FINAL REPORT

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SPECIFIC PROBLEMS IN COSMIC RAY RESEARCH SOLVABLE THROUGH USE OF PIONEERS 6-9 SPACECRAFTS

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The University of Texas at Dallas Pioneer program has seen the successful launch of four deep space probes. The first of these, Pioneer 6 (launched in 1965), provided the first measurements of the interplanetary cosmic ray flux, and the subsequent instruments have continued to provide new and important information on the nature of both galactic and solar cosmic rays.

Many of the results based on data from the Pioneer cosmic ray detectors have been published in the scientific literature or presented in papers delivered at scientific meetings. A listing of these presentations is given in the bibliography. A brief summary of the areas of study in which the Pioneer data have been used would include:

a) Studies of the temporal variation of galactic and solar flare particles;

b) Studies of the heliocentric longitude gradients in the solar flare cosmic ray flux using simultaneous measurements from several spacecrafts;

c) Studies of the decay phase of solar flare effects;

d) Studies of the correlation between the cosmic ray flux and the local interplanetary magnetic field;

e) Studies of the character of the particle anisotropy during the various phases of solar flare events;

f) Studies of the influence of interplanetary disturbances on the cosmic ray flux; and

g) Studies of low energy particle propagation during specific solar flare events.

Reduced data from the Pioneer 6-9 spacecrafts have been submitted to the National Space Science Data Center.

Pioneer 6, 7, 8 and 9 UTD Bibliography

Spacecrafts

6 — W. C. Bartley, K. G. McCracken, and U. R. Rao, "The Pioneer 6 Detector to Measure the Degree of Anisotropy of the Cosmic Radiation in the Energy Range 7.5 - 90 Mev/Nucleon," Rev. Sci. Instr., 38, 266-272, 1967.

6 — W. C. Bartley, K. G. McCracken, and U. R. Rao, "A Digital System for Accurate Time Sector Division of a Spin Stabilized Vehicle," IEEE Trans. Aerospace Electron. Systems, AES 3, 230-235, 1967.

6 — W. C. Bartley, R. P. Bukata, K. G. McCracken, and U. R. Rao, "Anisotropic Cosmic Radiation Fluxes of Solar Origin," J. Geophys. Res., 71, 3297-3304, 1966.

6 — K. G. McCracken and N. F. Ness, "The Collimation of Cosmic Rays by the Interplanetary Magnetic Field," J. Geophys. Res., 71, 3315-3318, 1966.

6 and 7 — K. G. McCracken, U. R. Rao, and R. P. Bukata, "Cosmic Ray Propagation Processes, I. A Study of the Cosmic Ray Flare Effect," J. Geophys. Res., 72, 4293-4324, 1967.

6 and 7 — U. R. Rao, K. G. McCracken, and R. P. Bukata, "Cosmic Ray Propagation Processes, II. The Energetic Storm Particle Event," J. Geophys. Res., 72, 4325-4342, 1967.

6 and 7 — U. R. Rao, K. G. McCracken, and W. C. Bartley, "Cosmic Ray Propagation Processes III. The Diurnal Anisotropy in the Vicinity of 10 Mev/Nucleon," J. Geophys. Res., 72, 4343-4350, 1967.

6 — K. G. McCracken, U. R. Rao, and R. P. Bukata, "Recurrent Forbush Decreases Associated with M-Region Magnetic Storms," Phys. Rev. Letters, 17, 928-932, 1966.

6 — R. P. Bukata and R. A. R. Palmeira, "The Effect of the Filamentary Interplanetary Magnetic Field Structure on the Solar Flare Event of May 4, 1960," J. Geophys. Res., 72, 5563-5568, 1967.

6 and 7 — R. P. Bukata, K. G. McCracken, and U. R. Rao, "A Comparison of the Characteristics of Co-Rotating and Flare-Initiated Forbush Decreases," Can. J. Phys., 46, S994-S998, 1968.

6 and 7 — R. P. Bukata, P. T. Gronstal, R. A. R. Palmeira, K. G. McCracken, and U. R. Rao, "Neutron Monitor and Pioneer 6 and 7 Observations of the January 28, 1967 Solar Flare Event," Solar Physics, 10, 198-211, 1969.

