’.  <u>Spin-off companies:</u> Optics11 (optical fiber sensing instruments), LUMICKS (single-molecule and cell-avidity analysis instruments) and Tritos Diagnostics (pathology with 3<sup>rd</sup> harmonic generation microscopy).  <u>Interactions with private companies:</u> Ninepoint Medical, Heidelberg Engineering.  <u>Other valorization activities:</u> one of staff members is director Demonstrator Lab (facility for students and researchers to transform ideas into products / companies; funded by the city of Amsterdam); translational research bringing new optical instruments to the clinic.</p>
<p><b>Master programs or -tracks associated with ‘Zwaartepunt’</b></p> <ul style="list-style-type: none"> <li>• MSc Physics and Astronomy (joint degree UvA &amp; VU; CROHO 65016), tracks: Biophysics and Biophotonics and Advanced Matter and Energy Physics.</li> <li>• MSc Medical Natural Sciences (CROHO 60800), tracks Physics of Life and Medical Physics.</li> <li>• MSc Science Business and Innovation (CROHO 69320), track Life and Health.</li> </ul>
<p><b>Size and intended expansion of the permanent scientific staff</b>  Staff 31-12-2018: 9.0 fte VU staff (Ariese, Avci, de Boer, Groot, Heller, Iannuzzi, Peterman, Stephens, Wuite);  Requested extension: 1.0 fte (1 junior).</p>

<b>VU Physics</b>
<b>'Zwaartepunt' 4:</b> Photosynthesis and Energy ('focusgebieden' Physics of Life & Health and Energy & Sustainability)
<p><b>Scientific content:</b> Experimental research into innovations in production and storage of energy, focusing on conversion of solar energy, in order to help the transition away from fossil fuels. VU physics has a unique breadth of facilities and expertise, ranging from (ultrafast) laser spectroscopy, via microscopy, biochemistry and molecular biology to the fabrication, characterization, and device physics of organic and hybrid solar cells. These tools are applied to understanding and improving energy harvesting and conversion in (biologic) photosynthesis, from the level of single molecules to whole organisms, and more recently towards solar energy devices.</p>
<p><b>Quality and Impact:</b>  <u>SEP evaluation:</u> World leading / excellent for research quality and relevance for society; very good for viability (2018, evaluation LaserLaB as a whole)  <u>Publications:</u> 49 / year (2016-2018 average)  <u>PhD defenses:</u> 15 (2016-2018)  <u>Spending on external grants:</u> M€2.78 / year (2016-2018 average)  <u>Embedding:</u> part of VU physics institute LaserLaB, active local collaborations with UvA and AMOLF and within the Netherlands (Wageningen, Groningen, Delft, TNO).  <u>Personal Grants:</u> 1 ERC Consolidator, 2 VICI, 3 VIDI, 2 NWO CW Top.  <u>Prizes and Honors:</u> Morino Award, DFG Mercado Fellow, KHMW member, Science BoRE member.  <u>NWA themes:</u> Turbosynthesis.  <u>Topsector:</u> High-Tech Systems and Materials, Energy, Life Sciences &amp; Health, Agri &amp; Food.  <u>EU:</u> via LaserLaB member of Laserlab Europe (joint research &amp; access), partner in 2 Marie Curie networks.</p>
<p><b>Master programs or -tracks associated with 'Zwaartepunt'</b></p> <ul style="list-style-type: none"> <li>• MSc Physics and Astronomy (joint degree UvA &amp; VU; CROHO 65016), tracks: Science for Energy and Sustainability, and Advanced Matter and Energy Physics.</li> <li>• MSc Science Business and Innovation (CROHO 69320), track Energy and Sustainability.</li> </ul>
<p><b>Size and intended expansion of the permanent scientific staff</b>  Staff 31-12-2018: 5.8 fte VU staff (Croce, Frese, von Hauff, Kennis, van Stokkum, Dekker)  Requested extension: 2.0 fte (2 junior)</p>

## VU Chemistry

**'Zwaartepunt' 1:** Medicinal Chemistry & Chemical Biology (('focusgebied': Chemistry of Life)

**Scientific content:** Medicinal Chemistry and Chemical Biology at VU constitutes one of the strongholds within the VU focus area Human Health and Life Sciences and the national focus area Chemistry of Life. Moreover, the research and teaching in this domain constitutes locally an important complementarity to the UvA and is also nationally relatively unique. Research perfectly aligns with the National Science Agenda (NWA) on e.g. personalized medicines. Research is centered around the main molecular disciplines in early discovery and around target- and systems-based biochemistry (Smit), molecular toxicology (Jennings), fragment-based design and synthesis (De Esch), and medicinal chemistry of GPCR ligands and drugs for Neglected Tropical Diseases (Leurs). Emphasis on the need for personalized approaches to drug discovery has recently been strengthened by the NWA and we therefore aim to invest in new biochemical approaches to understand personalized drug responses (1 TT-UD), next to an investment (1 HL) towards the study of the role of the microbiome in e.g. individual differences in drug metabolism and/or generation of bio-active molecules. Also, technological advances in neighbouring disciplines offer exciting new possibilities. With the wealth of new data coming from chemical and structural genomics projects (e.g. in ChemBL and PDB), AI and cheminformatics is currently seen as a game-changing and disruptive methodology for the design of new bioactive molecules. This area will be strengthened (1 TT-UD) in order to introduce new computational approaches in the existing research lines on fragment-based drug discovery and medicinal chemistry. Moreover, developments in physics currently allow the study of drug-protein interactions in previously unseen detail. Interactions can be studied at single molecule- and cellular-levels. To bridge this gap, we intend to invest in biophysics of drug-target interactions (1 TT-UD) to study such molecular interactions by various techniques (e.g. ITC, SPR, AFM, biosensors, high-end NMR, X-ray, ).

**Quality and Impact:** Research and teaching have recently been very positively reviewed in national context. In both cases, review committee's (SEP review committee for research; NVAO accreditation for BSc Pharm. Sci. & MSc DDS) praised the unique chemistry focus. Indicators of excellence also consist of publications in top international journals (e.g. Angewandte, JACS, Scientific Rep.), very high citation impact (H-indices 67, 46, 38, 27; Scopus 23.02.2019), presence at international (e.g. Gordon) conferences as invited or keynote lecturers, several competitive grants (VICI, Echo, Lift, coordinators of EU-ITN networks), committees of trust (NWO) and elected membership of Royal Netherlands Academy of Sciences and Arts (KNAW). Moreover, the VU groups have been very successful in obtaining grants from the Dutch Topinstitute Pharma and the EU-funded Innovative Medicines Initiative (IMI). Within these public-private partnerships, VU groups have developed and exchanged knowledge with small and large pharma partners. Two spin-off companies valorise our fundamental drug discovery knowledge: Griffin Discoveries and IOTA Pharmaceuticals.

### Associated master programmes:

- Master Drug Discovery & Safety, CROHO 66989
- Master Chemistry (JD with UvA), CROHO 65012
- Master Biomolecular Sciences, CROHO 65012
- Master Science, Business & Innovation, CROHO 65012
- Master Medical Natural Sciences, CROHO 65012

### Size and intended expansion of the permanent scientific staff

Permanent staff: 5.0 fte full professor, 2.0 fte UHD, 3.8 fte UD.

Requested extension: 3.0 fte TT and 1.0 fte full professor

1(tenure-track, TT) UD biochemistry of personalized medicine, 1 full professor chemical biology of the microbiome, 1 (TT) UD Computer-Aided Drug Design, 1 (TT) UD biophysical methods to study fundamentals of drug-protein interactions

## VU Chemistry

**'Zwaartepunt' 2:** Computational Chemistry ('focusgebied': Fundamentals of chemistry and chemical methods)

### Scientific content:

Research and teaching in computational and theoretical chemistry at VU and UvA are united in the Amsterdam Center of Multiscale Modeling (ACMM) and cover, in a complementary manner, a broad spectrum that ranges from mathematical developments via quantum chemistry and software development to conceptual chemical theory and simulation at longer time and length scales. Thus, VU and UvA focus on quantum chemistry and simulation, respectively, with sufficient fruitful overlap for synergistic interaction. The research of the four chairs in theoretical chemistry VU is centered around the physics and conceptual models of chemical bonding and reactivity (Bickelhaupt), relativistic effects and sub-system methods (Visscher), density functional (matrix) theory (Gori-Giorgi), and supramolecular quantum biochemistry (Fonseca Guerra). Research connects with the NWA e.g. in the topic Origins of life. In recent years, a gap is becoming manifest in a completely new line of theory that deals with a more interactive connection to experiment, i.e., theory-driven organic synthesis which integrates the chemical 'zwaartepunten' of computational chemistry and synthesis by replacing the approach of a priori design followed by synthesis by an integrated approach in which theory and experiment proceed continuously hand-in-hand. We wish to develop this approach towards maturity, based on a new sectorplan junior (UD) position, by introducing modern concepts and techniques from Computer Science (VU Computer Science 'Zwaartepunt' Data Analytics) in computational modeling (making use of knowledge rules from quantum chemistry instead of simple atom-connectivity rules). This position creates a valuable link with Computer Science and boosts chemical research and development. This also paves the road for a joint initiative with UvA to innovate our JD master Chemistry in which we aim to introduce a track addressing AI and other aspects of computer science in chemical modeling and chemistry in general.

**Quality and Impact:** (1) The VU group is one of the two pillars of the Amsterdam Center of Multiscale Modeling (ACMM) which is worldwide on the forefront of many novel developments in computational chemistry, enjoys a steadily growing number of associated groups (Twente, Eindhoven, Leiden, Nijmegen), and is recognized by the "Centre Européen de Calcul Atomique et Moléculaire" (CECAM); (2) The VU group is thriving scientifically and in terms of staff diversity. One of the achievements is the creation of complete gender balance by appointing two female UHDs to full professor (Gori-Giorgi and Fonseca Guerra); (3) The VU group is main developer of the Amsterdam Density Functional (ADF) software package which is co-developed, maintained and sold worldwide by the spin-off *Software for Chemistry & Materials* (SCM) to hundreds of groups in academia and industry. (4) The VU group has publications in top international journals (e.g. Angewandte, JACS, Chem. Sci., PNAS, Nat. Comm., PRL), very high citation impact (H-indices: 63, 44, 32, 26; WoS 08.03.2019), continuous presence at international conferences (invited, keynote), several competitive grants (3 VICI, ERC Consol, Echo, Lift, ARC CBBC, NWO Astrochem, NWO PEPSci, COST Action CM1105), and memberships of Royal Holland Society of Sciences and Humanities (KHMW), scientific advisory boards of chemistry institutes (Leiden, Girona), editorial (advisory) board memberships, and committees of trust (e.g., NWO, ERC).

