Program
Posters
Abstracts
Focus Groups
SAC/LOC/Sponsors

Program

Sun

SUNDAY 26 June 2016	
17:00	*Start of the registration*
17:20	*Arrival of the airport shuttle bus*
19:45	*Dinner*
21:00	*Euro2016 soccer live*

Mon

MONDAY 27 June 2016			
08:00-09:00	*Breakfast*		
09:00-09:15	15+0	**Organizers**	Welcome and Introduction
09:15-09:45	30+0	**Hans Zinnecker**	The legacy of Francesco Palla (1954-2016)
	Chair	**Diederik Kruijssen**	*Galactic Star Formation and Molecular Clouds*
09:45-10:25	30+10	**Eve Ostriker**	Galactic-Scale Star Formation
10:25-10:50	*Coffee break*		
10:50-11:30	30+10	**Enrique Vazquez-Semadeni**	Molecular Clouds: a collapsing paradigm
11:30-12:00	30	DISCUSSION (Moderator: **Andi Burkert**)	
12:00-12:30	30	POSTER SESSION	
12:30-14:00	*Lunch*		
	Chair	**Richard Crutcher**	*Turbulence and Filaments*
14:00-14:40	30+10	**Jouni Kainulainen**	The Rise and Fall(?) of Turbulence
14:40-15:20	30+10	**Rowan Smith**	Beads on a string: Filaments and star formation
15:20-15:50	20+10	**Philippe Andre**	The role of interstellar filaments in regulating the star formation efficiency in dense gas
15:50-16:20	*Coffee break*		
16:20-16:50	20+10	**Doris Arzoumanian**	The observed properties of a filament system in Orion B
16:50-17:20	20+10	**Alvaro Hacar**	Filament kinematics: from low- to high-mass star-forming clouds
17:20-17:50	20+10	**Phil Myers**	Lumpy filaments in a turbulent medium
17:50-18:30	40	DISCUSSION (Moderator: **Vera Koenyves**)	
18:30	*Dinner*		
21:00	*Euro2016 soccer live*		

Tue

TUESDAY 28 June 2016			
08:00-09:00	*Breakfast*		
	Chair	**Eugenio Schisano**	*Cluster Formation*
09:00-09:40	30+10	**Charles Lada**	Embedded Clusters and Star Formation
09:40-10:10	20+10	**Matthew Bate**	Combining radiative transfer and a diffuse ISM model to simulate star cluster formation
10:10-10:40	20+10	**Claudia Cyganowski**	Simultaneous low- and high-mass star formation in massive protoclusters: ALMA results
10:40-11:10	*Coffee break*		
11:10-11:40	20+10	**Helen Kirk**	Dense Core Mass Segregation in Orion A and B
11:40-12:30	50	DISCUSSION (Moderator: **Joao Alves**)	
12:30-14:00	*Lunch*		

Program

Tue

		Chair **Vera Koenyves**	*Cores, Collapse and Fragmentation*
14:00-14:40	30+10	**Rachel Friesen**	Cores and Collapse
14:40-15:10	20+10	**Sibylle Anderl**	CALYPSO studies of the CO snow line in young low-mass protostars
15:10-15:30	*Coffee break*		
15:30-16:00	20+10	**Michael Dunham**	MASSES: An SMA Large-Scale Program Surveying Protostars to Reveal How Stars Gain their Mass
16:00-16:30	20+10	**Juergen Steinacker**	Modeling the core-filament system L1689B: what to learn from spherical cylinders and the filament mass function
16:30-17:10	30+10	**Qizhou Zhang**	Fragmentation and protocluster formation
17:10-17:40	30	DISCUSSION (Moderator: **Henrik Beuther**)	
17:40-18:30	50	POSTER SESSION	
18:30	*Dinner*		

Wed

WEDNESDAY 29 June 2016			
08:00-09:00	*Breakfast*		
		Chair **Harold Yorke**	*From Low- to High-Mass Star Formation*
09:00-09:40	30+10	**Thomas Henning**	From low- to high-mass star formation
09:40-10:10	20+10	**Eric Keto**	Comparing Accretion in Low and High Mass Star Formation
10:10-10:40	*Coffee break*		
10:40-11:20	30+10	**Peter Schilke**	High-MassStar Formation
11:20-11:50	20+10	**Katharine Johnston**	A Keplerian-like disk around the forming O-type star AFGL 4176
11:50-12:30	40	DISCUSSION (Moderator: **Hendrik Linz**)	
12:30-14:00	*Lunch*		
		Chair **Hans Zinnecker**	*Magnetic Fields*
14:00-14:40	30+10	**Martin Houde**	Measurements of Magnetic Fields in the Early Phase of Star Formation
14:40-15:10	20+10	**Richard Crutcher**	The Next Major Step in Zeeman Studies of Magnetic Fields in Star Formation Regions
15:10-15:40	*Coffee break*		
15:40-16:10	20+10	**Chris McKee**	The Role of Magnetic Fields in Star Formation
16:10-16:40	20+10	**Juan-Diego Soler**	The magnetic field morphology in nearby molecular clouds
16:40-17:20	40	DISCUSSION (Moderator: **Fumitaka Nakamura**)	
17:20-18:30	30+40	**Tim de Zeeuw** ESO Director General	ESO's program: status and prospects
18:30	*Dinner*		

Program

Thu

			T H U R S D A Y 30 June 2016
08:00-09:00	*Breakfast*		
	Chair **Richard Klein**		*Disk Formation*
09:00-09:40	30+10	**John Tobin**	Revealing the Origins of Disks: Delving into Innermost Regions of Protostellar Systems
09:40-10:10	20+10	**Felipe Alves**	An ALMA view of B59: from collapsing cores to pre-Kuiper Belt structures
10:10-10:40	*Coffee break*		
10:40-11:10	20+10	**Henrik Beuther**	Fragmentation and massive disk formation
11:10-11:50	40	DISCUSSION (Moderator: **Mike Dunham**)	
	Chair **Rolf Kuiper**		*Stellar Feedback*
11:50-12:30	30+10	**Hector Arce**	Stellar Feedback During the Early Stages of Star Formation
12:30-14:00	*Lunch*		
14:00-14:30	20+10	**Joao Alves**	The Ophiuchus complex and the role of feedback
14:30-15:00	20+10	**Adam Ginsburg**	The effects and extent of feedback on dense prestellar gas near proto-OB stars
15:00-15:30	30	DISCUSSION (Moderator: **Patrick Hennebelle**)	
15:30-15:50	*Coffee break*		
15:50-17:10	80	Richard Klein Andi Burkert Hans Zinnecker	Focus Group 1: (Chair: **Joseph Mottram**) The Formation of Star Clusters: Theory Confronts Observation
		Chat Hull Baobab Liu	Focus Group 2: (Chair: **Hendrik Linz**) Magnetic fields and polarization in young stellar objects: interpreting the next generation of observations and simulations
17:10-17:20	*Changing rooms*		
17:20-18:40	80	Rolf Kuiper Patrick Hennebelle Diederik Kruijssen Anna McLeod	Focus Group 3: (Chair: **Sibylle Anderl**) The multi-scale nature and physical mechanisms of stellar feedback
		Matthias Gridschneder Seamus Clarke Eugenio Schisano Ke Wang	Focus Group 4: (Chair: **Juergen Steinacker**) Filaments, their formation, properties and evolution
18:40	*Bavarian Evening*		
21:00	*Euro2016 soccer live*		

Fri

			F R I D A Y 1 July 2016
08:00-09:00	*Breakfast*		
	Chair **Nami Sakai**		*Chemistry*
09:00-09:40	30+10	**Ewine van Dishoeck**	Astrochemistry: the past and next 10 years
09:40-10:10	20+10	**Aurore Bacmann**	The spatial distribution of complex organic molecules in prestellar cores
10:10-10:40	*Coffee break*		
10:40-11:00	15+5	**Poster Contest Winner**	Poster Contest Winner Presentation
11:00-11:50	50	FINAL DISCUSSION (Moderator: **Matthew Bate**)	
11:50-12:30	40+0	**Harold Yorke**	Conference summary
12:30-14:00	*Lunch*		
14:00	*Departure of the airport shuttle bus*		

Posters

Posters will be displayed in the foyer of the meeting room during the entire meeting

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P01	**Aida Ahmadi**	Disk kinematics in the high-mass star forming regions W3(H2O) and W3(OH)
P02	**Andreas Burkert**	ISM dynamics and star formation in gas-rich galactic disks
P03	**Che-Yu Chen**	Formation of Magnetized Pre-Stellar Cores in Turbulent Clouds
P04	**Hope Chen**	High-Dimensional Identification and Statistics of Star-Forming Substructures in GMCs
P05	**Roxana-Adela Chira**	Dust Radiative Transfer in Star-Forming Filaments
P06	**Seamus Clarke**	Pertubation growth in accreting filaments
P07	**Emily Drabek-Maunder**	Understanding the influence of outflows on Gould Belt clouds
P08	**Jan Forbrich**	The Orion Radio All-Stars: new perspectives in stellar radio astronomy
P10	**Matthias Gonzalez**	Simulations of massive magnetized dense core collapse
P11	**Matthias Gritschneder**	Filament fragmentation at arbitrary length scales
P12	**Stefan Heigl**	Non-linear dense core formation in filaments by gravitational fragmentation
P13	**Patrick Hennebelle**	Feedback: the impact of supernovae remnants and HII regions
P14	**Chat Hull**	Formation of proto-multiple stellar systems in a magnetized, fragmenting filament
P16	**Richard Klein**	Multi-Physics, Multi-scale Simulations of Star Formation in Filamentary Infrared Dark Molecular Clouds: A Hierarchical Approach from Large Scale Magnetized Clouds to Stellar Clusters
P17	**Vera Koenyves**	A census and properties of dense cores and filaments in the Aquila and Orion B cloud complexes
P18	**Diederik Kruijssen**	The physics setting the molecular cloud lifetime
P19	**Rolf Kuiper**	Multi-Physics of Feedback in Massive Star Formation
P20	**Hendrik Linz**	Painting better pictures of early massive SF in the aftermath of Herschel
P21	**Baobab Liu**	Circumstellar disks of the most vigorously accreting young stars
P22	**Anna McLeod**	Observing massive star formation feedback: what optical and near-infrared integral field spectroscopy can do for you
P23	**Joseph Mottram**	The role of local environment in the formation of massive stars
P24	**Fumitaka Nakamura**	Are Prestellar Cores Magnetically-Subcritical?
P25	**Yoko Oya**	Infalling-Rotating Envelopes and Disks around Low-Mass Protostars
P26	**Jaime Pineda**	On the fragmentation of filaments and the origin of wide separation multiples
P27	**Adele Plunkett**	Uncovering episodic outflows and their feedback in protostellar clusters
P28	**Andy Pon**	Observational Evidence for Turbulence Dissipating in Giant Molecular Clouds
P29	**Julia Roman-Duval**	Distribution and mass of diffuse and dense CO gas in the Milky Way
P30	**Michael Rugel**	Physical properties of transition regions between atomic and molecular gas in the interstellar medium with the THOR survey
P31	**Nami Sakai**	Chemical Diversity in Low-Mass Star-Forming Cores and It's Future toward the Protoplanetary Disks
P32	**Eugenio Schisano**	Wispy features in the Milky Way: a global view of filamentary structures in the Galactic Plane
P33	**Aurora Sicilia-Aguilar**	Multi-episodic and triggered star formation in IC 1396 A: A Herschel surprise and IRAM followup of a newly formed object
P34	**Ke Wang**	Automated identification of large-scale velocity-coherent filaments in the Galaxy
P35	**Harold Yorke**	Star Formation in the Early Universe
P36	**Hans Zinnecker**	Star formation in collapsing proto-clusters

Focus Groups

All focus groups will be on Thursday afternoon (30 June 2016).
The rooms will be announced on Thursday morning.

Focus Group 1 (*Chair:* Joseph Mottram)

The formation of star clusters: theory confronts observations

15:50-16:00 Richard Klein
Multi-Physics, Multi-scale Simulations of Star Formation in Filamentary Infrared Dark Molecular Clouds: A Hierarchical Approach from Large Scale Magnetized Clouds to Stellar Clusters

16:00-16:10 Andi Burkert
ISM dynamics and star formation in gas-rich galactic disks

16:10-16:20 Hans Zinnecker
Star formation in collapsing proto-clusters

16:20-17:10 *Discussion*

Focus Group 2 (*Chair:* Hendrik Linz)

Magnetic fields and polarization in young stellar objects: interpreting the next generation of observations and simulations

15:50-16:05 Chat Hull
The first polarization results from ALMA: filaments, disks, dust polarization, and scattering

16:05-16:20 Baobab Liu
Towards the era of multi-frequency polarization observations

16:20-17:10 *Discussion*

Focus Group 3 (*Chair:* Sibylle Anderl)

The multi-scale nature and physical mechanisms of stellar feedback

17:20-17:30 Rolf Kuiper
Multi-Physics of Feedback in Massive Star Formation

17:30-17:40 Patrick Hennebelle
Feedback: the impact of supernovae remnants and HII regions

17:40-17:50 Diederik Kruijssen
The physics setting the molecular cloud lifetime

17:50-18:00 Anna McLeod
Observing massive star formation feedback: what optical and near-infrared integral field spectroscopy can do for you

18:00-18:40 *Discussion*

Focus Group 4 (*Chair:* Juergen Steinacker)

Filaments, their formation, properties and evolution

17:20-17:30 Matthias Gritschneder
The Formation and Fragmentation of Filaments

17:30-17:40 Seamus Clarke
Pertubation growth in accreting filaments

17:40-17:50 Eugenio Schisano
Wispy features in the Milky Way: a gloal view of filamentary structures in the Galactic Plane

17:50-18:00 Ke Wang
The Largest Filaments in the Milky Way

18:00-18:40 *Discussion*

Committees

Scientific Advisory Comittee

Yuri Aikawa, Japan
Joao Alves, Austria
Aurore Bacmann, France
Matthew Bate, GB
Henrik Beuther, Germany
Alyssa Goodman, USA
Thomas Henning, Germany
Fabian Heitsch, USA
Anaelle Maury, France
Fumitaka Nakamura, Japan
Eve Ostriker, USA,
Nicola Schneider, France
Jürgen Steinacker, France

Local Organizing Committee

Jürgen Steinacker
Henrik Beuther
Hendrik Linz
Aida Ahmadi
Sibylle Anderl
Enrique Garcia-Garcia
Michael Rugel

Sponsors

Max-Planck-Institut für Astronomie, Heidelberg, Germany
Ernst-Rudolf-Schloessmann-Stiftung, Germany
DFG Priority Program 1573 "Physics of the Interstellar Medium"

R E V I E W S

Hector Arce   Y   U, Y   , US :
Stellar Feedback on Stellar Formation

Ewine van Dishoeck   U L   , L   , NL :
Learning about Early Star Formation from Chemical Processes

Rachel Friesen   U T   , T   , CA :
Understanding Cores and their Collapse

Thomas Henning   MPIA, H   , DE :
From Low- to High-mass Early-Phase Star Formation

Martin Houde   U W   O   , L   , CA :
The Role of Magnetic Fields in the Early Phase of Star Formation

Jouni Kainulainen   MPIA, H   , DE :
Just adding Complexity or Controling Agent? Turbulence in the Initial Phase of Star Formation.

Eve Ostriker   P   U, P   , US :
The Galactic View

Peter Schilke   U C   , C   , DE :
High-Mass Star Formation

Rowan Smith   U M   , M   , GB :
Early-Phase Star Formation in Filaments

John Tobin   U L   , L   , NL :
Revealing the Origins of Disks: Delving into Innermost Regions of Protostellar Systems

Enrique Vazquez-Semadeni   UNAM, M   C   , MX :
Molecular Clouds

Harold Yorke   JPL / C   T   , P   , US :
Conference Summary

Qizhou Zhang   C   H   , C   , US :
The Role of Fragmentation

Hans Zinnecker   DSI, S   , DE :
The Legacy of Francesco Palla

T A L K S

An ALMA view of B59: from collapsing cores to pre-Kuiper Belt structures

Felipe Alves
MPE, G , DE

ALMA has opened a new perspective on the observations of young stellar objects and protoplanetary disks. In this contribution, we report ALMA observations of B59 at 30 AU spatial resolution. Our data reveal substructures in Class 0/I/II objects with impressive detail. While the molecular line data is consistent with kinematical variations across distinct physical scales, the polarization show ordered magnetic fields in circumstellar disks.

Collaborators:

- G. Franco, UFMG, BR
- J. Girart, ICE, ES
- W. Vlemmings, OSO, SE
- D. Galli, INAF, IT
- A. Hacar, U. Vienna, AT
- H. Wiesemeyer, MPIfR, DE
- P. Caselli, MPE, DE

Suggested Session:

Disk Formation

The Ophiuchus complex and the role of feedback

Joao Alves
U V , V , AT

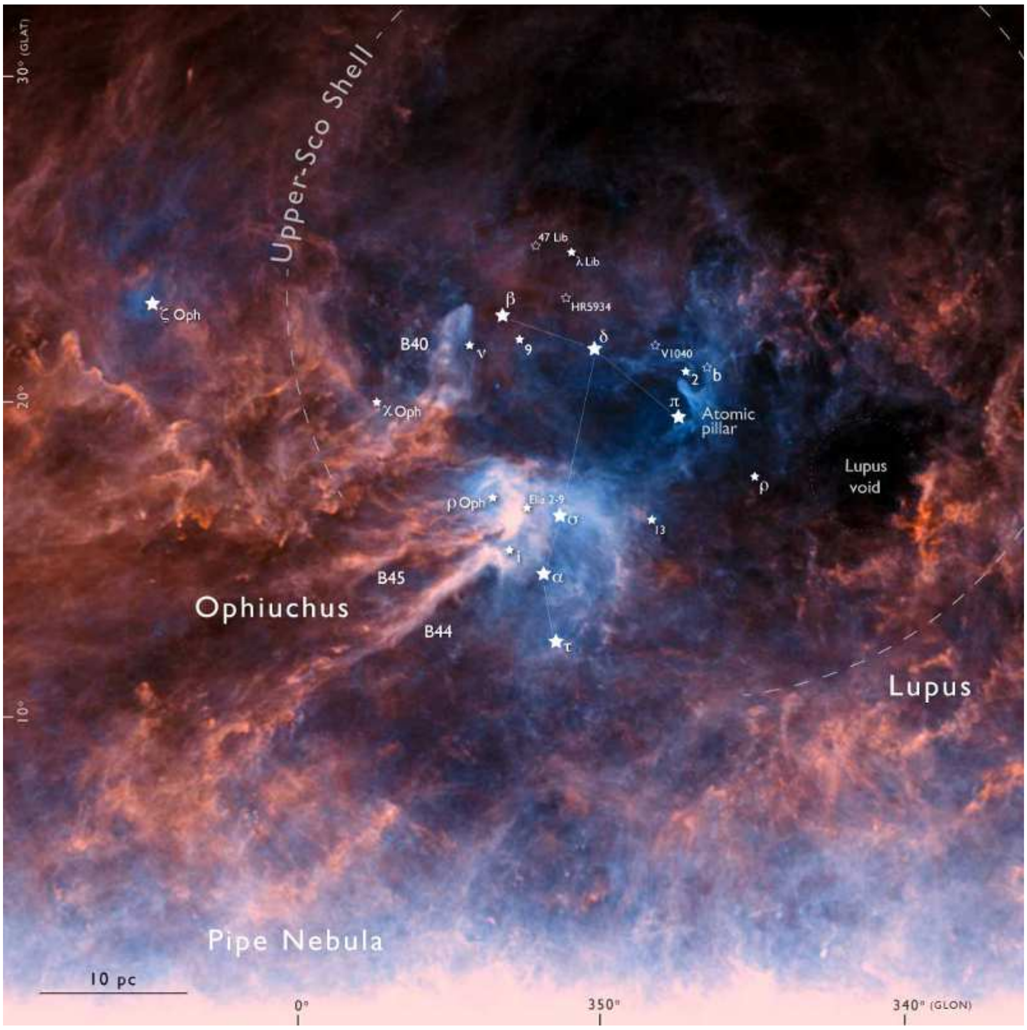
The last ten years of ISM and star formation research have brought imense progress driven largely by the availability of sensitive infrared and sub-millimeter telescopes both on the ground and in space. The new facilities have given us much needed resolution and sensitivity, but as important, they have given us the wide-field view, or the context, allowing for important missing connections to be revealed. In this talk we focus on the closest star forming complex to Earth, Ophiuchus, and present optical-depth and temperature maps of the entire complex using Planck, Herschel, and 2MASS/Nicest extinction data. The maps have a column density dynamic range covering three orders of magnitude (from 6×10^{20} cm^{-2} to 6×10^{23} cm^{-2}), and a spatial dynamic range covering four orders of magnitude (from about 2000 AU to 100 pc). This dynamic range, a dream only ten years ago, allow us to make surprising findings, e.g., all protostars in Ophiuchus (97%) can be readily associated with a particular source of feedback in the region and that the Ophiuchus filaments (up to 20 pc long) are also formed by the feedback from massive stars, in contrast with the currently accepted filament formation scenario of colliding flows orthogonal to the filament axis. We find a wide variety of filament widths and astonishingly beautiful cloud complexity down to the sub-parsec scale. Finally, we do **not** find N-PDFs to be log-normal, but power-laws, and argue that we as a community have been having an abusive relationship with 1D metrics. And that we should change.

Collaborators:

- M. Lombardi, IT
- C. Lada, US
- H. Bouy, ES
- A. Hacar, AT
- S. Meingast, AT
- J. Forbrich, AT
- J. Ascenso, PT

Suggested Session:

Stellar Feedback



Caption: Color composite of the Ophiuchus, Pipe Nebula, and Lupus cloud complexes (blue: extrapolated Planck 250 μm, green: Planck 350 μm, red: Planck 500 μm). Star symbols represent the position of massive ionizing stars (B3 or earlier) while symbol size represent relative brightness. Most of these stars have associated Hα extended emission while only the two fainter objects are not associated with WISE extended emission. Most if not all the stars are interacting with the molecular cloud complex and constitute the main source of heating (the bluer regions) and pressure in the complex.

