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AB: Within a 6-minute span on January 20, 2005, the count rate of the high-altitude neutron monitor at South Pole increased by a factor of 56. This was the largest increase of cosmic radiation ever recorded on the surface of Earth. Normalized to sea level, the event was second only to the famous 1956 ground level enhancement. The event was enormously anisotropic, as high-latitude stations outside Antarctica recorded an increase roughly a factor of 10 smaller. We employ observations from the Spaceship Earth network and other neutron monitors to derive the time profile, anisotropy, and energy spectrum of relativistic solar protons on January 20, 2005. We also model the event based upon the Boltzmann equation and conclude that this event may have featured a rare instance of wave excitation and nonlinear transport from streaming relativistic protons. Supported by NSF grant ATM-0000315, by the Thailand Research Fund, and by the Rachadapisek Sompoj Fund of Chulalongkorn University.
UR: http://neutronm.bartol.udel.edu/
DE: 2104 Cosmic rays
DE: 2114 Energetic particles (7514)
DE: 7845 Particle acceleration
DE: 7984 Space radiation environment
SC: SPA-Solar and Heliospheric Physics [SH]
MN: Fall Meeting 2005

New Search

AGU

Conditional Statistics of Magnetic Turbulence and the Lateral Transport of Solar Energetic Particles

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A topic of current interest in the cosmic ray community is the apparent conflict between two sets of spacecraft observations of solar energetic particles (SEP): 1. SEP from impulsive solar flares can exhibit "dropouts" in which the flux measured near Earth repeatedly disappears and reappears, as measured by the ACE spacecraft. This indicates that the density of SEP in space is highly filamented, and seems to imply very little lateral diffusion. 2. Observations from the IMP-8 and Ulysses spacecraft, while they were on opposite sides of the Sun, showed similar time-intensity profiles in the decay phases of nearly all SEP events. This indicates that the particles undergo substantial lateral diffusion, spreading throughout the entire inner solar system within a few days. Here we propose a way to reconcile these seemingly contradictory observations by taking into account the composite slab (longitudinal) + 2D (transverse) nature of interplanetary magnetic turbulence. There is evidence that particles mainly follow the magnetic field lines, i.e., the lateral diffusion of particles vs. time is related to the lateral diffusion of interplanetary magnetic field lines vs. distance, and this in turn is dominated by the 2D component. We generate realizations of magnetic turbulence by inverse Fourier transforms of *k*-space representations of fixed power spectrum and random phase, followed by tracing of the magnetic field lines. Our calculations show that over intermediate distance scales, magnetic field lines near **X**-points in the 2D turbulence spread rapidly in the lateral directions, whereas magnetic field lines near **O**-points remain within islands of the 2D turbulence, with lateral diffusion at the much slower rate associated with slab turbulence. Over a long distance scale, essentially all magnetic field lines have escaped from 2D islands and undergo substantial lateral diffusion.

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Computer Simulations of the Random Walk of Turbulent Magnetic Field Lines

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The motion of charged particles in space is dominated by the weak, random magnetic fields that permeate our solar system and our galaxy. Energetic charged particles follow helical orbits that approximately track the magnetic field lines. The field lines, in turn, undergo a complicated random walk due to the turbulence that is universally present in astrophysical fluids. Therefore, we aim to find the diffusion coefficient for the random walk of a magnetic field line, which is related to the particle diffusion. In our work, we simulate collections of magnetic field lines in two-component (2D+slab) turbulence by generating the magnetic field in wave vector space, which is a Komogorov spectrum at high k, and by using an inverse fast Fourier transform to convert them back to real space. In order to trace the field lines, we solve the equation of the field lines by a Runge-Kutta method with adaptive step sizes for more accuracy. We address both ensemble average statistics, with the goal of verifying previous analytic calculations, and conditional statistics, to explore the spatial dependence of the random walk. These calculations will help improve understanding of the transport of energetic particles (cosmic rays) in the solar system and the acceleration of energetic particles at nearly perpendicular shocks.

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Effects of Systematic Pitch-Angle Changes on Cosmic Ray Acceleration at Shocks and Compression Regions: Contribution of the Mirroring Effect

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It is commonly believed that most cosmic rays are accelerated at astrophysical shocks. Many works studying this acceleration mechanism have used a diffusion-convection equation (DC). Nevertheless, that is an approximate equation based on the diffusion approximation of a pitch-angle transport equation (PA). The PA approach is more precise and also more complicated. In this work, we solve the PA equation to simulate cosmic-ray particle transport at compression regions, with various compression widths, and shocks (zero width) by solving the pitch-angle transport equation with a finite-difference method and the diffusion-convection equation, which does not take systematic pitch-angle changing into account, with a shooting method. Moreover, we also vary the shock angle, defined as the angle between magnetic field lines and the normal to the shock/compression plane. The different results from the PA and approximate DC approaches are compared and analyzed to point out the effects of systematic pitch-angle changes on the shock acceleration mechanism. We conclude that the magnetic mirroring effect, which appears only in the pitch-angle treatment, can enhance the acceleration mechanism in cases of narrow compression widths.

Accurate Timing of Solar Energetic Particle Acceleration on April 15, 2001

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The largest relativistic (~1 GeV) solar proton event of the current 11-year solar cycle occurred on Easter (April 15) 2001. This event was observed as a ground level enhancement (GLE) by the 11-station *Spaceship Earth* network of neutron monitors. We derive time profiles of the density and anisotropy of solar energetic particles at Earth. These data are of unprecedented, 1-minute resolution, allowing the most accurate timing ever obtained regarding relativistic ion acceleration at the Sun. To extract information on the timing of solar particle acceleration, we apply simulation and fitting techniques developed at Chulalongkorn University (Ruffolo 1995; Ruffolo, Khumlumlert, and Youngdee 1998), which determine both the interplanetary transport conditions and the so-called injection profile, i.e., the number of particles accelerated at the Sun as a function of time. Interplanetary transport was rather diffusive in this event, with a radial mean free path of about 0.18 AU. We find that particle acceleration at the Sun began at 13:42 ± 1 min. Universal Time. This time is at or after the peak times of solar flare emissions (Hα or X-rays), but at about the same time as the onset of shock-related emissions (Type II and Type IV radio bursts). This favors the idea that a coronal mass ejection shock, not the flare itself, was responsible for relativistic ion acceleration during this gradual event.

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FINITE TIME SHOCK ACCELERATION AT INTERPLANETARY SHOCKS

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ABSTRACT: Observations of energetic ion acceleration at interplanetary shocks sometimes indicate a spectral rollover at ~ 0.1 to 1 MeV nucl^{-1}. This rollover is not well explained by finite shock width or thickness effects. At the same time, a typical timescale of diffusive shock acceleration is several days, implying that the process of shock acceleration at an interplanetary shock near Earth usually gives only a mild increase in energy to an existing seed particle population. This is consistent with a recent analysis of *ACE* observations that argues for a seed population at substantially higher energies than the solar wind. Therefore an explanation of typical spectra of interplanetary shock-accelerated ions requires a theory of finite-time shock acceleration, which for long times (or an unusually fast acceleration timescale) tends to the steady-state result of a power-law spectrum. We present analytic and numerical models of finite-time shock acceleration. For a given injection momentum p_0, after a very short time there is only a small boost in momentum, at intermediate times the spectrum is a power law with a hump and steep cutoff at a critical momentum, and at longer times the critical momentum increases and the spectrum approaches the steady-state power law. The composition dependence of the critical momentum is different from that obtained for other cutoff mechanisms. The results can be compared with observed spectra.

KEYWORDS: Space physics, solar energetic particles, computational physics

1. INTRODUCTION

Traveling shocks in interplanetary space cause acceleration of particles to high energy (>1 MeV). In diffusive shock acceleration theory, the acceleration of an energetic seed population ultimately results in a power law. The spectral form of Ellison and Ramaty (1985), a power law in momentum with an exponential rollover in energy, has proven useful in fitting spectra of solar energetic particles. The composition dependence of the rollover depends on the physical effect that causes the rollover. We argue that observed rollovers in the spectra of particles from interplanetary shocks are best explained as the acceleration of a suprathermal seed population (Desai et al. 2003) by the finite time available for the acceleration process, limiting the energy that can be achieved.

