

SFDE 2025

Book of Abstracts

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Abe, Daisei

Institution: Tohoku University

Growth of Massive Molecular Cloud Filament by Accretion Flows: New Mechanism to Support a Supercritical Filament against Radial Collapse

Observations indicate that dense molecular filamentary clouds are sites of present-day star formation. The filament width determines the most unstable scale for self-gravitational fragmentation and influences the stellar mass. Therefore, constraining the evolution of filaments and the origin of their properties is important for understanding star formation. Although some observations show a universal width of 0.1 pc, many theoretical studies predict the contraction of thermally supercritical filaments ($> 17 M_{\text{sun}} \text{ pc}^{-1}$) due to radial collapse. Through non-ideal magnetohydrodynamics simulations with ambipolar diffusion, we explore the formation and evolution of filaments via slow-shock instability at the front of accretion flows. We reveal that ambipolar diffusion allows the gas in the filament to flow across the magnetic fields around the shock front, forming dense blobs behind the concave points of the shock front. The blobs transfer momentum that drives internal turbulence. We name this mechanism the "STORM" (Slow-shock-mediated Turbulent flow Reinforced by Magnetic diffusion). The persistence and efficiency of the turbulence inside the filament are driven by the magnetic field and the ambipolar diffusion effect, respectively. The STORM mechanism can determine the internal turbulent structure of the filament and sustain its width even when the filament reaches very large line masses ($\sim 100 M_{\text{sun}} \text{ pc}^{-1}$).

Alexandr, Volvach

Institution: Radio Astronomy Laboratory CrAO

Kilomaser W51M as massive binary star system

W51 is located in the Giant Molecular Cloud of the Sagittarius spiral arm of the Milky Way. Among the giant molecular clouds, this is one of the few with a mass of more than 10^6 Mo. When mapping in a continuous spectrum, W 51 has a complex structure. High-resolution sub-arcsecond observations revealed three separate components: W51 IRS1, W51 Main, and W51 IRS2. For the first time in the World in the entire history of observations, a super powerful phenomenon of a water maser with amplitude of 140 kJy recorded in W 51 Main. According to the characteristics of the flare phenomenon obtained by us, W51 Main falls into the rank of kilomasers along with such an outstanding one as W49N. New parameters of water masers and the most important physical conclusions have obtained. The possibility of detecting gravitational waves from massive binary stars at the stage of evolution close to merging is considered for the case of W51 Main. An important conclusion obtained that galactic close massive star systems are promising for detecting gravitational waves from them in the range $\sim 10^{-6} - 10^{-7}$ Hz.

ANDRÉ, Philippe

Institution: CEA Paris-Saclay

The role of molecular filaments in star formation and the origin of the IMF

I will discuss insights into the origin of the stellar IMF based on a systematic census of prestellar cores and molecular filaments in nearby clouds taken as part of the Herschel Gould Belt survey, as well as higher-resolution observations with APEX/ArTéMiS, ALMA, and JWST. Our results point to the key role of the quasi-universal filamentary structure pervading molecular clouds. They suggest that the dense cores making up the peak of the prestellar core mass function (CMF) - and indirectly the peak of the IMF - result from gravitational fragmentation of molecular filaments near the critical mass per unit length. The Salpeter power-law tail of the CMF/IMF may be inherited from the filament line mass function (FLMF), which is observed to follow a Salpeter-like power law in the regime of thermally supercritical filaments. Overall, our observational findings support a filament paradigm for star formation and the IMF.

Arzoumanian, Doris

Kyushu Univ.

Evolution of magnetized hub-filament systems: Formation of star-clusters with low- to high-mass stars

Ballesteros-Paredes, Javier

Institution: Instituto de Radioastronomía y Astrofísica, UNAM, Campus morelia

Gravity or turbulence? The energy budget of molecular clouds and the star formation law

In this talk I will discuss the pros and cons of the collapse and the turbulent model of molecular cloud dynamics and star formation, and what exactly the molecular clouds' energy budget tells us; whether gravitational forces dominate over other sources of momentum, and what are the implications of the energy budget on the efficiency and rate of star formation. I will also show that the low values and the constancy of the "efficiency per free-fall time" arise naturally when clouds collapse. Our results imply that stellar feedback is the crucial ingredient to halt star formation, keeping the gas depletion time low on galactic levels. I will also show that the kinematic properties of young stars observed with Gaia are consistent with them being born from collapsing clouds rather than clouds supported by turbulence.

Bao, Truong

Institution: Korea Astronomy and Space Science Institute

Probing 3D B-fields using dust polarization and grain alignment theory

Magnetic fields (B-fields) are ubiquitous in the Universe and are thought to play an important role in various astrophysical processes. The polarization of starlight absorption and thermal emission induced by magnetically aligned grains is widely used to measure the two-dimensional magnetic field projected onto the plane-of-sky (POS); however, its component along the line of sight (LOS) is not yet constrained. In this talk, I introduce our new method to infer three-dimensional (3D) B-fields using starlight and thermal dust polarization combined with the modern magnetically enhanced radiative torque (MRAT) alignment theory and the effect of magnetic turbulence. We first perform synthetic observations of dust polarization of magnetohydrodynamic (MHD) simulations of a filamentary cloud with our updated POLARIS code, incorporating the modern MRAT theory. We test the new technique with synthetic observations and find that the B-field inclination angles with respect to the LOS can be accurately constrained by the synthetic starlight polarization efficiency or thermal dust polarization degree once the effects of grain alignment by MRAT, dust properties, and B-field fluctuations are well characterized. Compared to the true 3D magnetic fields, the new technique based on grain alignment physics is more accurate than the previous methods that assume uniform grain alignment. Our new technique unlocks the full potential of tracing 3D B-fields and constraining dust properties and grain alignment physics on multiple scales of the diffuse interstellar medium and star-forming regions using multi-wavelength polarimetric observations.

Barquero Alvarado, Joshua

Institution: University of Duisburg-Essen

Impact of magnetically-driven jets and radiative feedback on the formation of massive stars

Feedback from massive stars is a significant component in the evolution of giant molecular clouds. It combines several physical processes like the formation of magnetically-driven jets, irradiation and photoionization which are capable to restrain its growth and final mass. In this work, we include the MHD jet contribution self-consistently while including radiative forces and photoionization. Our objective is to understand the function that these feedback effects have on the outcome of the formation process while observing the physical mechanisms governing the disk and the low-density cavity.

To achieve this, we utilize the state-of-the-art code PLUTO, which solves the equations of non-ideal magnetohydrodynamics, with the addition of specialized modules for self-gravity, radiation transport and photoionization. We ran a set of simulations considering different stellar feedback effects switched on. All simulations start from the gravitational collapse of a molecular cloud of $100 M_{\odot}$, followed by the formation of an accretion disk and the self-consistent launch of magnetically-driven outflows. The stellar feedback effects are driven according to the stellar evolution tracks by Hosokawa & Omukai (2009). We stopped our simulations when accretion becomes negligible or the accretion disk is pushed away from the computational domain.

At early times, magnetically-driven outflows limit the stellar growth, while radiation and photoionization dominate at later times, after the star has reached the zero-age sequence. Radiation forces restrain the gravitational infall toward the disk, affect its gravito-centrifugal equilibrium, increase the outflow and completely halt accretion, resulting in a approximately $45 M_{\odot}$ star after 100 kyr of evolution. While photoionization shapes the bipolar outflow cavity, its addition did not significantly alter the final mass of the star but increases its accretion time by 20 kyr. In contrast, in simulations that do not include irradiation forces, accretion continues until later on and the star reaches a mass of $75 M_{\odot}$.

Benedettini, Milena

Institution: INAF -IAPS

A catalog of protostars and Young Stellar Objects in Perseus derived from Herschel far-infrared maps.

We present a catalog of protostars and Young Stellar Objects (YSOs) in the Perseus star forming region, observed in six far-infrared continuum maps produced by the PACS and SPIRE instruments on-board the Herschel satellite at 70, 100, 160, 250, 350 and 500 microns. The Herschel instruments are particularly sensitive to protostars in the younger evolutionary stages, namely Class 0 and I, still embedded in a robust dusty envelope responsible for the FIR emission and to evolved YSOs with transitional disks, that are optically thick and gas-rich protoplanetary disks with astronomical unit-scale inner disk clearings or radial gaps. However, they can miss the most tenuous, evolved YSOs, Class II and Class III of which the envelopes have started to dissipate.

To fully characterize the sources, we performed a simultaneous source detection and flux measurement in the six Herschel maps plus data from Spitzer at 24 micron, Scuba at 450 and 850 micron and Bolocam at 1100 micron. We then complemented the measured fluxes with available catalogs, to build an as-complete-as-possible SED covering a large spectral range, from optical to millimeter.

We will show a few examples of how the observed SEDs can be fitted with a grid of synthetic SEDs to gauge the possible presence around the protostar and characterize the three key components of the early phase of low-mass star formation: the envelope, the bipolar cavity opened by the outflow, and the disk, whose relevance changes during the evolutionary process, from the youngest deeply embedded protostars with powerful outflows to the pre-main-sequence stars with little or no disk and envelope contribution.

Benedettini, Milena

Institution: INAF - IAPS

Velocity structures in the ALMAGAL fields

The ALMAGAL large project observed 1013 candidate sites of high-mass star formation in the Galactic Plane with ALMA in continuum and lines around 1.4 mm. We investigated the kinematic state of the dense gas in the ALMAGAL fields by studying the correlation among the velocity of the structures: from the spatial scale of tenths of parsec to a thousand of au. We analyzed several molecular lines that probe dense gas at different levels of particle density (critical density of transitions from 5000 cm^{-3} to 5000000 cm^{-3}) and temperature (temperature of the upper level of transitions from 16 K to 131 K), extracting spectra averaged over several spatial scales. Remarkably, the ALMAGAL data provide the largest homogeneous and statistically significant sample of high-density gas tracer lines in high-mass star-forming sites ever observed.

At the clump scale, we identified the kinematically coherent, extended structures of gas present in each ALMAGAL field and estimated their size and average velocity. We identified the highest density component of gas in each field and measured their average velocity at the local standard of rest (vlsr), from which we derived the distance of the high-mass clump. We find that the velocity field of dense gas in high-mass star-forming clumps is an intricate web of components that sometimes overlap along the same line of sight.

At the core scale, we extracted average spectra of molecular lines on the footprint of the ALMAGAL cores and derived vlsr and a crude indicator of the core temperature. These small fragments inherit the velocity of the intra-clump material, within a few km/s, with only a few of them that may be dynamically perturbed.

We will present the results of our analysis and discuss them in the context of high-mass star formation theories.

Bisbas, Thomas

Institution: Research Center for Astronomical Computing, Zhejiang Lab

High-resolution 3D Astrochemical Simulations of Photodissociation Regions Across Diverse Environments

Photodissociation regions (PDRs) serve as critical interfaces between the ionized and molecular phases of the interstellar medium (ISM), hosting a complex interplay of chemical and physical processes. Using the advanced ray-tracing algorithm RAYTHEIA in the upgraded 3D-PDR code, we present the highest-resolution three-dimensional astrochemical simulations to date of a star-forming region, exploring its response to varying cosmic-ray ionization rates, FUV radiation fields, and metallicities (including different C/O and dust-to-gas ratios). Our study focuses on two key processes: the HI-to-H₂ transition and the C⁺/C/CO cycle, quantifying how their diagnostic emission lines evolve with ISM conditions. We generate synthetic observations of key tracers—including [CII] 158μm, both [CI] fine-structure lines, and the CO rotational ladder—and investigate how metallicity influences the CO-to-H₂ and [CI]-to-H₂ conversion factors. In low-metallicity ISM characterized by low C/O ratios, CO, C and C⁺ all decrease in both abundances and emission, though with differential biases. The low-J CO emission is found to be the most stable tracer for the molecular gas, while C and C⁺ trace H₂ gas only under limited conditions, in line with recent discoveries of [CI]-dark galaxies. Our results provide new insights into the environmental dependence of molecular cloud chemistry and offer essential constraints for interpreting observations of star-forming regions across cosmic time.

Brugaletta, Vittoria

Institution: University of Cologne

SILCC – IX. The multi-phase interstellar medium at low metallicity

Low-metallicity environments, characterized by inefficient cooling and low dust-to-gas ratios, exhibit reduced photoelectric (PE) heating compared to the solar neighborhood, where PE heating is a dominant process in the warm neutral interstellar medium (ISM). To investigate how metallicity (Z) affects the ISM's structure, evolution, and star formation, we present magnetohydrodynamic simulations of stratified ISM patches with metallicities ranging from $1/50 Z_{\odot}$ to $Z_{\odot}$ as part of the SILCC project.

Our simulations incorporate non-equilibrium chemistry, heating, and cooling of the ISM, as well as anisotropic cosmic ray (CR) transport and stellar feedback, including far-UV and ionizing radiation, stellar winds, supernovae, and CR injection. We introduce a novel model for calculating the CR heating rate, which is spatially and temporally variable, allowing us to directly compare the roles of PE and CR heating in the metal-poor ISM.

Our results show that CR heating becomes more dominant than PE heating at lower metallicities. We also find that the amount of cold and molecular gas decreases with decreasing metallicity, and that the low-metallicity gas forms less dense, larger, and more diffuse structures, while maintaining similar mass to those in higher-metallicity environments. These structural differences influence star formation and mass outflow rates, which remain relatively unchanged for $Z > 0.1 Z_{\odot}$ but decrease dramatically for $Z < 0.1 Z_{\odot}$. Despite these changes, we observe no significant alterations in the overall thermal structure of the ISM across the metallicity range.

Chetanil, Rishi

Institution: Aryabhata Research Institute Of Observational Sciences

Radiative Feedback and Cloud-Cloud Collisions as Precursors for Triggered Star Formation.

Star-forming regions (SFRs) are ideal for studying the characteristics of young stellar populations, such as their age, mass accretion rates, and other properties. These investigations become even more intriguing when the molecular cloud, where star formation may occur, is influenced by external factors like radiation. Massive stars, whether located within the cloud or at a distance, can significantly affect the cloud, potentially altering the star formation efficiency or rate, the cloud's structure and dynamics, and even the behaviour of the young stellar objects (YSOs).

We focused on bright-rimmed clouds (BRCs), the remnant clouds illuminated by nearby massive stars, and the YSOs embedded within these clouds. Here, we present the multi-wavelength analyses of BRC 44 utilising optical and near-infrared observations from the 3.6m Devasthal Optical Telescope (DOT), mid-infrared data from the Spitzer, and millimeter CO data from the Purple Mountain Observatory.

The stellar properties are analysed using optical and infrared data through spectral energy distribution (SED) fitting, spectroscopy, and color-magnitude diagrams. Meanwhile, the cloud's structure and dynamics are studied using CO data. In addition to radiative feedback, Cloud-Cloud Collisions (CCC) is an important mechanism that facilitates star formation, particularly massive star formation, as CCC is a progenitor for hub filament structures. We investigate the CCC scenario in the Sh2-140 region, southwest of BRC 44, using Herschel SPIRE and PACS data in conjunction with millimeter data to examine CCC, filament formation, and the young stellar objects that may arise from this mechanism.

Camacho, Vianey

Institution: National Taiwan Normal University, Center of Astronomy and Gravitation

Tracing cloud dynamics through stellar kinematics

The kinematics of young stellar clusters preserve key signatures of the dynamical state of their parent molecular clouds. Using simulations and observations of regions such as Orion and the Lagoon Nebula, we find that clusters formed in collapsing, gravity-dominated environments exhibit constant stellar velocity dispersions, consistent with expectations from violent relaxation. In contrast, clusters forming in turbulence-supported clouds display a different signature: massive stars attain higher velocity dispersions than their lower-mass counterparts. We interpret this behavior as a consequence of accretion-driven gravitational tightening, where massive stars form preferentially in denser, more interactive regions, leading to enhanced mass growth and dynamical encounters that increase their velocities. Meanwhile, low-mass stars, forming in less crowded environments, remain more dynamically quiescent. These results emphasize that the early dynamical imprint of the cloud, whether dominated by gravity or turbulence, can be traced in the emerging stellar populations.

