# Soft Protons in the magnetosphere focused by X-ray telescopes

## 1 Abstract

One of the major and unfortunately unforeseen sources of background for the current generation of X-ray telescopes, in particular the ESA X-ray satellite XMM-Newton, is due to soft (few tens-hundreds of keV) protons concentrated by the X-ray mirrors. The observing time lost is 40% in the case of XMM, affecting all the major broad science goals of this observatory, ranging from cosmology to astrophysics of neutron stars and black holes. The physical process at work and the connection with the magnetospheric population and acceleration sites originating the phenomenon are still poorly understood. The soft proton background can impact dramatically future large X-ray missions such as the ESA planned Athena mission[1]. We propose a multi-disciplinary team of astrophysicists and magnetopsheric physicists to meet at ISSI with the goal to advance our understanding of the phenomenon. We plan to investigate the rich datasets provided by the XMM and ESA magnetospheric mission CLUSTER over more than 15 years with the following objectives: (i) to gauge the flux of soft protons at the XMM satellite location and orientation in the magnetosphere; (ii) to provide a necessary in flight assessment of the physical process complementary to what obtained by laboratory experiments (iii) to learn lessons to mitigate the impact for future X-ray missions. **The support of ISSI is key to allow the meeting and sharing of expertise of two different communities with a broad and complex interdisciplinary goal leading to publication of refereed papers.**

## 2 Scientific rationale

X-ray telescopes are built to focus X-ray photons towards the detectors in the focal plane by a double low-angle scattering (grazing incidence) from concentric mirrors shells. It has been recognized with the advent of the modern X-ray observatories in orbit for the last two decades, Chandra and XMM-Newton, that protons of energies in the range of tens of keV up to few MeVs can scatter at low angles through the mirror shells and reach the focal plane. The protons can damage CCD detectors by delivering a non-ionising dose leading to a loss of spectral resolution. Their signal is indistinguishable from X-ray photons therefore it can not be rejected producing an enhanced background.

Soft protons focused on the focal plane during crossing of the Earth's radiation belt have been identified as the source of the damage to front illuminated CCDs on board Chandra during the first weeks of the mission, causing a loss of spectral resolution far more rapid than expected. XMM was launched in an orbit similar to Chandra and the detectors of XMM are kept closed with a thick aluminum filter below about 40000 km.

XMM highly eccentric elliptical orbit with an apogee of about 115000 km and a perigee of about 6000 km from Earth probes the full range of magnetospheric environments, from the inner magnetosphere to the solar wind when the satellite is outside the bow shock. Along its orbit the satellite is conjectured to encounter clouds of soft protons. These episodes are known as "soft proton flares": the time scale is extremely variable, ranging from hundreds of seconds to several hours, while the peak count rate can be more than three orders of magnitude higher than the quiescent one. The extreme time variability is the fingerprint of this background component, the Soft Proton (SP) component which should not be confused with solar flares. A light curve can immediately show the time intervals affected by a high background count rate. Such intervals are usually not suitable for scientific analysis unless the X-ray source to be studied is extremely bright (see Fig.1). They have to be rejected discarding all of the time intervals having a count rate above a selected threshold.

Besides this crucial but phenomenological knowledge, very little is known about soft protons. The SP spectrum has been investigated only recently besides early indication of large spectral variations. There is evidence that the higher the SP intensity, the flatter the spectrum. The basic response of the satellite is still unknown, with a coarse modelling of a vignetting function for SPs

[1] http://www.the-athena-x-ray-observatory.eu/

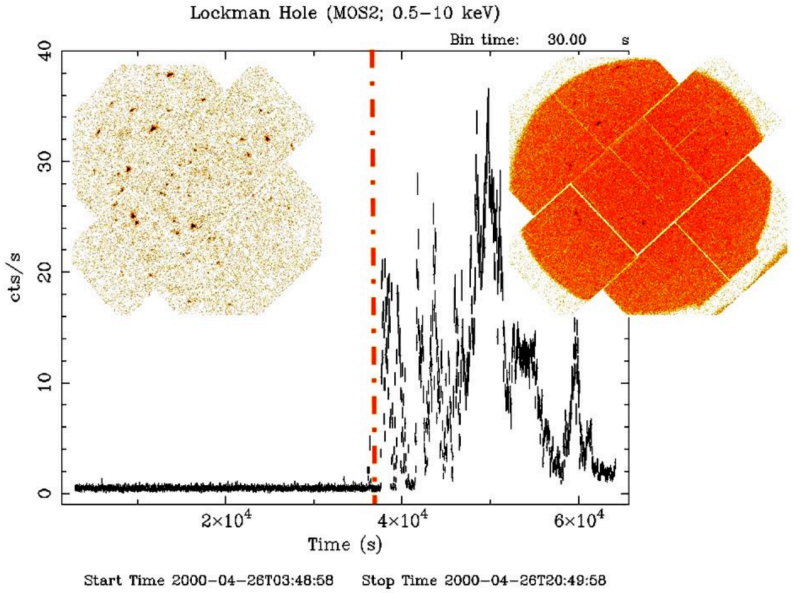


Figure 1: Example of XMM-Newton observation partly affected by soft protons. The flares are clearly visible in the second part of this light curve taken from one of the detectors on board XMM and their effect on the exposure quality can be evaluated comparing the image extracted from the first (left) and second half (right) of the observation.

which decreases less rapidly with increasing off-axis angle than does the vignetting function for X-rays (Kuntz & Snowden 2008) starting to be tested with detailed Geant4 simulations (Fioretti et al. 2016).

