

Multi-Scale Star Formation

Abstracts Book

CORE: A NOEMA large program to investigate fragmentation and disk kinematics during high-mass star formation

Ahmadi, Aida

Max Planck Institute for Astronomy

ABSTRACT: Many questions remain unanswered in the field of high-mass star formation. Among them are those pertaining to the fragmentation properties of high-mass gas clumps and the disk-like structures that form within them. To investigate such topics, we have undertaken a NOEMA large program (CORE, PI: Henrik Beuther) for 18 high-mass star forming clumps in the northern sky, resolving structures at mm wavelength on scales of $\sim 600\text{AU}$ ($\sim 0.3''$). Our observations are complemented with data from the 30m telescope in order to recover missing flux and probe large scale structures. In this talk, I will give an overview of the setup of the CORE project and its current status, along with preliminary results of a case study for W3(H₂O). With a broad range of observed molecules, we are able to disentangle different disk/core contributions and see two fragments within W3(H₂O). A stability analysis of the larger rotating structure around this clump furthermore proves it to be Toomre-unstable in parts, explaining the fragmentation we observe.

Stellar population parameters of the Milky Way Galaxy and photometric detection of satellite galaxy remnants

Alzate, Jairo

IRyA, UNAM

ABSTRACT: We attempt to estimate the star formation history of the stellar components of the Milky Way Galaxy. We perform a statistical analysis of the stellar photometry of each stellar population in the Galaxy. In particular, we use the maximum likelihood approach of Small et. al (2013) to recover the star formation history of each Galaxy component. From the derived star formation laws we build a synthetic model of our galaxy, which will be used to define criteria for the detection of satellite galaxy remnants in the Galactic halo.

The Galactic Distribution of High-Mass Star Formation Regions

Anderson, Loren

West Virginia University

ABSTRACT: In the WISE Catalog of Galactic HII Regions, we cataloged the locations of over 1000 known high-mass star formation regions, as well as thousands of candidate regions, spread across the Galactic disk. Since its publication, we have observed over 500 of these candidates in radio recombination line and radio continuum emission. The combined catalog of all known massive star formation regions in the Galaxy is statistically complete for all HII regions ionized by single O-stars. Using this catalog, we can determine the global properties of massive star formation in the Milky Way.

In our initial work, we have focused on identifying where our Galaxy is making stars by examining star formation in individual arms and as a function of height above and below the Galactic plane. Using clustering algorithms, we have identified the largest star forming complexes in the Galaxy. These first steps give us a glimpse of how global high-mass star formation proceeds in our Galaxy, and allow us to begin comparisons with similar external galaxies.

Observational constraints on the formation and evolution of molecular filaments

ANDRÉ, Philippe

CEA Saclay

ABSTRACT: Herschel imaging observations have emphasized the role of interstellar filaments in the star formation process. I will briefly summarize the main results obtained with Herschel on nearby molecular filaments, which support a scenario of low-mass star formation in two main steps: First, large-scale compression of interstellar material in supersonic MHD flows generates a cobweb of ~ 0.1 pc-wide filaments in the ISM; second, the densest filaments fragment into prestellar cores above the line-mass threshold for gravitational instability. I will then discuss molecular line observations with, e.g., IRAM and ALMA which suggest that star-forming filaments tend to form in sheet-like structures and to evolve through accretion of background cloud material while, at the same time, growing in internal complexity and fragmenting into cores. Finally, I will argue that the process of filament evolution is responsible for a characteristic efficiency of star formation in the dense gas of GMCs.

Star Formation Efficiency in the Outer Scutum-Centaurus Arm

Armentrout, William

West Virginia University

ABSTRACT: The Outer Scutum-Centaurus spiral arm (OSC) is the most distant known molecular spiral arm in the Milky Way. As such, it is affected by Galactic warp and rises above the range of most Galactic plane surveys. Almost nothing is known about this arm or the star formation therein. We have begun an extensive survey to identify and characterize high-mass star formation in the OSC. To date, we have detected high-mass star formation at 12 locations in the OSC, with the most distant source at 23.5 kpc from the Sun and 17 kpc from the Galactic Center. These regions represent star formation at low densities and low metallicities, similar to the conditions in galaxies like the Large Magellanic Cloud. Our observations of these sources include : (1) determining stellar mass from integrated continuum emission with the Very Large Array (VLA), and (2) measuring molecular gas mass from CO maps with the Green Bank Telescope (GBT) using ARGUS, the new 16-pixel focal plane array for millimeter spectroscopy. With these quantities, we can put constraints on the star formation efficiency of these distant outer Galaxy sources.

High- z Ly α sources search using the SHARDS survey

Arrabal Haro, Pablo

IAC

ABSTRACT: We have undertaken a comprehensive search for both Lyman Alpha Emitters (LAEs) and Lyman Break Galaxies (LBGs), in the GOODS-N field.

We have used for our search the SHARDS survey, consisting of a deep cosmological imaging survey, employing 24 medium band filters from 500 nm to 941 nm. To the best of our knowledge, this is the first time that both LAE and LBG are surveyed simultaneously, in a systematic way.

This search has been completed with ancillary data from ACS/WFC, Subaru, IRAC and other catalogs. After a careful selection process we find 296 sources. Most of the sources show rest-frame UV continua. A minority of them are pure LAEs, with virtually no continuum.

We derive the number of sources, star formation rates, luminosities, Equivalent Widths (EWs), Luminosity Functions (LFs) and clustering properties as a function of redshift. One important result from our search is that our numbers greatly differ from the numbers previously given by other authors. We do show that surveys made with broad band filters are prone to introduce unwanted sources. Our observations also match with the idea of an evolution between LAEs and LBGs, in which LAEs would be a initial stage of these galaxies.

Turbulence in HII Regions

Arthur, Jane

IRyA, UNAM

ABSTRACT: We study the scale dependence of turbulence inside real and simulated HII regions by applying statistical tools to optical emission-line spectroscopy. We compare the reliability of statistical methods such as structure functions and velocity channel analysis and show that only VCA can successfully recover the power-law index of the underlying velocity power spectrum of numerical simulations of evolving HII regions. Applied to real, high-resolution, spectroscopic observations of the Orion Nebula, we find that the velocity power spectrum is consistent with Kolmogorov theory, with a driving scale comparable to the autocorrelation length of dense cores in the surrounding Orion molecular filament. We also find that photoevaporation flows from globules and filaments in the Orion Nebula and subsonic turbulence in the photoionized gas contribute in equal measure to the observed fluctuations in the ionized density. Finally, comparison of the observational results with those from numerical simulations implies that the photoionized gas is confined to a thick shell, which is consistent with the inner region being evacuated by the action of stellar winds.

TBD

Ballesteros-Paredes, Javier

Instituto de Radioastronomía y Astrofísica, UNAM, Mexico

Explosive Outflows from Massive Protostars

Bally, John

University of Colorado

ABSTRACT: ALMA and adaptive optics observations of Orion's OMC1 / BNKL outflow confirm its explosive nature. This 10^{48} erg event may have been triggered by a protostellar merger resulting from the decay of a non-hierarchical system that resulted in the ejection of 3 massive stars and about 10 Solar masses of gas from the core. I will present new 0.05 arc-second resolution long-baseline ALMA data on Orion and discuss other Galactic explosive outflow candidates.

Explosive outflows similar to Orion may be associated with the ejection of some runaway stars, the production of IR-flares with luminosities between novae and supernovae, and have profound feedback impacts on their parent molecular clouds. Such mergers may be relatively common because massive protostars accreting at high rates develop AU-scale diameters, forming clusters have high stellar volume densities, and dense cores are dissipative. Such events may be responsible for some of the over 150 luminous IR-transients detected in nearby star-forming galaxies by the Spitzer warm-mission program SPIRITS during the last three years.

Cloud Structure OF Galactic OB Cluster Forming Regions From Combining Ground and Space Based Bolometric Observations

Baobab Liu, Haoyu

ESO-Garching

ABSTRACT: We have developed an iterative procedure to systematically combine millimeter and submillimeter images of OB cluster-forming molecular clouds which were taken by ground based (CSO, JCMT, APEX, IRAM-30m) and space telescopes (Herschel, Planck), to yield images which have high angular resolution but with little or no loss of extended structures. Based on the combined images, we have derived $\sim 10''$ resolution dust column density and temperature maps for seven extremely luminous ($L > 10^6 L_{\text{sun}}$) Galactic OB cluster-forming molecular clouds, namely W49A, W43-Main, W43-South, W33, G10.6-0.4, G10.2-0.3, G10.3-0.1, and three infrared dark clouds G11.11-0.12, G14.225-0.506, G28.34+0.06. These images reveal dramatically different cloud morphologies. For example, molecular clouds W49A and G10.6-0.4 show the highly centrally concentrated geometry, where the central parsec scale dense molecular clumps occupy 10%-20% of the overall cloud mass. The W43 molecular clouds, which are known to be relatively turbulent, show larger numbers of widely distributed localized gas cores/clumps. G10.3-0.1 and G10.2-0.3 are interacting with HII regions, and show large-scale clumpy ring-like morphology, or clumpy shells that are closely following the outer rim of the HII regions. Their different cloud morphology may indicate the very different modes of OB cluster-formation. We hypothesize that the massive molecular gas clumps located at the centre of G10.6-0.4 and W49A may be direct consequence of the global collapse of their parent molecular clouds. Such kind of massive clumps may be rare, which may eventually form gravitationally bound massive stellar clusters. They can be analogous to the young massive clusters or globular clouds found in the extragalactic surveys. In addition, we found that cloud

morphology can be used to systematically characterize the evolutionary stages of molecular clouds. Finally, we found that with the high angular resolution we achieved, our visual classification of cloud morphology can be linked to some systematically derived statistical quantities. These results may represent a very fundamental step forward in the studies of starbursts and star-formation laws in a systematic but model independent sense.

Star formation rates and efficiencies in the Galactic Centre

Barnes, Ashley

Liverpool John Moores University

ABSTRACT: The inner few hundred parsecs of the Milky Way harbours an environment which is extreme compared to Galactic disc star-forming regions. This region has gas densities, pressures, velocity dispersions, interstellar radiation field and cosmic ray ionisation rate orders of magnitude higher than the disc; akin to the environment found at high-redshift, at the peak of cosmic star formation. Previous studies have shown that the Galactic Centre as a whole (averaged ~ 100 parsec scales) is forming stars at a rate per unit mass of dense gas which is at least an order of magnitude lower than in the disc, potentially violating theoretical predictions. We investigate the progression of star formation within gravitationally bound clouds within this region on $\sim$ parsec scales, and find that 1—4 per cent of the cloud masses are converted into stars per free-fall time. These results appear to be similar to predictions from several "volumetric" star formation models, yet several caveats need to be addressed before a full comparison between these model predictions and observations in the Galactic Centre is possible. Here I will discuss possible explanations for this apparent dearth of star formation on global scales of ~ 100 parsec, and local scales of $\sim$ parsec within the Galactic Centre.

The Demographic Revolution from CHaMP and ThrUMMS: Physics of Molecular Clump Evolution

Barnes, Peter

University of Florida

ABSTRACT: We report new results on the physics and evolution of massive molecular clumps, the birthplaces of star clusters in the Milky Way. From an analysis of the J=1-0 emission from CO isotopologues, we show that ~75% of the mass of all molecular clouds, from small star-forming clumps to large GMCs, is contained within the parsec-scale clumps, and only ~25% of the mass is distributed in a diffuse molecular component, suggesting that parsec-scale clumps may be the true building blocks of the molecular ISM.

We show that in half of these clumps, their dense interiors are pressure-confined by a massive envelope, confirming theoretical expectations; the remainder may be dynamically evolving, or confined by an overlying HI layer. We also see evidence of slow, large-scale mass accretion in these clumps, with mass-doubling timescales of several tens of Myr, consistent with recent theoretical simulations. This also supports earlier CHaMP results suggesting that ~95% of clumps are quiescent, slowly evolving to a vigorous star-formation phase, which only then disperses the clump. We present detailed maps of physical parameters in these clumps, derived from both continuum and spectral-line data, and including the spatially-resolved CO-bright mass fraction. The inferred CO-dark mass fraction is seen to vary widely with location, consistent with recent GOTC+ results and numerical models.

We extend the new CO-to-H₂ conversion law from ThrUMMS (Barnes et al 2015), which has strong dependencies on both I_{CO} and Tex , and gives a much tighter correlation with other measures of mass than does the standard X-factor. The new law is easily applicable to a wide range of observational data.

Gas Flows and Star Formation in the Galactic Center

Battersby, Cara

Harvard-Smithsonian Center for Astrophysics

ABSTRACT: Star formation occurs in remarkably diverse environments throughout the universe, yet our understanding of this fundamental process is dominated by observations of nearby clouds, which show very little environmental variation. Observations of the early universe reveal prolific star formation in regions with gas densities and pressures orders of magnitude higher than in our solar neighborhood. The inner few hundred parsecs of the Milky Way, known as the Central Molecular Zone (CMZ), is the closest laboratory for testing star formation in the extreme environments (hot, dense, turbulent gas) that once dominated the universe. I will present a large-scale perspective on gas flows and star formation in the Galactic Center through a comparison of Herschel observations with recent simulations. Additionally, I will introduce preliminary results from CMZoom, a Submillimeter Array legacy survey to expose and characterize sites of star formation across the CMZ. These measurements allow us to address fundamental questions regarding the nature of star formation in extreme environments.

Star formation in compact groups

Bitsakis, Theodoros

IRyA, UNAM

ABSTRACT: Star formation is one of the most important properties to understand the formation and evolution of galaxies. Compact groups have been suggested as one of the most interesting environments to study this evolution since they occupy a unique position in the range of galaxy environments. In this talk, I will briefly describe the recent developments in the study of star formation in compact groups of galaxies. Modern technologies allowed us not only to study the dust obscured star formation activity, but also to identify the possible mechanisms driving its evolution.

Measuring star formation in resolved and unresolved galaxies

Boquien, Mederic

Universidad de Antofagasta

ABSTRACT: To understand when and how stars form across the universe, it is essential we are able to measure the star formation rate (SFR) of galaxies precisely and accurately. If we can count stellar cores and/or young stars in the most nearby star forming regions, the lack of sufficient spatial resolution does not allow this beyond a few Mpc, even with Hubble. To overcome this limitation, a range of SFR estimators has been developed for galaxies, relying directly or indirectly on the energetic radiation of short lived massive stars. In practice this means we can estimate the SFR of galaxies from their H α , ultraviolet, or infrared luminosity. This however depends on a number of assumptions: an initial mass function, a star formation history, proper correction for partial attenuation by dust and for the contamination of star formation tracing bands by older stars, etc. Unfortunately, there is increasing evidence that at least some of the most commonly used assumptions are not always valid, inducing systematic biases. In this contribution, I will show what numerical simulations of main sequence galaxies and observations of nearby galaxies can tell us about SFR estimators and their assumptions, from the effect of the spatial scale considered to the impact of the star formation history. I will conclude by presenting adaptive hybrid UV+IR SFR estimators that naturally correct for contamination of by old stars at both resolved and unresolved scales.

Revealing the demographics of protostars in massive protoclusters with ALMA

Brogan, Crystal

NRAO

ABSTRACT: A key open question in the formation and evolution of massive protoclusters is the sequence of formation of stars of different mass that ultimately leads to the stellar mass function. Do high or low mass stars form first, or coevally? The exquisite sensitivity and resolution afforded by ALMA allows us for the first time the ability to detect and resolve low mass cores and protostars in the deeply embedded hearts of very young massive protoclusters at distances > 1 kpc. I will present recent ALMA results that reveal the demographics of forming protostars within massive protoclusters, and highlight some of the remaining challenges.

SFR's derived from SED fitting

Bruzual, Gustavo

IRyA, UNAM

ABSTRACT: It has become common practice to derive global star formation rates of galaxies from spectral fits to their integrated spectral energy distributions (SEDs). I will present a critical view of this technique, describing the sources and quantifying the errors affecting these derivations of the SFR of galaxies.

Self-Regulated Multi-Scale Star Formation on the galaxy Main Sequence

Burkert, Andreas

Ludwig-Maximilians Universität München, Germany

ABSTRACT: I will summarize recent observations and theoretical work that demonstrate that star formation is a self-regulated multi-scale problem. The star formation rate is dominated by the accretion of gas from the intergalactic cosmic web and its subsequent flow through the diffuse and dense interstellar medium into sub-parsec scales clumps and filaments where it condenses into stars. The rate of star formation is regulated by a universal gas depletion timescale, the origin of which is still a mystery.

The Origins and Implications of Turbulence in Galaxies

Burkhart, Blakesley

Harvard CfA

ABSTRACT: In this talk I will discuss the origins of turbulence in galaxies via feedback and gravitational instability and how turbulence is connected to galaxy evolution in the context of the star formation rate, gas accretion onto galaxies, and galaxy gas fractions. I will also highlight how turbulence can be measured using new statistical diagnostic tools and how this opens up new avenues for understanding the physical processes of Milky-Way star formation.

Deciphering the origin of a network of parallel filaments in the infrared dark cloud G14.225-0.506

Busquet, Gemma

Institut de Ciències de l'Espai (IEEC-CSIC)

ABSTRACT: Filaments are ubiquitous structures in star-forming complexes, which often intersect in high-density regions associated with star formation, known as hub-filament systems. Despite filaments having been recognized more than 30 years ago, the ubiquity of such structures in star-forming regions, which has been recently highlighted by Herschel programs, has brought special attention to their formation mechanism and their role in the star formation process.

What is/are the physical agent(s) responsible of shaping the interstellar material into filamentary structures? How do they evolve? How filamentary structures fragment into dense cores to finally form a cluster?

With the aim of investigating the origin and evolution of filamentary structures and their subsequent fragmentation we started an observational project with different telescopes towards the Infrared Dark Cloud G14.225-0.506, performing a multi-wavelength and multi-scales study (from 30pc down to 0.01pc) of the cloud, including a polarimetric survey at optical and near-infrared wavelengths.

I will present spectroscopic results of several gas tracers at cloud scales, which unveil a network of filaments, constituting two hub-filament systems. The two hubs contain the main sites of star formation activity in the cloud, and present a different level of fragmentation. I'll discuss the possible origin of such structures, its fragmentation process, and the role of the magnetic field in regulating the collapse from large to small scales, leading to the formation of parallel elongated structures.

ENERGY BUDGET OF FORMING CLUMPS IN NUMERICAL SIMULATIONS OF COLLAPSING CLOUDS

Camacho, Vianey

IRyA, UNAM

ABSTRACT: We analyze the energy balance of clumps and cores in two SPH simulations of collapsing clouds. Feedback is not included, so all motions are due either to the initial decaying turbulence or to gravitational contraction. We find that: (i) the resulting full set of clumps follows the generalized energy equipartition relation, we interpret this as a natural consequence of gravitational contraction at all scales rather than virial equilibrium, (ii) the set of clumps with low column-density shows a large scatter around equipartition which, in more than half of the cases, is dominated by external turbulent compressions that assemble them, (iii) clumps lying in filaments tend to appear sub-virial, (iv) high-density cores that exhibit moderate kinetic energy excesses often contain stellar particles, and (v) cores with kinetic energy excess but no stellar particles are in a state of dispersal. In addition, we analyze observational surveys of dense cores embedded in filaments, in order to determine if their energy balance is modified by the flow along the filaments onto the cores.

Star formation, gas and dust in the IR dust bubbles complex S\,21-S\,24

Cappa, Cristina Elisabet

FCAG, UNLP, and IAR, CONICET, Argentina

ABSTRACT: We present a multi-wavelength study of an infrared dust bubble complex, 12 arcmin in size, which includes S\,21, S\,22, S\,23, and S\,24, infrared dark clouds and EGOs, is located at 3.7 kpc.

The study reveals the presence of many young stellar objects (YSOs) and their correlation with molecular gas and dust. The YSOs identified in IR point source catalogs indicate that the complex is a very active star forming region with sources in different evolutionary states.

The analysis of the molecular gas distribution is based on $\text{H}_2^{(2-1)}$, $\text{H}_3^{(2-1)}$, $\text{C}^{18}(2-1)$ (HPBW = 29 arcsec), and $\text{H}_3^{(3-2)}$ (HPBW = 21 arcsec) line data obtained with the APEX telescope, and dense gas tracers for selected fields in the complex from the MALT90 survey. The distribution of the interstellar gas at different temperatures is studied using submillimeter continuum data in the range 3.4 to 870 μm from Spitzer-GLIMPSE, WISE, Herschel-PACS and SPIRE, and ATLASGAL images.

Shell-like molecular structures bordering the IR bubbles were identified, along with cold dust clumps, which harbor YSOs. The presence of warm dust and radio continuum sources helps in the identification of the excitation sources.

The existence of outflow signatures linked to the YSOs is also investigated.

We compare the main parameters of the different sections of the complex in order to characterize the star formation process and to compare this complex with other complexes present in our Galaxy.

