MON-01

Linking Solar to Primordial and Galactic Composition

Johannes Geiss[1]

[1]*International Space Science Instiute*

Matter and energy content of the universe control its geometry and expansion, as well as the building of large scale structures. In the early universe, at the time of primordial nucleosynthesis, cosmic expansion was dominated by relativistic particles. Afterwards, during the period of stellar nucleosynthesis, Dark Matter contributed most of the universal energy density, until several Gigayears ago, the expansion began to speed up due to the growing influence of "Dark Energy".
Although Baryonic Matter never contributed more than ~20 percent of the universal density, investigation of its evolving composition remains indispensable for studying the physical nature of the universe. Abundances of the lightest nuclides not only give a precise value for the universal baryon/photon ratio, but they also provide information on other forms of matter.
Our concepts of nucleosynthesis are largely based on abundance measurements in the solar system. Chemical and isotopic analyses of meteorites, composition measurements in the solar wind and Jupiter, and solar spectroscopy and seismology, have yielded the abundances of nearly 300 nuclides in the Protosolar Cloud. This cloud represents a sample of Galactic matter frozen-in (in terms of nuclear evolution) 4.6 Gyr ago. Isotopic data from meteorites give no evidence for an exceptional nucleosynthetic history of solar system matter. Therefore, comparison of the composition in the Protosolar Cloud and the Galactic interstellar medium should lead to valid conclusions concerning the chemical evolution in the Galaxy during the last several Gyr. This evolution is not only determined by the stars inside the Milky Way, but also by infall of matter into the Galaxy and large-scale transport and loss of matter caused by fountains and Galactic winds.

Linking primordial to solar composition

Tutorial Talk

MON-02

THE EVOLUTION OF THE LIGHT ISOTOPES IN THE GALAXY

Nikos Prantzos[1]

[1]*Institut d'Astrophysique de Paris, France*

The light and fragile isotopes, from D to B11, are, in general, destroyed in stellar interiors (with the exception of robust He4). It is currently thought that D, He3 and He4 are essentially produced during the Big Bang, while the LiBeB isotopes are produced through cosmic ray (CR) interactions. I will review the present status of our understanding of light element evolution in the Milky Way, in the light of recent observational data. I will discuss, in particular: the degree of astration of D; the small stellar production of He3 ; the amount of primordial Li7 ; the evolution of Be and its implications for CR composition; the possibility of stellar production for B11 (and Li7); and the recent hints for a pre-galactic production of Li6.

Linking primordial to solar composition

Tutorial Talk

MON-03

Constraining primordial D/H from in situ and other observations

David Tytler[1]

[1] *UC San Diego, La Jolla, CA, USA*

Three methods of measuring the mean cosmological density of baryons now agree within about 10 to 30%: the cosmic microwave background, the D/H ratio using Standard Big Bang Nucleosynthesis, and the Lyman-alpha absorption from neutral Hydrogen in the intergalactic medium. Using this baryon density, Standard Big Bang Nucleosynthesis predicts precisely the D/H observed to QSOs. However it also predicts a factor 3 to 4 more 7Li than is seen in halo stars. There are theoretical models that can allow halo stars to destroy 7Li, but these models are challenged by both the amount of destruction and the lack of variation amongst stars with different mass. The baryon density also predicts systematically more 4He that most measurements over the last 20 years. We review the measurements of D in detail, we mention new measurements of 6Li and we mention possible modifications to BBN that might explain the tension between D, He and Li.

Linking primordial to solar composition

Invited Talk

MON-04

3He/H measurements

Thomas Bania[1]

[1]*Institute for Astrophysical Research, Department of Astronomy, Boston University, Boston, USA*

We are making precise determinations of the abundance of the light isotope of helium, 3He. The 3He abundance in Milky Way sources impacts stellar evolution, chemical evolution, and cosmology. The abundance of 3He is derived from measurements of the hyperfine line of 3He+ which has a rest wavelength of 3.46 cm (8.665 GHz). As with all the light elements, the present interstellar 3He abundance results from a combination of Big Bang Nucleosynthesis (BBNS) and stellar nucleosynthesis. We are measuring the 3He abundance in Milky Way H II regions and planetary nebulae (PNe). The source sample is currently comprised of 60 H II regions and 6 PNe. H II regions are examples of zero-age objects which are young relative to the age of the Galaxy. Therefore their abundances chronicle the results of billions of years of Galactic chemical evolution. PNe probe material which has been ejected from low-mass (M ≤ 2M_) to intermediate-mass (M □ 2−5M_) stars to be further processed by future generations. Because the Milky Way ISM is optically thin at centimeter wavelengths, our source sample probes a larger volume of the Galactic disk than does any other light element tracer of Galactic chemical evolution. The sources in our sample possess a wide range of physical properties (including object type, size, temperature, excitation, etc.). The 3He abundances we derive have led to what has been called “The 3He Problem”. Here we summarize the current status of the 3He experiment. We report on new observational results obtained with the NRAO Very Large Array (VLA), NRAO Green Bank (GBT), and NAIC Arecibo telescopes.

Linking primordial to solar composition

Invited Talk

MON-05

Dark Matter Searches

Klaus Pretzl[1]

[1]*Laboratorium für Hochenergiephysik, Universität Bern*

According to our present knowledge the matter energy budget of the universe consists of 74% dark energy, 22% dark matter and 4% baryonic matter. While the dark energy cannot be detected directly, searches for dark matter are performed with space born and earth bound detection devices assuming that the dark matter consists of weakly interacting massive particles, the socalled WIMP's. An overview of the present experimental situation is given.

Linking primordial to solar composition

Invited Talk

MON-06

Comets and Chemical Composition

Sofie N. Delanoye[1], Johan De Keyser[1]

[1]*Belgian Institute for Space Aeronomy (BIRA – IASB), 1180 Brussels, Belgium*

It is commonly believed that comets are made of primordial material. Contrary to meteorites, the other primordial bodies in our Solar System, comets contain also volatile components. As a consequence, they can reveal more information about the origin of our Solar System. Therefore, the ESA Rosetta mission has as purpose to learn more about comets and our Solar System by studying its target, comet Churyumov-Gerasimenko, on its journey to the Sun.
The mass spectrometers ROSINA DFMS and RTOF will measure the chemical composition of the coma. To interpret the future data and to obtain information on the variability of the cometary composition as a function of the distance to the Sun and to the nucleus, models of the chemistry in a cometary coma will be necessary. These models can also help to derive the composition of the nucleus from the coma composition.
However, programming the chemistry of a cometary coma is extremely complex due to the large number of species and reactions involved. Moreover, such a program needs to be very flexible since it is often necessary to change the species, reactions and reaction rates. Therefore, we have developed software to manage a database of species and reactions and to generate code automatically to compute source/loss balances. This database includes also the data from the UMIST database and the ion-molecule reactions collected by V. G. Anicich. The result is an enormous source of chemical reactions that can be used in chemical models, but it can also be useful to learn more about the influence of reaction rates, their uncertainties, … Moreover, the application of the database is not limited to comets.

Linking primordial to solar composition

Contributed Talk

MON-07

Elemental Abundances of the Bulk Solar Wind: Analyses from Genesis and ACE

Daniel B. Reisenfeld[1], Roger C. Wiens[2], Donald S. Burnett[3], Charles M. Hohenberg[6], Alexander Meshik[6], Robert O. Pepin[7], Richard H. Becker[7], Amy Jurewicz[5], James M. Raines[4], Thomas H. Zurbuchen[4]

[1]Dept. of Physics & Astronomy, University of Montana, 32 Campus, MT 59812, [2]Space Science and Applications, Los Alamos National Laboratory, ISR-1, MS D466, NM 87545, [3]Geology & Planetary Sciences, Caltech, MS 100-23, Pasadena, CA 91125, [4]Atmospheric, Oceanic, and Space Sciences, University of Michigan, MI 48109, [5]Center for Meteorite Studies, Arizona State University, P.O. Box 872504, AZ 85287, [6]Laboratory for Space Sciences, Physics Department, Washington University, MO 63130, [7]School of Physics & Astronomy, University of Minnesota, 116 Church St. SE, MN 55455

The NASA Genesis mission collected solar wind on ultrapure materials between November 30, 2001 and April 1, 2004. Here we report elemental abundance values of the light noble gases (He, Ne, and Ar) and the abundant metals, Mg and Fe, from laboratory analysis of Genesis collector materials. We compare the Genesis abundance values to elemental composition data from the ACE/SWICS spectrometer, finding agreement to within measurement uncertainty (with the possible exception of Ne). We apply the Genesis and ACE data to an analysis of the first ionization potential (FIP) fractionation of the solar wind, and compare this to the FIP analysis of Ulysses data from the previous solar cycle. We find agreement between all data sets (again, with the possible exception of Ne), indicating that the fractionation state of the solar wind is relatively stable.
In addition to samples exposed continuously throughout the Genesis collection period, samples were collected on arrays exposed for specific solar wind regimes (coronal hole, interstream and CME), as determined by an onboard algorithm. The algorithm used real-time spectrometer measurements of the solar wind proton density, velocity and temperature, the alpha/proton ratio and the angular distribution of suprathermal electrons to determine regime type. To collect regime-specific samples that more accurately reflect composition at the source point within the solar atmosphere, hysteresis was built into the algorithm to partially compensate for degradation of the correlation between solar wind speed and composition caused by hydrodynamic evolution of the flow between the photosphere and Genesis. We present an analysis using data from the ACE/SWICS spacecraft showing the success of these compensation efforts.

Linking primordial to solar composition, Solar sources and fractionation processes

Contributed Talk

MON-08

THE COMPOSITION OF GIANT PLANET ATMOSPHERES

Tobias Owen[1]

[1]Inst for Astronomy, University of Hawaii, Honolulu, Hawaii USA

The giant planets of our solar system display a surprising fundamental unity despite masses that vary by a factor of 22 and a ratio of carbon to hydrogen in their atmospheres that varies from 4 x solar to ~40 x solar. This atmospheric variation can be explained by the presence of a total quantity of heavy elements that is approximately 10 ± 2 ME for each planet. The atmosphere of Jupiter provides our best information about the probable nature of the heavy element complement as we have the most information about Jupiter's composition, thanks to the Galileo Probe. It appears that all of the heavy elements on Jupiter were collected in nearly solar proportions relative to each other and share approximately the same enrichment as carbon (4 ± 2) relative to hydrogen compared to solar abundances. This conclusion is reinforced by studies of the nitrogen isotopes in Jupiter's ammonia and has the further consequence that the heavy elements must have reached Jupiter in the form of low temperature (< 30 K) icy planetesimals. The results for Jupiter's atmosphere have obvious implications for the other giants, where only C/H has been determined this far. These implications can be easily tested by future atmospheric probes. Indeed, the lesson from Jupiter is that a probe into the atmosphere of a giant planet is equivalent in many ways to sample return from a terrestrial planet.

