

Simulation Tool to Assess the Performance of Advanced Compton Telescopes

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Abstract

Currently, a multitude of instrumental concepts for a so-called Advanced Compton Telescope (ACT) are under study in the US, Europe, and Japan. These instruments are exceedingly complex and will have to operate in the harsh space environment which is pervaded by intense particle and photon radiation fields. These radiation fields will give rise to an intense instrumental background against which the much smaller signals from celestial sources need to be discerned. Monte Carlo simulation is an effective approach to assess both the response and the instrumental background, and hence the scientific performance, of a given ACT concept in a given radiation environment. In order to meet better the requirements for studying the performance of these complex instruments, the already proven MGGPOD Monte Carlo suite is currently being upgraded. Improvements include: additional beam geometry and spectral options, capability of modeling polarized photons, additional output formats suitable for event reconstruction algorithms, and improved neutron interaction cross-sections.

The Simulation Code (Version 1.0)

MGGPOD Version 1.0 (Weidenspointner et al., *ApJS*, in press; astro-ph/0408399) is a suite of five closely integrated simulation packages (for an illustration, see the flow chart of the MGGPOD suite at right). In a nutshell, the capabilities and functioning of the packages are as follows:

- MGEANT (developed at NASA/GSFC, see e.g. Sturmer et al. 2004, A&A, 411, L81) is a multi-purpose simulation package that was created to increase the versatility of the GEANT Version 3.21 simulation tool. A modular, "object oriented" approach was pursued, allowing for rapid proto-typing of detector systems and easy generation of most of the radiation fields relevant to gamma-ray astronomy. Within the MGGPOD suite, MGEANT (i.e. GEANT) stores and transports all particles, and treats electromagnetic interactions from about 10 keV to a few TeV. MGEANT provides the option to use the GLECS package to take into account the energy of bound electrons in Compton and Rayleigh scatterings.

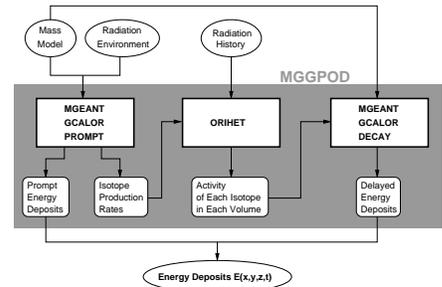
- GCALOR simulates hadronic interactions down to 1 MeV for nucleons and charged pions and down to thermal energies (10^{-5} eV) for neutrons. Equally important, this package provides access to the energy deposits from all interactions as well as to isotope production anywhere in the simulated set-up.

- PROMPT simulates prompt photon emission associated with the de-excitation of excited nuclei produced by neutron capture, inelastic neutron scattering, and spallation.

- ORIHET calculates the build-up and decay of ac-

tivity in any system for which the nuclide production rates are known. Hence ORIHET can be used to convert nuclide production rates, determined from simulations of cosmic-ray irradiation, to decay rates, which are necessary input for simulating the radioactive decays giving rise to the delayed background.

- DECAY enables MGGPOD to simulate radioactive decays.



The MGGPOD suite and documentation are available to the public for download at CESR from <http://sigma-2.cesr.fr/spi/MGGPOD/>.

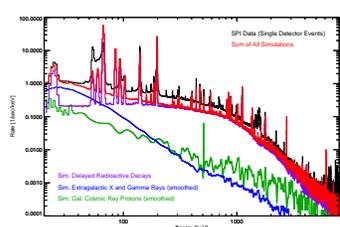
The various MGGPOD packages, including GEANT Version 3.21, have all been developed in the FORTRAN77 programming language. Therefore they cannot be used with the more recent Geant4 toolkit, which has been developed at CERN using the C++ language.

Some Applications of MGGPOD Version 1.0

The instrumental background of the TGRS Ge spectrometer onboard *Wind* has been successfully modelled using MGGPOD (e.g. Weidenspointner et al., 2004, *New Astronomy Reviews*, 48, 227; Weidenspointner et al., *ApJS*, in press).