CALYPSO studies of the CO snow line in young low-mass protostars

Sibylle Anderl
IPAG, G , FR

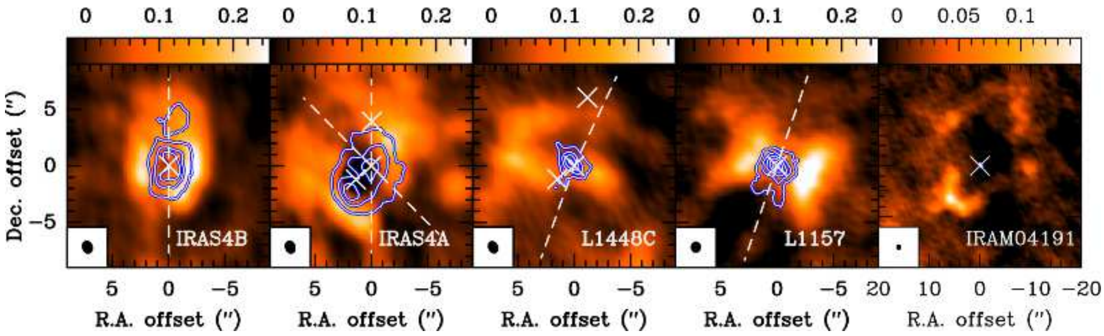
"Snow lines", marking regions where abundant volatiles freeze out onto the surface of dust grains, play an important role for planet growth and bulk composition in protoplanetary disks. They can already be observed in the envelopes of the much younger, low-mass Class 0 protostars that are still in their early phase of heavy accretion. The information on the sublimation regions of different kinds of ices can be used to understand the chemistry of the envelope, its temperature and density structure, and may even hint at the history of the accretion process. This information is crucial in order to get the full picture of the early protostellar collapse and the subsequent evolution of young protostars. As part of the CALYPSO IRAM Large Program, we have obtained observations of $C^{18}O$, N_2H^+ and CH_3OH towards nearby Class 0 protostars with the IRAM Plateau de Bure interferometer at sub-arcsecond resolution. For four of these sources we have modeled the emission using a chemical code coupled with a radiative transfer module. In these four sources, which are NGC 1333-IRAS4A, NGC 1333-IRAS4B, L1157, and L1448C, we observe an anti-correlation of $C^{18}O$ and N_2H^+ with N_2H^+ forming a ring (perturbed by the outflow) around the centrally peaked $C^{18}O$ emission. This emission morphology, which is due to N_2H^+ being chemically destroyed by CO, reveals the CO and N2 ice sublimation regions in these protostellar envelopes with unprecedented resolution. We also observe compact methanol emission towards three of the sources. Based on our chemical model and assuming temperature and density profiles from the literature, we find that for all four sources the CO snow line appears further inwards than expected from the binding energy of pure CO ices (~ 855 K). The emission regions of models and observations match for a higher value of the CO binding energy of 1200 K. With this value, the radius of the CO snow line corresponds to a dust temperature of ~ 24 K in our models. The binding energy for N_2 ices is modeled at 1000 K, also higher than for pure N2 ices. Furthermore, we find very low CO abundances inside the snow lines in our sources, about an order of magnitude lower than the total CO abundance observed in the gas on large scales in molecular clouds before depletion sets in. The high CO binding energy may hint at CO being frozen out in a polar ice environment like amorphous water ice or in non-polar CO_2-rich ice. The low CO abundances are comparable to values found in protoplanetary disks, which may indicate an evolutionary scenario where these low values are already established in the protostellar phase. While the emission morphology of these four sources can be well reproduced with temperature profiles based on their recent luminosities, this is not the case for the source IRAM 04191, which is surrounded by an extended N_2H^+ ring. In this talk, I will also discuss whether this emission morphology may trace a past accretion burst. Furthermore, an outlook will be given on the planned extension of these studies towards exploring the dynamics of the inner envelope.

Collaborators:

- S. Maret, IPAG, Fr
- and the CALYPSO team

Suggested Session:

Cores and Collapse



Caption : Emission of N_2H^+ and $C^{18}O$ towards IRAS4B, IRAS4A, L1448C, L1157, and IRAM04191. Colour background: N_2H^+ (1-0) emission integrated over all seven hyperfine components. The wedges show the N_2H^+ intensity scale in Jy/beam*km/s. The contours show integrated emission of $C^{18}O$ (2-1) in steps of 6 sigma (IRAS4A and 4B) or 3 sigma (L1448C and L1157), starting at 3 sigma, with sigma=(0.032, 0.027, 0.028, 0.030, 0.016) Jy/beam*km/s for IRAS4B, IRAS4A, L1448C, L1157, and IRAM04191 respectively. The filled ellipses in the lower left corner of the panels indicate the synthesized beam sizes of the N_2H^+ observations at 3 mm. The dashed white lines illustrate the small-scale outflow directions, and the white crosses show positions of continuum emission peaks at 1 and 3 mm. Note the different map scale for IRAM04191 that was chosen in order to display the full extent of the ring-like structure in N_2H^+.

The role of interstellar filaments in regulating the star formation efficiency in dense gas

Philippe André
CEA S , G - -Y , FR

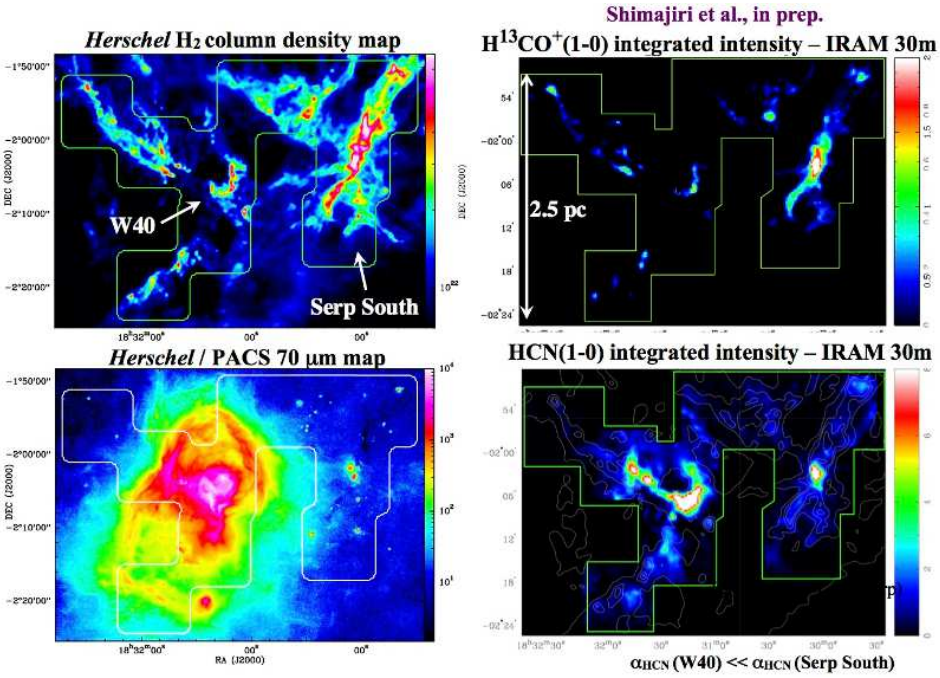
Imaging surveys at infrared and submillimeter wavelengths with the Spitzer and Herschel space observatories suggest that star formation in dense molecular gas is governed by essentially the same "law" in nearby Galactic clouds and distant external galaxies. This raises the possibility of a unified picture for star formation in the Universe from individual-cloud scales to galaxy-wide scales. I will summarize the star formation scenario favored by Herschel studies of the nearest molecular clouds of the Galaxy which point to the key role of the quasi-universal filamentary structure pervading the cold ISM. This filamentary scenario provides new insight into the efficiency of star formation in dense gas and the origin of the initial mass function. I will also discuss the results of recent molecular line mapping observations of the Aquila and Ophiuchus clouds with the IRAM 30m and MOPRA 22m telescopes, aimed at quantifying the ability of classical extragalactic tracers of dense molecular gas (e.g. HCN, HCO^+) to probe the mass of dense, star-forming filaments. While $H^{13}CN$ and $H^{13}CO^+$ are found to trace the dense filaments imaged with Herschel very well, the HCN and HCO^+ lines exhibit a strong dependence on the local intensity of the radiation field, which complicates the interpretation of the extragalactic correlation between HCN luminosity and star formation rate.

Collaborators:

- Y. Shimajiri, CEA Saclay, FR
- V. Könyves, CEA Saclay, FR
- N. Schneider, U Cologne, DE
- S. Bontemps, LAB Bordeaux, FR

Key Reference:
http://cdsads.u-strasbg.fr/abs/2014prpl.conf...27A

Suggested Session:
Filaments



Caption: Comparison of Herschel column density and 70 μm maps with $H^{13}CO^{+}$(1-0) and HCN(1-0) maps of the Aquila main cloud (from Shimajiri et al., in prep.)

The observed properties of a filament system in Orion B

Doris Arzoumanian
CEA, S , FR

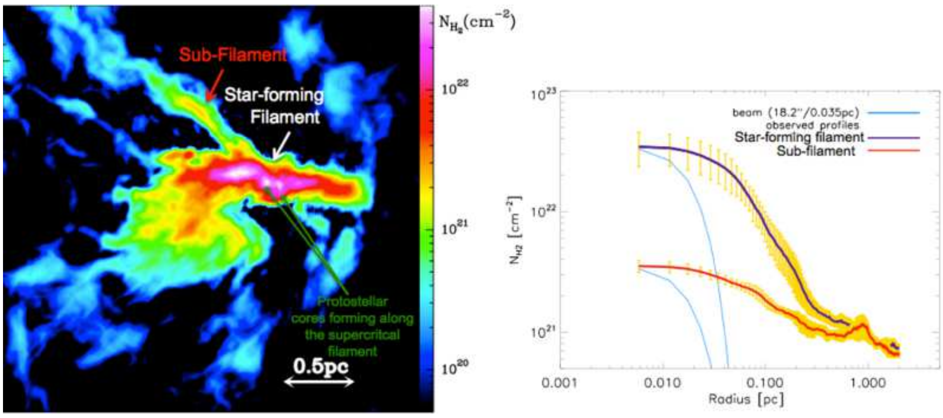
The highly filamentary structure of the interstellar medium is now impressively revealed by Herschel and Planck images. Previous observations have shown that molecular clouds are filamentary, however, only recently have interstellar filaments received special attention, thanks to the new observational results on the properties of filaments, demonstrating their key roles in the star formation process. I will present new results on the properties of a filament system discovered by Herschel in the northern part of the Orion B molecular cloud. The Herschel images display the filamentary structures of this system, where a thermally supercritical star forming filament (prestellar and protostellar cores are observed along its length) is surrounded by lower column density filaments. In particular, a well defined thermally subcritical and quiescent filament connected to the supercritical filament from the side.These two filaments, have central column densities (and masse per unit length) that differ by more than one order of magnitude, yet they show the same inner width of 0.1 pc. I will describe the kinematics of this filament system derived from maps of molecular line observations tracing the star forming dense filament (N_2H^+, HCO^+) and the lower column density surroundings (^{13}CO, $C^{18}O$). I will discuss what we can learn about the formation and evolution of this filament system combining the results derived from the Herschel submillimetre dust emission observations,the molecular line data and the large scale magnetic field structure obtained from Planck dust polarization observations.

Collaborators:

- P. Andre, CEA, FR
- A. Roy, CEA, FR

Suggested Session:

Filaments



Caption: Left: Column density map of the filament system in the North of the Orion B molecular cloud derived from Herschel observations. Right: Radial column density profiles perpendicular to the crests of the star-forming filament and the sub-filament.

The spatial distribution of complex organic molecules in prestellar cores

Aurore Bacmann

IPAG, G , FR

Complex organic molecules have long been detected in the hot cores of high- and low-mass star forming regions and have widely been used as hot core tracers, i.e. the presence of a hot core could be inferred from the detection of these species. Theoretically, these molecules were thought to form in the ice mantles on grain surfaces during the warm-up phase of the nascent protostar, from reactions between heavy radicals at temperatures close to 30-40 K, until they were released into the gas phase when the temperatures were high enough to sublimate the contents of the ices (typically around 100 K). The detections of complex organic molecules in prestellar cores at 10 K has cast doubts on this mechanism, as the temperatures are not high enough to warrant heavy radical diffusion on the grain surface. Various new models have now been proposed to account for the abundances of these species in the cold gas, but it is yet unclear whether complex organic molecules form from gas phase reactions which had been ignored up to now, or whether photoenergetic processes (e.g. cosmic rays, UVs) or chemical processes (e.g. chemical desorption/explosions) can provide heavy radicals with enough grain surface mobility.

Despite the new interest that the detection of complex organic molecules in prestellar cores has sparked, observations are still lacking which would help tackle the above-mentioned questions. In particular it is unclear how these species are spatially distributed. We present here mapping observations of two important terrestrial-like organic molecules, methyl formate and methanol, in the prestellar core L1689B. We find that the moderately extended emission of methyl formate is not consistent with the hypothesis that the molecule originates in a photodesorption region. We discuss the implications of this result in terms of possible formation mechanisms.

Collaborators:

- A. Faure, IPAG, FR
- E. Garcia, IPAG, FR

Key Reference:
http://adsabs.harvard.edu/abs/2012A%26A...541L..12B

Suggested Session:
Chemistry

Combining radiative transfer and a diffuse ISM model to simulate star cluster formation

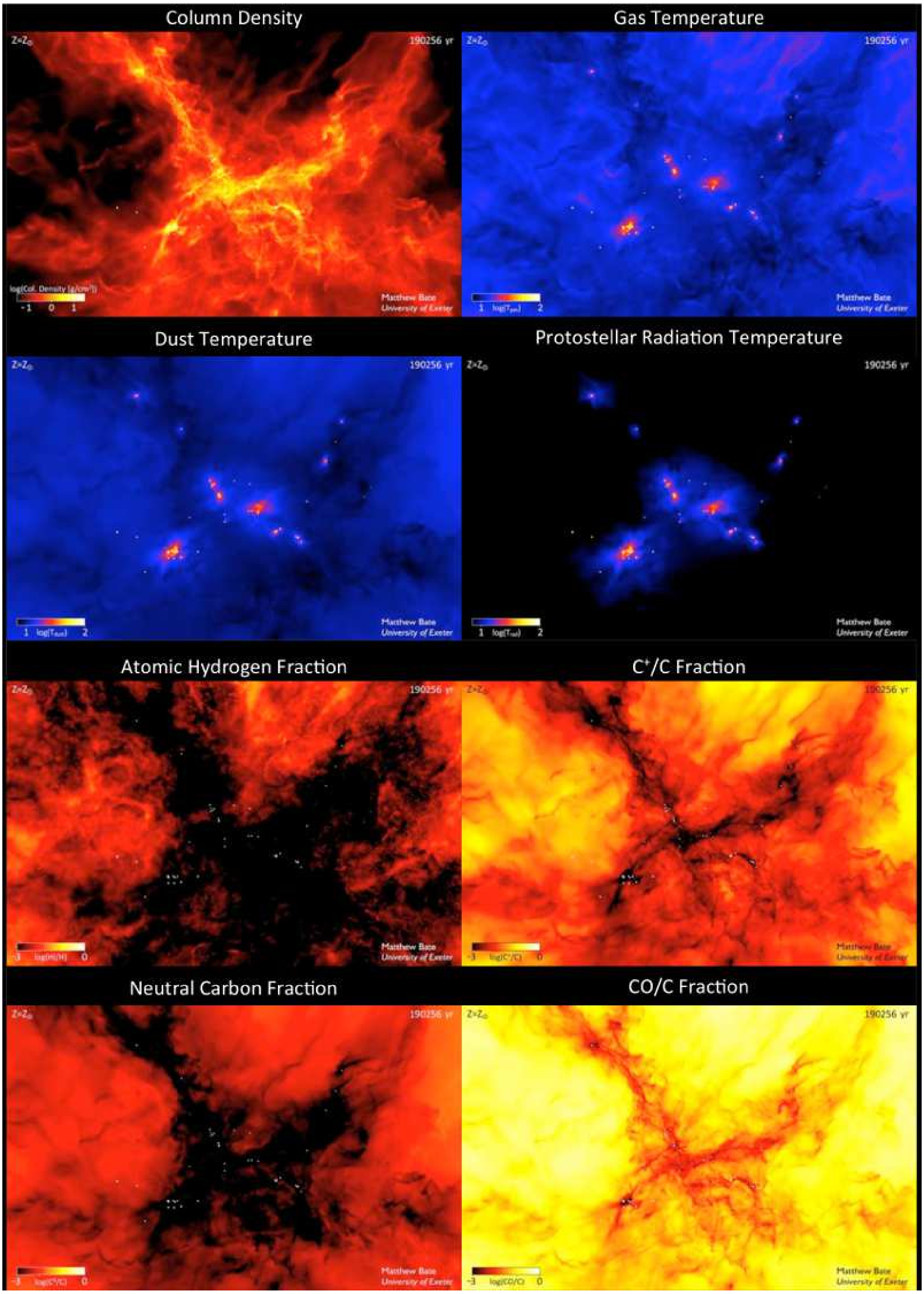
Matthew Bate
U E , E , GB

Over the past few years, hydrodynamical calculations of star formation and/or molecular cloud evolution have tended to use one of two methods to model the thermodynamics of the gas. Either they use a thermochemical model of the diffuse interstellar medium (ISM) but exclude heating from protostars, or they include radiative transfer from protostars but treat the low-density ISM as isothermal. Recently, we have developed a new method that combines these two approaches in order to more accurately model the thermodynamics of molecular clouds during star cluster formation. I will briefly describe the main aspects of the method, and then present new results from simulations of star cluster formation and compare them to results from earlier more simplified calculations and observations.

Collaborators:

- E. Keto, CfA, USA

Suggested Session:
Cluster Formation



Caption: A snapshot from a calculation of star cluster formation performed using the new method which, amongst other quantities, now allows us to produce maps of gas density, gas temperature, dust temperature, the protostellar radiation field, the fractions of atomic and molecular hydrogen, and the abundances of carbon in the forms of C^+, neutral carbon and CO.

Fragmentation and massive disk formation

Henrik Beuther
MPIA, H   , DE

How do high-mass gas clumps fragment? And how do the most massive disk-like structures form during this process? I will present results from a new large program at NOEMA (formerly Plateau de Bure Interferometer) resolving a large sample of high-mass star-forming regions at mm wavelength around 0.3” resolution. This program resolves the central cores and reveal the gas dynamics. These data will be complemented with recent even higher resolution (< 0.1”) data from ALMA and the VLA toward two specific case studies.

Suggested Session:
Disk Formation

The Next Major Step in Zeeman Studies of Magnetic Fields in Star Formation Regions

Richard Crutcher
U I   , U   , IL, US

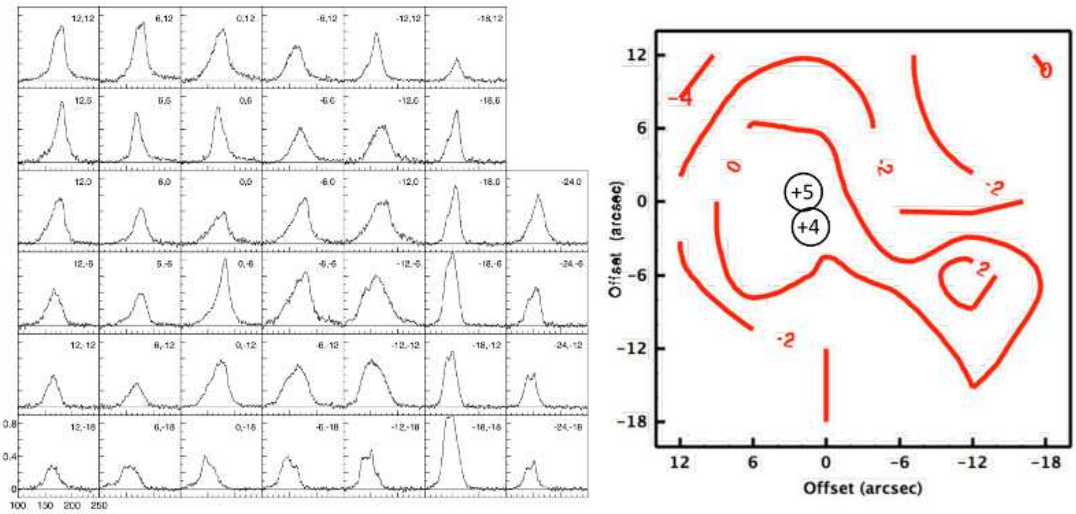
The precise role of magnetic fields in star formation remains unclear. Zeeman observations are crucial since they are the only available technique for directly measuring magnetic field strengths. In this talk I will discuss the first example of the next major advance in Zeeman studies of the role of magnetic fields in the star formation process - that is, fully spatially sampled high-resolution maps of magnetic field strengths that probe high gas density. This first case is the W3OH region of high-mass star formation. W3OH has an UCHII region, a very high-density molecular core (Turner-Welch object), and an extended region of high-density gas, so magnetic fields over a range of density and evolutionary state may be examined. Our fully spatially sampled map, which will be produced by combining our IRAM 30-m single-dish Zeeman mapping with our CARMA interferometer Zeeman observations, will have a spatial resolution of about 4”. These maps are made with the 226 GHz N=2-1 transition of CN, which has a critical excitation density of about 2×10^6 per cc. The figure of CN line intensity profiles (below) shows the tremendous spatial and kinematic structure present toward W3OH, and emphasizes the necessity of high angular resolution observations. The figure also shows a preliminary version of the IRAM single-dish map of the magnetic field strength B with two CN intensity and magnetic field ”hot spots” from our CARMA mapping superposed. Making the combined map with these IRAM and CARMA data that are in hand is underway now. Using this map, I will examine the relationship of the magnetic field to the spatial structure in the mass and the kinematics, the variation of the mass to magnetic flux ratio with mass and evolutionary state, and the scaling of B with density by comparing B inferred from our CN N=2-1 and published N=1-0 transitions (which have a ratio of critical densities of about 8). With these results I will discuss the astrophysical implications for the role of magnetic fields in star formation. Finally, I will explore the implications of this type of Zeeman mapping of magnetic field strengths for future studies with ALMA, and how questions about the precise role of magnetic fields in star formation may be answered.

Collaborators:

- E. Falgarone, ENS, FR
- N. Hakobian, UIUC, US
- P. Hily-Blant, UJF, FR
- C. Hull, CfA, US
- L. Looney, UIUC, US
- M. Lopez, IAR, AR
- R. Playback, UCB, US
- I. Stephens, BU, US
- T. Troland, UK, US

Suggested Session:

Magnetic Fields



Caption: W3OH CN N=2-1 Zeeman results. LEFT: CN line intensity profiles from IRAM 30-m telescope mapping (antenna temperature vs. channel number, channel spacing = 0.04 km/s). RIGHT: Preliminary line-of-sight B(mG) map. Red contours are from IRAM 30-m telescope mapping of the CN N=2-1 226 GHz transitions with 11” resolution; all observed positions shown at left have yet to be Zeeman fitted and included, so this is only the preliminary single-dish map of B(los). Black circles show the beam sizes and positions of two positions with CARMA interferometer CN Zeeman detections with 4” resolution; numbers within circles are line-of-sight B(mG). The (0,0) position is RA(2000) = 02:27:05.5, Dec(2000) = 61:52:32. These single-dish and interferometer CN Zeeman maps are being combined to make the 4” resolution maps of B(los) that will be presented and discussed at the meeting.

Simultaneous low- and high-mass star formation in massive protoclusters: ALMA results

Claudia Cyganowski
U S A , S A , GB

Most stars form in clusters, yet basic aspects of how this occurs remain unknown, including the relative birth order of high and low mass stars. In clump-scale “competitive accretion”-type models, massive stars and their surrounding cluster of lower mass stars form simultaneously. Thus a key, testable prediction of these models is that centrally condensed low-mass cores should exist within the accretion reservoir of a forming massive star.

I will present results from an ALMA Cycle 2 program to search for low-mass cores within the accretion reservoir of a high-mass (proto)cluster. Our ALMA mosaic achieves a dynamic range of ≈ 1000 at a linear resolution of ~ 1700 AU and reveals a rich population of low-mass cores surrounding the central, massive (proto)cluster members (see figure). Of these low-mass sources, the most centrally-condensed and ”core-like” are located in the outer reaches of the accretion reservoir (as traced by single-dish dust emission), $\sim 0.2 - 0.3$ pc from the central massive (proto)star. The central, massive (proto)star is accreting, as indicated by its active outflow activity. At least three of the low-mass cores are also driving outflows (traced by collimated ^{12}CO emission, observed with the SMA, and/or H_2CO and CH_3OH emission, observed with ALMA), suggesting that both high- and low-mass stars are forming (accreting) simultaneously within this (proto)cluster.

