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Dominion Radio Astrophysical Observatory

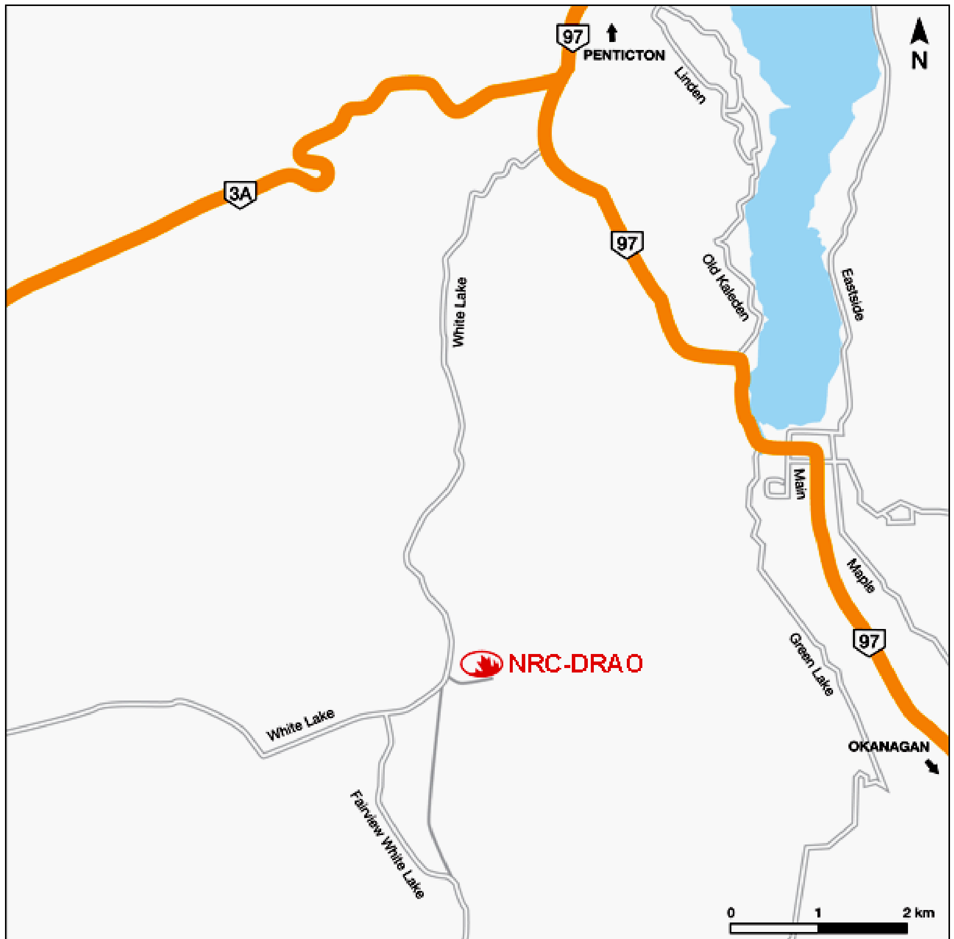
Open House 2010

Penticton, BC – September 25, 2010

Adam Farson VA7OJ & Walter Salden VE7WRS

Area map for DRAO site

[Driving directions]()



General view of site

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- **Overall view of 26m dish & main building**

50 years of radio-astronomy in Canada: 1956 - 1967

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- **1956: Dominion Astronomer, C.S. Beals, proposes a radio-telescope be built to study ISM (interstellar medium) in our galaxy, the Milky Way.**
- **1957: Nation-wide site survey selects present White Lake Basin site.**
- **1958: Construction begins.**
- **1959: 26m telescope, first instrument on site, completed. The 26m system is still active today, gathering data for leading-edge research.**
- **June 20, 1960: DRAO officially declared open.**
- **1965: Start of observations with 1.3km-long 22 MHz Array of wire dipoles suspended from wooden poles. 10 MHz array added later.**
- **These HF arrays gathered valuable data on quasars and revealed RF “haloes” around clusters of galaxies. Both were dismantled in 1970’s, but poles of 22 MHz array are still visible.**
- **1967: 26m DRAO telescope linked to 46m Algonquin Radio Telescope for first VLBI (Very Long Baseline Interferometry) experiment. This is equivalent to a 5000 km radio-interferometer!**
- **1967-69: Planning for Synthesis Telescope begins.**

The 26m telescope

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- **Walter VE7WRS is holding up the dish with one finger!**

Inside the 26m tower

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- **Interior of the support tower for the 26m dish.**

Close-up of dish structure

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- **The focus box (enclosing the LNA and 1st down-converter) and its supports are clearly visible. Note the IF coax link.**

The control room

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- **The 26m control console, with the antenna seen through the window.**

The signal-processing electronics (ADC, DSP, correlators) are in an EMC-conditioned room to the left of the control area. This room was locked and poorly lit; thus, no photos were possible.

The layout of the electronics for the Synthesis Telescope is similar (next few slides).

50 years of radio-astronomy in Canada: 1970’s – 2009

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- **1970: Construction of Synthesis Telescope begins.**
- **1972: Synthesis Telescope enters service on 1420 MHz (hydrogen line, the interstellar “calling frequency”) with 2 antennas, and pioneers observations of Galactic interstellar medium.**
- **1977: New linking technique allows combining data from single-antenna and synthesis telescopes. Still in extensive use today.**
- **1980: System expanded to four moveable 1420 MHz antennas on rails.**
- **1980’s – 1990’s: Major upgrades include a 408 MHz antenna and greatly-improved DSP electronics. DRAO now a National Research Facility.**
- **1990’s – 2000’s: CGPS (Canadian Galactic Plane Survey) drives additional upgrades: 7 antennas with dual-polarization feeds and even better DSP.**
- **1995 – 2009: Canadian-led international group of 96 scientists derives best-ever radio image of Milky Way at centimetric wavelengths.**
- **Techniques developed at DRAO are now in widespread use in radio-astronomy world-wide.**

Synthesis Telescope

The 7 antennas, with their rail track

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Photo: Dr. Ken Tapping

Synthesis Telescope:
antenna detail

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- **One of the 7 antennas, with rail track and electronics building.**

Radio-telescope demo

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- **A PhD candidate conducts a demo with an RF source (left) and a telescope model built around a consumer satellite TV dish (right).**

