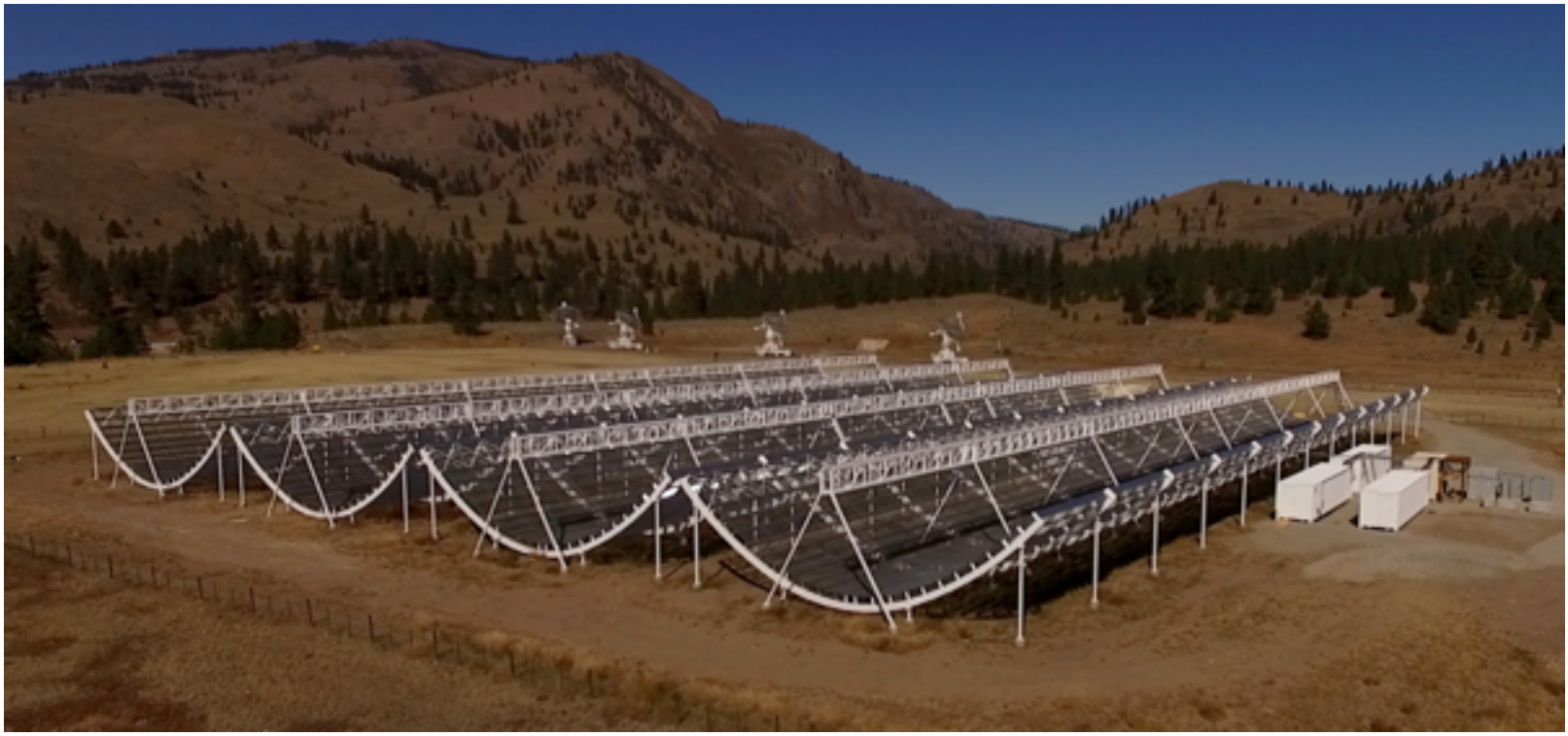
ROYAL ASTRONOMICAL SOCIETY OF CANADA - VICTORIA CENTRE

SKYNEWS



CHIME

The Canadian Hydrogen Intensity Mapping Experiment

The New Radio Telescope at the Dominion Radio Astrophysical Observatory Near Penticton