We propose a model for simulating shock acceleration of particles at interplanetary shocks to describe characteristics of solar energetic particle spectra that depend on the finite time in the acceleration process. The typical acceleration timescale t_{acc} (corresponding to observed mean free paths) is on the order of several days, so the process of shock acceleration at interplanetary shocks near the Earth should usually give only a mild increase in energy to an existing seed particle population.

EFFECT OF A TURBULENT MAGNETIC FIELD ON THE SHOCK DRIFT ACCELERATION OF PARTICLES AT A NEARLY PERPENDICULAR SHOCK

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ABSTRACT: Anomalous cosmic rays are accelerated at the solar wind termination shock, a "nearly perpendicular" shock in the sense that the magnetic field is nearly perpendicular to the shock normal. Here, a model of turbulent magnetic fields is used to explain how anomalous cosmic rays can drift along the termination shock all the way from the heliospheric equator to the pole or vice-versa. In non-turbulent magnetic fields which pass the shocks only one time, charged particles (which have to move along the magnetic field line) will encounter the shock many times due to diffusion in pitch angle. If we take the magnetic field turbulence into account, the magnetic field lines can cross a nearly perpendicular shock more than once, leading to enhanced acceleration. This work was supported by the Thailand Research Fund and the Rachadapisek Sompoj Fund of Chulalongkorn University.

KEYWORDS: Anomalous cosmic rays, solar wind termination shock, turbulent magnetic fields

INTRODUCTION

Cosmic rays are gamma rays or energetic particles from space and can be accelerated in many ways. A shock is region where the discontinuity of parameters of fluid occurs. A shock appears when two fluids with a relative velocity greater than the speed of sound encounter each other. A shock can accelerate existing ions to high energies to become cosmic rays, and cosmic rays called anomalous cosmic rays (ACR) are accelerated at the solar wind termination shock from 1 keV/nucleon to energies of tens of MeV/nucleon. Charged particles are known to move along the magnetic field line if the perpendicular diffusion coefficient is much smaller than the parallel diffusion coefficient (Jokipii 1987). At the solar wind termination shock, the mean magnetic field that is nearly perpendicular to the shock normal enhances the shock drift acceleration process, which can give much more energy to particles. Particles gain a large energy because particles that move along the magnetic field line at shock can cross the shock many times due to the turbulence of the magnetic field. Because the magnetic field is turbulent, the angle between the actual magnetic field line and the shock normal can vary. The change in the angle leads to different values of energy gained (Jokipii 1987) and the time for acceleration can be changed due to the number of shock-field crossings.

MODEL

The model of the magnetic field we use is a model used to explain the magnetic statistics in the interplanetary medium (Matthaeus, Goldstein, & Roberts 1990). The mean magnetic field and the turbulent magnetic field normal to the mean magnetic fields are combined in this model. The random magnetic field is divided into two terms which are called the "slab" component and "2D" component.

$$\vec{B} = B_0\hat{z} + \vec{b}(x,y,z) = B_0\hat{z} + \vec{b}^{2D}(x,y) + \vec{b}^{slab}(z),\ \ \vec{b}(x,y,z) \perp \hat{z}$$

The "slab" component depends on z only and the "2D" component depends on x and y only. We generate the random magnetic field in wave number space because we know its behavior in wave number space. The spectrum of a turbulent magnetic field for a large wave number must be

INHIBITION OF RANDOM WALK BY SYSTEMATIC FLOW IN TWO DIMENSIONS

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ABSTRACT: We numerically studied the random walk of field lines in a 2D field plus slab turbulence. The 2D field itself represents a systematic flow; the field lines are not diffusive since they always follow the contours of the 2D potential function (analogous to the stream function in fluid flow). In contrast, slab turbulence causes the field line trajectories to undergo a random walk in space. Here, we trace the field lines in the combination of these two fields and look their statistical behaviors. From the computer simulations, we found that where the 2D field is strong, the field line random walk is inhibited. The boundary of trapping is sharp and depends mainly on the structure of 2D field. Starting the field lines inside such a boundary, the diffusion of field lines systematically changes with a delay at the beginning due to the strong 2D field. Furthermore, we can mathematically define the boundary of trapping, which we call the local trapping boundary (LTB), as a trajectory of 2D turbulence where the mean 2D field is a local maximum. This study leads us to explain the dropouts of solar energetic particles in interplanetary space, since there is evidence that the 2D+slab turbulence model of magnetic field provides a good explanation for solar wind spectra and the parallel transport of solar energetic particles.

KEYWORDS: random walk, magnetic field, turbulence, diffusion

1. MOTIVATION

This paper concerns trajectories in a systematic flow that is superimposed on a random walk process in two dimensions. In particular, if the motion is a function of the parameter z, we consider that the velocity in two dimensions is given by

$$\vec{v} = \vec{v}_1(x,y) + \vec{v}_2(z), \tag{1}$$

where $\vec{v}_2(z)$ is a random field that in the absence of $\vec{v}_1$ will give rise to diffusion for z much greater than a finite correlation length ℓ_c. We find that a strong field $\vec{v}_1$ can suppress that diffusion, and derive a theory for the actual diffusion coefficient in the combined fields.

Our motivation to study this system arises from studies of magnetic field line trajectories in solar wind turbulence, which can be described by a two-component turbulence model:

$$\vec{B}(x,y,z) = B_0\hat{z} + \vec{b}_{2D}(x,y) + \vec{b}_{slab}(z), \tag{2}$$

where both $\vec{b}_{2D}$ and $\vec{b}_{slab}$ represent turbulent fluctuations. This two-component model, an archetype of anisotropic turbulence, was motivated by the observation that solar wind fluctuations are concentrated at wavenumbers nearly parallel and nearly perpendicular to the mean field (Matthaeus, Goldstein, and Roberts 1990), which are termed slab and 2D components, respectively. Furthermore, this model provides a good explanation of the parallel transport of solar energetic particles in interplanetary space (Bieber et al. 1994), providing a solution to the long-standing discrepancy

UNUSUAL FEATURES OF THE OCTOBER 28, 2003 GROUND LEVEL ENHANCEMENT

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ABSTRACT: The ground level enhancement (GLE) of October 28, 2003 was unusual in a number of respects. Instead of a single, anisotropic peak from the Sunward field direction followed by an isotropic decay in intensity, this event exhibited two highly anisotropic spikes from very different directions. The earliest onset was seen by Norilsk, Russia, which is surprising because this station at the time was viewing approximately anti-Sunward along the nominal Parker spiral direction. While that spike rapidly declined, another spike was observed by several neutron monitor stations, lasting about 60 minutes. This spike was also not from the Sunward field direction, but rather from a far South latitude. The decay of the event, on the other hand, was unusually slow. In fact, the particle intensity remained at elevated levels until the coronal mass ejection associated with the GLE arrived at Earth and swept the solar particles away. In addition, this event had an unusually hard energy spectrum compared to other GLEs. We report on observations of the event made by the Spaceship Earth neutron monitor network, together with preliminary modeling of the event based on the Boltzmann equation.

KEYWORDS: cosmic rays, solar ejecta, solar energetic particles, solar and heliospheric physics, diffusion and transport equation

1. INTRODUCTION

Energetic solar events at the Sun (like solar flares) are usually associated to the emission of energetic particles (mostly energetic protons). These solar energetic particles (SEPs) often reach the Earth and are detected by instruments located on spacecraft. A ground level enhancement (GLE) occurs whenever the intensity of SEPs arriving to the Earth's atmosphere is high enough to originate particle cascades that increase radiation levels at Earth's surface. GLEs are thus generally associated with very intense solar flares, and especially those originating at active regions facing the Earth at the time of the flare.