acecrafts

6	R. P. Bukata, W. R. Sheldon, U. R. Rao, and H. Carmichael, "Pioneer 6 Observations of Forbush-Type Modulation Phenomena in the Galactic Alpha Particle Flux," to appear in Acta Physica Hungarica, 1970.
6 and 7	R. P. Bukata, P. T. Gronstal, R. A. R. Palmeira, K. G. McCracken, and U. R. Rao, "Ground Based and Satellite Observations of the January 28, 1967 Solar Flare Event," to be published in Acta Physica Hungarica, 1970.
6	L. Adkison, A. A. J. Hoffman, and R. P. Bukata, "A Precursor to Geomagnetic Storms Occuring During the Quiet Sun," submitted to Solar Physics, 1970.
6	J. K. Balasubrahmanyan, E. C. Roelof, R. P. Bukata, and R. A. R. Palmeira, "Co-Rotating Modulations of Cosmic Ray Intensity Detected by Spacecrafts Separated in Solar Azimuth," to appear in Acta Physica Hungarica, 1970.
6 and 7	K. G. McCracken, U. R. Rao, and N. F. Ness, "Interrelationship of Cosmic Ray Anisotropies and the Interplanetary Magnetic Field," J. Geophys. Res., 73, 4159-4166, 1968.
6	K. G. McCracken, U. R. Rao, and R. P. Bukata, "Pioneer 6 Observations of the Solar Flare Particle Event of July 7, 1966," Proton Flare Project, IQSY 3, MIT Press, 329-336, 1969.
7, 8, and 9	K. G. McCracken and U. R. Rao, "Solar Cosmic Ray Phenomena," to appear in Space Science Reviews, 1971.
6 and 7	U. R. Rao, K. G. McCracken, and R. P. Bukata, "The Acceleration of Energetic Particle Fluxes in Shock Fronts in Interplanetary Space," Can. J. Phys, 46, S844-S848, 1968.

Spacecrafts

8	W. C. Bartley, R. L. Bickel, H. W. Glasscock, D. R. Stang, and J. M. Younse, "Recent Advances in Cosmic Ray Payloads for Interplanetary and Planetary Spacecrafts," IEEE National Telemetering Conference, 238, 1968.
8 and 9	R. P. Bukata, E. P. Keath, J. M. Younse, W. C. Bartley, K. G. McCracken, and U. R. Rao, "The Pioneer 8 and 9 Cosmic Ray Detector System," IEEE Transactions in Nuclear Science, NS17, 5, 18, 1970.
6,7,8,and 9	R. P. Bukata, U. R. Rao, K. G. McCracken, and E. P. Keath, "Observation of Solar Particle Fluxes over Extended Solar Longitudes" Solar Physics, 26 (1972) 229-240.
6,7,8,and 9	E. P. Keath, R. P. Bukata, K. G. McCracken, and U. R. Rao, "The Anomolous Distribution in Heliocentric Longitude of Solar Injected Cosmic Radiation," in Solar Physics, 18 (1971) 503-509.
8	K. G. McCracken, R. A. R. Palmeira, R. P. Bukata, U. R. Rao, and E. P. Keath, "A Co-Rotating Solar Cosmic Ray Enhancement Observed by Pioneer 8 and Explorer 34 on July 13, 1968," MO3 presented at the 11th International Conference on Cosmic Rays, Budapest, August, 1969.
6,7,8, and 9	K. G. McCracken, U. R. Rao, R. P. Bukata, and E. P. Keath, "The Decay Phase of Solar Flare Events," in Solar Physics, 18 (1971) 100-132.
6,7,8, and 9	K. G. McCracken and U. R. Rao, "Solar Cosmic Ray Phenomena," Space Science Review, 11, 155, 1971.

UTD Papers Delivered at Scientific Meetings

Spacecrafts	
6	W. C. Bartley, R. P. Bukata, K. G. McCracken, and U. R. Rao, "The Degree of Anisotropy of the Cosmic Radiation in the Energy Range 10 to 100 Mev," Symposium on Pioneer VI, 47th Annual Meeting of the AGU, Washington, D. C., April 19-22, 1966.
6	W. C. Bartley, R. P. Bukata, K. G. McCracken, and U. R. Rao, "Pioneer VI Measurements of the Degree of Anisotropy of the Galactic Cosmic Radiation," COSPAR, 7th International Space Science Symposium, Vienna, Austria, May 11-17, 1966.
6	W. C. Bartley, R. P. Bukata, K. G. McCracken, and U. R. Rao, "Solar-Induced Anisotropies of the Cosmic Radiation in the Energy Range 7.5 - 90 Mev per Nucleon," Joint Summer Meeting of the American Physical Society, Sociedad Mexicana de Fisica and the Canadian Association of Physicists, Mexico City, Mexico, August 29-31, 1966.
6	W. C. Bartley, R. P. Bukata, K. G. McCracken, and U. R. Rao, "Anisotropy of Cosmic Radiation of Solar Origin," Inter-Union (URSI, UGGI, UIA, COSPAR) Symposium on Solar-Terrestrial Physics, Belgrade, Yugoslavia, August 29 - September 2, 1966.
6	W. C. Bartley, R. P. Bukata, K. G. McCracken, and U. R. Rao, "Quiescent Anisotropy of Cosmic Radiation in the Energy Range 7.5 - 90 Mev per Nucleon," Inter-Union Symposium on Solar-Terrestrial Physics, Belgrade, Yugoslavia, August 29 - September 2, 1966.
6 and 7	R. P. Bukata, K. G. McCracken, and U. R. Rao, "Pioneer VI and VII Observations of Solar Induced Cosmic Radiation," 48th Annual Meeting of the AGU, Washington, D. C., April 17-20, 1967.
6 and 7	U. R. Rao and K. G. McCracken, "The Degree of Anisotropy of Galactic Cosmic Radiation in the Energy Range 7.5 - 90 Mev per Nucleon," 10th International Cosmic Ray Conference, Calgary, 1967
6 and 7	U. R. Rao, K. G. McCracken, and R. P. Bukata, "The Acceleration of Energetic Particle Fluxes in Shock Fronts in Interplanetary Space," 10th International Cosmic Ray Conference, Calgary, 1967.
6 and 7	R. P. Bukata, K. G. McCracken, and U. R. Rao, "Co-Rotating Modulation Phenomena," 10th International Cosmic Ray Conference, Calgary, 1967.