Carini, Roberta

Institution: INAF-OAR

Elemental abundances of young stellar objects in nearby star forming regions

Understanding the chemical abundances of members in star-forming regions (SFRs) is essential for constraining models of star formation and early stellar evolution as well as planet formation.

In this work, I present a detailed abundance analysis of lithium (Li) and barium (Ba) in pre-main sequence (PMS) stars located in six nearby SFRs: Chamaeleon I, epsilon-Cha, Lupus, Orion OB1, sigma-Orionis and Taurus.

The data were obtained as part of the PENELLOPE Large Programme, that complements the ULLYSES legacy programme on the Hubble Space Telescope by providing ground-based - VLT- optical and near infrared spectroscopy of more than 80 low-mass young stars, using high-resolution spectroscopy ($R > 70000$) with UVES or ESPRESSO, and medium- resolution (R between 10000 - 20000) spectroscopy with X-Shooter.

I analyzed the spectra of 50 sources of low-mass (K- and early M-type), using a homogeneous and self-consistent analysis pipeline. The use of uniformly reduced and analyzed data is essential to minimize systematics and allow meaningful comparisons across different star-forming regions.

I measured the strength of the lithium line at $6707.8 \text{ \AA}$ and derived the abundance of this element through equivalent width measurements and curves of growth. For the 12 class III stars I also derived barium abundances using the spectral synthesis method.

Since Lithium abundances is an age indicator in young stars, I determined the age of each SFR too, showing how it is relevant to include the determination of the veiling.

Cavalcante-Coelho, Yasmin

Institution: KNU/ Valongo Observatory

Different roads to bar growth: multiple pathways across galaxy masses?

Bars are elongated structures common in spiral galaxies and are important agents of secular evolution. We present a GALFITM multi-band mid-infrared 2D decomposition of 344 barred galaxies from the Spitzer Survey of Stellar Structure in Galaxies to infer the stellar mass associated with each structural component (i.e., disk, bulge, bar) and investigate how bar properties correlate with global galaxy characteristics. We find that the bar-to-total mass ratio is higher in more massive galaxies with prominent bulges. With Sérsic indices below 2, these bulges are consistent with photometric signatures of nuclear disks, coherent with the scenario that nuclear disks form and grow from bar-driven gas inflows. Together with a low bar fraction ($\sim 38\%$) in low-mass galaxies, these findings support a scenario in which bar formation and growth are actively occurring in lower-mass systems. We also find that – in contrast to the bar mass – the bar length does not follow a single linear trend with galaxy mass. In the massive end, the more massive a galaxy, the longer the bar; on the lower-mass end ($M^* < 10^{10} M_{\odot}$) bars remain approximately constant in size, resulting in longer bars than expected from the trend at the massive end. The tidal formation of bars in these lower mass systems, where environmental effects are expected to be more significant, may be an alternative bar formation scenario, distinct from the bar gravitational instability expected in higher-mass systems. A wide variety of bar mid-IR colors at the lower galaxy-mass end, extending to bar colors redder than their massive counterparts, points to a greater diversity in star forming activity in these low-mass systems. Altogether, these results indicate differences in how bars grow (in length and mass content) and in how they impact star formation activity in low- and high-mass galaxies, potentially shaped by environmental factors.

Chen, Vivien

Institution: Institute of Astronomy, National Tsing Hua University

Forming OB protostars in a highly structured rotating toroid with spiral filaments

Using ALMA, we have resolved molecular line and dust continuum emissions around the forming O-type protostar, IRAS 18089-1732, with angular resolutions ~ 50 mas (~ 120 au) in Band 6. This luminous (1.3×10^4 Lsun) hot molecular core is embedded in a large rotating toroid with spiral filaments, wherein two compact cores (fragments) form as potential seeds for stellar companions. Multiple transitions of CH₃CN and CH₃OH allow us to assess the physical conditions for the observed fragmentation. At a lower resolution of 0.3", magnetic fields appear controlled by rotation and present spiral-like morphology resembling a whirlpool. We will discuss the properties of this highly structured rotating accretion flow and the role of spiral filaments in forming a protocluster with O-type stars.

Chuang, Tsung-Han

Institution: National Taiwan Normal University

Modeling Streamer Structures in Collapsing Prestellar Cores

Streamers have been observed with high-resolution ALMA observations around many protoplanetary disks undergoing formation. They have been suggested to dominate the mass accretion budget from the collapsing prestellar core, and have important consequences on the disk dynamics. Understanding the formation of streamers is therefore important for explaining how protoplanetary disks receive mass from the envelope. We propose a model to explain the formation of streamer structures by considering density enhancements due to gravitational instability. We test our model against sources where streamers have been detected (ex. Per-emb-2 and Per-emb-50 observed with NOEMA) and fit for model parameters. This allows us to gain deeper insights into the physical origin of streamers and their role in mass transport from the core to the disk. This model can be applied to analyze new observations as well as archival data that show signs of streamers.

Cosentino, Giuliana

Institution: Institut de Radioastronomie Millimetrique (IRAM)

Feedback from Supernova Remnants in Molecular Clouds: How Shocks May Trigger Star Formation

Supernova remnants (SNRs) may drive large-scale low-velocity shocks that enhance the density of the surrounding Interstellar Medium (ISM). At the same time, they may also inject vast amounts of energy and momentum that perturb and disperse the ISM. This dynamic interplay may be crucial in regulating star formation within molecular clouds, yet direct observational evidence remains limited. In this talk, I will present our work addressing this gap through high-angular-resolution observations with ALMA. We focus on the large-scale shock driven by the SNR W44 into the molecular cloud G034.77–00.55. Traced by Silicon Monoxide (SiO) emission, the shock enhances the gas density to levels compatible with those required to ignite even massive star formation. At the shock interface, the dense, post-shocked material is organised into core-like structures that have properties of mass, density, size and viral state similar to those reported for cold cores in other star-forming regions. Furthermore, this post-shocked gas exhibits high levels of deuterium fractionation (up to 0.1) measured from N_2H^+ and N_2D^+ , and comparable to those typically measured in starless and pre-stellar cores. During the talk, I will also briefly introduce SHREC (SHock interactions between supernova REmnants and molecular Clouds), our large single-dish survey targeting SiO and H^{13}CO^+ toward ~ 30 SNRs known to interact with nearby molecular clouds. I will highlight the goals and technical design of the project and share first results from SNR IC443. At the interface between IC443 and clump G, we detect shocked gas with a mass of ~ 100 solar masses, where the density is enhanced by more than an order of magnitude—reaching values expected for triggering star formation. Our results suggest that SNR-driven shocks not only disrupt the ISM but may also locally promote conditions necessary for star formation.

Das, Indrani

Institution: Academia Sinica Institute of Astronomy and Astrophysics

How Does a Protostar Form by Magnetized Gravitational Collapse?

Star formation through the dynamical magnetized collapse remains an active area of astrophysical research. We carry out a comprehensive exploration on the magnetized gravitational collapse of a non-rotating self-gravitating initially spherically symmetric prestellar core using two-dimensional nonideal magnetohydrodynamic simulations incorporating ambipolar diffusion and Ohmic dissipation. Our study encompasses a broader range of equations of state (EOSs) in the form of $P(\rho) \propto \rho^{\Gamma}$, with the aim of constraining the choice of EOSs for allowing star formation. Our results reveal that the collapse with a Γ no stiffer than $4/3$, complemented by magnetized virial theorem, allows the dynamical contraction of the prestellar core to happen continuously where a central point mass forms and steadily builds up its mass from the infalling envelope, with a mass accretion rate of the order of $\dot{M}_{\text{c}} \sim \dot{M}_{\text{env}}/3$. The choice of an isothermal EOS most naturally facilitates the collapse as a magnetic analog of the inside-out collapse. In addition to that, our study exhibits that the nonisothermal magnetized collapse models with a Γ no stiffer than $4/3$ qualitatively demonstrate similar infall features to those of an isothermal EOS. Furthermore, the collapse models with a Γ stiffer than $4/3$ fail to ensure the sufficient cooling to allow the direct mass growth of the central point mass, thus delaying the infall. Our work can offer deeper insights in understanding the significance of EOSs on the magnetized gravitational collapse, enabling star formation.

de Isídio, Natanael

Institution: ESO, Garching

Probing galaxy quenching with IFS and simulations: Disentangling environmental and internal drivers

Satellites account for $\sim 50\%$ of nearby galaxies ($z < 0.2$) and dominate the quenched population below $\sim 10^{10.8} M_\odot$. For the first time, using robust statistics spanning isolated, group, and cluster galaxies, this work quantifies the relative roles of starvation, gas stripping, and AGN feedback in quenching galaxies. In this talk, I will present a statistically robust sample of ~ 5000 galaxies from the MaNGA survey, combining optical IFU data with deep atomic hydrogen (HI) observations to measure cold gas fractions. Using the `kinemetry` package, we compute and analyse kinematic asymmetries in both stellar and nebular gas velocity maps. These asymmetries serve as key diagnostics, as different quenching mechanisms imprint distinct kinematic signatures: starvation primarily depletes the gas reservoir, while gas stripping perturbs both the gaseous and stellar components. AGN feedback, however, is expected to affect only the gaseous kinematics. Our results reveal that starvation is ubiquitous (affecting $\sim 80\%$ of galaxies) and plays a major role in quenching both satellites and centrals across all stellar masses. Notably, only 16% of quenched galaxies exhibit stellar asymmetries, suggesting that the dominant quenching mechanisms do not strongly perturb stellar structure. To further validate these findings, we compare our observations with two hydrodynamical simulations (TNG50-1 and Magneticum), analysing over 10000 mock galaxies. By tracking cold gas fractions, X-ray luminosity, and satellite infall times, we find striking consistency between simulations and observations. Even in high-resolution simulations, asymmetric satellites are rare in the "satellite region" of the $M_\star$ -SFR plane, further supporting our main conclusions.

Duran Camacho, Eva

Institution: Instituto de Astrofísica de Canarias (IAC)

Modelling the Milky Way structure: impact on stellar and gaseous dynamics

With the goal of investigating the role of the Galaxy's large-scale dynamics on star formation, we use the hydrodynamical AREPO moving-mesh code to perform simulations of the Milky Way. Our models include a live stellar disc and bulge, a live dark matter halo, and a gaseous disc—evolved self-consistently with no fixed potentials and under isothermal equations of state.

We compare our results with 12CO and HI observations of the Milky Way by generating longitude-velocity diagrams of the projected gas surface densities. From these, we extract the skeletons of key features (spiral arms, bar) and terminal velocity contours, which we compare to observations via several diagnostic tools. Combining these, we identify a model that best reproduces the Milky Way's main features. This model shows multiple transient spiral arms and an inner bar. The gas dynamics reveal a central “butterfly” pattern in radial velocity, characteristic of spiral galaxies, as well as clear streaming motions around spiral arms.

This best-fit model serves as the base for simulations including more detailed ISM physics (e.g. chemistry, star formation, feedback) to study how star formation is regulated in the Milky Way. In this talk, I will highlight the need for tailored dynamical models like this for interpreting Galactic-scale star formation. I will present results on the kinematics of gas and stars, and compare them to the latest Gaia DR3 findings—demonstrating the synergy between cutting-edge simulations and observational data in the Gaia era.

Elbakyan, Vardan

Institution: University of Duisburg-Essen

Episodic Accretion in High-Mass Stars: Mechanisms and Observational Implications

High-mass young stellar objects (HMYSOs) exhibit episodic accretion bursts that significantly influence their evolution and feedback on their surroundings. Recent advancements in numerical simulations and observations have uncovered diverse mechanisms driving these bursts, ranging from thermal instabilities (TI) and magnetorotational instabilities (MRI) to gravitational fragmentation and planet disruption events. In this talk, I will present a synthesis of results from 1D and 3D simulations, highlighting the role of TI in shaping long-duration bursts and the critical contribution of planet disruption in explaining short, intense bursts observed in HMYSOs. I will discuss how accretion bursts impact circumstellar disc dynamics, stellar evolution, and feedback processes, including episodic outflows and ionizing radiation. Furthermore, I will address the limitations of current models in reproducing the full spectrum of observed bursts and outline future directions, including multi-dimensional modeling and improved observational constraints, to bridge the gap between theory and observations. This exploration provides new insights into the episodic nature of accretion across stellar masses, with implications for star formation and the evolution of protoplanetary environments.

Federman, Sam

Institution: INAF Osservatorio Astronomico di Capodimonte

Protostellar Jet Morphology, Kinematics, and Physical Conditions: Insights from JWST and VLT

Outflows of collimated jets and wide-angle winds are powered by and drive protostellar accretion, removing angular momentum from the system and allowing material to flow onto the central star. Such outflows limit the final mass of the forming star and eject mass and momentum far out into the surrounding environment, limiting star formation rates in molecular clouds and contributing to the shape of the IMF. With the integral field units on JWST and the VLT, we are now able to probe the inner regions of outflows from deeply embedded and extinguished protostars within 1000 au of the central protostar.

The larger field of view and wavelength coverage of JWST NIRSpec+MIRI MRS (3-28 microns), with an angular resolution of 0.2-0.4", is perfectly complemented by the higher spectral resolution ($R \sim 11,000$) and comparable angular resolution of VLT-ERIS. With these data we have examined the morphology and kinematics of the collimated jets of protostars from the IPA, HEFE, and JOYS+ programs. The jets, traced chiefly by shock-ionized lines of [Fe II], show shocked knots that are evidence of variations in the outflow with launching timescales of a few decades. The jets also show wiggles, possibly due to precession of the inner disk from which the jet is launched, as well as larger-scale bends and kinks. The jets widen with distance, and there are several examples of asymmetries between the blue- and red-shifted jets from a single source. Using the radial velocities to construct PV diagrams, we find that the jets accelerate to ~ 150 -200 km/s within a few hundred au of the central protostar. With the higher spectral resolution of ERIS, we find tentative evidence of jet rotation. Finally, we examine the physical conditions of the jets by fitting shock models to ratios of shocked ionic emission lines.

Flores, Christian

Institution: Academia Sinica, Institute of Astronomy and Astrophysics

Unveiling Protostellar Evolution Through Infrared and (sub)Millimeter Observations

Unveiling the early stages of stellar formation is essential for building a complete picture of how stars and planetary systems emerge and evolve. Yet, this remains one of the most challenging frontiers in the field, as it requires disentangling complex structures—such as envelopes, disks, and central protostars—across a wide range of spatial and spectral scales.

In this talk, I will present a pioneering multi-scale, multi-wavelength approach that combines infrared spectroscopic observations of protostellar sources, single-dish envelope characterization from JCMT, and ALMA observations of protoplanetary disks. This method allows us to simultaneously probe the key components of protostellar systems in a sample of ~ 30 young sources.

Spanning infrared to millimeter wavelengths, this strategy enables us to derive essential properties—including the masses of the protostar, disk, and envelope; the protostellar temperature, rotation rate, radius, and magnetic field strength—while also placing sources in chronological order. Crucially, it offers a way to test a variety of stellar evolutionary models during the deeply embedded phases, where observational constraints remain scarce.

This integrated observational framework allows us to connect theory with observation in the earliest stages of star formation. As next-generation thirty-meter-class facilities come online, this approach will become increasingly powerful in revealing the processes that shape stars and their surrounding environments from the very beginning.