Collaborators:

- C. Brogan, NRAO, US
- T. Hunter, NRAO, US
- R. Smith, Manchester, GB
- D. Kruijssen, ZAH/MPIA, DE
- I. Bonnell, U St Andrews, GB

Suggested Session:

Cluster Formation

MASSES: An SMA Large-Scale Program Surveying Protostars to Reveal How Stars Gain their Mass

Michael Dunham

C A/SAO, C , US

Low-mass stars form from the gravitational collapse of dense molecular cloud cores. While a general consensus picture of this collapse process has emerged, many details on how mass is transferred from cores to stars remain poorly understood. MASSES (Mass Assembly of Stellar Systems and their Evolution with the SMA), an SMA large-scale program, is surveying all 75 Class 0 and Class I protostars in the nearby Perseus Molecular Cloud in order to reveal the interplay between fragmentation, angular momentum, and mass outflows in regulating accretion and setting the final masses of stars. In this presentation I will highlight key science results from the first two years of MASSES observations.

Collaborators:

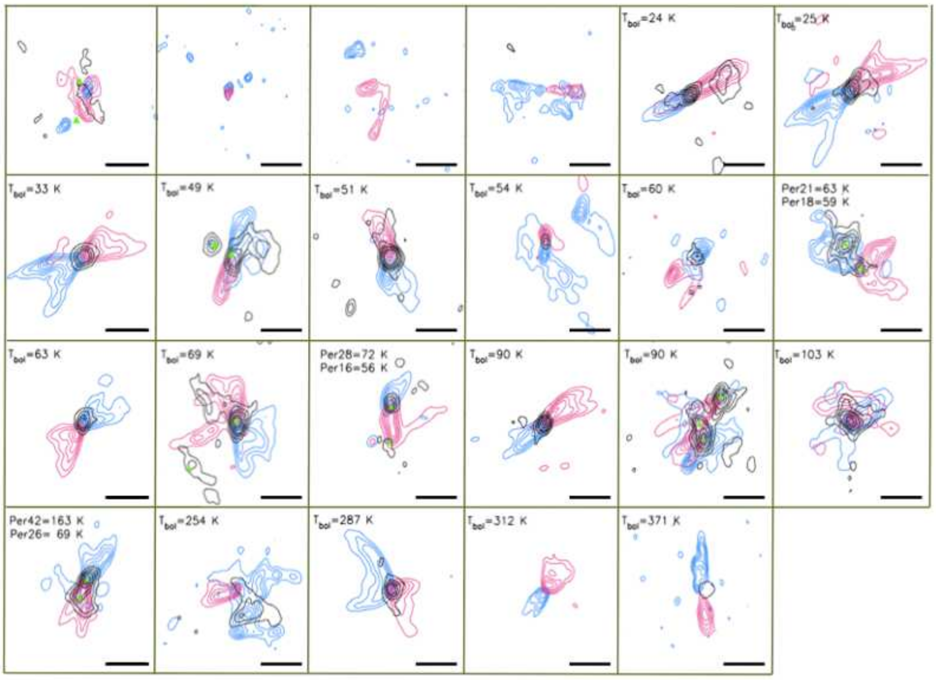
- P. Myers, CfA/SAO, US
- K. Lee, CfA/SAO, US
- H. Arce, Yale U, US
- T. Bourke, SKA, GB
- A. Goodman, Harvard, US
- J. Jorgensen, U Copenhagen, DK
- L. Kristensen, CfA/SAO, US
- S. Offner, U Mass Amherst, US
- J. Pineda, MPE, DE
- J. Tobin, U Leiden, NL
- E. Vorobyov, U Vienna, AU

Key Reference:

http://adsabs.harvard.edu/abs/2015ApJ...814..114L

Suggested Session:

Cores and Collapse



Caption: Molecular outflows driven by the 23 protostellar systems observed in the first year of MASSES observations. The red and blues contours show red and blueshifted ^{12}CO(2-1) emission, respectively, whereas the black contours show the 230 GHz continuum emission. All data were observed in the subcompact configuration of the SMA. The scale bar in each panel marks 4500 AU. The systems are ordered in increasing evolutionary stage, with the youngest objects at the top left and the oldest objects at the bottom right.

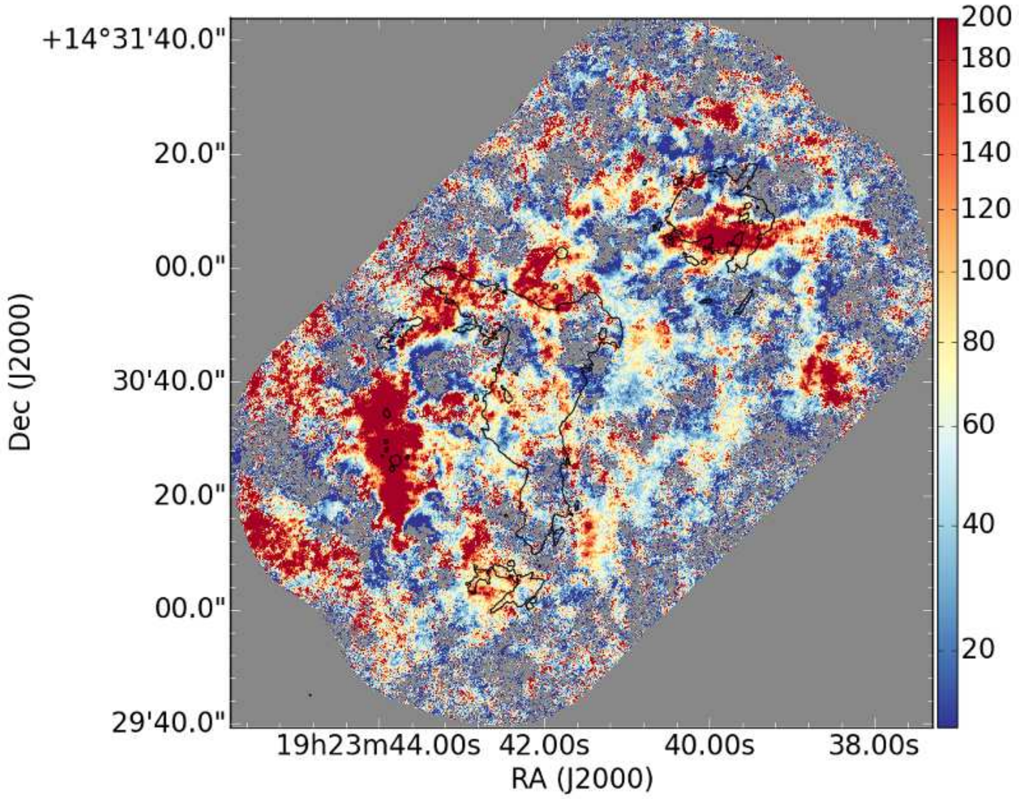
The effects and extent of feedback on dense prestellar gas near proto-OB stars

Adam Ginsburg
ESO, M , DE

For a large fraction of all stars, the earliest phase of their collapse occurs within the range of influence of high-mass stars. The temperature of the prestellar gas is expected to affect the fragmentation process, potentially increasing the typical fragment size and shifting the stellar mass function. The feedback from massive stars is therefore essential for determining what the second generation of stars in a cloud looks like. I will present ALMA observations of a high-mass star-forming region in which dozens of O-stars have already formed, yet the gas mass is still much larger than the stellar mass. Temperature measurements throughout the cloud reveal that regions within about 0.1 parsecs of high-mass protostars are significantly warmer than their surroundings, reaching temperatures of 100-200 K. However, a large fraction of the gas remains relatively cool, with T$<$ 50 K. Surprisingly, there is no sign of increased dense gas temperature near the ionized gas, suggesting that the photons from main sequence OB stars escape the cloud rather than heating the gas. The most massive cores also appear to be associated with the warmest gas in general.

Suggested Session:

Stellar Feedback



Caption: A temperature map using the H_2CO 3(2,1)-2(2,0)/3(0,3)-2(0,2) line ratio assuming LTE (which is an incorrect assumption!) and optically thin emission. The warmest features surround high-mass protostars. This map, made from ALMA data, includes only 12m data (it is missing short spacings) and therefore the temperatures are likely to be systematically overestimated. Nonetheless, the lack of correlation with the centimeter continuum emission (black contours) indicates that the evolved O-stars have little effect on the dense gas ($n_{crit} \sim 10^6$ cm^{-3}), while the proto-O-stars have a large effect on their surroundings.

Filament kinematics: from low- to high-mass star-forming clouds

Alvaro Hacar
I A, V , AT

The internal velocity structure of filaments and their correlation with their internal mass distribution is of fundamental importance for the interpretation of their evolution, fragmentation, and stability. Since the first millimeter line observations in molecular clouds, different studies have attempted to characterize the internal gas velocity field within these objects. However, only in the last years the systematic analysis of large-scale molecular surveys have revealed the extraordinary level of substructure (fibers and bundles) and internal motions (velocity dispersions, gradients, and streaming motions) of these gas filaments. During my talk, I will present a comparative study of the gas kinematic properties and internal structure of three prototypical low- and high-mass star-forming filaments, from the simplest Musca cloud, throughout the Taurus B213-L1495 region, to the massive Integral Shape Filament in Orion. In particular, I will discuss the implications of these results in our current description of the turbulent ISM and molecular cloud structure.

Collaborators:

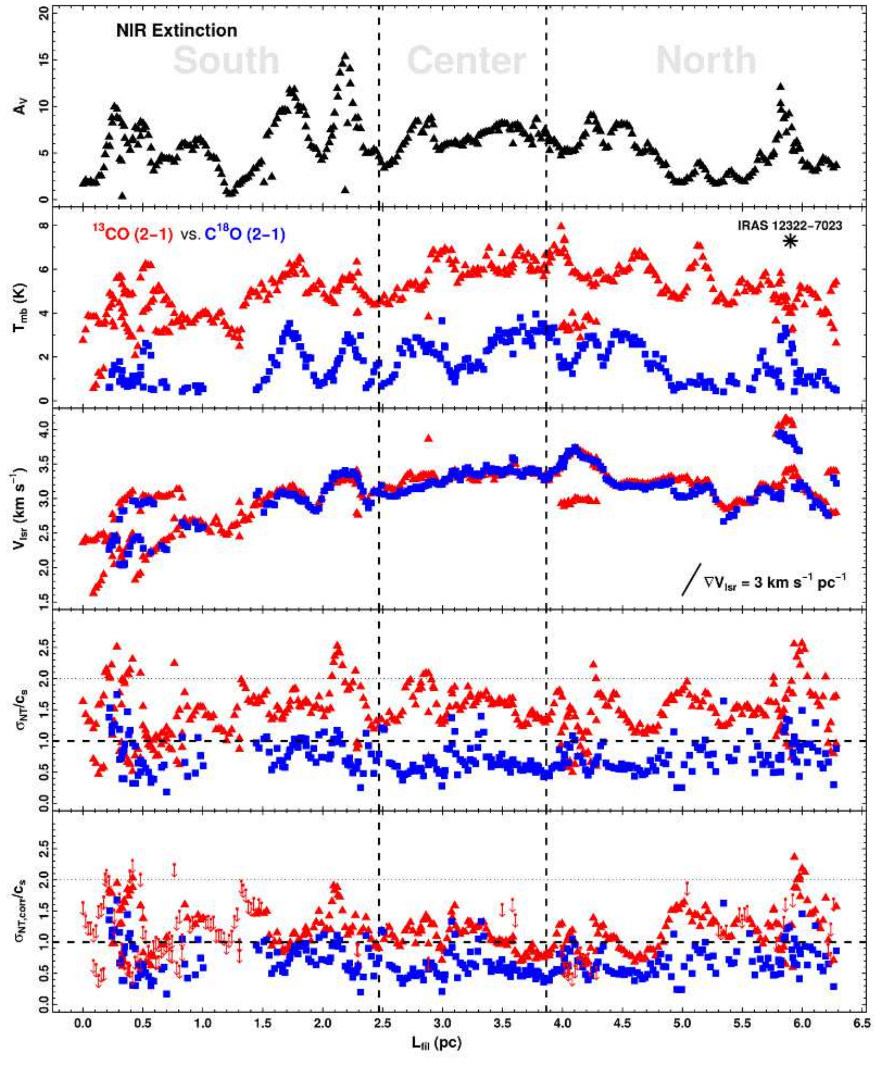
- M. Tafalla, OAN, ES
- J. Alves, IfA-UniVie, AT
- J. Kainulainen, MPIA, DE
- H. Beuther, MPIA, DE
- A. Burkert, USM, DE

Key Reference:

http://adsabs.harvard.edu/abs/2015arXiv151106370H

Suggested Session:

Filaments



Caption: Observational results combining both NIR extinction (black) and both ^{13}CO (red triangles) plus C^{18}O (blue squares) (2-1) line measurements along the main axis of Musca. From Top to Bottom: (1) Extinction profile obtained by Kainulainen et al. (2015); (2) CO main-beam brightness temperatures ($T_{\rm mb}$); (3) centroid velocity ($v_{\rm lsr}$); (4) non-thermal velocity dispersion along the line of sight ($\sigma_{\rm NT}$); and (5) opacity corrected non-thermal velocity dispersion along the line of sight ($\sigma_{\rm NT,corr}$). The velocity dispersion measurements are expressed in units of the sound speed c_s = 0.19 km/s at 10 K. In these last plots the horizontal lines delimitate to the sonic ($\sigma_{\rm NT}/c_s \leq 1$; thick dashed line) and transonic ($\sigma_{\rm NT}/c_s \leq 2$; thin dotted line) regimes, respectively. More than 6.5 pc long, the Musca cloud is the longest sonic-like filament detected in the ISM so far (Hacar et al 2015).

A Keplerian-like disk around the forming O-type star AFGL 4176

Katharine Johnston

U L , L , UK

I will present our ALMA line and continuum observations at 1.2mm with $\sim 0.3''$ resolution that uncover a Keplerian-like disk around the forming O-type star AFGL 4176. The first-moment maps, pixel-to-pixel line modelling and position-velocity diagrams of the CH_3CN J = 13-12 K-line emission all show a velocity gradient along the major axis of the source, coupled with an increase in velocity at small radii, consistent with Keplerian-like rotation. I will also present APEX ^{12}CO observations that show a large-scale outflow from AFGL4176 perpendicular to the major axis of mm1, supporting the disk interpretation. Finally, I will present our radiative transfer modelling of the ALMA data, showing that a Keplerian disk surrounding an O7 star, with a disk mass and radius of 12 $M_\odot$ and 2000 AU that reproduces the line and continuum data, further supporting our conclusion that our observations have uncovered a Keplerian-like disk around an O-type star.

Collaborators:

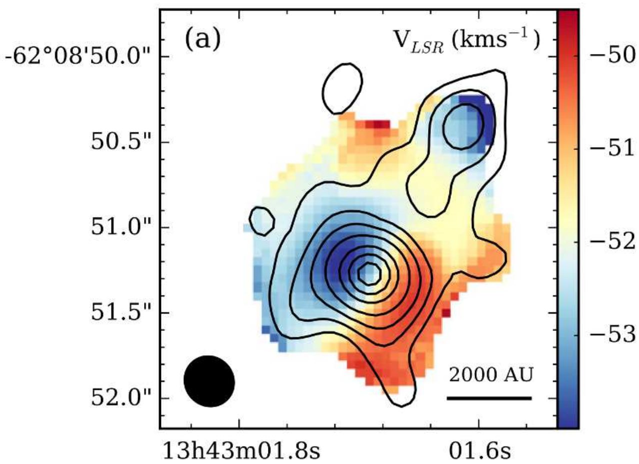
- T. Robitaille, MPIA, DE
- H. Beuther, MPIA, DE
- H. Linz, MPIA, DE
- P. Boley, Ural Federal U, RU
- R. Kuiper, MPIA/Eberhard Karls U, DE
- E. Keto, Harvard-Smithsonian CfA, US
- M. Hoare, U Leeds, GB

Key Reference:

http://adsabs.harvard.edu/abs/2015ApJ...813L..19J

Suggested Session:

Massive Star Formation



Caption: First-moment map of the CH_3CN J = 13-12, K = 3 emission from AFGL 4176 mm1 in colourscale. The contours show 1.2mm continuum emission (starting at 10 sigma). The beam is shown in the bottom left corner. A gradient in velocity of the CH_3CN line is clearly seen along the major axis of the continuum emission, exhibiting that expected from a Keplerian velocity field, where the peak velocities are seen either side of the continuum peak position (Figure adapted from Johnston et al. 2015).

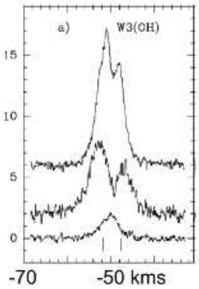
Comparing Accretion in Low and High Mass Star Formation

Eric Keto
C A, C , US

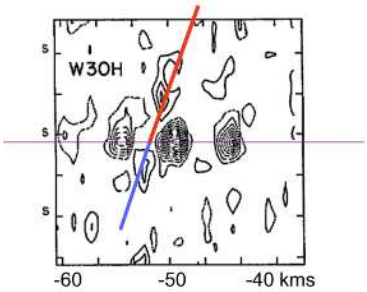
I will present new VLA observations of radio recombination lines (RRL) H66α and H92α in the HII region W3(OH) made at high enough spatial ($< 0.5''$) and spectral (~ 1 kms) resolution to resolve the ionized gas flow around this extremely young (still accreting) massive (O7) star. A comparison with previously published molecular line observations traces the star-forming accretion flow from the scale of the collapsing molecular envelope, through a rotationally-flattened molecular disk that penetrates the HII region, and finally outward in a pressure-driven ionized wind.
W3(OH) is the third HII region, along with W51e2 and G10.6-0.4 that we have observationally identified with this type of massive accretion flow. In contrast to our other two candidates which contain multiple O stars in their centers, W3(OH) may surround a single O7 star.
The structures in these massive accretion flows, the collapsing envelope, the accretion disk, and the clearing outflow, are analogous to those responsible for the observational differences between the class 0, class I/II, and class III phases of low-mass star formation. However because of the short time scale for massive star formation, these structures that appear sequentially in low-mass star formation all appear at the same time in high mass. Second, each of the three structures is different in the two cases. In high-mass star formation, the protostellar envelopes can be connected to larger-scale inflows. The disks are too massive to be described by the thin-disk approximation, yet may still be Toomre stable as our new observations of IRAS20126 indicate. The ionized outflow that clears the surrounding envelope is continuously fed by the massive accretion flow rather than by the central star and its remnant accretion disk as in low-mass star formation.
The question now is not whether high-mass star formation is a scaled-up version of low-mass, but exactly how different is it.

Suggested Session:

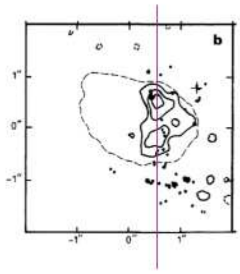
From Low- to High-Mass Star Formation



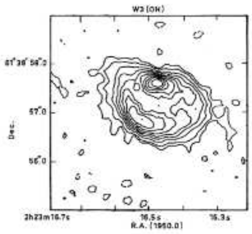
Single dish HCN and CS with the blue asymmetric profile showing infall.



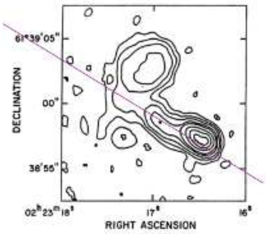
VLA position-velocity with 3 hyperfine lines of NH3 along the purple line showing the position of W3(OH). Red-blue emission on either side shows rotation.



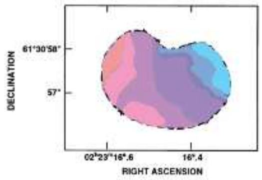
VLA map of NH3 absorption showing the accretion "disk" .



VLA map of 1.3 cm continuum. Two peaks show high density ionized gas at same position as the NH3 accretion "disk".



VLA map at 21 cm at a larger scale than the 1.3 cm. W3(OH) is lower right. The outflow from W3(OH) follows the purple line.



New VLA map of 3.6 cm RRL showing the twist in the veloci gradient as the ionized gas accelerates off the accretion disk to high Mach number in a pressure driven outflow.

Caption: A massive star-forming accretion flow in W3(OH)

Dense Core Mass Segregation in Orion A and B

Helen Kirk
NRC-H , V , CA

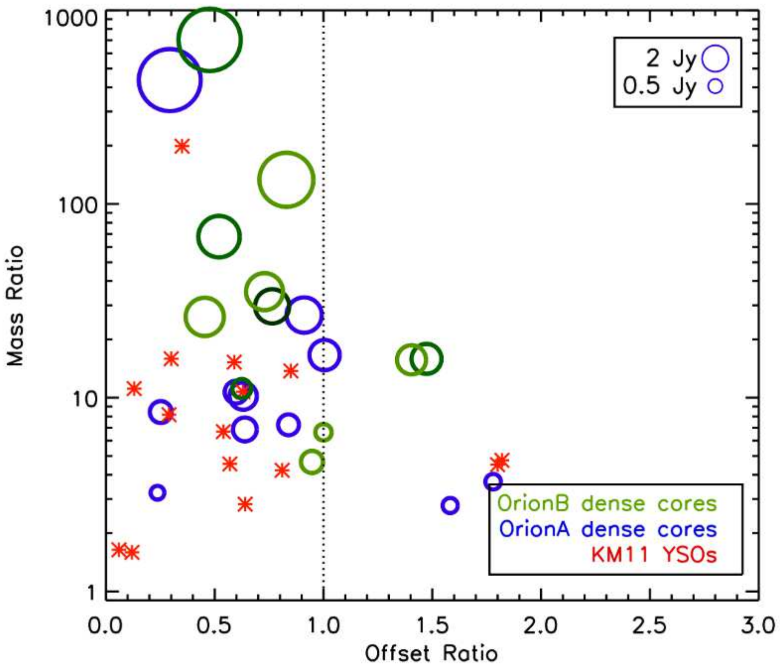
Observations of stellar clusters show evidence for mass segregation, even in very young systems, but the debate is not yet settled as to whether this segregation is truly primordial. We shed new light on this question by examining mass segregation at an earlier phase, in dense cores. We analyze clusters of dense cores in the Orion A and B molecular clouds, including a large massive star-forming cluster around the Integral Shaped Filament, as well as numerous smaller low-mass star-forming groups. Using observations from the JCMT Gould Belt Survey and two independent analysis methods, we find that most of the dense core clusters appear to be mass segregated. This suggests that stellar clusters may have some degree of primordial mass segregation imprinted on them from the the dense core formation stage.

Collaborators:

- J. Lane, UVic, CA
- the JCMT GBS team

Suggested Session:

Cluster Formation



Caption: The tendency for a central location of the most massive core in each dense core cluster. The horizontal axis shows the ratio of the separation of the most massive dense core from the cluster centre ("offset") to the median offset of all cluster members. Randomly located most massive dense cores would tend to be equally distributed above and below an offset ratio of 1. Dense core clusters in Orion B are shown in green, while those in Orion A are shown in blue. The red asterisks show a similar analysis on young stellar clusters by Kirk & Myers 2011.

