History
of
Canadian Radio Astronomy

TIM ROBISHAW
DRAO
20+ Hours of Interviews with 20 Early Canadian Radio Astronomers
Preparing book on CAN Radio Astro.
A Workshop on the History of Canadian Radio Astronomy

July 25-26, 2016

http://astroherzberg.org/radiohistory2016/
Jasper’s Canadian Radio Astronomy History

- Grew up in the Ottawa valley.
  - Household mantra: “This works so well we must take it apart to see why.”
- 1963: Graduated Queen’s University Engineering
  - 2 summers working at National Research Council in Ottawa
- 1965: MSc U Toronto Electrical Engineering
  - Don MacRae & Allan Yen

- 1965: Moved to Australia
  - PhD work at ANU
  - Supervised by John Bolton
  - 18+ months at Parkes
  - July 1969 Apollo 11 Landing
Karl Jansky
Bell Telephone Labs
Holmdel, New Jersey
7:10PM Sep 16, 1932
NEW RADIO WAVES TRACED TO CENTRE OF THE MILKY WAY

Mysterious Static, Reported by K. G. Jansky, Held to Differ From Cosmic Ray.

DIRECTION IS UNCHANING

Recorded and Tested for More Than Year to identify it as From Earth's Galaxy.

ITS INTENSITY IS LOW

Only Callulate Receiver Is Able to Register—No Evidence of Interstellar Signaling.

Discovery of mysterious radio waves which appear to come from the centre of the Milky Way galaxy was announced yesterday by the Bell Telephone Laboratories. The discovery was made during research studies on statics by Karl G. Jansky of the radio research department at Holmdel, N. J., and was described by him in a paper delivered before the International Conference on Radio Science in Washin.

Dr. Stilger concluded, at some distance above the earth's surface, and possibly produced by the earth's atmosphere.

The galactic radio waves, the announcement says, are short waves, 34-6 meters, at a frequency of about 20,000,000 cycles a second. The intensity of these waves is very low, so that a delicate apparatus is required for their detection.

Unlike most forms of radio disturbances, the report says, these newly found waves do not appear to be due to any terrestrial phenomena, but rather to come from some point far off in space—probably far beyond our solar system.

If these waves came from a terrestrial origin, it was reasoned, then they should have the same intensity all the year around. But their intensity varies regularly with the time of day and with the seasons, and they get much weaker when the earth, moving in its orbit, intercepts itself between the radio receiver and the source.

A preliminary report, published in the Proceedings of the Institute of Radio Engineers last December, described studies which showed the presence of three separate groups of static: Static from local thunderstorms, static from distant thunderstorms, and a "steady blue type static of unknown origin." Further studies this year determine the unknown origin of this third type to be from the direction of the centre of the Milky Way, the earth's own home galaxy.

Direction of Arrival Fixed.

The direction from which these waves arrive, the announcement asserts, has been determined by investigations carried out over a considerable period. Measurements of the horizontal component of the waves were taken on several days at intervals over a considerable period. Measurements of the horizontal component of the waves were taken on several days at intervals over a considerable period.
Canada’s First Radio Telescope (48”)

First observation of the Sun: 26 July 1946
Arthur Edwin Covington (1913-2001)
Solar Eclipse: 23 November 1946

1.5 million K sunspot
Goth Hill Observatory in Ottawa
SOLAR RADIOMETER FOR OPERATION IN THE 10-16 CM BAND
Calibration Horn Antenna

At Goth Hill...

…still in use at DRAO!
Norm Broten and the 10ft Dish
...operated until 1970.
Gladys A. Harvey

• The First Canadian Woman in Radio Astronomy
• Worked at NRC Radio and Elec. Eng. Division.
• Started at Goth Hill in 1948.

Interview with Gladys Harvey
August 10, 1991

M: I'm speaking today with Gladys Harvey north of Victoria who worked at the National Research Council for some years with the solar radio programme. Could we begin, first, just tell me something about your origins and your educational background?

August 1957
22 June 1949: The AAS meets in Ottawa. Grote Reber visits the 10.7-cm radiometer at Goth Hill.

Photo Credit: Grote Reber
10.7-cm Solar Flux Monitoring Program

- Moved to ARO and DRAO in early 1960s.
- Continues today at DRAO…

[Image: Solar Flux Units graph from 1945 to 2010, showing peaks and troughs.