Fukihara, Haruka

Institution: Kagoshima University

Impact of dust evolution on B-field diffusion in molecular cloud

Dust grains in molecular clouds play a critical role in regulating the ionization degree of gas and the coupling between gas and magnetic fields, primarily by adsorbing charged particles. The degree of the coupling, known as ambipolar diffusion, can be quantified by measuring the drift velocity between ions and neutral gas particles. Observations by Pineda et al. (2021) revealed a drift velocity of approximately 100 m/s in a filamentary molecular cloud using NH_3 and N_2H^+ lines, suggesting constraints on the magnetic field strength, ionization degree, and dust grain properties.

In this study, we explored whether the observed drift velocity can be explained using a standard MRN dust size distribution or if dust evolution is necessary. To do this, we combined a dust evolution model—including accretion and coagulation—with a chemical network to calculate the ambipolar diffusion strength and resulting drift velocity. Our calculations indicate that micron-sized dust grains are essential to reproduce the observed drift velocity at cloud core scales.

However, the required dust growth to micron size within cores would take 3–10 free-fall times (tff), while cores are expected to collapse within only 1–2 tff. Therefore, such growth is unlikely to occur within the core itself. Alternatively, we found that dust grains can grow to 1 μm during the earlier filament stage, where longer lifetimes (1–3 tff) and trans- or supersonic turbulence enhance dust coagulation.

These findings support a scenario in which dust grains grow before core formation—during the filamentary phase—thereby enabling ambipolar diffusion in the later core phase. We will also discuss how our model aligns with observational estimates of cosmic-ray ionization rates and magnetic field strengths.

Girart, Josep Miquel

Institution: Institut de Ciències de l'Espai (ICE), CSIC / IEEC

The ALMA view of Magnetized Star Formation

In this talk, I will review the present status of the studies, based on the dust polarization, of the role of magnetic fields around protostars. The sensitivity and image fidelity of ALMA has allowed carrying out detail studies over several tens of low and high mass star forming regions. In particular, I will present the results of BOPS and MagMaR. BOPS (B-field Orion Protostellar Survey) studied 61 protostars in Orion. This large sample has allowed to characterize the dust polarization properties. The dust polarization of 16 of the protostars arise from self-scattering, probably from the protoplanetary disks. For the rest of the sample, the dust polarization traces the magnetic field from the dense envelope. We make a classification based on the morphology of the magnetic fields. MagMaR (Magnetic Fields in Massive Star-forming Regions) selected around 30 high mass star forming regions.

Haugboelle, Troels

Institution: Niels Bohr Institute, University of Copenhagen

Late infall and accretion rejuvenating protoplanetary disks

Protoplanetary systems are traditionally believed to acquire their mass and angular momentum during the protostellar phase, strongly constraining disk evolution, planet formation, and the inclination and spin in the system. Recent findings, however, suggest that additional material from the protostellar environment is added through accretion streamers and late infall. This process not only increases the mass but also introduces significant angular momentum, potentially altering the star-disk system's orientation and allow late disks to maintain their size in a wind-driven scenario, without the need for viscous expansion.

Based on ab initio simulations of a star forming region and theoretical derivations, we show that the orientation of star-disk systems can change considerably during accretion, in particular for higher mass stars. While the change in orientation varies with stellar mass, it is consistent across different stars relative to their mass accrual. The post-collapse accretion phase tends to be more anisotropic than the initial collapse phase, aligning with the idea that infall occurs via streamers along a preferred direction, unlike the more isotropic early collapse. Environmental factors leads to a large variation in mass accretion history, with some stars gaining most of their mass during initial collapse and others receiving over half of their final mass from late infall. Stars experiencing significant late infall have higher angular momentum budgets, correlating with larger disk sizes. Late accretors, due to their significant infall, can appear younger than they are, being classified as Class 0 objects despite being more than a million years old. Supported by our unique zoom-in magnetohydrodynamical models that simultaneously reach sub-AU resolution and retain the larger environment and recent observations of late infall, this new understanding calls for significant revisions in late-time disk and planet formation theories.

He, ChongChong

Institution: The Australian National University

GPU-Accelerated Simulations of Star Formation and Feedback in Galaxies:

Future Prospects

Large-scale numerical simulations utilizing parallel CPU cores have been pivotal in predicting and interpreting observations of star formation, significantly advancing our understanding of this intricate phenomenon. In this talk, I will present my prior research on investigating the physics of star formation through radiation magneto-hydrodynamic (RMHD) simulations using RAMSES-RT. I will highlight the significant role of photoionization feedback on the timescale and efficiency of star formation, and explore the impact of magnetic fields on this process. Following this, I will introduce my current work on developing the next-generation, multi-physics, GPU-accelerated Adaptive Mesh Refinement RMHD code QUOKKA. This innovative tool is designed to unravel the mysteries of galactic winds and further explore the physics surrounding galactic-scale star formation.

Hensler, Gerhard

Institution: Department of Astrophysics,
University of Vienna

Star formation in ram-pressure stripped gas clouds

Galaxies in clusters move through the hot intra-cluster medium (IGM) mostly with virial velocities. By this, gas-rich galaxies are exposed to the drag force of the IGM and suffer gas stripping. This well-known ram-pressure stripping (RPS) process is observationally manifested and appears in various facets. Not only the radial truncation of gas disks with respect to the stellar component and the gas evacuation of dwarf galaxies, another fascinating process enters the focus of research: the formation of extragalactic star clusters in ram-pressure stripped gas clouds. These objects allow exploring a bunch of widely studied actual questions on the star-formation timescale, the initial mass function, the decoupling of clusters from the gas to become naked, the escape of Lyman continuum (LyC) radiation, and the gas dynamics of RPS. For these objectives we take advantage of the wealth of star clusters around the Virgo cluster spiral galaxy NGC 4254. 60 young clusters are identified in the FUV with different masses, ages, and separations from the main gas disk. Only half of them are still engulfed by HII regions. We derive age-dependent escape fractions of LyC radiation and star-formation quenching times due to gas evacuation, both depending on the mass of parent clouds. At low star-formation rates also the uncertainty of derived parameters on the stellar mass sampling are investigated and will be discussed here.

Hernandez, Svea

Institution: Space Telescope Science Institute

JWST/MIRI detection of [Ne V] and [Ne VI] in M83: Star Formation or AGN?

We exploit the unprecedented capabilities of JWST in the MIR using MIRI/MRS to perform a spatially-resolved study of the multi-phase ISM in the incredible nuclear starburst at the core of M83. Our detailed analysis probing the distribution of the multi-phase gas on spatial scales ~ 5 pc, is uncovering the effect recently-formed massive stars, observed with HST/COS, have on the reservoirs of gas and active star formation. We will report on the intriguing first detections of [Ne V] 14.3 micron and [Ne VI] 7.7 micron in this starburst region. We find that photoionization models of fast radiative shocks are able to reproduce the observed emission line fluxes only for the lowest preshock density available in the library. Additionally, comparison with tailored active galactic nuclei (AGN) photoionization models assuming a two-zone structure confirm that the observed high ionization fluxes are also compatible with emission expected from a cloud ionized by the radiation cone of an AGN. Previously known as a purely starburst system, these new findings on M83 demand a reassessment of its nature, and of objects similar to it, particularly now that we have access to the unparalleled infrared sensitivity and spatial resolution of JWST.

Hu, Huijie

Institution: University of Chinese Academy of Sciences

A recent rejuvenated star-forming galaxy with PAH detection in the Abell 2744 cluster

Polycyclic aromatic hydrocarbon (PAH) is ubiquitous and dominates the spectra of most galactic and extragalactic sources. Here we present GLASSID-7622 with PAH 3.3 μm detection by the James Webb Space Telescope (JWST) Near Infrared Spectrograph (NIRSpec) spectroscopy in the Abell 2744 cluster. It has been covered by MUSE with high-resolution optical IFU data. With 15-filter photometry from HST to JWST, we do the stellar population synthesis analysis with different SED fitting models. We find that GLASSID-7622 is a dwarf galaxy with a stellar mass of $10^{9.66} M_{\odot}$ at the redshift of 0.2958. Its star formation rate (SFR) is around $2 M_{\odot}/\text{yr}$, which is on the SFR main sequence at redshift around 0.3. The stellar metallicity of GLASSID-7622 is $\log(Z^*/Z_{\odot}) = 0.174$ with $E(B-V)$ of 0.292, $A_V = 0.769$. It has two stellar populations based on the star formation history analysis; one is very old, corresponding with absorption lines at optical wavelengths, and another one is very young and has recently experienced active star formation. We find that the projected distance to the nearest bright core of Abell 2744 is 356.6 kpc. All results suggest that the GLASSID-7622 is a dust-rich dwarf galaxy in the cluster environment, but has recent star formation. We also find the OI excess mainly located in the outer region, which may imply a shock-induced formation scenario. We detect a distinct tail in both Ha and OII 2D emission line maps. So GLASSID-7622 could be a recent infall dust-rich and rejuvenated star-forming galaxy triggered by shock from ram-pressure stripping.

Ito, Mana

Institution: University of Tsukuba

IMF transition across various environments in the early universe

Investigating the stellar initial mass function (IMF) is crucial for exploring the formation history of galaxies and stars. The IMF in a zero-metallicity environment at redshifts of $z \sim 20-30$ is known to be top-heavy, with a high abundance of massive stars with $M > 100 M_{\text{sun}}$. At even higher redshifts, based on the study by Ito & Omukai (2024), the typical mass of the IMF is expected to be even larger. Conversely, in metal-rich environments, the IMF is known to be bottom-heavy, with a higher fraction of low-mass stars ($M < 1 M_{\text{sun}}$). However, the IMFs in low-metallicity environments have not been well investigated in previous studies. A previous study on the transition of the IMF from the early universe to the present has been performed by Sharda & Krumholz (2022). In their calculations, they estimated the typical mass of the IMF by determining the temperature of the gas cloud from the balance between the heating and cooling rates during the mass accretion phase immediately after protostar formation. As a result, they confirm that the higher the metal content in the gas cloud, the smaller the mass. However, they define the abundance of chemical species only in terms of metallicity and do not take into account the density dependence within the gas cloud.

In this study, we first calculate the chemical evolution of gas clouds during runaway collapse process using a one-zone thermochemical evolution code. By considering the density dependence of chemical abundances, we investigate the stellar masses realized in more realistic star-forming environments. In this talk, I will report on the results of stellar mass calculations in metal-poor environments and discuss the differences in the IMF across various environments, including Galactic, Primordial, and Starburst conditions.

Jarvis, Emma

Institution: University of Toronto

Star Formation, ISM Structure, and Ionizing Photon Escape in M33's HII Regions

We present a detailed study of over 1000 HII regions in M33 using data from the imaging Fourier transform spectrometer, SITELLE as part of the Star formation, Ionized Gas, and Nebular Abundances Legacy Survey (SIGNALS). M33, one of the closest and most well-studied spiral galaxies, is ideal to explore HII regions and diffuse ionized gas (DIG) in an actively star-forming galaxy at high spatial resolution. With a mosaic of nine 11'x11' fields, our observations provide the largest integral field spectroscopy study of M33, enabling a spatially resolved study of the ionized ISM across various galactic environments. The high spectral ($R \sim 5000$) and spatial resolution (~ 1 pc) of the data allows us to resolve the internal structure of HII regions and their interaction with the surrounding ISM. From the SITELLE datacubes, we extract emission-line fluxes ($H\alpha$, S[II], N[II], O[III], $H\beta$, and O[II]) and derive key physical properties of each region such as position, velocity, luminosity, size, dust extinction, and line ratios. We classify regions as radiation-bounded or density-bounded and examine how this classification varies with local ISM conditions. We further explore how ionizing photon leakage from massive stars contributes to the ionization and spatial distribution of the DIG, and how escape fractions vary across different environments within the galaxy. These findings provide insight into the role of stellar feedback in shaping the ionized ISM, redistributing energy, and regulating star formation on galactic scales. This unique dataset offers new constraints on the interplay between massive stars, ISM structure and the energy budget of star formation.

Jun, Rui Lan

Institution: University of Tokyo

Connecting Dark Matter and Star Formation: Impact on the star formation rate-weighted power spectrum

The star-formation-rate (SFR)-weighted power spectrum plays a central role in interpreting line-intensity mapping (LIM) observations. LIM probes the integrated emission from unresolved galaxies in specific spectral lines, many of which are closely tied to the SFR. Since the measured power spectrum is flux-weighted, and the flux is related to the SFR for many emission lines, the SFR-weighted power spectrum is crucial for extracting astrophysical and cosmological insights.

Using the IllustrisTNG cosmological hydrodynamical simulations, we investigate the impact of secondary bias—specifically, the correlation between SFR and the clustering of haloes at fixed halo mass—on the LIM power spectrum. We find that secondary bias is present in the simulations, enhancing the large-scale power spectrum by approximately 5% at $z \sim 1.5$ compared to a case with uncorrelated (random) scatter in SFR.

We also observe a correlation between the SFRs of central and satellite galaxies in the same halo, which increases the small-scale power spectrum by about 10% relative to a scenario where central and satellite galaxies are randomly paired. This reflects the presence of galactic conformity.

To mitigate the impact of secondary bias we identify halo concentration and satellite mass as effective secondary parameters: concentration is relevant for haloes with $\log M < 12$, while satellite mass plays a larger role at $\log M > 12$.

These findings highlight the importance of understanding star formation in order to extract both astrophysical and cosmological information from the LIM power spectrum.

Kashiwagi, Raiga

Institution: National Astronomical Observatory of Japan

Unveiling Fundamental Processes of Filament-Filament Collisions: Toward Understanding the Hub-Filament Paradigm

Filamentary molecular clouds are recognized as primary sites of star formation (e.g., André et al. 2014). Observations suggest that active star formation, including the formation of massive stars and stellar clusters, often occurs at junctions of multiple filaments, known as hub-filament systems (e.g., Myers 2009; Kumar et al. 2020). In particular, most observed massive stars form at the hubs, a trend referred to as the hub-filament paradigm (Kumar et al. 2020). Motivated by these findings, we investigated filament-filament collisions as a potential formation mechanism for hub-filament systems. Using ideal magnetohydrodynamic simulations with self-gravity (Kashiwagi et al. 2023, 2024), we examined two representative collision geometries: parallel and orthogonal alignments of the filament major axes. In this talk, we present our findings on the fundamental evolutionary processes of filament-filament collisions, as well as the physical conditions under which the shocked region becomes gravitationally unstable. Deriving this collapse condition is crucial for understanding the initial conditions that lead to star formation. In parallel collisions, the shocked structure remains filamentary, with its stability governed by the magnetized critical line mass, regardless of the collision velocity. In orthogonal collisions, the shocked region becomes ellipsoidal, and its stability follows the magnetized critical mass of a sphere at low velocities, but exhibits strong velocity dependence at higher velocities. By analyzing the energy balance immediately after the filaments fully collide, we derived a critical condition for collapse: the magnitude of gravitational energy must exceed the combined kinetic, thermal, and magnetic energies. Otherwise, the shocked region expands. This study is the first to comprehensively reveal the fundamental evolutionary pathways of filament-filament collisions. We also discuss how collision geometry influences the stability of the shocked structures and the resulting star formation properties.

