The promises and challenges of the ALMA Wideband Sensitivity Upgrade

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Chapter 1

Invited talks

1.1 Session 1

The ALMA2030 Wideband Sensitive Upgrade - Status Update

Gonzalez, Alvaro [1]

[1] JAO

ALMA has been producing ground-breaking science since it became operative in 2011. The ALMA Development Roadmap was released in 2018 to prioritize the development necessary to significantly expand ALMA's capabilities and enable it to produce even more exciting science in the coming decades. The ALMA2030 Wideband Sensitivity Upgrade (WSU) is the top priority initiative for the Development Roadmap. The WSU will initially double, and eventually quadruple, ALMA's system instantaneous bandwidth and deliver improved sensitivity by upgrading the receivers, digital electronics, and correlator. The WSU will afford significant improvements for every future ALMA observation, whether it is focused on continuum or spectral line science. The improved sensitivity and spectral tuning grasp will open new avenues of exploration, increase sample sizes, and enable more efficient observations.
The WSU is now well underway with key subsystem under development, including new receivers, digitizers, data transmission system and correlator. In parallel, the observatory is advancing the detailed planning towards implementation through a careful project management and systems engineering approach, based on an integrated Conceptual System Design which outlines the hardware, software/computing and science operations aspects of the upgrade. The substantial gains in the observing efficiency enabled by the WSU will further enhance ALMA as the world leading facility for millimeter/submillimeter astronomy.

The WSU Advanced Technology ALMA Correlator (ATAC)

Brogan, Crystal [1]

[1] National Radio Astronomy Observatory

I will describe the capabilities of the WSU Advanced Technology ALMA Correlator (ATAC) which will handle both the 7m- and 12-array interferometric observations, as well as providing VLBI beamforming capability

From cold cores to protostars: the promises of WSU

Vastel , Charlotte [1]

[1] Institut de Recherche en Astrophysique et Planetologie

Molecular complexity in the earliest phases of star-forming regions will be presented in this talk. I will present recent results obtained with ALMA in the proto-typical prestellar core, L1544, and the proto-ninary system BHB07-11. The Atomis tool (ALMA Archive TOol for Molecular Investigations in Space: https://atomis.irap.omp.eu/) developped at IRAP will also be presented to the ALMA community to select in the ALMA archive observations of selected species towards the selected source.

1.2 Session 2

Development of Cryogenic IF Low Noise Amplifiers for the ALMA Wideband Sensitivity Upgrade

Gallego Puyol, Juan Daniel [1]

[1] Yebes Observatory

One of the primary objectives outlined in the ALMA Development Roadmap is to broaden the Intermediate Frequency (IF) bandwidth of the receivers for improved sensitivity. A crucial element in achieving this goal is the Cryogenic Low Noise IF Amplifier (CLNA), which necessitates an upgrade. The current generation of ALMA receivers in the most advanced bands offers two polarizations and two sidebands, delivering an instantaneous IF bandwidth of 8 GHz (per polarization and per sideband in the 4-12 GHz range).
Our ambitious aim in facilitating this upgrade was to demonstrate the feasibility of doubling the maximum instantaneous IF bandwidth (4-20 GHz) while preserving or improving the characteristics of existing amplifiers. An additional challenge involved obtaining amplifiers with low input reflection as it was anticipated that the devices used in the current receiver generation to mitigate reflection issues (isolators) would be challenging to obtain. Achieving low reflection was essential for ensuring good rejection of undesired sidebands in 2SB receivers, yet this conflicted with the imperative to obtain very low noise. Another significant constraint was the need for the amplifiers to have low power dissipation, given the limited cooling capacity of the receiver cryostat.
The development of these amplifiers has proven successful, meeting all specified requirements. Several demonstration prototypes have been built, and the results will be presented during the upcoming meeting.

IF processor for the ALMA Wideband Sensitivity Upgrade

Quertier , Benjamin [1]

[1] University of Bordeaux

A deep exploration of [CII] and dust continuum emission at high-z with the ALMA WSU

De Looze, Ilse [1]

[1] Ghent University

ALMA has been revolutionary in uncovering dusty galaxies at high-redshift. This efficient exploration of the dusty high-z Universe has uncovered that obscured star formation contributes significantly to the cosmic star formation rate density beyond z=6. Most of that knowledge remains biased to a subset of the brightest high-z galaxies. The upcoming ALMA upgrade will allow us to also probe the lower end of the infrared luminosity function, and will enable a statistical study of the dust content in high-redshift galaxies. At the same time, the work-horse [CII] line has been revolutionary in tracing star formation and cold gas in galaxies across cosmic time, especially in the high-redshift Universe. The ALMA upgrade will allow efficient surveys of dedicated parts of the sky to enlarge the current high-z galaxy sample sizes with [CII] detections, opening up a rich realm of scientific opportunities with studies of outflows, kinematics, luminosity functions and ISM physics. I will also discuss the future opportunities for unique synergies between JWST and the ALMA WSU.

1.3 Session 3

Evolved stars with ALMA after the WSU

Wouter , Vlemmings [1]

[1] Chalmers University of Technology

ALMA has made unique contributions to our understanding of the late stages of stellar evolution, but also provided new questions. will present an overview of a few recent advances made possible by ALMA and highlight some of the science that will be made possible with the upcoming ALMA upgrade

1.4 Session 4

Broadening ALMA's Scientific Potential through Wideband Observations of the Sun

Wedemeyer, Sven [1]

[1] University of Oslo

Despite the Sun standing out as the brightest source in the (sub)-millimeter sky, observing it presents significant challenges due to the rapid evolution of its complex small-scale structure on very short timescales. However, solar observations at (sub)-millimeter wavelengths offer immense diagnostic potential, as the continuum radiation in this range is closely linked to the electron temperature of the emitting layer. Additionally, with decreasing frequency, the (sub)-millimeter continuum originates from increasingly higher layers in the Sun's atmosphere. Fully exploiting these properties would enable the tracking of propagating phenomena such as waves and even perform three-dimensional tomography of the thermal structure with high temporal resolution. The anticipated results would have profound implications for understanding the fundamental physical processes behind the heating and activity of the solar atmosphere, and consequently, for comprehending stellar activity and its effects on exoplanet habitability.
Unlocking this scientific potential necessitates expanded instantaneous frequency coverage beyond ALMA's current capabilities. By employing numerical simulations, the presentation explores the potential of solar observations with increased instantaneous spectral bandwidth and compares this approach to simultaneous observations with sub-arrays.