The Role of Magnetic Fields in Star Formation

Chris McKee
UCB, B , US

Historically, it has been conjectured that ambipolar diffusion is essential for allowing gravitational forces to exceed magnetic forces in molecular clouds, thereby enabling star formation. However, Zeeman observations of magnetic field strengths in molecular cloud cores have failed to find evidence of cores that are magnetically dominated. Magnetic field in ideal magnetohydrodynamic (MHD) simulations of a region in a turbulent molecular cloud are in good agreement with the Zeeman observations of the line-of-sight magnetic field in molecular clouds. We show that the observed line-of-sight field in molecular clumps scales approximately as $n^{2/3}$ as inferred by observations for the total field; in addition, the total field in our simulation approximately obeys this scaling. The simulations show how tangling of the field lines reduces the field measured by the Zeeman effect. The observed mass-to-flux ratio is density weighted and underestimates the actual mass-to-flux ratio; we infer that the median mass-to-flux ratio of the cores in the observed sample is three times the critical value, confirming that ambipolar diffusion is relatively unimportant in these cores. Comparing simulations with an initially weak field (initial Alfven Mach number $\mathrm{M_A} = 10$) to one with an initially moderate field ($\mathrm{M_A} = 1$), we find that only the initially moderate field is in good agreement with the observations of magnetic field structure. Finally, we find some evidence for turbulent reconnection in our ideal MHD simulation: ideal MHD in the presence of turbulence is not ideal.

Collaborators:

- P.S Li, UCB
- R.I. Klein, LLNL/UCB

Key Reference:
http://mnras.oxfordjournals.org/content/452/3/2500.full.pdf

Suggested Session:
Magnetic Fields

Lumpy filaments in a turbulent medium

Phil Myers
C A, C , US

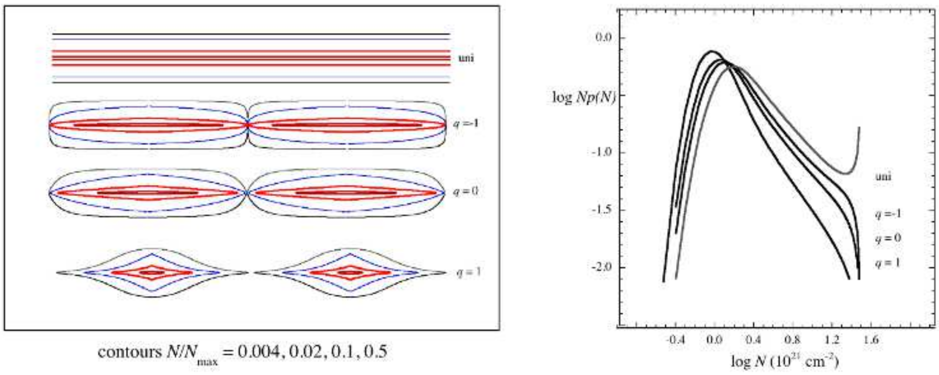
In star-forming molecular clouds, the distribution of column densities (N-pdf) is widely used as a global census of their star-forming potential. This talk interprets N-pdfs in terms of filaments, the main cloud component on scales 0.1-10 pc. The simplest model which matches observed filament properties and N-pdfs gives two results of interest. First, filaments must be radially concentrated in a spatially fluctuating background. This result supports the idea that supersonic turbulence generates filaments which condense and become self-gravitating, as seen in numerous simulations. Second, the typical filament must have significant variation of axial density – more than in a smooth filament with a few dense cores. Observed and simulated filaments also show significant peaks and valleys in their axial profiles, even when they lack well-defined cores. This result suggests that the axial structure of the typical filament may originate during its formation process, and not after Jeans fragmentation of an initially smooth filament in equilibrium.

Key Reference:
http://adsabs.harvard.edu/abs/2015ApJ...806..226M

Suggested Session:
Filaments

Filament N-pdfs rule out uniform axes, favor cores over spindles

Phil Myers • Harvard-Smithsonian Center for Astrophysics • Submission to EPOS 2016



Filament models assume Plummer-like radial density structure with constant radial scale length r_0 and power-law index p =2. Their axial structure is derived by assuming that the axial column density N_0 is either uniform, or nonuniform with probability density $p(N_0)$ varying as N_0^{-q}, with q = -1, 0, or 1. The column density N varies monotonically over 30 r_0 in the radial direction and 120 r_0 in the axial direction, from 0.1 to 30 10^{21} cm^{-2}. The corresponding probability density $p_{fil}(N)$ is convolved with a lognormal background $p_{bkg}(N)$ to give the N-pdf for each case. The distribution $p_{bkg}(N)$ has mean and standard deviation 0.7 and 0.3 10^{21} cm^{-2}. The case of uniform axial structure can be ruled out, since it is not seen in observed maps or N-pdfs. The cases of nonuniform axial structure resemble observations more closely for filaments dominated by cores ($q \sim 1$) than by spindles ($q \sim -1$).

Caption: N-pdfs rule out uniform axes, favor cores over spindles

The magnetic field morphology in nearby molecular clouds

Juan-Diego Soler
CEA/S , P , FR

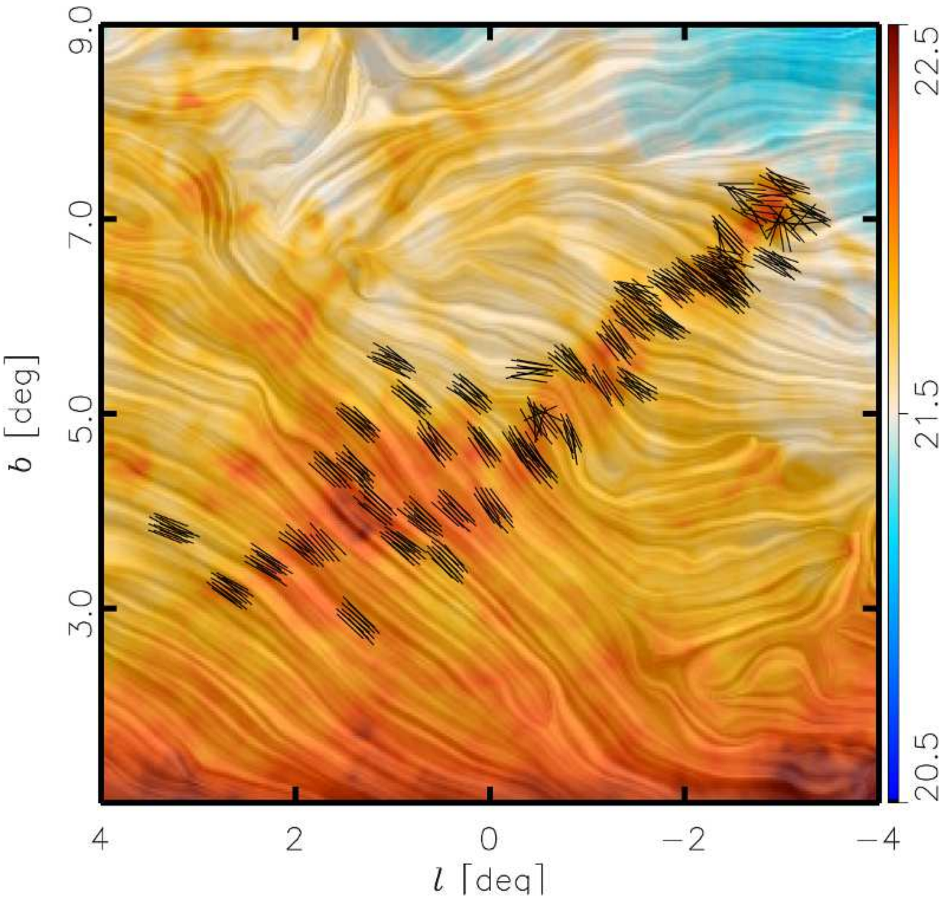
Within four nearby (less than 200 pc from the Sun) molecular clouds we evaluate statistically the structure of the interstellar magnetic field projected on the plane of sky inferred from the polarized thermal emission of Galactic dust observed by Planck at 353 GHz and from the polarization of visible/NIR light from background stars. First, we study the structure of the magnetic field within the area covered by a Planck-sized beam and evaluate the effect of background polarized emission. Second, we use the second-order structure function of the orientation angles to quantify the differences in the magnetic field morphology derived with each technique at comparable scales. Last, we discuss the implications of this study in previous analysis of the magnetic field morphology by Planck collaboration, where we found a change in the relative orientation between the magnetic field projected on the plane of sky and the gas column density structures. In simulations of magnetohydrodynamic turbulence in molecular clouds this trend in relative orientation is a signature of Alfvenic or sub-Alfvenic turbulence, implying that the magnetic field plays a significant dynamical role in the dynamics of the gas at the scales probed by Planck.

Collaborators:

- F. Alves, MPIE, DE
- A. Bracco, CEA/Saclay, FR
- F. Boulanger, IAS, FR
- P. Hennebelle, CEA/Saclay, FR
- F. Levrier, ENS, FR
- P. Martin, CITA, CA

Key Reference:
http://adsabs.harvard.edu/cgi-bin/bib_query?arXiv:1502.04123

Suggested Session:
Magnetic Fields



Caption: Magnetic field and column density measured by Planck towards the Pipe nebula. The "drapery" pattern indicates the orientation of magnetic field lines, orthogonal to the orientation of the submillimetre polarization. The black pseudo-vectors indicate the orientation of starlight polarization.

Modeling the core-filament system L1689B: what to learn from spherical cylinders and the filament mass function

Jürgen Steinacker
IPAG/MPIA, G , FR

For decades we have been missing a global answer to the question: what ends the life of a pre-stellar core and starts star formation? Is it the end of a supporting force based on magnetic fields or turbulence, is it an external kinetical trigger, or a mass overload? As the new

instruments better probe the complex filamentary network from which cores emerge, attention also turns to the role of the hosting filaments.
To characterize the physical properties like the spatial structure of density and temperature of a typical core-filament system, we have performed radiative transfer modeling of six FIR continuum maps of L1689B (Herschel PACS/SPIRE, SCUBA2) with a core that shows indication for infall (and rotational) motions.

- Starting with the analysis of the 850 μm map where the filament contributes little emission, we show that all maps are consistent with a core that is remarkably isothermal and very close to simple radial power-law density structure with an exponent of -2 down to 5000 AU.
- We discuss former 1D models reaching far out to the filament part, and the implications for using the results for a core mass function.
- Formerly derived central temperatures of 9-11 K and H_2 number densities of $1.9 - 2.2 \times 10^{11}$ m^{-3} are challenged by our model. We show that the ambiguity in the central parameters can only be removed by analyzing the radiation field and using the column density information.
- We test our assumptions about the core and filament contributions using RAMSES results (see Poster contribution by Stefan Heigl) for a self-gravitating filament.

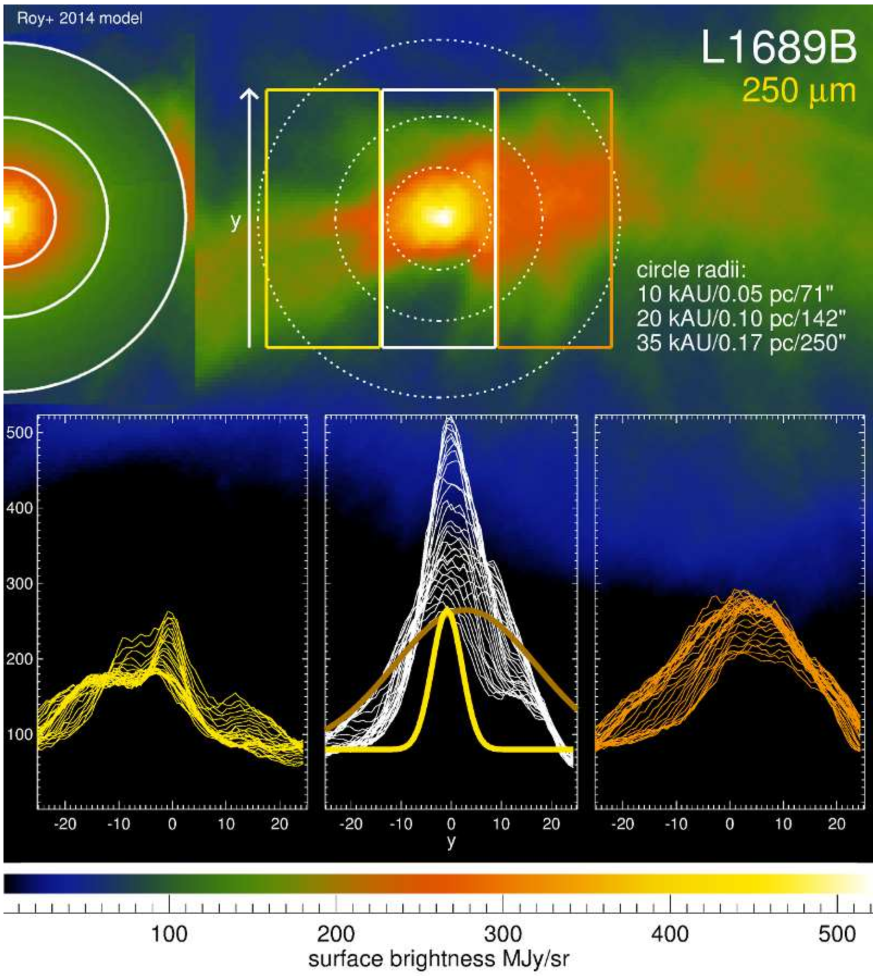
.

Collaborators:

- A. Bacmann, IPAG, FR
- Th. Henning, MPIA, DE
- S. Heigl, U Munich, DE

Suggested Session:

Cores and Collapse



Caption: The core-filament system of L1689B seen at 250 μm (background color map). Perpendicular stripes visualize the filament substructure and the embedded core. Thick lines show considered approximations of the filament contribution. The Roy+ 2014 model considers radial temperature and density variations of the azimuthally averaged emission stretching deep into the filament (top left).

POSTERS

Disk kinematics in the high-mass star forming regions W3(H2O) and W3(OH)

Aida Ahmadi
MPIA, H , DE

A large sample of high-mass star-forming regions has been observed at mm wavelength as part of the CORE large program at NOEMA, aiming to answer fundamental questions regarding fragmentation and disk formation during high-mass star formation. With a high spatial resolution of around 0.3”, we are able to differentiate between non-Keplerian structures and potential inner Keplerian accretion disks. Furthermore, with a broad range of observed molecules, we are able to disentangle different disk/core contributions. I will present preliminary results on our investigation of W3(H2O) and W3(OH) complexes with a focus on the innermost fragmentation of these regions and their disk kinematics.

Collaborators:

- H. Beuther, MPIA, DE
- J. Mottram, MPIA, DE
- and the CORE team

Key Reference:
http://adsabs.harvard.edu/abs/2013A%26A...558A..81B

Suggested Session:
Massive Star Formation

ISM dynamics and star formation in gas-rich galactic disks

Andreas Burkert
U M , M , DE

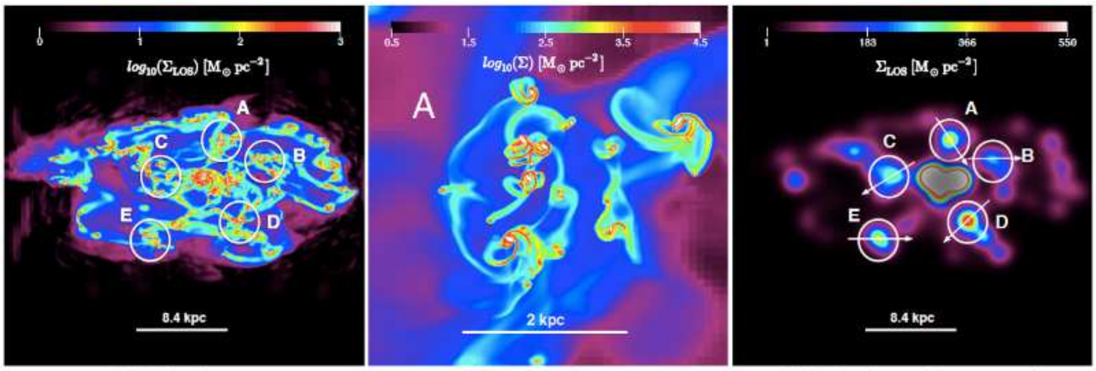
The interstellar medium of gas-rich galactic disks, especially at high, but also at low cosmic redshifts is dominated by a few very massive kpc sized gas clumps that dominate star formation and stellar feedback in these galaxies. In this contribution I demonstrate that these clumps are a natural outcome of gravitational disk instabilities, leading to smaller clumplets that lateron re-arrange themseves into large clump clusters. With the low resolution that is typical for observations of high-z galaxies, the theoretically predicted intricate substructure of these clump clusters cannot be resolved. I however will demonstrate that kinematical studies provide clear, indirect evidence for the observed unresolved clumps to consist of multiple substructures. I will discuss how star formation, stellar feedback and chemical enrichment proceeds in the complex, dynamical environment of a clump cluster with application to the origin of multi-component globular clusters, seed back holes and strong focussed gas outflows that feed the halos of galaxies and drive turbulence in the galactic disk.

Collaborators:

- M. Behrendt, MPE, DE
- M. Schartmann, Swinburne U, AU
- R. Genzel, MPE, DE

Key Reference:
http://adsabs.harvard.edu/abs/2015MNRAS.448.1007B

Suggested Session:
Molecular Clouds



(a) Surface density (b) Zoom onto cluster A (c) Surface density beam smeared

Caption: Left: ISM structure of a gas-rich, gravitationally unstable disk. Middle panel: Structure of clump clusters that formed in this disks. Right panel: Beam-smeared image for a galaxy located at redshift 2 where the clump clusters appear as large, homogeneous clouds.

Formation of Magnetized Prestellar Cores in Turbulent Cloud

Che-Yu Chen
UVA, C , US

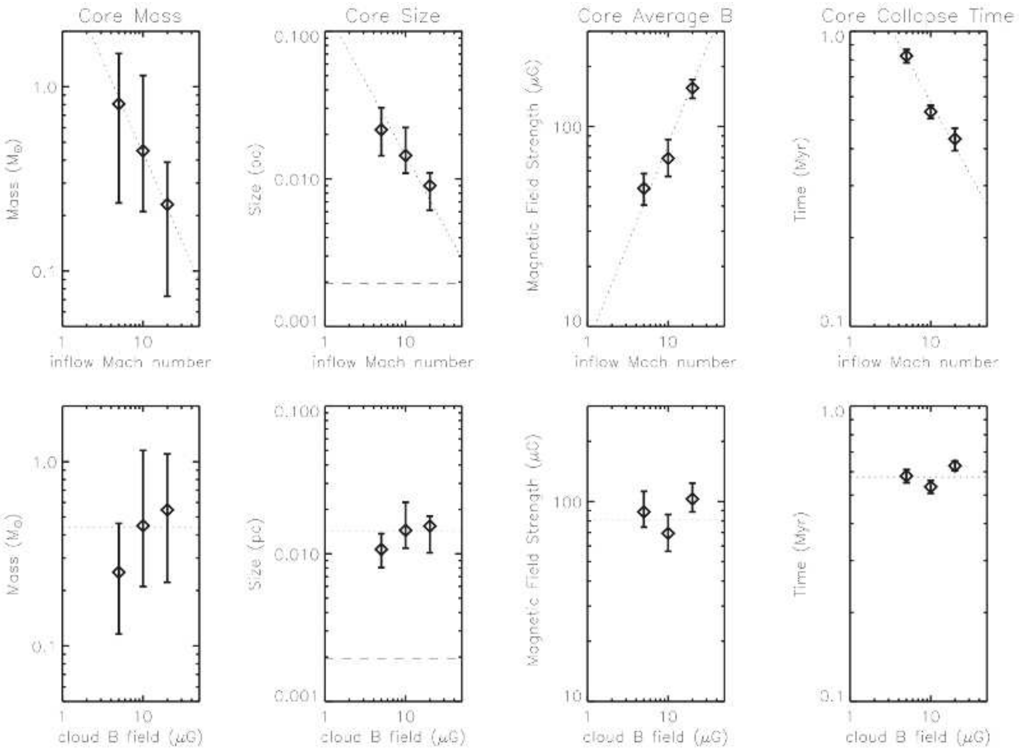
We showed in three-dimensional, turbulent MHD simulations that in typical GMC environments, the turbulence-compressed regions are strongly-magnetized sheet-like layers, within which dense filaments and embedded self-gravitating cores form via gathering material along the magnetic field lines. From our simulations, we identified hundreds of self-gravitating cores with masses, sizes, mass-to-magnetic flux ratios, and specific angular momenta comparable to observations. We found that core masses and sizes do not depend on the coupling strength between neutrals and ions, and ambipolar diffusion is not necessary to form low-mass supercritical cores. This is a result of anisotropic contraction along field lines, which can explain the fact that magnetically supercritical cores are commonly observed even in a strongly magnetized medium. We then confirmed the anisotropic core formation model in simulations with extended parameter space, and quantified how core properties depend on the pre-shock inflow velocity and upstream magnetic field strength. Our studies also suggest that cores acquire angular momentum from small-scale turbulence, which is independent in direction from the local magnetic field. As a result, the core's rotation axis would be poorly aligned with its mean magnetic field, presumably enabling the formation of protostellar disks by reducing the magnetic braking efficiency.

Collaborators:

- E. Ostriker, Princeton U, US

Key Reference:
http://adsabs.harvard.edu/abs/2015ApJ...810..126C

Suggested Session:
Cores and Collapse



Caption: Summary of simulated core statistical properties for models with different inflow Mach numbers (top row) and cloud magnetic fields (bottom row), with theoretical predictions from anisotropic core formation model (dotted lines). The dashed lines in the core size plots (second column) indicate the resolution of our simulations.

High-Dimensional Identification and Statistics of Star-Forming Substructures in GMCs

Hope Chen
H -S C A, C , US

Recently, astronomers have explored various physical parameters and statistical measurements in the pursuit of understanding the structure and star formation in GMCs. However, the exploration is often limited to empirically identifying structures and correlation. Moreover, the structure identification is often done using only the (2D) information confined to the plane of the sky, while the correlation is fitted between a priori chosen physical parameters (again, often 2D). This approach not only overlooks the rich potential in the high-dimensional data, but also introduces biases due to human decision.

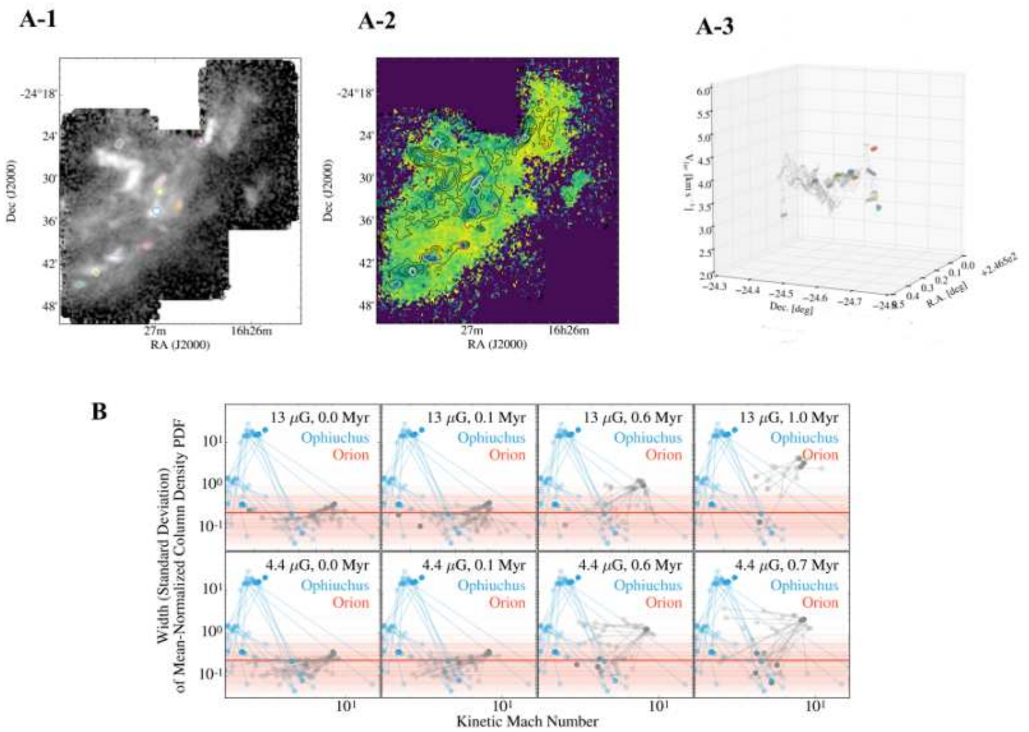
In the first part of this talk, I will present comparison between several structure identification algorithms including the density-based scanning (DBScan) and Dendrogram. I will present the efficiency of DBScan in identifying structures similar to the observed ”bundles” in Taurus, as well as in finding potentially star forming cores, using three- or higher-dimensional data. In the second part, I will introduce statistical methods for identifying trends in high-dimensional (¿3D) data, and unbiased ways for measuring the significance of correlation in the multi-dimensional parameter space. Lastly, I will showcase how these algorithms help with understanding the physical environments for substructure/star formation inside GMCs, by applying the algorithms on observational data (comprising data from the COMPLETE survey, the Herschel Gould Belt Survey, and the GBT Ammonia Survey (GAS) and simulations (mainly ENZO MHD simulations), and comparing the results in the multi-dimensional parameter space.

