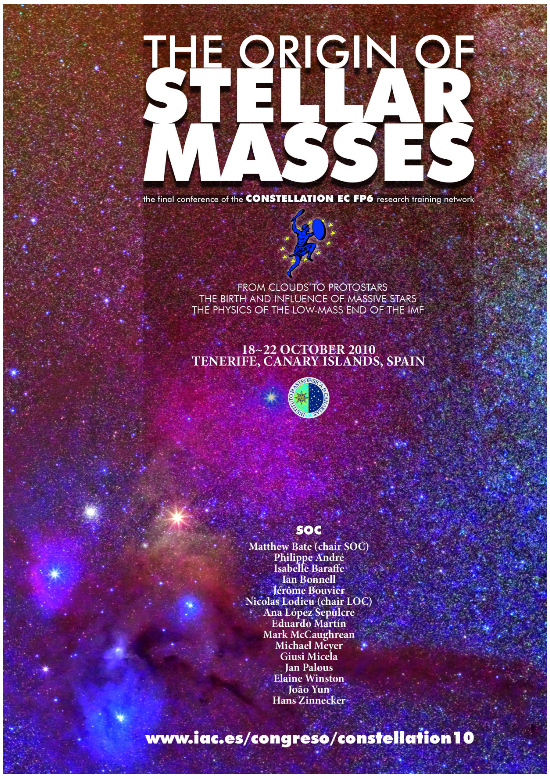
The Origin of Stellar Masses



a CONSTELLATION workshop

18 – 22 October 2010
Iberostar Grand Hotel Anthelia, Costa Adeje
Tenerife, Canary Islands, Spain

Programme and Abstracts

Editors: Nicolas Lodieu, Eduardo Martín, Victor Béjar,
Ramarao Tata, Karla Peña, Manuel Perger, Judith de Araoz Vigil

Organized by

INSTITUTO Ð ASTROFISICA Ð CANARIAS

A meeting of the CONSTELLATION Research Training Network

organised by the Instituto de Astrofísica de Canarias (IAC)

in the Iberostar Grand Hotel Anthelia,
Tenerife, Canary Islands, Spain

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General Information

1.1. Invited Speakers, SOC & LOC

Scientific Organizing Committee (SOC)

Matthew Bate (chair)	University of Exeter, UK
Philippe André	CEA/SAp Saclay, France
Isabelle Baraffe	University of Exeter, UK
Ian Bonnell	University of St Andrews, UK
Jérôme Bouvier	Laboratoire d'Astrophysique de Grenoble, France
Nicolas Lodieu	Instituto de Astrofísica de Canarias, Spain
Ana López Sepulcre	INAF-Osservatorio Astrofisico di Arcetri, Italy
Eduardo Martín	Centro de Astrobiología, Madrid, Spain
Mark McCaughrean	European Space Agency, The Netherlands
Michael Meyer	ETH Zurich, Switzerland
Giusi Micela	INAF/OAPa, Italy
Jan Palous	Astronomical Institute Prague, Czech Republic
Elaine Winston	University of Exeter, UK
João Yun	Universidade de Lisboa, Portugal
Hans Zinnecker	Astrophysikalisches Institut Potsdam, Germany

Local Organizing Committee (LOC)

Nicolas Lodieu (chair)	IAC, Spain
Judith de Araoz	IAC, Spain
Víctor Béjar	IAC, Spain
Eva Bejarano	IAC, Spain
Susie Burdett	University of Exeter, UK
Marcela Espinoza Contreras	IAC, Spain
Tanja Karthaus	IAC, Spain
Eduardo Martín (co-chair)	Centro de Astrobiología, Madrid, Spain
Karla Peña Ramírez	IAC, Spain
Manuel Perger	IAC, Spain
Ramarao Tata	IAC, Spain

Invited Speakers (I)

Lori Allen
Philippe André
Isabelle Baraffe
Shantanu Basu
Sylvain Bontemps
Jérôme Bouvier
Chris Brunt
Gilles Chabrier
Bruce Elmegreen
Lee Hartmann
Pavel Kroupa
Kevin Luhman
Phil Myers
Francesco Palla
Keivan Stassun
Jonathan Tan

1.2. Social Programme Information

The following social events are planned during the workshop:

Saturday 16 October

18:00 - 20:30 Registration in the Hotel lobby

Sunday 17 October

18:00 - 20:30 Registration and poster mounting
18:00 - 21:00 Welcome cocktail in the hotel (included in registration fees for participants)

Monday 18 October

08:00 - 12:30 Registration desk open
14:30 - 19:30 Registration desk open

Tuesday 19 October

08:00 - 14:30 Registration desk open

12:30 - 12:45 Group photograph outside the conference room

19:00 - 20:00 Wine tasting competition

We have organised a wine tasting competition (free for registered participants) where five wines will be offered. Each participant will be asked to recognise the origin of the wine after a first tasting. The winners will receive one bottle of wine.

Wednesday 20 October

All excursions are free for registered participants and 40€ for accompanying guests.

1) 13:30 - 18:00 Dolphins & whales watching trip

Participants registered to this excursion will leave the hotel by bus at 13:30 to the port of Los Gigantes (10 minutes away). The boat will leave the harbour at 14:30 for about 3 hours. We hope to see dolphins and whales and we will navigate close to the cliffs of Los Gigantes. Participants will also have the opportunity to swim in the bay of Masca (don't forget your swimming suit!) where a paella (typical Spanish dish) will be served. Drinks are included. Buses will leave the harbour around 17:30 and bring the participants back to the hotel around 18:00.
We strongly recommend you to bring the following items with you: suncream, sunglasses, hat, jacket or jumper, and swimming suit.

2) 13:00 - 18:00 Teide tour

Participants registered to this excursion will leave the hotel by bus at 13:00 to enjoy lunch in the restaurant "La Estancia" (13h30–14h30). Afterwards, they will visit the Teide National Park, classified a World Heritage Site by UNESCO in June 2007. They will stop at various places of interest, to discover and take pictures of the main attractions (rock formations, endemic plants, fauna, volcanic landscape, etc. . .) with the explanations of a guide. The bus will leave the last viewpoint around 17h to bring the participants back to the hotel around 18:00.
We strongly recommend you to bring the following items with you: suncream, sunglasses, hat, jacket or jumper, and swimming suit.

3) 13:00 - 15:45 Submarine tour
Participants registered to this excursion will leave the hotel by bus at 13:00. Participants will enjoy a dive on board a real submarine which will take you below the unexplored waters of San Miguel Marina. You will experience the true underwater world of Tenerife, previously reserved exclusively for divers. The dive will last 50 min and includes a comprehensive and educative explanation about the submarine life. The participants will be back at the hotel around 15h45.

3) 13:00 - 19:00 Masca hike
Participants registered to this excursion will leave the hotel by bus at 13:00 to reach the village of Masca in approximately 1 hour. Two personal guide will join the group to walk down the Masca valley to reach the black sand beach in about 3 hours. Participants will have the opportunity to swim in cristal-clear waters. After a break, the participants will go back to the harbour of Los Gigantes by boat where buses will wait to bring everyone back to the hotel around 18:30.
We strongly recommend you to bring the following items with you: suncream, sunglasses, hat, jacket or jumper, and swimming suit.

Thursday 21 October

19h30 - 23:00 Conference dinner at the "Bodega Tierra de Frontos", Granadilla de Abona

Bodega Tierra de Frontos is a local winery in a beautiful setting in Granadilla de Abona. The visit includes a brief tour of the installations and a dinner. The menu will be typical Canarian, accompanied by wine from the vineyard. The conference dinner is included in the registration fees for participants. Please be dressed appropriately.

1.3. Scientific Programme

Sunday 17 October

18:00 - 20:30	Registration and Welcome Cocktail	

Monday 18 October

Chair: Matthew Bate

8:40 - 9:00	Welcome	(Mark McCaughrean)
9:00 - 9:30	**(R)** Stellar mass: from birth to youth	(Francesco Palla)
9:30 - 10:00	**(R)** How do protostars get their mass?	(Philip Myers)
10:00 - 10:30	**(R)** From density fluctuations to prestellar cores: assembling stellar masses	(Gilles Chabrier)
10:30 - 11:00	*Coffee Break*	

Session 1: From Clouds to Cores to Protostars

Chair: Ian Bonnell

11:00 - 11:30	**(R)** The early stages of star formation in molecular clouds	(Chris Brunt)
11:30 - 12:00	**(R)** From filamentary clouds to prestellar cores to the stellar IMF	(Philippe André)
12:00 - 12:20	**(S)** Deriving dust core properties from recent Herschel maps	(Davide Elia)
12:20 - 12:40	**(S)** The Aquila prestellar core population revealed by Herschel	(Vera Konyves)
12:40 - 14:30	*Lunch*	

Chair: James Dale

14:30 - 15:00	**(R)** Seven Years in SpitzerLand	(Lori Allen)
15:00 - 15:20	**(C)** Observations of prestellar cores and the origin of the IMF	(Derek Ward-Thompson)
15:20 - 15:40	**(C)** Mass evolution in protostellar envelopes	(Jennifer Hatchell)
15:40 - 16:00	**(C)** The formation of prestellar cores	(Simon Glover)
16:00 - 16:20	**(C)** The IMF through cosmic time: from primordial to present-day star formation	(Paul Clark)
16:40 - 17:00	*Coffee Break*	

Chair: Stefanie Walch

17:00 - 17:30	**(R)** Clouds to cores to protostars: The influence of magnetic fields	(Shantanu Basu)
17:30 - 17:50	**(C)** Protostellar collapse: magnetic and radiative feedbacks on small-scale collapse and fragmentation	(Benoit Commercon)
17:50 - 18:10	**(C)** On the effect of magnetic fields and outflow feedback on the characteristic mass of the IMF	(Fumitaka Nakamura)
18:10 - 19:00	Discussion: From Clouds to Cores to Protostars	(Ian Bonnell)

Tuesday 19 October

Session 2: The Birth and Influence of Massive Stars

Chair: Ian Jan Palous

9:00 - 9:30	**(R)** The birth and influence of massive stars	(Jonathan Tan)
9:30 - 10:00	**(R)** Observations of the earliest phases of high-mass star formation	(Sylvain Bontemps)
10:00 - 10:20	**(C)** What the spatial distribution of stars can tell us about star formation	(Eli Bressert)
10:20 - 10:40	**(C)** The mass and density structure of infrared dark clouds	(Nicolas Peretto)
10:40 - 11:10	*Coffee Break*	

Chair: Giuseppina Micela

11:10 - 11:30	**(S)** A minimum surface density for OB star formation: An observational test	(Ana López-Sepulcre)
11:30 - 11:50	**(S)** Origin of high-mass stars in Cygnus-X	(Timea Csengari)
11:50 - 12:10	**(C)** The luminosity function and timescale of massive YSOs and compact HII regions	(Joseph Mottram)
12:10 - 12:30	**(C)** Triggered star formation and the young stellar population in bright-rimmed clouds	(Rumpa Choudhury)
12:30 - 12:45	*Conference Group Photograph*	
12:45 - 14:30	*Lunch*	

Chair: Elaine Winston

14:30 - 14:50	**(S)** Fragmenting shells and triggered star formation	(James Dale)
14:50 - 15:10	**(S)** Expanding shells require special conditions in molecular clouds	(Stefanie Walch)
15:10 - 15:30	**(C)** Ionisation feedback in star formation simulations	(Barbara Ercolano)
15:30 - 15:50	**(C)** Collisional formation of massive stars in accreting clusters	(Nickolas Moeckel)
15:50 - 16:20	*Coffee Break*	

Chair: Basmah Riaz

16:20 - 16:40	**(R)** Evidence for a top-heavy IMF in extreme star-bursts	(Pavel Kroupa)
16:40 - 17:00	**(S)** Properties of hierachically forming star clusters	(Thomas Maschberger)
17:00 - 17:20	**(C)** Circumstellar discs in the Arches starburst cluster	(Andrea Stolte)
17:20 - 17:40	**(C)** The present-day mass function of the Quintuplet cluster	(Benjamin Hussmann)
17:40 - 18:30	Discussion: Birth and Influence of Massive Stars	(Bruce Elmegreen)

Wednesday 20 October

Session 3: Stellar Multiplicity and Dynamics

Chair: Eduardo Martín

9:00 - 9:30	**(R)** Binary star formation	(Cathie Clarke)
9:30 - 9:50	**(C)** The dynamics of brown dwarf binaries	(Anthony Whitworth)
9:50 - 10:10	**(C)** Why very low-mass binaries are different	(Simon Goodwin)
10:10 - 10:30	**(C)** The effect of stellar density on stellar multiplicity	(Robert King)
10:30 - 11:00	*Coffee Break*	

Chair: Nicolas Lodieu

11:00 - 11:20	**(C)** A-star multiplicity and the companion mass function from stars to brown dwarfs	(Robert de Rosa)
11:20 - 11:40	**(C)** Inverse mass segregation in Taurus	(Richard Parker)
11:40 - 12:00	**(C)** Mass segregation in young stellar groups	(Helen Kirk)

13:00 - 20:00	*Excursions*

Thursday 21 October

Session 4: The Low-mass End of the IMF

Chair: Daniele Galli

9:00 - 9:30	**(R)** The low-mass IMF in nearest star-forming regions	(Kevin Luhman)
9:30 - 10:00	**(R)** The substellar IMF in young clusters	(Jérôme Bouvier)
10:00 - 10:20	**(C)** The stellar low-mass IMF: SDSS observations of 15 million M-dwarfs	(John Bochanski)
10:20 - 10:40	**(C)** A Comparison of protostellar luminosity functions across diverse star-forming environments	(Erin Kryukova)
10:40 - 11:10	*Coffee Break*	

Chair: Hans Zinnecker

11:10 - 11:30	**(S)** The spectroscopic mass function in the Upper Sco Association	(Nicolas Lodieu)
11:30 - 11:50	**(S)** Probing the low-mass end of the IMF in star-forming regions	(Catarina Alves de Oliveria)
11:50 - 12:10	**(S)** M-dwarfs to T-dwarfs: The low-mass IMFs in IC 4665 and IC 348	(Andrew Burgess)
12:10 - 12:30	**(S)** A multi-wavelength study of the young open cluster NGC 6823	(Basmah Riaz)

12:30 - 14:30	*Lunch*

Chair: Catarina Alves de Oliveira

14:30 - 15:00	**(S)** Near-IR and X-ray observations of the Serpens cloud	(Elaine Winston)
15:00 - 15:20	**(C)** First results from XMM-Newton investigations in lambda Orionis (XILO)	(Beate Stelzer)
15:20 - 15:40	**(C)** SMA survey of low-luminosity YSOs in Perseus	(Masaaki Hiramatsu)
15:40 - 16:00	**(C)** How to limit the effect of radiative feedback in lowmass star formation	(Dimitris Stamatellos)
16:00 - 16:30	*Coffee Break*	

Chair: Vera Konyves

16:30 - 16:40	**(C)** Herschel view of gas and dust in protoplanetary disks	(Christophe Pinte)
16:50 - 17:10	**(C)** Using observations of brown dwarf jets to investigate brown dwarf formation	(Emma Whelan)
17:10 - 17:30	**(C)** Molecular outflows in the substellar domain	(Ngoc Phan-Bao)
17:30 - 18:30	Discussion: Variation of the IMF?	(Nate Bastian)

20:00 - 23:00	*Closing Dinner*

Friday 22 October

Chair: Tim Harries

9:00 - 9:30	**(R)** The early evolution of low-mass stars and brown dwarfs	(Isabelle Baraffe)
9:30 - 9:50	**(S)** Constraints on theoretical stellar models: Empirical measurements of the masses of stars and brown at young ages	(Keivan Stassun)
9:50 - 10:10	**(C)** The Epsilon Indi B binary brown dwarf	(Catia Cardoso)
10:10 - 10:30	**(C)** Testing theory with dynamical masses and orbits of ultracool binaries	(Trent Dupuy)
10:30 - 10:50	**(C)** A new photometric mass scale	(Nathan Mayne)
10:30 - 11:00	*Coffee Break*	

Session 5: The Origin of Stellar Masses

11:20 - 11:50	**(R)** Initial conditions for star formation and the IMF	(Lee Hartmann)
11:50 - 12:30	Final summary and discussion	(Matthew Bate)

End of Conference

Invited reviews	**(R)**	**25+5 min**
Short Invited reviews	**(S)**	**15+5 min**
Contributed talks	**(C)**	**15+5 min**

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Invited and Contributed Talks

Topics:

Session 1 (S.1):	From Clouds to Cores to Protostars
Session 2 (S.2):	The Birth and Influence of Massive Stars
Session 3 (S.3):	Stellar Multiplicity and Dynamics
Session 4 (S.4):	The Low-mass End of the IMF
Session 5 (S.5):	The Origin of Stellar Masses

Welcome

Mark McCaughrean

Invited Review

Stellar mass: From Birth to Youth

Francesco Palla

In this introductory talk, I will review the main properties of the early evolution of young objects, from brown dwarfs, to low-intermediate-high mass stars. Most of the observational constraints on the mass of these objects rely on the use of simplified models of constant mass evolution. However, gaining mass is a disturbing effect for all stars (metaphorically speaking), and real stars are no exception. Accretion, slow or fast, can modify the mass gained at birth during the PMS phase and affect the interpretation of the observations of some key diagnostics. A brief discussion on the derivation of the IMF in the Orion Nebula Cluster will close the presentation.

Invited Review

How do protostars get their mass?

Philip C. Myers

We review current ideas about the origin of stellar masses, in the context of nearby star-forming regions. Like the Perseus molecular clouid complex, these generally have prominent filamentary structure with embedded cores and stars, and a few protoclusters with unusually high gas density extending over ~ 1 pc. Over a few Myr each protocluster typically forms a centrally condensed configuration of more than 100 stars, whose mass distribution approximates the stellar initial mass function (IMF). Questions to be discussed include the origin of star-forming cores; relation of their mass distribution to the IMF; core collapse and accretion; termination of infall; and the role of outflows, turbulence and magnetic forces in setting stellar masses.