There is no firm agreement as to the actual mechanism(s) underlying proton reflection. The multiple-scattering models developed immediately before and after the launch of XMM (Nartallo et al. 2001; Lo & Srour 2003) have been subsequently refined to include quasi-specular (Firsov) scattering (Lei et al. 2004) in order to match proton reflectivity measurements made on representative mirror flats. Aschenbach (2007) has used a quite distinct de Broglie wave analysis to estimate the proton response of XMM. No clear results have emerged yet and laboratory tests are still underway.

An investigation of the origin and energy spectrum of the population of SPs responsible of the flares in XMM is still lacking. A preliminary analysis of the distribution of flares as a function of orbital position, distance from the Earth, and orbital phase with respect to the Sun has been attempted by members of our team (Kuntz & Snowden 2008). The part of the orbit which seems more susceptible to SP flare is in the inner part of the magnetosphere, whereas greatest flare-free time occurs when the spacecraft is furthest from the Earth, either outside the bow-shock or deep within the magneto-tail. A recent development of that work based on XMM measurements from 2000 to 2010 for a total of 51 $\times 10^6$ s of data concluded that the statistical occurrence of flares (see left panel of Fig.2) is better sorted into higher and lower probability of flaring by magnetic topology: proton flares occurred the highest percentage of time when the spacecraft is on closed magnetic field lines (Walsh et al. 2014). Previous studies concluded that the probability of flaring increased when the spacecraft was near perigee (Carter & Read 2007). The analysis indicates proton flaring may depend more on magnetic topology than radial distance from the Earth.

A recent analysis done by the members of the team at INAF in the framework of the ESA Research and Development activity AREMBES (Athena Radiation Environment Models and x-ray Background Effects Simulators) collected about 100 $\times 10^6$ s of data performed between 2000 and 2012. The results (see right panel of Fig.2) put in perspective the various contributions highlighted by previous studies: within the general trend of a decreasing intensity with distance from Earth (shown by the mean count rate of the SP component) the day-side magnetosphere with closed field lines is more contaminated by soft proton flares than regions on the night side on open field lines (Ghizzardi et al. 2017, sub.).

A preliminary investigation has been conducted to compare the XMM SP component with environmental estimates of the soft proton particle flux recorded by solar wind monitors designed and calibrated to measure those particles. We compared the XMM data with data from Advanced

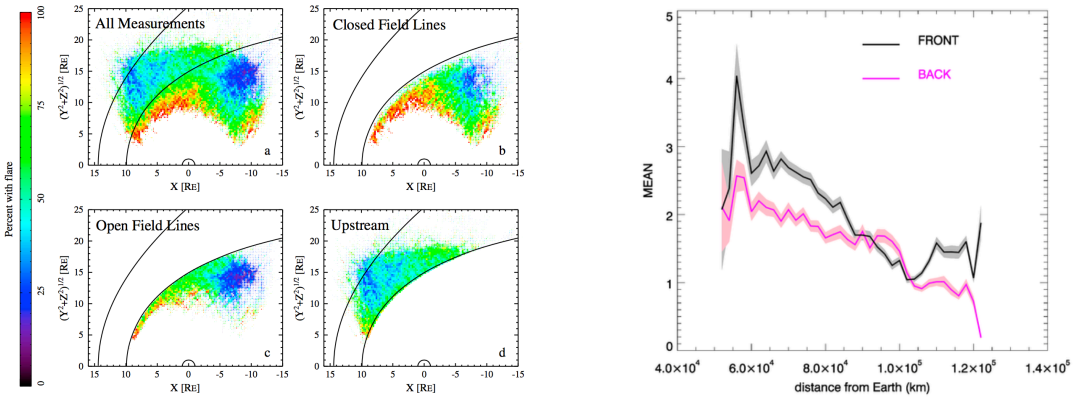


Figure 2: Left panel: (a) All measurements, (b) closed field lines, (c) open field lines, and (d) upstream. Percent of XMM CCD measurements with proton flaring sorted by magnetic topology. The color shows the number of measurements in each 0.25 $R_E$ (Earth radius) square bin. The positions are normalized with upstream solar wind conditions to a reference model magneto-pause (Shue et al., 1998). Figure taken from Walsh et al. (2014). Right panel: Mean count-rate of the SP component as a function of distance from Earth in the day-side (black) and in the night-side (magenta) of the magnetosphere. Figure taken from Ghizzardi et al. (2017).

