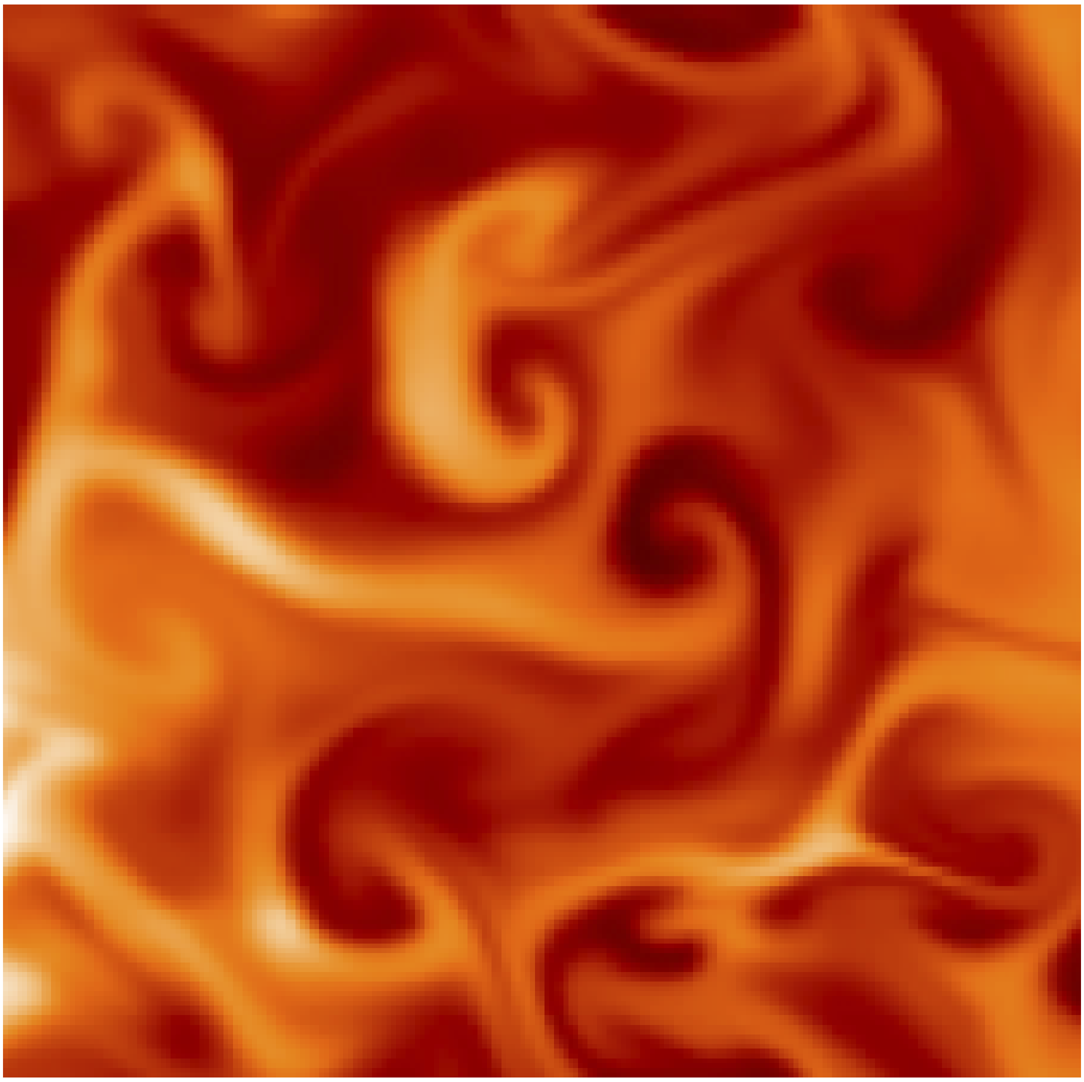

Physical Processes in the ISM

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MPE, Garching

DFG Priority Program 1573

ISM-SPP

Interstellar Medium

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MONDAY

09:00 Welcome by Andreas Burkert (USM/LMU)

► Introduction to ISM properties: from small to large scales

Chair: Henrik Beuther

09:15 Review talk: Introduction to ISM properties: from small to large scales
by Ralf Klessen (ZAH/ITA, University of Heidelberg)

► The multi-phase ISM

Chair: Henrik Beuther

09:55 Review talk: The multi-phase ISM
by Stefanie Walch (MPA, Garching)

10:35 Coffee and Tea Break / Poster Viewing

11:05 Contributed talk: Turbulent structure in bistable interstellar medium: a self-sustaining mechanism
by Kazunari Iwasaki (Nagoya University)

Nonlinear evolution of bistable interstellar medium is investigated using two-dimensional simulations with a realistic cooling rate, heat conduction, and physical viscosity. The calculation is performed in periodic boundary conditions without any external forcing. As the initial condition, spatially uniform unstable gas under thermal equilibrium is considered. At the initial stage, the unstable gas quickly segregates into two phases, or cold neutral medium (CNM) and warm neutral medium (WNM). After that, a self-sustained turbulent is observed where the CNM move around in the WNM. In a self-sustaining mechanism, it is found that interfacial medium (IFM) existing between the CNM and WNM plays a quite important role. The self-sustaining mechanism can be divided into two steps. First, the thermal conduction drives fast flows streaming into concave CNM surfaces toward the WNM. The kinetic energy of fast flows in the IFM is incorporated into that of the CNM through the phase transition. Second, turbulence inside the CNM deforms interfaces and forms other concave CNM surfaces, leading to fast flows in the IFM. The first step is repeated. In this manner, the self-sustaining mechanism works.

11:20 Contributed talk: The thickness distribution of interstellar filaments
by Evangelia Ntormousi (SAp/CEA Saclay)

Recent observational results have shown that local interstellar filaments follow a thickness distribution which is surprisingly narrowly peaked at 0.1 pc for a wide range of column densities. This fact is pertinent to the study of interstellar gases as a fingerprint of the physical mechanisms acting on that scale. But what can create structure of a characteristic size when both gravity and turbulence are scale-free? In this presentation we will show results of high-resolution, three-dimensional, non-ideal MHD simulations of the multi-phase ISM, performed with the AMR code RAMSES. Our detailed analysis of the filamentary structure emerging from these simulations shows that ambipolar diffusion is an excellent candidate for setting the typical thickness of the dense ISM filaments. In this paradigm-changing picture, dense filaments are not seen as a transient feature of ISM turbulence, but rather identified as the diffusive end of the turbulent cascade. This interpretation can have important implications in our understanding of not only the dynamical behavior of the ISM as a whole, but also of the initial conditions for star formation.

11:35 Contributed talk: Anomalous extinction: The degeneracy between dust composition and geometry
by Peter Scicluna (ESO)

The spatial distribution of dust has significant influence on the observed extinction curve. As a result, when observing anisotropic, clumpy or turbulent environments the aperture may contain a wealth of unresolved structure. Hence, observations only probe an effective optical depth and effective extinction curve. In order to elucidate and quantify the impact of unresolved structure we perform radiative transfer modeling of various dust geometries. We find that stars embedded in homogeneous, optically-thin unresolved spherical shells have steeper extinction curves than that of the input dust cross-sections, which would be recovered with pencil-beam observations. This is in agreement with previous studies of stars in homogeneous clouds. Similarly, the effective optical depth is lower than that of a pencil beam due to the collection of scattered light, resulting in an under-estimate of the dust column density from extinction measurements. Equal mass shells composed of optically thick clumps, on the other hand, are shown to have significantly flatter extinction than the cross-sections. The degree of flattening is determined by the wavelength at which the clumps become optically thick and the clump distribution, which determines the scattered light. Our models indicate that this leads to a log-normal distribution of R_V for different lines-of-sight into a clumpy shell. We expand our investigation to clumpy debris disc and molecular cloud analogues, with similar findings. We also show that, due to optical depth effects, the strength of the 2200AA feature can be significantly different in clumpy media. This affirms that changes in the extinction observed toward embedded objects are not robust probes of changes in dust composition. Hence, studies which use extinction to explore dust must make use of background sources or sufficiently high resolution observations to resolve out circumstellar structure. For typical seeing limited observations, these effects start to become significant when observing in Orion, and become stronger with increasing distance.

11:50 Contributed talk: Latest GREAT results from SOFIA
by Hans Zinnecker (Deutsches SOFIA Institut)

I will present a short summary of the status of SOFIA, the Stratospheric Observatory for Infrared Astronomy. SOFIA has been deployed to the Southern Hemisphere in July 2013 and completed 9 successful flights out of Christchurch, New Zealand. Some amazing results from from these FIR observations with GREAT are emerging, including detection of the 2.5 THz OH and 2.7 THz HD ground state rotational lines against strong continuum sources. The major HII regions in the Large and Small Magellanic Clouds have also been mapped in the [CII] line at 158μ.

▶ Molecular cloud properties

Chair: Cornelia Jäger

12:05 Review talk: Molecular cloud properties
by Alvaro Hacar (University of Vienna)

12:45 Lunch Break / Poster Viewing

14:15 Contributed talk: The structure of molecular clouds from 1000 AU to Orion
by Joao Alves (University of Vienna)

Understanding how matter is organized inside a molecular cloud is key to understand where and how stars form. In this talk we summarize the main results from our ongoing program on NIR extinction on nearby molecular clouds, complemented with recent Herschel archival data. Our sample comprises all the nearby molecular cloud complexes in their entirety, from Pipe Nebula to the Orion complex, studied on an unprecedented column density dynamic range from $4 \times 10^{20} cm^{-2}$ ($\mathrm{Av} \sim 0.2$ mag), well below the CO formation threshold, to several times $10^{23} cm^{-2}$ ($Av \sim 100$ mag), where most CO is depleted. We present a consistent set of basic physical properties for these objects (masses, distances, sizes), the PDF present for the first time the Core Mass Function for each cloud in the sample, mass-per-length, and an investigation into the meaning of the different column density PDFs for the different clouds.

14:30 Contributed talk: Properties of interstellar filaments observed with Herschel and 3D magnetic field structure derived from the polarization parameters observed with Planck
by Doris Arzoumanian (IAS Orsay)

Herschel dust continuum images have revealed the ubiquity of filaments in the interstellar medium (ISM) and their fundamental role in the star formation process. Planck dust polarization observations trace the magnetic field structure of the ISM.
Filamentary structures are formed by the interplay of interstellar turbulence, gravity and magnetic field. What is the role of these various processes in the formation and evolution of interstellar filaments?
One of the surprising result obtained from the analysis of the filament radial profiles observed with Herschel is the narrow distribution of their inner widths (~ 0.1 pc) regardless of their central column density and environment. This characteristic filament width is close to the sonic scale around which the transition between supersonic and subsonic turbulent motions occurs in the cold ISM. This result put forward the role of interstellar turbulence in forming the filaments.
Follow-up molecular line observations with the IRAM 30m telescope, have shown an increase in the non-thermal velocity dispersion of the densest filaments as a function of their central column density suggesting the role of gravity in the evolution of the dense self gravitating filaments which grow in mass by accretion of background material while fragmenting into prestellar cores.
The role of magnetic field in the formation and evolution of filaments is still debated. In order to investigate this issue, I will present how we model the 3D field structure and the polarization properties of interstellar filaments and their background clouds to interpret Planck observations of the polarized dust emission.

14:45 Contributed talk: Magnetic Fields in Bok globules
by Gesa Bertrang (ITAP, University of Kiel)

The influence of magnetic fields on the star-forming process is still under debate. A very good environment to study this influence is given in low-mass star-forming regions, so-called Bok globules. These objects are less affected by other processes, such as large-scale turbulences. The magnetic field strength and structure in the dense inner regions of these globules can be determined by observing the polarized reemission radiation of aligned dust grains in the sub-mm wavelength range. The magnetic field in the outer, less dense parts of the globules can be traced by observing polarized radiation of background stars in the optical or near-infrared. Thus, multi-wavelength observations reveal the magnetic field strength and structure on various scales across the entire globule. I will present the results of our imaging polarimetry study on Bok globules for which we carried out new polarimetric observations of the three globules CB68, B335 and CB54 in the near-infrared (with ISAAC/VLT and SOFI/NTT) and in the optical wavelength range (with IFOSC/IGO). The first part of our study, represented by CB68 and B335, is focused on ideal, very regularly shaped globules while in the second part globules with more complex morphologies are considered: CB54 shows strong long-scale turbulences but nevertheless, observations in the optical show ordered magnetic field lines in the outer, less dense parts of this globule. Together with archival sub-mm data (obtained with SCUBA/JCMT), we trace the magnetic fields in these objects on scales from 10'000 AU to 100'000 AU for the first time

15:00 Contributed talk: Effect of turbulence on the density statistics of molecular clouds: an observational view
by Jouni Kainulainen (MPIA, Heidelberg)

Supersonic turbulence has a profound impact on the density structure of the cold interstellar medium (ISM). Consequently, observations of the ISM density structure can be used to constrain the fundamental properties of turbulence. However in practice, connecting the observed density structure to theoretical predictions is greatly hampered by the inability of observations to probe the wide range of (column) densities present in the ISM. In this contribution, I present our recent observational works in which we analyze the density statistics of molecular clouds using a new dust extinction mapping technique that allows us to probe the clouds, in a uniformly calibrated manner, over a wide dynamic range of column densities. We employ the technique to study the column density probability distribution functions (PDFs) of molecular clouds and their relation to the turbulence energy in the clouds. Our results show that the molecular cloud PDFs correlate strongly with star-forming activity, and also strongly with the Galactic environment. In particular, clouds located in spiral arm regions contain considerably more high-column density gas than those in the Solar neighborhood. We analyze a set of numerical turbulence simulations to understand the origin of this trend. We show that one potential explanation for the high amount of dense gas in spiral arm clouds is provided by more compressive gas motions in those regions. Finally, we use our high-dynamic range column density data to constrain the correlation coefficient (b) between density variance and turbulence energy in molecular clouds. Our results suggest that b can vary between clouds depending on their large-scale, Galactic environment.

15:15 Contributed talk: Filamentary Structures in the ISM
by Rowan Smith (ZAH/ITA, University of Heidelberg)

Filaments are seen throughout the ISM, from long filamentary IRDCs to individual filamentary sites of star formation. Using the moving mesh code AREPO we can investigate filament formation on all scales, as the unique combination of a Lagrangian mesh with a Riemann solver results in an extremely accurate treatment of shocks and discontinuities. I will describe how filamentary molecular clouds are formed in spiral arms in a self-consistent galactic simulation with a cloud mass resolution of only $4\,\mathrm{M}_{\odot}$. I will use this to show how the velocities imprinted on the gas at its formation influence the future evolution and star formation of the resulting clouds. I will classify the structure of filaments within a suite of simulations and show how the intrinsic 3D properties of the filaments relate to that which is observed in 2D column density projections. The 3D filaments have a steeper profile than those seen in projection, and often overlap to produce braiding in the projected filament.

15:30 Coffee and Tea Break / Poster Viewing

► Turbulence in the ISM

Chair: Stefanie Walch

16:00 Review talk: Turbulence in the ISM
by Fabian Heitsch (University of North Carolina Chapel Hill)

16:30 Review talk: Molecular cloud formation in converging flows
by Patrick Hennebelle (SAp/CEA Saclay)

17:00 Contributed talk: On the characteristic mass of stars in stellar clusters
by Paul Clark (ZAH/ITA, University of Heidelberg)

To date, numerical studies of the IMF have adopted initial conditions that are very dense – often comparable to the densities of individual prestellar cores that are observed in giant molecular clouds (GMCs). These calculations, which start in the regime where the gas and dust are already strongly coupled, can say nothing about conditions we observe in nearby star-forming regions. In addition, the characteristic mass of the IMF in these simulations is strongly biased by their initial conditions. We will present a new suite of models that capture the formation of prestellar cores in GMCs, examining the sensitivity of the characteristic core mass to the environmental conditions in the cloud, such as the strength of the interstellar radiation field (ISRF), the cosmic-ray ionization rate, and the cloud's metallicity. These are the first calculations to self-consistently capture the transition between the line-cooling and dust cooing regime that has been proposed by Larson (2005) to set the mean Jeans mass for the fragmentation process. We will also discuss the relationship between the mass of the prestellar core, and the final mass of the young star, and where these new models fit into the "isolated v competitive accretion" debate. Finally, we will show how the observational properties of the cores, such as their column density and dust temperature profiles, vary as a function of the both the core's environment and its dynamical state (i.e. bound/prestellar v unbound/transient).