Invited Review

From density fluctuations to prestellar cores: assembling stellar masses

Gilles Chabrier

I will present a brief review on the two main modern theories aiming at describing the basic formation process of star formation leading to the observed IMF. One theory is based on prestellar mass cores set up by initial turbulent fluctuations while the second theory is based on competitive accretion within the cloud.

Session 1: From Clouds to Cores to Protostars

S1

Invited Review

The Early Stages of Star Formation in Molecular Clouds

Chris Brunt

In this review I will discuss molecular clouds as the mass reservoir for star formation in our Galaxy, focusing on their spatial and kinematic structure and on physical conditions that promote or inhibit star formation. As molecular clouds mark the transitional phase between continuous (nebulous) and discrete (core/stellar) structures, methods developed to analyse them have similarly incorporated both continuous and discrete aspects. I will review the advantages and disadvantages of these two complementary approaches and identify directions needed for future research.

Invited Review

From filamentary clouds to prestellar cores to the stellar IMF: First results from the Herschel Gould Belt Survey

Philippe André

The Herschel Space Observatory provides a unique opportunity to improve our global understanding of the earliest phases of star formation. I will present an overview of the first results from the Gould Belt survey, one of the largest key projects with Herschel. The immediate objective of this SPIRE/PACS imaging survey is to obtain complete samples of nearby prestellar cores and Class 0 protostars with well characterized luminosities, temperatures, and density profiles, as well as robust core mass functions and protostar luminosity functions, in a variety of star-forming environments. Thanks to its high sensitivity and large spatial dynamic range, this survey can also probe, for the first time, the link between diffuse cirrus-like structures and compact self-gravitating cores. The main scientific goal is to elucidate the physical mechanisms responsible for the formation of prestellar cores out of the diffuse interstellar medium, which is crucial for understanding the origin of the stellar initial mass function. Our first results, obtained toward the Aquila Rift and Polaris Flare regions during the 'Science Demonstration Phase' of Herschel, are very promising (see A&A Vol. 518, special issue on Herschel). Based on these early results, I will discuss preliminary implications for our understanding of the formation mechanism of prestellar cores and the link between the prestellar core mass function and the stellar initial mass function. Comparing and contrasting our Herschel results in Aquila and Polaris, we propose an observationally-driven scenario for core formation according to which complex networks of long, thin filaments form first within molecular clouds, probably as a result of interstellar MHD turbulence, and then the densest filaments fragment into a number of prestellar cores via gravitational instability.

Short Invited Review

Deriving dust core properties from recent Herschel maps

Davide Elia

I will present recent Herschel PACS/SPIRE observations, from 70 to 500 microns, part of the Hi-GAL and HOBYS key-projects. In particular, the new SPIRE maps of Vela-C cloud (HOBYS) allow a direct comparison with previous BLAST observations of the same star-forming region. The better performance of Herschel both in angular resolution and sensitivity gives us the chance to obtain a more robust statistics of the pre- and proto-stellar cores in Vela-C, and to better characterize the core mass function (CMF) towards lower masses. Then I will compare the Vela-C CMF with those derived from Herschel observations of two portions of the Galactic plane, namely the Hi-GAL tiles centered at l=30° and l=59°, respectively.

Short Invited Review

The Aquila prestellar core population revealed by Herschel

Vera Konyves

The origin and possible universality of the stellar initial mass function (IMF) is a major issue in astrophysics. One of the main objectives of the Herschel Gould belt survey is to clarify the link between the prestellar core mass function (CMF) and the IMF. We present and discuss the core mass function derived from Herschel data for the large population of prestellar cores discovered with SPIRE and PACS in the Aquila Rift cloud complex at d$\sim$260 pc. We detect a total of 541 starless cores in the entire $\sim$11 deg^2 area of the field imaged at 70–500μm with SPIRE/PACS. Most of these cores appear to be gravitationally bound, and thus prestellar in nature. Our Herschel results confirm that the shape of the prestellar CMF resembles the stellar IMF, with much higher quality statistics than earlier submillimeter continuum ground-based surveys.

Invited Review

Seven Years in SpitzerLand

Lori Allen

Since its launch seven years ago, the Spitzer Space Telescope has surveyed most of the molecular clouds within a kiloparsec of the Sun, yielding a sample of nearby young stars that is unprecedented in both size and completeness, and enabling statistically meaningful studies of young stars and their most fundamental proerties: where they form and how they evolve. Global star formation efficiencies are low (3 % - 6 % cloud-wide). Stellar surface densities range over 3 orders of magnitude within individual molecular clouds. Average stellar densities are not correlated with most global cloud properties (like total molecular gas mass or the number of young stars produced), but do show a dependence on the average gas density, as might be expected. The star formation rate – gas surface density relation is an order of magnitude larger than predicted from the Kennicutt relation used in extragalactic studies. New lifetimes have been derived for the empirical "classes" of young stars, based on their observed spectral energy distributions (often assumed to represent evolutionary state) for the more complete sample within 500 pc. I will present these and other results from the nearby cloud surveys (c2d, Taurus, Gould's Belt and Orion).

S1

Contributed Talk

Observations of prestellar cores and the origin of the IMF

Derek Ward-Thompson

The stellar initial mass function has been shown to be determined by the form of the prestellar core mass function. In this paper we present the latest results from Herschel and SCUBA2 of observations of prestellar cores. We explore the link between prestellar cores and Class 0 protostellar cores. We study the physical parameters of the cores, including their masses and radial density profiles. We present the first attempt at an evolutionary diagram for prestellar cores. Finally, we explore the link between prestellar cores and lower density CO cores to search for the origin of the prestellar core mass function.

Contributed Talk

Mass evolution in protostellar envelopes

Jennifer Hatchell, G. A. Fuller, M. Dunham, and E. Curtis

Star formation is a process of mass transfer from the parent molecular cloud through the dense protostellar envelope to disk and star. While the mass of the protostar itself is unknown, the mass of the accreting envelope can be estimated from submillimetre fluxes and molecular lines. Observational constraints on the evolution of envelope mass through the protostellar stages come from (1) the snapshot distribution of envelope masses for protostars evolving through the different classes and (2) the mass loss rates from their envelopes via molecular outflows. Using SCUBA and HARP observations of the Perseus molecular cloud, I show that mass loss in outflows is insufficient to set the star formation efficiency and thus the scaling between the CMF and the IMF. I also look at the extent to which varying times in the Class 0 phase affect the observed mass distributions, and what can therefore be concluded about the masses of cores which contribute stars to the IMF.

Contributed Talk

The formation of prestellar cores

Simon Glover, P. Clark, R. Shetty, R. Klessen

Understanding how dense prestellar cores form within Giant Molecular Clouds (GMCs) is of vital importance for a proper understanding of the earliest phases of star formation. Many observed cores have masses comparable to the mean Jeans mass of the gas in a GMC, leading one to expect that they will be highly sensitive to the thermodynamical behaviour of the gas. Despite this, most hydrodynamical or MHD models of core formation rely on very simplified prescriptions for treating the thermal evolution of the gas. We have attempted to address this weakness in previous models by performing high resolution hydrodynamical simulations of core formation that properly treat the effects of radiative heating and cooling, using a novel tree-based approach to account for dust shielding. Our simulations also follow the chemical evolution of the major gas coolants: for instance, we are able to follow the transition from C^{+} in the diffuse interclump regions in the GMC to C and then CO in the denser gas in the cores. We have used our simulations to explore the effects of the external environment – specifically, the strength of the ambient interstellar radiation field (ISRF) – on the formation of prestellar cores within the cloud, and will show that although large changes in the ISRF can lead to large changes in the observational appearance of the GMCs, they have a surprisingly small impact on core formation.

Contributed Talk

The IMF through cosmic time: from primordial to present day star formation

Paul Clark, Simon Glover, Ralf Klessen, Rowan Smith

The observed slope at the high-mass end of the initial mass function (IMF) displays a remarkable universality under a wide-variety of physical environments. We will present results from numerical simulations that cover a wide range of metallicities and environmental conditions, that demonstrate that the process of competitive accretion can provide a natural explanation for a universal slope in the IMF. In our discussion, we show how competitive accretion always dominates over the more traditional 'fragmentation' picture wherever star formation occurs in bound clusters. Further, we argue that clustered star formation has been the dominant mode of star formation, throughout cosmic time, dominating even the formation of the very first stars in the Universe – the so called Population III stars. We also discuss the ability of other physical processes to lessen the effects of further accretion onto protostellar cores. Current theoretical and numerical studies show that competitive accretion is robust against disrupting effects – such as feed-back from young stars, supersonic turbulence and magnetic fields – in all but the most extreme cases.

Invited Review

Clouds to Cores to Protostars: The Influence of Magnetic Fields

Shantanu Basu

We review recent work on the role of magnetic fields in the cloud to core transition as well as the transition of a core to a star-disk system. On the cloud scale, large scale nonlinear flows can create compressed cloud layers. If the cloud has a subcritical mass-to-flux ratio, ambipolar diffusion occurs rapidly in the compressed layers. The qualitative result is a handful of cores that are formed within elongated ridges, while the bulk of the cloud does not form stars. In the flux-freezing limit that may be applicable to photoionized molecular cloud envelopes, supersonic motions can persist for very long times if the cloud is subcritical. In the case of protostellar accretion, rapid magnetic diffusion (through ohmic dissipation with additional support from ambipolar diffusion) near the protostar causes dramatic magnetic flux loss. By doing so, it also allows the formation of a centrifugal disk, thereby avoiding the magnetic braking catastrophe.

Contributed Talk

Protostellar collapse: magnetic and radiative feedbacks on small-scale collapse and fragmentation

B. Commercon, P. Hennebelle, E. Audit, G. Chabrier and R. Teyssier

It is established that both radiative transfer and magnetic field have a strong impact on the collapse and the fragmentation of prestellar dense cores. We perform the first Radiation-Magneto-HydroDynamics (RMHD) numerical calculations at a prestellar core scale. I will first briefly discuss the RMHD solver we designed in the RAMSES code. Then I will present original AMR calculations including magnetic field (in the ideal MHD limit) and radiative transfer, within the Flux Limited Diffusion (FLD) approximation, of the collapse of a 1 solar mass dense core. We compare the results with calculations performed with a barotropic EOS. We show that radiative transfer has an important impact on the collapse and the fragmentation, through the cooling or heating of the gas, and is complementary of the magnetic field. A larger field yields a stronger magnetic braking, increasing the accretion rate and thus the effect of the radiative feedback. Even for a strongly magnetized core, where the dynamics of the collapse is dominated by the magnetic field, radiative transfer is crucial to determine the temperature and optical depth distributions, two potentially accessible observational diagnostics. A barotropic EOS cannot account for realistic fragmentation. The diffusivity of the numerical scheme, however, is found to strongly affect the output of the collapse, leading eventually to spurious fragmentation. Finally, I will investigate the effect of the initial angle between magnetic fields and the rotational axis. I will discuss the formation of a disk and present synthetic observational maps of the dust continuum emission (as seen with ALMA) and spectral energy distributions.

Contributed Talk

On the Effect of Magnetic Fields and Outflow Feedback on the Characteristic Mass of the Stellar IMF

Fumitaka Nakamura, Zhi-Yun, Li, Peng Wang, Tom Abel

We performed 3D MHD numerical simulations of cluster formation, treating stars as accreting sink particles. We used the ENZO AMR code with effective resolution of 2048^3. We found that a magnetic field of strength in the observed range decreases, rather than increases, the characteristic stellar mass. It reduces the number of relatively masssive stars that are formed through direct turbulent compression, because sub-regions of the clump with stellar masses are typically magnetically subcritical and cannot be compresses directly into collapse, and increases the number of low mass stars that are produced from the fragmentation of dense filaments. The filaments result from mass accumulation along the field lines. In order to become magnetically supercritical and fragment, the filament must accumulate a large enough column density, which yields a high density that is conducive to forming low mass stars. In addition, we found that the characteristic stellar mass is reduced further by outflow feedback. The conclusion is that both magnetic field and outflow feedback are important in shaping the stellar initial mass function.

Discussion panel

Discussion: From Clouds to Cores to Protostars

Ian Bonnell

Session 2: The Birth and Influence of Massive Stars

S2

Invited Review

The Birth and Influence of Massive Stars

Jonathan C. Tan

I review current open questions concerning the formation of massive stars and associated star clusters. What are their initial conditions? How is mass assembled into massive stars? What role does feedback play in setting the efficiency of star formation, both for the massive star itself and the surrounding cluster?

Invited Review

Observations of the earliest phases of high-mass star formation

Sylvain Bontemps

The properties of the earliest phases of the formation of high-mass stars should clearly discriminate the different theoretical views which may explain the origin of high-mass stars. These phases (pre-collapse cores and collapsing proto-stars) are however extremely difficult to recognize. They are short and the high-mass proto-stars are thus rare and distant. The high-mass proto-stars are also embedded in crowded and dense proto-clusters and could be detectable only in the far-infrared and sub-millimeter ranges. Finally in competitive accretion scenarii, the high-mass precursors could even be virtually impossible to recognize since they may not be associated, at any stages, with any high-mass cores or envelopes. I will review the very recent new observational results on the best candidates so far to be true precursors of OB stars with a focus on nearby regions, and on the efforts at the scale of the Galaxy to access large, representative samples of high-mass star formation sites which will be soon investigated with ALMA to search for individual collapsing objects forming high-mass stars at large Galactic distances.

Contributed Talk

Do All Stars in the Solar Neighbourhood Form in Dense Clusters?

Eli Bressert

We present the results of two recent studies regarding the clustering properties of young stars. First, we discuss a global study of young stellar object (YSO) surface densities (Σ) in star forming regions based on a comprehensive collection of it Spitzer Space Telescope surveys, which encompasses nearly all star formation in the solar neighbourhood. We show that the distribution of YSO surface densities is a smooth distribution, being adequately described by a lognormal function from a few to 103 YSOs per pc^2, with a peak at $\sim$ 22 stars pc^{-2} and a dispersion of $\sigma_{\log_{10}\Sigma} \sim$ 0.85. We do not find evidence for multiple discrete modes of star-formation (e.g. clustered and distributed).
Secondly, we address the issue of whether massive stars exclusively form in large stellar clusters or if they can form (albeit rarely) in relative isolation. Many studies have addressed this question from a variety of angles, however they have all been limited due to the unknown frequency of runaway high-mass stars (i.e. high-mass stars that formed in clusters but have been ejected due to dynamical interactions within the dense cluster cores). We use the VLT-FLAMES Tarantula Survey (PI Evans) to by-pass this limitation. We select O-stars outside the dense cluster R136 but within 30 Doradus that have the same radial velocity as their surrounding gas, are spatially associated with large gaseous filaments, and have multiple other high-mass stars nearby (within 5-15pc) that are also associated with the same gaseous filament. We find many examples of such stars, which rules out the possibility that they were ejected from R136 (although some clear runaways are also found). Including deep optical and near-IR imaging rules out large clusters around these stars, showing that high-mass stars can and do form in relative isolation. We briefly discuss the implications of this result.

Contributed Talk

The mass and density structure of infrared dark clouds

N. Peretto & G.A. Fuller

Infrared dark clouds (IRDCs) are pristine molecular clouds, believed to be the progenitors of star clusters. By statistically analysing the mass and density distributions of the 11000 galactic IRDCs of the Peretto & Fuller (2009) catalogue we extract important insights on the initial conditions for star formation in the Galaxy. While the mass distributions of IRDCs and fragments, i.e. the single peaked sub-structures within IRDCs, are similar to CO clumps and core mass distributions, respectively, the fragment volume density distributions show behaviours in contrast with the initial assumptions of current star formation models. We will discuss these results in the context of the origin of the mass distribution of stars.

Short Invited Review

A minimum surface density for OB star formation: An observational test

Ana López-Sepulcre

Recent theories predict that high-mass star formation may occur only above a minimum surface density of the parental molecular clump. With this in mind, we have searched for OB star formation signposts in a sample of 49 massive molecular clumps ($M > 100$ M$_\odot$), including both IR-dark and IR-loud sources and covering a wide range of surface densities. The aim was to look for evolutionary trends and test observationally the above mentioned theoretical prediction. Each of these sources has been mapped in the HCO$^+$(1–0), HCN(1–0), and C^{18}O(2–1) lines with the IRAM-30m telescope in Pico Veleta (Spain). Molecular outflows have been detected in 75 % of our targets. Remarkably, we measure a surface density threshold of 0.3 g/cm^2 above which the detection rate becomes 100 % and the outflows are on average more massive, lending support to the theoretical prediction. Subsequent observations in the SiO(2–1) and (3–2) transitions reveal an inverse correlation between the ratio of SiO luminosity to bolometric luminosity, $L_{\rm sio}/L_{\rm bol}$, and the ratio of bolometric luminosity to mass of the clumps, $L_{\rm bol}/M$, with more powerful jets corresponding to lower values of $L_{\rm bol}/M$. This suggests that the jet/outflow phase is more active in the earliest stages of stellar formation. The infall detection rate measured in our sample is low, but significantly higher in the IR-dark sub-sample, an indication that these objects could be associated with the onset of star formation.

