CORONAL LOOP VII WORKSHOP
Cambridge 21 – 23 July 2015
ABSTRACTS

SESSION 1: Coronal Heating: Global Active Region Models and Mechanisms

INVITED TALKS

IT1.1 *Mahboubeh Asgari-Targhi*
Title - Heating Mechanisms (Reconnections vs Waves)

Authors:
Mahboubeh Asgari-Targhi

Abstract:
The source of coronal heating is one of the most challenging problems in solar physics. In this talk, I will pay particular attention to waves and reconnection models; the two major theoretical models attempting to address the question of coronal heating. I will also briefly describe the roles spicules play in transporting energy and matter to the chromosphere and corona.

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IT1.2 *Ignacio Ugarte-Urra*
Title - A global picture of active regions: models meet observables.

Authors:
Ignacio Ugarte-Urra

Abstract:
Coronal physics is a discipline that has progressed from the discovery mode of its original space observations to a phase of a deep understanding of the very complex system that the solar atmosphere has revealed to be. Solar observations are now comprehensive, the diagnostics very specific and the statistics significant to build a global picture of phenomena like active regions. A parallel progression of computational resources has allowed numerical models to become sophisticated tools that reveal the variety of processes at play at the relevant spatial and temporal scales. Progress in our understanding of the closed corona and the formation of fundamental loop scales is dependent on our ability to make these two worlds meet beyond circumstantial evidence. We present a discussion of the current efforts from (Magneto) Hydrodynamic global simulations of active regions to explain the observed properties of solar active regions.

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IT1.3 *Tony Arber*
Title - Beyond hydro or MHD modelling

Authors:
Tony Arber

Abstract:
Ideal MHD is an accurate model for the global dynamics of coronal loops. Even for a completely collisionless plasma MHD can be shown to be accurate in determining stability thresholds and growth rates. This will be demonstrated through comparison theorems which will be briefly reviewed. The real problems come from the treating transport, both conduction and radiation, and non-Maxwellian distributions expected from reconnection. Such processes are not always dynamically important but when they are needed they pose a real problem for extended-MHD models. This talk will review the key additional physics that must be included and present some options for how these may be handled if we are to move beyond ideal, or indeed restive, MHD loop modelling.

CONTRIBUTED TALKS

CT1.1 *Clara Froment*
Title - Evidence for evaporation-incomplete condensation cycles in warm solar coronal loops

Authors:
C.Froment, F.Auchère, K.Bocchialini, E.Buchlin, C.Guennou, J.Solomon

Abstract:
Constant or quasi-constant heating at the base of magnetic loops leads to periodic cycles of evaporation and condensation of the plasma (thermal non-equilibrium). This phenomenon is often invoked to explain some aspects of the formation of prominences and coronal rain. However, it is commonly not considered to play a role in the heating of warm loops because it tends to cool the plasma down to chromospheric temperatures and the simulated emission does not match the properties of observed loops. Recent simulations have shown that these inconsistencies with observations may be due to oversimplifications of the geometries of the models.

In addition, our recent observations reveal that long-period intensity pulsations (several hours) are very common in solar coronal loops. These periods are consistent with those expected from thermal non-equilibrium. The aim of this work is to derive characteristic physical properties of the plasma for some of these events in order to test the potential role of thermal non-equilibrium in loop heating. We analyzed three events in detail using the six EUV coronal channels of SDO/AIA in order to obtain diagnostics of the thermal properties of the plasma. We performed both a Differential Emission Measure (DEM) and a time-lag analysis. We also propose a new method to isolate the relevant signal from the foreground and background emission. The three pulsating events exhibit the same main characteristics. The DEM undergoes long-period pulsations, which is a signature of periodic heating even though the loops are captured in their cooling phase, as is the bulk of the active regions.

We link long-period intensity pulsations to new signatures of loops heating. Our analysis of this phenomenon leads to strong evidence for evaporation and condensation cycles of the plasma. We thus witness simultaneously widespread cooling and thermal non-equilibrium. Finally, we discuss the implications of our new observations for both static and impulsive heating models.

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CT1.2 *David Brooks*
Title - Non-Thermal Motions in the Hot Cores of Solar Active Regions

Authors:
David H. Brooks & Harry P. Warren

Abstract:
Spectral lines widths are almost always larger than can be accounted for by thermal and instrumental broadening. The magnitude of this non thermal width in the hot cores of active regions can provide important constraints for theoretical models of coronal heating. We present new Hinode/EIS measurements of non-thermal broadening in 15 active region cores. These measurements show a decreasing trend in non-thermal velocity as a function of temperature. In fact, we find only modest non-thermal broadening at the highest temperatures (3-5MK). These trends and magnitudes appear to be inconsistent with those expected from reconnection jets in the corona, chromospheric evaporation induced by nanoflare heating, and Alfven wave turbulence models.

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CT1.3 *Giulio Del Zanna*
Title - On the active region cores

Authors:
Del Zanna, G., Mason, H.E.

Abstract:
High-resolution EUV observations from SDO/AIA and Hinode/EIS are used, together with updated atomic data and EIS calibration, to measure the physical characteristics of active region cores, and their relation to the other structures. Quiescent active region cores are found to have nearly isothermal distributions, with very little emission above 3 MK, and with a strongly peaked distribution in the 1-3 MK range. Spatial and temporal variability are briefly discussed. The iron abundance is found to vary, with enhancements of about a factor of three within the cores. The same occurs to the other low-FIP elements. X-ray spectroscopy from SMM/FCS confirms the results of the EUV observations for the hot cores.

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CT1.4 *Amy Winebarger*
Title - Nanoflare vs footpoint heating : Observational signatures

Authors:
A. Winebarger, C. Alexander, R. Lionello, J. Linker, Z. Mikic, C. Downs

Abstract:
Cooling structures observed in the solar corona have been used as an argument for so-called nanoflare heating. In this heating scenario, coronal structures undergo impulsive heating events; the energy can be distributed anywhere along the length of the loop. The plasma is then allowed to cool and drain until another heating even occurs. Another heating scenario that can also produce cooling structures is near-steady heating focused at the loop footpoints. In some cases, for highly stratified heating, no equilibrium solution can be found, and the plasma in the loop evolves with time. In this presentation, we show some observational signatures of these two heating scenarios. One particularly useful observable is the time delay between the appearances of the loop in different channels. We show the expected time delays of both nanoflare and footpoint heating and find that the time delays between certain channels can differentiate between the two heating scenarios.

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CT1.5 *Alexander Russell*

Title - Heating of braided coronal loops by turbulent 3D reconnection

Authors:
Alexander Russell, Gunnar Hornig & Anthony Yeates

Abstract:
Magnetic braiding is one of the leading mechanisms for heating coronal loops, however, understanding of this mechanism has changed dramatically in recent years. In particular, it is now recognised that the reconnection at the heart of this process is inherently 3D, may not feature true topological discontinuities, typically involves large numbers of turbulently forming and evolving reconnection regions, and often produces structures that are inconsistent with a Taylor relaxation model. Here, we look at some of the recent progress that has been made in dealing with this complex heating mechanism and present a new advance in magnetic relaxation theory that greatly improves prediction of the end state and the heating obtained from an initially braided coronal loop.

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CT1.6 *Sanjiv Tiwari*

Title - Suppression of heating of coronal loops rooted in opposite polarity sunspot umbrae

Authors:
S. K. Tiwari, J. Thalmann, A. Winebarger, N. Panesar, R. L. Moore

Abstract:
EUV observations of active region (AR) coronae reveal the presence of loops at different temperatures. To understand the mechanisms that result in hotter or cooler loops, we study a typical bipolar AR, near solar disk center, which has moderate overall magnetic twist and at least one fully developed sunspot of each polarity. From AIA 193 and 94 A images we identify many clearly discernible coronal loops that connect plage or a sunspot of one polarity to an opposite-polarity plage region. The AIA 94 \AA\ images show dim regions in the umbrae of the spots. To see which coronal loops are rooted in a dim umbral area, we performed a non-linear force-free field (NLFFF) modeling using photospheric vector magnetic field measurements obtained with the Heliosesmic Magnetic Imager (HMI) onboard SDO. After validation of the NLFFF model by comparison of calculated model field lines and observed loops in AIA 193 and 94A, we specify the photospheric roots of the model field lines. The model field then shows the coronal magnetic loops that arch from the dim umbral area of the positive-polarity sunspot to the dim umbral area of a negative-polarity sunspot. Because these coronal loops are not visible in any of the coronal EUV and X-ray images of the AR, we conclude they are the coolest loops in the AR. This result suggests that the loops connecting opposite polarity umbrae are the least heated because the field in umbrae is so strong that the convective braiding of the field is strongly suppressed.

From this result, we further hypothesize that the convective freedom at the feet of a coronal loop, together with the strength of the field in the body of the loop, determines the strength of the heating. In particular, we expect the hottest coronal loops to have one foot in an umbra and the other foot in opposite-polarity penumbra or plage (coronal moss), the areas of strong field in which convection is not as strongly suppressed as in umbrae. Many transient, outstandingly bright, loops in the AIA 94 A movie of the AR do have this expected rooting pattern. We will also present another example of AR in which we find a similar rooting pattern of coronal loops in the AIA movies.

POSTER PRESENTATIONS

P1.1 *Baolin Tan*

Title - Heating of Coronal Loops by Magnetic-Gradient Pumping Mechanism

Authors:
Baolin Tan

Abstract:
Coronal heating is a longstanding big mystery in astrophysics. Recently I proposed a new model of magnetic-gradient pumping (MGP) mechanism to explain the coronal heating processes (Tan, 2014, ApJ, 795, 140). In this work, I try to adopt this new mechanism to explain the detailed processes of coronal loop heating. The direction of magnetic gradient is downward in coronal loop, this may result MGP mechanism driving the energetic particles to move upward from the two foot-points and gather around the apex region in the loop. The gathering of energetic particles around the loop apex and their dissipating to the adjacent plasma will make the coronal become very hot. MGP is a long-term steady heating mechanism, which may explain the heating processes in solar active region, quiet regions, and the quiet Sun during the solar minimum.

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P1.2 *David Tsiklauri*

Title - The effect of plasma inhomogeneities on (i) radio emission generation by non-gyrotropic electron beams and (ii) particle acceleration by Langmuir waves

Authors:
David Tsiklauri

Abstract:
In solar coronal active regions and in interplanetary space, magnetic reconnection-generated electron beams are known to produce type III solar radio bursts. Because the emission is at electron plasma frequency, which is a proxy for electron density, these radio bursts when observed with high-time cadence radio instruments, such as LOFAR in the dynamical spectrum mode, can provide unique information about high frequency MHD waves which cannot be studied by SDO because of its low, 12 sec, cadence compared to LOFAR which has 0.1 ~ 0.001 sec cadence. The mechanism of the type III solar radio burst emission is also not fully understood. To shed further light on this unknown, extensive particle-in-cell simulations of fast electron beams injected in a background magnetised plasma with a decreasing density profile were carried out. These simulations were intended to further shed light on a newly proposed mechanism for the generation of electromagnetic waves in type III solar radio bursts [1]. Here recent progress in an alternative to the plasma emission model using Particle-In-Cell, self-consistent electromagnetic wave emission simulations of solar type III radio bursts will be presented. In particular, (i) Fourier space drift (refraction) of non-gyrotropic electron beam-generated wave packets, caused by the density gradient [1,2], (ii) parameter space investigation of numerical runs [3], (iii) concurrent generation of whistler waves [4] and a separate problem of (iv) electron acceleration by Langmuir waves in a background magnetised plasma with an increasing density profile [5] will be discussed. In all considered cases the density inhomogeneity-induced wave refraction plays a crucial role. In the case of non-gyrotropic electron beam, the wave refraction transforms the generated wave packets from standing into freely escaping EM radiation. In the case of electron acceleration by Langmuir waves, a positive density gradient in the direction of wave propagation causes a decrease in the wavenumber, and hence a higher phase velocity vph=Ï/k. The k-shifted wave is then subject to absorption by a faster electron by wave-particle interaction. The overall effect is an increased number of high energy electrons in the energy spectrum.

