Proposal for an ISSI International Team Project: Coronal Hard X-ray Sources

Team Leaders: Säm Krucker and Hugh Hudson

Abstract

We propose a small team (11 persons) to systematize our knowledge of hard X-ray emission from the solar corona. Coronal hard (>20 keV) X-rays differ fundamentally from the "footpoint" emission normally seen in solar flares and exhibit a wider array of properties. The corona should not generally be a strong bremsstrahlung source because of its low plasma density, but the observation of limb-occulted events such as that of 30 March 1969 (Frost and Dennis, 1971) contradicted this expectation. While hard X-ray footpoint emissions show where flare-accelerated electrons lose their energy, coronal hard X-ray sources might reveal emission from the acceleration site itself. Coronal hard X-ray observations therefore provide a great diagnostic tool for particle acceleration in solar flares. Now we can image these sources and also determine their spectra in some detail, using the RHESSI* observations. Neither these data nor those of the earlier *Yohkoh* observations have been treated systematically in the literature. Accordingly we plan to write one overview paper setting out the range of observations and interpretations derived from our discussions. Furthermore, we will relate these observations to each other, discuss their relationship and implications, and also encourage the publication of several more focused papers using RHESSI imaging spectroscopy. We ask for two meetings in late 2006 and early 2007, with the overview paper to be submitted by July 2007.

1 Scientific Rationale

1.1 Background

The solar corona generally has a mass distribution dictated by the hydrostatic law, barring large-scale flows. It is a low-beta plasma punctuated by discrete restructurings (flares/CMEs). Outside the active regions the corona has low temperatures ($\sim$1–2 MK) and low densities, corresponding to base pressures of 0.01–0.1 dynes/cm^2 and densities as low as 10^8 cm^{-3} in open-field regions. In active regions higher temperatures, densities, and pressures resulting from magnetic activity change the picture substantially. This ambient active-region material, plus the flare/CME ejecta during the event, apparently provide a thick enough target (Fletcher and Martens, 1998) for the bremsstrahlung to reach detectable levels.

1.2 Coronal Hard X-ray Sources

Solar flares of course emit copious quantities of hard X-radiation during the impulsive phase, showing that 10-100 keV electrons have major if not dominant significance for the primary flare energy release (e.g., Lin and Hudson, 1976). Such emission comes from the *footpoint regions* at the base of the corona, however, except during the Masuda phenomenon (Masuda et al., 1994). That something else fundamentally different might be happening far up in the corona first became evident from the remarkable event of 30 March 1969 (Frost and Dennis, 1971). This event, and others subsequently detected, came from active regions more than a

*Reuven Ramaty High Energy Solar Spectroscopic Imager

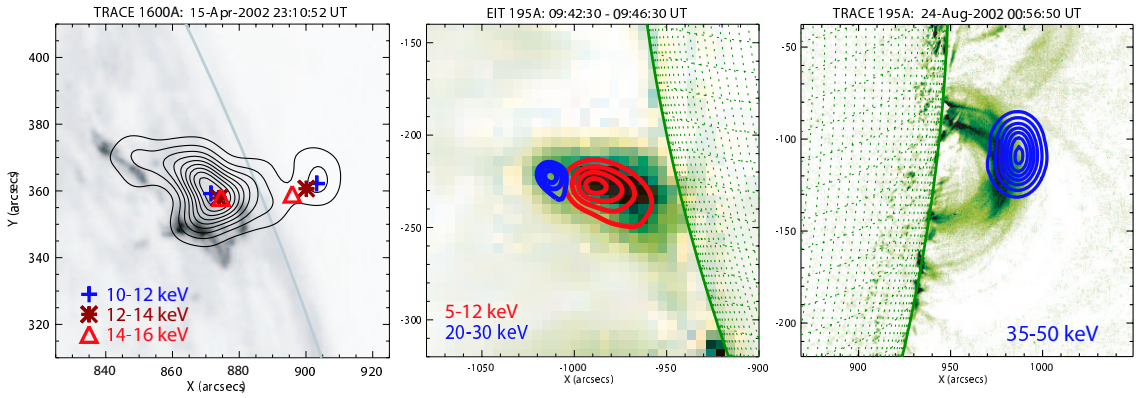

Figure 1: Three examples of RHESSI coronal hard X-ray sources (from Krucker 2006). *Left:* flare with thermal source above the main flare loop (after Sui and Holman, 2003). *Middle:* HXR above the loop-top source in a partially occulted flare. The red contours show the thermal flare emission, the blue contours give the location of an "above the loop top" source similar to the one in the Masuda flare. The HXR footpoints are occulted by the solar limb and therefore not visible. *Right:* coronal hard x-ray source seen *before* the impulsive phase of the 24 August 2002 flare.

day's rotation around the solar limb. This meant an "occultation height" of $\sim 2\ \ 10^4$ km, a region previously known in the high-energy sense only from the radio m-wave bursts (types I–V etc.); an over-the-limb angle of about 10° corresponds to about 10^4 km height and is generally sufficient to occult the footpoint sources (Tomczak, 2001).