Synthesis Telescope: IF racks

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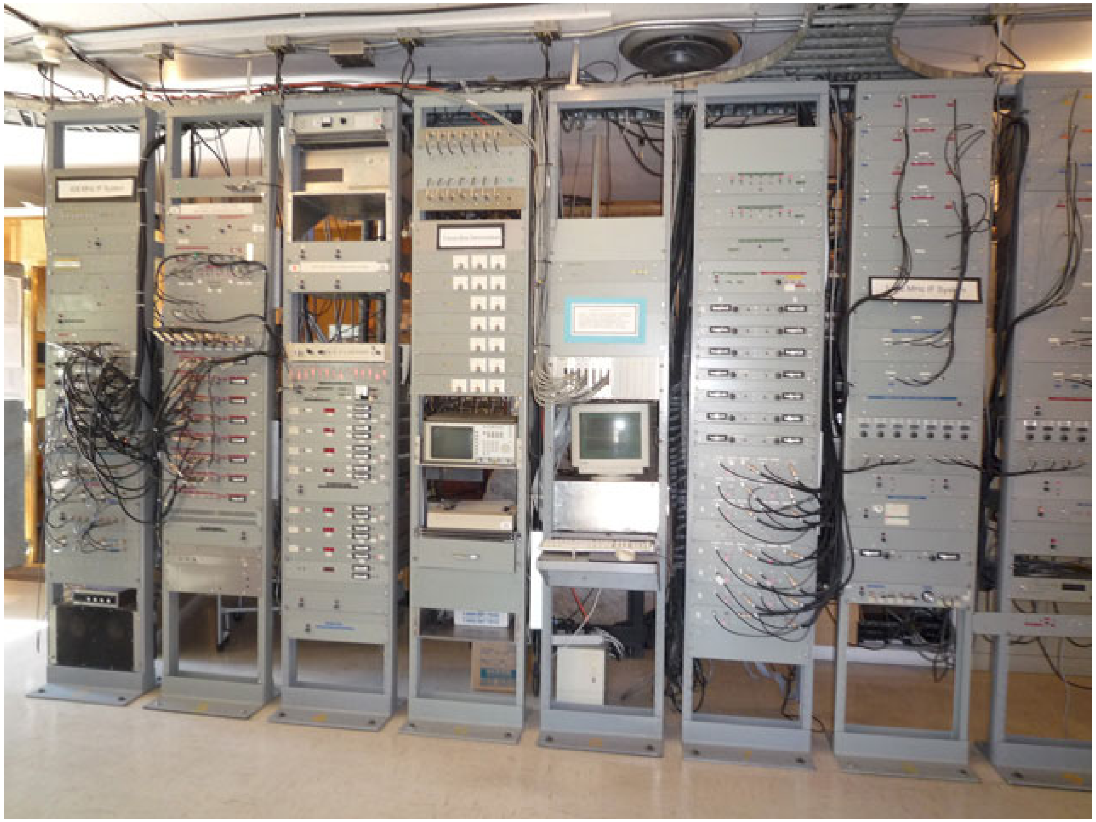
- **IF and LO equipment racks for the 1420 and 408 MHz receivers.**



Monitor rack

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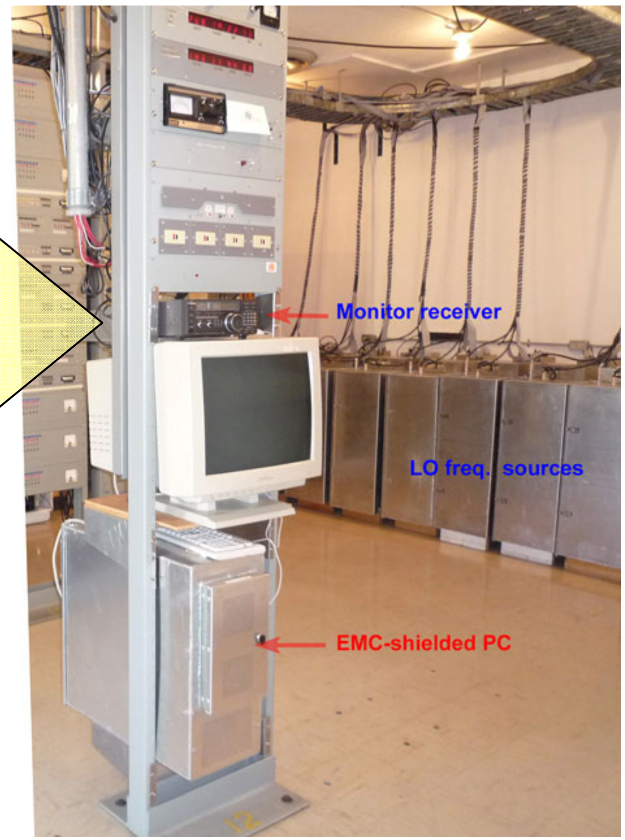
- **This is a monitor and test rack. Note the receiver and PC.**



EMC housing for PC

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EMC shielding detail

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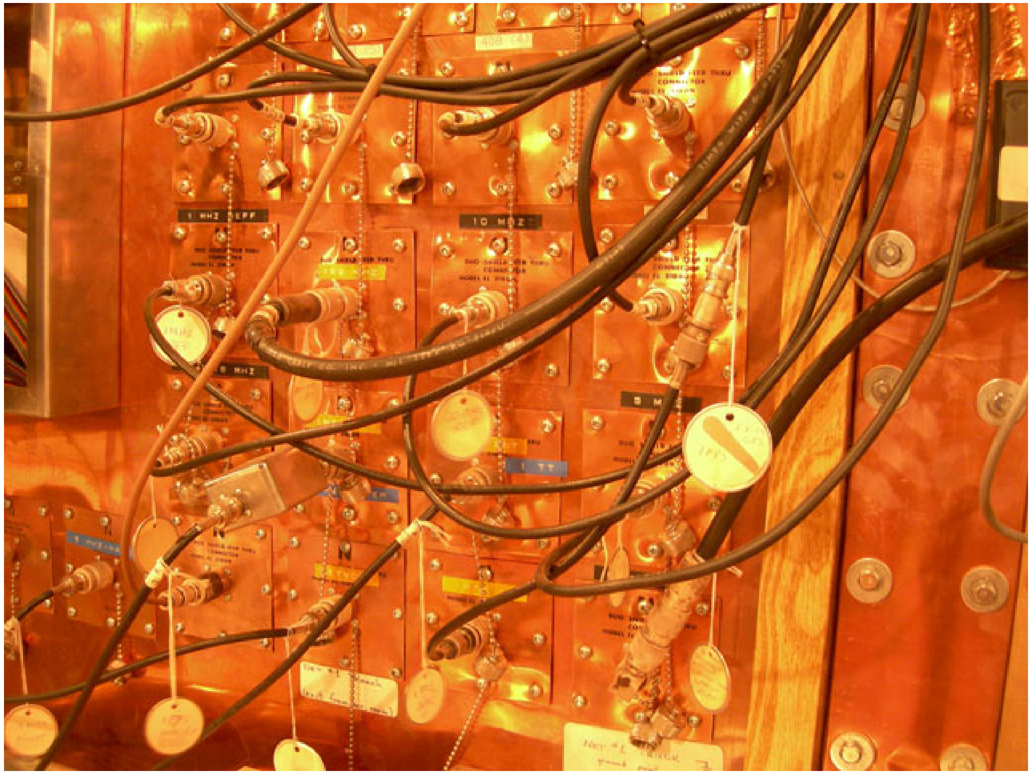
- **These are cable entries in the copper EMC shield wall of the electronics space.**



