The Canadian Astronomy Landscape: Science, Technology, Data and People

NTCO AGM 2024 – 22 February 2024

Luc Simard, Director-General, Herzberg Astronomy and Astrophysics Research Centre

Strengths of the Canadian Community

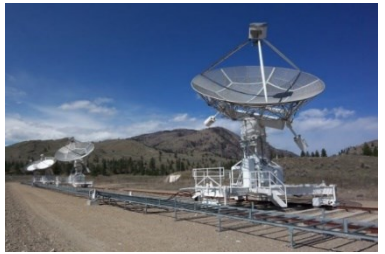
- Very creative and science-driven
- Experience with some of the best telescopes on the planet
- Able to very effectively build collaborations between universities, industry and government
- Able to engage in small, medium and large projects
- Planning through the Long Range Plan for Astronomy (2000, 2010 and 2020)
- Very well connected at the international level - Canadians are known to be excellent collaborators

Current “Canadian” Family of Telescopes

Plaskett, Victoria (1918)

McKellar, Victoria (1962)

Galt, Penticton (1960)



Synthesis Telescope, Penticton (1995)

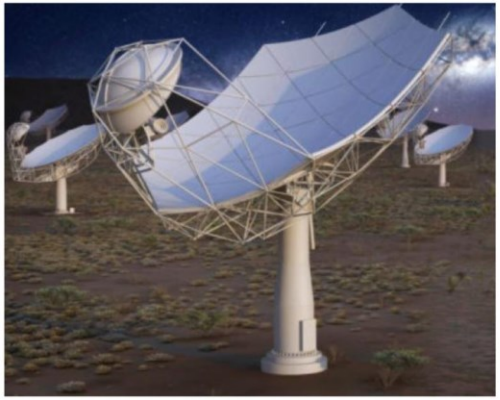
CHIME, Penticton (2017 CFI*)

Canada-France-Hawaii,
Hawai’i (1979)

Gemini, Hawai’i and Chile
(1999, 2000)

Atacama Large Millimeter Array, Chile (2012)

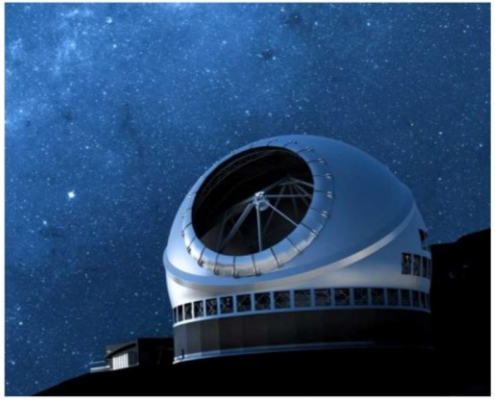
Future Facilities



Rendering of SKA Dishes
Source: SKA Organization

Square Kilometre Array (SKA)

- SKA is an international collaboration to build the world's largest radio telescope. The SKA will monitor the sky in great detail and map it hundreds of times faster than any current facility
- Canadian scientists, engineers and industry have been engaged in SKA design since its earliest stages over 20 years ago, and the SKA is the second highest priority for ground-based astronomy in the 2020 LRP for astronomy and astrophysics
- Canada led the design of the digital signal processors at the heart of the telescope arrays



Rendering of TMT
Source: TMT International Observatory

Thirty-Meter Telescope (TMT)

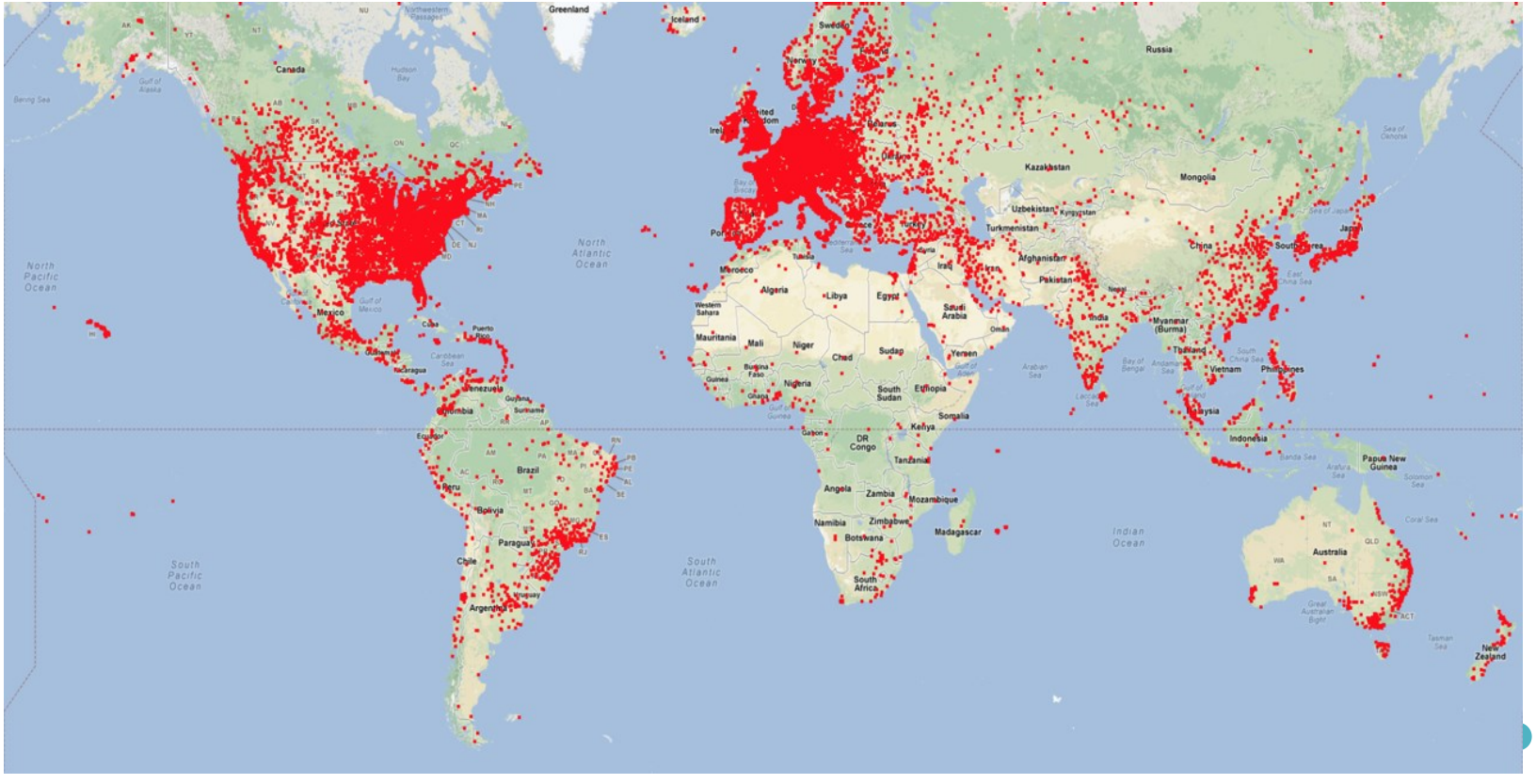
- TMT is an extremely large telescope with a 30-m primary mirror diameter. TMT will be 3-times as wide, with nine times more area, than the current largest visible-light telescopes in the world
- TMT will provide images more than 12 times sharper than those from the Hubble Space Telescope
- Observing in wavelengths ranging from the ultraviolet to the mid-infrared, this instrument will allow astronomers to address fundamental questions in astronomy ranging from understanding star and planet formation to unraveling the history of galaxies and the development of large-scale structure in the universe