Demonstrably coronal hard X-ray sources have occurred infrequently and have largely been studied individually. Figure 1 shows three examples from the RHESSI data (Krucker, 2006). In the following brief sections we describe various types of source, observation, or interpretation, ending with a rank speculation about "sunspot magnetospheres."

1.2.1 Masuda phenomenon

The remarkable observation of an "above-the-loop-top" hard X-ray source by Masuda et al. (1994) revealed the presence of a coronal hard X-ray source not at all similar to the kind originally discovered by Frost and Dennis (1971). Instead this source appeared in close connection with the impulsive phase of the flare, and it has thus been invoked to support the standard magnetic-reconnection flare model. Although it appears to be fundamentally important, other examples of the phenomenon have been hard to observe (but see Figure 1b). RHESSI now provides detailed spectra for these sources. **One major objective of our discussions will be to understand why such sources are so rare**.

1.2.2 Coronal current sheets

Sui and Holman (2003) observed a distinct coronal phenomenon at lower energies, a double thermal hard X-ray source for which a reconnection current sheet provides a plausible explanation. Figure 1 (left) shows RHESSI observations from the first flare found with this pattern. The spectra clearly show these sources to be thermal, as compared with the "superhot" or non-thermal spectrum inferred for the Masuda source. Furthermore, various types of source motions are observed that might reveal insights into the acceleration and heating processes in flares. **How is this related, then, to the Masuda phenomenon?**

1.2.3 Coronal thick targets

Two flares analyzed by Veronig and Brown (2004) show evidence *coronal thick-target* behavior. Again this presents a different morphology from the Masuda observation and does not require magnetic reconnection for its interpretation. **Are coronal thick-target sources consistent with fine-scale filamentation of flare energy release?**

1.2.4 Preflare coronal features

RHESSI's first γ-ray flare displayed a remarkable coronal source prior to the impulsive phase (Lin et al., 2003). The observed spectra are most likely produced by non-thermal electrons and the inferred total energy of this source was extremely large (Holman et al., 2003), and yet it did not show classical footpoint emission. Some flares also show "early impulsive" bursts with anomalous spectra (Sui et al., 2005). **How do we understand early-phase non-thermal sources conceptually?**

1.2.5 Counterparts of m-wave phenomena

The classical meter-wave coronal radio sources (e.g., Wild et al., 1963) each imply the presence of non-thermal electrons associated with flare and/or CME activity. These same electrons should be visible in hard X-ray bremsstrahlung, but arguably only the shock waves associated with Type II bursts have thus far been detected (Hudson et al., 2003). Presumably the limb-occulted sources (e.g., Frost and Dennis, 1971) fall in this category. **How do we relate the observed coronal hard X-ray sources to the "meter-wave zoo"?**

1.2.6 Sunspot magnetospheres

As a complete speculation, we note that the magnetic loops of the flaring active region should acquire a population of neutron-decay protons and electrons, analogous to the CRAND (Cosmic-Ray Albedo Neutron Decay) mechanism known to work in the Earth's radiation belts, but deriving neutrons from the flare γ-ray sources instead. These populations presumably have low intensities but long lifetimes, possibly modified by the "collapsing trap" physics (Karlický and Kosugi, 2004). **Are neutron-decay sources detectable?**

2 Expected output

We intend to write one "research review" paper along the lines of Cliver et al. (1986) or (in a different field) Miller et al. (1997). The main objective will be to systematize our knowledge of coronal hard X-ray emission. Essentially two solar maxima have elapsed since the Cliver et al. review, and we have learned many things. For the most part the new knowledge is in individual one-event papers, and we do not have a good synthesis yet of the nature of the observed phenomena and their broader implications. As a part of this effort to understand the newer data, we plan to work at assignments prior to and during the first meeting, and then to devote the second meeting to the review paper itself. We plan to submit this paper by the middle of 2007, nominally 1 July.

We understand that the list of items in Section 1 includes several specific items will involve separate publication. We therefore also intend to encourage members of the group to write papers on such subjects independently.

3 ISSI Implementation

The ISSI facility is ideal for this kind of workshop. The team leaders are familiar with the arrangements, and the team itself rather naturally came out to contain good representation from the different regions. We expect to proceed with minimal overhead on a clearly-defined program of substantial scientific importance.

