Stockholm, August 1956, Revisited

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Abstract—**Much of the modern-day foundations of the plasma universe can be traced to the International Astronomical Union Symposium number 6 held in August, 1956, in Stockholm, Sweden, and attended by "Olympians" such as Alfvén, Artsimovich, the Babcocks, Baños, Bennett, Biermann, Hanbury Brown, Buneman, Burbidge, Chandrasekhar, Cowling, Dungey, Ferraro, Fowler, Gold, Hoyle, Lehnert, Parker, Pease, Piddington, Pikelner, Schafranow, Shklovsky, Schlüter, Spitzer, Swann, Sweet, van de Hulst, and many other notables.**

I. Introduction

As I recall, it was a cold, gray, damp day on August 26, 1956, when I deplaned in Stockholm after the 14-hour DC-6 flight from Idlewild Airport in New York. As for my first time on European soil I made my way to my hotel, my mind took me back to the day several months earlier when a letter from Hannes Alfvén arrived, inviting me to give a paper on the recent work I had performed at the Lawrence Livermore National Laboratory on the "miniaturized" replication of cosmic morphologies in laboratory plasma physics experiments. My two-year leave of absence from Tufts University was coming to a close, and my wife and I were preparing to move our family to New Jersey where, at the age of 40, I had accepted the Department Headship and a Chair in Physics at Stevens Institute of Technology in Hoboken. I had shown the invitation to my wife, and she advised me that I must surely attend even though it would be necessary for us to pay travel expenses. Now, as I walked towards the hotel dining room the realization that I would actually meet and talk to some of the Olympians and royalty of the astrophysical community quickened my steps. And there, at dinner, at a roundtable gathering it was indeed my pleasure and enjoyment to meet and listen to the conversation of V. C. A. Ferraro, Fred Hoyle, Tom Gold, Oscar Buneman, and the redoubtable G. R. Burbidge. Ferraro had shipped for 22 hours in a tempest-tossed boat on the North Atlantic, but he was beginning to recover. The conversation was astrophysically erudite. My adventure in attempting to describe, perhaps too enthusiastically, some results of my recent experiments ended abruptly when Burbidge indicated that *he* had heard enough of the subject.

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The topics covered in the symposium constituted a rich, varied, weeklong astrophysical banquet, almost too much for a "rookie" like myself. Now, after rereading the *Proceedings* [1] thirty-two years later, a few observations follow on the subjects and presentations which interest me most and the developments over the last three decades which have been closest to my own work.

II. The Symposium

Magnetohydrodynamic (fluid hydrodynamic) theory, which is more applicable to the fluid body of the sun and stars (cf Baños, Davis, Kipper, Chandrasekhar in [1]) than to the ionized gases, did not venture very far into the compressible realm. Even though force-free fields are mentioned, their over-riding and ubiquitous significance was not yet appreciated. Their solutions were not yet sufficiently linked up with the minimum free-energy, force-free configurations of Beltrami [2]. I overheard Buneman ask a theoretician standing next to him, "Has anyone ever worked out the configuration $\nabla \times \boldsymbol{B} = \alpha \boldsymbol{B}$?" Magnetohydrodyamic experiments with liquid sodium and mercury demonstrated the presence of magnetohydrodynamic waves, and the possibility of a "series-wound" coherent monopolar dynamo in liquid sodium was discussed (Lehnert). Cowling's theorem that a dynamo cannot work unless there are asymmetries in the theta direction apparently was not successfully challenged.

Schlüter derived a fairly high-fidelity three-fluid model for an ionized gas in a magnetic field which was as mathematically tractable as any model up to that time.