A BRAIN study to tackle imaging in the ALMA 2030 era

Guglielmetti, Fabrizia [1]

[1] ESO

The ESO internal ALMA development study, BRAIN, utilizes Artificial Intelligence imaging algorithms for ALMA data [1,2]. Employing both astrostatistics and astroinformatics techniques, this study integrates interdisciplinary approaches spanning observational astronomy, statistics, algorithm development, and data science [3]. We offer compelling evidence of the benefits of these data driven methodologies in ALMA image analysis for operational and scientific purposes. Specifically, RESOLVE [4,5] and DeepFocus [6] show significant advantages, including improvements in data product quality and processing time reduction. These approaches pave the way for addressing the data analysis revolution expected by ALMA2030 [7]. Additionally, we introduce ALMASim, a new package aimed at advancing these fields by providing a refined ALMA simulator accessible to a wide audience. As of 2024, this study is nearing its end of term.
[1] Guglielmetti, F. et al Phys. Sci. Forum 2023, 9(1), 18 [2] Guglielmetti, F. et al Phys. Sci. Forum 2022, 5(1), 50 [3] Siemiginovska, A. et al arXiv:1903.06796 [4] Junklewitz. H. et al A&A, 586, A76 (2016) [5] Tychoniec, L. et al Phys. Sci. Forum 2022, 5(1), 52 [6] Delli Veneri, M. et al MNRAS, 518, 3 (2023) [7] Carpenter, J. et al "The ALMA Development Program: Roadmap to 2030", arXiv:2001.11076

Complex chemistry during the early stages of star formation

Jørgensen, Jes Kristian [1]

[1] Niels Bohr Institute, University of Copenhagen

The emergence of complex organic molecules in the interstellar medium is a fundamental puzzle of astrochemistry. Targeted observations with ALMA have opened the door to high-sensitivity spectral surveys over wide bandwidths to elucidate the chemical complexity of young stars in a systematic manner. Concerted efforts along these lines are needed to reveal the complex organic inventories and isotopic ratios depending on the physical environment and evolutionary past. Ultimately they will can address how much diversity in organic inventories we can expect for emerging planetary systems.

In this talk I will present the first results of our ALMA Large Program "Complex Organic Molecules in Protostars with ALMA Spectral Surveys (COMPASS)". The aim of the program is to perform unbiased line surveys of 11 nearby Solar-type protostars. The targeted protostars are known hosts of complex organic molecules and sample different natal environments and evolutionary stages thereby starting to address the relative importance of "nature" versus "nurture" for the resulting protostellar chemistry. I will discuss the potential for extending such studies to explore much wider parts of parameter space after the Wideband Sensitivity Upgrade as well as some of the challenges that must be tackled with such rich datasets.

ALMA WSU: Data Processing Challenges and Opportunities

Kepley, Amanda [1]

[1] National Radio Astronomy Observatory

The ALMA Wideband Sensitivity Upgrade (WSU) will increase the maximum number of channels ALMA is capable of producing from 15,000 to 1.2 million. This increase in the aggregate number of channels presents new challenges for processing ALMA data. In this talk, I will present estimates of the predicted distribution of WSU data properties – including data rates, visibility data volumes, and product sizes – based on extrapolations of current ALMA use patterns and compare them to the data properties ALMA is capable of producing today. I will also outline the current challenges with ALMA data processing and discuss ways to address these challenges in the WSU era.

The future of solar system observations with the ALMA Wideband Sensitivity Upgrade

Wampfler , Susanne [1]

[1] Center for Space and Habitability, University of Bern

ALMA has proven to be an invaluable tool for studying the origin and evolution of the building blocks of planetary systems, both in our solar system and beyond. ALMA's high sensitivity and large spectral coverage have provided us with an unprecedented view of many solar system objects. For instance, ALMA has allowed us to study the chemical composition of cometary comae in great detail, including determining variations in the spatial distribution of different species. However, because of the varying nature of comets, they remain challenging to observe and obtain reliable abundance estimates for, even with ALMA. Observations of comets will therefore greatly benefit from ALMA's Wideband Sensitivity Upgrade, offering increased sensitivity to access fainter isotopologue lines, reducing uncertainties on abundance ratios by enabling simultaneous observations of more species of interest in a single spectral setup, and by providing high resolution line profiles without the need to sacrifice bandwidth.

1.5 Session 5

Polarization over wide bandwidths - impact of ALMA WSU on studies of extreme Faraday rotation

Hovatta, Talvikki [1]

[1] Finnish Centre for Astronomy with ESO

Relativistic jets launched by supermassive black holes in the centers of active galaxies are some of the most energetic phenomena in the Universe. These jets shine brightly over the entire electromagnetic spectrum and are capable of accelerating particles to extreme energies. Although the exact jet launching mechanism is not yet understood, it is believed that magnetic fields anchored to the black hole or the accretion disk extract energy from the rotating system, launching relativistic bipolar outflows. One way to study the magnetic field structure in these jets is via modeling their linear polarization as a function of wavelength, which provides, for example, the Faraday rotation measure that is related to the line-of-sight magnetic field strength in the rotating medium. To probe the regions relevant for jet launching, one needs to observe at high millimeter wavelengths where the jets are fully opaque unlike in the centimeter wavelengths where synchrotron self-absorption is prominent. In 2016 we observed the archetypal quasar 3C273 in full polarization with ALMA at band 6 and detected a very high Faraday rotation measure of 5×10^5 rad/m^2 over the available instantaneous bandwidth. In our follow-up observations in 2018 the rotation measure is much lower and it cannot be detected over band 6 alone. In my talk, I will discuss the improvements expected in the modeling of the polarization of relativistic jets by the increase in the instantaneous bandwidth offered by the WSU.

The prospects of the ALMA wideband sensitivity upgrade for the study of nearby galaxies

Querejeta, Miguel [1]

[1] Observatorio Astronómico Nacional

ALMA is revolutionising our understanding of nearby galaxies by mapping large areas with resolutions that approach the scales of individual molecular clouds, primarily with bright molecular lines such as CO(2-1). This is yielding an unprecedented view on how the interstellar medium (ISM) is organised around dynamical structures such as rings, bars, and spiral arms. The use of additional lines and isotopologues, such as HCN or 13CO, provide an extra layer that permits us to gauge key properties such as gas density. Yet, to fully characterise the physical conditions of the ISM in nearby galaxies, it is crucial to map simultaneously as many lines as possible, including not only reliable dense gas tracers, but also tracers of shocks and other physical processes. In this talk, I will review some of the main science goals that can be tackled with the ALMA wideband sensitivity upgrade in the field of nearby galaxies. These include efficient multi-line and isotopologue mapping, as well as improved sensitivity to mm continuum. I will provide some examples of how NOEMA can already achieve some of these goals, which sets the path that ALMA could follow.

1.6 Session 7

Polarization studies and more with new ALMA capabilities

Beltrán, Maite [1]

[1] INAF-Osservatorio Astrofisico di Arcetri

In this talk, I will illustrate how the planned upgrade of ALMA instantaneous spectral bandwidth, starting with the new Band 2 capabilities, will improve our understanding of Galactic dust polarization and the role of magnetic fields in the star formation process. In addition to the advantages for continuum studies, Band 2 will also be important for spectral line studies, in particular of deuterated species, and this also be briefly discussed.

1.7 Session 8

ALMA 2040+, technologies beyond the current upgrade

Baryshev, Andrei [1]

[1] Kapteyn Astronomical Institute/NOVA

The upgrade of the ALMA Wideband Single-Channel Correlator (WSU) is currently underway, making it an opportune time to explore additional possibilities and technologies for further enhancing ALMA's capabilities. In this discussion, we will explore a broad range of potential technologies that could be implemented in the medium to long term, looking toward the years 2040 and beyond. These technologies include extended baselines, focal plane arrays, phased array feeds, additional antennas, and the construction of a large single-dish submillimeter telescope. Additionally, we will consider the technological advancements necessary to realize these goals.

