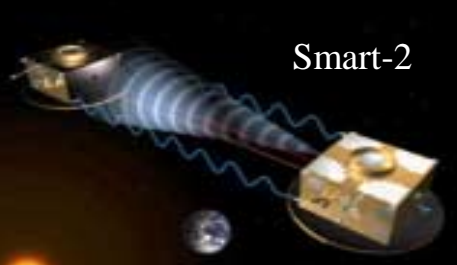


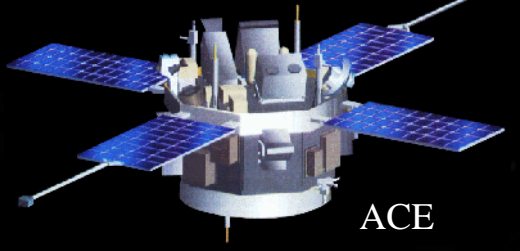
Planned Geant4-related ESA R&D

Petteri Nieminen
Space Environments and Effects Section
European Space Agency (ESTEC)
Noordwijk, The Netherlands

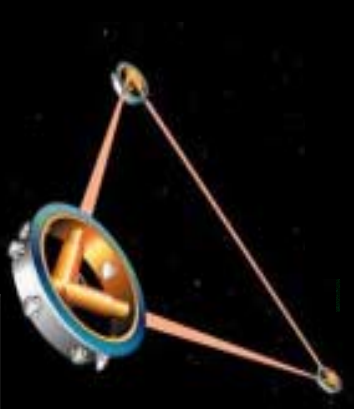
Petteri.Nieminen@esa.int



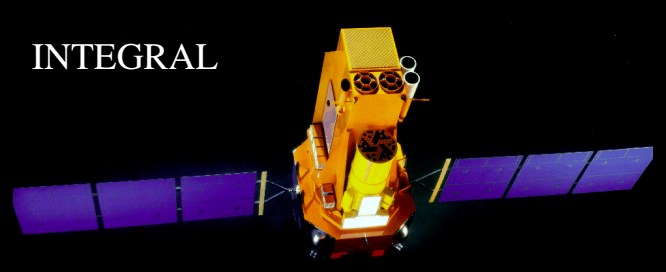
Smart-2



ACE



LISA



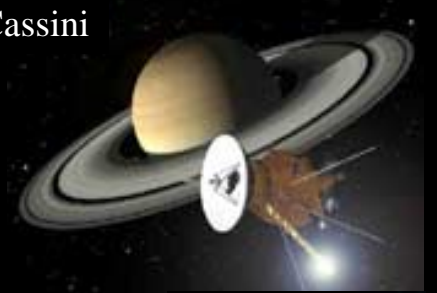
INTEGRAL



Bepi Colombo



GLAST



Cassini

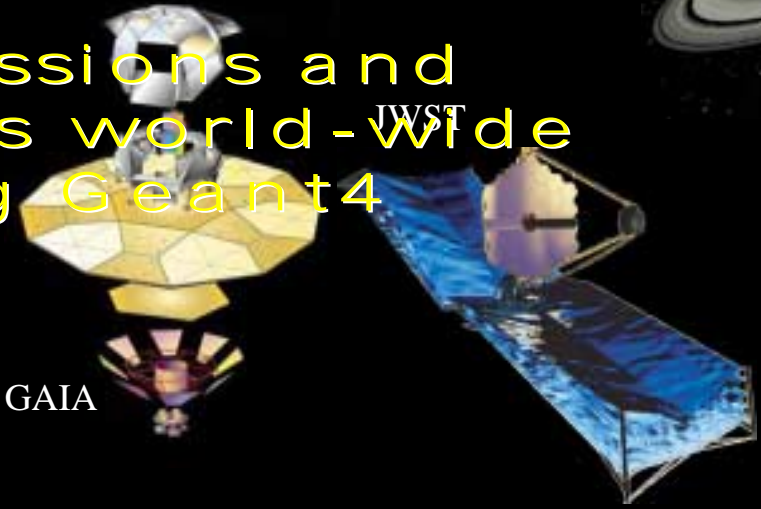
Space missions and experiments world-wide utilizing Geant4