Composition Explorer (ACE) satellite in orbit around L1 (Stone et al. 1998), chosen because it has a time span of available data comparable to the one we have for XMM. We used particle data from the Low energy Magnetic Spectrometers (LEMS), LEMS120 and LEMS30, of the EPAM instrument dedicated to monitor the low energy (46 keV - 4.8 MeV) protons (Gold et al. 1998). Of particular interest for our purposes are the low energy channels of those detectors, in particular the P2 channel that covers the 67-115 keV range for the LEMS120 which looks back towards the Earth's bow shock. The comparison between the XMM SP count rate and the ACE LEMS120 proton flux is shown in Fig.3: it is clear from the investigation of the plots that there is no striking correlation, besides a tendency for a lower envelope, meaning that given a high flux of soft protons in L1 we can expect a corresponding high level in XMM. However at any given flux in L1 there is a wide range of intensities of soft protons detected at the position of the XMM orbit, pointing to local (within the magnetosphere) acceleration sites for this particle component. If we divide our data when considering time intervals not affected by Solar Energetic Particle (SEP) events and time intervals during SEP events we can see that as expected the bulk of high proton fluxes in L1 corresponds to SEP events, however this does not lead to a tighter correlation between the two datasets. It should be noted that most of the time during SEP events XMM is not observing to prevent radiation damage. Therefore strong conclusions could not be reached besides an indication of the complexity of the problem and the various factors affecting the variable of interest here, i.e. the flux of soft protons entering the XMM telescopes. There are a large variety of acceleration sites for soft protons and their flux is possibly directionally dependent. A measurement of the soft proton flux needs to be performed in a location as close as possible to the conditions experienced by XMM at that specific time. **The proposed project will go beyond this unsuccessful effort and compare the data with the best available probe inside the magnetosphere, the Cluster satellite.**

The Cluster constellation, consisting of 4 spacecrafts flying in formation (Escoubet et al. 2001) is a successful ESA mission, probably the most successful plasma physics mission ever. The Cluster mission has been operated for 16 years. During this time period, the evolution of the orbit has enabled Cluster to sample many more magnetospheric regions than was initially anticipated. With its 4x20 $R_E$ elliptical polar orbit, Cluster traverses most of the regions relevant for XMM.

Members of our team are experts of the detectors on board Cluster providing the key proton flux measurements: the Cluster Ion Spectrometry (CIS - energies up to 30 keV) and the Research with Adaptive Particle Imaging Detectors (RAPID - energies in the range 27 keV - 1 MeV). Calibrated

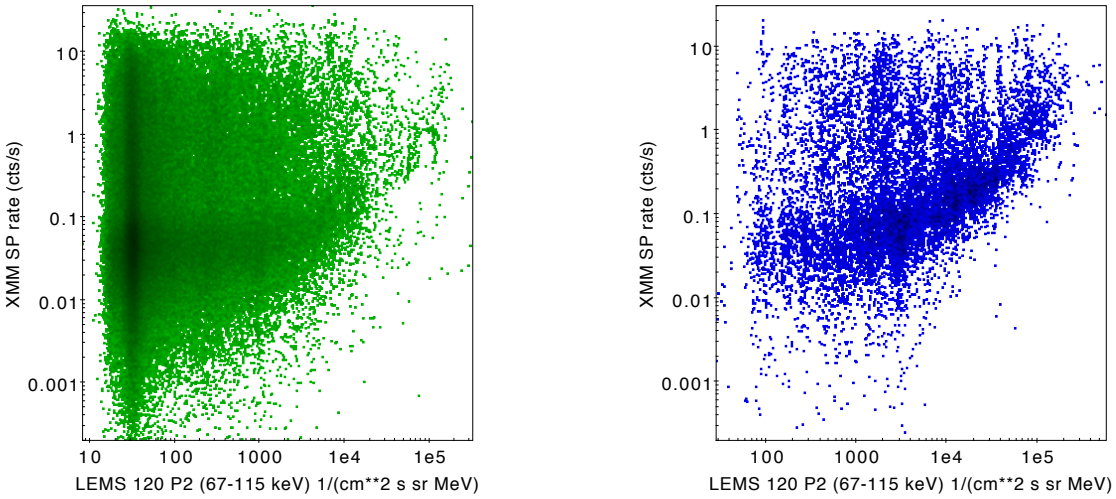


Figure 3: Left panel: Comparison of XMM SP rates and ACE LEMS120 proton flux in the P2 channel (67- 115 keV) during periods not affected by SEP events. Right panel: Same as the left panel but for periods during SEP events.

Cluster data from 2001 until 2015 are available via the Cluster Science Archive, hosted at the European Space Astronomy Centre (ESAC), Spain.

## 3 Timeliness of the project

The problem of soft protons is a major concern for future X-ray missions. The displacement damage to detectors causing charge transfer inefficiency and therefore loss of spectral resolution is not relevant for future detectors such as calorimeters, however the considerable loss of exposure time due to the sudden and intense increases of the background level is a serious issue for example for the planned ESA Athena observatory: first estimates based on an extrapolation of the XMM background foresees that the soft proton contamination will be even more serious than for XMM. A lot of activities are being planned by space agencies and in particular ESA to mitigate the current ignorance of the phenomenon, in particular for the lack of detailed experimental measurements of proton reflectivity. The theoretical modelling of the scattering process is not clearly assessed yet, as for example continuous updates are being considered such as Remizovich scattering (Remizovich et al. 1980). Given **the large datasets available for XMM and CLUSTER spanning more than 15 years and the bulk processing done for XMM by members of our team, this is the right time to perform a joint analysis with the aim of providing a measurement of the concentrating power of XMM optics**. This will complement the on ground experimental activities and will shed light on the physical process at work. A key input will be delivered to mission planning, such as for example the design of proton magnetic diverters to avoid contamination of the focal plane (Spiga et al. 2008, Willingale et al. 2015). Last but not least, a key input can be guidelines for the best orbit to choose for mission such as Athena: a choice between L2 or L1 for what concerns soft proton contamination (the final choice of the orbit for Athena is still under discussion).