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NEXT MEETING

Next Monthly Meeting
Wed March 8th 2017
7:30 PM in Rm A104
Bob Wright Centre
UVic Campus

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On the Cover
CHIME

What resembles four parallel snow boarding "half pipes" is not a new Olympic training facility. Rather it is an exciting new radio telescope located at the Dominion Radio Astrophysical Observatory near Penticton. It is called the Canadian Hydrogen Intensity Mapping Experiment or "***CHIME"*** for short. Your editor thought a major new project located in our own backyard would be a great article for SkyNews. He soon realized, however, that this was a deep topic and his astrophysics was in need of an upgrade. This launched a fascinating but rather haphazard internet journey. It resulted in a number of background articles on *Galactic Rotation Curves* (Sept) , *Cosmic Redshift Surveys* (Dec) and the *Big Bang's Thermal Footprint* (Jan). Avid SkyNews readers are now primed to learn about a new ***Cosmic Distance Ruler*** and an **Overview of *CHIME*.** The adventure begins on page 4. Read on!

Presidents Report
by Chris Purse

It will not be long until our outreach events for 2017 begin and planning is in full swing. I hope you will consider volunteering as there are many tasks that need to be done. You may do this by contacting our Outreach Coordinator, Ken, at outreach@victoria.rasc.ca.

One of the areas I would like to emphasize is new member recruitment. This year, we will have complementary copies of the current SkyNews magazine to give out at public outreach events. Centres have been given the option to purchase copies at a minimal cost so we will be giving this a try. If you know of friends and family who share your interest in astronomy, and who are not yet members, you may want to give them a copy! It is my hope that a group of members will take on member recruitment under the coordination of Deb, our Second Vice President, so that there is a presence at all of our outreach events. The goal will be to talk about our society, the benefits of membership, and give out the magazines. Please email Deb at vp2@victoria.rasc.ca if you would like to help out.

Our launch event this year will be Astronomy Day on Saturday, April 29. During the day we will be at the Royal BC Museum where there will be displays, the solar system, and talks about astronomy. We hope the Sun will make an all-day appearance so we can look at it this year! That evening will be the first of the Summer Star Parties at the DAO and we hope that clear skies will prevail.

The dates for the remainder of the Summer Star Parties at the DAO are not finalized but we are looking at the Saturdays from Astronomy Day until mid September. More about these dates will be announced as decisions are made.

Ken is also looking for volunteers for the community events we attend such as Buccaneer Days, the Saanich Strawberry Festival, and, of course, the Saanich Fair in September. Again please put your name on the volunteers list if you are able to help out.

We are planning to hold our annual RASCals Star Party from July 28 – 30. The National office has asked all of the centres to organize a public event on Saturday, July 29 in honour of the sesquicentennial so we have decided to hold the Star Party to be part of the national star party. I have been in communication with the District of Metchosin to see if we can secure the cricket field again this year.

One of the highlights this summer will be the solar eclipse on Monday, August 21. Many of the members will be travelling to the zone where totality will occur. However, Victoria, assuming clear skies, is in a good location as around 90% of the sun will be covered when the maximum occurs at 10:20 a.m. We hope to have some of the people who remain in Victoria out with solar telescopes so that members of the public can enjoy the eclipse.

Please be reminded to let me know at president@victoria.rasc.ca if you would like to participate in a bulk purchase of the **Explore the Universe Guide** as I introduced in my January message.

February 8th Meeting Presentation

Radio and Microwave Astronomy – History, Canadian Involvement, and Interesting Tidbits by Dr. Lisa Loche

Radio astronomy started in the early 1930's as an electrical engineering project and it took many years for the optical astronomy community to include it under the gilded Astronomy umbrella. Early experimentalists had a field day with surplus World War II equipment and the increased world-wide collaboration between researchers. I will explain and guide through this history up to the present, contrasting the new radio astronomy with the classic well-understood optical ideas, highlighting Canada's significant role in the growing field. Details on current instrument projects and observatories will also be presented.

