Solar-C science meeting

Note: A lunch buffet will be provided in the Medical Building (where the meetings are held). However, dinner will be held in New Hall (where most participants are staying). Unfortunately, dinner in New Hall is strictly between 6 and 7pm so the meetings will have to finish at 6.30pm the very latest to ensure everyone gets dinner!

Special presentation:
A new view of the solar corona with HiC
(Jonathan Cirtain, NASA MSFC)

The purpose of the 2012 Solar-C science meeting is (1) to update the solar and helio-physics community the model Solar-C payloads and the key operation features as well as some programmatic aspect, and (2) to present and discuss selected critical science issues in terms of the specifications of the strawman payloads. The meeting is designed to share the concept of the mission in the helio-physics community, and to solicit criticisms and better ideas for the improvement of the Solar-C mission definition. The meeting consists of several invited presentations (approx. 20-25min) on selected key topics with following discussions and short contribution presentations (approx. 20-15min). The invited presentations shall include tutorial chapter. The discussion after each presentation shall be led by the speaker of the invited presentation. The announcement opportunity for the new start of the ISAS medium class mission is expected to be issued in the present fiscal year. In response to the AO, the ISAS Solar-C working group is determined to submit the Solar-C mission proposal. Therefore, the 2012 Solar-C science meeting to be held at the beautiful campus of the St. Andrews University is quite timely and important. This is an open meeting, and we welcome your active participation

Meeting organizers:
H. Hara (NAOJ), K. Ichimoto (Kyoto), H. Isobe (contact, Kyoto), S. Tsuneta (chair, NAOJ), S. Antiochos (GSFC), M. Carlsson (Oslo), B. De Pontieu (Lockheed), J. Cirtain (MSFC)

Date: 2012 August 13 (Monday) 8:30-12:30, 13:30-18:00
Venue: St. Andrews University

All the presentation files will be available at
http://hinode.nao.ac.jp/meeting/limited/SOLARC120813/
after the meeting.

Agenda
8:30-8:45
Opening Session: [Chair: Doschek]
- Message from **Prof. Junjiro Onoda**, director general of ISAS/JAXA to be read by
Dr. Munetaka Ueno, director of the ISAS space science program office
- Message from NASA Headquarters
- Message from **Dr. Luigi Colangeli,** Head, ESA Solar System Missions Division and
Coordinator, ESA Solar System Mission

8:45-9:45
Session 1: Current status of SOLAR-C mission [Chair: Tarbell]
8:45-9:00
(1) Solar-C mission **Saku Tsuneta**

(2) Model instruments baseline specification and key open issues (SUVIT, LEMUR, XIT)
9:00-9:15 SUVIT **Kiyoshi Ichimoto**
9:15-9:30 LEMUR **Toshifumi Shimizu**

9:30-9:45 XIT **Taro Sakao**

==9:45-10:00 Coffee break==

10:00-12:30
Session 2: 3D magnetic field configuration and its dynamic behavior [Chair: Ichimoto]
10:00-10:25
(1) Formation and sensitivity of SUVIT lines in a dynamic atmosphere **Mats Carlsson**
10:25-10:50
(2) Zeeman diagnostics of chromospheric lines **Hector Soscas-Navarro**

10:50-11:10
Contribution: The Polarization of the h and k Lines of Mg II for Exploring with SOLAR-C the Magnetism of the Upper Solar Chromosphere **Luca Belluzzi & Javier Trujillo Bueno**

11:10-11:35
(3) What is the best way to use the chromospheric field information in coronal field extrapolation? **Thomas Wiegelmann**

11:35-12:00
(4) Observational manifestations of magneto-acoustic wave propagation in solar magnetic structures **Elena Khomenko** (speaker: H. Socas-Navarro)

12:00-12:30: Discussion [Chair: Ichimoto]

==12:30-13:30 Lunch==

13:30-13:50 [Chair: Hara]

Special presentation: A new view of the solar corona with HiC **Jonathan Cirtain**

13:50-15:30 [Chair: Carlsson]
Session 3: Chromospheric/coronal heating and fundamental plasma processes

