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LA-UR 06-1466

Institute of Geophysics and Planetary Physics
Los Alamos National Laboratory
2005 Annual Report

Mission of IGPP and Insitutional Goals

The Institute of Geophysics and Planetary Physics (IGPP) at Los Alamos National Laboratory (LANL) is a branch of the IGPP systemwide multicampus research unit of the University of California (UC). As such, the science mission of IGPP is "t*o promote and coordinate basic research on the understanding of the origin, structure, and evolution of the earth, the solar system, and the universe, and on the prediction of future changes, as they affect human life."*

In addition to its role as part of a UC MRU, IGPP at Los Alamos is also a Laboratory institutional center. The institutional goals of IGPP are:

(a) To enhance University-Laboratory relations by fostering collaborations between UC campus faculty, staff, students, and LANL staff;

(b) To provide LANL programs with input of new ideas, people, and contact with the university community at-large;

(c) To foster top-quality research at LANL in the more "basic" or "fundamental" aspects of fields that can be mapped to LANL mission thrust areas; and

(d) To provide a stimulating venue for LANL scientists to broaden their research horizons.

IGPP Activities

In order to achieve IGPP's goals, the institute supports small scale science involving Laboratory and University PI's, graduate students, and postdoctorial fellows. In addition, IGPP supports numerous workshops, i.e., scientific workshops designed to exchange information and research workshops designed to solve emerging and urgent problems.

The IGPP minigrant program, with a co-PI from the Laboratory and a co-PI from a University, presently supports about 40 graduate students and postdoctorial fellows, who spend a substantial fraction of their research time on-site at the Laboratory. Minigrants are selected via a peer review process, with input from an external advisory committee which meets at LANL in June each year. Minigrants normally cover a three year period.

IGPP also supports summer schools in areas of scientific interest to the Laboratory. Summer schools are supported in order to provide the necessary training to university graduate students so that they are well qualified to start a career on DOE critical research topics, immediately upon graduation.

IGPP Management

IGPP/LANL is a dynamic organization, and portfolios are adjusted according to changes in the scientific landscape and anticipated new directions within LANL. At present, management consists of a director, managers of four scientific focus areas, an administrative officer and secretary:

- Director: Gary Geernaert
  - Operations Administrative Specialist: Debra Saiz
  - Administrative Assistant: Deb Rivera
- Astrophysics focus area: Richard Epstein
- Space physics focus area: Reiner Friedel
- Geophysics focus area: Claudia Lewis
- Climate focus area: Manvendra Dubey
- Summer schools
  - Geophysics (SAGE): Scott Baldridge
  - Cosmology: Salman Habib
  - Carbon sequestration: Julianna Fessenden-Rahn

Steering Committees: *meets annually in June*

- External advisory board: chair, Jerry Schubert, UCLA
  - Astrophysics and cosmology: Bob Rosner (Chicago), George Fuller (UCSD)
  - Space physics: Chris Russell (UCLA), Mike Liemohn (Michigan), Janet Green (Colorado) as backup.
  - Climate/environment: John Roads (UCSD)
  - Geophysics: Jerry Schubert (UCLA), Freeman Gilbert (UCSD)
- Internal advisory board of partner divisions:
  - EES Division
  - ISR-Division
  - X-Division

The Orson Anderson scholar and the visitor program

The Laboratory supports the IGPP Orson Anderson scholar, for one year with funding from the LDRD program. The Orson Anderson scholar is selected each year, based on Laboratory science challenges and opportunities for collaboration with external institutions. In addition to the Orson Anderson Scholar, IGPP hosts visiting scholars with terms lasting up to six months.

During FY05, IGPP's scholars included:

(a) Orson Anderson scholar: Joshua Frieman, Fermi National Accelerator Laboratory
(b) Visiting scholar: Phil Kronberg, University of Toronto

IGPP's four scientific focus areas

1. Astrophysics Focus

Focus Leader: Richard I. Epstein repstein@lanl.gov

1.1 Overview

The Astrophysics Focus has supported research in Gamma-Ray astronomy, neutron star physics, supernova simulations and cosmological structure formation. High-energy gamma rays represent special probe of the Universe because they indicate non-thermal activities, i.e. cosmic particle accelerators. The Milagro wide field telescope of high energy gamma rays at LANL may be able to see the high energy tail of GRB spectra. A large data sample from a known source of high energy gamma rays, the Crab Nebula, has been accumulated by Milagro, and a first generation of analysis tools has been developed. The current research project increased the sensitivity of Milagro by improving its background rejection capabilities. In addition to Milagro, IGPP supports research which exploits other facilities, e.g., the Sloan Digital Sky Survey. As is becoming widely appreciated in many fields, we are now entering an age of sophisticated data analysis of observations matched to theory via very large scale computer simulations; this is the age of `predictive science'; in almost no other field has this strategy for scientific discovery become as widely important as in cosmology and astrophysics.

The IGPP supported work on multi-physics hydrodynamic simulations addresses formation, distribution, evolution and interactions of galaxies and the dynamics of clusters. Although radio pulsars can be exceptionally stable clocks, imperfections in the rotation of some pulsars have been monitored for some time, most notably glitches. Most work has focused on observations of glitches and timing noise, but there is also evidence, in some cases, for long-term, cyclical, but not precisely oscillatory, variations in pulsar spin on timescales of months to years. Such long-timescale variations are reminiscent of free precession; however, this explanation does not work if superfluid vortices are pinned to nuclei in the inner neutron star crust, as is supported by theories of the glitch phenomenon. Investigators have approached this question by producing a multi-component model for a rotating neutron star that includes the effects of crust-core couplings, vortex drag in the crust as well as in the core, imperfect rigidity of the crust, and magnetic field effects.

2005 Astrophysics Minigrant reports:

Migration of Pro-planets in Gaseous Disks
Principle Investigators: Hui LI, Los Alamos National Laboratory
Douglas Lin, University of California Santa Cruz
Ian Dubbs-Dixon, Graduate Student, University of California Santa Cruz

There are now about 150 extrasolar planetary systems discovered but major surprises have emerged. One is that very massive planets (up to 10 Jupiter masses) are found to orbit their central

stars very closely (at a fraction of Mercury's orbit). One popular theory is to postulate that giant planets were indeed formed farther out in the disks (several AUs) but have migrated inwards to the central star. But theoretical and some numerical studies have suggested that the migration might occur so rapidly that smaller planets do not have enough time to grow into giant planets before they have migrated all the way to the star (the Type I migration problem). We have proposed to study this problem using high-resolution hydro simulations of gaseous disks with embedded proto-planets. One key aspect is that we want to explore the role of vortices and how they affect the overall torque exerted on the proto-planet. The proposed research forms the part of the PhD research of I. Dubbs-Dixon from UC-Santa Cruz.
Link to: Migration of Pro-planets in Gaseous Disks

Cosmological Hydrodynamics with Adaptive Mesh Refinement
Principle Investigators: Salman Habib, Los Alamos National Laboratory
Dr. Katrin Heitmann, Los Alamos National Laboratory
Paul Richer, University of Illinois
Zarija Lukic, Graduate Student, University of Illinois

Multi-physics hydrodynamics simulations represent the frontier of cosmological and astrophysical simulation. These efforts address science problems of the first rank, such as the formation, distribution, evolution, and interaction of galaxies and the dynamics of clusters. Our research program targets simulation of cosmological flows including gravity, plasma physics, and gas dynamics via adaptive mesh refinement (AMR) codes combining both mesh-based and particle-mesh based solvers. We are applying this capability to the analysis of galaxy clusters and the distribution of matter on scales from hundreds of megaparsecs down to kiloparsecs. Our work is aimed at interpreting observational data from the Sloan Digital Sky Survey (SDSS), Chandra, XMM, and planned near-future observations such as the Constellation-X mission and the South Pole Telescope.
Link to: Cosmological Hydrodynamics with Adaptive Mesh Refinement

Background Characterization for Advanced Gamma-Ray Telescopes
Principle Investigators: Marc Kippen, Los Alamos National Laboratory
Derek Taurnear, Los Alamos National Laboratory
Mark McConnell, University of New Hampshire
Pete Bloser, Postdoc, University of New Hampshire

The inability to accurately simulate space background is currently limiting progress in the fledgling field of observational nuclear gamma-ray astronomy. We propose to improve this situation by performing a detailed study of the near-Earth space environment that the next-generation advanced gamma-ray telescopes will occupy. In particular, we propose to model the effects this environment will have on the background for gamma-ray telescopes being developed at LANL, UNH and elsewhere. Completion of a comprehensive background simulation system for this class of telescopes will be extremely important to all researchers in this field. Results will be used to predict science goals for future missions, and to allow useful analysis of the data once they are collected. Additionally, completion of these studies will place our collaboration in a

strong position to compete for funding from NASA for the development of one or more proposed missions.
Link to: Background Characterization for Advanced Gamma-Ray Telescopes

Improvement of Background Rejection in Milagro Using the Outrigger Array
Principle Investigators: Gus Sinnis, Los Alamos National Laboratory
Aous Abdo, Michigan State University
Jim Linnemann, Michigan State University

The Milagro gamma-ray observatory is a new type of TeV gamma-ray telescope, using the water Cherenkov technique to detect the extensive air showers produced by energetic gamma rays and cosmic rays. Here we report the results of the first year of effort in using the outrigger tank array to improve the ability of Milagro to reject events initiated by cosmic rays while retaining those initiated by gamma rays. The results of this effort will be an increased sensitivity for the Milagro instrument. This increased sensitivity will enhance all aspects of the physics goals of Milagro.
Link to: Improvement of Background Rejection in Milagro Using the Outrigger Array

Channeling Optics for High-Resolution Gamma-Ray Astronomy
Principle Investigators: Richard Epstein, Los Alamos National Laboratory
James Matteson, University of California San Diego
Slawomir Suchy, Graduate Student, University of California San Diego
Andy Chen, Graduate Student, University of California San Diego
Derek Tournear, Postdoc, Los Alamos National Laboratory

We are using the innovative gamma-ray optics developed at Los Alamos together with sensitive position and energy-resolved gamma-ray detectors developed at UCSD to create revolutionary, new astronomical gamma-ray telescopes that have far superior angular resolution. The successful completion of this work would put the LANL/UCSD collaboration in a strong position to compete for funding from NASA. Additionally, gamma-ray imaging and concentrating has potential importance for medical and homeland security applications; we would also seek programmatic funding from those sources.
Link to: Channeling Optics for High-Resolution Gamma-Ray Astronomy

How Violent is the IGM at High Redshift? The effect of feedback on the Lyman Alpha Forest
Principle Investigators: Katrin Heitmann, Los Alamos National Laboratory
Matias Zaldarriaga, Harvard University
Adam Lidz, Postdoc, Harvard University

The inter-galactic medium (IGM) seen in Lyman-alpha absorption towards distant quasars plays a very important role in cosmology. It offers a probe of matter clustering in the quasi-linear regime at redshift, $z\sim3$, as well as a window on the extent to which galaxy formation impacts subsequent structure formation. We propose to study the impact of galactic outflows on the statistics of the

Lyman-alpha forest using state-of-the-art numerical simulations, providing insights into galaxy formation and constraining any effect on cosmological parameter determination.
Link to: How Violent is the IGM at High Redshift?

The Highest Energy Emission from Gamma Ray Bursts
Principle Investigators: Brenda Dingus, Los Alamos National Laboratory
Albrecht Karle, University of Wisconsin

Gamma ray bursts (GRBs) may be the origin of the highest energy particles known, and detection of high energy gamma rays or neutrinos from these sources would be key to proving that this is the case. The data from the AMANDA neutrino detector and the Milagro gamma-ray detector are searched to look for the highest energy emission from gamma ray bursts. No significant excesses are found in either search and upper limits are determined.
Link to: The Highest Energy Emission from Gamma Ray Bursts

Presentation and Talks:
H. Li will be giving a seminar at Princeton University in April 2005 on Protoplanet migration.

Publications:
H. Li et al. 2005, \Potential Vorticity Evolution of a Protoplanetary Disk with an Embedded Protoplanet", Astrophys. J, May 20 issue (astroph/0503404)

C. Orban, Spring 2005, \Further Investigations of Disk Dynamics with an Embedded Protoplanet", Senior thesis report, UIUC.

Participating Graduate Students and Post-Docs:
Dubbs-Dixon (UCSC) visited LANL in the winter of 2004, implementing the planet acceleration routine for allowing the planet to migrate.

C. Orban (UIUC/T-6) spent part of summer of 2004 here at LANL and worked on analyzing new planet migration simulation results made with higher resolution and new hydro codes.