Observatory/University/Gov/Industry Partnerships

Nanotechnology
Advanced Electronics and Photonics
Photonics Fabrication Centre

The Importance of Digital Astronomy: CADC Worldwide User Community

CART



The Square Kilometre Array Observatory

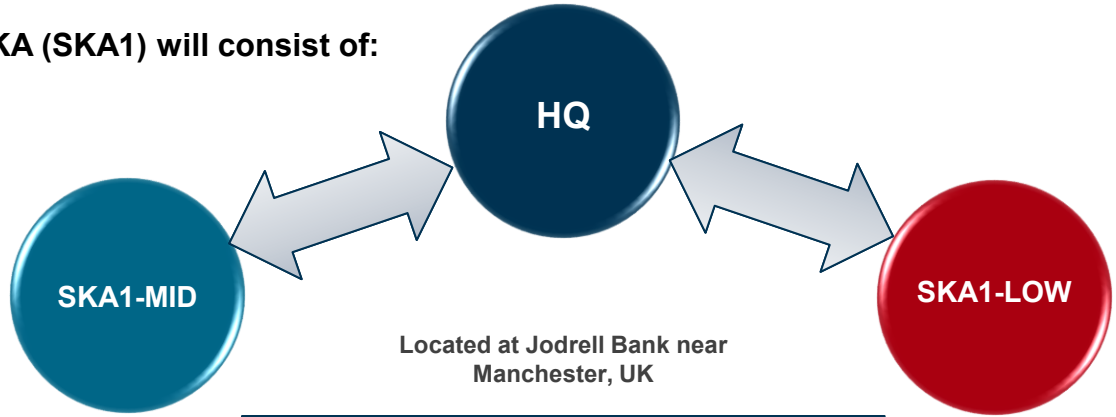
The SKA is a next-generation radio astronomy facility that will revolutionize our understanding of the Universe and the laws of fundamental physics. It will have a uniquely distributed character: one observatory, operating two telescopes on two continents (Australia and South Africa), with headquarters located in the United Kingdom.

The first phase of SKA (SKA1) will consist of:

Mid-frequency Array

Located in Karoo Desert, South Africa

197 radio dishes each with a diameter of 15 meters



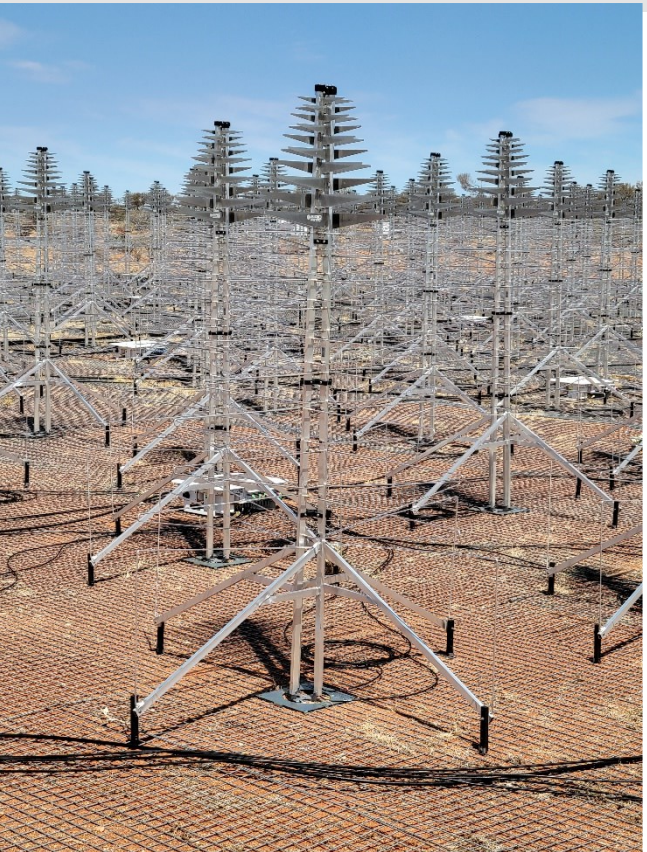
Located at Jodrell Bank near Manchester, UK

Low-frequency Array

Located in Western Australia

131,000 log-periodic antennas

October 23, 2023: SKA-LOW AAVS3 Station at Inyarrimanha Ilgari Bundara (Australia)



SKA Regional Centre (SRC) Capabilities

Science Enabling Applications
Analysis Tools, Notebooks, Workflows execution Machine Learning, etc

Distributed Data Processing
Computing capabilities provided by the SRCNet to allow data processing

Data Discovery
Discovery of SKA data from the SRCNet, local or remote, transparently to the user

Visualization
Advanced visualizers for SKA data and data from other observatories

Support to Science Community
Support community on SKA data use, SRC services use, Training, Project Impact Dissemination

Interoperability
Heterogeneous SKA data from different SRCs and other observatories

Data Management
Dissemination of Data to SRCs and Distributed Data Storage

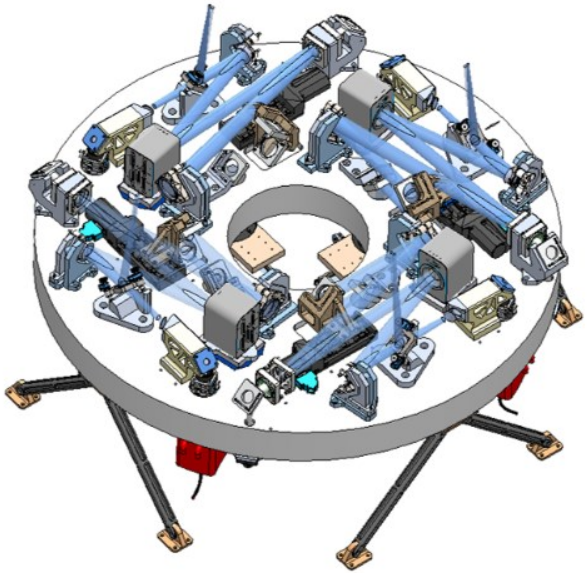
Canadian Hydrogen Observatory and Radio-transient Detector (CHORD)

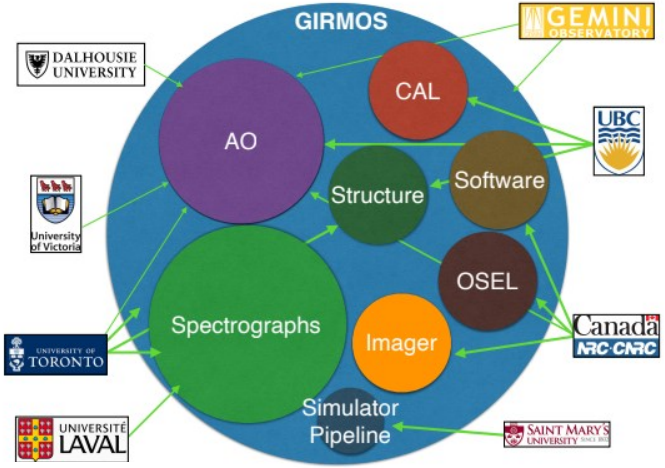
An artist's interpretation of the CHORD telescope array with the CHIME telescope visible on the right.

