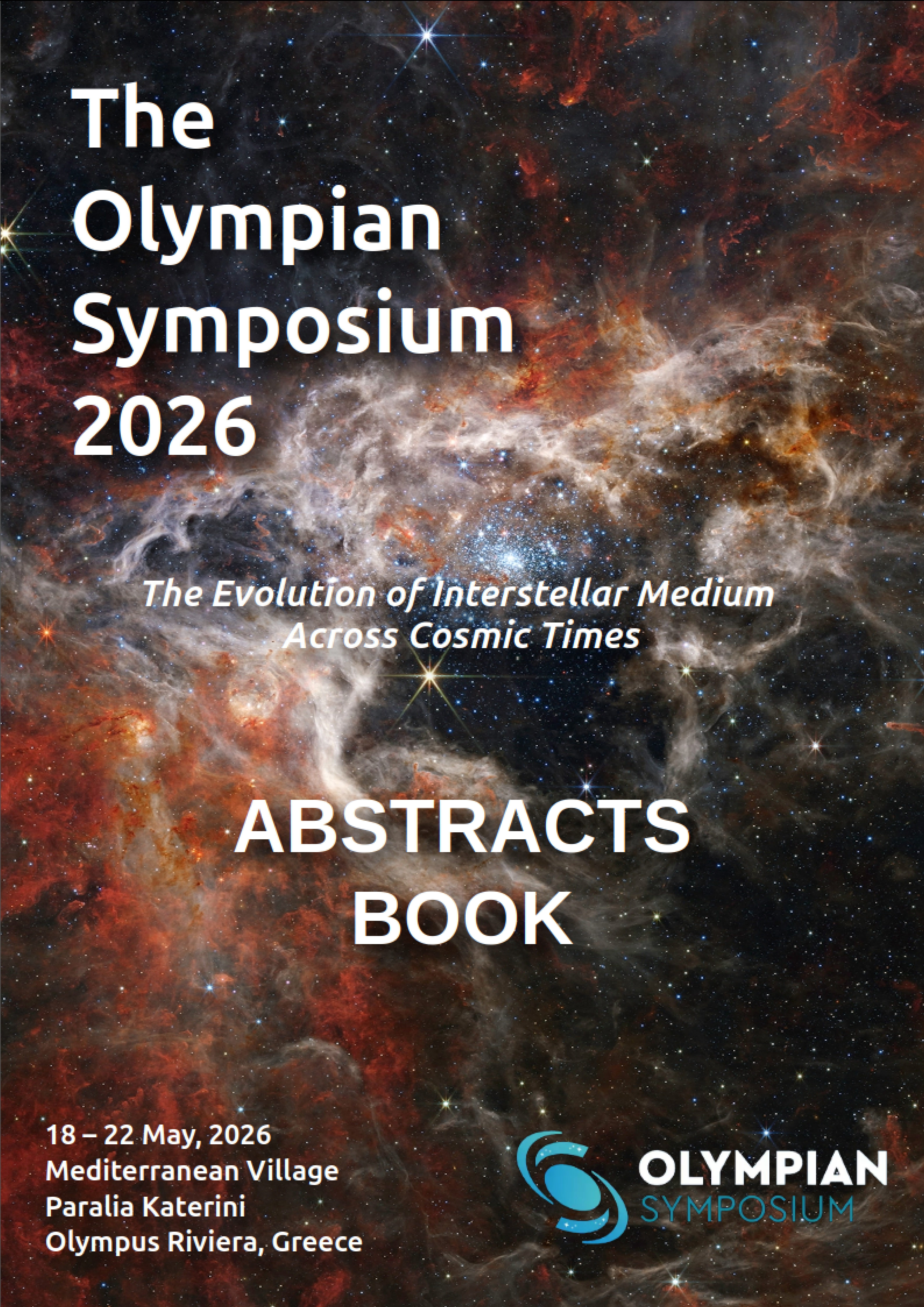

The Olympian Symposium 2026

The Evolution of Interstellar Medium Across Cosmic Times

ABSTRACTS BOOK

18 – 22 May, 2026
Mediterranean Village
Paralia Katerini
Olympus Riviera, Greece

OLYMPIAN SYMPOSIUM

The Olympian Symposium 2026
The Evolution of Interstellar Medium Across Cosmic Times
https://olympiansymposium.org/

Monday 18 May – Friday 22 May, 2026
Paralia Katerini, Olympus Riviera, Greece
Mediterranean Village Hotel

Cover image: JWST image of the Tarantula Nebula (NIRCam Image)
Credits: NASA, ESA, CSA, STScI, Webb ERO Production Team

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ZHEJIANG LAB
Intelligent Computing
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DEPARTMENT OF ASTROPHYSICS, ASTRONOMY & MECHANICS
SCHOOL OF PHYSICS
ARISTOTLE UNIVERSITY OF THESSALONIKI
REGIONAL UNIT OF PIERIA
REGION OF CENTRAL MACEDONIA

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Welcome to OS2026!

Dear Participants,

It is our great pleasure to welcome you to the Olympian Symposium 2026. This meeting brings together a diverse and vibrant community of researchers working across the interstellar medium, star formation, astrochemistry, and galaxy evolution, at a time when our field is being rapidly transformed by both cutting-edge observational facilities and advances in numerical modeling. From James Webb Space Telescope and Atacama Large Millimeter/submillimeter Array to large-scale simulations and emerging artificial intelligence methodologies, we are now able to explore the complexity of the ISM with unprecedented depth and precision. The Symposium aims to stimulate discussion, collaboration, and new ideas that will help shape the next generation of research in our field. We are especially delighted to host scientists from around the world, alongside early-career researchers whose contributions are essential to the future of astrophysics.

The Olympian Symposium series was established with the vision of creating a high-level international forum in an inspiring and historically rich setting. Since its inception in 2014, the conference has steadily grown in scope and impact, attracting leading experts from across the globe and building long-lasting collaborations. Over the years, it has evolved into a recognized platform for presenting cutting-edge results and discussing emerging challenges in astrophysics, while maintaining a strong emphasis on interaction, accessibility, and scientific excellence. Each edition builds upon this legacy, strengthening the Symposium's role as a meeting point between theory, observations, and data-driven approaches.

This year, we are also proud to introduce a new outreach initiative: the *Astronomy Park*, organized in collaboration with the Municipality of Katerini and under the auspices of the Hellenic Space Center. Taking place just before the conference, the Astronomy Park is designed to bring science closer to the public through interactive activities, including solar and nightsky observations, a portable planetarium, astrophotography exhibitions, and hands-on experiences for children and families. By connecting our scientific meeting with society at large, we hope to inspire curiosity, promote scientific thinking, and highlight the broader cultural and educational value of astronomy.

The OS2026 is kindly supported by Zhejiang Lab and the Intelligent Computing Journal. It is organized under the auspices of the Department of Astrophysics, Astronomy & Mechanics of the Aristotle University of Thessaloniki, and the Regional Unit of Pieria.

We thank you for being part of this effort and wish you a stimulating and productive Symposium!

Scientific Organizing Committee

Thomas G. Bisbas (Zhejiang Lab, China; co-chair)
Brandt Gaches (Duisburg-Essen, Germany; co-chair)
Munan Gong (University of Texas at El Paso, USA)
Desika Narayanan (University of Florida, USA)
Kathryn Grasha (ANU, Australia)
Hsi-An Pan (Tamkang University, Taiwan)
François Lique (Universite de Rennes, France)

Scientific Rationale

The interstellar medium plays a fundamental role in the life cycle of galaxies, acting as the reservoir from which stars and planetary systems form, and as the matter returned through stellar feedback processes. Tracing the evolution of the ISM from the early universe to the present day is essential to understanding galaxy formation, chemical enrichment, star formation histories, and the emergence of habitable environments.

Recent advances in both observations and numerical models – from JWST and ALMA to high-resolution simulations – now allow us to study the ISM across a wide range of epochs and environments. At the same time, the rapid development of artificial intelligence and machine learning is opening new avenues in numerical modeling, data analysis, and predictive simulations, enabling us to tackle the ISM's complexity in unprecedented ways.

This Symposium aims to bring together experts in galactic and extragalactic ISM studies, star formation, astrochemistry, and cosmology to synthesize our current understanding and chart future directions.

Discussion topics

1. Low-metallicity ISM
2. Extreme ISM environments
3. Feedback and the ISM lifecycle
4. Gaseous Environments Across Cosmic Epochs
5. Dusty Environments
6. Cosmic Rays, Magnetic Fields, and Turbulence in the ISM
7. The ISM Across Cosmic Time: Observational Frontiers
8. Numerical Models, Artificial Intelligence, and Machine Learning

Invited Speakers

- **Alex Cameron** (Oxford, UK & Niels Bohr Institute, Denmark)
- **Emanuele Daddi** (CEA, France)
- **Christoph Federrath** (ANU, Australia)
- **Reinhard Genzel** (MPE, Germany)
- **Brett McGuire** (MIT, USA)
- **Kate Pattle** (UCL, UK)
- **Jérôme Pety** (IRAM, France)
- **Julia Roman-Duval** (STScI, USA)
- **Jiayi Sun** (University of Kentucky, USA)
- **Linda Tacconi** (MPE, Germany)
- **Stefanie Walch-Gassner** (Cologne, Germany)

Pieria and Mt. Olympus

Under the imposing shadow of Mount Olympus, lies the land of Pieria. Pieria has over 100km of sandy coastline and the surrounding mountains are full of forests. It has been inhabited since the Bronze Age. Archaeological sites are scattered all over, most notably Dion, an important city of Ancient Macedonia, where Alexander the Great began his campaign from Greece to the end of the then-known world.

Olympus is one of the most famous mountains of the ancient world, mainly due to its sacredness to the ancient Greeks. All the snow-capped, majestic peaks of Mount Olympus awed the souls of ancient Greeks. They chose the highest peak, Mytikas, as the home of their twelve gods: **Zeus**, the King of Olympus, the lord of lightning, the punter and protector, the lover and the warlord; **Hera**, the wife of Zeus, protector of women and marriage; **Poseidon**, god of the sea, waters and springs, master of the seas and the geological phenomena; **Athena**, which started as a parton goddess of war and then evolved into a patron goddess of Athens and symbol of wisdom; **Dimitra**, the goddess of vegetation and agriculture, who especially protected cereal crops and farmers; **Hephaestus**, who was brilliant and ingenuous master of construction and metallurgy, a skilled and powerful craftsman; **Apollo**, the son of Zeus and Leto, the god of Light, Music, and Harmony; **Artemis**, the twin sister of Apollo, the goddess of wild nature and hunting, a protector of the countryside; **Hermes**, the messenger who brought messages to gods and people, protector of merchants, walkers and wrestlers; the blood-thirsty **Ares**, a war god, who represented the fury and the absurdity of the war; **Aphrodite**, who emerged from the sea, was the goddess of women's beauty and love; and finally **Hestia**, protector of family happiness.

Pieria was also home to the Muses. According to mythology, the nine Muses (**Calliope**, **Clio**, **Euterpe**, **Terpsichore**, **Meplomene**, **Thalia**, **Urania**, **Erato**, **Polymnia**) were the daughters of Zeus and Mnemosyne, protectors of the arts, literature and science. They were born in Pieria and lived on Mount Olympus, in the Olympian chambers, according to Hesiod's Theogony. Every Muse was a protector of a particular art or science.

In Pieria, the worship of **Orpheus**, a protector of music, was widespread. The mythical Orpheus was born in Pieria in a town called Livithra, where he also met his death by the Maenades, female followers of **Dionysus**, the god of wine. Orphic Mysteries, rituals of unknown content, took their name from Orpheus.

Today, Pieria is a tourist attraction for both historical reasons, as well as its natural beauty. It harmoniously combines the charm of the mountain, the delight of the sea and the interest of archaeological walks. Pieria welcomes you and invites you into an unforgettable journey in time and nature.

Timetable

I: Invited Talk (25 min), **C**: Contributed Talk (15 min)

Sunday, 17 May

17:00–21:30	**Registration**

Monday, 18 May

08:00–08:50	**Registration**		
08:50–09:00	**Welcome to OS2026!**		
	Feedback, Turbulence, and the ISM Lifecycle **Chair: Thomas Bisbas**		
09:00–09:25	I	**Stefanie Walch-Gassner**	Driving the ISM lifecycle
09:25–09:40	C	**Oerd Xhemollari**	Dense Gas Tracers as Temporal and Structural Evolution Markers of Molecular Clouds
09:40–09:55	C	**Tamara Koletic**	How Spiral Arms Filaments and Star Clusters are Related in a Simulated NGC 628 Galaxy
09:55–10:10	C	**Yuri Nishimura**	Why molecular lines trace star formation differently A unified view of density and chemistry from clouds to galaxies
10:10–10:25	C	**Nicolas Peschken**	Modelling outflows above the Milky Way Center
10:25–11:00	**Coffee break**		
	Cloud Evolution and Star Formation		
11:00–11:15	C	**Aayush Gautam**	Dynamical Evolution During Star Cluster Formation Crowding Multiplicity and Disk Dispersal
11:15–11:30	C	**Daisei Abe**	The Origin of Hub Filament Systems Radiation MHD Simulations toward Understanding Massive Star Formation
11:30–11:45	C	**Zoe Faes**	Bridging the scales from global galactic dynamics to local star formation
11:45–12:00	C	**Guillaume Vigoureux**	The Role of Radiative Supernova Remnants in the Ionization of the Galactic ISM

12:00–12:25	I	**Julia Roman-Duval**	Revealing the Cosmic Build up of Interstellar Dust with HST and JWST The Nearby Low Metallicity Universe as a Laboratory
12:25–12:45	**Poster presentations** Lennart Böhm, Timothy Faerber, James Garland, Katharina Immer, Emma Jarvis, Cheryl Lau, Esan Mouli Ghosh, Peter Schilke, Sengupta Dhrubojyoti, Masato Kobayashi, Natalie Lam, Adarsh Ranjan, Maria Jimena Rodriguez, Georgina Sampson Olalde, Patra Sudeshna		
12:40–16:00	**Lunch break / Beach time!**		
	Low-Metallicity and Dust Evolution **Chair: Gina Panopoulou**		
16:00–16:15	C	**Agata Karska**	The outer Galaxy as a template of low metallicity environments
16:15–16:30	C	**Léo Belloir**	Constraints on the efficiency of the photoelectric heating in a molecular ridge of the metal poor LMC
16:30–16:45	C	**Clarke Esmerian**	Modeling Cosmic Dust Evolution Atom by Atom in a Multiphase ISM
16:45–17:00	C	**Nick Andreadis**	The evolution of dust attenuation curves in the COLIBRE simulations
17:00–17:25	I	**Christoph Federrath**	The Link Between Turbulence and Star Formation
17:25–18:00	**Coffee break**		
	Dusty Environments and Chemical Enrichment		
18:00–18:15	C	**Alexia Anguera Ganzalez**	Chemical and Physical Evolution of Dense Gas in an IRDC Non LTE Chemistry and Feedback in G14.225 0.506
18:15–18:30	C	**Varsha Kulkarni**	Probing the Evolution of Interstellar Gas Metals and Dust Over Billions of Years
18:30–18:45	C	**Ryota Ikeda**	A census of distant dusty star forming galaxies from kpc to sub kpc scales using ALMA and JWST
18:45–19:00	C	**Siddharth Kumar**	Local enhancement of grain alignment near embedded protostars in the DR21 Ridge
19:00–19:15	C	**Yuki Isobe**	Tracing Early Chemical Enrichment in the Era of Ever Growing JWST Data
19:15–19:35	**Poster presentations** Suzanne Madden, Samantha Scibelli, Youxin Wang, Petia Yanchulova, Michael Busch, Madisen Johnson, Agnieszka Kobak, Jeremy Lim, Yuzuki Nagashima, James Nianias, Thomas Nordlander, Katherine Whitaker, Lara Pantoni		
21:00–23:00	**Welcome reception | Intelligent Computing Journal booth**		

Tuesday, 19 May

	Gaseous Environments Across Cosmic Epochs I Chair: Kathryn Grasha		
09:00–09:25	I	**Emanuelle Daddi**	The ebullient ISM of early quiescent galaxies
09:25–09:40	C	**Elisa Cataldi**	Tracing the Chemical Evolution of the High Redshift Interstellar Medium
09:40–09:55	C	**Leonardo Clarke**	Emission line Diagnostics at z greater than 2 A Probe of the Ionizing Spectrum and alpha Enhancement Beyond Cosmic Noon
09:55–10:10	C	**Souradeep Bhattacharya**	Probing chemical enrichment in star forming galaxies from direct O Ar and N abundances
10:10–10:25	C	**Blakesley Burkhart**	The Closest and Furthest Molecular Clouds Revealed via H2 Fluorescent Emission
10:25–11:00	**Coffee break**		
	Gaseous Environments Across Cosmic Epochs II		
11:00–11:25	I	**Alex Cameron**	Evolution of the ionized ISM across cosmic time
11:25–11:50	I	**Jiayi Sun**	Resolved Star Formation in Extreme Environments in the Local Universe
11:50–12:05	C	**Yao Yao**	Metallicity Calibrations for High Redshift Galaxies from Cosmological Simulations and Photoionization Modeling for the JWST Era
12:05–12:20	C	**Dominik Riechers**	Toward True Molecular Complexity in the Interstellar Medium at Early Cosmic Epochs
12:20–12:40	**Poster presentations** Ebihara Sho, Pablo Arriagada Torres, Thomas Herard-Demanche, Sean Linden, Emma Lundqvist, Luka Matijevic, Tomonari Michiyama, Utsav Siwakoti, Raghav Arora, Leonard Kaiser, Yang Meng-Zhe (x2), Divya Mishra, Daniel Seifried, Rowan Smith, Reagan Stanton, David Whitworth		
12:40–16:00	**Lunch break / Beach time!**		
	Extreme ISM Environments Chair: François Lique		
16:00–16:25	I	**Linda Tacconi**	Formation and Evolution of Galaxies: Star Formation and Dynamics I
16:25–16:50	I	**Reinhard Genzel**	Formation and Evolution of Galaxies: Star Formation and Dynamics II
16:50–17:05	C	**Frank Bigiel**	mm line ratios as probes of dense gas fractions and star formation efficiencies across local galaxies

17:05–17:20	C	**Ina Galic**	Probing Molecular Gas and Star Formation at Cloud Scales in M51 with NOEMA and JWST
17:20–17:35	C	**Robert Pascalau**	Dissecting The Alchemist NIRSpec IFU Reveals Turbulent Gas Inflows in a Complex Merger System at z≃10.17
17:35–18:05	**Coffee break**		
	Star Formation and ISM Across Environments		
18:05–18:20	C	**Neven Tomicic**	Star formation and properties of ionized gas at the galactic outskirts and in gas stripped galaxies
18:20–18:45	I	**Jérôme Pety**	Astrophysics meet data science for the study of Giant Molecular Clouds
18:45–19:00	C	**Jonathan Tan**	Frontiers of Massive Star Formation
19:00–19:15	C	**Ashley Barnes**	ALMA Central Molecular Zone Exploration Survey ACES Survey Overview and First Results
19:15–19:30	C	**Qing Liu**	Mapping the Diffuse ISM with Deep Wide field Optical Imaging

Wednesday, 20 May

Mt. Olympus hike, activities, free day!