Planet-forming disks in the WSU era

Miotello, Anna [1]

[1] ESO

Disks around protostars are thought to harbour on-going planet formation and/or recently formed planets. This picture is now supported by observations of rich, potentially planet-related, substructure. Therefore, it is essential to understand the physical and chemical nature of the protoplanetary building-blocks and their spatial distribution to better understand planet formation mechanisms and the demographics of the resulting planetary systems. In its first decade of operations ALMA has been transformational in the field of planet-forming disks, as it has enabled both moderate resolution (0.1" − 0.4", tens of au in nearby SFRs) statistical disk surveys and high resolution (down to 20 mas, 1 au in the closest disks) imaging studies. ALMA unprecedented sensitivity has also allowed us to shed light on the chemical composition of planet-forming disks. Nevertheless, improvements in data quality and sample size have possibly opened more questions than have been answered. In this talk I will review recent advancement in the field of planet-forming disks, with a a focus on results from ALMA Large Programs, and I will expand on the potential of WSU for this field.

Chapter 2

Solicited talks

2.1 Session 1

An ALMA archival perspective on the evolution of galaxy dynamics

Rizzo, Francesca [1]

[1] Kapteyn Astronomical Institute

ALMA is bringing us to the forefront of a revolutionary transformation in the field of galaxy formation and evolution, providing observations with high angular and spectral resolution that unveil intricate details of the interstellar medium (ISM) of galaxies over a wide range of cosmic history. This transformative perspective has challenged current galaxy evolution models and has contributed to constructing a nuanced understanding of the evolution of ISM properties and galaxy dynamics. However, even after 10 years of ALMA operation, the archive offers high-resolution observations only for < 50 intrinsically bright or gravitationally lensed galaxies. During this talk, I will discuss the importance of extending studies to the fainter but more abundant star-forming galaxy population. This will be possible thanks to the higher observing efficiency achievable thanks to the Wideband Sensitivity Upgrade.

Time domain science with ALMA and the Wideband Sensitivity Upgrade

Torne, Pablo [1]

[1] Institut de Radioastronomie Millimetrique (IRAM)

Time domain astronomy is key to understand astrophysical processes that vary in time. Unfortunately, many of these events are often elusive or difficult to study – either because they are unpredictable on-off events (like neutron star mergers, supernovae, gamma-ray-bursts or some fast radio bursts), or because the time scales are too short (less than a second) or too long (years or more) to be easily observed. There is a wealth of astronomical sources showing variability, from fast-spinning pulsars to evolving stars or tidal disruption events, with enormous differences in their characteristic time scales. In addition, some experiments require a very high timing accuracy, like gravity theory tests with radio pulsars. Offering the community observatories capable to observe in all the different time ranges and with sufficient sensitivity and timing accuracy is challenging. ALMA, with its broad wavelength range and superb sensitivity, is a fundamental instrument for time domain research; in particular because the millimetre window is often less explored in some of these experiments than other wavelengths. In this talk, we will focus on the requirements to enable, improve, or facilitate, time domain science with ALMA and the Wideband Sensitivity Upgrade. We will make some emphasis in the very-fast time domain (fractions of a second to minutes), which is typically the most difficult to access due to more stringent technical requirements.

EHT goals and ambitions in the WSU era

Impellizzeri, Violette [1]

[1] Leiden Observatory

Summary of wide-band receiver optics studies at NAOJ over the last decade

Kaneko , Keiko [1]

[1] NAOJ

The ALMA Science Archive, a reprocessing service and a science enabling infrastructure in the WSU era

Stoehr , Felix [1]

[1] ESO

The WSU will come with a large increase in the overall data-rate. The data volume will pose substantial challenges for astronomers to access, to recalibrate, reimage, and recombine the data according to their needs as well as to analyze the products. We describe the coming and planed developments for the ALMA Science Archive to allow astronomers to better deal with the WSU ALMA data and thus maximise the science return for the observatory.

2.2 Session 6

Updates on ALMA Band 6v2 Receiver Development

Navarrini, Alessandro [1]

[1] NRAO

We are developing an upgrade for the existing 211-275 GHz ALMA Band 6 receiver, referred to as Band 6v2. The new Band 6v2 receiver, based on a sideband separating SIS mixer architecture, will have a greatly increased IF bandwidth (baseline IF 4-16 GHz, goal IF 4-20 GHz) and a modestly expanded RF band (209-281 GHz) compared to the current Band 6. The Band 6v2 receiver consists of a new Cold Cartridge Assembly and a new Warm Cartridge Assembly designed to meet several challenging specifications that comply with the ALMA Wideband Sensitivity Upgrade requirements, including low noise (TSSB less than 53 K over 80% of the band), high image rejection (greater than 15 dB over 90% of the IF range), relatively flat receiver noise and gain vs frequency, as well as improved OMT and optics for lower sidelobe and cross-polarization levels. We are exploring several different configurations for the ALMA Band 6v2 sideband separating receiver, with improvements to all the major components, including optics, OMT, mixers, IF section, and local oscillator. The presentation will provide a brief overview of all the aforementioned aspects of the project.

ALMA Band 8 version2 receiver upgrade project

Kojima, Takafumi [1]

[1] NAOJ

We have initiated an upgrade project for the existing Atacama Large Millimeter/submillimeter Array (ALMA) Band 8 (radio frequency: 385-500 GHz) receiver cartridge with a substantially improved second-generation version, referred to here as “Band 8v”. This project is originated from significant advances in receiver technologies in the last decade, such as high critical current density superconductor-insulator-superconductor (SIS) mixers, wideband cryogenic low-noise amplifier, and high-performance waveguide components. These will allow us to realize a fundamentally re-designed receiver to cover a substantially wider intermediate frequency (IF) band with lower and flatter receiver noise temperature. In addition to those goals, lessons learned through the development, operation, and maintenance of the current ALMA Band 8 receiver cartridges will be appropriately addressed through this upgrade. In the conference, the project plan, receiver design, and its technical readiness will be presented.

ALMA Band 2

Phillips , Neil [1]

[1] ESO

Chapter 3

Contributed talks

3.1 Session 1

GPU Spectrometer for the Total Power Array

Kim, Jongsoo [1]

[1] Korea Astronomy and Space Science Institute

The rapid advancement in GPU (Graphic Processing Unit) technology, driven by the growing needs of artificial intelligence, has paved the way for significant improvements in astronomical data processing. The launch of the NVIDIA Grace Hopper superchip is a major breakthrough. It speeds up the transfer of data from antennas to GPU memory and greatly increases processing power. In light of these advancements, we propose the development of a new Total Power GPU Spectrometer (TPGS) to replace the existing ACA Spectrometer (ACAS) for the upcoming WSU phase. The TPGS is designed to produce full polarization products by processing digitized signals from each of the four TP antennas. It will play a crucial role in the calibration of pointing and focus for the antennas, thanks to its ability to generate cross-correlation products. Utilizing a FFX (Filter-FFT-Multiplication) architecture, the TPGS methodically processes data on a per spectral window basis, accommodating digitized signals across a vast 20 GHz bandwidth for each polarization, sideband, and antenna. This system uses a polyphase filter to isolate a specific spectral window, and then applies a Fast Fourier Transform (FFT) to the filtered signal to calculate auto-correlation. This design's flexibility in selecting spectral window bandwidths and FFT sizes ensures it meets the varied bandwidths and spectral resolutions for each spectral window.