[1] D. Tsiklauri, Phys. Plasmas 18, 052903 (2011); http://dx.doi.org/10.1063/1.3590928

[2] H. Schmitz, D. Tsiklauri, Phys. Plasmas 20, 062903 (2013);
http://dx.doi.org/10.1063/1.4812453
[3] R. Pechhacker, D. Tsiklauri, Phys. Plasmas 19, 112903 (2012);
http://dx.doi.org/10.1063/1.4768429
[4] M. Skender, D. Tsiklauri, Phys. Plasmas 21, 042904 (2014);
http://dx.doi.org/10.1063/1.4871723
[5] R. Pechhacker, D. Tsiklauri, Phys. Plasmas 21, 012903 (2014);
http://dx.doi.org/10.1063/1.4863494
This research is funded by the Leverhulme Trust Research Project Grant RPG-311

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P1.3 *Xia Fang*

Title - Multi-Dimensional Magnetohydrodynamic Modelling of Propagating Disturbances in Corona

Authors:
X. Fang, D. Yuan, T. Van Doorsselaere, R. Keppens, and C. Xia

Abstract:
Quasi-periodic propagating intensity disturbances (PDs) have been observed in large coronal loops in EUV images over a decade, and are widely accepted to be slow magnetosonic waves. However, spectroscopic observations from Hinode/EIS revealed their association with persistent coronal upflows, making this interpretation debatable. We perform a 2.5d thermal magnetohydrodynamic simulation to imitate the chromospheric evaporation in a post flare loop. Our model holds coronal, transition region, and chromosphere. We demonstrate the quasi periodic intensity variations captured by our synsized AIA 131and 94 emission maps well match the precious observations. With the particle tracers inside the simulation, we can confirm these intensity variations consist of reflecting standing slow mode waves and mass flows with a average speed of 300km/s in a 80 Mm length loop with an average temperature of 9 MK. Meanwhile the morphology of synsised AIA 1600 and 304 maps during the waves impacts reveals the transition region oscillations suggested by the radio observations.

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P1.4 *James Threlfall*

Title - Characteristics of solar particle acceleration in a non-flaring active region

Authors:
J. Threlfall, Ph.-A. Bourdin, T. Neukirch, C. E. Parnell

Abstract:
We present first results of test particle orbit calculations based on snapshots of an observationally driven MHD model of a non-flaring slowly-evolving solar active region [detailed in Bourdin et al., A&A 555, A123 (2013)]. The test particle (electron and proton) orbits are calculated using the relativistic guiding-centre approximation. Initial results suggest particles can be accelerated to non-thermal energies due to local reconnection electric fields, despite the lack of flare-like behaviour. We discuss the implications of these results and highlight several characteristic types of orbit behaviour within the simulated active region, in order to better understand the plasma response in such active region models at kinetic scales.

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P1.5 *Stephane Regnier*
Title - Cooling of multi-stranded coronal loop: comparison with observations

Authors:
S. Regnier

Abstract:
Solar active regions exhibit a discrete number of bright coronal loops which are subject to a series a heating and cooling events. The existence of these coronal loops is a consequence of small-scale energy deposition leading to the transport of heat along the loop. Based on a 1D multi-stranded model, we analyse the cooling of such loops using different scenarios: (i) stopping completely the energy deposition, (ii) decreasing the amount of energy deposited to reach a new steady state, (iii) imposing short-duration high-energy bursts on a background heating (steady state). The different scenarios are compared to observations of flares and their associated SDO/AIA light curves, and to the long-duration oscillations recently reported by Auchere et al. (2014). For both types of observations, the temperature of the coronal plasma can be estimated by using the combination of models and observations as a diagnostic tool.

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P1.6 *Yin Zhang*
Title - Dynamic evolution of EUV loops

Authors:
Yin Zhang

Abstract:
Observations of the solar corona with Yohkoh, SOHO and TRACE have revealed that individual coronal loops of active regions have their own temperatires from 1 to 5 MK. The cool (1-2 MK) EUV loops can be identified clearly by 171 A images. We investigate the dynamic evolution of well-observed cool loops which appeared in an ephemeral active region NOAA 10385 on 25 Dec, 2015, by using Solar Dynamics Observatory (SDO)/Atmospheric Imaging Assembly (AIA) multi-wavelength images. The photospheric properties of its footpoints are also discussed in detail by using SDO/Helioseismic and Magnetic Imager (HMI) magnetic and velocity field.

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P1.7 *Sergey Shestov*
Title - Nonlinear torsional Alfven waves in magnetic flux tubes

Authors:
S. Shestov, V.M. Nakariakov, S. Kuzin

Abstract:
Torsional Alfven waves are a type of magnetohydrodynamic waves in a non-uniform plasma, that travel at the Alfven speed along the magnetic field. In a straight field-alinged magnetic flux tube, these waves are azimuthal perturbations of the plasma that are accompanied by an azimuthal component of the magnetic field. The torsional waves are important because they may play role in coronal heating, efficiently transferring energy from lower solar atmosphere layers to corona (Ofman, 2005; Murawski 2015) and the wind acceleration.
A series of theoretical studies of coronal heating and solar wind acceleration by Alfven waves were carried out by many authors (e.g. Suzuki, 2011; Verdini et al. 2012) in 1D, i.e. for plane waves. A key ingredient of the models is the nonlinear cascade of the wave energy from low-frequency injection range to higher frequencies, where it becomes subject to dissipation by MHD and kinetic mechanisms.

In Alfven waves this effect becomes possible because of the non-linear interaction of the waves with the (nonlinearly) induced compressive perturbation. Vasheghani Farahani et al. (2011) and Vashehgani Farahani et al. (2012) studied nonlinear long-wavelength torsional Alfven wave in magnetic flux tube analytically in terms of the second order thin flux tube approximation (Zhugzhda, 1996). Compressive perturbations induced by axisymmetric torsional waves were found to oscillate at twice the frequency of the torsional wave. The back-reaction of the nonlinearly induced compressive perturbations resulted in the deformation of the axial wave profile, thus transferring energy to higher frequencies. In the weakly nonlinear regime the evolution of the wave profile is described by Cohen-Kulsrud equation.
We performed a numerically study the behaviour of a nonlinear torsional Alfven waves in a straight magnetic flux tube, aiming to verify the analytical findings and extend them on the strongly nonlinear regime. We used the Lare3D code, set up an equilibrium magnetic flux tube with a finite-beta plasma and simulated the evolution of standing and propagating torsional Alfven waves, paying attention to the nonlinear cascade, the wave front deformation, and compressive perturbations. Nonlinear torsional Alfven waves were found to be consistent with main features found in the asymptotic analytical consideration.

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P1.8 *Jarn Warnecke*

Title - Formation, evolution and oscillation of coronal loops in a 3D MHD simulation of the solar corona

Authors:
J. Warnecke, F. Chen, S. Bingert, H. Peter

Abstract:
To understand the formation of coronal loops and their dynamic evolution during the emergence of active regions, we build a realistic 3D coronal model that is driven by a flux emergence simulation. The output of that simulation at the photospheric level is taken as a time-dependent bottom boundary to drive our coronal simulation. This coronal simulation accounts for the energy balance as in the real corona including heat conduction, radiative losses and heating by Ohmic dissipation. This allows us to synthesise coronal emission that is directly comparable to observations. Our previous analysis of the coronal model has revealed that coronal loops are formed in response to the energy input brought by the enhanced upward Poynting flux at the coronal base, and that the evolution of apparent EUV loops and magnetic field lines can be different in a forming active region.

Along a quasi-static coronal loop the total current is roughly constant. In contrast, loops forming during the emergence of the active region possess a more complicated system of currents. There the currents have the same sign on both footpoints enforcing a non-forcefree magnetic field at the loop top. This can be explained by inclined magnetic field lines inside the loop moving into the active region in the photosphere.
This results in a strong Lorentz force pointing downward above the loop preventing it to emerge uniformly. This is essential to understand how the magnetic field evolves and moves with respect to the coronal loop seen in the EUV.

These emerging loops also show transverse oscillations. These are clearly apparent in EUV images synthesised from the in the simulation. The oscillation period for the loop oscillation is obtained from this synthetic emission. This can the be used to deduce the (average) magnetic field strength for the oscillating loop, similar to what has been done for observed loop oscillations on the Sun. Compared with the actual magnetic field in the loop, which drops from the footpoint to the apex, the deduced field strength is close to the average magnetic field strength that would give the same total wave travel time. This result has implications for observational studies of the coronal magnetic field

through the analysis of oscillations. With the help of the model we can understand what the average value for the magnetic field deduced from oscillations actually means.

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P1.9 *Iain Hannah*
Title - X-ray imaging spectroscopy of non-flaring active regions with NuSTAR

Authors:
Hannah, Smith, Marsh, Glesener, Krucker, Hudson, Grefenstette, Madsen,

Abstract:
We present imaging spectroscopy of coronal loops and active regions with the NuSTAR hard X-ray (HXR) telescope, searching for high temperature and non-thermal emission in the non-flaring Sun. Launched in 2012, NASA's astrophysics mission NuSTAR uses focusing optics to directly image X-rays between ~2-80 keV. In the band below ~50 keV the field of view is 12'x12' and the instrument has an energy resolution of ~0.4 keV. Although not optimized for solar observations, NuSTAR's high sensitivity can probe previously inaccessible X-ray emission from the Sun. NuSTAR has so far observed the Sun three times (during late 2014) and we present these first directly imaged X-rays from non-flaring active regions. Using NuSTAR's imaging spectroscopy capabilities we are able to derive the high temperature (> 4MK) characteristics of several active regions, investigating their possible multi-thermal and/or non-thermal nature. We also compare the thermal properties from EUV observations (in terms of the DEM) to those obtained with NuSTAR.

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P1.10 *Marcelo Lopez-Fuentes*
Title: Emission measure distribution of nanoflare-heated coronal loops

Authors:
Lopez-Fuentes, M., Klimchuk, J.A.

