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"RESEARCH IN PARTICLES AND FIELDS"

for

1 October 1973 - 31 March 1974

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SEMI-ANNUAL STATUS REPORT

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The present report covers the research activities in Cosmic Rays and Theory of Particles and Fields in Space supported under NASA Grant NGR 05-002-160.\*

The report is divided into sections which describe the various activities, followed by a bibliography.

I. Cosmic Rays (Vogt, Stone and Mewaldt)

This group's research program is directed toward the investigation of the astrophysical aspects of cosmic radiation and of the radiation environment of the Earth by means of particle-detector systems flown on spacecraft and balloons. The main efforts of the group, which are supported partially or fully by this grant, have been directed toward the following two categories of experiments.

A. EXPERIMENTS ON NASA SPACECRAFT

1. An Electron/Isotope Spectrometer (EIS) Launched on IMP-7 on 22 September 1972 and on IMP-8 on 26 October 1973.

This experiment is designed to measure the differential energy spectrum of electrons (0.18 to 2.8 MeV) and the differential energy spectra of the nuclear isotopes of hydrogen, helium, lithium, and beryllium (0.5 to ~ 50 MeV/nucleon). This experiment will allow studies of solar and galactic cosmic rays and of magnetospheric acceleration of charged particles and the interrelation of those particles to the particles trapped in and precipitated from the magnetosphere.

\* The NASA Technical Officer for this grant is Dr. A. G. Opp, NASA HQ., Physics and Astronomy Programs.

Both the IMP-7 and IMP-8 instruments are completely functional, providing simultaneous measurements at two well separated locations. This combination of measurements should be particularly useful in the separation of spatial and temporal effects in studies of the interplanetary propagation of solar flare particles, in studies of the access of solar flare particles into the magnetotail, and in studies of local acceleration processes in the magnetotail.

Results from two IMP-7 studies were presented at the Tucson meeting of the APS Cosmic Physics Division in December 1973. One of the topics, the observation of the isotopes of H and He in solar cosmic rays, will be the basis of G. J. Hurford's doctoral dissertation. At Tucson, a preliminary report was made of the continued observation of "<sup>3</sup>He-rich" solar particle events which had no corresponding enrichment in the deuterium or tritium fluxes. One such flare occurred on 14 February 1973 with a <sup>3</sup>He/<sup>4</sup>He ratio of 0.21. This ratio is comparable to the ratio observed with the Caltech OGO-6 experiment during the 14 October 1969 and the 24 November 1969 events.

These results have stimulated theoretical calculations by several other groups in an effort to understand the nuclear interaction and solar acceleration processes which could be responsible for the "<sup>3</sup>He-rich" events.

The other Tucson report was of observations of low energy H and He nuclei during solar quiet times. The observations were made in the 1.3 to 40 MeV/nucleon interval during several selected quiet periods from October, 1972, through March, 1973. The observed intensities are lower than previously reported quiet time spectra by other observers in this energy region. No evidence was found for a low energy turnup in the He spectrum down to 2.4 MeV/nucleon, the lowest energy for which the sensor has two parameter particle identification. Although the minimum intensities observed below 2.4 MeV/nucleon exceed those at higher energy, it was not possible at that time to accurately estimate the contribution of instrumental background to the counting rates. However, the periods of minimum H and He intensity below 2.4 MeV/nucleon

did not coincide, and the relative abundance of H and He was found to vary from period to period, with H/He ratios from  $\lesssim 3$  to  $\gtrsim 10$ . These results should be contrasted to those reported by Simpson and Tuzzolino (Ap. J. Letters, 185, L 149, 1973) which indicated a constant H/He ratio of  $5.0 \pm 0.5$ . An understanding of the origin of this low energy component will be significantly influenced by a more extensive analysis of the variations in the H/He abundance ratio.

A paper, "The Energy Spectrum of 0.16 to 2 MeV Electrons During Solar Quiet Times" has been accepted for publication in the Astrophysical Journal.

2. A Heavy Nuclei Experiment (HNE) to be Launched on HEAO-C in 1979.

The Heavy Nuclei Experiment (HNE) is a joint experiment involving this group and M. H. Israel, J. Klarmann (Washington Univ.), W. R. Binns (McDonnell-Douglas), and C. J. Waddington (Univ. of Minnesota). HNE is designed to measure the elemental abundances of relativistic high-Z cosmic ray nuclei ( $17 \leq Z \leq 130$ ). The results of such measurements are of significance to the studies of nucleosynthesis and stellar structures, the existence of extreme transuranic nuclei, the origin of cosmic rays, and the physical properties of the interstellar medium.