Planetary samples

Tutorial Talk

MON-09

Pre-solar grains found in meteorites and their compositions

Ulrich Ott[1]

[1]*Dept. of Geochemistry, Max-Planck-Institute for Chemistry, D-55128 Mainz, Germany*

One of the windows providing information on solid matter outside the Solar System is the study of circum-stellar (pre-solar) condensates preserved in primitive meteorites and interplanetary dust. Compared to remote observation, their study – conducted in the laboratory with state-of-the-art analytical techniques – offers unprecedented accuracy, although on a rather specific sample of matter. Pre-solar minerals identified include diamond, silicon carbide, graphite, refractory oxides (corundum, spinel, hibonite) and silicon nitride. These were found following the lead of isotopically unusual noble gases and are resistant to acids, a fact which is used in their isolation. Silicates, probably the most abundant among interstellar grains, have only recently been identified by in-situ search using the most modern SIMS equipment.
Central to the identification of circum-stellar minerals is the determination of isotopic compositions, which in many elements strongly deviate from the normal (Solar System) composition. In turn, the results from isotopic studies are also those that bear strongest on astrophysics. They allow pinpointing the grains' stellar sources among which Red Giants play a prominent role. Grain data provide important information on, e.g., oxygen isotopes and ^{26}Al in these stars. They also yield precise abundance patterns produced in the s-process. Compared to grains from Red Giants, grains with an inferred supernova origin are surprisingly rare. Those that have been found ("SiC-X" grains, diamonds) suggest that for the synthesis of heavy elements still another type of neutron capture ("neutron burst") with characteristic isotopic patterns may be important besides the classic s- and r-processes. An important aspect to put the results into context may be the apparently young age of the grains at the time they entered the Solar System.

Planetary samples

Invited Talk

MON-10

Solar abundance of O and Ne derived from solar wind observations

Peter Bochsler[1]

[1]*Physikalisches Institut, University of Bern, 3012 Bern/Switzerland*

Recently, a revision of the solar abundances of C, N, and O to substantially lower values (Asplund et al. 2005) has led to a controversy on solar opacities in the standard model and to the suggestion to revise the solar abundance of neon upward by as much as a factor of 1.6 (Bahcall et al. 2005) leading to enhanced solar neon/oxygen abundance ratios by a factor of 3. Neon/oxygen abundance ratios have been measured for over two decades in the solar wind under many circumstances and with several instruments. The solar wind ratio is 0.14 with a conservative error estimate of ± 0.03, consistent with the coronal value derived from solar energetic particle measurements (0.153 ± 0.004). The helium/neon abundance ratio in the solar wind has been well determined under several occasions with the Apollo foils (Geiss et al. 2004) and yielded an average helium/neon elemental abundance ratio of 530. The solar helium abundance is known precisely from helioseismological observations to be Y=0.245 ± 0.005 (Gough 2006). From these measurements we estimate the solar abundances of neon and oxygen, based entirely helioseismological on observations of helium and on solar wind abundance ratios, completely independent from photospheric determinations.
From the variability of the helium/oxygen- and helium/neon-ratio in the solar wind and from theoretical considerations we conclude that the helium/neon-ratio in the outer solar convective zone is 670 ± 200. Our best estimate of the solar neon abundance in logarithmic dex-units is [Ne]=8.08 ± 0.12, and the oxygen abundance amounts to [O]=8.90 ± 0.13.

Solar sources and fractionation processes

Contributed Talk

MON-11

Pickup Ions from Solar Wind - Dust Interactions in the Heliosphere: The Inner and Outer Sources

Nathan Schwadron[1], **George Gloeckler[2,3]**

[1]Dept of Astronomy, Boston University, Boston, MASS, 02215, USA, [2]Dept of Atmospheric, Oceanic and Space Science, Ann Arbor, MI, 48109, USA, [3]Dept of Physics and ITSP, University of Maryland, College Park, MD, USA

The combination of recent observational and theoretical work has completed the catalog of at least the major sources of Heliospheric Pickup Ions (PUIs). These PUIs are the seed population for anomalous cosmic rays (ACRs), which are accelerated to high energies at or beyond the termination shock (TS). For elements with high First Ionization Potentials (high-FIP atoms: e.g., H, He, Ne, etc), the dominant source of PUIs and ACRs is from neutral atoms that drifts into the heliosphere from the local interstellar medium (LISM) and, prior to ionization, are influenced primarily by solar gravitation and radiation pressure (for H). After ionization, these interstellar ions are picked up by the solar wind, swept out, and are either accelerated near the TS or beyond it. Elements with low first ionization potentials (low-FIP atoms: e.g., C, Si, Mg, Fe, etc) are also observed as PUIs by Ulysses and as ACRs by Wind and Voyager. But the low-FIP composition of this additional component reveals a very different origin. Low-FIP interstellar atoms are predominantly ionized in the LISM and therefore excluded from the heliosphere by the solar wind. Remarkably, a low-FIP component of PUIs was hypothesized by Banks all the way back in 1971, but was not observed directly until Geiss and Gloeckler discovered the Inner Source of PUIs in Ulysses/SWICS measurements in 1996. The leading concept for the generation of Inner Source PUIs involves an effective recycling of solar wind on grains near the Sun, as originally suggested by Banks. Based on this recycling process, the Inner Source should reveal a composition similar to the solar wind, which is consistent with observations. The difficulty, as pointed out by Wimmer-Schweingruber and Bochsler, is that sputtering should be more efficient than solar wind recycling, but sputtering would yield a very different Inner Source composition (essentially devoid of Ne), which is highly inconsistent with observations. These issues remain as puzzles in understanding the Inner Source. Voyager and Wind also observe low-FIP ACRs, and a grain-related source appears likely and necessary. Two concepts have been proposed to explain these low-FIP ACRs: the first concept involves the acceleration of the Inner Source of PUIs, and the second involves a so-called Outer Source of PUIs generated from solar wind interaction with the large population of grains in the Kuiper Belt. We review here the observational and theoretical work over the last decade that shows how solar wind and heliospheric grains interact to produce pickup ions, and, in turn, anomalous cosmic rays. Though observations show definitive evidence for low-FIP populations of pickup ions and anomalous cosmic rays, our understanding of the details of solar wind-grain interactions remains sketchy. Direct observations of PUI populations near the Sun and in the outer heliosphere are needed to more firmly resolve our understanding of solar wind-grain interactions in the heliosphere.

Cosmic rays

Contributed Talk

TUE-01

The New Solar Chemical Composition

Nicolas Grevesse[1]

[1]*Institut d'Astrophysique et de Geophysique and Centre Spatial de Liege Universite de Liege, Belgium*

We review our current knowledge of the solar chemical composition as determined from photospheric absorption lines and compare it with results obtained from other solar and solar system sources. In particular we describe the recent significant downward revisions of the solar photospheric abundances, mostly C, N and O, as a result of the use of a 3D hydrodynamical model of the solar atmosphere instead of the classical 1D hydrostatic models adopted since decades.

We shall analyse the various impacts of these new results in comparison with data from other sources. While resolving a number of problems, the new 3D-based solar element abundances also pose serious challenges, most notably for the standard solar model.

Solar sources and fractionation processes

Tutorial Talk

TUE-02

Solar Composition and Fractionation: the Solar Wind and Solar Energetic Particles

Edward Stone[1]

[1]220-47 Downs Laboratory, California Institute of Technology, Pasadena, CA 91125 USA

The solar wind and solar energetic particles (SEPs) provide samples of solar matter with elemental and isotopic abundances that have been fractionated by the physical processes underlying their origin and propagation. Two distinct SEP acceleration processes have been identified. Impulsive SEPs are samples of hot (~10^7 K) flare matter accelerated by small impulsive flares and exhibit large enhancements in ^{3}He and heavy ions arising from the impulsive acceleration process. Gradual SEPs are samples of suprathermal ions in the corona and solar wind that are accelerated by shocks driven by large coronal mass ejections. Variations in the elemental and isotopic abundances of gradual SEPs result from differences in the sources of suprathermal ions and from fractionation during shock acceleration and interplanetary propagation. Impulsive and gradual SEPs also exhibit a fractionation relative to photospheric abundances that depends on the first ionization potential (FIP) and is similar, but not identical, to the FIP-fractionation in the solar wind. An overview of the observational and theoretical understanding of these processes and of the derived solar abundances will be presented.

Solar sources and fractionation processes

Tutorial Talk

TUE-03

Spectroscopic Measurement of Coronal Compositions

Uri Feldman[1,2], Kenneth G. Widing[3,2]

[1]Artep Inc. 2922 Excelsior Spring Circle, Ellicott City, Columbia MD 21042, [2]E.O. Hulburt Center for Space Research, Naval Research laboratory Washington DC 20375-5352 USA, [3]Computational Physics Inc. Fairfax VA 22031

Although the elemental composition in all parts of the solar photosphere appears to be the same this is clearly not the case with the solar upper atmosphere. Spectroscopic studies show that in the corona elemental composition along solar equatorial regions is usually different from polar regions; composition in quiet Sun regions is often different from both coronal hole and active region compositions and the transition region composition is frequently different from the coronal composition at the same spatial location. In the course of the talk issues regarding the composition and time variability of plasmas in the solar upper atmosphere within h? 1.5 R? will be discussed.

Solar sources and fractionation processes

Invited Talk

TUE-04

Solar Gamma-Ray Spectroscopy

Ronald Murphy[1]

[1]*Naval Research Laboratory, Washington DC, USA*

Interactions of ions accelerated in solar flares produce gamma-ray lines and continuum and neutrons. These emissions contain a rich set of observable quantities that provides information about both the accelerated ions and the environment where the ions are transported and interact. Ion interactions with the various nuclei present in the ambient medium produce gamma-ray lines at unique energies. How abundance information is extracted from the measurements is discussed and results from analyses of a number of solar flares are presented. The analyses indicate that the composition of the ambient gas where the ions interact (typically at chromospheric densities) is different from that of the photosphere and more like the composition of the corona, exhibiting similar low-FIP elemental enhancements. Evidence for increased Ne/O and the photospheric 3He abundance is also discussed.

