Solar Energetic Particles (SEP), Solar Modulation and Space Radiation: New Opportunities in the AMS-02 Era

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Book of Abstracts

Solar Energetic Particles (SEP), Solar Modulation and Space Radiation: New Opportunities in the AMS-02 Era
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Monday Morning 1 / 0

The total modulation of cosmic rays in the heliosphere

Author: Marthinus Potgieter[1]

Co-authors: Mirko Boezio [2]; William Webber [3]

[1] *North-West Uiversity*

[2] *Universita e INFN, Trieste (IT)*

[3] *New Mexico State University*

Corresponding Author: marius.potgieter@nwu.ac.za

The remarkable exploration of the final frontier of the heliosphere started in December 2004 when Voyager 1 crossed the solar wind termination shock (TS) at 94 AU from the Sun. This was followed by Voyager 2 in August 2007 at 84 AU from the Sun. This points to a TS that moves and probably also a north-south asymmetry in the geometry of the heliosphere, apart from the predicted large nose-tail asymmetry. The most surprising observation was that the so-called anomalous cosmic rays (ACRs) were not accelerated at the TS but further away into the inner heliosheath. However, lower energy particles were clearly accelerated at the TS, including electrons around 10 MeV. The latter, exhibited amazing modulation features from the inner heliosphere, including the Jovian electrons, up to the TS and beyond. It has turned out the inner heliosheath, as the region between the TS and the heliopause (HP), acts as a steady modulation barrier to galactic cosmic rays, the lower the energy, the more so. This will be illustrated with a comprehensive numerical model in comparison with observations. The second extraordinary event was when Voyager 1 crossed the HP in August 2012 at 121.7 AU, while Voyager 2 has still not crossed it. This could however happen soon. The HP crossing by itself has produced new surprises and seems to be a wider region than anticipated. It additionally acts as a barrier through which the ACRs dropped away spectacularly while the galactic particles increased surprisingly much to what is now considered the very local interstellar values. Voyager 1 is now at 131 AU from the Sun, and Voyager 2 at 108 AU. Exploration of the whole heliosphere, and finally the crossing of the TS and later the HP have provided us with new and exciting observations, with ample challenges to theoretical and modelling approaches to the acceleration, transport and modulation of cosmic rays in the heliosphere, which will be reviewed in this presentation. And, in the process, new paradigms are put before us, to be amazed about and to enjoy studying.

Summary:

It is possible for the first time to describe the total modulation of cosmic rays in the heliosphere using Voyager observations from the Earth to the heliopause, and from the PAMELA space mission at the Earth, in comparison with comprehensive numerical models, which will be illustrated and discussed for galactic electrons in particular.

Thursday Afternoon 1 / 1

Galactic Cosmic Ray Proton Spectra during Solar Cycle 23 and 24 - Measurement Capabilities of the Electron Proton Helium Telescope on Board SOHO

Author: Patrick Kühl[1]

Co-authors: Andreas Klassen [1]; Bernd Heber [1]; Jan Gieseler [1]; Nina Dresing [2]

[1] *University of Kiel*

[2] *IEAP, Universtiy of Kiel, Germany*

Corresponding Author: kuehl@physik.uni-kiel.de

The solar modulation of galactic cosmic rays (GCR) can be studied in detail by long term variations of the GCR energy spectrum (e.g. on the scales of a solar cycle). With almost 20 years of data, the Electron Proton Helium INstrument (EPHIN) aboard SOHO is well suited for these kind of investigations.

Although the design of the instrument is optimized to measure proton and helium isotope spectra up to 50 MeV/nucleon the capability exist that allow to determine energy spectra above 800 MeV/nucleon. Therefore we developed a sophisticated inversion method to calculate such proton spectra. The method relies on a GEANT4 Monte Carlo simulation of the instrument and a simplified spacecraft model that calculates the energy response function of EPHIN for electrons, protons and heavier ions. In order to determine the energy spectra the resulting inversion problem is solved numerically. As a result we present galactic cosmic ray spectra from 1995 to 2015. For validation, the derived spectra are compared to AMS, BESS and PAMELA data. Furthermore we discuss the spectra with respect to the solar modulation.

Poster Session / **2**

Proton energy spectra during ground level enhancements as measured by EPHIN aboard SOHO

Author: Bernd Heber[1]

Co-authors: Andreas Klassen [1]; Konstantin Herbst [2]; Nina Dresing [3]; Patrick Kühl [1]

[1] *University of Kiel*

[2] *Christian-Albrechts-Universität zu Kiel*

[3] *IEAP, Universtiy of Kiel, Germany*

Corresponding Author: kuehl@physik.uni-kiel.de

Ground Level Enhancements (GLEs) are solar energetic particle (SEP) events that are recorded by ground-based instrumentation. The energy of the particles is so high that they produce secondary particles, i.e. protons and neutrons, which are detected as sudden increases in cosmic ray intensities measured by e.g. neutron monitors. Since the launch of SOHO in December 1995 the neutron monitor network recorded 16 GLEs. The Electron Proton Helium INstrument on board SOHO has been designed to measure protons and helium up to 53 MeV/nucleon as well as electrons up to 8.3 MeV. Above these energies, particles penetrate all detector elements and thus, a separation between different particle species becomes more complicated. Recently we developed a method that allows deriving the energy spectrum for penetrating protons up to almost 1 GeV/nucleon. In this contribution we present the integrated fluences of solar energetic protons for the 16 above-mentioned GLEs and compare them to previous results.

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Estimation of Akasofu parameter corrected by the solar wind dynamic pressure during three different HILDCAAs event.

Author: Binod Adhikari[1]

Co-authors: Ezequiel Echer [2]; Margarete oliveira domingues [2]; Odim Mendes Jr [2]

[1] *Amrit Science Campus, Kathmandu Nepal*

[2] *INPE*

Corresponding Author: binod.adhi@gmail.com

Disturbances of the geomagnetic field are caused by enhanced solar wind- magnetosphere electrodynamical coupling process. The principal cause of geomag- netic disturbance is the magnetic reconnection between the southward directed interplanetary magnetic field component and the northward directed magnetopause field, that establishes an electrodynamic coupling between the solar wind plasma and magnetosphere. In general, this coupling is controled by dominant structures emanating from the sun like sporadic coronal mass ejections (CMEs) and their interplanetary counterparts (ICMEs), around the solar maximum, and by corotating high-speed streams, including corotating interaction region (CIR), in the descending and minimum phases of solar cycle. These high speed streams are embedded with highly fluctuating Alfven waves, which produce phenomena called HILDCAA events (high-intensity, long duration, continuous AE activity). Our aim is to evaluate the solar wind energy input into the magnetosphere for three different classes of HILDCAAs. Two corrections on the energy coupling function are made: the first one is an already known correction in the magnetopause radius to take into account the variation in the solar wind pressure. The second correction on the Akasofu parameter, first proposed in this work, accounts for the reconnection efficiency as a function of the solar wind ram pressure. Geomagnetic indice (SYM-H) is also employed to study the cross-correlation of Akasofu parameter during these events. The good correlation between SYM-H index with our corrected Akasofu parameter is shown to be more adequate to explain HILDCAAs time energy balance.

Monday Afternoon 2 / 4

The Role of Solar and Solar Wind Forcing of Radiation Belt Particle Enhancements

Author: Daniel N. Baker[1]

[1] *University of Colorado Boulder*

Corresponding Author: daniel.baker@lasp.colorado.edu

Observational and numerical modeling evidence demonstrates that solar wind streams and coronal mass ejections drive coherent processes within the coupled near-Earth system. The magnetosphere progresses through a specific sequence of energy-loading and stress-developing states until the entire system suddenly reconfigures. Related long-term studies of relativistic electron fluxes in the Earth's magnetosphere have revealed many of their temporal occurrence characteristics and their relationships to solar wind drivers. Early work showed the obvious and powerful role played by solar wind speed in producing subsequent high-energy electron enhancements. More recent work has also pointed out the key role that the north-south component of the IMF plays: In order to observe major relativistic electron enhancements, there must typically be a significant interval of southward IMF along with a period of high (VSW≥500 km/s) solar wind speed. This has led to the view that enhancements in geomagnetic activity are normally a key first step in the acceleration of radiation belt electrons to high energies. A second step is suggested to be a period of powerful low-frequency waves that is closely related to high values of VSW or higher frequency ("chorus") waves that rapidly heat and accelerate electrons. Hence, magnetospheric storms provide a "seed" population, while high-speed solar wind drives the acceleration to relativistic energies in this two-step geomagnetic activity scenario. This picture seems to apply to most storms examined whether associated with high-speed streams or with CME-related events, but not all. In this talk, we address the storm relationships as they pertain to high-energy electron acceleration and transport. We also discuss various models of electron energization that have recently been advanced. We present remarkable new results from the Van Allen Probes (Radiation Belt Storm Probes) mission that confirm and greatly extend these key ideas.

Summary:

We use data from the NASA Van Allen Probes mission to study the changes in trapped radiation surrounding the Earth. We examine the dramatic acceleration, transport and loss of radiation belt properties by comparing with solar wind forcing by high speed solar wind streams and coronal mass ejections. Fascinating new aspects of radiation belt structure are presented and our latest understanding of physical mechanisms is summarized.

Tuesday Morning 1 / 5

Voyager Observations in the Outer Heliosphere and Interstellar Medium

Author: John Richardson[1]

Co-author: Team Voyager [2]

[1] *M.I.T.*

[2] *JPL*

Corresponding Author: ladybugrichardson@yahoo.com

The Voyager 1 spacecraft is now in the local interstellar medium (LISM). Voyager 2 is in the heliosheath, the region of shocked solar wind after the termination shock, and is approaching the heliopause. At the heliopause, the boundary between the solar wind and the LISM, galactic cosmic ray (GCR) intensities and the magnetic field magnitude increased and the anomalous cosmic ray (ACRs) and lower-energy particle intensities dropped to background levels. The complex structure of the heliopause region will be described. We show that Voyager 1 and 2 have observed very different heliosheath plasma flows and particle profiles upstream of the heliopause.
GCRs are modulated by the heliosphere; the Voyager data provide the first direct observations outside this modulation region. We show the GCR spectra and abundances in the LISM and compare to model predictions. It has been hypothesized that some modulation occurs outside the heliopause; we will show the latest intensity gradients in this region. The transport of GCRs is affected by the magnetic field turbulence and we will show the first direct measurements of the field in the LISM.
Before Voyager, ACRs were thought to be accelerated at the termination shock. Lower energy particles were accelerated at the shock, but the ACRs were not. The peak in ACR intensities was observed about 15 AU beyond the shock. We discuss several mechanisms which could accelerate these particles.