Through December, 1973, the HNE Team, supported by Ball Brothers Research Corporation, continued studies of various experiment configurations as part of the spacecraft and payload compatibility evaluation which MSFC prepared for presentation to NASA HQ in late December, 1973.

In February, 1974, HNE was selected by NASA for the restructured HEAO-C mission. Preparation was initiated for a program review at MSFC in May, 1974.

3. An Interstellar Cosmic Ray and Planetary Magnetospheres Experiment for the Mariner-Jupiter-Saturn (MJS) Missions.

This experiment has been proposed jointly by this group and F. B. McDonald, B. J. Teegarden, and J. H. Trainor (Goddard Space Flight Center)

and W. R. Webber (University of New Hampshire) and was selected as the Cosmic Ray Subsystem (CRS) for the MJS77 missions. The experiment is designed to measure the energy spectra, elemental and isotopic composition, and streaming patterns of galactic cosmic-ray nuclei from H to Fe over an energy range of 500 keV to 500 MeV/nucleon, and the energy spectra of electrons from 3 - 100 MeV. These measurements will be of particular importance to studies of stellar nucleosynthesis, and of the origin, acceleration, and interstellar propagation of cosmic rays. Measurements of the energy spectra and composition of energetic particles trapped in the magnetospheres of Jupiter and (possibly) Saturn will be used to study their origin and relationship to other physical phenomena and parameters of these planets. Measurements of the intensity and directional characteristics of solar and galactic energetic particles as a function of heliocentric distance will be used for in situ studies of the interplanetary medium and its boundary with the interstellar medium.

The definition phase of the experiment has been completed and NASA Headquarters has confirmed its selection as the Cosmic Ray Subsystem (CRS) for the MJS77 missions. The CRS complement of detectors now includes TET, an electron telescope developed under this grant.

The CRS hardware phase has begun, and the major hardware/component subcontracts have been negotiated.

4. A Heavy Isotope Spectrometer Telescope (HIST) to be Flown on ISEE-C (Heliocentric).

HIST is designed to measure the isotopic abundances and energy spectra of solar and galactic cosmic rays for all elements from lithium to nickel ( $3 \leq Z \leq 28$ ) over an energy range from several MeV/nucleon to several hundred MeV/nucleon. Such measurements are of importance to the study of the isotopic constitution of solar matter and of cosmic ray sources, the study of nucleosynthesis, questions of solar-system origin, studies of acceleration processes and studies of the life history of cosmic rays in the Galaxy.

The ISEE-C program is presently in the mission definition phase. Flight hardware work is scheduled to begin in FY 76, with launch planned for 1978.

This group's present activities for ISEE-C are exclusively supported by this grant.

B. ACTIVITIES IN SUPPORT OF OR IN PREPARATION OF SPACECRAFT EXPERIMENTS

These activities generally embrace prototypes of experiments on existing or future NASA spacecraft or they complement and/or support such observations.

1. The Positron-Negatron ( $e^{\pm}$ ) Experiment.

The  $e^{\pm}$  instrument is a balloon-borne magnetic spectrometer for the investigation of the energy spectra of cosmic-ray negatrons and positrons in the momentum range of about 10 to 1000 MeV/c. Yearly observations of the long-term variations of electron spectra were performed between 1968 and 1971 with balloon-flights under the Skyhook program at Fort Churchill, Canada.

Further observations were scheduled for the 1973 Fort Churchill Skyhook program. The instrument was launched on 15 July 1973 and both it and the balloon performed well. However, the balloon control instrumentation used by the NASA/ONR flight contractor failed and the flight could not be terminated in the parachute release of the gondola. The balloon, with the suspended Caltech/contractor payload, went out of control and continued its westerly drift (altitude ~ 150,000 ft.) beyond the continental limits of North America into Siberia/USSR. According to representatives of INTER COSMOS, the flight terminated - in an undetermined fashion - near Yakutsk, Siberia (according to Caltech's analysis, on 20 July 1973), and pieces of the heavily damaged flight train were brought to Moscow where they were inspected by a Caltech representative.

The Caltech  $e^{\pm}$  spectrometer gondola plus several flight barographs were totally destroyed. With it, the ongoing Caltech  $e^{\pm}$  research program was terminally crippled. No funds are available to rebuild the spectrometer.

