Report of the Visiting Committee on Astronomy in Israel

to

The Israel Academy of Sciences and Humanities

January 2002

Table of Contents

The Visiting Committee on Astronomy in Israel

Prof. George K. Miley – Chairman
Director, Leiden Observatory, Leiden University, The Netherlands

Prof. Jacob D. Bekenstein
The Hebrew University of Jerusalem, Israel

Prof. Richard S. Ellis
Director, Palomar Observatory, California Institute of Technology, USA

Dr. Yossi Segal – Secretary
The Israel Academy of Sciences and Humanities

1. INTRODUCTION AND CHARGE OF THE COMMITTEE:

This is a report of a committee appointed by the Israeli Academy of Science and Humanities to assess the status of observational astronomy in Israel and the degree to which national astronomy as a whole could benefit from participation in the GranTeCan (GTC) 10 meter telescope facility located in the Canary Islands.

1.1. Original Terms of Reference. The terms of reference given to the committee by the Israel Academy of Sciences and Humanities were:

1. to evaluate the quality and potential of astronomy research in Israel in comparison with the rest of the world.

2. to study the proposal of the National Center of Astronomy and to assess its investment and suitability to the requirements of Israel.

3. to advise Israel joining the GranTeCan telescope facility in Spain, its essence value and advantage to the Israeli scientific community in comparison with other telescope facilities.

4. to recommend to the Israel Academy whether to accept the proposal for a National Center of Astronomy and membership of the GranTeCan telescope facility and to advise on the steps and procedures for accomplishment.

1.2. Input to the Report. Our report is based on the following:

(i) a stay of the external members in Israel from 20th to 23rd January 2002, during which visits were made to the Hebrew University in Jerusalem and Tel Aviv University.

(ii) presentations about the on-going programmes of theoretical and observational astrophysics from representatives of Ben Gurion University, the Technion Institute and the Weizmann Institute as well as the above-mentioned departments.

(iii) intensive discussions with Israeli astronomers from all of the above institutes, some faculty deans, university vice-presidents for research and development, the chairman of the Israeli Science Foundation and the Chief Scientist of the Ministry of Science, Culture and Sport.

(iv) various background material requested by us in advance of our visit, concerning Israeli astronomy, its funding and studies of its international impact.

1.3. Terminology. During our visit to Israel, we became aware of some confusion in the usage of the words "astronomy" and "astrophysics". In Israel "astrophysics" is often used to refer to the discipline that elsewhere is known as "theoretical astrophysics". During the last century the discipline of astronomy has developed into a study of the physics of the Universe and elsewhere in the world "astrophysics" and "astronomy" are commonly used interchangeably. Throughout this report we shall use "astronomy" to refer to the whole discipline of astrophysics, both observational and theoretical.

1.4 Revised Terms of Reference. To allow a more focused consideration of the proposal in hand, after consultation with the President of the Academy, Professor Ziv, our terms of reference were modified. The revised charge of our committee is to advise on the strategic situation of ***observational*** astronomy in Israel in the context of the proposal for participation in GranTeCan and to examine possible alternative ways of obtaining access to large optical/infrared telescopes for Israeli astronomers.

We shall therefore comment on the strategic consequences both of participating in the GranTeCan Telescope project and of not doing so. Further, we consider possible alternatives for Israeli observational astronomy. It is our intention to provide sufficient information about the consequences of the various options to enable a considered strategic decision to be taken on the future of observational astronomy in Israel.

2. RATIONALE FOR FUNDING ASTRONOMY

We shall preface our report with some general remarks about the special aspects of astronomy that make it an important area for research funding.

Astronomy is a unique discipline because of its combined cultural and technological aspects. On the one hand, the astronomer is the ultimate historian who delves much further into the past than conventional historians. On the other hand astronomy drives the development of advanced technology, such as the most sensitive detectors of light and radio waves. Further, the wonder of the night sky combined with the philosophical questions raised by the evolution of the Universe have made astronomy one of the most accessible of the sciences to the general public.

A highly important social function of modern astronomy is in education. Astronomy consistently fascinates the public and regularly receives attention in the newspapers and other media of most developed countries. The story of the evolution of our Universe is an inspiring one, which can provide an ideal introduction for teenagers to the creative excitement of the exact sciences and stimulate students to embark on a scientific career. Moreover, teaching young children about the vastness and beauty of the heavens can help to form broad-minded citizens and tolerant human beings.

In recent years there has been increasing emphasis internationally in using observational astronomy for such "scientific outreach", both for stimulating science awareness amongst children and acquainting the adult public with some of the most exciting achievements of modern civilization. Such programs can play an important role in reaching out to women and minorities that are underrepresented in science.

In several countries a small fraction of the astrophysical research funding is earmarked for popularization. Such programmes have influenced teenagers to choose science as a career and have been important in convincing the general public about the need for funding astronomy and science in general. Popularizing astronomy is therefore important in obtaining wide support for funding astronomical research.

It is our experience that a ***national*** programme of astronomical research is an important ingredient in the success of such outreach programmes. The public can identify more easily with discoveries made or explained by researchers from their own country. To contribute to the success of such endeavours, the national program of astronomical research should be balanced, with a substantial component of ***observational*** astronomy. Although some theoretical work can be explained to a wide public, it is frequently the observations, (e.g. pictures of very distant galaxies or of gravitational lensing) that are most effective in stimulating public interest. This is an important element that should be taken into account by Israel in deciding whether to maintain a programme of observational astronomy.

So there are profound reasons for funding astronomy besides supporting a fundamental area of curiosity-driven research. The benefits that astronomy provides in stimulating technological development, education and culture are profound aspects that must be taken into account. Although astronomy is a relatively expensive science, it gives good value for the money.

3. ASTRONOMY IN ISRAEL

3.1 General Remarks. During our visit to Israel we were highly impressed by the breadth and excellence of Israeli astronomy. Many of the most fundamental scientific questions are being investigated and the impact of Israeli astronomers is high. The community as a whole has an outstanding reputation with good international connections.

