ISSN: 2182-7249

The CAAUL Gazette

The International Newsletter of the Centre for Astronomy and Astrophysics of the University of Lisbon

Winter 2012
Vol.1 – No.3

Introduction

ALMA – or *soul* in Portuguese – is a very appropriate name for one of the most ambitious astronomical projects in recent times. Why? Because it is attempting to unravel the mysteries of our very existence, from the birth of stars and planetary systems to galaxies and the very material that living organisms are made of. Shame the word does not have the same meaning in English though. Inaugurated on the 13th March in the Atacama desert in Chile, the **A**tacama **L**arge **M**illimeter/Submillimeter **A**rray is very exciting for CAAUL in that we have participation in this project with the objective of characterising the history of distant galaxies. We hope to present some initial results from our collaboration over the next few issues.

Whirling Southern Star Trails over ALMA
(Credit: ESO/B. Tafreshi (twanight.org))

In this issue, Marco Grossi, researcher at CAAUL, is presenting some initial findings of his collaboration with the Herschel Space Observatory, the largest infrared space telescope ever launched and designed to see the coldest and dustiest objects in space. Also, in this issue, Mario Santos from CENTRA discusses the conundrum of when the first galaxies formed.

This is all exciting stuff and luckily we have plenty of time for us to get our papers published in Science and Nature as we have at least another one hundred years until the end of the world (apparently, 20.12.2012 was a miscalculated expiry date for the Earth) – see the RedShift article by Rui Agostinho!

David Berry, General Editor

Director's Comment

Knowledge. This simple word embodies the core of our species. This is what has enabled us to thrive for thousands of years and, literally, shape our planet (sometimes not in the best possible way). This is also what Astronomy is all about. To know the Universe where we live in is to know our own most fundamental origins and understand where we are headed. What other way is there to avoid the fate of countless species that also populated our planet in the past, extinct by some major cosmic accident? But Astronomy is also more. Knowledge is the driver of so many technological breakthroughs needed to observe beyond the current frontiers, to take a more detailed look at our Cosmos. The developments of X-ray, Optical and Radio Astronomy are all linked to direct day-to-day applications (medical imaging or communications technology, for example). This is why CAAUL hosts a valiant team of people dedicated to the development and building of astronomical instrumentation. Over the last few years they have played significant roles in such projects as ESPRESSO and MOONS. For the future, CAAUL is contributing to the definition of the instrumentation suite for future fundamental missions/facilities such as JUICE, EChO and the E-ELT. So, CAAUL not only does Science, but is an active player in the building of instruments that allow for that unique Science to be done, and a little more of the Universe to be understood.

José Afonso, Director of CAAUL

Herschel Space Observatory (Source: ESA/AOES Medialab)

News from CAAUL

"Cool" Dust in Virgo Cluster Dwarf Galaxies: A Herschel View

The "average galaxy" is found in low-density, marginally bound groups. However 5 – 10% of galactic systems evolve in rich clusters containing several hundred galaxies. The stellar structure and the gas content of a galaxy can be severely modified inside a rich cluster, because of direct encounters with other members or the interaction with the hot intergalactic medium (whose pressure is much higher than that of the interstellar gas within the galaxies). Therefore, clusters are unique systems to investigate the influence of the environment on the life and evolution of galaxies.

The Virgo cluster, with 1500 catalogued members and a distance from our Galaxy of 17 Mpc, is the nearest rich cluster and the largest structure in our intergalactic neighborhood.

Multi-wavelength studies (from X-ray to radio) of nearby galaxy clusters, including Virgo, have largely contributed to our understanding of the effects of the cluster environment on the different galactic components (e.g. stars and gas). However, the properties of "cool" dust ($T < 30$ K), and how

Contents

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http://www.caaul.oal.ul.pt/gazette

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Upcoming Events

CAAUL's activity is present in major scientific events throughout the world. This section will keep you informed about up and coming events that the Centre organizes or participates in. You will find here notices of national and international conferences with the presence of CAAUL's researchers as well as major outreach events, often organized by the Astronomical Observatory of Lisbon (OAL) and with the support of CAAUL. Relevant funding opportunities, when available, will also be advertised here.