Solar sources and fractionation processes

Invited Talk

TUE-05

The Composition of the Solar Wind

George Gloeckler[1], Johannes Geiss[2]

[1]Dept. of AOSS, University of Michigan, Ann Arbor, MI 48109-2143, USA, [2]International Space Science Institute 3012 Bern, Switzerland

The solar wind charge state and elemental composition has been measured with the Solar Wind Ion Composition Spectrometers (SWICS) on Ulysses and ACE for a combined period for almost 25 years. This most extensive data set includes all varieties of solar wind flows and extends over more than one solar cycle. With SWICS the abundance of all charge states of He, C, N, O Ne, Mg, Si, S, Ar and Fe can be reliably determined (when averaged over sufficiently long time periods) under any solar wind flow conditions. Here we report primarily on results of our detailed analysis of the elemental composition and ionization states of the most unbiased solar wind from the polar coronal holes, and of the in-ecliptic wind sorted by solar wind speed. In particular, we will provide accurate values for the ^{20}Ne abundance, and of S, Ca and Ar as a function of solar wind speed. The systematics of the elemental composition and charge state distributions will be discussed.

Solar sources and fractionation processes

Invited Talk

TUE-06

Acceleration and Composition of Solar Wind Suprathermal Tails

Len Fisk[1]

[1]*Dept. of Atmospheric, Oceanic and Space Sciences, University of Michigan, Michigan 48109 USA*

One of the more significant observations in heliospheric physics in recent years has been the ubiquitous suprathermal tails, which appear to have the same spectral index of -5, when expressed as a distribution function. Moreover, this same spectral shape occurs for particles accelerated at the termination shock of the solar wind. A theory is presented for why this unique spectral shape occurs. It is argued that the particles are stochastically accelerated in compressional turbulence, and that an equilibrium is established when the particles receive energy from and do an equal amount of work on the turbulence. The suprathermal tails are formed by a process analogous to turbulent cascades. With these concepts it is possible to specify many aspects of the acceleration, including the energy at which the tails form and end, the pressure in the tails, and the likely composition of the accelerated particles.

Solar sources and fractionation processes

Invited Talk

TUE-07

Solar and Solar-Wind Composition Results from the GENESIS Mission

Roger Wiens[1], Donald Burnett[2], Charles Hohenberg[3], Alex Meshik[3], Robert Pepin[4], Richard Becker[4], Amy Jurewicz[5], Daniel Reisenfeld[8], Rainer Wieler[6], Ansgar Grimberg[6], Veronika Heber[6], Kevin McKeegan[7]

[1]Los Alamos National Laboratory, MS D466, Los Alamos, NM 87545 USA, [2]Geological & Planetary Sciences, Caltech, MS 100-23, Pasadena, CA 91125 USA, [3]Physics Department, Washington University, St. Louis, MO 63130 USA, [4]School of Physics & Astronomy, University of Minnesota, Minneapolis, MN 55455 USA, [5]Center for Meteorite Studes, Arizona State University, MC 1404, Tempe, AZ 85287 USA, [6]Isotope Geology NO C61, ETH, CH-8092 Zuerich, Switzerland, [7]Department of Earth & Space Sciences, UCLA, Los Angeles, CA 90095-1567 USA, [8]Department of Physics & Astronomy, U. of Montana, MS 1080, 32 Campus Dr., Missoula, MT 59812

The GENESIS mission returned samples of solar-wind to Earth in September, 2004 for ground-based analyses of solar-wind composition, particularly for isotope ratios. Substrates, consisting mostly of high-purity semiconductor materials, were exposed to the solar wind at L1 from December 2001 to April 2004. In addition to a bulk sample of the solar wind, separate samples of coronal hole, interstream, and coronal mass ejection material were obtained. While many of the substrates were broken upon landing due to the failure to deploy the parachute, a number of results have been obtained, and there is optimism that the primary science objectives will all be met. These include noble gas (He, Ne, Ar, Kr, Xe) isotope ratios in the bulk solar wind and in different solar-wind regimes, and the nitrogen and oxygen isotope ($^{18}O/^{17}O/^{16}O$) ratios to high precision.

The greatest successes to date have been with the noble gases. Light noble gases from bulk solar wind samples have been analyzed, and neon results were obtained at Wash. U. for separate solar-wind regimes. The regime compositions are identical within ±0.3%, suggesting the relative absence of isotopic fractionation by Coulomb drag on a time-integrated basis, at least for neon. Neon results from closed system stepped etching of bulk metallic glass have revealed the nature of isotopic fractionation as a function of depth, which in lunar samples have for years deceptively suggested a separate solar component (Grimberg et al, this meeting). Analysis of heavy noble gases is currently in progress at Wash. U.

Elemental ratios of low FIP elements have been measured using secondary ion mass spectrometry (SIMS). The current best estimate from GENESIS of the solar-wind Mg/Fe ratio is 0.78, in good agreement with spacecraft solar-wind data and photospheric absorption lines.

Solar-wind nitrogen and oxygen isotope ratios have not yet been measured. The talk will also include a status report on these and other planned measurements.

Solar sources and fractionation processes

Invited Talk

TUE-08

Stardust Results - Elemental and Isotopic Composition

George Flynn[1], Kevin McKeegan[2]

[1]Dept. of Physics, SUNY-Plattsburgh, Plattsburgh, NY 129901 USA, [2]Department of Earth and Space Sciences, UCLA, Los Angeles, CA 90095

The NASA Stardust spacecraft flew through the coma of comet Wild-2 at a speed of ~6 km/sec in January 2004.
Wild-2 is a short-period comet, believed to have formed in place in the Kuiper Belt, beyond the orbit of Neptune. The comet samples were delivered to Earth on January 15, 2006 and are currently being analyzed by Preliminary Examination Teams that include over 200 participants in laboratories on 4 continents. Dust was collected from the coma of Wild-2 by high-speed impact into two target materials: Al-foil surfaces and low-density silica aerogel. The impact craters in the Al-foils contain residue from the comet dust. Particles which impacted the aerogel received a more gentle deceleration, producing a damage “track,” typically several hundred times the particle diameter, with debris being deposited along the track walls. Frequently a particle is found at the end of the track. Both the residue in the craters and the material along the tracks have been analyzed to determine the chemical and isotopic compositions of the dust collected by Stardust at Wild-2. The analysis of dust from Wild-2 provides the first opportunity to compare material known to derive from the outer part of the solar system with material that formed in the inner solar system, sampled by primitive meteorites. This report will summarize what has been learned regarding elemental and isotopic compositions of a subset of collected particles and impact debris sampled by the Bulk Composition and Isotope Preliminary Examination Teams during its 6 month investigation.

Planetary samples

Invited Talk

TUE-09

Abundances of light elements in the Milky Way

Raffaele Gratton[1]

[1]*Osservatorio Astronomico di Padova, INAF, Vicolo dell'Osservatorio 5, 35122 Padova, Italy*

Abundances of light elements (^{6}Li, ^{7}Li, ^{9}Be, ^{11}B) in the Milky Way are reviewed, with special emphasis on metal poor stars. Observational concerns are discussed. The use of ^{7}Li as a cosmological probe and of ^{9}Be as a chronometer for the early evolution of our Galaxy are discussed.

Cosmic rays

Invited Talk

TUE-10

Isotopic Composition of the Solar System Inferred from in-situ Spacecraft Measurements

Reinald Kallenbach[1]

[1]*International Space Science Institute, Hallerstrasse 6, CH-3012 Bern, Switzerland*

Isotopic signatures of volatile elements are tracers for evolutionary processes during the formation of the Sun and the planets from an interstellar molecular cloud. These processes cause isotopic fractionation through chemical reactions such as ion-molecule and photochemical reactions in the protoplanetary accretion disk, nuclear processes and gravitational settling inside the Sun and in its atmosphere, plasma processes in the source regions of the solar wind, gravitational escape of gases from planetary atmospheres exposed to the solar wind and solar radiation, thermodynamic processes, a variety of accretion and adsorption processes and mixing of material from the interstellar environment with the material of the evolving solar system. A wealth of data on isotopic ratios has been derived from laboratory experiments on planetary samples, interplanetary dust particles, and on a variety of meteorites. Spectroscopic measurements with ground-based and spaceborn telescopes have added to the set of data.
An overview of the data set on the isotopic composition of solar system materials is given. The by far largest reservoir of solar material and consequently the best reference for the isotopic composition of the solar system in an astrophysical context is the Sun itself. Its isotopic composition can precisely be determined by in-situ measurements of the solar wind composition, if the fractionation strength of the solar wind acceleration processes is small. This fractionation strength is constrained by comparison of the isotopic compositions in different solar wind regimes inferred from in-situ spacecraft measurements with instrumentation on board SOHO and ACE. The newest values on the nitrogen and oxygen isotopic composition of the solar wind are given. The results are discussed in view of the evaluation of data from solar-wind implanted Genesis samples.

Solar sources and fractionation processes

Invited Talk

TUE-11

Coronal Effects on FIP Fractionation of the Solar Wind?

Thomas Zurbuchen[1]

[1]*Dept. of Atmospheric, Oceanic and Space Sciences, University of Michigan, Michigan 48109 USA*

The observed solar wind elemental composition shows fractionation relative to the First Ionization Potential (FIP). The quantitative amount of FIP fractionation is highly dependent on solar wind regime, but it has a substantial variability within each regime. We analyze this variability and find that it is correlated to the ionic charge state of the solar wind, which is set in the corona at around 1 MK or higher. This is highly unexpected, because FIP fractionation happens around 10,000 K, where the solar plasma undergoes the first ionization.
We address this finding using theoretical models of FIP fractionation of the corona and the solar wind.

Solar sources and fractionation processes

Invited Talk

WED-01

Solar Elemental Composition based on Studies of Solar Energetic Particles

C.M.S. Cohen[1], R.A. Mewaldt[1], R.A. Leske[1], A.C. Cummings[1], E.C. Stone[1], M.E. Wiedenbeck[2], T.T. von Rosenvinge[3]

[1]California Institute of Technology, Pasadena, CA USA, [2]Jet Propulsion Laboratory, Pasadena, CA USA, [3]NASA/Goddard Space Flight Center, Greenbelt, MD USA

In the past, the well-determined abundances of solar energetic particle (SEP) events have been used to infer the composition of the solar corona, particularly for rare elements such as P, Cr, and Mn, which are not routinely measured in the solar wind or spectroscopically in the corona. The assumption that the SEP composition closely mirrors that of the corona for large SEP events has been re-examined in light of the detailed measurements spanning several decades in energy from the Ultra Low Energy Isotope Spectrometer (ULEIS) and the Solar Isotope Spectrometer (SIS) on the ACE spacecraft. It is now clear that in many large SEP events the elemental composition is energy dependent, resulting from different spectral forms of the elements when plotted as a function of energy per nucleon. Deriving coronal abundances first requires understanding the effects of acceleration and transport on SEPs. Using data from ULEIS and SIS, we present examples of the variability of the elemental composition with energy and suggest they can be understood in terms of diffusion from the acceleration region near the interplanetary shock. We illustrate this by plotting the spectra as a function of rigidity which removes much of the compositional variations and allows approximately constant abundance ratios to be determined. We also present examples where the energy dependence is harder to explain and briefly review current hypotheses.