3.2 Funding level. ***Funding for astronomy in Israel is substantially below the level of that in most other developed countries***. This is illustrated in the table presented in Appendix A. We compared Israel with the Netherlands and the United Kingdom, both countries for which the funding situation is well known to us. In their relative expenditures on astronomy, the Netherlands and the United Kingdom are not exceptional among developed countries.

The fraction of astronomers in the population is similar in the UK, the Netherlands and Israel: about 1 in 160,000. However, astronomy funding in Israel is extremely low by any measure. The ratio of under-funding ***varies between 2 and 4,*** depending on whether one bases it on the relative GNPs, the relative number of astronomers, or the relative spending on civil research.

Most of this huge imbalance can be attributed to the fact that unlike the USA, Canada, Australia or most European countries, Israel does not participate in large observational facilities. In the case of the Netherlands more than half of the $45 M total expenditure on astronomy is devoted to funding optical/infrared observational facilities, about $5M to the European Southern Observatory (ESO), $16.9M to The European Space Agency (ESA) for their astronomy missions as well as supporting the Dutch share of the UK/NL facilities at La Palma and Hawaii. An additional $5M funds the Westerbork Synthesis Radio Telescope. A similar pattern is found in most other developed countries that have a significant programme of astronomical research.

3.3 Characteristics and Organization of Israeli Astronomy. Appendix B contains a table showing the approximate breakdown by institute of the number of Ph.D-level scientists presently working on specific areas of astronomy. It demonstrates that Israeli astronomy is very diverse, with fields of activity that includes cosmology, the nature of galaxies and stars and the study of extrasolar planets. Outside Israel the study of gravity waves is usually regarded as a branch of physics, but in Israel it is included within astronomy. There is particular emphasis in Israel on cosmology and high-energy explosive phenomena including studies of active galactic nuclei and gamma ray bursters. An instructive description of the history and structure of Israeli astronomy was provided to us by the internal member of our committee, Professor Bekenstein. This is also appended to this report (Appendix C).

The characteristic that sets Israel apart from most other astronomically mature countries is the relatively large focus on theory. About 80% of the astronomers are mainly engaged in theoretical research. We estimate that not more than 30% of US and European astronomers are theorists. Given the relative lack of spending on astronomical observing facilities by Israel over the years and the strength of theoretical physics in the country, we believe that the development of a large presence in theoretical astrophysics was sensible and strategically sound for building up Israeli astronomy.

Most of the theoretical groups are parts of large physics departments (Technion, Ben Gurion University, Weizmann Institute, Hebrew University of Jerusalem, Haifa University). Almost all the observational expertise is concentrated at the School of Physics and Astronomy of Tel Aviv University, the department that manages the Wise Observatory.

3.4. Quality of Observational Research in Israel. A key issue which relates to the merits of expanded funding for optical and infrared astronomy is the scientific impact of observational astronomy in Israel in recent years as well as the level of expertise appropriate for exploiting new large facilities such as the 10m GTC.

Whilst the committee was impressed with the achievements of the Wise 1m telescope and several long term programs undertaken with it, for example in supernova searches at intermediate redshift and AGN monitoring as a means for estimating black hole masses, many of the recent highlights have come from collaborations with external scientists who can provide access to more powerful facilities. Considering the modest size of the community, there is a healthy breadth of activity from planetary formation to questions of fundamental cosmological importance and several of the faculty are world leaders in their fields.

Although almost all of the traditional observers are in Tel Aviv University, a number of young astronomers with modeling or interpretational skills in other institutes clearly play a key role in important observational programs conducted overseas. Because astronomy develops rapidly, detailed proposals for use of a large telescope cannot be evaluated at this stage. However, it is the committee's strong impression that regular access to large facilities for Israeli astronomers would enable many world-class programs of high quality. Moreover, this would lead to a much-needed re-distribution of observational effort in the country.

4. OBSERVATIONAL ASTRONOMY: STRATEGIC CONSIDERATIONS

4.1. Synergy between Observations and Theory. The history of the past half-century has shown that although astronomical progress occurs through the constant interplay of observations and theory, new astronomical discoveries are usually driven by observations and technological advance. There are areas of astronomy for which an excellent theoretical group can excel and there are examples of world-leading theoretical institutes of astronomy. However, the separation of theory and observation increasingly leads to the situation where theorists become too remote from the phenomena that they are seeking to explain and likewise observations are carried out without any theoretical justification. The distinction between observational and theoretical astronomers has become increasingly blurred and interaction between theory and observation has become an essential in most areas of modern astronomy.

4.2. Choice of Optical/ Infrared Astronomy. The two regions of the spectrum accessible to ground-based observational facilities are the optical/ infrared and the radio, but it is at the optical/ infrared wavebands that the widest range of astrophysical diagnostics are located. There are large numbers of emission and absorption lines that can probe physical conditions in a variety of environments in the Universe ranging from the most distant quasars to the closest stars. Because of the wide applicability of optical/infrared astronomy and the existence of a well-established group of Israeli optical/infrared observational astronomers, involvement in an optical/infrared telescope is an obvious choice for continuing a wide-based observational astronomy programme in Israel.

4.3. International Situation. As we mentioned above, most developed countries have access to large modern ground-based optical telescopes. For the USA there is the twin Keck 10m telescopes, the pair of Gemini 8m telescope and several others. Most European countries (large and small) have access to the Very Large Telescope (VLT) in Chile via the European

Southern Observatory (ESO). The U.K., long a member of the Gemini consortium, has recently decided to join ESO. Australia and Canada are members of Gemini as well as having access to a range of 4m-class telescopes and radio astronomical facilities. During the past decade, Japan, who has long supported front-line facilities in radio astronomy and space astronomy, has built an 8-m diameter telescope in Hawaii.

4.4. National Situation. As we pointed out above, observational astronomy in Israel is substantially under-funded compared with most developed countries. Such activities in Israel have been dependent on a 1-m diameter telescope at the Wise Observatory, managed by Tel Aviv University, a telescope that is now 30 years old.