Bio: Dr. Lisa Shannon Locke was born in Hay River, NWT and received a B.Sc (Alberta), an M.Sc. (Cape Town, 2001) and PhD (Victoria, 2014) degrees all in electrical engineering specializing in low-noise microwave astronomy instrumentation. As a student, she worked at the Canadian Space Agency, CalTech's Owens Valley Observatory and the National Radio Astronomy Observatory in Green Bank, WV. After graduating, she spent 5 years at the Arecibo Observatory in Puerto Rico and joined the National Radio Astronomy Observatory's , expanded very large array (EVLA) at Socorro, NM. Her Phd thesis investigated the design and construction of a K-band feed for use on large radio astronomy reflectors. She is currently employed with NRC Herzberg and leads a multi-disciplinary project to build a S/C-band (2.8 – 5.18 GHz) receiver system.

See Page 4 for Upcoming Speakers

Our weekly **Astronomy Cafe** is an excellent, informal, way to meet us. New comers are especially encouraged. http://victoria.rasc.ca/events/astro-cafe/

Fairfield Community Centre - 1330 Fairfield Rd. Victoria.7:30pm

Contact: Reg Dunkley for further details
vp@victoria.rasc.ca
Every Monday at 7:30 PM

Email Lists

Observer / CU Volunteers / Members

Contact Chris Purse to subscribe

membership@victoria.rasc.ca

New Observers Group

Hosted by Sid Sidhu - 1642 Davies Road, Highlands. Call 250.391-0540 for information and directions.

Cattle Point observing in Victoria's own Urban Dark Sky Park:
http://victoria.rasc.ca/events/rascals-cattle-point/
Next Sessions : *Weather Permitting*
Friday February 3rd at 6:30PM
Friday March 3rd at 7:00 PM

Victoria Centre Observatory: Every Saturday Evening.
*Open to those on **the Active Observers list only***
Weather permitting. Dress warmly, and see you out there. Take care driving as it is the slippery season.

Membership Report - February 2017

Total membership is currently **240.** There are 13 members in the grace period which means their membership has expired in the past 2 months. Please contact Chris Purse (membership@victoria.rasc.ca) if you would like to check the status of your membership.

A New Cosmic Distance Ruler

by Reg Dunkley

Things were simpler in the good old days before 1980 when Vera Rubin published compelling evidence of **dark matter** … that mysterious and reclusive substance that only interacts gravitationally (see *Galactic Rotation Curves*, Sept SkyNews). The main constituents of ordinary matter, *protons and neutrons* belong to a class called **baryons** and this term is useful to differentiate it from dark matter.

While astronomers were still struggling to come to terms with dark matter the plot thickened. In 1998 a team, co-led by Australian astrophysicist Brian Schmidt and US astronomer Adam Riess, studied light curves of very distant Type 1a supernovae and discovered that the super novae were 10% to 15% fainter than they should be. This meant that they were further away and implied that the **rate of expansion of the Universe was increasing**. These results were confirmed by an independent supernovae study in 1999 led by US astrophysicist Saul Perlmutter. This was big news, particularly to the multitude of astronomers who reasoned that the rate of expansion which followed the Big Bang should slow down due to the attractive force of gravity. Either Einstein's gravitational theory was not quite right or there was a *something repulsive* in the Universe. This mysterious "*something"* was dubbed **dark energy**.. Schmidt, Riess and Perlmutter received the 2011 Nobel Prize in Physics for this discovery.

So the expansion rate, expressed by Hubble's Constant is not so constant after all. In order to learn what was going on, it is imperative to improve our measurements of how the expansion rate varied in much earlier times. This is easier said that done, however, as the supernovae standard candle distance measuring technique is stretched to the max. Fortunately during the past 15 years, astronomers have been hard at work refining an ingenious new distance measuring technique. It involves the scary term **Baryon Acoustic Oscillations** (BAO).