- McGill U.
- U. Toronto
- U. Calgary
- NRC
- Perimeter Institute
- INAF

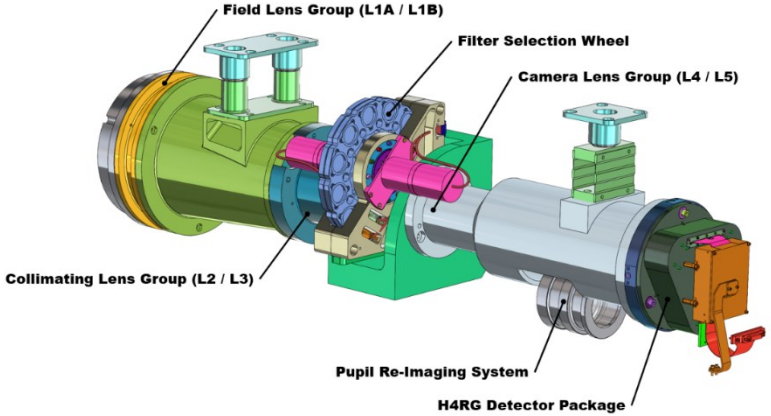
Gemini InfraRed Multi-Object Spectrograph (GIRMOS)

OSEL – Object Selection



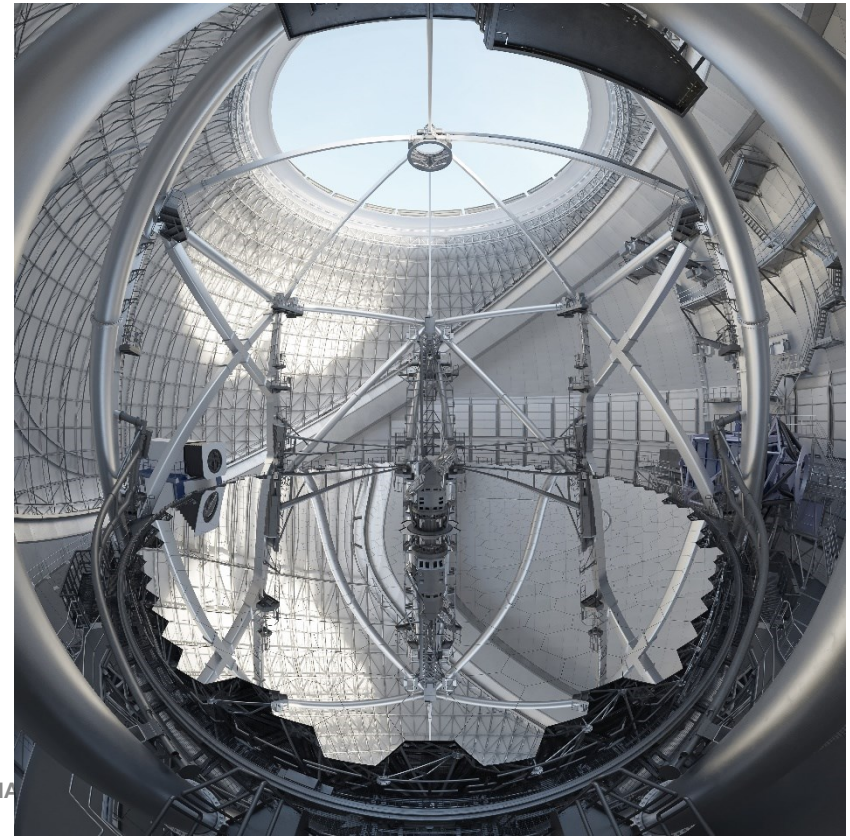


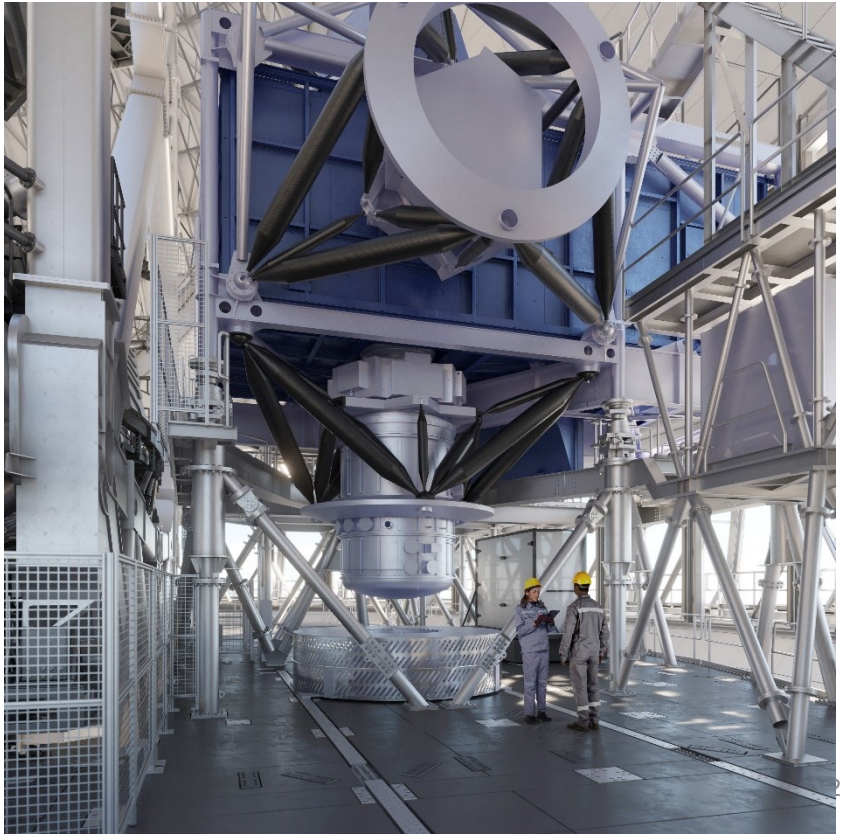