Conferences/Workshops:

25 February to 1 March 2013:
Shaping E-ELT Science and Instrumentation, ESO Garching, Germany

18 March to 22 March 2013:
44th Lunar and Planetary Science Conference, The Woodlands, Texas, USA

22 April to 26 April 2013:
The Modern Radio Universe 2013, Bonn, Germany

24 April to 26 April 2013:
8th Iberian Cosmology Meeting, Granada, Spain

13 May to 15 May 2013:
Euclid Mission Conference, Leiden, The Netherlands

27 May to 30 May 2013:
CosmoLens Conference - Marseille, France

10 June to 13 June 2013:
Astronomy Radio Sources and Society - The Wonderful Century, Leiden, The Netherlands

Outreach:

Awesome Universe Exhibition
This exhibition, celebrating the 50th anniversary of the European Southern Observatory, shows the Cosmos captured in ESO's various observatories, located in some of the most inhospitable places on Earth. The exhibition is on display in Lisbon from February 8 to May 5, at the National Museum of Natural History and Science. Associated with the exhibition, CAAUL and OAL organize 3 events entitled "Living in an Awesome Universe", taking place at OAL every first Saturday of the month, from March to May. Each event consists of a public talk, a musical performance and guided observations of the night sky.

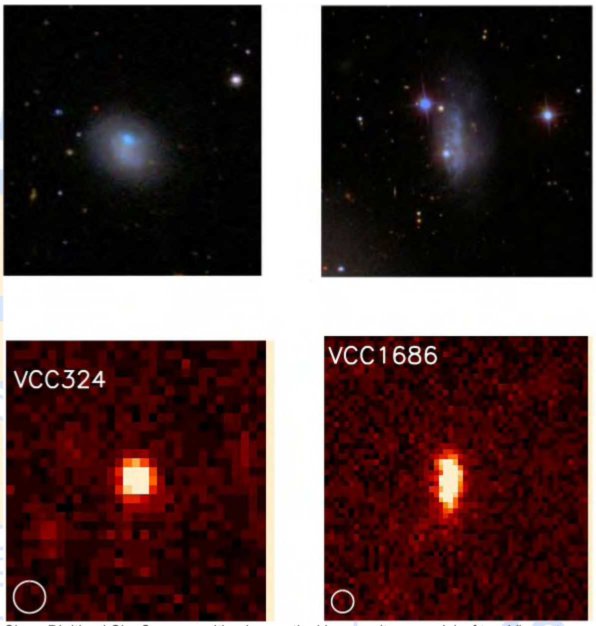
Every last Saturday of the month:
Nights at the Observatory
This public outreach activity takes place at the Astronomical Observatory of Lisbon. In each session there will be a public talk, usually given by a CAAUL researcher, and guided observations of the night sky.

For more information contact:
João Retrê

it can be affected by interactions in a cluster environment are still poorly known. This is mainly due to the fact that the emission from dust at these temperatures falls within the Far Infrared (FIR) and the sub-millimeter (submm) wavelength range (100 - 500 μm), a region of the electromagnetic spectrum which was largely unexplored before the launch of the Herschel Space Observatory in 2009. The advent of Herschel has been revolutionary in the field of FIR/submm astronomy: with a 3.5m collecting mirror (the largest single mirror ever built for a space telescope), it attains both improved sensitivity and high spatial resolution compared to any of the previous far-infrared telescopes.

In order to understand the role played by the cluster environment on the dust cycle of galaxies, the Herschel Virgo Cluster Survey is a Herschel Open Time Key Project to map an area of approximately 60 square degrees of the nearest big cluster in five bands from 100 to 500 μm.

Within the HeViCS consortium, CAAUL is responsible for the study of the dust properties of the star-forming dwarf galaxies. Their importance is that they allow us to study processes in the interstellar medium in galaxies with conditions similar to those found in the early Universe. Because they are smaller and fainter, only in the local Universe can we detect and study FIR emission from dwarf galaxies. So far we have detected about 40% of the Virgo star-forming dwarfs included in the region mapped by HeViCS, with dust masses ranging between 10^5 and 10^6 solar masses, about one hundredth of the stellar mass. Analysis of the FIR/submm data set is still ongoing and it will be combined with observations of the atomic and molecular gas components obtained with ground-based radio and millimeter telescopes to get a complete picture of the interstellar medium of these systems. Studying this sample of dwarfs is offering us the opportunity to study the properties of cosmic dust that appear to be different to that in our own Galaxy.



Sloan Digitised Sky Survey multi-colour optical images (top panels) of two Virgo star forming dwarf galaxies compared to the FIR emission at 250 μm detected with Herschel (bottom panels)

Marco Grossi

Arrivals and Departures

Silvio Lorenzoni Silvio Lorenzoni is starting his post-doctoral fellowship at CAAUL, after a long time spent in Florence and a PhD at the University of Oxford. At CAAUL he will continue his studies on galaxies on the edges of the observable Universe, their evolution and impact on the surrounding medium. Silvio is looking forward to continue his work and to contribute to CAAUL's studies on galaxy formation and evolution. He is also keen to live in Lisbon and enjoy the beautiful city that impressed him in his brief visit.

