Guest Editorial
Plasma Experiments in the Laboratory and in Space

THIS issue marks the third edition of the IEEE TRANSACTIONS ON PLASMA SCIENCE devoted to the study of space and cosmic plasma, in addition to a special issue devoted to plasma cosmology. Each of the four editions has carried a theme for the purpose of updating the field in current topics of interest. The primary theme of the first special issue (December 1986) was electrical engineering, plasma science, and the plasma universe. In that issue it was noted that with the coming of the space age and the subsequent discovery of magnetospheric–ionospheric electrical circuits in planetary magnetospheres, Kirchhoff's circuit laws and therefore electrical engineering were catapulted to dimensions eight orders of magnitude larger than previously investigated in the laboratory and nearly four orders of magnitude greater than that associated with the longest power distribution systems on earth. This discovery pushed electrical engineering as related to plasma science several orders of magnitude deeper into space, i.e., the dimension of the solar system. The first issue also reported on new discoveries in radio astronomy, a field first reported by the IEEE (or, more precisely, the Institute of Radio Engineers) [1], [2]. The renaissance of observational astronomical research in the 1960's and 1970's, fueled by the explosive development of electronics, space probes, and computers, set the stage for an unprecedented decade of discovery in the 1980's, when ten octaves of the electromagnetic spectrum were opened to cosmic research. The discovery of synchrotron-emitting plasma in the magnetospheres of the planets, in interstellar matter, and at the center of our galaxy spawned the concept of the plasma universe, an idea dating back to Kristian Birkeland (1867–1917) [3].

The theme of the second special issue (April 1989) was the golden anniversary of magnetic storms and the aurorae and was dedicated to Hannes Alfvén in recognition of his 80 years. It was exactly a half century earlier that Alfvén's paper "A Theory of Magnetic Storms and the Aurorae" was published in the *Proceedings of the Royal Swedish Academy of Sciences* (*Kungliga Svenska Vetenskapsakademiens Handlingar*, vol. 18, pp. 1–39, 1939). This remarkable paper contains concepts that continue to influence and guide modern space plasma physics. It was in this paper that Alfvén developed the guiding center approximation for determining the gross motion of charged particles trapped in a magnetic field and introduced the concept of a partial ring current formed from trapped radiation in the earth's magnetic field. Alfvén also expanded on the Birkeland idea of electric currents flowing along geomagnetic field lines. The existence of such field-aligned currents (now referred to as Birkeland currents or Birkeland–Dessler currents) was not widely accepted and could not be positively identified from surface magnetic field observations, and they became a source of controversy and intense debate. They are now regarded as an important element in the solar–terrestrial system, and many of the aurora, ionosphere, and magnetosphere papers published in the second special issue were related to Birkeland currents, including measurements of electric field and density and temperature fluctuations by Sweden's Viking satellite, close to polar orbit with an apogee of 13 000 km.

The theme of the February 1990 special issue was plasma cosmology, and this issue consolidated the findings presented by the participants to the first IEEE Workshop on Plasma Cosmology, La Jolla, California, February 20–22, 1989. This meeting and special issue led to the following characterization of plasma cosmology: (1) The same basic laws of plasma physics hold from laboratory and magnetospheric-heliospheric plasmas out to interstellar and intergalactic plasmas. (2) In order to understand plasma phenomena it is necessary to map not only the magnetic field but also the electric field and electric currents. (3) Space is filled with a network of currents which transfer energy and momentum over large or very large distances. The currents often pinch to filamentary or surface currents. The latter are likely to give space, including interstellar and intergalactic space, a cellular structure. (4) A number of plasma phenomena, such as double layers, critical velocity, pinch effects, and the properties of electric circuits, are of decisive importance in understanding the nature of the universe.

Since the publication of the first special issue, six years ago, discoveries in space and cosmic plasma have continued at a rapid pace. For example, the existence of electric fields in space is no longer in doubt; nor is the filamentary nature of the universe and the importance of laboratory plasma physics in understanding the new discoveries of the 1980's. This special issue on space and cosmic plasma is devoted to plasma experiments in the laboratory and in space. As in the previous special issues, the papers in this issue are ordered as to the dimension of the plasma under study. In size, these range from millimeter dimensioned laboratory plasmas to the Hubble dimension (10^{26} m) and beyond.

About half the papers derive from the 1991 "Alpbach Workshop," the International Workshop on Plasma Experiments in the Laboratory and in Space, held in Alpbach, Austria, from July 1 to July 6. The Alpbach papers form an appropriate and timely part of this special issue and provide updates on such phenomena as the critical ionization velocity effect, beam driven instabilities, active experiments and diagnostics, whistlers, energy transport, plasma erosion, double layers, turbulence, reconnection, plasma waves in space, and plasma cloud expansion.