Summary:

We discuss Voyager observations in the outer heliosphere and interstellar medium emphasizing energetic particle data.

Friday Morning 2 / 6

The space radiations as observed by the Energetic Particle Telescope

Author: Viviane Pierrard[1]

[1] *Belgian Institute for Space Aeronomy*

The Energetic Particle Telescope (EPT) is a new compact and modular ionizing particle spectrometer that was launched on 7 May 2013 to a LEO polar orbit at an altitude of 820 km onboard the ESA satellite PROBA-V. First results show electron, proton and helium ion fluxes in the South Atlantic

Anomaly (SAA) and at high latitudes, with high flux increases during SEP (Solar Energetic Particles) events and geomagnetic storms. Especially, on March 17, 2015, a big geomagnetic storm event injected unusual fluxes up to low radial distances in the radiation belts. EPT electron measurements show a deep dropout at L>4 starting during the main phase of the storm, associated to the penetration of high energy fluxes at L value lower than 2, filling completely the slot region. After 10 days, the formation of a new slot around L=2.8 separates the outer belt from the inner belt extending at other longitudes than the South Atlantic Anomaly. Two other major events appeared in January and June 2015, again with injection of electrons in the inner belt. These observations open many perspectives to better understand the source and loss mechanisms associated to the Van Allen belts.

Friday Afternoon 1 / 7

Impact of AMS-II measurements on reducing GCR model uncertainties

Author: Tony Slaba[1]

Co-authors: Pat O'Neill [2]; Serkan Golge [3]

[1] *NASA Langley Research Center*

[2] *NASA Johnson Space Center*

[3] *University of Houston/JSC NASA*

Corresponding Authors: tony.c.slaba@nasa.gov, john.w.norbury@nasa.gov

For vehicle design, shield optimization, mission planning, and astronaut risk assessment, the exposure from galactic cosmic rays (GCR) poses a significant and complex problem both in low Earth orbit and in deep space. To address this problem, various computational tools have been developed to quantify the exposure and risk in a wide range of scenarios. Generally, the tool used to describe the ambient GCR environment provides the input into subsequent computational tools and is therefore a critical component of end-to-end procedures. Over the past few years, several researchers have independently and very carefully compared some of the widely used GCR models to more rigorously characterize model differences and quantify uncertainties. All of the GCR models studied rely heavily on calibrating to available near-Earth measurements of GCR particle energy spectra, typically over restricted energy regions and short time periods. In this work, we first review recent sensitivity studies quantifying the ions and energies in the ambient GCR environment of greatest importance to exposure quantities behind shielding. Currently available measurements used to calibrate and validate GCR models are also summarized within this context. It is shown that the AMS-II measurements will fill a critically important gap in the measurement database. The emergence of AMS-II measurements also provides a unique opportunity to validate existing models against measurements that were not used to calibrate free parameters in the empirical descriptions. Discussion is given regarding rigorous approaches to implement the independent validation efforts, followed by recalibration of empirical parameters.

Friday Afternoon 1 / 8

GCR Simulator Development Status at the NASA Space Radiation Laboratory

Author: Tony Slaba[1]

Co-authors: John Norbury [2]; Steve Blattnig [1]

[1] *NASA Langley Research Center*

[2] *NASA*

Corresponding Authors: tony.c.slaba@nasa.gov, john.w.norbury@nasa.gov

There are large uncertainties connected to the biological response for exposure to galactic cosmic rays (GCR) on long duration deep space missions. In order to reduce the uncertainties and gain understanding about the basic mechanisms through which space radiation initiates cancer and other endpoints, radiobiology experiments are performed with mono-energetic ions beams. Some of the accelerator facilities supporting such experiments have matured to a point where simulating the broad range of particles and energies characteristic of the GCR environment in a single experiment is feasible from a technology, usage, and cost perspective. In this work, several aspects of simulating the GCR environment at the NASA Space Radiation Laboratory (NSRL) are discussed. First, comparisons are made between direct simulation of the external, free space GCR field, and simulation of the induced tissue field behind shielding. It is found that upper energy constraints at NSRL limit the ability to simulate the external, free space field directly (i.e. shielding placed in the beam line in front of a biological target and exposed to a free space spectrum). Second, a reference environment for the GCR simulator and suitable for deep space missions is identified and described in terms of fluence and integrated dosimetric quantities. Analysis results are given to justify the use of a single reference field over a range of shielding conditions and solar activities. Third, an approach for simulating the reference field at NSRL is presented. The approach directly considers the hydrogen and helium energy spectra, and the heavier ions are collectively represented by considering the linear energy transfer (LET) spectrum. While many more aspects of the experimental setup need to be considered before final implementation of the GCR simulator, this preliminary study provides useful information that should aid the final design. Possible drawbacks of the proposed methodology are discussed and weighed against alternative simulation strategies.

Tuesday Morning 2 / 9

The PAMELA experiment

Author: Mirko Boezio[1]

[1] *INFN - Sezione di Trieste*

Corresponding Author: mirko.boezio@ts.infn.it

The nine years of data taking in space of the PAMELA experiment are providing interesting information concerning the origin and propagation of both galactic and solar cosmic rays.
The precise measurement of the energy spectra of protons, helium and light nuclei and their isotopes, electrons and positrons, as well as of their arrival distribution allows for a careful study of the mechanisms of production, acceleration and propagation of cosmic rays in the galaxy and in the heliosphere.
The study of the time dependence of the various components of the cosmic radiations clearly shows solar modulation effects as well as charge sign dependence of these effects. PAMELA measurement of the energy spectra during solar energetic particle events fills the existing energy gap between the highest energy particles measured in space and the ground-based domain. Furthermore, providing pitch angle measurements, it allows the study of the effects of particle transport within interplanetary space over a broad range in energy. Moreover, by sampling the particle radiation in different regions of the magnetosphere, PAMELA data provide a detailed study of the Earth's magnetosphere.
This talk illustrates the scientific results obtained by the PAMELA experiment and their relevance for the study of SEP, solar modulation and Earth's magnetosphere.

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Design optimization using probabilistic solar energetic particle event exposures and risk

Author: Ryan Norman[1]

Co-authors: Charles Werneth [1]; Martha Clowdsley [1]; Steve Blattnig [1]

[1] *NASA*

Corresponding Author: ryan.b.norman@nasa.gov

A novel analysis method enabling design optimization for solar energetic particle event exposures and risk is presented. The method relies on NASA's HZETRN space radiation transport code to transport the proton spectrum of individual solar energetic particle events from a historical database of events through a radiation shield. The set of response functions from each individual solar energetic particle event is then treated in a probabilistic manner. This work specifically addresses whole body effective dose and risk of exposure induced death as the response functions of interest. By applying the statistics to the response after transport of all individual events, this method allows the real spectra of the solar energetic particle events to couple with shielding, giving exposures for realistic events. The speed and efficiency of HZETRN can be leveraged to explore a trade space throughout the design cycle of a mission, which allows the radiation shielding analysis to be an integral component of the mission design from the beginning, leading to a more optimal design.

Poster Session / 11

Non-parametric determination of p and He interstellar fluxes from TOA cosmic ray data

Authors: Alexandre Ghelfi[1]; David Alain Maurin[1]

Co-authors: Fernando De Carvalho Barao [2]; Laurent Yves Marie Derome [1]

[1] *Centre National de la Recherche Scientifique (FR)*

[2] *LIP Laboratorio de Instrumentacao e Fisica Experimental de Part*

Corresponding Author: dmaurin@lpsc.in2p3.fr

Top-of-atmosphere (TOA) cosmic-ray (CR) data from satellites and balloon-borne experiments are snapshots of the solar activity imprinted on the interstellar (IS) fluxes. Several snapshots are required to break the degeneracies between the 'unknown' IS flux shape and the modulation levels. Taking advantage of the recent high precision p and He data (AMS, BESS-Polar and PAMELA), we perform a fit of all available TOA snapshots to simultaneously constrain their modulation level and the underlying IS fluxes. The two novelties of this study are the use of a non-parametric shape for the IS fluxes, and of a Markov Chain Monte Carlo engine to extract the PDF and correlations (hence the confidence intervals) of the sought parameters. The outputs of the study are (i) the p and He IS fluxes (and uncertainties), and (ii) the solar modulation levels (and uncertainties) for each experiment. Although a systematic shift is observed between solar modulation levels extracted using either p or He TOA data, we find that within the uncertainties, the force-field approximation provides a good effective description of Solar modulation for TOA fluxes of CR nuclei.

Tuesday Afternoon 2 / 12

Neutron Monitors and cosmic-ray data for solar modulation studies: systematic uncertainties and modulation level time series

Author: David Alain Maurin[1]

Co-authors: Alexandre Ghelfi [1]; Laurent Yves Marie Derome [1]

[1] *Centre National de la Recherche Scientifique (FR)*

Corresponding Author: dmaurin@lpsc.in2p3.fr

Particles count rates at given Earth location and altitude result from the convolution of (i) the interstellar (IS) cosmic-ray fluxes outside the solar cavity, (ii) the time-dependent modulation of IS into Top-of-Atmosphere (TOA) fluxes, (iii) the rigidity cut-off (or geomagnetic transmission function) and grammage at the counter location, (iv) the atmosphere response to incoming TOA cosmic rays (shower development), and (v) the counter response to the various particles/energies in the shower. Count rates from neutron monitors or muon counters are therefore a proxy to solar activity. We present here how the uncertainties on the above ingredients impact count rate calculations, and how they translate into variation/uncertainties on the level of solar modulation (Maurin et al. 2015, AdSpR 55, 363). We then use an improved determination of the IS fluxes to compare solar modulation levels obtained from GCR data and from NMs.