## 4 Expected output

XMM and Cluster data will be analyzed in the context of the project. We expect the following products to be the outcome of the project:
i) a database of calibrated flux and spectra for protons in the range 10 keV-1 MeV from the CIS-RAPID data augmented with ancillary data such as magnetic field intensity and orientation. An empirical model for the soft proton intensities depending on solar activity, geomagnetic activity and on the magnetospheric region will be derived.
ii) a database of conjunctions between the XMM and Cluster satellites. The best characterization is expected to be achieved during conjunctions when both spacecraft are located in the same magnetospheric region as a function of geomagnetic activity. The above cited model will be used for cases in which conjunctions between XMM and Cluster satellites do not exist.
iii) a calibration of the XMM response to soft protons.

The scientific results will be published in peer-reviewed journals like Astronomy and Astrophysics (A&A), Monthly Notices of Royal Astronomical Society (MNRAS) and Space Science Re-

views (SSRv).

## 5 What is the value of ISSI

Our team is composed of European, coming from 3 different countries (Germany, Italy, Norway) and US scientists working on two ESA corner-stone missions and gathering very different expertise of X-ray astrophysics and magnetospheric physics very well suited to reach the objective of the proposal. We will benefit from the added value of the logistic from ISSI in Bern: even the necessary understanding of a common language between physicists coming from a very different background needs time to build up and meetings in an inspiring atmosphere will ease the process. The X-ray astrophysicists have already made an effort to bridge the gap with the magnetospheric community given the keen interest that the issue of soft protons raised. The datasets available for the projects are unique and large, comprising for both satellites more than 15 years of data. The members of the team have been key in the calibration and exploitation of the data from the two satellites and they are world-experts in the analysis of the XMM and CLUSTER data. Joining together these expertises for a truly multi-disciplinary objective is in summary the added value ISSI gives to the project.

## 6 Team members

The following participants have confirmed their availability to work in this team: Dr. Fabio Gastaldello (INAF/IASF-Milano) team leader; Dr. Silvano Molendi (INAF/IASF-Milano); Dr. Simona Ghizzardi (INAF/IASF-Milano); Dr. Andrea Tiengo (IUSS Pavia); Dr. Stein Haaland (University of Bergen); Dr. Elena Kronberg (Max Planck for Solar System Research (MPS)); Prof. Lynn Kistler (University of New Hampshire); Dr. Steve Snowden (NASA Goddard Space flight Center); Dr. K. D. Kuntz (Johns Hopkins University). Young scientists from the institutions involved in the magnetospheric research (MPS, University of Bergen) will be appointed if the proposal is accepted.

## 7 Schedule

We envisage the first meeting to take place in the Fall of 2017 to set up the project and conduct pilot studies with subsets of the available XMM and Cluster databases more suitable for a direct and quick comparison. In this first meeting the status of the existing databases and the best strategies for the cross-correlation will be discussed, guided by physical insight about the distribution of soft protons in the magnetosphere and acceleration/production processes. During the following year the team members will work on advancing the project. The first paper draft will be prepared during this time and we will meet again in the Fall of 2018 to discuss the drafts, finalizing them into papers and wrap up the project.

## 8 Facilities required

Use will be made of the standard facilities of ISSI. A meeting room for about 10 people is required, equipped with a projector and sufficient (wireless) Internet access. Some limited printing facility is needed. All these facilities are available at ISSI.

## 9 Financial support

We request the standard support for international teams (per diem & lodging).

# Appendices
# A References

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TEAM LEADER CV

NAME, First Name: Gastaldello, Fabio

Affiliation: IASF-Milano/INAF

Role in the project: XMM data analysis and its background characterization, in particular for what concern soft protons. I am involved in the mission design of Athena.

Current position: Staff Researcher @ IASF-Milano/INAF

Former Position(s): Short term Researcher @ IASF-Milano/INAF; Postdoc at University of California Irvine; Visiting Scientist at ESO and Tokyo University

Education: PhD in Astrophysics University of Milan 2004, Laurea Degree in Physics University of Milan 2000

Services in National and/or International Committees: Acted as panel member for Chandra and panel chair for the XMM-Newton time allocation committee. Member of the XIFU consortium as XIFU scientist. Member of the WFI consortium. Member of the Athena background working group.

Honors: Occhialini Fellowship.

Selected Publications: author or co-author of more than 70 papers with more than 1900 citations, H-index of 25.