Abstract:
The emission measure (EM) distribution of coronal loop plasmas has been recently used to test coronal heating mechanisms. In particular, it is argued that the amount of emitting plasma at the temperature of maximum emission relative to the plasma at 1 MK is determined by the kind of process producing the heating. The parameter commonly used to characterize the EM distribution is the slope of the log(EM) versus log(T) histogram between the above temperatures. In this work, we analyze the EM distribution obtained from a cellular automaton model of multi-stranded nanoflare-heated coronal loops. Our model (Lopez-Fuentes and Klimchuk 2015, ApJ, 799, 128) is based on the idea that footpoint motions produced by photospheric convection introduce magnetic stress between the elementary strands that form loops. When the stress becomes critical magnetic energy is released in the form of reconnection events identified as nanoflares. We simulate the plasma response to the nanoflares and obtain the EM distribution of the loop plasma. We test different model parameter combinations within solar values and find EM slopes that reproduce the observed ranges. We discuss the implications of these results for the coronal heating problem.

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P1.11 *Susanna Parenti*

Title - Off-limb hot thermal structure of AR 11459 with SOHO SUMER and Hinode/EIS

Authors:
S. Parenti, F. Reale, P. Testa, H. Mason, L. Teriaca, G. Del Zanna

Abstract:
The thermal structure of active regions and loops is crucial to characterize the way these structures are heated. In particular, much attention is devoted now to identify the properties of the high temperature component (> 3MK) of the plasma seen in non-flaring conditions. This, in fact, is the observational aspect which can help discriminating between the impulsive or steady heating mechanisms.
We present results of an investigation which combines rare SOHO/SUMER and HINODE/EIS observations of EUV emission in lines from Fe at high degrees of ionization of a region at the limb. LOCI and EM analysis has been performed to cover all ionization stages from Fe XIV to XIX. This allows inferring an upper limit to the EM in the 3 to 9 MK temperature range, both in structured and diffuse AR emission.

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P1.12 *Nicholeen Viall*

Title -Are Active Regions and the Quiet Sun Heated by the Same Mechanisms?

Authors:
Nicholeen Viall & James Klimchuk

Abstract:
How the solar corona is heated to temperatures of over 1 MK, while the photosphere below is only ~ 6000 K remains one of the outstanding problems in all of space science. Solving this problem is crucial for understanding Sun-Earth connections, and will provide new insight into universal processes such as magnetic reconnection and wave-particle interactions. We use a systematic technique to analyze the properties of coronal heating throughout the solar corona using data taken with the Atmospheric Imaging Assembly onboard the Solar Dynamics Observatory. Our technique computes cooling times of the coronal plasma on a pixel-by-pixel basis and has the advantage that it analyzes all of the coronal emission, including the diffuse emission surrounding distinguishable coronal features. We have already applied this technique to 15 different active regions, and find clear evidence for dynamic heating and cooling cycles that are consistent with the 'impulsive nanoflare' scenario. What about the rest of the Solar corona? Whether the quiet Sun is heated in a similar or distinct manner from active regions is a matter of great debate. In this paper, we apply our coronal heating analysis technique to quiet Sun locations. We find areas of quiet Sun locations that do undergo dynamic heating and cooling cycles, consistent with impulsive nanoflares. However, there are important characteristics that are distinct from those of active regions.

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P1.13 *Caroline Alexander*

Title - Modeling a full coronal loop observed with EIS and AIA

Authors:
C. E. Alexander, A. R. Winebarger

Abstract:
A complete understanding of coronal loop heating can only be achieved when simulations and observations are used together effectively. A crucial function of observers is to accurately measure

loop parameters (e.g., temperature, density, loop length, magnetic field strength, flows etc.) and use this analysis to infer the processes at work within the loop. These parameters should ideally be available to the community so that simulations can also be performed. This allows modelers the opportunity to contribute to the analysis of the loop by uncovering what initial conditions and heating parameters are needed to make sense of the observations. A recently observation of a coronal loop was detailed in Gupta et al. (2015) where they set out to do exactly this. They measured multiple parameters along the full length of the loop and provided the results of their data analysis so that the loop could be modeled. We set out to see if the 1-dimensional hydrodynamic loop code NRLSOLFTM (Mariska et al. 1982) could explain their observation. We measured the loop length and ran a number of simulations over a range of energies. We then used the provided information about the loop's temperature and density in order to hone in on which of our simulations was hitting the mark. The time that this simulation spent at the temperature Mg VII 278.4 A is sensitive to was also calculated. Since the loop was observed in this wavelength for at least 20 minutes our simulated loop should also last this long. However, we found that the time our simulated loop would radiate in Mg VII 278.4 A was less than the 20 minutes it was observed for. This suggests that impulsive heating of a single loop is not complex enough to explain this observation and reinforces the conclusion of Gupta et al that this structure is multi-stranded. An additional source of heating may also be at work in this case.

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P1.14 *Michael Hahn*

Title - Evidence for Wave Heating of the Quiet Corona

Authors:
Michael Hahn, Daniel Wolf Savin

Abstract:
We have inferred the properties of waves in quiet Sun regions based on spectroscopic line widths. The non-thermal line broadening is proportional to the amplitude of Alfvenic waves. Using a Potential Field Source Surface (PFSS) magnetic field model, we trace the evolution of line widths along inferred magnetic field lines. In order to mitigate line of sight effects, we select regions that are isothermal and where the field lines remain oriented close to perpendicular to the line of sight. Our results indicate that the waves are damped starting at a height that is positively correlated with the overall length of the loop. That is, for longer loops, the damping occurs starting at a larger height. This suggests that heating of quiet Sun loops occurs over a region centered on the loop top and extends over a large fraction of the loop and is global rather than local in nature. We estimate that there is enough energy flux in waves injected at the base of quiet Sun regions to account for coronal heating in such structures

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P1.15 *James A Klimchuk*

Title - Key Aspects of Coronal Heating

Authors:
James A. Klimchuk

Abstract:
We highlight ten key aspects of coronal heating that must be understood before we can consider the problem to be solved. (1) All coronal heating is impulsive. (2) The details of coronal heating matter. (3) The corona is filled with elemental magnetic stands. (4) The corona is densely populated with current sheets. (5) The strands must reconnect to prevent an infinite buildup of stress. (6) Nanoflares repeat with different frequencies. (7) What is the characteristic magnitude of energy release? (8)

What causes the collective behavior responsible for loops? (9) What are the onset conditions for energy release? (10) Chromospheric nanoflares are not a primary source of coronal plasma. Significant progress in solving the coronal heating problem will require a coordination of approaches: observational studies, field-aligned hydrodynamic simulations, large-scale and localized 3D MHD simulations, and possibly also kinetic simulations. There is a unique value to each of these approaches, and the community must strive to coordinate better.

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P1.16 *Jaroslav Dudik*
Title - Highly Squashed Expanding Magnetic Flux-Tubes in a Quiescent Solar Active Region

Authors:
Jaroslav Dudik (1), Elena Dzifcakova (1), Jonathan W. Cirtain (2)
(1) - Astronomical Institute of the Academy of Sciences of the Czech Republic, Fricova 298, 251 65 Ondrejov, Czech Republic
(2) - NASA Marshall Space Flight Center, VP 62, Huntsville, AL 35812, USA

Abstract:
We calculated the rate of the area expansion of the magnetic flux-tubes in a quiescent solar active region. The magnetic field was obtained using a potential extrapolation from the Hinode/SOT-SP photospheric magnetogram with 0.3"/px resolution. It is found that the 3D spatial distribution of the area expansion is strongly non-uniform, with active region cores having smaller expansion factors than the overlying loop-like structures. We find that these loop-like structures correspond to highly squashed magnetic flux-tubes characterized by locally lower expansion factors that are embedded in a smooth background. We argue that this effect may lead to higher densities and thus be responsible for creation of the observed coronal loops. Extrapolation based on submerged magnetic charges does not show this spatial structure.

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P1.17 *Philippa Browning*
Title - Forward modelling of plasma motions in flaring twisted coronal loops

Authors:
M Gordovskyy, P K Browning and E Kontar

Abstract:
Previous theoretical studies have shown that kink instability in twisted coronal loops may trigger magnetic reconnection and associated dissipation of magnetic energy. Here, we use a forward-modelling approach to consider resolved and unresolved plasma flows in flaring loops as potential diagnostics of the topology and temporal evolution of the energy release. We predict both bulk plasma flows and unresolved small-scale flows/turbulence in 3D MHD simulation models of flaring loops, in order to interpret EUV/SXR line shifts, and their thermal and non-thermal broadening in flares. We use ideal MHD to derive unstable twisted magnetic field configurations, then follow the subsequent evolution of the unstable flux tubes with resistive MHD, incorporating anomalous resistivity dependent on the local density and temperature. Thermal conduction and optically-thin radiative losses are included in the energy equation. Our model shows quite good agreement with observations: both the LOS average velocity and LOS velocity dispersion demonstrate substantial correlation with the temperature.

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P1.18 *Anton Reva*
Title – Wave-like formation of hot arcades

Authors:
A. Reva, S. Shestov, I. Zimovets, S. Bogachev, S. Kuzin

Abstract:
We present hot arcades observations by the Mg XII spectroheliograph on board CORONAS-F mission, which built direct monochromatic images of hot plasma in the Mg XII 8.42~\AA\ resonance line. The observed arcades formed four times at 09:18, 14:13, and 22:28 UT on February 28, 2002 and 00:40 UT on March 1, 2002. Each arcade evolved following the same scenario: a) a small flare (precursor) appeared near the edge of the still invisible arcade; b) the arcade brightened in a wave-like manner---closer loops brightened earlier; c) the arcade intensity gradually decreased for ∼1 hour. The wave speed was ∼700 km/s, and the distance between the hot loops was ∼50 Mm. The arcades formed without visible changes in their magnetic structure. We think that each arcade heated up due to the instabilities of the current sheet above the arcade, which were caused by an MHD wave excited by the precursor.

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P1.19 *Stephane Regnier*
Title - Temperature diagnostic of coronal loops

Authors:
S. Regnier, R. W. Walsh, C. E. Alexander

Abstract:
Solar active regions exhibit a discrete number of bright coronal loops which are subject to a series of heating and cooling events. The existence of those coronal loops is a consequence of small-scale energy deposition leading to the transport of heat along the loop. Based on a 1D multi-stranded hydrodynamic (MSHD) model, we describe the physical processes acting on a typical coronal loop subject to different energetization parameters (including heating and cooling). By comparing with Hinode/EIS and SDO/AIA, we thus provide temperature diagnostics of coronal plasma depending on the physical process at play: for the heating of loop, the amount of Doppler-shift provides an estimate of the loop temperature, whilst for the cooling, the timing of peaks of intensity allows to estimate the temperature of the plasma and the cooling profile.

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P1.20 *Inigo Arregui*
Title - Model comparison for the density structure across solar coronal loops

Authors:
I. Arregui, R. Soler

Abstract:
The spatial variation of physical quantities, such as the mass density, across coronal loop waveguides determines time and spatial scales for the wave energy damping, the creation of small spatial scales, and the amount of energy that can be dissipated at those scales. We have applied Bayesian inference and model comparison techniques to the determination of the cross-field density structuring in coronal loops using information on periods and damping times for resonantly damped transverse oscillations. Three types of analyses are here described using coronal seismology to infer the cross-field density variation. Parameter inference enables us to determine this density variation from

observed oscillation properties; in model comparison, we can assess the plausibility of alternative density models in view of data; finally, model averaging enables us to combine the alternative posteriors by weighting them with the evidence for each model, given the observed data.