Thursday Afternoon 2 / 13

Solar Protons above 500 MeV in Interplanetary Space and in the Sun's Atmosphere

Author: Allan Tylka[1]

Co-authors: C. K. Ng [2]; Don Smart [3]; Gerald Share [4]; Margaret Shea [3]; R. J. Murphy [5]; William Dietrich [6]

[1] *NASA-GSFC*

[2] *George Mason University*

[3] *SSSRC*

[4] *University of Maryland*

[5] *Naval Research Laboratory*

[6] *Praxis*

Monday Morning 2 / 14

Geomagnetic Cutoff Rigidity Values are a Valuable Tool in Analyzing Cosmic Radiation Measurements on the Earth and in Near-Earth Space

Author: Margaret Shea[1]

Co-author: Don Smart [1]

[1] *SSSRC*

Corresponding Author: sssrc@msn.com

Values of the Geomagnetic Cutoff Rigidity for locations on the Earth and in near-Earth space are a valuable tool for the analysis of cosmic radiation data. This paper presents an historical summary of the identification of cutoff rigidity values at the earth from the original Stormer theory to the determination of these values by the now accepted method of tracing cosmic ray trajectories through a mathematical model of the geomagnetic field. The initial calculations provided insight into a very complex array of allowed and forbidden particle paths from outer space to a specific location on the earth. While many individuals think there is a unique cutoff rigidity value for a location and direction in space, this is far from reality. There is an upper cutoff rigidity above which all particles are allowed and a lower cutoff rigidity below which all particles are forbidden. Between these values is the "penumbral region" - a chaotic structure of alternating allowed and forbidden orbits which can extend over several GV in rigidity particularly at mid latitudes. There is the additional complication that the geomagnetic center and geographic center of the earth are offset by ~430 km. The east-west effect provides an insight to the importance of knowing both the directional characteristics of a particle detector and its orientation with respect to the geomagnetic field.

The extension of the particle-tracing technique to include near-Earth space and the inclusion of magnetospheric models to the quiescent internal field representation was a normal evolution of the entire cutoff rigidity determination process. As a result of the magnetospheric configuration there are variations in the cutoff values and penumbral structure over the course of a day. These changes can be relatively dynamic during strong geomagnetic storms with the cutoff rigidity boundaries changing as much as approximately three quarters of a degree in latitude with each increment of Kp value. Finally, while a secondary effect, the long term secular variation of the geomagnetic field must be considered for extremely precise measurements. The standard cosmic ray trajectory program for particle tracing through an internal model of the geomagnetic field has been deposited in the NASA data center and can be downloaded.

Thursday Morning 2 / 15

SOLAR COSMIC RAY GROUND-LEVEL EVENT (GLE) ANISOTROPY

Author: Don Smart[1]

Co-author: Margaret Shea [1]

[1] *SSSRC*

Corresponding Author: sssrc@msn.com

The Archimedean spiral configuration in the interplanetary magnetic field controls the energetic particle flow out from the sun. Since it is much easier for a charged particle to propagate along a magnetic field than to cross a magnetic field, solar particle events from solar longitudes that are "well connected" to Earth via this Archimedean spiral path generally have prompt onsets and large anisotropies, whereas events from solar longitudes that are not "well connected" typically have longer onset delays and smaller anisotropies.

Irregularities in the interplanetary magnetic field and variability in the solar wind density and speed result in particle anisotropies that are extremely variable. When the mean free path of particle propagation between the Sun and Earth is deduced from the particle anisotropy, the computed mean free path is often of the order of 0.1 AU, but with an order of magnitude variation. The degree of particle anisotropy is time dependent. The most anisotropic values are observed during the event onset to the event maximum; the anisotropy decreases during the decline of the event. In the case of interplanetary shock dominated events, the anisotropy direction at low energies may actually reverse as the interplanetary shock passes the observer.

The most common method of observing particle anisotropy is by using a detector on a spinning satellite. Multiple sensors on a stabilized satellite can also be used to compute the particle anisotropy. In the case of using the Earth as a sensor platform, the analysis of data from multiple cosmic ray detectors at different longitudes (preferably in the polar regions) can determine the anisotropy during a solar cosmic ray ground-level event (GLE). After the anisotropy has been determined, the analysis of data from multiple cosmic ray detectors at different latitudes (cutoff rigidities) can be used to determine the GLE spectra.

There are measurements of very short duration transients (with time scales of the order of minutes) in the anisotropy during the rising phase of the event that probably relate to the acceleration source regions. The most anisotropic GLE on record occurred on 20 January 2005. It is possible, however, that the determination of this remarkable anisotropy was the result of improvements in detector technology and temporal resolution. If instrumentation of the same quality had been in operation during the large GLEs of the 17th-19th solar cycles some of those events such as the largest event in modern record on 23 February 1956 might have had similar anisotropies. Examples of the anisotropy of recent large GLEs will be presented.

Thursday Afternoon 2 / 16

X Flares and AMS-02 SEP Events at the Maximum of Cycle 24

Author: Richard Fisher[1]

Co-authors: Bryan Yamashiro [2]; Kristine Rock [3]; Veronica Bindi [2]

[1] *GSFC Heliophysics Sciience Division*

[2] *U. of Hawaii*

[3] *Retired*

Corresponding Author: richard.r.fisher@nasa.gov

Abstract
23 instrument systems on 7 space flight missions were used during 2014 to examine solar flare activity over the period 15 February 2011 to 26 September 2014 which includes the maximum of sunspot cycle 24. Subsequently additional data from 5 other missions were added to this set. Owing to the increase in research assets available during this period and the use of new orbits and technology, the composite database has unique spatial and temporal coverage of solar flare activity. Included in this data set are 33 X-class flare events, 21 high energy SEP events detected by the AMS-02 device integrated into the ISS, and a several long duration high energy gamma-ray events detected by FERMI. Also included in this set are 12 geomagnetic events (DST < - 100 nT), and one GLE solar cosmic-ray event.

Integrated soft x-ray fluxes, image time sequences, and difference image sequences of the disk, coronal mass ejection features, 14 mHz–10 kHz radio burst data and proton flux were examined for each of 61 events (33 X-flares, 23 M flares and 18 backside) with the aim of developing a characteristic observational model, focusing on LCPF, CME, Type III radio burst events, and SEP detections. This work outlines the
Parallels and differences detected between X-class flares and AMS0-2 SEP events of this sample.

In 33 of 33 cases EUV running difference sequences of Fe XII disk images show the initiation of an LCPF at or near the time of flare onset. Bubble-type CME's frequently occurred after X-flare initiation. In 28 of 32 cases the SWAVES instruments on the STEREO A, B, and WIND spacecraft detected Type III radio bursts coincident in time with the X-flare initiation. In the case of 5 X-flares and 6 AMS-02 events, proton enhancements were detected at all 1AU spacecraft locations, indicating event scales of a fraction of the solar system.

In the case of the 21 AMS-02 events the LCPF and subsequent bubble- type CMEs were detected for all AMS-02 events. This type of flare associated event
exhibited radio burst duration of > 2.5 hrs. AMS-02 events of this sample are poorly (or uncorrelated) with LCPF velocity, CME velocity or estimates of CME kinetic energy. AMS-02 events of this sample were characterized as 6 X-class flares, 11 M-class flares with a remaining 4 flares not observed or characterized by GOES (backside). NOAA x-ray class appears to be unrelated to AMS-02 event maximum energy. All AMS-02 events exhibit Type-III radio burst duration of > 2.5 hours
(10 kHz contour). This appears to be a sufficient condition for AMS-02 SEP events. X- and M-class radio burst duration of flares used in this study are generally found to be shorter than 2.5 hrs. This distinction may prove useful for further SWx investigation.

Tuesday Afternoon 1 / 17

Ion Flux Measurement with the AMS-02 Experiment

Author: Pierre Erwan Saouter[1]

[1] *Universite de Geneve (CH)*

Corresponding Author: pierre.erwan.saouter@cern.ch

The Alpha Magnetic Spectrometer (AMS-02) is a state-of-the-art particle physics detector operating as an external module on the International Space Station (ISS) since May 2011. One of the key

characteristics of AMS-02 is its capability to measure the relative abundances and absolute fluxes of the nuclear components of galactic cosmic rays in the kinetic energy range from 1 GeV/n to few TeV/n, from hydrogen up to iron ($Z = 26$) and above.

In this contribution, I will review the recent results from AMS-02 on cosmic ray nuclei heavier than Helium. Preliminary results for the fluxes of lithium, boron and carbon will be presented, as well as for their flux ratios. These measurements are important observables to better understand the propagation and acceleration of cosmic rays in the galaxy. The measurement of the fluxes spectral index dependence with rigidity will also be presented.

Friday Morning 1 / **18**

Characteristics of Long Duration Gamma-Ray Flares

Author: Gerald Share[1]

Co-authors: Allan Tylka [2]; Anne K. Tolbert [3]; Brian Dennis [4]; Richard Schwartz [3]; Ronald Murphy [5]; Stephen White [6]

[1] *University of Maryland*

[2] *none*

[3] *Catholic University*

[4] *NASA-GSFC*

[5] *Naval Research Lab*

[6] *Kirtland AFB*

Corresponding Author: gershare@aol.com

Fermi LAT has observed >100 MeV emission from at least twenty-five events following impulsive flares with GOES X-ray classes from M1.5 to X5.4. The emission is consistent with pion-decay radiation produced by > 300 MeV protons. Almost all the events are associated with fast (>800 km/s) CMEs, SEPs, and impulsive hard X-ray emission >100 keV. We discuss the time profiles of the LAT events on minute- and hour-long scales and information derived from a four-year systematic study of 95 energetic solar events and their association with sustained >100 MeV emission. We also discuss spectroscopic studies of the impulsive flares and sustained-emission phases that provide information on the numbers of >500 MeV protons and their spectra at the Sun and compare these properties with those observed in SEPs. This work was supported by the NSF-SHINE and NASA-Fermi-GI programs.

