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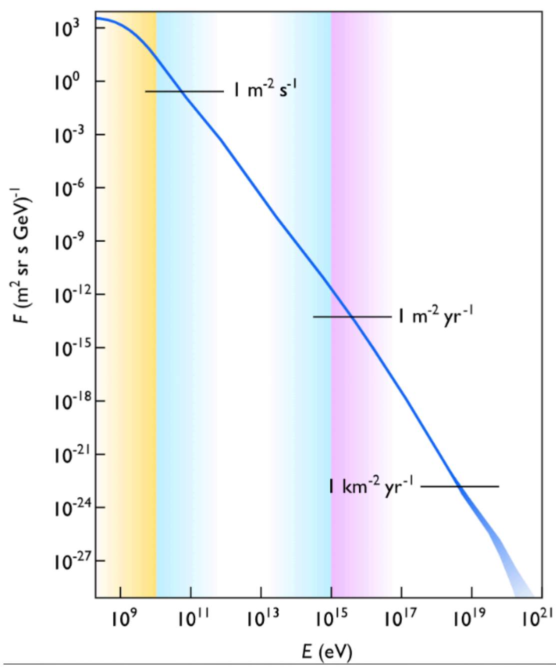
INTRODUCTION

Cosmic rays are high-energy particles or clusters of particles (primarily represented by protons or atomic nuclei) that move through space at nearly the speed of light. They originate from the Sun, from outside of the Solar System in our own galaxy and from distant galaxies. Upon impact with Earth's atmosphere, cosmic rays produce showers of secondary particles, some of which reach the surface, although the bulk is deflected off into space by the magnetosphere or the heliosphere.



Cosmic rays were discovered by Victor Hess in 1912 in balloon experiments, for which he was awarded the 1936 Nobel Prize in Physics.

Direct measurement of cosmic rays, especially at lower energies, has been possible since the launch of the first satellites in the late 1950s. Particle detectors similar to those used in nuclear and high-energy physics are used on satellites and space probes for research into cosmic rays. Data from the Fermi Space Telescope (2013) have been interpreted as evidence that a significant fraction of primary cosmic rays originate from the supernova explosions of stars. Based on observations of neutrinos and gamma rays from blazar TXS 0506+056 in 2018, active galactic nuclei also appear to produce cosmic rays.

COMPOSITION

Of primary cosmic rays, which originate outside of Earth's atmosphere, about 99% are the bare nuclei of well-known atoms (stripped of their electron shells), and about 1% are solitary electrons (that is, one type of beta particle). Of the nuclei, about 90% are simple protons (i.e., hydrogen nuclei); 9% are alpha particles, identical to helium nuclei; and 1% are the nuclei of heavier elements, called HZE ions. These fractions vary highly over the energy range of cosmic rays. A very small fraction are stable particles of antimatter, such as positrons or antiprotons. The precise nature of this remaining fraction is an area of active research. An active search from Earth orbit for anti-alpha particles has failed to detect them.

Upon striking the atmosphere, cosmic rays violently burst atoms into other bits of matter, producing large amounts of pions and muons (which have a short half-life) as well as neutrinos. The neutron composition of the particle cascade increases at lower elevations, reaching between 40% to 80% of the radiation at aircraft altitudes.

HISTORY

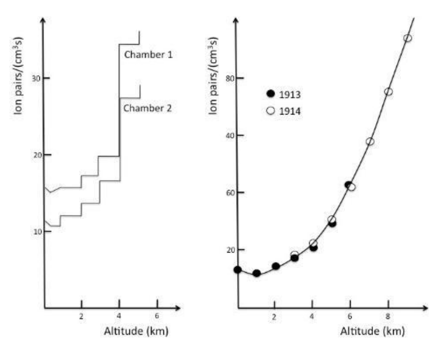
After the discovery of radioactivity by Henri Becquerel in 1896, it was generally believed that atmospheric electricity, ionization of the air, was caused only by radiation from radioactive elements in the ground or the radioactive gases or isotopes of radon they produce. Measurements of increasing ionization rates at increasing heights above the ground during the decade from 1900 to 1910 could be explained as due to absorption of the ionizing radiation by the intervening air

Discovery

In 1909, Theodor Wulf developed an electrometer, a device to measure the rate of ion production inside a hermetically sealed container, and used it to show higher levels of radiation at the top of the Eiffel Tower than at its base. However, his paper published in Physikalische Zeitschrift was not widely accepted. In 1911, Domenico Pacini observed simultaneous variations of the rate of ionization over a lake, over the sea, and at a depth of 3 metres from the surface. Pacini concluded from the decrease of radioactivity underwater that a certain part of the ionization must be due to sources other than the radioactivity of the Earth.

In 1912, Victor Hess carried three enhanced-accuracy Wulf electrometers to an altitude of 5,300 metres in a free balloon flight. He found the ionization rate increased approximately fourfold over the rate at ground level. Hess ruled out the Sun as the radiation's source by making a balloon ascent during a near-total eclipse. With the moon blocking much of the Sun's visible radiation, Hess still measured rising radiation at rising altitudes. He concluded that "The results of the observations seem most likely to be explained by the assumption that radiation of very high penetrating power enters from above into our atmosphere." In 1913–1914, Werner Kolhörster confirmed Victor Hess's earlier results by measuring the increased ionization enthalpy rate at an altitude of 9 km.