[Images: ARO and DRAO telescopes with text overlay: Ken Tapping]
The 21-cm Line

1945:
Henk van de Hulst predicts atomic hydrogen in space should emit radio waves at 1420.4058 MHz, or 21 cm.
“Early visitors to the Radio Field Station and to Goth Hill whom I can recall… were”----- Appleton, Hey, Ratcliffe, Bolton, Friis, Pawsey and van de Hulst. “I was introduced to Pawsey during one of his early visits to the RFS by W.J. Henderson; they attended Cambridge at the same time…” When Pawsey saw the 10-30 cm horn in 1948 (for absolute flux determination), “he told me about the 21 cm hydrogen line prediction and wondered whether I could make … any observations for its confirmation. As it stood, the instrumentation was hardly suitable. This was the first time that I had heard of the prediction and is one occasion when I realized the magnitude of the difficulties of switching from one promising area to another. I readily gave a negative reply and realized that I would be continuing solar noise work…”

Arthur Covington in Woody Sullivan’s, *The Early Years of Radio Astronomy*
Joe Pawsey: Founder of Australian Radio Astronomy

- Married Canadian Lenore Nicoll in 1935.
- Three visits to NRC in Ottawa:
  - 1941
  - 1947, meets Arthur Covington…
    - “At Ottawa, Covington is a young and inexperienced man working in relative isolation. He has got some thoroughly useful results by good honest work and perseverance.”
  - 1957, met with Don McKinley, Peter Millman, C.S. Beals, Norm Broten, and talked with Jack Locke about plans for DRAO.

200 MHz sea-cliff interferometer at Dover Heights, Sydney
Peter M. Millman (1906-1990) & Donald R. W. McKinley (1912-1984)
ground reflector mats for radar antennas

Delta Aquarid 1948
July 29
No interstellar meteors

McKinley (1951)
John Bolton (CSIRO) Gives Colloquia at NRC in 1950-51

Befriended Covington.

Notes from Vic Gaizauskas
1956: Jack Locke arranges a 6-part colloquium series at Dominion Observatory in Ottawa on radio astronomy.

Dominion Astronomer C.S. Beals sees John Bolton speak about radio astronomy at March 1956 AAS Meeting in Columbus, OH
1956: Jack Locke arranges a 6-part colloquium series at Dominion Observatory in Ottawa on radio astronomy.

Beals invites Bolton (now at Caltech) to Ottawa again to give a colloquium on radio astronomy.
62 Years Ago

“In the summer of 1956, when Helen Hogg came through Ottawa, a meeting was called with McKinley, Beals, Harrison (in place of Parsons), and myself to discuss the future of Canadian radio astronomy.”

Arthur Covington
1990 Interview with Richard Jarrell
The 21-cm Line

1945: Henk van de Hulst predicts atomic hydrogen in space should emit radio waves at 1420.4058 MHz, or 21 cm.

Six years pass with no discovery.
The 21-cm Line

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Henk van de Hulst predicts atomic hydrogen in space should emit radio waves at 1420.4058 MHz, or 21 cm.

Six years pass with no discovery.

March 25, 1951:
Harold “Doc” Ewen & Edward Purcell
(1952 Nobel Prize for NMR)
…measure the 21-cm line using a horn antenna sticking out of window of Lyman Hall at Harvard.
April 28, 1956
Harvard, Massachusetts

Somewhere in the nearly empty reaches of outer space, two hydrogen atoms collide. After a 100-million year journey at the speed of light, the signal generated by that accidental collision reaches a super-sensitive radio telescope antenna in Massachusetts and is recorded—and so one grain more is added to man’s knowledge of the universe.

Modern miracles like this happen every day at Harvard University’s Agassiz Station Observatory, where a giant new radio telescope, with its 60’ Kennedy antenna, is taking man further back in time...and further out into space...than he has ever been before.

The major reason for two recent trips made by myself to scientific meetings or institutions (American Astronomical Society, March 22-24 - Inauguration Ceremonies, Harvard 60 ft. radio telescope, April 28, 1956) has been to gain information on radio astronomy and its possible future use by our Branch.

Radio astronomy as an active branch of science has arisen from the discovery that, in addition to visual and photographic light, the sun, the stars, the planets, the gas clouds of the galaxy and the external galaxies all emit radiation of the order of centimeters or meters in wavelength. This relatively long wavelength radiation is electromagnetic radiation similar in its fundamental aspects to ordinary light and with suitable receiving equipment may be used to gain astronomical information about the positions, motions and physical characteristics of the heavenly bodies.

