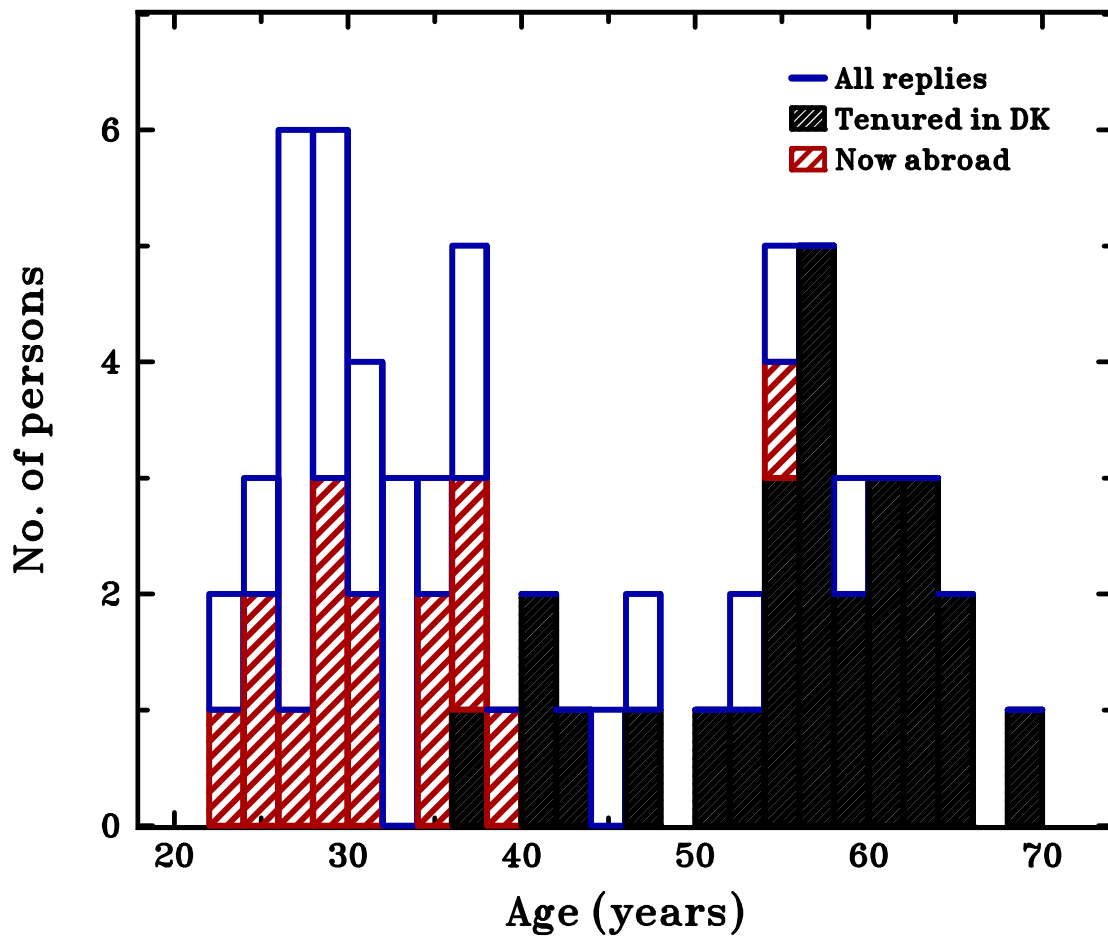


# DANISH ASTRONOMY 2010

A Report Prepared by  
the Board of the  
Ground-Based Astronomical Instrument Centre  
(Instrumentcenter for Jordbaseret Astronomisk Forskning, IJAF)

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The age profile of Danish astronomy as of January 2001. The figure is complete for the tenured staff in Denmark; other categories are counted from the questionnaire replies, which are about 80% complete.

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## Executive Summary

Danish astronomy today enjoys a good international reputation in a number of fields ranging from cosmology to stellar interiors. This is due to a community of strong individual researchers, excellent access to world-class observing facilities on the ground and in space, and extensive international collaboration. A talented young generation is ready and keen to shoulder this mantle in the new century. Innovative plans for the future abound. In short, a success story.

The year 2010 will mark a watershed, however. The science will be as exciting as ever, and Danish astronomers are actively planning to ensure that Denmark will remain visible at the frontiers. Danish astronomy is, however, not now structured, organised, and funded in a way that ensures its scientific health through the mass retirements around 2010. Action must be taken in the near future to clarify our visions for the long-term future, identify the main obstacles, and propose remedial action.

To prepare a solid basis for such action, the IJAF Board has prepared the present Report. First, a questionnaire survey of the Danish astronomical community was conducted. From this and other available material, the Board has attempted to identify the key issues and priorities. The IJAF Board itself has no mandate to recommend specific priorities for the future scientific effort or implement solutions to long-standing national-level structural and funding problems, and thus has not attempted to do so. The Report does, however, provide the background and recommend guidelines for initiatives to define and implement such solutions. Its specific recommendations are summarised below.

- 1: The age profile of the scientific staff must be improved as a matter of the highest priority and urgency. This issue is absolutely crucial for the future health of Danish astronomy.** Improvements in career structure should be implemented in parallel to enable and motivate staff to optimise the scientific and educational returns of their efforts.
- 2: Danish astronomy must remain fully integrated in the spectrum of front-line research facilities provided by ESO (VLT/VLTI, ALMA ...) and ESA (NGST, Planck, ...).** The future of Danish astronomy clearly requires full participation on the European scene.
- 3: A new national body responsible for continuing, long-term planning and coordination of all of Danish astronomy should be established.** The allocation of human resources to the planning, construction/execution, and analysis phases of major astronomical projects in Denmark needs to be better coordinated. A comprehensive plan should be prepared that takes into account the balance between current areas of strength vs. renewal, large projects vs. individual initiatives, experiment vs. theory, and ground vs. space. A new body with appropriately broad experience and mandate is needed to perform this task for Danish astronomy as a whole.
- 4: The institutional basis for the scientific returns of Danish investments in research organisations such as ESO, ESA, and NOT should be improved.** Current research staff conditions impede Denmark's ability to successfully conduct major, long-term research projects in astronomy.
- 5: A concerted effort to improve the Danish astronomy education should be established.** The present informal collaboration between institutes and individuals should be intensified to optimise the introduction of new teaching methods and materials in Denmark.
- 6: A stronger and better-organised effort to improve internal communication as well as public outreach should be made.** The effort in public outreach should be better organised and funded so as to create a more systematic and effective national outreach programme in astronomy. More frequent and systematic contacts between the astronomy groups will facilitate such initiatives.

# 1. Introduction and Background

Our understanding of the formation and evolution of the Universe has made tremendous strides over the last half-century, hand in hand with the development of physics and technology. New discoveries with ever more powerful telescopes, in the optical as well as in new wavelength domains mostly accessible from space, have supplied the pieces of the rich and varied tapestry that forms our present picture of the Universe. At the start of the new millennium, progress on all fronts is, if anything, accelerating even further. It is appropriate to reflect on the status and future of Danish astronomy in this context.

