
The Wonders of Star Formation
A tribute to Hans Zinnecker
Edinburgh, Scotland
3-7 September, 2018

John McIntyre Conference Centre
Edinburgh
UK

3rd - 7th September 2018

SOC
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John Bally (Colorado, USA)
Dimitris Stamatellos (UCLAN, UK)

LOC
Lyndsey Ballantyne
Ken Rice

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General Information

Information for Speakers

You are welcome to use your own laptops, but we will also be providing a Mac with OS X and a Windows machine for speakers to use. We can accomodate PDF, Keynote and Powerpoint. Please ensure you have uploaded and tested your talk on the computers prior to your session beginning, or have tested your own laptop/device.

All contributed talks are 15 minutes plus 5 minutes for questions, while invited review talks are 30 minutes plus 10 minutes for questions. Session chairs will give appropriate warnings when you are approaching your time limit. To ensure the smooth running of each session, please keep to time. Thank you!

Information for Posters

Posters are allocated a numbered board based on the session to which they've been allocated. The codes for these are shown in the rear of this booklet. Please affix your poster to the correct board using the velcro tabs provided. Posters **up to** A0 size in portrait (84.1 cm $\times 118.9$ cm) can be accommodated.

WiFi Access

The conference centre is equipped with EDUROAM for those that have access. There is an additional network called KEYSURF that can be joined by entering an email address.

Social Media

#HansFest

Open forum: The Challenges Ahead

On Tuesday (4 Sept.) and Thursday (6 Sept.) from 16:50 to 17:30, we will hold an "Open forum" discussion entitled "The Challenges Ahead".

We solicit your input on the following questions:

- What are the most important unsolved problems in star formation?
- What do you expect will be the biggest challenges in our areas of research during the next decades?
- What tools and approaches will be needed to address these issues?

You can submit your top-three topics as a short e-mail to John Bally before the meeting (john.bally@colorado.edu).

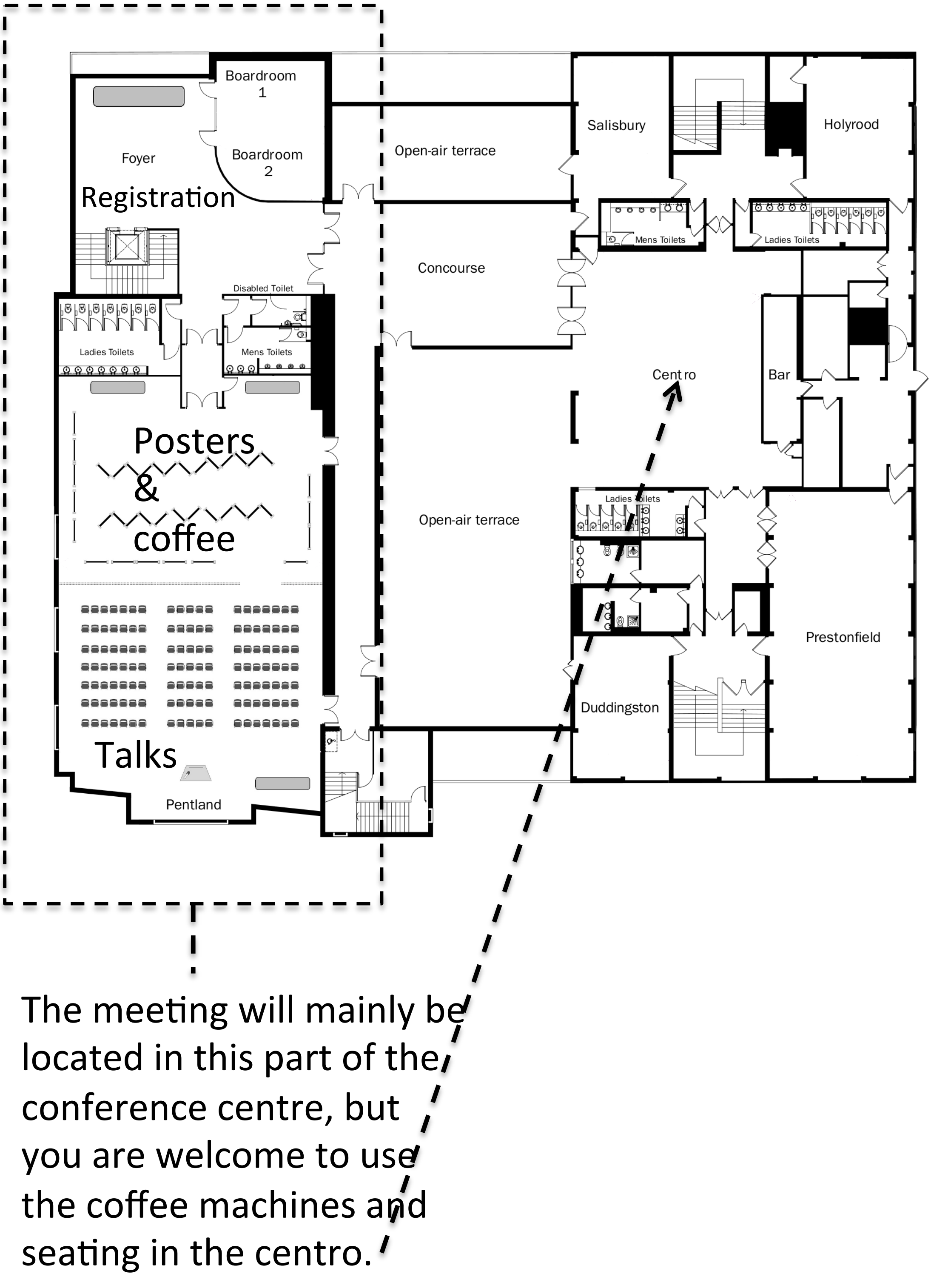
Alternatively, you can write your topics on the the sheet that will be handed out during registration. (To be turned-in during registration, or no latter than by the end of Monday's session.) The SOC will down-select the most compelling topics to be discussed Tuesday and Thursday.

Finally, since this is an open forum, topics will also be accepted during the discussion session.

The proposers of the chosen topics may be asked to make a short (2 to 3 min.) presentation (verbal only) during the discussion.

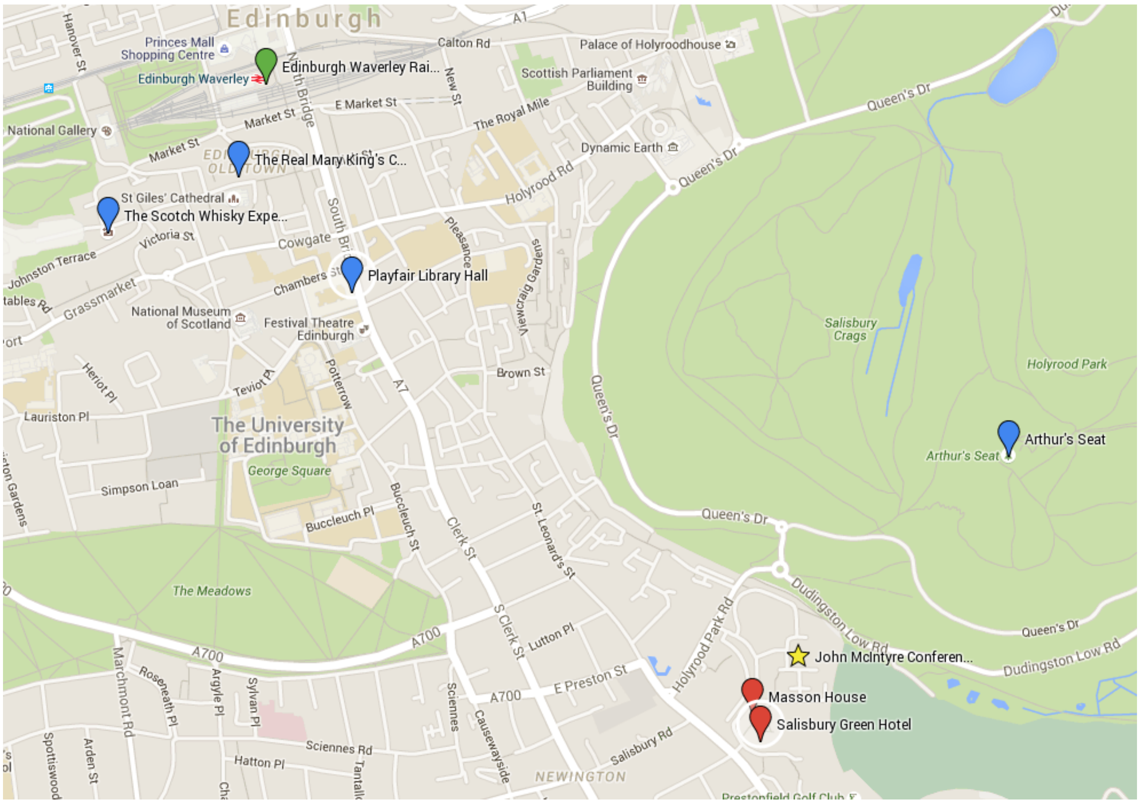
Think big and be creative.

Sunday 02/09/18		**Monday** 03/09/18	**Tuesday** 04/09/18	**Wednesday** 05/09/18	**Thursday** 06/09/18	**Friday** 07/09/18
	08:40	Registration 8:30				
	09:00	**Welcome** K. Rice 9:00	A. Young 9:00	**Review** S. Cabrit 9:00	Y. Fukui 9:00	A. Stutz 9:00
review talks 30+10 min	09:20	& A. Lagarini	B. Hasenberger 9:20	B. Reipurth 9:40	C. Wareing 9:20	C. Briceño 9:20
	09:40	**Review** S. Ragan 9:20	E. Koumpia 9:40	T. Geballe 10:00	F. Dinnbier 9:40	K. Kubiak 9:40
contributed talks 15+5 min	10:00	P. Clark 10:00	K. Tokuda 10:00	L. Tambovtseva 10:20	J. Palouš 10:00	G. Parmentier 10:00
	10:20	J. Stutzki 10:20	R. Kuiper 10:20	Coffee 10:40	J. Tan 10:20	C. Schoettler 10:20
	10:40	Coffeee 10:40	Coffee 10:40	T. Ray 11:10	Coffee 10:40	Coffee 10:40
	11:00	N. Schneider 11:10	K. Tanaka 11:10	V. Grinin 11:30	**Review** J. Tobin 11:10	R. Wünsch 11:10
	11:20	C. Gieser 11:30	A. Rosen 11:30	S. Geen 11:50	S. Kraus 11:50	B. Elmegreen 11:30
	11:40	K. Iwasaki 11:50	R. Banerjee 11:50	P. Klaassen 12:10	R. Köhler 12:10	D. Kruijssen 11:50
	12:00	S. Inutsuka 12:10	I. Bonnell 12:10	H. Zinnecker 12:30	B. Mathieu 12:30	M. Chevance 12:10
	12:20	T. Onishi 12:30	K. Johnston 12:30			P. Hennebelle 12:30
	12:40	Lunch 12:50	Lunch 12:50	Lunch 13:00	Lunch 12:50	Lunch 12:50
	14:00	M. Povich 14:00	R. Oudmaijer 14:00	**Excursions**	**Review** R. Parker 14:00	J. Bally 14:00
	14:20	E. Vazquez-Semadeni 14:20	G. Sandell 14:20		B. Brandl 14:40	H. Beuther 14:20
	14:40	J. Koda 14:40	J. Oliveira 14:40	Geological walk up	P. Schilke 15:00	P. André 14:40
	15:00	T. Montmerle 15:00	M. Rubio 15:00	Arthur's Seat	Coffee 15:20	M. Bate 15:00
		Coffee 15:20	Coffee 15:20			Coffee 15:20
	16:00	D. Ward-Thompson 15:50	S. Lumsden 15:50	Mary King's Close	A. Buckner 15:50	N. Lodieu 15:50
	16:20	J. Wurster 16:10	S. Walch 16:10		O. Lomax 16:10	M. Andersen 16:10
	16:40	Y. Aso 16:30	J. Wiseman 16:30	The Whisky Experience	B. Arnold 16:30	S. Glover 16:30
	17:00	C. Clarke 16:50	**Challenges** J. Bally 16:50		**Challenges** J. Bally 16:50	E. Becklin 16:50
	17:20	H. Yorke 17:10				M. McCaughrean 17:10
	17:40					& J. Rayner
	18:00					
Welcome drinks +	18:20					
registration	18:40	Wine and cheese reception				
	19:00	Royal Observatory				
John McIntyre	19:20	Blackford Hill				
Conference Centre,	19:40	(Limited space available)		Conference Dinner		
Pollock Halls	20:00			Playfair Library		
	20:20			Old College		
	20:40					
	21:00					
	21:20					



The meeting will mainly be located in this part of the conference centre, but you are welcome to use the coffee machines and seating in the centro.

Getting Around Edinburgh



The bus services in Edinburgh are generally rather good, the only inconvenience being you must have exact fare. If you want to pay with a note, drivers will take it and keep your change! Avoid this by downloading the Lothian Buses app, which helps you plan your journey and allows you to download a ticket onto your phone - info here: `http://lothianbuses.com/getting-around/smartphone-apps`

Services run all around the city, and you can travel up to 26 miles from the city center on a "single" (£1.70) ticket. However, a "single" is only valid for a single trip on a single bus. If you plan to travel on more than one bus, you can buy a day ticket for £4.00. A day & night ticket, which costs £3.50, can be purchased after 6.00 pm. Drivers only stop at designated bus stops - so be careful you aren't standing at the wrong stop!

Dining Options

There are many places to eat in Edinburgh. A small selection of some nearby and recommended places are listed below.

- The Salisbury Arms serves seasonal British food.

  `https://www.thesalisburyarmsedinburgh.co.uk/`

- For something different every time, and something that is part of a creative dining experience, try the Edinburgh Food Studio, open Thurs-Sat.

  `http://www.edinburghfoodstudio.com/restaurant`

- A pub serving real ale and Edinburgh's largest nachos.

  `http://www.theauldhoose.co.uk/`

- Tanjore is a good South Indian restaurant.

  `http://tanjore.co.uk/`

- Voujon is another very good Indian restaurant

  `http://www.voujonedinburgh.com/`

- Isola is an Italian restaurant with a Sardinian flavour.

  `http://www.ristoranteisola.co.uk/home`

- Hanedan Turkish restaurant.

  `http://www.hanedan.co.uk/`

- True Thai Cuisine - Haven't tried this restaurant since the change in name, but it certainly used to be a very good Thai restaurant, and no real reason to think that it still isn't one.

  `http://www.truethaicuisine.co.uk`

- Located next to the Mosque, Mosque Kitchen provides good quality Indian food at a very reasonable price.

  `http://www.mosquekitchen.com/index.html`

- Ting Thai Caravan is a casual diner serving South East Asian street food. If it happens to be full, Saboteur - Ting Thai's sister restaurant - is only a few doors away.

  `http://www.tingthai-caravan.com/`

- Spudulike - Originated in Edinburgh and was once a staple of student eating. There used to be one near Pollock Halls, but the closest is now in the Waverley Mall, next to Waverley train station.

  `http://www.spudulike.com`

Excursions

On Wednesday afternoon, we have set aside a few hours to allow everyone to explore Edinburgh, or join one of our excursions. See the conference website for more details.

Mary King's close (http://www.realmarykingsclose.com/) is a warren of underground streets that have remained frozen in time since the 17th century. Named after a prominent 1630's businesswoman, it is one of many wynds and closes where Old Town folk make their homes.

If you want to know more about whisky, then the Scotch whisky experience (www.scotchwhiskyexperience.co.uk) is for you! The tour will include information on how whisky is made, and you will be given the opportunity to sample several varieties.

For those of you who want to explore the great outdoors, there will be an informal hike to Arthur's Seat. The walk up has a rough path most of the way, and only at the very top does it start to become a little tricky, due to exposed rock which is quite slippy when wet, so wear suitable footwear!

Please note that for the tour of Real Mary Kings Close and the tour of the Scotch Whisky Experience the ticket price includes transport from Pollock Halls Campus to the Royal Mile where the tours are situated. This will leave Pollock Halls at 2:30pm. No return transport has been organised.

Useful Information

If you have any questions, please feel free to approach any member of the LOC during the conference, who will be happy to help. Alternatively, send an email to wonders@ph.ed.ac.uk, which will be monitored throughout the conference. For urgent matters, Ken Rice can be contacted on +44 (0)7737088432.

Emergency services	999
Edinburgh First	+44 (0)131 651 2189
Local taxis	+44 (0)131 228 1211 +44 (0)131 777 7777 +44 (0)131 229 2468

Code of Conduct

The organising committees are dedicated to providing a harassment-free conference experience for everyone, regardless of gender, sexual orientation, disability, physical appearance, body size, race, nationality, religion, or choice of text editor. We do not tolerate harassment of participants in any form.

Harassment includes offensive verbal comments related to gender, sexual orientation, disability, physical appearance, body size, race, religion, sexual images in public spaces, deliberate intimidation, stalking, following, harassing photography or recording, sustained disruption of talks or other events, inappropriate physical contact, and unwelcome sexual attention. Please follow these guidelines:

1. All communication should be appropriate for a professional audience including people of many different backgrounds. Sexual language and imagery is not appropriate for any event.

2. Do not insult or put down other attendees.

3. Behave professionally. Remember that harassment and sexist, racist, or exclusionary jokes are not appropriate.

If anyone would like to discuss any violations of this code of conduct, they can speak - in confidence - to Ken Rice. Alternatively, they can email wonders@ph.ed.ac.uk. Anyone asked to stop any inappropriate behaviour, is expected to comply immediately. The conference organisers reserve the right to exclude, without a refund of any charges that have been levied, anyone who violates this code of conduct.

Thank you for helping to make this a welcoming, friendly event for all[1].

[1]This code of conduct has been adapted from `software-carpentry.org/conduct.html`

Monday 3rd September 2018

SESSION 1: Molecular Clouds and Filaments

SOFIA and Herschel observations of fine structure cooling lines in Milky Way clouds (Invited Review)

09:20

Sarah Ragan[1]

[1] Cardiff University

Stars are born in the densest regions of molecular clouds, but the processes of cloud assembly and dispersal are poorly understood. Traditional cloud tracers like CO probe neither the formation nor the destruction phase of molecular clouds, but fine structure lines of ionised carbon ([CII]) and atomic oxygen ([OI]) are potentially crucial probes of the ISM at these important stages. I will present Herschel and SOFIA observations of fine structure line (FSL) tracers in dark Milky Way clouds obtained with Herschel-HIFI and SOFIA. Our observations show that even at a quiescent phase, there is significant FSL emission, both coincident with CO emission and extending well beyond the CO boundary. We also measure strong line emission with SOFIA from [CII] and [OI] in dark clouds in the Central Molecular Zone, allowing us to explore the effects of the high radiation environment compared with disk clouds. These results show how important SOFIA will be in understanding the origin of FSL emission, which is used as a tracer of star formation out to high redshift galaxies.