4 List of Participants

The following participants have confirmed their willingness to participate in the proposed projects (s. attached CV's for details):

- P. Cargill (UCL, UK): theory
- L. Fletcher (U. of Glasgow, UK): TRACE and RHESSI observations, theory
- H. Hudson (U. California, USA): Yokhok and RHESSI X-ray observations; history
- T. Kosugi (JAXA, Japan): Yohkoh X-ray and radio observations; theory; history
- S. Krucker (U. California, USA): RHESSI and solar imaging observations
- S. Masuda (STELab, Japan): Yohkoh X-ray observations
- L. Sui (NASA, USA): RHESSI X-ray observations
- M. Tomczak (Wroclaw, Poland): Yohkoh X-ray observations
- A. Veronig (U. Graz, Austria): Hα and X-ray observations
- L. Vlahos (U. Thessaloniki, Greece): theory
- S. White (U. Maryland, USA): radio observations and theory

This team has extensive experience covering essentially all aspects of the proposal.

5 Timeliness

The two sessions of the workshop will take place just at solar minimum, and coincidentally we expect the next solar observational satellites to be launched in this time frame: STEREO and Solar-B. We therefore feel that the timing of this particular topic will be optimally effective in helping to understand the new data from the next maximum – solar cycle 24.

6 Facilities required

No special facilities are required besides the usual ISSI workshop facilities: one meeting room with projector and internet access.

7 Financial Requirements

No special financial requirements besides the usual ISSI financial support is required. ISSI is asked to provide the living expenses of team members while they reside in Bern. For the two week-long meetings (6 days maximal stay per week), at most 132 person days is required for the 11 team members. Funding to cover travel costs is the responsibility of the team members.

References cited

Cliver, E. W., B. R. Dennis, A. L. Kiplinger, S. R. Kane, D. F. Neidig, N. R. Sheeley, and M. J. Koomen, 1986: Solar gradual hard X-ray bursts and associated phenomena. *ApJ*, **305**, 920–935.

Fletcher, L. and P. C. H. Martens, 1998: A Model for Hard X-Ray Emission from the Top of Flaring Loops. *ApJ*, **505**, 418–431.

Frost, K. J. and B. R. Dennis, 1971: Evidence from hard X-rays for two-stage particle acceleration in a solar flare. *ApJ*, **165**, 655.

Holman, G. D., L. Sui, R. A. Schwartz, and A. G. Emslie, 2003: Electron Bremsstrahlung Hard X-Ray Spectra, Electron Distributions, and Energetics in the 2002 July 23 Solar Flare. *ApJL*, **595**, L97–L101.

Hudson, H. S., J. I. Khan, J. R. Lemen, N. V. Nitta, and Y. Uchida, 2003: Soft X-ray observation of a large-scale coronal wave and its exciter. *Solar Phys*, **212**, 121–149.

Karlický, M. and T. Kosugi, 2004: Acceleration and heating processes in a collapsing magnetic trap. *Astron. Astrophys.*, **419**, 1159–1168.

Krucker, S., 2006: *Solar Flare Imaging in X-rays and Gamma-rays, ILWS workshop proceedings, Goa, India*.

Lin, R. P. and H. S. Hudson, 1976: Non-thermal processes in large solar flares. *Solar Phys*, **50**, 153–178.

Lin, R. P., S. Krucker, G. J. Hurford, D. M. Smith, H. S. Hudson, G. D. Holman, R. A. Schwartz, B. R. Dennis, G. H. Share, R. J. Murphy, A. G. Emslie, C. Johns-Krull, and N. Vilmer, 2003: RHESSI Observations of Particle Acceleration and Energy Release in an Intense Solar Gamma-Ray Line Flare. *ApJL*, **595**, L69–L76.

Masuda, S., T. Kosugi, H. Hara, S. Tsuneta, and Y. Ogawara, 1994: A Loop-Top Hard X-Ray Source in a Compact Solar Flare as Evidence for Magnetic Reconnection. *Nature*, **371**, 495.

Miller, J. A., P. J. Cargill, A. G. Emslie, G. D. Holman, B. R. Dennis, T. N. LaRosa, R. M. Winglee, S. G. Benka, and S. Tsuneta, 1997: Critical issues for understanding particle acceleration in impulsive solar flares. *J. Geophys. Res.*, **102**, 14631–14660.

Sui, L. and G. D. Holman, 2003: Evidence for the Formation of a Large-Scale Current Sheet in a Solar Flare. *ApJL*, **596**, L251–L254.

Sui, L., G. D. Holman, and B. R. Dennis, 2005: Nonthermal Spectral Flattening in Early Impulsive Flares. *AGU Fall Meeting Abstracts*, A291.

Tomczak, M., 2001: The analysis of hard X-ray radiation of flares with occulted footpoints. *Astron. Astrophys.*, **366**, 294–305.

Veronig, A. M. and J. C. Brown, 2004: A Coronal Thick-Target Interpretation of Two Hard X-Ray Loop Events. *ApJL*, **603**, L117–L120.