Kaur, Harmeen

Institution: Aryabhata Research Institute of observational sciences (ARIES), Nainital, India

Star Formation and Feedback in Ruprecht 32: A Multi-Wavelength Analysis

Young open clusters are distinctive subjects of astrophysical investigation. Most stars within these clusters form nearly simultaneously from the same Giant Molecular Cloud (GMC), encompassing a broad range of stellar masses within a relatively confined spatial volume. A defining characteristic of embedded clusters is their close physical association with interstellar gas and dust, whether cold or warm. The extent of their embedding in molecular gas indicates their evolutionary stage, thereby imprinting the fractal structure of the GMCs from which they originate. The dynamics of stars within these clusters and the structural evolution of embedded clusters over time provide valuable insights into the processes of star formation and stellar evolution. In the present study, we performed multi-wavelength analysis of the young star cluster Ruprecht 32 to understand the star formation scenario. We found that this region contains massive OB-type stars as member stars, and this region encompasses two reflection nebulae, BRAN 66A and BRAN 66B, having prominent radio emission. This region has an elongated morphology and is placed at a distance of ~ 3.6 kpc. Radio continuum emission, warm and cold dust emission distribution, temperature maps, molecular morphology, and various feedback pressures profoundly signify that massive stars affect their surrounding environment and generate further star formation. Hence, we identified filamentary features associated with BRAN 66B and feedback loops of star formation in these regions.

Khan, Zacariyya

Institution: University College London

HII Region Feedback: The Role of Magnetic Fields in Sequential Star Formation

Magnetic fields have long been understood to be ubiquitous across the ISM. Given their prevalence and strengths at high densities, it is unsurprising that magnetic fields have been hypothesized to have an active role in star formation – especially true in the case of massive star formation. Even before the start of the main sequence, massive stars can significantly alter their environments through outflows and HII regions that can reshape the surrounding gas and dust in the host molecular clouds. This can have consequences for future star formation in proximity to these early-type stars, potentially even leading to sequential star formation and further massive star formation. However, the wider effects of this on star formation rates and efficiency, as well as the role of magnetic fields in the process, is poorly understood at present. G34.26+0.15 is a hub-filament cloud at a distance of 3.3kpc. Its dense central hub contains multiple ultra-compact HII regions which have been extensively studied, indicative of massive star formation; these border an expanded HII region that appears to have substantially altered a portion of the cloud: a likely candidate for sequential massive star formation. We use this cloud as a case study, presenting an analysis of the magnetic field structure across the cloud, demonstrating how it has been substantially reshaped by the HII region, inferred from observations of polarised dust emission at 850um taken using the Submillimetre Common-User Bolometer Array-2 (SCUBA-2) and its polarimeter POL-2, mounted on the JCMT. We also present analysis of POL-2 observations of a sample of other HII regions across the Milky Way, at different stages of evolution and expansion. By comparing these different regions and their host clouds using modified version of the Histograms Of Relative Orientations method, we investigate the changing relationship between HII region expansion and magnetic fields over time.

Kim, Jeong-Gyu

Institution: Korea Institute of Advanced Study

Feedback-regulated Star Formation and Multiphase ISM: A Modern Theoretical Perspective

Massive stars formed in giant molecular clouds (GMCs) emit intense UV radiation and drive strong shocks via stellar winds and supernovae. The energy, momentum, and chemically enriched material injected by these feedback processes profoundly impact the evolution of GMCs, multiphase structure and multiscale dynamics of the interstellar medium, and gas flows in and out of galaxies, all of which are crucial in controlling future generation of star formation. In this talk, drawing from recent theoretical models and numerical simulations, I will overview our current understanding of interaction between feedback and the ISM and how this affects star formation and matter cycle on both cloud and galactic scales.

Kobayashi, Yudai

Institution: Kagoshima University

Development of 1-D non-ideal MHD simulation code towards understanding Long-term Evolution of Protoplanetary Disk

The recent high-resolution/high-sensitivity observation revealed the nature of the protoplanetary disks (PPDs) around Class 0/I young stellar objects (YSOs) (e.g., eDisk (Ohashi+23), VANDAM (Segura-Cox+18), CALYPSO (Maury+19), CAMPOS (Hsieh+24)). In particular, eDisk shows that disks around Class 0/I objects do not have ring/gap structures seen in PPDs around Class II objects. Those observations show that young disks have a mass smaller than 0.1 solar mass and a size smaller than 100 au.

Theoretically, magnetic fields are thought to play a crucial role in the formation and early evolution of PPDs. It has been investigated mainly using 3D non-ideal magnetohydrodynamics (MHD) simulations (e.g., Machida+11; Tomida+15; Masson+16; Tsukamoto+17, 23; Xu and Kunz 2021b).

These previous studies show that the disks with sizes of several 10 au form even in molecular clouds with magnetic field strengths comparable to the observation.

These simulation studies have revealed important mechanisms in the formation and evolution of PPDs, but there is still a major problem. The time scale for disk evolution that can be calculated by simulation is around 10 thousand years. On the other hand, the age of observed disks is thought to be around 1 million years after protostellar formation. The short integration time of the simulation is because 3D simulations require a high computational cost, and there is a huge gap between the age of the disk in the 3D simulation and the observed age of the disk.

In this study, we developed a 1D simulation code with low computational cost and calculated the evolution process of a disk about 0.1 million years after the protostellar formation. We have confirmed that the disk structure obtained by the simulation reproduces the analytical steady-state solutions of previous studies well.

Kornecki, Paula

Institution: Instituto de Astrofísica de Andalucía

Exploring Very High Energy Gamma-ray Emission from Star-forming Galaxies

Star-forming galaxies (SFGs) provide a unique laboratory for studying cosmic-ray (CR) acceleration and transport in environments shaped by massive stellar populations. Their non-thermal emission, including γ -rays, is primarily linked to star formation rather than active galactic nuclei, with a well-established correlation between their star formation rate (SFR) and radio/ γ -ray luminosity.

γ -rays are mostly produced by interactions between hadronic CRs and the interstellar medium (ISM), while CRs themselves are accelerated at supernova remnants (SNRs) and possibly in other sources within star-forming regions, such as young massive star clusters. These acceleration sites, abundant in SFGs, could significantly contribute to γ -ray emission, particularly in galaxies with high SFR. While GeV γ -ray emission from SFGs is clearly associated with SFR, the origin and intensity of their very-high-energy (VHE) counterparts remain uncertain due to observational limitations.

To investigate their role in the VHE γ -ray sky, we compiled a sample of GeV-detected SFGs and additional candidates from near-infrared surveys in the Local Volume. Using empirical models and observational constraints, we predicted their TeV spectra and assessed their detectability with ground-based observatories. Our results suggest that next-generation Cherenkov telescopes, such as the Cherenkov Telescope Array Observatory (CTAO), could detect a significant number of SFGs, offering a new window into the interplay between stellar populations, CR acceleration, and γ -ray production in these environments.

Koutoulaki, Maria

Institution: University of Leeds

A VLTI view of Massive Young Stellar Objects

Massive stars impact a vast range of scales and processes, from re-ionisation of the Universe, to the physical and chemical evolution of galaxies, to regulation of the interstellar medium, to formation of star clusters, and even to formation of planets around stars in such clusters. The formation and/or migration of these planets are significantly affected by the structure of the young inner disc and the physical processes that rule its early evolution. In recent years, significant progress has been made in understanding the formation of high-mass young stellar objects (HMYSOs; i.e. $M^* \geq 8 M_{\odot}$, $L_{\text{bol}} \geq 5 \times 10^3 L_{\odot}$). The latest observational and theoretical studies present evidence that HMYSOs are born in the same way as their low-mass counterparts, via disc accretion, rather than through coalescence of lower mass stars. While the existence of massive protostellar discs has now been established, little is known about how they eventually disperse, and how this is linked to the central protostar. A recent interferometric study at mid-infrared wavelengths (VLTI/MIDI) has shown substructures in the discs of 8 HMYSOs and one source showed a spiral-gap structure. These substructures could be the result of a forming companion, thus understanding their formation is of great importance since massive stars have a high binary fraction. Moreover, investigating their inner structure, where the mass transfer to the protostar takes place, gives us insights in determining the physical and dynamical characteristics, as well as the accretion/ejection processes in HMYSOs.

In this talk, I will present our results on spatially resolved observations of the continuum, Br γ , CO, and NaI emitting regions, with the latter spatially resolved for the first time using VLTI/GRAVITY in a small sample of MYSOs, and I will also show complementary VLTI/POINIER and VLTI/MATISSE observations.

Kummer, Kyra

Institution: University of Cape Town

IC 5332 as a Laboratory for Probing Outer-Disk Star Formation & HI Gas Properties

Understanding the physical processes that trigger and sustain star-formation in low-mass galaxies and low-density environments, such as the outer regions of the galactic disk, remains a key challenge for galaxy evolution models. IC 5332 is a nearby, nearly face-on, SABc galaxy with a low star-formation rate and a putative Type 2 XUV disk. Due to these properties, and a wide availability of high resolution multiwavelength data, IC 5332 provides an excellent opportunity to study the phenomenon of outer disk star-formation in detail. We combine new high-resolution MeerKAT HI observations with FUV, IR, and H α observations to explore the environmental and star-forming properties of its extended disk. We implement prevailing hybrid star-formation rate relations to produce spatially resolved maps of star-formation in IC 5332 at a 15'' resolution, corresponding to a spatial scale of ~ 0.65 kpc. These maps reveal that star-formation appears to persist even in the outskirts of the galactic disk.

Our analysis of the MeerKAT data applies tilted ring models to the HI cube, and reveals a warped, extended HI disk coincident with the XUV emission, and reaching more than 15 kpc from the galactic centre. Furthermore, the residuals show some HI gas in the outskirts that is not described by simple disk models. Such gas is likely associated with gas components lagging behind the bulk rotation of the galactic disk.

We compare the HI and star-formation properties of IC 5332, and evaluate our results in the context of other low-mass XUV disk galaxies to investigate the role of HI in the star-formation process. In this presentation of our work, we will discuss our findings, and their implications on our understanding of star-formation in galaxies with extended HI and UV disks.

Langa, Moses

Institution: Technical University of Kenya

Surveying SMGPS extended HII regions and SNRs associated with SEDIGISM molecular clouds

Massive stars release vast amounts of energy into the interstellar medium through their lifetime processes and supernova explosions, compressing nearby regions and triggering star formation. While triggering mechanisms have been studied on smaller scales, comprehensive analysis on a larger MilkyWay scale has been hindered by the lack of high-quality radio imaging and the limited angular resolution of molecular mapping. The significance of triggered star formation across the Galactic disc is, therefore, not well understood. This pilot study combines the SRAO MeerKAT Galactic Plane Survey (SMGPS) and the Structure, excitation, and dynamics of the inner Galactic interstellar medium (SEDIGISM) data to identify and examine molecular clouds associated with HII regions and supernovae remnants (SNRs). We focus on their physical properties and massive star formation potential. We identify 268 molecular clouds from the SEDIGISM tile that is found within the studied Galactic coordinate range in degrees ($341 \leq l \leq 343$ and $|b| \leq 0.5$), of which 159 clouds ($\sim 60\%$) are associated with SMGPS extended sources. Compared to unassociated clouds, we find that associated clouds exhibit significantly higher mean mass ($\sim 7000 M_{\odot}$ vs. $\sim 1900 M_{\odot}$) and average gas surface density ($\sim 88 M_{\odot}/\text{pc}^2$ vs. $\sim 66 M_{\odot}/\text{pc}^2$), but with slightly elevated virial parameters. We also find that the linewidth-size scaling relation reveals steeper scaling for associated clouds compared to unassociated clouds. These findings suggest an enhanced dynamical activity for the associated clouds and support the hypothesis that feedback from massive stars influences molecular cloud properties and may trigger star formation.

LE, NGAN

Institution: SAGI/IFIRSE & KASI

Probing the physical conditions and UV fields in embedded cluster Gy 3–7 in the outer Galaxy with SOFIA/FIFI-LS spectrometer

Far-infrared lines are important tracers of the gas cooling and heating processes induced by shocks and UV radiation during the early phases of star formation. The high-J CO ($J_{\text{up}} \geq 14$), OH, [OI], [CII] emission maps can allow us to constrain physical conditions like the gas temperatures, densities, and UV fields in embedded objects. Yet, the cooling via these far-infrared lines might depend on the conditions of the environment, e.g., metallicity. In this talk, I will present the results of far-infrared study in the low metallicity deeply embedded cluster Gy 3-7 located in the outer Galaxy star-forming region CMa-l224, using spectroscopic data from SOFIA/FIFI-LS. I will also further discuss the possible impact of metallicity on the total gas cooling in this embedded cluster.

LE, NGAN

Institution: SAGI & KASI

**Investigating Magnetic Fields and Their Dynamical Influence in the DR21
Filamentary Molecular Cloud**

Magnetic fields (B-fields) have been believed to play a vital role in star formation and in the evolution of molecular clouds, especially in the formation of filamentary clouds. To probe the morphology of B-fields, thermal dust polarization emission maps have traditionally been used. The Velocity Gradient Technique (VGT) has recently considered as a promising method that can reconstruct magnetic field structures using gas emission maps as well as infer the impact of stellar feedback in gravitation in the region. In this poster, I will present initial results on the magnetic field structure in the nearby DR21 filamentary molecular cloud, derived from thermal dust polarization observations obtained with SOFIA/HAWC+ and from the application of the newly developed VGT. I will compare the magnetic field morphologies revealed by both methods and discuss their differences and discuss what these differences could tell any impact of stellar feedback in gravitation in this DR21 filament.

Lee, Jeong-Eun

Institution: Seoul National University

Protostellar Envelope and Disk Chemistry Revealed by Episodic Accretion

Unraveling the chemical complexity of dense cores and protoplanetary disks is key to understanding the physical processes that govern star and planet formation. Molecular line observations serve as powerful diagnostics of the physical conditions and dynamical evolution of these regions. One of the major recent developments in low-mass star formation is the recognition of episodic accretion—a process characterized by long quiescent phases punctuated by short, intense accretion bursts—as a fundamental aspect of stellar mass growth. This framework has profound implications for astrochemistry, influencing molecular distributions in protostellar envelopes and revealing ice compositions in disks. In this presentation, I will explore how episodic accretion events impact the chemistry of young stellar objects, highlighting observations of various molecules—including complex organic species—in both envelopes and disks. I will also discuss how molecular line diagnostics trace dynamic processes, such as accretion, outflows, and disk evolution.

Lee, Yueh-Ning

Institution: National Taiwan Normal University

A new recipe for streamers around young protoplanetary disks

With advances in observations, it has become clear that the formation of the star and protoplanetary disk system is not from a uniform collapse of the prestellar core. Structures develop as mass is being fed to the system from larger scales. Notably, many observation of protoplanetary disks under formation show inward spiraling structures, which are given the name "streamers". One of the current explanation is that an over-dense clump gets smeared apart by differential motions in the stellar tidal field. However, it is in first place difficult to establish such an initial condition. On the other hand, the CMU model, being a particle trajectory model, is widely used for the streamer structure that develops within a hydrodynamic density and velocity field. In this presentation, I will propose new model that is based on a mechanism of unstable density enhancement in the envelope to describe the formation of streamers.

Liu, Junhao

Institution: National Astronomical Observatory of Japan

Condensations in massive protoclusters form by gravo-turbulent flows rather than magnetized collapse

High-mass stars form in protoclusters, where gravo-magnetic processes shape massive star-forming clouds and substructures to be elongated preferentially perpendicular to magnetic fields on the scales of 10 to 0.1 parsecs. Yet it remains unclear whether magnetic fields still govern the formation of smaller-scale (~ 1000 au) condensations in massive protoclusters, a key scale to understand the stellar initial mass function and multiplicity.

Here we report statistical evidence that the condensation elongation exhibits a preferentially more parallel alignment with magnetic fields on ~ 1000 au scales, based on high-resolution data from an ALMA dust polarization survey toward 30 massive star-forming regions. Our simulations of self-gravitating clustered massive star formation reveal that this more parallel alignment is exclusively observed in super-Alfvénic (turbulence dominates magnetic fields) models, whereas sub-Alfvénic (magnetic fields dominate turbulence) models distinctly exhibit a more perpendicular alignment.