Bruno Coelho Bruno Coelho has been working at CAAUL since May of 2012 under supervision of Dr. Marco Grossi. He used GMRT data in order to build HI maps of star forming dwarf galaxies in the Virgo cluster, which were then compared with Herschel's infrared data and with optical observations. The objective of this work is to study how the dense cluster environment affects the evolution of dwarf galaxies in terms of gas and dust content. Bruno will now be starting a PhD at Observatório do Valongo, in Rio de Janeiro, Brazil. "I am leaving this beautiful place with really nice people and great working environment, but I will always remember the wonderful time spent at CAAUL."

Cristina Fernandes Cristina Fernandes worked as a post-doctoral fellow in CAAUL for two years, after finishing her PhD in Oxford University. Her research revolves around the dynamics, structure and feedback processes of AGN. At CAAUL, she participated in the development of radio image stacking techniques, under the auspices of CAAUL's participation in the Evolutionary Map of the Universe survey, to be performed on the Australian SKA pathfinder. She was also involved in research into the nature of bulgeless galaxies, with emphasis on its star formation and on the puzzling bulgeless galaxies that host an AGN. She has now started a post-doctoral fellowship at the Observatório Nacional in Rio de Janeiro, Brazil. "Here in CAAUL I found an extremely friendly staff, a family-like environment, a very active group and an incredibly beautiful scenario in the premises of the historic Astronomical Observatory of Lisbon. The quality of research at CAAUL, its motivating environment, as well as Lisbon's thriving quality of life are some of the reasons why I would like to settle down my career at CAAUL later on."

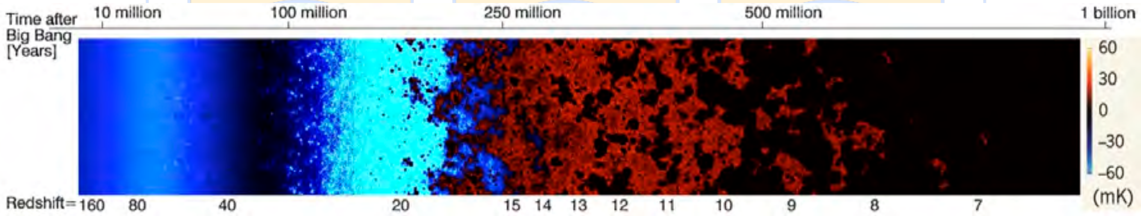
Javier Peralta Javier Peralta has now started a new post-doctoral fellowship at the Instituto de Astrofísica de Andalucia in Granada, Spain, after a very successful three year stay at CAAUL, working with the Planetary Atmospheres group. "During these three years I grew up both professional and personally in Portugal, up to the point of wishing to settle down in this country. Nevertheless, I have now started to work in Spain, collaborating with the Portuguese group and living with the "saudades" of whom takes a boat deep into the sea and only thinks to come back one day."

AstroConundrum

First Light

In recent years there has been a wealth of information for cosmologists on the evolution of our Universe. There is still however very little information about one important phase: the epoch when the first galaxies formed and the Universe went from the smooth initial state to the highly non-linear and diverse environment we see today. This is one of the most challenging conundrums faced by observational cosmology.

At first everything was dark. There were no galaxies or stars in the Universe, no nuclear reactions capable of producing energy and emit radiation that could then be caught by a distant but powerful telescope. This was almost 14 thousand million years ago, when the Universe was a mere 10 million years old. In fact, things were not completely dark. Some radiation should be seen due to the neutral hydrogen, which could be found almost everywhere in the Universe. Although in much less quantity than the pervading dark matter, it was still (and it is) the most abundant baryon in the Universe, signaling the underlying structure of the Universe like tiny markers trapped in the gravitational pull of dark matter. In its ground state, the interaction between the electron and proton spin generates a hyperfine splitting of the first energy level. This splitting corresponds to a very tiny separation, with an energy of only 6 micro-electron-Volt, a frequency of 1420 MHz or a wavelength of 21 cm. Because it is so small, this transition can be easily excited even when the energy emitted in the Universe is very weak. It is called the HI or 21cm signal.