Aside from the description of modeling aurora phenomena by laboratory terrella experiments (Bennett, Block), the only other laboratory experiments with magnetized plasma which modeled cosmic morphologies were those of Bostick. These experiments with jets of plasma shooting across magnetic fields showed the astonishing repulsive strength of mutual magnetic induction as these plasmoids bounced off one another like billiard balls. They also showed the creation of the morphology of barred-spiral galaxies. P.M.S. Blackett, the chairman of the session, even allowed me extra time to finish my presentation. R. S. Pease's, famous paper on the Pease–Braginski current limit followed my presentation. He remarked to me at the end of the session that I had handed him a "sticky wicket" because my act was a "difficult one to follow." The discussion on my presentation is printed in the Symposium *Proceedings* [1, pp. 97–98].

My paper did not explicitly advance the organic, paradigm connection between the laboratory-produced barred

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Fig. 1. Contents of "Electromagnetic phenomena in cosmical physics" in *Proc. Int. Astron. Union Symp. 6* (reference [1]).

spirals and the barred-spiral galaxies of the cosmos and the Hubble expansion of the cosmos, but this ansatz was soon to come [3]–[8]. This ansatz proposed that the two colliding jets of the cosmic barred spirals are the result of gravitationally produced Rayleigh–Taylor instability in the gravitational contraction of the primordial plasma across a primordial magnetic field. The ansatz thus shows how the rotations of the bar in one sense, and the background plasma and magnetic field in the opposite sense, produce a homopolar generator action. The ansatz also

invokes the concept, hinted at in 1908 by Birkeland [9] and justified in 1965 [7], [10], that the amperian currents generated are conducted through force-free plasma vortex filaments which are so configured as to *augment* the original background magnetic field. Thus the barred-spiral galaxy becomes a series-wound generator (dynamo) which coherently and efficiently is transforming gravitational energy to rotational energy and then to ever-increasing magnetic energy. The consequent repulsive mutual magnetic induction between neighboring galaxies thus produces the Hubble expansion without recourse to the currently popular refuge of the "Big Bang" [8]. However, this ansatz on galactic genesis apparently was forgotten as rapidly as it was advanced until Peratt [11], [12], employing Buneman's 3-D, particle-in-cell, fully electromagnetic simulation codes, produced barred-spiral morphologies almost identical to those created by the cosmos and in my laboratory. Furthermore, Peratt's simulation work now predicts that the synchrotron radiation from electrons in the ubiquitous vortex filaments of the cosmic plasma is responsible for the 2.7-K microwave background radiation which previously was thought to be the most supporting evidence for the existence of a "Big-Bang."

Presentations on solar and stellar rotational dynamics, magnetic fields, flares, prominences, sunspots, magnetic neutral points, and nuclear genesis were given by the Olympians Cowling, Severny, Spitzer, Sweet, Dungey, Piddington, the Babcocks, Ohman, Shajn, Mustel, Serkowski, Deutsch, Burbidge, Fowler, Bierman, Schlüter, Gold, Jensen, Terletzky, and Alfvén. The Babcocks' monumental observational work with the Zeeman effect was especially appreciated by me, an experimentalist. The great importance of magnetic neutral points was later to be recognized by laboratory work with the plasma focus and vacuum sparks when the performance of force-free vortex filaments in the role of current carriers was truly assessed. The plasma focus, with its rapid interruption of current, electromagnetic ram action which produces MeV ion and electron beams, densification of plasma in small volumes, 200-MG magnetic fields, fusion reactions of *D–D*, *D–T*, *D–C*, *D–N* [13], [14], is the laboratory paradigm for solar flares, solar hot spots, cosmic-ray production, and nuclear genesis in stellar atmospheres. The laboratory plasma focus, in its production of large ion clusters whose electrons are rapidly cooled by synchrotron radiation [13], is a paradigm of the process in which cosmic plasma becomes cosmic dust.

