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Invited Talks

Planning coordinated observations with IRIS

Paul Boerner, Lockheed Martin Solar and Astrophysics Laboratory

Much of the power of IRIS comes from the flexibility of its operating modes, which enable observers to optimize the cadence, spatial and spectral coverage and resolution for a particular science target and coordination. In this talk, we present a practical overview of how best to make these choices in consultation with the IRIS science team in order to ensure successful coordinated observations.

Chromospheric heating

Mats Carlsson, Institute of Theoretical Astrophysics, University of Oslo

In this talk, we will present 3D "realistic" radiation-MHD simulations spanning the solar atmosphere from the convection zone to the corona, and synthetic observations calculated from the simulations. We will especially focus on what the comparison between the synthetic observations and observations from the IRIS satellite tell us about the heating of the solar chromosphere. We will also employ semi-empirical modelling and 1D radiation hydrodynamics models to further our understanding of the heating of the solar chromosphere.

Solar flares: unresolved issues in the IRIS era

Lindsay Fletcher, University of Glasgow

The emphasis of the IRIS mission on the solar chromosphere and transition region makes it a particularly valuable mission for the study of solar flares. The behaviour of the lower atmosphere during flares, though perhaps less dramatic than coronal eruptions and brightenings, is equally important in understanding their basic physics. Many of the questions we seek to answer now with IRIS are of long standing, particularly about energy transport and dissipation, and centre on whether the rich chromospheric diagnostics available can discriminate between competing scenarios. I will revisit these questions, the progress that has been made in recent years, and discuss the role that IRIS can play in the development of flare physics.

Atmospheric dynamics/heating from coordinated IRIS/Hinode/ SDO observations

Joten Okamoto, ISAS/JAXA

Coronal heating and the acceleration of the solar wind are unsolved problems in solar physics. The propagation of Alfven waves along magnetic field lines is one of the candidate mechanisms for carrying energy to large distances from the surface and heat the coronal plasma. Although such waves are actually damped in short spatial and temporal scales in observations, it is still unclear whether any significant dissipation occurs, or whether most of the energy is merely converted from one wave mode to another.

In this talk, we show prominence observations coordinated with IRIS, Hinode/SOT, and SDO/AIA to find evidence and clues of dissipation. In the high-spatial, temporal, and spectral observation, we found temperature increase in oscillating small-scale structures and a characteristic phase difference between the transverse motions of the threads and the line-of-sight velocities.

These observational features support a scenario in which resonant absorption takes place on the surface of oscillating prominence flux tubes in the corona. In this particular model, the transverse shear motions from the dipole flow are enhanced by the azimuthal flows in the resonant layer, a process that can lead to the Kelvin-Helmholtz instability. This mechanism deforms the tube's boundaries and generates thin current sheets and turbulence, leading to dissipation of the wave energy into heat. This observation identifies the locations and form of energy dissipation to propose the existence of numerous thin current sheets with enhanced turbulent regions on the oscillating threads.

In addition to the scientific results, we will touch coordinated operations and the challenges of aligning the various instruments, in particular IRIS and Hinode/SOT.

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Chromospheric and transition region dynamics

Luc Rouppe van der Voort, Institute of Theoretical Astrophysics, University of Oslo

IRIS, with its unique instrumental capabilities, has opened a new window on the solar chromosphere and transition region. Detailed analysis of the first season of observations has provided a number of new insights, for example the prevalence of torsional motions and jets, presence of small-scale loops at transition region temperatures and low-altitude hot explosions. However, further quantification of the overall impact of these phenomena poses a formidable challenge. Observationally, this is further complicated by the fundamental limitation posed by the one-dimensional spectrograph slit when probing processes that are highly dynamic on short time scales and are spatially coupled over a relatively large area. In this talk, I will discuss the key contribution from context observations for the interpretation of IRIS observations. For example, coordinated observations with the Swedish Solar Telescope provide high resolution (spatially, temporally and spectrally) imaging and polarimetry of the photosphere and chromosphere over a wide area around the IRIS slit.

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Coronal science with IRIS

Paola Testa, Harvard-Smithsonian Center for Astrophysics

IRIS provides unprecedented high spatial, temporal and spectral resolution observations of the solar outer atmosphere, mainly of the chromosphere and transition region. Joint with Hinode (XRT and EIS), and SDO/AIA, these observations cover from the upper photosphere to the corona. I will focus on the coronal science accessible with IRIS data and discuss how these observations, coupled with detailed HD and MHD modeling including chromosphere, transition region and corona, provide tight constraints on the mechanisms of energy transport and heating of the plasma to coronal temperatures.

Tutorials

Flare simulations with RADYN, *Joel Allred & Adam Kowalski*

Optically thick line formation and interpretation of IRIS observables, *Mats Carlsson & Jorrit Leenaarts*

Bifrost simulations, *Boris Gudiksen & Juan Martinez-Sykora*

IRIS data analysis, *Tiago Pereira*

Contributed Talks

Magnetic Energy Dissipation during the 2014 March 29 Flare: Consistent Measurements in the Transition Region and Corona with IRIS and AIA/SDO

Aschwanden M.J. and De Pontieu, B.

Solar and Astrophysics Dept, Lockheed Martin ATC

We calculated the time evolution of the free magnetic energy during the 2014-Mar-29 flare (SOL2014-03-29T17:48), the first X-class flare detected by IRIS. The free energy was calculated from the difference between the nonpotential field, constrained by the geometry of observed loop structures, and the potential field. We use AIA/SDO and IRIS images to delineate the geometry of coronal loops in EUV wavelengths, as well as, for the first time here, to trace magnetic field directions in UV wavelengths in the chromosphere. We find an identical evolution of the free energy for both the coronal and chromospheric tracers, as well as agreement between AIA and IRIS results, with a peak free energy of $E_{\rm peak}(t_{\rm peak}) \approx (26 \pm 5) \times 10^{30}$ erg, which decreases by an amount of $\Delta E_{\rm free} \approx (19 \pm 2) \times 10^{30}$ erg during the flare decay phase. The consistency of magnetic energy measurements from both coronal and chromospheric tracers represents an independent test and corroboration of the COR-NLFFF method, which is designed to detect vertical currents manifested in helically twisted loops.

Pinning Down Coronal Heating Properties in the Presence of Non-Equilibrium Ionization

Stephen Bradshaw (1), Paola Testa (2)

(1) Rice University, (2) Harvard-Smithsonian Center for Astrophysics

We examine the effects that non-equilibrium ionization can have on the evolution of light curves emitted by transition region and coronal ions during impulsive heating, and how this can lead to the plasma and heating properties being misdiagnosed. Furthermore, through detailed numerical and forward modeling we demonstrate how the effects of non-equilibrium ionization can be mitigated and accounted for so that robust diagnostics can be developed.

Spectroscopic observations of evolving flare ribbon substructure suggesting origin in current sheet waves

Sean R. Brannon (1), Dana W. Longcope (2), Jiong Qiu (3)

Montana State University

A flare ribbon is the chromospheric image of reconnection at a coronal current sheet. The dynamics and structure of the ribbon can thus reveal properties of the current sheet, including motion of the reconnecting flare loops. We present imaging and spectroscopic observations from the Interface Region Imaging Spectrograph (IRIS) of the evolution of a flare ribbon at high spatial resolution and time cadence. These reveal small-scale substructure in the ribbon, which manifest as oscillations in both position and Doppler velocities. We consider various alternative explanations for these oscillations, including modulation of chromospheric evaporation flows. Among these we find the best support for some form of elliptical wave localized to the coronal current sheet, such as a tearing mode or Kelvin-Helmholtz instability.

This work is supported by contract 8100002702 from Lockheed Martin to Montana State University, a Montana Space Grant Consortium fellowship, and by NASA through HSR.

Recurrent jets observed by IRIS and SDO/AIA

Nai-Hwa Chen, D. E. Innes

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Simultaneous observations from the Interface Region Imaging Spectrograph (IRIS), consisting of spectra and slit-jaw images (SJI), and the Atmospheric Imaging Assembly (AIA) give vital information on jet dynamics in different layers of solar atmosphere. A series of jets, from the small bipole pairs beside the trailing spot of active region 11991 are observed as they crossed the IRIS slit. The images show standard-type jets: collimated outflows with bright roots in AIA 304Å (chromosphere), SJI 1400Å (transition region) and AIA 211Å (lower corona). During some ejections outward-moving darkening clouds covered the jets in EUV but not in the FUV images. The IRIS Si IV spectra, which are sensitive to transition region plasma, show strong blue-wing but no red-wing enhancements in the line profiles of the ejecta for all recurrent jets indicating the outward flows without twist. At the base regions of the jets, the associated flux is converging, emerging and eventually cancelling throughout the recurrent-jet period.

Probing 10 MK plasma with IRIS and SDO/AIA

Mark C. M. Cheung

Lockheed Martin Solar & Astrophysics Laboratory

IRIS slit-jaw images (SJI) in the 1330Å channel occasionally show diffuse features that resemble hot coronal loops observed in EUV images of the corona. IRIS FUV spectra reveal these intensity features to be due to emission in the Fe XXI 1354Å line, which forms at log T/K ~ 7. We perform differential emission measure (DEM) inversions on SDO/AIA observations of these regions and find good morphological match between Fe XXI intensity features in IRIS SJI and AIA-derived emission measure maps around log T/K ~ 7. This comparative study serves as one of several validation exercises of our DEM inversion method. The result underlines IRIS and AIA combined offers powerful diagnostic potential for thermal studies of chromospheric and coronal plasmas.

Driving Jets and Spicules with Alfven Waves: The Idea That Won't Go Away

Steven R. Cranmer (1,2) and Lauren N. Woolsey (2)

(1) University of Colorado, Boulder, (2) Harvard-Smithsonian Center for Astrophysics

University of Colorado Boulder

The idea that solar spicules are caused by upward forces associated with Alfven waves has been around for at least 30 years. However, with the more recent discovery of smaller/faster (Type II) spicules and even faster network jets in the transition region (TR), it is worthwhile to re-examine this family of models. We made use of time-dependent reduced MHD models of Alfven-wave turbulence in the chromosphere and corona (i.e., the van Ballegooijen BRAID code) and we took particular notice of the intermittent amplitude variability in the mid-chromosphere. At a height of about 900 km above the photosphere, the wave properties seem to be optimal to produce a spike of nonlinear mode conversion into a longitudinal, compressive fluctuation. These waves have been shown to be able to "puff up" the effective density scale height of the chromosphere, and thus temporarily increase the height of the TR. Using an existing grid of models, we computed the time-dependent TR height as an instantaneous response to the varying wave amplitudes and scale heights. Apparent upward velocities and recurrence timescales measured from the model time series agree quite well with the observed properties of IRIS network jets and Type II spicules.

Automatic event detection in search for inter-moss loops in IRIS Si IV slit-jaw images

Brian Fayock (1), Amy Winebarger (2), Bart De Pontieu (3)

University of Alabama in Huntsville

The high-resolution capabilities of the Interface Region Imaging Spectrometer (IRIS) mission have allowed the exploration of the finer details of the solar magnetic structure from the chromosphere to the lower corona that have previously been unresolved. Of particular interest to us are the relatively short-lived, low-lying magnetic loops that have foot points in neighboring moss regions. These inter-moss loops have also appeared in several pass bands of the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory, which are generally associated with temperatures that are at least an order of magnitude higher than that of the Si IV emission seen in the 1400Å pass band of IRIS slit-jaw images. While the emission lines seen in these pass bands can be associated with a range of temperatures, the simultaneous appearance of these loops in IRIS 1400Å and AIA 171Å, 193Å, and 211Å suggest that they are not in ionization equilibrium. To study these structures in detail, we have developed a series of algorithms to automatically detect signal brightening or events on a pixel-by-pixel basis and group them together as structures for each of the above data sets. These algorithms have successfully picked out all activity fitting certain adjustable criteria. The resulting groups of events are then statistically analyzed to determine which characteristics can be used to distinguish the inter-moss loops from all other structures. While a few characteristic histograms reveal that manually selected inter-moss loops lie outside the norm, a combination of several characteristics will need to be used to determine the statistical likelihood that a group of events be categorized automatically as loops of interest. The goal of this project is to be able to automatically pick out inter-moss loops from an entire data set and calculate the characteristics that have previously been determined manually, such as length, intensity, and lifetime. We will discuss the algorithms, preliminary results, and current progress of automatic characterization.

