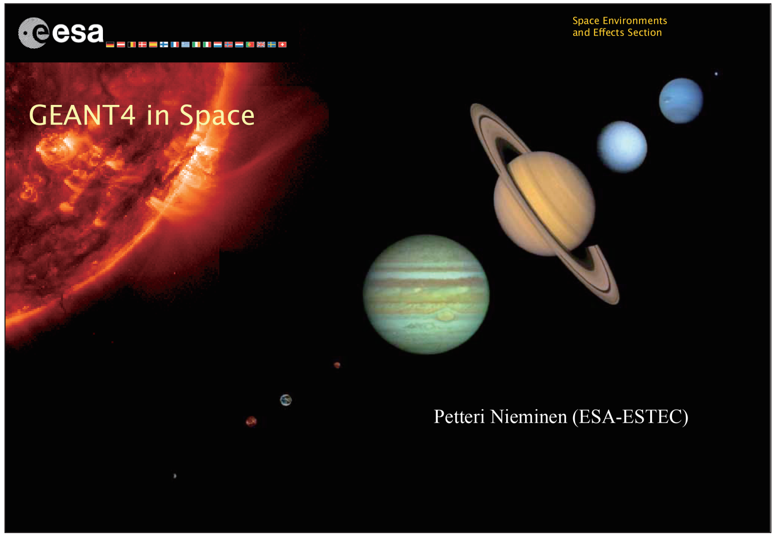
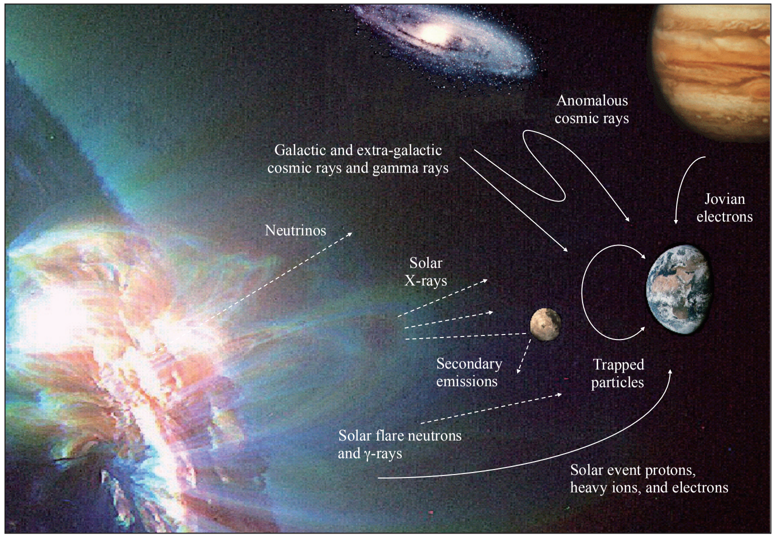


esa

Space Environments
and Effects Section

GEANT4 in Space

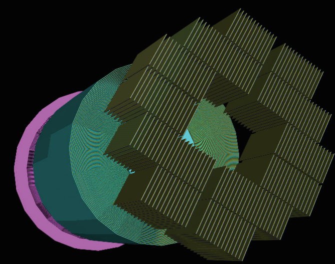
- Introduction
- Origins: Science missions and experiments
- ISS and human Exploration missions
- Lunar and planetary applications
- Shielding and component applications
- Spin-in and spin-off
- Relation to other MC codes and developments
- Further information
- Conlusions

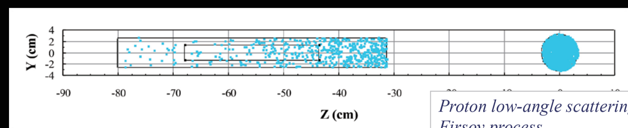


esa

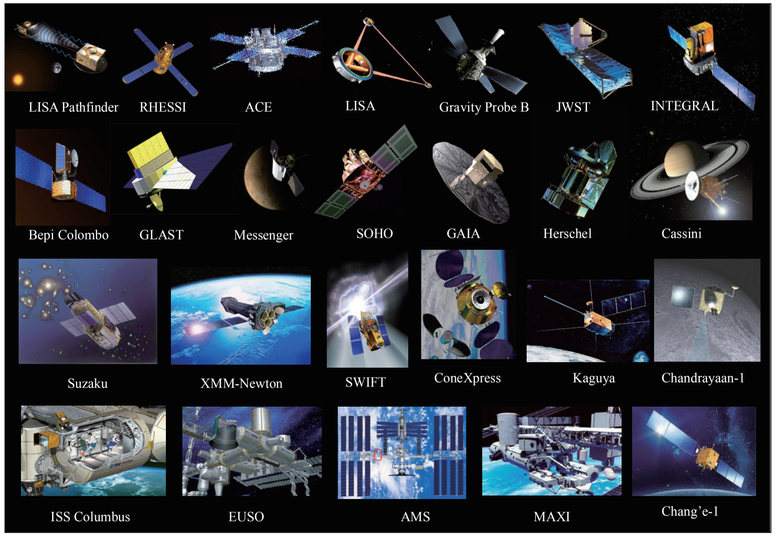
Space Environments
and Effects Section

“Historical” view: XMM–Newton





Proton low-angle scattering:
Firsov process

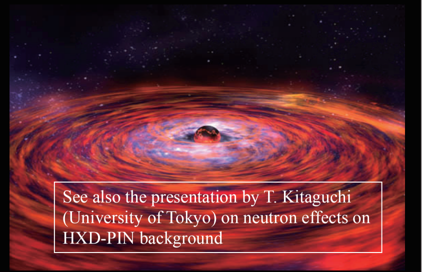


Suzaku

IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 53, NO. 3, JUNE 2006

Framework for a Geant4-Based Simulator of the Radiation Background and Detector Responses of the Space X-Ray Observatory Suzaku (Astro-E2)

Masanobu Ozaki, Shin Watanabe, Yukikatsu Terada, Takeshi Itoh, Masaki Kitsunezuka, Tetsuichi Kishishita, Yoshitaka Ishisaki, and Tadayuki Takahashi



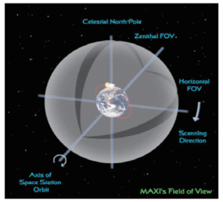
See also the presentation by T. Kitaguchi (University of Tokyo) on neutron effects on HXD-PIN background

Courtesy Masanobu Ozaki

ISS mission: GSC/MAXI

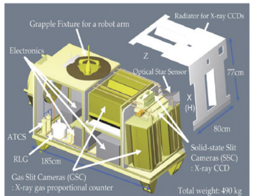
by JAXA and universities

Monitor of All-sky X-ray Image of 2-30 keV (GSC)



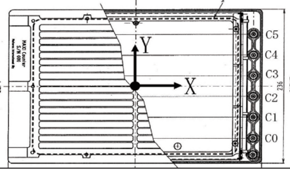
FOV : 1.5deg ×160deg

The FOVs sweep almost the entire sky during one ISS orbital period of 90 minutes. A point source stays in the FOV for 45 seconds.



The collimator:

Material : phosphor bronze
Thickness: 0.1 mm, Height: 118.4 mm
The interval between slats: 0.1 mm
128 slats for one GSC unit

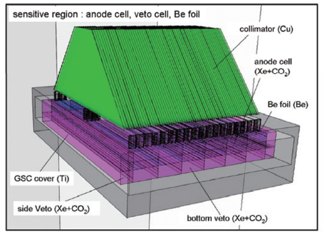


Courtesy Masanobu Ozaki

Detector Response Matrix (DRM) builder for GSC/MAXI

Ground calibration:
- Energy-PH relation, position-PH relation, energy resolution, position resolution
- The collimator response based on design value

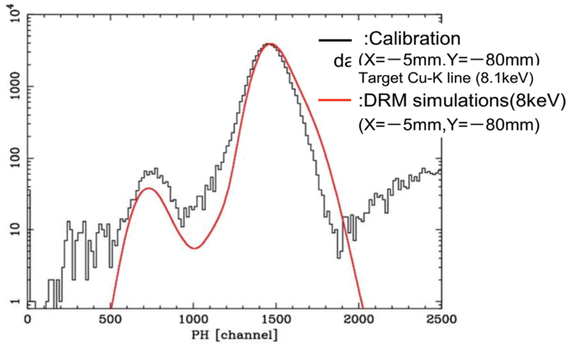
Geant4 simulation
- geometry from design sheet
- photoelectric absorption, energy deposition, multiple scattering
- considering L-escape



This document is provided by JAXA.