At the meeting of the American Astronomical Society at Columbus, Ohio, March 22-24, the most important single subject was radio astronomy. Numerous papers dealing with present operations and the progress in radio astronomy and a symposium was held dealing with instrumental problems and the interpretation of radio observations of both near and distant astronomical bodies.

The official opening of the new Harvard 60 ft. radio telescope on April 28 offered similar opportunities for studying the present position. A day of meetings was held and there were numerous opportunities for personal discussions with successful research workers in this field. In addition to these two meetings a series of six colloquia organized by Dr. J.J. Lockhead devoted to the subject of radio Astronomy has been held at the Dominion Observatory and attended by most of the scientists of the Ottawa area interested in this subject.

Without attempting to review the entire field it would appear for the type of astronomical studies occupying our major interest at Victoria, and to some extent at Ottawa namely galactic studies, that the introduction of radio techniques is very closely analogous to the revolution introduced into the practice of medicine by the use of X rays. Ordinary photographic and visual light is absorbed by the dust particles pervading the galaxy to such an extent that only a volume of space approximately 2,000 parsecs in diameter can be effectively examined. Making use of the long wavelength radiation (21 cm) produced by clouds of neutral hydrogen and presumably other atoms and molecules it is possible to penetrate to a distance 10 times as great.

While this does not make conventional astronomy obsolete any more than the introduction of X rays upset the direct use of the human eye, nevertheless it does place at a great disadvantage any major astronomical organization which does not have these techniques available.

C.S. Beals
Dominion Astronomer
Where Should DRAO Be Built?

In March of 1957 Ed Argyle and I set out from Ottawa in a Travelall, with some field intensity measuring equipment which we had gathered together, to test a number of preselected sites in British Columbia. We went by way of Greenbank and Owens Valley, the purpose being to use the measured interference levels at these sites as a basis of comparison. We first visited White Lake in early June and found it to be the best of all the sites we had visited, both in terms of interference and in convenience. At the end of June we were joined by Nick Patterson and George Aitken from NRC who made additional interference measurements and propagation tests in the 950 to 4000 MHz range. (Our own measurements were restricted to the 55 to 950 MHz range.) The NRC results confirmed the excellence of the site and a final decision to locate at White Lake was made following Dr. Beals's visit to the site in mid-July.

Jack Locke, 1st Officer in Charge
Green Bank, West Virginia, is the original site of the U.S. National Radio Astronomy Observatory, located in the 34,000 sq. km National Radio Quiet Zone.
March 1957 Site Testing
Locke and Argyle, during April and May, measured radio noise intensities in the 50 to 1000 mc/s band at two of the American sites: Greenbank, W.V., and Big Pine, Cal., so that comparison might be made between Canadian and American sites. Following this, they made preliminary measurements at several sites in British Columbia. During July and August, the combined NRC/Observatory group completed measurements at three of the most promising British Columbia sites and on the basis of these measurements, chose a site near Penticton as being the most suitable for the Dominion Observatory telescope. Subsequent to the loca-
PROBLEM: The Dominion Observatory doesn’t have a radio astronomer to become director of DRAO!

SOLUTION: Make one!
John Galt

1944-1945
Royal Canadian Navy Volunteer Reserve
Signal Corps Training as Radio Artificer
(War ended, never sent abroad.)
1945-1949: University of Toronto (Physics)
Summer 1948: Night assistant at David Dunlap Observatory
A photographic record of the year I spent in the Arctic operating the Dominion Observatory's Magnetic Station at Resolute Bay on Cornwallis Island.

John Galt.

1949-1950

Midnight sun near end of summer.
1950-1956
University of Toronto
PhD Physics

Summer 1952
Summer student at Dominion Astrophysical Observatory
Built photometer for Plaskett telescope with Ed Argyle

Summer 1954
Summer student at Dominion Astrophysical Observatory
June 29th solar eclipse expedition to Hansen, ONT “clouded out”
1956-1957

- Worked at Dupont for a year.
- Missed research and didn’t like the company.
- Applied to Leiden, Cambridge, and Jodrell Bank as a post-doctorate fellow.
- Lovell said, yes, you can come to Jodrell... but we’re not sure about the money.
- Applied for Dominion Observatory radio astronomer position, was interviewed by Beals and Locke.
- Was offered the position, but observatory wasn’t ready, so Dominion paid for John’s "postdoc" at Jodrell Bank where he was to learn the ropes of radio astronomy before returning to Canada to be the first director of DRAO.
1958: Jodrell Bank 250-ft Telescope
ON THE POSSIBILITY OF MEASURING INTERSTELLAR MAGNETIC FIELDS BY 21-CM ZEEMAN SPLITTING

Measurement of the small magnetic field believed to exist in interstellar space has so far eluded both optical and radio techniques. However, the introduction of large radio reflectors offers the possibility of determining longitudinal fields in localized interstellar regions by observing the Zeeman splitting of the 21-cm line of neutral hydrogen.