Non-equilibrium ionization of abundant elements in Bifrost

Thomas Golding (1), Jorrit Leenaarts (2), Mats Carlsson (3)

Institute of Theoretical Astrophysics, University of Oslo

We present a Bifrost 2D radiation-MHD simulation with an equation of state (EOS) that includes the effects of non-equilibrium ionization of hydrogen and helium. The ionization state of these abundant elements affect the energy balance, and therefore the temperature, in the chromosphere and transition region - regions where the gas is partially ionized. We are interested in the time dependent ion populations and need to solve a set of rate equations for relevant atomic states. The radiative rate coefficients that go into these equations are given by frequency integrals over the intensity. In multidimensional geometry the general frequency dependent intensity is not obtainable due to limitations in available computing power. To overcome this difficulty we use a simplified treatment of the radiative transfer.

The resulting simulation shows that the mean structure of the atmosphere changes. We compare to a similar simulation carried out with an EOS based on local thermodynamic equilibrium (LTE). The bound-free heating in the non-equilibrium model gives a chromosphere with a mean temperature a few hundred kelvin more than for the LTE simulation. The amount of mass of the gas in the temperature range between 10 and 20 thousand kelvin is, compared to the LTE-run, about 15 times higher. If we compare to a run including non-equilibrium ionization of hydrogen, but not helium, the amount of mass is higher by a factor of 3.5. We present these findings and discuss the possible consequences they might have for diagnostics such as the C II 1334/1335 and Mg II h&k.

High cadence IRIS observations of evaporating flare ribbon sources

David Graham (1), Gianna Cauzzi (2), & Luca Zangrilli (3)

Osservatorio Astrofisico di Arcetri

We present new results from IRIS showing the dynamic evolution of chromospheric evaporation in a flare ribbon, with the highest temporal and spatial resolution to date. IRIS observed the entire duration of an X-class event using a 9 second cadence 'sit and stare' mode. As the ribbon brightened successively at new positions along the slit, a unique impulsive phase evolution was observed for about 80 individual spatial pixels in both coronal (Fe XXI) and chromospheric (Mg II) lines.

Each activation of a new footpoint kernel displays the same initial coronal up-flows of up to ~350 km/s, co-temporal and co-spatial with chromospheric downflows up to 40 km/s. This represents one of the most convincing examples of the development and evolution of chromospheric evaporation. Further, the temporal evolution of flows is remarkably similar between all slit pixel positions, leading to the conclusion that the time of energy deposition in any one footpoint is short - between 30-60 seconds - and occurs in an area of less than 2". These are important considerations for inputs to hydrodynamic flare models.

IRIS observations and simulation of explosive events in the transition region

L.-J. Guo (1), D. E. Innes (2), Y.-M. Huang (3), A. Bhattacharjee (4)

Max Planck Institute for Solar System Research

Small-scale explosive events are thought to be related to magnetic reconnection. While Petschek reconnection has been considered as a reconnection mechanism for explosive events on the Sun for quite a long time, the fragmentation of a current sheet in the high-Lundquist-number regime caused by the plasmoid instability has recently been proposed as a possible mechanism for fast reconnection. The actual reconnection sites are too small to be resolved with images but these reconnection mechanisms, Petschek and the plasmoid instability, have very different density and velocity structures and so can be distinguished by high-resolution line profiles observations. We use high-resolution sit-and-stare spectral observations of the Si iv line, obtained by the IRIS spectrometer, to identify sites of reconnection, and follow the development of line profiles. The aim is to obtain a survey of typical line profiles produced by small-scale reconnection events on the Sun and compare them with theoretical line profiles of reconnecting current sheets to determine whether reconnection occurs via the plasmoid instability or the Petchek mechanism. To make direct comparison with IRIS observations, we set up a numerical experiment with a current sheet under high Lundquist number and use the simulation result to construct synthetic line spectra of the current sheet. The synthetic line spectra agree qualitatively with IRIS observations, suggesting that the plasmoid instability is a possible explanation for observed line spectra of the explosive events.

In addition, we present observations of an eruptive loop near the edge of a sunspot. The IRIS slit is mostly parallel to the loop and rastering across the loop several times. The line spectra of the loop suggest that there are rotational flows in the loop, whose velocities are a fraction of the Alfvén speed (~ 300 km/s). Whenever the high-speed rotational flows are observed in the loop, the loop also has enhanced emission, suggesting the existence of heating. To explain the observations of this eruptive loop, we set up a numerical model of a loop being slowly twisted by photospheric circular motion at its footpoints. The loop is constantly twisted until it reaches the threshold of kink instability, and localized small current sheets form in the loop. As a result, magnetic energy is dissipated by the current sheets causing an increase in thermal and kinetic energy. Comparison between observations and simulation suggests that the proposed model is able to explain the IRIS observations of the eruptive loop.

Solar prominences with IRIS

Petr Heinzel (1), Brigitte Schmieder (2), Jean-Claude Vial (3)

Astronomical Institute, Czech Academy of Sciences

Solar prominences have been observed by IRIS since early days of its operation. High-resolution spectra were acquired for both quiescent as well as for more dynamical structures and they revealed several new features. The spectra of Mg II lines have been analyzed using 1D or 2D NLTE codes, taking into account the effects of PRD on the resonance h and k lines, flows (Doppler dimming effect) and the prominence-corona transition region structure. We will summarize these first results obtained with IRIS.

UV SPECTRA, BOMBS, AND THE SOLAR ATMOSPHERE

Philip Judge

HAO

A recent analysis of UV data from the Interface Region Imaging Spectrograph IRIS reports plasma “bombs” with temperatures near 8×10^4 K and with electron densities $> \sim 5 \times 10^{13} \mathrm{cm}^{-3}$ in the solar photosphere. This is a curious result, firstly because most bomb plasma pressures fall well below photospheric pressures, and secondly, UV radiation cannot easily escape from the solar photosphere. I re-analyze the UV data. Based on the IRIS line and continuum data and on physical properties of the solar atmosphere, I conclude, that the UV emitting plasma must originate at least 550 km above the continuum photosphere, in the low chromosphere or higher. The earlier analysis adopts assumptions in the plasma’s thermal structure for which there is no supporting data or physical argument. Future IRIS observations must include a multiplet of O IV near 134 nm to constrain the thermal structure.

Multi-Spacecraft Observations of A Transition Region Reconnection Event

Charles Kankelborg, Hannah Alpert, and Sarah Jaeggli

Montana State University

While flares are among the most consequential manifestations of solar activity, there is much to learn by observing smaller reconnection events in the solar transition region (TR). In particular, the TR environment offers high emission measure and a short line-of-sight integration, allowing detailed and relatively uncluttered direct observations of the reconnection process. We report a well-resolved reconnection event in the solar transition region observed by IRIS on April 15, 2014. The event is resolved spatially and temporally in Si IV slit jaw images as a series of brightenings in a ribbon of pre-existing loops. In the spectra we see a complex, evolving velocity field indicated by blueshifts, redshifts, and nonthermal line broadenings. An associated footpoint region, resembling a flare ribbon, shows a strong redshift in Si IV. Imaging from AIA shows nearly simultaneous manifestation in all bands, suggesting localized heating. Magnetic field measurements from Hinode and HMI provide insight into the magnetic configuration of this event. After considering several alternatives, we interpret the data as a direct observation of reconnection in a TR current sheet. Implications are discussed for models of reconnection in the solar atmosphere.

IRIS observation of penumbral microjets in the chromosphere and their transition region counterpart

Yukio Katsukawa, Yasuhisa Kimura, Takenori J. Okamoto, Theodore D. Tarbell

National Astronomical Observatory of Japan

High-resolution imaging observations revealed lots of small-scale transient dynamics taking place in a sunspot chromosphere, such as penumbral microjets. It has not been well understood yet how such dynamics are driven and how they influence heating in transition region (TR) and corona. One of the reasons is lack of high-resolution observations in TR and corona to detect possible TR and coronal counterparts of the small-scale dynamics in the chromosphere. IRIS is expected to provide unique data for this kind of study owing to high-resolution spectroscopic information covering both the chromosphere and TR. We ran IRIS-HINODE joint observations (IHOP 250) in several sunspots. Highest cadence Ca II filtergrams were taken with HINODE SOT simultaneous with spectro-polarimetric observations of the photosphere. IRIS obtained Mg II, C II, and Si IV spectra with a high-temporal cadence sit-and-stare program with Mg II and Si IV slit-jaw (SJ) imaging observations. We identified most of the penumbral microjets seen in the HINODE Ca II filtergrams have spatial and temporal coincidence with sub-arcsecond bright dots seen in the Si IV SJ images. This suggests that the penumbral microjets in the chromosphere have an impact to the upper atmosphere. Some of the Si IV bright dots happened at the slit position, providing temporal evolution of Mg II, C II, and Si IV spectral profiles. We are going to discuss a possible mechanism of the Si IV emission associated with the penumbral microjets based on the observation.

Mg II h & k Line Emission Observed During a Solar Flare

Graham Kerr (1), Paulo Simoes (2), Jiong Qiu (3), Lyndsay Fletcher (4)

University of Glasgow

The bulk of the radiative output of a solar flare is emitted from the chromosphere, which produces enhancements in the optical and UV continuum, and in many lines, both optically thick and thin. We have, until very recently, lacked observations of one of the strongest of these lines: the Mg II h & k resonance lines. We present a detailed study of the response of these lines to a solar flare. The spatial and temporal behavior of the integrated intensities, k/h line ratios, line of sight velocities, line widths and line asymmetries were investigated during an M class flare. We find Redshifts of ~20 km/s and line broadenings at times and locations of significant intensity enhancements. Redshifts are observed at the outer edge of the flare ribbon and the lines show also a blue asymmetry in the most intense sources. The characteristic central reversal feature that is ubiquitous in quiet Sun observations is absent in flaring profiles. Subordinate lines in the Mg II passband are observed to be in emission in flaring sources, brightening and cooling in sync with the resonance lines. This work represents a first step in identifying potential diagnostic information of the flaring atmosphere using these lines, and provides observations to which synthetic spectra from advanced radiative transfer codes can be compared.