The CO-H₂ Conversion Factor and the Structure of Molecular Gas in $z < 1.5$ Galaxies

Carleton, Timothy

University of California, Irvine

ABSTRACT: From $z \sim 2$ until today, the cosmic star formation rate has declined by an order of magnitude, primarily driven by a smooth reduction of the star-forming activity of all galaxies rather than dramatic evolution in the prevalence of mergers or starbursts. Whether this decline stems from a reduction in the supply of molecular gas to galaxies or a decrease in the efficiency of converting molecular gas into stars remains an open question. Recent observations of carbon monoxide (CO) emission in high- z galaxies as part of the PHIBSS survey imply only modest evolution in the star-formation efficiency of main-sequence galaxies, with decreasing molecular gas fractions driving the decline in the cosmic star formation rate. However, these results rely on an uncertain conversion between a CO line luminosity and the total molecular gas mass. Motivated by the dependence of the CO-H₂ conversion factor (α_{CO}) on galaxy properties observed locally, we present an analysis of the relationship between α_{CO} and total mass surface density in star-forming systems at $z < 1.5$. We find that α_{CO} is independent of total mass surface density, with little deviation from the canonical Milky Way value. This runs contrary to a scenario in which α_{CO} decreases as surface density increases within extended clouds of molecular gas that potentially fuel clumps of star formation in $z \sim 1$ galaxies, similar to those observed in local ULIRGs. Instead, our results suggest that molecular gas, both at $z \sim 0$ and $z \sim 1$, is primarily in the form of self gravitating molecular clouds, and the process of star formation at $z \sim 1$ is remarkably similar to that observed in local star-forming systems.

Planet Formation at the Earliest Stages of Star Formation

Carrasco-Gonzalez, Carlos

Instituto de Radioastronomía y Astrofísica

ABSTRACT: The first long-baseline ALMA campaign resolved the disk around the young star HL Tau into a number of axisymmetric bright and dark rings. Despite the very young age of HL Tau, these structures have been interpreted as signatures for the presence of (proto)planets. The ALMA images triggered numerous theoretical studies based on disk-planet interactions, magnetically driven disk structures, and grain evolution. Of special interest are the inner parts of disks, where terrestrial planets are expected to form. However, the emission from these regions in HL Tau turned out to be optically thick at all ALMA wavelengths, preventing the derivation of surface density profiles and grain-size distributions. Here, we present the most sensitive images of HL Tau obtained to date with the Karl G. Jansky Very Large Array at 7.0 mm wavelength with a spatial resolution comparable to the ALMA images. At this long wavelength, the dust emission from HL Tau is optically thin, allowing a comprehensive study of the inner disk. Our optically thin data also suggest high density, fast grain growth, fragmentation, and formation of dense clumps in the inner densest parts of the disk. Our results suggest that the HL Tau disk may be actually in a very early stage of planetary formation, with planets not already formed in the gaps but in the process of future formation in the bright rings.

Massive stars and the dynamics of the ionized medium in giant gaseous nebulae

Castañeda, Héctor

Escuela Superior de Física y Matemáticas - Instituto Politécnico Nacional

ABSTRACT: We analyze the effect of the mechanical energy input from massive stars on the dynamics of the ionized gas in Giant HII Regions, the observed velocity field and the phenomenon of turbulence.

Did all stars born the same Thursday (and in the same place)?

Cerviño, Miguel

IAC, IAA-CSIC

ABSTRACT: The Single Stellar Population (SSP) concept is inherent to the modeling of galaxy evolution and star formation history inferences (ranking from stellar counting to the integrated light of stellar systems). The concept is intrinsically related with the mathematical separation of the stellar birth rate two **independent** functions (star formation history, SFR; and initial mass function, IMF), and its use as an input ingredient in stellar population studies.

Although useful in most cases, SFR and IMF are a shortcut to model galaxies without take into account the physical details of the star formation process into account: at the physics of star formation level, the stellar birth rate is not a separable function but an output of the the overall process. As consequence it leads to confusing situations (and discrepancies) when such shortcut is applied to system where the physics of star formation is at work (either in size or time scales).

In this talk I address the conceptual difficulties I had found when try to apply the IMF and SFR “concepts” to extremes cases with especial emphasis in the inclusion of a cluster mass functions in the stellar birth rate framework.

Filamentary Accretion Flow in the IRDC M17 SWex

Chen, Vivien

National Tsing Hua University

ABSTRACT: Although filamentary structures are ubiquitous in molecular clouds, basic observational constraints are needed to clarify the role of filaments in the mass assembling process. We have observed with ALMA the N₂H⁺ emission in the filamentary accretion flows in the remarkable IRDC complexes, M17 SWex, where a delayed onset of massive star formation was reported in the two hubs at the convergence of multiple filaments of parsec length. We derived the kinematics with the N₂H⁺ emission and found the line widths are smaller than those of ammonia, suggesting a transonic nature of dense gas in the filaments. Slow infall motions are detected along the filaments. Multiple velocity coherent substructures are present in both hubs, likely not yet reaching virial equilibrium.

The evolutionary cycling between molecular clouds, star formation, and feedback in nearby galaxies

Chevance, Mélanie

ARI/ZAH/Universität Heidelberg

ABSTRACT: The cloud-scale physics of star formation and feedback represent the main uncertainty in our understanding of galaxy formation. Previous attempts to constrain these processes observationally have necessarily been limited to the Local Group. We have developed a new statistical method (Kruijssen & Longmore 2014) to empirically measure quantities such as the molecular cloud lifetime, feedback timescale, feedback efficiency and star formation efficiency from observations of nearby galaxies. I will present the results from systematically applying this method to homogeneous ALMA observations of a large sample of star-forming disc galaxies out to 15 Mpc. This allows me to constrain the physical properties of star and cluster formation on cloud scales. I will show that comparing these cloud-scale quantities across a large sample of nearby star-forming galaxies, covering a variety of environments, give important clues to understand the interplay of the small-scale physics with galactic structure. These results fully exploit the resolving power of modern instruments such as ALMA and MUSE and represent a key step towards future studies of cloud-scale star formation and feedback in galaxies across cosmic time.

Building a (fully resolved) molecular cloud catalog of the Milky Way

Colombo, Dario

Max Planck Institute for Radio Astronomy

ABSTRACT: Modern high resolution, molecular gas surveys of the Galactic Plane are unveiling an astonishing picture of the three-dimensional gas organization of the Milky Way. This provides the opportunity to investigate the building blocks of the molecular medium, the Giant Molecular Clouds (GMCs), in an unprecedented level of detail. So far, however, such kind of study has been restricted to a handful of isolated targets, since common automatic segmentation methods, being severely affected by survey designs, are unable to decompose GMC-sized objects out from the diffuse medium in crowded Galactic regions. The algorithm we designed, SCIMES (Spectral Clustering for Interstellar Molecular Emission Segmentation), overcomes these limitations by considering the cloud segmentation problem in the broad framework of the graph theory. To prove this, we will present the SCIMES cloud catalog from the CO(3-2) High-Resolution Survey (COHRS) data. The clustering approach allows to automatically identify a variety of gas morphologies including coherent filaments and holes within the molecular interstellar medium. We will show how star formation efficiency, turbulence, and kinematics vary within those gas structures and with respect to the Galactic environments. Together, we will related the integrated properties of COHRS objects to the ones observed for molecular clouds in other regions of the Milky Way and nearby galaxies. This pioneer study will provide the guidelines for a future, systematic cataloging of all discrete molecular gas features of our own Galaxy.

Infall and Outflow Motions Towards a Sample of Massive Star Forming Regions

Cunningham, Nichol

Green Bank Observatory

ABSTRACT: Infall and outflow motions are an imperative part of the star formation process. In particular, we lack a clear understanding of how these processes change with evolutionary stage and how infall and outflow motions influence each other in massive young stellar objects (MYSOs). I will present results of an outflow and infall survey undertaken with the JCMT towards a sample of 33 MYSOs and ultra-compact HII (UCHII) regions drawn from the RMS survey. We identify the presence of a young, active outflow from SiO (8-7) emission and use previous CO (3-2) data (Maud et al. 2016) to determine outflow properties. The infall motions and bulk properties of each region are determined from the HCO⁺/H₁₃CO⁺ (4-3) emission. We compare both infall and outflow dynamics and properties with source evolution, mass, and luminosity. Active outflows are detected towards approximately 50% of our sample compared with only 10% of the sources displaying infall signatures. We detect outflow and infall motions across all evolutionary stages observed, suggesting a continuation of accretion with evolution. However, we find that when SiO is detected the region is younger compared with sources without an SiO detection. Thus, we find the higher energy SiO transitions appear to be associated with outflows driven by younger stars in the high mass regime in a similar manner to the low mass regime. In addition, I will finish by showing a comparison of our recent JCMT results, which trace larger spatial scales, with previous high spatial resolution SMA observations for a sub-sample of these regions (e.g. Cunningham et al. 2016).

SOFIA/FORCAST Imaging Studies of Massive Star Formation on Small and Large Scales

De Buizer, James

SOFIA/USRA

ABSTRACT: We know less about how high-mass stars form than low-mass stars like our Sun. This is due in large part to the fact that the highest-mass stars form in regions of extremely high extinction, hidden from study at a large range of wavelengths. Individual high-mass stars form at the centers of the densest and dustiest molecular cores which are in turn embedded within larger obscuring molecular clouds. Thermal infrared wavelengths, however, allow one to both observe the star formation occurring within these small-scale molecular cores as well as the larger-scale environment of the surrounding molecular cloud. The Stratospheric Observatory For Infrared Astronomy (SOFIA) and its mid-infrared camera, FORCAST, have been used over the last few years for two long-term projects; one aimed at understanding the arcsecond-scale circumstellar environment of individual (or small multiple) high-mass star systems in the earliest stages of forming within these cores, and the other aimed at understanding the arcminute-scale environments of the giant molecular clouds that clusters of such high-mass stellar systems form in. I will present recently published results from the study of high-mass star formation on small scales, and preliminary results from the study of high-mass star formation on large scales.

Early evolution of stellar populations in a giant star-forming complex: the Dragonfish nebula

de la Fuente, Diego

Instituto de Astronomía UNAM

ABSTRACT: The Dragonfish nebula is one of the largest star-forming complexes in the Milky Way. Despite a previous claim that the nebula was mainly ionized by a single super-OB association, various massive stellar populations were recently found to be responsible for providing the required Lyman-continuum photons. These massive populations include clusters of different ages, some of them deeply embedded, as well as field massive stars. The effects of stellar feedback are clearly visible as bubbles, cavities and pillars in the interstellar clouds that are part of the Dragonfish nebula.

Taking advantage of the great diversity of young stellar populations and clouds that are present in the Dragonfish complex, we are currently studying the simultaneous evolution of these subsystems and the interplay between them. In particular, a small region hosting a newborn cluster, Mercer 31, and a more evolved one, Mercer 30, seems to be an archetypal case of triggered star formation, which will allow us to test such scenario. On the other hand, we discuss the origin of the field massive stars. They may have been ejected from one of the known clusters, or from a former cluster that eventually disrupted; these objects could also have been born in isolation. Preliminary results will be presented and discussed.

Kinematics of extremely metal-poor galaxies: evidence for strong stellar feedback

Del Olmo García, Amanda

Instituto de Astrofísica de Canarias (IAC)

ABSTRACT: Extremely metal-poor (XMP) galaxies present large star-forming regions where the gas metallicity is smaller than the metallicity elsewhere in the galaxy. XMPs seem to have accreted nearly pristine gas clouds from the cosmic web that feed the star-formation process (Sanchez Almeida et al. 2013, 2015).

In this work (Olmo-Garcia et al. 2016), we analyze the kinematics of a sample of XMPs and their star-forming regions. The star-bursts show signs of being kinematically distinct entities within the galaxy. We also found some faint emission features with high velocity in the wings of H α . These faint components suggest that large amounts of gas are going away from the star-forming regions, with outflow rates much larger than the star-formation rates. The energy involved in these motions is in the range of core-collapse supernovae. These kinematical properties are consistent with the cosmic web accretion scenario, providing observational support for the cold-flow accretion predicted by the cosmological models of galaxy formation (e.g., Dekel et al. 2009).

The GLOSTAR VLA Galactic plane survey

Dzib, Sergio A.

Max Planck Insitut fuer Radioastronomie

ABSTRACT: The main objective of the GLOSTAR project is to provide a GLObal view on STAR formation in the Milky Way galaxy. Combining radio, submm and IR observations, it gathers data that yields information on the distances, composition, luminosities and masses of high-mass proto- and young stellar objects. The goal is a comprehensive picture of massive star formation and Galactic structure. Here, I will present our 4-8 GHz radio continuum and spectral line survey of the Galactic plane with the Jansky Very Large Array and its initial results. To measure the continuum emission and a total of 7 radio recombination lines, we employ two 1-GHz wide chunks of the WIDAR correlator. These we combine with high spectral resolution windows covering emission in the 6.7 GHz class II methanol maser line as well as 4.8 GHz formaldehyde emission and absorption. In the continuum we detect compact and hyper- and ultracompact HII regions (H/CHIIIRs) with unprecedented sensitivity. The methanol maser line traces high-mass young and protostars associated with H/UCHIIR and objects in earlier evolutionary stages. Once completed, the survey will cover the whole Galactic plane from the Galactic Center out to a longitude of 60 degrees and in addition, the Cygnus X region. The B- and D configuration data from our VLA survey will be combined with data acquired with the Effelsberg 100m telescope. This will ensure that the overall survey will not miss large spatial scales and indeed provide a global view of star formation in the Galaxy.

ESTIMATION OF THE STAR FORMATION RATE (SFR) THROUGH DATA ANALYSIS OF SWIFT'S LONG- GRBs FROM 2008 TO 2016

Elias Chavez, Mauricio

Benemérita Universidad Autónoma de Puebla

ABSTRACT: This work presents a research about the Star Formation Rate (SFR), using data analyzing of a sample from 2008 to 2016 of Gamma Ray Bursts (GRBs) submitted by Swift Gamma-Ray Burst Mission, This work is based on the empirical model proposed by Yüksel, Kistler & Beacom. (2008), basically the SFR is measured using long-GRBs considering a core-collapsed model of high rotating massive stars with low metallicity. Studying which accounts the production rate of long-GRBs with additional evolutive effects, parameterizing of the form, where is a unknown constant which include the total conversion of the SFR rate to GRB rate in a luminosity range given, finally we discuss the possible effect in the chemical evolution of galaxies at high redshift.

Coevolution between multiscale star-formation and AGN activity

Esparza Arredondo, Donaji Catalina A.

IRyA, UNAM

ABSTRACT: There are several observational evidences on the connection between active galactic nuclei (AGN) and their host galaxies. However, how these two phenomena are connected is poorly understood. The feeding of the super-massive black hole (SMBH) requires that the material travels from the host galaxy to the inner few parsec. Thus, a link between star-formation (SF) and AGN activity is expected. However, it is very difficult to study the SF at the central few parsecs because most of the SF tracers are contaminated by the AGN emission. Mid-infrared (MIR) observations offer a new opportunity to study tracers of SF and photoionization by the AGN. In particular we study how useful are: 1) the 11.3 micras polycyclic aromatic hydrocarbons (PAH) feature as a tracer of SF, and 2) the [SIV] emission line as tracer of AGN emission. We used these tools to study the coevolution at different spatial scales. We study the circumnuclear MIR emission in a sample of 19 local AGN with high spatial resolution spectra using T-ReCS (Gemini) and CanariCam (GTC), together with IRS/Spitzer observations. We found evidence supporting that the PAH emission is destroyed by the AGN radiation field in most of our objects. For larger distances, we found a good agreement for the relation between AGN bolometric luminosity and SF comparing numerical models and our results. However, an excess of SF compared with numerical simulations is observed at distances of 50 pc from the center. This might be due to extra enhancement of the SF at these distances not taken into account by the simulations.

What Determines Star Formation Rates?

Evans, Neal

University of Texas at Austin

ABSTRACT: The relations between star formation and gas have received renewed attention. We combine studies on scales ranging from local (within 0.5 kpc) to distant galaxies to assess what factors contribute to star formation. These include studies of star forming regions in the Milky Way, the LMC, nearby galaxies with spatially resolved star formation, and integrated galaxy studies. We test whether total molecular gas or dense gas provides the best predictor of star formation rate. The star formation "efficiency", defined as star formation rate divided by mass, spreads over a large range when the mass refers to molecular gas; the standard deviation of the log of the efficiency decreases by a factor of three when the mass of relatively dense molecular gas is used rather than the mass of all the molecular gas. We suggest ways to further develop the concept of "dense gas" to incorporate other factors, such as turbulence.

Using WEAVE spectrograph at WHT to study star formation on different scales

Farina, Cecilia

Isaac Newton Group of Telescopes, La Palma

ABSTRACT: WEAVE is the new wide-field (2-deg) spectroscopic facility for the 4.2-m William Herschel Telescope (WHT) on La Palma (Canary Islands). The fibre-fed spectrograph can analyse light from fibres deployed in one of three different modes in the focal plane: 1000 fibres placed on individual targets (i.e. MOS), individually-deployable integral field units (IFUs) or a large single IFU. The fibres feed a dual-beam spectrograph which either covers nearly all of the visible spectrum in a single exposure at a spectral resolution of $R \sim 5000$ or covers reduced wavelength ranges in both arms at a resolution of $R \sim 20000$. The instrument is currently being built and is expected to see its first light by mid-2018. WEAVE was designed to meet the instrumental and observational requirements of a diverse set of science surveys, which include Milky Way archeology, galaxy evolution and cosmology, as well as stellar and interstellar physics. In this talk I will give an overview of WEAVE characteristics, highlighting the possibilities it offers for studies of star formation at different scales.

Probing a molecular cloud from 0.01 to 10 pc scales: The CARMA Orion Survey

Feddersen, Jesse
Yale University

ABSTRACT: I present the first results of the CARMA Orion survey of the Orion A molecular cloud. We combine CARMA interferometry with zero-spacing data from the Nobeyama Radio Observatory 45m telescope. We map ^{12}CO , ^{13}CO , C^{18}O J(1-0) and other lines over 3 square degrees at scales from 0.01 to 10 pc with a velocity resolution of 0.1 km/s. This survey provides several times the angular resolution of other CO maps of comparable size. With this unique survey, the CARMA Orion collaboration will investigate multi-scale star formation, including the core mass function, filaments, turbulence, and feedback in both low and high mass star-forming environments in Orion A. As part of our study of feedback in Orion, I present a study of expanding shells found in the CARMA Orion data. These shells are likely produced by spherical stellar winds from young stars. I show the impact of these shells on the kinematics of the cloud and propose candidate driving sources.

Kinematical and Dynamical Study of IRAS 13481-6124 primary jet

Fedriani, Ruben

Dublin Institute for Advanced Studies

ABSTRACT: Protostellar jets from Massive Young Stellar Objects (MYSOs) provide us with a unique tool to understand the accretion and ejection mechanisms of high-mass star formation. So far, only a few massive jets have been observed at low spectral resolution in the near-IR, revealing the main physical properties of the primary flow. However, no information about the dynamical and kinematical properties could be retrieved. To overcome this lack of information, our group has recently surveyed a sample of ~ 20 massive jets at NIR high-spectral resolution with ESO VLT/ISAAC.

In this talk, I will present our results on the parsec scale jet driven by IRAS 13481-6124, a $20M_{\odot}$ MYSO. Our data retain fundamental information on the atomic (HI, [FeII]) and molecular (H₂) primary jet component extending from on source up to parsec scale.

On the one hand, a terminal velocity of the wind of 700 km s^{-1} was inferred studying the Brackett gamma line on source. On the other hand, velocities from ~ -300 to -100 km s^{-1} for the [FeII] component of the jet (ranging from $\sim 15000 \text{ au}$ to $\sim 1 \text{ pc}$ from the source) and velocities from -200 to few km s^{-1} for H₂ component ($\sim 15000 \text{ au}$ to $\sim 2.5 \text{ pc}$ from the source) were found. The inferred mass loss rate ranges from 0.8 to $3 \times 10^{-4} M_{\odot} \text{ yr}^{-1}$ along the whole jet, whereas the thrust increases from $8 \times 10^{-3} M_{\odot} \text{ yr}^{-1} \text{ km s}^{-1}$, at the tip of the jet, to $4 \times 10^{-2} M_{\odot} \text{ yr}^{-1} \text{ km s}^{-1}$ close to the driving source.

Finally, by comparing radio and NIR properties of the jet close to the source, we infer that the radio emission traces just a fraction ($\sim 10\%$) of the whole jet.