Post flight analysis clearly shows that this loss occurred due to technical and operational deficiencies in the NASA/ONR operated Skyhook program. It is particularly regrettable that a simple safety device for emergency termination of an out of control flight, allegedly for reasons of "economy", carried ordinary dry cells, whose operational temperature range was totally inadequate for typical environmental conditions, instead of the recommended Nicad devices. Thus, "savings" of a few dollars led to the irreplaceable loss of an instrument worth several hundred thousand dollars and the termination of a productive and vigorous research project.

## 2. The High Energy Isotope Spectrometer Telescope (HEIST).

HEIST is a balloon-borne detector system designed to provide high-resolution isotopic measurements for cosmic ray nuclei with  $3 \leq Z \leq 28$  in the energy interval  $60 \leq E \leq 700$  MeV/nucleon, complementing the measurements which this group has been selected to make with the HIST instrument on ISEE-C.

Three parallel development activities have been pursued. As described below, these activities have concentrated on the multiwire proportional chamber, the CsI scintillators, and the position-determining electronics.

A small scale version of a multiwire proportional chamber has been designed and fabricated. This small chamber has been used to study the gas gain characteristics of a variety of filling gasses. In addition, a delay line has been constructed and coupled to the cathode wires of the counter so that the signal output characteristics of the delay line could be determined for actual particle signals in the proportional chamber.

A full scale version of one of the CsI scintillators was purchased and a variety of development tests have been completed. The scintillator has been coupled to a single photomultiplier through light integration boxes of several different geometries in order to measure both the signal amplitude and the signal uniformity for each configuration. As



a result of these tests, it now appears feasible to eliminate the large light integration boxes which were originally envisaged. This makes possible a much more compact design for the crystal stack, yielding an increase in the geometrical factor of up to a factor of four.

The readout of the multiwire proportional chamber requires the development of special electronic circuitry. In particular, the position of an event in the chamber is determined by measuring the time difference in the arrival of the signal at the two ends of the delay line which is coupled to the chamber. This time difference must be measured to  $\Delta t \sim 2$  ns in order to obtain the desired spatial resolution. The flight electronics to accomplish this measurement has been designed and breadboarded. The circuits are undergoing extensive testing prior to fabrication of the flight versions.

### 3. Other Activities.

E. C. Stone is serving as NASA's Project Scientist for the MJS77 Mariner Jupiter Saturn missions. He wrote the rapporteur paper "Cosmic Ray Isotopes" for the 13th International Cosmic Ray Conference, Denver, Colorado.

R. E. Vogt has been appointed to NASA's Physical Sciences Committee (PSC). He is presently also serving on NASA's Mariner Jupiter Uranus Science Advisory Committee (MJUSAC).

## II. Theory of Particles and Fields in Space (Davis and Jokipii)

The research program of this group is directed toward investigations of the interplanetary medium, planetary magnetic fields, the cosmic ray interactions with the interplanetary and interstellar medium, radio-scintillation theory, and related problems.

### A. PIONEER 10 ENCOUNTER WITH JUPITER

1. A rapid analysis of the quick look data in collaboration with E. J. Smith of JPL and D. E. Jones at Brigham Young University gave a fit of the magnetometer observations to an eccentric dipole source whose parameters were published in the 25 January, 1974 issue of Science. This gave a fair fit over the trajectory from  $6 R_J$  (Jupiter radii) inbound to periapsis at  $2.84 R_J$  and then outbound to  $6 R_J$ . After further refinement of the input data including correction for the roll attitude of the spacecraft, a second least squares fit was made that has considerably smaller residuals inside  $5 R_J$  and that is useable out to about  $10 R_J$ . The characteristics of the two models are given in Table 1.

Table 1Eccentric Dipole Sources of the Jovian Magnetic Field

Components are given in a right-hand XYZ coordinate system whose Z-axis is northward along the rotation axis and whose X-axis is at zero longitude in System III. Longitudes are given in System III, in which longitudes increase from the X-axis toward the minus Y-axis.

