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COMMISSION B1 **COMPUTATIONAL ASTROPHYSICS**

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INTER-COMMISSION WORKING GROUP

Commissions B2, B3, C1, C2, F2,	**Education and Training in Astrobiology**
Commissions G1, G2 and G3	**Stars and stellar physics**

TRIENNIAL REPORT 2015-2018

1. Introduction

Commission B1 Computational Astrophysics started at the 2015 General Assembly following a proposal to the IAU from Simon Portegies Zwart, and Dmitry Bisikalo. Four Ordinary Members Sungsoo S. KIM (Korea), Irina N. Kitiashvili (USA), Garrelt Mellema (EU), Michael Shara (USA) with Christian Boily (EU) elected by the OC as Secretary. Commission H2 currently has 248 members.

The Commission B1 has identified five key activities for development:

- advertising the role of simulations in astronomy;
- stimulating the use and development of computer hardware
- develop and distribute public software in astronomy
- maintaining interdisciplinary links with scientists in other fields, including data and documentation, astroinformatics and astrostatistics, education and communication, stars and stellar physics.
- maintaining interdisciplinary links with scientists in computational science and informatics.

Our proposed commission exhibits broad palette of challenging informational and technical developments, including hardware and software. We therefore argue that the new commission should be part of Division B (Facilities, Technologies & Data Science). Astrophysics on digital computers is a relatively new discipline compared to optical telescopes, but algorithm design, mechanical calculators and orreri have considerable heritage and are important for computational astrophysics, education and outreach, and the commission on computational astrophysics should therefore also be part of the parent Division C (Education, Outreach and Heritage).

Astronomy is an empirical science in the sense that most major advances are motivated by observations. When people think of astronomy, they usually imagine a big telescope and pretty, colorful pictures of various space objects. However, even the prettiest picture is only a first step toward a true understanding of physical processes that shape an observational appearance of stellar and interstellar, dense and diffuse, luminous and

dark matter. Except for a few bodies of the Solar system, direct experimental studies of astronomical objects (including the Universe as a whole) are impossible, and we need to rely heavily on physical models, expressed as mathematical equations, to grasp underlying reasons for a specific observational result. In an overwhelming majority of cases these equations are too complicated to be solved analytically, and in all these cases we resort to numerical modeling. What had started long ago as Kepler's hand-written tables now has developed into the vast field of computational astrophysics. This field has reached a great success of its own as a powerful theoretical basis to study astrophysical processes. It is now also a mandatory tool both to prepare and to analyze ambitious observational programs. Numerical models are therefore at the heart of most astrophysical domains, at all scales, from nuclear fusion processes to cosmology, and cover all physical processes, including general relativity, hydrodynamics, radiative processes, chemistry, material processes and nuclear fusion. Computational astrophysics can be considered a third discipline, complementing observations and theory.

This commission has the potential to bridge the gap between other specializations in astronomy. So far, the commission has done relatively little to realize this organization. In the coming triennium we intend to change this and work on the cross-disciplinary aspects of this commission.

2. Developments within the past triennium

Computational astrophysics is not just a specialization of computational physics, but it opens new windows in the way we perceive and study the heavens. This rapidly growing (relatively) new discipline in astronomy combines modern computational methods, novel hardware design, advanced algorithms, original software implementations and associated technologies to discover new phenomena, and to make predictions in astronomy.

The goals for the commission was to combine efforts of scientists solving computationally demanding problems (gas dynamics, MHD, radiation transfer, N-body, data processing, etc.) in order to share approaches, ideas and methods; to assess the current level, requirements, bottle-necks and future prospects of numerical simulations; to ensure the needed level of synergy between various models; to probe the potential of citizen science and distributed computations; to organize conferences, workshops, computational astrophysics schools etc. There were similar past efforts, like the European AstroSim program, the East-Asian Numerical Astrophysics Meeting (EANAM) and the MODEST consortium. These communities promote collaboration and defined the direction of computational astrophysics in their respective regions.

In the last triennium we have objected to organize these activities from a more central perspective. The idea was to stimulate this via an IAU symposium on computational astrophysics in 2016. Regretfully, the conference was nog regarded sufficiently critical by the IAU and the proposal was rejected. In the mean time we have been an active community with many organized meetings and smaller workshops. However, we lack currently the momentum to work as a single body. Conferences are organized as subdisciplinary meetings. There is a clear need for a general computational astrophysics conference that binds the entire field, from high-performance computing to machine learning and big data analysis strategies.

More than 200 people are currently involved in developing and testing numerical models, and thousands of IAU members use numerical modeling as a tool. The community that relies on results of numerical models on a regular basis is considerably larger. We propose to inaugurate a commission for Computational Astrophysics in the IAU. This commission is motivated by the general importance of computing for the astronomical

community, and by the need within the computational community to become organized. The purpose of the commission is to inform fellow members of meetings, scientific advances and new techniques, and job openings, and to inform other astronomers and the IAU in general about noteworthy developments in our field.

3. Future prospectives

The need for the commission is even more urgent that it was at it's inauguration because the complexity of supercomputers as well as of numerical models grows rapidly.

The scientific domain of the commission of computational astrophysics is so broad that even within the commission it will be hard to get all parties interested in each individual's specialization. This difficulty is reflected in large number of highly specialized conferences and schools that have been organized by commission members. We will continue organizing such workshops, schools and conferences, but the general objective is to also organize a general computational astrophysics conference undre the IAU umbrella.

So far we have not defined specific working groups within the commission, but we will pay a more active role in this in the coming triennium. Working groups within the commission may include groups devoted to numerical methods around simulating specific physical processes, data mining, statistics, advanced algorithms and new emerging technologies. The combination the three disciplines of astronomy, physics and computing leads to a wide range of topics which covers all scales and a rich palette of statistics, geology, physics, chemistry, etc. In our opinion, computing should be interpreted in the broadest sense and may include hardware, algorithms, software, networking, data management, modeling, simulation, visualization, high-performance computing, machine learning and data intensive computing.

4. Closing remarks

Further activities require the coherent organization of the field. We envision a consortium in which scientific sourse code public and distributed freely. Numerical simulations should be reproducible, not only in principle but also in practice. While organizing the community we intend to emphasize these points. Further organization of the community will be realized by social media, including facebook and twitter. The public source code library can be hosted on a github-like environment and source code administration of the library could be pioneered via the Astronomical Source Code Library (ASCL). We further envision to organize a large conference which will help focus the community. This conference could be organized under the IAU umbrella.

Simon F. Portegies Zwart
president of the Commission