17:15 Contributed talk: Photoionization of the diffuse ionised gas in an MHD supernova-driven turbulent Interstellar Medium
by Jo Barnes (University of St Andrews)

We investigate 3D photoionisation models of the Diffuse Ionised Gas (DIG). Our simulations show that in a supernova-driven, turbulent magnetized medium photons from OB stars in the Galactic plane are able to travel many kiloparsecs and reach heights required to ionize the DIG. To reach these heights photons travel through ?bubbles? evacuated by supernovae close to the midplane of the simulations while traveling through diffuse low density regions at large heights. The ionizing luminosity required to create the DIG in our simulations is within the Galactic Lyman continuum budget. We also investigate the impact of additional heating on diagnostic line ratios at large height and find that photoionization heating alone, without the addition of a heating term that dominates at low density is unable to reproduce the observed ratios. The scale height of H? intensity in our simulations is smaller than that observed as a result of insufficient vertical pressure support.

17:30 Contributed talk: The molecular richness of diffuse ISM: a tracer of turbulent dissipation
by Edith Falgarone (LERMA/LRA ENS)

The diffuse interstellar medium has long been known to harbor a remarkable molecular richness, that cannot be understood in the framework of state-of-the-art UV-driven chemistry. Absorption spectroscopy performed with Herschel/HIFI reveals unexpected large abundances of small hydrides that are the building blocks of interstellar chemistry in the diffuse medium. Because they are so abundant and need only small amounts of $\mathrm{H_2}$ to form, these hydrides are new sensitive tracers, in the entire Galaxy of a poorly known component, the diffuse molecular gas.
Among them, CH+ and SH+ have highly endoenergic formation routes and have been proposed to be specific markers of turbulent dissipation occurring in diffuse molecular gas. Their elusive origin is therefore much more than a chemical riddle: it is rooted in the physics of the diffuse ISM, its turbulent dissipation rate in low-velocity shocks and/or shears, the formation of molecular clouds and connects with the broader issues of star formation and galaxy evolution.
Focus will be on (i) the unique informations on turbulent dissipation inferred from these hydrides absorption spectra in the framework of new chemical models, (ii) the turbulent origin of other species such as CO and (iii) the link between turbulent dissipation and $\mathrm{H_2}$ pure rotational emission of the diffuse ISM. If possible, results based on the all-sky CO emission obtained with Planck survey will be shown.

17:45 **Welcome Reception**

► Collapse of molecular clouds and the IMF

Chair: Simon Glover

9:00 Review talk: Collapse of molecular clouds and the IMF
by Matthew Bate (University of Exeter)

9:40 Contributed talk: Tracing the fragmentation of OMC1-north filament with the Submillimeter Array
by Paula Stella Teixeira (University of Vienna)

It is well established for several decades that filamentary structures are very common in star forming molecular clouds. Observational studies of how these structures evolve and fragment to form cores (and subsequently stars) may ultimately lead us to better understand how the core mass function (CMF) and stellar initial mass function (IMF) are assembled. The fragmentation of these filamentary structures may be probed by analyzing the spatial distribution and physical properties of dense cores. Due to their youth, protostars forming within these cores have not yet had enough time to move away from their birthsites and as such their spatial distribution is a fossil signature of the fragmentation scale of their parental filament. We report Submillimeter Array (SMA) 1.3mm observations of the OMC1 northern filaments that were previously identified from SCUBA JCMT 850 micron continuum and VLA ammonia observations. We discovered 24 new compact sources along an extent of $\sim 3'$ within the filaments. The sources range in mass from 0.5 to $2.8\,\mathrm{M}_\odot$ and 5 of them are driving CO molecular outflows. The millimeter emission is arising from the inner part of the envelope and circumstellar disk; these compact sources are therefore in the Class 0/I evolutionary phase. The spatial analysis of the protostars shows that these are divided into small groups, that coincide with previously identified clumps, and that these are separated by a quasi-equidistant length of $\sim 30'$ (0.06 pc). This separation is dominated by the Jeans length of the filament, and therefore indicates that the main physical process in the filament's evolution was thermal fragmentation. Within the protostellar groups, the typical separation is $\sim 7''$ (2800au), which is again consistent with the Jeans length of the parental clumps within which the protostars are embedded. These results point to hierarchical (2-level) thermal fragmentation process of the OMC1-n filament. We will also discuss how these findings compare with those of OMC3 (Takahashi et al., 2013), and how it connects with the hierarchical fragmentation of the larger scale Orion molecular cloud.

9:55 Contributed talk: Filament formation and star formation regulation in collapsing molecular clouds
by Enrique Vazquez-Semadeni (CRyA, UNAM)

I present results from numerical simulations and an analytical model of the formation and gravitational collapse of giant molecular clouds (GMCs). The clouds develop a network of filaments at various scales, whose physical properties we compare with recent observations. Simulations including ionizing stellar feedback show that its effect is the destruction of the local star-forming clump and suppression of its star formation activity, attaining final efficiencies of the order of 10%. An analytical model of this process matches, to within factors of a few, the evolutionary stages observed in GMCs in the LMC, the age histograms of embedded clusters in the Galaxy, the locus of low-mass star-forming clouds and high-mass star-forming clumps in the Kennicutt-Schmidt diagram, predicting that the former evolve into the latter, and the dependence of the SFR on cloud mass found by Gao & Solomon.

10:10 Contributed talk: The structure and star-forming fate of the Galactic centre cloud G0.253+0.016
by Katharine Johnston (MPIA, Heidelberg)

The massive infrared dark cloud G0.253+0.016 projected 45pc from the Galactic centre contains $10^5\,\mathrm{M}_\odot$ of dense gas whilst being mostly devoid of observed star formation tracers. To scrutinise the gas properties of G0.253+0.016, we have carried out a concerted SMA and IRAM 30m study of this enigmatic cloud in dust continuum, CO isotopologues as low-density tracers, as well as $\mathrm{CH_3OH}$ and SiO as shock tracers. In this talk, I will firstly discuss in detail the density structure of the cloud traced by column density PDFs and dendrograms, with relation to whether star formation is currently ongoing. I will then show how our observations suggest that G0.253+0.016 is colliding with another cloud - in fact, this may have been the formation scenario for G0.253+0.016. The collision will also likely affect its structure, internal turbulence, and final star-forming fate. I will finally discuss how G0.253+0.016 fits into our picture of the dynamics and geometry of the Galactic centre region. Specifically, I will show that the model of the 100pc Galactic centre ring put forward by Molinari et al. (2011) does not explain the observed longitude-velocity diagrams of the CMZ observed by Jones et al. (2012), and thus a different orientation and/or geometry is required.

10:25 Coffee and Tea Break / Poster Viewing

► Laboratory Astrophysics

Chair: Simon Glover

10:55 Review talk: Laboratory Studies of Dust Formation and Processing
by Cornelia Jäger (Universität Jena)

11:35 Contributed talk: Combining experimental techniques for comprehensive astrophysical case studies
by Holger Kreckel (MPIK, Heidelberg)

As an ever increasing number of molecules are observed in interstellar space, accurate laboratory data on their formation and destruction processes will be required to understand interstellar reaction networks. Astrochemical models have identified ion-molecule reactions as one of the drivers for the buildup of molecules in space. On the other hand, dissociative recombination with free electrons often terminates an ionic reaction chain and determines which neutral products are being formed. In order to model the abundance of individual species reliably, energy-resolved rate coefficients for all competing processes will be required.
At the Max-Planck-Institute for Nuclear Physics we intend to combine various experimental techniques to yield a comprehensive description of the relevant reactions for chosen important species. The new Cryogenic Storage Ring (CSR) will be equipped with a low-energy electron cooler and a neutral atom beamline. These facilities will allow for absolute rate coefficient measurements of dissociative recombination (DR) and ion-atom collision processes, involving cold molecular ions. Furthermore, a cryogenic 22-pole ion trap can be used for pre-cooling molecular ions, performing reaction studies with cold neutral molecules, and state-specific spectroscopy at variable temperatures.
With these techniques we aim to shed light on the puzzling nuclear spin distribution observed for interstellar H_3^+, where exchange reactions with molecular hydrogen play a role, as well as the nuclear-spin dependence of the DR reaction with cold H_3^+. Furthermore, we will investigate the gas-phase route to water formation, which begins with H_3^+ + O collisions and ends in the DR of cold $\mathrm{H_3O}^+$, resulting in the formation of water in space.
Additional fields of research will be the formation and destruction of organic molecules under interstellar conditions and early universe chemistry.

11:50 Contributed talk: Laboratory studies on electron collisions of atomic and molecular ions
by Andreas Wolf (MPIK, Heidelberg)

Low energy collisions of electrons with atomic and molecular ions are among the most basic microscopic interactions in the interstellar medium. Electron-ion recombination limits the abundance of charged atoms molecules and, as dissociative recombination of molecular ions, produces neutral radical fragments for gas phase reaction chains. Moreover, electron impact excitation can influence rotational, vibrational or fine-structure level populations. Results and future approaches for measurements on these process with a monoenergetic electron beam merged with a stored ion beam will be discussed, focusing on the development of the cryogenic electrostatic storage ring CSR in Heidelberg as the next generation facility for such laboratory studies.

► Chemical processes in the ISM

Chair: Dominik Schleicher

12:05 Review talk: Chemical processes in the ISM: Gas and molecules
by Simon Glover (ZAH/ITA, University of Heidelberg)

12:35 Lunch Break / Poster Viewing

14:05 Review talk: Chemical processes in the ISM: Dust
by Thomas Henning (MPIA, Heidelberg)

14:35 Contributed talk: Galactic dust as seen by Planck
by Marta Alves (Institut d'Astrophysique Spatiale (IAS))

The Planck all-sky survey has opened a new window in our understanding of interstellar dust emission in extending to sub-millimetre wavelengths and microwave frequencies the detailed mapping of dust emission provided by past infrared missions. Such a wide frequency coverage allows us to probe the spectral energy distribution (SED) of large and cold dust grains, which are the bulk of the dust mass. Therefore, it can help us disentangle the effects of dust column density, radiation field and grain properties, which contribute to the dust brightness. Early results from Planck revealed variations of the high-latitude dust temperature and emission cross-section, showing evolution of dust grains. The analysis of nearby molecular clouds also showed the cooling of the dust particles from diffuse regions to the densest parts, accompanied by an increase in the dust emissivity, which can be associated with grain growth through coagulation. I will present the all-sky model of dust emission based on Planck and IRAS data, from 353 to 3000 GHz, which delivers maps of dust temperature, optical depth and opacity spectral index, used to produce an all-sky map of the dust reddening. The challenges of using the dust opacity at 353 GHz as a tracer of the dust column density will be discussed. I will also show the results of detailed studies of the cirrus and the Galactic plane, where we are able to extend the analysis to frequencies below 353 GHz. A change in the shape of the dust spectrum relative to that extrapolated from far-infrared wavelengths is detected, which requires a description by alternative emission mechanisms.

14:50 Contributed talk: Formation signatures and carbon budget of molecular clouds
by Henrik Beuther (MPIA, Heidelberg)

The interstellar medium (ISM) is mainly comprised of ionized, neutral atomic and molecular gas. One of the most important constituents of these phases is carbon in its ionized/neutral/molecular form (C^+, C^0 and CO). However, until recently a coherent analysis of the different phases at adequate resolution (Jeans length ~ 0.2 pc) is lacking. We therefore conducted at study of the spectral lines of C^+ at 1.9THz, C^0 (at 492GHz), and CO(2-1) with Herschel/SOFIA, APEX and the IRAM 30m at high spatial resolution ($11'' - -13''$) for several infrared dark clouds (IRDCs). With the combined data of the different carbon phases we can address: (a) How do the relative abundances change with evolutionary stage? (b) Are the different phases mainly excited by internal or external radiation sources? (c) How important are the phase changes for the carbon cooling budget of the ISM? (d) Can we identify cloud formation signatures (e.g., turbulent flows)?

15:05 Contributed talk: Experimental investigation of the collision properties of micrometer-sized water ice particles
by Bastian Gundlach (TU Braunschweig)

Grain growth by coagulation of ice and dust particles has been postulated and observed in the densest and coldest interstellar clouds. Thus, we have performed laboratory experiments in order to simulate inter-particle collisions in these environments. The experiments were used to measure the sticking threshold of micrometer-sized water ice particles for different grain sizes, velocities, and temperatures. The results of these experiments are required to calibrate models of the dust-mass evolution in molecular clouds.

15:20 Contributed talk: Dust in the diffuse interstellar medium: Extinction, emission, linear and circular polarization
by Ralf Siebenmorgen (ESO)

We present a model for the diffuse interstellar dust that explains the observed wavelength-dependence of extinction, emission, linear and circular polarization of light. The model is set up with a small number of parameters. It consists of a mixture of amorphous carbon and silicate grains with sizes from the molecular domain of 0.5 up to about 500nm. Dust grains with radii larger than 6nm are spheroids. Spheroidal dust particles have a factor 1.5-3 larger absorption cross sections in the far IR than spherical grains of the same volume. Mass estimates derived from submillimeter observations that ignore this effect are overestimated by the same amount. In the presence of a magnetic field, spheroids may be partly aligned and polarize light. We find that polarization spectra help to determine the upper particle radius of the otherwise rather unconstrained dust size distribution. Stochastically heated small grains of graphite, silicates and polycyclic aromatic hydrocarbons (PAHs) are included. We tabulate parameters for PAH emission bands in various environments. They show a trend with the hardness of the radiation field that can be explained by the ionization state or hydrogenation coverage of the molecules. For each dust component its relative weight is specified, so that absolute element abundances are not direct input parameters. The model is confronted with the average properties of the Milky Way, which seems to represent dust in the solar neighborhood. It is then applied to specific sight lines towards four particular stars, one of it is the reflection nebulae NGC2023. For these sight lines, we present ultra-high signal-to-noise linear and circular spectro-polarimetric observations obtained with FORS at the VLT. Using prolate rather than oblate grains gives a better fit to observed spectra; the axial ratio of the spheroids is typically two and aligned silicates are the dominant contributor to the polarization.

15:35 Coffee and Tea Break / Poster Viewing

16:05 Contributed talk: Dust-to-gas ratio as a clue to the galactic evolution
by Svitlana Zhukovska (MPIA, Heidelberg)

Dust grains are indispensable part of the matter cycle, which plays an important role in many physical processes in the ISM. Interstellar dust content is determined by the interplay between dust formation by stars, destruction in the ISM and dust growth by mantle accretion in the ISM. The relative importance of these processes depends on both the stage of galactic evolution and metallicity that can be investigated with models of global dust evolution in the ISM. In my talk I will present applications of such models to study the star formation history of galaxies.

▶ Dependence of star formation on ISM properties

Chair: Svitlana Zhukovska

16:20 Review talk: Dependence of star formation on ISM properties
by Adam Leroy (NRAO, Charlottesville)

17:00 Contributed talk: An uncertainty principle for star formation - why galactic scaling relations break down below a certain spatial scale
by Diederik Kruijssen (MPA, Garching)

Galactic star formation (SF) relations are known to develop substantial scatter or even change form when considered below a certain spatial scale. I will quantify how this behavior should be expected due to the incomplete statistical sampling of independent star-forming regions. Other included limiting factors are the incomplete sampling of SF tracers from the stellar initial mass function and the spatial drift between gas and stars. I will present a simple uncertainty principle for SF, which can be used to predict and interpret the failure of galactic SF relations on small spatial scales. I show how the scatter and bias of SF relations are sensitive to the physical size and time-scales involved in the SF process. As a result, this new formalism provides a powerful tool to constrain largely unknown quantities such as the duration of SF. Using multiple gas tracers, it also allows one to map the density evolution of the ISM towards SF as a function of absolute time. I will present the first results of applying the uncertainty principle to observations, as well as some preliminary results from numerical simulations.