Poster Session / **19**

Study of Solar Energetic Particle Events for Support of Human and Robotic Spaceflight

Author: Bryan Yamashiro[1]

Co-authors: Richard Fisher [2]; Veronica Bindi [3]

[1] *University of Hawaii at Manoa*

[2] *GSFC/NASA/Emeritus*

[3] *University of Hawai'i at Manoa (US)*

Corresponding Author: byamashiro09@gmail.com

This study aims for a better interpretation of high-energy Solar Energetic Particle (SEP) events using the Alpha Magnetic Spectrometer (AMS-02), and the fleet of NASA solar observatories in space.

Future space exploration is dependent on an understanding of the radiation environment through the Solar System. AMS-02 is a particle detector installed on the International Space Station (ISS) that primarily focuses on high-energy physics.

As a heliospheric observatory, AMS-02 measures particle rigidities from 0.5 GV to a few TV and proton energies over 125 MeV. The AMS-02 energy detection range is relatively higher and more precise than any other detector in the NASA satellite fleet. AMS-02 recognition is vital to future missions in space considering that the isolated SEP events are highly energetic and reach the ISS in low Earth orbit. Between May 2011 and February 2014, AMS-02 detected 18 SEP events analyzed in this study.

The fleet of NASA spacecraft provides information about SEP events detected by AMS-02 and corresponding flare event parameters. High intensity solar events from May 2011 to February 2014, purely X- and M-class flares, are compared with AMS-02 SEP events to identify any correlations for the range of solar activity. AMS-02 SEP events invoke significant increases in proton flux, X-ray flux, and FERMI gamma ray bursts identified by various detectors in the highest respective energy range bins.

The 18 AMS-02 SEP events are not well associated with X-ray flux, large-scale coronal propagating front (LCPF) velocities, or coronal mass ejection (CME) energies and velocities. Notably, all AMS-02 SEP events show unique type III radio burst structures. The AMS-02 type III radio bursts comprise of low frequencies (14 MHz-10 kHz) with extended durations. A contour algorithm is used to isolate constant flux frequencies; exhibiting type III radio bursts over 2.5 hours for every AMS-02 event. Non-AMS-02 events typically average type III radio burst durations for 1.5 hours, even showing absences of radio bursts in certain scenarios. X-ray flux, LCPF velocities, and CME energies and velocities are poorly correlated to AMS-02 maximum-recorded energies, and prove unsatisfactory for SEP event predictions. Remarkably, long duration type III radio bursts appear to be sufficient conditions for AMS-02 SEP events in this sample.

Tuesday Morning 2 / 20

Neutron monitors as a traditional tool to study cosmic rays variability

Author: Ilya Usoskin[1]

[1] *University of Oulu*

Corresponding Author: ilya.usoskin@oulu.fi

A world-wide network of round-based neutron monitors (NMs) is a traditional tool to study variability of cosmic rays, both galactic cosmic rays (GCR) and solar energetic particles (SEPs). The network is in continuous operation since the 1950s and counts dozens of stations around the globe. Here, a brief review is given of the principles and methods of the NM operation and detection, of the methods of evaluating the cosmic ray flux, anisotropy and variability. The methods are based on the NM computed yield function and include global surveys, latitudinal surveys, analysis of GLE.
Some examples of the cosmic ray variability are given.

Tuesday Morning 1 / 21

Solar modulation of GCRs from the Balloon-Borne Experiment with a Superconducting Spectrometer (BESS)

Author: Kenichi Sakai[1]

Co-authors: Akira Itazaki [2]; Akira Kusumoto [2]; Akira Yamamoto [3]; Atsushi Horikoshi [4]; Eun Suk Seo [5]; Hideyuki Fuke [6]; John Mitchell ; Jonathan Ormes [7]; Jun NIshimura ; Junichi Suzuki [4]; Kazuma Takeuchi [2]; Ken-ichi Tanaka

[4]; Kenji Matsumoto [4]; Ki-Chun Kim [8]; Ko Abe [9]; Koji Yoshimura [10]; MASAYA HASEGAWA [4]; Makoto Sasaki [11]; Mitsuaki Nozaki [12]; Moohyung Lee [13]; Neeharika Thakur [14]; Nicolas Picot-Clemente [5]; Reiko Orito [15]; Robert Streitmatter [14]; Ryoko Shinoda [16]; Sadakazu Haino [17]; Shinya Matsuda [4]; Takamasa Yamagami [6]; Teruyuki Kumazawa [4]; Tetsuya Yoshida [6]; Thomas Hams ; Yasuhiro Makida [3]; Yoshiaki Shikaze [2]; Yoshiyuki Takasugi [2]; Yosuke Matsukawa [2]; Zachary Myers [8]

[1] *NASA/GSFC/CRESST/UMBC*

[2] *Kobe University*

[3] *High Energy Accelerator Research Organization (JP)*

[4] *KEK*

[5] *University of Maryland (US)*

[6] *ISAS/JAXA*

[7] *University of Denver*

[8] *University of Maryland*

[9] *University of Tokyo*

[10] *Okayama University*

[11] *NASA-Natl. Aeronaut. & Space Admin. (US)*

[12] *Kobe University (JP)*

[13] *University of Mayland*

[14] *NASA*

[15] *Tokushima University*

[16] *The University of Tokyo*

[17] *Academia Sinica (TW)*

Corresponding Author: kenichi.sakai@nasa.gov

The spectra of low-energy cosmic-ray protons, helium nuclei and antiprotons have been measured by BESS in 11 high-latitude balloon flights between 1993 and 2007. The original BESS experiment flew 8 times over Lynn Lake, Canada and once from Fort Sumner, USA during the period of 1993 through 2002. The long duration balloon (LDB) flights over Antarctica were carried out in 2004 and 2007 with BESS-Polar instrument. These measurements span a range of Solar activity from before the previous Solar minimum through Solar maximum (Cycle 23) and the latest Solar minimum, as well as a Solar magnetic field reversal from positive to negative in 2000. Since the low-energy region of the cosmic radiation is most intensively affected by solar modulation, the absolute fluxes and spectral shapes of primary protons and helium obtained with BESS are essential probes. These are combined with the simultaneous BESS antiproton measurements to probe the effect of charge-sign dependent drift on the entering cosmic rays.

Summary:

The BESS measurements are presented and compared to simple models of Solar modulation.

Poster Session / **22**

Solar Energetic Particle transport along meandering field lines and the interpretation of wide longitudinal events

Author: Frederic Effenberger[1]

Co-authors: Andreas Kopp [2]; Mike Marsh [3]; Silvia Dalla [3]; Timo Laitinen [3]

[1] *Stanford University*

[2] *University Kiel*

[3] *University of Central Lancashire*

Recent multi-spacecraft Solar Energetic Particle (SEP) observations have challenged the traditional view of SEP production and interplanetary transport. The observations suggest fast SEP access to a wide range of heliographic longitudes. The recent case studies that fit the SEP observations with 3-dimensional diffusive SEP transport simulations suggest a narrow source region, and strong cross-field diffusion beyond that permitted by the current theoretical understanding. Laitinen et al (2013) suggested a new approach to the modelling of interplanetary SEP transport, based on their finding that the cross-field diffusion early in an SEP event is not diffusive. The model incorporates field-line meandering into the Fokker-Planck (FP) transport equation framework. In this presentation, we report on the implementation of the new model within a stochastic differential equation framework for particle transport and field-line wandering. We show how it is able to reproduce the observed fast access of SEPs to wide range of longitudes with realistic interplanetary transport conditions even for a narrow source region. Results of a parametric analysis on how the level of interplanetary turbulence and the SEP source characteristics affect the SEP intensities at at 1 AU are presented, and we discuss the implications for the SEP event origins and the role of interplanetary turbulence in the interpretation of SEP observations.

Thursday Morning 2 / 23

Coronal mass ejections and large solar energetic particle events

Authors: Nat Gopalswamy[1]; Pertti Makela[2]

[1] *Nasa/GSFC, Greenbelt, MD 20771, USA*

[2] *Catholic University of America, Washington, DC 20064, USA*

Corresponding Author: pertti.a.makela@gmail.com

The relationship between Coronal mass ejection (CMEs) and large solar energetic particle (SEP) events became well established relatively recently (Kahler et al. 1978; Gosling 1993), not too long after the discovery of CMEs (Tousey, 1973). There was a paradigm shift from flares to CMEs as the main source of SEPs. There are still many questions regarding the CME-SEP relationship, which indicates huge variability in the source and environment parameters of SEP events. The source parameters include the location so the associated eruption on the Sun and kinematics of the associated CME. The environmental parameters include the ambient physical state (density, magnetic field and their combination in the form of the Alfven speed), presence of seed particles and the interaction of the associated CME with other CMEs and coronal holes. The variability also includes the changes associated with the solar cycle in the source and environment parameters. This talk summarizes some key results that highlight our current understanding of SEP events in relation to CMEs.

Friday Morning 2 / 24

Interpretation of Solar Flare Observations by Fermi-LAT and Other Instruments

Author: Vahe' Petrosian[1]

[1] *Stanford University*

Corresponding Author: vahep@stanford.edu

The Fermi Large Area Telescope (LAT) has detected more than 40 flares with significant flux above 100 MeV reaching to several GeV in some flares.
Most of these flares are detected many hours after the impulsive phase and some of these flare last for occur behind the limb as determined by STEREO observations. These observations when combined with those from instruments on

board other satellites such as RHESSI, SDO, STEREO and others have provided new insights and challenges on the radiation, transport and acceleration mechanisms. I will review these mechanisms and discuss how these observations allow us to determine whether the gamma-ray radiation is due to electron bremsstrahlung or decay of pions produced by accelerated ions, whether these particles are accelerated continuously in the low corona and/or in the CME driven shock, or promptly and stored for relatively long times in a high corona trap.

