Title of Proposal: Modelling Dense Stellar Systems

First day of meeting: 2006-08-21

Duration: 5 days

Location: Prague, Czech Republic

Coordinating IAU Division: VII — Galactic System

Supporting IAU Commissions:
26 — Double and Multiple Stars
33 — Structure and Dynamics of the Galactic System
35 — Stellar Constitution
37 — Star Clusters & Associations

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Expected or maximum number of participants: 400

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Preliminary Scientific Programme Topics:

The simultaneous advent of multi-wavelength observations of dense stellar systems, and their advanced simulations on powerful computers has led to a revolution in stellar research. The purpose of this symposium is to bring together researchers in stellar evolution, stellar dynamics, and stellar hydrodynamics, in a joint attempt to realistically model systems where stellar interactions are important. We will begin with an overview of the current observations of star clusters and galactic nuclei. Next we will have sessions on modelling local interactions (e.g. direct stellar collisions, perturbed binary evolution) and global interactions (e.g. whole cluster models, star formation in crowded regions). The symposium will culminate with discussion of the most complete models of stellar systems which include feedback between stellar dynamics, evolution and hydrodynamics, and a panel discussion on the future of this emerging and exciting field.

Preliminary Schedule:

Monday - observations

Confirmed invited speakers: Ivan King (USA), Eva Grebel (Switzerland), Frank Verbunt (Netherlands)

- Basic data of dense stellar systems
  - mass function down to the hydrogen burning limit, binary fraction in clusters
  - tidal tails & tidal streams
  - high accuracy proper motion and radial velocity surveys,
  - ellipticity, rotation
- Exotica
  - blue stragglers, hot HB stars, Xray binaries, millisecond pulsars
  - surveys, current interesting results (example from right now might be HST spectra of blue stragglers)

Tuesday - local interactions

Confirmed invited speakers: Francesca D'Antona (Italy), Peter Eggleton (USA), Natasha Ivanova (USA)

- Stellar evolutionary codes
  - stand-alone evolutionary codes
  - treating special cases (hot HB stars, blue stragglers)
- Stellar codes in binary (multiple) systems
  - X-ray binaries, ms pulsars, binary evolution
- Stellar codes under extreme conditions - collisions
  - production of exotica
  - interaction with dense interstellar medium (accretion disc, gas...)

Wednesday - global interactions

Confirmed invited speakers: Mirek Giersz (Poland), Hyung Mok Lee (Korea)

- Modelling techniques
  - N-body, Monte Carlo, Fokker-Plank, gas
- Modelling results
  - individual systems (LMC clusters, Milky Way clusters, galactic nuclei)

Thursday - putting all together

Confirmed invited speakers: Matthew Bate (UK), Fred Rasio (USA)

- Initial conditions
  - link between star formation and cluster formation, evolution during gas expulsion
  - star formation in crowded regions
- "Kitchen Sink" models
  - codes including both local and global interactions
  - feedback between stellar evolution, stellar dynamics, hydrodynamics
- Confrontation between models and observations

Friday - perspectives

- The Future of Modelling Dense Stellar Systems – panel discussion
- Conference Summary

Scientific Rationale:

Stars play a fundamental role in astronomy: much of information available to us about the universe comes from stars. Coeval associations of stars, *stellar clusters*, are equally central to astronomy: they are born at all epochs; their physical characteristics evolve constantly in time (they grow old); and eventually, they dissolve, or "die". Through star formation processes in clouds new clusters form in many a galactic and extragalactic environment. Stellar evolution in single and binary stars is intertwined with dynamical evolution of star clusters.

Material to form new star clusters consists of the remains of their dead ancestors, completing a life-cycle that lies at the cross-road of nearly every single field of research in modern astronomy, such as the formation and evolution of stars, stellar statistics and population analysis, dynamical evolution of star clusters; the formation of very dense stellar aggregates in young clusters in star forming regions as well as near the centre of our own and presumably other galaxies; the determination of the age of the oldest population of stars known in our Galactic globular clusters even bears an imprint to cosmology and cosmological timing.