In the presence of a weak magnetic field, the 21-cm line is split into three components, of frequency \( \nu_0 \pm \frac{eH}{4\pi \mu_0 c} \), \( \nu_0 + \frac{eH}{4\pi \mu_0 c} \), \( \nu_0 - \frac{eH}{4\pi \mu_0 c} \), where \( \nu_0 \) is the undispersed frequency of the line and \( H \) the longitudinal component of the magnetic field. Numerically, the frequency difference, \( \Delta \nu \), between the two \( \sigma \) components is 2.8 Mc/s per gauss. Thus a magnetic field of \( 10^{-4} \) gauss, such as is believed to exist in the Galaxy, gives \( \Delta \nu = 30 \) c/s.

Under normal circumstances the detection of such small shifts in the galactic emission profiles would hardly be possible, owing to their large Doppler broadening. On the other hand, relatively narrow profiles have been observed in absorption. Hagen, Lilley, and McClain (1955) have reported three narrow absorption lines in the 21-cm spectrum of the discrete source in Cassiopeia, presumably due to three individual \( \text{H} \alpha \) concentrations with different radial velocities. These lines have half-widths of about 10 kcc/s, in the center of which the radiation is almost completely absorbed. It may reasonably be assumed that the magnetic field is sensibly constant in direction over any one of the \( \text{H} \alpha \) concentrations responsible for the absorption lines.

The detection of a Zeeman shift less than 1 per cent of the line width could be accomplished by using the radio analogue of the optical method currently employed by Babcock (1953) for measuring weak solar fields. The frequency of a narrow-band receiver is set on the edge of the line near the point of maximum steepness, and the polarization of the antenna is switched to receive the two circular components alternately. The output at the switching frequency is given, in units of antenna temperature, by

\[
\Delta T = \frac{T_a \Delta \nu}{\mu},
\]

where \( T_a \) is the maximum decrease in antenna temperature of the absorption line, \( \Delta \nu = 2.8 \times 10^9 H \) c/s is the difference in frequencies between the two \( \sigma \) components, and \( \mu \) is the half-width of the absorption line, assumed of gaussian profile. Current results indicate values of \( T_a \) of the order of 1000° K if the Cassiopeia absorption lines are observed with a 150-foot reflector. Hence, with \( \mu = 10 \) kcc/s, we should expect \( \Delta T = 3 \times 10^9 \) degrees. Current techniques permit the detection of \( \Delta T = 1'' \) K (\( H = 3 \times 10^{-4} \) gauss), and instrumental improvements on this figure are likely in the future.

1420.4058 MHz
1.4 Hz/\( \mu \)G
The First 21-cm Zeeman Receiver
Built by John Galt
AN ATTEMPT TO DETECT THE GALACTIC MAGNETIC FIELD USING ZEEMAN SPLITTING OF THE HYDROGEN LINE

J. A. Galt,* C. H. Slater and W. L. H. Shuter

(Received 1959 July 1)

Summary

An attempt has been made to determine the strength of the galactic magnetic field by observing the inverse Zeeman effect on the 21 cm absorption line of neutral hydrogen. Preliminary measurements using the Cassiopeia A radio source have shown no detectable Zeeman effect. This indicates that the magnetic field component in the line of sight is less than $5 \times 10^{-6}$ oersted at the point in the Orion spiral arm where the absorption occurs.

1. Introduction.—A general magnetic field can be postulated to explain interstellar polarization of starlight, the cosmic ray spectrum, and the stability of the spiral arm structure of the galaxy. According to Chandrasekhar and Fermi (1), a magnetic field of the order of $7 \times 10^{-6}$ oersted may be expected although Davis and Greenstein (2) suggest fields up to $10^{-4}$ oersted.

Bolton and Wild (3) have suggested that the galactic magnetic field may be measured by observing the inverse Zeeman effect in the hyperfine structure of the 21 cm absorption spectrum of strong radio sources, using the radio analogue of Babcock's (4) method of measuring weak solar magnetic fields. The present paper reports an attempt to make this measurement.

