Evaluation of the master's program in Astronomy

Evaluated Material

The material used in this evaluation primarily consists of

- The program's self evaluation
- The program description and the program's learning outcomes
- Description and learning outcomes for a selection of courses
- Feedback from students through course evaluation and "studiebarometeret"

In addition, one of the committee members' own perceptions from recently being a student at the corresponding bachelor program ("Fysikk og Astronomi" (FA)) are included.

The appropriateness of the learning outcomes of the program in relation to further studies and relevance to working life

The academic environment

The astronomy Master's programme is evaluated in relation to NOKUT's § 2. *Accreditation of study offers*. The programme fulfils the requirements in every respect. The size of the department is suitable for the number of astrophysics students educated and the composition of the courses covers the discipline in a way that is appropriate to the aim of the education. Regarding §2.2 *Requirements for the programme* — The master's programme in astronomy satisfies the demands under §2.2. Upon completing the programme, the student is educated in a wide range of advanced subjects (mathematics, statistics, physics, and programming) and is able to understand and work on interdisciplinary projects. The student is taught to evaluate, gather the necessary tools, solve assignments, and present the results in both written and oral form. This is equivalent to assignment-solving in industry. The program is evaluated to be up-to-date and relevant for the commercial sector. Regarding §2.3 *Requirements for the academic environment*— The programme also fulfils the requirements for the academic environment. The educational competence of the staff is clear. The academic management is well-established, with a well-defined quality assurance procedure and a strong development track for the education. The programme is primarily taught by the academic staff who are active in conducting international level research with collaborations in and outside the country. The international nature of the institute (e.g. with many international staff) means that the students can take advantage of a scientifically strong and international staff with interesting challenges. Upon completing the programme the student is equipped to take on challenges in both research and industry to a satisfactory level.

As stated in the self evaluation, around 10% of students go abroad for one semester, primarily during the second semester. Work is being done to increase the percentage of people going abroad, especially in finding universities that could offer astronomy-specific exchange agreements. This work should be continued and even extended so that the goal of 20% of students going abroad is met.

Most dropouts from the programme appear to be due to personal factors. Some of this may be inadequate information prior to applying for a place. More information targeted at potential master

students, particularly at the bachelor degree (FA) at UiO could be given early on, for example regarding workload, potential master projects, and potential master supervisors, to mitigate this issue.

The course offer (assessed against academic content, work and teaching methods and assessment schemes)

The student pursuing the master's degree in astronomy is required to finish 60ECTS of courses before pursuing a 60ECTS thesis. 20ECTS of the courses have to be taken at the ITA, whilst 20ECTS are required to be taken at other institutes, usually in physics, mathematics, statistics or informatics. This underlines the interdisciplinary nature of the education on offer. Such an interdisciplinarity is suitable for research in astrophysics, which requires the application of knowledge from a variety of different scientific fields.

Among the courses offered by the institute, two are obligatory, one on radiative transfer (AST4310) and the other on extragalactic astronomy (AST4320). The recommendations offer specialization within theoretical physics: solar physics and extragalactic astronomy/cosmology. The specialization is driven by an elective course structure with recommended elective courses. In addition to the courses AST5210 – *Stellar Atmospheres I* and AST5220 – *Cosmology II*, nine more external courses are recommended as options: FYS4130 – *Statistical Mechanics*, FYS4160 – *The General Theory of Relativity*, FYS4170 – *Relativistic Quantum Field Theory*, STK4900 – *Statistical Methods and Applications*, MAT-INF4300 – *Partial differential equations and Sobolev spaces I*, INF5620 – *Numerical methods for partial differential equations*, INF5670 – *Numeriske metoder for Navier-Stokes likninger*, INF3380 – *Parallel programming for scientific problems*. A summary evaluation of each course is presented in Table 1. From the industry perspective it is recommended that STK4900 is also added to the recommended list for the solar physics specialisation. Since the market for data science and AI is a relevant segment in the job perspectives for the programme's graduates, where a knowledge in statistics is fundamental. The course composition offered does cover statistics as an integrated part of the course load, which is good, however it is likely to be an asset for the students to have access to a specialized statistics course.

