EMERGING RESEARCH FRONTS - 2009

October 2009

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Andrew W. Strong, Igor V. Moskalenko & Olaf Reimer talk with *ScienceWatch.com* and answer a few questions about this month's Emerging Research Front Paper in the field of Space Science.

Article: Diffuse Galactic continuum gamma rays: A model compatible with EGRET data and cosmic-ray measurements
Authors: Strong, AW;Moskalenko, IV;Reimer, O
Journal: ASTROPHYS J, 613 (2): 962-976 Part 1, OCT 1 2004
Addresses: Max Planck Inst Extraterr Phys, Postfach 1603, D-85740 Garching, Germany.
Max Planck Inst Extraterr Phys, D-85740 Garching, Germany.
NASA, Goddard Space Flight Ctr, Greenbelt, MD 20771 USA.
Ruhr Univ Bochum, D-44780 Bochum, Germany.

SW: Why do you think your paper is highly cited?

A large number of outstanding problems in physics and astrophysics are connected with studies of cosmic rays and the associated emission (radio, microwave, X-rays, gamma rays) produced during their propagation in interstellar space.

Among these problems are indirect searches for dark matter, the origin and propagation of cosmic rays, particle acceleration in putative cosmic ray sources—such as supernova remnants—and the interstellar medium, cosmic rays in other galaxies and the role they play in galactic evolution, studies of our local Galactic environment, cosmic ray propagation in the heliosphere, and the origin of extragalactic diffuse emission.

New or improved instrumentation to explore these open issues is ready or under development. A fleet of ground-based, balloon-borne, and spacecraft instruments measures many cosmic ray species, gamma rays, radio, and synchrotron emission.

Our state-of-the-art model, called Galactic Propagation, or GALPROP, is the only one which combines all cosmic-ray isotopes (from hydrogen to nickel) and other cosmic-ray particles (such as electrons, positrons, protons, and antiprotons) as well as photon emission mechanisms in a single self-consistent framework.

The paper describes the GALPROP model and the results of a study of propagation of cosmic rays in the Milky Way Galaxy and production of secondary particles and isotopes as well as associated diffuse gamma-ray and synchrotron emission.

SW: Does it describe a new discovery, methodology, or synthesis of knowledge?

The complex nature of current scientific goals, such as the detection of a weak dark matter signal on top of the intense diffuse gamma-ray emission produced by cosmic rays interacting with the interstellar medium, or the study of electrons and positrons in cosmic rays, requires reliable and detailed calculations. This dictates that a numerical model be used.

Many of the latest developments of astrophysics, and particle and nuclear physics, play a role in addressing these questions—cosmic ray acceleration and transport mechanisms, detailed maps of the three-dimensional Galactic gas distribution, detailed studies of the interstellar dust, radiation, and magnetic fields, and improved particle and nuclear cross-section data and codes. Achieving these scientific goals requires a realistic model, yet one which is simple to access and use.

As mentioned above, the paper described the best current model for propagation of cosmic rays in the Milky Way Galaxy and production of secondary particles and isotopes as well as associated diffuse gamma-ray and synchrotron emission.

It combined a new methodology—a numerical approach to a problem which is far beyond the simple analytical solutions which had dominated the subject in the past, plus the synthesis of using all available diverse types of data within a single model.

Because of the complex character of the model, its parts—such as distributions of gas and radiation field as well as descriptions of various processes—can also be used for many independent studies.

Coauthor
Igor V. Moskalenko

Coauthor
Olaf Reimer

SW: Would you summarize the significance of your paper in layman's terms?

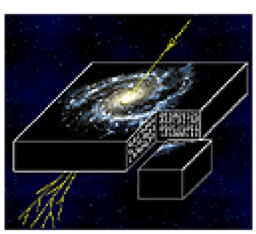
Exploration of the Milky Way galaxy and beyond, research in the astrophysics of cosmic rays and gamma rays are primary elements in many ground-based telescopes and balloon-borne and space missions. Such information may lead to breakthroughs and discoveries in many areas of astroparticle physics and cosmology.

Examples are the search for dark matter and antimatter, studies of the nucleosynthesis, acceleration of nuclei and their fragmentation through cosmic ray spectra and composition studies, the effects of heliospheric modulation, and the origin of Galactic and extragalactic diffuse gamma-ray emission.

The power of GALPROP to simultaneously predict many relevant observable quantities makes this model a unique tool in the analysis of data from a number of current and future balloon-borne and space missions.