Hess received the Nobel Prize in Physics in 1936 for his discovery.



Identification

In the late 1920s and early 1930s the technique of self-recording electroscopes carried by balloons into the highest layers of the atmosphere or sunk to great depths under water was brought to an unprecedented degree of perfection by the German physicist Erich Regener and his group. To these scientists we owe some of the most accurate measurements ever made of cosmic-ray ionization as a function of altitude and depth.

Ernest Rutherford stated in 1931 that "thanks to the fine experiments of Professor Millikan and the even more far-reaching experiments of Professor Regener, we have now got for the first time, a curve of absorption of these radiations in water which we may safely rely upon".

In the 1920s, the term cosmic rays was coined by Robert Millikan who made measurements of ionization due to cosmic rays from deep under water to high altitudes and around the globe. Millikan believed that his measurements proved that the primary cosmic rays were gamma rays; i.e., energetic photons. And he proposed a theory that they were produced in interstellar space as by-products of the fusion of hydrogen atoms into the heavier elements, and that secondary electrons were produced in the atmosphere by Compton scattering of gamma rays. But then, sailing from Java to the Netherlands in 1927, Jacob Clay found evidence, later confirmed in many experiments, that cosmic ray intensity increases from the tropics to mid-latitudes, which indicated that the primary cosmic rays are deflected by the geomagnetic field and must therefore be charged particles, not photons. In 1929, Bothe and Kolhörster discovered charged cosmic-ray particles that could penetrate 4.1 cm of gold. Charged particles of such high energy could not possibly be produced by photons from Millikan's proposed interstellar fusion process.[citation needed]

In 1930, Bruno Rossi predicted a difference between the intensities of cosmic rays arriving from the east and the west that depends upon the charge of the primary particles—the so-called "east-west effect". Three independent experiments found that the intensity is, in fact, greater from the west, proving that most primaries are positive. During the years from 1930 to 1945, a wide variety of investigations confirmed that the primary cosmic rays are mostly protons, and the secondary radiation produced in the atmosphere is primarily electrons, photons and muons. In 1948, observations with nuclear emulsions carried by balloons to near the top of the atmosphere showed that approximately 10% of the primaries are helium nuclei (alpha particles) and 1% are nuclei of heavier elements such as carbon, iron, and lead.

During a test of his equipment for measuring the east-west effect, Rossi observed that the rate of near-simultaneous discharges of two widely separated Geiger counters was larger than the expected accidental rate. In his report on the experiment, Rossi wrote "... it seems that once in a while the recording equipment is struck by very extensive showers of particles, which causes coincidences between the counters, even placed at large distances from one another." In 1937 Pierre Auger, unaware of Rossi's earlier report, detected the same phenomenon and investigated it in some detail. He concluded that high-energy primary cosmic-ray particles interact with air nuclei high in the atmosphere, initiating a cascade of secondary interactions that ultimately yield a shower of electrons, and photons that reach ground level.

Soviet physicist Sergei Vernov was the first to use radiosondes to perform cosmic ray readings with an instrument carried to high altitude by a balloon. On 1 April 1935, he took measurements at heights up to 13.6 kilometres using a pair of Geiger counters in an anti-coincidence circuit to avoid counting secondary ray showers.

Homi J. Bhabha derived an expression for the probability of scattering positrons by electrons, a process now known as Bhabha scattering. His classic paper, jointly with Walter Heitler, published in 1937 described how primary cosmic rays from space interact with the upper atmosphere to produce particles observed at the ground level. Bhabha and Heitler explained the cosmic ray shower formation by the cascade production of gamma rays and positive and negative electron pairs.

Energy distribution

Measurements of the energy and arrival directions of the ultra-high-energy primary cosmic rays by the techniques of density sampling and fast timing of extensive air showers were first carried out in 1954 by members of the Rossi Cosmic Ray Group at the Massachusetts Institute of Technology. The experiment employed eleven scintillation detectors arranged within a circle 460 metres in diameter on the grounds of the Agassiz Station of the Harvard College Observatory. From that work, and from many other experiments carried out all over the world, the energy spectrum of the primary cosmic rays is now known to extend beyond 1020 eV. A huge air shower experiment called the Auger Project is currently operated at a site on the Pampas of Argentina by an international consortium of physicists. The project was first led by James Cronin, winner of the 1980 Nobel Prize in Physics from the University of Chicago, and Alan Watson of the University of Leeds, and later by scientists of the international Pierre Auger Collaboration. Their aim is to explore the properties and arrival directions of the very highest-energy primary cosmic rays. The results are expected to have important implications for particle physics and cosmology, due to a theoretical Greisen–Zatsepin–Kuzmin limit to the energies of cosmic rays from long distances (about 160 million light years) which occurs above 1020 eV because of interactions with the remnant photons from the Big Bang origin of the universe. Currently the Pierre Auger Observatory is undergoing an upgrade to improve its accuracy and find evidence for the yet unconfirmed origin of the most energetic cosmic rays.