Courtesy Masanobu Ozaki

Comparison between ground calibration and DRM output



GLAST LAT | Geant4 in GLAST LAT

The GLAST Mission

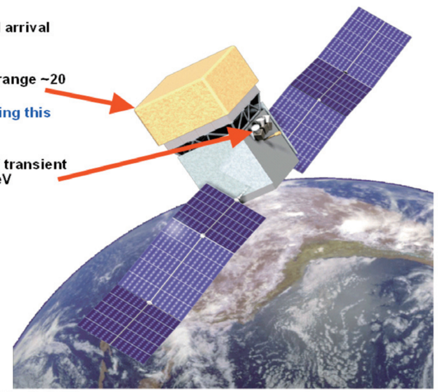
GLAST measures the direction, energy and arrival time of celestial gamma rays

-LAT measures gamma-rays in the energy range ~20 MeV - >300 GeV
- There is no instrument now covering this range!!

- GBM provides correlative observations of transient events in the energy range ~20 keV – 20 MeV

Courtesy R. Dubois (SLAC and F. Longo (INFN Trieste)

Orbit: 550 km, 28.5° inclination
Lifetime: 5 years (minimum)

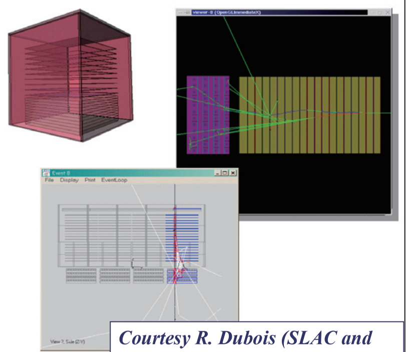


GLAST LAT G4 Sim

GLAST LAT | Geant4 workshop 2004

The MC Simulation

- G4 as proposed MC
- Learning G4 and development of GammaRayTel
- Standalone Packages
  - Test Beam 1999
  - Balloon Flight
- Geometry repository
- Gaudi integration
  - Managing the event loop
  - Source generation
  - Hit generation by G4
  - Digitization
  - Reconstruction
- G4 adopted as official MC
- Continuing validation activity
- MC data production phase



Courtesy R. Dubois (SLAC and F. Longo (INFN Trieste)

Geant4 2004 workshop | GLAST LAT Geant4 Simulation

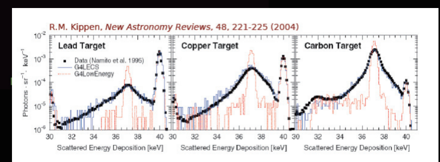
A GEANT4 Simulation System for the GLAST Burst Monitor