17:15 Contributed talk: Herschel and APEX study of the initial condition of high-mass star formation
by Sarah Ragan (MPIA, Heidelberg)

The question of how high-mass stars form relies fundamentally on the initial conditions. Due to the large distances to high-mass star-forming complexes and their precursors known as infrared-dark clouds (IRDCs), high-angular resolution is required to resolve individual cores. With the advent of Herschel, we now have access to the wavelength regime in which the cold dust comprising the clouds emits at its peak. As part of the Herschel guaranteed time key program "Earliest Phases of Star Formation (EPoS)" we obtained far-infrared maps of 45 IRDCs at all photometric bands from 70 to 500 microns. Within these clouds we have isolated a population of 500 protostellar cores closely following the distribution of dense gas. Fitting spectral energy distributions (SEDs) to each core, we estimate their average properties The cores are very cold (20 K) and have a range of four orders of magnitude in mass. A counterpart at 24 microns is common (67% of sample) and represents a more evolved sub-sample of cores. With follow-up, high-resolution ($7.8''$) APEX/SABOCA observations at 350 microns, we better constrain the Rayleigh-Jeans tail of the blackbody SED and also isolate colder and younger sources with no 70 micron Herschel component, indicating that they are pre-stellar/starless core candidates. These cold cores have masses up to $120\,\mathrm{M}_\odot$, bolometric luminosities below $50\,\mathrm{L}_\odot$, and bolometric temperatures below 30 K. These datasets together provide the evolutionary sequence from starless to protostellar on small spatial scales. With a full census of the earliest phases of star formation in IRDCs, we connect the mode of star formation back to the large-scale cloud properties to determine the requirements for the most massive stars and clusters to form.

17:30 Contributed talk: Deuteration and fragmentation in massive star-forming regions
by Javier A. Rodon (ESO)

Rodón, J. A., ESO
Beuther, H., MPIA, Heidelberg
Zhang, Q., Harvard-Smithsonian Center for Astrophysics
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In the last decade, we have started to spatially resolve the small gas and dust condensations in high-mass star-forming regions that will eventually become a massive star or system, finally being able to describe how those regions fragment. Recent works, for example Palau et al. 2013, show that there is no correlation between the fragmentation of a region and its physical properties. But what about its chemistry?
According to Fontani et al. 2011, an interesting chemical property to investigate is the deuteration fraction, since it can be used as a chemical clock. In this contribution we show the fragmentation properties and deuteration factors obtained for a group of massive star-forming regions with SMA, PdBI, and IRAM-30m observations, and discuss what the relationship between them tells us.

17:45 Contributed talk: Connecting diverse molecular cloud environments with nascent protostars in Orion
by Amelia Stutz (MPIA, Heidelberg)

Understanding how the gas environment within molecular clouds influences the properties of protostars is a key step towards understanding the physical factors that control star formation. We report on analysis of the connection between molecular cloud environment and protostellar properties using the Herschel Orion Protostar Survey (HOPS), a large multi-observatory survey of protostars consisting of data from Herschel, Spitzer, APEX, and other facilities. HOPS has produced well sampled 1 um to 870 um SEDs of over 300 protostars in the Orion molecular clouds - the most extensive survey of a single cloud complex to date. These data allow for the best determination of protostar properties in the largest high- and low-mass star-forming cloud complex within 500 pc of the Sun. Furthermore, the combination of APEX 870 um continuum observations with the HOPS/PACS 160 um data over the same area allows for a determination of the temperatures and column densities in the often filamentary dense gas surrounding the Orion protostars. Based on these data, we will link the protostellar properties with their environmental properties controlling for column density variations. Utilizing the diverse environments present within the Orion molecular clouds, we show how the luminosity and spacing of protostars in Orion depends on the local gas column density. We also report an unusual concentration of the youngest known protostars (the Herschel identified PBRS, PACS Bright Red Sources) in the Orion B cloud, and we discuss possible reasons for this concentration.

► Stellar feedback in the ISM

Chair: Enrique Vazquez-Semadeni

9:00 Review talk: Stellar feedback in the ISM
by Mordecai-Mark Mac Low (AMNH, New York)

9:40 Contributed talk: Molecular cloud formation in stellar feedback flows: Observing, demonstrating, quantifying
by Joanne Dawson (CSIRO Astronomy and Space Science)

I will examine the role of large-scale stellar feedback in the formation of new molecular clouds. The theoretical context for this is the compression, cooling and fragmentation of the atomic medium in turbulent shocks and flows, of which the ubiquitous “supershells” formed by multiple supernovae and stellar winds are one example. I will first report CO(J=1-0) and HI 21 cm observations of the molecular and atomic ISM in two Milky Way supershells, which demonstrate an enhanced level of molecularization over both objects, and hence provide evidence of increased molecular cloud production in volumes affected by large-scale stellar feedback. I will then discuss recent work on the Large Magellanic Cloud (LMC), in which we have carried out the first quantitative measurements of feedback-triggered molecular cloud formation in an entire galactic system. Our results suggest that $\lesssim 5-10$% of the total molecular mass in the LMC may have been formed as a direct result of large-scale stellar feedback. This approximate lower limit places constraints on the importance of OB-cluster feedback in the formation of new star-forming clouds, and suggests that it is not a dominant driver of molecular cloud production in the LMC.

9:55 Contributed talk: Disruption of GMCs by photoionization and stellar winds - setting the stage for supernovae.
by James Dale (Excellence Cluster Universe)

On the scale of galactic disks, supernovae are likely to be the most important form of stellar feedback on the ISM. However, the environment in which the supernovae explode is likely to have been strongly modified by the action of other kinds of feedback, particularly the earlier photoionization and winds from the exploding stars. I will present SPH simulations of a parameter space of giant molecular clouds which I have allowed to self-consistently form stars and in which I have simulated the effects of the UV radiation and winds from the O-stars that form. I will show how the degree of damage done to the clouds depends on their initial properties and discuss the consequences for the evolution of the larger-scale ISM in terms of the leakage of ionizing photons, metals, momentum and energy from the clouds.

10:10 Contributed talk: The evolution of molecular clouds under the influence of ionizing radiation
by Matthias Gritschneder (Univ. California, Santa Cruz)

We study the evolution of molecular clouds under the influence of ionizing radiation. First, we propose that the Pipe Nebula is an HII region swept up by the B2 star theta Ophiuchi. We propose the nebula is currently containing a three phase medium. By means of analytical calculations, we are able to show that the current size, mass and pressure of the region can be explained in this scenario. We then present simulations on the future evolution as soon as the massive star explodes in a supernova. We show that a surviving core at the border of the HII-region is getting enriched sufficiently with supernova material and is triggered into collapse fast enough to be consistent with the tight constraints put by meteoritic data on the formation of our Solar System. We therefore propose that the formation of the Solar System was triggered by the shock wave of a type IIa supernova interacting with surviving cold structures similar to the Pillars of Creation at the border of HII-regions.

10:25 Contributed talk: Feedback-driven turbulence in the multi-phase ISM
by Andrea Gatto (MPA, Garching)

Turbulence is believed to be a crucial component of the interstellar medium's energetic budget. However, its origin and injection scales are still a matter of debate. Following e.g. Mac Low & Klessen (2004), energy injection from Supernova explosions is able to generate and maintain the observed level of turbulence in the ISM, at least in "normal" star-forming galaxies. In addition, a non-negligible contribution might come from winds of high-mass stars. Using 3D, adaptive-mesh-refinement simulations, we model the generation of turbulence by stellar feedback. Within a representative piece of the multi-phase ISM, we inject stellar winds, following the stellar evolution algorithm of Ekstrom et al. (2012), and Supernova explosions, and we discuss the relative importance of these processes for driving turbulence. Furthermore, we compare how much feedback energy input is needed to maintain a certain level of turbulence with respect to the case of "artificially" driven turbulence. We show how the turbulence decays in a cooling flow and how this decay differs from the conventional, theoretically well established case of an isothermal medium.

10:40 Coffee and Tea Break / Poster Viewing

11:10 Contributed talk: Understanding ultracompact H II regions
by Thomas Peters (Universität Zürich)

H II regions are important signatures of star formation, play an important role in destroying the parental molecular clouds in which stars form, and, while still in the ultracompact phase, give insight into the process of high-mass star formation. I will present simulations that consistently follow the gravitational collapse of a massive molecular cloud, the subsequent build-up and fragmentation of the accretion disk surrounding the nascent massive star, and, for the first time, the interaction between its intense UV radiation field and the infalling material. I will show how these simulations help explain the origin of ultracompact H II region morphologies, their number statistics, their time variability, and the long-standing lifetime problem. Finally, I will present recent observational evidence that supports these simulations: the discovery of an ionization-driven molecular outflow in K3-50A, and the verification of statistical predictions for H II region variability in Sgr B2.

11:25 Contributed talk: An analytic model for the dynamics of the ionized outflows of massive protostars
by Eric Keto (Harvard-Smithsonian Center for Astrophysics)

HII regions are the clearest sign of the formation of the most massive stars, and ionization feedback could be responsible for a number of other phenomena observed in the ISM. For example, the general field of turbulence is suspected to be driven, at least in part, by the expansion of HII regions. Ionization feedback may also be responsible, along with stellar winds, for the bubbles seen everywhere in the Spitzer mid-IR survey of the Galactic disk (Churchwell 2008, mid-IR GLIMPSE survey). Ionized outflows with observed velocities too low to be consistent with stellar winds (Jaffee and Martin-Pintado 1999) could be expanding HII regions (Keto et al 2008) which themselves drive large-scale molecular outflows (Peters et al 2012) whose size and morphology (Klaassen et al 2011) are inconsistent with scaled up versions of the bipolar outflows of lower mass stars. What do we know about the dynamics of ionization feedback and the evolution of HII regions? Recent observational (Keto and Wood 2006) and numerical studies (Peters et al 2010) suggest that the dynamics of HII regions cannot be understood in isolation, but only in the environment of the accretion flows that form the massive stars or clusters. To further investigate the dynamics of accretion with ionization feedback, I put together a theoretical, analytical model for the evolution of an HII region in the thick disk of an accretion flow of the type thought to form massive stars. This model expands upon the earlier studies of Hollenbach et al 1994, Lugo et al 2004 by using the jump conditions to calculate the dynamics of the boundary of the HII region within the accretion flow. The model shows that the thick disk confines the ionized flow into a cometary or bipolar HII region, the two most common morphological types (De Pree et al 2005) depending on whether the ionizing is on or off the mid plane of the disk. The pressure in the ionized flow is always less than in the molecular disk so that gas from the disk crosses the ionization front and replenishes the outflowing mass. The HII region can be in steady-state and long-lived as long as the star maintains the same level of ionization and the accretion flow provides the same molecular density. The outflow velocities are supersonic reaching Mach numbers of 4 or 5 on relevant length scales. The acceleration is provided by the density gradient maintained in the flow by the gravitational pull of the massive protostar and disk. These simple analytic calculations elucidate interesting details on the dynamics of the flow and the shock and ionization fronts that may not be obvious in complex numerical calculations.

11:40 Contributed talk: Deciphering the violent interaction between very massive stars and their natal clouds in the Carina Nebula Complex
by Thomas Preibisch (USM/LMU)

The Carina Nebula constitutes the closest galactic analog of a giant extragalactic HII region. The combination of its large population of very massive stars and its moderate distance of 2.3 kpc makes it an ideal target for detailed studies of small-scale phenomena of the stellar feedback on the surrounding clouds in a starburst-like environment. In the last few years, we have performed several multi-wavelength surveys of the Carina Nebula that revealed the distributions and properties of the stars, the hot gas, and the cold gas in the cloud complex in unprecedented detail and sensitivity. The analysis of our Herschel far-infrared and APEX sub-millimeter surveys in combination with Spitzer mid-infrared and Chandra X-ray data reveals how the 1 million solar masses of gas and dust are distributed in widely different density and temperature regimes. The observed phases range from very cold and dense molecular cloud clumps, over parsec-sized cloud pillars that are shaped by very strong irradiation, and via several 100 000 solar masses of warmer, mostly atomic gas, up to the very hot X-ray emitting plasma in the extended super-bubble. Our data show how the violent feedback from the massive stars drives the evolution of the clouds in this giant complex over timescales of a few mega-years. In some locations, the initial dense molecular clouds are already completely dispersed, whereas in other locations the stellar feedback created new dense clouds by sweeping up and compressing lower-density gas, and triggers the formation of new generations of stars in compressed cloud pillars.

11:55 Contributed talk: Models for the circumstellar medium of massive runaway stars
by Dominique Meyer (AIfA, Bonn)

Observations of stellar wind bow shocks can be used to constrain stellar, circumstellar and interstellar medium (ISM) properties. This presentation aims at introducing a grid of two-dimensional hydrodynamical simulations of wind-ISM interaction of massive runaway stars. This explores the combined effects of space velocities (ranging from 20 to 70 km/s) and initial masses (ranging from 10 to 40 solar masses) of runaway stars on the structure of their bow shocks. The stellar evolution is followed from the main-sequence to the red supergiant phase. We included optically thin radiative cooling along with heating from H ionization for models involving main-sequence stars, and from the Galactic UV background for models involving red supergiant stars in our treatment of the gas, together with electronic thermal conduction.
We classify our models of bow shocks in accordance with the density and temperature conditions prevailing in those structures, discriminating between adiabatic and radiative cases. We dwell upon the mixing process induced by thermal conduction, which transports dusty ISM material into the inner layers of the bow shocks and influencing their luminosity. Together with H emission maps of our models of bow shocks, we have derive constraints which may help to observe and characterized this kind of stars.

12:10 Contributed talk: Dynamics of H II regions around exiled O stars
by Jonathan Mackey (AIfA, Bonn)

At least 25 per cent of massive stars are ejected from their parent cluster, becoming runaways or exiles, traveling with often-supersonic space velocities through the interstellar medium (ISM). Their H II regions can strongly impact the structure of the ISM: the overpressurized H II region imparts kinetic energy and momentum to the ISM; it compresses and/or evaporates dense clouds; and it can be used as a diagnostic of the properties of both the star and the ISM. Here we present the first three-dimensional simulations of the H II region around a massive star moving supersonically through a uniform, magnetised ISM, with properties appropriate for the nearby O star Zeta Oph. The H II region leaves an expanding overdense shell behind the star and, inside this, an underdense wake that should be filled with hot gas from the shocked stellar wind. The gas column density in the overdense shell is strongly influenced by the ISM magnetic field strength and orientation because shocks are weak and magnetic pressure is significant. Ionisation front stability is also affected by magnetic field orientation. For our model parameters, the kinetic energy feedback from the H II region is comparable to the mechanical luminosity of the stellar wind, and the momentum feedback rate is more than 100 times larger than that from the wind and about 10 times larger than the total momentum input rate available from radiation pressure. Compared to the star's eventual supernova explosion, the kinetic energy feedback from the H II region over the star's main sequence lifetime is more than 100 times less, but the momentum feedback is up to 4 times larger. Simulated observations in $\mathrm{H}\alpha$ and 21 cm neutral H lines are also presented and compared to observations.

12:25 Lunch Break / Poster Viewing

14:00 **Guided tour through Munich including visit to Nymphenburg Castle**

18:00 **Conference Dinner**

► The magnetised ISM

Chair: Rowan Smith

09:00 Review talk: The magnetised ISM: Theory
by Ellen Gould Zweibel (University of Wisconsin)

09:30 Review talk: The magnetized ISM: Observations
by Richard Crutcher (University of Illinois)

10:00 Contributed talk: Mapping the structure of the Galactic magnetic field with Planck
by Francois Boulanger (Institut d'Astrophysique Spatiale)

The Planck satellite has completed the first whole sky map of dust polarization in emission. The data is revealing a new sky we have started to explore. The observations have the sensitivity and angular resolution to image dust polarization over the whole sky. For the first time, we have the data needed to characterize the structure of the Galactic magnetic field and its coupling with interstellar matter and turbulence, in the diffuse interstellar medium and molecular clouds. The data analysis also involves the characterization of the polarization properties of dust. I will present the Planck observations, and the science questions we are investigating with results from the first Galactic Planck polarization papers.