A neutron monitor is a very appropriate instrument for detecting a GLE at any location of the world through the count rates of neutrons from the atmospheric showers produced by cosmic rays. Polar locations are much more likely to detect the enhancement, because charged particles are not deflected much by the Earth's magnetic field, which also provides better directional sensitivity. *Spaceship Earth* is a network of neutron monitors strategically deployed to provide precise, real-time, three-dimensional measurements of the cosmic ray angular distribution (Bieber et al. 2004). Spaceship Earth is a multinational collaboration collecting data from eleven neutron monitors located at different countries on four continents.

The three-dimensional distribution of SEPs arriving to the Earth usually presents similar features for any solar event: the first SEPs are detected from the direction of the magnetic field line coming from the Sun, afterwards the distribution gradually becomes isotropic, and finally the intensity decays with time. These features are understood by considering how SEPs travel along the interplanetary

ลักษณะไม่ปกติของการเพิ่มจำนวนรังสีคอสมิกที่ระดับพื้นดินเมื่อวันที่ 28 ตุลาคม 2546
UNUSUAL FEATURES OF THE OCTOBER 28, 2003 GROUND LEVEL ENHANCEMENT OF COSMIC RAYS

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John W. Bieber[1], Paul Evenson[1], Roger Pyle[1], David Ruffolo[2], and Alejandro Sáiz[2,3]
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บทคัดย่อ: การเพิ่มจำนวนรังสีคอสมิกที่ระดับพื้นดินเกิดขึ้นเมื่อการปะทุที่ดวงอาทิตย์เร่งอนุภาคพลังงานสูงจากดวงอาทิตย์ อนุภาคนี้ผ่านมายังบรรยากาศของโลกทำให้เกิดฝนรังสีคอสมิกและเพิ่มระดับรังสีที่พื้นผิวของโลก การเพิ่มนี้ถูกสังเกตโดยเครื่องวัดรังสีคอสมิกที่ตั้งบนพื้นโลกเช่น เครื่องวัดนิวตรอน เมื่อวันที่ 28 ตุลาคม 2546 เราพบลักษณะรังสีคอสมิกผิดปกติในหลายคุณสมบัติ เช่น ในเหตุการณ์ปกติความเข้มของรังสีคอสมิกสูงสุดที่เวลาหนึ่งๆเมื่อวัดในทิศทางของสนามแม่เหล็กจากดวงอาทิตย์และค่อยลดลงจนเมื่อวัดในทิศทางใดจะให้ความเข้มของรังสีคอสมิกเท่ากันแต่เหตุการณ์นี้วัดความเข้มของรังสีคอสมิกที่สูงมากได้ถึงสองครั้งในเวลาต่างกันและในทิศทางที่ต่างกันมาก สถานีตรวจวัดนิวตรอนที่ Norilsk ประเทศรัสเซียพบเหตุการณ์นี้เร็วที่สุดแต่ปกติแล้วเครื่องวัดนี้วัดอนุภาคในทิศตรงข้ามกับสนามแม่เหล็กจากดวงอาทิตย์ที่แบบเกลียว (Parker spiral) และพบว่าความเข้มลดลงอย่างรวดเร็ว และเพิ่มขึ้นอีกในเวลาต่อมาอย่างช้าประมาณ 60 นาทีที่สถานีบนตำแหน่งอื่นๆ ความเข้มสูงนี้ไม่ได้มาในทิศเดียวกับสนามแม่เหล็กจากดวงอาทิตย์แต่มาจากทิศทางที่ใกล้ขั้วโลกใต้ และความเข้มที่ลดลงในเวลาต่อมานั้นช้าเมื่อเทียบกับเหตุการณ์ปะทุทั่วไป ในความเป็นจริงแล้วความเข้มของอนุภาคจะยังมากกว่าปกติจนกว่าการปล่อยก้อนมวลจากดวงอาทิตย์ที่เกิดพร้อมกับการปะทุจะมาถึงและพาอนุภาคจากดวงอาทิตย์ไป

Abstract: A ground level enhancement (GLE) occurs when the intensity of solar energetic particles (SEPs) that arrive to the Earth after a solar flare is high enough to originate particle cascades in the atmosphere that increase radiation levels at Earth's surface. This enhancement is observed by ground-based cosmic ray detectors, like neutron monitors. The GLE of October 28, 2003 was unusual in a number of respects. Instead of a single, anisotropic peak from the Sunward field direction followed by an isotropic decay in intensity, this event exhibited two highly

การเร่งอนุภาคที่คลื่นกระแทกในเวลาจำกัดและสเปกตรัมของไอออนจากคลื่นกระแทกในตัวกลางระหว่างดาวเคราะห์

FINITE-TIME SHOCK ACCELERATION AND ION SPECTRA FROM INTERPLANETARY SHOCKS

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บทคัดย่อ: จากข้อมูลการสังเกตวัดไอออนพลังงานสูงซึ่งเกิดจากการเร่งที่คลื่นกระแทกในตัวกลางระหว่างดาวเคราะห์ พบว่าในหลายๆ ครั้งสเปกตรัมที่ได้จะเกิดการโค้งลงในช่วงพลังงาน 0.1 ถึง 10 MeV/นิวคลีออน เราเสนอว่าการโค้งลงนั้นอธิบายได้ในเทอมของช่วงเวลาจำกัดของกระบวนการการเร่ง ซึ่งเกี่ยวข้องกับอายุของคลื่นกระแทก ดังนั้นเราต้องการทฤษฎีใหม่สำหรับการเร่งอนุภาคในเวลาที่จำกัด ซึ่งที่เวลานานๆ นั้น (หรือกรณีอัตราการเร่งสูง) จะมีผลที่เข้าสู่สถานะอยู่นิ่งในรูปของกฎยกกำลัง ในงานวิจัยนี้เราเสนอแบบจำลองเชิงวิเคราะห์และเชิงตัวเลขของการเร่งอนุภาคในเวลาที่จำกัด ซึ่งแบบจำลองนี้สามารถอธิบายเชิงคุณภาพว่าทำไมมีการสังเกตสเปกตรัมที่แตกต่างมากจากคลื่นกระแทกที่มาจากการปล่อยก้อนมวลจากโคโรนาขณะที่ยังใกล้ๆกับดวงอาทิตย์และขณะที่อยู่ในตัวกลางระหว่างดาวเคราะห์ และแบบจำลองให้คำตอบเชิงปริมาณสำหรับคลื่นกระแทกในตัวกลางระหว่างดาวเคราะห์ ซึ่งให้ผลในรูปแบบของกฎยกกำลังที่ค่าพลังงานต่ำและต่อมาเกิดการโค้งลงที่ค่าพลังงานวิกฤต และยังทำนายว่าพลังงานวิกฤต ขึ้นกับมวลและประจุของไอออน ในลักษณะที่แตกต่างจากลักษณะที่ได้สำหรับผลทฤษฎีอื่นจากการวิจัยนี้สามารถอธิบายปัญหาที่ซับซ้อนในสเปกตรัมของไอออนและอิเล็กตรอนที่สังเกตวัดได้ ก่อนและหลังการผ่านของคลื่นกระแทกใน ตัวกลางระหว่างดาวเคราะห์

Abstract: Observations of energetic ion acceleration at interplanetary shocks often indicate a spectral rollover at ~ 0.1 to 10 MeV nucl^{-1}. We argue that this is best explained by the limited time duration of the process, related to the age

Injection and Transport of Relativistic Solar Protons along Both Legs of a Closed Interplanetary Magnetic Field Loop

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Abstract

Worldwide neutron monitor observations of relativistic solar protons on 1989 October 22 have proven puzzling, with an initial spike at some stations followed by a second peak, which is difficult to understand in terms of transport along a standard Archimedean spiral magnetic field or a second injection near the Sun. Here we analyze data from polar monitors, which measure the directional distribution of solar energetic particles (mainly protons) at rigidities of ~1-3 GV. This event has the unusual properties that the particle density dips after the initial spike, followed by a hump with bidirectional flows and then a very slow decay. The density and anisotropy data are simultaneously fit by numerically solving the partial differential equation of particle transport for various magnetic field configurations and then performing numerical convolutions to determine the best-fit injection function near the Sun. The data are not well fit for an Archimedean spiral field, a magnetic bottleneck beyond Earth, or particle injection along one leg of a closed magnetic loop. A model with simultaneous injection along both legs of a closed loop provides the best explanation: particles moving along the near leg make up the spike, those coming from the far leg make up the hump, and trapping in the loop accounts for the slow decay of the particle density. The injection of particles near the Sun exhibits a short, strong peak, extended injection at a low level over ≈ 100 minutes, and a sharp cutoff that is probably due to changing magnetic connection to the source. Refined fits indicate a very low spectral index of turbulence q, a mean free path of 2.2 to 3.3 AU, a loop length of 4.1 to 4.6 AU, and escape of relativistic protons from the loop on a time scale of 3 hours. The weak scattering is consistent with reports of weak fluctuations in magnetic loops and other regions of high Alfvén speed, while the low q value may indicate a lower correlation length as well.