High-energy gamma rays (>50 MeV photons) were finally discovered in the primary cosmic radiation by an MIT experiment carried on the OSO-3 satellite in 1967. Components of both galactic and extra-galactic origins were separately identified at intensities much less than 1% of the primary charged particles. Since then, numerous satellite gamma-ray observatories have mapped the gamma-ray sky. The most recent is the Fermi Observatory, which has produced a map showing a narrow band of gamma ray intensity produced in discrete and diffuse sources in our galaxy, and numerous point-like extra-galactic sources distributed over the celestial sphere.

SOURCES OF COSMIC RAYS

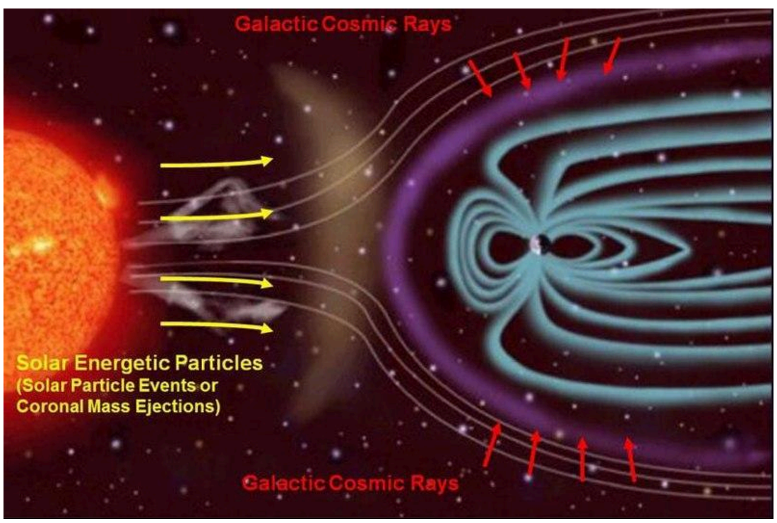
Early speculation on the sources of cosmic rays included a 1934 proposal by Baade and Zwicky suggesting cosmic rays originated from supernovae. A 1948 proposal by Horace W. Babcock suggested that magnetic variable stars could be a source of cosmic rays. Subsequently, Sekido et al. (1951) identified the Crab Nebula as a source of cosmic rays. Since then, a wide variety of potential sources for cosmic rays began to surface, including supernovae, active galactic nuclei, quasars, and gamma-ray bursts.

Later experiments have helped to identify the sources of cosmic rays with greater certainty. In 2009, a paper presented at the International Cosmic Ray Conference by scientists at the Pierre Auger Observatory in Argentina showed ultra-high energy cosmic rays originating from a location in the sky very close to the radio galaxy Centaurus A, although the authors specifically stated that further investigation would be required to confirm Centaurus A as a source of cosmic rays. However, no correlation was found between the incidence of gamma-ray bursts and cosmic rays, causing the authors to set upper limits as low as 3.4 × 10−6× erg·cm−2 on the flux of 1 GeV – 1 TeV cosmic rays from gamma-ray bursts.

In 2009, supernovae were said to have been "pinned down" as a source of cosmic rays, a discovery made by a group using data from the Very Large Telescope. This analysis, however, was disputed in 2011 with data from PAMELA, which revealed that "spectral shapes of [hydrogen and helium nuclei] are different and cannot be described well by a single power law", suggesting a more complex process of cosmic ray formation. In February 2013, though, research analyzing data from Fermi revealed through an observation of neutral pion decay that supernovae were indeed a source of cosmic rays, with each explosion producing roughly 3 × 1042 – 3 × 1043 J of cosmic rays.

Supernovae do not produce all cosmic rays, however, and the proportion of cosmic rays that they do produce is a question which cannot be answered without deeper investigation. To explain the actual process in supernovae and active galactic nuclei that accelerates the stripped atoms, physicists use shock front acceleration as a plausibility argument (see picture at right).

In 2017, the Pierre Auger Collaboration published the observation of a weak anisotropy in the arrival directions of the highest energy cosmic rays. Since the Galactic Center is in the deficit region, this anisotropy can be interpreted as evidence for the extragalactic origin of cosmic rays at the highest energies. This implies that there must be a transition energy from galactic to extragalactic sources, and there may be different types of cosmic-ray sources contributing to different energy ranges.



