Young Star Cluster Group Meeting in Bonn:

Do All Stars Form in Compact Clusters ?
From Certainties to Doubts

15 - 17 March 2010

http://www.astro.uni-bonn.de/~ycbonn/

The web site provides an up-to-date list of all participants

Argelander-Institut für Astronomie (AIfA)

Max Planck Institut für Radio-Astronomie (MPIfR)

SOC:

- Pavel Kroupa (AIfA)
- Karl Menten (MPIfR)
- Geneviève Parmentier (AIfA; Chair)
- Hans Zinnecker (Potsdam; co-Chair)

Practical Information

Meeting venue:
The Argelander-Institut für Astronomie, Auf dem Hügel 71, D-53121 Bonn (Endenich), Hörsaal 0.03, ground floor (immediately after entering the building, go to the right, make a dozen of steps and the lecture room is on your left; do *not* go through the staircase).

Social event:
Dinner on Tuesday evening. Harmonie restaurant, Frongasse 1, Bonn-Endenich

Your presentations

– There will be no poster session.

– Please bring your own laptop to present your slides.

– Talk durations are 15-min long.

– Similarly, trigger talks (denoted by 'TT' in the programme), which give the impetus to discussion sessions, must be at most 15-min long (i.e. $\sim$ 10 slides).

Wireless: there will be wireless internet access in the lecture room.

Meeting output
We kindly ask you to prepare a pdf file of your presentation. During the meeting, we will collect it so as to create a repository of all presentations.

In case of cancellation, please inform us asap – especially if you are a speaker. This will allow us to re-allocate your slot either to the discussion time or to somebody else.

We are looking forward to your active participation to this meeting, whose particular format has been especially designed to promote lively discussions and exchanges.

Programme as on 11 March 2010,
on behalf of the SOC,
Dr. Geneviève Parmentier

Programme

Monday 15 March [Morning]

Session A: Field Star Formation vs Clustered Star Formation
Part I - Session Chair: Susanne Pfalzner

How does star formation progress in GMCs?

9.00 - Welcome address [G. Parmentier]

9.05 - Meeting introduction [H. Zinnecker]

9.15 - A1: Finding protoclusters with ATLASGAL - The APEX telescope large area survey of the Galaxy at 870 microns [K. Menten]

9.40 - A2: Dusty protoclusters in molecular clouds [F. Wyrowski]

10.05 - A3: Some constraints on the formation efficiency of bound star clusters [S. Larsen]

10.30 .... Morning Coffee-Break

11.00 **Discussions** (Discussion leaders: Pfalzner & Schmeja)

TT1: What fraction of stars is formed in clusters ? [S. Schmeja]

Q1: What fraction of stars is really formed in (dense, compact) clusters?

Q2: How should we define a cluster? Where is its boundary? (+Tuesday morning)

Q3: In what sense are the stars forming in a GMC outside dense clusters ”isolated”?

Q4: What fraction of stars is formed in T associations?

Q5: What is the smallest cluster mass?

12.30 .... Lunch: MPIfR or Telekom Cantine

Monday 15 March [Afternoon]

Session A: Field Star Formation vs Clustered Star Formation Part II - Session Chair: Maria Messineo

The origin of field massive stars

14.00 - A4: Whence came the field? Constraints from the Companion Mass Ratio Distribution [M. Reggiani]

14.25 - A5: Star-loss from young low-N star clusters [C. Weidner]

14.50 - A6: Two-step-ejection of massive stars and the issue of their formation in isolation [J. Pflamm-Altenburg]

15.15 - : Open discussion - The Schilbach & Röser paper (2008 A&A 489, 105): On the origin of field O-type stars

15.30 .... Afternoon Coffee-Break

16.00 **Discussions** (Discussion leaders: Messineo & Gvaramadze)

TT2: On the origin of massive runaway stars [V. Gvaramadze]

Q1: What is the fraction of massive stars formed in the field?

Q2: Star formation triggered by runaway OB stars

Q3: What about runaway OB/WR stars in the LMC?