In the past decade, considerable progress has been made in the observations of dense stellar systems owing to more and more powerful telescopes and instrumentation. At optical wavelenghts, breakthroughs in resolving dense stellar systems have been made not only due to the superior resolution of the Hubble Space Telescope (most recently epitomized by the Advanced Camera for Surveys), but also by the ongoing efforts of developing adaptive optics systems that allow us to study the central regions of such systems from the ground. To name just two examples, these new observational techniques now permit us (1) to study the luminosity and mass functions even of young, massive, dust-obscured clusters, giving direct insight on the modalities of mass segregation, and (2) to study a high-density environment like our Galactic center, revealing the motions of stars around the central black hole. New multi-object spectrographs (e.g., at the Very Large Telescope of the European Southern Observatory) help us to measure the kinematics of individual stars in dense stellar systems, vital for determining velocity dispersions, masses, and other fundamental cluster parameters.

The theoretical study of dense stellar systems has as well seen a tremendous progress over the past decade, in part inspired by the evolution of special purpose computers by astronomers in Japan, but also a general improvement of large supercomputer facilities, which make it now possible to "observe" stellar clusters by means of simulation experiments. Theorists are now at the beginning of a period where it is possible to simulate the full life cycle of star clusters from their birth inside a gas cloud until their death by evaporation and disruption in the tidal fields of a mother galaxy, or more dramatically, of a central nucleus harboring a supermassive black hole.

Although much of the stellar content of the universe is not currently part of a dense stellar system, the study of these systems provides insight into a wide variety of fundamental astronomical questions. It is widely believed that star formation is a clustered process (whether in OB associations or in compact clusters). It is thus vital to understand under which circumstances what kind of dense stellar system forms and how, in detail, it evolves and disrupts. Star clusters epitomize simple stellar populations - a collection of stars all of the same distance, metallicity and age.

Studying these systems teaches us about stellar evolution and the impact of feedback as well as the origin and evolution of exotic objects, and provides insight into many unanswered problems in stellar evolution, e.g., the second-parameter problem or light element abundance anomalies. Globular cluster systems and disruption of individual clusters are unique tracers of galactic potentials. Dense star clusters are the best laboratories for studying the formation and physical nature of extreme stellar populations (like X-ray binaries or blue stragglers), and thus are ideal testbeds for population synthesis models and stellar evolution tracks, which in turn are essential to analyse the formation and evolution of galaxies. The proposed symposium promises to provide a comprehensive view of many aspects of these important components of the universe.

The proposed IAU symposium will cover the whole life cycle of star clusters from birth to dissolution, their internal evolution as well as their interaction with the environment. Topics to be covered are fundamental properties of Galactic globular clusters (as the standard prototypes of old evolved star clusters), tidal tails and streams by which they affect the stellar population of galactic haloes, recent progresses in stellar evolution, especially in non-standard cases important for star clusters (mass transfer and exchange of bodies in evolving close binaries, rejuvenation by direct or binary-induced collisions), theoretical prediction and observational constraints on exotic objects such as X-ray binaries, blue stragglers, pulsars, compact remnants of stellar evolution such as white dwarfs, neutron stars and stellar mass black holes. In young clusters theoretical and observational hints exist for intermediate mass black holes, which may be the result of merging of massive stars or of a population of stellar mass black holes. We will also cover recent developments in modelling techniques and hardware and software tools relevant to our field, up to the point where computer simulations provide us with data resembling real observations. Finally the formation phase of clusters, including observations of young massive clusters as well as recent theoretical studies of formation of a collection stars in molecular clouds and their consequences for initial conditions of clusters will be discussed.

Our proposed IAU symposium could be seen in a line with previous IAU symposia No. 113 "Dynamics of Star Clusters" in Princeton 1983, No. 174 "Dynamics of star clusters" in Japan 1995, and No. 208 "Astrophysical Supercomputing using Particle Simulations" in Japan 2001; and in part with two international conferences in Heidelberg, Germany, (2000, Dynamics of Star Clusters and The Milky Way) and Padova, Italy (2002, New Horizons in Globular Cluster Astronomy). The advanced pace of observational and theoretical progress makes it a high time to have a symposium on theory and observation of dense star clusters and stellar evolution by the year 2006 of the IAU GA in Prague. While being in line with the aforementioned symposia and international conferences (not only regarding the science contents but also regarding the active people organising the conferences and invited speakers) we stress that this time there will be decisive shift in focus: while in earlier symposia theory and observation were still well apart from each other and idealised models were unable to fully comprehend observations, we are now entering a phase where observation and theory are direct counterparts of each other, and this should be strongly emphasised in the program. Such new development was already clearly visible in the last of the aforementioned conferences in Padova.