FACULTY of ARTS & SCIENCE
UNIVERSITY of TORONTO

Defining and Building the DUNLAP INSTITUTE FOR ASTRONOMY AND ASTROPHYSICS

1. VISION

As a renewal of the memorial that founded the David Dunlap Observatory (DDO), the University of Toronto has ambitious plans to establish the Dunlap Institute for Astronomy and Astrophysics (Dunlap Institute, or simply Institute) in association with the Department of Astronomy and Astrophysics in the Faculty of Arts and Science. Creation of the Dunlap Institute presents a unique opportunity to ensure that the Dunlap name continues to be recognized internationally, in perpetuity, closely associated with excellence in astronomy and astrophysics.

When the David Dunlap Observatory opened, it housed the second largest telescope in the world; research at DDO underpinned the University's strong international reputation in astronomy and astrophysics; and personnel trained at DDO have branched out to advance the discipline within Canada and internationally. Likewise, the goals of the revitalized Dunlap legacy are set very high. The Dunlap Institute intends to become a major player on the world scene and through its programs and its alumni/ae to have a lasting impact on the discipline in the profound way that has come to be associated with the Dunlap name.

It is widely held that education is essential to the human mind and spirit, providing the basis for people individually and collectively to reach their full potential. Coupled with this is a hope that advances in science and technology can be harnessed in a constructive way to promote understanding and improve the human condition. The Dunlap Institute's academic program in astronomy and astrophysics, coupled with strong outreach to the public, exemplifies this vision. The program will build upon the principle of bringing strong research leaders together with top students and postdoctoral researchers and forefront facilities. As an academic unit, the Dunlap Institute will be headed by a Director. An Advisory Committee will provide ongoing oversight for the Institute.

This is an opportune time for such an initiative. There is intense public interest and a thirst for discovery and understanding. Indeed amazing observational advances are being made almost daily, and this pace seems certain to continue as giant telescopes now being built or planned, both on Earth and in space, come into operation. These new

observatories will be optimized to study the very fundamentals, nothing less than the structure and evolution of planetary systems, stars, galaxies, and the Universe. Complementary efforts in astrophysics, both on underlying basic theory and on modeling/numerical simulation using high performance computers, will be essential to understanding these observational advances.

The University of Toronto is well positioned to participate vigorously in these revolutionary endeavours based on its investments in personnel and related infrastructure in the Department of Astronomy and Astrophysics (DAA)[1] and DDO, hosting the Canadian Institute for Theoretical Astrophysics (CITA), leadership in the Cosmology and Gravity Program of the Canadian Institute for Advance Research (CIAR), and creation of a cluster of chairs under the Canada Research Chair (CRC) program. The stimulus provided by the endowment and establishment of the Dunlap Institute would enhance and consolidate the University's work in astronomy and astrophysics within the top tier internationally. The endowment would be subject to the stringent rules of the University re preservation of capital, with only the annual net income being expendable, thus ensuring the Institute's stability for the long term.

1.1 Scope of this Document

This document is fundamentally on the *raison d'être* of the Dunlap Institute, the vision and long-term mission. Because the Dunlap Institute will be endowed, its activities will extend and continue into the foreseeable future. And so in many aspects this document is like a charter, with the tone intentionally being permissive rather than prescriptive. The document also addresses the *modus operandi*, including some practical details of implementation in the here-and-now. The vision and plans discussed in this document will be subjected to peer review by an international panel of experts.

The document first outlines the mission and some guiding principles governing the nature of the Institute (§ 2). Though not the focus of this document, the broad range of exciting questions that can be addressed in this discipline is highlighted in § 3. Finally, this document addresses function and form – how the Dunlap Institute might be implemented such that the anticipated ambitious outcomes can be realized – with attention to the possible workings of the Institute as it is brought into being and made vibrant in the early years (§ 4).