Over the last 30 years, Danish astronomy has established a solid international reputation. Strong groups and individuals are making noted impacts in a wide range of fields, from cosmology to stellar interiors. Their research fully profits from the internationally outstanding facilities offered through the Danish memberships of ESO and ESA, supplemented by a few carefully optimised Danish and Nordic instruments. Theoretical research has received a powerful boost through the creation of the Theoretical Astrophysics Centre (TAC). Bright students are attracted to astronomy - and thus to the physical sciences - by the excitement of the field, receive a competitive education, and proceed to make valuable contributions to current and new research topics. Denmark is often mentioned in international circles as a country with a strong record in astronomy for its size.

In 2010 the scientific challenges will be as exciting as ever, and new, powerful instruments will be in or near operation to address them on the ground (ESO: VLT, VLTI, ALMA, ...) and in space (ESA: NGST, Planck, later GAIA, ...). At the same time, however, most of the current tenured scientific staff in Danish astronomy will retire, and a decade is in fact a short time to plan and carry out such tasks as renewing research staff or constructing major new research facilities. It is vitally important to ensure that Danish astronomy will continue to flourish and make competitive use of these rich opportunities. To achieve this, priorities and choices must be defined now to ensure the optimal deployment of all available resources, the continued international engagement of Danish astronomy and, above all, the influx of talented young scientists which is a prerequisite for all healthy science.

The Board of the *Ground-Based Astronomical Instrument Centre* (IJAF) is charged by the *Danish Natural Science Research Council* (SNF) to advise on the Danish participation in international ground-based astronomy. The Board (Appendix I) has decided to initiate a move towards a common national strategy for astronomy by preparing the present Report. The focus is on long-term goals, but recommendations are also presented for short- and medium-term action to improve the structure, organisation, and funding of Danish astronomy. No complete 'Master Plan' is presented, but the path towards one is laid out.

In preparation, a questionnaire has been widely disseminated to solicit the views of the Danish astronomical community at large. The many replies received provide the Report with a solid factual basis. Answers were both in semi-quantitative form, summarised in various ways below, and provided in the form of many very thoughtful comments which the Board has considered carefully. The Board has also studied similar planning documents issued in the USA and UK, and by ESO and NOT; despite the obvious differences between the user communities, many scientific and organisational issues remain very similar.

Below, Chapter 2 summarises the views and recommendations expressed in the questionnaire survey. Chapter 3 contains the general policy considerations of the Board, while Chapter 4 presents the specific recommendations and action items formulated by the Board. A summary in Danish of the background and recommendations is given in Chapter 5.

## **2. The Questionnaire Survey**

### **2.1 Organisation of the Survey**

Any successful planning effort must be based on the suggestions and opinions of the broadest possible cross-section of the user community. At the initiative of the IJAF Board, a broad and very constructive community discussion of the long-term prospects for Danish astronomy took place at the annual Astronomy Meeting in Nyborg on June 9, 2000. There was general consensus that a long-term planning survey should be organised by the IJAF Board, and that a draft report should be ready for discussion at the Astronomy Meeting in 2001.

As an essential preparation for the Report, community input was collected in a questionnaire survey. The questionnaire form and a cover letter (both reproduced in Appendix II) were distributed by e-mail and also posted at the IJAF web site. In order to obtain the broadest possible view of the long-term future of Danish astronomy, all Danish M.Sc. and Ph.D. students, postdocs etc. in Denmark and abroad as well as foreigners working in Denmark and scientists in related fields were included in the mailing list. Replies have been received from 56 individuals, representing ~80% of all scientists in Danish astronomy from the level of Ph.D. student and upward. The high rate of replies documents the keen interest of the community and provides a good basis for the recommendations in this Report.

After several iterations within the Board, a consolidated draft of the Report was announced on May 16, 2001, and posted at the IJAF web site (<http://www.astro.ku.dk/ijaf>) in preparation for a two-hour discussion session on May 31, 2001, at the Astronomy Meeting in Nyborg. The meeting was very well attended, with ~60 persons present, and the discussion was far-ranging and constructive. An extensively revised text was prepared on the basis of the suggestions and criticisms presented at the meeting and/or others received directly, and was posted at the IJAF web site for a final, month-long period of comments until August 15, 2001. Taking into account the further suggestions received by that date, the present final version of the Report has been prepared.

The following sections summarise the main thrust of the opinions of the respondents to the questionnaire. More thoughtful and innovative individual suggestions were made than can be included here, but all have been carefully considered and taken into account in developing the Board's recommendations. Visions for the future science will be discussed first, followed by a review of the strengths and weaknesses of the present situation and the proposals of the community for measures to preserve the health of Danish astronomy in the coming decade.

### **2.2 Astronomy Highlights in 2010**

By all indications, astronomy in 2010 will be more exciting than ever. While recognising the obvious uncertainties in projecting scientific developments so far into the future, the Board asked respondents to formulate their bold visions of the overall status of their fields

on the international scene a decade from now, uninhibited by practical concerns. The major trends which emerge from the replies can be summarised as follows:

*Cosmology* will surely remain a forefront field for decades to come. Chances are that some major questions will have been largely solved by 2010, but a great many new issues will no doubt have appeared in the general area of the formation of large scale structure and of galaxies and galaxy clusters. The role of Gamma-Ray Burst sources in the early evolution and nucleosynthesis of the Universe and in the formation of galaxies, as well as the physics of the sources themselves, will be much better understood. X-ray observations will be a standard item in the astronomer's toolbox. New giant telescopes on the ground (VLT/VLTI) and in space (NGST) will continue to lead the field. And (sub)millimetre astronomy from the ground (ALMA) and from space (Planck) will have had as-yet unforeseeable, but certainly major consequences for our understanding of the early stages of galaxy formation.

The *formation and evolution of galaxies* is rich in physical complexity and will also remain an active subject. However, large-scale surveys of Galactic stars, a strong Danish tradition, will likely be replaced by more detailed studies of distant galaxies and individual stars in Local Group galaxies with HST/NGST as well as the VLT. The ESA satellite GAIA will give the study of the Milky Way and Local Group galaxies a new boost after 2012. Detailed studies of nucleosynthesis in evolving galaxies should remain an area of active progress.

New facilities (SIRTF, Herschel, ALMA, NGST) in the infrared and (sub)mm regions will pave the way for tremendous progress in the study of *interstellar chemistry* and the *formation of stars and planets*, boosted by the new opportunities for high angular resolution (VLTI, ALMA) and progress in theoretical and laboratory atomic and molecular physics. The related new discipline of *astrobiology* is also expected to develop vigorously. The decade will no doubt bring further insight into *stellar structure and evolution*, primarily from progress in asteroseismology (including new results from Rømer and other satellites), but also through spectroscopic diagnostics of internal mixing processes in stars.

*Extrasolar planets* will remain a booming field through 2010 and long after; many new instruments are under way on the ground (HARPS, VLTI, Keck Interferometer), and extremely ambitious space projects targeted at Earth-like exoplanets are on the drawing board (Darwin/TPF). The *exploration of the Solar System* also appears to face a new upswing with projected major space missions to Mercury and to Mars, Europa, and other possible sites of life, fusing astronomical, geophysical, geological, and biological expertise in interdisciplinary studies. A major international effort to establish a reliable inventory of *Near Earth Asteroids* and their orbits and begin to study their physical properties in more detail appears to be a realistic possibility.