10:15 Contributed talk: Magnetic fields in high velocity clouds
by Alex Hill (CSIRO Astronomy & Space Science)

High velocity clouds (HVCs) observed around the Milky Way trace the interaction between the Galactic disk and halo and may provide fuel for star formation in the disk. However, hydrodynamic work suggests that HVCs should not be able to survive passage through the Galactic halo as far as observed. We present an analysis of Faraday rotation observations which we have used to measure magnetic fields of > 6 microGauss in two HVCs. The HVCs probe different halo environments, ~ 3 and ~ 30 kpc from the disk. Our data constrain the magnetic field geometry within the cloud. In the Smith Cloud, the detected magnetic field is associated with gas which has been stripped from the HVC by the ambient ISM. As gas clouds without any evidence for star formation, HVCs are also relatively simple tests cases of gas physics. Observations like ours provide tests for magnetohydrodynamic simulations of interacting gas.

10:30 Coffee and Tea Break / Poster Viewing

11:00 Contributed talk: Multi-wavelength polarization measurements tracing the ISM magnetic field
by Stefan Reißl (Univ. Kiel)

Magnetic fields in the interstellar medium (ISM) critically affect many astrophysical processes in various environments and scales, such as the collapse of molecular clouds, the formation of jets, and accretion of matter through circumstellar disks. However, vital questions still remain unanswered due to an apparently complex structure of the magnetic field on various scales and so far rather limited constraints from line-of-sight polarization measurements.
With the help of scattering and dichroic polarization mechanisms of stellar light and dust reemission radiation we study both, the properties of dust particles and the effects of magnetic fields in the ISM itself. Various dust grain properties, alignment mechanisms and advanced magneto-hydro dynamic (MHD) scenarios are considered to offer intensity and polarization maps for the analysis of a broad variety of observed ISM configurations. Processed ideal as well as more realistic MHD scenarios reveal the advantages and the potential of linear but also of circular polarization measurements as a promising source of additional information.
We present first results of synthetic continuum polarization maps resulting from post-processed MHD simulations combined with a model of non-spherical imperfectly aligned dust grains. In contrast to ideal scenarios, complex temperature, density distributions as well as corresponding magnetic field configurations lead to a wide variation of unexpected polarization effects and are often intuitively no longer accessible. These effects allow us to disentangle ambiguities in the interpretation of two-dimensional polarization maps and thus will subsequently lead to a more detailed understanding of the magnetic field morphology based on dedicated multi-scale, multi-wavelength polarization measurements.

11:15 Contributed talk: The far-infrared - radio correlation: Star formation and magnetic field amplification in the ISM
by Dominik Schleicher (Institut für Astrophysik Göttingen)

The presence of magnetic fields is well-established in the interstellar medium of galaxies, which can be probed via the far-infrared - radio correlation even at high redshift. The latter corresponds to a correlation between the star formation rate and the magnetic field strength in galaxies. In this talk, I will show how such a correlation can be obtained as a result of turbulent magnetic field amplification. For this purpose, I will present recent studies on turbulent magnetic field amplification at high Mach numbers, and show how the latter leads to a natural relation between the star formation rate and the magnetic field strength. For this purpose, I will assume that supernova explosions are the main drivers of turbulence, and derive the expected turbulent velocities and magnetic field strength as a function of the star formation rate. I will discuss the potential evolution of this correlation with redshift, and show that we expect a breakdown in the correlation when the timescale for inverse Compton scattering becomes shorter than the timescale for synchrotron emission. The evolution of this correlation will be tested with the SKA and its pathfinders in the coming years.

► ISM on Galactic Scales

Chair: Rowan Smith

11:30 Review talk: ISM on galactic scales: Observations
by Alberto Bolatto (University of Maryland)

12:00 Review talk: ISM on galactic scales: Theory
by Andreas Burkert (USM/LMU)

12:30 Lunch Break / Poster Viewing

14:00 Contributed talk: Dust luminosity as a tracer of gas mass and gas heating
by Brent Groves (MPIA, Heidelberg)

In the local universe the mass of gas in galaxies is usually measured through the combination of the 21 cm HI line, tracing the atomic gas, and the CO sub-millimeter lines that trace the molecular interstellar medium (ISM). However, the dust infrared continuum provides another tracer of the ISM mass, through two paths; the correlation of dust and gas mass, and the association of the total IR luminosity with CO luminosity (related to the Kennicutt-Schmidt relation). Here, using a matched sample of 36 galaxies from the KINGFISH (IR), HERACLES (CO), and THINGS (HI) surveys, we show the correlation of individual Herschel bands with the ISM mass. We find the tightest correlation of total gas mass with the longest wavelength data (SPIRE500), but that the molecular gas is more associated with the peak of the IR emission (e.g. PACS160). We provide fits to these relations for use with ongoing surveys with ALMA, and demonstrate how the equivalent widths of the CO lines provide an excellent tracer of the molecular gas fraction in galaxies.

14:15 Contributed talk: Structure formation and evolution in gas-rich disk systems
by Manuel Behrendt (MPE, Garching)

We perform high resolution hydrodynamical simulations of gas-rich disks to get a better understanding of the origin and peculiar properties of the dominating structures in z=2 massive disk galaxies. Their structure is irregular, they have highly turbulent motions and high gas fractions of 30-80%. Stars form with enormous rates of a factor of 10-100 higher than in the Milky Way. The star formation is concentrated in a few gigantic clumps of molecular gas, about 1000 times larger than present day molecular clouds. In our simulations, we follow the fragmentation process induced by gravitational instabilities from the beginning and the evolution up to a few orbital times. In this talk, I focus on axisymmetric instabilities described by an extended theory, which takes the thickness of the disk into account. Furthermore, I present the concept within the context of an idealized simulation of a disk in hydrostatic equilibrium.

14:30 Contributed talk: The survey of lines in M31 (SLIM): Investigating the origins of [CII] emission
by Maria Kapala (MPIA, Heidelberg)

The [CII] 158 micron line is typically the brightest emission line from star-forming galaxies and arises from both the ionized and neutral phases of the ISM. As a strong line it has been suggested both as a tracer of star-formation and a diagnostic of the ISM, but first we must distinguish the ISM phases it arises from and understand how it is excited.
To address these issues we have assembled a unique set of observations of regions across the disk in the Andromeda galaxy, including: [CII] 158 micron and [OI] 63 micron maps from Herschel PACS, optical integral field spectroscopy from PPAK on the Calar Alto 3.5m, Hubble imaging of the FUV-NIR, and Herschel dust continuum mapping from 70-500 microns.
We show preliminary results demonstrating how [CII] correlates with the far-IR continuum on 50 pc scales and reveal that star-forming regions of M31 do not show a “far-IR line deficit” even in regions of warm dust. Using the optical line emission, we determine the fraction of [CII] emission spatially associated with star-forming regions.
From the Hubble stellar data we find most of the UV that heats the dust, and presumably the [CII], originates from massive B stars, less massive (an older) than necessary to create HII regions.
Our results suggest that studies using C+ to trace the massive star-formation rate must take into account the contribution to ISM gas heating by older stellar populations.

14:45 Contributed talk: Evolution of molecular gas in spiral galaxies
by Jin Koda (Stony Brook University)

I will discuss the formation and evolution of giant molecular clouds (GMCs) in spiral galaxies. The evolution appears quite different between the molecule-rich and atom-rich galaxies. GMCs exist almost exclusively along HI spiral arms and filaments in atom-rich galaxies, suggesting that they form and finish their short lifetimes within the HI arms. However, in molecular-rich galaxies, GMCs are present everywhere independent of HI structures. Indeed, the molecular gas fraction remains high and almost constant during arm passage into the next inter-arm region. The gas remains molecular for a long time, suggesting long lifetimes of molecule, and presumably GMCs. The physical conditions of molecular gas change from spiral arms to inter-arm regions. An increase of the CO J=2-1 and 1-0 line ratio in spiral arms in M51 suggests density and/or temperature increases by a factor of 2-3 in GMCs in the arms, compared to their counterparts in the inter-arm regions. An analysis of high-resolution Milky Way survey data provided a more detailed, clear view - the fraction of dense (or warm) clumps increases dramatically in the spiral arms.

15:00 Contributed talk: Superbubbles as a physical process in the ISM
by Martin Krause (MPE, Garching)

With sizes from below 100 pc to just above 1kpc, superbubbles are structuring the ISM on scales in between the larger scale spiral arms and the smaller, turbulent molecular cloud scales. With 3D hydrodynamics simulation of the entire stellar evolution of and the interaction between an ensemble of massive stars we are able to explain at least some of the apparent width of observed bubbles via the Vishniac instability and the X-ray properties via an interplay between supernova heating and cooling via Rayleigh-Taylor-induced mixing. We investigate the effective energy input into the ISM which increases with stronger clustering. Applied to galaxy scale, we show that the expansion of superbubbles into gaseous halos of Lyman-break galaxies is able to produce the observed absorption systems at the correct column densities and velocities. In the Milky Way, we have recently measured the kinematics of hot bubble content over the entire galactic plane via γ-ray line tracers (26Al). Our results are consistent with young superbubbles located in the inner spiral arms of the Milky Way and having a global blow-out preference into the direction of Galactic rotation, away from the arms into the inter-arm region.

15:15 Contributed talk: Star formation and molecular gas outside galaxies
by Ute Lisenfeld (Universidad Granada)

In galaxy collisions gas and stars can be torn out of the parent galaxies, giving rise to tails and bridges of gas and to intergalactic star forming region of different sizes. These regions are ideal to study the conditions for the onset of star formation in very simple environments which are different from those in spiral galaxies.
I will describe and compare the molecular gas properties and the star formation in some of these systems and show that there is a broad range of SF activity present. I will discuss what we can learn about the formation of molecular gas and the properties and triggers of star formation.

15:30 Coffee and Tea Break / Poster Viewing

16:00 Contributed talk: The resolved ISM of our nearest spiral galaxy
by Andreas Schruba (MPE, Garching)

I summarize first results from a large CARMA survey to image CO(1-0) emission at high sensitivity and resolution (20pc, 1km/s) in the nearby Andromeda galaxy (M31). This survey augments a new extensive set of multi-wavelength data including Hubble, Spitzer, Herschel, VLA photometry and spectroscopy that provide an unprecedented knowledge of the stars, dust, and gas in M31. We are able to measure the properties of 500 giant molecular clouds (GMCs) and perform a statistical study of GMC properties across a wide range of environments. We determine the requirements for the formation of GMCs, measure their lifetimes, and study the timescale and efficiency of feedback. In addition, we measure the dust-to-gas ratio and calibrate the CO-to-H_2 factor on GMC scales. These observations will provide essential benchmarks for models of ISM balance, GMC and star formation in a typical L* galaxy - the galaxy type where most stars are forming.

16:15 Contributed talk: The sub-linear and non-universal Kennicutt-Schmidt relationship
by Rahul Shetty (ZAH/ITA, University of Heidelberg)

The star formation rate is observed to be strongly correlated with the gas surface density. This correlation is well described as a power-law with index N, now known as the Kennicutt-Schmidt (KS) relationship. Previous efforts have inferred $\mathrm{N} = 1.5$ when considering both resolved observations of galaxies as well as unresolved starbursting systems. More recently, analysis of resolved observations have resulted in a linear relationship, which is interpreted as evidence for a constant gas depletion time of 2 Gyr, though with significant scatter. Using a hierarchical Bayesian fitting method, I show that resolved observations of nearby disk galaxies from the STING and HERACLES sample actually strongly suggest a sub-linear relationship, with significant galaxy-to-galaxy variation. The hierarchical Bayesian method has the advantage of accurately accounting for statistical and systematic uncertainties, and simultaneously estimates the parameters for all individual galaxies as well as the mean value of the ensemble. The index N of individual galaxies ranges from 0.5 to 1.0, with the mean value of all galaxies $\mathrm{N} \sim 0.75$. Therefore, there is no universal KS law that can reproduce the observed trends for all galaxies. This indicates that other physical properties besides the CO traced gas influence the star formation rates, such as stellar content, gas fraction, and/or magnetic fields. More importantly, the sub-linearity in the KS relationship indicates that CO emission is not solely originating from star forming gas (e.g. "GMCs") but rather that CO also traces a non-star forming diffuse component. Consequently, the depletion time increases with increasing gas surface density, as traced by CO emission.

16:30 Contributed talk: Two regimes of star formation
by Javier Zaragoza-Cardiel (IAC)

We have used interacting galaxies to explore the properties of high luminosity star forming zones. With the GHaFaS Fabry-Perot spectrometer on the 4.2 m William Herschel Telescope (La Palma) we have used $\mathrm{H}\alpha$ emission to obtain complete 2D mapping in surface brightness, velocity, and velocity dispersion of 8 pairs of interacting galaxies. The detailed kinematics reveal global features such as inflows towards the nuclei of some systems, and expanding superbubbles characteristic of galactic superwinds.
Combining the information in the three types of maps we have determined the radii, velocity dispersions, luminosities and then the masses of some 500 HII regions. We find two distinct parametric relations between mean density and mass for regions in the highest luminosity range and at lower luminosities. We note that the most luminous regions show especially high values for their velocity dispersions, and use the evidence to support the hypothesis that these regions form from high mass molecular clouds which were originally gravitationally bound, while the lower luminosity regions formed within molecular clouds originally confined by external pressure. This is supported by the data of Wei et al. who detected, using CO observations in the Antennae, (which we have now confirmed using data from ALMA) two distinct sets of molecular clouds with a transition mass of $\sim 3 \times 10^6$ solar masses, a similar mass to the transition between the two regimes we find for the HII regions.
Our hypothesis is that the formation of the densest, most massive molecular clouds is favored by galaxy-galaxy interaction. Within these clouds massive star formation occurs more readily than in lower mass pressure-confined clouds.

► The ISM in the extreme environment of galactic centers

Chair: Avishai Dekel

16:45 Review talk: The ISM in the extreme environment of galactic centers
by Steven Longmore (Liverpool John Moores University)

17:25 Contributed talk: The ISM in the extreme environment of early-type galaxies
by Timothy Davis (ESO)

The centres of early-type galaxies are extreme environments, with strong radiation fields from old stars, high metallicities, alpha-enhancements, deep potential wells, and a high incidence of AGN. It has been shown in recent years that despite these extreme conditions a sizeable proportion of these galaxies have a cold ISM, with atomic/molecular gas and dust reservoirs. We have carried out a comprehensive survey of the cold and warm ISM in the volume-limited ATLAS-3D sample of early-type galaxies; our data include CO and HI maps, detections of high density molecular tracers, optical emission line ratios, and Herschel spectroscopy of the [CII], [OI] 63micron, and [NII] 122 and 205 micron lines plus the high-J CO ladder. Our data also allow us to probe the influence of a galaxy's cluster or group environment, AGN activity, and its dynamical state on the properties of its ISM. I will show that environment has a strong effect on the kinematics and chemistry of gas in early-type galaxies. In addition, spatially resolved measures of the star formation rate and the gas depletion timescales show that these massive galaxies have lower star-formation efficiencies than one might expect based on canonical star-formation relations. These observations of "normal" early-type galaxies in the local universe provide a useful comparison sample for local spirals, radio galaxies, central galaxies of cooling flow clusters, and systems at higher redshift. All of this information can be combined with our knowledge of the galaxies' stellar populations (ages, metallicities & kinematics) for insights into the formation and evolution of early-type galaxies, and enable us to make predictions which will be directly testable in the era of ALMA, CCAT and the LMT.

17:40 Contributed talk: Physical processes of gas ionization in the Galactic Center and the origin of 6.4 keV and absorption H_3^+ Lines from there
by Vladimir Dogiel (P.N.Lebedev Institute of Physics)

We investigate the origin of the diffuse 6.4 keV line emission and the source of H_2 ionization in the diffuse molecular gas of the Galactic center (GC) region. We showed that Fe atoms are most likely ionized by X-ray photons emitted by Sgr A* during a previous period of flaring activity of the supermassive black hole. The H_2 molecules of the diffuse gas can not be ionized by photons from Sgr A*, because soft photons are strongly absorbed in the interstellar gas around the central black hole. The molecular hydrogen in the GC region is most likely ionized by low-energy cosmic rays, probably protons rather than electrons, whose contribution into the diffuse 6.4 keV line emission is negligible.