The exciting array of potential programs has evolved and matured over the past decade, being summarized most recently in the forward-thinking Stepping Up Plan prepared by the Department of Astronomy and Astrophysics. Some concrete examples from this panoply are mentioned here, not to be overly prescriptive but to raise principles and issues of implementation.

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[1] According to the most recent major international review, in May 1999, the Department of Astronomy and Astrophysics is *the key element defining the University of Toronto as one of the most important centres of astronomy in North America.*

2. MISSION AND GUIDING PRINCIPLES

The multi-faceted Dunlap Institute is intended to assume a prominent leadership position in research, teaching and advanced training, and public outreach. The original gift of the David Dunlap Observatory placed the University of Toronto among the first rank of institutions in the world. The initiative made possible through this revitalization of the legacy will help ensure the premier status of the University in astronomy and astrophysics in perpetuity.

2.1 Objectives

Specific objectives of the Institute that should continue to resonate well into the future are:

- to be an international centre of research excellence where fellows and visitors will conduct and promote scholarly research in astronomy and astrophysics;
- to promote fruitful interaction between astronomers engaged in observations, experimentation, simulation, and theory;
- to provide the leadership and core strength to create major national and international research collaborations;
- to promote advanced training opportunities for graduate students, postdoctoral fellows, and research associates;
- to organize and host international scientific workshops and meetings;
- to explore and exploit the use of new technologies in advancing research in astronomy and astrophysics;
- to provide a primary means for channeling information on astronomy and astrophysics to the general public.

Features of the Dunlap Institute that will be important for achieving these objectives include:

- leadership, provided by key individuals of international stature;
- a stimulating environment provided by the close interaction of all levels of the research staff: chair-holders and cross-appointed faculty, research associates and postdoctoral fellows, graduate students and undergraduate specialists, and national and international visitors;
- an active visitors program, including specialized workshops and scientific meetings;

and more specifically on the technology front:

- an instrumentation development fund;
- leading-edge computing equipment;
- workshops and laboratories;
- technical personnel.

Astronomy and astrophysics research has an increasingly international reach; the Dunlap Institute must be engaged internationally. Research personnel will be a key focus, the goal being to create an international centre of excellence where fellows and visitors will join faculty and students to conduct and promote scholarly research in astronomy and astrophysics. The Institute will take an integrative approach in its programs, promoting fruitful interactions among astronomers pursuing different approaches to research – computational, experimental, instrumental, observational, and theoretical – and providing the foundation for creating major national and international research collaborations.

The stimulating milieu of the Dunlap Institute would be ideal for inspiring and enriching the best young minds in astronomy and astrophysics, be they research associates, postdoctoral fellows, graduate students, or senior undergraduate specialists. Just as personnel trained at the David Dunlap Observatory have fanned out into influential positions across Canada and internationally, alumni/ae of the Dunlap Institute would be expected to have a profound impact on the development of astronomy and astrophysics world wide.

Technology plays many roles in advancing this science. Dedicated experiments and more general-purpose scientific instrumentation are both valuable. The Dunlap Institute should participate in such experiments and the design, fabrication, and implementation of scientific instrumentation for well-defined and strategically-chosen research projects on world-class ground and space-based observatories.[2] In addition, the use of computers, both for simulations of complex phenomena and for analyzing massive amounts of data, has been revolutionary, and among new developments will be data mining in the era of virtual observatories. Thus a broad range of computational activities is expected to be of interest to the Institute. The exploitation of any technology of course requires skilled people. While people resources should be paramount, achieving the most effective balance with technology will be central to the success of the Dunlap Institute.

The mission of the Institute will remain unfulfilled unless the stunning results of research are brought with passion to the general public. Not only is public interest high, but astronomy is formally part of the elementary and secondary school curriculum in most provinces, and there is need for pre-service and in-service teacher education. There is already an existing informal network in the Greater Toronto Area, linking the University with the Royal Astronomical Society of Canada, the Mississauga Astronomical Society, the Royal Ontario Museum, the Ontario Science Centre, and York University. With the continuity of dedicated leadership in outreach that could be provided, the Dunlap Institute could be an effective main node in the cross-Canada astronomy public education network and be plugged into international networks as well.