Notes:

10:00 **Can we use [CII] to trace the formation of molecular clouds?**

Paul Clark[1]

[1] Cardiff University

The timescale over which GMCs form and disperse sets the timescale for star formation. Until recently, most observational studies of GMCs have focused on the molecular tracers, which are good probes of the cool interiors of the clouds, but have a limited ability to trace the dynamics of the transition to the warm neutral medium (WNM). In this study, we assess the ability of [CII] emission - the main coolant in the ISM - to trace the formation of GMCs from the turbulent WNM. We present the results of radiative transfer post-processed Arepo simulations, which contain a chemical and thermodynamical model of the ISM. We show that [CII] is a good tracer of the "dark", sub-100K H2 that surrounds the CO-bright gas. With [CII] we show that it is possible to follow the dynamics of the ISM in and around the molecular clouds, and it is thus a good probe of GMC formation. We also show how it is possible to trace the different scales of the turbulent ISM with the a combination of [CII] and CO isotopologues. We compare our results to those from recent SOFIA observations.

Notes:

[13CII] and [12CII] observations: optical depth effects and C^+ column-densities.

10:20

Jürgen Stutzki[1]

[1] Physikalisches Institut der Universität zu Köln

The [CII] fine structure line at 158 μm is, together with the [OI] 63 μm fine structure line, one of the strongest cooling lines of the star forming ISM, carrying up to a few percent of the total FIR intensity. The [CII] line thus is one of the signposts for active star formation also in distant galaxies, where ALMA can observed the line which is being shifted to the submm-atmospheric windows for high redshifts.

Since its first detection the question of how optically thin this line may be has been an open issue. This has been resolved recently, after some few pioneering observations with the KAO and Herschel/HIFI, with the opportunity to now routinely observe the [13CII] hyperfine lines with the upGREAT instrument onboard SOFIA. In this talk I will summarize the [13CII] results obtained with SOFIA, which show that in many bright star forming regions in the Milky Way, the line shows strong optical depth and self-absorption effects. The column densities are significantly larger than expected from standard Photodissociation Region models for star forming clouds. The large number of PDR surfaces along the line of sight corresponding to these column densities requires a clumpy or fractal, surface dominated structure of the clouds. The nature of the absorbing cold foreground gas is puzzling as it is not explained by any standard model of the ISM phases.

Notes:

11:10

[OI] 63 micron observations of S106 with upGREAT/SOFIA as a diagnostic for the evolution of massive stars

N. Schneider[1], M. Roellig[1], R. Simon[1], A. Gusdorf[2], S. Bontemps[3], F. Comeron[4]

[1] I. Physik. Institut, University of Cologne, Germany, [2] LERMA, Obs. de Paris, ENS, Paris, France, [3] OASU/LAB, University of Bordeaux, France, [4] ESO, Garching, Germany

Observations of the major cooling lines of the interstellar medium are needed to better understand the physical processes, such as mass accretion and ejection, and feedback (thermal heating, ionization, radiation pressure, stellar winds) involved in the formation and evolution of massive stars. For that, we observed the well-known bipolar HII region S106 in the CII 158 and OI 63 micron finestructure lines, and the CO 16-15, 11-10 transitions with the upGREAT instrument on SOFIA.

The OI 63 micron emission at 6 resolution is composed of several velocity components. High-velocity blue- and redshifted emission from accelerated photodissociated gas is associated with an accretion flow along the dark lane close to the massive binary system S106 IR. We employed the observed line intensities and ratios using the KOSMA-tau photodissociation region (PDR) model and consistently found a high FUV field (10^{4-5} G$_o$) and high densities (10^{4-5} cm^{-3}). The model shows that the OI 63 micron line is strongly foreground-absorbed but KOSMA-tau can be used to constrain the OI foreground.

We conclude that the binary system S106 IR is probably in an evolutionary stage where gas accretion is counteracted by the stellar winds and radiation, leading to the very complex spatial and kinematic emission of the various tracers. The jets and outflows are not well organized so that the emission distributions of the observed lines are more consistent with a competitive accretion or fragmentation-induced starvation star formation model than with the turbulent core model.

Notes:

Chemical Complexity of AFGL 2591

11:30

Caroline Gieser[1]

[1] Max Planck Institute for Astronomy

Hot cores are ideal laboratories to study the formation of simple and complex organic molecules. Here we present a detailed observational and modeling study of the chemistry of the prototypical hot core VLA 3 in the high-mass star-forming region AFGL 2591, where it evolves in unique conditions being isolated from other young OB stars with strong UV radiation. This region is part of the NOEMA (NOrthern Extended Millimeter Array) large program CORE targeting 20 such regions. Observations were carried out with NOEMA from 217 GHz to 221 GHz with a spectral resolution of ~ 2.7 km/s and to include large-scale emission observations with the IRAM 30 m telescope were complemented. Using the high spatial resolution (0.4" ~ 1300 AU at 3.3 kpc) we derived the physical structure (density and temperature) of the source using the 1.37 mm continuum, methyl cyanide and formaldehyde emission. In the spectra, we could identify in total 17 different species and 12 isotopologues among ~ 100 detected lines. Using XCLASS, we derived the rotation temperatures and column densities: AFGL 2591 has a high molecular abundance (e.g., SO2, SO, OCS) and shows a rich diversity in complex molecules (CH3OH, CH3CN, NH2CHO, C2H5CN, C2H3CN, CH3OCHO, CH3COCH3, CH3OCH3). Many species show an asymmetric distribution around the continuum peak which indicates a complex structure on small scales due to disk accretion and the outflow. As hot cores have a rich gas-phase chemistry, we modeled the chemical abundance with MUSCLE. The model includes the time-dependent gas-grain chemical model ALCHEMIC and finds the best-fit physical structure covering several stages of high-mass star formation. With this simplistic 1-d model, we are able to explain the abundance of $\sim 70\%$ of the species with a chemical age of ~ 50000 years and a best-fit physical structure comparable to the observed one. Thus, in agreement with previous studies of the region, AFGL 2591 VLA 3 seems to be in an early hot core stage. The observed chemical segregation can be partially explained by our model, but more sophisticated modeling is needed in order to explain the spatial distribution of certain species, e.g., by including shock chemistry and the complex physical structure of the source.

Notes:

11:50

The formation of molecular clouds by compression of two-phase atomic gases.

Kazunari Iwasaki[1]

[1] Osaka University

The formation of molecular clouds is one of the most important processes in star formation. Shock compression, which is a ubiquitous phenomenon, induces various instabilities: Thermal instability triggers the phase transition from warm atomic gases to cold clouds that evolve into molecular clouds, and magnetohydrodynamical instabilities combining with the thermal instability drive strong turbulence. Using numerical simulations including cooling/heating processes and non-equilibrium chemical reactions, we investigated the formation of molecular clouds by compression of HI clouds surrounded by the warm neutral medium. We found that magnetic fields provide a diversity of the structure of molecular clouds in the early phase. When gases are compressed nearly along magnetic fields, turbulence-dominated extended molecular clouds form. If magnetic fields are slightly tilted to shock compression, magnetic fields become important in the structure of molecular clouds and weaken turbulence, leading to dense molecular clouds. If the angle between magnetic fields and shock compression is too large, magnetic fields suppress the formation of molecular clouds.

Notes:

The formation and evolution of filamentary molecular clouds and Star Formation.

12:10

Shu-ichiro Inutsuka[1]

[1] Nagoya University

Recent observations have emphasized the importance of the formation and evolution of magnetized filamentary molecular clouds in the process of star formation. Theoretical and observational investigations have provided convincing evidence for the formation of molecular cloud cores by the gravitational fragmentation of filamentary molecular clouds. The size and total angular momentum of a protoplanetary disk are supposed to be related directly to the rotational property of the parental molecular cloud core where the central protostar and surrounding disk are born. In this talk we summarize our current understanding of various processes that are required in describing the filamentary molecular clouds and try to understand the origin of angular momenta of molecular cloud cores and its link to the mass function of cores and the stellar initial mass function.

Notes:

12:30

High-mass star formation in giant molecular clouds in the Magellanic Clouds

Toshikazu Onishi[1]

[1] Osaka Prefecture University

Most stars are born as clusters in Giant Molecular Clouds (hereafter GMCs), and therefore the understanding of the evolution of GMCs in a galaxy is one of the key issues to investigate the evolution of the galaxy. The recent state-of-the-art radio telescopes have been enabling us to reveal the distribution of GMCs extensively in the Galaxy as well as in the nearby galaxies, and the physical properties and the evolution of the GMCs leading to cluster formations are actively being investigated. Here we present studies of spatially resolved GMCs in the Magellanic Clouds(LMC/SMC), aiming at determining the origins of the observed turbulence and assessing the role of gas interaction in triggering star formation by the observations spanning a range of scales and environmental conditions. We have carried out ALMA observations toward ~ 10 GMCs located across the LMC by using ALMA mainly in the CO isotopologue lines of J=1-0 and 2-1 and continuum bands. The typical angular resolution is $1 \sim 3$ arcsecs; 1 arcsec corresponds to 0.24pc at the distance of the LMC. These clouds have different evolutionary stages spanning a wide range of star formation activity. The observations revealed the complex nature of the molecular gas in the LMC; full of filaments and clumps; we also quantify their density structure and velocity-size correlations. The comparison with the galactic GMCs indicates the similarity of multiple filaments entangled toward the region where high-mass stars are forming. Further high-resolution observations have been done toward N159, which is the most intense and concentrated molecular cloud as shown by the brightest CO J=3-2 source in the LMC. The spatial resolution is 0.06pc, which is high enough to spatially resolve high-density cores and narrow filaments. The observations revealed 0.1pc width filaments entangled as well as high density cores as the possible site of proto cluster formation. We have also carried out 0.3pc resolution observations of N83C, a high mass star-forming region in the SMC. The radiative transfer analysis suggests that the kinetic temperature is 40K and the density is a few $\times 10^4$cm^{-3}, which is consistent with the virial analysis. This high-density, implying a lack of lower-density envelope, and the high temperature indicates that UV radiation deeply penetrates into the clump and CO molecule is heavily photodissociated in the low-metalicity environment.

Notes:

X-raying the Bones of the Milky Way: Accelerating Star Formation Rates in Infrared Dark Clouds

14:00

Matthew Povich[1]

[1] Cal Poly Pomona

We present first results from a 500-ks Chandra X-ray Observatory survey of 4 prominent Galactic infrared dark cloud (IRDC) complexes. Large-scale, filamentary IRDCs trace Galactic spiral structure and provide the initial conditions for massive star cluster formation. Our X-ray survey has demonstrated that some of these cold, dense giant molecular clouds are replete with pre-main-sequence stars that boom with high-energy coronal emission. We match thousands of X-ray point sources to complementary 1-24 μm IR photometric catalogs to investigate the stellar populations in IRDCs, in particular spatial distributions, total stellar mass, duration of star formation, and frequencies of disks/protostars. Our initial analysis of the M17 SWex IRDC yields two perhaps surprising results: (1) X-ray point sources with no detected IR counterpart are found embedded within the IRDC filaments, frequently exhibiting variability indicative of coronal flares, and (2) an associated population of intermediate-mass, pre-main-sequence stars (IMPS) that lack mid-IR excess emission from inner dust disks. We find that star formation within IRDCs is more widespread in both space and time than would be expected based on the observed compact massive clusters/cores. This indicates either an accelerating star formation rate, consistent with theoretical models of hierarchical collapse in filamentary clouds, or a distributed mode of low- and intermediate-mass star formation that does not produce massive clusters.

Notes:

14:20

Hoyle Fragmentation in Turbulent Molecular Clouds: Sequential Onset of Contraction of Successively Smaller Scales

Enrique Vázquez-Semadeni[1]

[1] Universidad Nacional Autónoma de México

Diverse numerical and observational evidence suggests that star-forming, nearly isothermal molecular clouds (MCs) may be in a process of global gravitational contraction. As originally proposed by Hoyle (1953), in such a regime, a sequential destabilization of successively smaller masses should occur, leading to the fragmentation of the cloud and the formation of stellar-mass objects. Early criticisms of this mechanism argued that, for clouds with an initial mass just over the Jeans mass, the largest scales have the largest growth rates, and thus overwhelm the collapse of smaller scales, preventing fragmentation from actually occurring through this mechanism. We revisit the feasibility of Hoyle's fragmentation in the light of modern notions about molecular clouds: they may rapidly acquire masses much larger than their Jeans mass and contain turbulent, nonlinear density fluctuations that have shorter free-fall times. We then present a calculation of the sequential destabilization of successively smaller mass scales, describing the time at which fragments of such mass are expected to appear.

Notes:

ALMA CO absorption study - smallest GMC structures

14:40

Jin Koda[1]

[1] Stony Brook University

I will present an absorption study of the molecular ISM in the MW from ALMA Cycle 4. Two QSOs directly behind the MW mid-plane were observed at the rest frequencies of CO, 13CO, and C18O J=1-0 & 2-1. Their lines-of-sight run through and sample several GMCs in the MW disk. This absorption study shows the smallest spatial and velocity structures within the typical GMCs: the spatial scales of absorption features are determined by the apparent sizes of the QSOs (< 10 milliarcsec; or 10-100AU at 1-10 kpc) and ALMA permits significant detections at a high velocity resolution (below the sound speed of the cold ISM ~ 0.2 km/s). I will show the presence of (roughly) thermally bound small molecular droplets within GMCs. Their temperatures, from the line ratios, are typically much lower than the often-adopted temperature of GMCs. The smallest structures in GMCs are important for understanding the dissipation scale of turbulent energy cascade and the trigger of star formation. I will present a generalized picture of GMCs' internal structures from a synthesis of absorption features detected in this study.

Notes:

15:00

Molecular cloud ionization: where are the cosmic rays?

Thierry Montmerle[1]

[1] Institut d'Astrophysique de Paris, France

As has been known for a long time, molecular clouds are (weakly) ionized. This ionization couples them with the ISM magnetic field, and therefore plays an important role in star formation. The source of ionization is widely attributed to low-energy cosmic rays (say in the 1-100 MeV range). However, in the heliosphere these cosmic rays are strongly affected by the solar wind (i.e., the "solar modulation"), and their "demodulated" spectrum has been the subject of many calculations. Yet, to explain the ionization of molecular clouds, all require a huge, additional low-energy flux enhancement outside of the heliosphere (by several orders of magnitude depending on models). The Voyager 1 space probe, launched in 1977 (!), crossed the heliosphere boundary in 2012, and is now cruising in the local ISM at more than 140 au from the Sun, while still transmitting data. The results indicate a complete absence of a low-energy cosmic-ray excess (down to 3 MeV) over the most extreme "demodulated" spectra. On the other hand, the combination of high-energy gamma-ray (10 GeV-100 TeV) observations and dedicated mm observations of molecular clouds impacted by supernova remnants (thus accelerating cosmic rays in situ) indicate comparable enhancements (x 10-100) of high-energy cosmic rays (to explain their large gamma-ray flux) and of low-energy cosmic rays (to explain their high ionization). But for "passive" molecular clouds, recent work on low-energy cosmic-ray penetration has shown that, if the Voyager 1 cosmic-ray spectrum is valid in the average ISM, these cosmic rays fall short by at least 2-3 orders of magnitude to explain the observed ionization rates. So we're left with an unsuspected, major challenge: where are the cosmic rays ionizing the molecular clouds ?

Notes:

SESSION 2: Low-Mass Star Formation

The Wonders of Magnetic Fields in Star-forming Regions. 15:50

Derek Ward-Thompson[1]

[1] University of Central Lancashire

Measuring magnetic fields deep inside molecular clouds on scales relevant to the formation of stars is challenging. The POL-2 polarimeter with the SCUBA2 camera on the JCMT is a unique facility, as it can map the magnetic field within cold dense cores and filaments on scales of $\sim 1000\,\mathrm{AU}$ in nearby star-forming regions (e.g. the Gould Belt regions). BISTRO (B-fields In STar forming Region Observations) is a JCMT-EAO Large Program designed to map dust polarization in nearby star-forming regions using POL-2 and SCUBA2. This talk reports on the aims and scope of BISTRO and the first 2 years of results from the BISTRO regions. The data allow us to trace (via the Davis-Chandrasekhar-Fermi method) the magnetic field direction and strength in the centres of all of these regions. The goals are to answer currently open questions in star formation, such as the relative importance of magnetic fields and turbulence in star formation, and to test current models of star formation, such as the Herschel model of magnetic funnelling onto filaments.

Notes:

16:10 **Low-mass star formation with non-ideal magnetohydrodynamics**

James Wurster[1]
[1] University of Exeter

Magnetic fields are undeniably a critical component of star formation, with the initial strength of the magnetic field ultimately affecting the mass of the protostar and the characteristics of its environment. Previous studies have shown that strong magnetic fields inhibit disc formation and promote strong collimated outflows, while weak magnetic fields promote large discs and weak outflows. However, these results assume ideal magnetohydrodynamics (MHD), which is a poor approximation since the majority of the gas in a molecular cloud core is cold, neutral gas. Non-ideal MHD processes account for the motions of charged particles and how they interact with neutral particles. These processes, Ohmic resistivity, ambipolar diffusion and the Hall effect, depend on the local gas properties, magnetic field geometry, and the ionisation fraction. Particles are ionised from various sources, with the dominant source at early times being cosmic rays, suggesting that cosmic rays are instrumental in determining the ionisation fraction, and hence in shaping the evolution of the star formation process. In this talk I will present smoothed particle radiation non-ideal magnetohydrodynamics simulations of low-mass star formation in the presence of a strong magnetic field, following the gravitational collapse through the first and second hydrostatic core. I will focus on the effect of decreasing the ionisation rate from very high (ideal MHD) to canonical values for the Milky Way (non-ideal MHD). I will discuss how a massive protostellar disc can form in the presence of strong magnetic fields under specific circumstances, thus solving the magnetic braking catastrophe. I will also discuss how the initial cosmic ray ionisation rate affects the properties of the protostar itself, and the implications that this has on the origins of magnetic fields in stars.

Notes:

ALMA Observations of Serpens Main: Protostellar Evolution at the Class 0 Stage

16:30

Yusuke Aso[1]

[1] Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan

We observed three protostars, SMM11, SMM4A, and SMM4B, in the Serpens Main star forming cluster in 1.3 mm continuum, ^{12}CO $J = 2 - 1$ line, C^{18}O $J = 2 - 1$ line, and SO $J_N = 6_5 - 5_4$ line using ALMA during Cycle 3. These three protostars are deeply embedded, and not detected as a point source even in $70\,\mu\mathrm{m}$ by Herschel. Their SEDs indicate that all of them are in the Class 0 stage. Our ALMA data clearly show, however, that these three protostars have different physical and chemical properties. The continuum visibilities suggest that the disk with a radius of $\sim 240\,\mathrm{au}$ has already formed in SMM4A. On the other hand, SMM4B contains an embedded compact source ($r \sim 60\,\mathrm{au}$) surrounded by a spherical envelope, and SMM11 is surrounded by a spherical envelope without an embedded compact source. These results suggest disk growth among the three protostars: SMM4A has the most evolved disk, SMM4B possibly has an unresolved disk, and SMM11 is the youngest without such a disk. This scenario is also supported by C^{18}O abundance, opening angles of their ^{12}CO outflows, and the SO emission.