17.30 .... End of day 1/3

Tuesday 16 March [Morning]

Session B: Size and structure of young star clusters
Part I - Session Chair: Eva Grebel

(Proto-)Cluster sizes

9.00 - B1: The puzzle of the cluster-forming core mass-radius relation and why it matters [G. Parmentier]

9.25 - B2: What is an embedded cluster ? [S. Schmeja]

9.50 - B3: Why do clusters of different masses have a similar radius? [M. Gieles]

10.15 - : Open discussion - The influential Lada & Lada (2003) paper (ARA&A, 41, 57)

10.30 .... Morning Coffee-Break

11.00 **Discussions** (Discussion leaders: Grebel & Pfalzner)

TT3: What cluster sizes can tell us about their formation [S. Pfalzner]
Q1: How to define an embedded cluster? Where is its boundary? (+Monday morning)
Q2: How to define a gas-free cluster? Where is its boundary? (+Wednesday morning)
Q3: Why do clusters of different masses have a similar radius?

12.30 .... Lunch: MPIfR or Telekom Cantine

Tuesday 16 March [Afternoon]

Session B: Size and structure of young star clusters
Part II - Session Chair: Geneviève Parmentier

Mass segregation and substructures

14.00 - B4: Properties of hierarchically forming star clusters [T. Maschberger]

14.25 - B5: Star cluster mass segregation: primordial or evolutionary? The case of the young star cluster NGC 3603 [X. Pang]

14.50 - B6: The Spatial Distribution of Star Formation in the Solar Neighbourhood [E. Bressert]

15.15 - : Open discussion - Ascenso et al. papers about mass segregation (2009, Ap&SS 324, 113; 2009, A&A, 495, 147)

15.30 .... Afternoon Coffee-Break

16.00 **Discussions** (Discussion leaders: Parmentier & Stolte)

TT4: Mass segregation and substructures - observable or not? [A. Stolte]

Q1: Is there a way to prove mass segregation? Can we quantify mass segregation in young clusters?

Q2: Can the observational biases be minimised, such that the results are reliable?

Q3: Does theory provide measurable (bias-free) effects?

Q4: Is there a reliable, and consistent, way to detect mass segregation in observations and theory, rendering the results of both approaches comparable?

Q5: Are we able to distinguish dynamical and primordial mass segregation at all?

17.30 .... End of day 2/3

Wednesday 17 March [Morning]

Session C: Cluster photometry, cluster systems, observational biases

Part I - Session Chair: Soeren Larsen

Cluster systems and observational biases

9.00 - C1: Young stellar clusters in the Milky Way. Their current census and spatial distribution. [M. Messineo]

9.25 **Discussions** (Discussion leaders: Larsen & Bastian)

- TT5: The effects of completeness on samples and interpretations [N. Bastian]
- Q1: Criteria used to define a "stellar cluster"
- Q2: Observational biases
- Q3: The Kharchenko ASCC-2.5 sample

10.30 .... Morning Coffee-Break

Cluster system properties

11.00 - C2: Integrated colours and other parameters of the Galactic open clusters and SSP models [E. Schilbach]

11.25 **Discussions** (Discussion leaders: Larsen & Röser)

- TT6: The mass- and luminosity functions of open clusters in the solar neighbourhood [S. Röser]
- Q1: Significance of the IMF discreteness effect for cluster integrated photometry
- Q2: Sampling of the IMF: what do we know about the upper end of the IMF?
- Q3: The Galactic/extragalactic initial cluster mass function: present status

12.30 .... Lunch: MPIfR or Telekom Cantine

Wednesday 17 March [Afternoon]

Session C: Cluster photometry, cluster systems, observational biases

Part II - Session Chair: Karl Menten

Cluster photometry

14.00 - C3: Multi-wavelength analysis of candidate clusters: the cases of GLIMPSE9 and Cl1813-178 [M. Messineo]

14.25 **Discussions** (Discussion leaders: Menten & Hoffmeister)

TT7: Variability of young stars in young clusters [V. Hoffmeister]

Q1: Variability of young stars in young clusters: consequences for the interpretation of cluster HR-diagrams

Q2: Spectroscopic binary fraction of massive stars in young clusters

Q3: Variability in centres of massive clusters caused by stellar collisions

15.20 .... Break

Star formation in extreme environments

15.40 - C4: Star formation near the supermassive black hole in the Galactic center [H. Bartko]

16.05 - C5: The unexpected finding of discs in the Arches cluster - do we need to revise our notion of circumstellar disc survival? [A. Stolte]

16.30 **Discussions** (Discussion leaders: Menten & Gallagher)

TT8: M82 - Compact Star Clusters and Star Formation in a Starburst Furnace [J.S. Gallagher]

Q1: What role does pressure play in the formation of star clusters?