Short Invited Review

Origin of high-mass stars in Cygnus-X

Timea Csengari

I will present IRAM PdBI continuum and molecular line observations towards the 5 most massive dense cores of Cygnus X (Bontemps et al. 2009, arXiv: 0909.2315). Located at 1.7 kpc, Cygnus X offers the opportunity of reaching small scales (less than 2000 AU) to identify individual collapsing objects. A few, but massive fragments are found within these cores, a total of 9 are found to be precursor of OB stars. Comparing the fragmentation properties with theoretical predictions, it seems that the level of fragmentation in these cores is higher than in the turbulence regulated collapse scenario, but is not as high as expected in a pure gravo-turbulent scenario where the distribution of mass is dominated by low-mass protostars. To go one step further in understanding the origin of these massive protostars, we analysed the PdBI H13CO+ and H13CN line emission (Csengeri et al., submitted). In the turbulence regulation scenario, a strong micro-turbulence is expected which should be observed down to the smallest scales. On the other hand a significant effect of competitive accretion could be observed by means of a detailed kinematical study. In these dense gas tracers all the cores indeed exhibit very rich and complex kinematics such as several line components and interacting flows of dense gas are found just around protostars. The level of turbulent support at the scale of protostars is found to be smaller than pointed by previous single-dish observations, which suggest a dynamical origin and fast evolution for the fragmentation of dense cores. To put in context the origin of massive cores, the link between small ($\sim$0.01 pc) and large ($\sim$pc) scale kinematics must be investigated. I will briefly present our recent studies of the most massive structure within Cygnus X, the DR21 filament (Schneider et al. 2010, arXiv:1003.4198), that point to its dynamic origin.

Contributed Talk

The luminosity function and timescale of massive young stellar objects and compact HII regions

Joseph C. Mottram, Melvin G. Hoare & The RMS Survey Team

We present the first determination of the luminosity functions of massive young stellar objects (MYSOs) and compact HII (CHII) regions within the Milky Way galaxy. These are determined from the large, well-selected sample of these sources identified by the Red MSX Source (RMS) survey. The MYSO luminosity function shows that there is not a significant population of these objects with a luminosity above $\sim 7{\times}10^4 L_\odot$, whilst the luminosity function for CHII regions extends to $L \sim 6{\times}10^5 L_\odot$ as expected. The lifetimes of these phases are also calculated as a function of luminosity by comparison with the luminosity function for local main sequence OB stars. These indicate that the MYSO phase has a lifetime just over $\sim 10^5$ yrs, whilst the CHII region phase lasts of order $3{\times}10^5$ yrs or about 5 % of the exciting stars main sequence lifetime. The lack of MYSOs above $10^5 L_\odot$ is consistent with the scenario in which objects around $10 M_\odot$ are swollen and cool due to high accretion rates, but at higher masses contract rapidly to the main sequence allowing them to ionize their surroundings.

Contributed Talk

Triggered star formation and Young Stellar Population in Bright-Rimmed Clouds

Rumpa Choudhury, H. C. Bhatt, Bhaswati Mookerjea

Massive young stars play an important role in triggering the formation of subsequent generations of stars in the Bright-Rimmed Clouds (BRCs). We have used multiwavelength observations (optical to Far Infrared) to identify the nearly complete census of young stellar population in a few BRCs. Candidate Young Stellar Objects (YSOs) are identified by Mid-IR color indices and then followed by ground based photometric spectroscopic observations. Spectral type, effective temperature, extinction, mass, age, mass accretion rate etc. have been determined for individual YSOs. The spatial distribution of the YSOs and the ionising sources for each of the BRCs have been explored using the narrow band H-alpha images. Further the kinematics of the YSOs and the associated OB association are also studied to understand the triggering mechanism and timescale. We shall summarize the results of different BRCs to explain the effect of the environment in the context of triggered star formation scenario.

Short Invited Review

Fragmenting shells and triggered star formation

James Dale

I will present results from AMR and SPH simulations of the gravitational fragmentation of ballistically-expanding shells in which we explored the effects of the boundary conditions on the fragmentation, and of subsequent accretion on the final mass function. I will then present simulations of the external irradiation of a turbulent molecular cloud in which I study the effects of triggering on the stellar mass function and star formation efficiency. I will then discuss the implications of all this work for triggered star formation, from both observational and theoretical points of view.

Short Invited Review

Expanding shells require special conditions in molecular clouds.

Stefanie Walch

Shells, bubbles, and triggered star formation around young massive stars are frequently observed at all common wavelengths and throughout the galaxy. In numerical simulations with the SPH code SEREN, we investigate the formation of shell-like structures, which are swept up by expanding HII regions around young massive stars. We treat the ionising radiation with a well-tested HEALPix-based algorithm. The initial molecular cloud surrounding the ionising source is assumed to be fractal on large scales, where the fractal dimension $\mathrm{D_f}$ is variable. We allow $\mathrm{D_f}$ to span a broad range, covering the observed values ($\mathrm{D_f}=$ 2.2 – 2.5), as well as even more uniform setups (up to $\mathrm{D_f} = 2.9$). This model allows us to fully control the clumpiness and the richness in molecular cloud structure, which is impossible with conventional turbulent molecular cloud setups. We find that the formation of a partially intact shell structure requires a rather uniform molecular cloud with a fractal dimension of $\mathrm{D_f} > 2.5$, which implies that the interstellar gas in the vicinity of a young massive star is distributed rather evenly as compared to typically observed molecular clouds. In my talk I will discuss fractal molecular clouds, show the effect of ionising radiation for different initial conditions, and discuss possible conclusions on the formation of massive stars.

Contributed Talk

Ionisation feedback in star formation simulations

Barbara Ercolano

Observations of massive star forming regions show filamentary structures, bubbles and pillars that are often hailed as examples of ionisation feedback. Recent numerical simulations have achieved some success in reproducing some of the observed features, however the efficacy of the feedback mechanism is still under debate. Moreover, current star formation simulations necessarily employ a number of simplifying assumption in the solution of the radiative transfer and photoionisation problem which may limit the relevance of the results. In this talk I will examine the consequence of some of the most common approximations used and show the results of our ungoing efforts to a more holistic approach to include RT and photoionisation in the context of large scale hydrodynamical simulations.

Contributed Talk

Collisional formation of massive stars in accreting clusters

Nickolas Moeckel, Cathie Clarke

We investigate the radial contraction of forming protoclusters using an extension of n-body techniques that incorporates the accretional growth of stars from a background potential. We target our experiments toward populous (n $\sim$ 30000) clusters likely to experience collisions as a result of accretion-driven contraction, and we verify that in less extreme star forming environments like Orion, the stellar density is low enough that collisions are unimportant. We find that the character of the collision process is not such that it is a route toward smoothly filling the top end of the mass spectrum. Instead, runaway growth of one or two extreme objects occurs within less than 1 Myr after accretion stops, resulting in a few extreme objects with masses several times the maximum reached by accretion. We compare the characteristics of these clusters to massive galactic clusters like the Arches.

Invited Review

Evidence for a top-heavy IMF in extreme star-bursts

Pavel Kroupa

Ultra compact dwarf galaxies (UCDs) show a larger M/L than star clusters but are collisionless. The high M/L values may be a result of a top-heavy IMF contributing remnants in large numbers. Also, some globular clusters show evidence for an abnormally depleted low-mass stellar mass function. This may be due to significant mass loss from a top-heavy IMF in an initially mass segregated cluster. These scenarios allow us (with Joerg Dabringhausen and Michael Marks) to distill a possible systematically varying IMF top-heaviness with star-burst density.

Short Invited Review

Properties of hierachically forming star clusters

Thomas Maschberger

I show results of an analysis of the calculations by Bonnell et al. 2003 and 2008 where between a few hundred and about 2500 stars/sink particles are formed. Via identifying subclusters one can follow quantitatively the time-evolution of structure, mass segregation and the higher-mass initial mass function. I find that the properties of the subclusters depend on their evolutionary stage, with evidence for primordial mass segregation. The upper limit of the initial mass function is not consistent with the generally assumed 150 $M_\odot$ for the physical upper limit, but is increasing with an increasing number of stars that are formed. I will also discuss whether this n-dependent upper limit is present in observational data.

Contributed Talk

Circumstellar discs in the Arches starburst cluster

Andrea Stolte

From theoretical and observational grounds it may be unexpected to find discs around massive stars in a starburst cluster environment. Theoretically, the intense UV radiation field might destroy discs as soon as the high-mass O stars switch on. Observationally, disc lifetimes are suggested to be shorter than 1 Myr in Herbig Be stars. We have detected a significant sample of 23 L-band excess sources in the Galactic centre Arches cluster at an age of 2.5 Myr. The L-band excess sources with known proper motions are genuine members to the cluster. The three sources with SINFONI spectra all display CO bandhead emission in the K-band spectrum, with indication of rotation in the line profiles. In this contribution, I will show the evidence that these sources are optically thick circumstellar discs and argue that the host stars cover spectral types as early as B3. I will discuss the implications for disc survival in a starburst cluster environment in comparison to Herbig Be stars found in nearby star-forming regions. This finding lends new support to the paradigm of high-mass star formation via disc accretion.

Contributed Talk

The present day mass function of the Quintuplet cluster - star formation in the extreme environment of the Galactic centre

Benjamin Hußmann, Andrea Stolte, Wolfgang Brandner

The three young, massive star clusters found in the galactic centre region (Young Nuclear Cluster, Arches and Quintuplet cluster) are among the six most massive, open clusters in our galaxy with masses similar to low-mass, extragalactic starburst clusters. As the extreme conditions for star formation in this region are likely comparable to the ones found in the HII regions in starburst galaxies these clusters serve as templates for extragalactic starburst clusters. These clusters constitute unique laboratories for stellar evolution, as they contain large numbers of stars in the entire mass range and therefore sample the present day mass function (PDMF) up to the most massive stars. The Quintuplet cluster with an age of about 4 Myr displays the lowest spatial density of the three Galactic centre clusters. In order to derive an unbiased sample of cluster stars and determine the mass function correctly, cluster and field stars have to be discerned out to radii where the member density drops below the field star density. We used proper motion measurements to establish a membership sample. The cluster stars were selected based on their individual proper motion, which was determined by comparing two high precision astrometric VLT/NACO datasets with a time baseline of 5 years. From this selection of cluster members the PDMF of the Quintuplet cluster is derived for the first time.

Discussion panel

Discussion: Birth and Influence of Massive Stars

Bruce Elmegreen

Session 3: Stellar Multiplicity and Dynamics

S3

Invited Review

Binary star formation

Cathie Clarke

During the 1990s, binary star formation became one of the critical litmus tests of star formation theory, a development driven both by the availability of systematic binarity surveys and the advent of codes with the capability of following collapse to stellar densities. To some extent, this effort has slowed due in part to an observational concentration on the search for planetary mass companions together with the push, on the theory side, towards cluster scale simulations.
Eduardo Delgado, who died tragically in 2007, was one of the researchers who most thoroughly explored the consequences of the hydrodynamic codes available at the time for the statistical properties of binary stars. Although a theorist, he recognised that observational data provides the most exacting calibrator of theoretical models and was always scrupulous in comparing model outputs with observations. In this review, I take a look at how the field has moved on since Eduardo's death: for example, some of the results he obtained (regarding the predicted plethora of low mass companions at large radii) were almost certainly an artefact of the isothermal equation of state employed at the time. Indeed, the notable development since Eduardo's time has been the pursuit, by a number of groups, of simulations that include additional physics such as magnetic fields, radiative transfer and mechanical and thermal feedback. These simulations are just beginning to be brought to bear on the binary star formation problem. I shall argue that the subject is ripe for re-investigation, both theoretical and observational, and emphasise that one of the most basic theoretical problems (which Eduardo was working on at the time of his death: namely the common existence in nature of binaries of highly unequal mass) remains unsolved today.

Contributed Talk

The Dynamics of Brown Dwarf Binaries

Anthony Whitworth, Murat Kaplan

It appears that a brown dwarf in a wide orbit ($>$ 100 AU) around a Sun-like star is more likely than a field brown dwarf to be in a close ($\sim$ 5 AU) binary system with another brown dwarf. In principle these close BD/BD binaries could have formed elsewhere, and then been captured. By means of a large ensemble of N-body simulations, we show that this has too low probability to play a significant role in their genesis. This them implies that close BD/BD binaries are formed in orbit around Sun-like stars, possibly by disc fragmentation.

Contributed Talk

Why very low-mass binaries are different

Simon Goodwin

Very low-mass binaries (VLMBs) with system masses <0.2 $M_\odot$ appear to be tighter and less frequent than binaries around higher-mass stars which are thought to form by disc fragmentation. I will show that disc fragmentation cannot occur in systems with masses <0.2 $M_\odot$ and so there should be a discontinuity in binary properties at this mass. I will speculate on how VLMBs might form.

Contributed Talk

The Effect of Stellar Density on Stellar Multiplicity

Robert King, Richard Parker, Jenny Patience, Simon Goodwin

Combining high resolution images and N-body simulations, we are investigating the multiplicity of T Tauri stars as a function stellar density in 6 star-forming regions. We will present the results of this comparison determined over a common separation range of ∼40–400 AU for systems with flux ratios of ∼3.5 magnitudes. Previous studies have noted the stark difference in multiplicity between Taurus and the ONC, but a direct comparison of several regions has been hindered by observational sensitivities and low number statistics.

We find a steadily decreasing rate of multiplicity with increasing stellar density which is compared with models tailored to the properties of each region and accounting for observational biases. This comparison indicates that the variation of multiplicity with stellar density is consistent with a formation scenario involving a constant initial binary fraction and subsequent stripping of binaries by stellar encounters. We will then discuss a further comparison of the separation distribution of a subset of clusters with similar densities to probe possible primordial differences in multiplicity.

Contributed Talk

A-Star Multiplicity and the Companion Mass Function - from Stars to Brown Dwarfs

R. J. De Rosa, J. Patience, C. Marois, B. Macintosh, R. Doyon, I. Song, A. Schneider, J. Graham, N. McConnell, M. Bessell

We present the first volume-limited ($D < 75$ pc) multiplicity survey of over 400 A-type stars over the separation range of 10 to 2000 AU. Understanding the multiplicity of these massive stars allows the investigation of binary formation models, the unexplained X-ray emission of a subset of A-stars, the stability of circumstellar disks and the formation of planetary systems. Utilising adaptive-optics systems at five 3-8m telescopes, we have characterised the binary population of A-type stars to a sensitivity limit reaching the bottom of the Main Sequence. The binary population shows an increase in the multiplicity fraction for early-type primaries relative to lower-mass stars. The peak of the separation distribution is also significantly larger, at 350 AU (c.f. 40 AU for solar-type primaries), which may have implications for planet formation. The companion mass function is also resolved, indicating higher frequency of lower-mass companions. For the youngest subset of the sample, the sensitivity is sufficient to detect brown dwarfs, and we present the first measurement of the frequency of substellar companions to massive stars.

Contributed Talk

Inverse mass segregation in Taurus

Richard Parker, Jerome Bouvier, Simon Goodwin, Estelle Moraux, Richard Allison, Sylvain Guieu and Manuel Guedel

I will present results of a search for mass segregation in Taurus using the new Minimum Spanning Tree (MST) technique. This method compares the MSTs of any chosen subset of objects to the MSTs of random objects in a cluster. In contrast to Orion, where strong mass segregation is observed, the most massive stars in Taurus are preferentially located on the outskirts of the stellar aggregates. We also find that most low-mass stars are mass segregated when compared to random sets of stars.

Contributed Talk

Mass Segregation in Young Stellar Groups

Helen Kirk & Phil Myers

We identify fourteen well-defined young stellar groups in nearby star-forming regions, having typically 15-40 members with accurate spectral types, complete down to $\sim 0{,}02 M_{solar}$. Most groups have a stellar mass ratio $M_{max}/M_{min} >$20, consistent with random sampling of the IMF. The most massive star in a group tends to lie near the group centre, resembling the mass segregation seen in older clusters with more members. In these young groups, such a concentration of massive stars is unlikely to arise dynamically, since the typical member age is at most one or two crossing times. Instead, this mass segregation seems to arise because more massive stars tend to form in central positions of high density.

Session 4: The Low-mass End of the IMF

S4

Invited Review

The low-mass IMF in the nearest star-forming regions

Kevin Luhman

I will review the latest measurements of the IMF of low-mass stars and brown dwarfs in the nearest star-forming regions and the constraints that they provide for theories of the origin of IMF. In particular, I will examine whether there is evidence for significant variations in the IMFs of these regions and I will describe the current constraints on the minimum mass of the IMF.

Invited Review

The substellar IMF in young clusters

Jérôme Bouvier

Estimates of the substellar IMF have now been derived for a number of young open clusters (30–600 Myr) down to 20–30 Jupiter masses and for various star forming regions (1–5 Myr) down to a few Jupiter masses. We will review recent results regarding the shape of the substellar IMF and its sensitivity (or lackof) to environmental conditions, and discuss its temporal evolution in populated clusters.

Contributed Talk

The Stellar Low-Mass IMF: SDSS Observations of 15 Million M Dwarfs

John J. Bochanski, Suzanne L. Hawley, Kevin R. Covey, Andrew A. West, I. Neill Reid, David A. Golimowski, Zeljko Ivezic

We report on new measurements of the luminosity function (LF) and mass function (MF) of field low-mass dwarfs derived from Sloan Digital Sky Survey (SDSS) Data Release 6 (DR6) photometry. The analysis incorporates ~15 million low-mass stars (0.1 $M_\odot < M <$ 0.8 $M_\odot$), spread over 8,400 square degrees. Stellar distances are estimated using new photometric parallax relations, constructed from ugriz photometry of nearby low-mass stars with trigonometric parallaxes. We use a technique that simultaneously measures Galactic structure and the stellar LF from 7 $<$ M_r $<$ 16. We compare the LF to previous studies and convert to a MF using empirical mass-luminosity relations. The system MF, measured over $-1.0 < \log M/M_\odot < -0.1$, is well-described by a log-normal distribution with $M_o = 0.25$ $M_\odot$. We stress that our results should not be extrapolated to other mass regimes. Our work generally agrees with prior low-mass stellar MFs and places strong constraints on theoretical star-formation studies.