Notes:

SPECIAL SESSION: Capturing the Spirit of Hans

16:50 **An overview of Hans's many contributions to astronomy**

Cathie Clarke[1]

[1] Institute of Astronomy, University of Cambridge

The distinctive voice of Hans has shaped the field of star formation over many decades. Indeed nobody who has attended star formation meetings over that period can be unaware of his wide ranging interests in theory, observations and instrumentation, and his ability to synthesise these in the pursuit of 'the big questions'. In this brief talk I will select some well known and some lesser known themes that have remained close to Hans's heart and which remain at the forefront of our current quest to understand how star formation, binary formation and cluster formation all fit together.

Notes:

SOFIA Today and Tomorrow

17:10

Hal Yorke[1]
[1] USRA-SOFIA

During Hans Zinneckers tenure as SOFIA's Deputy Director of Science Mission Operations, SOFIA transitioned from a developmental project into full mission operations. His science vision was always a driving force. At the same time, Hans was an ambassador for the young observatory, touting its early accomplishments and putting them in perspective of the grand scheme of astrophysics. Since Hans departure from the mission I only overlapped with him a few months SOFIA has continued to improve, as its newest instrument HAWC+ reached maturity. SOFIAs capabilities will continue to grow, as both science and flight operations are further refined, as the Observatory prepares for its next instrument HIRMES, and as a yet unknown Next Generation Science Instrument is being selected by NASA. As can be expected from a mid- to far-infrared facility the only such facility available to the astronomical community for more than a decade to come the wonders of star formation are top on SOFIAs scientific agenda.

Notes:

Tuesday 4th September 2018

SESSION 2: Low-Mass Star Formation (continued)

09:00

Synthetic molecular line observations of the first hydrostatic core

Alison Young[1]

[1] University of Exeter

The first hydrostatic core (FHSC) is the first stable object predicted to form during the gravitational collapse of a pre-stellar core. There are now many observations from far-infrared to radio of young, low-luminosity protostellar sources but observational identification of the FHSC remains elusive. Specific observational characteristics are required in order to distinguish these objects from embedded young protostars and "starless" cores. Differences in the chemical composition of a pre-stellar core before and after FHSC formation will lead to variation in the observational characteristics. We have post-processed high resolution SPH simulations of early star formation with the KROME chemistry solver using a network of around 7000 gas phase and gas-grain reactions. The calculated chemical abundances were used to generate synthetic line emission maps. We will present these new synthetic observations and discuss what line observations are likely to reveal about the kinematics and evolutionary stage of these very young objects, and how this can inform the search for the FHSC.

Notes:

A physically motivated dense-core extraction technique applied to Herschel/Planck observations

09:20

Birgit Hasenberger[1], João Alves[1, 2]

[1] University of Vienna, [2] Harvard-Smithsonian Center for Astrophysics

The evolution of dense cores in molecular clouds represents the earliest stage in the formation process of stars and planets. We are able to observe this stage by using multi-wavelength observations in the far-infrared and sub-mm range, which allow us to map nearby molecular cloud complexes in their entirety and resolve the core population embedded within them. A variety of algorithms were developed to extract cores from observational data. However, in the most commonly used algorithms, core boundaries are based on the two-dimensional morphology of structures in the available maps and do not impose criteria on the physical properties of the region. This renders the physical interpretation and the comparability of studies challenging.

I will present a new method to define core boundaries observationally, based on the physical properties of the medium in a molecular cloud. We model the flux distribution along the line of sight by taking into account the extent of structures on the plane of the sky, allowing us to derive estimates for the three-dimensional density and temperature. Subsequently, we can estimate the energy budget of cloud material in terms of its gravitational and thermal energy. The balance between these two contributions defines the boundaries of our cores. We illustrate the advantages and caveats associated with this approach by applying it to Herschel/Planck observations of the Pipe nebula. Comparing with molecular line data, we show that the minimum temperatures in cores are well-approximated by our method. We study in detail the derived core properties of this cloud, in particular the distribution of core masses.

With this tool at hand, we are able to consistently define core samples in nearby molecular clouds, allowing us to compare core properties within individual clouds as well as between clouds. The development of a physically motivated core extraction algorithm thus represents an essential first step towards a deeper understanding of the processes involved in star formation.

Notes:

09:40

The chemical structure of the Class 0 protostellar envelope NGC 1333 IRAS 4A

Evgenia Koumpia[1]

[1] University of Leeds

It is not well known what drives the chemistry of a protostellar envelope, in particular the role of the stellar mass and the protostellar outflows on the chemical enrichment of such environments. We study the chemical structure of the Class 0 protostellar envelope NGC 1333 IRAS 4A in order to (i) investigate the influence of the outflows on the chemistry and (ii) compare it with a typical high-mass protostellar envelope. In Koumpia et al. 2017 we present JCMT line mapping (360-373 GHz) and HIFI pointed spectra (626.01-721.48 GHz). To study the envelope chemistry, we derive empirical molecular abundance profiles for all observed species using the Monte Carlo radiative transfer code (RATRAN) and adopting a 1D dust density/temperature profile from the literature. We compare our best-fit observed abundance profiles with the predictions from the 1D pseudo-time-dependent gas-grain chemical code (ALCHEMIC). The derived abundance profiles fit well the outer envelope with the exceptions of HCN, HNC, CN and CO. These species require an enhanced UV field which points towards an outflow cavity. The abundances with respect to H2 are 1-2 orders of magnitude lower than those observed in the high mass protostellar envelope (AFGL 2591) while they are found to be similar within factors of a few when they are estimated with respect to CO. Such chemical differentiation can be explained by the temperature differences especially the absence of a freeze-out zone in the high mass case. We conclude that the the observed abundances can be explained by passive heating towards the high mass protostellar envelope, while the presence of UV cavity channels become more important toward the low mass protostellar envelope.

Notes:

A detailed ALMA study of an early stage of protostar formation in a highly dynamical dense core

10:00

Kazuki Tokuda[1]

[1] Osaka Prefecture University

Observational studies of the earliest stage of star formation is a key to investigate the initial conditions of star formation, e.g., the way of the fragmentation and the dynamical collapse. One of the observational difficulties is to appropriately identify such high-density cores just around the moment of protostar formation because the timescale is quite short. Although some ALMA 12m array observations toward dense cores often fail to detect well-developed structures, our recent ALMA observations toward a protostellar core, MC27/L1521F in Taurus, have been revealing highly complex structure, such as arc-like structures and fragmentation of starless dense gas, with the sizes several tens au to a few thousands of au at an early stage of the low-mass multiple protostar formation. These facts suggest that the initial condition of star formation is highly dynamical in nature, which is considered to be a key factor in understanding fundamental issues of star formation such as the formation of multiple stars and the origin of the initial mass function of stars (Tokuda et al. 2014, 2016). Further high-angular resolution observations have been done toward this source in ALMA Cycle 3 with the beam size of ~ 20 au. The observation resolved for the first time the rotation of the tiny disk around the associated VeLLO (Very Low-Luminosity Object) and revealed that the stellar mass gets already ~ 0.2 $M_{\odot}$ in spite of the low luminosity of $L < 0.07$ $L_{\odot}$. Furthermore, although the VeLLO is located just at the very center is located just at the center of the high-density core, mass inflow on to the protostar seems to be halted (Tokuda et al. 2017). We suggest that a highly dynamical (turbulent) environment seen in this system may be a hint to understand the sudden stop of the mass accretion. Actually, the high resolution 12CO observations resolved for the first time complex warm ($> 15 - 60$ K) filamentary/clumpy structures, which have not been observed in cold cores like this, with the sizes from a few tens of au to ~ 1000 au. We suggest that the warm CO gas may be consequences of shock heating or turbulent dissipation induced by interactions among the different density/velocity components originated from the turbulent motions in the core (Tokuda et al. 2018, ApJ in press). These facts may challenge our current understanding of the low-mass (multiple) star formation, in particular, the relation between the mass accretion process onto the protostar/circumstellar disk and the turbulent motions. We are also revisiting the source selection of such high-density cores as possible sources having complex structures by using our ACA survey, ALMA archives, and new large aperture single-dish surveys, and will present the future prospects.

Notes:

SESSION 3: High-Mass Star Formation

10:20

Accretion and Feedback in the Formation of Massive Stars

Rolf Kuiper[1]

[1] University of Tübingen

In the course of their accretion phase, massive (proto)stars impact their natal environment in a variety of feedback effects such as thermal heating, protostellar jets and outflows, radiation forces, as well as photoionization and HII regions. Here, I present our most recent simulation results in terms of the relative strength of the feedback components and the size of the reservoir from which the forming stars gain their masses. For the first time, these simulations include all of the feedback effects mentioned above which allows us to shed light on the physical reason for the upper mass limit of present-day stars. Furthermore, we predict the fragmentation of massive circumstellar accretion disks as a viable road to the formation of spectroscopic massive binaries and the recently observed strong accretion bursts in high-mass star forming regions.

Notes:

Theoretical Modeling of Massive Star Formation

11:10

Kei Tanaka[1]

[1] Osaka University

Despite their importance in various fields of astrophysics- the formation of massive stars is not understood well compared to low-mass star formation. Stars with over 100 Msun had especially been theoretically considered to be hardly formed due to their own radiation feedback even though they do exist. To understand massive star formation under the strong feedback, we construct a theoretical model self-consistently including multiple feedback processes, i.e., MHD disk winds, radiation pressure, and photoevaporation, while following protostellar evolution in collapsing massive gas cores (Tanaka et al. 2017, ApJ, 835, 32). Although the radiation pressure had been regarded to be the crucial feedback in the formation of massive stars, we find that the MHD disk winds have the strongest impact on setting star formation efficiencies (SFEs) from natal cloud cores. In this sense, massive star formation is similar to low-mass star formation. The radiation pressure becomes significant to widen the outflow cavity causing reductions of SFE only in the formation of very-massive stars $\sim> 100$ Msun at clump surface densities lower than $\sim< 0.1$ g cm^{-2}. We find no evidence of the maximum stellar mass up to 500Msun even under multiple feedback. which is consistent with recent observations reporting the existence of stars with initial masses of up to 300 Msun in 30 Doradus. We also apply our model to low metallicity environments to connect massive star formation in the present-day universe to that in the early universe (Tanaka et al. 2018, accepted by ApJ, arXiv:1804.01132). At the metallicity lower than 10^{-2} Zsun, the photoevaporation becomes significant and reduces SFEs in the formation of over-20 Msun stars. This is because the ionizing photons are less absorbed by dust grains at lower metallicities. Our result suggests massive stars would be rarer in extremely metal-poor environments of 10^{-5} - 10^{-3} Zsun (if the core-mass-function does not change), which is consistent to no clear signatures of the pair, instability supernovae in abundance patterns of metal-poor stars in our galaxy. Finally, we would like to mention our observational modeling. To test our theoretical model and to analyze physical properties of massive protostars which deeply embedded in molecular clouds, we perform the radiative transfer calculations providing synthetic observational models. Our synthetic observational model shows consistent properties of observed massive protostars (Tanaka et al. 2016, ApJ, 818, 52; Tanaka et al, 2017, ApJ, 849, 133, etc).

Notes:

11:30

The Formation of Massive Stars with Radiative and Protostellar Outflow Feedback

Anna Rosen[1]

[1] Harvard-Smithsonian Center for Astrophysics

Massive stars play an essential role in the Universe. They are rare, yet the energy and momentum they inject into the interstellar medium with their intense radiation fields dwarfs the contribution by their vastly more numerous low-mass cousins. During their formation, feedback from their intense radiation fields and magnetically launched, collimated protostellar outflows can limit their growth by accretion. In this talk, I will present a series of adaptive mesh refinement 3D radiation-(magneto)hydrodynamics simulations of the collapse of initially turbulent, massive pre-stellar cores that include radiative feedback from both the direct stellar and dust-reprocessed radiation fields and outflow feedback from the accreting stars. We find that mass is channeled to the stellar system via gravitational and Rayleigh-Taylor (RT) instabilities through nonaxisymmetric disks and filaments that self-shield against radiation pressure while allowing for radiation to escape through optically thin regions. Inclusion of feedback from protostellar outflows punches holes in the ISM along the stars polar directions, thereby increasing the sizee of optically thin regions where radiation can escape. This effect makes mass accretion via RT instabilities less significant. Furthermore, precession of the outflows due to the star being pushed around by the turbulent accretion flow cause the opening angles of the entrained material to increase with time. This effect, including the enhanced radiative heating by the escape of stellar radiation, further reduces accretion onto the massive star as compared to feedback from radiation alone. Our results suggest that disk accretion is therefore a requirement for the birth of massive stars, especially at late times.

Notes:

Formation of High Mass Stars and Magnetic Fields

11:50

Robi Banerjee[1]

[1] Hamburger Sternwarte

Magnetic fields are an elemental part of the interstellar medium (ISM) that has a large impact on the dynamics of the ISM on various spatial scales. Here, I'll talk about the long-standing issue of how to generate magnetically supercritical cloud cores, which are essential to understanding star formation in our own Galaxy. Furthermore, I'll discuss the impact of magnetic fields on the formation of high mass stars.

Notes:

12:10 **Competitive accretion and high-mass star formation in clusters**

Ian Bonnell[1]

[1] University of St Andrews

I will discuss how high-mass star formation can occur do to ongoing accretion in stellar clusters. This is an unavoidable outcome of the cluster formation process and can explain both the existence of high mass stars and the stellar IMF. Binary high mass stars are an important outcome of high mass star formation and I will present recent results of how magnetic fields can aid in this process. Binary mergers may be a relevant process in forming the highest mass stars.

Notes:

A high-resolution picture of fragmentation and accretion in the AFGL 4176 disk

12:30

Katharine Johnston[1]

[1] University of Leeds

Prior to ALMA, there were few well-resolved observations of disks around forming massive stars, with almost all previous observations having fewer than five resolution elements across the disk (Beltrán & de Wit 2016). We have used the long-baseline capabilities of ALMA to observe, resolve and characterise the structure and fragmentation of the best example to date of a disk around a forming O-type star. Our earlier Cycle 1 observations of the AFGL4176 disk, also taken at 1.2mm, showed that it is in near-Keplerian rotation (Johnston et al. 2015), but the physical resolution in this case was limited to ~ 1250 AU. Now we have observed the K ladder of CH3CN J=13-12 and 1.2mm continuum again at a resolution of $\sim 0.05''$ or 200AU, obtaining 20 resolution elements across this $r \sim 2000$ AU disk. With this resolution, we can determine the accretion kinematics in fine detail across the disk as well as how they are affected by fragmentation and the possible formation of proto-companions. In this talk, I will review our results from previous observations of AFGL 4176 as well as present our findings from the new observations, shedding some light on the processes which dominate disk accretion for high-mass stars.

Notes:

14:00

The formation and evolution of the intermediate mass Pre-Main Sequence Herbig Ae/Be stars

Rene Oudmaijer[1]

[1] University of Leeds

The formation mechanisms of low mass stars and high mass stars show large differences as well as similarities. In the intermediate mass range we can expect the formation scenario to switch from magnetically controlled accretion, at low masses, to the currently unknown massive star forming mechanism. The intermediate mass pre-Main Sequence Herbig Ae/Be stars are the ideal object class to study this problem. Here we present the results of two of our recently completed surveys and give an update on one on-going large study. These are an X-Shooter spectroscopic survey, a linear spectropolarimetric survey, as well as a study all these objects placed in the HR diagram using parallaxes provided by GAIA. The X-Shooter survey of 90 Herbig Ae/Be objects is the largest such spectroscopic study to date. The data, covering the blue to NIR, are used to derive fundamental properties of the stars and their accretion rates in a homogeneous manner. We will provide evidence that the highest mass Herbig stars can not be accreting in the same way as lower mass stars (and can therefore act as an optically visible proxy for Massive Star formation). The linear spectropolarimetry across Ha of 56 objects provides information on the geometry of the stars' circumstellar disks at scales of order a few stellar radii. We show that the Herbig Be objects are surrounded by (accretion) disks reaching onto the stars, whereas the Herbig Ae stars are very similar to the T Tauri stars, which can be explained by magnetospheric accretion. Finally, using GAIA DR2 we place more than 150 objects in the HR diagram, an increase of a factor of ten to previous such studies and zoom in on the differences in accretion rates, infrared excess, variability and evolutionary status of these objects on their way to the Main Sequence. If time permits, we will then give an overview of our optical interferometric studies of hydrogen line emission of these objects.

Notes:

NGC7538 - our key to understanding high mass star formation 14:20

Göran Sandell[1]
[1] IfA, Hilo, Hawaii

The molecular cloud south of the small HII region NGC 7538 harbors several young massive stars, of which at least three, IRS1, IRS9 and NGC 7538S, are all centers of young clusters. At a distance of 2.65 kpc NGC 7538 is by no means the closest high-mass star forming region, but the extreme youth of these stars make them key targets for our understanding of high mass star formation. IRS1, an O7 star, is still heavily accreting with an accretion rate of a few $\times 10^{-4}$ MSun/yr, which quenches the formation of an HII region. NGC 7538 South, now an early B-star $\sim$ 80" south of IRS1, has an even higher accretion rate, $\sim 2 \times 10^{-3}$ MSun/yr, only faint free-free emission and it drives a compact molecular outflow. Both stars are almost certainly surrounded by accretion disks. Here we look at new SOFIA/GREAT data as well as archive data from Herschel (PACS & SPIRE) and SOFIA FORCAST. We also re-examine data from OSO, FCRAO, JCMT, BIMA, and CARMA as well recent literature to refine the characteristics of IRS1 and S. Our view is that high-mass stars do not form as high mass stars. They start with much lower mass but inside a very dense core, so that they continue to accrete matter with a very high accretion rate until the mass reservoir runs out.

Notes:

14:40

Herschel Spectroscopy of Massive YSOs in the Magellanic Clouds

Joana Oliveira[1]

[1] Keele University

As the nearest gas-rich galaxies, the Large and Small Magellanic Clouds (LMC and SMC) offer the exciting opportunity to bridge the gap between star formation processes on large galaxy-wide scales and on the small scales of individual Young Stellar Objects (YSOs). These metal-deficient galaxies also provide an invaluable window into the star formation process at low metallicity, a region in the parameter space that remains relatively unexplored. I present the results of spectroscopic observations obtained with PACS and SPIRE/FTS onboard the Herschel Space Observatory. The sample of massive SMC and LMC YSOs is well characterised at near, and mid-IR wavelengths, and includes both deeply embedded sources and compact HII regions. The strengths of key gas-phase cooling species ([OI], [CII], H2O, CO, OH) are measured as probes of the physical conditions of the gas surrounding the YSOs. While [OI], [CII] and CO emission are easily and widely detected, H2O and OH emission seems weak or absent in most YSOs. [OI] and [CII] emission originate mostly from photo-dissociation regions (PDRs). When compared with Galactic sources, Magellanic YSOs clearly exhibit higher photoelectric efficiency (measured by the ratio of line emission to total IR flux), likely a consequence of the reduced grain charge observed in Magellanic environments. In terms of standard PDR models, the observations suggest a lower G0/n ratio (G0: strength of the FUV radiation field- n: hydrogen cloud density), that is interpreted in the context of a change in ISM structure and PDR distribution in low metallicity galaxies (increased mean free path of UV photons and ISM porosity). This could have important consequences for feedback processes in the Magellanic Clouds. The CO ladder is used to constrain the density and temperature of the emitting gas. Our observations probe the colder CO components (rotational temperatures less than 200 K). Despite the very different spatial scales sampled and evolutionary stages of the sources, the derived CO temperatures for Galactic and Magellanic YSOs over the SPIRE range are similar and insensitive to source properties. Furthermore, PDR heating cannot be responsible for the excitation of CO gas; both on SFR-wide scales and on the scales of individual objects, shock-heated gas seems to be the origin of most CO emission in Magellanic YSOs. We also constrain the cooling budget of the YSO envelopes. Our observations suggest that OH and H2O provide only a modest contribution to the cooling of massive YSOs in the Magellanic Clouds. We compare the cooling budgets for Galactic and Magellanic samples, and discuss potential environmental effects.