During the last two decades the Wise Observatory has made heroic contributions to observational astronomy, but the restriction to a 1m aperture on a mediocre observing site has been a severe limitation to the science that can be done. With the advent of the new generation of large optical telescopes such a facility has become even less competitive. We are therefore convinced that access to much larger optical/infrared telescopes is needed if Israel is to keep internationally competitive in observational areas to which the Wise Observatory has contributed substantially during the past.

Access to a 8 - 10m telescope could allow Israeli astronomers to carry out forefront research in additional areas in which they already have a strong theoretical presence. The resultant interplay between observations, interpretation and theoretical modeling would not only stimulate present areas of national excellence, but could also be a catalyst in establishing areas of astronomical research that are not at present undertaken in Israel.

Israeli theoretical astronomy could provide “added value” to the involvement in a large telescope project. As we mentioned above, there are few other countries in which astronomical theory is so relatively strong. Moreover, access to a large telescope facility would enhance Israel's ability to attract top international postdocs and foremost staff astronomers.

Deciding ***not*** to join a large observational facility at this time will also have very profound consequences for the future of astronomy in Israel. Although the Wise Observatory can still be used in a few important “niche” areas of astronomy for the coming few years, it is clear to us that ***without participating in a larger telescope project, Israel would be effectively opting out of mainstream observational astronomy***. Not only would this jeopardize the future of the excellent astronomy department at Tel Aviv, but it would also have national strategic consequences for education, science outreach, culture and Israel's place in the developed world.

5. CONSIDERATION OF OPTIONS

Although the Committee was presented with a single option for the provision of large telescope access (namely a share in the GranTeCan telescope at present near completion in the Canary Islands), it is helpful to contrast the merits of this option against alternatives. As discussed, the ultimate decision of which of these options to pursue is the responsibility of the Academy.

5.1 The GranTeCan Option. The GranTeCan (GTC) is a 10 meter segmented mirror telescope being constructed on the Canary Island of La Palma (Spain). It will be operated by the Instituto de Astrofisica de Canarias (IAC) and at least 70% of the observing time will belong to the Spanish astronomical community. The proposal submitted by the Tel Aviv astronomers argues for a 10% share, which represents a capital one-off payment of $10M and an estimated annual operating contribution of $600K. The telescope is expected to be operational in 2004 with competitive instrumentation shortly thereafter. Current partners in the GTC include the Autonomous University of Mexico and the University of Florida.

GTC is broadly a copy of the 10-year old Keck design. At first sight this may appear to represent out-dated technology. However, it is common for telescopes of a given design and aperture to be replicated over an interval of at least a decade and perform world-class science for many decades. Indeed, the large 10-meter aperture is an almost unique feature (c.f. many 6.5-8m aperture telescopes also still under construction in the US and Chile) and there is no question that the Keck design, which incorporates large Nasmyth platforms and a Cassegrain focus, provides versatility for instruments of various kinds.

The La Palma site represents one of the best world-class sites known for faint object optical and infrared astronomy. Although the number of clear nights is not as great as at the northern Chilean sites and although the seeing is slightly inferior to that in Mauna Kea (site of the Keck telescopes), La Palma has other redeeming features, not least the proximity to Israel. It is without question the best-known site in Europe and a very dark one. Experience over 20 years suggests it is particularly reliable in the summer months for optical studies and sufficiently cold in the winter for thermal infrared studies.

An interesting feature of Israeli participation in GranTeCan is the potential for access to the other telescopes on La Palma including the well-instrumented UK/Dutch 4.2m William Herschel Telescope (WHT) . Quasi-simultaneous access to this intermediate-size telescope with a wider field would be particularly important for a full exploitation of the GTC and the possibility for a "weighted" exchange of nights should be incorporated into any agreement.

Another attractive aspect of this option is the complementary nature of the Israeli and Spanish astronomical communities. The strong theoretical emphasis in Israel contrasts with the more traditional observational community in Spain and particularly at the IAC. The collaborations that would inevitably arise might permit Israel to secure a larger share of the observing time on the GTC than that formally corresponding to its contribution. However, the committee was disappointed to learn that few steps had been taken by Israeli astronomers to properly evaluate the interests of their potential Spanish colleagues.

The committee concluded that the GTC proposal is an interesting and viable option for Israel. Indeed, it is one of the few available on the large telescope "market" at the present time. The option may only be open for a limited time and there is therefore some urgency in starting negotiations.

Key issues of concern discussed included (i) the optimum fraction of Israeli access, (ii) the likelihood that Spain and its current partners would complete the telescope and provide a good suite of first generation instruments on time, and (iii) the reliability of the operation and its cost.

The committee supports access at the 10% level as this would provide around 25 nights per year for an active community in the steady state of at least 8-12 astronomers. It does not believe access at a level below 8% would be worth the administrative and financial investment. There is some worry that full-time operation could be delayed beyond 2004 and that the current operational budget estimates are inadequate. In some respects a segmented mirror telescope is more difficult to maintain and operate than a conventional telescope and the IAC staff may find themselves inexperienced in some key areas. After weighing the possibilities, the committee supports access to the GTC as an exciting and immediate opportunity.

If Israeli involvement in GTC is funded nationally, there should be national participation in its management and in the time allocation process, i.e. with representation from institutes other than Tel Aviv University.

5.2 The ESO Option. A more reliable (but costly) alternative to the GTC option would be to apply for membership of the ESO, which operates many telescopes in Chile (including the 4 x 8m VLT) on behalf of most European Community nations.

ESO represents the astronomical equivalent of the European partnership in experimental particle physics embodied by CERN. Membership is fixed at a level scaled by GDP and not negotiable. The benefits are much wider than mere access to forefront facilities and include *juste retour* to participating nations in industrial contracts (which can represent a useful showcase for high tech companies). ESO membership would guarantee a continuing share in future large astronomical projects including the planned Atacama Large Millimetre Array (ALMA), scheduled to operate from about 2008, and a proposed giant segmented mirror telescope with a diameter of up to 100m envisaged for 2015 - 2020.