However, many respondents also recall that the frontiers of science move in unpredictable ways, viz. the explosion in extrasolar planet research since 1995 or in Gamma-Ray Bursts since 1997. If, e.g., gravitational waves were to be detected during the decade, a new field of gravitational astrophysics would be expected to develop very rapidly. Future planning should include the freedom to pursue such developments as they appear.

## 2.3 Current Strengths of Danish Astronomy

### 2.3.1 Science

Fields in which Danish astronomy is currently considered to be prominent internationally include cosmology and Gamma-Ray Burst research; formation and evolution of galaxies, including the Milky Way in particular; theoretical and observational helio- and asteroseismology and other studies of stellar structure and composition; computational astrophysics, including advanced magnetohydrodynamical simulations of a wide range of astrophysical plasmas; and the construction and operation of astronomical instrumentation. Many front-line investigations are under way, and there are numerous ideas and proposals for new research initiatives in these as well as in new, promising fields.

### 2.3.2 Staffing and Funding

One strength of Danish astronomy is perceived to be the presence of a 'critical mass' of strong individual researchers with vigorous international contacts and collaborations. This is complemented by a good influx of bright students.

The number and distribution of the tenured research staff in Danish astronomy (as of January 2001) is summarised below. The corresponding age profile is shown in the cover figure, which is essentially identical to that on the cover of the *"Review of Danish Physics"* (Ministry of Education and Research, 1992) except for the 10-year increase in age.

Institute	Theory	Observation	Total
NBifAFG (Astronomical Observatory)	4*	11	15*
IFA	2	4	6
DRI		3	3
NORDITA	1		1
Total	7*	18	25*

\* One additional position in theory is currently being advertised.

The table also indicates the number of tenured staff whose current research is predominantly theoretical or observational in nature. Several individuals are active in both fields, and whether or not the theoretical underpinning has been developed in Denmark, full scientific interpretation is included in the great majority of 'observational' papers.

There is consensus that the research tools available to Danish astronomy are first-rate, both in quality and supply. The ready access to world-leading research facilities funded through the Danish participation in ESO and ESA is clearly invaluable, and there is adequate funding to ensure an effective use of the Danish 1.5m telescope in Chile and the NOT. Provided that access to the full complement of scientific tools at ESO and ESA is secured also for the future, Danish astronomy will enjoy excellent conditions in this respect also in 2010.

### 2.3.3 Structure and Planning

Respondents (including both Danish students abroad and foreigners here) emphasise the broad, competitive Danish M.Sc. education and good interaction between observational and theoretical studies and between ground and space based research as important assets of Danish astronomy, and recent recruitment statistics confirm its attraction for young students.

Flexible and informal planning allows effective student use of observational facilities such as the NOT and the 1.5m telescope in Chile. The freedom, through these telescopes, to address scientific questions the solution of which requires longer continuous observing periods than normally possible at international observatories, is valued by many.

## **2.4 Current Weaknesses of Danish Astronomy**

### *2.4.1 Science*

Some respondents point out that a number of scientific fields of future importance are poorly developed in Denmark, e.g. interstellar chemistry, research on extrasolar planets, or gravitational astronomy. Many regret that Danish involvement in instrumentation for major new ground and space base projects (VLT, ALMA, NGST, GAIA, ...) is now rather modest, and some would like to become involved in such work.

### *2.4.2 Staffing and Funding*

An overwhelming majority of respondents identify the lack of renewal of the scientific staff and of credible career opportunities as the greatest single obstacle to a healthy Danish astronomy in 2010. Prospects for openings appear equally poor in the universities, at TAC, and at the single dedicated research institute in the field (DSRI). The contrast between the prospects for funding major projects and for hiring the staff necessary to do the corresponding science is as striking as it is discomfoting. "*Seemingly hopeless*", "*Simply a disaster*", or "*There is no such thing!*" are characteristic reactions to the question on 'career structure'.

Difficulties arise already at the Ph.D. student level due to the severe lack of fellowships and rigid funding rules (both worst in Copenhagen). Thus, many qualified students cannot get a Ph.D. in Denmark, and many of the best candidates go abroad. Another important factor is the lack of regular university postdoc programs and the short duration of postdoc positions funded by other sources. At higher levels, recruitment programmes do exist (e.g. SNF), but require a commitment that a tenured post be subsequently advertised, a difficult condition in present university circumstances. These problems are not new, but now clearly damage morale on both sides of the generation gap. It is alarming that almost half of the current Danish Ph.D. students and postdocs have gone abroad, many clearly without hope to return ("*We who ran away appreciate the efforts of those who stayed behind*"). Others, e.g. with a family, tend instead to drop out at the M.Sc. or Ph.D. stage; and so they should, because industry expects applicants above 35 to have management as well as scientific experience.

But even for tenured staff there is no effective system of promotion or other incentives for scientific productivity, and the lack of regular sabbatical leaves - another respect where Denmark lags many other developed countries - is an added impediment to scientific renewal. A radical re-thinking of the staffing structure for scientists in astronomy and related fields is necessary for Denmark to remain visible in astronomy and similar fields. Several respondents also note a certain lack of innovation and enthusiasm in the teaching, presumably linked to these fundamental problems of career structure and staff renewal.

### *2.4.3 Structure and Planning*

Next in importance, respondents mention a lack of overall vision, leadership, and clear priority setting for Danish astronomy as a whole. Too many projects are being conducted in groups of sub-critical size, and opportunities for innovation and synergy are lost due to ineffective communication. Some initiatives have been undertaken by individuals or groups with

no basis in a framework of well-defined common priorities, without a realistic long-term view of the resources needed to complete them, and sometimes on an implicit assumption that the rest of the community could be relied upon to secure appropriate scientific returns. As a result, projects may end up being stretched too thin, especially as regards manpower, with delays, frustration, and loss of scientific opportunity as a consequence. Conversely, other projects seem to continue more on the strength of past merits than their current or future importance, and resources are tied up which could be used better elsewhere. The problem is exacerbated by the fact that most major external funding sources (i.e. those allowing to hire people) tend to be narrowly focused and time-limited ('cigar boxes').

#### *2.4.4 Internal Organisation*

Respondents note that even small, geographically close groups may pursue related projects with little coordination, not only in research but also e.g. in teaching. Apart from being a sub-optimal use of scarce resources, the lack of an agreed vision and common plan leads to a lack of enthusiasm and sense of a common purpose, and discourages new major initiatives. It also contributes to a weak and incoherent effort in public outreach and hence in public appreciation of the achievements of Danish astronomy.

## **2.5 Recommendations for Future Action**

### *2.5.1 Career Path*

A large number of remedies are proposed, including many that are bold and innovative. However, most are not new, and many require too radical revision of rigid national academic and labour policy regulations to even be described in any detail here. The undercurrent is strong and unmistakable, however: A decade of empty talk and no action on this key and totally predictable problem is now seriously damaging the credibility of Danish science as a career option for the young generation. Prompt action is needed to restore it.

### *2.5.2 Recruitment*

The generally keen public interest in astronomy helps to recruit students to not only astronomy, but also to the other physical sciences. However, efforts are needed to improve the outreach to both high schools and the general public. More foreign Ph.D. students and postdocs are suggested as another way to foster more attractive environments in the institutes.