[2] Canada's current decadal Long Range Plan (LRP) for astronomy and astrophysics, and its recent Mid-Term Review, gives as its highest priority for universities *the creation of laboratories for experimental astrophysics*, pointing to the *disappearance of university instrumentation laboratories as a potential point of critical failure in Canadian astronomy.* It is essential for our graduate students to be trained in the development of first rank hardware for the next generation of international and world observatories.

2.2 Ethos: Responsive and Adaptable

The fundamental ethos of the Dunlap Institute must be to be responsive and adaptable. It should be recognized that not all of the specific programs and activities illustrated below need be in place simultaneously or in perpetuity. Indeed, the range of possibilities will no doubt outstrip the available core funding, and so it will be incumbent on the Institute to identify new opportunities, to set priorities, to optimize its programs, and to leverage its resources to achieve the highest impact. When it comes to personnel, the Institute must have programs and policies to engender responsiveness and flexibility, and for any permanent/continuing appointments must attract clever people who as individuals and as part of the team embody these criteria.

A corollary is that as an organizational strategy the Institute should adopt a project focus, at any given time being engaged in a limited number of specific programs targeted explicitly to achieving success on particular challenging questions.

2.3 Dynamic Links to Other Academic Units

In addition to close interactions with DAA and CITA, the Dunlap Institute stands to benefit both itself and the University by establishing interdisciplinary and/or cross-disciplinary links to other academic units/activities in the University. Perhaps the more obvious are to physics[3] (whence the name "astrophysics" after all) but bridges to other physical and life sciences should explored vigorously too.[4] On the technology side there is much to gain as well through interactions with the physical sciences and engineering.[5] Astronomical investigations have very demanding requirements and present many exciting challenges across a range of disciplines. Modern technical shops are becoming increasingly expensive, both in the sophisticated equipment required and in the skilled personnel to run it. Thus attention should be given to a possible tiered structure with both local resources and resources shared across several disciplines, in for example a joint high-level physical sciences technical services. In outreach and broader education in the public sector, links to the Ontario Institute for Studies in Education in the university (OISE/UT) would be valuable.

2.4 The Dunlap Medal

To contribute to its stature and lasting presence on the world scene, the Dunlap Institute would offer an internationally-significant and distinctive award for achievement in astronomy and astrophysics. As well as the medal and cash award with ceremonial presentation, the Institute would host distinguished lectures in conjunction with the event, both technical and for the general public.

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[3] Current examples would include particle astrophysics (SNO and SNOLab and dark matter detection) and gravity-wave detection (LIGO and LISA).

[4] Emergent areas enjoy names like astrochemistry, astrobiology, bioastronomy, cosmochemistry, … Links to mathematics, Institute for Applied and Interdisciplinary Mathematics (I-AIM), Fields Institute too.

[5] For example, aerospace and satellite technology (UTIAS); material science, MEMS, and nanotechnology (electrical engineering, mechanical engineering, Nortel Institute, physics, chemistry); light interactions with materials (Institute of Optical Sciences); structural design (civil engineering).

2.5 Mandate of the Dunlap Institute

To complement and reinforce the above and to position the Institute both within the University in which it is embedded and beyond, it is perhaps useful to wrap up this prospect by enunciating rudiments, along the lines of a mandate.

Fundamentally, the Dunlap Institute will provide leadership in and support of astrophysical research of international prominence. The Dunlap Institute may engage in and support each of the several approaches to research – computational, experimental, instrumental, observational, and theoretical – with a holistic outlook, tying into advanced training and effective outreach.

With the supplementary funding endowed in the Dunlap Institute the commitment is to enrich the astronomy and astrophysics research enterprise at the University of Toronto, complementing, adding new dimensions to, and growing beyond what is already possible through the Department of Astronomy and Astrophysics and the Canadian Institute for Theoretical Astrophysics.