Thursday, 21 May

	Role of Magnetic Fields in shaping the ISM **Chair: Daniel Seifried**		
09:00–09:25	I	**Kathrin Pattle**	Interstellar Magnetic Fields From Star Formation to Galaxy Evolution
09:25–09:40	C	**Aris Tristis**	Ambipolar diffusion and the mass to flux ratio in turbulent collapsing clouds
09:40–09:55	C	**Gina Panopoulou**	Towards a 3D view of the magnetized ISM in the Solar neighborhood
09:55–10:10	C	**Theotokis Georgatos**	The influence of magnetic fields in Cloud Cloud Collisions
10:10–10:25	C	**Szu-Ting Chen**	The Magnetic Field in Star Forming Regions of the Perseus Molecular Cloud
10:25–11:00	**Coffee break**		
	Cosmic Rays, Astrochemistry and Molecular Diagnostics		
11:00–11:15	C	**Nick Indriolo**	Mapping the Cosmic Ray Ionization Rate in the Solar Neighborhood

11:15–11:30	C	**Theodoros Topkaras**	Cosmic ray investigation with KOSMA-τ
11:30–11:45	C	**Shmuel Bialy**	Cold Clouds as Cosmic Ray Detectors
11:45–12:00	C	**Emma Weiss Nielsen**	Complex organic molecules and cosmic ray ionisation rate towards the massive protostar Cepheus A HW2
12:00–12:25	I	**Brett McGuire**	AstroAMASE Leveraging Machine Learned Chemical Intuition for Molecular Assignment and Discovery
12:20–12:40	**Poster presentations** Anna Dignan, Emma Nigou, Nikolaus Sulzenauer, Ben Wakefield, Reiji Arai, Katarzyna Dutkowska, Abubakar Fadul, Christine Greif, Akash Gupta, Hans Christian Poosch, Ameya Uday Nagdeo, Victoria Williamson, Birka Zimmerman, Kathryn Grasha, Thomas Bisbas		
12:40–15:45	**Lunch break / Beach time!**		
⚠15:45⚠	**CONFERENCE PHOTO**		
	AI-Driven Astrochemistry and the Multiphase ISM **Chair: Christine Greif**		
16:00–16:15	C	**David Robinson**	Emulating non equilibrium chemical networks with machine learning
16:15–16:30	C	**Caterina Bracci**	Machine Learning Insights into the Structure and Properties of Ionized Nebulae
16:30–16:45	C	**Donghui Quan**	ChemiVerse Construction and Modeling of Interstellar Chemical Reaction Networks for Intelligent Astrochemical Exploration
16:45–17:00	C	**Tianwei Zhang**	Spectuner-D1: Efficient spectral line fitting of interstellar molecules using deep reinforcement learning
17:00–17:15	C	**Shivan Khullar**	Bridging the scales hyper Lagrangian refinement in RMHD star formation simulations embedded in galactic environments
17:15–17:35	**Special talk by Astronaut Bonnie Dunbar**		
17:35–19:30	**Poster session**		
19:30–23:00	**Conference dinner | Greek “Glenti” | Poster Awards**		

Friday, 22 May

	Multi-Scale Structure and ISM Dynamics **Chair: Masato Kobayashi**		
09:00–09:15	C	**Juan Diego Soler**	The physical conditions of local star formation as revealed by neutral atomic hydrogen HI and 3D dust

09:15–09:30	C	**Shih-Ping Lai**	Reconstructing the Layered Magnetic Field in Orion KL Velocity Resolved CO 3-2 Polarization from the Goldreich Kylafis Effect with ALMA
09:30–09:45	C	**Bin Jia**	Physical and Chemical Conditions of Molecular Gas in NGC 1068 The nuclear feedback in the circumnuclear disk and starburst ring
09:45–10:00	C	**Jocabed Martinez Lopez**	Molecular gas and outflows in galaxies from cosmic noon to the present day
10:00–10:15	C	**Lewis Miller**	Turbulence is not the same everywhere mapping how galaxies stir their gas
10:15–10:30	C	**Bo Peng**	FLAMES Comprehensive View of Far Infrared Fine Structure Lines with New Answers and New Questions
10:30–11:00	**Coffee break**		
	Local Universe and Star Formation Diagnostics		
11:00–11:15	C	**Cosima Eibensteiner**	Star Formation Scaling Relations in the Local Group from the Local Group L-Band Survey LGLBS
11:15–11:30	C	**Samuel Crowe**	Widespread Star Formation and Ionized Gas Filamentation in Sgr C
11:30–11:45	C	**Shusuke Utsumi**	A Theoretical Prediction of Naked First Cores An Observationally Accessible Pathway to Brown Dwarfs
11:45–12:00	C	**Konstantinos Kostaros**	New GR tests using spectral line radiation backgrounds
12:00–12:15	C	**Jonathan Shelest**	T|3D Presenting The First 3D Temperature Map Of Our Galaxy
12:15–16:00	**Lunch break / Beach time!**		
	Multiphase ISM in Starbursts and AGN **Chair: Theodoros Topkaras**		
16:00–16:15	C	**Mathilde Bouvier**	Sulphur bearing species probe stellar feedback processes in the starburst galaxy NGC 253
16:15–16:30	C	**Yuze Zhang**	Combining Radiative Transfer and Kinematics Models for AGN Molecular Outflows
16:30–16:45	C	**Lara Pantoni**	MICONIC The impact of AGN feedback on the nuclear multiphase ISM of Centaurus A revealed by JWST MIRI MRS
16:45–17:00	C	**Jaiden Peltonen**	Bridging the Gap in the New Era of Star Formation
17:00–17:30	**General Discussion – Conclusions – Final Remarks**		

Oral presentations

Monday, 18 May – Morning session

	Feedback, Turbulence, and the ISM Lifecycle **Chair: Thomas Bisbas**		
09:00–09:25	I	**Stefanie Walch-Gassner**	Driving the ISM lifecycle
09:25–09:40	C	**Oerd Xhemollari**	Dense Gas Tracers as Temporal and Structural Evolution Markers of Molecular Clouds
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Driving the ISM Life Cycle

Author: Stefanie Walch-Gassner (University of Cologne)
E-mail: Stefanie Walch-Gassner <walch@ph1.uni-koeln.de>

The interstellar medium (ISM) is a dynamic, multi-phase environment whose continuous transformation regulates star formation and, ultimately, galaxy evolution. This talk explores the physical processes that drive the ISM life cycle, focusing on the interplay between gas cooling, gravitational collapse, stellar feedback, and large-scale galactic dynamics. Energy and momentum input from massive stars–through stellar winds, radiation, and supernova explosions–disrupt dense gas, generate turbulence, and launch outflows, thereby reshaping the structure and phase balance of the ISM. At the same time, cooling and compression in turbulent flows promote the formation of molecular clouds, closing the cycle.

Using state-of-the-art numerical simulations, we examine how feedback and galactic environment jointly regulate star formation. Understanding the drivers of the ISM life cycle is essential for connecting small-scale star formation physics to the macroscopic evolution of galaxies, offering key insights into observable properties such as gas phase structure, star formation laws, and galactic winds.

Dense Gas Tracers as Temporal and Structural Evolution Markers of Molecular Clouds

Author: Oerd Xhemollari (University of Cologne)
E-mail: Oerd Xhemollari <xhemollari@ph1.uni-koeln.de>
Co-Authors: Daniel Seifried (University of Cologne)

The chemistry of star-forming clouds reveals how gas evolves from diffuse to dense phases, but chemical reactions cannot always keep up with the rapid dynamics of turbulence and gravitational collapse. As a result, molecular abundances often fall out of equilibrium, making it unclear which species reliably trace certain regions within the cloud. To address this, we present non-equilibrium molecular abundances for chemical species not yet explored in 3D-MHD simulations of forming molecular clouds. We chemically post-process tracer particles from the SILCC-Zoom simulations with the astrochemistry pipeline of Panessa et al. (2023), using the latest public KIDA network with >8,000 reactions and 557 species. By analyzing the temporal and structural evolution of molecular abundances, we identify in detail the formation regions of major dense-gas tracers such as CS, SO, HCN, HNC, and N_2H^+. This enables us to assess their reliability as tracers of dense gas under highly dynamically conditions, only possible by the non-equilibrium chemical modeling we implemented here.

Consistent with recent observational studies, our column-density maps reveal that N_2H^+ acts as a more selective tracer of dense gas compared to the other species. We also compare abundance evolution across cloud environments and find systematic differences between hydrodynamic and MHD clouds: magnetic fields delay chemical evolution and reduce formation efficiency at fixed dynamical time, highlighting their impact. We demonstrate that part of this timing offset can be mitigated when tracer abundances are interpreted as indicators of evolutionary stage rather than as functions of density alone. Moreover, we discuss which ranges of volume density and column density are preferentially traced by each molecule, and how these ranges increase by orders of magnitude as clouds evolve. This provides a physical interpretation for the observational presence of “dense-gas tracers” in diffuse regions. Finally, through synthetic observations, we examine how excitation conditions and optical depth effects influence the accuracy of column density estimates. Overall, our results connect the evolving chemistry of dense gas with its observable line emission, refining how molecular tracers are used to infer cloud evolution.

How Spiral Arms, Filaments, and Star Clusters are Related in a Simulated NGC 628 Galaxy

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Co-Authors: Rachel Pillsworth (McMaster University); Ralph Pudritz (McMaster University)

JWST observations have provided evidence to the hierarchical nature of filaments in the interstellar medium, with lengths spanning from a few kiloparsecs down to sub-parsec scales. In particular, JWST images of NGC 628 show the strong association of young star clusters with the dusty filaments that dominate its spiral arms. These observations are important because the processes leading to star cluster formation and if they are fragmenting out of these filaments can be investigated in some detail. We use RAMSES, a multiscale magnetohydrodynamic code to simulate a two-arm spiral galaxy with initial conditions chosen to match properties of NGC 628. With the filament analysis code FilFinder we identify filamentary structure and derive probability density functions (PDF) for the filament lengths and masses.

Using a clustering algorithm, we identify star clusters formed between 268-278 Myr and follow this same population as the galaxy evolves for 60 Myr. We find that these clusters form preferentially along the arms with average velocities directed toward the center of the galaxy following the path of the arms. Moreover, by computing the cluster mass PDF, we have discovered that the mass power-law index of emerging star clusters exactly matches that of filaments. Therefore, the properties of young star clusters are inherited from the gravitational fragmentation of their host filaments. Finally, we find that the arms themselves exhibit similar pattern speeds to observations of NGC 628 and a pitch angle that decreases as the galaxy evolves and the arms unfurl. This talk will emphasize what these new simulation results reveal about star cluster formation in spiral galaxies such as NGC 628.

Why molecular lines trace star formation differently: A unified view of density and chemistry from clouds to galaxies

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Co-Authors: nan

Molecular line luminosities are widely used as tracers of star formation activity in galaxies, yet the physical and chemical origin of the observed diversity in line-infrared luminosity relations remains unclear. In particular, different molecular species and transitions exhibit systematically different slopes, and relations measured on cloud scales do not trivially extrapolate to galaxy-integrated values, challenging a universal interpretation of these correlations. Here we present a unified framework that connects molecular line emission to star formation across scales, based on gas density distributions and density-dependent chemistry. We compiled molecular line and infrared luminosities from the literature across spatial scales ranging from individual molecular clouds (<10 pc) to entire galaxies (>1 kpc), covering transitions including CO (1-0, 3-2), HCN (1-0, 3-2), CN (1-0), and N_2H^+ (1-0). We confirm that the slopes of the line–SFR relations vary with molecular species and transition, and that cloud-scale and galaxy-scale relations are systematically misaligned in a transition-dependent manner.

To interpret these trends within a unified framework, we developed a model that combines a gas density probability distribution consisting of a lognormal component and a power-law tail with non-LTE radiative transfer calculations. By explicitly accounting for density-dependent molecular abundances, the model naturally reproduces the observed diversity of line-SFR relations across scales. In particular, the behavior of N_2H^+ is well explained only when realistic abundance variations with gas density are included, consistent with recent Galactic cloud observations. Our results demonstrate that line-SFR relations primarily reflect how each line traces the underlying gas density distribution through its excitation and chemistry. This framework provides a coherent link from cloud-scale chemistry to galaxy-integrated star formation, explaining the observed diversity among molecular lines.

Modelling outflows above the Milky Way Center

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Recent observations of the Galactic Centre challenge our understanding of stellar feedback and the origin of large-scale outflows. The detection of cold, dense molecular gas in nuclear outflows above the Central Molecular Zone (CMZ), together with the presence of the Fermi and eROSITA bubbles, is unexpected given the relatively low present-day star formation rate and the quiescent state of Sgr A*. I investigate whether star formation and stellar feedback alone can drive winds capable of producing these features, using a high-resolution MHD simulation of the Galactic Centre performed with the PIERNIK code. The simulation reaches parsec-scale resolution, capturing both the extreme ISM conditions within the CMZ and the multiphase outflows that develop from it. Driven by the combined effects of radial gas inflows along the Galactic bar's dust lanes and stellar feedback, star formation follows a cyclic pattern, with episodes of starbursts separated by quiescent phases. This variability leads to strong, episodic outflows and galactic fountains. I analyse the morphology, kinematics, and multiphase structure of the resulting winds, with particular emphasis on cold HI clouds launched from the CMZ at velocities of several hundred km/s up to 2 kpc above the Galactic plane, and compare them to observations.

Dynamical Evolution During Star Cluster Formation - Crowding, Multiplicity and Disk Dispersal

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Most stars are born in the crowded environments of gradually forming star clusters. Such environments are expected to play a crucial role in the formation of stellar and planetary systems. In particular, it has been proposed that the birth of massive stars cannot be achieved via classical core accretion scenarios and instead requires high number densities of lower-mass stars to help channel global gas infall leading to competitive accretion and even protostellar mergers. Such conditions would also impact the multiplicity properties of the resulting stars. Furthermore, in these environments low-mass stars and their protoplanetary disks are expected to suffer tidal truncation and high intensities of UV radiation driving photoevaporative massloss that may dramatically alter final planetary system properties. Here we summarize results from a comprehensive suite of numerical simulations of gradually forming star clusters that explore these processes.

Using a modified version of NBODY6, we introduce stars gradually to achieve a range of star formation efficiencies per free-fall time from 0.01 to 1, as well as the instantaneous case. Stars are born with 50% primordial binarity, randomly drawn from a standard initial mass function and giving unbiased formation locations and kinematics, approximating turbulent core accretion (TCA) from a spherical clump. We then examine how the local stellar density crowding and multiplicity of the bound component evolves around the massive stars. We find stellar cusps and high triple+ multiplicity fractions develop while the cluster is still forming. We compare our results to those from the STARFORGE simulation, where massive stars are seen to grow via competitive accretion leading to steeper stellar cusps. We then compare these profiles to stellar profiles around forming massive stars determined from NIR (HST & LBT) and sub-mm (ALMA) observations. Finally, we summarize the impact of cluster environment on disk properties finding that external photoevaporation typically plays a dominant role. Future prospects for advancing the simulations via coupled NBODY and MHD evolution are briefly discussed.

The Origin of Hub-Filament Systems: Radiation-MHD Simulations toward Understanding Massive Star Formation

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Stars are born in filamentary molecular clouds, and observations show that nearly all high-mass stars form in so-called "hub–filament systems" (Kumar et al. 2020). A hub–filament system consists of multiple filaments converging to a common intersection, referred to as the hub. Motivated by these recent observational findings, a new paradigm for high-mass star formation is emerging. Observations suggest that hub–filament systems exhibit strong gas accretion along the filaments. Such accretion is expected to trigger gravitational fragmentation in circumstellar disks, potentially leading to the formation of high-mass binaries. Moreover, observations indicate that the star formation efficiency—the fraction of gas mass converted into stars—is generally low, and the physical mechanism responsible for this remains under debate. In hub–filament systems, filamentary inflows drive high-mass star formation at the hub, while radiation feedback from the forming massive stars disperses the diffuse gas, thereby suppressing the star formation efficiency. To understand both the origin of high-mass binaries and the low star formation efficiency, it is essential to investigate the process self-consistently—from the large-scale environment down to the scales of disk fragmentation. A comprehensive understanding of the formation and evolution of hub–filament systems would address these issues simultaneously; however, their origin is not yet well understood.

In this study, we investigate the formation of filaments by shock compression in molecular clouds using the radiation-MHD simulation code Athena++ (Stone et al. 2020; Tomida & Stone 2023; Kim et al. 2017, 2018), which includes radiation feedback. We find that large-scale flows driven by shocks gather pre-existing filaments and assemble them into a hub. We also identify the possibility that fluid instabilities, such as the nonlinear thin-shell instability (Vishniac 1993), assist the formation of the hub. Furthermore, our analysis of gas accretion onto the hub shows that dense gas flows into the hub, while diffuse gas is blown away by radiation feedback. This behavior is not only consistent with the observed filamentary accretion but also supports a scenario in which massive star formation proceeds while keeping the star formation efficiency low. Finally, by analyzing the angular momentum of the hub, we obtain insights into the formation of high-mass binaries.