### *2.5.3 Education*

The early involvement of students in observing projects at the 1.5m telescope and NOT is noted as a strong point which could be further developed. Continued emphasis on basic physics and computational skills is recommended to prepare students for future changes in research orientations, and also for alternative careers outside astronomy.

### *2.5.4 Planning and Organisation*

Many respondents call for a mechanism to improve the information, long-term overall planning, and coordination concerning major scientific, technical, and educational initiatives, and for a clearer decision-making structure. This would also minimise the risk that scientific developments may become driven more by special-purpose funds happening to be available at a certain time than by deliberate consideration of overall long-term scientific benefit.

### 2.5.5 Facilities

The replies give ample evidence that not only the newest ESO and ESA facilities (e.g. VLT, XMM-Newton) will be heavily used, but also those now in progress or being projected (ALMA, NGST, Planck, ...). Indeed, the main bottleneck in making full use of them will likely be the lack of fully experienced scientists. Powerful super computers will be important, both in theoretical astrophysics and data analysis, and adequate access should be secured.

### 2.5.6 Instrumentation Projects

An important question for the future is whether Denmark should continue to be involved in the construction of major hardware and/or software components of new instrumentation. A large majority of respondents (roughly 3/4) do in fact favour such engagements. The perceived benefits are a better understanding of instrument performance - hence richer scientific returns - and the privilege of *Guaranteed Time* after completion. About 1/3 of the respondents are willing to invest a significant part of their time in such projects. However, it is noted that proper conditions for such participation need to be developed.

### 2.5.7 Support

Technical support is generally viewed as satisfactory and is likely to remain so, even if co-ordination with NOT plans could be improved. Time-consuming administrative duties seem to be continually increasing, but still require considerable scientific background; it is proposed that support by a dedicated person with an appropriate (scientific) background would be a way to liberate significant amounts of research time for the staff.

### 2.5.8 Communication and Outreach

Many respondents propose to intensify the regular exchanges of views on scientific issues, both nationally and within the larger institutes. The annual Astronomy Meetings serve a useful role, but cannot alone fill the need for regular interaction. Such contacts should be encouraged on a more systematic and frequent basis than previously.

There is also a strong convergence of opinion that a stronger and more unified effort in public outreach should be made, in close cooperation with DSRI and the Planetaria, and with a stronger involvement of professionals, both on the astronomical and media sides of the issue. Proposals include a series of TV programmes on "Science Through Astronomy" after German and US models; more targeted information to decision makers; and setting up a "hot-line" to high schools engaged in astronomy projects.

## 3. General Policy Considerations by the Board

Our vision of the Universe is becoming larger and richer almost day by day, and some of the grand questions of its origin and evolution are on the verge of being answered. The decade before us will be exciting indeed, and projects under study or already under way promise new and radically different ways of exploring the Universe even after 2010. As is abundantly evident, both from research proposals now being prepared and from the questionnaire survey, the Danish astronomical community is fully equipped and actively preparing to play its part, both in 'established' areas developed by existing research groups and in new fields being taken up by the younger generation, often during Ph.D. and postdoc fellowships abroad. The concern of the IJAF Board is to turn this rich potential into vibrant and viable reality.

For Denmark, 2010 marks a watershed due to well-known, inexorable demographic changes. Like other sciences, astronomy faces an almost total replacement of research staff around that time, and despite years of debate no national policy to cope with this issue is yet in place. Danish astronomy rates very favourably in international comparisons, but indications are that if present policies continue to 2010, it will wither and dry out. Whether or not new funds become available to help smoothing the recruitment profile, action must be taken already now to define and implement policies that will focus the assets and alleviate the present weaknesses of Danish astronomy in order to secure its scientific health at the end of the decade. Achieving this will require near-term improvements in the funding and staffing policies, structure, and internal organisation of Danish astronomy.

The present section discusses the main policy issues which the Board considers to be important for the future, based on the likely development of the science and taking into consideration the replies to the questionnaire as well as other recent long-term plans (USA, UK, ESO, NOT, ...). From this general discussion, a number of specific recommendations are then derived in the following section.

### 3.1 Scientific Horizons

Scientific visions for the future must be the basis of any meaningful planning, and Danish astronomy abounds in visions and plans on all relevant time scales. In the following, the Board attempts to identify some main trends of probable relevance to the Danish scene in world astronomy in 2010, but without speculating in detail.

The Board agrees with the community view that *cosmology*, the *formation and evolution of galaxies*, the *formation of stars and planets*, and the search for and study of *extrasolar planets* are likely to be major areas of research activity in 2010. Undoubtedly, several others like interstellar chemistry, stellar structure and evolution, compact objects, Solar-System research, and numerical simulations of astrophysical phenomena will be important as well. Within this broad spectrum, a limited number of focal points for the Danish effort will have to be chosen with care and followed up systematically and coherently (see below). Scientific priorities need to be reviewed at short intervals to optimise the effort and seize exciting new opportunities.

The questionnaire survey provides gratifying confirmation that the current plans for Danish participation in the new and projected large European astronomical research facilities are on track to meet the foreseeable demand through the decade and beyond. Measured in terms of projected research effort, the *ESO Very Large Telescope (VLT)* emerges as the top priority through 2010, including a significant user community for its high-resolution interferometric mode (the *VLTI*). Next in importance through 2005 follow the ESO medium-size facilities at the La Silla Observatory in Chile, including a continued strong demand for the Danish 1.5m telescope there, for the NOT on La Palma, and for HST. In the same period, at a somewhat lower level of effort, follow the satellite projects Rømer/MONS, XMM-Newton, and preparations for GAIA. Towards the end of the decade the use of the smaller facilities is foreseen to decrease as attention turns to the new, powerful observatories scheduled to enter operation at that time on the ground (ALMA) and in space (NGST, Planck/Herschel, later GAIA). For data reduction and to maintain a healthy balance between observation/experiment and theoretical analysis, the use of supercomputers is foreseen to remain high, second only to the VLT in terms of projected use of research time.

In summary, present plans for the development of the main European astronomical research organisations, ESO and ESA, are well poised to serve the needs of Danish astronomy through 2010, assuming that scientific priorities develop within currently foreseeable horizons. Conversely, given proper working conditions, Danish astronomers are also preparing to make effective use of these tools throughout the decade and beyond.

### **3.2 Staffing and Funding**

A healthy science needs a healthy mix of scientists. Regrettably, the narrowly peaked age profile of the tenured Danish astronomers has only been shifted during the last decade, but has seen hardly any improvement in shape (see cover figure). A whole generation of young scientists has been lost already; in still another decade, virtually the whole present research staff will be gone. Capable young scientists are keen to join, but see no long-term credible scientific career prospects in Denmark, at least before 2010. And while most astronomy graduates must and already do pursue alternative careers, astronomy as a science will wither unless *some* of the brightest can continue in the field. Research opportunities are being lost already because of understaffing, but the impact on student motivation and staff morale is a greater danger in the longer term. Prompt action is needed to restore the credibility of astronomy as a career option in Denmark; years of procrastination and empty words must be replaced by action very soon.

The problem is common to all the physical and several other sciences and cannot be solved internally in the community. Yet, in the case of astronomy, the solution is not necessarily just a question of large amounts of new money. The total funding to Danish astronomy through the universities, DSRI, and TAC, the contributions to ESA, ESO, and NOT, and a large variety of public and private grants, is in fact quite considerable; the challenge is to apply these funds most effectively towards the goal of a healthy Danish astronomy in 2010.