Gastaldello et al, 2017, ExpA. Subm – The origin of the focused and unfocused XMM particle background

**Curriculum Vitae - Stein Haaland**

HAALAND, Stein
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University of Bergen
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**Role in project:**
Provide magnetospheric context, interpretation of Cluster particle data.

**Current and former positions:**
2009 - present
UNIS, Svalbard: Course responsible, teaching "AGF 345, AGF 845 - Polar Magnetospheric Substorm" (MSc, PhD level)

2008 - present
Max-Planck Institute for Solar Systems Research, Katlenburg-Lindau/Göttingen, Germany: Research Scientist: Involved in analysis of data from the Cluster mission. Faculty member, International Max-Planck Research School.

2005 - present
University of Bergen, Norway: Professor II: Coordinating Norwegian Cluster studies; student supervision. Lecturing special courses for Master & PhD students. Since 2015: Research scientist at the Birkeland Center for Space Science (European Centre for Excellence); mainly conducting research on interhemispheric asymmmetries.

2004 - 2006
University of Oslo (Andøya Rocket Range), Norway: Lecturing, FYS5610 - Magnetospheric Substorms" special course for Master and Ph.D students.

2002 - 2007
Max-Planck Institute for extraterrestrial Physics, Garching, Germany: Research Scientist: Involved in analysis of data from the Cluster EDI instrument. Magnetopause studies.

1999 - 2003
International Space Science Institute, Bern, Switzerland: Postdoctoral Research Fellow.

**Education**
Ph.D., Space science, University of Bergen, Norway.

**Services in National and/or International Committees (last ones):**
Member of organization committees for a number of Cluster meetings, AGU Chapmann, Cospar meetings, 2004-2017.

**Honors**:
Recipient, Fridtjof Nansen Stipend from the Norwegian Academy of Science and Letters, 2014
Recipient, ESA Cluster Team Achievement Award, 2010.
Recipient, Fridtjof Nansen Stipend from the Norwegian Academy of Science and Letters, 2003.

**Selected publications (of approx 90):**

Haaland, S., B. Lybekk, L. Maes, K. Laundal, A. Pedersen, P. Tenfjord, A. Ohma, N. Østgaard, J. Reistad and K. Snekvik; North-south asymmetries in cold plasma density in the magnetotail lobes: Cluster observations, J. Geophys. Res. Space. Phys., doi:10.1002/2016JA023404, 2016

Haaland, S.; Eriksson, A.; André, M.; Maes, L.; Baddeley, L.; Barakat, A.; Chappell, R.; Eccles, V.; Johnsen, C.; Lybekk, B.; Li, K.; Pedersen, A.; Schunk, R.; Welling, D., "*Estimation of cold plasma outflow during geomagnetic storms",* Journal of Geophysical Research, Volume 120, 2015

Haaland, S., J. Reistad, P. Tenfjord, J. Gjerloev, L. Maes, J. DeKeyser, R. Maggiolo, C. Anekallu, and N. Dorville, "*Characteristics of the flank magnetopause: Cluster observations"*, J. Geophys. Res. Space Physics, 119, doi:10.1002/2014JA020539, 2014.

Paschmann, G.; Haaland, S.**;** Sonnerup, B.; Knetter, T.,
*"Discontinuities and Alfvenic fluctuations in the solar wind",* Annales Geophysicae, vol. 31, Issue 5, 2013.

Haaland, S.; E. A. Kronberg, P. W. Daly, M. Fränz, L. Degener, E. Georgescu, and I. Dandouras,
*"Spectral characteristics of protons in the Earth's plasmasheet: statistical results from Cluster CIS and RAPID",*
Annales Geophysicae, Volume 28, No 8, 2011.

## Kistler, Lynn M

Professor, Dept. of Physics and Space Science Center, Univ New Hampshire, Durham, NH
**Role:** Expert in magnetospheres, and the plasma dataset from the Cluster
**Positions:**

| | | |
|---|---|---|
| 2013-present | Director, Space Sci. Center | University of New Hampshire |
| 2009-present | Professor | University of New Hampshire |
| 2002-2009 | Associate Professor | University of New Hampshire |
| 1996-2002 | Research Associate Professor | University of New Hampshire |
| 1991-1996 | Research Assistant Professor | University of New Hampshire |
| 1990-1991 | Research Scientist 2 | University of New Hampshire |
| 1988-1990 | Visiting Scientist | Max-Planck-Institut für extraterrestrische Physik |
| 1987-1988 | Research Associate | University of Maryland |

**Education:**

| | | | |
|---|---|---|---|
| Harvey Mudd College | Claremont, CA | Physics | B.S. 1981 |
| University of Maryland | College Park MD | Physics | M.S. 1983 |
| University of Maryland | College Park, MD | Physics | Ph.D.1987 |

**Professional Service:**

*National Aeronautics and Space Administration*

NASA Advisor Council, Heliophysics Subcommittee (2016-present)
NASA Heliophysics Subcommittee - Mission Planning Working Group (Roadmap) (2008)
NASA Heliophysics Lunar Science Subpanel, NASA Heliophysics Subcommittee (2006 - 2007)
Sun-Earth Connection Roadmap Committee (1999)
NASA Proposal Review Panels (Various)

*National Academy*

Decadal Strategy for Solar and Space Physics Panel, member Solar-Wind Magnetospheric Interactions Group (2010-2011)

**Honors:**

American Geophysical Union

Fellow of the American Geophysical Union, 2016
Exellence in Refereeing, JGR-Space Physics, 2014.