Simulations Showing the Evolution of the HI signal throughout the Developing Universe

At this early stage in the evolution of our Universe there is actually a radiation capable of exciting the 21 cm line: the cosmic microwave radiation (CMB), which had been released just a bit before (in cosmological scales!), some 380 thousand years after the Big Bang. It is the afterglow of the plasma of photons, electrons and protons that filled the primordial Universe. During this period with no stars, called the "Dark Ages", the CMB can be absorbed by the neutral hydrogen 21 cm transition, creating "holes" on the observed sky that can be used to study the Universe. This is similar to learning about the shape of a tree by just observing its shadow. As the Universe gets older and expands, the wavelength of these absorbed photons will be stretched to much longer wavelengths, around 15 meters or a frequency of 19 MHz, lower than the typical radio FM frequencies of 100 MHz. If we could measure this absorption signal at such low radio frequencies, we would be able to observe the Universe at a very early stage when the first non-linear structures are yet to be formed. This is the cosmologists dream-land: without complicated astrophysical processes to worry about, they can use simple linear equations to understand the signal that we observe and relate it directly to cosmology. Moreover, by changing the frequency of observation one can probe different slices of the Universe at different stages of its evolution, just like tuning the frequency in a radio to listen to different radio stations, and, by looking across the sky, we could take a truly 3 dimensional tomographic picture of the evolution of the Universe in its early beginnings! Unfortunately, due to the interference from the ionosphere at these low frequencies, we would probably need to build such a large telescope on the Moon.

Things are not completely hopeless from Earth, however. First, if the absorption process is still happening some 200 million years after the Big Bang, this will translate to frequencies of about 50 MHz, which is already more manageable from the ground. Second, there is another more dramatic event occurring in the Universe that has become the Holy Grail for cosmologists: First Light and the subsequent Epoch of Reionization. As the first stars and galaxies appear in the Universe, following the baryonic infall into the potential wells of dark matter, the X-ray emission from these galaxies will first heat up the hydrogen gas throughout the Universe and, almost at the same time, the strong emission of ultraviolet photons will start ionizing the neutral hydrogen. This process of Reionization lasted for about 500 million years and is extremely efficient: today, more than 99% of all the hydrogen in the Universe is ionized and only a small fraction can be found trapped in clouds inside galaxies, protected from the ultraviolet radiation by dust particles. Since the hydrogen gas is hotter than the CMB during Reionization, we will see the HI/21 cm signal in emission: as neutral hydrogen atoms decay from the highest to the lowest energy level of the hyperfine transition, they emit a small amount of radiation that will add to the total CMB radiation at the 21cm wavelength. The observed difference is small – just a mere 0.02K on top of the CMB 2.73K temperature. Moreover, as Reionization progresses, there will be large patches of ionized hydrogen in the Universe for which the HI signal will be zero. We should then observe large dark bubbles surrounding dark matter halos (with many galaxies inside these giant bubbles!) corresponding to about 1 degree size on the sky. Once the Reionization process is complete, the signal will be zero everywhere.

In order to probe the distant HI signal, we will need large radio-interferometers, made of several elements (antennas) whose signal is multiplied in a computer and combined to make an image of the sky (a truly "software telescope"). This is because the resolutions needed at the observed frequencies will require a telescope of about 1 Km in size – something very hard to achieve with a single dish! There are at the moment several low frequency radio-telescopes in construction or already in operation, with the aim of probing this epoch and understanding how and when it happen: LOFAR in the Netherlands, which is already taking data and might be the first to observe the signal from Reionization (maybe in 2014); MWA from Australia (2016), PAPER in South Africa (2016) and the future SKA phase 1 (2018) and then phase 2 (2025) which will be the ultimate "low frequency 21cm experiment" with a total area of several square kilometers. The detection of this signal will open up a new observational window for cosmology, allowing the probing of a completely unexplored phase in the evolution of the Universe.

Mario Santos, CENTRA

RedShift

The Mayan Calendar: the End of the World ...but not quite yet

In the last year we saw a variety of people proclaiming the end of the world on December 20th, which should be followed by a new, more perfect, humankind on the planet. This social event was based on the counting of the Mayan Calendar and became more "soundly convincing" with the use of modern scientific knowledge but wrongly associated with it. To understand the claims, let's clarify the calendar cycles used by the Mayas, which included different ways of counting periods of time.