These findings offer compelling statistical evidence that the formation of small-scale condensations is governed by turbulence rather than magnetic fields in the context of clustered massive star formation. Moreover, turbulence imposes a preferential misalignment between the magnetic field and rotation axis of condensations, which can potentially reduce the magnetic braking efficiency, facilitate the formation of large protostellar disks, and allow disk fragmentation to occur.

Liu, Zhaoxuan

Institution: Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU),
The University of Tokyo

A PAH deficit in the starburst core of a distant spiral galaxy

We present high-resolution and spatially-matched observations with JWST and ALMA of a starburst galaxy (PACS-830) at $z=1.46$. The NIRCам observations mainly trace the stellar light while the CO ($J=5-4$) observations map the dense molecular gas at kpc scales. Both datasets reveal the morphology to be that of a gas/dust rich bulge with two extending arms, together resembling a grand-design spiral galaxy. The more pronounced arm contributes $21 \pm 6\%$ of the total CO emission.

These results further demonstrate that starburst activity at high redshift can be triggered, without even undergoing a highly disruptive major merger. We then assess the strength and distribution of star formation using two tracers: (1) Polycyclic Aromatic Hydrocarbons (PAHs) emission detected at $8\mu\text{m}$ (L_8) with a MIRI/F1800W image, and (2) L_{IR} , inferred from the CO ($J=5-4$) ALMA map. The spatial profiles of the L_{IR} and L_8 are found to be dissimilar thus leading to a significant deficit of mid-IR (L_8) emission in the nucleus. We hypothesize that this is due to the destruction of PAH molecules by the intense ionizing radiation field, as seen in star-forming regions of nearby galaxies, and consistent with the galaxy-wide properties of distant starbursts. This study reveals spatial variations in the L_8 to L_{IR} ratio for the first time in the distant universe ($z>1$), in agreement with expectations from theory. Our analysis underscores the pivotal role of joint high-resolution observations with JWST and ALMA in discerning the different phases of the interstellar medium (ISM) and revealing internal physics in galaxy substructures.

Qiuyi Luo

NAOJ

Formation of Low-mass multiples in High-Mass Cluster Forming Region

Most stars form in multiple systems, with profound implications in numerous astronomical phenomena intrinsically linked to multiplicity. However, our knowledge about the process on how multiple stellar systems form is incomplete and biased toward nearby molecular clouds forming only low-mass stars, which are unrepresentative of the stellar population in the Galaxy. Most stars form within dense cores in clusters alongside high-mass stars ($>8 M_{\odot}$), as likely the Sun did. Here we report deep ALMA 1.33 mm dust continuum observations at ~ 160 au spatial resolution, revealing 67 low-mass multiple systems embedded in 23 high-mass cluster-forming regions, as part of the Digging into the Interior of Hot Cores with ALMA (DIHCA) survey. We find that the companion separation distribution presents a distinct peak at ~ 1200 au, in contrast to the one at ~ 4000 au observed in nearby low-mass regions. The shorter fragmentation scale can be explained by considering the higher pressure exerted by the surrounding medium, which is higher than the one in low-mass regions, due to the larger turbulence and densities involved. Because the peak of the companion separation distribution occurs at much larger scales than the expected disk sizes, we argue that the observed fragmentation is produced by turbulent core fragmentation. Contrary as predicted, the multiplicity fraction remains constant as the stellar density increases. We propose that in the extremely dense environments where high-mass stars form, dynamical interactions play an important role in disrupting weakly bound systems.

Mamta, Mamta

Institution: Aryabhata Research Institute of Observational Sciences (ARIES)

Unveiling the Dynamics of Star Formation in BRC 68: Insights from ALMA and QUARKS Observations

ALMA/QUARKS observations of bright-rimmed cloud BRC 68 provide unprecedented insights into the earliest stages of massive star formation. Using high-resolution (<0.1 pc) continuum and molecular line data, we trace the complete evolutionary sequence from prestellar cores to active protostars. We have identified nine dense cores using 1.3 mm continuum emission, eight of which satisfy the modified Kauffmann-Pillai criterion for massive star formation. CH_3OH emission serves as a sensitive probe of warm, dense gas in the earliest active phases, while H_2CO traces the kinematics of collapsing material. We detect the onset of feedback through SiO/SO outflows emerging from the youngest protostars. The cloud's irradiated edge, sharply defined in CCH emission, shows where external radiation drives the star formation process. Filamentary structures observed in ^{13}CO to channel material toward the growing cores, sustaining their development. These findings provide a comprehensive view of the initial conditions and early evolution of massive stars, highlighting how radiation both compresses the natal cloud and initiates the collapse of individual cores. The study establishes BRC 68 as a key template for understanding the birth environments of massive stars in our Galaxy.

Marx, Frederike

Institution: University of Duisburg-Essen

The Early Stages of Protoplanetary Disk Formation

In this work we investigate the early stages of the formation of disks around protostars. We present 2D axially symmetric MHD simulations of the collapse of a rotating molecular cloud with an initial density distribution following a Bonnor-Ebert-sphere into the 1st and 2nd hydrostatic Larson core. We perform a parameter study for a range of initial cloud masses and aim to simulate the first few thousand years of disk evolution including the launching, acceleration, collimation, and initial propagation of the jet. The remnants of the first core collapsing into the second core form a Keplerian disk, which is flattened quickly by angular momentum and grows outwards over time due to infalling gas with higher angular momentum, reaching an extent of over 100 AU.

Mathew, Sajay Sunny

Institution: Australian National University

The Turbulent Origin of the Initial Mass Function

Understanding the stellar mass distribution within a young cluster—known as the initial mass function (IMF)—is essential for comprehending the chemical enrichment, energy output, and dynamical evolution of galaxies. Fully capturing the origin of the IMF requires an extensive understanding of star formation, which is inherently a multi-scale and chaotic process, governed by a complex interplay of different physical mechanisms. In my work, I conduct a series of three-dimensional magnetohydrodynamical (MHD) simulations of star cluster formation that incorporate gravity, turbulence, magnetic fields, stellar radiative heating, and outflow feedback. I demonstrate that simultaneously including all of these mechanisms is critical, as each has a significant and distinct impact on the resulting IMF. My findings show that cloud properties—such as the turbulence driving mode, virial parameter, and Mach number—play a key role in shaping the IMF. Furthermore, I show that stellar dynamical interactions are particularly important in determining the sub-stellar end of the IMF. In conclusion, accurately modelling the IMF requires considering both the initial conditions of the molecular cloud and the interactions among forming stars.

Mayer, Alexander

Institution: Max Planck Institute for Astrophysics

Formation of protostars and protostellar disks under the influence of non-ideal magnetohydrodynamics in the turbulent interstellar medium

While recent observations of young protostellar disks have revealed much about their structure, their formation process from molecular cloud cores and subsequent evolution remains relatively poorly understood. In particular, the role of the magnetic field in regulating the angular momentum budget of the system is a central issue. In this talk, zoom-in simulations from a turbulent interstellar medium to protostars are presented, with a spatial range spanning more than 10 orders of magnitude. Using a newly developed implementation of non-ideal magnetohydrodynamics (MHD) for the moving-mesh code AREPO, we compare models without magnetic fields, with ideal MHD and finally including ambipolar diffusion. While disks of several 10s of astronomical units readily form without magnetic fields, ideal MHD strongly suppresses disk formation through magnetic braking and outflows. Non-ideal MHD does in a subset of cases lead to disk formation, but these disks are distinct from those without magnetic fields in size and structure. We show that where comparison can be made, our results are consistent with earlier studies of isolated cloud core collapse. We conclude that non-ideal MHD effects are prominent in the disk formation process even when fully self-consistent turbulent initial conditions are used, and their importance is not limited to idealized collapse scenarios. As such, both realistic initial conditions and the use of an appropriate magnetic field model are crucial in modeling the formation of protostellar disks. Finally, the effects of radiative transfer on disk structure and the impact of magnetic fields in the formation of multiples are briefly discussed.

Menéndez-Delmestre, Karín

Institution: Valongo Observatory, Federal University of Rio de Janeiro

PAHs as Probes of ISM Astrochemistry in Star-Forming and AGN-Dominated Environments

Star formation and black hole growth are key drivers of galaxy evolution, and both leave imprints on the chemistry of the interstellar medium (ISM). Polycyclic aromatic hydrocarbons (PAHs) offer a powerful way to trace this astrochemical processing, responding sensitively to local radiation fields across galactic environments. Using JWST/MIRI observations, we spatially resolve PAH emission in nearby Seyfert galaxies across concentric annular regions that extend from a central AGN into the outer disk. This approach allows us to probe the astrochemistry of the ISM as a function of distance from the AGN, and to disentangle how local radiation fields shape PAH properties — a key step in connecting star formation and nuclear activity at galactic scales. We have also studied a large sample of (>500) luminous and ultra-luminous galaxies from the ATLAS catalog to explore how different globally-dominating radiation fields alter PAH populations in highly obscured systems. We decompose the Spitzer/IRS spectra of these galaxies to isolate the PAH emission (PAHFIT) and determine the molecular diversity of PAHs using the NASA Ames PAH Database, a large spectroscopic library of PAH molecules. We find that the PAH molecules that dominate the emission in these dusty systems are small (< 50 carbons), neutral molecules with a chemical composition mostly restricted to carbon and hydrogen (so-called “pure PAHs”). Most interestingly, we find that variations exist in the proportion of charged and neutral PAHs for galaxies with stronger AGNs, where the harsher radiation field of AGNs appear to drive a stronger proportion of neutral and small PAHs. Our results show that AGN alter the ISM astrochemistry without destroying PAHs and suggest an altered pathway for these complex molecules in these environments: PAH-dehydrogenation and PAH-breakdown into smaller PAH molecules appear as dominant pathways to the PAH lifecycle in AGNs’ harsher radiation environment. This is in agreement with laboratory works pointing to the stability of PAH molecules and motivates further use of PAHs to probe for the radiation field in these dusty, extreme environments.

Micic, Marko

Institution: University of Oklahoma

Impact of low mass galaxy interactions of star formation

I will present the largest catalog of isolated dwarf galaxy pairs and groups derived from the DESI Early Data Release. 1200 dwarf galaxy pairs and 200 dwarf galaxy groups span a wide range of stellar masses (10^5 - 3×10^9 Msol), mass ratios (1:1-4000:1), projected separations (0.5-100kpc), and redshifts (0.015-1.5). We are able, for the first time, to perform an in depth study of star formation in low-mass interacting systems with respect to the aforementioned parameters. We uncover dramatic evolution of NUV-r, r-K, U-V, V-J, and g-r colors, tracing various aspects of star formation processes and histories. We also compare the star formation in paired/grouped dwarfs to two control samples: (1) isolated dwarf galaxies; (2) non-isolated paired/grouped dwarfs (i.e., paired/grouped dwarfs in the vicinity of a massive neighbor). We uncover various intricacies of star formation processes in each control sample, providing a more complete picture of the baryon cycle at lowest mass scales.

Micic, Marko

Institution: University of Oklahoma

Gargantuan quasar positive feedback at $z=2.95$

Black holes can launch relativistic outflows consisting of ionized matter. These energetic jets can interact with the ambient medium and induce a variety of astrophysical phenomena. It has been observed that when jets intercept a cloud of gas, they can push the material in lateral directions, trigger intensive episodes of star formation, and create stellar clusters consisting of tens of thousands of stars. Here, we report the discovery of an X-ray jet and hotspot associated with a $z=2.95$ quasar powered by a black hole weighing one billion solar masses. Optical Subaru imaging reveals a nearly continuous arc of clumpy emission oriented perpendicularly to the direction of the jet, extending for over 250 kiloparsecs. The redshift analysis of the brightest clumps using the EAZY code indicates that the arc and the jet are spatially correlated. Further investigation of the physical properties of the clumps using the FAST++ reveals that they contain billions or even tens of billions of stars and are as massive as the Milky Way. The clumps also exhibit extreme levels of ongoing star formation, in line with starbursting galaxies. The quasar jet is likely interacting with a hypermassive reservoir of gas and inducing the formation of galaxy-sized stellar clusters. Positive feedback on such a scale has never been observed before and can significantly affect our understanding of galaxy evolution.

Mininni, Chiara

Institution: INAF-IAPS

Molecular and continuum emission: a morphological comparison in ALMAGAL clumps

The analysis of the line emission at millimetric wavelengths is a powerful tool for studying the kinematic and thermal conditions of the gas in star-forming regions. However, the question of how well different species trace the emission of dust in the continuum at various scales has been addressed in the literature either by comparing the region of emission of the different lines with the region emitting in the continuum or by using intensity correlators, such as Spearman's coefficient. In this work, we present an innovative approach to this problem based on the analysis of the correlation between the morphology of the moment-0 maps of lines from eight of the most common molecular species observed in high-mass star-forming (H_2CO , CH_3OH , DCN , HCCCN , CH_3CN , CH_3OCHO , SiO , and SO) regions and the continuum emission from dust at 1.4 mm on an unprecedented statistically robust sample. The observations are part of the ALMAGAL program, which has observed more than 1000 candidate high-mass star-forming clumps with the ALMA interferometer at 1.4 mm. Observed clumps cover different evolutionary stages and fragmentation properties, and have masses above $500 M_\odot$. The morphological analysis is based on the astroHOG package, using the method of the histogram of oriented gradients (HOG). We run the comparison with astroHOG over the all the continuum emission and over compact cores only. We found that the analysed species can be divided into two groups. CH_3CN , DCN , HCCCN , and CH_3OCHO show a good correlation, while for H_2CO , CH_3OH , SO , and SiO , the emission mostly does not follow the morphology of the dense part of the continuum, nor of the diffuse emission.

Mutale, Mubela

Institution: University of Leeds

Radio surveys of young HII regions

To understand the birth of massive stars, we first need to understand the environments in which they form. Young HII regions are arguably the closest tracers of massive star formation as they directly reflect the interaction of a newly born high-mass star and its ambient medium. The hypercompact (HC) phase is presumably the earliest stage in the evolution of an HII region, and thus the most ideal window through which to view the birth of massive stars. However, these objects are rare and difficult to observe. I will discuss work done with the Ku-band Galactic Reconnaissance Survey (KuGARS) to detect these rare objects and present an estimate of their statistical lifetime. The ultracompact (UC) HII region phase has similar importance, as it overlaps significantly with the main-sequence lifetime of a massive star, therefore playing an important role in improving our understanding of the birth of massive stars. The lifetime of an UC HII region is estimated to be of the order 10^4 years. However, previous studies have shown that the number of UC HII regions is inconsistent with their estimated lifetime. HII regions expand with time, thus their lifetimes scale directly with their size. Studies carried out on samples subject to selection biases have estimated that 80% of UC HII regions have underestimated sizes, implying a longer lifetime than 10^4 years. In this talk, I will present a large unbiased sample of HII regions drawn from the SARA0 MeerKAT Galactic Plane Survey (SMGPS). In this unbiased sample, I find that roughly a third of the UC HII regions have underestimated sizes. Therefore, while this implies a longer lifespan than the dynamical age of an UC HII region, it only provides a partial solution to the problem.