Notes:

Massive YSO in star forming region in the Magellanic Clouds 15:00

Monica Rubio[1]

[1] Universidad de Chile

Understanding the process of star formation in low metallicity systems is one of the key studies in the early stages of galaxy evolution. The Magellanic Clouds, being the nearest examples of low metallicity systems, allow us to study in detail their star forming regions. As a consequence of their proximity, we can resolve the molecular clouds and the regions of star formation individually, and increase our knowledge of the interaction of young luminous stars with their environment. We will present results of multi-wavelength studies of LMC and SMC massive star forming regions, which includes properties of the cold and CO-dark molecular gas, the embedded massive young population associated with molecular clouds, and the interaction of newly born stars with the surrounding interstellar medium.

Notes:

15:50 **Radio Jets from Massive Protostars as a Probe of Evolution**

Stuart Lumsden[1]

[1] University of Leeds

We now know that radio emission from the infrared bright massive protostars is almost ubiquitous, and that it mostly presents itself in the form of jets. However, given the radiative outer envelope of a hot star the exact process by which these jets emerge is still unclear (eg geometrically collimated stellar winds versus x-winds from a cool swollen supergiant like protostar versus driving from the accretion disc processes alone). I will present more recent results which help to illuminate these questions, as well as showing how they fit into a broader picture presented by near infrared spectroscopic evolutionary sequences.

Notes:

Molecular cloud formation and dispersal by stellar feedback

16:10

Steffi Walch[1]
[1] University of Cologne

Star formation takes place in the densest and coldest parts of the interstellar medium (ISM), in dark molecular clouds. These are swept up by multiple supernova explosions on scales of several hundred parsec. While condensing out of the warm ISM, the clouds are continuously fed with fresh gas. Thus, the turbulent substructure and magnetic field properties are imprinted during cloud formation. The formation of dense clouds from the multi-phase ISM, the onset of star formation, and the evolution of the molecular clouds under the impact of stellar feedback from newly born massive stars is studied in high-resolution simulations within the SILCC project. I will present some of the latest results on the evolution of the clouds after the onset of star formation, which is governed by stellar feedback. For example, we find that the detailed cloud substructure determines the clouds' vulnerability to stellar feedback processes, in particular to ionizing radiation. Moreover, the ionization state of the gas can be highly variable on scales of tens of parsec due to small-scale turbulent motions within the star-forming clouds, which shield and release the ionizing radiation. This leads to a flickering of the young HII regions.

Notes:

SESSION 4: Jets and Outflows

16:30

HH 212: The Most Beautiful Jet

Jennifer Wiseman[1]
[1] NASA/GSFC

HH 212, described by Hans Zinnecker as The Most Beautiful Jet, is a spectacularly collimated jet with symmetric shocks and a very young Class 0 source. Its youth, symmetry, edge-on perspective, and bow shocks make it a spectacular test case for study of how a very young protostar develops and interacts with its environment. I will present a review of all we have learned about HH 212 by observing its shock emission, molecular cloud core and envelope, driving source, and shock interactions with its surrounding molecular cloud core.

Notes:

Wednesdy 5th September 2018

SESSION 4: Jets and Outflows (continued)

Jets and Outflows (Invited Review)

09:00

Sylvie Cabrit[1]
[1] TBD

TBD

Notes:

09:40

Herbig-Haro Flows from Multiple Stellar Systems

Bo Reipurth[1]

[1] University of Hawaii

Observational evidence increasingly suggests that there may be a causal link between multiplicity and major Herbig-Haro activity, specifically that the dynamical decay of triple or multiple systems may lead to massive outbursts of outflow. I will discuss the physical basis for this, and present detailed new observations of HH flows and their sources.

Notes:

Highly Excited Molecular Hydrogen in Herbig-Haro 7 10:00

Tom Geballe[1]
[1] Gemini Observatory

Almost three decades ago Hans, I and our collaborators wrote a paper on velocity-resolved observations from UKIRT of the H_2 1-0 S(1) line in several Herbig-Haro objects. We concluded that near the tips of the HH objects, where the jet speeds exceed that at which H_2 would be completely collisionally dissociated in the shocks, the H_2 line emission must originate in molecular gas already entrained in the jet. Since then I have continued to be puzzled by the apparent contradictions in the observed H_2 line intensity ratios in numerous outflows, and those expected from continuous shocks, which are required to prevent dissociation of the H_2 in shocks due to high velocity outflows and jets. Recently, I and colleagues revisited one of the objects, HH7, with much more advanced instrumentation at Gemini North, and appear to have solved that mystery, only to have come upon a new one. We have detected H_2 lines in HH7, and more recently in OMC-1, with upper state energies ranging up to the dissociation energy of H_2, which cannot be readily explained by either collisional shocks or UV fluorescence. I will present these data and discuss possible origins for this extremely hot H_2.

Notes:

10:20

Studies of young stars with accretion, and outflow-tracing spectral lines

Larisa Tambovtseva[1]

[1] Pulkova Astronomical Observatory

We present results of the non-LTE modeling of the hydrogen emission spectra in the low mass stars (T Tau stars, TTSs) and the intermediate mass stars (the Herbig AeBe stars, HAEBEs). With the help of the emission lines tracing accretion and outflow regions surrounding a young star we investigate physical and geometrical properties of these regions which cannot be resolved with telescopes. A mutual modeling of the hydrogen line profiles and interferometric functions permitted us to restrict a range of the model parameters and obtain reliable results. We accumulated statistical data that allowed us to find a link between parameters of the HAEBEs and parameters of their emitting regions. First results of the non-LTE modeling of the Balmer lines in TTS binary S CrA are presented.

Notes:

A wonder of star formation - watching a massive star grow 11:10

Bringfried Stecklum[1]

[1] Thüringer Landessternwarte

In autumn 2015 the flaring of methanol masers in S255IR signalled an event that turned out to be an accretion outburst from the most massive young stellar object known to date. Our investigation is based on data ranging from the meter-wave to X-ray spectral domain. It revealed expected and unexpected results for what concerns the formation of massive stars which will be summarised. This phenomenon precisely matches the topic of the conference.

Notes:

11:30

The UX Ori type activity in young cool stars

Vladimir Grinin[1]

[1] Pulkovo Astronomical Observatory

Variable circumstellar extinction is one of the main sources of photometric activity in young stars. The most spectacular form of this type of activity is observed in UX Ori stars (UXOrs). Up to recent times, this family of young variables consisted mainly of Herbig Ae stars and a few T Tauri stars. However, during the last few years, the number of cool UXOrs increased substantially. A new variety of the UXORs has appeared; the so-called dippers. In my short review I will show a few examples of such stars. Some of them are weak line T Tauri stars, which is quite surprising. In some of them, a combination of the AA Tau and UX Ori types of activity has been observed simultaneously. Investigations of such objects opens new opportunities for the study of the nearest environment of young stars and their accretion activity.

Notes:

SESSION 5: Triggering and Feedback from Massive Stars

The (Un)predictability of Star Formation on a Cloud Scale. 11:50

Sam Geen[1]

[1] Universität Heidelberg

In this talk I will discuss how sensitive the SFE of molecular clouds is to randomised inputs in the star formation feedback loop, and to what extent relationships between emergent cloud properties and the SFE can be recovered using a Bayesian mixed-effects model. I introduce the YULE suite of 26 radiative magnetohydrodynamic (RMHD) simulations of a 10,000 solar mass cloud similar to those in the solar neighbourhood with photoionisation feedback. The simulations use the same initial global properties but vary the initial mass function (IMF) sampling and initial cloud velocity structure. The final SFE lies between 6 and 23% when either of these parameters are changed. The number of photons emitted early in the cluster's life and the length of the cloud provide are the strongest predictors of the SFE. The HII regions evolve following an analytic model of expansion into a roughly isothermal density field. The more efficient feedback is at evaporating the cloud, the less the star cluster is dispersed. We argue that this is because if the gas is evaporated slowly, the stars are dragged outwards towards surviving gas clumps due to the gravitational attraction between the stars and gas. While star formation and feedback efficiencies are dependent on nonlinear processes, statistical models describing cloud-scale processes can be constructed that recover underlying trends.

Notes:

12:10

Carinas Pillars of Destruction: the view from ALMA

Pamela Klaassen[1]

[1] UK Astronomy Technology Centre

Massive stars cause strong feedback onto their natal environment, and shape its future ability to make further stars. They inject enormous amounts of energy and turbulence into their surroundings, and create or reveal dense pillars of gas and dust towards the edges of the cavities they clear. The shapes of these pillars are well reproduced in many different kinds of feedback models, but their internal structures vary significantly (and measurably) from model to model. The distinguishing properties include differences in internal velocity gradients, pillar velocity offsets with respect to the cloud rims they are attached to, and their internal velocity dispersions. These pillar properties are testable with observations of the molecular gas within such pillars. Here we present the first ALMA survey focusing on the internal dynamics of 13 pillars which are being shaped by the high-mass stars in the Carina nebula. We will present our ^{12}CO/^{13}CO/C^{18}O and 1.3 mm continuum observations in the these pillars which show beautiful and varied kinematic properties which are more reminiscent of the structures formed in the simulations of Dale et al. (2012) and Gritschneder et al. (2009) than those of Gritschneder et al. (2010).

Notes:

SPECIAL SESSION: Reminiscences

My passion for star formation (and the ISM) 12:30

Hans Zinnecker[1]

[1] Deutsches SOFIA Institut, Universität Stuttgart; retired

I started my scientific career as a theoretical physicist in quantum field theory (1977) at the Technical University Munich. Then I turned to astrophysics and star formation in the far-infrared (balloon) group at MPE Garching and obtained a PhD (1981) on the theory of the stellar initial mass function. I spent 4 influential post-doc years (1983-1987) at the Royal Observatory Edinburgh (ROE) where they trained me in near-infrared observations. I had the opportunity to participate in several observing runs at UKIRT on Mauna Kea and learnt how to write observing proposals. A particular interest of mine that emerged was the study of embedded star clusters, young binary stars and protostellar jets. Later, I returned to Germany (MPE Garching, working both in Reinhard Genzel's infrared group and the ROSAT X-ray group). In 1990, I moved on to the University of Wuerzburg, and spent 5 years in the star formation group of Harold Yorke and his students, as a fellow of the German Science Foundation (DFG). In 1995, Guenter Hasinger hired me, finally on a permanent job, at the newly founded Astrophysical Institute Potsdam, and for the next 15 years I remained the head of the star formation group there. In 2010, encouraged by Eric Becklin, I joined the SOFIA project (Univ Stuttgart) and spent 6 years at NASA-Ames California as the Science Mission Operations deputy director (together with SMO director Erick Young). During those final years of my career I turned from a stellar to an interstellar astronomer, with a growing interest in simple molecules and astrochemistry in the ISM. I retired in December 2016 and since then moved to live in Chile with my (Chilean) wife Andrea. I regularly attend the journal clubs at the ESO and ALMA Headquarters in Santiago de Chile. It is still great fun to connect with young astronomers and share/stimulate their passion for science. I, for one, had the good fortune to witness the incredible progress over the last 40 years in the theory and observations of the star formation process (and because of my dual training could enjoy both). I met many giants in the field who inspired me, and attended many many conferences (200-300), but the initial inspiration came from my physics teacher in my home town Dinkelsbuehl who in turn had taken a course in stellar evolution from that red giant R. Kippenhahn and made me understand the HR-diagram at age 18. In my reminiscences, I will try to describe what an extraordinary rollercoaster ride it was, from small beginnings to full circle !!
PS. See also my interview in Bo Reipurth's Star Formation Newsletter 246 for more details about my research interests and achievements.

Notes:

Thursday 6th September 2018

SESSION 5: Triggering and Feedback from Massive Stars (continued)

09:00

Triggered star formation

Yasuo Fukui[1]

[1] Nagoya University

A review of triggered high-mass star formation is presented.

Notes:

MHD simulation of cloud formation by the thermal instability and consequent massive star feedback

09:20

C.J. Wareing[1], J.M. Pittard[1], S.A.E.G. Falle[1]

[1] University of Leeds

We have used the AMR magnetohydrodynamic code, MG, to perform 3D MHD simulations of the formation of a molecular cloud through the action of the thermal instability, with self-gravity and magnetic fields. Two initial diffuse atomic conditions have been investigated: 1) a 100 pc-diameter 17,500 solar mass spherical cloud; and 2) a 200 pc-diameter 135,000 solar mass spherical cloud. For both initial conditions, we investigated the hydrodynamic case of no magnetic field and the magnetic case of magnetic/thermal pressure equivalence (plasma beta=1). We have further investigated the evolution of the clouds in the presence of galactic shear. We have found a range of structures form with molecular cloud densities. In particular, the hydrodynamic case leads to the formation of a clumpy spherical molecular cloud, until shear is introduced, which extends the structure into a thick corrugated sheet-like cloud, eventually collapsing into a thin sheet. The magnetic case sees material trace a flow along the magnetic field lines and form an initially thick, but at late times thin, corrugated sheet-like cloud perpendicular to the magnetic field. In projection, the cloud appears remarkably filamentary. The introduction of galactic shear triggers high-density thermal condensations at earlier times, accelerating the evolution of the molecular cloud and in the magnetic case, a large inclination to the magnetic field away from the perpendicular cloud formed in non-shear case. At high resolution, we have examined the evolution of individual clumps, their collisions and their evolution towards star-forming cores. Into these structures we have introduced mechanical stellar feedback from single and multiple massive stars ranging from 15 to 120 solar masses and their consequent supernovae. Throughout, we have tracked the dynamic and thermal evolution of the molecular material, revealing information about the survival of the molecular cloud. We conclude with a demonstration that the striking structure of the Rosette Nebula can be understood in terms of these cloud formation models with supporting evidence from Planck-based magnetic field observations and Gaia-based proper motions of the stars in the central cluster.

Notes:

09:40

Disentangling the relative contribution of supernovae, stellar winds and ionising radiation on shaping the structure of galactic discs

Frantisek Dinnbier[1]

[1] University of Cologne

Massive stars play a crucial role in shaping the structure of the gas disk in spiral galaxies, mainly with supernovae (SNe), stellar winds and ionising radiation. While stellar winds and ionising radiation act throughout the whole lifetime of the massive star, SNe start acting after a delay of ~ 3 Myr. For a star cluster populated by a standard IMF, the energy carried by ionising photons and stellar winds decreases rapidly after ~ 5 Myr, while the energy in SNe stays almost constant up to ~ 35 Myr. The energy budget imparted to the interstellar medium by massive stars depends on the energy released by particular feedback process and on the coupling efficiency for the process, which depends strongly on the properties of the ambient gas.

We investigate the relative importance of these feedback mechanisms using 3D hydrodynamic simulations with the AMR code Flash. For this purpose we significantly improved the FLASH code, partly within the SILCC collaboration (www.astro.uni-koeln.de/ silcc). For example, we include a new algorithm to model sink particles, which represent star clusters, and we model the feedback from these clusters using the stellar wind models associated with the Geneva stellar evolution tracks for massive stars. Ionizing radiation from multiple star clusters is modelled with the novel radiative transfer method (TreeRay). The temperature of the HII regions is calculated self-consistently as TreeRay is coupled with the chemical network, which also includes the heating and cooling processes.

We find that ionising radiation strongly impacts the chemical state of the gas. The ionising radiation increases the mass fraction of ionised hydrogen by a factor of ~ 3, and also decreases the mass fraction of H_2 by a factor of 2 to 5 in comparison to a model without ionising radiation. With respect to stellar winds, ionising radiation is also more efficient at reducing the star formation rate since the radiation from the ionising source can travel to a significant distance immediately after the cluster formation, while the role of winds is more local. Winds are also unable to destroy more massive clouds. When acting together with supernovae, the role of winds is subordinate to ionising radiation (when comparing mass fractions of hydrogen phases and the star formation rate). We also find that the structure of the gaseous disc and the outflow rate strongly depend on a parameter for supernova implementation, which has not been discussed before; this leads to a new criterion for supernova prescription.

Notes:

Gould's Belt and beyond - II.

10:00

Jan Palouš[1], Sona Ehlerova[1], Cyril Ron[1]

[1] Astronomical Institute of the CAS, Czech Republic

With GAIA astrometric data we derive the kinematical parameters of the Gould's belt and compute formation places of its young stars and OB associations. Their kinematics shows that they have been formed within a sheet-like region about 20 Myrs ago. The Gould's belt is compared to the galactic supershell GS242-03+37, which can be explained as expanding structure more than 100 Myr old. There, the formation of star clusters started less than 40 Myr ago, when the ISM density increased due to galactic differential rotation. Similarly in the Solar vicinity, after about 50 Myr of expansion, the star formation process was triggered in a supershell wall, where the density of the ISM has been increased, creating young stars and OB associations of the Gould's belt.

Notes:

10:20

Massive star formation

Jonathan Tan[1]

[1] Chalmers University

Understanding the birth of massive stars is a long-standing challenge of modern astrophysics. Completely different accretion mechanisms of Core Accretion, Competitive Accretion and Protostellar Collisions continue to be invoked to explain observed regions of massive star formation, including the closest example in the Orion KL Nebula. Here I discuss the latest theoretical and observational results, including the modeling and search for massive prestellar cores, infall envelopes, disks and outflows. I also summarise the most current scenarios to explain the spectacular activity in Orion KL.

Notes:

SESSION 6: Multiple Systems

Revolutionizing our View of Disk and Multiple Star Formation: New Frontiers Explored by ALMA and the VLA (Invited Review) 11:10

John Tobin[1]

[1] University of Oklahoma

Protostellar disks are thought to form early in the star formation process due to conservation of angular momentum. These disks are the future sites of planet formation, but may also be the sites of binary/multiple star formation if the disk is massive enough to be gravitationally unstable. There is now growing evidence that a substantial amount of disk evolution takes place during the protostellar phase and that these embedded protostellar disks may be the true initial conditions of planet formation. Using ALMA and the VLA, we are conducting large continuum surveys (with a few molecular lines) of protostars in the nearby Perseus and Orion star forming regions (with 15-40 AU resolution) to characterize the size, masses, and physical density structure of disks throughout the protostellar phase. The multi-wavelength data enable us to assess their planet forming potential in terms of disk mass, grain growth, and radial distribution of grain sizes. At the same time, we are using these survey data to conduct the broadest characterization of protostellar multiplicity to date.