Wild, J. P., S. F. Smerd, and A. A. Weiss, 1963: Solar Bursts. *Ann. Revs. Astron. Astrophys.*, **1**, 291.

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Curriculum Vitae

Personal Data:

Name:	Samuel (Säm) Krucker
Date of birth:	June 13, 1967
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Education & Professional Status:

1987 - 1992	Study of experimental physics, Swiss Federal Institute of Technology (ETH) Zürich, Switzerland
1993 - 1996	PhD student at the Institute of Astronomy, ETH Zürich (Prof. A. O. Benz)
November 1996	Ph. D. Thesis: "Small Solar Flares in Radio and X-rays: Microflares and Radio Bursts"
1997 - 2000	Post-doctorate position at the Space Sciences Laboratory, University of California, Berkeley (with Prof. R. P. Lin)
2000 to present	Assistant research physicist at the Space Sciences Laboratory

Experience relevant to the proposal:

Co-Investigator of the NASA small explorer mission RHESSI; involvement in RHESSI hardware, software, operation, and data analysis and interpretation. Extensive experience in data analysis and interpretation of solar observations in radio waves, in the optical range, in EUV, and X-rays.

Publications

I have published 50 papers in refereed journals, 14 as a first author. Selected papers relevant to the proposal:

1. Säm Krucker & Robert P. Lin: *'Relative Timing and Spectra of Solar Flare Hard X-ray Sources'*, Solar Physics 210, 229, 2002
2. Säm Krucker, Hurford,G.J., and Lin,R.P.: *'Hard X-ray Source Motions in the July 23, 2002 Gamma-ray Flare'*, ApJL, 595, L103, 2003
3. Lin, R.P., Krucker, S., and 11 coauthors.:*'RHESSI Observations of Particle Acceleration and energy Release in an Intense Solar Gamma-Ray Line Flare'*, ApJL, 595, L69, 2003
4. Säm Krucker, M.D. Fivian & Robert P. Lin: *'Hard X-ray footpoint motions in solar flares: comparing magnetic reconnection models with observations'*, Advance in Space Research, 35, Issue 10, 1707, 2005

Curriculum Vitae

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Personal:

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Education:

Undergraduate degree: Rice University, B.A. *cum laude* Physics, Math, 1961
Graduate degree: University of California (Berkeley), Ph.D., Physics, 1966

Employment:

University of California, Berkeley (1966)
University of California, San Diego (1966-1991)
University of Hawaii (1991-1996)
Solar Physics Research Corp. (1996-2002)
University of California, Berkeley (2001-present)

Visitor appointments (recent):

University of Glasgow, UK (2005-present), Honorary Research Fellow
Osservatorio Astronomico di Palermo, Italy (2005), Visiting Astronomer

Research interests:

Magnetospheric physics
X-ray and γ-ray astronomy
Infrared astronomy
Solar flares and CMEs
Solar coronal physics
Solar infrared/submillimeter astronomy
Solar radius
Solar energy distribution

Publications and presentations:

http://sprg.ssl.berkeley.edu/∼hhudson/publications.html
http://sprg.ssl.berkeley.edu/∼hhudson/presentations.html

Often-cited publications:

Hudson, H. S., *Solar flares, microflares, nanoflares, and coronal heating*, Solar Physics 133, 357 (1991)

Hudson, H. S. *Thick-Target Processes and White-Light Flares*, Solar Physics 24, 414 (1972)

Lin, R. P. & Hudson, H. S. *Non-thermal processes in large solar flares*, Solar Physics 50, 153 (1976)

Willson, R. C. & Hudson, H. S. *The sun's luminosity over a complete solar cycle* Nature 351, 42 (1991)

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I. Present Position: Professor of Physics and Head of Space and Atmospheric Physics Group, The Blackett Laboratory, Imperial College of Science Technology and Medicine.

II. Sample Publications

(1) Some Implications of the Nanoflare Concept, (**P.J. Cargill**), **Astrophys. J., 422**, 381-393, 1994.

(2) The Cooling of Solar Flare Plasmas: 1. Theoretical Considerations, (**P.J. Cargill**, J. T. Mariska and S. K. Antiochos), **Astrophys. J., 439**, 1034-1043, 1995.

(3) Diagnostics of Coronal Heating, (**P.J. Cargill**), in **Infrared Tools for Solar Astrophysics: What's Next?,** Ed. J. Kuhn and M. Penn, World Scientific Publishing, 17-29, 1995.

(4) Do Protons or Electrons Dominate Particle Acceleration in Solar Flares?, (**P.J. Cargill**), **EOS, Trans. AGU, 77(37),** 353-357, 1996.

(5) A Nanoflare Explanation for the Heating of Coronal Loops Observed by Yohkoh, (**P.J. Cargill** and J. A. Klimchuk), **Astrophys. J., 478,** 799-806, 1997.