* Now at the Dominion Radio Astrophysical Observatory, Penticton, British Columbia, Canada.
8. Conclusions.—No significant Zeeman effect has been detected and it is probable that the longitudinal component of the magnetic field in the clouds of neutral hydrogen which produce absorption is less than $5 \times 10^{-5}$ oersted. It should be noted that the line of sight in the direction of Cassiopeia A is inclined at an angle of about $45^\circ$ to the Orion spiral arm so that, if the general magnetic field is aligned with the arm, then the corresponding upper limit to the field must be raised by a factor of $\sqrt{2}$ over that quoted.

9. Acknowledgments.—The authors wish to thank Professor A. C. B. Lovell.
February 1959: 26-m Arrives
RADIO TELESCOPE TRUCKED TO SITE

First truckloads of the 200-ton White Lake radio telescope are being moved from Okanagan Falls to the site three miles away. Here a huge casting and three spars move out, escorted by an RCMP patrol car. The 25 carloads must be moved now, while roads are hard enough to support heavy loads. Assembly will commence in May. (Herald Staff Photo)
February 1959: 26-m Arrives
OFFICIAL OPENING

MONDAY 20 JUNE 1960
AT 4:00 P.M.

PENTICTON B.C.
BACK ROW
Dr. T.R. Hartz, Dr. J.I. Yen, W.M. Thomson, Dr. C. Olgers, W.J. Medd, Dr. J.A. Salt, F. Park,
W. Broten, J. Grant, R.W. Tanner, Dr. F.C. Wright.

THIRD ROW
H. Prousse, A.R. Hamilton, Dr. D.S. Boeschen, Dr. J.H. Reck, D.R. Hansen, Dr. D.W. McKinley,
Dr. D.C. Ross, R. Creesebeck, Dr. J.T. Warren, Dr. R.W. Chisholm.

SECOND ROW
Miss M. Burland, Dr. C.W. Costain, Dr. E.W. Currie, P.E. Argyle, Miss E. Northcott, Dr. H.P. Cuff,
Dr. V. Wolfson, Dr. R. Cole, Dr. R.E. Hogg, Dr. J.C. Noyes, Miss J. Stilwell, W.H. Stilwell.

FRONT ROW
Dr. P.M. Milman, A.E. Covington, Dr. R.M. Patric, Mrs. Patric, Dr. J.L. Locke, Dr. W. Schmidt,
Dr. H.S. Hogg, Dr. C.S. Beals, Dr. C.A. Harrover, Dr. J.F. Heard, Mrs. Noyes.

ABSENT WHEN PICTURE WAS TAKEN
B.L. White, Dr. H.L. Welsh, J.M. Lansinger, W. Penfield, S.H. Medsger.
A close-up of the paraboloid. I asked Dr. Galt to give me a photograph showing him at work; this was his contribution.
Radio Telescope ‘Ear’ To Take Pulse of Space

By BILL STAVDAL (Herald Staff Reporter)

The turn of the earth dims the stars and sends most astronomers home and makes the Department of Mines and Technical Surveys. Dr. Locke is one of the astronomers who will spend time at the Penticton site.

Radio Telescope Project Taking Shape at White Lake Site

$500,000 Worth of Curiosity Sits in a Dish in the Hills

Paul St. Pierre continues the voyage of reduction around B.C.

$700,000

When the Heavens Declare Their Glory

So the Staff Sweats It Out

Jack,” said one of the men in the main building. “Did you realize your office is over the furnace room? You’ll get a rumble. And it’ll be hot.

“Would cost:

$750,000

Since White Lake Observatory has been established with taxpayers’ money and is the outcome of four years of hard work by federal civil servants, one might ask what practical value these far-distant studies have.

Four thousand years of research have brought explorers general information of only one-fifth of the Milky Way.

But radio-astronomy is expected to spur considerable advance in space research and Canada’s “big ear” — the new 84-foot, $1750,000 radio-telescope at nearby White Lake — will make a major contribution in man’s understanding of the universe.

B.C. Expert Evaluates Astronomy

FOUR THOUSAND YEARS: ONLY ONE-FIFTH OF THE WAY

Thursday, June 23, 1960
The 22.5 MHz Array

1698 Telephone Poles
Carman Costain: 1st Canadian to earn Ph.D. in Radio Astronomy
January 1965
Algonquin Radio Observatory
The Construction of the 150-ft Telescope in the Media

Canada To Build Giant Telescope, Ottawa Citizen, Aug, 30, 1960, p35

NRC Telescope Tender Bid—Decision Soon, Ottawa Citizen, Oct 13, 1962, p38

Ottawa Citizen Newspapers

Canada to Build Giant Telescope, Ottawa Citizen, Aug, 30, 1960, p35

NRC Telescope Tender Bid - Decision Soon, Ottawa Citizen, Oct 13, 1962, p38

$16M CAD 2018
“To the Edge of the Universe” (1969)