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P1.21 *Paul Wright*

Title - Regularized EMD maps of non-flaring active regions

Authors:
Paul J. Wright, Iain G. Hannah

Abstract:
The extreme-ultraviolet (EUV) signatures of heated material in the solar atmosphere have been continuously monitored by the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory (SDO) for over five years. These high temporal and spatial resolution images combined with the computational fast regularized method (Hannah & Kontar 2012) allow maps of the underlying emission measure distribution (EMD) to be obtained. From this the thermal evolution (both temporally and spatially) of non-flaring active regions can be studied. Here we present an initial analysis of the evolution of EMD maps in non-flaring active regions to probe the heating mechanisms in the solar atmosphere.

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P1.22 *Avyarthana Ghosh*

Title – IRIS and EIS observations of Fan Loops Emanating from a Sunspot

Authors:
Avyarthana Ghosh, D. Tripathi, Girjesh Gupta, Venessa Polito, H. Mason

Abstract:
Active regions are generally comprised of various kinds of loop structures observed at different temperatures. Here we study a set of fan loops to derive physical plasma parameters. The loop system, which emanated from the umbral region of a Sunspot was observed by the Extreme-ultraviolet Imaging Spectrometer (EIS) onboard Hinode and Interface Regions Imaging Spectrometer (IRIS). Having simultaneous observations from Hinode and IRIS, we have derived the absolute plasma flows, electron densities and temperature in these structures.

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P1.23 *Girjesh Gupta*

Title - Physical Plasma Parameters Along the Full Loop Length of a Coronal Loop

Authors:
Girjesh R. Gupta, Durgesh Tripathi, Helen E. Mason

Abstract:
Coronal loops are the basic structures of the solar corona. Understanding of the physical mechanisms behind the loop heating, plasma flows, and filling are still considered a major challenge in solar physics. This problem makes coronal loops an interesting target for detailed study. We present spectroscopic observations of a full coronal loop in various spectral lines as recorded by the Extreme-ultraviolet Imaging Spectrometer on-board Hinode. We derive physical plasma parameters such as electron density, temperature, pressure, column depth, and filling factors along the loop length from one foot-point to the other. The obtained parameters indicate that loop has asymmetric density

distribution with respect to gravitational stratification of the solar atmosphere. These new measurements of physical plasma parameters may provide important constraints on the modeling of the mass and energy balance in coronal loops.

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P1.24 *Giulio Del Zanna*
Title - CHIANTI version 8

Authors:
Del Zanna, G., Dere, K., Young, P., Landi, E., Mason, H.E.

We present version 8 of the CHIANTI database. This version includes a significant amount of new data and ions, mostly calculated with the R-matrix suite of codes by the UK APAP network.
The new data represent a significant improvement in the soft X-ray, EUV and UV spectral regions, where several space missions are currently observing. In particular, all the coronal iron ions have improved atomic data, which affect the analyses of Hinode EIS and SDO/AIA data. New data for neutral and low charge states are also added. The data are assessed, but to improve the modelling of low-temperature plasma the effective collision strengths for the new datasets are not fitted as previously done. A change of format was needed for this purpose. A revised DEM package is also presented.

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P1.25 *Cooper Downs*
Title - Characterizing A Closed Field Coronal Heating Model Inspired by Wave Turbulence

Authors:
Cooper Downs, Roberto Lionello, Zoran Mikic, Jon Linker, Marco Velli

Abstract:
Understanding the nature of coronal heating and solar wind acceleration is a key goal in solar and heliospheric research. In this work we investigate a wave-turbulence driven (WTD) phenomenology developed for the heating of closed coronal loops. To do so, we employ an implementation of non-WKB equations designed to capture the large-scale propagation, reflection, and dissipation of wave turbulence along a loop and attempt to address which properties the model must possess to be a viable model for coronal heating. The parameter space of this model is explored by solving the coupled WTD and hydrodynamic equations in 1D for an idealized loop over a range of model parameters. Further, the relevance to a range of solar conditions is established by computing solutions for several hundred loops extracted from a realistic 3D coronal field, including along quiet-sun and active region lines-of-sight. Due to the implicit dependence of the WTD heating model on loop geometry and plasma properties along the loop and at the footpoints, we find that this model can significantly reduce the number of free parameters when compared to traditional empirical heating models, and still robustly describe a broad range of quiet-sun and active region conditions. The importance of the self-reflection term in producing realistic heating scale heights and thermal non-equilibrium cycles is also discussed, which has relevance to the heating and cooling signatures often observed in active region cores.

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P1.26 *Will Barnes*

Title - Effects of Ion Heating on Emission Measure of Coronal Loops in Active Region Cores

Authors:
Will T. Barnes, Stephen J. Bradshaw

Abstract:
In coronal heating simulations, the tenuous coronal plasma is often treated as a single fluid whose electron and ion populations have reached collisional equilibrium. However, this assumption is not valid in the event of impulsive heating events (e.g. nanoflares). Furthermore, when a two-fluid treatment is applied, it is often tacitly assumed that the electron species is the recipient of the energy released by the as-yet-unknown coronal heating source. In this poster, we present a modified version of the popular Enthalpy-Based Thermal Evolution of Loops (EBTEL) model that adopts a two-fluid treatment, allowing the electron and ion temperatures to evolve separately. We then use this model to carry out simulations for both electron and ion heating for a variety of heating frequencies, using a power-law distribution for the heating function amplitudes. We analyze the coronal differential emission measure (as calculated by EBTEL) for ion and electron heating in order to show how observations may be misinterpreted when it is assumed that the electron species only are heated. This has important implications for the interpretation of faint, hot plasma signatures in observations and may help to constrain measurements of heating frequency in active region cores.

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P1.27 *Gerry Doyle*

Title - Active region upflows: 1. Multi-instrument observations

Authors:
K. Vanninathan, M.S. Madjarska, K. Galsgaard, Z. Huang, J.G. Doyle

Abstract:
Upflows at the edges of active regions (called AR outflows), are studied using multi-instrument observations. This study intends to provide the first direct observational evidence on whether chromospheric jets play an important role in furnishing mass that could sustain coronal upflows. The evolution of the photospheric magnetic field associated with the footpoints of the upflow region and the plasma properties of active region upflows are investigated aiming at providing such information for benchmarking data-driven modelling. By spatially and temporally combining multi-instrument observations obtained with the Extreme-ultraviolet Imaging Spec- trometer on board the Hinode, the Atmospheric Imaging Assembly and the Helioseismic Magnetic Imager instruments on board the Solar Dynamics Observatory and the Interferometric BI-dimensional Spectro-polarimeter installed at the National Solar Observatory, Sac Peak, we study the plasma parameters of the upflows and the impact of the chromosphere on active region upflows. Our analysis shows that the studied active region upflow presents similarly to those studied previously, i.e. it displays blue- shifted emission of 5 -20 km/s in Fe xii and Fe xiii and its average electron density is 1.8 10^9 cm^{-3} at 1 MK. The time variation of the density is obtained showing no change (in a 3sigma error). The plasma density along a single loop is calculated revealing a drop of 50% over a distance of ?20 000 km along the loop. We find a second velocity component in the blue wing of the Fe xii and Fe xiii lines at 10^5 km/s reported only once before. For the first time we study the time evolution of this component at high cadence and find that it is persistent during the whole observing period of 3.5 hours with variations of only ±15 km/s. We also, for the first time, study the evolution of the photospheric magnetic field at high cadence and find that magnetic flux diffusion is responsible for the formation of the upflow region. High cadence HÎ± observations are used to study the chromosphere at the footpoints of the upflow region. We find no significant jet-like (spicule/rapid blue excursion) activity to account for several hours/days of plasma upflow. The jet-like activity in this region is not continuous and blueward

asymmetries are a bare minimum. Using an image enhancement technique for imaging and spectral data, we show that the coronal structures seen in the AIA 193 A channel is comparable to the EIS Fe xii images, while images in the AIA 171 A channel reveals additional loops that are a result of contribution from cooler emission to this channel. Our results suggest that at chromospheric heights there are no signatures that support the possible contribution of spicules to active region upflows. We suggest that magnetic flux diffusion is responsible for the formation of the coronal upflows. The existence of two velocity components possibly indicate the presence of two different flows which are produced by two different physical mechanisms, e.g. magnetic reconnection and pressure-driven.

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P1.28 *Amy Winebarger*
Title - Determining the Frequency of Coronal Heating with the Marshall Grazing Incidence X-ray Spectrometer (MaGIXS)

Authors:
Amy Winebarger, Sabrina Savage, Ken Kobayashi, Jonathan Cirtain (NASA MSFC),
Patrick Champey (University of Alabama, Huntsville), Peter Cheimets, Leon Golub, Ed DeLuca, Paola Testa, Katherine Reeves (Smithsonian Astrophysical Observatory), Harry Warren (Naval Research Lab), Stephen Bradshaw (Rice University), David McKenzie (Montana State University), Helen Mason, Giulio Del Zanna (University of Cambridge), Robert W. Walsh (University of Central Lancashire)

Abstract:
Since the discovery of million-degree coronal temperatures by Edlen and Grotrian in the 1930s, a major problem in solar physics has been to determine the mechanisms that transfer and dissipate energy into the corona. Determining how frequently energy was released in the corona may provide an important clue to the heating and dissipation mechanism(s). Using a novel implementation of corrective optics, the Marshall Grazing Incidence X-ray Spectrometer (MaGIXS), a sounding rocket instrument scheduled to fly in 2018-2019, will measure, for the first time, the solar spectrum from 6 to 24 Angstroms with a ~6” resolution (2.8” /pixel) over an 8’ slit. Because emission lines formed at high temperatures dominate the soft X-ray regime, X-ray spectroscopic techniques yield insights to fundamental physical processes that are not accessible by any other means. The goal of MaGIXS is to make four fundamental observations to determine definitively the frequency of heating in an active region core: the relative amount of high temperature emission in coronal structures, the relative and absolute abundances of the coronal structures, the time variation of coronal structures in the Fe XVII spectral line, and the detection of non-Maxwellian electron distributions. In this poster, we will describe the scientific goals and expected outcomes of the MaGIXS rocket flight.

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P1.29 *Vanessa Polito*
Title - Simultaneous HINODE/EIS and IRIS observation of an X-class flare

Authors:
V. Polito, J. Reep, K. Reeves, P. Simoes, G. Del Zanna, H. Mason & L. Golub

Abstract:
In this work we present a recent observation of an X class flare obtained with the Interface Region Imaging Spectrometer (IRIS), the EUV Imaging Spectrometer (EIS) on board the HINODE satellite and the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI). Thanks to the high temporal resolution of the IRIS and EIS spectroscopic observations, we are able to track the fast chromospheric evaporation from the flare footpoints during the early impulsive phase. In particular, strong

blueshifts (of the order of 200 km/s) are simultaneously observed in both IRIS Fe XXI 1354 A and HINODE/EIS Fe XXIII 263 A hot (>10 MK) emission lines at different locations along the flare ribbons. RHESSI hard X ray images and high resolution IRIS Slit-Jaw images are used to precisely locate the flare kernels where the blueshifted emission originates. Hot emission from the filled coronal loops is also observed in the AIA 131 and HINODE/EIS Fe XXIII images for several minutes after the evaporation takes place. Multi-wavelength SDO/AIA and spectroscopic EIS and IRIS observations provide density and temperature diagnostics over time. Finally, we have run 1D hydrodynamics simulations with the HYDRAD code to compare the plasma observables against theoretical predictions.