Astro-E2



XMM-Newton



GAIA



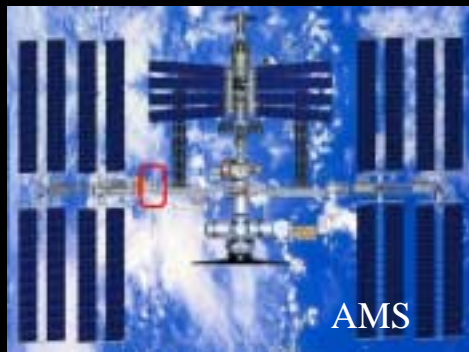
SWIFT



ISS Columbus



EUSO



AMS



MAXI

Observations on the use of Geant4 for ESA:

- Extensive use in *Space Science* missions and experiments (starting from XMM-Newton analysis 1997)
- Emerging use in *Manned* (ISS) and *Exploration* missions
- Certain further developments needed in Geant4 physics and other kernel capabilities for the above
- ***Earth Observation, Telecommunication, Navigation***: These are more “utilitarian” application domains, where materials and components engineering issues are prominent, and where often the industry, rather than academia, has the main role in doing radiation analyses. In these domains, Geant4 is used in a limited way thus far.
- => Geant4 is, in principle, in good position to expand to the above domains as many of the presently used engineering tools are either proprietary, limited in scope, incompatible with each other, or outdated.
- => Need for easy-to-use engineering tools, interfaces and applications utilising Geant4 physics and other capabilities allowing rapid radiation analyses (a la MULASSIS), addressing the radiation effects on new technologies.



Envisat

ESA Geant4 R&D characteristics

- Small internal team at ESA; project support
- A large number of external collaborations
- Funding from several, separate ESA programmes and sources:
 - General Studies Programme (GSP)
 - Technology Research Programme (TRP)
 - General Support Technology Programme (GSTP)
 - Portugal Task Force (PTF)
 - Exploration Programme (Aurora)
 - Consultancy agreements
- Geographical distribution of activities desirable
- ESA never signed the Geant4 Memorandum of Understanding, but this did not stop technical work from taking place!



ESA Radiation Modelling R&D in 2004

Human effects	ISS/Columbus dose calculations, GSP, 2001-05, [KTH Stockholm, EAC, Karolinska Institut, others]	VR dose tool for ISS/Columbus, GSP, start 2003 [IFE Norway]	Cellular/DNA effects simulation, GSP, start 2004 [INFN Genova]	Radiation exposure and mission strategies, AURORA, start 2003 [Alenia + subcontractors]
	Shielding and Interactions Software, TRP for Science missions, start 2002 [QinetiQ + subcontractors]	Simulations for EUSO and AMS, PTF, 2003-04 [LIP Lisbon]	Radiation monitors flying on PROBA, INTEGRAL, Rosetta	Identification of small, low-energy radiation detectors, GSP, start 2003 [PSI]
Instruments and missions	Displacement damage simulation, GSP+GSTP, 2001-2003, [Univ. Cologne] + internal work in TOS-QCA		Identifying component effects models for Geant4, GSP, start 2003 [ONERA]	
	Radiation Effects Analysis Tools, TRP, 2000-2006 [QinetiQ, BISA, SIRA]	Radiation Effects on Advanced Technologies: Models and Software, TRP, planned for 2004	Radiation exposure and mission strategies, AURORA, start 2003 [Alenia + subcontractors]	
Physics model development in the Geant4 Collaboration [CERN, INFN, HIP, others]	Radiation shielding and effects physics models, AURORA, start mid-2003 [QinetiQ]			
Shielding	Data analysis from near-Earth radiation monitors, TRP, start 2003 [ONERA + sub-contractors]	Solar particle models, TRP, 2000-2002 [Univ. Barcelona] + TOS-EES work on SPE models	Mars environment simulations, GSP [Univ. Bern] + PTF [LIP Lisbon], start in 2004	Mars radiation models, AURORA, proposed 2004
	Near-Earth		Interplanetary/planetary	



Geant4 for Space Science and Engineering: past, ongoing and planned developments

- MULASSIS, in SPENVIS and as a stand-alone version
- Sector Shielding Analysis Tool (SSAT), stand-alone
- Low-energy e.m. extensions for high-resolution analyses
- Hadronic physics models for heavy ions
- General Particle Source (GPS), Geant4 release
- Radioactive Decay Module (RDM), Geant4 release
- CAD tool front-end, stand-alone – more work needed
- ESABASE geometry converter
- Prediction of displacement damage effects
- Framework study for component radiation effects models (SEE)
- MAGNETOCOSMICS and AEROCOSMICS
- Interface to Mars environment models