### Associated master programmes:

- Master Chemistry (JD with UvA), CROHO 65012

### Size and intended expansion of the permanent scientific staff

Permanent staff: 4.0 fte full professor

Requested extension: 1.0 fte (tenure-track) UD in theory-driven organic synthesis together with Synthesis

## VU Chemistry

**'Zwaartepunt' 3:** Synthesis ('focusgebieden': Fundamentals of chemistry and chemical methods & Chemistry of Life)

**Scientific content:** Research and teaching in Organic Chemistry and Synthesis at VU constitute an essential pillar for the VU focus area Human Health and Life Sciences. Moreover, Organic Synthesis is a crucial discipline for the national focus areas Fundamentals of chemistry and chemical methods as well as for Chemistry of Life. The research and teaching in this domain are fully complementary to that of the UvA. Where a large part of the research of HIMS (UvA) is in the context of *Sustainable Chemistry*, the CPS (VU) department focuses on chemistry in the context of *Life & Health*. Top level research in Organic Synthesis at the VU focuses on new synthetic methodologies in order to access building blocks and high-added value end-products to develop molecular probes and drugs in the *Life & Health* domain as well as in the context of sustainable production processes for medicines of the 21st century. The research aligns with several topics of the National Science Agenda (NWA), e.g., bio-based building blocks. To further strengthen in the focus area Chemistry of Life, we plan to invest in a TT-UD position on *Sustainable Manufacturing of Therapeutics*. The synthesis of high added value compounds, such as APIs, starting from bio-based building blocks (from non-edible sources) is underexplored and current synthetic pathways mainly rely on chemistry developed for utilization of mineral oil. Fundamental research towards completely new chemistry, especially for application driven manufacturing processes is crucial to develop a more sustainable, crude oil independent pharma industry. The position bridges existing expertise in biomimetic synthesis & peptidomimetics (Grossman) and synthetic & bioorganic chemistry (Orru). Next to this, we will reinforce our position in the focus area Fundamentals of Chemistry and Chemical Methods with a junior TT position Theory-Driven Organic Synthesis, preserving a balanced age distribution of our staff. The position establishes new research that integrates experimental and computational approaches to molecular and supramolecular design and synthesis (with Bickelhaupt; see Comput. Chem.). This position creates a valuable link with our colleagues in Computer Science (AI). At the same time, it paves the way for the innovation of our JD master program Chemistry (with UvA).

**Quality and Impact:** Both research and teaching in this domain have recently been very positively reviewed in the SEP research evaluation as well as in the NVAO re-accreditation for the BSc Pharmaceutical Sciences and BSc Chemistry (JD with UvA) and MSc Drug Discovery & Safety teaching programs and MSc Chemistry (JD with UvA). Further indicators of excellence consist of publications in top international journals (e.g. Nature Comm, Angew. Chem., Chem. Rev., ACS Chem. Biol.) good citation impact (H-indices 38, 36, 21, WoS 24.02.2019) of the relatively young staff, continuous presence at international conferences as invited or keynote lecturers (e.g. Gordon Conferences, ECHC2018 etc) or organizing conference chairs (ECHC2016), competitive grants in national funding schemes: a.o. several ECHO and TOP-grants, VICI as well as international funding schemes: a.o. ERC starting & proof of concept, two Innovative Medicines Initiative grants (public-private partnerships: CHEM21 and ELF).

### Associated master programmes:

- Master Chemistry (JD with UvA), CROHO 65012
- Master Drug Discovery & Safety, CROHO 66989
- Master Science, Business & Innovation, CROHO 65012

### Size and intended expansion of the permanent scientific staff

Permanent staff: 2.0 full professor, 1.0 fte UHD, 1.0 fte UD

Requested extension: 1.0 fte (tenure-track) UD in *Sustainable Manufacturing of Therapeutics*



<b>VU Chemistry</b>
<b>'Zwaartepunt' 4:</b> Analytical Chemistry & Spectroscopy ('focusgebieden': Chemistry of Life, Fundamentals of chemistry and chemical methods)
<p><b>Scientific content:</b> Research and teaching in Analytical Chemistry at VU and UvA is united in CASA, which is the recognized national focal point for analytical sciences. CASA is a leading partner in TI-COAST, the Dutch initiative on analytical science and technology comprising over 80 companies, institutes and academic groups. The research and teaching at VU in this domain complements the analytical chemical activities at UvA in a highly synergistic way, incl. 10 joined PhD students and shared facilities. VU research centres around novel multidimensional analytics addressing critical queries pertaining to the focus areas Chemistry of Life as well as Chemical Methods. The VU group focuses on analytical hyphenation, integration and miniaturization for in-depth macromolecular characterization and high-resolution bioactivity screening (Somsen), and cutting-edge <i>in situ</i> medical diagnostics based on ambient mass spectrometry (Takats). The societal need for innovative analytics has recently been highlighted by the NWA as expressed in the route "Measuring and detecting" and other NWA topics (e.g. personalised medicine), which perfectly align with VU research. Latest technological advances in analytical resolving power offer exciting possibilities to maximize synergy with VU strengths in molecular approaches in early drug discovery and biochemistry. We will invest in (1 TT-UD) bioanalysis of complex natural products aiming to discover new chemistries with relevant biological and potential pharmacological activities, and (1 TT-UD) novel analytical strategies for studying the role of protein heterogeneity in biological and pharmacological function. These new research lines will directly interface with VU groups in the areas of medicinal and computational chemistry, and interactions with neuroscience, computer science (data mining, AI, and visualization) and the Amsterdam University Medical Center are foreseen.</p>
<p><b>Quality and Impact:</b> The research and teaching in this domain have recently been very positively reviewed in national context. Indicators of excellence also include publications in top international journals (e.g. Analytical Chemistry, Cancer Cell, Sensors and Actuators B), high citation impact (H-indices 39, 39; Scopus 26.02.2019), continuous presence at international conferences as invited or keynote speakers, competitive grants (ERC Consolidator, VENI, NWO CHIPP and TA, TTW, WADA), committees of trust (NWO), editorships (J. Chromatogr. B, Clin. Mass. Spectr.), and symposium organizing and scientific committees. The VU group is particularly successful in engaging public-private partnerships (a.o. with DSM, AkzoNobel, BASF, Roche, Bruker, Sciex) and involved in several EU-ITN networks and programs of TI-COAST. Research innovations are valorised in high-end analytical instruments, such as the GC fractionator and the Fractionate<sup>TM</sup> (marketed by Da Vinci Lab Solutions and Spark Holland). The CASA groups at VU and UvA are co-founders and coordinators of the internationally renowned and highly successful track Analytical Sciences of the MSc Chemistry program (80-100 new students/y) and, supported by COAST, of the national MSc+ program for top talent MSc students in analytical sciences.</p>
<p><b>Associated master programmes:</b></p> <ul style="list-style-type: none"> <li>• Master Drug Discovery &amp; Safety, CROHO 66989</li> <li>• Master Chemistry (JD with UvA), CROHO 65012</li> <li>• Master Biomolecular Sciences, CROHO 66990</li> <li>• Master Science, Business &amp; Innovation, CROHO 69320</li> <li>• Master Medical Natural Sciences, CROHO 60800</li> </ul>
<p><b>Size and intended expansion of the permanent scientific staff</b>  Permanent staff: 2.0 fte full professor, 1.0 fte UHD, 1.0 fte UD, 1.0 fte TT  Requested extension: 1.0 fte (TT) UD Bioanalysis of complex natural products, 1.0 fte (TT) UD Analytics for protein structure-activity relations</p>

<b>VU Mathematics</b>
<b>'Zwaartepunt' 1:</b> Dynamical Systems – Computational Mathematics ('focusgebieden' <i>Dynamic Data, Geometric and Stochastic Evolution, and Networks</i> )
<p><b>Scientific content:</b> The main research topics in the Dynamical Systems group are</p> <ol style="list-style-type: none"> <li>1. <i>Dynamics on networks.</i> The dynamics of systems with a network structure, such as neuronal networks, metabolic pathways and power grids, display extraordinary dynamical behaviour such as synchronization. We study the relation between the architecture of a network and its dynamics.</li> <li>2. <i>Applications in systems biology.</i> In a thriving collaboration with the systems biology group, we study bifurcation theory for metabolic pathways, optimization problems, stochasticity in signal transduction and community microbiology.</li> <li>3. <i>Computational dynamics.</i> We develop methods to capture rigorously important aspects of dynamical systems based on computer calculations, using both functional analysis and computational Conley index theory. This leads to computer-assisted theorems uncovering properties of dynamical systems not accessible to traditional pen-and-paper analysis only.</li> <li>4. <i>Emergence of patterns.</i> the interaction of a large number of entities, each of which behaves according to rather simple but nonlinear rules, often lead to unexpected emergent patterns. We develop methods to study the dynamics of such patterns, which range from atomic lattices in composite materials to eddies in the atmosphere and oceans.</li> <li>5. <i>Topological methods.</i> Morse-Conley-Floer theory uncovers deep relations between dynamical systems and partial differential equations on the one hand, and geometry and topology on the other. We develop this theory further, in both analytic and computational settings, and study its implications for specific applications, such as traveling waves in PDEs, and finite- as well as infinite-dimensional Hamiltonian dynamics (including braided and knotted orbits) inspired by mathematical physics.</li> <li>6. <i>Dynamics and data.</i> Data can be used to calibrate and improve dynamic models (data assimilation). On the other hand, ideas from dynamical systems can be deployed to extract information from data sets (e.g. time series). One example is the use of topological data analysis (which studies the "shape of data") to describe how the topology of a data set changes quantitatively over time.</li> </ol>
<p><b>Quality and Impact:</b> The 2015 research evaluation panel concluded that the research group in Dynamical Systems is excellent (world leading). Grants include 1 NWO-VICI, 1 NWO-VIDI, 2 NWO-VENI, and NWO-TOP1 and TOP2 grants, an NWO-cluster tenure-track grant "Topological Data Analysis", as well as an NWA grant in the "Gravity — a new voyage of discovery" consortium.</p>
<p><b>Master programs or –tracks:</b></p> <ul style="list-style-type: none"> <li>• MSc Mathematics (CROHO 66980)</li> <li>• MSc Business Analytics, (CROHO 66856)</li> <li>• MSc Stochastics and Financial Mathematics (CROHO 60801)</li> </ul>
<p><b>Size and intended expansion of the permanent scientific staff</b>  Permanent scientific staff: 6.0 fte (Botnan, Hulshof, Planqué, Rink, Van den Berg, Van der Vorst)  Requested extension: 3.5 fte</p>

## VU Mathematics

**“Zwaartepunt” 2’:** Stochastics – Mathematical Data Science (‘focusgebieden’ *Networks* and *Statistical Learning*)

**Scientific content:** The main research topics in the Stochastics group are

1. *High-dimensional and non-parametric Bayesian inference.* In our theoretical statistical research there is special attention for model selection and recovery problems, as well as the determination of convergence rates of parameter estimation and uncertainty quantification.