Wind has spent virtually the whole mission in interplanetary space, well away from near-Earth radiation backgrounds. The overall continuum background is very well reproduced (within 15%). The simulation is also very successful in modelling the more than 200 lines that are observed in the spectrum. Most (about 87%) of the lines are reproduced, with the ratio of simulated and actual line count rates clustering around a value of one with no trend in energy.

MGGPOD has also been employed to predict the instrumental background of the



PROMPT package was not yet included in these simulations.

Recently, the MGGPOD suite has been applied to modelling the instrumental background of the

Reuven Ramaty High-Energy Solar Spectroscopic Imager

(Wunderer et al., 2004, Proc. of 5th INTEGRAL Workshop, in press). This is the first time MGGPOD is used for modelling the instrumental background of an instrument in low-Earth orbit. This case is particularly difficult because activation during passages through the South-Atlantic Anomaly (SAA) gives rise to a strong and time-variable background component. These preliminary results are encouraging, the overall spectrum is well reproduced. As expected for a mission in low-Earth orbit, the background is dominated by decays of radioactive isotopes produced during SAA passages. However, both SAA induced continuum and line components are overproduced, indicating the need for refining the modeling of the time-dependent activation during SAA passages.

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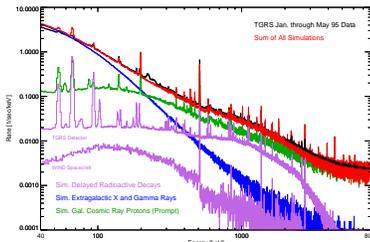
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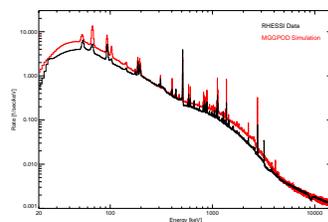
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SPI Ge spectrometer onboard INTEGRAL (Weidenspointner et al., 2004, *New Astronomy Reviews*, 48, 227) and to study its line background in detail to improve background modeling for scientific analyses, in particular of the 511 keV positron annihilation line (Weidenspointner et al., 2003, A&A 411, L113; Teegarden et al., 2004, Proc. of 5th INTEGRAL Workshop, in press). Similar to TGRS, SPI is operated in a highly elliptical orbit and spends most of its time above the Earth's radiation belts. Again, the overall background is well reproduced, and so are many lines. It has to be emphasized that the



MGGPOD Version 1.1

The additions and improvements of the original MGGPOD Version 1.0 were driven by the requirements for studying various instrument concepts for Advanced Compton Telescopes (ACT) in the framework of the international ACT Vision Mission Study Team (see poster 16.18 by Boggs). These upgrades will soon be publicly released in Version 1.1 of the MGGPOD suite, after completing rigorous testing by the ACT Collaboration.

- Introduction of new beam geometries and spectral models. These allow e.g. to simulate radiation fields whose intensity varies with zenith angle, which is required to model Earth albedo radiation in low-Earth orbit, or atmospheric background at balloon altitudes. The models for the various radiation fields (Earth albedo gamma and neutron radiations, geomagnetically trapped radiations, Galactic cosmic rays, diffuse cosmic photons, ...) relevant for ACT studies are described in poster 16.24 by Tourneir et al.

- Implementation of new output formats suitable for event reconstruction algorithms. An ACT will maximize the information provided by each source photon, and minimize the instrumental background, by reconstructing as far as possible the interaction sequence of each event. The baseline event reconstruction tools adopted by the ACT collaboration are presented in poster 16.26 by Zoglauer et al.

- One of the many exciting science goals of ACT is to measure polarization. To assess the sensitivity of the various concepts, the GLEPS package is now available in MGGPOD. GLEPS, which is described in poster 41.01 by McConnell, is an extension of the GLECS GEANT3 Low-Energy Compton Scattering Package to include the effects of polarized incident photons in the Compton and Rayleigh scattering processes.

- The standard set of neutron cross-sections available for GCALOR does not cover all elements/isotopes relevant for ACT studies. We are therefore converting the JENDL evaluated neutron cross-sections into GCALOR format, complemented by other databases for the few isotopes missing in JENDL.