Wait! It is not as bad as it sounds. Let me explain. We have just learned that *baryon* is a code word for ordinary matter. An a*coustic oscillation* is just a fancy expression for a sound wave. These particular sound waves however occurred in the primordial plasma during the initial 380,000 years after the Big Bang. The January SkyNews contained an article on ***"Big Bang's Thermal Footprint"***. You may recall that the Planck Observatory measured the *Cosmic Microwave Background* at a detailed resolution. This field was very uniform but contained minor temperature variations.

Hotter areas reflected "over dense" fluctuations of plasma and dark matter. Stronger gravitational attraction in these denser regions would compress and heat up the plasma and increase the radiation pressure. Now radiation pressure is not a big deal in our rarified outer space but it is a different ballgame in a very hot plasma. This plasma consisted of a fluid of photons, electrons and baryons (protons). The electrons and protons were too hot to combine into hydrogen atoms and remained ionized. The photons were strongly influenced by the electric charge of the free electrons and protons and were closely bound to the plasma. This produced a *radiation pressure* that was a force to be reckoned. It easily resisted gravitational compression forces and launched outward moving spherical sound waves of baryons. Meanwhile the reclusive dark matter would remain near the centre of the fluctuation. These waves are the Baryon Acoustic Oscillations (BAO).

A very interesting process occurs when the plasma expands and cools to 3000 degrees K. It allows electrons and protons to recombine into neutral hydrogen atoms. Photons are no longer influenced by charged particles and are allowed to escape. The associated radiation pressure suddenly drops and the thin spherical shell of denser hydrogen stalls. The black body radiation captured by Planck is a snapshot of numerous overlapping hydrogen shells at the time of .

Upcoming Speakers

Wednesday March 8th 2017
Dr. Julia Foght; "Bugs in Space!? A Microbiologist's View of Astrobiology and the Habitable Zone"
Wednesday April 12th 2017
Kyle Oman; TBD
Wednesday May 10th 2017
Benjamin Gerard; Imaging Other Worlds
Wednesday June 14th 2017
Preparing for the Solar Eclipse. … Information and Hints from Several Speakers

recombination. The excess of gas now found in those shells together with the dark matter located at the centre of the shells make those regions slightly more dense and through gravity more likely to form galaxies.

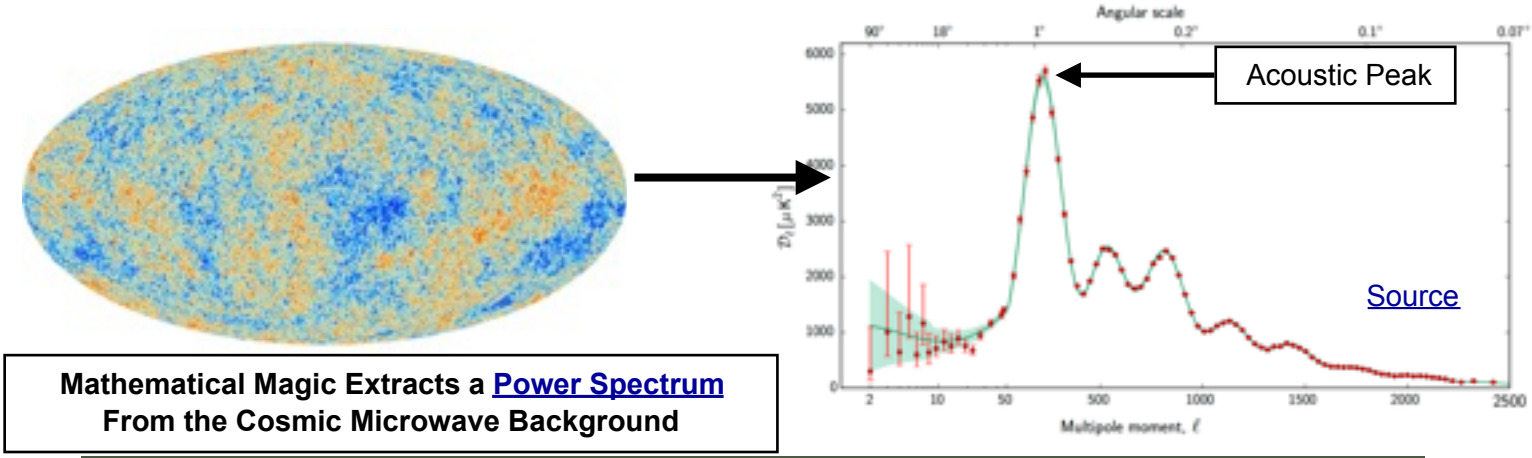
In the December SkyNews an article on the *Cosmic Redshift Surveys* revealed that rather than being randomly distributed, galaxies were actually concentrated on the cellular walls of bubble like voids. The node at the intersection of two bubbles was associated with a galactic "supercluster". This raises the profound question: **Are the minor fluctuations detected in the Cosmic Microwave Background (CMB) imprinted into the large scale structure of the Universe?**