S. Li has been converted to an LTSM at T-7.
He is continually carrying out new simulations and providing the numerical code support.

Z. Lukic, Graduate Student, University of Illinois

P. Bloser, Postdoc, University of New Hampshire

S. Suchy, Graduate Student, University of California-San Diego

A. Chen, Graduate Student, University of California-San Diego

D. Tournear, Postdoc, Los Alamos National Laboratory, ISR-1

Dr. Adam Lidz, Post-doctoral Fellow, Harvard University

Visitors to LANL and/or to the University:

Ian Dubbs-Dixon will be visiting the Lab in summer and H. Li will visit UCSC in summer.

2. Space Physics

Focus Leader: Reiner Friedel, friedel@lanl.gov

2.1 Focus area overview

The objectives of the proposed research are to characterize and understand the mechanisms that govern space weather. This includes the propagation of solar disturbances and their interaction with Earth's magnetosphere, ionosphere and atmosphere**.** This also includes sudden releases of solar wind energy inside Earth's magnetosphere, known as "magnetospheric substorms." Specific processes include acceleration, transport, and variability of electrons and ions. Integral elements of this program are the analysis of satellite and ground data to improve our understanding of the characteristic processes and the development and application of models that incorporate the improved physical understanding of the geospace environment.

Leveraging against LANL facilities and databases, e.g., linkage to multi-cluster satellite experiments or computer simulation codes, is strongly encouraged. In particular, use of the extensive measurements from the LANL geosynchronous instruments and GPS instruments in encourage, which are unique LANL assets.

2005 Space Physics Minigrant reports:

Full Particle Simulations of Magnetic Reconnection at the Magnetopause
Project Investigators: Gianni Lapenta, Los Alamos National Laboratory
William Daughton, Los Alamos National Laboratory
Homa Karimabadi, University of California San Diego
Jonathan Driscoll, Graduate Student, University of California San Diego

Our goal was to start a systematic study of collisionless magnetic reconnection process at the dayside magnetopause. Many important details of reconnection at the magnetopause remain poorly understood (steady versus non-steady reconnection, preferred location of onset, etc.). During this cycle, we attacked this problem by reconsidering the problem of reconnection onset and its subsequent evolution as a function of guide field. Our approach was based on a combination of nonlocal Vlasov linear theory, analytical theory, and full particle simulations. Our results were surprising: (i) In the linear regime, we demonstrated the existence of a new "intermediate" regime as a function of guide field. (ii) We found no support for any of the previous nonlinear theories. In particular, the prediction that tearing would saturate at minute amplitudes in the presence of a guide field turned out to be incorrect. Our finding suggests that both anti-parallel and component merging can occur at the magnetopause.
Link to: Full Particle Simulations of Magnetic Reconnection at the Magnetopause

Thin Current Sheet Instabilities and Collisionless Magnetic Reconnection
Project Investigators: Giovanni Lapenta, Los Alamos National Laboratory
Peter Yoon, University of Maryland

We developed a technique for solving the linearized Vlasov-Maxwell set of equations,in which the perturbed distribution function is described as an infinite series of orthogonal functions, chosen as Hermite-Grad polynomials. The orthogonality properties of such functions allow us to decompose the Vlasov equation into a set of infinite coupled equations. This technique is based on solid but easy concepts, not attempting to evaluate the integration over the unperturbed trajectories and can be applied on any equilibrium. Although the solutions are approximate, because they neglect contributions of higher order coefficients of the series, the physical meaning of the low-order coefficients is clear. This allows us to know exactly on which assumptions the approximation is made and gives a snapshot on which quantities are dominant in the equilibrium. Furthermore the accuracy of solution, which depends on the number of terms taken in account in the Hermite series, appears to be merely a problem of computational power. The method has been tested setting an initial 1-D Harris equilibrium that is known to give rise to several instabilities, like tearing, drift-kink, lower-hybrid. To compare, the same problem has also been studied using particle-in-cell simulations.
Link to: Thin Current Sheet Instabilities and Collisionless Magnetic Reconnection

A Study of Precipitation Losses of MeV Electrons Using Multiple Balloon and Multiple Satellite Observations
Project Investigators: Reiner Friedel, Los Alamos National Laboratory
Robert Lin, University of California Berkeley

During the first year of this IGPP grant we have thus far conducted the balloon campaign to acquire the unique MINIS data set. The campaign was an overall success with six balloons making a total of twenty-four days of observation. Three balloons, two southern and one northern, were aloft and making observations during the magnetic storm, and MeV precipitation events of January 21st. Data from that day, in particular, is well suited to perform the satellite-balloon correlation study that this IGPP mini-grant set out to do. Since the completion of the campaign, John Sample, the graduate student involved in the project, has begun to process the data into a form that can be connected to in situ satellite measurements. First results of the campaign have been presented at the Spring AGU and the 2nd Annual AOGS meetings. John Sample and Reiner Friedel, the LANL PI also discussed the necessary steps in processing the data during a week-long workshop following the successful balloon campaign. Revised Work Plan for FY 06: The second year of the IGPP mini-grant will be dedicated to performing the correlation work with LANL satellite data. Thus far no visits by the graduate student to LANL have occurred, but such a visit is being planned for FY 05. The second year should involve significant time with the graduate student visiting LANL to bring the data sets together and work with the LANL PI in constructing any models necessary to connect the data sets. Changes to the budget: The most significant change to the budget is the dropping of the graduate student salary, in its entirety, from the mini-grant. This is possible because John Sample is the recent recipient of an NSF Graduate Research Fellowship. The second year s budget thus supports travel for the graduate student to LANL, and support for the LANL PI.
Link to: A Study of Precipitation Losses of MeV Electrons Using Multiple Balloon and Multiple Satellite Observations

Observing the Heliosphere in Energetic Neutral Atoms
Project Investigators: Herb Funsten, Los Alamos National Laboratory
Gary Zank, University of California Riverside
Nicolai Pogorelov, Vladimir Florinski, Jacob Heerikhuisen, University Co-Investigators:

The main goal of this proposal is to understand the passage of interstellar hydrogen through the heliosphere. While the solar wind plasma contains a large fraction of neutral atoms, the source of these is not the Sun; rather, these neutrals have propagated into the heliosphere from interstellar space. Through the process of charge-exchange, interstellar neutrals affect the bulk dynamics of the outer solar wind, generating pick-up ions as well as energetic neutral atoms. Any model of the heliosphere therefore requires a detailed neutral atom component.
Link to: Observing the Heliosphere in Energetic Neutral Atoms

Radial Evolution of Solar Wind Structure
Project Investigators: Ruth Skoug, Los Alamos National Laboratory
Christopher Russell, University of California Los Angeles
Lan Jian, Graduate Student, University of California Los Angeles

A key element of successful solar terrestrial predictions is to be able to predict how solar wind structure evolves radially as it propagates from the sun. This effort examines available solar wind data over a variable range of radial separations, examining both stream interactions and interplanetary coronal mass ejections, both to gather empirical understanding of their evolutions and to provide constraints for existing MHD models. The major results in year 1 concerned establishing baseline conditions at 1AU as a function of the phase of the solar cycle. Preparations were also made for the second year's effort exploring the heliocentric radial gradient in the structure and dynamics of the solar wind.
Link to: Radial Evolution of Solar Wind Structure

The Formation of the Cold Dense Plasma Sheet
Project Investigators: Michelle Thomsen, Los Alamos National Laboratory
Joachim Raeder, University of New Hampshire
Wenhui Li, Graduate Student, University of New Hampshire

Earth's geomagnetic tail consists of the tail lobes and the plasma sheet that separates the lobes. During most times the plasma of the plasma sheet is hot (~5 keV) and tenuous (<~0.1 cm^{-3}), which we call the Hot Tenuous Plasma Sheet (HTPS.) Since the plasma of the plasma sheet is supplied either by reconnection at the dayside magnetopause or by ionospheric outflow, and because these processes subside during times of geomagnetic quiet, one would assume that during such times the plasma sheet would become even less dense. However, often the opposite is observed. During times of several hours of northward Interplanetary Magnetic Field (IMF), and when geomagnetic activity ceases, oftentimes a Cold Dense Plasma Sheet (CDPS) is observed. The density of the CDPS can be as high as several cm^{-3} and the plasma temperature drops well below 1 keV. The CDPS is observed more often near the flanks, but at times extends throughout the plasma sheet. Several mechanisms have been proposed to explain the CDPS, in particular plasma diffusion across the magnetopause, plasma mixing due to Kelvin-Helmholtz vortices, and dual lobe magnetic reconnection. Understanding the CDPS formation is important because the plasma sheet provides the seed populations for the Ring Current and the Radiation Belts, which can become substantially enhanced when the IMF turns southward after a CDPS episode, and when the ensuing magnetic storm pushes the plasma into the inner magnetosphere.

The objective of this project is to establish the physical processes that lead to the formation of the CDPS and to investigate their dependence on the solar wind and IMF parameters.
Link to: The Formation of the Cold Dense Plasma Sheet

Radial Diffusion Modeling with Data Assimilation
Project Investigators: Geoffrey Reeves, Los Alamos National Laboratory
Richard M. Thorne, University of California, Los Angeles
Yuri Shpirts, Graduate Student, University of California Los Angeles

In this study we propose to incorporate data assimilation techniques into a radial diffusion model of relativistic electrons in the outer radiation belt. The model parameters responsible for stochastic processes will be adjusted first empirically and later by means of data assimilation procedures to give the best fit to observations. We will also perform validation of our results by solving the inverse problem and thus obtain stochastic parameters from the measurements. We propose to assimilate LANL data into computer simulation code using parameter estimation techniques to understand the processes that influence space weather. The techniques and tools developed in this study may in future be applied to more comprehensive global models.
Link to: Radial Diffusion Modeling with Data Assimilation

Multi-Satellite Observation of Substorm Expansion Onset in the Geosynchronous and Mid-tail Regions
Project Investigators: Joseph Borovsky, Los Alamos National Laboratory
Robert McPherron, University of California Los Angeles
Tung-Shin Hsu, Post Graduate Researcher, University of California Los Angeles

Substorms are so complex that many issues related to them remain very controversial. Many models have been proposed to explain substorm activity. These models can be broadly classified into two categories depending on the cause of the expansion onset. The first invokes processes in the near-Earth region ($|X| \leq \sim 15$ Re) or some feed back instabilities near the ionosphere. The other invokes mid-tail magnetic reconnection beyond $|X| \approx 15$ Re as a source of plasma flowing earthward. Deceleration of this earthward flowing plasma and pileup of magnetic flux pileup close to the Earth is then the cause of near-Earth disturbances. A possible way to distinguish the cause of substorm expansion onset is to examine the relative timing of magnetotail disturbances. If the near-Earth region is the source region of substorm onset, a disturbance should be first observed in the near-Earth region and later in the midtail. Similarly, the opposite time delay should be observed if the mid-tail reconnection is the source of substorm expansion onset. Our project proposes to use magnetic data from multiple spacecraft in the tail to make a statistical examination

of the relative timing of phenomena at different distances. Chance conjunctions of GOES, WIND, Geotail, Cluster, INTERBALL, and possibly Double Star will be used to find the statistical patterns of delay between different regions. Data from auroral imagers, ground magnetometers, Pi 2 pulsation detectors, and synchronous particle detectors will be used to establish accurate onset times.
Link to: Multi-Satellite Observation of Substorm Expansion Onset in the Geosynchronous and Mid-tail Regions

Quantifying the Low Energy Geosynchronous Plasma Environment
Project Investigators: Michele Thomsen, Los Alamos National Laboratory
Mark Moldwin, University of California Los Angeles
Hanying Wei, Graduate Student, University of California Los Angeles
Erik Winegar, Undergraduate Student, University of California Los Angeles

The cold ions of the outer plasmasphere and trough region play an important role in modulating the particle and wave environment in the inner magnetosphere. The Magnetospheric Plasma Analyzer (MPA) geosynchronous database provides information about the behavior of this regime over a complete solar-cycle. We propose to develop a model of the low energy ion density and temperature, separated by region (trough or plasmasphere) to understand the diurnal, annual, solar cycle, and geomagnetic dependence of these regimes. This model will contribute to the quantitative characterization of the geosynchronous orbit space environment and will contribute to ongoing modeling efforts of better understanding the spacecraft charging environment and the relativistic electron environment that contributes to spacecraft degradation. In addition, the intrinsic merit of this proposal is that it allows for the first time a study of the solar cycle variations of the outer plasmaspheric density and temperature.