Chromospheric Evaporation and Plasma Dynamics of a Solar Flare from IRIS Observations

Alexander G. Kosovichev (1,2), Viacheslav M. Sadykov (1-4), Santiago Vargas Dominguez (5), Ivan N. Sharykin (3), Alexei B. Struminsky (3,4), and Ivan Zimovets (3)

(1) New Jersey Institute of Technology, (2)NASA Ames Research Center, (3) Space Research Institute, Moscow, Russia, (4) Moscow Institute of Physics and Technology, (5) Observatorio Astronomico Nacional, Universidad Nacional de Colombia, Bogota, Colombia

NJIT

A moderate M1.0 class flare of 12 June, 2014 (SOL2014-06-12T21:12) was simultaneously observed by NASA's Interface Region Imaging Spectrograph (IRIS), and New Solar Telescope (NST) at the BBSO. Our analysis of the IRIS data in different spectral lines reveals strong redshifted jet-like flow with the speed of ~100 km/s of the chromospheric material before the flare. Strong nonthermal emission of the CII k 1334.5Å transition region line is observed at the beginning of the impulsive phase in several small (with a size of ~1 arcsec) points. It is also found that the CII k line is redshifted across the flaring region before, during and after the impulsive phase. A peak of integrated emission of the hot (10 MK) plasma in the Fe XXI 1354.1Å line is detected approximately 5 minutes after the integrated emission peak of the lower temperature CII k. A strong blueshift of the Fe XXI line across the flaring region corresponds to evaporation flows of the hot chromospheric plasma with a speed of 50 km/s. Additional analysis of the RHESSI data supports the idea that the upper chromospheric dynamics observed by IRIS has features of "gentle" evaporation driven by heating of the solar chromosphere by accelerated electrons and by a heat flux from the flare energy release site.

Evaporation flows in a bright kernel of a X1.6 flare observed on 2014 October 22 by IRIS, Hinode, and RHESSI

Kyoung-Sun Lee (1), Shinsuke Imada (2), Kyoko Watanabe (3), Yumi Bamba (4)

ISAS/JAXA

We investigated an X1.6 flare that occurred at the AR 12192 on 2014 October 22 at 14:02 UT observed by IRIS, Hinode, and RHESSI. Using those multiple observations, we found a bright kernel that showed an intensity enhancement in multi-wavelengths. Taking advantage of the spectroscopic observation of the IRIS and EIS, we measured Doppler velocities in the bright kernel through the chromosphere and corona. We selected O I, Si IV, Fe XII and Fe XXI lines from the IRIS and He II, Fe XII, Fe XV, and Fe XXIV lines from the EIS. Few minutes after the flare onset, emissions from hotter coronal lines, Fe XV –Fe XXIV (2-16 MK), show upflows (30-200 km s-1) while chromospheric temperature lines of He II and Si IV (~0.1 MK) found to be downflows (30-60 km s-1). The lowest temperature line of O I (~ 30000 K) has no significant Doppler velocity variation. In addition, white light and Hard X-ray emission were also detected at this kernel from SOT RGB bands, IRIS continuum and RHESSI. These results present that the upflows indicate the chromospheric evaporated flows and the downflows may be the compression due to the explosive evaporation. Furthermore, those upflows and downflows were observed more than an hour after the flare onset, we will discuss the temporal evolution of the Doppler velocity in different spectral lines using the high time cadence observation from IRIS.

Prominence plasma and magnetic field structure - A coordinated observation with IRIS, Hinode and THEMIS

Peter J. Levens(1), Brigitte Schmieder(2), Nicolas Labrosse(3), Arturo López Ariste(4)

University of Glasgow

During an international campaign in 2014, utilizing both space-based (IRIS and Hinode) and ground-based (THEMIS) instruments, we focused on observing prominences. We compare IRIS observations with those of Hinode (EIS and SOT) in order to build a more complete picture of the prominence structure for a quiescent prominence observed on 15 July 2014. THEMIS provides valuable information on the orientation and strength of the internal magnetic field. Here we find there is almost ubiquitously horizontal field with respect to the local limb, with possibly a turbulent component. The Mg II lines form the majority of our IRIS analysis, with a mixture of reversed and non-reversed profiles present in the prominence spectra. Comparing the differences between the Mg II data from IRIS and the Ca II images from SOT provides an intriguing insight into the prominence legs in these channels. We present plasma diagnostics from IRIS, with line of sight velocities of around 10 km/s in either direction along the magnetic loops of material in the front of the prominence, and line widths comparable to those found for prominences by previous authors (e.g., Schmieder et al. 2014).

Chromospheric Evaporation in an X1.0 Flare on 2014 March 29 Observed with IRIS and EIS

Ying Li (1), Mingde Ding (2), Jiong Qiu (1)

(1) Montana State University, (2) Nanjing University

Montana State University

Chromospheric evaporation refers to dynamic mass motions in flare loops as a result of rapid energy deposition in the chromosphere. These have been observed as blueshifts in X-ray and extreme-ultraviolet (EUV) spectral lines corresponding to upward motions at a few tens to a few hundreds of kilometers per second. Past spectroscopic observations have also revealed a dominant stationary component, in addition to the blueshifted component, in emission lines formed at high temperatures (~10 MK). This is contradictory to evaporation models predicting predominant blueshifts in hot lines. The recently launched Interface Region Imaging Spectrograph (IRIS) provides high resolution imaging and spectroscopic observations that focus on the chromosphere and transition region in the UV passband. Using the new IRIS observations, combined with coordinated observations from the EUV Imaging Spectrometer, we study the chromospheric evaporation process from the upper chromosphere to corona during an X1.0 flare on 2014 March 29. We find evident evaporation signatures at two flare ribbons separating from each other, suggesting that chromospheric evaporation takes place in successively formed flaring loops throughout the flare. Most importantly, we detect dominant blueshifts in the high temperature Fe XXI line, in agreement with theoretical predictions. In addition, we find that, in this flare, gentle evaporation is observed at some locations at the rise of the flare, and that at some other locations, explosive evaporation occurs near the peak of the flare. There is a conversion from gentle to explosive evaporation as the flare evolves.

The formations of the O I 135.56 nm and the C I 135.58 nm lines and their potential diagnostics

Hsiao-Hsuan Lin (1), Mats Carlsson (2), Jorrit Leenaarts (3)

ITA, UIO

The O I 135.56 nm and the C I 135.58 nm lines are covered by NASA/SMEX mission Interface Region Imaging Spectrograph(IRIS) and their behavior has also been reported during solar are in 1970s (Cheng et al. 1980). In this work we will report the potential diagnostics from both lines. The O I and the C I lines can both be good velocity diagnostics, and while they form at slightly different layers, the velocity gradient at their line forming region can also be detected. The line core intensity of both the O I and the C I lines are correlate with the electron density, and their line ratio [C I/O I] has inverse proportionality to the electron density. The non-thermal line width of the O I line is very sensitive to the velocity profile hence can also provide a constraint on the micro-turbulence.

IRIS Observations of Novel, Hybrid Prominence-Coronal Rain Complexes in Supra-arcade Fan Geometries

Wei Liu (1, 2), Patrick Antolin (3), Xudong Sun (2), Takenori Okamoto (4), Thomas Berger (5)

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Solar prominences and coronal rain are intimately related phenomena, both involving cooling condensation as part of the return flow of the chromosphere-corona mass cycle (e.g., Antolin et al. 2010, ApJ; Berger et al. 2011, Nature), yet with distinct morphologies and dynamics. Quiescent prominences consist of numerous long-lasting, filamentary, and often turbulent flows, while coronal rain is more transient and falls relatively faster along well-defined coronal loops. The physical reason behind such differences remains unclear. We report a novel type of geometry of hybrid prominence-coronal rain complexes in arcade-fan structures observed by IRIS and SDO/AIA, which may provide new insights to this question. The fan region above the arcade hosts a prominence sheet consisting of vertical threads with broad Mg II k/h line widths. As the prominence material descends to the arcade, it turns into coronal rain sliding down active region loops with line widths 2-3 times narrower. We propose that such different line widths indicate distinct plasma and magnetic conditions. The supra-arcade fan (cf., similar to those in flares; McKenzie 2013, ApJ) is likely situated in a current sheet, where the magnetic field is weak and the plasma-beta could be high, a favorable condition for producing turbulent flows like those filamentary prominence threads. In contrast, the underlying arcade likely has a stronger magnetic field and a low-beta environment, such that the coronal rain is guided along magnetic field lines. We will discuss the implication of these novel observations for identifying the probable mechanisms behind the morphological and dynamical differences between the solar prominence and coronal rain phenomena.

Mg II lines during the X-class flare on 2014 March 29 observed by the Interface Region Imaging Spectrograph (IRIS)

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Mg II lines represent one of the strongest emissions from the chromospheric plasma during solar flares. We study the Mg II lines in an X1-class flare on 2014 March 29 (SOL2014-03-29T17:48) observed by the Interface Region Imaging Spectrograph (IRIS). IRIS detected great intensity enhancements of the Mg II h and k lines, subordinate lines and several metallic lines at the footprints during this flare. Their light curves increase and peak contemporarily with the HXR emission, but decay more gradually. There are large red asymmetries in Mg II h and k lines after the peak time which might be caused by downward motions of the chromospheric plasmas and/or associated with cooling of flaring loops. We use non-LTE radiative transfer codes to synthesize the Mg II lines and we compare the computed spectra with the IRIS observations. We show how these lines depend on various flare conditions, and namely on characteristics of the electron beams during the impulsive phase of the flare.

Observations and simulations of nonequilibrium ionization effects on the Si IV 1402 angs to O IV 1401 angs ratio.

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Bay Area Environmental Research Institute

In observations, it is well know that the intensity of Si IV 1402Å is larger than that of O IV 1401Å, for instance, seen by IRIS. In addition, it is also known that these observations have a large discrepancy with CHIANTI and with synthetic observations from simulations. For the latter, the synthetic Si IV 1402Å intensity is much smaller than the synthetic O IV 1401Å intensity. The synthesis of 2D radiative MHD simulations taking into account time-dependent non-equilibrium ionization of silicon and oxygen reduces this discrepancy between observations and simulations. Moreover, we compare the emission of Si IV 1402Å and O IV 1401Å for various targets on the Sun using IRIS. We find that the intensity ratio between these lines is dependent on the intensity. This dependence is also reproduced in 2D radiative MHD models when one takes into account time dependent non-equilibrium ionization of silicon and oxygen. Note that this behavior complicates the studies of abundances or the constraints used for non-gaussian profiles, which have been proposed as alternative explanations for the observed ratio. We will use our time-dependent non-equilibrium ionization simulations to describe the physical mechanisms behind these observed properties.

The Mg II triplet lines as a diagnostic for heating in the lower chromosphere

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Institute of Theoretical Astrophysics, University of Oslo

The Mg II h&k lines are widely used to study the solar chromosphere, in particular with IRIS. In the same spectral region lies a triplet of subordinate lines, of which there are few studies. In this work we use 3D rMHD simulations and synthetic spectra to investigate how these triplet lines are formed. Formed in the lower chromosphere, we find that in quiet Sun the lines are overwhelmingly in absorption, with a small minority (~0.5% of the cases) in emission. Despite being rare, emission in these lines can be used as a diagnostic for strong temperature increases in the lower chromosphere. We find that emission usually takes place with temperature increases above 1500 K (between the line wing formation region and the lower chromosphere) and electron densities above 10^{18} m^{-3}. One can use a peak-to-wing intensity ratio to obtain a rough estimate of the temperature increase in the lower chromosphere. Additional information can also be inferred from the shape of the line profiles. Looking at IRIS observations we find both absorption and emission line profiles with similar shapes to the synthetic spectra, which suggests that these lines represent a useful diagnostic that complements the h&k lines.

Spectroscopic observation and modeling of a solar flare with IRIS and Hinode/EIS

Vanessa Polito (1), Kathy Reeves (2), Jeffrey Reep (3), Giulio Del Zanna (4), Helen Mason (4), Leon Golub (5)

University of Cambridge

In this work we present the study of a solar flare recently observed by both the Interface Region Imaging Spectrometer (IRIS) and the EUV Imager Spectrometer (EIS) on board Hinode. Spectroscopic observations are essential in order to study the physical parameters of the flaring plasma (i.e., flows, density, emissivity etc.) as a function of space and time. By combining the two high resolution spectrometers IRIS and Hinode/EIS, we can improve the diagnostic capabilities over a broader range of temperatures and spatial coverage in the solar atmosphere. We also use the 1D hydrodynamics code HYDRAD to discuss our observational results in terms of different heating mechanism scenarios. Understanding the physical mechanism responsible for flares at different scales, i.e., from nano to large size events, still represents one of the most challenging open problem in solar physics.