50 years of radio-astronomy in Canada: Present & future

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- **2010: DRAO is leading GMIMS (Global Magneto-Ionic Medium Survey), an international group of telescopes in Canada, Australia, Germany & China to survey polarization/frequency behaviour of astronomical radio emissions.**
- **This will yield unique information about ISM (interstellar medium), which alters polarization of radio waves passing through it, and thus:**
- **about sources of galactic radio signals, in which electrons and magnetic fields interact. This knowledge will guide future telescope development.**
- **Solar Radio Monitoring Programme (based at DRAO since 1990) was pioneered by Arthur Covington in Ottawa, in 1946, using WW2 surplus radar gear.**
- **This programme takes daily, accurately-calibrated measurements of the 10.7 cm solar radio flux, and disseminates the results internationally.**
- **The 10.7 cm solar flux data is widely used for “space weather” application by many agencies, including NASA, NOAA, USDOD, and by power utilities, satellite operators and HF radio users (amateur and commercial).**

Solar Flux Monitors

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- **The newer 10.7cm (2.8 GHz) solar monitor. Equipment bldg. to right.**

Solar Flux Monitors & Building

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- **Older (r.) and newer (l.) 2.8 GHz monitors, and equipment building.**

John White VA7JW will give a presentation on the Penticton solar Observatory soon.

Technology development at DRAO: Radio receivers

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- DRAO has 3 areas of strength: radio receivers, antenna design and DSP.
- DRAO is a leader in the development of array receivers for radio telescopes.
- Such receivers are the RF equivalent of a digital camera on an optical telescope, being able to image multiple pieces of the sky simultaneously.
- To aid in this work, DRAO is also collaborating closely with university partners and semiconductor firms to develop CMOS LNA's offering a low noise figure (< 0.2 dB) at ambient temperature, thus eliminating the expensive helium-cooling systems required by current HEMT LNAs.
- Typically, current receivers employ an LNA preceded by RF filters to reduce terrestrial interference and followed by a down-converter with a low-noise mixer and a spectrally-pure LO. The IF is filtered and fed to an ADC, which digitizes the signal and drives the correlator system.
- The newest trend is direct-sampling SDR, in which the LNA feeds ADC's sampling at RF (typically 1.5 – 2 GHz) digitize the signal and feed digital down-converters. These provide a down-sampled bitstream to the correlator.

Front-end evolution

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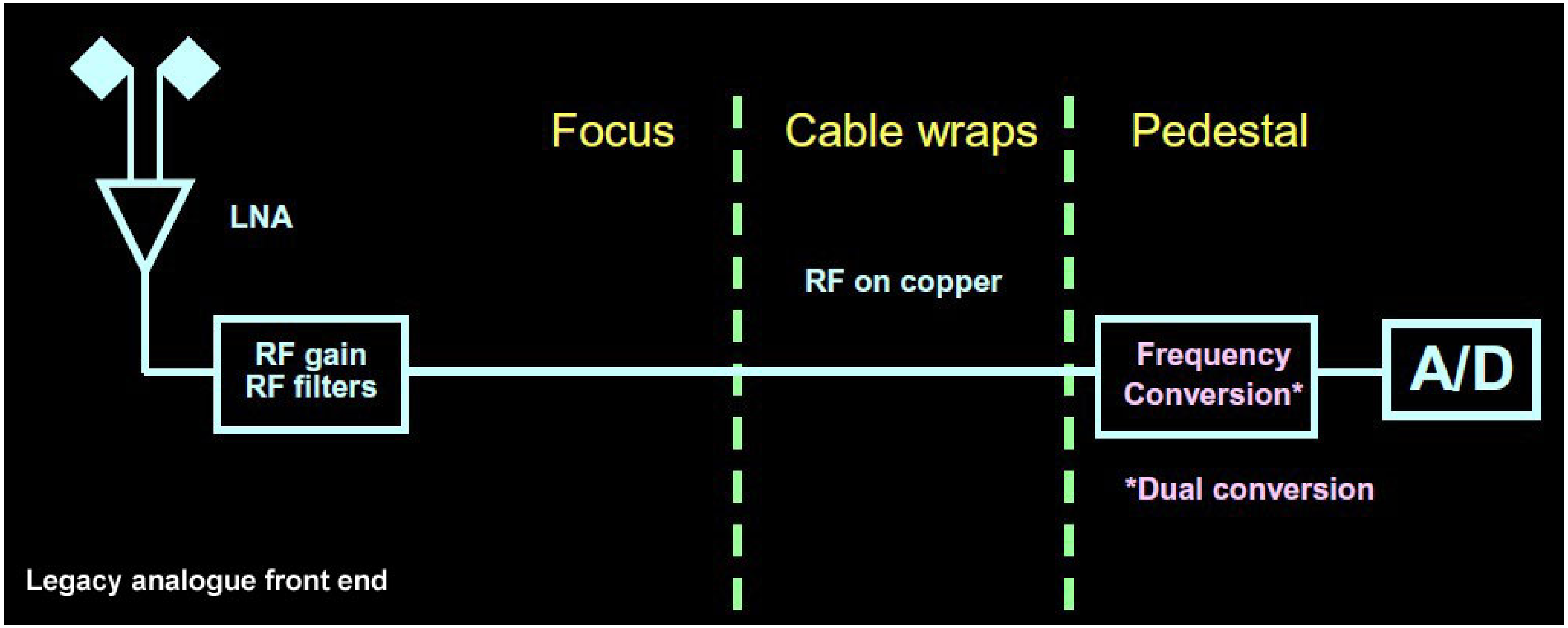
- The legacy analogue front end used in earlier instruments. The LNA is in the focus box, and the amplified signal is fed to the down-converter in the pedestal via a waveguide or coax run.