The objectives of this proposed research are to quantify the density and temperature distributions of the low energy ion population at geosynchronous orbit. Over 12 years of MPA data will allow an examination of how the geosynchronous space environment changes at all time scales up to a solar cycle. The study will include an examination of the diurnal, annual, solar cycle, and geomagnetic activity dependence on the density and temperature of the plasmaspheric and trough populations.
Link to: Quantifying the Low Energy Geosynchronous Plasma Environment

Presentation and Talks:

G. Lapenta, P. Kronberg, *A comparison of observations and simulations in the jets of the radio galaxies 3C303 and 3C274 (Messier 87)*, 46th Annual Meeting of the APS Division of Plasma Physics, Miniconference on Astrophysical Jets, November 15-19, Savannah, Georgia, USA, 2004.

H. Li, G. Lapenta, J. Finn, *3D MHD Simulations of Large-Scale Structures of Magnetic Jets*, 46th Annual Meeting of the APS Division of Plasma Physics, Miniconference on Astrophysical Jets, November 15-19, Savannah, Georgia, USA, 2004.

G. Lapenta, *Automatic Adaptive Mesh Technics in Mono- and Multi-Dimensional PIC Codes*, 7th

International School/Symposium for Space Simulation, Kyoto, Japan, March 26-31, 2005.

G. Lapenta, W. Daughton, J.U. Brackbill, P. Ricci, *3D Kinetic Magnetic Reconnection*, 9th Easter Plasma Meeting, Torino, Italy, April 3-5, 2005.

G. Lapenta, *Kinetic Approach to microscopic-macroscopic coupling in fusion plasmas*, 47th Annual Meeting of the APS Division of Plasma Physics, October 24-28, Denver, Colorado, 2005.

C. T. Russell, The Earth's Magnetosphere, presented at Sun-Earth Connection Physics: The GeoImpact of CMEs, CIRs, and Ordinary Solar Wind, Merida, Mexico, November, 2004.

L. Jian, C. T. Russell, and J. T. Gosling, Using the total perpendicular pressure to diagnose corotating interaction regions and ICMEs, presented at Sun-Earth Connection Physics: The GeoImpact of CMEs, CIRs, and Ordinary Solar Wind, Merida, Mexico, November 2004.

L. Jian, C. T. Russell, and J. T. Gosling, Diagnostics of solar wind processes using the total perpendicular pressure, presented at Fall AGU Meeting, Eos. Trans. AGU, 85(47), Fall Meeting Supl., Abstract SH23A-04, F1491, 2004.

L. Jian, C. T. Russell, J. T. Gosling, and J. G. Luhmann, Characterizing stream interactions and ICMEs using total perpendicular pressure, presented at European Geosciences Union General Assembly, Vienna, April, 2005.

L. Jian, C. T. Russell, J. T. Gosling, and J. G. Luhmann, Using Total Perpendicular Pressure to Diagnose Stream Interactions, presented at Spring AGU Meeting, Eos, Trans. AGU, 86(18), Jt. Assem. Suppl., Abstract SH51A-07, JA459, 2005.

L. Jian, C. T. Russell, J. T. Gosling, and J. G. Luhmann, Identifying and Characterizing ICMEs Using Total Perpendicular Pressure, presented at Spring AGU, 86(18), Jt. Assem. Suppl., Abstract SH53A-11, JA466, 2005.

L. Jian, C. T. Russell, J. T. Gosling and J. G. Luhmann, Measurements of heating at Stream-Stream Interfaces, presented at Solar Wind 11 – SOHO 16, Whistler, British Columbia, June 2005.

L. Jian, C. T. Russell, J. T. Gosling, and J. G. Luhmann, Total pressure signature as a qualitative indicator of the impact parameter during ICME encounters, presented at Solar Wind 11 – SOHO 16, Whistler, British Columbia, June 2005.

L. Jian, C. T. Russell, J. T. Gosling, and J. G. Luhmann, Solar cycle variation of the properties of stream interaction regions (SIRs), presented at the SHINE Workshop 2005, Kona, HI, July, 2005.

L. Jian, C. T. Russell, J. T. Gosling, and J. G. Luhmann, Identifying and distinguishing ICMEs and stream interaction regions (SIRs), presented at the SHINE Workshop 2005, Kona, HI, July 2005.

L. Jian, C. T. Russell, J. T. Gosling, and J. G. Luhmann, Solar cycle variation of the properties of interplanetary coronal mass ejections (ICMEs), presented at the SHINE Workshop 2005, Kona, HI, July 2005.

Shprits Y. Y. , Thorne R. M., Friedel R., Reeves G. D, Radial Diffusion Modeling with Data Derived Effective Lifetimes, *Fall AGU meeting*, San Francisco, CA, December, 2004.

Shprits Y. Y. , Thorne R. M., Horne, R. B, 3D Radiation Belt Code, Feedbacks Between Acceleration Mechanisms and Loss, *Chapman conference on Recurrent Geomagnetic Activity*, Manus, Brazil, February, 2005

R. M. Thorne and Y. Shprits, Variability of outer zone electrons during recurrent corotating solar wind streams, *Chapman conference on Recurrent Geomagnetic Activity*, Manaus, Brazil, February 2005.

Friedel R. and Shprits Y. , Relativistic Electron Losses During the Main phases of the Storms, *Radiation Belts Workshop*, Hermanus, South Africa, 2005

Shprits Y. Y. , Thorne R. M., Friedel R., Reeves G. D, Radial Diffusion Modeling: Comparison with CRRES Observations, *Chapman Conference on Magnetospheric ULF Waves,*, Sun Diego, CA, March, 2005

Shprits Y. Y. , Kondrashov D., Thorne R. M., Ghil, M., Reeves, G. Friedel, R., Nonlinear Parameter Estimation in Space Physics, *General Assembly of the European Geophysical Union,* Vienna, Austria, April, 2005
Shprits Y. Y. , Thorne R. M., Friedel R., Reeves G. D, Radial Diffusion with Data Derived Lifetimes using Various Field Models, *General Assembly of the European Geophysical Union,* Vienna, Austria, April, 2005

Shprits, Y. Y., R. M. Thorne, G. D. Reeves, and R. Friedel, "Radial Diffusion Modeling with variable outer boundary: Comparison with observations", *Chapman Conference on ULF waves*, San Diego, CA , March, 2005.

Shprits Y. Y. , Thorne R. M., Friedel R., Reeves G. D, "Radial Diffusion with Data Derived Lifetimes using L* derived boundary conditions", *GEM workshop*, Santa Fe, NM, June, 2005

Publications:

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Participating Graduate Students and Post-Docs:

J. Driscoll, Graduate Student, University of California-San Diego

S. Markidis, University of New Mexico

J. Ju, University of New Mexico

G. Zuccaro, Politecnico di Torino, Italy

C. Tronci, Imperial College, London

E. Camporeale, Queen Mary University, London

J. King, University of Michigan

C. Serazio, Politecnico di Torino, Italy

A. Marocchino, Politecnico di Torino, Italy

L. Jian, Graduate Student, University of California-Los Angeles

W. Li, Graduate Student, University of New Hamphsire

Y. Shprits, Graduate Student, University of California-Los Angeles
The Graduate student Yuri Shprits was awarded MS degree in December 2004, PhD candidate degree in December 2004 and PhD degree in September 2005 and will continue working at UCLA on the department of Atmospheric and Oceanic Sciences.

T. Hsu, Post Graduate Researcher, University of California-Los Angeles

E. Winger, Undergraduate Student, University of California-Los Angeles

H. Wei, Graduate Student, University of California-Los Angeles

Workshops:

Shprits Y. Y., Variability of the Relativistic electrons in the Radiation Belts., invited seminar at the Aerospace Corporation, El Segundo CA, November 2004.

Thorne R. M., Source and loss processes for outer radiation belt relativistic electrons, invited seminar at the Aerospace Corporation, El Segundo CA, February 2005.

Thorne R. M., J. Bortnik, Sprits Y. Y., O'Brien, P., The effects of both ULF and EMIC waves on relativistic electron dynamics during storms", invited talk at the
"Chapman conference on Magnetospheric ULF Waves, San Diego, CA, March
2005.

3. Solid Earth Geoscience

Focus Leader: Claudia Lewis clewis@lanl.gov

3.1 Focus area overview

This focus supports a breadth of basic research concerning planetary surfaces and interiors, including numerical, experimental, and field studies of the structure, properties, processes, and dynamics of terrestrial and giant planets.

The range of topics is broad, including:

- geochemistry (planetary evolution; hydrothermal alteration)
- geomaterials (elastic behavior)
- human origins
- hydrogeology (reaction kinetics; flow, transport, and reactions in porous media; hydrostratigraphy)
- mantle convection and supercontinent cycles
- seismology (free oscillations; fluid migration in volcanoes)
- spatial geostatistics

Many of these projects take advantage of LANL facilities (neutron scattering, remote sensing, high resolution microscopy, high performance computing, Lunar Prospector) or LANL capabilities (computational fluid dynamics, finite-element modeling, clay mineralogy, nonlinear acoustics). Nearly all of these projects represent the principal research of graduate students or postdoctoral fellows.

Projects for FY05 included innovative research in areas of current, strong international scientific interest:

- Elastic strain measured by GPS and InSAR for applications in Earth lithospheric processes
- Earthquake seismology and seismotectonics--rupture processes
- Planetary origins

2005 Solid Earth Minigrant reports:

Silicate Reaction Kinetics in a Major Aquifer in New Mexico

Project Investigators: George Guthrie, Los Alamos National Laboratory
Chen Zhu, Indiana University
Hui Tan, PhD Student, Indiana University
Tracee Imai, Undergraduate Student, Indiana University

The objective of this research project is to address a significant and long-standing problem in modern geochemistry and hydrogeology: The 2 to 6 orders of magnitude discrepancy of silicate

dissolution rates between those derived from field sites and those derived from laboratory measurements. We want to test the hypothesis that field and experimental conditions are intrinsically different from those in the laboratory, in terms of biological activity, solid surface properties, solution chemistry, and transport properties. We combine the strength and expertise of the *Indiana University* (geochemical modeling, field-emission gun scanning electron microscopy (FEG-SEM), availability of High-Resolution Transmission Electron Microscopy (HRTEM)) and *Los Alamos National Laboratory* (clay mineralogy, HRTEM expertise, and hydrogeological modeling) to conduct a multi-disciplinary field, microscopy, and modeling study of the kinetic rates and mechanisms of silicate reactions in a large aquifer in New Mexico. The involvement of students accomplishes both goals of a more detailed study and education of students.
Link to: Silicate Reaction Kinetics in a Major Aquifer in New Mexico

Behavior of Th and Sm in planetary surface and Magmatic Environments. Extending remotely sensed chemical data to better understand planetary evolution.
Project Investigators: David Vaniman, Los Alamos National Laboratory
Charles Shearer, University of New Mexico
Justin Hagerty, Postdoc, Los Alamos National Laboratory
James Karner, Postdoc, University of New Mexico
Paul Burger, Graduate Student, University of New Mexico

Thorium and samarium provide process information in terrestrial and lunar geologic systems, acting as "ideally" incompatible elements that partition into early melts, retaining evidence of primitive ratios and abundances in their source regions. They also reveal details of crystallization or impact history based on later partitioning. In this study we analyzed relations among these two elements in primary lunar basaltic glasses, in crystallization of the Makaopuhi lava lake, and in lunar regolith. Results of the study show that Th concentrations and Sm/Th ratios in lunar volcanic glasses indicate that there are distinct reservoirs with various enrichments and fractionations of both Th and Sm; that there is a clear relationship between mare basalts and specific mantle compositions; that distribution coefficients ($D^{ol/melt}$) for highly incompatible elements such as Sm and Th decrease with decreasing temperature; and that the regolith-forming process fractionates Sm and Th as a result of comminution and volatilization processes.
Link to: Behavior of Th and Sm in planetary surface and Magmatic Environments.