Bridging the scales from global galactic dynamics to local star formation

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Understanding the interplay between galactic dynamics, magnetic fields, star formation, and stellar feedback is crucial for achieving a comprehensive model of star formation in the ISM. To explore how stars form in different environments, we simulate 16 individual main sequence galaxies with stellar masses ranging from $10^{9.5}$ to 10^{11} solar masses with bulk properties based on the PHANGS survey. We then zoom into different regions of each galaxy to characterise how star formation varies in relation to global galactic properties and those of the local ISM. The galaxies are modelled with the 3D magnetohydrodynamic code AREPO and include stellar feedback, live radiative transfer, non-equilibrium chemistry, and magnetic fields. We do not impose an external galactic potential, instead allowing structures to emerge self-consistently from initial conditions. Star formation is simulated with a sub-grid module which forms 'star' particles in the base resolution regions of the galaxies and continuously accreting 'sink' particles in the zoom regions, both with photoionising and supernova feedback. This yields a realistic model of the ISM (and allows us to produce H_2, H, H+, and CO maps), providing a 'galactic laboratory' to study the interaction of stars and gas, star formation and stellar feedback, chemistry, radiative processes and magnetic fields.

To extend our laboratory from galactic scales to solar mass scales, we improve upon existing zoom-in methods with a novel 'Lagrangian zoom' method by defining a dynamic zoom region of interest and tracing its evolution in time. Ensuring that the resolution of the Lagrangian volume corresponding to the zoom region is consistent over time and implementing a series of nested shells of increasing resolution around the region of interest helps to prevent low-resolution contamination and boundary artifacts. The reliability of our zoom simulations is evaluated by comparing them to the original simulation according to a set of parameters that are either resolution-agnostic or whose dependency on resolution is well-constrained. This framework provides a more self-consistent method for multi-scale galaxy simulations, offering a better characterisation of the role of the galactic environment in star formation and the gas cycle across the scales. We apply this zoom method to regions in the spiral arms, the inter-arms, the central molecular zone, and the outer galaxy for each of our simulations with the aim of revealing systematic variations in star formation properties in different environments and comparing these to the empirical star formation laws.

The Role of Radiative Supernova Remnants in the Ionization of the Galactic ISM

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Supernova remnants (SNRs) are major drivers of turbulence in the Milky Way and play a central role in the exchange of mass and energy between the different phases of the interstellar medium (ISM). Yet, despite their importance, very few tracers of old, radiative SNRs have been identified, and their contribution to the global ionization of the ISM remains largely unquantified. Following the identification of a potential tracer of old radiative SNRs (1), we performed detailed modeling of SNR evolution and their interaction with the surrounding medium using the Paris Durham shock code. The code was recently extended to compute the production of multi-ionized species, as well as both continuum emission and line emission across more than one million radiative transitions (2).

To quantify the global impact of SNRs on the thermochemical state of the ISM and derive the statistical properties of potential tracers, we developed a Galaxy-wide distribution model that accounts for both core-collapse and thermonuclear supernovae, and incorporates key features such as spiral arms, Galactic flaring, and the variation of star formation rate, ambient density, UV radiation field, and magnetic field with galactocentric distance. As a first application, the results of the model were compared with two infrared Galactic surveys of the fine-structure lines of N+ observed by COBE (3) and the Herschel Space Telescope (4). The analysis shows that SNRs make an unavoidable contribution to N+ emission along random lines of sight. Preliminary results indicate that at least 30% of the N+ in the Galaxy is produced by SNRs, primarily through collisional processes, suggesting that SNRs may be a significant source of ionization in Milky Way-like galaxies. This finding is remarkably robust, showing only a weak dependence on the specific parameters governing the SNR distribution.

(1) Godard, B., Pineau des Forêts, G., et al. 2024b, A&A, 689, A25 (2) Godard, B., Pineau des Forêts, G., et al. 2024a, A&A, 688, A169 (3) Bennett, C. L., Fixsen D. J., et al. 1994, ApJ, 434, 587 (4) Goldsmith, P. F., Yildiz, U. A., et al. 2015, ApJ, 814, 133

Revealing the Cosmic Build-up of Interstellar Dust with HST and JWST — The Nearby Low Metallicity Universe as a Laboratory

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Variations in the abundance and properties of interstellar dust have important implications for our ability to trace the chemical enrichment of the universe, stellar mass assembly, and galaxy evolution. I will present results from several observational efforts to characterize the variations of the dust content and properties within and between galaxies, in particular with metallicity. First, the dust, metal, and gas contents of nearby low metallicity galaxies were measured using UV absorption spectroscopy with Hubble, demonstrating a factor 5-10 increase of the dust abundance from the diffuse to dense ISM, likely caused by dust growth in the ISM, even in very low metallicity systems such as Sextans A (7% solar metallicity). Furthermore, the fraction of metals locked in dust grains decreases with decreasing metallicity (by a factor of 4 between the Milky Way and Sextans A at 7% solar metallicity), consistent with a metallicity-dependent timescale for ISM dust growth. As a result, the dust-to-gas ratio (D/G) decreases faster than metallicity. This variation of the dust-to-metal and dust-to-gas ratios is predicted by chemical evolution models that include dust growth in the ISM, dust destruction by supernova shocks, and dust dilution by inflows of pristine gas.

However, a tension still remains between dust-to-gas ratio measurements obtained from far-infrared emission in nearby galaxies and dust-to-gas ratio estimates from rest-frame UV spectroscopy in nearby galaxies and high-redshift neutral gas systems. Efforts to measure the dust content of nearby low metallicity galaxies with extinction mapping may resolve this tension. In addition, ongoing efforts to measure the properties and abundance of the smallest dust grains, polycyclic aromatic hydrocarbons (PAHs), in Sextans A with JWST are revealing, for the first time at this low metallicity, compact (pc-scale) clumps of PAH emission that are likely active sites of in-situ PAH growth within a dense, well-shielded phase of the ISM. These results demonstrate that PAHs can form and survive in extremely metal poor environments common in the early Universe. Ratios between the 3.3, 7.7, and 11.3 μm PAH features indicate that the PAH grains in Sextans A are small and neutral, with no evidence of significant processing from the hard radiation fields within the galaxy. These results favor inhibited grain growth over enhanced destruction as the origin of the low PAH abundance in Sextans A. Further efforts are ongoing to characterize the PAH abundance and properties in nearby low metallicity galaxies.

Monday, 18 May – Afternoon session

	Low-Metallicity and Dust Evolution **Chair: Gina Panopoulou**		
16:00–16:15	C	**Agata Karska**	The outer Galaxy as a template of low metallicity environments
16:15–16:30	C	**Léo Belloir**	Constraints on the efficiency of the photoelectric heating in a molecular ridge of the metal poor LMC
16:30–16:45	C	**Clarke Esmerian**	Modeling Cosmic Dust Evolution Atom by Atom in a Multiphase ISM
16:45–17:00	C	**Nick Andreadis**	The evolution of dust attenuation curves in the COLIBRE simulations
17:00–17:25	I	**Christoph Federrath**	The Link Between Turbulence and Star Formation
17:25–18:00	**Coffee break**		
	Dusty Environments and Chemical Enrichment		
18:00–18:15	C	**Alexia Anguera Ganzalez**	Chemical and Physical Evolution of Dense Gas in an IRDC Non LTE Chemistry and Feedback in G14.225 0.506
18:15–18:30	C	**Varsha Kulkarni**	Probing the Evolution of Interstellar Gas Metals and Dust Over Billions of Years
18:30–18:45	C	**Ryota Ikeda**	A census of distant dusty star forming galaxies from kpc to sub kpc scales using ALMA and JWST
18:45–19:00	C	**Siddharth Kumar**	Local enhancement of grain alignment near embedded protostars in the DR21 Ridge
19:00–19:15	C	**Yuki Isobe**	Tracing Early Chemical Enrichment in the Era of Ever Growing JWST Data
19:15–19:35	**Poster presentations** Suzanne Madden, Samantha Scibelli, Youxin Wang, Petia Yanchulova, Michael Busch, Madisen Johnson, Agnieszka Kobak, Jeremy Lim, Yuzuki Nagashima, James Nianias, Thomas Nordlander, Katherine Whitaker, Lara Pantoni		

The outer Galaxy as a template of low-metallicity environments

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The outer Galaxy provides a unique opportunity to study the impact of metallicity on star formation at a spatial resolution sufficient to resolve individual clumps and cores. The metallicity declines as a function of Galactocentric radius and is in between that of the Magellanic Clouds and the inner Galactic disk. The gas disk starts to both warp and flare just outside the Solar circle, suggesting that dynamical processes might affect molecular gas in different ways than inside the Solar circle (<8.2 kpc). The number density of molecular clouds is lower in the outer Galaxy, resulting in fewer cloud-cloud collisions. The reduced abundances of dust and molecules heavier than H_2 affect the overall gas and dust cooling budget. The average flux of cosmic rays and the ultraviolet radiation field strengths are lower, but both high energy particles and radiation penetrate deeper into the clouds due to less shielding.

The differences in environmental conditions and the high fraction of atomic-to-molecular gas are expected to lower the star formation rate per surface area.Together with the well studied, higher-metallicity local molecular clouds, the clouds in the outer Milky Way offer a unique opportunity to study the impact of metallicity on star formation. In this talk, I will present the first research highlights from the recently completed APEX legacy survey, 'Outer Galaxy High Resolution Survey' (OGHReS), as well as new perspectives from the upcoming CCAT 'Galactic Ecology' (GEco) survey. I will discuss important characteristics of the structure, star formation, and chemistry of the outer Galaxy, emphasizing differences with the Solar neighborhood.

Constraints on the efficiency of the photoelectric heating in a molecular ridge of the metal-poor LMC

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The Large Magellanic Cloud (LMC) provides a unique laboratory to understand the interaction between the interstellar medium (ISM) and massive star formation, in a galaxy with a low metallicity, a milestone to understand interstellar media at an earlier evolutionary stage than the Milky Way. The LMC's proximity to our Galaxy permits observation of its dusty and gaseous infrared emission at a parsec-scale resolution, thereby enabling study of interstellar properties at the scale of a molecular cloud. The SOFIA Legacy Program (LMC+) [1] has observed the [CII] λ158 μm and [OIII] λ88 μm lines in the southern molecular ridge at a resolution of 2.5 pc. These new observations provide access to the dominant cooling lines in the neutral and ionised ISM, enabling investigation of the major heating and cooling mechanisms in the three massive star-forming regions, N158, N159 and N160. In neutral regions, the main mechanism responsible for the gas heating is the photoelectric effect. This process consists in the ejection of an electron from a dust grain after the absorption of a UV photon.

The objective of this work is to combine data acquired by the SAGE [2] survey with Spitzer (3.6 to 70 microns), the HERITAGE [3] survey with Herschel (100 to 250 microns), and new data from SOFIA, with the aim of creating maps of dust properties and constraining the efficiency of the photoelectric heating of the gas in this region. To that end, we have homogenized our multi-wavelength maps to an optimal, common resolution and pixel grid. We took particular care in the estimate of the non-Gaussianity of our uncertainties and their correlations. The spatially-resolved spectral energy distribution of each pixel was then fitted with the hierarchical Bayesian code, HerBIE [4], using the THEMIS dust model [5,6]. Two original aspects are presented in our work. The first one is that the modeling we perform allows us to compare the efficiency of the photoelectric heating to the actual mass of its carriers, and not only to their luminosity. The second one, is that, using ancillary data, we provide a phase decomposition of the [CII] luminosity. Doing so, the efficiency we estimate is less biased by the [CII] linked to other heating mechanism. Our results confirm that the photoelectric heating is dominated by the smallest grains. In addition, the overall efficiency of the heating appears reduced, because of the lower abundance of these grains, relative to the gas, in the LMC. These results therefore provide an empirical prescription to account for gas heating at early evolutionary stages of the interstellar medium.

References

[1] Fischer et al, A&A, 702 (2025) [2] Meixner et al, ApJ, 132 (2006) [3] Meixner et al, ApJ, 146 (2013) [4] Galliano, MNRAS, 476 (2018) [5] Jones et al, A&A, 558 (2013) [6] Jones et al, A&A, 602 (2017)

Modeling Cosmic Dust Evolution Atom-by-Atom in a Multiphase ISM

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Cosmic dust is a fundamentally important component of the ISM, both because of its impact on observable quantities and its dynamical influence. Dust grains potentially mediate feedback mechanisms such as radiation pressure, multiple cooling and heating processes, interstellar molecule formation, and the coupling of neutral gas to magnetic fields. However, the importance and relative strengths of these effects are very uncertain, in large part because many basic questions about the origin, evolution, and properties of cosmic dust remain unanswered. Our group is addressing these questions by conducting a large program of molecular dynamics simulations of individual dust grains in which every atom is accounted for. These have enabled, for the first time, estimation of some grain physical processes rates (i.e. accretion, coagulation, shattering) from first principles.

I will overview these results and discuss their implications for dust evolution in the interstellar medium. I will also present high-resolution fluid-dynamical simulations of kpc-scale ISM patches which include a novel model for the evolution of cosmic dust grains in a turbulent, multiphase medium. These ISM simulations incorporate the results of our molecular dynamics calculations, providing predictions for the dust chemical composition and size distribution which are fully coupled to the physics of the dust grain lifecycle in the ISM. These simulations therefore enable us to address many open questions in cosmic dust theory and the ISM generally with unprecedented physical fidelity.

The evolution of dust attenuation curves in the COLIBRE simulations

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The advent of JWST has already provided spectra for thousands of galaxies at unprecedented redshifts. Understanding the physics of ISM dust is key to making the most out of these high-redshift surveys, since dust attenuates stellar light, significantly influencing the observed spectra. On the theoretical front, dust has been poorly constrained by large-volume simulations so far, due to the complexity of modelling different dust species and their evolution in the ISM. COLIBRE is a new, state-of-the-art galaxy formation simulation suite that –for the first time– incorporates a multi-grain, live dust model in a full cosmological volume down to z=0. We use the dust radiative transfer code SKIRT to postprocess a wide range of COLIBRE galaxies up to z~10, and produce mock SEDs and integrated dust attenuation curves that we can directly compare with recent observations.

We demonstrate that the live treatment of dust physics naturally reproduces the observed diversity of attenuation laws, and the transition from "grey" curves at high redshifts to steeper ones in the local universe. Subsequently, we leverage the full information about the composition and distribution of dust to disentangle the contribution of the two competing drivers of attenuation curve shape: the star-dust geometry and the intrinsic evolution of the grain size distribution. We thus provide a physically grounded framework for interpreting high-z observations, and showcase the potential of next-generation simulations to shed light on the complex physics of the ISM and its evolution though cosmic time.

The Link Between Turbulence and Star Formation

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Supersonic turbulence in the interstellar medium regulates when, where, and how stars form by simultaneously creating dense, gravitationally unstable structures and providing support against global collapse. I will discuss recent theoretical and numerical advances that connect the statistical properties of turbulence - such as density and velocity fluctuations - to the star formation rate and the initial mass function. I will also discuss the key roles that magnetic fields, radiation, and stellar feedback play in star formation. These results help establish turbulence as a key physical mechanism controlling star formation across galactic environments, including in the high-redshift Universe.

Chemical and Physical Evolution of Dense Gas in an IRDC: Non-LTE Chemistry and Feedback in G14.225–0.506

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Infrared dark clouds (IRDCs) represent a crucial stage in the evolution of the interstellar medium (ISM), where cold, dense gas begins to collapse under the influence of gravity, magnetic fields and feedback, enriching its chemistry. The massive hub–filament system G14.225–0.506 provides an excellent laboratory to investigate how these processes regulate the earliest phases of high-mass star formation. Large-scale NH_3 observations indicate that its two main hubs, G14.2-N and G14.2-S, share similar initial physical conditions (Busquet et al. 2013). However, interferometric studies reveal striking differences in their fragmentation properties, with G14.2-S showing a higher degree of fragmentation despite comparable density structures (Busquet et al. 2016), possibly linked to variations in the magnetic field configuration (Añez-López et al. 2020).

We present new SMA 1.3 mm continuum observations and a molecular line survey aimed at characterizing the chemical and physical evolution of protostellar cores within both hubs. At the angular resolution of our data, we identify two cores in G14.2-N and four in G14.2-S. Despite its lower fragmentation level, the northern hub hosts a chemically rich hot core, MM1. Using XCLASS to model more than 30 molecular species, we derive strong temperature gradients and find that key tracers such as CH_3OH and H_2CO exhibit significant deviations from Local Thermodynamic Equilibrium (LTE), demonstrating that non-LTE treatments are essential to accurately constrain the physical conditions in protostellar environments. We also detect active molecular outflows traced by a broad range of species, including CH_3OH, CS, SiO, SO, H_2CO, and CO. Moment maps show that while molecular emission closely follows the strongest continuum peaks (MM1, MM4, and MM5), in other regions it is dominated by outflowing gas rather than by the dust cores themselves.

When combined with recent VLA observations revealing a higher concentration of YSOs and non-thermal radio sources in G14.2-N (Díaz-Márquez et al. 2024), our results support an evolutionary sequence across the cloud, from the younger southern hub to the more evolved northern hub. This evolution appears to be increasingly shaped by internal feedback processes and may be further influenced by the proximity of the M17 H II region.

Our study highlights how chemical complexity, departures from LTE, and feedback signatures provide powerful diagnostics of the rapid diversification of dense gas in IRDCs, offering new insight into how the physical and chemical properties of the ISM evolve during the earliest stages of massive star formation.