Front-end evolution:
digital signal transfer

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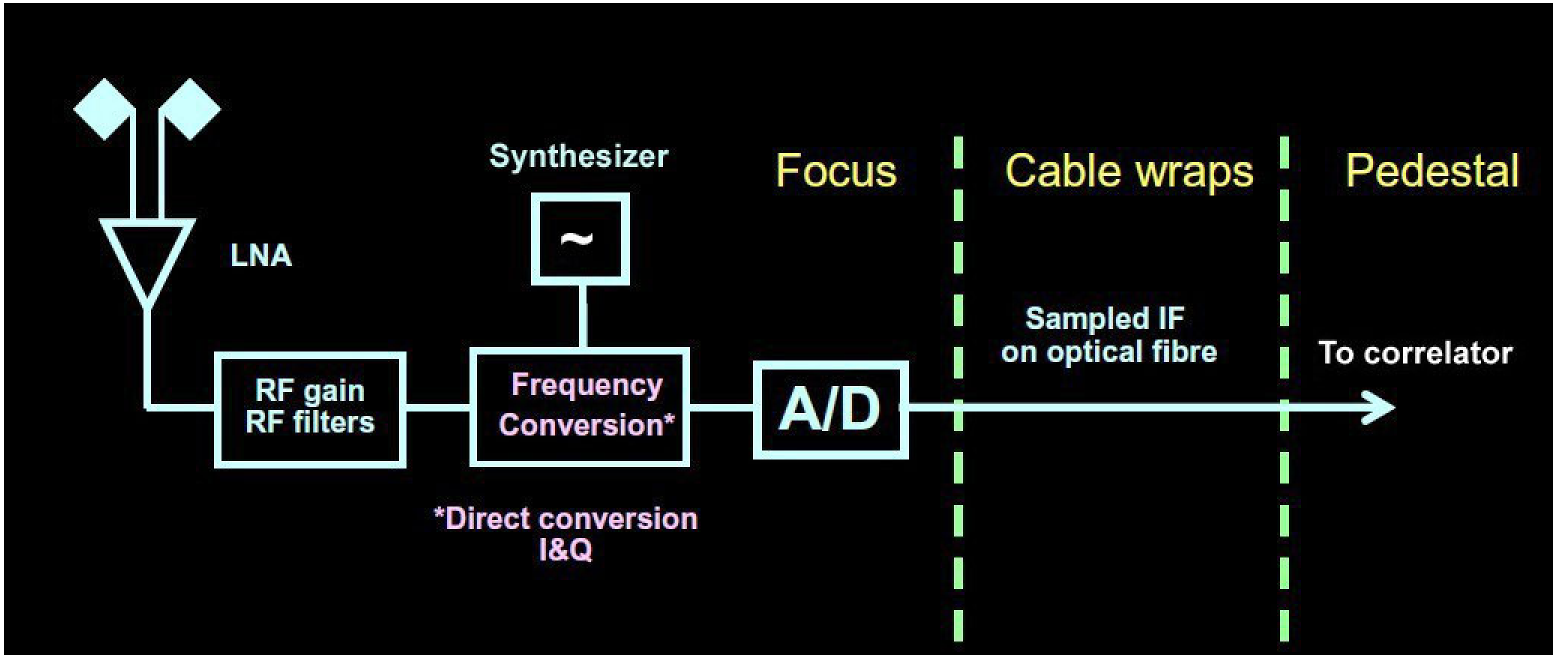
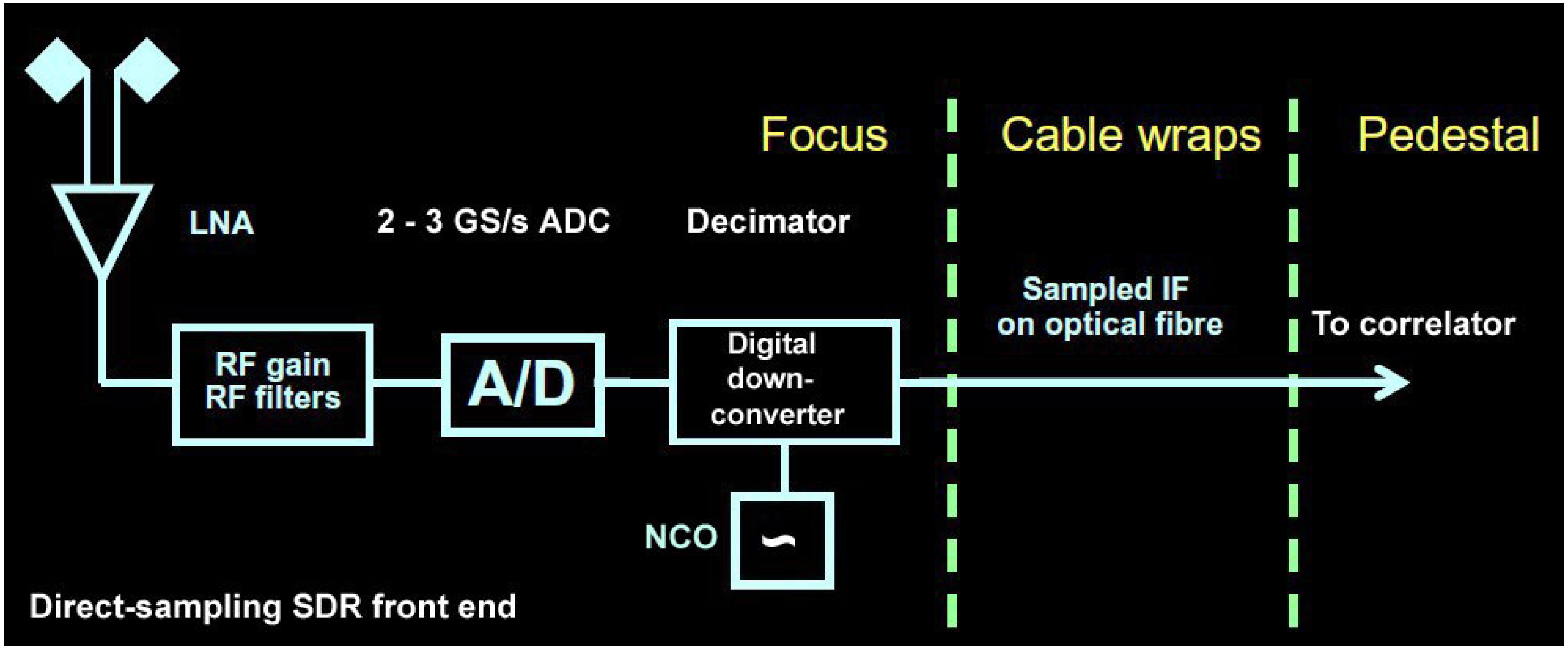
- **In the next evolutionary stage, the down-converter, synthesizer and ADC are collocated and located in the focus box. The digitized signal is fed to the correlator in the pedestal via an optical-fibre link.**



Front-end evolution: SDR!