Q2: If pressure is a significant driver of cluster formation, why do clusters in quiescent low-pressure and violent high-pressure environments have similar radii?

Q3: The initial conditions for massive cluster formation (e.g. 30 Doradus)

17.30 .... End of meeting

List of contributions

(with presenter names in alphabetical order)

Star formation near the Supermassive Black Hole in the Galactic Center (C5)

Hendrik Bartko

The effects of completeness on samples and interpretations (TT5)

Nate Bastian

The Spatial Distribution of Star Formation in the Solar Neighbourhood (B4)

Eli Bressert

We present recent findings of young stellar objects (YSO) surface densities in star forming regions based on a comprehensive collection of Spitzer surveys. Our results show that the star-formation surface density is a featureless power-law from a few to 10^3 YSOs per pc^2, which put several perceptions of star formation into question. We show that previous definitions of "clusters", based on surface density criteria, are arbitrary. This leads us to conclude that clusters are not a unique mode of star formation, but there exists a continuous distribution ranging from distributed to highly clustered. This is expected if star formation proceeds hierarchically. Our results suggest that "clusters" are not fundamental units in the star formation process, but simply the high density tail end of a continous distribution.

M82: Compact Star Clusters and Star Formation in a Starburst Furnace (TT8)

J. S. Gallagher U. Wisconsin-Madison (presenter) & L. J. Smith (STScI)

M82 is one of the nearest luminous starburst galaxies, supporting intense star formation that is producing numerous compact star clusters. A combination of HST U-band imaging and ground-based spectra have established that these clusters exist over a range of ages from <10 Myr to >200 Myr. Rapid star formation thus has occurred throughout this period, which corresponds to the time scale of the interaction with M81. Even though the high levels of internal extinction in M82 introduces biases, the large numbers of clusters still allow some basic limits to be placed on cluster production and survival. Observations of young massive stars in a few relatively unobscured areas, as well as the structures of winds emanating from the starburst clumps, provide further evidence of the importance of star formation in compact units in this type of situation.

Why do clusters of different masses have a similar radius? (B3)

Mark Gieles

Over several orders of magnitude in mass, star clusters have radii of a couple of parsecs. This is found for both young and old (globular) clusters. This remarkable feature has several intriguing implications, the most obvious being that massive clusters are denser than low mass clusters. Although this is well known and commonly accepted, a successful explanation for the near constant radius of clusters has yet to be given. Several possibilities have been tried in cluster formation models, such as mass dependent star formation efficiency. A simple model, that combines relations for stellar lifetimes and dynamical evolution time scales of the cluster, is presented. The model successfully re-produces the constant radius when starting with a constant cluster density for all masses initially. The results are confirmed by a series of N-body simulations.

On the origin of massive runaway stars (TT2)

Vasilii Gvaramadze

Variability of young clusters (TT7)

Vera Hoffmeister & Rolf Chini

HR diagram sequences of young clusters from different epochs show variability on all time scales, moving individual stars from the heavily reddened high-mass regime into the moderately reddened low-mass regime. Sometimes stars will be shifted even to the left of the ZAMS which would qualify them as non-members in a single epoch observation. Thus the interpretation of single-epoch HR diagrams and the modeling of evolutionary tracks have to be aware of possibly large short-term variations. Our so far fairly static view of star formation may be severely misleading [+movies of multi-epoch JHK color-color and color magnitude diagrams of young clusters]

Some constraints on the formation efficiency of bound star clusters (A3)

Soeren Larsen

Properties of hierarchically forming star clusters (B5)

Thomas Maschberger

We 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 upper mass function. We find that the properties of the subclusters depend on their evolutionary stage, with evidence for primordial mass segregation and an upper truncation mass of the IMF that depends on the richness of the subclusters.

Finding protoclusters with ATLASGAL - The APEX telescope large area survey of the galaxy at 870 microns (A1)

Karl Menten

Young stellar clusters in the Milky Way. Their current census and spatial distribution (C1)

Maria Messineo

In the last decade there has been a revolution in our knowledge on Galactic young stellar clusters. More than 1500 candidate clusters have been discovered from the 2MASS and Spitzer surveys, doubling the number of previously known stellar clusters in the Galactic Disk. Their census is, however, very incomplete. So far we have only detected clusters that reside in the near side of the Galaxy, with a few exceptions (e.g. W49). We probably know only 5 % of the total number of galactic stellar clusters. I will present an overview of the recent searches for Galactic stellar clusters, and of our current knoeldge on their spatial distribution. Even with this significant undersampling, the larger sample opens new insights on the structure of the Milky Way, and on its current star formation. There are interesting correlations between the distribution of the clusters with respect to known Galactic structures and compared to theoretically predicted features, which I will discuss.