The Wideband Submillimeter Array: Current Status and Future Plans

Kovacs, Attila [1]

[1] Center for Astrophysics/Submillimeter Array City

The Submillimeter Array was conceived more than 2 decades ago as the world's first submillimeter interferometer capable of sub-arcsecond imaging in the frequency range from 200 to 700 GHz. It began full science operations in 2004 with a suite of double side band SIS mixer receivers operating in the 230, 345, and 690 GHz bands, with each receiver producing an IF bandwidth of 2 GHz, matched a purpose-built ASIC correlator combined the signals from the different antenna pairs for a total processed on-sky bandwidth of up to 8 GHz. Incremental improvements to the receivers, coupled with the development and deployment of the SWARM correlator, have resulted in significant improvements in sensitivity, enabled in part by an expansion of on-sky bandwidth, currently capable of a spectral grasp of up to 48 GHz. The observatory is currently undertaking a major upgrade to the SMA – known as the wideband SMA (wSMA) project – which will deliver more sensitive instrumentation, wider bandwidths, and dual-band full-polarization capabilities. In this presentation, I will discuss current status of and future plans for the wSMA, with particular focus on challenges faced for the ever-increasing bandwidth being delivered by the instrument, in the context of the upcoming WSU upgrade.

An overview of issues and lessons learnt working with the ACES ALMA Large Program

Barnes, Ashley [1]

[1] ESO

The ALMA Cycle 8 large project ACES (ALMA Central Molecular Zone Exploration Survey) aims to map the entire Centre of the Milky Way with unprecedented spatial dynamic range in a number of lines and continuum in ALMA Band 3. The final cubes produced as part of this project will contain over 5,000 individual ALMA pointings, or around 500,000 individual beams, across more than 15,000 channels (equating to terabytes in size per cube). These data are extraordinary at present, but they may become somewhat routine after the ALMA Wideband Sensitivity Upgrade. During this talk, I will give a brief introduction to the large program and then discuss the issues we have encountered, along with lessons learnt, during the reduction and analysis of this dataset.

NASCENT-stars large program: origin of molecular complexity towards emerging high-mass protostars

Csengeri, Timea [1]

[1] Laboratoire d'astrophysique de Bordeaux

During the star formation process, the interstellar medium gets enriched in a complex zoo of molecules. The extremely rich chemistry of the star forming gas holds the key to constrain the link between the chemistry of disks and their forming planetary systems. It is, however, unclear what are the key physical conditions that influence the emerging complex chemistry, and how the fundamental properties of the emerging star, or stellar clusters impact its evolution.
In this context, wide-band receivers open a new era by allowing us to perform quasi-instantaneously spectral surveys that are required for a more robust estimation of molecular abundances. The NASCENT-stars project (PI: Csengeri) is a large observing program started in 2023 at the IRAM NOEMA observatory with 228 hours allocated at the telescope making use of the newly commissioned high spectral resolution (250 kHz) and wide-band observing mode. Overall, we observe a 46.5 GHz non-continuous bandwidth to characterize the physico-chemical conditions of the most active star forming regions of the Cygnus-X molecular complex at the scale of 1400 au probing statistically significant samples individual protostellar envelopes. I would like to highlight the first results of NASCENT-stars and our efforts to develop artificial intelligence and machine learning methods facilitating the exploitation of these rich datasets. Results of this project should pave the way to the spectacular science cases enabled by the ALMA WSU.

3.2 Session 2

Impact of LO Leakage in the New IF Frequency Range of the ALMA Wideband Sensitivity Upgrade

Chiong, Chau Ching [1]

[1] Institute of Astronomy and Astrophysics, Academia Sinica

We reviewed the LO scheme in the current and the on-going upgraded receiver bands in ALMA system. Except Band 1, the fundamental frequency of the existing local oscillators in the ALMA receivers ranges from 12.4 to 25.8 GHz followed by various type of frequency multiplier. The frequency of these signals will overlap the new IF frequency range in the ALMA WSU (4-16, 4-20 GHz etc.). Therefore, spurious signal may enter in the new IF range due to the YIG leakage. To investigate the impact to the system, the leakage power level at the IF output from the YIG is measured with a W-band receiving system. Recommendations will be made for the new first and second LO schemes and the IF signal path.

A preview of the ALMA WSU: prospects of the wide-band spectral observation of high-z galaxies

Yoon, Ilsang [1]

[1] NRAO

One of many benefits from ALMA WSU is efficient spectral line observation of high-z galaxies. In this talk, I will provide the analysis result of the two recent cycle 9 ALMA DDT programs that observed JWST discovered z>10 galaxy candidates, GHZ1 and GHZ2. Due to the design of the observing program searching for the redshifted [OIII] emission line, the observing blocks have 26-30 GHz bandwidth in band 6 with 4 spectral tunings, which is close to the ALMA WSU in band 6 with one spectral tuning. Although no significant emission is detected from the proposed z>10 targets, the observed data includes 'serendipitous' multiple significant line emissions from the locations of other 'intermediate redshift' JWST galaxies in the target field. Given the similarity of spectral bandwidth, the resulting ALMA data from these programs shows the promises of ALMA WSU to observe high-z galaxies with serendipitously detected multiple lines in a single spectral tuning and also challenges us to robustly identify the detected FIR ISM cooling lines from galaxies in a wide range of redshifts.

Unveiling the Cosmic History of Gas and Dust with Broad ALMA Bandwidths

Boogaard, Leindert [1]

[1] MPIA

In search of our Cosmic Origins, molecular deep fields have provided an unprecedented view on the evolution of the cosmic molecular gas through time. These spectral-scan mosaics, conducted on the worlds largest interferometers (e.g., the 200h ALMA/ASPECS large program), map the total gas and dust content of the universe and have, in the last decade, revealed its evolution similar to the cosmic density of star formation for the first time. Yet, it has also become clear that further progress is limited with current facilities, unless significantly larger time investments are made. The 2-4x increase in total bandwidth from ALMA Wideband Sensitivity Upgrade is an critical development in this regard: as the efficiency of spectral scan surveys scales linearly with bandwidth, a 4x increase in bandwidth will be instrumental to enable the next-generation of molecular deep fields and spectral scan surveys. The large instantaneous bandwidths will also critically improve the dust continuum sensitivity. For both nearby and distant galaxies, a 4x larger bandwidth will enable a near complete spectroscopic inventory in a single tuning. Including the overall gains in sensitivity from upgrading the ALMA signal-chain, the WSU will greatly enhance the efficiency ALMA in unveiling gas and dust in galaxies through cosmic time.