This work was supported by NASA at Caltech (under grant NAG5-12929), JPL, and GSFC.

Solar sources and fractionation processes

Invited Talk

WED-02

The Solar Isotopic Composition as Determined Using Solar Energetic Particles

R. A. Leske[1], R. A. Mewaldt[1], C. M. S. Cohen[1], A. C. Cummings[1], E. C. Stone[1], M. E. Wiedenbeck[2], T. T. von Rosenvinge[3]

[1]California Institute of Technology, Mail Code 220-47, Pasadena, CA 91125 USA, [2]Jet Propulsion Laboratory, MS 169-327, Pasadena, CA 91109 USA, [3]NASA/Goddard Space Flight Center, Code 661, Greenbelt, MD 20771 USA

Solar energetic particles (SEPs), like the solar wind, provide a direct sample of the Sun from which solar composition may be determined. Using high-resolution measurements from the Solar Isotope Spectrometer (SIS) onboard NASA's Advanced Composition Explorer (ACE) spacecraft, we have studied the isotopic composition of SEPs at energies =20 MeV/nucleon in large SEP events. We present SEP isotope measurements of C, O, Ne, Mg, Si, S, Ar, Ca, Fe, and Ni made in more than 40 large events from the launch of ACE in late 1997 to the present. The isotopic composition is highly variable from one SEP event to another due to mass fractionation that presumably occurs during the acceleration and/or transport of these particles. We show that various isotopic and elemental enhancements are correlated with each other, discuss the corrections used to account for the compositional variability, and obtain estimated solar isotopic abundances. We compare the solar values and their uncertainties inferred from SEPs with those that are available from solar wind and meteoritic measurements and find generally good agreement.

This work was supported by NASA at Caltech (under grant NAG5-12929), JPL, and GSFC.

Solar sources and fractionation processes

Invited Talk

WED-03

Interpreting the Composition Large Solar Energetic Particle Events

R. A. Mewaldt[1], C. M. S. Cohen[1], G. M. Mason[2], A. C. Cummings[1], M. I. Desai[3], R. A. Leske[1], E. C. Stone[1], T. T. von Rosenvinge[4], M. E. Wiedenbeck[5]

[1]Caltech, Pasadena CA 91125, USA, [2]JHU/APL, Laurel MD 20723, USA, [3]Southwest Research Institute, San Antonio TX 78238, USA, [4]NASA/Goddard Space Flight Center, Code 661, Greenbelt MD 20771 USA, [5]Jet Propulsion Laboratory MS169-327, Pasadena, CA 91109 USA

We review evidence regarding the composition of particles accelerated in large, gradual solar energetic particle (SEP) events. According to the two-class paradigm in place at the start of solar cycle 23, impulsive SEP events accelerate heated flare material, while gradual SEP events are accelerated out of the solar wind by shocks driven by fast coronal mass ejections (CMEs). However, data from solar cycle 23 have shown that energetic ions in gradual events often include composition signatures associated with impulsive events, including enrichments in 3He, heavy elements such as Fe, and ionic charge states indicative of ~10 MK temperatures. In addition, gradual SEP events differ in composition from bulk solar wind in several key respects, including their FIP fractionation patterns, implying that solar wind is not the principal seed population for these events. Several lines of evidence show that CME-driven shocks accelerate principally suprathermal ions with velocities several times that of the solar wind. The suprathermal pool incorporates ions from impulsive solar flares and previous gradual events, CIR events, pickup ions, CME ejecta, and the suprathermal tail of the solar wind. This paper reviews evidence for the sources of ions accelerated in gradual SEP events, considers the composition and available densities of suprathermal ions, and describes models that attempt to account for the surprisingly variable composition of gradual SEP events. We find that below ~1 MeV/nucleon most events are Fe-rich compared to the average SEP composition at ~10 MeV/nucleon. Large, gradual SEP events above 10 MeV/nucleon occur mainly during periods when the intensity of suprathermal ions in the inner heliosphere is high due to flare activity, but also in large part due to the remnants of previous gradual SEP events. The composition at higher energies is more variable because of spectral effects.

Solar sources and fractionation processes

Invited Talk

WED-04

What determines the composition of SEPs in gradual events?

Martin A. Lee[1]

[1]Space Science Center, Institute for the Study of Earth, Oceans and Space, Univ. of New Hampshire

Gradual events are evidently accelerated by coronal/interplanetary shocks driven by coronal mass ejections. This talk addresses the different factors which determine the composition of the accelerated ions. The first factor is the set of available seed populations including the solar wind core and suprathermal tail, remnant impulsive events from preceding solar flares, and remnant gradual events. The second factor is the fractionation of the seed ions by the injection process, that is, what fraction of the ions are extracted by the shock to participate in diffusive shock acceleration. Injection is a controversial topic since it depends on the detailed electromagnetic structure of the shock transition and the transport of ions in these structured fields, both of which are not well understood or determined theoretically. The third factor is fractionation during the acceleration process due to the dependence on the mass/charge ratio of ion transport in the turbulent electromagnetic fields adjacent to the shock. Of crucial importance in the last two factors is the magnetic obliquity of the shock. The form of the proton-excited hydromagnetic wave spectrum is also important. Finally, more subtle effects on ion composition arise from the superposition of ion contributions over the time history of the shock along the observer's magnetic flux tube, and the sequence of flux tubes sampled by the observer.

Solar sources and fractionation processes

Invited Talk

WED-05

3He-rich Solar Energetic Particle Events

Glenn Mason[1]

[1]*Johns Hopkins University / Applied Physics Laboratory, Laurel, MD 20723, USA*

Solar energetic particle events with enormous (up to 10^4) enrichments of the rare isotope 3He were discovered in the 1970s. In addition to the 3He enrichment, these events show enhancements of heavier elements increasing with mass from a factor of ~10 for Fe/O, to several hundred for UH nuclei. The isotopic composition of these events is also enhanced towards higher masses, e.g., 22Ne/20Ne is enhanced by up to a factor of ~4 compared with solar system abundances. The ionization states of the ions are distinctly higher than for coronal material or for energetic particles observed in large solar particle events, evidence of a hot source or stripping of the ions. These events are closely associated with short duration electron events. Although many 3He-rich events have no obvious source on the Sun, others are associated with short duration ("impulsive") X-ray flares and Type-III radio emission, and a few are associated with narrow Coronal Mass Ejections (CMEs). Although the small size of the ion events makes it likely that many are below detection threshold, the association with Type-III bursts and impulsive electron events suggests that over the surface of the Sun, there are hundreds or even thousands of such events per year during the peak of the sunspot cycle. Indeed, 3He has been found to been present in the interplanetary suprathermal and energetic particle populations up to 90% of the time during solar maximum. Many theoretical mechanisms have been proposed to explain the mass fractionation, with resonance plasma heating theories being the most promising. Many new features of these events have been recently discovered using powerful new instruments on the ACE, SOHO, TRACE, RHESSI, and Wind spacecraft together with ground based observations. This review emphasizes compositional features of 3He-rich events, summarizes recent advances in theoretical modeling, and presents recent progress in identifying the solar source regions.

Solar sources and fractionation processes

Invited Talk

WED-06

The Seed Population for Heavy Ions in Large Solar Energetic Particle Events

Mihir I. Desai[1], G. M. Mason[2], C. M. S. Cohen[3], R. A. Mewaldt[3], S. M. Krimigis[2], R. E. Gold[2], J. E. Mazur[4], J. R. Dwyer[5]

[1]Southwest Research Institute, San Antonio, TX, 78238, USA, [2]The Johns Hopkins University, Applied Physics Laboratory, Laurel MD 20723, USA, [3]California Institute of Technology, Pasadena, CA 91125, USA, [4]The Aerospace Corporation, 15049 Conference Center Drive, CH3/210 Chantilly, VA 20151, [5]Florida Institute of Technology, Melbourne, FL 32901, USA

Large, CME shock-associated solar energetic particle (LSEP) events have long been assumed to accelerate coronal or solar wind material, and have been used to infer the composition of these material reservoirs. However, recent measurements on ACE have revealed that surprisingly, there are complex and unsystematic differences between the LSEP ion abundances and the solar wind, re-opening the question of the identity of the particle population being energized in these events. Using high-resolution mass spectrometers ULEIS and SIS on board ACE, we have surveyed the ion composition in 64 LSEP events of solar cycle 23. Our results show the following:

- The Fe spectra steepen at lower energies than O, a hallmark of shock acceleration.
- The rare isotope 3He is found in 46% of the events in quantities greatly enhanced over the corona or the solar wind.
- The low energy average Fe/O ratio is enhanced over coronal or solar wind values between factors of ~2-40 from one event to another.
- Heavy ion abundances from C-Fe show systematic M/Q-dependent enhancements when compared with those measured in the quiet corona.

Taken together, these results confirm the role of CME-driven shocks in energizing the particles up to ~60 MeV/nucleon, but also show that the seed population is not dominated by ions originating from the bulk corona or the thermal solar wind. Rather, it appears that the source material for CME-associated LSEP events originates predominantly from a suprathermal population with enriched heavy ion abundances that are remarkably similar to those seen in the smaller impulsive flare-related SEP events. These new results indicate that current LSEP models must take account of this dynamic suprathermal seed population as a critical pre-cursor to the CME shock acceleration processes.

Solar sources and fractionation processes

Invited Talk

WED-07

Early universe abundances

Hubert Reeves[1]

[1]CNRS, Paris, France

Geiss Celebration Talk

WED-08

Johannes Geiss: The humble Beginnings of an Octogenarian

Friedrich Begemann[1]

[1]*Max-Planck-Institut für Chemie, Mainz, Germany*

Geiss Celebration Talk

WED-09

Johannes Geiss' Investigations of the Composition Matter: Solar Wind, Interstellar Gas, Comets and the Inner Source

George Gloeckler[1]

[1]*University of Michigan, Ann Arbor, MI 48109-2143, USA*

Geiss is a world leader and foremost expert on measurements and interpretation of composition of matter that reveals the history, present state, and future of astronomical objects. He was first to measure the composition of the solar wind noble gases when in the late 1960s he flew his brilliant solar wind collecting foil experiments on the five Apollo missions to the moon. Always at the forefront of the art of composition measurements, he with his colleagues determined the isotopic and elemental composition of the solar wind using instruments characterized by innovative design that have provided the most comprehensive record of the solar wind composition under all solar wind conditions at all helio-latitudes. He discovered the „Inner Source“ and heavy interstellar pickup ions from which the composition of the neutral gas of the Local Interstellar Cloud is determined. Johannes Geiss played a key role both in the in-situ measurements of molecular ions in comets and the interpretation of these data. He and co-workers measured the composition of plasmas in the magnetospheres of Earth and Jupiter. I will highlight Johannes Geiss' many discoveries and seminal contributions to our knowledge of the composition of matter of the Sun, interstellar gas and heliospheric regions.