Friday Morning 1 / 25

Fermi Large Area Telescope observations of high-energy gamma-ray emission from behind-the-limb solar flares

Author: Melissa Pesce-Rollins[1]

Co-authors: Alice Allafort [2]; Fatima Rubio da Costa [2]; Nicola Omodei [2]; Vahe' Petrosian [3]; Wei Liu [2]

[1] *INFN-Pisa*

[2] *Stanford*

[3] *Stanford University*

Corresponding Author: melissa.pesce.rollins@pi.infn.it

Fermi LAT >30 MeV observations of the active Sun have increased the number of detected solar flares by almost a factor of 10 with respect to previous space observations. Of particular interest are the recent detections of three solar flares whose position behind the limb was confirmed by the STEREO-B satellite. These observations sample flares from active regions originating from behind both the eastern and western limbs and include an event associated with the second ground level enhancement event (GLE) of the 24^{th} Solar Cycle. While gamma-ray emission up to tens of MeV resulting from proton interactions has been detected before from occulted solar flares, the significance of these particular events lies in the fact that these are the first detections of >100 MeV gamma-ray emission from footpoint-occulted flares. These detections present a unique opportunity to diagnose the mechanisms of high-energy emission and particle acceleration in solar flares. We will present the Fermi-LAT, RHESSI and STEREO observations of these flares and discuss the various emission scenarios for these sources.

Tuesday Afternoon 1 / 26

Measurement of the time dependence of the cosmic ray electron and positron flux with the AMS Experiment

Author: Stefan Schael[1]

Co-authors: Henning Gast [1]; Nikolas Zimmermann [1]

[1] *Rheinisch-Westfaelische Tech. Hoch. (DE)*

Corresponding Author: stefan.schael@physik.rwth-aachen.de

Measurements by the AMS experiment of the time dependence of the electron and of the positron flux in primary cosmic rays in the energy range from 0.5 GeV upwards are presented. The characteristics of the very accurate data will be discussed.

Poster Session / **27**

ESTIMATING POSSIBLE BACKGROUND SOURCES FOR AN ANTIDEUTERON COSMIC FLUX USING A MONTE CARLO GENERATOR

Author: Diego Gomez Coral[1]

Co-authors: Arturo Menchaca Rocha [1]; Philip von Doetinchem [2]; Varlen Grabski [1]

[1] *Instituto de Física, Universidad Nacional Autónoma de México (UNAM), México, D. F. 01000, Mexico.*

[2] *Physics and Astronomy Department, University of Hawaii, Honolulu, Hawaii 96822, USA.*

The determination of an antideuteron component in the cosmic-ray flux is one of the most interesting topics in the current search for exotic sources of antimatter, such as dark matter annihilation. Experiments like AMS-02 and GAPS were developed with, among others, the aim to search for a detectable antideuteron flux, over a wide energy range. In this task, it is also important to produce the best possible estimates of a secondary antideuteron background. Inelastic collisions undergone by primary cosmic particles with interstellar and atmospheric matter, as well as with the detector matter itself are considered here. For that purpose we use the widely used EPOS-LHC Monte Carlo generator, coupled with an event-by-event coalescence-model afterburner, to simulate antideuteron production in high energy proton-proton and proton-nucleus collisions.

Tuesday Afternoon 2 / **28**

TIME DEPENDENCE OF THE COSMIC-RAY ELECTRON AND POSITRON SPECTRA MEASURED BY PAMELA EXPERIMENT DURING THE 23TH SOLAR MINIMUM

Author: Riccardo Munini[1]

[1] *INFN - Universita Studi Trieste*

Corresponding Author: riccardo.munini@ts.infn.it

The satellite-borne PAMELA experiment has been continuously collecting data since 15th June 2006, when it was launched from the Baikonur cosmodrome to detect the charged component of cosmic rays over a wide energy range and with unprecedented statistics. The apparatus design is particularly suited for particle and antiparticle identification. The PAMELA experiment has measured the time variation of electron and positron spectrum at Earth in great detail, extending the measurement down to 70 MeV. The spectra have been evaluated during the A<0 solar minimum of
cycle 23 i.e. from July 2006 to December 2009, over six-months intervals. These spectra provide important information for the
study of CR propagation inside the heliosphere and the investigation of the charge-sign dependent solar modulation.

Thursday Morning 1 / **29**

Kinetic simulations of particle acceleration at collisionless shocks

Author: Damiano Caprioli[1]

[1] *Princeton University*

Corresponding Author: dam.caprioli@gmail.com

I present some recent results of large particle-in-cell (PIC) and hybrid (kinetic ions-fluid electrons) simulations of particle acceleration at non-relativistic collisionless shocks.
Ion acceleration efficiency and magnetic field amplification are investigated in detail as a function of shock inclination and strength, and compared with predictions of diffusive shock acceleration theory. In particular, I discuss how ions are injected in the acceleration process, also putting forward a minimal model able to reproduce spectrum and normalization of the supra-thermal particles. Moreover, I show full PIC simulations attesting to electron diffusive acceleration at shocks with different inclinations, also discussing the role of ion- and electron-induced instabilities. Finally, I outline the observational counterparts of such a theory of ion acceleration in supernova remnants and heliospheric shocks.

Monday Afternoon 1 / 30

Overview of Solar Energetic Particle Event Observations and Open Questions

Author: Christina Cohen[1]

[1] *Caltech*

Corresponding Author: cohen@srl.caltech.edu

Current measurements of solar energetic particles (SEPs) are more comprehensive than ever before, spanning orders of magnitude in energy and intensity, covering electrons and ions from H to Ni, and made at locations throughout the heliosphere and around the Sun. This talk will review the current capabilities and measurement techniques employed to create this wealth of information and illustrate how it is connected to observations on the Sun and at Earth to study the causes and effects of the radiation component of space weather. The specific capability of simultaneous, multi-point SEP observations has raised several questions regarding our understanding of particle acceleration and transport. These open questions will be reviewed and discussed in light of potential contributions from the PAMELA and AMS SEP measurements.

Tuesday Afternoon 1 / 31

Precision Measurement of the Proton and Helium Fluxin Primary Cosmic Rays with AMS-02

Author: Nicola Tomassetti[1]

[1] *Centre National de la Recherche Scientifique (FR)*

Corresponding Author: nicola.tomassetti@cern.ch

Knowledge of the precise rigidity dependence of the proton and helium fluxes in cosmic rays is important in understanding their origin, acceleration and propagation processes. We present a precision measurement of the proton flux at rigidity from 1 GV to 1.8 TV
and the helium flux at rigidity from 2 GV to 3 TV. The measurement is based on the data collected by the Alpha Magnetic Spectrometer experiment on the International Space Station. We present the detailed variation with rigidity of the flux spectral indices.
The proton and helium fluxes are found to progressively harden at rigidities larger than 100 GV. The rigidity dependence of the helium flux spectral index is similar to that of the proton spectral index though the magnitudes are different. Remarkably, the spectral index of the proton to helium flux ratio increases with rigidity up to 45 GV and then becomes constant. The flux ratio above 45 GV is well described by a single power law.

Thursday Afternoon 1 / **32**

Magnetospheric Effects on High Energy Solar Particles: PAMELA Measurements

Author: Georgia de Nolfo[1]

[1] *NASA/GSFC*

Solar Energetic Particles (SEPs) are accelerated at the Sun in solar flares or by the shocks formed by Coronal Mass Ejections (CMEs). However, the effects of transport en route to Earth often obscures which process dominates, and when. At the highest energies, the effects of transport can be minimal, providing an opportunity to resolve the origin of particle acceleration. The Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA) instrument provides new and unique observations that can help separate the effects of acceleration and transport. Furthermore, PAMELA bridges a critical gap in energy between space-based and ground-based measurements. We report on the PAMELA observations of the 2012 May 17 ground level enhancement (GLE). PAMELA observations reveal two distinct populations, a low-energy SEP population that exhibits significant scattering or redistribution and a high-energy population that reaches the Earth relatively unaffected by dispersive transport effects. We conclude that the scattering or redistribution at low energies takes place locally revealing effects of SEP transport in the Earth's magnetosphere, in particular, the magnetosheath. The redistribution may derive from large amplitude standing mirror mode waves in the magnetosheath.

Monday Afternoon 2 / **33**

Forbush Decreases: The View From Space

Author: Ian Richardson[1]

Co-author: Hilary Cane [2]

[1] *University of Maryland*

[2] *University of Tasmania*

Corresponding Author: ian.g.richardson@nasa.gov

Short term (<~1 week duration) decreases, typically of a few percent, in the intensity of galactic cosmic rays (GCRs) were first observed by Forbush (1937) and Hess and Demmelmair (1937) using ionization chambers. They were later shown, using neutron monitors, to originate in the interplanetary medium (Simpson, 1954) and to be of two types: "Recurrent", which recur with the solar rotation period and are associated with corotating high-speed streams, and "nonrecurrent", caused by the passage of transient solar wind structures associated with coronal mass ejections at the Sun. Events in the latter class are generally termed "Forbush decreases", although this term has also been used to include recurrent depressions. A focus of this presentation will be observations of Forbush decreases made by spacecraft, which do not suffer from the diurnal intensity variations present in neutron monitor observations on the ground, and can be related directly to solar wind structures passing the observing spacecraft.