Modeling the chromospheric emission of the 29 March 2014 X1.0 flare using radiative hydrodynamic simulations

Fatima Rubio da Costa (1), Lucia Kleint (2), Vahe' Petrosian (3), Wei Liu (4)

Stanford University

The X1.0 flare on 29 March 2014 was well observed by IRIS and RHESSI among other space- and ground-based instruments. This allows us to estimate the variation of the spectral parameters of the accelerated electrons and to calculate the electron heating rate using the unified Stanford particle acceleration and transport code, which is then applied as input to the radiative RADYN code. This self-consistent method permits us to constrain the characteristics of the acceleration mechanism. We will present our simulation results as well as the evolution of several synthetic lines and its comparison with the IRIS observations.

Full Disk Variability of Mg II h

Donald Schmit (1), Bart De Pontieu (2), Scott McIntosh (3), Paul Bryans (4)

BAERI

The Mg II h and k doublet are two of the primary spectral lines observed by IRIS. These lines are tracers of the magnetic and thermal environment that spans from the photosphere to the upper chromosphere. In this work, we use a double gaussian model to fit the Mg II h profile for a full Sun mosaic dataset taken 24-Aug-2014. We use the ensemble of high-quality profile fits to conduct a statistical study on the variability of the emission line profile as it relates the magnetic structure and (center-to-limb) viewing angle. In addition to the differences that arise from magnetic structure, we also quantify the variability that occurs within each region that can be attributed to fine structure and temporal dynamics. While the average quiet sun profile contains a self-reversal, approximately 20% of plage profiles and a small fraction of internetwork profiles are observed to be pure emission lines with a single peak. We find that the intensity of the profile peaks are largely independent of the depth and width of the reversed core. The center to limb variation of the profile is similar the prediction of semi-empirical models of the solar atmosphere. This work can serve as a measurement baseline for detailed time-dependent studies of the dynamic chromosphere and a primary reference for solar and stellar spectral irradiance studies.

Largely shifted Fe XXI 1354.08 line in magnetic reconnection and chromospheric evaporation

Hui Tian, Gang Li, Kathy K. Reeves, John Raymond, Fan Guo, Wei Liu, Bin Chen, Nick Murphy

Harvard-Smithsonian Center for Astrophysics

IRIS has observed signatures of the Fe XXI 1354.08Å line in more than 100 flares. In many of them, the entire Fe XXI line are blueshifted by up to 350 km/s around the flare ribbons, which is consistent with the scenario of chromospheric evaporation in postflare loops. The blue shifts usually peak before the GOES soft X-Ray peaks, and generally correlate with the hard X-Ray fluxes as measured by RHESSI or approximated by the derivative of GOES fluxes. The standard flare model also predicts downflow (and upflow) plasma having a speed close to the Alfven speed. Yet, spectroscopic observations of such outflows, especially the downflows, are extremely rare. We report the detection of a greatly redshifted (~125 km/s along the line of sight) Fe xxi feature with a ~100 km/s nonthermal width at the reconnection site of a flare. The redshifted Fe xxi feature coincides spatially with the loop-top X-ray source observed by RHESSI and are interpreted as signature of downward moving reconnection outflow/retracting loops.

Quiescent prominence threads observed by IRIS in the h & k doublet of Mg II and comparison with profiles from NLTE models

J.-C. Vial (1), G. Pelouze (2), P. Heinzel (3), L. Kleint (4), U. Anzer (5)

Institut d'Astrophysique Spatiale

With the launch of the IRIS mission it is now possible to obtain high resolution prominence spectra and to begin to disentangle the contributions of the many (apparent or not) threads which structure prominences.

We compared unique spectral observations obtained in the Mg II h and k lines on a polar crown prominence with the radiative outputs from one-dimensional models built with NLTE codes (Heinzel et al. 2014). We characterize the profiles obtained with two calibration procedures, with attention paid to the absolute values, FWHM, line shifts and the ratio of k to h intensities. We also show that at the scale of less than one arcsec, one can detect line-of-sight velocities of about 10 km/s.

We find a range of static low pressure, low thickness, low temperature models which could fit k or h observed values but which cannot satisfy the low k/h observed value. We investigate whether these low values require the inclusion of horizontal flows. Another class of models including horizontal velocities, is also investigated where the pressure is kept low but thickness and temperature are increased up to the observed thickness value and up to 15 000 K, respectively.

An IRIS study of penumbral microjets

Gregal Vissers, Luc Rouppe van der Voort and Mats Carlsson

Institute of Theoretical Astrophysics, University of Oslo

Penumbral microjets are prime examples of short-lived, fine structure dynamics in the lower atmosphere of active regions, and in sunspot penumbrae in particular. So far, these events have only been studied in Ca II H and Ca II 8542Å, where they have been shown to display Ellerman bomb-type spectral profiles (i.e., dark line cores flanked - often asymmetrically - by inner wing enhancements), suggesting obscuration closer to line center by overlying canopy fibrils.

Using data from co-observation campaigns of the Swedish 1-m Solar Telescope (SST) with the Interface Region Imaging Spectrograph (IRIS), we investigate these microjets further and study their signature in the IRIS UV diagnostics, after positive identification in the SST Ca II 8542Å images. We find correlating signal in the IRIS slit-jaw images for many events, most clearly so in the Mg II k slit-jaws (and to a lesser extent in Si IV and C II images), while the response in the UV spectra generally appears to be modest. Here we present an analysis of their visibility, time evolution and spectral signature in several diagnostics, and discuss these results in light of earlier studies of penumbral microjets.

ALMA and IRIS - A combined new view of the solar chromosphere

Sven Wedemeyer (1,2), Tim Bastian (3), Hugh Hudson (4,5), Bart De Pontieu (6)

(1) University of Oslo, Norway, (2) European ARC, Czech node, Ondrejov, Czech Republic, (3) National Radio Astronomy Observatory, USA, (4) UC Berkeley, USA, (5) University of Glasgow, UK, (6) LMSAL, USA

University of Oslo, Norway

The Atacama Large Millimeter/submillimeter Array is an interferometric array consisting of 66 antennas located at an altitude of 5000 m in the Chilean Andes. While recent observations of "night-time" (i.e., non-solar) targets have already produced a number of amazing first results, the technically challenging solar observing modes are currently under development. We anticipate regular observations to begin in late 2016.

The solar radiation at wavelengths observed by ALMA originates from the chromosphere, where the height of the sampled layer increases with selected wavelength. The continuum intensity is linearly correlated to the local gas temperature in the probed layer, which makes ALMA essentially a linear thermometer. In combination with its impressive temporal, spectral, and (for the mm range) spatial resolution, ALMA opens up a new window on the Sun with a multitude of scientific applications, ranging from ultra-high cadence wave studies to flare observations.

Simultaneous observations with other telescopes would further strengthen this potential. In particular, IRIS would provide very complementary diagnostics, which - in combination with rich ALMA data sets - allows for unprecedented studies of the chromospheric structure, dynamics and energy balance.

Here we give an overview of ALMA's capabilities, potential science cases, and possible coordinated campaigns with IRIS.

Transition Region Dynamics and Density Measurements in a Well-Observed Flare

Jean-Pierre Wuelser

Lockheed Martin Solar & Astrophysics Lab

The M1.8 flare on 2014 February 13 was well-observed by IRIS, RHESSI, and SDO. The event featured a failed filament eruption. A narrow lane of transition region plasma underneath the rising filament showed oppositely directed high speed outflows that are suggestive of reconnection. O IV density measurements at the flare footpoints show the highest transition region density at the location and time of impulsive HXR emission.

The Chromosphere above the sunspot umbra as seen in the New Solar Telescope and Interface Region Imaging Spectrograph

V. Yurchyshyn, P. Goode, V. Abramenko, & A. Kilcik

(1) Big Bear Solar Observatory/NJIT & (2)Korea Astronomy and Space Science Institute

Recent observations of sunspot's umbra suggested that it may be finely structured at a sub-arcsecond scale representing a mix of hot and cool plasma elements. In this study we report observations from the New Solar Telescope (NST) of the umbral spikes, which are cool jet-like structures seen in the chromosphere of an umbra. Our analysis indicates that the spikes are not associated with photospheric umbral dots and they tend to occur above darkest parts of the umbra, where magnetic fields are strongest. The spikes exhibit up and down oscillatory motions and their spectral evolution suggests that they might be driven by upward propagating shocks generated by photospheric oscillations.

We analyze sunspot oscillations using Interface Region Imaging Spectrograph (IRIS) data and narrow-band NST images and found long term variations in the intensity of chromospheric shocks. Also, sunspot umbral flashes (UFs) appear as narrow bright lanes running along the light bridges (LBs) and clusters of umbral dots (UDs). Time series suggested that UFs preferred to appear on the sunspot-center side of LBs, which may indicate the existence of a compact sub-photospheric driver of sunspot oscillations. We find that the sunspot's umbra appears bright in IRIS images above LBs and UDs. Co-spatial and co-temporal SDO/AIA data showed that these locations were associated with bright foot-points of umbral loops suggesting that LBs may play an important role in heating these loops. The power spectra analysis showed that the intensity of umbral oscillations significantly varies across the umbra and with height, suggesting that umbral non-uniformities and the structure of sunspot magnetic fields may play a role in wave propagation and heating of umbral loops.

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Posters

Poster #1

Semiempirical Modeling of Sunspots

E. Avrett (1), H. Tan (2), E. Landi (3), W. Curdt (4), and J.-P. Wuelser (4)

Smithsonian Astrophysical Observatory

Semiempirical modeling attempts to match an observed spectrum by finding the temperature distribution and other parameters along the line of sight such that the calculated spectrum agrees with the observed one. We find such a model for a large sunspot umbra based on the SUMER sunspot spectrum from 668 to 1475Å. We compare the center-to-limb Mg II k line profiles observed with IRIS with the profiles calculated from this model. The corresponding quiet-Sun profiles agree, but the calculated sunspot profiles have substantially smaller intensities than observed. We find that including incident radiation from the surrounding active region can lead to agreement.

Poster #2

Quasi-Periodic Fluctuations and Chromospheric Evaporation in a Solar Flare Ribbon Observed by IRIS

J. W. Brosius (CUA at NASA/GSFC), A. N. Daw (NASA/GSFC)

Catholic University of America

IRIS obtained rapid cadence (9.4 s) stare spectra of an M7 flare ribbon in AR 12036 on 2014 April 18. Chromospheric emission lines exhibit quasi-periodic intensity and velocity fluctuations in the ribbon prior to the appearance of Fe XXI emission. The time separation between successive intensity peaks eventually decreases by a factor around 2 in the brightest portion of the ribbon. Blueshifts that correspond to upward velocities around 150 km/s are observed in Fe XXI line emission when it first appears, at which time the chromospheric lines appear to be at rest. The Fe XXI upward velocity generally decreases in time while its intensity increases, reaching values of zero at and after the times of maximum intensity. During this flare the Fe XXI line's profile is well fit with only one Gaussian component that is either wholly blueshifted or wholly at rest; no significant secondary blueshifted or redshifted components are observed. We discuss the implications of these observations for flare models.