Contributed Talk

A Comparison of Protostellar Luminosity Functions Across Diverse Star Forming Environments

E. Kryukova & S.T. Megeath

A fundamental questions is "How does environment affect star formation and the properties of nascent stars?". We approach this question through a study of over 600 Spitzer-identified protostars from the nearby (within 1 kpc) star forming clouds Orion A & B, Cep OB3, Serpens, Perseus, Ophiuchus, Taurus, Lupus, Chamaeleon, and Mon R2, which encompass a range of cloud environments. We use Spitzer 3 to 24 micron photometry combined with 2MASS J, H, and K photometry and calculate bolometric luminosities. We find bolometric luminosities using an empirically derived mid-IR/bolometric luminosity relationship. Luminosity functions are then created for each cloud, and are corrected for multiple sources of contamination. In each cloud, the luminosity function peaks near 1 $L_\odot$, and in the more massive clouds that form higher mass stars, the luminosity functions show a tail extending up towards 1000 $L_\odot$. A comparison of the luminosity functions shows that clouds which form high mass stars, such as Orion or Cep OB3, have distinctly different luminosity functions from clouds which do not form high mass stars, such as Taurus or Ophiuchus. In Orion and Serpens, we find that the luminosity functions of protostars in dense environments are statistically different than those in more isolated environments, with the luminosity function in dense environments extending to higher luminosities. We discuss possible reasons for this difference.

Short Invited Review

The spectroscopic mass function in the Upper Sco Association

Nicolas Lodieu

The aim of the project is to determine as accurately as possible the shape of the mass function across the stellar/substellar boundary in the young (5∼2 Myr) and nearby (d = 145 pc) Upper Sco association. We have obtained multi-fibre optical spectroscopy of 94 photometric low-mass star and brown dwarf candidates in Upper Sco with the AAOmega spectrograph on the Anglo-Australian telescope. We have derived the spectral types, measured the equivalent widths of Halpha and gravity-sensitive features, estimated the effective temperatures and masses for each new spectroscopic member. Combining the current optical spectroscopy presented here with near-infrared spectroscopy obtained for the faintest photometric candidates, we confirm the shape and slope of our earlier photometric mass function. The mass function peaks at 0.2 $M_{\odot}$ and is flat in the substellar regime, corroborating the original hypothesis that Upper Sco may possess an excess of brown dwarfs compared to other young regions.

S4

Short Invited Review

Probing the low-mass end of the IMF in star-forming regions

Catarina Alves de Oliveira

One of the most attempted goals of star formation theories is to determine the dominant process by which brown dwarfs form and the implications of the environment on its outcome. Current theories must be able to reproduce not only the observed shape of the IMF, but predict observable properties of clusters such as multiplicity, mass segregation, frequency and sizes of discs, accretion, etc. The new observational frontier is therefore the detection and characterization of very low mass objects in star forming regions, to confront model predictions from numerical simulations of the collapse of molecular clouds to the observed properties of YSOs. I will present the results of a major observational study aimed at uncovering the low mass population of the 1 Myr old Rho Ophiuchi molecular cloud. Candidate BDs with masses down to the planetary regime have been identified using the deepest near-IR imaging survey of the entire region (WIRCAM/CFHT), and archival Spitzer and Subaru data. A spectroscopic follow-up of these candidates has been conducted using several facilities (TNG, GTC, NTT, VLT) to ascertain their spectral types and masses, and ultimately, to construct the low-mass end of the IMF for this star forming region. I will also present preliminary results of an analogous survey targeting IC 348.

Short Invited Review

M-Dwarfs to T-Dwarfs: the Low-Mass Initial Mass Function in IC 4665 and IC 348

Andrew Burgess

The low-mass end of the initial mass function (IMF) needs to be constrained to further current star formation theories and models. IC 4665 is a fairly young (∼30Myr) star cluster and is 356 pc distant towards the constellation Ophiuchus. Proper motion is low at −4 to −7.5 mas/yr and extinction is also low and present at A_v ∼0.59±0.15 mag. WIRCam Y, J, H and Ks observations were made using the CFHT and spanned 10 cluster fields (of total footprint ∼1.1 sq. deg.) and two control fields of $20' \times 20'$ each. Colour magnitude diagrams were used to compare the photometrically selected cluster member candidates to the 30Myr BT-SETTL model and previous radial velocity and/or spectroscopically confirmed cluster members. Contamination by field stars was assessed using the control fields. Masses were then assigned using the comparison model, before the lognormal and power law IMFs were calculated and compared to the IMFs derived for other open clusters.

Short Invited Review

A multi-wavelength study of the young open cluster NGC 6823

Basmah Riaz

NGC 6823 is a young open cluster that lies at a distance of ∼2 kpc in the Vulpecula OB1 association. Previous studies using CCD photometry and spectroscopy have identified a trapezium system of bright O- and B-type stars at its center, along with some 100 massive O- B- and A-type stars in the cluster. We present deep optical VRI and near-infrared JHK observations, complemented with Spitzer/IRAC observations, with an aim to identify the young low-mass population as well as the disk candidates in this region. The cluster shows variable extinction, with Av ranging between ∼2 and 20 magnitude. After applying an extensive selection criteria in order to correct for field star contamination, our final candidate member sample consists of 177 young stellar objects (YSOs), with a mean Av∼3 mag. A 62 % fraction of these are Class II systems, 4 % are Class I/Flat systems, while 34 % are Class III/photospheric sources. Our survey reaches down to I∼21 mag. We have constructed the initial mass function (IMF) of the cluster from ∼1.5 $M_\odot$ down to ∼0.05 $M_\odot$. The IMF shows a rise towards lower masses, with a peak at masses between 0.08 and 0.1 $M_\odot$. The age distribution for NGC 6823 shows accelerated star formation activity in the last ∼1 Myr, with a large ∼87 % fraction of candidate members lying at ages of ∼0.1–1 Myr. This young population is also the less massive in the cluster (<0.6 $M_\odot$). We discuss the possibility that the formation of this new generation of young low-mass stars may have been triggered by the massive stars in the cluster.

Short Invited Review

Near-IR & X-ray Observations of the Serpens Cloud

Elaine Winston

Here I will present the results of a combined study in the near-IR and X-rays of the Serpens North and South young star forming regions. Both Serpens North and South are nearby regions of embedded star formation, located in the Gould Belt. The near-IR observations were obtained using WIRCAM on CFHT, covering the Y, J, H, Ks and methane bands. These data were combined with observations in X-rays taken with ACIS-I on Chandra. While the infrared wavelengths are sensitive to circumstellar excess, the X-rays allow us to identify diskless Class III members of the cluster. Further, faint brown dwarfs can be identified in the near-IR, providing an insight into the very low mass population of these two regions. The distance to the clusters has recently been brought into debate, with the most commonly accepted distance of 260 pc falling short of the distance obtained using the X-ray Luminosity Function of 360 pc, and the parallax measurment to one YSO of 410 pc. I will present the XLF to the North region, showing how a greater distance of 360pc better fits both the X-ray and spectral data.

S4

Contributed Talk

First results from XMM-Newton Investigations in Lambda Orionis (XILO): Multi-wavelength study of the young cluster Collinder 69

B. Stelzer, D. Barrado y Navascues, N. Huelamo, M. Morales-Calderon, A. Bayo

The lambda Orionis Star Forming Region (1–6 Myr, 400 pc) is a complex of star forming clouds surrounded by a molecular ring with ∼5 deg radius which was probably formed by a supernova explosion. For a complete picture of star formation, believed to be determined by the supernova blast, the large-scale distribution of the pre-main sequence population in lambda Ori needs to be examined. We have embarked on a multi-wavelength study (XMM-Newton/X-ray, CFHT/optical, Spitzer/IR) of selected areas within this intriguing star forming complex that enable us to identify young stars and brown dwarfs. Our study comprises various areas within the cloud complex, including the central star cluster Collinder 69, the dark clouds B30, B35, LDN1603 and LDN 1588 within the cavity, and a concentration of B stars near the north-east of the molecular ring. This data set is among the most extended X-ray surveys carried out with XMM-Newton in a coherent star forming environment. Here, I discuss the results of our multi-wavelength study for the central cluster Collinder 69 with an updated census of the low-mass stellar population. I present initial results from a comparison of the properties of the young stars among the lambda Ori subgroups (X-ray luminosity function, spatial distribution, age, disk fraction, IMF).

Contributed Talk

SMA Survey of Low Luminosity Young Stellar Objects in Perseus

Masaaki Hiramatsu, Nagayoshi Ohashi (ASIAA), Vivien Chen (NTHU), Munetake Momose (Ibaraki U.), Yoshito Shimajiri, Ryohei Kawabe (NAOJ)

Very Low Luminosity Objects (VeLLOs), which have internal luminosity less than 0.1 $L_{\odot}$, are considered to be either extremely young protostars (hereafter Type 1) or young brown dwarfs (Type 2) based on their low luminosity. VeLLOs can offer insights into the onset of gravitational collapse of the cores and the formation process of the substellar objects. Early studies showed a wide range of the observed VeLLO properties, perhaps due to confusion of the two types, with outflow momentum flux from 1.5×10^{-5} to $5.0\times10^{-8} M_{\odot}$ km/s/yr and continuum flux density from 29 to 7 mJy. In the attempt to build a systematic approach for the classification of VeLLOs, we carried out a survey toward eight low luminosity objects in Perseus with the SMA to study their compact 230 GHz continuum emission and CO (2-1) outflow activities. The continuum emission clearly divides the selected sources into two groups: strong (>30 mJy) emission in three sources resembling Type 1 and weak ($<$ 10 mJy) emission similar to Type 2 in the other five. The three Type 1 sources are embedded in centrally concentrated SCUBA cores while two Type 2 sources appear to be at the periphery of a SCUBA core or inside a smoother core. Such a behavior indicates a close relationship between the mass assembling process with the final masses of the sources. We therefore suggest the continuum emission to be a good indicator for VeLLO type classification. On the other hand, the CO outflow momentum appears less correlated with the continuum flux and has a continuous distribution from 2.9×10^{-8} to $4.6\times10^{-6} M_{\odot}$ km/s/yr.

Contributed Talk

How to limit the effect of radiative feedback in low-mass star formation

D. Stamatellos, A. Whitworth

The first generation of stars which form in a collapsing cloud affects the subsequent star formation due to radiative and mechanical feedback (i.e. outflows/jets). We will focus on the effect of radiative feedback. At the initial stages of the formation of a star, its luminosity, due to accretion of mass onto it, is large enough to heat and stabilize its surrounding medium, preventing any further star formation. This is problematic as the formation of low-mass stars, brown dwarfs, and low mass-ratio binaries is suppressed. We will discuss whether episodic accretion can limit the effect of radiative feedback.

Contributed Talk

Herschel view of gas and dust in protoplanetary disks

C. Pinte and the GASPS Team

Primordial protoplanetary discs consist 99 % out of gas, and only 1 % out of dust, but the gas phase remained difficult to observe so far. Herschel offers a unique opportunity to probe the warm atomic and molecular layers of discs, from low mass T Tauri stars to intermediate and high mass Herbig Ae/Be stars. We present the first results of fine structure line emission and photometry from the Herschel Open Time Key Program GASPS (Gas in Protoplanetary Systems), which is observing a sample of 250 discs, concentrating on emission lines of [OI], [CII], H_20 and CO. These observations are interpreted in light of a grid of 300,000 models combining state-of-the-art radiative transfer and chemical codes. The first results of the GASPS survey indicates the main gas heating mechanisms as a function of the spectral type of the central object and offers insights on the relative evolution of the dust and gas phases in dics. We will also illustrate how the combination of Herschel line observations with continuum data and/or with rotational lines in the (sub-)millimetre regime, in particular CO lines, is required for a detailed characterisation of the physical and chemical properties of young stellar objects.

Contributed Talk

Using Observations of Brown Dwarfs Jets to Investigate Brown Dwarf Formation

Emma Whelan, Tom Ray, Catherine Dougados, Francesca Bacciotti

It is now apparent that proto-stellar -like outflow activity extends to the brown dwarf (BD) mass regime. Indeed 2MASS1207−3932, the lowest mass galactic object known to drive a jet, is only 24 Jupiter masses. The strong connection between accretion and outflow activity is now well accepted therefore it it not surprising that an actively accreting BD can drive a jet. However a detailed study of the properties of such jets can be used to better understand accretion activity and thus can contribute to the debate on BD formation mechanisms. In particular it is important to know how the mass ejection to accretion rate in BDs compares to that measured in low mass stars. Results presented in Whelan et al. 2009 for the BD jets observed to date suggest that this could be much higher for BDs. In addition, observations of episodic outflow activity in low mass stars have been used to infer episodic accretion. Early observations hint that BD jets also demonstrate such episodic behaviour. In the last 5 years we have been leading a project to search for and better understand BD optical jets. In this talk we will summarise our results to date and discuss their relevance to the debate on brown dwarf formation. At present the main focus of this work is to constrain the mass ejection to accretion rate and to extend the observations to other wavelength regimes e.g. near infrared through observations with state of the art instruments like XSHOOTER on the VLT.

Contributed Talk

Molecular Outflows in the Substellar Domain

N. Phan-Bao, C.-F. Lee, P. Ho

Phan-Bao et al. (2008) presented the first confirmed detection of a bipolar molecular outflow from the young brown dwarf ISO-Oph 102 of 60 M_J in rho Ophiuchi. The detection suggests that brown dwarfs and low-mass stars likely share the same formation mechanism. In this talk, we report our on-going search for molecular outflows from young objects in rho Ophiuchi and Taurus with masses ranging from 30 to 90 M_J using Combined Array for Research in Millimeter-wave Astronomy (CARMA) and Submillimeter Array (SMA). The observations of the earliest stages of brown dwarf formation will significantly improve our understanding of the formation of substellar objects.

Discussion panel

Discussion: Variation of the IMF?

Nate Bastian

Invited Review

The early evolution of low-mass stars and brown dwarfs

Isabelle Baraffe

I will discuss the early evolution of low mass stars and brown dwarfs and will analyse the main uncertainties in current evolutionary models, including the effects of rotation, magnetic field and early accretion history on young object's structure. Special attention will be paid to the well known spread in HRD observed in star formation regions and young clusters for objects of a few Myr old and to the lithium depletion, used as an age indicator and a criterion for cluster membership for low mass stars

Short Invited Review

Constraints on Theoretical Stellar Models: Empirical Measurements of the Masses of Stars and Brown Dwarfs at Young Ages

Keivan G. Stassun

We present a summary of the current sample of young stars and brown dwarfs with direct and accurate mass measurements, and we summarize the extent to which the masses predicted by current theoretical pre-main-sequence evolution models for these objects agree with the empirical determinations. We highlight a few recent discoveries among the sample of young eclipsing binaries that may have particularly important implications for the nature and origin of the initial mass function at very low masses, including: (1) the effects of magnetic activity on the inferred masses of very low mass stars and brown dwarfs, (2) the protostellar collapse and accretion histories of close binaries, and (3) the frequency of high-order (e.g. triple) systems.

Contributed Talk

epsilon Indi Ba, Bb: dynamical masses and spectroscopic study of the nearest brown dwarf binary system to Earth

Cátia V. Cardoso

Binary brown dwarf systems provide crucial benchmarks for testing the low-mass end of evolutionary models as both components will have the same age and chemical composition. ϵ Indi Ba, Bb, (T1 and T6), are the closest known brown dwarfs to Earth (3.6224 pc). Moreover, with a K4.5 star companion, ϵ Indi A, allows the break of the substellar mass-age degeneracy. Our observations using the ESO VLT include relative and absolute astrometric monitoring and high angular resolution optical, near-infrared, and thermal-infrared imaging and medium-resolution spectroscopy. Using our spectroscopic observations and $VRIzJHKL'M'$ broad-band photometry of the individual components we derived luminosities of log $= -4.699\pm0.017$ and -5.232 ± 0.020, effective temperatures of 1300 - 1340 K and 880 - 940 K and surface gravities of log g = 5.25 and 5.50 for ϵ Indi Ba and Bb respectively. The relative orbital motion of the brown dwarfs has been monitored since June 2004 with the VLT NACO near-IR adaptive optics system determining a total dynamical system mass of 121±1 M_{Jup}, significantly in excess of previous estimates. Combining our system mass determination and derived luminosity, evolutionary models predict an age of 3.7–4.3 Gyr, also significantly higher than previous estimates. We have also been monitoring the absolute astrometric motion of the system since August 2005 against a network of field stars using the VLT FORS2 optical imager and we will present the individual masses of *epsilon* Indi Ba, Bb, which assuming they are coeval will be able to test the mass-luminosity relation for intermediate age brown dwarfs without the usual ambiguity due to age. This system will allow us to test the predictions of evolutionary and atmospheric models with a precision never obtained before, and give a tightly constrained benchmark that the next generation of models must be able to reproduce.

Contributed Talk

Testing Theory with Dynamical Masses and Orbits of Ultracool Binaries

Trent Dupuy (CfA/SAO), Michael Liu (IfA/Hawaii)

Direct mass measurements are essential to test the evolutionary and atmospheric models that underpin studies of very low-mass objects. I will present results from our program to test models using precise dynamical masses (as good as 2 %) for ultracool binaries, based on IR parallaxes from CFHT, near-IR spectroscopy, and Keck laser guide star AO astrometry for a sample of over 30 objects since 2005. In just the last 2 years, we have more than tripled the number of late-M, L, and T dwarf binaries with dynamical masses. We find that the temperatures predicted by evolutionary models for most field binaries of known mass are discrepant with those derived from fitting the observed spectra with model atmospheres, indicating systematic errors of $\sim$200 K (or 30–40 % in radius). For the rare field binaries in triple systems that have age determinations from their solar-type primaries, we find that evolutionary models systematically underpredict luminosities by a factor of $\sim$2 at a given mass, which means that model-based substellar mass determinations (e.g., for the low-mass IMF) may be systematically overestimating masses. Finally, we have employed our large sample of binary orbits to carry out a novel test of the earliest evolutionary stages, by using the distribution of orbital eccentricities to distinguish between competing models of brown dwarf formation.