" Radiation Effects on Advanced Technologies: Models and Software "

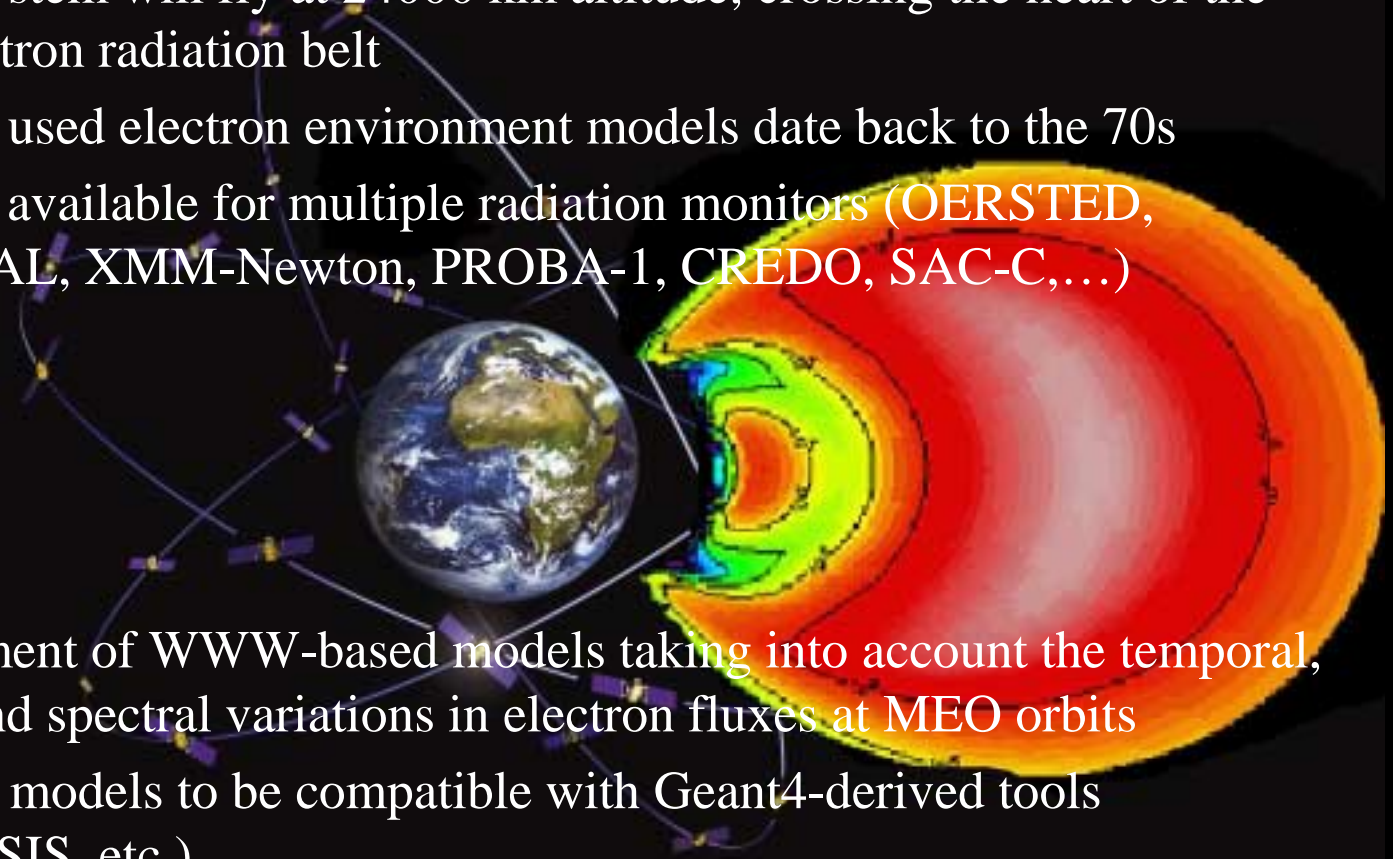
- Open Competition, start by end of 2004
- Development of easy-to-use interfaces from the Geant4 radiation transport software to Web-based engineering systems, for instance SPENVIS, and to CAD tools;
- Interfaces to Non-Ionising Energy Loss and total dose simulation tools for solar cells, CCDs, and materials;
- Single Event Effects simulation and generic microdosimetry calculation capabilities for arbitrary materials and sensitive volumes;
- Capability to use SPENVIS sectoring tool geometries for Geant4-based flux and dose analyses;
- Simulation of ground-based testing and recommendations on improved test techniques;
- Identification and development of effects models for various technologies;
- Reverse Monte Carlo (?)
- Development of new electromagnetic and hadronic physics models and other Geant4 kernel capabilities (e.g. in geometry) to extend useability of Geant4 to a broad range of space engineering analyses.