Using Neutron Computed Tomography to Determine the Influence of Pore Structure and Mineralogy on Two-Phase Flow and Transport in Fractured and Faulted Geologic Media
Project Investigators: Claudia Lewis, Los Alamos National Laboratory
Laurel Goodwin, University of Wisconsin
Joanne Fredrich, Sandia National Laboratory
Jennifer Wilson, PhD Student, University of Texas Austin
Paul Riley, Graduate Student, University of Wisconsin

We explored ways to quantify fault-zone modification of porous rock at two very different scales. At the μm scale, we focused on fault impacts on porosity and unsaturated permeability. At the m scale, we investigated the spatial distribution of small faults we have shown to be preferential fluid pathways in the vadose zone. We focused on faults in ignimbrite, the primary geologic material on which LANL is situated. Our work demonstrates that small faults are preferentially clustered

around map-scale faults, such that they should impact flow to the water table only within a ~600 m wide envelope around each large fault. We were not able to obtain good images of 3D pore networks across fault/matrix interfaces, probably because grain thicknesses in glassy ignimbrites are much less than in the sandstones that have been the focus of previous studies. Neutron computed tomography, however, shows promise in defining unsaturated flow pathways through faulted ignimbrite, but with resolution limited to 10s of µm.
Link to: Using Neutron Computed Tomography to Determine the Influence of Pore Structure

Nonlinear Response of Granular and other Materials
Project Investigators: Paul Johnson, Los Alamos National Laboratory
Robert Guyer, University of Massachusetts

Seminal laboratory studies show that a broad class of materials exhibit *Nonlinear Nonequilibrium Dynamics (NND)*. NND is comprised of modulus softening and markedly increased dissipation induced by large dynamic strains, the *nonlinear fast dynamics*. This is followed by memory of softening after wave forcing—an extended recovery to the equilibrium modulus, the *slow dynamics*. Recently, we have shown that granular media exhibit significant NND in the laboratory[1]. This past year, we have observed NND for granular media *in the Earth* using an active source. We induced the NND by applying a large vibrator to layered granular media (sediments) at a site near Austin, Texas. While the NND regime has major implications for probing the physics of granular media, it also has significant consequences to predicting sediment response during earthquake strong ground motions, the cause of damage and injury during a large earthquake.
Link to: Nonlinear Response of Granular and other Materials

Measuring and Modeling Fluid Movements in Volcanoes: Insight from Continuous Broadband Seismic Monitoring at Galeras Volcano, Columbia
Project Investigators: Leigh House, Los Alamos National Laboratory
Douglas Dreger, University of California Berkeley

Volcanic seismic events provide our best window for viewing the movement of hydrothermal or magmatic fluid in volcanoes. What we see depends on the model we use to interpret the events. In 1993, tornillos, distinctive seismic events with screw-like ("scalloped") envelope profiles, preceded several ash eruptions at Galeras Volcano, Colombia. Were they precursors and, if so, what is their significance? To answer this question, we study tornillos recorded with broadband seismometers installed December 1997 as part of a cooperative project between the German and Colombian Geological Surveys. These tornillos are multichromatic with a varying number of spectral peaks between frequencies of 1 and 40 Hz. Careful inspection of these three-component recordings shows that each tornillo waveform can be divided into three segments. The initial onset is very small compared to the amplitude of the long-lasting coda, usually impulsive, and found on the vertical component. About 0.3 s later, a transition wavelet lasting between 2 and 3 s arrives on both horizontal components as well as the vertical component. This wavelet is generally complex, but is made up of contributions at several discrete frequencies. The coda of the tornillos follows, and has the distinctive, screw-like, scalloped envelope that gives tornillos their name. During the interval of time represented by this dataset (December 1999 to December 2004), t_{S-P} and the

polarization for spectral peaks between 1.4 and 4 Hz change very little, suggesting that tornillos always occur in the same place. There are, however, both differences in the onset and the transition wavelet from one tornillo to the next and variations which appear to be time-dependent. We examine the beginnings of many tornillos in search of the process that excites them and investigate whether and how the first 3 s of the tornillo relate to the characteristics of the coda. We also review triggered data recorded at a seismic station near Valles Caldera to determine if similar events are found there.
Link to: Measuring and Modeling Fluid Movements in Volcanoes:

Using Pressure Interference Tests to Infer Large-Scale Spatial Statistics of Randomly Heterogeneous Geologic Media
Project Investigators: Daniel Tartakovsky, Los Alamos National Laboratory
Shlomo Neuman, University of Arizona
Ayelet Blattstein, Graduate Student, University of Arizona

Our **goal** is to develop a way to infer the spatial statistics of permeability and storage capacity or porosity in multiscale, randomly heterogeneous geologic media on the basis of large-scale pressure interference tests. To achieve this goal, we pursue the following **objectives:**

(1) Develop analytical or, where necessary, numerical ensemble moment solutions for the stochastic equations that govern groundwater flow to a well in two- and three-dimensional domains, having properties that behave as random fractals with truncated power variograms, based on nonlocal recursive moment equations in spatially bounded and infinite real and/or Laplace-transformed time domains. Test the solutions against numerical Monte Carlo simulations.

(2) Develop methods to infer the spatial statistics of medium permeability and specific storage (or, equivalently, porosity) from pressure interference tests graphically or by inversion based on our newly developed analytical and/or numerical solutions, as well as Monte Carlo results.

(3) Test our novel methods of inference on synthetically generated data.

(4) Use our new methods to infer the spatial statistics of fractured tuffs on the basis of existing pressure interference data from a University of Arizona experimental site near Superior, Arizona.
Link to: Using Pressure Interference Tests to Infer Large-Scale Spatial Statistics of Randomly Heterogeneous Geologic Media

Hydrothermal Activity in Carbonaceous Parent Bodies
Project Investigators: Bryan Travis, Los Alamos National Laboratory
Gerald Shubert, University of California Los Angeles
Jennifer Palguta, Graduate Student Researcher, University of California Los Angeles

I visited Los Alamos from June 27 – July 8 during which time I worked directly with Bryan Travis. Over the course of my stay, I began familiarizing myself with the code MAGHNUM so that I could begin modifying it to model hydrothermal alteration on carbonaceous chondrite parent bodies. In my meetings with Dr. Travis, he explained the structure and capabilities of

MAGHNUM. By understanding MAGHNUM's setup, I have been able to determine the best way to couple MAGHNUM with the code PHREEQC which will be responsible for calculating the change of anhydrous minerals to hydrous minerals during fluid transport.
Link to: Hydrothermal Activity in Carbonaceous Parent Bodies

Deep Structure and Processes of the Colorado Plateau and its Margins
Project Investigators: Scott Baldridge, Los Alamos National Laboratory
James Ni, New Mexico State University
Richard Aster, New Mexico Institute of Mining and Technology
Stephen Grand, University of Texas Austin

Ristra 1.5 station installation was completed in March 2005, with a total of 18 instruments installed, extending from the center of the Colorado Plateau, across the Sevier thrust belt, to almost 100 km into the Great Basin. Data archival and preliminary data analysis is underway and will be expanded during the second year of this project as the data archive grows. IGPP funding over the first year of the project has facilitated productive interaction between students and researchers from New Mexico State University, New Mexico Institute of Mining and Technology, The University of Texas at Austin, The University of Missouri at Columbia, Arizona State University and LANL.
Link to: Deep Structure and Processes of the Colorado Plateau and its Margins

Heterogeneity of Stress in the Crust and its Effect on Earthquake Rupture
Project Investigators: Michael Fehler, Los Alamos National Laboratory
Ralph Archuleta, University of California Santa Barbara
Daniel Lavallee, Associate Researcher, University of California Santa Barbara
Shuo Ma, Graduate Student, University of California Santa Barbara

This research project is based on the premise that one can capture heterogeneous features of the slip (or stress) on a fault with a stochastic model. The stochastic model can then be used to generate equivalent synthetic distributions of the stress on the fault as input to dynamic modeling of the earthquake rupture. We have made significant progress in areas related to the validation of the stochastic model and its consequences on the ground motions (Lavallée and Archuleta, 2003; and Lavallée *et al*. 2005). Based on the superposition of seismic waves and the Central Limit Theorem, we have laid the basis for a unified picture of earthquake variability from its recording in the ground motions to its inference in source models. This theory stipulates that the random properties of the ground motions and the source for a single earthquake should be both distributed according to a Lévy law. Our investigation of the random properties of the source model and peak ground acceleration (PGA) of the 1999 Chi Chi earthquake confirms this theory (Lavallée and Archuleta, 2005). As predicted by the theory, we found that the tails of the probability density functions (PDF) characterizing the slip and the PGA are governed by a parameter, the Lévy index, with almost the same values close to 1. The PDF tail controls the frequency at which extreme large events can occur. These events are the large stress drops—or asperities—distributed over the fault surface and the large PGA observed in the ground motion. Our results suggest that the frequency of these events is coupled: the PDF of the PGA is a direct consequence of the PDF of the asperities.

Link to: Heterogeneity of Stress in the Crust and its Effect on Earthquake Rupture

Geostatistical Analysis of an Experimental Stratigraphy
Project Investigators: Carl Gable, Los Alamos National Laboratory
Mark Person, Indiana University

A high-resolution stratigraphic image of a flume-generated deposit was scaled up to sedimentary basin dimensions where a natural log hydraulic conductivity (ln(K)) was assigned to each pixel on the basis of gray scale and conductivity end-members. The synthetic ln(K) map has mean, variance, and frequency distributions that are comparable to a natural alluvial fan deposit. A geostatistical analysis was conducted on selected regions of this map containing fluvial, fluvial/floodplain, shoreline, turbidite, and deepwater sedimentary facies. Experimental ln(K) variograms were computed along the major and minor statistical axes and horizontal and vertical coordinate axes. Exponential and power law variogram models were fit to obtain an integral scale and Hausdorff measure, respectively. We conclude that the shape of the experimental variogram depends on the problem size in relation to the size of the local-scale heterogeneity.At a given problem scale, multilevel correlation structure is a result of constructing variogram with data pairs of mixed facies types. In multiscale sedimentary systems, stationary correlation structure may occur at separate scales, each corresponding to a particular hierarchy; the integral scale fitted thus becomes dependent on the problem size. The Hausdorff measure obtained has a range comparable to natural geological deposits. It increases from nonstratified to stratified deposits with an approximate cutoff of 0.15. It also increases as the number of facies incorporated in a problem increases. This implies that fractal characteristic of sedimentary rocks is both depositional process–dependent and problem-scale-dependent.
Link to: Geostatistical Analysis of an Experimental Stratigraphy

Presentation and Talks:

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Zhu, C., A.E. Blum, D.R. Veblen (2004) Feldspar dissolution rates and clay precipitation in the Navajo aquifer at Black Mesa, Arizona, USA. Proceedings form the 11thWater/Rock Interaction Conference, Saratoga Springs, New York (accepted).

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Hereford, A.G., Guthrie, G.D. Jr., Keating, E.H., Zhu, C., and **Zhu**, L. (2005) Silicate reaction kinetics in the Pajarito Plateau, New Mexico. *Geological Society of America Abstr. with Programs,* v. 37, no.7, p. 381.

Imai, Tracee, and Zhu, C., 2002, Undergraduate research at the University of Pittsburgh. *Geological Society of America Abstr. with Programs.*

Poster presentation of the abstract "The behavior of Thorium in lunar picritic magmas: Implications for the bulk Thorium content of the lunar mantle and lunar heat flow," at the 34th Lunar and Planetary Science Conference.

Poster presentation of the abstract "Closed system behavior of trace elements during basalt crystallization in the Makaopuhi lava lake, Hawaii." *Fall 2003 Conference of the American Geophysical Union*

Poster presentation of the abstract "Closed system behavior of trace elements during basalt crystallization in the Makaopuhi lava lake, Hawaii: A natural laboratory for understanding basaltic magmatism on the terrestrial planets" *35th Lunar and Planetary Science Conference*.

Oral presentation of the abstract "Thorium and Sm in lunar pyroclastic glasses: Insights into the composition of the lunar mantle and basaltic magmatism on the Moon." *35th Lunar and Planetary Science Conference.*

P. Riley, L.B. Goodwin, and C.J. Lewis, "Spatial distribution of deformation bands in the Pajarito fault zone, New Mexico: Implications for vadose zone fluid flow", *Geol. Soc. Am. Abstr. with Prog.* **37**, No. 7, 374 (2005).

J.E. Wilson, L.B. Goodwin, and C.J. Lewis, "Diagenesis of deformation-band faults: The record and mechanical consequences of vadose-zone flow and transport in the Bandelier Tuff, Los Alamos, NM", *Geol. Soc. Am. Abstr. with Prog.*, **37**, No. 7,168 (2005).

L.B. Goodwin, J.E. Wilson, G.C. Rawling, C.J. Lewis, and J.L. Wilson, "A natural laboratory approach to understanding fluid-fault interactions", *Wisconsin Geological and Natural History Survey*, Oct. 5, 2004.