Preliminary Design Review



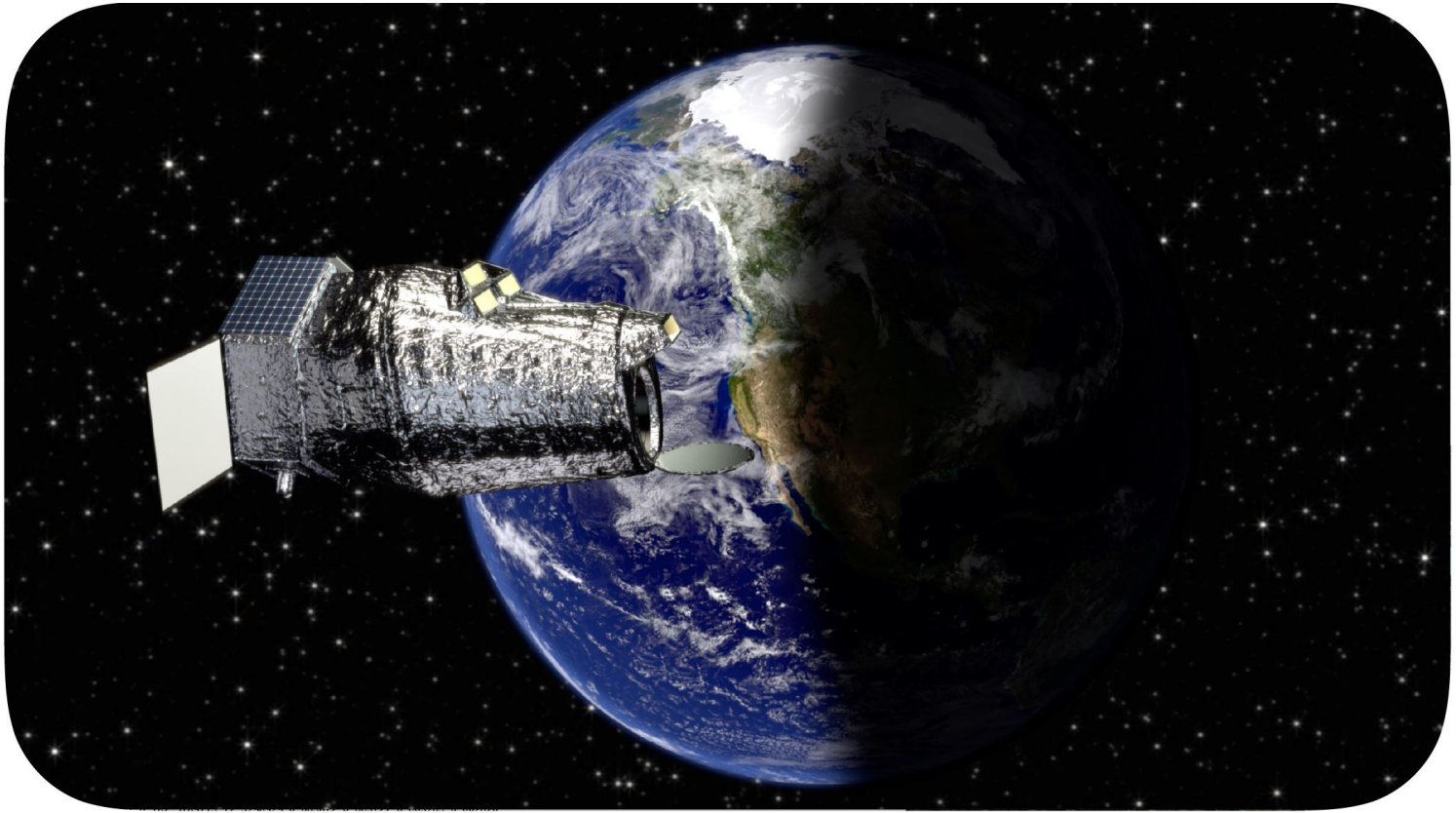
IMGR – Near IR Imager

Thirty Meter Telescope

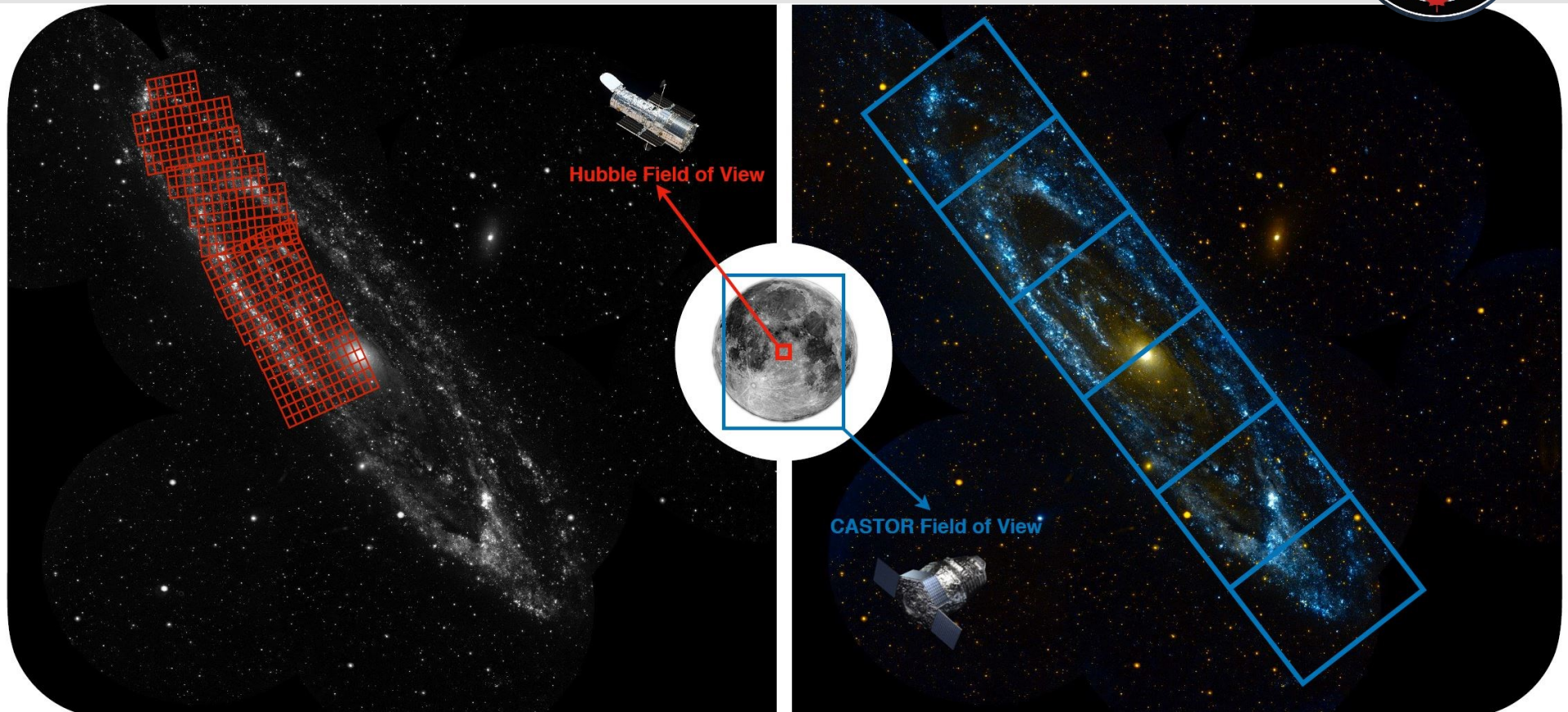




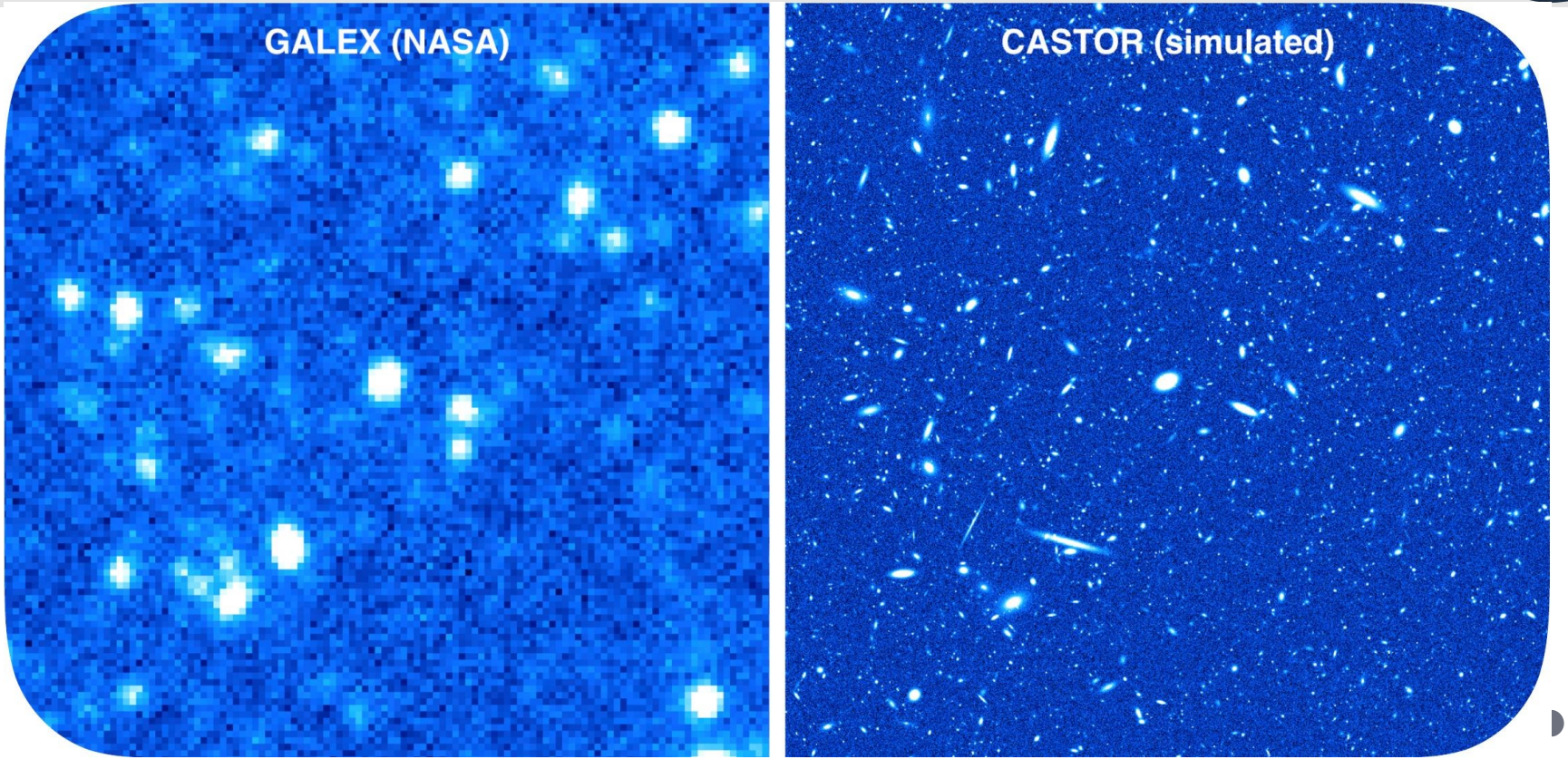
The Cosmological Advanced Survey Telescope for Optical and ultraviolet Research (CASTOR)