On the Estimation of Solar Energetic Particle Injection Timing from Onset Times near Earth

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Abstract

We examine the accuracy of a common technique for estimating the start time of solar energetic particle injection based on a linear fit to the observed onset time versus the inverse of particle velocity. This is based on a concept that the first arriving particles move directly along the magnetic field with no scattering. We check this by performing numerical simulations of the transport of solar protons with kinetic energies between 2 and 2000 MeV from the Sun to the Earth, for several assumptions regarding interplanetary scattering and the duration of particle injection. For this purpose, we use a finite differences method to numerically solve the Boltzmann equation. We then analyze the results using the inverse velocity fit. We find that in most cases, the onset times align close to a straight line as a function of inverse velocity. Despite this, the estimated injection time is typically in error by several minutes. Also, the estimated path length can deviate greatly from the actual path length along the interplanetary magnetic field. The major difference between the estimated and actual path lengths implies that the first arriving particles cannot be viewed as moving directly along the interplanetary magnetic field.

1. Introduction

An important issue when studying solar events is the exact time when energetic particles are first released from the Sun or its vicinity. This is crucial to understanding the mechanisms of particle acceleration and where it takes place [e.g., 11]. When inferring the start time of particle release, t_0, one has to take into account the many different processes acting on the particles from their release until the time of detection, $t_{\rm onset}$, at spacecraft or Earth-based instruments. First the particles (most of them protons) are released with a finite duration of injection at the Sun, and with velocity $v = \beta c$. Because they are charged particles, their motion mostly follows the interplanetary magnetic field, gyrating with a pitch angle θ (defined as the angle between the velocity and the mean field). At the same time, the particles suffer interplanetary scattering due to resonant interactions

The Princess Sirindhorn Neutron Monitor Simulation

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Abstract

Neutron Monitors are devices for detecting neutrons from the sky. The detection of neutrons allows us to study the astrophysical phenomena in the outer space. The neutron counting rates are used to predict the arrival of high energy primary cosmic rays, which cause many serious effects to our technologies. In this paper, a study has been carried out to determine the function of the neutron monitors components using computer simulations with GEANT4 program. The geometry used in the simulations is obtained from the Princess Sirindhorn Neutron Monitor. The simulations provided energy distribution in the neutron counters and the functions of the major components in the neutron monitors (the lead producer, the inner moderator, and the reflector) have been studied. The simulations also indicate the contribution of charged particles arriving into the detector besides neutrons.

1 Introduction

The sky is not nearly as benign as we might think, even with respect to the cosmic ray showers in the atmosphere. Therefore, the atmospheric environment is the result from high-energy cosmic rays traveling through the Earth's magnetosphere, striking air molecules, and generating a cascade of several particles showering toward the ground.

Cosmic rays are termed for energetic particles coming from outer space. They are produced from objects such as neutron stars, black hole etc. The Sun is the primary source for cosmic rays entering the Earth. The arrivals of solar cosmic rays cause many problems, from low to serious level, to our technologies. Their arrival is related to violent events on the Sun's surface.

Monitoring cosmic rays helps us to predict their arrivals. This is useful to reduce and protect damages from the entering of high-energy solar cosmic rays. Scientists setup neutron monitors stations in order to detect neutrons from the sky. These neutrons are produced in the atmosphere from the cosmic ray showers. The neutron counts in the detectors are the indicators for the flux of the entering cosmic rays, which is related to the astrophysical phenomena in the space.

The Princess Sirindhorn Neutron Monitor Station Project is planned to set a neutron monitor station at Doi Intanon, Chaingmai Province, Thailand. This future station will be the second most sensitive detectors of neutrons from relativistic solar cosmic rays and will be in the top-five worldwide in terms of total cosmic ray counting rates. The Princess Sirindhorn Neutron Monitor is the NM64 detector type; the prototype was originally

high-purity germanium detector and gamma spectroscopy analysis system and comparing to the standard soil (IAEA SOIL 6) at Office of Atoms for Peace (OAP). The measuring time of all sand samples is 10,000 seconds. Some radioisotopes such as K-40, Cs-137, Tl-208, Bi-212, Pb-212, Bi-214, Pb-214, Ra-226 and Ac-228, were found in sand samples. The activity of Ra-226 and Cs-137 in those samples are provided and they were found in normal level.

D0086-RELATIVISTIC SOLAR PROTONS ON 1989 OCTOBER 22: INJECTION AND TRANSPORT ALONG BOTH LEGS OF A CLOSED INTERPLANETARY MAGNETIC LOOP

~~John W. Bieber, Paul Evenson, Roger Pyle~~, David Ruffolo[(a)], Paisan Tooprakai[(b)], Manit Rujiwarodom[(b)], Thiranee Khumlumlert[(c)], Maneenate Wechakama[(d)], John W. Bieber[(e)], Paul Evenson, Roger Pyle[(e)]

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Abstract: Worldwide neutron monitor observations of relativistic solar protons on 1989 October 22 have proven puzzling, with an initial spike at some stations followed by a hump with bidirectional flows and a very slow decay. We analyze data from polar monitors, which measure the directional distribution of solar energetic particles (mainly protons) at rigidities of ~1-3 GV. The inferred density and anisotropy are simultaneously fit by simulating the particle transport for various magnetic field configurations and determining the best-fit injection function near the Sun. The data are not well fit for an Archimedean spiral field, a magnetic bottleneck beyond Earth, or particle injection along one leg of a closed magnetic loop. A model with simultaneous injection along both legs of a closed loop provides the best explanation. Refined fits indicate a very low spectral index of turbulence, $q < 1$, and hence an unusually low correlation length of magnetic fluctuations in the loop, a loop length of 4.7±0.3 AU, and escape from the loop on a time scale of 3 hours.

D0087-Effect of Hard Magnetic Materials on Magnetoimpedance in CoAg Mechanical Alloys

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Abstract: Magnetoimpedace (MI) in $Co_{30}Ag_{70}$ mechanical alloys was studied. After milling Co and Ag powders for 30 hours, hard magnetic $SmCo_5$ was added to the samples for 0%, 5% and 10% by weight. Cobalt-silver mechanical alloys exhibited MI of 1.4-2.9 % under 3.3 kA/m field in a frequency range of 10 kHz to 1 MHz. It implied that the field sensitivity of skin depth increased with frequencies and the characteristic frequency was not observed. The MI diminished with increasing magnetic hardness as a result of $SmCo_5$ addition. The results confirmed the link between the MI effect and the magnetic softness of materials.

D0088-Construction and use program ImageAKS1.0 in Biological Science

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Abstract: An experimental mouse was given toxic things or poison, so there was a little wound in its stomach. The wound could not be identified the size because its figure was not measurable. Image AKS 1.0 program can do both analyse the figure and measure the length of the wound. It can also be applied with other materials. Image J1.33u, developed by National Institutes of Health, USA, has the same function, but it's complicated in use. In addition, its figure analysed system doesn't work well. Image AKS 1.0 program-is more interesting because it works comfortably and effectively.