In order to answer that question astronomers employed mathematical magic to perform an angular decomposition of the CMB variations into a series of wave elements. See the ***power spectrum graph,*** which plots temperature variations vs the angular scale of these wave elements. Notice that there is a **pronounced peak** for features with an angular diameter near one degree! What would cause this? Well the longest distance a sound wave can travel during the 380,000 year period between the big bang and recombination is called the **sound horizon**. Cosmological models show that this sound horizon corresponds to this fundamental acoustic peak and has after expansion a value of ~480 million light years. Notice two smaller peaks which are harmonics of the dominate acoustic peak and provide additional insight to important cosmological parameters. There is an excellent video that relates CMB temperature variations to the BAO power spectrum.

The strong signature detected in the CMB, motivated astronomers to hunt for a similar spike embedded in cosmic redshift surveys. This is a more challenging task because there were many more complex processes acting over billions of years to obscure any signals. In 2005, however, a team lead by Daniel Eisenstein employed statistical sorcery to successfully detect the imprint of the acoustic peak in super clusters of luminous redshifted galaxies from the Sloan Digital Sky Survey. Eisenstein called this the "**smoking gun"** which **confirms that tiny seeds of variation embedded in the CMB played a role shaping the large scale structures of the Universe!** He shared the 2014 Shaw Astronomy award for this discovery. Data quality and analysis methods continue to improve. The most recent analysis involved the more precise Planck CMB data as well as the Baryon Oscillation Spectroscopic Survey (BOSS) of redshift galaxies.

One of the benefits of this research is that this BAO sound horizon acts as a new standard cosmic distance ruler. By comparing the peak in the angular scale of the CMB to the peak in angular scale in the galactic super clusters one **could geometrically determine the distances separating the CMB from these large scale structures.** This technique is immune to effects like interstellar dust which adds uncertainties to standard distance candles such as the supernovae technique.

The BAO cosmic ruler is particularly well suited to measure how the expansion rate of the Universe varied in much earlier times. **It is the primary goal of an innovative experiment located in BC called CHIME. Read all about it in the next article!**



Mathematical Magic Extracts a Power Spectrum From the Cosmic Microwave Background