3.3 Session 3

GARD SIS Junction Fabrication Process to serve Next Generation Receivers for ALMA

Pavolotsky, Alexey [1]

[1] Chalmers University of Technology / GARD

ALMA Development Roadmap sets the goal of "increase of the receiver IF bandwidth by at least a factor of two" to address the three new fundamental science drivers: the origin of galaxies, the origins of chemical complexity and the origin of planets. From the SIS mixer device perspective, the goal of increasing the IF bandwidth by at least a factor of two translates into requirement to decrease of and keep tight control over the SIS junction capacitance, which is responsible for IF response roll off at higher frequencies. In turn, that calls for (1) the SIS junctions with a smaller area and, hence, capacitance, and (2) the material system for the SIS junctions tunnel barrier having a lower specific capacitance. Supported by ESO and in collaboration with NAOJ and NOVA, GARD was running the studies addressing both goals. As the outcome of the studies, GARD currently supports the process for fabricating of SIS junctions with AlN tunnel barrier and the junction area down to 1 sq.um or a bit below. The GARD SIS design rule supports the junctions with RnA>5 Ohm/sq.um along with the specific capacitance Cs(RnA) specification. The SIS junction quality characterized by the ratio of subgap to normal resistances, Rj/Rn>20 (often better). At the workshop, we will present the details about the GARD SIS fabrication process and design rule, as well as the available results of measurements of SIS mixer demonstrators utilizing the SIS junctions made with the upgraded GARD fabrication process.

Advanced Waveguide Components and Technology for 2SB dual polarization receiver cartridges

Desmaris, Vincent [1]

[1] Chalmers University of Technology

The ALMA WSU strives for "increase of the receiver IF bandwidth by at least a factor of two", as well an improvement of the beam squint performance of some existing cartridges in order to keep ALMA at the forefront of astrophysical facilities and to address three new fundamental science drivers: the origin of galaxies, the origins of chemical complexity and the origin of planets Aiming the two abovementioned challenges, an ESO study exploring advanced waveguide components and technologies for 2SB dual polarization receiver cartridges started in Dec 2023. The study focuses on the development of micro machined waveguide technology and its possible implementation in the form of form of low loss OMTs for band 7 and Band 9, which currently employs polarization splitting using grids. The developed technology employs photolithographically defined components exhibiting ultimate in linear dimension and superior surface accuracy enabling potentially large structure still with low loss. Additionally, the waveguide technology developed also enabled drop-in waveguide matched loads for the frequencies of B7 and B9 that will provide compact and reliable solution for use in respective 2SB mixers. At the workshop we will present the initial results and prospective of this collaborative study run between NOVA and GARD.

3.4 Session 4

Optimising the Data Processing and Quality Assurance strategy in the WSU era

Randall, Suzanna [1]

[1] ESO

The advent of the Wideband Sensitivity Upgrade (WSU) is expected to bring about increased data rates and volumes, posing a substantial challenge to the existing ALMA data processing workflow. In response, significant automation and adaptation will be necessary. This adaptation will involve a shift towards per-Execution Block (EB) calibration, occurring as soon as possible after each observation. It is likely that the current strategy of Quality Assurance (QA2) at the Member ObsUnitSet level will be revised, and that some form of QA will happen at the Group ObsUnitSet level. This entails evaluating combined images from various arrays, incorporating 12-m, 7-m and TP data when needed to fulfill the objectives of the proposed Science Goal. The envisaged changes aim to enhance efficiency and optimise ALMA's science output in the WSU era.

Getting ready for ultra-wide spectral scans: Reflections on the ALCHEMI Large Program

Martín, Sergio [1]

[1] ESO-JAO

For decades we have been limited by sensitivity, bandwidth or a combination of both in order to cover very large spectral windows. ALMA just made it possible and it is about to multiply its speed to make it a routine. I would like to share the experience from more than two decades working on spectral line surveys and in particular some reflections from the ALCHEMI Large Program experience. ALCHEMI stands for the ALMA Comprehensive High-resolution Extragalactic Molecular Inventory, and it is the culmination of line surveys covering ALMA Bands 3 through 7 towards one of the nearest and most prolific extragalactic molecular emitters. Both the tools we currently use and even our own mindset may still be shaped by the limited data we had up until ALMA opened its eyes, and may be simply futile to deal with the datasets to come with WSU. I will present some of the ALCHEMI results and my own reflections on the journey of this fantastic dataset to publication.

3.5 Session 5

Accelerating massive data processing in Python with Heat

Comito, Claudia [1]

[1] Forschungszentrum Jülich, Jülich Supercomputing Centre

Processing massive scientific datasets is challenging. In astrophysics as in the vast majority of research communities, the standard approach involves breaking up and analyzing data in smaller chunks, an inefficient and very prone-to-errors process. The problem is exacerbated on GPUs, because of the smaller available memory. Popular solutions to distribute NumPy/SciPy computations are based on task parallelism, introducing significant runtime overhead, complicating implementation, and often limiting GPU support to one vendor.
In this talk, I will present an alternative based on data parallelism. The open-source library Heat [1] builds on PyTorch and the Message Passing Interface protocol to simplify porting of NumPy/SciPy-based code to multi-CPU, multi-GPU clusters. From a user perspective, Heat can be used seamlessly in the Python array ecosystem (numpy, scipy, xarray etc.). Under the hood, massive memory-intensive operations are distributed transparently via MPI communication.
I will not bore you with technical details, but rather show you practical situations in which your Python pipeline could benefit from using Heat as a backend for massive array manipulations, statistics, signal processing, machine learning, etc.
[1] https://github.com/helmholtz-analytics/heat

On-the-fly data reduction by streaming processing of visibilities

Dijkema, Tammo Jan [1]

[1] ASTRON

Realising the scientific ambitions of ALMA's Wideband Sensitivity Upgrade (WSU) will require a significant increase in IF and correlator bandwidth. This will result in a larger output data rate of the correlator, putting increasing demands on storage capacity and I/O for the buffering of raw visibility data. To reduce the costs (in terms of energy consumption and hardware) of handling the raw visibility data, we started the Streaming Visibility Processing (SVP) development study in September 2023. The aim of this project is to demonstrate a prototype data processing pipeline that captures the visibility output stream from the ALMA correlator, performs a number of observation-dependent visibility processing steps and only stores the visibilities after reducing the visibility data volume.
Possible examples of such data-volume reducing initial processing steps are Baseline-Dependent Averaging (BDA) and visibility data compression using the Dysco algorithm. Although these techniques are not lossless, they can be configured in such a way that the increase in the thermal noise level of the final images is less than 1% while the data volume is reduced by an order of magnitude. A demonstration of this trade-off and its implications for ALMA science is part of the development study.

3.6 Session 6

ALMA Past and Future Contributions to a Full Understanding of the Baryon Cycle

Peroux, Celine [1]

[1] ESO

The study of high-redshift galaxies is key to our global understanding of galaxy formation and evolution. In particular, the baryon cycle is a critical component of the complex interplay between the accretion of material, the physics that drives the buildup of stars out of this gas, the subsequent chemical evolution and feedback processes, and the reionisation of the Universe. ALMA to date offers an unprecendented combination of sensitivity, spatial resolution and frequency coverage in the millimetric (mm) and sub-mm domain. Together, these powerful capabilities have transformed our understanding of the (sub)mm extragalactic sky, enabled detailed studies the ISM of both local and the highest-redshift galaxies and redefined our view of the global dust and gas properties of the Universe over large look-back times. These discoveries have in turn both triggered and provided new constraints on theoretical models of galaxy formation and evolution in the early Universe. In this talk, I will point out some of the ALMA results that have shaped this new era. I also propose to highlight what might be possible for studies of the cold and distant Universe during the WSU commissioning phase as well as when the upgrade is completed.