D0089-Design and Development of High Voltage Ramp Generator for Driving PZT Transducer

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D0060-A NOVEL FABRICATED ACOUSTIC EMISSION SENSORS USING PVDF FILM

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Abstract: A novel fabricated acoustic emission (AE) sensors using polyvinylidine fluoride (PVDF) is presented. Unlike general AE sensors employing lead zirconate titanate (PZT), the PVDF sensor offers not only flexibility with lightweight but also relatively low acoustic impedance. The sensor has been calibrated using a standard AE source from ASTM Standard No. E976-84. The measurement of frequency response was performed with raw time domain signals using Fourier Transform. The results show that the resonance frequency is of 38 kHz, with the standard deviation of 0.1687. The proposed PVDF sensor can achieve highly repeatability, hence giving an alternated of AE sensor for Nondestructive testing (NDT) in industrial applications.

D0061-SAWTOOTH MECHANISM OF PARTICLE ACCELERATION AT SHOCKS IN RANDOM MAGNETIC FIELDS

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Abstract: Since there is a discontinuity in the magnetic field and plasma speed at the shock in a space plasma, the charged particles that pass the shock are accelerated and gain energy. The charged particles are known to move mainly along magnetic field lines. If the magnetic field line crosses the shock many times like a sawtooth, the particles that follow the magnetic field lines can cross the shock many times. The diffusion in pitch angle can cause the particles to encounter the shock several times at each magnetic field-shock crossing. The statistics of the magnetic field–shock crossings can be used to develop the sawtooth mechanism of particle acceleration, including the resulting particle spectrum, which can be applied to help explain cosmic ray spectra in various astrophysical situations. This work was supported by the Thailand Research Fund and the Rachadapisek Sompoj Fund of Chulalongkorn University.

D0062-$\pi\pi$ REACTION IN NON-RELATIVISTIC QUARK MODEL

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Abstract: The reaction $\pi^+\pi^- \rightarrow \pi^+\pi^-$ is studied in the non-relativistic quark model with the $^3P_0$ quark-antiquark dynamics. The cross section of the reaction $\pi^+\pi^- \rightarrow \pi^+\pi^-$ is well reproduced even for rather high energies.

D0063-Magnetic Field Shimming for Magnetic Resonance Magnet

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Abstract: The magnet that needed shimming is an electromagnet with iron poles having two parallel pole faces 6.0 cm apart and of 7.5 cm radius. In order to measure the field homogeneity accurately, ^{1}H NMR (nuclear magnetic resonance) method was used. A small NMR probe, at 11.5 MHz, containing a sample of vegetable oil of diameter 2.5 mm and 5 mm high and a probe holder which could move the sample to any point in the magnet gap were constructed. Before shimming, the magnetic field in the central plane of 1.5 cm radius had homogeneity about 2000 ppm with respect to the field at the center of the magnet gap. Two methods of magnetic field shimming were used. One was passive shimming using 2 soft iron rings with inner radius 6.5 cm, outer radius 7.5 cm and 0.3 cm thickness. The rings were placed on the two pole faces and the field homogeneity was found to have improved from 2000 ppm in the region of interest to about 500 ppm. Fine shimming was done by active shimming, for

which 8 sets of shim coils were built, each set to give the axial field (B_z) to vary proportionally as x, y, z, xz, yz, (y^2-z^2), (x^2-z^2) and $(2z^2-y^2-x^2)$. The field homogeneity was found to be within 50 ppm in the flat region of $z = \pm 1.25$ mm bound by x = -1.5 to 0 cm and y = 0 to 1.5 cm.

D0064-RELATIVISTIC PARTICLE INJECTION AND INTERPLANETARY TRANSPORT DURING THE JANUARY 20, 2005 GROUND LEVEL ENHANCEMENT OF COSMIC RAYS

Evenson[3], Roger Pyle[3], Marc Duldig[4], John Humble[5]
Alejandro Sáiz[1,2], David Ruffolo[1], Manit Rujiwarodom[2], John Bieber[3], John Clem[3], Paul Evenson[3], Roger Pyle[3], Marc Duldig[4], John Humble[5]
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Abstract: Besides producing the largest ground level enhancement (GLE) in half a century, the relativistic solar particles detected during the event of January 20, 2005 showed some interesting temporal and directional features, including extreme anisotropy. In this paper we analyze the time evolution of cosmic ray density and anisotropy as characterized by data from the "Spaceship Earth" network of neutron monitors by using numerical solutions of the Fokker-Planck equation for particle transport. We find that a sudden change in the transport conditions during the event is needed to explain the data, and we propose that this change was caused by the solar particles themselves.

D0065-Investigation of hexagonal phase generation in cubic GaN films on GaAs

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[2]Department of Advanced Materials Science, Graduate Schools of Frontier Sciences, the University of Tokyo, 5-1-5 Kash niwanoha, Kashiwa, Chiba, 277-8561, Japan.

Abstract: cubic GaN (*c*-GaN) films were grown on GaAs (001) substrates at growth temperatures ranging from 900 to 960.C by MOVPE. The investigational results indicate that the structural phase transition of GaN from cubic to hexagonal structures is much dependent on the growth temperature. Transmission electron microscopy (TEM) results show that the GaN films grown at lower growth temperature (900.C) condense with the cubic structure and contain bands of stacking faults (SFs) parallels to {111} planes. While, the generation of hexagonal phase GaN was observed in the GaN films grown at higher growth temperature (960.C). Based on XRD analysis, it is found that the *c*-GaN films with cubic phase purity higher than 85% were obtained at growth temperature of 900.C. While, further increase of growth temperature up to ~960oC results in the structural phase transition of GaN layers exhibited a transition from cubic to mixed cubic/hexagonal phase. An amount of hexagonal phase inclusion in such high temperature grown layer was calculated to be higher than ~40%.In addition, the results from PL, which agrees well with the results from TEM and XRD,confirmed that the growth temperature much affects on the generation of hexagonal phase GaN in the *c*-GaN films.

D0066-GROWTH AND CHARACTERIZATION OF Cu-Ga-Se THIN FILMS GROWN BY MOLECULAR BEAM DEPOSITION METHOD

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Abstract: Cu-Ga-Se polycrystalline thin films were prepared by the molecular beam deposition (MBD) method using the 2-stage (Cu-rich and Cu-off) growth process on soda-lime glass substrates as well as Mo coated soda-lime glass substrates at 520°C. Using this technique, the 1.5-2.0 μm thick Cu-Ga-Se thin films of varied Cu/Ga-ratio from 1.45 to 0.70 were fabricated. X-ray diffraction (XRD) and atomic force microscopy (AFM) techniques were used to investigate the structural and morphology evolution of the Cu-Ga-Se films from the Cu-rich (Cu/Ga=1.45) to the Cu-poor (Cu/Ga=0.70) compositions. From series of XRD patterns, all MBD polycrystalline Cu-Ga-Se thin films show strong (112) preferred orientation. The lattice constants (a and c) were almost constant over the range of Cu/Ga-ratio from 1.45 to 0.70. No significant 2 shift of the (112) peak was observed except for

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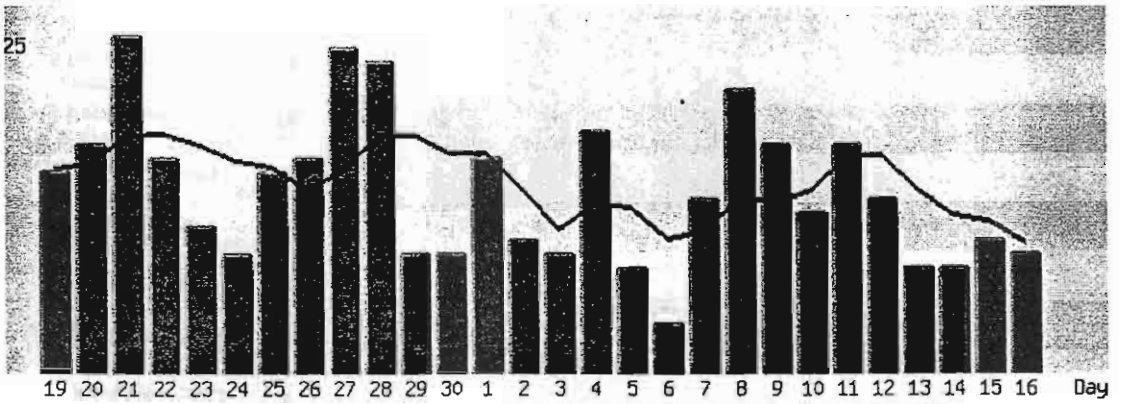

