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Formation, Detection, and Characterization of Extrasolar Habitable Planets

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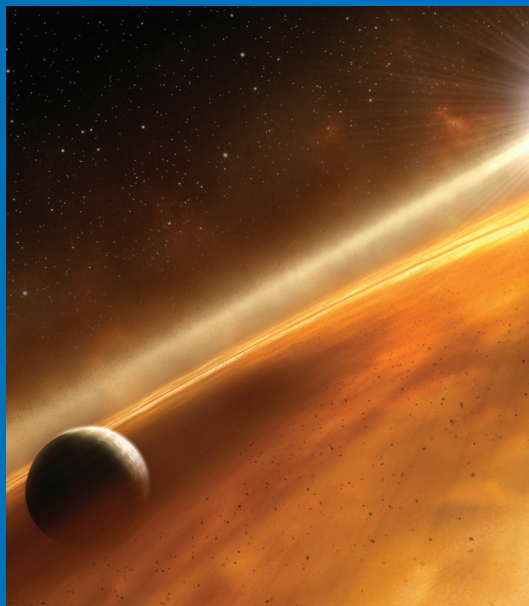
Nader Haghighipour

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OF EXTRASOLAR HABITABLE PLANETS

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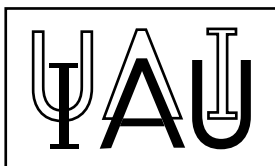
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INTERNATIONAL ASTRONOMICAL UNION
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**FORMATION, DETECTION,
AND CHARACTERIZATION OF
EXTRASOLAR HABITABLE
PLANETS**

**PROCEEDINGS OF THE 293rd SYMPOSIUM OF
THE INTERNATIONAL ASTRONOMICAL UNION
HELD IN BEIJING, CHINA
AUGUST 27-31, 2012**

Edited by

NADER HAGHIGHIPOUR
University of Hawaii, USA



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Preface

The detection of planets around other stars is undoubtedly one of the triumphs of modern astronomy. Not only do these planets prove that our solar system is not unique, they also reveal many new physical and dynamical characteristics that are unseen among the planets of our solar system and are unexplainable by the conventional theories of planet formation and dynamics. The challenges associated with these discoveries have made astronomers revisit planetary theories and have revolutionized our understanding of the formation and evolution of planetary systems.

Almost two decades after the discovery of the first extrasolar planet, and with now more than 1700 of these objects discovered and over 3000 candidates awaiting confirmation, these challenges still continue. On the observational front, despite breakthroughs such as imaging giant planets (e.g. HR 8799), detecting super-Earth planets in the habitable zone (e.g. GJ 667Cc), identifying sub-Earth and Moon-sized planets (e.g., Kepler 37b), and discovering planetary systems in circumbinary orbits (e.g., Kepler 47), a major shift has been made towards a more challenging task: detecting and characterizing Earth-sized planets in the habitable zones of solar-type and cooler stars. Several large ground-based surveys such as HARPS, M_{Earth}, M_{2K}, and LCES have already produced promising results. The successful operations of the CoRoT and *Kepler* space telescopes have also made significant contributions by detecting several planetary systems such as those of Kepler 10 and Kepler 90 (a solar system analog), and the most prominent transiting super-Earth, CoRoT 7b.

On the theoretical front, the challenges are even larger. Despite more than a decade of work on the formation and dynamical evolution of extrasolar planets, many fundamental issues are still unresolved. As in our solar system, it is not clear how extrasolar giant planets are formed. Nor is it fully understood how some of these planets acquired high orbital eccentricities, why some have very large semimajor axes and regarding the formation of terrestrial/habitable planets, it is not evident how the migration of giant planets affects the formation of smaller bodies in those systems. With the discovery of several super-Earths during the past several years, fundamental theoretical work is also underway to understand the interior dynamics of these bodies, as well as their atmospheres and magnetic fields, and the connections between these properties and the habitability of super-Earths and the possibility of the detection of their biosignatures.

The 2012 IAU General Assembly provided a very timely occasion to organize a full symposium on the advancements made in extrasolar planetary science, in particular on the formation and detection of terrestrial and habitable planets. The symposium was timely in the sense that it coincided with the announcement of many discoveries with *Kepler* and CoRoT. The aim of the symposium was to have a diverse scientific program covering topics related to habitability and the challenges associated with the formation and detection of habitable planets. The topics covered by the symposium included the following

- Methods of detecting habitable planets and mass determination
- Models of the formation of terrestrial/habitable planets
- Water on Earth and in other Solar System bodies
- Processes affecting close-in planets (tides, tidal-locking, radiation)
- Habitability and habitable zone
- Interior dynamics of habitable planets
- Atmospheric models and habitability

- Planetary magnetic fields and their connection to habitability
- Prospects for the detection of biosignatures
- State of current searches for habitable planets
- Future prospects for the detection of extrasolar habitable planets
- Habitability in extreme planetary systems
(multiple planets, binary stars, moons, Trojan planets).

The program consisted of a series of invited talks as well as a rich collection of contributed oral and poster presentations. Speakers presented the current state of research on the habitability of Earth and the progress made towards its associated challenges. The symposium also fostered discussions on the implications of this research for detecting similar planets around other stars.

As one can imagine, the organization of such a large symposium and the preparation of its proceedings is a tremendous undertaking that is beyond the capability of one person. I had the pleasure of working with a great team of colleagues who did not hesitate to help at any stage of the work, beginning from the preparation of the very first letter of intent, to putting the final touches on this proceedings; a process that took over three years.

I am indebted to many individuals for the success of this symposium. My special thanks go to Julie Fletcher at the NASA Astrobiology Institute for her tremendous help in designing the poster and website of the conference. I am thankful to Ian Corbett, the IAU general secretary at the time, for his availability, responsiveness, and his infinite amount of patience. I am also thankful to Alan Boss and Bill Irvine for their help and support during the preparation of the symposium proposal and other organizational matters. I am grateful to Ji-Lin Zhou and the members of his group at the Nanjing University for their help with printing the symposium poster.

The scientific richness of the symposium would not have been possible without the great help of the scientific organizing committee. I am thankful to the members of the SOC for their help in selecting talks and especially Alan Boss, Rudolf Dvorak, Fred Masset, Sylvio Ferraz-Mello, Krzysztof Gozdziewski, and Ji-Lin Zhou for their great help and willingness to referee the articles in these proceedings. Each contribution in this book has been reviewed by one of these individuals and by myself. I would also like to thank the authors for their participation in this symposium, their willingness to contribute to these proceedings, and for their cooperation and responsiveness during the editorial process.

Finally, this symposium would not have materialized without the support of several sponsoring organizations. I am thankful to the IAU Division of Planetary Science and its president at the time, Karen Meech, the IAU Commissions 51 and 53 (Bioastronomy and Extrasolar Planets) lead by Bill Irvine and Alan Boss, and to the NASA Astrobiology Institute (deputy director, Ed Goolish) for their support of the original proposal of this symposium. I am also grateful to the office of the IAU General Assembly and the NASA Astrobiology Institute, in particular Melissa Kirven-Brooks, for providing financial support that made the participation of many students and young researchers possible.

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December 20, 2013*

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