(6) Critical Issues for Understanding Particle Acceleration in Impulsive Solar Flares, (J. A. Miller, **P.J. Cargill**, A. G. Emslie, G. D. Holman, B. R. Dennis, T. D. LaRosa, R. M. Winglee, S. G. Benka and S. Tsuneta), **J. Geophys. Res., 102**, 14631-14660, 1997.

(7) Theories of Heating and Particle Acceleration in the Solar Corona, (**P.J. Cargill**), **Adv. Space Res., 26(11)**, 1759-1768, 2000.

(8) Solar Flares: Particle Acceleration Mechanisms, (**P.J. Cargill**), in **Encyclopedia of Astronomy and Astrophysics**, Ed. P. Murdin, 2546-2549, 2000.

(9) Spectroscopic diagnostics of nanoflare-heated coronal loops, (J.A. Klimchuk and **P.J. Cargill), Astrophys. J., 553**, 440-448, 2001.

(10) Overview of SOHO-15 and thoughts about future directions, (**P.J. Cargill**), in **Proc. SOHO-15, ESA SP-575**, 324-330, 2004.

(11) Particle acceleration in stressed coronal magnetic fields, (R. Turkmani, L. Vlahos, K. Galsgaard, **P. J. Cargill** and H. Isliker), **ApJ Lett, 620**, L59-L62, 2005.

(12) Particle acceleration in stochastic current sheets in stressed coronal active regions (R. Turkmani, **P. J. Cargill**, K. Galsgaard, L. Vlahos and H. Isliker), **Astron. Astrophys**., in press, 2006.

(13) Particle acceleration in solar flares: the role of a turbulent global coronal magnetic field, (**P. J. Cargill**, L. Vlahos, R. Turkmani, K. Galsgaard and H. Isliker), Space Science Reviews, in press, 2006

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Relevant Employment and Educational History

Education

10/85 - 06/89	B.Sc. (Hons, 1st class), University of Glasgow
10/89 - 12/92	Ph. D., University of Glasgow (award, July 1993)

Employment

01/93 - 01/96	Postdoctoral Researcher, Utrecht University, The Netherlands
02/96 - 12/97	Research Fellow, European Space Agency, Noordwijk, The Netherlands
12/97 - 05/98	Honorary research fellow, Glasgow University (awaiting US visa)
05/98 - 03/00	Senior Physicist, Lockheed Martin Solar and Astrophysics Lab, California
04/00 - 09/00	PPARC-funded Postdoctoral Researcher, University of Glasgow
10/00 - 01/06	Lecturer in Astronomy, University of Glasgow
02/06-present	Reader in Solar Physics, University of Glasgow

Research Experience
Extensive experience in (1) the development of test-particle codes for acceleration and transport of charged particles in magnetised plasmas, with solar and astrophysical applications; (2) the analysis of data from instruments including *Yohkoh* SXT/HXT, SoHO/CDS/MDI/EIT and TRACE. Experience in mission operations: as (1) SOHO Science Operations Leader/Joint Observing Program leader (1 month) at the SOHO Experimenters Operations Facility at NASA/Goddard Spaceflight Center; (2) *Yohkoh* SXT Chief Observer at ISAS Japan (4 months), commanding and monitoring the telescope; (3) RHESSI Chief Observer, Berkeley, USA (2 weeks)

Publications Summary
40 refereed articles (including 3 book chapters), 29 conference proceedings, popular articles and book reviews.

Selected Research-Related Public Service Positions
PPARC Solar System Science Advisory Panel (Sept 2004 – Aug 2007)
PPARC Astrogrid Science Advisory Group (May 2003 -)
Advanced Technology Solar Telescope Science Working Group Member (Aug 2005 -)
American Astronomical Society Hale and Harvey Prize Committee (2003 -)
UK Science Definition Team for STEREO SECCHI instruments
Working Group Leader - RHESSI satellite workshop series (Oct 2002 -)
Board of European Physical Society Solar Physics Division (Sep 2002 -)
Editorial Board for the Journal 'Solar Physics' (2006-2009)
Co-editor, UK Solar Physics Newsletter

Teaching Activities

Summer School Teaching
PPARC summer courses in Solar and Solar-Terrestrial Physics, 2000, 2002-2005
April 2002 – 'Solar Magnetism' Spring School, Dwingeloo, the Netherlands
March 2006 – "The Physics of the Sun: The Active Sun on your Active Desktop", L'Aquila, Italy

University Teaching
Level 1 Stellar Structure and Evolution (Utrecht University, 8 hrs); Life in the Universe (10hrs); Observational Methods (8 hrs); Physics for Engineers Tutorials (5 hours); Solar System Physics I (6hrs)
Level 2 Stars and their Spectra (10 hrs)
Level 3/4 Stellar Structure and Evolution I (10 hrs); Instruments for Optical and Radio II(10 hrs); Natural and Laboratory Plasmas II (10 hrs)
Postgrad. Solar active regions and Flares (3 hrs)