Poster #3

Intensity and emission along the coronal loops -- from observations and simulations

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(1) Max Planck Institute for Solar System Research, (2) Indian Institute of Astrophysics

Spectral observations of the solar transition region (TR) and corona show broadening of spectral lines beyond what is expected from thermal and instrumental broadening. The remaining non-thermal broadening is significant (5-30 km/s) and correlated with the intensity. Here we study spectra of the TR Si IV 1403Å line obtained at high resolution with the Interface Region Imaging Spectrograph (IRIS). We find that the large improvement in spatial resolution (0.33 arcsec) of IRIS compared to previous spectrographs (2 arcsec) does not resolve the non-thermal line broadening which in most regions remains at pre-IRIS levels of about 20 km/s. This invariance to spatial resolution indicates that the processes behind the broadening occur along the line-of-sight (LOS) and/or on spatial scales (perpendicular to the LOS) smaller than 250 km. Both effects appear to play a role.

Comparison with IRIS chromospheric observations shows that, in regions where the LOS is more parallel to the field, magneto-acoustic shocks driven from below impact the TR and can lead to significant non-thermal line broadening. This scenario is supported by MHD simulations. While these do not show enough non-thermal line broadening, they do reproduce the long-known puzzling correlation between non-thermal line broadening and intensity. This correlation is caused by the shocks, but only if non-equilibrium ionization is taken into account. In regions where the LOS is more perpendicular to the field, the prevalence of small-scale twist is likely to play a significant role in explaining the invariance and correlation with intensity.

Poster #4

Why Is Non-thermal Line Broadening of Spectral Lines in The Lower Transition Region Independent of Spatial Resolution?

B. De Pontieu, S. McIntosh, J. Martinez-Sykora, H. Peter, T.M.D. Pereira

LMSAL

Spectral observations of the solar transition region (TR) and corona show broadening of spectral lines beyond what is expected from thermal and instrumental broadening. The remaining non-thermal broadening is significant (5-30 km/s) and correlated with the intensity. Here we study spectra of the TR Si IV 1403Å line obtained at high resolution with the Interface Region Imaging Spectrograph (IRIS). We find that the large improvement in spatial resolution (0.33 arcsec) of IRIS compared to previous spectrographs (2 arcsec) does not resolve the non-thermal line broadening which in most regions remains at pre-IRIS levels of about 20 km/s. This invariance to spatial resolution indicates that the processes behind the broadening occur along the line-of-sight (LOS) and/or on spatial scales (perpendicular to the LOS) smaller than 250 km. Both effects appear to play a role.

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Poster #5

Outreach Spectrograph for IRIS (OSIRIS)

Fernando Delgado (1), Sarah Jaeggli (2), Charles C. Kankelborg (3)

Montana State University, Bozeman

Astronomy and physics-related public outreach events typically include solar-telescopes that observe the sun through H-alpha filters. The Outreach Spectrograph for IRIS (OSIRIS) provides an alternative way of view the sun during such outreach events. It is intended to observe and resolve the emission profiles of the sodium D lines (589 nm – 589.6 nm), and the H-α line (656.3 nm). OSIRIS will allow volunteers to engage the general audience in discussions about the composition of the sun and stars, and the basic physical concepts of Kirchoff's radiation laws. OSIRIS will be an attachable unit to Newtonian telescopes with equatorial mounts. The spectrograph will be in a compact in-Littrow configuration to minimize its size and will use a CMOS camera connected to a laptop via USB for viewing and recording.

Poster #6

Enhancement of Hydrogen emission during flare onset and main phase with radiative-hydrodynamic simulations and their diagnostics from multiwavelength observations

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Department of Mathematics and Information Sciences, University of Northumbria, UK

In this study we present a comparison of the evolution of flare emissions in IRIS observations during the onset and main phase with updated radiation-hydrodynamical simulations (Zharkova and Kobylinsky 1993). Recently, Heinzel and Kleint (2014) detected Balmer Continuum enhancement observed with IRIS during the X1 flare SOL2014-03-29 appearing during the flare onset. Further analysis has been conducted of this and other data, in order to find the mechanisms displaying such enhancements including radiation, thermal and non-thermal processes by electron beams. Beam characteristics for these events are derived from the RHESSI spectra. The resulting continuum enhancements and line emission features are compared to, and explained using the predictions derived from radiation-hydrodynamical models of elementary flare structures in the presence of electron beams with the characteristics derived from observation. The numerical method is enhanced by using updated forms of the source functions and higher precision processes, in order to produce more accurate solutions. Additionally, the solutions are expanded over a time series to explain the evolution of Lyman, Balmer and Pashen continuum enhancements and line profile features throughout the duration of a flare. The emission enhancements at the flare onsets are explored for the occurrences of sunquakes.

Poster #7

Why is IRIS important to solar wind research?

Haihong Che

UMD/GSFC

IRIS observations of chromosphere and transition region can play an important role in the solar wind research. Different from the traditional picture of solar wind in which the hot plasma in the outer layer of the corona is steadily pushed into the space by its pressure, new observations of solar corona (Feldman & Landi, JGR, 2005, Marsch, ILWS workshop, 2006) discovered that solar wind originates very close to the solar surface and escapes into interplanetary space along the open field lines. These open field lines are believed to be produced through nanoflares—magnetic reconnection of small magnetic loops. Emerging of magnetic loops dominate the physical processes in the chromosphere and transition region. Increasing observations of magnetosphere of the Earth and solar flares found that energetic electron beams are produced during magnetic reconnection, and data from STEREO, IRIS, sounding rocket experiments and radio observations suggest that nanoflares can accelerate electron beams to kinetic energies of keV and higher. Based on these observations, our recent studies (Che et al., PRL,112, 2014 and ApJL, 795, 2014) show that the nonlinear evolution of two-stream instability, driven by nanoflare-produced keV electron beams can produce an isotropic high energy tail in the electron velocity distribution function, as well as kinetic Alfven wave and whistler wave turbulence in the inner corona. We show that the heated plasma can escape along the open field lines and determine the global thermal properties of solar wind, advecting the kinetic turbulence into the interplanetary space and produce a background solar wind field fluctuations on kinetic scales. This new model successfully bridges the existing observations on the solar wind kinetic turbulence, solar wind heating and acceleration. However, our current knowledge of nanoflares limits our deep understanding on how nanoflares shape the global properties of solar wind. IRIS observations of nanoflares will enable us for the first time to answer questions such as 1) where nanoflares occur? 2) Is magnetic reconnection the mechanism for nanoflares to release energy? 3) can and how nanoflares produce energetic particles? 4) what is occurrence rate of nanoflares?

Poster #8

Quiet sun magnetic field evolution observed with Hinode SOT and IRIS

Catherine Fischer (1), Nazaret Bello González (2), Reza Rezaei (3)

Kiepenheuer Institut für Sonnenphysik

We have calibrated and aligned a co-spatial and co-temporal 3 hour quiet sun time series taken with the Hinode and IRIS satellites. Hinode SOT observed full Stokes profiles of the Fe I 630 nm line pairs with the Spectro-polarimeter (SP) scanning an ~9 arcsec region with a cadence of around 70 seconds. The Broadband Filter Imager (BFI) observed in Ca II H with a cadence of around 30 s which was complemented by magnetograms and dopplergrams constructed from Na D I 589.6 nm measurements observed by the Narrowband Filter Imager (NFI). The IRIS satellite recorded slit jaw images in the passband of 2832Å (112 s cadence), 1400Å (23 s) and with a cadence of 19 s at 2796Å. The spectrograph recorded spectra in several passbands including the Mg II k and h lines performing a 2 step raster with a 9.6 s step cadence.

We study magnetic elements seen in SP and NFI data undergoing a magnetic field intensification process accompanied by the development of bright points in the Ca II H images which we identify as convective collapse events. In addition we study pairs of magnetic elements involved in flux cancellation. The magnetic elements pass the IRIS slit at different stages of these processes. The IRIS Magnesium lines spectra are analyzed to investigate the response of the chromosphere to the magnetic events in the photosphere below. We present the temporal evolution of the atmospheric parameters from the photosphere to the transition region during these occurrences and compare the results to convective collapse and flux cancellation models.

Poster #9

A Steady-state Supersonic Downflow in the Transition Region above a Sunspot Umbra

T. Straus (1), B. Fleck (2), V. Andretta (1)

(1) INAF/OAC, (2) ESA

ESA

Sunspots have been an area of intense research ever since Hale's discovery of strong magnetic fields in these structures. Here we report on the detection of a particular sunspot phenomenon: a small-scale (~ 1.5 Mm), supersonic downflow of about 90 km/s in the transition region above a light-bridged sunspot umbra. The observations were obtained with the Interface Imaging Region Spectrograph (IRIS) on 2 September 2013 from 16:39 to 17:58 UT in the sunspot of AR 11836 near disk center. Slit length and width were 68" and 0.166", respectively. The cadence of the time series was 3 s, with exposure times of 2 s. The observations comprise nine spectral windows: C II 1336Å, Fe XII 1349Å, Cl I 1352Å, O I 1356Å, Si IV 1394Å, Si IV 1403Å, NUV at 2786Å and 2831Å, and Mg II h and k 2796Å. The spectral window containing the Si IV 1403Å line also includes the O IV 1400Å, 1401Å, and 1405Å lines, the last one blended with a S IV line. The downflow shows up as red-shifted, well-separated "satellite" lines of the Si IV and O IV transition region lines and is remarkably steady over the observing period of nearly 80 min. The satellite lines do not participate in the 3-min shock wave Doppler maneuvres of the main component. The downflow is not visible in the chromospheric lines, which only show an intensity enhancement at the location of the downflow. The density inferred from the line ratio of the redshifted satellites of the O IV lines ($N_e = 10^{10.5\pm0.3}$ cm^{-3}) is only a factor 2.5 smaller than the one inferred from the main components ($N_e = 10^{10.9\pm0.2}$ cm^{-3}). Consequently, this implies a substantial mass flux ($\sim 4 \times 10^{-7}$ g cm^{-2} s^{-1}), which would evacuate the overlying corona on time scales of the order of 10 s. We interpret these findings as evidence of a stationary termination shock of a supersonic siphon flow in a cool loop rooted in the central umbra of the spot. Such stationary shocks have been predicted for siphon flows in hot coronal loops by Noci (1981).

Poster #10

Hydrogen Balmer continuum detected by IRIS during solar flares

Petr Heinzel (1), Lucia Kleint (2), Sam Krucker (3)

Astronomical Institute, Czech Academy of Sciences

There exists a long-lasting effort to detect the hydrogen Balmer recombination continuum around the Balmer limit during solar flares. However, this spectral region exhibits rather complicated behavior where the blue continuum is blended by many metallic lines and the Balmer-continuum emission itself is difficult to disentangle. On the other hand, with IRIS we were able to detect this continuum on the background of extended Mg II photospheric wings, where the intensity contrast is large enough. We show the results of our analysis of the IRIS NUV spectra and correlate the continuum light curves with HXR ones from RHESSI. Radiometrically calibrated IRIS spectra are compared with NLTE simulations of the continuum formation during the precipitation of the electron beams.

Poster #11

Flux emergence observed by IRIS spectrometer

Petr Heinzel (1), Brigitte Schmieder (2), Michalina Grubecka (3), Arkadiusz Berlicki (3), Pierre Mein (2)

Astronomical Institute, Czech Academy of Sciences

A flux emergence in the active region AR 111850 was observed by several instruments on the ground and in space on September 24, 2013, during a few hours (09:24 UT-12:04 UT). Interface Region Imaging Spectrograph (IRIS) provided a large raster of spectra covering the whole active region (800 arcsec x 120 arcsec) and SJI in 280 nm channel. The Multi-channel Subtractive Double Pass spectrograph (MSDP) operating at the Meudon solar tower and THEMIS/MTR provided Hα images and spectra. The brightenings occurring in the wings of the Mg II and Hα lines, at different locations in the active region during the emergence, are interpreted as due to the presence of a hot plasma in the photosphere or lower chromosphere (Ellerman bombs).