### **3.3 Structure and Planning**

To be effective, scientists must have access to state-of-the-art research tools, often needing timescales of years or decades from inception to fruition. And whether tenured or temporary, they must be employed under conditions that allow - indeed even encourage - them to deploy their time and talents effectively on projects of high priority. Improvements in long-term planning and institutional structures are needed to achieve this goal.

The IJAF Board reviews the short- and mid-term activity plans of the Centre, but these cover only one segment of Danish ground-based observational astronomy. A high-level plan is needed to ensure that the stated goals of all major projects are consistent with available resources over the project lifetime. A new, national-level Board should be charged with this task for all ground and space based astronomy in Denmark. The aim is not to micro-manage or to freeze all resources into a rigid set of tasks, but to ensure that projects are started on a realistic basis and will be followed up properly. Accordingly, the Board should not control minor research projects of little impact on community resources. Moreover, plans should maintain some re-deployable capacity to follow up important new developments; indeed, a coherent long-term plan will facilitate the rational use of shorter-term project funds to secure the continued services of key staff. To accomplish these goals, programmes to which major Danish resources are committed over longer periods should not be too narrow in scope.

The IJAF Board notes that while the need for more unified and visible planning emerges strongly from the questionnaires, some reservations on the above proposal were expressed in the later discussions. Yet, while fears for loss of scientific autonomy are understandable, autonomy only makes true sense if decisions can be carried through in practice. The Board firmly believes that any drawbacks of this nature are outweighed by the overall benefits of rational national planning and is unanimous in maintaining its proposal.

Scientific manpower being our scarcest resource, its optimum use is of paramount importance in long-term planning. A key question in this respect is whether one should commit to providing hardware and/or software components of major ground or space instrumentation projects, previously a strong tradition in Denmark. As ample experience shows, such engagements imply the commitment of sizeable community resources over long periods and therefore require particularly careful consideration and planning.

Engagements in major ground or space based experiments should in principle be a function primarily of the scientific plans of the community, both qualitatively and quantitatively. The projected scientific returns of supplying major hardware or software instrument components are increased influence on and insight in the final instrument capabilities, privileged access to *Guaranteed Time*, and increased credibility of the group - and the country - as a partner in major international projects. These potential rewards must, however, be carefully weighed in each case against their associated cost in terms of scientific manpower.

One possible policy would be to decide to no longer engage in instrumentation projects, but focus on the use and interpretation of data from the international facilities. Denmark would be almost alone among astronomically developed countries in doing so, but conditions are different here. In Denmark, astronomical research is carried out predominantly by university faculty. Declining and unpredictable funding for the universities and increasing teaching and administrative load on staff imply progressively less time for research, and its use must be planned with increased care. Limited involvement in the definition and specification phases of major international projects may remain feasible even under present circumstances, but actual project responsibility in addition to scientific exploitation is another matter.

If, on the other hand, it is decided to continue to supply major hardware or software components of large instrumentation projects, as a clear majority of respondents favour, such projects will require that suitably trained and motivated PIs can be identified and be allowed to devote the necessary effort to the task. Conditions for doing so in the universities have deteriorated over the last decade to the point where a deliberate policy is required. DSRI has the mandate, and is in principle structured, to undertake the construction, operation, and scientific use of space-based instrumentation, but for any ground-based and non-DSRI space projects a new institutional structure will be necessary, and the human resources available to such undertakings must be substantially strengthened. Major projects should no longer be undertaken unless there is an explicit assurance that these conditions will be fulfilled.

### **3.4 Internal Organisation**

The Danish astronomical community is too small to afford the present lack of coordination of effort. Grand visions may be conceived by individuals, but bringing major initiatives to fruition requires the informed support and collaboration of many. Similarly, as seen from

the outside, while scientific successes tend to be associated with the leading individuals, failures reflect on the community as a whole. This experience applies equally in the areas of science, education, and public outreach.

Given the convergence of overall interests, geographical proximity, and good personal relations prevailing in Danish astronomy, achieving better overall momentum through better coordination of effort would appear to be more a question of thought and discipline than of greatly increased effort and overall funding. The benefits of such coordination should greatly outweigh the drawbacks in terms of somewhat more limited individual freedom - often more a matter of perception than reality.

## **4. Specific Recommendations and Action Items**

Based on the input received from the community (Chapter 2) and the general policy considerations presented above (Chapter 3), the IJAF Board has formulated a set of specific short- and medium-term recommendations and action items which should be addressed as a matter of urgency to ensure the future health of Danish astronomy. Some concern national policies or authorities or institutions of higher learning and research and should be forwarded through the appropriate channels. Others are directed at the community itself, to be acted upon by individuals and institute or group leaders in concert. The recommendations are grouped in the same categories as the preceding chapters.

The Board presents these recommendations in the full conviction that astronomy will remain a vibrant science well beyond 2010, and that Danish astronomers are capable and eager to contribute significantly to its progress throughout the period considered here. Indeed, so many plans exist for exciting and valuable research projects that a key task will be to select from this 'embarrassment of riches' that subset which will make the most effective scientific impact within available resources. After full consideration, *the Board has decided to **not** present specific choices and priorities among current projects in this report, as it has neither the full scientific expertise nor the mandate to do so.* This will be a key and urgent task for the new planning and coordination committee proposed below.

### **4.1 Staffing and Funding**

*4.1.1 The age profile of the scientific staff must be improved as a matter of the highest priority and urgency. This is absolutely crucial for the future health of Danish astronomy.*

Renewing staff in Denmark now is the only realistic alternative to massive foreign recruitment to universities and research institutions in 2010. New blood is needed at all levels, from Ph.D. student to Associate Professor, and all conceivable funding schemes (SNF, EU, private...) should be exploited with imagination and flexibility. Attention must be given to attracting candidates with a broad background, and to preserving a proper balance between theory and observation. More postdoc positions of duration longer than one year will be needed to attract the best. Improvements - including radical changes - in the career structure for all staff should be studied and implemented in parallel, to ensure that the new staff will be able to make a significant impact on the international scene.

#### *4.1.2 Danish astronomy must remain fully integrated in the network of front-line research facilities at ESO (VLT/VLTI, ALMA ...) and ESA (NGST, Planck, ...).*

Progress in astronomy is discovery-driven: The scientific frontier is increasingly defined by the largest, most powerful instruments. The 20th century left Europe fully competitive in the world as regards astronomical research facilities on the ground and in space. The current scientific planning of the Danish astronomical community assigns high priority to the competitive use of the ESO and ESA facilities which are under construction or in advanced planning stages for deployment later in the decade. It is of vital importance that Denmark remain a full partner in the future European front-line facilities.

In any plausible staffing scenario, scientific returns will be limited by available scientific manpower. Accordingly, human resources now invested in older instruments (e.g. the 1.5m telescope or NOT) should be progressively redirected to the new facilities towards the end of the decade. Until then, the smaller telescopes should be properly maintained and equipped with instruments which have been carefully optimised for maximum scientific returns of the manpower invested in their construction and operation. Small hands-on instruments at or near the university institutes are useful for teaching purposes, but the efforts spent on operating them should also be judged with care.