	Preliminary Model (D <sub>1</sub> )	Improved Model (D <sub>2</sub> )
<u>Dipole Moment</u>		
M <sub>X</sub>	-0.630 Gauss R <sub>J</sub> <sup>3</sup>	-0.547 Gauss R <sub>J</sub> <sup>3</sup>
M <sub>Y</sub>	0.781	0.494
M <sub>Z</sub>	3.826	3.932
M	3.955	4.000
Tilt from Z-axis	14 <sup>o</sup> .7	10 <sup>o</sup> .6
System III Longitude	231 <sup>o</sup>	222 <sup>o</sup>
<u>Dipole Location</u>		
X	-0.19 R <sub>J</sub>	-0.105 R <sub>J</sub>
Y	-0.04	-0.008
Z	0.12	0.030
Distance from center	0.228	0.110
Latitude	31 <sup>o</sup> .7	15 <sup>o</sup> .9
System III Longitude	168 <sup>o</sup>	176 <sup>o</sup>
Square root of mean residual	0.153 Gauss R <sub>J</sub> <sup>3</sup>	0.085 Gauss R <sub>J</sub> <sup>3</sup>

The procedures for describing the data by means of a spherical harmonic analysis have been developed and yield results reasonably consistent with the  $D_2$  model. Exploration is still in progress to determine the most appropriate range of data to use for the evaluation of the spherical harmonic coefficients.

2. In collaboration with E. J. Smith of JPL, the Pioneer 10 magnetometer data have been examined for clues as to the structure of Jupiter's outer magnetosphere. There is no doubt that it is very soft, the field strength changing relatively slowly with radius. Hence moderate changes in solar wind momentum density can lead to large changes in the position of the magnetopause and bow shock. The field lines inside the magnetopause in the regions at  $10^h$  and  $5^h$  local time appear to be directed mainly southward across the equator, implying that the field lines are closed in these regions and have the general topology of dipole field lines. Over much of the Pioneer 10 trajectory inside the magnetosphere the radial component of  $\underline{B}$  is larger than expected on the dipole model. This observation is consistent with an outward stretching of the dipole field line loops by centrifugal effects in corotating plasma near the equatorial plane.

#### B. COSMIC RAY DIFFUSION

Jokipii continued his work on the fundamental theory of charged particle scattering by an irregular magnetic field. He has been able to show that, for reasonable types of fluctuations, the large non-resonant terms found by other workers have a simple explanation and disappear if the proper variables are used. In particular, if the pitch angle cosine  $\mu = \underline{w} \cdot \underline{B} / wB$  relative to the local magnetic field is used, the usual Fokker-Planck, resonant expressions arise. Previous work was in terms of  $\mu_A = \underline{w} \cdot \underline{B}_0 / wB_0$ , the pitch angle relative to the average magnetic field  $\underline{B}_0$ . Corrections to the Fokker-Planck formalism must come from terms of higher order in the fluctuating field. This work helps to clarify the applicability of the Fokker-Planck formalism. This work has been submitted for publication in the Astrophysical Journal.

BIBLIOGRAPHY

1971

- Belcher, J. W., "Alfvén Waves in the Interplanetary Medium," Thesis, California Institute of Technology (1971)
- Belcher, J. W., "A Wave Driven Model of the Solar Wind," Trans. Am. Geophys. Union, 52, 335 (1971)
- Belcher, J. W., "Alfvénic Wave Pressures and the Solar Wind," Astrophys. J. 168, 509 (1971)
- Belcher, J. W., and L. Davis, Jr., "Large Amplitude Alfvén Waves in the Interplanetary Medium, 2," J. Geophys. Res., 76, 3534 (1971)
- Beuermann, K. P., "Secondary Electrons and Photons in the Upper Atmosphere," J. Geophys. Res., 76, 4291 (1971)
- Evans, L. C., "Magnetospheric Access of Solar Particles and the Configuration of the Distant Geomagnetic Field," Thesis, California Institute of Technology (1971)
- Evans, L. C., and E. C. Stone, "Polar Cap Observations of Delayed Solar Particle Events and the Configuration of the Distant Geomagnetic Field," Trans. Am. Geophys. Union, 52, 904 (1971)
- Garrard, T. L., and R. E. Vogt, "The Production of Secondary Protons in the Atmosphere by Cosmic Rays," Trans. Am. Geophys. Union, 52, 893 (1971)
- Gunter, D. L., J. E. Lupton, E. C. Stone, and R. E. Vogt, "Propagation of Solar Flare Electrons," Trans. Am. Geophys. Union, 52, 889 (1971)
- Hollweg, J. V., "Density Fluctuations Driven by Alfvén Waves," J. Geophys. Res., 76, 5155 (1971)
- Hollweg, J. V., "Collisionless Solar Wind, 2, Variable Electron Temperature," J. Geophys. Res. 76, 7491 (1971)
- Hollweg, J. V., "Nonlinear Landau Damping of Alfvén Waves," Phys. Rev. Letters, 27, 1349 (1971)