- **Here, the analogue mixer and synthesizer (local oscillator) have been eliminated, and the ADC samples the amplified signal at RF. The ultimate goal is to integrate the entire front end onto a single IC, placed right behind the antenna. Room-temperature low-noise LNA's facilitate this.**



“Legacy” ADC unit

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- **This box contains 2 ADC’s (in small shield cans) and their associated digital electronics.**

Low Noise Amplifier (LNA)

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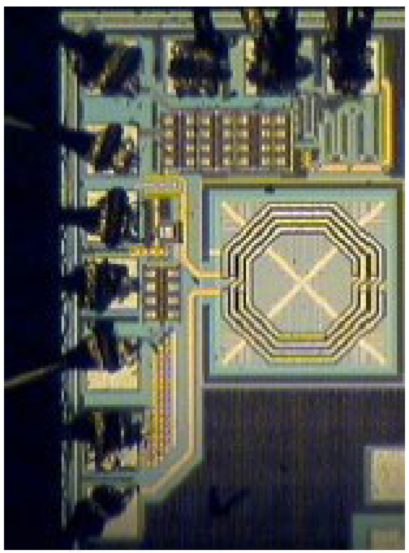
- **Earlier LNA's (e.g. at Jodrell Bank) are helium-cooled HEMT amplifiers.**
  - **Noise temperature T = 15°K (NF = 0.22 dB).**

- **DRAO is collaborating with University of Calgary & industrial partners to develop room-temperature CMOS LNA's.**
  - **Noise temperature = 14°K (NF = 0.2 dB).**
  - **Eliminates costly, unreliable helium cooling system.**
  - **Much lower power consumption.**
  - **Can be integrated with ADC, DDC and NCO on a single CMOS IC.**
  - **In 1 – 2 GHz range, RF filters can also be integrated onto IC.**
  - **Much shorter RF lead lengths; can be mounted right behind antenna.**

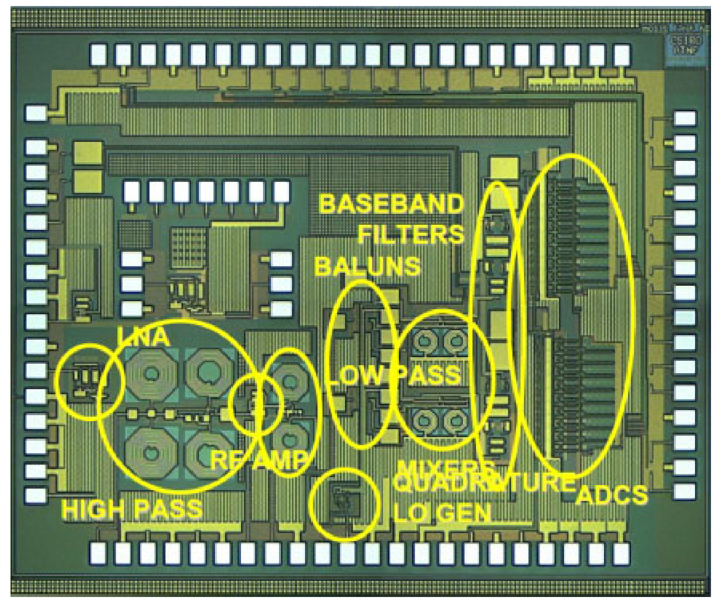
Integrated front-end packages

- **Examples of integrated RF front ends.**

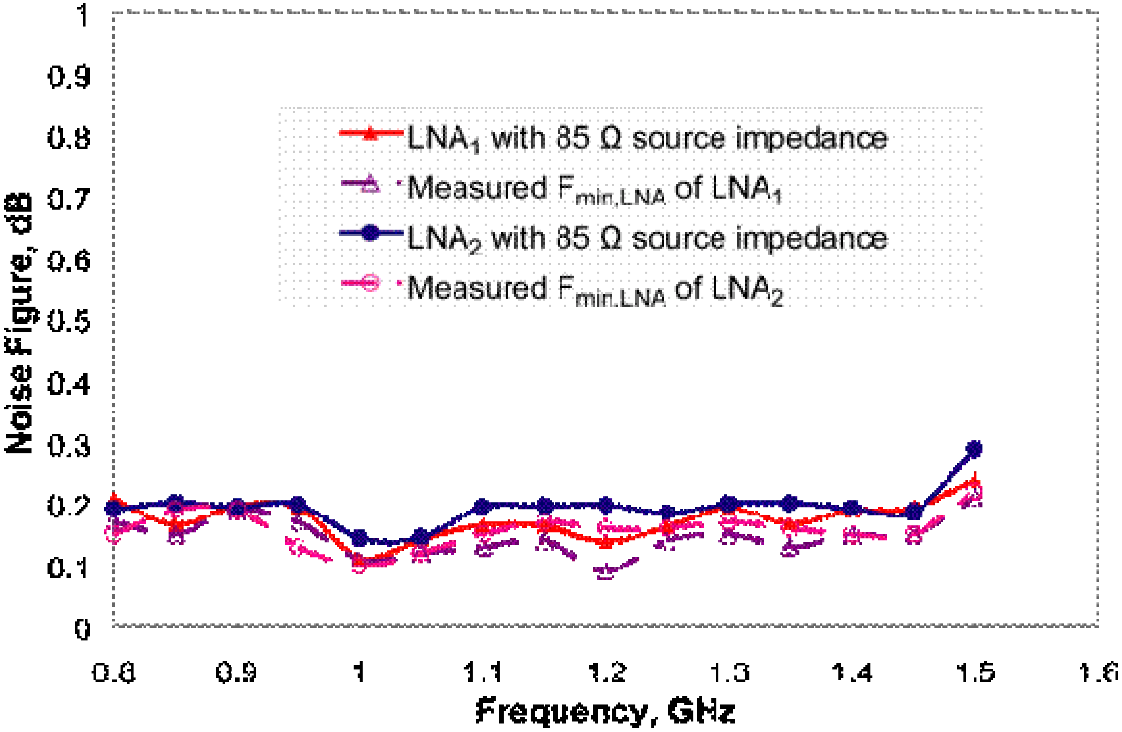
University of Calgary
9 nm 14°K LNA chip



CSIRO (Australia, 2008) prototype integrated
300 MHz – 1.7 GHz receiver chip, 3.5 X 2.75 mm