NASA Group Achievement Awards

AMPTE Mission, 1985
FAST Mission, 1995
ACE Mission, 1998
SEC Roadmap Committee, 2000

ESA Group Achievement Award

CLUSTER Science, 2004, 2015

**Selected Publications:**


Kistler, L. M., and C. G. Mouikis (2016), The inner magnetosphere ion composition and local time distribution over a solar cycle, *Journal of Geophysical Research (Space Physics)*, *121*(3), 2009–2032, doi:10.1002/2015JA021883.

Kistler, L. M., C. G. Mouikis, and K. J. Genestreti (2013), In-flight Calibration of the Cluster/CODIF sensor, *Geoscientific Instrumentation*, *3*(1), 221–250, doi:10.5194/gid-3-221-2013

Kistler, L.M., C.G. Mouikis, B. Klecker, I. Dandouras, The cusp as a source for oxygen in the plasma sheet during geomagnetic storms, *J. Geophys. Res.,* 115, A03209, doi:10.1029/2009JA014838, 2010.

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**Ghizzardi Simona** **23 March 2017**

Affiliation: IASF-Milano/INAF

Role in the Project:
Expertise in calibration of X-ray instruments and analysis of the XMM-Newton soft proton background.

Current Position: Researcher at IASF-Milano/INAF

Previous Positions:
December 2001-present: Researcher at IASF-Milano/INAF
April 1999 - December 2001: Researcher (Short Term) at IASF-Milano/INAF

Education:
February 1999 Ph.D. State University of Milan
Thesis: "Global morphological properties of galaxy clusters in different cosmologies."
Supervisor: Silvio Bonometto

Services in National and/or International Committees (last ones):
1999-2002 Member of the XMM-Newton/EPIC Calibration Team.
2016-present Member of the Athena Background Working Group

Selected Publications:

Ghizzardi et al., 2017, ExpA *subm* – Impact of the magnetospheric environment on the XMM-Newton background.

Ghizzardi, S.; De Grandi, S.; Molendi, S., 2014, A&A, 570, 117 – Metal distribution in sloshing galaxy clusters: the case of A496

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Ghizzardi, S.; Rossetti, M.; Molendi, S. 2010, A&A, 516, 32 – Cold fronts in galaxy clusters

Ghizzardi, S., 2002, https://www.cosmos.esa.int/web/xmm-newton/calibration-documentation, – In flight calibration of the PSF for the PN camera

Ghizzardi, S., 2001, https://www.cosmos.esa.int/web/xmm-newton/calibration-documentation, – In flight calibration of the PSF for the MOS1 and MOS2 cameras

**TEAM CORE MEMBER CV**

**NAME, First Name:** KRONBERG, Elena

**Affiliation:** Max Planck Institute for Solar System Research (MPS), Göttingen, Germany

**Role in the project:** team member, data analysis of Cluster energetic particle observations

**Current position:** 2006-present, scientist (MPS), Göttingen, Germany

2016-present, guest at Ludwig Maximillian University (LMU), Munich, Germany

**Former Position(s):** 2006, PostDoc (MPS) ), Göttingen, Germany

2001-2002, Scientific assistant, Altai State University

**Education:** 2006, Dr. rer. nat., Technical University of Braunschweig, Germany

2001, Master in Physics, Altai State University

**Services in National and/or International Committees (last ones):**

2013-2016, proposal reviewer: NSF, NASA review panel, Swedish National Space Board, Hungarian National Research Development and Innovation Office, Czech Science Foundation; 2013, Scientific committee: Cluster 23rd Workshop

**Honors**: 2015, Co-Investigator of the THOR/CMS instrument; 2010, Co-Investigator of the Cluster/RAPID instrument, Science Working Team; 2012, Leading ISSI team on "Heavy ions: their dynamical impact on the magnetosphere"; 2010, Team Achievement Award, RAPID Team, Cluster Workshop, Greece; 2001, Award for achievements in science, 7th Russian scientific conference for students in physics and young scientists, St. Peterburg, Russia

**Selected Publications:**

**Kronberg E. A.**, E.E. Grigorenko, S. E. Haaland, P. W. Daly, D. C. Delcourt, H. Luo, L. M. Kistler and I. Dandouras, Distribution of energetic oxygen and hydrogen in the near-Earth plasma sheet, J. Geophys. Res., 120, 10.1029/2014JA020882, 2015

**Kronberg E. A.**, S. E. Haaland, P. W. Daly, E. Grigorenko, L. M. Kistler, M. Fränz, and I. Dandouras, Oxygen and hydrogen abundance in the near-Earth magnetosphere: Statistical results on the response to the geomagnetic and solar wind activity conditions, J. Geophys. Res., 117, A12208, 10.1029/2011JA018071, 2012

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**SNOWDEN, STEVEN L.** **23 March 2017**

Affiliation: NASA/Goddard Space Flight Center

Role in the Project: Contributions related to experience in empirical modeling of the XMM-Newton soft proton background.