Israeli membership of ESO would cost around $10-12M as a one-off capital payment (an entry fee comparable to the GTC), but the annual operational contribution would be significantly higher (2 - 4 times greater). Unlike GTC, ESO covers travel and boarding expenses for one person per project. Although Israel would then have no more than a 2% access to the ESO observatories, the reduced ownership fraction c.f. GTC would be offset by access to a much wider range of facilities in the present and future, (including forefront millimeter-wave telescopes) and the fact that the four VLT 8 m telescopes operate mostly as independently. The ESO site has on average more than 20% clear nights than La Palma so in terms of guaranteed access to forefront large telescopes the options are approximately similar. Also, through ESO membership, Israelis would be eligible for ESO positions, such as postdoctoral fellowships at Garching and in Chile.

Observing time is allocated on all ESO facilities according to peer review; no guarantee is formally possible. This contrasts with the GTC option where Israel would presumably operate its own national committee and be assured time each cycle. There are merits for both routes. In the case of the GTC option, Israeli astronomers could confidently plan long term science programs of high impact. This is an important consideration in a highly competitive world. In the case of ESO, there is a self-improving competitive hurdle to overcome in submitting an application for time alongside UK, French and German competitors; as a result collaborative programs with astronomers from other ESO member states are likely to arise naturally. In the same way that Israel's status in CERN and ESRF has benefited physicists, so Israel's joining ESO would have strategic and long term advantages for national astronomy.

The committee was unable to judge the political feasibility of ESO membership as an alternative to the GTC participation. Would Israel we willing to take this step? In many countries (e.g. recently in the UK) participation in an international organization such as ESO represents a strategic political decision taken outside regular research funding sources. Would ESO be willing to accept Israel as a member state? Several other countries, including Australia, Finland, Ireland and Spain are considering applying for membership and formal negotiations have been opened between ESO and Spain. The ESO and GTC options may ultimately be connected since access to GTC may represent part of the entry fee, if Spain joins ESO.

5.3 The 4m Option: Most nations with mature observational communities have progressed in their access to large facilities (8-10m telescopes) by way of 2-2.5m and 4m telescopes. It is natural to question whether this makes sense for Israel, particularly in view of the fact that there are many well-instrumented 4m telescopes on good sites whose operational budgets are under pressure as those nations redirect their attention to funding yet larger telescopes. The committee considered, by way of a hypothetical example, access at the 40% level to a modern 4m telescope such as the William Herschel Telescope on La Palma (such a large share of the WHT is not known to be available). The annual operating share in this option would likely be comparable to that for the GTC option, but the initial entrance fee would probably be significantly less.

Although this option would provide some temporary invigoration of Israeli astronomy, the committee concluded it is not a logical solution that makes good strategic sense. Most available 4 metre telescopes are 20-30 years old and the maintenance of their ageing instrumentation would be a formidable challenge. Investing at a more modest level in the latest generation of facilities would be more appropriate.

5.4 Other Options: The Committee wishes to dispel alternative ideas for gaining access to large telescope time that arose in its discussions**.**

The "Pay-Per-View" Option: It is occasionally suggested that astronomers could construct an innovative science program, raise national resources purely for that initiative and then buy telescope time overseas on an ad hoc basis, perhaps enhancing the likelihood of success by providing an innovative instrument.

Quite apart from the difficulty of breaking into well-established national and international agreements that govern the operation of most large telescopes, such a mode of operation does not provide the necessary strategic change for improving Israel's long-term position in the subject. The Committee is concerned to ensure a continuing participation in forefront observational astronomer that will introduce young students to the challenges as a foundation for the future.

The "Parasitic" Option**:** It is likewise occasionally suggested that the present vitality of observational astronomy in Israel, gained through collaborative access to non-Israeli facilities such as the Keck observatory and Hubble Space Telescope, is adequate and moreover that the necessity to aggressively bid for foreign partnerships through a demonstration of unique Israeli skills is sufficient to ensure a vibrant community.

The key points here are synergy and intellectual leadership. Formal access to large telescope time provides the necessary national focus for the community to ensure long-term planning and Israeli leadership essential for introducing new students to observational astronomy. Ownership of the facilities is needed for a strategic long-term benefit for the community.

The final option is ***status quo***. By arguing that the proposed access to GTC or ESO membership is too costly, the Israeli community would effectively be abandoning mainstream observational astronomy and undoing the excellent progress achieved with the 1m Wise Observatory since 1971. Although further theoretical or other observational initiatives might be proposed, the strategic outcome would be unclear.

5.5 Astronomical Instrumentation. An important by-product of formal participation in a large astronomical telescope partnership in many countries is the training of instrument builders who go on to develop novel techniques, which can often transform the subject. Examples include new detectors, optical designs and multiplexing capabilities. Many of the breakthroughs in modern astronomy have resulted from collaborations between astronomers and engineers with technical skills.

The Committee was unable to conduct a thorough survey of the potential in the Israeli universities to respond to the GTC or ESO options in this respect, or to investigate possibilities for Israeli industry. Nonetheless, it was convinced that there are some opportunities that could be encouraged by ensuring greater synergy across the various campuses. The likelihood of progress in this area would probably be greater in the case of the ESO option. Partnerships with "high-tech" industries are particularly encouraged by ESO as a means of *juste retour,* so we would expect advanced high-tech firms in Israel to benefit if Israel joined the organization. Besides the commercial benefits that would accrue from ESO contracts, international astronomy could be a very visible "showcase" for Israeli industry.

6. RECOMMENDATIONS

On the basis of the above considerations we have reached the following conclusions and recommendations:

6.1. Israel needs access to a large optical/IR telescope if it is to continue research in mainstream observational astronomy.

6.2. We strongly endorse the goals of the proposal that was presented to us, namely to provide modern competitive observational facilities for Israeli astronomy. However, it is important that the necessary funding should not come at the expense of the support for the many excellent theoretical research programmes in Israeli astronomy.

6.3. Of the several options that we considered in Section 5, membership of ESO is the only presently viable alternative to the GranTeCan participation. A decision between these options is however urgent and if it is decided to proceed we suggest the following immediate steps:

(i) The Academy should initiate informal discussions with the ESO to ascertain the likelihood that an application to join would be successful and on what timescale.