Geiss Celebration Talk

THU-01

Particle Acceleration at Interplanetary Shocks: Fractionation of SEP events

Gary P. Zank[1], Gang Li[1], Olga Verkhoglyadova[1]

[1]*IGPP, University of California, Riverside, CA 92521, USA*

Understanding the problem of particle acceleration at interplanetary shocks is assuming increasing importance, especially in the context of understanding the space environment. The basic physics was thought to have been established in the late 1970's and 1980's, but detailed interplanetary observations are not easily interpreted in terms of the simple original models of particle acceleration at shock waves. Three fundamental aspects make the interplanetary problem much more complicated than the typical astrophysical problem: the time dependence of the acceleration and the solar wind background; the geometry of the shock; and the long mean free path for particle transport away from the shock wave. These aspects have been explored in the context of proton acceleration at interplanetary shocks. Understanding this is of importance to understanding the acceleration of heavy ions at interplanetary shocks since wave excitation, and hence particle scattering, at oblique shocks is controlled by the protons and not the heavy ions. The heavy ions behave as test particles and their acceleration characteristics are controlled by the properties of proton excited turbulence. As a result, the resonance condition for heavy ions introduces distinctly different signatures in abundance, spectra, and intensity profiles, depending in ion mass and charge. Self-consistent models of heavy ion acceleration and the resulting fractionation are discussed. This will include discussion of the injection problem and the acceleration characteristics of quasi-parallel and quasi-perpendicular shocks.

Solar sources and fractionation processes

Invited Talk

THU-02

Ionic Charge States of Solar Energetic Particles: a Clue to the Source

Berndt Klecker[1]

[1] *Max-Planck-Institut für extraterrestrische Physik, 85741 Garching, Germany*

The ionic charge distributions of solar energetic particles (SEP) as observed in interplanetary space provide fundamental information about the origin of these particles, and the acceleration and propagation processes at the Sun and in interplanetary space. In this paper we review the new measurements of ionic charge states with advanced instrumentation onboard the SAMPEX, SOHO, and ACE spacecraft that provide ionic charge measurements of unprecedented sensitivity and over the wide energy range of ~ 0.01 to 70 MeV/n (for Fe). These new measurements showed that the mean ionic charge of heavy ions is generally increasing with energy. In large SEP events related to interplanetary coronal mass ejections and interplanetary shocks (*gradual* events), the mean ionic charge at energies of ~ 100 keV/n is generally consistent with solar wind charge states. At higher energies a large event-to-event variability is observed, with a mean ionic charge of Fe often as high as ~18-20 at energies of 10s of MeV/n. For ^{3}He- and Fe-rich events (*impulsive* events) the mean ionic charge increases significantly with energy for *all* events, for Fe from ~14 to ~20 in the energy range ~0.18 to 0.55 MeV/n. The energy dependence of the ionic charge of heavy ions shows that the previous interpretation of the mean ionic charge being determined only by the ambient temperature was too simplistic. The strong energy dependence as observed in impulsive SEP events can be consistently explained by the combined effects of acceleration, charge stripping in a dense environment low in the corona, and interplanetary propagation, providing constraints for the temperature, density, and acceleration time scales in the source region. In gradual events, the energy dependence provides information on the various possible sources contributing to the accelerated population, i.e. solar wind and suprathermal particles from previous (or contemporary) impulsive events, as will be discussed in this paper.

Solar sources and fractionation processes

Invited Talk

THU-03

Galactic Wind: mass fractionation and CR reacceleration?

Heinrich Völk[1]

[1]*Max-Planck-Institut für Kernphysik, Heidelberg*

The pressure gradient of the escaping Galactic Cosmic Rays (GCRs) drives an outflow from the Galaxy, reaching superso- nic velocities at distances ~20 kpc and asymptotic speeds of several 100 km/s. The mass loss with rate ~1 Solar mass/yr should carry a considerable fraction of hot Supernova Rem- nant matter in which the Cosmic Rays were originally embe- ded. Its enrichment with explosive nucleosynthesis material then slows down the chemical evolution of the Galaxy, compe- ting with residual accretion of basically primordial materi- al from the environment of the Milky Way. The predominant star formation in the spiral arms together with the Galactic rotation induces outward propagating velocity variations in the wind that steepen into a sawtooth shock wave reminiscent of the CIRs in the Solar Wind. In contrast to these the slip between the rotation of the magnetized gas and the spiral arms allows GCRs, reaccelerated in this wave train, to escape back to the disk. This population reaches energies up to several 10**18 eV to naturally explain the particle population between the “knee” and the “ankle” of the CR energy spectrum.

Cosmic rays

Invited Talk

THU-04

The Composition of Primary Galactic Cosmic Rays--An Overview

M. E. Wiedenbeck[1], W.R. Binns[2], A.C. Cummings[3], G. de Nolfo[4], M.H. Israel[2], R.A. Leske[3], R.A. Mewaldt[3], E.C. Stone[3], T.T. von Rosenvinge[4]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 USA, [2]Washington University, St. Louis MO 63130 USA, [3]California Institute of Technology, Pasadena, CA 91125 USA, [4]NASA/Goddard Space Flight Center, Greenbelt, MD 20771 USA

The galactic cosmic rays, which include essentially all of the stable and long-lived nuclides in the periodic table, consist of a mixture of „primary“ material synthesized in stars and „secondary“ material produced by nuclear fragmentation reactions in the interstellar medium. Based on observations of selected purely-secondary nuclides it is possible to model the secondary production in the Galaxy and correct the observed abundances of other species to derive their primary component. The primaries reflect the composition of the accelerated „source“ material and provide a set of isotopically-resolved abundances that can be used to study both the origin of cosmic rays and questions related to stellar nucleosynthesis and galactic chemical evolution. In addition, a number of long-lived radioactive nuclides can be used to constrain several important time scales for cosmic-ray acceleration and transport. Cosmic-ray composition measurements with isotopic resolution and high statistical accuracy are now available from the ACE and Ulysses missions for elements up through the iron peak. We will review these observations, the constraints on interstellar propagation available from the secondary and radioactive species, and the source composition derived from them. This composition bears a striking similarity to the abundances found in solar system material, at least for refractory nuclides, and suggests that cosmic rays are accelerated from interstellar material that contains contributions from a wide range of stellar sources. The data also indicate that the composition of interstellar matter has evolved relatively little in the 4.5 Gyr since the formation of the solar system. Cosmic-ray composition does, however, show the effects of significant elemental fractionation with volatile elements systematically depleted by factors ~5 relative to refractories. The observed fractionation provides constraints on the cosmic-ray injection and acceleration mechanisms and has been used to suggest that the shock acceleration and subsequent sputtering of charged interstellar dust grains may play a major role in the production of cosmic rays.
This work was supported by NASA at Caltech (under grant NAG5-12929), JPL, Washington University, and GSFC.

Cosmic rays

Tutorial Talk

THU-05

Wolf-Rayet Stars, OB Associations, and the Origin of Galactic Cosmic Rays

W.R. Binns[1], M.H. Israel[1], L.M. Scott[1], M.E. Wiedenbeck[4], M. Arnould[2], A.C. Cummings[6], J.S. George[6], S. Goriely[2], R.A. Leske[6], R.A. Mewaldt[6], E.C. Stone[6], T.T. von Rosenvinge[5], G. Meynet[3]

[1]Washington University, St. Louis, MO 63130, USA, [2]Institut d'Astronomie et d'Astrophysique, U.L.B. Bruxelles, Belgique, [3]Geneva Observatory, 1290 Sauverny, Switzerland, [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA, [5]NASA/Goddard Space Flight Center, Greenbelt, MD 20771 USA, [6]California Institute of Technology, Pasadena, CA 91125 USA

We have measured the isotopic abundances of neon and several refractory species in the galactic cosmic rays (GCRs) using the Cosmic Ray Isotope Spectrometer (CRIS) aboard the ACE spacecraft. The 22Ne/20Ne ratio at the cosmic-ray source that we have obtained is enhanced by a factor of 5.3±0.3 over that in the solar wind. Our ACE-CRIS data, and data from other experiments, are compared to recent results from two-component Wolf-Rayet (WR) models. The three largest deviations of galactic cosmic-ray isotope ratios from solar-system ratios predicted by these models, 12C/16O, 22Ne/20Ne, and 58Fe/56Fe, are, in fact, very close to those observed. Furthermore, all of the isotope ratios that we have measured are consistent with a GCR source consisting of ~20% of WR material mixed with ~80% material with solar-system composition. Since WR stars are evolutionary products of OB stars, and most OB stars exist in OB associations that form superbubbles, the good agreement of our data with WR models suggests that OB associations within superbubbles are the likely source of at least a substantial fraction of GCRs.

Cosmic rays

Invited Talk

THU-06 moved to Posters, see Poster-11

THU-07

Interstellar Dust at the Galactic Cosmic Ray Source

Andrew Westphal[1], John Bradley[2]

[1]Space Sciences Laboratory, University of California at Berkeley, CA 94720 USA, [2]Institute of Geophysics and Planetary Physics, Lawrence Livermore National Laboratory, CA 94550

The composition of ultraheavy galactic cosmic rays (GCRs) strongly hints that refractory elements in GCRs originate in interstellar dust accelerated to very high speeds by supernova shocks in superbubbles. At the time that this idea was originally proposed by Meyer, Drury and Ellison, the possibility that these interstellar dust grains might be observed in the laboratory was considered to be remote. Recently, however, Westphal and Bradley suggested that certain enigmatic grains in Interplanetary Dust Particles called GEMS (Glass Embedded with Metals and Sulfides) might be surviving members of this population of interstellar dust at the GCR source. Here I review the evidence that GCRs originate in interstellar gas and dust, and discuss the possibility that this dust may be already present in terrestrial laboratories, especially in light of new observations of GEMS-like grains in Stardust cometary samples. Finally, I suggest tests that could definitively test this idea.

Cosmic rays

Invited Talk

THU-08

The Ultra Heavy Elements in the Cosmic Radiation

Jake Waddington[1]

[1]*University of Minnesota, USA*

The concept that all of the elements in the periodic table were accelerated to relativistic energies was confirmed by the discovery of nuclei significantly heavier than iron in the primary cosmic rays. These “ultra heavy” nuclei must all have been synthesized in endothermic reactions, occurring predominately in the final stages of stellar evolution. Determination of the relative abundances of these nuclei should provide new insights into the nuclear processes in some of the most energetic events in the life cycle of stars. The very low abundances of these nuclei relative to those of the exothermic lighter nuclei have made progress difficult. In addition, the effects of apparent preferential acceleration mechanisms and of propagation through the interstellar medium have distorted the source abundances. The history of the original discovery of the presence of these nuclei will be followed by a summary of the present state of knowledge of the observed abundances. The effects of acceleration biases and of interstellar propagation will be discussed. Finally some of the possibilities for further advances will be outlined.