TO THE EDGE OF THE UNIVERSE

Director Cameraman  GRANT CRABTREE
Penticton Camera    ROY LUCKOW
Technical Advisors  N. W. BRO TEN
                   DR. G. A. MILLER

Slides from Mount Wilson and Palomar Observatories
Copyright by California Institute of Technology
and Carnegie Institute of Washington
“To the Edge of the Universe”
Construction of Ribs
19 May 1966
ARO 150-ft “First Light”

Observational Highlights from the Algonquin Radio Observatory 1959 - 1986

A Brief History of the Algonquin 150-ft / 46-m Radio Telescope

A RADIO TELESCOPE IS BORN
7:30pm to 12pm; observations on 2 sources. At 12:30, low gain required some “receiving” otherwise successful.

http://www.arocanada.com/ARO/people/John_Kenneth_Ayre.htm
Introduction: ARO 150-ft / 46-m Telescope

- The *Algonquin* telescope began operation in May 1966. It was the largest ever built in Canada.
- It was one of the first large telescopes designed to operate at wavelengths as short as 3-cm (10 GHz).
- It was the largest fully-steerable telescope in North America dedicated to radio astronomy until the 100-m *Green Bank Telescope* (GBT) in 2000.
- Had plans for its *resurfacing* gone forward, it would have become one of the largest capable of observing at 115 GHz (possibility even 230 GHz).
- Alas, in 1986, when the refurbishment project was cancelled, it became the first major national facility ever to face being put into mothballs.
The Early Days of the Canadian Long Baseline Interferometer Experiment

... From NOT an Astronomers Viewpoint

Joseph Fletcher :: "The Canadian Long Baseline Interferometer"
Putting a clock on the train at Chalk River
Joe Fletcher wearing the tie
John Galt and Jack Locke in the DRAO control room
“Fringe Searchers” at work ...

... Norm Broten

>>> Allen Yen

\\ John Galt
May 22, 1967

Leaving Algonquin at 6 a.m. for Ottawa to describe the discovery at the URSI Congress.
American Academy of Arts and Sciences
1971 Rumford Prize

Awarded by the American Academy of Arts and Sciences to
The Canadian Research Team for work in the field of
Long-Baseline Interferometry
Institute of Electrical and Electronics Engineers
2010 Milestone Award

IEE MILESTONE IN ELECTRICAL ENGINEERING AND COMPUTING

First Radio Astronomical Observations Using VLBI, 1967

On the morning of 17 April 1967, radio astronomers used this radiotelescope at DRAO and a second one at the Atacama Radio Observatory located 3074 km away to make the first successful radio astronomical observations using Very Long Baseline Interferometry. Today, VLBI networks span the globe, extend into space, and continue to make significant contributions to both radio astronomy and geodesy.

September 2010

IEEE

• The Pacemaker
• The Integrated Circuit
• Liquid Crystal Display
• The Internet
• The Laser
• The Computer
• The Compact Disc
• The Mercury Spacecraft
RM Sources in the CGPS...

Open symbols = -RM
Filled symbols = +RM

Published as of 2001: 27 pulsars, 40 EGS
...with the latest data (2015).

>1500 new RM sources in the **CGPS** region!

Open symbols = -RM
Filled symbols = +RM
Queen’s Radio Observatory: A Canadian Training Ground

1962-75
Vic Hughes,
George Harrower,
Alan Bridle
supervised 20+ grad theses

Kronberg  McCutcheon
JCMT: Canada Gets into Star Formation

SCUBA-2

ACISIS: Spectral Line Backend
VSOP:
VLBI Space Observatory Program

S2 LBI Correlator:
Employed VHS tapes
CHIME

The Canadian Hydrogen Intensity Mapping Experiment is a revolutionary new Canadian radio telescope designed to answer major questions in astrophysics & cosmology.
Fast Radio Bursts
Next Generation Very Large Array
Thanks...

Sheila & Rena Galt
Chris Purton
John Locke
Dave Routledge
Rob Roger
Joseph Fletcher
Mary Ferguson
Vic Gaizauskas
Bob Hayward
Miller Goss

George Aitken
Jasper Wall
Ellen Bouton
Richard & Martha Jarrell
Woody Sullivan
Tom Landecker
Peter Dewdney
Brent Carlson
Ken Tapping