2. *Statistical inference in survival analysis.* We focus on non- and semiparametric inference techniques for complex survival analysis, and resampling techniques for multivariate data and empirical processes.

3. *Statistics for life sciences.* This research includes development, assessment and application of statistical models and tools for complex data structures such as networks. We have a special interest in modeling electrophysiological and neuroimaging data, where we focus on inference problems for spatio-temporal dynamics of ongoing cortical activity, and in cellular and genetic networks.

4. *Analytics and optimization.* The group is specialized in stochastic processes such as queueing systems and their controlled counterpart, Markov decision processes, but also covers related fields such as combinatorics, simulation, machine learning and statistics as they are often combined in the decision processes. Typical application areas are health care logistics and dynamic pricing.

5. *Probability theory.* In our research on percolation theory, we study parametrized infinite networks with special attention to the critical point, that is, the value of the parameter around which qualitative changes in the network occur. Our modern research in this direction uses ideas from complex analysis. We also study random walks, queueing systems, and the Ising model for describing ferro-magnetics.

6. *Forensic probability and statistics.* The evaluation of the evidential value of, say, (partial) DNA matches is not straightforward, with many practical, philosophical, and theoretical questions. We have strong connections with the Netherlands Forensic Institute. We monitor the need for, and carry out the application of probability theory in this rapidly developing domain, as well as statistical inference for forensic genetics.

**Quality and Impact:** The 2015 research evaluation panel concluded that the research group in Stochastics is very good and its societal impact is excellent (world leading). Grants include 1 NWO-VICI, 1 STW-grant, an NWO-cluster tenure-track grant “Statistical Neuroscience”, 2 postdocs financed by grants Topsector Logistiek, PhD projects financed by companies, (e.g. ACLA, Bejo Zaden, KLM, PON, Tata Steel), and two postdocs financed by ‘Topsector’ *Logistiek* grants.

### Master programs or –tracks:

- MSc Mathematics (CROHO 66980)
- MSc Business Analytics, (CROHO 66856)
- MSc Stochastics and Financial Mathematics (CROHO 60801)

### Size and intended expansion of the permanent scientific staff

Permanent scientific staff: 7.8 fte VU-staff (Bekker, Belitser, Bhulai, De Gunst, Dobler, Hindriks, Koole, Meester)

Requested extension: 3.5 fte

## 8. Requested positions per discipline

### VU Computer Science

VU Computer Science will use the requested funds to invest in two new groups (Data Analytics, Security) consisting of one full professor and one tenure track position for each group, plus three tenure track positions in other topics to strengthen existing groups (ethical computing, energy-efficient computing and hybrid intelligence). This forms a balanced investment across the breadth of the Department. Of the investments, the Data Analytics moves beyond our current strength areas, while the other positions deepen areas in which we have strong international reputations.

VU Computer Science, 'zwaartepunt' 1 (Quantitative Data Analytics). We request a full professor and one tenure track position to underpin work in various longstanding application areas that are worked on within departmental groups, with other groups at VU or with external partners (see Section 7 - 'Zwaartepunt' 1). Given the magnitude and significance of the research direction, only the substantial effort of a research group headed by a full professor will have sufficient impact. This group will strengthen the currently limited core data analytics research activity at the VU, will build on various existing collaborations, and will create the mass to be internationally competitive within this field. The interdisciplinary nature of the 'Zwaartepunt' fits the VU and its compact campus very well. The group will reinforce the AI section, and ample collaboration is anticipated with groups in and outside the department. Of note, it will align with positions requested for 'Zwaartepunt' *Stochastics – Mathematical Data Science* within the VU Mathematics and 'Zwaartepunt' *Theory-Driven Organic Synthesis* within the Chemistry department at VU. We expect this new foundational group to tie together much of the work done in various application areas, leveraging communalities and producing reusable analytics workflows and technologies.

VU Computer Science, 'zwaartepunt' 2 (Assessing and Evaluating Security). We request a full professor and one tenure track position, to start a second group in security research that will complement the existing group as well as existing national foundational security research with its systems level focus (see Section 7 - 'Zwaartepunt' 2). Given the magnitude and importance of the planned research into the principles of secure design in tomorrow's systems, only the substantial effort of a research group headed by a full professor will have sufficient impact. The foundational research may be rooted in theory of computing, usability, other principled fields, and work side by side with the more pragmatic systems security group already present. The new research direction directly strengthens the foundation of the existing security group at the VU, which ranks among the best in the world, but with a narrow focus and limited faculty staff. The VU security research is currently strongly driven by a practical, systems approach and a focus on today's hardware and software. Complementing this research with more principled research will provide a strong, well-rounded basis that offers more funding opportunities (e.g., it is a key topic explicitly listed in the national cyber security agenda and recent NWO calls), more options for collaboration both within the department and with outside groups, and more choice and expertise in our curriculum. Moreover, by its explicit adjacency in research focus to the systems group at VU, it will occupy a unique position in the Netherlands, where currently no such focus exists. By strengthening its security research, VU will not only be able to offer a comprehensive security track in the bachelor program and cater to the needs of a society that desperately needs a diverse palette of security expertise, but also expand our dominant research position in adjacent areas. These areas have always held the interest of the VU security researchers, but proved difficult to combine with ongoing activities. The new focus will boost these links and encourage also existing researchers "to cross the aisle".

VU Computer Science, 'zwaartepunt' 3 (Ethical Computing). We request a tenure track position to strengthen research on ethical characteristics of algorithms. We expect this position to lead to collaboration within various groups in the department, due to its general research focus on transparency in data integration, privacy concerns in security and medical data, fairness in data analytics (see Section 7 - 'Zwaartepunt' 3). Although the study of ethics in computing has a long tradition (dating back to the work of Norbert Wiener in the late '40s and early '50s), it has recently come into sharp focus because of the recent revolutions in big data analytics and artificial intelligence. Industry, governments and society at large are asking questions about the ethical premises of autonomous systems, data privacy and large-scale analytics. Ethical computing as targeted for this 'Zwaartepunt' encompasses the theme of explainable AI (XAI), but is intentionally defined as broader. It also encompasses the study of algorithms and methods for social robotics, systems security and responsible data science. This allows this position to form a bridge between the computer systems research groups and the AI/Data Science groups within the Department. Depending on the profile of the candidate, the position will be embedded in one of the four AI & Data Science research groups of the Department.

VU Computer Science, 'zwaartepunt' 4 (Energy Efficient Computing). We request a tenure track position to study energy-efficient programming and scheduling methods. This position is expected to lead to collaboration between the computer systems groups and the software development group (Green IT) within the department, fostering new infrastructural developments and generating ample possibilities for valorisation (see Section 7 - 'Zwaartepunt' 4). The new assistant professor will have a clear focus on energy-efficient processing of large-scale distributed sensor data and will benefit from existing expertise at the VU on HPC (Bal), stream reasoning and deep learning (Urbani, Hoogendoorn), big data management and scheduling (Iosup), Cloud- and Edge-computing (Wang), and green IT (Lago). The new topic comes with many additional scientific challenges that are not covered by the existing staff. Foremost, new infrastructures are arising where processing can be done more (energy)efficiently on computers closer to the data, called Edge or Fog resources. As an example, an eHealth application may process data on a person's smart watch, a connected smartphone, an in-house server, or a remote cloud. It thus is very important that applications can run anywhere on such heterogeneous systems and that schedulers are developed that take good, energy-efficient decisions of which computations to execute where. This task is highly challenging, as the energy and performance properties of all infrastructure components and their interconnection networks must be considered. In summary, new programming paradigms for heterogeneous IoT systems are needed, together with new resource management and scheduling techniques.

VU Computer Science, 'zwaartepunt' 5 (Hybrid Intelligence). We request a tenure track position to strengthen existing research within the department in this promising and timely area. The position will directly strengthen collaboration with TU Delft, where similar positions are being requested. It will further cement ties with partners in Amsterdam and nationally (see Section 7 - 'Zwaartepunt' 5). The positions for ethical computing and hybrid intelligence will be embedded in one of four existing groups: User-Centred Data Science, Social AI, Computational Intelligence or Knowledge Representation & Reasoning, to be decided depending on the specific profile of the selected candidates. In any case these positions will form productive bridges between these four existing groups in the Department, as well as with the newly-to-be-established Data Analytics group. The CS Department at the VU has a strong culture of interdisciplinary collaborations with other faculties on the campus. All three 'zwaartepunten' reinforce that strength: data-science with intended collaborations with mathematics for foundational theory and with health, bioinformatics and finance as application areas; ethical computing with Law, Social Sciences and Philosophy; and hybrid intelligence with Linguistics, Social Science and Psychology.

VU Computer Science			
Priority	Individual positions and subsequent research themes	'Zwaartepunt'	Requested budget
1	Full professor <i>Quantitative Data Analytics</i>	1. Quantitative Data Analytics	180K
2	Full professor <i>Assessing and Evaluating Security</i>	2. Assessing and Evaluating Security	180K
3	tenure track position <i>Quantitative Data Analytics</i>	1. Quantitative Data Analytics	120K
4	Tenure track position (*) <i>Assessing and Evaluating Security</i>	2. Assessing and Evaluating Security	120K
5	Tenure track position <i>Ethical Computing</i>	3. Ethical Computing	120K
6	Tenure track position <i>Energy-efficiency and Distributed Sensor Processing</i>	4. Energy-efficient computing	120K
7	Tenure track position <i>Hybrid Intelligence</i>	5. Hybrid Intelligence	120K
Total requested budget for VU Computer Science			960K

(\*) We fully expect to reach the target of 35% female candidates across our new positions. Anticipating that recruiting female candidates in security may be particularly challenging; if this threshold is not achieved, this position may be changed in profile in order to attract an additional female candidate. We would then fund the tenure track position *Assessing and Evaluating Security* from other departmental funding sources.