Professional Affiliations
American Astronomical Society, American Geophysical Union, Royal Astronomical Society

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Professional Experience:

1976 – 1988: Research Associate, Tokyo Astronomical Observatory, University of Tokyo
1985 – 1986: Visiting Scientist at NASA's GSFC (NRC Research Associate))
1988 – 1991: Associate Professor, Faculty of Science, University of Tokyo
1992 – 1998: Professor, National Astronomical Observatory (of Japan) (NAOJ)
1996 – 1998: Director, Solar Facilities of the Nobeyama Radio Observatory (NRO), NAOJ
1996 – 1998: Head, Division of Solar Physics, NAOJ
1998 – present: Professor, ISAS (currently ISAS/JAXA)
1998 – 2004: Deputy Project Manager for *Yohkoh* satellite
1998 – present: Project Manager for Solar-B satellite
1999 – 2003: Director, Usuda Deep Space Center, ISAS
2000 – 2005: Director, Department of Basic Space Science, ISAS
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Published Papers:

Has published 94 papers in refereed journals (lead author in 13 of these) and 88 papers in edited books and proceedings (lead author in 23 of these), and edited as a coeditor 2 proceedings for international colloquia. Selected papers relevant for the proposal follow.

1. Radio and X-ray Observations of a Multiple Impulsive Solar Burst with High Time Resolution; **T. Kosugi**, Solar Phys. **71**, 91-105, (1981)
2. The Hard X-ray Telescope (HXT) for the SOLAR-A Mission; **T. Kosugi**, K. Makishima, T. Murakami, T. Sakao, T. Dotani, M. Inda, K. Kai, S. Masuda, H. Nakajima, Y. Ogawara, M. Sawa, & K. Shibasaki, Solar Phys. **136**, 17-36, (1991)
3. A Loop-Top Hard X-ray Source in a Compact Solar Flare as Evidence for Magnetic Reconnection; S. Masuda, **T. Kosugi**, H. Hara, S. Tsuneta, & Y. Ogawara, Nature, **371**, 495-497, (1994)
4. The Scaling Law between Electron Time-of-Flight Distances and Loop Lengths in Solar Flares; M. J. Aschwanden, **T. Kosugi**, H. S. Hudson, M. J. Wills, & R. A. Schwartz, Astrophys. J. **470**, 1198-1217, (1996)
5. Solar Flare Energy Release and Particle Acceleration as Revealed by Yohkoh HXT; **T. Kosugi**, in R. Ramaty, N. Mandzhavidze, and X.-M. Hua (eds.), "High Energy Solar Physics" (AIP Conf. Proc. 374), pp.267-274, (1996)

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1994 – 2002: Research Associate, Nagoya University
2002 – present: Associate Professor, Nagoya University

Societies:

- Astronomical Society of Japan
- Society of Geomagnetism and Earth, Planetary and Space Sciences
- American Geophysical Union
- International Astronomical Union

Research Topics:

Solar Physics: particle acceleration, plasma heating, magnetic reconnection

Published Papers:

Has published 38 papers in refereed journals. Selected papers relevant for the proposal:

Masuda, S., T. Kosugi, H. Hara, S. Tsuneta, and Y. Ogawara:
A Loop-Top Hard X-ray Source in a Compact Solar Flare as Evidence for Magnetic Reconnection,
Nature, 371, 495-497, 1994.

Masuda, S., J. Sato, T. Kosugi, and T. Sakao:
Spectral Characteristics of Above-the-Looptop Hard X-ray Source,
Adv. Space Res., 26, 493-496, 2000.

Somov, B. V., T. Kosugi, S. A. Bogachev, S. Masuda, and T. Sakao:
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01/2005	Ph. D., Catholic University of America
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1995	M. Sc., Physics, Nanjing Normal University, China
1992	B. Sc., Physics, Nanjing Normal University, China

Experience:

2001-01/2005	Research Assistant, NASA Goddard Space Flight Center
1999-2001	Teaching Assistant, Catholic University of America
1995-1999	Assistant Professor, Nanjing University of Posts & Telecom., China

Affiliations: American Astronomical Society - Solar Physics Division
American Geophysical Union

Selected Publications:

- Sui, L., Holman, G. D., White, S. M, Zhang, J., Multiwavelength Analysis of a Solar Flare on 2002 April 15, ApJ, 2005, 633, 1175

- Sui, L., Holman, G. D., Dennis, B. R., Determination of Low-Energy Cutoffs and Total Energy of Nonthermal Electrons in a Solar Flare on 2002 April 15, ApJ, 2005, 626, 1102