(ii) The Academy should declare a strong interest in opening formal negotiations with the Director of the IAC concerning Israel's participation in GranTeCan. The key issues discussed in Section 5.2 should be clarified.

(iii) In parallel with the above approaches, representatives of the Israeli astronomical community should establish contact with their Spanish counterparts to address likely synergies in research programs and the provision of instrumentation.

6.4. The consequence of taking no immediate action is that observational astronomy in Israel will become non-competitive internationally and will almost certainly decline into insignificance. This will have implications both nationally and for the excellent Tel Aviv group.

6.5. Israel should consider devoting substantially more funds to astronomy for two strategic reasons. First, Israeli astronomy is substantially under-funded by international standards, (a factor of at least 2 by any index compared to the situation in comparable developed countries). Secondly, besides being one of the most fundamental of research disciplines, astronomy can play an inspirational role in education, persuade young people to embark on a scientific career. Observational astronomy needs the most sophisticated of equipment and has frequently driven the development of new technologies.

6.6. The provision of some additional funding for astronomy postdocs (theoretical and observational) would be cost effective in ensuring optimal exploitation of a new observational facility.

Acknowledgement: We thank the Academy for their hospitality and in particular Dr. Yossi Segal for organizing the visit and providing expert guidance and assistance throughout the review.

7. Appendices

A. Funding of Astronomy in Israel: International Comparisons

B. Astronomy in Israel: Fields and Locations

C. History and Structure of Astronomical Research in Israel

APPENDIX A

FUNDING OF ASTRONOMY IN ISRAEL: INTERNATIONAL COMPARISONS

Approximate comparisons of the funding level of astronomy in Israel with those of astronomy in two typical developed countries**.** The disparity is mainly due to lack of spending by Israel on observational facilities, either via the membership of international organizations or nationally.

	ISRAEL	**NETHER-LANDS**	**UNITED KINGDOM**	**ISRAEL ASTRONOMY UNDER-FUNDING**
Astronomy Funding	\$6M	\$45M	\$174M	
Population	6.1M	15.8M	59M	
Ast. Expenditure/ head	\$1	\$2.9	\$2.9	**2.9** (NL) **2.9** (UK)
No. funded professional Ph.D Astronomers	52	102	425	
Ph.D Astronomers/head	8.5×10^{-6}	6.5×10^{-6}	7.2×10^{-6}	
Funding per astronomer	\$115,000	\$440,000	\$409,000	**3.8** (NL) **3.6** (UK)
GNP (1999)	\$106B	\$380B	\$1070B	
Ast. Expenditure /GNP	5.5×10^{-5}	14×10^{-5}	11×10^{-5}	**2.6 (NL) 2.0** (UK)
Civil Research Spending (1999)	\$2.5B	\$5.1B	\$7.6B	
Ast. Expenditure/ Civil Research Spending	0.0024	0.0088	0.0029	**3.7** (NL) **3.0** (UK)

This table has been compiled using the following information.

- For the Netherlands we used data given in the October 2001 strategic plan “Astronomy in the Netherlands” compiled by the Dutch astronomers together with the Netherlands Organization for Scientific Research (NWO).

- For the United Kingdom, we used data supplied to us by the UK Particle and Astronomy Research Council (PPARC).

- For Israel we took the data on astronomy research funding supplied to us by the Academy. In Israel an average of US $1M annually was spent in funding astronomy and space research projects. This according to figures from the Israel Science Foundation - ISF, the US-Israel Bi-national Science Foundation - BSF and the German-Israeli Foundation for Research and Development - GIF, the main foundational sources of basic research grants in Israel. In addition, the Israeli universities support a total of about 52 Ph.D level research staff and about 30 Ph.D students engaged in astrophysical research, whose cost per person we estimate as equal to the Netherlands university staff, bringing the cost of the Israeli university departments to about $5M per year, and the total funding for Israeli astronomy to ~ $6M per year.

APPENDIX B
ASTRONOMY IN ISRAEL: FIELDS AND LOCATIONS
Approximate Number of Faculty Members per Field

FIELD	TEL-AVIV UNIVERSITY	HEBREW UNIVERSITY	TECHNION	WEIZMANN	BEN GURION UNIVERSITY	HAIFA UNIVERSITY	COLLEGE OF JUDEA AND SAMARIA
Stellar	4	8	2	-	-	2	-
Cosmology/Galaxies	5	3	1	1	2	-	-
Active Galaxies /Quasars	2	1	1	1	-	-	-
High Energy	3	1	2	2	3	-	-
Gravity	-	2	1	-	4	-	1
TOTAL	**14**	**15**	**7**	**4**	**9**	**2**	**1**

APPENDIX C

HISTORY AND STRUCTURE OF ASTRONOMICAL RESEARCH IN ISRAEL

J. Bekenstein

C.1 FORMATIVE PERIOD

The present structure of the research groups in Israel devoted to astronomy and related subjects reflects the late flowering of this type of work in the country. N. Rosen worked on gravitation theory already from his arrival at the Technion (Israel Institute of Technology) in 1953, but he applied novel gravitational theories to cosmology only in the early 1970's. In the mid 1960's gravity theorist G. Tauber joined Tel-Aviv University and developed the kinetic theory in strong gravity fields. In the same epoch, at the Hebrew University, G. Rakavy and Z. Barkat moved from nuclear physics to astrophysics thus originating the “Rakavy" astrophysical group.

At much the same time observer Eliah Leibowitz returned to Tel-Aviv University and initiated the first planned astronomical group in the country, following the vision of Y. Ne'eman. The George and Florence Wise Observatory of Tel-Aviv University, with its 1 m telescope, became operational in 1971. In the early 1970's the Tel-Aviv group included as well B. Kozlovsky, A. Yahil, A. Harpaz, G. Shaviv and R. Steinitz. They were joined by a number of long-term visitors. Among these were J. and N. Bahcall who in 1972 discovered the optical counterpart of the galactic X-ray source Her X-1 with the Mitzpeh Ramon telescope.   The group also included Irena Kupo, an immigrant astronomer from Russia who in 1972, together with A. Eviathar and Y. Mekler of the sister department of Geophysics and Space Science at Tel-Aviv, used the 1 m telescope to discover the sulfur clouds surrounding Jupiter and originating in the volcanoes of its moon Io. An early attempt at Tel-Aviv University to start a solar research group failed.