13:50-14:15
(5) Potential capability of SOLAR-C coronal instruments for coronal heating problem **Hirohisa Hara**
14:15-14:35
Contribution talk: Constraining solar atmospheric heating mechanisms by measuring the energy flow from photosphere to corona **Bart De Pontieu**
14:35-15:00
(6) Investigating fundamental physical processes by Solar-C **Hiroaki Isobe**

15:00-15:30 Discussion [Chair: Carlsson]

15:30-15:45 ==Coffee break==

15:45-16:15
Session 4: prediction of Solar Flares [Chair: Isobe]
15:45-16:15
(7) For the Prediction of Solar Eruptions **Kanya Kusano**
16:15-16:45
Session 5: Solar-C and societal effects of the Sun [Chair: Isobe]
16:15-16:45
(8) How can Solar-C address the issue on the long-term solar variability and the Earth climate? **Sami Solanki**

16:45-17:00 [Chair: Isobe]

Discussion on Sessions 4 & 5

17:00-18:00
Session 6: General discussion session
Discussion leader: Tsuneta/Cirtain

18:00 Adjourn

Abstract
(1) Solar-C mission **Saku Tsuneta**

(2) Model instruments baseline specification and key open issues (SUVIT, LEMUR, XIT)
The Solar UV-Visible-IR Observing Telescope for Solar-C **Kiyoshi Ichimoto**
(SUVIT) aims to measure the magnetic fields and plasma motions in the lower solar atmosphere from the photosphere to the uppermost chromosphere with the highest angular resolution and spectropolarimetric precesion ever achieved. The system consists of a ¯1.5m apearture Gregorian telescope and a focal plane instrument package equiped with narrowband/broadband filter imagers and a Littrow-type spectrograph. Our design goal of SUVIT is to realize the following performances to employ the advantage of the space (=ultimate observing site) to the utmost;
- diffraction limitted angular resolution (¯3 times of SOT/Hinode),
- large field of view that covers typical active regions (¯200"x200"),
- wide wavelength coverage including CaII 854nm/HeI 1083nm for chromospheric magnetic field measurements, MgII 280nm for observing chromospheric fine scale dynamics, and some visible photospheric lines,
- high precesion spectro-polarimetry (10^-4) that works fast enough to 'freeze' the chromospheric dynamic phenomena.

Current design concept including the instruments baseline specification, system configuration, optical layout, data aquisition scheme, etc. will be presented together with some key issues to be addressed.

LEMUR **Toshifumi Shimizu**

To achieve the science goals of the Solar-C mission, simultaneous spectroscopic measurements in emission lines and continua sampling all the temperature regions present in the solar atmosphere are required with resolving 0.3" spatial scale and effective area an order of magnitude higher than currently available instruments.

This measurements are realized by an EUV-FUV spectroscopic telescope, which has been proposed to ESA as LEMUR (Large European Module for solar Ultraviolet Research), i.e., a large EUV/FUV high-throughput telescope feeding a scientific payload of high-resolution imaging spectrographs and cameras. LEMUR will provide the crucial link between the photospheric and chromospheric magnetic field and plasma characteristics obtained by the SUVIT and the images of the corona provided by the XIT. For coronal heating studies, the following three issues should be well considered in the design; how well we can diagnose the temperature range showing the rapid morphological changes from the transition region to the corona; how well we can diagnose hot (5MK) coronal plasma with FeXVIII and others; and how well we can evaluate the energy and mass flows from observations. These issues will be discussed in the presentation.

XIT **Taro Sakao**

The X-ray/EUV telescope (XIT) for Solar-C provides imaging information of the corona where magnetic or kinetic energy from the lower atmosphere eventually dissipates, leading to heating of the corona as well as dynamic activities which could even influence