- Jokipii, J. R., "Acceleration and Deceleration of Cosmic Rays in the Solar Wind," *Phys. Rev. Letters*, 26, 666 (1971)
- Jokipii, J. R., "Cosmic Ray Acceleration: Recent Theoretical and Observational Results," *Bull. Am. Phys. Soc.*, 16, 485 (1971)
- Jokipii, J. R., "Mechanism for Confinement of Cosmic Rays in the Galaxy," *Proc. 12th International Cosmic Ray Conference, Hobart, Tasmania* (1971)
- Jokipii, J. R., "Propagation of Cosmic Rays in the Solar Wind," *Reviews of Geophysics and Space Physics*, 9, 27 (1971)
- Lupton, J. E., and E. C. Stone, "Transport of Solar Flare Protons - Comparison of a New Analytic Model with Spacecraft Measurements," *Conf. Papers, 12th Int. Cosmic Ray Conf., Hobart*, 2, 492 (1971)
- Lupton, J. E., and E. C. Stone, "Calculations Concerning the Evolution of a Spectral Feature During the Decay Phase of a Solar Flare Proton Event," *Trans. Am. Geophys. Union*, 52, 890 (1971)
- Masley, A. J., E. C. Stone, and J. A. Lockwood, "Storm Morphology," 51st Ann. Meeting Am. Geophys. Union, OGO-6, Symposium, April 1971
- Murray, S. S., "Propagation of 1-10 MeV Solar Flare Protons in Interplanetary Space," Thesis, California Institute of Technology (1971)
- Murray, S. S., E. C. Stone, and R. E. Vogt, "Interplanetary Deceleration of Solar Cosmic Rays," *Phys. Rev. Letters*, 26, 663 (1971)
- Owens, A. J., and J. R. Jokipii, "Cosmic Ray Modulation by an Angle Dependent Solar Wind," *Astrophys. J.*, 167, 169 (1971)
- Rhodes, E. J., E. J. Smith, and J. W. Belcher, "Interplanetary Sector Boundaries," *Trans. Am. Geophys. Union*, 52, 337, (1971)
- Scholer, M. and J. W. Belcher, "The Effect of Alfvén Waves on MHD Fast Shocks," *Solar Physics*, 16, 472 (1971)

Stone, E. C., and L. C. Evans, "The Electron Polar Cap Boundary and the Limit of Open Geomagnetic Field Lines," Trans. Am. Geophys. Union, 52, 904 (1971)

Stone, E. C., "Energetic Particle Access to the Polar Magnetosphere," Fall Annual Meeting of the American Geophysical Union, (1971)

1972

- Brown, J. W., and E. C. Stone, "High Energy Electron Spikes at High Latitudes," *J. Geophys. Res.*, 77, 3384 (1972)
- Cummings, A. C., E. C. Stone, and R. E. Vogt, "Interplanetary Diffusion Coefficients for Cosmic Rays," *Trans. Am. Geophys. Union*, 53, 1083, (1972)
- Davis, L., Jr., "Alfvén Waves in the Solar Wind," *Bull. Am. Phys. Soc.*, 17, 136 (1972)
- Davis, L., Jr., "The Configuration of the Interplanetary Field," *Proc. Leningrad Symposium on Solar-Terrestrial Physics*, Publ. in Solar Terrestrial Physics/1970, edited by E. R. Dyer, Part II, pp. 32-48 (1972), Reidel, Dordrecht-Holland
- Davis, L., Jr., "The Interplanetary Magnetic Field," Solar Wind, Ed. C. P. Sonett, P. J. Coleman, Jr., and J. M. Wilcox, U. S. Government Printing Office, Washington, D. C., p. 93 (1972)
- Evans, L. C., and E. C. Stone, "The Electron Polar Cap and the Boundary of the Open Geomagnetic Field Lines," *J. Geophys. Res.*, 77, 5580 (1972)
- Fanselow, J. L., and E. C. Stone, "Geomagnetic Cutoffs for Cosmic Ray Protons for Seven Energy Intervals Between 1.2 and 39 MeV," *J. Geophys. Res.*, 77, 3999 (1972)
- Garrard T. L., "A Quantitative Investigation of the Solar Modulations of Cosmic-Ray Protons and Helium Nuclei," Thesis, California Institute of Technology (1972)
- Garrard, T. L., E. C. Stone, and R. E. Vogt, "Cosmic-Ray Hysteresis and Spatial Features of the Modulation Region," *Trans. Am. Geophys. Union*, 53, 1083, (1972)
- Garrard, T. L., E. C. Stone, and R. E. Vogt, "Solar Modulation of Cosmic-Ray Protons and Alpha Particles," *Bull. Am. Phys. Soc.*, 17, 455 (1972)