Andrew S. Hoover
R. Marc Kippen

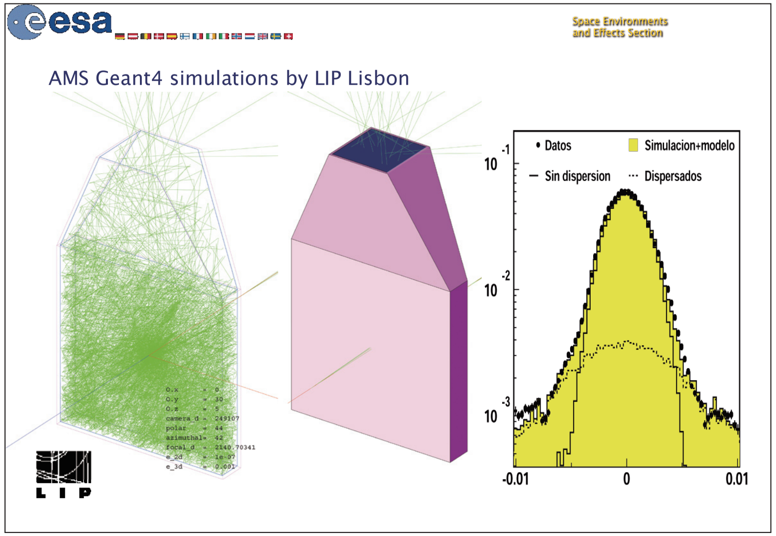
Space and Atmospheric Sciences Group

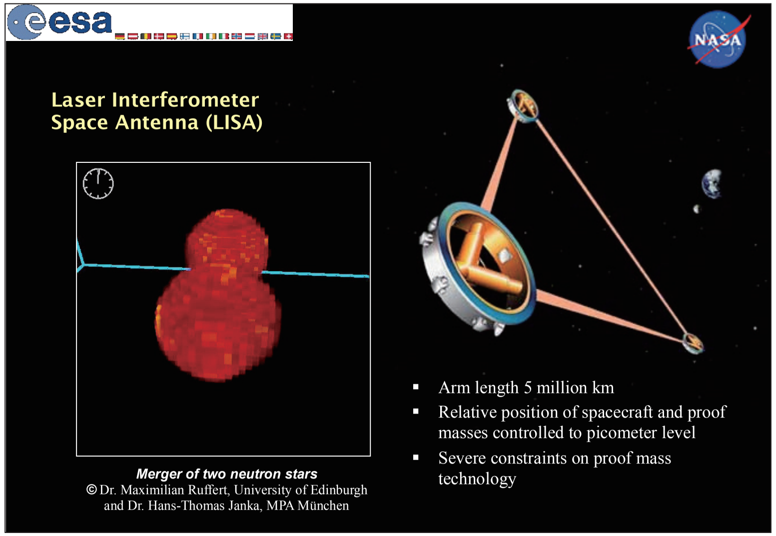
Los Alamos National Laboratory

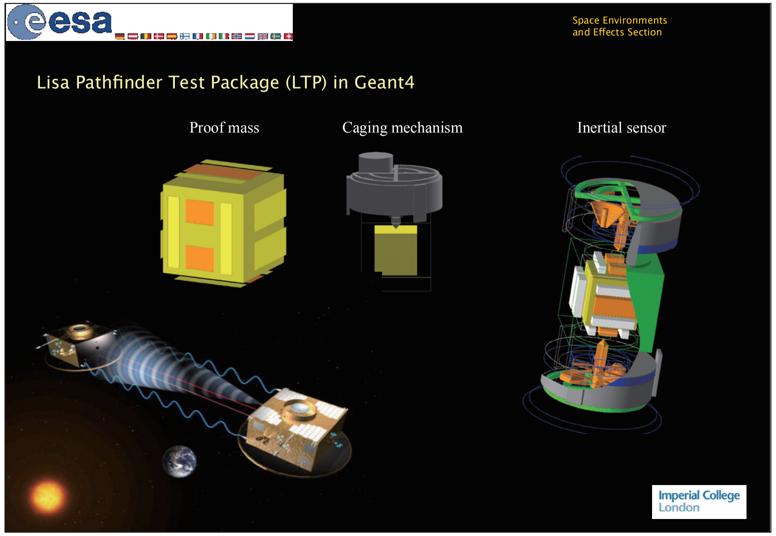
G4LECS

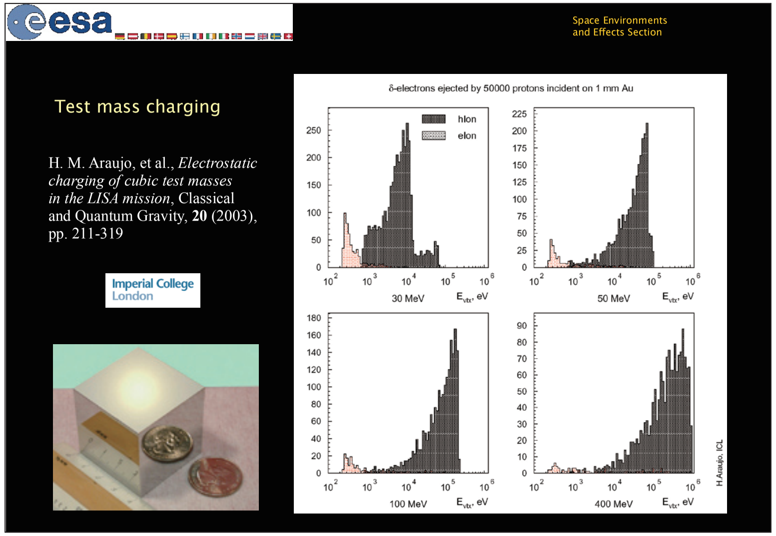


GEANT4 Space Users Workshop









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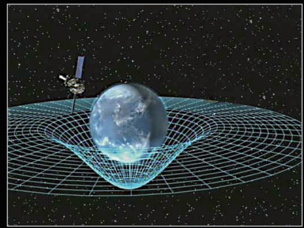
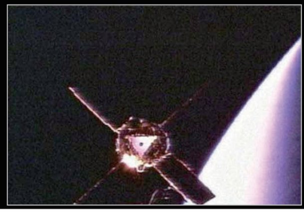
Gravity Probe B

Launch April 20, 2004

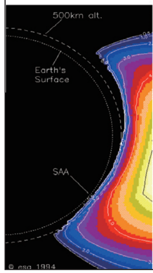


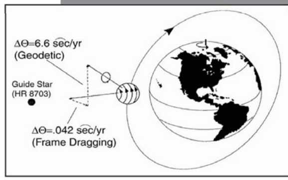


Gravity Probe B

Courtesy Peter Wass

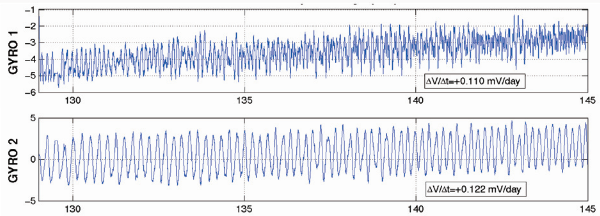
- Aims to detect geodetic and frame-dragging effects on free-falling gyroscopes in low earth orbit - 600km 90° inc
- Gyroscopes accumulate charge from SAA
- GP-B payload also includes a high energy proton monitor (30-500MeV)



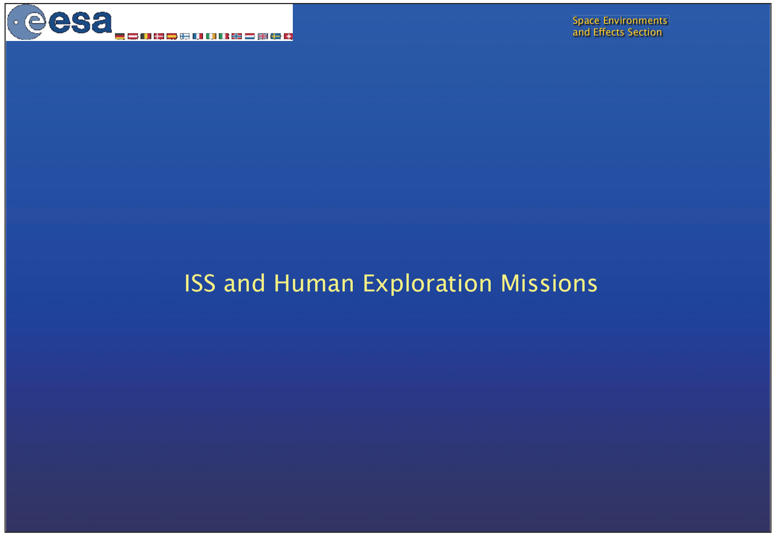


Results and data comparison

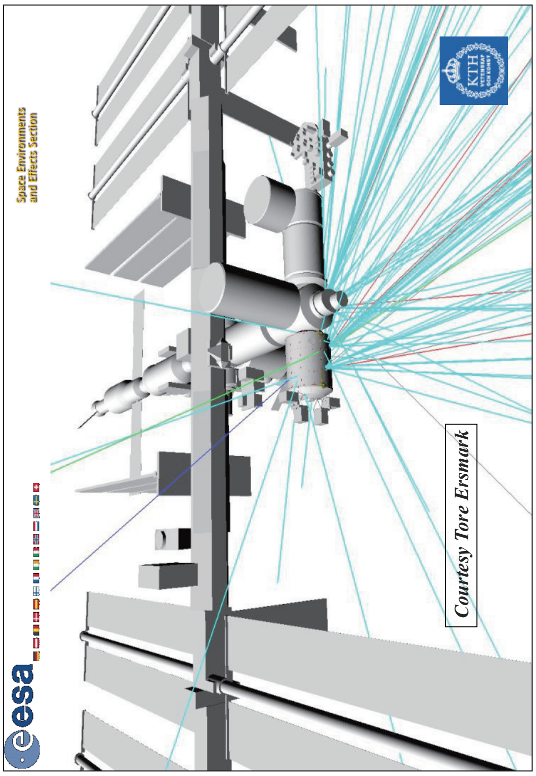
- The average charging rate, calculated from simulations is +12.5e/s
- Charging rate measured on orbit is +0.11mV/day or +8.0e/s
- Actual rate could be higher – analysis is ongoing