To accomplish this, the Dunlap Institute may mount its own programs (projects) or work to build programs in collaboration with local, Canadian, or international researchers. In establishing such programs, the Institute may entertain written proposals containing the usual elements: goals, milestones, budget, and management. Programs will normally be of finite duration, clearly defined at the outset, and will have strong review requirements. Preference will be given to programs that seed new activity or leverage additional contributions.

3. RESEARCH DIRECTIONS

It is not for this document to chart out particular areas of research for the Dunlap Institute over set time scales. A longer view is needed, laying out the vast potential for the Institute. Nevertheless, it is possible to give some flavour of the deep research questions being confronted and acknowledge the promise of technology in getting at the answers.

3.1 Questions

In the rapidly developing field of astronomy and astrophysics, looking into a crystal ball and making predictions and pronouncements on the directions of research, even for a limited 10-year horizon, requires humility![6] Among top picks might be:

- nature of the Universe;[7]
- gravity;[8]
- structure formation;[9]
- life elsewhere in the Universe.[10]

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[6] One can look back at the situation 100 years ago, 50 years ago, 30 years ago, or just 10 years ago, and ask what could have been predicted as the big questions, especially those on which there would be significant progress on various time scales; even with hindsight, how well would one do? What will this document look like in a 100 years!

[7] This is now refined by the discovery that the Universe is dominated not by baryons, but by dark matter and dark energy. Progress in constraining the nature of dark energy should come through a variety of complementary approaches (weak lensing, distant supernovae, CMB analysis). It seems now within experimental reach to actually detect dark matter in the laboratory. The new Sudbury underground facility provides a unique environment to mount sensitive experiments. This will require "outside the box" thinking and interdisciplinary cooperation, and of course interesting technology development.

[8] GPB is finally in orbit. Astrophysics offers environments with strong gravity, and of course there is the physics of the Planck scale to be understood. LIGO (or LIGO II) and LISA are aimed at detecting gravitational waves. A new opportunity, building on precision CMB measurements, is to detect the B-mode polarization, thus probing the early universe.

[9] First light and reionization are fundamental. WMAP has highlighted some issues of timing. Formation of supermassive black holes is a challenge. The major epoch of star formation and nucleosynthesis has to be probed. Direct detections of young galaxies using the Spitzer Space Telescope, BLAST, the Herschel Space Observatory, JWST, and ALMA will be exciting. Formation of molecular clouds and stars is a complex phenomenon that needs to be observed in various stages. Modeling and theoretical understanding is important for everything from the formation of planets to the evolution of galaxy systems. Large scale simulations now successfully follow gravity into the non-linear regime, and including the gas physics and star formation and feedback is the next big challenge. Progress requires a healthy blend of observational, experimental (instrumentation), simulation, and theoretical efforts.

[10] A recent conference "The heavy element trail from the Big Bang to habitable planets" emphasized the tremendous range of challenges. Astrobiology conferences also highlight the interdisciplinarity. So do Martian meteorites. Promoting that exhilarating sense that the field is ripe for advances is the discovery of extrasolar planets. Even the preliminary results from planet-finding programs show that extrasolar planetary systems are not all like our own, requiring major theoretical rethinking. But the real hope is that we can come to measure physical properties of planets through recording their spectra, moving the field beyond simple discovery of planets, which is of course challenging, to a physical understanding, which is illuminating. This ties into understanding planet evolution in the solar system and even ongoing global change. Perhaps this is how people felt a hundred years ago as they set out to understand the spectra of stars and nebulae.

These are perhaps "safe" picks, in being broadly defined. But they are also heady challenges in which – perhaps amazingly to those outside the field – it is realistic that progress can be made. It will be most effective for the Institute to search out opportunities and then focus its resources through particular research projects to ensure a recognized impact on answering the big questions.