Probing the Evolution of Interstellar Gas, Metals, and Dust Over Billions of Years

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Understanding the evolution of the gas, metals, and dust in the interstellar medium (ISM) of galaxies with cosmic time is crucial to understanding the complex processes involved in galaxy evolution, including chemical enrichment and feedback. Spectroscopy of distant galaxies and quasars offer powerful probes of the different ISM phases. We report results from observations of the atomic, ionized, and condensed phases of the ISM in galaxies using a combination of absorption spectroscopy (HST, VLT, Magellan), integral field spectroscopy (MaNGA, VLT MUSE, JWST MRS), and imaging (HST). Our observations of damped Lyman-alpha absorbers (DLAs) in quasar spectra at redshifts $0 < z < 6$ allow us to chart the chemical enrichment history of the ISM over $> 90\%$ of the cosmic history.

We find that the ISM at redshifts $4 < z < 6$ shows a wide diversity of chemical enrichment histories, ranging from metal-poor (< 0.01 solar, indicating modest rate of chemical evolution) to metal-rich (solar or supersolar, indicating highly accelerated chemical evolution). The C/O, Si/O abundance ratios in the ISM of some of these galaxies reveal consistency with $> 30\%$ enrichment by Population III stars. In a study of the warm and cool gas in galaxy halos mapped with IFS, and a comparison of the kinematics, ionization, and metallicity of this gas with the ionized gas in inner star-forming regions in the galaxies, we find consistency with a co-rotation of the cool gas out to > 10 effective radii with inner parts of the galaxy disks, hints of changes in gas ionization, (potentially due to the stronger intergalactic radiation field at larger galactocentric distance), and consistency with smooth metallicity gradients. Our spatially resolved maps of gas metallicity provide constraints on models of the metal distribution in galaxy disks and halos, indicating consistency with higher metallicity and higher ionization parameter for gas at higher elevation angles, as expected for outflows.

Finally, our JWST studies of the composition, structure, and extinction properties of the dust grains in both the diffuse and dense ISM of galaxies at $0 < z < 1.5$ indicate that dust grains in distant galaxies differ in physical and chemical properties from grains in local galaxies.

A census of distant dusty star-forming galaxies from kpc to sub-kpc scales using ALMA and JWST

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Dusty star-forming galaxies (DSFGs) or submillimeter galaxies (SMGs) at high redshift are the most likely ancestors of massive elliptical galaxies that dominate the central potential of galaxy clusters we see today. Mergers or large-scale gas inflow in isolated disks are possible scenarios explaining observed high star formation rate, but the exact triggering mechanism is under debate. In this talk, I present Formation of Substructure in Luminous SMGs (FOSSILS), an ALMA survey to obtain the largest sample ($N > 50$) of SMGs resolved at 300-400 pc resolution (0.06" in angular scale) in FIR continuum. This first statistical sample of highly resolved ALMA images provides a remarkably wide variety of structures, including clumps and spirals traced by the FIR continuum. Nonetheless, about one-third of the sample exhibits a compact, featureless morphology. This possible dichotomy in our sample implies that there are multiple mechanisms for triggering starbursts in SMGs: secular instability in gas-rich disks and efficient gas inflows induced by dissipative processes, as supported by a recent joint ALMA and JWST study (Ikeda et al. 2026). Finally, I will also discuss an ongoing effort to obtain CO, [CI], and [CII] line observations of DSFGs in a galaxy cluster at cosmic noon, aimed at accurately deriving their molecular gas masses and assessing their impact on studies of gas-phase metallicity and environmental effects.

Local enhancement of grain alignment near embedded protostars in the DR21 Ridge

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Magnetic fields are a fundamental component of the interstellar medium (ISM), yet they cannot be observed directly and must instead be inferred through indirect tracers. Polarized thermal dust emission is a good tracer of magnetic fields in many ISM conditions, as dust grains are generally expected to be well aligned with the magnetic field. In this work, we investigate the leading theory of grain alignment, Radiative Torque Alignment (RAT), focusing on its prediction of enhanced grain alignment in the vicinity of embedded protostars. While this prediction has been explored through analytical models and magnetohydrodynamic simulations, observational evidence has remained limited. Using 214 μm SOFIA/HAWC+ polarimetric observations of the high-mass star-forming region DR21, we perform a statistical analysis of the polarization fraction, polarization angle dispersion, and grain alignment efficiency to examine this effect near embedded protostars. We find evidence of enhanced polarization near DR21(OH) at intensities where depolarization is typically observed. This conclusion is further strengthened by comparison with predictions from a simple analytical model of a centrally heated envelope surrounding a luminous protostar, which shows good agreement with the observed trends. Our results indicate that grain alignment via radiative torques remains efficient near embedded protostars and that polarized thermal dust emission can therefore be used to probe magnetic fields in the densest regions of star formation.

Tracing Early Chemical Enrichment in the Era of Ever-Growing JWST Data

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Gas-phase chemical abundance ratios reflect contributions from different mass stars and distinct dust-depletion patterns. The general picture of chemical enrichment at z~0 has been challenged by high-z N/O-enhanced galaxies (NOEGs) discovered with the JWST. Interestingly, about half of NOEGs are reported to have AGN signatures such as broad-line regions. Stacking NIRSpec spectra of z=4-7 AGNs found in the JADES survey, we find that the broad-line AGN stack exhibits high [N/O]>0.4 and high electron density (~1e4 cm-3) comparable to those of high-z NOEGs, which links N-rich, dense star formation analogous to proto-globular clusters and black hole seeding. Conversely, the low [C/O]=-0.70, moderate [Ne/O]=-0.09, and low [Ar/O]=-0.28 ratios measured in the stacked spectrum of the general population of ~600 SFGs at z=4-7 remarkably agree with dominant yields from massive stars. For the first time at z>4, we report that the stacked spectrum exhibits low [Si/O]=-0.63, suggesting rapid formation of silicate dust. We also discuss high [Fe/O]>0 of our stacks of young SFG populations, motivating further exploration of anomalous chemical enrichment in more metal-poor, earlier formation stages.

Tuesday, 19 May – Morning session

	Gaseous Environments Across Cosmic Epochs I **Chair: Kathryn Grasha**		
09:00–09:25	I	**Emanuelle Daddi**	The ebullient ISM of early quiescent galaxies
09:25–09:40	C	**Elisa Cataldi**	Tracing the Chemical Evolution of the High Redshift Interstellar Medium
09:40–09:55	C	**Leonardo Clarke**	Emission line Diagnostics at z greater than 2 A Probe of the Ionizing Spectrum and alpha Enhancement Beyond Cosmic Noon
09:55–10:10	C	**Souradeep Bhattacharya**	Probing chemical enrichment in star forming galaxies from direct O Ar and N abundances
10:10–10:25	C	**Blakesley Burkhart**	The Closest and Furthest Molecular Clouds Revealed via H2 Fluorescent Emission
10:25–11:00	**Coffee break**		
	Gaseous Environments Across Cosmic Epochs II		
11:00–11:25	I	**Alex Cameron**	Evolution of the ionized ISM across cosmic time
11:25–11:50	I	**Jiayi Sun**	Resolved Star Formation in Extreme Environments in the Local Universe
11:50–12:05	C	**Yao Yao**	Metallicity Calibrations for High Redshift Galaxies from Cosmological Simulations and Photoionization Modeling for the JWST Era
12:05–12:20	C	**Dominik Riechers**	Toward True Molecular Complexity in the Interstellar Medium at Early Cosmic Epochs
12:20–12:40	**Poster presentations** Ebihara Sho, Pablo Arriagada Torres, Thomas Herard-Demanche, Sean Linden, Emma Lundqvist, Luka Matijevic, Tomonari Michiyama, Utsav Siwakoti, Raghav Arora, Leonard Kaiser, Yang Meng-Zhe (x2), Divya Mishra, Daniel Seifried, Rowan Smith, Reagan Stanton, David Whitworth		

The ebullient ISM of early quiescent galaxies

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Recent advances from both James Webb Space Telescope and Atacama Large Millimeter/submillimeter Array have begun to shed light on the intriguing properties of the interstellar medium (ISM) in the first generation of quenched galaxies, likely preserving imprints of their quenching pathways.

A number of surprising features are emerging from our CII and continuum imaging with ALMA: high dust luminosities not attributable to ongoing star formation; dust that may be even warmer than in star-forming galaxies, yet not obviously powered by stellar radiation; and large fluctuations in the inferred gas-to-dust ratios. At the same time, we find no clear deviation in the cross-calibration among different gas tracers.

We also identify intriguing alignments between ISM components and positive structures in residual images following subtraction of the main galaxy body in JWST data. These features point to the complex environments of early quiescent galaxies and suggest a significant role for mergers and interactions—either as part of their formation process or in their subsequent evolution.

Tracing the Chemical Evolution of the High-Redshift Interstellar Medium

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Understanding when and how galaxies enriched their interstellar medium with heavy elements is key to reconstructing the physical processes that regulate galaxy evolution, particularly during critical phases such as Cosmic Noon and the epoch of reionization. Thanks to ultra-deep JWST/NIRSpec spectroscopy from the MARTA survey, combined with an extensive high-redshift compilation, we investigate the chemical enrichment of the ISM in ~500 star-forming galaxies spanning $1 < z < 6$ with unprecedented detail. By leveraging both direct electron-temperature measurements and newly calibrated strong-line diagnostics tailored to high-redshift ISM conditions, we build the most comprehensive and self-consistent view to date of the optical N/O-O/H relation beyond the local Universe. This large dataset reveals a mild but systematic nitrogen enhancement at Cosmic Noon, which is metallicity-dependent, with the largest offsets observed at low metallicity. These trends point to a complex interplay between star formation, nucleosynthetic yields, gas inflows, and metal-loaded outflows shaping the chemical state of the ISM. I will discuss several physical scenarios capable of reproducing the observed behavior, including bursty star formation histories, differential metal loading, and the accretion of pristine gas. Finally, I will present new abundance measurements for multiple ionic species - including carbon, argon, sulfur, and helium - providing complementary probes of distinct nucleosynthetic channels and ISM phases. Together, these results offer new insight into how the chemical and physical properties of the interstellar medium evolve across cosmic time, shedding light on the mechanisms that regulate star formation and gas cycling in the early Universe.

Emission-line Diagnostics at z >= 2: A Probe of the Ionizing Spectrum and alpha Enhancement Beyond Cosmic Noon

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Tracing the evolution of strong rest-optical emission-line ratios through cosmic time is critical to our understanding of the evolving conditions within star-forming galaxies. Of particular interest is the connection between ISM ionizing conditions and the chemical abundance patterns (i.e., α/Fe) in massive stars that provide the ionizing radiation field. Changes in the α/Fe ratio result in changes to the hardness of the ionizing spectrum, which in turn influence the observed emission-line ratios from H II regions. To date, samples of star-forming galaxies at $z > 3$ have been limited in number, making it difficult to directly trace the effects of evolving abundance patterns on rest-optical emission-line ratios. Here we present several key rest-optical emission-line ratios in a sample of 763 star-forming galaxies at $1.4 < z < 7$ drawn from JADES DR3. These emission-line ratios include: [O III]/Hβ, [N II]/Hα, [S II]/Hα, [O I]/Hα, O32, R23, Ne3O2, and RO2Ne3. This analysis represents a new frontier in high-redshift studies, leveraging the largest current sample at $z > 3$ to probe ISM ionizing conditions using common diagnostic diagrams. We find evidence for a harder ionizing spectrum at $z \sim 3.5$ compared to $z \sim 2$ at fixed gas-phase metallicity, resulting in a pronounced shift in the star-forming galaxy locus on the [N II]/Hα BPT diagram and the O32 vs. R23 diagram. At $z > 3.5$, star-forming galaxies occupy a common locus, indicating that ISM ionizing conditions at fixed gas-phase metallicity do not evolve strongly at these early cosmic times. These evolving trends in emission-line diagrams over cosmic time echo the progression in the α/Fe ratio vs. Fe/H among Galactic stars, highlighting the connection between lookback and archeological studies of galaxy formation.

Probing chemical enrichment in star-forming galaxies from direct O, Ar & N abundances

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Distinct sets of elements are produced from different nucleosynthesis processes in galaxies that occur in core-collapse supernovae (CCSNe), Type-Ia supernovae (SNe Ia), asymptotic-giant-branch stars (AGBs), and various other enrichment sources. I will discuss both supernova and AGB enrichment in galaxies, as probed from integrated deep emission-line spectra of star-forming galaxies (SFGs) with direct elemental abundances from JWST observations at z~1-8 as well as SDSS & DESI (& PFS@Subaru) at z<0.5.

We have recently shown that for SFGs, the oxygen-to-argon abundance ratio, log(O/Ar), vs Ar abundance, 12+log(Ar/H), is analogous to alpha-enrichment ([α/Fe]) vs metallicity ([Fe/H]) for stars. This allows galactic chemical enrichment from SNe to be interpreted for SFGs, that are the vast majority of galaxies in the universe, beyond the confines of individual stars in local group galaxies (and massive ellipticals) where [α/Fe] and [Fe/H] are measurable. At low-z (z<0.3) with SDSS observations of ~3000 SFGs, we show that galaxy chemical enrichment history is driven primarily by the interplay of CCSNe and SNe Ia, with their impact varying with galaxy mass. With a smaller sample of 11 SFGs at high-z (z~1.3-7.7) with JWST/NIRSPEC and Keck/MOSFIRE, we show that MW-like CCSNe and SNe Ia dominated enrichment processes occur at least out to z~4, beyond which rapid but intermittent star-formation may be at play.

On the other hand, AGB nucleosynthesis is probed in SFGs from relative abundances of N & O. NIRSPEC@JWST observations revealed a handful of SFGs at high-z with high N/O abundance ratio at low O/H, dubbed extreme N-emitters. Some attribute this to extreme enrichment mechanisms active only in the early universe. However, we found high N/O at low O/H for a sample of 19 low-z (z<0.5) SFGs (a five-fold increase compared to earlier) using DESI DR1 spectra. The enhanced N/O values can be explained using galactic chemical evolution (GCE) models having long-lived N-enhancement from AGBs, coupled with strong outflows.

I will also show the first direct elemental abundances of SFGs from the Prime Focus Spectrograph Galaxy Evolution Survey underway at the Subaru Telescope.

The Closest and Furthest Molecular Clouds Revealed via H_2 Fluorescent Emission

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Far-ultraviolet (FUV) fluorescent emission from molecular hydrogen (H_2) is a powerful tracer of the dynamic boundary layers where the interstellar medium transitions from atomic to star forming molecular gas. In this talk, I will highlight how this diagnostic of molecular clouds enables us to trace the lifecycle of molecular gas—from the closest interstellar clouds to the most distant galaxies observed by JWST. Close to home, we have uncovered Eos, the nearest and largest molecular cloud on the sky at just 94 parsecs, the first molecular complex identified directly in H_2 FUV fluorescence. Eos provides an unprecedented laboratory to study a ultra-close hot/cold interface region, multiphase molecular gas at the interface of extreme stellar feedback, and motivates future space missions in the FUV. At the opposite end of the distance ladder, I will present a theoretical framework for interpreting H_2 FUV fluorescence in the distant Universe, applied to stacked JWST/NIRSpec spectra of galaxies at $z \geq 7$. These data show tantalizing evidence for H_2 emission in galaxies during cosmic dawn. Together, these results demonstrate how FUV fluorescent H_2 provides a powerful window on the life cycle of molecular gas—from the edge of our Local Bubble to cosmic dawn.

Evolution of the ionized ISM across cosmic time

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The ionized ISM in star-forming galaxies provides valuable insights into the properties of young stellar populations and the gas from which they've formed. Observations of emission lines - arising from gas photoionized by young massive stars - can provide insights into chemical abundances, temperatures, densities, ionizing properties, dust properties, and star formation rates.

Moreover, the relative brightness of these emission features allows them to be studied at large cosmic distances. In recent years, JWST/NIRSpec spectroscopy has enabled such measurements to be made out to very early epochs of galaxy formation, < 400 Myr before the Big Bang.

In this talk, I will review recent advances enabled by JWST/NIRSpec in our understanding of the evolution of ISM properties across cosmic time, focusing on new measurements at z>2 and discuss key outstanding questions.

Resolved Star Formation in Extreme Environments in the Local Universe

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Starburst systems represent the most extreme star-forming environments in the present-day universe. I will showcase recent results from highly resolved observations of local starbursts, focusing on starburst galaxy centers and merger-driven starburst galaxies. In galaxy centers, the interstellar medium (ISM) is regulated by a complex interplay of external and self-gravity, ordered motions (e.g., rotation and shear), and random motions (e.g., turbulence). Star-forming gas reaches densities and pressures far exceeding those in galaxy disks, enabling the formation of extraordinary objects such as super star clusters, where stellar feedback can become inefficient and star formation efficiencies exceptionally high. In merger-driven starbursts, chaotic kinematics and shocks assemble dense, over-pressurized gas structures that likewise form stars with high efficiency, as the whole system evolves toward a new equilibrium. These observations highlight key physical ingredients that are likely important also at earlier cosmic time.

Metallicity Calibrations for High-Redshift Galaxies from Cosmological Simulations and Photoionization Modeling for the JWST Era

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Gas-phase metallicity is a fundamental tracer of galaxy evolution, yet strong-line calibrations derived from local galaxies become biased at high redshift due to evolving interstellar medium (ISM) conditions. With JWST now enabling direct metallicity measurements via auroral lines at $z>2$, a consistent theoretical framework for interpreting strong-line diagnostics across cosmic time is urgently needed.

We present a first-principles framework to derive redshift-dependent metallicity calibrations for galaxies at $z=2$-7. Our approach combines the cosmological simulation ASTRID with stellar population synthesis and MAPPINGS V photoionization modeling. HII region properties are computed self-consistently for young star clusters using an analytic feedback model, capturing the coupled evolution of stellar feedback, ionization parameter, and local ISM density. The resulting emission-line predictions are validated against observed star-formation rate indicators and the [OIII] luminosity function.

From this model, we derive calibrations for common optical (R23, O3N2, N2, O32) and UV (C3O3, N3O3) diagnostics. We find significant redshift evolution in these relations, driven primarily by changing ionization conditions. A Bayesian analysis quantifies calibration performance under varying signal-to-noise, enabling diagnostic recommendations as a function of redshift and data quality. These results provide a practical framework for interpreting JWST spectroscopy and tracing chemical evolution from cosmic noon to the epoch of reionization.