The lunar period of 29.5 days between two consecutive full moons has been studied by other civilizations and gave rise to the use of the month. However, the Mayans adopted a shorter period of only 20 days (the total number of fingers and toes), called the Uinal. Why? Some historians say that it comes from the necessity of counting 260 days (the Tzolkin cycle) corresponding to the time interval between successive harvests of the corn fields, their basic nourishment source, but a cycle also used in religious ceremonies. Since 260 = 20 x 13 this cycle requires the counting of a second running number, so, each Tzolkin day (a kyn) had two tags: one from the 20 days' names plus a number from 1 to 13. It would be equivalent nowadays to number sequential days of the year as: Jan 1st, Feb 2nd, Mar 3rd, ... Nov 11th, Dec 12th, Jan 13th, Feb 14th, etc.

The Tzolkin is very short to be useful to record social events or historical ephemeris. They had a parallel count of days based on eighteen "short months" of 20 days each (Uinal), giving a short year of 360 days (18x20), the Tun, also used for astronomical events. This numbering scheme is closer to the modern calendar, with two tags assigned to each day, one for the month (1-18) and another for the day (1-20). In order to make it closer to the solar year, 5 extra days (the epagomenal) were added at the end but considered of great misfortune. The solar year of 365 days was called the Haab. On daily life, one can imagine people referring to that day in both the Tzolkin or the Haab counts. What a mess. Well… that's no more complicated than the various religious calendars, all lunar cycle based, we have nowadays.

An interesting question arises: when are the tags for a particular day repeated again on both counts simultaneously (e.g. Tzolkin=1.1 and Haab 1.1)? It will be after 18,980 days = 52 Haab years = 73 Tzolkin cycles, since 52*365 = 73*260. The 52 became a magic number for the Mayans in the sense that they believed the sun's diurnal motion in the sky could stop every 52 solar years, destroying the planet and killing humankind. Therefore, many (≈40,000) human sacrifices were done during those years.

The accounting of historical events needs a much longer cycle and for that, a positional system with extra places was used: K.T.U.K where Kin runs 0..19 , Uinal runs 0..17, Tun and Katun, both run 0..19, providing a total of 18*203 = 144000 days = 394.521 Haab solar years = 400 Tun short years (360 days). This is called the Long Count or the Baktun cycle. By including an extra place, the Baktun number 0..19, the counting scheme extends its capability of unique dates to 8000 Tun short years = 7890.41 Haab solar years (365 days) = 7885.01 Julian years (365.25 days). This is called the Pictun cycle.

Some historians (Goodman, 1905, Martinez, 1926 and Thompson, 1950, or GMT) more or less agree on a starting date of the Mayan calendar (B.K.T.U.K = 0.0.0.0.0) on September 6, 3114 B.C. = Julian Day 584,284 since the Long Count always begins on a 4 Ahau (Tzolkin) = 8 Kumhu (Haab), among other considerations.

The Mayan Calendar

The debate last year was about the ending of Baktun's 13th cycle (12.19.19.17.19) which is followed by the start of the next one (13.0.0.0.0). One of the problems is related to the conversion of Mayan dates to Julian, or Gregorian ones. The end date of the cycle is 12.19.19.17.19 = Dec 20, 2012 (JD 2456282) only if one uses the Julian calendar (365.25 days/year) for all dates before September 3, 1752, and a Gregorian calendar (365.2425 days/year) after that, a system that is only used in Britain and former colonies.

If one considers that after October 4, 1582 all Catholic countries used the Gregorian calendar, then 12.19.19.17.19 = Jan 15, 2013 = 2456308 JD implying that the end of the world just happened this past January, as we all noticed!

The crucial detail is on the correlation date between the start of the Mayan calendar and a Julian date, a calendar well documented. The GMT correlation introduces a strange gap of ≈ 640 years without any written documents or Mayan monuments, between the "Fall of the Maya Empire" in 909, and the arrival of the Spanish Conquistadores (1541) (sic, Vollemaere, A. Leon, 1982). By stressing that dates on Mayan documents, stelae or monuments never refer to baktun numbers above 10, plus a much better match between maya predictions and real occurrence of solar and lunar eclipses in the Yucatan peninsula between the 1 AD and 1600 AD, Vollemaere (also Weitzel and Vaillant) set a correlation that clears the gap problem: 0.0.0.0.0 = Apr 26th, 2594 BC = 774080 JD, which is a shift of 520 years to the GMT date.

If this is the solution then Dec 20, 2012 = 11.13.12.14.4 is not at all the end of a cycle, but the real end of the world will be in 11.19.19.17.19 = June 1st, 2138 in a true Gregorian date… if no major catastrophic event happens before. Don't miss it!

Rui Agostinho

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ISSN: 2182-7249

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