3.2 Exploiting Technology

There are continuing dramatic improvements in technology that change what is possible[11] and positive feedback too, demanding more of and creating new technology.

A given facility can also redefine its mission in response to evolving research opportunities.[12]

Generally, a lot of what is found exciting today came almost serendipitously by having clever people using first-rate technology to explore the universe, often in search of something definite but not unusually turning up new and unexpected directions for research.[13]

There are of course celebrated cases where there was a vision followed to fruition[14] and one should strive for more.

This perspective of deep synergism should inform the strategy and programs considered by the Dunlap Institute.

[11] For example, the Canada France Hawaii Telescope (CFHT) was built in the era of photographic plates but now with the Megaprime CCD camera is embarked on a Legacy Survey to probe, among other things, the nature of dark energy, something certainly not on the original agenda.

[12] A key project for the Hubble Space Telescope was measurement of H_o, but HST's impact through the Hubble Deep Field, and other more "local" phenomena from planets to star forming regions, has arguably been more profound.

[13] Today on the threshold of mega-observatories like the Atacama Large Millimetre Array (ALMA) and the James Web Space Telescope (JWST), one wonders with great anticipation what will be discovered beyond the exciting plans laid out so far in advance by the original science teams.

[14] A prime example would be theoretical insight into the diagnostic potential of Cosmic Microwave Background (CMB) fluctuations and the present boom in precision cosmology.

4. IMPLEMENTATION

4.1 Director and Advisory Committee

The Dunlap Institute will be headed by a Director, appointed by the University under its Policy on the Appointment of Academic Administrators as the "chief executive officer." The Director will report through the Dean of Arts and Science allowing the Institute to draw effectively on the resources of the University. An Advisory Committee will be struck to provide ongoing oversight for the Dunlap Institute, meeting at least annually.

4.2 Academic Personnel

The strategy for bringing the Dunlap Institute to a high international stature is rooted in the research and advanced education carried out by personnel associated with the Institute. The opportunities created through the Dunlap Institute would attract top ranked astronomers and astrophysicists to Toronto and the appropriate engagement and support of such personnel would be a significant focus and commitment.

(i) Expert Faculty, Distinguished Chairs, Research Professorships

It is important that the Dunlap Institute benefit from expert faculty members attuned to the particular goals on which the Institute chooses to focus from time to time. These faculty members would bring critical expertise in theme research fields[15] in which the Institute was determined to make an impact through specific programs.[16] They would provide leadership in these areas both directly and through their teaching and supervision of research fellows and graduate students and would perforce guide the development and teaching of astronomy and astrophysics throughout Canada and internationally.

There are a number of effective arrangements that could be contemplated. For example, commitments could be formalized for specific terms or projects by cross-appointment (status only) from the Department of Astronomy and Astrophysics and from cognate departments as appropriate. Alternatively, and/or in addition, the Institute could create a few distinguished, permanently-endowed chairs, and/or Research Professorships with either career (more normal) or limited-term (more flexible) appointments.

(ii) Research Associates and Postdoctoral Fellows

As demonstrated by the success of CITA, a continually changing pool of talented individuals with three to five year postdoctoral or research associate appointments would enable the Dunlap Institute to respond rapidly to changing research themes in astronomy and astrophysics. Young researchers are approaching their productive best and have the

[15] Broadly defined these could encompass those fields of long standing and healthy maturity (relatively speaking at the time, e.g., currently observational cosmology), others more recently developed (e.g., star and planet formation), and those rapidly emerging (e.g., astrobiology).
[16] This might be through individual effort or the concerted strength of a large team dedicated to a particular project. The latter appears to be becoming much more prevalent in this discipline.

freedom to focus on their research; as such they are a cost-effective investment.[17] The Dunlap Institute could create focused teams for concerted attacks on particular scientific problems[18] or targeting development of specific instrumentation or experiments.