Toward True Molecular Complexity in the Interstellar Medium at Early Cosmic Epochs

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It is now well established that the availability of cold molecular gas in galaxies is the main driver of the rise and decline of cosmic star formation through the history of the universe. This, in turn, governs the assembly of baryonic mass along the nodes of the cosmic web. Large samples of galaxies both on and off the star formation "main sequence" have been studied using the most common tracers, such as CO and [CII], in targeted and in volume-limited surveys to establish the general picture; however, studies in the local universe reveal that extracting the governing physical principles (e.g., buildup of dense cores, the growth of chemical complexity, and gas infall and feedback processes) requires additional tracers. Here we describe recent progress in this field based on ultra-broad molecular line scans (spanning bandwidths up to >2 THz) and targeted surveys of key molecular species and their excitation toward active galaxies in the early universe, using major facilities such as ALMA, JWST, NOEMA, and the VLA. These studies have substantially advanced our understanding of how different physical processes leave their imprint on the ISM, on stellar populations, and - in some cases - even on the cosmic microwave background. We conclude by discussing how upcoming facilities will open an even broader region of the parameter space for probing galaxy and star formation across the full history of the universe.

Tuesday, 19 May – Afternoon session

	Extreme ISM Environments **Chair: François Lique**		
16:00–16:25	I	**Linda Tacconi**	Formation and Evolution of Galaxies: Star Formation and Dynamics I
16:25–16:50	I	**Reinhard Genzel**	Formation and Evolution of Galaxies: Star Formation and Dynamics II
16:50–17:05	C	**Frank Bigiel**	mm line ratios as probes of dense gas fractions and star formation efficiencies across local galaxies
17:05–17:20	C	**Ina Galic**	Probing Molecular Gas and Star Formation at Cloud Scales in M51 with NOEMA and JWST
17:20–17:35	C	**Robert Pascalau**	Dissecting The Alchemist NIRSpec IFU Reveals Turbulent Gas Inflows in a Complex Merger System at z≃10.17
17:35–18:05	**Coffee break**		
	Star Formation and ISM Across Environments		
18:05–18:20	C	**Neven Tomicic**	Star formation and properties of ionized gas at the galactic outskirts and in gas stripped galaxies
18:20–18:45	I	**Jérôme Pety**	Astrophysics meet data science for the study of Giant Molecular Clouds
18:45–19:00	C	**Jonathan Tan**	Frontiers of Massive Star Formation
19:00–19:15	C	**Ashley Barnes**	ALMA Central Molecular Zone Exploration Survey ACES Survey Overview and First Results
19:15–19:30	C	**Qing Liu**	Mapping the Diffuse ISM with Deep Wide field Optical Imaging

Formation and Evolution of Galaxies: Star Formation and Dynamics I

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Deep and increasingly complete multi-wavelength look-back surveys provided a wealth of information about the formation and evolution of galaxies over cosmic time. With the advent of sensitive ground-based adaptive optics assisted integral field instruments, submm interferometers like ALMA and NOEMA, and JWST in space the emphasis is shifting from assembly populations censuses to understanding the internal physical and dynamical processes driving galaxy evolution. In this presentation, we will review results from some spatially resolved, multi-wavelength studies of star-forming galaxies, focusing on the epochs associated with the peak ($z \sim 1-3$) of star formation, but including the newest results at higher redshifts as well. We discuss the latest results on the incidence and prevalence of rotating, turbulent disks with redshift, but emphasize the interesting kinematics present once signatures of rotation are removed from these galaxies. We know that star-forming galaxies contained were much more gas rich at earlier cosmic epochs than at the present time. Disk fragmentation and instabilities are efficient in driving the internal galaxy dynamics in such gas rich environments. We will show examples of galaxies exhibiting strong radial flow signatures in their disks, sometimes along bars and spiral arms. Taken together with deep imaging, the emerging kinematic observations show that disk fragmentation and instabilities, as well as powerful star formation and AGN driven outflows strongly influence the evolution of disks and central bulges.

In this talk, we focus on the global structural and kinematic properties star forming galaxies from our team's large observational campaigns of ionized (GALPHYS and KMOS^{3D}) and molecular (PHIBSS and NOEMA^{3D}) gas

Formation and Evolution of Galaxies: Star Formation and Dynamics II

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Deep and increasingly complete multi-wavelength look-back surveys provided a wealth of information about the formation and evolution of galaxies over cosmic time. With the advent of sensitive ground-based adaptive optics assisted integral field instruments, submm interferometers like ALMA and NOEMA, and JWST in space the emphasis is shifting from assembly populations censuses to understanding the internal physical and dynamical processes driving galaxy evolution. In this presentation, we will review results from some spatially resolved, multi-wavelength studies of star-forming galaxies, focusing on the epochs associated with the peak ($z \sim 1-3$) of star formation, but including the newest results at higher redshifts as well. We discuss the latest results on the incidence and prevalence of rotating, turbulent disks with redshift, but emphasize the interesting kinematics present once signatures of rotation are removed from these galaxies. We know that star-forming galaxies contained were much more gas rich at earlier cosmic epochs than at the present time. Disk fragmentation and instabilities are efficient in driving the internal galaxy dynamics in such gas rich environments. We will show examples of galaxies exhibiting strong radial flow signatures in their disks, sometimes along bars and spiral arms. Taken together with deep imaging, the emerging kinematic observations show that disk fragmentation and instabilities, as well as powerful star formation and AGN driven outflows strongly influence the evolution of disks and central bulges.

In this presentation we describe evidence of radial flows, star formation and AGN driven outflows, dark matter content and sub-Toomre scale structures in these systems.

mm-line ratios as probes of dense gas fractions and star formation efficiencies across local galaxies

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I will present a series of recent results from ALMA and IRAM campaigns targeting -in particular density-sensitive - molecular line ensembles like HCN, HCO+, HNC, CS or N2H+ and low-J CO, but also a range of faint CO isotopologues like 13CO or C18O across and among nearby spiral galaxies. The data situation of resolved "mm-spectroscopy" across nearby galaxies has improved dramatically over the last ~10 years and significant progress was made probing canonical, extragalactic, density-sensitive line ratios like HCN/CO or HCO+/CO and their relation to star formation in diverse samples of around 30 nearby galaxies. I will present results from the kpc-scale ALMA ACA survey ALMOND, targeted higher-resolution ALMA follow-up and the NOEMA Large Program SWAN, mapping these molecular lines directly at cloud scales in M51. In this talk, I will synthesize the key results from these campaigns and what they tell us about dense gas fractions and star formation efficiencies across local spiral galaxies, including the impact of local conditions and galaxy dynamics on these quantities.

Probing Molecular Gas and Star Formation at Cloud Scales in M51 with NOEMA and JWST

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With the advanced capabilities of facilities such as NOEMA and JWST, we have entered a new era of resolving the interstellar medium (ISM) at higher sensitivity and spatial resolution. This enables us to resolve individual galactic environments and reveals important properties about star formation in nearby galaxies.

A prime example of these advances is the IRAM NOEMA Large Program SWAN (PIs: Eva Schinnerer, Frank Bigiel), which observed 3 – 4 mm molecular line emission in M51 at ~125 pc resolution, resolving faint species such as N_2H^+ and HNCO on giant molecular cloud (GMC) scales. We combined SWAN with JWST-FEAST (PI: Angela Adamo) Paschen-α emission, which provides a dust-unobscured view of recent star formation at ~6 pc resolution, allowing us to directly link molecular gas properties to star formation across a range of galactic environments.

We investigated the impact of star formation rate on bulk molecular gas chemistry using ^{12}CO, ^{13}CO, and C^{18}O line ratios. The observed trends are consistent with expectations from selective nucleosynthesis and/or optical depth effects and agree with previous kpc-scale studies, while revealing clear variations between galactic environments.

Furthermore, we examined the Gao–Solomon relation across M51 using multiple dense gas tracers (HCN, HCO^+, and N_2H^+) to test its universality, assess whether the scatter in the relation is environmentally driven, and determine whether star formation is primarily regulated by variations in dense gas content or by changes in star formation efficiency. We find that the relation varies systematically across environments, exhibiting sub-linear behavior in all regions except the northern spiral arm. Enhanced star formation in the central region is primarily driven by increased efficiency, whereas the spiral arms show, on average, suppressed star formation due to lower efficiency. The spiral arms themselves differ - with localized regions of enhanced star formation being linked to increased efficiency in the northern arm and an excess of dense gas in the southern arm. These variations highlight the central role of gas kinematics in regulating star formation across M51, with the AGN-driven outflow in the centre and enhanced turbulence in the southern arm reducing the efficiency of dense gas, while slow shocks ($<$20 km s^{-1}) in the southern arm lead to the accumulation of dense gas.

Dissecting The Alchemist: NIRSpec/IFU Reveals Turbulent Gas Inflows in a Complex Merger System at z=10.17

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JWST revealed that most high-redshift galaxies have bursty star formation histories which are regulated by stellar/AGN feedback and gas inflows/outflows. According to theoretical models, feedback predominantly removes metal-rich gas, while subsequent starbursts are triggered by mergers and metal-poor gas inflows. Hence, gas-phase metallicity holds key insights about the baryonic processes shaping early galaxies.

In this talk, we will present the first medium-resolution NIRSpec/IFU study of spatially resolved interstellar medium (*ISM*) properties in the lensed MACS0647-JD system (lensing magnification = 8; redshift z=10.17). Combining the direct-Te metallicity and the ionised gas velocity dispersion maps, we infer highly turbulent and metal poor gas between two metal enriched components detected in both NIRSpec/IFU and NIRCam photometry. Together with the observation of tentative AGN signatures in these metal poor inter-clump regions, this potentially suggests shocked gas accretion. Furthermore, this hypothesis is backed up by 1) a significant spatial correlation between gas dispersion and metallicity in individual pixels (p-value of 1.25e-3) and 2) a peculiar spatial distribution of low ionisation gas (as traced by [O II] emission); this appears to be offset and significantly more extended than the distribution of high ionisation lines.

The centroid of peak Hgamma line emission in the system has a substantial spatial offset (0.1 arcsec) with respect to the stellar continuum centroid; the latter coincides with the location of the more massive clump in the system. This is a smoking gun evidence of a recent starburst in the system, possibly associated with a merger. On a pixel-by-pixel scale, we obtain a tentative correlation (p=0.017) between the stellar mass density inferred from spectrophotometric SED fitting and direct-Te metallicities, possibly revealing that, within the first 500 Myr after the Big Bang, the system is undergoing the first steps towards building establishing a resolved mass-metallicity relation (rMZR). This could also mean that MACS0647-JD is observed in an early merger stage since the metals did not have time to mix well enough yet. Even more interesting, the North-Eastern region of this system (located between the two stellar clumps) has a lower stellar mass, low metallicity and high star formation burstiness, potentially indicating a very recent star formation enhancement that could have been triggered by a metal-poor gas inflow.

The Carbon Abundance resulting from integrated aperture spectrum is inconsistent with production by Core-Collapse Supernovae (CCSNe) but it can be accounted for by faint pop III SNe. The Neon Abundance offers a somewhat contrasting picture; while log(Ne/O) is sub-solar in every region of the system, our values can be explained by massive CCSNe progenitors (>30 $M_{\odot}$) dominating the chemical enrichment pathway in the system. This can serve as a further indicator of very recent star formation.

Star formation and properties of ionized gas at the galactic outskirts and in gas-stripped galaxies

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The ionised gas is an important component of the interstellar medium (ISM) that can provide insights into the different physical processes affecting the gas and star formation across galaxies. In-situ formation of young stars in the unusual galactic environments could be provided by observing the outskirts of nearby galaxies and across galaxies that are gas-stripped due to ram-pressure effects in galactic clusters.

We analyzed the properties of the ionised gas (diffuse ionised gas fractions, gas-phase metallicities, and the source ionisation) across the gas-stripped galaxies and across nearby galaxies. We utilized optical IFU observations of primarily 71 gas-stripped and control galaxies from the GASP survey (MUSE/ESO), and secondly, of a few nearby galaxies (PMAS/Calar Alto observations of NGC 2276 and the PINGS survey). These properties were measured and compared between different environments (center vs. outskirts, dense vs. diffuse gas, disks vs. stripped tails, gas-stripped vs. normal galaxies). We found that a large fraction of the gas in the outskirts and the stripped tails of ram-pressure galaxies is at least partly ionized by processes other than ionisation from the young stars. Our hipothesys is that those processes are probably due to slow mixing and shocks, and accretion of inter-cluster and interstellar medium gas that are preserved by intra-cluster magnetic effects.

We further compare the SFR values retrieved from different tracers (Balmer line emission and UV emission from young stars) in order to test if the SFR prescriptions change in the outskirts of galactic disks and in the stripped tails.

Astrophysics meet data science for the study of Giant Molecular Clouds

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DAOISM (Deep Analysis Of the Inter-Stellar Medium) is a collaborative project between observational astronomers, theoretical astrophysicists and data scientists. We aim at bridging Galactic and extragalactic studies of Star formation in relation with the molecular interstellar medium by developing advanced statistical methods and data mining techniques and performing deep observations of the cold interstellar medium. These new approaches are urgently needed as the latest generation of astronomical data and models for the ISM now regularly attains volumes that defy human capacity for visual inspection and a complexity level that is intractable to the simple correlation analysis methods employed in the field.

In this talk, I will review the progress made in characterizing the physical and chemical properties of Giant Molecular Clouds using mission maps of multiple molecular lines. These include the determination of the H_2 column density and thus the cloud mass, the evaluation of the far UV illumination, the thermal pressure, the ionization fraction in different regions of the clouds, and the characterization of the filamentary structures and of the turbulent velocity field. These results required the development of a robust method to denoise spectral line cubes, an accurate emulation of a sophisticated modeling code (e.g., the Meudon PDR code) with a fast neural network, and a new fast Bayesian framework that takes into account additive and multiplicative noise, censored information, and a spatial regularization to retrieve the spatial distribution of the gas fundamental parameters (pressure, total extinction, and FUV illumination) from emission line maps.

• Bron et al. 2021, A&A, 645, 28B, "Tracers of the ionization fraction in dense and translucent gas. I. Automated exploitation of massive astrochemical model grids" • Gratier et al. 2021, A&A, 645, 27G, "Quantitative inference of the H2 column densities from 3 mm molecular emission: case study towards Orion B" • Roueff et al. 2021, A&A, 645, 26R, "C18O, 13CO, and 12CO abundances and excitation temperatures in the Orion B molecular cloud. Analysis of the achievable precision in modeling spectral lines within the approximation of the local thermodynamic equilibrium" • Pety et al. 2022, EPJ Web of Conferences, 265, "Revealing which combinations of molecular lines are sensitive to the gas physical parameters of molecular clouds" • Gerin et al. 2022, Proceedings of the 7th Chile-Cologne-Bonn Symposium, 230, "Multi-dimension analysis of molecular clouds: The example of Orion B" • Gaudel et al. 2023, A&A, 670, 59A, "Gas kinematics around filamentary structures in the Orion B cloud" • Einig et al., 2023, A&A, 677, A158, "Deep learning denoising by dimension reduction: Application to the ORION-B line cubes" • Palud et al., 2023, A&A, 678, A198, "Neural network based emulation of astrophysical models" • Palud et al., accepted by IEEE Transactions on Signal Processing, "Efficient Sampling of Non Log-Concave Posterior Distributions With Mixture of Noises" • Santa-Maria et al., 2023, A&A, 679, A4, "HCN emission from translucent gas and UV-illuminated cloud edges revealed by wide-field IRAM 30m maps of Orion B GMC"

Frontiers of Massive Star Formation

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Massive stars impact the interstellar and intergalactic media throughout cosmic history. However, several different theoretical formation mechanisms, including core accretion, competitive accretion, and protostellar collisions, remain actively investigated with no consensus yet achieved. I highlight several recent advances in our understanding of massive star formation, including: latest results of JWST and ALMA studies of individual test cases in our Galaxy; results of surveys of large samples of such protostars and how these constrain a protostellar evolutionary sequence; and a prediction of how massive star formation proceeded in the very early universe leading to supermassive star progenitors of supermassive black holes.

ALMA Central Molecular Zone Exploration Survey (ACES) – Survey Overview and First Results

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The interstellar medium (ISM) regulates the baryon cycle of galaxies by setting how efficiently gas condenses into stars and how effectively feedback returns mass, momentum, and energy to the surrounding medium. In the most extreme environments, this coupling can shift dramatically as the thermodynamic state, turbulence, magnetic support, and energetic particle/radiation fields reshape cloud structure, chemistry, and the pathways to star formation.

The Galactic Centre provides the closest laboratory in which these processes can be studied across spatial scales spanning spanning more than 4 orders of magnitude in spatial scale - from an entire galactic nucleus (>100 pc) down to individual units of star formation (i.e. cores <0.1 pc). Within this, the Central Molecular Zone (CMZ), a ring-like reservoir of molecular gas in the inner few hundred parsecs of the Milky Way, is the most extreme star-forming environment in our whole Galaxy, with unusually high gas densities, temperatures, pressures, and velocity dispersions, and pervasive strong magnetic fields. As such, it offers a crucial bridge between local star formation under "normal" disk conditions and the ISM physics that dominates other galactic centres and high-redshift systems.

I will introduce the CMZ and present an overview of the cycle 8 ALMA large programme [ACES (ALMA CMZ Exploration Survey)][1], a wide-area Band 3 spectral imaging survey mapping the inner ~100 pc at ~1.5 arcsec (~0.1 pc) angular resolution and 0.2 to 3 km/s spectral resolution. ACES targets more than 70 spectral features tracing density, temperature, chemistry, shocks, ionized gas, and feedback, enabling a multi-phase, multi-scale view of the CMZ gas cycle from global inflow to dense core-forming structures. ACES is a collaborative effort that tightly couples ALMA observations with theory and simulations, using the CMZ as a benchmark for interpreting extreme ISM physics more broadly.