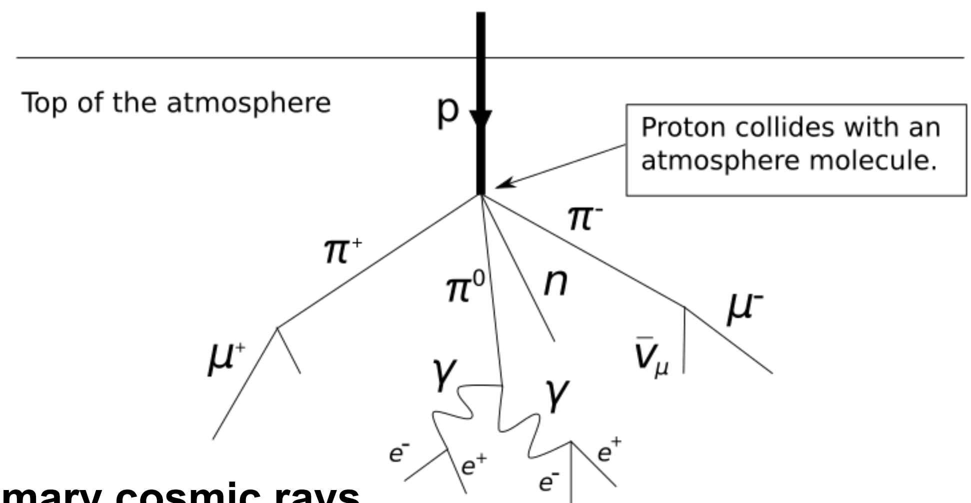
TYPES

Cosmic rays can be divided into two types:

galactic cosmic rays (GCR) and extragalactic cosmic rays, i.e., high-energy particles originating outside the solar system, and solar energetic particles, high-energy particles (predominantly protons) emitted by the sun, primarily in solar eruptions.

However, the term "cosmic ray" is often used to refer to only the extrasolar flux.

Cosmic rays originate as primary cosmic rays, which are those originally produced in various astrophysical processes. Primary cosmic rays are composed mainly of protons and alpha particles (99%), with a small amount of heavier nuclei (≈1%) and an extremely minute proportion of positrons and antiprotons. Secondary cosmic rays, caused by a decay of primary cosmic rays as they impact an atmosphere, include photons, hadrons, and leptons, such as electrons, positrons, muons, and pions. The latter three of these were first detected in cosmic rays.



Primary cosmic rays

Primary cosmic rays mostly originate from outside the Solar System and sometimes even outside the Milky Way. When they interact with Earth's atmosphere, they are converted to secondary particles. The mass ratio of helium to hydrogen nuclei, 28%, is similar to the primordial elemental abundance ratio of these elements, 24%. The remaining fraction is made up of the other heavier nuclei that are typical nucleosynthesis end products, primarily lithium, beryllium, and boron. These nuclei appear in cosmic rays in much greater abundance (≈1%) than in the solar atmosphere, where they are only about 10−11 as abundant as helium. Cosmic rays composed of charged nuclei heavier than helium are called HZE ions. Due to the high charge and heavy nature of HZE ions, their contribution to an astronaut's radiation dose in space is significant even though they are relatively scarce.

This abundance difference is a result of the way in which secondary cosmic rays are formed. Carbon and oxygen nuclei collide with interstellar matter to form lithium, beryllium and boron in a process termed cosmic ray spallation. Spallation is also responsible for the abundances of scandium, titanium, vanadium, and manganese ions in cosmic rays produced by collisions of iron and nickel nuclei with interstellar matter.

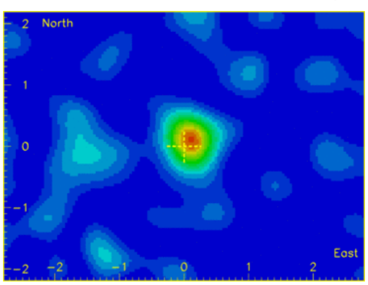
At high energies the composition changes and heavier nuclei have larger abundances in some energy ranges. Current experiments aim at more accurate measurements of the composition at high energies.

Secondary cosmic rays

When cosmic rays enter the Earth's atmosphere, they collide with atoms and molecules, mainly oxygen and nitrogen. The interaction produces a cascade of lighter particles, a so-called air shower secondary radiation that rains down, including x-rays, protons, alpha particles, pions, muons, electrons, neutrinos, and neutrons.[67] All of the secondary particles produced by the collision continue onward on paths within about one degree of the primary particle's original path.

Typical particles produced in such collisions are neutrons and charged mesons such as positive or negative pions and kaons. Some of these subsequently decay into muons and neutrinos, which are able to reach the surface of the Earth. Some high-energy muons even penetrate for some distance into shallow mines, and most neutrinos traverse the Earth without further interaction. Others decay into photons, subsequently producing electromagnetic cascades. Hence, next to photons, electrons and positrons usually dominate in air showers. These particles as well as muons can be easily detected by many types of particle detectors, such as cloud chambers, bubble chambers, water-Cherenkov or scintillation detectors. The observation of a secondary shower of particles in multiple detectors at the same time is an indication that all of the particles came from that event.

Cosmic rays impacting other planetary bodies in the Solar System are detected indirectly by observing high-energy gamma ray emissions by gamma-ray telescope. These are distinguished from radioactive decay processes by their higher energies above about 10 MeV.