1D non-LTE models with a « hot spot » can explain the enhancement of intensities in the observed lines.

Poster #12

Correcting for long term trends in the IRIS flat fields

Sarah A. Jaeggli, Jean-Pierre Wulser, Paul Boerner, Hui Tian, Steven Saar, Bart De Pontieu

Montana State University

Increasing dose accumulation burn-in is an expected effect of the exposure of a detector to light of short wavelengths, while exposure to longer wavelengths can reverse sensitivity losses. For IRIS, repeated exposure has resulted in decreased sensitivity and a noticeable burn-in pattern in the lines of C II in the FUV spectrograph and in the FUV slit-jaw, while the NUV spectrograph and slit-jaw channels show increased sensitivity. In this poster we examine the long term changes the flat field patterns for the IRIS sit-jaw imager and spectrographs based on monthly calibration sequences. We discuss how the spatially dependent sensitivity changes due to burn-in can be taken into account to improve the calibration of intensity.

Poster #13

Study of umbral flashes in the chromosphere

Jayant Joshi

Institute for Solar Physics, Stockholm University

We studied umbral flashes in a sunspot observed in the Ca II 854.2 nm line observed with the Swedish 1-m Solar Telescope (SST). The spectro-polarimetric observations were carried out at twelve wavelength positions in the Ca II line with the cadence of $\sim$ 30 seconds and the whole observation sequence last for 2 hours and 38 minutes. For retrieving physical parameters we performed NLTE inversions of the Ca II line using the NICOLE inversion code. We studied phase relations between oscillations at two atmospheric heights in the temperature as well as in the Doppler velocities.

Poster #14

Dynamical Horizontal magnetic fields in a sunspot light bridge observed with Hinode and IRIS

Ryuichi Kanoh(1), Toshifumi Shimizu(2)

The University of Tokyo

In sunspot light bridges (LBs), horizontal magnetic fields often appears and induces various activities, such as brightening, high-speed material flows and plasma ejections. However, we have not understood their short-term temporal evolution and counterparts in the upper atmosphere. For above reasons, we present co-observation of Solar Optical Telescope (SOT) on board Hinode satellite and Interface Region Imaging Spectrograph (IRIS) mission to determine the short-term dynamic properties of a LB with highly inclined magnetic fields. Our analysis reveals that once the horizontal fields emerge, asymmetric Stokes V profiles are identified at each edge of the horizontal fields. One shows blueshift with opposite polarity compared with surroundings, and another one shows supersonic redshift with same polarity compared with surroundings. These pairs imply that there are rapid flows along the horizontal fields. Additionally, according to the orientation of the horizontal fields, we conclude that the horizontal fields have omega-loop structure and are from under the photosphere. Moreover, there is a relationship between existence of the horizontal fields and Si IV ($10^{4.9}$ K) intensity enhancement. These features are not observed without the horizontal fields. In this presentation, we will discuss about mechanisms of these features.

Poster #15

Study of propagating processes of MHD waves from the photosphere to the corona with IRIS and Hinode

Ryuichi Kanoh(1), Shinsuke Imada(2)

The University of Tokyo

MHD waves may play important role in supplying energy from the photosphere to the corona. There have been lots of detections of MHD waves in the solar atmosphere. Next important step is to couple the photosphere, chromosphere, transition region and corona by means of waves.

In this study, we focus on network region observed with Hinode and IRIS simultaneously on 2015 February 12. By using SOT/SP data, we performed Fast Fourier Transform, and identified isolated common peaks in the power spectra of the line-of-sight (LOS) magnetic flux and the LOS velocity. The oscillation periods are located around 5 min. Although there are other possibilities like opacity effect, one interpretation is that these features are caused by MHD waves driven by p-modes. On the other side, we also identified periodic signal in LOS velocity and line strength in IRIS data. In this poster, we will show relationship between Hinode data and IRIS data and discuss their interpretation.

Poster #16 (e-Poster)

Observational study of Ca II K and Mg II h/k line formations in various solar conditions

Tomoko Kawate, Kiyoshi Ichimoto, Satoru UeNo, Ken'ichi Otsuji, Tetsu Anan, Akiko Tei, Takahito Sakaue

Queen's University Belfast

Since July 2013, IRIS has been providing high resolution UV spectroscopic data, which are novel for solar observations. Though the UV spectral data obtained by IRIS contains a lot of information of the dynamics of chromosphere and transition region, interpreting the data is not straightforward because they are highly complex.

On the other hand, since Ca II H/K can be observed from ground, it is much easier to access and there are plenty of preceding observations. Mg II h/k show similar characteristics to Ca II H/K in their transitions, line shapes, and formation temperature, though the formation height of Mg II h/k is a little higher than Ca II H/K because of its higher opacity due to the higher abundance.

Our motivation is to understand the formation of Mg II h/k by comparing its manifestation with Ca II H/K, and to examine what is the unique information from Mg II h/k compared with Ca II H/K in the actual solar phenomena. We performed spectroscopic observations with Domeless Solar Telescope at Hida Observatory of Kyoto University in Japan simultaneously with IRIS. The data are spectroheliograph in Ca II K, H-alpha and Ca II IR 8542Å of quiet, plage, sunspot and flaring regions.

With the obtained data set, we compared the spectral manifestations of Mg II h/k and Ca II K and found that the relative intensity of Mg II h/k and Ca II K cannot be explained with a single Planck function at the wavelengths of the two lines. Our results suggest that the temperature of formation heights of these lines is different and the difference changes systematically with the conditions of the atmosphere.

Poster #17

Simultaneous observation of a hot explosion by NST and IRIS

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(1) Korea Astronomy and Space Science Institute (KASI), (2) Big Bear Solar Observatory (BBSO), (3) Department of Physics and Astronomy, Seoul National University , (4) Korea University of Science and Technology, (5) Korea Astronomy and Space Science Institute

In this study, we present the simultaneous observation of the so-called hot explosion in the cool atmosphere of the Sun made by New Solar Telescope (NST) of Big Bear Solar Observatory (BBSO) and Interface Region Imaging Spectrograph (IRIS) in space. The data obtained during joint IRIS-NST-DST observation on 30 July 2014. Additionally we examined the SDO data also. The explosion started around 19:20 UT and lasted for about 20 minutes. Our findings are as follows: (1) the IRIS brightening related to the explosion was observed in 3 channels of slit-jaw images; (2) IRIS spectra show highly blue- and red-shifted wing profiles for C II, Si IV, Mg II lines; (3) from NST Fast Imaging Solar Spectrograph (FISS) data, wing brightening occurred in H-alpha and Ca II bands and related surge was observed in both bands; (4) from SDO data, we observed the brightening in AIA 1600Å images but there were no brightenings in AIA 171Å and 304Å images; (5) regarding the hot explosion, we found a significant variation of positive flux from HMI and NST Near IR Imaging Spectropolarimeter (NIRIS) data. These observations suggest that the hot explosion contain high up and downward moving plasma and occur by magnetic reconnection in the lower atmosphere of the Sun. In addition, we will give detailed implications of the hot explosions in the solar atmosphere.

Poster #18 (e-Poster)

Radiative MHD Simulations of Formation and Dynamics of Internetwork Magnetic Field and Its Effects in the Solar Chromosphere

Irina Kitiashvili

NASA Ames Research Center

The ubiquitous internetwork magnetic field plays a crucial role in the energetics and dynamics of the solar atmosphere. However, the nature and properties of this small-scale and rapidly evolving field are not well understood. I will present new results of 3D radiative MHD simulations, which show that the internetwork (IN) field can be a result of a local dynamo action in a shallow subsurface layer of quiet-Sun regions. The simulations reveal the physical mechanism of the IN field, its subsurface and atmospheric structure, and the energy spectrum. The simulation results are compared with recent observational results from Hinode and IRIS.

Poster #19

One-dimensional numerical simulations and observations of MHD wave propagation in the solar chromospheric regions with strong magnetic fields

Shunya Kono, Takaaki Yokoyama, Shin Toriumi, Yukio Katsukawa

The University of Tokyo

It has been suggested that Alfven waves, generated in the photosphere and propagating along a magnetic flux tube, can carry enough energy to the upper atmosphere and the dissipation of the waves is one of the possible mechanisms to heat the solar atmosphere. In this presentation, we report on our numerical and observational works of the MHD wave propagation in the solar chromosphere with strong magnetic fields.

First, we performed one-dimensional numerical simulations of MHD waves that propagate along a strong, open flux tube in the chromosphere. In order to investigate the dissipation of Alfven waves, we studied the top and bottom boundaries of the simulated chromosphere to know how the reflection occurs to trap the Alfven waves in the chromosphere. As a result, 60--70% of the incident Alfvenic pulse waves with frequencies of 10--100 mHz are reflected at the transition region and most of reflected waves from the transition region penetrate into the convection zone without being reflected at the bottom of the photosphere. The result suggests that it is important to take the energy flux going from the top and bottom boundaries of the chromosphere into account for the dissipation of Alfven waves in the chromosphere. In addition to that, in the case where the initial velocity amplitude of Alfven wave is set to be 1.0 km/s, the compressible waves generated by the nonlinear effect may have enough energy to heat the chromosphere.

Second, we analyzed the observational data of sunspot oscillations obtained through the co-observation campaign of the IRIS and Hinode (HOP250). In both the UV images and chromospheric spectra, it was found that the oscillations propagate from umbra to penumbra with a deceleration.

The apparent speeds decrease from about 50 km/s in umbra and 10 km/s in penumbra respectively. The Fourier analysis of the chromospheric and photospheric data revealed that, in the umbral region the peak of power spectrum at the photosphere appears at frequency of 2 mHz. The wave modes with such frequency are cut off at the certain height in the chromosphere and the peaks of power spectrum at the upper chromospheric height appear at frequency of 6 mHz and 2 mHz in the umbra and the penumbra, respectively. These difference in propagating speeds and peak frequencies between the umbra and the penumbra may be caused by the topological effect of the open magnetic field lines if we assume the waves propagate along the magnetic field lines.

Poster #20 (e-Poster)

New Spectral Constraints from IRIS on Models of White-Light Flare Emission

Adam F. Kowalski (1, 2), Adrian N. Daw (2), Joel C. Allred (2), Gianna Cauzzi (3) ((1) University of Maryland College Park, (2) NASA Goddard Space Flight Center, (3) National Solar Observatory & INAF)

University of Maryland College Park & NASA/GSFC

The ultraviolet and optical (white-light) continuum emission during the impulsive phase of solar flares often represents the majority of the radiated flare energy, yet its spectral energy distribution remains largely unconstrained. Broad wavelength coverage spectra at near-ultraviolet and blue wavelengths obtained over 30 years ago and have led to the conclusion that optically thin hydrogen recombination radiation is the dominant component to solar flare radiation, but the brightest kernels were poorly sampled spectrally. Recent Sun-as-a-star observations of solar flares with SOHO/VIRGO suggest there to be a significant T~9000 K blackbody component as well, similar to the broadband color distribution observed during much more energetic flares on other stars. We use NUV and FUV data of the brightest solar flare kernels observed by IRIS to place constraints on the presence of this hot blackbody component in large solar flares. The results for the March 29th, 2014 X-class flare are compared to continuum spectra and chromospheric condensation velocity predictions from the next generation of radiative-hydrodynamic models.