## **4.2 Structure and Planning**

#### *4.2.1 A new national body responsible for continuing, long-term planning and coordination of all of Danish astronomy should be established.*

In order to alleviate the present coordination problems, a new Board should be appointed to establish a long-term plan and advise on overall priorities for the major engagements of Danish astronomy. Contacts with appropriate authorities should be established soon to clarify the status and charge of the Board, which could consist of ~6 persons, appointed in their personal capacity for 3-5-year terms and collectively possessing a broad range of scientific expertise in ground and space based observational and theoretical astronomy as well as relevant neighbouring disciplines. The Board could appoint ad-hoc working groups from time to time to study specific issues in depth.

The plan prepared by the Board would contain an inventory of all major projects engaging a significant part of the community, whether ground or space based. End-to-end resource requirements and milestones should be defined for all projects and worked into an overall schedule. The plan should be regularly reviewed and updated in an open and transparent manner in consultation with the community, e.g. in preparation for the annual Astronomy Meetings. Funding agencies should consult the Board before investing in major astronomy projects to ensure that the necessary scientific manpower and other resources will be available to the new project from inception through scientific analysis. Conversely, Board approval would constitute a community commitment to the project through its useful life.

#### *4.2.2 The institutional basis for the scientific returns of Danish investments in research organisations such as ESO, ESA, and NOT should be improved.*

In order for Denmark to retain its long-term visibility in astronomy, an institute structure is needed which includes competitive scientific returns from major European space and/or ground-based astronomy projects among its explicit goals and commitments, can deploy staff resources accordingly, and at the same time interact better with the universities and students and better establish new cooperations with previously unrelated fields

(geophysics, laboratory physics, biology, ...) than typical sectorial research institutions. Specific funding schemes aside, a structure modeled on the present *Instrument Centres* appears worthy of study. Essentially, such a unit would be responsible for ensuring a certain volume of actual astronomical research within the current SNF paradigm of competitive proposals and regular peer performance reviews, rather than being limited to IJAF's current role of just offering tools to the community. Non-traditional national funding would be needed, but such a unit would also be better able to attract external funds, e.g. from the EU, where competition from large, well-organised and well-funded groups is fierce.

As the eventual scientific returns will be primarily limited by the same scarce human resources, it would be a wise investment to grant PIs of approved projects at the largest international facilities (e.g. the VLT, ALMA, HST, or NGST) a similar type of financial support as now awarded by NASA to American PIs of approved projects at the HST.

### **4.3 Internal Organisation**

#### *4.3.1 A concerted effort to improve Danish astronomy education should be established.*

A joint effort should be made by IFA and NBIfAFG to develop a well-designed, integrated set of courses and corresponding modern teaching tools, possibly in cooperation with Lund and/or other Nordic universities; some initiatives are already under way. The establishment of a formal *Graduate School* in astrophysics should be considered. Continued emphasis on basic physics and computational skills is important to prepare students for future changes in research orientations - and for some, for careers outside astronomy.

Large-scale archiving of astronomical data of all kinds, augmented by effective search and retrieval systems (the "Virtual Observatory" concept) is rapidly becoming a research tool on a par with the acquisition of new data. The training of the future Danish astronomers should also equip them to take advantage of these new possibilities.

#### *4.3.2 A stronger and better-organised effort to improve internal communication and public outreach should be made.*

A concerted, effective programme of public outreach should be organised on a national basis to avoid duplication and dispersion of effort, as for education above. Funding will be needed, e.g. by allocating 1-2% of major research grants to this purpose in analogy with current NASA policy, as well as suitable training of staff. Maximum synergy should be sought with similar efforts in physics and/or the natural sciences as a whole in order to achieve professional standards for the communication as well as in the science.

Better and more frequent informal scientific contacts between junior and senior researchers within and across institutes will stimulate ideas and cooperation on all fronts, improve community support for ongoing projects, and make it easier to find resources for new initiatives. Such exchanges should be actively and systematically encouraged.

## 5. Dansk resumé

### 5.1 Baggrund

Dansk astronomi i dag er velkendt og respekteret på den internationale scene. Fremstående danske forskningsindsatser gøres på en lang række felter, fra kosmologi til stjernernes indre. Det danske medlemskab af ESO og ESA giver danske forskere adgang til de mest avancerede astronomiske forskningsfaciliteter i verden, og dansk astronomi er helt integreret i det nordiske, europæiske og internationale samarbejde. Astronomiens umiddelbare tiltrækning på videbegærlige unge sikrer en god tilgang af dygtige studerende, ikke blot til astronomi, men til de fysiske fag i almindelighed. Set udefra er dansk astronomi en succeshistorie.

Alt tegner også til, at astronomiens udvikling til 2010 og fremefter bliver om muligt endnu mere spændende end nu. Der er godt håb om, at nogle af de vigtigste spørgsmål vedrørende universets opståen, struktur og udvikling vil blive vidtgående besvaret i denne periode, og der lægges mange og ambitiøse planer for dansk astronomis deltagelse i udviklingen. Danske astronomer kan endvidere se frem til at kunne udnytte den næste generation endnu mere ydedygtige europæiske forskningsfaciliteter gennem ESO og ESA.

Men der også nogle store sten på vejen: I 2010 vil næsten hele den faste forskerstab være pensioneret, og dansk astronomis nuværende økonomiske, stabsmæssige og organisatoriske grundlag er utilstrækkeligt til at sikre en sund udvikling gennem denne kritiske fase. Et tiår går hurtigt i denne sammenhæng. Det haster derfor med at identificere de vigtigste betingelser for, at udviklingen kan drejes til gavn for dansk astronomi og dens rolle i dansk forskning. En første, afgørende forudsætning er, at faget selv organiserer sig, så der opnås det bedst mulige videnskabelige udbytte af de ressourcer, som er og kan forudses at være til rådighed gennem institutterne og fra statslige og andre finansieringskilder.

Styregruppen for SNF's *Instrumentcenter for Jordbaseret Astronomisk Forskning (IJAF)* har besluttet at tage hul på denne udfordring med nærværende rapport. Som forberedelse hertil har gruppen gennemført en spørgeskemaundersøgelse af dansk astronomi i bredeste forstand (skema og følgebrev gengives i Appendix II). De 56 modtagne svar repræsenterer ca. 80% af alle danske astronomer fra Ph.D.- til professor-niveau, inklusive udenlandske forskere i Danmark og danskere i udlandet. Sammen med en række nylige udenlandske strategirapporter (bl.a. fra USA, UK, ESO og NOT) afgiver dette fyldige materiale et godt grundlag for gruppens analyse, prioriteringer og anbefalinger. Gruppen er imidlertid bevidst ikke gået ind i vurderinger og prioritering af bestemte forskningsprojekter, da den ikke har mandat hertil.