Southern hemisphere jets and molecular outflows observed with Gemini and APEX: the case of HH 137 and HH 138

Ferrero, Leticia Virginia

Observatorio Astronómico de Córdoba (OAC), Argentina

ABSTRACT: As part of a multi-frequency study of southern hemisphere jets and molecular outflows being carried out with Gemini and APEX, in this contribution, we present a detailed analysis of HH 137 and HH 138. Several 2.12 micron knots linked to HH137 are identified in the Gemini image, as well as in Spitzer images. $^{12}\text{CO}(3-2)$, $^{13}\text{CO}(3-2)$, and $\text{C}^{18}\text{O}(3-2)$ line data reveal the molecular counterpart of HH 137. Spitzer combined images suggest the location of the exciting source of HH 137, almost coincident with a high-density molecular clump detected in C^{18}O . We derive the main physical parameters of the molecular clump and the molecular outflow, and propose a simple scenario for the whole complex.

Detailed study of the kinematic and physical properties of the GHIRs in interacting/merging galaxies

Firpo, Verónica

Universidad de La Serena

ABSTRACT: The knowledge of the physical and chemical processes of the Giant Star Forming Regions is giving great progress especially the new information provided by the large telescopes. Using high-resolution spectroscopic from MIKE/Magellan and the high-spatial spectroscopic from IFU/Gemini, this work is focus around of the violent star-forming processes in interacting/merging galaxies. In order to characterise the physical processes that govern the massive star formation, we carrying out a detailed study of the kinematic and physical properties of the ionised gaseous component. These regions reveal a complex internal kinematic, which can be identified by asymmetric line profiles and multiple components. The future estimation of physical properties such as the electron densities, temperatures and chemical abundances of the different kinematical components will allow us carry out a chemodynamic analysis of these star-forming regions.

Magnetic Fields in Star Formation: A Detailed BLASTPol Study of the Vela C Giant Molecular Cloud

Fissel, Laura

National Radio Astronomy Observatory

ABSTRACT: We present BLASTPol polarization observations of Vela C, which have been used to create the most detailed magnetic field map ever made of a giant molecular cloud forming high mass stars. We show that empirical models of changes in polarization fraction and local dispersion in field direction across Vela C show considerable promise for probing both the 3-D orientation of the magnetic field and characterizing the degree of disorder in the field. These same empirical models have been applied to synthetic polarization maps derived from numerical simulations of star formation, and the resulting comparisons imply that a decrease in polarization efficiency for deeply embedded dust is required to fully explain our observed drop in polarization fraction with column density. Finally, we show comparisons between BLASTPol polarization data and molecular line emission maps from a large-scale Mopra survey of Vela C. We find that gas structures apparent in integrated line strength maps of molecules tracing lower density gas (such as ^{12}CO) are preferentially oriented parallel to the magnetic field, while cloud structures apparent in line emission maps of intermediate and high-density molecular gas tracers show on average perpendicular or no preferred orientation with respect to the magnetic field. These observations are consistent with a dynamically important cloud magnetic field.

First Science from the Green Bank Ammonia Survey

Friesen, Rachel

University of Toronto

ABSTRACT: The past several years have seen a tremendous advancement in our ability to characterize the structure of nearby molecular clouds traced by large-scale continuum surveys. Critical, comparable data on the dense gas kinematics and temperatures are needed to understand the history and future fate of star-forming material. Filling this gap is the Green Bank Ammonia Survey (GAS), an ambitious legacy survey for the GBT to observe key molecular tracers of dense gas within all Gould Belt clouds visible from the northern hemisphere. I will present some of the first science results from GAS, whose goals are to 1) evaluate the stability of dense gas structures as a function of scale, 2) track the dissipation of turbulence and evolution of angular momentum in filaments and cores, and 3) quantitatively test predictions of models of core and filament formation via mass flows and accretion.

Tracing protostellar accretion with chemistry

Frimann, Søren

Institute of Cosmos Sciences, University of Barcelona, Spain

ABSTRACT: Understanding how young stellar objects gain their mass is a fundamental question of star formation with important implications for the physical and chemical evolution of young systems. Specifically, the question at hand is whether accretion rates onto protostars characterised by short episodic bursts or by a smooth decline from early to late stages.

Episodic outbursts are well established in the pre-main-sequence stage where they manifest themselves as FU Orionis objects, which are young stars whose luminosities are observed to increase by an order of magnitude or more over a short period of time. For the youngest protostars, still embedded within their natal core, such bursts are very challenging to observe directly and indirect methods have to be used to trace their accretion histories.

One indirect approach is to use chemistry to trace the accretion histories. During an accretion burst CO ice will sublime from dust grains over an extended region due to the increased heating from the protostar. Once the burst has ended the CO will stay in the gas phase for a long time leaving an observable imprint of the burst.

In the talk, I will present both numerical and observational results of using CO freezeout and sublimation chemistry to study episodic accretion. In the numerical study (Frimann et al. 2016) we created synthetic C18O maps of a large MHD simulation and found that it is possible to measure an observable imprint following an accretion burst. In the observational study (Frimann et al. submitted) we analysed C18O observations from the Submillimeter Array towards 21 embedded protostars in Perseus. Our analysis indicate that roughly half of these sources show evidence of enhanced accretion in the past.

Dense Gas, Interstellar Pressure, and Star Formation in Four Nearby Star-Forming Galaxies

Gallagher, Molly

Ohio State University

ABSTRACT: Observations of star-forming regions in the Milky Way tell us that gas density plays a central role in star formation. However, both the exact role of gas density in star formation and the physical drivers of the gas density distribution are hotly debated and poorly constrained by observations. I will present new ALMA observations mapping high critical density mm-wave transitions (dense gas tracers, HCN, HCO⁺, and CS) across the entire inner ~6kpc of four nearby star-forming galaxies: NGC3351, NGC3627, NGC4254, and NGC4321. These observations, obtained as complementary data to the EMPIRE IRAM-30m large program, are among the first whole-galaxy maps of dense gas tracers targeting normal star-forming disk galaxies. We find strong correlations in all systems between HCN/CO, tracing the dense gas fraction, and environment (e.g. stellar surface density, gas surface density, radius). Surprisingly, we also find very strong trends in the IR/HCN ratio with environment. Our results indicate that as the mean gas density increases and approaches the effective critical density of HCN, HCN emission no longer only traces the gas involved in star formation. In other words, star formation does not occur in gas above some threshold density but rather occurs in denser gas for clouds with higher mean density.

From Clouds to Stars: Multi-Scale Studies of Star (Cluster) Formation

Galvan-Madrid, Roberto

IRyA, UNAM

ABSTRACT: A summary will be given of our efforts to map in great detail the gas and dust participating in star formation from full GMCs (~ 100 pc) down to sub-core (< 0.01 pc) scales. For this, a combination of interferometric, ground-based single dish and space-based observations is needed. Emphasis will be given to our results in Galactic regions that appear to be forming massive star clusters. Possible links between the resolved properties of these local cases of “extreme” star formation and those of extragalactic star formation will be discussed.

Kinematics of Class 0 protostellar envelopes from the CALYPSO survey

Gaude1, Mathilde

CEA Saclay

ABSTRACT: One of the main challenges to the formation of solar-like stars is the “angular momentum problem”: if the angular momentum of the gas contained in a typical star-forming core is totally transferred to the star during the accretion phase, the gravitational force of the star can not counter the centrifugal force. Studying the kinematics of protostellar cores and understanding the distribution of the angular momentum during the main accretion phase is of uttermost importance to test possible solution to this problem. It's why Class 0 protostars are key objects: they grow by accretion of the matter from the surrounded envelope ($M_{\text{env}} \gg M_{\text{star}}$) extending to scales $\sim 10\,000$ AU. By the end of this phase, more than 90% of the final stellar mass has been accreted, therefore making the Class 0 phase a cornerstone stage for the resolution of the angular momentum problem.

In order to tackle this issue, the CALYPSO (Continuum and Lines in Young Protostellar Objects, PI : Ph. André) IRAM large program provides Plateau de Bure Interferometer (PdBI) and the 30m telescope observations of the dust continuum emission and a dozen of molecular lines from a sample of 17 Class 0 protostars.

We used the C18O(2-1) and N2H+(1- 0) molecular lines to trace kinematic of the envelopes combining PdBI and 30m dataset to probe scales down to 50 AU in the envelope (0.5") and provide a high dynamic range allowing to reach the outer envelope scales (10 000 AU).

I will present the method used to link the two molecular lines information, also knowing that N2H+ is chemically destroyed by C18O, and to create radial profiles of the rotation motions along the plane perpendicular to the outflows from 50 to 5000 AU for a sample of protostellar envelopes. This analysis allow us to establish angular momentum radial profiles which can be compared to expected outcomes from protostellar collapse models, therefore hedding light an angular momentum conservation during the main accretion phase in a large sample of prototypical Class 0 objects.

The effects and importance of feedback on high-mass star formation within massive clusters

Ginsburg, Adam
NRAO

ABSTRACT: The formation of massive clusters is governed by feedback on multiple scales, from the parsec-scale destructive feedback of HII regions and supernovae to the much smaller range of possibly productive thermal feedback. I will present ALMA and JVL A observations of a high-mass star-forming region in which dozens of O-stars have already formed, yet the gas mass is still much larger than the stellar mass. The most massive protostellar 'cores' consist of surprisingly large volumes of warm gas, yet dense gas around other high-mass stars appears untouched by their radiation. While main-sequence high mass stars are evaporating their surrounding material, they are doing so inefficiently, suggesting that protocluster clumps form stars until they are able to exhaust their food source. Thermal feedback from accreting stars appears to be the most important process governing stellar masses in these systems, with the most massive stars regulating their own cores' formation.

The magnetic structure of molecular filaments

Gómez, Gilberto

IRyA - UNAM

ABSTRACT: We study the structure of magnetic fields around filaments in simulations of molecular clouds undergoing large scale gravitational collapse. Simulations of this kind have shown filaments that are not in static equilibrium, but are instead long-lived flow structures that accrete from their environment while simultaneously feeding gas to clumps, either embedded within the filaments or at the nodes of hub-and-spoke structures. The magnetic field is dragged by the flow around the filaments, and so, its structure reflects this flow. Around the filaments, the gas is being accreted toward the filament and the magnetic lines are then perpendicular to the filament. As the density increases, the flow begins to turn and the accretion changes from two-dimensional (perpendicular) to one-dimensional (along the filament). In this region, the magnetic field lines become parallel to the filament. In the central parts of the filament, the magnetic field is again perpendicular to the filament as the lines on either side of the filament must connect. This U-shaped magnetic lines are therefore a direct result of the filaments-as-flow-structures scenario.

Fundamental properties of the eclipsing pre-main sequence components of MML 53

Gómez Maqueo Chew, Yilen

Instituto de Astronomía - UNAM

ABSTRACT: Eclipsing binaries are systems that allow the direct measurement of both the masses and radii of stars. These systems are fundamental for calibrating stellar evolution models by providing observational evidence against which the theories must be compared. For the youngest ages, there are very few eclipsing binaries known. MML53, member of Upper Centaurus-Lupus sub-association, is composed of two solar-type stars that are eclipsing and a third outer star. It is only now that environment dependent properties can be explored. first eclipsing binary discovered outside of the Orion Nebula Cluster. Here, I will present the eclipsing binary model, the measured constraints on the third star and the challenges of studying young stars. I will discuss how measuring these fundamental stellar properties can inform stellar models at the youngest ages.

Polarization structure of protostellar shocks

Gómez-Ruiz, Arturo

CONACYT-Instituto Nacional de Astrofísica, Óptica y Electrónica

ABSTRACT: Magnetic fields are thought to play an important role in the star formation process. Due to their high brightness and compact nature, methanol masers are suitable tools for high angular resolution observations of weak linear and circular polarization. In this talk I will present recent efforts made with the Very Large Array to measure the polarization properties of class I methanol masers at 44 GHz. The methanol masers are found tracing bow shock structures from the outflows in massive star forming regions. The polarization structure in protostellar bow shocks is presented for a couple of massive protostars. Along the bow shocks, a gradient in the direction of the polarization vectors is observed. A comparison with the magnetic field structure at larger scales is provided, as well as with the polarization properties from the cores. The polarization structure in shocks follows a pattern different from that observed from dust continuum polarization maps. A discussion of the behavior of the polarization structure at different scales, relevant for interpreting the polarization vectors from the shocks, is presented.

Consequences of Scale Free Fragmentation in Star Formation

Guszejnov, David

Caltech

ABSTRACT: The formation of structures in molecular gas is heavily influenced by supersonic turbulence that leads to an almost self-similar fragmentation cascade down to the stellar size scales. In this work we present a simple analytic model that can reproduce and explain the scaling of several major physical quantities. Among others we find that the power law slopes of -2 for the gas density PDF and the IMF are the consequences of scale free fragmentation. If we assume the driving force behind fragmentation is the Jeans instability we also find that the slope of the stellar correlation function becomes a robust -2, close to the observed values. Furthermore, with the added assumption of conserved phase space density for stars, the model can also reproduce the slope of the cluster mass profile.

Galaxy Zoo: comparing the star formation properties of spiral galaxies by arm multiplicity

Hart, Ross

The University of Nottingham

ABSTRACT: Visual spiral structure is a common feature in the discs of low-redshift galaxies. Spiral arms gather the gas in galaxy discs into concentrated regions, which in turn are the primary sites of star formation. Although spiral arms are common in low-redshift galaxies, our understanding of how spiral arms affect star formation is still incomplete. In particular, the mechanisms that drive grand design, two-armed spiral structure differ from those that lead to the appearance of more flocculent, many-armed spiral structure. In this talk, I will show that galaxies with different spiral arm numbers have very different recent star formation properties using a sample of 6,000 SDSS galaxies visually classified thanks to Galaxy Zoo 2. By combining our Galaxy Zoo visual statistics with SFR measures from the ultraviolet and infrared, we show that many-armed spiral galaxies have distinct colours compared to two-armed spiral galaxies, despite having little deviation in their current SFRs or gas fractions. We attribute the differences to the star formation in two-armed spirals being significantly reddened by dust, with the implication that stars form in different conditions in two-armed galaxies compared to their many-armed counterparts. This study allows for the comparison of the properties of an unparalleled sample of spirals, giving an insight in to the impact that spiral structure has on gas and star formation in galaxy discs.

The small scales of star formation

Hennebelle, Patrick

CEA, Saclay, France

ABSTRACT: I will review our current understanding of the small scales important for the star formation process. For the sake of simplicity I will tentatively distinguish four scales, namely : the clusters, the filaments, the molecular cores and the centrifugally supported discs. For these four objects I will describe our current understanding of their formation and evolution from a theoretical and observational point of view. For all of them, I will emphasize the questions and the physical processes that remain to be clarified.

A large scale survey of Herbig Ae/Be stars in the Orion Star Forming Complex - GAIA view

Hernandez, Jesus

Instituto de Astronomía, UNAM, sede Ensenada

ABSTRACT: Based on infrared data from the 2MASS and WISE catalogs we have performed a selection of intermediate mass stars (spectral types F5 or earlier) candidates that potentially have protoplanetary disks. Of particular interest are Herbig Ae/Be candidates, which exhibit near infrared excesses produced in the inner wall located at the dust destruction radius and emission lines produced by accretion mechanisms. In an area of ~ 1000 square degree we have found 85 HAeBe candidates with distances included in the first GAIA Data Release. We have concluded the optical spectroscopic observations of the selected candidates using the spectrographs OSU-CCDS at the observatory MDM and the Boller & Chivens at the observatory San Pedro Martir. These data is used to estimate stellar parameters for our sample. Our main goal is to build a large scale census of protoplanetary disks around intermediate mass stars that will contribute to a better understanding of the star forming and disk evolution processes, as well as possible relationships between the environment and the spatial distribution of stars in this mass regime.

A Catalog of the Southern Molecular Cloud Physical Properties from the ThrUMMS Survey

Hernandez, Audra

University of Wisconsin-Madison

ABSTRACT: The Three-mm Ultimate Mopra Milky Way Survey (ThrUMMS) provides a uniform and unbiased mapping of a 60deg X 2deg region of our Galaxy's southern plane (fourth-quadrant) in three CO-isotopologues and CN. We present a new catalog of southern molecular clouds identified from the 13CO data. We applied the dendrogram based algorithm SCIMES (Spectral Clustering for Interstellar Molecular Emission Segmentation; Colombo et al. 2015) on the J=1-0 data cubes using two different cloud extraction methods: A traditional intensity based cloud extraction (lex) and a column density based extraction (Nex), inspired by current galactic disk and molecular cloud models that define cloud structures based on simulated mass or mass density data cubes. For the lex extraction method we find a total of 6,338 molecular clouds, of which 589 are clusters (i.e., comprised of at least 2 dendrogram leaves). For the Nex extraction, we find a total of 25,891 molecular clouds, of which 3310 are clusters. We present our initial estimates of the cloud physical properties, including their temperatures, column densities, velocity dispersion, elongation, and mass surface densities, as well as their distribution throughout the Galactic plane. Since ThrUMMS provides simultaneous mapping for all three CO-isotopologues, excitation temperatures on the (l,b,v) pixel scale are measured directly from the 12CO for the 13CO based column density measurements. We derive the kinematic distances for all molecular structures using the Galactic rotation model of Reid et al. (2014). Additionally, we will present our analyses on the dynamical state of the clusters. At this time, for the lex clusters, we find that the power-law relation $\sigma/R^{(1/2)} \sim \Sigma^n$ (e.g. Heyer et al. 2009) of $n \sim 2.11 \pm 0.10$ (near) and $n \sim 2.92 \pm 0.21$ (far). These indices are larger than that expected for virialized clouds ($n_{\text{vir}}=0.5$).

VLA centimetric observations towards IRAS16293-2422

Hernández-Gómez, Antonio

IRyA-UNAM; IRAP-UPS

ABSTRACT: We present high angular resolution observations taken with the VLA at 3, 6, 10, 15, 33 and 41 GHz of the Class 0 protostellar system IRAS16293-2422 formed by the IRAS16263A and IRAS16293B sources. We measured the absolute and relative proper motion of these sources, including of the ejecta arising from IRAS16293A. We found that the relative motion between sources A1 and A2 cannot be described by a Keplerian orbit since the position angle of the vector joining these sources began to decrease after a period of 25 years increasing by about 50 degrees. This leads us to the idea that A1 is actually not a protostar, but a shocked region from a precessing jet driven by a protostar within IRAS16293A. We looked at the ejecta A2alpha and found that the size of this ejecta has increased with time and that its spectral index seems to have changed within 4 years. We also computed the spectral energy distribution of both IRAS16293A and IRAS16293B sources and looked for a break at 3 GHz in the spectral index derived for IRAS16293B, but did not find any. Finally, we found from our VLA data and ALMA observations ranging from 220 GHz to 690 GHz that the size of IRAS16293B increases with frequency up to 41 GHz, remaining roughly constant at higher frequencies, giving us a clue about the nature of the emission for this source.

The SFR of compact, coloured galaxies

Hidalgo-Gàmez, Ana M.

Escuela Superior de Física y Matemáticas, IPN

ABSTRACT: The Star Formation Rate of the so-called Green Pea galaxies, which have been discovered recently, seems to be very high. This is mostly based on the large intensity of the oxygen line at 5007 Å. Due to the redshifts of these galaxies, such line is observed in the r band, which give them the characteristic green colour. Galaxies with the same properties but with other colours, because they are at other redshift, have been proposed. Although some purple and bright blue galaxies with large EW of [OIII]5007 have been detected, they might be not the same kind of galaxies than the Green Peas. We have determined the Star Formation Rate of the three type of coloured galaxies from Galex images. From these results, it might seem that they are not the same kind of galaxies at different redshift, as some authors suggested.

Probing turbulent, multi-scale, magnetized star formation with ALMA observations and next-generation AREPO simulations

Hu11, Chat

Harvard/NRAO

ABSTRACT: The first polarization data from ALMA have been delivered, and are both expanding and confounding our understanding of the role of magnetic fields in low-mass star formation. Here I will show the highest resolution and highest sensitivity polarization images ever made of a Class 0 protostellar source. These new ALMA observations of the source, known as Ser-emb 8, achieve 140 AU resolution, allowing us to probe polarization -- and thus magnetic field orientation -- in the innermost regions surrounding the protostar. The collapse of strongly magnetized dense gas is predicted to pinch the magnetic field into an hourglass shape that persists down to scales <100 AU. However, in contrast with more than 50 years of theory, the ALMA data definitively rule out an hourglass morphology and instead reveal a chaotic magnetic field that has not been inherited from the field in the interstellar medium surrounding the source. We have simulated the star formation process with cutting-edge, moving-mesh AREPO simulations on scales from a million AU (5 pc) down to 60 AU. We find that only in the case of a very strong magnetic field (~ 100 microgauss on 5 pc scales) is the field direction preserved from cloud to disk scales. When the field is weak we find that it is cloud-scale turbulence -- not the large-scale magnetic field -- that dictates the magnetic field morphology immediately surrounding the protostar.