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P1.30 *Hugh Hudson*
Title - EVE inference of the properties of CME progenitor loops

Authors:
H. Hudson

Abstract:
The occurrence of a CME corresponds well with dimmings that EVE can observe in many iron emission lines. We find these dimmings to be most pronounced - up to 10% of the total pre-event irradiance - in lines of Fe IX-XII predominantly. By assuming this dimming to result from the eruption of a previously established coronal structure (loop, channel, or flux rope), we estimate its mean parameters (mass, density, temperature) for the X-class flares of Cycle 24 as observed by the MEGS-A spectrometer on board SDO.

SESSION 2: Transition Region-Corona Connection

INVITED TALKS

IT2.1 *Bart De Pontieu*

Title - Observations and modeling of the chromosphere and its connections to the outer atmosphere

Authors:
Bart De Pontieu

Abstract:
The chromosphere processes all magneto-convective energy that drives coronal heating and requires a heating rate that is at least as large as for the corona. Many questions remain about what heats the chromosphere and how it is connected with the transition region and corona. In this talk I will highlight some recent results that are based on the synergy of high-resolution observations from space-based (e.g., IRIS, SDO, Hinode) and ground-based instruments with advanced numerical modeling. I will review recent progress on understanding the role of ion-neutral interactions in heating the magnetic chromosphere, correlations between chromospheric and coronal heating, the role of shocks in the quiet and magnetic chromosphere and transition region, the role of jets in the chromosphere and beyond, and chromospheric observations of magnetic waves and their dissipation.

*

IT2.2 *Pia Zacharias*

Title - Classical TR vs low lying loops

Authors:
Pia Zacharias

Abstract:
Understanding the structure and dynamics of the solar transition region and its connection to coronal structures such as hot loops, has been a major challenge for the past decades. To explain the observed low-temperature emission measure distribution, it was suggested that small magnetic loops, effectively isolated from the hotter corona, provide most of the quiet solar EUV output at temperatures below 1MK. However, the spatial resolution of the observations available until a decade ago was inadequate to confirm this hypothesis. Recent IRIS observations have revealed a wealth of short, low-lying, relatively cool loops that vary rapidly on time-scales of minutes and have no contact with the corona. Several properties of these previously unresolved fine-structured (UFS) loops are remarkably similar to what is found in realistic 3D models spanning the convection zone to corona region. These models predict highly dynamic spectral lines originating in the lower transition region with low-lying, episodically heated loops that arise naturally. We will discuss the characteristics of these UFS loops, which give direct insight into the coronal heating mechanism and present some new studies on their dynamic nature.

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IT2.3 *Tiago Pereira*
Title - The Role of Spicules

Authors:
Tiago M. D. Pereira

Abstract:
Spicules are the most apparent feature of the chromosphere. They are observed everywhere in the Sun. Despite numerous observations they are still difficult to understand and many questions remain. What is their role in supplying the corona with energy and mass? What is their thermal evolution? Are they real mass motions or just an optical illusion? Hinode observations show that spicules are more dynamic than previously thought. Using IRIS observations we can see the transition region continuation of the Hinode spicules after they disappear from the Ca II H filtergrams, suggesting that they are being violently heated. In this talk I will discuss the latest results from IRIS and ground-based observations and how they can be used to place constraints on conflicting interpretations of spicules and their role in energising the chromosphere and corona.

CONTRIBUTED TALKS

CT2.1 *Jeffrey Reep*
Title - Modeling chromospheric nanoflares

Authors:
Reep, Bradshaw, & Alexander

Abstract:
High densities and up-flows of material are often observed in active region loops, where the temperatures exceed a few million K. Energy carried to the chromosphere drives evaporation that carries hot plasma into the corona, thus raising the density and temperature. Using hydrodynamic modeling, we examine the possibility of direct chromospheric heating in the form of nanoflares, focusing in particular on the depth in the chromosphere at which the loop is heated. The depth at which the energy is released (or deposited) is directly related to the speed of flows and the amount of mass carried by the flows. We will show that explosive evaporation -- a characteristic of full-scale flares -- can occur in much smaller events under the right conditions. We also forward model spectral emissions to directly compare observations to the predictions of this model.

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CT2.2 *Richard Morton*
Title - Insights from Hi-C into the structure and dynamics of an AR Transition Region

Authors:
R. Morton, J. McLaughlin, A. Winebarger

Abstract:
Just before the launch of IRIS, the Hi-resolution Coronal Imager (Hi-C) was able to provide a glimpse of the Transition Region. Launched on a sounding rocket, Hi-Cs primary focus during its short flight was an active region close to disk centre. The AR comprised of significant regions of moss, which meant Hi-C was able to provide a unique view of the TR of hot loops. I will discuss some of the details of the AR TR that have come to light from the Hi-C data. Briefly, Hi-C was able to resolve fine-scale structure in the dark patches of the moss, revealing elongated flux-tubes. The resolution of Hi-C allows for the measurement of the transverse spatial scales of the structures and calculation of filling

factors for the moss regions. The results are compared with filling factor estimates derived from EIS data of the same region. I suggest these features are the lower legs of hot AR loops but there exact relation to soft x-ray loops remains unclear. Additionally, the ability to resolve the fine-scale structure also reveals it is highly dynamic, demonstrating swaying motions and the presence of field aligned plasma motions.

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CT2.3 *Kryzysztof Barczynski*
Title - Miniature coronal loops

Authors:
K. Barczynski, H. Peter

Abstract:
The High-resolution Coronal Imager (Hi-C) revealed tiny elongated loop-like structures with lengths of the order of 1 Mm. having a width of only 200 km or less they reach temperatures of at least 1 MK. To understand these features we analyse images of the coronal emission in 193 A from Hi-C together with the photospheric magnetic field from the HMI magnetograms. In addition we also make use of the UV and EUV wavebands aqcuired with SDO/AIA during the Hi-C observations. From the Hi-C observation we identified four miniature loop-like structures in a plage area. The various AIA channels we used to align the maps of the photospheric magnetic field with the Hi-C images and to study the thermal structure of the atmosphere by means of a differential emission measure (DEM) analysis.
The analysis of the loop-like structures in Hi-C revealed that their motion is consistent with granular motions, suggesting a close connection of these hot structures to the small-scale magnetic features in the photosphere. The length of the loop-like features is comparable to the size of a granule, so that these could be miniature coronal loops just spanning across one single granule. Also the lifetime of the loop-like features of a few minutes supports this interpretation of being loops across granules. In the HMI magnetograms the plage region hosting these loop-like structures seems to be unipolar. However, the careful correlation of the Hi-C images and magnetograms shows that typically one footpoint of the structure is near a patch of strong magnetic field, while the other footpoint is where HMI indicates very weak field. Thus it might be that some hidden opposite polarity exists near the stronger patch or network/plage magnetic field, and that these two are connected by the tiny hot Hi-C loop-like features. Observation of small-scale flux emergence in the quiet Sun and network regions would support this interpretation.
Analysing the thermal structure of the atmosphere above the loop-like features reveals that there is no significant amount of hot material, i.e. hotter than some 2 MK. This is unlike in moss features, that are also covered by Hi-C. There we find an abundance of hot material above the bright moss elements, supporting the interpretation that the moss is (in part) heated by thermal conduction of the really hot material in larger loops emerging from the moss region. This cannot be the case for the tine loop-like features we study, because there the hot plasma in possibly associated larger loops being rooted in these features is missing.
From this we conclude that miniature loop-like structures might arise from small-scale flux emergence events in plage areas. Unlike moss they would be primarily heated by the interaction of the emerging magnetic flux tube with the pre-existing magnetic field in the plage area. there are only these few examples found during the short five minutes Hi-C rocket flight, so the conclusions will have to remain a bit vague until we can acquire more data of coronal plasma with comparable spatial and temporal resolution.

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CT2.4 *Paola Testa*

Title - Coronal science with IRIS

Authors:
P. Testa, B. De Pontieu, J. Allred, M. Carlsson, F. Reale, V. Hansteen

Abstract:
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 present new IRIS coronal studies (of the corona in non-flaring conditions) 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.

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CT2.5 *Clementina Sasso*

Title - Transition Region cool loops: the case of optically thick radiative losses

Authors:
Sasso, C., Andretta, V., Spadaro, D.

Abstract:
The existence of small and cool magnetic loops, directly connected to the chromosphere but thermally insulated from the corona, was proposed to explain the origin of the EUV output at temperatures below 1 MK. In a previous work (Sasso et al. 2012), dedicated to study the conditions of existence and stability of these loops, we obtained through hydrodynamic simulations stable, quasi-static low-lying cool loops ($T < 0.1$ MK), under different and more realistic assumptions than the optically thin radiative loss function with respect to previous works. We also showed that their emission, plus the emission of intermediate temperature loops ($0.1 < T < 1$ MK), obtained in the same conditions, could account for the observed radiative output below 1 MK.

Since we also showed that the shape of the radiative loss function below 0.1 MK is crucial to determine the conditions under which cool loops could exist in the solar atmosphere, in the present work, we continue the exploration of the conditions of existence and stability of these loops by using a calculated, optically thick radiative loss function taken from the literature (Kuin & Poland, 1991) together with a density-dependent background heating.

We find that it is possible to obtain quasi-static (velocities lower than 1 km/s) cool loops, only by using a constant heating rate per particle. We also obtain quasi static intermediate temperature loops, using the same optically thick radiative loss function, and calculate the contributions of the cool and intermediate-temperature loops to the transition region DEM (differential emission measure). We find that a combination of these loops, precisely because of their computed pressures, gives a DEM with a shape that can be compared to the observed one (except for an excess emission due to the high density of the cool loops with $4.6 < \log T_{max} < 4.8$).

In this work we show also a dynamic loop and its calculated DEM, and find that it reproduces quite well the observed DEM.

POSTER PRESENTATIONS

P2.1 *Markus J Aschwanden*

Title –Magnetic Coupling between Chromosphere and Corona

Authors:
Aschwanden, M.J.

Abstract:

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 to trace magnetic field directions in UV wavelengths in the chromosphere and transition region. 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_{free} (t_{peak}) ~ (45 +/- 2) x 10^{30} erg, which decreases by an amount of Delta E_{free} ~ (29 +/- 3) x 10^{30} erg during the flare decay phase. The consistency of free energies measured from different EUV and UV wavelengths for the first time here, demonstrates that vertical electric currents and there associated magnetic non-potentiality (manifested in form of helically twisted loops) can be detected and measured from both chromospheric and coronal tracers.

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P2.2 *Ben Snow*

Title - Chromospheric seismology above sunspot umbrae

Authors:
B. Snow

Abstract:

The acoustic resonator is an important model to explain the three-minute oscillations above sunspot umbrae. The steep temperature gradients at the photosphere and transition region provide the cavity for the resonator, which allows waves to be both partially transmitted and partially reflected. It is found that by analysing the velocity spectra present in the corona, one can estimate the depth of the chromospheric cavity. The magnetic field above umbrae is modelled numerically in 1.5D with slow-magnetoacoustic wave trains travelling along magnetic fieldlines. Resonances are driven by applying continuous random noise as small velocity perturbations to the upper convection zone. Energy escapes the resonating cavity and produces upwards propagating wave trains moving into the corona. The depth of the chromospheric cavity is varied and the resultant coronal velocity spectra are analysed. The results show that the gradient of the coronal velocity spectra is directly correlated with the chromospheric temperature configuration; as the chromospheric depth increases, the spectral gradient becomes shallower. When line of sight integration is performed, the resultant frequency spectra demonstrate a bandwidth containing excited frequencies which becomes narrower as the chromospheric depth increases. These two results provide potentially useful diagnostics for the chromospheric temperature profile by consideration of the coronal velocity oscillations.