### 5.2 Generelle overvejelser

#### 5.2.1 Dansk astronomi i 2010

Den astronomiske forskningsfront vil utvivlsomt fortsat gøre store fremskridt i det næste tiår. Kosmologi, galaksers dannelse og udvikling og stjerners og planeters oprindelse og udvikling må forventes at stå i centrum. Danmark skal og vil være med på de vigtigste felter, men må forudses ikke at have kapacitet til en stor indsats på dem alle. Der må derfor prioriteres og planlægges omhyggeligt, så der på den ene side udvikles lovende styrkepunkter i forskningen, på den anden side bevares mulighed for løbende at revurdere og omprioritere indsatsen, når nye opdagelser sker og frontforskningen skifter spor. ESOs og ESAs planer

for de næste ti år giver et godt grundlag herfor, og de planlagte faciliteter vil blive udnyttet intenst.

### 5.2.2 Bemanding og finansiering

Danske astronomer har p.t. gode økonomiske forhold, hvad angår deltagelse i internationale forskningsfaciliteter. Det altoverskyggende problem er *rekruttering og fornyelse* af den videnskabelige stab. Aldersprofilen af den faste stab er stort set uændret de sidste 10 år - blot er alle blevet 10 år ældre - og en hel generation unge er allerede tabt for dansk forskning (jvf. forsidefiguren). Det helt forudsigelige problem med generationsskiftet er blevet diskuteret lige så længe, men indtil nu uden konkrete resultater. Udsigterne til at få Ph.D.-stipendium, postdoc stilling og fast ansættelse i Danmark falder i denne rækkefølge fra små over mikroskopiske til usynlige. Halvdelen af den unge generation af danske astronomer er allerede rejst til udlandet uden udsigt til at vende tilbage. En løsning af dette problem har højst prioritet af alle, hvis Danmark skal forblive synlig på det astronomiske verdenskort i 2010.

### 5.2.3 Struktur og planlægning

Forskningsindsatsen i dansk astronomi, og hermed det videnskabelige udbytte af det danske medlemskab af ESO og ESA, er altovervejende baseret på universitetsinstitutterne i København og Århus. I tidligere tider muliggjorde bemandingen, at der kunne sættes på en dansk deltagelse i større, langvarige forskningsprojekter, omfattende både videnskabelig udnyttelse og levering af større komponenter eller programpakker til internationale instrumentprojekter. Under de nuværende forhold er dette ikke længere muligt. Et nyt stabsmæssigt og økonomisk grundlag må til, hvis Danmark ønsker fortsat at høste det fulde videnskabelige udbytte af sine internationale engagementer, herunder i højteknologiske instrumentprojekter. I modsat fald vil det være mere rationelt at koncentrere den videnskabelige arbejdskraft om indsamlingen og fortolkningen af data.

Den overordnede planlægning og koordinering af større projekter må også forbedres. De senere års 'cigarkasse'-finansiering har tilskyndet til iværksættelse af projekter, herunder instrumentprojekter, på *ad hoc*-basis. Fraværet af en samlet, langsigtet plan for udnyttelsen af de tilgængelige personale- og andre ressourcer vanskeliggør en forsvarlig gennemførelse af sådanne projekter, herunder opnåelsen af et videnskabeligt udbytte, som står i rimeligt forhold til den samlede investering. Dette virker i det lange løb negativt på motivationen, både indenfor og udenfor astronomernes egen kreds. Der bør derfor snarest oprettes et organ, som kan varetage den overordnede planlægning af alle større astronomiske projekter i Danmark, såvel i rummet som på Jorden.

### 5.2.4 Intern organisation

Der er i dansk astronomi en lang række værdifulde individuelle initiativer indenfor både forskning, undervisning og formidling, men indsatsen sker for spredt og ukoordineret. En bedre og mere systematisk regelmæssig kontakt mellem de forskellige grupper og enkelte forskere vil kunne bidrage til et væsentlig bedre udbytte af den samlede indsats på alle tre områder.

## **5.3 Konkrete anbefalinger**

### **Bemanding og finansiering**

*5.3.1 Rekrutteringen af næste generation forskere må iværksættes omgående og effektivt.*  
Intet tiltag er vigtigere for forskningens fremtid eller mere hastende end dette. Det må følges op med en hensigtsmæssig modernisering af stillingsstrukturen.

*5.3.2 Danmark må fortsat deltage fuldt ud i de europæiske forskningsorganisationer.*  
Fuld adgang til ESOs og ESAs faciliteter er vital for dansk astronomi, også i fremtiden.

### **Struktur og planlægning**

*5.3.3 Der må indføres en overordnet planlægning og koordinering af al dansk astronomi.*  
Der behøves et nyt organ til at opstille en samlet, langsigtet planlægning og prioritering af alle større astronomiske projekter, såvel jord- som rumbaserede. Sammensætning af og reference for et sådant organ må klarlægges snarest.

*5.3.4 En bedre organisatorisk basis for forskningsindsatsen er nødvendig.*  
Der må skabes et nyt og bedre institutmæssigt grundlag for forskningsindsatsen, så fremt universiteterne fortsat skal kunne sikre et forsvarligt videnskabeligt udbytte af Danmarks medlemskab i ESO og ESA. Dette er specielt kritisk for en evt. fortsat dansk deltagelse i højteknologiske instrument projekter både på jorden og i rummet.

### **Intern organisation**

*5.3.5 Uddannelserne i astronomi bør koordineres bedre på nationalt plan.*  
En bedre koordination af indsatsen vil kunne forbedre kvaliteten af metoder og materialer i undervisningen uden unødigt dobbeltarbejde.

*5.3.6 Intern og ekstern kommunikation indenfor og fra dansk astronomi bør forbedres.*  
Bedre intern kommunikation vil kunne føre til et mere frugtbart samarbejde om både forskning, undervisning og formidling til offentligheden. På det sidste område bør der endvidere ske en professionalisering af indsatsen, så astronomiens betydning for dansk forskning og forskeruddannelse gøres klarere for både befolkning og beslutningstagere.

## Abbreviations and Acronyms

<b>ALMA</b>	Atacama Large Millimetre Array (new global radio telescope project in Chile)
<b>Darwin</b>	Projected interferometric ESA mission to search for terrestrial planets
<b>DSRI</b>	Dansk Rumforskningsinstitut Danish Space Research Institute
<b>ESA</b>	European Space Agency
<b>ESO</b>	European Southern Observatory
<b>GAIA</b>	ESA satellite project to perform all-sky astrometry and photometry from 2012
<b>HARPS</b>	High Accuracy Radial-velocity Planetary Search (new spectrometer at ESO)
<b>Herschel</b>	Far-infrared space observatory (ESA, launch ~2007)
<b>HST</b>	Hubble Space Telescope (NASA/ESA)
<b>IJAF</b>	Instrumentcenter for Jordbaseret Astronomisk Forskning Ground Based Astronomical Instrument Centre
<b>IFA</b>	Institut for Fysik og Astronomi, Århus Universitet Institute of Physics and Astronomy, University of Århus
<b>NASA</b>	National Aeronautics and Space Administration (USA)
<b>NBIfAFG</b>	Niels Bohr Institutet for Astronomi, Fysik & Geofysik, Københavns Universitet Niels Bohr Institute for Astronomy, Physics & Geofysik, Copenhagen Univ.
<b>NGST</b>	Next Generation Space Telescope, (NASA/ESA HST successor, launch ~2009)
<b>NOT</b>	The Nordic Optical Telescope on La Palma, Canary Islands
<b>PI</b>	Principal Investigator
<b>Planck</b>	ESA satellite to study the cosmic microwave background; launch ~2007
<b>SIRTF</b>	Space InfraRed Telescope Facility (NASA)
<b>SNF</b>	Statens Naturvidenskabelige Forskningsråd Danish Natural Science Research Council
<b>TAC</b>	Teoretisk Astrofysik Center (Danmarks Grundforskningsfond) Theoretical Astrophysics Centre
<b>TPF</b>	Terrestrial Planet Finder, possible future NASA mission
<b>VLT</b>	ESO's 4x8m Very Large Telescope at Cerro Paranal, Chile
<b>VLTI</b>	ESO's Very Large Telescope Interferometer (4x8m + 3x1.8m telescopes)
<b>XMM</b>	Now XMM-Newton; X-ray Multi-mirror Mission (ESA)