► Cosmic rays and their impact on the ISM

Chair: Ellen Gould Zweibel

09:00 Review talk: Cosmic rays and their impact on the ISM
by Tsuyoshi Inoue (Aoyama Gakuin University)

09:40 Contributed talk: Cosmic ray propagation in molecular clouds
by Sabrina Casanova (MPIK, Heidelberg)

We solve the transport equations of cosmic rays inside a molecular cloud assuming an arbitrary energy and space dependent diffusion coefficient. Cosmic rays penetrating the cloud produce γ-ray emission through pp collisions with the ambient gas. For small diffusion coefficients inside the cloud we expect the γ-ray spectrum from the cloud to be harder than the Galactic diffuse emission spectrum, mainly due to the slower penetration of the low energy particles towards the core of the cloud. Moreover we study the influence of the gas density profile on the γ-ray emission. Finally we present predictions for present and future telescopes to observe γ-ray emission from molecular clouds and from their dense cores.

09:55 Contributed talk: Cosmic ray driven Galactic outflows and the evolution of cosmic ray spectra
by Philipp Girichidis (MPA, Garching)

We explore the impact of cosmic rays (CR) on the structure of the ISM, the turbulence in the Galactic disk, and how/to what extent cosmic rays drive Galactic outflows. We include the production of cosmic rays in SN remnants in a stratified box and follow the coupled system of gas and cosmic ray fluid self-consistently in three-dimensional adaptive mesh refinement simulations. The coupled system of MHD equations combines the gas as well as 10 different CR energy fluids for different CR energies. We include anisotropic diffusion along the magnetic field lines and energy dependent diffusion coefficients for the 10 CR fluids. We thus do not only follow the net effects of CRs on the Galactic outflows but also investigate how the CR energy spectra evolve in the Galactic disk and which CR energy range is most important for the dynamics in different regions of the ISM and for Galactic outflows.

10:10 Contributed talk: The cosmic-ray ionization rate in the Central parsec of the Galaxy
by Miwa Goto (USM/LMU)

Cosmic ray is a unique place that high-energy astrophysics meets low-energy chemistry. The ion molecule H_3^+ is the best chemical probe of the cosmic ray ionization rate, because of the simplicity of the chemical process. Meanwhile, a new γ-ray observation identified a point like source near Sgr A*. To produce the γ-ray flux discovered by HESS collaboration by a neutral pion decay, one needs cosmic-ray proton flux as high as 7×10^4 protons/cm^2/s/str/(nucleon/GeV), which is 10^5 times higher than the solar neighborhood. Such a high proton flux calls for the hydrogen ionization rate 10^5 times larger than the Galactic disk, while there is no hint of such enhanced cosmic ray flux found in view of H_3^+ chemistry. The huge discrepancy underscores our limited understanding of high energy environment in the central parsec of the Galaxy.

10:25 Contributed talk: Probing cosmic rays in nearby giant molecular clouds with the Fermi Large Area Telescope
by Ruizhi Yang (Purple Mountain Observatory)

We report the results of our study on the energy spectra and absolute fluxes of cosmic rays (CRs) in the Local Galaxy based on three-year γ-ray observations of ten nearby giant molecular clouds (GMCs) belongs to the Gould Belt, with the Fermi Large Area Telescope (LAT). The γ-ray signals obtained with high statistical significance allow the determination of γ-ray spectra above 300 MeV with adequate precision for extraction of the energy distributions of CRs in these clouds. Remarkably, both the derived spectral indices and the absolute fluxes of CR protons in the energy interval 10-100 GeV are in good agreement with the recent direct measurements of local CRs by the PAMELA experiment. This is a strong evidence for a quite homogeneous distribution of CRs, at least within several hundred parsecs of the Local Galaxy. Combined with the well established energy-dependent time of escape of CRs from the Galaxy, $\tau(E) \sim E^{-\delta}$ with $\delta \simeq 0.5 - 0.6$, the measured spectrum implies a CRs spectral index of the (acceleration) source of $E^{-2.3}$. At low energies, the spectra of γ-rays appear to vary from one cloud to another. This implies spatial variations of the energy spectra of CR below 10 GeV which at such low energies could be naturally explained by the impact of the propagation effects as well as by the contribution of CR locally accelerated inside the clouds.

10:40 Coffee and Tea Break / Poster Viewing

▶ The ISM at high redshift

Chair: Ellen Gould Zweibel

11:10 Review talk: The ISM at high redshift: Observations
by Linda Tacconi (MPE, Garching)

11:40 Review talk: The ISM at high redshift: Theory
by Avishai Dekel (The Hebrew University)

12:10 Contributed talk: Turbulence and the formation of supermassive black holes at high redshift
by Muhammad Latif (Institute for Astrophysics, Göttingen)

Supermassive black holes have been observed even at redshift 7, their formation and growth need to be highly efficient in order to obtain final masses of more than $10^9 \mathrm{M}_\odot$ solar. Theoretical models suggest the formation of their seeds in dark matter halos with virial temperatures above 10^4 K at $z \sim 15$, as such halos may cool efficiently via atomic hydrogen. At the same time, in order to avoid strong fragmentation, the formation of molecular hydrogen needs to be suppressed, requiring strong radiation backgrounds. In this conference, I will present cosmological hydrodynamics simulations following the collapse in these halos from large cosmological scales down to scales of ~ 1 AU. The hydrodynamical evolution is followed beyond the formation of the first peak. The simulations demonstrate clearly that occasional fragmentation occurs, but does not prevent the growth of a central massive object. I will stress the role of turbulence and numerical resolution for such studies. Furthermore, I will show how massive seeds can be obtained from direct-collapse scenario of black hole formation.

12:25 Contributed talk: Outflows and the multi-phase turbulent structure of the ISM in high-redshift galaxies
by Thorsten Naab (MPA, Garching)

Outflows and the structure of the ISM in high-redshift galaxies
Recent observations of high-redshift galaxies indicate that the conditions in their ISM are distinctively different to local galaxies. High formation rates of stars embedded in an extremely dense and highly turbulent interstellar medium with high molecular gas fractions and strong gas outflows are ubiquitous. We present new high-resolution sub-parsec scale adaptive mesh simulations of stratified disks to demonstrate how rapidly H_2 and CO molecules can form in such an extreme environment and how the evolution and subsequent explosions of massive stars shape the ISM and drive turbulence as well as mass-loaded outflows in agreement with current observations at redshifts $z \sim 1 - 2$. For this project we acknowledge support from DFG priority program 1573.

12:40 Lunch Break and End of Conference

POSTERS

▶ Poster session: The multi-phase ISM

Poster P01 Supernova Ejecta Mixing in Galactic Disks
by Christian Baczynski (ZAH/ITA, University of Heidelberg)

We present a suite of simulations of a vertical stratified box with extents of ± 20 kpc and a footprint of 1 kpc^2 including self-gravity, supernova feedback, magnetic fields and a resolution of 2 pc. We are able to resolve the ISM structure in the disk midplane and follow SN ejecta using tracer particles based on an Monte-Carlo advection scheme. The large vertical extents allow us to follow galactic fountains and investigate if galactic reaccretion of ejecta plays a role in uniformly mixing ejecta into the ISM. Additionally we are able to look at initial conditions for cloud formation, in particular spread in initial metallicities. Lastly we will have an estimate of how long it takes to form an equilibrated distribution (if there is one) of ejecta throughout the disk.

Poster P02 THOR - The HI, OH, Recombination Line Survey of the Milky Way
by Simon Bihr (MPIA, Heidelberg)

How do molecular clouds form from the diffuse atomic interstellar medium? To address this and further questions we are conducting the THOR survey, a galactic plane survey ($l = 15$ to 60 dec and $b = -1$ to $+1$ dec) of the 21 cm HI line, four OH lines, and 20 recombination lines as well as the continuum from 1 to 2 GHz at a spatial resolution of ~ 20 arcsec. We got granted 110 hours at the VLA in C-configuration. To test the configuration, we did a pilot study around the active star forming region W43 in 2012. The data analysis is work in progress and we combined our data with the VGPS survey (VLA Galactic plane survey - HI in D-configuration). This allows us to reconstruct all spatial scales down to $0.2 - 0.5$ pc. We will compare our data with CO data to study the cloud formation from the atomic to the molecular phase. We find significantly higher HI column densities for W43 than for other regions such as Perseus. The reason for these high column densities is under discussion, but we argue, that the strong interstellar radiation field of W43 prevents the formation of molecular hydrogen.

Poster P03 On the connection between HI self-absorption and the presence of molecular gas
by Jonathan Heiner (CRyA, UNAM Morelia)

Cold, self-absorbing atomic hydrogen can be seen as absorption features in the broader HI profile. However, unless emission of molecular gas (typically CO) at the same velocity as the absorption feature is detected, it is not always possible to distinguish between self-absorption and the lack of HI emission. Ideally one would want to dispense with the need to detect molecular emission, since not all molecular gas is visible in tracer lines such as CO. It is also important to distinguish whether gas is flowing into, or exiting a gas cloud.
We present simulations featuring decaying turbulence, where molecular clouds form in filamentary structures that resemble observed molecular clouds. In order to determine when and where molecular gas has formed, we used a simple recipe involving the local visual extinction and temperature. Then, we produced synthetic observations of the simulations.
After separating the absorption features from those due to the absence of atomic gas, we compared to what extent and on what scale the HI self-absorption (HISA) correlates with the molecular column density. In actual observations it is possible to use the second derivative of the brightness temperature profile to find potential HISA features. We verified how well the second derivative traces the molecular gas. While it does a rather poor job at the sub-parsec scale, the agreement improves significantly at scales of several parsec, although it does not become a perfect tracer.
Additionally, we show the evolution of the probability density functions within the simulation volume, which informs us of the state of the gas (for example whether it is forming stars). Our simulations are dominated by colliding gas flows, which can be seen in position/velocity cuts through the simulation volume. Finally, I will discuss what improvements to the model are needed in order to truly distinguish between situations where atomic gas flows into the cloud and where atomic gas is leaving, for example due to photodissociation of the molecular gas.

Poster P04 Instability of Evaporation Fronts in the ISM
by Jeong-Gyu Kim (Seoul National University)

The neutral component of the interstellar medium (ISM) is segregated into the cold neutral medium (CNM) and warm neutral medium (WNM) as a result of thermal instability. It was found that the CNM–WNM evaporation interface, across which the CNM undergoes thermal expansion, is linearly unstable to corrugational disturbances, in complete analogy with the Darrieus-Landau instability (DLI) of terrestrial flames. To explore dynamical consequences of the DLI in the ISM, we perform a full linear stability analysis of the DLI as well as nonlinear hydrodynamic simulations in the presence of thermal conduction but without magnetic fields. We find that the DLI is suppressed at short length scales via heat transport. The time and length scales of the fastest growing mode are squarely and inversely proportional to the evaporation flow speed of the CNM relative to the interface, respectively. In the nonlinear stage, the front deforms into a finger-like structure, rather than a cusp, protruding toward the WNM, and soon reach a steady state where the evaporation rate is increased by a factor of ~ 2.4 compared to the initial value. We demonstrate that the front shape and the enhancement in the evaporation rate are determined primarily by the density ratio between the CNM and WNM.

Poster P05 The Tiny Scale Structure of the Interstellar Medium
by Catherine McEvoy (Queen's University Belfast)

The tiny scale structure (from 1 AU to 1 pc) of the ISM is generally poorly understood. High resolution optical spectroscopic observations, both new and archival, have been used to delve into this tiny structure to see just how ubiquitous it is and to try to understand what causes such variation to occur.
Interstellar absorption lines from a selection of 96 O and B type stars spectra, observed at two epochs, have been directly compared to look for fine scale variation in the structure of the interstellar medium over time. Two sets of data were compared, UVES data ($R = 80\,000$) with approximately 6 years between epochs and McDonald data ($R = 140\,000$) with approximately 20 years between epochs. Each interstellar line has been cross correlated with its equivalent in the other epoch and one divided by the other to look for any residuals, in a search for changes in the profile of each absorption line.
We find tentative changes for tiny-scale structure in 7 sight lines in Na and/or Ca that we will follow up with third epoch observations.

Poster P06 X-Ray Absorption in the ISM: From C to Si
by Norbert S. Schulz (MIT)

The interstellar medium (ISM) absorbs and scatters X-rays and its signatures can be used to diagnose its states of matter, compositions, and dynamical properties. With the availability of precision X-ray optics and spectrometers as onboard the Chandra X-ray Observatory, scattering halos around bright X-ray sources and K/L shell X-ray absorption are now observed and measured in detail. This presentation summarizes the progress made so far in the determination of K/L shell edge fine structures from elements such as C, N, O, Ne, Mg, Si, and Fe. The edge structures and line absorptions contain valuable information about the cold, warm, and hot phases of the ISM, dust depletions and velocity dispersions.

Poster P07 Search for tiny scale structure in the interstellar medium
by Jonathan Smoker (ESO (VLT))

We describe a search for tiny-scale structure in the interstellar medium using archive twin-epoch measurements of resolution $42\,000$ and $120\,000$ towards hundreds of stars. Our aim is to discover more examples of time-variation in the interstellar medium and determine if they can be explained by varying physical conditions, the statistical properties of the ISM, or by "real" structures such as sheets or filaments.

▶ Poster session: Molecular cloud properties

Poster P08 Analysis of structural scaling of molecular clouds with wavelet cross-correlation.
by Tigran Arshakian (Universität zu Köln)

We develop a wavelet-based cross-correlation (WCC) method to study the correlation between characteristic structures in molecular clouds as a function of scale. The method compares a pair of maps observed in different tracers, at different wavelengths or in different velocity ranges. Advantages of the WCC: (i) it allows to measure the correlation coefficient and structural offset between two maps as a function of scale, (ii) allows to weight individual pixels by their observational significance, and (iii) is robust against the noise. Application of the WCC to simulated fBm (fractional Brownian motion) maps shows that the cross-correlation coefficient can strongly depend on the scale and correlation coefficient and offset can be recovered robustly regardless of noise. Analysis of the G333 molecular line maps (13CO and C18O) reveals a large scale gradient in the structural distribution. This could indicate a density structure where every core shows a low density tail in a preferred direction. Applications of the WCC to molecular line maps of the Rosette, Cygnus, Perseus, and IC 348 molecular clouds will be also discussed. By tracing the correlated structural changes between different maps of a molecular cloud the WCC detects scales representing the structural changes such as chemical and phase transitions.

Poster P09 A Multi-Scale Continuum and Line Exploration of the Most Luminous Star Formation Region in the Milky Way. The Mass Structure of the Giant Molecular Cloud.
by Roberto Galvan-Madrid (ESO, Garching)

Hauyu Baobab, Liu, ASIAA
Zhi-Yu, Zhang, Purple Mountain
Tzu-Cheng, Peng, ESO

The Multi-Scale Continuum and Line Exploration of W49 (MUSCLE W49) is a comprehensive gas and dust survey of the parental giant molecular cloud (GMC) of W49A, the most luminous ($L \sim 10^{7.3} L_\odot$) star-formation region in the Milky Way. The project has multiple components that cover the entire GMC at different scales and angular resolutions. We present results from observations with the SMA and the VLA, as well as the PMO 14 m telescope, the IRAM 30 m telescope, and the JCMT. We derive the basic properties of the GMC at all scales, from 0.05 pc to > 100 pc. We find that the GMC is distributed in a hierarchical network of filaments that is forming a young massive cluster (YMC), or a system of YMCs. Approximately 17% of the mass ($\sim 3 \times 10^5\,\mathrm{M_\odot}$) is concentrated in 0.1% of the volume (radius ~ 6 pc), where the mass surface density is $> 1000\,\mathrm{M_\odot}$ pc^{-2}. In spite of having already a stellar content of several times $10^4\,\mathrm{M_\odot}$, only ~ 1% of the gas has been photoionized. Likely, the resulting stellar content will remain as a gravitationally bound massive star cluster, or a small system of star clusters.

Poster P10 Turbulent assembly of molecular clouds
by Juan Camilo Ibañez (AMNH, New York)

Studying how self-gravitating turbulence in the interstellar medium determines the morphology, density profile and velocity dispersion of dense molecular clouds is key to understand the initial conditions of star formation. We use the Flash adaptive mesh refinement magnetohydrodynamics code to perform three-dimensional numerical simulations of a vertical column of the interstellar medium covering a square kiloparsec of a disk galaxy, with conditions similar to those of the solar neighborhood. A constant supernova rate drives turbulence in the ISM, determining the velocity dispersion resisting gravitational collapse, as well as the vertical structure of the galactic fountain. We focus mesh refinement on the dense, gravitationally bound clouds in the simulated volume to determine their structure and collapse rate. We present high resolution density and velocity profiles of individual, self-gravitating, clouds forming in a turbulent stratified medium.