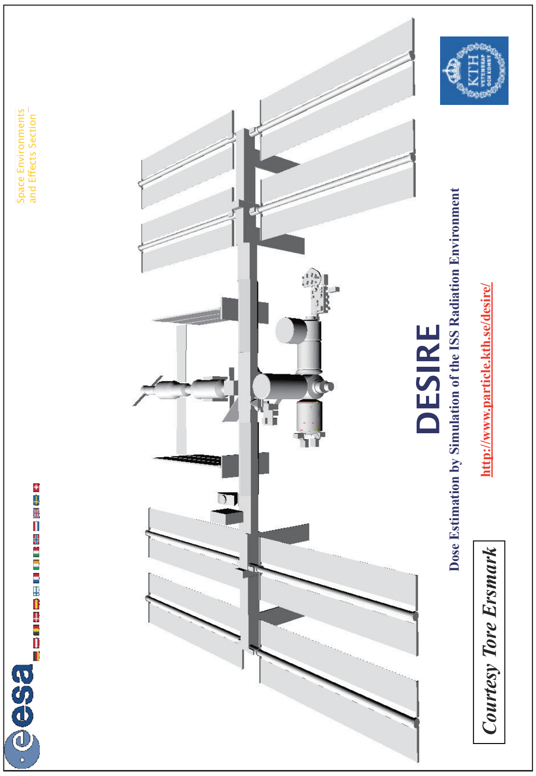


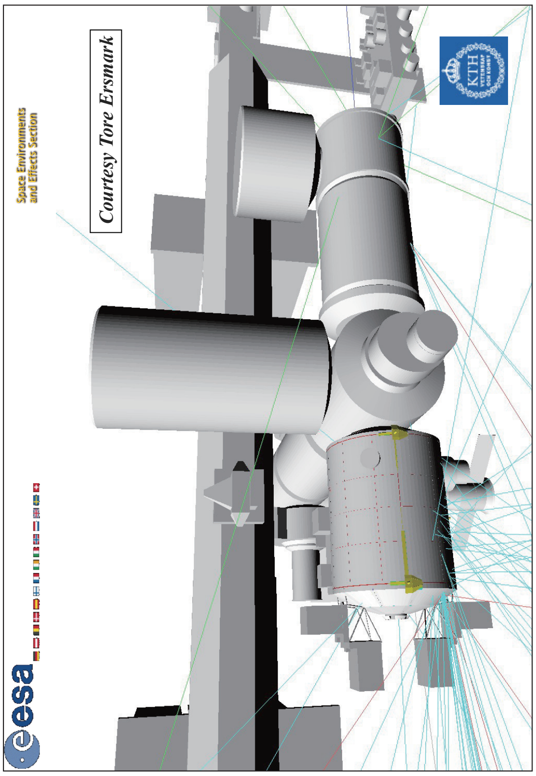
Courtesy Peter Wass



ISS and Human Exploration Missions







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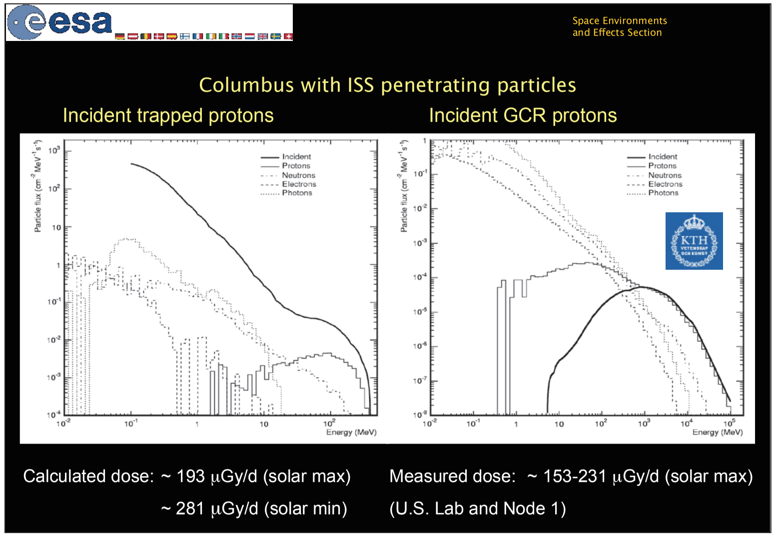
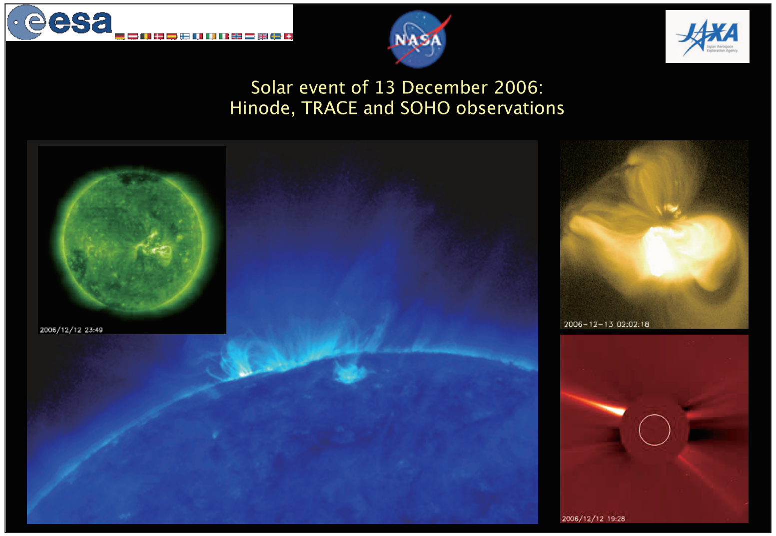
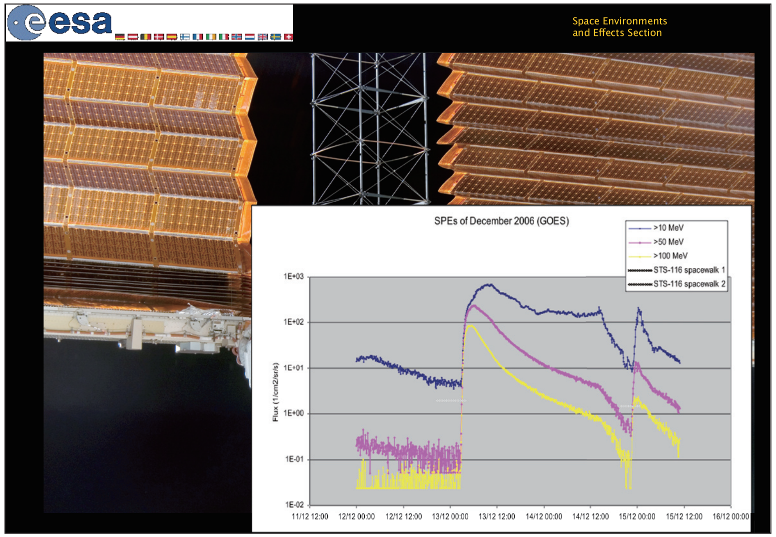

esa
Space Environments and Effects Section
Columbus with ISS penetrating particles
Incident trapped protons
Incident GCR protons
Incident
Protons
Neutrons
Electrons
Photons
Particle flux (cm⁻² MeV⁻¹ s⁻¹)
Energy (MeV)
KTH
Calculated dose: ~ 193 μGy/d (solar max)
~ 281 μGy/d (solar min)
Measured dose: ~ 153-231 μGy/d (solar max)
(U.S. Lab and Node 1)


esa
NASA
JAXA
Solar event of 13 December 2006:
Hinode, TRACE and SOHO observations
2006/12/12 23:49
2006-12-13 02:02:18
2006/12/12 19:28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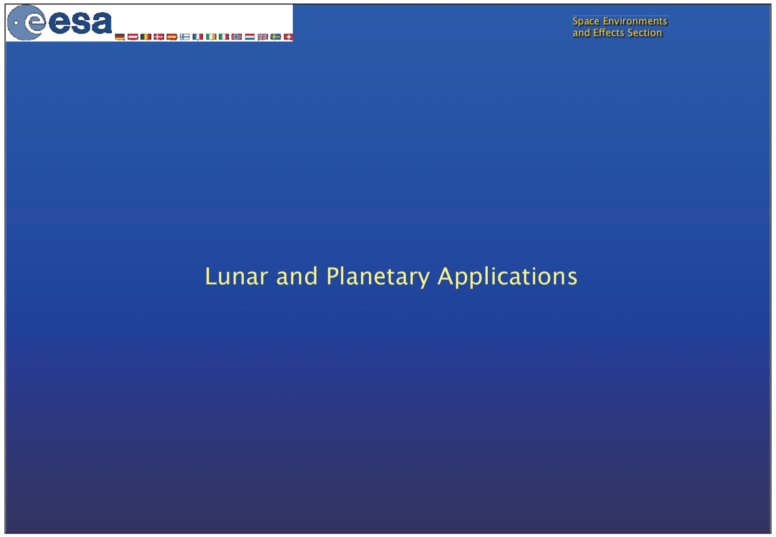
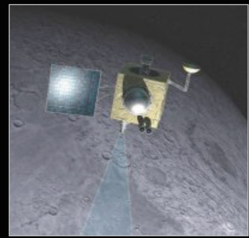
Space Environments and Effects Section
SPEs of December 2006 (GOES)
>10 MeV
>50 MeV
>100 MeV
STS-116 spacewalk 1
STS-116 spacewalk 2
Flux (1/cm2/sr/s)
1E+03
1E+02
1E+01
1E+00
1E-01
1E-02
11/12 12:00
12/12 00:00
12/12 12:00
13/12 00:00
13/12 12:00
14/12 00:00
14/12 12:00
15/12 00:00
15/12 12:00
16/12 00:00