Typical 1.4 GHz LNA noise figure vs. frequency



Technology development at DRAO: Antenna design

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- **DRAO has designed and built low-cost, high performance radio antennas using the latest composite materials and techniques.**
- **This work enabled the DRAO team to win the 2008 JEC Composites Asia International Award for Innovative Applications in Aerospace Composites, which has attracted widespread interest from the composites industry.**
- **Such antennas are essential to the success of new projects requiring many (up to 1000) small-diameter radio-telescopes to make rapid images of the entire sky.**
- **These telescopes will be able to detect and image some of the weakest extended radio emissions from the universe, significantly advancing our understanding of the Universe and the origins of solar systems such as our own.**
- **This large-number, small-diameter telescope concept also originated at DRAO in the 1980s, and is now central to the design of new radio telescope facilities in the US, Australia, and South Africa.**
- **The concept is being advanced for the Square Kilometre Array (SKA), a global project that aims to build the world's largest radio-telescope.**
- **We will see some of the RF hardware being developed for the SKA in the slides to follow, most notably the PHAD (Phased Array Demonstrator).**

Antenna lab overview

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- **This is an overall view of the antenna design/assembly lab.**

PHAD
(Phased Array Demonstrator)

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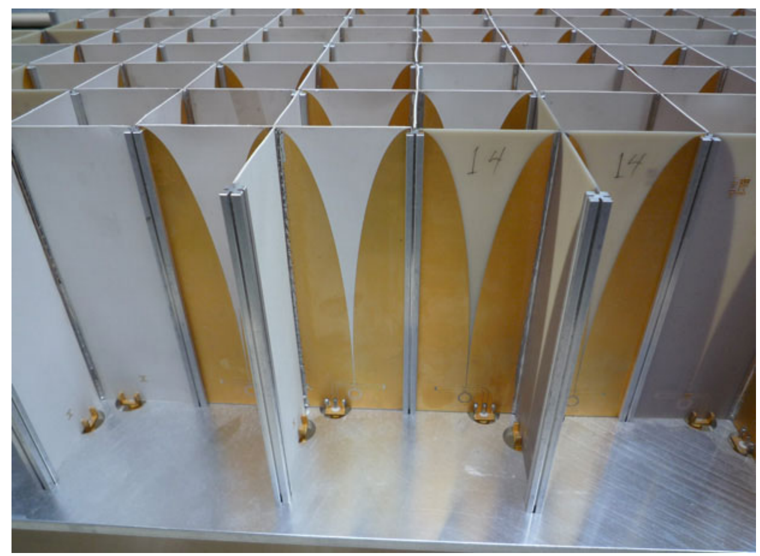
- **PHAD is a 1 – 2 GHz demonstration system using a matrix of 180 Vivaldi horn antenna elements fabricated from microwave PCB stock. Each element feeds an integrated receiver immediately behind it.**
- **The digitized outputs from the receivers are multiplexed and fed to a recording system for off-line processing. Although not yet sufficiently sensitive or broadband for astronomical observations, PHAD is serving well as a proof-of-concept.**

Single element (20mm long, 7.6mm spacing)

Matrix detail



Complete PHAD unit

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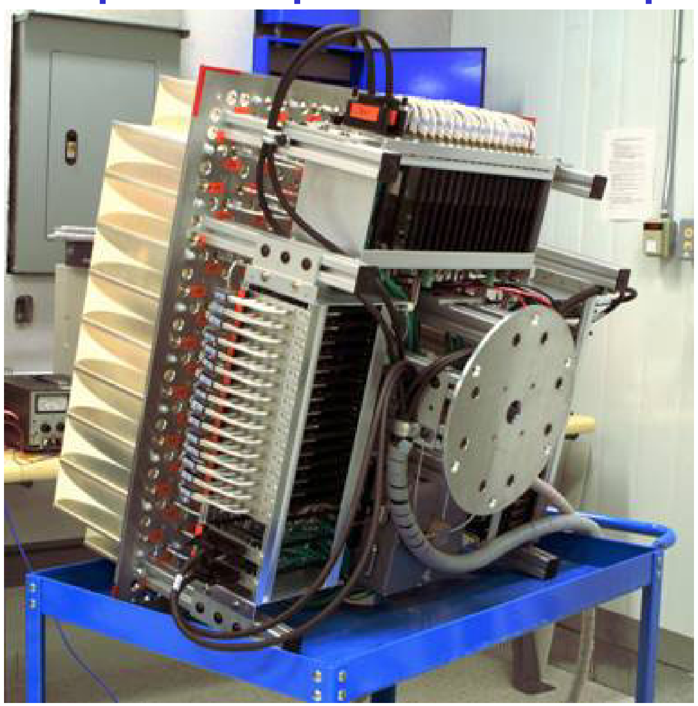
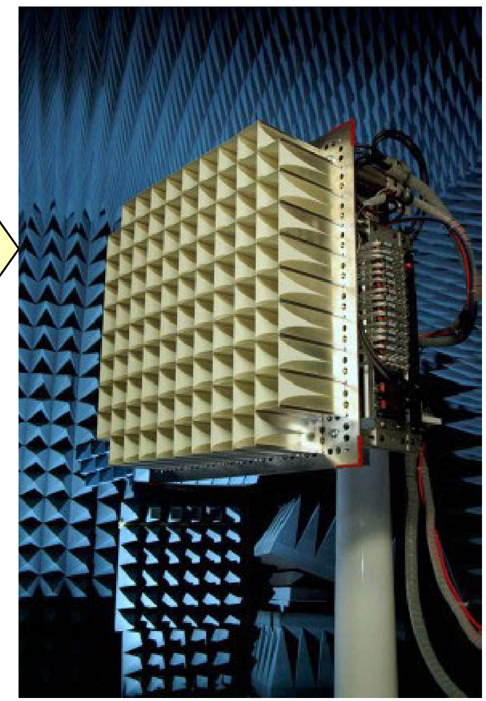
- **Complete PHAD. The 180 receivers are behind the antenna elements. Beam-forming (beam steering) will be performed digitally by manipulating amplitude & phase relationships of the signals in the correlator.**



PHAD in the anechoic chamber



Technology development at DRAO: DSP

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- **Early DSP for Synthesis Telescope was first application. DSP group now does cutting-edge R&D for observatories around the world.**
- **The DSP subsystem of a radio-telescope is termed a correlator. It consists of ultra-high-speed processors, FPGA's etc. Projects include:**
  - **Space-VLBI Correlator, used in VLBI Space Observatory run by the Japanese Institute for Space and Aeronautical Science, and combining data from terrestrial radio-telescopes and the HALCA orbiting satellite radio-telescope.**
  - **ACSIS (Autocorrelation Spectrometer and Imaging System) correlator for the James Clerk Maxwell Telescope (JCMT) in Hawaii. This instrument features a unique, real-time data-processing system.**
  - **Wideband Digital Architecture (WIDAR) design, used in the correlator system designed and assembled at DRAO for the Expanded Very Large Array (EVLA) in New Mexico, USA. This system is as fast as the today's best supercomputers!**
  - **a very fast real-time computer system for the adaptive optics systems of the Thirty Metre Telescope (TMT), a 30m diameter optical telescope being developed by a US-led consortium that includes Canada.**