## VU Physics

VU Physics requests up to 8 positions to strengthen and modernize our research 'Zwaartepunten' (see table 3). All but one will be junior, tenure-track positions. This is a deliberate choice given the age distribution in the department (with an overrepresentation of mid-career scientists in the higher ranks, aged 47-53). One of the key goals of VU physics is to improve the gender balance of our academic staff to better reflect that of our students / PhD students. To highlight this ambition, the highest priority position requested is for an excellent woman candidate in one of our four 'Zwaartepunten'. New future directions of the VU physics 'Zwaartepunten' are discussed below.

VU Physics 'zwaartepunt' 1, Particle & Gravitational Physics. One experimental senior position and one theoretical junior position are requested to expand our leading national role in gravitational physics. VU physics was the first in the Netherlands (together with Nikhef) to embark on the interferometric detection of gravitational waves (in 2005) in the VIRGO (and later also LIGO) collaboration and involved in the first, seminal detection of gravitational waves by LIGO. Currently, van den Brand is spokesperson of VIRGO. Focus of VU physics (coordinated within Nikhef) will be on instrumentation and data analysis for tests of general relativity and new ways to study black holes to learn about particle physics and cosmology. The (optical) instrumentation focus will connect naturally to LaserLaB and the new mechanical Engineering with UT at VU.

(a) Senior experimentalist with focus on instrumentation. This person is expected to immediately play a leading role in ongoing experiments at Advanced VIRGO and LIGO and prepare for new instruments, including the 3<sup>rd</sup> generation Einstein telescope. Required is expert knowledge of the interferometric instrumentation and expert understanding of its impact on the science program. Furthermore, this person should spot opportunities for synergy, partnerships and innovation in instrumentation. Leadership in analysis of the gravitational wave data is needed.

(b) Junior theorist with focus on data analysis. This person will be involved in data analysis of Advanced VIRGO data and next-generation experiments. Particular emphasis will be on characterizing the noise properties of interferometric detectors. It is of utmost importance to understand transient noise sources, since they can produce signals that are very similar to 'real' detections.

VU Physics 'zwaartepunt' 2, Quantum Metrology and Laser Applications. Another approach to answer fundamental questions about the building blocks of matter and the foundations of space and time are ultraprecise laser measurements of narrow quantum-mechanical resonances in atoms and molecules at low energies (e.g. laser-cooled to low temperatures), in order to detect small deviations from current theories like QED and the Standard Model. Such 'tabletop' experiments probe matter at a completely different energy scale than particle accelerators and are sensitive to deviations from current theories in other ways. A key strength of VU physics is its world-leading infrastructure consisting of advanced lasers and measurement techniques. Highly successful examples are tests of QED using Ramsey-comb spectroscopy, precision spectroscopy in helium Fermi-gas and Bose-Einstein condensate and high-precision determination of the H<sub>2</sub> dissociation energy, and the world's first molecular fountain. To strengthen this 'Zwaartepunt', two junior positions are requested.

a) Junior experimentalist developing a line of research performing ultra-precision frequency measurements in atomic/molecular systems to test QED theory and to measure values of fundamental constant (fine-structure constants, particle masses). This program may also involve the development of novel matter-control methods, such as laser cooling of molecules, optical lattices and ion traps.

b) Junior experimentalist measuring phenomena connected to fundamental physics at the atomic scale, such as variation of fundamental constants, parity violation, CP-violation (through measurement of electric dipole moments), quantum interferometric approaches with ultracold matter to probe gravity effects, search for forces mediated by new bosons, probing of higher dimensions.

For both positions we foresee strong connections with VU efforts within ARCNL.

VU Physics 'zwaartepunt' 3, Photonics for Life and Health. Given the aging population, there is an increasing need for more, better, more cost-effective and personalized medical care. Photonics is a key technology that is currently already frequently used in diagnosis and therapy but has an even larger potential because of its relatively low cost, potential for high resolution, throughput, speed and minimal invasiveness. Within this 'Zwaartepunt', one experimental junior position is requested to expand the activities in the development of optical techniques for biomedical applications. The research lines will be partly located in the VUmc imaging center, to further improve translation to the clinic with Amsterdam UMC partners. The biomedical center of gravity in the National Agenda Photonics is in Amsterdam. VU research in this field is tightly connected to valorization activities (spin-offs, Demonstrator lab, the SBI BSc and MSc programs). Focus of this new hire will be in the area of wave-front shaping, miniature endoscopy, exploration of imaging through multimode fibers, to image deeper and with more contrast in tissue or in the body and/or computational imaging, including the use of artificial intelligence in image interpretation, to better integrate the imaging process with diagnosis.

VU Physics 'zwaartepunt' 4, Photosynthesis and Energy. Two experimental junior positions are requested to expand the activities within this 'Zwaartepunt' in two areas.

(a) Spectroscopy of energy materials and devices. Building on the current strength in laser spectroscopy (LaserLaB) and materials fabrication, characterization, and device physics an expansion is foreseen in optical spectroscopy of materials, such as nanostructures, 2D materials, organic and/or hybrid semiconductors, thin-film semiconductors, or related topics. This expansion will strengthen the synergy between the efforts in spectroscopy of photosynthesis and in energy devices. The ideal candidate has a background in condensed matter physics and/or physical chemistry, with a strong focus on advanced spectroscopy (including ultrafast, non-linear, multidimensional, IR, Raman).

(b) *In vivo* spectroscopy. Research in photosynthesis is moving from *in vitro* to *in vivo* studies, on chloroplasts, cells and intact organisms, in order to study photosynthesis in its full complexity. Therefore, a position is requested for an experimentalist who will develop and apply novel instrumentation for *in vivo* spectroscopy, which will strengthen and broaden the leading position of VU in advanced biospectroscopy. Excellent facilities and expertise are available in house for modification of organisms (algae and plants), production of hybrid systems. Collaborations are expected with the Biophysics group at Wageningen University. Valorization activities (e.g. with Demonstrator lab) are foreseen to commercialize instrumentation for research and agriculture.



VU Physics			
Priority	Individual positions and subsequent research themes	'Zwaartepunt'	Requested budget
1	Junior tenure-track gender (f) position	Any	150K
2	Senior professor Gravitational Physics	1. Particle and Gravitational Physics (a)	250K
3	Junior tenure track position Photonics for Life and Health	3. Photonics for Life and Health (a)	150K
4	Junior tenure track position Spectroscopy of energy materials and devices	4. Photosynthesis and energy (a)	150K
5	Junior tenure track position Ultra-precision frequency experiments	2. Quantum metrology and laser applications (a)	150K
6	Junior tenure track position <i>In vivo</i> spectroscopy	4. Photosynthesis and energy (b)	150K
7	Junior tenure track position Gravitational Wave Physics	1. Particle and Gravitational Physics (b)	120K
8	Junior tenure track position Fundamental physics at the atomic scale	2. Quantum metrology and laser applications (b)	150K
Total requested budget for VU Physics			1,270K

## VU Chemistry

VU Chemistry proposes 8 positions (at least 35% female, preferably 50%) that serve our ambitions to excel in research and education, to improve diversity of staff, and to rejuvenate the age composition of our staff. The latter target is addressed by focussing on junior tenure-track (UD) positions which have the additional advantage of offering naturally a higher percentage of female candidates. In the past period, we have strengthened our 'zwaartepunten' (Computational Chemistry; Synthesis; Medicinal Chemistry & Chemical Biology; Analytical Chemistry & Spectroscopy) along the translational line from molecule to medicine. Here, we augment this by proposing a senior (HL) position on the chemical biology of the (gut) microbiome. The other positions serve the start-up of new research lines that strengthen the fundamentals of each 'Zwaartepunt' as well as the internal cohesion within Chemistry and towards Physics and Computer Science. This is done in complementary and synergistic collaboration between VU (chemistry of life) and UvA (sustainability).

VU Chemistry, 'zwaartepunt' 1, Medicinal Chemistry & Chemical Biology. We request one senior and three junior staff members to strengthen this 'Zwaartepunt':

(a) Junior TT: Biochemistry of Personalized Medicine. Individual variation in drug metabolism and elimination are important contributing factors to both, drug efficacy and drug safety, and drastically affects how different patients react to certain medicines. In this new research line, the molecular basis of individual variation in ADMET (Absorption, Distribution, Metabolism, Excretion and Toxicology) will be elucidated by e.g. linking drug metabolism, drug transport to variation in gene and protein function. Moreover, the utilization of human induced pluripotent stem cells differentiated into different ADMET relevant tissues such as liver, kidney, intestine and vasculature will be an important new technological development to drive a new age of drug development and safety.

(b) Senior HL: Chemical Biology of the Microbiome. Gut microbiota have both direct and indirect effects on drug and xenobiotic metabolisms, and this has important consequences for both efficacy and toxicity of a number of drugs. To decipher how the gut microbiome impacts human disease and/or drug effectiveness, it is crucial to understand the (bio)chemical transformations carried out by the gut microbiome. To gain mechanistic insights, this new research line will uncover the molecular basis for the metabolic activities of the gut microbiome by linking metabolism to genes and enzymes. Ultimately, this will deliver new methods for the controlled manipulation of the metabolic activities of the microbiome and also aid in our understanding of the contribution of the microbiome in the individual responsiveness to drugs.

(c) Junior TT: Computer-Assisted Drug Design. This position plays an important role in improving the molecular understanding of ligand-protein interactions using Computer-Aided Drug Design (CADD). CADD tools are used to explore the features of ligand-protein interactions in all chemical dimensions (including affinity, binding kinetics and binding thermodynamics). The work combines biochemical and biophysical data as well as structural information. Whereas several archetypical protein targets will be explored in unprecedented detail to improve fundamental molecular understanding, the insights gained will be extended towards complete protein families and genetic differences on species and individual level. The combined data are linked and stored in curated, open chemogenomics databases. Using these accumulating resources, machine learning and artificial intelligence approaches will retrieve useful molecular information that allows the efficient fragment-based design of ligands with well-defined pharmacodynamic properties for specific targets, personalized medicines and highly effective drug combination therapies.

(d) Junior TT: Biophysical Analysis of Drug-Target Interactions. In recent years, new biophysical techniques have become available to study the intrinsically complex molecular drug-target interactions, allowing the study of e.g. thermodynamic and conformational aspects of such bimolecular interactions. In this new research line, which also connects with Analyt. Chem. & Spectr., new biophysical strategies will be employed to study the interaction of small molecule drugs and/or large anti-body-based drugs with important protein drug targets. The department has access to high-end NMR, X-ray, isothermal calorimetry and surface plasmon resonance equipment, whereas links with the VU Physics department will also allow the use of newer technologies (Wuite, Ianuzzi). Moreover, with the development of new highly sensitive biosensor techniques, also very sensitive microscopy techniques will become available to study conformational changes of drug target proteins upon engagement by drug molecules.