" Radiation Effects on Advanced Technologies:
Models and Software "

Round Table on the technical contents of the activity:
Einstein Conference Room, ESTEC,
on **7 June 2004**, from 09.30

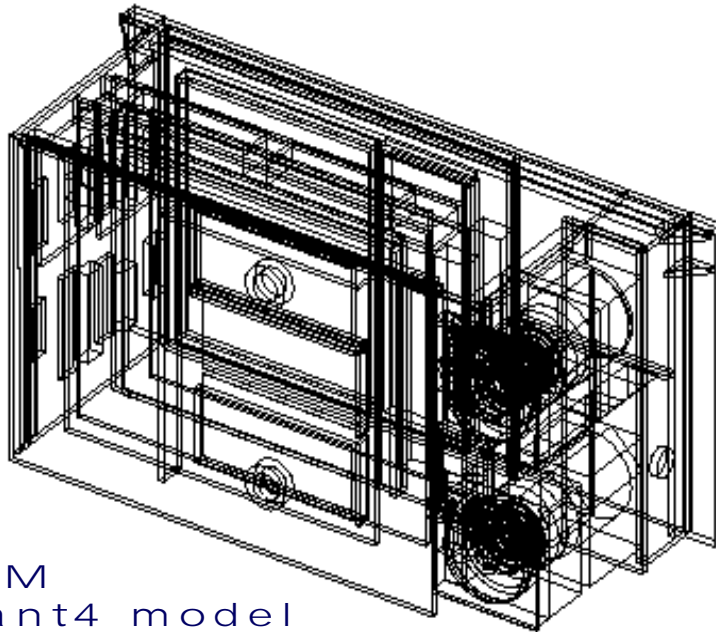
" Energetic Electron Environment Models for MEO "

- Galileo system will fly at 24000 km altitude, crossing the heart of the outer electron radiation belt
- Currently used electron environment models date back to the 70s
- New data available for multiple radiation monitors (OERSTED, INTEGRAL, XMM-Newton, PROBA-1, CREDO, SAC-C,...)



- Development of WWW-based models taking into account the temporal, spatial, and spectral variations in electron fluxes at MEO orbits
- Output of models to be compatible with Geant4-derived tools (MULASSIS, etc.)
- Statement of Work finalised, Open Competition in ~September 2004

ESA Standard Radiation Environment Monitor (SREM)