Contributed Talk

A new photometric mass scale

Mayne, Nathan & Cameron Bell

Many mass functions, including the deepest available originate from photometric measures of the masses. For young clusters these masses depend critically on the ages assumed. Naylor (2009) showed that ages derived from main-sequence members are a factor two older than those derived by traditional pre-main-sequence methods. Using the older age can change the derived masses by a factor two. We present evidence that the pre-main-sequence data can be reconciled with the older ages, and thus the older ages are correct. This implies that our masses for young stars may be too small be a factor two. We derive new mass functions based on these new ages, and discuss their implications for star formation.

Session 5: The Origin of Stellar Masses

S5

Contributed Talk

Initial conditions for star formation and the IMF

Lee Hartmann

I will consider the impact of initial conditions for molecular cloud formation on the resulting stellar IMF, which are key for understanding both the potential role of gravitational focusing (aka competitive accretion) and the processes of fragmentation on small scales, taking into consideration the presentations made at this conference.

Conference Summary

Final summary and discussion

Matthew Bate

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Posters

Poster abstracts ordered alphabetically by first author name.

Dynamical mass segregation in young star clusters

Richard Allison

I will present N-body simulations of initially clumpy and cool star clusters, and a new method that can be used to detect and quantify mass segregation. I will discuss how these initial conditions affect the evolution of star clusters leading to the onset of mass segregation, the formation of trapezium systems, massive star ejections and the dynamical destruction of the clusters themselves.

3D hydrodynamical simulations of substellar objects' atmospheres

Veronica Arias

Since the 1995 discovery of the first Brown Dwarf and the first Extrasolar Giant Planet, hundreds of these Sub-stellar Objects (SSO) have been detected. With surface temperatures below 2000K, convection is the dominant energy transport mechanism and plays a key role in the thermal structure and chemical mixing of their atmospheres. Modeling such cool atmospheres has proven to be challenging. An enormous progress has been made in the treatment of opacities and in the development of an Equation of State (EOS), but the mixing length theory (MLT) is still widely used as an approximation for convection. We treat convection in a more realistic way. We use the FLASH Code to perform 3D hydrodynamical simulations in order to study the various effects of convection in the SSO atmospheres. Since molecules form at such low temperatures and these chemical processes can energetically play an important role for the onset of convection, the choice of the EOS is crucial. We have coupled to the FLASH code a realistic and detailed EOS, which is a module of the PHOENIX code. This EOS can handle the low temperatures encountered in the sub-stellar objects' atmospheres through a detailed treatment of the physical and chemical phenomena. We will present the advantages and limitations of this approach, and the current status of the project.

Filamentary structures revealed by Herschel.

Doris Arzoumanian

The SPIRE and PACS images from the Gould Belt key program observed by Herschel reveal fascinating, omnipresent filamentary structures as well as numerous dense cores embedded in the filaments (André et al. 2010). I will present some preliminary analysis of the radial profiles of the filaments present in three fields observed with Herschel: Aquila rift, Polaris flare and IC 5146. This study coming from the observed properties (length, width, column density, critical line mass) of the filaments enables us to constrain the theories (gravitational collapse, cloud turbulence, magnetic field) on the formation of the filaments in star forming regions.

The influence of massive stars on star formation in Cepheus OB2: Results from the IPHAS H-alpha survey

Geert Barentsen

The INT Photometric H-Alpha Survey (IPHAS) is a 1800 deg^2 survey of the Northern Galactic Plane, reaching down to r' $\sim$ 21 and nearing completion in 2010. We demonstrate how the survey can be used to (1) reliably select T-Tauri candidates and (2) constrain the accretion rates within 0.5 dex. IPHAS is a necessary addition to spectroscopic surveys because it allows large and uniform samples of accretion rates to be obtained with a precise handle on the selection effects.
We apply the method on a region of 7 deg^2 towards Cepheus OB2 and obtain 110 T-Tauri candidates with accretion rates greater than $10^{-9,5}$ $M_\odot$. Most of the bright candidates are confirmed by previous studies. In addition, we discover 50 new faint, low-mass candidates (r' $>$ 18.0; $M_* < 0.5$ $M_\odot$) which are densely clustered near the molecular clouds IC1396a and IC1396n. We show that these clouds are sites of ongoing star formation, driven by radiative implosion due to the massive star system HD206267A (O6.5V) at a distance of 5 to 15 pc. In contrast, within 2.5 pc from these hot stars we observe a decrease of accretion rates, which may be due to the destructive effects of UV-photoevaporation. Finally, we use our statistical sample to test recent claims on the steep dependency of accretion rates on stellar mass, and find that this dependency is largely due to selection and systematic effects.

Physical Conditions of a Low-Mass Class 0 Source in Ophiuchus

Mary Barsony

The outflow driven by the Class 0 protostar, IRAS 16253-2429, is associated with bipolar cavities visible in scattered mid-infrared light, which we refer to as the Wasp-Waist Nebula. IRS scan mapping with Spitzer reveals an S-shaped morphology in six different pure rotational transitions of H_2. This is the least luminous Class 0 flow mapped in the pure rotational H_2 lines by three orders of magnitude. Spatially resolved excitation analysis shows remarkably constant temperatures of $\sim$ 1000K in the shocked gas. The mass of hot H_2 is of order 10^{-3} of the cold (30K) CO in the outflow. Comparison of the H_2 data with detailed shock models shows the emitting gas is passing through J- $n_H < 10^3$ cm^{-3} for the blue-shifted lobe. Shock velocities are 5 km s^{-1} $< v_s < 10$ km s^{-1} for the red-shifted gas and $v_s = 10$ km s^{-1} for the blue-shifted gas. Initial transverse (to the shock) magnetic field strengths for the red-shifted lobe are in the range 10μG-32μG, and just 3 μG for the blue-shifted lobe. Additionally, a map of the protostellar envelope in absorption in the 11.3 μm PAH feature is presented for the first time.

The early dynamical evolution of Eta-Chamaeleontis

Christophe Becker

Eta Chamaeleontis is a remarkable young ($\sim$ 9 Myr) association. It is sparse and compact (18 systems are concentrated in a 1 pc radius), and presents a mass function that is comparable to other rich open clusters in the mass range 0.15-4 $M_\odot$. However it presents some non standard mass distribution features (deficit of low mass stars and brown dwarfs, lack of wide binaries, mass segregation).
Moraux et al. (2007) performed N-body simulations and found that these properties can result from dynamical evolution, when starting with a “universal” log-normal IMF but a very compact configuration. In this poster, we present new N-body numerical simulations of the early dynamical evolution of Eta-Cha. More realistic initial conditions taking into account the presence of primordial binaries, cluster substructures and/or subvirial conditions have been tested.

The WFCAM Transit Survey: searching for low-mass eclipsing binaries

Jayne Birkby

Double-lined eclipsing binary systems (EBs) provide the most accurate way to measure fundamental properties, such as the mass and radius, of very low-mass stars and brown dwarfs (BDs). We present here the WFCAM Transit Survey (WTS); an ambitious, near-IR photometric monitoring campaign of $\sim$ 6000 M-dwarfs across four 1.5 deg^2 fields situated > 5 degrees above and below the galactic plane. We utilize a unique opportunity provided by the highly efficient queue-scheduled operational mode of the UKIRT to observe our fields, with at least one visible at any time, when atmospheric conditions and RA coverage are unsuitable for other ongoing UKIRT programs. By probing the peak of the M-dwarf spectral energy distribution ($13 < J < 17$), we obtain a statistically significant sample of low-mass stars, which allows us to place meaningful constraints on the occurrence and formation of substellar objects around M-dwarfs. In addition, we can accurately measure the distribution of their masses, radii, mass ratios and separations. The WTS has achieved one thousand epochs after 2 years in one of our target fields and will continue until April 2012. We are probing orbital periods between 0.1-10 days. Our light curves have a per data point photometric precision of $\sim$ 3-4 mmag for the brightest objects, with RMS scatter $<$ $1\,\%$ for $J < 16$, which is amply sufficient to detect BDs and can even reveal Earth-size companions around M-dwarfs. I report here on the goals of our survey, our most recent low-mass EBs results and the properties of our M-dwarf target sample. I also discuss our processing methods and how we combat the challenges encountered when observing occultations of faint red stars and the spectroscopic follow-up required to confirm them.

Comparison between SPH and AMR simulations of cloud-cloud collisions

Thomas G. Bisbas

We compare SPH and AMR simulations of two homogenous clouds which undergo head-on collision, a possible mechanism for the formation of super star clusters. The basic thermodynamics of radiative cooling are taken into account. We explore numerical techniques to obtain convergence between the SPH and AMR results.

From M dwarfs to brown dwarfs: Binary properties at the low mass end of the stellar mass function

Wolfgang Brandner

We have carried out the largest high angular resolution M-dwarf binary survey to date. 800 young M dwarfs within $\sim$ 50 pc of the Sun, and with spectral types in the range M0 to M6 were surveyed for visual companions in the i- and z-band with a typical angular resolution of 100 mas. The study was carried out using the two Lucky Imaging cameras AstraLux and AstraLux Sur at the Calar Alto 2.2m telescope in Spain and the ESO 3.5 New Technology Telescope in Chile, respectively. The primary goals of the survey are i) identify short-period binaries suitable to improve the mass-luminosity relation for stars of MK type later than M3V, which is still poorly calibrated, ii) study binary properties as a function of primary mass, and compare the observed properties with model predictions, and binary properties of more massive stars and of brown dwarfs, and iii) identify binaries suitable for high-precision astrometric monitoring for future exoplanet surveys using interferometry. We report on the how binary properties change with primary mass, and investigate how the early- to mid-M dwarf binary sample with primary masses in the range $\sim$ 0.15 to 0.5 solar masses compare to the binary properties of very-low-mass stars and brown dwarfs on the one hand, and those of solar type star on the other hand. We discuss the findings in the framework of recent theoretical investigations on the formation of low-mass stars and brown dwarfs.

Clouds to Cores: A 3.4mm Continuum Emission Study of Circumstellar Material in Ophiuchus

Joanna Bulger

Circumstellar disks are the birth sites of planet formation. Both disk mass and dust opacity spectral index are crucial disk parameters in understanding the early stages of planet formation. These properties are directly measured from millimeter continuum emission, that is sensitive to the optically thin, cooler outer regions of circumstellar disks. The results presented are of a 3.4mm continuum survey using the OVRO interferometer, on a sample of 34 members of the rho Ophiuchi molecular cloud, one of the nearest sites of ongoing clustered star formation. The sample consists of both starless clumps and Class 0-II young stellar objects, spanning the evolutionary sequence of low mass star formation. These observations investigate circumstellar material in the form of a circumstellar disk and surrounding envelope. Continuum emission is detected in 22 of the sources at a 3σ level (typically 0.9 mJy), with a typical beam size of $3''.7\times2''.3$. The measured fluxes of the brightest Class 0 and faintest Class II range from 227 mJy to 3 mJy. The dust opacity spectral index, indicative of grain growth, of these sources has been determined from these flux measurements, taken in combination with previous millimeter wavelength observations obtained from the literature. Estimations of the total disk masses of these sources have been directly calculated from the measured flux densities.

Activity and Rotation in the Zero Age Main Sequence cluster h Per

Marilena Caramazza

We describe the initial results of the deep Chandra/ACIS-I observation of h Persei, a young (13 Myr) cluster at the transition between the Pre Main Sequence and the Zero Age Main Sequence phases. This is crucial age at which the stars should reach the fastest rotation, since the contraction has finished and there has not been enough time for losing significant angular momentum via magnetic braking. Taking advantage of the long Chandra observation ($\sim$200 ks), we detected 1010 X-ray sources, 800 of which have been identified as photometric members of the cluster on the basis of the observations taken during the Monitor program. The detected members have L_x is in the range 29.3-31.8 erg/sec. We have analyzed L_x/L_{bol} for our sources, finding we have reached the unsaturated regime for solar mass stars, while we have observed just the tail of the distribution for lower mass stars.

Mass and radius of hybrid stars using Nambu-Jona-Lasinio model

Jaziel Coelho

We investigate the hadron-quark phase transition inside neutron stars and obtain mass-radius relations for hybrid stars. The equation of state for the quark phase using the standard NJL model is too soft leading to an unstable star and suggesting a modification of the NJL model by introducing a momentum cutoff dependent on the chemical potential. However, even in this approach, the instability remains. In order to remedy the instability we suggest the introduction of a vector coupling in the NJL model, which makes the EoS stiffer, reducing the instability. We conclude that the possible existence of quark matter inside the stars require high densities, leading to very compact stars.

IMF or IMFs ?

Sami Dib

The stellar initial mass function (IMF) is one of the cornerstones of modern astrophysics and its universality or potential variation has very important consequences on the evolution of galaxies and their chemical enrichment, the dynamics of interstellar gas, and the evolution of individual stellar clusters. In this poster, I will discuss the evolution of the dense core mass function (DCMF) in a star forming clump, and the transition from the DCMF to the stellar initial mass function IMF. In particular, I will demonstrate how several physical processes such as the coalescence of cores, gas accretion by the cores and feedback in the form of stellar winds by the newly formed massive stars shape the DCMF and the corresponding IMF. The influence of different clump and core properties (i.e., their density profiles, their contractions timescales, concentrations, and level of turbulence) in the context of this Accretion-Collapse-Feedback model will be presented, and their role in generating variations in the IMF of stellar clusters highlighted. Finally, I will address, whether the metallicity of the gas influences the shape of the stellar IMF.

The effect of dust cooling in the fragmentation of star-forming clouds for the transition from Pop. III to Pop. II

Gustavo Dopcke

The first burst of star formation in the Universe is thought to give rise to massive stars, with current theory predicting masses in the range 20-150 $M_\odot$. This contrasts with present-day star formation, which tends to yield stars with masses less than 1 $M_\odot$, and so at some point in the evolution of the Universe there was a transition from primordial (Pop III) star formation to the mode of star formation that we see today (Pop II/I). The most widely accepted cause for this transition is metal enrichment of the interstellar medium by the previous generations of stars. This suggests that there may be a "critical metallicity" at which the mode of star formation changes.

We investigate the effects of the cooling due to dust grains on the collapse of low metallicity star forming clouds and the Pop III/II transition. Making use of 3D numerical models to follow the thermal evolution of clouds with different metallicities, we study self-consistently the evolution of the gas and dust temperatures during the collapse, and determine the properties of the cloud at the point at which it undergoes gravitational fragmentation. This allows us to investigate the role that dust cooling may play in the transition from a Pop III IMF composed predominantly of high-mass stars to the IMF we observe today.

Examining the properties and dynamics of young protoclusters: striving to unravel the initial conditions and triggers of star formation.

Ana Duarte-Cabral

The formation of stars in molecular clouds begins with the fragmentation and collapse of clumps and cores, either through simple self gravitational collapse or triggered by an external event. The star formation activity within a given cloud is specific to that cloud, where the imprints of the initial conditions are often still seen in the properties of the gas and dust of young protoclusters. We present our work in the Serpens Main Cluster, a young protocluster whose gas emission provides evidence for the event which triggered the most recent star forming episode. We studied its gas properties using CO isotopologues from which we proposed a scenario for the star formation trigger, tested further with SPH simulations. We are extending this work to other regions within the Gould Belt with a variety of star forming efficiencies, in search of the particular physical properties and dynamics of a molecular cloud that allow or prevent clouds to be in the verge of forming stars.

X-ray irradiated protoplanetary discs

Barbara Ercolano

The later stages of low mass stars formation invariably occur via accretion through a (protoplanetary) discs. The study of the evolution and final dispersal of these gaseous dusty discs is key to both the star and planet formation process and it is intimately linked to the X-ray properties of the newly formed star. Accretion is thought to be driven by magnetorotational instabilities which require a low level ionization, provided by X-ray irradiation, in order to couple the gas to the magnetic field. Dispersal is also thought to be driven by X-rays through the photoevaporation process. In this talk I will discuss recent results of numerical simulations of the ionization structure and evolution of X-ray irradiated discs in the context of recent observations.

Search and spectroscopic characterization of ultracool subdwarfs.

Marcela Espinoza Contreras & Nicolas Lodieu

Ultracool subdwarfs are important tracers of the chemical enrichment of the Galaxy and likely belong to the first generation of stars. We have cross-matched several large database, including UKIDSS (UKIRT Infrared Deep Sky Survey), SDSS (Sloan Digital Sky Survey), and 2MASS (Two Micron All Sky Survey), to look for ultracool subdwarf candidates i.e. metal-poor dwarfs with spectral types later than M5. We have obtained optical spectra of a large sample of candidates with VLT/FORS2 and GTC/OSIRIS to confirm (or otherwise) their low-metallicity status. In this poster, we present the photometric selection and preliminary results of the spectroscopic follow-up.

NGC604 at the NIR: searching the new generation of stars

Cecilia Fariña

We present a Near Infrared photometric study focused on the location and characterization of the new born stellar content of NGC 604. NGC 604 in M33, together with 30 Doradus in the LMC, are the most outstanding massive star formation regions in the Local Group. The study and understanding of these regions provide clues to the still unknown issues and open questions about star formation in general and particularly about high mass star formation. NGC 604 has been the target of many important studies during the past few decades, from which is known that the Giant HII Region of NGC 604 is ionized by more than 200 OB stars immerse in complex environment with a puzzling geometry and dynamics. Many WR and RSG were identified within its stellar population where there are also signs of active star formation. Our contribution to the knowledge of NGC 604 stellar content and its environment is in the NIR wavelength range. NIR observations constitute an important source of information specially in star formation regions, and is not yet fully explored in NGC 604. By means of NIR images taking with Gemini-NIRI in JHKs and BrG, PaB, and H2 we characterized the young stellar content of NGC 604, finding that almost 20 % of the field sources exhibit intrinsic IR excess. We ascertained the location of these objects, which points to the places were star formation processes are taking place. This study will be followed with new spectroscopic observations to disentangling the real nature of some of these sources.