VU Chemistry, 'zwaartepunt' 2, Computational Chemistry. We request one junior staff member to strengthen this 'Zwaartepunt':

(a) Junior TT: Theory-Driven Organic Synthesis: This position establishes a new research line that integrates experimental and computational approaches to molecular and supramolecular design and synthesis. In theory-driven organic synthesis, the entire process ranging from design, via experimental quest, till optimization of a new synthetic tool, is characterized by an integrated approach of computational exploration and analysis in concert with experimental organic synthesis. It involves the development of new software tools that couple multiscale quantum chemical methods with modern concepts from computer sciences, in particular, artificial intelligence (AI) modules with specialized knowledge rules for individual types of tasks. The position links directly with the 'Zwaartepunt' Quantitative Data Analytics of VU Computer Science. This will boost rational (theory-based) design

from a single molecular level to complex multi-step synthesis and create connections between chemical theory, synthesis and computer sciences.

VU Chemistry, 'zwaartepunt' 3, Synthesis. We request one junior staff member to strengthen this 'Zwaartepunt':

(a) Junior TT: Sustainable Manufacturing of Therapeutics.

A lack of sustainable production methods challenges cost-effective and environmentally-responsible delivery of tailored Active Pharmaceutical Ingredients (APIs). Biomass, especially if derived from non-edible sources or from food industry waste, can be regarded as a renewable source of building blocks for synthesizing products with a higher added value. While most scientific efforts have focused so far on the production of high volume, low-cost commodity chemicals, the synthesis of high added value bio-based compounds, such as APIs, is underexplored. The current synthetic pathways towards these highly valued compounds are predominantly based on building blocks derived from mineral oil. This position focuses on fundamental research towards completely novel chemistry, especially for application driven manufacturing processes in the pharma industry based on bio-synthetic procedures that utilize bio-based (crude-oil independent) building blocks. The position bridges organic, medicinal and peptide chemistry and will have access to state-of-the art structure elucidation facilities (X-ray and NMR) as well as additional biophysical and analytical instrumentation (ITC, SPR, CD, high-resolution HPLC-MS/MS).

VU Chemistry, 'zwaartepunt' 4, Analytical Chemistry & Spectroscopy. We request two junior staff members to strengthen this 'Zwaartepunt':

(a) Junior TT: Bioanalysis and Characterization of Complex Natural Products. Natural products are one of the ways forward for the discovery of new drugs to tackle unmet clinical needs. Yet, the determination of the chemical composition of promising natural resources (e.g. plant extracts or snake venoms) is highly challenging within the field of Analytical Chemistry. The techniques best positioned to tackle such mixtures experimentally include mass spectrometry and chromatography, or new alternative techniques. These include combinations of the above methods and the simultaneous integration of high-resolution determination of biological activities of the various constituents of natural mixtures. The new research line will develop efficient data mining and visualization techniques to aid in the determination of the chemical structures of biologically relevant constituents of complex natural mixtures. This position will strengthen the 'Zwaartepunt' of Analytical Chemistry & Spectroscopy in Amsterdam, as organized in the Center of Analytical Sciences Amsterdam (CASA).

(b) Junior TT: Analytics for Protein Structure-Activity Relations. Many functional proteins exhibit an inherent, but essential, heterogeneity due to extensive post-translation modifications. To decipher the role of protein heterogeneity in biological and pharmacological function, it is critical to resolve proteoforms and determine their individual activity. This TT position establishes a new research line that integrates detailed protein structural characterization with activity assessment of essential proteoforms. This involves development of analytical platforms combining high-resolution native protein separations with miniaturized functional assays in parallel to mass spectrometric structural assignment. The research will be augmented by the design of dedicated computational approaches establishing appropriate correlations between complex protein structural data and functional properties. Comprehending protein heterogeneity will ultimately drive the rational development and production of highly valued (industrial) enzymes and biopharmaceuticals.

VU Chemistry			
Priority	Individual positions and subsequent research themes	'Zwaartepunt'	Requested budget
1	Junior TT: Biochemistry of Personalized Medicine Elucidation of molecular basis of individual variation in ADMET by linking drug metabolism/ transport to variation in gene and protein function.	1. Medicinal Chemistry & Chemical Biology	150K
2	Junior TT: Theory-Driven Organic Synthesis Quantum chemical exploration, couple multiscale QM methods with artificial intelligence modules	2 Computational Chemistry	150K
3	Senior HL: Chemical Biology of the Microbiome: Molecular basis for the metabolic activities, new methods for controlled manipulation of metabolic activities	1. Medicinal Chemistry & Chemical Biology	250K
4	Junior TT: Bioanalysis of Complex Natural Products New hybrid methodologies for analysing complex natural-product mixtures, including data mining and visualization	4. Analytical Chemistry & Spectroscopy	150K
5	Junior TT: Sustainable Manufacturing of Therapeutics Novel chemistry for application-driven manufacturing in pharma industry based on bio-synthetic procedures	3. Synthesis	150K
6	Jr TT: Computer-Assisted Drug Design: Combining biochemical/physical data, insight into protein families, machine learning for personalized medicines	1. Medicinal Chemistry & Chemical Biology	120K
7	Jr. TT: Biophysical Analysis of Drug-Target Interactions New biophysical strategies for studying the interaction of small molecule drugs and antibody-based drugs	1. Medicinal Chemistry & Chemical Biology	150K
8	Junior TT: Analytics for Protein Structure-Activity Relations Elucidation role of protein heterogeneity, analytical strategies combining high-resolution native protein separations	4. Analytical Chemistry & Spectroscopy	150K
Total requested budget for VU Chemistry			1,270K

## VU Mathematics

In line with its long-term strategy, the Department of Mathematics aims to strengthen its principal research lines in *Dynamical Systems* and *Stochastics* in the areas computational mathematics, including modeling, and data science. The requested positions all lie in the focus areas at the interface between the NDNS+ and STAR clusters, as outlined in the nationally coordinated plan laid down in the 'sectorbeeld'. On the one hand, the internal connections between dynamical systems and stochastics will be reinforced through requested positions in the 'focusgebieden' *Statistical Learning* and *Dynamic Data*. On the other hand, the links with adjoining areas will be enhanced through requested positions in the 'focusgebieden' *Geometric and Stochastic Evolution* (connection to the GQT cluster) and *Networks* (connection to the DIAMANT cluster). Networks have both important stochastic and dynamic features and the proposed positions will thus also generate natural opportunities for uniting the two viewpoints. By bolstering the distinct and coherent profile of the department, these positions will lead to a quality stimulus which will further boost the international visibility of the department and its local, national and international connections. At the same time, the department aims to improve its gender balance. In particular, the Department of Mathematics requests one position for an excellent female applicant in any area of applied and computational mathematics, which can be anticipated to strengthen either of its principal research lines *Dynamical Systems* and *Stochastics*; we count it half towards the either, but describe it immediately below. All but one of the requested positions are junior positions. This is a deliberate choice, given the relatively high senior/junior staff ratio in the department. In Stochastics this ratio is somewhat smaller and the requested Full Professor position in Fundamental Data Science is to firmly propel the new initiatives in this area.

0. *Applied and Computational Mathematics*. The Department of Mathematics is strongly committed to improving the gender balance of its staff. While we strive to hire multiple female colleagues as part of the *Sectorplan*, there is compelling evidence that the likelihood of hiring excellent female mathematicians is strongly increased when advertising for a position without specifying a specific subfield of mathematics. For this reason we request one position for a strong female candidate in the very broad area of applied and computational mathematics. We thus purposefully do not designate any preferred subfield. Indeed, we are convinced that any female researcher in applied and computational mathematics will strengthen the strategic focus of the department on dynamical systems and stochastics.

In 'zwaartepunt' 1 *Dynamical Systems – Computational Mathematics* the Department of Mathematics requests three positions:

1. *Data Assimilation and Data Driven Dynamics*. The department aims to broaden its excellent dynamical systems research with a new hire focusing on dynamics of systems for which the nonlinearities are imprecisely known or have weakly constrained parameters. The need to analyze such problems arises from the unrelenting quest to understand the dynamics of complex (networked) systems in which the phenomena are too impenetrable for the nonlinearities to be derived from first principles. Such multi-scale models typically appear in the life and earth sciences. Indeed, weather forecasting and climate modelling are prime (by now almost classical) examples, whereas in systems biology, neuroscience and genetics the number of variables describing the dynamics is so vast, and their values are so difficult to measure/quantify, that novel approaches are necessary. Examples of mathematical progress in this direction include model reduction techniques, topological data analysis, and computational dynamics. The research area is complementary to the existing expertise of the dynamics group, and is expected to strengthen the bonds with the applied analysis groups at UU, TUE and UT. This position is in the 'focusgebied' *Dynamic Data*.
2. *Dynamics on Large Networks*. The interaction of a large number of entities often leads to rich, complex and unexpected collective behaviour. One example is synchronisation: the process by which neurons fire simultaneously and social consensus is reached. Other emergent dynamics occurs when cars drive on a busy road, when atoms self-organise in composite materials, or when a power failure leads to a black-out. The modelling of such collective phenomena leads to dynamical systems on very large networks, and to partial differential equations in the infinite-dimensional continuum limit. The interest in this topic has been rapidly increasing in the last few years: it requires the development of new mathematical theory, and has many direct relations to applications as well. Central questions are: How to describe the relation between the network structure and the emergent dynamics in such large networks? And how can one exploit these novel mathematical insights both to do useful, reliable computations on these networks, and to control them effectively? This position connects particularly well to current research in the department on bifurcation theory, computational dynamics and partial differential equations, it has the potential for collaborative research with the network statistics group, and it will increase the interaction with at the applied analysis group at TUE and the systems biology group at VU. This position is in the 'focusgebieden' *Networks* and *Geometric and Stochastic Evolution*.
3. *Geometric PDEs*. The dynamical systems group has a long tradition in applying variational, topological and geometric techniques to concrete models from areas such as pattern formation, material science and systems biology. These models usually take the form of partial differential

equations (PDEs), sometimes enhanced by nonlocal (in time or space), stochastic or curvature-related terms. While many properties of PDE models are known in simple cases, the impact of geometric, nonlocal and stochastic influences on the evolutionary properties of solutions is ill understood. Such effects are often crucial in applications, and mathematical research is needed to provide structural insights. While the focus for this position is on developing novel theory for these systems, one may think of PDE models ranging from Einstein's equations of relativity to the motions of cell walls in biology. This links well with current research interests in the department and there are ample connections to work done at TUD, UL, RU. This position is in the 'focusgebied' *Geometric and Stochastic Evolution*.