A look at the correlator lab

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- **Subsystem test area, with card frame in foreground.**

X-ray machine & re-work station *for multi-layer boards*

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Correlator card frame

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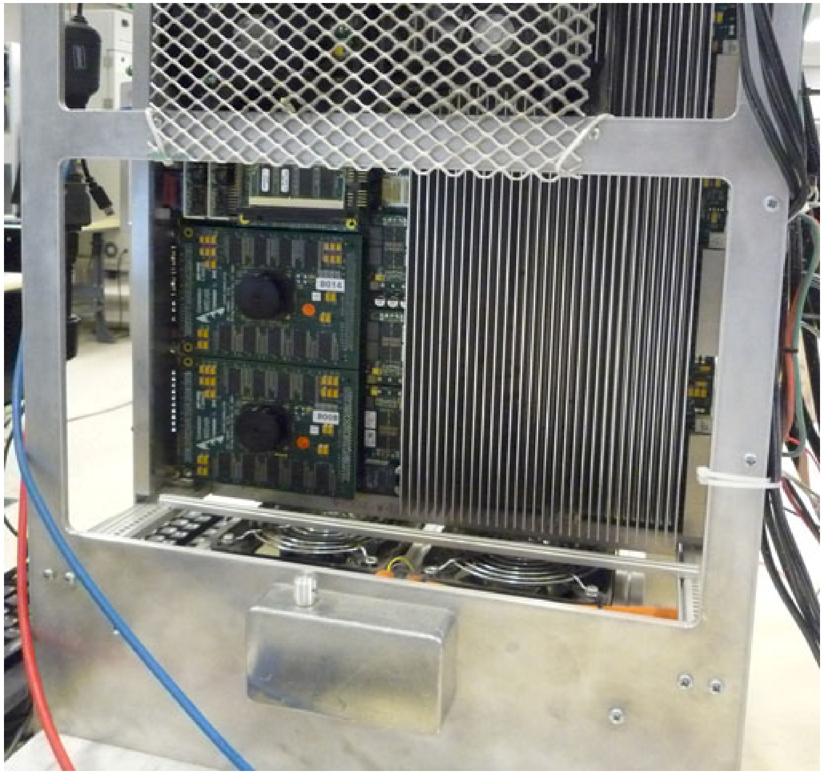
- **Note large heatsink on component side of board.**



Typical correlator boards

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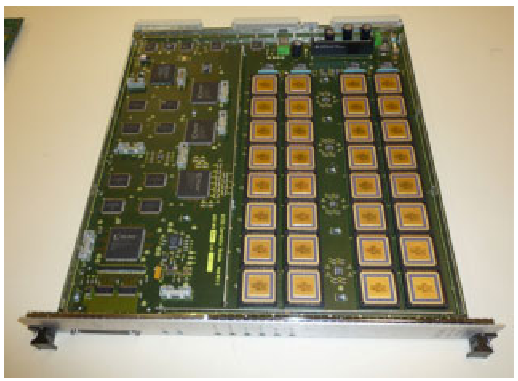
- **Some boards are 16 x 19”, up to 28 layers, with up to 200 ball-grid IC’s (up to 1000 solder points each!)**



The X-ray machine is used to inspect the solder connections under the IC’s.

EMC testing, and engineers at work

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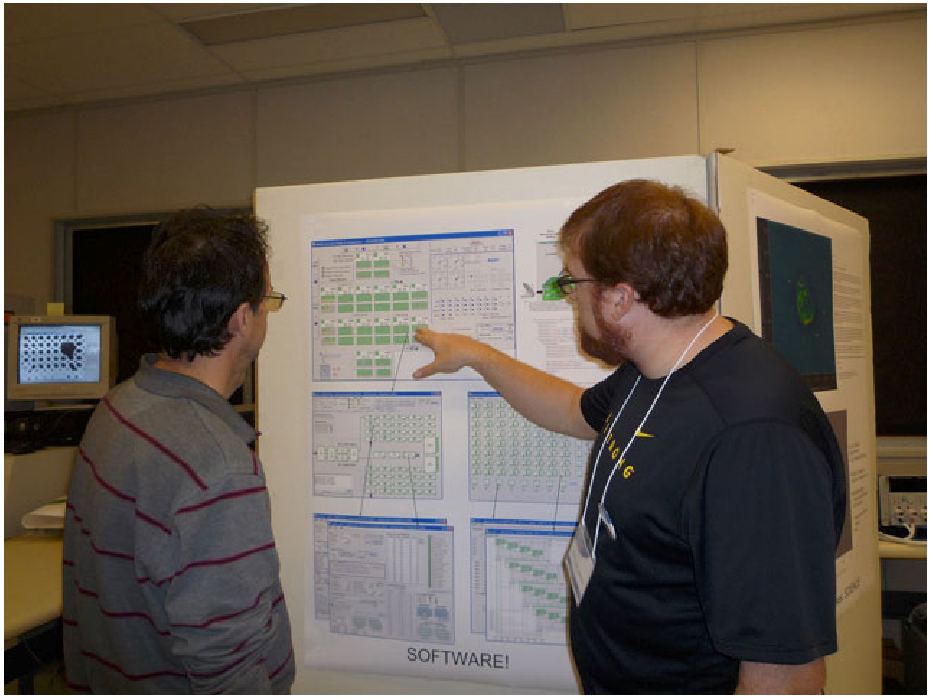
EMC test chamber

DRAO engineer explaining details to VE7WRS



EVLA correlator in equipment room

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- **Part of the working EVLA correlator in its enclosures.**

The digitized signals from the telescopes' receivers are fed to the correlator for downstream processing.

The correlator also executes beam-forming tasks in the digital domain.