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P2.3 *Vincenzo Andretta*

Title - The role of type II spicules in the lower transition region

Authors:
V. Andretta, J. A. Klimchuk, B. Fleck, C. Sasso, Th. Straus

Abstract:
The past few years saw a renewed interest in the long-standing, yet neglected problem of the failure of the various coronal heating models to account for the radiative emission of the transition region below 0.1 MK. At the same time, observational progress in the past decade has revived the debate about the role of spicules, in particular of the faster "type II" spicules, in the energetics of the solar corona. We re-examined this latter issue taking into consideration the possibility that type II spicules could explain the observed radiative output of the lower transition region, thus providing an overall coherent picture of the energetics of the entire solar transition region, which can now be quantitatively verified by the currently available instrumentation.

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P2.4 *Harry Warren*

Title - Measuring Elemental Abundances in Impulsive Heating Events with EIS

Authors:
Harry Warren

Abstract:
It is well established that elemental abundances vary in the solar atmosphere and that this variation is organized by first ionization potential (FIP). Previous studies have indicated that in the solar corona low FIP elements, such as Fe, Si, and Mg, are enriched relative to high FIP elements, such as H, He, C, N, and O. In this paper we report on measurements of plasma composition made during transient heating events observed at transition region temperatures with the Extreme Ultraviolet Imaging Spectrometer (EIS) on Hinode. During these events the intensities of O IV, V, and VI emission lines are enhanced relative to emission lines from Mg V, VI, and VII and indicate a composition close to that of the photosphere. Differential emission measure calculations show a broad distribution of temperatures in these events. Long-lived coronal structures, in contrast, show an enrichment of low FIP elements and relatively narrow temperature distributions. We conjecture that plasma composition is an important signature of the coronal heating process, with impulsive heating leading to the evaporation of unfractionated material from the lower layers of the solar atmosphere and higher frequency heating leading to the accumulation of low-FIP elements in the corona.

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P2.5 *Giuseppe Nistico*

Title - 3D reconstruction of coronal loops in active regions by Principal Component Analysis

Authors:
Giuseppe Nistico', Valery M. Nakariakov

Abstract:
Knowing the three-dimensional (3D) structure of coronal loops is an important task in the wave-based diagnostic of the solar corona. The combination of different points of observation in space, such as those provided by SDO and STEREO, allows us to stereoscopically measure a limited number of 3D tie-points, which irregularly sample the loop length. Here, we propose a new method to reconstruct the loop shape and best fit the 3D tie-points by the Principal Component Analysis. This method is show to precisely determine the main parameters that define a coronal loop, such as the

minor and major axes, the loop plane, the azimuthal and inclination angle. The technique is suitable for serial reconstruction of active regions, providing a useful tool for comparison between observations and theoretical magnetic field extrapolations, and forward modeling of MHD oscillations in coronal loops.

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P2.6 *Craig Johnston*

Title - A Computational Method for Modelling Chromospheric Evaporation

Authors:
Craig Johnston

Abstract:
We present the results of 1D field-aligned simulations that study the plasma response to variations in coronal heating. We treat thermal conduction by using Super Time Stepping methods (Meyer et al, MNRAS, 2012). The basic loop model consists of a hydrostatic equilibrium in thermal balance between conduction, optically thin radiation and heating. Then we include an additional release of energy, across the coronal part of the loop to increase the temperature. This drives a conduction front downwards into the transition region and facilitates chromospheric evaporation. We show that, using Super Time Stepping methods for thermal conduction, we can fully resolve the temperature and density profiles without prohibitive time-step restrictions.

SESSION 3: Fine Scale Structure and Non-Equilibrium Processes

INVITED TALKS

IT3. 1 *Patrick Antolin*
Title – Fine-scale structuring, braiding and heating of loops from thermal and wave instabilities

Authors:
P. Antolin, G. Vissers, T. Okamoto, L. Rouppe van der Voort

Abstract:
The organisation of fine-scale structure in the coronal high-Reynolds environment is a major unknown on which dissipative processes leading to significant heating ultimately rely. A multi-strand loop substructure in which strands are thermodynamically independent is usually invoked for explaining observations. In this talk I will present observational evidence of fine-scale structure in loops and numerical results supporting a major role of thermal and wave instabilities behind this morphology. Coronal rain, a thermal instability phenomenon in coronal loops in which coronal plasma cools down to transition region (TR) and chromospheric temperatures, allows to probe the local and global topology of coronal structures at the currently highest achievable spatial resolution. Recent observations combining SST, Hinode, IRIS and SDO will be presented, which indicate a very high co-spatial degree below 0.3" of the multi-thermal emission from coronal rain. Coronal rain is multi-stranded and clumpy, indicating strong transverse and longitudinal inhomogeneity within thermally unstable loops. At the smallest detected scales of 0.2" the strand-like structure is highly reminiscent of the MHD thermal mode. The strand-like and the clumpy structure extend from the chromospheric range to (at least) the TR range, suggesting an important role of thermal instability in the shaping of fundamental loop substructure. The clumpy structure often appears in sequential chains, suggesting the presence of dynamic instabilities, a scenario supported by observed velocity shear and by numerical simulations. Braided structure and, especially, transverse oscillations are commonly observed in coronal rain. Through 3D MHD simulations of transverse MHD waves combined with proper forward modelling I will show that resonant absorption couples with Kelvin-Helmholtz instabilities to produce strand-like structure, braiding and heating within loops. Recent observations of prominences with IRIS match well the observational signatures predicted by the model.

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IT3.2 *Bruno Coppi*
Title – Realistic Magnetic Reconnection Processes and their Role in the Dynamics of Coronal Loops

Authors:
Bruno Coppi

Abstract:
The experimental observations of coronal loops have led to suggest that loop topologies, as in the case of magnetically confined toroidal plasmas, are susceptible to the excitation of modes producing magnetic reconnection. Within the relatively broad category of modes of this kind those that can emerge in collisionless regimes are given special attention. Then the presence of plasma density and

temperature gradients as well as non-thermal features of the particle distributions in momentum space can have important effects. In the case of laboratory plasmas the frequency of oscillations and the associated phase velocities of the observed modes have led to establish that a finite "inductivity" [1] rather than an electrical resistivity should be introduced in the relevant theory as the main factor on which reconnection depends. Then the experimentally identified [2] phase velocities and their direction can be reproduced. This factor makes the theory applicable to astrophysical structures, and to loops in particular, easier than that depending on mode-particle resonance processes [3]. A remaining difficulty is that of finding modes, like the so-called "internal kink modes", with a prevalent poloidal mode number $m^0 = 1$, for which the width of the reconnection layer is not unrealistically small, when applied to astrophysical structures, like in the case of the well known tearing modes. The reconnecting layer is that where the "frozen-in-law" is violated and the most visible effect of internal kink modes is that of producing sawtooth oscillations of the plasma pressure providing evidence for the intermittent nature of magnetic reconnection. The emergence of temperature and density spatial (radial) singularities, associated with reconnecting modes in the presence of significant temperature and density gradients, are pointed out. *Sponsored in part by the U.S. Department of Energy.

[1] B. Coppi, *Bull. Am. Phys. Soc*. **45**, (2000) 366.
[2] P. Buratti, *et al*., 2014 "Magnetic islands rotation in JET",41st EPS Conference on Plasma Physics (Berlin, 2014) ECA vol. 38F, paper P1.014.
[3] B. Coppi, L. Sugiyama, J. W-K Mark, and G. Bertin, *Ann.Phys*. **119**, (1979) 370.

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IT3.3 *Peter Young*

Title – Coronal loop diagnostics – developments and limitations

Authors:
Peter Young

Abstract:
Spectroscopic plasma diagnostics for coronal loops will be discussed with a particular focus on how diagnostics have developed during the Hinode/EIS mission (2006-present). EIS gives access to many very good density diagnostics but early work found discrepancies between different ions. The effects of recent updates to CHIANTI on the diagnostics will be presented. Velocity and line width measurements are sensitive to both interpretation and instrumental effects, and recent progress will be summarized. Element abundance studies from EIS data are becoming increasingly common and I will describe techniques and recent results. The IRIS instrument gives very high spatial resolution observations of loop footpoints through the density-sensitive O IV emission lines, and a comparison with EIS will be made.

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IT3.4 *Jaroslav Dudik*
Title - Advances in treating non-equilibrium processes

Authors:
J. Dudik

Abstract:
We will review the recent advances in non-equilibrium modeling of coronal loop plasma, with particular attention to the non-equilibrium ionization and non-Maxwellian distributions. The non-equilibrium ionization modelling will focus on 1-D hydrodynamic loop codes incorporating impulsive heating by "nanoflares", as well as the generalized collisional-radiative (GCR) approach, and the theoretical observables identified. The possible presence of energetic particles and their consequences for modeling of synthetic spectra will be discussed together with observational attempts at establishing upper limits to the number of energetic particles at different energies.

CONTRIBUTED TALKS

CT3.1 *Peter Cargill*
Title - Avalanche models for coronal energy release

Authors:
A.W. Hood, P.K. Browning & P.J. Cargill

Abstract:
Since the pioneering work of Lu and Hamilton, magnetic avalanche models have been a popular scenario for coronal energy release ranging from small flares (Vlahos et al, ApJ 608, 540, 2004) to nanoflare swarms (Lopez-Fuentes & Klimchuk, ApJ, 719, 591, 2014). To date all models have been cellular automata (i.e. rules-based) or use incomplete versions of the equations of magnetohydrodynamics. We will present the first fully 3D MHD simulations of an avalanche such as may occur in a nanoflare storm. We create a large array of twisted flux threads, of which only one is unstable to the kink instability. When the sense of twist is the same for all the threads, the unstable thread can destabilise almost all the others by an avalanche-like process, This leads to bursty energy release and the final outcome is a single magnetic structure with weak twist. The avalanche can be "blocked" by, for example, inclusion of threads of opposite twist.

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CT3.2 *Hirohisa Hara*
Title - Unresolved Plasma Motions in Coronal Loops

Authors:
Hirohisa Hara

Abstract:
The so-called non-thermal broadening of coronal emission lines is the central topic of this study. It has been interpreted as a result of plasma motions that are associated with waves, plasma turbulence, and unresolved bulk Doppler flows with the velocity dispersion, etc. The magnetic field lines in a coronal loop that we observe with an instrument of a few arcsec spatial resolving performance are mostly aligned to each thread structure that consists of the coronal loop. Processes in the coronal threads that cause enhanced line broadening produce non-uniform velocity fields in the corona. Here we report the non-thermal broadening with respect to the loop geometry from observers based on the *Hinode* EIS observations. We assess the extent of anisotropy of the non-thermal broadening with respect to the loop geometry and discuss its relation to coronal heating.