I will highlight early results and discuss the major analysis challenges posed by ACES, including the very large data volume and the intrinsic complexity of line-rich, high-dynamic-range emission in the CMZ. Meeting these challenges has already driven, and will continue to require, new developments in reduction and analysis techniques. Together, ACES and its associated modelling efforts provide a legacy foundation for connecting resolved Galactic Centre physics to the ISM lifecycle and star formation in extreme environments across cosmic time.

[1]: https://sites.google.com/view/aces-cmz/home

Mapping the Diffuse ISM with Deep Wide-field Optical Imaging

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Interstellar dust grains absorb and scatter the interstellar radiation field. The resulting diffuse Galactic light, which is resolved as "cirrus" at high Galactic latitude in optical imaging, is a unique probe of the *diffuse*, *optically-thin* ISM. Imaging of the optical cirrus is historically difficult because the signal is very faint and is highly sensitive to sky-subtraction systematics. Only recently have dedicated low-surface-brightness (LSB) instrumentation and data reduction strategies made it possible to reliably detect cirrus over wide areas and to push into the ultra-faint regime most relevant for the diffuse ISM. In this talk, I will present deep imaging of the optical cirrus from the **Dragonfly Telephoto Array** and the **Euclid Space Telescope**, and highlight how dust-scattered light can be used as a novel tracer of the warm neutral medium (WNM) in the Milky Way. I will show first results that incorporate intensity statistics, power spectra, and wavelet scattering transforms to quantify optical cirrus morphology, and compare them with multi-wavelength ISM tracers (Herschel, WISE, Planck, and HI). Such analysis, if combined with numerical simulations, has the potential to link coherent structures in diffuse ISM to the underlying physical processes in the WNM that shape them (e.g., turbulence, thermal instability). Finally, I will discuss why the characterization of optical cirrus is increasingly important for many extragalactic LSB science (e.g., dwarf galaxies, tidal streams) and how deep learning approaches can circumvent the systematics by disentangling cirrus light from extragalactic light.

Thursday, 21 May – Morning session

	Role of Magnetic Fields in shaping the ISM Chair: Daniel Seifried		
09:00–09:25	I	**Kathrin Pattle**	Interstellar Magnetic Fields From Star Formation to Galaxy Evolution
09:25–09:40	C	**Aris Tristis**	Ambipolar diffusion and the mass to flux ratio in turbulent collapsing clouds
09:40–09:55	C	**Gina Panopoulou**	Towards a 3D view of the magnetized ISM in the Solar neighborhood
09:55–10:10	C	**Theotokis Georgatos**	The influence of magnetic fields in Cloud Cloud Collisions
10:10–10:25	C	**Szu-Ting Chen**	The Magnetic Field in Star Forming Regions of the Perseus Molecular Cloud
10:25–11:00	**Coffee break**		
	Cosmic Rays, Astrochemistry and Molecular Diagnostics		
11:00–11:15	C	**Nick Indriolo**	Mapping the Cosmic Ray Ionization Rate in the Solar Neighborhood
11:15–11:30	C	**Theodoros Topkaras**	Cosmic ray investigation with KOSMA-τ
11:30–11:45	C	**Shmuel Bialy**	Cold Clouds as Cosmic Ray Detectors
11:45–12:00	C	**Emma Weiss Nielsen**	Complex organic molecules and cosmic ray ionisation rate towards the massive protostar Cepheus A HW2
12:00–12:25	I	**Brett McGuire**	AstroAMASE Leveraging Machine Learned Chemical Intuition for Molecular Assignment and Discovery
12:20–12:40	**Poster presentations** Anna Dignan, Emma Nigou, Nikolaus Sulzenauer, Ben Wakefield, Reiji Arai, Katarzyna Dutkowska, Abubakar Fadul, Christine Greif, Akash Gupta, Hans Christian Poosch, Ameya Uday Nagdeo, Victoria Williamson, Birka Zimmerman, Kathryn Grasha, Thomas Bisbas		

Interstellar Magnetic Fields: From Star Formation to Galaxy Evolution

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Recent advances in submillimetre dust emission polarimetry are revolutionizing our understanding of the magnetic fields which thread the interstellar media of the Milky Way and other galaxies. In this talk I will discuss the insights which we are gaining into the energy balance, dynamics and evolution of the magnetized interstellar medium, on size scales ranging from nearby star-forming regions to the discs and superwinds of the starburst galaxies, using the JCMT and ALMA. I will particularly discuss how we can infer the dynamic importance of magnetic fields from observations of magnetic field geometries in the dense interstellar medium, and the emerging evidence for how the interaction between magnetic fields, outflows and feedback may influence star formation efficiency on both small and large scales.

Ambipolar diffusion and the mass-to-flux ratio in turbulent collapsing clouds

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Given the low ionization fraction of molecular clouds, ambipolar diffusion inevitably sets in at some stage during the star-formation process. However, computational challenges have hindered a comprehensive exploration of the effects of ambipolar diffusion in three dimensions. In this talk, I will present results from 3-dimensional non-ideal MHD chemo-dynamical simulations of turbulent collapsing molecular clouds where the resistivities are self-consistently calculated from a non-equilibrium chemical network consisting of 115 species, and with a different mean collisional rate used for each charged species in the network. These simulations reveal that, contrary to "conventional wisdom", the features of the neutral-ion drift velocity become increasingly complex in the presence of turbulence, with many vectors even pointing outward from the cloud’s center. I will discuss the implications of this behavior for the spatial and temporal evolution of the true (i.e. differential) mass-to-flux ratio. To assess observational biases in measuring the neutral-ion drift, I have also conducted a number of non-LTE line radiative-transfer experiments and developed a roadmap to observationally constraint it. Finally, I will compare the true and observationally inferred mass-to-flux ratios, highlighting key biases and their implications.

Towards a 3D view of the magnetized ISM in the Solar neighborhood

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The Galactic magnetic field is one of the least understood components of the ISM. It influences processes over a large range of scales, from star-formation to the diffusion of cosmic rays within the Galaxy. However, the effects of the magnetic field remain poorly understood, in part due to difficulties in measuring its properties over a large enough dynamic range in scale. With the advent of Gaia, a new era for magnetic field studies has begun. We can now probe the magnetic field properties in 3D, using stellar polarimetry and Gaia distances. I will describe recent progress on mapping the magnetic field with this technique, leading to new insights on the magnetized ISM in the Solar neighborhood.

The influence of magnetic fields in Cloud-Cloud Collisions

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Cloud–cloud collisions are often discussed in the context of highly supersonic flows, yet their role in triggering star formation remains uncertain in this regime. In contrast, the turbulent nature of GMCs naturally gives rise to frequent low-supersonic collisions, which may play a more important role in shaping star-forming structures. Here, we explore how magnetic fields aligned with the collision direction influence the filamentary morphology and star formation that develops in such low-velocity cloud–cloud collisions.

We find that collisions produce two characteristic filamentary patterns: a *hub–filament system*, where radially oriented filaments feed a central condensation, and a *spider's-web* morphology composed of intersecting filaments that fragment into multiple substructures. In non-magnetic collisions, the transition between these morphologies is set by a collision-velocity threshold. Magnetic fields slow the fragmentation of the shocked layer, broaden filaments, and shift the boundary between these regimes to higher velocities, thereby increasing the likelihood of forming *hub-filament systems*.

In this talk, I will show how these contrasting filamentary patterns emerge in simulations with and without magnetic fields and explain how magnetic regulation of low-velocity cloud collisions reshapes when and where stars form, with direct consequences for the range of stellar masses.

[1]: https://raw.githubusercontent.com/theogeo1996/Olympian_Symposium/main/Collisionplots.pdf

The Magnetic Field in Star-Forming Regions of the Perseus Molecular Cloud.

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Magnetic fields play a crucial role in regulating star formation by providing support, influencing fragmentation, and core collapse. To assess their impact, we investigate the magnetic field strength and its distribution in the Perseus molecular cloud, focusing on IC348, L1448, L1455, NGC 1333, and B1. We estimate the plane-of-sky field strength using the Davis–Chandrasekhar–Fermi (DCF) method and its modified approaches, combining JCMT polarization data with N_2H^+ (1–0) and NH_3 (1,1) spectral line data from NRO and GBT. The average field strength calculated by the DCF method is around a few hundred μG, consistently higher than the results obtained from the modified methods. The observed mass-to-flux ratio with all the methods shows a transition from subcritical in filaments to supercritical in the cores. In addition, we found that the nonthermal FWHM from N_2H^+ are systematically broader than those from NH_3. We use a simple filamentary model to show that these linewidth differences could arise from tracing distinct density regimes, while the abundance ratio remains constant. We further calculated the energy budgets and found that the fraction of magnetic energy increases in the NH_3-traced inner regions. These results are consistent with the ambipolar diffusion model, indicating a weakening magnetic field and increasing gravitational dominance toward core centers.

Mapping the Cosmic-Ray Ionization Rate in the Solar Neighborhood

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Chemical complexity in the molecular interstellar medium (ISM) is driven by fast ion-molecule reactions. This network of chemical reactions requires a source of ionization, and as molecular gas is generally well shielded from ionizing UV photons, cosmic rays provide the dominant source of ionization in such environments. The impact of cosmic rays on atomic and molecular hydrogen is parameterized as the cosmic-ray ionization rate (CRIR; number of ionizations per atom/molecule per unit time), which serves as an important input variable in astrochemical modeling. We use observations of H_3^+ , a molecule with very simple formation and destruction pathways, in combination with advanced 3D chemical modeling to infer the CRIR in diffuse molecular gas along sight lines toward bright, early type stars. Until recently, it was impossible to constrain the location of the absorbing gas along a sight line, but with Gaia extinction maps we can now link molecular absorption features to physical complexes of dust and gas in the local (1 kpc) ISM. This has allowed us to begin creating the first 3D map of CRIRs in the solar neighborhood, and to investigate correlations with properties such as location, gas density, distance from proposed cosmic-ray acceleration sites, and more. Here, I will present the results of our recent H_3^+ survey using IRTF/iSHELL, which has more than doubled the number of sight lines where we have precision estimates of the CRIR, and enabled the investigation of spatial variations in the cosmic-ray flux.

Cosmic ray investigation with KOSMA-τ

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Cosmic rays are key components of the interstellar medium (ISM) and play a fundamental role in galaxy evolution. The ionization of hydrogen by cosmic rays (ζ_{CR}) significantly influences the chemistry of molecular clouds by altering the formation/destruction pathways of chemical species. Moreover, ζ_{CR} is considered to be attenuated beyond a column density threshold. This attenuation shows a spatial profile different from that of the UV attenuation. Thus, from their varying relative importance, some additional complexity arises.

We use the sophisticated spherical PDR code KOSMA-τ to investigate the impact of cosmic rays on the physical structure and chemistry of modeled molecular clumps, as well as to generate line-intensity grids for comparison with observations. We simulate a wide range of initial conditions that span densities of $n = 10^0$–$10^6\mathrm{cm}^{-3}$, far-ultraviolet radiation fields of $\chi_0 = 10^{-0.1}$–10^6 Draine, and cosmic-ray ionization rates of $\zeta_{CR} = 10^{-18}$-$10^{-13}\mathrm{s}^{-1}$. We find that some species show monotonic changes with ζ_{CR}, while others increase and then have a sharp decrease, highlighting the complex balance of formation and destruction. Spherical integration of local abundances (i.e., $X_{species}$) provides a measure for identifying species sensitive to CR. Species observable in the 1-3 mm range with current ground-based telescopes (e.g., SO_2, HCO^+) exhibit non-monotonic changes and strong sensitivity to CRs, while CO and H_2 are destroyed, pushing the cloud to be H- and [CI]-rich. Our simulations enable us to construct grids (n, FUV, ζ_{CR}) that show several lines sensitive to CR effects (e.g., C-ladder, HCO^+), which may serve as tools for measuring the cosmic ray rate in an observed molecular cloud.

Cold Clouds as Cosmic Ray Detectors

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Stars form within dense molecular gas, where cosmic rays regulate ionization, chemistry, and magnetic coupling. Yet measuring the cosmic-ray ionization rate (ζ) in these environments has remained a persistent challenge. I will present recent JWST observations of the starless core Barnard 68, revealing the first direct detection of cosmic-ray-excited H_2 emission—a long-predicted but previously undetected signature. This allows a direct measurement of ζ, establishing molecular clouds as vast, naturally occurring CR detectors floating in space.

Complex organic molecules and cosmic ray ionisation rate towards the massive protostar Cepheus A HW2

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Cosmic rays (CRs) are important drivers for molecular chemistry in star-forming regions, and laboratory experiments have shown that CRs can stimulate the release of complex organic molecules (COMs) such as methanol. Observationally, this has primarily been tested in cold, low-mass cores, so studying how CRs affect COM formation in a higher ionised environment is of great interest. We have analysed spectra from a single dish observation by the Onsala 20 m telescope towards the high-mass protostar Cepheus A HW2, which is known to host an ionised jet. Consistent with previous studies, two primary velocity components were identified, one of which is associated with most of the COM's emission in the region. Column densities and relative abundances of the detected ions and COMs (such as methanol, acetaldehyde and methyl-formate) were estimated from rotational diagrams and single transitions. Deuterium fractions were also estimated, and the volume density of molecular hydrogen was constrained from a RADEX grid search. Electron fractions and CR ionisation rates were estimated through analytic chemistry using different ions as probes.

AstroAMASE: Leveraging Machine-Learned Chemical Intuition for Molecular Assignment and Discovery

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The advent of broadband, high-spectral resolution receivers and correlators on telescopes like ALMA, NOEMA, and the SMA provides detailed maps of chemically rich regions which contain a full spectral line survey in each of many thousands of pixels. Next-generation facilities and upgrades like ALMA WSU, the ngVLA, and the SKA will greatly magnify these datasets. Yet, the analysis of even a single spectrum's chemical content is a process that can still take hours or days, even with some degree of automation. AstroAMASE is an automated line identification and prediction tool built on the framework originally built for laboratory analysis (AMASE: Automated Mixture Analysis via Structural Evaluation). I'll present an overview of this tool which can rapidly (minutes) and accurately ($\sim 98\%$ validated assignments) determine linewidths, vlsr values, and assign most known chemical signatures including reasonable guesses at temperatures and column densities. Further, I'll discuss its ability to suggest other likely molecules to be present in the source, including those not in databases or with prior laboratory measurements.

Thursday, 21 May – Afternoon session

	AI-Driven Astrochemistry and the Multiphase ISM **Chair: Christine Greif**		
16:00–16:15	C	**David Robinson**	Emulating non equilibrium chemical networks with machine learning
16:15–16:30	C	**Caterina Bracci**	Machine Learning Insights into the Structure and Properties of Ionized Nebulae
16:30–16:45	C	**Donghui Quan**	ChemiVerse Construction and Modeling of Interstellar Chemical Reaction Networks for Intelligent Astrochemical Exploration
16:45–17:00	C	**Tianwei Zhang**	Spectuner-D1: Efficient spectral line fitting of interstellar molecules using deep reinforcement learning
17:00–17:15	C	**Shivan Khullar**	Bridging the scales hyper Lagrangian refinement in RMHD star formation simulations embedded in galactic environments
17:15–17:35	**Special talk by Astronaut Bonnie Dunbar**		

Emulating non-equilibrium chemical networks with machine learning

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The abundances of various ions and molecules in the interstellar medium have important consequences for emission and absorption lines seen in galaxy observations and the radiative cooling of the gas. The chemical composition of the ISM evolves due to interactions of gas particles with each other as well as with photons, cosmic rays, and dust grains. Quantitatively, this evolution is described by a non-equilibrium chemical network consisting of coupled differential equations for the abundance of each species. Even for a simple molecule like CO, so many species are involved in its production that solving the full relevant chemical network is computationally impractical in most simulations of galaxy evolution. As an alternative approach, we develop machine learning methods to emulate non-equilibrium ISM chemical networks for use in hydrodynamic simulations. We generate a suite of training runs of a chemical network with over 600 ionic and molecular species, sampling values for the gas density, temperature, and cell size, as well as the incident radiation field strength. We train an autoencoder to project the full space of abundances down to a lower-dimensional latent space and emulate the evolution of the latent variables across arbitrary time steps using the relevant gas and radiation field parameters. In a simulation, this emulator can be implemented by 1) applying the encoder network to the current chemical abundances to get latent variables, 2) evolving these latent variables forward with the appropriate time step and local radiation field and gas properties, and 3) applying the decoder network to translate from latent variables back to the full set of (evolved) abundances.

Machine Learning Insights into the Structure and Properties of Ionized Nebulae

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Investigating the conditions of the ionised ISM is key to understanding star formation and chemical enrichment in galaxies. Modern spectroscopic surveys require novel methods that efficiently classify nebulae and characterise their physical conditions in large datasets.

I present a neural network method for the segmentation of IFS cubes to identify different ionised nebulae, isolating them from the surrounding diffuse ionised gas. Crucially, the model exploits the full IFS data to define physically meaningful nebular boundaries that account for line-of-sight superpositions, capabilities that standard line-ratio diagnostics lack.

I also present a machine-learning-powered statistical framework to infer ISM physical conditions, providing full posterior distributions that quantify uncertainties, something typically not captured by standard neural networks. The inferred metallicity, ionisation parameter, and relative abundances are consistent with results from standard Bayesian methods, but are evaluated $\sim 10^{3-4}$ times faster, enabling efficient analysis of current and future spectroscopic surveys.

Together, these machine learning techniques offer a promising route to extract detailed ISM physics from modern (IF) spectroscopic campaigns probing the star formation and feedback scales in the local Universe.