UTD Papers Delivered at Scientific Meetings, Continued

Spacecrafts

6 and 7	K. G. McCracken, U. R. Rao, and R. P. Bukata, "The Anisotropic Propagation of Cosmic Rays Generated in Solar Flares," 10th International Conference on Cosmic Radiation, Calgary, Alberta, June 19-30, 1967.
6 and 7	R. P. Bukata, "Anisotropic Proton Propagation Observed with Pioneers 6 and 7," invited paper presented at Midwest Cosmic Ray Conference, State University of Iowa, March 1, 1968.
8	E. P. Keath, R. P. Bukata, and K. G. McCracken, "Pioneer 8 Observations of Solar Induced Cosmic Radiation in the Energy Range 3 - 70 Mev," Midwest Cosmic Ray Conference, State University of Iowa, March 1, 1968.
6 and 7	R. P. Bukata, "Summary of Low Energy Solar Proton Events," invited paper presented at the 7th Aerospace Sciences Conferences, New York City, January, 1969.
6	V. K. Balasubrahmanyan, E. C. Roelof, R. P. Bukata, and R. A. R. Palmeira, "Co-Rotating Modulations of Cosmic Ray Intensity Detected by Spacecrafts Separated in Solar Azimuth," 11th International Cosmic Ray Conference, Budapest, 1969.
6	R. P. Bukata, W. R. Sheldon, U. R. Rao, and H. Carmichael, "Pioneer 6 Observations of Forbush-Type Modulation in the Galactic Alpha Particle Flux," 11th International Cosmic Ray Conference, Budapest, 1969.
6 and 7	R. P. Bukata, P. T. Gronstal, R. A. R. Palmeira, K. G. McCracken, and U. R. Rao, "Ground Based and Satellite Observations of the January 28, 1967 Solar Flare Event," 11th International Cosmic Ray Conference, Budapest, 1969.
8	K. G. McCracken, R. A. R. Palmeira, R. P. Bukata, U. R. Rao, F. R. Allum, and E. P. Keath, "A Co-Rotating Cosmic Ray Enhancement Observed by Pioneer 8 and Explorer 34 on July 13, 1968," 11th International Cosmic Ray Conference Budapest, 1969.
8	E. P. Keath, R. P. Bukata, K. G. McCracken, and U. R. Rao, "Non-Diffusive Temporal Variations of the Solar Cosmic Ray Flux," Fall Meeting of the American Geophysical Union, San Francisco, December, 1969.

UTD Papers Delivered at Scientific Meetings, Continued

Spacecrafts

8 and 9	R. P. Bukata, P. T. Gronstal, and R. A. R. Palmeira, "A Study of the March 30, 1969 Solar Flare Event," Tripartite Meeting of the Canadian Association of Physicists, American Physical Society, and Re Sociedad Mexicana de Fisica, Winnipeg, Canada, June, 1970.
8 and 9	R. A. R. Palmeira, F. R. Allum, K. G. McCracken, U. R. Rao, R. P. Bukata, and E. P. Keath, "Low Energy Proton Increases Measured by the IMP 5 and Pioneers 8 and 9 Spacecrafts," invited paper presented at the Fall Meeting of the American Geophysical Union, San Francisco, 1970.
6, 7, 8, and 9	E. P. Keath, R. P. Bukata, K. G. McCracken, and U. R. Rao, "Longitudinal Gradients in the Solar Cosmic Ray Flux," Presented at the 57nd Annual Spring Meeting of the American Geophysical Union, Washington, D. C., 1970.