SREM
Geant4 model



INTEGRAL



ROSETTA



PROBA-1



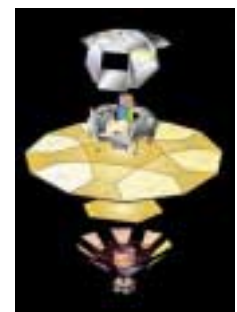
HERSCHEL



GSTB V2

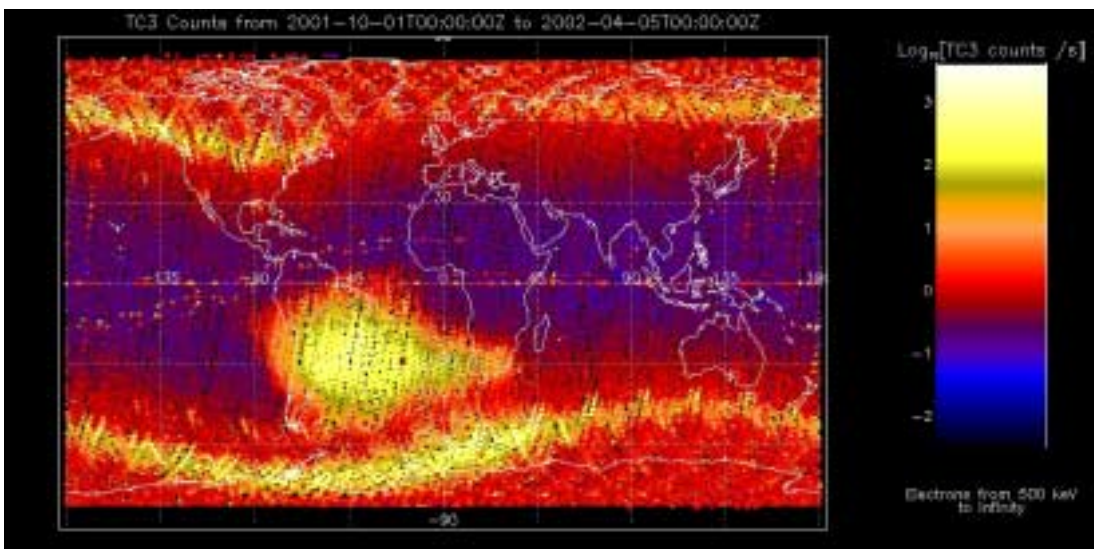
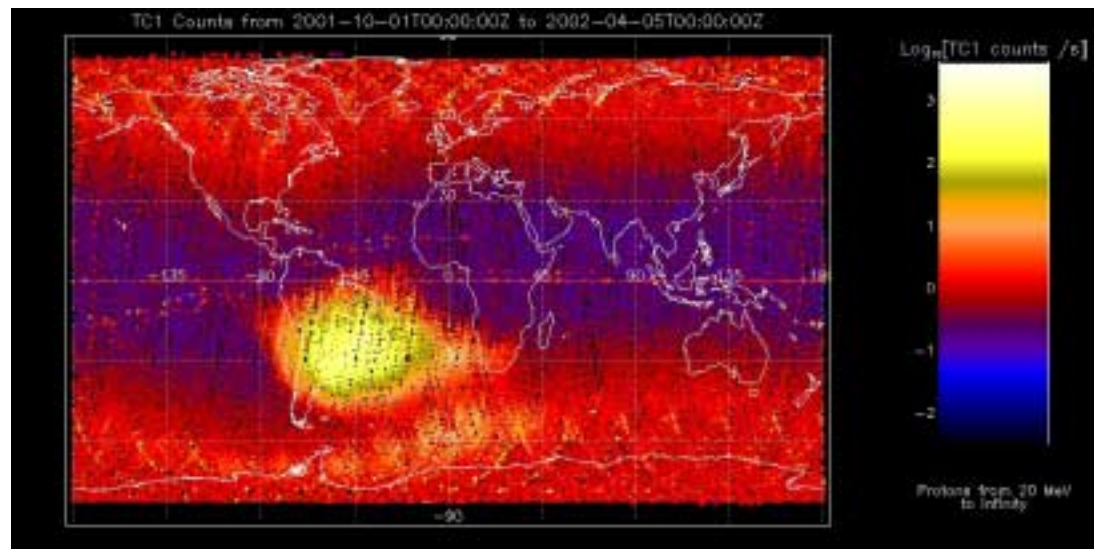
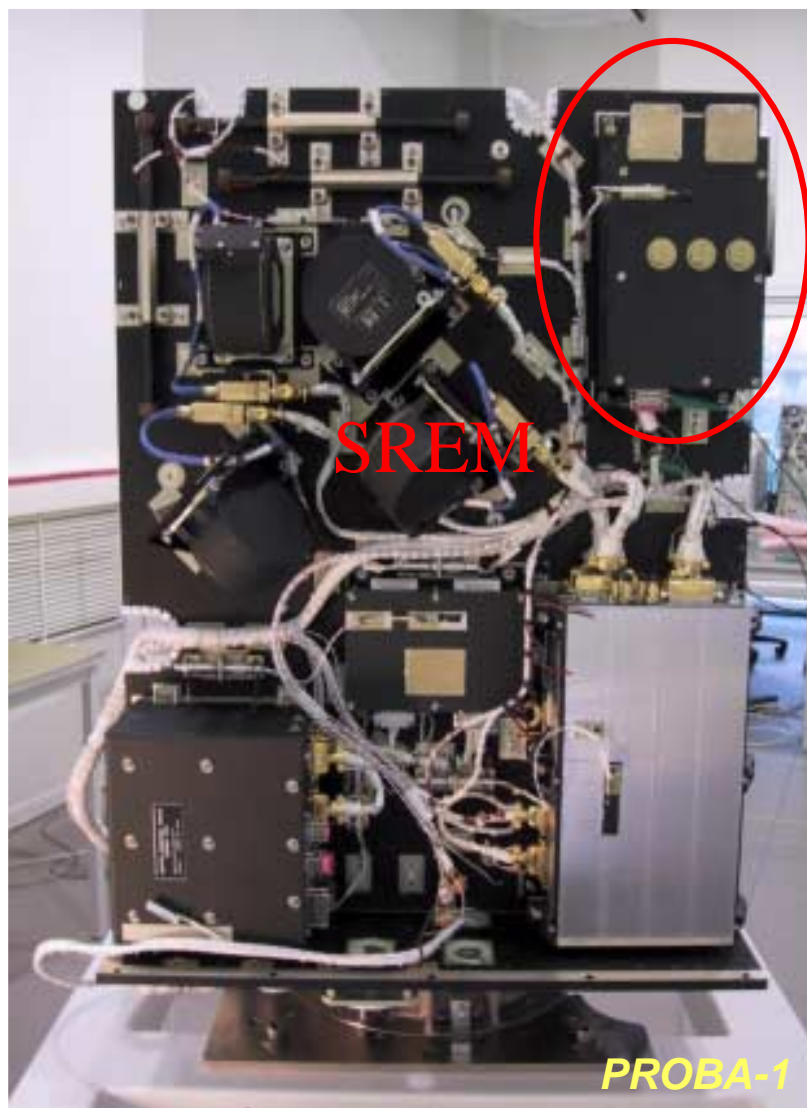