Nakamura, Fumitaka

Institution: NAOJ

Unveiling Stellar Feedback and Cloud Structure in the ρ Ophiuchi A Region with ALMA and JWST: Discovery of Substellar Cores, C¹⁸O Striations, and Protostellar Outflows

In clustered star-forming regions, stellar feedback such as HII regions/PDRs and protostellar jets/outflows shapes cloud structures and influences subsequent star formation processes. Using high-resolution ALMA millimeter and JWST infrared data, we analyze the cloud structure and the impact of stellar feedback in the dense cluster-forming region Oph A. The ALMA 1.3 mm dust continuum image reveals 7 small substellar cores: Three core are associated with point-like near-infrared emission and therefore we propose that they are young substellar objects. Other cores without compact infrared emission have masses of $\sim 10^{-2}$ Msun with a mean density of $\sim 10^8/\text{cm}^3$. They are likely gravitationally-bound substellar cores. They appear to be connected by faint CO finger-like structures extended from VLA 1623A/B, suggesting that they might have been ejected from VLA 1623A. CO (J=2-1) and near-infrared observations reveal multiple protostellar outflows/jets from protostars. Strong CO emission traces the eastern edge of the Oph A ridge, forming a part of the expanding HII/PDR bubble driven by the nearby Herbig Be star S1.

The northern ridge segment appears "blown out," with warm gas flowing westward toward the GSS 30 region.

We also found several C18O (J=2-1) striations in the S1 bubble which align with magnetic field structures. The position-velocity diagrams show a wave-like velocity pattern, possibly reflecting magnetohydrodynamic waves.

The stellar feedback in Oph A affects most of the area and plays a significant role in shaping Oph A's complex cloud structure.

Nakamura, Fumitaka

Institution: NAOJ

Revealing dense core formation mechanism in molecular clouds: Evidence favoring turbulent over gravitational fragmentation

Stars form from dense cores in turbulent molecular clouds. According to standard scenario of star formation, dense cores are created by cloud fragmentation. However, the physical mechanisms underlying this process remain to be fully understood based on observations. We aim to investigate the cloud fragmentation process in nearby clouds, focusing on the role of self-gravity and turbulence.

Using astrodendro on Herschel data, we identified dense cores and measured their masses and separations across 14 clouds. These clouds were categorized into three groups based on star formation capability: quiescent, low-mass, and intermediate-mass star-forming clouds. We then compared the observed core properties with predictions from gravitational and turbulent fragmentation. We identified 8416 cores in total: 677, 3886, and 3853 in quiescent, low-mass, and intermediate-mass star-forming clouds, respectively. We found that across all clouds, core mass and separation are significantly smaller than predictions from gravitational fragmentation, but consistent with turbulent fragmentation. The characteristic core mass and separation are likely determined by the sonic scale (L_s), below which thermal pressure dominates over turbulent pressure. For nearby clouds, L_s is measured to be 0.1 pc, closely matching the peak separation.

The characteristic core mass, estimated as the mass enclosed within a radius $L_s/2$, also agrees with observed core masses. These findings indicate that core formation is primarily driven by turbulent fragmentation rather than gravitational fragmentation. Our conclusion can also be extended to high-mass star-forming clumps, where previous studies have suggested a preference for gravitational fragmentation.

Even in these clumps, the core separation distribution peaks around $L_s \sim 0.02\text{--}0.04$ pc--significantly shorter than in nearby clouds--yet already exceeds the Jeans unstable threshold due to the high densities. This suggests that turbulent fragmentation remains the dominant core formation mechanism across a wide range of cloud environments.

Nguyen, Chau Giang

Institution: Korea Astronomy and Space Science Institute (KASI), Korea University of Science and Technology (UST)

Grain Alignment and Disruption Dynamic in Low/Intermediate-mass Class 0/I YSOs constrained by Dust emission Polarization

Dust grains play an important role in probing the dynamic importance of magnetic fields in star-forming regions; controlling the magnetic resistivity, and seeding the planet formation; yet their properties and dynamics remain unclear. Observations toward low/intermediate-mass Class 0/I YSOs by ALMA reveal the existence of very large grains (VLGs) beyond $>10\mu\text{m}$ at ~ 500 au scale; and unexpected high polarization degrees $\sim 5\text{-}30\%$ at $\sim 500\text{-}1000$ au scale. Previous studies suggest that VLGs formed inside protostellar disks can migrate toward the inner envelope via outflows; and their efficient alignment with magnetic fields (B) on this scale can help explain ALMA dust polarization. However, how VLGs experience efficient magnetic alignment in such strong gaseous damping environments, and whether VLGs survive RAdiative Torque Disruption (RATD) while transporting inside outflows remains unclear. We address the first question by performing the synthetic dust polarization modeling with POLARIS and confronting results with ALMA observation. Our results indicate that protostellar grains must be superparamagnetic (with $N_{\text{cl}} \sim 10^2\text{-}10^4$ iron atoms/cluster), with sizes greater than $>10\mu\text{m}$ at $\sim 500\text{-}1000\text{au}$ scale, and can have efficient magnetic alignment by the joint action of super-Barnett relaxation, Inelastic relaxation, and Magnetically enhanced RAdiative Torques mechanisms. Then, we conduct numerical modeling of RATD alongside grain dynamics, and implement RATD in POLARIS to understand its impact on dust polarization. We find that when the center luminosity of the object exceeds $L_{\text{center}} > 5L_{\text{sun}}$, RATD can rapidly clear out dust grains greater than $>1\text{-}3\mu\text{m}$ with tensile strengths $S_{\text{max}} \sim 10^3\text{-}10^4$ erg/cm³ at the outflow base just after ~ 1 yr. This activity temporarily prevents large grains from migrating toward the inner envelope; while letting the high abundance of small grains below $<3\mu\text{m}$ dominate outflows until $L_{\text{center}} < 5L_{\text{sun}}$. RATD can reduce $p(\%)$ observed in $\sim 500\text{-}1000$ au scale, but only if the intermediate-mass protostar maintains $L_{\text{center}} \sim 100L_{\text{sun}}$ for over >20 yrs.

Nguyen, B-Ngoc

Institution: Vietnam National Space Center

Studying Magnetic Fields and Dust Physics using the Dust Polarization

Observations

Magnetic fields (B-fields) are thought to play an important role in the formation and evolution of interstellar clouds and protostars. A vast amount of polarization data from thermal dust emission is a valuable tool for studying B-fields and dust in star-forming regions.

In this talk, I will present our study on B-fields toward several molecular clouds using observations from SOFIA/HAWC+ and JCMT/Pol-2. Then, I will focus on probing dust physics, including the process of grain alignment and rotational disruption due to radiative torques (RATs), using dust polarization data observed toward several molecular clouds. We apply the RAT theory to explain the decrease of the polarization fraction toward the dense region (aka. polarization hole).

Nguyen, Binh

Institution: University of Washington

Deep rivers can still be plumbed: A multi-band search for neighbors of high-redshift massive quiescent galaxies in COSMOS-Web

High-redshift ($z > 3$), massive quiescent galaxies (QGs) offer an important window into early Universe galaxy formation. Previous works, both simulations and observations of low- z equivalents, have predicted a broad range of properties in these QGs, from the ability to heighten the quenching fraction of their neighbors (i.e. galactic conformity) to the likelihood of having stronger clustering signals in their local environment. However, due to a scarcity in highly-resolved deep-field observations up until recently, these properties have not been thoroughly investigated and pose unresolved questions in galaxy evolution. Using new photometric-redshift catalogs derived from JWST NIRCам data in the COSMOS-Web field, we search for potential low-mass neighbors over a sample of nine spectroscopically-confirmed massive quiescent galaxies at $z > 3$. We find substantial populations of neighbors, mostly morphologically irregular, which exhibit active star formation, contrary to the conformity effect observed at low- z . These neighbors concentrate around their quiescent centrals with higher abundances than in the background COSMOS-Web field and in semi-analytical simulations, which confirms preexistent theories on clustering strength around QGs but also questions whether our current models have fully encompassed the many physical complexities of galaxy quenching. Lastly, we also report on two candidate $3 < z < 4$ protoclusters consisting of a quiescent, intermediate-mass central surrounded by star-forming neighbors. These findings overall pave novel paths towards understanding the mechanisms of quiescent galaxies, while also signaling an opportune era to examine these objects after the advent of JWST.

Nguyen Luong, Quang

Institution: CEA Saclay / NATASSO

Dust grain evolution from star-forming filaments to T-Tauri protoplanetary disks: Results from NIKA2 observations of the Taurus B211/B213 filament in the GASTON large program

Understanding the evolution of dust properties in molecular clouds is important for tracing the star formation process through submm observations. To understand the evolution of dust properties in molecular clouds in the course of the star formation process, we constrain the changes in the dust emissivity index

of dust grains from star-forming filaments to prestellar and protostellar cores to T Tauri stars, and also across the radial profiles of the filament. Using the NIKA2 continuum camera on the IRAM 30~m telescope, we observed the Taurus B211/B213 filament at 1.2~mm and 2~mm with unprecedented sensitivity and used the resulting continuum maps to derive the dust emissivity index β . Our complete sample of more than 105 objects detected in the β map of the B211/B213 filament indicates that, overall, the overall dust emissivity index β decreases from filament and prestellar cores ($\beta \sim 2 \pm 0.5$) to protostellar cores ($\beta \sim 1.2 \pm 0.2$) to T-Tauri protoplanetary disk ($\beta < 1$). The averaged dust emissivity index β across the B211/B213 filament exhibits a flat ($\beta \sim 2 \pm 0.3$) profile and show no variation across the radial profiles. This may imply that dust grain sizes are rather homogeneous in the filament, start to grow significantly in size only after the onset of the gravitational contraction/collapse of prestellar cores to protostars, reaching big sizes in T Tauri protoplanetary disks. This evolution from the parent filament to T-Tauri disks happens on a timescale of about 1-2~Myr.

Nhan, ICISE

Institution: svsvadv

Test

Test abstract

Nozaki, Shingo

Institution: Kyushu University

Influence of Gas Inflow from the Surroundings of Star-forming Cores on Protostellar Mass Growth

Observations of star-forming regions have shown that stars form in molecular cloud cores due to gravitational collapse. Moreover, some recent observations indicate that the dense matter outside prestellar cores can supply mass to cores. These findings suggest that the ambient environment surrounding the cores contributes significantly to the star formation process in molecular cloud cores. Thus, it is crucial to theoretically investigate how far the gas accreting onto protostars extends beyond the cores, and how the gas outside the cores influences the mass evolution of protostars and disks. To understand these aspects, we conduct numerical simulations across multiple spatial scales.

To investigate mass reservoirs for protostars, we conducted parsec-scale numerical simulations with passive tracer particles. Star-forming cores were identified by tracing the trajectories of tracer particles falling onto protostars. Our results show that the identified star-forming cores do not always coincide with the high-density regions identified as cores in observations. In particular, in clustered star-forming environments, the cores often fragment into clumpy structures due to selective accretion onto protostars.

To investigate the impact of gas outside the cores on the growth of protostellar and disk mass, we performed core-scale numerical simulations. In these simulations, we calculated the evolution of cores embedded in envelopes with different density distributions. Our results reveal that the mass accretion rate onto protostars is temporarily enhanced in the model with high-density external envelope. Furthermore, we find that the gas outside the cores affects not only the protostellar mass growth, but also the protostellar-to-disk mass ratio and the balance between mass accretion onto the star and mass ejection via outflows. These findings indicate that ambient gas surrounding molecular cloud cores plays a crucial role in determining stellar masses, highlighting the need to consider the broader core environment in models of star formation.

Nucara, Alice

Institution: INAF-IAPS

The Rosetta Stone project: a self-consistent simulation-to-observation study of massive star-forming clumps

Star formation, in particular in massive star-forming regions, is a multi-scale process. To provide a quantitative characterization of how the initial conditions of clumps and environment affect the observed fragmentation properties, we developed the Rosetta Stone project. Rosetta Stone is an end-to-end (simulations $\Leftrightarrow$ observations) framework based on the systematic production of realistic synthetic observations of massive clump fragmentation.

As a first case study, we compared ALMA 1.3 mm continuum dust emission observations from the SQUALO survey (Traficante et al. 2023) with a newly developed set of 24 radiative magneto-hydrodynamical simulations of high-mass clump fragmentation (Lebreuilly+, submitted). The simulations have been initialized combining typical values of clump mass (500, 1000 $M_{\odot}$) and radius (~ 0.4 pc), with two levels of turbulence (Mach number: 7, 10), and three clump magnetizations (normalized mass to magnetic flux ratio: $\sim 3, 10, 100$). The simulations have been post-processed using RADMC-3D and CASA software to mimic the Herschel and SQUALO observing wavelengths (Tung+, submitted), and SQUALO interferometric (ALMA main array and ACA) features (Nucara+, submitted). Following the clump evolution as a function of the (synthetic) luminosity/mass ratio evolutionary parameter with two initial turbulent seeds, and along three orthogonal projections, we have based our analysis on a statistically significant collection of ~ 1000 synthetic maps. Combined results from our models, synthetic observations, and SQUALO observations favor a scenario in which fragmentation occurs throughout the whole clump evolution. Moreover, the process appears to be multi-scale (fragments multiplicity @7000AU $\ll$ sinks multiplicity @400AU) and hierarchical (fragment formation efficiency > sink formation efficiency). Among the adopted initial conditions, magnetic fields have the largest impact on the fragmentation outcome in both models and synthetic observations favoring clump collapse and reducing fragmentation.

OJHA, DEVENDRA

Institution: Tata Institute of Fundamental Research (TIFR)

Accretion Outburst: A window to the innermost region of protoplanetary discs

It is becoming increasingly clear that young stellar objects (YSOs) undergo multiple episodes of luminosity outbursts, with accretion rates enhanced by a factor of a few to a hundred over timescales ranging from months to centuries. These outbursts, marked by excess high-energy radiation, reshape the thermal, chemical, and physical structure of the circumstellar environment. By perturbing the steadily accreting star-disk system, they also provide us an unprecedented window into the dynamics of the innermost regions of the accretion disc. In this talk, I will present some new insights into the mechanisms that trigger and regulate these outbursts, based on our decade-long observational campaign of eruptive objects—Monitoring FU Orionis and EX Orionis Sources (MFES). Our findings also uncovered how outbursts drive a migration of the accretion flow, confirming predictions from 3D MHD simulations of magnetospheric accretion.

Olguin Choupay, Fernando

Institution: Kyoto University

Rotation and infall in high-mass YSOs

Disk are thought to be important to the formation of high-mass stars, as these alleviate the radiation pressure over the accretion flow. The development of instruments with higher angular has allowed us to increasingly find disk-like structures and to trace the gas kinematics closer to the massive star. Here we present a study toward 30 fields observed with ALMA. We find gas velocity gradients consistent with rotation and rotation+infall. Most of these gradients can be explained with roughly a Keplerian power laws, but most strikingly, many of the position velocity diagrams show asymmetries. We discuss the origin of these asymmetries, which can be the result of a combination of factors including: clumpy environment, anisotropic collapse (with some sources showing evidence of streamers), or high infall/accretion rates which wouldn't allow the formation of uniform Keplerian disks.

Oya, Yoko

Institution: Kyoto University

Elias 29: Low-Mass Star Formation in a Warm Environment

A wide variety of planetary systems have been discovered in recent decades. The origin of their diversity, both in physics and chemistry, probably resides in the earliest history of the planetary system formation, namely, what happened during the protostellar phases. As well, the relation between physical and chemical diversities and environment has attracted broad attention in astrochemistry, astrophysics, and planetary science.

Elias 29, a Class I low-mass protostellar source in Ophiuchus, has been known to be grown-up in a warm region illuminated by nearby stars. We performed molecular line observations toward this source with ALMA as an individual project and as a part of a large project 'FAUST'. We delineated the distribution of the current gas temperature. It is indeed confirmed that the current gas temperature is as high as 20-30 K in a quiescent region even at a distance of 1000 au from the protostar. We also found some hot spots with a high temperature (>50 K) besides the vicinity of the protostar. The SO emission is locally enhanced in the hot spots. They are explained by a local heating due to outflow-/jet- driven shocks.