Notes:

11:50

VLTI Imaging of a High-Mass Protobinary System: Unveiling the Dynamical Processes in High-Mass Star Formation

Stefan Kraus[1], Jaques Kluskai[1], Alexander Kreplin[1], Matthew Bate[1], Tim Harries[1], Karl-Heinz Hofmann[2], Edward Hone[1], John Monnier[3], Gerd Weigelt[2], Narsireddy Anugu[1], Willem-Jan de Wit[4], Markus Wittkowski[4]

[1] University of Exeter, [2] Max-Planck-Institut für Radioastronomie, [3] University of Michigan, [4] ESO

High-mass stars exhibit a significantly higher multiplicity frequency than low-mass stars, likely refecting differences in how they formed. Theory suggests that high-mass binaries may form by the fragmentation of self-gravitational discs or by alternative scenarios such as disc-assisted capture. In this talk we report the discovery of a close (57.9 mas = 170 au) high-mass protobinary, IRAS17216-3801, where our VLTI/GRAVITY+AMBER near-infrared interferometry allows us to image the circumstellar discs around the individual components with 3 milliarcsecond resolution. We estimate the component masses to 20 and 18 $M_{\odot}$ and find that the radial intensity profiles can be reproduced with an irradiated disc model, where the inner regions are excavated of dust, likely tracing the dust sublimation region in these discs. The circumstellar discs are strongly misaligned with respect to the binary separation vector, indicating a young dynamical age of the IRAS 17216-3801 system and that tidal realignment of the discs is still ongoing.

Our GRAVITY observation also constrain the origin of spectral line emission associated with the Br-gamma hydrogen recombination line and the CO bandheads. We measure a higher Br-gamma line luminosity at the position of the secondary than at the primary. This suggests that the secondary disrupts the accretion stream on the primary and channels most of the infalling material onto the circumsecondary disc, confirming the prediction of hydrodynamic simulations. We resolved for the first time the CO line-emitting region in a massive YSO and find that this neutral gas is located between the two components, possibly tracing extended gas streams between the two discs.

The IRAS17216-3801 system is 3 times more massive and about 5 times more compact than other high-mass multiplies imaged at infrared wavelength and the first high-mass protobinary system where the circumstellar dust discs could be spatially resolved. This opens exciting new opportunities for studying star-disc interactions and the role of multiplicity in high-mass star formation.

Notes:

Pre-main-sequence Binaries and the Origin of Field Stars

12:10

Rainer Köhler[1]

[1] University of Vienna

Pre-main-sequence binary stars are one of Hans' favorite topics. The multiplicity surveys he initiated 25 years showed that all or nearly all T Tauri stars in Taurus-Auriga are part of binary or multiple systems. For a long time it was common knowledge that the binary frequency is lower in the Orion Nebula Cluster (ONC), but recent results have shown that this is only true for wide binaries. Close binaries (10-60 AU) are as common in the ONC as in Taurus. Wide binaries are destroyed by dynamical interactions in dense clusters, but close binaries are too stable and stay together for life. This raises the question: If all stars form in binaries, and close binaries survive even in dense clusters, why do we not find these binaries among the solar-type stars in our neighbourhood? One explanation is that neither Taurus nor the ONC are typical for the regions where the field stars formed. I will review what we know about binary stars in other star-forming regions and point out possible answers to the question.

Notes:

12:30

An Observational Study of Accretion Flows in Short-Period Pre-Main Sequence Binaries

Robert D. Mathieu[1] Benjamin Tofflemire[1]

[1] University of Wisconsin-Madison

Over the past thirty years, a detailed picture of star formation has emerged that highlights the significance of the interaction between a pre-main sequence star and its protoplanetary disk. This star-disk interaction has been extensively characterized in the case of single stars, revealing implications for pre-main sequence stellar evolution and planet formation. Many stars, however, form in binary or higher-order systems where orbital dynamics fundamentally alter this star-disk interaction. Orbital resonances are capable of clearing the central region of a protoplanetary disk, leaving the possibility for three stable accretion disks: a circumstellar disk around each star and a circumbinary disk. In this model, accretion onto the stars is predicted to proceed in periodic streams that form at the inner edge of the circumbinary disk, cross the dynamically cleared gap, and feed circumstellar disks or accrete directly onto the stars themselves. This pulsed-accretion paradigm predicts bursts of accretion that are periodic with the orbital period, where the duration, amplitude, location in orbital phase, and which star is preferentially fed, all depend on the orbital parameters. To test these predictions, we have conducted an intensive time-series observational campaign combining multi-color photometry and high-resolution spectroscopy. Within these data we search for periodic trends in the accretion rate and in the velocity structures of accretion-tracing emission lines. I will present results highlighting the detection of periodic enhanced accretion events in two eccentric binaries (DQ Tau and TWA 3A) and evidence for preferential mass accretion onto the TWA 3A primary. Both results are presented in the context of recent hydrodynamic simulations of binary accretion.

Notes:

SESSION 7: Clusters

Internal processes in star clusters (Invited review)

14:00

Richard Parker[1]

[1] University of Sheffield

An often-quoted introduction to journal articles is that "all stars form in clusters", but is this the case and why do we care? In this review I will discuss what fraction of stars form or spend time in clusters. I will then highlight several internal processes in clusters that significantly influence the constituent stars and may affect both planet formation and galaxy evolution. I will conclude by posing several outstanding questions that upcoming facilities could help to address.

Notes:

14:40 **Studying Star and Planet Formation with METIS on the ELT**

Bernhard Brandl[1]

[1] Leiden University

The Mid-IR ELT Imager and Spectrograph (METIS) will be one of the first three scientific instruments on ESO's 39m Extremely Large Telescope (ELT). Working in the thermal infrared with an angular resolution of a few tens of milliarcseconds, METIS will be a fantastic instrument for the study of star and planet formation. In my talk I will briefly introduce METIS and highlight its potential for discoveries in the area of star and planet formation in the next decade. Last but not least I will highlight the important role that Hans Zinnecker played toward the realization of METIS.

Notes:

Formation of clusters containing high-mass stars

15:00

Peter Schilke[1]

[1] University of Cologne

A significant fraction of stars, including our sun, have formed in clusters containing high-mass stars. Yet, the low-mass population in such clusters remain poorly studied. I will present ALMA observations of two high-mass star containing cluster regions, and discuss statistical properties of the clusters, such as the clump mass function, distances and sub-clumping.

Notes:

15:50

Dance of the Stars: An analysis of the spatial evolution in two clusters

Anne Buckner[1]

[1] University of Leeds

Despite considerable efforts, there is still little consensus on the formation of high mass stars. Forming almost exclusively in associations, groups and clusters, it is important to understand how high mass stars cluster together w.r.t their lower mass counterparts. Specifically analyses of the intensity, correlation and comparative spatial distribution of high and low mass stars in these regions is required to better distinguish between the different star formation models. As such, we have developed a novel clustering tool based on the Hopkins statistic, INDICATE (Buckner et al. 2018), to assess the clustering tendencies of stellar datasets which we have applied to catalogues of the young Carina Nebula and more evolved Upper Scorpius OB association. In this talk I discuss the comparative differences between the spatial properties of high and low mass members in the two regions and the subsequent implications for their star formation histories.

Notes:

Modelling the structure of star clusters with fractional Brownian motion

16:10

Oliver Lomax[1]

[1] Cardiff University

The degree of fractal substructure in molecular clouds can be quantified by comparing them with Fractional Brownian Motion (FBM) surfaces or volumes. These fields are self-similar over all length scales and characterised by a drift exponent H, which describes the structural roughness. Given that the structure of molecular clouds and the initial structure of star clusters are almost certainly linked, it would be advantageous to also apply this analysis to clusters. Currently, the structure of star clusters is often quantified by applying Q analysis. Q values from observed targets are interpreted by comparing them with those from artificial clusters. These are typically generated using a Box-Fractal (BF) or Radial Density Profile (RDP) model. We present a single cluster model, based on FBM, as an alternative to these models. Here, the structure is parameterised by H, and the standard deviation of the log-surface/volume density s. The FBM model is able to reproduce both centrally concentrated and substructured clusters, and is able to provide a much better match to observations than the BF model. We show that Q analysis is unable to estimate FBM parameters. Therefore, we develop and train a machine learning algorithm which can estimate values of H and s with uncertainties. This provides us with a powerful method for quantifying the structure of star clusters in terms which relate to the structure of molecular clouds. We use the algorithm to estimate the H and s for several young star clusters, some of which have no measurable BF or RDP analogue.

Notes:

16:30

Quantifying velocity structure in star forming regions

Becky Arnold[1]

[1] University of Sheffield

Several methods have been devised for quantitatively analysing the spatial structure of star forming regions e.g. the Q parameter (Cartwright and Whitworth 2004, Allison et. al 2009, S Maschberger & Clarke 2011). These methods have been valuable and well used by the field. However there are not similar methods of quantitatively analysing the velocity structure of star forming regions. With the advent of Gaia the field has access to an unprecedented quantity of high quality velocity data. In order to take full advantage of this, new methods are required to quantitatively analyse it. A new method for quantifying and investigating velocity structure in star forming regions will be presented. This method can be applied to data with any number of dimensions, and requires no assumptions about the size or morphology of the region. The method will be applied to simple simulated clusters such as expanding and collapsing Plummer spheres and the results discussed. It will then be demonstrated that the method is robust against high incompleteness and large uncertainties in simulated datasets. To conclude the method will be applied to observational data and the results interpreted.

Notes:

Friday 7th September 2018

SESSION 7: Clusters (continued)

Cluster formation in Orion: the slingshot mechanism

09:00

Amelia Stutz[1]

[1] Universidad de Concepcion

By observationally scrutinizing the nearest cluster in formation, we gain new insights into cluster formation physics. The Integral Shaped Filament (ISF) is home to the nearest significant protocluster, the Orion Nebula Cluster (ONC). Based on a high density of observables of both the gas and stars, we previously proposed the "slingshot" mechanism, requiring that the gas ISF oscillate "ejecting" stars to explain the stellar kinematics. The B-field morphology (helical) and strength, compared with the gas mass distribution, indicates that magnetic instabilities may be propagating through the cloud driving the oscillations in the ISF. In recent work we investigate the slingshot effect on the ONC structure. We show that the stellar density follows a Plummer profile with inner softening scale a=0.36 pc, while the gas follows a cylindrical power law and that the filament is gas-mass dominated everywhere. The cluster crossing time is ~ 0.5 Myr, nearly identical to the filament oscillation timescale. These results indicate that the gas density regulates the star density in the ONC. Recent results indicate that clouds enveloped in helical fields are common and that the gas PV data in the Orion ISF are consistent with a torsional wave. We suggest that star clusters that form in oscillating filaments are ultimately ejected, thereby terminating their formation phase, much like the "slingshot" for protostars. Observations of the B-field configuration in the gas are essential to interpret protocluster formation processes; I will present our current modeling of synthetic Zeeman and dust polarization observations revealing the dependence of the observables on the assumed B-field configuration. I will present our newest Gaia, radial velocity (APOGEE2S, and eventually SDSSV), and simulation work aimed at testing the "slingshot".

Notes:

09:20

Stellar Demographics in Orion

César Briceño[1]

[1] Cerro Tololo Inter-American Observatory (CTIO)

I will present a map of the young low-mass stellar populations across the Orion OB1 association spanning 180 sq.deg. This large scale effort - which has produced over 2000 confirmed members - is the result of a wide area synoptic photometric survey spanning a baseline of ~ 10 yr combined with followup spectroscopy using many facilities. The discovery of several new clusters with ages up to 10-15 Myr speak of a rich star forming history. The characterization of these optically revealed somewhat older populations provide a window into the first ten million years of the evolution of solar-like and lower mass stars and their planetary systems.

Notes:

On the nature of the Orion Belt Population sources

09:40

Karolina Kubiak[1]
[1] University of Vienna

The Orion Belt population (OBP, Kubiak et al. 2017) is a newly described young, rich, and massive population in the vicinity of the epsilon Ori supergiant. In this contribution, we present an analysis of the spectral energy distributions (SED) of all candidate sources from the OBP. We constructed SEDs for all sources in the selected field using archival data over a broad spectral range. To analyse the nature of the sources, we use SED modeling based on the new models by T. Robitaille (2017). These models can be used to determine specific parameters for a given young star, such as the properties of the central source, the size and mass of the disk, and more generally any parameter which may affect the SED. We also looked for signs of variability at both optical and infrared wavelengths among the members of the OBP. Our findings show that there are a significant amount of passive circumstellar disks within the OBP, and that more than 10% of these sources show variability at a significant level in the optical and infrared.

Notes:

10:00

Three Star Formation Relations (and Strengthened Cluster Survival) with One Single Model

Genevieve Parmentier[1]

[1] Universität Heidelberg

I shall present a semi-analytical model of star cluster formation in which, locally, the gas of cluster-forming clumps is turned into stars with a constant star formation efficiency per free-fall time. This yields a density profile for the embedded cluster steeper than that of the residual star-forming gas, in agreement with the quadratic star formation relation observed in the Solar neighbourhood. This physically-motivated set-up of cluster formation conditions yields a star formation efficiency threshold for cluster survival following instantaneous gas expulsion as low as 13%, i.e. more than a factor of two smaller than earlier predictions. Building on the same cluster formation model, I shall also discuss the pitfalls of interpreting star formation relations. Three different slopes for star formation relations (1.0, 1.5, 2.0) emerge, which stem from how star formation activity and gas content are measured, and not from variations in the physics of star formation itself.

Notes:

Making runaways: the ejection of stars from clusters due to dynamical evolution

10:20

Christina Schoettler[1]

[1] University of Sheffield

Using N-body simulations probing the early phases of star cluster evolution we investigate the mass and velocity distributions of stars that have been ejected from young clusters. Observations indicate that 'runaway stars' found at large distances from star-forming regions moving at high velocities are high-mass stars, i.e. O or B stars. Until now observational limitations have made it difficult to find any low-mass 'runaway' stars but this should change with Gaia. In our parameter space study we simulate star-forming regions with a broad set of initial conditions: subvirial vs supervirial, sub-structured vs roughly uniform, different initial densities and the presence/absence of initial binaries and stellar evolution. We investigate the effect each of these different conditions have on ejection rates and ejection velocities of high-mass and low-mass stars. Depending on initial conditions we find a large number of ejected stars at runaway velocities are in fact low-mass and that they can outnumber massive OB-runaways.

Notes:

11:10 **The Origin of Globular Clusters and their multiple populations**

Richard Wünsch[1]

[1] Astronomical Institute - CAS

It has been found by both spectroscopic and photometric observations that globular clusters (GCs) include two or more populations of stars differing in their chemical composition. Specifically, stars show variability in abundances of light chemical elements and the observed patterns can be understood by assuming that some stars have been formed out of the gas enriched by products of high-temperature hydrogen burning.

We develop a model in which the subsequent stellar populations in GCs are formed out of winds of massive stars of the first population. In dense and massive young star clusters, the hot gas originating from wind-wind collisions becomes thermally unstable and forms dense warm gaseous structures that sink into the cluster centre where they accummulate, cool further due to self shielding of the ionising radiation of stars, and form new stars.

We use a fast semi-analytic code to follow the evolution of the star cluster during the the first several Myr (before supernovae start to explode), for various combinations of parameters given by stellar evolution and stellar wind models, to identify regions of parameter space where the secondary star formation occurs. Then, we simulate the selected models using 3D radiation-hydrodynamic code. This allows us to explore the interaction of individual stellar winds, the formation of dense warm structures and secondary star formation in detail, and obtain more accurate and better justified results. Furthermore, we synthetically observe the simulations and predict profiles of the recombination lines formed in the ionised gas that would allow tests of the model by observations from radio telescopes.

Notes:

SESSION 8: The Galactic Context

Star Formation over Cosmic Time

11:30

Bruce Elmegreen[1]
[1] IBM

The average rate of star formation in the universe increases with time at first as galaxies grow in size by the accretion of cosmic gas, and then it decreases with time after a redshift of around 1.5 as a result of a depletion in the reservoir of cold gas for further accretion. This decreasing reservoir occurs because the dark matter concentrations around galaxies larger than or equal to the current mass of the Milky Way heat the remaining accretion to such a high temperature that it cannot readily fall into the star-forming regions for consumption. Only lower mass galaxies continue to accrete and form stars after this time, but their star formation rates per unit cold gas mass are low as a result of their low average densities, low metallicities, and high dark matter fractions.

Notes:

11:50

The physics encoded by the star formation relation

Diederik Kruijssen[1]

[1] Universität Heidelberg

I will present a brief review of various incarnations of the star formation relation between the gas mass (density) and the star formation rate (density) in analytical and numerical models. I will focus on its environmental dependence, its regulation by the interplay between star formation and feedback, and its dependence on the timescales governing the underlying physical processes, which in turn introduces a strong spatial scale dependence of the star formation relation. Together, these dependences may help unify the great variety of empirical manifestations of the star formation relation in observed systems.

Notes:

A systematic characterisation of the evolutionary cycling between molecular clouds, star formation, and feedback in nearby galaxies.

12:10

Mélanie Chevance[1]

[1] Universität Heidelberg

Star formation is one of the main drivers of galaxy evolution, but an understanding of this process remains elusive. This is caused by a lack of systematic observational constraints on cloud scales - previous attempts to observationally constrain the physics of star formation and feedback have necessarily been limited to few anecdotal cases in the Local Group. However, star formation in galaxies is expected to be highly dependent on the galactic structure and environment, as it results from a competition between mechanisms such as gravitational collapse, shear, spiral arm passages, cloud-cloud collisions, and feedback. A statistically representative sample of galaxies is therefore needed to probe the wide range of conditions under which stars form. For the first time, we can now carry out a systematic characterisation of the evolutionary timeline of molecular clouds and star-forming regions across the nearby Universe, enabling us to determine which of these different processes drive the cloud lifecycle as a function of the environment. I will present the results from systematically applying the statistical method of Kruijssen & Longmore (2014) and Kruijssen et al. (2018) to homogeneous ALMA + optical observations at 50 pc resolution of a large sample of star- forming disc galaxies out to 17 Mpc, obtained in the context of the PHANGS collaboration. This method exploits the spatial scale dependence of the star formation law to constrain the timeline and efficiencies for star formation and feedback on the cloud scale, across a wide variety of galactic environments. I will show that molecular clouds undergo universally fast and inefficient star formation, due to short molecular cloud lifetimes (10-20 Myr) and rapid cloud destruction by stellar feedback (1-4 Myr), but will also demonstrate that the details of the star formation and feedback processes vary considerably with the galactic environment. I will conclude by discussing the physical implications of these results, as well as some of the major open questions. These observations settle a long- standing question on the multi-scale lifecycle of gas and stars in galaxies, and open up the exciting prospect of studying cloud-scale star formation and feedback in galaxies across cosmic time.

Notes:

SESSION 9: The IMF

12:30

What sets the stellar initial mass function?

Patrick Hennebelle[1]
[1] CEA, Saclay

I will present new ideas to explain the origin of the IMF, in particular the origin of its peak and the reason of its apparent universality. These studies are based on analytical calculations and high resolution numerical simulations that include careful resolution studies and some simplified treatment of the gas thermodynamics. I will stress the essential role played by the dust opacity at high density and the so-called first Larson core, in combination with the stabilizing influence of the tidal forces.