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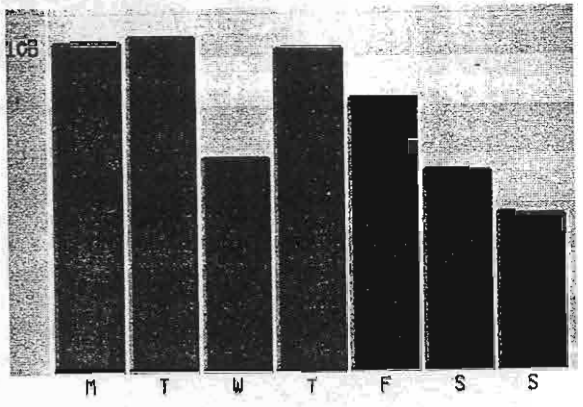

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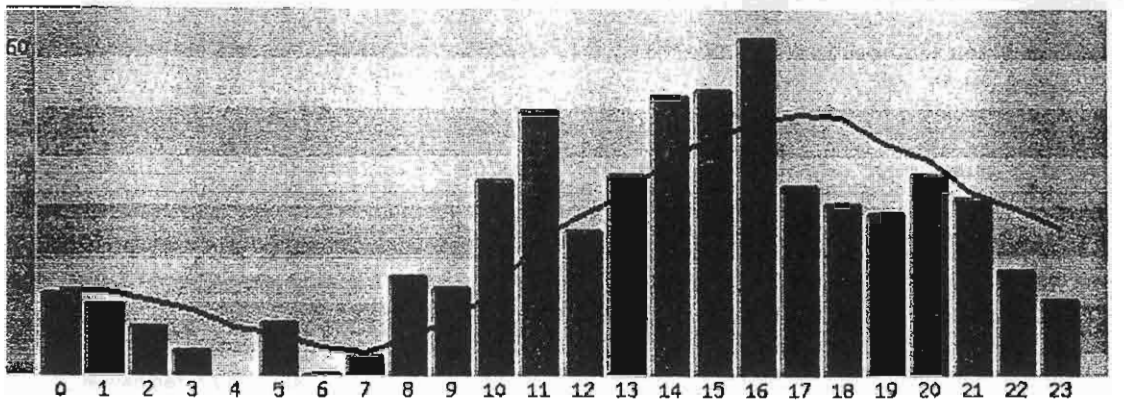

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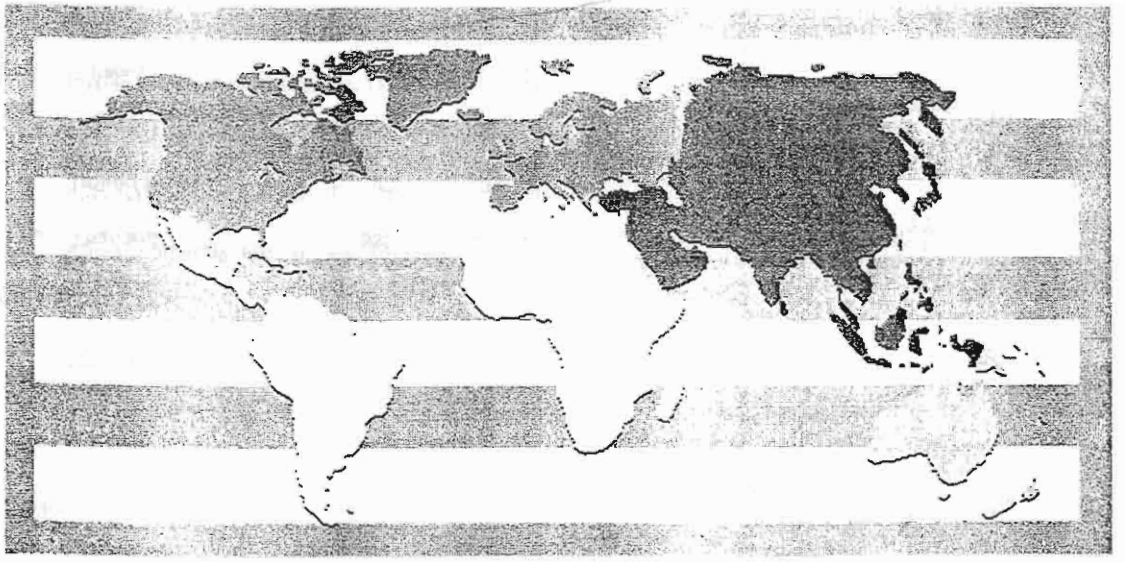

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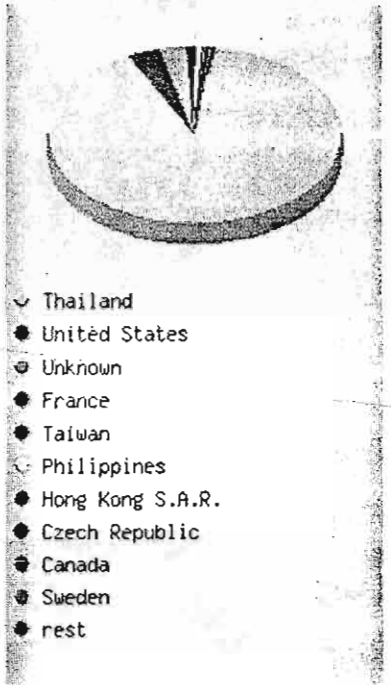
1.	Thailand	530	89.7 %
2.	United States	23	3.9 %
3.	France	4	0.7 %
4.	Taiwan	3	0.5 %
5.	Philippines	3	0.5 %
6.	Hong Kong S.A.R.	2	0.3 %
7.	Czech Republic	2	0.3 %
8.	Canada	1	0.2 %
9.	Sweden	1	0.2 %
10.	Australia	1	0.2 %
11.	Cambodia	1	0.2 %
12.	New Zealand	1	0.2 %



Unknown	18	3.0 %
Total	591	100.0 %

Providers/domains

1.	UniNet Thailand Education and Research Network, Thailand	10
2.	ac.th, Thailand	6
3.	chula.th, Thailand	5
4.	Telephone Org. Thailand, Thailand	3
5.	Asia Infonet Co., Ltd., Thailand	2
6.	Kasetsart University, Thailand	2
7.	Loxley Information Company, Thailand	1
8.	esinc.net, United States	1
9.	Internet Thailand Co. Ltd., Thailand	1
10.	KSC Commercial Internet Co., Thailand	1
	Unknown	1
	The rest	5
	Total	38

Cities

1.	Bangkok	1
	Unknown	37
	Total	38

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14

Top 1000 Thailand

Top 1000 ■ Science ■ Physics and astronomy

Top 1000

1		(1)	Doodaw.com	2197
2	↑	(4)	For Knowledge and News about Space Weath	91
3	↓	(2)	The beginner Skywatcher's web site	62
4	↑	(6)	BUNDID OBSERVATORY	22
5	↓	(3)	Thai Amateur Telescope Making	20
6	↓	(5)	Ring of Sky	19
7		(7)	YUPA 150	5
8	↑	(10)	Welcome to www.design-alternative.com	3
9	↓	(8)	600 mm. Telescope made in Thailand	2
10	↓	(9)	welcome to unitedcolors	1
11		(11)	Telescopes for Ameteur	1
12		(12)	Service Center Physics Department Faculty of Science Chula	0
13		(13)	Fiber Optics Kit	0
14		(14)	Basic Science in School	0

15	(15)	ฟาเมีย ฟักรนง	0
16	(16)	watchirawut	0
17	(17)	airplan	0

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For Knowledge and News about Space Weath - (Physics and astronomy) 14 January 2004 14:05

Summary

Measuring since ...	22 August 2003
Total number of page views up till now	1170
Busiest day so far	13 January 2004
Page views	91

Forecast for today

On average 42 percent of the daily visits are made before 14:05. Based on the number of visitors of 17 today so far, today your site may have 40 page views (+/- 6).