Current Position: NASA XMM-Newton Project Scientist

Previous Positions:

1997–2010: NASA XMM-Newton Guest Observer Facility - Lead Scientist and Deputy Project Scientist

1993–1997: NASA ROSAT Guest Observer Facility - Scientific Staff
1987–1993: ROSAT Project (University of Wisconsin resident at the MPE)

Education:

1986 Ph.D. Physics, University of Wisconsin - Madison
Thesis: "Neutral Hydrogen and the Spatial Structure of the Diffuse Soft X-ray Background"
Minor: Distributed (Astronomy, Mathematics, and Statistics)
1979 M.S. Physics, University of Wisconsin - Madison
1978 B.S. Physics, Mathematics, and Astronomy, University of Washington

Services in National and/or International Committees (last ones):

NASA EUCLID Science Center PDR panel.
Chandra proposal review panel chair
Einstein Fellowship review panel member

Honors:

2015 NASA/GSFC John C. Lindsay Award
2015 NASA Honor Award – Exceptional Scientific Achievement Medal

Selected Publications:


Lallement, R., et al. 2016, A&A, 595, 131 – On the distance to the North Polar Spur and the local CO-$H_2$ factor

Kuntz, K. D., et al. 2015, ApJ, 808, 143 – The Solar Wind Charge-exchange Production Factor for Hydrogen

Collier, M. R. 2015, RScI, 86, 1301 – Invited Article: First flight in space of a wide-field-of-view soft x-ray imager using lobster-eye optics: Instrument description and initial flight results

Snowden, S. L., et al. 2015, ApJ, 806, 120 – The North Galactic Pole Rift and the Local Hot Bubble

Snowden, S. L., et al. 2014, ApJL, 791, 14 – Pressure Equilibrium between the Local Interstellar Clouds and the Local Hot Bubble

Galeazzi, M., et al. 2014, Nature, 512, 171 – The origin of the local 1/4-keV X-ray flux in both charge exchange and a hot bubble

Walsh, B. M., et al. 2016, Space Weather, 12, 387 – Energetic particle impact on X-ray imaging with XMM-Newton

Snowden, S. L., et al. 2009, ApJ, 691, 372 – Observation of Solar Wind Charge Exchange Emission from Exospheric Material in and Outside Earth's Magnetosheath

Snowden, S. L., et al. 2008, A&A, 478, 615 – A catalog of galaxy clusters observed by XMM-Newton

Snowden, S. L., et al. 2008, A&A, 478, 575 – The EPIC-MOS particle-induced background spectra

MEMBERS TEAM CV

NAME, First Name: TIENGO, Andrea
Affiliations: Scuola Universitaria Superiore IUSS Pavia; INAF/IASF-Milano; INFN/Sezione di Pavia

Role in the project: Experience in the XMM calibration and analysis. Relevant role in the soft proton phenomenon characterization.

Current position: researcher (assistant professor) in Astronomy and Astrophysics at IUSS Pavia. Responsible for the Science and Technologies Academic Class and Director of ICARO (IUSS Center for Astronomical and Remote-sensing Observations) at IUSS Pavia.

Former Positions: EPIC instrument expert (1999-2001), ESA XMM-Newton Science Operation Centre, VILSPA, Madrid (Spain); research fellowship (2002), Institute of Astronomy Anton Pannekoek, Amsterdam University, (The Netherlands); PhD in Physics, Astrophysics and Applied Physics (2003-2005), Università degli Studi di Milano (Italy); Research fellowship on X-ray emission properties of isolated neutron stars (2006-2007) and Research Fellow on XMM-Newton/EPIC on-board software maintenance and instrument calibration (2007-2011), INAF-IASF Milano

Education: Master degree in Physics (1999) and PhD in Physics, Astrophysics and Applied Physics (2005), Università degli Studi di Milano

Selected Publications: *An accreting pulsar with extreme properties drives an ultraluminous x-ray source in NGC 5907* (Israel et al. 2017, Science 355, 817); *A variable absorption feature in the X-ray spectrum of a magnetar* (Tiengo et al. 2013, Nature, 500, 312); *The Dust-scattering X-ray Rings of the Anomalous X-rayPulsar 1E 1547.0-5408* (Tiengo et al. 2010, ApJ 710, 227); *XMM-Newton Discovery of 7 s Pulsations in the Isolated Neutron Star RX J1856.5-3754* (Tiengo & Mereghetti 2007, ApJ 657, L101); *The X-ray afterglow of GRB 030329* (Tiengo et al. 2003, A&A 409, 983); *The European Photon Imaging Camera on XMM-Newton: The MOS cameras* (Turner et al. 2001, A&A 365, L27)

# Curriculum Vitae

## K.D. Kuntz

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Physics and Astronomy
Johns Hopkins University,
3400 North Charles Street,
Baltimore, MD 21218

*Home Address*
2327 North Calvert Street
Baltimore, MD 21218
(410) 366-4236

### Research Interests:

My primary interest has the study of the hot Galactic ISM using X-ray observations of the diffuse emission in the Galaxy and the diffuse emission in normal spiral disks. The diffuse hot ISM traces the bulk of the energy input to the ISM and it contains the bulk of the newly created elements, yet the mass of hot gas, the volume that it fills, and its abundances are very poorly known. Since the measure of the emission from the diffuse ISM requires accurate removal of instrumental backgrounds and other cosmic backgrounds, I have devoted considerable effort to characterize and model the X-ray emission due to solar wind charge exchange (SWCX) from the heliosphere and the magnetosheath using a combination of archival X-ray and solar-wind data.