Notes:

Outflow Structure, N-body Interactions, and the Origin of the IMF

14:00

John Bally[1]

[1] University of Colorado, Boulder

Many protostellar outflows exhibit abrupt flow orientation changes and evidence for large mass-loss rate and velocity variations. These properties can be explained by episodic accretion and accretion bursts triggered by dynamical interactions with sibling stars. Some outflows such as Orion BN/KL and DR21 were energized by powerful explosions possibly triggered by violent interactions in compact stellar groups. Most low-mass stars are born in non-hierarchical multiples which tend to re-arrange into hierarchical systems; such dynamical reconfigurations can eject component proto-stars at low-speeds. Most massive stars tend to form in high-stellar density proto-clusters where N-body dynamics occasionally eject high-velocity runaway stars. Such an event occurred in Orion a mere 550 years ago and produced an explosive outflow. N-body interactions resulting in ejection can halt stellar growth. The dynamical evolution of forming stellar systems may be more important in determining stellar masses and establishing the Initial Mass Function (IMF) than the initial conditions in the parent cloud.

Notes:

14:20 **Fragmentation and disk formation in high-mass star formation**

Henrik Beuther[1]

[1] Max Planck Institute for Astronomy

Fragmentation processes take place on almost all spatial scales, from large molecular clouds via star-forming regions and cores down to disk scales. Since the early evolutionary stages are deeply embedded, within the natal gas and dust cocoons, they can best be studied at high spatial resolution with interferometers at comparably long wavelengths. I will present fragmentation and disk formation results from the NOEMA large program CORE resolving a sample of luminous high-mass star-forming regions at ∼0.3" resolution in the mm continuum and spectral line emission. Going to even higher resolution (< 0.1"), fragmentation and disk studies with ALMA and the VLA will be presented.

Notes:

The role of molecular filaments in the origin of the IMF

14:40

Philippe André[1], V. Könyves[1], Z. Arzoumanian[2], A. Roy[1]

[1] CEA, Saclay, [2] Nagoya University

The origin of the initial mass function (IMF) is one of the most debated issues in astrophysics, and a topic that has fascinated Hans since the beginning of his career. I will discuss new insights into this problem based on a systematic census of prestellar cores and molecular filaments in nearby clouds taken as part of the Herschel Gould Belt survey. The Herschel results point to the key role of the quasi-universal filamentary structure pervading molecular clouds. They suggest that the dense cores making up the peak of the prestellar core mass function (CMF) - and indirectly the peak of the IMF - result from gravitational fragmentation of molecular filaments near the critical mass per unit length. The Salpeter power-law tail of the CMF/IMF may arise from a combination of two effects: 1) a power-law distribution of filament masses per unit length built up by accretion, and 2) the differential growth of a Kolmogorov-like initial spectrum of density fluctuations along the filaments.

Notes:

15:00 **The origin and variation of the stellar initial mass function**

Matthew Bate[1]

[1] University of Exeter

I will discuss results from numerical simulations of star cluster formation that investigate the dependence of the stellar initial mass function (IMF) on variations of the initial conditions and environment of molecular clouds. The dependencies of the IMF on cloud density, metallicity, magnetic fields, turbulence, and the level of the interstellar radiation field will all be addressed.

Notes:

The photometric and astrometric mass functions in galactic open clusters.

15:50

Nicolas Lodieu[1]
[1] IAC, Tenerife

The latest release of the UKIRT Infrared Deep Sky Survey (UKIDSS) Galactic Clusters Survey (GCS) made public near-infrared photometry in six passbands (ZYJHK1K2) and accurate proper motions measured from the multiple epochs of observations obtained as part of the GCS. The main scientific goal of the UKIDSS GCS is to investigate the shape and universality of the Initial Mass Function (Salpeter 1955) in the low-mass and substellar regimes. We analysed the photometric and astrometric data in four galactic regions which harbour the largest mean proper motions (between approximately 25 to 50 mas/yr) among the 10 regions surveyed by the GCS: Upper Scorpius (age=5 Myr, d=145 pc; Lodieu et al. 2007, 2008, 2013), Alpha Per (85 Myr, 170 pc; Lodieu et al. 2012b), the Pleiades (125 Myr, 120 pc; Lodieu et al. 2012), and Praesepe (590 Myr, 182 pc; Boudreault et al. 2012). We selected photometrically and astrometrically hundreds of cluster member candidates in these four regions in an homogeneous manner based on their positions in colour-magnitude and vector point diagrams. We have also analysed the photometric data for another two regions where the GCS-based astrometry is not available, sigma Orionis (3-5 Myr, 352 pc; Lodieu et al. 2009) and IC4665 (27 Myr, 350 pc; Lodieu et al. 2011). The cluster sequences are well-defined in colour-magnitude diagrams and the members stand out in the proper motion diagrams. We derived the luminosity and mass functions for all these regions, using the latest state-of-the-art isochrones to convert magnitudes into masses. We find that all mass functions are very similar in the 0.6-0.03 Msun mass interval and in agreement with the log-normal form of the field mass function by Chabrier (2005), pointing towards a universal mass function. This talk will focus on several key results obtained from our homogeneous study: 1) comparison of the cluster sequences with the Lyon group models 2) comparison of the mass functions in the low-mass and substellar regimes 3) comparison of the photometric binary fractions in the low-mass and brown dwarf regimes with the predictions from simulations.

Notes:

16:10

The formation of massive star clusters and their Initial Mass Function

Morten Andersen[1]

[1] Gemini Observatory

How massive star clusters form and what their Initial Mass Function (IMF) is are topics that have been close to Hans' research and have been at the heart of our understanding of star formation. Learning about their formation can teach us of how globular clusters were formed and studying their IMF is closely related to the question of whether the IMF is universal. Here we present previous and current work with Hans to study in detail the nearby young massive star clusters, in particular R136 within 30 Doradus in the Large Magellanic Cloud based on high spatial resolution observations. The derived IMF for the clusters is discussed, together with their velocity dispersion, which together will inform us if they can survive and potentially evolve into low-mass globular cluster analogues or disperse into the field star population. The differences and similarities between stars formed in massive clusters and low-mass clusters is discussed. We further discuss the discovery of several potential proto-clusters that may evolve into massive star clusters.

Notes:

The initial mass function of Population III stars: where do we stand?

16:30

Simon Glover[1]

[1] University of Heidelberg

The formation of the first stars, the so-called Population III or Pop. III stars, was a key event in the history of our Universe. These first stars had a profound effect on their surroundings in the form of radiative, mechanical and chemical feedback, and understanding the details of Pop. III star formation is crucial for understanding the initial conditions for later generations of star formation. The form of the Pop. III initial mass function (IMF) is of particular importance. Its upper mass limit and slope help determine the amount of feedback produced by a given amount of Pop. III star formation, while its lower mass limit determines whether it is possible for any Pop. III stars to survive until the present day. In this talk, I will review our current state of knowledge of the Pop. III IMF, focussing on the most important open questions and our prospects for placing observational constraints on it in the near future.

Notes:

16:50

Thirty six year of adventures in Observational Star Formation with Hans Zinnecker

Eric Becklin[1, 2]

[1] USRA/SOFIA, [2] Department of Physics and Astronomy, UCLA

In this talk I will discuss my years of scientific adventure, interaction, and collaboration with Hans. I first met Hans in 1982 while observing at the IRTF on Mauna Kea, where he had come from Germany as a graduate student to watch me, Gareth Wynn-Williams, Reinhard Genzel and Dennis Downs observe W51 at 10 and 20 microns. Our paths crossed again in 1985-86 when we were both at the ROE at the invitation of Malcolm Longair. Our joint interest in discovering Brown Dwarfs brought us together again at several meetings as well as at the Institute for Astronomy in Hawaii in the 1990s, where I followed his work with John Rayner on HH212 quite closely. In 2000, Hans invited me to his new institute in Potsdam; this was a very memorable visit for me. At the AG Potsdam meeting in 2009, which Hans helped organize, we spent a considerable amount of time discussing star formation in Orion and what we could do both with Keck and SOFIA. Hans joined the SOFIA team as the Deputy Director shortly thereafter. Together we helped inspire a Keck proper motion survey in the OMC1 and later the SOFIA FORCAST observations of the OMC1 (De Buizer etal 2012 ApJL). I will finish my talk with a discussion of Hans important role on SOFIA until he retired in 2016.

Notes:

Hans: Astronomer, Colleague and Friend

17:10

Mark McCaughrean[1], John Rayner[2]
[1] ESA/ESTEC, [2] IfA, University of Hawaii

We'll offer some words, images, and thoughts on our experiences with Hans from when we were all at the Royal Observatory Edinburgh in the 1980s until the present day. Many emails, postcards, on the spot World Cup reports, telephone calls, faxes, and other methods of communication have been involved as we've dispersed to various locations around the world, although the chances of meeting Hans in person at any given moment always seemed much higher than statistically likely. Particular scientific highlights include studies of low-mass objects in the Trapezium Cluster and other OB clusters, and the protostellar jets HH211 and HH212, the discoveries of which owe much to Hans' unique ways of working. But life with Hans has always been about so much more than science.

Notes:

Posters

		Molecular Clouds and Filaments
1A	**Daniel Seifried**	*Dust polarisation observations of simulated molecular clouds*
2A	**Marion Wienen**	*Temperature and 3D distributions of high-mass star-forming regions in the inner Galaxy*
3A	**Asmita Bhandare**	*Core and disk properties: from low- to high-mass star formation*
4A	**Jennifer Wiseman**	*The Detection of Complex Organic Molecules in the Large Magellanic Cloud with ALMA*
		Low-Mass Star Formation
1B	**Mary Barsony**	*Detection of photospheric features in the near-infrared spectrum of a Class 0 protostar*
2B	**Agnieszka Mirocha**	*Tracing UV fields around low-mass protostars with IRAM 30m*
3B	**Francesco Fontani**	*Fragmentation properties of massive protostellar clumps*
4B	**Ant Whitworth**	*A critical ram-pressure for star formation*
5B	**Pierre Marchand**	*The Hall effect in star formation*
6B	**Alejandro Santamaria-Miranda**	*The early stages of substellar formation in Lupus 1 and 3 clouds with ALMA*
7B	**Dominique Segura-Cox**	*Ringed substructure in the dust disk of the Class I protostar IRS63*
8B	**Mauricio Tapia**	*New visit to the star-forming cores in the centre of the Trifid Nebula: Herschel, Spitzer and Calar Alto views*
9B	**Christian Flores Gonzales**	*Magnetic fields of young stars with iSHELL*
10B	**Tomoyuki Kudo**	*A spatially resolved AU-scale inner disk around DM Tau*
11B	**Ken Rice**	*Directly observing self-gravitating spiral waves with ALMA*
12B	**Carlos Contreras Peña**	*Determination of the outburst rate from 1 million years monitoring of planet-forming YSOs*
		High-Mass Star Formation
1C	**Aida Ahmadi**	*Disk kinematics and stability in high-mass star formation: the link between observations and simulations*
2C	**Nathaniel Kee**	*Near-star radiative feedback and the stellar upper mass limit*
3C	**Kisetsu Tsuge**	*Massive star formation triggered by galactic tidal interaction in the LMC*
4C	**Chumpon Wichittanakom**	*Determination of accretion rates of Herbig Ae/Be stars*
5C	**Nanda Kumar**	*Ionised accretion in very high-mass stars: accelerating and rotating infall*
6C	**Paolo Persi**	*Near and Mid Infrared Observations of High Mass Young Stellar Objects*
7C	**Bringfried Stecklum**	*A Wonder of Star Formation - Watching a Massive Star Grow*
		Jets and Outflows
1D	**Anton Feeney-Johansson**	*Observing the jet of the low-mass YSO DG Tau with LOFAR*
2D	**Philip Lucas**	*YSO variability as seen with VVV/VVVX and UKIDSS*
3D	**Agata Karska**	*Deeply-embedded protostars driving outflows in the Outer Galaxy*
4D	**Anders Kölligan**	*Jets and outflows of massive protostars - From cloud collapse to jet launching and cloud dispersal*
5D	**Tom Douglas**	*Ionization, Radiation Pressure and Outflows in Massive Star Formation - A parameter survey in 2D Monte-Carlo RHD*
6D	**Thomas Stanke**	*An unbiased CO outflow survey in Orion from ALCOHOLS (APEX Large CO Heterodyne Orion Legacy Survey): first results*

		Triggering and Feedback from Massive Stars
1E	**Ken Marsh**	*RCW 120: A case of hit and run, elucidated by multi-temperature dust mapping*
		Multiple Systems
1F	**Kristin Lund**	*The formation of high-mass binary star systems*
2F	**Andrew F. Nelson**	*All about GG Tau A*
3F	**Oleg Malkov**	*Binary stars and the fundamental initial mass function*
		Clusters
1G	**Alice Perez Blanco**	*Clustering properties of Herbig Ae/Be stars*
2G	**Emma Daffern-Powell**	*Creating free-floating planets in young star forming regions*
3G	**Sergei Nayakshin**	*What separates stellar and planetary mass companion formation?*
4G	**Viktor Zivkov**	*Investigating the intermediate/low-mass PMS populations across the Magellanic System: method and first results*
5G	**Rhana Nicholson**	*Rapid destruction of protoplanetary discs in different star forming environments*
6G	**Megan Reiter**	*Cluster dynamics in the typical birthplaces of stars and planets*

1A

Dust polarisation observations of simulated molecular clouds

Daniel Seifried

We present novel simulations of molecular cloud formation in galactic disks within the SILCC collaboration (Seifried et al., 2017, MNRAS, 472, 4797). The simulations combine for the first time high spatial resolution (0.1 pc), the impact of the large-scale, galactic environment, as well as a detailed chemical network for H_2 and CO formation. The simulations thus provide a unique tool to discuss various important aspects: the chemical and dynamical evolution of molecular clouds as e.g. affected by close by supernovae, and the comparison with actual observations by means of synthetic observations. We will show that both, H_2 and CO have to be modelled on-the-fly in the simulations with sub-parsec resolution (~ 0.1 pc). This leads to a complex behaviour of the transition of atomic hydrogen to molecular hydrogen, where H_2 is present even in rather low-density gas (~ 30 cm$^{-}3$) as it is transported there from the denser regions by turbulent mixing. Furthermore, in view of the strongly increasing number of polarisation observations, we particularly focus on synthetic dust polarisation maps created with the POLARIS code, which - as the first - contains a self- consistent description of dust grain alignment efficiencies (Seifried et al., 2018, arxiv:1804.10157). We will show that observed polarisation vectors in clouds probe the real field structure with an accuracy of about 5 degree and that de-polarisation on clouds scales results from strongly tangled field lines rather than inefficient grain alignment. Furthermore, in light of the recently observed change in the orientation of magnetic fields with respect to dense structures(e.g. Soler et al., 2017, A&A, 603, A64), we will discuss whether the observability of this change of orientation depends e.g. on the magnetic field strength or the direction under which the clouds are seen.

2A

Temperature and 3D distribution of high-mass star-forming regions in the inner Galaxy

Marion Wienen

The initial conditions of molecular clumps, in which high-mass stars form, are still largely unknown. In particular, progress requires to study objects in the early evolutionary stages, before ultracompact HII regions have formed and the newly formed high-mass (proto)stars emerge in the infrared. These phases are best searched for and detected by (sub)millimeter dust continuum and high-density molecular tracers. ATLASGAL, the first unbiased dust continuum survey of the whole inner Galactic plane at 870 micron, provides a global view of cold dust and star formation at submillimeter wavelengths. Although the earliest phases of high-mass star formation can be identified by the dust continuum, directly probing the material from which the stars form, there is still a lack of physical properties. Molecular line observations are a powerful tool that can be used to estimate distances and gas properties, which are key to determining the properties of star-forming regions. We therefore followed up 1200 dust clumps identified by ATLASGAL in the (1-1) to (3-3) inversion transitions of the high-density tracer ammonia, which is an excellent probe of massive clumps with low temperatures. I will show that the analysis of the so far largest ammonia sample of massive star-forming sources reveals a clear trend of increasing rotational temperatures and line widths found from the earliest to the later evolutionary stages. We identified about 700 molecular cloud complexes consisting of about 3500 ATLASGAL sources based on spatial and kinematic information. An unbiased 3D view of these massive star-forming sites within our Galaxy will be presented. I will briefly outline how we used HI data to solve the distance ambiguity for complexes found within the solar circle. I will also show a correlation that was found between the number of ATLASGAL sources as a function of galactocentric radius and the position of the spiral arms revealing a link between them. In particular, the assignment of distances allowed us to estimate clump masses and sizes, to evaluate their stability via their virial mass and to study the star formation activity within numerous molecular clouds.

3A

Core and disk properties: from low- to high-mass star formation

A. Bhandare, R. Kuiper, Th. Henning, C. Fendt, G.D. Marleau

Stars are formed by the gravitational collapse of dense, gaseous and dusty cores within magnetized molecular clouds. Understanding the complexity of the numerous physical processes involved in the very early stages of star formation requires detailed thermodynamical modeling in terms of radiation transport and phase transitions. For this we use a realistic gas equation of state via a density and temperature-dependent adiabatic index and mean molecular weight to model the phase transitions. We perform molecular core collapse simulations including the stages of first and second hydrostatic core formation in spherical symmetry using a gray treatment of radiative transfer coupled with hydrodynamics as detailed in Bhandare et al. 2018 (subm.). We investigate the properties of Larson's first and second cores and expand these collapse studies, for the first time to span a wide range of initial cloud masses from 0.5 Msun to 100 Msun. Thereby, we reveal a strong dependence of a variety of first core properties on the initial cloud mass. We find that the first core radius and mass increase from the low-mass to the intermediate-mass regime and decrease from the intermediate-mass to the high-mass regime. Most importantly, the lifetime of first cores strongly decreases towards the intermediate- and high-mass regime. In this talk, I will demonstrate that low-mass protostars evolve through two distinct stages of formation of the first and second hydrostatic cores. In contrast, in the high-mass star formation regime, the collapsing cloud cores rapidly evolve through the first collapse phase and essentially immediately form Larson's second cores. Furthermore, based on our new 2D radiation-magneto-hydrodynamics simulations, I will discuss the impact of different cloud properties on the formation of early disks around these objects.

4A

The Detection of Complex Organic Molecules in the Large Magellanic Cloud with ALMA

Marta Sewilo, Remy Indebetouw, Steven B. Charnley, Sarolta Zahorecz, Joana M. Oliveira, Jacco Th. van Loon, Jacob L. Ward, C.-H. Rosie Chen, **Jennifer Wiseman**, Yasuo Fukui, Akiko Kawamura, Margaret Meixner, Toshikazu Onishi, Peter Schilke

Using the Atacama Large Millimeter/submillimeter Array (ALMA) 1.3 mm observations, we detected complex organic molecules (COMs) dimethyl ether (CH_3OCH_3) and methyl formate (CH_3OCHO), together with their parent species methanol (CH_3OH), in two locations in the prominent star-forming region N113 in the Large Magellanic Cloud (LMC). The initial results were reported in Sewilo et al. (2018, ApJ, 853L, 19). This is the first time the interstellar COMs containing more than six atoms have been detected outside the Galaxy and in a low-metallicity environment. Rotational temperatures ($T_{\rm rot} \sim 130$ K) and total column densities ($N_{\rm rot} \sim 10^{16}$ cm^{-2}) have been calculated for two 1.3 mm continuum sources with COMs detection (N113 A1 and B3) based on multiple transitions of CH_3OH. The physical and chemical properties of these sources, and the association with the H_2O and OH maser emission, indicate that they are hot cores. Prior to this study, only one hot core had been identified in the LMC, but no COMs were detected (Shimonishi et al. 2016). The fractional abundances of COMs in N113 scaled by a factor of 2.5 to account for the lower metallicity in the LMC are comparable to those found at the lower end of the range in Galactic hot cores.

