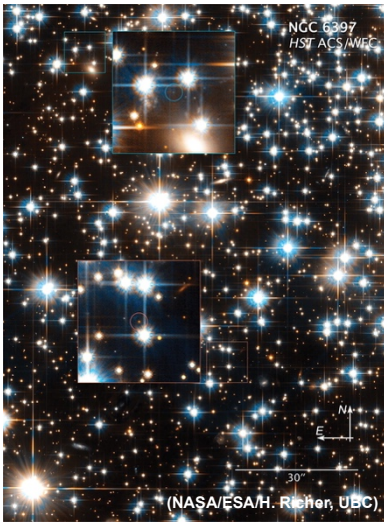


## Unveiling the Cosmos: A vision for Canadian Astronomy



This image from the *Hubble Space Telescope* shows hundreds of stars in exquisite detail. Canadians have made use of such images to measure the ages of some of the oldest stellar systems in our Galaxy.

Astronomy and astrophysics is one of Canada's most prominent research fields, both nationally and internationally. With access to some of the best facilities both on Earth and in space, our universities are able to attract the best students and faculty from around the world. The successes of our community have been well-documented by independent studies, most notably by the Expert Panel on the State of Science and Technology in Canada published in 2012 by the Council of Canadian Academies, that place Canadian astronomy either at or close to number one in the world. Canadian achievements in astronomy, both in scientific research and in technological and industrial innovation, are a source of pride for all Canadians.

### Canada's decadal plan for astronomy

Astronomy combines the development of leading-edge technology and computing with the quest to answer fundamental questions of wide public interest. To maintain our excellence and leadership in this field, it is essential to design and have access to state-of-the-art facilities, most of which require a decade or more of preparation. Large modern observatories are almost all international collaborations that share costs and expertise, and avoid duplication.

From broad community consultations, Canadian astronomers have published decadal Long Range plans, which provide coordinated visions of facilities, data analysis, and archiving, based on opportunities, schedules, and Canadian expertise. Our current Plan (LRP2010) has just been reviewed and updated by a Mid-Term Review (MTR) panel of experts. The plan is a bold and exciting one, which ensures that Canada is positioned to develop and exploit new technology that will address current questions, and make exciting new discoveries.

### Profound questions shape remarkable opportunities

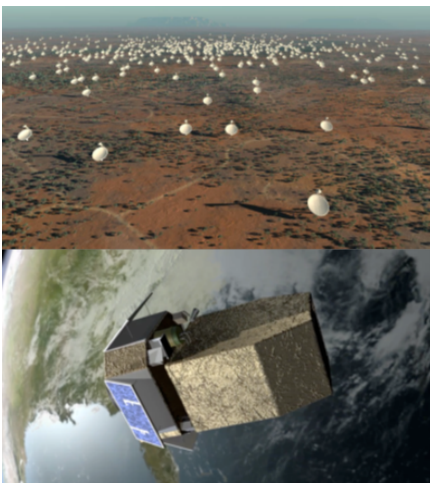


**Cosmology:** Canadian astronomers use large telescopes to detect galaxies at the edge of the cosmos (right), to understand how the structure of the Universe developed, and to uncover the mysterious nature of dark matter and dark energy. To find the first galaxies, the Canadian Space Agency (CSA) has partnered with NASA and the European Space Agency to build the *James Webb Space Telescope* (JWST, left). Due to launch in 2018, this successor to the enormously successful *Hubble Space Telescope* will peer back in time to view the origins of our Universe. Looking farther ahead, Canadians are excited by

the opportunity to participate in the WFIRST (NASA) and LiteBIRD (Japan Aerospace Exploration Agency) missions. WFIRST will make unprecedented measurements of the influence of dark energy on our Universe, while LiteBIRD is designed to detect the signature of gravitational waves emitted during the early inflation of our Universe.



This image from the *Hubble Space Telescope* includes the faintest objects ever observed: distant galaxies at the edge of the observable universe.



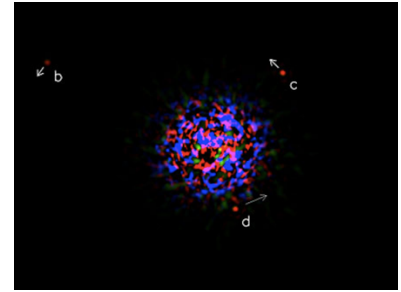
**Galaxies and stars:** Astronomers strive to understand how stars form and assemble themselves into the beautiful, complex structures that are galaxies (right). This problem requires a multi-faceted approach that uses light from all parts of the electromagnetic spectrum. The *Square Kilometre Array* (SKA, left, top) will detect radio waves emitted from gas, planets, stars and galaxies. It will also provide new tests of Einstein's theory of gravity. The *Maunakea Spectroscopic Explorer* (MSE) will look for the oldest stars and provide the definitive picture of how dark matter structure has developed. The exciting combination of *JWST*, *WFIRST* and the Canadian designed *CASTOR* telescope (bottom left) will enable astronomers to directly observe the growth of galaxies from their beginnings 13 billion years ago to the present day. Looking farther ahead, the *Athena* space telescope will detect X-rays to study how enormous black holes grow in galaxies.