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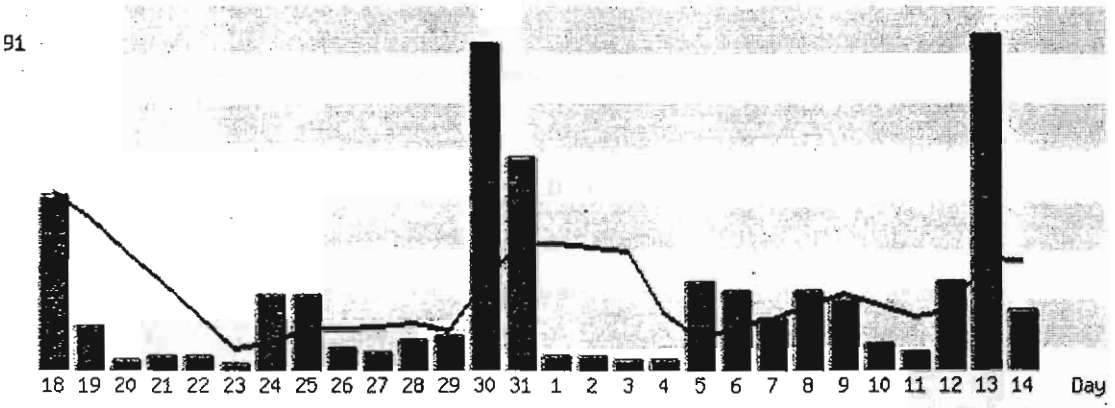
Last 10 visitors

1.	14 January	10:10	Thailand (ac.th)
2.	14 January	10:10	UniNet Thailand Education and Research Network, Thailand
3.	14 January	10:17	KSC Commercial Internet Co., Thailand
4.	14 January	10:19	Telephone Org. Thailand, Thailand
5.	14 January	10:26	Thailand (cscoms.th)
6.	14 January	10:27	UniNet Thailand Education and Research Network, Thailand
7.	14 January	12:54	Thailand (chula.th)
8.	14 January	13:47	Thailand (ac.th)

	14 January	13:48	Thailand (ac.th)
10.	14 January	13:53	Thailand (ac.th)

Page views per day



Page views per day

18 December 2003	48
19 December 2003	13
20 December 2003	4
21 December 2003	5
22 December 2003	5
23 December 2003	3
24 December 2003	21
25 December 2003	21
26 December 2003	7
27 December 2003	6

ecember 2003	9
29 December 2003	10
30 December 2003	88
31 December 2003	58
1 January 2004	5
2 January 2004	5
3 January 2004	4
4 January 2004	4
5 January 2004	25
6 January 2004	22
7 January 2004	15
8 January 2004	22
9 January 2004	20
10 January 2004	8
11 January 2004	6
12 January 2004	25
13 January 2004	91
14 January 2004	17
Total	567

Country of origin

1.	Thailand	1049	89.7 %
2.	United States	49	4.2 %

3.	France	6	0.5 %
4.	Philippines	6	0.5 %
5.	Taiwan	5	0.4 %
6.	China	4	0.3 %
7.	Japan	3	0.3 %
8.	United Kingdom	2	0.2 %
9.	Czech Republic	2	0.2 %
10.	Sweden	2	0.2 %
	Unknown	25	2.1 %
	The rest	17	1.5 %
	Total	1170	100.0 %

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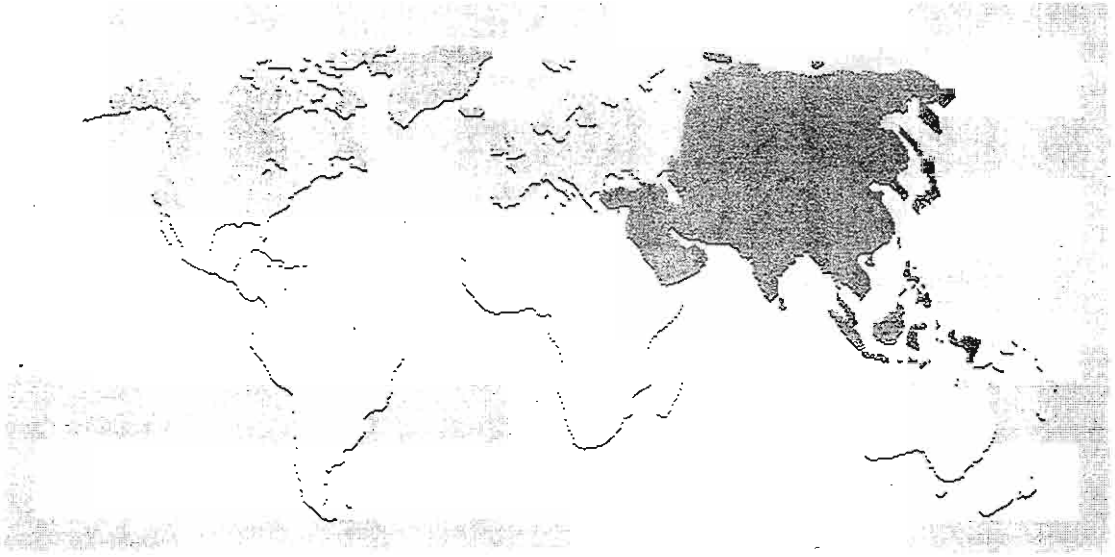
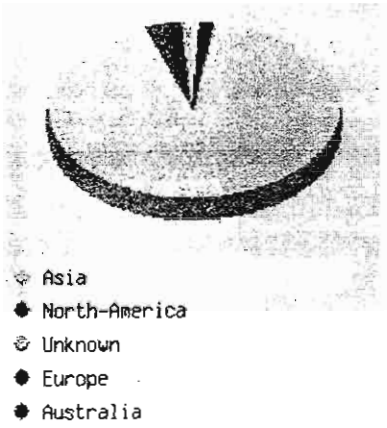
For Knowledge and News about Space Weath - (Physics and astronomy) 14 January 2004 14:13

Continent of origin



Continent of origin

1.	Asia	1075	91.8 %
2.	North-America	50	4.3 %
3.	Europe	17	1.5 %
4.	Australia	4	0.3 %
	Unknown	25	2.1 %
	Total	1171	100.0 %



Country of origin

1.	Thailand	1049	89.6 %
2.	United States	49	4.2 %
3.	Philippines	6	0.5 %
4.	France	6	0.5 %
5.	Taiwan	5	0.4 %
6.	Japan	4	0.3 %
7.	China	4	0.3 %
8.	Germany	2	0.2 %
9.	Sweden	2	0.2 %
10.	Cambodia	2	0.2 %
11.	Myanmar	2	0.2 %
12.	Czech Republic	2	0.2 %

13.	United Kingdom	2	0.2 %
14.	Hong Kong S.A.R.	2	0.2 %
15.	Canada	1	0.1 %
16.	Austria	1	0.1 %
17.	Denmark	1	0.1 %
18.	United Arab Emirates	1	0.1 %
19.	Russia	1	0.1 %
20.	New Zealand	1	0.1 %
21.	Iceland	1	0.1 %
22.	Australia	1	0.1 %
23.	Singapore	1	0.1 %
	Unknown	25	2.1 %
	Total	1171	100.0 %

Providers/domains

1.	Telephone Org. Thailand, Thailand	9
2.	ac.th, Thailand	7
3.	Communication Authority, Thailand	5
4.	UniNet Thailand Education and Research Network, Thailand	4
5.	Siam Global Access, Thailand	3
6.	Shinawatra Group, Thailand	3
7.	Internet Thailand Co. Ltd., Thailand	3

8.		
9.	co.th, Thailand	2
10.	Loxley Information Company Ltd., Thailand	2
	The rest	5
	Total	45