Moreover, we revealed that Elias 29 has a peculiar chemical composition; this source is abundant in SO and SO₂, while it is poor in complex organic molecules and hydrocarbons. We also found that the deuterium fractionation ratio of HCO⁺ is as low as <1 % in the quiescent region. These chemical characteristics can be attributed to the warm environment during the prestellar phase.

Elias 29 is an interesting source, where we see the effects on the chemical evolution by both the physical conditions in the past and at current.

Partmann, Christian

Institution: CCA, Flatiron Institute

Star Formation, feedback, and black hole growth in nuclear clusters of low-mass galaxies

Many low-mass galaxies host dense nuclear star clusters (NSCs) at their center. Some of these NSCs show evidence of ongoing star formation and signatures of black hole activity. This makes NSCs promising candidates for the origin of intermediate mass black hole seeds (IMBHs), which might form via stellar collisions and their subsequent growth through gas accretion and mergers is facilitated by the gravitational potential of the host star cluster.

With a novel set of high-resolution simulations of low-mass galaxies with nuclear star clusters, I explore the interplay between nuclear star formation, stellar feedback, and black hole growth. These galaxy scale simulations achieve solar-mass gas resolution (refined to <0.01 Msun inside the NSC), have a resolved three-phase interstellar medium (ISM), and account for non-equilibrium heating, cooling, and molecular chemistry processes. Star formation is modeled with a locally mass- and momentum-conserving prescription that samples the full initial mass function with individual stars. Massive stars form HII regions and explode as resolved supernovae. Nuclear stellar dynamics is integrated with an accurate algorithmic regularization scheme to allow for collisional gravitational interactions. IMBH accretion from the multiphase interstellar medium is modeled with a sink particle prescription that incorporates various wind feedback models.

In my talk, I will analyze the co-evolution of NSCs, IMBHs, and the ISM, and demonstrate that nuclear star formation is crucial for regulating the gas flows in the galactic center and the circumnuclear disc around the IMBH. Using the same simulation model, I will also present initial results from cosmological simulations of the formation of the first dense star clusters at high-redshift and discuss these findings in the context of recent JWST observations.

Pastrav, Bogdan Adrian

Institution: Institute of Space Science (ISS)

The interplay between star-formation, dust/ISM properties and galaxy integrated quantities in the local Universe

We present results of a detailed study of a sample of low-redshift galaxies, based on previous work, that aims to connect both local / resolved and integrated galaxy properties with those of dust, ISM and star-formation. Dust temperatures are determined based on the galaxy dust masses previously calculated through a self-consistent method, considering a modified black-body (MBB) function to characterise the cold dust emission spectral energy distribution (SED), without the need to actually perform an SED fit. The range and average temperatures values are found to be consistent within errors with values from other studies. At the same time, the dust emissivity index (β) for each galaxy is also calculated, and its evolution with temperature quantified. It is investigated if the dust emissivity index can be predicted from other relation (e.g. if it scales with) or other local / integrated dust/ISM or galaxy property, and which star-formation or ISM related quantity traces dust temperature. In this respect, new and established relations between the dust temperature, β , the surface densities of dust, star-formation and stellar mass, and other related local and integrated quantities are presented and analysed. We also show the extent of dust distribution compared with the star-formation and the stellar continuum one (quantified by the corresponding surface densities and scale-lengths / effective radii), as a function of stellar mass. The results and conclusions can be relevant for higher redshift studies and latest surveys.

Peltonen, Joshua

Institution: University of Alberta

Bridging the Gap in the New Era of Star Formation

With the advent of JWST imaging in the Local Group, young stellar objects (YSOs) are being observed in a broader range of environments than ever before, which will revolutionize our understanding of star formation if their properties can be modelled accurately. However, a gap has developed between observations and the models used to make useful predictions of the physical properties. We aim to bridge the gap between these YSO observations and models by utilizing the methods that have been applied to older populations of stars with great success. Using the latest YSO radiation transfer and stellar evolution models, we have developed a population synthesis code that can generate YSO populations within a vast parameter space that accounts for details like binaries, clustering, and extinction. We then use Bayesian inference to determine the age and mass of an observed population of YSOs. We begin with a proof of concept by comparing the results of applying this new code to YSOs in the recent JWST images of NGC 604 within M33 and previous Spitzer studies of the LMC. We find the direct star formation efficiency of a second generation of star formation currently taking place in NGC 604. This new method allows us to directly determine the recent star formation history, giving an unprecedented look at the effect of the large-scale environment on individual star formation.

Pezzuto, Stefania

Institution: INAF - IAPS

The giant molecular cloud in Orion: physical results from the Herschel observations of Orion A

The formation of high-mass stars is one of the unsolved problems in the theory of star formation. Beside the big challenges of modelling the collapse of a dusty core from the early phases, we face also the observational difficulty given by the distance where the sites of formation of massive stars are found. As the number of stars per given mass intervals decreases with the mass, massive stars are rare and all the Earth nearby clouds only form intermediate- to low-mass stars. Thus, we have to look for high-mass formation sites quite far from the sun, from ~ 1 kpc and farther away. The only exception is the giant molecular cloud projected against the Orion constellation that is at less than 500 pc from us. For this reason, Orion is the testbed for any theory of massive star formation because we can reach high sensitivity in mass, so that we can get a complete knowledge of the mass spectrum; and high spatial resolution, thus observing single cores instead of clumps containing many cores inside (see e.g., the Hi-GAL survey).

In this talk I present the first results of the analysis of the Herschel observations, part of the Herschel Gould Belt Survey (HGBS), of the southern region of Orion, namely Orion A. From the H₂ column density map, the morphology of the cloud can be derived in connection with the problem of the distance variation throughout the region. The catalog of cold dense cores, both pre- or proto- stellar in nature, is discussed along with the core mass function, with particular emphasis on the case of L1641.

Polak, Brooke

Institution: American Museum of Natural History

Runaway Stars Ejected by Subcluster Mergers

Runaway stars are traditionally thought to form via two mechanisms: dynamical ejection and the binary supernova scenario (BSS). We introduce a third: the subcluster ejection scenario (SCES), where stars from infalling subclusters are ejected by tidal interactions with the growing cluster's gravitational potential. Using a star-by-star simulation of a star cluster forming from a $10^6 M_{\odot}$ gas cloud in the TORCH framework, we show that hierarchical subcluster mergers naturally lead to runaway stars. These runaways, formed during late-stage mergers, are anisotropically distributed and share similar ages, velocities, and trajectories. Some SCES events also produce runaway binaries, which can later experience additional velocity boosts via BSS, potentially creating hypervelocity stars. SCES signatures in observed runaway groups offer insight into the cluster formation process. We further investigate how replacing spherical initial conditions with self consistent ones can potentially enhance the production of SCES runaway stars.

Porter, Lori

Institution: Columbia University

Simulating High-Velocity Clouds in the Observational Plane: An Initial Study with the Smith Cloud

High-velocity clouds (HVCs) have the potential to fuel future star formation in the Galaxy, but to do so, they must survive their passage through the hot halo. While recent work has improved our understanding of the survival criterion for cloud-wind interactions, few observational comparisons exist that explore this criterion. We therefore present an initial comparison of simulations with the Smith Cloud (SC; $d = 12.4$ kpc, $l, b = 40^\circ, -13^\circ$), recently mapped with neutral hydrogen observations from the high-resolution GALFA-HI survey. We use observed properties of the Smith Cloud to motivate simulations of comparable clouds in wind tunnel simulations with Enzo-E, an adaptive mesh refinement MHD code. For both observations and simulations, we utilize moment maps and characterize turbulence through a projected first-order velocity structure function and do the same for HI column density with a normalized autocovariance function. Using these properties as common comparison metrics, we evaluate how well simulations replicate observations, show the relevance of turbulent radiative mixing layer (TRML) entrainment to HVCs, and investigate how various initial cloud conditions (such as radius, metallicity, thermal pressure, viewing angle, and distance) affect the presented statistics. We also make suggestions on how to further improve such simulations to better match observed HVCs.

Prieto, Almudena

Institution: Instituto Astrofisica Canarias

Observatory University of Munich

The PARSEC view of star formation and the interstellar medium in galaxies

The PARSEC project is a multiwavelength investigation of the centers of galaxies at parsec scales. In this presentation, I will provide a direct visualization of the star formation process in the centers of galaxies, resolved into their building blocks—the star clusters.

I will address the triggering process of star formation in a range of galaxies with different morphologies and levels of nuclear activity. This triggering process will be connected to a permeating interstellar medium, resolved into a fine network of molecular and dust filaments that enshroud and feed the star clusters. The analysis of hundreds of clusters and their molecular cloud precursors allows us to determine the timescale of major star formation episodes, from the molecular core to the pre-cluster phase to the cluster phase. With this information, an accurate estimate of the star formation rate at both cluster and galaxy scales will be presented. The properties of star clusters at parsec scales will be compared with equivalent measurements in our Milky Way and with recent results on resolved star clusters at high redshift. I will show how this parsec-scale view of star formation reveals very similar properties between galaxies of different age and even between the local and the high redshift Universe.

Ramkumar, Ria

Institution: Cardiff University

Characterising Magnetic Field Properties During the Formation of Star Cluster Progenitors

Gravity, turbulence, and magnetic fields are thought to be the three main factors influencing star formation. In Peretto et al. 2023 the gravity and turbulence in a sample of star-forming clumps and their parent molecular clouds were investigated. The findings of this study were that clumps are dynamically decoupled from their parent molecular clouds - this result might indicate that the star formation process has a preferred spatial and/or density scale on which it occurs. It is unknown as to the physical reason why this decoupling may take place. I have begun research into the magnetic field counterpart of the Peretto et al. 2023 study, aiming to observe whether the dynamical decoupling is accompanied by a decoupling in the properties of the magnetic field at the different spatial scales of cloud and clump. I present my research comparing the magnetic fields of a sample of infrared dark clouds and their parent molecular clouds using dust polarisation data from JCMT POL-2 and Planck respectively. It is found that the direction of the magnetic field within the small-scale dense clumps tends to differ from the direction of the magnetic field in the large-scale more diffuse clouds for all samples. A HRO analysis also shows links between correspondence of the magnetic field vector with the intensity gradient and the virial ratio parameter. These results seem to imply that the star-forming clumps are indeed magnetically decoupled from their parent molecular clouds, in accordance with the findings of Peretto et al. 2023.

Rani, Raffaele

Institution: National Tsing Hua University

Turbulence modes in Galactic plane clouds in CHIMPS2

CHIMPS2 is the follow-up to the $^{13}\text{CO}/\text{C}^{18}\text{O}$ (3 - 2) Heterodyne Inner Milky Way Plane Survey (CHIMPS) and the CO Hi-Resolution Survey (COHRS) and is a Large Program on the JCMT. The CHIMPS2 Inner Galaxy observations cover longitudes between 16° and 47° with $-0.5^\circ \leq b \leq 0.5^\circ$. When combined with the complementary $^{13}\text{CO}/\text{C}^{18}\text{O}/^{12}\text{CO}(1-0)$ survey at the Nobeyama 45m at matching 15 arcsec resolution and sensitivity, and other current CO surveys, CHIMPS2 provides a complete set of transition data with which to calculate accurate column densities, gas temperatures and turbulent Mach numbers, that would otherwise rely on estimations and underlying assumptions.

We construct a novel catalogue of CHIMPS2 Inner Galaxy sources and link their positions, physical properties and star-forming efficiency to the solenoidal modes of turbulence in the clouds (defined as the solenoidal fraction, the relative fraction of power in the solenoidal modes of the density momentum field). The range of Galactic longitudes covered by CHIMPS2 allows us to probe the relationship between turbulence modes and different Galactic environments, covering, in particular, the transition into the region spanned by the rotation of the Galactic bar and arm and inter-arm regions. Our investigation confirms the negative correlation between star formation efficiency and solenoidal turbulence found in CHIMPS and shows that the solenoidal fraction is highest in the Inner Galaxy (within about 3 kpc of the Galactic centre) and declines with a shallow gradient with increasing Galactocentric distance. In addition, we extend this analysis to a selection of targets in the Central Molecular Zone.

Ray, Barshan

Institution: Indian Institute of Science Education and Research Kolkata

Time Evolution of the Protoplanetary Disk Size under Non-ideal

Magnetohydrodynamics

Magnetic fields play an important role in the formation and evolution of an accretion disk around a protostar, also known as a protoplanetary disk. Recent studies, via simple assumptions, describe analytical methods linking the geometry of large scale magnetic fields threading a star forming core to the disk size, with ambipolar diffusion shown to be the primary non-ideal MHD effect in alleviating the "magnetic catastrophe" which prevents Keplerian disk formation.

These analytical descriptions have achieved good agreement with numerical experiments, and provide key insights into disk size population. To build upon this model, we implement the full solution for the self-similar collapse of an isothermal sphere as the envelope surrounding the core, which in turn yields the salient feature of this approach -- the time evolution of the system. Through this time-dependent model, we investigate how the interplay between ambipolar diffusion and field accretion behaves over the inevitable time evolution of the backdrop of a collapsing gas envelope, to ultimately determine the disk size evolution. By applying the full solution of the evolving, collapsing envelope, we observe a disk radius and a central mass that grow sub-linearly over time, during early stages of collapse.

Redaelli, Elena

Institution: European Southern Observatory

Molecules as probes to unveil how stars form

Research into star formation is a highly active area of modern astrophysics. Stars are born in dense and cold environments known as molecular clouds, which appear as dark patches in the night sky as optical radiation cannot penetrate them. Since these clouds are composed of molecules, molecular transitions at radio and microwave wavelengths represent an ideal diagnostic tool for probing these phases of the interstellar medium. In my talk, I will demonstrate how this analysis allows us to infer the physical and chemical structure of star-forming regions and understand their evolution. I will showcase examples of the effectiveness of this technique in both low-mass and high-mass regimes, each presenting its unique challenges.

Reiter, Megan

Institution: Rice University

Feedback on large and small scales

Energetic and momentum feedback from high-mass stars – radiation, winds, and eventually supernovae - affect the interstellar medium and star formation on all scales. Together, feedback processes illuminate, heat, evaporate, and fundamentally reshape everything in the surrounding environment, regulating star formation on the large scale of galaxies by determine the lifetime of molecular clouds to the small scales of planet-forming disks around nearby low-mass stars. On large scales, feedback clears the gas from star forming regions, perhaps altering the star formation efficiency per free fall time before ultimately ending star formation. On small scales, the community is increasingly examining the impact of feedback from the environment on the evolution of planet-forming disks in the region. External UV irradiation from nearby high-mass stars will evaporate disks from the outside-in, reducing the time and materials available to make planets. New surveys and instruments have unlocked the high-mass star-forming environment in the Milky Way and nearby galaxies, permitting observations of a wide range of environments in different galactic contexts and a range of ages. Progress is accelerating with results from the James Webb Space Telescope which probes younger, more embedded regions. This talk will review where we are and where we are going as current and upcoming capabilities continue to reveal how feedback affects the evolution of star-forming regions.