Collaborators:

- A. Goodman, CfA, US
- J. Pineda, MPE, DE
- B. Burkhart, CfA, US
- P. Myers, CfA, US
- D. Collins, Florida State U, US

Suggested Session:

Molecular Clouds



Caption: A. Identification of cores in the four-dimensional space, composed of RA, Dec, velocity, and velocity dispersion; using the NH_3 emission data from the GBT Ammonia Survey (GAS), and the density based scanning (DBScan) clustering algorithm. (A-1) The cores identified in the four-dimensional space, on the map of integrated NH_3 emission. (A-2) The cores identified in the four-dimensional space, on the map of velocity dispersion, with contours showing the integrated NH_3 emission. This map shows that the DBScan algorithm, applied in the four-dimensional space, successfully recognizes the "coherent cores" similar to those observed by Goodman et al. (1998) and Pineda et al. (2010), and provides a natural boundary defined by connectedness in the four-dimensional space. (A-3) The cores identified in the four-dimensional space, in the three-dimensional RA-Dec-velocity (position-position-velocity) space. The plot also shows the "noisy samples" given by the clustering algorithm. B. Comparison of GMCs in observations (Ophiuchus in blue and Orion in red) to results of simulations (ENZO MHD; in gray), in the two-dimensional space composed of the local column density PDF width and the Mach number. Each data point represents a substructure inside (observational and simulated) GMCs identified using the Dendrogram algorithm, with the lines showing hierarchy between Dendrogram-identified substructures. The top/bottom rows show MHD simulations with high/low magnetic field strengths, respectively. The evolution time of simulations increase from the left toward the right.

Dust Radiative Transfer in Star-Froming Filaments

Roxana-Adela Chira
MPIA, H , DE

Dust emission surveys at sub-mm and far-infrared wavelengths, e. g. by Herschel, provide new possibilities to study star formation in filamentary molecular clouds. The column density and temperature profiles that are derived with these observations have shown astronomers new details about the structure and star-formation potential of those objects, but also depend on many assumptions on both the observational and model side. How would those filaments look like if we observe them from another direction? Do observations in dust emission and extinction reflect the same properties of filaments? We apply our three-dimensional dust radiative transfer code on models of clumpy filaments, predict the distributions of observable quantities and discuss the results in context of observational routines.

Collaborators:

- R. Siebenmorgen, ESO, DE
- T. Henning, MPIA, DE
- J. Kainulainen, MPIA, DE

Suggested Session:

Filaments

Perturbation growth in accreting filaments

Seamus Clarke

C U, C , GB

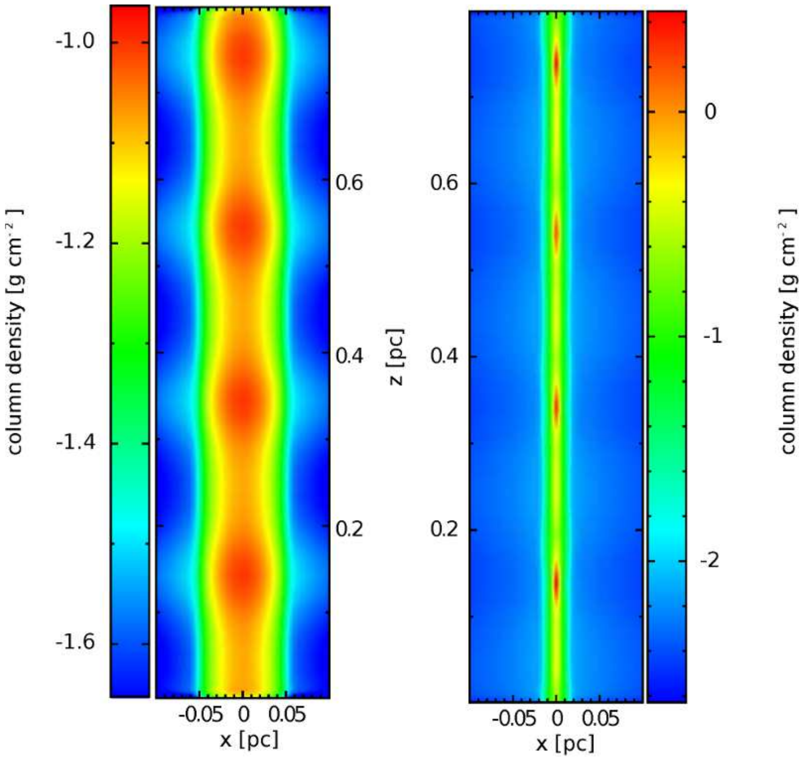
We use smoothed particle hydrodynamic simulations to investigate the growth of perturbations in infinitely long, initially sub-critical but accreting filaments. The growth of these perturbations leads to filament fragmentation and the formation of cores. Most previous work on this subject has been confined to the growth and fragmentation of equilibrium filaments and has found that there exists a preferential fragmentation length scale which is roughly 4 times the filament's diameter. Our results show a more complicated dispersion relation with a series of peaks linking perturbation wavelength and growth rate. These are due to gravo-acoustic oscillations along the longitudinal axis during the sub-critical phase of growth, when the filament is far from equilibrium. The positions of the peaks in growth rate have a strong dependence on both the mass accretion rate onto the filament and the temperature of the gas. When seeded with a multi-wavelength density power spectrum there exists a clear preferred core separation equal to the largest peak in the dispersion relation. Our results allow observers to estimate a minimum age for a filament which is breaking up into regularly spaced fragments, as well as a maximum accretion rate. We apply the model to recent observations of fragmenting sub-filaments in Taurus and find accretion rates consistent with those estimated by observers.

Collaborators:

- A.P. Whitworth, Cardiff U, GB
- D.A. Hubber, LMU Munich, DE

Suggested Session:

Filaments



Caption: The column density projected onto the x-z plane at two different times. On the left, at t = 0.15 Myr, the filament has formed on the z axis, it is sub-critical and confined by the ram pressure of the accreting gas. On the right, at t = 0.55 Myr, the filament has become supercritical and is contracting radially, the seeded perturbations become sites of local collapse.

Understanding the influence of outflows on Gould Belt clouds

Emily Drabek-Maunder

I , L , GB

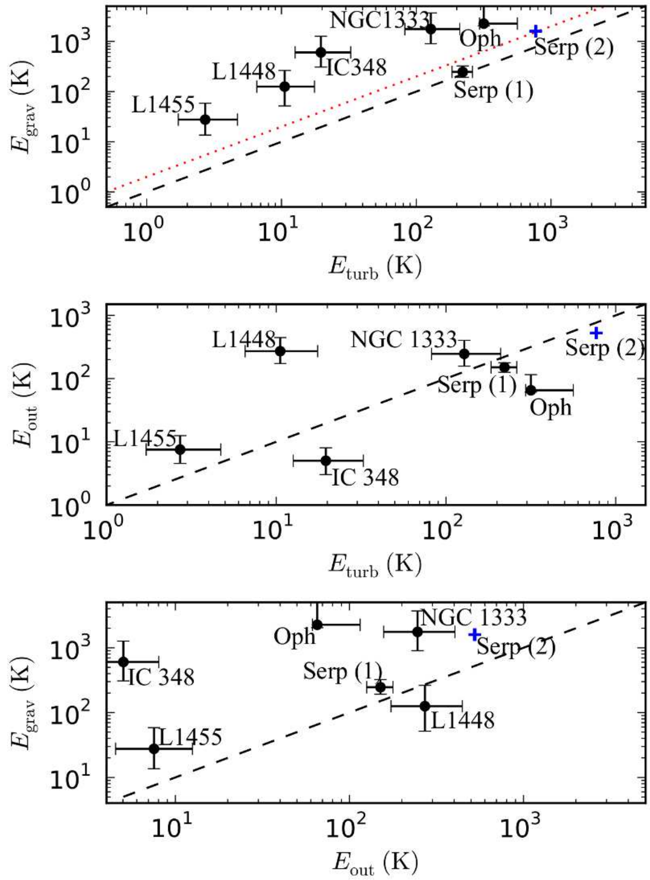
Using James Clerk Maxwell Telescope (JCMT) Gould Belt Survey data from CO J=3-2 isotopologues, we present a meta-analysis of the outflows and energetics of star-forming regions in several Gould Belt clouds. The majority of the regions are strongly gravitationally bound. There is evidence that molecular outflows transport large quantities of momentum and energy. Outflow energies are at least 20 per cent of the total turbulent kinetic energies in all of the regions studied and greater than the turbulent energy in half of the regions. However, we find no evidence that outflows increase levels of turbulence, and there is no correlation between the outflow and turbulent energies. Even though outflows in some regions contribute significantly to maintaining turbulence levels against dissipation, this relies on outflows efficiently coupling to bulk motions. Other mechanisms (e.g. supernovae) must be the main drivers of turbulence in most if not all of these regions.

Collaborators:

- J. Hatchell, Exeter, GB
- J.V. Buckle, Cambridge, GB
- J. Di Francesco, Victoria, CA
- J. Richer, Cambridge, GB

Key Reference:
http://mnrasl.oxfordjournals.org/content/457/1/L84.full.pdf

Suggested Session:
Stellar Feedback



Caption: This is a comparison between the turbulent kinetic, gravitational binding and outflow energies in multiple Gould Belt star-forming regions. Top: Comparison between the cloud turbulent kinetic ($E_{\rm turb}$) and gravitational binding energies ($E_{\rm grav}$), where the dashed line is $E_{\rm turb} = E_{\rm grav}$ and the dotted line shows $2E_{\rm turb} = E_{\rm grav}$. Centre: Comparison between the cloud turbulent kinetic and outflow kinetic ($E_{\rm out}$) energies, where the dashed line is $E_{\rm turb} = E_{\rm out}$. Bottom: Comparison between the outflow kinetic and cloud gravitational binding energies, where the dashed line is $E_{\rm out} = E_{\rm grav}$.

The Orion Radio All-Stars: new perspectives in stellar radio astronomy

Jan Forbrich
U V /C A, V , AT

In recent years, the sensitivity upgrades of both the NRAO Karl G. Jansky Very Large Array (VLA) and the NRAO Very Long Baseline Array (VLBA) have provided us with a much improved perspective on stellar centimeter radio emission. This is particularly true for young stellar objects where both radio and X-ray emission trace high-energy processes in the innermost vicinities of these objects. I will present first results of a deep C-band radio survey of the

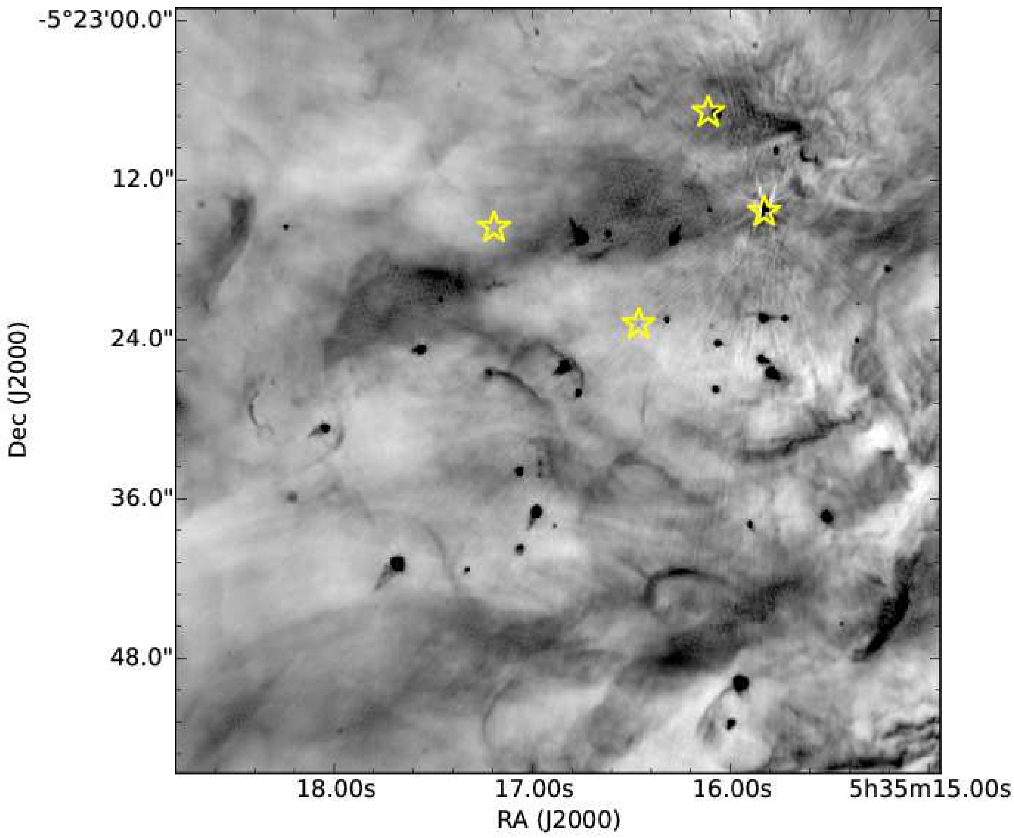
Orion Nebula Cluster (ONC), using the VLA and the VLBA, where additionally almost 24h of VLA observations were accompanied by simultaneous X-ray observations with Chandra. The VLA data have unveiled 556 compact radio sources in the ONC, a sevenfold increase over previous studies, as well as complex emission structures on a wide range of spatial scales, including the proplyds. The high sensitivity of the radio observations allow us to better disentangle thermal and nonthermal radio emission by assessing spectral indices, polarization, and variability. Combined with simultaneous radio-X-ray time domain information and comprehensive astrometric VLBA follow-up observations (not least as a decisive criterion of nonthermal emission), this project is providing unprecedented constraints on the magnetospheric activity of young stellar objects across a mass range from M dwarfs to massive stars and a new perspective on the impact of the massive Trapezium stars on their environment.

Collaborators:

- V. Rivilla, Arcetri, IT
- K. Menten, MPIfR, DE
- M. Reid, CfA, US
- C. Chandler, NRAO, US
- U. Rau, NRAO, US
- S. Bhatnagar, NRAO, US
- S.J. Wolk, CfA, US
- S. Meingast, Vienna, US

Suggested Session:

From Low- to High-Mass Star Formation



Caption: VLA view of the inner ONC, a small fraction of the survey field. These images show wideband continuum data with a reference frequency of 6.1 GHz (C-band). The locations of the main Trapezium stars Theta1 Ori A-D are marked with star symbols.

Prestellar core's chemistry: Modelling of the methanol emission in the prestelar core L1689B

Enrique Garcia-Garcia
IPAG, G , FR

The recent detections in prestellar cores of carbon chain molecules with six or more atoms, more commonly known as complex organic molecules (COMs), has provided a big challenge for the astrochemical community in the recent years. COMs are believed to be synthesised in the very first phases of star formation on the surface of dust grains. Simple molecules are hydrogenated and COMs form with the aid of mobile radicals (e.g. HCO) in the warm up phase at temperatures of 30-40 K. In the following stages and with the increase of the temperature (around 100 K), the content of the iced mantles is released to the gas phase. However, the low temperatures found in prestellar cores (close to 10 K) have cast doubts on this scenario; the mobility of radicals under this temperatures should be almost negligible. Recently, new astrochemical models have appeared. Non-thermal desorption processes like secondary UV photons, cosmic rays and chemical desorption reactions among others can provide radicals with enough mobility.
Beside the formation routes, there are still lot of open questions about the COMs formation in prestellar cores. In this contribution, we present the detailed modelling of the methanol (CH_3OH) emission (one of the most simple COMs) in the prestellar core L1689B. The emission is study using RATRAN, a 1-D non-LTE open code that calculates both the radiative transfer and the excitation of molecular lines based on the Monte Carlo method. We find that the methanol emission is better reproduced with profiles that present a higher density ($> 10^6$ cm^{-3}) and a lower temperature (< 7 K) in the central position of the cores. However, we discuss the effect of different source models and how the variation of this two parameters affects the modelling.

Collaborators:

- A. Bacmann, IPAG, FR
- A. Faure, IPAG, FR

Suggested Session:

Chemistry

Simulations of massive magnetized dense core collapse

Matthias Gonzalez
U P D - CEA, S , FR

Discs and outflows are observational features of star formation. While discs and outflows formation is becoming increasingly constrained thanks to radiation magnetohydrodynamics models in the context of low-mass star formation, it is not the case for massive star formation. We will present results of massive magnetized dense core collapse simulations including radiative feedback and ambipolar diffusion. We will show how magnetic fields and radiative feedback work together to launch outflows. We will study the formation and properties (early evolution and fragmentation) of the disc around the massive protostars.

Collaborators:

- B. Commercon, ENS Lyon, FR
- N. Vaytet, NBI, Copenhagen, DK
- J. Masson, U Exeter, GB
- G. Chabrier, ENS Lyon, FR

Suggested Session:

Massive Star Formation

Filament fragmentation at arbitrary length scales

Matthias Gritschneder
U M , M , DE

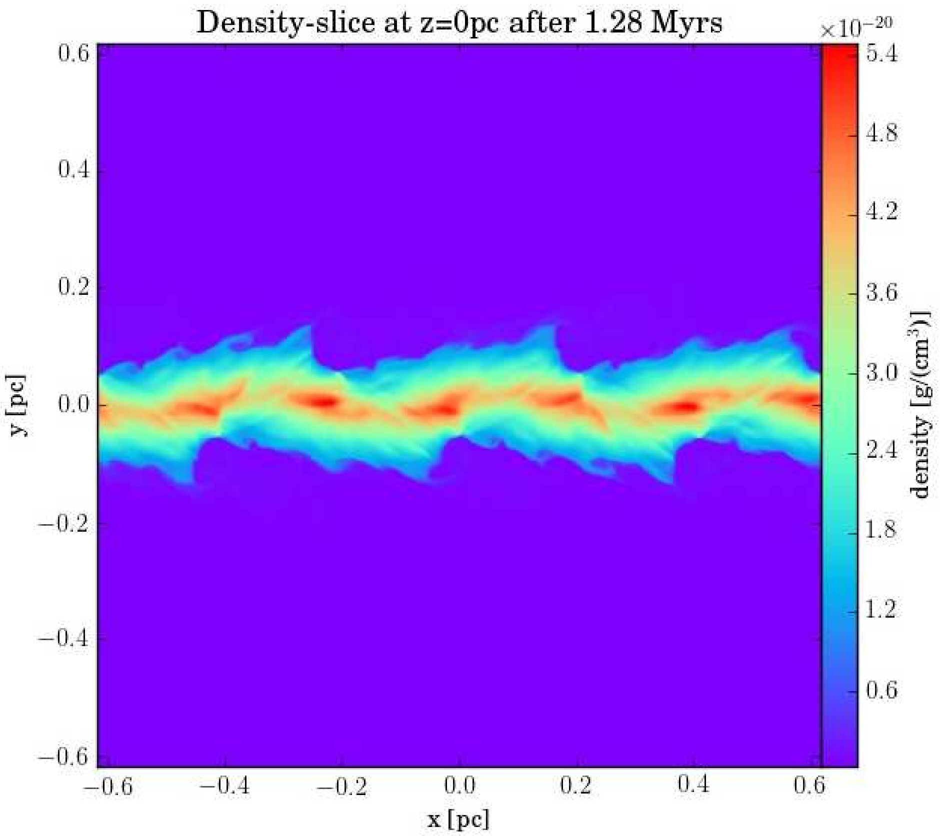
We analyze the stability of filaments in equilibrium between gravity and internal as well as external pressure using the grid based AMR-code RAMSES. It is well known that a straight marginable stable cylinder fragments into cores if the density is slightly perturbed. The cores form on the length scale of the fastest growing mode, set by the mass-to-line ratio of the filament. However, we discovered that a homogenous cylinder in a stable configuration starts to oscillate, is triggered into fragmentation, and collapses when it is bent, e.g. with a slight sinusoidal perturbation. This previously unstudied behaviour is important as it allows a filament to fragment at any given scale, as long as it has slight bends. In our realization in the figure below, the spacing between the cores matches the wavelength of the sinusoidal perturbation. We present a large scale parameter study investigating different wavelengths, different perturbations and various initial densities. With the help of these, we derive the oscillation period as well as the collapse timescale analytically from first principles. Furthermore, we study the behavior of a flow around the bent cylinder. The resulting surface perturbations are very reminiscent of the striation observed e.g. around B44.

Collaborators:

- A. Burkert, U Munich, DE
- S. Heigl, U Munich, DE

Suggested Session:

Filaments



Caption: KHI-instabilities around a bent cylinder in hydrostatic equilibrium. Cores have formed with a separation equal to the wavelength of the initial geometrical perturbation of the cylinder.

Non-linear dense core formation in filaments by gravitational fragmentation

Stefan Heigl

U M , M , DE

We present a solution for the observed core fragmentation of filaments in the Taurus L1517 dark cloud which previously could not be explained. Observations suggest that core formation is connected to the filamentary structure of the cloud gas, but it remains unclear which process is responsible. We show that, for certain inclinations of the filaments, the gravitational instability process of an isothermal cylinder can account for the exhibited fragmentation in L1517 under the assumption that the perturbation grows on the dominant wavelength.
We use three-dimensional numerical simulations with the code RAMSES, estimate observed column densities and line-of-sight velocities, and compare them to the observations. We argue that a major part of the evolution of the fragmentation is non-linear and this has a considerable impact on the evolution of the observables. Our method also allows us to estimate the external pressure in the surrounding medium.