CT3.3 *James A Klimchuk*
Title - The Onset of Magnetic Reconnection

Authors:
James A. Klimchuk and Lars Daldorff

Abstract:
A fundamental question concerning magnetic energy release on the Sun is why the release occurs only after substantial stresses have been built up in the field. If reconnection were to occur readily, the released energy would be insufficient to explain coronal heating, CMEs, flares, jets, spicules, etc. How can we explain this switch-on property? What is the physical nature of the onset conditions? One idea involves the "secondary instability" of current sheets, which switches on when the rotation of the magnetic field across a current sheet reaches a critical angle. Such conditions would occur at the boundaries of flux tubes that become tangled and twisted by turbulent photopheric convection, for example. Other ideas involve a critical thickness for the current sheet. We report here on the preliminary results of our investigation of reconnection onset. Unlike our earlier work on the secondary instability (Dahlburg, Klimchuk, and Antiochos 2005), we treat the coupled chromosphere-corona system. Using the BATS-R-US MHD code, we simulate a single current sheet in a sheared magnetic field that extends from the chromosphere, through the transition region, and into the corona. Driver motions are applied at the base of the model. The configuration and chromosphere are both idealized, but capture the essential physics of the problem. The advantage of this unique approach is that it resolves the current sheet to the greatest extent possible while maintaining a realistic solar atmosphere. It thus bridges the gap between "reconnection in a box" studies and studies of large-scale systems such as active regions. One question we will address is whether onset conditions are met first in the chromosphere or corona.

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CT3.4 *Fabio Reale*
Title - Analysis of time-resolved emission from bright hot pixels of an active region observed in the EUV band with SDO/AIA

Authors:
E. Tajfirouze, F. Reale, A. Petralia, P. Testa

Abstract:
Evidence for small amounts of very hot plasma has been found in active regions and might be the indication of an impulsive heating, released at spatial scales that are smaller than the cross section of a single loop. We investigate the heating and substructure of coronal loops by analyzing the light curves in the smallest resolution elements of solar observations in the EUV band from the Atmospheric Imaging Assembly on-board the Solar Dynamics Observatory. In the hypothesis that coronal loops consists of bundles of fine unresolved strands, we model the evolution of a bundle of strands for a single pixel image of a coronal active region along the line of sight by means of a hydrodynamic 0D loop model.
The light curves obtained from the random combination of those of single strands are compared to the observed light curves either in a single pixel or in a row of pixels, using two independent methods: one is an artificial intelligent system and the other is a simple cross-correlation technique.
We explore the space of the parameters to constrain the distribution of the heating events, their duration and their spatial size, and, as a feedback on the data, their signatures on the light curves.
Both comparison methods are unanimous in an individual set of parameter related to a particular set of realizations to reproduce the observed feature of single and few integrated pixels over a visible part of an active region loop.

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CT3.5 *Simon Candelaresi*
Title - Current Sheet Formation During the Ideal Relaxation of Magnetic Fields

Authors:
Simon Candelaresi, David Pontin and Gunnar Hornig

Abstract:
We investigate the existence of magnetohydrostatic equilibria and the formation of current concentrations in highly braided and sheared magnetic fields. Such fields have geometries and topologies which can occur in coronal loops. Parker (1972) hypothesised that for sufficiently braided fields in an ideal evolution there should be singular current concentrations forming. Our test fields qualify as highly braided, according to Parker's definition, i.e. their twist is not uniform along the field lines. For simulating the field relaxation we use our own numerical code GLEMuR which uses a Lagrangian description of the fluid and mimetic differential operators which greatly enhance numerical accuracy. The field's topology is perfectly conserved in this ideal evolution where the field lines connect between two perfectly conducting plates. For all the test cases we observe current concentrations of finite sizes, contrary to the initial hypothesis. We further perform numerical experiments of fields with magnetic nulls and confirm the formation of singular current concentrations.

POSTER PRESENTATIONS

P3.1 *Xia Fang*
Title - Multidimensional modelling of Coronal Rain

Authors:
Xia Fang, Rony Keppens, Chun Xia, Tom Van Doorsselaere

Abstract:
We present multidimensional, magnetohydrodynamic simulations of coronal rain appearance with grid-adaptive computations covering a long (>6 hour) timespan in which shows that rain showers can occur in limit cycles for the first time in 2.5D setups. The simulations show how thermal instability can induce a spectacular display of in situ forming blob-like condensations which then start their intimate ballet on top of initially linear force-free magnetic arcades. We quantify how in-situ forming blob-like condensations grow along and across field lines, and point out the correlation between condensation rates and the cross-sectional size of loop systems where catastrophic cooling takes place. We discuss dynamical, multi-dimensional aspects of the rebound shocks generated by the siphon inflows and quantify the thermodynamics of a prominence-corona-transition-region like structure surrounding the blobs. Our virtual coronal rain displays the deformation of blobs into V-shaped features, interactions of blobs due to mostly pressure-mediated levitations, and gives the views of blobs that evaporate in situ or are siphoned over the apex of the background arcade. We find plenty of shear flows generated with relative velocity difference around 80 km/s in our simulations. These shear flows are siphon flows set up by multiple blob dynamics and they in turn affect the deformation of the falling blobs. In particular, we show how shear flows can break apart blobs into smaller fragments, within minutes.

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P3.2 *Sofia-Paraskevi Moschou*

Title - 3D Simulations on Coronal Rain Events

Authors:
S. P. Moschou, R. Keppens, C. Xia, X. Fang

Abstract:
We present 3D numerical simulations on coronal rain phenomena in a magnetic configuration of a quadrupolar arcade system. A magnetohydrodynamic simulation including three gain-loss terms, anisotropic thermal conduction, optically thin radiative losses, and parametrised heating is used to construct a realistic arcade configuration from chromospheric to coronal heights. The plasma evaporation from chromospheric and transition region heights eventually causes localised runaway condensation events and plasma blobs are formed due to thermal instability, that evolve dynamically in the heated arcade part and move gradually downwards due to interchange type dynamics. Unlike earlier 2.5D simulations, in this case there is no large scale prominence formation observed, but a continuous coronal rain develops which shows clear indications of Rayleigh-Taylor or interchange instability, that causes the denser plasma located above the transition region to fall down, as the system seeks stability. Linear stability analysis is used in the non-linear regime for gaining insight and giving a prediction of the system's evolution. After the plasma blobs descend through interchange, they follow the magnetic field topology more closely in the lower coronal regions, where they are guided by the magnetic dips.

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P3.3 *Frederic Auchere*

Title – Random Amplitude Pulse Trains in Solar Coronal Loops

Authors:
F. Auchere, C. Froment, K. Bocchialini, E. Buchlin, J. Solomon

Abstract:
We present a detailed analysis of the properties of the Fourier and wavelet power spectra of slow periodic pulsations observed in solar coronal loops and described by Froment et al. Our primary aim was to re-assess critically the significance of the detections. This requires proper estimation of the frequency dependence and statistical properties of the several components constituting the power spectra. This includes recognition of the possible modification of the spectral shape by pre-processing of the data. We demonstrate that de-trending tends to produce false detections around the frequency cut-off of the applied filter. In addition, we show that the models of white and red noise built in the widely used wavelet code of Torrence & Compo in most cases cannot adequately represent the power spectrum of coronal time series, thus also possibly leading to false positives. Both effects suggest that several reports of periodic phenomena in the corona should be re-examined. However, the Torrence & Compo code effectively computes rigorous confidence levels if it is fed with pertinent models of mean power spectra, and we give practical information on the corresponding manner to call the core routines. We remind the meaning of the default confidence levels output by the code and we propose new Monte Carlo-derived confidence levels that take into account the total number of degrees of freedom in the wavelet spectra. In this way, we confirm that the peaks of power detected by Froment et al. in extreme-ultraviolet light curves from the Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA) telescope have less than 0.1% chance of being caused by stochastic processes. We further show that, in addition to the power law expected from a background stochastic process, the power spectra exhibit the discrete harmonics and continuous component characteristic of signals formed by periodic pulses of random amplitudes.

While not excluding other possibilities, the discovery that the observed light curves are random amplitude pulse trains is consistent with the physical interpretation proposed by Froment et al. in terms of periodic cycles of evaporation and incomplete condensation.

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P3.4 *Elena Dzifcakova*

Title - Electron kappa-distributions and the non-equilibrium ionization in the transition region and solar corona

Authors:
Elena Dzifcakova, Jaroslav Dudik, Simon Mackovjak

Abstract:
The presence of the kappa-distributions or distributions exhibiting high-energy tails in the solar corona and transition region can be expected due to particle acceleration processes arising as a result of nanoflare heating in the solar corona. Generally, the non-Maxwellian distributions change the ionization, recombination, and excitation rates. The ionization and recombination rates influence the ionization equilibration times. Changes in the non-equilibrium ionization state due to heating and cooling plasma for the Maxwellian and kappa-distributions for simple heating and cooling functions are modeled. Characteristic times to achieve the ionization equilibrium for different distributions, temperatures and the electron densities are compared. Possible application of the kappa-distributions for the estimation of the electron beam effects on observed spectra is demonstrated using a very simple model. It is shown that non-equilibrium plasma can look like multi-thermal plasma characterized by a DEM. If the non-equilibrium ionization occurs during the presence of kappa-distributions in the transition region, higher ionization states can be formed at much lower temperatures than for the Maxwellian distribution, by up to one order in extreme cases.

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P3.5 *Antonino Petralia*

Title - Coronal loops activated by downfalling fragments of a solar eruption

Authors:
A. Petralia, F. Reale, S. Orlando, P. Testa

Abstract:
We study the downfall of dense and cool fragments from a strong solar eruption, and in particular those channelled in loops inside active regions. We see the flux tubes brightening due to the interaction. We study whether and how this interaction is able to heat the loop plasma. We use a 3D MHD model of spherical dense blobs falling inside a corona with a curved magnetic field, with different assumptions on the background atmosphere (low vs high pressure) and on the intensity of the magnetic field.

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P3.6 *Daniel Price*

Title - Physics of outflows near solar active regions

Authors:
Daniel Price and Youra Taroyan

Abstract:
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 loop simulations incorporating the effects of non-equilibrium ionisation and use those to create synthetic line profiles in order to replicate the spectroscopic observations. The results of the forward modelling support a scenario whereby long loops consisting of multiple strands undergo a cyclical process of impulsive heating and cooling.

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P3.7 *Fabio Reale*

Title - 3D MHD modeling of coronal loops

Authors:
F. Reale, et al.

Abstract:
We extend modeling single bright coronal loops to include the interaction with a non-uniform magnetic field. The field is stressed by footpoint rotation in the central region and its energy is dissipated into heating through the induced currents. We model an entire single magnetic flux tube with gravity of a curved loop, in the solar atmosphere from the high-beta chromosphere to the low-beta corona through the steep transition region. The magnetic field expands from the chromosphere to the corona. We obtain a loop evolution typical of previous loop modeling. The plasma confined in the flux tube is gradually heated to active region temperature (~3 MK) and upflows from the chromosphere gradually fill the core of the flux tube. We discuss different magnetic diffusion scenarios.