The stimulating environment of the Dunlap Institute would be a magnet for postdoctoral scholars with their own funding (e.g., postdoctoral fellowships from the Natural Sciences and Engineering Research Council [NSERC], the Canadian Space Agency [CSA], International Awards from the US National Science Foundation [NSF], etc.). In some cases, such as the current NSERC fellowships, the basic award would need to be supplemented in the form of a prestigious Dunlap fellowship to be competitive. This is an example of the leverage that would characterize the Dunlap Institute strategy.

(iii) Students

Students would also gravitate to the inspiring milieu of the Dunlap Institute, to be enriched by close interactions with the more senior personnel. The Dunlap Institute need not develop an accredited graduate program of its own. Graduate students would register in the astronomy and astrophysics program of the Department of Astronomy and Astrophysics or in one of the cognate departments[19] as appropriate and would be supervised by faculty in the Dunlap Institute with appropriate cross-appointments. The high-quality students that would be attracted to the Dunlap Institute would usually arrive with their own scholarship funding, e.g., from NSERC, provincial governments, or foreign equivalents. But given the intense competition for the best students, the prestige of Dunlap scholarships as a supplement to these awards would be a valuable recruiting tool (and excellent leverage again).

Likewise, senior undergraduate specialists in astronomy and astrophysics, planetary sciences, engineering, etc. will benefit from close one-on-one interactions. With its emphasis on research productivity, and exploitation of modern technologies in instrumentation, experimentation, and computation (see § 4.3), the Dunlap Institute would provide a rich training ground for all of these exceptional students.

(iv) Visitors Program

A sign of a healthy and influential institute is its strong ties to the international community. The Dunlap Institute would be a key node on the international circuit that active researchers would want to visit, in order to exchange new observations, ideas, and theories, and to plan new initiatives. Visitors would come for various periods of time, from a few days to deliver a colloquium, to a term or more (e.g., on sabbatical leave) to engage in collaborative work at the Dunlap Institute.

[17] As emphasized in Canada's current decadal Long Range Plan (LRP) for astronomy and astrophysics, and its recent Mid-Term Review, Canada presently offers relatively few opportunities for funding people at this level, making this aspect of the Dunlap Institute all the more compelling.
[18] There are different organizational models, including the successful Canada-France-Hawaii Legacy Survey.
[19] Including Chemistry, Computer Science, Geology, Mathematics, Physics, and many Departments in Engineering.

4.3 Capitalizing on Technology

(i) Instrumentation

Activity in development of instrumentation and in experimental astrophysics is both unifying and enabling. It broadens and deepens student experience. New leadership opportunities are opened up internationally and nationally. It is essential for the emerging cohort, our graduate students, to be trained in the development of first rank hardware for the next generation of international and world observatories. Assignment of personnel to these development projects – deep engagement rather than simply turning over money – is essential. The Dunlap Institute would rise to this challenge, building on the legacy of DDO and the University of Toronto Southern Observatory (UTSO) and the new missions arising in the Stratospheric Telescope Integration Facility, with a multi-pronged expansion in astronomical instrumentation and experiments.[20] This program will produce tremendous opportunities for leverage, by providing seed or matching funds (e.g., for NSERC, NSF, and Canada Foundation for Innovation [CFI] competitions) and by forming strategic partnerships with other institutions.

Focusing on telescopes for the moment, there are real benefits – both in recruiting quality faculty and students and in accomplishing ground-breaking research – that accompany access to private facilities, as many of the top universities appreciate. While there are distinct benefits that accrue to (even partial) ownership of a private telescope, construction and ongoing operation of a major telescope facility is a costly venture which requires access to significant amounts of capital and/or a particularly rich flow of endowment/operating income. While the Dunlap Institute should not rule out investment in a major telescope, this is not seen to be the optimal strategy.