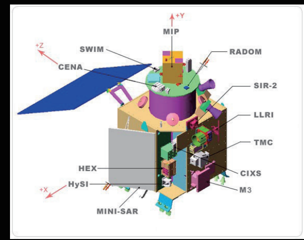

esa
Space Environments and Effects Section
Lunar and Planetary Applications

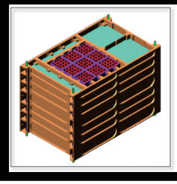
Kaguya

Lunar Gamma Ray Spectrometer (GRS) in the 100 keV to 12 MeV region ; see the presentations by N. Yamashita and S. Kobyashi (Waseda University)

Chandrayaan-1







High-energy X-ray Spectrometer (HEX) in 30-250 keV energy region; see presentation by Manju Sudhakar (ISRO)

ESA collaboration with European instruments C1XS, SIR-2, SARA

... and Further Lunar Missions and Analyses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ScienceDirect
Advances in Space Research 40 (2007) 338–341
ADVANCES IN SPACE RESEARCH (a COSPAR publication)

DRAFT VERSION JANUARY 22, 2008
Preprint typeset using LaTeX style emulateapj v. 7/15/03

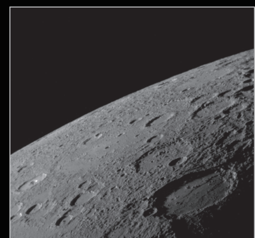
THE GAMMA-RAY ALBEDO OF THE MOON

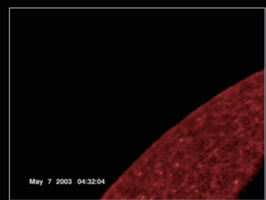
IGOR V. MOSKALENKO[1]
Hansen Experimental Physics Laboratory, Stanford University, Stanford, CA 94305
AND
TROY A. PORTER
Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA 95064
Draft version January 22, 2008

ABSTRACT

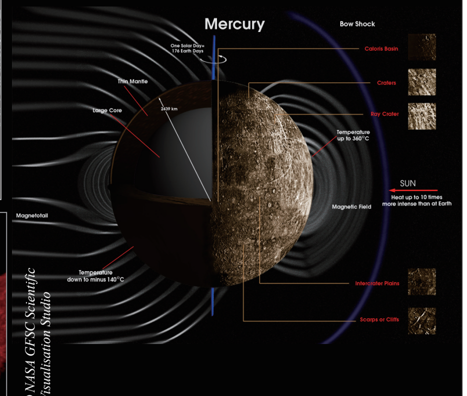
We use the GEANT4 Monte Carlo framework to calculate the γ-ray albedo of the Moon due to interactions of cosmic ray (CR) nuclei with moon rock. Our calculation of the albedo spectrum agrees with the EGRET data. We show that the spectrum of γ-rays from the Moon is very steep with an effective cutoff around 3–4 GeV (600 MeV for the inner part of the Moon disk) and exhibits a narrow pion-decay line at 67.5 MeV, perhaps unique in astrophysics. Apart from other astrophysical sources, the albedo spectrum of the Moon is well understood, including its absolute normalisation; this makes it a useful "standard candle" for γ-ray telescopes. The steep albedo spectrum also provides a unique opportunity for energy calibration of γ-ray telescopes, such as the forthcoming Gamma Ray Large Area Space Telescope (GLAST). Since the albedo flux depends on the incident CR spectrum which changes over the solar cycle, it is possible to monitor the CR spectrum using the albedo γ-ray flux. Simultaneous measurements of CR proton and helium spectra by the Payload for Antimatter-Matter Exploration and Light-nuclei Astrophysics (PAMELA), and observations of the albedo γ-rays by the GLAST Large Area Telescope (LAT), can be used to test the model predictions and will enable the LAT to monitor the CR spectrum near the Earth beyond the lifetime of the PAMELA.

Messenger

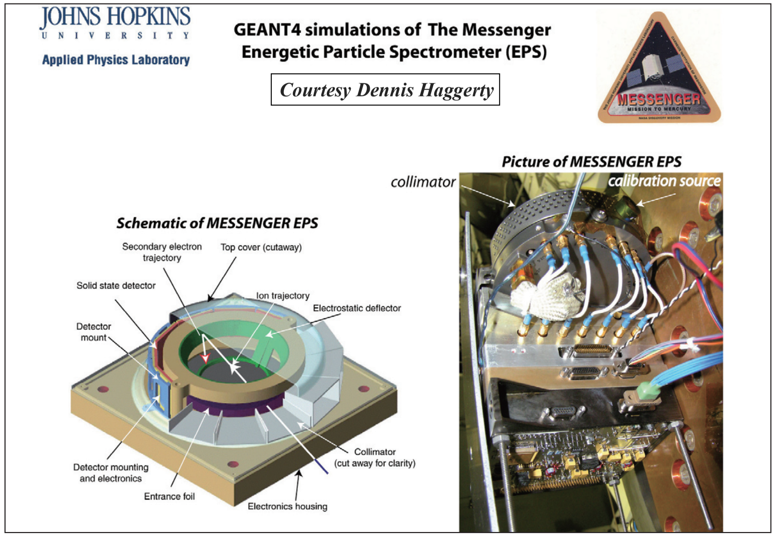


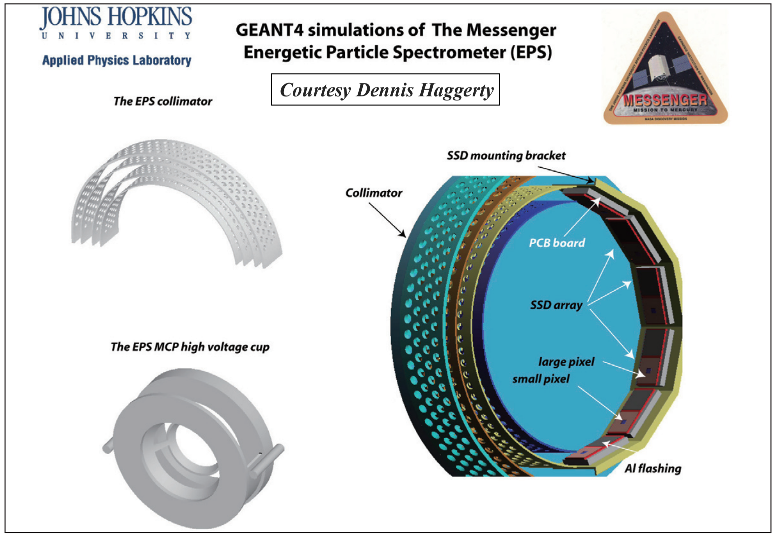


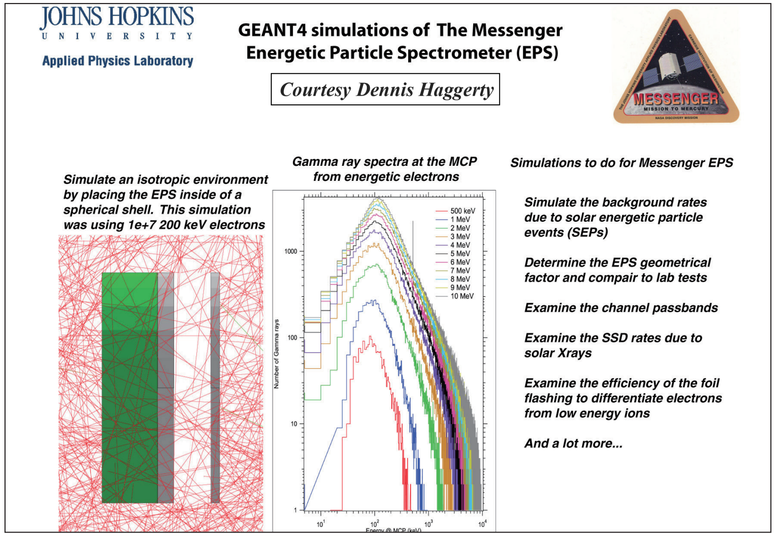
Mercury transit between Sun and TRACE spacecraft