An extraordinary outburst in the massive protocluster NGC6334I

Hunter, Todd

NRAO

ABSTRACT: Our August 2015 ALMA observations of the massive Galactic protocluster NGC6334I at 3 and 1.3 mm with a resolution of 0.17" (220 AU) revealed that the dust emission from the dominant core, MM1, has increased by a factor of 4, with a corresponding change in its morphology compared to 2008 observations with the SMA at 1.3 mm. Furthermore, single-dish maser monitoring at HartRAO finds that the maser species in this region (H₂O, CH₃OH) went into a flared state only two months before our ALMA observation. In July-August 2016, we obtained ALMA DDT observations at 1.1 and 0.87 mm, which confirm that the (sub)millimeter flaring has continued for at least a year. These remarkable {\it simultaneous} increases suggest a sudden accretion event in the growth of a massive protostar in which the luminosity has surged by a factor of about 60, similar to predictions by Meyer et al. (2016). These data provide direct observational evidence of episodic accretion in a high mass protostar and affords a unique opportunity to assess the ongoing impact of this event on the surrounding cluster.

Collapse of super-Alfvénic molecular clouds in a turbulent ISM.

Ibañez-Mejia, Juan Camilo

University of Cologne

ABSTRACT: Understanding the relative importance of magnetic fields in the formation, evolution, and collapse of molecular clouds and their envelopes is critical for understanding the star formation process. Recent observations suggest that low column density material tends to preferentially align along magnetic field lines while high column density gas switches to a preferentially perpendicular alignment. This has been regarded as a transition from super-Alfvénic to sub-Alfvénic turbulence as gas flows from the clouds envelope onto the cloud. We implement high resolution, three-dimensional, MHD simulations of a kiloparsec scale vertical column of the ISM, including supernova-driven turbulence, a static galactic disk gravitational potential, gas heating and cooling and gas self-gravity, allowing clouds to self-consistently form out of the turbulent ISM. We analyze the potential role of magnetic fields for constraining gas flows in and around dense clouds, as well as the orientation of the magnetization relative to the density distribution. We find similar trends for the direction of the magnetization relative to the density structures in the low density envelopes and a transition to a random alignment above a certain density threshold. We show how this change in alignment is consistent with a transition from trans-Alfvénic to super-Alfvénic flows as gas is accreted onto the cloud, and gravity takes hold of dense structures. We find that magnetic fields can constrain gas flows in the clouds envelopes, but cannot support dense clouds from collapsing.

The Formation and Destruction of Molecular Clouds and Galactic Star Formation

Inutsuka, Shu-ichiro

Nagoya University

ABSTRACT: We discuss an overall picture of star formation in the Galaxy. Recent high-resolution magneto-hydrodynamical simulations of two-fluid dynamics with cooling/heating and thermal conduction have shown that the formation of molecular clouds requires multiple episodes of supersonic compression. This finding enables us to create a new scenario of molecular cloud formation as the interacting shells or bubbles in galactic scale. We estimate the ensemble-averaged growth rate of individual molecular clouds, and predict the associated cloud mass function. This picture naturally explains the accelerated star formation over many million years that was previously reported by stellar age determination in nearby star forming regions. The recent claim of cloud-cloud collisions as a mechanism for forming massive stars and star clusters can be naturally accommodated in this scenario. This explains why massive stars formed in cloud-cloud collisions follows the power-law slope of the mass function of molecular cloud cores repeatedly found in low-mass star forming regions.

The EMPIRE Nearby Galaxy Dense Gas Survey

Jimenez-Donaire, Maria Jesus

ZAH, University of Heidelberg

ABSTRACT: I will present the first results from our IRAM-30m large program EMPIRE, a ~500h survey that provides full maps of high critical density tracers like HCN or HCO⁺ across the entire star forming disks of 9 nearby disk galaxies. The key goal of the survey is to understand how dense gas fractions and star formation efficiencies vary across and among galaxies and how they relate to local ISM conditions. We analyzed these quantities in the entire galaxy sample, finding a variable dense gas fraction and efficiency of the dense gas to form stars, which I will discuss in the context of Milky Way work and theoretical expectations. In particular, a variable efficiency appears at odds with a whole class of models triggered by Milky Way work. EMPIRE also provides high signal-to-noise ¹³CO and C¹⁸O data and isotopologues of dense gas tracers (e.g. H¹³CN). These optically thin lines are important column density tracers and can be used to constrain abundance variations and optical depths across our galaxies. Such quantities are crucial to understand the ISM density distribution accross normal disk galaxies.

Steady march of feedback-driven star formation: Galactic high mass star forming regions

Jose, Jessy

Kavli Institute for Astronomy & Astrophysics

ABSTRACT: A longstanding question in the field of star formation is whether there are universal relationships between the star formation parameters and the observable local environment. In general, the active giant molecular clouds contains various sub-structures such as, HII regions, clusters, filaments, pillar like structures, bright- rimmed clouds etc. Some of these structures are created due to the gravitational collapse of the isolated dense molecular clumps where as, others are created due to feedback effect from massive stars via strong stellar winds and ionizing radiation. However, whether the outcome of star formation process such as the form of IMF, star formation efficiency and star formation rate of these various complex structures in a given molecular cloud has any systematic variation with respect to their local environment is not well understood. In our observational campaign using deep NIR and MIR data sets, we targeted various sub-structures within massive star forming regions. Systematic analysis of the stellar census and column density maps have been performed to estimate the density structure, IMF, star formation rate and efficiency. With the uniform data sets, we analyze how the star formation properties at different parts of individual regions vary with respect to the dense gas fraction as well as the amount of input energy from massive stars. A comparative analysis of the feedback influenced stellar aggregates in the vicinity of the massive stars with the global star formation activity of the GMCs has been performed. Our analysis suggests that the stellar feedback from massive stars influence only to its more localized neighborhood and may not have a measurable impact on the global star formation activities of the regions in this study.

Multi-Scale Star Formation in the Galactic Center Environment

Kauffmann, Jens

Max-Planck-Institut fuer Radioastronomie

ABSTRACT: The Galactic Center Molecular Cloud Survey (GCMS) has produced the first comprehensive survey of all major molecular clouds in the Central Molecular Zone (CMZ), i.e., the inner ~ 150 pc of the Milky Way. Data from the SMA reveal the kinematics and the density structure of many clouds for the first time (Kauffmann et al. 2013, 2016a,b). An ongoing massive survey on ALMA (30h total) provides additional detail and probes new relevant physics.

The study of these clouds is of critical importance: the star formation in the dense gas of the CMZ is suppressed by a factor ~ 10 , compared to the rest of the Milky Way. This provides essential constraints on the workings of the centers of our own and other galaxies. Some of the physics acting in the CMZ might also be relevant for the evolution of starburst galaxies in the near and distant cosmos.

I will summarize initial results from this survey. First data from the SMA reveal unusually dense and massive molecular clouds that do, however, contain surprisingly little substructure. In other words, the density gradients in most CMZ clouds appear to be much more shallow than the r^{-2} relation seen elsewhere in the Milky Way. The same data also offer a potential explanation: the clouds appear to be rather unbound on large spatial scales. In addition, first data from ALMA reveal parsec-sized shock fronts in some CMZ clouds. Processes like cloud-cloud collisions might constantly perturb the clouds and thus suppress star formation.

This study underlines the multi-scale nature of star formation in the Milky Way. The CMZ molecular clouds are apparently influenced by the overall conditions prevailing in the Galactic Center. The CMZ is thus a unique nearby laboratory for work on multi-scale star formation.

The Role of Line-Driven Outflows in the Formation of Massive Protostars

Kee, Nathaniel

University of Tübingen

ABSTRACT: Hot, luminous stars are known to drive strong mass loss (10^{-10} to 10^{-4} $M_{\odot}/\text{yr}$) from their surfaces through UV-scattering forces. High-mass stars already drive such strong winds while still in their accretion epoch. Therefore, stellar UV-scattering forces efficiently ablate material off the surface of massive protostars' circumstellar disks, and perhaps even shut off the final accretion through the last several stellar radii and onto the protostar. By using a fully three-dimensional UV-scattering prescription (Castor, Abbott, and Klein 1975; Cranmer and Owocki 1995), we quantify the role of radiative ablation in altering the disk's accretion rate onto a forming massive star as this flow passes onto the stellar surface. Particular emphasis is given to the potential impact of this process on the stellar upper mass limit.

Tracing massive stellar feedback in the Milky Way Galaxy

Kendrew, Sarah

European Space Agency

ABSTRACT: The Milky Way Project has proven to be an effective way of leveraging the contributions of citizen scientists around the world for data discovery from the Spitzer galactic plane surveys GLIMPSE and MIPS GAL. By combining the classification data from MWP with survey catalogues at other wavelengths, we can study the distribution and properties of gas and dust in the vicinity of young massive stars throughout the galactic plane using statistical methods. I will present the methods developed for this work and our latest results, showing how we can which visualize the effects of bubble expansion and energy injection into the ISM following massive star formation. This is particularly relevant for our understanding of sequential or triggered star formation. I will compare and contrast this work with other recently published results in this area.

Dense Cores Under Pressure : Early Results from GAS

Kirk, Helen

Herzberg Astrophysics, National Research Council of Canada

ABSTRACT: The Green Bank Ammonia Survey (GAS) is a 200+ hour survey on the Green Bank Telescope to map ammonia in nearby molecular clouds, revealing the temperature and kinematics of the dense gas in these star-forming environments. I present the first results of an analysis of the stability of dense star-forming cores in the Orion A molecular cloud, using a combination of GAS data and information from the JCMT Gould Belt Survey. A comparison of the thermal pressure, non-thermal motions, self-gravity, and ambient (external cloud) pressure shows that most of the dense cores are bound. Intriguingly, the majority of this binding is due to pressure from the ambient molecular cloud material, rather than an individual core's self gravity. These results are consistent with less direct estimates made earlier in the Ophiuchus and Perseus molecular clouds. If a similar result is found in a larger range of nearby molecular cloud environments, this will point to pressure, a factor often ignored in energetic analyses of cores, being a key element in the formation of stars.

Multi-Physics, Multi-scale Simulations of Star Formation in Filamentary Infrared Dark Molecular Clouds: From Large Scale Magnetized Clouds to Stellar Clusters

Klein, Richard

University of California, Berkeley

ABSTRACT: The origin and formation of stellar clusters remains a fundamental grand challenge in astrophysics. Tackling such a challenge requires complex multi-physics simulations that must include a large range of physical processes, including: self-gravity; supersonic turbulence; hydrodynamics; outflows; radiation and magnetic fields. However, the high degree of non-linear coupling and feedback mechanisms among these processes, along with the enormous dynamical range in time and spatial scales, make such simulations difficult to produce. In this talk I shall present new simulations that for the first time investigate star formation with fully coupled multi-physics that include feedback from protostellar outflows and radiative transfer traversing the large scales of the ISM (~ 1 kpc) down to the micro-scales of protostars and clusters. I shall first discuss our new large scale, multi-physics simulations using a hierarchical zoom-in AMR approach. Using our 3D adaptive mesh refinement (AMR) code, ORION2, we produce simulations that include magnetic fields, radiation transport, turbulence, and highly energetic protostellar outflows. These simulations, for the first time, follow the gravitational collapse (over a spatial dynamic range of several decades) of a magnetized, supersonically turbulent, massive molecular cloud through to the formation of dense IRDCs and multiple turbulent clumps inside these IRDCs, which then gravitationally collapse resulting in the creation of star-forming cores. The magnetized cores are further evolved to form protostars and stellar clusters via AMR zoom-in simulations. Complex filamentary structures emerge naturally from the simulations. Magnetic field lines pierce the dark cloud filaments primarily in the direction normal to the filament axis. We then perform deep zoom-in simulations into the structure of the main IRDC filament that include the fully coupled physics and continue the simulations to

study the formation and properties of a stellar cluster inside IRDCs. I shall discuss the effects of both radiative feedback and protostellar outflow feedback from the protocluster on the surrounding environs and (1) the formation of the resultant IMF and its agreement with the Chabrier IMF, (2) the Proto-stellar Mass function and the Proto-stellar Luminosity function and make detailed comparisons with several theoretical models and with observations, (3) the multiplicity fractions within the cluster and comparisons with observations of Class I protostars, (4) the cluster luminosity and comparisons with observations and finally, (5) the comparison of our proto-stellar outflows with theoretical models and recent observations. We find that the star formation efficiency is super-linear in time $\propto t^{**2}$ resulting in a star formation rate that is in good agreement with recent observations. I shall then present preliminary results that start from a ~ 500 pc portion of a galactic disk that has been evolved for 380 Million years with conditions comparable to the solar neighborhood in terms of total ISM gas surface density, gravitational potential of the stellar disk, background galactocentric rotation and shear rates and mean magnetic field. Using a hierarchical AMR zoom-in approach, we resolve down to the formation of stars with fully coupled physics spanning a spatial dynamic range of ~ 1 kpc to 25 AU.

Jets and Outflows of Massive Protostars

Kölligan, Anders

Tübingen University

ABSTRACT: We model the long term evolution of magnetized, massive prestellar cores from their initial gravitational collapse, through the formation of a circumstellar disks, the launching of fast collimated jets and wide angle winds, to the final cloud dispersal and outflow broadening.

Our simulations resolve a high dynamic range in space and time and enable us to analyze the physical mechanisms of the jet launching in detail, investigate feedback properties of the outflow and distinguish various effects leading to outflow broadening.

We study how our spherical coordinate system, its boundaries, initial conditions and different numerical parameters influence disk formation and jet launching and compare these results with established theoretical models for stationary jets (e.g. Blandford and Payne (1982); Pelletier and Pudritz (1992); Lynden-Bell (2003)) and with recent observations (e.g. Sanna et al. (2015)).

AMBER/VLTI Medium spectral resolution observations of the CO emitting region in the Herbig B[e] star HD50138

Koutoulaki, Maria

Dublin Institute for Advanced Studies

ABSTRACT: Protoplanetary disks are the birth place of planets. However, although the large scale disc is understood in some detail, very little is known about the inner 5 au at which the main physical processes take place: accretion, ejection and planetary formation. For the nearest sites of star formation, this region is inaccessible to standalone telescopes, and only recently optical and infrared (IR) interferometers have been able to spatially resolve it. In particular hot H I emission, like the Br γ line emission, as well as molecular emission lines, like the H₂ and CO, are expected to be emitted within this region. Several interferometric studies have successfully detected and constrained the origin of the Br γ line emitting region in discs. However, the detection and constrain of the location of the inner disk molecular component has been so far quite elusive.

In this talk, I will present one of the very few interferometric observations of the near-IR CO bandhead emission in a Herbig Be star. The observations were performed with the ESO-VLTI instrument AMBER at medium spectral resolution. The observations show a very bright CO emission from the transitions 2-0, 3-1, 4-2, 5-3, 6-4, 7-5. Our results show a clear increase of the visibilities within the CO emission for several of the transitions. This indicates that the CO emission is more compact than the continuum emitting region, giving a clear constrain on the size of the CO emitting region.

This result is of paramount importance to constrain the chemistry and physical properties of circumstellar disks around different type of systems such as young stellar objects or post-main sequence stars.

Mass Segregation in Star-Forming Regions on Multi-Spatial Scales

Kuhn, Michael

Universidad de Valparaíso

ABSTRACT: The spatial distributions of stars with different stellar masses (i.e. mass segregation) in young stellar clusters has been considered a possible method to test theoretical models of clustered star formation. Our study is based on the MYStIX survey which provides a sample of 31,000 young stars in 20 nearby star-forming regions. We present the use of the two-point correlation function to statistically test for the existence of mass segregation. This method has the advantage that it can distinguish different mass segregation behavior on different spatial scales, unlike other methods that where mass segregation properties are summarized as a single number. The MYStIX clusters analyzed with this method show diverse results: OB stars are usually more concentrated than stars of lower mass, but in some regions the distribution of OB stars closely follows that of low-mass stars. Mass segregation occasionally appears on length-scales of a few tenths of parsecs, but in other cases segregation can be seen over length scales of several parsecs. A few cases, most notably NGC 1893, exhibit inverse mass segregation. In many regions mass segregation is seen for masses down to 1.5 Mo, not just for OB stars. We find that there is no correlation between the extent of mass segregation and cluster age. Altogether, these results do not support simple theories of mass segregation based on two-body dynamical relaxation and may require the presence of primordial mass segregation.

O-star binary systems in formation

Kumar, Nanda

University of Hertfordshire, Hatfield, UK

ABSTRACT: Adaptive optics observations of compact HII regions will be presented. A pair of near equal brightness point sources separated between 3000-5000 AU are found in the core of 7 out of 20 targets studied. One of these sources is always redder and/or more embedded than the other. Detailed observations of two prototypical targets, that are among the nearest and most luminous, show evidence that the source pair is embedded in a common flattened rotating structure. These luminous targets also display candidates of extended ionised disks and radiation Rayleigh-Taylor instabilities. The observations depict O-star binary systems in formation.

Analytical CMF from filaments: Under what circumstances can filament fragmentation explain the CMF?

Lee, Yueh-Ning

AIM/CEA Saclay

ABSTRACT: Observations have shown that many star-forming regions appear to be filamentary. I will introduce a newly developed model to account for the 2-step star formation, such that molecular clouds form filaments as a first step, and then the filaments fragment into star-forming cores. To well characterize this 2-step process, we need to understand 1) the filament population, i.e. their number distribution of mass per unit length and strength of magnetic field, 2) how these filaments of different properties fragment into cores of different mass distribution. This model follows the Hennebelle-Chabrier CMF theory, adapted to the filamentary geometry. It counts the number of objects that are virially unstable at all scales, given the scale- and density-dependence of different supports against self-gravity, such as thermal pressure, turbulence, and magnetic field. We succeed in describing the fragmentation of a filament into small groups of cores, as seen in several observations, by looking at the largest and smallest unstable objects. This is a unique behavior as result of the cylindrical geometry. Finally, the system CMF is obtained by convolving the fragmentation of individual filaments with the filament population. This will give us some hint of the level of magnetization in the filamentary molecular clouds.

A bipolar molecular jet in NGC2023 MM1

Liao, Li-Wen

National Tsing Hua University

ABSTRACT: We have observed a bipolar molecular jet in NGC 2023 MM1 with the Submillimeter Array (SMA). NGC 2023 MM1, a class 0 protostar in Orion ($d \sim 460$ pc) with luminosity $L \sim 7 L_{\text{sun}}$, is driving a large-scale CO bipolar outflow previously observed with JCMT. With an angular resolution of $4''$ and a spectral resolution of 2 km/s, our observations show a highly collimated bipolar jet close to the source in both CO (2-1) and SiO (5-4) emissions. We have resolved the red-shifted jet into two compact knots, which show weak velocity gradients perpendicular to the jet axis with a specific angular momentum of approximately 160 AU km/s. Such velocity gradients may trace tentative jet rotation.

Formation and Structure of Magnetized Protoplanetary Disks

Lizano, Susana

IRyA, UNAM

ABSTRACT: Protoplanetary disks are expected to form as a result of the gravitational collapse of magnetized rotating dense cores. Analytic work and numerical simulations that show that a substantial level of magnetic field diffusion has to occur at high densities in order to form the observed rotationally supported disks. I will discuss the radial and vertical structure of magnetized accretion disks irradiated by the central star, expected to form in this process. The mass-to-flux ratio is a critical parameter that determines the structure and evolution of these disks. This ratio can be determined observationally in the near future with radio interferometers like the Atacama Large Millimeter Array in Chile.

Angular momentum in bipolar outflows

Lopez Vazquez, Alejandro

IRyA, UNAM

ABSTRACT: We present a semianalytical model of the interaction of two winds to explain the observed rotation the bipolar outflows (e.g. Zapata et al. 2015). Considering that the bipolar outflow is a mixing layer formed by the shock between an isotropic stellar wind and a rotating cloud in gravitational collapse. We assume symmetry with respect to the cloud's rotational axis and solved the hydrodynamics equations. We find the shape of the layer, the velocity field, the surface density and the angular momentum rate of the material in the layer. For weak stellar winds, we have spherical lobes and for strong stellar winds, we have elongates lobes in the direction of the cloud's rotational axis. In the order to compare with observations, we obtain the radial velocity on the line of sight.

Detection and characterisation of emission line galaxies in SHARDS

Lumbreras-Calle, Alejandro

Instituto de Astrofísica de Canarias

ABSTRACT: Star-forming galaxies show a variety of morphological and stellar properties at different epochs of cosmic evolution. To understand the evolution of these properties we build a sample of star-forming galaxies at intermediate-to-low redshift. We use the database from SHARDS survey, as its depth (up to magnitude ~ 26) and its spectro-photometric properties ($R \sim 50$) provides us with a unique tool to find emission lines. A new algorithm is developed to identify low-redshift ($z < 0.35$) star-forming galaxies by finding the [OIII] and H α emission lines simultaneously. A subsequent spectral energy distribution (SED) fitting is performed on the selected sample, using additional ancillary data from the ALHAMBRA survey, in order to derive stellar population parameters. We find 155 star-forming galaxies, for which we derive equivalent widths (EW), and absolute fluxes of both emission lines from the photometric data. We detect EW as low as 12 Å with median values for the sample of ~ 40 Å in [OIII] and ~ 70 Å in H α . Results from the SED fitting show the need of a young stellar population (median age ~ 6.5 Myr), with low metallicity (1/5 of solar) and extinction ($A_V \sim 0.12$) and an old stellar population dominating the mass in order to reproduce the observed SED. This study will be extended in the future with morphological and spectral analysis.