PLANCK



GAIA

ESA Standard Radiation Environment Monitor (SREM)



A U R O R A

ESA manned and unmanned Solar System Exploration initiative in 20-30 years' time frame. Early items for radiation environments and effects:

- ✓ Radiation Shielding and Effects (QinetiQ, U.K.)
- ✓ Radiation Exposure and Mission Strategies for Interplanetary Manned Missions (Alenia Aerospazio, I + subcontractors)
- ✓ Geant4-DNA project continuation (INFN Genova, I)
- ✓ Detailed and global Mars radiation environment models (Univ. of Bern, LIP Lisbon; also a new R&D item late 2004)
- ✓ VR radiation visualisation tool development for DESIRE (IFE, N)

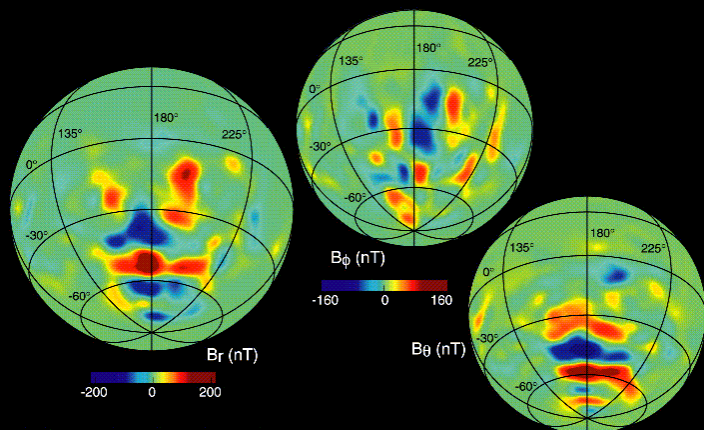
Preparation for 2005-2009 programme underway: Internal proposal for a range of radiation environments and effects items

Other items:

- Next internal call for ESA GSP proposals in 2005
- ESA “Ariadna” (pre-GSP) call for proposals coming out on 17 May 2004
- “Innovation Triangle Initiative” out 2004
- Geant4 Space Users’ Homepage: Continuous updates of User publications
- Coordination of developments and applications between the various Space Agencies and Institutes