CASTOR - Canada's Space Telescope: Wide Field of View



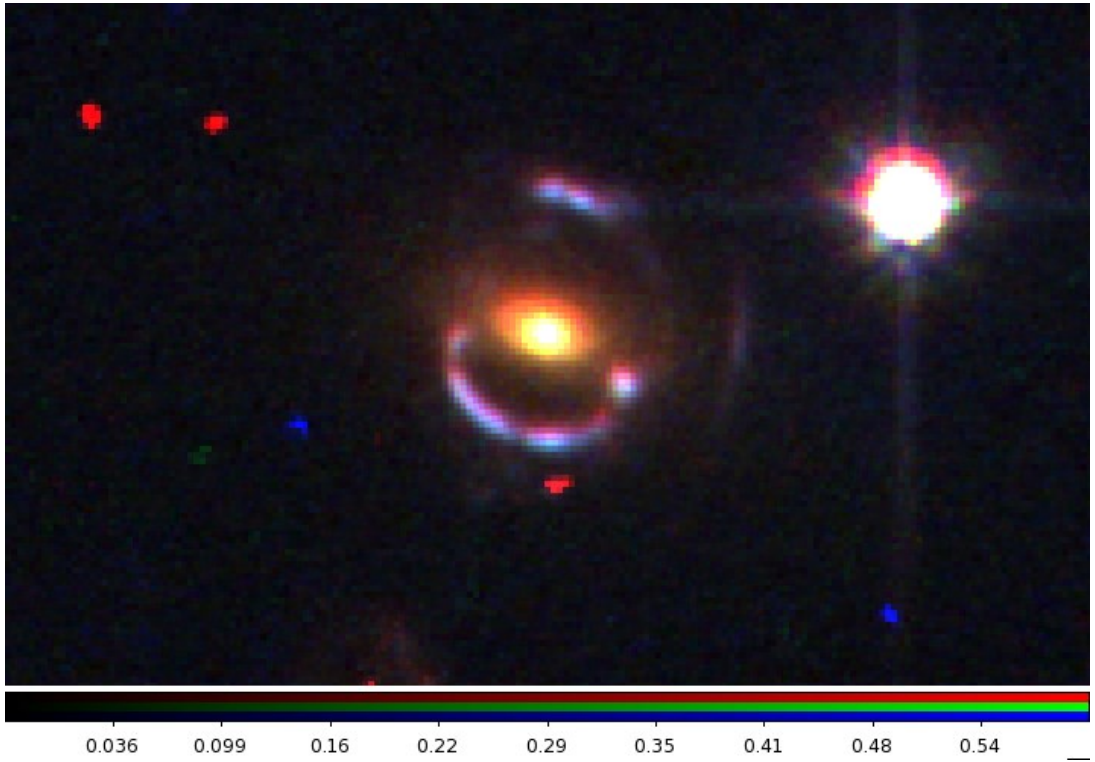
CASTOR - Canada's Space Telescope: Excellent Image Quality



“Big Data” and the Dawn of Machine Learning

Three ‘types’ of images selected from the Hubble Space Telescope Legacy Archive, each is distinct based on content of the image.

Machine Learning for Finding Scientifically Interesting Objects



Gravitational Lenses in Hubble Space Telescope images

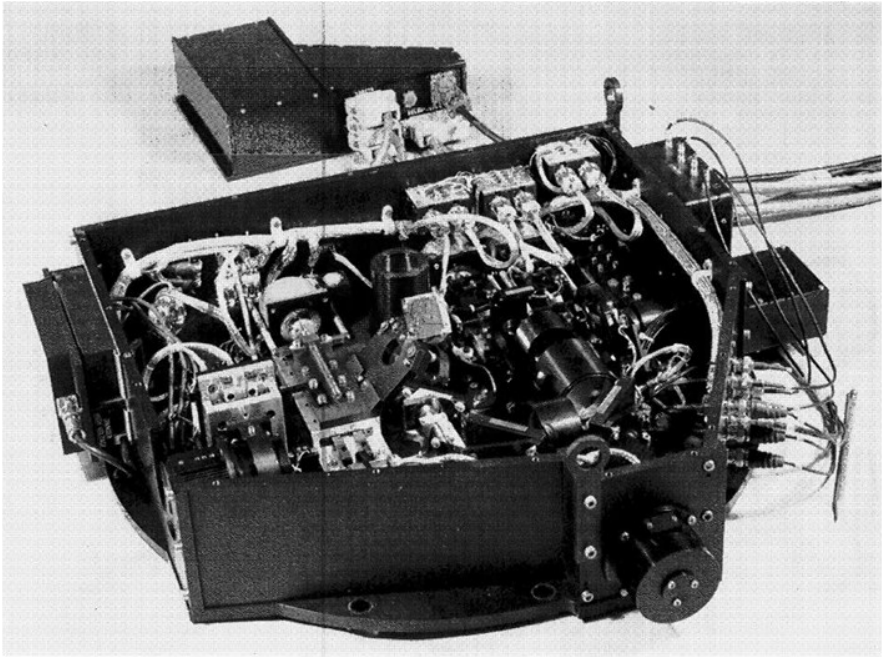
Beautiful examples of Einstein's Theory of General Relativity: bending of light due to the curvature of space-time itself

They are indeed lenses magnifying distant regions of the Universe

Arcs through Time: An Adaptive Optics (Canadian) Story

System	Facility	Year	Milestones
High-Resolution Camera (HRCAM)	CFHT	1989	“You can do that???”
PUEO	CFHT	1998	Deformable Mirror Turn-key AO
ALTitude conjugate Adaptive optics for the InfraRed (ALTAIR)	Gemini	2004 (NGS) 2007 (LGS)	Know thy turbulence profile
Gemini Planet Imager (GPI)	Gemini	2013	Miniaturized deformable mirror (This one goes up to 0.90)
RAVEN	Subaru	2014	Multi-Object AO science demonstrator (Only do AO where you need to)
Gemini IR Multi-Object Spectrograph (GIRMOS)	Gemini	2027	Facility-class MOAO TMT IRMOS Pathfinder (“NFIRAOS-IRMOS”)
Narrow-Field InfraRed AO System (NFIRAOS)	TMT	2030s	End-to-end observatory integration Multiple deformable mirrors Fast target acquisition

An Adaptive Optics Story: High-Resolution Camera (HRCAM; 1989)