Major telescopes and experiment collaborations are perennially short of money, manpower, and expertise to keep the expensive instrumentation up to date. Therefore, a focus on timely instrumentation projects offers cost-effective benefits and more immediate access to such opportunities. An alternative strategy for the Dunlap Institute – with a more modest budget (and less demanding cash flow requirements too) – would be to acquire access through a focused development of key instrumentation (or components), on a time-limited, project basis tuned to the Institute's scientific strengths and ambitions. DAA's collaboration with the Observatories of the Carnegie Institution of Washington (OCIW) on the development of instrumentation for the 6.5-m Magellan Telescopes is illustrative. Excellent examples of leveraged access to forefront observational opportunities through engagement in instrumentation are Toronto's contributions to the Boomerang and BLAST collaborations and to the Atacama Cosmology Telescope.

[20] There is an enormous potential range which could include development of nanosatellites, stratospheric experiments, instrumentation for access to existing ground-based telescopes, a large optical telescope (30-m telescope, TMT) and its instrumentation, and next-generation facilities in space.

By assuming a leadership role in instrumentation, it can be anticipated that Dunlap Institute personnel would be exceptionally well positioned scientifically to take advantage of the new technologies for well-posed research projects. The Dunlap Institute would also get the intellectual benefits for faculty, research associates, and students to be derived from participating in the design and construction.

(ii) Computation

In a discipline largely constrained by remote sensing, computational astrophysics is a rapidly developing field that provides another way to "observe" the workings of the physical universe. Many of the grand challenge problems in computation involve astrophysics, e.g., cosmic structure formation evolving from the early universe, and star formation. This area of research is also very dependent on technology, well beyond simply using computers as a day-to-day tool. Certainly keeping computing facilities close to the leading edge has contributed to CITA's success, by enabling such computationally-intensive research projects[21] and attracting the key scientific and technical personnel.

Modern telescopes and space missions generate enormous data sets, hitherto unimaginable. Aggressive computation, again well beyond the norm, is required for systematic processing and analysis of the data acquired in modern observing campaigns and ultimately made available, in the era of the virtual observatory, through multi-wavelength archival data bases distributed world wide. Researchers at the University of Toronto have developed expertise in processing such data, whether it be extraction of point sources, weak lensing signals, cosmological parameters, smooth images, etc.[22] This has required new algorithms and significant computing power and disk space and has produced end products of interest to the wider community.[23]

In a leadership and consolidating role the Dunlap Institute could capitalize on the needs for such on-going efforts by fostering a processing and analysis centre. Through such an initiative, the Institute would broaden the experience for students, refine expertise and infrastructure to support research projects on the telescopes and observatories that are being put in place through Canada's LRP, and focus on problem-solving common across areas.[24] An essential point is that top-tier computing facilities need to be upgraded continually and supported by specialized personnel, and in Canada they have historically not been sustained at the level available to the very best centres world wide. With a targeted processing and analysis strategy there is a great opportunity to be an attractor of new resources (people, expertise, skills, leading-edge hardware), leveraged through CSA, NSERC, and CFI.

[21] Further examples: MHD studies of the formation of galactic black holes; hydrodynamical studies of planet formation; supernova explosions; galaxy mergers.
[22] For the record, these include CFRS, CNOC, CFHLS, RCS; EXPLORE; Boomerang, CBI, Boom2k, Planck; BLAST, Herschel/SPIRE, SCUBA2; IRAS, ISO, MSX, Spitzer; MIGA, VGPS, IGPS.
[23] No major archival service has been established, though T-space being developed through the University of Toronto Library could be very useful and is being investigated.
[24] Indeed, much of the high-level mathematics underpinning the analysis is applicable more broadly, and so this could resonate strongly with I-AIM (Institute for Applied and Interdisciplinary Mathematics).

4.4 Administrative and Technical Support and Library Facilities

The scientific, technical, management, and outreach activities of the Institute will demand expert support from dedicated staff, some continuing staff-appointed and others on contract. These areas of service will include: personnel; business (budget, finance, procurement, and grants); project management; engineering and design; electrical, optical, and machine shops; computing; web and other organizational and outreach services; etc. The balance among these areas will depend on the specific directions chosen and priorities established by the Institute from time to time.