Poster P11 CO isotope chemistry in GMC simulations: impact of the ^{12}CO/^{13}CO ratio on column density estimates
by László Szücs (ZAH/ITA, University of Heidelberg)

Carbon monoxide molecule (CO) and its isotopes are frequently used as tracers of column density in studies of the dense interstellar medium. The most abundant CO isotope, ^{12}CO, is usually optically thick in intermediate and high density regions and so provides only a lower limit for the column density. In these regions, less abundant isotopes are used, such as ^{13}CO. To relate observations of ^{13}CO to the ^{12}CO column density, a constant ^{12}CO/^{13}CO isotopic ratio is often adopted. In this work, we examine the impact of two effects – selective photodissociation of ^{13}CO and chemical fractionation – on the ^{12}CO/^{13}CO isotopic ratio, using numerical simulations. We follow the coupled chemical, thermal and dynamical evolution of isolated molecular clouds in several different environments and post-process our simulation results with line radiative transfer in order to obtain maps of the emergent ^{13}CO emission. We compare emission maps produced assuming a constant isotopic ratio with the ones based on a more self-consistent calculation, and also compare the ^{12}CO column density maps derived from the emission maps. We find a close correlation between the ^{12}CO column density and the isotopic ratio with only a weak dependence on the cloud properties. At low and high column densities, the column density estimates that we obtain with the approximation of constant isotopic ratio agree with those derived from the self-consistent model. At intermediate column densities, the approximate model over-predicts the ^{12}CO column density by a factor of a few, but we show we can correct for this. This allows us to obtain more accurate ^{13}CO emission maps from simulations and to improve ^{12}CO column densities estimates from observations.

► Poster session: Turbulence in the ISM

Poster P12 Numerical simulations of shock-cloud interactions
by Robertas Aluzas (School of Physics and Astronomy, University of Leeds)

The interstellar medium (ISM) is highly structured and inhomogeneous. Density enhancements (clouds) that occupy a small volume fraction can dominate the mass fraction. The interaction between clouds and flows is a key process affecting the behavior and evolution of the ISM, with implications for star formation and galaxy evolution. For instance, dense clouds may be destroyed by a flow, while at other times they may be compressed to the point that star formation is initiated.
Consequently, the physical interaction between a shock and a cloud, has attracted a lot of study, including various multi-physics models. However, very little work yet concerns the presence of multiple clouds and their mutual effect on a flow. I will present new results of numerical simulations of shock interactions with many clouds. The aim of this work is to self-consistently model the evolution of the flow due to the presence of multiple clouds and the evolution of the clouds due to the mass-loaded flow.
In purely hydrodynamic simulations we find that although upstream clouds are effective at slowing down the shock the turbulence and momentum in the mass-loaded flow generally destroys downstream clouds faster. The effect is particularly significant for clouds denser than the average cloud in the distribution.
In MHD simulations the magnetic fields impose structure on the interacting flow. Compared to the purely hydrodynamic case we find that perpendicular and oblique fields lead to clumpiness, while "flux-ropes" in the parallel case create two distinct downstream regions, which in extreme cases can cause radically different cloud evolution depending on the exact position of downstream clouds.

Poster P13 Molecular cloud formation in colliding bubbles: A study of Lupus I
by Benjamin Gaczkowski (USM/LMU)

The Lupus I cloud complex is located in the collision zone between two expanding superbubbles that are driven by the massive stars in two sub-groups of the ScoCen OB association. With a distance of just 150 pc, it represents the nearest example where we can study how such a collision process forms new dense clouds in the ISM. With multi-wavelength data available, we are able to conduct a comprehensive investigation of the physical structure of the cloud and its surroundings. We infer from these data the temperature and density distribution of the Lupus I cloud, its total mass, the small-scale structure, as well as the clump- and core-mass functions. The complete data set will be compared to detailed numerical models of expanding bubbles and colliding flows in the ISM that are developed by members of our team, and will advance our understanding of the effects of massive star feedback on the surrounding ISM.

Poster P14 The density distribution in thermally bistable turbulent flows
by Adriana Gazol (CRyA,UNAM)

We numerically study the volume density probability density function (n-PDF) and the column density probability density function (σ-PDF) resulting from thermally bistable turbulent flows with and without self-gravity. For this aim we analyze three- dimensional hydrodynamic models in periodic boxes of 100pc by side with forced turbulence at large scales and different Mach numbers (M). At low densities ($n \lesssim 0.6\,\mathrm{cm}^{-3}$), the n-PDF is well described by a lognormal distribution, but as consequence of the nonlinear development of thermal instability (TI), the logarithmic variance of the distribution increases faster with M than it does in the isothermal case. For the dense gas ($n \gtrsim 7.1\,\mathrm{cm}^{-3}$) the shape of the PDF depends on the Mach number and change in the presence of self-gravity in low M models. On the other hand, for non self gravitating models, σ-PDF at high column densities is well described by a lognormal for all the values of M and, due to the presence of TI, the width of the distribution is systematically larger than in the isothermal case but follows a similar behavior as M increases. When gravity is included, the shape of the σ-PDF at high column densities depends on the value of M.

Poster P15 Turbulent ISM and star formation in the prototypical Antennae galaxy merger
by Cinthya N. Herrera (NAOJ)

The Antennae are a spectacular example of a burst of star formation triggered by the encounter of two galaxies. They are an ideal source to understand how the dynamics of galaxies in mergers trigger the star formation. In the Antennae, most of the newly formed stars are observed in massive clusters (up to $10^7\,\mathrm{M}_\odot$), dubbed super star clusters, located in the region where the two galaxies collide. Their formation must involve a complex interplay of merger-driven gas dynamics, turbulence fed by galaxy interaction and dissipation of the kinetic energy of the gas.
We will present ALMA CO(3-2) observations and VLT near-IR H_2 spectro-imaging observations. The data show that the kinetic energy of the galaxies is not thermalized in large scale shocks, but it drives turbulence in the molecular ISM much stronger than observed in the Milky Way. Near-IR spectral diagnostics show that most of the H_2 line emission is shock-powered and traces the dissipation of the gas turbulent kinetic energy. We relate the H_2 emission to the loss of kinetic energy required to form gravitationally bound clouds. This interpretation is supported by the discovery of a compact, bright H_2 emitter source located where the velocity gradient in the interaction region is observed to be the largest, at the interface of red- and blue-shifted gas. The characteristics of this source suggest that we are witnessing the formation, initiated by turbulent dissipation, of a cloud massive enough to form a super star cluster. Does turbulence play a similar role in other environments? We will discuss our plans of investigating the turbulence-driven star formation in different environments. ALMA Cycle 1 observations of shock tracers in the Antennae (proposal accepted in first priority) will be key to reach our goals.

Poster P16 Turbulence properties of shocked HI gas associated with Galactic supernova remnants
by Ji-hyun Kang (Korea Astronomy and Space Science Institute)

Turbulence study of the neutral hydrogen gas associated with supernova remnants (SNRs) has not been done so far, in spite of the fact that many HI surveys have been used to characterize the turbulent interstellar medium. This is mainly because the shocked HI emission of SNRs is difficult to be distinguished from the ambient HI emission in the Galactic Plane. We notice that some expanding HI shells of Galactic SNRs have observed at high velocities, and they are free from the contamination of other Galactic HI gas at such high velocities. In the Arecibo HI Inner Galactic Plane Survey data, four of these SNRs are detected and resolved at such high velocities, which enables us to investigate the turbulence properties of internal HI structures of SNRs. We present our preliminary results. We estimated the HI column density power spectra of four Galactic supernova remnants, W44, W51C, G54.4-0.3, and CTB80. We find that they follow a power-law with a slope of about -3, except CTB80, of which slope is flatter. This value is similar to those derived using the HI data in the Galaxy and the Large Magellanic Cloud. We discuss parameters affecting on the determination of the spectral slope, such as the integrated velocity range, the noise pattern of the data, and the edge effect. We also present the HI column density probability distribution functions of the same sources.

Poster P17 Understanding turbulence in the ISM through the power spectrum
by Lukas Konstandin (ZAH/ITA, University of Heidelberg)

Observations reveal that supersonic turbulence is prevalent in star forming clouds. The density and velocity field within these clouds indicate complex, chaotic, and filamentary structures, where turbulent motions interact with shocks. Therefore, understanding the properties of turbulence is a prerequisite for developing a comprehensive theory of star formation in the ISM. We study a set of three-dimensional numerical simulations of driven, isothermal, turbulence with r.m.s. Mach numbers ranging from the subsonic to the highly supersonic regime. We focus our analysis on spectral behavior of the decomposed velocity field into transversal $\nabla \cdot u_s = 0$ and longitudinal $\nabla \times u_c = 0$ modes. These components have different effects, leading to vortex structures for u_s and shocks and rarefactions for u_c, where only the longitudinal mode is directly coupled to the gravitational field. The two components are themselves coupled and exchange energy. We find that the asymmetric transfer of energy from transversal to longitudinal component, and vice versa, introduces a forcing dependence to the total and decomposed power spectra. We measure the local scaling exponents of the power spectra with a hierarchical Bayesian method, which has the advantage that statistical and systematic uncertainties are treated self consistently. The scaling exponents are in agreement with a Burgers spectrum with a scaling exponent of -2 for the longitudinal modes and a pure compressive forcing field. The scaling exponents of the transversal spectrum driven with a pure solenoidal forcing field are in agreement with the Kolmogorov prediction of $-5/3$ in a limited inertial range. This discrepant behavior shows the complexity of the problem and indicates that various processes affect the power spectrum.

Poster P18 Molecular Tracers of Turbulent Shocks in GMCs
by Andy Pon (University of Leeds)

Molecular clouds exhibit large linewidths, which are usually interpreted as being due to supersonic turbulence. This turbulence plays a key role in many theories of star formation, as it is believed to help support and fragment molecular clouds. Current numerical MHD simulations show that the turbulent energy of a molecular cloud dissipates on the order of a crossing time, but do not explicitly follow how this energy is released. We have run models of C-type shocks, based on Kaufman & Neufeld (1996), propagating into gas with densities near 1 000 cm^3 at velocities of a few km/s, appropriate for the ambient conditions inside of a molecular cloud, to determine which species and transitions dominate the cooling and radiative energy release associated with the dissipation of turbulent energy in shocks within molecular clouds. Combining these shock models and estimates for the rate of turbulent energy dissipation (Basu & Murali 2001), we produce synthetic CO spectra and predict those line emissions that will be observable with current and upcoming observational facilities such as Herschel, SOFIA, ALMA, and CCAT. We compare our synthetic shock spectra to the photodissociation region (PDR) models of Kaufman et al. (1999) and show that mid-J CO lines (e.g., CO J = 7 to 6) from molecular clouds illuminated by standard interstellar radiation fields are dominated by emission from shocked gas. We also present Herschel observations of these shock tracing lines.

References:
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Kaufman, M. J. & Neufeld, D. A. 1996, ApJ, 456, 250
Kaufman, M. J., Wolfire, M. G., Hollenbach, D. J., & Luhman, M. L. 1999, ApJ, 527, 795

► Poster session: Collapse of molecular clouds and the IMF

Poster P19 GANDALF : Graphical Astrophysics code for N-body Dynamics And Lagrangian Fluids
by David Hubber (Excellence Cluster Universe, Garching)

We present GANDALF, a new hybrid SPH and N-body code for combined star formation, planet formation and star cluster studies. GANDALF is written in C++ to perform the main hydrodynamic and gravitational computations. GANDALF also includes a python library to allow interactive simulations and visualisation. Initial conditions can also be generated inside python allowing simple control of setting up, running a simulation, analysing and visualising it from a single python script. GANDALF uses hybrid parallelisation of OpenMP and MPI and is currently available as a beta-release at https://github.com/gandalfcode/gandalf.

Poster P20 Initiating Clustered Star Formation: the Hierarchical Structure of Dense Molecular Clumps
by Ke Wang (ESO, Garching)

We present high-resolution Submillimeter Array (SMA) 1.3 and 0.88 mm broad band observations, and Jansky Very Large Array (JVLA) observations in NH_3 (J,K) = (1,1) up to (5,5), as well as H_2O and CH_3OH maser lines toward the two most massive and dense molecular clumps ($\gtrsim 10^3\,M_\odot$ within < 1 pc) in the filamentary IR-dark cloud (IRDC) G11.11-0.12, also known as the "Snake" nebula. The sensitive high-resolution images reveal hierarchical fragmentation from the ~ 1 pc clump scale down to ~ 0.01 pc condensation scale. At each fragmenting scale, the mass of the fragments is orders of magnitude larger than the thermal Jeans mass. This is common to all the four clumps that we have studied in three IRDCs, suggesting that turbulence plays a dominant role in the initial stages of clustered star formation. Masers, shock heated NH_3 gas, and outflows indicate intense ongoing star formation in some cores while no such signatures are found in others. Furthermore, chemical differentiation between the cores reflects a sequential growth of these star formation seeds. The mass function of the resolved condensations is consistent with a power law with an index of $\alpha = 2.0 \pm 0.2$ and a turnover at $2.7\,M_\odot$. Our combined SMA+JVLA observations of several IRDC clumps have presented so far the deepest view of the early stages prior to the hot core phase, revealing snapshots of physical and chemical properties at various stages along an apparent evolutionary sequence.

▶ Poster session: Laboratory Astrophysics

Poster P21 A 3D Molecular Fragmentation Imaging detector for future Dissociative Recombination studies at the Cryogenic Storage Ring
by Arno Becker (MPIK, Heidelberg)

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O. Novotný, Columbia Astrophysics Laboratory, New York, USA
K. Spruck, Institut für Atom- und Molekülphysik, Gießen
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Dissociative recombination of molecular ions is an important process in the gas phase chemistry of the interstellar medium. This process has been successfully studied for a wide range of systems in storage ring merged-beam experiments using, e.g., the Test Storage Ring (TSR) in Heidelberg. However, for cold ion chemistry processes these experiments hit limitations. On the one hand the thermal radiation in the room-temperature devices used so far excites rotational modes of many molecules. On the other hand the beam storage lifetimes are often too short for the decay of excited states.
To enable preparation of molecules in or near the rovibrational ground state the new Cryogenic Storage Ring (CSR), currently under construction at the Max Institute for Nuclear Physics in Heidelberg, will be cooled down to ~ 10 K. With these low temperatures extremely high vacuum better than 10^{-13} mbar can be achieved giving rise to much longer storage times. The electrostatic design with ion beam energies up to 300 keV per unit charge in combination with a low-energy electron cooler will allow the study of molecular ions with up to 160 atomic mass units. With merged velocity matched electron beams collision energies down to ~ 10 K can be reached.
The fragmentation of the molecular ions will be studied by fast-beam coincidence fragmentation imaging. The nearly coincident neutral fragments from single dissociative recombination events will be detected by a 3D imaging system developed in the present work. The detector consists of two MCPs in Chevron configuration with an active diameter of 120 mm and a phosphor screen operated inside the CSR cryostat. The phosphor screen will be observed from outside the CSR cryostat by a fast camera system developed at Université catholique de Louvain, Louvain-la-Neuve, Belgium. The requirements of the CSR regarding the huge temperature range from operation at 10 K to bake-out at 520 K as well as an extremely high vacuum of better than 10^{-13} mbar placed strong demands on the design. In addition the dead time and timing resolution have to be in the ns range or better in order to temporally distinguish between impinging particles from each dissociation event.
The detector system will be installed already for the first commissioning phase of the CSR and used for the first laser interaction experiments at cryogenic temperature conditions. The design of this cryogenic detection system will be presented.