Multi-wavelength analysis of candidate clusters: the cases of GLIMPSE9 and Cl1813-178 (C3)

Maria Messineo

The recent 2MASS and Spitzer/GLIMPSE surveys have revealed over a thousand candidate stellar clusters, which are hiding behind copious amounts of dust and gas in the Galactic plane. By combining multi-wavelenght information (near-, mid-infrared, radio and X data), it is possible to characterize new candidate clusters, and to identify massive clusters. Only a dozen massive ($> 10^4$ Msun) stellar clusters are currently known in the Milky Way. I will present examples of multi-wavelength analysis of candidate clusters, and unveil their massive stellar content. The clusters GLIMPSE9 and Cl18-13-178 are particularly interesting because they are the first Galactic clusters known to be associated with supernovae remnants, therefore enabling us to estimate the masses of the supernovae progenitors.

Star cluster mass segregation: primordial or evolutionary? (B6)

Xiaoying Pang

Mass segregation is expected to exist in old star clusters such as globular clusters due to dynamical evolution. However, in the young star cluster NGC 3603 which is only 1 Myr old, it already shows pronounced mass segregation as old star clusters. This interesting "Aging" problem in NGC 3603 triggers us to investigate the origin of the mass segregation in star clusters. Is dynamical evolution fast enough to generate such significant mass segregation in such a short time? Or it is a result of primordial effect? We are using HST/WFPC2 data to investigate which is the culprit for the "Aging" problem in NGC 3603.

The puzzle of the cluster-forming core mass radius relation and why it matters (B1)

Geneviève Parmentier

What cluster sizes might possibly tell us about cluster formation (TT3)

Susanne Pfalzner

Two-step-ejection of massive stars and the issue of their formation in isolation (A6)

Jan Pflamm-Altenburg

In this paper we investigate the combined effect of massive binary ejection from star clusters and a second acceleration of a massive star during a subsequent supernova explosion. We call this the two-step-ejection scenario. The main results are: i) Massive field stars produced via the two-step-ejection process can not in the vast majority of cases be traced back to their parent star clusters. These stars can be mistakenly considered as massive stars formed in isolation. ii) The expected O star fraction produced via the two-step-ejection process is of the order of 1–4 per cent, in quantitative agreement with the observed fraction of candidates for isolated-O-star formation. iii) Stars ejected via the two-step-ejection process can get a higher final velocity (up to 1.5–2 times higher) than the pre-supernova velocity of the massive-star binary.

Whence came the field? Constraints from the Companion Mass Ratio Distribution (A4)

Maddalena Reggiani & Michael R. Meyer

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. If not, we can explore further whether: a) dynamical evolution from birth site to field could be responsible (e.g. Goodwin, 2009); or b) whether the sample in question contributes in a significant way to the field star population. We consider samples of companions for M dwarfs, G and OB stars, found in a variety of environments, and we compare them with populations of binaries generated by random pairing from the assumed IMF for a fixed primary mass. Work to date (e.g. Metchev & Hillenbrand, 2008) suggests that we can reject the hypothesis that the companion mass ratio distribution of solar mass field stars were drawn from random pairing of the single star IMF. We extend this analysis to a broader range of primary masses and compare the CMRD of field stars, open clusters, and star-forming regions.

The mass- and luminosity functions of open clusters in the solar neighbourhood (TT6)

Siegfried Röser & Elena Schillbach

From a magnitude limited sample of open cluster we derived their mass- and luminosity functions. Implications will be discussed.

Integrated colours and other parameters of the Galactic open clusters and SSP models (C2)

Elena Schilbach (Presenter), Anatoly Piskunov & Nina Kharchenko

We intend to present data on integrated colours in $BVJHK$-passbands and tidal masses for a sample of 650 local Galactic open clusters. The data will be compared to present-day SSP models widely used in extragalactic studies. We will show that a considerable disagreement on the model prediction with the observed data we have recently found can be explained by a number of effects nowadays normally neglected in the models. The basic reasons of the disagreement are necessity to discretize SSP-models of normal clusters, and to take into account the mass loss due to evaporation of cluster stars. These results are important for studying star formation histories of external galaxies.