H band polarization towards the molecular cloud associated to IRAS18236-1205

Luna, Abraham

INAOE

ABSTRACT: Using the new infrared image polarimeter POLICAN, at the Guillermo Haro Astrophysical Observatory in Cananea Sonora Mexico, we investigate the role of the magnetic fields in the process of star formation. We observed polarized emission in H band towards the molecular cloud associated to the source IRAS18236-1205. This source is observed as a continuous dark cloud in the K band along the complete cloud but segmented in 8microns. At the densest region of the molecular cloud, the IRAS source, we obtained a strong correlation in the orientation between the observed out-flow molecular and the orientation of the polarization vectors, but a 20 deg deviation between the Milky Way Galactic plane field. Using the Chandrasekhar-Fermi method we calculated the magnetic field intensity in the cloud.

CALIBRANDO LA TASA DE FORMACIÓN ESTELAR EN H α Y FUV PARA GALAXIAS TARDÍAS.

Magaña Serrano, Marco Antonio

Escuela Superior de Física y Matemáticas -IPN

ABSTRACT: The Star Formation Rate of a sample of 38 late spiral galaxies was obtained using the H α and UV emission, from H α and continuous images. These H α images were reduced and calibrated using the software MIDAS. The FUV SFR was obtained using GALEX data. The star formation rate in FUV is always higher than the H α SFR, up to a factor of ten. On the other hand, the efficiency of star formation for this kind of galaxies is determined, concluding that late-type galaxies have lower efficiency than those studied by Kennicutt for earlier galaxies. On the other hand, possible correlations between SFR and some global parameters of these galaxies such as radius at 25 isophote, density of superficial brightness, blue absolute magnitude and gas density, were considered, but none was clearly found.

The Infrared and Radio Fluxes of Galactic HII Regions

Makai, Zoltan

West Virginia University

ABSTRACT: We derive infrared and radio fluxes of 800 Galactic HII regions in the longitude range $17.5^\circ < l < 65^\circ$. Our sample contains all known HII regions in this zone, as cataloged in the Wide-Field Infrared Survey Explorer (WISE) catalog of Galactic HII regions. We compute flux densities at six wavelengths in the infrared (Spitzer-GLIMPSE $8\mu\text{m}$, WISE $12\mu\text{m}$ and $22\mu\text{m}$, Spitzer-MIPSGAL $24\mu\text{m}$, and Herschel Hi-GAL $70\mu\text{m}$ and $160\mu\text{m}$) and two in the radio (MAGPIS 20cm and VGPS 21cm).

All infrared fluxes are strongly correlated with the radio fluxes, with the $24\mu\text{m}$ fluxes showing the strongest correlation. These results are unchanged with HII region size or Galactocentric radius (R_{gal}). We find that, overall, the most dominant emission origins from cold dust grains, traced by $70\mu\text{m}$ and $160\mu\text{m}$ emission. The infrared colors of 98% of all HII regions, regardless of size, satisfy the IRAS color criteria of Wood & Churchwell (1989) thought to select only ultra-compact HII regions. This indicates that there may be far fewer true ultra-compact HII regions in the Galaxy, and the ultra-compact lifetime problem significantly less acute.

The infrared/radio flux ratio increases with HII region size, which may be intrinsic to the regions or may be caused by radio optical depth effects. The analyzed data show that the contribution of the $12\mu\text{m}$ polycyclic aromatic hydrocarbon (PAH) features is less intense than the $8\mu\text{m}$ PAH features.

We find a clear negative trend for the flux ratios of $8\mu\text{m}/21\text{cm}$ as a function of Galactocentric radius in agreement with previous extragalactic results, perhaps indicating a decrease in the PAH abundance with increasing R_{gal} . Investigation of infrared flux ratios as a function of Galactocentric radius shows that there is no detectable shift between the mean HII region ratios, independent of R_{gal} .

Evolutionary models of accretion disks: IR emission and snowlines evolution

Manzo Martínez, Ezequiel

IRyA, UNAM

ABSTRACT: We present models of irradiated accretion disks undergoing viscous evolution. The evolution of the central star and the decrease of the mass accretion rate with age are both taken into account. Our models also include an outer region in the disk where the surface density falls-off exponentially. We use these models to reproduce the observed distributions of median IR slopes in stellar clusters of different ages. This allows us to find models that represent the most probable evolutionary stage of the disk at each age. Finally, we make predictions on how the shape and location of different snowlines should evolve in time.

Searching for compact radio sources associated to UCHII regions

Masqué, Josep Maria

Departamento de Astronomía (Univ. de Guanajuato)

ABSTRACT: Ultra-Compact (UC)HII regions represent a very early stage of massive star formation whose structure and evolution are not yet fully understood. Interferometric observations in recent years show that some UCHII regions have associated compact sources of uncertain nature. Based on this, we carried out VLA 1.3 cm observations in the A configuration of selected UCHII regions in order to report additional cases of compact sources embedded in UCHII regions. From the observations, we find 13 compact sources associated to 9 UCHII regions. Although we cannot establish an unambiguous nature for the newly detected sources, we assess some of their observational properties.

According to the results, we can distinguish between two classes of compact sources. One class corresponds to sources that probably are deeply embedded in the dense ionized gas of the UCHII region. These sources are being photo-evaporated by the exciting star of the region. They may play a crucial role in the evolution of the UCHII region as the photo-evaporated material could replenish for 10^4 - 10^5 yr the expanding plasma and might provide a solution to the so-called 'lifetime' problem for these regions. The other class of compact sources is not associated with the densest ionized gas of the region. Most of these sources appear unresolved and their properties are varied. We speculate on the similarity between these sources and those of the Orion population of radio sources.

Zooming in to the heart of W33A MM1-Main: A spiral filament feeding the candidate disc

Maud, Luke

Leiden University

ABSTRACT: W33A region was observed at band 6 and 7 with ALMA to search for a disc as was suggested by SMA data. With the highest resolution observations at sub/mm wavelengths to-date ($\sim 0.2''$ or 500 au) there is no evidence of pure Keplerian rotation. However, there is a clear velocity gradient over the core region hinting at an underlying disc, although this could also be from a binary system. There is a larger scale spiral-like filament that could be interpreted as 'feeding' the MM1 core. I will present these observations and propose possible formation scenarios for the high-mass protostars in the region.

The stellar environment of compact star clusters as a function of cluster age in M81

Mayya, Yalia Divakara

INAOE

ABSTRACT: The nearby spiral galaxy M81 harbours more than 200 blue stellar clusters that are more compact than 10 pc. These clusters are found in the spiral arms, in majority of the cases within large-scale (~ 100 pc) stellar complexes. We determined the ages of compact and the extended population using two complementary techniques. For the former, we determined ages using the optical spectra obtained with the GTC/OSIRIS, whereas for the latter we obtained the turn-off ages using the HST-based color-magnitude diagram of individual stars. In this work, I will present the result for 40 compact-extended cluster pairs whose age extends from very young to around a billion year. We find some trends between the compact cluster age and the presence of an extended population. Implications of these results on the cluster formation and evolution scenarios will be discussed in the presentation.

Turbulence Analysis on Galactic Plane Molecular Clouds

Medina, Sac Nicté

Max Planck Institut für Radioastronomie

ABSTRACT: The turbulence is an intrinsic physical property in the Molecular Cloud and an essential key to understand the star formation process in the Galaxy. We will present a statistical turbulence study on a Giant Molecular Clouds (GMC) sample that were extracted with the SCIMES algorithm from Colombo et al. (2015). The data were taken with the APEX telescope (Atacama Pathfinder EXperiment telescope) by a galactic plane survey. In particular, we are focus on the line $^{13}\text{CO}(2-1)$.

We have applied the Velocity Channel Analysis (VCA) technique of Lazarian and Pogosyan (2000) on the brightness distribution of GMCs, some of them corresponding to the most massive and highly sub-structured complexes observed. For our analysis, we let the thickness of the velocity slices vary from the velocity resolution (0.5 km s^{-1}) up to the thickest slice case, corresponding to collapsed map that include the whole velocity range of the cloud in one channel. We computed the power spectra of the data and correct the effects of measured noise and beam smearing following a method described in Brunt & Mac Low (2004). We present the normalized power spectra profiles of the GMCs and their corresponding power law index. We will show our index results and how they compare with the expectations and with different reported results from the literature.

Probing the circum-galactic gas with VUDS

Méndez-Hernández, Hugo

Instituto de Física y Astronomía-Universidad de Valparaíso

ABSTRACT: Our current understanding of galaxy formation is based on studies of i) stars ii) star formation and iii) multi-phase gas, but the link between all these components is missing, providing us an incomplete and fragmented view of all the involved processes. Several studies based on simulations and theoretical analysis suggest that galaxies acquire most of their baryons by funneling cold gas, through cold filamentary streams deep inside dark matter (Birnboim+2003; Keres+2005; Keres +2009), moreover these cold streams should be detectable by absorption or emission, covering 25% of the area around galaxies ($z < 2.5$) at radii between 20 and 100 kpc, and flowing in with velocities $> 200 \text{ km s}^{-1}$ (Dekel+09). Moreover, the popular scenario for the transition between the blue and the red sequence invokes a phase when the gas is expelled from the galaxies via strong winds (e.g., di Matteo et al. 2005; Hopkins et al. 2010).

As as a very first step, in order to understand how gas flows in and out of galaxies, we focused our attention to the interface between galaxies and the Intergalactic Medium: the circum galactic medium (CGM). A way to probe the CGM around star-forming galaxies is to look for absorptions that the CGM around foreground galaxies imprints in the spectra of bright background galaxies. By using different lines-of-sight we can get useful information on the overall kinematics, chemical abundances, and (in some cases) estimates of the mass flux of cool material entrained in an in-outflow, which can be achieved by selecting close galaxy pairs where background galaxies provide information on the spatial distribution of circumgalactic gas surrounding the foreground galaxies (Steidel+10). For this purpose we have selected a sample of ~ 3000 close (2-250 kpc) galaxy pairs from the Vimos Ultra-Deep Survey (VUDS) in order to probe the circumgalactic medium (CGM) around galaxies at $2 < z < 4$, aiming at identifying cold accretion gas (inflows) or

high velocity stellar winds (outflows) that could be related to the quenching or enhancement (triggering?) of star formation in these galaxies. So far, we have detected strong absorption features in both individual and stacked background galaxies spectra. By doing this, we are able to trace the average absorptions line strengths (i.e. Ly- alpha CIV, OISIII, CIV, AIII) out to galacto-centric radii of 150 kpc on stacked spectra, and absorptions line strengths up to ~250 kpc in some individual cases. I will present these results in a context where the circumgalactic gas is distributed symmetrically around every galaxy (Steidel+10), and relate this with a star-formation enhancement/quenching event.

The Star Formation Rate of the Milky Way as a $z=0$ template for other galaxies.

Molinari, Sergio

INAF-IAPS

ABSTRACT: The VIALACTEA project created a unified framework for the latest generation Galactic Plane continuum and spectroscopic surveys from the infrared to the radio. Deploying a homogeneous analysis and classification scheme for almost 100,000 dense clumps with heliocentric distance determinations, we are now able to complete the first resolved map of the Star Formation Rate in the Milky Way and analyse in detail its variation with Galactocentric distance and with respect to spiral arms, as well as in comparison to star formation triggering agents. A Galactic Star Formation Law can be built from the ground-up with unprecedented statistical significance, providing insights as to possibly dominant features that determine its shape. These results are analysed against simple observables, like integrated monochromatic fluxes from the infrared to the radio, and compared to integrated indicators widely used to infer the SF Rate in external galaxies.

The Formation of Massive Clusters and the Origin of their Stellar Mass Function

Motte, Frederique

IPAG Grenoble and CEA Saclay

ABSTRACT: Studying extreme protoclusters is necessary to test if star formation and the IMF origin can be independent of cloud local characteristics. Herschel/HOBYS revealed high-density cloud filaments, which are forming clusters of OB-type stars. Given their high star formation activity, these so-called mini-starburst cloud ridges could be seen as “miniature and instant models” of starburst galaxies. Their characteristics challenge star formation models and shed light on the origin of massive clusters.

In one of these ridges called W43-MM1, the star formation efficiency increases with volume gas density and contradicts statistical models of star formation rates (SFR). Moreover, its core mass function (CMF), measured for solar-type to O-type stars, suggests that the initial mass function (IMF) may not be determined, in these extreme environments, at the prestellar stage. Interpretations for these anomalous SFR and CMF will be proposed in the framework of the dynamical formation of cloud ridges followed by bursts of high-mass star formation.

Are XMP galaxies primitive disks fed by cold-flow accretion?

Muñoz-Tuñón, Casiana

Instituto de Astrofísica de Canarias

ABSTRACT: We have evidences that some Extremely Metal Poor Galaxies (XMP) are fed by cold-flow accretion. They rotate and their metallicity drops at the main starburst. Gas inflow from the cosmic web is the best possible explanation. Independent photometry data also indicate that XMPs are disk-like galaxies with masses down to 10^7 solar mass. We are carrying out a large observational program with the intermediate dispersion spectrograph (IDS) at the 2.5 Isaac Newton Telescope at the ORM (La Palma). The aim is to confirm, for the XMP class, the rotation and metallicity drop at the starburst. If stablished we will have identified a sample of primitive disks in the local universe in the process of assembly. They will allow for follow up in-depth studies of disk formations, scientifically important but technically impossible at high redshift. In the talk I will present the first results of the survey.

Measuring Rotation in Protostellar Envelopes: ALMA Observations of Edge-On Orion Protostars

Nagy, Zsolia

Max Planck Institute for Extraterrestrial Physics

ABSTRACT: We present ALMA imaging of four class-I edge-on Orion protostars in ^{12}CO , ^{13}CO , and C ^{18}O 2-1 transitions at a $\sim 1.7''$ angular resolution. The sources were selected based on an HST NICMOS and WFC3 imaging survey which shows disks visible in near-IR absorption. The edge-on geometry of the sources provides an excellent opportunity to study the gas kinematics in the protostellar envelopes. In addition to their edge-on orientation, the studied protostars are in relative isolation.

We used data from the 12-m and ACA arrays of ALMA in addition to total power observations to recover the extended emission. Due to the high angular resolution, the data directly probe gas acceleration near the protostars down to scales of 700 AU. We identify outflow cavities in the data as well as the kinematic signatures of disk rotation, envelope infall and envelope rotation. However, the data do not show the axial symmetry assumed in standard rotating collapse models. Instead, they suggest a highly asymmetric envelope structure with infall concentrated in streams of gas.

Proplyd-like objects in the Cygnus OB2 region

Natacha Laura, Isequilla

Universidad de La Plata - Facultad de Ciencias Astronomicas y Geofisicas - Argentina

ABSTRACT: Massive stars produce a strong flow of ionizing radiation affects the evolution of protostars present nearby, can create protoplanetary disks or proplyds. Paradoxically, they are the most difficult for a star evolves environments. Proplyds prototypes have been observed in the Orion Nebula and characterized in detail. Recently they detected similar to the proplyds objects, but larger and denser in ionized regions such as M8 or Cygnus OB2. Here we present observations of Cygnus OB2 region in the continuous radio arcsec resolution, using the Metrewave Giant Radio Telescope (India) at frequencies of 325 and 610 MHz. In the field observed detect sources Proplyd type. Some of them show negative spectral indices. To determine whether these values are due to non-thermal emission, we draw electron density maps, optical depth and emission measurement and analyze the distributions found. We present our results here.

High-mass star formation in the W43-MM1 protocluster

Nony, Thomas

IPAG

ABSTRACT: The W43-MM1 protocluster, being extreme in terms of cloud concentration (2×10^4 Msun within 16 pc^3) and star formation activity ($\text{SFR} \sim 6000 \text{ Msun/Myr}$), is a case-study to confront star formation models up to their limits. In Cycles 2 and 3, ALMA performed a deep, large mosaic of the W43-MM1 ridge. The 1mm image reveals a hub of spiraling filaments and a rich cluster of about 300 cores with ~ 2000 AU sizes and masses up to 100 Msun. The resulting core mass function definitively is 'top-heavy', for both the low- and high-mass regimes. About 20 protostars have been identified thanks to well-collimated CO and SiO outflows and hot gas tracers. Moreover, few candidates of high-mass prestellar cores are found in this protocluster at the very beginning of its formation. It casts doubts on the very existence of a high-mass prestellar core phase in the high-mass star formation scenario.

SEDs of nearby star-forming galaxies with the new PARSEC evolutionary tracks: Star formation rates and Dust Attenuation Properties

Obi, Ikechukwu Anthony

International School for Advanced Studies, Trieste

ABSTRACT: With the last updated PARSEC tracks we compute the ionizing photon budget, the integrated stellar light and the supernova rates predicted by young simple stellar population models. Using CLOUDY, we also calculate the intensities of some selected emission lines and include them in the integrated SSP spectra. With the new SSPs in GRASIL we are thus able to predict the panchromatic spectrum and the main recombination lines of star forming galaxies of any type. We re-calibrate the non-thermal emission with the well observed nearby normal star-forming galaxy M100 because the new models take into account recent advances in the CCSN explosion mechanisms indicating a range of massive stars where the stars fail to explode. The thermal emission takes into account the full dependence of the electron temperature on metallicity and the effect of considering different IMF upper mass limits. We check the thermal radio emission model on selected well studied star forming regions in NGC6946 and we focus on the differences between normal star forming galaxies and galaxies dominated by starbursts. The realistic treatment of dust performed by GRASIL allow us to highlight the impact of the newly added recombination lines in the determination of the attenuation properties of star-bursting and normal star-forming galaxies. We provide a new set of SFR calibrations (from optical to radio) which could be applicable to young galaxies at high redshifts.

New insights into massive star formation from galaxy-wide surveys of the LMC

Ochsendorf, Bram

Johns Hopkins University

ABSTRACT: The proximity and face-on orientation of the Large Magellanic Cloud (LMC) offers a unique opportunity to study star formation from galactic to individual giant molecular cloud (GMC) scales.

I will first highlight results from a large statistical survey in the LMC that has established the location, clustering, and propagation of massive star formation within GMCs. This study employs an unbiased dataset of ~700 massive young stellar objects, ~200 GMCs, and ~100 young (< 10 Myr) optical stellar clusters. This data properly samples massive star formation as a function of GMC structure, star formation activity, evolutionary stage, and is unparalleled by any Galactic study to date. The main results: (i) Massive stars do not typically form at the highest column density of parent GMCs. This has important implications for GMC evolution/disruption and the initial conditions for massive star formation. (ii) The rate of massive star formation is significantly boosted in clouds near stellar clusters. This reveals an intimate connection between different generations of massive stars on timescales up to 10 Myr.

We have quantified this connection between different generations of massive stars by deriving the star formation rates and efficiencies of all massive star forming regions across the face of the LMC. The main result: the rate of massive star formation is a time-variable quantity, which appears to ramp up when stellar clusters emerge and boost the formation of subsequent generations of massive stars. In addition, on GMC scales, the star formation efficiency declines with increasing cloud mass. This trend persists in similar studies performed in our Galaxy. I will show how these results challenge turbulence-regulated star formation models, and instead illustrates the importance of stellar feedback in setting the absolute massive star formation rate.

Misaligned molecular outflows and precessing jet towards the massive young stellar object G034.5964-01.0292

Ortega, Martin

IAFE-CONICET/UBA, Argentina

ABSTRACT: The red MSX source G034.5964-01.0292 (MSXG34), catalogued as a massive young stellar object (YSO), was observed in several atomic and molecular transitions with the aim of study the relation between molecular outflows and jets. Based on observations of the 12CO J=3-2 line, with an angular resolution of 22 arcsec, carried out with the Atacama Submillimeter Telescope Experiment (ASTE), we discovered misaligned red and blue-shifted molecular outflows associated with the source.

Using near-infrared data acquired with Gemini-NIRI at the JHKs-broad-bands and narrow-bands centered at the emission lines of [FeII], H2 1-0 S(1), H2 2-1 S(1), Br gamma, and CO 2-0 (bh), we studied the circumstellar environment of the central source with an angular resolution of 0.4 arcsec. The H2 1-0 S(1) continuum subtracted image, reveals several knots and filaments at large spatial scale around the point source, in perfect matching with the distribution of the red and blue-shifted molecular outflows.