A Window on Cosmic Evolution through ALMA Calibrator Data

Bollo, Victoria [1]

[1] ESO

The ALMACAL survey, a comprehensive study of ALMA calibrator data, has been pivotal in advancing our scientific understanding in many areas. This talk will review the major milestones achieved, with a particular focus on the molecular gas evolution traceable by CO emission within the calibrator fields. I will present new results of the blind CO search using all available calibrator data until May 2022 in Band 3 and 6, accumulating about 540 hours. The upcoming ALMA Wideband Sensitivity upgrade, promising a fourfold increase in bandwidth, will significantly enhance the frequency coverage of each calibrator data set. I will discuss the impact of these upgrades on the ALMACAL survey in terms of the improved emission-line sensitivity and much increased line search efficiency of ALMA, which will revolutionize our understanding of the cosmic evolution of cold gas.

Widening our view of the hot Universe

Di Mascolo, Luca [1]

[1] Université Côte d'Azur

Throughout the past decade, the superior capabilities of the Atacama Large Millimeter/Submillimeter Array (ALMA) have allowed astronomers to gain an unprecedented perspective on the Sunyaev-Zeldovich (SZ) effect – a peculiar spectral signature imprinted in the ubiquitous cosmic microwave background by the warm/hot gas across the Universe. ALMA observations of the SZ effect over scales of a few arcseconds have started rivaling the more traditional X-ray measurements in terms of both resolution and sensitivity, conclusively establishing the central role of the SZ effect in the study of the thermal evolution of cosmic structures. However, the exploration of the SZ Universe with ALMA is still limited to only to a handful of pioneering studies targeting individual and/or somewhat extreme cases. In fact, the faint and diffuse nature of the SZ signal largely hampers its characterization due to major limitations inherent to radio-interferometric measurements – namely, large-scale filtering, missing fluxes on smaller scales, and significant noise correlation in the image. Systematically extending our observational reach of the SZ effect will thus require a major advance that minimizes the impact of sparse sampling of the visibility plane while enhancing overall continuum sensitivity. In my talk, I will present detailed forecasts to discuss how the wideband sensitivity upgrade will be specifically suited for addressing such issues in the context of ALMA SZ observations.

Exploring boundaries for wider RF and wider IF bands for ALMA SIS receivers

Belitsky, Victor [1]

[1] GARD, Chalmers University

Group for Advanced Receiver Development (GARD) at Chalmers University actively participates in development of instrumentation for ALMA, e.g., ALMA Band 5 and, recently, ALMA Band 2. GARD involved in the ESO supported ALMA Development Study, by running project "ALMA Band 6 and 7 Cold Cartridge Demonstrator". We would like to present recent progress of this project work towards SIS mixer receiver covering 210-375 GHz RF band and having 4-20 GHz IF band. We plan to present results of development and tests of various components for such receiver. We show the results on the development of wideband optics and corrugated feed for such broadband receiver that has key importance as it would ensure feasibility of such receiver effective coupling to the antenna. We will present results of the development of the broadband OMT that is known using single feed for both polarizations and providing superior beam alignment on sky between the two polarization in the ALMA receivers as compared to polarizing grids. We will show results of the development of the 2SB mixer components and measurement results of the DSB mixer chip. Finally, we will present proposed 3D CAD model for such receiver in the ALMA cartridge environment.

Study of potential upgrades for the ALMA Band 7 receiver

Risacher, Christophe [1]

[1] IRAM

We will present the work performed during a 2-year feasibility study to assess possible upgrades of the ALMA Band 7 receivers. The main upgrade goals are to at least double the IF bandwidth from 4-8 GHz to for example 4-20 GHz, to extend the RF bandwidth to have more overlap with ALMA Band 6, and to improve the beam squint, by using orthomode transducers rather than wire grids. The study was completed in September 2023 and showed full designs for various components which could indeed allow fulfilling most of the new requirements. We highlight though that performing all these upgrades while keeping as good noise temperature as the current Band 7 will be very challenging.

3.7 Session 7

Band-4+5 Receiver Front-End: Idea and Initial Development in East Asia Consortium

Hwang, Yuh-Jing [1]

[1] Academia Sinica Institute of Astronomy and Astrophysics

We propose an upgrade to the ALMA Wideband Sensitivity Upgrade (WSU) by developing a new receiver with increased RF and IF bandwidth. The new receiver will cover the RF frequency of the original Band-4 and Band-5 with continuous frequency tuning over dual polarizations, dual sidebands with instantaneous intermediate frequency (IF) bandwidth up to 16 GHz per sideband and per polarization.
Both the SIS-based receiver and HEMT-based receiver schemes are considered. The SIS-based receiver is considered as the baseline design, a sideband separation downconverter with the input fed by the ellipsoidal mirror pairs, corrugated feedhorn and the orthomode transducer form the cold cartridge assembly (CCA). The niobium-based SIS junctions will be fabricated to form mixer chips, and integrated into the mixer blocks with WR-5.44 waveguide 3-dB quadrature hybrid couplers, cryogenic IF low-noise amplifiers, and 2-20 GHz coaxial 3-dB quadrature hybrid couplers to form sideband separating down-converters. For the HEMT-based receiver scheme, the cryogenic InP HEMT low-noise amplifiers (LNAs) chains cover 125 - 211 GHz operated in 15-K ambient temperature will be the key components, to suppress multiple reflection ripples, cryogenic 2SB mixers are considered. To avoid the possible interference between LO and IF signals, the LO fundamental frequency are chosen in 24 - 32 GHz, followed by a frequency tripler to form the phase-lock loop with 72 - 96 GHz frequency tuning range.

Towards a Producible ALMA2030-Ready Sideband-Separating Band 9 Receiver

Hesper, Ronald [1]

[1] Kapteyn Astronomical Institute, University of Groningen

In the last quarter of 2022, the NOVA Sub-mm Instrumentation Group (University of Groningen) finalized an ESO-cofunded study on the possibility of upgrading the current ALMA double sideband (DSB) Band 9 (602-720GHz) receivers to a sideband-separating (2SB) architecture. Besides the 2SB conversion itself, several other enhancements in line with the ALMA2030 roadmap were studied, in particular aspects of the Wideband Sensitivity Upgrade (WSU). A proof-of-concept Band 9 2SB mixer with an IF band of 4-20 GHz was demonstrated. Compared to the 4-12 GHz IF of the existing DSB Band 9 receivers, this represents a fourfold increase in exported IF bandwidth (from 2 x 8 GHz to 4 x 16 GHz). Another subject that was studied was the possibility to enhance the polarimetric performance of Band 9; for this a straw-man design of an OMT-based architecture (rather than the current grid-based design) was presented. In the currently running follow-up study “Towards a Producible ALMA2030-Ready Band 9 CCA” (also co-funded by ESO, with Observatorio Astronómico de Yebes and Chalmers University as partners), we address the lessons learned in the former study with the goal of arriving at a reviewable 2SB Band 9 WSU-compliant receiver prototype with polarimetric performance (cross-polar and beam squint) on par with the other OMT-based ALMA bands. We present the up-to-date results of this study (started Oct 2024).