Poster P22 Far-infrared to millimeter opacity of amorphous Mg/Fe-silicates at low temperatures
by Pierre Mohr (Astrophysikalisches Institut und Universitäts-Sternwarte Jena)

We present laboratory measurements of the wavelength-dependent dust opacity for amorphous Mg/Fe-silicate particles in the far-infrared range. Such amorphous silicates represent likely the major dust component in interstellar space. Their opacity bears a strong temperature dependence, which is not yet fully explored. We have synthesized silicates with a variable Mg/Fe ratio and have measured their absorption spectra in a wavelength range between 50 micrometers and 4 millimeters at temperatures down to 10 K. We find additionally a systematic dependence of the opacity on the iron content, which is probably related to the incorporation of iron ions as both network formers and network modifiers.

Poster P23 Dissociative recombination measurements on halogen-hydride ions relevant for astrochemistry
by Oldrich Novotny (Columbia Astrophysics Laboratory)

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Dissociative recombination (DR) of molecular ions is a key chemical process in the cold interstellar medium (ISM). DR affects the composition, charge state, and energy balance of such environments. Astrochemical models of the ISM require reliable total DR cross sections as well as knowledge of the chemical composition and excitation states of the neutral DR products. Theory cannot reliably provide these data.
We have systematically measured DR for many astrophysically relevant molecular ions utilizing the TSR storage ring at the Max-Planck-Institute for Nuclear Physics in Heidelberg, Germany. We used the merged ion-electron beam technique combined with an energy- and position-sensitive imaging detector and are able to study DR down to plasma temperatures of 10 K. The DR count rate is used to obtain an absolute DR rate coefficient. Additionally we determine the masses of the DR products by measuring their kinetic energy. This allows us to assign particular DR fragmentation channels and to obtain their branching ratios. Moreover, the distribution of detected fragment distances provides information on the kinetic energy released in DR and thus also on the internal excitation of the DR products. All of this information is particularly important for understanding DR of heteronuclear polyatomic ions.
HCl and HF molecules were recently identified as potentially good tracers for molecular hydrogen in interstellar clouds [1,2]. To use these tracers the underlying chlorine and fluorine chemistry must be understood. Current astrochemical models, however, lack reliable DR data. To this end we have measured DR for HCl+, D2Cl+, HF+, D2F+, and CF+.
This work is supported in part by the Max Planck Society, NASA, and the NSF.
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[2] D.A. Neufeld et al 2010 A&A 518 5

Poster P24 Development of a particle detector for reaction studies on singly charged ions in interstellar conditions

by Kaija Spruck (Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen)

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The study of ion chemistry in the interstellar medium (ISM) requires among others knowledge about cross sections and branching ratios for the recombination of atomic and molecular ions with low-energy electrons. In the case of singly charged atomic ions, experimental studies only exist for the lightest systems while for the heavier systems of astrophysical relevance, i.e., N+ to Ni+, all rate coefficients come from theory. By including theoretical rate coefficients of dielectronic recombination (DR) into gas grain-models of dense, cold interstellar clouds, it has been found that DR of these singly charged species could potentially change their abundances by more than a factor of 10. [1] However the database on reliable DR data for atomic ions relevant to the chemistry of molecular clouds is only incomplete.
Laboratory electron-ion collision experiments are non-trivial as most of the reactions of interest take place in temperature and density conditions which are much below laboratory standards. In addition, for the singly charged atomic ions mentioned above, studies of DR in past electron cooler storage rings have been hindered by field ionization of the resonant states in the strong dipole magnets of these devices. The electrostatic Cryogenic Storage Ring (CSR) [2], currently under construction at the Max Planck Institute for Nuclear Physics in Heidelberg, will allow experiments with atomic, molecular and cluster ions at beam energies up to 300 keV per unit charge in extreme high vacuum (XHV) condition. Collisions of stored atomic ions with electrons provided by an electron cooler will lead to reaction products with charge states that differ from those of the primary particles. These particles will be identified in a particle spectrometer area that follows the interaction region. It consists of a bending deflector of the storage ring and a highly efficient, large-aperture single particle counting detector that is movable within the CSR cryostat and able to operate at the ambient temperature of approximately 10 K.
Here we report on the development of the electric particle identification spectrometer and the counter based on a converter plate and secondary electron detection by a micro-channel plate. The layout is compatible with the cryogenic operating conditions and a high-temperature bake out of up to 520 K.
References
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[2] von Hahn et al., NIM-B, 269, 2871-2874 (2011)

► Poster session: Chemical processes in the ISM

Poster P25 Quantal determination of the mobility of ground and excited C+ ions evolving in a cooled helium gas

by Moncef Bouledroua (Faculté de Médecine & LPR)

We propose in this work to look at the mobility of C+ ions moving in a neutral helium gas. The calculations are performed for the cooled buffer gas into three steps. The first step consists of calculating the interaction potentials corresponding to the dimers which dissociate into C+(2P)-He(1S) and C+(4P)-He(1S). This task is accomplished with MOLPRO. Then, following the suggestions stated in a recent paper [1], we compute the energy-dependent thermophysical cross sections by using a full quantum-mechanical method, which yields in particular the quantal phase shifts. The final step aims at the use of the computed cross sections within the Viehland GRAMCHAR FORTRAN code [2, 3] to get the mobility of the ions at fixed temperatures.
References:
[1] S. Matouba, H. Tanuma, and K. Ohtsuki, J. Phys. B 41, 145205 (2008).
[2] L. Viehland, Chem. Phys. 179, 71 (1994).
[3] L. Viehland, private communications.

Poster P26 KROME: a package to easily embed the chemistry in 3D cosmological codes
by Stefano Bovino (Georg-August Universität Göttingen)

The study of the ISM includes a large set of processes and phenomena that needs an accurate modeling and which are often CPU-demanding: chemistry, cooling, heating, dust evolution, photochemistry, and many others. To cope with these we developed a package, named KROME, which is designed to manage the chemistry and the related phenomena with ease. It consists of a Python pre-processor that creates the Fortran routines needed by any advanced hydrodynamical code aimed at studying the properties of the ISM. The code provides a good compromise between flexibility and numerical efficiency and can be applied to many different environments. It includes also an accurate description of dust. In this poster I will introduce the main features of the KROME package and show how it can be easily embedded in 3D cosmological code like ENZO, FLASH and RAMSES, giving some example of the various applications.

Poster P27 H_2 formation in astrophysical models: the effect of dust temperature fluctuations
by Emeric Bron (LUTH - Observatoire de Paris/Université Paris Diderot)

The process of H_2 formation on dust grains is the first step in the increase in chemical complexity leading to the multitude of molecules revealed by the latest generation of telescopes. It controls the transition from atomic to molecular gas and the resulting molecular chemistry through the central role of H_2 in the chemical network. The formation rate in a diffuse medium has been inferred from Copernicus and FUSE observations ([1],[2]). Observations of H_2 emission in PDRs by ISO and Spitzer ([3],[4]) revealed efficient formation on warm grains, while experimental studies showed the Langmuir-Hinshelwood mechanism to be efficient only in a limited range of low grain temperatures. Mechanisms involving chemisorbed atoms have been proposed to overcome this contradiction, for instance the Eley-Rideal mechanism ([5]).
As the smallest grains dominate the total available dust surface in the gas ([6]), they are the main actors in H_2 formation. But small dust grains in unshielded environments like PDRs are known to undergo strong temperature fluctuations due to UV photon absorption. A constant grain temperature can thus not be assumed when computing H_2 formation rates in such environments.
I will present a comprehensive computation of the H_2 formation rate that includes fluctuating dust temperatures, using a master equation approach to compute the grain temperature distribution and the resulting average formation rate. For the first time, we show that grain temperature fluctuations make the Langmuir-Hinshelwood mechanism surprisingly efficient at the edge of PDRs (comparable to the Eley-Rideal efficiency), since fluctuating grains spend most of their time below their average temperature.
This computation of the formation rate, including the full treatment of temperature fluctuations and an up-to-date micro-physical model, is implemented in full cloud simulations with the Meudon PDR Code. I will present how this new formalism impacts cloud structure and chemistry, and analyse the variation of formation efficiency with astrophysical conditions (gas density, temperature, ambient radiation field).
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[6] Compiègne, M., Verstraete, L., Jones, A., Bernard, J.-P., Boulanger, F., Flagey, N., Le Bourlot, J., Paradis, D., Ysard, N. 2011, A&A, 525, id.A103

Poster P28 The chemical evolution in the early phases of massive star formation
by Thomas Gerner (MPIA, Heidelberg)

Understanding the chemical evolution of young (high-mass) star-forming regions is a central topic in star formation research. The chemistry is employed as a unique tool: 1) to investigate the underlying physical processes and 2) to characterize the evolution of the chemical composition. With these aims in mind, we observed a sample of 59 high-mass star-forming regions at different evolutionary stages varying from the early starless phase of Infrared Dark Clouds (IRDC) to High Mass Protostellar Objects (HMPO) to Hot Molecular Cores (HMC) and, finally, Ultra Compact HII regions (UCHII) at 1mm and 3mm with the IRAM 30m telescope. We determined their large-scale chemical abundances and column densities and found that the chemical composition evolves along with the evolutionary stages.
We modeled the chemical evolution in these environments, using a 1D physical model where density and temperature vary from stage to stage coupled with an advanced gas-grain chemical model. This helped us to constrain physical parameters of these clouds such as the temperature and provided us with chemical ages for each phase.

Poster P29 Stellar Sources of Interstellar Dust: Molecular TiC Clusters in Dust Nucleation Processes
by Beate Patzer (Zentrum für Astronomie und Astrophysik, TU Berlin)

Dust particles have an important impact on the astrophysics of the interstellar medium (ISM) ranging from chemistry and thermodynamics of the gas up to the dynamics of star formation. The life-cycle of interstellar dust begins with the nucleation and growth of grains in explosive ejecta or steady winds of stars. Investigations of pre-solar grains enclosed in meteorites, for example, revealed graphites to be rich in internal TiC inclusions providing important information on the stellar conditions in which theses grains have been formed.
In this contribution we focus on the study of the nucleation of titanium carbide particles from the gas phase. Therefore, the necessary molecular properties of titanium carbide clusters have been estimated using quantum chemical density functional theories. We present results on the dust nucleation of titanium carbide and discuss further extensions and perspectives.

Poster P30 Physical Conditions in Shocked Clouds of the Vela Supernova Remnant: New Results from High-Resolution HST/STIS Observations of HD 72350 and HD 72648
by Adam Ritchey (University of Washington)

We present a detailed analysis of the physical conditions in shocked interstellar clouds along two lines of sight through the Vela supernova remnant using new high-resolution HST/STIS spectra acquired at FUV wavelengths. From the relative populations of collisionally-excited fine-structure levels in C I and O I, we derive unique solutions for the gas density and kinetic temperature in discrete radial velocity bins along each line of sight. Observations of collisionally-excited Si II provide electron densities, which are used, in conjunction with the previously-derived densities and temperatures, to estimate the strength of the local radiation field from a consideration of the ionization balance between neutral and singly-ionized carbon. Finally, variations in nickel depletion levels allow us to estimate the degree to which dust grains have been destroyed in the highly compressed regions. We discuss the implications of these new results for models of cloud compression and dust grain destruction in supernova shocks.

▶ Poster session: Dependence of star formation on ISM properties

Poster P31 Simulating an Accreting, Star Forming Galactic Disc
by Maximilian Brunner (USM/LMU, München)

In galaxies stars are formed from a reservoir of cold molecular gas. For star formation to continue this reservoir has to be fueled with extragalactic material or else the gas is depleted. In this project we use the SPH-code GADGET to simulate a spiral galaxy that is constantly fed with new gas at a rate of five solar masses per year. We find that the star formation rate tries to adjust to the accretion rate in order to achieve equilibrium in a way that is expected from theory. We also see that the properties of the interstellar medium in our disc evolve over time as the system is influenced by the constant supply of new material.

Poster P32 Turbulence in Molecular Clouds: Measuring the density distribution
by Adam Ginsburg (University of Colorado, Boulder / ESO)

Turbulence is one of the primary processes governing star formation. Many recent theories have determined the overall star formation rate of gas and even the shape of the initial mass function based purely on turbulent initial conditions. The key property governing star formation rates is the density distribution of the gas, which determines how much gas is above some “critical density” for the gas to become self-gravitating and initiate star formation. I will present a new method for measuring the shape of the density distribution in quiescent molecular clouds. These measurements are performed using ubiquitous low-frequency lines of $\mathrm{H_2CO}$ and CO to measure the local density distribution. These measurements are used to place precise constraints on the shape of the density distribution of the gas. We distinguish between different analytic forms of the density distribution function, and in one case rule out a lognormal as the underlying distribution.

Poster P33 Radio-FIR correlation as a probe to interplay between star formation as ISM
by Fatemeh Tabatabaei (MPIA, Heidelberg)

We investigate the correlation between the radio continuum and far-infrared (FIR) emission in the Fireworks galaxy NGC6946. The nonthermal radio-FIR correlation changes with both star formation and magnetic field strengths. The FIR-to-radio ratio is linearly correlated with the total magnetic field strength. This connection is self-consistent and independent from the star formation feedback. This is the first evidence of the importance of the magnetic fields in controlling the radio-FIR correlation in a galaxy. A scale-by-scale analysis of the radio-FIR correlation in NGC6946 and other nearby galaxies M31, M33, M51, and the LMC shows that the smallest scale on which the correlation holds changes with the degree of the regularity of the magnetic field and hence the propagation length of cosmic ray electrons.
We further study the role of gas density and radiation field on the radio-FIR correlation in NGC6946.

Poster P34 Gas distribution and Star formation activities in the Galactic Plane
by Nalin Vutisalchavakul (University of Texas at Austin)

Combining several large scale Galactic plane surveys, we studied the gas distribution and star formation activities in part of the Galactic plane. Star formation rates were determined from infrared data obtained from WISE and Spitzer surveys. The Bolocam Galactic Plane Survey provided the data of 1.1mm dust continuum and dense gas tracers, while the Galactic Ring Survey provided the data of 13CO. We investigated the relation between gas mass and star formation rates at different spatial scales to study the star formation relation in the Milky Way and connect the result to extragalactic studies.

▶ Poster session: Stellar feedback in the ISM

Poster P35 Gas kinematics of supergiant shells in two nearby galaxies.
by Oleg Egorov (Sternberg Astronomical Institute of Lomonosow Moscow State University)

We present observations and analysis of two dwarf Irr galaxies in M81 group - IC 2574 and Holmberg II. Their 21 cm images of these galaxies show multiple shell-like structures with sizes up to 1-2 kpc, so-called supergiant shells (SGS), most probably created by stellar feedback from several generations of stars. According to modern understanding the SGS expansion triggers new bursts of star formation in their rims. This is what one can see in IC 2574 and Holmberg II - most active star formation regions are located on the edges of SGSs. Using our observational data in $\mathrm{H\alpha}$ and [SII] lines obtained with Fabry-Perot Interferometer at the 6 m telescope of Russian Academy of Science and archival data in HI 21 cm from THINGS survey we provided the detailed study of ionized and neutral gas kinematics in the two galaxies. We estimated expansion velocities of multiple shell-like structures and correlate them with the energy sources responsible for their creation. We considered how the induced star formation influences the kinematics of parent HI SGS.

Poster P36 Why stellar winds seem to be (ir-)relevant
by Katharina Fierlinger (USM/LMU)

Giant molecular clouds (GMCs) are reshuffled by feedback of massive stars: Stellar winds and supernova (SN) explosions of massive stars create bubbles in the interstellar medium (ISM) and insert newly produced heavy elements and kinetic energy into their surroundings. Most of this energy is however thermalized and immediately lost via radiative cooling. In this work we estimate the amount of feedback energy that is retained as kinetic energy when the bubble walls have decelerated to the sound speed of the ambient medium. The feedback of the most massive still existing star outweighs the feedback from less massive stars. Thus our numerical simulations follow the evolution of a 60 solar mass star, which is the best match between the available stellar models, the assumed cloud mass and the initial mass function (IMF). Another key aspect is the relevance of stellar winds. In our model the wind inserts 2.34 times the energy of a SN. Additionally bubbles serve as pressure reservoirs and thus enhance the amount of energy retained as kinetic energy of the cold GMC gas. During the pressure driven phases of the bubble evolution the retained energy depends on the scales of the mixing processes in the ISM. Without the wind of the progenitor only 0.1 percent of the SN energy input are retained, whereas taking into account wind-blown bubbles, feedback energy efficiencies of a few percent can be reached.