A point of concern with the academic content provided is that the range of astrophysics courses offered is quite narrow. Currently the courses offered at the Master's level do not include major areas of astrophysics such as exoplanets, high energy astrophysics, transient astronomy, star-formation, the interstellar medium. Of course, the programme is deliberately focussed to follow the areas of expertise of the institute and to provide an education most suitable to serve the needs of the student population coming to the ITA. This focus may, however, be detrimental to students contemplating an astrophysics research career outside of Oslo and it should be consistently borne in mind how best to facilitate those students.

The courses being offered at ITA are primarily project-based. The students are taught to evaluate, gather the necessary tools needed, solve assignments, and present the results both in written and oral form. Project-based assessment is a popular form of evaluation with the students and also offers a relevant skill for students for working with, e.g. an astronomy-related project later on. Care is taken to keep the overall load of these projects reasonable proportional to the course credit. With the switch to project-based evaluation the grades have in general remained constant overall regardless of the evaluation form, which is a good indicator of the reliability of the project-based assessment. Overall, the learning outcomes of the courses are highly relevant for the master projects that the students will pursue. The students also learn several applicable and transferable skills both in project management, cooperation, as well as programming/statistics and modelling that they will be doing in their respective courses.

Master's thesis

The thesis corresponds to 60ECTS. This is supervised by a researcher in the field, typically a professor or associate professor. One thing to consider in the development of the programme is the level of demand for a 30 or 45 ECTS thesis, as it might be relevant for some students to have more than 60ECTS in courses.

Table 1: Evaluation of the course composition

Course	Industry relevant software	Industry relevant hard skills	Industry relevant soft skills
AST4310 – Radiative Processes in Astrophysics	Python, Julia, git	Interdisciplinary problem-solving; Programming, mathematics, physics, statistics	Project assessments, Written project presentations
AST4320 – Cosmology and Extragalactic Astronomy		Interdisciplinary problem-solving; Programming, mathematics, physics, statistics	Project assessments, Written and oral project presentations
AST5110 – Numerical Modeling	Google cloud, Python, Git, cuda	Interdisciplinary problem-solving; Programming, mathematics, physics, statistics Advanced programming and fluid dynamics	Project assessments, Written and oral project presentations
AST5210 – Stellar Atmospheres I	Python, git	Interdisciplinary problem-solving; Programming, mathematics, physics, statistics	Project assessments, Written and oral project presentations
AST5220 – Cosmology II		Interdisciplinary problem-solving; Programming, mathematics, physics, statistics Statistical physics, Big data	Project assessments, Numerical Analysis. Written and oral project presentations.
AST5240 – Cosmological Component Separation		Interdisciplinary problem-solving; Programming, mathematics, physics, statistics	Project assessments, Numerical Analysis. Written and oral project presentations

The subject composition

There is little-to-no active research being conducted by private companies with the institute, which is not unreasonable. Given the fundamental character of the research conducted at the ITA, one would not expect a strong commercial component. The curriculum, as noted above, is highly relevant however, for the non-academic job market with transferable skills in physics, statistics, programming, and machine learning. The non-academic jobs that the students get are jobs where modelling and/or data analysis is key. These are skills that are thoroughly taught to the students through these courses and through their work with their thesis. In particular, the transferable skills

in programming, problem solving and project-based work gives the students a good basis for work in a wide variety of fields.

The master's program in astronomy ensures that the graduate student is versatile

- The course composition ensures that the student knows how to use a large toolkit to solve complicated problems.
- Through the work with the master's thesis the student is taught to set milestones and evaluate him/her-self continuously to be able to reach milestone goals.
- The student learns to be critical and evaluate assignments from a multidisciplinary perspective.
- The student learns to communicate results through several project assignments and not only the final master thesis exam, both in oral and written form.
- Because of the project-oriented setup in the course composition, the student will have normalized the process of communicating results. This will be of create value in an industry environment and when meeting clients.

These are skills that are will be of great value in the industry, and the graduate will be able to take on assignments that are both technical and/or functional in nature when entering the job market.