CHIME An Overview
by Reg Dunkley

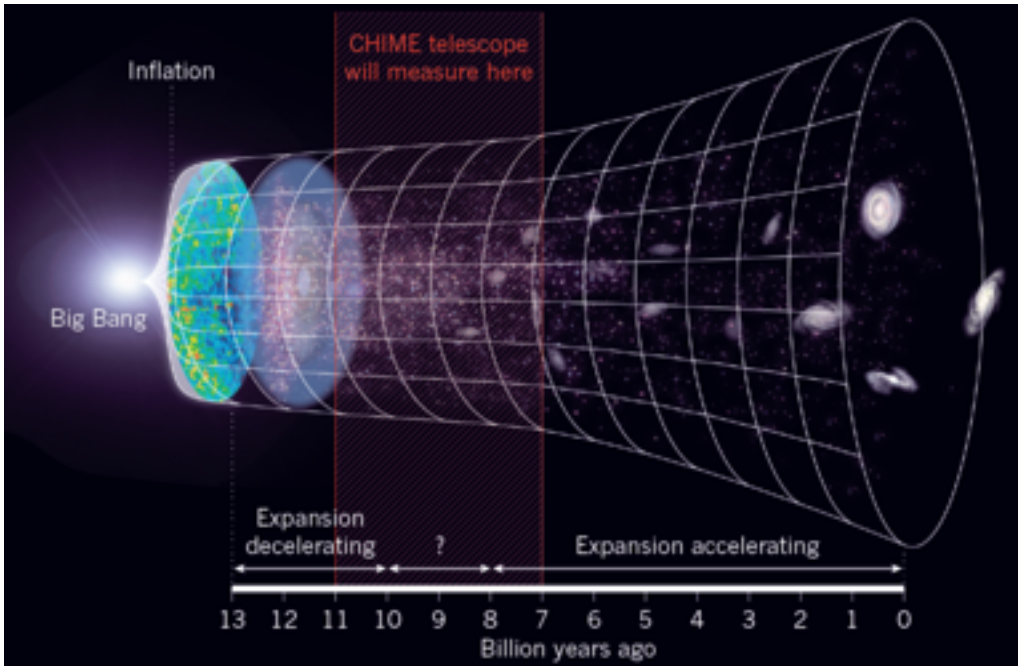
CHIME, the **Canadian Hydrogen Intensity Mapping Experiment** is an exciting and ambitious project with a goal to measure the expansion history of the Universe. This information may provide important insight into the properties of dark energy. It will achieve this by conducting a survey of the intensity of neutral Hydrogen over a vast volume of the Universe.

You may recall from the article on Galactic Rotation Curves (Sept SkyNews) that neutral Hydrogen consists of a single proton and electron and both particles have a property called spin. When the spin shifts or flips from one mode to another this emits radiation in the 21 cm wavelength band at a frequency of 1420 Mhz. Enormous quantities of neutral Hydrogen in the Universe are emitting this radiation both near and far. At great distances, cosmological expansion will stretch or "redshift" this wavelength. By tuning (changing the frequency) of a radio telescope, one is able to dial in and map the intensity of Hydrogen that corresponds to a specific distance and time. It is essentially a "time machine"!

These maps or layers of Hydrogen intensity should be imprinted with Baryon Acoustic Oscillations (BAO). Each layer, therefore should contain it's own BAO cosmic distance ruler. By analyzing each of these maps by techniques discussed in the previous article the angle of the BAO acoustic peaks can be obtained for a variety of distances. By comparing these angles for various redshifts the expansion history of the Universe can be acquired.

It sounds easy doesn't it? In reality, however, it is an extremely challenging undertaking. This did not deter the partners **of the CHIME collaboration: University of British Columbia, University of Toronto, McGill University and the Dominion Radio Astrophysical Observatory (DRAO)**. They designed a specialized radio telescope that is currently under construction at the DRAO near Penticton. It consists of four parallel 20 m wide by 100 m long parabolic cylinders that are fixed to the ground. This array is oriented in a North-South direction and is a meridian transit drift scan telescope which surveys half the celestial sphere every 24 hours.

This radio telescope is called an interferometer and consists of many closely spaced radio receivers. There are 256 receivers evenly spaced along the focal axis of each parabolic cylinder. The number of receivers for the entire array totals 1024 but each unit is dual polarized which doubles the data feed. The signal strength from these distant Hydrogen sources are incredibly weak. The large 8000 m^2 collecting area of the telescope together with



The Expansion of the Universe is Speeding Up!

CHIME Will Survey the Adolescent Phase of the Universe 7 to 11 Billion Years Ago

Source

low noise amplifier technology will boost these feeble signals. The telescope will capture all signals in the 400 MHz to 800 MHz frequency range. These signals will first be digitized and then bundled into 1024 narrower frequency bands or channels.