Cosmic rays

Invited Talk

THU-09

The Effect of the Local Bubble Environment on the Ionization and Composition of Interstellar Matter in the Solar Proximity

Priscilla Frisch[1]

[1]*Dept. Astronomy and Astrophysics, 5640 S. Ellis Ave., Chicago, IL 60637, USA*

The composition and ionization of interstellar matter (ISM) at the Sun are regulated by two phenomena characterizing nearby ISM (<400 parsecs or <1200 light years). The first phenomenon is the „Local Bubble“ (LB), a giant ISM void with very low minimum densities (<10^-26 gr/cc), and bounded by regions with massive stars and supernova that disrupt natal molecular clouds and drive moderately high-velocity ISM into the LB interior void. The Sun is located in such a driven ISM parcel, which is low density (<10^-24 gr/cc) and flowing with a velocity ~18 km/s through the local standard of rest. The flow upwind direction is towards the Sco-Cen (SCA) stellar association. The salient question in deciphering the underlying composition of ISM at the Sun is understanding the ionization balance and history of this flow, which both depend on the Local Bubble environment.

ISM ionization at the Sun is regulated by radiation from nearby hot stars, by X-ray emission from plasma inside and supernova remnants bordering the LB, by attenuated galaxy-halo radiation, and by emission from the hot cloud edge in contact with the LB plasma. The ~30% ionization of ISM at the Sun is set by this radiation field. An extended diffuse H+ region is seen nearby in the upwind direction.

The composition and density of local ISM follows from a likely origin in a superbubble shell driven by a recent supernova in the upwind SCA. The ISM velocity indicates the gas-dust balance has been altered by interstellar shocks. Data showing high refractory element abundances in local gas confirm this, and indicate that dust-grain composition and destruction are important for understanding local ISM gas-phase abundances. Ionization corrections are especially important for constraining local abundances of elements with first ionization potential less than ~25 eV, such as Ne, Ar, and He.

Interstellar gas

Invited Talk

THU-10

Interplanetary Shocks and „Suprathermal“ Flare Particles

Tycho von Rosenvinge[1], Hilary Cane[1,2], Ian Richardson[1,3]

[1]Astroparticle Physics Laboratory, NASA/Goddard Space Flight Center, Greenbelt, MD 20771 USA, [2]Bruny Island Radio Spectrometer, 42 Lighthouse Road, Bruny Island, Tasmania, 7150, Australia, [3]University of Maryland, College Park, Maryland, 20742 USA

We use ion-composition data from ACE/ULEIS, low energy electrons from ACE/EPAM, high energy protons from SoHO/ERNE, radio data from Wind/WAVES, and solar wind data from ACE/SWEPAM and ACE/MAG to investigate the solar and interplanetary circumstances near the times of passage of near-Earth shocks. We are particularly interested in claims that local acceleration by some interplanetary shocks produces Fe/O >0.3 (‘Fe-rich’ shocks). The choice of the specific interval used to calculate the Fe/O ratio is extremely important because shock-accelerated particles can be masked by particles from flare events, related or unrelated to the shock, that have Fe/O >0.3. We conclude that shock- accelerated populations have Fe/O<0.3. We illustrate 5 events which have been reported to be Fe-rich and for which Fe/O increases with energy in the 0.5-2 MeV/nuc range. We find that in each case there are direct flare particles included in the averaging time interval. We also demonstrate that the Fe/O ratio increases as a result of the averaging time interval being too large.

Solar sources and fractionation processes

Contributed Talk

THU-11

Compositional Variability in Solar Particle Events: Some Early History

Stamatios Krimigis[1,2]

[1]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA, [2]Academy of Athens, Soranou Efesiou 4, 115 27 Athens, Greece

In the late 60s the solar abundance of He was an important input to the discussion of universal abundances (Hoyle and Tayler, 1964). Because a spectroscopic determination was not possible, a combination of spectroscopic results (Lambert, 1967) of H/M (M stands for medium nuclei) and solar cosmic ray measurements of He/M (Fichtel, 1970) was used to deduce a H/He ratio of ~16 ? 2, all before the Geiss era. The He/M ratio was determined from nuclear emulsions on rocket flights (e. g. Biswas et al, 1966) at fairly high energies, typically 12-95 Mev/nuc. The motivation of Armstrong and Krimigis (1971) using Explorer-35 data was to look at much lower energies (~0.5 Mev/nuc), integrate over entire events and test the variability of the He/M ratio. The result was a value of He/M ~20?10, very different from that of ~58 ? 5 measured in rocket flights. The implication was that of either energy dependence in the ratio or that brief exposures during rocket flights were not representative of typical events. What transpired next was a heated exchange of letters to the editor of JGR (Ian Axford) among Fichtel et al and Armstrong and Krimigis that could not be printed. In the end, Axford forced a joint paper by Armstrong, Krimigis, Reames and Fichtel (1972) that displayed both measurements and allowed as to how there may well be an energy dependence to the He/M ratio in solar events. It is interesting to note that issues of compositional variability among events and within an event are still with us some 35 years later, and continue to obscure the true composition of solar material at the source.
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Solar sources and fractionation processes

Contributed Talk

THU-12

Energy Dependant Solar Wind Helium and Neon Data from Genesis

Ansgar Grimberg[1], Donald S. Burnett[2], Fritz Bühler[3], Peter Bochsler[3], Veronika S. Heber[1], Heinrich Baur[1], Rainer Wieler[1]

[1]Isotope Geology and Mineral Resources, ETH Zürich NW C, Clausiusstr. 25, CH-8092 Zürich, Switzerland, [2]Geological and Planetary Sciences, Caltech, Pasadena, CA 91125, USA, [3]Physikalisches Institut, University of Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland

Here we present helium and neon data obtained from a metallic glass sample flown on NASA's Genesis mission (Wiens, this meeting). This specially designed target allows depth- and thus energy-dependant isotope distribution profiling of solar wind ions collected during the entire exposure time of Genesis. The major objective of this study is to shed new light on the putative "SEP" Ne component reported from lunar soil samples and to get precise compositional data over the entire energy range of solar wind noble gases.
Neon isotopes released from the metallic glass show a composition that becomes progressively heavier with depth and data points plot on a mass fractionation line. This is in perfect agreement with simulations calculated with the SRIM code suggesting ion irradiation of a solar wind with uniform neon composition for all regimes that gets fractionated upon implantation. Extending this model to conditions expected for lunar soil samples eliminates the necessity of an independent "SEP" Ne component with a composition different from the solar wind as has been suggested for many years. However, surprisingly high $^{20}Ne/^{22}Ne$ ratios in a small gas fraction released from very close to the surface might suggest this fraction to be very slow current-sheet solar wind that shows a depletion of the heavy isotopes relative to solar wind implanted with higher energies.
The interpretation of the He isotopic depth distribution is more complicated. The $^{3}He/^{4}He$ ratio pattern cannot be explained solely by a mass dependant fractionation trend as predicted for neon. Nor can it be interpreted as solar wind already fractionated before implantation, e.g. by inefficient coulomb drag. First calculations incorporating diffusion processes within the sample look promising but are constrained by the good agreement of the He concentration measured in the metallic glass and other Genesis samples. New calculations including a molecular contamination as found on many Genesis samples tend to reproduce the observed $^{3}He/^{4}He$ pattern.

Solar sources and fractionation processes

Contributed Talk

THU-13

Isotope Fractionation Induced by the Genesis Solar Wind Concentrator

V.S. Heber[1], R.C. Wiens[2], C. Olinger[2], D.S. Burnett[3], H. Baur[1], U. Wiechert[4], R. Wieler[1]

[1]ETH Zürich, Institute for Isotope Geology , NW C, Clausiusstrasse 25, 8092 Zürich, Switzerland , [2]LANL, Space & Atmospheric Sci. , Los Alamos, NM 87544, USA, [3]CalTech, JPL, Pasadena, CA 91109, USA, [4]AG Geochemie, FU Berlin, 12249 Berlin, Germany

To determine the O and N isotopic composition of the present day solar wind (SW) is one of the key goals of the Genesis SW collection mission, as the SW is a proxy for the solar nebula. In order to achieve high precision isotope compositions of O and N a concentrator was designed to provide a~20x larger fluences of implanted SW ions by accelerating and focussing ions onto a target by an electrostatic mirror. This concentration process induced mass fractionation of the implanted SW ions as function of the radial position on the target. Correction of it will be based on a combination of the measured radial fractionation of Ne isotopes with results of simulations of the implantation process using the actual performance of the concentrator and SW conditions during exposure.

Here we present He and Ne abundances and Ne isotopic composition data along one arm of the gold cross that framed the 4 concentrator sub-targets. He and Ne were released from pits by UV laser ablation using a UV laser. Repeat analyses were performed on 12 different positions distributed over the whole radius (30mm) of the cross.

He and Ne abundances increase from the edge (at 30mm) towards the centre of the concentrator cross, e.g., Ne from 3.5E+12ions/cm2 (at 29.4mm) to 3.4E+13ions/cm2 (at1 mm). Thus, the concentration factor increases by a factor of ~10, confirming post-flight models for Ne. However, measured Ne abundances are ~30% lower than expected. The measured Ne isotopes show a large fractionation as function of the target radius. d22Ne (relative to SW 20Ne/22Ne of 13.83) ranges from –19‰ (at 29.4mm) to +62‰ (at 1mm), reflecting a preferential implantation of the heavier isotope towards the centre of the target. Generally, there is a good agreement between the observed and the modelled fractionation curves, however the modelled curve does not reproduce the general monotonous decrease of the d22Ne towards the edge.

Solar sources and fractionation processes

Contributed Talk

FRI-01

Interstellar gas and Local Interstellar Cloud (LIC) Composition

Rosine Lallement[1]

[1]Service d'Aéronomie du CNRS, Verrières-le-Buisson, France

The Local Interstellar Cloud surrounding the Sun is generally considered as a typical warm and diffuse cloudlet, itself embedded in a typical hot gas bubble blown by a series of consecutive supernovae. A number of measurements, including abundance data, have apparently contradicted this "normality" of our interstellar environment but have finally been explained. In the mean time, new puzzling observations have been obtained. I will review past and recent results on the local ISM, related in particular to this question: are we in a peculiar region of the galaxy or are we still missing some aspects of the physical state of the multi-phase interstellar medium?