By the other hand, the emission in the JHKs-broad-bands shows, with great detail, the presence of a cone-like shape nebula extending to the north/northeast of the point source, which appears to be attached to it by a jet-like structure. In the three bands the nebula is resolved in a twisted-shaped feature composed by two arc-like features and a bow shock-like structure seen mainly in the Ks-band, which strongly suggests the presence of a precessing jet.

It is really puzzling the orientation of the molecular outflows (pointing the redshifted one towards the northwest and the blueshifted one towards the southwest), compared with the cone-like shaped nebula (pointing towards the northeast). The presence of a not resolved system of YSOs could explain both, the precessing jet through tidal interactions between companion stars and the misaligned molecular outflows.

Constraints from mid-infrared wavelengths in spectral energy distribution fitting methods

Pappalardo, Ciro

Institute of Astronomy and Space Sciences Lisbon

ABSTRACT: In the last decade an enormous growth of data available to the scientific community allowed, for the first time in astronomy, a truly panchromatic approach. In the field of galaxy evolution this new data shed light on fundamental correlations, linking the dust component of a galaxy with its star formation rate (SFR).

In this talk I will examine the correlations between dust and SFR adding into the analysis additional parameters, tightly linked to both stellar and dust components. The caveat for such investigation is that it requires the presence of mid-infrared (MIR) data in order to accurately disentangle the two emissions. Selecting a sample of ~ 800 galaxies with photometry between $0.15 < \lambda < 500 \mu\text{m}$, we analysed them with different spectral energy distribution fitting methods. In a secondary step we removed alternatively MIR data, leaving unconstrained the region between $3 \mu\text{m}$ and $250 \mu\text{m}$. We repeated then the fitting process to quantify how the lack of MIR data affects such kind of analysis.

The dust luminosities and the SFR correlates strongly, but when both parameters have low values, the scatter in the correlation increases. We found that selecting galaxies according to the fraction of ultraviolet emission absorbed by dust, the data spread reduces drastically. This indicates that galaxies with similar absorption coefficients, despite a different SFR, have a similar balance between the fraction of dust heated by the star formation and the interstellar radiation field.

Dust masses and SFR also correlates, but they show a weaker link with respect to the dust luminosities. The scatter in this case is due to a difference in the intensity of the interstellar radiation field produced by stars in late evolutionary stages, which shifts the galaxies position in the dust mass-SFR plane. We show that selecting galaxies according to the intensity of the radiation field, the scatter in this correlation is strongly reduced.

The link between dust and star formation is quite complex, with still many aspects to be investigated. In this context the MIR emission plays a crucial role, since it can be due to both star and dust components.

Multi-scale and multi-wavelength study of the UCHII G45.47+0.05 surroundings

Paron, Sergio

IAFE CONICET/UBA

ABSTRACT: We present a multi-scale study of the interstellar medium around the UCHII region G45.47+0.05 (hereafter G45) which is located at the distance of about 8 kpc. First, using public infrared and molecular line data we found a large HII region that it is interacting with a molecular cloud that in turn shows some signs of star formation. G45 lies towards a border of this large HII region and shows extended 4.5 μ m emission, suggesting the presence of shocked H₂ likely due to outflow activity.

Using the Atacama Submillimeter Telescope Experiment (ASTE) we observed several molecular lines (12CO, 13CO J=3-2, HCO⁺ J=4-3, and CS J=7-6) towards G45 with an angular resolution of 22" and discovered not aligned red- and blue-shifted molecular outflows.

Finally, from near-infrared data acquired with NIRC2 at Gemini-North and using the adaptive optic system ALTAIR to achieve an angular resolution of about 0.1", we found a point source lying 3" northwards the maximum of the UCHII region as seen in radio continuum emission. This high-resolution observations allowed us to distinguish a curved jet emerging from the point source and two arc-like features related to it, which strongly suggest a precessing jet scenario. Thus, we could resolve the circumstellar environment (in scale of a thousand AU) of a distant young stellar object.

Beyond the Peak Spatially resolved CO Excitation in the Local Universe

Pellegrini, Eric

ITA-ZAH Uni. Heidelberg

ABSTRACT: I will present Beyond The Peak, the only spatially-resolved Herschel Spectroscopic survey to map sample of 21 nearby galaxies nuclear in $12\text{CO } J=1-0$ to $J=13-12$. These galaxies represent a broad range of key physical properties, including luminosity, gas and stellar mass, star-formation density, and infrared activity. I will present a local characterizing CO excitation over a range of star-forming intensities and AGN activity, averaged on sub- and kilo-parsec scales, using a new metric, J_{avg} , the luminosity-weighted average CO transition, as a useful measure of CO excitation.

Results: We find a variety of ISM heating tracers correlate with J_{avg} including dust color, dust radiation field density, and most importantly star formation rate surface density. Each of these intensive quantities reveal new trends when viewed in the surface density plane, hidden in prior spatially un-resolved analyses based on luminosities covering many orders of magnitude. These observations form a basis for interpreting mid-J emission from high redshift galaxies with a now quantifiable uncertainty.

Using synthetic observations to constrain the evolution high tracers in molecular clouds

Peñaloza, Camilo
Cardiff University

ABSTRACT: Over the past decade, there has been a move to better connect observations with numerical simulations by using time dependent chemical networks to follow the chemical evolution. However the computational cost of chemical networks has limited the variety of tracers, especially high density ones or complex molecules. In this work we performed a set of smooth particle hydrodynamics (SPH) simulations with time-dependent chemistry. The simulations are then post processed using a time-dependant chemistry algorithm with a full chemical network that can correctly reproduce the chemical abundance of high density tracers. Finally, we use radiative transfer (via RADMC-3D) to create synthetic integrated emission maps. Synthetic emission maps are created for different lines of high density tracers, such as HCN, to study the mass resolution necessary to create reliable synthetic images. Furthermore, we show how the emission changes as the cloud evolves and how it relates to the structure of the cloud and its environment.

The dynamics of infrared dark clouds

Peretto, Nicolas

Cardiff University

ABSTRACT: Star formation can be seen as the process that transfers matter from large diffuse interstellar clouds to compact nuclear burning balls of gas. This process takes place over many orders of magnitude in spatial scales and densities. Observationally characterising the physics that governs that transfer as a function of scale/density is at the centre of current star formation research. Here, we will present the study of a sample of 27 infrared dark clouds for which the density structure, gas kinematics, energy balance, and escape velocity have been estimated from a few tenths of a parsec scale to several tens of parsecs. Using both IRAM 30m N₂H+(1-0) maps for the dense gas and GRS 13CO(1-0) observations for the more diffuse gas, we are able to identify significant changes in the cloud properties as we probe larger distances to its centre. We will discuss the existence of a scale at which clouds eventually switch from being self-gravitating to gravitationally unbound structures.

Continuum Emission Diagnostics for Prestellar Clumps in the CHaMP Survey

Pitts, Rebecca

University of Florida

ABSTRACT: To address persistent mysteries about the physical and chemical conditions characteristic of high-mass star-forming regions, I have gathered FIR and sub-millimeter continuum data from multiple observatories, and begin fitting pixel-by-pixel modified Planck SEDs to the 303 prestellar and protostellar clumps in the Census of High- And Medium-mass Stars (CHaMP) survey . I have begun modifying the SED-fitting program Mosaic-Math to allow for a dust emissivity parameter and dust-to-gas-ratio, and model the uncertainties in the fit with Markov Chain Monte Carlo methods. I use fitting parameters output by Mosaic-Math to calculate dust-based molecular hydrogen masses and luminosities to compare to similar measures computed using CO, especially ^{12}CO , as a molecular gas tracer. Recent results from Barnes et al. (2015), Kong et al. (2015), and Narayanan & Krumholz (2014) suggest the large fractions of H_2 not being traced by CO (aptly-named CO-dark gas) may be overstated due to improper calibration of the conversion from CO line intensity to H_2 column density. Therefore, I use molecular gas masses traced by dust to estimate the bias in the the traditional X-factor equation and the conversion methods for other species.

From kpcs to the central parsec of galaxies: direct visualization of the feeding process of nuclear star formation and a black hole

Prieto, Almudena

IAC

ABSTRACT: We present the first panchromatic "parsec-scale" view of the star forming and black hole feeding process in the centre of some of the nearest, medium to low activity galaxies nucleus. The talk will focus on the emblematic galaxy NGC 1097, a low activity galactic nucleus surrounded by a face-on view of a remarkable star forming ring. The assembled radio, millimetre, IR, optical, and UV data, all at subarcsec, ~ 10 pc FWHM, resolution scale, allows us to characterise the individual emission of several hundred of young star clusters in the ring and trace the filamentary dust and molecular gas material that nourish both and at the same time the star clusters and the central black hole.

Giant Molecular Filaments in the Milky Way

Ragan, Sarah

Cardiff University

ABSTRACT: Throughout the Milky Way, molecular clouds typically appear filamentary in morphology on what seems like all possible scales. Using the wealth of Galactic plane survey data, we have identified velocity-coherent filaments on up to 100-pc size scales. This discovery enables us to begin connecting the ubiquitous filamentary clouds to Galactic structure. I will review the identification and characterisation of giant molecular filaments (GMFs) in the Galaxy, highlighting the advantages and biases inherent in different methods. GMFs are found both clearly aligned with spiral arms and in inter-arm regions of the Galactic plane, providing an interesting basis with which to compare them to their extragalactic analogues. GMFs are an important new laboratory in which we can gain a greater understanding of how molecular cloud and star formation depends on their Galactic environment.

Deriving the Star Formation History of Stellar Systems Containing Few Stars

Ramirez Siordia, Victor Hugo

IRyA, UNAM

ABSTRACT: The Star Formation History (SFH) of resolved stellar systems, like globular clusters and satellite galaxies of the Milky Way, can be determined from their current stellar content using one or more color magnitude diagrams (CMD) describing the photometry of the stars in the system. Evolved theoretical starbursts can be plotted as isochrones on these CMDs. The shape of the isochrone is a function of age and metallicity. By obtaining the best fitting isochrone we can recover the most likely SFH of such systems. We present and use a Bayesian Maximum Likelihood method which enables us to recover SFHs even if only a small number of stars (hundreds) is available.

Exploring the role of large scale flows in molecular cloud formation in spiral galaxies

Ramón-Fox, Gerardo

University of St. Andrews

ABSTRACT: Star formation is a process that initiates in the large-scale dynamics of a galaxy and takes place in the small scales as individual star forming events. As the interstellar gas flows into a spiral arm, it forms a shock where the change in density, coupled to self-gravity and thermal instabilities, leads to the formation of molecular clouds. Internal dynamics in these clouds drive self-gravitating clumps where star formation occurs on dynamical timescales. The efficiency of star formation increases with gas density inside these structures. The interplay between these processes at different scales can be studied with the help of numerical simulations. We present results of high-resolution smoothed particle hydrodynamics and N-body simulations of a model spiral galaxy. Our model has a mass resolution in the gas component down to 45 solar masses. Compared to previous work, these simulations allow us to study galactic scale flows in spiral structure that forms self-consistently in a live stellar disc rather than using an imposed potential. We identify clouds in the simulation and trace their evolution and dynamics. The Lagrangian nature of our code allows us to trace the origin of the gas forming the clouds. We also study the cloud's physical parameters (e. g. mass, radius, velocity dispersion) and the relations between these parameters. These simulations provide a ground for studying the environmental dependence of cloud properties in a galaxy and for a global understanding of the conditions for star formation.

Near-Infrared Polarimetry of the S235 star-forming complex

Rangaswamy, Devaraj

INAOE

ABSTRACT: The S235 star-forming complex, with a size of 12.5 pc at a distance of 1.8 kpc, is situated on the outer Milky Way disk in the Perseus spiral arm. It contains two molecular clouds, S235 main and S235AB, each associated with expanding H ii regions ionized by massive stars. We present near-infrared H-band (1.6 μm) linear polarization measurements obtained for stars spread across a 20 arcmin region, carried out using the Mimir instrument. The background star light polarimetry probes the plane-of-sky magnetic field orientation of the S235 complex. The magnetic field lines appear to be pushed into a similar spherical-shell like morphology as seen for the expanding H ii region in S235 main. This may be due to strong magnetic field in the shell at regions of high density.

Evidence of inflow towards star-forming core from the external gas reservoir

Ren, Jeremy

National Astronomical Observatories, Chinese Academy of Sciences

ABSTRACT: The star-forming core should have a sufficient mass storage to feed the central star in particular for massive star formation. One possibility is the external supply, as suggested by the competitive accretion model (Bonnell & Bate 2006) and observed converging flows in the filament structures (e.g. Kirk et al. 2013; Peretto et al. 2013). In this work we present more evident cases that the external gas is being injected into the young star forming cores with considerable accretion rate of $>10^{-4}$ Msun/year. In our two investigated regions, the mass inflow could be driven by gas flow along the filament and the outflow from a companion core, respectively. In both regions, the flow is resolved around the star-forming core, and is terminated at the core, suggesting that the gas has mostly entered the core.

Insufficient Reservoirs of Molecular Gas to Form a Second Stellar Population in LMC Massive Star Clusters.

Rendón, Juan

University of Antioquia

ABSTRACT: Using photometric and spectroscopy data, it has been found that very massive and advanced ages ($> 6\text{Gyr}$) globular clusters (GC) have multiple stellar populations. Many theories have been proposed to explain the origin of the material that gave rise to these new populations, one of them explains that the massive GC ($> 10^4 M_{\odot}$) could accrete material from the interstellar medium and can retain a little fraction of the gas $\sim 0\%$ of the initial mass in the GC. In our study we used GC with masses $> 10^4 M_{\odot}$ and ages between 200 Myr and 1 Gyr with images of CO $J=1 \rightarrow 0$ in the Large Magellanic Cloud. We found that 30 clusters that accomplish with the characteristics of mass and age, and only in 3 of them we could detect that the GC are surrounded by an amount of material that is $< 2\%$ of the total mass of the cluster, which is insufficient to form a meaningful star population if all that quantity of material is converted to stars.

Systematic study of young star clusters in the galaxy NGC 253

Rodriguez, Jimena

IALP (CONICET-UNLP)

ABSTRACT: We carried out a search and identification of young stellar groups on a large area of the spiral galaxy NGC 253. The study was based on images of five fields observed with the ACS/WFC camera of the Hubble Space Telescope. For the identification of these groups, we have used different search methods over a selection of bright blue stars. These methods consist in perform a large scale search by means of building stellar density maps, and then, a more detailed search using the PLC method that takes into account the spatial distance between objects. As a result, we have estimated sizes and densities of the identified groups and we have built their corresponding radial density profiles, colour-magnitude diagrams and luminosity functions. These tools have allowed us to derive the fundamental characteristics of the groups. Moreover, we found an important variation of the reddening throughout the galaxy, and we were able to establish different structures at several levels of stellar density that reveal the hierarchical structure of the young population in NGC 253.

Star Formation at High redshifts

Rodríguez Espinoza, José Miguel

Instituto de Astrofísica de Canarias

ABSTRACT: I will discuss star Formation at very high z 's, including star formation of LAEs and LBGs. I will also comment on the fact that recurrent star formation is seen in some sources. Finally I will show the existence of large Lyman alpha Blobs, which are typically powered by several Lyman alpha emitting sources that are concurrently undergoing violent star formation. This work is based on studies of the SHARDS survey, carried out with GTC/OSIRIS

A survey of 44-GHz Class I methanol masers toward High Mass Protostellar Objects

Rodríguez-Garza, Carolina

IRyA, UNAM

ABSTRACT: We present results of 44-GHz Class I methanol maser observations made with the Very Large Array toward a sample of 55 High Mass Protostellar Objects. We found a 44% detection rate of the methanol maser emission. We also present a comparison of the location of the 44-GHz masers with respect to shocked gas traced by the Extended Green Objects seen in the Spitzer/IRAC bands.

EARLY SCIENCE WITH THE LARGE MILLIMETER TELESCOPE: a 3 mm spectral line survey of massive protostars with class I methanol masers

Rodríguez-Garza, Carolina

IRyA, UNAM

ABSTRACT: We present new millimeter spectral line observations of 38 massive star-forming regions in the Milky Way. The observations were part of the Early Science Program of the Large Millimeter Telescope, using the wide-band Redshift Search Receiver (RSR). Our primary goal was to search for possible maser emission in the class I methanol transitions at 84.521 and 95.169 GHz and the class II transitions at 107.013 and 108.893 GHz. Nevertheless, the 73 to 111 GHz RSR bandpass covers many other spectral lines that are common in star-forming regions. Although the spectral resolution of the RSR is quite low (~ 100 km/s), we were able to unambiguously identify a number of spectral lines. We show an overview of the molecular lines detected and present an analysis of the correlation between the different methanol transitions. Confirmation of maser emission will require follow-up observations, but our survey found numerous regions with rich molecular emission.

Non-Thermal Emission From Protostellar Jets

Rodríguez-Kamenetzky, Adriana

Instituto de Astronomía Teórica y Experimental (IATE), Córdoba, Argentina.

ABSTRACT: Deeply embedded protostellar jets are well known to be dominated by emission of thermal electrons. Interestingly, non-thermal emission in some protostellar jets has been detected through negative spectral indices, with the exception of HH 80-81 (one of the most powerful and brightest jets known) for which linearly polarized radio emission was also detected. This was interpreted as a synchrotron component produced by a small population of relativistic particles, that might be accelerated in strong interactions of the jet with the ambient medium. In this work we present results of an observational campaign with the JVL A to study synchrotron emission from a sample of protostellar jets, and discuss in the context of particle acceleration. We analyze high sensitivity multi-frequency data of three representative protostellar jets: HH 80-81, Triple Source in Serpens, and HH 1-2; which are known to be driven by a massive, intermediate, and low-mass protostar, respectively. Our results provide strong evidences that some protostellar jets are more complex than previously thought, clearly differing from the simple thermal structure commonly associated with them.

W3: An intimate approach to massive star cluster formation

Román-Zúñiga, Carlos

Instituto de Astronomía UNAM

ABSTRACT: Our multi-wavelength study of the young star content in the W3 Complex (Román-Zúñiga et al. 2015) revealed important details about the early evolution a family of at least five entangled young star clusters hosting massive stars. We found that strong gas outflows in the main embedded cluster, account for rapid gas removal, which can explain the large fraction of disks across the complex despite the absence of parental gas in the central cluster IC 1795. Also, we found significant substructure in the spatial distribution of young stars, suggesting that formation was not centralized but organized in sub-clusters. Our new deep, high resolution images (GTC/CIRCE) of the W3(OH) cluster group reveal in detail the structure and content of sub-clusters, while radial velocity information from SDSS APOGEE-2 H-band spectra provide crucial information about the internal kinematics and the massive stellar content across the W3 cluster system (Román-Zúñiga et al. 2017 in prep). Altogether, these new datasets provide crucial insight on the process of formation and early evolution of massive clusters and are key for studies of more distant massive complexes. For instance, GTC images could tease upcoming edge quality infrared imaging data from the JWST.

An Unstable Truth: How Massive Stars get their Mass

Rosen, Anna

University of California, Santa Cruz

ABSTRACT: Massive stars play an essential role in the Universe. They are rare, yet the energy and momentum they inject into the interstellar medium with their intense radiation fields dwarfs the contribution by their vastly more numerous low-mass cousins.

Previous studies have concluded that the feedback associated with massive stars' radiation fields is an important mechanism regulating their formation. Therefore detailed simulation of the formation of massive stars requires an accurate treatment of radiation. For this purpose, we have developed a new, highly accurate radiation algorithm that properly treats the absorption of the direct radiation field from stars and the re-emission and processing by interstellar dust. We use our new tool to perform three-dimensional radiation-hydrodynamic simulations of the collapse of massive pre-stellar cores with laminar and turbulent initial conditions and properly resolve regions where we expect instabilities to grow. We find that mass is channeled to the stellar system via gravitational and Rayleigh-Taylor (RT) instabilities, in agreement with previous results using stars capable of moving, but in disagreement with methods where the star is held fixed or with simulations that do not adequately resolve the development of RT instabilities. For laminar initial conditions, proper treatment of the direct radiation field produces later onset of instability, but does not suppress it entirely provided the edges of radiation-dominated bubbles are adequately resolved. Instabilities arise immediately for turbulent pre-stellar cores because the initial turbulence seeds the instabilities. Our results suggest that RT features are significant and should be present around accreting massive stars throughout their formation.