Poster Session / **34**

Inter-Relationship of Solar and Interplanetary Phenomena During Solar Cycles 23 and 24

Author: Ian Richardson[1]

Co-authors: Hilary Cane [2]; Tycho von Rosenvinge [3]

[1] *University of Maryland*

[2] *University of Tasmania*

[3] *NASA/Goddard Space Flight Center*

Corresponding Author: ian.g.richardson@nasa.gov

Solar energetic particle events, specifically those including ~25 MeV protons, observed by the STEREO spacecraft and/or at the Earth since 2006 and cataloged by Richardson et al. (2014), show evidence of clustering in time during the rise of Solar Cycle 24, with groups of events occurring at intervals of around 6 months. By considering separately the occurrence rates of events with sources in the north or south solar hemisphere, we suggest that these "periodicities" in the SEP rates have continued through much of the cycle so far, but that the rates vary independently in each hemisphere. In particular, they are typically in anti-phase except early in the cycle, when they were closer in phase. We examine how these variations in the SEP rate are related to other phenomena such as the sunspot number and area in each hemisphere, rates of coronal mass ejections at the Sun and interplanetary coronal mass ejections at Earth, the interplanetary magnetic field, solar magnetic field ("Sun as a star"), geomagnetic activity and the galactic cosmic ray intensity. Most obviously, and not unexpectedly, the SEP rate closely follows the sunspot number and area in the same hemisphere, including the sunspot maximum in the north that was followed two years later by the southern maximum. We also note the remarkably different time-development of activity in the northern and southern hemispheres during Cycle 24 compared to Cycle 23, where the rise and fall of activity in each hemisphere was more symmetrical. The ~6 month periodicities are similar to the "~150 day" periodicities reported in various solar and interplanetary phenomena during other solar cycles. Understanding the underlying processes driving such variations may help to improve space weather forecasting on time scales of many months.

Thursday Afternoon 1 / 35

Geomagnetically trapped, albedo and solar particles: trajectory analysis and flux reconstruction with PAMELA

Author: Alessandro Bruno[1]

[1] *INFN sezione di Bari; Department of Physics, University of Bari, Italy*

Corresponding Author: alessandro.bruno@ba.infn.it

The PAMELA satellite experiment, operating since 2006 June, is providing precise and detailed measurements of the radiation environment in low Earth orbit, including galactic, solar and under-cutoff cosmic-rays. The analysis of the different components is supported by an accurate trajectory tracing simulation based on a realistic modeling of the Earth's magnetosphere, which enables the investigation of particle propagation in the geomagnetic field and the discrimination between populations of interplanetary and atmospheric origin. The under-cutoff particles are classified into geomagnetically trapped and albedo: the former consist of inner belt particles with trajectories satisfying the adiabatic conditions, confined to the South Atlantic Anomaly (SAA) at PAMELA altitudes; the latter are subdivided into quasi-trapped, concentrating in the equatorial region, and un-trapped, spreading over all sub-cutoff latitudes and including both short-lived (precipitating) and long-lived (pseudo-trapped) components. The trajectory information is also exploited to evaluate the angular distribution of Solar Energetic Particle (SEP) fluxes, by estimating the asymptotic directions of approach and the entry points in the magnetosphere. The SEP energy spectra are reconstructed as a function of the pitch-angle with respect to the Interplanetary Magnetic Field (IMF) direction, allowing the investigation of possible anisotropies and thus improving the interpretation of the solar events observed by PAMELA during solar cycles 23 and 24.

Monday Morning 2 / 36

Cosmic Ray Modulation over the 22 Year Magnetic Cycle Observed by Neutron Monitors

Author: Pierre-Simon Mangeard[1]

Co-authors: Alejandro Saiz Rivera [2]; David Ruffolo [2]; Paul Evenson [3]; Suttiwat Madlee [2]; Tanin Nutaro [4]; Waraporn Nuntiyakul [4]

[1] *National Astronomical Research Institute of Thailand (NARIT), Chiang Mai 50200, Thailand*

[2] *Department of Physics, Faculty of Science, Mahidol University, Bangkok 10400, Thailand*

[3] *Bartol Research Institute and Department of Physics and Astronomy, University of Delaware, Newark, DE 19716, USA*

[4] *Department of Physics, Faculty of Science, Ubon Ratchathani University, Ubon Ratchathani 34190, Thailand*

Corresponding Author: evenson@udel.edu

Neutron monitors (NMs) are large ground-based instruments for precise time tracking of the variations in the Galactic cosmic ray (GCR) flux at the GeV-range. NMs count the secondary particles (mostly neutrons) issued from the interaction of the cosmic rays in the Earth's atmosphere. The sensitivity to GCR variations depends on the geomagnetic cutoff at the location of measurement as well as on the altitude of detection. Since late 2007, the Princess Sirindhorn Neutron Monitor (PSNM), at the summit of Doi Inthanon, Thailand's highest mountain (2565 m altitude), has recorded the flux of galactic cosmic rays with the world's highest vertical rigidity cutoff for a fixed station, 16.8 GV. We present here the observations of PSNM since the beginning of its operation. We have also developed Monte Carlo simulations of cosmic ray interactions in the atmosphere and in PSNM (with its surroundings), which includes the tracing of cosmic ray trajectories through Earth's magnetic field to model the cosmic ray suppression at low rigidity at the location of PSNM. The simulated count rate is in reasonable agreement with the data. Variations of the GCR flux, such as the solar modulation effect, are investigated for the first time with a fixed ground-based NM at such a high geomagnetic cutoff, and the observed solar modulation is much weaker than predicted by the force field model with Φ inferred from NM data at low cutoff. We also discuss the effect of solar magnetic polarity as determined by a recent series of latitude surveys, and an apparently long time lag between solar polarity reversal and the GCR minimum. Partially supported by a postdoctoral fellowship from Mahidol University, the Thailand Research Fund (BRG 5880009, PHD/0136/2552), the Graduate School of Mahidol University and US National Science Foundation awards PLR-1341562, PLR-1245939, and their predecessors.

Poster Session / **37**

Diffusive Propagation of Galactic Cosmic Rays in a Two Halo Scenario

Author: Nicola Tomassetti[1]

[1] *Centre National de la Recherche Scientifique (FR)*

Corresponding Author: nicola.tomassetti@cern.ch

The study of antimatter particles in cosmic rays excites many physicists who believe in the possibility that these particles come from annihilation of dark matter particles. This possibility is very difficult to prove because antiparticles are also created
by collisions of ordinary cosmic rays with the interstellar medium. For example, collisions of energetic protons can produce antiprotons or positrons. Hence the level of antimatter arising from cosmic-ray collisions has to be calculated. However, calculations of antimatter production depend crucially on our knowledge of cosmic-ray propagation: what happen to cosmic rays when they propagate through the Galaxy?

In this work, I presents new calculations aimed to explain recent, conflicting observations on protons, nuclei, anisotropy, and gamma-rays. In contrast to standard calculations, I suggest that cosmic rays experience different propagation properties when traveling in different regions of the Galaxy. This

possibility leads to a remarkably enhanced antimatter production. At the highest energies detectable by the AMS experiment, antiprotons and positrons are approximately 5 times more abundant. Current models describing antimatter data in terms of dark matter must also take into account this possibility, which will be tested soon by additional data expected to be released from AMS.

Thursday Morning 1 / **38**

The Theory of SEP Acceleration and Transport

Author: Martin Lee[1]

[1] *University of New Hampshire*

Corresponding Author: marty.lee@unh.edu

Solar energetic particles (SEPs) are a major constituent of the inner heliosphere during "Solar Maximum" conditions. SEPs occur in two basic classes of events. "Gradual" events are large, infrequent, last for days, are proton-rich, and are associated with coronal mass ejections (CMEs) and type II radio bursts. "Impulsive" events are small, frequent, last for hours, are electron-rich, and are associated with type III radio bursts. Both classes originate in flares/active regions at the Sun. However, gradual events are accelerated over an extended region in longitude, latitude and radial distance. Acceleration at shocks driven by CMEs best accounts for the observed characteristics of gradual events, whereas acceleration in solar flares at sites of magnetic reconnection, either by stochastic acceleration or reconnection-driven shocks, best accounts for impulsive events. It must also be emphasized that the observed temporal, spatial and energy spectral structure of these events is strongly influenced by particle transport in the solar wind. This presentation addresses the theory of shock acceleration as applied to gradual events, including the basic elements of first-order Fermi and shock drift acceleration, wave excitation (which enhances the efficiency of shock acceleration), the effect of shock obliquity, the nature of injection, and the escape of particles upstream of the shock. The presentation also addresses the basic mechanisms of reconnection-associated acceleration including stochastic (second-order Fermi) acceleration. The theory of particle transport in the corona and solar wind will be presented briefly, including the determination of the diffusion tensor. Special attention will be devoted to the origin, energy spectra and transport of SEPs at ground-level-event (GLE) energies. Finally, outstanding challenges for the theory of SEP acceleration and transport are addressed including seed particle injection rates, acceleration at nearly perpendicular shocks, the origin(s) of extreme variability and large spatial extent in SEP intensity, and the puzzling composition of impulsive events.

Poster Session / **39**

Historic Record of Neutron Monitor Ground-level Count Rates at the Solar Minimum of Solar Cycle 23-24

Author: Suyeon Oh[1]

Co-authors: John W Bieber [2]; Jongil Jung [3]; Paul Evenson [2]; Yu Yi [4]

[1] *Chonnam National University*

[2] *University of Delaware*

[3] *Chungnam National University*

[4] *Chungman National University*

Corresponding Author: iapetus85@gmail.com

For more than half a century, Neutron monitors have recorded the flux of galactic cosmic rays. During the recent, prolonged, deep minimum in solar activity, many sources indicate that modulated galactic cosmic rays have attained new Space Age highs. However, reported neutron monitor rates

are ambiguous; some record new highs while others do not. This work examines the record of 15 long-running neutron monitors to evaluate cosmic ray fluxes during the recent extraordinary solar minimum in a long-term context. We show that ground-level neutron rates did reach a historic high during the recent solar minimum, and we present a new analysis of the cosmic ray energy spectrum in the year 2009 versus year 1987. To do this, we define a reference as the average of eight high-latitude neutron monitors, four in the northern hemisphere (Apatity, Inuvik, Oulu, Thule) and four in the southern hemisphere (Kerguelen, McMurdo, Sanae Terre Adelie). In this study, we present the trend of galactic cosmic rays at the recent solar minimum.

Poster Session / **40**

Characteristic of the Neutron Monitor Settled in Daejeon, South Korea and Another NM to be Installed at Jang-Bogo Station in the Antarctic.