### Education:

2000 − Ph.D. − Astronomy, University of Maryland, College Park
1988 − M.S. − Astronomy, University of Hawaii, Manoa
1985 − B.S. − Physics, Massachusetts Institute of Technology

### Positions Held:

2010− Research Scientist The Johns Hopkins University
2005−2010 Associate Research Scientist The Johns Hopkins University
2001−2005 Post-doctoral Research Associate University of Maryland, Baltimore County (in the UMBC-NASA/GSFC/LHEA Joint Center for Astrophysics)
1996−2000 Graduate Research Assistant, University of Maryland, College Park
1993−1996 Graduate Teaching Assistant, University of Maryland, College Park
1988−1993 Science Data Analyst, Space Telescope Science Institute

## List of Publications

### Primary Publications (Refereed Journals):

"The Solar Wind Charge-exchange Production Factor for Hydrogen", **K. D. Kuntz** et al, 2015, ApJ, 808, 143
"Pressure Equilibrium between the Local Interstellar Clouds and the Local Hot Bubble", S. L. Snowden et al, 2014, ApJL, 806, 120
"On Lunar Exospheric Column Densities and Solar Wind Access Beyond the Terminator from ROSAT Soft X-ray Observations of Solar Wind Charge Exchange", M. R. Collier et al, 2014, JGR, in press
"The origin of the 'local' 1/4 keV flux in both charge exchange and a hot bubble", M. Galleazzi, 2014, Nature, in press
"Energetic particle impact on X-ray imaging with XMM-Newton", B. Walsh et al, 2014, Space Weather, in press
" XMM-Newton Observations of MBM 12: More Constraints on the Solar Wind Charge Exchange and Local Bubble Emissions", 2011, D. Koutroumpa et al, ApJ, 726, 91
"Solar Wind Charge Exchange Emission from the Helium Focusing Cone: Model to Data Comparison", 2009, Koutroumpa et al, ApH 697, 1214
"Observation of Solar Wind Charge Exchange Emission from Exospheric Material in and Outside Earth's Magnetosheath", S. L. Snowden et al., 2009, ApJ 691, 372

TEAM CORE MEMBER CV

NAME, First Name: Molendi, Silvano

Affiliation: IASF-Milano/INAF

Role in the project: I will bring my more than decadal experience in X-ray background characterization to the project. I have contributed to the work on the backgrounds for the BeppoSAX MECS and PDS instruments and for the XMM-EPIC instrument. The reference cosmic background papers for BeppoSAX MECS (Vecchi, Molendi et al. 1998, 94 citations) and XMM-EPIC (De Luca & Molendi 2004, 231 citations) were both produced by my group. I play a key role in the background effort for ATHENA. I have provided a comprehensive review of the background related requirements. I am chair of the background topical panel for the Athena Study Science Team. I am Project Scientist for the ESA background related tender AREMBES and Project Manager for the proposed ESA background related tender EXACRAD.

Current position: Primo Ricercatore @ IASF-Milano/INAF

Former Position(s): Ricercatore @ IASF-Milano/INAF; Postdoc at Max Planck Institut fuer Extraterrestrische Physik; Visiting Scientist at ESO

Education: Phd in Astrophysics University of Milan 1993, Laurea Degree in Physics University of Milan 1989

Services in National and/or International Committees (last ones): Acted as panel member for Chandra and panel chair for the XMM-Newton time allocation committee. Member of the XIFU consortium as XIFU scientist. Member of the WFI consortium. Topical panel chair of the Athena Study Science Team. Project Scientist for the ESA Tender “AREMBES”. Project Manager for the proposed ESA Tender “EXACRAD”.

Honors: In 2002 he was awarded the “Le Scienze” prize for astrophysics.

Selected Publications: Amongst my most influential papers are: the BeppoSAX papers on cluster temperature (De Grandi & Molendi 2002) and metal abundance profiles (De Grandi & Molendi 2001), 197 and 194 citations respectively; an early XMM-Newton paper (Molendi & Pizzolato 2001), 127 citations, where we found that the gas in so called cooling-flow systems showed very little evidence of being multi-phase; the reference paper on the XMM-Newton measurement of the Cosmic X-Ray Background (De Luca & Molendi 2004), 231 citations; a recent paper (Leccardi & Molendi 2008) where we studied cluster temperature profiles with XMM-Newton, providing for the first time a detailed analysis of systematics including a suite of simulation designed to determine the effect of incorrect estimates of the different background components on the temperature measurements, 110 citations.