Interstellar COMs may be a chemical link to the prebiotic molecules that were involved in the processes leading to the origin of life (Ehrenfreund & Charnley 2000). The presence of COMs in the low-metallicity LMC indicates that a possibility of the emergence of life as it happened on Earth is open in low-metallicity systems in the early universe.

1B

Detection of Photospheric Features in the Near-Infrared Spectrum of a Class 0 Protostar

Mary Barsony

We present a near-infrared K-band Keck spectrum of S68N, a Class 0 protostar in the Serpens molecular cloud. The spectrum shows photospheric absorption features and emission lines. We model the absorption component as a stellar photosphere plus circumstellar emission with wavelength-dependent extinction. A Markov Chain Monte Carlo analysis shows that the most likely model parameters are consistent with a low-temperature, low-gravity photosphere, with significant extinction, but only modest continuum veiling. Its 3260K effective temperature is similar to that of older, more evolved pre-main-sequence stars, but its surface gravity of log g 2.4 cm s-2, is approximately 1 dex lower. This implies that the radius of this protostar is a factor of 3 times larger than that of million year old T-Tauri stars. The modest veiling is consistent with a circumstellar disk with near-IR emission similar to somewhat more evolved Class I protostars. Along with the high extinction, this suggests that most of the circumstellar material resides in a cold envelope, as expected for a Class 0 protostar. This is the first detection and analysis of a Class 0 photospheric absorption spectrum.

2B

Tracing UV fields around low-mass protostars with IRAM 30m

Agnieszka Mirocha

A new-born protostar forms in dense cores deep inside molecular cloud. Due to high extinction in the optical range, observations at long-wavelengths are needed. In particular, submillimeter spectra include rotational lines of key molecules which are useful probes of physics and chemistry around low-mass protostars. Here we analyse molecular emission from the Serpens Main star forming regions using IRAM 30 m single dish telescope. HCN, CN, and CS emission is modelled using radiative transfer code RADEX to determine the gas physical conditions and molecular abundances. The presence of UV radiation in these regions is identified and compared to models of dense envelopes irradiated by UV photons. Thus, we gain new understandings of chemical and physical processes around low-mass protostars.

3B

Fragmentation properties of massive protocluster gas clumps

Francesco Fontani

Fragmentation of massive dense molecular clouds is the starting point in the formation of rich clusters and massive stars. Theory and numerical simulations indicate that the population of the fragments (number, mass, diameter, separation) resulting from the gravitational collapse of such clumps is probably regulated by the balance between the magnetic field and the other competitors of self-gravity, in particular turbulence and protostellar feedback. We have observed 11 massive, dense, and young star-forming clumps with the Atacama Large Millimeter Array (ALMA) in the thermal dust continuum emission at 1 mm with an angular resolution of 0.25 arcseconds with the aim of determining their population of fragments. We find fragments on sub-arcsecond scales in 8 out of the 11 sources. The ALMA images indicate two different fragmentation modes: a dominant fragment surrounded by companions with much smaller mass and size and many (8 or more) fragments with a gradual change in masses and sizes. On average, the largest number of fragments is found towards the warmer and more massive clumps. Also the warmer clumps tend to form fragments with larger mass and size. To understand the role of the different physical parameters to regulate the final population of the fragments, we have simulated the collapse of a massive clump of 100 and 300 solar masses having different magnetic support. The simulations indicate that: (1) fragmentation is inhibited when the initial turbulence is low independent of the other physical parameters. (2) a filamentary distribution of the fragments is favoured in a highly magnetised clump.

4B

A critical ram-pressure for star formation

Ant Whitworth

In turbulent star formation, molecular-line emission is very effective at cooling the gas immediately behind shocks, but is very ineffective at cooling any pre-stellar cores that then try to condense out of the resulting cold dense gas. In contrast, dust cooling is very effective in cooling this cold dense gas – thereby enabling it to condense out dynamically and fragment, producing low-mass stars – but only if the shock ram-pressure exceeds a critical value, $P_{\rm MIN}$. For a gas-to-dust ratio of 100, $P_{\rm MIN} \sim 4 \times 10^{-11}\,{\rm dyne}$ (corresponding to $P_{\rm MIN}/k_{\rm B} \sim 3 \times 10^5\,{\rm cm}^{-3}\,{\rm K}$). This condition translates into a minimum column-density for low-mass star formation, $\Sigma_{\rm MIN} \sim 100\,{\rm M}_\odot\,{\rm pc}^{-2}$, a minimum extinction, $A_{\rm V.MIN} \sim 9\,{\rm mag}$, a maximum characteristic mass, $M_{\rm MAX}(T) \sim {\rm M}_\odot\,(T/10\,{\rm K})^2$, and a maximum characteristic length-scale, $L_{\rm MAX}(T) \sim 0.1\,{\rm pc}\,(T/10\,{\rm K})$, where T is the gas-kinetic temperature; only $M_{\rm MAX}$ and $L_{\rm MAX}$ depend on T.

5B

The Hall effect in star formation

Pierre Marchand

The regulation of angular momentum is a key issue in star formation, and this has been a major concern in numerical simulations. Recently, several studies have shown that non-ideal MHD was the best candidate to solve the magnetic braking catastrophe and the magnetic flux problem. However, these studies often omit the Hall Effect, one of the three decoupling processes of non-ideal MHD, while it may have a sizeable influence on a collapsing core. I will first explain in what extent the Hall Effect can act on the distribution of angular momentum during the early phases of star formation, then I will present the complexity of its numerical treatment. Especially, conserving the angular momentum is a difficult task.

6B

The early stages at substellar formation in Lupus 1 and 3 clouds with ALMA

Alejandro Santamaria-Miranda

The formation of brown dwarfs is still under debate. While the latest discoveries point towards a scaled-down version of the star formation process, other models, such as embryo ejection or stellar disk fragmentation, may not be discarded. Here we present our latest ALMA cycle 3 (band 6) continuum observations of Lupus 1 and 3 star formation regions based on previous ASTE/AzTEC observations and a set of previously known class II substellar objects from the literature. We classify these sources using the spectral energy distribution obtained from archival data. We report nine new sources that could be classified as either prestellar cores or deeply embedded protostar candidates, three new class I objects, and one new class II. Additionally we also detected six previously known class II systems, some of them in the boundary between brown dwars and very low mass stars. We probe the turbulent fragmentation and core collapse formation scenarios for the prestellar cores or deeply embedded protostar candidates and we compare the dust masses of the disk for the class II objects with previous studies. Future observations will help us to unveil their true nature.

7B

Ringed Substructure in the Dust Disk of Class I Protostar IRS 63

Dominique Segura-Cox

Circumstellar disks are a fundamental component of the low-mass star formation process yet their properties are only beginning to be revealed in detail during the earliest Class 0 and Class I phases due to the dense gas and dust envelopes present at early times. The release of ALMA Science Verification Data of the older Class II protostar HL Tau revealed dark gaps and dust rings in disk sparking the question: how early can disk substructures possible signs of CO freeze-out or the beginning of planet formation at early times be found in young disks? We have detected dust rings in the disk of Class I protostar IRS 63 via 1.3 mm ALMA continuum observations with 7 AU resolution- making IRS 63 the youngest protostellar disk with evidence of multiple ringed substructures to-date. The presence of these substructures at such an early time indicates that dust rings may be a ubiquitous feature across many stages of protostellar evolution. Here we present the properties of the ringed dust substructures of the disk of IRS 63- consider formation mechanisms of the rings, and discuss future paths of study for disk substructure in the earliest phases of star formation.

8B

New visit to the star-forming cores in the centre of the Trifid nebula: Herschel, Spitzer and Calar Alto views.

M. Tapia, P. Persi, C. Román-Zúñiga, D. Elia, F. Giovannelli, L.Sabau-Graziati

A new detailed infrared (IR) study of eight star-forming dense condensations (TCs) in M 20, the Trifid nebula, will be presented. We aim at determining the physical properties of the dust in such globules and establish the presence and properties of their embedded protostellar and/or young stellar population. For this we analysed new Herschel far-IR and Calar Alto near-IR images of the region, combined with Spitzer/IRAC archival observations. We confirm the presence of several young stellar objects (YSOs), most with mid-IR colours of Class II sources in all but one of the observed cores. Five TCs are dominated in the far-IR by Class I sources with bolometric luminosities between 100 and 500 Lo. We discovered a counterjet to HH 399 jet and its protostellar engine inside the photodissociation region TC2, as well as another bipolar outflow system- signposted by symmetric H_2 emission knots, embedded in TC3. We also obtained a revised value for the distance to M 20 of 2.0 +- 0.1 kpc.

9B

Magnetic fields of Young Stars with iSHELL

Christian Flores Gonzalez

Magnetic fields (B) are thought to be one of the fundamental drivers in the evolution of pre-main sequence stars. They regulate the angular momentum of the system, prevent the star from reaching disrupting velocities, collimate winds and outflows into jets, and channel material from the disk inner edge onto the star along magnetic field lines. Despite their undeniable importance, only a small number of young stars have measured B field strengths. Fewer than 40 Class II sources and only one Class I source have reported B field strengths in the literature, which represent only a small fraction of young stars. In this work, we present a method to measure precise B field strengths, effective temperatures, surface gravities, and projected rotational velocities of young stars using iSHELL, the new high-resolution NIR immersion grating spectrograph on IRTF. We coupled the MOOGStokes radiative transfer code with the MARCS stellar atmospheric models to synthesize stellar spectra. We modified oscillator strengths from the VALD3 atomic line database by comparing our synthetic spectra with recent iSHELL K-band solar observations. We also characterized iSHELLs spectral response to account for its effect on the synthetic spectrum. We assessed our synthetic spectrum uncertainties by modeling 12 well studied main-sequence and post-main sequence stars with known literature parameters. We estimated a 1 sigma effective temperature uncertainty of 75 K and a gravity uncertainty of 0.18 dex. Additionally, we derived new metallicities, projected rotational velocities, and microturbulent velocities for 10 of these stars. We applied this technique to a well studied Class II source (BP Tau) and a Class I source (V347 Aur) to measure their B field strengths, effective temperatures, gravities, and projected rotational velocities.

10B

A Spatially Resolved AU-scale Inner Disk around DM Tau

Tomoyuki Kudo

We present ALMA observations of the dust continuum emission at 1.3 mm and 12CO line emission of the transitional disk around DM Tau. The DM Tau's disk has been thought to possess a dust-free inner cavity, based on the absence of near-infrared excess on its spectral energy distribution (SED). Previous observations were, however, unable to reveal the cavity; instead, a dust ring 20 au in radius was seen. The superb angular resolution achieved in the new ALMA observations, 4331 mas, allows us to discover an au-scale inner dust ring, confirming previous SED modeling results. The location of the inner ring is comparable to that of the main asteroid belt in the solar system. As a disk with an "exo-asteroid belt", the DM Tau system offers valuable clues to our understanding of disk evolution and planet formation in the terrestrial planet forming region.

11B

Directly observing self-gravitating spiral waves with ALMA

Ken Rice, Cassandra Hall, Duncan Forgan, Tim Harries

The advent of the Atacama Large Millimeter/submillimeter Array (ALMA) has allowed us to probe down to the midplane of protostellar discs with unprecedented resolution. A surprising result of these observations is that a significant fraction of those systems that have been observed show signs of structure in their discs; rings and spirals may be the norm, rather than the exception. What causes such structures is still not clear. One possibility is interactions between the disc and a planetary, sub-stellar, or stellar companion. In the case of spirals, though, an alternative is the gravitational instability. The gravitational instability, however, requires that the disc be massive, and cold. Hence, this can only really operate in very young systems, and may play a key role in mass accretion during the earliest stages of star formation. Here we present some preliminary results from an analysis that aims to constrain the conditions under which we may be able to directly observe self-gravitating spiral density waves in very young protostellar systems. If the accretion rate is above $\sim 10^{-7}$ $M_{\odot}$/yr, grand design two-armed spirals dominate, and have amplitudes comparable to the background surface density (i.e., $\delta\Sigma/\Sigma \sim 0.5 - 1$). For accretion rates below $\sim 10^{-7}$ $M_{\odot}$/yr, the spirals are quite weak, and tend to be dominated by higher-m modes ($m > 2$). Therefore, observing self-gravitating spirals is easiest in systems that are strongly accreting (i.e., $\dot{M} > 10^{-7}$ $M_{\odot}$/yr). However, if some grain growth has already occurred, gas drag can lead to the solid density being enhanced in the spirals waves, making it possible to detect such waves even in systems that are accretion at below 10^{-7} $M_{\odot}$/yr. This would, however, require being able to resolve the more filamentary spiral structures. Such solid enhancements would also influence the wavelength across which spirals could be observed even in strongly accreting systems. Directly observing spirals density waves in very young protostellar systems can therefore not only provide information as to how a self-gravitating phase influences the growth of the central star, it will also provide clues as to the role that this early stage of star formation plays in the growth of planet-building material.

12B

Determination of the outburst rate from 1 million years monitoring of planet-forming YSOs

Carlos Contreras Peña

We have determined the rate of large accretion events in class II young stellar objects (YSOs) by comparing the all-sky digitized photographic plate surveys provided by SuperCOSMOS with the latest data release from Gaia (DR2). The long mean baseline of 55 years along with a large sample of class II YSOs (~ 15000) allows us to study approximately 1 million YSO years. Our search for high-amplitude variable stars yields 112 objects with $\Delta R \geq 1$ mag, most of which are found at amplitudes between 1 and 3 mag with a peak at around 2 mag. The light curves of most YSOs in this group show irregular variability or long-lasting fading events. We show that variability in this group is best explained by hot spots due to accretion, representing extreme cases of this type of variability, or by variable extinction. The number of variable YSOs drops dramatically at $\Delta R \geq 3$ mag and they seem to represent a different population, being dominated by objects that can be classified as showing longterm outbursts. We find 9 objects that are consistent with undergoing large, long lasting accretion events, 4 of them previously unknown. This yields and outburst rate of 10^{-5} outbursts per star per year, with a 90% confidence interval [6×10^{-6}, 2×10^{-5}] outbursts per star per year. This represents the first robust determination of the outburst rate in class II YSOs and shows that YSOs in their planet-forming stage do in fact undergo large accretion events, and with timescales of $\sim 100,000$ years. We will discuss the effects that these events can have on planet formation and evolution during the class II stage of young stellar evolution.

1C

Disk Kinematics and Stability in High-Mass Star Formation: The link between observations and simulation

Aida Ahmadi

In recent years, we have been able to resolve rotating structures surrounding the most luminous cores and find differentially rotating disk-like structures, making a case for high-mass star formation being a scaled-up version of low-mass star formation in this context. However, the properties of these disk-like structures have yet to be comprehensively characterised. Using the IRAM NOrthern Extended Millimeter Array (NOEMA) and the IRAM 30-m telescope- the CORE survey has obtained high-resolution (0.35"- 700 AU at 2 kpc) observations of 20 well-known highly luminous star-forming regions in the 1.37 mm wavelength regime in both line and dust continuum emission. I will present our findings on the disk-scale kinematics of the sample with a focus on the W3(H2O) star-forming region. We find that different fragmentation processes can contribute to the final stellar mass distribution within a single region, with core fragmentation on large scales and disk fragmentation on smaller spatial scales. With temperature information obtained from radiative transfer modelling of the dense-gas tracer CH3CN, we are able to study the Toomre stability of these structures and predict their fate in the disk fragmentation scenario. Furthermore, we use radiation hydrodynamic simulations to test the applied methods and investigate the limits of what current observations can unveil.

2C

Near Star Radiative Feedback and the Stellar Upper Mass Limit

Nathaniel Dylan Kee

Studies of the formation of high-mass stars must take into account the role of feedback from the forming sta's extreme luminosity (10^3–10^6 $L_\odot$) and mass loss rate (10^{-10}–10^{-5} $M_\odot$/yr). However, these simulations generally track the infalling gas only to a distance of a few au from the star. To be accreted, material must contend with these feedback processes all the way down to the stellar surface. In this region, the scattering of UV photons off the spectral lines of ionized metal species can generate accelerations tens of times stronger than local gravity, providing a difficult barrier for accretion to overcome.

This talk presents the first simulations of such feedback on these final miles of accretion, and discusses its role in setting the upper mass limit of stars.

3C

Massive star formation triggered by galactic tidal interaction in the LMC

K. Tsuge, H. Sano, K. Tachihara, Y. Fukui

Revealing the mechanism of massive cluster formation is one of the most important issues of astronomy. To better understand the massive cluster formation, we analyzed the HI data of the whole Large Magellanic Cloud (LMC) taken with ATCA & Parkes (Kim et al. 2001). It has been known that the HI gas consists of two velocity components (L, and D-components) (Luks & Rohlfs 1992), and we have decomposed the spectra by Gaussian fittings and investigate their spatial distributions. As a result, we suggest that they are colliding toward the HI Ridge at the southeastern end of the LMC where young massive cluster R136 and $\sim$ 400 O/WR stars are being formed (Fukui et al. 2017). The collision is evidenced by the bridge features connecting the two HI components in the velocity space, and complementary spatial distributions between the L, and D-components. We also investigate the correlation between the Planck / IRAS data of dust optical depth and the HI intensity, and found evidence for the low-metallicity gas possibly originated from the Small Magellanic Cloud (SMC) flowing into the LMC by the tidal interaction. We propose a hypothesis that the inflow of the low-metallicity gas from the SMC and the collision with the LMC gas triggered the formation of R136 and the surrounding high-mass stars. Fujimoto & Noguchi (1990) advocated that the last tidal interaction between the LMC and the SMC about 0.2 Gyr ago induced gas dragging and collision of the L, and D-components. This model was later confirmed by numerical simulations (Bekki & Chiba 2007). We suggest that the molecular cloud of 10^6 solar mass embedded in the dense HI gas was formed at the shock-compressed interface between the colliding L, and D-components, leading to the formation of R136. In addition to R136, we investigated HI clouds around LHA 120-N 44 (N44), which is the second most active massive star forming regions and suggest the same triggering scenario by the colliding HI gas (Tsuge et al. 2018 submitted). Furthermore, we analyzed HI data toward other 18 star forming regions and found the similar properties for all regions. From these results, we discuss that 80 % of the massive star formation in the LMC was presumably triggered by tidal interaction between the LMC and SMC.

4C

Determination of Accretion Rates of Herbig Ae/Be Stars

Chumpon Wichittanakom

Herbig Ae/Be stars (HAeBes) are intermediate pre-main-sequence stars which masses range from about 2-10 Msun. They play an important role in understanding massive star formation. Because they bridge the gap between low-mass stars whose formation is well understood and high-mass stars whose formation is still unclear. This work presents a spectroscopic study of the stellar properties and mass accretion rates of 30 HAeBes in the same approach. The stellar parameters of temperature, reddening, distance, radius, luminosity, mass, age and surface gravity are determined using a combination of Intermediate Dispersion Spectrograph (IDS) spectra, stellar atmospheric models, previous photometry, the Gaia DR2 parallaxes, theoretical pre-main-sequence evolutionary tracks and isochrones. The observed Halpha profiles are measured and corrected with intrinsic absorption profiles. The continuum flux density at the central wavelength of the profile is obtained from spectral energy distribution of a model atmosphere to calculate line flux and line luminosity. The mass accretion rates can be determined from the power-law relationship between accretion luminosity and line luminosity. The mass accretion rate increases with stellar mass. It also indicates a difference between HAes and HBes. This suggests that a different process of accretion may occur around 2-4 Msun.