Getting results:
typical radio image

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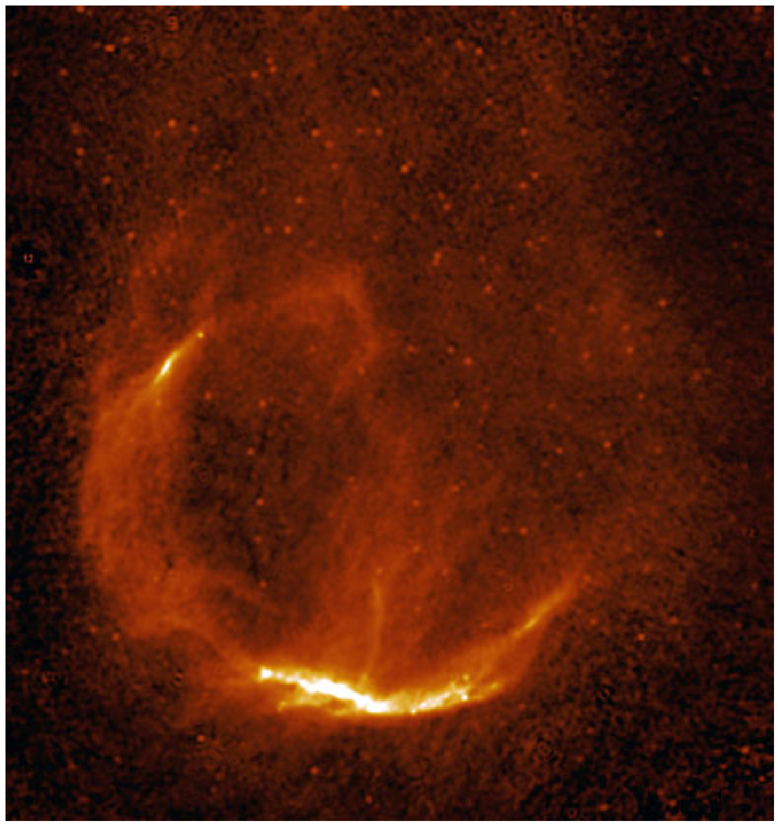
- **CTA 1 supernova remnants, 1420 MHz radio emissions (2008, Pineault, DRAO)**



Getting results:
Milky Way radio map

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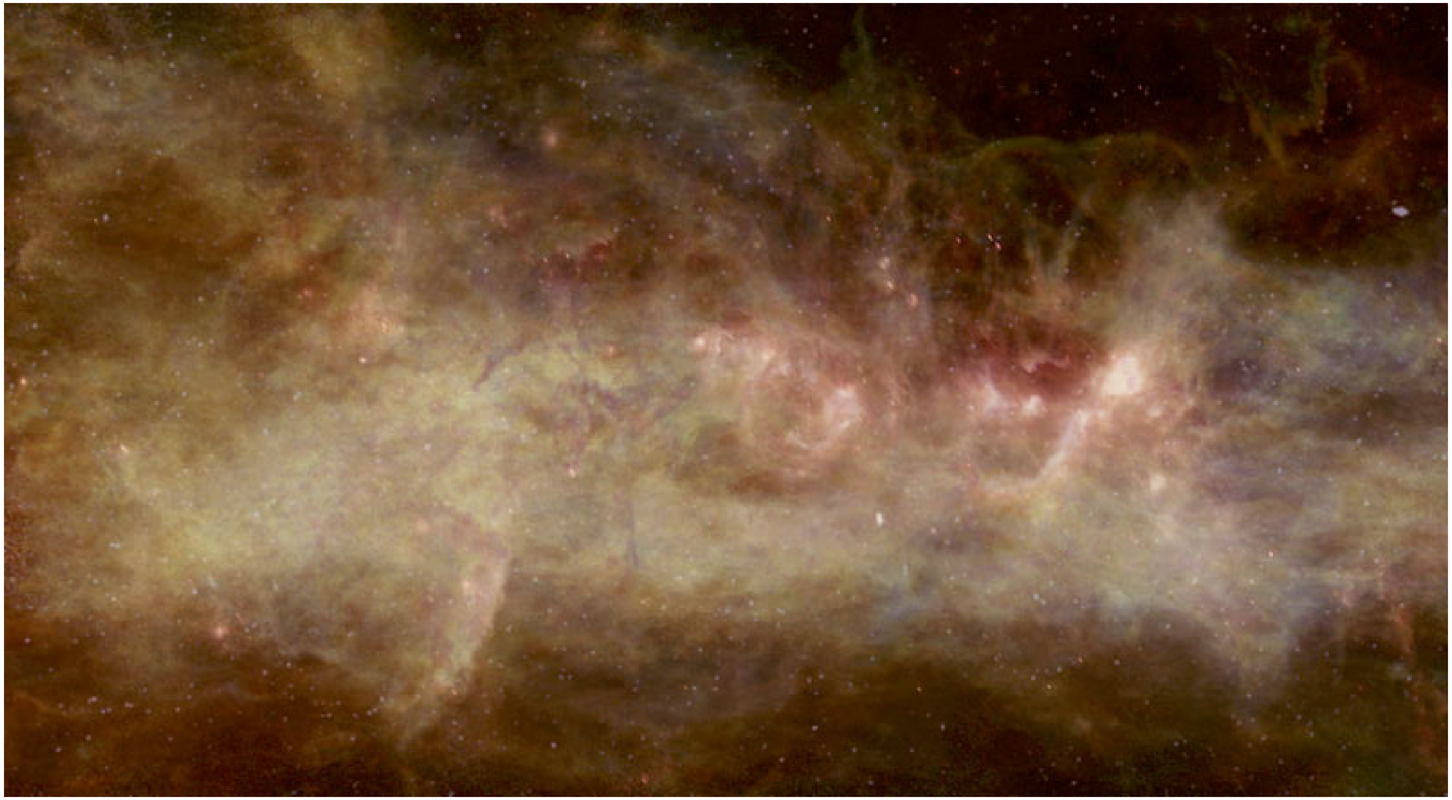
Mid-plane of the [Milky Way](), near the constellation Perseus. (Credit: J. English, U. of Manitoba)



And on a lighter note….

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- **After our tour of the DRAO facility, we took a pleasant, leisurely tour of Okanagan Valley wine country. We stopped at several wineries, including Red Rooster and Kettle Valley, and took in the gorgeous late-summer weather and the beautiful landscape.**

A bottle in the hand…

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- **…is worth two in the bush!** ***(We were stopped at a couple of checkpoints thoughtfully provided by the local gendarmerie as a service to wine-tasters, but we did OK.)***

Links for further study

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- [Highlights of DRAO]
- [Visiting DRAO]
- [NRC Solar Radio Monitoring Programme]
- http://www.ieee.ca/millennium/drao/DRAO_more.html
- http://www.casca.ca/ecass/issues/2007-ws/features/ska/ska.htm
- http://en.wikipedia.org/wiki/Dominion_Radio_Astrophysical_Observatory
- http://vengshoel.com/wordpress/?p=454
- [Riometer Stations]
- [EVLA Correlator]
- [Square Kilometre Array (SKA) South Africa]