In 'Zwaartepunt' 2 *Stochastics – Mathematical Data Science* the Department of Mathematics requests three positions. Concerning the national embedding of the positions 1 and 2 in the 'focusgebied' *Statistical Learning* we remark that the clusters NDNS+ and STAR will start a national focus group on the Mathematics of Machine Learning. The two clusters will make seed money available to kick-start this.

1. *Fundamentals of Data Science*. There is a worldwide, persistent and accelerating trend in which mathematical statistics directs itself towards learning from *big* data, also called statistical learning. While the department already conducts research in this area, the aim of the establishment of a chair in this area is to place the department at the forefront of these exciting developments. The chair will be key in boosting the visibility and quality of our fundamental statistics research, and its occupant will act as a linking pin to applied areas. Statistical learning has become an indispensable part of many educational programs within the Faculty of Science and beyond, especially in mathematics, business analytics and computer science. The chair will bring new impulses to these educational activities, which is highly desirable in view of the rapidly growing numbers of students interested in the field. This position is the counterpart of the requested full professor position in Data science of the VU-Computer Science department, and will give more depth to our collaboration with their Artificial Intelligence group. It will also bring joint research with the Mathematical Statistics group in Leiden, and increase the possibilities for research collaboration with companies. This position is in the 'focusgebied' *Statistical Learning*.
2. *Computational Statistics*. The field of stochastic algorithms, such as Markov chain Monte Carlo methods and stochastic optimization techniques like stochastic gradient descent (used in the training of neural networks), is undergoing rapid development, due to the increase of computational power and the growth of available data. This position is focused on the mathematical exploration of these modern developments at the intersection of statistics and machine learning. The research may concern theory, for example to understand algorithmic complexity, as well as methodological advances, for example in the use of parallel computing architectures. The research has strong links with the theoretical and applied statistics, as well as analytics and optimization research in our Stochastics group, and connects to research in the statistics groups of UL, TUD, and TU. This position is in the 'focusgebied' *Statistical Learning*.
3. *Statistics for Network Data*. This position will further strengthen the fundamental pillar of the research in statistical data analysis. The researcher on this position will perform fundamental mathematical research concerning statistical models and methods for the analysis of complex network data. This may concern Gaussian graphical modelling, broadly used for application in the life sciences, but also statistical estimation in network graphs, network topology inference, processes on graphs, statistical theory for analysis of network flow data, or more general graphical models. This research will naturally complement and strengthen the existing research in statistics for networks which is, through its focus on applications in the life sciences, neuroscience, traffic and communication networks, of a more applied nature. It will also complement research activities within the 'zwaartekrachtprogramma' NETWORKS in which the statistical component does not play a prominent role. This position and the junior statistical learning position requested by our colleagues from the UvA, will fill this gap, each from a different angle. The foundation for research within NETWORKS has already been laid via three joint PhD projects with researchers from the UvA. This position is in the 'focusgebied' *Networks*.

VU Mathematics			
Priority	Individual positions and subsequent research themes	'Zwaartepunt'	Requested budget
1	Junior: TT/Assistant/Associate professor, <i>Female</i> Research theme: Dynamic Data/Statistical Learning/Networks/Geometrical and Stochastic Evolution In particular: <i>Applied and computational mathematics</i>	1. Dynamical Systems and/or 2. Stochastics	120K
2	Senior: Full professor Research theme: Statistical Learning In particular: <i>Fundamentals of data science</i>	2. Stochastics	180K
3	Junior: TT/Assistant/Associate professor Research theme: Dynamic Data In particular: <i>Data assimilation and data driven dynamics</i>	1. Dynamical Systems	120K
4	Junior: TT/Assistant/Associate professor Research theme: Statistical Learning In particular: <i>Computational statistics</i>	2. Stochastics	120K
5	Junior: TT/Assistant/Associate professor Research themes: Networks and Stochastic Evolution In particular: <i>Dynamics on large networks</i>	1. Dynamical Systems	120K
6	Junior: TT/Assistant/Associate professor Research theme: Networks In particular: <i>Statistics for network data</i>	2. Stochastics	120K
7	Junior: TT/Assistant/Associate professor Research theme: Geometrical and Stochastic Evolution In particular: <i>Geometric PDEs</i>	1. Dynamical Systems	120K
Total requested budget for VU Mathematics			900K

## 9. Smart Parameters: goals and monitoring

<b>Table 4 VU Computer Science</b>		
	<b>Huidig (31-12-2018)</b>	<b>Ambitie 2024</b>
Aantal vast aangesteld WP	20.8	27
Aantal tenure trackers	8.8	13
Aantal WP met geclausuleerd vast dienstverband	0.0	0
Aantal post-docs	23.6	31
Aantal vrouwen, vast aangesteld WP	4.5	9
Aantal vrouwen in tenure tracks	1.0	4
Aantal vrouwelijk WP met geclausuleerd vast dienstverband	0.0	0
Aantal vrouwelijke post-docs	4.7	9
Percentage vrouwen in de nieuwe sectorplanaanstellingen:	-	≥35%



<b>Table 4 VU Physics</b>		
	<b>Huidig (31-12-2018)</b>	<b>Ambitie 2024</b>
Aantal vast aangesteld WP	22.7	29
Aantal tenure trackers	2.4	6
Aantal WP met geclausuleerd vast dienstverband	0.0	0
Aantal post-docs	21.4	28
Aantal vrouwen, vast aangesteld WP	3.0	6
Aantal vrouwen in tenure tracks	1.4	3
Aantal vrouwelijk WP met geclausuleerd vast dienstverband	0.0	0
Aantal vrouwelijke post-docs	4.0	8
Percentage vrouwen in de nieuwe sectorplan aanstellingen:	-	≥35%

<b>Table 4</b> <b>VU Chemistry</b>		
	<b>Huidig</b> <b>(31-12-2018)</b>	<b>Ambitie</b> <b>2024</b>
Aantal vast aangesteld WP	23.3	30
Aantal tenure trackers	1.4	5
Aantal WP met geclausuleerd vast dienstverband	0.0	0
Aantal post-docs	17.1	22
Aantal vrouwen, vast aangesteld WP	4	8
Aantal vrouwen in tenure tracks	0.4	3
Aantal vrouwelijk WP met geclausuleerd vast dienstverband	0.0	0
Aantal vrouwelijke post-docs	4.2	8
Percentage vrouwen in de nieuwe sectorplanaanstellingen:	–	≥35%

<b>Table 4</b> <b>VU Mathematics</b>		
	<b>Huidig</b> <b>(31-12-2018)</b>	<b>Ambitie</b> <b>2024</b>
Aantal vast aangesteld WP	15.6	20
Aantal tenure trackers	4.0	9
Aantal WP met geclausuleerd vast dienstverband	0.0	0
Aantal post-docs	2.0	3
Aantal vrouwen, vast aangesteld WP	1.6	4
Aantal vrouwen in tenure tracks	0.0	3
Aantal vrouwelijk WP met geclausuleerd vast dienstverband	0.0	0
Aantal vrouwelijke post-docs	0.0	1
Percentage vrouwen in de nieuwe sectorplanaanstellingen:	-	≥35%

Table 5 VU Computer Science		Gemiddelde per jaar over periode 2016-2018	Ambitie 2024
Quality	<b>Total number</b> of competitive grants awarded in the period 2016-2018	<ul style="list-style-type: none"> <li>• ERC Synergy</li> <li>• ERC Advanced</li> <li>• ERC Consolidator</li> <li>• <b>ERC Starting: 2</b></li> <li>• <b>NWO Veni: 4</b></li> <li>• <b>NWO Vidi: 2</b></li> <li>• <b>NWO Vici: 1</b></li> </ul>	X
	<b>Total number</b> of Nobel Spinoza, Stevin and IEEE awards, awarded to researchers employed by the university on 31-12-2018	0	
	Average number of peer review articles and review conference proceedings per year in the period 2016-2018	252	
	Other parameters of esteem	<ul style="list-style-type: none"> <li>• 2 Members of the Academia Europaena</li> <li>• 1 KNAW member</li> <li>• 1 Young Academy KNAW membership</li> </ul>	
Relevance	Average amount of NWA grants per year, awarded in the period 2016-2018, in M€	0	0.6
	Average amount of Topsector grants per year, awarded in the period 2016-2018, in M€	0	0.20
	Average amount of the industrial contribution to public private collaborations per year, in the period 2016-2018, in M€	0.21	0.30
	Average expenses/turn-over per year in the period 2016-2018 of 2 <sup>nd</sup> , 3 <sup>rd</sup> , 4 <sup>th</sup> (= gifts) flow of funds in M€	3.7	5.7
	Total number of start-ups / spin-offs in the period 2016-2018	0	3
	Total number of <u>new patents filed</u> in the period 2016-2018	0	0
	Societal collaborations (narrative)	See below	

**Societal collaborations:** VU Computer Science has a long history of interaction with societal partners. In addition to our standard interactions with our university partners (primarily with UVA Ivl), we have close collaborations with NWO's CWI. We are a founding member of Amsterdam Data Science, AMS Sec (for security applications), ACBA (for interactions with partners from Amsterdam's 'Zuidas' and other local industry), as well as a collection of city, provincial and national government projects. The department has invested considerable resources in standardisation activity, working closely with W3C (the World-Wide Web Consortium). In this regard, we have chaired standardisation working groups at W3C and have contributed heavily to technology for OWL. Lastly, we are active participants in a host of European research projects via various Commission funding instruments.