ChemiVerse: Construction and Modeling of Interstellar Chemical Reaction Networks for Intelligent Astrochemical Exploration

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The central goal of astrochemistry is to understand the formation, evolution, and destruction of interstellar molecules. However, the reaction pathways associated with the more than 340 molecules detected in the interstellar medium are quite complex and environment-dependent. Existing chemical reaction networks are limited in scale, updated infrequently, and often affected by inconsistencies among heterogeneous data sources, which hinders the systematic characterization of interstellar chemical processes. To address these challenges, we develop an intelligent-computing–driven framework for astrochemical modeling based on a "data–model–observation" loop. First, we construct ChemiVerse, an interstellar chemical reaction data platform that integrates literature, laboratory, and theoretical data to build the largest comprehensive reaction network to date. Building on this foundation, we develop GraSSCoL (Graph-to-SMILES and Supervised Contrastive Learning), which combines molecular graph representations with contrastive learning to intelligently expand reaction pathways while preserving physicochemical plausibility, thereby providing new candidate reactions for multiphase chemical models. On the observational side, we develop Spectuner, an automated spectral recognition system that enables rapid fitting and screening of molecular lines from astronomical observations, substantially improving identification efficiency. In parallel, we are constructing SpectroVerse, a comprehensive interstellar molecular spectral library that integrates experimental, theoretical, and AI-generated spectra to support observational interpretation and inversion modeling. Together, these efforts establish a systematic framework for reaction network construction, multiphase chemical modeling, and intelligent spectral analysis, advancing AI-enabled astrochemistry toward greater integration, automation, and scalability.

Spectuner-D1: Efficient spectral line fitting of interstellar molecules using deep reinforcement learning

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Spectral lines from interstellar molecules provide crucial insights into the physical and chemical conditions of the interstellar medium. Traditional spectral line analysis relies heavily on manual intervention, which becomes impractical when handling the massive datasets produced by modern facilities like ALMA. To address this challenge, we introduce a novel deep reinforcement learning framework to automate spectral line fitting. Using observational data from ALMA, we train a neural network that maps both molecular spectroscopic data and observed spectra to physical parameters such as excitation temperature and column density. The neural network predictions can serve as initial estimates and be further refined using a local optimizer. Our method achieves consistent fitting results compared to global optimization with multiple runs, while reducing the number of forward modeling runs by an order of magnitude. We apply our method to pixel-level fitting for an observation of the G327.3-0.6 hot core and validate our results using XCLASS. We perform the fitting for typical complex organic molecules of hot cores, including CH_3OH, CH_3OCHO, CH_3OCH_3, C_2H_5CN, and C_2H_3CN. For a 100×100 region covering 5 GHz bandwidth, the fitting process requires 4.9 to 41.9 minutes using a desktop with 16 cores and one consumer-grade GPU card.

Bridging the scales: hyper-Lagrangian refinement in RMHD star formation simulations embedded in galactic environments

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Star formation is an inherently multi-scale, multi-physics process. A major open question is how strongly the galactic environment influences the internal dynamics of giant molecular clouds (GMCs) and their star formation outcomes (e.g. the SFE/SFR or the IMF) given the vast disparity in physical scales involved. Simulating such a high dynamic range of scales has historically proven difficult. The FORGE'd in FIRE project is a set of cosmological radiation-MHD simulations that self-consistently bridge scales from Mpcs to AUs. These simulations employ a hyper-Lagrangian refinement scheme that concentrates resolution in targeted regions of interest. I will present recent work validating this hyper-Lagrangian refinement approach for star formation (collapse) problems, along with initial results studying star formation across different environments (and redshifts). I will also discuss the importance of using realistic initial and boundary conditions in star formation simulations, as it pertains to the SFR and IMF in GMCs.

Friday, 22 May – Morning session

	Multi-Scale Structure and ISM Dynamics **Chair: Masato Kobayashi**		
09:00–09:15	C	**Juan Diego Soler**	The physical conditions of local star formation as revealed by neutral atomic hydrogen HI and 3D dust
09:15–09:30	C	**Shih-Ping Lai**	Reconstructing the Layered Magnetic Field in Orion KL Velocity Resolved CO 3-2 Polarization from the Goldreich Kylafis Effect with ALMA
09:30–09:45	C	**Bin Jia**	Physical and Chemical Conditions of Molecular Gas in NGC 1068 The nuclear feedback in the circumnuclear disk and starburst ring
09:45–10:00	C	**Jocabed Martinez Lopez**	Molecular gas and outflows in galaxies from cosmic noon to the present day
10:00–10:15	C	**Lewis Miller**	Turbulence is not the same everywhere mapping how galaxies stir their gas
10:15–10:30	C	**Bo Peng**	FLAMES Comprehensive View of Far Infrared Fine Structure Lines with New Answers and New Questions
10:30–11:00	**Coffee break**		
	Local Universe and Star Formation Diagnostics		
11:00–11:15	C	**Cosima Eibensteiner**	Star Formation Scaling Relations in the Local Group from the Local Group L-Band Survey LGLBS
11:15–11:30	C	**Samuel Crowe**	Widespread Star Formation and Ionized Gas Filamentation in Sgr C
11:30–11:45	C	**Shusuke Utsumi**	A Theoretical Prediction of Naked First Cores An Observationally Accessible Pathway to Brown Dwarfs
11:45–12:00	C	**Konstantinos Kostaros**	New GR tests using spectral line radiation backgrounds
12:00–12:15	C	**Jonathan Shelest**	T|3D Presenting The First 3D Temperature Map Of Our Galaxy

The physical conditions of local star formation as revealed by neutral atomic hydrogen (HI) and 3D dust

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Neutral atomic hydrogen (HI) represents more than half of the gas mass in the Milky Way. It is a critical tracer of the interstellar medium (ISM) dynamics, sampling both the cold, pre-molecular state before star formation and the warm, diffuse ISM before and after star formation. However, its ubiquity and complexity have made it challenging to integrate HI into the overall picture of star formation to date. We present a reconstruction of local ISM motions by combining a state-of-the-art three-dimensional model of the dust distribution within 1.25 kpc of the Sun with HI emission observations. Using the histogram of oriented gradients (HOG) machine-vision algorithm, we exploited the morphological similarity between these tracers to assign line-of-sight velocities to dust parcels over distances and produce a face-on map of the local ISM's heliocentric motions. We used the resulting maps to calculate the amplitude of streaming motions, kinetic energy and momentum distributions, and the mass flow rates in the local ISM. Our results indicate that the current local supernova tally is insufficient to account for the large-scale motions in the Solar neighborhood, suggesting that Galactic dynamics influence the initial conditions of local star formation.

Reconstructing the Layered Magnetic Field in Orion KL: Velocity-Resolved CO (3–2) Polarization from the Goldreich–Kylafis Effect with ALMA

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We present ALMA observations of polarized 12CO (3–2) emission and 1.3 mm dust continuum polarization toward Orion KL, probing magnetic field structure across different physical layers in a region shaped by a recent explosive event. CO polarization arising from the Goldreich–Kylafis effect reveals complex, velocity-dependent behavior, including systematic 90° polarization flips along redshifted outflow fingers at distances of ∼500 au from the explosion center. Statistical comparisons between CO and dust polarization angles show strong regional and velocity-dependent variations, inconsistent with a single, uniform magnetic field traced by both diagnostics. These results indicate that CO and dust polarization probe distinct layers along the line of sight. By combining velocity-resolved CO polarization with continuum constraints, we reconstruct the magnetic field morphology and find that, despite local polarization reversals, the large-scale field geometry is largely preserved. The inferred field structure reflects the combined influence of the Orion KL explosive outflow and the pre-existing large-scale magnetic field, demonstrating the power of molecular line polarization to resolve magnetic fields in dynamically complex star-forming regions.

Physical and Chemical Conditions of Molecular Gas in NGC~1068: The nuclear feedback in the circumnuclear disk and starburst ring

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We investigate the physical and chemical conditions of molecular gas in the nearby active galaxy NGC 1068, which hosts both an active galactic nucleus and intense star formation. Our analysis focuses on the circumnuclear disk and the starburst ring in order to assess whether nuclear feedback influences the molecular gas on kiloparsec scales. We use archival ALMA observations of several low J molecular transitions that provide broad spatial coverage and robust signal to noise. The data are analyzed using a hierarchical Bayesian framework that couples non-LTE radiative transfer with time dependent chemical modelling. To reduce the computational cost, direct chemical calculations are replaced by a neural network emulator trained on a large grid of chemical models. This approach allows us to derive spatially resolved constraints on gas density, kinetic temperature, column density, and cosmic ray ionization rate across the galaxy. We find clear radial and azimuthal variations in all physical parameters. The circumnuclear disk exhibits the highest gas densities and elevated cosmic ray ionization rates. The stellar bar and parts of the starburst ring show enhanced gas temperatures. Regions aligned with the expected outflow direction preferentially favour a heating scenario over a quiescent cloud scenario. In addition, CO line profiles near the inner edge of the starburst ring display non Gaussian features, indicating dynamically disturbed gas. These results provide evidence that the nuclear outflow in NGC 1068 affects not only the circumnuclear disk but also the inner regions of the starburst ring.

Molecular gas and outflows in galaxies from cosmic noon to the present day

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Feedback from supernovae and active galactic nuclei drives galactic outflows that expel and heat molecular gas, the fuel of star formation. Molecular outflows have been primarily studied in luminous galaxies (starbursts and AGNs), while in typical star-forming galaxies the signal is too faint for individual detection. I apply stacking methods to CO(1-0) spectra at ~1 kpc scales to detect faint molecular outflows in nearby star-forming galaxies from the EDGE-CALIFA survey. After characterizing regions by physical properties (e.g., star formation rate, offset from the main-sequence, AGN activity), I find no significant outflow signal except when stacking regions with star formation surface densities greater than 0.01 $M_{\odot}$/yr/kpc2. Upper limits on outflow mass and velocity indicate no significant impact on star formation in these galaxies. Additionally, I will present new results on the neutral outflows, molecular gas, and star formation efficiency in a lensed, low-stellar mass (~1e9 $M_{\odot}$) galaxy at z~2 to understand how outflows regulate star formation during cosmic noon.

Turbulence is not the same everywhere: mapping how galaxies stir their gas

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Turbulence critically shapes the structure and dynamics of the interstellar medium (ISM). While theory and simulations predict that multiple turbulent environments can coexist within a galaxy, direct measurements of how turbulence varies across external galaxies have been limited by observational constraints. Using high-resolution ALMA observations of CO (J=2–1), we present the first full-disk, spatially-resolved measurements of turbulence in the nearby spirals NGC 7793 and NGC 1313. In particular, we measure the turbulence driving parameter, b; a dimensionless quantity that evaluates how turbulence is injected into the ISM. Most previous studies have been forced to assume a constant value of b, limiting our ability to understand how ISM dynamics and star formation respond to local galactic environments. Applying a novel roving-kernel technique, we map the local Mach number, density dispersion, and b across the arms, inter-arm regions, rings, and outskirts of the galaxies, and find that each substructure hosts a distinct turbulent regime depending on the galactic environment. These results demonstrate that turbulence driving is neither universal nor uniform within galaxies, and that local galactic structure plays a major role in shaping ISM dynamics and star formation. We link the changing turbulent environments with other environmental tracers and specifically star formation indicators.

FLAMES: Comprehensive View of Far-Infrared Fine Structure Lines with New Answers & New Questions

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Far-infrared fine structure lines (FIR FSLs) are powerful tools in studying the physical condition of interstellar medium (ISM). However, many gaps remain in the study of these lines, especially between the study of FIR FSLs and the optical strong lines, and between the local and high redshift galaxies, which limits our capability in systematically comparing and combining multi-wavelength observations from powerful facilities like ALMA and JWST. In this talk, I will present a comprehensive catalog including most of the global FIR FSL data of both low- and high-z galaxies collected from the literature covering a large range of galaxy types, with rich ancillary optical and mid-infrared data. Based on this comprehensive catalog, I will give a renewed view of the empirical FIR FSL relations, and demonstrate the canonical factors behind these lines aided by the photoionization models. I will highlight the new results enabled by combining the multi-wavelength data, including the identification of [O III]88 contribution from AGN, the coherence between all the neutral and ionized gas emission in both FIR and optical, the dichotomy between the ionized&neutral gas and the dust that results in "line deficit" of, not only [C II], but all the lines including H alpha, as well as the consequent crisis of the star formation rate measurement in dusty galaxies and the quest for an updated view of ISM. I will conclude with the multi-wavelength diagnostic power of FIR FSLs and the prospect use of these tools.

Star Formation Scaling Relations in the Local Group from the Local Group L-Band Survey (LGLBS)

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We present the VLA Local Group L-Band Survey (LGLBS) and one of the first science results. We use new 120pc resolution HI data from combined VLA C + D and GBT observations, together with archival UV, optical, infrared, and CO mapping data, to test star-formation scaling relations in six local group galaxies: M31, M33, IC 10, IC 1613, NGC 6822, and WLM. Radial profiles show that while the HI surface density declines only mildly with radius (extending out to $\sim 2-5$ optical radii for the dwarfs), both stellar-mass and star-formation-rate surface densities decrease sharply, producing an outwardly falling star-formation efficiency (SFE). Classical relations are recovered: Σ_{SFR} correlates weakly with ΣHI, nearly linearly with ΣH_2 where CO is detected, and shows intermediate behavior with total gas. On ~100 pc scales, SFE increases with $\Sigma_\star$ and the molecular-to-atomic gas ratio (Rmol) rises with the ISM dynamical equilibrium pressure PDE, extending pressure–phase balance trends into the HI-dominated, low-metallicity regime. Across all galaxies, the resolved Σ_{SFR} - PDE relation is present but exhibits larger scatter in dwarfs, consistent with stochastic star formation and non-local heating. Feedback yields (Υ_{fb} = PDE / Σ_{SFR} cluster around $\sim 10^3$ km s^{-1} in HI-dominated regions, slightly below those in molecular-rich spirals, implying environment-dependent coupling between stellar feedback and ISM pressure. This work allows us to place the six Local Group galaxies in the general context of the galaxy population in the present-day universe.

Widespread Star Formation and Ionized Gas Filamentation in Sgr C

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The stellar life cycle in the Central Molecular Zone (CMZ), the extreme region within a Galactocentric radius of ~300 parsecs, remains poorly understood. We present James Webb Space Telescope (JWST) near-infrared observations of the CMZ star-forming molecular cloud Sagittarius C (Sgr C) that shed light on this process. JWST reveals outflows, in the form of atomic and molecular hydrogen shocks, from several low- to high-mass protostars widely distributed throughout the cloud. In particular, the inner outflow vicinity of two massive protostars, each with an SED-fit mass of ~20 solar masses, is probed with unprecedented resolution, and corroborated by dust continuum and molecular line data from the ALMA radio observatory, demonstrating a noteworthy similarity to other massive protostars in the solar neighborhood. We also report the discovery of a new star-forming region, ~1' to the west of Sgr C, hosting two prominent bow-shocks driven by at least two actively-forming YSOs. In addition to star formation, we present evidence that the Sgr C HII region, associated with the main star-forming cloud, is evolving under magnetically dominated conditions.

Unlike any HII region in the Solar vicinity, the Sgr C plasma displays a remarkably filamentary structure in JWST Brα observations. The brightest of these filaments are also visible in the radio continuum with the ALMA and MeerKAT observatories, and radio spectral index measurements indicate the presence of both thermal free-free and magnetically-stimulated synchrotron emission. We argue that the strong (~1 mG) CMZ magnetic fields have confined the plasma flow in Sgr C to rope-like filaments or sheets, and present radiative magnetohydrodynamic simulations of highly magnetized HII region evolution that support our interpretation. Corroborating this claim on the observational side, we observe a statistically significant peak in the distribution of Brα filament orientations perpendicular to the galactic plane, or along the poloidal component of the global CMZ magnetic field, as well as a plasma β below 1, even in the densest regions. We speculate that all mature HII regions in the CMZ, and galactic nuclei in general, evolve in a magnetically dominated, low plasma β regime, with consequences for our understanding of stellar feedback in extreme environments.

A Theoretical Prediction of Naked First Cores: An Observationally Accessible Pathway to Brown Dwarfs

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Brown dwarfs are astronomical objects that occupy the intermediate regime between planets and stars, and they generally have masses of 0.01-0.08 solar mass. Because their central temperatures do not rise sufficiently, they may undergo temporary deuterium fusion, but they do not reach sustained nuclear fusion that converts hydrogen into helium. A unified picture of brown-dwarf formation has not yet been established, and many theories have been proposed. For example, one hypothesis is that brown dwarfs form as a scaled-down version of the standard star-formation process via fragmentation of molecular-cloud filaments; however, its validity remains unclear, partly because filaments with the theoretically predicted width of about 0.001 pc have not been adequately observed.

In this study, we focused on a newly proposed formation mechanism in which a close encounter between two circumstellar disks can trigger brown-dwarf formation (Fu+2025), and we tested its plausibility. Close circumstellar disks can form a filamentary tidal bridge through gravitational instability, and a brown dwarf may form when this structure undergoes gravitational collapse. We systematically computed disk encounters under realistic conditions using hydrodynamical numerical simulations. We find that, in order for a disk encounter to form a brown dwarf, (a) the disks must be massive enough to fragment via gravitational instability prior to the encounter, and (b) the encounter must bring the disks to within a distance comparable to the disk radius; thus, the required encounter conditions are strongly constrained. We therefore conclude that close encounters of circumstellar disks are unlikely to be a dominant pathway for brown-dwarf formation.

We further note that similar interactions may occur even before the birth of protostars, and we propose a new formation mechanism based on encounters between first hydrostatic cores. A first core is a transient object formed immediately after the first collapse in standard star-formation theory, and in the spherically symmetric case it maintains a hydrostatic equilibrium structure for about 1e3 yr. Its initial mass is approximately 0.01 solar mass; it gains mass by accretion from the surrounding envelope and eventually evolves into a protostar after the second collapse of the central region. Our hydrodynamical simulations show that, when a first core with an accreting envelope encounters and interacts with another first core, the surrounding envelope can be dispersed while the hydrostatic structure of the core is preserved. The resulting "Naked First Core" (NFC) is expected to evolve into an object with a mass of about 0.01 solar mass, because subsequent mass accretion is halted; in terms of mass, this corresponds to a brown dwarf. We estimate that, in a typical cluster environment, on the order of several tens of NFCs can be formed over the cluster lifetime.