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**Head of the IJAF Centre:**

Lektor Johannes Andersen, NBIfAFG, University of Copenhagen



**QUESTIONNAIRE SURVEY:  
"DANISH ASTRONOMY 2010"**

**Appendix II.**

Dear colleague,

The next decade will see a virtual 'phase transition' in Danish astronomy. New great research facilities in space and on the ground will appear, others will be retired from service, and the tenured research staffs will undergo corresponding profound changes. Especially in such a period, with uncertain funding and staffing policies for the university and research institutes but increasing general emphasis on project oriented funding for both hardware and staff, it is important that we, as a community, define and maintain our own scientific priorities for the development of Danish astronomy. And any major structural changes, like other major projects, have timescales of a decade.

The general issue was discussed at the "Astrophysics" session during the Danish Astronomy meeting at Nyborg Strand last June. A broad consensus was reached that a report should be prepared to lay out the prospects for the future and present a comprehensive set of goals for Danish astronomy in 2010 and recommendations for actions to be taken to reach those goals. The IJAF Board, already appointed to advise the SNF on matters related to international cooperation in astronomy, was considered to be a suitable body to conduct such a survey, and the Board has decided to take up this challenge.

The Board has examined the ways in which such a report might become most useful in future policy decisions at higher levels, notably in connection with the impending ESO decision on the millimetre array ALMA. An obvious condition is that it should be based on input from the broadest possible community of Danish astronomers, including technical staff, M.Sc. and Ph.D. student, Danes abroad, and visitors to Denmark. The Questionnaire Survey which is announced by this mail is therefore conducted in English, and the Report will also be prepared in English, with a summary in Danish.

In your reply, you are strongly encouraged to disregard the inherited framework of existing projects, institutional structures, and funding uncertainties. What is needed is your best vision of where your field, and Danish astronomy as a whole, will have its place on the international scene in 2010, given a favourable situation. And your opinions are also needed to identify favourable factors as well as possible obstacles on the road to those goals. In thinking ahead, please keep in mind, however, that significant increases in overall staff and funding are unlikely.

The questionnaire form prepared by the Board follows below. A corresponding web based form, which can be filled in and submitted on-line, will also be available at the URL: <http://www.astro.ku.dk/ijaf/da2010/da2010.html>. You are free to use either of these. Individual replies will be held in complete confidence by the Board.

--->> **DEADLINE: JANUARY 15, 2001** <<---

It is planned to post a first draft of the report on the IJAF web site around February 1, 2001, with an option for submitting suggestions for improvement by a certain date. The revised report will then be placed at the web site around March 1 for a final round of comments. You will be alerted by e-mail when new versions are posted on the web, and we look forward to your comments. Thank you in advance for your contribution.

On behalf of the IJAF Board, and with best regards,

Johannes Andersen

**QUESTIONNAIRE: DANISH ASTRONOMY 2010**

**-oOo-**

**DEADLINE FOR REPLIES: JANUARY 15, 2001**

=====

Name:.....

(To be used for supplementary inquiries and to check duplicate replies;  
all replies will be held confidential)

Age:....

Institute:.....

Type of position (tick):

- Tenured scientist ( )
- Technical, engineer ( )
- Postdoc, visitor, ... ( )
- Ph.D. student: ( )
- M.Sc. student: ( )

Current and planned field(s) of research (tick):

Now 2005 2010

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---- ---- ----

- Astroparticle physics, early universe ( ) ( ) ( )
- Cosmology and structure formation ( ) ( ) ( )
- Physics of QSOs, GRBs and other compact objects ( ) ( ) ( )
- Structure & evolution of galaxies (also Milky Way) ( ) ( ) ( )
- Formation, structure and evolution of stars ( ) ( ) ( )
- Instrument development ( ) ( ) ( )
- Solar and planetary systems science ( ) ( ) ( )
- Other (indicate which): ..... ( ) ( ) ( )

Which are, in your view, the current major strengths of Danish astronomy:

Major weaknesses:

Which areas should be of highest priority in future Danish astronomy?

(Indicate priorities 1, 2, 3, ... in the boxes below)

2005 2010 Later

- Astroparticle physics, early universe ( ) ( ) ( )
- Cosmology and structure formation ( ) ( ) ( )
- Physics of QSOs, GRBs and other compact objects ( ) ( ) ( )
- Structure & evolution of galaxies (also Milky Way) ( ) ( ) ( )
- Formation, structure and evolution of stars ( ) ( ) ( )
- Solar and planetary systems science ( ) ( ) ( )
- Other (indicate which): ..... ( ) ( ) ( )

How do you perceive the status of your field internationally, and the contributions of Danish astronomy to it, in 2010?

Which major facilities do you expect to use in your own future research?  
(Estimate percentage of your time for research around each epoch, also for preparation of projects and /or data analysis after their completion):

	2005	2010	Later
ESO VLT	( )	( )	( )
ESO VLTI	( )	( )	( )
ESO La Silla	( )	( )	( )
ESO SEST/AST	( )	( )	( )
ESO ALMA	( )	( )	( )
DK 1.5m	( )	( )	( )
NOT	( )	( )	( )
MONS	( )	( )	( )
HST/NGST	( )	( )	( )
Chandra/XMM	( )	( )	( )
Integral	( )	( )	( )
Planck/FIRST	( )	( )	( )
GAIA	( )	( )	( )
Data archives	( )	( )	( )
Supercomputers	( )	( )	( )
Other (specify):	( )	( )	( )

Do you recommend Danish involvement in the design and construction of hardware for these or any other future facilities?

If yes, which project(s)? .....

If yes, would you be involved in such hardware projects, and if so, how much?  
(Please give estimated percentage of your research time, one line per project)

Project:..... ( )%

Which are the major obstacles to a healthy Danish astronomy in 2010?  
(Indicate your order of priority by 1, 2, 3, ... in the boxes below)

- Lack of facilities: ( )
- Lack of manpower: ( )
- Inadequate career structure: ( )
- Inadequate educational structure: ( )
- Inadequate institutional structure: ( )
- Lack of coherent planning: ( )
- Lack of technical support: ( )
- Lack of public outreach: ( )

Please give your suggestions for improvements on each of these points, keeping in mind that any overall expansion from present is unlikely (free format):

Facilities:

Recruitment:

Career path:

Education:

Organisation:

Planning:

Support:

Outreach:

Any other comments:

Please submit by January 15, 2001, using the web-based version of this form at the IJAF web page, or by e-mail to [ijaf@astro.ku.dk](mailto:ijaf@astro.ku.dk) ("Subject": DA2010).