Poster #21

Waves and Flows in Prominence Barbs

T.A. Kucera (1), L. Ofman (2), K. Knizhnik (3), B. Schmieder (4)

NASA GSFC

We discuss waves and flows seen in and around prominence barbs. These include observations from 2012 October 10 and 2012 February 14 taken with Hinode/SOT showing vertically propagating waves. The fluctuations of Ca II intensities in the 2012 October observations show evidence for nonlinearity, and we have modeled them as nonlinear magnetosonic waves using 2D and 3D numeric MHD models. Similar waves are present in a prominence barb observed with IRIS. We will also discuss EUV Doppler velocities associated with prominence barbs observed by Hinode/EIS.

Poster #22 (e-Poster)

Simultaneous IRIS and CRISP observations of the 2014 September 6 M-class flare

David Kuridze

Astrophysics Research Centre, Queen's University, Belfast

The M1.1 solar flare was observed by IRIS and the CRISP imaging spectropolarimeter at the Swedish Solar Telescope (SST) on September 6, 2014. The CRISP dataset includes imaging spectroscopy in Hα 6563Å, Ca II 8542Å and Fe I 6302Å with a 12 second cadence for a complete scan. We examine the flare kernel/ribbon morphology and evolution at various positions across the line profiles. The data can be used as a proxy to derive the temporal and spatial energy distribution during the event. Imaging spectropolarimetry in the Fe I line reveals the evolution of the photospheric magnetic field throughout the 2 hour observing sequence.

Poster #23 (e-Poster)

The Response of the Solar Chromosphere and Transition Region to a Coronal Rain Event

Hannah Kwak (1), Jongchul Chae (2)

Seoul National University, Seoul, Korea

We report that a strong downflow event caused three-minute oscillations in the solar atmosphere. Our observations were carried out by using the Fast Imaging Solar Spectrograph (FISS) of the 1.6 meter New Solar Telescope (NST) and the Interface Region Imaging Spectrograph (IRIS). Our main findings are as follows: (1) The strong downflow was seen at the Hα absorption line at first, and then appeared at the Si IV and C II emission lines. It seems that the characteristics of the downflow are consistent with a coronal rain event. (2) After the event, oscillations of velocity were identified in the chromospheric lines and transition region lines. (3) The amplitudes of oscillations were 2 km/s at Mg II line and 3 km/s at C II and Si IV lines and decreased with time. (4) The period of the oscillation was 2.67 minutes at first, but gradually increased with time. Our findings are in agreement with Chae & Goode (2015) 's theory that of acoustic waves generated by a disturbance in a gravitationally-stratified medium.

Poster #24

Imaging Spectroscopy of the Upper Chromosphere and Transition Region with IRIS

Scott W. McIntosh, Paul Bryans, Bart De Pontieu

HAO/NCAR

We use novel rapid rasters of multiple targets taken by IRIS to explore the dimensionality of the connection between the upper chromosphere and transition region. These observations allow us to better establish the connectivity (or to express the historical difficulty in establishing the connectivity) between the lower and outer solar atmosphere. These modes of operation of IRIS can provide strong requirements on the next generation of spectroscopic investigations of the upper chromosphere, transition region and low corona.

Poster #25 (e-Poster)

IRIS Observations of ``Propagating Coronal Disturbance'' (PCD) Footpoints

Scott W. McIntosh, Bart De Pontieu, Ineke De Moortel

HAO/NCAR

The Interface Region Imaging Spectrograph (IRIS) provides an unparalleled opportunity to explore the (thermal) interface between the chromosphere, transition region, and the coronal plasma observed by the Atmospheric Imaging Assembly (AIA) of the Solar Dynamics Observatory (SDO). The SDO/AIA observations of a coronal loop footpoint show strong recurring upward propagating signals - "propagating coronal disturbances" (PCDs) with apparent speeds of order 120 km/s. That signal has a clear signature in the slit-jaw images of IRIS in addition to identifiable spectral signatures and diagnostics in the Mg II h (2803Å) and Si IV (1403Å) lines. Line profile asymmetry analysis reveals that strong asymmetries are present in both spectral lines that are co-temporal, co-spatial and exhibit a similar high speed with the coronal counterparts. These high speed signatures are consistent with episodically driven flows from the chromosphere into the corona. Further, in analyzing the Mg II h line, we are able to observe the presence of magnetoacoustic shock waves that are also present in the vicinity of the coronal loop footpoints. We see there is enough of a correspondence between the shock propagation in Mg II h, the evolution of the Si IV line profiles, and the PCD evolution to indicate that these waves are also an important ingredient for PCDs - at least for the location studied here - such that waves and flows both appear to be contributing to the signals observed.

Poster #26 (e-Poster)

Statistical Study of jets emanating from the periphery of Active Region

Sargam Mulay (1), Durgesh Tripathi (2), Giulio Del Zanna (3), Helen Mason(4)

University of Cambridge, UK

We report the observations of 20 UV/EUV jets observed by Solar Dynamic Observatory (SDO) at the periphery of the active regions (ARs) during June 2010 to June 2013. We classify them as standard jets and blowout jets according to their morphological features. Using multiwavelength observations from AIA and HMI, we calculated the velocities and studied the magnetic activity. We also discussed the role of Hard X-ray source associated with them and their association with the non-thermal type III radio bursts using RHESSI and WIND-WAVES observations respectively. We performed a Differential Emission Measure (DEM) analysis using the code developed by Hannah and Kontar (2012) to get the temperature structure at the jet footpoint and along the jet spire.

Poster #27

IRIS-Hinode collaborative observations: Prominence rotation?

Joten Okamoto

ISAS/JAXA

Prominences are very exciting structures observed in high-spatial resolution. Since Hinode was launched in 2006, we have found many kinds of motions in prominences and they provide us new insights on the solar physics such as vertical oscillations of fine threads (e.g., Okamoto et al. 2007) and dark hot bubbles and plumes (e.g., Berger et al. 2011). In addition to the high-spatial imaging, IRIS started to take spectral data of small scale structures from 2013. It is expected to improve our understanding of prominences and their motions.

In this presentation, I would like to introduce peculiar motions of fine structures in a prominence observed by Hinode/SOT and IRIS. The bundle of fine structures suddenly appeared in SOT/Ca images, and moved upward with a speed of 10-45 km/s. After reaching at some height, they flowed horizontally along magnetic field lines. At the maximum height, IRIS spectra show double components that consist of static profiles of around 0 km/s and strong blueshifts of 20-50 km/s. This phenomenon might be explained by unwinding motions as a result of magnetic reconnection between prominence fields and newly-emerging helical magnetic fields. However, the observational features look different from those of jets and surges, which are considered to be caused by reconnection.

Poster #28

3D motions of spicules and propagation of waves observed with IRIS and Hinode

Fuko Baba (1), Joten Okamoto (2), Saku Tsuneta (2), Yukio Katsukawa (3)

(1)U. Tokyo(2)ISAS/JAXA(3)NAOJ

University of Tokyo

It is considered that the propagation of Alfven waves transports energy into corona. High-resolution observations by Hinode/SOT have revealed dynamical motions and waves that are one of the candidates to heat the chromosphere and the corona. For further understanding of the energy transfer and the role of waves in the chromosphere, we performed coordinated observations of spicules by Hinode and IRIS. These imaging and spectral data provide us useful information of chromospheric dynamics.

We analyzed a spicule that elongates along the slit and detected a line-of-sight (LOS) oscillation that are interpreted as a wave propagating with a period of 120 sec and a phase speed of 500 km/s in the Mg II k spectra. This spicule also had fluctuation on the plane of the sky (POS) with a period of 130 sec in the Ca II H images. The phase difference of LOS and POS oscillations is about 180 degree. We investigated the 3D motions of this spicule and concluded the motion is rotation of the spicule or torsional and swaying. We also show another example of a spicule suggesting torsional motion.

Poster #29

Computer Vision Code for Microflare Detection: Preliminary Results

Bala Poduval (1), C.E. DeForest (2)

(1) Space Science Institute, (2) SWRI

Automated Microevent-finding Code (AMC) is a computer vision code for detecting micro flares in solar UV/EUV images. It is built on SWAMIS (The Southwest Automatic Magnetic Identification Suite), developed earlier by DeForest and Lamb (Ap J, 666, 2007) for feature tracking. Presented here are the vision code and the preliminary results of a study of microflares detected in the multispectral SDO/AIA data. Also presented are the associated magnetic field properties deduced using the SDO/HMI magnetograms.

Poster #30 (e-Poster)

Physics of outflows near solar active regions

Daniel Price (1), Youra Taroyan (2)

Aberystwyth University

Hinode/EIS observations have revealed outflows near active regions which remain unexplained. An outflow region observed by the EUV Imaging Spectrometer (EIS) that appears slightly redshifted at low temperatures and blueshifted at higher temperatures is presented. We conduct simulations and use those to create synthetic line profiles in order to replicate the observed line profiles. The results of the forward modelling support a scenario whereby long loops consisting of multiple strands undergo a cyclical process of heating and cooling on timescales of approximately 80 min.

Poster #31

Diagnostic potential and IRIS observations of CII 1335 Å line

Bhavna Rathore (1) , Mats Carlsson (2), Jorrit Leenaarts (3), Tiago Pereira (4) and Bart De Pontieu (5)

Institute of Theoretical Astrophysics, University of Oslo

The strongest lines in the IRIS FUV1 window come from singly ionized carbon, at wavelengths of 1334-1335Å. The lines are formed in the upper chromosphere and lower transition region and show great promise for the diagnostics of the dynamic upper chromosphere. These resonance lines are formed in the optically thick, non-LTE regime. Three-dimensional radiative magnetohydrodynamic models give a unique insight into their formation. In this work we study the formation of these C II lines to explore their diagnostic potential. Using synthetic spectra from 3D models we study how the thermodynamic state of the atmosphere influences the spectral profiles. We also compare the synthetic profiles with observations from IRIS.

Poster #32

On the temporal evolution of spicules observed with IRIS, SDO, and Hinode

L. Rouppe van der Voort, H. Skogsrud, B. De Pontieu, T. Pereira

Institute of Theoretical Astrophysics, University of Oslo

Spicules are ubiquitous fast moving jets observed off-limb in strong chromospheric spectral lines, usually in Ca II H or H-alpha. Recent multispectral studies of spicules indicate they are the site of heating to at least transition region temperatures. With the recent launch of IRIS and the use of the SDO and Hinode, we currently have the unique opportunity to study spicules in multiple passbands at the same time from a seeing free environment. This enables us to study the thermal evolution of spicules. A recent study showed that spicules appear in several chromospheric and transition region spectral lines and it was found that the spicules continue their evolution in hotter passbands after they fade from Ca II H. In this follow up paper we answer some of the questions that were raised in the introductory study. We find that a typical spicule, in quiet Sun regions, has a visible component in all the mentioned spectral passbands in addition to C II 1330Å. The Ca II H component typically fades away and the evolution continues in the other passbands. Most Ca II H spicules that fade leave a faint trace in space-time diagrams. We find that Ca II H spicules are more similar to Mg II 2976Å spicules than the introductory study reported. From a sample of 54 spicules, we find that 44% of the Si IV 1400Å spicules are brighter toward the top. 56% of the spicules show an increase in Si IV 1400Å emission when the Ca II H 3968Å component fades. We find several examples of spicules that fade from other passbands than Ca II H 3968Å, and we note that if a spicule fades from a passband, it also fades from the passbands with lower average formation temperature. We discuss what these new multi-spectral results mean for the classification of type I and II spicules.