MARS CRUSTAL MAGNETISM

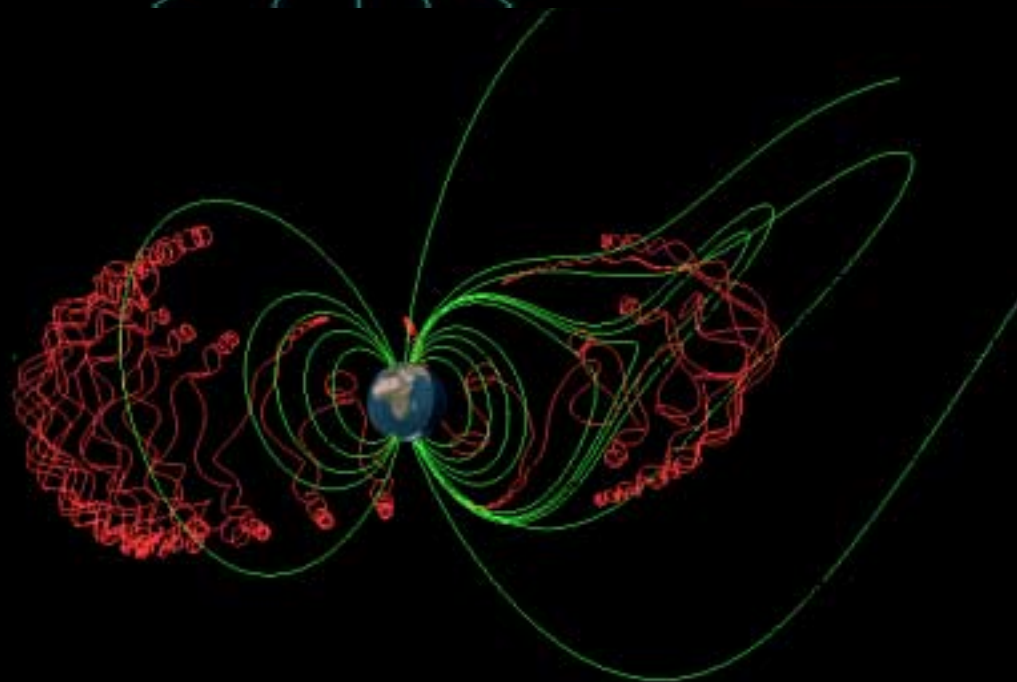
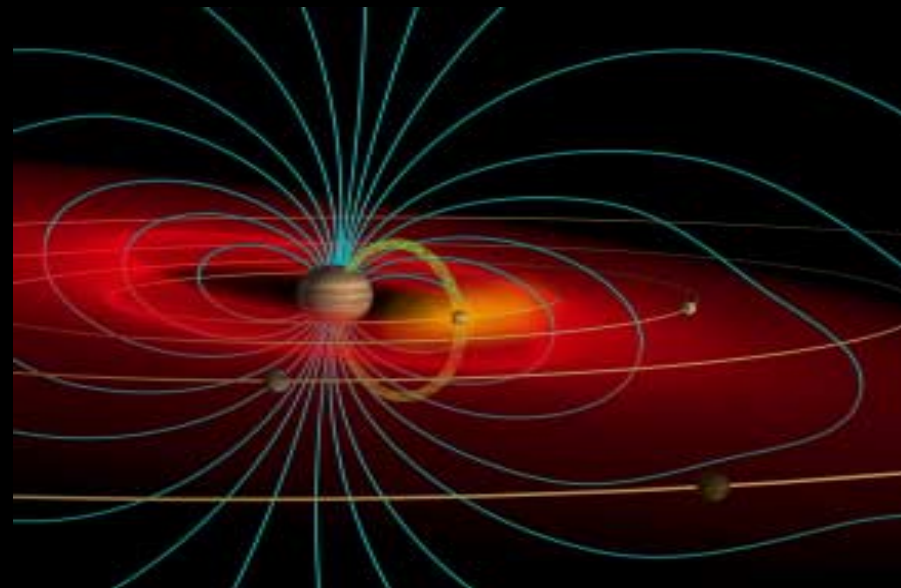
MGS MAG/ER



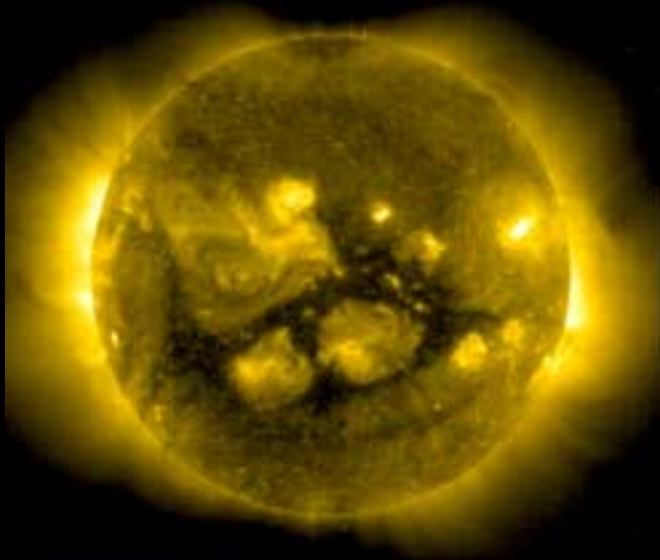
MGS at mapping orbit altitude ~400 km
1° by 1° resolution

Connerney et al., *Geophys. Res. Lett.*, 28, 4015-4018, 2001.