An interferometer is of great value because it can improve the resolution and narrow the beam width of the radio telescope. The simplest interferometer consists of two antennas separated by a baseline. When one multiplies together the voltages from these antennas, the resultant pattern consists of a series of fringes. These "interference fringes" arise because the signal from a source reaches each antenna at slightly different times and the signals are not in phase. The system that combines these voltages is called the **Correlator** and it **is at the heart of the interferometer**. The CHIME Correlator will have to process the voltages from each pairing of the 1024 receivers and then for each of the 1024 frequency channels. Then double those numbers to include the dual polarization information captured by the receivers. The number of required computations is truly astronomic! In order to meet this demand, CHIME is taking advantage of the parallel computing capacity found are on standard computer graphics boards (GPU's). The mathematics involved are rather brutal and the computational challenge of the CHIME Correlator will be an order of magnitude greater than any existing interferometer. The massive CHIME data volume will be stored on disk and archived offsite for astronomical analysis.

The CHIME interferometer will narrow the beam width to ~ 0.31 deg at 800 MHz and to ~0.62 at 400 MHz. The field of view will be nearly 180 degrees along the North-South axis but will be 1.3 deg (800 MHz) to 2.5 deg (400 MHz) along the East-West direction.

A beam width of 0.31 degrees can barely detect an object the size of the Sun or the Moon. This does not sound very impressive for the owner of an optical telescope who dwells in a realm of much much shorter wavelengths. The CHIME telescope, however, has been specifically optimized to detect those BAO cosmic rulers. You may recall that 13.7 billion years ago at the time of the Cosmic Microwave Background the BAO subtended an angle of ~ 1 degree. This angle increases with large scale structures at closer distances.

When dealing in cosmological distances, astronomers prefer to talk in redshifts. Usually denoted by the **letter "z"** a **redshift** is calculated by **dividing the amount a wavelength is stretched** due to cosmological expansion **by the wavelength at rest**. So on Earth the redshift z = 0 since the wavelength is not stretched at all. At the time of the CMB, however, the redshift z = 1089! CHIME has been designed to operate between redshifts of 0.8 and 2.5. For a frequency "channel" of 400 MHz (z = 0.8 and ~ 7 Billion years ago) the BAO angle is ~ 3.0 degrees. At 800 MHz (z = 2.5 and ~ 11 Billion years ago) the BAO angle is 1.3 degrees.

CHIME promises to greatly extend the distance measurement range and is more efficient and feasible than attempting to make millions of redshift measurements from distant dim galaxies. It is hoped that CHIME will determine the inflection point where the Universe transitions from a decreasing expansion rate to an increasing expansion rate. CHIME is also of value to monitor Pulsars and Fast Radio Bursts.This experiment, therefore, is well positioned to make significant contributions to Cosmology and the understanding of dark energy.

But will CHIME work? Well the good news is that as smaller 2 cylinder prototype called Pathfinder is already gathering data. There are big challenges, however, including subtracting foreground noise generated by humans, the Sun and the Milky Way as well as minimizing CHIME instrument noise.

This Canadian collaboration is an example of conducting "Big Science" on a shoe string budget. CHIME was reduced from 5 cylinders to 4 due to the drop in the Canadian dollar. The use of low noise cell phone amplifiers and graphical processing units resulted in substantial savings. This is an exciting and innovative project that highlights the level of talent in the Canadian radio astronomy community.

Construction of the cylinders is completed and currently about half of the receivers are installed. "First Light" or should I say "First Fringe" could occur late this summer. The Hydrogen Intensity Survey of the Universe will begin soon afterwards. It may be a great time to tour the DRAO after the Solar Eclipse!

RASC Victoria Centre Council 2016 / 2017

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Online Resources

Magazines

SkyNews Our National RASC Newsletter
Sky & Telescope Magazine
Astronomy Magazine
Astronomy Now Astronomy in the UK
Amateur Astronomy Magazine
Astrophotography Magazine

Borrowing Telescopes

The centre has telescopes for new and seasoned observers that members can use. Contact Sid Sidhu from the email list