The Department of Astronomy and Astrophysics has developed a library of international stature that owes much of its quality to its long association with the David Dunlap Observatory. This library, increasingly providing services in electronic form, would be a major asset to the Dunlap Institute, as it has been to CITA.

4.5 Resources

The ongoing health of the Dunlap Institute will be underwritten in large part by the expendable income from the new endowment. There are other complementary resources historically associated with the David Dunlap Observatory that, through the metamorphosis of the memorial, the University intends will accrue to the Dunlap Institute, thus bolstering its success.

The Dunlap Institute should be expected to enhance its influence several fold by using its funding as the critical lead contribution to build strategic collaborations and to exploit matching and leveraging opportunities on a time-limited, project basis.[25] In this way Dunlap Institute personnel could develop and/or gain access to, for example, the most advanced instruments, the largest telescopes, and/or the fastest computers.

4.6 Budget

In advancing its mission in astronomy and astrophysics, major categories of expense for the Dunlap Institute will include but not be limited to:

- salaries and stipends for personnel, at many levels, to carry out research;
- scholarships and fellowships;
- research expenses;
- visitors program;
- scientific workshops and meetings;
- administrative services;
- workshops, laboratories, and related technical services;
- instrumentation and new technology – both the subject of research and to enable research – including computing equipment;

[25] One concrete example is the current formal collaboration of the University with the Observatories of the Carnegie Institution of Washington on the Magellan Project

- Dunlap Medal;
- outreach.

Relative priorities and distribution will change from time to time and will be set by the Director.

4.7 Space

The University will provide space for the Dunlap Institute on the St. George campus, in close proximity to the Department of Astronomy and Astrophysics, the Canadian Institute for Theoretical Astrophysics, and the Department of Physics. Efforts would be made to provide a physical presence for the Institute that distinguishes it prominently amidst these surroundings.

(i) First Steps

A detailed proposal has been prepared in which the Dunlap Institute would be located in the Nursing Building to the immediate east of the McLennan Labs, once that is vacated by the present occupants (later in 2005). This would provide space for a wide range of activities: offices for scientific personnel, administrative and technical support, laboratories and workshops, computing services, library facilities, interaction areas like small classrooms, (video-)conference rooms, and lounge.

The total space is about 1,500 net assignable square metres, providing some space toward consolidation of Department of Astronomy and Astrophysics activities as well, including vacating temporary space in the Greenhouse Tower, a new undergraduate laboratory, and priority use of a modern lecture hall for undergraduate and graduate classes and all astrophysics colloquia and seminars. It would allow the creation of cognate research clusters (grouping faculty, postdoctoral and graduate researchers and their support) and housing of some major projects. However, from the planning analysis so far, it appears that there is not enough space in this building for the Institute and all of DAA, not to mention CITA as well.

There would be one-time-only costs associated with establishing the Dunlap Institute, including modest renovations to this new space, associated furnishings, refurbishment of instrumentation laboratories and shops, and acquisition of computing equipment.

(ii) Longer Term

It is desirable to bring together all of the astronomy and astrophysics activities represented in the Dunlap Institute, DAA, and CITA. Among the possibilities are additions to the Nursing Building site and complete redevelopment. In any case, new funding will have to be identified. One appropriate route would be to leverage Dunlap Institute and other private funds through the Canada Foundation for Innovation and the Ontario Research Fund.

5. SUMMING UP

Creation of the Dunlap Institute for Astronomy and Astrophysics presents a unique opportunity to ensure that the Dunlap name continues to be recognized internationally, in perpetuity, closely associated with excellence in astronomy and astrophysics. Renewal of the Dunlap memorial in the new form of a world-class institute is a very exciting prospect for the University of Toronto. It is a privilege that requires careful stewardship. The vision and plans presented here illuminate the path ahead. The University looks forward to bringing the Dunlap Institute into being in such a way as to maximize the great potential of its academic mission.

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