Collaborators:

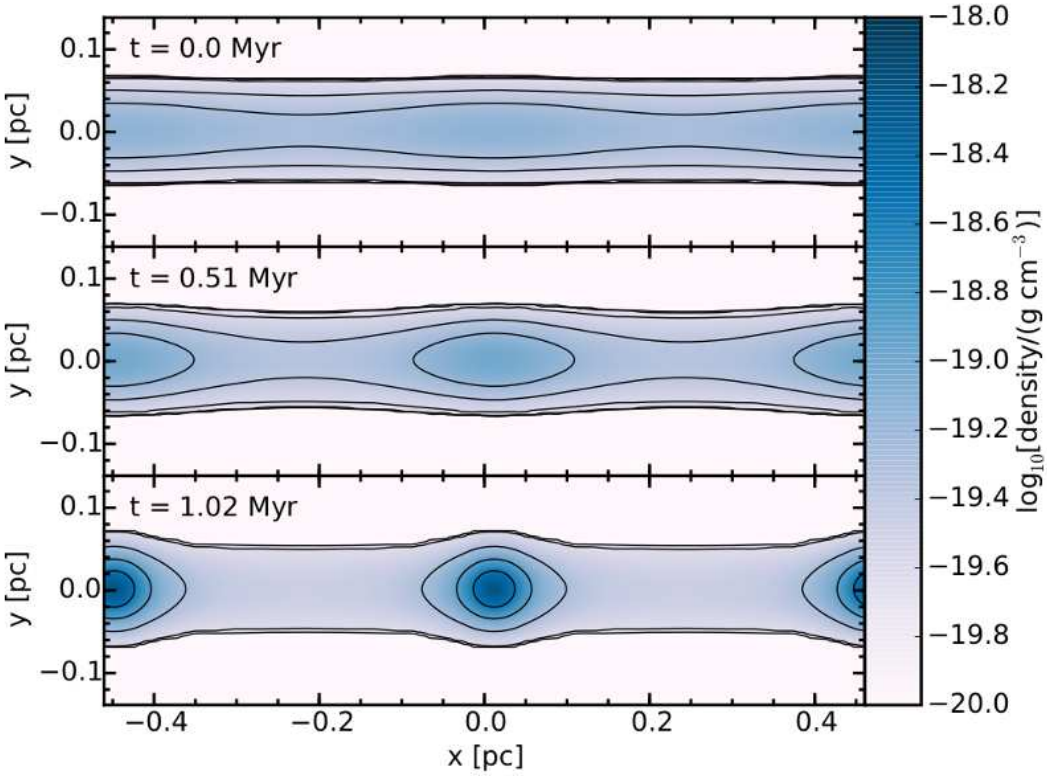
- A. Burkert, U Munich, DE
- A. Hacar, U Vienna, AT

Key Reference:

http://adsabs.harvard.edu/abs/2016arXiv160102018H

Suggested Session:

Filaments



Caption: Change from linear (first two panels) to non-linear evolution (third panel) in a density cut through the centre of the filament.

Feedback: the impact of supernovae remnants and H II regions

Patrick Hennebelle
CEA, P , FR

One major issue in our understanding of the star formation process is how to limit the collapse of giant molecular clouds, that is to say explain the star formation efficiency of about 5-10% inferred from observations. The most promising mechanism to accomplish this is the feedback due to the massive stars. How this may exactly works however remains uncertain. In the talk I will present a series of studies aiming to precisely quantify the influence of H II regions and supernovae explosions arising in molecular clouds or in their neighborhood. In particular, I will argue that the exact influence of the feedback depends sensitively on the correlation between the massive stars and the dense gas leading to large uncertainties.

Collaborators:

- Samuel Geen, CEA, FR
- Olivier Iffrig, CEA, FR
- Pascal Tremblin, CEA, FR

Key Reference:
http://adsabs.harvard.edu/abs/2015A%26A...576A..95I

Suggested Session:
Stellar Feedback

The dynamical properties of dense filaments in the infrared dark cloud G035.39-00.33

Jonathan Henshaw
LJMU, L , GB

Infrared Dark Clouds provide an exciting opportunity to identify the initial conditions for massive star formation. I will review our work from a recent series of papers that serves as a case study of IRDC G035.39-00.33, a massive, filamentary molecular cloud in an early stage of evolution.
I will compare and contrast high-sensitivity and high-spectral resolution IRAM 30m data (large-scale, ~ 0.5 pc resolution) and high-angular resolution data obtained with the Plateau de Bure Interferometer (small-scale, $<$ 0.1 pc resolution). Both data sets are extremely complex, with multiple spectral features at any given position. I will reveal that, in contrast to how G035 appears in extinction or column density maps (as a single filamentary structure), it, in fact, comprises a serpentine network of morphologically distinct and mildly supersonic sub-filaments. Whilst global velocity gradients throughout each sub-filament are small, there is evidence for dynamic processes on local scales. This suggests that the kinematics are influenced by the dense (and in some cases, starless) cores. The physical properties of these cores have been derived using 3.2mm continuum emission from the PdBI, and we identify possible candidates for the progenitors of intermediate-to-high-mass stars.

Collaborators:

- P. Caselli, MPE, DE
- F. Fontani, INAF, IT
- I. Jimenez-Serra, UCL, GB
- J.C. Tan, U Florida, US

Key Reference:
http://ukads.nottingham.ac.uk/abs/2014MNRAS.440.2860H

Suggested Session:
Filaments

Formation of proto-multiple stellar systems in a magnetized, fragmenting filament

Chat Hull
H /NRAO, C , US

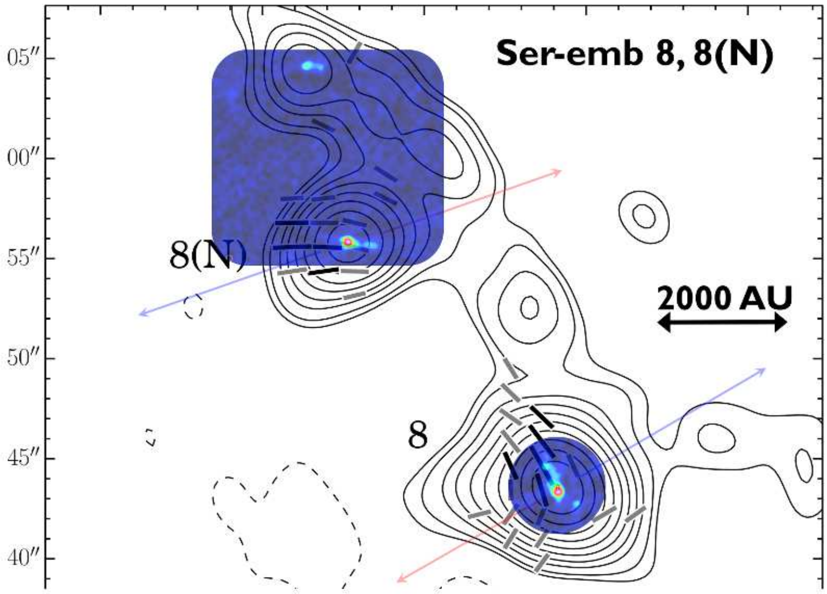
In just the past few years, it has become clear that filamentary structures are present in the star-formation process across many orders of magnitude in spatial scale, from the galactic scales probed by Planck and Herschel all the way down to the AU-scale structures that ALMA has revealed within protoplanetary disks. A similar story can be told of magnetic fields, which play a role in star formation across the same vast range of size scales. Here I show filamentary structures near three protostars in the Serpens Main star-forming region, as seen with both CARMA (at 1000 AU scales) and ALMA (at 150 AU scales!). Even at such high resolution, the ALMA data reveal that the main sources have a number of nearby condensations/companions, which may be the beginnings of multiple star systems. Additionally, the filamentary structures along which these companions lie coincide in a tantalizing way with the magnetic fields we mapped with CARMA. The morphology of the magnetic fields both in the filamentary companions and toward the peaks of the cores will be revealed by new Cycle 2 ALMA polarization data. These data comprise the highest resolution observations to date of polarized dust emission from Class 0 protostars, and will shed light on the role of magnetic fields in the formation of filaments, inner envelopes, and protoplanetary disks at 100 AU scales.

Collaborators:

- J.M. Girart, ICE, ES
- R. Plambeck, UCB, US
- R. Crutcher, UIUC, US
- Z.-Y. Li, UVa, US
- S.-P. Lai, NTHU, TW
- P. Cortes, ALMA, CL
- R. Rao, ASIAA, US
- M. Dunham, CfA, US
- and the TADPOL collaboration

Key Reference:
http://adsabs.harvard.edu/cgi-bin/bib_query?arXiv:1310.6653

Suggested Session:
Magnetic Fields



Caption: ALMA and CARMA observations of two Class 0 protostellar cores in the Serpens Main star-forming region. The black contours trace the CARMA 1.3 mm dust continuum; the line segments represent the inferred magnetic field orientation from the CARMA polarization data. The colorscale shows the ALMA 1.3 mm dust continuum data, highlighting tiny filamentary condensations that lie along the CARMA magnetic field. The red and blue arrows indicate the red- and blueshifted outflow lobes emanating from the two protostars.

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

Richard Klein
UC B /LLNL, B , US

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

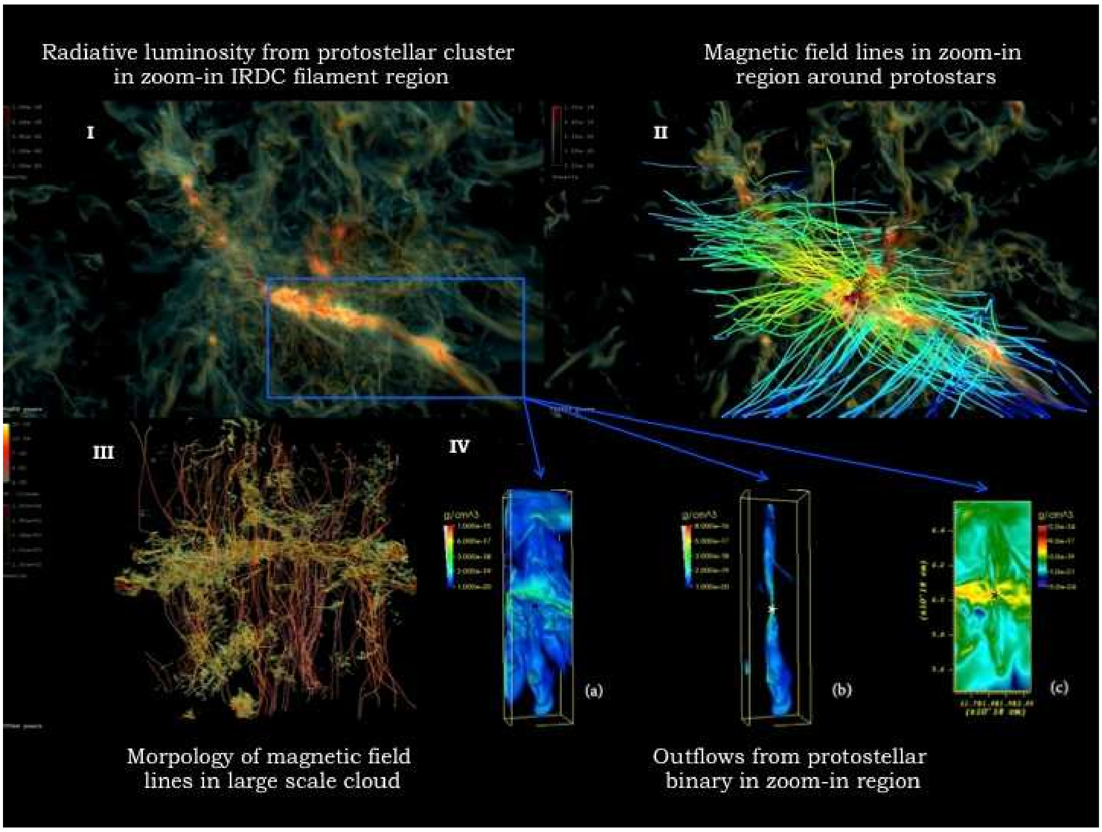
to form protostars and stellar clusters via AMR zoom-in simulations. Complex filamentary structures emerge naturally from the simulations. Magnetic field lines pierce the dark cloud filaments primarily in the direction normal to the filament axis. We then perform deep zoom-in simulations into the structure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

Collaborators:

- PS. Li, UC Berkeley, US
- C.F. McKee, UC Berkeley, US
- S. Li, UC Berkeley,US
- C. Safranek-Schrader, UC Berkeley, US
- M. Krumholz, ANU, AU
- E. Ostriker, Princeton U, US
- J. Stone, Princeton U, US
- C.-G. Kim, Princeton U , US

Key Reference:
http://adsabs.harvard.edu/abs/2015MNRAS.452.2500L

Suggested Session:
Stellar Feedback



Caption: The dynamics and evolution of a large-scale turbulent magnetized cloud are followed to the formation of a stellar cluster with Orion2 AMR radiation-magneto-hydrodynamic Zoom-in simulations. In panel (I) after 690,000 years the gravitational collapse of a large magnetized supersonically turbulent cloud has formed an IRDC filament. Within the dense IRDC filament ~ 4 pc in linear scale and with several levels of additional mesh refinement, a protostellar cluster consisting of ~ 40 protostars has formed after 690,000 years. The bright orange yellow regions are the radiative luminosity emitted by the cluster and the individual stars that have formed within the IRDC filaments. The protostars interact with their surroundings with radiation and protostellar outflow feedback supplying radiative heating and momentum to their environs. In panel (II) we see the morphology of the magnetic field lines deep into the zoom-in region and note that magnetic field lines are locally perpendicular to the main filament. In panel (III) we show the global structure of the magnetic field lines throughout the large-scale turbulent cloud and in panel (IV) we show outflows from a proto-stellar binary deep within the zoom-in cluster region: (a) volume rendering of total gas around a collimated outflow from the proto-stellar binary, (b) volume rendering of outflow gas with speed > 5 km s^{-1} showing the high velocity collimated outflow, (c) density slice through the binary shows the total gas around the outflow. The height of the bounding box is about 0.36 pc.

A census and properties of dense cores and filaments in the Aquila and Orion B cloud complexes

Vera Könyves
CEA, G - -Y , FR

One of the main scientific goals of the Herschel Gould Belt Survey is to elucidate the physical mechanisms responsible for the formation and evolution of prestellar cores in molecular clouds. Based on Herschel/SPIRE-PACS photometric data, we have recently identified a large

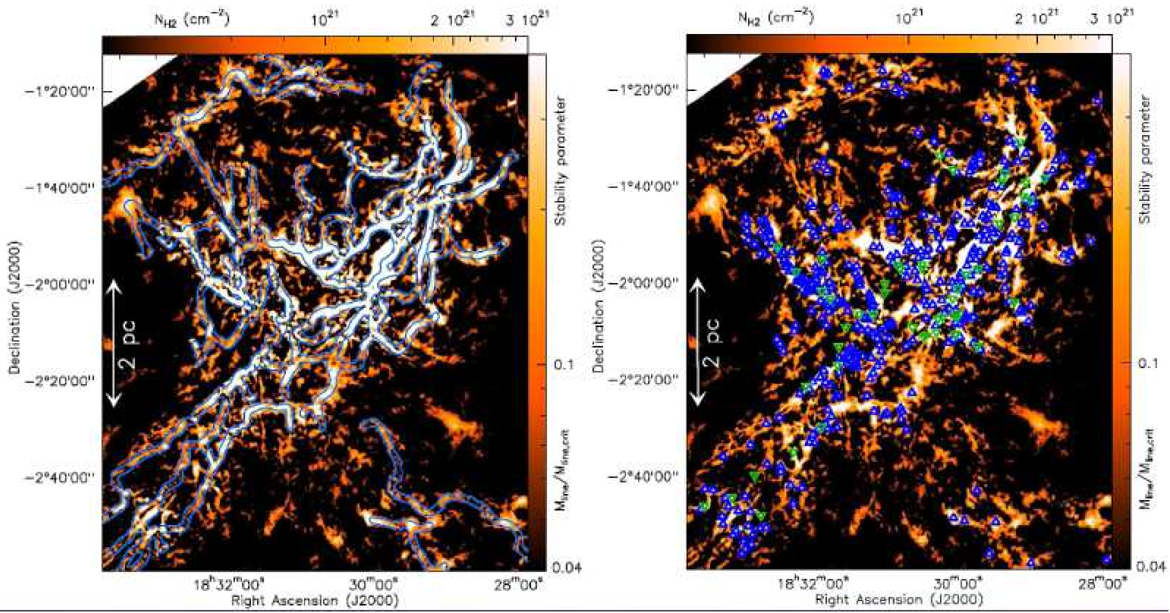
sample of such cores in the Aquila and Orion B molecular clouds.
Our Herschel observations also provide an unprecedented census of filaments in the nearby clouds and suggest an intimate connection between these filaments and the formation process of prestellar cores. We will compare and contrast some properties of the dense cores in the Aquila and Orion B complexes, such as their distributions in the filamentary background, masses, lifetimes, and formation thresholds.
In summary, our Herschel findings support a filamentary paradigm for the early stages of star formation, where the cores result primarily from the gravitational fragmentation of marginally supercritical filaments.

Collaborators:

- Ph. André, CEA, FR
- and the Herschel Gould Belt consortium

Key Reference:
http://adsabs.harvard.edu/abs/2015A%26A...584A..91K

Suggested Session:
From Low- to High-Mass Star Formation



Caption: Curvelet component of a portion of the Herschel H_2 column density map in Aquila, which is also equivalent to a map of the mass per unit length along the filaments (Andre et al. 2010). Left: The typical ~ 0.1 pc width of the filaments (Arzoumanian et al. 2011) is marked by the blue contours and the unstable filaments are highlighted in white. Right: In the same map, prestellar cores (blue triangles) and protostellar cores (green triangles) are overlaid (Könyves et al. 2015).

The physics setting the molecular cloud lifetime

Diederik Kruijssen
ARI/ZAH, H , DE

A wide range of recent work shows that galactic star formation (SF) relations between the gas mass (density) and the star formation rate (density) develop substantial scatter or even change form when considered below a certain spatial scale. In this talk, I will present our team's recent work on exploiting this multi-scale behaviour to determine ill-constrained, cloud-scale quantities such as the cloud lifetime, SF/feedback time-scales, SF efficiencies, feedback velocities, mass loading factors, and gravitational instability lengths, using galaxy-scale observations. This new method allows the constraints on SF and feedback from detailed solar neighbourhood studies to be extended across a more representative sample of extragalactic environments. The method has been validated using high-resolution numerical simulations of SF in disc galaxies. Since EPoS 2014, we have applied the formalism to a range of nearby galaxies, providing statistically representative measurements of the above cloud-scale quantities in M33, M31, as well as using high-resolution ALMA Cycle 2 observations of the nearby flocculent spiral NGC 300. These quantities provide a unique insight into the physics setting the molecular cloud lifetime, the star formation efficiency, and the disruption of clouds by feedback. In the ALMA era, our new technique enables the detailed characterisation of the SF process on the cloud scale in galaxies out to z=4, i.e. across a cosmologically representative part of the galaxy population rather than the limited sample of Local Group galaxies where such measurements were previously possible. This enables the systematic study of SF physics as a function of the cosmic environment.

Collaborators:

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- D. Haydon, ARI/ZAH, DE
- A. Hygate, MPIA, DE
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- E. van Dishoeck, Leiden, NL
- J. Dalcanton, Washington U, US

Key Reference:
http://adsabs.harvard.edu/abs/2014MNRAS.439.3239K

Suggested Session:
Galactic Star Formation

Multi-Physics of Feedback in Massive Star Formation

Rolf Kuiper
U T¨ , T¨ , DE

Stars are born within gas mass reservoirs, which collapse under their own gravity. Especially in the case of massive (proto)stars, a variety of feedback effects are opposing gravity and impact the natal environment of the forming star. We have performed simulations of the collapse of pre-stellar mass reservoirs including the feedback effects of thermal pressure, centrifugal forces, protostellar outflows, thermal radiation pressure, stellar radiation pressure, and ionization, i.e. high thermal pressure due to the formation of an HII region. In more than 30 individual core collapse simulations, we determine the importance of each of the individual feedback effects as well as their interplay, by including and excluding their contributions in the equations solved. The newly developed ionization solver makes use of a hybrid scheme for radiation transport and takes into account direct ionization by the UV spectrum of the protostar as well as diffuse UV from direct recombination into the ground state. Further numerical highlights of this study include sub-AU resolution around the forming protostar, the use of frequency-dependent ray-tracing for the stellar radiative feedback, and following the collapse over up to ten free-fall times in each of the simulations, covering the whole accretion phase of the protostar up to disk disruption. After stellar accretion has ceased, we quantify the efficiency of the individual feedback components in terms of the final mass of the star and the mass loss of the initial mass reservoir (see right panel of figure for an example data set). We find ionization feedback plays a role as important as radiative forces. Although initially the HII region is limited to the bipolar low-density cavity of the protostellar outflow, it increases the opening angle with time (see left panel of figure). Moreover, the experiments are performed for two different initial conditions representing different star formation scenarios with either a limited 100 $M_\odot$ mass reservoir corresponding to an isolated pre-stellar core or with a (virtually unlimited) 1000 $M_\odot$ large-scale mass reservoir corresponding to a globally collapsing region fed by filaments.

Collaborators:

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Key Reference:
http://adsabs.harvard.edu/abs/2015ApJ...800...86K

Suggested Session:
Massive Star Formation

Painting better pictures of early massive SF in the aftermath of Herschel

Hendrik Linz
MPIA, H , DE

While in 2006, the Herschel mission was still in its planning stage, 10 years later we are still harvesting the fruits that this satellite has given us in the meantime. At MPIA, we have followed a strategy to scrutinise a pre-selected sample of very young high-mass star-forming clumps (IRDCs and ISOSS-sources) in great detail within our Herschel programme "EPOS". While the population of Herschel point sources embedded in these regions has been addressed earlier, we discuss here the morphological FIR fine-structure of the regions and their relation to the gas properties. We will present individual follow-up studies with both single-dish telescopes and interferometers. The IRAM 30-m, APEX and MOPRA studies highlight the chemical complexity of the regions and put a simple IRDC vs HMPO divide into question. Especially the interferometer studies reveal the complex dynamics within the more filamentary clumps on linear scales $<$ 10,000 AU. Several (partly merging) velocity components can often be distinguished already with our NOEMA studies. For one grand-design IRDC filament we managed to secure 3-mm mosaicking data with ALMA over an extent of $>$ 7 pc, which reveals a mazy composition of sub-filaments in dense-gas tracers like N_2H^+ that is not obvious in the IRDC's mid- and far-IR continuum appearance. Putting all our results together, we discuss to what extent this multi-facetted phenomenology can also be retrieved from current models of early (higher-mass) star formation.

Collaborators:

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- O. Krause, MPIA, DE
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- T. Vasyunina, SAP, DE

Key Reference:

http://adsabs.harvard.edu/abs/2015A%26A...581A.119B

Suggested Session:

Massive Star Formation

Circumstellar disks of the most vigorously accreting young stars

Baobab Liu

ESO, M , DE

We imaged a sample of unusually actively accreting young stellar objects (YSOs), namely the FU Orionis objects, with extremely high contrast and resolution, using the Subaru 8.2 m Telescope. These observations unveiled large-scale gas arms and arcs surrounding the protostars. They are smoking guns of chaotic gravitational interactions between protostars and protoplanetary disks, which are kneading the protoplanetary disk material into condensed gas clumps. The occasional violent accretion of young stars may be via engulfing those condensed gas clumps with the large-scale gas arms and arcs.