5C

Ionized accretion in very high mass stars: Accelerating and rotating infall

Nanda Kumar

In assembling the highest mass stars, the role of ionized accretion has been long hypothesized. Using a suite of adaptive optics VLT/SINFONI and ALMA observations we have uncovered accelerating and rotating infall motions in the H29-alpha radio recombination lines towards a O-stellar pair, located in the G333.6-0.2 region, arguably the most luminous nearby star forming region of the Milkyway. It is a thin flattened high-density ionized gas structure forming the hub of radiation blown bipolar bubble. The hub is at the convegence center of multiple molecular filaments.

6C

Near and Mid Infrared Observations of High Mass Young Stellar Objects.

Paolo Persi

We have observed in the near and mid infrared a sample of high mass young stellar objects in order to understand the mechanisms of formation of these sources. In particular we have searched for the H2 shocks. From their spectral energy distributions obtained combining observations at different wavelengths, we have obtained the physical parameters such as the mass accretion rate, the disk mass and the luminosity of these sources.

7C

A Wonder of Star Formation - Watching a Massive Star Grow

Bringfried Stecklum

In autumn 2015 the flaring of methanol masers in S255IR signalled an event that turned out to be a disc-mediated accretion outburst from the most massive young stellar object known to date. Our investigation of the NIRS3 event rests on data ranging from the meter-wave to X-ray spectral domains. For the first time, the full diversity of accretion burst-induced phenomena could be witnessed. The findings will be briefly summarised, with emphasis on the latest results.

1D

Observing the Jet of the Low-Mass YSO DG Tau A with LOFAR

Anton Feeney-Johansson

Using the Low-Frequency Array (LOFAR)- the low-mass young stellar object (YSO) DG Tau A was detected at 152 MHz- only the second time that a YSO has been observed with LOFAR. Non-thermal synchrotron emission is detected in both the jet and the counter-jet.- the first time that such emission has been observed towards a YSO at such low frequencies. The synchrotron emission is almost certainly due to particles in the jet being accelerated to relativistic velocities in shocks- by diffusive shock acceleration- and is characterized by a negative spectral index. Previous observations at higher frequencies show a negative spectral index- as expected. However- in this observation a turnover is detected in the spectrum of the bow shock in the jet- making this the first time that such a turnover has been detected in non-thermal emission towards a YSO. We examine likely causes for the turnover and note that- interestingly- the counter-jet does not show such a turnover with the flux increasing in accordance with its spectral index. These results show that LOFAR could be very useful for studying non-thermal emission from YSOs and determining the physical properties of their jets.

2D

YSO Variability as seen with VVV/VVVX and UKIDSS

Philip Lucas

VVV and UKIDSS have revealed a large population of highly variable YSOs across the Galactic plane, with ($1 < \Delta K < 5$ mag). Most of the "eruptions" appear to be examples of episodic accretion, on a timescale of years, as opposed to variable extinction. However, the light curves are diverse: the VVV sample includes long period variables and slowly rising variables as well as more sudden eruptions. These differences suggest that more than 1 mechanism may be causing instabilities in YSO discs. We present the most recent results, including the UKIDSS sample in nearby SFRs, a newly enlarged VVV sample with $\Delta K > 3$ mag and variability in pre-selected massive YSO samples. We also briefly summarise the available and upcoming VVV/VVVX survey products, including the IR proper motions where Gaia cannot see and PSF photometry.

3D

Deeply-embedded protostars driving outflows in the Outer Galaxy

A. Karska, M. Sewilo, B. A. Whitney, B. H. K. Yung, W. Fischer, D. Elia, M. Meade, B. Babler, T. P. Robitaille, R. Indebetouw, M. Boyer, J. Wisemann, D. Padgett, R. Szczerba, N. Siódmiak, B. Deka-Szymankiewicz, D. Itrich

We present a preliminary analysis of the 34 square degrees region (L220) in the Outer Galaxy with longitudes from l=215 deg to l=227 deg and the full latitude extent of the Spitzer GLIMPSE360 survey (b from -2.3 deg to 0.5 deg) at these longitudes. L220 is home to a very young star-forming complex that is the most concentrated source of outflows in the GLIMPSE360 survey. Our goal is to uncover and characterize a completely unstudied population of intermediate- and low-mass Young Stellar Objects (YSOs) in L220. We are performing a census of YSOs using color-color and color-magnitude selection criteria, and modeling of their spectral energy distributions (SEDs), combined with the visual inspection of multiwavelength images. The L220 region samples three different spiral arms and inter-arm regions. This provides an opportunity to study both very active and more quiescent areas. With the kinematic information from the CO data, we will be able to associate YSO candidates with spiral arms and study star formation properties as a function of Galactocentric radius (thus metallicity). Our analysis is mostly based on the Spitzer GLIMPSE360 3.6 and 4.5 microns data, combined with the near-IR photometry from 2MASS, and WISE 12 microns data. The results of our study on L220 are a valuable complement to the recent Herschel Hi-GAL study of this region. In this preliminary analysis, we concentrate on the CMa OB1 association, which encompasses the area harboring clusters of YSOs with outflows.

4D

Jets and outflows of massive protostars - From cloud collapse to jet launching and cloud dispersal

Anders Kölligan

We model the long-term evolution of magnetized, massive prestellar cores from their initial gravitational collapse, through the formation of circumstellar disks, the launching of fast collimated jets and wide angle winds, to the final cloud dispersal. Our simulations resolve a high dynamic range in space and time and enable us to analyze the physical mechanisms of the jet launching process and disk formation in detail and give novel insights into these processes and their dependence on simulational parameters. In a comprehensive convergence study, we investigate computational conditions necessary to resolve (pseudo-) disk formation, jet launching processes and analyze possible caveats. We explore the magneto-hydrodynamic processes of the collapse of massive prestellar cores in detail, including an analysis of the forces involved and their temporal evolution for up to two free-fall times. We compare these results with established theoretical models for stationary jets and analyze how their principles work during such a collapse simulation. Thereby, we show a comprehensive evolutionary picture of the collapse of a massive prestellar core with a detailed analysis of the physical processes involved and our high-resolution simulations can resolve a magneto-centrifugal and a magnetic pressure driven outflow separately. Our convergence study reveals several caveats concerning the resolution requirements for different physical processes.

5D

Ionization, Radiation Pressure and Outflows in Massive Star Formation - A parameter survey in 2D Monte-Carlo RHD

Tom Douglas

We present 2D cylindrically symmetric numerical simulations of the formation of massive stars from 100 $M_{\odot}$ spherical cores using Monte Carlo-based radiation hydrodynamics (RHD). We survey the parameter space in rotation rate of the core, radial density profile, subgrid outflow prescription used and physics included. The central stars form via spherical and then disc accretion and produce fast, radiation-driven and ionised bipolar cavities. We find that the efficiency of the accretion is reduced in the presence of a strong mechanical outflow and photoionisation. The evolution the accretion rate on to the protostar is found to be consistent with both observational constraints and previous simulations of massive star formation in 3D. In the fiducial model accretion proceeds at 0.5-3 $\times$ 10^{-3} $\mathrm{M}_{\odot}$ for 20 k Yr before it terminates and the circumstellar disc is removed when the central star has reached a mass $\sim 27 M_{\odot}$. Disc masses (defined as material bound with sufficient rotational energy to support itself against gravity) as a fraction of stellar mass increase steadily and reach values of $\sim$ 1Synthetic observations of the models in the radio, mm and infra-red for both continuum and line emission are produced and compared to observations. These observations are then used in order to reconstruct stellar and disc parameters as would be inferred from real observations.

6D

An unbiased CO outflow survey in Orion from ALCOHOLS (APEX Large CO Heterodyne Orion Legacy Survey): first results

Thomas Stanke

The APEX Large CO Heterodyne Orion Legacy Survey (ALCOHOLS), performed with the SuperCam 64 pixel heterodyne array on APEX in the CO(3-2) line covers 2.3 square degrees (complementary in area coverage to the JCMT Goulds Belt legacy survey part in Orion), with the main aim to obtain a full account of the high-velocity CO gas in protostellar outflows over an entire giant molecular cloud. I will present first result on a sample of 31 molecular outflows extracted from the survey, which stand out as all being at the same distance, observed with a uniform data set, and covering all flows to their full extent.

1E

RCW 120: A case of hit and run, elucidated by multi-temperature dust mapping

Ken Marsh, Ant Whitworth, Olly Lomax

We present a new interpretation of the observed geometry of the star-forming bubble surrounding the RCW 120 HII region, based on resolution-enhanced images of warm dust at multiple temperatures and opacity index values. These were made using Herschel data with our recently-developed Bayesian estimation procedure, PPMAP. The projected geometry of the bubble boundary is found to change dramatically over the temperature range 8-50 K, from a ragged, clumpy appearance at low temperatures to one which is accurately circular at higher temperatures except for a previously-reported opening in the north. From a comparison with Spitzer data, we infer that the $\sim 30\,\mathrm{K}$ dust resides in the photodissociation region whose geometry, based on its observed centre-to-edge contrast, is consistent with that of a spherical shell. The displacement of the O8 ionising star from the geometric centre of the shell argues against the conventional interpretation in terms of a Stroemgren sphere. However, given the measured proper motion of the star, the observations are consistent with a model in which the star originated from a cloud-cloud collision, with initial ionisation occurring 30,000 years ago. The bubble that we see today is then the fossilised remnant of the original expansion of the HII region, following which the O star has been fleeing its formation site, ploughing through the HII region at supersonic speed.

1F

The formation of high-mass binary star systems

Kristin Lund

We develop a semi-analytic model to investigate how accretion onto wide low-mass binary stars can result in a close high-mass binary system. The key ingredient is to allow mass accretion while limiting the gain in angular momentum. We envision this process as being regulated by an external magnetic field during infall. Molecular clouds are made to collapse spherically with material either accreting onto the stars or settling in a disk. Our aim is to determine what initial conditions are needed for the resulting binary to be both massive and close. Whether material accretes, and what happens to the binary separation as a result, depends on the relative size of its specific angular momentum, compared to the specific angular momentum of the binary. When we add a magnetic field we are introducing a torque to the system which is capable of stripping the molecular cloud of some of its angular momentum, and consequently easing the formation of high-mass binaries. Our results suggest that clouds in excess of 1000 M and radii of 0.5 pc or larger, can easily form binary systems with masses in excess of 25 M and separations of order 10 R with magnetic fields of order 100 G (mass-to-flux ratios of order 5).

2F

All about GG Tau A

Andrew F. Nelson

GG Tau is one of the best studied forming multiple star systems in the sky, with a plethora of data available at all wavelengths. Here, I describe a set of numerical models using SPH to simulate the evolution of GG Tau A. These models are able to reproduce many of the observed features of the system and to attribute their presence to physical causes. I will discuss predictions made by previous theoretical studies, in which the binary was predicted to be in either a 32 AU orbit near apoapse, or a 62 AU orbit near periapse, with a near degeneracy between the quality of either fit. I will show that the degeneracy can be broken in favor of the 62 AU orbit. Finally, I will discuss some predictions for the future behavior of the system and potential observations that could be of value.

3F

Binary stars and the fundamental initial mass function

Oleg Yu. Malkov

We have carried out Monte Carlo simulations by which we generated populations of binaries combining random pairing (and other scenarios of binary star formation) with different IMF for primary components. We involve different initial parameters and distributions over orbital parameters, and account for stellar evolution. Selection effects are considered as well. We show how various pairing scenarios (including random pairing) combined with Salpeter or Kroupa IMF may describe the distributions of catalogued samples of observed visual binaries, corrected for selection effects, if the binarity rate of main-sequence field stars is close to 100% (including invisible stellar mass companions).

1G

Clustering properties of Herbig Ae/Be stars

Alice Perez Blanco

It is a well-established result that many stars do not form in isolation; young stars are usually found to be members of clusters. But little is known or understood about the origin of the clusters. In particular, evidence that pre-main sequence stars of intermediate (2-10Msun) and higher masses are found in clusters has been found in several studies at optical and infrared wavelengths (e.g. Waters & Waelkens 1998, and their references). Additionally, there has been an increased interest in the study of intermediate-mass stars in the past ten years. Here we study Herbig Ae/Be stars which are optically visible pre-main sequence stars of intermediate-mass. They represent the most massive objects to experience an optically visible pre-main sequence phase, bridging the gap between low- and high-mass stars. Building on the ideas from Testi et al. (1997, 1998, 1999) who analyzed the occurrence of young stellar clusters around Herbig Ae/Be stars from near-infrared images, we are investigating the presence of clusters around previously known and newly discovered intermediate-mass pre-main sequence Herbig Ae/Be stars with the detailed astrometric data offered by Gaia. This will enable us to determine the position of the Herbig Ae/Be stars in the HR diagram and allow us to detect and confirm the presence of the clusters around them. In the poster, we outline the results obtained with Gaia DR1 through the algorithm we developed for the detection and analysis of the clusters and clustering properties of the Herbig Ae/Be stars and present preliminary results for Gaia DR2.

2G

Creating Free-Floating Planets in Young Star Forming Regions

Emma Daffern-Powell

The majority of stars form in clustered environments where close encounters with passing stars can affect planetary systems through a variety of mechanisms, including the disruption of orbits and the exchange of planets between systems. In particular, it is possible for a planet to be ejected as a result of encounters, where it may either remain as a free-floating planet or be captured by another system. In this way, encounters contribute to the observed population of free-floating planets, as well as the diverse range of orbital properties observed in exoplanets.

I am using N-body simulations of star-forming regions to investigate the creation and capture of free-floating planets, as well as their corresponding orbital properties. Our simulations cover a range of initial conditions for clustered environments, including densities and dynamical states, and we use observations of exoplanets to inform our choice of the initial distributions of planetary orbits. In this talk I will present results which show that the fraction of free-floating planets created is a strong function of the initial properties of the cluster, and that planets can be captured onto extremely wide orbits that are consistent with some extreme exoplanets - many of which are good candidates for direct imaging surveys.

3G

What separates stellar and planetary mass companion formation?

Sergei Nayakshin

Recent data suggests that there is much more affinity between formation of planet/brown dwarf mass companions and stellar mass secondaries than usually assumed. In particular, the frequency of detection of gas giant planets more massive than 4 Jupiter masses and brown dwarfs circling the host star at separations less than ~ 1 AU is not correlated with the host star metallicity (Santos et al 2017, Troup et al 2017). This is reminiscent of properties of stellar mass binaries (Raghavan et al 2010) and is contrary to the results for lower mass planets (Fischer & Valenti 2005). This implies that massive planets and brown dwarfs on short period orbits formed by gravitational disc fragmentation at ~ 100 AU followed by disc migration all the way down to < 1 AU.

In this poster I will present 3D numerical simulations of gas-grain dynamics of self-gravitating massive class 0/class I discs to try and shed some light on the unexpected affinity between stellar and sub-stellar companions to stars.

4G

Investigating intermediate/low-mass PMS populations across the Magellanic System: Method and first results

Viktor Zivkov

Near-infrared photometry from the VISTA Survey of the Magellanic Clouds (VMC, 5sigma limits: Y=22.3mag, J=21.9mag, Ks=20.6mag) allows us to census recent star formation across the entire Magellanic System, sampling a range of environmental conditions (e.g. sub-solar metallicity). We developed an automated method using colour-magnitude diagram analysis to disentangle young stars from the field and to identify PMS stars down to ~ 1 Msun. Based on synthetic cluster tests covering a wide range of cluster masses and ages, our method detects PMS populations up to an age of ~ 10 Myr for cluster masses > 1000 Msun. Our sensitivity increases considerably for younger ages: for < 2 Myr we can identify PMS populations in clusters down to 250Msun. I will present our method, give a summary of the main outcomes of our extensive synthetic cluster tests, and show results from applying the method to a ~ 1.5 square degree pilot field in the LMC. Overall, we find a lower limit of ~ 2200 PMS candidates. The young stars show an inhomogeneous and clustered spatial distribution: large star forming complexes consist of multiple high PMS density peaks. The PMS populations are mostly located along ridges and filaments with bright far-infrared emission, following the dust distribution. Where young (< 10 Myr) high mass stars are present, we observe a correlation between the dust emission and the number of young stars. We also find evidence for a very young PMS population (~ 1 Myr), likely associated with the large emission nebula N148, and co-spatial with significant CO emission. The number of detected PMS stars in this newly discovered population is similar to that of the N51 complex (which contains the well studied OB associations LH60 and LH63), however the population near N148 contains no young massive stars. Our method clearly shows the significant potential of the VMC survey to identify and characterise the intermediate/low-mass young stellar population on the scale of the whole the Magellanic System, something that had not been possible so far.

5G

Rapid destruction of protoplanetary discs in different star forming environments

Rhana Nicholson

The environment in which stars are born affects the formation and evolution of their protoplanetary discs. From close encounters with neighbouring stars stripping material, to massive stars emitting far ultra violet (FUV) and extreme ultra violet (EUV) radiation that causes disc dispersal, cluster environments play a strong role. Observations of star forming regions show sub-structured clusters with no primordial mass segregation. Evolution of cluster environments eventually causes this substructure to be wiped out over time, creating spatially smooth clusters that are centrally concentrated. Previous studies about the effects of external photoevaporation on protoplanetary discs have mainly concentrated on initially smooth, centrally concentrated cluster where stars are primordially mass segregated, recreating environments that are similar to the present day conditions of the ONC. We investigate how the effects of photoevaporation varies in clusters based on their initial conditions, concentrating on the initial substructure, density and virial ratio. We shall present these results at this conference.

6G

Cluster dynamics in the typical birthplaces of stars and planets

Megan Reiter

Stellar feedback permeates high-mass star-forming regions, fundamentally shaping the cradle of star and planet formation. Photoionizing radiation from high-mass stars may destroy the disks around still-forming low-mass stars. At the same time, Solar System meteorites suggest that at least one supernova seeded the proto-Solar nebula with radioactive isotopes that play a central role in the evolution of terrestrial planet embryos. Whether feedback helps or hinders planet formation depends critically on the morphology and dynamics of the natal cluster (e.g., Lichtenberg et al. 2016). This is because star formation is a fundamentally dynamic process where the movement of individual objects (1 pc in 1 Myr for a velocity 1 km/s) results in significant changes in a given stars environment during formation (e.g., Kuznetsova et al. 2015). Here, we present first results from a new survey to measure radial velocities of low-mass stars in a truly high-mass star forming region, the Carina Nebula. Together with proper motions from GAIA, this provides the first comprehensive study of the 3D kinematics in a truly high-mass star-forming region, allowing us to:

- constrain the time that low-mass stars spend subject to disk-destroying radiation from nearby high-mass stars and the fraction polluted with supernova ejecta;
- measure kinematic substructure and model its evolution to test high-mass star-formation theories; and
- model the dynamical evolution of the cluster to determine how typical Sun-like birth conditions are.