Much of the work presented at the Symposium involved rotation (and of course magnetic fields), but apparently none of the Olympians was inclined to grapple with the process whereby cosmic rotations are originated. The plasma focus and the galactic-genesis anstaz have been more revealing on the question of the origin of cosmic rotations and magnetic fields. The origin of the primordial plasma is probably involved in the fluctuations of the vacuum. The origin of the primordial magnetic field is probably the spontaneous organization of the energy of the protons and electrons (from neutron decay) into force-free, minimum free-energy vortex filaments. If nature can execute such organization in the plasma focus, she can certainly do so with the primordial plasma.

The force-free minimum free-energy plasma vortex filament in toroidal form has recently been invoked by Wells [15] to explain both the Titius-Bode spacing of the planetary orbits and the planetary azimuthal velocities of our solar system.

The use of cosmic-ray intensity measurements to explore the magnetic fields of interplanetary space brought forward presentations by some of the Olympians of whom I had heard (Forbush, Block, Simpson, Parker, and Swann), and those of whom I had not. My Ph.D. thesis had been performed in cosmic rays under the guidance of A. H. Compton and Marcel Schein.

On the last day of the Symposium (Saturday) there was a surprise performance by some from the Russian delegation. Golovin and Artsimovich reported on their progress in controlled thermonuclear research. I missed some of their presentation because of my scheduled departure. They presented work on the pinch effect with an axial magnetic field. Spectacular Russian CTR revelations had already been made at Harwell in April of 1956, but the United States was still dragging its feet in the matter of releasing its classified CTR information.

Alfvén had announced on Friday that the Swedish Solar Observatory on the Island of Capri had identified a strong solar flare, and that 24 hours from that time we should look for a commencement of a truly elegant auroral display. On Saturday evening of that interminably long night in the DC-6 across the North Atlantic I awoke, remembering Alfvén's invitation to view the auroral display. Fortunately, I had a window seat on the starboard side, and as I rolled by head towards the window the dazzling northern lights were filling the sky. Not only had Alfvén and his Swedish friends proved to be most gracious, generous, and genial hosts, but their beauteous plasma universe was right on schedule. At that moment it was certainly "the best show in town."

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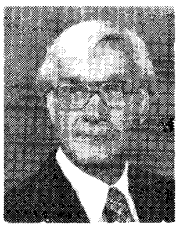
Winston H. Bostick was born in Freeport, IL, on March 5, 1916. He received the B.S. and Ph.D. degrees in physics from the University of Chicago where A. H. Compton was his adviser for a thesis (1941) on cosmic rays.

From 1941 to 1945 he worked on pulse transformer design at the MIT Radiation Laboratory and wrote four chapters in their Technical Series on that subject. From 1946 to 1948 he worked on building the MIT microwave linear electron accelerator. During 1948–1954 he was an Associate Professor in physics at Tufts University, with research in plasma physics (pinch effect). During 1954–1956 he was a Staff Member LLL, with research on high-velocity plasma jets in magnetic fields (article in *Sci. Amer.*, Oct. 1957, "Plasmoids"), he was the George Meade Bonde Professor of Physics (1956–1981) at Stevens Institute of Technology in Hoboken, NJ, and Department Head (1956–1968), with research on plasma focus and plasma vortex phenomena. In 1970 he was an UNESCO Visiting Professor at the University of Buenos Aires. Since 1981 he has had Professor Emeritus status. His main research interests are in plasma focus, plasma vortex phenomena, simulation of cosmical astrophysics by plasma physics experiments in the laboratory, proving that the Hubble expansion can be produced by repulsive mutual-magnetic induction between neighboring galaxies which are acting as self-excited homopolar generators. He is a Consultant to LANL and LLNL.



Dr. Bostick was co-editor of the *Proceedings of the 1st and 2nd International Conferences on Energy Storage, Compression, and Switching*, in Asti, Italy (1974), and Venice, Italy (1978). He has been the Gravity Research Foundation Essay Contest winner: A 1958 Fourth Prize, and a 1961 First Prize. During 1961–1962 he was the recipient of a NSF Senior Postdoctoral Fellowship held at Fontenay-aux-Roses, France.