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# Foreword: A Conclusion to the ISSI Series on Astrophysical Magnetic Fields

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Magnetic fields are a fundamental component of the physical world on all scales—as constituents of the electromagnetic environment of all matter. The interaction between the magnetic fields and matter is at the heart of many dynamic processes that shape astrophysical objects and their environments. Regions of space threaded by magnetic fields control or at least influence the interactions that take place between them. Observing and understanding magnetic fields and the role they play in physical processes in the solar system and beyond have been the subject of a series of Workshops and publications by the International Space Science Institute since 2008.

The first three volumes covered the origin and dynamics of solar magnetism, the magnetic fields of the planets, and the magnetic field of the Earth. These were meant to constitute a trilogy of magnetic fields within the confines of the solar system. Then came the fourth volume which extended the coverage to the whole Universe, but concentrating on large-scale magnetic fields, comparable to, or smaller in magnitude than those directly measured within the solar system. The four volumes are:

The Origin and Dynamics of Solar Magnetism, M.J. Thompson, A. Balogh, J.L. Culhane, Å. Nordlund, S.K. Solanki, J.-P. Zahn (Eds.), Space Science Series of ISSI, Volume 32, ISBN 978-1-4419-0238-2, published in May 2009
Reprinted from Space Science Reviews Volume 144, Nos. 1–4, 2009

Planetary Magnetism, U.R. Christensen, A. Balogh, D. Breuer, K.-H. Glaßmeier (Eds.), Space Science Series of ISSI, Volume 33, ISBN 978-1-4419-5900-3, published in September 2010
Reprinted from Space Science Reviews Volume 152, Nos. 1–4, 2010

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Terrestrial Magnetism, G. Hulot, A. Balogh, U.R. Christensen, C. Constable, M. Mandea, N. Olsen (Eds.), Space Science Series of ISSI, Volume 36, ISBN 978-1-4419-7954-4, published in January 2011
Reprinted from Space Science Reviews Volume 155, Nos. 1–4, 2010

Large-Scale Magnetic Fields in the Universe, R. Beck, A. Balogh, A. Bykov, R.A. Treumann, L.M. Widrow (Eds.), Space Science Series of ISSI, Volume 39, ISBN 978-1-4614-5727-5, published in October 2012
Reprinted from Space Science Reviews Volume 166, Nos. 1–4 and Volume 169, 2012

The current volume contains reviews of completely new aspects of magnetic fields in the astrophysical Universe—and in many cases of aspects of physical processes and phenomena fundamentally different from those addressed in the first four volumes. The strength of the magnetic fields of the compact objects reviewed in this volume is up to 8 to 10 orders of magnitude higher than that of typical sunspots which are the strongest fields in the solar system. Large-scale astrophysical magnetic fields, such as interstellar and galactic fields are weaker still than the fields experienced in the solar system. The gap between field strengths covered in the previous volumes and those in astrophysical object and environments addressed in the present volume is illustrated in Fig. 1.

The first four volumes in the ISSI series on magnetism have left open the questions related to the generation and effects of the very strong magnetic fields found near the most compact objects in the Universe. The motivation for the current volume has been to complete the review of such magnetic fields, associated with Magnetic Stars, White Dwarfs, Neutron Stars and Active Galactic Nuclei (AGNs) and their environments. The reviews presented here describe the current understanding of how the extremely strong magnetic fields of these objects are generated, how they interact with matter and how they generate the broad range of observed phenomena, among them shock waves and many different types of radiation over a very broad spectrum. Of particular interest are the phenomena leading to the generation of astrophysical jets and their complex physics, the occurrence of Gamma Ray Bursts, the formation and extreme properties of relativistic shocks and the production of high-energy particles by the cosmic engines. Radio pulsars (highly magnetised neutron stars) have been studied for the last half century; these have magnetic fields in the range $10^{11}$ to $10^{13}$ G. In such strong fields the basic physics changes for the reason that the electron Larmor (gyro) radius drops below the Bohr (atomic) radius. Magnetars are also neutron

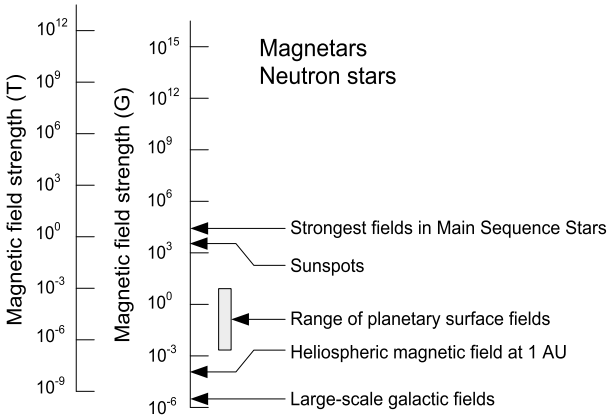


**Fig. 1** The range of astrophysical magnetic field strengths, covering 21 orders of magnitude, effectively representative of the whole spectrum of astrophysical phenomena in the Universe. The lower part of the graph shows the topics covered by four previous volumes in the Space Science Series of ISSI; the objects with extremely high magnetic fields, neutron stars, magnetars, are the subject of the current volume

stars, but with magnetic fields in the range $10^{13}$ to $10^{16}$ G. The two or more orders of magnitude difference in the magnetic fields of these objects leads to differences in their energetic output. In particular, the explosive energy in the observed "giant flares" from magnetars, powered by the dissipation of magnetic energy, is of order $10^{44}$ ergs, about 12 orders of magnitude more energetic than the largest of solar flares. We are indeed in the presence of extreme physical phenomena, ascribed to the ability of these exceptional astrophysical objects to generate the exceptionally strong magnetic fields.

There are fifteen review papers in this volume, providing a comprehensive and up-to-date coverage of a field that remains in a state of rapid evolution. With this volume, the ISSI series on astrophysical magnetic fields concludes an ambitious review of topics that are central to the progress of astrophysics and our understanding of the Universe.

The ISSI Workshop on the Strongest Magnetic Fields in the Universe was held in ISSI, Bern, Switzerland on 3–7 February 2014. The Convenors of the Workshop (André Balogh, Vasily Beskin, Maurizio Falanga, Maxim Lyutikov, Sandro Mereghetti, Tsvi Piran and Rudolf Treumann) and the Editors of this volume are greatly indebted to all the participants of the Workshop who brought their broad range of expertise and interest in astrophysics to deepen our understanding of the issues related to the extreme magnetic fields in the Universe and their parent objects. The resulting collection of review papers was the outcome of the exchanges and fruitful collaboration among the participants; we thank them for their successful efforts to integrate the lessons learned in the different topics, as the reviews in the volume testify. Thanks are also due to the reviewers of the papers; in all cases the reviews were thorough and constructive and the volume bears witness to their contribution. We thank the staff of ISSI for their dedicated support: Prof. Rafael Rodrigo, Executive Director, and his colleagues Jennifer Fankhauser, Andrea Fischer, Saliba Saliba and Silvia Wenger. Finally the Editors thank the staff of Space Science Reviews, as well as the production staff for their patience on occasion and for an excellently produced volume.