Author: Jongil Jung[1]

Co-authors: Paul Evenson [2]; Suyeon Oh [3]; Yu Yi [4]

[1] *Chungnam National Uniyversity*

[2] *University of Delaware*

[3] *Chonnam National University*

[4] *Chungnam National University*

Corresponding Author: iapetus85@gmail.com

The level of solar activity determine the amount of cosmic radiation entering Earth's atmosphere. The count of cosmic rays increase as solar minimum approaches. Neutron monitor is an instrument to measure neutrons by atmospheric secondary cosmic ray particles on ground-base. In 2011, a neutron monitor was installed at the Korea Research Institute of Standard Science (KRISS), Daejeon, South Korea and has acquired data since November 2011. It is located at the 36.4 N and 127.26 E. The Daejeon neutron monitor has higher cutoff rigidity than 10 GV. It means that Daejeon neutron monitor has a great advantage to particular data analysis of high energy cosmic ray. Currently, we're planning a neutron monitor installed at Jangbogo station in the Antarctic from this December. Jangbogo station is located at the Terra Nova bay on Northern Victoria (74.62 S, 164. 22 E). In this work, we introduce some scientific results by Daejeon neutron monitor and the installation procedure of another NM at Jangbogo station in the Antarctic.

Poster Session / **41**

Diffusive shock acceleration and the coupled hydromagnetic wave excitation in the low corona

Author: Gen Li[1]

Co-author: Martin Lee [1]

[1] *University of New Hampshire*

Acceleration of GeV protons in magnetically well-connected strong GLEs tends to begin at ~2 solar radii whereas GLEs associated with shocks that begin above ~3 solar radii tend to compensate by having higher shock speeds. We present an analytical stationary diffusive shock acceleration model discussing the dependence of the upstream particle escape rate on the proton excited waves in the turbulent sheath and the interplanetary waves in the ambient solar wind. The model indicates that increased seed particle density and wave excitation may effectively reduce the particle escape rate from the scatter-dominated turbulent sheath upstream of the shock into interplanetary space. The

higher seed particle density and the stronger magnetic field strength at smaller solar radii may be responsible for the efficient acceleration of high-energy particles in GLEs.

Friday Afternoon 1 / 42

Validation of NASA Space Radiation Analysis Tools with ISS Radiation Environment Monitor (REM) Data

Author: Martha S. Clowdsley[1]

[1] *NASA Langley Research Center, Hampton, VA*

Corresponding Author: john.w.norbury@nasa.gov

A variety of computational tools and models are used by NASA to evaluate astronaut radiation exposure in support of vehicle design and mission planning efforts. These space radiation analysis tools include radiation environment models, transport codes, and vehicle shielding models. Measurements made with the Radiation Environment Monitor (REM) units currently onboard the International Space Station (ISS) provide an opportunity to perform end-to-end validation of these tools. NASA's Advanced Exploration Systems program supports an effort to perform this validation analysis. Under this project, ISS models have been updated to more accurately represent the shielding masses surrounding the REM units and comparisons between calculated results and measurement data have been completed. The calculated results accurately model the time dependence of the varying environment within the station but underestimate the total dose by approximately 25% at higher latitudes, where the environment is more like the free space environment, and by approximately 60% near the equator. In an effort to better understand this underestimation, the sensitivity of calculated results to a variety of model assumptions has been examined and will be presented.

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The Dynamic GLE Proton Spectrum of 2001 April 15 and 2005 January 20

Author: James M Ryan[1]

[1] *University of New Hampshire*

We report the proton spectrum of two GLEs, 2001 April 15 and 2005 January 20. Using two instruments, the Climax neutron monitor and the Milagro ground based TeV gamma-ray telescope, we constructed the spectrum of the highest energy part of the GLE spectrum. The many available rigidity thresholds in the Milagro instrument, coupled with the nearby Climax NM, allows one to construct a differential spectrum above 1 GV rigidity. We find that the impulsive, anisotropic phase of both events is systematically harder than the delayed isotropic phase. We fit both spectra to power laws in energy with exponential roll overs. We find that the roll over energy abruptly drops after the anisotropic phase and seems to remain roughly constant thereafter. Because the roll over energy embodies important physics in the shock acceleration process, this implies that if the particles in the delayed phase came directly from the shock, the conditions changed significantly or that the original population injected by the shock has been modified by transport effects.

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The Advanced Neutron Spectrometer for Manned Exploration

Author: Mark Christl[1]

[1] *Marshall Space Flight Center - Nasa*

An Advanced Neutron Spectrometer (ANS) is being developed to measure neutron spectrum in support future manned exploration mission. A prototype instrument has been designed and is being fabricated for a technology demonstration on board the ISS starting in 2016. The ANS measurement technique offers an improvement over the existing gate and capture method employed in boron dope plastic scintillators. The ANS uses a composite scintillator fabricated with 99% plastic scintillator (PVT) and a small amount of scintillating glass fibers (1% by volume) doped with Lithium. The timing characteristics of the two scintillators are sufficiently different to readily identify which component generated any light pulse. This difference is exploited to provide clear identification of the signal generated through neutron moderation in the PVT and the capture of the thermalized neutron in the glass fibers. Test exposures using mono-energetic neutron beams are planned for PTB and a space based exposure is planned for late 2016 on the ISS. The technique and status of this development will be discussed.

Thursday Afternoon 2 / **45**

Geomagnetic cutoff simulations for low-energy cosmic rays

Author: Philip von Doetinchem[1]

[1] *University of Hawaii at Manoa*

Low-energy cosmic rays and solar particles are strongly deflected by Earth's geomagnetic field. Due to the structure of the field a location and direction depend geomagnetic cutoff is apparent. This presentation will present geomagnetic cutoff simulations using the PLANETOCOSMICS software with the IGRF geomagnetic field and the Tsyganenko magnetosphere. The development over time during the AMS-02 data taking period will be discussed.

Monday Afternoon 1 / **46**

Particle Acceleration in the inner Heliosphere: Diffusive Shock Acceleration and Quiet-Time Processes

Author: Gary P Zank[1]

[1] *Center for Space Plasma and Aeronomic Research (CSPAR) and Department of Space Science, University of Alabama in Huntsville*

Gradual solar energetic particle events are thought to be due to diffusive particle acceleration at coronal mass ejection driven shocks. By contrast, impulsive events are associated typically with particle acceleration somehow associated with solar flares and impulsive events low in the solar corona. Other events exhibit characteristics of both impulsive and gradual events, sometimes called mixed events. At other times, during quiet periods in the inner heliosphere, energetic particle distributions are observed frequently. The acceleration mechanism for the last remains largely unknown, although various suggestions have been put forward. We will present an overview of diffusive shock acceleration as it applies to the gradual and mixed solar energetic problem. The importance of understanding this as a dynamical rather than a stationary process will be discussed, the role of shock obliquity addressed, maximum particle energy from a shock discussed, the particle injection problem considered, and accelerated particle spectral properties described. If time permits, we will discuss briefly the acceleration of particles in the vicinity of the heliospheric current sheet during quiet periods by magnetic islands, also known as flux ropes.

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Extreme Fluxes in SEP Events: Physical and Methodological Restrictions

Author: Leonty I. Miroshnichenko[1]

[1] *N.V. Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN), Russian Academy of Sciences, Troitsk, Moscow Region, 142190, Russia - D.V. Skobeltsyn Institute of Nuclear Physics (SINP), M.V. Lomonosov Moscow State University, 119234, Moscow, Russia*

Radiation conditions at the Earth's orbit, disturbances of the ionosphere, state of the ozone layer, ionization in the upper atmosphere and other geophysical phenomena are determined, to a considerable extent, by variations of the fluxes of solar energetic particles (SEPs), or solar cosmic rays (SCRs) accelerated at/near the Sun, directly in the flares and/or at the fronts of CME-driven shocks. These particles are registered near the Earth in the form of Solar Proton Events (SPEs). SPE extensions for the range of relativistic SEP energies - Ground Level Enhancements (GLEs) of SCRs - are of special interest. Occurrence rates, magnitudes and significance (geoefficiency) of those phenomena vary rather strongly in dependence on the level of solar activity (SA). It is suggested to consider the problem for different stages of 11-year solar cycle, at different levels of SA and different occurrence rates of extreme solar flares/CMEs, for different epochs of the solar evolution (in particular, for the epoch of "young" Sun).
Since 1942 there are systematic ground-based observations of GLEs, and direct measurements of SEP fluxes are carried out from the beginning of "space era". Indirect data on SCRs in the past may be obtained from some natural archives (nitrates in the ancient Antarctic and Arctic ices, radiocarbon 14C in the tree rings, 10Be, 26Al and other cosmogenic isotopes in lake sediments etc.). At present, we have information on a few extreme SPEs for the period of last 1200 years (from 775AD). Amongst them, the most known is a flare of 1 September 1859 r. («Carrington Event»). By nitrate data starting from 1561, in the combination with the results of real measurements of SCRs in modern epoch, we constructed a distribution function of SPEs by their fluences suitable for the prediction of hazardous radiation fluxes.
For the present, available data of observations and methods of investigations do not allow to estimate maximum potentialities of solar accelerator(s). This restricts considerably an extrapolation of obtained results for the past and future, for the epochs with the levels of SA different from the modern one. Nevertheless, data on SCRs and their geophysical effects allow us to understand better the mechanisms of solar-terrestrial relations and space weather. In its turn, this is important for modeling the evolution of terrestrial biosphere in the past and future, as well as for the quest of possible traces of life at the Mars and other planets of the Solar System.

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NASA galactic cosmic radiation environment model: Badhwar - O'Neill (2014)

Author: Ryan Rios[1]

Co-authors: Pat O'Neill [1]; Serkan Golge [2]; Tony Slaba [3]

[1] *NASA Johnson Space Center*

[2] *University of Houston/JSC NASA*

[3] *NASA Langley Research Center*

Corresponding Author: ryan.r.rios@nasa.gov

The Badhwar-O'Neill (BON) Galactic Cosmic Ray (GCR) flux model has been used by NASA to certify microelectronic systems and in the analysis of radiation health risks for human space flight missions. Of special interest to NASA is the kinetic energy region below 4.0 GeV/n due to the fact that exposure from GCR behind shielding (e.g., inside a space vehicle) is heavily influenced by the GCR particles from this energy domain. The BON model numerically solves the Fokker-Planck differential equation to account for particle transport in the heliosphere due to diffusion, convection, and adiabatic deceleration under the assumption of a spherically symmetric heliosphere. The model utilizes a comprehensive database of GCR measurements from various particle detectors to determine boundary conditions. By using an updated GCR database and improved model fit parameters, the new BON model (BON14) is significantly improved over the previous BON models for describing the GCR radiation environment of interest to human space flight.