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J.E. Wilson, L.B. Goodwin, and C.J. Lewis, "A record of fluid-fault interactions in the vadose zone: Lessons on the 4D evolution of fluid - fault systems". *Gordon Research Conference on Rock Deformation* August 8-13, 2004, Mount Holyoke College, South Hadley, MA

M. Wilding, C. Lesher, J. E. Wilson, and L. B. Goodwin, "Neutron imaging of geologic samples, with and without fluids", *IGPP-Sponsored Workshop on Fluid Flow and Transport through Faulted Ignimbrites and other Porous Media*, Sept. 10, 2003.

Pearce, F., P. Bodin, T. Brackman, Z. Lawrence, J. Gomberg, J. Steidl, F-Y. Menq, R. Guyer, K. Stokoe and P. Johnson, Site-specific, nonlinear soil response using an active source, XXII EGS General Assembly, Vienna, Austria, April 24-19, 2005.

Pearce, F. Induced strong ground motion, MIT Earth Resources Laboratory, July 15, 2005.

Johnson, P. Nonclassical nonlinear behavior: nonequilibrium nonlinear dynamics in solids, 10th International Workshop on Nonlinear Elasticity in Materials, Taurmina, Italy, June 24-30, 2005.

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Johnson, P. and X. Jia, Nonlinear Dynamics, Granular Media and Dynamic Earthquake Triggering, 10th International Workshop on Nonlinear Elasticity in Materials, Taurmina, Italy, June 24-30, 2005.

Muller, M., J. TenCate, T. Darling, A. Sutin, R. Guyer, M. Talmant, P. Laugier and P. Johnson, Nonlinear Resonant Ultrasound Spectroscopy (NRUS) for bone micro-damage assessment, IEEE Ultrasonics Symposium, Rotterdam, Netherlands, September 18-21, 2005.

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Parts of this research was presented at the 2005 SCEC meeting, the 2005 CIMMS meeting held at the California Institute of Technology, and the 2005 AGU meeting.

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J.J. Hagerty, C.K. Shearer, and D. Vaniman "Closed system behavior of trace elements during basalt crystallization in the Makaopuhi lava lake, Hawaii"

In review, *American Mineralogist:*
P. Burger, D. Vaniman, C.K. Shearer, and J.J. Karner, Behavior of Th and REE during regolith formation processes on the Moon. Implications for remote sensing of the surfaces of airless planetary bodies. *Geochimica et Cosmochimica Acta.*

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Participating Graduate Students and Post-Docs:

Hui Tan, *Indiana University*, Ph.D. student

Tracee Imai, undergraduate student (graduated)

J. Hagerty, Postdoc, University of New Mexico

J. Karner, Postdoc, University of New Mexico

P. Burger, Graduate Student, University of New Mexico

J. Wilson, PhD Student, University of Texas, Austin
J.E. Wilson, 2004, "Characteristics of faults in nonwelded ignimbrites from the Pajarito Plateau and implications for fluid flow". Ph.D. thesis, New Mexico Institute of Mining and Technology, Socorro, NM (2004).

P. Riley, Graduate Student, University of Wisconsin

D. Pasqualini, Postdoc (transitioned to TSM, March, 2005)
Fred Pearce, Graduate Student, MIT
The strong ground motion work is the primary topic of his doctoral dissertation at MIT.

M. Muller (Université of Paris VII)
The work begun at Los Alamos and continuing at the Université Paris VI is the basis of her doctoral dissertation.

T. Brunet (Université of Marne-la-Vallée, France)
His work on granular media is the basis of his doctoral dissertation.

A. Blattstein, Graduate Student, University of Arizona
Two graduate students have been involved with the project, one formally and one informally. Ms. Ayelet Blattstein is completing her M.S. degree at the University of Arizona Department of Hydrology and Water Resources. Mr. Stefano Cintoli, a former student of Professor Vittorio Di Federico at DISTART, Università di Bologna, Bologna, Italy, has spent 9 months with us at the University of Arizona during 2003 – 2004, helping us to conduct our research on multiscale spatial variability. Mr. Cintoli defended his doctoral dissertation based mainly on work he has conducted with us. This work has so far led to two publications (listed in the previous section).

Ayelet spent part of summer 2005 at LANL working with Dr. Daniel M. Tartakovsky, as discussed earlier.

The project is also benefiting informally from research conducted under an NSF/ITR project by another U of A doctoral student, Mr. Bwalya Malama. Bwalya has completed the development of a numerical inverse code for nonlocal ensemble moment equations describing transient flow in two-dimensional, randomly heterogeneous formations. We intend to use his code under this project, as described in the previous section.
During spring 2006 we expect Dr. Monica Riva, Assistant Professor at the Polytechnic University of Milan, Italy, to visit the University of Arizona and work jointly with the PIs, Drs. Neuman and Tartakovsky, in advancing our analytical and inverse modeling work.

J. Palguta, Graduate Student Researcher, University of California-Los Angeles

S. Ma, Graduate Student, University of California-Santa Barbara

D. Lavallée, Associate Researcher, University of California-Santa Barbara

Visitors to LANL and/or to the University:

Dr. George Guthrie came to the campus for an extended visit in August 2003 and advised graduate student Hui Tan. The geochemical modeling work Hui Tan is performing for his thesis is closely related to the successful mineral carbonation experiments and modeling research program on-going at LANL. These two projects complement each other in understanding the complex interplay of primary mineral dissolution and secondary mineral precipitation, aqueous solution chemistry, and mineral surface properties.

Dr. Guthrie's advice to the graduate student also lends expertise that is lacking at the University: clay mineralogy. The graduate student is currently collecting mineral separate for further analysis. The interactions for graduate students with National Laboratories broaden their professional horizon. Overall, the funding and participation of LANL scientists contributed to the education and human resource development.

In fiscal year 2002, Dr. George Guthrie gave an invited seminar at the University. The seminar was well received. Some faculty members contacted Dr. Guthrie for possible, additional collaboration between Los Alamos National Laboratory and the University. Dr. Chen Zhu visited Los Alamos National Laboratory in May 2002 to work with Dr. George Guthrie. Dr. Zhu also had conferences and discussions with Drs. Bill Carey, Rick Warren, and Vaniman.

Pearce worked at LANL August 2004-August 2005, and begans studies at MIT September 2005.

Muller worked at LANL from August 2004-December 2004.

Pearce visited MIT to give presentation in July 2005

Johnson visited MIT in October 2005.

Johnson worked at U. Marne-la-Valle and U. Paris VI from Septemeber-December 2005.

Johnson and Pearce visited U. Memphis/USGS Memphis in February 2005.

Johnson and Pearce visited and conducted field experiments at UT Austin in May, 2005.

Guyer worked at LANL from June-August 2005.

4. Complex Dynamical Climate and Environmental Systems

Focus Leader: Manvendra Dubey dubey@lanl.gov

4.1 Focus area overview

The Earth System represents one of the more complex and challenging systems to observe, simulate, and predict. The importance of understanding it is underscored by potential impacts of human activities such as carbon dioxide emissions from energy production on our climate. This focus area encompasses the dynamical, physical, and biogeochemical processes that regulate our climate system. A particular goal is to elucidate non-linear interactions between the atmosphere, ocean, biosphere, and cryosphere. This is achieved by integrating the following research elements: coupled-climate modeling, carbon cycle science, carbon sequestration, aerosols, clouds, remote sensing, biogeochemistry, eco-hydrology, uncertainty analysis, paleo-climate records, hydrogen economy and other energy infrastructure issues.

This focus area contributes to an improved understanding of the change in the Earth's energy balance by anthropogenic greenhouse gases and aerosols, their effects on our climate, and implications for future energy policies. It integrates small collaborative projects between LANL scientific staff and academic groups to support LANL's energy security goal aimed at helping the world meet its growing energy demands while managing risks to our environment. In addition, scientific advances in process level knowledge, systems theory and uncertainty in this project will contribute to improved methods to assess uncertainties in nuclear weapon simulations of design and safety, and it will aid our understanding of Homeland Security issues involving the fate and transport of chemical, biological, and nuclear agents.

The oceanic thermohaline circulation is the key mechanism by which heat is transported from the tropical to Polar Regions. It represents one of the least understood elements in global climate models. This problem was tackled by developing diagnostics for oceanic thermohaline overturning in a coupled ocean-atmosphere model (HYCOM-GISS). Its impact was evaluated in centennial scale integrations with a prescribed rise in carbon dioxide at 1% a year rate to value twice pre-industrial levels. Results showed a warming of about 2 C in global mean surface air-temperature with a virtually unchanged Atlantic meridional overturning. The finding of the insensitivity of the oceanic circulation in this model to the doubling of carbon dioxide should be examined to other coupled climate models.

The potential disintegration of the Western Antarctic Ice Sheet (WAIS) from the anthropogenic greenhouse gas forcing could have significant impact on both regional and global scales. Mechanistic studies of this were performed using the Los Alamos coupled ocean and sea ice model (POP-CICE). It was concluded that the WAIS is unstable, and that the ocean circulation is highly sensitive to its configuration. Simulation results demonstrate that the Southern Ocean circulation could be strengthened by up to 32% and sea surface temperatures could drop by as much as 0.75C. These effects also propagate through the globe weakening the North Atlantic deep circulation by 6.5% and temperature drops by about 0.2C. These findings open new directions in the role of the Antarctic as an important component of the global climate system. Another important void in coupled-climate modeling is the treatment of snow packs. To fill this gap a realistic multi-layer snow model is being added to the Los Alamos sea ice model.

A fundamental understanding of the dynamic behavior of ice is needed to predict the flow of ice sheets in the polar and high altitude terrestrial environment. An apparatus to study in situ ice deformation under laboratory conditions with state of the art diagnostics using LANL's neutron scattering facilities was constructed to perform controlled experiments to help achieve this.

Increased radioactive forcing by greenhouse gases is expected to enhance the frequency of extreme events like wildfires and hurricanes. LANL has developed physics based models to simulate such events using a high-resolution atmospheric model (HIGRAD). To evaluate regional effects in a global change context adaptive mesh refinement with grid nesting (AMR) capabilities are being added to these models. AMR will allow calculations to zoom in on given areas and to move this high-resolution region from one location to another, thus allowing the accurate tracking of a wildfire or hurricane using high resolution only as required. Further with AMR more global scale changes can be specified as boundary conditions and their regional effects examined quantitatively.

To understand the global carbon cycle, in particular the role of natural terrestrial sinks that determine the rate of accumulation of carbon dioxide in the atmosphere, an eddy flux system to measure net carbon dioxide exchange over the Valles Caldera grasslands has been installed. This field station that has been measuring the net carbon dioxide uptake for a year is now part of DOE's AMERIFLUX network. It is designed to investigate the impacts of changes in the nitrogen cycle by cattle and elk enclosures on the grassland carbon dynamics.

In the topical area of paleo-climate reconstruction, records from deep sea coral, bogs and tree-rings were dated and analyzed for nitrogen and carbon isotopes. Evidence for periodic large-scale drought and fire consistent with the Pacific Decadal Oscillation was discovered in the Jemez Mountains. A deep core was drilled in the early summer 2004 in the Valles Caldera in partnership with USGS that will provide valuable information on the past millennia climate variation in southwest US. We are continuing to support the analysis work of this core postdoctoral support.

DOE has committed to aggressive R&D funding towards a transition from the present carbon-based economy to a clean hydrogen economy. To prepare for this proactively both the environmental benefits and risks of future global hydrogen economy scenarios were examined using a global atmospheric chemistry model (MOZART). We focused on the effects of reduction of nitrogen oxides from switching to fuel cells, as well as hydrogen leaks from the production, distribution, and use of hydrogen. The benefits include improvements of air quality on a regional scale. The risks included (1) a reduction of global oxidative capacity and (2) a small increase in stratospheric water that could increase halocarbon induced ozone levels there, but can be managed by reducing the leaks and/or by delaying the transition to the hydrogen economy after 2050.

Remote sensing of high-resolution multispectral thermal data is beginning to provide valuable data on characteristics of the earth surface temperature, aerosols, clouds and water. However, a considerable amount of tuning is necessary to extract the relative data. One of our projects applied a novel method of temperature emissivity separation using spectral mixture analysis to this problem. This allows us to estimate average atmospheric and surface temperature, as well as column water vapor below the sensor. The results of this work indicate that good end-member classes are required to achieve increases accuracy in thermal information extracted from hyperspectral sensors.

The history of the other planets such as Mars offers useful information related to the Earth's past and future. Motivated by this, a study is investigating the details of large-scale impact structures on Mars left by impacts. This work has mapped out the rampant craters and secondary structures on the Martian regolith. Intelligent pattern recognition and feature detection tools (GENIE) are being applied to extract mechanistic information (e.g craters, ejecta, secondary crater fields, and rays) from these rich data sets.