What fraction of stars is formed in clusters? (TT1)

Stefan Schmeja

There is increasing evidence that only a certain fraction of the YSOs in a molecular cloud belong to rich clusters, while the rest is found in small groups and dispersed over the entire area. In a survey of the Perseus molecular cloud, Hatchell et al. (2005) found that 40-60% of the protostars and prestellar cores are located in small clusters ($< 50\ M_\odot$) and isolated objects. Investigations in other Galactic star-forming regions yield a percentage of distributed populations between 20% and 60% (Allen et al. 2007; Romn-Ziga et al. 2008; Koenig et al. 2008; Schmeja et al. 2008). However, there are probably large uncertainties due to possible incompleteness of the samples and the definition of the clusters, which depends on the method and is often somewhat arbitrary. What is a good method to determine the fraction of stars forming in clusters in a homogeneous way? Is this fraction similar in different clouds? Is the fraction of stars in clusters a direct consequence of the star formation process, dependent on the initial conditions in a cloud, or does it vary stochastically?

What is an embedded cluster? (B2)

Stefan Schmeja

Unlike gravitationally bound open and globular clusters, embedded clusters do not have clearly defined boundaries. They usually show a low-density halo surrounding the dense cluster cores and a smooth transition to the distributed YSO population spread throughout the entire molecular cloud. So how do you define an embedded cluster? Is it misleading to call stellar density enhancements "clusters", given that a large fraction of them may dissolve early and not become gravitationally bound open clusters?

Mass segregation - observable or not? (TT4)

Andrea Stolte

In the past few years, there have been numerous simulations modelling primordial and dynamical mass segregation and its observable effects in star clusters. Several suggestions concerning the evolutionary state of clusters with mass segregation are made to confirm mass segregation: i) the flattening of the IMF, ii) a faster dynamical evolution/dispersal timescale, iii) observable changes in the cluster density profile.

At the same time, observations of young stellar clusters in the Milky Way, the Magellanic clouds, and even M82 appear to confirm mass segregation. Yet, the dynamical evolution timescale is often comparable to the cluster age, such that dynamical segregation (equipartition) cannot easily be distinguished from primordial segregation for most clusters, and in particular for dense starburst clusters with short dynamical timescales.

The increasing evidence for mass segregation in young star clusters is mitigated, however, by the revelation of substantial biases suggested to influence mass segregation measurements in young clusters. Hence, we are at the point where we have to re-define our observational analysis confirming mass segregation and establish procedures that ensure an unbiased result of the presence or absence of mass segregation.

Reliable observable evidence will be the only means to confirm or reject theoretical theses about the intensity and effects of both primordial and dynamical segregation.

For the discussion, I will briefly contrast the most recent theories on the effects of mass segregation in young clusters and the observational evidence for mass segregation collected over the past few years. As the starting point for the latest controversy, I will review the observational biases hampering the detection of mass segregation as found by Ascenso et al. (2009a,b).

The unexpected finding of discs in the Arches cluster: Do we need to revise our notion of circumstellar disc survival? (C4)

Andrea Stolte, Wolfgang Brandner, Mark Morris, Andrea Ghez (and the proper motion survey team)

High-resolution HKL observations with the Keck telescope have revealed a substantial number of L-band excess sources in the Galactic center Arches cluster. These sources are confirmed as optically thick circumstellar discs on the basis of CO emission in their spectra, and as cluster members on the basis of proper motion membership.

Here, I will briefly introduce the proper motion membership survey of four starburst clusters in the Milky Way, and will then present the results of the disc detection in the Arches under the aspect of disc survival in extreme star-forming environments.

Star-loss from young low-N star clusters (A5)

Carsten Weidner

One important question in relation of distributed and isolated star-formation is whether or not escaping stars from very young star clusters can significantly contribute to the fraction of distributed stars. We study this question with the use of Monte-Carlo N-body calculations. The amount and properties of escaping stars from low-N (N = 100 and 1000) young embedded star clusters are studied over the first 5 Myr of their existence, each repeated a 100 times with different random seeds. Besides the number of stars also different initial radii and binary populations are examined as well as virialised and collapsing clusters.

Dusty protoclusters in molecular clouds (A2)

Friedrich Wyrowski