Observational study of H to H₂ transition in the interstellar medium

Roshi, Anish

National Radio Astronomy Observatory

ABSTRACT: A fundamental aspect of the star-formation process is that it is extremely dynamic, involving a continuous gas flow from galactic (kpc) scales down to stellar scales. At some point in this process, the atomic (HI) gas needs to make a transition to molecular (H₂) gas and subsequently evolves to an active star-forming cloud. In many cases, these transition regions can be probed through absorption of the 21 cm line emission from the warm atomic gas by the colder foreground HI gas. This is referred to as HI self-absorption (HISA). Such HISA-producing regions produce observable low frequency (< 1 GHz) carbon recombination lines (CRLs). In this talk, we present the results of a program to observe CRLs toward HISA regions with the Green Bank and Arecibo telescopes. Following the work of Roshi and Kantharia (2011), we use CRL and HI data to constrain the physical properties of the HISA regions and the background FUV radiation flux density, as well as to derive H₂ formation and dissociation rates in the cloud interior.

OH gas properties and feedback in the Milky Way as seen in the THOR survey

Rugel, Michael

Max-Planck-Institute for Astronomy

ABSTRACT: Using the THOR survey (The HI/OH/Recombination survey of the Milky Way), we present OH ground state absorption observations against galactic and extragalactic continuum sources in the galactic plane. We determine kinematic properties, optical depth profiles and column densities for each absorption detection. The line ratios give insight into the excitation properties of the diffuse OH gas. The OH absorption detections are compared to existing galactic surveys in atomic and molecular gas tracers, such as ^{13}CO emission (GRS) and HI absorption observations (THOR). We compare kinematics of these tracers and the abundances in order to investigate which gas phase the OH traces. While the kinematic signatures indicate mixing of lower and higher density gas, OH is tracing both the molecular and atomic components of the ISM. The radio recombination lines obtained with this survey are employed to study feedback mechanisms: The comparison to publicly available surveys in atomic and molecular gas allow us to study their interaction.

Star formation in extreme environment: the case of Centaurus A

Salome, Quentin

Institut d'Astrophysique Spatiale

ABSTRACT: Star formation is one of the key mechanisms driving the formation and the evolution of galaxies across cosmic times. The physical properties and dynamics of the molecular gas influence the star formation efficiency, and therefore play a role in the growth of galaxies. Looking at large scales is therefore essential to understand the multi-scale physics of star formation. The environment may play a role in star formation. In particular, recent studies suggest that AGN can regulate the gas accretion and thus slow down star formation (negative feedback). However, evidence of AGN positive feedback is also invoked in a few radio galaxies (eg. Centaurus A, Minkowski's Object, 3C 285, ...).

I will present different studies of the northern filaments of Centaurus A at different resolutions. These filaments extend on scales up to 15 kpc, aligned with the radio-jet, and show evidence of recent star formation (Rejkuba et al. 2001). Along the radio jet, at the intersection of the radio jet and a HI shell (Schiminovich et al. 1994), CO emission has been detected with SEST in the shell (Charmandaris et al. 2000). We detect CO in a much larger area along the filaments with APEX, including outside the HI gas (Salomé Q et al. 2016a).

By confronting the CO emission from APEX to archival Herschel-FIR and GALEX-FUV data, we determined that the gas in the filaments is very inefficient to form stars (with depletion time of a few Gyr) compared to star-forming disc galaxies (Leroy et al. 2013; Salomé Q. et al. 2016b). This is strengthened by archival ALMA data that revealed the presence of unresolved CO(2-1) emitting clumps. We showed that these clumps are probably not gravitationally bound. By comparison with neutral HI (from VLA) and ionised gas (from MUSE), we confirmed evidence of a dynamical effect of the radio jet on the gas along the jet direction.

We recently performed ALMA observations along the filaments, at a resolution of ~ 20 pc. Such resolution enables to separate giant molecular without resolving them. I will present a statistical study of the clumps in the filaments, based

on their mass and size, to study their stability. In particular, the probability distribution function of the mass can provide information on the turbulence in the clumps.

An ALMA view of SgrB2: continuum characterization and spectral line survey

Sanchez-Monge, Alvaro
University of Cologne

ABSTRACT: The giant molecular cloud complex SgrB2 is the most massive region with ongoing star formation in the Galaxy. It is located at a projected distance of about 100 pc along the plane to the Galactic Center and at 8.5 kpc from the Sun. The whole complex contains a total gas mass of 10^7 Msun, with the main sites of active star formation corresponding to the hot molecular cores SgrB2-N and SgrB2-M that are located at the center of the complex. They contain more than 50 high-mass stars with spectral types ranging from O5 to B0, and constitute one of the best laboratories for the search of new chemical species in the Universe.

We have conducted a high-spatial resolution, spectral line survey of the two hot cores SgrB2-M and SgrB2-N with ALMA. Despite their similar masses ($3\text{--}7 \times 10^4$ Msun) and luminosities ($1\text{--}6 \times 10^5$ Lsun), the ALMA observations reveal clear differences between the two objects. A study of the continuum emission reveals a clearly fragmented structure in SgrB2-M, while SgrB2-N remains monolithic and contains one of the, probably, most massive, not fragmented condensations in the Galaxy. Furthermore, SgrB2-M and SgrB2-N have a very different chemical composition, with M being rich in sulphur-bearing molecules and N in complex organics. The observational results are compared with previous VLA and SMA observations and with 3D radiative transfer models that reproduce the structure of the SgrB2 complex from 100 au to 45 pc scales.

Here we present the first results of the ALMA project as well as some new tools to characterise the continuum emission in line-rich sources, as well as the spectral line properties.

SOFIA, a unique observatory for studying star formation process

Sandell, Göran

SOFIA/USRA

ABSTRACT: SOFIA, the Stratospheric Observatory for Infrared Astronomy, is now in full operations and is the only FIR mission for years to come. In Cycle 6 we offer more than 600 hrs of observing time with six different instruments. SOFIA is a Boeing 747-SP airplane with a 2.5 m telescope, operating at altitudes from 12 to 14 km, above 99% of the water vapor in the Earth's atmosphere. The telescope is diffraction limited at wavelengths beyond $\sim 15 \mu\text{m}$. At $100 \mu\text{m}$ the resolution is $\sim 10''$, which is comparable to the angular resolution of large ground based mm/sub-mm telescopes such as APEX, IRAM, JCMT, and LMT. SOFIA extends the wavelength coverage from sub-millimeter to far- and mid-infrared and allows studies of molecules and fine structure lines using instruments like GREAT, FIFI-LS, EXES, and in 2019 also HIRMES. FORCAST and HAWC+ provide mid- and FIR-imaging capabilities. HAWC+, our FIR camera is also an imaging polarimeter. In this poster we summarize the characteristics of some of the instruments and give some examples of recent results.

Gas dynamics driven by an O-type YSO: from 0.1 pc down to 100 AU

Sanna, Alberto

MPIfR

ABSTRACT: G023.01-00.41 is a luminous ($4 \times 10^4 L_{\odot}$) star-forming region at an HMC stage, which stands out among the strongest Galactic CH₃OH maser sources, and shows a unique CH₃OH maser fountain spouted from its HMC center. With the aim of characterising the core/outflow dynamics around an O-type YSO at different scales, in the past few years we have performed an observational campaign towards the HMC of G023.01-00.41 with several interferometric facilities, including: SMA at 230 and 345 GHz (HPBW of 3"-0.7"), JVLA at 8, 22 and 45 GHz (HPBW of 0.3"-0.1"), ALMA data at 230 GHz (HPBW of 0.2"), and VLBI observations at 1, 6, and 22 GHz (HPBW of 10-1 mas).

In this talk, I will present a comprehensive picture of the outflowing gas from the HMC, from the Spitzer green fuzzy emission at 4.5 μm , through the SMA CO and SiO secondary outflow components, and down to the primary outflow, which is underlined by a (collimated) radio thermal jet (JVLA) and strong H₂O maser shocks (VLBI multi epochs). I will show that the momentum-transfer efficiency, between the inner jet emission ($< 3 \times 10^3$ AU) and the extended outflow of entrained ambient gas ($> 10 \times 10^3$ AU), is near unity. A unique piece of information comes from the first picture of both the 3D kinematics and the magnetic field morphology of gas within 1000 AU of the HMC center, as obtained from 6.7 GHz CH₃OH maser observations (VLBI multi epochs). Maser cloudlets trace an ordered motion away from the HMC center, which recollimates towards the outflow axis. Locally (5-10 AU), the masing gas shows a significant alignment between the velocity and magnetic field vectors. This last finding might explain the high degree of (primary and secondary) outflow collimation. On the other hand, the dust emission in the SMA bands shows fragmentation at radii greater than about 5000 AU from the driving source of the outflow, which coincides with the dust continuum peak in the region. HMC lines are only detected towards this core. I will finally present brand-new ALMA observations in band

6 of the HMC (observed in September), which were designed to complement the spatial resolution (800 AU) of the JVLA observations.

HCN Hyperfine Analysis of Massive Clumps

Schap, William

University of Florida

ABSTRACT: We report a new analysis protocol for HCN hyperfine data, based on the PySpecKit package (Ginsburg & Mirocha 2011), and results of using this new protocol to analyze a sample area of 7 massive molecular clumps from the CHaMP survey (Barnes et al. 2011), in order to derive maps of column density for this species. There is a strong correlation between the HCN integrated intensity, I_{HCN} , and previously reported I_{HCO^+} in the clumps, but $I_{\text{N}_2\text{H}^+}$ is not well-correlated with either of these other two “dense gas tracers”. The four fitted parameters from PySpecKit in this region range over $\text{VLSR} = 8\text{--}10$ km/s, $\sigma_V = 1.2\text{--}2.2$ km/s, $T_{\text{ex}} = 4\text{--}15$ K, and $\tau = 0.2\text{--}2.5$. These parameters allow us to derive a column density map of these clouds, without limiting assumptions about the excitation or opacity. A more traditional (linear) method of converting I_{HCN} to total mass column gives much lower clump masses than our results based on the hyperfine analysis. This is primarily due to areas in the sample region of low I , low T_{ex} , and high τ . We conclude that there may be more dense gas in these massive clumps not engaged in massive star formation than previously recognized. If this result holds for other clouds in the CHaMP sample, it would have dramatic consequences for the calibration of the Kennicutt-Schmidt star formation laws, including a large increase in the gas depletion time-scale in such regions.

From large to small scales: mass reservoirs in NGC6334

Schilke, Peter

University of Cologne

ABSTRACT: Observations with the Herschel Satellite have torn down the wall between large-scale and small-scale studies, and put the spotlight on the cascades of mass flow from large to small scales, which are an important ingredient in star formation. I will present large-scale APEX observations of molecular lines in the high-mass star-forming filament NGC6334, and discuss what can be learned from an analysis of the mass reservoirs and velocity field.

Searching for collimated outflows candidates in massive star-forming regions.

Sergio, Omar

Instituto Nacional de Astrofísica, Óptica y Electrónica.

ABSTRACT: The formation of massive stars remains as an unsolved problem in modern astrophysics. Understanding their formation is imperative, because they dominate the luminosity, kinematic and chemical enrichment of the ISM. Nevertheless, despite the significant observational and theoretical advances that had been made, a consensus about how this objects are formed has't been established. In this work we tried to answer whether massive protostars present a phase in which fast and collimated outflows are a key characteristic of the formation process, similar to the low-mass regime. We selected a sample of massive protostellar objects candidates from the GLIMPSE and ATLASGAL surveys and mapped them in the SiO (5-4) line with the IRAM-30m telescope. We detected the emission in all objects. In one case we found extremely high velocity emission, that if similar to low-mass outflows, would then be associated with fast and collimated outflows. To date only a handful of massive protostars have been confirmed with extremely high velocity emission, therefore our finding is an important addition that will require interferometric follow-up observations. In our work we present the physical conditions determined from the molecular emission and we also compare with the structures imaged in the mid-infrared. Finally we put in context our sample with other larger samples in which the SiO emission has been studied.

The Very Large Array ammonia observations of the HH 111/HH 121 protostellar system: a detection of a new source with a peculiar chemistry

Sewilo, Marta

NASA Goddard Space Flight Center

ABSTRACT: We present the results of Very Large Array NH₃ (1,1) and (2,2) observations of the HH 111/HH 121 protostellar system located in L1617 in the Orion B molecular cloud. HH 111, with a spectacular collimated optical jet, is one of the most well-known Herbig-Haro objects. We report a detection of a new source (NH₃-S) in the vicinity of HH 111/HH 121 (~15 arcsec or 7200 AU from the HH111 jet source), in two epochs of the ammonia observations. Interestingly, this constitutes the first detection of this source, in a region which has been thoroughly covered previously by both continuum and spectral line interferometric observations. The properties of NH₃-S, including the fact that it is located in the Spitzer dark cloud, and the proximity to the Herbig-Haro jets indicate that it may be an externally illuminated molecular clump. The Herbig-Haro objects thus provide a useful tool for studying molecular clumps through their response to radiation; in turn, the elucidated clumpiness of molecular clouds is of relevance to the initiation of star formation. We combine the VLA ammonia data with the JCMT HCN and HCO⁺ and the archival ALMA Band 6 (1 mm) molecular line and continuum data to study the physical, chemical, and kinematic properties of NH₃-S.

Multiplicity of Pre-Main Sequence M-dwarfs in Young Moving Groups (YMGs)

Shan, Yutong

Harvard University

ABSTRACT: Pre-main sequence (PMS) binary stars are immediate products from one of the dominant yet significantly less-understood channels of the star-formation process. YMGs are sparse ensembles of PMS stars with relatively well-determined ages and uniform histories, making their multiplicity properties a valuable data point for constraining star formation theories and isolating subsequent evolutionary effects. Recently, many low-mass YMG members have been newly identified, though the multiplicity situations of these stars are hitherto unclear. Here we present data and analysis from our Magellan Adaptive Optics (MagAO) campaign to image more than 100 K- and M-dwarf members of several YMGs in the southern sky, revealing ~ 30 previously unresolved visual stellar companions at separations of ~ 3 — 300 AU.

Our study provides statistics for PMS M-dwarf multiples in an intermediate regime of orbital distance (across the hard-soft boundary), including distributions in physical separations and mass ratios. When combined with the SACY survey for YMG systems with sunlike primaries (e.g. Elliott et al. 2015), we are able to provide an updated measurement of young-star multiplicity as a function of stellar mass, age, and environment, with significantly more statistical power at lower masses. We hope to discuss any implications for the universality and scalability of star formation and evolution processes, as well as comparisons to measurements in related populations (e.g. cluster, field, young, old, FGK stars) which form a storyline that theory must explain.

Universality of the relationship between the star formation rate and the mass of dense gas

Shimajiri, Yoshito

CEA

ABSTRACT: Essentially the same relation between star formation rate (SFR) and mass of dense gas above the threshold (M_{dense}) is found in nearby clouds [$\text{SFR}/M_{\text{dense}}=4.6 \times 10^{-8}$, Lada et al. 2010] and external galaxies [$\text{SFR}/M_{\text{dense}}=1.8 \times 10^{-8}$, Gao & Solomon 2004]. A very similar relation can be derived from the Herschel results in nearby clouds, suggesting that the star formation scenario sketched above may well apply to the ISM of other galaxies (Andre et al. 2014). In other words, there may be a quasi-universal star formation law" converting the dense molecular gas of supercritical filaments into stars above the threshold at $A_V = 8 \text{ mag}$. They, however, used the different dense gas tracers. To investigate the universal star formation law converting the dense molecular gas into stars, wide-field mapping observations in the same dense gas tracers are crucial. We carried out wide-field line mapping observations in dense gas tracers HCN(1–0), H₁₃CN(1–0), HCO⁺(1–0), and H₁₃CO⁺(1–0) with a spatial resolution of $\sim 0.04 \text{ pc}$ toward the Aquila, Ophiuchus, and Orion B clouds using the IRAM 30m, MOPRA 22m, and Nobeyama 45m telescopes in the on-the-fly mode. In the three regions, the spatial distribution of H₁₃CO⁺ and H₁₃CN emission is very similar to that seen in the column density maps derived from the Herschel Gould Belt Survey data, showing that the H₁₃CO⁺ and H₁₃CN lines are good tracers of the dense filaments detected by Herschel. The HCN and HCO⁺ intensities are more poorly correlated with column density and tend to be stronger in stronger FUV field. We also estimated the mass of dense gas $M(\text{Herschel} > 8 \text{ mag})$ from the Herschel column density toward the area above $A_V = 8 \text{ mag}$ and regarded $M(\text{Herschel} > 8 \text{ mag})$ as M_{dense} . As a result, we found that $\alpha(\text{Herschel-HCN})$ conversion factor spans a wide range of values of 35–454. The obtained $\alpha(\text{Herschel-HCN})$ values are much larger than those found in the external galaxies and are strongly correlated with the local FUV field strength. The $\alpha(\text{Herschel-HCN})$ values decrease as the strength of the FUV radiation field increases, scaling as $\alpha(\text{Herschel-HCN})\text{-fit} = 332.2 \times G(0, \text{total})^{-0.23}$. The SFRs from the number count

of the Class II objects in the observed clouds is estimated to be $(1.0\text{--}22.0)\times 10^{-6}$ Msun/yr. We found that the relationship between SFR and M_{dense} in our observing clouds can be expressed as $\text{SFR}/M_{\text{dense}} = (1.5\text{--}3.5)\times 10^{-8}$. The SFR- M_{dense} relation in our study is consistent with that of Lada et al. (2010). We estimated the dense gas mass for the external galaxies using our relation of $\alpha(\text{Herschel-HCN})\text{-fit} = 332.2 \times G(0, \text{total})^{-0.23}$. We concluded that the relationship between the star formation rate and the mass of the dense gas in the external galaxies is likely to be similar to that in the nearby star-forming regions. Our result supports the views that the relationship between the star formation rate and the mass of the dense gas, i.e., the star formation efficiency in dense gas, is quasi-universal on the scale from >10 kpc to 1-10 pc.

Dust emission of protoplanetary disks

Sierra, Anibal

Instituto de Radioastronomía y Astrofísica, UNAM

ABSTRACT: We study the emission of protoplanetary disks with a vortex. We introduce an analytically dust differential accumulation within the vortex, which changes the dust to gas mass ratio and the slope of the dust size particle distribution, and compare these results (images + SED) with a model with a constant dust to gas mas ratio (1/100) and fixed slope of the dust particle size distribution.

Formation of stellar clusters in galactic spiral arms

Smilgys, Romas

University of St Andrews

ABSTRACT: {We investigate the triggering of star formation and the formation of stellar clusters in molecular clouds that form as the ISM passes through spiral shocks. We use the Lagrangian nature of SPH simulations to trace how the star forming gas is gathered into self-gravitating cores that collapse to form stars. We find that the large-scale flows are necessary to produce the dense clouds where gravitational collapse and star formation occur. Local gravitational collapse requires densities in excess of $>10^3 \text{ cm}^{-3}$ which occur on size scales of $\approx 1 \text{ pc}$ for low-mass star forming regions ($<100 M_{\odot}$), and up to sizes approaching 10 pc for higher-mass regions ($>10^3 M_{\odot}$). Star formation in the 250 pc region lasts throughout the 5 Myr timescale of the simulation and produces stellar clusters up to several $10^4 M_{\odot}$ with half-mass radii of $1\text{-}2 \text{ pc}$. These clusters grow through accreting both gas and stars. The hierarchical merging process also results in significant age spreads of up to several Myr .

The role of the magnetic field in the formation of density structures in molecular clouds as revealed by dust polarized thermal emission

Soler, Juan Diego

CEA/Saclay

ABSTRACT: We present a study of the relative orientation between the total gas column density structures, inferred from the Herschel submillimetre observations, and the magnetic field projected on the plane of sky, inferred from the polarized thermal emission of Galactic dust observed by Balloon-borne Large-Aperture Submillimetre Telescope for Polarimetry (BLASTPol) at 250, 350, and 500 μ m, towards the Vela C region, a massive molecular complex located at approximately 700 pc from the Sun.

We find that the relative orientation changes progressively with increasing column density, from mostly parallel or having no preferred orientation to mostly perpendicular, in agreement with previous studies by the Planck collaboration towards nearby ($d < 450$ pc) molecular clouds.

We discuss the implication of these observational results in terms of the physical conditions in a set of molecular clouds selected from numerical simulations of turbulent, magnetized, self-gravitating, multi-phase, supernovae-regulated medium within a 1-kiloparsec-side stratified box. We describe the relative orientation trends found in the density and magnetic field structures in 3D, and in the corresponding synthetic observations of column density and polarization, and discuss its connection with the role of the magnetic field, turbulence, and gravity in the formation of density structures in the ISM.

Presented on behalf of the BLASTPol collaboration in association with P. Hennebelle.

TOWARDS A COMPLETE STUDY OF THE INITIAL MASS FUNCTION AND EARLY KINEMATICS EVOLUTION OF THE 25 ORIONIS STELLAR GROUP

Suárez, Genaro

Instituto de Astronomía UNAM

ABSTRACT: The ~7-10 Myr old stellar group 25 Orionis is one of the most numerous and spatially dense populations at this age within the ~400 pc from the Sun and presents minimum extinction. These properties make 25 Ori an ideal laboratory to study the Initial Mass Function (IMF) in the entire mass range ($0.01 < m/M < 10.0$). We will present the first results of a project to construct the photometric and spectroscopic IMF with a statistically complete sample across the whole mass spectrum of this stellar group.