Our climate dynamical systems focus area should produce more accurate methods to assess climate variability and changes by developing robust parameterizations of ocean-ice-atmosphere couplings, validating processes and improving the numeric in models. A focus is on capturing dynamics of higher order turbulence statistics, including fluxes of momentum, heat, and mass (including greenhouse gases) within and between media (e.g., between the atmosphere and ocean, and atmosphere and biosphere). In addition, an improved understanding of the conditions, which lead to rapid climate change, both on regional and global scales, involving the atmosphere and ocean, will be sought. To accomplish this, intensive modeling studies of complex integrated systems (with focus on regional and global climate, and integration with field observations will be carried out, in particular where sensitivity, uncertainty, and performance metrics will be linked to system design. Integration of models, observations, and experiments is central to raising climate change science from a diagnostic to predictive realm.

2005 Complex Dynamical Minigrant reports:

Automated Feature Detection and Hydrocode Modeling of Impact-Related Structures on Mars

Project Investigators: Galen Gisler, Los Alamos National Laboratory
Erik Asphaug, University of California Santa Cruz
Catherine Plesko, Graduate Student, University of California Santa Cruz

We are studying large-scale impact structures on planets (Mars in particular), exploiting extended impact aftermaths (craters, ejecta, secondary crater fields, and rays) to better constrain target geologies and the detailed mechanics of planetary cratering. Our goals include forward modeling of impacts on Mars, with special attention devoted to the fate of ejecta (secondary craters, and devolatilization of the surface), together with remote sensing analysis of Mars image products.

In the first year we achieved the significant milestone of completing much of the remote sensing application development. We developed algorithms to rapidly and automatically extract a list of crater center coordinates and radii from a satellite image.
Link to: Automated Feature Detection and Hydrocode Modeling of Impact-Related Structures on Mars

The Middle Awash Region Structural Transition Zone: Age constraints on volcanotectonic and sedimentation processes and paleontalogical resources
Project Investigators: Giday WoldeGabriel, Los Alamos National Laboratory
Tim White, University of California Berkeley

The IGPP/LDRD minigrant supported geological investigation in the northern part of the Middle Awash project study area. The National Science Foundation primarily funds the multidisciplinary international geological and paleoanthropological research. The purpose of the geological investigation is to document the complex tectonic and volcanic processes that led to the development of the Middle Awash region of the southern Afar Rift. The Middle Awash region is located within a tectonic and volcanic transition zone from the continental Main Ethiopian Rift to the proto-oceanic rift segment of the Afar Rift. Distinct tectonic, volcanic, and geomorphic features manifested along both rift margins and the intervening rift floor characterizes the Middle Awash region. The trend of the western margin was modified from NE to NS, whereas the southeastern escarpment changed from NE to EW directions. These changes are also reflected in the intervening rift floor. The rift floor is funnel-shaped and more than150 km wide within the transition zone compared with the narrower (80 km) floor of the adjacent northern Main Ethiopian Rift. This is also true for the Quaternary axial rift zone that widens northward into the central Afar Rift. All of these structural modifications are attributed to the tectonic interactions among the boundary faults of the two oceanic rift basins of the Red Sea and the Gulf of Aden with the continental Main Ethiopian Rift.
Link to: The Middle Awash Region Structural Transition Zone:

Improved Combustion Physics of the LANL Wildland Fire Prediction Model (FIRETEC)
Project Investigators: Rod Linn, Los Alamos National Laboratory
Thomas Fletcher, Brigham Young University
Michael Clark, Graduate Student, Brigham Young University

The objective of this research is to continue to improve the combustion model used in the LANL Wildland Fire Prediction Model (FIRETEC), which was developed to predict the spread of wildland fires. In the development of FIRETEC, a simple heuristic formulation was used, based on an assumed probability density function, to account for the combined reactions of solid and gas phase. This research seeks to improve the modeling of the physics of solid and gas phase combustion, as well as turbulence-chemistry interactions, without significant increases in computational requirements. We anticipate that an improved model can become a useful tool in predicting wildfire behavior including fire spread rate, ground-to-crown transitions, and flare-ups.
Link to: Improved Combustion Physics of the LANL Wildland Fire Prediction Model (FIRETEC)

Deep Coring of the Valles Caldera: Obtaining a Long-Term Paleoclimate Record for Northern New Mexico
Project Investigators: Jeff Heikoop, Los Alamos National Laboratory
Peter Fawcett, University of New Mexico

The goal of this proposed work is to obtain and analyze a deep (~82 m) sediment core from a lacustrine sequence in the Valles Caldera, northern New Mexico. Our work focuses on

determining the paleoenvironmental record of a long-lived lake in the caldera and ultimately will allow us to develop a paleoclimatic record for this part of northern New Mexico for a glacial-interglacial cycle from the middle Pleistocene. Work on this core includes developing an age model (via radiocarbon dating, argon-argon dating, tephrochronolgy, paleomagnetic stratigraphy, and experimental uranium series work on clays), sedimentologic and stratigraphic analyses (mineralogy, sedimentary facies and structures including varves if present), geochemical analyses including XRF and XRD work, paleomagnetic/rock magnetic analyses of the fine fraction present, and stable isotope analyses of organic materials present.
Link to: Deep Coring of the Valles Caldera:

Mixed Phase Clouds: Remote Sensing and Climate Change
Project Investigators: Petr Chylek, Los Alamos National Laboratory
Qiang Fu, University of Washington
Steve Robinson, Graduate Student, University of Washington

Study of the noise in individual MODIS long-wave infrared spectral bands noise estimates for the MODIS instruments mounted on the Terra and Aqua satellites have been performed at the detector level during prelaunch testing as well as during on-orbit analysis. Practical use of satellite data often requires large spatial sampling, which consists of radiation reflected from both sides of the scan mirror and quantified by multiple detectors. Differences in detector sensitivities and inconsistencies in response versus scan angle properties of both sides of the scan mirror add to the apparent error of the calibrated data.
Link to: Mixed Phase Clouds: Remote Sensing and Climate Change

Biosphere-atmosphere CO2 exchange of terrestrial ecosystems: Combining high resolution measurements and models to understand the global atmospheric carbon budget
Project Investigators: Nate McDowell, Los Alamos National Laboratory
William Pockman, University of New Mexico
David Hanson, University of New Mexico
Jim Randerson, University of California Irvine
Chris Bickford, Graduate Student, University of New Mexico

A mechanistic understanding of the controls over the growing atmospheric CO_2 burden remains elusive. Models using the stable carbon isotope ratio of atmospheric CO_2 ($\delta_{13}C$) have shown that the terrestrial biosphere absorbs a large portion of CO_2 from the atmosphere annually. Unfortunately, the location and magnitude of this "sink" remains in question due in part to limitations in our knowledge of the isotopic composition of photosynthetic assimilation, respiration, and isotopic disequilibrium; limitations that force models to make tenuous assumptions regarding these fluxes. We propose a two-part approach to assessing these assumptions. First, we will apply a new, high-frequency (~2 minutes) $\delta_{13}C$ measurement system, Tunable Diode Laser Absorption Spectroscopy, to examine mechanisms controlling biosphere-atmosphere CO_2 exchange. Second, we will use this mechanistic knowledge within a model of the global carbon budget to assess model sensitivity to the assumptions, and will then re-examine predictions of the terrestrial carbon sink. This project will be the first to make high-frequency measurements of the isotopic composition of ecosystem-scale assimilation, respiration, and disequilibrium, and the first

to quantify mechanisms controlling these factors. The use of high-resolution measurements for parameterization will substantially improve the accuracy of our model.
Link to: Biosphere-atmosphere CO2 exchange of terrestrial ecosystems:

An Upper-Ocean Model for Climate Sensitivity and Variability Simulations
Project Investigators: Philip Jones, Los Alamos National Laboratory
James McWilliams, University of California Los Angeles

This purpose of this project is the development and application of an upper-ocean model (UOM) for use in global climate simulations in the framework of the national Community Climate System Model (CCSM). The development objective is to implement the UOM algorithm in LANL's Parallel Ocean Program, version 2 (POP2) that will soon become the standard (full-depth) oceanic component in CCSM. The prototype application will use the POP2 UOM coupled to the CCSM atmosphere, sea ice, and land surface components to demonstrate an alternative and more physically meaningful measure of "climate sensitivity" to greenhouse gas changes. Auxiliary applications to natural variability and biogeochemical coupling will ensue through several collaborations.
Link to: An Upper-Ocean Model for Climate Sensitivity and Variability Simulations

Dissecting the Critical Lings between Ecology and Hydrology: Quantifying spatial and temporal variability of water fluxes and nutrient distributions in environmentally sensitive woodlands
Project Investigators: Brent Newman, Los Alamos National Laboratory
Andrew Campbell, New Mexico Tech
Daniel Slattery, Graduate Student, New Mexico Tech

Recent research has shown that natural tracer modeling based on the analyses of soil water content, pore water stable isotopes (δD and $\delta^{18}O$), and pore water anion concentrations can produce information about the spatially and temporally variable dynamics of arid and semiarid near-surface environmental systems that have previously not been obtainable. Understanding such complex, nonlinear dynamics is a critical part of U.S. environmental and climate change science priorities. An existing piñon-juniper, paired watershed study site at Bandelier National Monument and a long-term piñon-juniper woodland study site at Los Alamos National Laboratory provide a unique experimental basis to implement these underutilized, but powerful modeling and analysis techniques with the goal of understanding the spatial and temporal variations in water content and nutrient (nitrogen) distributions, and evaporation and percolation fluxes. We expect these results to be a significant contribution to our understanding of complex linkages between ecological and hydrological processes and will provide critical information on basic and applied science questions in semiarid environments.
Link to: Dissecting the Critical Lings between Ecology and Hydrology:

Presentation and Talks:

Plesko, C. S., S. P. Brumby, E. Asphaug, "A Comparison of Automated and Manual Crater Counting Techniques in Images of Elysium Planitia." American Astronomical Society Department of Planetary Sciences Annual Meeting, November 2004

Plesko, C. S., S. P. Brumby, E. Asphaug, "A Comparison of Automated and Manual Surveys of Small Craters in Elysium Planitia." 36th Annual Lunar and Planetary Science Conference, Abstract # 1971, March 14-18, 2005

Plesko, C. S., E. Asphaug, G. R. Gisler, M. L. Gittings "Verification and Validation of the RAGE Hydrocode in Preparation for Investigation of Impacts into a Volatile-Rich Target." Workshop on the Role of Volatiles and Atmospheres on Martian Impact Craters, July 2005.

Plesko, C. S., E. Asphaug, G. R. Gisler, M. L. Gittings "Hydrocode Modeling of Asteroid Impacts into a Volatile-Rich Martian Surface: Initial Results" American Astronomical Society Department of Planetary Sciences Annual Meeting, September 2005

Clark, M., T. H. Fletcher, and R. R. Linn, "Improvements to a Wildland Fire Model," poster presented at the 19th Annual ACERC Conference, Provo, Utah (February 17-18, 2005).

Fawcett, P.J., Heikoop, J., Goff, F., Allen, C.D., Anderson, R.S., Donohoo-Hurley, L., Geismman, J.W., Johnson, C., WoldeGabriel, G., and Fessenden-Rahn, J., 2005, Climate change over a glacial-interglacial cycle from the mid Pleistocene: A lacustrine record from the Valles Caldera, New Mexico, 2005 American Geophysical Union Annual Fall Meeting.

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Fawcett, P.J., Goff, F., Heikoop, J., Allen, Craig D., , Donohoo-Hurley, L.*, Wawrzyniec, T.F., Geissman J.W., Fessenden-Rahn, J., WoldeGabriel, G., and Schnurrenberger, D., 2004, Deep Coring in the Valles Caldera, Northern New Mexico to Obtain a Long-Term Paleoclimatic Record, EOS Transactions, American Geophysical Union, v. 85 T43C-1346.

Publications:

WoldeGabriel, G., W. Henry Gilbert, William K. Hart, Paul R. Renne, Stanley H. Ambrose, Geological Context of the Pleistocene Daka Member of the Bouri Formation (submitted for a monograph chapter on the Pliocene Daka Member of the Bouri Formation, UC Press, B. Asfaw and H. G. Gilbert, editors)).

WoldeGabriel, G., W. K. Hart, P. P. Renne, Y. Haile-Selassie, and T. D. White, Late Miocene Chronostratigraphy of the Adu-Asa Formation of the Transition Zone, Afar Rift, Ethiopia (submitted for a second monograph chapter on the late Miocene geology, UC Press, Y. Haile-Selassie and G. WoldeGabriel, editors).