The star formation rate of supersonic turbulence

Christoph Federrath

I will show results from recent high-resolution numerical simulations of self-gravitating turbulence. Sink particles are used to model the collapse and accretion of dense cores, and thus to measure the mass function and star formation rates of the dense gas. It is shown that the star formation rate depends sensitively on the turbulence forcing. In particular, compressive (curl-free) forcing produces star formation rates more than one order of magnitude higher than solenoidal (divergence-free) forcing at the same RMS Mach number. This suggests that analytic models of the star formation rate should take the turbulence forcing into account, as the rate depends more strongly on the forcing than on the Mach number of the turbulence.

Westerlund 1: a 2D approach for the study of its elongated shape and its spatially varying IMF

Mario Gennaro

Westerlund 1 (Wd1) is the most massive compact young stellar cluster in the Local Group, comparable in mass to Super Star Clusters in starburst galaxies. As so, it is one of the few test cases in the Milky Way for the study of intense events of star formation over the entire range of stellar masses. Moreover, given its large total mass, Wd1 can also be considered as a prototype for the study of stellar dynamics in precursors of Globular Cluster. I'll present a new approach in the study of Wd1 properties, which incorporates a 2D mapping of the incompleteness correction, and a new probabilistic technique to obtain an optimized field decontamination when using only photometric data. The cleaned colour-magnitude diagram, together with up-to-date MS and PMS stellar models, is used to derive basic properties of the cluster such as distance, extinction and age. We found values of d = 4 kpc, Ak = 0.9 mag and t = 4 Myr. Our new 2D approach furthermore facilitates an unbiased study of the spatial properties of Wd1, without any a priori assumption on the cluster symmetry and on the structure of the completeness pattern. Thanks to that we are able to investigate the local variations of the IMF slope which indicate that mass segregation is present in Westerlund 1. From the analysis of stellar density contours we infer that Wd1 has a quite elongated shape; we have already found indications of elongation in our previous study (Brandner et al., 2008) where, on the other hand, we assumed a spherical shape for the incompleteness pattern; the findings of the present work indicate that elongation is even more pronounced and then that an asymmetric incompleteness correction is necessary to correctly determine the shape of Wd 1. The observed elongation points to the fact that the internal dynamics of Wd 1 is probably not trivial and probably the overall structure is not in dynamical equilibrium, a challenge for theoretical studies of clusters dynamical evolution.

A new look at G353.2+0.9: cloud cores and star formation

Andrea Giannetti

We identify multiple cores in different molecules and transitions, and perform a comparative study through LTE and LVG analyses. Particular attention is given to the elephant-trunk structure pointing towards the open cluster Pis-24. The molecular clump associated with this feature appears to be very dense and hosts young stellar objects; one of these is located at its apex. The bright elongated structure, usually referred to as the "ionization front" is not associated with any molecular material, and is therefore most likely not an ionization front. This finding effectively proves that the stars of Pis-24 are the main source of excitation of G353.2+0.9. With our JHK photometry we identify and classify the embedded sources. We confirm the presence of an abnormal reddening law in this region. We find highly reddened sources, up to $A_v \sim 30$ mag, several of which show a NIR excess, proving the existence of a very young population of embedded stellar objects. Our deep NIR photometry also allows us to establish the eventual presence of evolutionary gradients and of an increase in surface density of stars, witnessing the presence of deeply embedded, recently-formed star clusters.

Influence of the Initial Conditions on Star Formation

Philipp Girichidis

The influence of the initial conditions during the collapse of the gas cloud on the fragmentation, the local formation process and the evolution of mass accretion onto the protostellar cores is still unclear and can not be quantified, yet. Among the initial conditions, the interplay between the density distribution, the structure of turbulent motion, the rotation of the gas cloud and self-gravity are likely to have the first important impact, and trigger the fragmentation process long before other physical processes like radiation and the initiation of nuclear burning play a significant role. In order to shed light on the connection between these initial properties of the cloud a systematic investigation of the influence of the initial density profile and turbulent motion was performed. For each of four different density profiles and six supersonic turbulent velocity fields a three-dimensional collapse simulation was carried out in order to examine the cloud evolution, the fragmentation process, the number of formed protostars and the accretion onto these protostars. The simulated cloud comprises 100 solar masses in a sphere with a diameter of 0.2 pc. We found a strong correlation of the initial density profile and the resulting stellar distribution. Flat density profiles form multiple star clusters, strong concentrated profiles form a dominant central star and in some cases, depending on the turbulent velocity field, a compact star cluster. All simulated clouds show a primordial mass segregation, where the accretion onto the most massive central stars is significantly decreased as soon as other stars are formed around it. This leads to the conclusion that the stellar mass of the most massive stars is mainly determined by the time between their formation and the formation of surrounding companions.

The Etelman Astronomical Observatory: The United States' Southeastern most Observatory

Cynthia Gomez-Martin

The Etelman Astronomical Observatory (EAO) is located on the beautiful Caribbean island of St. Thomas, Virgin Islands. The observatory houses a 0.5-m robotic telescope with imaging capabilities at optical wavelengths. This observatory is maintained by the College of Science and Mathematics, University of The Virgin Islands. EAO is located on one of the highest points of St. Thomas (18^o 21' N 65^o W at an elevation of 420 meters). Thus making it the south-easternmost optical observatory in the United States. We will show the potential this small observatory for this community, particularly for exoplanet searches.

Dense core formation in supersonic turbulent converging flows

Hao Gong

We present results from numerical simulations of dense core formation in converging, turbulent flows within Giant Molecular Clouds (GMCs). Filamentary high density regions form in the post-shock layer because of converging flows initiated by turbulence and enhanced by self-gravity. Dense cores form and evolve inside these filaments. The core building and collapse stages which were identified in 1D spherical simulations are again seen in the non-spherical case. The velocity dispersion is low in high density filaments and even lower in dense cores. We also show that cores identified from the gravitational potential of surface density are comparable to cores identified by the gravitational potential of volume density. We find that the median core mass is proportional to the inverse of the Mach number of the large-scale converging flows. This result can be understood analytically based on gravitational instability in shocked layers. The first core forms at a time that varies inversely as the square root of the Mach number; this can also be understood analytically.

The extinction map of the Arches starburst cluster in the Galactic center

Maryam Habibi

The Galactic center is the most active site of star formation in the Milky Way Galaxy, where particularly high-mass stars have formed very recently and are still forming today. The Arches cluster is a young, massive starburst cluster, near the Galactic center.
From wide field JHK imaging we derive the extinction map of the region.
We are analyzing 2 epochs of K band images of the Arches cluster obtained by NACO's adaptive optics system in order to obtain proper motion membership and derive the density map of the cluster.
In the poster, we will present a first analysis of the distribution of cluster members in the wider area around the cluster core. These data will ultimately allow us to derive the large scale properties of the Arches cluster, such as the total cluster mass, the true extent and the initial mass function.

A Methane Imaging Survey for T Dwarf Candidates in Rho Ophiuchi

Karl Haisch Jr.

We report the results of the first deep, wide-field, near-infrared methane imaging survey of the Rho Ophiuchi cloud core to search for T dwarfs. Among the 6587 objects detected, 22 were identified as T dwarf candidates. Brown dwarf models indicate that at the age and distance of the Rho Ophiuchi cloud, these T dwarf candidates have masses between 1 and 2 Jupiter masses. If confirmed as genuine T dwarfs, these objects would be the youngest, lowest mass, and lowest gravity free-floating objects ever directly observed. The existence of these candidates suggests that the initial mass function of the Rho Ophiuchi cloud extends well into the regime of planetary mass objects (planemos), and lends support to the possibility that planemos can form via the same process as that for stars. On theoretical grounds, there is some critical mass and density below which cloud fragmentation and gravitational collapse is not feasible. In this context, it is highly suggestive that none of our 22 planemo candidates (and none of 9 more planemo candidates in the CrA cloud identified by us using the same methods) have spectral types later than T6, despite the fact that our surveys are sensitive to spectral types as late as T8. A large fraction ($59\,\% \pm 16\,\%$) of our T dwarf candidates appear to be surrounded by circumstellar disks, and thus represent the lowest mass objects yet found to harbor circumstellar disks.

Star Formation as seen by the Herschel HOBYS key program

Tracey Hill

With its unprecedented spatial resolution and high sensitivity, Herschel is revolutionizing our understanding of high mass star formation in the far-infrared to submillimeter regime. The Herschel imaging survey of OB Young Stellar objects (HOBYS) key program (see Motte, Zavagno, Bontemps et al, http://starformation-herschel.iap.fr/hobys/) specifically targets nearby burgeoning young stellar objects. HOBYS aims to discover and characterize the earliest evolutionary stages of intermediate to high-mass stars and assess the importance of triggering in these regions. I will present multi-wavelength PACS (70, 160 μm) and SPIRE (250, 350, 500 μm) Herschel images of a number of early targets of the HOBYS program including, the Vela and M16 regions. Dust temperature and density maps have revealed a temperature gradient in the molecular clouds. Herschel also provides unique coverage of the spectral energy distribution peak, significantly constraining fits and thus determination of the temperature, mass and luminosity of the individual protostars identified in the regions. Using these fundamental parameters we can examine evolutionary scenarios of clusters as well as individual protostars seen within each of the regions of interest. The fundamental properties (luminosity and mass) of YSOs in the HOBYS fields will be used to constrain their evolutionary stage and lifetime of intermediate- and high-mass YSOs, ultimately improving our understanding of high-mass star formation.

Hybrid SPH/N-body simulations of the formation of star clusters

David Hubber

Simulations of star clusters are usually divided into two separate regimes; the self-gravitating (magneto-)hydrodynamic evolution of the gas, and the N-body evolution of the young stars formed in the protocluster. While often modeled as two separate and distinct phases with separate codes, the transition between the two may be blurred in the context of triggered star formation and the delayed dispersion of the gas due to feedback. We present hybrid SPH/N-body simulations of cluster formation and evolution using the SEREN code. The ballistical motion of the stars is integrated with a high-order Hermite integrator, as used in many current N-body codes, whereas the background gas is modeled using a low-resolution SPH simulation with a lower-order integrator. The stars can interact with the gas by way of gravitational forces and mechanical and radiative feedback thereby taking advantage of the various algorithms already implemented into the SPH code. We discuss the assumptions made in implementing the hybrid code, and the consequences of following the transition from the gaseous phase to the final N-body phase fully and consistently on the final stellar and binary properties.

The evolution of magnetic fields in OB-type stars from the study

Swetlana Hubrig

Massive stars drive the evolution of galaxies through their photons, winds, and violent deaths, from the era of re-ionization until today. To date, however, only a small number of O, early B-type, and Wolf-Rayet stars have been investigated for magnetic fields, and as a result, only about a dozen magnetic early B-type stars and only a few magnetic O stars are known. In our poster, we will report on our recent study of magnetic fields in O and early B-type stars in clusters at different ages, which was undertaken to constrain magnetic field evolution and the conditions, which enable the presence of magnetic fields in massive stars.

Project 1640: an innovative high contrast imager for the discovery and characterization of brown dwarfs

Stephanie Hunt

Recent developments in the field of high contrast imaging are opening up a new parameter space in the detection of low mass companions. The discovery, characterization and statistical analysis of low mass objects that span the planetary-stellar mass boundary will allow new insight into their formation and composition.

Project 1640 is an innovative new high contrast imager, combining a Lyot Coronagraph and an Integral Field Spectrograph, mounted behind the Palomar Hale Telescope AO system. The instrument's hyperspectral nature permits both the application of speckle suppression techniques and the retrieval of broadband spectra for objects imaged. In addition, the instrument's spatial resolution allows companionship to be established with only 2 epochs of data, by analysis of shared parallax, as opposed to the more traditional shared proper motion. I report here the first discoveries made with this instrument, their significance to the study of low mass companions and the effect of ongoing upgrades to both the instrument and the Palomar AO system to our potential target range.

The fragmentation of expanding shells

Kazunari Iwasaki

We investigate the gravitational fragmentation of expanding shells by using the three-dimensional Godunov smoothed particle hydrodynamics. We calculate the evolution of shells which expand into the uniform cold gas with a steady energy input from the center. In order to save the number of SPH particles and to resolve the thickness of the shell, we consider not the whole but a part of the shell by imposing on the rotational periodic boundary condition. We find that the gravitational instability in the expanding shells grows with a larger growth rate and a shorter wavelength than the prediction of the linear analysis under the thin-shell approximation by Elmegreen (1994). This large growth rate is attributed to the thermal pressure of the hot bubble which pushes the shells outward. In our poster, we will present the detailed mechanism of the gravitational fragmentation of expanding shells.

Evolution of protostars and episodic accretion

Alberic Joos de ter Beerst

Some regions of star formation (Perseus, Serpens, Ophiucus, Lupus. . .) are now measured at different wavelengths. (Enoch et al. 2009) and (Evans et al. 2009) calculated the total luminosity and the mean frequency of the spectrum emitted by a lot of protostars. Both these quantities give respectively the bolometric luminosity and the bolometric temperature and are plotted in the bolometric diagram (Myers & Ladd 93). The measures show a large spread in this diagram. This spread is often explain by the episodic accretion: the pre-stellar core is not accreting matter at a continuous accreting rate but at an irregular accretion rate, with a succession of high accretion rate (bursts) and low accretion rate (quiescent phases). The episodic accretion was also recently proposed by Baraffe et al. (2009) to explain the spread in HR diagrams after 1 Myr. The existing models (Young et al. 2005; Myers et al. 1998) used a continuous accreting rate to predict the evolution of the protostar in the diagram. Like the previous works, we simulate the evolution of a protostar and the evolution of the bolometric luminosity and temperature with a star-disk-envelope system. Unlike the existing models, we simulate the evolution of the accreting protostar (radius and luminosity) with the Lyon stellar evolution code. The effect of the accretion on the protostars is not negligible on the bolometric luminosity and the bolometric temperature.

Optical and Infra-red Survey of the Young Stellar Population Associated with the Star-forming Complex Sh2-252 (NGC 2175)

Jessy Jose

Sh2-252 is a large HII region ionized by the O6.5 star HD 42088, associated with the cluster NGC 2175 and is a part of the Gem OB association. The sub regions Sh2-252 A, B and C of this complex are assumed to be formed as a direct result of the interaction of the massive star HD 42088 with the surrounding molecular cloud. Hence this complex is an ideal target to study the properties of the young stellar objects (YSOs) and initial mass function (IMF) in extreme star forming conditions. We have performed deep optical imaging survey of the region in the V and I_c bands over an area of $\sim 1^\circ \times 1^\circ$ down to 23 magnitude in V. Using the Spitzer-IRAC observations, we identified $\sim$ 500 candidate YSOs (Classes 0/I/II) indicating the richness of this complex with the young stellar population. Spatial distribution of these candidate YSOs shows number of sub clustering across the region and most of them are seem to be obscured in the optical observations. $H\alpha$ slitless spectroscopy survey of the region helps identifying over 50 $H\alpha$ emitting sources. The location of these candidate YSOs on the $(V-I)/V$ colour-magnitude diagram reveals that $\sim$ 90 % of the YSOs are seem to have ages $\leq$ 5 Myr with a median age of $\sim$ 2-3 Myr and have masses in the range of 0.3 - 2.5 $M_\odot$. The characteristics of the YSOs, evolutionary scenario and IMF of the complex will be discussed in this presentation.

G29.96-0.02: Fitting of the full SED

Jason Kirk

We present spectra of the Ultra-Compact HII region G29.96-0.02 taken with the SPIRE FTS on-board the Herschel Space Telescope. We detect the 12CO and 13CO ladder of lines and the [CI] line of neutral carbon. The FTS spectra are combined with ISO SWS and LWS spectra and literature fluxes to present a detailed spectral energy distribution (SED) of the source spanning three orders of magnitude. The quality of the SED longwards of 100 micron allows us to fit a grey body with an accuracy rarely obtained with previous instruments. The bolometric luminosity of the observed SED is coincident with that of the newly formed O-star that is powering the HII region.

The Initial Mass Function and internal dynamics of the starburst cluster Westerlund 1 from near-infrared adaptive optics observations

Natalia Kudryavtseva

Starburst clusters are well known for their high rate of star formation. Around ten starburst clusters are currently known in our galaxy and Westerlund 1 (Wd 1) with its rich population of high-mass stars is the most massive one. Strong winds and ultraviolet radiation from massive stars in the center of Wd1 have cleared away nearby material, giving a chance better to resolve individual cluster members. Very close location of Wd 1 to the galactic plane ($b = -0.35°$), yields a strong contamination by fore- and background nonmembers. For unbiased determination of the cluster parameters and IMF, we have made a proper motion membership selection, based on 2 epochs NACO/VLT observations with a 5 years time baseline. At the age of 4 Myr, the stars in Wd 1 are only a little affected by dynamical evolution, that's why present-day mass function of Wd 1 is identical with the initial mass function. We discuss physical and dynamical properties of Wd 1 and present a new estimate of the intermediate to low-mass IMF of the cluster.

New Nahual: Possibilities for Star Formation Studies

Eduardo L. Martín

In this presentation we will show our concept for a next-generation near-infrared multi-object intermediate resolution spectrograph for the 10.4-m Gran Telescopio Canarias, and we will discuss the science cases that are related to the topics relevant for this conference, such as the dynamics of low-mass stars and brown dwarfs in galactic embedded clusters, and the search for hot jupiters around T-Tauri stars.

The Vela Molecular Ridge: a laboratory for testing physical scenarios leading to a standard IMF

Fabrizio Massi

The Vela Molecular Ridge is a close-by (d$\sim$700 pc) Giant Molecular Cloud Complex in the Galactic Plane hosting intermediate-mass star formation. Many young embedded star clusters are emerging from the parental gas, enabling one to study their IMF with the same observational and instrumental biases. A 1 square degrees area of cloud D has been observed in a wide range of wavelengths, with imaging and maps in the NIR, MID to FIR (Spitzer, BLAST), and in the mm continuum and line (SEST). These data allowed us to derive a molecular clump mass function and to compare the IMFs of the associated clusters. I will present the results and shortly discuss the caveats to be taken into account in such determination.