1st Mercury flyby, 14.1. 2008


JOHNS HOPKINS
UNIVERSITY
Applied Physics Laboratory
GEANT4 simulations of The Messenger Energetic Particle Spectrometer (EPS)
Courtesy Dennis Haggerty
MESSENGER
MISSION TO MERCURY
Schematic of MESSENGER EPS
Secondary electron trajectory
Top cover (cutaway)
Solid state detector
Ion trajectory
Electrostatic deflector
Detector mount
Detector mounting and electronics
Entrance foil
Collimator (cut away for clarity)
Electronics housing
Picture of MESSENGER EPS
collimator
calibration source


JOHNS HOPKINS
UNIVERSITY
Applied Physics Laboratory
GEANT4 simulations of The Messenger Energetic Particle Spectrometer (EPS)
Courtesy Dennis Haggerty
MESSENGER
MISSION TO MERCURY
The EPS collimator
The EPS MCP high voltage cup
SSD mounting bracket
Collimator
PCB board
SSD array
large pixel
small pixel
Al flashing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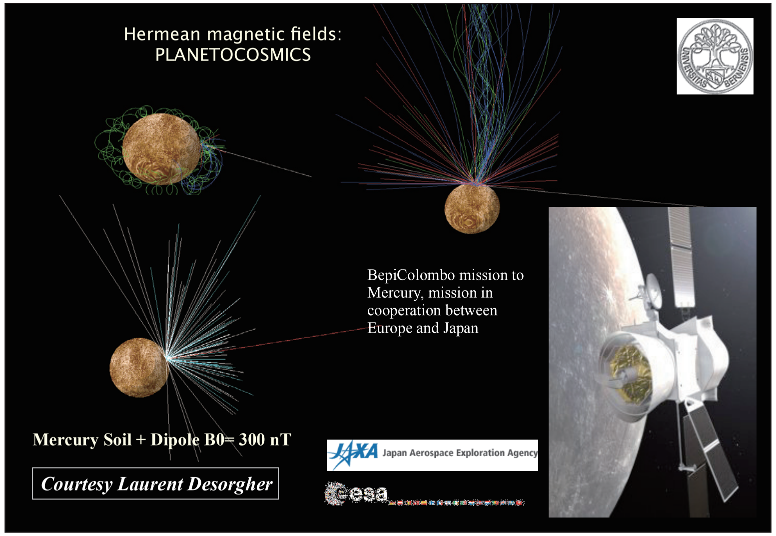
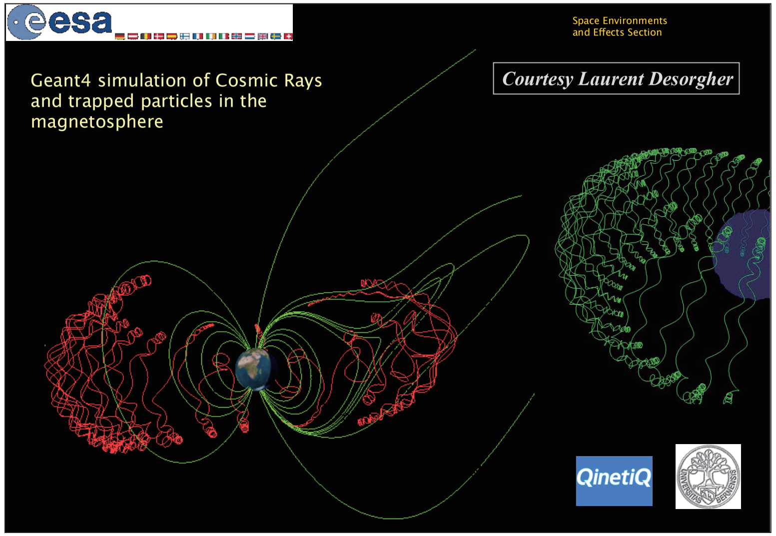
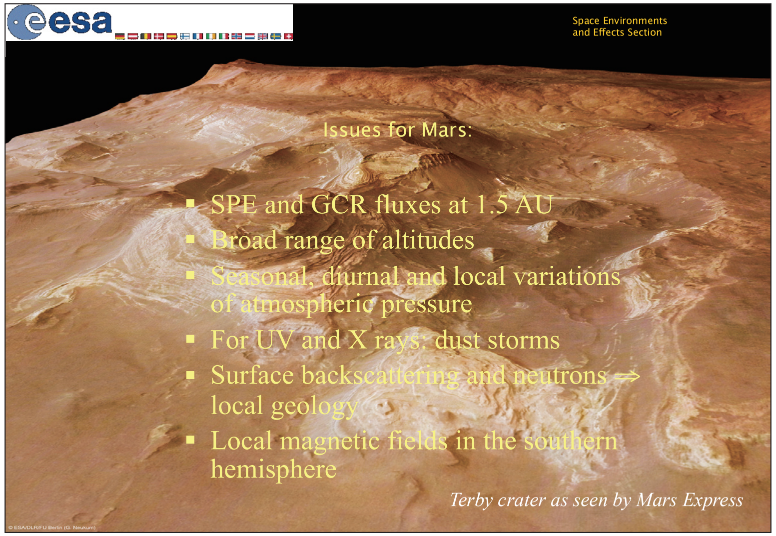
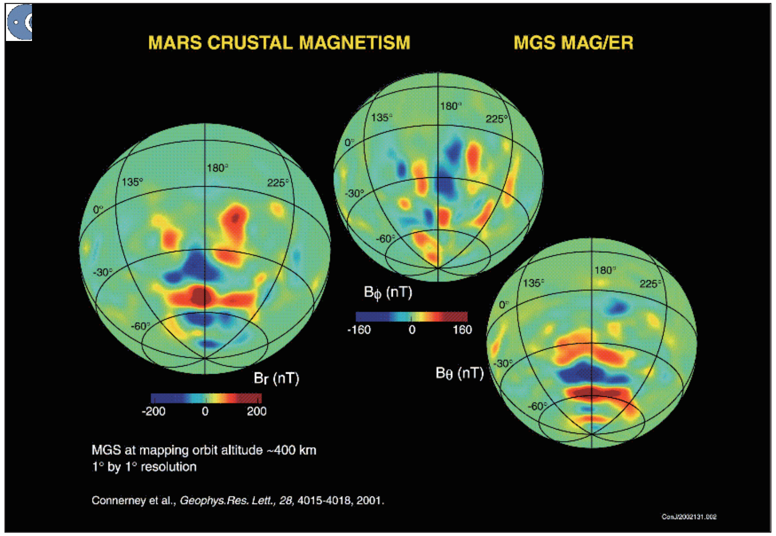
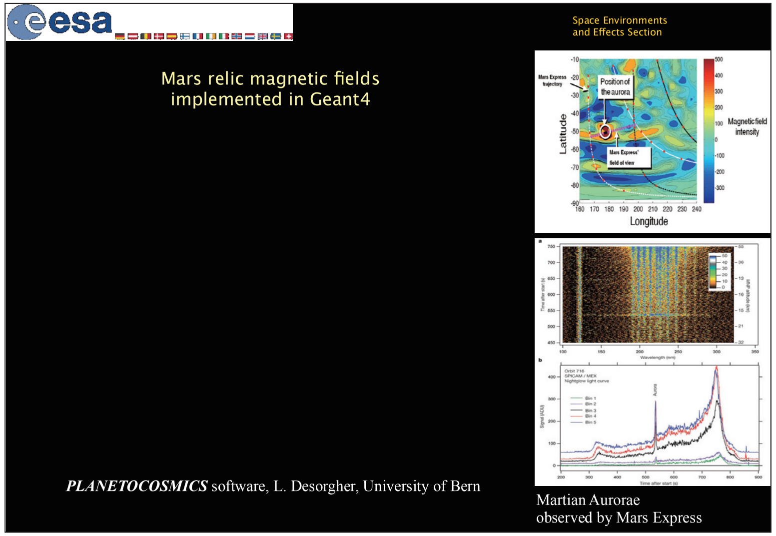
UNIVERSITY
Applied Physics Laboratory
GEANT4 simulations of The Messenger Energetic Particle Spectrometer (EPS)
Courtesy Dennis Haggerty
MESSENGER
MISSION TO MERCURY
Simulate an isotropic environment by placing the EPS inside of a spherical shell. This simulation was using 1e+7 200 keV electrons
Gamma ray spectra at the MCP from energetic electrons
500 keV
1 MeV
2 MeV
3 MeV
4 MeV
5 MeV
6 MeV
7 MeV
8 MeV
9 MeV
10 MeV
Number of Gamma rays
Energy @ MCP (keV)
Simulations to do for Messenger EPS
Simulate the background rates due to solar energetic particle events (SEPs)
Determine the EPS geometrical factor and compair to lab tests
Examine the channel passbands
Examine the SSD rates due to solar Xrays
Examine the efficiency of the foil flashing to differentiate electrons from low energy ions
And a lot more...