McClure et al. 1989, PASP, 101, 1156

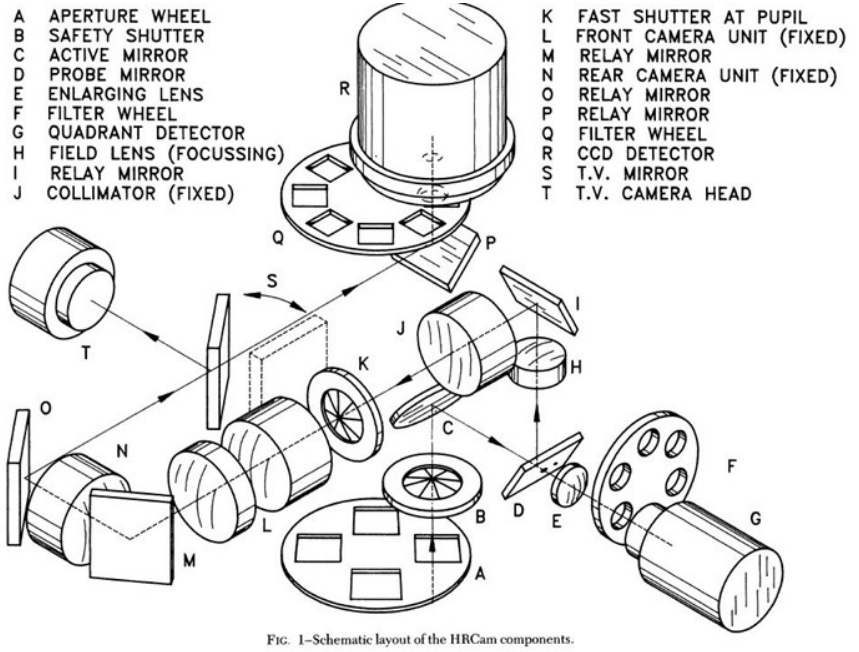


FIG. 1–Schematic layout of the HRCam components.

Fast tip-tilt mirror – No deformable mirror!
500 Hz

An Adaptive Optics Story: High-Resolution Camera (HRCAM)

HIGH-RESOLUTION IMAGING OF VIRGO CLUSTER GALAXIES. I. THE DISTANCE BASED ON THE BRIGHTEST STARS IN NGC 4571[1]

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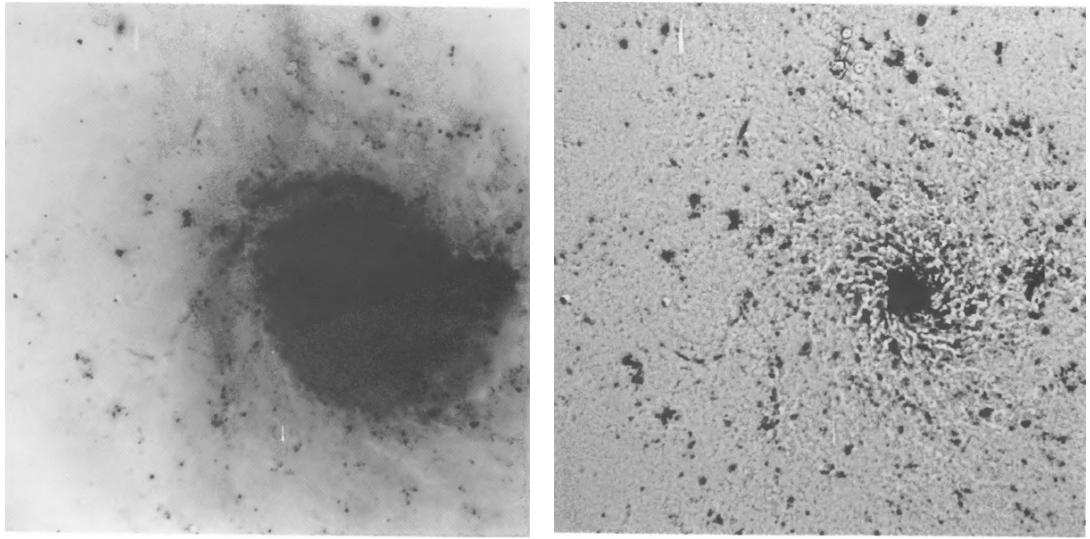
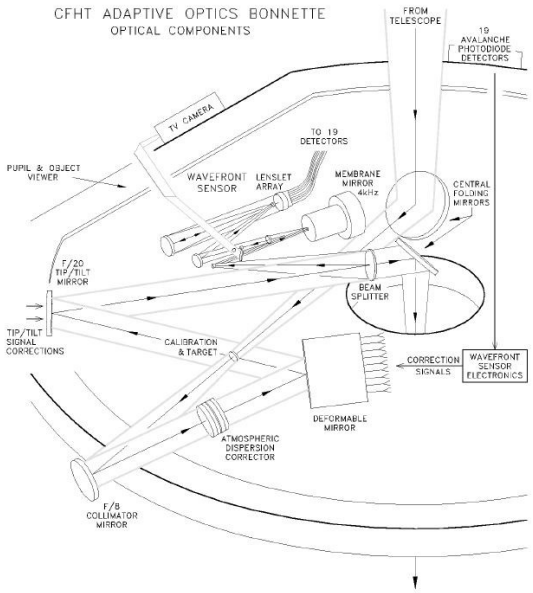


Seeing of 0”.4 FWHM!

Individual stars were resolved

PUEO: The CFHT Adaptive Optics Bonnette (1998)



NATIONAL RESEARCH COUNCIL CANADA

Performance of the Canada-France-Hawaii Telescope Adaptive Optics Bonnette

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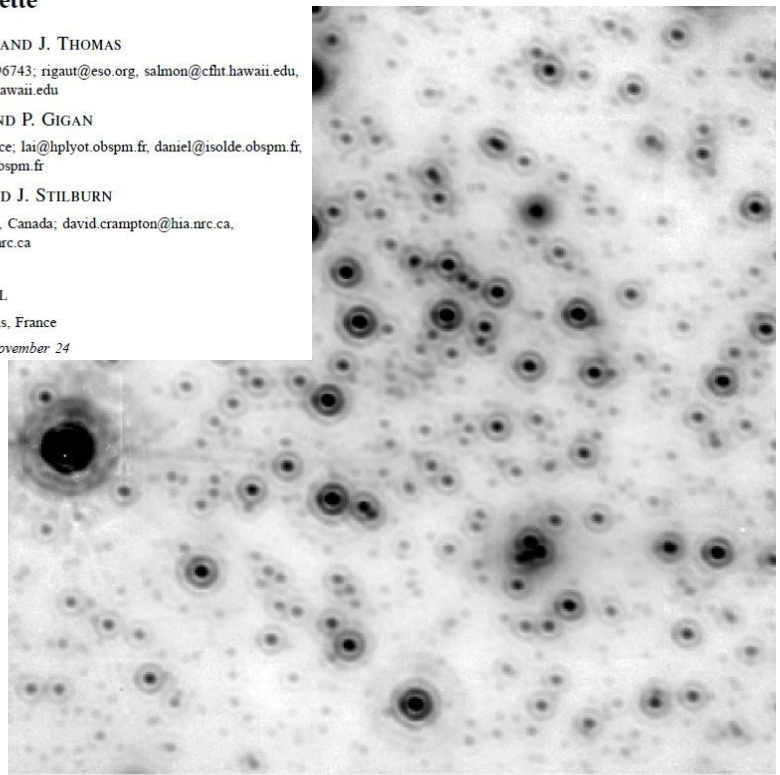
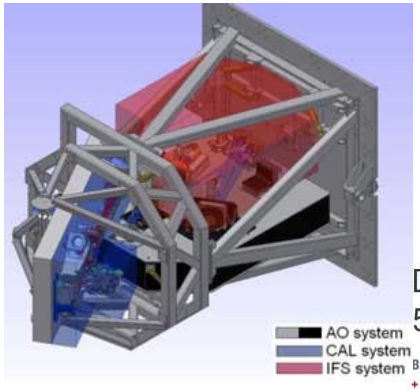
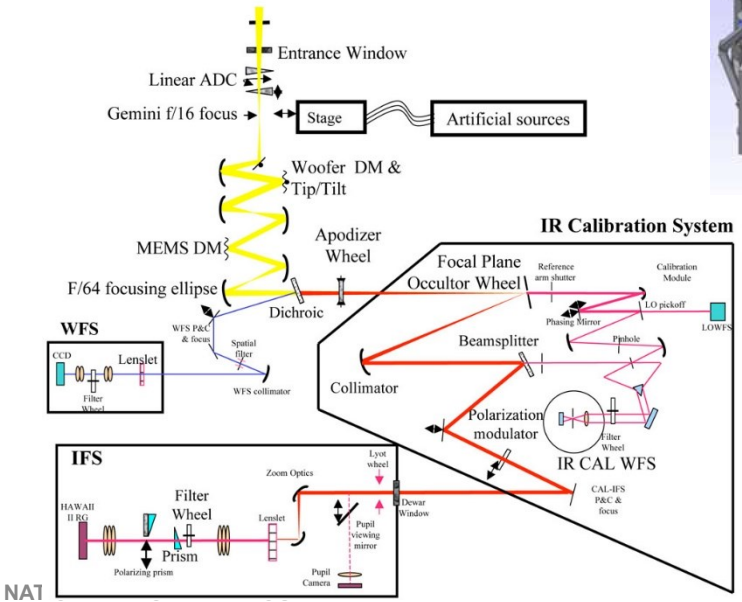