The properties of discs around accreting brown dwarfs.

Nathan Mayne

We present a grid of models of accreting brown dwarf systems with circumstellar discs. The calculations involve a self-consistent solution of both vertical hydrostatic and radiative equilibrium along with a sophisticated treatment of dust sublimation. Analysis of the disc structures and simulated observations (SEDs and photometric magnitudes) reveals a natural dichotomy in accretion rates, with logmdot > -9 and ≤ -9 classed as extreme and typical accretors respectively. Derivation of ages and masses from our simulated photometry using isochrones is demonstrated to be unreliable even for typical accretors. We also suggest improved selection criteria in several colour indices. We show that as accretion rates increase brown dwarf disc systems are less likely to be correctly identified. This suggests that systems with higher accretion rates would be preferentially lost during brown dwarf target selection meaning observations used to assert a $\dot{M} \propto M_*^2$ relationship may contain an intrinsic selection bias. Finally, we present an online interface allowing public access to the simulated grid and an associated online fitting tool with uncertinaties and degeneracy analysis.

Collisions of supersonic clouds

Andrew McLeod

We present simulations of collisions between molecular clouds. The simulations are performed with the SEREN SPH code. We examine the results of cloud collisions between low-mass cores of $\sim$ 0.2–10 $M_\odot$ modeled as Bonner-Ebert spheres. We consider the effects of varying mass, impact parameter, collision velocity, internal turbulence and the external pressure environment. We find that these cloud-cloud collisions can lead to cloud disruption, merging or collapse. We also examine collisions between larger clouds of up to 500 $M_\odot$. We explore the effect of various density profiles, such as uniform density clouds, strongly turbulent and fractal clouds. Each collision can produce a shock compressed layer which then fragments into filaments. A first generation of stars condenses out of the densest part of these filaments. This network of filaments can then collapse to form a dense protocluster and a second generation of stars forms from infalling gas. Higher velocity collisions can excite the non-linear thin shell instability (NTSI). The SEREN SPH code treats the energy equation and the associated transport of heating and cooling radiation. The formation of protostars is captured by introducing sink particles.

Star formation in the outer Galaxy: NGC 1893

Giuseppina Micela

I will present the result of a multiwavelength campaign on NGC 1893, a star forming region at about 12 kpc from the Galactic Center. The observations include the data from a large Chandra/Spitzer project supported by ground based optical and NIR photometry. We have used NIR (ground and Spitzer) photometry to identify stars with circumstellar disks, and X-rays as independent membership criterion to identify Weak Line T Tauri stars that have already dissipated their disks. The cluster is very reach with several hundreds of members. Based on WTTSs we have determined the cluster parameters (distance, age, and average reddening). We have also verified that the disk frequency in this region is comparable with that measured in nearby star forming regions. Finally the X-ray properties of the cluster members have been derived.

A variation of the IMF in ultra-compact dwarf galaxies?

Steffen Mieske

I will give a summary over our ongoing projects to test for a variation of the IMF in ultra-compact dwarf galaxies. Those objects, intermediate between star clusters and dwarf galaxies, exhibit dynamical M/L ratios on average $\sim$ 30–50 % above predictions from stellar populations models assuming a canonical IMF. I will review the possibilities to observationally verify either a bottom- or top-heavy IMF in UCDs, and how to distinguish this from the possibility of "cosmological", dark matter. UCDs are presumably formed in extremely dense environments under enormous radiation densities, and are thus well suited laboratories for testing the (non-)universality of the IMF.

A Source to Warp/Tilt Disks

Michele M. Montgomery

Shapes of disks such as protostellar and protoplanetary disks can reveal fluid flow patterns which in turn can tell us about the physics and some properties of the fluid flow. Analysis of the physics and properties thus reveal why disks can be warped or tilted. We present a model on how accretion disks can warp/tilt that depends on the mass of the compact object, the mass transfer rate, and the speed(s) of the fluid flow but does not depend on magnetic fields or radiation sources.

A new molecular outflow in the Vulpecula Rift

Joseph C. Mottram

We have discovered a new massive molecular outflow in the Vulpecula Rift associated with a cold molecular core in our 45″ resolution FCRAO ^{12}CO and ^{13}CO (J=1−0) Exeter Northern Galactic Plane CO Survey observations. At this resolution it is potentially one of the most massive found thus far and, with a ratio of M_{out}/M_{core} of ∼0.8, much higher than typical. We present the initial detection, along with JCMT HARP-B follow-up observations at 15″ resolution in ^{12}CO, ^{13}CO and C^{18}O (J=3−2), HCO^{+} and H^{13}CO^{+} (J=4−3) and SiO (J=8−7) which show that the outflow is still active and breaks up into several components.

A deep Chandra observation of the S254-S258 star forming complex

Paola Mucciarelli

In the S254–S258 region a dense cluster of very young stellar objects is sandwiched between two HII regions. This remarkable configuration has led to conjectures that the two B stars exciting the HII regions may have been dynamically ejected from the central cluster, or, alternatively, that the current star formation activity in the central cloud is triggered at the intersection of the two expanding HII regions. In the second case, the two B stars should belong to a slightly (few Myr) older stellar generation, but, interestingly, no associated young low-mass stars could be identified so far around them; this lead to speculations of a case of isolated formation of massive stars.
In order to solve this puzzle, we have performed a deep Chandra X-ray observation of this extraordinary star forming region and detected more than 360 X-ray sources. This yields, for the first time, a reasonably complete sample of all young stars in the region, avoiding the usual bias introduced when selecting samples based only on infrared excess. We will present the first results of our ongoing analysis. Combination of our X-ray catalog with optical and infrared data allows us to study the stellar properties of the young objects and to infer the star formation history of this interesting region.

Clumps to cores distributions in W43 complex and others

Quang Nguyen-Luong

W43 complex lies at a fairly dynamical place on the Galactic Plane: the meeting point of the Scutum-Crux Galactic arm and the bar at a distance of 6 kpc to the Sun. The global structure of atomic and molecular gas in W43 indicates that its structure is consistent with results from dynamical numerical simulations of covering flows. The recent observations from different galactic plane surveys offer a fuller spectrum of photometric data: from 70 micron to 1.1mm. The data set allows us to separate the different populations of objects and follow them from clumps to core scales. We aim at comparing the distributions function, mass functions at different wavelengths. We also try to characterize the special features of W43 compared to other region.

Formation of Molecular Cloud Precursors from Colliding Superbubbles

Evangelia Ntormousi

We investigate the formation of Molecular Cloud Complexes from expanding and colliding superbubbles, blown by realistic, time-dependent stellar winds and supernova explosions from young OB associations. The "converging flows" scenario for cloud formation is thus here implemented without artificial initial velocity or density perturbations, letting the latter arise naturally from the physics relevant to the problem. We present two-dimensional, very high resolution hydrodynamical simulations of wind-blown superbubbles, following their evolution and collision, both in a uniform and in a turbulent diffuse medium. Simulations are performed with the hydrodynamical grid code RAMSES, properly adapted to model the energy and mass input from the young stars according to population synthesis models and with cooling and heating functions calculated for the ISM. In both cases, the expansion and the collision between two superbubbles trigger the formation of cold and dense gas clumps. In the case of the turbulent medium we are also able to reproduce the observed anisotropies in triggered cloud formation regions. We find that many clouds are pressure supported, others are rotation supported, but there are also many which would be unstable to gravitational collapse. Future simulations in 3d with Adaptive Mesh Refinement will give us more insight on the full structure, kinematics, and masses of the formed clouds.

Early results from SCUBA2

David Nutter

In this talk, I will highlight some of the early results from the initial “shared risks” observing period of SCUBA2 on the JCMT. In particular I will show data from the JCMT Gould Belt Survey of nearby star-forming regions, and detail how these data will be used to improve our understanding of the star-formation process. The questions that we seek to answer with these data include the relationship between the mass function of pre-stellar cores at the lowest masses, and the relative lifetimes of the different evolutionary stages of star formation. I will also use some far-infrared data from the Akari satellite to demonstrate why SCUBA2 data is essential to complement the data from the Herschel satellite, and why the long wavelength provided by SCUBA2, together with shorter wavelength data from Herschel will break the degeneracy between temperature and column density.

Photoevaporation of Discs

James Owen

The evolution of circumstellar discs, which contain the reservoir from which the star accretes and planets may form is heavily influenced by heating and irradiation from the central star. Photoevaporation by irradiation from the central star has been proposed as the mechanism that terminates the disc accretion phase and removes the remaining material. In this talk I will review the possible photoevaporation models and present results from our recent calculations of photoevaportion by X-rays. Young low-mass stars are strong emitters in the X-rays and can produce very large photoevaporation rates - comparable with measured accretion rates in YSOs - implying that photoevaporation will have a strong influence on the final stages of star and planet formation. I will present a results from a study that shows a simple model combining viscous evolution and X-ray photoevaporation can explain the current observations of disc evolution. Finally I will consider the implications of X-ray photoevaporation on the formation of very low mass stars.

When clusters trigger a second stellar generation?

Jan Palous

Conditions for fragmentation of shells outside of a star cluster are discussed. Using the infinitesimally thin shell approximation, we estimate the minimum energy input and density of the ambient medium, and we give restrictions on the small and large scale fluctuations in the ISM distribution. Later, these estimates will be tested with 3D hydrodynamical simulations. We also discuss the bimodal solution for the star cluster wind and estimate conditions under which the secondary star formation occurs inside the cluster.

Submm/mm emission across the Stellar/Substellar Boundary in Taurus

Jenny Patience

With a combination of submm and mm bolometer arrays, we have observed a sample of 24 low mass stars and brown dwarfs, spanning the M2-M9 spectral types in the Taurus star-forming region. This study extends mass range coverage of previous larger scale surveys of pre-Main Sequence stars in Taurus. Of the 12 targets observed with SHARCII at 350μm and the 12 targets observed with MAMBO at 1.2mm, 9 are detected for the first time at these wavelengths. The fluxes range from 2.8mJy at 1.2mm for the brown dwarf CFHT Tau 6 to 2.6Jy at 350μm for the low mass star IRAS04158. In conjunction with previously reported fluxes at other wavelengths, we have modeled the SEDs of these system with the radiative transfer code MCFOST to estimate disk properties such as disk mass and dust properties.

Characterization of T-type planetary mass objects candidates in the σ Orionis cluster

Karla Peña Ramírez

There are only two T-type planetary mass objects candidates in the σ Orionis cluster: S Ori 70 (S Ori J053810.1 -023626) and S Ori 73 (S Ori J053814.4-024511). S Ori 70 has a confirmed spectral type T5.5 while S Ori 73 has not any confirming spectra to date.
We intend to estimate the spectral type of S Ori 73 using $JHCH_{4\mathrm{off}}$ photometry from HAWK-I/VLT. This is the first attempt to provide a spectral type in the case of S Ori 73.
We compare the H-$CH_{4\mathrm{off}}$ color from S Ori 70 and S Ori 73, with H-$CH_{4\mathrm{off}}$ color from a wide spectral range objects, from F type stars to late T field dwarfs. Methane nature of S Ori 73 is confirmed. The locations of S Ori 70 and 73 in the J-H vs. H-$CH_{4\mathrm{off}}$ color-color diagram are consistent with T8 and T4 spectral types respectively.

A search for low-mass objects in unexplored regions of Taurus-Auriga

Manuel Perger

We present first results from the search for new low-mass members in Taurus-Auriga. We made use of the near-infrared UKIDSS Galactic Clusters Survey which covers a yet unexplored region north of the main clouds of this very young and nearby star-forming region. Our search criteria include magnitude and color limits and proper motions assigned for brighter sources using additional 2MASS data. With the calculation of a high-resolution near-infrared extinction map and the dereddening of the photometry, we were able to narrow down the search and compare the candidates with recent models. We observed spectroscopically around 100 candidates in the optical wavelengths with e.g. ISIS, ALFOSC, CAFOS and OSIRIS. We measured various spectral indices and typical line features such as H_{α} or the sodium and potassium doublets to assign spectral type and membership of the candidates. By this research, we hope to make a contribution to the missing M dwarfs in this important star-forming region, renew its mass function and might even find some more insights into the formation process of very low-mass objects.

First results from the VISTA Science Verification mini-survey in Orion

Monika Petr-Gotzens

ESO has recently put into operations the world's currently largest near-infrared survey instrument – VISTA. Prior to VISTA's start, a wide-field imaging survey in the Orion star-forming region, encompassing a 30 square degree area centered on the Orion Belt stars were carried out, as part of the VISTA Science Verification Programme. The observations mapped young stars and brown dwarfs in various environments and at different stages of their evolution, from embedded $\lesssim$1 Myr old populations to $\sim$10 Myr old stars in the wide-spread OB-association Ori OB1a. Approximately 3 million sources, including several hundred brown-dwarf candidates, have been detected in 5 broad-band imaging filters ($YZJHK_S$) down to an unprecedented typical limiting magnitude of, e.g. $K_S\approx$18.8 mag, $J\approx$20.6 mag, $Y\approx$21.3 mag.
In this contribution I will outline the characteristics of the VISTA-Orion survey, and highlight examples of the numerous scientific applications facilitated by our survey. Such will include the search for young very low-mass stars and brown-dwarfs, the study of variations in the substellar IMF, the photometric selection of candidate T-dwarfs, and the identification of near-infrared scattered light signatures from embedded protostars.

The Star Formation Processes in the W3 GMC

Danae Polychroni

The star forming process and the effects the environment has on it is one of the most fundamental question currently in star formation. It is currently thought that the turbulence present in molecular clouds is very important in regulating the star formation process. However it is not well understood what effects the environment can have on the internal properties and therefore the star formation process in a molecular cloud. The W3 Giant Molecular Cloud is an ideal laboratory to study the effects the environment has on the star formation process, since within it coexist two modes of star formation (spontaneous and triggered). We present here a multi-wavelength study of this cloud using new and existing observations (HARP, FCRAO, SPITZER and SCUBA) in the IR and sub-millimeter. We calculate the gas temperatures across the cloud (and therefore its mass) for the first time in such large scales and resolution and find a temperature gradient across the cloud that we identify as an age sequence. We calculate the fraction of the gas across the cloud that goes into dense potentially star forming structures and we identify IR counterparts (young stellar objects) to such sub-millimeter dense cores. We find no evidence for different luminosity functions between the two regions (triggered and spontaneous) and no increase in the star formation efficiency caused by triggering. Furthermore, we find evidence that the larger line widths present in the triggered region of the cloud is a result of feedback from the young stellar objects formed there. We conclude, therefore, that while triggering creates new dense structure in the affected regions of the cloud, it does not affect the physical processes of star formation once a dense core has formed.

The Spitzer IRS Protostar Survey of the Orion Molecular Cloud Complex

Charles A. Poteet

The Orion Molecular Cloud complex is the most active region of star formation within 500 pc of the Sun, where the Spitzer Space Telescope has identified over 400 protostellar candidates in a variety of environments, from dense clusters to isolation. With the Spitzer Infrared Spectrograph (IRS), we have obtained 5-36 micron follow-up spectroscopy of 349 protostellar candidates; these data are the first detailed mid-Infrared spectroscopic survey of a large number of protostars in a single complex at a common distance. The spectra are being used in combination with the Herschel Orion Protostar survey (HOPS) to determine the fundamental parameters of 278 protostars. We concentrate in this presentation on results from analyses of the mid-infrared IRS spectra alone. We first describe how sources can be classified by their mid-IR spectra and show the statistics of source classification (i.e., number of Class 0, Class I, Flat-spectrum sources and contamination). We then present an analysis of the copious silicate and ice absorption features, examining their presence and depth as a function of both evolutionary class and cloud environment. We also present the first unambiguous (and rare) detection of crystalline silicate absorption features from a cold protostellar envelope; we suggest this is material carried by winds and outflows from the hot inner regions to the outer cold envelope.

The Spectroscopic Signature of FU Orionis

Stacie Powell

FU Orionis objects represent a small class of pre-main-sequence stars, originally classified by a large increase in optical brightness of ~ 4 magnitudes or more due to long periods of rapid accretion in their protoplanetary disks. Planetary migration theories suggest the abundance of hot Jupiters could be considerably higher in pre-main-sequence stars. If an FU Orionis object had such a planet embedded in the disk, this would manifest as time-dependent distortions in the optical line profiles of these objects, sustained over different epochs. Previous observations of FU Ori, the prototype of this class, have shown evidence of periodic variations in the photospheric lines on timescales of a few days. New high-resolution spectra of FU Ori were taken from the SOPHIE échelle spectrograph over a series of 21 nights in 2007 and from the HARPS spectrograph over 7 nights in 2010. The analysis of the optical line profiles at each epoch is presented, and compared with the predictions of non-axisymmetric structure arising from the signature of a hot Jupiter embedded in the disk.

Last Results from Project MASGOMAS (MAssive Stars in Galactic Obscured MAssive clusterS)

Sebastián A. Ramírez-Alegría

We want to present our program MASGOMAS (MAssive Stars in Galactic Obscured MAssive clusterS), with its objectives, methodology and first results. MASGOMAS is a compilation of cluster candidates, from previous catalogue of galactic clusters (Bica et al. 2003; Dutra et al. 2003 and Mercer et al. 2005), obtained using 2MASS infrared photometry. In order to increase the infrared information of the candidates, we completed near-infrared photometry and H-, K-band filter spectroscopy for 9 of them, concluding with an full analysis of the stellar content for 3 of the candidates, deriving its distance, differential extinction, minimum stellar mass and age. Our near-infrared data was also complemented with SPITZER imaging of our candidates and visual spectroscopy for some specific stars in each of the 3 published clusters.