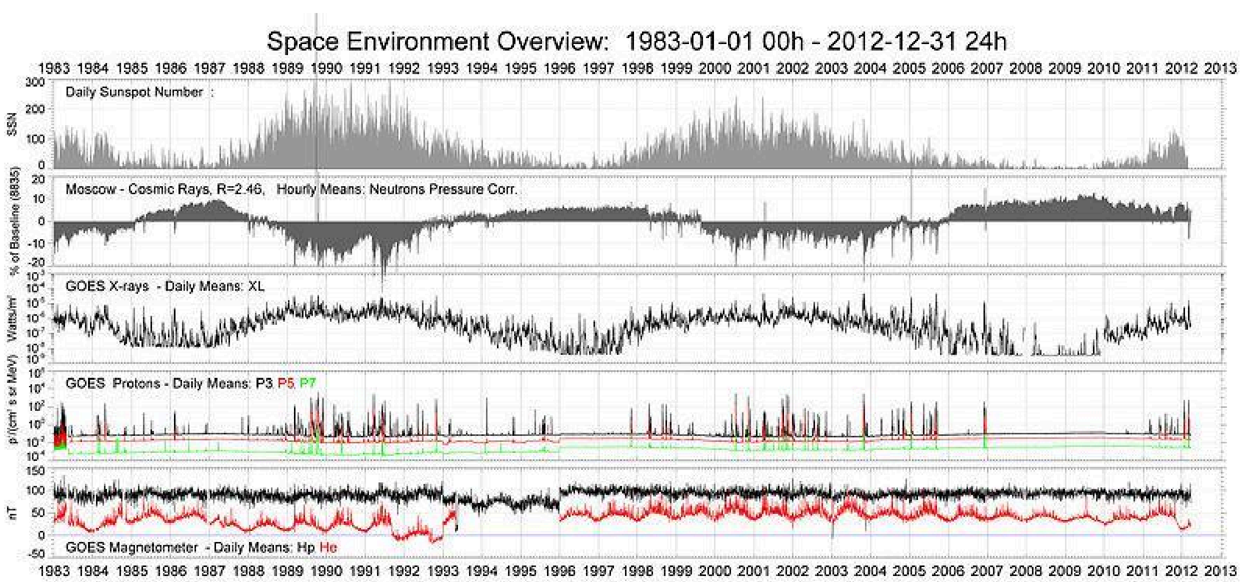


<u>Cosmic-ray flux</u>

The flux of incoming cosmic rays at the upper atmosphere is dependent on the solar wind, the Earth's magnetic field, and the energy of the cosmic rays. At distances of ≈94 AU from the Sun, the solar wind undergoes a transition, called the termination shock, from supersonic to subsonic speeds. The region between the termination shock and the heliopause acts as a barrier to cosmic rays, decreasing the flux at lower energies (≤ 1 GeV) by about 90%. However, the strength of the solar wind is not constant, and hence it has been observed that cosmic ray flux is correlated with solar activity.

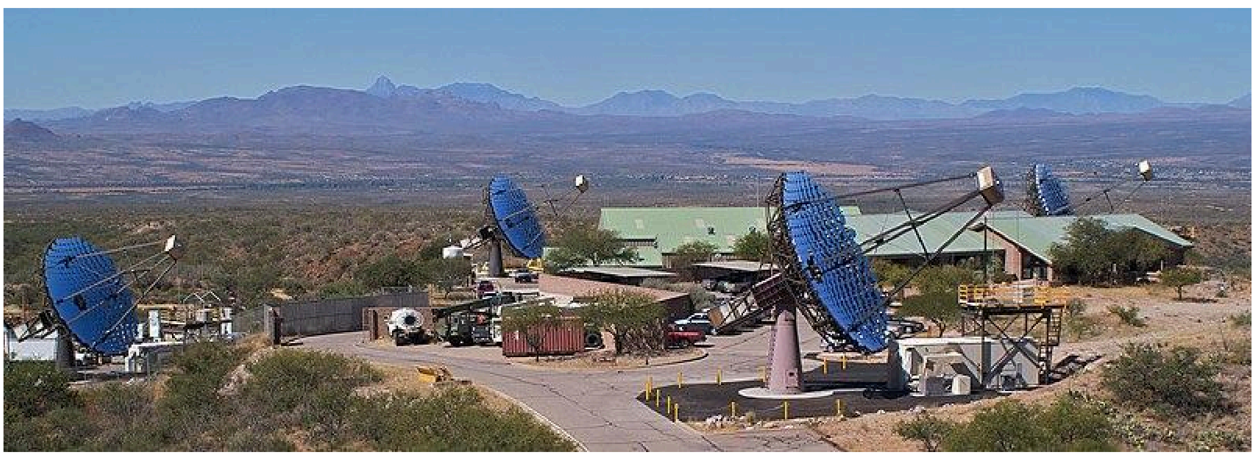
In addition, the Earth's magnetic field acts to deflect cosmic rays from its surface, giving rise to the observation that the flux is apparently dependent on latitude, longitude, and azimuth angle.

The combined effects of all of the factors mentioned contribute to the flux of cosmic rays at Earth's surface. The following table of participial frequencies reach the planet[69] and are inferred from lower-energy radiation reaching the ground.



DETECTION METHODS

There are two main classes of detection methods. First, the direct detection of the primary cosmic rays in space or at high altitude by balloon-borne instruments. Second, the indirect detection of secondary particle, i.e., extensive air showers at higher energies. While there have been proposals and prototypes for space and balloon-borne detection of air showers, currently operating experiments for high-energy cosmic rays are ground based. Generally direct detection is more accurate than indirect detection. However the flux of cosmic rays decreases with energy, which hampers direct detection for the energy range above 1 PeV. Both direct and indirect detection are realized by several techniques.



