

THE ORIGINS OF STRUCTURE IN THE UNIVERSE

CANADIAN ASTRONOMY AND ASTROPHYSICS IN THE 21ST CENTURY



2017 Pre-Budget Consultation

Submission of the Coalition for Canadian Astronomy

August 2016

Executive Summary

Canada is a world leader in Astronomy and Astrophysics, the result of a long-term plan that identifies priority projects to sustain excellence in the field. That plan has been a remarkable success, with Canadian scientists, universities and industry reaping the benefits of participation in major international astronomy facilities.

The Coalition for Canadian Astronomy, comprising all astronomy stakeholders in this country, has identified four priority projects for the remainder of this decade. Canada's participation in one – the Thirty Meter Telescope – is fully funded and will cement Canada's leading position in ground-based astronomy.

The next phase in the plan is to grow Canada's leadership in space astronomy. There are several pending opportunities to develop a world-class space astronomy program. However, these opportunities require long-term funding for space astronomy within the Canadian Space Agency (CSA) of roughly \$30 million annually, a rate commensurate with its investment in space astronomy for much of the past decade.

Recent investment in space astronomy has dropped to roughly half the required level because of the general decline in the CSA's overall budget. This lack of investment puts Canada's position as a leading space-faring nation at risk because it forces the Agency to take a very short-term view, while ambitious space missions take years to plan.

Recommendation #1

Increase overall CSA funding. A properly funded, ambitious and responsive space agency is the lynchpin for Canada's continued success in space exploration in general, and astrophysics in particular.

Recommendation #2

Allocate \$1 million for a "phase zero" study of Canada's possible *leadership role* in future missions, such as the CASTOR space telescope project.

Introduction

The Coalition for Canadian Astronomy is composed of:

- Academia: represented by the Association of Canadian Universities for Research in Astronomy (ACURA) and its 20 member universities;
- Professional astronomers: represented by the Canadian Astronomical Society (CASCA); and
- Industry: represented by Canadian companies involved in major astronomy projects.

The Coalition's submission is focused on the importance of engagement in world-leading facilities as a means of sustaining Canada's leadership in astronomy while offering all astronomy stakeholders the opportunity to succeed on the global stage.

Such potential is already being realized through Canada's involvement in signature projects like the Thirty Meter Telescope (TMT). Similar opportunities will present themselves in the coming years with the Square Kilometer Array (SKA), the Wide Field Infrared Survey Telescope (WFIRST) and the CASTOR Telescope.

Canada's position as a leader in ground-based astronomy has been secured by funding of the TMT and for the next several years Canada's position as a leading nation in space-based astrophysics seems bright through our involvement in the James Webb Space Telescope (JWST), scheduled for launch in 2018.

However, the JWST is a short-lifetime mission (5-11 years) and planning for space missions must take place over a timescale that spans many years (in some cases decades). Canada's position as leader in space-based astronomy is at risk because cuts to the Canadian Space Agency (CSA) severely restrict its scope for planning future missions. Therefore, we urge the Government to provide the CSA with the funding needed to maximize Canada's potential – both scientific and industrial – as a leading space-faring country.

Canadian Astronomy and Astrophysics: A Scientific Success Story

In standard impact analyses, Canada is ranked #1 in the G8 in Astronomy and Astrophysics and these results have been achieved despite a notably lower relative investment than other countries. Within Canada, the field has a higher world impact than any other science or engineering research area.

The Council of Canadian Academies and a report by Hickling, Arthurs & Low to the National Research Council (NRC) have documented this success, from which all astronomy stakeholders have benefited. For example, the number of universities with graduate programs in astronomy has grown from 3 in the 1960s to 20, and the population engaged in astronomy research in Canada doubles every decade. The membership of CASCA has more than tripled. Meanwhile, Canadian industry has reaped hundreds of millions of dollars in direct astronomy support work and resulting spin-offs, with new industries and companies created – and with more to come.

None of this happened by chance. The Canadian astronomy community is united behind the Long Range Plan for Astronomy and Astrophysics (LRP), which calls for Canadian participation in the next generation of global astronomy projects. The horizon for this planning document is ten years (2010-2020) and it is based on extensive consultation with the astronomy community

and external peer review. A Mid-Term Review (MTR), which was recently completed, takes place to ensure the LRP remains on track.

LRP Priorities and Status

With the LRP as a roadmap, the Coalition is focused on four immediate priority projects, which are complementary in nature and selected to sustain Canadian leadership.

1. Thirty Meter Telescope (TMT)

The TMT was conceived and designed by Canadian astronomers and industry and will be the world's most powerful ground-based telescope. A partnership in TMT is the highest priority in the LRP and Canada is a founding project partner. The other partners are China, India, Japan, the University of California and Caltech.

Canada invested around \$30 million in the initial design of TMT and in 2015 the Government committed \$243.5 million to construction. The bulk of that investment will be spent in Canada on construction of the Canadian-designed telescope enclosure and the adaptive optics system, which is essentially the “heart” of the TMT.

Scientific Impact

The TMT will address the most profound scientific questions, such as the nature of the dark matter and energy that comprises our universe and whether there is life elsewhere.

Economic Impact

Canada's investment in TMT construction is essentially an in-kind contribution in which two major telescope components will be built here by Canadian companies. At least 20 companies across Canada will be involved in TMT construction in areas like skilled manufacturing and adaptive optics, both fields that have enormous spin-off potential – upwards of \$500 billion according to estimates from the NRC.