White, T. D., G. WoldeGabriel, B. Asfaw, S. Ambrose, Y. Beyene, R. L. Bernor, J.-R. Boisserie, B. Currie, H. Gilbert, Y. Haile-Selassie, W. K. Hart, L. Hlusko, F. C. Howell1, R. T. Kono, A. Louchart, C. O. Lovejoy, P. R. Renne, H. Saegusa, E. S. Vrba, H. Wesselman, & G. Suwa, Asa Issie, Aramis, and the Origin of Australopithecus, Nature, 2006 (in press).

Clark, M., “Improvements to a Wildland Fire Model”, informal presentation to the Missoula Fire Sciences Laboratory (October 6, 2004).

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Participating Graduate Students and Post-Docs:

C. S. Plesko, Graduate Student, University of California-Santa Cruz
Catherine Plesko passed her qualifying exam in March, and has advanced to candidacy. LANL-PI Gisler was a member of the examination committee. She worked as a teaching assistant for winter quarter 2005 in order to learn more about teaching. She developed laboratory exercises and taught three discussion sections. Plesko worked at LANL for two months during the summer, during which time she attended Dimitri Mihalas’ class on Radiation Hydrodynamics, and did a reading course on high-pressure geochemistry with Ken Wohletz in addition to her research. She presented her work at several conferences and workshops as noted above, and gave her first formal seminar presentation in September at the German Aerospace Center (DLR) in Berlin.

K. Brudvik, Department of Integrative Biology, UC Berkeley
.
L. Morgan, Department of Earth and Planetary Science, UC Berkeley

M.l Clark Graduate Student, Brigham Young University

L. Donohoo-Hurley, Phd Student, University of New Mexico
Linda Donohoo-Hurley is a PhD student working with Geissman and Fawcett at UNM, on the paleomagnetic and rock magnetic properties of the sediment core. She has been very involved in all stages of the project as noted above, and successfully defended her PhD thesis proposal (comprehensive exams) in April 2005. She will be presenting the results of her work at the Annual Geological Society of America meeting in Salt Lake City in October 2005.

C. Johnson, Graduate Student, University of New Mexico
Catrina Johnson is an M.S. student working with Fawcett who started in the Fall 2004 semester and is working on major and minor element geochemistry of the sediment as well as conducting X-ray diffraction work to determine core mineralogy including clay mineralogy. She successfully defended her M.S. thesis proposal in April 2005. She is currently conducting geochemical analyses of the core.

S. Robinson, Graduate Student, University of Seattle

C. Bickford, Graduate Student, University of New Mexico

D. Slattery, Graduate Student, New Mexico Tech

Visitors to LANL and/or to the University:

October 04, Gisler to UCSC
January 05, Gisler to UCSC
March 05, Gisler to UCSC for Plesko's qualifying exam
March 05, Plesko to LANL for security and SAGE training
May 05, Gisler to UCSC
June 21-Septeber 2 05, Plesko to LANL
August 05, Asphaug to LANL

Mr. Clark visited LANL, collaborated with Dr. Linn's group and worked on code

Fawcett and graduate students visited the stable isotope facility at Los Alamos on Tuesday August 16, 2005 to discuss progress on the project with Jeff Heikoop, Giday WoldeGabriel and Julianna Fessenden-Rahn. Results from both UNM and LANL investigators were compared and a tentative chronology for the core was discussed.

IGPP Summer Schools

IGPP hosted three summer schools in FY05: Summer Applied Geophysics Experience (SAGE); the Carbon Sequestration Summer School; and the Cosmology Summer Workshop. These in turn are described in more detail in the following pages.

SAGE –
Summer of Applied Geophysical Experience

Description. Imagine an educational program in which: (1) a small number of the best, highly motivated undergraduate and graduate students from around the world participate, (2) students with diverse educational and professional experience work together in small teams, learning from each other, (3) students work closely on a daily basis with faculty and industry professionals, (4) students gain experience in both in applied and basic research, and (5) students gather, process, and interpret their own data and present oral and written reports. SAGE, the Summer of Applied Geophysical Experience *is* that program in geophysics. SAGE, sponsored by University of California's (UC's) branch of the Institute of Geophysics and Planetary Physics at the Los Alamos National Laboratory, is a four-week-long, intensive field-based geophysics course for upper-level undergraduate students, graduate students, and selected professionals. The program is held in June and July of each year. Students apply geophysical methods to basic and applied earth-science problems, such as characterization of contaminated waste sites and structure of sedimentary basins. Because of its emphasis on "hands on" training in field techniques, and on processing and interpretation of data gathered by the students, SAGE significantly augments the standard classroom educational experience. SAGE, the only course of its kind in the world, attracts students internationally. The faculty consists of instructors from Los Alamos and six educational institutions (Table 1), augmented by personnel from companies. SAGE mobilizes an extensive array of geophysical equipment and expertise from universities and the private sector. Over its 22-year history, SAGE has trained approximately 575 students. SAGE may be taken for graduate credit at the University of California.

The goals of SAGE are: (1) to encourage undergraduate students to continue with graduate education in geophysics or other earth-science-related fields, (2) to assist graduate students in establishing careers in geophysics in the public- and private-sectors, (3) to offer educational opportunities beyond those provided by individual educational institutions.

SAGE has received awards from the American Geophysical Union (1998) and the Society of Exploration Geophysicists (2000).

Importance. SAGE addresses critical needs in attracting students to the geophysical sciences, in enhancing their education in geophysics, and in promoting employment of students in the field. SAGE relates directly to detection of buried military structures, treaty-verification and nuclear-explosion monitoring, environmental cleanup, reservoir characterization for hydrocarbon resources, and CO2 sequestration. After completing their graduate education, SAGE students are employed typically by energy, geotechnical, and environmental companies, and by the national laboratories. SAGE assists in recruiting personnel for employment at Los Alamos.

(3) Accomplishments and Progress. Over its 23-year history, SAGE has worked in many areas in the Santa Fe-Espanola area on a variety of geophysical problems. For the last several years, work has concentrated in the rapidly developing Eldorado area south of Santa Fe, and on Cochiti Pueblo to the west. We are working closely with the Office of the State Engineer, the U.S. Geological Survey, and other governmental agencies, and with the Environmental Office of Cochiti Pueblo. This collaboration is exciting for two reasons. First, it provides geophysical and geological data that address issues related to groundwater resources, in some cases providing directly detection of shallow groundwater. The data are actively sought by these agencies. Second, it demonstrates to students the applications of geophysics to important societal issues. This application of geophysics has been very popular with the SAGE students.

The recent SAGE 2005 was held in Santa Fe, New Mexico, from June 17 through July 13. Including students who doubled as teaching assistants, thirty students (22 undergraduates; 4 graduates; 4 PhDs) from 21 different institutions attended SAGE. Techniques used included ground-penetrating radar, magnetics and transient electromagnetics, seismic refraction and reflection, gravity, magnetotellurics, and global-positioning surveying. Projects included:

(a) Geophysical surveys of an unexcavated archaeological site managed by LANL's RRES-ECO group. The surveys will contribute, in part, to the Laboratory's efforts to prioritize and evaluate the numerous archaeological resources for which it is responsible. Surveys conducted during SAGE were able to determine the thickness and extent of collapsed domiciles beneath a cover of rubble and soil, and to locate a buried kiva.

(b) Investigation of fault zones bounding a major structural basin of the Rio Grande rift west of Santa Fe, New Mexico. This was part of a continuing study of the tectonics of the region. In part, the surveys helped to characterize groundwater resources adjacent to Cochiti Pueblo, including the depth to the water table and water quality. Seismic surveys were able to determine the amount of vertical offset along a major basin-bounding fault zone (~350 m), to locate a buried basalt flow, and to approximately locate two individual fault strands.

Although students work in teams, they completed the program by individually presenting their research results in oral and written form.

In addition to the main, four-week-long program, a follow-up workshop for the SAGE undergraduate students is held during the first week of January. This workshop allowed the students to continue their work from the main summer SAGE program, providing a more in-depth opportunity to process and interpret their results. Two students are selected to attend the annual meeting of the Society of Sigma Xi, and to present their SAGE results in student poster sessions.

CARBON SEQUESTRATION SUMMER SCHOOL

Background: Building on the success of 2004, the Research Experience in Carbon Sequestration (RECS) reflected the main elements of DOE's Carbon Sequestration Program, highlighting cutting edge research and development (R&D) and showcasing major DOE sequestration initiatives. RECS served to integrate sequestration science among DOE, national laboratories, international organizations, universities and industry, networked young researchers and established a foundation for U.S. academic, scientific and technical excellence in the field.

The program was co-directed by LANL and EnTech which managed the overall program design, planning, implementation, follow-up and outreach. RECS co-Directors established organizational and technical linkages to DOE's Regional Partnership Program, the Carbon Sequestration Leadership Forum (CSLF), the International Energy Agency's Zero Emissions Technology Initiative, and national laboratories and universities throughout the U.S. An executive committee was established to evaluate applications, determine logistics and outreach activities, and provide curricula input, technical oversight and integration.

Objective and Goals: The primary objective of the program was to establish a first-of-its-kind, high-level summer research experience that reflected the pillars of DOE's Carbon Sequestration Program (i.e. Monitoring, Mitigation and Verification, Long Term Storage of CO_2, and CO_2 Capture), networked young researchers and established U.S. academic, scientific and technical excellence in the field. The specific goals of the program were to:

- Provide an overview of the technologies, theory, economics, and novel approaches to capture CO_2 from mixed-gas streams.
- Develop a basis for understanding the factors that determine the long-term containment of CO_2 in geologic systems.
- Explore below- and above-ground methods for monitoring CO_2 in geologic systems.
- Demonstrate the integration of field and laboratory data with predictions of the fate of CO_2 in geologic systems, with a particular emphasis on integrating process-level information with system-level decisions.
- Stimulate innovative discussions on problem solving related to carbon capture and storage.
- Enhance U.S. excellence in the field of carbon sequestration.
- Facilitate carbon sequestration networks and possible future collaborations.
- Provide high visibility to the DOE Carbon Sequestration Program.
- Incubate an institutional structure that could serve as a pipeline for industry to recruit highly skilled students.

Approach: The program had 21 graduate students and postdocs from Harvard, Yale, Rice, MIT, Columbia, Los Alamos National Laboratory, New Mexico Tech., Montana State University, University of Kansas, UC Santa Barbara, University of Texas, University of Mexico, and University of Calgary in Alberta Canada. The course was 14 days long and divided evenly among lectures, field work and student projects/presentations. The fieldwork focused on MMV technology strategies, implementation, and measurements at the Kinder Morgan facility named SACROC in Snyder Texas. Data collected from the fieldwork was analyzed and presented by the students at the end of the course. The students also used state-of-the-art systems models to determine the best reservoir type to store CO_2 (either basalt, limestone, or sandstone reservoirs). The students also presented the results of this modeling effort to the course and teachers.

Sponsorship: The program was funded by the Institute of Geophysical and Planetary Physics (IGPP) and by DOE's Office of Fossil Energy and the National Energy Technology Laboratory.

Picture taken at Kinder Morgan's SACROC facility. Students given safety briefing, tour of facilities, and time in the field to collect measurements on CO_2 flux, water chemistry, and CO_2 isotopes.

COSMOLOGY SUMMER WORKSHOP/SCHOOL

The Santa Fe topical workshop for 2005 [July 5-22, 2005, http://t8web.lanl.gov/people/salman/sf05/] concentrated on recent developments in cosmology, especially those related to current and expected observational advances, including the cosmic microwave background (CMB), large-scale structure, and dark matter and energy/early universe. The workshop was held at St. John's College. There were approximately 75 participants, including 25 graduate students and a similar number of post-docs. As always, discussion was emphasized with the workshop organization centered around review talks, short technical talks, and discussion sessions. There were review talks on the microwave background, dark energy observations, galaxy clusters, neutrino physics, globular clusters, inflation, the Lyman-alpha forest, and the formation and evolution of galaxies. Josh Frieman gave a public lecture on the Sloan Digital Sky Survey.

Scholars at IGPP Los Alamos

The general responsibility of the scholars is to conduct his/her own research while in residence at LANL, and participate in the development of new initiatives within LANL and the broader scientific community. The Orson Anderson Scholar during FY05 was Joshua Frieman, from

Fermi National Accelerated Laboratory. Joshua's area of expertise is in modeling for quintessential inflation. The FY04 was Dr. Fernando F. Grinstein, from US Naval Research Laboratory, Washington DC; Fernando's areas of expertise are boundary layer modeling, with an emphasis on large eddy simulation. In addition Professor Phil Kronberg, the FY03 Orson Anderson scholar and currently our visiting scholar, continues his affiliation in IGPP as a resident scholar, on an appointment with funding from programmatic sources in ISR, D, and T divisions.