Direct detection

Direct detection is possible by all kinds of particle detectors at the ISS, on satellites, or high-altitude balloons. However, there are constraints in weight and size limiting the choices of detectors.

An example for the direct detection technique is a method based on nuclear tracks developed by Robert Fleischer, P. Buford Price, and

Robert M. Walker for use in high-altitude balloons.[73] In this method, sheets of clear plastic, like 0.25 mm Lexan polycarbonate, are stacked together and exposed directly to cosmic rays in space or high altitude. The nuclear charge causes chemical bond breaking or ionization in the plastic. At the top of the plastic stack the ionization is less, due to the high cosmic ray speed. As the cosmic ray speed decreases due to deceleration in the stack, the ionization increases along the path. The resulting plastic sheets are "etched" or slowly dissolved in warm caustic sodium hydroxide solution, that removes the surface material at a slow, known rate. The caustic sodium hydroxide dissolves the plastic at a faster rate along the path of the ionized plastic. The net result is a conical etch pit in the plastic. The etch pits are measured under a high-power microscope (typically 1600× oil-immersion), and the etch rate is plotted as a function of the depth in the stacked plastic.

This technique yields a unique curve for each atomic nucleus from 1 to 92, allowing identification of both the charge and energy of the cosmic ray that traverses the plastic stack. The more extensive the ionization along the path, the higher the charge. In addition to its uses for cosmic-ray detection, the technique is also used to detect nuclei created as products of nuclear fission.

Indirect detection

There are several ground-based methods of detecting cosmic rays currently in use, which can be divided in two main categories: the detection of secondary particles forming extensive air showers (EAS) by various types of particle detectors, and the detection of electromagnetic radiation emitted by EAS in the atmosphere.

Extensive air shower arrays made of particle detectors measure the charged particles which pass through them. EAS arrays can observe a broad area of the sky and can be active more than 90% of the time. However, they are less able to segregate background effects from cosmic rays than can air Cherenkov telescopes. Most state-of-the-art EAS arrays employ plastic scintillators. Also water (liquid or frozen) is used as a detection medium through which particles pass and produce Cherenkov radiation to make them detectable.[74] Therefore, several arrays use water/ice-Cherenkov detectors as alternative or in addition to scintillators. By the combination of several detectors, some EAS arrays have the capability to distinguish muons from lighter secondary particles (photons, electrons, positrons). The fraction of muons among the secondary particles is one traditional way to estimate the mass composition of the primary cosmic rays.

An historic method of secondary particle detection still used for demonstration purposes involves the use of cloud chambers to detect the secondary muons created when a pion decays. Cloud chambers in particular can be built from widely available materials and can be constructed even in a high-school laboratory. A fifth method, involving bubble chambers, can be used to detect cosmic ray particles.

More recently, the CMOS devices in pervasive smartphone cameras have been proposed as a practical distributed network to detect air showers from ultra-high-energy cosmic rays. The first app to exploit this proposition was the CRAYFIS (Cosmic RAYs Found in Smartphones) experiment. In 2017, the CREDO (Cosmic Ray Extremely Distributed Observatory) Collaboration released the first version of its completely open source app for Android devices. Since then the collaboration has attracted the interest and support of many scientific institutions, educational institutions and members of the public around the world. Future research has to show in what aspects this new technique can compete with dedicated EAS arrays.

The first detection method in the second category is called the air Cherenkov telescope, designed to detect low-energy (<200 GeV) cosmic rays by means of analyzing their Cherenkov radiation, which for cosmic rays are gamma rays emitted as they travel faster than the speed of light in their medium, the atmosphere. While these telescopes are extremely good at distinguishing between background radiation and that of cosmic-ray origin, they can only function well on clear nights without the Moon shining, have very small fields of view, and are only active for a few percent of the time.

A second method detects the light from nitrogen fluorescence caused by the excitation of nitrogen in the atmosphere by particles moving through the atmosphere. This method is the most accurate for cosmic rays at highest energies, in particular when combined with EAS arrays of particle detectors. Similar to the detection of Cherenkov-light, this method is restricted to clear nights.

Another method detects radio waves emitted by air showers. This technique has a high duty cycle similar to that of particle detectors. The accuracy of this technique was improved in the last years as shown by various prototype experiments, and may become an alternative to the detection of atmospheric Cherenkov-light and fluorescence light, at least at high energies.

EFFECTS

Cosmic rays have also risk for the manned space flight between planets

Cosmic rays penetrate into the earth from any direction of space Cosmic rays have such agreat energy that they might damage the object ,they can change the situation of electrical intrigated circuits.