Table 5 VU Physics		Gemiddelde per jaar over periode 2016-2018	Ambitie 2024
Quality	<b>Total number</b> of competitive grants awarded in the period 2016-2018	<ul style="list-style-type: none"> <li>ERC Synergy</li> <li><b>ERC Advanced: 2</b></li> <li>ERC Consolidator</li> <li>ERC Starting</li> <li><b>NWO Veni: 4</b></li> <li><b>NWO Vidi: 1</b></li> <li>NWO Vici</li> </ul>	X
	<b>Total number</b> of Nobel Spinoza, Stevin and IEEE awards, awarded to researchers employed by the university on 31-12-2018	0	
	Average number of peer review articles and peer review conference proceedings per year in the period 2016-2018	272	
	Other parameters of esteem	<ul style="list-style-type: none"> <li>Research quality SEP (2018): world leading / excellent</li> <li>Total number of research grants (2016-2018): 51</li> <li>Awards: Physica Prize, Gruber Cosmology Prize, Breakthrough Prize in Fundamental Physics, NWO Physics valorization prize (3x), G.G. Stokes Award, Optical Society Fellow, Fellowship of the American Physical Society (2x), Templeton Prize, VU University Research Chair (2x))</li> <li>Organization of prestigious international conferences: Gordon Research Conference (2x), 17<sup>th</sup> International Congress of Photosynthesis, European Conference on Spectroscopy of Biological Molecules.</li> </ul>	
Relevance	Average amount of NWA grants per year, awarded in the period 2016-2018, in M€	0	0.6
	Average amount of Topsector grants per year, awarded in the period 2016-2018, in M€	0.12	0.20
	Average amount of the industrial contribution to public private collaborations per year, in the period 2016-2018, in M€	0.15	0.20
	Average expenses/turn-over per year in the period 2016-2018 of 2 <sup>nd</sup> , 3 <sup>rd</sup> , 4 <sup>th</sup> (= gifts) flow of funds in M€	7.0	9.9
	Total number of start-ups / spin-offs in the period 2016-2018	7	12
	Total number of <u>new patents filed</u> in the period 2016-2018	20	10 p/y
	Societal collaborations (narrative)	See below	

**Societal collaborations:** VU physics has been very successful in valorisation efforts. VU physics is a partner in the institute ARCNL, is involved in several other industrial collaborations (e.g. with Shell, Ninepoint Medical, Heidelberg Engineering, ASML, VDL) and leads efforts to bring physics inventions to the clinic (in collaboration with Amsterdam UMC and others). Furthermore, several highly successful startup companies are based on inventions from VU physicist, including Optics11, Innoseis, OPNT, LUMICKS, and Tritos diagnostics (together more than 75 employees). This has resulted in 3 NWO Physics Valorization Prizes. VU physics is a key player in Demonstrator Lab, a facility for students and researchers to transform ideas into products / companies; funded by the city of Amsterdam. In the 2018 SEP evaluation of LaserLaB Amsterdam, Relevance to Society was marked world leading / excellent, in the words of the evaluation committee "The societal relevance of LaserLaB is amazingly strong. The work on technology transfer being carried out at LaserLaB is creative, unique, and sets an example for other such groups elsewhere in Europe." Furthermore, VU physics research connects to the crucial societal challenges in human health and the energy transition.

Table 5 VU Chemistry		Gemiddelde per jaar over periode 2016-2018	Ambitie 2024
Quality	<b>Total number</b> of competitive grants awarded in the period 2016-2018	<ul style="list-style-type: none"> <li>• ERC Synergy</li> <li>• ERC Advanced</li> <li>• ERC Consolidator</li> <li>• <b>ERC Starting: 1</b></li> <li>• <b>NWO Veni: 1</b></li> <li>• NWO Vidi</li> <li>• <b>NWO Vici: 1</b></li> </ul>	X
	<b>Total number</b> of Nobel Spinoza, Stevin and IEEE awards, awarded to researchers employed by the university on 31-12-2018	0	
	Average number of peer review articles and peer review conference proceedings per year in the period 2016-2018	138	
	Other parameters of esteem	<ul style="list-style-type: none"> <li>• KNAW membership</li> <li>• KHMW membership</li> <li>• ARC CBBC membership</li> <li>• Several editorial board memberships at the department of renowned international magazines</li> <li>• Membership at "committees of trust" (NWO, ERC, visitations of other institutes)</li> <li>• Many invites / keynote lectures at international conferences</li> <li>• Organizing several conferences by our staff</li> <li>• Excellent assessment of our research and education during visitations in 2017 and 2018</li> <li>• Successful spin-offs (SCM, Griffin, IOTA)</li> </ul>	
Relevance	Average amount of NWA grants per year, awarded in the period 2016-2018, in M€	0	0.6
	Average amount of Topsector grants per year, awarded in the period 2016-2018, in M€	0	0.20
	Average amount of the industrial contribution to public private collaborations per year, in the period 2016-2018, in M€	0.31	0.40
	Average expenses/turn-over per year in the period 2016-2018 of 2 <sup>nd</sup> , 3 <sup>rd</sup> , 4 <sup>th</sup> (= gifts) flow of funds in M€	5.8	8.8
	Total number of start-ups / spin-offs in the period 2016-2018	4	7
	Total number of <u>new patents filed</u> in the period 2016-2018	2	1 p/y
	Societal collaborations (narrative)	See below	

**Societal collaborations:** VU chemistry has been very successful in valorization efforts. VU chemistry valorises its state-of-the-art expertise through three different spin-offs: (i) Software for Chemistry & Materials (SCM) which co-develops and sells the ADF code of the theoretical chemistry group to hundreds of academic and industrial laboratories worldwide; (ii) Griffin Discovery which has converted novel GPCR ligands with anti-inflammatory properties into clinical candidates; (iii) IOTA Pharmaceuticals which offers unique fragment libraries as well as fragment-based drug discovery services to the pharmaceutical sciences community. These spin-offs have together around 22 employees. Just as important is the pivotal role of VU chemistry in the translational chain of drug development from molecule to patient within the Amsterdam Institute of Molecules Medicines and Systems (AIMMS). Within the context of AIMMS valorization strategies have been developed that aim at economic target groups such as pharmaceutical companies. This resulted in the above-mentioned spin-offs and various patents. In addition, a respectable number of the compounds developed and studied have been adopted by the scientific research community as important research tools (e.g., a dozen VUF compounds are made commercially available by companies like Tocris Ltd). In collaboration with VU physics and the faculties of social and of economical sciences, a chair for Science Business & Innovation has been appointed, that contributes to increasing entrepreneurial thinking of the students and organizes collaboration events with e.g. large pharmaceutical companies. Through a chair in theoretical chemistry, VU chemistry is also an associated partner in the Advanced Research Center - Chemical Building Blocks Consortium (ARC CBBC). There are industrial collaborations with Nouryon (former AkzoNobel Polymer Chemistry), DSM and others. VU chemistry research connects to crucial societal challenges in human health with a second pillar focusing on sustainability (interaction and synergy with UvA).



Table 5 VU Mathematics		Gemiddelde per jaar over periode 2016-2018	Ambitie 2024
Quality	<b>Total number</b> of competitive grants awarded in the period 2016-2018	<ul style="list-style-type: none"> <li>• ERC Synergy</li> <li>• ERC Advanced</li> <li>• ERC Consolidator</li> <li>• ERC Starting</li> <li>• NWO Veni</li> <li>• <b>NWO Vidi: 1</b></li> <li>• NWO Vici</li> </ul>	X
	<b>Total number</b> of Nobel Spinoza, Stevin and IEEE awards, awarded to researchers employed by the university on 31-12-2018	0	
	Average number of peer review articles and peer review conference proceedings per year in the period 2016-2018	61	
	Other parameters of esteem	<ul style="list-style-type: none"> <li>• Research quality (SEP 2015) very good (excellent in dynamical systems); relevance to society excellent</li> <li>• Membership &amp; chair NWO ENW-Tafel Wiskunde</li> <li>• Chair CO-Platform Wiskunde Nederland</li> <li>• Member Applied Mathematics Committee European Mathematical Society</li> <li>• Chair Mathematics cluster NDNS+</li> <li>• Chair Mathematics Advisory Board Lorentz Center</li> <li>• Memberships NWO jury committees</li> <li>• Several editorial board memberships of renowned international journals</li> <li>• Local and scientific organization of prestigious international conferences (European Conference of Mathematical and Theoretical Biology, European Meeting of Statisticians)</li> <li>• Successful spin-offs (CCmath, Prompt Business Analytics, Stokhos)</li> </ul>	
Relevance	Average amount of NWA grants per year, awarded in the period 2016-2018, in M€	0.04	0.2
	Average amount of Topsector grants per year, awarded in the period 2016-2018, in M€	0.10	0.15
	Average amount of the industrial contribution to public private collaborations per year, in the period 2016-2018, in M€	0.15	0.20
	Average expenses/turn-over per year in the period 2016-2018 of 2 <sup>nd</sup> , 3 <sup>rd</sup> , 4 <sup>th</sup> (= gifts) flow of funds in M€	0.9	1.8
	Total number of start-ups / spin-offs in the period 2016-2018	3	5
	Total number of <u>new patents filed</u> in the period 2016-2018	0	0

	Societal collaborations (narrative)	See below
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**Societal collaborations:** We have a strong tradition in mathematics for society. This is one of the factors that distinguishes us from the other mathematics departments at general universities in the Netherlands. Our most important collaboration areas are in business analytics, with a wide of range of application areas, such as healthcare, emergency services (e.g. ambulance planning), safety and security, call centers, airlines, public transport, finance, entertainment, culture, social networks (e.g. twitter), telecommunications, road-traffic and mobility, amongst others. We are co-founder of the Patient flow Improvement Center Amsterdam (PICA). Over the past few years, PICA has evolved into an influential platform for exchanging knowledge and experience between healthcare practitioners and academics. We are also co-founder of the Amsterdam Center for Business Analytics (ACBA). ACBA is a collaboration between the Faculty of Economic Sciences, the Department of Mathematics, Computer Science and CWI. Other important societal collaborations are in the life sciences: there are long-standing joint projects with several biology and medical groups of VU and VUmc, especially within the Neuroscience Campus Amsterdam. Finally, we have close ties to the Netherlands Forensic Institute (NFI). This has led to methodologies for familial search in a DNA data base which are used in practice. We are also involved in training legal representatives like judges, prosecutors, and lawyers in probabilistic interpretation and weighing of evidence

<b>Table 6 VU Computer Science</b>		
	<b>Gemiddelde 2016 - 2018</b>	<b>Ambitie 2024</b>
Instroom bachelorstudenten per oktober*	275	400
Percentage vrouwen	25%	30%
Instroom masterstudenten per oktober*	231	300
Percentage vrouwen	30%	35%
Rendement BSc-diploma's**	64%	70%
Rendement MSc-diploma's**	59%	70%
Aantal promoties binnen de discipline:	12	15
Percentage vrouwelijke promoties:	20%	30%

\* In consultation with the UvA, the nationally agreed weighting percentages for the Joint Degree programs between VU and UvA have been adapted.

B Artificial Intelligence: till 31-10-2018 B Lifestyle Informatics CROHO: 56983

M Bioinformatics and Systems Biology: till 31-10-2018 M Bioinformatics CROHO 60106

From 2018 : Ma Bioinformatics & System Biology (jd) VU - UvA: 67.5% - 32.5%

M Computer Science (jd): including M Computer Science (VU)

M Information sciences: 1 year master

M Computational Science (jd) VU - UvA: 0% - 100%

\*\* The VSNU only recently delivered the revised 1cHO files. This has the following consequences:

- The performance data of the last cohort (BSc cohort 2014 and of the MSc cohort 2015) are not yet known and are therefore not included.
- The corrections of numbers of the Joint Degree programs have not been processed yet. This means the Joint Degree numbers are not included.