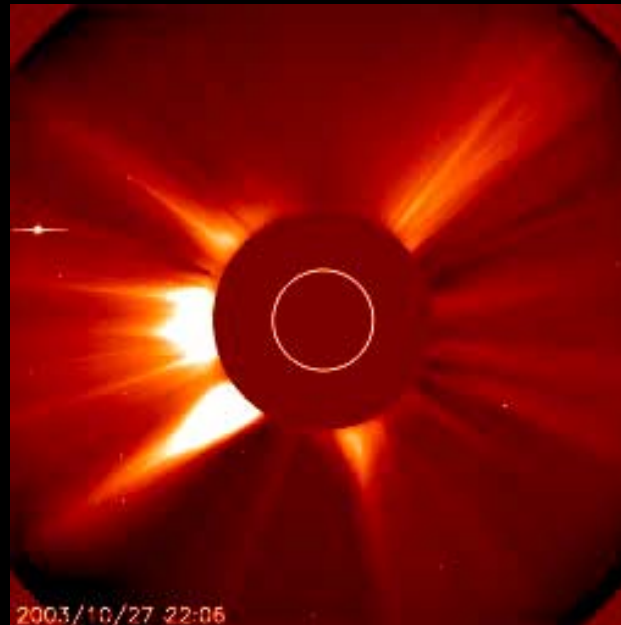
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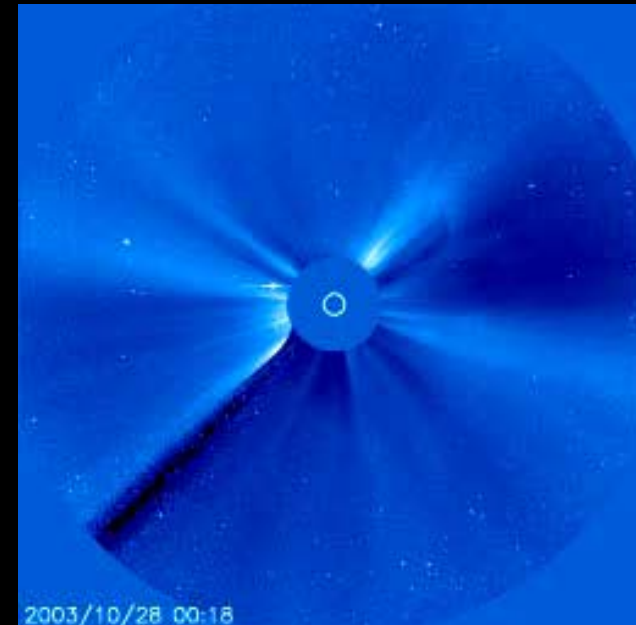
Space Radiation: Solar Events of October-November 2003



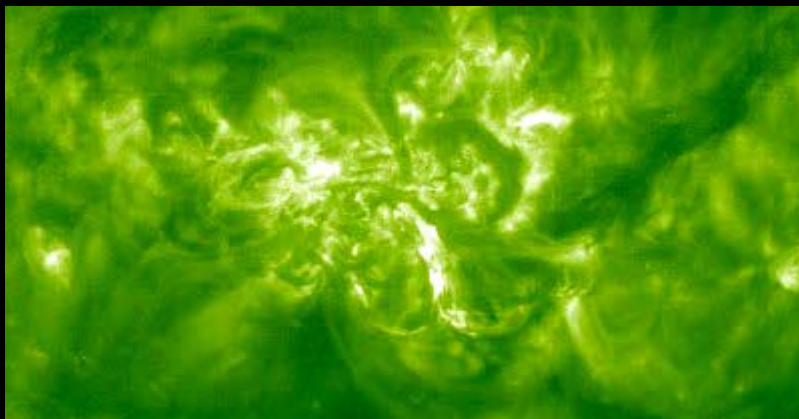
2003/10/15 01:06



2003/10/27 22:06



2003/10/28 00:16



Images by the ESA/NASA SOHO spacecraft