We will show the first photometric IMF of the 25 Orionis stellar group into the whole mass range. Additionally, we will present the following advances in the collection of required spectra: i) 50 new confirmed M0-M6 spectral type members using SDSS-III/BOSS low-resolution optical spectra (Suárez et al. in prep.). ii) OAN-SPM/Echelle spectra of 100% of the expected members with $m > 2.0$ M. iii) SDSS-IV/APOGEE-2 high resolution spectra to cover the 100% of the expected members in the mass range $0.40 < m/M < 6.0$. iv) MMT/Hectospec low resolution spectra to cover the 80% of our candidate members in the mass range $0.09 < m/M < 0.6$. v) GTC/OSIRIS low resolution spectra of 70% of our candidate members with $m < 0.02$ M.

High resolution spectra (OAN-SPM, APOGEE-2) will provide radial velocities which will allow us to study the kinematics of the group along with available proper motion information, in order to determine if 25 Orionis is a gravitationally bound stellar group.

Properties of Starless Clumps through Protoclusters from the BGPS

Svoboda, Brian

University of Arizona

ABSTRACT: The study of the earliest evolutionary phases of HMSFRs (starless clumps) has been difficult due to their distance, deeply-embedded environments, and historical lack of blind surveys to identify them. To this end, we identify a subsample of 2223 (47.5% total) starless clump candidates (SCCs) from the $\lambda=1.1$ mm Bolocam Galactic Plane Survey. We analyze the physical properties, boundedness, and timescales of SCCs compared to protostellar clumps with statistically robust samples. The median SCC is marginally sub-virial ($\alpha \sim 0.7$) where $>75\%$ with well-constrained distances are gravitationally bound ($\alpha < 2$), and we find statistical evidence that the ratio of SCC to protostellar-clump phase timescales varies proportional to the clump mass as $M^{-0.4}$. In addition, ALMA observations of the 12 most massive SCCs within 5 kpc show significant fragmentation, chemical diversity, and hitherto unobserved low-luminosity protostellar activity. Analysis of the fragmentation mass and length scale distributions are used to place this unique sample in the context of HMSF theories and simulations.

A new infrared view of the NGC 6634-V region

Tapia, Mauricio

Instituto de Astronomia UNAM-Ensenada

ABSTRACT: A comprehensive analysis is presented of the most recent infrared observations of the small, very young and enigmatic infrared nebula associated with NGC 6334-V. We re-analyzed images from the pitzer/IRAC (3.6 to 8 μm), Herschel/SPIRE/PACS (70 to 500 μm), VISTA (1.2 to 2.2 μm), VLT/VISIR (11.3 to 18.7 μm) and HST/NICMOS (2.0 μm) archives. The very high spatial resolution from the latter two sets, combined with very recent sub-millimetre maps, allow us to suggest several possible star-formation scenarios that explain the observed infrared and radio properties of the region. Evidence is provided of the presence of a small population of low and medium-mass young stars embedded in the infrared reflection nebulosity NGC 6334-V that coexist with the nearby much younger Class 0 protostars. On a larger spatial scale and by means of near-IR photometry, we determine the properties of the stellar population of the star cluster embedded in the extended radio HII region that seems to enclose the much younger NGC 6334-V region. MT acknowledges PAPIIT-UNAM grant IN-104316.

The heating efficiency and the star formation rate in very young stellar clusters

Tapia Schiavon, Luis Fernando

IRyA, UNAM

ABSTRACT: We present a preliminary results of the three-dimensional numerical simulation exploring the filamentary formation induced by stellar winds. We calculated the heating efficiency and star formation rate in the filamentary structure into the stellar cluster volume. In our models, we used the GUACHO code (see Esquivel et al. 2009 & Raga et al. 2009) to perform all numerical simulations. The code solves the hydrodynamic equations including radiative losses (atomic and molecular), isotropic thermal conduction, photoevaporation, the gravity of the stellar objects, and the self-gravity of the gas. We also considered the evolution of 110 ionic/atomic/molecular species.

Mid-IR and Centimeter Observations of 20 High-Mass Protoclusters in the Milky Way

Towner, Allison

University of Virginia

ABSTRACT: On sizescales of 0.1 pc, Extended Green Objects (EGOs, so named due to their extended 4.5 micron emission) are thought to harbor massive young stellar objects in an evolutionary phase in which mass accretion is actively driving outflows. We have been conducting a multi-wavelength examination of a sample of 20 EGOs in the Milky Way with distances of 1 to 8 kpc. Here, we present results from 1.3 cm JVLA observations of these objects with 1" - 3" resolution (~5000 AU) in the continuum and in NH₃ inversion transitions from (1,1) to (6,6). Our 1.3 cm continuum observations are the most sensitive observations of these objects to date at this frequency, and have allowed us to assess the presence of free-free emission. The ladder of NH₃ inversion transitions allows us to probe the morphology, kinematics, and physical properties of the dense gas in these EGOs. We will also present new SOFIA mid-IR data for a subset of the sample that will be used to refine the luminosity of these massive protoclusters.

On the origin of non-thermal motions in massive star forming clumps

Traficante, Alessio

INAF-IAPS

ABSTRACT: In this talk I will discuss the results obtained combining data from massive clouds, clumps and cores to investigate the observed non-thermal motions in massive star formation. It is still unclear if the formation of massive stars occurs in pressure-confined regions, supported against a quick collapse by the highly turbulent medium and possibly magnetic fields, or if the gravity is the driver of the observed non-thermal motions, leading to a much faster, gravo-turbulent collapse.

There is an increasing evidence that the Larson line-width size relationship, often interpreted as a consequence of the turbulence that drives the non-thermal motions in massive regions, is violated. Instead, a significant contribution to the observed supersonic motions may be driven by the gravity itself, modifying the relation in a dependence of the line-width with both the size and the mass surface density of the regions.

I will show the results obtained combining Hi-GAL dust continuum with MALT90 line emission data to obtain the gravo-turbulent properties of a large sample of hundreds of clumps. In particular, I will show that these data do not follow the Larson relationships. I will discuss the major implications of this result in the context of the main star formation theories available today

An accreting and converging filamentary hub in MonR2

Trevino-Morales, Sandra Patricia

Instituto de Ciencia de Materiales de Madrid (ICMM - CSIC)

ABSTRACT: In the last years, the satellite Herschel revealed that molecular clouds are formed by complex networks of filaments intersecting in high-density regions called hubs. Star formation within molecular clouds has been found to occur preferentially along these filaments, with high-mass stars forming at the hubs. This is the case of MonR2, at a distance of only 830 pc, is the most active star formation site in the Monoceros molecular cloud. It contains a cluster of recently formed high-mass stars driving an ultracompact HII region, that expands and has created a cavity free of molecular gas surrounded by a series of photon-dominated regions. Herschel observations in the continuum reveal a filamentary network converging into the central hub that hosts the HII region. However, these continuum observations lack the kinematic information, which is fundamental to characterize and understand the motion of the gas forming the stars. We have carried out large-scale maps of MonR2 in several molecular tracers lines with the IRAM-30m telescope. The high spatial (0.12 pc) and spectral (0.25 km/s) resolution, together with the large covered area (7x6 pc²) allow us to study in detail the filamentary structure and its kinematic properties. We have identified a number of velocity-coherent filaments with velocity gradients of 1-2 km/s/pc, corresponding to mass accretion rates of 10⁻³ Mo/yr. The filaments have signs of fragmentation indicating that stars can also form along the filaments before all the mass is gathered in the central hub. Finally, we find hints of a spiral structure connecting the filaments and approaching the expanding HII region. Overall, this suggests the idea of a young HII region breaking out of the dense filamentary hub where it was formed, with material still flowing inward along the filaments.

Deuteration around the ultracompact HII region Mon R2

Trevino-Morales, Sandra Patricia

Instituto de Ciencia de Materiales de Madrid (ICMM - CSIC)

ABSTRACT: MonR2 is the most active star formation site in the Monoceros molecular cloud. It contains a cluster of recently formed high-mass stars driving an HII region that is surrounded by a series of photon-dominated regions (PDRs). On basis of IRAM-30m observations, we have studied the chemistry toward two positions (namely IF and MP2) in Mon R2. We found a rich chemistry, the list of detected molecules including typical PDR tracers, complex molecules, deuterated species, ionic species and radio recombination lines. In particular, we performed a detailed study of the deuterated molecules (C2D, DCN, DNC, DCO⁺, D2CO, HDCO, NH2D, and N2D⁺) and a comparison of our results with those presented in other works for different sources, as well as with the pseudo time-dependent model. Our high spectral resolution observations allow to resolve three velocity components associated with different PDRs exposed to different UV radiation fields. We calculate the deuterium fraction ($D_{\text{frac}} = [XD]/[XH]$) of the different species to be about 0.01, except for HCO⁺ and N2H⁺ with values 10 times lower. The D_{frac} values found in MonR2 are similar to those measured in the Orion Bar, and are well explained with a pseudo-time dependent gas-phase model for an object with an age of 0.1 Myr. The deuterium chemistry is used to study the evolutionary stage of different low-mass and high-mass star forming regions. However, chemistry is more complex in massive star forming regions than in the nearby low-mass protostars and a complete chemical model involving several deuterated compounds is necessary to determine the protostellar age.

boloSource() for the analysis of diffuse emission and crowded-field photometry

Vavrek, Roland

European Space Agency

ABSTRACT: An extraordinary feature exhibited by the Herschel maps of star forming complexes is the ubiquitous pattern of filaments never seen before in the far-infrared down to ~ 6 arcseconds spatial resolution. Morphological and complexity analysis of large fields is essential to understand the link between diffuse ISM structure and embedded star formation (SF). Preserving statistical properties of the diffuse background while a large number of [UTF-8?]'disturbing' foreground- and embedded sources are present is a non-trivial task. Source-free clean maps provided by the novel boloSource() package enable us to study the spatial properties of background emission not being biased by the sharp fingerprint of embedded features. The boloSource() algorithm works on the flux calibrated Herschel/PACS detector timeline, it aims to separate sky signal from detector $1/f$ noise and applies an adaptive interpolation method which simulates the power spectrum of instrument noise reconstructed from the observation itself. These interpolated source-free timelines are re-projected onto a map using inversion algorithms standard for Herschel data processing (e.g. JScanam, Unimap, Scanamorphos). Besides the good quality of point-source subtracted maps, the boloSource algorithm provides an alternative way of source photometry in crowded fields, and can mitigate the impact of reconstruction artifacts of mapping algorithms.

Global Hierarchical Collapse in Molecular Clouds

Vazquez-Semadeni, Enrique

IRyA UNAM

ABSTRACT: I argue that molecular clouds (MCs) and their substructure (clumps and cores) may be in a state of Global Hierarchical Collapse (GHC), consisting of collapses within collapses. I then describe the main features of this proposed regime. The clouds form by condensation in the warm diffuse atomic phase triggered by compressions, and, upon the transition to the cold dense phase, their Jeans mass drops by a factor $\sim 10^4$, so that the clouds rapidly become strongly gravitationally unstable and begin to collapse globally. Since the clouds are nearly isothermal, the global collapse implies a secular reduction of the average Jeans mass within the clouds. The compression also produces turbulence within the MCs, which induces a spectrum of density fluctuations, with the densest regions having the smallest sizes. Once the average Jeans mass in the MC become of the order of the mass of the small-scale fluctuations, these begin to collapse, but may complete their collapse earlier than the larger-scale, less dense fluctuations, because of their shorter free-fall time. Moreover, the small-scale fluctuations ride on the large-scale collapse flow, and accrete onto the troughs of the large-scale gravitational potential. Moreover, the large-scale collapse deviates from isotropy because at those scales the clouds contain many Jeans masses, implying that thermal pressure is negligible. Thus the large-scale collapse flow consists of sheets and filaments that accrete onto the main collapse centers. The small-scale collapses form low-mass cores that ride over the filamentary flow to those large-scale centers (massive clumps) that accrete both gas and stars through the filaments. This flow regime explains several observed features of star forming regions and their embedded young clusters, like an apparently subvirial state of dense cores, an increasing star formation rate, the YSO age distribution, and mass and age gradients within the clusters.

Star formation efficiency in tidal tails of mergers

Vega-Acevedo, Ignacio

Instituto Politécnico Nacional

ABSTRACT: The star formation in distant galaxies occurs in a very turbulent ISM similar to the mergers in the local Universe. Interstellar turbulence has dropped in today's spiral galaxies, but is boosted up again when collisions occur. Hence, nearby mergers provide a unique opportunity to study the conditions of the star-forming ISM in environments resembling those present at high redshift. We have studied the star formation, SF, along the tidal tails of six interacting systems using high-resolution HI images from VLA and UV images from GALEX. Star formation rates have been obtained for those clumps with HI masses larger than 10^8 Msun which have UV emission. The efficiency of the SF is larger in these clumps, $SFE=10^{-10}$ yr $^{-1}$, than in isolated spiral galaxies, $SFE=10^{-11}$ yr $^{-1}$. We also studied the Kennicutt-Schmith, KS, law and check if the SF proceeds in such clumps as in massive on the tails, self-gravitating objects. And we observed that there is a relation between the KS and the state of the merger, which can be driven by the efficiency.

Star formation and dust heating in Andromeda

Viaene, Sebastián

Universiteit Gent

ABSTRACT: The closest large galaxy to our own Milky Way is Andromeda (M31). Its proximity allows observations of superb spatial resolution at all wavelengths, while maintaining the global picture. Within the Herschel Exploitation of Local Galaxy Andromeda (HELGA) framework, we have combined observations of M31 ranging from the ultra-violet to millimeter wavelengths. In this wavelength range, we can probe the physics of stars and dust, and their complex connection with each other. I will discuss the results of our analysis of this rich dataset, including the spatially resolved star formation law in the galaxy. I will also present a 3D radiative transfer model of the galaxy and link the dust emission back to the stellar populations that heat up the dust.

Mapping the extent and spatial distribution on a kpc scale of star formation in cluster galaxies at $z \sim 0.5$ with the Grism Lens-Amplified Survey from Space (GLASS)

Vulcani, Benedetta

University of Melbourne

ABSTRACT: What physical processes regulate star formation in dense environments? Understanding why galaxy evolution is environment dependent is one of the key questions of current astrophysics. I will present the first characterization of the spatial distribution of star formation on a kpc scale in cluster galaxies at $z \sim 0.5$, and compare to a field control sample, in order to quantify the role of different physical processes that are believed to be responsible for shutting down star formation. The analysis makes use of data from the Grism Lens-Amplified Survey from Space (GLASS), a large HST cycle-21 program targeting 10 massive galaxy clusters with extensive HST imaging from CLASH and the Frontier Field Initiative. The program consists of 140 primary and 140 parallel orbits of near-infrared WCF3 and optical ACS slitless grism observations, which result in 3D spectroscopy of hundreds of galaxies. The grism data are used to produce spatially resolved maps of the star formation density, while the stellar mass density and optical surface brightness are obtained from multiband imaging. I will describe quantitative measures of the spatial location and extent of the star formation rate. I will show that a diversity of broad band and H α morphologies is detected in both clusters and field, suggesting a diversity of physical processes. Regular morphology is mostly consistent with star formation diffused uniformly across the stellar population (mostly in the disk component, when present). Asymmetric/jellyfish morphology is consistent with ram pressure stripping or other non-gravitational processes. Ram pressure stripping appears significantly less prominent in the field than in clusters, where the most common morphology/mechanism appears to be consistent with minor gas rich mergers or clump accretion.

I will also show how the properties of H α emitters correlate to a number of tracers of the cluster environment to give a better insight on its role in driving galaxy transformations. The peak of the H α emission is offset with respect to the peak of the UV-continuum and in 60% of the cases it points away from the cluster center. Decomposing the offset into a radial and tangential component, the observed distribution of offset ratio for the infalling galaxies is consistent with cosmological predictions that assume that the offset correlates with the galaxy velocity at the time of the observation, and the effects of ram pressure stripping. Our clusters span a wide range of morphologies, as probed by the different surface mass density distributions and X ray emissions, but these do not seem to have great impact on H α morphologies. The lack of strong correlations does not allow us to identify a unique strong environmental effect that originates from the cluster center. In contrast, trends with local density appear stronger. Therefore, we conclude that local effects, uncorrelated to the cluster-centric radius, play a role in shaping galaxy properties.

This work demonstrates that while environment specific mechanisms affect galaxy evolution at this redshift, they are diverse and their effects subtle. A full understanding of this complexity requires larger samples and detailed and spatially resolved physical models. The characterization of the spatial distribution of H α provides a new window, yet poorly exploited, on the mechanisms that regulate star formation and morphological transformation in dense environments.

Title

Zamora-Avilés, Manuel

U. Michigan

ABSTRACT:

ALMA observations to the hot core that it isn't: Orion KL

Zapata, Luis

IRyA, UNAM

ABSTRACT: In this talk, I will present the results of recent ALMA millimeter/submillimeter (150, 345, and 650 GHz) continuum observations to the eponymous hot molecular core located in Orion KL. These sensitive and sub-arcsecond angular resolution observations reveal that most of the emission is extended, and there are not compact sources associated with young massive protostars heating the hot molecular gas. However, we found millimeter/submillimeter compact emission associated with the Source I, BN, probably from source n, and other radio/infrared sources within the FWHM of ALMA. This result argues in favor that this hot molecular core is likely heated from outside rather than in inside by massive protostars.

Star formation in interacting galaxies

Zaragoza Cardiel, Javier

Instituto de Astronomía UNAM

ABSTRACT: We have used observations from the IR to the UV of 46 pairs of interacting galaxies and 39 normal spiral galaxies to identify ~700 star forming regions. We have analyzed the SEDs to derive parametric SFHs using CIGALE (Code Investigating GALaxy Emission). We have derived SFRs, stellar masses, recent burst ages, recent burst fraction, and dust attenuation, for the resolved star forming regions. I will present the differences and similarities between normal spirals and interacting galaxies of the resolved star forming main sequence, burst ages, and dust attenuation. I will also present the results of the kinematics of molecular and ionized gas in three luminous infrared galaxies (Zaragoza-Cardiel et al., 2016) using the Atacama Large Millimeter/submillimeter Array (ALMA), and the Galaxy H α Fabry-Perot System interferometer (GHaFaS). We have observed that the surface densities of the ionized and molecular gas in these LIRGs are between the normal star formation in nearby galaxies and the extreme star formation observed at higher redshifts. We use the high velocity resolution of both instruments to extract the internal velocity dispersion of the star forming regions, and we find that the denser ones, are dominated by self-gravity instead of external pressure.

LMT study of 1.1mm cores in Orion A molecular cloud

Zepeda, Daisy

INAOE

ABSTRACT: We present a new 1.1 mm continuum map of the northern end of the Orion A Molecular Cloud, the so called OMC-3 region. We focus on the embedded condensations around the dense core MMS5. In order to map both the small and large scale structures, we combine 1.1mm dust continuum image taken with AzTEC camera mounted on the Atacama Submillimeter Telescope Experiment (ASTE), with an effective spatial resolution of $40''$, with the image taken with the same camera but on the Large Millimeter Telescope (LMT), that in its early science configuration used a 32m diameter dish, resulting in a resolution of $8.5''$.

We find at least 20 new 1.1mm cores of small scale ($\approx 0.05\text{pc}$), two 1.1mm cores related with protostars discovered with SPITZER, and other two cores related with C18O emission. In this work we calculate the clump properties from the dust continuum emission and compare them with clumps found in complementary 12CO (6-5) data. We discuss the difference between these two data sets in terms of the different clump properties obtained from the millimeter and sub-millimeter emission. We finally present a discussion on the scientific impact of deep large scale mapping of molecular clouds with the LMT.

Multi-scale star formation studies with SOFIA

Zinnecker, Hans

Deutsches SOFIA Institut, Univ. Stuttgart

ABSTRACT: SOFIA, the airborne stratospheric observatory for infrared astronomy, is in full swing and is contributing many exciting results to star formation at various scales from galaxy scales to molecular cloud scales and on to clump and core scale. Examples include the mapping of M51 in the [CII] fine structure cooling line at 1.90 THz, the observation of infall and accretion rates in protocluster clouds via redshifted ammonia absorption at 1.81 THz, warm and shocked outflows at high J CO THz rotational transitions, as well as detection of ground-state water 6.1 μ m absorption in a massive protostar disk/outflow system. Measurements of polarised far-infrared continuum emission from grains aligned by magnetic fields can trace the structure and orientation of magnetic fields in dark clouds and also in protostellar and pre-stellar cores. Finally, a future new far-infrared spectrometer will be able to measure HD 112 μ m emission in proto-stellar and proto-planetary disks, crucial to infer the H₂ disk gas masses. SOFIA is more than a follow-up mission to Herschel and can go so much further.