- Hollweg, J. V., "Alfvénic Motions in the Solar Atmosphere," *Astrophys. J.*, 177, 225 (1972)
- Hollweg, J. V., "Supergranulation-Driven Alfvén Waves in the Solar Chromosphere, and Related Phenomena," *Cosmic Electrodynamics*, 2, 423 (1972)
- Hollweg, J. V., and J. R. Jokipii, "Heat Conduction in a Turbulent Magnetic Field, with Application to Solar-Wind Electrons," *J. Geophys. Res.*, 77, 3311 (1972)
- Hollweg, J. V., and J. R. Jokipii, "Wavelength Dependence of the Interplanetary Scintillation Index," *Solar Wind*, Ed. C. P. Sonett, P. J. Coleman, Jr. and J. M. Wilcox, U. S. Government Printing Office, Washington, D. C., p. 494 (1972)
- Jokipii, J. R., "Fokker-Planck Equations for Charged-Particle Transport in Random Fields," *Astrophys. J.*, 172, 319 (1972)
- Jokipii, J. R., "Propagation of Solar Cosmic Rays in the Solar Wind," in "Solar Activity Observations and Predictions" Ed. P. S. McIntosh and M. Dryer, Vol. 30 of *Progress in Astronautics and Aeronautics*, MIT Press, (1972)
- Jokipii, J. R., and L. C. Lee, "Velocity of the Solar Wind as Determined from Interplanetary Scintillations," *Astrophys. J.*, 172, 729 (1972)
- Jokipii, J. R., and E. C. Stone, "Solar-Flare Cosmic Rays Beyond the Modulation Boundary," *Trans. Am. Geophys. Union*, 53, 1083 (1972)
- Lupton, J. E., "Solar Flare Particle Propagation - Comparison of a New Analytic Solution with Spacecraft Measurements," Thesis, California Institute of Technology (1972)
- Lupton, J. E., and E. C. Stone, "Electron Scattering Effects in Typical Cosmic Ray Telescopes," *IEEE Transactions of Nuclear Science*, NS-19, 562 (1972)

- Lupton, J. E., and E. C. Stone, "Measurement of Electron Detection Efficiencies in Solid State Detectors," Nucl. Instr. and Methods, 98, 189 (1972)
- Marshall, F. E., and E. C. Stone, "Propagation of Solar Flare Protons at Early and Late Times," Trans. Am. Geophys. Union, 53, 1085 (1972)
- Owens, A. J., and J. R. Jokipii, "Cosmic Ray Scintillations: 1. Inside the Magnetosphere," J. Geophys. Res., 77, 6639 (1972)
- Stone, E. C., "Solar Particle Propagation," Bull. Am. Phys. Soc., 17, 552 (1972)
- Stone, E. C., and F. E. Marshall, "Comparison of Calculated and Observed Corotation Events," Trans. Am. Geophys. Union, 53, 1086 (1972)

1973

- Brown, J. W., "A Satellite Measurement of Cosmic-Ray Abundances and Spectra in the Charge Range  $2 \leq Z \leq 10$ ," Thesis, California Institute of Technology (1973)
- Brown, J. W., E. C. Stone, and R. E. Vogt, "Measurement of the Cosmic-Ray Be/B Ratio and the Age of Cosmic Rays," Conf. Papers, 13th Int. Cosmic Ray Conf., Denver, 1, 484 (1973)
- Brown, J. W., E. C. Stone, and R. E. Vogt, "Rigidity Dependence of the Relative Elemental Abundances of Cosmic Rays ( $3 \leq Z \leq 8$ )," Bull. Am. Phys. Soc., 18, 540 (1973)
- Brown, J. W., E. C. Stone, and R. E. Vogt, "The Elemental Abundance Ratios of Interstellar Secondary and Primary Cosmic Rays," Conf. Papers, 13th Int. Cosmic Ray Conf., Denver, 1, 556 (1973)
- Cummings, A. C., "A Study of Cosmic-Ray Positron and Electron Spectra in Interplanetary and Interstellar Space and the Solar Modulation of Cosmic Rays," Thesis, California Institute of Technology (1973)
- Cummings, A. C., E. C. Stone, and R. E. Vogt, "Analytic Approximations in the Study of the Solar Modulation of Electrons," Conf. Papers, 13th Int. Cosmic Ray Conf., Denver, 2, 765 (1973)
- Cummings, A. C., E. C. Stone, and R. E. Vogt, "Evidence for Primary Interstellar Cosmic-Ray Electrons," Conf. Papers, 13th Int. Cosmic Ray Conf., Denver, 1, 340 (1973)
- Cummings, A. C., E. C. Stone, and R. E. Vogt, "Interplanetary Diffusion Coefficients for Cosmic Rays," Conf. Papers, 13th Int. Cosmic Ray Conf., Denver, 2, 772 (1973)