space environment around the Earth. The XIT currently under consideration consists of a normal-incidence (NI) EUV imager and/or a grazing-incidence (GI) soft X-ray imager with spectroscopic capability. The NI imager aims to achieve ultra-high-resolution imagery (0.2"-0.3" resolution) of the Sun's corona in EUV wavelengths with its emphasis on attaining phenomenological connectivity of the low corona with regard to the chromosphere and the transition region. Also, this telescope is expected to serve as a context imager for LEMUR. The present baseline is to employ three wavelength channels such as 171 A, 94 A and 304 A. For the GI imager, we wish to implement first-ever soft X-ray imaging-spectroscopic capability via photon-counting approach. The imager is to have mirror angular resolution of 1" and will have an energy range from ¯0.5 to ¯10 keV, thus covering a wide temperature range of the coronal plasmas (from ¯<1 MK to >30 MK) and should be particularly powerful in investigating high-temperature and/or high-energy aspects of coronal activities in the soft X-ray range, including magneto-hydrodynamic structures around the reconnection region in flares. Baseline specifications and primary scientific targets of XIT will be presented together with major open issues will be discussed.

Session 2: 3D magnetic field configuration and its dynamic behavior
(1) Formation and sensitivity of SUVIT lines in a dynamic atmosphere **Mats Carlsson**
The formation of the Mg II h & k, Ca II IRT and the He I 10830 lines in a dynamic atmosphere will be reviewed. Emphasis will be on the discovery space for SUVIT, especially on what we can learn about the dynamic chromosphere from observations in these lines and the importance of high spatial resolution. What is the advantage of a spatial resolution twice to three times higher than that of IRIS? Do we expect to see spatial features smaller than 100 km in size?

(2) Zeeman diagnostics of chromospheric lines **Hector Soscas-Navarro**

I will discuss some aspects related to how much physical information from the solar atmosphere can be retrieved from spectro-polarimetric observations of chromospheric lines. I will focus on diagnostics based on the Zeeman effect of lines such as the CaII infrared triplet. The reliability of inversion techniques will be explored by comparing inversion results to time-dependent 3D numerical simulations of the chromosphere.

Contribution:

The Polarization of the h and k Lines of Mg II for Exploring with SOLAR-C the Magnetism of the Upper Solar Chromosphere **Luca Belluzzi & Javier Trujillo Bueno**

Spectroscopy of the h and k lines of MgII with novel space telescopes, like the Interface Region Imaging Spectrograph (IRIS), will provide precious information on temperatures, flows and waves in the chromospheres and transition region of the Sun. However, the magnetic field information is encoded in the spectral line polarization, whose measurement with high spatial and/or temporal resolution requires the development of larger aperture telescopes such as SOLAR-C. Here we show the results of a detailed theoretical investigation whose goal is to understand the physical mechanisms that control the polarization across these resonance lines, and to achieve a realistic radiative transfer modeling in the presence of arbitrary magnetic fields. While the linear polarization of the MgII h and k lines is dominated by scattering processes and the Hanle effect, the circular polarization is controlled by the longitudinal Zeeman effect. We show that the joint action of partial frequency redistribution (PRD) and quantum interference between the upper J-levels of the h and k lines produces a complex fractional linear polarization (Q/I) profile with large polarization amplitudes in the blue and red wings, and a negative feature in the spectral region

between the two lines. In the core of the k line, PRD effects alone produce a triplet peak structure in the Q/I profile, whose line center amplitude (of the order of 1% in the absence of magnetic fields) is very sensitive to magnetic field strengths weaker than 100 G. In addition to the Hanle effect in the core of the k line, we also emphasize the diagnostic potential of the circular polarization produced by the Zeeman effect in the h and k lines, as well as in other MgII lines located in their wings. Our results strongly encourage the development of a UV spectropolarimeter for SOLAR-C, in order to systematically explore the magnetism of the upper solar chromosphere via the measurement and modeling of the polarization produced by the Hanle and Zeeman effects in the MgII h and k lines.