Despite being an important stage that all stars may pass through, first cores have not yet been observationally confirmed. Traditionally, direct observation of a first core has been considered difficult because a thick envelope absorbs radiation originating from the first core. However, an NFC may be observable because its envelope is tenuous. Therefore, our conclusions not only propose a new formation pathway for brown dwarfs, but also provide implications for the observability of first cores.

New GR tests using spectral line radiation backgrounds

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Supermassive black holes (SMBHs) at the centers of galaxies, illuminated by their accretion disks, can reveal valuable information on BH physics via their shadows.

BH shadow imaging can be used to test the properties of BHs through strong-field gravitational lensing, but the extraction of strong-gravity signatures is challenging. At the same time, the observed radiation encodes information on the astrophysical environment as well, so disentangling gravitational physics from accretion astrophysics is crucial. These difficulties could be overcome if one were to utilise spectral line radiation emanating from cooler parts of the extended accretion disk, the so-called Broad Line Region (BLR), and in particular its predicted neutral phase, as a more distant, but still strong SMBH illuminator, found at $r \sim (10^2 - 10^4)R_g(R_g = GM/c^2)$. Spectral line emission from the transitional region between the inner disk and the outer BLR may be ideal for obtaining a cleaner image of the light-ring against a non-luminous background, not affected by the emission and all the dynamical effects taking place near the ISCO. Furthermore, some additional interesting phenomenology can be related to such an illuminator.

We find that a fascinating first-order effect of BLR illumination of SMBHs is an Einstein-ring-related feature, an Einstein hourglass, together with strong line features in the spectrum, which are smoking gun signals of BH lensing, that can facilitate the measurement of the BH mass and further enable the study of strong-lensing signatures beyond the first order. Higher-order effects associated with the light-ring can then constrain the BH spin, and even identify deviations from the Kerr spacetime, providing a cleaner route for strong gravity tests.

T|3D – Presenting The First 3D-Temperature-Map Of Our Galaxy

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The multiphase structure of the interstellar medium (ISM) is fundamental to star formation and gas cycling in galaxies, yet until today, we have lacked a 3D view of where these phases exist in galactic space.

In this talk I will present the first 3D dust map of gas temperature across the neutral ISM revealing the spatial distribution of cold ($T \leq 300K$), unstable ($300 < T < 6000K$), and warm ($T \geq 6000K$) neutral medium (CNM/UNM/WNM, respectively), within 500 pc of the Sun and with ∼2 pc resolution. This is achieved by combining state-of-the-art 3D dust maps with a new 3D model of the UV radiation field, accounting for individual O/B stars and clusters.

I will show that the CNM and UNM dominate near the Galactic midplane, transitioning to WNM beyond $|z| \sim 150$ pc. Strikingly, $\sim 40\%$ of the ISM mass in the disk resides in the thermally unstable regime, providing direct evidence that turbulent mixing operates faster than thermal equilibration. I will discuss how this connects to ISM turbulence, molecular cloud formation, and the gas cycling processes that fuel star formation in galaxies.

Friday, 22 May – Afternoon session

	Multiphase ISM in Starbursts and AGN Chair: Theodoros Topkaras		
16:00–16:15	C	**Mathilde Bouvier**	Sulphur bearing species probe stellar feedback processes in the starburst galaxy NGC 253
16:15–16:30	C	**Yuze Zhang**	Combining Radiative Transfer and Kinematics Models for AGN Molecular Outflows
16:30–16:45	C	**Lara Pantoni**	MICONIC The impact of AGN feedback on the nuclear multiphase ISM of Centaurus A revealed by JWST MIRI MRS
16:45–17:00	C	**Jaiden Peltonen**	Bridging the Gap in the New Era of Star Formation

Sulphur-bearing species probe stellar feedback processes in the starburst galaxy NGC 253

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Star formation (SF) is a key process of the interstellar medium (ISM) and is intimately linked with the evolution of galaxies. While SF processes in starburst (SB) galaxies, which are galaxies powered by high rates of massive star formation, have long been subjects of interest in extragalactic astronomy, the starburst behaviour and its role in galaxy evolution is still not well understood (e.g. Callanan+2021).

We do know that the feedback processes – including shocks, turbulence, and ionisation by cosmic-rays and ultraviolet radiations – associated with intense SF interact and reshape the surrounding material, which will be used to form future generation of stars (e.g. Semenov+2021). Hence, they may contribute to the quenching of SB activity. It is thus crucial to constrain and characterise the SF-related feedback processes to understand how they influence the ISM, and ultimately, the evolution of star-forming galaxies.

Recently, the ALMA Comprehensive High-resolution Extragalactic Molecular Inventory large programme (ALCHEMI; Martín+2021) has imaged the CMZ of NGC 253 at ~27 pc spatial resolution, and provided a most complete unbiased molecular survey (from 84.2 to 373.2 GHz) towards the Central Molecular Zone (CMZ) of the starburst galaxy NGC 253. Using ALCHEMI, we performed a complete investigation the most abundant S-bearing species, known to be unique tracers of star-formation processes in our Galaxy (e.g Hatchell+1998, Li+2015, Widicus-Weaver+2017). Combining both observations and chemical modelling, we could constrain the physical conditions probed by the S-bearing species in the CMZ of NGC 253 and disentangle the two main stellar feedback processes at the origin of their emission (shocks versus thermal evaporation). We showed that S-bearing species are great tracers for ongoing star formation in the starburst environment of NGC 253 (Bouvier+2024; Bouvier+ in prep.).

Combining Radiative Transfer and Kinematics: Models for AGN Molecular Outflows

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Active galactic nuclei (AGNs) influence their host galaxies through powerful winds that drive large-scale outflows, regulating star formation by heating, removing, or compressing the interstellar medium (ISM). Despite their importance for galaxy–supermassive black hole co-evolution, the impact of AGN-driven feedback on the surrounding molecular gas reservoir remains poorly understood. In this talk, we present a first kinematics study of outflowing molecular gas in a typical circumnuclear disk (CND) using a 3D radiative transfer code coupled with kinematic models. We explore both a fully outflowing disk and a partially outflowing disk in which the outflow velocity depends inversely on gas density. For the fully outflowing CND, we find that increasing outflow velocity, decreasing outflow inclination, and increasing disk compactness all lead to more complex synthetic line profiles, with additional strong effects on the line-of-sight velocity centroids and component widths. In the partially outflowing case, the line profile structure similarly depends on the density–velocity relation. This work represents a first step toward a kinematics-based radiative transfer framework for extra-galactic circumnuclear environments, with future works including inner AGN structures such as the torus and combining radiative transfer with chemical modeling.

MICONIC: The impact of AGN feedback on the nuclear multiphase ISM of Centaurus A revealed by JWST/MIRI-MRS.

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Galaxy mergers represent a critical and complex phase in galaxy evolution, often triggering nuclear activity and intense episodes of central star formation that can profoundly influence the subsequent evolution of the system. In this talk, I present new insights into the impact of active galactic nucleus (AGN) feedback on the multi-phase interstellar medium (ISM) in the central region ($\sim 7-14'' \sim 100-200$ pc) of Centaurus A, the nearest active radio galaxy ($D_L = 3.5$ Mpc).

This study is part of the Guaranteed Time Observations (GTO) program *Mid-Infrared Characterization of Nearby Iconic Galaxy Centers* (MICONIC) of the MIRI European Consortium. Thanks to the high spectral resolving power of JWST/MIRI-MRS across the $4.9-27.9\,\mu$m wavelength range, we obtained unprecedentedly rich mid-infrared spectra of the nuclear environment at sub-arcsecond angular resolution ($1'' \sim 17$ pc).

These observations reveal clear signatures of shock-excited gas and strong energetic processing driven by the AGN.

We identify and model emission from ionized gas (Alonso-Herrero et al. 2025), rotational transitions of molecular hydrogen (Evangelista et al. 2026), and polycyclic aromatic hydrocarbon (PAH) features (Pantoni et al. 2026). By combining diagnostic line ratios, gas kinematics, and detailed spectral line-profile fitting, we characterize the physical conditions of the ISM and assess the relative contributions of shocks and AGN radiation in shaping the circum-nuclear medium.

Bridging the Gap in the New Era of Star Formation

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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. We present a new approach to charecterizing YSO populations by applying the technique of population synthesis originally developed for older stellar populations. Using the latest YSO radiation transfer and stellar evolution models, we have developed a population synthesis code that can generate YSO populations, accounting for details like binaries, clustering, extinction, and stochastic sampling. We used this new code to determine the properties of YSOs in the recent JWST images of NGC 604 within M33 and previous Spitzer studies of the LMC. The age and mass we determined of these YSO populations is consistent with previous studies using alternative approaches. However, this new framework allowed us to find the direct star formation rate of the star formation currently taking place in NGC 604 for the first time. Armed with this new framework we can determine the direct star formation properties of JWST identified YSO populations across the Local Group giving an unprecedented look at the effect of the large-scale environment on individual star formation.

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54	Jiang, Xuejian	Zhejiang Lab
55	Johnson, Madisen	Rutgers University
56	Kaiser, Leonard	I. Physics Institute, University of Cologne
57	Karska, Agata	Nicolaus Copernicus University in Torun
58	Khullar, Shivan	CCA, Flatiron Institute
59	Kobak, Agnieszka	Nicolaus Copernicus University in Toruń
60	Kobayashi, Masato	National Institute for Fusion Science
61	Koletic, Tamara	McMaster University
62	Kostaros, Konstantinos	Aristotle University of Thessaloniki
63	Kulkarni, Varsha	University of South Carolina
64	Kumar, Siddharth	Chalmers University of Technology, Sweden
65	Kyrmanidou, Martina	Emirates Airline
66	Lai, Shih-Ping	National Tsing Hua University
67	Lam, Natalie	UCLA
68	Lau, Cheryl	National Center for Theoretical Sciences (Physics Division), National Taiwan University
69	Lim, Jeremy	University of Hong Kong
70	Linden, Sean	University of Arizona
71	Lique, Francois	IPR - University of Rennes
72	Liu, Mengting	Zhejiang Laboratory
73	Liu, Qing	Leiden Observatory
74	Lundqvist, Emma	Stockholm University
75	Madden, Suzanne	CEA, Saclay
76	Martinez Lopez, Jocabed	Universidad de Concepcion
77	Matijević, Luka	University of Zagreb, Faculty of Science, Bijenicka cesta 32, 10000 Zagreb, Croatia
78	McGuire, Brett	MIT
79	Michiyama, Tomonari	Shunan Univresity

80	Miller, Lewis	Australian National University
81	Mishra, Divya	Texas A&M University
82	Moustakas, Christos	Aristotle University of Thessaloniki
83	Nagdeo, Ameya Uday	Indian Institute of Astrophysics, Bangalore
84	Nianias, James	University of Hong Kong
85	Nielsen, Emma Weiss	Niels Bohr Institute, University of Copenhagen
86	Nigou, Emma	LPENS
87	Nishimura, Yuri	University of Tsukuba
88	Nordlander, Thomas	Uppsala University
89	Panopoulou, Gina	Chalmers University of Technology
90	Pantoni, Lara	Ghent University
91	Pascalau, Robert	Kavli Institute for Cosmology, University of Cambridge
92	Pattle, Kate	University College London (UCL)
93	Peltonen, Jaiden	University of Alberta
94	Peng, Bo	Max Planck Institute for Astrophysics
95	Peschken, Nicolas	Florence University
96	Pety, Jérôme	IRAM & Obs. de Paris
97	Poosch, Hans-Christian	Max Planck Institute for Extraterrestrial Physics
98	Quan, Donghui	Xi’an Jiaotong Liverpool University
99	Ranjan, Adarsh	Space Telescope Science Institute
100	Riechers, Dominik	Universität zu Köln
101	Riesco, Clemente	Observatoire de Paris
102	Robinson, David	Tsinghua University
103	Rodriguez, Jimena	Space Telescope Science Institute
104	Roman-Duval, Julia	Space Telescope Science Institute
105	Sampson Olalde, Georgina	AIM (CEA DAp)
106	Schilke, Peter	University of Cologne
107	Scibelli, Samantha	NRAO
108	Seifried, Daniel	1. Physics Institute, University of Cologne
109	Sengupta, Dhrubojyoti	CNRS Gif-Sur-Yvette & CEA Paris-Saclay, France
110	Shelest, Jonathan	Technion – Israel Institute of Technology
111	Siwakoti, Utsav	University of Kansas
112	Smith, Rowan	University of St Andrews
113	Stanton, Reagan	University of South Carolina
114	Strigachev, Anton	Institute of Astronomy and NAO, BAS
115	Sulzenauer, Nikolaus	Max Planck Institute for Radio Astronomy
116	Sun, Jiayi	University of Kentucky
117	Tacconi, Linda	Max Planck Institut für Extraterrestrische Physik
118	Tan, Jonathan	Chalmers Univ. and Univ. of Virginia
119	Tomicic, Neven	University of Zagreb, Faculty of Science
120	Topkaras, Theodoros	I. Physikalisches Institut, Universität zu Köln
121	Tritsis, Aris	Ecole Polytechnique Federral de Lausanne
122	Utsumi, Shusuke	Nagoya University
123	Vigoureux, Guillaume	Ecole Normale Supérieure
124	Wakefield, Ben	University College London (UCL)

125	Walch, Stefanie	University of Cologne
126	Wang, Youxin	Max-Planck-Institut für Radioastronomie
127	Werts, Lucy Day	Intelligent Computing (Zhejiang Lab)
128	Whitaker, Kate	UMass Amherst
129	Whitworth, David	ENS Lyon
130	Williamson, Victoria	Rutgers University
131	Xhemollari, Oerd	University of Cologne
132	Yanchulova, Petia	Institute of Astronomy, Bulgarian Academy of Sciences
133	Yang, Meng-Zhe	National Tsing Hua University
134	Yao, Yao	Australian National University
135	Zhang, Tianwei	Zhejiang Laboratory
136	Zhang, Yuze	Leiden Observatory
137	Zhu, Zhengping	Zhejiang Laboratory
138	Zimmermann, Birka	I. Physics Institute, University of Cologne


Natural environment
1. Mt. Olympus National Park
2. Pieria Mountain
3. Enipeas Canyon
4. Agia Kori Stream
5. Vrondou Caves
6. Orlias Stream
Wetlands:
1. Aliakmonas Delta
2. Wetland of Alikes Kitros
3. Wetland of Nei Pori
Traditional Villages:
1. Palios Panteleimonas
2. Palii Pori
3. Palia Skotina
4. Palia Leptokiaria
5. Skotina (Morna)
6. Kolindros
Monasteries:
1. St. Dionisios of Olympus Main (Old) Monastery Mt. Olympus
2. St. Dionisios of Olympus Recent Monastery Litochoro
3. Osios Efrem of Syria Monastery Kontariotisa
4. Monastery of Virgin Mary Makrirahi
5. St. George Monastery Korinos
6. St. George Church Kolindros
7. St. George Monastery Ritini
8. Monument of St. Payl Crossing Methoni
9. St. Athanasios Church Kitros
History & Culture:
1. Makrigialos
2. Pidna
3. Kitros- Louloudies
4. Dion Archeological Park
5. Dion Acheological Museum
7. Livithra
8. Mount Olympus Geological Museum
9. Mount Olympus Natural History Museum
10. Maritime Museum of Litohoro
11. Kolindros Folklore Museum
6. Platamona's Castle
Mountain Refuges:
Mt. Olympus
1. D. Boudolas 1100m
2. S.Agapitos 2100m
3. H.Kakalos 2650m
4. G.Apostolidis 2760m
Pieria Mountain
6. Ano Milia 1000m
7. Sarakatsana 1680m
Airport
Railway Station
Highway Exit
Port
OLYMPUS riviera
PIERIA - GREECE
To FYROM
E-90
EGNATIA ODOS
E-75
To Ioannina
To Igoumenitsa
To Vergina
To Alexandria
Thessaloniki
Megali Gefyra
Paliampela
Aiginio
Livadi
Kastania
Kolindros
Katachas
Nea Agathoupoli
Methoni
Aigiannis
Palaio Eleftherochori
Makrigialos
Palaiostani
Sfendami
Alonia
Pidna
Alikes
Riakia
Koukos
Kitros
Trilofos
Elafos
Katalonia
Exochi
Sevasti
Nea Trapezounta
Toxo
Ano Agios Ioannis
Kato Agios Ioannis
Korinos
Moschopotamos
Meliadi
Elatochori
Palaio Keramidi
Nea Chrani
Ganochora
Lagorachi
Aronas
Neo Keramidi
Kalithea
Andromachi
Neokesaria
Peristasi
Paralia
Ritini
Vria
Moschochori
Svoronos
KATERINI
Kato Milia
Olympiaki Akti
Ano Milia
Mesea Milia
Rachi
Lofos
Karies
Fotina
Kontariotisa
Agios Spiridonas
Nea Efesos
Pieria Mountains
Skotina
Morna
Fteri
Vrondou
Palea Vrondou
Karitsa
Petra
Mt. Titaros
Dion
Kalivia Varikou
Agios Dimitrios
Rema Orlia
Agia Kori
Limenas Litochorou
Olympus National Park
Plaka Litochorou
Litochoro
Mt. Olympos
Leptokaia
Mitikas 2918m
Levithra
Palaia Leptokaria
Paralia Skotinas
Skotina
Paralia Panteleimona
Ano Skotina
Neos Panteleimonas
Platamonas
Palaios Panteleimonas
Nei Pori
Palei Pori
To Veria
To Vergina
To Kozani
To Livadi
To Elassona
To Karia
To Kalipefki
To Meteora
To Athens
E4
Thermaikos Gulf
HOTEL & SPA MEDITERRANEAN VILLAGE
HOTEL MEDITERRANEAN RESORT
ADULT HOTEL MEDITERRANEAN PRINCESS
HOTEL OLYMPUS MEDITERRANEAN
GREECE
EUROPE
Promachonas
Doirani
Evzoni
Kipi
Kavala
Thessaloniki
Katerini
Olympus
Meteora
Ioannina
Igoumenitsa
Larissa
Volos
Patra
ATHENS

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