Ritter, Jelena

Institution: Max Planck Institute for Astrophysics

How AGN feedback shapes molecular gas reservoirs in $z \sim 3$ quasars

Understanding the regulation of star formation in massive galaxies requires detailed studies of their cold gas reservoirs across cosmic time. While extended Ly-alpha nebulae discovered around active galactic nuclei (AGN) reveal the presence of cool halo gas, it remains unclear how this diffuse phase connects to the cold molecular gas that directly fuels star formation. In this study, we leverage ALMA CO(4-3) observations of 37 quasars at $z \sim 3$ – all of which have been previously mapped in Ly-alpha with VLT/MUSE - to investigate how the molecular gas content relates to quasar and halo properties. In a subset of these targets, the CO emission extends out to halo scales, revealing large molecular gas reservoirs surrounding the quasars. We find that systems with lower black hole mass and Eddington ratio exhibit higher CO detection rates and lower Ly-alpha surface brightness. This result suggests that radiative feedback regulates cold gas survival and potential star formation activity in dusty, gas-rich environments, leading to suppressed Ly-alpha emission. Additionally, I will discuss evidence for gas depletion in systems with multiple companions as they approach the quasar's massive halo. This work provides new insights into the physical processes that govern cold gas retention and star formation in the most massive galaxies at cosmic noon.

Saavedra, Javier

Institution: University of Memphis

prISM break! How superbubbles escape the ISM or fragment trying

There are several questions about how supernovae (SNe)-driven superbubbles regulate star formation in disk galaxies. We seek to answer this by considering how distinct phases of bubble growth produce different outcomes for the bubble. These phases are characterized by 4 timescales: the hot gas cooling time, the duration of SNe detonation, the time until bubble breakout, and the time until bubble fragmentation. We then use the self-similar evolution of a bubble passing through one or more of these phases to determine which galactic environments lead to a superbubble breaking out to drive an outflow versus fragmenting and mixing back into the ISM. Our analysis concludes that outflows are the most common fate for SNe-driven superbubbles and that these happen before SNe stop detonating and before the interior cools. We also found that fragmentation can occur in galactic environments with low gas fractions and high gravitational potential.

Salinas, Javiera

Institution: Universidad Nacional Autónoma de México

Unveiling velocity structures in the massive protocluster G012.80: N_2H^+ as a tracer of filament evolution

We study the dense $\text{N}_2\text{H}^+(1-0)$ gas in the nearby (2.4 kpc) and massive ($4.6 \times 10^3 M_\odot$) protocluster G012.80 observed as part of the ALMA-IMF Large Program (Motte et al. 2022). We model the full N_2H^+ emission finding $\sim 55\%$ of the spectra associated with 2 velocity components (peaks separated by 2.1 km s^{-1}), and the remainder well-fit by a single component. We observe absence of N_2H^+ emission in the G012 center, where $\text{H41}\alpha$ and continuum emission are concentrated, likely due to radiative feedback effects arising from massive star formation. In PV diagrams, we observe zig-zag and twisting velocity structures pervasively in the dense gas traced by our N_2H^+ observations. The PV structures and velocity gradients (VG) in the two main filamentary structures (R1 & R2) are markedly different: R1 exhibit a helical feature potential associated with filament rotation, a velocity gradient along the filament with a timescale of 0.09 Myr, and low cores abundance while, R2 present quiescent velocities related to the high abundance of masive cores and lacks velocity gradients in the same direction of the R1 VG. We estimate H_2 masses in both filaments and calculate line-mass profiles that are well-described by power-law relations in both filaments. We use protostellar cores masses to estimate SFR and SFE in both filaments founding that R2 forms more masses per Myr ($72 M_\odot \text{ Myr}^{-1}$) and with double efficiency of R1 ($24 M_\odot \text{ Myr}^{-1}$). Considering kinematic and all previous differences, we propose that R1 is at an earlier evolutionary stage than R2, revealing that filaments within the same protocluster can follow distinct evolutionary paths.

Sanhueza, Patricio

Institution: The University of Tokyo

The Magnetic Field at the Onset of High-mass Star Formation

A complete understanding of the initial conditions of high-mass star formation and what processes determine multiplicity require the study of the magnetic field in young, massive cores. Using ALMA 250 GHz polarization observations ($0.3'' = 1000$ au) and ALMA 220 GHz high-angular resolution observations ($0.05'' = 160$ au), we have performed a full energy analysis including the magnetic field at core scales and have assessed what influences the multiplicity inside a massive core previously believed to be in the prestellar phase (G11.92 MM2 core with a mass of 31 M_{sun}). At high-resolution, the MM2 core fragments into a binary system with a projected separation of 505 au and a binary mass ratio of 1.14. We estimate in this core a magnetic field strength of 6.2 mG and a mass-to-magnetic flux ratio of 18. The MM2 core is strongly subvirialized with a virial parameter of 0.064, including the magnetic field. The high mass-to-magnetic flux ratio and low virial parameter indicate that this massive core is very likely undergoing runaway collapse, which is in direct contradiction with the core-accretion model. The MM2 core is embedded in a filament that has a velocity gradient consistent with infall. In line with clump-fed scenarios, the core can grow in mass at a rate of $1.9\text{--}5.6 \times 10^{-4} M_{\text{sun}}/\text{yr}$. In spite of the magnetic field having only a minor contribution to the total energy budget at core scales (a few 1000s au), it likely plays a more important role at smaller scales (a few 100s au) by setting the binary properties. Considering energy ratios and a fragmentation criterion at the core scale, the binary system could have been formed by core fragmentation. The binary system properties, however, are also consistent with radiation-magnetohydrodynamic simulations with super-Alfvénic, supersonic (or sonic) turbulence that form binaries by disk fragmentation.

Soliman, Nadine

Institution: Caltech

Star Formation in Different (Dust) Environments

Interstellar dust plays a central role in the physical processes that regulate star formation. Dust governs how gas cools, absorbs radiation, and evolves chemically, making it a key driver of the thermal and dynamical evolution of star-forming regions. However, dust properties, such as grain size and spatial distribution, can vary significantly across galactic environments and within individual giant molecular clouds (GMCs), leading to complex and often non-linear impacts on star formation.

We present results from high-resolution radiation-dust-magnetohydrodynamic (RDMHD) simulations conducted with the STARFORGE framework. These simulations explicitly evolve dust grain dynamics and thermochemistry alongside radiative transport, thermochemistry, star formation, and stellar feedback. Specifically, they relax common assumptions by varying the grain size distribution and allowing the dust to decouple from the gas dynamics.

Generally, increasing grain size at fixed dust mass modifies competing thermochemical processes, rendering the net impact on star formation challenging to predict. Our simulations reveal that larger grains suppress star formation efficiency by up to an order of magnitude, an effect much stronger than equivalent variations in metallicity. This suppression arises from reduced dust opacity, which allows radiation to penetrate more deeply into the cloud, raising gas temperatures and ionization levels, thereby halting star formation.

Moreover, we find that dust dynamically decouples from gas on AU to parsecs scales. This decoupling is driven by radiation from massive stars (above a few solar masses), which clears dust from within ~ 1000 AU of the stars. As a result, the local dust-to-gas ratio is reduced by two orders of magnitude, creating dust-evacuated regions that alter the circumstellar environments and influence key processes such as disk chemistry and thermodynamics.

These results demonstrate that microphysical dust variations can strongly influence star formation. By moving beyond idealized dust treatments, our simulations offer new insight into how dust shapes the diversity of star-forming conditions.

Sridhar, Amrutha

Institution: Indian Institute of Astrophysics

Constraining the High-Mass Stellar IMF in Galaxies: A Pilot Method Using UVIT and H α –MUSE Observations Applied to NGC 628

We present a pilot method to estimate the high-mass stellar initial mass function (IMF) across spiral arms, interarm, and spur regions in galaxies, and we applied it to the nearby face-on galaxy NGC 628. We used H α maps from VLT/MUSE and far-/near-ultraviolet (FUV/NUV) images from UVIT to extract Star-forming complexes (SFCs), and also used ALMA data to delineate the molecular gas distribution.

We got the approximate number of O stars, B0 ($M^* > 10 M_{\odot}$) and B1 ($3 M_{\odot} \leq M^* \leq 10 M_{\odot}$) stars from H α and UV emissions. Using the ratios of O to B0 and B0 to B1 stars, we derived two IMF slope estimates: α_1 (O/B0) and α_2 (B0/B1). Assuming that H α traces only O8-type stars, α_1 aligns with the canonical IMF. However, SFCs populated with O stars up to $100 M_{\odot}$, α_1 becomes significantly steeper. In contrast, α_2 remains insensitive primarily to changes in the upper-end O star population, with a mean $\alpha_2 = 2.64 \pm 0.14$. Restricting the analysis to blue SFCs (FUV-NUV ≤ 0.3) yields a tighter distribution with $\alpha_2 = 2.43 \pm 0.06$. We find no significant variation in IMF slopes between arm and spur regions. However, α_2 shows correlations with various star formation properties of SFCs.

Stecklum, Bringfried

Institution: Thuringian State Observatory

Tracing the variability of massive young stellar objects

Edwin Hubble's identification of NGC 2261 as a variable nebula provided the first evidence of light echoes and shadowing effects within reflection nebulae. Later, the erratic behavior of the young star R Mon was identified as the reason. Numerous young stellar objects (YSOs) subsequently observed also exhibit variable illumination when emerging from their parental cloud. However, deeply embedded massive YSOs (MYSOs) are harder to detect due to significant extinction, although their nebulae might be revealed in the near infrared. The variability becomes most obvious to objects seen close to edge-on by changes in the surface brightness of the outflow cavities. This allows us to derive characteristics on the dust configuration and improve the coverage of light curves. We present findings for three MYSOs based on NEOWISE data spanning more than a decade, which illustrate the potential of this kind of investigation.

Takaishi, Daisuke

Institution: Kagoshima University

Competitive roles of turbulence and magnetic field on the formation of unipolar outflows in isolated molecular cloud cores

We investigate the impact of the turbulence and magnetic field on the formation of unipolar outflows in the gravitational collapse of isolated low-mass cloud cores using three-dimensional nonideal magnetohydrodynamics simulations. We find that the unipolar outflows are formed in the cloud cores with the super-Alfvénic turbulence of $MA > 1$, where MA is the Alfvén Mach number of the initial cloud core. In contrast, the bipolar outflows are formed in the cloud cores with $MA < \sim 1$. Our results suggest that the strengths of the turbulence and magnetic field of the cloud core play a key role in the formation of unipolar outflows. We also find that no outflow is formed in cloud cores with the strong magnetic field of the dimensionless mass-to-flux ratio $\mu = 2$. Our results indicate that the outflow morphologies are tracers to indirectly estimate the strengths of the turbulence and magnetic field of the parent cloud cores.

Truong Le, Gia Bao

Institution: Korea Astronomy and Space Science Institute

Probing 3D B-fields using dust polarization and grain alignment theory

Magnetic fields (B-fields) are ubiquitous in the Universe and are thought to play an important role in various astrophysical processes. The polarization of starlight absorption and thermal emission induced by magnetically aligned grains is widely used to measure the two-dimensional magnetic field projected onto the plane-of-sky (POS); however, its component along the line of sight (LOS) is not yet constrained. In this talk, I introduce our new method to infer three-dimensional (3D) B-fields using starlight and thermal dust polarization combined with the modern magnetically enhanced radiative torque (MRAT) alignment theory and the effect of magnetic turbulence. We first perform synthetic observations of dust polarization of magnetohydrodynamic (MHD) simulations of a filamentary cloud with our updated POLARIS code incorporating the modern MRAT theory. We test the new technique with synthetic observations and find that the B-field inclination angles with respect to the LOS can be accurately constrained by the synthetic starlight polarization efficiency or thermal dust polarization degree once the effects of grain alignment by MRAT, dust properties, and B-field fluctuations are well characterized. Compared to the true 3D magnetic fields, the new technique based on grain alignment physics is more accurate than the previous methods that assume uniform grain alignment. Our new technique unlocks the full potential of tracing 3D B-fields and constraining dust properties and grain alignment physics on multiple scales of the diffuse interstellar medium and star-forming regions using multi-wavelength polarimetric observations.

Walter, Fabian

Institution: Max Planck Institute for Astronomy

Extreme star formation in the most luminous quasars in the Epoch of Reionization

Quasars are the brightest, non-transient objects observed at high redshifts, $z > 7$, which makes them unique probes of early star formation and the formation of the earliest massive galaxies. I will present recent very high-resolution (few 100pc) ALMA observations of a number of quasar host galaxies in the Epoch of Reionization that shed new insights on the star formation, gas content, and kinematics in these enigmatic sources. These ALMA observations are complemented by JWST observations to detect the quasar hosts and possible signs for outflows. The observations point at extreme star formation surface densities of $\sim 1000 \text{ M}_{\odot}/\text{kpc}^2$ in many quasar host galaxies, rivalling nearby Galactic star forming regions, albeit on many kiloparsec (galactic) scales.

Yoshino, Aoto

Institution: The University of Tokyo

Core Growth and Triggered Star Formation Probed by Numerical Simulation of Core Collisions and Mergers

Stars form through the gravitational contraction of dense cores in molecular clouds. Recent theoretical and observational studies indicate the possibility of core growth, in which the core mass increases during star formation (e.g., Pelkonen et al. 2021; Yano et al. 2024; André et al. 2014; Takemura et al. 2021).

Using core catalogs from the Herschel Gould Belt Survey, we evaluated the Bonnor-Ebert mass ratios ($\alpha_{\rm BE} = M_{\rm core} / M_{\rm BE, crit}$) for dense cores in nearby star-forming regions, including Lupus I, Ophiuchus, Corona Australis, and Taurus L1495. The analysis shows that most cores are gravitationally stable, with a median value of $\alpha_{\rm BE} \sim 0.1$. To initiate star formation from such stable cores, external factors such as core collisions may be necessary.

We conducted parameter search of core collisions using three-dimensional hydrodynamic simulations with adaptive mesh refinement (AMR) and sink particles, employing the ENZO code. The simulation results can be categorized based on the BE mass ratios of the cores, collision velocities, and impact parameters.

Our simulations reveal that collisions between gravitationally stable cores ($\alpha_{\rm BE} \sim 0.1$) at the sound speed, the typical velocity expected from molecular cloud turbulence at the core scale, lead to the merger of the cores without their destruction, promoting core growth. Furthermore, in collisions between less massive cores with $\alpha_{\rm BE} \approx 0.25$, collisional compression can lead to the formation of a single protostar. This result suggests that interactions between such less massive, gravitationally stable cores can also play an important role in star formation.

Additionally, core collisions can efficiently acquire mass over short timescales and tend to produce asymmetric structures around the formed protostars. These features suggest that core collisions may also contribute to the formation of streamer-like structures, which are often found in high spatial resolution observations.

Zamora, Sandra

Institution: Scuola Normale Superiore di Pisa

Understanding and interpreting the stellar populations and the chemical abundances at $z \sim 8.7$.

The chemical and galactic evolution of the Universe is a fundamental question in modern astrophysics, recently advanced by observations from the JWST. These high-quality observations not only enhance our knowledge of the gas properties, also provide an opportunity to study stellar populations and their key characteristics, an area that has received less attention in much of the current research.

In this work, we separately analyze the stellar populations using techniques typically applied in low-redshift studies and investigate the conditions of the gas. Then we connect these results by applying models of ionization and shocks, providing a more comprehensive understanding of the interplay between the stars and gas. An ideal laboratory to study star-formation at high-redshift, low-metallicity, high density environments is EGSY8P7, a bright galaxy at $z=8.683$. We used observations from JWST-NIRSpec to explore the spatially resolved UV-optical rest-frame wavelengths. The low-resolution data provide valuable insights into the young, ionizing stellar populations, allowing us to calculate properties such as stellar mass and the effective temperature of massive stars. The high-resolution enable us to analyze the chemical abundances and the extreme conditions of the interstellar medium. Additionally, we analyse the properties of an outflow found in the same observations.

Finally, by combining the ionized and stellar properties, we constructed a comprehensive picture of star formation in this object, including the use of new diagnostic diagrams at low-abundances. With this information, we aim to investigate the role of outflows in feedback processes and develop a broader understanding of star formation in high-redshift galaxies.