(3) What is the best way to use the chromospheric field information in coronal field extrapolation? **Thomas Wiegelmann**
With current instruments on board of Hinode and SDO the magnetic field vector becomes is routinely measured in the photosphere. Force-free magnetic field models are used to extrapolate these measurements upward into the solar atmosphere. A complication in this approach is that the plasma Beta in the photosphere is high and only becomes low in the upper chromosphere and corona. Consequently the force-free field assumption is questionable in the lowest atmospheric layers. We developed a method, called preprocessing, to estimate the chromospheric magnetic field vector from photospheric measurements and to derive consistent boundary conditions for a force-free coronal magnetic field modelling. Any chromospheric observations, like H-Alpha images and line-of-sight chromospheric measurements improve the estimation of the chromospheric field vector and lead to more reliable coronal magnetic field models. In principle it would be ideal to derive boundary conditions for nonlinear force-free field modelling

directly from measurements of the chromospheric magnetic field vector. It is important to understand influence of line formation in the corrugated atmosphere. Different formation heights of these lines could be well treated by a correlation analysis of Solar-C chromospheric measurements with the model field.

(4) Observational manifestations of magneto-acoustic wave propagation in solar magnetic structures **Elena Khomenko** (speaker: H. Socas-Navarro)
We discuss the signatures, produced by waves propagating in the magnetized solar atmosphere on polarization line profiles of different spectral lines.
We make use of simulations of observationally-driven magneto-acoustic waves in a sunspot model from Felipe et al. (2012) to synthesize the Stokes profiles of some often used spectral lines, as FeI 6302 A and IR CaII triplet. The later lines sample chromospheric heights. It is shown that waves produce a measurable effect into the amplitudes and displacement of the Stokes profiles.

Special presentation: **J. Cirtain A new view of the solar corona with HiC**
The High resolution Coronal Imager (Hi-C) is a Ritchey-Chretian telescope with a back-thinned CCD. The first launch of the instrument occurred 11 July 2012 from White Sands Missile Range, U.S.A. The instrument achieved 0.2 arcsecond resolution for a subset of all images collected at a wavelength centered at 193A. We will introduce the Solar-C advocate community to these unprecedented images and discuss the implications for the coronal instrumentation planned for Solar-C.
Session 3: Chromospheric/coronal heating and fundamental plasma processes

(5) Potential capability of SOLAR-C coronal instruments for coronal heating problem

Hirohisa Hara

The coronal heating problem, why the solar corona is heated to a million degree, has been tackled from many observations to reveal the fundamental heating process. I first review what has been observed in relation to the coronal heating and their interpretations. Secondly, I show what could be expected from the SOLAR-C coronal instruments under study. A question is whether the SOLAR-C instruments can measure quantities such as the energy flow to the corona and the energy dissipation in the corona. Another question is whether different heating mechanisms so far proposed are distinguished from observations of the SOLAR-C instruments.

Contribution talk:

Constraining solar atmospheric heating mechanisms by measuring the energy flow from photosphere to corona **Bart De Pontieu**

I will briefly review how Solar C's suite of instruments (SUVIT, LEMUR and XIT) will be able to provide constraints on various candidate heating mechanisms in the solar atmosphere. I will focus in particular on chromospheric heating, the role of spicules in providing hot plasma to the corona, and on characterizing the properties, propagation and dissipation of Alfven waves in the solar atmosphere.

The solar chromosphere forms a crucial interface region between the solar photosphere and the heliosphere. It requires over 30 times more energy than the corona and heliosphere combined. I will briefly illustrate how the combination of Solar C's high resolution spectropolarimetric measurements of the chromosphere and massively parallellized numerical simulations that incorporate non-equilibrium ionization and non-local radiative transfer will provide new insights into how the chromosphere is energized.

Spicules, at the interface between chromosphere and corona, have recently been suggested to play a role in the mass and energy balance of the corona. Yet their formation mechanism and impact on the corona remain unclear because of limitations in current observations. I will briefly illustrate how Solar C's high spatio-temporal resolution and excellent spectral coverage over a large field of view covering a wide range of temperatures will provide breakthroughs in our understanding of how the magnetic field mediates the formation of spicules, and how much hot plasma is provided to the corona in association with spicules.
Alfven waves have long been considered a prime candidate mechanism to not only transport magnetoconvective energy from the photosphere into the atmosphere, but to also drive coronal heating or accelerate the solar wind. Recently a variety of instruments have revealed the presence of Alfven waves throughout the solar atmosphere. Solar C's broad temperature coverage and high spatio-temporal resolution will for the first time allow a detailed accounting of the properties of these waves throughout the various temperature regimes, thus providing insight into where the waves are reflected, mode-converted and/or dissipated. This will constrain and test the viability of various wave heating models of the solar atmosphere.