Poster #33

Multi-thermal Energies of Solar Flares

Danny Ryan (1), Markus Aschwanden (2), Paul Boerner (2), Amir Caspi (3), James McTiernan (4), Harry Warren (5)

(1) Royal Observatory, Belgium, (2) Lockheed Martin Solar and Astrophysics Laboratory, (3) Southwest Research Institute, (4) University of California, (5) Naval Research Laboratory

Measuring energy partition in solar eruptions is key to understanding how different processes affect their evolution. In order to improve our knowledge on this topic, we are participating in a multi-study project to measure the energy partition of 400 M- and X-class flares and associated coronal mass ejections (CMEs). In this study we focus on the flare thermal energies of 391 of these events. We improve upon previous studies in the following ways: 1) We determine thermal energy using spatially resolved multi-thermal differential emission measures (DEMs) determined from AIA (Atmospheric Imaging Assembly) rather than relying on the isothermal assumption; 2) We determine flare volumes by thresholding these DEM maps rather than relying on single passband observations which may not show the full flare volume; 3) We analyze a greater number of events than previous similar studies to increase the statistical reliability of our results. We find that the thermal energies of these flares lie in the range $10^{26.8}$—10^{32} erg. These results are compared to those of Aschwanden et al. (2014) who examined a subset of these events. They determined the dissipated non-potential magnetic energy which is thought to be the total energy available to drive solar eruptions. For the 171 events common to both studies, we find that the ratio of flare thermal energy to dissipated magnetic energy ranges from 2%—40%. This is an order of magnitude higher than previously found by Emslie et al. (2012). This may be because Emslie et al. (2012) had to assume the amount of non-potential magnetic energy, or that they relied on the isothermal assumption to determine flare thermal energies. Future studies in this project will include examining the radiative energies of the corona and chromosphere. For flares where observations are available, we hope to use IRIS in combination with other instruments to better understand the importance of these radiative processes relative to the global partition of energy. The improved results found here and in future studies in this project will thus help us better understand the role played by flare thermal and radiative processes in dissipating the overall energy of solar eruptions.

Poster #34

Lower Atmospheric Signatures of Solar Flares Associated with Seismicity

Jamie Ryan (1), Sarah Matthews (2), Lucie Green (3)

University College London, Mullard Space Science Laboratory

Local helioseismic events or sunquakes are the propagation of acoustic waves in the sub-photosphere in response to solar flares. The progenitors of sunquakes are thought to be either shocks, radiative backwarming, direct particle collision or sudden magnetic field reconfiguration. Each of these mechanisms relies on the transport of energy from the corona to the photosphere, and the physical conditions existing in the chromosphere such as magnetic configuration and density. Thus, to understand sunquakes and their relationship to solar flares, we need to understand how energy moves through the entire solar atmosphere and the physical conditions that are present. White light flares are often present at the sunquake's point of origin, and although they are difficult to observe due to the bright background optical emission, they can provide insight into mechanisms of energy transport to the photosphere. The majority of the energy released by a flare is deposited in the lower solar atmosphere and manifests itself in the form of enhanced hard X-ray, UV and optical radiation. Hard X-ray footpoints and UV ribbons observed in the chromosphere directly map to the reconfiguring magnetic fields during the flare. Ribbons therefore provide an important observational tool for understanding the magnetic reconnection process and how magnetic energy is transported from high to low altitudes. Using observations of an X1 solar flare with associated seismicity on the 29th of March 2014 from the Solar Dynamics Observatory's (SDO) Helioseismic Imager (HMI) and Interface Region Imaging Spectrograph (IRIS), white light-enhanced regions in the photosphere are spatially and temporally aligned with higher altitude ribbons in the chromosphere. Energies associated with the flare at various altitudes are calculated to try to constrain when and where energy is being deposited in the solar atmosphere. Spectroscopic data from IRIS are used to probe the physical conditions in the chromosphere, providing information needed to identify which of the various progenitors of sunquakes are present.

Poster #35

Mag squared: understanding chromospheric magnetic structures through analysis of the IRIS Magnesium II spectrum

M. Snow (1), Giuliana de Toma (2), Scott McIntosh (3), Han Uitenbroek (4)

University of Colorado / LASP

The Interface Region Imaging Spectrograph (IRIS) regularly makes a raster observation of the full solar disk, taking Magnesium II spectra at each dwell point. We will use the high spectral resolution line profiles from IRIS along with magnetic field information from the Solar Dynamics Observatory Helioseismic and Magnetic Imager (SDO/HMI) to create a database of radiance spectra of various magnetic structures such as plage and active network. Using irradiance spectra from the SOlar Radiation and Climate Experiment/SOLar-STellar Irradiance Comparison Experiment (SORCE/SOLSTICE), we can use this database to reconstruct irradiance variability and therefore gain a better understanding of the contribution of the different magnetic structures to that variability.

Poster #36

Comparison of IRIS Spectra with Some Deep Magnetograms from SOT/SP and NFI

Ted Tarbell

LMSAL

I have been looking at some high-cadence SP and NFI observations with good magnetic sensitivity, taken in coordination with IRIS. These include some runs of IHOP 243 and other impromptu collaborations. The goal is to see how accurately a time series of IRIS spectra can be coaligned with the magnetic measurements, and what might be learned about chromospheric heating or dynamical events from them.

Poster #37

Multi-wavelength observation of dynamic response of chromosphere in a flare with a coordinated observation between Hida, Hinode and IRIS

A. Tei, T. Sakaue, A. Asai, T. Kawate, J. Okamoto, S. UeNo, K. Ichimoto, K. Shibata

Kwasan and Hida Observatories, Graduate School of Science, Kyoto University

Although it is known that dynamic phenomena occur in the chromosphere in relation to a flare, its real nature and origin are still unknown observationally and theoretically. Detailed study of flare kernels is important since it will leads to the understanding of heating mechanism of chromosphere and energy release process in the corona.

To obtain a data set of flare in multi-wavelength with ever highest temporal and spatial resolutions, we performed a coordinated observation with Hida/IRIS/ Hinode, in 2014 November 11. We succeeded in getting proper data set for our aim by the coordinated observation. With Domeless Solar Telescope at Hida Observatory of Kyoto University in Japan, we performed slit scan spectroscopic observation of Ca II K, Ca II 8542Å and H-alpha simultaneously. With Hinode/SOT, high resolution images of Ca II H and G-band, and photospheric magnetogram ware also taken, too. With IRIS, in the sit-n-stare mode, we got spectrum data including Mg II k/h, Mg triplet, C II, Si IV, Fe XXI, and other chromospheric lines.

In our analysis, the red asymmetry was detected during the impulsive phase of the flare in most lines showing flare emission, Mg II h/k, Mg II triplet, C II and Si IV, Ca II K , Ca II IR 8542Å and H-alpha. Resulting peak velocities are in a range from 40 to 80 km/sec. Additionally, there were no detectable difference in the start time of the red asymmetry between any lines which show the asymmetry with a time resolution of 10 s. Red asymmetry, which lasts for 1 min or so, consists of short lived multiple components with a lifetime of nearly our temporal resolution. Furthermore, we found that the relative intensity and strength of red asymmetry of Mg II triplet lines with respect to those of Mg II h/k changed during the flare.

We will show these observational results and discuss them.

Poster #38

Prevalence of small-scale jets from the network structures of the solar transition region

Hui Tian, Ed DeLuca, Steve R. Cranmer, Bart De Pontieu, Hardi Peter, Sean McKillop, Kathy K. Reeves, Mari Paz Miralles, Patrick McCauley, Rebecca T. Arbacher, and the IRIS team

Harvard-Smithsonian Center for Astrophysics

IRIS observations in the 1330Å, 1400Å and 2796Å passbands have revealed prevalent small-scale jet-like features with apparent speeds of ~80-250 km/s from the network structures in coronal holes and quiet Sun regions. Their widths are often ~300 km or less. The apparent speeds and maximum heights of the jets are smaller in the quiet Sun than in coronal holes. Many of these jets show up as elongated features with enhanced line width in maps obtained with transition region (TR) lines, suggesting that these jets reach at least ~10^5 K and they constitute an important element of TR structures. These ubiquitous high-reaching jets are likely an intermittent but persistent source of mass and energy for the corona and solar wind. The generation of these jets in the network and the accompanying Alfvén waves is also consistent with the "magnetic furnace model" of solar wind. The large speeds suggest that magnetic forces may play an important role in the generation and acceleration of the network jets. At least some network jets are likely the on-disk counterparts and TR manifestation of type-II spicules observed in the chromosphere above limb.

Poster #39

SSALMON - The Solar Simulations for the Atacama Large Millimeter Observatory Network

Sven Wedemeyer (1,2) for the SSALMON group

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ALMA provides a new powerful tool for observing the solar chromosphere at high spatial, temporal, and spectral resolution, which will allow for addressing fundamental scientific questions. Based on first solar test observations, observing strategies for regular solar campaigns are currently under development. State-of-the-art numerical simulations of the solar atmosphere and modeling of instrumental effects can help in this respect, constraining and optimizing future observing modes for ALMA. On September 1st, 2014, the Solar Simulations for the Atacama Large Millimeter Observatory Network (SSALMON) has been initiated with the aim to coordinate related activities and to promote the scientific potential of ALMA observations of the Sun. The network is connected to two currently ongoing ALMA development studies but focuses in particular on modeling aspects. As of March 1st, 2015, 55 scientists from 15 countries have joined the international SSALMONetwork. Among the affiliations are NRAO, ESO, NAOJ, the Czech ALMA ARC node at Ondrejov, ESA and many more. A number of expert teams is currently formed, which will work on specific tasks in preparation of future regular ALMA observations and their interpretation. Registration and more information at http://www.ssalmon.uio.no

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Poster #40

An Investigation of Magnetic Thresholds for the Production of IRIS Network Jets

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The enhanced resolution provided by IRIS has allowed for the direct observation of small-scale features in the chromosphere and transition region. One feature identified in IRIS observations is jet-like emission from bright network patches. In this project, we compare the network jets presented by Tian et al. (2014, Science) with magnetogram data from Helioseismic and Magnetic Imager (HMI) on Solar Dynamics Observatory. We search for a correlation between jet productivity and the magnetic field strength of the local supergranular network. We are also working to develop new image processing techniques to identify and track network jets, using machine learning and pattern recognition used in other disciplines. This multidisciplinary effort will allow us to accurately identify and characterize small-scale, transient features in existing IRIS data. With an expanded catalog of features and the identification of correlations between supergranular magnetic field strength and jet production, we can make better estimates of the mass and energy budget contained in these network jets.

Poster #41

Absolute Calibration of the IRIS Spectrographs

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The IRIS team has been tracking the relative sensitivity of IRIS since first-light on 2013 July 17. An absolute calibration, however, has been elusive until SORCE/SOLSTICE successfully resumed observations in 2014. This poster will present the results of the IRIS - SOLSTICE cross-calibration and the IRIS throughput trending.

Poster #42

SWAP and IRIS observations

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We focus on observations linking the chromosphere, transition region, and extended corona, and on tracing the flow of energy and plasma into the corona and heliosphere. Using the Interface Region Imaging Spectrograph (IRIS) and Sun Watcher with Active Pixels and Image Processing (SWAP) EUV solar telescope on-board the Project for On-Board Autonomy 2 (PROBA2) spacecraft, we look for connections between the regions. In particular, we look at fan structures and signatures of reconnection created in post flare loop systems, such as those observed on October 14, 2014. This eruption led to the formation of perhaps the largest post-eruptive loop system in solar cycle 24. This particular loop system grew to unprecedented heights in the wake of the eruption, we look for signatures of this reconnection event and others lower down using IRIS observations.