- Cummings, A. C., E. C. Stone, and R. E. Vogt, "Interstellar Electron Spectrum from the Galactic Non-Thermal Radio Emission," Conf. Papers, 13th Int. Cosmic Ray Conf., Denver, 1, 335 (1973)
- Davis, L., Jr., E. J. Smith, and D. E. Jones, "Comments on Paper by N. F. Ness, K. W. Behannon, R. P. Lepping, and K. H. Schratten, 'Use of Two Magnetometers for Magnetic Field Measurements on a Spacecraft'," J. Geophys. Res., 78, 4803 (1973)
- Evans, L. C., and E. C. Stone, "Access of Solar Cosmic Rays into the Polar Regions," Conf. Papers, 13th Int. Cosmic Ray Conf., Denver, 2, 1094 (1973)
- Garrard, T. L., E. C. Stone, and R. E. Vogt, "Relation of the Radial Gradient of Cosmic-Ray Protons to the Size of the Solar-Modulation Region," Conf. Papers, 13th Int. Cosmic Ray Conf., Denver, 2, 1336 (1973)
- Garrard, T. L., E. C. Stone, and R. E. Vogt, "Solar Modulation of Cosmic-Ray Protons and He Nuclei," Conf. Papers, 13th Int. Cosmic Ray Conf., Denver, 2, 732 (1973)
- Garrard, T. L., E. C. Stone, and R. E. Vogt, "The Isotopes of H and He in Solar Cosmic Rays," High Energy Phenomena on the Sun Symposium Proceedings Sept. 28-30, 1972, Ed. R. Ramaty and R. G. Stone, GSFC Preprint X-693-73-193, p. 341 (1973)
- Garrard, T. L., E. C. Stone, and R. E. Vogt, "The Isotopes of H and He in Solar Cosmic Rays," Conf. Papers, 13th Int. Cosmic Ray Conf., Denver, 2, 1485 (1973)
- Hollweg, J. V., "Alfvén Waves in a Two-Fluid Model of the Solar Wind," Astrophys. J., 181, 547 (1973)

- Hollweg, J. V., "Alfvén Waves in the Solar Wind: Wave Pressure, Poynting Flux, and Angular Momentum," *J. Geophys. Res.*, 78, 3643 (1973)
- Hurford, G. J., R. A. Mewaldt, E. C. Stone, and R. E. Vogt, "Measurements of the Flux of Low-Energy Solar-Flare Positrons," *Conf. Papers*, 13th Int. Cosmic Ray Conf., 2, 1613 (1973)
- Hurford, G. J., R. A. Mewaldt, E. C. Stone, and R. E. Vogt, "Observations of Low Energy Hydrogen and Helium Isotopes during Solar Quiet Times," *Conf. Papers*, 13th Int. Cosmic Ray Conf., Denver, 1, 93 (1973)
- Hurford, G. J., R. A. Mewaldt, E. C. Stone, and R. E. Vogt, "Observations of the Ratio of Low-Energy Cosmic-Ray Positrons and Electrons," *Bull. Am. Phys. Soc.*, 18, 569 (1973)
- Hurford, G. J., R. A. Mewaldt, E. C. Stone, and R. E. Vogt, "Observations of the Ratio of Low-Energy Cosmic-Ray Positrons and Electrons during Solar Quiet Times," *Conf. Papers*, 13th Int. Cosmic Ray Conf., Denver, 1, 330 (1973)
- Hurford, G. J., R. A. Mewaldt, E. C. Stone, and R. E. Vogt, "Observations of the Time-Variations and Anisotropy of 0.16 to 3 MeV Electrons," *Conf. Papers*, 13th Int. Cosmic Ray Conf., Denver, 1, 334 (1973)
- Hurford, G. J., R. A. Mewaldt, E. C. Stone, and R. E. Vogt, "Observations of 0.16 to 3 MeV Electrons during Solar Quiet Times," *Bull. Am. Phys. Soc.*, 18, 568 (1973)
- Hurford, G. J., R. A. Mewaldt, E. C. Stone, and R. E. Vogt, "The Energy Spectrum of 0.16 to 3 MeV Electrons during Solar Quiet Times," *Conf. Papers*, 13th Int. Cosmic Ray Conf., Denver, 1, 324 (1973)
- Jokipii, J. R., "Magnetic Fields and the Distribution of Cosmic Rays in the Galaxy," *Comments on Astrophysics and Space Physics*, 5, 125 (1973)