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Precise Measurement of the Monthly Proton Flux with AMS-02 on the ISS

Author: Cristina Consolandi[1]

Co-authors: Claudio Corti [1]; Julia Hoffman [1]; Kathryn Whitman [1]; Veronica Bindi [1]

[1] *University of Hawai'i at Manoa (US)*

Corresponding Author: cristina.consolandi@cern.ch

The Alpha Magnetic Spectrometer (AMS-02) is a high-energy particle
detector designed to perform fundamental physics research in space.
It was installed on the International Space Station (ISS) on May 19, 2011,
where it will operate for the next decade.
During the first 30 months of operations, AMS-02 collected 41 billion events
of cosmic rays between 1 GV and 1.8 TV.
In this work, we analyze the detailed time variation of the proton flux with
a 27 days time-based integration i.e. Bartels rotation.
While at high energy the spectra remains
stable versus time, the low-energy range exhibits a decreasing general trend,
strongly reflecting the increase of the solar activity that recently reached its maximum.
In addition to the overall modulation effect, the monthly AMS-02 proton flux
shows variations related to the short-time solar activity i.e.
Coronal Mass Ejections and Forbush decreases.

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Solar modulation of proton LIS with spacecrafts, ballons and neutron monitors

Author: Claudio Corti[1]

Co-authors: Cristina Consolandi [1]; Julia Hoffman [1]; Kathryn Whitman [1]; Veronica Bindi [1]

[1] *University of Hawai'i at Manoa (US)*

Corresponding Author: claudio.corti@cern.ch

Galactic cosmic rays (GCRs) entering the heliosphere are disturbed by the magnetic field of the Sun, which varies with a period of 11 years. The solar modulation affects the GCR fluxes up to

few tens of GeV, modifying the shape and the intensity of the local interstellar spectrum (LIS). The time variation of the galactic cosmic protons at Earth can be studied indirectly on ground with the neutron monitors (NMs) and directly from space with AMS-02 (2011-now), PAMELA (2006-2010) and BESS (1993-2007). A new parametrization of the LIS will be presented, based on the latest data from AMS-02 and Voyager 1. Using the framework of the force-field approximation, the solar modulation parameter will be extracted from the time-dependent proton fluxes measured by PAMELA and BESS. The results will be compared with the modulation parameter inferred by NMs.

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AMS-02 latest results

Author: Veronica Bindi[1]

[1] *University of Hawai'i at Manoa (US)*

Corresponding Author: veronica.bindi@cern.ch

The Alpha Magnetic Spectrometer (AMS-02) is a general-purpose high-energy particle physics detector. It was installed on the International Space Station (ISS) in May 2011 to conduct a unique long-duration mission of fundamental physics research in space. Precision measurements by the Alpha Magnetic Spectrometer on the International Space Station of the primary cosmic-ray particles and nuclei fluxes and their ratios will be presented.

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Short-term Solar Activity Measured by AMS-02

Author: Kathryn Whitman[1]

Co-authors: Claudio Corti [1]; Cristina Consolandi [1]; Julia Hoffman [1]; Veronica Bindi [1]

[1] *University of Hawai'i at Manoa (US)*

Corresponding Author: kathryn.whitman@cern.ch

The Alpha Magnetic Spectrometer (AMS-02) with its acceptance of about 0.45 m^2 sr, is the largest Solar Energetic Particle (SEP) detector in space. It was installed on the International Space Station (ISS) on May 19, 2011, where it will take data for the duration of the station (~2024). In the first 3 years of operations, AMS-02 detected and measured many events related to short-term solar activity, including 1) the highest energy SEPs produced during M- and X-class flares and fast coronal mass ejections and 2) temporary reductions in GCR flux, known as Forbush decreases. AMS-02 is able to perform precise measurements in a short period of time, which is typical of these transient phenomena, and to collect enough statistics to measure fine structures and time evolution of the spectrum. Preliminary analyses of selected Forbush decreases and SEP events will be presented. AMS-02 observations, with their unprecedented resolution and high statistics, can therefore help to understand the influence of short-term solar activity on the proton flux at Earth.

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Latest results from AMS-02 on the ISS

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The total modulation of cosmic rays in the helioshpere

Corresponding Author: marius.potgieter@nwu.ac.za

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Corresponding Author: veronica.bindi@cern.ch

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Latest results from AMS-02 on the ISS

Corresponding Author: veronica.bindi@cern.ch

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Open discussion and final remarks

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Space Radiation Current Status and Next

Author: Edward Semones[1]

[1] *NASA*

Astronaut exposure to galactic cosmic rays (GCR) and solar particle events (SPEs), presents a critical challenge for long duration space exploration missions. Experimental studies have shown that HZE nuclei found in the GCR produce both qualitative and quantitative differences in biological effects compared to terrestrial radiation, leading to large uncertainties in predicting exposure outcomes to humans. Radiation risks include carcinogenesis, degenerative tissue effects such as cataracts or heart disease, and potential effects to the central nervous system (CNS). For International Space Station (ISS) missions and design studies of exploration of cis-lunar space and Mars, NASA uses the quantity risk of exposure-induced death (REID) to limit astronaut risks. Critical to the estimates of REID is the detailed understanding of the space radiation environments expected in the destinations and timeframes being considered. Overview of the relevant issues of estimating astronaut risks in context with emerging findings from AMS-02 will be discussed.

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Space Radiation, current status and next

Author: Edward Semones[1]

[1] *NASA*

Astronaut exposure to galactic cosmic rays (GCR) and solar particle events (SPEs), presents a critical challenge for long duration space exploration missions. Experimental studies have shown that HZE nuclei found in the GCR produce both qualitative and quantitative differences in biological effects compared to terrestrial radiation, leading to large uncertainties in predicting exposure outcomes to humans. Radiation risks include carcinogenesis, degenerative tissue effects such as cataracts or heart disease, and potential effects to the central nervous system (CNS). For International Space Station (ISS) missions and design studies of exploration of cis-lunar space and Mars, NASA uses the quantity risk of exposure-induced death (REID) to limit astronaut risks. Critical to the estimates of REID is the detailed understanding of the space radiation environments expected in the destinations and timeframes being considered. Overview of the relevant issues of estimating astronaut risks in context with emerging findings from AMS-02 will be discussed.

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The Space Radiation Environment on the Surface of Mars Measured with the RAD Instrument on the Mars Science Laboratory

Corresponding Author: don.hassler@ias.u-psud.fr

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The Space Radiation Environment on the Surface of Mars Measured with the RAD Instrument on the Mars Science Laboratory

Author: Hassler Don[1]

[1] *Southwest Research Institute, Boulder, CO, USA & Institut d'Astrophysique Spatiale, Orsay, France*

The Radiation Assessment Detector (RAD) is a compact, lightweight energetic particle analyzer currently operating on the surface of Mars as part of the Mars Science Laboratory (MSL) Mission. RAD is providing the first measurements of the energetic particle radiation environment on the surface of another planet due to solar flares, coronal mass ejections (CMEs), and galactic cosmic rays (GCRs). RAD is providing synoptic measurements of the energetic particle environment at a 2nd location in heliosphere (other than near-Earth or L1), and will aid heliospheric modeling over solar cycle. These observations of SEP fluxes are contributing to a solar energetic particle (SEP) event database at Mars and the Martian surface to aid prediction of Solar Particle Events (SPEs), including onset, temporal & size predictions. This presentation will provide an overview of the RAD investigation and present measurements of the solar flare, GCR and radiation environment on the surface of Mars, and discuss the importance of providing broad heliospheric coverage for situational awareness of space weather as we plan to send humans out into deep space and to Mars.
RAD is supported by NASA (HEOMD) under JPL subcontract #1273039 to SwRI, and by DLR in Germany under contract with Christian-Albrechts-Universitat (CAU).

Poster Session / **69**

The Neutron Monitor Database (NMDB)

Author: Christian Steigies[1]

[1] *Institut für Experimentelle und Angewandte Physik Christian-Albrechts-Universität zu Kiel*

Since the International Geophysical Year (IGY) in 1957-58 cosmic rays are routinely measured by many ground-based Neutron Monitors (NM) around the world. The World Data Center for Cosmic Rays (WDCCR) was established as a part of this activity and is providing a database of cosmic-ray neutron observations in unified formats. However, that standard data comprises only of one hour averages, whereas most NM stations have been enhanced at the end of the 20th century to provide data in one minute resolution or even better. This data was only available on the web-sites of the institutes operating the station, and every station invented their own data format for the high-resolution measurements. There were some efforts to collect data from several stations, to make this data available on FTP servers, however none of these efforts could provide real-time data for all stations. In 2008 and 2009 an EU FP7 project (NMDB: real-time database for high-resolution Neutron Monitor measurements, http://nmdb.eu) was funded by the European Commission, and a new database was set up by several Neutron Monitor stations in Europe and Asia to store high-resolution data and to provide access to the data in real-time (i.e. less than five minute delay). By storing the measurements in a database, a standard format for the high-resolution measurements is enforced. This database is complementary to the WDCCR, as it does not (yet) provide all historical data, but the creation of this effort has spurred a new collaboration between Neutron Monitor scientists worldwide, (new) stations have gone online (again), new projects are building on the results of NMDB (SEPSever, HESPERIA), new users outside of the Cosmic Ray community are starting to use NM data for new applications like soil moisture measurements using Cosmic Rays. These applications are facilitated by the

easy access to the data with the http://nest.nmdb.eu interface that offers access to all NMDB data for all users.