Cosmic rays ionize nitrogen and oxygen molecules in the atmosphere, which leads to a number of chemical reactions. Cosmic rays are also responsible for the continuous production of a number of unstable isotopes, such as carbon-14, in the Earth's atmosphere through the reaction:

n + 14N → p + 14C

Cosmic rays kept the level of carbon-14[84] in the atmosphere roughly constant (70 tons) for at least the past 100,000 years,[citation needed] until the beginning of above-ground nuclear weapons testing in the early 1950s. This fact is used in radiocarbon dating.[citation needed]

Reaction products of primary cosmic rays, radioisotope half-lifetime, and production reaction

- Tritium (12.3 years): 14N(n, 3H)12C (
- spallation)
- Beryllium-7 (53.3 days)
- Beryllium-10 (1.39 million years): 14N(n,p α)10Be (spallation)
- Carbon-14 (5730 years): 14N(n, p)14C (neutron activation)
- Sodium-22 (2.6 years)
- Sodium-24 (15 hours)
- Magnesium-28 (20.9 hours)
- Silicon-31 (2.6 hours)
- Silicon-32 (101 years)
- Phosphorus-32 (14.3 days)

- Sulfur-35 (87.5 days)
- Sulfur-38 (2.84 hours)
- Chlorine-34 m (32 minutes)
- Chlorine-36 (300,000 years)
- Chlorine-38 (37.2 minutes)
- Chlorine-39 (56 minutes)
- Argon
- -39 (269 years)
- Krypton-85 (10.7 years)

Effect on electronics

Cosmic rays have sufficient energy to alter the states of circuit components in electronic integrated circuits, causing transient errors to occur (such as corrupted data in electronic memory devices or incorrect performance of CPUs) often referred to as "soft errors". This has been a problem in electronics at extremely high-altitude, such as in satellites, but with transistors becoming smaller and smaller, this is becoming an increasing concern in ground-level electronics as well. Studies by IBM in the 1990s suggest that computers typically experience about one cosmic-ray-induced error per 256 megabytes of RAM per month. To alleviate this problem, the Intel Corporation has proposed a cosmic ray detector that could be integrated into future high-density microprocessors, allowing the processor to repeat the last command following a cosmic-ray event. ECC memory is used to protect data against data corruption caused by cosmic rays.

In 2008, data corruption in a flight control system caused an Airbus A330 airliner to twice plunge hundreds of feet, resulting in injuries to multiple passengers and crew members. Cosmic rays were investigated among other possible causes of the data corruption, but were ultimately ruled out as being very unlikely.

In August 2020 scientists reported that ionizing radiation from environmental radioactive materials and cosmic rays may substantially limit the coherence times of qubits if they aren't shielded adequately which may be critical for realizing fault-tolerant superconducting quantum computers in the future.

Merid of cosmic rays

The composition of cosmic rays is important because these rays are a direct sample of matter from outside the solar syatem and contain elements are much too rare to be spectroscopic line from other stars.

They also provide important information on the chemical evolution of the universe

Demerid of cosmic rays

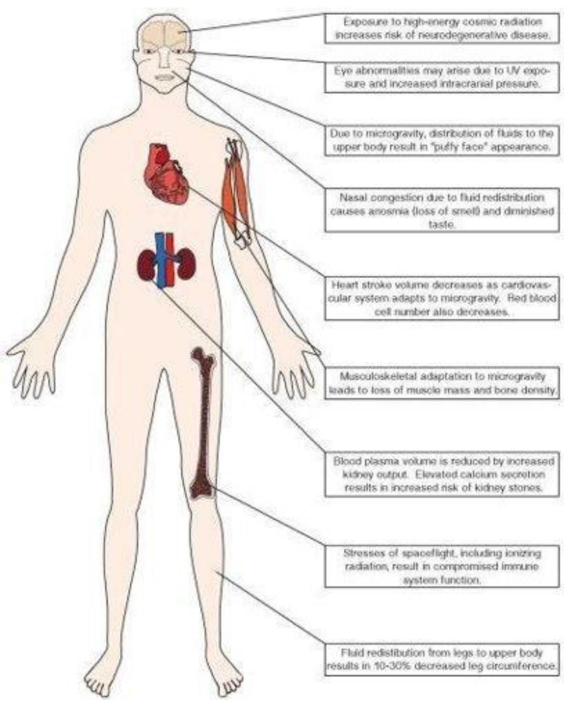
Cosmic rays can damage our DNA and cause cancer and radiation sickness.

Scientists will have to figure out how to protect astronauts from cosmic rays mars when cosmic rays hit earth’s atmosphere, they crush into atoms and molecules of gas.

Effect of cosmic rays in human body

Cosmic rays collision in the body can be harmful because they can damage the DNA in cell. Remember,a single cosmic rays has a large amount of energy. If it collides with DNA, it will destroy part of that DNA stran.

DNA contains instruction for the cell to function properly.



RESEARCH AND EXPERIMENTS

There are a number of cosmic-ray research initiatives, listed below.