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Fig. 1. Attendees to the 1991 "Alpbach Workshop," the International Workshop of Plasma Experiments in the Laboratory and in Space, held at the Hotel Alphof in Alpbach, Austria, on July 1–6. The approximately 60 participants came from Japan, the United States, and Europe for the purpose of bringing space and laboratory communities together. The meeting convenors were C.-G. Fälthammar of the Royal Institute of Technology, Stockholm; W. Riedler of the Space Research Institute, Graz; G. Haerendel of the Max Planck Institute for Extraterrestrial Physics, Garching; C. Kennel, University of California, Los Angeles; P. Kintner, Cornell University, Ithaca; and N. Rynn, University of California, Irvine. The U.S. program Committee was chaired by N. Rynn and included C. Chan, Northeastern University; M. Hudson, Dartmouth College; P. Kintner, Cornell; and R. Stenzel, University of California, Los Angeles. The European Program Committee included C.-G. Fälthammar, W. Riedler and G. Haerendel. The next workshop will be held in Banff, Alberta, Canada, June 21–25, 1993, and will be chaired by R. Merlino, University of Iowa, Iowa City.

In addition, this issue carries papers on solar, stellar, and interstellar plasma; galactic and cosmic plasma; and plasma phenomena in cosmological context. The manifestation of electric currents in interstellar molecular clouds, circumstellar matter in supernovas, and in solar morphology and stellar formation is discussed. On the next size scale of the hierarchy, the formation and equilibrium of intergalactic filaments are given. Acceleration mechanisms in cosmic plasma are discussed, as are the properties of charged particle beams in cosmic ray generation. This section includes aspects of dust-grain-plasma interactions and instabilities in the cosmic environment.

The study of cosmological issues concerns plasma science on the largest scale in the hierarchy of the plasma universe. These studies involve issues such as the remarkable continuity of radiation over the entire electromagnetic spectrum; the properties of the cosmic microwave background; Thomson scattering of microwaves from density fluctuations in cosmic plasma; red shifts in plasma absorption and plasma emission lines by Compton, Wolf, Doppler, and gravitational effects; and the unification of gravity and electromagnetism.

This issue also carries a historical section. For nearly 50 years after Langmuir coined the term "plasma" and for some 30 years after "A Theory of Magnetic Storms and the Aurorae," the importance or existence of plasma in the solar system was disputed. While today the solar system is universally treated as an immense plasma laboratory that allows *in situ* measurement of a rich variety of plasmas, a dispute still exists regarding the importance or existence of plasma just beyond the range of diagnostic-bearing spacecraft. S. Brush and H. Alfvén examine critically the history of space and cosmic plasma in the evolution of science.

Finally, it is appropriate that this special issue covers a wide range of plasma phenomena, from laboratory experiments to cosmological issues as these ideas were pioneered by Kristian Birkeland, today recognized as the father of plasma experiments in the laboratory and space [3]-[5]. We may remember Birkeland's prophetic statement:

> From the conceptions to which our experimental analogies lead us, it is possible to form, in a natural manner, an interesting theory of the origin of worlds. This theory differs from all earlier theories in that it assumes the existence of a universal directing force of electro-magnetic origin in addition to the force of gravitation, in order to explain the formation round the sun of planets—which have almost circular orbits and are almost in the same plane—of moons and rings about the planets, and of spiral and annular nebulae.

Birkeland's pioneering work, *The Norwegian Aurora Polaris Expedition 1902–1903*, which also describes his plasma experiments, is as modern today as when first printed, describing in great detail charged particle beam propagation in magnetic fields, radio emission, and the translation of this new knowledge to dimensions greatly exceeding the size of his experimental apparatus. Birkeland concluded his work with another prophetic statement, written 20 years before the term "plasma," as related to physical science, existed:

> According to our manner of looking at matter, every star in the universe would be the seat and field of activity of electric forces of a strength that no one could imagine.
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> We have no certain opinion as to how the assumed enormous electric currents with enormous tension are produced, but is certainly not in accordance with the principles we employ in technics on the earth at the present time. One may well believe, however, that a knowledge in the future of the electrotechnics of the heavens would be of great practical value to our electrical engineers.
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> It seems to be a natural consequence of our points of view to assume that the whole of space is filled with electrons and flying electric ions of all kinds. We have assumed that each stellar system in evolutions throws off electric corpuscles into space. It does not seem unreasonable therefore to think that the greater part of the material masses in the universe is found, not in the solar systems or nebulae, but in "empty space."

It is in this spirit that the guest editors present this special issue on space and cosmic plasma. We graciously thank NSF's Division of Atmospheric Sciences and NASA Headquarters, Space Physics Division, for partial support of this special issue.

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