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P3.8 *Duncan Stackhouse*

Title - Numerical and Observational Examination of the Spectral Variation of Extended Coronal Hard X-ray Sources

Authors:
Duncan Stackhouse, Eduard Kontar

Abstract:
The ability of RHESSI imaging spectroscopy to resolve structure in the X-ray emission present in solar flares opened up greater possibilities for probing the accelerated electrons responsible for emitting these photons. The 2005 August 23 flare shows an extended loop morphology over a large range of energies. We examine the electron distribution along the spatial extent of the emission to see if and how it changes. We present a one-dimensional model of the corona in a regime with coulomb collisions and a localised stochastic acceleration akin to a looptop acceleration region. Ballistic and diffusive transport are studied and the variation of the density weighted mean electron flux, <nVF>, in space is compared with the RHESSI results, providing constraints on the dominant processes in the corona. We shall also compare with imaging spectroscopy results from a more common looptop plus footpoints X-ray source. The validity of the leaky box Fokker Planck approximation will also be commented on.

P3.9 *James A Klimchuk*

Title - Intensity Conserving Spline Interpolation (ICSI): A New Tool for Spectroscopic Analysis

Authors:
James A. Klimchuk, Spiros Patsourakos, & Durgesh Tripathi

Abstract:
Spectroscopy is an extremely powerful tool for diagnosing astrophysical and other plasmas. For example, the shapes of line profiles provide valuable information on the distribution of velocities along an optically thin line-of-sight and across the finite area of a resolution element. A number of recent studies have measured the asymmetries of line profiles in order to detect faint high-speed upflows, perhaps associated with coronal nanoflares or perhaps associated with chromospheric nanoflares and type II spicules. Over most of the Sun, these asymmetries are very subtle, so great care must be taken. A common technique is to perform a spline fit of the points in the profile in order to extract information at a spectral resolution higher than that of the original data. However, a fundamental problem is that the fits do not conserve intensity. We have therefore developed an iterative procedure called Intensity Conserving Spline Interpolation that does preserve the observed intensity within each wavelength bin. It improves the measurement of line asymmetries and can also help with the determination of line blends.

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P3.10 *Juraj Lorincik*

Title - The EUV Emission Lines observed by Hinode/EIS: Average spectra, densities, and missing pixels

Authors:
Juraj Lorincik, Jaroslav Dudik, Elena Dzifcakova

Abstract:
We analyze the Hinode/EIS off-limb observations performed during HOP 265 on 2014 November 4. A prominent system of coronal loops in the AR NOAA 12197 is observed in numerous Fe IX-XIII lines. We selected boxes in several isolated loop areas of and calculate the average spectra over these boxes. This is done in two ways: First one utilizes the interpolated spectra as given by the standard EIS_PREP routine. The second one leaves the missing pixels out of the averaging; a technique used for diagnosing the kappa-distributions by Dudik et al. (2015, ApJ, submitted). In doing so, we avoid the areas where the missing pixels are located within the line core. We show that, if there are no missing pixels in the line core, these two methods produce comparable results. Background subtraction and the subsequent diagnostics of electron density using Fe XI, XII, and XIII ratios is performed and the role of the background-subtraction on the density diagnostics is discussed.

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P3.11 *Jaroslav Dudik*

Title - Diagnostics of kappa-distributions in a transient coronal loop using Hinode/EIS and SDO/AIA observations obtained during HOP 226

Authors:
Jaroslav Dudik (1), Simon Mackovjak (2), Elena Dzifcakova (1), Juraj Lorincik (2), Giulio Del Zanna (3), David R. Williams (4), Marian KarlickÃ½ (1), Helen E. Mason (3), Pavel KotrÄ (1), FrantiÅ¡ek FÃ¡rnÃk (1) and Alena ZemanovÃ¡ (1)

(1) - Astronomical Institute of the Academy of Sciences of the Czech Republic, Fricova 298, 251 65 Ondrejov, Czech Republic

(2) - DAPEM, Faculty of Mathematics, Physics and Computer Science, Comenius University, Mlynska Dolina F2, 842 48 Bratislava, Slovakia
(3) - Department of Applied Mathematics and Theoretical Physics, CMS, University of Cambridge, Wilberforce Road, Cambridge CB3 0WA, United Kingdom
(4) - Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Dorking, Surrey RH5 6NT, United Kingdom

Abstract:
We report on the observations and diagnostics of a transient coronal loop observed by SDO/AIA and Hinode/EIS. The AIA data are used to derive the DEMs and to study the temporal evolution of the loop and its relation to neighbouring activity including a preceding B-class flare and several jets. The Hinode/EIS observations in Fe XI-XIII are used to derive the plasma density and perform the diagnostics of temperature and kappa. The diagnostics using the Fe XI 257.7A self-blend show that the plasma is likely highly non-Maxwellian with kappa < 2. Atomic data uncertainties and the effect of plasma multithermality (DEM) is discussed, neither of which change the result of non-Maxwellian diagnostics.

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P3.12 *Matthew West*

Title - SWAP Observations of Post-flare Loops and the Effects of Background Coronal Conditions

Authors:
Matthew J West, Daniel B Seaton

Abstract:
On 14 October 2014 the Sun Watcher with Active Pixels and Image Processing (SWAP) EUV solar telescope on-board the Project for On-Board Autonomy 2 (PROBA2) spacecraft observed an eruption that led to the formation of perhaps the largest post-eruptive loop system seen in the solar corona in solar cycle 24. The initial eruption occurred at about 18:30 UT on 14 October, behind the East Solar limb, and was observed as a coronal mass ejection and an M2.2 solar flare. In the 48 hours following the eruption, the associated post-eruptive loops grew to a height of approximately 400000 km (>0.5 solar-radii) at rates between 2-6 km/s. The event is discussed how the background corona, through which the eruption propagated, may have determined the height to which reconnection and consequently the post eruption loops could grow.

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P3.13 *Marina Skender*

Title -Estimation of the back-illumination of the chromosphere for the 2011-02-15 flare

Authors:
Marina Skender, Vincenzo Andretta, Michal Varady, Petr Heinzel

Abstract:
One of the main ingredients of the energetics of the flaring chromosphere is back-illumination from the flaring corona. In the recent time observational data became available, which can be used as empirical constrain for the back-illumination. In this study the EUV heating of the solar chromosphere is inferred in gradual phase of the flare 2011-02-15. Overlying EUV loops are assumed to have a semi-circular static symmetric configuration, Refs. [1-2]. SDO AIA and EVE data are utilised for estimating the spatial and spectral distribution of the EUV emitter sources, following the procedure analogous to analysis in Ref. [3]. Further modelling is performed by the FLARIX code, Refs. [4-7]. Preliminary inferring of the energetics of the EUV coronal back-illumination is presented.

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P3.14 *Kalman Knizhik*
Title - MHD Simulations of the Interaction of Two Twisted Flux Tubes - Implications for Coronal Heating

Authors:
K. J. Knizhnik, S. K. Antiochos, C. R. DeVore, J. A. Klimchuk, P.F. Wy

Abstract:
The nature of the heating of the Sun's corona has been a long-standing unanswered problem in solar physics. Beginning with the work of Parker (1972), many authors have argued that the corona is continuously heated through numerous small-scale reconnection events known as nanoflares. In these nanoflare models, braiding of magnetic flux tubes by surface motions causes the field to become misaligned. The current sheet separating oppositely oriented field will reconnect, converting the energy stored in the magnetic field into heat. The problem with these models, however, is that the braiding required for this process is expected to inject a net helicity into the corona. While helicity is conserved under reconnection, EUV and X-ray images of coronal loops reveal incredibly smooth, laminar structure. The recently proposed helicity condensation model (Antiochos, 2013) resolves this difficulty, and explains how reconnection transports helicity throughout the solar atmosphere, resulting in a smooth, hot corona. In this model, reconnection between adjacent flux tubes, twisted up by surface convection, transports helicity to ever larger scales, ultimately condensing in filament channels. The reconnection that occurs throughout the solar atmosphere not only results in a smooth corona, but its net effect is to convert the magnetic energy injected by surface motions into heat. In this work, we use the Adaptively Refined MHD Solver (ARMS) to perform 3D MHD simulations that dynamically resolve regions of strong current to study the reconnection between two twisted flux tubes in a plane-parallel Parker configuration. We investigate the energetics of the process, and show that the flux tubes accumulate stress gradually before undergoing impulsive reconnection. We place constraints on the amount of heating expected from such reconnection. Finally, we study the motion of the individual field lines during the impulsive reconnection events.

P3.15 *Michael Hahn*
Title - Influence of Multiple Ionization on Studies of Nanoflare Heated Plasmas

Authors:
Michael Hahn, Daniel Wolf Savin

Abstract:
The spectrum emitted by a plasma depends on the charge state distribution (CSD) of the gas. This, in turn, is determined by the corresponding rates for electron-impact ionization and recombination. Current CSD calculations for solar physics do not account for electron-impact multiple ionization (EIMI), a process in which multiple electrons are ejected by a single electron-ion collision. We have

estimated the EIMI cross sections for all charge states of iron using a combination of the available experimental data and semi-empirical formulae. We then modeled the CSD and observed the influence of EIMI compared
to only including single ionization. One case of interest for solar physics is nanoflare heating. Recent work has attempted to predict the spectra of impulsively heated plasmas in order to identify diagnostics arising from non-equilibrium ionization that can constrain the nanoflare properties, but these calculations have ignored EIMI. Our findings suggest that EIMI can have a significant effect on the CSD of a nanoflare-heated plasma, changing the ion abundances by up to about 50%.

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PT3.16 *Brian Fayock*

Title - Automatic Event Detection Algorithm: Application to Time Lag Analysis Between C II and Si IV Slit-jaw Images of the Interface Region Imaging Spectrograph

Authors:
Brian Fayock, Bart De Pontieu, Amy Winebarger

Abstract:
The finer details of the solar magnetic structure from the chromosphere to the lower corona are now within reach for analysis due to the high-resolution capabilities of the Interface Region Imaging Spectrograph (IRIS). One of the most important aspects of these fine structures is the time scale of their evolution. To study the statistical nature of these structures in detail, we have developed an algorithm to automatically detect signal brightening or events on a pixel-by-pixel basis. This algorithm has already been used to successfully pick out events that fit certain adjustable criteria and group them together as structures, which can be analyzed in terms of typical length scales. From a different perspective, we have applied this algorithm to the C II and Si IV slit-jaw images of IRIS to calculate peak-emission time differences between the two channels. The results, though still open to interpretation, suggest the possibility of determining typical ionization time scales for C II and Si IV for different structures as well as the time scale of the heating mechanism responsible for their production. We will present our method of analysis and interpretation of the results.

SESSION 4: Wrap up Session

INVITED TALK

IT4.1 *Philippa Browning and Harry Warren*
Title - What doesn't match between theory and observations - a theorist's perspective

Authors:
P K Browning

Abstract:
This talk will summarise key theories for loop heating, including models based on reconnection, waves and turbulence, and ways they can be tested by observations. Many different models seem, with suitable parameter choices, predict reasonable heating rates, so how can we distinguish which is really the dominant mechanism (or mechanisms), and does this depend on the loop properties? I will mention some ways in which theories can be tested against observations, such as forward modelling of observables, DEM distributions, scaling laws. What are the relative merits of different models based on such tests so far, and what further work is needed, both in terms of making testable predictions from models and in new observations? I will also discuss what essential elements may be missing in current theoretical models, such as "complexity" and kinetic effects.