Interstellar gas

Tutorial Talk

FRI-02

D/H and the structures of nearby warm interstellar clouds

Jeffrey L. Linsky[1]

[1]*University of Colorado and National Institute of Standards and Technology, CO 80309-0440 USA*

Analysis of spectra obtained with the FUSE and other ultraviolet satellites now provide new understanding of the deuterium abundance in the local region of the Galactic disk. The wide range of gas-phase D/H measurements obtained outside of the Local Bubble can now be explained as due to different amounts of deuterium depletion on carbonaceous grains. The total D/H ratio including deuterium in the gas and dust phases is at least 23 parts per million of hydrogen, which is providing a challenge to models of Galactic chemical evolution. Analysis of HST and ground-based spectra of many lines of sight to stars within the Local Bubble have identified many interstellar velocity components which are consistent with more than 10 velocity vectors. We have identified the structures of 10 nearby warm interstellar clouds on the basis of these velocity vectors and common temperatures and depletions. We estimate the distances and masses of these clouds and compare their locations with cold interstellar clouds.

Interstellar gas

Invited Talk

FRI-03

Interstellar Dust in the Solar System

Harald Krueger[1], Nicolas Altobelli[2], Eberhard Gruen[3,4], Sascha Kempf[3], Markus Landgraf[5], Ralf Srama[3], Stefan Helfert[3], Georg Moragas-Klostermeyer[3]

[1]MPI fuer Sonnensystemforschung, 37191 Katlenburg-Lindau, Germany , [2]NASA/JPL, Pasadena, California, USA, [3]MPI fuer Kernphysik, 69117 Heidelberg, Germany, [4]HIGP, University of Hawaii, Honolulu, HI 96822, USA, [5]European Space Agency, ESOC, 64293 Darmstadt

The Ulysses spacecraft has been orbiting the Sun on a highly inclined ellipse almost perpendicular to the ecliptic plane (inclination 79 deg, perihelion distance 1.3 AU, aphelion distance 5.4 AU) since it encountered Jupiter in 1992. The in-situ dust detector on board continuously measures interstellar dust grains with masses up to 10^-13 kg, penetrating deep into the Solar System. The flow direction is close to the mean apex of the Sun's motion through the local interstellar cloud (LIC), and the grains act as tracers of the physical conditions in the LIC. The intrinsic size distribution of interstellar grains in the LIC extends to grain sizes larger than those detectable by astronomical observations. The existence of such 'big' interstellar grains is also indicated by observations of radar meteors entering the Earth's atmosphere. The Ulysses measurements showed that the dust-to-gas mass ratio in the local interstellar cloud is several times higher than the standard interstellar value derived from cosmic abundances, implying the existence of inhomogeneities in the diffuse interstellar medium on relatively small length scales.
While the Ulysses dust instrument monitored the interstellar dust stream at high ecliptic latitude between 3 and 5 AU, interstellar impactors were also identified in the data sets measured with the in-situ dust detectors on board Cassini, Galileo and Helios, covering a distance range between 0.3 and 3 AU in the ecliptic plane. The data provide evidence for alteration of the interstellar dust stream in the inner solar system, caused by the solar radiation pressure force, gravitational focussing and interaction of charged grains with the time varying interplanetary magnetic field. We review the in-situ interstellar dust measurements obtained from a fleet of four spacecraft in the Solar System and present the latest results from the Ulysses interstellar dust measurements.

Interstellar gas

Contributed Talk

FRI-04

Probing Interstellar Composition and Parameters with In-Situ Particle Observations

Eberhard Moebius[1]

[1]Space Science Center and Dept. of Physics, University of New Hampshire, Durhma, NH 03824, USA

The neutral interstellar gas flows through the solar system as an interstellar wind and thus has become accessible to in-situ diagnostics by means of pickup ion and neutral gas observation techniques. Both have contributed significantly to our knowledge of the composition and physical parameters of the surrounding interstellar medium. Pickup ion observations with time-of-flight mass spectrometers have provided densities for H and He, elemental composition for O and Ne as seen in interplanetary space, as well as the $^{3}He/^{4}He$ isotopic ratio. The latter has also been obtained using foil implantation techniques on the MIR space station, a technique pioneered in the Apollo program on the moon for solar wind. While isotopic ratios are indicative of the interstellar medium values as measured, element composition is altered in the heliospheric interface region. After the pristine inflow characteristics of He, to which the interface is almost perfectly transparent, has already been determined with high precision using direct neutral atom imaging, following up with O and H will provide a quantitative tool to determine the filtering independently. The observation techniques and their results will be described followed by a discussion of the implications of the compositional information for the interstellar medium and the evolution of matter.

Interstellar gas

Invited Talk

FRI-05

Filtration of interstellar H, O, N atoms through the heliospheric interface

Vladislav Izamodenov[1,2,3]

[1]School of Mechanics and Mathematics, Moscow State University, Russia, [2]Space Research Institute (IKI) Russian Academy of Sciences, [3]Institute for Problems in Mechanics Russian Academy of Sciences

Interstellar atoms penetrate deep into the heliosphere after passing the heliospheric interface, the region of interaction of the solar wind with the interstellar medium. The heliospheric interface serves as a filter for the interstellar atoms of hydrogen, oxygen and nitrogen because of their coupling with plasma by charge exchange. The filtration has great importance for the determination of local interstellar abundances of these elements, which becomes now possible due to measurements of interstellar pickup ions by Ulysses and ACE, and anomalous cosmic rays by Voyagers, Ulysses, ACE, SAMPEX and Wind. The filtration of the different elements depends on the level of their coupling with the plasma in the interaction region. We study the dependence of the filtration on the local interstellar proton and H atom number densities and evaluate the effects of charge exchange and electron impact ionization on the filtration. We explore the influence of electron temperature in the inner heliosheath on the filtration process. Using our filtration coefficients and SWICS/Ulysses pickup ion measurements local interstellar abundances of the considered elements.

Interstellar gas

Invited Talk

FRI-06

Composition of Anomalous Cosmic Rays

A. C. Cummings[1], E. C. Stone[1]

[1]Space Radiation Lab, California Institute of Technology, Pasadena CA 91125 USA

The „classic“ anomalous cosmic ray (ACR) component has its origin as interstellar neutral gas, which drifts into the heliosphere, becomes ionized in the solar wind, picked up by the magnetic field, and carried to the outer heliosphere where the pickup ions are accelerated to hundreds of MeV, presumably at the solar wind termination shock. The elemental composition of the ACR source material of many ACR ions, i.e., the interstellar neutral gas, is reasonably well known from pickup ion studies and other studies of the local interstellar medium. Thus ACR composition studies center on injection and acceleration at the termination shock, since there is good information on the input and output of the diffusive shock acceleration process. Recently, Voyager 1 (V1) crossed the termination shock at 94 AU. Although the expected accelerated source spectra of ACRs were not observed at the position on the shock where V1 crossed, other likely acceleration sites include the flanks of the shock or positions on the shock near its pole or equator. We will review and update previous work on the elemental composition of ACRs in view of the latest results. In addition, we will review the isotopic and charge-state composition studies of ACRs. Finally, we will review and update studies of the so-called „minor“ ACR ions, such as Na, Mg, S, and Si, which appear to be singly-ionized ions from an outer heliospheric source such as the Kuiper Belt.

Interstellar gas

Invited Talk

POSTER-01

Nickel Isotopic Abundances and Nickel/Iron Elemental Abundance Ratio in the Solar Wind: Results from SOHO/CELIAS/MTOF

Reto Karrer[1], Peter Bochsler[1], Corrado Giammanco[1], Fred Ipavich[2], John Paquette[2], Peter Wurz[1]

[1]Physikalisches Institut, University of Bern, [2]Department of Physics, University of Maryland

With CELIAS/MTOF on SOHO we derive the relative abundances of the nickel isotopes with mass 58, 60 and 62 in the solar wind. In addition we measure the elemental abundance ratio of nickel to iron. We use data accumulated during ten years of SOHO operation to get sufficiently high counting statistics comparing periods of different solar wind velocities. We compare our values with the meteoritic ratios, which are believed to be a reliable reference for the solar system and also for the solar outer convective zone, since neither element is volatile and no meteoritic isotopic fractionation is expected. Furthermore, meteoritic isotopic abundances agree with the terrestrial values and can be considered to be a reliable reference for the solar isotopic composition. A first preliminary inspection of the raw MTOF-data shows that the solar wind elemental Ni/Fe-ratio and the isotopic composition of solar wind nickel are consistent with the meteoritic values. This supports the concept that low-FIP elemental are fed without fractionation into the solar wind. It explains the absence of substantial isotopic fractionation effects for medium and heavy ions in the solar wind. We also compare the data with solar energetic particle (SEP) results and photospheric values. A detailed analysis of instrumental effects and measurement efficiencies will be presented.

Solar sources and fractionation processes

Poster

POSTER-02

withdrawn

POSTER-03

Measurement of the Elemental Abundances of the Ultra-Heavy Galactic Cosmic Rays (30<=Z<=40) with the TIGER Experiment

B.F. Rauch[1], S. Geier[4], L.M. Barbier[2], W.R. Binns[1], J.R. Cummings[2], G.A. de Nolfo[2], **M.H. Israel[1]**, J.T. Link[1], R.A. Mewaldt[4], J.W. Mitchell[2], S.M. Schindler[4], L.M. Scott[1], E.C. Stone[4], R.E. Streitmatter[2], C.J. Waddington[3]

[1]Washington University, St. Louis, MO 63130 USA, [2]NASA/Goddard Space Flight Center, Code 661, Greenbelt, MD 20771 USA, [3]University of Minnesota, Minneapolis, MN 55455 USA, [4]California Institute of Technology, Pasadena, CA 91125 USA

Observations of Ultra-Heavy galactic cosmic rays (GCR) help to distinguish the possible origins of GCRs. The Trans-Iron Galactic Recorder(TIGER) is designed to measure the charge (Z) and energy of GCRs using a combination of scintillation counters, Cherenkov counters, and a scintillating fiber hodoscope. TIGER has accumulated data on two successful flights from McMurdo, Antarctica: the first launched in December of 2001 with a total flight duration of 31.8 days and the second in December of 2003 with a total flight duration of 18 days. The two flights of TIGER achieved sufficient statistics and charge resolution to resolve ~140 particles with Z > 30 and energy >300 MeV/nucleon, and have obtained the best measurements to date of the elemental abundances of Zn (Z=30), Ga (Z=31), Ge (Z=32), and Se (Z=34). We present a preliminary analysis of the combined data from both flights for Ultra-Heavy GCRs and discuss the results in the context of different GCR source models.