- Jokipii, J. R., "Radial Variation of Magnetic Fluctuations and the Cosmic Ray Diffusion Tensor in the Solar Wind," *Astrophys. J.*, 182, 585 (1973)
- Jokipii, J. R., "The Rate of Separation of Magnetic Lines of Force in a Random Magnetic Field," *Astrophys. J.*, 183, 1029 (1973)
- Jokipii, J. R., "Turbulence and Scintillations in the Interplanetary Plasma," *Annual Review of Astronomy and Astrophysics*, 11, 1 (1973)
- Jokipii, J. R., and L. C. Lee, "On the Relation Between the Pattern and Wind Velocity in Interplanetary Scintillations," *Astrophys. J.*, 182, 317 (1973)
- Jokipii, J. R., and I. Lerche, "On the Transport of Charged Particles in Turbulent Fields: Comparison of a Exact Solution with the Quasilinear Approximation," *Plasma Physics*, 15, 619 (1973)
- Jokipii, J. R., and J. Marburger, "Homogeneity Requirements for Minimizing Self-Focusing Damage by Strong Electromagnetic Waves," *App. Phys. Letters*, 23, 696 (1973)
- Jokipii, J. R., and E. C. Stone, "Solar-Flare Cosmic Rays at and Beyond the Modulation Boundary," *J. Geophys. Res.*, 78, 3150 (1973)
- Lupton, J. E., and E. C. Stone, "Solar Flare Particle Propagation - Comparison of a New Analytic Solution with Spacecraft Measurements," *J. Geophys. Res.*, 78, 1007 (1973)
- Owens, A. J., and J. R. Jokipii, "A Relation Between Cosmic Ray Fluctuations, Gradient, and Diffusion Coefficient," *Conf. Papers*, 13th Int'l. Cosmic Ray Conf., Denver, 2, 777 (1973)
- Owens, A. J., and J. R. Jokipii, "Interplanetary Scintillations of Cosmic Rays," *Astrophys. J. Letters*, 181, L147 (1973)

Stone, E. C., "Cosmic Ray Isotopes," Conf. Papers, 13th Int. Cosmic Ray  
Conf., Denver, 5, 3615 (1973)

1974

- Hurford, G. J., R. A. Mewaldt, E. C. Stone, and R. E. Vogt, "Observations of H and He Isotopes in Solar Cosmic Rays," *Bull. Am. Astron. Soc.*, Part II, 6, 270 (1974)
- Hurford, G. J., R. A. Mewaldt, E. C. Stone, and R. E. Vogt, "The Energy Spectrum of 0.16 to 2 MeV Electrons During Solar Quiet Times," *Astrophys. J.* (1974) (in press)
- Jokipii, J. R., and A. J. Owens, "Interpretation of Observed Charge States of Low-Energy Solar Particles," *J. Geophys. Res.*, (1974) (in press)
- Mewaldt, R. A., G. J. Hurford, E. C. Stone, R. E. Vogt, "Observations of Low Energy Hydrogen and Helium Nuclei during Solar Quiet Times," *Bull. Am. Astron. Soc.*, Part II, 6, 274 (1974)
- Owens, A. J., and J. R. Jokipii, "Cosmic Ray Scintillations, 2. General Theory of Interplanetary Scintillations," *J. Geophys. Res.*, 79, 895 (1974)
- Owens, A. J., and J. R. Jokipii, "Cosmic Ray Scintillations, 3. The Low-Frequency Limit and Observations of Interplanetary Scintillations," *J. Geophys. Res.*, 79, 907 (1974)
- Owens, A. J., and J. R. Jokipii, "The Low Frequency Limit and Observations of Interplanetary Scintillations," *J. Geophys. Res.*, (1974) (in press)
- Smith E. J., L. Davis, Jr., D. E. Jones, D. S. Colburn, P. J. Coleman, Jr., P. Dyal, and C. P. Sonett, "Magnetic Field of Jupiter and Its Interaction with the Solar Wind," *Science*, 183, 305 (1974)