Ground-based

-
- Akeno Giant Air Shower Array
- Chicago Air Shower Array
- CHICOS
- CLOUD
- CRIPT
- GAMMA
- GRAPES-3

- HAWC
- HEGRA
- High Energy Stereoscopic System
- High Resolution Fly's Eye Cosmic Ray Detector
- IceCube
- KASCADE
- MAGIC
- MARIACHI
- Milagro
- NMDB
- Pierre Auger Observatory
- QuarkNet
- Spaceship Earth
- Telescope Array Project
- Tunka experiment
- VERITAS
- Washington Large Area Time Coincidence Array

Satellite

- ACE (Advanced Composition Explorer)
- Alpha Magnetic Spectrometer
- Cassini–Huygens
- Fermi Gamma-ray Space Telescope
- HEAO 1, HEAO 2, HEAO 3
- Interstellar Boundary Explorer
- Langton Ultimate Cosmic-Ray Intensity Detector
- PAMELA
- Solar and Heliospheric Observatory
- Voyager 1 and Voyager 2

Balloon-borne

- Advanced Thin Ionization Calorimeter
- BESS
- Cosmic Ray Energetics and Mass (CREAM)
- HEAT (High Energy Antimatter Telescope)
- PERDaix
- TIGER Archived 3 May 2012 at the Wayback Machine
- TRACER (cosmic ray detector)

CONCLUSIONS

After the discovery of the cosmic rays by Viktor Hess in 1912, this phenomenon is still today one of the greatest mysteries of astrophysics. Even if the composition is well known for energies below some TeV and the energy distribution is well observed until an energy of around 1018 eV, the sources and the propagation of these ionised particles are yet not known and understood. During the last century a lot of models, which try to explain the observed properties, are conceived, of which the leaky box model is the most successful. Knowing the abundances of the various kinds of secondary nuclei, produced via spallation while propagating through the interstellar medium, we can determine several parameters of the propagation models of cosmic rays in the Galaxy. This determination allows us to restrict some of these propagation models. Especially the boron-to-carbon ratio has always been considered the best quantity to study diffusion properties. In the leaky box model the relative abundance of stable secondary nuclei is completely determined by the average matter thickness (grammage) traversed by the particles. Additionally this model describes the energy dependence of the traversed matter, explaining the observed B/C ratio, by using a slope, named the spectral index. The spectral index shapes the B/C ratio at high energies and its measurement has become a crucial astrophysical feature, because of its importance for the propagation model constraints. The direct detection of high energy cosmic rays up to ∼ 1015 eV could be assured by space based experiments like AMS (∼ 1012 eV) or balloon experiments like CREAM. At an energy of 1012 eV the B/C ratios differ in approximately one order of magnitude for a spectral index value of 0.3 and 0.85, which permits an easier identification of the exact value from the measured data. For balloon experiments, which fly at an altitude of about 40 km, the direct detection of the cosmic-ray particles is biased by the secondary particles, produced via interaction with atmospheric particles in the Earth's upper atmosphere. For increasing energies this secondary production becomes more important and influences the B/C ratios, measured at a depth of 5 g/cm2 . These become at this depth flatter and practically constant for high energies, where a spectral index of 0.85 is more affected as the smaller indices. For taking into account the absorption and the secondary production, during the propagation of the cosmic rays in the Earth's atmosphere, a matrix method, estimating this effect, was conceived and implemented. For calculating this response matrix the total and partial inelastic cross sections of nucleus-nucleus reactions were needed. Some approaches exist to calculate these cross sections, which have been presented in this thesis and two of them were used for the matrix calculation. Here we got help from David Maurin, who provides his USINE software for the implementation. The matrix method is easy to handle and permits the reconstruction of the top of atmosphere fluxes from the measured atmospheric fluxes. For this reconstruction the matrix had to be inverted, which could cause unfolding problems. The procedure of correcting distortions, due to statistical errors, is known as unfolding. In this work, we tested our response matrix for unfolding problems for a atmospheric depth of 5 g/cm2 , a measuring time of 100 days, a detector acceptance of 1 m2 sr, and 30 energy bins for the whole considered energy range. Because the eigenvalues of the corresponding response matrix are close to one, no unfolding problem had been observed and therefore, there is no need to unfold the reconstructed data for this depth. By using the calculated cross sections, we have to be aware of the introduced systematic errors in our reconstruction, induced by the errors on the cross sections. The influence of the systematic errors on the B/C ratios had been analysed for three different spectral indices. Large spectral indices are more affected at high energies by the systematical error as smaller indices. This systematical error was calculated by using an error of 10% on the fragmentation cross sections and 5% on the total inelastic cross sections. This does not allow us to make an exact extrapolation of the spectral index from the data taken, but we can estimate lower and upper limits for it, which had been calculated for three different spectral indices. At last, the statistical error of the data had been analysed. For all the spectral indices examined the statistical error dominates the systematical error up to an energy of around 200 GeV/n for a measuring time of 100 days a detector acceptance of 1 m2 sr, and 30 energy bins for the whole considered energy range. The propagation of cosmic rays in the Earth's atmosphere and its effects on data have been investigated. A method for an extrapolation to the TOA fluxes has been conceived, successfully implemented, and tested. The influence of the errors on the cross sections has been estimated for various spectral indices. This conceived method can be easily enlarged to calculate the interaction of cosmic rays in the detectors itself. For this additionally, a simulation of the detectors AMS and CREAM would permit the preparation of the data analysis for these two detectors. In this thesis only perpendicular fluxes were considered. A next step would be to take into account the zenith angle, under which the cosmic rays arrive on the detector. In order to generate a general program, applicable to other detectors, additionally features will be implemented.

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