Also in the early 1970's the Technion's received its first astrophysicist, A. Finzi, who worked on high-energy astrophysics and galactic structure in virtual isolation at the Faculty of Mathematics. J. Shaham founded a dedicated theoretical astrophysics group at the Hebrew University in 1972; renowned work on neutron stars ensued. Shaham was joined by the veteran gravity theorist J. Katz, as well as by G. Horwitz, who turned to gravitation research from statistical physics. By 1973 Y. Avni, M. Milgrom and M.

Elitzur from the Weizmann Institute were returning from postdoctoral stints in which they had switched from particle physics to astrophysical endeavors right after their doctorates. Coevally gravitational theory research began at Ben-Gurion University with M. Carmeli followed a little later by J. Bekenstein and Elhanan Leibowitz (brother of Tel-Aviv observer Leibowitz), while astrophysicist R. Steinitz moved here from Tel-Aviv.

In the mid-1970's observer H. Netzer was recruited by Tel-Aviv University and started the Tel-Aviv's group's commitment to observations of active galactic nuclei. An attempt to start a radio astronomy group at Tel-Aviv did not yield fruits. And in the later 1970's Elitzur and Yahil moved to the United States.

In the early 1980's the Tel-Aviv group received astrophysicists M. Livio and O. Regev, astrophysicist turned observer T. Mazeh, as well cosmologist Y. Rephaeli and somewhat later relativist-astrophysicist I. Goldman. In the same years gravity theorist and astrophysicist T. Piran and cosmologist A. Dekel joined the Hebrew University's Shaham group. In these same years, Avni left the Weizmann Institute for Harvard University and Shaham left for Columbia University. The administratively separate Rakavy group at the Hebrew University had been growing apace: Y. Tuchman, A. Glasner and I. Lichtenstadt joined its astrophysical section which specialized then exclusively in the late stages of stellar evolution. Gravity theorist Ch. Charach returned to Ben-Gurion University, but soon turned to other research. In the early 1980's a rearrangement gave rise to the present large group at the Technion: Shaviv, Livio and Regev moved there from Tel-Aviv. They were joined by veteran Technion particle physicists A. Dar who began turning his attention from high energy physics to astrophysics. In the mid-1980's A. Davidson, a particle physicist whose research turned increasingly towards cosmological issues, moved from the Weizmann Institute to Ben-Gurion University. Observer N. Brosch joined the Tel-Aviv group while astrophysicist D. Eichler joined Ben-Gurion University.

This Appendix is partly based on Yuval Ne'eman's lecture "From the Quark to the Cosmos: Seventy Years of Physics in Israel", given before the Israel Academy of Sciences in 1998.

C.2 CRYSTALLIZATION

The period 1990-2000 witnessed a great expansion, restructuring and crystallization leading to the present astrophysical community. J. Bekenstein moved to the Hebrew University's Shaham group, while the Rakavy group diversified by acquiring cosmologist Y. Hoffman, astrophysicists A. Wandel and S. Balberg and fluid dynamicist E. Livne. Astrophysicists A. Sternberg and A. Levinson and observers Sara Beck and D. Maoz and joined the by now large Tel-Aviv group. Milgrom, the sole member of the Weizmann Institute astronomy group for many years, was joined by astrophysicists V. Usov and E. Waxmann. The Technion group was augmented by gravity theorist A. Ori, cosmologist A. Nusser and astrophysicist A. Laor while Livio left for the United States. Astrophysicist M. Gedalin, gravity theorist E. Guendelman and cosmologist R. Brustein joined the group at Ben-Gurion University. That group also accreted three Russian immigrant scientists: A. Kaganovich (gravitation and cosmology), E. Griv (stellar dynamics) and late in the decade Y. Lyubarsky (pulsars). Haifa University started its own astronomy group made up of stellar theorists Harpaz and N. Soker. And the College of Judea and Samaria hired gravity theorist M. Schiffer.

The last decade of the 20-th century also witnessed several new observational projects in Israel. The Technion's group developed an X-ray telescope for the Technion made satellite. The first version of the instrument was destroyed by the failure of the Russian launching rocket. The second version was successful put into orbit later in the Tech-Sat. At Tel-Aviv University Brosch developed an ultraviolet imager, TAUVEX, for observations from orbit. Delays in the Russian program to launch the satellite have put the program in jeopardy, though launching of TAUVEX by an Indian rocket may still occur. At the College of the Jordan Valley, L. Postul'nik, a Russian immigrant scientist, erected a 2.5 m radiotelescope, RT-2.5, which observed in conjunction with Russia's RATAN 600 m dish. RT-2.5 was used mostly for solar observations. Already dating from the last years of the previous decade, the Emilio Segre Cosmic Ray Observatory on Mount Hermon, established by Russian immigrants scientists L. Dorman and M. Katz of the College of the Jordan Valley, concentrated on forecasting communications disturbances due to solar flares. The group at the College of the Jordan Valley is no longer active. At Ben-Gurion University a collaboration of Eichler with the group for solar energy research is using a 25 m parabolic light collector to detect Cherenkov optical pulses originating from gamma ray bursts, or signals from any unexpected rapidly changing optical source.

In line with the rapid increase of the Israeli astronomical community in the last decade of the twentieth century, the expansion continues. In 2001 four new faculty members were hired: N. Saviv (G. Shaviv's son), a high energy astrophysicist, by Hebrew University's Shaham group, E. Behar (astrophysical plasma diagnostics) by the Technion, T. Alexander (supermassive black holes) by the Weizmann Institute and R. Barkana (cosmology) by Tel-Aviv University. T. Broadhurst, an observer, has arrived to a long term visiting position at the Hebrew University's Shaham group. Israel may soon join the field of observational cosmology if, as intended, the Weizmann Institute hires S. Hanany, member of the MAXIMA and PLANCK collaborations investigating the cosmological microwave background.