The institute may want to reach out to earlier students working at different places to present themselves and what they do to the current crop of students. This could increase the overall feel of work life relevance among the students, and perhaps get students in touch with companies looking to hire well-trained graduates.

Research relevance

Given the institute's focus on three research areas, the students should be well equipped to pursue cutting-edge research in these areas. The fact that the students must take some courses at other institutes broadens the students' knowledge. The direction of travel in astrophysics, as with most scientific research, is an increasing reliance on sophisticated statistical and data methods and computation. The fact that a significant fraction of the students' courses are in these areas bodes well for students being equipped to pursue a PhD after finishing their master's. The fact that most courses being offered at ITA are project-based further prepares the students for pursuing a research-based job / PhD in the future.

The limited exchange possibilities may be a hinderance for students pursuing a PhD internationally. However, the strong international staff connections may help mitigate some of this. However, the very narrow range of astrophysical subjects taught at the institute is perhaps more of a risk in this regard, given the increasingly competitive nature of PhD positions internationally. This lack of broad research connections to the broader trends in the astronomical community could play a negative role in the knowledge of the astronomy research being conducted outside of ITA.

Learning environment

Taking a look at "Studentbarometeret", it is apparent that the social satisfaction is high. The scores for the social learning environment is constantly higher than both the university and national averages, and the overall satisfaction is at the maximum possible score for 2020. The fact that all students share both the desk space and the adjacent break room together potentially plays a large role here. In addition, the fact that AFU organizes events for the master's students further builds upon the social aspect. Also considering that most courses are project-based motivates students to

cooperate and work with course-related stuff together, further improving the social environment for the students. Socially and learning environment-wise, ITA seems to be doing things right, even through the pandemic which halted much of the social possibilities.

Implementation

It is a little hard to understand why the institute offers two courses, AST5110— *Numerical Modeling* and AST5240— *Cosmological Component Separation*, that are not on the recommended list for Master's students in astrophysics.

Programme recommendations

To make the graduates more explicitly relevant to data-science/AI positions, it is proposed that the course STK4900 or equivalent is also added to the list of recommended elective courses for solar physics.

The programme is good at ensuring that project-based courses are not overwhelming for the students and the work load is proportional to the number of credits that the course offers. This is a difficult assessment to make, and active oversight in all project-based courses needs to be kept continously to ensure that this remains the case.

The demand for master theses worth 30ECTS and/or 45ECTS in addition to the one worth 60ECTS should be assessed. There may be a need for variation on the size of the master thesed being offered.

Former students working in different industries should be kept in contact with where possible and perhaps invited to the institute to increase the connection to the current generation of students. This may also lead to companies perhaps hosting presentations and seeking to connect with astronomy students, which in turn might increase the feel for job relevance among the students.

The communication of the workload and content of the Master's programme to potential bachelor students wishing to pursue a master's in astronomy should be considered carefully with a view to hopefully reducing the dropout-rate even below the current relatively low level, by giving the bachelor students a more realistic picture of what it takes to pursue a master's degree. This could be done in cooperation with the Institute of Physics and their study administration.

The rather narrow range of astrophysics courses currently on offer may be a hindrance to the development of new, exciting areas of astrophysics at the institute in the long term, since students from Oslo will be restricted in the areas that they are likely to be able to go on to do a PhD and hence a research career in, even if they go abroad. For this reason, it is imperative that the institute extends the capability for students to take international exchanges with courses that are not within the current curriculum, and finds other ways to introduce the students to subjects that are not taught in the current programme.

Conclusions

The astronomy master's programme is increasingly popular, has high satisfaction with the students, is well-run, and is strongly geared to highly-employable skills and cutting-edge research training and should doubtless be continued. From an industry perspective, the graduates finishing a master in astronomy will be well qualified to take one a large variety of jobs in industry. The committee wishes to stress this point: the quality of the training received by the students, while quite focussed and

highly specialised, is of an exceptionally high standard, is very up-to-date, and in- and outside of academia is extremely well-regarded. Continuing the watchful, proactive evolution the study has been undergoing for the past 5+ years will surely keep the study programme at this really high level.