Circumstellar discs in binary systems

Krisada Rawiraswattana

We perform SPH simulations of the evolution of circumstellar discs in binary systems. We investigate how discs are perturbed by low-mass companions, either in the plane of the disc or inclined to it. We examine how these perturbations might affect both disc fragmentation and core accretion.

Binary formation mechanisms. Constraints from the Companion Mass Ratio

Maddalena Reggiani

We present a statistical comparison of the mass ratio distribution of companions, as observed in different multiplicity surveys, to a recent estimate of the single object mass function (Chabrier 2005). The main goal of our analysis is to test whether or not the observed companion mass ratio distribution (CMRD) as a function of primary star mass and star formation environment is consistent with having been drawn from the field star IMF. We consider samples of companions for M dwarfs, G and OB stars, found in the field, open clusters, and star-forming regions, and we compare them with populations of binaries generated through Monte Carlo simulations by random pairing from the assumed IMF for a fixed primary mass. The analysis of connections between the CMRD and the IMF over a broad range of primary masses and variety of environments can help in discriminating different binary formation mechanisms and investigating about the origin of the field.

The 10μm and 20μm Silicate Emission Features in Brown Dwarf Disks

Basmah Riaz

We present a compositional analysis of the 10μm and 20μm silicate emission features for brown dwarf disks in the Taurus star-forming region. The crystallinity level at larger radii in these brown dwarf disks has not decreased, which indicates efficient diffusion of crystalline material from the warm/inner region to the cold/outer parts in these sub-stellar disks. The grain growth levels do not show any particular trend with the radial distance. Most disks show similar large-grain mass fractions in the inner and outer disk regions. The disk structure in both the inner and outer regions is found to be more affected by the crystallinity level in the disk. The strengths in the 10μm and 20μm features are similar for most disks, except three cases where the disk has flared up at longer wavelengths. For nearly 80 % of the disks, the mass fraction of small ISM-like dust grains is negligible (< 5 %) in the outer disk region. For most sources, we find nearly equal fractions for the large-grain and crystalline mass fractions, indicating both processes to be active in these disks. The median crystalline mass fraction for the Taurus brown dwarfs is found to be a factor of $\sim$2 higher than the median for the higher mass T Tauri stars in Taurus. A (weak) anti-correlation between the X-ray emission strength and the extent of crystallinity in the disk is observed, suggesting X-rays to be an important dust amorphization agent in these disks.

An Infrared Characterization of the Orion Nebula Cluster

Gaetano Scandariato

We present the latest results from our analysis of the JHK photometry of the ONC, which covers 30' $\times$40' around the Trapezium asterism, reaching magnitudes as low as to K=21. We analyze the color-magnitude diagrams and we compare the observed contaminant population to the synthetic galactic population, deriving the OMC-1 extinction map across the whole surveyed area. For $\sim$500 sources with cross-matched optical photometry and known spectral type we use synthetic IR photometry to analyze the correlation among the IR magnitude excesses. The reddening law and the correlation between magnitude excesses are then combined to consistently derive mass, extinction and IR excess assuming a 1Myr isochrone. Finally we derive the completeness- and contamination-corrected low-mass ($M<0.3M_\odot$) and substellar Initial Mass Function of the Orion Nebula Cluster. Our results suggest that while the largest fraction of sources with IR excess compatible with circumstellar disks is found in the inner core (projected radius < 0.7 pc), the IMF does not show significant variations across the cluster: it is peaked between $0.3M_\odot$ and $0.1M_\odot$ and continuously decreases in the brown dwarfs domain.

The Most Massive Stars

Oliver Schnurr

The presently accepted upper stellar mass limit is 150 solar masses. However, new studies of the brightest WN-type members within two star clusters, R136 and NGC 3603 challenge this limit. R136 appears to host stars whose initial masses are significantly in excess of 150 $M_\odot$, with consideration given to possibly binarity, on the basis of spectroscopic radial velocity studies, X-ray observations and dynamical effects in dense clusters. The high mass star content of the Arches cluster is placed within this context, as is the potential significance of a higher stellar mass limit for the integrated properties of young, spatially unresolved star clusters.

Magnetically driven outflows during massive star formation

Daniel Seifried

We present collapse simulations of high mass, rotating and magnetized molecular cloud cores. The combined effect of rotation and magnetic fields leads to the occurrence of outflow phenomena. Our special interest lays in the long term evolution of large scale outflows appearing already in the early phase of stellar evolution. These outflows seem to release a significant amount of mass into the ambient medium and therefore reduce the rate of accretion onto the protostar. The removal of angular momentum also affects the stability of the disk. Fragmentation of the disk at later stages seems to have a significant effect on the further evolution of the outflow as well as on the accretion history of the individual protostars. We are following the long term evolution of the simulation with the help of sink particles. With this technique we are able to examine whether magnetically driven outflows are persistent or just transient features. In the former case outflows should be able to open channels of low density gas through which radiation can escape.

Morphology of Bubble N107

Vojtech Sidorin

I will present a multiwavelength study of the bubble N107, a distinct structure in the interstellar medium discovered with the Spitzer GLIMPSE survey (Churchwell et al. 2006). We complement the morphological picture of the structure with HI and CO observations, and also use this gas emission to derive the total mass of the bubble and masses of molecular cloud fragments found at the bubble's periphery.

The story of protostellar cores.

Rowan J. Smith

The evolution of protostellar cores towards their final stellar mass depends on two major factors; the intrinsic properties of the core, and those of the environment. In this talk I shall discuss both these regimes. Firstly I shall present a detailed analysis of the structures of collapsing cores from a large simulation, and show that three quarters of them are better described as filaments than as spheroids. Possible consequences of this include; departures from the expected line profiles, accretion being more difficult to stop with feedback, and an increased likelihood of core fragmentation. Further, the flow of accreted material from the environment onto the core, is highly asymmetric, with most of the accretion occurring along a few dense accretion streams.
Secondly I shall discuss the effect of the surrounding environment using a simulated GMC. In unbound regions of the molecular cloud there is distributed star formation with an efficiency as low as 1 %, but in bound regions star clusters can form with an efficiency of up to 40 %. Intriguingly there is a difference in the final stellar masses formed from the cores in both regions. In the clustered regions a full IMF is formed, but in the distributed regions the stellar masses cluster around the local Jeans mass and lack both low and high mass stars.

Tidal forces as a regulator of star formation in Taurus: a numerical study

Andrés Suárez-Madrigal

Taurus molecular cloud constitutes a typical example of the low-mass star forming regions, i.e., regions that form only low-mass stars at a low rate ($\sim$1 %). Magnetic and turbulent support have been presented as possible mechanism for preventing a more vigorous star formation regime, as they could provide cloud support. In this context, the evaluation of the gravitational energy of clouds has usually been done considering only the mass distribution of the cloud as a source of the gravitational potential. However, as it has been shown using semianalitical calculations, tidal forces due to the mass external to the cloud may not necessarily be negligible and can play a major role in its future disruption or collapse. The present work tests such calculations through SPH simulations of filamentary molecular clouds embedded in the gravitational potential of the Galaxy. We find that the evolution of such molecular clouds is strongly dependent on their alignment with respect to the Galaxy center, showing that tidal forces from the Galaxy affect largely the formation of denser regions, and hence stars, within the cloud. The dynamical results from the simulations are in accordance with previous semi-analytical energy analysis.

The Spiral Structure of the Outer Milky Way

Lee James Summers

Molecular Clouds are the sites of all known Galactic star formation, hence any attempt to understand the process by which the stars form must include an understanding as to the formation, evolution and properties of the host Molecular Cloud. Star Forming Molecular Clouds tend to be concentrated within the Spiral Arms of the Galaxy, so the knowledge as to the locations of these Spiral Arms would be useful. This work, using 12/13CO data taken from observations from the Exeter-FCRAO CO Galactic Plane Survey, supplemented by CGPS HI data, maps the location of the Spiral structure of the Outer Galaxy in both space and velocity over the Galactic Longitude range of 55 - 193 degrees. We also present re-sampled spatially convolved position-position-velocity maps of the Spiral Arms. The maps are then subject to a clump/cloud finding analysis, the results of which are presented here.

Radiation Pressure Problem in the Massive Star Formation: Shielding by the Dust-Free Disk

Kei Tanaka

In the formation of the massive stars, the radiation pressure acting the dust grains exceeds the gravitational force. The strong radiation pressure would disturb the mass accretion, and may limit the stellar masses. The radiation pressure force is thought to act strongest at first absorbed region, i.e. behind the dust sublimation front. To overcome the direct stellar radiation feedback, it is argued that the ram pressure with high accretion rates (Wolfire & Cassinelly 1987, in spherical accretion) or gravity force with sufficient radial surface density (Tanaka & Nakamoto 2010, Kuiper et al. 2010, in disk accretion) is needed. However, previous works assumed that the dust-free region (>2000K) is optically thin and neglected the gas opacity. Since the gas opacity is not equal to completely zero, it seems necessary to take into account the gas opacity to investigate the dense disk structure.

In this work, we semi-analytically calculate the structures of the dust-free disks, taking into account the gas opacity. In the result, we show that the dust-free disk is optically thick for a wide range of parameters. Thus, the dust sublimation front would be shielded by the optically thick dust-free disk from direct stellar feedback, and accretion flow is not halted there. In this poster, we present structures of the innermost accretion disks and the condition for disk shielding.

Strong effects of cosmic rays on the characteristic mass of young stars in starbursts

Wing-Fai Thi

Up to half of all the stars in the Universe form in starbursts spectacular events during which the star formation rate of a galaxy rises from few solar masses per year, typical of spirals such as the Milky-Way, to several hundred and even thousands of solar masses per year, as in the local Ultra Luminous Infrared Galaxies or their early Universe counterparts. While stars form invariably out of molecular hydrogen throughout the Universe, it is in the densest and UV-shielded phase where the star formation initial conditions, and the characteristic mass of the emergent young stars are truly set. We show that cosmic ray energy densities U_{CR} $\sim$$10^3$–$10^4$ times higher than those in the Galaxy will be typical in the interstellar medium of extreme starbursts, **fundamentally altering the initial conditions for star formation during their galaxy-wide star forming episodes.** Solving the coupled chemical and thermal state equations for dense UV-shielded gas reveals that the very elevated cosmic ray energy background in such galaxies will raise the minimum temperature of this phase from $Tk_{min} \sim 10$ K, as in the Milky-Way, to $Tk_{min} \sim 50$–100 K over their entire starburst volume. These new initial conditions for star formation, and the resulting large characteristic mass of young stars of $M_{ch} \sim 3$–10 $M_{\odot}$, represent a new imperative for high-density star formation in the Universe, with cosmic rays as the key driving mechanism, operating efficiently in the high dust extinction environments of extreme starbursts.

Tidally induced brown dwarf and planet formation in circumstellar discs

Ingo Thies

Since most stars are born in clusters gravitational interactions between cluster members during encounters may significantly affect the evolution of circumstellar discs. Recent findings suggest that tidal perturbations of typical circumstellar discs due to passing stars may inhibit rather than trigger disc fragmentation in typical protoplanetary discs with radii around 40 AU and masses below 0.1 $M_{\odot}$. Here we show that the tidal forces during star-star encounters can trigger fragmentation between 100 AU and 200 AU in extended and massive discs (≈ 0.5 $M_{\odot}$) that are observed around young stars. In our computations, otherwise non-fragmenting massive discs, once perturbed, fragment into several objects between about 0.01 and 0.1$M_{\odot}$, i.e. over the whole brown dwarf mass range. Typically these orbit on highly eccentric orbits or are even ejected, and sometimes even form binaries. Our scenario provides a possible formation mechanism for brown dwarfs and very massive planets which, interestingly, leads to a mass distribution consistent with the canonical substellar IMF.

Numerical Models of the First Cores: Comparison with Observed Candidates

Kengo Tomida

The first core is a transient hydrostatic object formed in the early phase of low-mass star formation process. Forty years have passed since Larson (1969) theoretically proposed this object, but it has never been confirmed by observation. However, the first core is a crucial object because it will give us direct evidence to constrain and understand the low-mass star formation process if we could observe it.
Recently, Chen et al. (2010) reported detection of a first core candidate. NAOJ group and collaborators (Kawabe et al., in preparation) also found a peculiar dense core in a nearby star-forming region. In order to confirm whether they are first cores or not, we compare these observations with theoretical models. We calculate intensity distribution and SED expected for the first core models obtained from our radiative MHD simulations by post-processing radiation transfer. We find surprisingly good agreement in the observed properties between our observations and simulations. Therefore we believe that this object will be another first core candidate, although we require more extensive observations using many wavelengths such as Herschel and ALMA to derive a firm conclusion.

Super-star clusters vs OB associations

Carsten Weidner

Super-star clusters are probably the largest star-forming entities in our local Universe, containing hundreds of thousands to millions of young stars usually within less than a few parsecs. While no such systems are known in the Milky Way, they are found especially in pairs of interacting galaxies but also in some dwarf galaxies like R 136 in the Large Magellanic Cloud. With the use of 3D-SPH calculations we show that a natural explanation for this phenomenon is the presence of shear in normal spiral galaxies which facilitates the formation of low-density loose OB associations from giant molecular clouds instead of dense super star clusters. In contrast, in interacting galaxies and in dwarf galaxies, regions can collapse without having a large-scale sense of rotation. This lack of rotational support allows the giant molecular clouds to concentrate into a single, dense and gravitationally bound system.

3D hydrodynamic simulations of gas reinserted within super star clusters

Richard Wunsch

It has been shown that very massive and compact clusters evolve in the so called bimodal regime. The gas reinserted by massive stars into the ISM in the outer parts of the cluster accelerates and flows out as a cluster wind, while the gas reinserted in the central region becomes thermally unstable, cools down and forms dense clumps. We use 3D hydrodynamic simulations to study the ISM within such clusters. The cluster is modeled as a set of stars blowing winds with properties obtained from stellar evolution models. This enables us to follow in detail the process of the thermalization of the mechanical energy of the winds and formation of the hot ISM inside the cluster. In this way we estimate the heating efficiency - an important and poorly-constrained parameter which determines the fraction of the reinserted gas that leaves the cluster as a wind. The remaining part stays inside, forming dense clumps which eventually transform into a new generation of stars.

Pre-main sequence stars as seen by AKARI all-sky survey

Sarolta Zahorecz

We present an analysis of AKARI (Murakami et al. 2007) Far-Infrared Surveyor (FIS, Kawada et al. 2007) and Infrared Camera (IRC), Spitzer Space Telescope (SST; Werner et al. 2004) Infrared Array Camera (IRAC; Fazio et al. 2004) and Mid-Infrared Photometer for Spitzer (MIPS; Rieke et al. 2004) data as well as various other photometric data of the Taurus-Auriga-Perseus-Serpens region. Our aim was to locate and describe young stellar objects (YSOs), and to test the potential of AKARI FIS data in the classification of YSOs. We successfully modeled YSOs with the models of Robitaille (2007). We estimated the physical parameters of the young stars and their environments and the variation of these parameters. This research is part of the AKARI Mission Program "Star Formation".

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Useful Information and Notes

Useful Telephone Numbers

Emergency (Fire — Police — Ambulance)	112
Health Emergencies	061
Health Centre (Costa Adeje)	922 711 533
Hospiten Sur (Las Americas)	922 750 022
Costa Adeje Hospital	922 752 626
Local Police	922 716 508
National Police (Las Americas)	922 797 811
Guardia Civil Puesto de Adeje	922 710 003
Missing children	116000
Radio taxi Villa de Adeje	922 715 407
Radio taxi Arona	922 796 611
Buses Titsa	922 531 300
Reina Sofía Sur Airport	922 759 200/922 759 510
Los Rodeos North Airport	922 635 800/922 635 998
Iberia	902 400 500/922 759 285
Air Europa	902 401 501/922 759 244
Spanair	902 131 415/922 759 150
Tourist Offices Playa de las Americas	922 797 668 / 922 750 633
IAC main reception desk in La Laguna	922 605 200
Hotel Anthelia reception	992 713 335

Nearby Restaurants

Restaurant	Address	Phone	Speciality
Coeur de Filet	Playa Fañabé, local 21	922 71 78 93	Mediterranean
El Torito	Urb. El Beril. Res. Mango. La Caleta	922 78 20 46	Meat specialities
El Molino Blanco	Avda. de Austria, 5. San Eugenio Alto	922 79 89 87	Meat specialities
Otelo II	Playa de Fañabé, Local 22	922 71 63 42	Canarian cuisine
Poseidon	Londres - Paseo Marítimo	922 71 33 35	Canarian cuisine
Banana Garden	Palm Beach Avda. Rafael Puig Lluvina	922 79 03 65	Mexican cuisine
Gran Reserva	Calle Londres, 4 CC Sunwing	922 71 44 92	Meat specialities
La Torre del Mirador	Avda. Marítima Bahía del Duque	922 71 21 09	Seafood
La Nonna	Playa del Duque promenade		Spanish cuisine
El Patio	Calle Gran Bretaña	922 746 061	International food
Las Aguas	Avda. Bruselas s/n	922 74 69 00	Nouvelle cuisine
Restaurante Italiano Bianco	Centro Comercial Plaza del Duque	922 717 388	Italian cuisine
La Trattoria	Alcalde Walter Paetmann, s/n	922 74 69 00	Italian cuisine
La Tasca	Alcalde Walter Paetmann, s/n	922 74 69 00	Tapas and wine
La Hacienda	Alcalde Walter Paetmann, s/n	922 74 69 00	Steak house cuisine
Mesón Castellano	Antonio Domíguez Alfonso. Playa de Las Americas	922 79 63 05	Cuisine from Salamanca
Mesón Las Rejas	Carretera General del Sur 1 Arona	922 72 08 94	Grilled Meat
Restaurante Celso	El Cabezo 48 La Caleta	922 71 01 89	Fresh fish
Monte Christo	Urb. Mare Verde, Calle Bruselas	922 71 57 57	Italian cuisine

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