- Sui, L., Modeling Solar Flare Hard X-ray Images and Spectra Observed with RHESSI, Doctoral Dissertation, 2005, Catholic University of America

- Sui, L., Holman, G. D., Dennis, B. R., Evidence for Magnetic Reconnection in Three Homologous Solar Flares observed by RHESSI, ApJ, 2004, 612, 546

- Sui, L., Holman, G.D., Evidence of the Formation of a Large-scale Current Sheet in a Solar Flare", ApJ , 2003, 596, L251

- Holman, G. D., Sui, L., Schwartz, R. A., Emslie, A. G., Electron Bremsstrahlung Hard X-Ray Spectra, Electron Distributions and Energetics in the 2002 July 23 Solar Flare, ApJ, 2003, 595, L97

- Sui, L., Holman, G. D., Dennis, B. R., Sam K., Schwartz, R. A., Tolbert K, Modeling Images and Spectra of a Solar Flares Observed by RHESSI on Feb 20, 2002, Solar Physics, 2002 , 210, 245

CURRICULUM VITAE

PERSONAL DATA	
SURNAME	Tomczak
NAME	Michał
DATE OF BIRTH	August 5, 1960
ADDRESS	Astronomical Institute of the University of Wrocław ul. Kopernika 11, 51-622 Wrocław, Poland
TELEPHONE	~48 71 372 93 74
E-MAIL ADDRESS	tomczak@astro.uni.wroc.pl
MARITAL STATUS	Married (two children)
NATIONALITY	Polish
EDUCATION	
1984	Master of astronomy
1994	Ph.D.
2001	DSc. degree
EMPLOYMENT	
1984-1994	Assistant
1994-2003	Adjunct
2003-	Professor of the University of Wrocław
WORK INTEREST AND EXPERIENCE	Analysis and interpretation of X – ray observations of solar flares: flare morphology, energy release, particle acceleration and propagation, chromosphere evaporation, Neupert effect; X – ray plasma ejections; Coronal Mass Ejections. Lectures with students of astronomy and physics: basics of astronomy and astrophysics, image processing, solar physics. Director of the Astronomical Institute since 2002.
HONOURS	Several individual rewards of the Rector of the University of Wrocław; two rewards of the Polish Minister of Education
REFERENCES	Tomczak, M. 1997, A&A, 317, 223 Jakimiec, J., Tomczak, M., Falewicz, R., et al. 1998, A&A, 334, 1112 Tomczak, M. 1999, A&A, 342, 583 Tomczak, M. 2001, A&A, 366, 294 Mrozek, T. & Tomczak, M. 2004, A&A, 415, 377 Tomczak, M. 2004, A&A, 417, 1133 Tomczak, M. 2005, ASR, 35, 1732

CURRICULUM VITAE

ASTRID VERONIG

PERSONAL DATA

Nationality	Austria
Date of birth	7 September 1970
Academic degrees	PhD in Astronomy, with distinction M.Sc. degree in Astronomy, with distinction B.Sc. level in Astronomy, Physics, German Philology and Philosophy
Address	Institute of Physics/IGAM Karl-Franzens-Universität Graz, Universitätsplatz 5, A-8010 Graz Phone: +43 316 380 8609, Fax: +43 316 380 9825, Email: asv@igam.uni-graz.at
Current Position	Staff scientist at the Institute of Physics, University of Graz, Austria

SCIENTIFIC EDUCATION AND CAREER

1988	Start of the study of Astronomy, Physics, German Philology and Philosophy at the Karl-Franzens-Universität (KFU) Graz
Jan 1997 – Dec 1998	Research student at the Space Resarch Institute of the Austrian Academy of Sciences and the Institute of Astronomy/KFU
Apr 1997 & Nov 1998	Visiting fellowship Astronomical Observatory Trieste (Italy)
Feb – Dec 1999 & Nov – Dec 2000	Software-Scientist at the *Atmospheric Remote Sensing and Climate System Research Group*/KFU
Apr 1999 – Jun 2002	Research assistant at the FWF (Austrian Science Fund) project P-13653 PHY *Solar Variability and its Relevance for the Solar-Terrestrial Environment*
June 2002	PhD in Astronomy/Solar Physics, thesis: *Solar Flares – The Neupert Effect, the Chromospheric Evaporation Model and Coronal Heating*
Jul 2002 – Dec 2004	Post-doc scientist, FWF project P-15344 *A Solar Flare Recognition and Analysis System*
Oct 2002 – May 2003	Visiting fellowship Goddard Space Flight Center/NASA (Greenbelt, MD, USA)
Since Jan 2005	Staff scientist at the Institute of Physics/KFU

RESEARCH

Main Interests:

High-energy aspects of solar flares: X-ray observations and diagnostics, energy transport processes, flare energy budget, multi-wavelength investigations