Financial Requirements

Canada's TMT commitment is fully funded and there is no budget request for 2017.

2. Square Kilometre Array (SKA)

The SKA will be the largest and most powerful radio telescope ever built. Much of its science case was conceived and developed by Canadian astronomers and Canada has been a member of the SKA consortium since its inception. We have been engaged in planning and governance for 20 years, spending around \$25 million on design studies, technology demonstrators and pre-construction.

Participation in the SKA is one of the top two recommendations in the LRP. Canada is positioned to deliver the “correlator” for the first phase of the project that will combine the signals from the thousands of dishes in the array into a single image. The correlator is the central and most challenging component of this phase.

Scientific Impact

The SKA is a landmark global research facility (on the scale of the Large Hadron Collider), with an estimated scientific lifetime of at least 50 years. It aims to address some of the largest questions in physics and cosmology, like the nature of dark energy, dark matter, gravity and

magnetism, and the origin of life.

Economic Impact

All work anticipated for Canada is in highly skilled sectors. Previous investments in radio astronomy research have a proven track record of delivering long-term economic spin-offs (everything from WiFi to brain imaging). A 2014 report prepared for the NRC projected the market for SKA-related technologies will be US\$138 billion by 2019.

Financial Requirements

As a long-term project, there are no new financial requirements for the SKA in 2017.

3. Wide Field Infrared Survey Telescope (WFIRST)

WFIRST is a NASA observatory designed to settle essential questions in the areas of dark energy, exoplanets and infrared astrophysics. Participation in a dark energy mission is the top space-based recommendation in LRP2010 and the MTR. Through the CSA, Canada has a long history of participation in space-based astronomy.

Scientific Impact

WFIRST is designed to study the most important questions in astronomy, such as the nature of dark matter, dark energy and gravity itself, and to obtain images and spectra of exoplanets around nearby stars. WFIRST images will be as sharp as those of the Hubble Space Telescope, but 100 times larger. This allows it to survey the astronomical sky with speed and accuracy, uncovering millions of galaxies.

Financial Requirements

NASA has formally started the WFIRST mission as its next major flagship observatory. WFIRST is currently in the formulation phase with launch expected in 2024. CSA appears able to fund some Canadian participation at a modest level, and based on the assumption of a continuing commitment, there are no financial requirements for Canada at this time.

4. Cosmological Advanced Survey Telescope for Optical and Ultraviolet Research (CASTOR)

CASTOR is a proposed CSA-led mission that would make a unique, powerful and lasting contribution to astrophysics by providing panoramic, high-resolution imaging in the ultraviolet/optical spectral region. This mission would far surpass any ground-based optical telescope in terms of angular resolution and would provide ultra-deep imaging in three broad filters to supplement longer-wavelength data from planned international dark energy missions, like WFIRST. Combining the largest focal plane ever flown in space, no planned or proposed astronomical facility would exceed CASTOR in its potential for discovery at these wavelengths.

Most notably, this would be a *Canadian-led mission*, taking us to the next echelon of space-based astrophysics.

Scientific Impact

No astronomical facility has had a greater impact than the Hubble Space Telescope, which is one of the most productive instruments in the history of science. As Hubble is expected to cease operations before the end of the decade, CASTOR is essentially a replacement, but with 200 times the sky coverage. The telescope will greatly enhance scientific knowledge in the areas of dark

energy and cosmology, galaxy evolution, the formation and evolution of cosmic structure, stellar astrophysics and the outer solar system.

Economic Impact

CASTOR has the potential to be a Canadian-led project with enormous economic and innovation impact that captures the imagination of the Canadian public like few scientific projects before it. It would be a flagship project for the CSA with a high level of international visibility. CASTOR could even exceed the level of visibility of Hubble, which would be an incredible feat for Canada.

Financial Requirements

For now, \$1 million is needed for a “phase zero” study of Canada’s leadership in CASTOR.

Funding for the Canadian Space Agency

Space astronomy projects must be funded through the CSA, though in recent years its budget has dwindled to a level that cannot support the high priority projects in the LRP, like WFIRST and CASTOR. Canada’s space program is underfunded by a large factor compared with all other space-faring nations.

As a first step, the CSA budget needs to be increased to a level that ensures the sustainability of Canada’s space ecosystem. Canada needs to develop a vision for the CSA which includes space missions like those identified in the LRP, as well as technology development to ensure Canadian industry has the capacity to support those missions.

The broader vision for the CSA should include a plan for space astronomy. To that end, the LRP takes into account future opportunities that will maintain Canadian leadership by retaining the best scientists and engineers and working with our aerospace contractors at the forefront of technology. The best opportunities for Canada in space astronomy are WFIRST and CASTOR, and pursuing those requires CSA to invest \$30 million per year over 15 years in this field.

CASTOR in particular offers a paradigm-shifting opportunity to take the lead on a unique telescope project that is already of world-wide interest. The CSA has completed studies that show its feasibility and hardware requirements, but it lacks the long-term budget to begin pursuing it. Losing the opportunity for Canada to lead CASTOR would be tragic.

Therefore, the Government needs to lay out a vision for the CSA that includes a robust program of space astronomy missions, and to then provide adequate funding to enact that vision.