Collaborators:

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- T.-S. Pyo, NAOJ, JP
- M. Fukagawa, NAOJ, JP
- M. Tamura, Univ. Tokyo, JP
- Th. Henning, MPIA, DE
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Suggested Session:

Disk Formation

Observing massive star formation feedback: what optical and near-infrared integral field spectroscopy can do for you

Anna McLeod

ESO, G , DE

Throughout their entire life, massive stars deeply affect their surroundings: via outflows when they first form, via strong stellar winds and powerful ionising radiation later on, and via energetic supernovae explosions when their life ends. These effects can be followed and quantified by simulating their formation and evolution within molecular clouds, but observationally speaking, the quantification of the feedback mechanisms is very difficult. The difficulties can, however, be overcome in the era of integral field spectroscopy (IFS). The results of recent observations of a variety of structures and environments will be shown, carried out with the IFS MUSE and KMOS at the VLT, operating in the optical and near-infrared respectively. In our observational campaign we targeted pillar-like structures, HII regions and massive star forming regions like W49 and W33, detecting photo-evaporative flows, ultra-compact HII regions, expanding bubbles and accretion features (as shown in the figure). With the unprecedented combination of spatial and spectral resolution of IFS, we were also able to detect and classify the possible massive O-stars responsible for the feedback in these regions. Ultimately, we will discuss how the comparison of several regions can lead to a quantification of massive star formation feedback.

Collaborators:

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- R. Galvan-Madrid, IRyA, MX
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- M. Gritschneder, USM, DE
- P. Klaassen, ROE, GB
- H.-Y. Lu, ESO, DE
- J. Mottram, MPIA, DE
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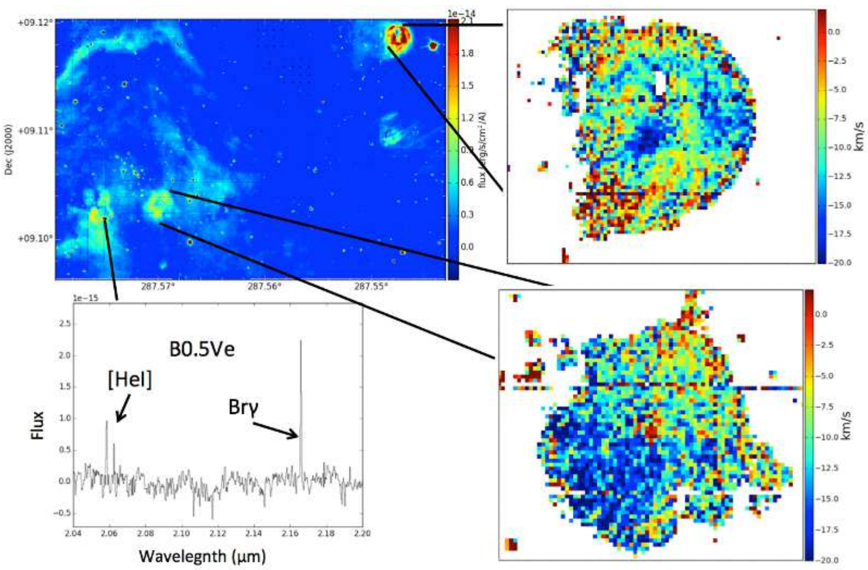
- S. Ramsay, ESO, DE

Key Reference:

http://adsabs.harvard.edu/abs/2015MNRAS.450.1057M

Suggested Session:

Stellar Feedback



Caption: KMOS Br gamma integrated intensity map of the massive star forming region W49A (upper left panel), where ongoing feedback can be observed. The upper right panel shows a zoom-in of the corresponding velocity map of a ring-like structure seen in the Br gamma map, at the center of which a massive young stellar object (YSO) is found: the ring-like structure is recovered by the velocity map, and shows a layered shape. The lower right panel is the same as the previous one around another massive YSO, but this time the velocity structure shows a gradient of about 10 km/s in North-East/South-West direction, most probably indicating infall or outflow. The lower left panel shows the extracted near-infrared spectrum of a star, with which a tentative classification of a B0.5Ve star was possible.

The role of local environment in the formation of massive stars

Joseph Mottram

MPIA, H , DE

How do the composition and kinematics of massive star forming environments affect the properties of the high-mass protostars that are forming in them? How is the degree of fragmentation and mass on disk-like scales related to the larger reservoir of dust and gas that they reside in? Are the 10^{-4} $M_{\odot}$/yr and higher mass accretion rates and/or flattened envelope structures required by many current theories to form the most massive stars seen in real systems? Does feedback have more of an impact on large or small scales and what is the size (and shape) of the mass reservoir systems forming massive stars? These are all key questions to developing a full, comprehensive and prescriptive theory of how the most massive stars form. What is more, answering them requires multi-scale observations of both the continuum and molecular lines. I will present early results from the CORE NOEMA large program, which is designed to answer such questions by combining observations with multiple PdBI configurations and the IRAM 30m of 20 high-mass star forming regions with $L > 10^4$ $L_{\odot}$. As such we have one of the largest datasets to date of high-mass star-forming regions with sensitivity to emission on spatial scales from ~ 0.4 pc to < 1000 AU, ideal for tackling these fundamental questions.

Collaborators:

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- F. Bosco, MPIA, DE
- and the CORE team

Key Reference:

http://adsabs.harvard.edu/abs/2013A%26A...558A..81B

Suggested Session:

Massive Star Formation

Are Prestellar Cores Magnetically-Subcritical?

Fumitaka Nakamura

NAOJ, M , JP

Magnetic fields play an important role in the process of star formation. However, it remains uncertain how important the magnetic field is. Previous Zeeman observations are mainly done with HI and OH. However, HI and OH do not trace dense gas but only trace the less-dense gas in clouds or envelopes of dense cores. CN traces the dense gas with 10^5 cm^{-3}. But, CN Zeeman observations are limited toward high-mass-star-forming regions where already stars are formed.

To constrain the role of magnetic field in the process of gravitational contraction of cores, we carried out the Zeeman observations using the Nobeyama 45-m telescope. Our target line is a CCS (JN=43-32) line at 45 GHz. CCS is abundant only in the PRESTELLAR phase and the critical density is about 10^4 cm^{-3}. CCS also show relatively large Zeeman splitting. Therefore, CCS is the best line to trace the magnetic field associated with dense cores. To do the Zeeman observations, we first developed the 45 GHz-band dual-linear polarization receiver and a spectrometer with 60 Hz resolution, and installed them in the Nobeyama 45-m system.

Then we conducted the CCS (43-32) Zeeman observations toward TMC-1, a well-studied prestellar core in Taurus molecular cloud. We simultaneously observed CCS (JN=43-32) and HC_3N (J=5-4) and detected the Stokes V spectrum of CCS with 135 GHz splitting of S/N ~ 9, and no split for the HC_3N spectrum. The HC_3N line is a non-Zeeman line, and no-detection

of HC_3N Stokes-V verifies the robust detection of CCS Zeeman splitting. The detected split 135 GHz of CCS corresponds to the field strength of 211 micro-Gauss. The density of gas traced with CCS is estimated to be 3×10^4 cm^{-3}. from the LVG analysis using multi-line data. The estimated plasma beta is 0.01. Using this value, the flux-to-mass ratio is estimated to be more than twice the critical value, where we used the column density of a few times 10^{22} cm^{-3} estimated from $C^{18}O$ and extinction data. If we take into account the inclination assuming a plan-parallel sheet-like geometry, the flux-to-mass ratio is 5. In other words, the TMC-1 is magnetically subcritical. This is the first discovery of a magnetically subcritical core.
By May 2016, we plan to observe one or two more prestellar cores. So, I will include results of these additional observations in my presentation. In my presentation, I will discuss the importance of magnetic field in the evolution of prestellar cores, based on our observational results.

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Key Reference:
http://ads.nao.ac.jp/doi/10.1093/pasj/psv088

Suggested Session:
Magnetic Fields

Infalling-Rotating Envelopes and Disks around Low-Mass Protostars

Yoko Oya
U T , T , JP

One of the important frontiers in star-formation studies is to understand when and how rotationally-supported disks are formed around young low-mass protostars. This is essentially a problem of conservation and dissipation of the angular momentum of the infalling gas, and is possibly related to the outflow phenomenon. We here report high-spatial-resolution observations toward a few protostars with ALMA to tackle with this problem.
L1527 (d = 137 pc) is a low-mass Class 0-I source, which is known as a typical warm-carbon-chain chemistry (WCCC) source characterized by rich carbon-chain molecules. In this source, an infalling-rotating envelope (IRE) is selectively traced by CCH, c-C_3H_2, and CS, which is beautifully reproduced by the simple ballistic model (Figure a), as shown in Figure (c). The centrifugal barrier of the IRE is thus clearly identified at the radius of 100 AU, which is defined as the perihelion radius in the ballistic model (a half of the centrifugal radius). We also observed the evolved WCCC source, TMC-1A, and found that the above feature of the IRE is seen in this Class I source. Outflow components are also identified in L1527 and the other WCCC source IRAS 15398-3359, whose kinematic structures are essentially explained with a parabolic model. In addition to the WCCC sources, we also analyzed the ALMA archival data toward IRAS 16293-2422 Source A (d = 120 pc), which is known as a typical hot corino source, characterized by rich complex organic molecules (COMs). In this source, OCS is found to trace the IRE, which can also be explained by the simple ballistic model. Although the IREs are traced by different molecular species in the WCCC and hot corino sources, their kinematic structures can be explained by the same IRE model. The analysis of the IRE is of particular importance, because it gives us estimates of the protostellar mass and the specific angular momentum of the IRE.
Moreover, the H_2CO lines toward L1527 and IRAS 15398-3359 as well as the H_2CS lines toward IRAS 16293-2422 Source A have high-velocity components concentrated to the protostar

(Figure e), suggesting the existence of rotationally-supported disks inward of the centrifugal barrier. The kinematic structure of H_2CS inward of the centrifugal barrier in IRAS 16293-2422 is well explained by the Keplerian model with the protostellar mass (0.75 $M_\odot$) derived from the above analysis (Figure f).

These results provide us an important clue to understanding physical structures of the transition zone from the IRE to the rotationally-supported disk. It is generally thought that the disk radius is close to the centrifugal radius. However, the high-angular-resolution observations reveals that this expectation is too simplified. The infalling gas seems to keep infalling to the centrifugal barrier to some extent in the above sources. Such a feature of the transition zone may be related to launching mechanisms of molecular outflows through the angular momentum of the infalling gas.

Collaborators:

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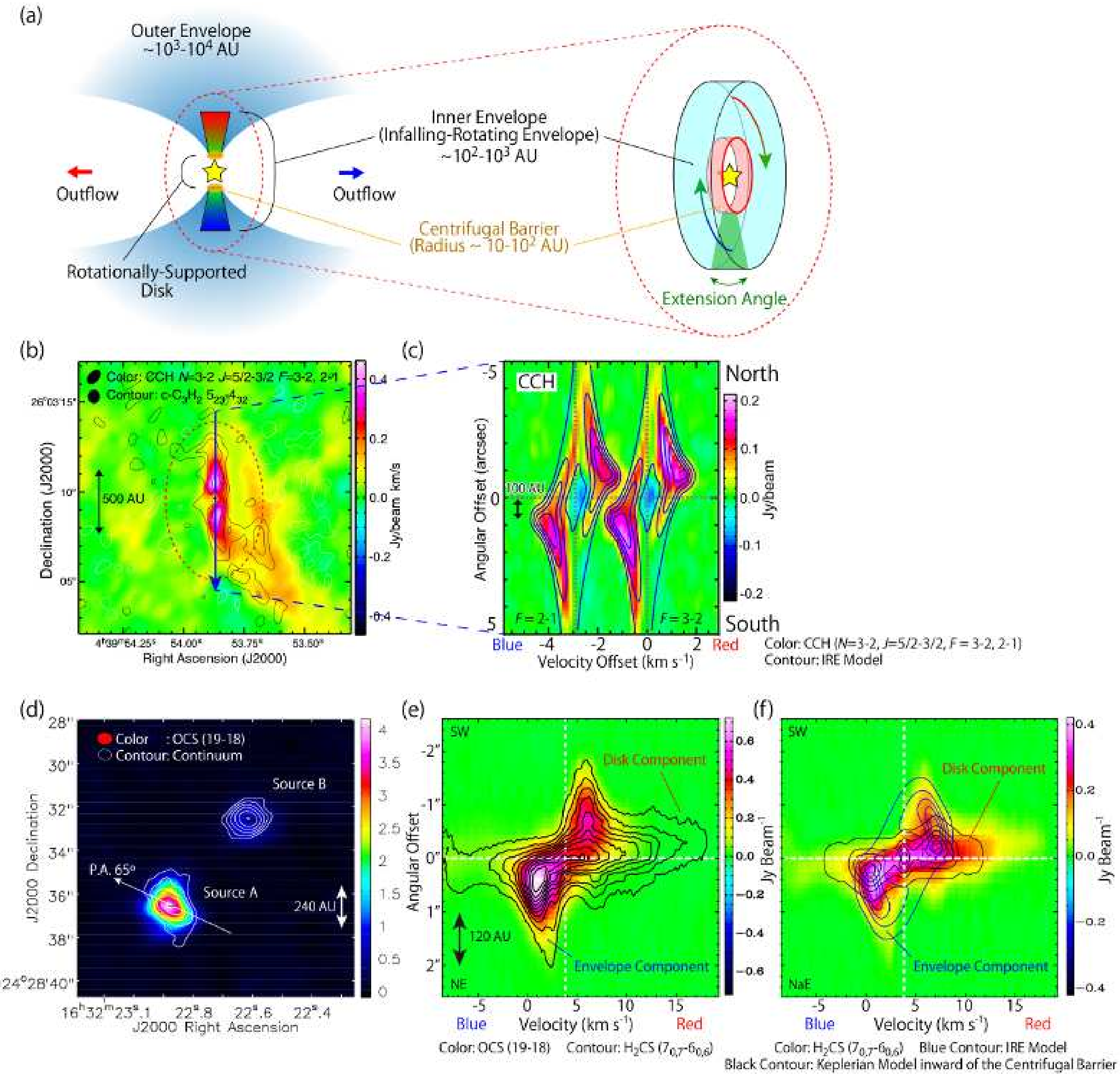
Key Reference:

http://adsabs.harvard.edu/abs/2015ApJ...812...59O

Suggested Session:

Disk Formation



Caption: (a) Schematic illustration of the gas components in a protostellar core. The kinematic structure in the inner envelope component, which is assumed to be cylindrical around the protostar, is analyzed with our infalling-rotating envelope model. (b) Integrated intensity maps of CCH (color) and c-C_3H_2 (black contours) toward L1527. The area surrounded by a dashed red ellipse corresponds to the inner envelope component in panel (a). (c) Position-velocity diagrams of the two hyperfine components of CCH (color) toward L1527 and the result of the infalling-rotating envelope model (blue contours). The position axis is shown by a blue arrow in panel (b). Blue contours are every 20% from 5% of the peak intensity. (d) Integrated intensity map of OCS (color) and the continuum map (white contours) toward IRAS 16293-2422. Contour levels for the continuum are 10, 20, 40, 80, 160, and 320 σ, where σ = 2 mJy/beam. (e) Position-velocity diagrams of OCS (color) and H_2CS (black contours) toward IRAS 16293-2422 Source A. The position axis is shown by a white arrow in panel (d). Black contours are every 20 σ starting from 10 σ where σ = 2.0 mJy/beam. (f) Position-velocity diagrams of H_2CS (color) and the results of the infalling-rotating envelope model (blue contours) and the Keplerian model inward of the centrifugal barrier (black contours). The position axis is the same as that in panel (e). Contours for the two models are every 20% from 5% of the peak intensity in the each model.

On the fragmentation of filaments and the origin of wide separation multiples

Jaime Pineda

MPE, M , DE

The initial multiplicity of stellar systems is highly uncertain, but it provides an important constrain to the understanding of star formation. A number of mechanisms have been proposed to explain the origin of binary and multiple star systems, including core fragmentation, disk fragmentation and stellar capture. Observations show that protostellar and pre-main-sequence multiplicity is higher than the multiplicity found in field stars, which suggests that dynamical interactions occur early, splitting up multiple systems and modifying the initial stellar separations. Here we report observations of a wide-separation (1,000 au) quadruple system composed of a young protostar and three gravitationally bound dense gas condensations. These condensations are the result of fragmentation of dense gas filaments, and each condensation is expected to form a star on a time-scale of 40,000 years. We determine that the closest pair will form a bound binary, while the quadruple stellar system itself is bound but unstable on timescales of 500,000 years (comparable to the lifetime of the embedded protostellar phase). These observations suggest that filament fragmentation on length scales of about 5,000 au offers a viable pathway to the formation of multiple systems.

Collaborators:

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- A.A. Goodman, CfA, US
- P. Caselli, MPE, DE
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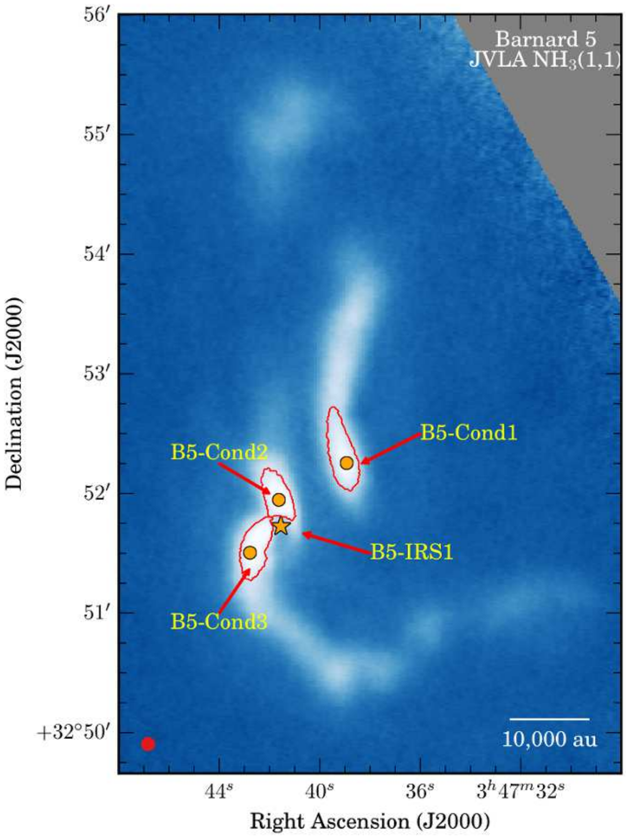
Key Reference:

http://adsabs.harvard.edu/abs/2015Natur.518..213P

Suggested Session:

Fragmentation



Caption: High-angular resolution image of dense gas and stellar progenitors. Background image shows the dense gas traced by $NH_3(1,1)$ and observed using the Jansky VLA and GBT. It reveals two filaments, which together host three gravitationally bound condensations. Red contours and circles show the condensation boundaries and centers, while the star indicates the protostar location. The angular resolution of the observations and scalebar are shown in the bottom left and bottom right corner, respectively.

Uncovering episodic outflows and their feedback in protostellar clusters

Adele Plunkett
ESO, S , CL

Protostars drive energetic jets that entrain surrounding gas in the form of outflows, simultaneously injecting momentum in the surrounding gas. Hence, outflows are a bridge for feedback from individual protostars to their nascent cluster environment. The outflow morphology and efficiency of momentum transfer between jet-outflow-cluster likely determines the extent to which outflows provide significant feedback to regulate ongoing star formation. This is especially relevant in clusters, which are the most common environments for star formation. Comprehensive observing campaigns of outflow feedback in clusters should incorporate single dish and interferometer observations that are sensitive to emission on cluster (few parsecs) to core (hundreds of AU) scales, respectively. Here we present such observations and analysis of the protostellar cluster Serpens South, which is experiencing an early and active phase of star formation. Following the combination of IRAM + CARMA (single dish + interferometer) maps of Serpens South, recent ALMA observations feature several cases of complex outflow morphologies near the central "hub" region that we mapped. The complementary ALMA, CARMA, and IRAM observations probe scales ranging from 400 AU to 0.8 pc. High-resolution observations clearly link outflows with their driving sources, and in this case they reveal an episodic accretion and launch mechanism. Highly-collimated, episodic outflows likely provide efficient momentum transfer for driving turbulence. This suite of observations provides constraints for simulations of protostellar outflows in clusters that (should) include episodic accretion and outflow-driven turbulence.

Collaborators:

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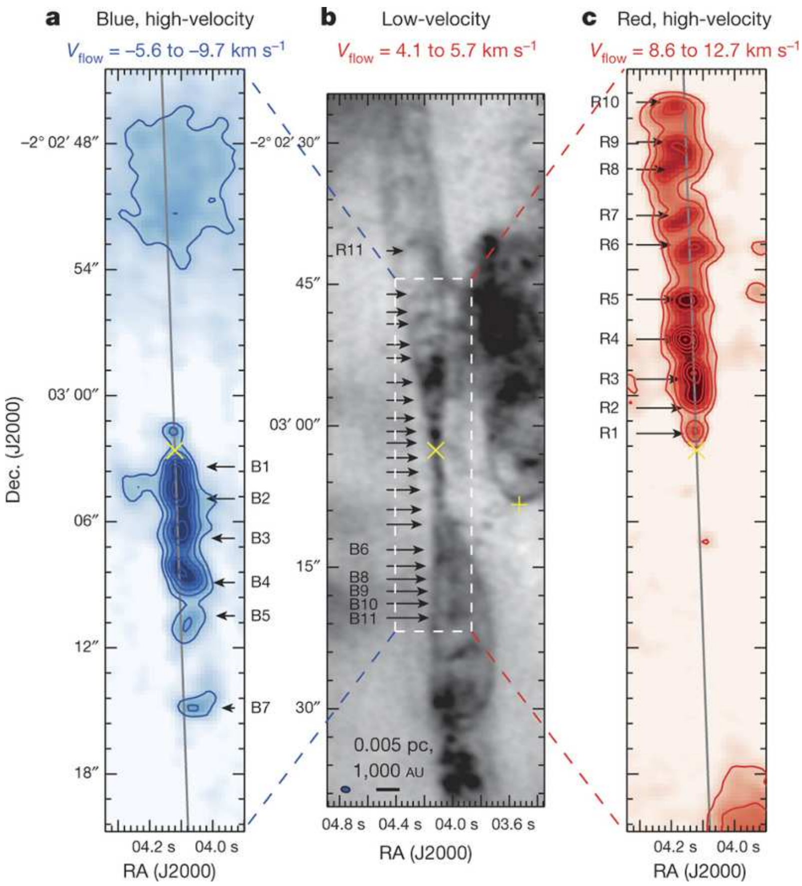
Key Reference:
http://adsabs.harvard.edu/abs/2015Natur.527...70P

Suggested Session:
Stellar Feedback



Caption: Episodic outflow from the protostar CARMA-7 (yellow cross) in Serpens South. Here we show a region about 1′ (0.1 pc) in length, and in total we mapped $2' \times 4'$ in Serpens South where more than 10 protostars reside. Panels (a, c) show high-velocity blueshifted and redshifted CO (2-1) emission, respectively. Panel (b) includes low-velocity CO emission, showing the cavity surrounding collimated ejecta. Labels B1-B11 and R1-R11 indicate 22 ejecta features. The grey lines mark the 4 degree position angle of the C7 outflow lobes, which are very collimated and include episodic bursts. The yellow "plus" symbol marks a neighbouring protostar, CARMA-6, which also drives an outflow with velocities not shown here. (Figure from Plunkett et al. 2015, Nature.)

Observational Evidence for Turbulence Dissipating in Giant Molecular Clouds

Andy Pon
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Simulations show that the supersonic turbulence in molecular clouds will dissipate rapidly, on the order of crossing times, if the turbulence is not further driven. We have run models of low velocity shocks in fully molecular conditions to show that CO lines are the most effective lines at removing turbulent energy from a cloud. We also predict that mid-J CO lines, towards regions with interstellar radiation fields of the order of unity, should trace a hot gas component created by the dissipation of turbulent energy. We present observations of low-mass and high-mass star-forming showing signs of just such a hot gas component and discuss the implications of these observations in terms of this shock dissipation framework.