C.3. FACULTY

All astronomical research - broadly defined - in Israel is carried out at the universities (of which only Bar-Ilan University has no group on the subject by explicit planning), the Weizmann Institute, the Technion and the College of Judea and Samaria. In Tel-Aviv University astronomers and astrophysicists are grouped in the autonomous Department of Astronomy and Astrophysics (part of the School of Physics and Astronomy), which comprises the Sackler Institute of Astronomy and the Wise Observatory. In the other institutions astrophysical groups, which include researchers in gravitation theory, are informal sections of the physics departments, faculties or institutes (in the Weizmann Institute of the Department of Condensed Matter Physics). A very large fraction of the 50 or so researchers concerned received their Ph. D. training in Israel. All have had postdoctoral and other, sometimes extensive, research experience, usually in the United States.

The Weizmann Institute and Tel-Aviv University groups developed under long range, research oriented planning. At the other extreme are the groups at Ben-Gurion University, Haifa University, the College of Judea and Samaria and the Rakavy group, whose growth was either haphazard or dictated by considerations other than astrophysically related research. These last groups comprise a substantial fraction of workers whose positions are either of an adjunct nature, or else teaching dedicated. No doubt many of these people could make a much larger research contribution if they were not loaded down by relatively heavy teaching loads or obligations to research defense related research contracts. The Shaham group at the Hebrew University and the Technion group occupy an intermediate position: while research oriented development is evident, the groups are perhaps too diversified to achieve the maximum impact possible for their size.

C.4. OTHER HUMAN RESOURCES

As elsewhere, in Israel the main research resource after the faculty are Ph. D. research students and postdoctoral fellows. Most Ph. D. students are home grown. There are no undergraduate degrees in astronomy in Israel, but some undergraduate level astronomy courses aimed at both general students and physics degree students are offered at Ben-Gurion University, the Hebrew University, Tel-Aviv University and the Technion (there are no undergraduate studies at the Weizmann Institute). M. Sc. and Ph. D. degrees in physics with a specialization in astronomy are offered by all the mentioned institutions (including the Weizmann Institute).

Research students in these institutions mostly arrive with an undergraduate degree in physics and proceed to obtain an M. Sc. degree on the way to a Ph. D. program. Most of the mentioned institutions also offer a direct Ph. D. program for students with especially high standing.

All astronomy groups apart from that at the College of Judea and Samaria have Ph. D. students. At Ben-Gurion University, Tel-Aviv University, the Technion and the Weizmann Institute the research student to tenure-track faculty ratio is about 1:1. In the Hebrew University's Shaham group it is nearer to 2:1. Research students are scanty at the Rakavy group and at Haifa University. Ph. D. students in Israel are supported by a combination of department scholarships, teaching assistantships and, particularly at the latter stages of their work, their adviser's research grants. Nationwide scholarships for talented students (Clore scholarships) also exist; they are very rare but a few students of the astrophysics groups have enjoyed their support. As for the bulk of Ph. D. students, the need for researchers to partly or fully support them has been known to curtail the latter's ability to hire a postdoc.

Postdoctoral fellows trained outside Israel (US, UK, Canada, Netherlands, Germany, Italy, Japan, India) can be found in the astrophysical groups; Israeli postdoctoral fellows are rare and not encouraged. The typical postdoctoral fellow to tenure-track faculty ratio in the last years has been about 1:5 at Tel-Aviv University, 1:3 at the Technion, Weizmann Institute and Ben-Gurion University, and 1:2 at Hebrew University's Shaham group. The Hebrew University and the Technion have dedicated postdoctoral fellowships (Lady Davis Foundation and other sources) requiring a comparable matching contribution from the sponsoring faculty member's research grants. So does the Sackler Institute for Theoretical Physics at Tel-Aviv University and the Technion Institute of Theoretical Physics. At the Weizmann Institute and

Ben-Gurion University, de Shalit and Kreitman postdoctoral fellowships, respectively, are freer but competitive. The Central Planning and Grants Committee (VATAT) of the Council of Higher Education makes postdoctoral fellowships available to the universities, but each of these also requires substantial matching funds by the sponsoring faculty member. The tax-free postdoctoral stipends are low (US$ 1500 per month including all fringe benefits); this together with the volatile political situation in the region has made it difficult to hire the cream of the postdoctoral crop. Considerable potential exists for fruitfully employment of more postdoctoral fellows in astronomy in Israel.

Since the 1970's there has existed a considerable pool of Israeli astronomers and astrophysicists abroad, many with an Israeli Ph.D. Most recruitment to faculty positions in Israel has drawn from this pool, but historically Israel has been able to reabsorb only a fraction of the astronomers it has produced. Some members of the pool, N. Bahcall, A. Königl, O. Lahav, A. Yahil, for example, have made their careers outside Israel. Some others, notably gravity theorist A. Feinstein, astrophysicists N. Arav, E. Maoz, R. Saari, J. Grannot, and Y. Friedman, and cosmologists S. Zaroubi and T. Kolatt, are potential candidates for further recruitments.

C.5. INTERUNIVERSITY INTERACTION

In the 1970's it was common for individual researchers to frequently visit neighboring institutions. This activity has traditionally been more popular with the younger workers; consequently the aging of the astronomical community in Israel led to its weakening.

In the 1970's Tauber organized a national relativistic astrophysics seminar, which took place periodically in Tel-Aviv University, and operated for a number of years. In the mid 1980's this tradition was renewed by Dekel who, with cooperation from colleagues at Tel-Aviv University and the Technion, organized an ambulant national astrophysics seminar which convened alternatively at a different institution. For many years a session of the seminar doubled with the astrophysical session at the annual meeting of the Israeli Physical Society. Despite changes of organizer and occasional interruptions, the national seminar is still active. At present it is held at Newe Shalom, a settlement more or less equidistant from Tel-Aviv and Jerusalem, and close to the Weizmann Institute.