The origin of chemical complexity: in the earth of young forming planetary system

De Simone, Marta [1]

[1] ESO

Early planetary system formation reveals intricate chemistry with abundant prebiotic molecules in protostellar environments that serves as a crucial diagnostic tool for understanding underlying physical processes. Protostellar systems, at high angular resolution (below 100 au), exhibit complex interconnected physical processes, expanding beyond the traditional model of accreting central objects ejecting powerful jets to include compact disks, accretion streamers, shocks, and disk winds. The interplay between accretion and ejection mechanisms has a key role in

the distribution of gas and dust in the disk, influencing the chemical content inherited by forming planets. In this contribution, I will show the intricate picture at 50 au of the IRAS 4A2 protostar within the ALMA LP FAUST. This protostar hosts a compact (below 100 au) hot (above 100 K) dense (above 10^7 cm^{-3}) region rich in prebiotic complex organic molecules, and launches a large bipolar jet. The combination of high angular (scales of 50 au) and spectral resolution (below 0.5 km/s) observations with multiline radiative transfer analysis, revealed the various component of the inner regions of the system: a stratified chemical and physical structure and a wide disk wind. The Alma WSU will provide the unique combination of high angular resolution and sensitive observations with a large bandwidth at high spectral resolution that is crucial for the chemical inventory and physical characterization of planet forming regions.

Robust temperatures and luminosities of cores in 1000 high-mass cluster-forming regions with ALMAGAL

Jones, Beth [1]

[1] Universität zu Köln

The ALMA Large Program ALMAGAL has observed over 1000 high-mass star forming clumps and unveiled the many ∼1000 au embedded protostellar cores embedded. For the first time, homogeneous interferometric spectral line data at sub-km/s resolution are available toward a significant fraction of the total Galactic population of high-mass star formation sites. With great data comes great challenges, both in computational power for data handling but also in the application of state-of-the-art analysis techniques with efficiency, automation and reproducibility.
We present our spectral line fitting procedures with XCLASS to recover reliable temperatures for over 1400 protostellar cores detected in CH3CN. Whilst we converge towards obtaining reliable distributions of temperatures, luminosities and masses, our conclusions remain limited by the restricted set of transitions within the ALMAGAL bandwidth. MCMC realisations identify the degeneracies and uncertainties on the derived parameters and we demonstrate need for more comprehensive line coverage to better characterise both sources in earlier stages of evolution and the hottest inner regions of protostellar cores through vibrationally excited molecular transitions. We also present our first results from novel Machine Learning techniques to recover underlying density and temperature structures, deriving, in place of core-average properties, the observable profiles required for comparison to simulations.

3.8 Session 8

Rivers in the sky: streamers as catalysts for physical and chemical changes in protostars and disks

Valdivia Mena, Maria Teresa [1]

[1] Max Planck Institute for Extraterrestrial Physics

Streamers, infalling gaseous structures ranging from a few hundred to over 10,000 astronomical units, have been identified as a new method of supplying material to protostellar and protoplanetary disks, thanks to recent high-resolution observations with ALMA and NOEMA. To date, about 30 streamers have been discovered at various stages of star formation. However, the full impact of these "rivers in the sky" on our understanding of star and planet formation remains unclear. It is still uncertain which molecules best trace these structures, and the effects of this infall on the disk itself and its interaction with the protostar are just beginning to be investigated using high-resolution ALMA observations.
In this presentation, I'll share our most recent findings about streamers, particularly from the NOEMA large program PRODIGE. I'll discuss their impact on the physical and chemical conditions of the disk, and explore the new and exciting possibilities the ALMA WSU will open. ALMA is a critical tool for detecting these structures, and the increased bandwidth and quicker integration times will help us identify the most effective streamer-tracing molecules, examine the shocks generated at their landing sites in disks, and potentially reveal their structure in dust emission.

Revealing the gas properties of the most typical planet-forming disks

Kurtovic, Nicolas [1]

[1] Max Planck Institute for Extraterrestrial Physics

Planets are formed from the gas and dust in disks around young stars, both of which will benefit from the Wideband Sensitivity Upgrade. However, the largest limitation to analyzing the emission from these disks will continue to be the limited angular resolution and image reconstruction methods. In this talk, I will present how visibility-based techniques can efficiently recover the gas morphology and brightness temperature in compact and faint disks, where image-based techniques are unable to operate. These techniques will be crucial to optimize the recovery of information of the improved spectral scan capabilities. These results are part of Kurtovic & Pinilla (subm.)

Science drivers and technical considerations for an ALMA Focal Plane Array

Magdis, Georgios [1]

[1] DAWN

The deployment of focal plane arrays (FPAs) is a very promising approach/upgrade that can unlock ALMA's full scientific potential by exploiting its unique sensitivity and resolving capabilities to their maximum, while increasing its mapping speed and efficiency. In this talk I will discuss the main science drivers, the scientific impact and the technical considerations for this endeavor that we are currently putting together as part of the recently commenced 3-years ALMA development study: "Scientific opportunities and technical considerations for the development of ALMA focal plane arrays".

Revealing the volatile planet formation reservoir with ALMA spectral line surveys

Booth, Alice [1]

[1] Cambridge

Protoplanetary disks host the dust, gas and ice that will form new solar systems. Therefore, it is key to understand disk chemistry when considering the composition of planets and the potential habitability of these systems. Due to the line sensitivity of ALMA, we have now detected many rare isotopologues and complex organic molecules in disks for the first time. In particular, serendipitous line detections and unbiased line surveys have been key in revealing these new molecules. In this talk, I will summarize the new detections from ALMA highlighting the results from line surveys of disks around intermediate-mass stars where we can access the thermal sublimation of H2O and organic-rich ices. I will show how these disks are our best opportunity to recover the total volatile reservoir during the epoch of planet formation. In addition, I will share some first results from the ongoing unbiased 124 GHz line survey of 40 gas-rich disks with Submillimeter Array (SMA-SPEC). The WSU will revolutionize disk chemistry observations with the increase in survey speed and the observable bandwidth. This promises the detection of key isotopologues and pre-biotic molecules in disks that will enable us to fill the key gap in following the journey of volatiles from dark clouds and protostars all the way through to planets and comets.

Chapter 4

Posters

4.1 Session 2

Cosmic Rays at the ALMA sites: impact on thin gate-size electronics and radiation exposure

Baudry, Alain [1]

[1] University of Bordeaux, L.A.B.