An Adaptive Optics Story: Gemini Planet Imager (GPI; 2013)

Extreme AO (Strehl~0.9)
Imaging polarimeter/IFS
0.9-2.4 microns
Contrast ratio of 10^6





Discovery and spectroscopy of the young jovian planet 51 Eri b with the Gemini Planet Imager

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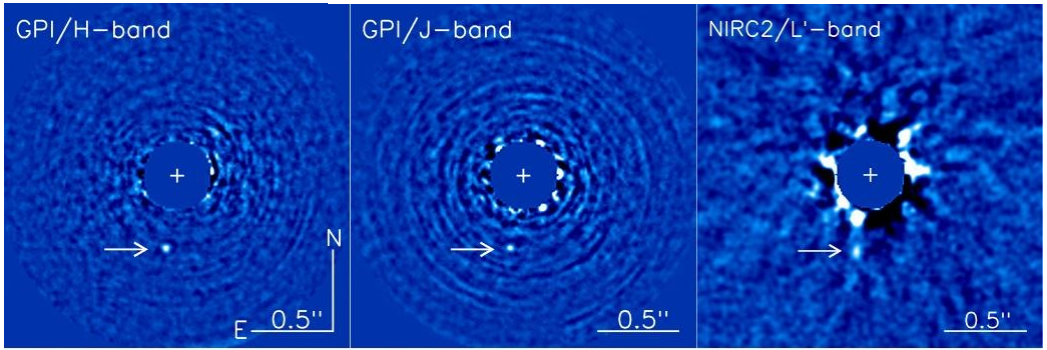
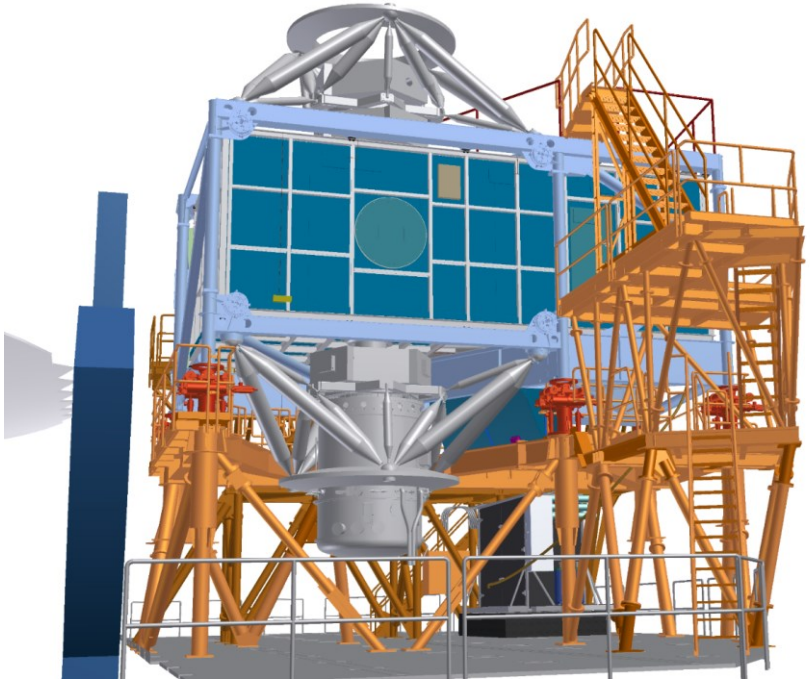
+ See all authors and affiliations

Science 02 Oct 2015:
Vol. 350, Issue 6256, pp. 64-67
DOI: 10.1126/science.aac5891



TMT Narrow-Field IR AO System (NFIRAOS)



- Dual-conjugate Laser Guide Star AO System – most complex AO system ever designed
- Physically large (11 x 8 x 5 m)
- Feeds three infrared instruments
- Operates at -30C to reduce thermal background
- Ready at TMT first light
- Industrial partners: ABB, INO, Sightline Engineering, Quantum Technology

Benefits of Industry Connections

- Brings new expertise and design/build practices to increasingly large and complex projects
- Many technologies developed in industry bring new capabilities to astronomy
- Direct economic benefits to Canadians
- Increased Canadian competitiveness through technology transfers
- Wealth of non-astronomy applications (e.g., amusement rides, quantum computers, eyecare, online shopping, network access for remote communities, …)
- Better astronomical instrumentation systems

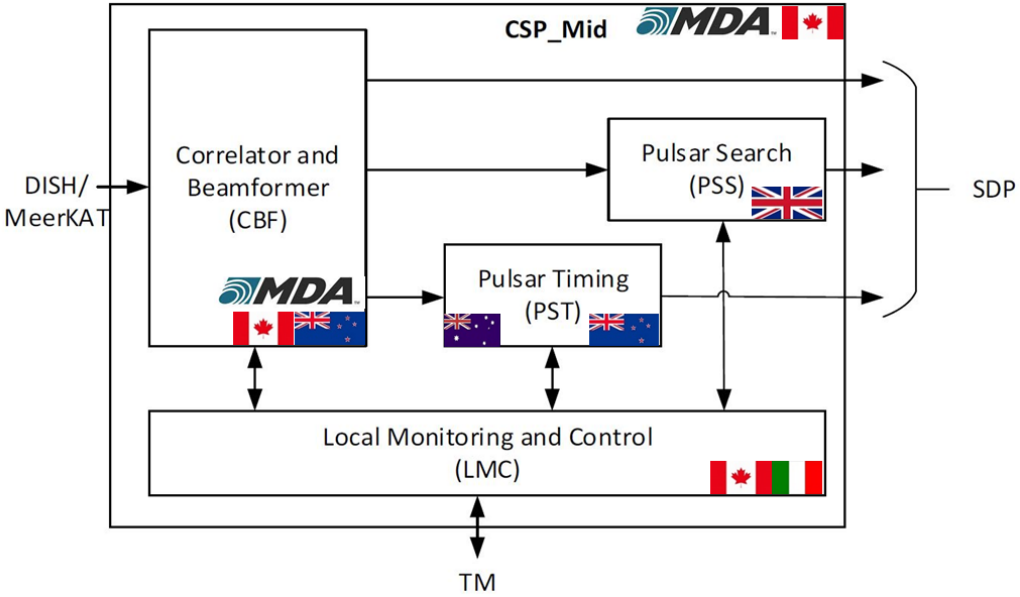
Composite Material Radio Reflectors

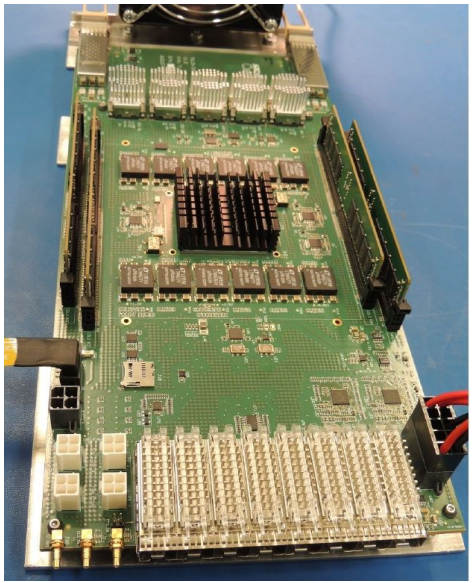
15-m Dish Verification Antenna – 1 @ DRAO