Cities

1.	Bangkok	3
	Unknown	42
	Total	45

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Top 1000 ▶ Thailand

Top 1000 ▶ Science ▶ Physics and astronomy

Top 1000

1		(1)	Doodaw.com	1590
2		(2)	For Knowledge and News about Space Weath	128
3		(3)	BUNDID OBSERVATORY	22
4		(4)	Thai Amateur Telescope Making	14
5		(5)	YUPA 150	7
6	↑	(7)	600 mm. Telescope made in Thailand	5
7	↑	(13)	Service Center Physics Department Faculty of Science Chula	2
8	↓	(6)	welcome to unitedcolors	2
9		(9)	Fiber Optics Kit	2
10	↑	(11)	พานิช ผู้พรรณ	2
11	↑	(12)	The beginner Skywatcher's web site	0
12	↑	(14)	Ring of Sky	0
13	↓	(8)	Welcome to www.design-alternative.com	0
14	↑	(15)	Telescopes for Ameteur	0

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For Knowledge and News about Space Weath - (Physics and astronomy) 8 June 2004 14:09

Summary

Measuring since ...	22 August 2003
Total number of page views up till now	3769
Busiest day so far	7 June 2004
Page views	128

Forecast for today

On average 42 percent of the daily visits are made before 14:09. Based on the number of visitors of 78 today so far, today your site may have 185 page views (+/- 12).

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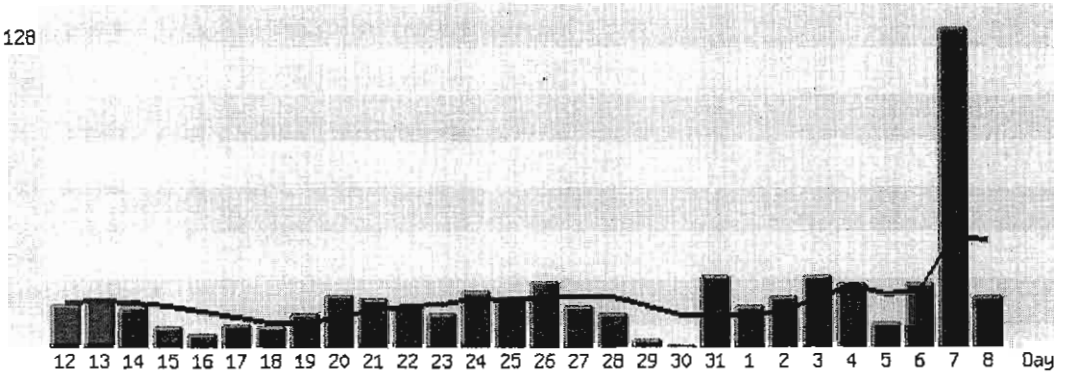
Last 10 visitors

1. 8 June 13:28 Thailand (ac.th)
2. 8 June 13:30 JPNIC, Japan
3. 8 June 13:53 Internet Thailand Co. Ltd., Thailand
4. 8 June 13:55 Internet Thailand Co. Ltd., Thailand
5. 8 June 13:56 Internet Thailand Co. Ltd., Thailand
6. 8 June 14:05 Asia Infonet Co., Ltd., Thailand
7. 8 June 14:06 Telephone Org. Thailand, Thailand
8. 8 June 14:06 Thailand (ac.th)

9. 8 June 09:41 Thailand (ac.th)

10. 8 June 09:43 Asia Infonet Co., Ltd., Thailand

Page views per day



Page views per day

12 May 2004	18
13 May 2004	20
14 May 2004	17
15 May 2004	9
16 May 2004	6
17 May 2004	10
18 May 2004	9
19 May 2004	14
20 May 2004	22
21 May 2004	20

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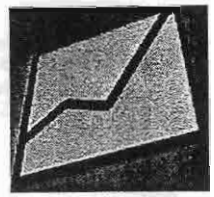
19 January 2005 13:52



Google
Search

Top 1000 | Thailand

Top 1000 ■ Science ■ Physics and astronomy

Top 1000

1		(1)	Doodaw.com	2646	(+8)	
2	↑	(7)	007payakorn	259	(+254)	
3	↓	(2)	For Knowledge and News about Space Weath	49	(+12)	
4	↓	(3)	MetScience in Space	26	(+8)	
5		(5)	BUNDID OBSERVATORY	25	(+9)	

6	↓	(4)	สัตตเลขพยากรณ์	22	(+4)
7	↑	(8)	Chinese Zodiac Prediction Science	10	(+5)
8	↑	(11)	welcome to unitedcolors	5	(+4)
9		(9)	YUPA 150	5	(+2)
10	↓	(6)	600 mm. Telescope made in Thailand.	3	(-2)
11	↑	(12)	Welcome to www.design-alternative.com	2	(+1)
12	↑	(13)	Fiber Optics Kit	1	(+0)
13	↑	(17)	Basic Science in School	1	(+1)
14		(14)	ฟาเบีย ฝ์ทรนง	1	(+0)
15		(15)	The beginner Skywatcher's web site	0	(+0)
16		(16)	Service Center Physics Department Faculty of Science Chula	0	(+0)
17	↓	(10)	Telescopes for Ameteur	0	(-2)
18		(18)	Thai Amateur Telescope Making	0	(+0)
19		(19)	ยินดีต้อนรับสู่การศึกษาและพยากรณ์เลข□	0	(+0)
20		(20)	007payakorn	0	(+0)

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For Knowledge and News about Space Weath - (Physics and astronomy) 19 January 2005 13:49

Summary

Measuring since ...	22 August 2003
Total number of page views up till now	9489
Busiest day so far	7 June 2004
Page views	128

Forecast for today

On average 38 percent of the daily visits are made before 13:49. Based on the number of visitors of 9 today so far, today your site may have 23 page views (+/- 5).

Google
Search

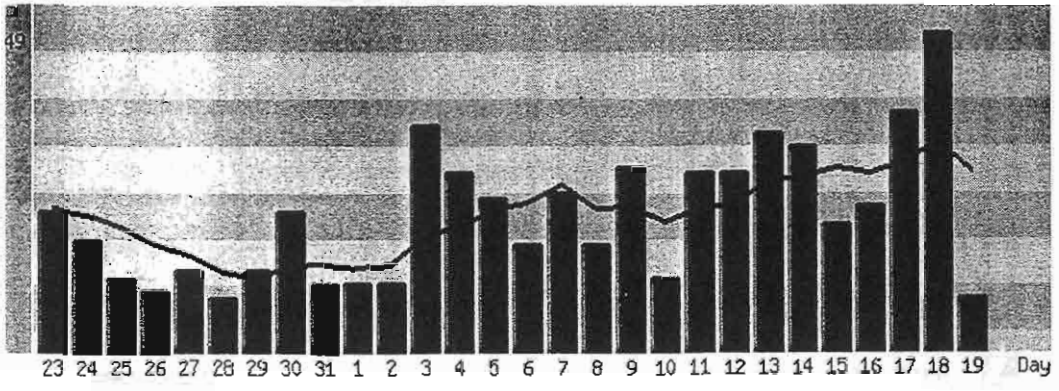
Last 10 visitors

1.	18 January	21:41	Asia Infonet Co., Ltd., Thailand
2.	19 January	00:08	Asia Infonet Co., Ltd., Thailand
3.	19 January	00:41	C.S.Communications Co., Ltd, Thailand
4.	19 January	07:45	Siam Global Access, Thailand
5.	19 January	09:01	Internet Thailand Co. Ltd., Thailand
6.	19 January	10:04	Ji-NET, Thailand
7.	19 January	12:25	Hitachi Information Systems, Japan
8.	19 January	13:12	UniNet Thailand Education and Research Network, Thailand

9. 19 January 13:42 UniNet Thailand Education and Research Network, Thailand

10. 19 January 13:49 UniNet Thailand Education and Research Network, Thailand

Page views per day



Page views per day

23 December 2004	22
24 December 2004	18
25 December 2004	12
26 December 2004	10
27 December 2004	13
28 December 2004	9
29 December 2004	13
30 December 2004	22
31 December 2004	11
1 January 2005	11