Cosmic rays

Poster

POSTER-04

COMPARISON OF ICMES OBSERVED WITH ACE/SWICS AND ULYSSES/SWICS

Anita Kilchenmann[1], Rudolf von Steiger[1]

[1]*International Space Science Institute, Hallerstrasse 6, 3012 Bern, Switzerland*

We compare Interplanetary Coronal Mass Ejections (ICMEs) observed with ACE/SWICS with ICMEs observed with Ulysses/SWICS between 1996 and 2002. The ICMEs were identified using compositional signatures such as enhanced Fe charge states, enhanced O^{7+}/O^{6+} ratio and enhanced He/p ratio. For the O^{7+}/O^{6+} and the Q_{Fe} signatures we apply a solar wind speed dependent threshold and for the He/p ratio a constant value of 6%. We compare the occurrence rates of the ICMEs and the individual compositional signatures, both for the full set of ICMEs and for the subset having a magnetic cloud signature. We further analyze the rates measured at Ulysses as a function of latitude, normalized to the rates measured with ACE at low latitudes in order to remove solar cycle effects. We find a significant latitude dependence of ICMEs even at solar maximum.

Solar sources and fractionation processes

Poster

POSTER-05

Acceleration of heavy ions at CME-driven Interplanetary Shocks Near Earth

Frederic Allegrini[1], Mihir I. Desai[1], Harald Kucharek[2], Glenn M. Mason[3], Eberhard Moebius[2]

[1]Space Science and Engineering Division, Southwest Research Institute, San Antonio, TX, USA, [2]Space Science Center, University of New Hampshire, Durham, NH, USA, [3]Department of Physics, University of Maryland, College Park, MD, USA

Interplanetary (IP) shocks driven by coronal mass ejections (CMEs) are known to accelerate ions up to 10s of MeV in energy. Since the CMEs and their shocks propagate through the ambient solar wind, it was generally believed that their seed particles originate from the solar wind. However, advanced composition instruments such as the Ultra Low-Energy Isotope Spectrometer (ULEIS) and the Solar Energetic Particle Ionic Composition Analyzer (SEPICA) on board NASA's Advanced Composition Explorer (ACE) have shown that a substantial fraction of such CME-driven IP shocks accelerate tracer ions like 3He and He+ that are extremely rare in the thermal solar wind plasma. Since both these species are relatively more abundant in the energy region between ~2-100 keV/nucleon, their mere presence in the accelerated populations points to an origin in the suprathermal tail. In this presentation, we will survey the ACE/ULEIS, ACE/SEPICA measurements between November 1997 and October 2000 and identify all CME-driven IP shocks that accelerated both 3He and He+ ions. We will compare the measurements of these rare ion species with those of the more common heavier ions from C-Fe. We will perform detailed case studies of individual events along with a comprehensive statistical survey and investigate the ion injection and acceleration efficiencies as a function of their mass-to-charge (M/Q) ratio. We will also compare properties of the accelerated ions with the locally measured shock strength parameters.

Solar sources and fractionation processes

Poster

POSTER-06

Long-Term Fluences of Solar Energetic Particles from H to Fe

R. A. Mewaldt[1], G. M. Mason[2], C. M. S. Cohen[1], D. K. Haggerty[2], A. J. Davis[1], M. I. Desai[3]

[1]Caltech, Pasadena, CA 91125, USA, [2]JHU/APL, Laurel, MD 29723, USA, [3]Southwest Research Institute, San Antonio TX 78238, USA

Data from ACE and GOES have been used to measure the fluence spectra of solar energetic particles (SEPs) for H, He, O, and Fe, over the period from September 1997 to December 2005. The spectra were measured by the ULEIS, EPAM, SIS and CRIS instruments on ACE and the EPS sensor on GOES-8, GOES-10, and GOES-11 and extend in energy from ~100 keV/nucleon to ~100 MeV/nucleon. Year by year spectra for each species were corrected for galactic cosmic-ray (GCR) contributions and the resulting SEP fluence spectra were fit by conventional spectral forms. We address the following questions: What spectral shapes best represent the fluence spectra? How do the slopes of the fluence spectra vary from year to year? How much do the average intensities vary from year-to-year as a function of energy? How does the composition vary from year to year?

Solar sources and fractionation processes

Poster

POSTER-07

Elemental Composition and Energy Spectra of Galactic Cosmic Rays during Solar Cycle 23

M.H. Israel[1], J.S. George[2], W.R. Binns[1], A.C. Cummings[2], A.J. Davis[2], G.A. de Nolfo[3], K.A. Lave[1], R.A. Leske[2], R.A. Mewaldt[2], L.M. Scott[1], E.C. Stone[2], T.T. von Rosenvinge[3], M.E. Wiedenbeck[4]

[1]Washington University, St. Louis, MO 63130 USA, [2]California Institute of Technology, Pasadena, CA 91125 USA, [3]NASA/Goddard Space Flight Center, Greenbelt, MD 20771 USA, [4]Jet Propulsion Laborator, California Institute of Technology, Pasadena, CA 91109 USA

We report the elemental abundances and spectra of galactic cosmic-ray nuclei with nuclear charge 5=Z=28 and energies between 50 and 500 MeV/nucleon measured by the Cosmic-Ray Isotope Spectrometer (CRIS) instrument on NASA's Advanced Composition Explorer (ACE) spacecraft. We present results for a period of minimum solar activity between August 1997 and April 1998, and for a period of maximum solar activity between May 2001 and September 2003. Data are excluded from time intervals during which there was a significant flux of solar energetic particles.

Cosmic rays

Poster

POSTER-08

The Chemical Composition of Interstellar Matter at the Solar Location

Jonathan Slavin[1], **Priscilla Frisch[2]**

[1]Harvard-Smithsonian CfA, 60 Garden St., Cambridge, MA 02138, USA, [2]Dept. Astronomy and Astrophysics, University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637, USA

he elemental composition of the interstellar medium (ISM) is derived from data on optical, ultraviolet, and extreme ultraviolet absorption lines from over 30 elements found in warm and cold clouds. Elements found to be underabundant in the interstellar gas when compared to solar abundances are generally assumed to be condensed onto dust grains. More recently, considerable uncertainty surrounds the use of solar abundances as a benchmark for the ISM. In the case of the very low density, warm interstellar cloud surrounding the Sun (the Local Interstellar Cloud or LIC), we have an especially strong handle on cloud properties because interstellar neutrals have penetrated the heliosphere and formed various populations that are measured by spacecraft. The surrounding interstellar cloud is partially ionized because the optical depth to H and He ionizing radiation is less than 2-3 throughout the cloud. In order to correct for the partially ionized state of the surrounding ISM, we have thus undertaken a series of studies of the radiative transfer properties of the LIC for the purpose of developing a precise estimate of the ionization corrections required to correctly interpret ISM data inside of the heliosphere and towards nearby stars (e.g. Slavin and Frisch, 2002). We will report on our most recent models, which use modern rates for the Mg+ --> Mg0 dielectronic recombination coefficient, and focus exclusively on the cloud feeding ISM into the heliosphere. By tying our results to observed column densities of several ions as well as the in situ data on the He density and temperature, we can deduce the required abundances for various elements including C, N, O, Mg, Si, S, and Fe.

Interstellar gas

Poster

POSTER-09

Determination of Sulfur Abundance in the Solar Wind

Corrado Giammanco[1], Peter Bochsler[1], Reto Karrer[1], Fred Ipavich[2], John Paquette[2], Peter Wurz[1]

[1]Physikalisches Institut der Universität Bern, Switzerland, [2]University of Maryland

The determination of solar chemical abundances is made comparing the solar spectra with synthetic ones obtained for different sets of abundances and physical conditions. Although such inferred results are reliable, they are model dependent. Therefore, one compares them with the values for the local interstellar medium (LISM). The argument is that they must be similar, but even for LISM abundance determination models play a fundamental role (i.e. temperature fluctuations, clumpiness, photon leaks). There are still two possible comparisons: One with the meteoritic values, the second with solar wind abundances. In this work we derive the solar wind abundance of sulfur relative to calcium and silicon, two neighboring low-FIP elements, using 10 years of CELIAS/MTOFdata, and comparing it with the solar sulfur abundance determined from spectroscopic observations and with solar energetic particles. Sulfur is a moderately volatile element, hence, there is a risk of meteoritic sulfur being depleted relative to non-volatile elements, if compared to original solar system values. From our first measurements we do not observe such a depletion.

Solar sources and fractionation processes

Poster

POSTER-10

An Update on Studies of Ultra-Heavy Elements in Solar Energetic Particles Above 10 MeV/nucleon

R. A. Leske[1], R. A. Mewaldt[1], C. M. S. Cohen[1], A. C. Cummings[1], E. C. Stone[1], M. E. Wiedenbeck[2], T. T. von Rosenvinge[3]

[1]California Institute of Technology, Mail Code 220-47, Pasadena, CA 91125 USA, [2]Jet Propulsion Laboratory, MS 169-327, Pasadena, CA 91109 USA, [3]NASA/Goddard Space Flight Center, Code 661, Greenbelt, MD 20771 USA

Measurements below several MeV/nucleon show that abundances of elements heavier than Ni (Z=28) can be enhanced relative to oxygen by factors of ~100 to 1000 (depending on species) in impulsive solar energetic particle (SEP) events. At higher energies, even large gradual events are often iron-rich and might contain admixtures of flare seed material. The Solar Isotope Spectrometer (SIS) on NASA's ACE spacecraft measures the composition of energetic nuclei for elements up to ~Zr (Z=40) at energies from ~10 to =100 MeV/nucleon. We use SIS data to examine ultra-heavy (UH) SEPs above 10 MeV/nucleon that can be used to test models of acceleration and abundance enhancements in both gradual and impulsive events. We find that the long-term average composition for elements from Z=30 to 40 is similar to standard solar system values, but there is considerable event-to-event variability. Although most of the UH fluence arrives during large gradual events, UH abundances are relatively more enhanced in impulsive events, with the (34=Z=40)/O ratio on average ~50 times higher in impulsive events than in gradual events. At energies above 10 MeV/nucleon, the most extreme event in terms of UH composition detected so far took place on 23 July 2004 and had a (34=Z=40)/O enhancement of ~250-300 times the standard solar value.
This work was supported by NASA at Caltech (under grant NAG5-12929), JPL, and GSFC.

Solar sources and fractionation processes

Poster

Poster-11

THE COMPOSITION OF GALACTIC COSMIC RAYS & THE NATURE & MIXING OF THE INTERSTELLAR MEDIUM

Richard Lingenfelter[1], James Higdon[2]

[1]Center for Astrophysics & Space Sciences, University of California, La Jolla, CA, 92093-0424, USA, [2]W. M. Keck Science Center, Claremont Colleges, Claremont, CA, 91711-5916, USA

The differences between the composition of Galactic cosmic rays and that of the interstellar medium are manifold, and they contain a great bonanza of new information about the varying processes that created them. For these differences reveal much about the initial mixing of freshly synthesized matter, the chemistry and differentiation of the interstellar medium, and the mechanisms and environment of ion injection and acceleration. Here we briefly explore these processes and show how they combine to create the peculiar, but potentially universal, composition of the cosmic rays.

Cosmic rays

Poster