This beautiful image of a galaxy shows the power of combining different types of data. The blue light shows gas in the galaxy, observed in radio waves. Dust is observed in the infrared, and shown here in green and red colours. These data complement the more familiar view of galaxies, where only starlight is seen. Radio: VLA/AUI; infrared, Spitzer/NASA.



**Planets and the origins of life:** Perhaps the most exciting of astronomers' ambitions today is the search for planets around nearby stars (right) and, ultimately, the search for signs of life on those planets. The Thirty Meter Telescope (TMT, left) will be one of the largest in the world. A highly capable observatory, it will make a transformative impact on all areas of astronomy. In particular, it will be able not only to find



This famous Keck telescope image shows the direct detection of three planets (labeled b, c and d) around the star HR8799. Light from the star itself has been greatly suppressed to reveal the planets. Canadian astronomer C. Marois of NRC and his team used both Gemini and Keck telescopes for the work.

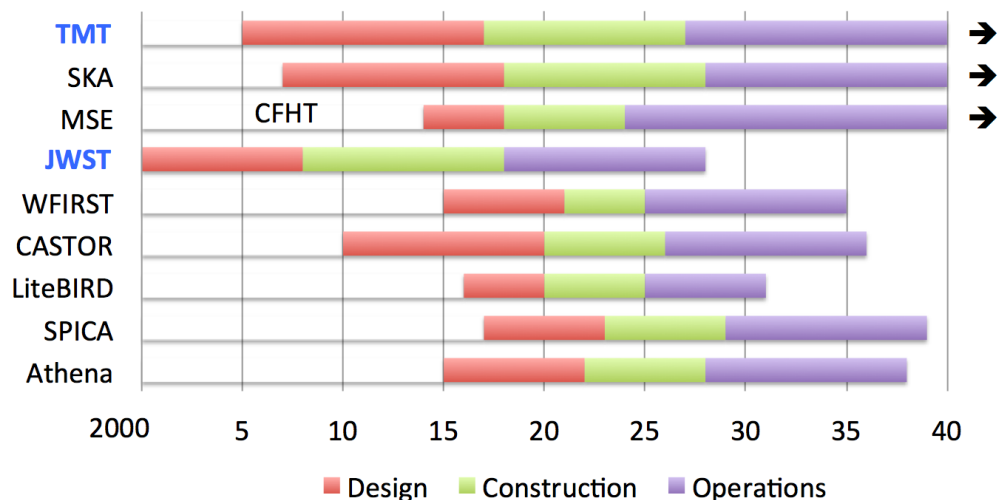
small planets around distant stars, but also to measure the properties and compositions of their atmospheres - work that will begin with the Canadian instrument on JWST. The *SPICA* space telescope will enable a detailed study of the gas disks around young stars, from which such planets eventually form.

## Funding Requirements

**Major ground-based facilities have to be funded on an individual basis, and administered by the National Research Council (NRC), unless funded by the Canada Foundation for Innovation (CFI). This process can result in considerable uncertainties and delays in Canada joining new large facilities. Space projects must be funded through the CSA. In recent years, the CSA budget available for space science has dwindled to a level that cannot support the high priority projects in the LRP.** By many measures, Canada's space program is underfunded by a large factor compared with all other space-faring nations. Our community regards it as vital that this budget be increased to a level where we can maintain and pursue the excellent international opportunities we have developed. **All these major facilities require at least a decade of commitment and work to go from initial designs and partnership, to completion.**

Construction funding has been secured for Canada's participation in JWST and TMT. The Canadian share, especially in costly space projects, is often a small one, but ensures the basic facility access our community needs, and enables us to participate in design and development. Both on the ground and in space, all projects involve contracts and expertise development by Canadian high-tech industry (with commensurate opportunities to compete world-wide), as well as attracting and retaining the best scientists and engineers. These projects need commitments now so as to develop today's opportunities into tomorrow's reality.

## Approximate timeline of LRP new facilities (JWST and TMT are funded and under way)



The first three facilities are ground-based facilities, which can have long lifetimes as they can be maintained and upgraded. The other six facilities are space-based and are shown with their likely operational lifetimes. All timelines are subject to change as projects evolve, but overlapping access to the range of facilities is a feature of the LRP. The MSE is a replacement of CFHT on the same site. The order in which facilities appear in the chart does not represent priority.

For more information, contact [CASCA-President@casca.ca](mailto:CASCA-President@casca.ca).

The full Mid-Term Review is at <http://casca.ca/wp-content/uploads/2016/03/MTR2016nocover.pdf>.