(6) Investigating fundamental physical processes by Solar-C
Hiroaki Isobe
Understanding the elementary plasma processes, such as magnetic reconnection, waves, turbulence and particle acceleration, is the basis to understand the various solar phenomena in which they are involved. Since they are commonly found in other astrophysical, space and laboratory plasmas, the solar atmosphere can be also considered as a laboratory for the basic plasma processes. Many of the unresolved problems are related to the following issues: (1) how fast magnetic dissipation (reconnection) is realized in highly

conducting plasmas (Lundquist number ¯10^14) and (2) how the kinetic scales (¯1m) and the global scale (¯10000km) are coupled. Although the kinetic scales are still smaller than the achievable spatial resolution by many orders of magnitude, the high-resolution and high-cadence imaging and spectroscopy by LEMER and XIT will be strong tools to study the meso-scale (i.e., between global and kinetic scales) structure and dynamics that have not been investigated before. Furthermore, spectroscopic and polarimetric observation of the chromosphere by SUVIT will provide unprecedented data to study the physics in partially ionized plasmas. In this talk I will review the current status of "sun-as-a-plasma-lab" studies and discuss the perspective of Solar-C observation. Topics to be discussed include role of slow shocks and plasmoids in magnetic reconnection, distinguishing electron heating and ion heating in magnetic reconnection and wave dissipation, and effects of neutrals in chromosphere and prominences.

Session 4: prediction of Solar Flares

(7) For the Prediction of Solar Eruptions **Kanya Kusano**

Solar flares and coronal mass ejections, the most catastrophic eruptions in our solar system, have been known to affect terrestrial environments and infrastructure. However, because their triggering mechanism is still not sufficiently understood, our capacity to predict the occurrence of solar eruptions is substantially hindered. Even though various models have been proposed to determine the onset of solar eruptions, the types of magnetic structures capable of triggering these eruptions are still unclear. In this session, we discuss about how Solar-C can contribute to the development of algorithm for the prediction of solar eruptions. Recent studies suggest that both the accumulation of free energy and the trigger of reconnection have to be detected in order to achieve the deterministic forecast of solar eruptions. In particular, the

measurements of three-dimensional structure of twisted flux rope and the small scale disturbance of the polarity inversion line in the chromosphere are crucial for the former and the latter, respectively. Multi-layer magnetic field observation capability of Solar-C is promising for this purpose. We also discuss about what we should observe with Solar-C to implement the data-driven numerical simulations of solar eruptions.

Session 5: Solar-C and societal effects of the Sun

(8) Solar C and societal effects of the Sun **Sami Solanki**

The Sun varies on all time scales sampled so far and it influences the Earth on many of these. On short timescales of minutes to days, CMEs, flares, etc. are geoeffective, while on longer time scales the main contributor is thought to be the Sun's irradiance, which has been invoked to affect the Earth's climate (other solar quantities, such as the Sun's open magnetic flux or solar wind have also been invoked). This talk will concentrate mainly on the longer-term variability of the Sun, in particular its irradiance, and its influence on Earth.

There are a number of open and contentious questions in solar irradiance variability research, two very major ones being:

1. By how much has the solar irradiance increased from the Maunder minimum to the present day average?
2. How strongly does the irradiance in the UV (in particular between 200 and 400 nm) vary over the colar cycle?

For both these questions the answers provided in the recent literature differ by as much as an order of magnitude. Part of the problem lies therein that solar irradiance variability is driven mainly by small-scale magnetic fields at the solar surface, whose properties are insufficiently known, due to lack of observations (in particular in the near-UV) of sufficiently high resolution to resolve them completely. Solar-C has the potential to provide a breakthrough, by combining the following advantages:

a) being able to image in the UV,
b) reaching sufficiently high spatial resolution,
c) providing data under nearly constant conditions,
d) providing high-quality magnetic field data concurrently with the images.

Session 6: General discussion session

End