Calian SED (Saskatoon, SK) Composite Carbon Fiber Antenna (6- and 10-m) for Q/V band satellite communications (March 2019)

SKA Central Signal Processor (CSP)

- 2012-2018 International design consortium led by Canada (NRC and MDA)

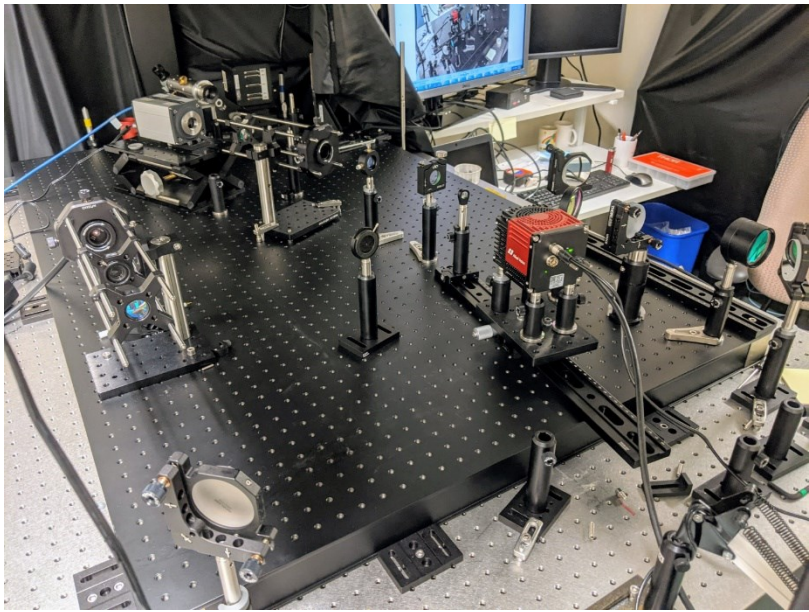




TALON-DX

Development of High-Potential Technologies through On-Sky Prototyping

- REVOLT: New AO bench installed at the Coudé focus of the Dominion Astrophysical Observatory's 1.2m telescope in Victoria, BC.
- New technologies:
  - HEART Real-time Controller (RTC)
  - FLIR C-Blue One CMOS High-Speed Camera
  - New low-voltage deformable mirror developed with NRC NANO Research Centre and U. Manitoba
  - Open-loop AO for GIRMOS
  - Photonic correlation spectrograph developed with NRC AEP Research Centre / UofT / Queen's U at Belfast
  - First light August 2022

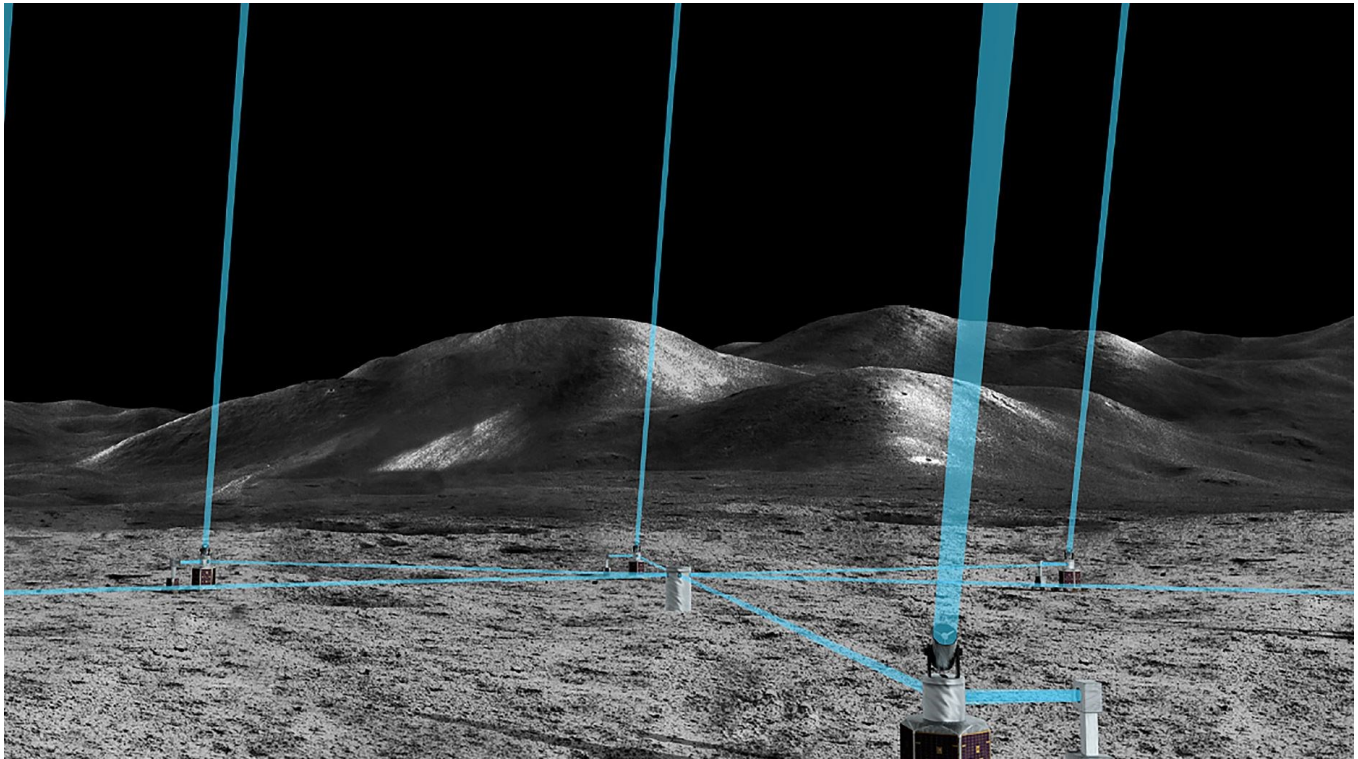


The Future - Partnerships

- The special blend of Canadian partnerships will remain one of our greatest strengths
- Industry will remain key to the realization of astronomy projects
- Convergence between astronomy and industry needs will ensure two-way benefits
- Industrial applications will continue to come from advances meant for fundamental science often in unexpected areas
- Range of career options will continue to widen for young scientists and engineers trained to bridge the gap between fundamental science and industry (NTCO!)

The Future - Technology

NIAC PI: Kenneth Carpenter (Goddard; January 2024 Phase I)



Artemis-enabled Stellar Interferometer (AeSI) at visible and UV wavelengths over kilometric distances

- Resolved stellar surfaces
- Inner accretion disks of black holes
- Surface features and weather patterns on the nearest exoplanets

Congratulations NTCO team!