Hermean magnetic fields:
PLANETOCOSMICS
BepiColombo mission to Mercury, mission in cooperation between Europe and Japan
Mercury Soil + Dipole B0= 300 nT
Courtesy Laurent Desorgher
JAXA Japan Aerospace Exploration Agency
esa









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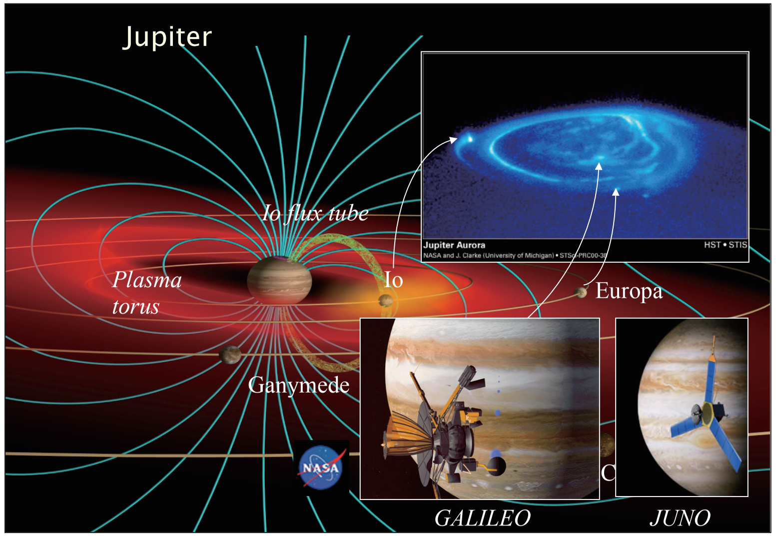
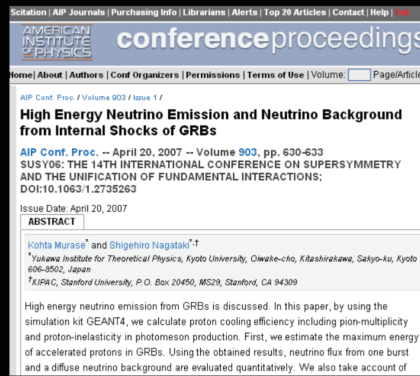
Jupiter



Cosmological and Theoretical Astrophysics Studies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AIP Conf. Proc. / Volume 903 / Issue 1 /

High Energy Neutrino Emission and Neutrino Background from Internal Shocks of GRBs

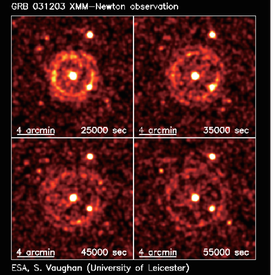
AIP Conf. Proc. -- April 20, 2007 -- Volume 903, pp. 630-633
SUSY06: THE 14TH INTERNATIONAL CONFERENCE ON SUPERSYMMETRY AND THE UNIFICATION OF FUNDAMENTAL INTERACTIONS;
DOI:10.1063/1.2735263

Issue Date: April 20, 2007

ABSTRACT

Kohta Murase[*] and Shigehiro Nagataki[*,†]
[*]Yukawa Institute for Theoretical Physics, Kyoto University, Oiwake-cho, Kitashirakawa, Sakyo-ku, Kyoto 606-8502, Japan
[†]KIPAC, Stanford University, P.O. Box 20450, MS29, Stanford, CA 94309

High energy neutrino emission from GRBs is discussed. In this paper, by using the simulation kit GEANT4, we calculate proton cooling efficiency including pion-multiplicity and proton-inelasticity in photomeson production. First, we estimate the maximum energy of accelerated protons in GRBs. Using the obtained results, neutrino flux from one burst and a diffuse neutrino background are evaluated quantitatively. We also take account of



GRB 031203 X-ray afterglow as observed by XMM-Newton

esa

Space Environments and Effects Section

Shielding and Component Applications

Application of the RADSAFE Concept

Vanderbilt University
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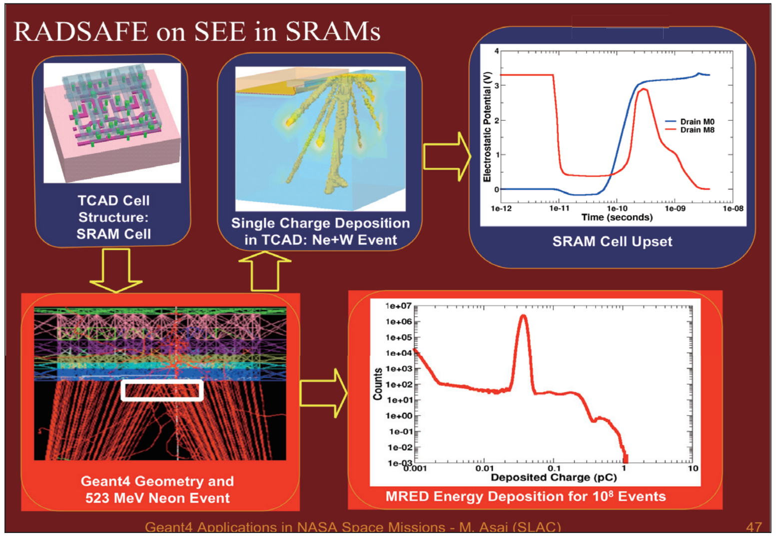