GALPROP is a current state-of-the-art cosmic ray propagation code and has become a standard analysis tool in cosmic ray and diffuse gamma-ray research (e.g., it is the model adopted for the interpretation of Galactic emission for the Large Area Telescope on Fermi).

Figure 1 [+] details



GALPROP logo...

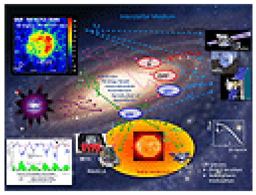
Figure 2 [+] details

The GALPROP code can be used to address topics as diverse as cosmic ray isotopic composition, calculation of the background for indirect dark matter searches and propagation of a potential dark matter signal, to providing the gamma-ray background model for the analysis of gamma-ray sources.

At the same time, it provides a unified framework for the interpretation of data collected by many different kinds of experiments. This powerful approach emphasizes the inter-relationship between different types of data, and allows the researcher to systematically study their importance for a global picture of the high-energy Galaxy.

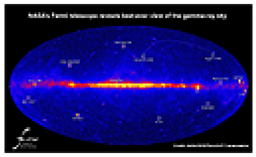
SW: How did you become involved in this research and were any particular problems encountered along the way?

Andrew Strong:



A schematic view of cosmic ray...

Figure 3 [+] details



A skymap >100 MeV...

I have been interested in high-energy astrophysics since my doctoral thesis, and have participated in a number of space missions on this topic from the pioneering times onward. My first attempt to construct this type of model of cosmic ray propagation and the diffuse emission of the Galaxy started with a research student in 1991. However, it did not develop into the current project until December of 1996 when Igor Moskalenko, a theoretician working in particle astrophysics, proposed we combine forces and work on the model together.

As often happens in science, Igor and I worked in the same group in the Max-Planck-Institute for Extraterrestrial Physics in Garching for half a year and knew little about each other's work. It was necessary to go to a meeting of the COMPTEL collaboration in ESA/ESTEC, in Noordwijk, The Netherlands, to learn of each other's work and to form a long-term collaboration.

At that time we decided that the code should be made publicly available. The objectives to make the code public were (i) to encourage people to take part in its development which may create a synergistic effect, and (ii) to give people an opportunity to use it for many applications that we could not have imagined at that time. It turned out to become a very successful project.

The first version of GALPROP was made generally available to the public in 1998, and a dedicated website with a new advanced version went online in 2006. The project is constantly developing and has been funded by NASA through various research grants since 1999. The current team has several members, each making important contributions. A new version will be released this year. Despite the progress, there is always a great deal more to be done to make the model more realistic and to make use of new data, etc.

Olaf Reimer, the other author on this paper, was a member of the EGRET team of NASA's Gamma Ray Observatory, and provided the essential insight into details of this experiment which was the main focus of this paper. Like Andrew and Igor, Olaf is now part of the Fermi Gamma Ray Observatory collaboration.

SW: Do you foresee any social or political implications for your research?

Particle astrophysics, which has recently emerged as an interdisciplinary science, is flourishing nowadays. It was born in the early days of cosmic-ray physics about a century ago and then reborn twice more, first with the launch of the first X-ray telescopes, and then with the apparent discovery that the matter in the universe is dominated by something unknown, the dark matter.

The latter rebirth brought an army of particle physicists into astrophysics. Particle astrophysics is now a busy intersection between high-energy astrophysics, particle physics, and cosmology. It happens that our research, which started before the current boom in particle astrophysics, is currently at the forefront.

The availability of computer resources and our free, but sophisticated code enables undergraduates, graduates, and postdocs from educational and scientific institutions from around the world to enter the fascinating field of astroparticle physics and conduct their own research at the leading edge.

Andrew W. Strong, Ph.D.
Max-Planck-Instituts für extraterrestrische Physik (MPE)
Garching, Germany
Web | Web

Igor V. Moskalenko, Ph.D.
Senior Staff Scientist
Hansen Experimental Physics Laboratory
& Kavli Institute for Particle Astrophysics and Cosmology
Stanford University
Stanford, CA, USA
Web

Olaf Reimer,Ph.D.
Professor and Chair of Experimental Astro- & Particle Physics
Institut für Astro- und Teilchenphysik
Leopold-Franzens-Universität Innsbruck

Innsbruck
Austria
&
Kavli Institute for Particle Astrophysics and Cosmology
Stanford University
Stanford, CA, USA
Web

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2009 : October 2009 - Emerging Research Fronts : Andrew Strong, Igor Moskalenko & Olaf Reimer: Exploration of the Milky Way Galaxy