Poster P37 Impact of Supernovae on Molecular Cloud Evolution - Dynamics and Structure
by Bastian Körtgen (Hamburg Observatory)

Feedback from massive stars is thought to be a main agent in controlling star formation and determining the evolution of molecular clouds. On the one hand, they continuously inject energy into the ambient medium through their winds and their ionizing radiation. On the other hand, they end their short lives as a supernovae, injecting a huge amount of energy in a short amount of time into the interstellar medium. Hence, massive stars should influence their close environments as well as the global dynamics of the molecular clouds in which they are embedded. Yet, it is unclear to what extent the feedback from massive stars affect the star formation rate and efficiency and the global lifetime of molecular clouds. In this work we focus our study on the effect of supernovae on the dynamics and structure of molecular clouds by means of 3D MHD simulations. With our numerical experiments based on colliding flow simulations we are able to probe how efficiently energy is injected to the surrounding interstellar medium and whether supernovae are able to disrupt entire molecular clouds. Furthermore, we are able to probe the possible effect of triggered and continued star formation by the supernoave shock fronts.

Poster P38 A grid of models for wind bow shocks from massive runaway stars
by Dominique Meyer (AIfA, Bonn)

This poster presents a grid of models following the wind-ISM interaction of massive runaway stars from the main-sequence to the supernova stage. The included physics takes into account optically-thin radiative heating and cooling, together with electronic thermal conduction and assumes that the stars are moving in a medium which density corresponds to the one of the Galactic plan. Emissions maps and luminosities have been calculated, and they allow to investigate the location of the emissions (e.g. the Halpha emissions) in the bow shock.

Poster P39 Exploring cluster-scale triggering in Sco Cen
by Nicholas Moeckel (USM/LMU Munich)

The Scorpius-Centaurus OB association is the nearest region of recent massive star formation. With several distinct stellar groups ranging in age from a few to 15 Myr, it presents an interesting labratory to explore the interaction between stellar feedback, the ISM, and the formation of clusters and associations from molecular clouds. An apparent age sequence along the association raises the possibility of cluster-scale triggering, or at least sculpting, of one subgroup (Upper Scorpius) by the wind and supernova driven bubble generated by another (Upper Centaurus-Lupus). We report on our recent efforts to numerically model this region.

Poster P40 Properties of protostellar outflows from IR-spectroscopy in NGC 1333
by Volker Weiss (Thüringer Landessternwarte)

In order to help clarifying the role of protostellar jets and outflows as potential drivers for stirring the turbulence of molecular clouds, we assess physical parameters of outflows such as energy and momentum and combine near-infrared and radio data of well-investigated regions, use excitation models to account for missing transitions, and keep the time-variability of the flows as well as their geometry in mind. We will apply the derived results for outflows identified in H_2 surveys (GLIMPSE follow-up, UWISH2) to improve the overall statistics.

▶ Poster session: The magnetised ISM

Poster P41 Magnetic Fields in the Primordial ISM
by Jennifer Schober (ZAH/ITA, University of Heidelberg)

Magnetic fields influence many processes in the ISM strongly. In the primordial ISM they are usually not considered, as they are assumed not to be dynamically important yet. In the presence of turbulence, however, the small-scale dynamo can amplify weak seed fields by randomly stretching, twisting and folding the field lines. The details of this process depend on the nature of turbulence, i.e. on the hydrodynamic and magnetic Reynolds numbers and on the compressibility of the gas. To calculate the growth rate of the small-scale dynamo and the saturation field strength in the primordial ISM we model a typical young galaxy, where turbulence is generated by accretion and supernovae. We follow the exponential growth of the magnetic field on the viscous scale and also the subsequent transport of the magnetic energy to larger scales. Depending on the parameters of our model we find that a saturation field strength of roughly 10^{-5} G is reached within 4 to 270 Myr. Thus, we expect that the presence of turbulence leads to strong unordered magnetic fields already in the primordial ISM.

Poster P42 Wide-field Near-Infrared Polarimetry of the Orion A molecular cloud
by Amnart Sukom (The Graduate University for Advanced Studies)

We present first wide-field deep near-infrared imaging polarimetry ($15' \times 60'$) of the Orion A Integral Shape Filament obtained with SIRPOL, simultaneous JHKs imaging polarimeter on the IRSF telescope. Most derived magnetic field orientations from aperture polarimetry are perpendicular to the elongation of the ISF. The extended H-band polarization pattern confirms the hourglass shaped structure on M42 that consistent with sub-mm dust emission polarization. The polarization coefficients, the correlations between P(H) and H-Ks, for OMC-1, OMC-2, OMC-3, OMC-4 are 6.1, 2.9, 4.8 and 4.3, respectively.

▶ Poster session: ISM on Galactic Scale

Poster P43 A High-dispersion molecular gas component in nearby galaxies
by Anahi Caldu Primo (MPIA, Heidelberg)

We present evidence for the presence of a high-dispersion molecular gas component in nearby galaxies as traced through the CO(2-1) emission. The measured dispersion is higher than predicted if it was just due to the cold dense molecular gas phase in a galaxy's disk. Our analysis is based on a comprehensive study of the velocity dispersions of the atomic and molecular gas components in the disks ($R < R25$) of a sample of 12 nearby galaxies. To obtain reliable measurements of the velocity dispersion, we stack regions after accounting for intrinsic velocity shifts due to rotation and large-scale galactic motions. We stack using various parameters: galacto-centric distance, star formation rate surface density, HI surface density, H_2 surface density, and total gas surface density. We fit single-Gaussian components and measure average velocity dispersions for the atomic gas of 11.9 ± 3.1 km/s and for the molecular gas of 12.0 ± 3.9 km/s. The CO velocity dispersions are thus similar to the corresponding ones of HI, with an average ratio of Sigma(HI)/Sigma(CO)= 1.0 ± 0.2, irrespective of the stacking parameter. The measured CO velocity dispersions are significantly higher (by at least a factor of ~ 2) than expected from just the cold molecular gas phase that is thought to be associated with star formation in the disk. Such a high dispersion implies an additional thick molecular gas disk (possibly as thick as the HI disk).

Poster P44 [CII] and Hydrogen Species in LITTLE THINGS Dwarf Galaxies: The Extremely Metal-Poor Regime
by Phil Cigan (New Mexico Tech)

Many FIR studies target systems that have typical or enhanced abundances of heavy elements, but what is the picture for the low-metallicity regime? We present a comparison of HI and [CII] observations for five extremely metal-poor dwarf galaxies from the LITTLE THINGS survey. The galaxies we discuss have $12 + \log(\mathrm{O/H}) = 7.4 - 7.8$, some of the lowest-metallicity galaxies observed in [CII]. Our galaxies are of particular interest because we probe the regime of normal and typical dwarfs, which exhibit much more moderate star formation than those observed in other Herschel programs. This is important because they represent a much larger fraction of the dwarf population, and because they probe quite different ISM conditions - namely, the combination of extremely low metallicity with reduced ionizing radiation and mechanical agitation from star formation. We note a generally linear relation between HI and [CII] surface brightness in our sample, and we explore avenues of quantifying the molecular species of hydrogen without the aid of CO, which is extremely difficult to detect in faint, metal-poor systems.

Poster P45 CO at Low-metallicity: Molecular Clouds in the dwarf galaxy WLM
by Deidre Hunter (Lowell Observatory)

B. G. Elmegreen, C. Verdugo, M. Rubio, E. Brinks, A. Schruba
Metallicity is not a passive result of galaxy evolution, but a crucial driver. Dwarf galaxies are low in heavy elements, which has consequences for the ability to form cold, dense clouds that form stars. Molecular cores shrink and atomic envelopes grow in star-forming clouds as the metallicity drops (Bolatto et al. 2011). For this reason, CO had not been detected at $\log(\mathrm{O/H}) + 12 < 8.0$ (Schruba et al. 2012). We have now broken this metallicity barrier with CO 3-2 detections in two regions of the nearby dwarf galaxy WLM, which has $\log(\mathrm{O/H}) + 12 = 7.8$ (Elmegreen et al. 2013). We present these observations and the analysis of sub-mm and FIR observations that allowed us to estimate the cloud masses to be of order $10^5 \mathrm{M}_\odot$. Our Herschel [CII]158 micron map of the photo-dissociation region of one of our CO detections shows directly the extended envelope of the molecular cloud (Cigan et al, in prep and this meeting).

Poster P46 A multi-wavelength look at the multi-phase merger driven wind in NGC 2146
by Kathryn Kreckel (MPIA, Heidelberg)

Galactic winds are important for regulating feedback within galaxies and contribute to shaping the multi-phase ISM. We employ optical IFU observations and Herschel PACS spectroscopy to examine the kinematics and energetics of the outflow within NGC 2146. Hosting a starburst driven wind similar to M82, this late-phase merger and LIRG exhibits evidence for outflows in the dust as well as the atomic, ionized and molecular gas phases. We will present our results in understanding the physical conditions of the outflow and the role it plays in the evolution of this galaxy.

Poster P47 A filamentary gas wisp in the disk of the milky way
by Guangxing Li (MPIfR, Bonn)

Guang-Xing Li, Friedrich Wyrowski, Karl Menten and Arnaud Belloche
Max-Planck Institut fuer Radioastronomie, Bonn, Germany

Star formation occurs in molecular gas. In the previous studies, the structure of the molecular gas has been studied in terms of molecular clouds, but overlooked beyond the cloud scale. In this work, we present an observational study of the molecular gas at l≈50. The molecular gas is found in the form of a huge (≈500 pc) filamentary gas wisp. The gas wisp has a large physical extent and a velocity dispersion of 5 km/s. The eastern part of the filamentary gas wisp is 130 pc above the Galactic disk (which corresponds to 1.5–4 e-folding scale-heights), and the total mass of the gas wisp is $\geq$ 1e5 solar mass. The gas wisp is composed of two molecular clouds and an expanding bubble. The velocity structure of the gas wisp can be explained as a smooth quiescent component disturbed by the expansion of a bubble. The fact that the length of the gas wisp is much larger than the thickness of the molecular disk of the Milky Way is consistent with the cloud formation scenario in which the gas is cold prior to the formation of molecular clouds. Star formation in the filamentary gas wisp occurs at the edge of a bubble, which is consistent with some models of triggered star formation.

Poster P48 A multi-phase chemodynamical evolution of dwarf galaxies
by Mykola Petrov (University of Vienna)

The galactic evolution is dominated by gas dynamics which can include gas infall and outflows, galactic fountains, and more and can be understandable due to differences in dynamics, thermal energies and element abundances of the gas phases. To follow the chemical and temporal evolution of galaxies it is necessary to model the gasdynamics combined with stellar dynamics, the star-gas energy and mass exchanges and the interactions between gas phases. We study importance and influence of gas-phase interactions on the gas dynamics and chemistry in dwarf galaxies scale.

Poster P49 Cold dust in the giant barred galaxy NGC1365
by Fatemeh Tabatabaei (MPIA, Heidelberg)

Bars are generally considered as an important transform mechanism of molecular gas toward the central regions of galaxies. Numerical simulations suggest that barred galaxies tend to have more of their gas mass concentrated in their centers. On the other hand, it is possible that the central mass concentration is affected by more than just the presence of bars. We mapped the giant barred galaxy, NGC1365, at 870 micron with LABOCA, the Large APEX Bolometer Camera, allowing us to probe the central mass concentration as well as the rate at which the gas flows to the center. We derived the gas mass from the measurements of the dust emission, resulting in a sub-Galactic CO-to-$\mathrm{H_2}$ conversion factor in the central disk. Taking into account the metallicity variation, the central gas mass concentration decreases to only 20% at $R < 3.6$ kpc. On the other hand, the timescale on which the gas flows into the center, is relatively short. This indicates that the current central mass in NGC1365 is evolving fast because of the strong bar.

► Poster session: ISM in the extreme environment of galactic centers

Poster P50 Hydrodynamical simulations of a compact source scenario for the Galactic Center cloud G2
by Alessandro Ballone (USM/MPE, Garching)

A. Ballone, M. Schartmann, A. Burkert, S. Gillessen, R. Genzel, T.K. Fritz, F. Eisenhauer, O Pfuhl, T. Ott

The origin of the dense gas cloud G2 discovered in the Galactic Center (Gillessen et al. 2012) is still a debated puzzle. G2 might be a diffuse cloud or the result of an outflow from an invisible star embedded in it. I will present the first attempt of detailed simulations of the evolution of winds on G2's orbit, including both the hydrodynamic interaction with the hot atmosphere present in the Galactic Center and the extreme gravitational field of the supermassive black hole: we find that both must be taken in account when modelling such a source scenario. We also find that in this scenario most of the Brγ luminosity is expected to come from the densest part of the wind, which has a highly filamentary structure with low filling factor. For our assumptions, the observations can be best matched by a mass outflow rate of $dM_\mathrm{w}/dt = 8.8 \times 10^{-8}\,\mathrm{M_\odot}$/yr and a wind velocity of $v_\mathrm{w} = 50$ km/s. These values are compatible with those of a young TTauri star wind, as already suggested by Scoville & Burkert (2013).

Poster P51 The curious case of CO and HCN in Sgr B2(M)
by Anika Schmiedeke (Universität zu Köln)

The Sagittarius B2 (Sgr B2) molecular cloud is a well-known region of high-mass star formation close to the Galactic Center. Its hot molecular core Sgr B2 (M) contains at least 36 HII regions and 12 sub-mm cores. A full line survey of Sgr B2 (M) has been obtained using the HIFI spectrometer aboard of the Herschel Observatory as part of the guaranteed-time key-project "Herschel/HIFI Observations of EXtraOrdinary Sources: The Orion and Sagittarius B2 Starforming Regions"(HEXOS, PI: E. Bergin, U. Michigan).
We determine the physical structure of Sgr B2(M) using continuum maps for the density structure and selected molecular line spectra and maps (CO, HCN, their isotopologues and in the case of HCN also the vibrationally excited lines) for the kinematic gas properties. HCN serves as a tracer of the innermost temperature and velocity field. In that approach, the HIFI Sgr B2(M) survey provides the necessary variety both in molecules and covered frequency range and ancillary SMA interferometric data adds the necessary spatial resolution
We employ a detailed three-dimensional radiative transfer modeling approach that includes a self-consistent determination of the dust temperature. The former is calculated using LIME (Brinch), the latter using RADMC-3D (developed by C. Dullemond). With this toolkit, we are able to make dust continuum images as well as spectral line cubes. The maps are convolved with the uv-coverage or beam of the observations for comparison reasons.
In the case of Sgr B2(M), we are able to reproduce the continuum covering the frequency range from ~ 300 GHz to 2000 GHz. In order to reproduce the line strength of the CO transitions, we need to raise the gas temperature in the center of the the hot molecular core over the dust temperature suggesting the presence of shocks.

► Poster session: Cosmic rays and their impact on the ISM

Poster P52 Gamma-ray emission from the vicinity of Westerlund 1
by Stefan Ohm (University of Leicester)

Westerlund 1 (Wd 1) is the most massive stellar cluster in the Galaxy and associated with an extended region of TeV emission. Here we report the results of a search for GeV γ-ray emission in this region. The analysis is based on ~ 4.5 years of Fermi-LAT data and reveals significantly extended emission which we model as a Gaussian, resulting in a best-fit sigma of $\sigma_S = (0.475 \pm 0.05)$ deg and an offset from Wd 1 of ~ 1 deg. A partial overlap of the GeV emission with the TeV signal as reported by H.E.S.S. is found. We investigate the spectral and morphological characteristics of the γ-ray emission and discuss its origin in the context of two distinct scenarios. Acceleration of electrons in a Pulsar Wind Nebula provides a reasonably natural interpretation of the GeV emission, but leaves the TeV emission unexplained. A scenario in which protons are accelerated in or near Wd 1 in supernova explosion(s) and are diffusing away and interacting with molecular material, seems consistent with the observed GeV and TeV emission, but requires a very high energy input in protons, $\sim 10^{51}$ erg, and rather slow diffusion. Observations of Wd 1 with a future γ-ray detector such as CTA provide a very promising route to fully resolve the origin of the TeV and GeV emission in Wd 1 and provide a deeper understanding of the high-energy astrophysics of massive stellar clusters.

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