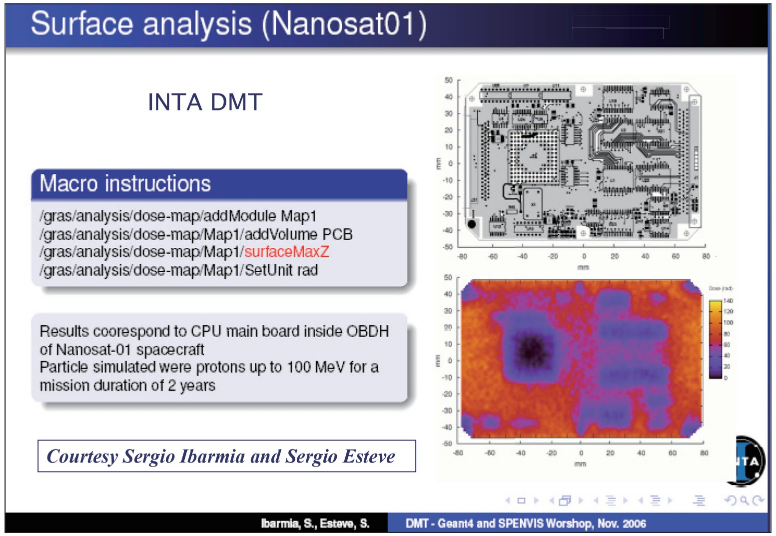

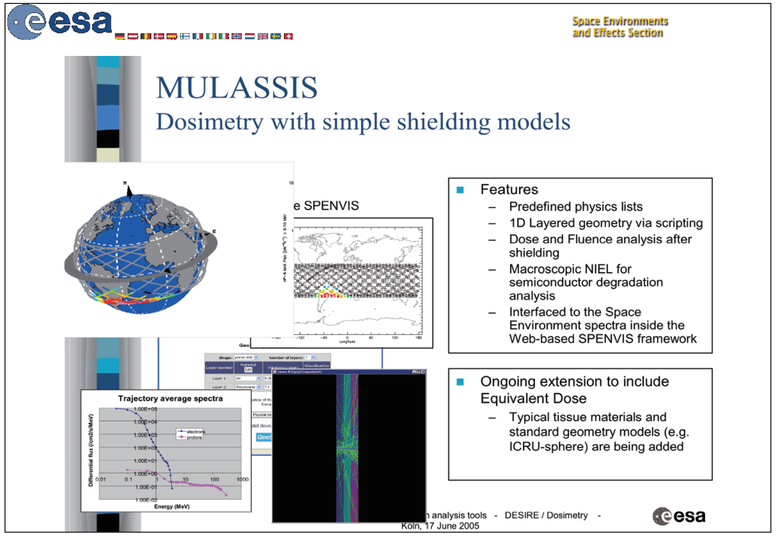

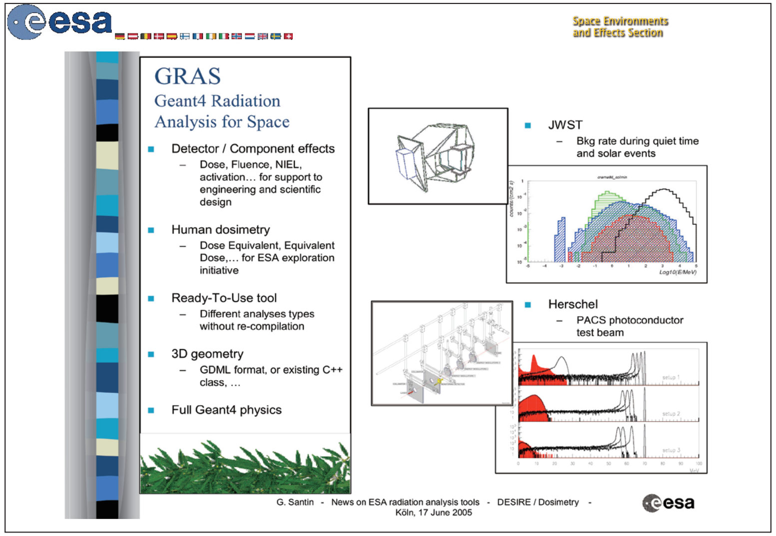

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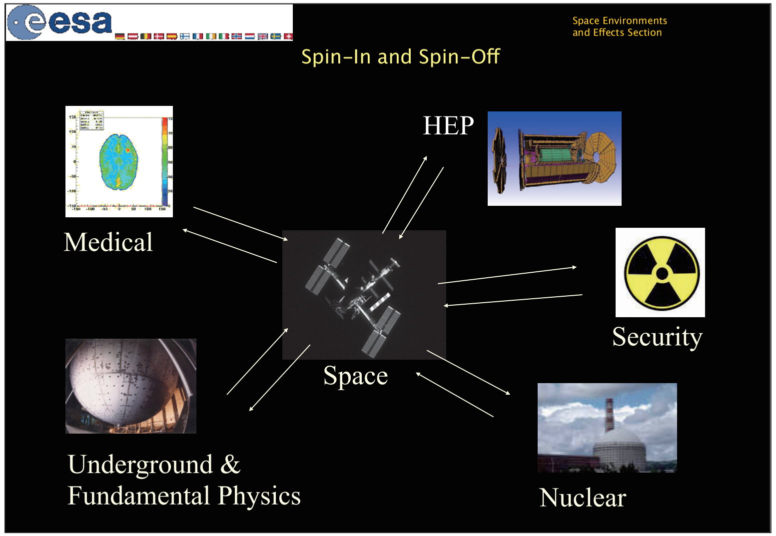
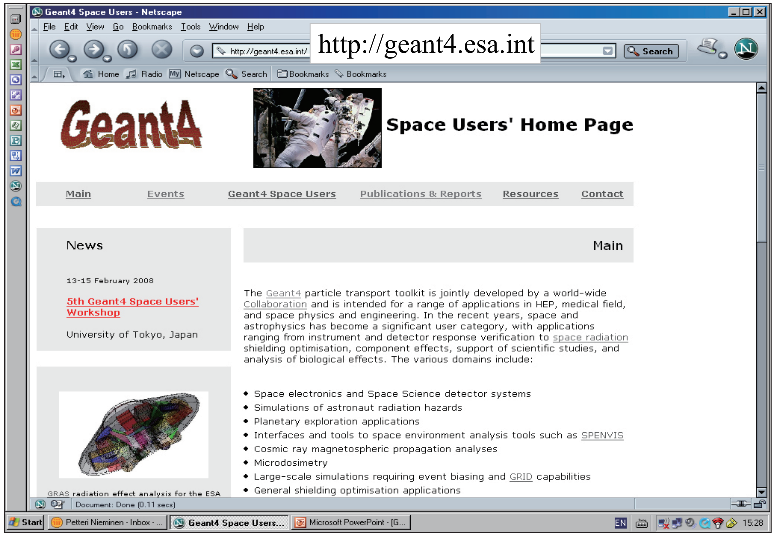


Relation to Other MC Codes and Developments

- *PHITS*: Heavy ion transport capabilities; importance especially for shielding applications in the Human Exploration domain (including ISS)
- *NOVICE*: Well-established and fast inverse MC capabilities for Space Industry; importance especially for electron-dominated environments (Telecom, Navigation, Jovian environment)
- Discussion, collaboration and cross-comparisons with these developments, and others, is vital



Conclusions

- GEANT4 in space now since 10 years
- Importance of Universities and students both in developments and applications
- GEANT4 and its auxiliary applications are extensively used for mission support in the various Space Agencies and institutes worldwide
- Space Science, Manned Missions, other mission categories, as well as environmental aspects and electronics engineering all need to be considered
- Various scientific and engineering tools and applications based on GEANT4 continue to emerge, “distilling” the extensive GEANT4 capabilities
- Heavy ion hadronic physics becoming more important due to increased Exploration activities, and also because of the generally increasing use of sensitive electronics (SEE)
- Opportunities for further collaborations and interactions with other communities (HEP, medical,…)

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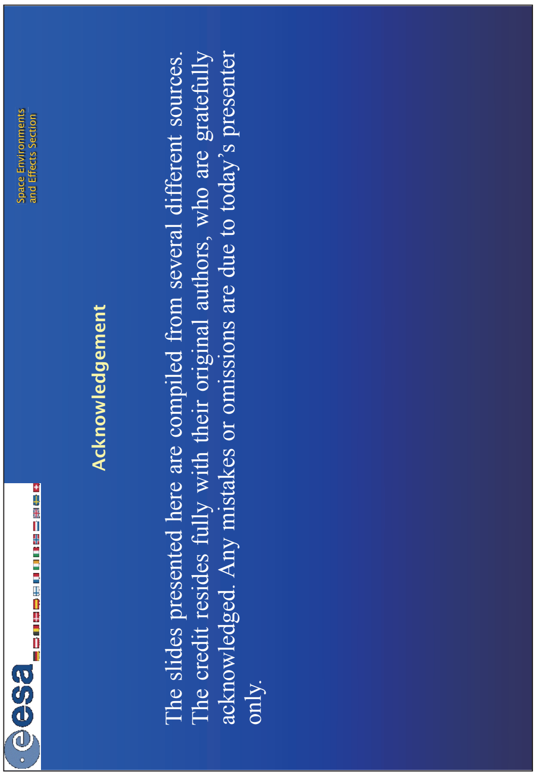

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