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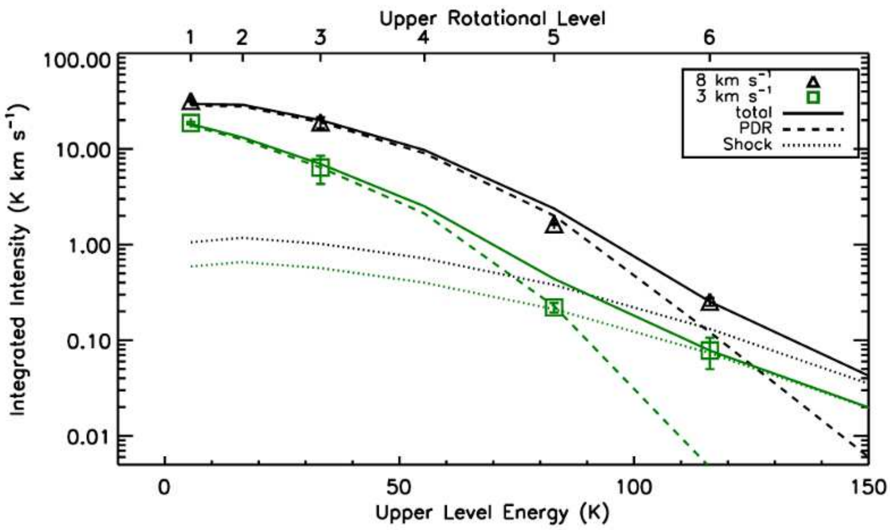
Key Reference:
http://adsabs.harvard.edu/abs/2014MNRAS.445.1508P

Suggested Session:
Turbulence



Caption: CO observations towards the Perseus B1-E5 starless clump are shown as the points. The triangles (black) and squares (green) are for the 8 and 3 km/s components detected in the spectra, respectively. The dashed line shows the best fit PDR model, for the ambient unshocked gas, while the dotted line shows the best fit model for the hot, shock heated gas. The solid line shows the combined fit. Note that the CO 6-5 transition has too large of an integrated intensity for the PDR models, such that a hot gas component is required to fit the complete CO SLED.

Distribution and mass of diffuse and dense CO gas in the Milky Way

Julia Roman-Duval

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Emission from carbon monoxide (CO) is ubiquitously used as a tracer of dense star forming molecular clouds. There is, however, growing evidence that a significant fraction of CO emission originates from diffuse molecular gas. Quantifying the contribution of diffuse CO-emitting gas is vital for understanding the relation between molecular gas and star formation. We examine the Galactic distribution of two CO-emitting gas components, a high column density component detected in ^{13}CO and ^{12}CO, and a low column density component detected in ^{12}CO, but not in ^{13}CO. The "diffuse" and "dense" components are identified using a combination of smoothing, masking, and erosion/dilation procedures, making use of three large-scale ^{12}CO and ^{13}CO surveys of the inner and outer Milky Way. The diffuse component, which globally represents 25 (1.5×10^8 M$_{\odot}$) of the total molecular gas mass (6.5×10^8 M$_{\odot}$), is more extended perpendicular to the Galactic plane. The fraction of diffuse gas increases from 15% at a galactocentric radius of 3 kpc to 50

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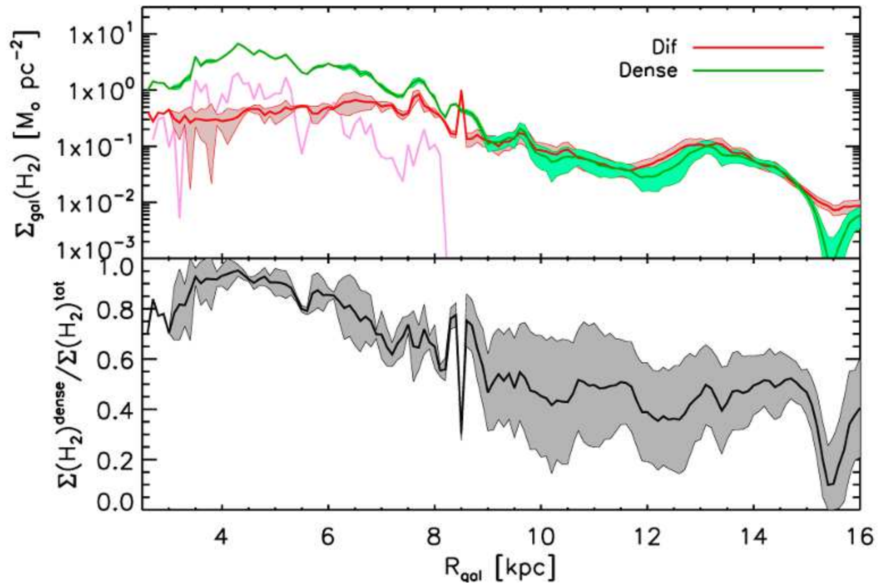
Key Reference:

http://arxiv.org/abs/1601.00937

Suggested Session:

Molecular Clouds



Caption: Average Galactic H2 surface densities of the diffuse (red, detected in ^{12}CO, undetected in ^{13}CO) and dense (green, detected in ^{12}CO and ^{13}CO) components as a function of Galactocentric radius (in bins of width 0.1 kpc), in logarithmic scale, combining all data sets (GRS, UMSB and EXFC surveys). In the inner Galaxy, the pink line indicates the surface density of H$_2$ in molecular clouds identified in Roman-Duval et al. (2010).

Physical properties of transition regions between atomic and molecular gas in the interstellar medium with the THOR survey

Michael Rugel
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What are the physical properties and the morphology of the transition regions between atomic and molecular gas in giant molecular clouds? Diffuse OH gas has been found previously in transition regions between atomic and molecular gas, and therefore is a promissing tool to investigate these questions.
As part of the THOR project (THOR - The HI, OH, Recombination Line survey of the Milky Way), we map four OH ground state hyperfine transitions (1612, 1665, 1667 and 1720 MHz) in the northern part of the Milky Way (l = 15deg - 67deg, $|b|$ = +/- 1deg) with 20″ resolution. We present absorption observations against galactic and extragalactic continuum sources. We determine kinematic properties, optical depth profiles and column densities for each absorption detection. The line ratios of the four transitions give insight into the excitation properties of the diffuse OH gas.
The OH absorption detections are compared to existing galactic surveys in atomic and molecular gas tracers, such as ^{13}CO (GRS), HI absoprtion and emission observations (THOR/VGPS) and dense gas tracers such as HCO^{+} (BGPS), in order to investigate turbulent properties and ionization levels in different density regimes of molecular and atomic gas. Investigation of OH absorption in different environments, such as their the vicinity to HII regions or SNR, and its location in the galactic plane, will allow us to test influences of external physical processes.

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Suggested Session:

Molecular Clouds

Chemical Diversity in Low-Mass Star-Forming Cores and It's Future toward the Protoplanetary Disks

Nami Sakai
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It is well known that low-mass protostellar cores show significant chemical diversity. One distinct case is hot corino chemistry characterized by rich saturated complex organic molecules, while the other distinct case is warm carbon-chain chemistry (WCCC) characterized by rich carbon-chain molecules. However, only a few sources each are definitively classified into them, and the statistics is apparently poor. To overcome this situation, we have conducted an unbiased survey of chemical composition toward 37 Class 0 and Class I protostars in the Perseus molecular cloud complex at the 1.3 mm and 3 mm bands with the IRAM 30 m telescope and the NRO 45 m telescope, respectively. We have detected multi-transition lines of CCH, c-C_3H_2, and CH_3OH toward most of the sources. The result shows clear chemical diversity, where many intermediate sources between the two distinct cases are found. Especially, we have found a marginal but interesting trend that isolated sources and sources in cloud peripheries tend to be like the WCCC source. The relative occurrence of each category (hot corino chemistry, WCCC, or intermediate) as well as preferential association of the sources in each category with a specific part of the cloud complex will give us an important clue to understanding the origin of the chemical diversity in terms of evolutionary and/or environmental effects.

More importantly, we have recently studied sub-arcsecond molecular distributions in the prototypical WCCC source L1527 and the prototypical hot corino source IRAS 16293-2422 observed with ALMA, and have found that the chemical diversity is also evident in the closest vicinity (100 AU) around the protostar. In the WCCC source L1527, the infalling-rotating envelope is well traced by CCH, c-C_3H_2, and CS, and its centrifugal barrier r = 100 AU is highlighted by SO. Carbon-chain molecules are depleted onto dust grain after passing through the centrifugal barrier, and are thought to be delivered to the protoplanegary disk in the solid phase. In the hot corino source, the infalling-rotating envelope is traced by OCS, and its centrifugal barrier (r = 50 AU) is highlighted by the saturated organic molecules, CH_3OH and $HCOOCH_3$. Considering these ALMA results along with the chemical diversity of the protostellar cores found in the Perseus region, significant chemical diversity is expected in a disk-forming zone (~ 100 AU) and even in protoplanetary disks. Thus, the chemical diversity is becoming more and more important in considering the "chemical" origin of the Solar System.

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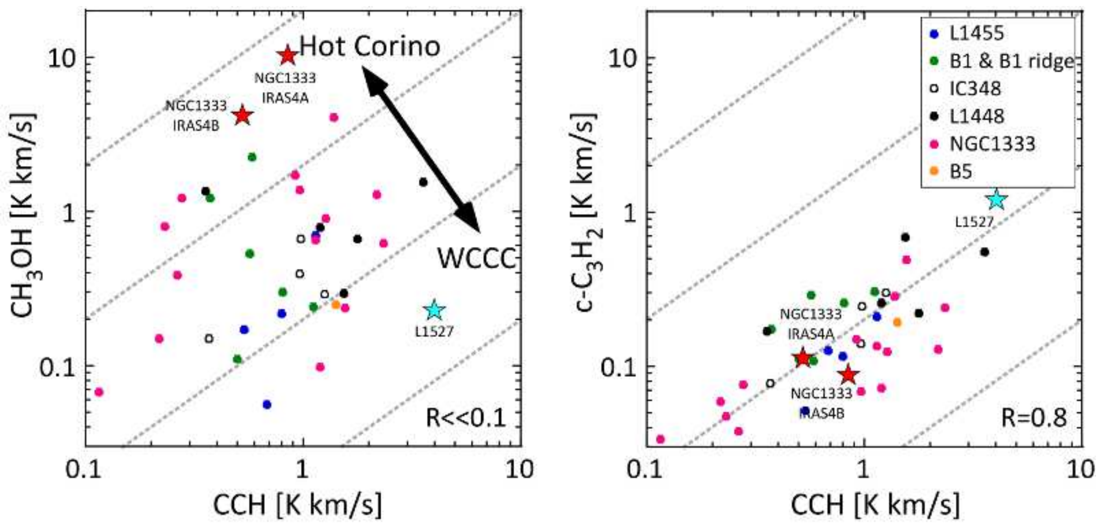
Key Reference:

http://ads.nao.ac.jp/abs/2014ApJ...791L..38S

Suggested Session:

Chemistry



Caption: (Left) The correlation plot between the integrated intensities of the the CCH (N=3-2, J=7/2-5/2, F=4-3, E_u = 25 K) and CH_3OH (J=5-4, K=0 A, E_u = 50 K) line. (Right) The correlation plot between the integrated intensities of the the CCH (N=3-2, J=7/2-5/2, F=4-3, E_u = 25 K) and c-C_3H_2 ($3_{21}2_{12}$, E_u = 18 K) line.

Wispy features in the Milky Way: a global view of filamentary structures in the Galactic Plane

Eugenio Schisano

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The last years have seen a gradual, but steady, increase of interest toward the earlier stages of star formation driven by the availability of high-sensitivity and high-resolution observations at infrared/mm wavelengths. Particular attention has been paid on characterizing the inital seeds of star formation and their surrounding enviroment. Not surprisingly, there are several hints of a connection between intermediate-scale substructures of molecular clouds and pre/protostellar condensations. These substructures, but often the overall molecular cloud itself, have a filamentary shape. Filaments are extremely recurrent and represent a dominant morphology all the Galaxy: from single isolated to multiple nesting objects, from faint and tenuous to bright and dense structures. Furthermore, they are observed over a wide range of scales, from about 0.01 to 10 pc, always associated with young stars or star precursors. Several questions arise from such an overwhelming richness: Can we determine the reasons behind such a variety? Do they inherit measurable properties allowing us to identify the physical process that formed them? What is the filament role in the star formation? Do they really represent an intermediate, eventually stable, configuration between large molecular clouds and clumps/cores? Are they strictly necessary to form stars? With such an increasing interest of community on filamentary structures, it is important to physically characterize an unbiased sample of filaments embedded in different enviroments. In this work I present a robust sample of more than 2000 elongated, filamentary-like objects selected from a larger list of almost 30,000 candidates identified on Herschel dust continuum maps all along the Milky Way. The filaments in the robust sample lie between galactic longitudes 20 and 55 degrees and are confirmed as velocity-coherent features through detailed analysis of Galactic Ring Survey ^{13}CO line data. The classification of remaining candidates is currently ongoing as part of VIALACTEA project by means of available molecular line datasets. We measure masses, densities, mean temperatures, lengths, widths, velocity gradients along the structure, occurence of local star formation activity, etc., for most objects in the robust sample. Such a statistical sample allows us to test the universality of the new, recently proposed, paradigm of star formation in which filamentary shapes have a fundamental role. Finally, we investigate the relation between the turbulent state of interstellar medium and the galactic distribution of filaments to shed light on over the process that form them.

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Suggested Session:

Filaments

Multi-episodic and triggered star formation in IC 1396 A: A Herschel surprise and IRAM followup of a newly formed object

Aurora Sicilia-Aguilar

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IC 1396 A is a textbook example of a cometary-shaped bright-rimmed cloud at the edge of the IC 1396 HII region that surrounds the young Tr 37 cluster. After more than 40 years of studies in the optical and IR, and many young stars found within the globule, a proof of triggering by the expanding ionization front remained nevertheless elusive. And then Herschel came. Our Herschel/PACS program surprisingly revealed a new, highly-embedded, intermediate-mass Class 0 object just behind the ionization rim. The object is so embedded that it was not even detected in the deep Spitzer observations, and so compact that it could not be discerned from previously existing millimeter observations. The Herschel data show the star-forming history of IC 1396 A in a new light. Through the eyes of Herschel, IC 1396 appears as a diversified structure where several episodes of star formation have occurred within the last few Myr. IC 1396 A and Tr 37 are part of a cluster made of smaller, distinct structures or "mini-clusters" resulting from several episodes of star formation. Our new IRAM data reveal the dynamics at the tip of IC 1396 A and around the Class 0 source, showing how the formation of new stars proceeds in the globule, carving away the remaining parts of the dense molecular cloud. I will present our Herschel/PACS data and velocity-resolved IRAM molecular line observations, discussing the "mini-cluster" structure of the region, the dynamics of the star-formation process, and the connection between IC1396 A and Tr 37.

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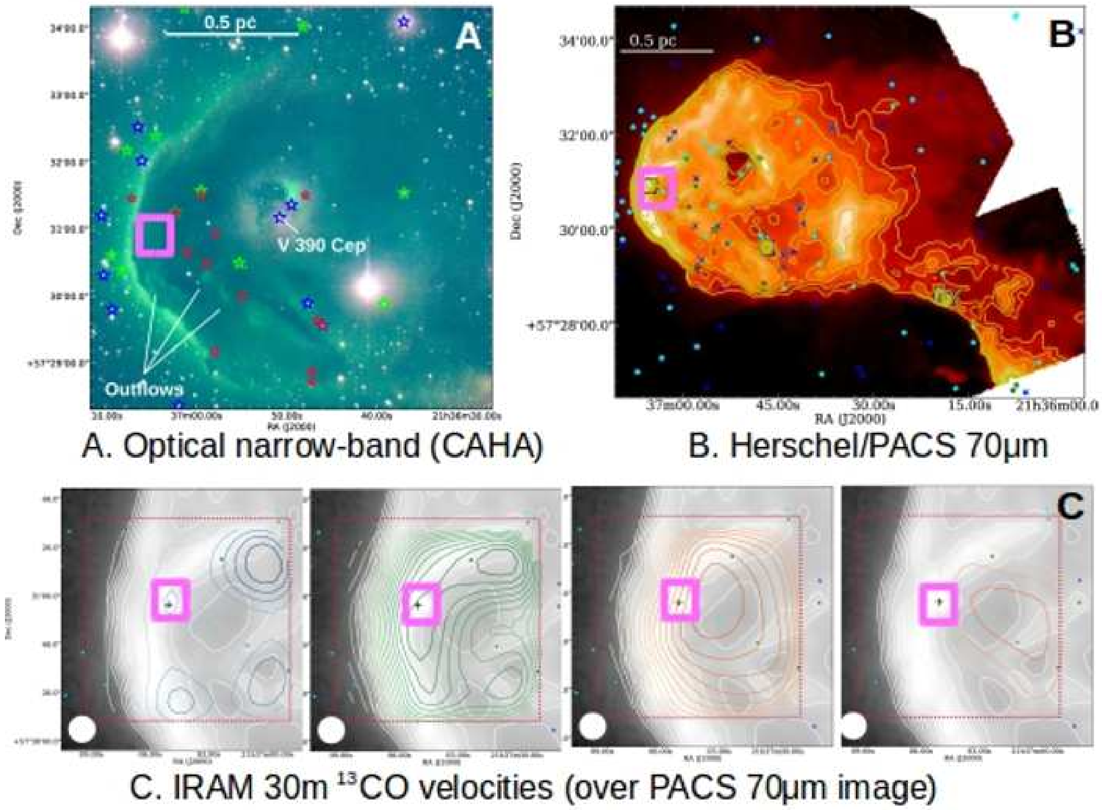
Key Reference:

http://adsabs.harvard.edu/abs/2014A%26A...562A.131S

Suggested Session:

Cluster Formation



Caption: A multi-wavelength picture of the IC 1396 A globule. The location of the Class 0 object is marked with a pink box. The source (with its outflow) is only detected in the far-IR and longer wavelengths (Sicilia-Aguilar et al. 2013, 2014, 2015, 2016 in prep).

Automated identification of large-scale velocity-coherent filaments in the Galaxy

Ke Wang
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On the upper end of the filamentary hierarchy of the interstellar medium are large-scale gaseous filaments (10-100 pc). What is their distribution in our Galaxy and what role they play in Galactic star formation? Answer to the question is important for a critical comparison with theoretical studies. Since EPoS 2014, several groups have made progress in identifying and characterizing more filaments using different methods, either through targeted or blinded searches. However, all those methods rely on manual visual inspection and have been applied to a small fraction of the Galactic plane. Inherent bias and small Galactic coverage of these studies make it difficult to derive robust cross comparison and conclusive statistics.
We have developed an algorithm to automate the identification process, by connecting voxels in the position-position-velocity space using data from Galactic plane surveys. We have identified 56 large-scale filaments and derived mass, length, linearity, velocity gradient, temperature, fragmentation, Galactic location and orientation angle. The filaments are widely distributed across the Galactic disk, with 55% located within ± 20 pc from the Galactic mid-plane. This sample of filaments provides the first comprehensive catalog for comparison with spiral arm models and numerical simulations of filamentary cloud formation.

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Key Reference:
http://adsabs.harvard.edu/abs/2015MNRAS.450.4043W

Suggested Session:
Filaments

Star Formation in the Early Universe

Harold Yorke
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Stars and protostars accreting at sufficiently high rates are unable to thermally adjust and will bloat up to radii typical of protostars on the Hayashi track, irregardless of whether central hydrogen-burning has commenced. For Pop III star formation this means that very massive M $\sim$ several 100 $M_\odot$ or even supermassive M $\sim$ 100,000 $M_\odot$ stars can form without radiative feedback limiting the final mass. The metal-free accreting gas is virtually opacity-free to the cool radiation emitted by the $\sim 5,000$ K stellar surface. The resulting final mass thus depends on how long accretion onto the star can be maintained at sufficiently high rates. If accretion occurs in episodic bursts, the critical average accretion rate that prevents a star from reaching main sequence radii can be lower than for slowly varying accretion. This effect is relevant for both Pop III star formation and present-day massive star formation.

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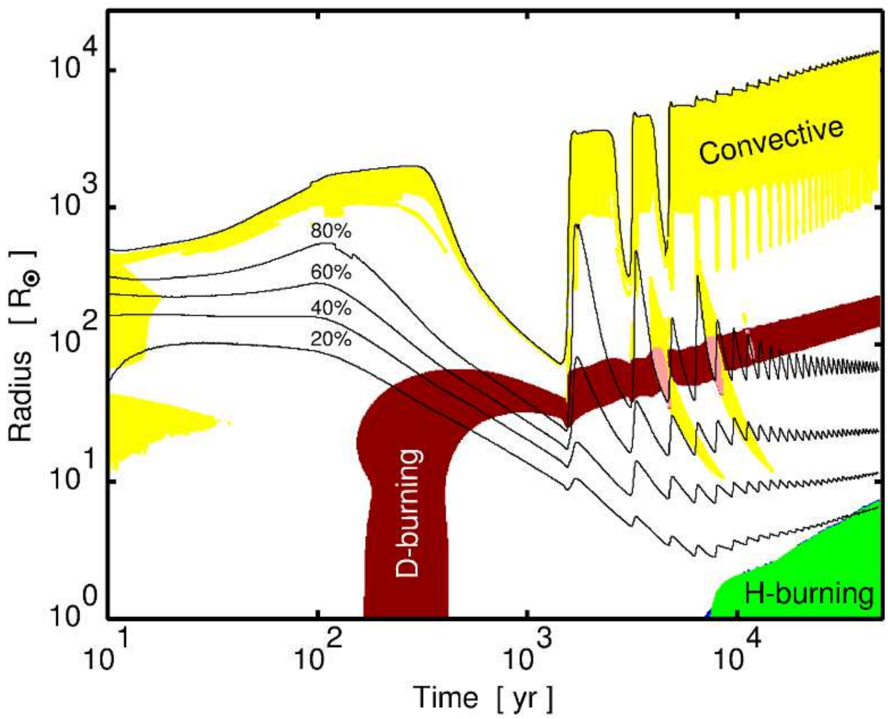
Key Reference:
http://adsabs.harvard.edu/abs/2015MNRAS.452..755S

Suggested Session:
Massive Star Formation



Caption: The evolution of the stellar interior structure for a primordial protostar accreting metal-free gas in 100-yr "bursts" at 1 $M_\odot$/yr alternating with more quiescent phases of dM/dt = 0.001 $M_\odot$/yr lasting 1080 yr. The black solid lines indicate the positions of the mass coordinates for 100% (stellar surface), 80%, 60%, 40%, and 20% of the total stellar mass. The yellow (white) regions denote convective (radiative) layers with no nuclear burning. The brown (green) regions show radiative deuterium-burning (convective hydrogen-burning) layers. The pink regions are deuterium-burning convection zones.

Star formation in collapsing proto-clusters

Hans Zinnecker
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Infall signatures (red shifted absorption of NH_3 rotational transitions) of neutral gas onto bright dust continuum clumps have been detected with SOFIA GREAT at 1.81 THz in a number of cases in APEX/ATLASGAL GPS sources. High accretion rates of the order of 10^{-3} $M_\odot$/yr have been derived. This new observational techniques holds great promise for understanding the early phases of clustered star formation. Follow-up high spatial resolution submm imaging of these proto-clusters is now needed to study the fragmentation process into low- and high-mass proto-stars.

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Key Reference:

http://adsabs.harvard.edu/abs/2015arXiv151008374W

Suggested Session:

Cluster Formation