Generation in the Earth's atmosphere of multiple secondary Cosmic Rays (CRs) impacts the (ultra)thin gate size electronics embedded in many modules of the ALMA Wideband Sensitivity Upgrade (WSU) project. Around $5.6x10^{-5}$ Single Event Upsets (SEUs) per device and hour have already been observed in the FPGAs of the current correlator. Despite advances in integration designs and configuration integrity testing in the latest FPGAs, Single Event Effects (SEEs) are expected to appear in devices that format the digital samples at the AOS antennas and, later, in the WSU correlator at the OSF. We have used our multi-applications numerical platforms to successfully compare the Software Error Rate (SER) observed in the current correlator with our simulations to extract the neutrons (dominant risk) and protons cross-sections and SER at the ALMA sites. A first, rough prediction at the level of ∼10 events per month in the 226 Agilex FPGAS (10-nm) of the WSU correlator could be closely examined with our numerical tools, including the impact of extreme Solar events. Biological cells are also impacted by the CRs. We evaluate the yearly dose exposure to be ∼4.8 mSv (AOS) and ∼1.8 mSv (OSF) with additional ambient dose up to ∼1 mSv (Solar events). We propose to deploy at the ALMA sites a compact, low power consumption, remotely operated neutron spectrometer similar to spectrometers used in Antarctica and on top of high mountains for a precise SEE analysis and space weather monitoring.

4.2 Session 3

Future of Observations in the mm/sub-mm Range: GARD's Novel Technologies for ALMA and Beyond

Joint, Fran cois [1]

[1] Chalmers University of Technology

The ALMA project has revolutionized mm and sub-mm radioastronomy, enhancing our cosmic understanding from planetary formation to the chemistry of the cosmos. GARD builds on this legacy, advancing the next generation of FIR instrumentation to extend technological limits. This presentation will show several ground-breaking technologies developed at GARD, designed to enhance sensitivity, bandwidth, and the overall observational capabilities of future radio observatories. Central to our advancements is the development of wide-bandwidth SIS mixers, which are engineered to achieve a 56% fractional bandwidth in the 211-375 GHz frequency range, effectively covering ALMA bands 6 and 7. By incorporating a metallic substrate and employing a metallic finline waveguide-to-substrate transition, these mixers are tailored to optimize the operational bandwidth of the receivers, and effectively addressing the challenges of dielectric losses. We also highlight significant advancements in the IF backend circuitry, featuring the integration of wideband superconducting bias-T alongside IF transformers and hybrid circuits. The hybrid circuits employ parallel plate coupled line couplers, enabling operation across a broad frequency range from 4 to 20 GHz. Finally, we showcase a quasi-optic, scalable dichroic mirror, initially designed for the Q-band (35-55 GHz) and potentially extendable to THz frequencies. We are exploring 3D printing technology for its manufacturing.

4.3 Session 4

The ALMA 2030 Data Challenges - preparing the user community and the ARCs for the future

Toribio, Carmen [1]

[1] Chalmers University of Technology

As the ALMA Wideband Sensitivity Upgrade (WSU) gets implemented, the most obvious impact for users will be the amount of data delivered by the telescope. There will be the need to automatise the scientific analysis of ALMA data as much as possible and have the computing resources ready for the task. The user community needs to prepare to process future datasets, and the ALMA Regional Centres (ARCs) to provide the necessary support and computing resources for them.
Inspired by the SKA Observatory Data Challenges, in this poster we would like to propose to carry out the ALMA2030 Data Challenges. In participating, the goal for the scientists will be to carry out the scientific analysis of the challenge datasets. The goal for the ARCs will be to prepare their infrastructures to support participants in the challenges. Ideally, one would need to establish different challenges for the variety of ALMA science cases by mimicking ALMA data products in the post-WSU era. To make this a useful exercise and prepare suitable data challenges, we will use this poster to survey the ALMA community on the future needs for the different scientific cases and the interest in participating in them.

4.4 Session 5

Impact of WSU on Spectral Index Determination and Calibration Methods

Tafoya, Daniel [1]

[1] Chalmers University of Technology

Impact of WSU on Spectral Index Determination and Calibration Methods Poster abstract: The Wideband Sensitivity Upgrade (WSU) promises to revolutionise ALMA's performance, particularly enhancing spectral index (alpha) determination and expanding calibration strategies. This poster highlights the significant advancements introduced by the WSU, focusing on its impact on the precision of alpha measurements and the calibration methods.
The expanded frequency range and the wider bandwidth provided by the WSU will be instrumental in reducing the uncertainty of alpha measurements, which introduces a new realm of flux calibration possibilities. Also, the larger continuum bandwidth in ALMA observations raises the SNR of calibrator gain solutions, enabling the use of fainter, closer quasars as phase calibrators. This is especially beneficial in high-frequency (HF) bands, where accuracy in phase transfer is critical due to larger relative antenna position errors. Moreover, the increased SNR allows for more precise calibration of narrow spectral windows, providing greater resilience against instrumental drifts. It also opens up the potential for shorter calibration cycles, reducing residual phase errors, particularly important for long baseline and HF observations.
Lastly, the WSU's broader bandwidth makes continuum self-calibration feasible for a larger number of science targets, significantly mitigating residual antenna position errors even when the SNR is low. This represents a major step forward in achieving higher accuracy and efficiency in astronomical research.

ALMA PI science with subarrays - Making ALMA observations post WSU even more efficient

König, Sabine [1]

[1] Chalmers University of Technology

The Wide Sensitivity Upgrade (WSU) project for ALMA will increase the sensitivity of observations with larger instantaneous spectral bandwidths, improved receiver performances, and better correlator quantization. However, certain aspects of ALMA observations post WSU could even further be improved by implementing a sub-array observing mode for PI science - simultaneous observations using subgroups of antennas of the ALMA main array. The impact of such an observing mode would be particularly strong on multi-wavelength studies, the investigation of transient phenomena, and time domain astronomy, as well as coordinated observations with other facilities. This poster will present some typical science cases and specific programs that could benefit from a PI sub-array observing mode, with a potential for further increasing the efficiency of ALMA observations in the post-WSU era.

4.5 Session 7

InGaAs mHEMT MMIC Technology for Low Noise Amplifiers in Radio Astronomy

Pütz, Patrick [1]

[1] Max Planck Institute for Radio Astronomy

4.6 Session 8

Broadband observations at 3mm: The role of the environment on star- and disk-formation

Pineda, Jaime E. [1]

[1] MPE

The star- and disk-formation process involves balancing gravity, turbulence, and magnetic fields. Turbulence and magnetic fields attempt to slow down the gravitational collapse. Thanks to high-angular resolution interferometric observations, much progress has been made in studying the disk properties. Unfortunately, little progress has been made in understanding the role of the environment in the formation and evolution of star- and disks.
I present NOMEA observations at 3mm. Thanks to the instantaneous 16 GHz bandwidth, we carry out different goals simultaneously. I will show the results of three different aspects enabled by these observations: (1) the first systematic estimate of the number of streamers on embedded protostars, (2) the first large-scale cosmic ray ionization rate and electron fraction maps, and (3) a determination of the power spectrum of turbulence over more than 2-orders of magnitude for ions and neutrals down to the ambipolar diffusion scale. These results show that (1) the delivery of mass down to disk scales is highly asymmetric, with streamers playing an important role, (2) clear evidence for locally generated cosmic rays which will affect the coupling between magnetic fields and gas, and (3) we show a clear power-law behavior down to mpc scales but without evidence for the ambipolar diffusion scale.
These results show the power of broadband observations to explore the role of the environment in star- and disk-formation, which will be enabled by WSU