Microflares and coronal heating

Flare-CME relationship, flare waves

International Collaborations:

Astronomical Institute, Academy of Sciences of the Czech Republic, Czech Republic
Astronomical Institute of the Slovak Academy of Sciences, Slovakia
Department of Physics & Astronomy, University of Glasgow, Scotland, U.K.
Hvar Observatory, University of Zagreb, Croatia
NASA Goddard Space Flight Center, MD, USA
Observatoire de Paris, Meudon, France

Publications:

Author/co-author of 25 papers in refereed journals and about 50 articles in conference proceedings, editor of 2 books

TEACHING

Courses on solar physiscs and computational methods at the University of Graz since 1999

AWARDS

Josef-Krainer-Förderungspreis 2003 (young scientists award for special achievement in Sciences)

Loukas Vlahos – Curriculum Vitae

Personal data **Name:** Vlahos, Loukas
Born: Levadia (Greece) 22-04-1949
Nationality: Greek
Marital status: married, two daughters
Languages: English, Greek
Present position: Associate Professor, University of Thessaloniki, Greece
Head of Department
Address: Dep. of Physics, University of Thessaloniki
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Studies	**Feb. 1976**	**MSc, University of Maryland, USA**
	April 1980	PhD, University of Maryland, USA
Employment	**1**980 – 1985	Research associate , University of Maryland, USA
	1985 – 1990	Assistant professor, University of Thessaloniki, Greece
	1990-– present:	Associate Professor , University of Thessaloniki, Greece

Research interests	Plasma, Solar Physics and High Energy Astrophysics
Scientific publications	100
PhD supervision	3 completed (as supervisor) , and 2 underway
Referee	for A&A, ApJ, MNRAS, Solar Physics

Teaching experience
- 40 courses between 1976 and today on various topics in (astro)physics, both at the introductory and advanced level;
- Supervision of 30 diploma theses;

-

Loukas Vlahos – recent articles

- *Particle acceleration in multiple dissipation regions,*
  Azner K., **Vlahos L.** Astroph. J. (Lett), 605, L69-L72 (2004)
- *On the Self-Similarity of Unstable Magnetic Discontinuities in Solar Active Regions,*
  Vlahos L., Georgoulis M. Astroph. J., 603, L61-L64 (2004)
- *Anomalous transport of magnetized electrons interacting with EC waves,*
  Tsironis C., **Vlahos L.**, Plasma Physics and Controlled Fusion, 47, 131-142 (2005)
- *Particle acceleration in stressed coronal magnetic fields,*
  Turkmani R., **Vlahos L.,** Galsgaard K., Cargill P. J., Isliker H.,
  Astroph. J. (Lett), 620, L59-L62 (2005)
- *Generation and saturation of large scale flows in flute turbulence,*
  Sandberg I., Isliker H., Pavlenko V. N., Hitzanidis K., **Vlahos L.,**
  Physics of Plasmas, 12, 32503 (2005)

Curriculum Vitae

Stephen M. White

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Education

Ph.D. in Theoretical Physics, University of Sydney, 1979–84

B. Sc. with honours, first class (majoring in Theoretical Physics, Physics and Pure Mathematics), Australian National University, 1975–78

Essendon High School (dux, 1974), Melbourne, Australia

Appointments

Associate Research Scientist, Department of Astronomy, University of Maryland, 1991-present

Faculty Research Associate, Department of Astronomy, University of Maryland, 1987–1991

Alexander-von-Humboldt Scholar, Max Planck Institut fur Astrophysik, Garching-bei-Munchen, West Germany, 1986–87

Faculty Research Associate, Astronomy Program, University of Maryland, 1985–86

Publications

123. *"Updated Expressions for Determining Temperatures and Emission Measures from GOES Soft X–ray Measurements"*, **S. M. White**, R. J. Thomas & R. A. Schwartz, Solar Physics, 227, 231, 2005.

121. *"High Cadence Radio Observations of an EIT Wave"*, **S. M. White** & B. J. Thompson, Ap. J. Lett., 620, L63, 2005.

115. *"Radio and Hard X–ray Images of High–Energy Electrons in a Compact X-class Solar Flare"*, **S. M. White**, S. Krucker, K. Shibasaki, T. Yokoyama, M. Shimojo & M. R. Kundu, Astrophys. J. Lett., 595, L111, 2003.

116. *"NoRH and RHESSI observations of the X 1.5 flare of April 21, 2002"*, M. R. Kundu, V. I. Garaimov, **S. M. White**, & S. Krucker, Astrophys. J., 600, 1052, 2004.

114. *"Quasiperiodic pulsations in a solar microwave burst"*, V. V. Grechnev, **S. M. White** & M. R. Kundu, Astrophys. J., 588, 1163, 2003.

March, 2006