Closeout report from the Orson Anderson Scholar: Joshua Frieman

During my tenure as an Anderson Scholar in the first half of 2005, I was able to complete work on some projects, make good progress on others, and initiate yet others that are still in the works. The relative freedom from home-institution bureaucratic responsibilities afforded by this opportunity played a significant role in this, for which I am grateful.

<u>Work done:</u>

With Rogerio Rosenfeld, a long-distance collaborator from Brazil, I completed a paper on a new model for quintessential inflation, presenting a simple particle-physics inspired model that naturally incorporates an accelerated Universe both at very early times (i.e., inflation) and at very late times (i.e., dark energy). I also made progress on a study of what can be learned about dark matter halo profiles from statistical weak lensing measurements, using N-body simulations. This work was completed not long after the end of my term at LANL. Balancing these theoretical efforts, I continued to work on planning for the Sloan Digital Sky Survey-II (SDSS) Supernova Survey, which began in September of 2005, and for the Dark Energy Survey (DES), a proposed project which would start collecting data in late 2009.

<u>Initiatives:</u>

While at LANL, I worked with K. Heitmann, S. Habib, G. Jungman, D. Holz, and others as an external collaborator on their LDRD proposal to study large-scale structure in simulations and in the SDSS. I am also involved in their new proposal to study Dark Energy and the Cosmic Web.

Also while at LANL, I discussed with S. Habib and others the idea of a large, multi-institution effort in N-body simulations aimed at achieving the necessary precision for analyzing future dark energy surveys, such as DES, LSST, SNAP/JDEM, etc. As an outgrowth of this, Habib is now PI of a proposal to carry out this project and just submitted a letter of intent to the SciDac program at DOE. This proposal will involve LANL, Fermilab, and several Universities.

<u>Publications:</u>

``A Simple Model for Quintessential Inflation," by R. Rosenfeld and
J. Frieman, astro-ph/0504191,
JCAP, 0509, 003 (2005)

``Cross-Correlation Lensing: Determining Galaxy and Cluster Mass Profiles from Statistical Weak Lensing Measurements," by David E. Johnston, Erin S. Sheldon, Argyro Tasitsiomi, Joshua A. Frieman, Risa Wechsler, Timothy A. McKay, astro-ph/0507467, to appear in Astrophysical Journal

``The Fall 2004 SDSS Supernova Survey," by
Masao Sako, Roger Romani, Josh Frieman, Jen Adelman-McCarthy, Andrew
Becker, Fritz DeJongh, Ben Dilday, Juan Estrada, John Hendry, Jon
Holtzman, Jared Kaplan, Rick Kessler, Hubert Lampeitl, John Marriner,
Gajus Miknaitis, Adam Riess, Douglas Tucker, J. Barentine, R.
Blandford, H. Brewington, J. Dembicky, M. Harvanek, S. Hawley, C.
Hogan, D. Johnston, S. Kahn, B. Ketzeback, S. Kleinman, J.
Krzesinski, D. Lamenti, D. Long, R. McMillan, P. Newman, A. Nitta, R.
Nichol, R. Scranton, E. Sheldon, S. Snedden, C. Stoughton, D. York, the SDSS Collaboration
astro-ph/0504455, in Proceedings of the 22nd Texas Symposium on Relativistic Astrophysics

Presentations:

ISR Colloquium, February 2005
``Probing Dark Energy: SDSS and the Dark Energy Survey"

I gave similar presentations at the LANL Cosmology Day Symposium and at the LANL PNAC Theory Workshop, both held while I was in residence. A similar presentation was also given as a Physics Dept. colloquium at UC Davis in April 2005, during my Anderson scholarship.

Other Activities:

While at LANL, I participated in the Theoretical Division's 2-day workshop on Particle and Nuclear Astrophysics and Cosmology (PNAC). In addition to giving a presentation, with several other external participants I co-authored a short report providing a brief evaluation of the on-going activities in this area at LANL.

Phil Kronberg’s 2005 Contribution to IGPP
Summary of Activities and Publications

Most of the research described below is connected to, or constitutes extensions of the LDRD and LDRD/ER “Magnetic Universe/Life Cycles of Galaxies” programs, of which Phil Kronberg is a member since coming to LANL as IGPP Orson Anderson Scholar in 2002/3.

A common scientific motivation for many of the itemized projects below is to explore the role of magneto-plasmas and magnetic fields in many astrophysical contexts on large scales. A companion aim is to provide data and insights for plasma and fusion science using large scale astrophysical systems as plasma “laboratories”, taking advantage of the enormous scalability of many magneto-plasma phenomena. In our work over my last 3 years in EES/IGPP we have also shown how cosmic ray acceleration processes in the Universe can be illuminated by studies of some largest scale astrophysical systems. (work ongoing with S.A. Colgate (T-6) and H. Li (X-1)).

1. Philipp Kronberg was one of an international author panel that published, in 2005, "*Cosmic Magnetic Fields*" the latest textbook on this subject: Springer Verlag, October 2005, ISBN 3-540-24175-2.

2. Kronberg has led, and is leading several interrelated projects to probe diffuse synchrotron radiation on intergalactic scales within the local universe out to 150 megaparsecs. The most prominent of these programs has involved a novel combination of the Arecibo telecope in Puerto Rico and the NRC-DRAO Interferometer at Penticton BC. The first phase analysis is complete and a paper was submitted in late 2005, reporting a new discovery of diffuse extragalactic radiation. This has important implications for the acceleration and diffusion of cosmic rays in intergalactic space, and introduces a potential new tracer of large scale structure in the universe which appears more weighted to distributed energy than to baryonic mass (e.g. galaxies).

3. During 2005, a sequel project was launched to similarly image two additional galaxy supercluster areas. As of December 2005 nearly all of the Arecibo and DRAO observations were completed. In addition to the collaborators in 1, (C.J. Salter P. Perillat (Cornell/Arecibo) and R. Kothes at NRC-DRAO Canada), Torsten Ensslin, a leader of the German PLANCK cosmic background team, has joined this second phase.

4. Related diffuse synchrotron radiation searches are continuing with collaborators at NRAO, Socorro, NRL (Washington DC) and Max-Planck-Institut für Astrophysik at Garching (MPA). Collaborators are R. Perley (NRAO), N. Kassim and A.Cohen (NRL), and T.A. Enβlin (MPA-Garching) and G. Giovannini (Bologna, Italy. These involve analysis of data, now collected, from the Green Bank Telescope (GBT), the VLA (New Mexico), the Westerbork Synthesis Radio telescope (WSRT, Netherlands).

The scientific aim of the above projects, on which P. Kronberg is the P.I., is to press the detection limits of magnetic fields on the largest physical scales observable down towards $\sim 10^{-8}$ G. This is the best direct method for measuring the magnetic energy that galactic black holes have deposited into the IGM outside of clusters over cosmic time. The wider aim has been to explore plasma conditions in intergalactic space in the régimes of density and magnetic energy.

5. Kronberg and Lapenta (T15) completed and published results of a new computational + observational investigation that successfully models both the collimation, and ultimate auto-disruption of extragalactic radio source jets. Their paper describing the first phase of this new ongoing project was published in 2005. Related work is ongoing.

6. Kronberg's Faraday rotation measure data has been combined with galaxy count data in a joint project undertaken in 2004/5, with S. Habib (T-8) and Y-Z. Zhu (T-8). This constituted the first search for Faraday rotation by the very dilute plasma in large scale

galaxy filaments of the low redshift universe. The project was successfully completed in 2005, and published in the Jan 20 2006 issue of the Astrophysical Journal.

7. In a new cross-disciplinary project using all-sky astrophysical data, P. Kronberg (IGPP), and D. Higdon(D-1) and M.B. Short (D-1) are co-developing statistical methods to optimally extract information from Faraday rotation measure data that Kronberg brought from the University of Toronto to LANL. Postdoc Short has made the first conference presentation on this effort. The project's first phase was brought to completion during 2005, and a paper was submitted for publication in January 2006.

8. A magnetic field probe of over 100 galaxy clusters was undertaken in 2004 and 2005, using a combination of satellite X-ray data from the ROSAT and XMM satellites. Partners in this project were Philipp Kronberg and Quentin Dufton (LANL), Francesco Miniati (MPA Garching, Germany and ETH Zürich, Switzerland) and Hans Bőhringer (MPE Garching, Germany). The project, now acquiring more X-ray satellite data, consists in a statistical probe of the magneto-ionic conditions around clusters of galaxies, where the radio and X-ray emission is too faint to be fully probed with current instruments.

9. During 2005, Philipp Kronberg has co-supervised an M.Sc. ("Diplomarbeit") student Martin Bernet at the ETH in Zürich, Switzerland. The thesis was submitted in August. It involved a "deep universe" probe out to cosmological redshifts of 3 using Kronberg's latest Faraday rotation measure data. Collaborators were the other co-supervisor, Prof. Simon Lilly, and Dr. Francesco Miniati, both of the ETH. Publications are in preparation.

10. In 2005 P. Kronberg (LANL), and S. Lilly and F. Miniati (ETH, Switzerland) were awarded observing time on the European Southern Observatory's VLT optical telescope to provide data for a new probe of extragalactic magnetic fields at large redshift by combining (radio) Faraday rotation data with deep optical spectroscopy of selected quasars. The optical spectra were acquired with the ESO VLT in August/September 2005. These, Kronberg's Faraday rotation measurements, and mathematical models are being combined to probe for magnetic fields at cosmologically large redshifts. Such results, hitherto almost non-existent, are needed to provide "hard" data for simulation studies of galaxy and structure evolution. They also provide tests for the origin of cosmological magnetic fields.

During 2005, Philipp Kronberg had several conference presentations, and gave 4 invited talks. He was on the Scientific Organizing Committee of an international conference "*The Origin and Evolution of Cosmic Magnetism*" in Bologna, Italy in 2005, and a referee for 6 papers.

Refereed journal publications and book chapters published in 2005

1. *Lapenta, G. and Kronberg, P.P.* ``Simulations of Astrophysical Jets: Collimation and Expansion into Radio Lobes'' *Astrophysical Journal* **625** 37-50, 2005

2. *Kronberg, P.P.* ``Energy and Magnetic Field beyond Clusters: Expectation and Evidence'' *The Magnetized Plasma in Galaxy Evolution* Eds:K. Chyzy, K. Otmianowska-Mazur, M.

Soida, and R.-J. Dettmar, Jagiellonian University, Kraków. Max-Planck-Gesellschaft Conf. Proc. p.p. 239-246, 2005.

3. *Kronberg, P.P.* ``The Astrophysical Importance of Low-Level, Low Frequency Intergalactic Radiometry" *From Clark Lake to the Long Wavelength Array: Bill Erickson's Radio Science* ASP Conf. Series, V 345, 142-148, 2005.

4. *Kronberg, P.P.* ``Galaxy to IGM Feedback of Magnetic Energy and Implications for UHECR's" *Rencontres de Moriond: Very High Energy Phenomena in the Universe* (book) eds. J. Tranh Van & J. Dumarché (7 pages) 2005.

5. *Kronberg, P.P.* ``Magnetic Fields in Galaxy Systems, Clusters, and Beyond'' in *Cosmic Magnetic Fields* (279 pages) eds. R. Wielebinski and R. Beck, Springer Verlag Heidelberg, (book chapter) pp. 9 – 39, 2005.

6. *Bernet, Martin* ``Cosmic magnetic fields at high redshifts" M.Sc. (diploma) thesis, ETH (Swiss Federal Institute of Technology) Zürich. (Supervised by P. Kronberg) August 2005.

Invited talks in 2005:

Dominion Radio Astrophysical Observatory, Penticton BC Canada February 16th 2005
``Black holes, cosmic magnetic fields, their interconnections & consequences"

Rencontres de Moriond La Thuile Italy March 2005
``Galaxy-to-IGM Feedback of Magnetic Energy and the Propagation of UHECR's"

National Radio Astronomy Observatory, Socorro NM April 2005
``Recent research on radio source lobes, jets, and some connections to IGM physics"

Conference on the Origin \& Evolution of Cosmic Magnetism, Bologna Italy, August 2005
``Radio Sources, IGM Magnetic Fields, CR's & Structure Evolution"

Prepared by Philipp Kronberg Jan. 27th , 2006.