Interaction of Israeli astronomers has also taken place at various international conferences and workshops held in Israel over the years (see below for a partial list). But there is no dedicated institution, such as CITA in Canada, or IUCAA in India, which serves as a center for interuniversity collaborations in astronomy. As a result the absurd situation whereby Israeli astronomers from different institutions meet more often overseas than in Israel is a common occurrence.

C.6. FUNDING FOR ASTRONOMY IN ISRAEL

C.6.1 Support Level. Although Israel ranks first among developed nations in the percentage of the gross national product earmarked for civilian research and development (an average of 4.2% in the years 1998, 1999 and 2000), and only sixth (after Switzerland, Finland, Japan, Sweden and the US) *in per capita* investment for the same item (figures from Israel's Central Bureau of Statistics), support of astronomical research in Israel is comparatively low. Out of the average annual US$ 2.7B of civilian research spending in the mentioned triennial period (of which about US$ 200M is allocated to basic research), an average of US $0.99M annually went to astronomy, astrophysics and space research projects. This according to figures from the Israel Science Foundation - ISF, the US-Israel Binational Science Foundation - BSF and the German-Israeli Foundation for Research and Development - GIF, the main foundational sources of basic research grants in Israel. If one adds expenditures of the universities for salaries of astronomers, etc., one comes up with a total annual expenditure for astronomy of about $6M.

By comparison the Netherlands whose GNP and GNP *per capita* are four times and twice, respectively, those of Israel, and which spends 2% of its GNP on civilian research, invests a comparatively large sum, US$ 50M annually, in astronomy, astrophysics and space science (including the country's contributions to the European Space Organization and the European Southern Observatory) to keep active an astronomical community only about twice as numerous as Israel's.

Recruitment of postdoctoral fellows and support of Ph. D. research students in their later years in Israel would be problematic if not for the funds to complement university and foundation fellowships and scholarships. In the astronomical sciences these come mainly from grants to researchers from the aforementioned ISF, BSF and GIF foundations. The ISF also supported, in the framework of its Centers of Excellence series, the “Multi-wavelength Astronomy Center” of the Tel-Aviv University observers for the period 1994-

2000 to the tune of about US$200,000 annually. In the triennial period 1998-2000 ISF contributed to astronomically oriented projects, including the Tel-Aviv center, an average of US$ 0.41M annually, or 41% of the total foundation support for astronomy mentioned earlier. The BSF and GIF, which do not support projects every year, contributed an average 50% and 9% respectively.

Almost all the workers mentioned in Table I are qualified to apply for foundation research grants. Applications for research grants in astronomy and allied disciplines have success ratios ranging from 40% for the ISF to 15% for the GIF. The typical ISF grant for a single researcher is US$ 30,000 annually for a theorist, and a bit larger for observers. Grants from the BSF and GIF are intended only for Israeli-US or Israel-German cooperations, and today are somewhat smaller than the ISF's. In almost all cases, grants by these foundations run for three years.

C.6.2 University Sources. Evidently a large fraction of the outlay for astronomical research, which has not been accounted for above, is accounted by salaries. For the tenure-track workers these are provided entirely by the universities, institutes or colleges, but many of the adjunct investigators are partly supported by research contracts, or special fellowships for immigrant scientists (Barecha and, more recently, Kamea fellowships).

Long and short term visitors from abroad have been a common sight at the Hebrew University's Shaham group, and at the astrophysical groups in the Weizmann Institute, the Technion and Tel-Aviv University. Ben-Gurion University's group has made great strides in this respect in the last decade. The Lady Davis Foundation, operating at the Hebrew University and at the Technion, has supported a number of illustrious visitors to the respective groups at these institutions, as has the Technion Institute for Theoretical Physics. The Kreitman Foundation at Ben-Gurion University, the Albert Einstein Minerva Center at the Weizmann Institute and the Sackler Institute for Theoretical Physics at Tel-Aviv University have played similar roles for these institutions. Some visitors from the UK have been supported by the exchange program of the Israel Academy of Sciences and Humanities with the Royal Society.

University based funds have also supported conferences and workshops on astronomy and related areas. Thus the Technion Institute of Theoretical Physics supported the 1997 international workshop at the Technion on black holes and singularities whose main funding came from the ISF, as well as the

1998 international conference at the Technion on astrophysical fluids. Over the last two decades the Institute of Advanced Study of the Hebrew University, with additional funding from the BSF and the Rothschild Foundation, has sponsored a series of astrophysical winter schools (part of the program of the noted Jerusalem Winter School); these have taken place about once in three years. And two international and widely attended Marcel Grossman conferences on gravitation and astrophysics were held at the Hebrew University with the university's support, in 1985 and in 1997. The Weizmann Institute sponsored an international workshop on galaxy dynamics in 1984, as well as one on astroparticle physics for 2001; the last has been postponed due to the regional turbulence.

C.6.3 Support for International Collaborations. Insofar as postdoctoral fellows in astronomy often come to Israel from groups overseas, which collaborate with Israeli groups, the aforementioned research grants from the ISF, BSF and GIF all indirectly support international collaborations by Israeli astronomers. The BSF and GIF alone also offer, as part of their grants, funds for travel and *per diem* expenses of Israeli faculty and overseas colleagues who plan to visit each other to coordinate common research. A number of well-known collaborations involving Israel astronomers have already benefited from these grants.

Israel's Ministry of Science, Culture and Sport also maintains a program of grants supporting collaborations between Israeli and overseas scientists from a number of countries. The grants are usually triennial. In 1999 the average grant was worth $40,000 annually, and the success ratio for applications was about 20% for some disciplines. This resource has yet to be exploited systematically by the astronomical community.

All astronomers taken into account in Table I are qualified to apply for foundation research grants. Applications for research grants in astronomy and allied disciplines have success ratios ranging from 40 % for the ISF to 15 % for the GIF. The typical ISF grant for a single researcher is US $ 30,000 annually for a theorist, and a bit larger for observers. Grants from the BSF and GIF are intended only for Israeli-US or Israel-German cooperations, and are today somewhat smaller than the ISF's. In almost all cases, grants by these foundations run for three years.