<b>Table 6 VU Physics</b>		
	<b>Gemiddelde 2016 - 2018</b>	<b>Ambitie 2024</b>
Instroom bachelorstudenten per oktober*	99	200
Percentage vrouwen	34%	42%
Instroom masterstudenten per oktober*	43	75
Percentage vrouwen	29%	35%
Rendement BSc-diploma's**	62%	70%
Rendement MSc-diploma's**	70%	70%
Aantal promoties binnen de discipline:	19	27
Percentage vrouwelijke promoties	20%	30%

\* In consultation with the UvA, the nationally agreed weighting percentages for the Joint Degree programs between VU and UvA have been changed.

B Natuur- & Sterrenkunde (jd) VU-UvA: 20% - 80%

M Physics and Astronomy (jd)VU-UvA: 20% - 80%

\*\* The VSNU only recently delivered the revised 1cHO files. This has the following consequences:

- The performance data of the last cohort (BSc cohort 2014 and of the MSc cohort 2015) are not yet known and are therefore not included.
- The corrections of numbers of the Joint Degree programs have not been processed yet. This means the Joint Degree numbers are not included.

<b>Table 6 VU Chemistry</b>		
	<b>Gemiddelde 2016 - 2018</b>	<b>Ambitie 2024</b>
Instroom bachelorstudenten per oktober*	166	250
Percentage vrouwen	45%	50%
Instroom masterstudenten per oktober*	136	175
Percentage vrouwen	50%	55%
Rendement BSc-diploma's**	69%	70%
Rendement MSc-diploma's**	66%	70%
Aantal promoties binnen de discipline:	8,6	18
Percentage vrouwelijke promoties	21%	40%

\* In consultation with the UvA, the nationally agreed weighting percentages for the Joint Degree programs between VU and UvA have been changed.

B Scheikunde (jd) VU-UvA: 40% - 60%

M Chemistry (jd) VU-UvA: 50% - 50%

\*\* The VSNU only recently delivered the revised 1cHO files. This has the following consequences:

- The performance data of the last cohort (BSc cohort 2014 and of the MSc cohort 2015) are not yet known and are therefore not included.
- The corrections of numbers of the Joint Degree programs have not been processed yet. This means the Joint Degree numbers are not included.

<b>Table 6</b> <b>VU Mathematics</b>		
	<b>Gemiddelde 2016 - 2018</b>	<b>Ambitie 2024</b>
Instroom bachelorstudenten per oktober*	148	200
Percentage vrouwen	35%	40%
Instroom masterstudenten per oktober	72	100
Percentage vrouwen	31%	40%
Rendement BSc-diploma's**	70%	70%
Rendement MSc-diploma's**	70%	70%
Aantal promoties binnen de discipline:	6,7	9
Percentage vrouwelijke promoties	15%	25%

\* B Mathematics: till 31-10-2018 B Wiskunde CROHO: 56980

\*\* The VSNU only recently delivered the revised 1cHO files. This has the following consequences:

- The performance data of the last cohort (BSc cohort 2014 and of the MSc cohort 2015) are not yet known and are therefore not included.
- The corrections of numbers of the Joint Degree programs have not been processed yet. This means the Joint Degree numbers are not included.

## 10. Appendix A

### Permanent staff per discipline and 'Zwaartepunt'

<b>Table 7</b> <b>VU, Computer science, 1. Quantitative data analytics</b>			
Researcher's name	% appointment	Position	Line of research
Eiben	0.5	Full professor	
Hoogendoorn	1.0	Associate prof (UHD)	
Klein	1.0	Assistant prof (UD)	
Gerritsen	1.0	Assistant prof (UD)	
<b>Total size</b>	<b>3.5 fte</b>		

<b>Table 7</b> <b>VU, Computer science, 2. Assessing and evaluating security</b>			
Researcher's name	% appointment	Position	Line of research
Bos	1.0	Full professor	
Giuffrida	1.0	Assistant prof (UD)	
Razavi	1.0	Assistant prof (UD)	
<b>Total size</b>	<b>3.0 fte</b>		

<b>Table 7</b> <b>VU, Computer science, 3. Ethical computing</b>			
Researcher's name	% appointment	Position	Line of research
Van Harmelen	0.5	Full professor	
Eiben	0.5	Full professor	
Hindriks	0.5	Full professor	
Schlobach	0.5	Associate prof (UHD)	
Van Ossenbruggen	0.4	Associate prof (UHD)	
<b>Total size</b>	<b>2.4 fte</b>		

<b>Table 7</b> <b>VU, Computer science, 4. Energy efficient computing</b>			
Researcher's name	% appointment	Position	Line of research
Bal	1.0	Full professor	
Urbani	1.0	Assistant prof (UD)	
Makkes	1.0	Tenure track	
Hijma	1.0	Tenure track	
Bazoubandi	1.0	Tenure track	
<b>Total size</b>	<b>5.0 fte</b>		

<b>Table 7</b> <b>VU, Computer science, 5. Hybrid intelligence</b>			
Researcher's name	% appointment	Position	Line of research
Van Harmelen	0.5	Full professor	
Hindriks	0.5	Full professor	
Ten Teije	0.5	Associate prof (UHD)	
Schlobach	0.5	Associate prof (UHD)	
<b>Total size</b>	<b>2.0 fte</b>		

## VU Physics

<b>Table 7</b> <b>VU, Physics, 1. Particle &amp; Gravitational Physics</b>			
Researcher's name	% appointment	Position	Line of research
Raven	1.0	Full professor	
Rojo	1.0	Tenure track	
Mulders	1.0	Full professor	
vd Brand	1.0	Full professor	
Bulten	1.0	Assistant prof (UD)	
<b>Total size</b>	<b>5.0 fte</b>		

<b>Table 7</b> <b>VU, Physics, 2. Quantum Metrology and Laser Applications</b>			
Researcher's name	% appointment	Position	Line of research
Bethlem	1.0	Associate prof (UHD)	
Eikema	1.0	Full professor	
Ubachs	1.0	Full professor	
Vassen	1.0	Associate prof (UHD)	
<b>Total size</b>	<b>4.0 fte</b>		

<b>Table 7</b> <b>VU, Physics, 3. Photonics for Life and Health</b>			
Researcher's name	% appointment	Position	Line of research
Heller	1.0	Assistant prof (UD)	
Wuijte	1.0	Full professor	
Peterman	1.0	Full professor	
Ariese	1.0	Associate prof (UHD)	
Groot	1.0	Full professor	
de Broer	1.0	Full professor	
Iannuzzi	1.0	Full professor	
Avci	1.0	Tenure track	
Stephens	1.0	Associate prof (UHD)	
<b>Total size</b>	<b>9.0 fte</b>		

<b>Table 7</b> <b>VU, Physics, 4. Photosynthesis and Energy</b>			
Researcher's name	% appointment	Position	Line of research
Croce	1.0	Full professor	
Kennis	1.0	Full professor	
van Stokkum	1.0	Associate prof (UHD)	
Frese	1.0	Assistant prof (UD)	
von Hauff	1.0	Associate prof (UHD)	
Dekker	0.8	Associate prof (UHD)	
<b>Total size</b>	<b>5.8 fte</b>		



## VU Chemistry

<b>Table 7</b> <b>VU, Chemistry, 1. Medicinal Chemistry and Chemical Biology</b>			
Researcher's name	% appointment	Position	Line of research
Leurs	1.0	Full professor	
van Esch	1.0	Full professor	
Smit	1.0	Full professor	
Jennings	1.0	Full professor	
van Muijlwijk-Koezen	1.0	Full professor	
Geerke	1.0	Associate prof (UHD)	
Vos	1.0	Assistant prof (UD)	
Commandeur	1.0	Associate prof (UHD)	
Wijtmans	1.0	Assistant prof (UD)	
Siderius	0.8	Assistant prof (UD)	
Vischer	1.0	Assistant prof (UD)	
<b>Total size</b>	<b>10.8 fte</b>		

<b>Table 7</b> <b>VU, Chemistry, 2. Computational Chemistry</b>			
Researcher's name	% appointment	Position	Line of research
Bickelhaupt	1.0	Full professor	
Fonseca Guerra	1.0	Full professor	
Gori Giorgi	1.0	Full professor	
Visscher	1.0	Full professor	
<b>Total size</b>	<b>4.0 fte</b>		

<b>Table 7</b> <b>VU, Chemistry, 3. Synthesis</b>			
Researcher's name	% appointment	Position	Line of research
Orru	1.0	Full professor	
Grossman	1.0	Full professor	
Ruijter	1.0	Associate prof (UHD)	
Hennig	1.0	Assistant prof (UD)	
<b>Total size</b>	<b>4.0 fte</b>		

<b>Table 7</b> <b>VU, Chemistry, 4. Analytical Chemistry &amp; Spectroscopy</b>			
Researcher's name	% appointment	Position	Line of research
Somsen	1.0	Full professor	
Takats	1.0	Full professor	
Lingeman	1.0	Associate prof	
Kool	1.0	Assistant prof	
Haselberg	1.0	Tenure track	
<b>Total size</b>	<b>5.0 fte</b>		

## VU Mathematics

<b>Table 7</b> <b>VU Mathematics, 1. Dynamical Systems – Computational Mathematics</b>			
Researcher's name	% appointment	Position	Line of research
Botnan	1.0	Tenure tracker	
Hulshof	1.0	Full professor	
Planqué	1.0	Assistant prof (UD)	
Rink	1.0	Full professor	
Van den Berg	1.0	Full professor	
Van der Vorst	1.0	Full professor	
<b>Total size</b>	<b>6.0 fte</b>		

<b>Table 7</b> <b>VU Mathematics, 2. Stochastics – Mathematical Data Science</b>			
Researcher's name	% appointment	Position	Line of research
Bekker	1.0	Assistant prof (UD)	
Belitser	1.0	Associate prof (UHD)	
Bhulai	1.0	Full professor	
De Gunst	0.8	Full professor	
Dobler	1.0	Tenure tracker	
Hindriks	1.0	Tenure tracker	
Koole	0.8	Full professor	
Meester	1.0	Full professor	
Van der Mei	0.2	Full professor	
<b>Total size</b>	<b>7.8 fte</b>		